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SAMPLE DATA

This appendix contains sample data for various parts of the Bluetooth baseband specification. All sample data are provided for reference purpose only; they are intended as a complement to the definitions provided elsewhere in the specification. They can be used to check the behavior of an implementation and avoid misunderstandings. Fulfilling these sample data is a necessary but not sufficient condition for an implementation to be fully Bluetooth compliant.

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1 ENCRYPTION SAMPLE DATA

This section contains four sets of sample data for the encryption process.

With respect to the functional description of the encryption engine in the Bluetooth baseband specification, the contents of registers and resulting concurrent values are listed as well. This by no means excludes different implementations (as far as they produce the same encryption stream) but is intended to describe the functional behavior.

In case of misunderstandings or inconsistencies, these sample data form the normative reference.

1.1 GENERATING KC' FROM KC,

where Kc'(x) = g2(x)(Kc(x) mod g1(x)).

```
Note: All polynomials are in hexadecimal notation.
      'L' is the effective key length in bytes.
      The notation 'p: [m]' implies that deg(p(x)) = m.

                              MSB                                       LSB
L = 1
g1:                 [8]       00000000 00000000 00000000 0000011d
g2:                 [119]     00e275a0 abd218d4 cf928b9b bf6cb08f
Kc:                           a2b230a4 93f281bb 61a85b82 a9d4a30e
Kc mod g1:          [7]       00000000 00000000 00000000 0000009f
g2(Kc mod g1):      [126]     7aa16f39 59836ba3 22049a7b 87f1d8a5
-------------------------------------------------------------
L = 2
g1:                 [16]      00000000 00000000 00000000 0001003f
g2:                 [112]     0001e3f6 3d7659b3 7f18c258 cff6efef
Kc:                           64e7df78 bb7ccaa4 61433123 5b3222ad
Kc mod g1:          [12]      00000000 00000000 00000000 00001ff0
g2(Kc mod g1):      [124]     142057bb 0bceac4c 58bd142e 1e710a50
-------------------------------------------------------------
L = 3
g1:                 [24]      00000000 00000000 00000000 010000db
g2:                 [104]     000001be f66c6c3a b1030a5a 1919808b
Kc:                           575e5156 ba685dc6 112124ac edb2c179
Kc mod g1:          [23]      00000000 00000000 00000000 008ddbc8
g2(Kc mod g1):      [127]     d56d0adb 8216cb39 7fe3c591 1ff95618
-------------------------------------------------------------
L = 4
g1:                 [32]      00000000 00000000 00000001 000000af
g2:                 [96]      00000001 6ab89969 de17467f d3736ad9
Kc:                           8917b4fc 403b6db2 1596b86d 1cb8adab
Kc mod g1:          [31]      00000000 00000000 00000000 aa1e78aa
g2(Kc mod g1):      [127]     91910128 b0e2f5ed a132a03e af3d8cda
-------------------------------------------------------------
```

Sample Data

```
L = 5
g1:                [40]        00000000 00000000 00000100 00000039
g2:                [88]        00000000 01630632 91da50ec 55715247
Kc:                            785c915b dd25b9c6 0102ab00 b6cd2a68
Kc mod g1:         [38]        00000000 00000000 0000007f 13d44436
g2(Kc mod g1):     [126]       6fb5651c cb80c8d7 ea1ee56d f1ec5d02
------------------------------------------------------------
L = 6
g1:                [48]        00000000 00000000 00010000 00000291
g2:                [77]        00000000 00002c93 52aa6cc0 54468311
Kc:                            5e77d19f 55ccd7d5 798f9a32 3b83e5d8
Kc mod g1:         [47]        00000000 00000000 000082eb 4af213ed
g2(Kc mod g1):     [124]       16096bcb afcf8def 1d226a1b 4d3f9a3d
------------------------------------------------------------
```


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Sample Data

```
L = 7
g1:                [56]        00000000 00000000 01000000 00000095
g2:                [71]        00000000 000000b3 f7fffce2 79f3a073
Kc:                            05454e03 8ddcfbe3 ed024b2d 92b7f54c
Kc mod g1:         [55]        00000000 00000000 0095b8a4 8eb816da
g2(Kc mod g1):     [126]       50f9c0d4 e3178da9 4a09fe0d 34f67b0e
------------------------------------------------------------
L = 8
g1:                [64]        00000000 00000001 00000000 0000001b
g2:                [63]        00000000 00000000 a1ab815b c7ec8025
Kc:                            7ce149fc f4b38ad7 2a5d8a41 eb15ba31
Kc mod g1:         [63]        00000000 00000000 8660806c 1865deec
g2(Kc mod g1):     [126]       532c36d4 5d0954e0 922989b6 826f78dc
------------------------------------------------------------
L = 9
g1:                [72]        00000000 00000100 00000000 00000609
g2:                [49]        00000000 00000000 0002c980 11d8b04d
Kc:                            5eeff7ca 84fc2782 9c051726 3df6f36e
Kc mod g1:         [71]        00000000 00000083 58ccb7d0 b95d3c71
g2(Kc mod g1):     [120]       016313f6 0d3771cf 7f8e4bb9 4aa6827d
------------------------------------------------------------
L = 10
g1:                [80]        00000000 00010000 00000000 00000215
g2:                [42]        00000000 00000000 0000058e 24f9a4bb
Kc:                            7b13846e 88beb4de 34e7160a fd44dc65
Kc mod g1:         [79]        00000000 0000b4de 34171767 f36981c3
g2(Kc mod g1):     [121]       023bc1ec 34a0029e f798dcfb 618ba58d
------------------------------------------------------------
L = 11
g1:                [88]        00000000 01000000 00000000 0000013b
g2:                [35]        00000000 00000000 0000000c a76024d7
Kc:                            bda6de6c 6e7d757e 8dfe2d49 9a181193
Kc mod g1:         [86]        00000000 007d757e 8dfe88aa 2fcee371
g2(Kc mod g1):     [121]       022e08a9 3aa51d8d 2f93fa78 85cc1f87
------------------------------------------------------------
L = 12
g1:                [96]        00000001 00000000 00000000 000000dd
g2:                [28]        00000000 00000000 00000000 1c9c26b9
Kc:                            e6483b1c 2cdb1040 9a658f97 c4efd90d
Kc mod g1:         [93]        00000000 2cdb1040 9a658fd7 5b562e41
g2(Kc mod g1):     [121]       030d752b 216fe29b b880275c d7e6f6f9
------------------------------------------------------------
L = 13
g1:                [104]       00000100 00000000 00000000 0000049d
g2:                [21]        00000000 00000000 00000000 0026d9e3
Kc:                            d79d281d a2266847 6b223c46 dc0ab9ee
Kc mod g1:         [100]       0000001d a2266847 6b223c45 e1fc5fa6
g2(Kc mod g1):     [121]       03f11138 9cebf919 00b93808 4ac158aa
------------------------------------------------------------
```

```
L = 14
g1:                 [112]       00010000 00000000 00000000 0000014f
g2:                 [14]        00000000 00000000 00000000 00004377
Kc:                             cad9a65b 9fca1c1d a2320fcf 7c4ae48e
Kc mod g1:          [111]       0000a65b 9fca1c1d a2320fcf 7cb6a909
g2(Kc mod g1):      [125]       284840fd f1305f3c 529f5703 76adf7cf
-------------------------------------------------------------
L = 15
g1:                 [120]       01000000 00000000 00000000 000000e7
g2:                 [7]         00000000 00000000 00000000 00000089
Kc:                             21f0cc31 049b7163 d375e9e1 06029809
Kc mod g1:          [119]       00f0cc31 049b7163 d375e9e1 0602840e
g2(Kc mod g1):      [126]       7f10b53b 6df84b94 f22e566a 3754a37e
-------------------------------------------------------------
L = 16
g1:                 [128]       00000001 00000000 00000000 00000000 00000000
g2:                 [0]         00000000 00000000 00000000 00000001
Kc:                             35ec8fc3 d50ccd32 5f2fd907 bde206de
Kc mod g1:          [125]       35ec8fc3 d50ccd32 5f2fd907 bde206de
g2(Kc mod g1):      [125]       35ec8fc3 d50ccd32 5f2fd907 bde206de
-------------------------------------------------------------
```

1.2 FIRST SET OF SAMPLE DATA

```
Initial values for the key, pan address and clock

K'c1[0]   = 00   K'c1[1]   = 00    K'c1[2]   = 00    K'c1[3]  = 00
K'c1[4]   = 00   K'c1[5]   = 00    K'c1[6]   = 00    K'c1[7]  = 00
K'c1[8]   = 00   K'c1[9]   = 00    K'c1[10]  = 00    K'c1[11] = 00
K'c1[12]  = 00   K'c1[13]  = 00    K'c1[14]  = 00    K'c1[15] = 00

Addr1[0] = 00   Addr1[1] = 00    Addr1[2] = 00
Addr1[3] = 00   Addr1[4] = 00    Addr1[5] = 00

CL1[0]  = 00   CL1[1]  = 00    CL1[2]  = 00    CL1[3]  = 00


=============================================================================================
         Fill LFSRs with initial data
=============================================================================================

  t  clk#    LFSR1    LFSR2     LFSR3      LFSR4           X1 X2 X3 X4   Z  C[t+1] C[t] C[t-1]

  0     0    0000000* 00000000* 000000000* 0000000000*     0  0  0  0    0  00     00   00
  1     1    0000000* 00000001* 000000000* 0000000001*     0  0  0  0    0  00     00   00
  2     2    0000000* 00000002* 000000000* 0000000003*     0  0  0  0    0  00     00   00
  3     3    0000000* 00000004* 000000000* 0000000007*     0  0  0  0    0  00     00   00
  4     4    0000000* 00000008* 000000000* 000000000E*     0  0  0  0    0  00     00   00
  5     5    0000000* 00000010* 000000000* 000000001C*     0  0  0  0    0  00     00   00
  6     6    0000000* 00000020* 000000000* 0000000038*     0  0  0  0    0  00     00   00
```

Sample Data

7	7	0000000*	00000040*	000000000*	0000000070*	0	0	0	0	0	00	00	00
8	8	0000000*	00000080*	000000000*	00000000E0*	0	0	0	0	0	00	00	00
9	9	0000000*	00000100*	000000000*	00000001C0*	0	0	0	0	0	00	00	00
10	10	0000000*	00000200*	000000000*	0000000380*	0	0	0	0	0	00	00	00
11	11	0000000*	00000400*	000000000*	0000000700*	0	0	0	0	0	00	00	00
12	12	0000000*	00000800*	000000000*	0000000E00*	0	0	0	0	0	00	00	00
13	13	0000000*	00001000*	000000000*	0000001C00*	0	0	0	0	0	00	00	00
14	14	0000000*	00002000*	000000000*	0000003800*	0	0	0	0	0	00	00	00
15	15	0000000*	00004000*	000000000*	0000007000*	0	0	0	0	0	00	00	00
16	16	0000000*	00008000*	000000000*	000000E000*	0	0	0	0	0	00	00	00
17	17	0000000*	00010000*	000000000*	000001C000*	0	0	0	0	0	00	00	00
18	18	0000000*	00020000*	000000000*	0000038000*	0	0	0	0	0	00	00	00
19	19	0000000*	00040000*	000000000*	0000070000*	0	0	0	0	0	00	00	00
20	20	0000000*	00080000*	000000000*	00000E0000*	0	0	0	0	0	00	00	00
21	21	0000000*	00100000*	000000000*	00001C0000*	0	0	0	0	0	00	00	00
22	22	0000000*	00200000*	000000000*	0000380000*	0	0	0	0	0	00	00	00
23	23	0000000*	00400000*	000000000*	0000700000*	0	0	0	0	0	00	00	00
24	24	0000000*	00800000*	000000000*	0000E00000*	0	1	0	0	1	00	00	00
25	25	0000000*	01000000*	000000000*	0001C00000*	0	0	0	0	0	00	00	00
26	26	0000000	02000000*	000000000*	0003800000*	0	0	0	0	0	00	00	00
27	27	0000000	04000000*	000000000*	0007000000*	0	0	0	0	0	00	00	00
28	28	0000000	08000000*	000000000*	000E000000*	0	0	0	0	0	00	00	00
29	29	0000000	10000000*	000000000*	001C000000*	0	0	0	0	0	00	00	00
30	30	0000000	20000000*	000000000*	0038000000*	0	0	0	0	0	00	00	00
31	31	0000000	40000000*	000000000*	0070000000*	0	0	0	0	0	00	00	00
32	32	0000000	00000001	000000000*	00E0000000*	0	0	0	1	1	00	00	00
33	33	0000000	00000002	000000000*	01C0000000*	0	0	0	1	1	00	00	00
34	34	0000000	00000004	000000000	0380000000*	0	0	0	1	1	00	00	00
35	35	0000000	00000008	000000000	0700000000*	0	0	0	0	0	00	00	00
36	36	0000000	00000010	000000000	0E00000000*	0	0	0	0	0	00	00	00
37	37	0000000	00000020	000000000	1C00000000*	0	0	0	0	0	00	00	00
38	38	0000000	00000040	000000000	3800000000*	0	0	0	0	0	00	00	00
39	39	0000000	00000080	000000000	7000000000*	0	0	0	0	0	00	00	00

Start clocking Summation Combiner

40	1	0000000	00000100	000000000	6000000001	0	0	0	0	0	00	00	00
41	2	0000000	00000200	000000000	4000000003	0	0	0	0	0	00	00	00
42	3	0000000	00000400	000000000	0000000007	0	0	0	0	0	00	00	00
43	4	0000000	00000800	000000000	000000000E	0	0	0	0	0	00	00	00
44	5	0000000	00001001	000000000	000000001D	0	0	0	0	0	00	00	00
45	6	0000000	00002002	000000000	000000003B	0	0	0	0	0	00	00	00
46	7	0000000	00004004	000000000	0000000077	0	0	0	0	0	00	00	00
47	8	0000000	00008008	000000000	00000000EE	0	0	0	0	0	00	00	00
48	9	0000000	00010011	000000000	00000001DD	0	0	0	0	0	00	00	00
49	10	0000000	00020022	000000000	00000003BB	0	0	0	0	0	00	00	00
50	11	0000000	00040044	000000000	0000000777	0	0	0	0	0	00	00	00
51	12	0000000	00080088	000000000	0000000EEE	0	0	0	0	0	00	00	00
52	13	0000000	00100110	000000000	0000001DDD	0	0	0	0	0	00	00	00
53	14	0000000	00200220	000000000	0000003BBB	0	0	0	0	0	00	00	00
54	15	0000000	00400440	000000000	0000007777	0	0	0	0	0	00	00	00
55	16	0000000	00800880	000000000	000000EEEE	0	1	0	0	1	00	00	00
56	17	0000000	01001100	000000000	000001DDDD	0	0	0	0	0	00	00	00
57	18	0000000	02002200	000000000	000003BBBB	0	0	0	0	0	00	00	00
58	19	0000000	04004400	000000000	0000077777	0	0	0	0	0	00	00	00
59	20	0000000	08008800	000000000	00000EEEEE	0	0	0	0	0	00	00	00
60	21	0000000	10011000	000000000	00001DDDDD	0	0	0	0	0	00	00	00

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61	22	0000000	20022000	000000000	00003BBBBB	0	0	0	0	0	00	00	00
62	23	0000000	40044000	000000000	0000777777	0	0	0	0	0	00	00	00
63	24	0000000	00088001	000000000	0000EEEEEE	0	0	0	0	0	00	00	00
64	25	0000000	00110003	000000000	0001DDDDDD	0	0	0	0	0	00	00	00
65	26	0000000	00220006	000000000	0003BBBBBB	0	0	0	0	0	00	00	00
66	27	0000000	0044000C	000000000	0007777777	0	0	0	0	0	00	00	00
67	28	0000000	00880018	000000000	000EEEEEEE	0	1	0	0	1	00	00	00
68	29	0000000	01100031	000000000	001DDDDDDC	0	0	0	0	0	00	00	00
69	30	0000000	02200062	000000000	003BBBBBB8	0	0	0	0	0	00	00	00
70	31	0000000	044000C4	000000000	0077777770	0	0	0	0	0	00	00	00
71	32	0000000	08800188	000000000	00EEEEEEE0	0	1	0	1	0	01	00	00
72	33	0000000	11000311	000000000	01DDDDDDC1	0	0	0	1	0	00	01	00
73	34	0000000	22000622	000000000	03BBBBBB83	0	0	0	1	1	11	00	01
74	35	0000000	44000C44	000000000	0777777707	0	0	0	0	1	10	11	00
75	36	0000000	08001888	000000000	0EEEEEEE0E	0	0	0	1	1	01	10	11
76	37	0000000	10003111	000000000	1DDDDDDC1D	0	0	0	1	0	01	01	10
77	38	0000000	20006222	000000000	3BBBBBB83B	0	0	0	1	0	11	01	01
78	39	0000000	4000C444	000000000	7777777077	0	0	0	0	1	01	11	01
79	40	0000000	00018888	000000000	6EEEEEE0EF	0	0	0	1	0	10	01	11
80	41	0000000	00031110	000000000	5DDDDDC1DE	0	0	0	1	1	00	10	01
81	42	0000000	00062220	000000000	3BBBBB83BC	0	0	0	1	1	01	00	10
82	43	0000000	000C4440	000000000	7777770779	0	0	0	0	1	01	01	00
83	44	0000000	00188880	000000000	6EEEEE0EF2	0	0	0	1	0	11	01	01
84	45	0000000	00311100	000000000	5DDDDC1DE5	0	0	0	1	0	10	11	01
85	46	0000000	00622200	000000000	3BBBB83BCB	0	0	0	1	1	01	10	11
86	47	0000000	00C44400	000000000	7777707797	0	1	0	0	0	01	01	10
87	48	0000000	01888801	000000000	6EEEE0EF2F	0	1	0	1	1	11	01	01
88	49	0000000	03111003	000000000	5DDDC1DE5E	0	0	0	1	0	10	11	01
89	50	0000000	06222006	000000000	3BBB83BCBC	0	0	0	1	1	01	10	11
90	51	0000000	0C44400C	000000000	7777077979	0	0	0	0	1	00	01	10
91	52	0000000	18888018	000000000	6EEE0EF2F2	0	1	0	1	0	10	00	01
92	53	0000000	31110030	000000000	5DDC1DE5E5	0	0	0	1	1	11	10	00
93	54	0000000	62220060	000000000	3BB83BCBCB	0	0	0	1	0	00	11	10
94	55	0000000	444400C1	000000000	7770779797	0	0	0	0	0	10	00	11
95	56	0000000	08880183	000000000	6EE0EF2F2F	0	1	0	1	0	00	10	00
96	57	0000000	11100307	000000000	5DC1DE5E5F	0	0	0	1	1	01	00	10
97	58	0000000	2220060E	000000000	3B83BCBCBF	0	0	0	1	0	00	01	00
98	59	0000000	44400C1C	000000000	770779797E	0	0	0	0	0	11	00	01
99	60	0000000	08801838	000000000	6E0EF2F2FC	0	1	0	0	0	01	11	00
100	61	0000000	11003070	000000000	5C1DE5E5F8	0	0	0	0	1	11	01	11
101	62	0000000	220060E0	000000000	383BCBCBF0	0	0	0	0	1	01	11	01
102	63	0000000	4400C1C0	000000000	70779797E0	0	0	0	0	1	11	01	11
103	64	0000000	08018380	000000000	60EF2F2FC1	0	0	0	1	0	10	11	01
104	65	0000000	10030701	000000000	41DE5E5F82	0	0	0	1	1	01	10	11
105	66	0000000	20060E02	000000000	03BCBCBF04	0	0	0	1	0	01	01	10
106	67	0000000	400C1C05	000000000	0779797E09	0	0	0	0	1	10	01	01
107	68	0000000	0018380A	000000000	0EF2F2FC12	0	0	0	1	1	00	10	01
108	69	0000000	00307015	000000000	1DE5E5F825	0	0	0	1	1	01	00	10
109	70	0000000	0060E02A	000000000	3BCBCBF04B	0	0	0	1	0	00	01	00
110	71	0000000	00C1C055	000000000	779797E097	0	1	0	1	0	10	00	01
111	72	0000000	018380AA	000000000	6F2F2FC12F	0	1	0	0	1	11	10	00
112	73	0000000	03070154	000000000	5E5E5F825E	0	0	0	0	1	11	11	10
113	74	0000000	060E02A8	000000000	3CBCBF04BC	0	0	0	1	0	11	11	11
114	75	0000000	0C1C0550	000000000	79797E0979	0	0	0	0	1	00	11	11
115	76	0000000	18380AA0	000000000	72F2FC12F2	0	0	0	1	1	10	00	11
116	77	0000000	30701541	000000000	65E5F825E5	0	0	0	1	1	11	10	00
117	78	0000000	60E02A82	000000000	4BCBF04BCB	0	1	0	1	1	00	11	10

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118	79	0000000	41C05505	000000000	1797E09796	0	1	0	1	0	11	00	11
119	80	0000000	0380AA0A	000000000	2F2FC12F2C	0	1	0	0	0	01	11	00
120	81	0000000	07015415	000000000	5E5F825E59	0	0	0	0	1	11	01	11
121	82	0000000	0E02A82A	000000000	3CBF04BCB2	0	0	0	1	0	10	11	01
122	83	0000000	1C055054	000000000	797E097964	0	0	0	0	0	01	10	11
123	84	0000000	380AA0A8	000000000	72FC12F2C9	0	0	0	1	0	01	01	10
124	85	0000000	70154151	000000000	65F825E593	0	0	0	1	0	11	01	01
125	86	0000000	602A82A3	000000000	4BF04BCB26	0	0	0	1	0	10	11	01
126	87	0000000	40550546	000000000	17E097964C	0	0	0	1	1	01	10	11
127	88	0000000	00AA0A8D	000000000	2FC12F2C99	0	1	0	1	1	01	01	10
128	89	0000000	0154151A	000000000	5F825E5932	0	0	0	1	0	11	01	01
129	90	0000000	02A82A34	000000000	3F04BCB264	0	1	0	0	0	10	11	01
130	91	0000000	05505468	000000000	7E097964C9	0	0	0	0	0	01	10	11
131	92	0000000	0AA0A8D0	000000000	7C12F2C992	0	1	0	0	0	01	01	10
132	93	0000000	154151A1	000000000	7825E59324	0	0	0	0	1	10	01	01
133	94	0000000	2A82A342	000000000	704BCB2648	0	1	0	0	1	00	10	01
134	95	0000000	55054684	000000000	6097964C91	0	0	0	1	1	01	00	10
135	96	0000000	2A0A8D09	000000000	412F2C9923	0	0	0	0	1	01	01	00
136	97	0000000	54151A12	000000000	025E593246	0	0	0	0	1	10	01	01
137	98	0000000	282A3424	000000000	04BCB2648D	0	0	0	1	1	00	10	01
138	99	0000000	50546848	000000000	097964C91A	0	0	0	0	0	01	00	10
139	100	0000000	20A8D090	000000000	12F2C99235	0	1	0	1	1	00	01	00
140	101	0000000	4151A120	000000000	25E593246A	0	0	0	1	1	11	00	01
141	102	0000000	02A34240	000000000	4BCB2648D5	0	1	0	1	1	01	11	00
142	103	0000000	05468481	000000000	17964C91AB	0	0	0	1	0	10	01	11
143	104	0000000	0A8D0903	000000000	2F2C992357	0	1	0	0	1	00	10	01
144	105	0000000	151A1206	000000000	5E593246AE	0	0	0	0	0	01	00	10
145	106	0000000	2A34240C	000000000	3CB2648D5C	0	0	0	1	0	00	01	00
146	107	0000000	54684818	000000000	7964C91AB8	0	0	0	0	0	11	00	01
147	108	0000000	28D09030	000000000	72C9923571	0	1	0	1	1	01	11	00
148	109	0000000	51A12060	000000000	6593246AE2	0	1	0	1	1	10	01	11
149	110	0000000	234240C0	000000000	4B2648D5C5	0	0	0	0	0	00	10	01
150	111	0000000	46848180	000000000	164C91AB8A	0	1	0	0	1	01	00	10
151	112	0000000	0D090301	000000000	2C99235714	0	0	0	1	0	00	01	00
152	113	0000000	1A120602	000000000	593246AE28	0	0	0	0	0	11	00	01
153	114	0000000	34240C04	000000000	32648D5C51	0	0	0	0	1	10	11	00
154	115	0000000	68481809	000000000	64C91AB8A2	0	0	0	1	1	01	10	11
155	116	0000000	50903012	000000000	4992357144	0	1	0	1	1	01	01	10
156	117	0000000	21206024	000000000	13246AE288	0	0	0	0	1	10	01	01
157	118	0000000	4240C048	000000000	2648D5C511	0	0	0	0	0	00	10	01
158	119	0000000	04818090	000000000	4C91AB8A23	0	1	0	1	0	00	00	10
159	120	0000000	09030120	000000000	1923571446	0	0	0	0	0	00	00	00
160	121	0000000	12060240	000000000	3246AE288D	0	0	0	0	0	00	00	00
161	122	0000000	240C0480	000000000	648D5C511B	0	0	0	1	1	00	00	00
162	123	0000000	48180900	000000000	491AB8A237	0	0	0	0	0	00	00	00
163	124	0000000	10301200	000000000	123571446F	0	0	0	0	0	00	00	00
164	125	0000000	20602400	000000000	246AE288DF	0	0	0	0	0	00	00	00
165	126	0000000	40C04800	000000000	48D5C511BE	0	1	0	1	0	01	00	00
166	127	0000000	01809001	000000000	11AB8A237D	0	1	0	1	1	00	01	00
167	128	0000000	03012002	000000000	23571446FA	0	0	0	0	0	11	00	01
168	129	0000000	06024004	000000000	46AE288DF5	0	0	0	1	0	01	11	00
169	130	0000000	0C048008	000000000	0D5C511BEA	0	0	0	0	1	11	01	11
170	131	0000000	18090011	000000000	1AB8A237D5	0	0	0	1	0	10	11	01
171	132	0000000	30120022	000000000	3571446FAA	0	0	0	0	0	01	10	11
172	133	0000000	60240044	000000000	6AE288DF55	0	0	0	1	0	01	01	10
173	134	0000000	40480089	000000000	55C511BEAA	0	0	0	1	0	11	01	01
174	135	0000000	00900113	000000000	2B8A237D54	0	1	0	1	1	10	11	01

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175	136	0000000	01200227	000000000	571446FAA8	0	0	0	0	0	01	10	11
176	137	0000000	0240044E	000000000	2E288DF550	0	0	0	0	1	00	01	10
177	138	0000000	0480089C	000000000	5C511BEAA0	0	1	0	0	1	11	00	01
178	139	0000000	09001138	000000000	38A237D540	0	0	0	1	0	01	11	00
179	140	0000000	12002270	000000000	71446FAA81	0	0	0	0	1	11	01	11
180	141	0000000	240044E0	000000000	6288DF5503	0	0	0	1	0	10	11	01
181	142	0000000	480089C0	000000000	4511BEAA06	0	0	0	0	0	01	10	11
182	143	0000000	10011381	000000000	0A237D540D	0	0	0	0	1	00	01	10
183	144	0000000	20022702	000000000	1446FAA81A	0	0	0	0	0	11	00	01
184	145	0000000	40044E04	000000000	288DF55035	0	0	0	1	0	01	11	00
185	146	0000000	00089C08	000000000	511BEAA06A	0	0	0	0	1	11	01	11
186	147	0000000	00113810	000000000	2237D540D5	0	0	0	0	1	01	11	01
187	148	0000000	00227021	000000000	446FAA81AA	0	0	0	0	1	11	01	11
188	149	0000000	0044E042	000000000	08DF550355	0	0	0	1	0	10	11	01
189	150	0000000	0089C085	000000000	11BEAA06AA	0	1	0	1	0	10	10	11
190	151	0000000	0113810A	000000000	237D540D54	0	0	0	0	0	10	10	10
191	152	0000000	02270215	000000000	46FAA81AA9	0	0	0	1	1	10	10	10
192	153	0000000	044E042A	000000000	0DF5503553	0	0	0	1	1	10	10	10
193	154	0000000	089C0854	000000000	1BEAA06AA7	0	1	0	1	0	01	10	10
194	155	0000000	113810A8	000000000	37D540D54E	0	0	0	1	0	01	01	10
195	156	0000000	22702150	000000000	6FAA81AA9D	0	0	0	1	0	11	01	01
196	157	0000000	44E042A0	000000000	5F5503553A	0	1	0	0	0	10	11	01
197	158	0000000	09C08540	000000000	3EAA06AA75	0	1	0	1	0	10	10	11
198	159	0000000	13810A80	000000000	7D540D54EA	0	1	0	0	1	10	10	10
199	160	0000000	27021500	000000000	7AA81AA9D5	0	0	0	1	1	10	10	10
200	161	0000000	4E042A00	000000000	75503553AB	0	0	0	0	0	10	10	10
201	162	0000000	1C085400	000000000	6AA06AA756	0	0	0	1	1	10	10	10
202	163	0000000	3810A800	000000000	5540D54EAC	0	0	0	0	0	10	10	10
203	164	0000000	70215000	000000000	2A81AA9D58	0	0	0	1	1	10	10	10
204	165	0000000	6042A001	000000000	5503553AB0	0	0	0	0	0	10	10	10
205	166	0000000	40854002	000000000	2A06AA7561	0	1	0	0	1	10	10	10
206	167	0000000	010A8004	000000000	540D54EAC3	0	0	0	0	0	10	10	10
207	168	0000000	02150009	000000000	281AA9D586	0	0	0	0	0	10	10	10
208	169	0000000	042A0012	000000000	503553AB0C	0	0	0	0	0	10	10	10
209	170	0000000	08540024	000000000	206AA75618	0	0	0	0	0	10	10	10
210	171	0000000	10A80048	000000000	40D54EAC30	0	1	0	1	0	01	10	10
211	172	0000000	21500091	000000000	01AA9D5861	0	0	0	1	0	01	01	10
212	173	0000000	42A00122	000000000	03553AB0C3	0	1	0	0	0	11	01	01
213	174	0000000	05400244	000000000	06AA756186	0	0	0	1	0	10	11	01
214	175	0000000	0A800488	000000000	0D54EAC30D	0	1	0	0	1	01	10	11
215	176	0000000	15000911	000000000	1AA9D5861A	0	0	0	1	0	01	01	10
216	177	0000000	2A001223	000000000	3553AB0C35	0	0	0	0	1	10	01	01
217	178	0000000	54002446	000000000	6AA756186A	0	0	0	1	1	00	10	01
218	179	0000000	2800488D	000000000	554EAC30D5	0	0	0	0	0	01	00	10
219	180	0000000	5000911B	000000000	2A9D5861AA	0	0	0	1	0	00	01	00
220	181	0000000	20012236	000000000	553AB0C355	0	0	0	0	0	11	00	01
221	182	0000000	4002446C	000000000	2A756186AA	0	0	0	0	1	10	11	00
222	183	0000000	000488D9	000000000	54EAC30D54	0	0	0	1	1	01	10	11
223	184	0000000	000911B2	000000000	29D5861AA8	0	0	0	1	0	01	01	10
224	185	0000000	00122364	000000000	53AB0C3550	0	0	0	1	0	11	01	01
225	186	0000000	002446C8	000000000	2756186AA0	0	0	0	0	1	01	11	01
226	187	0000000	00488D90	000000000	4EAC30D540	0	0	0	1	0	10	01	11
227	188	0000000	00911B20	000000000	1D5861AA81	0	1	0	0	1	00	10	01
228	189	0000000	01223640	000000000	3AB0C35502	0	0	0	1	1	01	00	10
229	190	0000000	02446C80	000000000	756186AA05	0	0	0	0	1	01	01	00
230	191	0000000	0488D901	000000000	6AC30D540B	0	1	0	1	1	11	01	01
231	192	0000000	0911B203	000000000	55861AA817	0	0	0	1	0	10	11	01

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232	193	0000000	12236407	000000000	2B0C35502F	0	0	0	0	0	01	10	11
233	194	0000000	2446C80E	000000000	56186AA05F	0	0	0	0	1	00	01	10
234	195	0000000	488D901C	000000000	2C30D540BF	0	1	0	0	1	11	00	01
235	196	0000000	111B2039	000000000	5861AA817E	0	0	0	0	1	10	11	00
236	197	0000000	22364072	000000000	30C35502FD	0	0	0	1	1	01	10	11
237	198	0000000	446C80E4	000000000	6186AA05FB	0	0	0	1	0	01	01	10
238	199	0000000	08D901C8	000000000	430D540BF6	0	1	0	0	0	11	01	01
239	200	0000000	11B20391	000000000	061AA817EC	0	1	0	0	0	10	11	01

```
Z[0]  = 3D
Z[1]  = C1
Z[2]  = F0
Z[3]  = BB
Z[4]  = 58
Z[5]  = 1E
Z[6]  = 42
Z[7]  = 42
Z[8]  = 4B
Z[9]  = 8E
Z[10] = C1
Z[11] = 2A
Z[12] = 40
Z[13] = 63
Z[14] = 7A
Z[15] = 1E

================================================================================================
         Reload this pattern into the LFSRs
         Hold content of Summation Combiner regs and calculate new C[t+1] and Z values
================================================================================================
LFSR1  <= 04B583D
LFSR2  <= 208E1EC1
LFSR3  <= 063C142F0
LFSR4  <= 0F7A2A42BB
C[t+1] <= 10

================================================================================================
         Generating 125 key symbols (encryption/decryption sequence)
================================================================================================
```

240	1	04B583D	208E1EC1	063C142F0	0F7A2A42BB	0	1	0	0	0	10	11	01
241	2	096B07A	411C3D82	0C78285E1	1EF4548577	1	0	1	1	1	10	10	11
242	3	12D60F4	02387B04	18F050BC3	3DE8A90AEF	0	0	1	1	0	01	10	10
243	4	05AC1E9	0470F609	11E0A1786	7BD15215DF	0	0	0	1	0	01	01	10
244	5	0B583D2	08E1EC13	03C142F0C	77A2A42BBF	1	1	0	1	0	00	01	01
245	6	16B07A5	11C3D827	078285E18	6F4548577E	0	1	0	0	1	11	00	01
246	7	0D60F4B	2387B04F	0F050BC30	5E8A90AEFD	1	1	1	1	1	00	11	00
247	8	1AC1E97	470F609E	1E0A17860	3D15215DFA	1	0	1	0	0	11	00	11
248	9	1583D2E	0E1EC13D	1C142F0C0	7A2A42BBF4	0	0	1	0	0	01	11	00
249	10	0B07A5D	1C3D827B	18285E181	74548577E9	1	0	1	0	1	10	01	11
250	11	160F4BB	387B04F7	1050BC302	68A90AEFD2	0	0	0	1	1	00	10	01
251	12	0C1E976	70F609EE	00A178605	515215DFA5	1	1	0	0	0	00	00	10
252	13	183D2ED	61EC13DD	0142F0C0B	22A42BBF4B	1	1	0	1	1	01	00	00
253	14	107A5DA	43D827BA	0285E1817	4548577E97	0	1	0	0	0	00	01	00
254	15	00F4BB4	07B04F74	050BC302F	0A90AEFD2E	0	1	0	1	0	10	00	01
255	16	01E9769	0F609EE8	0A178605E	15215DFA5C	0	0	1	0	1	11	10	00
256	17	03D2ED3	1EC13DD0	142F0C0BD	2A42BBF4B9	0	1	0	0	0	00	11	10
257	18	07A5DA7	3D827BA0	085E1817B	548577E972	0	1	1	1	1	11	00	11

Sample Data

258	19	0F4BB4F	7B04F740	10BC302F6	290AEFD2E5	1	0	0	0	0	01	11	00
259	20	1E9769F	7609EE80	0178605ED	5215DFA5CA	1	0	0	0	0	10	01	11
260	21	1D2ED3F	6C13DD01	02F0C0BDA	242BBF4B94	1	0	0	0	1	00	10	01
261	22	1A5DA7E	5827BA03	05E1817B4	48577E9729	1	0	0	0	1	01	00	10
262	23	14BB4FC	304F7407	0BC302F69	10AEFD2E53	0	0	1	1	1	00	01	00
263	24	09769F9	609EE80E	178605ED2	215DFA5CA7	1	1	0	0	0	10	00	01
264	25	12ED3F2	413DD01C	0F0C0BDA4	42BBF4B94F	0	0	1	1	0	00	10	00
265	26	05DA7E5	027BA038	1E1817B49	0577E9729F	0	0	1	0	1	01	00	10
266	27	0BB4FCA	04F74071	1C302F693	0AEFD2E53F	1	1	1	1	1	11	01	00
267	28	1769F95	09EE80E3	18605ED27	15DFA5CA7F	0	1	1	1	0	11	11	01
268	29	0ED3F2B	13DD01C6	10C0BDA4F	2BBF4B94FE	1	1	0	1	0	10	11	11
269	30	1DA7E56	27BA038D	01817B49F	577E9729FD	1	1	0	0	0	10	10	11
270	31	1B4FCAD	4F74071B	0302F693E	2EFD2E53FB	1	0	0	1	0	01	10	10
271	32	169F95B	1EE80E37	0605ED27D	5DFA5CA7F7	0	1	0	1	1	01	01	10
272	33	0D3F2B7	3DD01C6E	0C0BDA4FB	3BF4B94FEF	1	1	1	1	1	00	01	01
273	34	1A7E56F	7BA038DC	1817B49F6	77E9729FDE	1	1	1	1	0	01	00	01
274	35	14FCADF	774071B9	102F693ED	6FD2E53FBD	0	0	0	1	0	00	01	00
275	36	09F95BE	6E80E373	005ED27DB	5FA5CA7F7B	1	1	0	1	1	10	00	01
276	37	13F2B7C	5D01C6E7	00BDA4FB6	3F4B94FEF7	0	0	0	0	0	11	10	00
277	38	07E56F9	3A038DCE	017B49F6C	7E9729FDEE	0	0	0	1	0	00	11	10
278	39	0FCADF2	74071B9C	02F693ED8	7D2E53FBDD	1	0	0	0	1	10	00	11
279	40	1F95BE5	680E3738	05ED27DB0	7A5CA7F7BA	1	0	0	0	1	11	10	00
280	41	1F2B7CA	501C6E71	0BDA4FB60	74B94FEF74	1	0	1	1	0	01	11	10
281	42	1E56F94	2038DCE2	17B49F6C0	69729FDEE8	1	0	0	0	0	10	01	11
282	43	1CADF29	4071B9C4	0F693ED80	52E53FBDD1	1	0	1	1	1	11	10	01
283	44	195BE53	00E37389	1ED27DB01	25CA7F7BA3	1	1	1	1	1	01	11	10
284	45	12B7CA6	01C6E713	1DA4FB602	4B94FEF747	0	1	1	1	0	01	01	11
285	46	056F94C	038DCE26	1B49F6C04	1729FDEE8E	0	1	1	0	1	11	01	01
286	47	0ADF299	071B9C4D	1693ED808	2E53FBDD1C	1	0	0	0	0	10	11	01
287	48	15BE532	0E37389A	0D27DB011	5CA7F7BA38	0	0	1	1	0	10	10	11
288	49	0B7CA64	1C6E7135	1A4FB6022	394FEF7471	1	0	1	0	0	01	10	10
289	50	16F94C9	38DCE26A	149F6C044	729FDEE8E2	0	1	0	1	1	01	01	10
290	51	0DF2993	71B9C4D4	093ED8089	653FBDD1C4	1	1	1	0	0	00	01	01
291	52	1BE5327	637389A9	127DB0112	4A7F7BA388	1	0	0	0	1	11	00	01
292	53	17CA64E	46E71353	04FB60224	14FEF74710	0	1	0	1	1	01	11	00
293	54	0F94C9C	0DCE26A6	09F6C0448	29FDEE8E21	1	1	1	1	1	01	01	11
294	55	1F29939	1B9C4D4D	13ED80890	53FBDD1C42	1	1	0	1	0	00	01	01
295	56	1E53272	37389A9A	07DB01121	27F7BA3884	1	0	0	1	0	10	00	01
296	57	1CA64E5	6E713534	0FB602242	4FEF747108	1	0	1	1	1	00	10	00
297	58	194C9CB	5CE26A69	1F6C04485	1FDEE8E210	1	1	1	1	0	11	00	10
298	59	1299397	39C4D4D3	1ED80890A	3FBDD1C420	0	1	1	1	0	00	11	00
299	60	053272F	7389A9A6	1DB011214	7F7BA38840	0	1	1	0	0	11	00	11
300	61	0A64E5E	6713534C	1B6022428	7EF7471081	1	0	1	1	0	00	11	00
301	62	14C9CBD	4E26A699	16C044850	7DEE8E2102	0	0	0	1	1	10	00	11
302	63	099397A	1C4D4D32	0D80890A0	7BDD1C4205	1	0	1	1	1	00	10	00
303	64	13272F4	389A9A65	1B0112141	77BA38840B	0	1	1	1	1	00	00	10
304	65	064E5E8	713534CB	160224283	6F74710817	0	0	0	0	0	00	00	00
305	66	0C9CBD1	626A6997	0C0448507	5EE8E2102E	1	0	1	1	1	01	00	00
306	67	19397A3	44D4D32E	180890A0E	3DD1C4205C	1	1	1	1	1	11	01	00
307	68	1272F46	09A9A65D	10112141D	7BA38840B8	0	1	0	1	1	10	11	01
308	69	04E5E8C	13534CBA	00224283A	7747108171	0	0	0	0	0	01	10	11
309	70	09CBD19	26A69975	004485075	6E8E2102E3	1	1	0	1	0	10	01	10
310	71	1397A32	4D4D32EB	00890A0EA	5D1C4205C7	0	0	0	0	0	00	10	01
311	72	072F465	1A9A65D7	0112141D5	3A38840B8F	0	1	0	0	1	01	00	10
312	73	0E5E8CA	3534CBAF	0224283AA	747108171F	1	0	0	0	0	00	01	00
313	74	1CBD194	6A69975E	044850755	68E2102E3E	1	0	0	1	0	10	00	01
314	75	197A329	54D32EBC	0890A0EAB	51C4205C7D	1	1	1	1	0	01	10	00

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315	76	12F4653	29A65D79	112141D56	238840B8FA	0	1	0	1	1	01	01	10
316	77	05E8CA6	534CBAF2	024283AAD	47108171F4	0	0	0	0	1	10	01	01
317	78	0BD194D	269975E5	04850755B	0E2102E3E9	1	1	0	0	0	11	10	01
318	79	17A329A	4D32EBCB	090A0EAB6	1C4205C7D2	0	0	1	0	0	00	11	10
319	80	0F46535	1A65D797	12141D56D	38840B8FA5	1	0	0	1	0	11	00	11
320	81	1E8CA6A	34CBAF2F	04283AADA	7108171F4B	1	1	0	0	1	01	11	00
321	82	1D194D5	69975E5F	0850755B4	62102E3E97	1	1	1	0	0	01	01	11
322	83	1A329AA	532EBCBF	10A0EAB68	44205C7D2F	1	0	0	0	0	11	01	01
323	84	1465355	265D797F	0141D56D1	0840B8FA5E	0	0	0	0	1	01	11	01
324	85	08CA6AB	4CBAF2FF	0283AADA2	108171F4BC	1	1	0	1	0	01	01	11
325	86	1194D56	1975E5FF	050755B45	2102E3E979	0	0	0	0	1	10	01	01
326	87	0329AAD	32EBCBFF	0A0EAB68A	4205C7D2F3	0	1	1	0	0	11	10	01
327	88	065355A	65D797FF	141D56D14	040B8FA5E7	0	1	0	0	0	00	11	10
328	89	0CA6AB4	4BAF2FFF	083AADA28	08171F4BCF	1	1	1	0	1	11	00	11
329	90	194D569	175E5FFF	10755B450	102E3E979E	1	0	0	0	0	01	11	00
330	91	129AAD3	2EBCBFFF	00EAB68A1	205C7D2F3C	0	1	0	0	0	10	01	11
331	92	05355A6	5D797FFF	01D56D142	40B8FA5E78	0	0	0	1	1	00	10	01
332	93	0A6AB4D	3AF2FFFE	03AADA285	0171F4BCF1	1	1	0	0	0	00	00	10
333	94	14D569B	75E5FFFD	0755B450A	02E3E979E2	0	1	0	1	0	01	00	00
334	95	09AAD37	6BCBFFFA	0EAB68A15	05C7D2F3C4	1	1	1	1	1	11	01	00
335	96	1355A6E	5797FFF4	1D56D142A	0B8FA5E788	0	1	1	1	0	11	11	01
336	97	06AB4DC	2F2FFFE8	1AADA2854	171F4BCF11	0	0	1	0	0	11	11	11
337	98	0D569B8	5E5FFFD0	155B450A9	2E3E979E23	1	0	0	0	0	11	11	11
338	99	1AAD370	3CBFFFA1	0AB68A153	5C7D2F3C46	1	1	1	0	0	10	11	11
339	100	155A6E0	797FFF43	156D142A7	38FA5E788D	0	0	0	1	1	01	10	11
340	101	0AB4DC0	72FFFE87	0ADA2854E	71F4BCF11B	1	1	1	1	1	10	01	10
341	102	1569B81	65FFFD0E	15B450A9D	63E979E236	0	1	0	1	0	11	10	01
342	103	0AD3703	4BFFFA1C	0B68A153B	47D2F3C46C	1	1	1	1	1	01	11	10
343	104	15A6E07	17FFF438	16D142A76	0FA5E788D8	0	1	0	1	1	10	01	11
344	105	0B4DC0F	2FFFE870	0DA2854EC	1F4BCF11B0	1	1	1	0	1	11	10	01
345	106	169B81F	5FFFD0E1	1B450A9D8	3E979E2360	0	1	1	1	0	01	11	10
346	107	0D3703F	3FFFA1C3	168A153B0	7D2F3C46C1	1	1	0	0	1	10	01	11
347	108	1A6E07E	7FFF4386	0D142A761	7A5E788D83	1	1	1	0	1	11	10	01
348	109	14DC0FD	7FFE870C	1A2854EC2	74BCF11B07	0	1	1	1	0	01	11	10
349	110	09B81FB	7FFD0E19	1450A9D84	6979E2360E	1	1	0	0	1	10	01	11
350	111	13703F6	7FFA1C33	08A153B09	52F3C46C1C	0	1	1	1	1	11	10	01
351	112	06E07EC	7FF43867	1142A7612	25E788D838	0	1	0	1	1	00	11	10
352	113	0DC0FD8	7FE870CF	02854EC25	4BCF11B071	1	1	0	1	1	11	00	11
353	114	1B81FB1	7FD0E19E	050A9D84B	179E2360E3	1	1	0	1	0	00	11	00
354	115	1703F62	7FA1C33D	0A153B096	2F3C46C1C7	0	1	1	0	0	11	00	11
355	116	0E07EC4	7F43867B	142A7612C	5E788D838E	1	0	0	0	0	01	11	00
356	117	1C0FD88	7E870CF6	0854EC259	3CF11B071C	1	1	1	1	1	01	01	11
357	118	181FB11	7D0E19ED	10A9D84B3	79E2360E38	1	0	0	1	1	11	01	01
358	119	103F622	7A1C33DA	0153B0967	73C46C1C71	0	0	0	1	0	10	11	01
359	120	007EC45	743867B5	02A7612CE	6788D838E3	0	0	0	1	1	01	10	11
360	121	00FD88B	6870CF6B	054EC259C	4F11B071C6	0	0	0	0	1	00	01	10
361	122	01FB117	50E19ED7	0A9D84B38	1E2360E38C	0	1	1	0	0	10	00	01
362	123	03F622F	21C33DAE	153B09671	3C46C1C718	0	1	0	0	1	11	10	00
363	124	07EC45F	43867B5C	0A7612CE2	788D838E30	0	1	1	1	0	01	11	10
364	125	0FD88BF	070CF6B9	14EC259C4	711B071C61	1	0	0	0	0	10	01	11

1.3 SECOND SET OF SAMPLE DATA

```
Initial values for the key, BD_ADDR and clock

K'c2[0]   = 00   K'c2[1]   = 00    K'c2[2]   = 00    K'c2[3]  = 00
K'c2[4]   = 00   K'c2[5]   = 00    K'c2[6]   = 00    K'c2[7]  = 00
K'c2[8]   = 00   K'c2[9]   = 00    K'c2[10]  = 00    K'c2[11] = 00
K'c2[12]  = 00   K'c2[13]  = 00    K'c2[14]  = 00    K'c2[15] = 00

Addr2[0] = 00   Addr2[1] = 00    Addr2[2] = 00
Addr2[3] = 00   Addr2[4] = 00    Addr2[5] = 00

CL2[0]  = 00   CL2[1]  = 00    CL2[2]  = 00    CL2[3]  = 03


=============================================================================================
         Fill LFSRs with initial data
=============================================================================================

  t  clk#    LFSR1    LFSR2     LFSR3      LFSR4           X1 X2 X3 X4   Z  C[t+1] C[t] C[t-1]

  0     0    0000000* 00000000* 000000000* 0000000000*     0  0  0  0    0  00     00   00
  1     1    0000001* 00000001* 000000001* 0000000001*     0  0  0  0    0  00     00   00
  2     2    0000002* 00000002* 000000002* 0000000003*     0  0  0  0    0  00     00   00
  3     3    0000004* 00000004* 000000004* 0000000007*     0  0  0  0    0  00     00   00
  4     4    0000008* 00000008* 000000008* 000000000E*     0  0  0  0    0  00     00   00
  5     5    0000010* 00000010* 000000010* 000000001C*     0  0  0  0    0  00     00   00
  6     6    0000020* 00000020* 000000020* 0000000038*     0  0  0  0    0  00     00   00
  7     7    0000040* 00000040* 000000040* 0000000070*     0  0  0  0    0  00     00   00
  8     8    0000080* 00000080* 000000080* 00000000E0*     0  0  0  0    0  00     00   00
  9     9    0000100* 00000100* 000000100* 00000001C0*     0  0  0  0    0  00     00   00
 10    10    0000200* 00000200* 000000200* 0000000380*     0  0  0  0    0  00     00   00
 11    11    0000400* 00000400* 000000400* 0000000700*     0  0  0  0    0  00     00   00
 12    12    0000800* 00000800* 000000800* 0000000E00*     0  0  0  0    0  00     00   00
 13    13    0001000* 00001000* 000001000* 0000001C00*     0  0  0  0    0  00     00   00
 14    14    0002000* 00002000* 000002000* 0000003800*     0  0  0  0    0  00     00   00
 15    15    0004000* 00004000* 000004000* 0000007000*     0  0  0  0    0  00     00   00
 16    16    0008000* 00008000* 000008000* 000000E000*     0  0  0  0    0  00     00   00
 17    17    0010000* 00010000* 000010000* 000001C000*     0  0  0  0    0  00     00   00
 18    18    0020000* 00020000* 000020000* 0000038000*     0  0  0  0    0  00     00   00
 19    19    0040000* 00040000* 000040000* 0000070000*     0  0  0  0    0  00     00   00
 20    20    0080000* 00080000* 000080000* 00000E0000*     0  0  0  0    0  00     00   00
 21    21    0100000* 00100000* 000100000* 00001C0000*     0  0  0  0    0  00     00   00
 22    22    0200000* 00200000* 000200000* 0000380000*     0  0  0  0    0  00     00   00
 23    23    0400000* 00400000* 000400000* 0000700000*     0  0  0  0    0  00     00   00
 24    24    0800000* 00800000* 000800000* 0000E00000*     1  1  0  0    0  01     00   00
 25    25    1000000* 01000000* 001000000* 0001C00000*     0  0  0  0    0  00     00   00
 26    26    0000001  02000000* 002000000* 0003800000*     0  0  0  0    0  00     00   00
 27    27    0000002  04000000* 004000000* 0007000000*     0  0  0  0    0  00     00   00
 28    28    0000004  08000000* 008000000* 000E000000*     0  0  0  0    0  00     00   00
 29    29    0000008  10000000* 010000000* 001C000000*     0  0  0  0    0  00     00   00
 30    30    0000010  20000000* 020000000* 0038000000*     0  0  0  0    0  00     00   00
 31    31    0000020  40000000* 040000000* 0070000000*     0  0  0  0    0  00     00   00
 32    32    0000040  00000001  080000000* 00E0000000*     0  0  1  1    0  01     00   00
 33    33    0000080  00000002  100000000* 01C0000000*     0  0  0  1    1  00     00   00
 34    34    0000101  00000004  000000001  0380000000*     0  0  0  1    1  00     00   00
```

Sample Data

35	35	0000202	00000008	000000002	0700000000*	0	0	0	0	0	00	00	00
36	36	0000404	00000010	000000004	0E00000000*	0	0	0	0	0	00	00	00
37	37	0000808	00000020	000000008	1C00000000*	0	0	0	0	0	00	00	00
38	38	0001011	00000040	000000011	3800000000*	0	0	0	0	0	00	00	00
39	39	0002022	00000080	000000022	7000000000*	0	0	0	0	0	00	00	00

Start clocking Summation Combiner

40	1	0004044	00000100	000000044	6000000001	0	0	0	0	0	00	00	00
41	2	0008088	00000200	000000088	4000000003	0	0	0	0	0	00	00	00
42	3	0010111	00000400	000000111	0000000007	0	0	0	0	0	00	00	00
43	4	0020222	00000800	000000222	000000000E	0	0	0	0	0	00	00	00
44	5	0040444	00001001	000000444	000000001D	0	0	0	0	0	00	00	00
45	6	0080888	00002002	000000888	000000003B	0	0	0	0	0	00	00	00
46	7	0101111	00004004	000001111	0000000077	0	0	0	0	0	00	00	00
47	8	0202222	00008008	000002222	00000000EE	0	0	0	0	0	00	00	00
48	9	0404444	00010011	000004444	00000001DD	0	0	0	0	0	00	00	00
49	10	0808888	00020022	000008888	00000003BB	1	0	0	0	1	00	00	00
50	11	1011110	00040044	000011111	0000000777	0	0	0	0	0	00	00	00
51	12	0022221	00080088	000022222	0000000EEE	0	0	0	0	0	00	00	00
52	13	0044442	00100110	000044444	0000001DDD	0	0	0	0	0	00	00	00
53	14	0088884	00200220	000088888	0000003BBB	0	0	0	0	0	00	00	00
54	15	0111109	00400440	000111111	0000007777	0	0	0	0	0	00	00	00
55	16	0222212	00800880	000222222	000000EEEE	0	1	0	0	1	00	00	00
56	17	0444424	01001100	000444444	000001DDDD	0	0	0	0	0	00	00	00
57	18	0888848	02002200	000888888	000003BBBB	1	0	0	0	1	00	00	00
58	19	1111090	04004400	001111110	0000077777	0	0	0	0	0	00	00	00
59	20	0222120	08008800	002222220	00000EEEEE	0	0	0	0	0	00	00	00
60	21	0444240	10011000	004444440	00001DDDDD	0	0	0	0	0	00	00	00
61	22	0888480	20022000	008888880	00003BBBBB	1	0	0	0	1	00	00	00
62	23	1110900	40044000	011111100	0000777777	0	0	0	0	0	00	00	00
63	24	0221200	00088001	022222200	0000EEEEEE	0	0	0	0	0	00	00	00
64	25	0442400	00110003	044444400	0001DDDDDD	0	0	0	0	0	00	00	00
65	26	0884800	00220006	088888800	0003BBBBBB	1	0	1	0	0	01	00	00
66	27	1109000	0044000C	111111000	0007777777	0	0	0	0	1	01	01	00
67	28	0212001	00880018	022222001	000EEEEEEE	0	1	0	0	0	11	01	01
68	29	0424002	01100031	044444002	001DDDDDDC	0	0	0	0	1	01	11	01
69	30	0848004	02200062	088888004	003BBBBBB8	1	0	1	0	1	10	01	11
70	31	1090008	044000C4	111110008	0077777770	0	0	0	0	0	00	10	01
71	32	0120010	08800188	022220010	00EEEEEEE0	0	1	0	1	0	00	00	10
72	33	0240020	11000311	044440020	01DDDDDDC1	0	0	0	1	1	00	00	00
73	34	0480040	22000622	088880040	03BBBBBB83	0	0	1	1	0	01	00	00
74	35	0900081	44000C44	111100080	0777777707	1	0	0	0	0	00	01	00
75	36	1200103	08001888	022200101	0EEEEEEE0E	0	0	0	1	1	11	00	01
76	37	0400207	10003111	044400202	1DDDDDDC1D	0	0	0	1	0	01	11	00
77	38	080040E	20006222	088800404	3BBBBBB83B	1	0	1	1	0	01	01	11
78	39	100081C	4000C444	111000808	7777777077	0	0	0	0	1	10	01	01
79	40	0001038	00018888	022001010	6EEEEEE0EF	0	0	0	1	1	00	10	01
80	41	0002070	00031110	044002020	5DDDDDC1DE	0	0	0	1	1	01	00	10
81	42	00040E0	00062220	088004040	3BBBBB83BC	0	0	1	1	1	00	01	00
82	43	00081C1	000C4440	110008081	7777770779	0	0	0	0	0	11	00	01
83	44	0010383	00188880	020010103	6EEEEE0EF2	0	0	0	1	0	01	11	00
84	45	0020707	00311100	040020206	5DDDDC1DE5	0	0	0	1	0	10	01	11
85	46	0040E0E	00622200	08004040C	3BBBB83BCB	0	0	1	1	0	11	10	01
86	47	0081C1D	00C44400	100080819	7777707797	0	1	0	0	0	00	11	10
87	48	010383A	01888801	000101032	6EEEE0EF2F	0	1	0	1	0	11	00	11
88	49	0207075	03111003	000202064	5DDDC1DE5E	0	0	0	1	0	01	11	00

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Sample Data

89	50	040E0EA	06222006	0004040C8	3BBB83BCBC	0	0	0	1	0	10	01	11
90	51	081C1D5	0C44400C	000808191	7777077979	1	0	0	0	1	00	10	01
91	52	10383AB	18888018	001010323	6EEE0EF2F2	0	1	0	1	0	00	00	10
92	53	0070756	31110030	002020646	5DDC1DE5E5	0	0	0	1	1	00	00	00
93	54	00E0EAC	62220060	004040C8C	3BB83BCBCB	0	0	0	1	1	00	00	00
94	55	01C1D59	444400C1	008081919	7770779797	0	0	0	0	0	00	00	00
95	56	0383AB2	08880183	010103232	6EE0EF2F2F	0	1	0	1	0	01	00	00
96	57	0707565	11100307	020206464	5DC1DE5E5F	0	0	0	1	0	00	01	00
97	58	0E0EACA	2220060E	04040C8C8	3B83BCBCBF	1	0	0	1	0	10	00	01
98	59	1C1D594	44400C1C	080819191	770779797E	1	0	1	0	0	00	10	00
99	60	183AB28	08801838	101032323	6E0EF2F2FC	1	1	0	0	0	00	00	10
100	61	1075650	11003070	002064647	5C1DE5E5F8	0	0	0	0	0	00	00	00
101	62	00EACA1	220060E0	0040C8C8E	383BCBCBF0	0	0	0	0	0	00	00	00
102	63	01D5943	4400C1C0	00819191D	70779797E0	0	0	0	0	0	00	00	00
103	64	03AB286	08018380	01032323A	60EF2F2FC1	0	0	0	1	1	00	00	00
104	65	075650C	10030701	020646475	41DE5E5F82	0	0	0	1	1	00	00	00
105	66	0EACA18	20060E02	040C8C8EA	03BCBCBF04	1	0	0	1	0	01	00	00
106	67	1D59430	400C1C05	0819191D4	0779797E09	1	0	1	0	1	00	01	00
107	68	1AB2861	0018380A	1032323A9	0EF2F2FC12	1	0	0	1	0	10	00	01
108	69	15650C3	00307015	006464752	1DE5E5F825	0	0	0	1	1	11	10	00
109	70	0ACA186	0060E02A	00C8C8EA4	3BCBCBF04B	1	0	0	1	1	00	11	10
110	71	159430C	00C1C055	019191D48	779797E097	0	1	0	1	0	11	00	11
111	72	0B28618	018380AA	032323A90	6F2F2FC12F	1	1	0	0	1	01	11	00
112	73	1650C30	03070154	064647520	5E5E5F825E	0	0	0	0	1	11	01	11
113	74	0CA1860	060E02A8	0C8C8EA40	3CBCBF04BC	1	0	1	1	0	11	11	01
114	75	19430C0	0C1C0550	19191D480	79797E0979	1	0	1	0	1	11	11	11
115	76	1286180	18380AA0	12323A900	72F2FC12F2	0	0	0	1	0	11	11	11
116	77	050C301	30701541	046475201	65E5F825E5	0	0	0	1	0	11	11	11
117	78	0A18602	60E02A82	08C8EA402	4BCBF04BCB	1	1	1	1	1	10	11	11
118	79	1430C04	41C05505	1191D4804	1797E09796	0	1	0	1	0	10	10	11
119	80	0861808	0380AA0A	0323A9008	2F2FC12F2C	1	1	0	0	0	01	10	10
120	81	10C3011	07015415	064752011	5E5F825E59	0	0	0	0	1	00	01	10
121	82	0186022	0E02A82A	0C8EA4022	3CBF04BCB2	0	0	1	1	0	10	00	01
122	83	030C045	1C055054	191D48044	797E097964	0	0	1	0	1	11	10	00
123	84	061808A	380AA0A8	123A90088	72FC12F2C9	0	0	0	1	0	00	11	10
124	85	0C30115	70154151	047520111	65F825E593	1	0	0	1	0	11	00	11
125	86	186022A	602A82A3	08EA40222	4BF04BCB26	1	0	1	1	0	00	11	00
126	87	10C0455	40550546	11D480444	17E097964C	0	0	0	1	1	10	00	11
127	88	01808AA	00AA0A8D	03A900888	2FC12F2C99	0	1	0	1	0	00	10	00
128	89	0301155	0154151A	075201111	5F825E5932	0	0	0	1	1	01	00	10
129	90	06022AA	02A82A34	0EA402222	3F04BCB264	0	1	1	0	1	00	01	00
130	91	0C04555	05505468	1D4804445	7E097964C9	1	0	1	0	0	10	00	01
131	92	1808AAA	0AA0A8D0	1A900888A	7C12F2C992	1	1	1	0	1	00	10	00
132	93	1011555	154151A1	152011115	7825E59324	0	0	0	0	0	01	00	10
133	94	0022AAB	2A82A342	0A402222B	704BCB2648	0	1	1	0	1	00	01	00
134	95	0045556	55054684	148044457	6097964C91	0	0	0	1	1	11	00	01
135	96	008AAAC	2A0A8D09	0900888AE	412F2C9923	0	0	1	0	0	01	11	00
136	97	0115559	54151A12	12011115D	025E593246	0	0	0	0	1	11	01	11
137	98	022AAB2	282A3424	0402222BA	04BCB2648D	0	0	0	1	0	10	11	01
138	99	0455564	50546848	080444575	097964C91A	0	0	1	0	1	01	10	11
139	100	08AAAC8	20A8D090	100888AEA	12F2C99235	1	1	0	1	0	10	01	10
140	101	1155591	4151A120	0011115D5	25E593246A	0	0	0	1	1	00	10	01
141	102	02AAB22	02A34240	002222BAA	4BCB2648D5	0	1	0	1	0	00	00	10
142	103	0555644	05468481	004445755	17964C91AB	0	0	0	1	1	00	00	00
143	104	0AAAC88	0A8D0903	00888AEAA	2F2C992357	1	1	0	0	0	01	00	00
144	105	1555911	151A1206	011115D55	5E593246AE	0	0	0	0	1	01	01	00
145	106	0AAB222	2A34240C	02222BAAA	3CB2648D5C	1	0	0	1	1	11	01	01

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146	107	1556445	54684818	044457555	7964C91AB8	0	0	0	0	1	01	11	01
147	108	0AAC88B	28D09030	0888AEAAA	72C9923571	1	1	1	1	1	01	01	11
148	109	1559117	51A12060	11115D555	6593246AE2	0	1	0	1	1	11	01	01
149	110	0AB222F	234240C0	0222BAAAB	4B2648D5C5	1	0	0	0	0	10	11	01
150	111	156445F	46848180	044575557	164C91AB8A	0	1	0	0	1	01	10	11
151	112	0AC88BF	0D090301	088AEAAAE	2C99235714	1	0	1	1	0	10	01	10
152	113	159117F	1A120602	1115D555D	593246AE28	0	0	0	0	0	00	10	01
153	114	0B222FE	34240C04	022BAAABA	32648D5C51	1	0	0	0	1	01	00	10
154	115	16445FD	68481809	045755574	64C91AB8A2	0	0	0	1	0	00	01	00
155	116	0C88BFA	50903012	08AEAAAE8	4992357144	1	1	1	1	0	01	00	01
156	117	19117F5	21206024	115D555D1	13246AE288	1	0	0	0	0	00	01	00
157	118	1222FEA	4240C048	02BAAABA2	2648D5C511	0	0	0	0	0	11	00	01
158	119	0445FD5	04818090	057555744	4C91AB8A23	0	1	0	1	1	01	11	00
159	120	088BFAA	09030120	0AEAAAE88	1923571446	1	0	1	0	1	10	01	11
160	121	1117F55	12060240	15D555D11	3246AE288D	0	0	0	0	0	00	10	01
161	122	022FEAA	240C0480	0BAAABA22	648D5C511B	0	0	1	1	0	00	00	10
162	123	045FD54	48180900	175557444	491AB8A237	0	0	0	0	0	00	00	00
163	124	08BFAA9	10301200	0EAAAE889	123571446F	1	0	1	0	0	01	00	00
164	125	117F553	20602400	1D555D113	246AE288DF	0	0	1	0	0	00	01	00
165	126	02FEAA7	40C04800	1AAABA227	48D5C511BE	0	1	1	1	1	10	00	01
166	127	05FD54F	01809001	15557444F	11AB8A237D	0	1	0	1	0	00	10	00
167	128	0BFAA9F	03012002	0AAAE889E	23571446FA	1	0	1	0	0	00	00	10
168	129	17F553F	06024004	1555D113D	46AE288DF5	0	0	0	1	1	00	00	00
169	130	0FEAA7E	0C048008	0AABA227A	0D5C511BEA	1	0	1	0	0	01	00	00
170	131	1FD54FC	18090011	1557444F5	1AB8A237D5	1	0	0	1	1	00	01	00
171	132	1FAA9F9	30120022	0AAE889EB	3571446FAA	1	0	1	0	0	10	00	01
172	133	1F553F2	60240044	155D113D7	6AE288DF55	1	0	0	1	0	00	10	00
173	134	1EAA7E4	40480089	0ABA227AE	55C511BEAA	1	0	1	1	1	00	00	10
174	135	1D54FC9	00900113	157444F5D	2B8A237D54	1	1	0	1	1	01	00	00
175	136	1AA9F93	01200227	0AE889EBA	571446FAA8	1	0	1	0	1	00	01	00
176	137	1553F26	0240044E	15D113D75	2E288DF550	0	0	0	0	0	11	00	01
177	138	0AA7E4C	0480089C	0BA227AEA	5C511BEAA0	1	1	1	0	0	00	11	00
178	139	154FC98	09001138	17444F5D4	38A237D540	0	0	0	1	1	10	00	11
179	140	0A9F931	12002270	0E889EBA9	71446FAA81	1	0	1	0	0	00	10	00
180	141	153F262	240044E0	1D113D753	6288DF5503	0	0	1	1	0	00	00	10
181	142	0A7E4C5	480089C0	1A227AEA7	4511BEAA06	1	0	1	0	0	01	00	00
182	143	14FC98B	10011381	1444F5D4F	0A237D540D	0	0	0	0	1	01	01	00
183	144	09F9316	20022702	0889EBA9E	1446FAA81A	1	0	1	0	1	11	01	01
184	145	13F262D	40044E04	1113D753D	288DF55035	0	0	0	1	0	10	11	01
185	146	07E4C5A	00089C08	0227AEA7A	511BEAA06A	0	0	0	0	0	01	10	11
186	147	0FC98B4	00113810	044F5D4F5	2237D540D5	1	0	0	0	0	01	01	10
187	148	1F93169	00227021	089EBA9EB	446FAA81AA	1	0	1	0	1	11	01	01
188	149	1F262D2	0044E042	113D753D7	08DF550355	1	0	0	1	1	10	11	01
189	150	1E4C5A4	0089C085	027AEA7AE	11BEAA06AA	1	1	0	1	1	10	10	11
190	151	1C98B48	0113810A	04F5D4F5C	237D540D54	1	0	0	0	1	10	10	10
191	152	1931691	02270215	09EBA9EB8	46FAA81AA9	1	0	1	1	1	01	10	10
192	153	1262D22	044E042A	13D753D71	0DF5503553	0	0	0	1	0	01	01	10
193	154	04C5A44	089C0854	07AEA7AE2	1BEAA06AA7	0	1	0	1	1	11	01	01
194	155	098B488	113810A8	0F5D4F5C4	37D540D54E	1	0	1	1	0	11	11	01
195	156	1316910	22702150	1EBA9EB89	6FAA81AA9D	0	0	1	1	1	11	11	11
196	157	062D220	44E042A0	1D753D712	5F5503553A	0	1	1	0	1	11	11	11
197	158	0C5A440	09C08540	1AEA7AE25	3EAA06AA75	1	1	1	1	1	10	11	11
198	159	18B4880	13810A80	15D4F5C4B	7D540D54EA	1	1	0	0	0	10	10	11
199	160	1169100	27021500	0BA9EB897	7AA81AA9D5	0	0	1	1	0	01	10	10
200	161	02D2201	4E042A00	1753D712E	75503553AB	0	0	0	0	1	00	01	10
201	162	05A4403	1C085400	0EA7AE25C	6AA06AA756	0	0	1	1	0	10	00	01
202	163	0B48807	3810A800	1D4F5C4B8	5540D54EAC	1	0	1	0	0	00	10	00

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203	164	169100F	70215000	1A9EB8971	2A81AA9D58	0	0	1	1	0	00	00	10
204	165	0D2201E	6042A001	153D712E3	5503553AB0	1	0	0	0	1	00	00	00
205	166	1A4403C	40854002	0A7AE25C6	2A06AA7561	1	1	1	0	1	01	00	00
206	167	1488079	010A8004	14F5C4B8D	540D54EAC3	0	0	0	0	1	01	01	00
207	168	09100F2	02150009	09EB8971B	281AA9D586	1	0	1	0	1	11	01	01
208	169	12201E5	042A0012	13D712E37	503553AB0C	0	0	0	0	1	01	11	01
209	170	04403CA	08540024	07AE25C6E	206AA75618	0	0	0	0	1	11	01	11
210	171	0880795	10A80048	0F5C4B8DD	40D54EAC30	1	1	1	1	1	11	11	01
211	172	1100F2A	21500091	1EB8971BA	01AA9D5861	0	0	1	1	1	11	11	11
212	173	0201E54	42A00122	1D712E374	03553AB0C3	0	1	1	0	1	11	11	11
213	174	0403CA9	05400244	1AE25C6E9	06AA756186	0	0	1	1	1	11	11	11
214	175	0807952	0A800488	15C4B8DD3	0D54EAC30D	1	1	0	0	1	11	11	11
215	176	100F2A5	15000911	0B8971BA6	1AA9D5861A	0	0	1	1	1	11	11	11
216	177	001E54A	2A001223	1712E374C	3553AB0C35	0	0	0	0	1	00	11	11
217	178	003CA94	54002446	0E25C6E98	6AA756186A	0	0	1	1	0	11	00	11
218	179	0079528	2800488D	1C4B8DD31	554EAC30D5	0	0	1	0	0	01	11	00
219	180	00F2A50	5000911B	18971BA62	2A9D5861AA	0	0	1	1	1	10	01	11
220	181	01E54A0	20012236	112E374C4	553AB0C355	0	0	0	0	0	00	10	01
221	182	03CA940	4002446C	025C6E988	2A756186AA	0	0	0	0	0	01	00	10
222	183	0795280	000488D9	04B8DD310	54EAC30D54	0	0	0	1	0	00	01	00
223	184	0F2A500	000911B2	0971BA620	29D5861AA8	1	0	1	1	1	10	00	01
224	185	1E54A00	00122364	12E374C40	53AB0C3550	1	0	0	1	0	00	10	00
225	186	1CA9400	002446C8	05C6E9880	2756186AA0	1	0	0	0	1	01	00	10
226	187	1952800	00488D90	0B8DD3101	4EAC30D540	1	0	1	1	0	11	01	00
227	188	12A5000	00911B20	171BA6202	1D5861AA81	0	1	0	0	0	10	11	01
228	189	054A000	01223640	0E374C404	3AB0C35502	0	0	1	1	0	10	10	11
229	190	0A94000	02446C80	1C6E98808	756186AA05	1	0	1	0	0	01	10	10
230	191	1528001	0488D901	18DD31011	6AC30D540B	0	1	1	1	0	10	01	10
231	192	0A50003	0911B203	11BA62023	55861AA817	1	0	0	1	0	11	10	01
232	193	14A0006	12236407	0374C4047	2B0C35502F	0	0	0	0	1	11	11	10
233	194	094000C	2446C80E	06E98808E	56186AA05F	1	0	0	0	0	11	11	11
234	195	1280018	488D901C	0DD31011D	2C30D540BF	0	1	1	0	1	11	11	11
235	196	0500030	111B2039	1BA62023A	5861AA817E	0	0	1	0	0	11	11	11
236	197	0A00060	22364072	174C40475	30C35502FD	1	0	0	1	1	11	11	11
237	198	14000C0	446C80E4	0E98808EA	6186AA05FB	0	0	1	1	1	11	11	11
238	199	0800180	08D901C8	1D31011D5	430D540BF6	1	1	1	0	0	10	11	11
239	200	1000301	11B20391	1A62023AB	061AA817EC	0	1	1	0	0	10	10	11

```
Z[0]  = 25
Z[1]  = 45
Z[2]  = 6B
Z[3]  = 55
Z[4]  = 5F
Z[5]  = C2
Z[6]  = 20
Z[7]  = E5
Z[8]  = C4
Z[9]  = F8
Z[10] = 3A
Z[11] = F1
Z[12] = FF
Z[13] = 89
Z[14] = 02
Z[15] = 35

================================================================================================
         Reload this pattern into the LFSRs
```


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```
         Hold content of Summation Combiner regs and calculate new C[t+1] and Z values
================================================================================================
LFSR1  <= 1C45F25
LFSR2  <= 7FF8C245
LFSR3  <= 1893A206B
LFSR4  <= 1A02F1E555
C[t+1] <= 10

================================================================================================
         Generating 125 key symbols (encryption/decryption sequence)
================================================================================================
```

240	1	1C45F25	7FF8C245	1893A206B	1A02F1E555	1	1	1	0	1	10	10	11
241	2	188BE4A	7FF1848B	1127440D7	3405E3CAAB	1	1	0	0	0	01	10	10
242	3	1117C95	7FE30917	024E881AF	680BC79557	0	1	0	0	0	01	01	10
243	4	022F92B	7FC6122F	049D1035E	50178F2AAF	0	1	0	0	0	11	01	01
244	5	045F257	7F8C245E	093A206BD	202F1E555E	0	1	1	0	1	10	11	01
245	6	08BE4AE	7F1848BC	127440D7A	405E3CAABC	1	0	0	0	1	01	10	11
246	7	117C95C	7E309178	04E881AF4	00BC795579	0	0	0	1	0	01	01	10
247	8	02F92B8	7C6122F0	09D1035E8	0178F2AAF2	0	0	1	0	0	11	01	01
248	9	05F2570	78C245E1	13A206BD0	02F1E555E5	0	1	0	1	1	10	11	01
249	10	0BE4AE1	71848BC2	07440D7A0	05E3CAABCA	1	1	0	1	1	10	10	11
250	11	17C95C3	63091784	0E881AF40	0BC7955795	0	0	1	1	0	01	10	10
251	12	0F92B87	46122F09	1D1035E80	178F2AAF2B	1	0	1	1	0	10	01	10
252	13	1F2570F	0C245E12	1A206BD01	2F1E555E56	1	0	1	0	0	11	10	01
253	14	1E4AE1F	1848BC25	1440D7A03	5E3CAABCAC	1	0	0	0	0	00	11	10
254	15	1C95C3E	3091784A	0881AF407	3C79557958	1	1	1	0	1	11	00	11
255	16	192B87D	6122F094	11035E80F	78F2AAF2B1	1	0	0	1	1	01	11	00
256	17	12570FA	4245E128	0206BD01E	71E555E562	0	0	0	1	0	10	01	11
257	18	04AE1F4	048BC250	040D7A03D	63CAABCAC5	0	1	0	1	0	11	10	01
258	19	095C3E8	091784A0	081AF407A	479557958A	1	0	1	1	0	01	11	10
259	20	12B87D1	122F0941	1035E80F4	0F2AAF2B14	0	0	0	0	1	11	01	11
260	21	0570FA3	245E1283	006BD01E9	1E555E5628	0	0	0	0	1	01	11	01
261	22	0AE1F46	48BC2506	00D7A03D2	3CAABCAC50	1	1	0	1	0	01	01	11
262	23	15C3E8C	11784A0C	01AF407A5	79557958A0	0	0	0	0	1	10	01	01
263	24	0B87D18	22F09419	035E80F4A	72AAF2B140	1	1	0	1	1	11	10	01
264	25	170FA30	45E12832	06BD01E94	6555E56280	0	1	0	0	0	00	11	10
265	26	0E1F460	0BC25065	0D7A03D28	4AABCAC501	1	1	1	1	0	00	00	11
266	27	1C3E8C0	1784A0CB	1AF407A50	1557958A03	1	1	1	0	1	01	00	00
267	28	187D181	2F094196	15E80F4A0	2AAF2B1406	1	0	0	1	1	00	01	00
268	29	10FA302	5E12832C	0BD01E941	555E56280C	0	0	1	0	1	11	00	01
269	30	01F4604	3C250658	17A03D283	2ABCAC5019	0	0	0	1	0	01	11	00
270	31	03E8C09	784A0CB0	0F407A506	557958A033	0	0	1	0	0	10	01	11
271	32	07D1812	70941960	1E80F4A0C	2AF2B14066	0	1	1	1	1	11	10	01
272	33	0FA3024	612832C1	1D01E9419	55E56280CD	1	0	1	1	0	01	11	10
273	34	1F46049	42506583	1A03D2832	2BCAC5019A	1	0	1	1	0	01	01	11
274	35	1E8C093	04A0CB07	1407A5065	57958A0335	1	1	0	1	0	00	01	01
275	36	1D18127	0941960F	080F4A0CB	2F2B14066B	1	0	1	0	0	10	00	01
276	37	1A3024F	12832C1F	101E94196	5E56280CD7	1	1	0	0	0	00	10	00
277	38	146049F	2506583E	003D2832C	3CAC5019AE	0	0	0	1	1	01	00	10
278	39	08C093E	4A0CB07D	007A50658	7958A0335D	1	0	0	0	0	00	01	00
279	40	118127C	141960FA	00F4A0CB0	72B14066BA	0	0	0	1	1	11	00	01
280	41	03024F8	2832C1F4	01E941961	656280CD74	0	0	0	0	1	10	11	00
281	42	06049F1	506583E9	03D2832C2	4AC5019AE9	0	0	0	1	1	01	10	11
282	43	0C093E2	20CB07D2	07A506585	158A0335D3	1	1	0	1	0	10	01	10
283	44	18127C5	41960FA5	0F4A0CB0B	2B14066BA7	1	1	1	0	1	11	10	01
284	45	1024F8A	032C1F4B	1E9419616	56280CD74F	0	0	1	0	0	00	11	10
285	46	0049F15	06583E97	1D2832C2C	2C5019AE9F	0	0	1	0	1	10	00	11

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286	47	0093E2B	0CB07D2F	1A5065859	58A0335D3E	0	1	1	1	1	00	10	00
287	48	0127C56	1960FA5E	14A0CB0B2	314066BA7D	0	0	0	0	0	01	00	10
288	49	024F8AD	32C1F4BC	094196164	6280CD74FB	0	1	1	1	0	11	01	00
289	50	049F15A	6583E978	12832C2C8	45019AE9F6	0	1	0	0	0	10	11	01
290	51	093E2B5	4B07D2F0	050658591	0A0335D3ED	1	0	0	0	1	01	10	11
291	52	127C56B	160FA5E0	0A0CB0B22	14066BA7DA	0	0	1	0	0	01	01	10
292	53	04F8AD7	2C1F4BC1	141961645	280CD74FB5	0	0	0	0	1	10	01	01
293	54	09F15AF	583E9783	0832C2C8A	5019AE9F6A	1	0	1	0	0	11	10	01
294	55	13E2B5E	307D2F06	106585915	20335D3ED5	0	0	0	0	1	11	11	10
295	56	07C56BD	60FA5E0D	00CB0B22B	4066BA7DAA	0	1	0	0	0	11	11	11
296	57	0F8AD7A	41F4BC1B	019616457	00CD74FB54	1	1	0	1	0	10	11	11
297	58	1F15AF4	03E97836	032C2C8AF	019AE9F6A9	1	1	0	1	1	10	10	11
298	59	1E2B5E9	07D2F06C	06585915E	0335D3ED52	1	1	0	0	0	01	10	10
299	60	1C56BD2	0FA5E0D8	0CB0B22BC	066BA7DAA4	1	1	1	0	0	10	01	10
300	61	18AD7A5	1F4BC1B0	196164578	0CD74FB549	1	0	1	1	1	11	10	01
301	62	115AF4B	3E978361	12C2C8AF0	19AE9F6A92	0	1	0	1	1	00	11	10
302	63	02B5E96	7D2F06C2	0585915E0	335D3ED524	0	0	0	0	0	10	00	11
303	64	056BD2D	7A5E0D85	0B0B22BC1	66BA7DAA49	0	0	1	1	0	00	10	00
304	65	0AD7A5B	74BC1B0A	161645783	4D74FB5493	1	1	0	0	0	00	00	10
305	66	15AF4B6	69783615	0C2C8AF07	1AE9F6A926	0	0	1	1	0	01	00	00
306	67	0B5E96D	52F06C2B	185915E0F	35D3ED524C	1	1	1	1	1	11	01	00
307	68	16BD2DB	25E0D857	10B22BC1F	6BA7DAA499	0	1	0	1	1	10	11	01
308	69	0D7A5B7	4BC1B0AF	01645783F	574FB54933	1	1	0	0	0	10	10	11
309	70	1AF4B6F	1783615F	02C8AF07F	2E9F6A9266	1	1	0	1	1	01	10	10
310	71	15E96DF	2F06C2BF	05915E0FF	5D3ED524CC	0	0	0	0	1	00	01	10
311	72	0BD2DBF	5E0D857F	0B22BC1FE	3A7DAA4998	1	0	1	0	0	10	00	01
312	73	17A5B7F	3C1B0AFE	1645783FD	74FB549331	0	0	0	1	1	11	10	00
313	74	0F4B6FF	783615FD	0C8AF07FA	69F6A92662	1	0	1	1	0	01	11	10
314	75	1E96DFF	706C2BFB	1915E0FF5	53ED524CC4	1	0	1	1	0	01	01	11
315	76	1D2DBFE	60D857F6	122BC1FEB	27DAA49988	1	1	0	1	0	00	01	01
316	77	1A5B7FD	41B0AFEC	045783FD7	4FB5493310	1	1	0	1	1	10	00	01
317	78	14B6FFA	03615FD8	08AF07FAE	1F6A926620	0	0	1	0	1	11	10	00
318	79	096DFF4	06C2BFB1	115E0FF5D	3ED524CC40	1	1	0	1	0	01	11	10
319	80	12DBFE8	0D857F63	02BC1FEBB	7DAA499881	0	1	0	1	1	10	01	11
320	81	05B7FD0	1B0AFEC6	05783FD77	7B54933103	0	0	0	0	0	00	10	01
321	82	0B6FFA1	3615FD8C	0AF07FAEF	76A9266206	1	0	1	1	1	00	00	10
322	83	16DFF42	6C2BFB18	15E0FF5DE	6D524CC40C	0	0	0	0	0	00	00	00
323	84	0DBFE85	5857F631	0BC1FEBBD	5AA4998819	1	0	1	1	1	01	00	00
324	85	1B7FD0B	30AFEC62	1783FD77A	3549331033	1	1	0	0	1	00	01	00
325	86	16FFA16	615FD8C5	0F07FAEF5	6A92662067	0	0	1	1	0	10	00	01
326	87	0DFF42D	42BFB18B	1E0FF5DEA	5524CC40CE	1	1	1	0	1	00	10	00
327	88	1BFE85B	057F6317	1C1FEBBD5	2A4998819C	1	0	1	0	0	00	00	10
328	89	17FD0B7	0AFEC62E	183FD77AA	5493310339	0	1	1	1	1	01	00	00
329	90	0FFA16F	15FD8C5C	107FAEF55	2926620672	1	1	0	0	1	00	01	00
330	91	1FF42DF	2BFB18B9	00FF5DEAA	524CC40CE5	1	1	0	0	0	10	00	01
331	92	1FE85BF	57F63172	01FEBBD55	24998819CA	1	1	0	1	1	00	10	00
332	93	1FD0B7F	2FEC62E4	03FD77AAA	4933103394	1	1	0	0	0	00	00	10
333	94	1FA16FF	5FD8C5C9	07FAEF555	1266206728	1	1	0	0	0	01	00	00
334	95	1F42DFF	3FB18B93	0FF5DEAAA	24CC40CE51	1	1	1	1	1	11	01	00
335	96	1E85BFF	7F631727	1FEBBD554	4998819CA3	1	0	1	1	0	11	11	01
336	97	1D0B7FE	7EC62E4F	1FD77AAA9	1331033947	1	1	1	0	0	10	11	11
337	98	1A16FFC	7D8C5C9F	1FAEF5553	266206728E	1	1	1	0	1	10	10	11
338	99	142DFF9	7B18B93F	1F5DEAAA7	4CC40CE51D	0	0	1	1	0	01	10	10
339	100	085BFF3	7631727F	1EBBD554E	198819CA3B	1	0	1	1	0	10	01	10
340	101	10B7FE6	6C62E4FF	1D77AAA9C	3310339477	0	0	1	0	1	00	10	01
341	102	016FFCC	58C5C9FE	1AEF55538	66206728EE	0	1	1	0	0	00	00	10
342	103	02DFF98	318B93FC	15DEAAA70	4C40CE51DC	0	1	0	0	1	00	00	00

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Sample Data

343	104	05BFF31	631727F8	0BBD554E1	18819CA3B9	0	0	1	1	0	01	00	00
344	105	0B7FE62	462E4FF1	177AAA9C2	3103394772	1	0	0	0	0	00	01	00
345	106	16FFCC5	0C5C9FE2	0EF555384	6206728EE4	0	0	1	0	1	11	00	01
346	107	0DFF98A	18B93FC4	1DEAAA709	440CE51DC9	1	1	1	0	0	00	11	00
347	108	1BFF315	31727F88	1BD554E12	0819CA3B93	1	0	1	0	0	11	00	11
348	109	17FE62A	62E4FF11	17AAA9C24	1033947726	0	1	0	0	0	01	11	00
349	110	0FFCC54	45C9FE22	0F5553849	206728EE4C	1	1	1	0	0	01	01	11
350	111	1FF98A8	0B93FC44	1EAAA7093	40CE51DC99	1	1	1	1	1	00	01	01
351	112	1FF3150	1727F889	1D554E127	019CA3B933	1	0	1	1	1	10	00	01
352	113	1FE62A0	2E4FF112	1AAA9C24F	0339477267	1	0	1	0	0	00	10	00
353	114	1FCC541	5C9FE225	15553849E	06728EE4CF	1	1	0	0	0	00	00	10
354	115	1F98A82	393FC44B	0AAA7093C	0CE51DC99F	1	0	1	1	1	01	00	00
355	116	1F31504	727F8897	1554E1279	19CA3B933E	1	0	0	1	1	00	01	00
356	117	1E62A09	64FF112F	0AA9C24F2	339477267D	1	1	1	1	0	01	00	01
357	118	1CC5412	49FE225E	1553849E4	6728EE4CFB	1	1	0	0	1	00	01	00
358	119	198A824	13FC44BC	0AA7093C9	4E51DC99F7	1	1	1	0	1	10	00	01
359	120	1315049	27F88979	154E12792	1CA3B933EE	0	1	0	1	0	00	10	00
360	121	062A093	4FF112F3	0A9C24F24	39477267DC	0	1	1	0	0	00	00	10
361	122	0C54127	1FE225E6	153849E48	728EE4CFB8	1	1	0	1	1	01	00	00
362	123	18A824E	3FC44BCD	0A7093C91	651DC99F71	1	1	1	0	0	11	01	00
363	124	115049C	7F88979A	14E127922	4A3B933EE2	0	1	0	0	0	10	11	01
364	125	02A0938	7F112F35	09C24F244	1477267DC5	0	0	1	0	1	01	10	11

1.4 THIRD SET OF SAMPLES

```
Initial values for the key, pan address and clock

K'c3[0]   = FF   K'c3[1]   = FF    K'c3[2]   = FF    K'c3[3]  = FF
K'c3[4]   = FF   K'c3[5]   = FF    K'c3[6]   = FF    K'c3[7]  = FF
K'c3[8]   = FF   K'c3[9]   = FF    K'c3[10]  = FF    K'c3[11] = FF
K'c3[12]  = FF   K'c3[13]  = FF    K'c3[14]  = FF    K'c3[15] = FF

Addr3[0] = FF   Addr3[1] = FF    Addr3[2] = FF
Addr3[3] = FF   Addr3[4] = FF    Addr3[5] = FF

CL3[0]  = FF   CL3[1]  = FF    CL3[2]  = FF    CL3[3]  = 03


=============================================================================================
         Fill LFSRs with initial data
=============================================================================================

  t  clk#    LFSR1    LFSR2     LFSR3      LFSR4           X1 X2 X3 X4   Z  C[t+1] C[t] C[t-1]

  0     0    0000000* 00000000* 000000000* 0000000000*     0  0  0  0    0  00      00   00
  1     1    0000001* 00000001* 000000001* 0000000001*     0  0  0  0    0  00      00   00
  2     2    0000003* 00000002* 000000003* 0000000003*     0  0  0  0    0  00      00   00
  3     3    0000007* 00000004* 000000007* 0000000007*     0  0  0  0    0  00      00   00
  4     4    000000F* 00000009* 00000000F* 000000000F*     0  0  0  0    0  00      00   00
  5     5    000001F* 00000013* 00000001F* 000000001F*     0  0  0  0    0  00      00   00
  6     6    000003F* 00000027* 00000003F* 000000003F*     0  0  0  0    0  00      00   00
  7     7    000007F* 0000004F* 00000007F* 000000007F*     0  0  0  0    0  00      00   00
  8     8    00000FF* 0000009F* 0000000FF* 00000000FF*     0  0  0  0    0  00      00   00
  9     9    00001FF* 0000013F* 0000001FF* 00000001FF*     0  0  0  0    0  00      00   00
 10    10    00003FF* 0000027F* 0000003FF* 00000003FF*     0  0  0  0    0  00      00   00
 11    11    00007FF* 000004FF* 0000007FF* 00000007FF*     0  0  0  0    0  00      00   00
 12    12    0000FFF* 000009FF* 000000FFF* 0000000FFF*     0  0  0  0    0  00      00   00
 13    13    0001FFF* 000013FF* 000001FFF* 0000001FFF*     0  0  0  0    0  00      00   00
 14    14    0003FFF* 000027FF* 000003FFF* 0000003FFF*     0  0  0  0    0  00      00   00
 15    15    0007FFF* 00004FFF* 000007FFF* 0000007FFF*     0  0  0  0    0  00      00   00
 16    16    000FFFF* 00009FFF* 00000FFFF* 000000FFFF*     0  0  0  0    0  00      00   00
 17    17    001FFFF* 00013FFF* 00001FFFF* 000001FFFF*     0  0  0  0    0  00      00   00
 18    18    003FFFF* 00027FFF* 00003FFFF* 000003FFFF*     0  0  0  0    0  00      00   00
 19    19    007FFFF* 0004FFFF* 00007FFFF* 000007FFFF*     0  0  0  0    0  00      00   00
 20    20    00FFFFF* 0009FFFF* 0000FFFFF* 00000FFFFF*     0  0  0  0    0  00      00   00
 21    21    01FFFFF* 0013FFFF* 0001FFFFF* 00001FFFFF*     0  0  0  0    0  00      00   00
 22    22    03FFFFF* 0027FFFF* 0003FFFFF* 00003FFFFF*     0  0  0  0    0  00      00   00
 23    23    07FFFFF* 004FFFFF* 0007FFFFF* 00007FFFFF*     0  0  0  0    0  00      00   00
 24    24    0FFFFFF* 009FFFFF* 000FFFFFF* 0000FFFFFF*     1  1  0  0    0  01      00   00
 25    25    1FFFFFF* 013FFFFF* 001FFFFFF* 0001FFFFFF*     1  0  0  0    1  00      00   00
 26    26    1FFFFFF  027FFFFF* 003FFFFFF* 0003FFFFFF*     1  0  0  0    1  00      00   00
 27    27    1FFFFFF  04FFFFFF* 007FFFFFF* 0007FFFFFF*     1  1  0  0    0  01      00   00
 28    28    1FFFFFF  09FFFFFF* 00FFFFFFF* 000FFFFFFF*     1  1  0  0    0  01      00   00
 29    29    1FFFFFF  13FFFFFF* 01FFFFFFF* 001FFFFFFF*     1  1  0  0    0  01      00   00
 30    30    1FFFFFF  27FFFFFF* 03FFFFFFF* 003FFFFFFF*     1  1  0  0    0  01      00   00
 31    31    1FFFFFF  4FFFFFFF* 07FFFFFFF* 007FFFFFFF*     1  1  0  0    0  01      00   00
 32    32    1FFFFFF  1FFFFFFF  0FFFFFFFF* 00FFFFFFFF*     1  1  1  1    0  10      00   00
 33    33    1FFFFFF  3FFFFFFE  1FFFFFFFF* 01FFFFFFFF*     1  1  1  1    0  10      00   00
 34    34    1FFFFFF  7FFFFFFC  1FFFFFFFF  03FFFFFFFF*     1  1  1  1    0  10      00   00
```

35	35	1FFFFFF	7FFFFFF9	1FFFFFFFF	07FFFFFFFF*	1	1	1	1	0	10	00	00
36	36	1FFFFFF	7FFFFFF3	1FFFFFFFF	0FFFFFFFFF*	1	1	1	1	0	10	00	00
37	37	1FFFFFF	7FFFFFE7	1FFFFFFFF	1FFFFFFFFF*	1	1	1	1	0	10	00	00
38	38	1FFFFFF	7FFFFFCF	1FFFFFFFF	3FFFFFFFFF*	1	1	1	1	0	10	00	00
39	39	1FFFFFF	7FFFFF9F	1FFFFFFFF	7FFFFFFFFF*	1	1	1	1	0	10	00	00

Start clocking Summation Combiner

40	1	1FFFFFF	7FFFF3F	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	01	10	00
41	2	1FFFFFF	7FFFE7F	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	1	10	01	10
42	3	1FFFFFF	7FFFCFF	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	10	10	01
43	4	1FFFFFF	7FFF9FF	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	00	10	10
44	5	1FFFFFF	7FFF3FF	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	11	00	10
45	6	1FFFFFF	7FFE7FE	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	1	00	11	00
46	7	1FFFFFF	7FFCFFC	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	00	00	11
47	8	1FFFFFF	7FF9FF9	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	10	00	00
48	9	1FFFFFF	7FF3FF3	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	0	01	10	00
49	10	1FFFFFF	7FE7FE6	1FFFFFFFF	7FFFFFFFFF	1	1	1	1	1	10	01	10
50	11	1FFFFFE	7FFCFFCC	1FFFFFFFE	7FFFFFFFFF	1	1	1	1	0	10	10	01
51	12	1FFFFFC	7FF9FF99	1FFFFFFFC	7FFFFFFFFF	1	1	1	1	0	00	10	10
52	13	1FFFFF8	7FF3FF33	1FFFFFFF8	7FFFFFFFFF	1	1	1	1	0	11	00	10
53	14	1FFFFF0	7FE7FE67	1FFFFFFF0	7FFFFFFFFF	1	1	1	1	1	00	11	00
54	15	1FFFFE0	7FCFFCCF	1FFFFFFE1	7FFFFFFFFF	1	1	1	1	0	00	00	11
55	16	1FFFFC0	7F9FF99F	1FFFFFFC3	7FFFFFFFFF	1	1	1	1	0	10	00	00
56	17	1FFFF80	7F3FF33E	1FFFFFF87	7FFFFFFFFE	1	0	1	1	1	00	10	00
57	18	1FFFF00	7E7FE67C	1FFFFFF0F	7FFFFFFFFC	1	0	1	1	1	00	00	10
58	19	1FFFE01	7CFFCCF8	1FFFFFE1E	7FFFFFFFF8	1	1	1	1	0	10	00	00
59	20	1FFFC03	79FF99F0	1FFFFFC3C	7FFFFFFFF0	1	1	1	1	0	01	10	00
60	21	1FFF807	73FF33E0	1FFFFF878	7FFFFFFFE1	1	1	1	1	1	10	01	10
61	22	1FFF00F	67FE67C0	1FFFFF0F0	7FFFFFFFC3	1	1	1	1	0	10	10	01
62	23	1FFE01E	4FFCCF80	1FFFFE1E1	7FFFFFFF87	1	1	1	1	0	00	10	10
63	24	1FFC03C	1FF99F00	1FFFFC3C3	7FFFFFFF0F	1	1	1	1	0	11	00	10
64	25	1FF8078	3FF33E01	1FFFF8787	7FFFFFFE1E	1	1	1	1	1	00	11	00
65	26	1FF00F0	7FE67C02	1FFFF0F0F	7FFFFFFC3C	1	1	1	1	0	00	00	11
66	27	1FE01E1	7FCCF805	1FFFE1E1E	7FFFFFF878	1	1	1	1	0	10	00	00
67	28	1FC03C3	7F99F00A	1FFFC3C3C	7FFFFFF0F0	1	1	1	1	0	01	10	00
68	29	1F80787	7F33E015	1FFF87878	7FFFFFE1E1	1	0	1	1	0	10	01	10
69	30	1F00F0F	7E67C02A	1FFF0F0F0	7FFFFFC3C3	1	0	1	1	1	11	10	01
70	31	1E01E1E	7CCF8054	1FFE1E1E1	7FFFFF8787	1	1	1	1	1	01	11	10
71	32	1C03C3C	799F00A9	1FFC3C3C3	7FFFFF0F0F	1	1	1	1	1	01	01	11
72	33	1807878	733E0152	1FF878787	7FFFFE1E1E	1	0	1	1	0	00	01	01
73	34	100F0F0	667C02A5	1FF0F0F0F	7FFFFC3C3C	0	0	1	1	0	10	00	01
74	35	001E1E0	4CF8054B	1FE1E1E1F	7FFFF87878	0	1	1	1	1	00	10	00
75	36	003C3C1	19F00A96	1FC3C3C3F	7FFFF0F0F0	0	1	1	1	1	00	00	10
76	37	0078783	33E0152C	1F878787F	7FFFE1E1E1	0	1	1	1	1	01	00	00
77	38	00F0F07	67C02A59	1F0F0F0FF	7FFFC3C3C3	0	1	1	1	0	11	01	00
78	39	01E1E0E	4F8054B3	1E1E1E1FF	7FFF878787	0	1	1	1	0	11	11	01
79	40	03C3C1C	1F00A966	1C3C3C3FF	7FFF0F0F0F	0	0	1	1	1	11	11	11
80	41	0787838	3E0152CC	1878787FF	7FFE1E1E1E	0	0	1	1	1	11	11	11
81	42	0F0F070	7C02A598	10F0F0FFF	7FFC3C3C3C	1	0	0	1	1	11	11	11
82	43	1E1E0E0	78054B30	01E1E1FFF	7FF8787878	1	0	0	1	1	11	11	11
83	44	1C3C1C0	700A9660	03C3C3FFE	7FF0F0F0F0	1	0	0	1	1	11	11	11
84	45	1878380	60152CC0	078787FFC	7FE1E1E1E0	1	0	0	1	1	11	11	11
85	46	10F0700	402A5980	0F0F0FFF8	7FC3C3C3C0	0	0	1	1	1	11	11	11
86	47	01E0E00	0054B300	1E1E1FFF0	7F87878780	0	0	1	1	1	11	11	11
87	48	03C1C00	00A96601	1C3C3FFE0	7F0F0F0F00	0	1	1	0	1	11	11	11
88	49	0783800	0152CC03	18787FFC0	7E1E1E1E01	0	0	1	0	0	11	11	11

Sample Data

89	50	0F07000	02A59806	10F0FFF80	7C3C3C3C03	1	1	0	0	1	11	11	11
90	51	1E0E000	054B300D	01E1FFF00	7878787807	1	0	0	0	0	11	11	11
91	52	1C1C001	0A96601A	03C3FFE01	70F0F0F00F	1	1	0	1	0	10	11	11
92	53	1838003	152CC035	0787FFC03	61E1E1E01E	1	0	0	1	0	10	10	11
93	54	1070007	2A59806B	0F0FFF807	43C3C3C03C	0	0	1	1	0	01	10	10
94	55	00E000F	54B300D7	1E1FFF00F	0787878078	0	1	1	1	0	10	01	10
95	56	01C001F	296601AE	1C3FFE01F	0F0F0F00F1	0	0	1	0	1	00	10	01
96	57	038003F	52CC035C	187FFC03F	1E1E1E01E2	0	1	1	0	0	00	00	10
97	58	070007F	259806B8	10FFF807F	3C3C3C03C4	0	1	0	0	1	00	00	00
98	59	0E000FE	4B300D71	01FFF00FE	7878780788	1	0	0	0	1	00	00	00
99	60	1C001FD	16601AE2	03FFE01FD	70F0F00F10	1	0	0	1	0	01	00	00
100	61	18003FA	2CC035C5	07FFC03FB	61E1E01E21	1	1	0	1	0	11	01	00
101	62	10007F4	59806B8B	0FFF807F7	43C3C03C43	0	1	1	1	0	11	11	01
102	63	0000FE8	3300D717	1FFF00FEE	0787807887	0	0	1	1	1	11	11	11
103	64	0001FD0	6601AE2F	1FFE01FDC	0F0F00F10E	0	0	1	0	0	11	11	11
104	65	0003FA0	4C035C5F	1FFC03FB8	1E1E01E21D	0	0	1	0	0	11	11	11
105	66	0007F40	1806B8BE	1FF807F70	3C3C03C43B	0	0	1	0	0	11	11	11
106	67	000FE81	300D717C	1FF00FEE1	7878078877	0	0	1	0	0	11	11	11
107	68	001FD02	601AE2F8	1FE01FDC2	70F00F10EF	0	0	1	1	1	11	11	11
108	69	003FA05	4035C5F0	1FC03FB84	61E01E21DE	0	0	1	1	1	11	11	11
109	70	007F40B	006B8BE0	1F807F708	43C03C43BC	0	0	1	1	1	11	11	11
110	71	00FE816	00D717C0	1F00FEE11	0780788778	0	1	1	1	0	10	11	11
111	72	01FD02C	01AE2F81	1E01FDC23	0F00F10EF1	0	1	1	0	0	10	10	11
112	73	03FA059	035C5F02	1C03FB847	1E01E21DE3	0	0	1	0	1	10	10	10
113	74	07F40B3	06B8BE05	1807F708F	3C03C43BC7	0	1	1	0	0	01	10	10
114	75	0FE8166	0D717C0B	100FEE11E	780788778F	1	0	0	0	0	01	01	10
115	76	1FD02CD	1AE2F817	001FDC23D	700F10EF1F	1	1	0	0	1	11	01	01
116	77	1FA059B	35C5F02F	003FB847A	601E21DE3F	1	1	0	0	1	10	11	01
117	78	1F40B37	6B8BE05E	007F708F4	403C43BC7F	1	1	0	0	0	10	10	11
118	79	1E8166E	5717C0BD	00FEE11E9	00788778FF	1	0	0	0	1	10	10	10
119	80	1D02CDC	2E2F817A	01FDC23D3	00F10EF1FE	1	0	0	1	0	01	10	10
120	81	1A059B9	5C5F02F5	03FB847A6	01E21DE3FD	1	0	0	1	1	01	01	10
121	82	140B373	38BE05EB	07F708F4C	03C43BC7FB	0	1	0	1	1	11	01	01
122	83	08166E7	717C0BD7	0FEE11E98	0788778FF7	1	0	1	1	0	11	11	01
123	84	102CDCF	62F817AE	1FDC23D31	0F10EF1FEF	0	1	1	0	1	11	11	11
124	85	0059B9F	45F02F5C	1FB847A63	1E21DE3FDE	0	1	1	0	1	11	11	11
125	86	00B373E	0BE05EB9	1F708F4C7	3C43BC7FBC	0	1	1	0	1	11	11	11
126	87	0166E7D	17C0BD72	1EE11E98F	788778FF78	0	1	1	1	0	10	11	11
127	88	02CDCFB	2F817AE5	1DC23D31F	710EF1FEF1	0	1	1	0	0	10	10	11
128	89	059B9F7	5F02F5CA	1B847A63F	621DE3FDE2	0	0	1	0	1	10	10	10
129	90	0B373EF	3E05EB94	1708F4C7F	443BC7FBC4	1	0	0	0	1	10	10	10
130	91	166E7DF	7C0BD728	0E11E98FF	08778FF788	0	0	1	0	1	10	10	10
131	92	0CDCFBE	7817AE50	1C23D31FF	10EF1FEF10	1	0	1	1	1	01	10	10
132	93	19B9F7D	702F5CA1	1847A63FE	21DE3FDE21	1	0	1	1	0	10	01	10
133	94	1373EFB	605EB942	108F4C7FC	43BC7FBC43	0	0	0	1	1	00	10	01
134	95	06E7DF7	40BD7285	011E98FF8	0778FF7886	0	1	0	0	1	01	00	10
135	96	0DCFBEF	017AE50A	023D31FF0	0EF1FEF10D	1	0	0	1	1	00	01	00
136	97	1B9F7DF	02F5CA15	047A63FE1	1DE3FDE21A	1	1	0	1	1	10	00	01
137	98	173EFBF	05EB942B	08F4C7FC3	3BC7FBC434	0	1	1	1	1	00	10	00
138	99	0E7DF7F	0BD72856	11E98FF87	778FF78869	1	1	0	1	1	00	00	10
139	100	1CFBEFF	17AE50AC	03D31FF0F	6F1FEF10D3	1	1	0	0	0	01	00	00
140	101	19F7DFE	2F5CA159	07A63FE1E	5E3FDE21A7	1	0	0	0	0	00	01	00
141	102	13EFBFC	5EB942B3	0F4C7FC3C	3C7FBC434F	0	1	1	0	0	10	00	01
142	103	07DF7F8	3D728566	1E98FF878	78FF78869F	0	0	1	1	0	00	10	00
143	104	0FBEFF0	7AE50ACD	1D31FF0F0	71FEF10D3E	1	1	1	1	0	11	00	10
144	105	1F7DFE1	75CA159B	1A63FE1E1	63FDE21A7D	1	1	1	1	1	00	11	00
145	106	1EFBFC3	6B942B36	14C7FC3C3	47FBC434FB	1	1	0	1	1	11	00	11

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146	107	1DF7F86	5728566D	098FF8786	0FF78869F7	1	0	1	1	0	00	11	00
147	108	1BEFF0C	2E50ACDB	131FF0F0C	1FEF10D3EF	1	0	0	1	0	11	00	11
148	109	17DFE19	5CA159B6	063FE1E19	3FDE21A7DF	0	1	0	1	1	01	11	00
149	110	0FBFC33	3942B36D	0C7FC3C32	7FBC434FBF	1	0	1	1	0	01	01	11
150	111	1F7F866	728566DB	18FF87865	7F78869F7E	1	1	1	0	0	00	01	01
151	112	1EFF0CC	650ACDB6	11FF0F0CB	7EF10D3EFC	1	0	0	1	0	10	00	01
152	113	1DFE199	4A159B6D	03FE1E196	7DE21A7DF9	1	0	0	1	0	00	10	00
153	114	1BFC333	142B36DB	07FC3C32C	7BC434FBF3	1	0	0	1	0	00	00	10
154	115	17F8666	28566DB6	0FF878659	778869F7E6	0	0	1	1	0	01	00	00
155	116	0FF0CCC	50ACDB6D	1FF0F0CB3	6F10D3EFCC	1	1	1	0	0	11	01	00
156	117	1FE1999	2159B6DA	1FE1E1966	5E21A7DF99	1	0	1	0	1	10	11	01
157	118	1FC3332	42B36DB5	1FC3C32CC	3C434FBF33	1	1	1	0	1	10	10	11
158	119	1F86664	0566DB6B	1F8786599	78869F7E67	1	0	1	1	1	01	10	10
159	120	1F0CCC8	0ACDB6D6	1F0F0CB33	710D3EFCCE	1	1	1	0	0	10	01	10
160	121	1E19991	159B6DAC	1E1E19666	621A7DF99D	1	1	1	0	1	11	10	01
161	122	1C33323	2B36DB58	1C3C32CCC	4434FBF33B	1	0	1	0	1	00	11	10
162	123	1866647	566DB6B0	187865999	0869F7E676	1	0	1	0	0	11	00	11
163	124	10CCC8F	2CDB6D60	10F0CB333	10D3EFCCEC	0	1	0	1	1	01	11	00
164	125	019991E	59B6DAC0	01E196666	21A7DF99D9	0	1	0	1	1	10	01	11
165	126	033323C	336DB580	03C32CCCD	434FBF33B3	0	0	0	0	0	00	10	01
166	127	0666478	66DB6B01	07865999A	069F7E6766	0	1	0	1	0	00	00	10
167	128	0CCC8F0	4DB6D603	0F0CB3334	0D3EFCCECD	1	1	1	0	1	01	00	00
168	129	19991E1	1B6DAC07	1E1966669	1A7DF99D9B	1	0	1	0	1	00	01	00
169	130	13323C3	36DB580E	1C32CCCD3	34FBF33B37	0	1	1	1	1	10	00	01
170	131	0664786	6DB6B01C	1865999A7	69F7E6766F	0	1	1	1	1	00	10	00
171	132	0CC8F0D	5B6D6039	10CB3334F	53EFCCECDF	1	0	0	1	0	00	00	10
172	133	1991E1A	36DAC073	01966669E	27DF99D9BF	1	1	0	1	1	01	00	00
173	134	1323C35	6DB580E6	032CCCD3C	4FBF33B37E	0	1	0	1	1	00	01	00
174	135	064786A	5B6B01CD	065999A78	1F7E6766FC	0	0	0	0	0	11	00	01
175	136	0C8F0D5	36D6039B	0CB3334F0	3EFCCECDF9	1	1	1	1	1	00	11	00
176	137	191E1AA	6DAC0737	1966669E1	7DF99D9BF3	1	1	1	1	0	00	00	11
177	138	123C354	5B580E6E	12CCCD3C3	7BF33B37E7	0	0	0	1	1	00	00	00
178	139	04786A9	36B01CDC	05999A787	77E6766FCE	0	1	0	1	0	01	00	00
179	140	08F0D53	6D6039B8	0B3334F0E	6FCCECDF9C	1	0	1	1	0	11	01	00
180	141	11E1AA6	5AC07370	166669E1D	5F99D9BF38	0	1	0	1	1	10	11	01
181	142	03C354C	3580E6E0	0CCCD3C3A	3F33B37E70	0	1	1	0	0	10	10	11
182	143	0786A99	6B01CDC0	1999A7875	7E6766FCE1	0	0	1	0	1	10	10	10
183	144	0F0D533	56039B81	13334F0EB	7CCECDF9C2	1	0	0	1	0	01	10	10
184	145	1E1AA66	2C073703	06669E1D6	799D9BF385	1	0	0	1	1	01	01	10
185	146	1C354CC	580E6E06	0CCD3C3AC	733B37E70B	1	0	1	0	1	11	01	01
186	147	186A998	301CDC0C	199A78759	66766FCE17	1	0	1	0	1	10	11	01
187	148	10D5331	6039B818	1334F0EB2	4CECDF9C2F	0	0	0	1	1	01	10	11
188	149	01AA662	40737031	0669E1D65	19D9BF385E	0	0	0	1	0	01	01	10
189	150	0354CC5	00E6E063	0CD3C3ACB	33B37E70BD	0	1	1	1	0	00	01	01
190	151	06A998A	01CDC0C6	19A787596	6766FCE17B	0	1	1	0	0	10	00	01
191	152	0D53315	039B818C	134F0EB2C	4ECDF9C2F6	1	1	0	1	1	00	10	00
192	153	1AA662A	07370318	069E1D659	1D9BF385ED	1	0	0	1	0	00	00	10
193	154	154CC54	0E6E0630	0D3C3ACB3	3B37E70BDB	0	0	1	0	1	00	00	00
194	155	0A998A8	1CDC0C60	1A7875967	766FCE17B6	1	1	1	0	1	01	00	00
195	156	1533151	39B818C0	14F0EB2CE	6CDF9C2F6C	0	1	0	1	1	00	01	00
196	157	0A662A3	73703180	09E1D659D	59BF385ED8	1	0	1	1	1	10	00	01
197	158	14CC547	66E06301	13C3ACB3A	337E70BDB0	0	1	0	0	1	11	10	00
198	159	0998A8E	4DC0C602	078759675	66FCE17B61	1	1	0	1	0	01	11	10
199	160	133151D	1B818C05	0F0EB2CEB	4DF9C2F6C2	0	1	1	1	0	01	01	11
200	161	0662A3B	3703180B	1E1D659D6	1BF385ED85	0	0	1	1	1	11	01	01
201	162	0CC5477	6E063017	1C3ACB3AC	37E70BDB0B	1	0	1	1	0	11	11	01
202	163	198A8EF	5C0C602F	187596759	6FCE17B617	1	0	1	1	0	10	11	11

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203	164	13151DE	3818C05F	10EB2CEB2	5F9C2F6C2F	0	0	0	1	1	01	10	11
204	165	062A3BC	703180BF	01D659D65	3F385ED85E	0	0	0	0	1	00	01	10
205	166	0C54779	6063017E	03ACB3ACB	7E70BDB0BD	1	0	0	0	1	11	00	01
206	167	18A8EF2	40C602FD	075967597	7CE17B617B	1	1	0	1	0	00	11	00
207	168	1151DE4	018C05FA	0EB2CEB2F	79C2F6C2F7	0	1	1	1	1	11	00	11
208	169	02A3BC9	03180BF5	1D659D65E	7385ED85EE	0	0	1	1	1	01	11	00
209	170	0547793	063017EB	1ACB3ACBC	670BDB0BDC	0	0	1	0	0	10	01	11
210	171	0A8EF27	0C602FD6	159675978	4E17B617B9	1	0	0	0	1	00	10	01
211	172	151DE4E	18C05FAD	0B2CEB2F1	1C2F6C2F73	0	1	1	0	0	00	00	10
212	173	0A3BC9C	3180BF5A	1659D65E3	385ED85EE6	1	1	0	0	0	01	00	00
213	174	1477938	63017EB5	0CB3ACBC6	70BDB0BDCC	0	0	1	1	1	00	01	00
214	175	08EF270	4602FD6A	19675978D	617B617B99	1	0	1	0	0	10	00	01
215	176	11DE4E1	0C05FAD5	12CEB2F1A	42F6C2F733	0	0	0	1	1	11	10	00
216	177	03BC9C3	180BF5AA	059D65E34	05ED85EE67	0	0	0	1	0	00	11	10
217	178	0779387	3017EB55	0B3ACBC68	0BDB0BDCCF	0	0	1	1	0	11	00	11
218	179	0EF270F	602FD6AA	1675978D0	17B617B99F	1	0	0	1	1	01	11	00
219	180	1DE4E1F	405FAD54	0CEB2F1A1	2F6C2F733F	1	0	1	0	1	10	01	11
220	181	1BC9C3F	00BF5AA9	19D65E342	5ED85EE67F	1	1	1	1	0	10	10	01
221	182	179387F	017EB552	13ACBC684	3DB0BDCCFE	0	0	0	1	1	10	10	10
222	183	0F270FF	02FD6AA5	075978D09	7B617B99FC	1	1	0	0	0	01	10	10
223	184	1E4E1FF	05FAD54A	0EB2F1A12	76C2F733F9	1	1	1	1	1	10	01	10
224	185	1C9C3FE	0BF5AA94	1D65E3425	6D85EE67F2	1	1	1	1	0	10	10	01
225	186	19387FD	17EB5529	1ACBC684B	5B0BDCCFE4	1	1	1	0	1	01	10	10
226	187	1270FFA	2FD6AA53	15978D096	3617B99FC9	0	1	0	0	0	01	01	10
227	188	04E1FF5	5FAD54A7	0B2F1A12C	6C2F733F93	0	1	1	0	1	11	01	01
228	189	09C3FEB	3F5AA94E	165E34258	585EE67F27	1	0	0	0	0	10	11	01
229	190	1387FD7	7EB5529C	0CBC684B1	30BDCCFE4F	0	1	1	1	1	10	10	11
230	191	070FFAE	7D6AA538	1978D0962	617B99FC9E	0	0	1	0	1	10	10	10
231	192	0E1FF5C	7AD54A70	12F1A12C4	42F733F93D	1	1	0	1	1	01	10	10
232	193	1C3FEB9	75AA94E1	05E342588	05EE67F27A	1	1	0	1	0	10	01	10
233	194	187FD73	6B5529C3	0BC684B10	0BDCCFE4F4	1	0	1	1	1	11	10	01
234	195	10FFAE6	56AA5386	178D09621	17B99FC9E8	0	1	0	1	1	00	11	10
235	196	01FF5CC	2D54A70C	0F1A12C43	2F733F93D0	0	0	1	0	1	10	00	11
236	197	03FEB98	5AA94E19	1E3425887	5EE67F27A1	0	1	1	1	1	00	10	00
237	198	07FD731	35529C33	1C684B10F	3DCCFE4F42	0	0	1	1	0	00	00	10
238	199	0FFAE63	6AA53866	18D09621F	7B99FC9E84	1	1	1	1	0	10	00	00
239	200	1FF5CC6	554A70CD	11A12C43F	7733F93D09	1	0	0	0	1	11	10	00

```
Z[0]  = 59
Z[1]  = 3B
Z[2]  = EF
Z[3]  = 07
Z[4]  = 13
Z[5]  = 70
Z[6]  = 9B
Z[7]  = B7
Z[8]  = 52
Z[9]  = 8F
Z[10] = 3E
Z[11] = B9
Z[12] = A5
Z[13] = AC
Z[14] = EA
Z[15] = 9E
```


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Sample Data

```
================================================================================================
         Reload this pattern into the LFSRs
         Hold content of Summation Combiner regs and calculate new C[t+1] and Z values
================================================================================================
LFSR1  <= 1521359
LFSR2  <= 528F703B
LFSR3  <= 0AC3E9BEF
LFSR4  <= 4FEAB9B707
C[t+1] <= 00

================================================================================================
         Generating 125 key symbols (encryption/decryption sequence)
================================================================================================
```

240	1	1521359	528F703B	0AC3E9BEF	4FEAB9B707	0	1	1	1	1	00	10	00
241	2	0A426B3	251EE076	1587D37DE	1FD5736E0F	1	0	0	1	0	00	00	10
242	3	1484D67	4A3DC0ED	0B0FA6FBD	3FAAE6DC1E	0	0	1	1	0	01	00	00
243	4	0909ACF	147B81DA	161F4DF7A	7F55CDB83D	1	0	0	0	0	00	01	00
244	5	121359E	28F703B5	0C3E9BEF5	7EAB9B707B	0	1	1	1	1	10	00	01
245	6	0426B3C	51EE076B	187D37DEB	7D5736E0F6	0	1	1	0	0	00	10	00
246	7	084D679	23DC0ED6	10FA6FBD7	7AAE6DC1EC	1	1	0	1	1	00	00	10
247	8	109ACF2	47B81DAC	01F4DF7AF	755CDB83D8	0	1	0	0	1	00	00	00
248	9	01359E4	0F703B59	03E9BEF5E	6AB9B707B1	0	0	0	1	1	00	00	00
249	10	026B3C8	1EE076B3	07D37DEBD	55736E0F63	0	1	0	0	1	00	00	00
250	11	04D6791	3DC0ED67	0FA6FBD7A	2AE6DC1EC7	0	1	1	1	1	01	00	00
251	12	09ACF22	7B81DACF	1F4DF7AF4	55CDB83D8F	1	1	1	1	1	11	01	00
252	13	1359E44	7703B59E	1E9BEF5E8	2B9B707B1F	0	0	1	1	1	10	11	01
253	14	06B3C88	6E076B3C	1D37DEBD0	5736E0F63F	0	0	1	0	1	01	10	11
254	15	0D67911	5C0ED678	1A6FBD7A1	2E6DC1EC7E	1	0	1	0	1	01	01	10
255	16	1ACF223	381DACF0	14DF7AF42	5CDB83D8FD	1	0	0	1	1	11	01	01
256	17	159E446	703B59E0	09BEF5E85	39B707B1FA	0	0	1	1	1	10	11	01
257	18	0B3C88C	6076B3C0	137DEBD0A	736E0F63F4	1	0	0	0	1	01	10	11
258	19	1679118	40ED6780	06FBD7A15	66DC1EC7E8	0	1	0	1	1	01	01	10
259	20	0CF2231	01DACF00	0DF7AF42A	4DB83D8FD1	1	1	1	1	1	00	01	01
260	21	19E4463	03B59E01	1BEF5E854	1B707B1FA3	1	1	1	0	1	10	00	01
261	22	13C88C6	076B3C03	17DEBD0A9	36E0F63F47	0	0	0	1	1	11	10	00
262	23	079118C	0ED67807	0FBD7A152	6DC1EC7E8E	0	1	1	1	0	01	11	10
263	24	0F22318	1DACF00E	1F7AF42A4	5B83D8FD1D	1	1	1	1	1	01	01	11
264	25	1E44630	3B59E01C	1EF5E8548	3707B1FA3B	1	0	1	0	1	11	01	01
265	26	1C88C61	76B3C039	1DEBD0A91	6E0F63F477	1	1	1	0	0	11	11	01
266	27	19118C3	6D678073	1BD7A1523	5C1EC7E8EF	1	0	1	0	1	11	11	11
267	28	1223187	5ACF00E6	17AF42A46	383D8FD1DE	0	1	0	0	0	11	11	11
268	29	044630E	359E01CC	0F5E8548D	707B1FA3BD	0	1	1	0	1	11	11	11
269	30	088C61C	6B3C0399	1EBD0A91A	60F63F477B	1	0	1	1	0	10	11	11
270	31	1118C39	56780733	1D7A15234	41EC7E8EF6	0	0	1	1	0	10	10	11
271	32	0231872	2CF00E67	1AF42A468	03D8FD1DEC	0	1	1	1	1	01	10	10
272	33	04630E5	59E01CCE	15E8548D1	07B1FA3BD8	0	1	0	1	1	01	01	10
273	34	08C61CB	33C0399D	0BD0A91A3	0F63F477B1	1	1	1	0	0	00	01	01
274	35	118C396	6780733A	17A152347	1EC7E8EF63	0	1	0	1	0	10	00	01
275	36	031872D	4F00E674	0F42A468E	3D8FD1DEC7	0	0	1	1	0	00	10	00
276	37	0630E5A	1E01CCE8	1E8548D1D	7B1FA3BD8E	0	0	1	0	1	01	00	10
277	38	0C61CB5	3C0399D0	1D0A91A3B	763F477B1C	1	0	1	0	1	00	01	00
278	39	18C396A	780733A0	1A1523477	6C7E8EF639	1	0	1	0	0	10	00	01
279	40	11872D5	700E6741	142A468EF	58FD1DEC72	0	0	0	1	1	11	10	00
280	41	030E5AB	601CCE83	08548D1DF	31FA3BD8E5	0	0	1	1	1	00	11	10
281	42	061CB57	40399D07	10A91A3BF	63F477B1CB	0	0	0	1	1	10	00	11
282	43	0C396AF	00733A0F	01523477E	47E8EF6396	1	0	0	1	0	00	10	00
283	44	1872D5F	00E6741F	02A468EFD	0FD1DEC72C	1	1	0	1	1	00	00	10

Sample Data

284	45	10E5ABE	01CCE83F	0548D1DFA	1FA3BD8E58	0	1	0	1	0	01	00	00
285	46	01CB57C	0399D07F	0A91A3BF4	3F477B1CB0	0	1	1	0	1	00	01	00
286	47	0396AF9	0733A0FE	1523477E9	7E8EF63961	0	0	0	1	1	11	00	01
287	48	072D5F3	0E6741FD	0A468EFD2	7D1DEC72C3	0	0	1	0	0	01	11	00
288	49	0E5ABE7	1CCE83FA	148D1DFA4	7A3BD8E587	1	1	0	0	1	10	01	11
289	50	1CB57CE	399D07F4	091A3BF49	7477B1CB0F	1	1	1	0	1	11	10	01
290	51	196AF9D	733A0FE9	123477E92	68EF63961E	1	0	0	1	1	00	11	10
291	52	12D5F3B	66741FD2	0468EFD25	51DEC72C3C	0	0	0	1	1	10	00	11
292	53	05ABE77	4CE83FA4	08D1DFA4B	23BD8E5879	0	1	1	1	1	00	10	00
293	54	0B57CEE	19D07F49	11A3BF496	477B1CB0F2	1	1	0	0	0	00	00	10
294	55	16AF9DC	33A0FE92	03477E92C	0EF63961E4	0	1	0	1	0	01	00	00
295	56	0D5F3B8	6741FD25	068EFD259	1DEC72C3C9	1	0	0	1	1	00	01	00
296	57	1ABE771	4E83FA4B	0D1DFA4B3	3BD8E58793	1	1	1	1	0	01	00	01
297	58	157CEE2	1D07F496	1A3BF4967	77B1CB0F26	0	0	1	1	1	00	01	00
298	59	0AF9DC5	3A0FE92D	1477E92CE	6F63961E4D	1	0	0	0	1	11	00	01
299	60	15F3B8B	741FD25A	08EFD259C	5EC72C3C9B	0	0	1	1	1	01	11	00
300	61	0BE7716	683FA4B4	11DFA4B39	3D8E587937	1	0	0	1	1	10	01	11
301	62	17CEE2D	507F4968	03BF49672	7B1CB0F26E	0	0	0	0	0	00	10	01
302	63	0F9DC5B	20FE92D0	077E92CE4	763961E4DC	1	1	0	0	0	00	00	10
303	64	1F3B8B6	41FD25A0	0EFD259C9	6C72C3C9B9	1	1	1	0	1	01	00	00
304	65	1E7716D	03FA4B40	1DFA4B393	58E5879373	1	1	1	1	1	11	01	00
305	66	1CEE2DB	07F49680	1BF496727	31CB0F26E6	1	1	1	1	1	11	11	01
306	67	19DC5B7	0FE92D00	17E92CE4E	63961E4DCD	1	1	0	1	0	10	11	11
307	68	13B8B6F	1FD25A00	0FD259C9C	472C3C9B9A	0	1	1	0	0	10	10	11
308	69	07716DF	3FA4B400	1FA4B3938	0E58793735	0	1	1	0	0	01	10	10
309	70	0EE2DBF	7F496800	1F4967271	1CB0F26E6A	1	0	1	1	0	10	01	10
310	71	1DC5B7F	7E92D000	1E92CE4E2	3961E4DCD4	1	1	1	0	1	11	10	01
311	72	1B8B6FF	7D25A001	1D259C9C4	72C3C9B9A9	1	0	1	1	0	01	11	10
312	73	1716DFF	7A4B4002	1A4B39389	6587937352	0	0	1	1	1	10	01	11
313	74	0E2DBFF	74968005	149672713	4B0F26E6A5	1	1	0	0	0	11	10	01
314	75	1C5B7FE	692D000B	092CE4E26	161E4DCD4B	1	0	1	0	1	00	11	10
315	76	18B6FFC	525A0017	1259C9C4D	2C3C9B9A96	1	0	0	0	1	10	00	11
316	77	116DFF8	24B4002F	04B39389B	587937352C	0	1	0	0	1	11	10	00
317	78	02DBFF1	4968005F	096727136	30F26E6A58	0	0	1	1	1	00	11	10
318	79	05B7FE3	12D000BF	12CE4E26C	61E4DCD4B1	0	1	0	1	0	11	00	11
319	80	0B6FFC7	25A0017F	059C9C4D8	43C9B9A963	1	1	0	1	0	00	11	00
320	81	16DFF8E	4B4002FF	0B39389B1	07937352C6	0	0	1	1	0	11	00	11
321	82	0DBFF1C	168005FF	167271363	0F26E6A58C	1	1	0	0	1	01	11	00
322	83	1B7FE38	2D000BFF	0CE4E26C7	1E4DCD4B18	1	0	1	0	1	10	01	11
323	84	16FFC70	5A0017FF	19C9C4D8F	3C9B9A9631	0	0	1	1	0	11	10	01
324	85	0DFF8E1	34002FFF	139389B1E	7937352C62	1	0	0	0	0	00	11	10
325	86	1BFF1C3	68005FFF	07271363D	726E6A58C4	1	0	0	0	1	10	00	11
326	87	17FE387	5000BFFE	0E4E26C7B	64DCD4B188	0	0	1	1	0	00	10	00
327	88	0FFC70F	20017FFD	1C9C4D8F6	49B9A96311	1	0	1	1	1	00	00	10
328	89	1FF8E1F	4002FFFB	19389B1ED	137352C623	1	0	1	0	0	01	00	00
329	90	1FF1C3F	0005FFF7	1271363DB	26E6A58C46	1	0	0	1	1	00	01	00
330	91	1FE387F	000BFFEE	04E26C7B6	4DCD4B188C	1	0	0	1	0	10	00	01
331	92	1FC70FF	0017FFDC	09C4D8F6D	1B9A963118	1	0	1	1	1	00	10	00
332	93	1F8E1FF	002FFFB8	1389B1EDA	37352C6231	1	0	0	0	1	01	00	10
333	94	1F1C3FF	005FFF70	071363DB4	6E6A58C462	1	0	0	0	0	00	01	00
334	95	1E387FE	00BFFEE0	0E26C7B68	5CD4B188C5	1	1	1	1	0	01	00	01
335	96	1C70FFC	017FFDC1	1C4D8F6D1	39A963118A	1	0	1	1	0	11	01	00
336	97	18E1FF9	02FFFB82	189B1EDA2	7352C62315	1	1	1	0	0	11	11	01
337	98	11C3FF2	05FFF705	11363DB45	66A58C462B	0	1	0	1	1	11	11	11
338	99	0387FE4	0BFFEE0A	026C7B68B	4D4B188C56	0	1	0	0	0	11	11	11
339	100	070FFC9	17FFDC15	04D8F6D16	1A963118AD	0	1	0	1	1	11	11	11
340	101	0E1FF92	2FFFB82B	09B1EDA2C	352C62315A	1	1	1	0	0	10	11	11

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Sample Data

341	102	1C3FF24	5FFF7057	1363DB458	6A58C462B4	1	1	0	0	0	10	10	11
342	103	187FE48	3FFEE0AE	06C7B68B0	54B188C569	1	1	0	1	1	01	10	10
343	104	10FFC90	7FFDC15C	0D8F6D161	2963118AD2	0	1	1	0	1	01	01	10
344	105	01FF920	7FFB82B9	1B1EDA2C2	52C62315A5	0	1	1	1	0	00	01	01
345	106	03FF240	7FF70573	163DB4584	258C462B4B	0	1	0	1	0	10	00	01
346	107	07FE481	7FEE0AE6	0C7B68B08	4B188C5696	0	1	1	0	0	00	10	00
347	108	0FFC902	7FDC15CD	18F6D1610	163118AD2D	1	1	1	0	1	00	00	10
348	109	1FF9204	7FB82B9A	11EDA2C20	2C62315A5B	1	1	0	0	0	01	00	00
349	110	1FF2408	7F705735	03DB45841	58C462B4B6	1	0	0	1	1	00	01	00
350	111	1FE4810	7EE0AE6B	07B68B082	3188C5696C	1	1	0	1	1	10	00	01
351	112	1FC9021	7DC15CD6	0F6D16105	63118AD2D8	1	1	1	0	1	00	10	00
352	113	1F92042	7B82B9AD	1EDA2C20B	462315A5B0	1	1	1	0	1	00	00	10
353	114	1F24084	7705735A	1DB458416	0C462B4B61	1	0	1	0	0	01	00	00
354	115	1E48108	6E0AE6B5	1B68B082C	188C5696C3	1	0	1	1	0	11	01	00
355	116	1C90211	5C15CD6A	16D161059	3118AD2D86	1	0	0	0	0	10	11	01
356	117	1920422	382B9AD5	0DA2C20B3	62315A5B0D	1	0	1	0	0	10	10	11
357	118	1240845	705735AA	1B4584167	4462B4B61A	0	0	1	0	1	10	10	10
358	119	048108A	60AE6B55	168B082CF	08C5696C34	0	1	0	1	0	01	10	10
359	120	0902114	415CD6AB	0D161059E	118AD2D869	1	0	1	1	0	10	01	10
360	121	1204228	02B9AD56	1A2C20B3D	2315A5B0D2	0	1	1	0	0	11	10	01
361	122	0408451	05735AAD	14584167B	462B4B61A4	0	0	0	0	1	11	11	10
362	123	08108A2	0AE6B55B	08B082CF7	0C5696C348	1	1	1	0	0	10	11	11
363	124	1021144	15CD6AB6	1161059EF	18AD2D8690	0	1	0	1	0	10	10	11
364	125	0042289	2B9AD56C	02C20B3DE	315A5B0D20	0	1	0	0	1	10	10	10

1.5 FOURTH SET OF SAMPLES

```
Initial values for the key, pan address and clock

K'c4[0]   = 21   K'c4[1]   = 87    K'c4[2]   = F0    K'c4[3]  = 4A
K'c4[4]   = BA   K'c4[5]   = 90    K'c4[6]   = 31    K'c4[7]  = D0
K'c4[8]   = 78   K'c4[9]   = 0D    K'c4[10]  = 4C    K'c4[11] = 53
K'c4[12]  = E0   K'c4[13]  = 15    K'c4[14]  = 3A    K'c4[15] = 63

Addr4[0] = 2C   Addr4[1] = 7F    Addr4[2] = 94
Addr4[3] = 56   Addr4[4] = 0F    Addr4[5] = 1B

CL4[0]  = 5F   CL4[1]  = 1A    CL4[2]  = 00    CL4[3]  = 02


=============================================================================================
         Fill LFSRs with initial data
=============================================================================================

  t  clk#    LFSR1    LFSR2     LFSR3      LFSR4           X1 X2 X3 X4   Z  C[t+1] C[t] C[t-1]

  0     0    0000000* 00000000* 000000000* 0000000000*     0  0  0  0    0  00      00   00
  1     1    0000000* 00000001* 000000001* 0000000001*     0  0  0  0    0  00      00   00
  2     2    0000001* 00000002* 000000002* 0000000003*     0  0  0  0    0  00      00   00
  3     3    0000002* 00000004* 000000004* 0000000007*     0  0  0  0    0  00      00   00
  4     4    0000004* 00000009* 000000008* 000000000F*     0  0  0  0    0  00      00   00
  5     5    0000008* 00000013* 000000010* 000000001E*     0  0  0  0    0  00      00   00
  6     6    0000010* 00000027* 000000021* 000000003D*     0  0  0  0    0  00      00   00
  7     7    0000021* 0000004F* 000000043* 000000007A*     0  0  0  0    0  00      00   00
  8     8    0000042* 0000009F* 000000087* 00000000F4*     0  0  0  0    0  00      00   00
  9     9    0000084* 0000013F* 00000010F* 00000001E9*     0  0  0  0    0  00      00   00
 10    10    0000108* 0000027F* 00000021F* 00000003D2*     0  0  0  0    0  00      00   00
 11    11    0000211* 000004FE* 00000043E* 00000007A5*     0  0  0  0    0  00      00   00
 12    12    0000422* 000009FC* 00000087C* 0000000F4A*     0  0  0  0    0  00      00   00
 13    13    0000845* 000013F8* 0000010F8* 0000001E94*     0  0  0  0    0  00      00   00
 14    14    000108B* 000027F0* 0000021F1* 0000003D29*     0  0  0  0    0  00      00   00
 15    15    0002117* 00004FE1* 0000043E3* 0000007A52*     0  0  0  0    0  00      00   00
 16    16    000422E* 00009FC2* 0000087C6* 000000F4A4*     0  0  0  0    0  00      00   00
 17    17    000845D* 00013F84* 000010F8C* 000001E948*     0  0  0  0    0  00      00   00
 18    18    00108BA* 00027F08* 000021F18* 000003D290*     0  0  0  0    0  00      00   00
 19    19    0021174* 0004FE10* 000043E30* 000007A520*     0  0  0  0    0  00      00   00
 20    20    00422E8* 0009FC21* 000087C61* 00000F4A41*     0  0  0  0    0  00      00   00
 21    21    00845D1* 0013F842* 00010F8C3* 00001E9482*     0  0  0  0    0  00      00   00
 22    22    0108BA3* 0027F084* 00021F186* 00003D2905*     0  0  0  0    0  00      00   00
 23    23    0211747* 004FE109* 00043E30C* 00007A520B*     0  0  0  0    0  00      00   00
 24    24    0422E8F* 009FC213* 00087C619* 0000F4A417*     0  1  0  0    1  00      00   00
 25    25    0845D1E* 013F8426* 0010F8C32* 0001E9482F*     1  0  0  0    1  00      00   00
 26    26    108BA3D  027F084D* 0021F1864* 0003D2905E*     0  0  0  0    0  00      00   00
 27    27    011747B  04FE109B* 0043E30C9* 0007A520BC*     0  1  0  0    1  00      00   00
 28    28    022E8F6  09FC2136* 0087C6192* 000F4A4179*     0  1  0  0    1  00      00   00
 29    29    045D1EC  13F8426C* 010F8C325* 001E9482F2*     0  1  0  0    1  00      00   00
 30    30    08BA3D9  27F084D8* 021F1864B* 003D2905E5*     1  1  0  0    0  01      00   00
 31    31    11747B3  4FE109B0* 043E30C97* 007A520BCA*     0  1  0  0    1  00      00   00
 32    32    02E8F67  1FC21360  087C6192E* 00F4A41795*     0  1  1  1    1  01      00   00
 33    33    05D1ECF  3F8426C1  10F8C325C* 01E9482F2B*     0  1  0  1    0  01      00   00
 34    34    0BA3D9F  7F084D82  01F1864B8  03D2905E56*     1  0  0  1    0  01      00   00
```

Sample Data

35	35	1747B3E	7E109B04	03E30C970	07A520BCAC*	0	0	0	1	1	00	00	00
36	36	0E8F67C	7C213608	07C6192E1	0F4A417958*	1	0	0	0	1	00	00	00
37	37	1D1ECF8	78426C11	0F8C325C3	1E9482F2B1*	1	0	1	1	1	01	00	00
38	38	1A3D9F0	7084D822	1F1864B86	3D2905E563*	1	1	1	0	1	01	00	00
39	39	147B3E1	6109B044	1E30C970C	7A520BCAC6*	0	0	1	0	1	00	00	00

Start clocking Summation Combiner

40	1	08F67C2	42136088	1C6192E18	74A417958D	1	0	1	1	1	01	00	00
41	2	11ECF84	0426C111	18C325C30	69482F2B1B	0	0	1	0	0	00	01	00
42	3	03D9F08	084D8222	11864B861	52905E5637	0	0	0	1	1	11	00	01
43	4	07B3E10	109B0444	030C970C3	2520BCAC6E	0	1	0	0	0	01	11	00
44	5	0F67C21	21360889	06192E186	4A417958DC	1	0	0	0	0	10	01	11
45	6	1ECF843	426C1112	0C325C30C	1482F2B1B8	1	0	1	1	1	11	10	01
46	7	1D9F086	04D82225	1864B8619	2905E56370	1	1	1	0	0	01	11	10
47	8	1B3E10D	09B0444B	10C970C32	520BCAC6E1	1	1	0	0	1	10	01	11
48	9	167C21B	13608897	0192E1865	2417958DC3	0	0	0	0	0	00	10	01
49	10	0CF8436	26C1112F	0325C30CB	482F2B1B87	1	1	0	0	0	00	00	10
50	11	19F086D	4D82225E	064B86197	105E56370F	1	1	0	0	0	01	00	00
51	12	13E10DB	1B0444BC	0C970C32F	20BCAC6E1F	0	0	1	1	1	00	01	00
52	13	07C21B7	36088979	192E1865E	417958DC3F	0	0	1	0	1	11	00	01
53	14	0F8436E	6C1112F2	125C30CBD	02F2B1B87F	1	0	0	1	1	01	11	00
54	15	1F086DD	582225E4	04B86197B	05E56370FF	1	0	0	1	1	10	01	11
55	16	1E10DBA	30444BC9	0970C32F7	0BCAC6E1FF	1	0	1	1	1	11	10	01
56	17	1C21B75	60889793	12E1865EE	17958DC3FF	1	1	0	1	0	01	11	10
57	18	18436EA	41112F27	05C30CBDD	2F2B1B87FF	1	0	0	0	0	10	01	11
58	19	1086DD4	02225E4E	0B86197BA	5E56370FFF	0	0	1	0	1	00	10	01
59	20	010DBA8	0444BC9D	170C32F74	3CAC6E1FFF	0	0	0	1	1	01	00	10
60	21	021B750	0889793A	0E1865EE8	7958DC3FFF	0	1	1	0	1	00	01	00
61	22	0436EA0	1112F274	1C30CBDD0	72B1B87FFE	0	0	1	1	0	10	00	01
62	23	086DD40	2225E4E9	186197BA1	656370FFFC	1	0	1	0	0	00	10	00
63	24	10DBA81	444BC9D3	10C32F743	4AC6E1FFF8	0	0	0	1	1	01	00	10
64	25	01B7502	089793A7	01865EE86	158DC3FFF1	0	1	0	1	1	00	01	00
65	26	036EA05	112F274E	030CBDD0D	2B1B87FFE3	0	0	0	0	0	11	00	01
66	27	06DD40B	225E4E9C	06197BA1A	56370FFFC6	0	0	0	0	1	10	11	00
67	28	0DBA817	44BC9D39	0C32F7434	2C6E1FFF8D	1	1	1	0	1	10	10	11
68	29	1B7502E	09793A72	1865EE868	58DC3FFF1B	1	0	1	1	1	01	10	10
69	30	16EA05D	12F274E5	10CBDD0D0	31B87FFE36	0	1	0	1	1	01	01	10
70	31	0DD40BA	25E4E9CB	0197BA1A1	6370FFFC6D	1	1	0	0	1	11	01	01
71	32	1BA8174	4BC9D397	032F74343	46E1FFF8DA	1	1	0	1	0	11	11	01
72	33	17502E8	1793A72F	065EE8687	0DC3FFF1B4	0	1	0	1	1	11	11	11
73	34	0EA05D0	2F274E5E	0CBDD0D0F	1B87FFE369	1	0	1	1	0	10	11	11
74	35	1D40BA0	5E4E9CBD	197BA1A1F	370FFFC6D2	1	0	1	0	0	10	10	11
75	36	1A81741	3C9D397B	12F74343F	6E1FFF8DA5	1	1	0	0	0	01	10	10
76	37	1502E82	793A72F6	05EE8687F	5C3FFF1B4B	0	0	0	0	1	00	01	10
77	38	0A05D05	7274E5ED	0BDD0D0FF	387FFE3696	1	0	1	0	0	10	00	01
78	39	140BA0B	64E9CBDA	17BA1A1FF	70FFFC6D2C	0	1	0	1	0	00	10	00
79	40	0817416	49D397B4	0F74343FE	61FFF8DA59	1	1	1	1	0	11	00	10
80	41	102E82C	13A72F69	1EE8687FD	43FFF1B4B3	0	1	1	1	0	00	11	00
81	42	005D058	274E5ED2	1DD0D0FFA	07FFE36966	0	0	1	1	0	11	00	11
82	43	00BA0B0	4E9CBDA5	1BA1A1FF5	0FFFC6D2CD	0	1	1	1	0	00	11	00
83	44	0174160	1D397B4A	174343FEA	1FFF8DA59B	0	0	0	1	1	10	00	11
84	45	02E82C0	3A72F695	0E8687FD4	3FFF1B4B37	0	0	1	1	0	00	10	00
85	46	05D0580	74E5ED2B	1D0D0FFA9	7FFE36966E	0	1	1	1	1	00	00	10
86	47	0BA0B00	69CBDA56	1A1A1FF53	7FFC6D2CDC	1	1	1	1	0	10	00	00
87	48	1741600	5397B4AC	14343FEA6	7FF8DA59B8	0	1	0	1	0	00	10	00
88	49	0E82C01	272F6959	08687FD4D	7FF1B4B370	1	0	1	1	1	00	00	10

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89	50	1D05802	4E5ED2B3	10D0FFA9A	7FE36966E0	1	0	0	1	0	01	00	00
90	51	1A0B004	1CBDA566	01A1FF535	7FC6D2CDC0	1	1	0	1	0	11	01	00
91	52	1416009	397B4ACC	0343FEA6B	7F8DA59B80	0	0	0	1	0	10	11	01
92	53	082C013	72F69599	0687FD4D7	7F1B4B3701	1	1	0	0	0	10	10	11
93	54	1058026	65ED2B33	0D0FFA9AF	7E36966E03	0	1	1	0	0	01	10	10
94	55	00B004D	4BDA5667	1A1FF535E	7C6D2CDC06	0	1	1	0	1	01	01	10
95	56	016009B	17B4ACCE	143FEA6BD	78DA59B80D	0	1	0	1	1	11	01	01
96	57	02C0137	2F69599D	087FD4D7B	71B4B3701A	0	0	1	1	1	10	11	01
97	58	058026F	5ED2B33B	10FFA9AF6	636966E034	0	1	0	0	1	01	10	11
98	59	0B004DF	3DA56677	01FF535ED	46D2CDC068	1	1	0	1	0	10	01	10
99	60	16009BF	7B4ACCEF	03FEA6BDB	0DA59B80D0	0	0	0	1	1	00	10	01
100	61	0C0137F	769599DF	07FD4D7B7	1B4B3701A1	1	1	0	0	0	00	00	10
101	62	18026FE	6D2B33BE	0FFA9AF6E	36966E0342	1	0	1	1	1	01	00	00
102	63	1004DFC	5A56677D	1FF535EDD	6D2CDC0684	0	0	1	0	0	00	01	00
103	64	0009BF9	34ACCEFB	1FEA6BDBB	5A59B80D09	0	1	1	0	0	10	00	01
104	65	00137F2	69599DF7	1FD4D7B76	34B3701A12	0	0	1	1	0	00	10	00
105	66	0026FE5	52B33BEF	1FA9AF6EC	6966E03424	0	1	1	0	0	00	00	10
106	67	004DFCA	256677DF	1F535EDD8	52CDC06848	0	0	1	1	0	01	00	00
107	68	009BF94	4ACCEFBE	1EA6BDBB0	259B80D091	0	1	1	1	0	11	01	00
108	69	0137F29	1599DF7C	1D4D7B760	4B3701A123	0	1	1	0	1	10	11	01
109	70	026FE53	2B33BEF9	1A9AF6EC0	166E034246	0	0	1	0	1	01	10	11
110	71	04DFCA7	56677DF2	1535EDD81	2CDC06848D	0	0	0	1	0	01	01	10
111	72	09BF94F	2CCEFBE4	0A6BDBB03	59B80D091B	1	1	1	1	1	00	01	01
112	73	137F29E	599DF7C9	14D7B7607	33701A1236	0	1	0	0	1	11	00	01
113	74	06FE53C	333BEF93	09AF6EC0E	66E034246C	0	0	1	1	1	01	11	00
114	75	0DFCA79	6677DF26	135EDD81D	4DC06848D8	1	0	0	1	1	10	01	11
115	76	1BF94F2	4CEFBE4D	06BDBB03B	1B80D091B1	1	1	0	1	1	11	10	01
116	77	17F29E5	19DF7C9A	0D7B76077	3701A12363	0	1	1	0	1	00	11	10
117	78	0FE53CA	33BEF934	1AF6EC0EF	6E034246C6	1	1	1	0	1	11	00	11
118	79	1FCA794	677DF269	15EDD81DF	5C06848D8C	1	0	0	0	0	01	11	00
119	80	1F94F29	4EFBE4D2	0BDBB03BE	380D091B19	1	1	1	0	0	01	01	11
120	81	1F29E53	1DF7C9A5	17B76077D	701A123633	1	1	0	0	1	11	01	01
121	82	1E53CA6	3BEF934B	0F6EC0EFB	6034246C66	1	1	1	0	0	11	11	01
122	83	1CA794D	77DF2696	1EDD81DF6	406848D8CD	1	1	1	0	0	10	11	11
123	84	194F29B	6FBE4D2C	1DBB03BED	00D091B19B	1	1	1	1	0	11	10	11
124	85	129E536	5F7C9A59	1B76077DA	01A1236337	0	0	1	1	1	00	11	10
125	86	053CA6C	3EF934B3	16EC0EFB4	034246C66E	0	1	0	0	1	10	00	11
126	87	0A794D9	7DF26967	0DD81DF69	06848D8CDD	1	1	1	1	0	01	10	00
127	88	14F29B3	7BE4D2CF	1BB03BED3	0D091B19BB	0	1	1	0	1	01	01	10
128	89	09E5366	77C9A59F	176077DA6	1A12363377	1	1	0	0	1	11	01	01
129	90	13CA6CD	6F934B3F	0EC0EFB4D	34246C66EF	0	1	1	0	1	10	11	01
130	91	0794D9B	5F26967F	1D81DF69A	6848D8CDDF	0	0	1	0	1	01	10	11
131	92	0F29B37	3E4D2CFE	1B03BED35	5091B19BBE	1	0	1	1	0	10	01	10
132	93	1E5366F	7C9A59FD	16077DA6B	212363377C	1	1	0	0	0	11	10	01
133	94	1CA6CDF	7934B3FB	0C0EFB4D6	4246C66EF9	1	0	1	0	1	00	11	10
134	95	194D9BE	726967F6	181DF69AD	048D8CDDF2	1	0	1	1	1	11	00	11
135	96	129B37D	64D2CFED	103BED35B	091B19BBE5	0	1	0	0	0	01	11	00
136	97	05366FA	49A59FDA	0077DA6B7	12363377CA	0	1	0	0	0	10	01	11
137	98	0A6CDF5	134B3FB4	00EFB4D6E	246C66EF95	1	0	0	0	1	00	10	01
138	99	14D9BEA	26967F69	01DF69ADD	48D8CDDF2B	0	1	0	1	0	00	00	10
139	100	09B37D4	4D2CFED2	03BED35BB	11B19BBE56	1	0	0	1	0	01	00	00
140	101	1366FA8	1A59FDA5	077DA6B77	2363377CAC	0	0	0	0	1	01	01	00
141	102	06CDF51	34B3FB4A	0EFB4D6EF	46C66EF959	0	1	1	1	0	00	01	01
142	103	0D9BEA2	6967F695	1DF69ADDF	0D8CDDF2B2	1	0	1	1	1	10	00	01
143	104	1B37D45	52CFED2A	1BED35BBF	1B19BBE564	1	1	1	0	1	00	10	00
144	105	166FA8A	259FDA54	17DA6B77E	363377CAC8	0	1	0	0	1	01	00	10
145	106	0CDF515	4B3FB4A9	0FB4D6EFC	6C66EF9591	1	0	1	0	1	00	01	00

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146	107	19BEA2B	167F6952	1F69ADDF8	58CDDF2B22	1	0	1	1	1	10	00	01
147	108	137D457	2CFED2A5	1ED35BBF1	319BBE5645	0	1	1	1	1	00	10	00
148	109	06FA8AF	59FDA54A	1DA6B77E2	63377CAC8B	0	1	1	0	0	00	00	10
149	110	0DF515F	33FB4A95	1B4D6EFC4	466EF95916	1	1	1	0	1	01	00	00
150	111	1BEA2BF	67F6952A	169ADDF88	0CDDF2B22C	1	1	0	1	0	11	01	00
151	112	17D457F	4FED2A55	0D35BBF10	19BBE56459	0	1	1	1	0	11	11	01
152	113	0FA8AFE	1FDA54AB	1A6B77E20	3377CAC8B3	1	1	1	0	0	10	11	11
153	114	1F515FD	3FB4A957	14D6EFC40	66EF959166	1	1	0	1	1	10	10	11
154	115	1EA2BFA	7F6952AF	09ADDF880	4DDF2B22CC	1	0	1	1	1	01	10	10
155	116	1D457F4	7ED2A55F	135BBF100	1BBE564598	1	1	0	1	0	10	01	10
156	117	1A8AFE8	7DA54ABF	06B77E200	377CAC8B31	1	1	0	0	0	11	10	01
157	118	1515FD0	7B4A957F	0D6EFC401	6EF9591663	0	0	1	1	1	00	11	10
158	119	0A2BFA1	76952AFE	1ADDF8803	5DF2B22CC7	1	1	1	1	0	00	00	11
159	120	1457F42	6D2A55FD	15BBF1007	3BE564598E	0	0	0	1	1	00	00	00
160	121	08AFE84	5A54ABFB	0B77E200F	77CAC8B31C	1	0	1	1	1	01	00	00
161	122	115FD09	34A957F7	16EFC401F	6F95916639	0	1	0	1	1	00	01	00
162	123	02BFA12	6952AFEF	0DDF8803E	5F2B22CC73	0	0	1	0	1	11	00	01
163	124	057F424	52A55FDF	1BBF1007D	3E564598E7	0	1	1	0	1	01	11	00
164	125	0AFE848	254ABFBF	177E200FA	7CAC8B31CF	1	0	0	1	1	10	01	11
165	126	15FD090	4A957F7E	0EFC401F5	795916639E	0	1	1	0	0	11	10	01
166	127	0BFA121	152AFEFD	1DF8803EA	72B22CC73C	1	0	1	1	0	01	11	10
167	128	17F4243	2A55FDFA	1BF1007D4	6564598E78	0	0	1	0	0	10	01	11
168	129	0FE8486	54ABFBF4	17E200FA8	4AC8B31CF0	1	1	0	1	1	11	10	01
169	130	1FD090C	2957F7E8	0FC401F51	15916639E1	1	0	1	1	0	01	11	10
170	131	1FA1219	52AFEFD1	1F8803EA3	2B22CC73C2	1	1	1	0	0	01	01	11
171	132	1F42432	255FDFA2	1F1007D47	564598E785	1	0	1	0	1	11	01	01
172	133	1E84865	4ABFBF44	1E200FA8F	2C8B31CF0B	1	1	1	1	1	11	11	01
173	134	1D090CB	157F7E88	1C401F51E	5916639E17	1	0	1	0	1	11	11	11
174	135	1A12196	2AFEFD11	18803EA3C	322CC73C2E	1	1	1	0	0	10	11	11
175	136	142432C	55FDFA23	11007D479	64598E785C	0	1	0	0	1	01	10	11
176	137	0848659	2BFBF446	0200FA8F2	48B31CF0B9	1	1	0	1	0	10	01	10
177	138	1090CB2	57F7E88C	0401F51E4	116639E173	0	1	0	0	1	00	10	01
178	139	0121964	2FEFD118	0803EA3C8	22CC73C2E6	0	1	1	1	1	00	00	10
179	140	02432C9	5FDFA230	1007D4791	4598E785CD	0	1	0	1	0	01	00	00
180	141	0486593	3FBF4461	000FA8F23	0B31CF0B9B	0	1	0	0	0	00	01	00
181	142	090CB26	7F7E88C3	001F51E47	16639E1736	1	0	0	0	1	11	00	01
182	143	121964D	7EFD1187	003EA3C8F	2CC73C2E6C	0	1	0	1	1	01	11	00
183	144	0432C9B	7DFA230E	007D4791E	598E785CD8	0	1	0	1	1	10	01	11
184	145	0865936	7BF4461C	00FA8F23C	331CF0B9B0	1	1	0	0	0	11	10	01
185	146	10CB26D	77E88C38	01F51E479	6639E17361	0	1	0	0	0	00	11	10
186	147	01964DA	6FD11870	03EA3C8F2	4C73C2E6C2	0	1	0	0	1	10	00	11
187	148	032C9B4	5FA230E1	07D4791E4	18E785CD84	0	1	0	1	0	00	10	00
188	149	0659368	3F4461C2	0FA8F23C9	31CF0B9B09	0	0	1	1	0	00	00	10
189	150	0CB26D0	7E88C384	1F51E4793	639E173612	1	1	1	1	0	10	00	00
190	151	1964DA0	7D118709	1EA3C8F27	473C2E6C24	1	0	1	0	0	00	10	00
191	152	12C9B41	7A230E12	1D4791E4E	0E785CD848	0	0	1	0	1	01	00	10
192	153	0593683	74461C24	1A8F23C9C	1CF0B9B091	0	0	1	1	1	00	01	00
193	154	0B26D06	688C3848	151E47938	39E1736123	1	1	0	1	1	10	00	01
194	155	164DA0D	51187091	0A3C8F271	73C2E6C247	0	0	1	1	0	00	10	00
195	156	0C9B41A	2230E123	14791E4E3	6785CD848F	1	0	0	1	0	00	00	10
196	157	1936835	4461C247	08F23C9C6	4F0B9B091E	1	0	1	0	0	01	00	00
197	158	126D06A	08C3848E	11E47938D	1E1736123C	0	1	0	0	0	00	01	00
198	159	04DA0D5	1187091C	03C8F271B	3C2E6C2478	0	1	0	0	1	11	00	01
199	160	09B41AA	230E1238	0791E4E37	785CD848F1	1	0	0	0	0	01	11	00
200	161	1368354	461C2470	0F23C9C6F	70B9B091E3	0	0	1	1	1	10	01	11
201	162	06D06A9	0C3848E1	1E47938DF	61736123C6	0	0	1	0	1	00	10	01
202	163	0DA0D52	187091C3	1C8F271BE	42E6C2478D	1	0	1	1	1	00	00	10

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203	164	1B41AA4	30E12387	191E4E37C	05CD848F1A	1	1	1	1	0	10	00	00
204	165	1683549	61C2470F	123C9C6F9	0B9B091E34	0	1	0	1	0	00	10	00
205	166	0D06A92	43848E1E	047938DF3	1736123C68	1	1	0	0	0	00	00	10
206	167	1A0D524	07091C3C	08F271BE7	2E6C2478D1	1	0	1	0	0	01	00	00
207	168	141AA49	0E123879	11E4E37CF	5CD848F1A2	0	0	0	1	0	00	01	00
208	169	0835492	1C2470F3	03C9C6F9F	39B091E345	1	0	0	1	0	10	00	01
209	170	106A925	3848E1E6	07938DF3F	736123C68B	0	0	0	0	0	11	10	00
210	171	00D524A	7091C3CD	0F271BE7E	66C2478D16	0	1	1	1	0	01	11	10
211	172	01AA495	6123879B	1E4E37CFD	4D848F1A2D	0	0	1	1	1	10	01	11
212	173	035492A	42470F36	1C9C6F9FB	1B091E345B	0	0	1	0	1	00	10	01
213	174	06A9255	048E1E6C	1938DF3F6	36123C68B7	0	1	1	0	0	00	00	10
214	175	0D524AB	091C3CD8	1271BE7EC	6C2478D16E	1	0	0	0	1	00	00	00
215	176	1AA4957	123879B1	04E37CFD8	5848F1A2DD	1	0	0	0	1	00	00	00
216	177	15492AF	2470F363	09C6F9FB0	3091E345BA	0	0	1	1	0	01	00	00
217	178	0A9255E	48E1E6C7	138DF3F61	6123C68B75	1	1	0	0	1	00	01	00
218	179	1524ABD	11C3CD8F	071BE7EC3	42478D16EB	0	1	0	0	1	11	00	01
219	180	0A4957B	23879B1F	0E37CFD87	048F1A2DD6	1	1	1	1	1	00	11	00
220	181	1492AF6	470F363F	1C6F9FB0E	091E345BAD	0	0	1	0	1	10	00	11
221	182	09255EC	0E1E6C7F	18DF3F61D	123C68B75B	1	0	1	0	0	00	10	00
222	183	124ABD9	1C3CD8FF	11BE7EC3A	2478D16EB6	0	0	0	0	0	01	00	10
223	184	04957B3	3879B1FE	037CFD874	48F1A2DD6D	0	0	0	1	0	00	01	00
224	185	092AF66	70F363FD	06F9FB0E9	11E345BADB	1	1	0	1	1	10	00	01
225	186	1255ECD	61E6C7FA	0DF3F61D3	23C68B75B7	0	1	1	1	1	00	10	00
226	187	04ABD9B	43CD8FF5	1BE7EC3A7	478D16EB6E	0	1	1	1	1	00	00	10
227	188	0957B37	079B1FEA	17CFD874E	0F1A2DD6DD	1	1	0	0	0	01	00	00
228	189	12AF66F	0F363FD4	0F9FB0E9C	1E345BADBB	0	0	1	0	0	00	01	00
229	190	055ECDE	1E6C7FA9	1F3F61D39	3C68B75B76	0	0	1	0	1	11	00	01
230	191	0ABD9BC	3CD8FF53	1E7EC3A73	78D16EB6EC	1	1	1	1	1	00	11	00
231	192	157B379	79B1FEA7	1CFD874E6	71A2DD6DD9	0	1	1	1	1	11	00	11
232	193	0AF66F3	7363FD4E	19FB0E9CD	6345BADBB2	1	0	1	0	1	01	11	00
233	194	15ECDE6	66C7FA9D	13F61D39A	468B75B765	0	1	0	1	1	10	01	11
234	195	0BD9BCC	4D8FF53A	07EC3A735	0D16EB6ECA	1	1	0	0	0	11	10	01
235	196	17B3799	1B1FEA75	0FD874E6A	1A2DD6DD94	0	0	1	0	0	00	11	10
236	197	0F66F33	363FD4EA	1FB0E9CD5	345BADBB28	1	0	1	0	0	11	00	11
237	198	1ECDE67	6C7FA9D5	1F61D39AA	68B75B7650	1	0	1	1	0	00	11	00
238	199	1D9BCCF	58FF53AB	1EC3A7354	516EB6ECA0	1	1	1	0	1	11	00	11
239	200	1B3799E	31FEA756	1D874E6A8	22DD6DD940	1	1	1	1	1	00	11	00

```
Z[0]  = 3F
Z[1]  = B1
Z[2]  = 67
Z[3]  = D2
Z[4]  = 2F
Z[5]  = A6
Z[6]  = 1F
Z[7]  = B9
Z[8]  = E6
Z[9]  = 84
Z[10] = 43
Z[11] = 07
Z[12] = D8
Z[13] = 1E
Z[14] = E7
Z[15] = C3
```


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Sample Data

```
================================================================================================
         Reload this pattern into the LFSRs
         Hold content of Summation Combiner regs and calculate new C[t+1] and Z values
================================================================================================
LFSR1  <= 0E62F3F
LFSR2  <= 6C84A6B1
LFSR3  <= 11E431F67
LFSR4  <= 61E707B9D2
C[t+1] <= 00

================================================================================================
         Generating 125 key symbols (encryption/decryption sequence)
================================================================================================
```

240	1	0E62F3F	6C84A6B1	11E431F67	61E707B9D2	1	1	0	1	0	00	11	00
241	2	1CC5E7F	59094D63	03C863ECE	43CE0F73A5	1	0	0	1	0	11	00	11
242	3	198BCFF	32129AC6	0790C7D9D	079C1EE74A	1	0	0	1	1	01	11	00
243	4	13179FE	6425358C	0F218FB3A	0F383DCE94	0	0	1	0	0	10	01	11
244	5	062F3FD	484A6B19	1E431F675	1E707B9D28	0	0	1	0	1	00	10	01
245	6	0C5E7FB	1094D632	1C863ECEB	3CE0F73A50	1	1	1	1	0	11	00	10
246	7	18BCFF7	2129AC64	190C7D9D7	79C1EE74A1	1	0	1	1	0	00	11	00
247	8	1179FEE	425358C8	1218FB3AE	7383DCE942	0	0	0	1	1	10	00	11
248	9	02F3FDD	04A6B190	0431F675D	6707B9D285	0	1	0	0	1	11	10	00
249	10	05E7FBB	094D6320	0863ECEBB	4E0F73A50B	0	0	1	0	0	00	11	10
250	11	0BCFF77	129AC640	10C7D9D77	1C1EE74A16	1	1	0	0	0	11	00	11
251	12	179FEEE	25358C80	018FB3AEE	383DCE942C	0	0	0	0	1	10	11	00
252	13	0F3FDDC	4A6B1900	031F675DD	707B9D2859	1	0	0	0	1	01	10	11
253	14	1E7FBB8	14D63200	063ECEBBA	60F73A50B3	1	1	0	1	0	10	01	10
254	15	1CFF771	29AC6401	0C7D9D774	41EE74A167	1	1	1	1	0	10	10	01
255	16	19FEEE2	5358C803	18FB3AEE9	03DCE942CE	1	0	1	1	1	01	10	10
256	17	13FDDC4	26B19007	11F675DD2	07B9D2859C	0	1	0	1	1	01	01	10
257	18	07FBB88	4D63200E	03ECEBBA4	0F73A50B38	0	0	0	0	1	10	01	01
258	19	0FF7711	1AC6401D	07D9D7748	1EE74A1670	1	1	0	1	1	11	10	01
259	20	1FEEE23	358C803B	0FB3AEE91	3DCE942CE1	1	1	1	1	1	01	11	10
260	21	1FDDC47	6B190076	1F675DD23	7B9D2859C2	1	0	1	1	0	01	01	11
261	22	1FBB88F	563200ED	1ECEBBA47	773A50B385	1	0	1	0	1	11	01	01
262	23	1F7711E	2C6401DB	1D9D7748F	6E74A1670A	1	0	1	0	1	10	11	01
263	24	1EEE23D	58C803B6	1B3AEE91E	5CE942CE15	1	1	1	1	0	11	10	11
264	25	1DDC47A	3190076C	1675DD23D	39D2859C2B	1	1	0	1	0	01	11	10
265	26	1BB88F4	63200ED9	0CEBBA47A	73A50B3856	1	0	1	1	0	01	01	11
266	27	17711E8	46401DB2	19D7748F5	674A1670AD	0	0	1	0	0	11	01	01
267	28	0EE23D0	0C803B64	13AEE91EA	4E942CE15B	1	1	0	1	0	11	11	01
268	29	1DC47A0	190076C8	075DD23D4	1D2859C2B7	1	0	0	0	0	11	11	11
269	30	1B88F41	3200ED90	0EBBA47A9	3A50B3856E	1	0	1	0	1	11	11	11
270	31	1711E83	6401DB20	1D7748F53	74A1670ADC	0	0	1	1	1	11	11	11
271	32	0E23D07	4803B641	1AEE91EA7	6942CE15B8	1	0	1	0	1	11	11	11
272	33	1C47A0F	10076C82	15DD23D4F	52859C2B71	1	0	0	1	1	11	11	11
273	34	188F41E	200ED905	0BBA47A9E	250B3856E3	1	0	1	0	1	11	11	11
274	35	111E83C	401DB20A	17748F53D	4A1670ADC7	0	0	0	0	1	00	11	11
275	36	023D078	003B6414	0EE91EA7A	142CE15B8E	0	0	1	0	1	10	00	11
276	37	047A0F0	0076C828	1DD23D4F5	2859C2B71C	0	0	1	0	1	11	10	00
277	38	08F41E1	00ED9050	1BA47A9EA	50B3856E39	1	1	1	1	1	01	11	10
278	39	11E83C2	01DB20A0	1748F53D5	21670ADC72	0	1	0	0	0	10	01	11
279	40	03D0785	03B64141	0E91EA7AA	42CE15B8E4	0	1	1	1	1	11	10	01
280	41	07A0F0A	076C8283	1D23D4F54	059C2B71C8	0	0	1	1	1	00	11	10
281	42	0F41E14	0ED90507	1A47A9EA9	0B3856E390	1	1	1	0	1	11	00	11
282	43	1E83C29	1DB20A0F	148F53D52	1670ADC720	1	1	0	0	1	01	11	00
283	44	1D07853	3B64141E	091EA7AA5	2CE15B8E40	1	0	1	1	0	01	01	11

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284	45	1A0F0A6	76C8283C	123D4F54B	59C2B71C81	1	1	0	1	0	00	01	01
285	46	141E14C	6D905079	047A9EA97	33856E3902	0	1	0	1	0	10	00	01
286	47	083C299	5B20A0F2	08F53D52F	670ADC7204	1	0	1	0	0	00	10	00
287	48	1078533	364141E4	11EA7AA5E	4E15B8E408	0	0	0	0	0	01	00	10
288	49	00F0A67	6C8283C8	03D4F54BC	1C2B71C811	0	1	0	0	0	00	01	00
289	50	01E14CE	59050791	07A9EA978	3856E39022	0	0	0	0	0	11	00	01
290	51	03C299C	320A0F23	0F53D52F1	70ADC72045	0	0	1	1	1	01	11	00
291	52	0785339	64141E47	1EA7AA5E2	615B8E408A	0	0	1	0	0	10	01	11
292	53	0F0A673	48283C8E	1D4F54BC4	42B71C8115	1	0	1	1	1	11	10	01
293	54	1E14CE6	1050791C	1A9EA9788	056E39022B	1	0	1	0	1	00	11	10
294	55	1C299CD	20A0F239	153D52F10	0ADC720456	1	1	0	1	1	11	00	11
295	56	185339B	4141E472	0A7AA5E20	15B8E408AC	1	0	1	1	0	00	11	00
296	57	10A6736	0283C8E4	14F54BC41	2B71C81158	0	1	0	0	1	10	00	11
297	58	014CE6C	050791C9	09EA97882	56E39022B0	0	0	1	1	0	00	10	00
298	59	0299CD9	0A0F2393	13D52F104	2DC7204561	0	0	0	1	1	01	00	10
299	60	05339B3	141E4726	07AA5E208	5B8E408AC3	0	0	0	1	0	00	01	00
300	61	0A67366	283C8E4C	0F54BC411	371C811587	1	0	1	0	0	10	00	01
301	62	14CE6CC	50791C98	1EA978822	6E39022B0F	0	0	1	0	1	11	10	00
302	63	099CD99	20F23930	1D52F1045	5C7204561E	1	1	1	0	0	01	11	10
303	64	1339B33	41E47260	1AA5E208B	38E408AC3D	0	1	1	1	0	01	01	11
304	65	0673666	03C8E4C0	154BC4117	71C811587A	0	1	0	1	1	11	01	01
305	66	0CE6CCC	0791C980	0A978822E	639022B0F5	1	1	1	1	1	11	11	01
306	67	19CD999	0F239301	152F1045C	47204561EB	1	0	0	0	0	11	11	11
307	68	139B332	1E472603	0A5E208B9	0E408AC3D6	0	0	1	0	0	11	11	11
308	69	0736664	3C8E4C06	14BC41172	1C811587AD	0	1	0	1	1	11	11	11
309	70	0E6CCC8	791C980C	0978822E5	39022B0F5A	1	0	1	0	1	11	11	11
310	71	1CD9990	72393019	12F1045CB	7204561EB4	1	0	0	0	0	11	11	11
311	72	19B3320	64726033	05E208B97	6408AC3D69	1	0	0	0	0	11	11	11
312	73	1366640	48E4C067	0BC41172F	4811587AD3	0	1	1	0	1	11	11	11
313	74	06CCC81	11C980CF	178822E5E	1022B0F5A6	0	1	0	0	0	11	11	11
314	75	0D99903	2393019E	0F1045CBC	204561EB4C	1	1	1	0	0	10	11	11
315	76	1B33206	4726033D	1E208B979	408AC3D699	1	0	1	1	1	10	10	11
316	77	166640D	0E4C067B	1C41172F2	011587AD33	0	0	1	0	1	10	10	10
317	78	0CCC81B	1C980CF6	18822E5E5	022B0F5A66	1	1	1	0	1	01	10	10
318	79	1999036	393019EC	11045CBCA	04561EB4CD	1	0	0	0	0	01	01	10
319	80	133206C	726033D9	0208B9794	08AC3D699B	0	0	0	1	0	11	01	01
320	81	06640D9	64C067B3	041172F29	11587AD337	0	1	0	0	0	10	11	01
321	82	0CC81B3	4980CF66	0822E5E53	22B0F5A66F	1	1	1	1	0	11	10	11
322	83	1990366	13019ECC	1045CBCA6	4561EB4CDF	1	0	0	0	0	00	11	10
323	84	13206CC	26033D98	008B9794D	0AC3D699BE	0	0	0	1	1	10	00	11
324	85	0640D98	4C067B31	01172F29B	1587AD337C	0	0	0	1	1	11	10	00
325	86	0C81B30	180CF662	022E5E537	2B0F5A66F9	1	0	0	0	0	00	11	10
326	87	1903660	3019ECC5	045CBCA6F	561EB4CDF3	1	0	0	0	1	10	00	11
327	88	1206CC1	6033D98A	08B9794DE	2C3D699BE6	0	0	1	0	1	11	10	00
328	89	040D983	4067B315	1172F29BD	587AD337CC	0	0	0	0	1	11	11	10
329	90	081B306	00CF662A	02E5E537A	30F5A66F98	1	1	0	1	0	10	11	11
330	91	103660C	019ECC55	05CBCA6F4	61EB4CDF31	0	1	0	1	0	10	10	11
331	92	006CC19	033D98AB	0B9794DE8	43D699BE62	0	0	1	1	0	01	10	10
332	93	00D9833	067B3156	172F29BD0	07AD337CC5	0	0	0	1	0	01	01	10
333	94	01B3066	0CF662AC	0E5E537A0	0F5A66F98B	0	1	1	0	1	11	01	01
334	95	03660CD	19ECC559	1CBCA6F41	1EB4CDF317	0	1	1	1	0	11	11	01
335	96	06CC19B	33D98AB2	19794DE83	3D699BE62F	0	1	1	0	1	11	11	11
336	97	0D98336	67B31565	12F29BD06	7AD337CC5F	1	1	0	1	0	10	11	11
337	98	1B3066D	4F662ACA	05E537A0C	75A66F98BF	1	0	0	1	0	10	10	11
338	99	1660CDB	1ECC5594	0BCA6F418	6B4CDF317E	0	1	1	0	0	01	10	10
339	100	0CC19B7	3D98AB29	1794DE831	5699BE62FC	1	1	0	1	0	10	01	10
340	101	198336F	7B315653	0F29BD062	2D337CC5F9	1	0	1	0	0	11	10	01

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341	102	13066DE	7662ACA7	1E537A0C5	5A66F98BF2	0	0	1	0	0	00	11	10
342	103	060CDBC	6CC5594F	1CA6F418B	34CDF317E4	0	1	1	1	1	11	00	11
343	104	0C19B78	598AB29F	194DE8317	699BE62FC9	1	1	1	1	1	00	11	00
344	105	18336F1	3315653F	129BD062E	5337CC5F92	1	0	0	0	1	10	00	11
345	106	1066DE2	662ACA7E	0537A0C5C	266F98BF25	0	0	0	0	0	11	10	00
346	107	00CDBC5	4C5594FD	0A6F418B9	4CDF317E4B	0	0	1	1	1	00	11	10
347	108	019B78B	18AB29FA	14DE83172	19BE62FC96	0	1	0	1	0	11	00	11
348	109	0336F16	315653F4	09BD062E5	337CC5F92C	0	0	1	0	0	01	11	00
349	110	066DE2D	62ACA7E8	137A0C5CA	66F98BF258	0	1	0	1	1	10	01	11
350	111	0CDBC5B	45594FD1	06F418B95	4DF317E4B1	1	0	0	1	0	11	10	01
351	112	19B78B6	0AB29FA2	0DE83172B	1BE62FC962	1	1	1	1	1	01	11	10
352	113	136F16C	15653F45	1BD062E57	37CC5F92C5	0	0	1	1	1	10	01	11
353	114	06DE2D9	2ACA7E8B	17A0C5CAE	6F98BF258B	0	1	0	1	0	11	10	01
354	115	0DBC5B2	5594FD16	0F418B95D	5F317E4B16	1	1	1	0	0	01	11	10
355	116	1B78B64	2B29FA2C	1E83172BB	3E62FC962C	1	0	1	0	1	10	01	11
356	117	16F16C8	5653F458	1D062E577	7CC5F92C58	0	0	1	1	0	11	10	01
357	118	0DE2D91	2CA7E8B0	1A0C5CAEF	798BF258B1	1	1	1	1	1	01	11	10
358	119	1BC5B23	594FD161	1418B95DF	7317E4B163	1	0	0	0	0	10	01	11
359	120	178B647	329FA2C2	083172BBF	662FC962C7	0	1	1	0	0	11	10	01
360	121	0F16C8E	653F4584	1062E577F	4C5F92C58E	1	0	0	0	0	00	11	10
361	122	1E2D91C	4A7E8B09	00C5CAEFE	18BF258B1C	1	0	0	1	0	11	00	11
362	123	1C5B238	14FD1613	018B95DFC	317E4B1639	1	1	0	0	1	01	11	00
363	124	18B6471	29FA2C27	03172BBF9	62FC962C72	1	1	0	1	0	01	01	11
364	125	116C8E2	53F4584E	062E577F3	45F92C58E4	0	1	0	1	1	11	01	01

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2 FREQUENCY HOPPING SAMPLE DATA

The section contains three sets of sample data showing the basic and adapted hopping schemes for different combinations of addresses and initial clock values.

2.1 FIRST SET

```
Hop sequence {k} for PAGE SCAN/INQUIRY SCAN SUBSTATE:
CLKN start:      0x0000000
UAP / LAP:       0x00000000
#ticks:          0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
                 -------------------------------------------------------
0x0000000:         0 |    2 |    4 |    6 |    8 |   10 |   12 |   14 |
0x0008000:        16 |   18 |   20 |   22 |   24 |   26 |   28 |   30 |
0x0010000:        32 |   34 |   36 |   38 |   40 |   42 |   44 |   46 |
0x0018000:        48 |   50 |   52 |   54 |   56 |   58 |   60 |   62 |
0x0020000:         0 |    2 |    4 |    6 |    8 |   10 |   12 |   14 |
0x0028000:        16 |   18 |   20 |   22 |   24 |   26 |   28 |   30 |
0x0030000:        32 |   34 |   36 |   38 |   40 |   42 |   44 |   46 |
0x0038000:        48 |   50 |   52 |   54 |   56 |   58 |   60 |   62 |

Hop sequence {k} for PAGE STATE/INQUIRY SUBSTATE:
CLKE start:      0x0000000
UAP / LAP:       0x00000000
#ticks:          00 01 02 03 | 04 05 06 07 | 08 09 0a 0b | 0c 0d 0e 0f |
                 -----------------------------------------------------
0x0000000:       48 50 09 13 | 52 54 41 45 | 56 58 11 15 | 60 62 43 47 |
0x0000010:       00 02 64 68 | 04 06 17 21 | 08 10 66 70 | 12 14 19 23 |
0x0000020:       48 50 09 13 | 52 54 41 45 | 56 58 11 15 | 60 62 43 47 |
0x0000030:       00 02 64 68 | 04 06 17 21 | 08 10 66 70 | 12 14 19 23 |
...
0x0001000:       48 18 09 05 | 20 22 33 37 | 24 26 03 07 | 28 30 35 39 |
0x0001010:       32 34 72 76 | 36 38 25 29 | 40 42 74 78 | 44 46 27 31 |
0x0001020:       48 18 09 05 | 20 22 33 37 | 24 26 03 07 | 28 30 35 39 |
0x0001030:       32 34 72 76 | 36 38 25 29 | 40 42 74 78 | 44 46 27 31 |
...
0x0002000:       16 18 01 05 | 52 54 41 45 | 56 58 11 15 | 60 62 43 47 |
0x0002010:       00 02 64 68 | 04 06 17 21 | 08 10 66 70 | 12 14 19 23 |
0x0002020:       16 18 01 05 | 52 54 41 45 | 56 58 11 15 | 60 62 43 47 |
0x0002030:       00 02 64 68 | 04 06 17 21 | 08 10 66 70 | 12 14 19 23 |
...
0x0003000:       48 50 09 13 | 52 22 41 37 | 24 26 03 07 | 28 30 35 39 |
0x0003010:       32 34 72 76 | 36 38 25 29 | 40 42 74 78 | 44 46 27 31 |
0x0003020:       48 50 09 13 | 52 22 41 37 | 24 26 03 07 | 28 30 35 39 |
0x0003030:       32 34 72 76 | 36 38 25 29 | 40 42 74 78 | 44 46 27 31 |

Hop sequence {k} for SLAVE PAGE RESPONSE SUBSTATE:
CLKN* =          0x0000010
UAP / LAP:       0x00000000
#ticks:          00 | 02 04 | 06 08 | 0a 0c | 0e 10 | 12 14 | 16 18 | 1a 1c | 1e
                 ---------------------------------------------------------------
0x0000012:       64 | 02 68 | 04 17 | 06 21 | 08 66 | 10 70 | 12 19 | 14 23 | 16
0x0000032:       01 | 18 05 | 20 33 | 22 37 | 24 03 | 26 07 | 28 35 | 30 39 | 32
0x0000052:       72 | 34 76 | 36 25 | 38 29 | 40 74 | 42 78 | 44 27 | 46 31 | 48
0x0000072:       09 | 50 13 | 52 41 | 54 45 | 56 11 | 58 15 | 60 43 | 62 47 | 00

Hop sequence {k} for MASTER PAGE RESPONSE SUBSTATE:
Offset value:    24
CLKE* =          0x0000012
UAP / LAP:       0x00000000
#ticks:          00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
                 -----------------------------------------------------------------
0x0000014:       02 68 | 04 17 | 06 21 | 08 66 | 10 70 | 12 19 | 14 23 | 16 01 |
0x0000034:       18 05 | 20 33 | 22 37 | 24 03 | 26 07 | 28 35 | 30 39 | 32 72 |
0x0000054:       34 76 | 36 25 | 38 29 | 40 74 | 42 78 | 44 27 | 46 31 | 48 09 |
0x0000074:       50 13 | 52 41 | 54 45 | 56 11 | 58 15 | 60 43 | 62 47 | 00 64 |
```

Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence; ie, non-AFH):
CLK start: 0x0000010
UAP/LAP: 0x00000000

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010:	08 66	10 70	12 19	14 23	16 01	18 05	20 33	22 37
0x0000030:	24 03	26 07	28 35	30 39	32 72	34 76	36 25	38 29
0x0000050:	40 74	42 78	44 27	46 31	48 09	50 13	52 41	54 45
0x0000070:	56 11	58 15	60 43	62 47	32 17	36 19	34 49	38 51
0x0000090:	40 21	44 23	42 53	46 55	48 33	52 35	50 65	54 67
0x00000b0:	56 37	60 39	58 69	62 71	64 25	68 27	66 57	70 59
0x00000d0:	72 29	76 31	74 61	78 63	01 41	05 43	03 73	07 75
0x00000f0:	09 45	13 47	11 77	15 00	64 49	66 53	68 02	70 06
0x0000110:	01 51	03 55	05 04	07 08	72 57	74 61	76 10	78 14
0x0000130:	09 59	11 63	13 12	15 16	17 65	19 69	21 18	23 22
0x0000150:	33 67	35 71	37 20	39 24	25 73	27 77	29 26	31 30
0x0000170:	41 75	43 00	45 28	47 32	17 02	21 04	19 34	23 36
0x0000190:	33 06	37 08	35 38	39 40	25 10	29 12	27 42	31 44
0x00001b0:	41 14	45 16	43 46	47 48	49 18	53 20	51 50	55 52
0x00001d0:	65 22	69 24	67 54	71 56	57 26	61 28	59 58	63 60
0x00001f0:	73 30	77 32	75 62	00 64	49 34	51 42	57 66	59 74
0x0000210:	53 36	55 44	61 68	63 76	65 50	67 58	73 03	75 11
0x0000230:	69 52	71 60	77 05	00 13	02 38	04 46	10 70	12 78
0x0000250:	06 40	08 48	14 72	16 01	18 54	20 62	26 07	28 15
0x0000270:	22 56	24 64	30 09	32 17	02 66	06 74	10 19	14 27
0x0000290:	04 70	08 78	12 23	16 31	18 03	22 11	26 35	30 43
0x00002b0:	20 07	24 15	28 39	32 47	34 68	38 76	42 21	46 29
0x00002d0:	36 72	40 01	44 25	48 33	50 05	54 13	58 37	62 45
0x00002f0:	52 09	56 17	60 41	64 49	34 19	36 35	50 51	52 67
0x0000310:	38 21	40 37	54 53	56 69	42 27	44 43	58 59	60 75
0x0000330:	46 29	48 45	62 61	64 77	66 23	68 39	03 55	05 71
0x0000350:	70 25	72 41	07 57	09 73	74 31	76 47	11 63	13 00
0x0000370:	78 33	01 49	15 65	17 02	66 51	70 67	03 04	07 20
0x0000390:	68 55	72 71	05 08	09 24	74 59	78 75	11 12	15 28
0x00003b0:	76 63	01 00	13 16	17 32	19 53	23 69	35 06	39 22
0x00003d0:	21 57	25 73	37 10	41 26	27 61	31 77	43 14	47 30
0x00003f0:	29 65	33 02	45 18	49 34	19 04	21 08	23 20	25 24

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with all channel used; ie, AFH(79)):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels:0x7fffffffffffffffffff

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	08 08	10 10	12 12	14 14	16 16	18 18	20 20	22 22
0x0000030	24 24	26 26	28 28	30 30	32 32	34 34	36 36	38 38
0x0000050	40 40	42 42	44 44	46 46	48 48	50 50	52 52	54 54
0x0000070	56 56	58 58	60 60	62 62	32 32	36 36	34 34	38 38
0x0000090	40 40	44 44	42 42	46 46	48 48	52 52	50 50	54 54
0x00000b0	56 56	60 60	58 58	62 62	64 64	68 68	66 66	70 70
0x00000d0	72 72	76 76	74 74	78 78	01 01	05 05	03 03	07 07
0x00000f0	09 09	13 13	11 11	15 15	64 64	66 66	68 68	70 70
0x0000110	01 01	03 03	05 05	07 07	72 72	74 74	76 76	78 78
0x0000130	09 09	11 11	13 13	15 15	17 17	19 19	21 21	23 23
0x0000150	33 33	35 35	37 37	39 39	25 25	27 27	29 29	31 31
0x0000170	41 41	43 43	45 45	47 47	17 17	21 21	19 19	23 23
0x0000190	33 33	37 37	35 35	39 39	25 25	29 29	27 27	31 31
0x00001b0	41 41	45 45	43 43	47 47	49 49	53 53	51 51	55 55
0x00001d0	65 65	69 69	67 67	71 71	57 57	61 61	59 59	63 63
0x00001f0	73 73	77 77	75 75	00 00	49 49	51 51	57 57	59 59
0x0000210	53 53	55 55	61 61	63 63	65 65	67 67	73 73	75 75
0x0000230	69 69	71 71	77 77	00 00	02 02	04 04	10 10	12 12
0x0000250	06 06	08 08	14 14	16 16	18 18	20 20	26 26	28 28
0x0000270	22 22	24 24	30 30	32 32	02 02	06 06	10 10	14 14
0x0000290	04 04	08 08	12 12	16 16	18 18	22 22	26 26	30 30
0x00002b0	20 20	24 24	28 28	32 32	34 34	38 38	42 42	46 46
0x00002d0	36 36	40 40	44 44	48 48	50 50	54 54	58 58	62 62
0x00002f0	52 52	56 56	60 60	64 64	34 34	36 36	50 50	52 52
0x0000310	38 38	40 40	54 54	56 56	42 42	44 44	58 58	60 60
0x0000330	46 46	48 48	62 62	64 64	66 66	68 68	03 03	05 05
0x0000350	70 70	72 72	07 07	09 09	74 74	76 76	11 11	13 13
0x0000370	78 78	01 01	15 15	17 17	66 66	70 70	03 03	07 07
0x0000390	68 68	72 72	05 05	09 09	74 74	78 78	11 11	15 15
0x00003b0	76 76	01 01	13 13	17 17	19 19	23 23	35 35	39 39
0x00003d0	21 21	25 25	37 37	41 41	27 27	31 31	43 43	47 47
0x00003f0	29 29	33 33	45 45	49 49	19 19	21 21	23 23	25 25

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with channels 0 to 21 unused):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels:0x7fffffffffffc00000

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	30 30	32 32	34 34	36 36	38 38	40 40	42 42	22 22
0x0000030	24 24	26 26	28 28	30 30	32 32	34 34	36 36	38 38
0x0000050	40 40	42 42	44 44	46 46	48 48	50 50	52 52	54 54
0x0000070	56 56	58 58	60 60	62 62	32 32	36 36	34 34	38 38
0x0000090	40 40	44 44	42 42	46 46	48 48	52 52	50 50	54 54
0x00000b0	56 56	60 60	58 58	62 62	64 64	68 68	66 66	70 70
0x00000d0	72 72	76 76	74 74	78 78	45 45	49 49	47 47	51 51
0x00000f0	53 53	57 57	55 55	59 59	64 64	66 66	68 68	70 70
0x0000110	45 45	47 47	49 49	51 51	72 72	74 74	76 76	78 78
0x0000130	53 53	55 55	57 57	59 59	61 61	63 63	65 65	23 23
0x0000150	33 33	35 35	37 37	39 39	25 25	27 27	29 29	31 31
0x0000170	41 41	43 43	45 45	47 47	61 61	65 65	63 63	23 23
0x0000190	33 33	37 37	35 35	39 39	25 25	29 29	27 27	31 31
0x00001b0	41 41	45 45	43 43	47 47	49 49	53 53	51 51	55 55
0x00001d0	65 65	69 69	67 67	71 71	57 57	61 61	59 59	63 63
0x00001f0	73 73	77 77	75 75	66 66	49 49	51 51	57 57	59 59
0x0000210	53 53	55 55	61 61	63 63	65 65	67 67	73 73	75 75
0x0000230	69 69	71 71	77 77	66 66	68 68	70 70	76 76	78 78
0x0000250	72 72	74 74	23 23	25 25	27 27	29 29	26 26	28 28
0x0000270	22 22	24 24	30 30	32 32	68 68	72 72	76 76	23 23
0x0000290	70 70	74 74	78 78	25 25	27 27	22 22	26 26	30 30
0x00002b0	29 29	24 24	28 28	32 32	34 34	38 38	42 42	46 46
0x00002d0	36 36	40 40	44 44	48 48	50 50	54 54	58 58	62 62
0x00002f0	52 52	56 56	60 60	64 64	34 34	36 36	50 50	52 52
0x0000310	38 38	40 40	54 54	56 56	42 42	44 44	58 58	60 60
0x0000330	46 46	48 48	62 62	64 64	66 66	68 68	34 34	36 36
0x0000350	70 70	72 72	38 38	40 40	74 74	76 76	42 42	44 44
0x0000370	78 78	32 32	46 46	48 48	66 66	70 70	34 34	38 38
0x0000390	68 68	72 72	36 36	40 40	74 74	78 78	42 42	46 46
0x00003b0	76 76	32 32	44 44	48 48	50 50	23 23	35 35	39 39
0x00003d0	52 52	25 25	37 37	41 41	27 27	31 31	43 43	47 47
0x00003f0	29 29	33 33	45 45	49 49	50 50	52 52	23 23	25 25

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with even channels used):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels:0x55555555555555555

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	08 08	10 10	12 12	14 14	16 16	18 18	20 20	22 22
0x0000030	24 24	26 26	28 28	30 30	32 32	34 34	36 36	38 38
0x0000050	40 40	42 42	44 44	46 46	48 48	50 50	52 52	54 54
0x0000070	56 56	58 58	60 60	62 62	32 32	36 36	34 34	38 38
0x0000090	40 40	44 44	42 42	46 46	48 48	52 52	50 50	54 54
0x00000b0	56 56	60 60	58 58	62 62	64 64	68 68	66 66	70 70
0x00000d0	72 72	76 76	74 74	78 78	00 00	04 04	02 02	06 06
0x00000f0	08 08	12 12	10 10	14 14	64 64	66 66	68 68	70 70
0x0000110	00 00	02 02	04 04	06 06	72 72	74 74	76 76	78 78
0x0000130	08 08	10 10	12 12	14 14	16 16	18 18	20 20	22 22
0x0000150	32 32	34 34	36 36	38 38	24 24	26 26	28 28	30 30
0x0000170	40 40	42 42	44 44	46 46	16 16	20 20	18 18	22 22
0x0000190	32 32	36 36	34 34	38 38	24 24	28 28	26 26	30 30
0x00001b0	40 40	44 44	42 42	46 46	48 48	52 52	50 50	54 54
0x00001d0	64 64	68 68	66 66	70 70	56 56	60 60	58 58	62 62
0x00001f0	72 72	76 76	74 74	00 00	48 48	50 50	56 56	58 58
0x0000210	52 52	54 54	60 60	62 62	64 64	66 66	72 72	74 74
0x0000230	68 68	70 70	76 76	00 00	02 02	04 04	10 10	12 12
0x0000250	06 06	08 08	14 14	16 16	18 18	20 20	26 26	28 28
0x0000270	22 22	24 24	30 30	32 32	02 02	06 06	10 10	14 14
0x0000290	04 04	08 08	12 12	16 16	18 18	22 22	26 26	30 30
0x00002b0	20 20	24 24	28 28	32 32	34 34	38 38	42 42	46 46
0x00002d0	36 36	40 40	44 44	48 48	50 50	54 54	58 58	62 62
0x00002f0	52 52	56 56	60 60	64 64	34 34	36 36	50 50	52 52
0x0000310	38 38	40 40	54 54	56 56	42 42	44 44	58 58	60 60
0x0000330	46 46	48 48	62 62	64 64	66 66	68 68	00 00	02 02
0x0000350	70 70	72 72	04 04	06 06	74 74	76 76	08 08	10 10
0x0000370	78 78	78 78	12 12	14 14	66 66	70 70	00 00	04 04
0x0000390	68 68	72 72	02 02	06 06	74 74	78 78	08 08	12 12
0x00003b0	76 76	78 78	10 10	14 14	16 16	20 20	32 32	36 36
0x00003d0	18 18	22 22	34 34	38 38	24 24	28 28	40 40	44 44
0x00003f0	26 26	30 30	42 42	46 46	16 16	18 18	20 20	22 22

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with odd channels used):

CLK start: 0x0000010

ULAP: 0x00000000

Used Channels:0x2aaaaaaaaaaaaaaaaaaa

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	09 09	11 11	13 13	15 15	17 17	19 19	21 21	23 23
0x0000030	25 25	27 27	29 29	31 31	33 33	35 35	37 37	39 39
0x0000050	41 41	43 43	45 45	47 47	49 49	51 51	53 53	55 55
0x0000070	57 57	59 59	61 61	63 63	33 33	37 37	35 35	39 39
0x0000090	41 41	45 45	43 43	47 47	49 49	53 53	51 51	55 55
0x00000b0	57 57	61 61	59 59	63 63	65 65	69 69	67 67	71 71
0x00000d0	73 73	77 77	75 75	01 01	01 01	05 05	03 03	07 07
0x00000f0	09 09	13 13	11 11	15 15	65 65	67 67	69 69	71 71
0x0000110	01 01	03 03	05 05	07 07	73 73	75 75	77 77	01 01
0x0000130	09 09	11 11	13 13	15 15	17 17	19 19	21 21	23 23
0x0000150	33 33	35 35	37 37	39 39	25 25	27 27	29 29	31 31
0x0000170	41 41	43 43	45 45	47 47	17 17	21 21	19 19	23 23
0x0000190	33 33	37 37	35 35	39 39	25 25	29 29	27 27	31 31
0x00001b0	41 41	45 45	43 43	47 47	49 49	53 53	51 51	55 55
0x00001d0	65 65	69 69	67 67	71 71	57 57	61 61	59 59	63 63
0x00001f0	73 73	77 77	75 75	03 03	49 49	51 51	57 57	59 59
0x0000210	53 53	55 55	61 61	63 63	65 65	67 67	73 73	75 75
0x0000230	69 69	71 71	77 77	03 03	05 05	07 07	13 13	15 15
0x0000250	09 09	11 11	17 17	19 19	21 21	23 23	29 29	31 31
0x0000270	25 25	27 27	33 33	35 35	05 05	09 09	13 13	17 17
0x0000290	07 07	11 11	15 15	19 19	21 21	25 25	29 29	33 33
0x00002b0	23 23	27 27	31 31	35 35	37 37	41 41	45 45	49 49
0x00002d0	39 39	43 43	47 47	51 51	53 53	57 57	61 61	65 65
0x00002f0	55 55	59 59	63 63	67 67	37 37	39 39	53 53	55 55
0x0000310	41 41	43 43	57 57	59 59	45 45	47 47	61 61	63 63
0x0000330	49 49	51 51	65 65	67 67	69 69	71 71	03 03	05 05
0x0000350	73 73	75 75	07 07	09 09	77 77	01 01	11 11	13 13
0x0000370	03 03	01 01	15 15	17 17	69 69	73 73	03 03	07 07
0x0000390	71 71	75 75	05 05	09 09	77 77	03 03	11 11	15 15
0x00003b0	01 01	01 01	13 13	17 17	19 19	23 23	35 35	39 39
0x00003d0	21 21	25 25	37 37	41 41	27 27	31 31	43 43	47 47
0x00003f0	29 29	33 33	45 45	49 49	19 19	21 21	23 23	25 25

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2.2 SECOND SET

```
Hop sequence {k} for PAGE SCAN/INQUIRY SCAN SUBSTATE:
CLKN start:     0x0000000
ULAP:           0x2a96ef25
#ticks:         0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
                -----------------------------------------------------
0x0000000:        49 |   13 |   17 |   51 |   55 |   19 |   23 |   53 |
0x0008000:        57 |   21 |   25 |   27 |   31 |   74 |   78 |   29 |
0x0010000:        33 |   76 |    1 |   35 |   39 |    3 |    7 |   37 |
0x0018000:        41 |    5 |    9 |   43 |   47 |   11 |   15 |   45 |
0x0020000:        49 |   13 |   17 |   51 |   55 |   19 |   23 |   53 |
0x0028000:        57 |   21 |   25 |   27 |   31 |   74 |   78 |   29 |
0x0030000:        33 |   76 |    1 |   35 |   39 |    3 |    7 |   37 |
0x0038000:        41 |    5 |    9 |   43 |   47 |   11 |   15 |   45 |

Hop sequence {k} for PAGE STATE/INQUIRY SUBSTATE:
CLKE start:     0x0000000
ULAP:           0x2a96ef25
#ticks:         00 01 02 03 | 04 05 06 07 | 08 09 0a 0b | 0c 0d 0e 0f |
                -----------------------------------------------------
0x0000000:      41 05 10 04 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
0x0000010:      49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
0x0000020:      41 05 10 04 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
0x0000030:      49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
...
0x0001000:      41 21 10 36 | 25 27 38 63 | 31 74 65 59 | 78 29 61 00 |
0x0001010:      33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |
0x0001020:      41 21 10 36 | 25 27 38 63 | 31 74 65 59 | 78 29 61 00 |
0x0001030:      33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |
...
0x0002000:      57 21 42 36 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
0x0002010:      49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
0x0002020:      57 21 42 36 | 09 43 06 16 | 47 11 18 12 | 15 45 14 32 |
0x0002030:      49 13 34 28 | 17 51 30 24 | 55 19 26 20 | 23 53 22 40 |
...
0x0003000:      41 05 10 04 | 09 27 06 63 | 31 74 65 59 | 78 29 61 00 |
0x0003010:      33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |
0x0003020:      41 05 10 04 | 09 27 06 63 | 31 74 65 59 | 78 29 61 00 |
0x0003030:      33 76 02 75 | 01 35 77 71 | 39 03 73 67 | 07 37 69 08 |

Hop sequence {k} for SLAVE PAGE RESPONSE SUBSTATE:
CLKN* =         0x0000010
ULAP:           0x2a96ef25
#ticks:         00 | 02 04 | 06 08 | 0a 0c | 0e 10 | 12 14 | 16 18 | 1a 1c | 1e
                ---------------------------------------------------------------
0x0000012:      34 | 13 28 | 17 30 | 51 24 | 55 26 | 19 20 | 23 22 | 53 40 | 57
0x0000032:      42 | 21 36 | 25 38 | 27 63 | 31 65 | 74 59 | 78 61 | 29 00 | 33
0x0000052:      02 | 76 75 | 01 77 | 35 71 | 39 73 | 03 67 | 07 69 | 37 08 | 41
0x0000072:      10 | 05 04 | 09 06 | 43 16 | 47 18 | 11 12 | 15 14 | 45 32 | 49

Hop sequence {k} for MASTER PAGE RESPONSE SUBSTATE:
Offset value:   24
CLKE* =         0x0000012
ULAP:           0x2a96ef25
#ticks:         00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
                -----------------------------------------------------------------
0x0000014:      13 28 | 17 30 | 51 24 | 55 26 | 19 20 | 23 22 | 53 40 | 57 42 |
0x0000034:      21 36 | 25 38 | 27 63 | 31 65 | 74 59 | 78 61 | 29 00 | 33 02 |
0x0000054:      76 75 | 01 77 | 35 71 | 39 73 | 03 67 | 07 69 | 37 08 | 41 10 |
0x0000074:      05 04 | 09 06 | 43 16 | 47 18 | 11 12 | 15 14 | 45 32 | 49 34 |
```

Sample Data

Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence; ie, non-AFH):
CLK start: 0x0000010
ULAP: 0x2a96ef25

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010:	55 26	19 20	23 22	53 40	57 42	21 36	25 38	27 63
0x0000030:	31 65	74 59	78 61	29 00	33 02	76 75	01 77	35 71
0x0000050:	39 73	03 67	07 69	37 08	41 10	05 04	09 06	43 16
0x0000070:	47 18	11 12	15 14	45 32	02 66	47 60	49 64	04 54
0x0000090:	06 58	51 52	53 56	08 70	10 74	55 68	57 72	59 14
0x00000b0:	61 18	27 12	29 16	63 30	65 34	31 28	33 32	67 22
0x00000d0:	69 26	35 20	37 24	71 38	73 42	39 36	41 40	75 46
0x00000f0:	77 50	43 44	45 48	00 62	26 11	69 05	73 07	36 17
0x0000110:	40 19	04 13	08 15	38 25	42 27	06 21	10 23	12 48
0x0000130:	16 50	59 44	63 46	14 56	18 58	61 52	65 54	28 64
0x0000150:	32 66	75 60	00 62	30 72	34 74	77 68	02 70	20 01
0x0000170:	24 03	67 76	71 78	22 09	58 43	24 37	26 41	68 47
0x0000190:	70 51	36 45	38 49	72 55	74 59	40 53	42 57	44 78
0x00001b0:	46 03	12 76	14 01	48 07	50 11	16 05	18 09	60 15
0x00001d0:	62 19	28 13	30 17	64 23	66 27	32 21	34 25	52 31
0x00001f0:	54 35	20 29	22 33	56 39	19 04	62 63	66 00	07 73
0x0000210:	11 10	54 69	58 06	23 75	27 12	70 71	74 08	76 33
0x0000230:	01 49	44 29	48 45	13 35	17 51	60 31	64 47	05 41
0x0000250:	09 57	52 37	56 53	21 43	25 59	68 39	72 55	78 65
0x0000270:	03 02	46 61	50 77	15 67	51 36	17 18	19 34	41 24
0x0000290:	43 40	09 22	11 38	57 28	59 44	25 26	27 42	29 63
0x00002b0:	31 00	76 61	78 77	45 67	47 04	13 65	15 02	37 71
0x00002d0:	39 08	05 69	07 06	53 75	55 12	21 73	23 10	33 16
0x00002f0:	35 32	01 14	03 30	49 20	75 60	39 48	43 56	00 66
0x0000310:	04 74	47 62	51 70	08 68	12 76	55 64	59 72	61 18
0x0000330:	65 26	29 14	33 22	69 20	73 28	37 16	41 24	77 34
0x0000350:	02 42	45 30	49 38	06 36	10 44	53 32	57 40	63 50
0x0000370:	67 58	31 46	35 54	71 52	28 13	73 03	75 11	34 17
0x0000390:	36 25	02 15	04 23	42 21	44 29	10 19	12 27	14 48
0x00003b0:	16 56	61 46	63 54	22 52	24 60	69 50	71 58	30 64
0x00003d0:	32 72	77 62	00 70	38 68	40 76	06 66	08 74	18 01
0x00003f0:	20 09	65 78	67 07	26 05	44 29	32 23	36 25	70 43

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with all channel used; ie, AFH(79)):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels:0x7fffffffffffffffffff

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	55 55	19 19	23 23	53 53	57 57	21 21	25 25	27 27
0x0000030	31 31	74 74	78 78	29 29	33 33	76 76	01 01	35 35
0x0000050	39 39	03 03	07 07	37 37	41 41	05 05	09 09	43 43
0x0000070	47 47	11 11	15 15	45 45	02 02	47 47	49 49	04 04
0x0000090	06 06	51 51	53 53	08 08	10 10	55 55	57 57	59 59
0x00000b0	61 61	27 27	29 29	63 63	65 65	31 31	33 33	67 67
0x00000d0	69 69	35 35	37 37	71 71	73 73	39 39	41 41	75 75
0x00000f0	77 77	43 43	45 45	00 00	26 26	69 69	73 73	36 36
0x0000110	40 40	04 04	08 08	38 38	42 42	06 06	10 10	12 12
0x0000130	16 16	59 59	63 63	14 14	18 18	61 61	65 65	28 28
0x0000150	32 32	75 75	00 00	30 30	34 34	77 77	02 02	20 20
0x0000170	24 24	67 67	71 71	22 22	58 58	24 24	26 26	68 68
0x0000190	70 70	36 36	38 38	72 72	74 74	40 40	42 42	44 44
0x00001b0	46 46	12 12	14 14	48 48	50 50	16 16	18 18	60 60
0x00001d0	62 62	28 28	30 30	64 64	66 66	32 32	34 34	52 52
0x00001f0	54 54	20 20	22 22	56 56	19 19	62 62	66 66	07 07
0x0000210	11 11	54 54	58 58	23 23	27 27	70 70	74 74	76 76
0x0000230	01 01	44 44	48 48	13 13	17 17	60 60	64 64	05 05
0x0000250	09 09	52 52	56 56	21 21	25 25	68 68	72 72	78 78
0x0000270	03 03	46 46	50 50	15 15	51 51	17 17	19 19	41 41
0x0000290	43 43	09 09	11 11	57 57	59 59	25 25	27 27	29 29
0x00002b0	31 31	76 76	78 78	45 45	47 47	13 13	15 15	37 37
0x00002d0	39 39	05 05	07 07	53 53	55 55	21 21	23 23	33 33
0x00002f0	35 35	01 01	03 03	49 49	75 75	39 39	43 43	00 00
0x0000310	04 04	47 47	51 51	08 08	12 12	55 55	59 59	61 61
0x0000330	65 65	29 29	33 33	69 69	73 73	37 37	41 41	77 77
0x0000350	02 02	45 45	49 49	06 06	10 10	53 53	57 57	63 63
0x0000370	67 67	31 31	35 35	71 71	28 28	73 73	75 75	34 34
0x0000390	36 36	02 02	04 04	42 42	44 44	10 10	12 12	14 14
0x00003b0	16 16	61 61	63 63	22 22	24 24	69 69	71 71	30 30
0x00003d0	32 32	77 77	00 00	38 38	40 40	06 06	08 08	18 18
0x00003f0	20 20	65 65	67 67	26 26	44 44	32 32	36 36	70 70

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with channels 0 to 21 unused):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels:0x7fffffffffffffc00000

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	55 55	50 50	23 23	53 53	57 57	52 52	25 25	27 27
0x0000030	31 31	74 74	78 78	29 29	33 33	76 76	32 32	35 35
0x0000050	39 39	34 34	38 38	37 37	41 41	36 36	40 40	43 43
0x0000070	47 47	42 42	46 46	45 45	55 55	47 47	49 49	57 57
0x0000090	59 59	51 51	53 53	61 61	63 63	55 55	57 57	59 59
0x00000b0	61 61	27 27	29 29	63 63	65 65	31 31	33 33	67 67
0x00000d0	69 69	35 35	37 37	71 71	73 73	39 39	41 41	75 75
0x00000f0	77 77	43 43	45 45	53 53	26 26	69 69	73 73	36 36
0x0000110	40 40	57 57	61 61	38 38	42 42	59 59	63 63	65 65
0x0000130	69 69	59 59	63 63	67 67	71 71	61 61	65 65	28 28
0x0000150	32 32	75 75	53 53	30 30	34 34	77 77	55 55	73 73
0x0000170	24 24	67 67	71 71	22 22	58 58	24 24	26 26	68 68
0x0000190	70 70	36 36	38 38	72 72	74 74	40 40	42 42	44 44
0x00001b0	46 46	65 65	67 67	48 48	50 50	69 69	71 71	60 60
0x00001d0	62 62	28 28	30 30	64 64	66 66	32 32	34 34	52 52
0x00001f0	54 54	73 73	22 22	56 56	37 37	62 62	66 66	25 25
0x0000210	29 29	54 54	58 58	23 23	27 27	70 70	74 74	76 76
0x0000230	76 76	44 44	48 48	31 31	35 35	60 60	64 64	23 23
0x0000250	27 27	52 52	56 56	39 39	25 25	68 68	72 72	78 78
0x0000270	78 78	46 46	50 50	33 33	51 51	35 35	37 37	41 41
0x0000290	43 43	27 27	29 29	57 57	59 59	25 25	27 27	29 29
0x00002b0	31 31	76 76	78 78	45 45	47 47	31 31	33 33	37 37
0x00002d0	39 39	23 23	25 25	53 53	55 55	39 39	23 23	33 33
0x00002f0	35 35	76 76	78 78	49 49	75 75	39 39	43 43	40 40
0x0000310	44 44	47 47	51 51	48 48	52 52	55 55	59 59	61 61
0x0000330	65 65	29 29	33 33	69 69	73 73	37 37	41 41	77 77
0x0000350	42 42	45 45	49 49	46 46	50 50	53 53	57 57	63 63
0x0000370	67 67	31 31	35 35	71 71	28 28	73 73	75 75	34 34
0x0000390	36 36	42 42	44 44	42 42	44 44	50 50	52 52	54 54
0x00003b0	56 56	61 61	63 63	22 22	24 24	69 69	71 71	30 30
0x00003d0	32 32	77 77	40 40	38 38	40 40	46 46	48 48	58 58
0x00003f0	60 60	65 65	67 67	26 26	44 44	32 32	36 36	70 70

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with even channels used):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels:0x55555555555555555555

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	52 52	16 16	20 20	50 50	54 54	18 18	22 22	24 24
0x0000030	28 28	74 74	78 78	26 26	30 30	76 76	78 78	32 32
0x0000050	36 36	00 00	04 04	34 34	38 38	02 02	06 06	40 40
0x0000070	44 44	08 08	12 12	42 42	02 02	44 44	46 46	04 04
0x0000090	06 06	48 48	50 50	08 08	10 10	52 52	54 54	56 56
0x00000b0	58 58	24 24	26 26	60 60	62 62	28 28	30 30	64 64
0x00000d0	66 66	32 32	34 34	68 68	70 70	36 36	38 38	72 72
0x00000f0	74 74	40 40	42 42	00 00	26 26	66 66	70 70	36 36
0x0000110	40 40	04 04	08 08	38 38	42 42	06 06	10 10	12 12
0x0000130	16 16	56 56	60 60	14 14	18 18	58 58	62 62	28 28
0x0000150	32 32	72 72	00 00	30 30	34 34	74 74	02 02	20 20
0x0000170	24 24	64 64	68 68	22 22	58 58	24 24	26 26	68 68
0x0000190	70 70	36 36	38 38	72 72	74 74	40 40	42 42	44 44
0x00001b0	46 46	12 12	14 14	48 48	50 50	16 16	18 18	60 60
0x00001d0	62 62	28 28	30 30	64 64	66 66	32 32	34 34	52 52
0x00001f0	54 54	20 20	22 22	56 56	14 14	62 62	66 66	02 02
0x0000210	06 06	54 54	58 58	18 18	22 22	70 70	74 74	76 76
0x0000230	76 76	44 44	48 48	08 08	12 12	60 60	64 64	00 00
0x0000250	04 04	52 52	56 56	16 16	20 20	68 68	72 72	78 78
0x0000270	78 78	46 46	50 50	10 10	46 46	12 12	14 14	36 36
0x0000290	38 38	04 04	06 06	52 52	54 54	20 20	22 22	24 24
0x00002b0	26 26	76 76	78 78	40 40	42 42	08 08	10 10	32 32
0x00002d0	34 34	00 00	02 02	48 48	50 50	16 16	18 18	28 28
0x00002f0	30 30	76 76	78 78	44 44	70 70	34 34	38 38	00 00
0x0000310	04 04	42 42	46 46	08 08	12 12	50 50	54 54	56 56
0x0000330	60 60	24 24	28 28	64 64	68 68	32 32	36 36	72 72
0x0000350	02 02	40 40	44 44	06 06	10 10	48 48	52 52	58 58
0x0000370	62 62	26 26	30 30	66 66	28 28	68 68	70 70	34 34
0x0000390	36 36	02 02	04 04	42 42	44 44	10 10	12 12	14 14
0x00003b0	16 16	56 56	58 58	22 22	24 24	64 64	66 66	30 30
0x00003d0	32 32	72 72	00 00	38 38	40 40	06 06	08 08	18 18
0x00003f0	20 20	60 60	62 62	26 26	44 44	32 32	36 36	70 70

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with odd channels used):

CLK start: 0x0000010

ULAP: 0x2a96ef25

Used Channels:0x2aaaaaaaaaaaaaaaaaaa

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	55 55	19 19	23 23	53 53	57 57	21 21	25 25	27 27
0x0000030	31 31	77 77	03 03	29 29	33 33	01 01	01 01	35 35
0x0000050	39 39	03 03	07 07	37 37	41 41	05 05	09 09	43 43
0x0000070	47 47	11 11	15 15	45 45	07 07	47 47	49 49	09 09
0x0000090	11 11	51 51	53 53	13 13	15 15	55 55	57 57	59 59
0x00000b0	61 61	27 27	29 29	63 63	65 65	31 31	33 33	67 67
0x00000d0	69 69	35 35	37 37	71 71	73 73	39 39	41 41	75 75
0x00000f0	77 77	43 43	45 45	05 05	31 31	69 69	73 73	41 41
0x0000110	45 45	09 09	13 13	43 43	47 47	11 11	15 15	17 17
0x0000130	21 21	59 59	63 63	19 19	23 23	61 61	65 65	33 33
0x0000150	37 37	75 75	05 05	35 35	39 39	77 77	07 07	25 25
0x0000170	29 29	67 67	71 71	27 27	63 63	29 29	31 31	73 73
0x0000190	75 75	41 41	43 43	77 77	01 01	45 45	47 47	49 49
0x00001b0	51 51	17 17	19 19	53 53	55 55	21 21	23 23	65 65
0x00001d0	67 67	33 33	35 35	69 69	71 71	37 37	39 39	57 57
0x00001f0	59 59	25 25	27 27	61 61	19 19	67 67	71 71	07 07
0x0000210	11 11	59 59	63 63	23 23	27 27	75 75	01 01	03 03
0x0000230	01 01	49 49	53 53	13 13	17 17	65 65	69 69	05 05
0x0000250	09 09	57 57	61 61	21 21	25 25	73 73	77 77	05 05
0x0000270	03 03	51 51	55 55	15 15	51 51	17 17	19 19	41 41
0x0000290	43 43	09 09	11 11	57 57	59 59	25 25	27 27	29 29
0x00002b0	31 31	03 03	05 05	45 45	47 47	13 13	15 15	37 37
0x00002d0	39 39	05 05	07 07	53 53	55 55	21 21	23 23	33 33
0x00002f0	35 35	01 01	03 03	49 49	75 75	39 39	43 43	07 07
0x0000310	11 11	47 47	51 51	15 15	19 19	55 55	59 59	61 61
0x0000330	65 65	29 29	33 33	69 69	73 73	37 37	41 41	77 77
0x0000350	09 09	45 45	49 49	13 13	17 17	53 53	57 57	63 63
0x0000370	67 67	31 31	35 35	71 71	35 35	73 73	75 75	41 41
0x0000390	43 43	09 09	11 11	49 49	51 51	17 17	19 19	21 21
0x00003b0	23 23	61 61	63 63	29 29	31 31	69 69	71 71	37 37
0x00003d0	39 39	77 77	07 07	45 45	47 47	13 13	15 15	25 25
0x00003f0	27 27	65 65	67 67	33 33	51 51	39 39	43 43	77 77

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2.3 THIRD SET

```
Hop sequence {k} for PAGE SCAN/INQUIRY SCAN SUBSTATE:
CLKN start:      0x0000000
ULAP:            0x6587cba9
#ticks:          0000 | 1000 | 2000 | 3000 | 4000 | 5000 | 6000 | 7000 |
                 -------------------------------------------------------
0x0000000:         16 |   65 |   67 |   18 |   20 |   53 |   55 |    6 |
0x0008000:          8 |   57 |   59 |   10 |   12 |   69 |   71 |   22 |
0x0010000:         24 |   73 |   75 |   26 |   28 |   45 |   47 |   77 |
0x0018000:          0 |   49 |   51 |    2 |    4 |   61 |   63 |   14 |
0x0020000:         16 |   65 |   67 |   18 |   20 |   53 |   55 |    6 |
0x0028000:          8 |   57 |   59 |   10 |   12 |   69 |   71 |   22 |
0x0030000:         24 |   73 |   75 |   26 |   28 |   45 |   47 |   77 |
0x0038000:          0 |   49 |   51 |    2 |    4 |   61 |   63 |   14 |

Hop sequence {k} for PAGE STATE/INQUIRY SUBSTATE:
CLKE start:      0x0000000
ULAP:            0x6587cba9
#ticks:          00 01 02 03 | 04 05 06 07 | 08 09 0a 0b | 0c 0d 0e 0f |
                 -----------------------------------------------------
0x0000000:       00 49 36 38 | 51 02 42 40 | 04 61 44 46 | 63 14 50 48 |
0x0000010:       16 65 52 54 | 67 18 58 56 | 20 53 60 62 | 55 06 66 64 |
0x0000020:       00 49 36 38 | 51 02 42 40 | 04 61 44 46 | 63 14 50 48 |
0x0000030:       16 65 52 54 | 67 18 58 56 | 20 53 60 62 | 55 06 66 64 |
...
0x0001000:       00 57 36 70 | 59 10 74 72 | 12 69 76 78 | 71 22 03 01 |
0x0001010:       24 73 05 07 | 75 26 11 09 | 28 45 13 30 | 47 77 34 32 |
0x0001020:       00 57 36 70 | 59 10 74 72 | 12 69 76 78 | 71 22 03 01 |
0x0001030:       24 73 05 07 | 75 26 11 09 | 28 45 13 30 | 47 77 34 32 |
...
0x0002000:       08 57 68 70 | 51 02 42 40 | 04 61 44 46 | 63 14 50 48 |
0x0002010:       16 65 52 54 | 67 18 58 56 | 20 53 60 62 | 55 06 66 64 |
0x0002020:       08 57 68 70 | 51 02 42 40 | 04 61 44 46 | 63 14 50 48 |
0x0002030:       16 65 52 54 | 67 18 58 56 | 20 53 60 62 | 55 06 66 64 |
...
0x0003000:       00 49 36 38 | 51 10 42 72 | 12 69 76 78 | 71 22 03 01 |
0x0003010:       24 73 05 07 | 75 26 11 09 | 28 45 13 30 | 47 77 34 32 |
0x0003020:       00 49 36 38 | 51 10 42 72 | 12 69 76 78 | 71 22 03 01 |
0x0003030:       24 73 05 07 | 75 26 11 09 | 28 45 13 30 | 47 77 34 32 |

Hop sequence {k} for SLAVE PAGE RESPONSE SUBSTATE:
CLKN* =          0x0000010
ULAP:            0x6587cba9
#ticks:          00 | 02 04 | 06 08 | 0a 0c | 0e 10 | 12 14 | 16 18 | 1a 1c | 1e
                 ---------------------------------------------------------------
0x0000012:       52 | 65 54 | 67 58 | 18 56 | 20 60 | 53 62 | 55 66 | 06 64 | 08
0x0000032:       68 | 57 70 | 59 74 | 10 72 | 12 76 | 69 78 | 71 03 | 22 01 | 24
0x0000052:       05 | 73 07 | 75 11 | 26 09 | 28 13 | 45 30 | 47 34 | 77 32 | 00
0x0000072:       36 | 49 38 | 51 42 | 02 40 | 04 44 | 61 46 | 63 50 | 14 48 | 16

Hop sequence {k} for MASTER PAGE RESPONSE SUBSTATE:
Offset value:    24
CLKE* =          0x0000012
ULAP:            0x6587cba9
#ticks:          00 02 | 04 06 | 08 0a | 0c 0e | 10 12 | 14 16 | 18 1a | 1c 1e |
                 -----------------------------------------------------------------
0x0000014:       65 54 | 67 58 | 18 56 | 20 60 | 53 62 | 55 66 | 06 64 | 08 68 |
0x0000034:       57 70 | 59 74 | 10 72 | 12 76 | 69 78 | 71 03 | 22 01 | 24 05 |
0x0000054:       73 07 | 75 11 | 26 09 | 28 13 | 45 30 | 47 34 | 77 32 | 00 36 |
0x0000074:       49 38 | 51 42 | 02 40 | 04 44 | 61 46 | 63 50 | 14 48 | 16 52 |
```

Hop sequence {k} for CONNECTION STATE (Basic channel hopping sequence; ie, non-AFH):
CLK start: 0x0000010
ULAP: 0x6587cba9

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010:	20 60	53 62	55 66	06 64	08 68	57 70	59 74	10 72
0x0000030:	12 76	69 78	71 03	22 01	24 05	73 07	75 11	26 09
0x0000050:	28 13	45 30	47 34	77 32	00 36	49 38	51 42	02 40
0x0000070:	04 44	61 46	63 50	14 48	50 05	16 07	20 09	48 11
0x0000090:	52 13	06 15	10 17	38 19	42 21	08 23	12 25	40 27
0x00000b0:	44 29	22 31	26 33	54 35	58 37	24 39	28 41	56 43
0x00000d0:	60 45	77 62	02 64	30 66	34 68	00 70	04 72	32 74
0x00000f0:	36 76	14 78	18 01	46 03	72 29	42 39	44 43	74 41
0x0000110:	76 45	46 47	48 51	78 49	01 53	50 63	52 67	03 65
0x0000130:	05 69	54 55	56 59	07 57	09 61	58 71	60 75	11 73
0x0000150:	13 77	30 15	32 19	62 17	64 21	34 31	36 35	66 33
0x0000170:	68 37	38 23	40 27	70 25	27 61	72 71	76 73	25 75
0x0000190:	29 77	78 00	03 02	31 04	35 06	01 16	05 18	33 20
0x00001b0:	37 22	07 08	11 10	39 12	43 14	09 24	13 26	41 28
0x00001d0:	45 30	62 47	66 49	15 51	19 53	64 63	68 65	17 67
0x00001f0:	21 69	70 55	74 57	23 59	53 22	35 12	37 28	67 14
0x0000210:	69 30	23 32	25 48	55 34	57 50	39 40	41 56	71 42
0x0000230:	73 58	27 36	29 52	59 38	61 54	43 44	45 60	75 46
0x0000250:	77 62	15 00	17 16	47 02	49 18	31 08	33 24	63 10
0x0000270:	65 26	19 04	21 20	51 06	06 54	65 42	69 58	18 46
0x0000290:	22 62	55 64	59 01	08 68	12 05	71 72	75 09	24 76
0x00002b0:	28 13	57 66	61 03	10 70	14 07	73 74	77 11	26 78
0x00002d0:	30 15	47 32	51 48	00 36	04 52	63 40	67 56	16 44
0x00002f0:	20 60	49 34	53 50	02 38	38 78	12 05	14 13	44 07
0x0000310:	46 15	16 17	18 25	48 19	50 27	24 33	26 41	56 35
0x0000330:	58 43	20 21	22 29	52 23	54 31	28 37	30 45	60 39
0x0000350:	62 47	00 64	02 72	32 66	34 74	08 01	10 09	40 03
0x0000370:	42 11	04 68	06 76	36 70	70 31	42 35	46 43	74 39
0x0000390:	78 47	48 49	52 57	01 53	05 61	56 65	60 73	09 69
0x00003b0:	13 77	50 51	54 59	03 55	07 63	58 67	62 75	11 71
0x00003d0:	15 00	32 17	36 25	64 21	68 29	40 33	44 41	72 37
0x00003f0:	76 45	34 19	38 27	66 23	11 71	05 18	07 22	13 20

Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with all channel used; ie, AFH(79)):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels:0x7fffffffffffffffffff

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	20 20	53 53	55 55	06 06	08 08	57 57	59 59	10 10
0x0000030	12 12	69 69	71 71	22 22	24 24	73 73	75 75	26 26
0x0000050	28 28	45 45	47 47	77 77	00 00	49 49	51 51	02 02
0x0000070	04 04	61 61	63 63	14 14	50 50	16 16	20 20	48 48
0x0000090	52 52	06 06	10 10	38 38	42 42	08 08	12 12	40 40
0x00000b0	44 44	22 22	26 26	54 54	58 58	24 24	28 28	56 56
0x00000d0	60 60	77 77	02 02	30 30	34 34	00 00	04 04	32 32
0x00000f0	36 36	14 14	18 18	46 46	72 72	42 42	44 44	74 74
0x0000110	76 76	46 46	48 48	78 78	01 01	50 50	52 52	03 03
0x0000130	05 05	54 54	56 56	07 07	09 09	58 58	60 60	11 11
0x0000150	13 13	30 30	32 32	62 62	64 64	34 34	36 36	66 66
0x0000170	68 68	38 38	40 40	70 70	27 27	72 72	76 76	25 25
0x0000190	29 29	78 78	03 03	31 31	35 35	01 01	05 05	33 33
0x00001b0	37 37	07 07	11 11	39 39	43 43	09 09	13 13	41 41
0x00001d0	45 45	62 62	66 66	15 15	19 19	64 64	68 68	17 17
0x00001f0	21 21	70 70	74 74	23 23	53 53	35 35	37 37	67 67
0x0000210	69 69	23 23	25 25	55 55	57 57	39 39	41 41	71 71
0x0000230	73 73	27 27	29 29	59 59	61 61	43 43	45 45	75 75
0x0000250	77 77	15 15	17 17	47 47	49 49	31 31	33 33	63 63
0x0000270	65 65	19 19	21 21	51 51	06 06	65 65	69 69	18 18
0x0000290	22 22	55 55	59 59	08 08	12 12	71 71	75 75	24 24
0x00002b0	28 28	57 57	61 61	10 10	14 14	73 73	77 77	26 26
0x00002d0	30 30	47 47	51 51	00 00	04 04	63 63	67 67	16 16
0x00002f0	20 20	49 49	53 53	02 02	38 38	12 12	14 14	44 44
0x0000310	46 46	16 16	18 18	48 48	50 50	24 24	26 26	56 56
0x0000330	58 58	20 20	22 22	52 52	54 54	28 28	30 30	60 60
0x0000350	62 62	00 00	02 02	32 32	34 34	08 08	10 10	40 40
0x0000370	42 42	04 04	06 06	36 36	70 70	42 42	46 46	74 74
0x0000390	78 78	48 48	52 52	01 01	05 05	56 56	60 60	09 09
0x00003b0	13 13	50 50	54 54	03 03	07 07	58 58	62 62	11 11
0x00003d0	15 15	32 32	36 36	64 64	68 68	40 40	44 44	72 72
0x00003f0	76 76	34 34	38 38	66 66	11 11	05 05	07 07	13 13

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with channels 0 to 21 unused):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels:0x7fffffffffffc00000

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	29 29	53 53	55 55	72 72	74 74	57 57	59 59	76 76
0x0000030	78 78	69 69	71 71	22 22	24 24	73 73	75 75	26 26
0x0000050	28 28	45 45	47 47	77 77	66 66	49 49	51 51	68 68
0x0000070	70 70	61 61	63 63	23 23	50 50	25 25	29 29	48 48
0x0000090	52 52	72 72	76 76	38 38	42 42	74 74	78 78	40 40
0x00000b0	44 44	22 22	26 26	54 54	58 58	24 24	28 28	56 56
0x00000d0	60 60	77 77	68 68	30 30	34 34	66 66	70 70	32 32
0x00000f0	36 36	23 23	27 27	46 46	72 72	42 42	44 44	74 74
0x0000110	76 76	46 46	48 48	78 78	32 32	50 50	52 52	34 34
0x0000130	36 36	54 54	56 56	38 38	40 40	58 58	60 60	42 42
0x0000150	44 44	30 30	32 32	62 62	64 64	34 34	36 36	66 66
0x0000170	68 68	38 38	40 40	70 70	27 27	72 72	76 76	25 25
0x0000190	29 29	78 78	34 34	31 31	35 35	32 32	36 36	33 33
0x00001b0	37 37	38 38	42 42	39 39	43 43	40 40	44 44	41 41
0x00001d0	45 45	62 62	66 66	46 46	50 50	64 64	68 68	48 48
0x00001f0	52 52	70 70	74 74	23 23	53 53	35 35	37 37	67 67
0x0000210	69 69	23 23	25 25	55 55	57 57	39 39	41 41	71 71
0x0000230	73 73	27 27	29 29	59 59	61 61	43 43	45 45	75 75
0x0000250	77 77	46 46	48 48	47 47	49 49	31 31	33 33	63 63
0x0000270	65 65	50 50	52 52	51 51	59 59	65 65	69 69	71 71
0x0000290	22 22	55 55	59 59	61 61	65 65	71 71	75 75	24 24
0x00002b0	28 28	57 57	61 61	63 63	67 67	73 73	77 77	26 26
0x00002d0	30 30	47 47	51 51	53 53	57 57	63 63	67 67	69 69
0x00002f0	73 73	49 49	53 53	55 55	38 38	65 65	67 67	44 44
0x0000310	46 46	69 69	71 71	48 48	50 50	24 24	26 26	56 56
0x0000330	58 58	73 73	22 22	52 52	54 54	28 28	30 30	60 60
0x0000350	62 62	53 53	55 55	32 32	34 34	61 61	63 63	40 40
0x0000370	42 42	57 57	59 59	36 36	70 70	42 42	46 46	74 74
0x0000390	78 78	48 48	52 52	76 76	23 23	56 56	60 60	27 27
0x00003b0	31 31	50 50	54 54	78 78	25 25	58 58	62 62	29 29
0x00003d0	33 33	32 32	36 36	64 64	68 68	40 40	44 44	72 72
0x00003f0	76 76	34 34	38 38	66 66	29 29	23 23	25 25	31 31

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with even channels used):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels:0x55555555555555555555

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	20 20	52 52	54 54	06 06	08 08	56 56	58 58	10 10
0x0000030	12 12	68 68	70 70	22 22	24 24	72 72	74 74	26 26
0x0000050	28 28	44 44	46 46	76 76	00 00	48 48	50 50	02 02
0x0000070	04 04	60 60	62 62	14 14	50 50	16 16	20 20	48 48
0x0000090	52 52	06 06	10 10	38 38	42 42	08 08	12 12	40 40
0x00000b0	44 44	22 22	26 26	54 54	58 58	24 24	28 28	56 56
0x00000d0	60 60	76 76	02 02	30 30	34 34	00 00	04 04	32 32
0x00000f0	36 36	14 14	18 18	46 46	72 72	42 42	44 44	74 74
0x0000110	76 76	46 46	48 48	78 78	78 78	50 50	52 52	00 00
0x0000130	02 02	54 54	56 56	04 04	06 06	58 58	60 60	08 08
0x0000150	10 10	30 30	32 32	62 62	64 64	34 34	36 36	66 66
0x0000170	68 68	38 38	40 40	70 70	24 24	72 72	76 76	22 22
0x0000190	26 26	78 78	00 00	28 28	32 32	78 78	02 02	30 30
0x00001b0	34 34	04 04	08 08	36 36	40 40	06 06	10 10	38 38
0x00001d0	42 42	62 62	66 66	12 12	16 16	64 64	68 68	14 14
0x00001f0	18 18	70 70	74 74	20 20	50 50	32 32	34 34	64 64
0x0000210	66 66	20 20	22 22	52 52	54 54	36 36	38 38	68 68
0x0000230	70 70	24 24	26 26	56 56	58 58	40 40	42 42	72 72
0x0000250	74 74	12 12	14 14	44 44	46 46	28 28	30 30	60 60
0x0000270	62 62	16 16	18 18	48 48	06 06	62 62	66 66	18 18
0x0000290	22 22	52 52	56 56	08 08	12 12	68 68	72 72	24 24
0x00002b0	28 28	54 54	58 58	10 10	14 14	70 70	74 74	26 26
0x00002d0	30 30	44 44	48 48	00 00	04 04	60 60	64 64	16 16
0x00002f0	20 20	46 46	50 50	02 02	38 38	12 12	14 14	44 44
0x0000310	46 46	16 16	18 18	48 48	50 50	24 24	26 26	56 56
0x0000330	58 58	20 20	22 22	52 52	54 54	28 28	30 30	60 60
0x0000350	62 62	00 00	02 02	32 32	34 34	08 08	10 10	40 40
0x0000370	42 42	04 04	06 06	36 36	70 70	42 42	46 46	74 74
0x0000390	78 78	48 48	52 52	76 76	00 00	56 56	60 60	04 04
0x00003b0	08 08	50 50	54 54	78 78	02 02	58 58	62 62	06 06
0x00003d0	10 10	32 32	36 36	64 64	68 68	40 40	44 44	72 72
0x00003f0	76 76	34 34	38 38	66 66	06 06	00 00	02 02	08 08

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Sample Data

Hop Sequence {k} for CONNECTION STATE (Adapted channel hopping sequence with odd channels used):

CLK start: 0x0000010

ULAP: 0x6587cba9

Used Channels:0x2aaaaaaaaaaaaaaaaaaa

#ticks:	00 02	04 06	08 0a	0c 0e	10 12	14 16	18 1a	1c 1e
0x0000010	23 23	53 53	55 55	09 09	11 11	57 57	59 59	13 13
0x0000030	15 15	69 69	71 71	25 25	27 27	73 73	75 75	29 29
0x0000050	31 31	45 45	47 47	77 77	03 03	49 49	51 51	05 05
0x0000070	07 07	61 61	63 63	17 17	53 53	19 19	23 23	51 51
0x0000090	55 55	09 09	13 13	41 41	45 45	11 11	15 15	43 43
0x00000b0	47 47	25 25	29 29	57 57	61 61	27 27	31 31	59 59
0x00000d0	63 63	77 77	05 05	33 33	37 37	03 03	07 07	35 35
0x00000f0	39 39	17 17	21 21	49 49	75 75	45 45	47 47	77 77
0x0000110	01 01	49 49	51 51	03 03	01 01	53 53	55 55	03 03
0x0000130	05 05	57 57	59 59	07 07	09 09	61 61	63 63	11 11
0x0000150	13 13	33 33	35 35	65 65	67 67	37 37	39 39	69 69
0x0000170	71 71	41 41	43 43	73 73	27 27	75 75	01 01	25 25
0x0000190	29 29	03 03	03 03	31 31	35 35	01 01	05 05	33 33
0x00001b0	37 37	07 07	11 11	39 39	43 43	09 09	13 13	41 41
0x00001d0	45 45	65 65	69 69	15 15	19 19	67 67	71 71	17 17
0x00001f0	21 21	73 73	77 77	23 23	53 53	35 35	37 37	67 67
0x0000210	69 69	23 23	25 25	55 55	57 57	39 39	41 41	71 71
0x0000230	73 73	27 27	29 29	59 59	61 61	43 43	45 45	75 75
0x0000250	77 77	15 15	17 17	47 47	49 49	31 31	33 33	63 63
0x0000270	65 65	19 19	21 21	51 51	11 11	65 65	69 69	23 23
0x0000290	27 27	55 55	59 59	13 13	17 17	71 71	75 75	29 29
0x00002b0	33 33	57 57	61 61	15 15	19 19	73 73	77 77	31 31
0x00002d0	35 35	47 47	51 51	05 05	09 09	63 63	67 67	21 21
0x00002f0	25 25	49 49	53 53	07 07	43 43	17 17	19 19	49 49
0x0000310	51 51	21 21	23 23	53 53	55 55	29 29	31 31	61 61
0x0000330	63 63	25 25	27 27	57 57	59 59	33 33	35 35	65 65
0x0000350	67 67	05 05	07 07	37 37	39 39	13 13	15 15	45 45
0x0000370	47 47	09 09	11 11	41 41	75 75	47 47	51 51	01 01
0x0000390	05 05	53 53	57 57	01 01	05 05	61 61	65 65	09 09
0x00003b0	13 13	55 55	59 59	03 03	07 07	63 63	67 67	11 11
0x00003d0	15 15	37 37	41 41	69 69	73 73	45 45	49 49	77 77
0x00003f0	03 03	39 39	43 43	71 71	11 11	05 05	07 07	13 13

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3 ACCESS CODE SAMPLE DATA

Different access codes (GIAC, DIACs, others...)

LAP with LSB as rightmost bit.

	Bit transmit order on air		
	---------->		
LAP:	Preamble:	Sync word:	Trailer:
000000	5	7e7041e3 4000000d	5
ffffff	a	e758b522 7ffffff2	a
9e8b33	5	475c58cc 73345e72	a
9e8b34	5	28ed3c34 cb345e72	a
9e8b36	5	62337b64 1b345e72	a
9e8b39	a	c05747b9 e7345e72	a
9e8b3d	5	7084eab0 2f345e72	a
9e8b42	5	64c86d2b 90b45e72	a
9e8b48	a	e3c3725e 04b45e72	a
9e8b4f	a	8c7216a6 bcb45e72	a
9e8b57	a	b2f16c30 fab45e72	a
9e8b60	5	57bd3b22 c1b45e72	a
9e8b6a	a	d0b62457 55b45e72	a
9e8b75	a	81843a39 abb45e72	a
9e8b81	5	0ca96681 e0745e72	a
9e8b8e	a	aecd5a5c 1c745e72	a
9e8b9c	5	17453fbf ce745e72	a
9e8bab	a	f20968ad f5745e72	a
9e8bbb	5	015f4a1e f7745e72	a
9e8bcc	a	d8c695a0 0cf45e72	a
9e8bde	5	614ef043 def45e72	a
9e8bf1	a	ba81ddc7 a3f45e72	a
9e8c05	5	64a7dc4f 680c5e72	a
9e8c1a	5	3595c221 960c5e72	a
9e8c30	a	cb35cc0d 830c5e72	a
9e8c47	5	12ac13b3 788c5e72	a
9e8c5f	5	2c2f6925 3e8c5e72	a
9e8c78	5	3a351c84 078c5e72	a
9e8c92	5	7396d0f3 124c5e72	a
9e8cad	5	5b0fdfc4 6d4c5e72	a
9e8cc9	a	aea2eb38 e4cc5e72	a
9e8ce6	5	756dc6bc 99cc5e72	a
9e8d04	5	214cf934 882c5e72	a
9e8d23	5	37568c95 b12c5e72	a
9e8d43	5	72281560 f0ac5e72	a
9e8d64	5	643260c1 c9ac5e72	a
9e8d86	a	e044f493 986c5e72	a
9e8da9	5	3b8bd917 e56c5e72	a
9e8dcd	a	ce26edeb 6cec5e72	a
9e8df2	a	e6bfe2dc 13ec5e72	a
9e8e18	a	82dcde3d c61c5e72	a
9e8e3f	a	94c6ab9c ff1c5e72	a

Sample Data

9e8e67	a	969059a6 799c5e72	a
9e8e90	a	c4dfccef 425c5e72	a
9e8eba	5	3a7fc2c3 575c5e72	a
9e8ee5	5	57985401 69dc5e72	a
9e8f11	5	0ae2a363 623c5e72	a
9e8f3e	a	d12d8ee7 1f3c5e72	a
9e8f6c	5	547063a8 0dbc5e72	a
9e8f9b	5	063ff6e1 367c5e72	a
9e8fcb	a	c9bc5cfe f4fc5e72	a
9e8ffc	5	2cf00bec cffc5e72	a
9e902e	a	8ec5052f 5d025e72	a
9e9061	5	1074b15e 61825e72	a
9e9095	a	9d59ede6 2a425e72	a
9e90ca	a	f0be7b24 14c25e72	a
9e9100	5	10e10dd0 c0225e72	a
9e9137	a	f5ad5ac2 fb225e72	a
9e916f	a	f7fba8f8 7da25e72	a
9e91a8	5	2f490e5b c5625e72	a
9e91e2	a	94979982 91e25e72	a
9e921d	5	26cda478 2e125e72	a
9e9259	a	aacb81dd 26925e72	a
9e9296	a	bfac7f5b da525e72	a
9e92d4	a	c9a7b0a7 cad25e72	a
9e9313	a	c142bdde 32325e72	a
616cec	5	586a491f 0dcda18d	5
616ceb	5	37db2de7 b5cda18d	5
616ce9	5	7d056ab7 65cda18d	5
616ce6	a	df61566a 99cda18d	5
616ce2	5	6fb2fb63 51cda18d	5
616cdd	5	472bf454 2ecda18d	5
616cd7	a	c020eb21 bacda18d	5
616cd0	a	af918fd9 02cda18d	5
616cc8	a	9112f54f 44cda18d	5
616cbf	5	488b2af1 bf4da18d	5
616cb5	a	cf803584 2b4da18d	5
616caa	a	9eb22bea d54da18d	5
616c9e	a	a49cb509 9e4da18d	5
616c91	5	06f889d4 624da18d	5
616c83	a	bf70ec37 b04da18d	5
616c74	a	ed3f797e 8b8da18d	5
616c64	5	1e695bcd 898da18d	5
616c53	a	fb250cdf b28da18d	5
616c41	5	42ad693c 608da18d	5
616c2e	a	a5b7cc14 dd0da18d	5
616c1a	a	9f9952f7 960da18d	5
616c05	a	ceab4c99 680da18d	5
616bef	a	d403ddde fdf5a18d	5
616bd8	5	314f8acc c6f5a18d	5
616bc0	5	0fccf05a 80f5a18d	5
616ba7	5	25030d57 7975a18d	5
616b8d	a	dba3037b 6c75a18d	5
616b72	5	4439ce17 13b5a18d	5

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Sample Data

616b56	a	8d417247 5ab5a18d	5
616b39	5	6a5bd76f e735a18d	5
616b1b	5	592e8166 b635a18d	5
616afc	5	28609d46 cfd5a18d	5
616adc	5	51cb8c1f 4ed5a18d	5
616abb	5	7b047112 b755a18d	5
616a99	5	4871271b e655a18d	5
616a76	5	24bdc8c4 9b95a18d	5
616a52	a	edc57494 d295a18d	5
616a2d	a	f989f30f 6d15a18d	5
616a07	5	0729fd23 7815a18d	5
6169e0	a	8bf0ba4f 81e5a18d	5
6169b8	a	89a64875 0765a18d	5
61698f	5	6cea1f67 3c65a18d	5
616965	5	2549d310 29a5a18d	5
61693a	5	48ae45d2 1725a18d	5
61690e	5	7280db31 5c25a18d	5
6168e1	a	ce1b9f34 61c5a18d	5
6168b3	5	4b46727b 7345a18d	5
616884	a	ae0a2569 4845a18d	5
616854	a	ea5fc581 4a85a18d	5
616823	5	33c61a3f b105a18d	5
6167f1	a	c49fb8c5 63f9a18d	5
6167be	5	5a2e0cb4 5f79a18d	5
61678a	5	60009257 1479a18d	5
616755	a	86314e62 eab9a18d	5
61671f	5	3defd9bb be39a18d	5
6166e8	a	bff7e728 c5d9a18d	5
6166b0	a	bda11512 4359a18d	5
616677	5	6513b3b1 fb99a18d	5
61663d	a	decd2468 af19a18d	5
616602	a	f6542b5f d019a18d	5
6165c6	a	dc44b49b d8e9a18d	5
616589	5	42f500ea e469a18d	5
61654b	a	bf2885e1 34a9a18d	5
61650c	a	ec4c69b5 4c29a18d	5

4 HEC AND PACKET HEADER SAMPLE DATA

This section contains examples of HECs computed for sample UAP and packet header contents (Data). The resulting 54 bit packet headers are shown in the rightmost column. Note that the UAP, Data and HEC values are in hexadecimal notation, while the header is in octal notation. The header is transmitted from left to right over the air.

UAP	Data	HEC	Header (octal)
00	123	e1	770007 007070 000777
47	123	06	770007 007007 700000
00	124	32	007007 007007 007700
47	124	d5	007007 007070 707077
00	125	5a	707007 007007 077070
47	125	bd	707007 007070 777707
00	126	e2	077007 007007 000777
47	126	05	077007 007070 700000
00	127	8a	777007 007007 070007
47	127	6d	777007 007070 770770
00	11b	9e	770770 007007 777007
47	11b	79	770770 007070 077770
00	11c	4d	007770 007070 770070
47	11c	aa	007770 007007 070707
00	11d	25	707770 007070 700700
47	11d	c2	707770 007007 000077
00	11e	9d	077770 007070 777007
47	11e	7a	077770 007007 077770
00	11f	f5	777770 007070 707777
47	11f	12	777770 007007 007000

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5 CRC SAMPLE DATA

This section shows the CRC computed for a sample 10 byte payload and a UAP of 0x47.

Data:
-----

data[0] = 0x4e
data[1] = 0x01
data[2] = 0x02
data[3] = 0x03
data[4] = 0x04
data[5] = 0x05
data[6] = 0x06
data[7] = 0x07
data[8] = 0x08
data[9] = 0x09

UAP = 0x47

==> CRC = 6d d2

Codeword (hexadecimal notation):

4e 01 02 03 04 05 06 07 08 09 6d d2

NB: Over the air each byte in the codeword
    is sent with the LSB first.

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6 COMPLETE SAMPLE PACKETS

6.1 EXAMPLE OF DH1 PACKET

```
Packet header: (MSB...LSB)
--------------------------
LT_ADDR = 011
TYPE = 0100 (DH1)
FLOW = 0
ARQN = 1
SEQN = 0

Payload: (MSB...LSB)
--------------------
payload length: 5 bytes
logical channel = 10 (UA/I, Start L2CAP message)
flow = 1
data byte 1 = 00000001
data byte 2 = 00000010
data byte 3 = 00000011
data byte 4 = 00000100
data byte 5 = 00000101

HEC and CRC initialization: (MSB...LSB)
---------------------------------------
uap = 01000111

NO WHITENING USED




AIR DATA (LSB...MSB)

Packet header (incl HEC):
-------------------------
111111000
000000111000
000111000
000111111000000000000000

Payload (incl payload header and CRC):
--------------------------------------------------------------
01110100
10000000
01000000
11000000
00100000
10100000
1110110000110110
```

6.2 EXAMPLE OF DM1 PACKET

```
Packet header: (MSB...LSB)
--------------------------
LT_ADDR = 011
TYPE = 0011 (DM1)
FLOW = 0
ARQN = 1
SEQN = 0

Payload: (MSB...LSB)
--------------------
payload length: 5 bytes
logical channel = 10 (UA/I, Start L2CAP message)
flow = 1
data byte 1 = 00000001
data byte 2 = 00000010
data byte 3 = 00000011
data byte 4 = 00000100
data byte 5 = 00000101

HEC and CRC initialization: (MSB...LSB)
---------------------------------------
uap = 01000111

NO WHITENING USED




AIR DATA (LSB...MSB)

Packet header (incl HEC):
-------------------------
111111000
111111000000
000111000
111000000111111111111000

Payload (incl payload header, FEC23, CRC and 6 padded zeros):
-------------------------------------------------------------
0111010010 11001
0000000100 01011
0000110000 11110
0000100000 00111
1010000011 01100
1011000011 00010
0110000000 10001
```

7 WHITENING SEQUENCE SAMPLE DATA

This section shows the output of the whitening sequence generator.

Whitening Sequence (=D7)	Whitening LFSR D7.....D0
1	1111111
1	1101111
1	1001111
0	0001111
0	0011110
0	0111100
1	1111000
1	1100001
1	1010011
0	0110111
1	1101110
1	1001101
0	0001011
0	0010110
0	0101100
1	1011000
0	0100001
1	1000010
0	0010101
0	0101010
1	1010100
0	0111001
1	1110010
1	1110101
1	1111011
1	1100111
1	1011111
0	0101111
1	1011110
0	0101101
1	1011010
0	0100101
1	1001010
0	0000101
0	0001010
0	0010100
0	0101000
1	1010000
0	0110001
1	1100010
1	1010101
0	0111011
1	1110110

Sample Data

1	1111101
1	1101011
1	1000111
0	0011111
0	0111110
1	1111100
1	1101001
1	1000011
0	0010111
0	0101110
1	1011100
0	0101001
1	1010010
0	0110101
1	1101010
1	1000101
0	0011011
0	0110110
1	1101100
1	1001001
0	0000011
0	0000110
0	0001100
0	0011000
0	0110000
1	1100000
1	1010001
0	0110011
1	1100110
1	1011101
0	0101011
1	1010110
0	0111101
1	1111010
1	1100101
1	1011011
0	0100111
1	1001110
0	0001101
0	0011010
0	0110100
1	1101000
1	1000001
0	0010011
0	0100110
1	1001100
0	0001001
0	0010010
0	0100100
1	1001000
0	0000001
0	0000010

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Sample Data

0	0000100
0	0001000
0	0010000
0	0100000
1	1000000
0	0010001
0	0100010
1	1000100
0	0011001
0	0110010
1	1100100
1	1011001
0	0100011
1	1000110
0	0011101
0	0111010
1	1110100
1	1111001
1	1100011
1	1010111
0	0111111
1	1111110
1	1101101
1	1001011
0	0000111
0	0001110
0	0011100
0	0111000
1	1110000
1	1110001
1	1110011
1	1110111
1	1111111

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8 FEC SAMPLE DATA

```
================================================
 Rate 2/3 FEC -- (15,10) Shortened Hamming Code
================================================

Data is in hexadecimal notation, the codewords are in binary notation. The codeword bits
are sent from left to right over the air interface. The space in the codeword indicates
the start of parity bits.

Data:           Codeword:

0x001       1000000000 11010
0x002       0100000000 01101
0x004       0010000000 11100
0x008       0001000000 01110
0x010       0000100000 00111
0x020       0000010000 11001
0x040       0000001000 10110
0x080       0000000100 01011
0x100       0000000010 11111
0x200       0000000001 10101
```

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9 ENCRYPTION KEY SAMPLE DATA

Explanation:

For the sections 9.1 - 9.5, the hexadecimal sample data is written with the least significant byte at the leftmost position and the most significant byte at the rightmost position. Within each byte, the *least significant bit* (LSB) is at the rightmost position and the *most significant bit* (MSB) is at the leftmost position Thus, a line reading:

aco: 48afcdd4bd40fef76693b113

means aco[0]=0x48, ac[1]=0xaf, ..., aco[11]=0x13. The LSB of aco[11] is ‘1’ and the MSB of aco[11] is ‘0’.

Key [i]: denotes the ith sub-key in Ar or A'r;
round r: denotes the input to the rth round;
added ->: denotes the input to round 3 in A'r after adding original input (of round 1).

9.1 FOUR TESTS OF E1

```
rand    :00000000000000000000000000000000
address :000000000000
key     :00000000000000000000000000000000
round  1:00000000000000000000000000000000
Key [ 1]:00000000000000000000000000000000
Key [ 2]:4697b1baa3b7100ac537b3c95a28ac64
round  2:78d19f9307d2476a523ec7a8a026042a
Key [ 3]:ecabaac66795580df89af66e66dc053d
Key [ 4]:8ac3d8896ae9364943bfebd4969b68a0
round  3:600265247668dda0e81c07bbb30ed503
Key [ 5]:5d57921fd5715cbb22c1be7bbc996394
Key [ 6]:2a61b8343219fdfb1740e6511d41448f
round  4:d7552ef7cc9dbde568d80c2215bc4277
Key [ 7]:dd0480dee731d67f01a2f739da6f23ca
Key [ 8]:3ad01cd1303e12a1cd0fe0a8af82592c
round  5:fb06bef32b52ab8f2a4f2b6ef7f6d0cd
Key [ 9]:7dadb2efc287ce75061302904f2e7233
Key [10]:c08dcfa981e2c4272f6c7a9f52e11538
round  6:b46b711ebb3cf69e847a75f0ab884bdd
Key [11]:fc2042c708e409555e8c147660ffdfd7
Key [12]:fa0b21001af9a6b9e89e624cd99150d2
round  7:c585f308ff19404294f06b292e978994
Key [13]:18b40784ea5ba4c80ecb48694b4e9c35
Key [14]:454d54e5253c0c4a8b3fcca7db6baef4
round  8:2665fadb13acf952bf74b4ab12264b9f
Key [15]:2df37c6d9db52674f29353b0f011ed83
Key [16]:b60316733b1e8e70bd861b477e2456f1
Key [17]:884697b1baa3b7100ac537b3c95a28ac
```

Sample Data

```
round  1:158ffe43352085e8a5ec7a88e1ff2ba8
Key [ 1]:e9e5dfc1b3a79583e9e5dfc1b3a79583
Key [ 2]:7595bf57e0632c59f435c16697d4c864
round  2:0b5cc75febcdf7827ca29ec0901b6b5b
Key [ 3]:e31b96afcc75d286ef0ae257cbbc05b7
Key [ 4]:0d2a27b471bc0108c6263aff9d9b3b6b
round  3:e4278526c8429211f7f2f0016220aef4
added ->:f1b68365fd6217f952de6a89831fd95c
Key [ 5]:98d1eb5773cf59d75d3b17b3bc37c191
Key [ 6]:fd2b79282408ddd4ea0aa7511133336f
round  4:d0304ad18337f86040145d27aa5c8153
Key [ 7]:331227756638a41d57b0f7e071ee2a98
Key [ 8]:aa0dd8cc68b406533d0f1d64aabacf20
round  5:84db909d213bb0172b8b6aaf71bf1472
Key [ 9]:669291b0752e63f806fce76f10e119c8
Key [10]:ef8bdd46be8ee0277e9b78adef1ec154
round  6:f835f52921e903dfa762f1df5abd7f95
Key [11]:f3902eb06dc409cfd78384624964bf51
Key [12]:7d72702b21f97984a721c99b0498239d
round  7:ae6c0b4bb09f25c6a5d9788a31b605d1
Key [13]:532e60bceaf902c52a06c2c283ecfa32
Key [14]:181715e5192efb2a64129668cf5d9dd4
round  8:744a6235b86cc0b853cc9f74f6b65311
Key [15]:83017c1434342d4290e961578790f451
Key [16]:2603532f365604646ff65803795ccce5
Key [17]:882f7c907b565ea58dae1c928a0dcf41
sres    :056c0fe6
aco     :48afcdd4bd40fef76693b113
----------------------------------------
rand    :bc3f30689647c8d7c5a03ca80a91eceb
address :7ca89b233c2d
key     :159dd9f43fc3d328efba0cd8a861fa57
round  1:bc3f30689647c8d7c5a03ca80a91eceb
Key [ 1]:159dd9f43fc3d328efba0cd8a861fa57
Key [ 2]:326558b3c15551899a97790e65ff669e
round  2:3e950edf197615638cc19c09f8fedc9b
Key [ 3]:62e879b65b9f53bbfbd020c624b1d682
Key [ 4]:73415f30bac8ab61f410adc9442992db
round  3:6a7640791cb536678936c5ecd4ae5a73
Key [ 5]:5093cfa1d31c1c48acd76df030ea3c31
Key [ 6]:0b4acc2b8f1f694fc7bd91f4a70f3009
round  4:fca2c022a577e2ffb2aa007589693ec7
Key [ 7]:2ca43fc817947804ecff148d50d6f6c6
Key [ 8]:3fcd73524b533e00b7f7825bea2040a4
round  5:e97f8ea4ed1a6f4a36ffc179dc6bb563
Key [ 9]:6c67bec76ae8c8cc4d289f69436d3506
Key [10]:95ed95ee8cb97e61d75848464bffb379
round  6:38b07261d7340d028749de1773a415c7
Key [11]:ff566c1fc6b9da9ac502514550f3e9d2
Key [12]:ab5ce3f5c887d0f49b87e0d380e12f47
round  7:58241f1aed7c1c3e047d724331a0b774
Key [13]:a2cab6f95eac7d655dbe84a6cd4c47f5
```

Sample Data

```
Key [14]:f5caff88af0af8c42a20b5bbd2c8b460
round  8:3d1aaeff53c0910de63b9788b13c490f
Key [15]:185099c1131cf97001e2f36fda415025
Key [16]:a0ebb82676bc75e8378b189eff3f6b1d
Key [17]:cf5b348aaee27ae332b4f1bfa10289a6
round  1:2e4b417b9a2a9cfd7d8417d9a6a556eb
Key [ 1]:fe78b835f26468ab069fd3991b086fda
Key [ 2]:095c5a51c6fa6d3ac1d57fa19aa382bd
round  2:b8bca81d6bb45af9d92beadd9300f5ed
Key [ 3]:1af866df817fd9f4ec00bc704192cffc
Key [ 4]:f4a8a059c1f575f076f5fbb24bf16590
round  3:351aa16dec2c3a4787080249ed323eae
added ->:1b65e2167656d6bafa8c19904bd79445
Key [ 5]:8c9d18d9356a9954d341b4286e88ea1f
Key [ 6]:5c958d370102c9881bf753e69c7da029
round  4:2ce8fef47dda6a5bee74372e33e478a2
Key [ 7]:7eb2985c3697429fbe0da334bb51f795
Key [ 8]:af900f4b63a1138e2874bfb7c628b7b8
round  5:572787f563e1643c1c862b7555637fb4
Key [ 9]:834c8588dd8f3d4f31117a488420d69b
Key [10]:bc2b9b81c15d9a80262f3f48e9045895
round  6:16b4968c5d02853c3a43aa4cdb5f26ac
Key [11]:f08608c9e39ad3147cba61327919c958
Key [12]:2d4131decf4fa3a959084714a9e85c11
round  7:10e4120c7cccef9dd4ba4e6da8571b01
Key [13]:c934fd319c4a2b5361fa8eef05ae9572
Key [14]:4904c17aa47868e40471007cde3a97c0
round  8:f90817724 98fed41b6ffd72b71fcf6c6
Key [15]:ea5e28687e97fa3f833401c86e6053ef
Key [16]:1168f58252c4ecfccafbdb3af857b9f2
Key [17]:b3440f69ef951b78b5cbd6866275301b
sres    :8d5205c5
aco     :3ed75df4abd9af638d144e94
----------------------------------------
rand    :0891caee063f5da1809577ff94ccdcfb
address :c62f19f6ce98
key     :45298d06e46bac21421ddfbed94c032b
round  1:0891caee063f5da1809577ff94ccdcfb
Key [ 1]:45298d06e46bac21421ddfbed94c032b
Key [ 2]:8f03e1e1fe1c191cad35a897bc400597
round  2:1c6ca013480a685c1b28e0317f7167e1
Key [ 3]:4f2ce3a092dde854ef496c8126a69e8e
Key [ 4]:968caee2ac6d7008c07283daec67f2f2
round  3:06b4915f5fcc1fc551a52048f0af8a26
Key [ 5]:ab0d5c31f94259a6bf85ee2d22edf56c
Key [ 6]:dfb74855c0085ce73dc17b84bfd50a92
round  4:077a92b040acc86e6e0a877db197a167
Key [ 7]:8f888952662b3db00d4e904e7ea53b5d
Key [ 8]:5e18bfcc07799b0132db88cd6042f599
round  5:7204881fb300914825fdc863e8ceadf3
Key [ 9]:bfca91ad9bd3d1a06c582b1d5512dddf
Key [10]:a88bc477e3fa1d5a59b5e6cf793c7a41
```

Sample Data

```
round  6:27031131d86cea2d747deb4f756143aa
Key [11]:f3cfb8dac8aea2a6a8ef95af3a2a2767
Key [12]:77beb90670c5300b03aa2b2232d3d40c
round  7:fc8c13d49149b1ce8d86f96e44a00065
Key [13]:b578373650af36a06e19fe335d726d32
Key [14]:6bcee918c7d0d24dfdf42237fcf99d53
round  8:04ef5f5a7ddf846cda0a07782fc23866
Key [15]:399f158241eb3e079f45d7b96490e7ea
Key [16]:1bcfbe98ecde2add52aa63ea79fb917a
Key [17]:ee8bc03ec08722bc2b075492873374af
round  1:d989d7a40cde7032d17b52f8117b69d5
Key [ 1]:2ecc6cc797cc41a2ab02007f6af396ae
Key [ 2]:acfaef7609c12567d537ae1cf9dc2198
round  2:8e76eb9a29b2ad5eea790db97aee37c1
Key [ 3]:079c8ff9b73d428df879906a0b87a6c8
Key [ 4]:19f2710baf403a494193d201f3a8c439
round  3:346bb7c35b2539676375aafe3af69089
added ->:edf48e675703a955b2f0fc062b71f95c
Key [ 5]:d623a6498f915cb2c8002765247b2f5a
Key [ 6]:900109093319bc30108b3d9434a77a72
round  4:fafb6c1f3ebbd2477be2da49dd923f69
Key [ 7]:e28e2ee6e72e7f4e5b5c11f10d204228
Key [ 8]:8e455cd11f8b9073a2dfa5413c7a4bc5
round  5:7c72230df588060a3cf920f9b0a08f06
Key [ 9]:28afb26e2c7a64238c41cefc16c53e74
Key [10]:d08dcafc2096395ba0d2dddd0e471f4d
round  6:55991df991db26ff00073a12baa3031d
Key [11]:fcffdcc3ad8faae091a7055b934f87c1
Key [12]:f8df082d77060252c02d91e55bd6a7d6
round  7:70ec682ff864375f63701fa4f6be5377
Key [13]:bef3706e523d708e8a44147d7508bc35
Key [14]:3e98ab283ca2422d56a56cf8b06caeb3
round  8:172f12ec933da85504b4ea5c90f8f0ea
Key [15]:87ad9625d06645d22598dd5ef811ea2c
Key [16]:8bd3db0cc8168009e5da90877e13a36f
Key [17]:0e74631d813a8351ac7039b348c41b42
sres    :00507e5f
aco     :2a5f19fbf60907e69f39ca9f
----------------------------------------
rand    :0ecd61782b4128480c05dc45542b1b8c
address :f428f0e624b3
key     :35949a914225fabad91995d226de1d92
round  1:0ecd61782b4128480c05dc45542b1b8c
Key [ 1]:35949a914225fabad91995d226de1d92
Key [ 2]:ea6b3dcccc8ee5d88de349fa5010404f
round  2:8935e2e263fbc4b9302cabdfc06bce3e
Key [ 3]:920f3a0f2543ce535d4e7f25ad80648a
Key [ 4]:ad47227edf9c6874e80ba80ebb95d2c9
round  3:b4c8b878675f184a0c72f3dab51f8f05
Key [ 5]:81a941ca7202b5e884ae8fa493ecac3d
Key [ 6]:bcde1520bee3660e86ce2f0fb78b9157
round  4:77ced9f2fc42bdd5c6312b87fc2377c5
```


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Sample Data

```
Key [ 7]:c8eee7423d7c6efa75ecec0d2cd969d3
Key [ 8]:910b3f838a02ed441fbe863a02b4a1d0
round  5:fe28e8056f3004d60bb207e628b39cf2
Key [ 9]:56c647c1e865eb078348962ae070972d
Key [10]:883965da77ca5812d8104e2b640aec0d
round  6:1f2ba92259d9e88101518f145a33840f
Key [11]:61d4cb7e4f8868a283327806a9bd8d4d
Key [12]:9f57de3a3ff310e21dc1e696ce060304
round  7:cc9b5d0218d29037e88475152ebebb2f
Key [13]:7aa1d8adc1aeed7127ef9a18f6eb2d8e
Key [14]:b4db9da3bf865912acd14904c7f7785d
round  8:b04d352bedc02682e4a7f59d7cda1dba
Key [15]:a13d7141ef1f6c7d867e3d175467381b
Key [16]:08b2bc058e50d6141cdd566a307e1acc
Key [17]:057b2b4b4be5dc0ac49e50489b8006c9
round  1:5cfacc773bae995cd7f1b81e7c9ec7df
Key [ 1]:1e717950f5828f3930fe4a9395858815
Key [ 2]:d1623369b733d98bbc894f75866c544c
round  2:d571ffa21d9daa797b1a0a3c962fc64c
Key [ 3]:4abf27664ae364cc8a7e5bcf88214cc4
Key [ 4]:2aaedda8dc4933dd6aeaf6e5c0d5a482
round  3:e17c8e498a00f125bf654c938c23f36d
added ->:bd765a3eb1ae8a796856048df0c1bab2
Key [ 5]:bc7f8ab2d86000f47b1946cc8d7a7a2b
Key [ 6]:6b28544cb13ec6c5d98470df2cf900b7
round  4:a9727c26f2f06bd9920e83c8605dcd76
Key [ 7]:1be840d9107f2c9523f66bb19f5464a1
Key [ 8]:61d6fb1aa2f0c2b26fb2a3d6de8c177c
round  5:aeff751f146eab7e4626b2e2c9e2fb39
Key [ 9]:adabfc82570c568a233173099f23f4c2
Key [10]:b7df6b55ad266c0f1ff7452101f59101
round  6:cf412b95f454d5185e67ca671892e5bd
Key [11]:8e04a7282a2950dcbaea28f300e22de3
Key [12]:21362c114433e29bda3e4d51f803b0cf
round  7:16165722fe4e07ef88f8056b17d89567
Key [13]:710c8fd5bb3cbb5f132a7061de518bd9
Key [14]:0791de7334f4c87285809343f3ead3bd
round  8:28854cd6ad4a3c572b15490d4b81bc3f
Key [15]:4f47f0e5629a674bfcd13770eb3a3bd9
Key [16]:58a6d9a16a284cc0aead2126c79608a1
Key [17]:a564082a0a98399f43f535fd5cefad34
sres    :80e5629c
aco     :a6fe4dcde3924611d3cc6ba1


========================================
```

9.2 FOUR TESTS OF E21

```
rand    :00000000000000000000000000000000
address :000000000000
round  1:00000000000000000000000000000000
Key [ 1]:00000000000000000000000000000006
Key [ 2]:4697b1baa3b7100ac537b3c95a28dc94
round  2:98611307ab76bbde9a86af1ce8cad412
Key [ 3]:ecabaac66795580df89af66e665d863d
Key [ 4]:8ac3d8896ae9364943bfebd4a2a768a0
round  3:820999ad2e6618f4b578974beeedf9e7
added ->:820999ad2e6618f4b578974beeedf9e7
Key [ 5]:5d57921fd5715cbb22c1bedb1c996394
Key [ 6]:2a61b8343219fdfb1740e9541d41448f
round  4:acd6edec87581ac22dbdc64ea4ced3a2
Key [ 7]:dd0480dee731d67f01ba0f39da6f23ca
Key [ 8]:3ad01cd1303e12a18dcfe0a8af82592c
round  5:1c7798732f09fbfe25795a4a2fbc93c2
Key [ 9]:7dadb2efc287ce7b0c1302904f2e7233
Key [10]:c08dcfa981e2f4572f6c7a9f52e11538
round  6:c05b88b56aa70e9c40c79bb81cd911bd
Key [11]:fc2042c708658a555e8c147660ffdfd7
Key [12]:fa0b21002605a6b9e89e624cd99150d2
round  7:abacc71b481c84c798d1bdf3d62f7e20
Key [13]:18b407e44a5ba4c80ecb48694b4e9c35
Key [14]:454d57e8253c0c4a8b3fcca7db6baef4
round  8:e8204e1183ae85cf19edb2c86215b700
Key [15]:2d0b946d9db52674f29353b0f011ed83
Key [16]:76c316733b1e8e70bd861b477e2456f1
Key [17]:8e4697b1baa3b7100ac537b3c95a28ac
Ka      :d14ca028545ec262cee700e39b5c39ee
----------------------------------------
rand    :2dd9a550343191304013b2d7e1189d09
address :cac4364303b6
round  1:cac4364303b6cac4364303b6cac43643
Key [ 1]:2dd9a550343191304013b2d7e1189d0f
Key [ 2]:14c4335b2c43910c5dcc71d81a14242b
round  2:e169f788aad45a9011f11db5270b1277
Key [ 3]:55bfb712cba168d1a48f6e74cd9f4388
Key [ 4]:2a2b3aacca695caef2821b0fb48cc253
round  3:540f9c76652e92c44987c617035037bf
added ->:9ed3d23566e45c007fcac9a1c9146dfc
Key [ 5]:a06aab22d9a287384042976b4b6b00ee
Key [ 6]:c229d054bb72e8eb230e6dcdb32d16b7
round  4:83659a41675f7171ea57909dc5a79ab4
Key [ 7]:23c4812ab1905ddf77dedaed4105649a
Key [ 8]:40d87e272a7a1554ae2e85e3638cdf52
round  5:0b9382d0ed4f2fccdbb69d0db7b130a4
Key [ 9]:bdc064c6a39f6b84fe40db359f62a3c4
Key [10]:58228db841ce3cee983aa721f36aa1b9
round  6:c6ebda0f8f489792f09c189568226c1f
Key [11]:a815bacd6fa747a0d4f52883ac63ebe7
```

Sample Data

```
Key [12]:a9ce513b38ea006c333ecaaefcf1d0f8
round  7:75a8aba07e69c9065bcd831c40115116
Key [13]:3635e074792d4122130e5b824e52cd60
Key [14]:511bdb61bb28de72a5d794bffbf407df
round  8:57a6e279dcb764cf7dd6a749dd60c735
Key [15]:a32f5f21044b6744b6d913b13cdb4c0a
Key [16]:9722bbaeef281496ef8c23a9d41e92f4
Key [17]:807370560ad7e8a13a054a65a03b4049
Ka      :e62f8bac609139b3999aedbc9d228042
----------------------------------------
rand    :dab3cffe9d5739d1b7bf4a667ae5ee24
address :02f8fd4cd661
round  1:02f8fd4cd66102f8fd4cd66102f8fd4c
Key [ 1]:dab3cffe9d5739d1b7bf4a667ae5ee22
Key [ 2]:e315a8a65d809ec7c289e69c899fbdcc
round  2:ef85ff081b8709405e19f3e275cec7dc
Key [ 3]:df6a119bb50945fc8a3394e7216448f3
Key [ 4]:87fe86fb0d58b5dd0fb3b6b1dab51d07
round  3:aa25c21bf577d92dd97381e3e9edcc54
added ->:a81dbf5723d8dbd524bf5782ebe5c918
Key [ 5]:36cc253c506c0021c91fac9d8c469e90
Key [ 6]:d5fda00f113e303809b7f7d78a1a2b0e
round  4:9e69ce9b53caec3990894d2baed41e0d
Key [ 7]:c14b5edc10cabf16bc2a2ba4a8ae1e40
Key [ 8]:74c6131afc8dce7e11b03b1ea8610c16
round  5:a5460fa8cedca48a14fd02209e01f02e
Key [ 9]:346cfc553c6cbc9713edb55f4dcbc96c
Key [10]:bddf027cb059d58f0509f8963e9bdec6
round  6:92b33f11eadcacc5a43dd05f13d334dd
Key [11]:8eb9e040c36c4c0b4a7fd3dd354d53c4
Key [12]:c6ffecdd5e135b20879b9dfa4b34bf51
round  7:fb0541aa5e5df1a61c51aef606eb5a41
Key [13]:bf12f5a6ba08dfc4fda4bdfc68c997d9
Key [14]:37c4656b9215f3c959ea688fb64ad327
round  8:f0bbd2b94ae374346730581fc77a9c98
Key [15]:e87bb0d86bf421ea4f779a8eee3a866c
Key [16]:faa471e934fd415ae4c0113ec7f0a5ad
Key [17]:95204a80b8400e49db7cf6fd2fd40d9a
Ka      :b0376d0a9b338c2e133c32b69cb816b3
----------------------------------------
rand    :13ecad08ad63c37f8a54dc56e82f4dc1
address :9846c5ead4d9
round  1:9846c5ead4d99846c5ead4d99846c5ea
Key [ 1]:13ecad08ad63c37f8a54dc56e82f4dc7
Key [ 2]:ad04f127bed50b5e671d6510d392eaed
round  2:97374e18cdd0a6f7a5aa49d1ac875c84
Key [ 3]:57ad159e5774fa222f2f3039b9cd5101
Key [ 4]:9a1e9e1068fede02ef90496e25fd8e79
round  3:9dd3260373edd9d5f4e774826b88fd2d
added ->:0519ebe9a7c6719331d1485bf3cec2c7
Key [ 5]:378dce167db62920b0b392f7cfca316e
Key [ 6]:db4277795c87286faee6c9e9a6b71a93
```

```
round  4:40ec6563450299ac4e120d88672504d6
Key [ 7]:ec01aa2f5a8a793b36c1bb858d254380
Key [ 8]:2921a66cfa5bf74ac535424564830e98
round  5:57287bbb041bd6a56c2bd931ed410cd4
Key [ 9]:07018e45aab61b3c3726ee3d57dbd5f6
Key [10]:627381f0fa4c02b0c7d3e7dfbffc3333
round  6:66affa66a8dcd36e36bf6c3f1c6a276e
Key [11]:33b57c925bd5551999f716e138efbe79
Key [12]:a6dc7f9aa95bcc9243aebd12608f657a
round  7:450e65184fd8c72c578d5cdecb286743
Key [13]:a6a6db00fd8c72a28ea57ea542f6e102
Key [14]:dcf3377daeb2e24e61f0ad6620951c1f
round  8:e5eb180b519a4e673f21b7c4f4573f3d
Key [15]:621240b9506b462a7fa250da41844626
Key [16]:ae297810f01f43dc35756cd119ee73d6
Key [17]:b959835ec2501ad3894f8b8f1f4257f9
Ka      :5b61e83ad04d23e9d1c698851fa30447
========================================
```

9.3 THREE TESTS OF E22

(for K_master and overlay generation)

```
rand    :001de169248850245a5f7cc7f0d6d633
PIN     :d5a51083a04a1971f18649ea8b79311a
round  1:001de169248850245a5f7cc7f0d6d623
Key [ 1]:d5a51083a04a1971f18649ea8b79311a
Key [ 2]:7317cdbff57f9b99f9810a2525b17cc7
round  2:5f05c143347b59acae3cb002db23830f
Key [ 3]:f08bd258adf1d4ae4a54d8ccb26220b2
Key [ 4]:91046cbb4ccc43db18d6dd36ca7313eb
round  3:c8f3e3300541a25b6ac5a80c3105f3c4
added ->:c810c45921c9f27f302424cbc1dbc9e7
Key [ 5]:67fb2336f4d9f069da58d11c82f6bd95
Key [ 6]:4fed702c75bd72c0d3d8f38707134c50
round  4:bd5e0c3a97fa55b91a3bbbf306ebb978
Key [ 7]:41c947f80cdc0464c50aa89070af314c
Key [ 8]:680eecfa8daf41c7109c9a5cb1f26d75
round  5:21c1a762c3cc33e75ce8976a73983087
Key [ 9]:6e33fbd94d00ff8f72e8a7a0d2cebc4c
Key [10]:f4d726054c6b948add99fabb5733ddc3
round  6:56d0df484345582f6b574a449ba155eb
Key [11]:4eda2425546a24cac790f49ef2453b53
Key [12]:cf2213624ed1510408a5a3e00b7333df
round  7:120cf9963fe9ff22993f7fdf9600d9b8
Key [13]:d04b1a25b0b8fec946d5ecfa626d04c9
Key [14]:01e5611b0f0e140bdb64585fd3ae5269
round  8:a6337400ad8cb47fefb91332f5cb2713
Key [15]:f15b2dc433f534f61bf718770a3698b1
Key [16]:f990d0273d8ea2b9e0b45917a781c720
Key [17]:f41b3cc13d4301297bb6bdfcb3e5a1dd
Ka      :539e4f2732e5ae2de1e0401f0813bd0d
```

Sample Data

```
----------------------------------------
rand    :67ed56bfcf99825f0c6b349369da30ab
PIN     :7885b515e84b1f082cc499976f1725ce
round  1:67ed56bfcf99825f0c6b349369da30bb
Key [ 1]:7885b515e84b1f082cc499976f1725ce
Key [ 2]:72445901fdaf506beb036f4412512248
round  2:6b160b66a1f6c26c1f3432f463ef5aa1
Key [ 3]:59f0e4982e97633e5e7fd133af8f2c5b
Key [ 4]:b4946ec77a41bf7c729d191e33d458ab
round  3:3f22046c964c3e5ca2a26ec9a76a9f67
added ->:580f5ad359e5c003ae0da25ace44cfdc
Key [ 5]:eb0b839f97bdf534183210678520bbef
Key [ 6]:cff0bc4a94e5c8b2a2d24d9f59031e19
round  4:87aa61fc0ff88e744c195249b9a33632
Key [ 7]:592430f14d8f93db95dd691af045776d
Key [ 8]:3b55b404222bf445a6a2ef5865247695
round  5:83dcf592a854226c4dcd94e1ecf1bc75
Key [ 9]:a9714b86319ef343a28b87456416bd52
Key [10]:e6598b24390b3a0bf2982747993b0d78
round  6:dee0d13a52e96bcf7c72045a21609fc6
Key [11]:62051d8c51973073bff959b032c6e1e2
Key [12]:29e94f4ab73296c453c833e217a1a85b
round  7:08488005761e6c7c4dbb203ae453fe3a
Key [13]:0e255970b3e2fc235f59fc5acb10e8ce
Key [14]:d0dfbb3361fee6d4ffe45babf1cd7abf
round  8:0d81e89bddde7a7065316c47574feb8f
Key [15]:c12eee4eb38b7a171f0f736003774b40
Key [16]:8f962523f1c0abd9a087a0dfb11643d3
Key [17]:24be1c66cf8b022f12f1fb4c60c93fd1
Ka      :04435771e03a9daceb8bb1a493ee9bd8
----------------------------------------
rand    :40a94509238664f244ff8e3d13b119d3
PIN     :1ce44839badde30396d03c4c36f23006
round  1:40a94509238664f244ff8e3d13b119c3
Key [ 1]:1ce44839badde30396d03c4c36f23006
Key [ 2]:6dd97a8f91d628be4b18157af1a9dcba
round  2:0eac5288057d9947a24eabc1744c4582
Key [ 3]:fef9583d5f55fd4107ad832a725db744
Key [ 4]:fc3893507016d7c1db2bd034a230a069
round  3:60b424f1082b0cc3bd61be7b4c0155f0
added ->:205d69f82bb17031f9604c465fb26e33
Key [ 5]:0834d04f3e7e1f7f85f0c1db685ab118
Key [ 6]:1852397f9a3723169058e9b62bb3682b
round  4:2c6b65a49d66af6566675afdd6fa7d7d
Key [ 7]:6c10da21d762ae4ac1ba22a96d9007b4
Key [ 8]:9aa23658b90470a78d686344b8a9b0e7
round  5:a2c537899665113a42f1ac24773bdc31
Key [ 9]:137dee3bf879fe7bd02fe6d888e84f16
Key [10]:466e315a1863f47d0f93bc6827cf3450
round  6:e26982980d79b21ed3e20f8c3e71ba96
Key [11]:0b33cf831465bb5c979e6224d7f79f7c
Key [12]:92770660268ede827810d707a0977d73
```

```
round  7:e7b063c4e2e3110b89b7e1631c762dd5
Key [13]:7be30ae4961cf24ca17625a77bb7a9f8
Key [14]:be65574a33ae30e6e82dbd2826d3cc1a
round  8:7a963e37b2c2e76b489cfe40a2cf00e5
Key [15]:ed0ba7dd30d60a5e69225f0a33011e5b
Key [16]:765c990f4445e52b39e6ed6105ad1c4f
Key [17]:52627bf9f35d94f30d5b07ef15901adc
Ka      :9cde4b60f9b5861ed9df80858bac6f7f


========================================
```

9.4 TESTS OF E22 WITH PIN AUGMENTING

for PIN lengths 1,...,16 bytes

```
rand    :24b101fd56117d42c0545a4247357048
PIN length =16 octets
PIN     :fd397c7f5c1f937cdf82d8816cc377e2
round  1:24b101fd56117d42c0545a4247357058
Key [ 1]:fd397c7f5c1f937cdf82d8816cc377e2
Key [ 2]:0f7aac9c9b53f308d9fdbf2c78e3c30e
round  2:838edfe1226266953ccba8379d873107
Key [ 3]:0b8ac18d4bb44fad2efa115e43945abc
Key [ 4]:887b16b062a83bfa469772c25b456312
round  3:8cd0c9283120aba89a7f9d635dd4fe3f
added ->:a881cad5673128ea5ad3f7211a096e67
Key [ 5]:2248cbe6d299e9d3e8fd35a91178f65b
Key [ 6]:b92af6237385bd31f8fb57fb1bdd824e
round  4:2648d9c618a622b10ef80c4dbaf68b99
Key [ 7]:2bf5ffe84a37878ede2d4c30be60203b
Key [ 8]:c9cb6cec60cb8a8f29b99fcf3e71e40f
round  5:b5a7d9e96f68b14ccebf361de3914d0f
Key [ 9]:5c2f8a702e4a45575b103b0cce8a91c6
Key [10]:d453db0c9f9ddbd11e355d9a34d9b11b
round  6:632a091e7eefe1336857ddafd1ff3265
Key [11]:32805db7e59c5ed4acabf38d27e3fece
Key [12]:fde3a8eedfa3a12be09c1a8a00890fd7
round  7:048531e9fd3efa95910540150f8b137b
Key [13]:def07eb23f3a378f059039a2124bc4c2
Key [14]:2608c58f23d84a09b9ce95e5caac1ab4
round  8:461814ec7439d412d0732f0a6f799a6a
Key [15]:0a7ed16481a623e56ee1442ffa74f334
Key [16]:12add59aca0d19532f1516979954e369
Key [17]:dd43d02d39ffd6a386a4b98b4ac6eb23
Ka      :a5f2adf328e4e6a2b42f19c8b74ba884
----------------------------------------
rand    :321964061ac49a436f9fb9824ac63f8b
PIN length =15 octets
PIN     :ad955d58b6b8857820ac1262d617a6
address :0314c0642543
round  1:321964061ac49a436f9fb9824ac63f9b
```

Sample Data

```
Key [ 1]:ad955d58b6b8857820ac1262d617a603
Key [ 2]:f281736f68e3d30b2ac7c67f125dc416
round  2:7c4a4ece1398681f4bafd309328b7770
Key [ 3]:43c157f4c8b360387c32ab330f9c9aa8
Key [ 4]:3a3049945a298f6d076c19219c47c3cb
round  3:9672b00738bdfaf9bd92a855bc6f3afb
added ->:a48b1401228194bad23161d7f6357960
Key [ 5]:c8e2eaa6d73b7de18f3228ab2173bc69
Key [ 6]:8623f44488222e66a293677cf30bf2bb
round  4:9b30247aad3bf133712d034b46d21c68
Key [ 7]:f3e500902fba31db9bae50ef30e484a4
Key [ 8]:49d4b1137c18f4752dd9955a5a8d2f43
round  5:4492c25fda08083a768b4b5588966b23
Key [ 9]:9d59c451989e74785cc097eda7e42ab8
Key [10]:251de25f3917dcd99c18646107a641fb
round  6:21ae346635714d2623041f269978c0ee
Key [11]:80b8f78cb1a49ec0c3e32a238e60fddf
Key [12]:beb84f4d20a501e4a24ecfbde481902b
round  7:9b56a3d0f8932f20c6a77a229514fb00
Key [13]:852571b44f35fd9d9336d3c1d2506656
Key [14]:d0a0d510fb06ba76e69b8ee3ebc1b725
round  8:6cd8492b2fd31a86978bcdf644eb08a8
Key [15]:c7ffd523f32a874ed4a93430a25976de
Key [16]:16cdcb25e62964876d951fdcc07030d3
Key [17]:def32c0e12596f9582e5e3c52b303f52
Ka      :c0ec1a5694e2b48d54297911e6c98b8f
----------------------------------------
rand    :d4ae20c80094547d7051931b5cc2a8d6
PIN length =14 octets
PIN     :e1232e2c5f3b833b3309088a87b6
address :fabecc58e609
round  1:d4ae20c80094547d7051931b5cc2a8c6
Key [ 1]:e1232e2c5f3b833b3309088a87b6fabe
Key [ 2]:5f0812b47cd3e9a30d7707050fffa1f2
round  2:1f45f16be89794bef33e4547c9c0916a
Key [ 3]:77b681944763244ffa3cd71b248b79b5
Key [ 4]:e2814e90e04f485958ce58c9133e2be6
round  3:b10d2f4ac941035263cee3552d774d2f
added ->:65bb4f82c9d5572f131f764e7139f5e9
Key [ 5]:520acad20801dc639a2c6d66d9b79576
Key [ 6]:c72255cdb61d42be72bd45390dd25ba5
round  4:ead4dc34207b6ea721c62166e155aaad
Key [ 7]:ebf04c02075bf459ec9c3ec06627d347
Key [ 8]:a1363dd2812ee800a4491c0c74074493
round  5:f507944f3018e20586d81d7f326aae9d
Key [ 9]:b0b6ba79493dc833d7f425be7b8dadb6
Key [10]:08cd23e536b9b9b53e85eb004cba3111
round  6:fff450f4302a2b3571e8405e148346da
Key [11]:fec22374c6937dcd26171f4d2edfada3
Key [12]:0f1a8ef5979c69ff44f620c2e007b6e4
round  7:de558779589897f3402a90ee78c3f921
Key [13]:901fb66f0779d6aad0c0fba1fe812cb5
```

Sample Data

```
Key [14]:a0cab3cd15cd23603adc8d4474efb239
round  8:b2df0aa0c9f07fbbaa02f510a29cf540
Key [15]:18edc3f4296dd6f1dea13f7c143117a1
Key [16]:8d3d52d700a379d72ded81687f7546c7
Key [17]:5927badfe602f29345f840bb53e1dea6
Ka      :d7b39be13e3692c65b4a9e17a9c55e17
----------------------------------------
rand    :272b73a2e40db52a6a61c6520549794a
PIN length =13 octets
PIN     :549f2694f353f5145772d8ae1e
address :20487681eb9f
round  1:272b73a2e40db52a6a61c6520549795a
Key [ 1]:549f2694f353f5145772d8ae1e204876
Key [ 2]:42c855593d66b0c458fd28b95b6a5fbf
round  2:d7276dc8073f7677c31f855bde9501e2
Key [ 3]:75d0a69ae49a2da92e457d767879df52
Key [ 4]:b3aa7e7492971afaa0fb2b64827110df
round  3:71aae503831133d19bc452da4d0e409b
added ->:56d558a1671ee8fbf12518884857b9c1
Key [ 5]:9c8cf1604a98e9a503c342e272de5cf6
Key [ 6]:d35bc2df6b85540a27642106471057d9
round  4:f41a709c89ea80481aa3d2b9b2a9f8ca
Key [ 7]:b454dda74aeb4eff227ba48a58077599
Key [ 8]:bcba6aec050116aa9b7c6a9b7314d796
round  5:20fdda20f4a26b1bd38eb7f355a7be87
Key [ 9]:d41f8a9de0a716eb7167a1b6e321c528
Key [10]:5353449982247782d168ab43f17bc4d8
round  6:a70e316997eeed49a5a9ef9ba5e913b5
Key [11]:32cbc9cf1a81e36a45153972347ce4ac
Key [12]:5747619006cf4ef834c749f2c4b9feb6
round  7:e66f2317a825f589f76b47b6aa6e73fb
Key [13]:f9b68beba0a09d2a570a7dc88cc3c3c2
Key [14]:55718f9a4f0b1f9484e8c6b186a41a4b
round  8:5f68f940440a9798e074776019804ada
Key [15]:4ecc29be1b4d78433f6aa30db974a7fb
Key [16]:8470a066ffb00cda7b08059599f919f5
Key [17]:f39a36d74e960a051e1ca98b777848f4
Ka      :9ac64309a37c25c3b4a584fc002a1618
----------------------------------------
rand    :7edb65f01a2f45a2bc9b24fb3390667e
PIN length =12 octets
PIN     :2e5a42797958557b23447ca8
address :04f0d2737f02
round  1:7edb65f01a2f45a2bc9b24fb3390666e
Key [ 1]:2e5a42797958557b23447ca804f0d273
Key [ 2]:18a97c856561eb23e71af8e9e1be4799
round  2:3436e12db8ffdc1265cb5a86da2fed0b
Key [ 3]:7c0908dcbc73201e17c4f7aa1ab8aec8
Key [ 4]:7cb58833602fbe4194c7cc797ce8c454
round  3:caed6af4226f67e4ad1914620803ef2a
added ->:b4c8cf04389eac4611b438993b935544
Key [ 5]:f4dce7d607b5234562d0ebb2267b08b8
```


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Sample Data

```
Key [ 6]:560b75c5545751fd8fa99fa4346e654b
round  4:ee67c87d6f74bb75db98f68bff0192c1
Key [ 7]:32f10cefd8d3e6424c6f91f1437808af
Key [ 8]:a934a46045be30fb3be3a5f3f7b18837
round  5:792398dcbeb8d10bdb07ae3c819e943c
Key [ 9]:a0f12e97c677a0e8ac415cd2c8a7ca88
Key [10]:e27014c908785f5ca03e8c6a1da3bf13
round  6:e778b6e0c3e8e7edf90861c7916d97a8
Key [11]:1b4a4303bcc0b2e0f41c72d47654bd9f
Key [12]:4b1302a50046026d6c9054fc8387965a
round  7:1fafddc7efa5f04c1dec1869d3f2d9bb
Key [13]:58c334bb543d49eca562cdbe0280e0fc
Key [14]:bdb60d383c692d06476b76646c8dec48
round  8:3d7c326d074bd6aa222ea050f04a3c7f
Key [15]:78c0162506be0b5953e8403c01028f93
Key [16]:24d7dbbe834dbd7b67f57fcf0d39d60f
Key [17]:2e74f1f3331c0f6585e87b2f715e187e
Ka      :d3af4c81e3f482f062999dee7882a73b
----------------------------------------
rand    :26a92358294dce97b1d79ec32a67e81a
PIN length =11 octets
PIN     :05fbad03f52fa9324f7732
address :b9ac071f9d70
round  1:26a92358294dce97b1d79ec32a67e80a
Key [ 1]:05fbad03f52fa9324f7732b9ac071f9d
Key [ 2]:2504c9691c04a18480c8802e922098c0
round  2:0be20e3d76888e57b6bf77f97a8714fb
Key [ 3]:576b2791d1212bea8408212f2d43e77e
Key [ 4]:90ae36dcce8724adb618f912d1b27297
round  3:1969667060764453257d906b7e58bd5b
added ->:3f12892849c312c494542ea854bfa551
Key [ 5]:bc492c42c9e87f56ec31af5474e9226e
Key [ 6]:c135d1dbed32d9519acfb4169f3e1a10
round  4:ac404205118fe771e54aa6f392da1153
Key [ 7]:83ccbdbbaf17889b7d18254dc9252fa1
Key [ 8]:80b90a1767d3f2848080802764e21711
round  5:41795e89ae9a0cf776ffece76f47fd7a
Key [ 9]:cc24e4a86e8eed129118fd3d5223a1dc
Key [10]:7b1e9c0eb9dab083574be7b7015a62c9
round  6:29ca9e2f87ca00370ef1633505bfba4b
Key [11]:888e6d88cf4beb965cf7d4f32b696baa
Key [12]:6d642f3e5510b0b043a44daa2cf5eec0
round  7:81fc891c3c6fd99acc00028a387e2366
Key [13]:e224f85da2ab63a23e2a3a036e421358
Key [14]:c8dc22aaa739e2cb85d6a0c08226c7d0
round  8:e30b537e7a000e3d2424a9c0f04c4042
Key [15]:a969aa818c6b324bae391bedcdd9d335
Key [16]:6974b6f2f07e4c55f2cc0435c45bebd1
Key [17]:134b925ebd98e6b93c14aee582062fcb
Ka      :be87b44d079d45a08a71d15208c5cb50
----------------------------------------
rand    :0edef05327eab5262430f21fc91ce682
```

Sample Data

```
PIN length =10 octets
PIN     :8210e47390f3f48c32b3
address :7a3cdfe377d1
round  1:0edef05327eab5262430f21fc91ce692
Key [ 1]:8210e47390f3f48c32b37a3cdfe377d1
Key [ 2]:c6be4c3e425e749b620a94c779e33a7e
round  2:07ca3c7a7a6bcbc31d79a856d9cffc0e
Key [ 3]:2587cec2a4b8e4f996a9ed664350d5dd
Key [ 4]:70e4bf72834d9d3dbb7eb2c239216dc0
round  3:792ad2ac4e4559d1463714d2f161b6f4
added ->:7708c2ff692f0ef7626706cd387d9c66
Key [ 5]:6696e1e7f8ac037e1fff3598f0c164e2
Key [ 6]:23dbfe4d0b561bea08fbcef25e49b648
round  4:7d8c71a9d7fbdcbd851bdf074550b100
Key [ 7]:b03648acd021550edee904431a02f00c
Key [ 8]:cb169220b7398e8f077730aa4bf06baa
round  5:b6fcaa45064ffd557e4b7b30cfbb83e0
Key [ 9]:af602c2ba16a454649951274c2be6527
Key [10]:5d60b0a7a09d524143eca13ad680bc9c
round  6:b3416d391a0c26c558843debd0601e9e
Key [11]:9a2f39bfe558d9f562c5f09a5c3c0263
Key [12]:72cae8eebd7fabd9b1848333c2aab439
round  7:abe4b498d9c36ea97b8fd27d7f813913
Key [13]:15f27ea11e83a51645d487b81371d7dc
Key [14]:36083c8666447e03d33846edf444eb12
round  8:8032104338a945ba044d102eabda3b22
Key [15]:0a3a8977dd48f3b6c1668578befadd02
Key [16]:f06b6675d78ca0ee5b1761bdcdab516d
Key [17]:cbc8a7952d33aa0496f7ea2d05390b23
Ka      :bf0706d76ec3b11cce724b311bf71ff5
----------------------------------------
rand    :86290e2892f278ff6c3fb917b020576a
PIN length = 9 octets
PIN     :3dcdffcfd086802107
address :791a6a2c5cc3
round  1:86290e2892f278ff6c3fb917b0205765
Key [ 1]:3dcdffcfd086802107791a6a2c5cc33d
Key [ 2]:b4962f40d7bb19429007062a3c469521
round  2:1ec59ffd3065f19991872a7863b0ef02
Key [ 3]:eb9ede6787dd196b7e340185562bf28c
Key [ 4]:2964e58aacf7287d1717a35b100ae23b
round  3:f817406f1423fc2fe33e25152679eaaf
added ->:7e404e47861574d08f7dde02969941ca
Key [ 5]:6abf9a314508fd61e486fa4e376c3f93
Key [ 6]:6da148b7ee2632114521842cbb274376
round  4:e9c2a8fac22b8c7cf0c619e2b3f890ed
Key [ 7]:df889cc34fda86f01096d52d116e620d
Key [ 8]:5eb04b147dc39d1974058761ae7b73fc
round  5:444a8aac0efee1c02f8d38f8274b7b28
Key [ 9]:8426cc59eee391b2bd50cf8f1efef8b3
Key [10]:8b5d220a6300ade418da791dd8151941
round  6:9185f983db150b1bccab1e5c12eb63a1
```


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```
Key [11]:82ba4ddef833f6a4d18b07aa011f2798
Key [12]:ce63d98794682054e73d0359dad35ec4
round  7:5eded2668f5916dfd036c09e87902886
Key [13]:da794357652e80c70ad8b0715dbe33d6
Key [14]:732ef2c0c3220b31f3820c375e27bb29
round  8:88a5291b4acbba009a85b7dd6a834b3b
Key [15]:3ce75a61d4b465b70c95d7ccd5799633
Key [16]:5df9bd2c3a17a840cdaafb76c171db7c
Key [17]:3f8364b089733d902bccb0cd3386846f
Ka      :cdb0cc68f6f6fbd70b46652de3ef3ffb
----------------------------------------
rand    :3ab52a65bb3b24a08eb6cd284b4b9d4b
PIN length = 8 octets
PIN     :d0fb9b6838d464d8
address :25a868db91ab
round  1:3ab52a65bb3b24a08eb6cd284b4b9d45
Key [ 1]:d0fb9b6838d464d825a868db91abd0fb
Key [ 2]:2573f47b49dad6330a7a9155b7ae8ba1
round  2:ad2ffdff408fcfab44941016a9199251
Key [ 3]:d2c5b8fb80cba13712905a589adaee71
Key [ 4]:5a3381511b338719fae242758dea0997
round  3:2ddc17e570d7931a2b1d13f6ace928a5
added ->:17914180cb12b7baa5d3e0dee734c5e0
Key [ 5]:e0a4d8ac27fbe2783b7bcb3a36a6224d
Key [ 6]:949324c6864deac3eca8e324853e11c3
round  4:62c1db5cf31590d331ec40ad692e8df5
Key [ 7]:6e67148088a01c2d4491957cc9ddc4aa
Key [ 8]:557431deab7087bb4c03fa27228f60c6
round  5:9c8933bc361f4bde4d1bda2b5f8bb235
Key [ 9]:a2551aca53329e70ade3fd2bb7664697
Key [10]:05d0ad35de68a364b54b56e2138738fe
round  6:9156db34136aa06655bf28a05be0596a
Key [11]:1616a6b13ce2f2895c722e8495181520
Key [12]:b12e78a1114847b01f6ed2f5a1429a23
round  7:84dcc292ed836c1c2d523f2a899a2ad5
Key [13]:316e144364686381944e95afd8a026bb
Key [14]:1ab551b88d39d97ea7a9fe136dbfe2e1
round  8:87bdcac878d777877f4eccf042cfee5e
Key [15]:70e21ab08c23c7544524b64492b25cc9
Key [16]:35f730f2ae2b950a49a1bf5c8b9f8866
Key [17]:2f16924c22db8b74e2eadf1ba4ebd37c
Ka      :983218718ca9aa97892e312d86dd9516
----------------------------------------
rand    :a6dc447ff08d4b366ff96e6cf207e179
PIN length = 7 octets
PIN     :9c57e10b4766cc
address :54ebd9328cb6
round  1:a6dc447ff08d4b366ff96e6cf207e174
Key [ 1]:9c57e10b4766cc54ebd9328cb69c57e1
Key [ 2]:00a609f4d61db26993c8177e3ee2bba8
round  2:1ed26b96a306d7014f4e5c9ee523b73d
Key [ 3]:646d7b5f9aaa528384bda3953b542764
```

Sample Data

```
Key [ 4]:a051a42212c0e9ad5c2c248259aca14e
round  3:a53f526db18e3d7d53edbfc9711041ed
added ->:031b9612411b884b3ce62da583172299
Key [ 5]:d1bd5e64930e7f838d8a33994462d8b2
Key [ 6]:5dc7e2291e32435665ebd6956bec3414
round  4:9438be308ec83f35c560e2796f4e0559
Key [ 7]:10552f45af63b0f15e2919ab37f64fe7
Key [ 8]:c44d5717c114a58b09207392ebe341f8
round  5:b79a7b14386066d339f799c40479cb3d
Key [ 9]:6886e47b782325568eaf59715a75d8ff
Key [10]:8e1e335e659cd36b132689f78c147bda
round  6:ef232462228aa166438d10c34e17424b
Key [11]:8843efeedd5c2b7c3304d647f932f4d1
Key [12]:13785aaedd0adf67abb4f01872392785
round  7:02d133fe40d15f1073673b36bba35abd
Key [13]:837d7ca2722419e6be3fae35900c3958
Key [14]:93f8442973e7fccf2e7232d1d057c73a
round  8:275506a3d08c84e94cc58ed60054505e
Key [15]:8a7a9edffa3c52918bc6a45f57d91f5d
Key [16]:f214a95d777f763c56109882c4b52c84
Key [17]:10e2ee92c5ea1ddc5eb010e55510c403
Ka      :9cd6650ead86323e87cafb1ff516d1e0
----------------------------------------
rand    :3348470a7ea6cc6eb81b40472133262c
PIN length = 6 octets
PIN     :fcad169d7295
address :430d572f8842
round  1:3348470a7ea6cc6eb81b404721332620
Key [ 1]:fcad169d7295430d572f8842fcad169d
Key [ 2]:b3479d4d4fd178c43e7bc5b0c7d8983c
round  2:af976da9225066d563e10ab955e6fc32
Key [ 3]:7112462b37d82dd81a2a35d9eb43cb7c
Key [ 4]:c5a7030f8497945ac7b84600d1d161fb
round  3:d08f826ebd55a0bd7591c19a89ed9bde
added ->:e3d7c964c3fb6cd3cdac01dda820c1fe
Key [ 5]:84b0c6ef4a63e4dff19b1f546d683df5
Key [ 6]:f4023edfc95d1e79ed4bb4de9b174f5d
round  4:6cd952785630dfc7cf81eea625e42c5c
Key [ 7]:ea38dd9a093ac9355918632c90c79993
Key [ 8]:dbba01e278ddc76380727f5d7135a7de
round  5:93573b2971515495978264b88f330f7f
Key [ 9]:d4dc3a31be34e412210fafa6eca00776
Key [10]:39d1e190ee92b0ff16d92a8be58d2fa0
round  6:b3f01d5e7fe1ce6da7b46d8c389baf47
Key [11]:1eb081328d4bcf94c9117b12c5cf22ac
Key [12]:7e047c2c552f9f1414d946775fabfe30
round  7:0b833bff6106d5bae033b4ce5af5a924
Key [13]:e78e685d9b2a7e29e7f2a19d1bc38ebd
Key [14]:1b582272a3121718c4096d2d8602f215
round  8:23de0bbdc70850a7803f4f10c63b2c0f
Key [15]:8569e860530d9c3d48a0870dac33f676
Key [16]:6966b528fdd1dc222527052c8f6cf5a6
```


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```
Key [17]:a34244c757154c53171c663b0b56d5c2
Ka      :98f1543ab4d87bd5ef5296fb5e3d3a21
----------------------------------------
rand    :0f5bb150b4371ae4e5785293d22b7b0c
PIN length = 5 octets
PIN     :b10d068bca
address :b44775199f29
round  1:0f5bb150b4371ae4e5785293d22b7b07
Key [ 1]:b10d068bcab44775199f29b10d068bca
Key [ 2]:aec70d1048f1bbd2c18040318a8402ad
round  2:342d2b79d7fb7cd110379742b9842c79
Key [ 3]:6d8d5cf338f29ef4420639ef488e4fa9
Key [ 4]:a1584117541b759ba6d9f7eb2bedcbba
round  3:9407e8e3e810603921bf81cfda62770a
added ->:9b6299b35c477addc437d35c088df20d
Key [ 5]:09a20676666aeed6f22176274eb433f4
Key [ 6]:840472c001add5811a054be5f5c74754
round  4:9a3ba953225a7862c0a842ed3d0b2679
Key [ 7]:fad9e45c8bf70a972fcd9bff0e8751f5
Key [ 8]:e8f30ff666dfd212263416496ff3b2c2
round  5:2c573b6480852e875df34b28a5c44509
Key [ 9]:964cdba0cf8d593f2fc40f96daf8267a
Key [10]:bcd65c11b13e1a70bcd4aafba8864fe3
round  6:21b0cc49e880c5811d24dee0194e6e9e
Key [11]:468c8548ea9653c1a10df6288dd03c1d
Key [12]:5d252d17af4b09d3f4b5f7b5677b8211
round  7:e6d6bdcd63e1d37d9883543ba86392fd
Key [13]:e814bf307c767428c67793dda2df95c7
Key [14]:4812b979fdc20f0ff0996f61673a42cc
round  8:e3dde7ce6bd7d8a34599aa04d6a760ab
Key [15]:5b1e2033d1cd549fc4b028146eb5b3b7
Key [16]:0f284c14fb8fe706a5343e3aa35af7b1
Key [17]:b1f7a4b7456d6b577fded6dc7a672e37
Ka      :c55070b72bc982adb972ed05d1a74ddb
----------------------------------------
rand    :148662a4baa73cfadb55489159e476e1
PIN length = 4 octets
PIN     :fb20f177
address :a683bd0b1896
round  1:148662a4baa73cfadb55489159e476eb
Key [ 1]:fb20f177a683bd0b1896fb20f177a683
Key [ 2]:47266cefbfa468ca7916b458155dc825
round  2:3a942eb6271c3f4e433838a5d3fcbd27
Key [ 3]:688853a6d6575eb2f6a2724b0fbc133b
Key [ 4]:7810df048019634083a2d9219d0b5fe0
round  3:9c835b98a063701c0887943596780769
added ->:8809bd3c1a0aace6d3dcdca4cf5c7d82
Key [ 5]:c78f6dcf56da1bbd413828b33f5865b3
Key [ 6]:eb3f3d407d160df3d293a76d1a513c4a
round  4:7e68c4bafa020a4a59b5a1968105bab5
Key [ 7]:d330e038d6b19d5c9bb0d7285a360064
Key [ 8]:9bd3ee50347c00753d165faced702d9c
```

Sample Data

```
round  5:227bad0cf0838bdb15b3b3872c24f592
Key [ 9]:9543ad0fb3fe74f83e0e2281c6d4f5f0
Key [10]:746cd0383c17e0e80e6d095a87fd0290
round  6:e026e98c71121a0cb739ef6f59e14d26
Key [11]:fa28bea4b1c417536608f11f406ea1dd
Key [12]:3aee0f4d21699df9cb8caf5354a780ff
round  7:cd6a6d8137d55140046f8991da1fa40a
Key [13]:372b71bc6d1aa6e785358044fbcf05f4
Key [14]:00a01501224c0405de00aa2ce7b6ab04
round  8:52cd7257fe8d0c782c259bcb6c9f5942
Key [15]:c7015c5c1d7c030e00897f104a006d4a
Key [16]:260a9577790c62e074e71e19fd2894df
Key [17]:c041b7a231493acd15ddcdaee94b9f52
Ka      :7ec864df2f1637c7e81f2319ae8f4671
----------------------------------------
rand    :193a1b84376c88882c8d3b4ee93ba8d5
PIN length = 3 octets
PIN     :a123b9
address :4459a44610f6
round  1:193a1b84376c88882c8d3b4ee93ba8dc
Key [ 1]:a123b94459a44610f6a123b94459a446
Key [ 2]:5f64d384c8e990c1d25080eb244dde9b
round  2:3badbd58f100831d781ddd3ccedefd3f
Key [ 3]:5abc00eff8991575c00807c48f6dbea5
Key [ 4]:127521158ad6798fb6479d1d2268abe6
round  3:0b53075a49c6bf2df2421c655fdedf68
added ->:128d22de7e3247a5decf572bb61987b4
Key [ 5]:f2a1f620448b8e56665608df2ab3952f
Key [ 6]:7c84c0af02aad91dc39209c4edd220b1
round  4:793f4484fb592e7a78756fd4662f990d
Key [ 7]:f6445b647317e7e493bb92bf6655342f
Key [ 8]:3cae503567c63d3595eb140ce60a84c0
round  5:9e46a8df925916a342f299a8306220a0
Key [ 9]:734ed5a806e072bbecb4254993871679
Key [10]:cda69ccb4b07f65e3c8547c11c0647b8
round  6:6bf9cd82c9e1be13fc58eae0b936c75a
Key [11]:c48e531d3175c2bd26fa25cc8990e394
Key [12]:6d93d349a6c6e9ff5b26149565b13d15
round  7:e96a9871471240f198811d4b8311e9a6
Key [13]:5c4951e85875d663526092cd4cbdb667
Key [14]:f19f7758f5cde86c3791efaf563b3fd0
round  8:e94ca67d3721d5fb08ec069191801a46
Key [15]:bf0c17f3299b37d984ac938b769dd394
Key [16]:7edf4ad772a6b9048588f97be25bde1c
Key [17]:6ee7ba6afefc5b561abbd8d6829e8150
Ka      :ac0daabf17732f632e34ef193658bf5d
----------------------------------------
rand    :1453db4d057654e8eb62d7d62ec3608c
PIN length = 2 octets
PIN     :3eaf
address :411fbbb51d1e
round  1:1453db4d057654e8eb62d7d62ec36084
```

Sample Data

```
Key [ 1]:3eaf411fbbb51d1e3eaf411fbbb51d1e
Key [ 2]:c3a1a997509f00fb4241aba607109c64
round  2:0b78276c1ebc65707d38c9c5fa1372bd
Key [ 3]:3c729833ae1ce7f84861e4dbad6305cc
Key [ 4]:c83a43c3a66595cb8136560ed29be4ff
round  3:23f3f0f6441563d4c202cee0e5cb2335
added ->:3746cbbb418bb73c2964a536cb8e83b1
Key [ 5]:18b26300b86b70acdd1c8f5cbc7c5da8
Key [ 6]:04efc75309b98cd8f1cef5513c18e41e
round  4:c61afa90d3c14bdf588320e857afdc00
Key [ 7]:517c789cecadc455751af73198749fb8
Key [ 8]:fd9711f913b5c844900fa79dd765d0e2
round  5:a8a0e02ceb556af8bfa321789801183a
Key [ 9]:bb5cf30e7d3ceb930651b1d16ee92750
Key [10]:3d97c7862ecab42720e984972f8efd28
round  6:0b58e922438d224db34b68fca9a5ea12
Key [11]:4ce730344f6b09e449dcdb64cd466666
Key [12]:38828c3a56f922186adcd9b713cdcc31
round  7:b90664c4ac29a8b4bb26debec9ffc5f2
Key [13]:d30fd865ea3e9edcff86a33a2c319649
Key [14]:1fdb63e54413acd968195ab6fa424e83
round  8:6934de3067817cefd811abc5736c163b
Key [15]:a16b7c655bbaa262c807cba8ae166971
Key [16]:7903dd68630105266049e23ca607cda7
Key [17]:888446f2d95e6c2d2803e6f4e815ddc9
Ka      :1674f9dc2063cc2b83d3ef8ba692ebef
----------------------------------------
rand    :1313f7115a9db842fcedc4b10088b48d
PIN length = 1 octets
PIN     :6d
address :008aa9be62d5
round  1:1313f7115a9db842fcedc4b10088b48a
Key [ 1]:6d008aa9be62d56d008aa9be62d56d00
Key [ 2]:46ebfeafb6657b0a1984a8dc0893accf
round  2:839b23b83b5701ab095bafd162ec0ac7
Key [ 3]:8e15595edcf058af62498ee3c1dc6098
Key [ 4]:dd409c3444e94b9cc08396ae967542a0
round  3:c0a2010cc44f2139427f093f4f97ae68
added ->:d3b5f81d9eecd97bbe6ccd8e4f1f62e2
Key [ 5]:487deff5d519f6a6481e947b926f633c
Key [ 6]:5b4b6e3477ed5c2c01f6e607d3418963
round  4:1a5517a0efad3575931d8ea3bee8bd07
Key [ 7]:34b980088d2b5fd6b6a2aceeda99c9c4
Key [ 8]:e7d06d06078acc4ecdbc8da800b73078
round  5:d3ce1fdfe716d72c1075ff37a8a2093f
Key [ 9]:7d375bad245c3b757380021af8ecd408
Key [10]:14dac4bc2f4dc4929a6cceec47f4c3a3
round  6:47e90cb55be6e8dd0f583623c2f2257b
Key [11]:66cfda3c63e464b05e2e7e25f8743ad7
Key [12]:77cfccda1ad380b9fdf1df10846b50e7
round  7:f866ae6624f7abd4a4f5bd24b04b6d43
Key [13]:3e11dd84c031a470a8b66ec6214e44cf
```

```
Key [14]:2f03549bdb3c511eea70b65ddbb08253
round  8:02e8e17cf8be4837c9c40706b613dfa8
Key [15]:e2f331229ddfcc6e7bea08b01ab7e70c
Key [16]:b6b0c3738c5365bc77331b98b3fba2ab
Key [17]:f5b3973b636119e577c5c15c87bcfd19
Ka      :38ec0258134ec3f08461ae5c328968a1

========================================
```

9.5 FOUR TESTS OF E3

```
rand    :00000000000000000000000000000000
aco     :48afcdd4bd40fef76693b113
key     :00000000000000000000000000000000
round  1:00000000000000000000000000000000
Key [ 1]:00000000000000000000000000000000
Key [ 2]:4697b1baa3b7100ac537b3c95a28ac64
round  2:78d19f9307d2476a523ec7a8a026042a
Key [ 3]:ecabaac66795580df89af66e66dc053d
Key [ 4]:8ac3d8896ae9364943bfebd4969b68a0
round  3:600265247668dda0e81c07bbb30ed503
Key [ 5]:5d57921fd5715cbb22c1be7bbc996394
Key [ 6]:2a61b8343219fdfb1740e6511d41448f
round  4:d7552ef7cc9dbde568d80c2215bc4277
Key [ 7]:dd0480dee731d67f01a2f739da6f23ca
Key [ 8]:3ad01cd1303e12a1cd0fe0a8af82592c
round  5:fb06bef32b52ab8f2a4f2b6ef7f6d0cd
Key [ 9]:7dadb2efc287ce75061302904f2e7233
Key [10]:c08dcfa981e2c4272f6c7a9f52e11538
round  6:b46b711ebb3cf69e847a75f0ab884bdd
Key [11]:fc2042c708e409555e8c147660ffdfd7
Key [12]:fa0b21001af9a6b9e89e624cd99150d2
round  7:c585f308ff19404294f06b292e978994
Key [13]:18b40784ea5ba4c80ecb48694b4e9c35
Key [14]:454d54e5253c0c4a8b3fcca7db6baef4
round  8:2665fadb13acf952bf74b4ab12264b9f
Key [15]:2df37c6d9db52674f29353b0f011ed83
Key [16]:b60316733b1e8e70bd861b477e2456f1
Key [17]:884697b1baa3b7100ac537b3c95a28ac
round  1:5d3ecb17f26083df0b7f2b9b29aef87c
Key [ 1]:e9e5dfc1b3a79583e9e5dfc1b3a79583
Key [ 2]:7595bf57e0632c59f435c16697d4c864
round  2:de6fe85c5827233fe22514a16f321bd8
Key [ 3]:e31b96afcc75d286ef0ae257cbbc05b7
Key [ 4]:0d2a27b471bc0108c6263aff9d9b3b6b
round  3:7cd335b50d09d139ea6702623af85edb
added ->:211100a2ff6954e6e1e62df913a656a7
Key [ 5]:98d1eb5773cf59d75d3b17b3bc37c191
Key [ 6]:fd2b79282408ddd4ea0aa7511133336f
round  4:991dccb3201b5b1c4ceff65a3711e1e9
Key [ 7]:331227756638a41d57b0f7e071ee2a98
```

```
Key [ 8]:aa0dd8cc68b406533d0f1d64aabacf20
round  5:18768c7964818805fe4c6ecae8a38599
Key [ 9]:669291b0752e63f806fce76f10e119c8
Key [10]:ef8bdd46be8ee0277e9b78adef1ec154
round  6:82f9aa127a72632af43d1a17e7bd3a09
Key [11]:f3902eb06dc409cfd78384624964bf51
Key [12]:7d72702b21f97984a721c99b0498239d
round  7:1543d7870bf2d6d6efab3cbf62dca97d
Key [13]:532e60bceaf902c52a06c2c283ecfa32
Key [14]:181715e5192efb2a64129668cf5d9dd4
round  8:eee3e8744a5f8896de95831ed837ffd5
Key [15]:83017c1434342d4290e961578790f451
Key [16]:2603532f365604646ff65803795ccce5
Key [17]:882f7c907b565ea58dae1c928a0dcf41
kc      :cc802aecc7312285912e90af6a1e1154
----------------------------------------
rand    :950e604e655ea3800fe3eb4a28918087
aco     :68f4f472b5586ac5850f5f74
key     :34e86915d20c485090a6977931f96df5
round  1:950e604e655ea3800fe3eb4a28918087
Key [ 1]:34e86915d20c485090a6977931f96df5
Key [ 2]:8de2595003f9928efaf37e5229935bdb
round  2:d46f5a04c967f55840f83d1cdb5f9afc
Key [ 3]:46f05ec979a97cb6ddf842ecc159c04a
Key [ 4]:b468f0190a0a83783521deae8178d071
round  3:e16edede9cb6297f32e1203e442ac73a
Key [ 5]:8a171624dedbd552356094daaadcf12a
Key [ 6]:3085e07c85e4b99313f6e0c837b5f819
round  4:805144e55e1ece96683d23366fc7d24b
Key [ 7]:fe45c27845169a66b679b2097d147715
Key [ 8]:44e2f0c35f64514e8bec66c5dc24b3ad
round  5:edbaf77af070bd22e9304398471042f1
Key [ 9]:0d534968f3803b6af447eaf964007e7b
Key [10]:f5499a32504d739ed0b3c547e84157ba
round  6:0dab1a4c846aef0b65b1498812a73b50
Key [11]:e17e8e456361c46298e6592a6311f3fb
Key [12]:ec6d14da05d60e8abac807646931711f
round  7:1e7793cac7f55a8ab48bd33bc9c649e0
Key [13]:2b53dde3d89e325e5ff808ed505706ae
Key [14]:41034e5c3fb0c0d4f445f0cf23be79b0
round  8:3723768baa78b6a23ade095d995404da
Key [15]:e2ca373d405a7abf22b494f28a6fd247
Key [16]:74e09c9068c0e8f1c6902d1b70537c30
Key [17]:767a7f1acf75c3585a55dd4a428b2119
round  1:39809afb773efd1b7510cd4cb7c49f34
Key [ 1]:1d0d48d485abddd3798b483a82a0f878
Key [ 2]:aed957e600a5aed5217984dd5fef6fd8
round  2:6436ddbabe92655c87a7d0c12ae5e5f6
Key [ 3]:fee00bb0de89b6ef0a289696a4faa884
Key [ 4]:33ce2f4411db4dd9b7c42cc586b8a2ba
round  3:cec690f7e0aa5f063062301e049a5cc5
added ->:f7462a0c97e85c1d4572fd52b35efbf1
```

Sample Data

```
Key [ 5]:b5116f5c6c29e05e4acb4d02a46a3318
Key [ 6]:ff4fa1f0f73d1a3c67bc2298abc768f9
round  4:dcdfe942e9f0163fc24a4718844b417d
Key [ 7]:5453650c0819e001e48331ad0e9076e0
Key [ 8]:b4ff8dda778e26c0dce08349b81c09a1
round  5:265a16b2f766afae396e7a98c189fda9
Key [ 9]:f638fa294427c6ed94300fd823b31d10
Key [10]:1ccfa0bd86a9879b17d4bc457e3e03d6
round  6:628576b5291d53d1eb8611c8624e863e
Key [11]:0eaee2ef4602ac9ca19e49d74a76d335
Key [12]:6e1062f10a16e0d378476da3943842e9
round  7:d7b9c2e9b2d5ea5c27019324cae882b3
Key [13]:40be960bd22c744c5b23024688e554b9
Key [14]:95c9902cb3c230b44d14ba909730d211
round  8:97fb6065498385e47eb3df6e2ca439dd
Key [15]:10d4b6e1d1d6798aa00aa2951e32d58d
Key [16]:c5d4b91444b83ee578004ab8876ba605
Key [17]:1663a4f98e2862eddd3ec2fb03dcc8a4
kc      :c1beafea6e747e304cf0bd7734b0a9e2
----------------------------------------
rand    :6a8ebcf5e6e471505be68d5eb8a3200c
aco     :658d791a9554b77c0b2f7b9f
key     :35cf77b333c294671d426fa79993a133
round  1:6a8ebcf5e6e471505be68d5eb8a3200c
Key [ 1]:35cf77b333c294671d426fa79993a133
Key [ 2]:c4524e53b95b4bf2d7b2f095f63545fd
round  2:ade94ec585db0d27e17474b58192c87a
Key [ 3]:c99776768c6e9f9dd3835c52cea8d18a
Key [ 4]:f1295db23823ba2792f21217fc01d23f
round  3:da8dc1a10241ef9e6e069267cd2c6825
Key [ 5]:9083db95a6955235bbfad8aeefec5f0b
Key [ 6]:8bab6bc253d0d0c7e0107feab728ff68
round  4:e6665ca0772ceecbc21222ff7be074f8
Key [ 7]:2fa1f4e7a4cf3ccd876ec30d194cf196
Key [ 8]:267364be247184d5337586a19df8bf84
round  5:a857a9326c9ae908f53fee511c5f4242
Key [ 9]:9aef21965b1a6fa83948d107026134c7
Key [10]:d2080c751def5dc0d8ea353cebf7b973
round  6:6678748a1b5f21ac05cf1b117a7c342f
Key [11]:d709a8ab70b0d5a2516900421024b81e
Key [12]:493e4843805f1058d605c8d1025f8a56
round  7:766c66fe9c460bb2ae39ec01e435f725
Key [13]:b1ed21b71daea03f49fe74b2c11fc02b
Key [14]:0e1ded7ebf23c72324a0165a698c65c7
round  8:396e0ff7b2b9b7a3b35c9810882c7596
Key [15]:b3bf4841dc92f440fde5f024f9ce8be9
Key [16]:1c69bc6c2994f4c84f72be8f6b188963
Key [17]:bb7b66286dd679a471e2792270f3bb4d
round  1:45654f2f26549675287200f07cb10ec9
Key [ 1]:1e2a5672e66529e4f427b0682a3a34b6
Key [ 2]:974944f1ce0037b1febcf61a2bc961a2
round  2:990cd869c534e76ed4f4af7b3bfbc6c8
```

```
Key [ 3]:8147631fb1ce95d624b480fc7389f6c4
Key [ 4]:6e90a2db33d284aa13135f3c032aa4f4
round  3:ceb662f875aa6b94e8192b5989abf975
added ->:8b1bb1d753fe01e1c08b2ba9f55c07bc
Key [ 5]:cbad246d24e36741c46401e6387a05f9
Key [ 6]:dcf52aaec5713110345a41342c566fc8
round  4:d4e000be5de78c0f56ff218f3c1df61b
Key [ 7]:8197537aa9d27e67d17c16b182c8ec65
Key [ 8]:d66e00e73d835927a307a3ed79d035d8
round  5:9a4603bdef954cfaade2052604bed4e4
Key [ 9]:71d46257ecc1022bcd312ce6c114d75c
Key [10]:f91212fa528379651fbd2c32890c5e5f
round  6:09a0fd197ab81eb933eece2fe0132dbb
Key [11]:283acc551591fadce821b02fb9491814
Key [12]:ca5f95688788e20d94822f162b5a3920
round  7:494f455a2e7a5db861ece816d4e363e4
Key [13]:ba574aef663c462d35399efb999d0e40
Key [14]:6267afc834513783fef1601955fe0628
round  8:37a819f91c8380fb7880e640e99ca947
Key [15]:fdcd9be5450eef0f8737e6838cd38e2b
Key [16]:8cfbd9b8056c6a1ce222b92b94319b38
Key [17]:4f64c1072c891c39eeb95e63318462e0
kc      :a3032b4df1cceba8adc1a04427224299
----------------------------------------
rand    :5ecd6d75db322c75b6afbd799cb18668
aco     :63f701c7013238bbf88714ee
key     :b9f90c53206792b1826838b435b87d4d
round  1:5ecd6d75db322c75b6afbd799cb18668
Key [ 1]:b9f90c53206792b1826838b435b87d4d
Key [ 2]:15f74bbbde4b9d1e08f858721f131669
round  2:72abb85fc80c15ec2b00d72873ef9ad4
Key [ 3]:ef7fb29f0b01f82706c7439cc52f2dab
Key [ 4]:3003a6aecdee06b9ac295cce30dcdb93
round  3:2f10bab93a0f73742183c68f712dfa24
Key [ 5]:5fcdbb3afdf7df06754c954fc6340254
Key [ 6]:ddaa90756635579573fe8ca1f93d4a38
round  4:183b145312fd99d5ad08e7ca4a52f04e
Key [ 7]:27ca8a7fc703aa61f6d7791fc19f704a
Key [ 8]:702029d8c6e42950762317e730ec5d18
round  5:cbad52d3a026b2e38b9ae6fefffecc32
Key [ 9]:ff15eaa3f73f4bc2a6ccfb9ca24ed9c5
Key [10]:034e745246cd2e2cfc3bda39531ca9c5
round  6:ce5f159d0a1acaacd9fb4643272033a7
Key [11]:0a4d8ff5673731c3dc8fe87e39a34b77
Key [12]:637592fab43a19ac0044a21afef455a2
round  7:8a49424a10c0bea5aba52dbbffcbcce8
Key [13]:6b3fde58f4f6438843cdbe92667622b8
Key [14]:a10bfa35013812f39bf2157f1c9fca4e
round  8:f5e12da0e93e26a5850251697ec0b917
Key [15]:2228fe5384e573f48fdd19ba91f1bf57
Key [16]:5f174db2bc88925c0fbc6b5485bafc08
Key [17]:28ff90bd0dc31ea2bb479feb7d8fe029
```

Sample Data

```
round  1:0c75eed2b54c1cfb9ff522daef94ed4d
Key [ 1]:a21ceb92d3c027326b4de775865fe8d0
Key [ 2]:26f64558a9f0a1652f765efd546f3208
round  2:48d537ac209a6aa07b70000016c602e8
Key [ 3]:e64f9ef630213260f1f79745a0102ae5
Key [ 4]:af6a59d7cebfd0182dcca9a537c4add8
round  3:8b6d517ac893743a401b3fb7911b64e1
added ->:87e23fa87ddf90c1df10616d7eaf51ac
Key [ 5]:9a6304428b45da128ab64c8805c32452
Key [ 6]:8af4d1e9d80cb73ec6b44e9b6e4f39d8
round  4:9f0512260a2f7a5067efc35bf1706831
Key [ 7]:79cc2d138606f0fca4e549c34a1e6d19
Key [ 8]:803dc5cdde0efdbee7a1342b2cd4d344
round  5:0cfd7856edfafac51f29e86365de6f57
Key [ 9]:e8fa996448e6b6459ab51e7be101325a
Key [10]:2acc7add7b294acb444cd933f0e74ec9
round  6:2f1fa34bf352dc77c0983a01e8b7d622
Key [11]:f57de39e42182efd6586b86a90c86bb1
Key [12]:e418dfd1bb22ebf1bfc309cd27f5266c
round  7:ee4f7a53849bf73a747065d35f3752b1
Key [13]:80a9959133856586370854db6e0470b3
Key [14]:f4c1bc2f764a0193749f5fc09011a1ae
round  8:8fec6f7249760ebf69e370e9a4b80a92
Key [15]:d036cef70d6470c3f52f1b5d25b0c29d
Key [16]:d0956af6b8700888a1cc88f07ad226dc
Key [17]:1ce8b39c4c7677373c30849a3ee08794
kc      :ea520cfc546b00eb7c3a6cea3ecb39ed

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Core System Package [Controller volume]
Part H



SECURITY SPECIFICATION

This document describes the specification of the security system which may be used at the link layer. The Encryption, Authentication and Key Generation schemes are specified. The requirements for the supporting process of random number generation are also specified.

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1 SECURITY OVERVIEW

Bluetooth wireless technology provides peer-to-peer communications over short distances. In order to provide usage protection and information confidentiality, the system provides security measures both at the application layer and the link layer. These measures are designed to be appropriate for a peer environment. This means that in each device, the authentication and encryption routines are implemented in the same way. Four different entities are used for maintaining security at the link layer: a Bluetooth device address, two secret keys, and a pseudo-random number that shall be regenerated for each new transaction. The four entities and their sizes are summarized in Table 1.1.

Entity	Size
BD_ADDR	48 bits
Private user key, authentication	128 bits
Private user key, encryption configurable length (byte-wise)	8-128 bits
RAND	128 bits

Table 1.1: Entities used in authentication and encryption procedures.

The Bluetooth device address (BD_ADDR) is the 48-bit address. The BD_ADDR can be obtained via user interactions, or, automatically, via an inquiry routine by a device.

The secret keys are derived during initialization and are never disclosed. The encryption key is derived from the authentication key during the authentication process. For the authentication algorithm, the size of the key used is always 128 bits. For the encryption algorithm, the key size may vary between 1 and 16 octets (8 - 128 bits). The size of the encryption key is configurable for two reasons. The first has to do with the many different requirements imposed on cryptographic algorithms in different countries – both with respect to export regulations and official attitudes towards privacy in general. The second reason is to facilitate a future upgrade path for the security without the need of a costly redesign of the algorithms and encryption hardware; increasing the effective key size is the simplest way to combat increased computing power at the opponent side.

The encryption key is entirely different from the authentication key (even though the latter is used when creating the former, as is described in Section 6.4 on page 783). Each time encryption is activated, a new encryption key shall be generated. Thus, the lifetime of the encryption key does not necessarily correspond to the lifetime of the authentication key.

It is anticipated that the authentication key will be more static in its nature than the encryption key – once established, the particular application running on the device decides when, or if, to change it. To underline the fundamental impor-

tance of the authentication key to a specific link, it is often be referred to as the link key.

The RAND is a pseudo-random number which can be derived from a random or pseudo-random process in the device. This is not a static parameter, it will change frequently.

In the remainder of this chapter, the terms user and application will be used interchangeably to designate the entity that is at either side.

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2 RANDOM NUMBER GENERATION

Each device has a pseudo-random number generator. Pseudo-random numbers are used for many purposes within the security functions – for instance, for the challenge-response scheme, for generating authentication and encryption keys, etc. Ideally, a true random generator based on some physical process with inherent randomness should be used as a seed. Examples of such processes are thermal noise from a semiconductor or resistor and the frequency instability of a free running oscillator. For practical reasons, a software based solution with a pseudo-random generator is probably preferable. In general, it is quite difficult to classify the randomness of a pseudo-random sequence. Within this specification, the requirements placed on the random numbers used are non-repeating and randomly generated.

The expression ‘non-repeating’ means that it shall be highly unlikely that the value will repeat itself within the lifetime of the authentication key. For example, a non-repeating value could be the output of a counter that is unlikely to repeat during the lifetime of the authentication key, or a date/time stamp.

The expression ‘randomly generated’ means that it shall not be possible to predict its value with a chance that is significantly larger than 0 (e.g., greater than $1/2^L$ for a key length of L bits).

The LM may use such a generator for various purposes; i.e. whenever a random number is needed (such as the RANDs, the unit keys, K_{init}, K_{master}, and random back-off or waiting intervals).

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3 KEY MANAGEMENT

It is important that the encryption key size within a specific device cannot be set by the user – this should be a factory preset entity. In order to prevent the user from over-riding the permitted key size, the Bluetooth baseband processing shall not accept an encryption key given from higher software layers. Whenever a new encryption key is required, it shall be created as defined in Section 6.4 on page 783.

Changing a link key shall also be done through the defined baseband procedures. Depending on what kind of link key it is, different approaches are required. The details are found in Section 3.2.7 on page 760.

3.1 KEY TYPES

The link key is a 128-bit random number which is shared between two or more parties and is the base for all security transactions between these parties. The link key itself is used in the authentication routine. Moreover, the link key is used as one of the parameters when the encryption key is derived.

In the following, a session is defined as the time interval for which the device is a member of a particular piconet. Thus, the session terminates when the device disconnects from the piconet.

The link keys are either semi-permanent or temporary. A semi-permanent link key may be stored in non-volatile memory and may be used after the current session is terminated. Consequently, once a semi-permanent link key is defined, it may be used in the authentication of several subsequent connections between the devices sharing it. The designation semi-permanent is justified by the possibility of changing it. How to do this is described in Section 3.2.7 on page 760.

The lifetime of a temporary link key is limited by the lifetime of the current session – it shall not be reused in a later session. Typically, in a point-to-multipoint configuration where the same information is to be distributed securely to several recipients, a common encryption key is useful. To achieve this, a special link key (denoted master key) may temporarily replace the current link keys. The details of this procedure are found in Section 3.2.6 on page 759.

In the following, the current link key is the link key in use at the current moment. It can be semi-permanent or temporary. Thus, the current link key is used for all authentications and all generation of encryption keys in the on-going connection (session).

In order to accommodate different types of applications, four types of link keys have been defined:

- the combination key K_{AB}
- the unit key K_A
- the temporary key K_{master}
- the initialization key K_{init}

Note: the use of unit keys is deprecated since it is implicitly insecure.

In addition to these keys there is an encryption key, denoted K_c. This key is derived from the current link key. Whenever encryption is activated by an LM command, the encryption key shall be changed automatically. The purpose of separating the authentication key and encryption key is to facilitate the use of a shorter encryption key without weakening the strength of the authentication procedure. There are no governmental restrictions on the strength of authentication algorithms. However, in some countries, such restrictions exist on the strength of encryption algorithms.

The combination key K_{AB} and the unit key K_A are functionally indistinguishable; the difference is in the way they are generated. The unit key K_A is generated in, and therefore dependent on, a single device A. The unit key shall be generated once at installation of the device; thereafter, it is very rarely changed. The combination key is derived from information in both devices A and B, and is therefore always dependent on two devices. The combination key is derived for each new combination of two devices.

It depends on the application or the device whether a unit key or a combination key is used. Devices which have little memory to store keys, or are installed in equipment that will be accessible to a large group of users, should use their own unit key. In that case, they only have to store a single key. Applications that require a higher security level should use the combination keys. These applications will require more memory since a combination key for each link to a different device has to be stored.

The master key, K_{master}, shall only be used during the current session. It shall only replace the original link key temporarily. For example, this may be utilized when a master wants to reach more than two devices simultaneously using the same encryption key, see Section 3.2.6 on page 759.

The initialization key, K_{init}, shall be used as the link key during the initialization process when no combination or unit keys have been defined and exchanged yet or when a link key has been lost. The initialization key protects the transfer of initialization parameters. The key is derived from a random number, an L-octet PIN code, and a BD_ADDR. This key shall only be used during initialization.

The PIN may be a fixed number provided with the device (for example when there is no user interface as in a PSTN plug). Alternatively, the PIN can be selected by the user, and then entered in both devices that are to be matched. The latter procedure should be used when both devices have a user interface, for example a phone and a laptop. Entering a PIN in both devices is more secure than using a fixed PIN in one of the devices, and should be used whenever possible. Even if a fixed PIN is used, it shall be possible to change the PIN; this is in order to prevent re-initialization by users who once got hold of the PIN. If no PIN is available, a default value of zero may be used. The length of this default PIN is one byte, PIN(default) = 0x00. This default PIN may be provided by the host.

For many applications the PIN code will be a relatively short string of numbers. Typically, it may consist of only four decimal digits. Even though this gives sufficient security in many cases, there exist countless other, more sensitive, situations where this is not reliable enough. Therefore, the PIN code may be chosen to be any length from 1 to 16 octets. For the longer lengths, the devices exchanging PIN codes may not use mechanical (i.e. human) interaction, but rather may use software at the application layer. For example, this can be a Diffie-Hellman key agreement, where the exchanged key is passed on to the K_{init} generation process in both devices, just as in the case of a shorter PIN code.

3.2 KEY GENERATION AND INITIALIZATION

The link keys must be generated and distributed among the devices in order to be used in the authentication procedure. Since the link keys shall be secret, they shall not be obtainable through an inquiry routine in the same way as the Bluetooth device addresses. The exchange of the keys takes place during an initialization phase which shall be carried out separately for each two devices that are using authentication and encryption. The initialization procedures consist of the following five parts:

- generation of an initialization key
- generation of link key
- link key exchange
- authentication
- generation of encryption key in each device (optional)

After the initialization procedure, the devices can proceed to communicate, or the link can be disconnected. If encryption is implemented, the E_0 algorithm shall be used with the proper encryption key derived from the current link key. For any new connection established between devices A and B, they should use the common link key for authentication, instead of once more deriving K_{init} from the PIN. A new encryption key derived from that particular link key shall be created next time encryption is activated.

If no link key is available, the LM shall automatically start an initialization procedure.

3.2.1 Generation of initialization key, K_{init}

A link key is used temporarily during initialization, the initialization key K_{init}. This key shall be derived by the E_{22} algorithm from a BD_ADDR, a PIN code, the length of the PIN (in octets), and a random number IN_RAND. The principle is depicted in Figure 6.4 on page 783. The 128-bit output from E_{22} shall be used for key exchange during the generation of a link key. When the devices have performed the link key exchange, the initialization key shall be discarded.

When the initialization key is generated, the PIN is augmented with the BD_ADDR. If one device has a fixed PIN the BD_ADDR of the other device shall be used. If both devices have a variable PIN the BD_ADDR of the device that received IN_RAND shall be used. If both devices have a fixed PIN they cannot be paired. Since the maximum length of the PIN used in the algorithm cannot exceed 16 octets, it is possible that not all octets of BD_ADDR will be used. This procedure ensures that K_{init} depends on the identity of the device with a variable PIN. A fraudulent device may try to test a large number of PINs by claiming another BD_ADDR each time. It is the application's responsibility to take countermeasures against this threat. If the device address is kept fixed, the waiting interval before the next try may be increased exponentially (see Section 5.1 on page 775).

The details of the E_{22} algorithm can be found in Section 6.3 on page 781.

3.2.2 Authentication

The authentication procedure shall be carried out as described in Section 5 on page 773. During each authentication, a new AU_RAND_A shall be issued.

Mutual authentication is achieved by first performing the authentication procedure in one direction and then immediately performing the authentication procedure in the opposite direction.

As a side effect of a successful authentication procedure an auxiliary parameter, the Authenticated Ciphering Offset (ACO), will be computed. The ACO shall be used for ciphering key generation as described in Section 3.2.5 on page 758.

The claimant/verifier status is determined by the LM.

3.2.3 Generation of a unit key

A unit key K_A shall be generated when the device is in operation for the first time; i.e. not during each initialization. The unit key shall be generated by the E_{21} algorithm as described in Section 6.3 on page 781. Once created, the unit key should be stored in non-volatile memory and very rarely changed. If after initialization

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the unit key is changed, any previously initialized devices will possess a wrong link key. At initialization, the application must determine which of the two parties will provide the unit key as the link key. Typically, this will be the device with restricted memory capabilities, since this device only has to remember its own unit key. The unit key shall be transferred to the other party and then stored as the link key for that particular party. So, for example in Figure 3.1 on page 757, the unit key of device A, K_A, is being used as the link key for the connection A-B; device A sends the unit key K_A to device B; device B will store K_A as the link key K_{BA}. For another initialization, for example with device C, device A will reuse its unit key K_A, whereas device C stores it as K_{CA}.

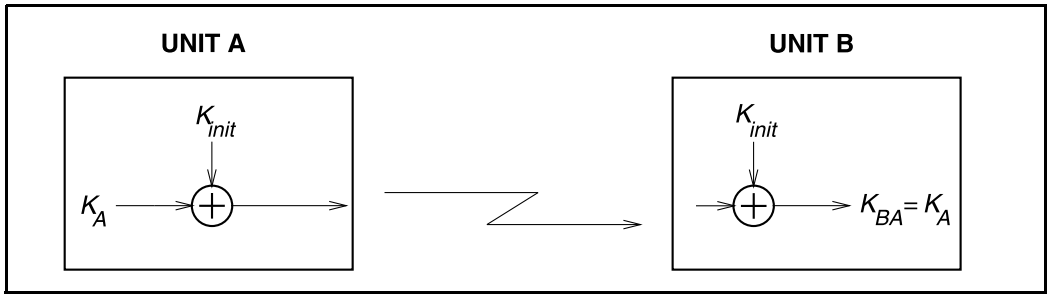


Figure 3.1: Generation of unit key. When the unit key has been exchanged, the initialization key is discarded in both devices.

3.2.4 Generation of a combination key

To use a combination key, it is first generated during the initialization procedure. The combination key is the combination of two numbers generated in device A and B, respectively. First, each device shall generate a random number, LK_RAND_A and LK_RAND_B. Then, utilizing E_{21} with the random number and their own BD_ADDRs, the two random numbers

$$LK\_K_A = E_{21}(LK\_RAND_A, BD\_ADDR_A), \quad \text{(EQ 1)}$$

and

$$LK\_K_B = E_{21}(LK\_RAND_B, BD\_ADDR_B), \quad \text{(EQ 2)}$$

shall be created in device A and device B, respectively. These numbers constitute the devices' contribution to the combination key that is to be created. Then, the two random numbers LK_RAND_A and LK_RAND_B shall be exchanged securely by XORing with the current link key, K. Thus, device A shall send $K \oplus LK\_RAND_A$ to device B, while device B shall send $K \oplus LK\_RAND_B$ to device A. If this is done during the initialization phase the link key $K = K_{init}$.

When the random numbers LK_RAND_A and LK_RAND_B have been mutually exchanged, each device shall recalculate the other device's contribution to the combination key. This is possible since each device knows the Bluetooth device address of the other device. Thus, device A shall calculate (EQ 2) on page 757 and device B shall calculate (EQ 1) on page 757. After this, both devices shall combine the two numbers to generate the 128-bit link key. The combining operation is a simple bitwise modulo-2 addition (i.e. XOR). The result shall be stored in device A as the link key K_{AB} and in device B as the link key K_{BA}. When both devices have derived the new combination key, a mutual authentication procedure shall be initiated to confirm the success of the transaction. The old link key shall be discarded after a successful exchange of a new combination key. The message flow between master and slave and the principle for creating the combination key is depicted in Figure 3.2 on page 758.

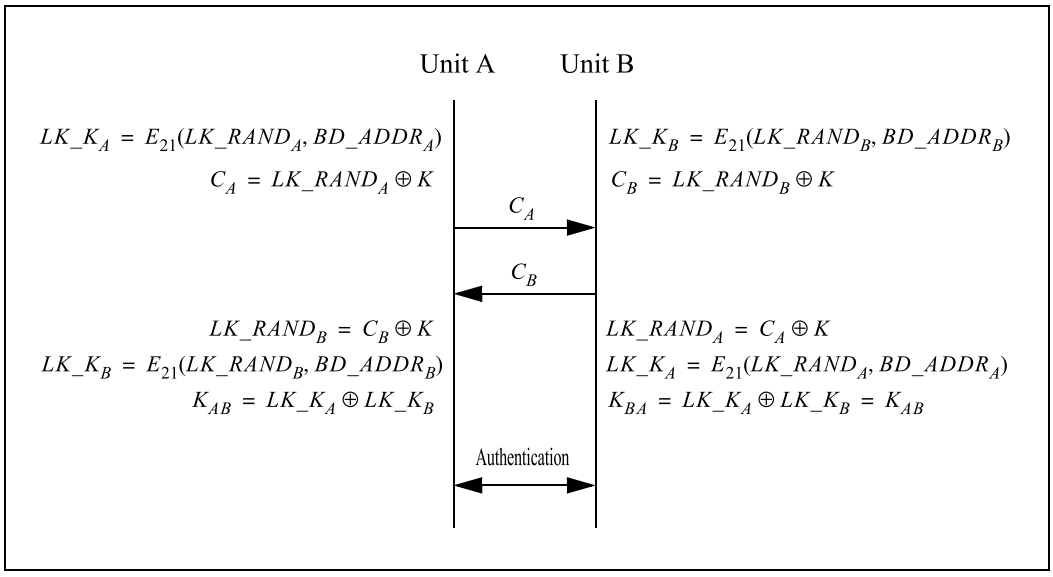


Figure 3.2: Generating a combination key. The old link key (K) is discarded after the exchange of a new combination key has succeeded

3.2.5 Generating the encryption key

The encryption key, K_C, is derived by algorithm E_3 from the current link key, a 96-bit Ciphering OFfset number (COF), and a 128-bit random number. The COF is determined in one of two ways. If the current link key is a master key, then COF shall be derived from the master BD_ADDR. Otherwise the value of COF shall be set to the value of ACO as computed during the authentication procedure. Therefore:[1]

1. $x \cup y$ denotes the concatenation of x and y.

$$\mathrm{COF} = \begin{cases} \mathrm{BD\_ADDR} \cup \mathrm{BD\_ADDR}, & \text{if link key is a master key} \\ \mathrm{ACO}, & \text{otherwise.} \end{cases} \quad \text{(EQ 3)}$$

There is an explicit call of E_3 when the LM activates encryption. Consequently, the encryption key is automatically changed each time the device enters encryption mode. The details of the key generating function E_3 can be found in Section 6.4 on page 783.

3.2.6 Point-to-multipoint configuration

It is possible for the master to use separate encryption keys for each slave in a point-to-multipoint configuration with ciphering activated. Then, if the application requires more than one slave to listen to the same payload, each slave must be addressed individually. This can cause unwanted capacity loss for the piconet. Moreover, a slave might not be capable of switching between two or more encryption keys in real time (e.g., after looking at the LT_ADDR in the header). Thus, the master cannot use different encryption keys for broadcast messages and individually addressed traffic. Therefore, the master may tell several slave devices to use a common link key (and, hence, indirectly also to use a common encryption key) and may then broadcast the information encrypted. For many applications, this key is only of temporary interest. In the following discussion, this key is denoted by K_{master}.

The transfer of necessary parameters shall be protected by the routine described in Section 3.2.8 on page 760. After the confirmation of successful reception in each slave, the master shall issue a command to the slaves to replace their respective current link key by the new (temporary) master key. Before encryption can be activated, the master shall also generate and distribute a common EN_RAND to all participating slaves. Using this random number and the newly derived master key, each slave shall generate a new encryption key.

Note that the master must negotiate the encryption key length to use individually with each slave that will use the master key. If the master has already negotiated with some of these slaves, it has knowledge of the sizes that can be accepted. There may be situations where the permitted key lengths of some devices are incompatible. In that case, the master must exclude the limiting device from the group.

When all slaves have received the necessary data, the master can communicate information on the piconet securely using the encryption key derived from the new temporary link key. Each slave in possession of the master key can eavesdrop on all encrypted traffic, not only the traffic intended for itself. The master may tell all participants to fall back to their old link keys simultaneously.

3.2.7 Modifying the link keys

A link key based on a unit key can be changed. The unit key is created once during first use. Typically, the link key should be changed rather than the unit key, as several devices may share the same unit key as link key (e.g. a printer whose unit key is distributed to all users using the printer's unit key as link key). Changing the unit key will require re-initialization of all devices connecting. Changing the unit key can be justified in some circumstances, e.g. to deny access to all previously allowed devices.

If the key change concerns combination keys, then the procedure is straightforward. The change procedure is identical to the procedure described in Figure 3.2 on page 758, using the current value of the combination key as link key. This procedure can be carried out at any time after the authentication and encryption start. Since the combination key corresponds to a single link, it can be modified each time this link is established. This will improve the security of the system since then old keys lose their validity after each session.

Starting up an entirely new initialization procedure is also possible. In that case, user interaction is necessary since a PIN will be required in the authentication and encryption procedures.

3.2.8 Generating a master key

The key-change routines described so far are semi-permanent. To create the master link key, which can replace the current link key during a session (see Section 3.2.6 on page 759), other means are needed. First, the master shall create a new link key from two 128-bit random numbers, RAND1 and RAND2. This shall be done by

$$K_{master} = E_{22}(\text{RAND1}, \text{RAND2}, 16). \quad \text{(EQ 4)}$$

This key is a 128-bit random number. The reason for using the output of E_{22} and not directly choosing a random number as the key, is to avoid possible problems with degraded randomness due to a poor implementation of the random number generator within the device.

Then, a third random number, RAND, shall be transmitted to the slave. Using E_{22} with the current link key and RAND as inputs, both the master and the slave shall compute a 128-bit overlay. The master shall send the bitwise XOR of the overlay and the new link key to the slave. The slave, who knows the overlay, shall recalculate K_{master}. To confirm the success of this transaction, the devices shall perform a mutual authentication procedure using the new link key. This procedure shall then be repeated for each slave that receives the new link key. The ACO values from the authentications shall not replace the current ACO, as this ACO is needed to (re)compute a ciphering key when the master falls back to the previous (non-temporary) link key.

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The master activates encryption by an LM command. Before activating encryption, the master shall ensure that all slaves receive the same random number, EN_RAND, since the encryption key is derived through the means of E_3 individually in all participating devices. Each slave shall compute a new encryption key as follows:

$$K_C = E_3(K_{master}, \text{EN\_RAND}, \text{COF}) \quad \text{(EQ 5)}$$

where the value of COF shall be derived from the master's BD_ADDR as specified by equation (EQ 3) on page 759. The details of the encryption key generating function are described in Section 6.4 on page 783. The message flow between the master and the slave when generating the master key is depicted in Figure 3.3. Note that in this case the ACO produced during the authentication is not used when computing the ciphering key.

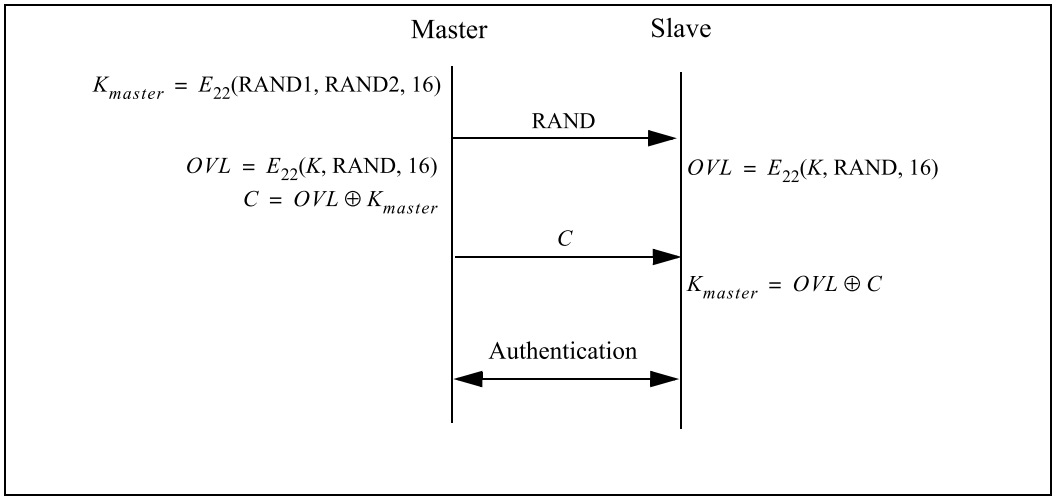


Figure 3.3: Master link key distribution and computation of the corresponding encryption key.

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4 ENCRYPTION

User information can be protected by encryption of the packet payload; the access code and the packet header shall never be encrypted. The encryption of the payload shall be carried out with a stream cipher called E_0 that shall be re-synchronized for every payload. The overall principle is shown in Figure 4.1 on page 763.

The stream cipher system E_0 shall consist of three parts:

- the first part performs initialization (generation of the payload key). The payload key generator shall combine the input bits in an appropriate order and shall shift them into the four LFSRs used in the key stream generator.
- the second part generates the key stream bits this shall use a method derived from the summation stream cipher generator attributable to Massey and Rueppel. The second part is the main part of the cipher system, as it will also be used for initialization.
- the third part performs encryption and decryption.

The Massey and Rueppel method has been thoroughly investigated, and there exist good estimates of its strength with respect to presently known methods for cryptanalysis. Although the summation generator has weaknesses that can be used in correlation attacks, the high re-synchronization frequency will disrupt such attacks.

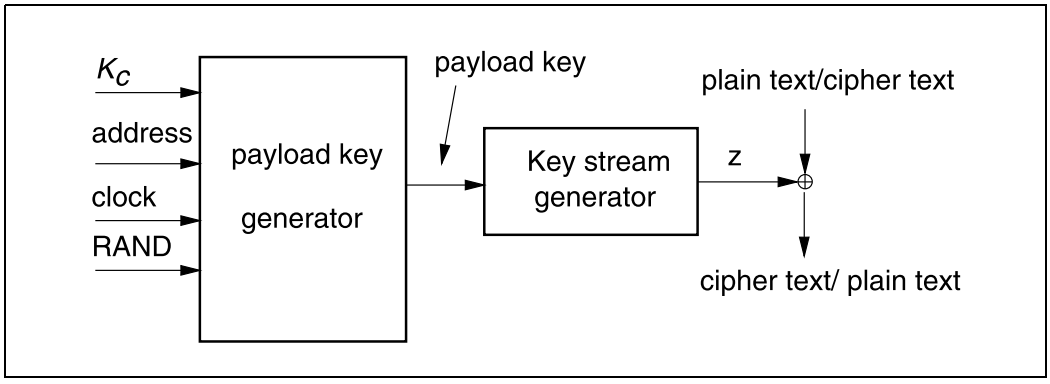


Figure 4.1: Stream ciphering for Bluetooth with E_0.

4.1 ENCRYPTION KEY SIZE NEGOTIATION

Each device implementing the baseband specification shall have a parameter defining the maximal allowed key length, L_{max}, $1 \leq L_{max} \leq 16$ (number of octets in the key). For each application using encryption, a number L_{min} shall be defined indicating the smallest acceptable key size for that particular application. Before generating the encryption key, the devices involved shall negotiate to decide the key size to use.

The master shall send a suggested value, $L_{sug}^{(M)}$, to the slave. Initially, the suggested value shall be set to $L_{max}^{(M)}$. If $L_{min}^{(S)} \leq L_{sug}^{(M)}$, and, the slave supports the suggested length, the slave shall acknowledge and this value shall be the length of the encryption key for this link. However, if both conditions are not fulfilled, the slave shall send a new proposal, $L_{sug}^{(S)} < L_{sug}^{(M)}$, to the master. This value shall be the largest among all supported lengths less than the previous master suggestion. Then, the master shall perform the corresponding test on the slave suggestion. This procedure shall be repeated until a key length agreement is reached, or, one device aborts the negotiation. An abort may be caused by lack of support for L_{sug} and all smaller key lengths, or if $L_{sug} < L_{min}$ in one of the devices. In case of an abort link encryption can not be employed.

The possibility of a failure in setting up a secure link is an unavoidable consequence of letting the application decide whether to accept or reject a suggested key size. However, this is a necessary precaution. Otherwise a fraudulent device could enforce a weak protection on a link by claiming a small maximum key size.

4.2 ENCRYPTION OF BROADCAST MESSAGES

There may be three settings for the baseband regarding encryption:

1. No encryption.
   This is the default setting. No messages are encrypted
2. Point-to-point only encryption.
   Broadcast messages are not encrypted. This may be enabled either during the connection establishment procedure or after the connection has been established.
3. Point-to-point and broadcast encryption.
   All messages are encrypted. This may be enabled after the connection has been established only. This setting should not be enabled unless all affected links share the same master link key as well as the same EN_RAND value, both used in generating the encryption key.

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4.3 ENCRYPTION CONCEPT

Broadcast traffic	Individually addressed traffic
No encryption	No encryption
No encryption	Encryption, K_{master}
Encryption, K_{master}	Encryption, K_{master}

Table 4.1: Possible encryption modes for a slave in possession of a master key.

For the encryption routine, a stream cipher algorithm is used in which ciphering bits are bit-wise modulo-2 added to the data stream to be sent over the air interface. The payload is ciphered after the CRC bits are appended, but, prior to the FEC encoding.

Each packet payload shall be ciphered separately. The cipher algorithm E_0 uses the master Bluetooth device address (BD_ADDR), 26 bits of the master real-time clock (CLK $_{26\text{-}1}$) and the encryption key K_C as input, see Figure 4.2 on page 766 (where it is assumed that device A is the master).

The encryption key K_C is derived from the current link key, COF, and a random number, EN_RAND_A (see Section 6.4 on page 783). The random number shall be issued by the master before entering encryption mode. Note that EN_RAND_A is publicly known since it is transmitted as plain text over the air.

Within the E_0 algorithm, the encryption key K_C is modified into another key denoted K'_C. The maximum effective size of this key shall be factory preset and may be set to any multiple of eight between one and sixteen (8-128 bits). The procedure for deriving the key is described in Section 4.5 on page 769.

The real-time clock is incremented for each slot. The E_0 algorithm shall be re-initialized at the start of each new packet (i.e. for Master-to-Slave as well as for Slave-to-Master transmission). By using $CLK_{26\text{-}1}$ at least one bit is changed between two transmissions. Thus, a new keystream is generated after each re-initialization. For packets covering more than a single slot, the Bluetooth clock as found in the first slot shall be used for the entire packet.

The encryption algorithm E_0 generates a binary keystream, K_{cipher}, which shall be modulo-2 added to the data to be encrypted. The cipher is symmetric; decryption shall be performed in exactly the same way using the same key as used for encryption.

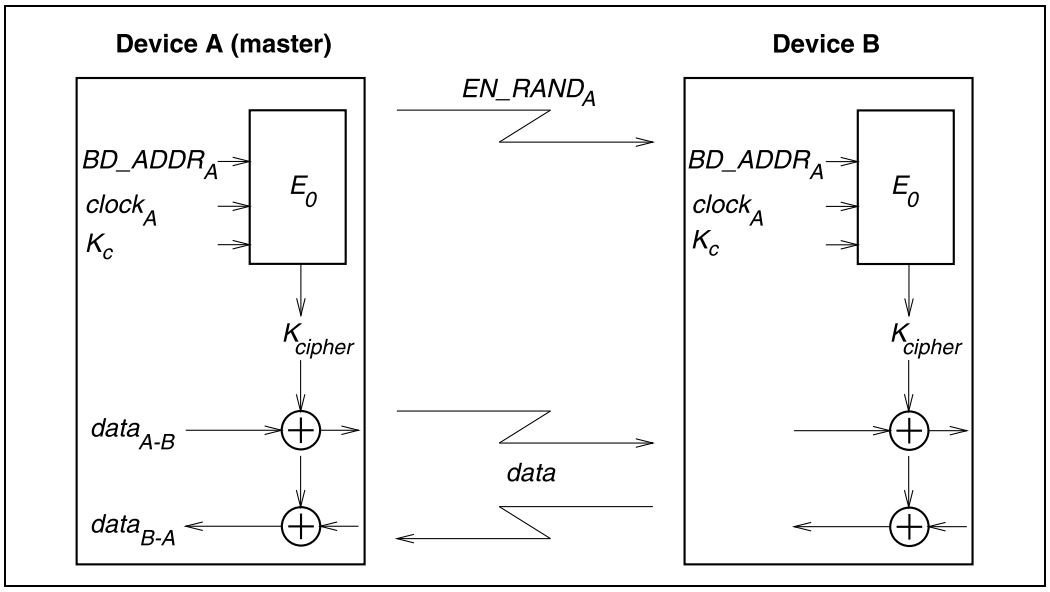


Figure 4.2: Functional description of the encryption procedure

4.4 ENCRYPTION ALGORITHM

The system uses linear feedback shift registers (LFSRs) whose output is combined by a simple finite state machine (called the summation combiner) with 16 states. The output of this state machine is the key stream sequence, or, during initialization phase, the randomized initial start value. The algorithm uses an encryption key K_C, a 48-bit Bluetooth address, the master clock bits CLK_{26-1}, and a 128-bit RAND value. Figure 4.3 on page 767 shows the setup.

There are four LFSRs ($LFSR_1$,...,$LFSR_4$) of lengths $L_1 = 25$, $L_2 = 31$, $L_3 = 33$, and, $L_4 = 39$, with feedback polynomials as specified in Table 4.2 on page 767. The total length of the registers is 128. These polynomials are all primitive. The Hamming weight of all the feedback polynomials is chosen to be five – a reasonable trade-off between reducing the number of required XOR gates in the hardware implementation and obtaining good statistical properties of the generated sequences.

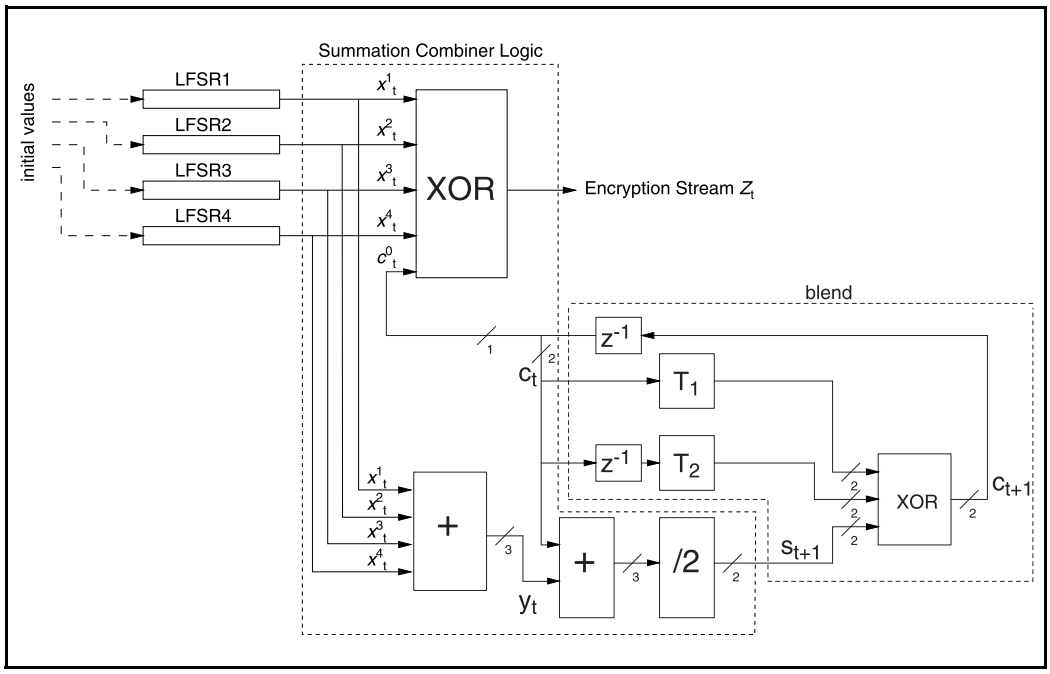


Figure 4.3: Concept of the encryption engine.

i	L_i	**feedback** $f_i(t)$	**weight**
1	25	$t^{25} + t^{20} + t^{12} + t^8 + 1$	5
2	31	$t^{31} + t^{24} + t^{16} + t^{12} + 1$	5
3	33	$t^{33} + t^{28} + t^{24} + t^4 + 1$	5
4	39	$t^{39} + t^{36} + t^{28} + t^4 + 1$	5

Table 4.2: The four primitive feedback polynomials.

Let x_t^i denote the tth symbol of LFSR_i. The value y_t is derived from the four-tuple $x_t^1, \ldots, x_t^4$ using the following equation:

$$y_t = \sum_{i=1}^{4} x_t^i, \qquad \text{(EQ 6)}$$

where the sum is over the integers. Thus y_t can take the values 0,1,2,3, or 4. The output of the summation generator is obtained by the following equations:

$$z_t = x_t^1 \oplus x_t^2 \oplus x_t^3 \oplus x_t^4 \oplus c_t^0 \in \{0, 1\}, \qquad \text{(EQ 7)}$$

$$s_{t+1} = (s^1_{t+1}, s^0_{t+1}) = \left\lfloor \frac{y_t + c_t}{2} \right\rfloor \in \{0, 1, 2, 3\}, \quad \text{(EQ 8)}$$

$$c_{t+1} = (c^1_{t+1}, c^0_{t+1}) = s_{t+1} \oplus T_1[c_t] \oplus T_2[c_{t-1}], \quad \text{(EQ 9)}$$

where $T_1[.]$ and $T_2[.]$ are two different linear bijections over GF(4). Suppose GF(4) is generated by the irreducible polynomial $x^2 + x + 1$, and let α be a zero of this polynomial in GF(4). The mappings T_1 and T_2 are now defined as:

$$T_1: \text{GF}(4) \rightarrow \text{GF}(4)$$
$$x \mapsto x$$
$$T_2: \text{GF}(4) \rightarrow \text{GF}(4)$$
$$x \mapsto (\alpha + 1)x.$$

The elements of GF(4) can be written as binary vectors. This is summarized in Table 4.3.

x	$T_1[x]$	$T_2[x]$
00	00	00
01	01	11
10	10	01
11	11	10

Table 4.3: The mappings T_1 and T_2.

Since the mappings are linear, they can be implemented using XOR gates; i.e.

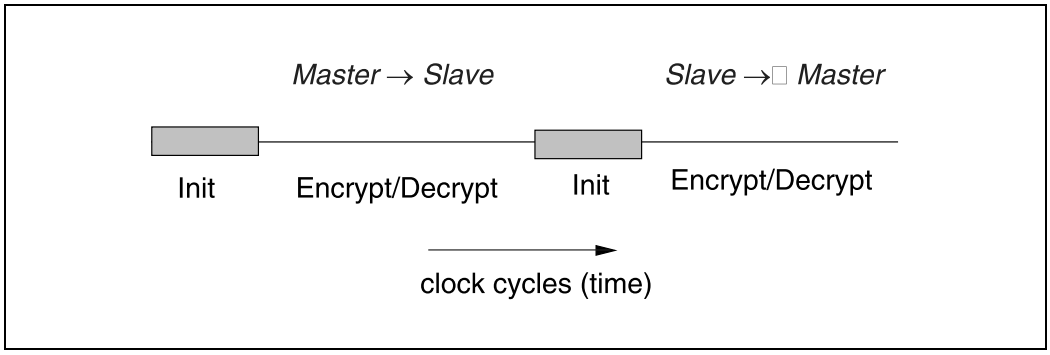
$$T_1: \quad (x_1, x_0) \mapsto (x_1, x_0),$$
$$T_2: \quad (x_1, x_0) \mapsto (x_0, x_1 \oplus x_0).$$

4.4.1 The operation of the cipher

Figure 4.4 on page 768 gives an overview of the operation in time. The encryption algorithm shall run through the initialization phase before the start of transmission or reception of a new packet. Thus, for multislot packets the cipher is initialized using the clock value of the first slot in the multislot sequence.

Figure 4.4: Overview of the operation of the encryption engine. Between each start of a packet (TX or RX), the LFSRs are re-initialized.

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4.5 LFSR INITIALIZATION

The key stream generator is loaded with an initial value for the four LFSRs (in total 128 bits) and the 4 bits that specify the values of c_0 and c_{-1}. The 132 bit initial value is derived from four inputs by using the key stream generator. The input parameters are the key K_C, a 128-bit random number RAND, a 48-bit Bluetooth device address, and the 26 master clock bits $CLK_{26\text{-}1}$.

The effective length of the encryption key may vary between 8 and 128 bits. Note that the actual key length as obtained from E_3 is 128 bits. Then, within E_0, the key length may be reduced by a modulo operation between K_C and a polynomial of desired degree. After reduction, the result is encoded with a block code in order to distribute the starting states more uniformly. The operation shall be as defined in (EQ 10) on page 770.

When the encryption key has been created the LFSRs are loaded with their initial values. Then, 200 stream cipher bits are created by operating the generator. Of these bits, the last 128 are fed back into the key stream generator as an initial value of the four LFSRs. The values of c_t and c_{t-1} are kept. From this point on, when clocked the generator produces the encryption (decryption) sequence which is bitwise XORed to the transmitted (received) payload data.

In the following, octet i of a binary sequence X is $X[i]$. Bit 0 of X is the LSB. Then, the LSB of $X[i]$ corresponds to bit $8i$ of the sequence X, the MSB of $X[i]$ is bit $8i+7$ of X. For instance, bit 24 of the Bluetooth device address is the LSB of BD_ADDR[3].

The details of the initialization shall be as follows:

1. Create the encryption key to use from the 128-bit secret key K_C and the 128-bit publicly known EN_RAND. Let $L, 1 \le L \le 16$, be the

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effective key length in number of octets. The resulting encryption key is K'_C:

$$K'_C(x) = g_2^{(L)}(x)(K_C(x) \bmod g_1^{(L)}(x)), \qquad \text{(EQ 10)}$$

where $\deg(g_1^{(L)}(x)) = 8L$ and $\deg(g_2^{(L)}(x)) \leq 128 - 8L$. The polynomials are defined in Table 4.4.

2. Shift the 3 inputs K'_C, the Bluetooth device address, the clock, and the six-bit constant 111001 into the LFSRs. In total, 208 bits are shifted in:

   a) Open all switches shown in Figure 4.5 on page 771;

   b) Arrange inputs bits as shown in Figure 4.5; Set the content of all shift register elements to zero. Set $t = 0$.

   c) Start shifting bits into the LFSRs. The rightmost bit at each level of Figure 4.5 is the first bit to enter the corresponding LFSR.

   d) When the first input bit at level i reaches the rightmost position of $LFSR_i$, close the switch of this LFSR.

   e) At $t = 39$ (when the switch of $LFSR_4$ is closed), reset both blend registers $c_{39} = c_{39-1} = 0$; Up to this point, the content of c_t and c_{t-1} has been of no concern. However, their content will now be used in computing the output sequence.

   f) From now on output symbols are generated. The remaining input bits are continuously shifted into their corresponding shift registers. When the last bit has been shifted in, the shift register is clocked with input = 0;

      Note: When finished, $LFSR_1$ has effectively clocked 30 times with feedback closed, $LFSR_2$ has clocked 24 times, $LFSR_3$ has clocked 22 times, and $LFSR_4$ has effectively clocked 16 times with feedback closed.

3. To mix initial data, continue to clock until 200 symbols have been produced with all switches closed ($t = 239$);

4. Keep blend registers c_t and c_{t-1}, make a parallel load of the last 128 generated bits into the LFSRs according to Figure 4.6 at $t = 240$;

After the parallel load in item 4, the blend register contents shall be updated for each subsequent clock.

L	deg	$g_1^{(L)}$	deg	$g_2^{(L)}$
1	[8]	00000000 00000000 00000000 0000011d	[119]	00e275a0 abd218d4 cf928b9b bf6cb08f
2	[16]	00000000 00000000 00000000 0001003f	[112]	0001e3f6 3d7659b3 7f18c258 cff6efef
3	[24]	00000000 00000000 00000000 010000db	[104]	000001be f66c6c3a b1030a5a 1919808b
4	[32]	00000000 00000000 00000001 000000af	[96]	00000001 6ab89969 de17467f d3736ad9

Table 4.4: Polynomials used when creating K'_C. [1]

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L	deg	$g_1^{(L)}$	deg	$g_2^{(L)}$
5	[40]	00000000 00000000 00000100 00000039	[88]	00000000 01630632 91da50ec 55715247
6	[48]	00000000 00000000 00010000 00000291	[77]	00000000 00002c93 52aa6cc0 54468311
7	[56]	00000000 00000000 01000000 00000095	[71]	00000000 000000b3 f7fffce2 79f3a073
8	[64]	00000000 00000001 00000000 0000001b	[63]	00000000 00000000 a1ab815b c7ec8025
9	[72]	00000000 00000100 00000000 00000609	[49]	00000000 00000000 0002c980 11d8b04d
10	[80]	00000000 00010000 00000000 00000215	[42]	00000000 00000000 0000058e 24f9a4bb
11	[88]	00000000 01000000 00000000 0000013b	[35]	00000000 00000000 0000000c a76024d7
12	[96]	00000001 00000000 00000000 000000dd	[28]	00000000 00000000 00000000 1c9c26b9
13	[104]	00000100 00000000 00000000 0000049d	[21]	00000000 00000000 00000000 0026d9e3
14	[112]	00010000 00000000 00000000 0000014f	[14]	00000000 00000000 00000000 00004377
15	[120]	01000000 00000000 00000000 000000e7	[7]	00000000 00000000 00000000 00000089
16	[128]	1 00000000 00000000 00000000 00000000	[0]	00000000 00000000 00000000 00000001

Table 4.4: Polynomials used when creating K'_c. . [1]

1. All polynomials are in hexadecimal notation. The LSB is in the rightmost position.

In Figure 4.5, all bits are shifted into the LFSRs, starting with the least significant bit (LSB). For instance, from the third octet of the address, BD_ADDR[2], first BD_ADDR_{16} is entered, followed by BD_ADDR_{17}, etc. Furthermore, CL_0 corresponds to CLK_1,..., CL_{25} corresponds to CLK_{26}.

Note that the output symbols $x_t^i, i = 1, \ldots, 4$ are taken from the positions 24, 24, 32, and 32 for $LFSR_1$, $LFSR_2$,$LFSR_3$, and $LFSR_4$, respectively (counting the leftmost position as number 1).

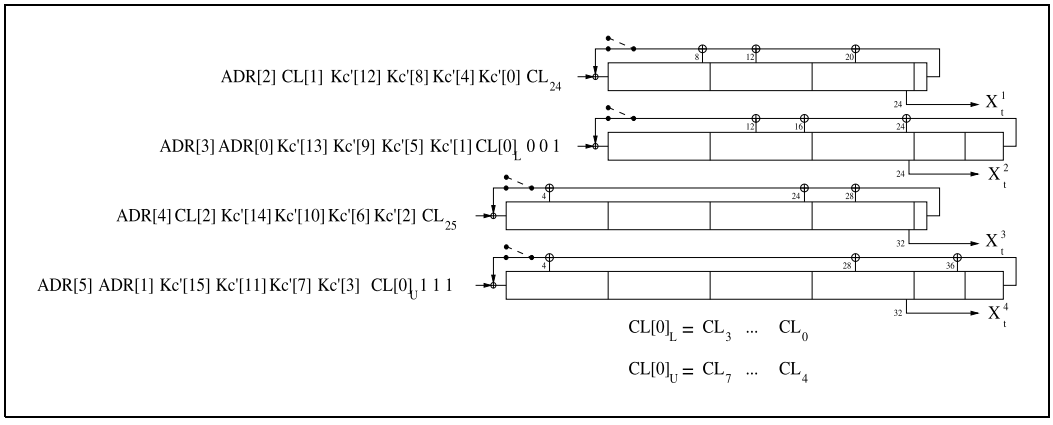


Figure 4.5: Arranging the input to the LFSRs.

In Figure 4.6, the 128 binary output symbols Z_0,..., Z_{127} are arranged in octets denoted Z[0],..., Z[15]. The LSB of Z[0] corresponds to the first of these symbols, the MSB of Z[15] is the last output from the generator. These bits shall be loaded into the LFSRs according to the figure. It is a parallel load and no update of the blend registers is done. The first output symbol is generated at the same time. The octets shall be written into the registers with the LSB in the leftmost position (i.e. the opposite of before). For example, Z_{24} is loaded into position 1 of $LFSR_4$.

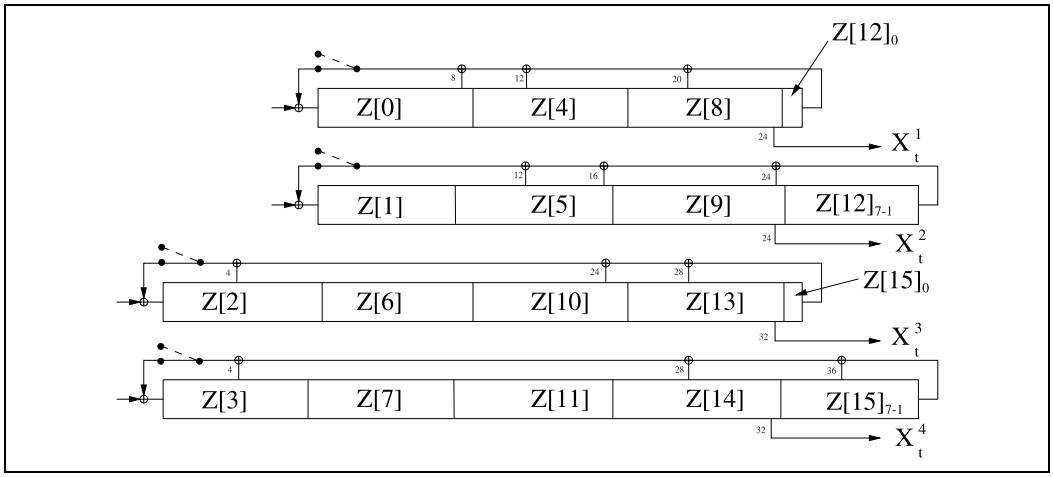


Figure 4.6: Distribution of the 128 last generated output symbols within the LFSRs.

4.6 KEY STREAM SEQUENCE

When the initialization is finished, the output from the summation combiner is used for encryption/decryption. The first bit to use shall be the one produced at the parallel load, i.e. at $t = 240$. The circuit shall be run for the entire length of the current payload. Then, before the reverse direction is started, the entire initialization process shall be repeated with updated values on the input parameters.

Sample data of the encryption output sequence can be found in [Part G] Section 1 on page 649. A necessary, but not sufficient, condition for all Bluetooth compliant implementations of encryption is to produce these encryption streams for identical initialization values.

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5 AUTHENTICATION

Authentication uses a challenge-response scheme in which a claimant's knowledge of a secret key is checked through a 2-move protocol using symmetric secret keys. The latter implies that a correct claimant/verifier pair share the same secret key, for example K. In the challenge-response scheme the verifier challenges the claimant to authenticate a random input (the challenge), denoted by AU_RAND_A, with an authentication code, denoted by E_1, and return the result SRES to the verifier, see Figure 5.1 on page 773. This figure also shows that the input to E_1 consists of the tuple AU_RAND_A and the Bluetooth device address (BD_ADDR) of the claimant. The use of this address prevents a simple reflection attack[1]. The secret K shared by devices A and B is the current link key.

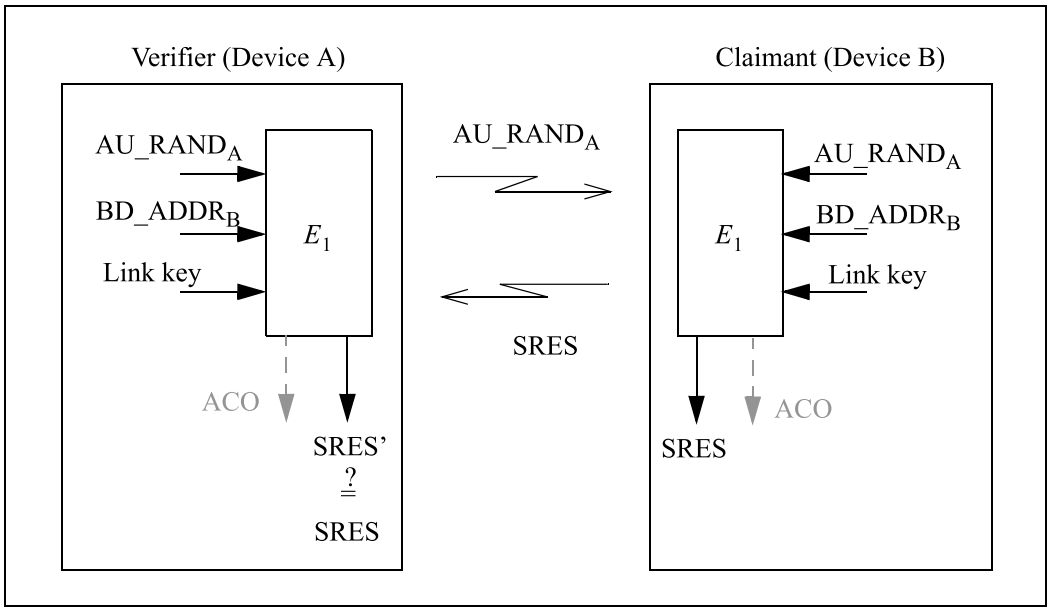


Figure 5.1: Challenge-response for the Bluetooth.

The challenge-response scheme for symmetric keys is depicted in Figure 5.2 on page 774.

1. The reflection attack actually forms no threat because all service requests are dealt with on a FIFO bases. When preemption is introduced, this attack is potentially dangerous.

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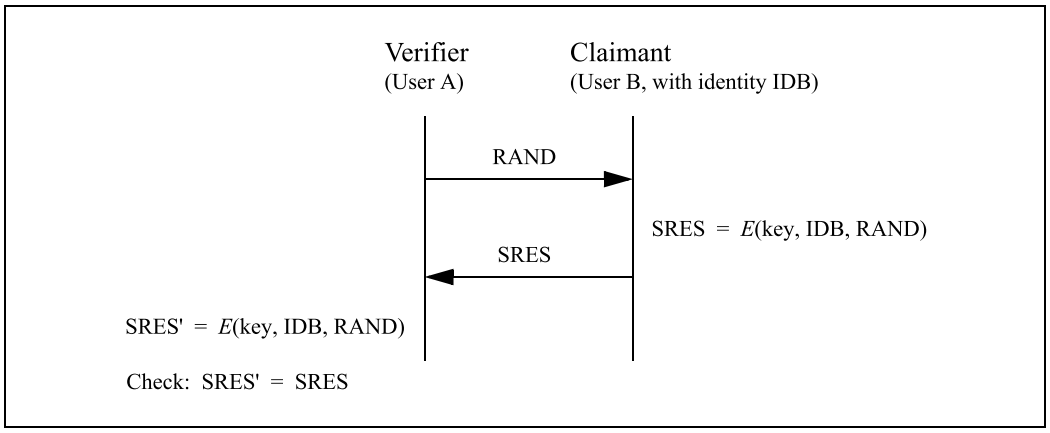


Figure 5.2: Challenge-response for symmetric key systems.

The verifier is not required to be the master. The application indicates which device has to be authenticated. Some applications only require a one-way authentication. However, some peer-to-peer communications, should use a mutual authentication in which each device is subsequently the challenger (verifier) in two authentication procedures. The LM shall process authentication preferences from the application to determine in which direction(s) the authentication(s) takes place. For mutual authentication with the devices of Figure 5.1 on page 773, after device A has successfully authenticated device B, device B could authenticate device A by sending an AU_RAND_B (different from the AU_RAND_A that device A issued) to device A, and deriving the SRES and SRES' from the new AU_RAND_B, the address of device A, and the link key K_{AB}.

If an authentication is successful the value of ACO as produced by E_1 shall be retained.

5.1 REPEATED ATTEMPTS

When the authentication attempt fails, a waiting interval shall pass before the verifier will initiate a new authentication attempt to the same claimant, or before it will respond to an authentication attempt initiated by a device claiming the same identity as the failed device. For each subsequent authentication failure with the same Bluetooth device address, the waiting interval shall be increased exponentially. That is, after each failure, the waiting interval before a new attempt can be made, could be for example, twice as long as the waiting interval prior to the previous attempt[1]. The waiting interval shall be limited to a maximum. The maximum waiting interval depends on the implementation. The waiting time shall exponentially decrease to a minimum when no new failed attempts are made during a certain time period. This procedure prevents an intruder from repeating the authentication procedure with a large number of different keys.

To make the system less vulnerable to denial-of-service attacks, the devices should keep a list of individual waiting intervals for each device it has established contact with. The size of this list may be restricted to only contain the N devices with which the most recent contacts have been made. The number N may vary for different devices depending on available memory size and user environment.

1. Another appropriate value larger than 1 may be used.

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6 THE AUTHENTICATION AND KEY-GENERATING FUNCTIONS

This section describes the algorithms used for authentication and key generation.

6.1 THE AUTHENTICATION FUNCTION E_1

The authentication function E_1 is a computationally secure authentication code. E_1 uses the encryption function SAFER+. The algorithm is an enhanced version of an existing 64-bit block cipher SAFER-SK128, and it is freely available. In the following discussion, the block cipher will be denoted as the function A_r which maps using a 128-bit key, a 128-bit input to a 128-bit output, i.e.

$$\begin{aligned} A_r\colon\ \{0,1\}^{128}\times\{0,1\}^{128} &\rightarrow \{0,1\}^{128} \\ (k\times x) &\mapsto t. \end{aligned} \qquad \text{(EQ 11)}$$

The details of A_r are given in the next section. The function E_1 is constructed using A_r as follows

$$\begin{aligned} E_1\colon\ \{0,1\}^{128}\times\{0,1\}^{128}\times\{0,1\}^{48} &\rightarrow \{0,1\}^{32}\times\{0,1\}^{96} \\ (K,\text{RAND},\text{address}) &\mapsto (\text{SRES},\text{ACO}), \end{aligned} \qquad \text{(EQ 12)}$$

where $\text{SRES} = Hash(K, \text{RAND}, \text{address}, 6)[0, \ldots, 3]$, where $Hash$ is a keyed hash function defined as[1],

$$\begin{aligned} &Hash\colon\{0,1\}^{128}\times\{0,1\}^{128}\times\{0,1\}^{8\times L}\times\{6,12\}\rightarrow\{0,1\}^{128} \\ &(K, I_1, I_2, L) \mapsto A'_r([\tilde{K}], [E(I_2, L) +_{16} (A_r(K, I_1)\oplus_{16} I_1)]), \end{aligned} \qquad \text{(EQ 13)}$$

and where

$$\begin{aligned} &E\colon\{0,1\}^{8\times L}\times\{6,12\}\rightarrow\{0,1\}^{8\times 16} \\ &(X[0,\ldots,L-1], L) \mapsto (X[i(\text{mod L})]\ \text{ for } i = 0...15), \end{aligned} \qquad \text{(EQ 14)}$$

is an expansion of the L octet word X into a 128-bit word. The function A_r is evaluated twice for each evaluation of E_1. The key $\tilde{K}$ for the second use of A_r (actually A'_r) is offset from K as follows[2]

1. The operator $+_{16}$ denotes bytewise addition mod 256 of the 16 octets, and the operator $\oplus_{16}$ denotes bytewise XORing of the 16 octets.
2. The constants are the largest primes below 257 for which 10 is a primitive root.

$$
\begin{aligned}
\tilde{K}[0] &= (K[0] + 233) \mod 256, & \tilde{K}[1] &= K[1] \oplus 229, \\
\tilde{K}[2] &= (K[2] + 223) \mod 256, & \tilde{K}[3] &= K[3] \oplus 193, \\
\tilde{K}[4] &= (K[4] + 179) \mod 256, & \tilde{K}[5] &= K[5] \oplus 167, \\
\tilde{K}[6] &= (K[6] + 149) \mod 256, & \tilde{K}[7] &= K[7] \oplus 131, \\
\tilde{K}\{8\} &= K[8] \oplus 233, & \tilde{K}[9] &= (K[9] + 229) \mod 256, \\
\tilde{K}[10] &= K[10] \oplus 223, & \tilde{K}[11] &= (K[11] + 193) \mod 256, \\
\tilde{K}[12] &= K[12] \oplus 179, & \tilde{K}[13] &= (K[13] + 167) \mod 256, \\
\tilde{K}[14] &= K[14] \oplus 149, & \tilde{K}[15] &= (K[15] + 131) \mod 256.
\end{aligned}
\qquad \text{(EQ 15)}
$$

A data flowchart of the computation of E_1 is shown in Figure 6.1 on page 778. E_1 is also used to deliver the parameter ACO (Authenticated Ciphering Offset) that is used in the generation of the ciphering key by E_3, see equations (EQ 3) on page 759 and (EQ 23) on page 783. The value of ACO is formed by the octets 4 through 15 of the output of the hash function defined in (EQ 13) on page 777, i.e.

$$\text{ACO} = Hash(K, \text{RAND}, \text{address}, 6)[4, \ldots, 15]. \qquad \text{(EQ 16)}$$

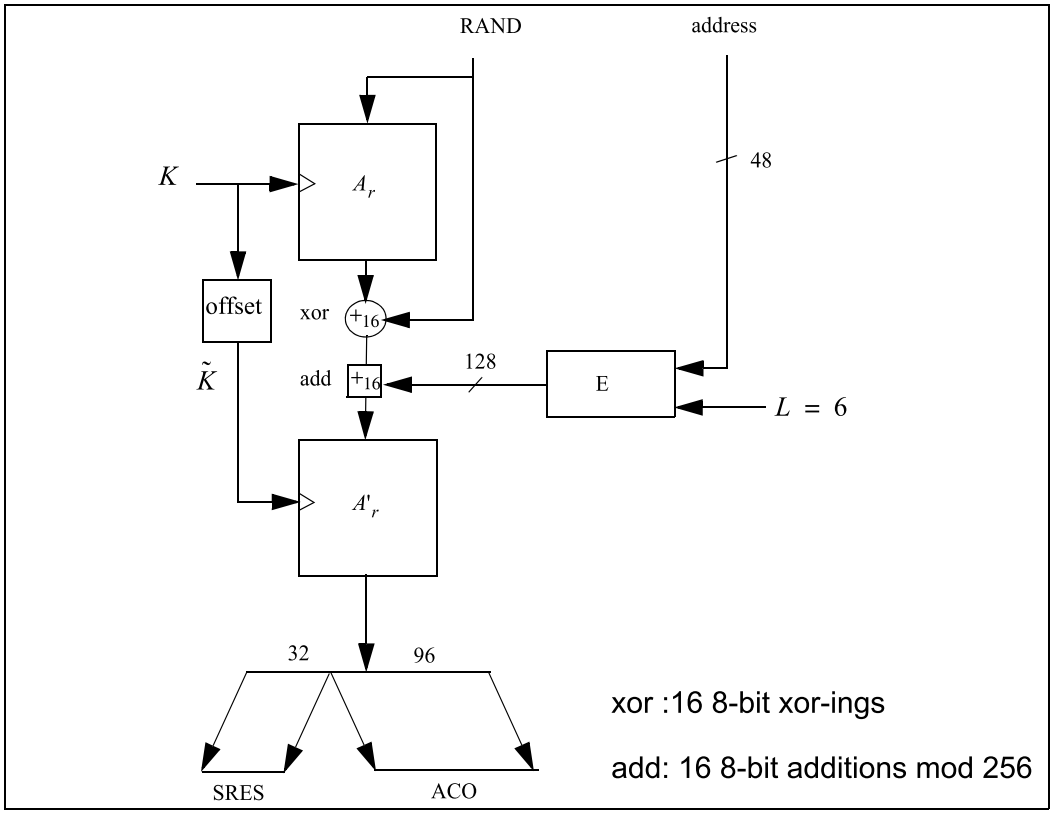


Figure 6.1: Flow of data for the computation of E_1.

6.2 THE FUNCTIONS A_r AND A'_r

The function A_r is identical to SAFER+. It consists of a set of 8 layers, (each layer is called a round) and a parallel mechanism for generating the sub keys $K_p[j]$, $p = 1, 2, \ldots, 17$, which are the round keys to be used in each round. The function will produce a 128-bit result from a 128-bit random input string and a 128-bit key. Besides the function A_r, a slightly modified version referred to as A'_r is used in which the input of round 1 is added to the input of round 3. This is done to make the modified version non-invertible and prevents the use of A'_r (especially in E_{2x}) as an encryption function. See Figure 6.2 on page 780 for details.

6.2.1 The round computations

The computations in each round are a composition of encryption with a round key, substitution, encryption with the next round key, and, finally, a Pseudo Hadamard Transform (PHT). The computations in a round shall be as shown in Figure 6.2 on page 780. The sub keys for round $r, r = 1, 2, \ldots, 8$ are denoted $K_{2r-1}[j]$, $K_{2r}[j]$, $j = 0, 1, \ldots, 15$. After the last round $K_{17}[j]$ is applied identically to all previous odd numbered keys.

6.2.2 The substitution boxes “e” and “l”

In Figure 6.2 on page 780 two boxes are shown, marked “e” and “l”. These boxes implement the same substitutions as are used in SAFER+; i.e. they implement

$$\begin{aligned} e, l &: \{0, \ldots, 255\} \rightarrow \{0, \ldots, 255\}, \\ e &: i \mapsto (45^i \pmod{257}) \pmod{256}, \\ l &: i \mapsto j \text{ s.t. } i = e(j). \end{aligned}$$

Their role, as in the SAFER+ algorithm, is to introduce non-linearity.

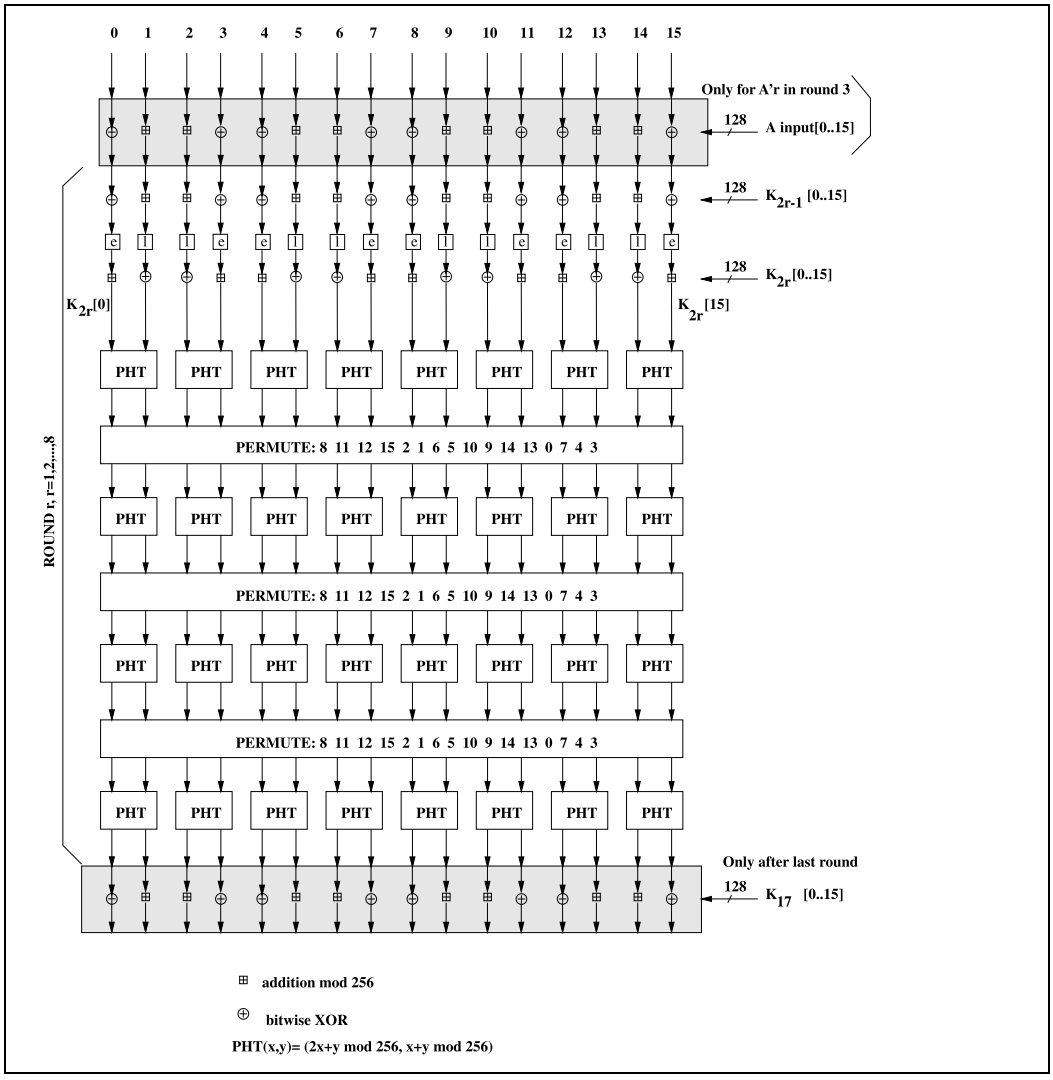


Figure 6.2: One round in A_r and A'_r. The permutation boxes show how input byte indices are mapped onto output byte indices. Thus, position 8 is mapped on position 0 (leftmost), position 11 is mapped on position 1, et cetera.

6.2.3 Key scheduling

In each round, 2 batches of 16 octet-wide keys are needed. These round keys are derived as specified by the key scheduling in SAFER+. Figure 6.3 on page 781 gives an overview of how the round keys $K_p[j]$ are determined. The bias vectors B_2, B_3, ..., B_{17} shall be computed according to following equation:

$$B_p[i] = ((45^{(45^{17p+i+1} \bmod 257)} \bmod 257) \bmod 256), \text{ for } i = 0, \ldots, 15. \qquad \text{(EQ 17)}$$

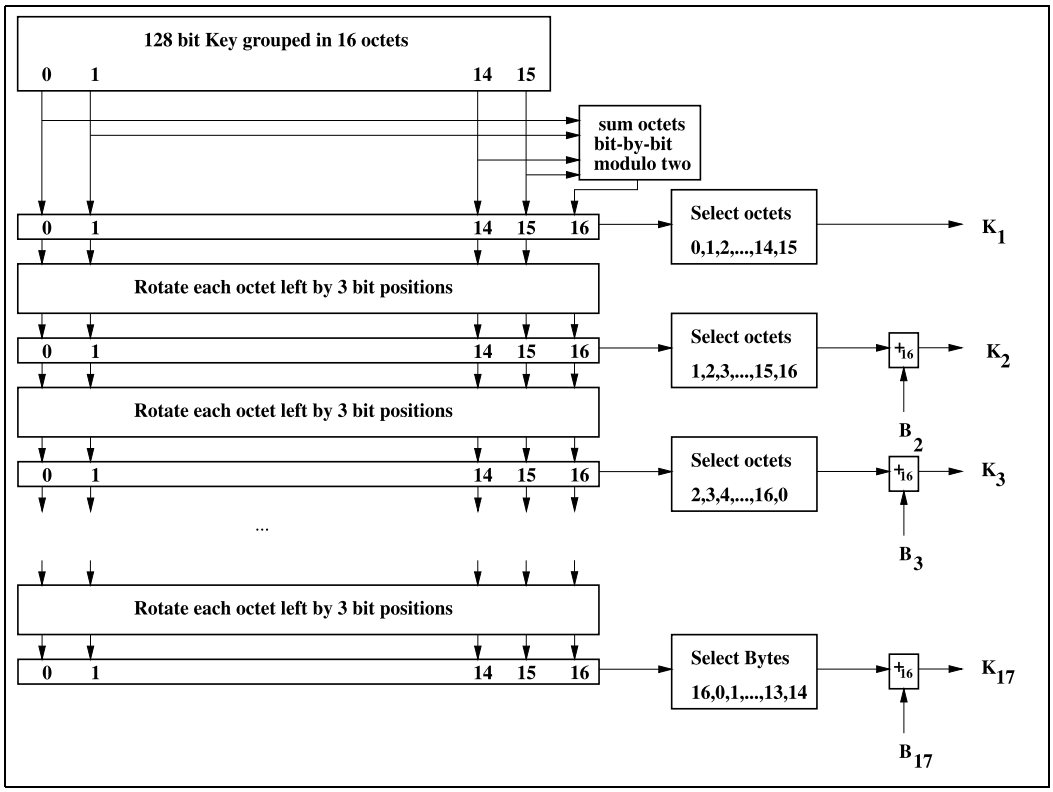


Figure 6.3: Key scheduling in A_r.

6.3 E_2-KEY GENERATION FUNCTION FOR AUTHENTICATION

The key used for authentication shall be derived through the procedure that is shown in Figure 6.4 on page 783. The figure shows two modes of operation for the algorithm. In the first mode, E_{21} produces a 128-bit kink key, K, using a 128-bit RAND value and a 48-bit address. This mode shall be utilized when creating unit keys and combination keys. In the second mode, E_{22} produces a 128-bit link key, K, using a 128-bit RAND value and an L octet user PIN. The second mode shall be used to create the initialization key, and also when a master key is to be generated.

When the initialization key is generated, the PIN is augmented with the BD_ADDR, see Section 3.2.1 on page 756 for which address to use. The augmentation shall always start with the least significant octet of the address immediately following the most significant octet of the PIN. Since the maximum length of the PIN used in the algorithm cannot exceed 16 octets, it is possible that not all octets of BD_ADDR will be used.

This key generating algorithm again exploits the cryptographic function. E_2 for mode 1 (denoted E_{21}) is computed according to following equations:

$$E_{21}: \{0,1\}^{128} \times \{0,1\}^{48} \rightarrow \{0,1\}^{128}$$
$$(\text{RAND}, \text{address}) \mapsto A'_r(X, Y) \qquad \text{(EQ 18)}$$

where (for mode 1)

$$\begin{cases} X = \text{RAND}[0 \ldots 14] \cup (\text{RAND}[15] \oplus 6) \\ Y = \bigcup_{i=0}^{15} \text{address}[i \pmod 6] \end{cases} \qquad \text{(EQ 19)}$$

Let L be the number of octets in the user PIN. The augmenting is defined by

$$\text{PIN}' = \begin{cases} \text{PIN}[0 \ldots L-1] \cup \text{BD\_ADDR}[0 \ldots \min\{5, 15-L\}], & L < 16, \\ \text{PIN}[0 \ldots L-1], & L = 16, \end{cases} \qquad \text{(EQ 20)}$$

Then, in mode 2, E_2 (denoted E_{22}) is

$$E_{22}: \{0,1\}^{8L'} \times \{0,1\}^{128} \times \{1, 2, \ldots, 16\} \rightarrow \{0,1\}^{128}$$
$$(\text{PIN}', \text{RAND}, \text{L}') \mapsto A'_r(X, Y) \qquad \text{(EQ 21)}$$

where

$$\begin{cases} X = \bigcup_{i=0}^{15} \text{PIN}'[i \pmod{L'}], \\ Y = \text{RAND}[0 \ldots 14] \cup (\text{RAND}[15] \oplus L'), \end{cases} \qquad \text{(EQ 22)}$$

and $L' = \min\{16, L+6\}$ is the number of octets in PIN'.

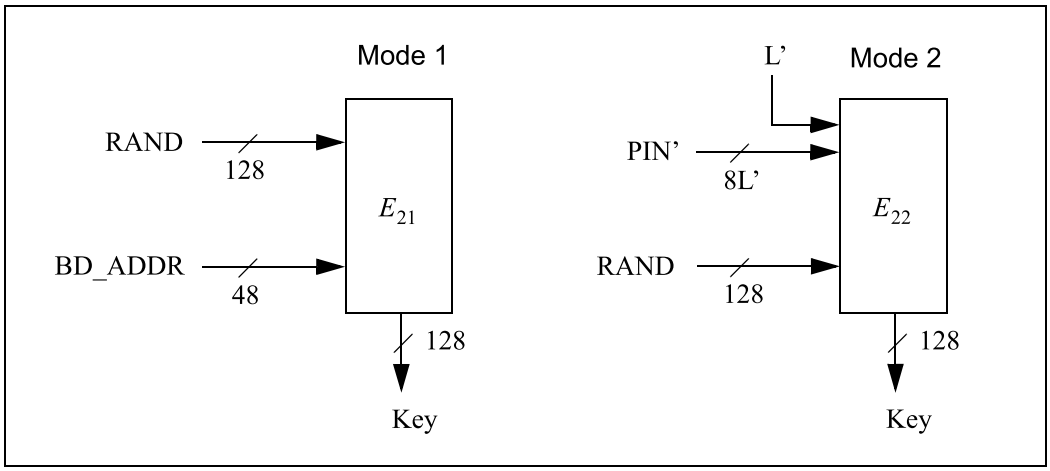


Figure 6.4: Key generating algorithm E_2 and its two modes. Mode 1 is used for unit and combination keys, while mode 2 is used for K_{init} and K_{master}.

6.4 E_3-KEY GENERATION FUNCTION FOR ENCRYPTION

The ciphering key K_C used by E_0 shall be generated by E_3. The function E_3 is constructed using A'_r as follows

$$E_3: \{0,1\}^{128} \times \{0,1\}^{128} \times \{0,1\}^{96} \rightarrow \{0,1\}^{128}$$
$$(K, \text{RAND}, \text{COF}) \mapsto Hash(K, \text{RAND}, \text{COF}, 12) \qquad \text{(EQ 23)}$$

where $Hash$ is the hash function as defined by (EQ 13) on page 777. The key length produced is 128 bits. However, before use within E_0, the encryption key K_C is shortened to the correct encryption key length, as described in Section 4.5 on page 769. A block scheme of E_3 is depicted in Figure 6.5.

The value of COF is determined as specified by equation (EQ 3) on page 759.

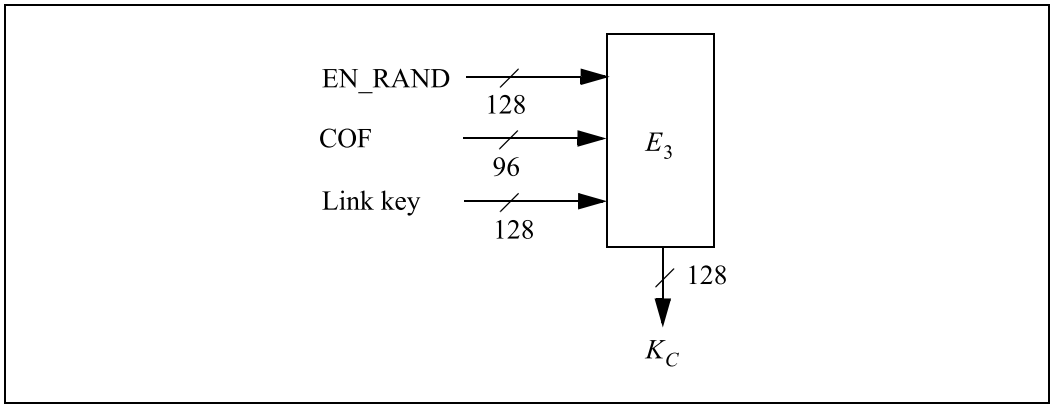


Figure 6.5: Generation of the encryption key.

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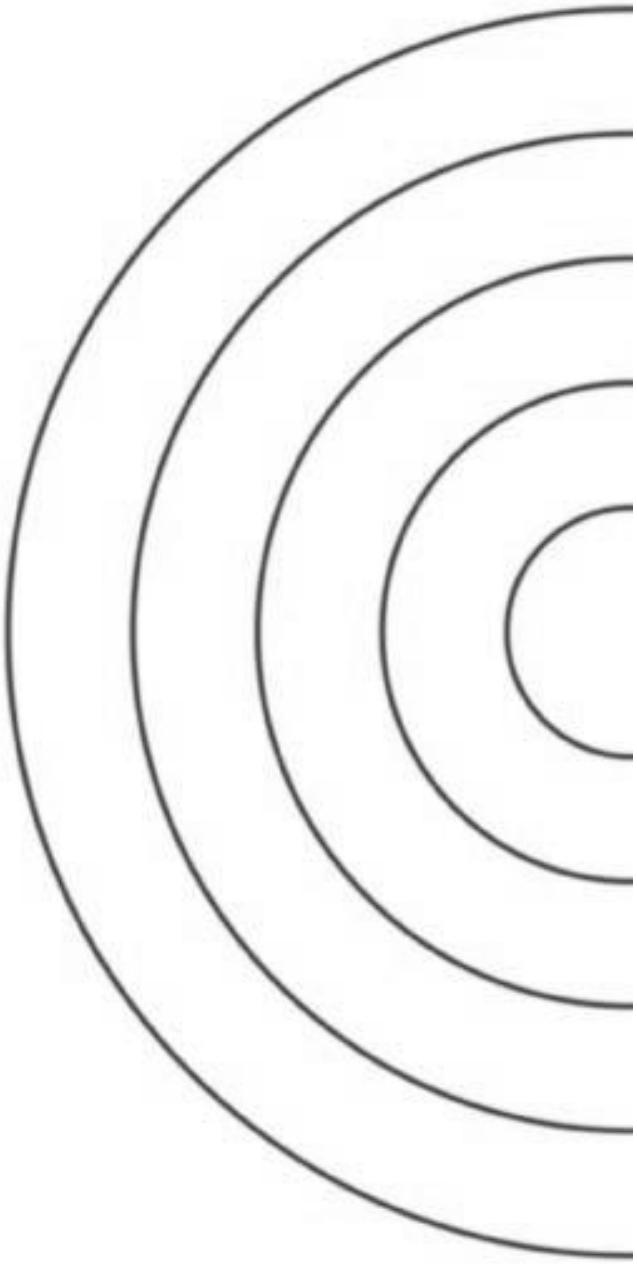
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Specification of the Bluetooth System

Wireless connections made easy

Core System Package
[Host volume]

Version 1.2
05 November 2003

1.2

Bluetooth®

Revision History

The Revision History is shown in the “Appendix” on page 53[vol. 0].

Contributors

The persons who contributed to this specification are listed in the “Appendix” on page 53[vol. 0].

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Core System Package [Host volume]
Part A



LOGICAL LINK CONTROL AND ADAPTATION PROTOCOL SPECIFICATION

The Bluetooth logical link control and adaptation protocol (L2CAP) supports higher level protocol multiplexing, packet segmentation and reassembly, and the conveying of quality of service information. The protocol state machine, packet format and composition are described in this document.

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1 INTRODUCTION

This section of the Bluetooth Specification defines the Logical Link Control and Adaptation Layer Protocol, referred to as L2CAP. L2CAP is layered over the Link Controller Protocol and resides in the data link layer as shown in Figure 1.1. L2CAP provides connection-oriented and connectionless data services to upper layer protocols with protocol multiplexing capability, segmentation and reassembly operation, and group abstractions. L2CAP permits higher level protocols and applications to transmit and receive upper layer data packets (L2CAP Service Data Units, SDU) up to 64 kilobytes in length. L2CAP also permits per-channel flow control and retransmission via the Flow Control and Retransmission Modes.

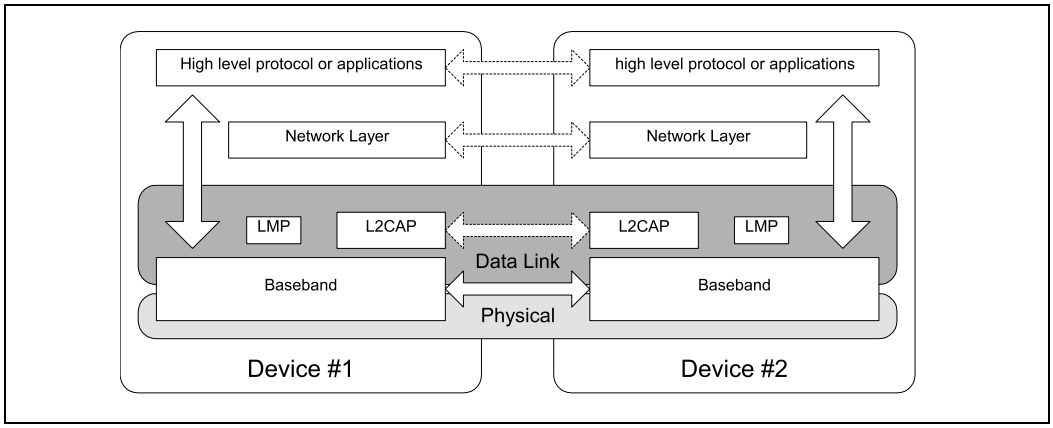


Figure 1.1: L2CAP within protocol layers

The L2CAP layer provides logical channels, named L2CAP channels, which are mapped to L2CAP logical links supported by an ACL logical transport, see baseband specification [vol.2, part B] Section 4.4 on page 86.

1.1 L2CAP FEATURES

The functional requirements for L2CAP include protocol/channel multiplexing, segmentation and reassembly (SAR), per-channel flow control, error control and group management. Figure 1.2 on page 22 illustrates how L2CAP data flows fit into the Bluetooth Protocol Stack. L2CAP lies above the Link Controller Protocol and interfaces with other communication protocols such as the Bluetooth Service Discovery Protocol (SDP), RFCOMM, Telephony Control (TCS) and Bluetooth Network Encapsulation Protocol (BNEP). Voice-quality channels for audio and telephony applications and synchronous transparent connections are usually run over synchronous logical transports, see [vol.2, part B] Section 4.3 on page 86. Packetized audio data, such as IP Telephony, may be sent using communication protocols running over L2CAP.

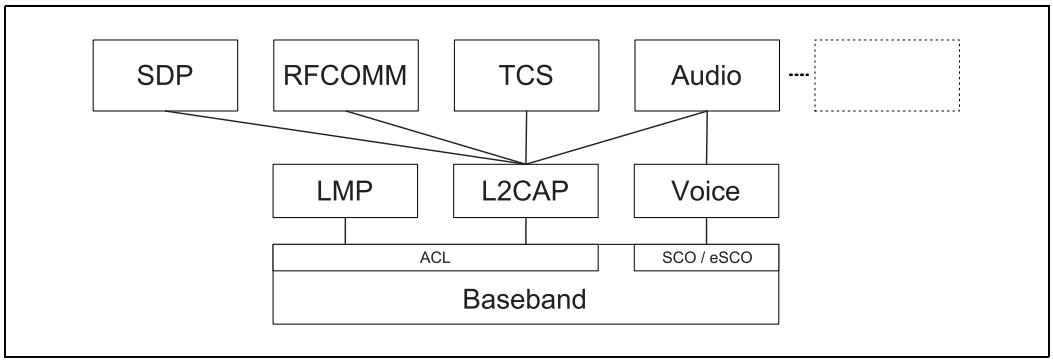


Figure 1.2: L2CAP data flows in Bluetooth Protocol Architecture

Figure 1.3 on page 22 breaks down L2CAP into its architectural components. The Channel Manager provides the control plane functionality and is responsible for all internal signalling, L2CAP peer-to-peer signalling and signalling with higher and lower layers. It performs the state machine functionality described in Section 6 on page 67 and uses message formats described in Section 4 on page 41, Section 5 on page 57. The Retransmission and Flow Control block provides per-channel flow control and optional retransmission for applications that require it. The Resource Manager is responsible for providing a frame relay service to the Channel Manager, the Retransmission and Flow Control block and those application data streams that do not require Retransmission and Flow Control services. It is responsible for coordinating the transmission and reception of packets related to multiple L2CAP channels over the facilities offered at the lower layer interface.

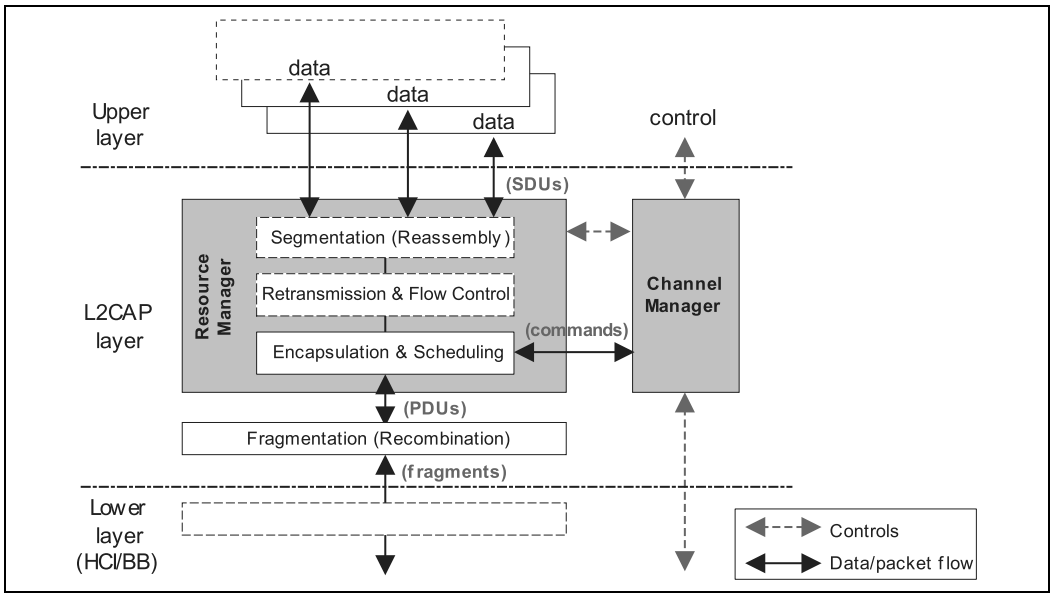


Figure 1.3: L2CAP architectural blocks

- *Protocol/channel multiplexing*

  L2CAP supports multiplexing because the Baseband Protocol does not support any 'type' field identifying the higher layer protocol being multiplexed above it.

  During channel setup, protocol multiplexing capability is used to route the connection request to the correct upper layer protocol.

  For data transfer, logical channel multiplexing is needed to distinguish between multiple upper layer entities. There may be more than one upper layer entity using the same protocol.

- *Segmentation and reassembly*

  With the frame relay service offered by the Resource Manager, the length of transport frames is controlled by the individual applications running over L2CAP. Many multiplexed applications are better served if L2CAP has control over the PDU length. This provides the following benefits:

  a) Segmentation will allow the interleaving of application data units in order to satisfy latency requirements.

  b) Memory and buffer management is easier when L2CAP controls the packet size.

  c) Error correction by retransmission can be made more efficient.

  d) The amount of data that is destroyed when an L2CAP PDU is corrupted or lost can be made smaller than the application's data unit.

  e) The application is decoupled from the segmentation required to map the application packets into the lower layer packets.

- *Flow control per L2CAP channel*

  When several data streams run over the same L2CAP logical link, using separate L2CAP channels, each channel may require individual flow control. Also L2CAP provides flow control services to profiles or applications that need flow control and can avoid having to implement it. Due to the delays between the L2CAP layers, stop-and-go flow control as employed in the baseband is not sufficient. A window based flow control scheme is provided. The use of flow control is an optional aspect of the L2CAP protocol.

- *Error control and retransmissions*

  Some applications require a residual error rate much smaller than the baseband can deliver. L2CAP includes optional error checks and retransmissions of L2CAP PDUs. The error checking in L2CAP protects against errors due to the baseband falsely accepting packet headers and due to failures of the HEC or CRC error checks on the baseband packets. Retransmission Mode also protects against loss of packets due to flush on the same logical transport. The error control works in conjunction with flow control in the sense that the flow control mechanism will throttle retransmissions as well as first transmissions. The use of error control and retransmission procedures is optional.

- *Fragmentation and Recombination*

  The lower layers have limited transmission capabilities and may require fragment sizes different from those created by L2CAP segmentation. Therefore layers below L2CAP may further fragment and recombine L2CAP PDUs to create fragments which fit each layer capabilities. During transmission of an L2CAP PDU, many different levels of fragmentation and recombination may occur in both peer devices.

  The HCI driver or controller may fragment L2CAP PDUs to honor packet size constraints of a host controller interface transport scheme. This results in HCI data packet payloads carrying start and continuation fragments of the L2CAP PDU. Similarly the link controller may fragment L2CAP PDUs to map them into baseband packets. This results in baseband packet payloads carrying start and continuation fragments of the L2CAP PDU.

  Each layer of the protocol stack may pass on diffferent sized fragments of L2CAP PDUs, and the size of fragments created by a layer may be different in each peer device. However the PDU is fragmented within the stack, the receiving L2CAP entity still recombines the fragments to obtain the original L2CAP PDU.

- *Quality of Service*

  The L2CAP connection establishment process allows the exchange of information regarding the quality of service (QoS) expected between two Bluetooth devices. Each L2CAP implementation monitors the resources used by the protocol and ensures that QoS contracts are honored.

1.2 ASSUMPTIONS

The protocol is designed based on the following assumptions:

1. The ACL logical transport and L2CAP logical link between two devices is set up using the Link Manager Protocol. The baseband provides orderly delivery of data packets, although there might be individual packet corruption and duplicates. No more than 1 unicast ACL logical transport exists between any two devices.
2. The baseband always provides the impression of full-duplex communication channels. This does not imply that all L2CAP communications are bi-directional. Multicasts and unidirectional traffic (e.g., video) do not require duplex channels.
3. The L2CAP layer provides a channel with a degree of reliability based on the mechanisms available at the baseband layer and with optional additional packet segmentation and error detection that can be enabled in the enhanced L2CAP layer. The baseband performs data integrity checks and resends data until it has been successfully acknowledged or a timeout occurs. Because acknowledgements may be lost, timeouts may occur even after the data has been successfully sent. The link controller protocol uses a 1-bit sequence number. Note that the use of baseband broadcast packets is prohibited if reliability is required, since all broadcasts start the first segment of an L2CAP packet with the same sequence bit.
4. Some applications will expect independent flow control, independence from the effects of other traffic and, in some cases, better error control than the baseband provides. The Flow and Error Control block provides two modes. Retransmission Mode offers segmentation, flow control and L2CAP PDU retransmissions. Flow control mode offers just the segmentation and flow control functions. If Basic L2CAP mode is chosen, the Flow and Error Control block is not used.

1.3 SCOPE

The following features are outside the scope of L2CAP's responsibilities:

- L2CAP does not transport audio or transparent synchronous data designated for SCO or eSCO logical transports.
- L2CAP does not support a reliable multicast channel. See Section 3.2 on page 34.
- L2CAP does not support the concept of a global group name.

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1.4 TERMINOLOGY

The following formal definitions apply:

Term	Description
Upper layer	The system layer above the L2CAP layer, which exchanges data with L2CAP in the form of SDUs. The upper layer may be represented by an application or higher protocol entity known as the Service Level Protocol. The interface of the L2CAP layer with the upper layer is not specified.
Lower layer	The system layer below the L2CAP layer, which exchanges data with the L2CAP layer in the form of PDUs, or fragments of PDUs. The lower layer is mainly represented within the Bluetooth Controller, however a Host Controller Interface (HCI) may be involved, such that an HCI host driver could also be seen as the lower layer. Except for the HCI functional specification (in case HCI is involved) the interface between L2CAP and the lower layer is not specified.
L2CAP channel	The logical connection between two endpoints in peer devices, characterized by their Channel Identifiers (CID), which is multiplexed on the L2CAP logical link, which is supported by an ACL logical transport, see [vol.2, part B] Section 4.4 on page 86
SDU, or L2CAP SDU	Service Data Unit: a packet of data that L2CAP exchanges with the upper layer and transports transparently over an L2CAP channel using the procedures specified here. The term SDU is associated with data originating from upper layer entities only, i.e. does not include any protocol information generated by L2CAP procedures.
Segment, or SDU segment	A part of an SDU, as resulting from the Segmentation procedure. An SDU may be split into one or more segments. Note: this term is relevant only to the Retransmission Mode and Flow Control Mode, not to the Basic L2CAP Mode.
Segmentation	A procedure used in the L2CAP Retransmission and Flow Control Modes, resulting in an SDU being split into one or more smaller units, called Segments, as appropriate for the transport over an L2CAP channel. Note: this term is relevant only to the Retransmission Mode and Flow Control Mode, not to the Basic L2CAP Mode.
Reassembly	The reverse procedure corresponding to Segmentation, resulting in an SDU being re-established from the segments received over an L2CAP channel, for use by the upper layer. Note that the interface between the L2CAP and the upper layer is not specified; therefore, reassembly may actually occur within an upper layer entity although it is conceptually part of the L2CAP layer. Note: this term is relevant only to the Retransmission Mode and Flow Control Mode, not to the Basic L2CAP Mode.
PDU, or L2CAP PDU	Protocol Data Unit a packet of data containing L2CAP protocol information fields, control information, and/or upper layer information data. A PDU is always started by a Basic L2CAP header. Types of PDUs are: B-frames, I-frames, S-frames, C-frames and G-frames.

Table 1.1: Terminology

Term	Description
Basic L2CAP header	Minimum L2CAP protocol information that is present in the beginning of each PDU: a length field and a field containing the Channel Identifier (CID)
Basic information frame (B-frame)	A B-frame is a PDU used in the Basic L2CAP mode for L2CAP data packets. It contains a complete SDU as its payload, encapsulated by a basic L2CAP header.
Information frame (I-frame)	An I-frame is a PDU used in the Retransmission Mode and the Flow Control Mode. It contains an SDU segment and additional protocol information, encapsulated by a basic L2CAP header
Supervisory frame (S-frame)	An S-frame is a PDU used in the Retransmission Mode and the Flow Control Mode. It contains protocol information only, encapsulated by a basic L2CAP header, and no SDU data.
Control frame (C-frame)	A C-frame is a PDU that contains L2CAP signalling messages exchanged between the peer L2CAP entities. C-frames are exclusively used on the L2CAP signalling channel.
Group frame (G-frame)	G-frame is a PDU exclusively used on Connectionless L2CAP channels in the Basic L2CAP mode. It contains a complete SDU as its payload, encapsulated by a specific header.
Fragment	A part of a PDU, as resulting from a fragmentation operation. Fragments are used only in the delivery of data to and from the lower layer. They are not used for peer-to-peer transportation. A fragment may be a Start or Continuation Fragment with respect to the L2CAP PDU. A fragment does not contain any protocol information beyond the PDU; the distinction of start and continuation fragments is transported by lower layer protocol provisions. Note: Start Fragments always begin with the Basic L2CAP header of a PDU.
Fragmentation	A procedure used to split L2CAP PDUs to smaller parts, named fragments, appropriate for delivery to the lower layer transport. Although described within the L2CAP layer, fragmentation may actually occur in an HCI host driver, and/or in the Controller, to accomodate the L2CAP PDU transport to HCI data packet or baseband packet sizes. Fragmentation of PDUs may be applied in all L2CAP modes. Note: in version 1.1, Fragmentation and Recombination was referred to as “Segmentation and Reassembly“.
Recombination	The reverse procedure corresponding to fragmentation, resulting in an L2CAP PDU re-established from fragments. In the receive path, full or partial recombination operations may occur in the Controller and/or the Host, and the location of recombination does not necessarily correspond to where fragmentations occurs on the transmit side.
Maximum Transmission Unit (MTU)	The maximum size of payload data, in octets, that the upper layer entity is capable of accepting, i.e. the MTU corresponds to the maximum SDU size.

Table 1.1: Terminology

Term	Description
Maximum PDU payload Size (MPS)	The maximum size of payload data in octets that the L2CAP layer entity is capable of accepting, i.e. the MPS corresponds to the maximum PDU payload size. Note: in the absence of segmentation, or in the Basic L2CAP Mode, the Maximum Transmission Unit is the equivalent to the Maximum PDU payload Size and shall be made equal in the configuration parameters.
Signalling MTU (MTU_{sig})	The maximum size of command information that the L2CAP layer entity is capable of accepting. The MTU_{sig}, refers to the signalling channel only and corresponds to the maximum size of a C-frame, excluding the Basic L2CAP header. The MTU_{sig} value of a peer is discovered when a C-frame that is too large is rejected by the peer.
Connectionless MTU (MTU_{cnl})	The maximum size of the connection packet information that the L2CAP layer entity is capable of accepting. The MTU_{cnl} refers to the connectionless channel only and corresponds to the maximum G-frame, excluding the Basic L2CAP header. The MTU_{cnl} of a peer can be discovered by sending an Information Request.
MaxTransmit	In Retransmission mode, MaxTransmit controls the number of transmissions of a PDU that L2CAP is allowed to try before assuming that the PDU (and the link) is lost. The minimum value is 1 (only 1 transmission permitted). Note: Setting MaxTransmit to 1 prohibits PDU retransmissions. Failure of a single PDU will cause the link to drop. By comparison, in Flow Control mode, failure of a single PDU will not necessarily cause the link to drop.

Table 1.1: Terminology

2 GENERAL OPERATION

L2CAP is based around the concept of *'channels'*. Each one of the endpoints of an L2CAP channel is referred to by a *channel identifier (CID).*

2.1 CHANNEL IDENTIFIERS

A channel identifier (CID) is the local name representing a logical channel endpoint on the device. The null identifier (0x0000) is an illegal identifier and shall never be used as a destination endpoint. Identifiers from 0x0001 to 0x003F are reserved for specific L2CAP functions. Implementations are free to manage the remaining CIDs in a manner best suited for that particular implementation, with the provision that two simultaneously active L2CAP channels shall not share the same CID. Table 2.1 on page 29 summarizes the definition and partitioning of the CID name space.

CID assignment is relative to a particular device and a device can assign CIDs independently from other devices (unless it needs to use any of the reserved CIDs shown in the table below). Thus, even if the same CID value has been assigned to (remote) channel endpoints by several remote devices connected to a single local device, the local device can still uniquely associate each remote CID with a different device.

CID	Description
0x0000	Null identifier
0x0001	Signalling channel
0x0002	Connectionless reception channel
0x0003-0x003F	Reserved
0x0040-0xFFFF	Dynamically allocated

Table 2.1: CID name space

2.2 OPERATION BETWEEN DEVICES

Figure 2.1 on page 30 illustrates the use of CIDs in a communication between corresponding peer L2CAP entities in separate devices. The connection-oriented data channels represent a connection between two devices, where a CID identifies each endpoint of the channel. The connectionless channels restrict data flow to a single direction. These channels are used to support a channel 'group' where the CID on the source represents one or more remote devices. There are also a number of CIDs reserved for special purposes. The signalling channel is one example of a reserved channel. This channel is used to create and establish connection-oriented data channels and to negotiate changes in the characteristics of connection oriented and connectionless channels. Support for a signalling channel within an L2CAP entity is mandatory.

Note: it is assumed that an L2CAP signalling channel is available immediately when an ACL logical transport is established between two devices, and L2CAP traffic is enabled on the L2CAP logical link.
Another CID is reserved for all incoming connectionless data traffic. In the example below, a CID is used to represent a group consisting of device #3 and #4. Traffic sent from this channel ID is directed to the remote channel reserved for connectionless data traffic.

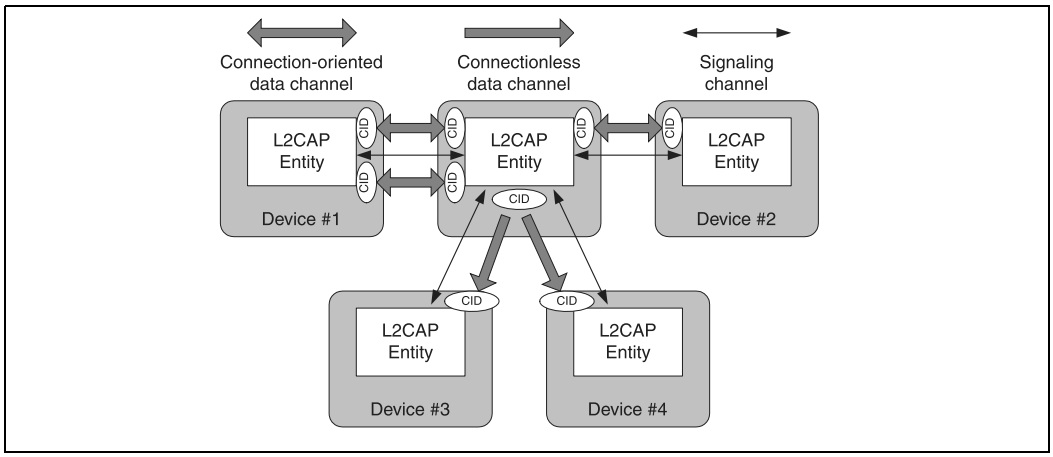


Figure 2.1: Channels between devices

Table 2.2 on page 30 describes the various channels and their source and destination identifiers. A CID is allocated to identify the local endpoint and shall be in the range 0x0040 to 0xFFFF. Section 6 on page 67 describes the state machine associated with each connection-oriented channel. Section 3.1 on page 33 describes the packet format associated with bi-directional channels and Section 3.2 on page 34 describes the packet format associated with uni-directional channels.

Channel Type	Local CID (sending)	Remote CID (receiving)
Connection-oriented	Dynamically allocated	Dynamically allocated
Connectionless data	Dynamically allocated	0x0002 (fixed)
Signalling	0x0001 (fixed)	0x0001 (fixed)

Table 2.2: Types of Channel Identifiers

2.3 OPERATION BETWEEN LAYERS

L2CAP implementations should follow the general architecture described below. L2CAP implementations transfer data between upper layer protocols and the lower layer protocol. This document lists a number of services that should be exported by any L2CAP implementation. Each implementation shall also support a set of signalling commands for use between L2CAP implementations. L2CAP implementations should also be prepared to accept certain types of events from lower layers and generate events to upper layers. How these events are passed between layers is implementation specific.

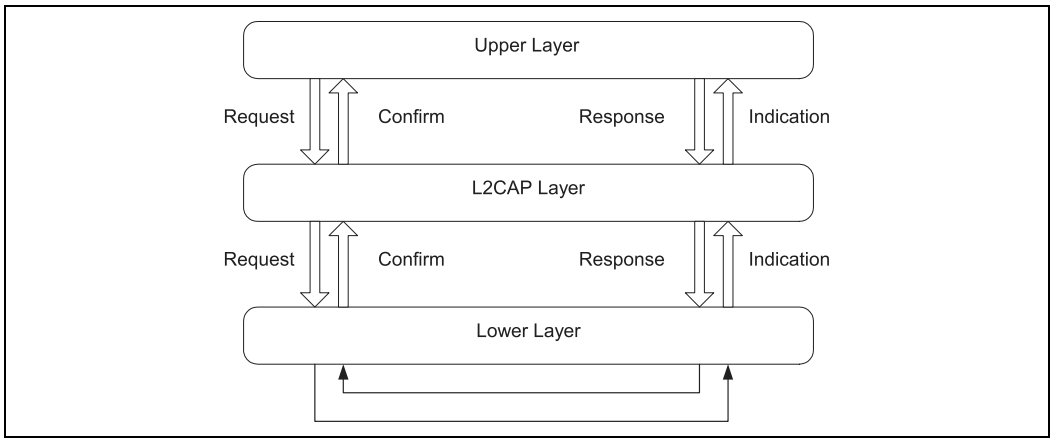


Figure 2.2: L2CAP transaction model.

2.4 MODES OF OPERATION

L2CAP may operate in one of three different modes as selected for each L2CAP channel by an upper layer.

The modes are:

- Basic L2CAP Mode (equivalent to L2CAP specification in Bluetooth v1.1) [1]
- Flow Control Mode
- Retransmission Mode

The modes are enabled using the configuration procedure. The Basic L2CAP Mode is the default mode, which is used when no other mode is agreed.

In Flow Control and Retransmission modes, PDUs exchanged with a peer entity are numbered and acknowledged. The sequence numbers in the PDUs are used to control buffering, and a TxWindow size is used to limit the required buffer space and/or provide a method for flow control. In addition to the window size, the Token Bucket size parameter of the flow specification can be used to

1. Specification of the Bluetooth System v1.1 (Feb 22nd 2001): volume 1, part D.

dimension the buffers; in particular on channels that do not use flow and error control.

In Flow Control Mode no retransmissions take place, but missing PDUs are detected and can be reported as lost.

In Retransmission Mode a timer is used to ensure that all PDUs are delivered to the peer, by retransmiting PDUs as needed. A go-back-n repeat mechanism is used to simplify the protocol and limit the buffering requirements.

3 DATA PACKET FORMAT

L2CAP is packet-based but follows a communication model based on *channels*. A channel represents a data flow between L2CAP entities in remote devices. Channels may be connection-oriented or connectionless.
All packet fields shall use Little Endian byte order.

3.1 CONNECTION-ORIENTED CHANNEL IN BASIC L2CAP MODE

Figure 3.1 on page 33 illustrates the format of the L2CAP PDU within a connection-oriented channel. In basic L2CAP mode, the L2CAP PDU on a connection-oriented channel is also referred to as a "B-frame".

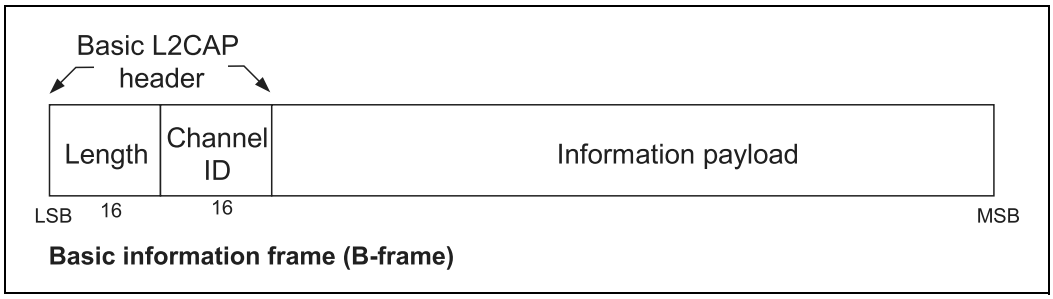


Figure 3.1: PDU format in Basic L2CAP mode on connection-oriented channels (field sizes in bits)

The fields shown are:

- *Length: 2 octets (16 bits)*

  Length indicates the size of the information payload in octets, excluding the length of the L2CAP header. The length of an information payload can be up to 65535 octets. The Length field is used for recombination and serves as a simple integrity check of the recombined L2CAP packet on the receiving end.

- *Channel ID: 2 octets*

  The channel ID (CID) identifies the destination channel endpoint of the packet.

- *Information payload: 0 to 65535 octets*

  This contains the payload received from the upper layer protocol (outgoing packet), or delivered to the upper layer protocol (incoming packet). The MTU is determined during channel configuration (see Section 5.1 on page 57). The minimum supported MTU for the signalling PDUs (MTU_{sig}) is 48 octets (see Section 4 on page 41).

3.2 CONNECTIONLESS DATA CHANNEL IN BASIC L2CAP MODE

Figure 3.2 illustrates the L2CAP PDU format within a connectionless data channel. Here, the L2CAP PDU is also referred to as a "G-frame".

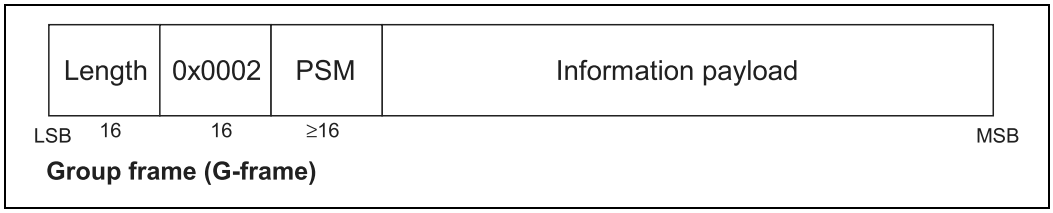


Figure 3.2: L2CAP PDU format in Basic L2CAP mode on Connectionless channel

The fields shown are:

- *Length: 2 octets*

  Length indicates the size of information payload plus the PSM field in octets.

- *Channel ID: 2 octets*

  Channel ID (0x0002) reserved for connectionless traffic.

- *Protocol/Service Multiplexer (PSM): 2 octets (minimum)*

  For information on the PSM field see Section 4.2 on page 44.

- *Information payload: 0 to 65533 octets*

  The payload information to be distributed to all members of the piconet. Implementations shall support a connectionless MTU (MTU_{cnl}) of 48 octets on connectionless channels. Devices may also explicitly change to a larger or smaller connectionless MTU (MTU_{cnl}).

  Note: the maximum size of the Information payload field decreases accordingly if the PSM field is extended beyond the two octet minimum.

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3.3 CONNECTION-ORIENTED CHANNEL IN RETRANSMISSION/FLOW CONTROL MODES

To support flow control and retransmissions, L2CAP PDU types with protocol elements in addition to the Basic L2CAP header are defined. The information frames (I-frames) are used for information transfer between L2CAP entities. The supervisory frames (S-frames) are used to acknowledge I-frames and request retransmission of I-frames.

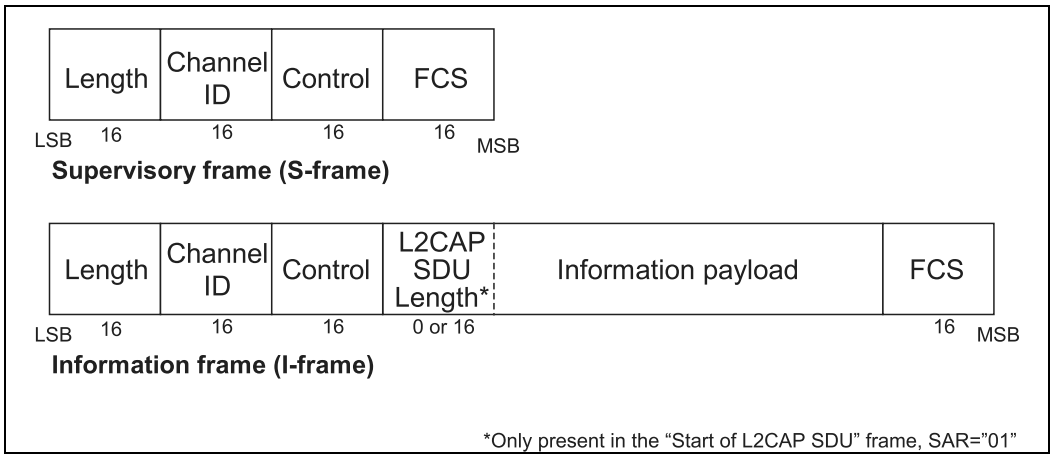


Figure 3.3: L2CAP PDU formats in Flow Control and Retransmission Modes

3.3.1 L2CAP header fields

- *Length: 2 octets*

  The first two octets in the L2CAP PDU contain the length of the entire L2CAP PDU in octets, excluding the Length and CID field.

  For I-frames and S-frames, the Length field therefore includes the octet lengths of the Control, L2CAP SDU Length (when present), Information octets and frame check sequence (FCS) fields.

  If the L2CAP SDU length field is present then the maximum number of Information octets in one I-frame is 65529 octets. If the L2CAP SDU length field is not present then the maximum number of Information octets in one I-frame is 65531 octets.

- *Channel ID: 2 octets*

  This field contains the Channel Identification (CID).

3.3.2 Control field (2 octets)

The Control field identifies the type of frame. The control field will contain sequence numbers where applicable. Its coding is shown in Table 3.1 on page 36. There are two different frame types, Information frame types and Supervisory frame types. Information and Supervisory frames types are distinguished by the rightmost bit in the Control field, as shown in Table 3.1 on page 36.

- *Information frame format (I-frame)*

  The I-frames are used to transfer information between L2CAP entities. Each I-frame has a TxSeq(Send sequence number), ReqSeq(Receive sequence number) which may or may not acknowledge additional I-frames received by the data link layer entity, and a retransmission bit (R bit) that affects whether I-frames are retransmitted.

  The SAR field in the I-frame is used for segmentation and reassembly control. The L2CAP SDU Length field specifies the length of an SDU, including the aggregate length across all segments if segmented.

- *Supervisory frame format (S-frame)*

  S-frames are used to acknowledge I-frames and request retransmission of I-frames. Each S-frame has an ReqSeq sequence number which may acknowledge additional I-frames received by the data link layer entity, and a retransmission bit (R bit) that affects whether I-frames are retransmitted.

  Defined types of S-frames are RR (Receiver Ready) and REJ (Reject).

Frame type	**16**	**15**	**14**	**13**	**12**	**11**	**10**	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**
I	SAR		ReqSeq						R	TxSeq						0
S	X	X	ReqSeq						R	X	X	X	S		0	1

X denotes reserved bits. Shall be coded 0.

Table 3.1: Control Field formats

- *Send Sequence Number - TxSeq (6 bits)*

  The send sequence number is used to number each I-frame, to enable sequencing and retransmission.

- *Receive Sequence Number - ReqSeq (6 bits)*

  The receive sequence number is used by the receiver side to acknowledge I-frames, and in the REJ frame to request the retransmission of an I-frame with a specific send sequence number.

- *Retransmission Disable Bit - R (1 bit)*

  The Retransmission Disable bit is used to implement Flow Control. The receiver sets the bit when its internal receive buffer is full, this happens when one or more I-frames have been received but the SDU reassembly function has not yet pulled all the frames received. When the sender receives a frame with the Retransmission Disable bit set it shall disable the RetransmissionTimer, this causes the sender to stop retransmitting I-frames.

  R=0: Normal operation. Sender uses the RetransmissionTimer to control retransmission of I-frames. Sender does not use the MonitorTimer.

  R=1: Receiver side requests sender to postpone retransmission of I-frames. Sender monitors signalling with the MonitorTimer. Sender does not use the RetransmissionTimer.

  The functions of ReqSeq and R are independent.

- *Segmentation and Reassembly - SAR (2 bits)*

  The SAR bits define whether an L2CAP SDU is segmented. For segmented SDUs, the SAR bits also define which part of an SDU is in this I-frame, thus allowing one L2CAP SDU to span several I-frames.

  An I-frame with SAR=”Start of L2CAP SDU” also contains a length indicator, specifying the number of information octets in the total L2CAP SDU. The encoding of the SAR bits is shown in Table 3.2.

00	Unsegmented L2CAP SDU
01	Start of L2CAP SDU
10	End of L2CAP SDU
11	Continuation of L2CAP SDU

Table 3.2: SAR control element format.

- *Supervisory function - S (2 bits)*

  The S-bits mark the type of S-frame. There are two types defined: RR (Receiver Ready) and REJ (Reject). The encoding is shown in Table 3.3.

00	RR - Receiver Ready
01	REJ - Reject
10	Reserved
11	Reserved

Table 3.3: S control element format: type of S-frame.

3.3.3 L2CAP SDU length field (2 octets)

When a SDU spans more than one I-frame, the first I-frame in the sequence shall be identified by SAR=01=”Start of L2CAP SDU”. The L2CAP SDU Length field shall specify the total number of octets in the SDU. The L2CAP SDU Length field shall be present in I-frames with SAR=01 (Start of L2CAP SDU), and shall not be used in any other I-frames. When the SDU is unsegmented (SAR=00), L2CAP SDU Length field is not needed and shall not be present.

3.3.4 Information payload field (0 to 65531 octets)

The information payload field consists of an integral number of octets. The maximum number of octets in this field is the same as the negotiated value of the MPS configuration parameter. The maximum number of octets in this field is also limited by the range of the basic L2CAP header length field. For I-frames without an SDU length field, this limits the maximum number of octets in the field to 65531. For I-frames with an SDU length field, SAR=01, this limits maximum number of octets in the field to 65529. Thus, even if an MPS of 65531 has been negotiated, the range of the basic L2CAP header length field will restrict the number of octets in this field when an SDU length field is present to 65529.

3.3.5 Frame check sequence (2 octets)

The Frame Check Sequence (FCS) is 2 octets. The FCS is constructed using the generator polynomial $g(D) = D^{16} + D^{15} + D^2 + 1$ (see Figure 3.4). The 16 bit LFSR is initially loaded with the value 0x0000, as depicted in Figure 3.5. The switch S is set in position 1 while data is shifted in, LSB first for each octet. After the last bit has entered the LFSR, the switch is set in position 2, and the register contents are transmitted from right to left (i.e. starting with position 15, then position 14, etc). The FCS covers the Basic L2CAP header, Control, L2CAP-SDU length and Information payload fields, if present, as shown in Figure 3.3 on page 35.

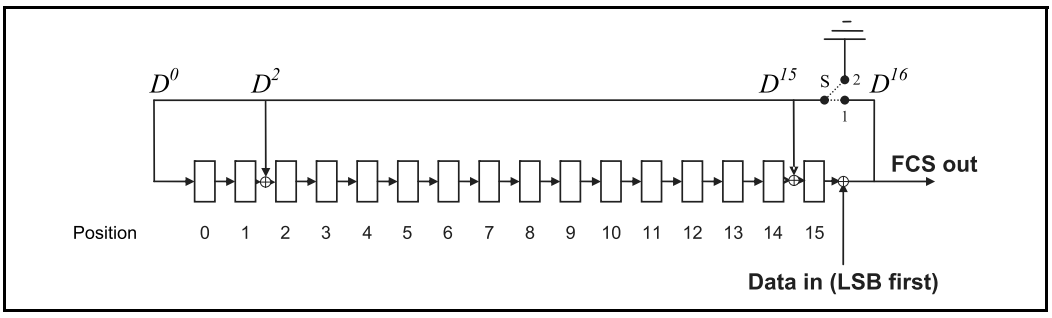


Figure 3.4: The LFSR circuit generating the FCS.

Position	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
LFSR	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0

Figure 3.5: Initial state of the FCS generating circuit.

Examples of FCS calculation, $g(D) = D^{16} + D^{15} + D^2 + 1$:

1. ***I Frame***
   Length = 14
   Control = 0x0002 (SAR=0, ReqSeq=0, R=0, TxSeq=1)
   Information Payload = 00 01 02 03 04 05 06 07 08 09 (10 octets, hexadecimal notation)
   ==> FCS = 0x6138
   ==> Data to Send = 0E 00 40 00 02 00 00 01 02 03 04 05 06 07 08 09 38 61 (hexadecimal notation)

2. ***RR Frame***
   Length = 4
   Control = 0x0101 (ReqSeq=1, R=0, S=0)
   ==> FCS = 0x14D4
   ==> Data to Send = 04 00 40 00 01 01 D4 14 (hexadecimal notation)

3.3.6 Invalid frame detection

A received PDU shall be regarded as invalid, if one of the following conditions occurs:

1. Contains an unknown CID.
2. Contains an FCS error.
3. Contains a length greater than the maximum PDU payload size (MPS).
4. I-frame that has fewer than 8 octets.
5. I-frame with SAR=01 (Start of L2CAP SDU) that has fewer than 10 octets.
6. I-frame with SAR bits that do not correspond to a normal sequence of either unsegmented or start, continuation, end for the given CID.
7. S-frame where the length field is not equal to 4.

These error conditions may be used for error reporting.

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4 SIGNALLING PACKET FORMATS

This section describes the signalling commands passed between two L2CAP entities on peer devices. All signalling commands are sent to the signalling channel with CID 0x0001. This signalling channel is available as soon as an ACL logical transport is set up and L2CAP traffic is enabled on the L2CAP logical link. Figure 4.1 on page 41 illustrates the general format of L2CAP PDUs containing signalling commands (C-frames). Multiple commands may be sent in a single C-frame. Commands take the form of Requests and Responses. All L2CAP implementations shall support the reception of C-frames with a payload length that does not exceed the signaling MTU. The minimum supported payload length for the C-frame (MTU_{sig}) is 48 octets. L2CAP implementations should not use C-frames that exceed the MTU_{sig} of the peer device. If they ever do, the peer device shall send a Command Reject containing the supported MTU_{sig}. Implementations must be able to handle the reception of multiple commands in an L2CAP packet.

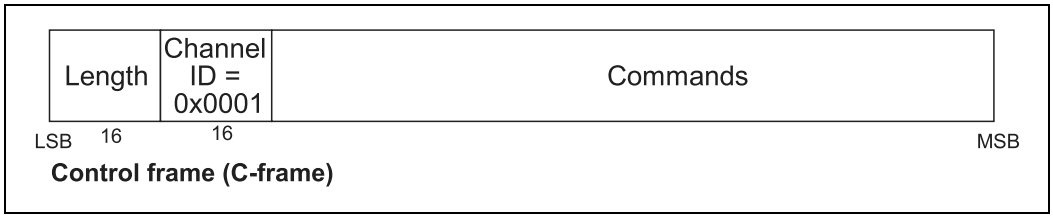


Figure 4.1: L2CAP PDU format on the signalling channel

Figure 4.2 displays the general format of all signalling commands.

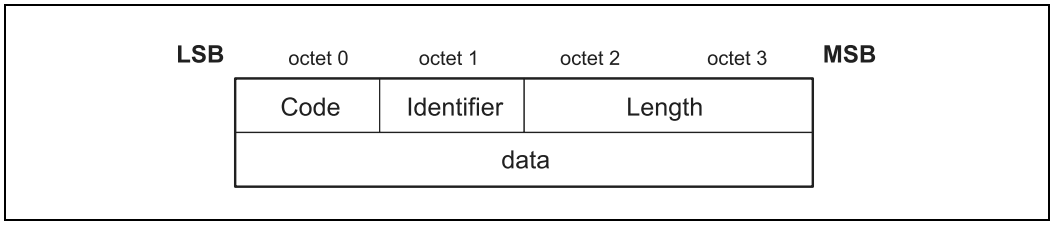


Figure 4.2: Command format

The fields shown are:

- *Code (1 octet)*

  The Code field is one octet long and identifies the type of command. When a packet is received with an unknown Code field, a Command Reject packet (defined in Section 4.1 on page 43) is sent in response.

  Table 4.1 on page 42 lists the codes defined by this document. All codes are specified with the most significant bit in the left-most position.

Code	Description
0x00	RESERVED
0x01	Command reject
0x02	Connection request
0x03	Connection response
0x04	Configure request
0x05	Configure response
0x06	Disconnection request
0x07	Disconnection response
0x08	Echo request
0x09	Echo response
0x0A	Information request
0x0B	Information response

Table 4.1: Signalling Command Codes

- *Identifier (1 octet)*

  The Identifier field is one octet long and matches responses with requests. The requesting device sets this field and the responding device uses the same value in its response. Between any two devices a different Identifier shall be used for each successive command. Following the original transmission of an Identifier in a command, the Identifier may be recycled if all other Identifiers have subsequently been used.

  RTX and ERTX timers are used to determine when the remote end point is not responding to signalling requests. On the expiration of a RTX or ERTX timer, the same identifier shall be used if a duplicate Request is re-sent as stated in Section 6.2 on page 74.

  A device receiving a duplicate request should reply with a duplicate response. A command response with an invalid identifier is silently discarded. Signaling identifier 0x00 is an illegal identifier and shall never be used in any command.

- *Length (2 octets)*

  The Length field is two octets long and indicates the size in octets of the data field of the command only, i.e., it does not cover the Code, Identifier, and Length fields.

- *Data (0 or more octets)*

  The Data field is variable in length. The Code field determines the format of the Data field. The length field determines the length of the data field.

4.1 COMMAND REJECT (CODE 0x01)

A Command Reject packet shall be sent in response to a command packet with an unknown command code or when sending the corresponding response is inappropriate. Figure 4.3 on page 43 displays the format of the packet. The identifier shall match the identifier of the command packet being rejected. Implementations shall always send these packets in response to unidentified signalling packets. Command Reject packets should not be sent in response to an identified Response packet.

When multiple commands are included in an L2CAP packet and the packet exceeds the signalling MTU (MTU_{sig}) of the receiver, a single Command Reject packet shall be sent in response. The identifier shall match the first Request command in the L2CAP packet. If only Responses are recognized, the packet shall be silently discarded.

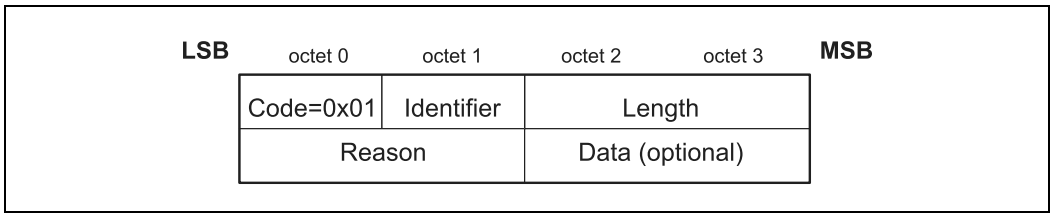


Figure 4.3: Command Reject packet

Figure 4.3 shows the format of the Command Reject packet. The data fields are:

- *Reason (2 octets)*

  The Reason field describes why the Request packet was rejected, and is set to one of the Reason codes in Table 4.2.

Reason value	Description
0x0000	Command not understood
0x0001	Signalling MTU exceeded
0x0002	Invalid CID in request
Other	Reserved

Table 4.2: Reason Code Descriptions

- *Data (0 or more octets)*

  The length and content of the Data field depends on the Reason code. If the Reason code is 0x0000, “Command not understood”, no Data field is used. If the Reason code is 0x0001, “Signalling MTU Exceeded”, the 2-octet Data field represents the maximum signalling MTU the sender of this packet can accept.

  If a command refers to an invalid channel then the Reason code 0x0002 will be returned. Typically a channel is invalid because it does not exist. The data field shall be 4 octets containing the local (first) and remote (second) channel endpoints (relative to the sender of the Command Reject) of the disputed channel. The remote endpoint is the source CID from the rejected command. The local endpoint is the destination CID from the rejected command. If the rejected command contains only one of the channel endpoints, the other one shall be replaced by the null CID 0x0000.

Reason value	Data Length	Data value
0x0000	0 octets	N/A
0x0001	2 octets	Actual MTU_{sig}
0x0002	4 octets	Requested CID

Table 4.3: Reason Data values

4.2 CONNECTION REQUEST (CODE 0x02)

Connection request packets are sent to create an L2CAP channel between two devices. The L2CAP channel shall be established before configuration begins. Figure 4.4 illustrates a Connection Request packet.

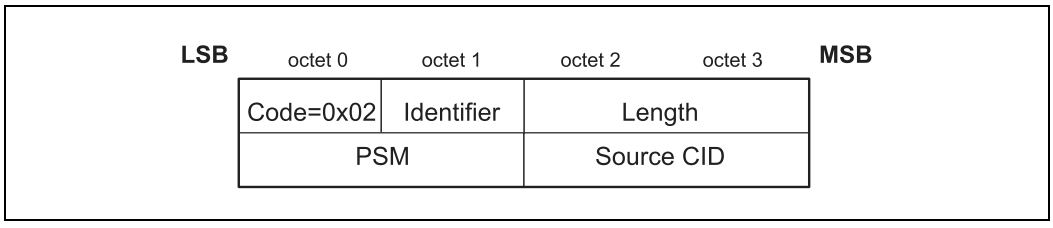


Figure 4.4: Connection Request Packet

The data fields are:

- *Protocol/Service Multiplexor - PSM (2 octets (minimum))*

  The PSM field is at least two octets in length. The structure of the PSM field is based on the ISO 3309 extension mechanism for address fields. All PSM values shall be ODD, that is, the least significant bit of the least significant octet must be ’1’. Also, all PSM values shall have the least significant bit of the most significant octet equal to ’0’. This allows the PSM field to be extended beyond 16 bits. PSM values are separated into two ranges. Values in the first range are assigned by the Bluetooth SIG and indicate protocols. The second range of values are dynamically allocated and used in conjunction with the Service Discovery Protocol (SDP). The dynamically assigned values may be used to support multiple implementations of a particular protocol.

PSM value	Description
0x0001	Service Discovery Protocol
0x0003	RFCOMM
0x0005	Telephony Control Protocol
0x0007	TCS cordless
0x000F	BNEP
0x0011	HID Control
0x0013	HID Interrupt
0x0015	UPnP (ESDP)
0x0017	AVCTP
0x0019	AVDTP
Other < 1000	RESERVED
[0x1001-0xFFFF]	DYNAMICALLY ASSIGNED

Table 4.4: Defined PSM Values[1]

1. The most recent PSM assignments can be found in the Assigned Numbers database on the Bluetooth member website.

- *Source CID - SCID (2 octets)*

  The source CID is two octets in length and represents a channel endpoint on the device sending the request. Once the channel has been configured, data packets flowing to the sender of the request shall be sent to this CID. Thus, the Source CID represents the channel endpoint on the device sending the request and receiving the response.

4.3 CONNECTION RESPONSE (CODE 0x03)

When a device receives a Connection Request packet, it shall send a Connection Response packet. The format of the connection response packet is shown in Figure 4.5.

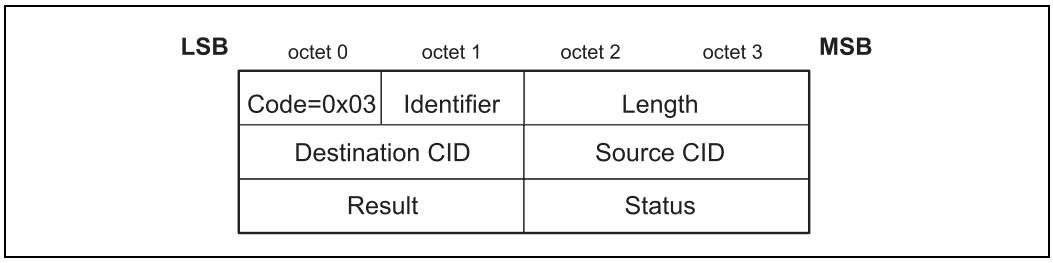


Figure 4.5: Connection Response Packet

The data fields are:

- *Destination Channel Identifier - DCID (2 octets)*

  This field contains the channel endpoint on the device sending this Response packet. Thus, the Destination CID represents the channel endpoint on the device receiving the request and sending the response.

- *Source Channel Identifier - SCID (2 octets)*

  This field contains the channel endpoint on the device receiving this Response packet. This is copied from the SCID field of the connection request packet.

- *Result (2 octets)*

  The result field indicates the outcome of the connection request. The result value of 0x0000 indicates success while a non-zero value indicates the connection request failed or is pending. A logical channel is established on the receipt of a successful result. Table 4.5 on page 46 defines values for this field. The DCID and SCID fields shall be ignored when the result field indicates the connection was refused.

Value	Description
0x0000	Connection successful.
0x0001	Connection pending
0x0002	Connection refused – PSM not supported.
0x0003	Connection refused – security block.
0x0004	Connection refused – no resources available.
Other	Reserved.

Table 4.5: Result values

- *Status (2 octets)*

  Only defined for Result = Pending. Indicates the status of the connection. The status is set to one of the values shown in Table 4.6 on page 47.

Value	Description
0x0000	No further information available
0x0001	Authentication pending
0x0002	Authorization pending
Other	Reserved

Table 4.6: Status values

4.4 CONFIGURATION REQUEST (CODE 0x04)

Configuration Request packets are sent to establish an initial logical link transmission contract between two L2CAP entities and also to re-negotiate this contract whenever appropriate. During a re-negotiation session, all data traffic on the channel should be suspended pending the outcome of the negotiation. Each configuration parameter in a Configuration Request shall be related exclusively to either the outgoing or the incoming data traffic but not both of them. In Section 5 on page 57, the various configuration parameters and their relation to the outgoing or incoming data traffic are shown. If an L2CAP entity receives a Configuration Request while it is waiting for a response it shall not block sending the Configuration Response, otherwise the configuration process may deadlock.

If no parameters need to be negotiated then no options shall be inserted and the continuation flag (C)shall be set to zero. L2CAP entities in remote devices shall negotiate all parameters defined in this document whenever the default values are not acceptable. Any missing configuration parameters are assumed to have their most recently explicitly or implicitly accepted values. Even if all default values are acceptable, a Configuration Request packet with no options shall be sent. Implicitly accepted values are default values for the configuration parameters that have not been explicitly negotiated for the specific channel under configuration.

Each configuration parameter is one-directional. The configuration parameters describe the non default parameters the device sending the Configuration Request will accept. The configuration request can not request a change in the parameters the device receiving the request will accept.

If a device needs to establish the value of a configuration parameter the remote device will accept, then it must wait for a configuration request containing that configuration parameter to be sent from the remote device.

See Section 7.1 on page 79 for details of the configuration procedure.

Figure 4.6 defines the format of the Configuration Request packet.

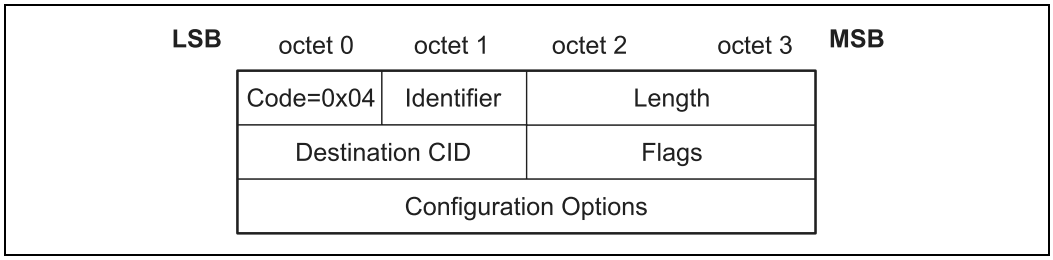


Figure 4.6: Configuration Request Packet

The data fields are:

- *Destination CID - DCID (2 octets)*

  This field contains the channel endpoint on the device receiving this Request packet.

- *Flags (2 octets)*

  Figure 4.7 shows the two-octet Flags field. Note the most significant bit is shown on the left.

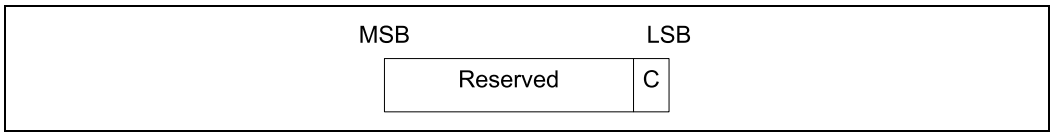


Figure 4.7: Configuration Request Flags field format

Only one flag is defined, the Continuation flag (C).

When all configuration options cannot fit into a Configuration Request with length that does not exceed the receiver's MTU_{sig}, the options shall be passed in multiple configuration command packets. If all options fit into the receiver's MTU_{sig}, then they shall be sent in a single configuration request with the continuation flag set to zero. Each Configuration Request shall contain an integral number of options - partially formed options shall not be sent in a packet. Each Request shall be tagged with a different Identifier and shall be matched with a Response with the same Identifier.

When used in the Configuration Request, the continuation flag indicates the responder should expect to receive multiple request packets. The responder shall reply to each Configuration Request packet. The responder may reply to each Configuration Request with a Configuration Response containing the same option(s) present in the Request (except for those error conditions more appropriate for a Command Reject), or the responder may reply with a "Success" Configuration Response packet containing no options, delaying those options until the full Request has been received. The Configuration Request packet with the continuation flag cleared shall be treated as the Configuration Request event in the channel state machine.

When used in the Configuration Response, the continuation flag shall be set to one if the flag is set to one in the Request. If the continuation flag is set to one in the Response when the matching Request has the flag set to zero, it indicates the responder has additional options to send to the requestor. In this situation, the requestor shall send null-option Configuration Requests (with continuation flag set to zero) to the responder until the responder replies with a Configuration Response where the continuation flag is set to zero. The Configuration Response packet with the continuation flag set to zero shall be treated as the Configuration Response event in the channel state machine.

The result of the configuration transaction is the union of all the result values. All the result values must succeed for the configuration transaction to succeed.

Other flags are reserved and shall be set to zero. L2CAP implementations shall ignore these bits.

- *Configuration Options*

  A list of the parameters and their values to be negotiated shall be provided in the Configuration Options field. These are defined in Section 5 on page 57. A Configuration Request may contain no options (referred to as an empty or null configuration request) and can be used to request a response. For an empty configuration request the length field is set to 0x0004.

4.5 CONFIGURATION RESPONSE (CODE 0X05)

Configuration Response packets shall be sent in reply to Configuration Request packets except when the error condition is covered by a Command Reject response. Each configuration parameter value (if any is present) in a Configuration Response reflects an 'adjustment' to a configuration parameter value that has been sent (or, in case of default values, implied) in the corresponding Configuration Request. For example, if a configuration request relates to traffic flowing from device A to device B, the sender of the configuration response may adjust this value for the same traffic flowing from device A to device B, but the response can not adjust the value in the reverse direction.

The options sent in the Response depend on the value in the Result field. Figure 4.8 on page 50 defines the format of the Configuration Response packet. See also Section 7.1 on page 79 for details of the configuration process.

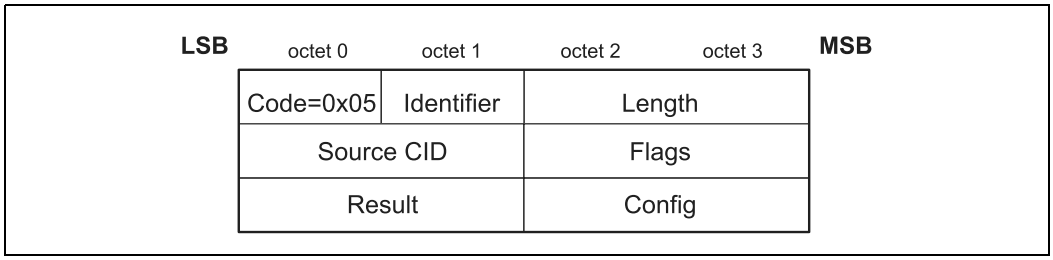


Figure 4.8: Configuration Response Packet

The data fields are:

- *Source CID - SCID (2 octets)*

  This field contains the channel endpoint on the device receiving this Response packet. The device receiving the Response shall check that the Identifier field matches the same field in the corresponding configuration request command and the SCID matches its local CID paired with the original DCID.

- *Flags (2 octets)*

  Figure 4.9 displays the two-octet Flags field. Note the most significant bit is shown on the left.

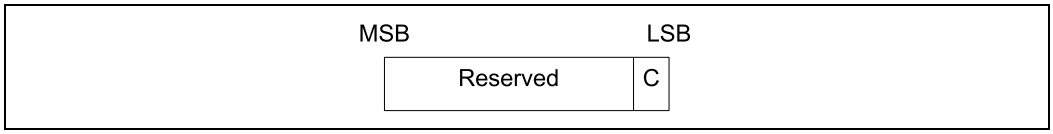


Figure 4.9: Configuration Response Flags field format

Only one flag is defined, the Continuation flag (C).

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More configuration responses will follow when C is set to one. This flag indicates that the parameters included in the response are a partial subset of parameters being sent by the device sending the Response packet.

The other flag bits are reserved and shall be set to zero. L2CAP implementations shall ignore these bits.

- *Result (2 octets)*

  The Result field indicates whether or not the Request was acceptable. See Table 4.7 on page 51 for possible result codes.

Result	Description
0x0000	Success
0x0001	Failure – unacceptable parameters
0x0002	Failure – rejected (no reason provided)
0x0003	Failure – unknown options
Other	RESERVED

Table 4.7: Configuration Response Result codes

- *Configuration Options*

  This field contains the list of parameters being configured. These are defined in Section 5 on page 57. On a successful result, these parameters contain the return values for any wild card parameter values (see Section 5.3 on page 60) contained in the request.

  On an unacceptable parameters failure (Result=0x0001) the rejected parameters shall be sent in the response with the values that would have been accepted if sent in the original request. Any missing configuration parameters are assumed to have their most recently accepted values and they too shall be included in the Configuration Response if they need to be changed.

  Each configuration parameter is one-directional. The configuration parameters describe the non default parameters the device sending the Configuration Request will accept. The configuration request can not request a change in the parameters the device receiving the request will accept.

  If a device needs to establish the value of a configuration parameter the remote device will accept, then it must wait for a configuration request containing that configuration parameter to be sent from the remote device.

  On an unknown option failure (Result=0x0003), the option types not understood by the recipient of the Request shall be included in the Response unless they are hints. Hints are those options in the Request that are skipped if not understood (see Section 5 on page 57). Hints shall not be included in the Response and shall not be the sole cause for rejecting the Request.

  The decision on the amount of time (or messages) spent arbitrating the channel parameters before terminating the negotiation is implementation specific.

4.6 DISCONNECTION REQUEST (CODE 0x06)

Terminating an L2CAP channel requires that a disconnection request be sent and acknowledged by a disconnection response. Figure 4.10 on page 52 shows a disconnection request. The receiver shall ensure that both source and destination CIDs match before initiating a channel disconnection.

Once a Disconnection Request is issued, all incoming data in transit on this L2CAP channel shall be discarded and any new additional outgoing data shall be discarded. Once a disconnection request for a channel has been received, all data queued to be sent out on that channel shall be discarded.

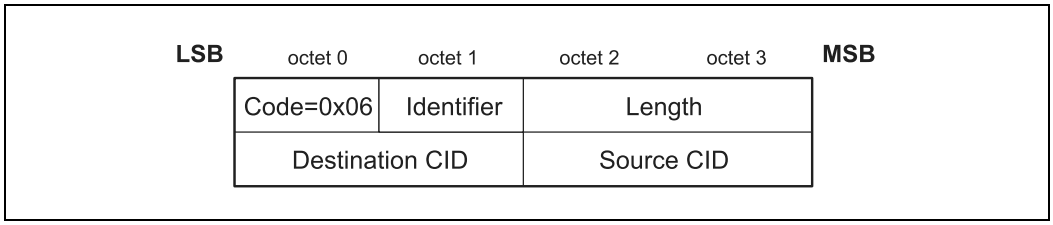


Figure 4.10: Disconnection Request Packet

The data fields are:

- *Destination CID - DCID (2 octets)*

  This field specifies the endpoint of the channel to be disconnected on the device receiving this request.

- *Source CID - SCID (2 octets)*

  This field specifies the endpoint of the channel to be disconnected on the device sending this request.

The SCID and DCID are relative to the sender of this request and shall match those of the channel to be disconnected. If the DCID is not recognized by the receiver of this message, a CommandReject message with ’invalid CID’ result code shall be sent in response. If the receiver finds a DCID match but the SCID fails to find the same match, the request should be silently discarded.

4.7 DISCONNECTION RESPONSE (CODE 0x07)

Disconnection responses shall be sent in response to each valid disconnection request.

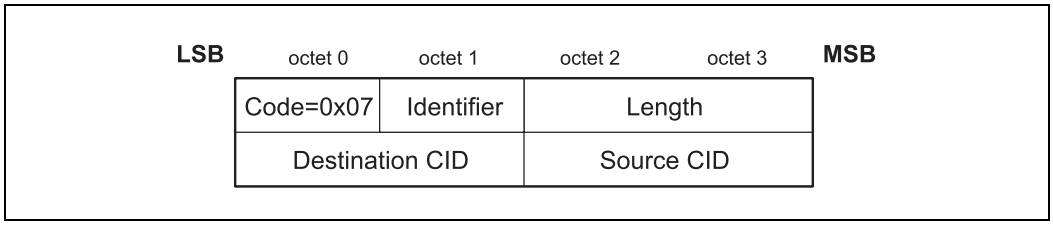


Figure 4.11: Disconnection Response Packet

The data fields are:

- *Destination CID - DCID (2 octets)*

  This field identifies the channel endpoint on the device sending the response.

- *Source CID - SCID (2 octets)*

  This field identifies the channel endpoint on the device receiving the response.

  The DCID and the SCID (which are relative to the sender of the request), and the Identifier fields shall match those of the corresponding disconnection request command. If the CIDs do not match, the response should be silently discarded at the receiver.

4.8 ECHO REQUEST (CODE 0x08)

Echo requests are used to request a response from a remote L2CAP entity. These requests may be used for testing the link or for passing vendor specific information using the optional data field. L2CAP entities shall respond to a valid Echo Request packet with an Echo Response packet. The Data field is optional and implementation specific. L2CAP entities should ignore the contents of this field if present.

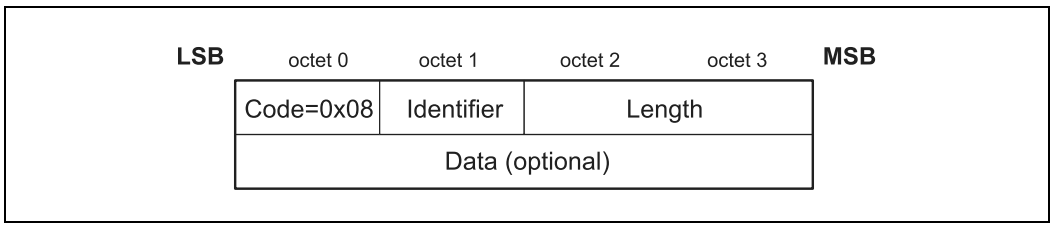


Figure 4.12: Echo Request Packet

4.9 ECHO RESPONSE (CODE 0x09)

An Echo response shall be sent upon receiving a valid Echo Request. The identifier in the response shall match the identifier sent in the Request. The optional and implementation specific data field may contain the contents of the data field in the Request, different data, or no data at all.

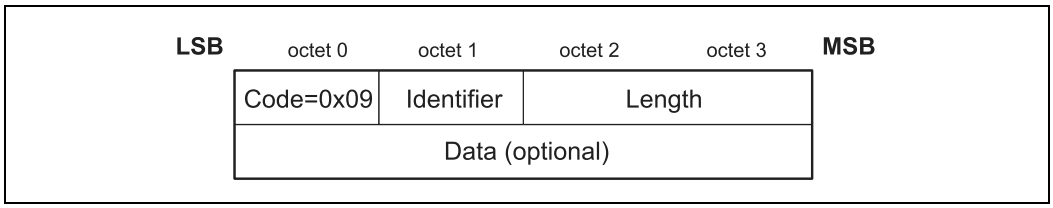


Figure 4.13: Echo Response Packet

4.10 INFORMATION REQUEST (CODE 0X0A)

Information requests are used to request implementation specific information from a remote L2CAP entity. L2CAP implementations shall respond to a valid Information Request with an Information Response. It is optional to send Information Requests.

An L2CAP implementation shall only use optional features or attribute ranges for which the remote L2CAP entity has indicated support through an Information Response. Until an Information Response which indicates support for optional features or ranges has been received only mandatory features and ranges shall be used.

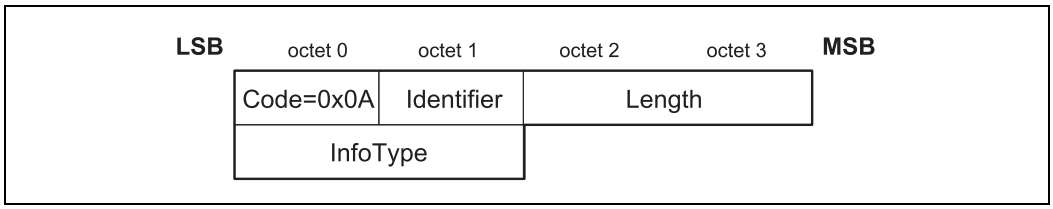


Figure 4.14: Information Request Packet

The data fields are:

- *InfoType (2 octets)*

  The InfoType defines the type of implementation specific information being requested. See Section 4.11 on page 55 for details on the type of information requested.

Value	Description
0x0001	Connectionless MTU
0x0002	Extended features supported
Other	Reserved

Table 4.8: InfoType definitions

4.11 INFORMATION RESPONSE (CODE 0X0B)

An information response shall be sent upon receiving a valid Information Request. The identifier in the response shall match the identifier sent in the Request. The data field shall contain the value associated with the InfoType field sent in the Request, or shall be empty if the InfoType is not supported.

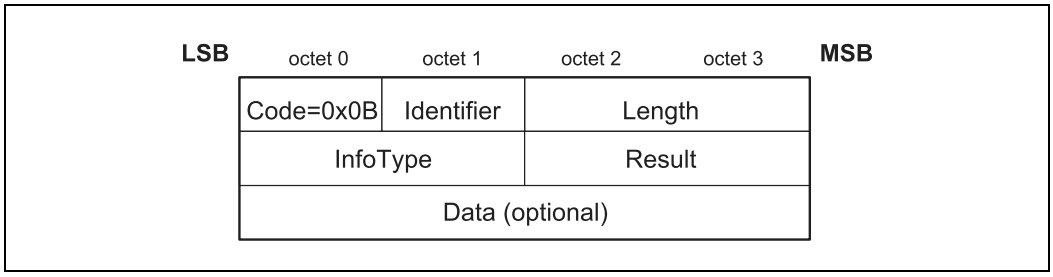


Figure 4.15: Information Response Packet

The data fields are:

- *InfoType (2 octets)*

  The InfoType defines the type of implementation specific information that was requested. This value shall be copied from the InfoType field in the Information Request.

- *Result (2 octets)*

  The Result contains information about the success of the request. If result is "Success", the data field contains the information as specified in Table 4.10 on page 56. If result is "Not supported", no data shall be returned.

Value	Description
0x0000	Success
0x0001	Not supported
Other	Reserved

Table 4.9: Information Response Result values

- *Data (0 or more octets)*

  The contents of the Data field depends on the InfoType.
  For InfoType = 0x0001 the data field contains the remote entity's 2-octet acceptable connectionless MTU. The default value is defined in Section 3.2 on page 34.

  For InfoType = 0x0002, the data field contains the 4 octet L2CAP extended feature mask. The feature mask refers to the extended features that the L2CAP entity sending the Information Response supports. The feature bits contained in the L2CAP feature mask are specified in Section 4.12 on page 56.

Note: L2CAP entities of versions prior to version 1.2, receiving an Information Request with InfoType = 0x0002 for an L2CAP feature discovery, will return an Information Response with result code "Not supported".

InfoType	Data	Data Length (octets)
0x0001	Connectionless MTU	2
0x0002	Extended feature mask	4

Table 4.10: Information Response Data fields

4.12 EXTENDED FEATURE MASK

The features are represented as a bit mask in the Information Response data field (see Section 4.11 on page 55). For each feature a single bit is specified which shall be set to 1 if the feature is supported and set to 0 otherwise. All unknown, reserved, or unassigned feature bits shall be set to 0.

The feature mask shown in Table 4.11 on page 56 consists of 4 octets (numbered octet 0 ... 3), with bit numbers 0 ... 7 each. Within the Information Response packet data field, bit 0 of octet 0 is aligned leftmost, bit 7 of octet 3 is aligned rightmost.

Note: the L2CAP feature mask is a new concept introduced in Bluetooth v1.2 and thus contains new features introduced after Bluetooth v1.1.

No.	Supported feature	Octet	Bit
0	Flow control mode	0	0
1	Retransmission mode	0	1
2	Bi-directional QoS[1]	0	2
31	Reserved for feature mask extension	3	7

Table 4.11: Extended feature mask.

1. Peer side supports upper layer control of the Link Manager's Bi-directional QoS, see Section 5.3 on page 60 for more details.

5 CONFIGURATION PARAMETER OPTIONS

Options are a mechanism to extend the configuration parameters. Options shall be transmitted as information elements containing an option type, an option length, and one or more option data fields. Figure 5.1 illustrates the format of an option.

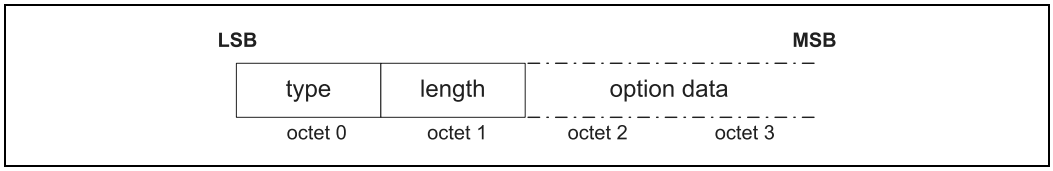


Figure 5.1: Configuration option format

The configuration option fields are:

- *Type (1 octet)*

  The option type field defines the parameters being configured. The most significant bit of the type determines the action taken if the option is not recognized.

  0 - option must be recognized; if the option is not recognized then refuse the configuration request

  1 - option is a hint; if the option is not recognized then skip the option and continue processing

- *Length (1 octet)*

  The length field defines the number of octets in the option data. Thus an option type without option data has a length of 0.

- *Option data*

  The contents of this field are dependent on the option type.

5.1 MAXIMUM TRANSMISSION UNIT (MTU)

This option specifies the maximum SDU size the sender of this option is capable of accepting for a channel. The type is 0x01, and the payload length is 2 octets, carrying the two-octet MTU size value as the only information element (see Figure 5.2 on page 58). Unlike the B-Frame length field, the I-Frame length field may be greater then the configured MTU because it includes the octet lengths of the Control, L2CAP SDU Length (when present), and frame check sequence fields as well as the Information octets.

MTU is not a negotiated value, it is an informational parameter that each device can specify independently. It indicates to the remote device that the local device can receive, in this channel, an MTU larger than the minimum required. All L2CAP implementations shall support a minimum MTU of 48 octets, however some protocols and profiles explicitly require support for a

larger MTU. The minimum MTU for a channel is the larger of the L2CAP minimum 48 octet MTU and any MTU explicitly required by the protocols and profiles using that channel. (Note: the MTU is only affected by the profile directly using the channel. For example, if a service discovery transaction is initiated by a non service discovery profile, that profile does not affect the MTU of the L2CAP channel used for service discovery).

The following rules shall be used when responding to a configuration request specifying the MTU for a channel:

- A request specifying any MTU greater than or equal to the minimum MTU for the channel shall be accepted.
- A request specifying an MTU smaller than the minimum MTU for the channel may be rejected.

The signalling described in Section 4.5 on page 50 may be used to reject an MTU smaller than the minimum MTU for a channel. The "failure-unacceptable parameters" result sent to reject the MTU shall include the proposed value of MTU that the remote device intends to transmit. It is implementation specific whether the local device continues the configuration process or disconnects the channel.

If the remote device sends a positive configuration response it shall include the actual MTU to be used on this channel for traffic flowing into the local device. This is the minimum of the MTU in the configuration request and the outgoing MTU capability of the device sending the configuration response. The new agreed value (the default value in a future re-configuration) is the value specified in the request.

The MTU to be used on this channel for the traffic flowing in the opposite direction will be established when the remote device sends its own Configuration Request as explained in Section 4.4 on page 47.

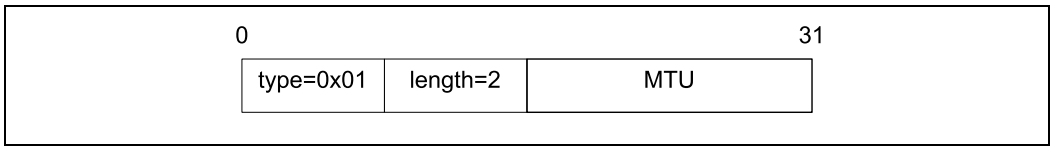


Figure 5.2: MTU Option Format

The option data field is:

- Maximum Transmission Unit - MTU (2 octets)

  The MTU field is the maximum SDU size, in octets, that the originator of the Request can accept for this channel. The MTU is asymmetric and the sender of the Request shall specify the MTU it can receive on this channel if it differs from the default value. L2CAP implementations shall support a minimum MTU size of 48 octets. The default value is 672 octets[1].

5.2 FLUSH TIMEOUT OPTION

This option is used to inform the recipient of the Flush Timeout the sender is going to use. The Flush Timeout is defined in the Baseband specification “Flushing payloads” on page 130[vol. 2]. The type is 0x02 and the payload size is 2 octets.

If the remote device returns a negative response to this option and the local device cannot honor the proposed value, then it shall either continue the configuration process by sending a new request with the original value, or disconnect the channel. The flush timeout applies to all channels on the same ACL logical transport and other channels on the same ACL logical transport may therefore have other values.

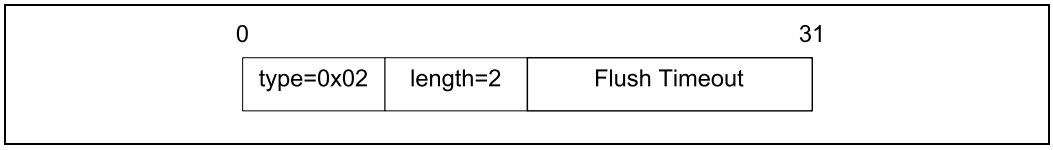


Figure 5.3: Flush Timeout option format.

The option data field is:

- *Flush Timeout*

  This value is the Flush Timeout in milliseconds. This is an asymmetric value and the sender of the Request shall specify its flush timeout value if it differs from the default value of 0xFFFF.

  Possible values are:

  0x0001 - no retransmissions at the baseband level should be performed since the minimum polling interval is 1.25 ms.

  0x0002 to 0xFFFE - Flush Timeout used by the baseband.

  0xFFFF - an infinite amount of retransmissions. This is also referred to as a ’reliable channel’. In this case, the baseband shall continue retransmissions until physical link loss is declared by link manager timeouts.

1. The default MTU was selected based on the payload carried by two baseband DH5 packets (2*341=682) minus the baseband ACL headers (2*2=4) and L2CAP header (6).

5.3 QUALITY OF SERVICE (QOS) OPTION

This option specifies a flow specification similar to RFC 1363[1]. Although the RFC flow specification addresses only the transmit characteristics, the Bluetooth QoS interface can handle the two directions (Tx and Rx) in the negotiation as described below.

If no QoS configuration parameter is negotiated the link shall assume the default parameters. The QoS option is type 0x03.

In a configuration request, this option describes the outgoing traffic flow from the device sending the request. In a positive Configuration Response, this option describes the incoming traffic flow agreement to the device sending the response. In a negative Configuration Response, this option describes the preferred incoming traffic flow to the device sending the response.

L2CAP implementations are only required to support 'Best Effort' service, support for any other service type is optional. Best Effort does not require any guarantees. If no QoS option is placed in the request, Best Effort shall be assumed. If any QoS guarantees are required then a QoS configuration request shall be sent.

The remote device's Configuration Response contains information that depends on the value of the result field (see Section 4.5 on page 50). If the request was for Guaranteed Service, the response shall include specific values for any wild card parameters (see Token Rate and Token Bucket Size descriptions) contained in the request. If the result is "Failure – unacceptable parameters", the response shall include a list of outgoing flow specification parameters and parameter values that would make a new Connection Request from the local device acceptable by the remote device. Both explicitly referenced in a Configuration Request or implied configuration parameters can be included in a Configuration Response. Recall that any missing configuration parameters from a Configuration Request are assumed to have their most recently accepted values.

If a configuration request contains any QoS option parameters set to "do not care" then the configuration response shall set the same parameters to "do not care". This rule applies for both Best Effort and Guaranteed Service.

1. Internet Engineering Task Force, "A Proposed Flow Specification", RFC 1363, September 1992.

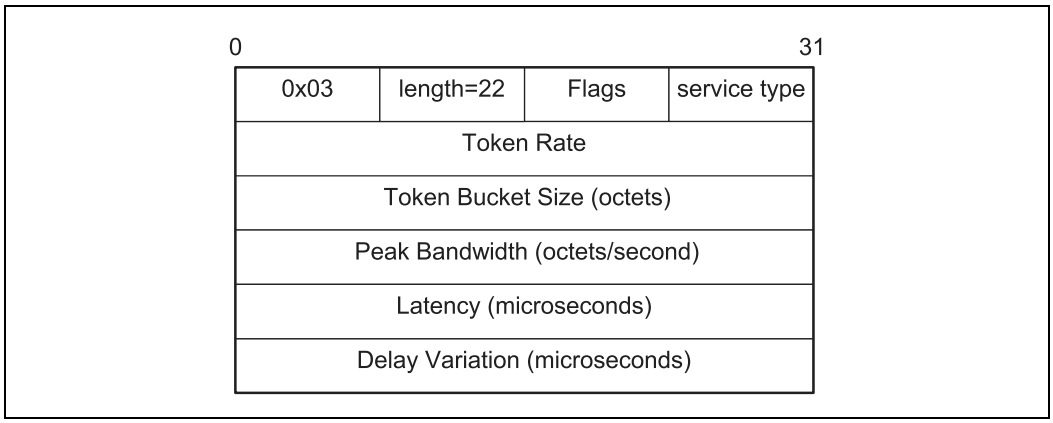


Figure 5.4: Quality of Service (QoS) option format containing Flow Specification.

The option data fields are:

- *Flags (1 octet)*

  Reserved for future use and shall be set to 0 and ignored by the receiver.

- *Service Type (1 octet)*

  This field indicates the level of service required. Table 5.1 on page 61 defines the different services available. The default value is ‘Best effort’.

  If ’Best effort’ is selected, the remaining parameters should be treated as optional by the remote device. The remote device may choose to ignore the fields, try to satisfy the parameters but provide no response (QoS option omitted in the Response message), or respond with the settings it will try to meet.

  If ’No traffic’ is selected, the remainder of the fields shall be ignored because there is no data being sent across the channel in the outgoing direction.

Value	Description
0x00	No traffic
0x01	Best effort (Default)
0x02	Guaranteed
Other	Reserved

Table 5.1: Service type definitions

- *Token Rate (4 octets)*

  The value of this field represents the average data rate with which the application transmits data. The application may send data at this rate continuously. On a short time scale the application may send data in excess of the average data rate, dependent on the specified Token Bucket Size and Peak Bandwidth (see below). The Token Bucket Size and Peak Bandwidth allow the application to transmit data in a 'bursty' fashion.

The Token Rate signalled between two L2CAP peers is the data transmitted by the application and shall exclude the L2CAP protocol overhead. The Token Rate signalled over the interface between L2CAP and the Link Manager shall include the L2CAP protocol overhead. Furthermore the Token Rate value signalled over this interface may also include the aggregation of multiple L2CAP channels onto the same ACL logical transport.

The Token Rate is the rate with which traffic credits are provided. Credits can be accumulated up to the Token Bucket Size. Traffic credits are consumed when data is transmitted by the application. When traffic is transmitted, and there are insufficient credits available, the traffic is non-conformant. The Quality of Service guarantees are only provided for conformant traffic. For non-conformant traffic there may not be sufficient resources such as bandwidth and buffer space. Furthermore non-conformant traffic may violate the QoS guarantees of other traffic flows.

The Token Rate is specified in octets per second. The value 0x00000000 indicates no token rate is specified. This is the default value and means “do not care”. When the Guaranteed service is selected, the default value shall not be used. The value 0xFFFFFFFF is a wild card matching the maximum token rate available. The meaning of this value depends on the service type. For best effort, the value is a hint that the application wants as much bandwidth as possible. For Guaranteed service the value represents the maximum bandwidth available at the time of the request.

- *Token Bucket Size (4 octets)*

  The Token Bucket Size specifies a limit on the 'burstiness' with which the application may transmit data. The application may offer a burst of data equal to the Token Bucket Size instantaneously, limited by the Peak Bandwidth (see below). The Token Bucket Size is specified in octets.

  The Token Bucket Size signalled between two L2CAP peers is the data transmitted by the application and shall exclude the L2CAP protocol overhead. The Token Bucket Size signalled over the interface between L2CAP and Link Manager shall include the L2CAP protocol overhead. Furthermore the Token Bucket Size value over this interface may include the aggregation of multiple L2CAP channels onto the same ACL logical transport.

  The value of 0x00000000 means that no token bucket is needed; this is the default value. When the Guaranteed service is selected, the default value shall not be used. The value 0xFFFFFFFF is a wild card matching the maximum token bucket available. The meaning of this value depends on the service type. For best effort, the value indicates the application wants a bucket as big as possible. For Guaranteed service the value represents the maximum L2CAP SDU size.

  The Token Bucket Size is a property of the traffic carried over the L2CAP channel. The Maximum Transmission Unit (MTU) is a property of an L2CAP implementation. For the Guaranteed service the Token Bucket Size shall be smaller or equal to the MTU.

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- *Peak Bandwidth (4 octets)*

  The value of this field, expressed in octets per second, limits how fast packets from applications may be sent back-to-back. Some systems can take advantage of this information, resulting in more efficient resource allocation.

  The Peak Bandwidth signalled between two L2CAP peers specifies the data transmitted by the application and shall exclude the L2CAP protocol overhead. The Peak Bandwidth signalled over the interface between L2CAP and Link Manager shall include the L2CAP protocol overhead. Furthermore the Peak Bandwidth value over this interface may include the aggregation of multiple L2CAP channels onto the same ACL logical transport.

  The value of 0x00000000 means "don't care". This states that the device has no preference on incoming maximum bandwidth, and is the default value. When the Guaranteed service is selected, the default value shall not be used.

- *Access Latency (4 octets)*

  The value of this field is the maximum acceptable delay of an L2CAP packet to the air-interface. The precise interpretation of this number depends on over which interface this flow parameter is signalled. When signalled between two L2CAP peers, the Access Latency is the maximum acceptable delay between the instant when the L2CAP SDU is received from the upper layer and the start of the L2CAP SDU transmission over the air. When signalled over the interface between L2CAP and the Link Manager, it is the maximum delay between the instant the first fragment of an L2CAP PDU is stored in the Host Controller buffer and the initial transmission of the L2CAP packet on the air.

  Thus the Access Latency value may be different when signalled between L2CAP and the Link Manager to account for any queuing delay at the L2CAP transmit side. Furthermore the Access Latency value may include the aggregation of multiple L2CAP channels onto the same ACL logical transport.

  The Access Latency is expressed in microseconds. The value 0xFFFFFFFF means “do not care” and is the default value. When the Guaranteed service is selected, the default value shall not be used.

- *Delay Variation (4 octets)*

  The value of this field is the difference, in microseconds, between the maximum and minimum possible delay of an L2CAP SDU between two L2CAP peers. The Delay Variation is a purely informational parameter. The value 0xFFFFFFFF means “do not care” and is the default value.

5.4 RETRANSMISSION AND FLOW CONTROL OPTION

This option specifies whether retransmission and flow control is used. If the feature is used incoming parameters are specified by this option.

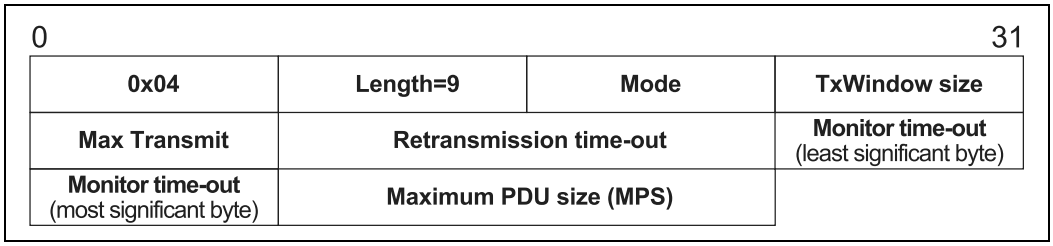


Figure 5.5: Retransmission and Flow Control option format.

The option data fields are:

- *Mode (1 octet)*

  The field contain the requested mode of the link. Possible values are shown in Table 5.2 on page 64.

Value	Description
0x00	Basic L2CAP mode
0x01	Retransmission Mode
0x02	Flow control mode
Other values	Reserved for future use

Table 5.2: Mode definitions.

  The Basic L2CAP mode is the default. If Basic L2CAP mode is requested then all other parameters shall be ignored.

  Retransmission mode should be enabled if a reliable channel has been requested, or if the L2CAP Flush Time-Out is long enough to contain the round-trip delay of a retransmission request.

- *TxWindow size (1 octet)*

  This field specifies the size of the transmission window for flow control mode and retransmission mode. The range is 1 to 32.

  This parameter should be negotiated to reflect the buffer sizes allocated for the connection on both sides. In general, the Tx Window size should be made as large as possible to maximize channel utilization. Tx Window size also controls the delay on flow control action. The transmitting device can send as many PDUs fit within the window.

- *MaxTransmit (1 octet)*

  This field controls the number of transmissions of a single I-frame that L2CAP is allowed to try in Retransmission mode. The minimum value is 1 (one transmission is permitted).

  MaxTransmit controls the number of retransmissions that L2CAP is allowed to try in Retransmission mode before accepting that a packet and the link is lost. Lower values might be appropriate for services requiring low latency. Higher values will be suitable for a link requiring robust operation. A value of 1 means that no retransmissions will be made but also means that the link will be dropped as soon as a packet is lost. MaxTransmit shall not be set to zero.

- *Retransmission time-out (2 octets)*

  This is the value in milliseconds of the retransmission time-out (this value is used to initialize the RetransmissionTimer, see below).

  The purpose of this timer in retransmission mode is to activate a retransmission in some exceptional cases. In such cases, any delay requirements on the channel may be broken, so the value of the timer should be set high enough to avoid unnecessary retransmissions due to delayed acknowledgements. Suitable values could be 100’s of milliseconds and up.

  The purpose of this timer in flow control mode is to supervise I-frame transmissions. If an acknowledgement for an I-frame is not received within the time specified by the RetransmissionTimer value, either because the I-frame has been lost or the acknowledgement has been lost, the timeout will cause the transmitting side to continue transmissions. Suitable values are implementation dependent.

- *Monitor time-out (2 octets)*

  This is the value in milliseconds of the interval at which S-frames should be transmitted on the return channel when no frames are received on the forward channel. (this value is used to initialize the MonitorTimer, see below).

  This timer ensures that lost acknowledgements are retransmitted. Its main use is to recover Retransmission Disable Bit changes in lost frames when no data is being sent. The timer shall be started immediately upon transitioning to the open state. It shall remain active as long as the connection is in the open state and the retransmission timer is not active. Upon expiration of the Monitor timer an S-frame shall be sent and the timer shall be restarted. If the monitor timer is already active when an S-frame is sent, the timer shall be restarted. An idle connection will have periodic monitor traffic sent in both directions. The value for this time-out should also be set to 100’s of milliseconds or higher.

- *Maximum PDU payload Size - MPS (2 octets)*

  The maximum size of payload data in octets that the L2CAP layer entity is capable of accepting, i.e. the MPS corresponds to the maximum PDU payload size.

The settings are configured separately for the two directions of an L2CAP connection. For example, an L2CAP connection can be configured as Flow Control

mode in one direction and Retransmission mode in the other direction. If Basic L2CAP mode is configured in one direction and Retransmission mode or Flow control mode is configured in the other direction on the same L2CAP channel then the channel shall not be used.
Note: this asymmetric configuration only occurs during configuration.

6 STATE MACHINE

This section is informative. The state machine may not represent all possible scenarios.

6.1 GENERAL RULES FOR THE STATE MACHINE:

- It is implementation specific, and outside the scope of this specification, how the transmissions are triggered.
- "Ignore" means that the signal can be silently discarded.

The following states have been defined to clarify the protocol; the actual number of states and naming in a given implementation is outside the scope of this specification:

- CLOSED – channel not connected.
- WAIT_CONNECT – a connection request has been received, but only a connection response with indication “pending” can be sent.
- WAIT_CONNECT_RSP – a connection request has been sent, pending a positive connect response.
- CONFIG – the different options are being negotiated for both sides; this state comprises a number of substates, see Section 6.1.3 on page 69
- OPEN – user data transfer state.
- WAIT_DISCONNECT – a disconnect request has been sent, pending a disconnect response.

Below the L2CAP_Data message corresponds to one of the PDU formats used on connection-oriented data channels as described in section 3, including PDUs containing B-frames, I-frames, S-frames.

Some state transitions and actions are triggered only by internal events effecting one of the L2CAP entity implementations, not by preceding L2CAP signalling messages. It is implementation-specific and out of the scope of this specification, how these internal events are realized; just for the clarity of specifying the state machine, the following abstract internal events are used in the state event tables, as far as needed:

- *OpenChannel_Req* – a local L2CAP entity is requested to set up a new connection-oriented channel.
- *OpenChannel_Rsp* – a local L2CAP entity is requested to finally accept or refuse a pending connection request.
- *ConfigureChannel_Req* – a local L2CAP entity is requested to initiate an outgoing configuration request.
- *CloseChannel_Req* – a local L2CAP entity is requested to close a channel.
- *SendData_Req* – a local L2CAP entity is requested to transmit an SDU.
- *ReconfigureChannel_Req* – a local L2CAP entity is requested to reconfigure the parameters of a connection-oriented channel.

There is a single state machine for each L2CAP connection-oriented channel that is active. A state machine is created for each new L2CAP_ConnectReq received. The state machine always starts in the CLOSED state.

To simplify the state event tables, the RTX and ERTX timers, as well as the handling of request retransmissions are described in Section 6.2 on page 74 and not included in the state tables.

L2CAP messages not bound to a specific data channel and thus not impacting a channel state (e.g. L2CAP_InformationReq, L2CAP_EchoReq) are not covered in this section.

The following states and transitions are illustrated in Figure 6.1 on page 76.

6.1.1 CLOSED state

Event	Condition	Action	Next State
OpenChannel_req	-	Send L2CAP_ConnectReq	WAIT_CONNECT_RSP
L2CAP_ConnectReq	Normal, connection is possible	Send L2CAP_ConnectRsp (success)	CONFIG (substate WAIT_CONFIG)
L2CAP_ConnectReq	Need to indicate pending	Send L2CAP_ConnectRsp (pending)	WAIT_CONNECT
L2CAP_ConnectReq	No resource, not approved, etc	Send L2CAP_ConnectRsp (refused)	CLOSED
L2CAP_ConnectRsp	-	Ignore	CLOSED
L2CAP_ConfigReq	-	Send L2CAP_CommandReject (with reason Invalid CID)	CLOSED
L2CAP_ConfigRsp	-	Ignore	CLOSED
L2CAP_DisconnectReq	-	Send L2CAP_DisconnectRsp	CLOSED
L2CAP_DisconnectRsp	-	Ignore	CLOSED
L2CAP_Data	-	Ignore	CLOSED

Table 6.1: CLOSED state event table.

Notes:

- The L2CAP_ConnectReq message is not mentioned in any of the other states apart from the CLOSED state, as it triggers the establishment of a new channel, thus the branch into a new instance of the state machine.

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6.1.2 WAIT_CONNECT_RSP state

Event	Condition	Action	Next State
L2CAP_ConnectRsp	Success indicated in result	Send L2CAP_ConfigReq	CONFIG (substate WAIT_CONFIG)
L2CAP_ConnectRsp	Result pending	-	WAIT_CONNECT_RSP
L2CAP_ConnectRsp	Remote side refuses connection	-	CLOSED
L2CAP_ConfigReq	-	Send L2CAP_CommandReject (with reason Invalid CID)	WAIT_CONNECT_RSP
L2CAP_ConfigRsp	-	Ignore	WAIT_CONNECT_RSP
L2CAP_DisconnectRsp	-	Ignore	WAIT_CONNECT_RSP
L2CAP_Data	-	Ignore	WAIT_CONNECT_RSP

Table 6.2: WAIT_CONNECT_RSP state event table.

Notes:

- An L2CAP_DisconnectReq message is not included here, since the Source and Destination CIDs are not available yet to relate it correctly to the state machine of a specific channel.

6.1.3 WAIT_CONNECT state

Event	Condition	Action	Next State
OpenChannel_Rsp	Pending connection request is finally acceptable	Send L2CAP_Connect_Rsp (success)	CONFIG (substate WAIT_CONFIG)
OpenChannel_Rsp	Pending connection request is finally refused	Send L2CAP_Connect_Rsp (refused)	CLOSED
L2CAP_ConnectRsp	-	Ignore	WAIT_CONNECT
L2CAP_ConfigRsp	-	Ignore	WAIT_CONNECT
L2CAP_DisconnectRsp	-	Ignore	WAIT_CONNECT
L2CAP_Data	-	Ignore	WAIT_CONNECT

Table 6.3: WAIT_CONNECT state event table.

Notes:

- An L2CAP_DisconnectReq or L2CAP_ConfigReq message is not included here, since the Source and Destination CIDs are not available yet to relate it correctly to the state machine of a specific channel.

6.1.4 CONFIG state

As it is also described in Section 7.1 on page 79, both L2CAP entities initiate a configuration request during the configuration process. This means that each device adopts an initiator role for the outgoing configuration request, and an acceptor role for the incoming configuration request. Configurations in both directions may occur sequentially, but can also occur in parallel.

The following substates are distinguished within the CONFIG state:

- WAIT_CONFIG – a device has sent or received a connection response, but has neither initiated a configuration request yet, nor received a configuration request with acceptable parameters.
- WAIT_SEND_CONFIG – for the initiator path, a configuration request has not yet been initiated, while for the response path, a request with acceptable options has been received.
- WAIT_CONFIG_REQ_RSP – for the initiator path, a request has been sent but a positive response has not yet been received, and for the acceptor path, a request with acceptable options has not yet been received.
- WAIT_CONFIG_RSP – the acceptor path is complete after having responded to acceptable options, but for the initiator path, a positive response on the recent request has not yet been received.
- WAIT_CONFIG_REQ – the initiator path is complete after having received a positive response, but for the acceptor path, a request with acceptable options has not yet been received.

According to Section 6.1.1 on page 68 and Section 6.1.2 on page 69, the CONFIG state is entered via WAIT_CONFIG substate from either the CLOSED state, the WAIT_CONNECT state, or the WAIT_CONNECT_RSP state. The CONFIG state is left for the OPEN state if both the initiator and acceptor paths complete successfully.

For better overview, separate tables are given: Table 6.4 shows the success transitions; therein, transitions on one of the minimum paths (no previous non-success transitions) are shaded. Table 6.5 on page 71 shows the non-success transitions within the configuration process, and Table 6.6 on page 72 shows further transition cause by events not belonging to the configuration process itself. The following configurtion states and transitions are illustrated in Figure 6.2 on page 77.

Previous state	Event	Condition	Action	Next State
WAIT_CONFIG	*ConfigureChannel_Req*	-	Send L2CAP_ConfigReq	WAIT_CONFIG_REQ_RSP
WAIT_CONFIG	L2CAP_ConfigReq	Options acceptable	Send L2CAP_ConfigRsp (success)	WAIT_SEND_CONFIG

Table 6.4: CONFIG state/substates event table: success transitions within configuration process.

Previous state	Event	Condition	Action	Next State
WAIT_CONFIG_REQ_RSP	L2CAP_ConfigReq	Options acceptable	Send L2CAP_Config Rsp (success)	WAIT_CONFIG_RSP
WAIT_CONFIG_REQ_RSP	L2CAP_ConfigRsp	Remote side accepts options	- (continue waiting for configuration request)	WAIT_CONFIG_REQ
WAIT_CONFIG_REQ	L2CAP_ConfigReq	Options acceptable	Send L2CAP_Config Rsp (success)	OPEN
WAIT_SEND_CONFIG	*ConfigureChannel_Req*	-	Send L2CAP_Config Req	WAIT_CONFIG_RSP
WAIT_CONFIG_RSP	L2CAP_ConfigRsp	Remote side accepts options	-	OPEN

Table 6.4: CONFIG state/substates event table: success transitions within configuration process.

Previous state	Event	Condition	Action	Next State
WAIT_CONFIG	L2CAP_ConfigReq	Options not acceptable	Send L2CAP_Config Rsp (fail)	WAIT_CONFIG
WAIT_CONFIG	L2CAP_ConfigRsp	-	Ignore	WAIT_CONFIG
WAIT_SEND_CONFIG	L2CAP_ConfigRsp	-	Ignore	WAIT_SEND_CONFIG
WAIT_CONFIG_REQ_RSP	L2CAP_ConfigReq	Options not acceptable	Send L2CAP_Config Rsp (fail)	WAIT_CONFIG_REQ_RSP
WAIT_CONFIG_REQ_RSP	L2CAP_ConfigRsp	Remote side rejects options	Send L2CAP_Config Req (new options)	WAIT_CONFIG_REQ_RSP
WAIT_CONFIG_REQ	L2CAP_ConfigReq	Options not acceptable	Send L2CAP_Config Rsp (fail)	WAIT_CONFIG_REQ
WAIT_CONFIG_REQ	L2CAP_ConfigRsp	-	Ignore	WAIT_CONFIG_REQ
WAIT_CONFIG_RSP	L2CAP_ConfigRsp	Remote side rejects options	Send L2CAP_Config Req (new options)	WAIT_CONFIG_RSP

Table 6.5: CONFIG state/substates event table: non-success transitions within configuration process.

Previous state	Event	Condition	Action	Next State
CONFIG (any substate)	*CloseChannel_Req*	Any internal reason to stop	Send L2CAP_ Disconnect Req	WAIT_ DISCONNECT
CONFIG (any substate)	L2CAP_Disconnect Req	-	Send L2CAP_ Disconnect Rsp	CLOSED
CONFIG (any substate)	L2CAP_Disconnect Rsp	-	Ignore	CONFIG (remain in sub-state)
CONFIG (any substate)	L2CAP_Data	-	Process the PDU	CONFIG (remain in sub-state)

Table 6.6: CONFIG state/substates event table: events not related to configuration process.

Notes:

- Receiving data PDUs (L2CAP_Data) in CONFIG state should be relevant only in case of a transition to a reconfiguration procedure (from OPEN state). Discarding the received data is allowed only in Retransmission Mode. Discarding an S-frame is allowed but not recommended. If a S-frame is discarded, the monitor timer will cause a new S-frame to be sent after a time out.
- Indicating a failure in a configuration response does not necessarily imply a failure of the overall configuration procedure; instead, based on the information received in the negative response, a modified configuration request may be triggered.

6.1.5 OPEN state

Event	Condition	Action	Next State
SendData_req	-	Send L2CAP_Data packet according to configured mode	OPEN
ReconfigureChannel_req	-	Complete outgoing SDU Send L2CAP_ConfigReq	CONFIG (substate WAIT_CONFIG_RSP)
CloseChannel_req	-	Send L2CAP_DisconnectReq	WAIT_DISCONNECT
L2CAP_ConnectRsp	-	Ignore	OPEN
L2CAP_ConfigReq	Incoming config. options acceptable	Complete outgoing SDU Send L2CAP_ConfigRsp (ok)	CONFIG (substate WAIT_CONFIG_REQ)
L2CAP_ConfigReq	Incoming config. options not acceptable	Complete outgoing SDU Send L2CAP_ConfigRsp (fail)	OPEN
L2CAP_DisconnectReq	-	Send L2CAP_DisconnectRsp	CLOSED
L2CAP_DisconnectRsp	-	Ignore	OPEN
L2CAP_Data	-	Process the PDU	OPEN

Table 6.7: OPEN state event table.

6.1.6 WAIT_DISCONNECT state

Event	Condition	Action	Next State
L2CAP_ConnectRsp	-	Ignore	WAIT_DISCONNECT
L2CAP_ConfigReq	-	Send L2CAP_CommandReject with reason Invalid CID	WAIT_DISCONNECT
L2CAP_ConfigRsp	-	Ignore	WAIT_DISCONNECT
L2CAP_DisconnectReq	-	Send L2CAP_DisconnectRsp	CLOSED
L2CAP_DisconnectRsp	-	-	CLOSED
L2CAP_Data	-	Ignore	WAIT_DISCONNECT

Table 6.8: WAIT_DISCONNECT state event table.

6.2 TIMERS EVENTS

6.2.1 RTX

The Response Timeout eXpired (RTX) timer is used to terminate the channel when the remote endpoint is unresponsive to signalling requests. This timer is started when a signalling request (see Section 7 on page 79) is sent to the remote device. This timer is disabled when the response is received. If the initial timer expires, a duplicate Request message may be sent or the channel identified in the request may be disconnected. If a duplicate Request message is sent, the RTX timeout value shall be reset to a new value at least double the previous value. When retransmitting the Request message, the context of the same state shall be assumed as with the original transmission. If a Request message is received that is identified as a duplicate (retransmission), it shall (should??) be processed in the context of the same state which applied when the original Request message was received.

Implementations have the responsibility to decide on the maximum number of Request retransmissions performed at the L2CAP level before terminating the channel identified by the Requests. The one exception is the signalling CID that should never be terminated. The decision should be based on the flush timeout of the signalling link. The longer the flush timeout, the more retransmissions may be performed at the physical layer and the reliability of the channel improves, requiring fewer retransmissions at the L2CAP level.

For example, if the flush timeout is infinite, no retransmissions should be performed at the L2CAP level. When terminating the channel, it is not necessary to send a L2CAP_DisconnectReq and enter WAIT_DISCONNECT state. Channels can be transitioned directly to the CLOSED state.

The value of this timer is implementation-dependent but the minimum initial value is 1 second and the maximum initial value is 60 seconds. One RTX timer shall exist for each outstanding signalling request, including each Echo Request. The timer disappears on the final expiration, when the response is received, or the physical link is lost. The maximum elapsed time between the initial start of this timer and the initiation of channel termination (if no response is received) is 60 seconds.

6.2.2 ERTX

The Extended Response Timeout eXpired (ERTX) timer is used in place of the RTX timer when it is suspected the remote endpoint is performing additional processing of a request signal. This timer is started when the remote endpoint responds that a request is pending, e.g., when an L2CAP_ConnectRsp event with a "connect pending" result (0x0001) is received. This timer is disabled when the formal response is received or the physical link is lost. If the initial timer expires, a duplicate Request may be sent or the channel may be disconnected.

If a duplicate Request is sent, the particular ERTX timer disappears, replaced by a new RTX timer and the whole timing procedure restarts as described previously for the RTX timer.

The value of this timer is implementation-dependent but the minimum initial value is 60 seconds and the maximum initial value is 300 seconds. Similar to RTX, there MUST be at least one ERTX timer for each outstanding request that received a Pending response. There should be at most one (RTX or ERTX) associated with each outstanding request. The maximum elapsed time between the initial start of this timer and the initiation of channel termination (if no response is received) is 300 seconds. When terminating the channel, it is not necessary to send a L2CAP_DisconnectReq and enter WAIT_DISCONNECT state. Channels should be transitioned directly to the CLOSED state.

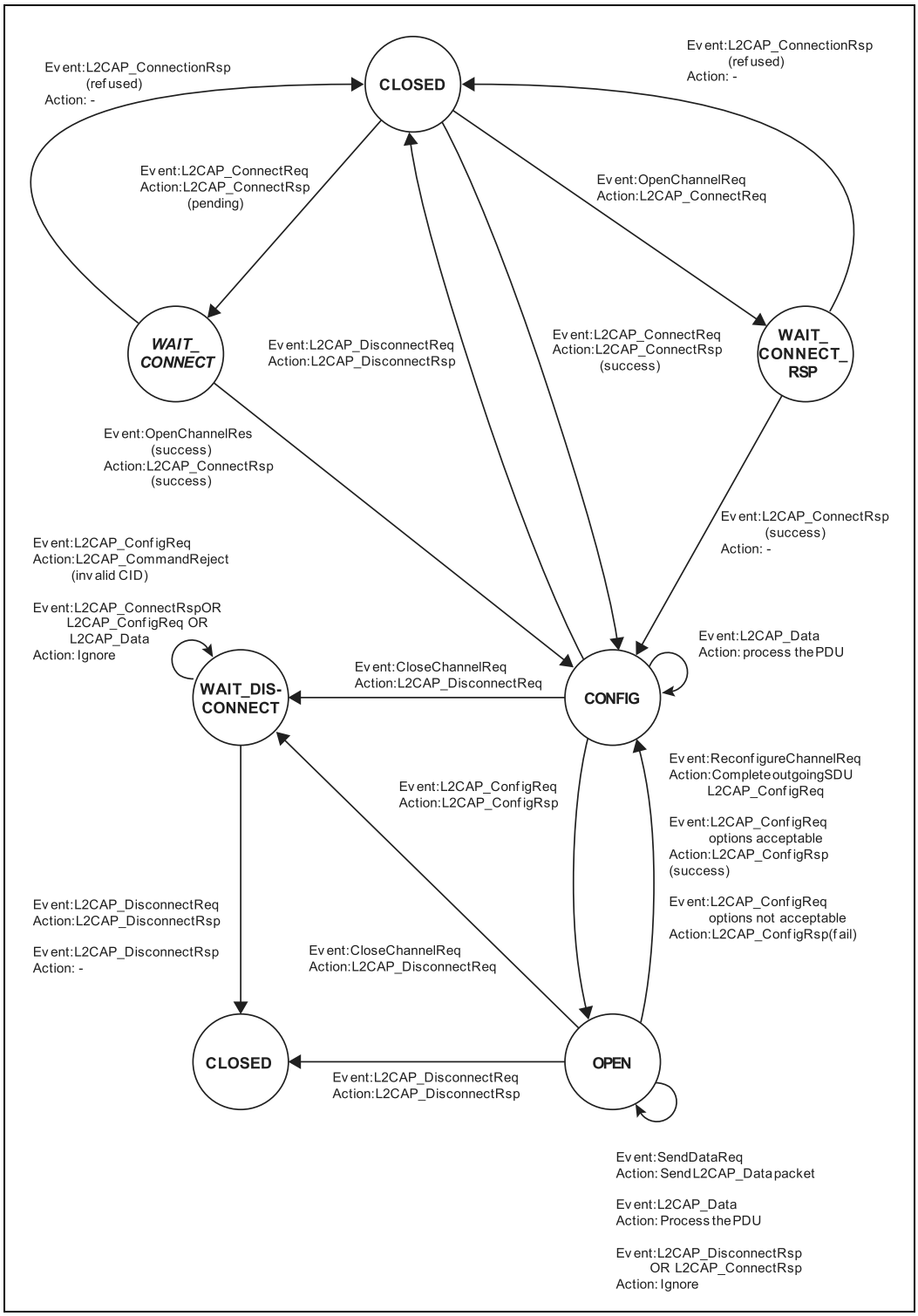


Figure 6.1: States and transitions.

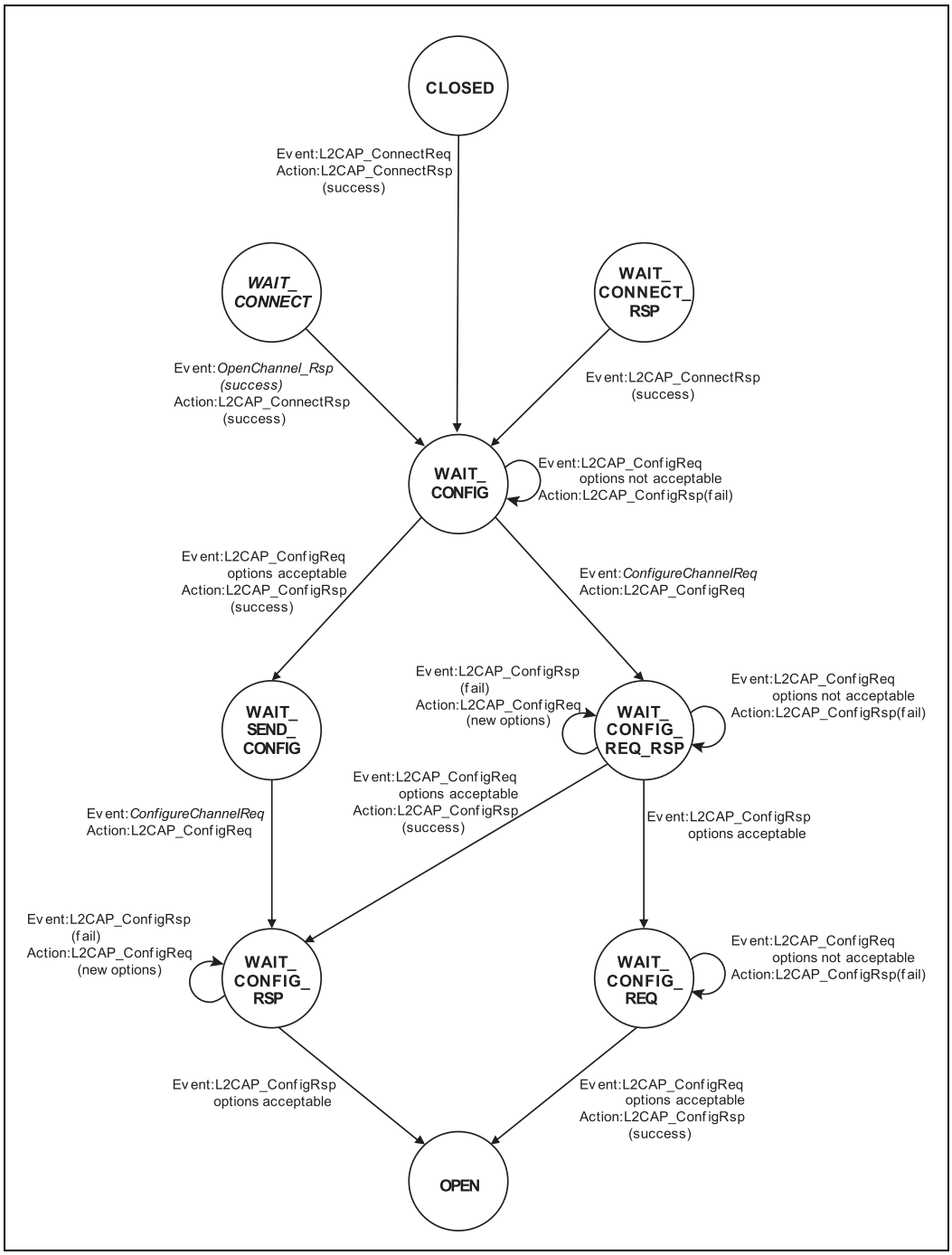


Figure 6.2: Configuration states and transitions.

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7 GENERAL PROCEDURES

This section describes the general operation of L2CAP, including the configuration process, the handling and the processing of user data for transportation over the air interface. This section also describes the operation of L2CAP features including the delivery of erroneous packets, the flushing of expired data and operation in connectionless mode.

Procedures for the flow control and retransmission modes are described in Section 8 on page 87.

7.1 CONFIGURATION PROCESS

Configuring the channel parameters shall be done independently for both directions. Both configurations may be done in parallel. For each direction the following procedure shall be used:

1. Informing the remote side of the non-default parameters that the local side will accept using a Configuration Request
2. Remote side responds, agreeing or disagreeing with these values, including the default ones, using a Configuration Response.
3. The local and remote devices repeat steps (1) and (2) until agreement on all parameters is reached.

This process can be abstracted into the initial Request configuration path and a Response configuration path, followed by the reverse direction phase. Reconfiguration follows a similar two-phase process by requiring configuration in both directions.

The decision on the amount of time (or messages) spent configuring the channel parameters before terminating the configuration is left to the implementation, but it shall not last more than 120 seconds.

7.1.1 Request path

The Request Path can configure the following:

- requester's incoming MTU.
- requester's outgoing flush timeout.
- requester's outgoing QoS.
- requester's incoming flow and error control information.

Table 7.1 on page 80 defines the configuration options that may be placed in a Configuration Request.

Parameter	Description
MTU	Incoming MTU information
FlushTO	Outgoing flush timeout
QoS	Outgoing QoS information
RFCMode	Incoming Retransmission and Flow Control Mode

Table 7.1: Parameters allowed in Request

The state machine for the configuration process is described in Section 6 on page 67.

7.1.2 Response path

The Response Path can configure the following:

- responder's outgoing MTU, that is the remote side's incoming MTU.
- remote side's flush timeout.
- responder's incoming QoS Flow Specification (remote side's outgoing QoS Flow Specification).
- responder's Outgoing Flow and Error Control information

If a request-oriented parameter is not present in the Request message (reverts to last agreed value), the remote side may negotiate for a non-default value by including the proposed value in a negative Response message.

Parameter	Description
MTU	Outgoing MTU information
FlushTO	Incoming flush timeout
QoS	Incoming QoS information
RFCMode	Outgoing Retransmission and Flow Control Mode

Table 7.2: Parameters allowed in Response

7.2 FRAGMENTATION AND RECOMBINATION

Fragmentation is the breaking down of PDUs into smaller pieces for delivery from L2CAP to the lower layer. Recombination is the process of reassembling a PDU from fragments delivered up from the lower layer. Fragmentation and Recombination may be applied to any L2CAP PDUs.

7.2.1 Fragmentation of L2CAP PDUs

An L2CAP implementation may fragment any L2CAP PDU for delivery to the lower layers. If L2CAP runs directly over the link controller protocol, then an implementation may fragment the PDU into multiple baseband packets for transmission over the air. If L2CAP runs above the host controller interface, then an implementation may send HCI transport sized fragments to the Controller which passes them to the baseband. All L2CAP fragments associated with an L2CAP PDU shall be passed to the baseband before any other L2CAP PDU for the same logical transport shall be sent.

The two LLID bits defined in the first octet of baseband payload (also called the frame header) are used to signal the start and continuation of L2CAP PDUs. LLID shall be ’10’ for the first segment in an L2CAP PDU and ’01’ for a continuation segment. An illustration of fragmentation is shown in Figure 7.1 on page 81. An example of how fragmentation might be used in a device with HCI is shown in Figure 7.2 on page 82.

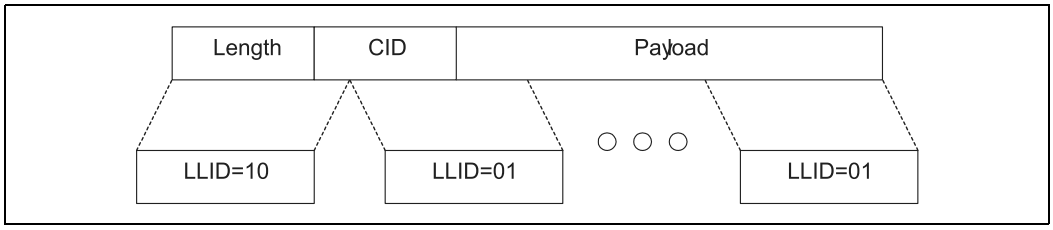


Figure 7.1: L2CAP fragmentation.

Note: The link controller is able to impose a different fragmentation on the PDU by using "start" and "continuation" indications as fragments are translated into baseband packets. Thus, both L2CAP and the link controller use the same mechanism to control the size of fragments.

7.2.2 Recombination of L2CAP PDUs

The link controller protocol attempts to deliver ACL packets in sequence and protects the integrity of the data using a 16-bit CRC. When errors are detected by the baseband it uses an automatic repeat request (ARQ) mechanism.

Recombination of fragments may occur in the Controller but ultimately it is the responsibility of L2CAP to reassemble PDUs and SDUs and to check the length field of the SDUs. As the baseband controller receives ACL packets, it either signals the L2CAP layer on the arrival of each baseband packet, or accumulates a number of packets (before the receive buffer fills up or a timer expires) before passing fragments to the L2CAP layer.

An L2CAP implementation shall use the length field in the header of L2CAP PDUs, see Section 3 on page 33, as a consistency check and shall discard any L2CAP PDUs that fail to match the length field. If channel reliability is not needed, packets with invalid lengths may be silently discarded. For reliable channels, an L2CAP implementation shall indicate to the upper layer that the channel has become unreliable. Reliable channels are defined by having an infinite flush timeout value as specified in Section 5.2 on page 59. For higher data integrity L2CAP should be operated in the Retransmission Mode.

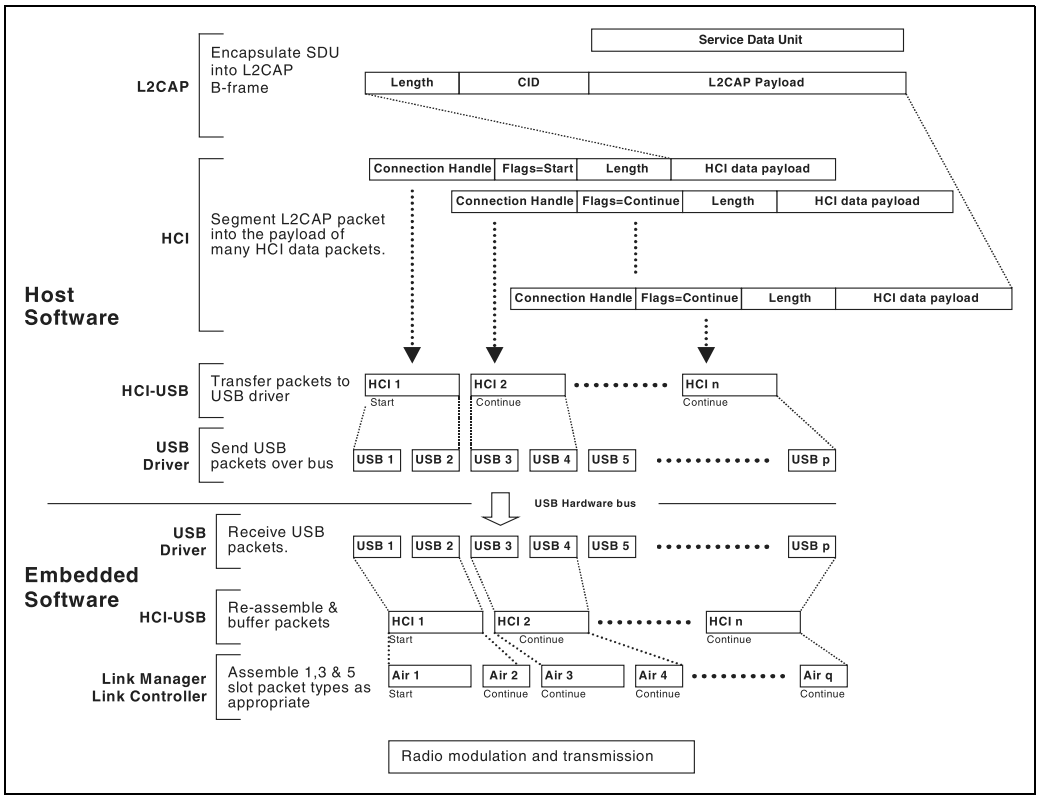


Figure 7.2: Example of fragmentation processes in a device with HCI.

7.3 ENCAPSULATION OF SDUs

All SDUs are encapsulated into one or more L2CAP PDUs.

In Basic L2CAP mode, an SDU shall be encapsulated with a minimum of L2CAP protocol elements, resulting in a type of L2CAP PDU called a Basic Information Frame (B-frame).

Segmentation and Reassembly operations are only used in Retransmission mode and Flow Control mode. SDUs may be segmented into a number of smaller packets called SDU segments. Each segment shall be encapsulated with L2CAP protocol elements resulting in an L2CAP PDU called an Information Frame (I-frame).

The maximum size of an SDU segment shall be given by the Maximum PDU Payload Size (MPS). The MPS parameter may be exported using an implementation specific interface to the upper layer.

Note that this specification does not have a normative service interface with the upper layer, nor does it assume any specific buffer management scheme of a host implementation. Consequently, a reassembly buffer may be part of the upper layer entity. It is assumed that SDU bounderies shall be preserved between peer upper layer entities.

7.3.1 Segmentation of L2CAP SDUs

In Flow Control or Retransmission modes, incoming SDUs may be broken down into segments, which shall then be individually encapsulated with L2CAP protocol elements (header and checksum fields) to form I-frames. I-frames are subject to flow control and may be subject to retransmission procedures. The header carries a 2 bit SAR field that is used to identify whether the I-frame is a 'start', 'end' or 'continuation' packet or whether it carries a complete, unsegmented SDU. Figure 7.3 on page 83 illustrates segmentation and fragmentation.

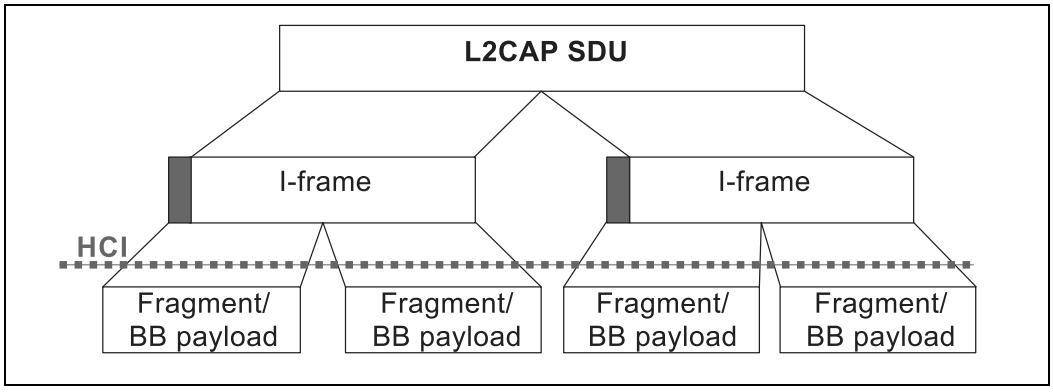


Figure 7.3: Segmentation and fragmentation of an SDU.

7.3.2 Reassembly of L2CAP SDUs

The receiving side uses the SAR field of incoming 'I-frames' for the reassembly process. The L2CAP SDU length field, present in the "start of SDU" I-frame, is an extra integrity check, and together with the sequence numbers may be used to indicate lost L2CAP SDUs to the application. Figure 7.3 on page 83 illustrates segmentation and fragmentation.

7.3.3 Segmentation and fragmentation

Figure 7.4 on page 84 illustrates the use of segmentation and fragmentation operations to transmit a single SDU. Note that while SDUs and L2CAP PDUs are transported in peer-to-peer fashion, the fragment size used by the Fragmentation and Recombination routines is implementation specific and may not be the same in the sender and the receiver. The over-the-air sequence of baseband packets as created by the sender is common to both devices.

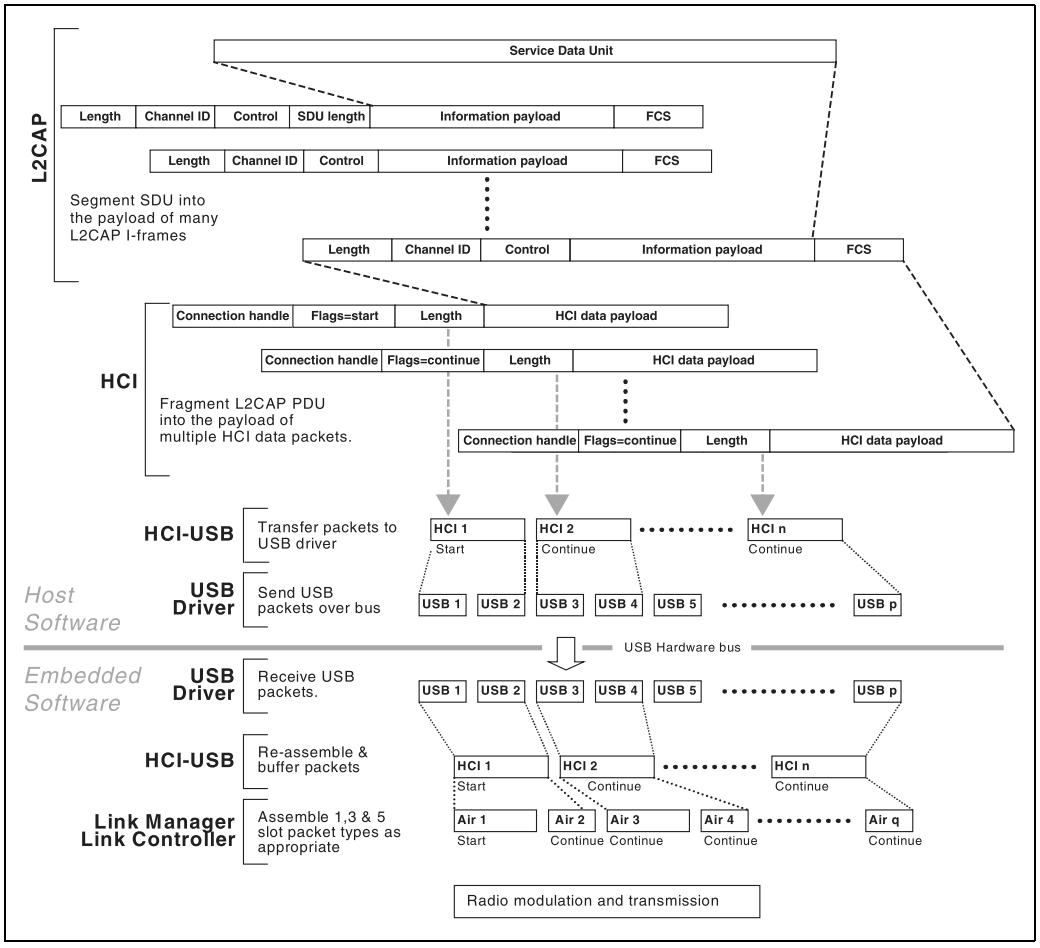


Figure 7.4: Example of segmentation and fragment processes in a device with HCI[1]

1. For simplicity, the stripping of any additional HCI and USB specific information fields prior to the creation of the baseband packets (Air_1, Air_2, etc.) is not shown in the figure.

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7.4 DELIVERY OF ERRONEOUS L2CAP SDUS

Some applications may require corrupted or incomplete L2CAP SDUs to be delivered to the upper layer. If delivery of erroneous L2CAP SDUs is enabled, the receiving side will pass information to the upper layer on which parts of the L2CAP SDU (i.e., which L2CAP frames) have been lost, failed the error check, or passed the error check. If delivery of erroneous L2CAP SDUs is disabled, the receiver shall discard any L2CAP SDU segment with any missing frames or any frames failing the error checks. L2CAP SDUs whose length field does not match the actual frame length shall also be discarded.

7.5 OPERATION WITH FLUSHING

In the L2CAP configuration, the Flush Time-Out may be set separately per L2CAP channel, but there is only one flush mechanism per ACL logical transport in the baseband.

When there is more than one L2CAP channel mapped to the same ACL logical transport, the automatic flush time-out does not discriminate between L2CAP channels. The automatic flush time-out flushes a specific L2CAP PDU. The HCI Flush command flushes all outstanding L2CAP PDUs for the ACL logical transport. Therefore, care has to be taken when using the Automatic Flush Time-out and the HCI Flush command:

1. For any connection to be reliable at the L2CAP level, it should use L2CAP retransmission mode if it is mapped to an ACL logical transport with a finite automatic flush time-out. In retransmission mode, loss of flushed L2CAP PDUs on the channel is detected by the L2CAP ARQ mechanism and they are retransmitted.
2. There is only one automatic flush time-out setting per ACL logical transport. Therefore, all time bounded L2CAP channels on an ACL logical transport with a flush time-out setting should configure the same flush time-out value at the L2CAP level.
3. If Automatic Flush Time-out is used, then it should be taken into account that it only flushes one L2CAP PDU. If one PDU has timed out and needs flushing, then others on the same logical transport are also likely to need flushing. Therefore, when retransmission mode is used, flushing should be handled by the HCI Flush command so that all outstanding L2CAP PDUs are flushed.

7.6 CONNECTIONLESS DATA CHANNEL

In addition to connection-oriented channels, L2CAP also has a connectionless channel. The connectionless channel allows transmission to all members of the piconet. Data sent through the connectionless channel is sent in a best-effort manner. The connectionless channel has no quality of service and is unreliable. L2CAP makes no guarantee that data sent through the connectionless channel successfully reaches all members of the piconet. If reliable group transmission is required, it must be implemented at a higher layer.

Transmissions to the connectionless channel will be sent to all members of the piconet. If this data is not for transmission to all members of the piconet, then higher level encryption is required to support private communication.

The local device will not receive transmissions on the conectionless channel, therefore, higher layer protocols must loopback any data traffic being sent to the local device.

An L2CAP service interface could provide basic group management mechanisms including creating a group, adding members to a group, and removing members from a group.

Connectionless data channels shall not be used with Retransmission Mode or Flow Control Mode.

8 PROCEDURES FOR FLOW CONTROL AND RETRANSMISSION

When Flow Control mode or Retransmission mode is used, the procedures defined in this chapter shall be used. Including the numbering of information frames, the handling of SDU segmentation and reassembly, and the detection and notification of errored frames. Retransmission mode also allows the sender to resend errored frames on request from the receiver.

8.1 INFORMATION RETRIEVAL

Before attempting to configure flow control- or retransmission mode on a channel, it is mandatory to verify that the suggested mode is supported by performing an information retrieval for the "Extended features supported" information type (0x0002). If the information retrieval is not successful or the "Extended features mask" bit is not set for the wanted mode, the mode shall not be suggested in a configuration request.

8.2 FUNCTION OF PDU TYPES FOR FLOW CONTROL AND RETRANSMISSION

Two frame formats are defined for flow control and retransmission modes (see Section 3.3 on page 35). The I-frame is used to transport user information instead of the B-frame. The S-frame is used for signalling.

8.2.1 Information frame (I-frame)

I-frames are sequentially numbered frames containing information fields. I-frames also include the functionality of RR frames (see below).

8.2.2 Supervisory Frame (S-frame)

The S-frame is used to control the transmission of I-frames. The S-frame has two formats: Receiver Ready (RR) and Reject (REJ).

8.2.2.1 Receiver Ready (RR)

The receiver ready (RR) S-frame is used to:

1. Acknowledge I-frames numbered up to and including ReqSeq - 1.
2. Enable or disable retransmission of I-frames by updating the receiver with the current status of the Retransmission Disable Bit.

The RR frame has no information field.

8.2.2.2 Reject (REJ)

The reject (REJ) S-frame is used to request retransmission of all I-frames starting with the I-frame with TxSeq equal to ReqSeq specified in the REJ. The value of ReqSeq in the REJ frame acknowledges I-frames numbered up to and including ReqSeq - 1. I-frames that have not been transmitted, shall be transmitted following the retransmitted I-frames.

When a REJ is transmitted, it triggers a REJ Exception condition. A second REJ frame shall not be transmitted until the REJ Exception condition is cleared. The receipt of an I-frame with a TxSeq equal to the ReqSeq of the REJ frame clears the REJ Exception. The REJ Exception condition only applies to traffic in one direction. Note: this means that only valid I-frames can be rejected.

8.3 VARIABLES AND SEQUENCE NUMBERS

The sending peer uses the following variables and Sequence numbers:

- TxSeq – the send Sequence number used to sequentially number each new I-frame transmitted.
- NextTxSeq – the Sequence number to be used in the next new I-frame transmitted.
- ExpectedAckSeq – the Sequence number of the next I-frame expected to be acknowledged by the receiving peer.

The receiving peer uses the following variables and Sequence numbers:

- ReqSeq – The Sequence number sent in an acknowledgement frame to request transmission of I-frame with TxSeq = ReqSeq and acknowledge receipt of I-frames up to and including (ReqSeq-1)
- ExpectedTxSeq – the value of TxSeq expected in the next I-frame.
- BufferSeq – When segmented I-frames are buffered this is used to delay acknowledgement of received I-frame so that new I-frame transmissions do not cause buffer overflow.

All variables have the range 0 to 63. Arithmetic operations on state variables (NextTXSeq, ExpectedTxSeq, ExpectedAckSeq, BufferSeq) and sequence numbers (TxSeq, ReqSeq) contained in this document shall be taken modulo 64.

To perform Modulo 64 operation on negative numbers multiples of 64 shall be added to the negative number until the result becomes non-negative.

8.3.1 Sending peer

8.3.1.1 Send sequence number TxSeq

I-frames contain TxSeq, the send sequence number of the I-frame. When an I-frame is first transmitted, TxSeq is set to the value of the send state variable NextTXSeq. TxSeq is not changed if the I-frame is retransmitted.

8.3.1.2 Send state variable NextTXSeq

The CID sent in the information frame is the destination CID and identifies the remote endpoint of the channel. A send state variable NextTxSeq shall be maintained for each remote endpoint. NextTxSeq is the sequence number of the next in-sequence I-frame to be transmitted to that remote endpoint. When the link is created NextTXSeq shall be initialized to 0.

The value of NextTxSeq shall be incremented by 1 after each in-sequence I-frame transmission, and shall not exceed ExpectedAckSeq by more than the maximum number of outstanding I-frames (TxWindow). The value of TxWindow shall be in the range 1 to 32.

8.3.1.3 Acknowledge state variable ExpectedAckSeq

The CID sent in the information frame is the destination CID and identifies the remote endpoint of the channel. An acknowledge state variable ExpectedAckSeq shall be maintained for each remote endpoint. ExpectedAckSeq is the sequence number of the next in-sequence I-frame that the remote receiving peer is expected to acknowledge. (ExpectedAckSeq – 1 equals the TxSeq of the last acknowledged I-frame). When the link is created ExpectedAckSeq shall be initialized to 0.
Note that if the next acknowledgement acknowledges a single I-frame then it's ReqSeq will be expectedAckSeq + 1.

If a valid ReqSeq is received from the peer then ExpectedAckSeq is set to ReqSeq. A valid ReqSeq value is one that is in the range ExpectedAckSeq ≤ ReqSeq ≤ NextTxSeq.

Note: The comparison with NextTXSeq must be ≤ in order to handle the situations where there are no outstanding I-frames.

These inequalities shall be interpreted in the following way: ReqSeq is valid, if and only if (ReqSeq-ExpectedAckSeq) mod 64 ≤ (NextTXSeq-ExpectedAckSeq) mod 64. Furthermore, from the description of NextTXSeq, it can be seen that (NextTXSeq-ExpectedAckSeq) mod 64 ≤ TxWindow.

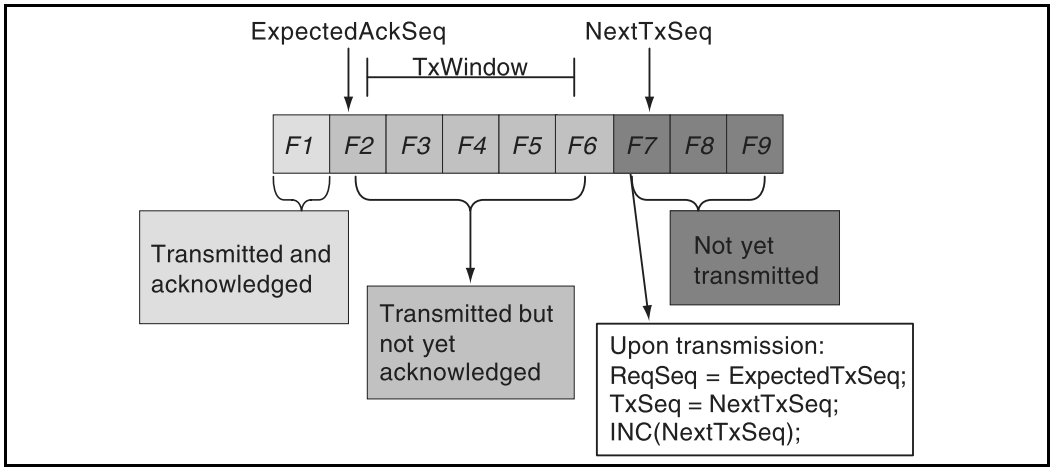


Figure 8.1: Example of the transmitter side

Figure 8.1 on page 90 shows TxWindow=5, and three frames awaiting transmission. The frame with number *F7* may be transmitted when the frame with *F2* is acknowledged. When the frame with *F7* is transmitted, TxSeq is set to the value of NextTXSeq. After TxSeq has been set, NextTxSeq is incremented.

The sending peer expects to receive legal ReqSeq values, these are in the range ExpectedAckSeq up to and including NextTxSeq. Upon receipt of a ReqSeq value equal to the current NextTxSeq all outstanding I-frames have been acknowledged by the receiver.

8.3.2 Receiving peer

8.3.2.1 Receive sequence number ReqSeq

All I-frames and S-frames contain ReqSeq, the send Sequence number (TxSeq) that the receiving peer requests in the next I-frame.

When an I-frame or an S-frame is transmitted, the value of ReqSeq shall be set to the current value of the receive state variable ExpectedTxSeq or the buffer state variable BufferSeq. The value of ReqSeq shall indicate that the data link layer entity transmitting the ReqSeq has correctly received all I-frames numbered up to and including ReqSeq – 1.

Note: The option to set ReqSeq to BufferSeq instead of ExpectedTxSeq allows the receiver to impose flow control for buffer management or other purposes. In this situation, if BufferSeq<>ExpectedTxSeq, the receiver should also set the retransmission disable bit to 1 to prevent unnecessary retransmissions.

8.3.2.2 Receive state variable, ExpectedTxSeq

Each channel shall have a receive state variable (ExpectedTxSeq). The receive state variable is the sequence number (TxSeq) of the next in-sequence I-frame expected.

The value of the receive state variable shall be the last in-sequence, valid I-frame received.

8.3.2.3 Buffer state variable BufferSeq

Each channel may have an associated BufferSeq. BufferSeq is used to delay acknowledgement of frames until they have been pulled by the upper layers, thus preventing buffer overflow. BufferSeq and ExpectedTxSeq are equal when there is no extra segmentation performed and frames are pushed to the upper layer immediately on reception. When buffer space is scarce, for example when frames reside in the buffer for a period, the receiver may choose to set ReqSeq to BufferSeq instead of ExpectedTxSeq, incrementing BufferSeq as buffer space is released. The windowing mechanism will ensure that transmission is halted when ExpectedTxSeq - BufferSeq is equal to TxWindow.

Note: Owing to the variable size of I-frames, updates of BufferSeq may be based on changes in available buffer space instead of delivery of I-frame contents.

I-Frames shall have sequence numbers in the range ExpectedTxSeq ≤ TxSeq < (BufferSeq + TxWindow).

On receipt of an I-frame with TxSeq equal to ExpectedTxSeq, ExpectedTxSeq shall be incremented by 1 regardless of how many I-frames with TxSeq greater than ExpectedTxSeq were previously received.

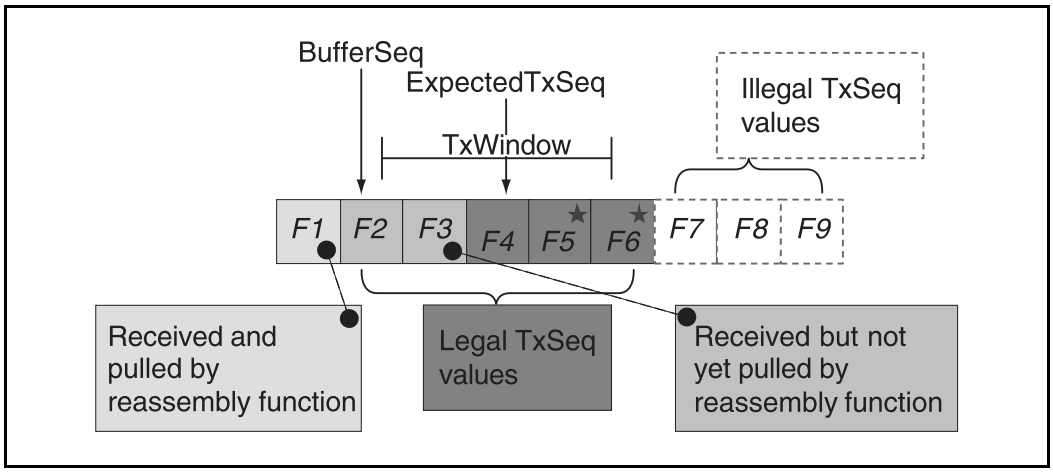


Figure 8.2: Example of the receiver side

Figure 8.2 on page 92 shows TxWindow=5. *F1* is successfully received and pulled by the upper layer. BufferSeq shows that *F2* is the next I-frame to be pulled, and ExpectedTxSeq points to the next I-frame expected from the peer. An I-frame with TxSeq equal to 5 has been received thus triggering an REJ exception. The star indicates I-frames received but discarded owing to the REJ exception. They will be resent as part of the error recovery procedure.

In Figure 8.2 on page 92 there are several I-frames in a buffer awaiting the SDU reassembly function to pull them and the TxWindow is full. The receiver would usually disable retransmission by setting the Retransmission Disable Bit to 1 and send an RR back to the sending side. This tells the transmitting peer that there is no point in performing retransmissions. Both sides will send S-frames to make sure the peer entity knows the current value of the Retransmission Disable Bit.

8.4 RETRANSMISSION MODE

8.4.1 Transmitting frames

A new I-frame shall only be transmitted when the TxWindow is not full. No I-frames shall be transmitted if the last RetransmissionDisableBit (R) received is set to one.

A previously transmitted I-frame may be retransmitted as a result of an error recovery procedure, even if the TxWindow is full. When an I-frame is retransmitted it shall always be sent with the same TxSeq value used in its initial transmission.

The state of the RetransmissionDisableBit (R) is stored and used along with the state of the RetransmissionTimer to decide the actions when transmitting I-frames. The RetransmissionTimer is running whenever I-frames have been sent but not acknowledged.

8.4.1.1 Last received R was set to zero

If the last R received was set to zero, then I-frames may be transmitted. If there are any I-frames which have been sent and not acknowledged then they shall be retransmitted when the RetransmissionTimer elapses. If the retransmission timer has not elapsed then a retransmission shall not be sent and only new I-frames may be sent.

a) If unacknowledged I-frames have been sent and the RetransmissionTimer has elapsed then an unacknowledged I-frame shall be retransmitted. The RetransmissionTimer shall be restarted.

b) If unacknowledged I-frames have been sent, the Retransmission timer has not elapsed then a new I-frame shall be sent if one is waiting and no timer action shall be taken.

c) If no unacknowledged I-frames have been sent, and a new I-frame is waiting, then the new I-frame shall be sent, the RetransmissionTimer shall be started and if the MonitorTimer is running, it shall be stopped.

d) If no unacknowledged I-frames have been sent and and no new I-frames are waiting to be transmitted, and the RetransmissionTimer is running, then the retransmission timer shall be stopped and the monitor timer shall be started.

The table below summarizes actions when the RetransmissionTimer is in use and R=0.

Unacknowledged I-frames sent = Retransmission Timer is running	Retrans-mission Timer has elapsed	New I-frames are waiting	Transmit Action	Timer Action
True	True	True or False	Retransmit un-acknowledged I-frame	Restart Retransmission Timer
True	False	True	Transmit new I-frame	No timer action
True	False	False	No transmit action	No Timer action
False	False	True	Transmit new I-frame	Restart Retransmis-sion Timer
False	False	False	No Transmit action	If MonitorTimer is not running then restart MonitorTimer

Table 8.1: Summary of actions when the RetransmissionTimer is in use and R=0.

If the RetransmissionTimer is not in use, no unacknowledged I-frames have been sent and no new I-frames are waiting to be transmitted

a) If the MonitorTimer is running and has not elapsed then no transmit action shall be taken and no timer action shall be taken.

b) If the MonitorTimer has elapsed then an S-frame shall be sent and the MonitorTimer shall be restarted.

If any I-frames become available for transmission then the MonitorTimer shall be stopped, the RetransmissionTimer shall be started and the rules for when the RetransmissionTimer is in use shall be applied.

When an I-frame is sent ReqSeq shall be set to ExpectedTxSeq, TxSeq shall be set to NextTxSeq and NextTxSeq shall be incremented by one.

8.4.1.2 Last received R was set to one

If the last R received was set to one, then I-frames shall not be transmitted. The only frames which may be sent are S-frames. An S-frame shall be sent according to the rules below:

a) If the MonitorTimer is running and has not elapsed then no transmit action shall be taken and no timer action shall be taken.

b) If the MonitorTimer has elapsed then an S-frame shall be sent and the MonitorTimer shall be restarted.

8.4.2 Receiving I-frames

Upon receipt of a valid I-frame with TxSeq equal to ExpectedTxSeq, the frame shall be accepted for the SDU reassembly function. ExpectedTxSeq is used by the reassembly function.

The first valid I-frame received after an REJ was sent, with a TxSeq of the received I-frame equal to ReqSeq of the REJ, shall clear the REJ Exception condition.

The ReqSeq shall be processed according to Section 8.4.6 on page 97.

If a valid I-frame with TxSeq ≠ ExpectedTxSeq is received then an exception condition shall be triggered which is handled according to Section 8.4.7 on page 97.

8.4.3 I-frames pulled by the SDU reassembly function

When the L2CAP layer has removed one or more I-frames from the buffer, BufferSeq may be incremented in accordance with the amount of buffer space released. If BufferSeq is incremented, an acknowledgement shall be sent to the peer entity.

Note: Since the primary purpose of BufferSeq is to prevent buffer overflow, an implementation may choose to set BufferSeq in accordance with how many new incoming I-frames could be stored rather than how many have been removed.

The acknowledgement may either be an RR or an I-frame. The acknowledgement shall be sent to the peer L2CAP entity with ReqSeq equal to BufferSeq. When there are no I-frames buffered for pulling ExpectedTxSeq is equal to BufferSeq.

If the MonitorTimer is active then it shall be restarted to indicate that a signal has been sent to the peer L2CAP entity.

8.4.4 Sending and receiving acknowledgements

Either the MonitorTimer or the RetransmissionTimer shall be active while in Retransmission Mode. Both timers shall not be active concurrently.

8.4.4.1 Sending acknowledgements

Whenever an L2CAP entity transmits an I-frame or an S-frame, ReqSeq shall be set to ExpectedTxSeq or BufferSeq.

8.4.4.2 Receiving acknowledgements

On receipt of a valid S-frame or I-frame, the ReqSeq contained in the frame shall acknowledge previously transmitted I-frames. ReqSeq acknowledges I-frames with a TxSeq up to and including ReqSeq – 1.

The following rules shall be applied:

1. If the RetransmissionDisableBit changed value from 0 to 1 (stop retransmissions) then the receiving entity shall
    a) If the RetransmissionTimer is running then stop it and start the MonitorTimer.
    b) Store the state of the RetransmissionDisableBit received.
2. If the RetransmissionDisableBit changed value from 1 to 0 (start retransmissions) then the receiving entity shall
    a) Store the state of the RetransmissionDisableBit received.
    b) If there are any I-frames that have been sent but not acknowledged, then stop the MonitorTimer and start the RetransmissionTimer.
    c) Any buffered I-frames shall be transmitted according to Section 8.4.1 on page 93.
3. If any unacknowledged I-frames were acknowledged by the ReqSeq contained in the frame, and the RetransmissionDisableBit equals 1 (retransmissions stopped), then the receiving entity shall
    a) Follow the rules in Section 8.4.1 on page 93.
4. If any unacknowledged I-frames were acknowledged by the ReqSeq contained in the frame and the RetransmissionDisableBit equals 0 (retransmissions started) then the receiving entity shall
    a) If the RetransmissionTimer is running, then stop it.
    b) If any unacknowledged I-frames have been sent then the RetransmissionTimer shall be restarted.

c) Follow the rules in Section 8.4.1 on page 93.

d) If the RetransmissionTimer is not running and the MonitorTimer is not running, then start the MonitorTimer.

On receipt of a valid S-frame or I-frame the ReqSeq contained in the frame shall acknowledge previously transmitted I-frames. ExpectedAckSeq shall be set to ReqSeq to indicate that the I-frames with TxSeq up to and including (ReqSeq - 1) have been acknowledged.

8.4.5 Receiving REJ frames

Upon receipt of a valid REJ frame, where ReqSeq identifies an I-frame not yet acknowledged, the ReqSeq acknowledges I-frames with TxSeq up to and including ReqSeq - 1. Therefore the REJ acknowledges all I-frames before the I-frame it is rejecting.

ExpectedAckSeq shall be set equal to ReqSeq to mark I-frames up to and including ReqSeq - 1 as received.

NextTXSeq shall be set to ReqSeq to cause transmissions of I-frames to resume from the point where TxSeq equals ReqSeq.

If ReqSeq equals ExpectedAckSeq then the REJ frame shall be ignored.

8.4.6 Waiting acknowledgements

A counter, TransmitCounter, counts the number of times an L2CAP PDU has been transmitted. This shall be set to 1 after the first transmission. If the RetransmissionTimer expires the following actions shall be taken:

1. If the TransmitCounter is less than MaxTransmit then:

   a) Increment the TransmitCounter

   b) Retransmit the last unacknowledged I-frame, according to Section 8.4.1 on page 93.

2. If the TransmitCounter is equal to MaxTransmit this channel to the peer entity shall be assumed lost. The channel shall move to the CLOSED state and appropriate action shall be taken to report this to the upper layers.

8.4.7 Exception conditions

Exception conditions may occur as the result of physical layer errors or L2CAP procedural errors. The error recovery procedures which are available following the detection of an exception condition at the L2CAP layer in Retransmission Mode are defined in this section.

8.4.7.1 TxSeq Sequence error

A TxSeq sequence error exception condition occurs in the receiver when a valid I-frame is received which contains a TxSeq value which is not equal to the expected value, thus TxSeq is not equal to ExpectedTxSeq.

The TxSeq sequence error may be due to three different causes:

- *Duplicated I-frame*

  The duplicated I-frame is identified by a TxSeq in the range BufferSeq to ExpectedTxSeq – 1 (BufferSeq ≤TxSeq<ExpectedTxSeq). The ReqSeq and RetransmissionDisableBit shall be processed according to Section 8.4.4 on page 96. The Information field shall be discarded since it has already been received.

- *Out-of-sequence I-frame*

  The out-of-sequence I-frame is identified by a TxSeq within the legal range. The ReqSeq and RetransmissionDisableBit shall be processed according to Section 8.4.4 on page 96.

  A REJ exception is triggered, and an REJ frame with ReqSeq equal to ExpectedTxSeq shall be sent to initiate recovery. The received I-frame shall be discarded.

- *Invalid TxSeq*

  An invalid TxSeq value is a value that does not meet either of the above conditions. An I-frame with an invalid TxSeq is likely to have errors in the control field and shall be silently discarded.

8.4.7.2 ReqSeq Sequence error

An ReqSeq sequence error exception condition occurs in the transmitter when a valid S-frame or I-frame is received which contains an invalid ReqSeq value. An invalid ReqSeq is one that is not in the range ExpectedAckSeq ≤ ReqSeq ≤ NextTxSeq.

The L2CAP entity shall close the channel as a consequence of an ReqSeq Sequence error.

8.4.7.3 Timer recovery error

If an L2CAP entity fails to receive an acknowledgement for the last I-frame sent, then it will not detect an out-of-sequence exception condition and therefore will not transmit an REJ frame.

The L2CAP entity that transmitted an unacknowledged I-frame shall, on the expiry of the RetransmissionTimer, take appropriate recovery action as defined in Section 8.4.6 on page 97.

8.4.7.4 Invalid frame

Any frame received which is invalid (as defined in Section 3.3.6 on page 40) shall be discarded, and no action shall be taken as a result of that frame.

8.5 FLOW CONTROL MODE

When a link is configured to work in flow control mode, the flow control operation is similar to the procedures in retransmission mode, but all operations dealing with CRC errors in received packets are not used. Therefore

- REJ frames shall not be used in Flow Control Mode.
- The RetransmissionDisableBit shall always be set to zero in the transmitter, and shall be ignored in the receiver.

The behaviour of flow control mode is specified in this section.

Assuming that the TxWindow size is equal to the buffer space available in the receiver (counted in number of I-frames), in flow control mode the number of unacknowledged frames in the transmitter window is always less than or equal to the number of frames for which space is available in the receiver. Note that a missing frame still occupies a place in the window.

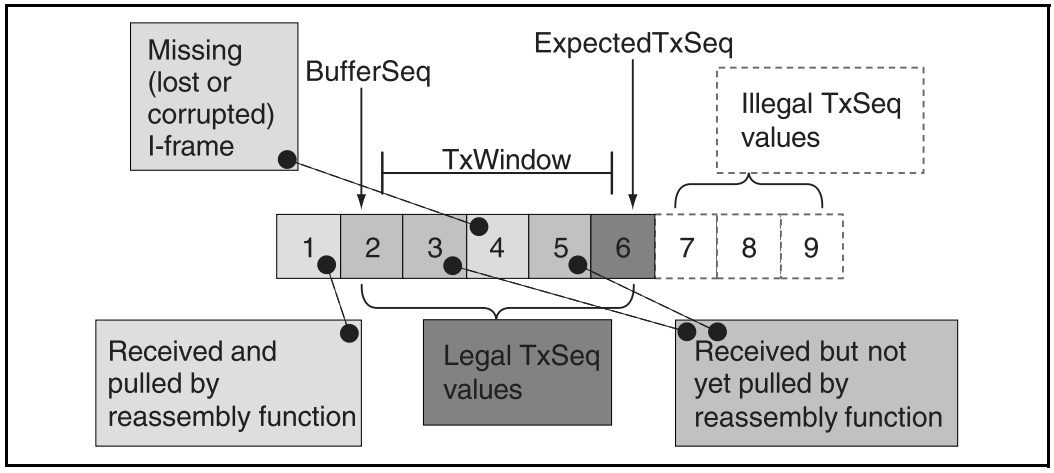


Figure 8.3: Overview of the receiver side when operating in flow control mode

8.5.1 Transmitting I-frames

A new I-frame shall only be transmitted when the TxWindow is not full.

Upon transmission of the I-frame the following actions shall be performed:

- If no unacknowledged I-frames have been sent then the MonitorTimer shall be stopped and the RetransmissionTimer shall be started.
- If any I-frames have been sent and not acknowledged then the RetransmissionTimer remains active and no timer operation is performed.

The control field parameter ReqSeq shall be set to ExpectedTxSeq, TxSeq shall be set to NextTXSeq and NextTXSeq shall be incremented by one.

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8.5.2 Receiving I-frames

Upon receipt of a valid I-frame with TxSeq equal to ExpectedTxSeq, the frame shall be made available to the reassembly function. ExpectedTxSeq shall be incremented by one. An acknowledgement shall not be sent until the SDU reassembly function has pulled the I-frame.

Upon receipt of a valid I-frame with an out-of-sequence TxSeq (see Section 8.5.6 on page 101) all frames with a sequence number less than TxSeq shall be assumed lost and marked as missing. The missing I-frames are in the range from ExpectedTxSeq (the frame that the device was expecting to receive) up to TxSeq-1, (the frame that the device actually received). ExpectedTxSeq shall be set to TxSeq +1. The received I-frame shall be made available for pulling by the reassembly function. The acknowledgement shall not occur until the SDU reassembly function has pulled the I-frame. The ReqSeq shall be processed according to Section 8.5.4 on page 100.

8.5.3 I-frames pulled by the SDU reassembly function

When the L2CAP layer has removed one or more I-frames from the buffer, BufferSeq may be incremented in accordance with the amount of buffer space released. If BufferSeq is incremented, an acknowledgement shall be sent to the peer entity. If the MonitorTimer is active then it shall be restarted to indicate that a signal has been sent to the peer L2CAP entity.

Note: Since the primary purpose of BufferSeq is to prevent buffer overflow, an implementation may choose to set BufferSeq in accordance with how many new incoming I-frames could be stored rather than how many have been removed.

The acknowledgement may be an RR or an I-frame. The acknowledgement shall be sent to the peer L2CAP entity with ReqSeq equal to BufferSeq. When there is no I-frame buffered for pulling, ExpectedTxSeq is equal to BufferSeq.

8.5.4 Sending and receiving acknowledgements

One of the timers MonitorTimer or RetransmissionTimer shall always be active while in Flow Control mode. Both timers shall never be active concurrently.

8.5.4.1 Sending acknowledgements

Whenever a data link layer entity transmits an I-frame or a S-frame, ReqSeq shall be set to ExpectedTxSeq or BufferSeq.

8.5.4.2 Receiving acknowledgements

On receipt of a valid S-frame or I-frame the ReqSeq contained in the frame shall be used to acknowledge previously transmitted I-frames. ReqSeq acknowledges I-frames with a TxSeq up to and including ReqSeq – 1.

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1. If any outstanding I-frames were acknowledged then
    a) Stop the RetransmissionTimer
    b) If there are still unacknowledged I-frames then restart the RetransmissionTimer, otherwise start the MonitorTimer.
    c) Transmit any I-frames awaiting transmission according to Section 8.5.1 on page 99.

ExpectedAckSeq shall be set to ReqSeq to indicate that the I-frames with TxSeq up to and including ExpectedAckSeq have been acknowledged.

8.5.5 Waiting acknowledgements

If the RetransmissionTimer expires the following actions shall be taken:
The I-frame supervised by the RetransmissionTimer shall be considered lost, and ExpectedAckSeq shall be incremented by one.

1. If I-frames are waiting to be sent
    a) The RetransmissionTimer is restarted
    b) I-frames awaiting transmission are transmitted according to Section 8.5.1 on page 99.
2. If there are no I-frames waiting to be sent
    a) If there are still unacknowledged I-frames the RetransmissionTimer is restarted, otherwise the MonitorTimer is started.

8.5.6 Exception conditions

Exception conditions may occur as the result of physical layer errors or L2CAP procedural errors. The error recovery procedures which are available following the detection of an exception condition at the L2CAP layer in flowcontrol only mode are defined in this section.

8.5.6.1 TxSeq Sequence error

A TxSeq sequence error exception condition occurs in the receiver when a valid I-frame is received which contains a TxSeq value which is not equal to the expected value, thus TxSeq is not equal to ExpectedTxSeq.

The TxSeq sequence error may be due to three different causes:

- *Duplicated I-frame*

  The duplicated I-frame is identified by a TxSeq in the range BufferSeq to ExpectedTxSeq – 1. The ReqSeq shall be processed according to Section 8.5.4 on page 100. The Information field shall be discarded since it has already been received.

- *Out-of-sequence I-frame*

  The out-of-sequence I-frame is identified by a TxSeq within the legal range ExpectedTxSeq < TxSeq < (BufferSeq + TxWindow). The ReqSeq shall be processed according to Section 8.5.4 on page 100.

  The missing I-frame(s) are considered lost and ExpectedTXSeq is set equal to TxSeq+1 as specified in Section 8.5.2 on page 100. The missing I-frame(s) are reported as lost to the SDU reassembly function.

- *Invalid TxSeq*

  An invalid TxSeq value is a value that does not meet either of the above conditions and TxSeq is not equal to ExpectedTxSeq. An I-frame with an invalid TxSeq is likely to have errors in the control field and shall be silently discarded.

8.5.6.2 ReqSeq Sequence error

An ReqSeq sequence error exception condition occurs in the transmitter when a valid S-frame or I-frame is received which contains an invalid ReqSeq value. An invalid ReqSeq is one that is not in the range ExpectedAckSeq ≤ ReqSeq ≤ NextTXSeq.

The L2CAP entity shall close the channel as a consequence of an ReqSeq Sequence error.

8.5.6.3 Timer recovery error

An L2CAP entity that fails to receive an acknowledgement for an I-frame shall, on the expiry of the RetransmissionTimer, take appropriate recovery action as defined in Section 8.5.5 on page 101.

8.5.6.4 Invalid frame

Any frame received that is invalid (as defined in Section 3.3.6 on page 40) shall be discarded, and no action shall be taken as a result of that frame, unless the receiving L2CAP entity is configured to deliver erroneous frames to the layer above L2CAP. In that case, the data contained in invalid frames may also be added to the receive buffer and made available for pulling from the SDU reassembly function.

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APPENDIX A: CONFIGURATION MSCs

The examples in this appendix describe a sample of the multiple possible configuration scenarios that might occur.

Figure I illustrates the basic configuration process. In this example, the devices exchange MTU information. All other values are assumed to be default.

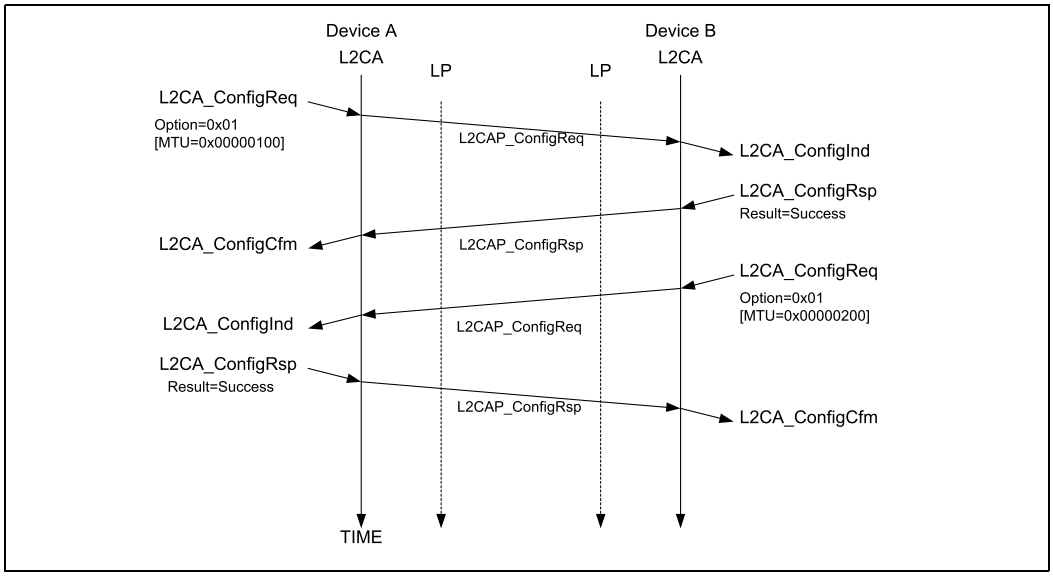


Figure I: Basic MTU exchange

Figure II on page 108 illustrates how two devices interoperate even though one device supports more options than the other does. Device A is an upgraded version. It uses a hypothetically defined option type 0x20 for link-level security. Device B rejects the command using the Configuration Response packet with result 'unknown parameter' informing Device A that option 0x20 is not understood. Device A then resends the request omitting option 0x20. Device B notices that it does not need to such a large MTU and accepts the request but includes in the response the MTU option informing Device A that Device B will not send an L2CAP packet with a payload larger than 0x80 octets over this channel. On receipt of the response, Device A could reduce the buffer allocated to hold incoming traffic.

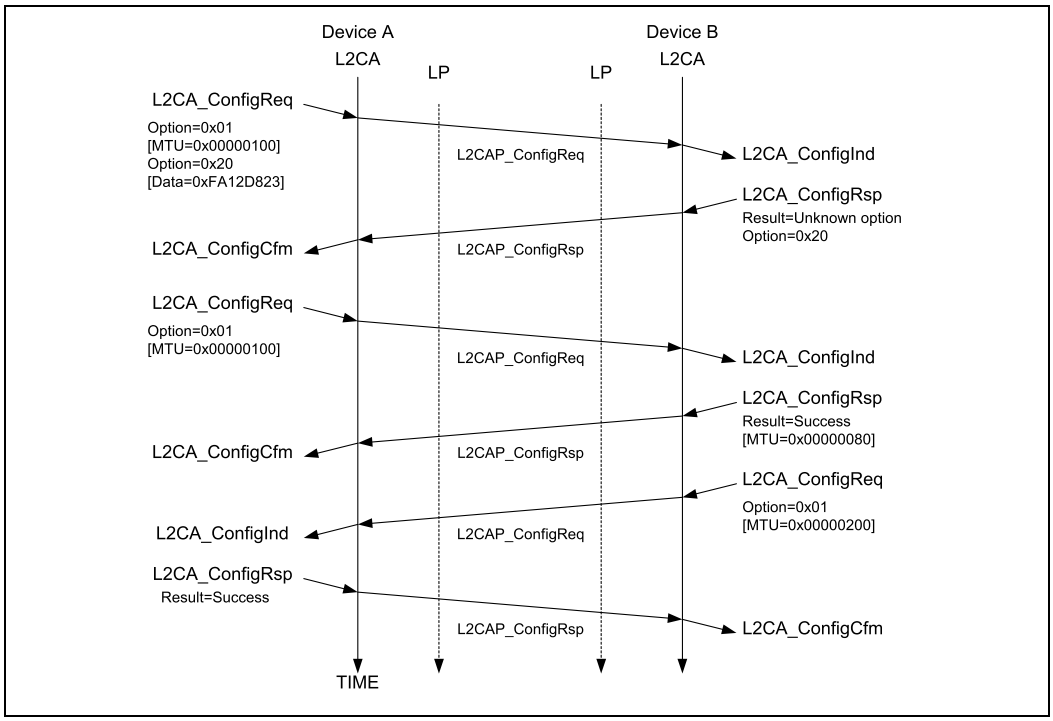


Figure II: Dealing with Unknown Options

Figure III on page 109 illustrates an unsuccessful configuration request. There are two problems described by this example. The first problem is that the configuration request is placed in an L2CAP packet that cannot be accepted by the remote device, due to its size. The remote device informs the sender of this problem using the Command Reject message. Device A then resends the configuration options using two smaller L2CAP_ConfigReq messages.

The second problem is an attempt to configure a channel with an invalid CID. For example device B may not have an open connection on that CID (0x01234567 in this example case).

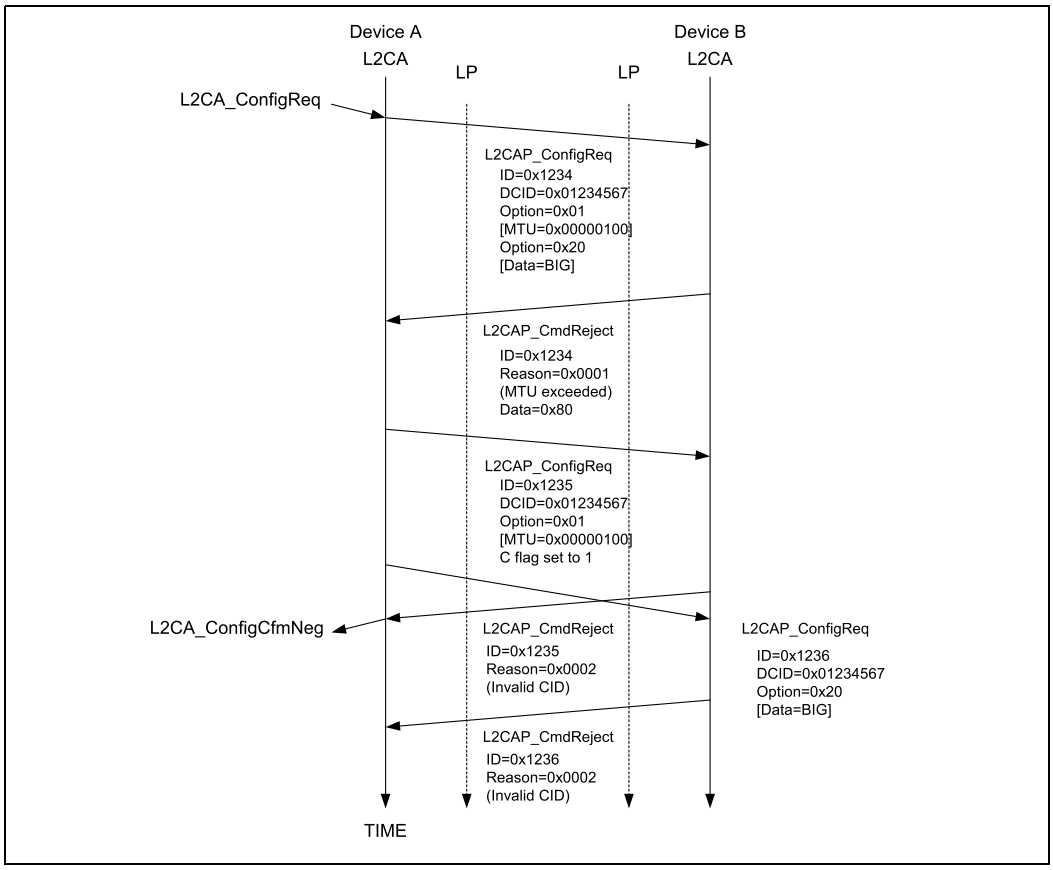


Figure III: Unsuccessful Configuration Request



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Core System Package [Host volume]
Part B



SERVICE DISCOVERY PROTOCOL (SDP)

This specification defines a protocol for locating services provided by or available through a Bluetooth device.

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1 INTRODUCTION

1.1 GENERAL DESCRIPTION

The service discovery protocol (SDP) provides a means for applications to discover which services are available and to determine the characteristics of those available services.

1.2 MOTIVATION

Service Discovery in the Bluetooth environment, where the set of services that are available changes dynamically based on the RF proximity of devices in motion, is qualitatively different from service discovery in traditional network-based environments. The service discovery protocol defined in this specification is intended to address the unique characteristics of the Bluetooth environment. See Section , “Appendix A – Background Information,” on page 157, for further information on this topic.

1.3 REQUIREMENTS

The following capabilities have been identified as requirements for version 1.0 of the Service Discovery Protocol.

1. SDP shall provide the ability for clients to search for needed services based on specific attributes of those services.
2. SDP shall permit services to be discovered based on the class of service.
3. SDP shall enable browsing of services without a priori knowledge of the specific characteristics of those services.
4. SDP shall provide the means for the discovery of new services that become available when devices enter RF proximity with a client device as well as when a new service is made available on a device that is in RF proximity with the client device.
5. SDP shall provide a mechanism for determining when a service becomes unavailable when devices leave RF proximity with a client device as well as when a service is made unavailable on a device that is in RF proximity with the client device.
6. SDP shall provide for services, classes of services, and attributes of services to be uniquely identified.
7. SDP shall allow a client on one device to discover a service on another device without consulting a third device.
8. SDP should be suitable for use on devices of limited complexity.
9. SDP shall provide a mechanism to incrementally discover information about the services provided by a device. This is intended to minimize the quantity

of data that must be exchanged in order to determine that a particular service is not needed by a client.

10. SDP should support the caching of service discovery information by intermediary agents to improve the speed or efficiency of the discovery process.
11. SDP should be transport independent.
12. SDP shall function while using L2CAP as its transport protocol.
13. SDP shall permit the discovery and use of services that provide access to other service discovery protocols.
14. SDP shall support the creation and definition of new services without requiring registration with a central authority.

1.4 NON-REQUIREMENTS AND DEFERRED REQUIREMENTS

The Bluetooth SIG recognizes that the following capabilities are related to service discovery. These items are not addressed in SDP version 1.0. However, some may be addressed in future revisions of the specification.

1. SDP 1.0 does not provide access to services. It only provides access to information about services.
2. SDP 1.0 does not provide brokering of services.
3. SDP 1.0 does not provide for negotiation of service parameters.
4. SDP 1.0 does not provide for billing of service use.
5. SDP 1.0 does not provide the means for a client to control or change the operation of a service.
6. SDP 1.0 does not provide an event notification when services, or information about services, become unavailable.
7. SDP 1.0 does not provide an event notification when attributes of services are modified.
8. This specification does not define an application programming interface for SDP.
9. SDP 1.0 does not provide support for service agent functions such as service aggregation or service registration.

1.5 CONVENTIONS

1.5.1 Bit And Byte Ordering Conventions

When multiple bit fields are contained in a single byte and represented in a drawing in this specification, the more significant (high-order) bits are shown toward the left and less significant (low-order) bits toward the right.

Multiple-byte fields are drawn with the more significant bytes toward the left and the less significant bytes toward the right. Multiple-byte fields are transferred in network byte order. See section 4.1 on page 131.

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2 OVERVIEW

2.1 SDP CLIENT-SERVER INTERACTION

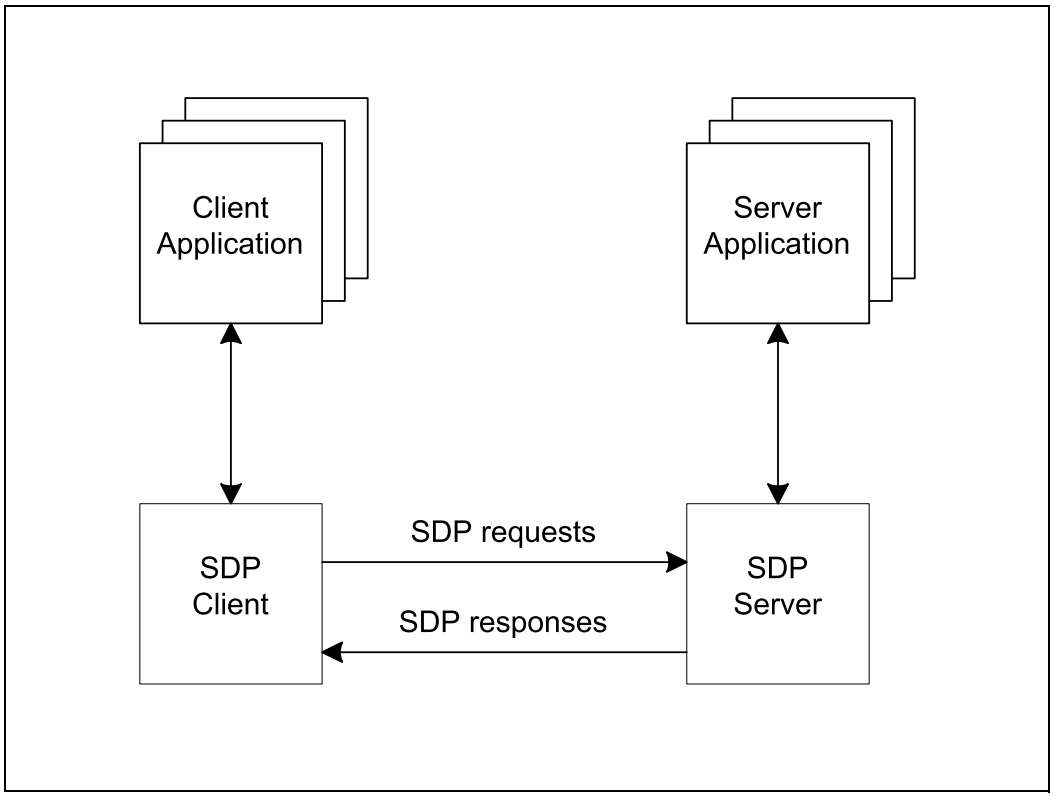


Figure 2.1:

The service discovery mechanism provides the means for client applications to discover the existence of services provided by server applications as well as the attributes of those services. The attributes of a service include the type or class of service offered and the mechanism or protocol information needed to utilize the service.

As far as the Service Discovery Protocol (SDP) is concerned, the configuration shown in Figure 1 may be simplified to that shown in Figure 2.

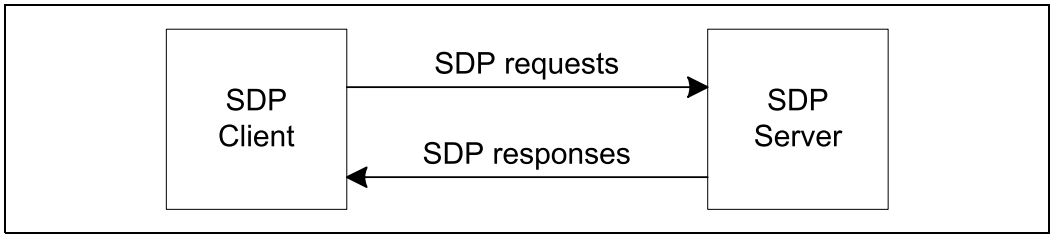


Figure 2.2:

SDP involves communication between an SDP server and an SDP client. The server maintains a list of service records that describe the characteristics of services associated with the server. Each service record contains information about a single service. A client may retrieve information from a service record maintained by the SDP server by issuing an SDP request.

If the client, or an application associated with the client, decides to use a service, it must open a separate connection to the service provider in order to utilize the service. SDP provides a mechanism for discovering services and their attributes (including associated service access protocols), but it does not provide a mechanism for utilizing those services (such as delivering the service access protocols).

There is a maximum of one SDP server per Bluetooth device. (If a Bluetooth device acts only as a client, it needs no SDP server.) A single Bluetooth device may function both as an SDP server and as an SDP client. If multiple applications on a device provide services, an SDP server may act on behalf of those service providers to handle requests for information about the services that they provide.

Similarly, multiple client applications may utilize an SDP client to query servers on behalf of the client applications.

The set of SDP servers that are available to an SDP client can change dynamically based on the RF proximity of the servers to the client. When a server becomes available, a potential client must be notified by a means other than SDP so that the client can use SDP to query the server about its services. Similarly, when a server leaves proximity or becomes unavailable for any reason, there is no explicit notification via the service discovery protocol. However, the client may use SDP to poll the server and may infer that the server is not available if it no longer responds to requests.

Additional information regarding application interaction with SDP is contained in the Bluetooth Service Discovery Profile document.

2.2 SERVICE RECORD

A service is any entity that can provide information, perform an action, or control a resource on behalf of another entity. A service may be implemented as software, hardware, or a combination of hardware and software.

All of the information about a service that is maintained by an SDP server is contained within a single service record. The service record consists entirely of a list of service attributes.

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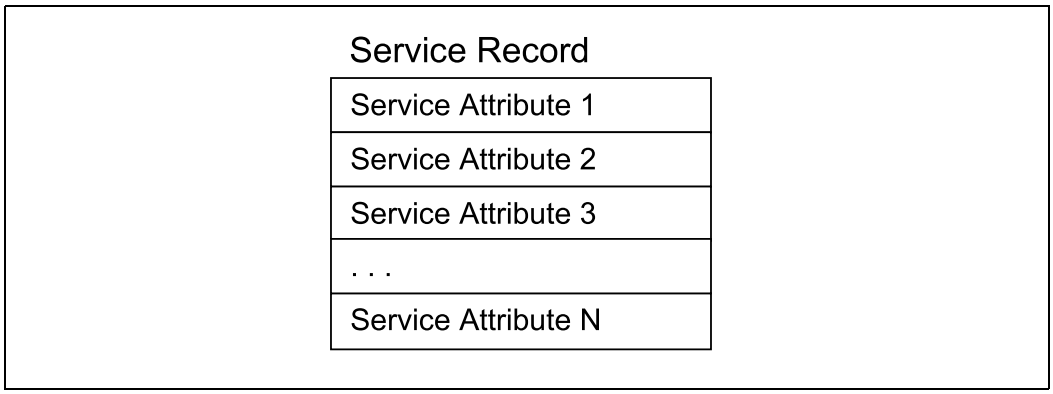


Figure 2.3: Service Record

A service record handle is a 32-bit number that uniquely identifies each service record within an SDP server. It is important to note that, in general, each handle is unique only within each SDP server. If SDP server S1 and SDP server S2 both contain identical service records (representing the same service), the service record handles used to reference these identical service records are completely independent. The handle used to reference the service on S1 will be meaningless if presented to S2.

The service discovery protocol does not provide a mechanism for notifying clients when service records are added to or removed from an SDP server. While an L2CAP (Logical Link Control and Adaptation Protocol) connection is established to a server, a service record handle acquired from the server will remain valid unless the service record it represents is removed. If a service is removed from the server, further requests to the server (during the L2CAP connection in which the service record handle was acquired) using the service's (now stale) record handle will result in an error response indicating an invalid service record handle. An SDP server must ensure that no service record handle values are re-used while an L2CAP connection remains established. Note that service record handles are known to remain valid across successive L2CAP connections while the ServiceDatabaseState attribute value remains unchanged. See the ServiceRecordState and ServiceDatabaseState attributes in section 5 on page 145.

There is one service record handle whose meaning is consistent across all SDP servers. This service record handle has the value 0x00000000 and is a handle to the service record that represents the SDP server itself. This service record contains attributes for the SDP server and the protocol it supports. For example, one of its attributes is the list of SDP protocol versions supported by the server. Service record handle values 0x00000001-0x0000FFFF are reserved.

2.3 SERVICE ATTRIBUTE

Each service attribute describes a single characteristic of a service. Some examples of service attributes are:

ServiceClassIDList	Identifies the type of service represented by a service record. In other words, the list of classes of which the service is an instance
ServiceID	Uniquely identifies a specific instance of a service
ProtocolDescriptorList	Specifies the protocol stack(s) that may be used to utilize a service
ProviderName	The textual name of the individual or organization that provides a service
IconURL	Specifies a URL that refers to an icon image that may be used to represent a service
ServiceName	A text string containing a human-readable name for the service
ServiceDescription	A text string describing the service

See section 5.1 on page 145, for attribute definitions that are common to all service records. Service providers can also define their own service attributes.

A service attribute consists of two components: an attribute ID and an attribute value.

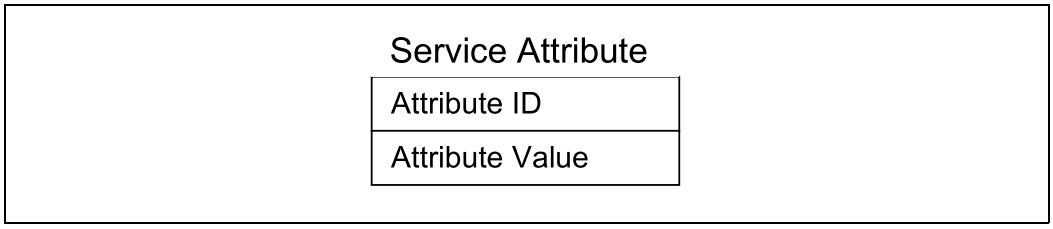


Figure 2.4: Service Attribute

2.4 ATTRIBUTE ID

An attribute ID is a 16-bit unsigned integer that distinguishes each service attribute from other service attributes within a service record. The attribute ID also identifies the semantics of the associated attribute value.

A service class definition specifies each of the attribute IDs for a service class and assigns a meaning to the attribute value associated with each attribute ID.

For example, assume that service class C specifies that the attribute value associated with attribute ID 12345 is a text string containing the date the service was created. Assume further that service A is an instance of service class C. If service A's service record contains a service attribute with an attribute ID

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of 12345, the attribute value must be a text string containing the date that service A was created. However, services that are not instances of service class C may assign a different meaning to attribute ID 12345.

All services belonging to a given service class assign the same meaning to each particular attribute ID. See section 2.6 on page 121.

In the Service Discovery Protocol, an attribute ID is often represented as a data element. See section 3 on page 127.

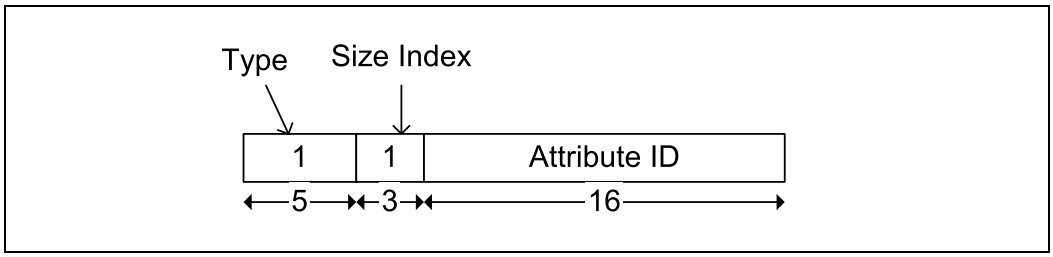


Figure 2.5:

2.5 ATTRIBUTE VALUE

The attribute value is a variable length field whose meaning is determined by the attribute ID associated with it and by the service class of the service record in which the attribute is contained. In the Service Discovery Protocol, an attribute value is represented as a data element. (See section 3 on page 127.) Generally, any type of data element is permitted as an attribute value, subject to the constraints specified in the service class definition that assigns an attribute ID to the attribute and assigns a meaning to the attribute value. See section 5 on page 145, for attribute value examples.

2.6 SERVICE CLASS

Each service is an instance of a service class. The service class definition provides the definitions of all attributes contained in service records that represent instances of that class. Each attribute definition specifies the numeric value of the attribute ID, the intended use of the attribute value, and the format of the attribute value. A service record contains attributes that are specific to a service class as well as universal attributes that are common to all services.

Each service class is also assigned a unique identifier. This service class identifier is contained in the attribute value for the ServiceClassIDList attribute, and is represented as a UUID (see section 2.7.1 on page 123). Since the format and meanings of many attributes in a service record are dependent on the service class of the service record, the ServiceClassIDList attribute is very important. Its value should be examined or verified before any class-specific attributes are used. Since all of the attributes in a service record must conform to all of the service's classes, the service class identifiers contained in the ServiceClassIDList attribute are related. Typically, each service class is a subclass

of another class whose identifier is contained in the list. A service subclass definition differs from its superclass in that the subclass contains additional attribute definitions that are specific to the subclass. The service class identifiers in the ServiceClassIDList attribute are listed in order from the most specific class to the most general class.

When a new service class is defined that is a subclass of an existing service class, the new service class retains all of the attributes defined in its superclass. Additional attributes will be defined that are specific to the new service class. In other words, the mechanism for adding new attributes to some of the instances of an existing service class is to create a new service class that is a subclass of the existing service class.

2.6.1 A Printer Service Class Example

A color postscript printer with duplex capability might conform to 4 ServiceClass definitions and have a ServiceClassIDList with UUIDs (See section 2.7.1 on page 123.) representing the following ServiceClasses:

DuplexColorPostscriptPrinterServiceClassID,
ColorPostscriptPrinterServiceClassID,
PostscriptPrinterServiceClassID,
PrinterServiceClassID

Note that this example is only illustrative. This may not be a practical printer class hierarchy.

2.7 SEARCHING FOR SERVICES

Once an SDP client has a service record handle, it may easily request the values of specific attributes, but how does a client initially acquire a service record handle for the desired service records? The Service Search transaction allows a client to retrieve the service record handles for particular service records based on the values of attributes contained within those service records.

The capability search for service records based on the values of arbitrary attributes is not provided. Rather, the capability is provided to search only for attributes whose values are Universally Unique Identifiers[1] (UUIDs). Important attributes of services that can be used to search for a service are represented as UUIDs.

2.7.1 UUID

A UUID is a universally unique identifier that is guaranteed to be unique across all space and all time. UUIDs can be independently created in a distributed fashion. No central registry of assigned UUIDs is required. A UUID is a 128-bit value.

To reduce the burden of storing and transferring 128-bit UUID values, a range of UUID values has been pre-allocated for assignment to often-used, registered purposes. The first UUID in this pre-allocated range is known as the Bluetooth Base UUID and has the value 00000000-0000-1000-8000-00805F9B34FB, from the Bluetooth Assigned Numbers document. UUID values in the pre-allocated range have aliases that are represented as 16-bit or 32-bit values. These aliases are often called 16-bit and 32-bit UUIDs, but it is important to note that each actually represents a 128-bit UUID value.

The full 128-bit value of a 16-bit or 32-bit UUID may be computed by a simple arithmetic operation.

$$128\_bit\_value = 16\_bit\_value * 2^{96} + Bluetooth\_Base\_UUID$$

$$128\_bit\_value = 32\_bit\_value * 2^{96} + Bluetooth\_Base\_UUID$$

A 16-bit UUID may be converted to 32-bit UUID format by zero-extending the 16-bit value to 32-bits. An equivalent method is to add the 16-bit UUID value to a zero-valued 32-bit UUID.

Note that two 16-bit UUIDs may be compared directly, as may two 32-bit UUIDs or two 128-bit UUIDs. If two UUIDs of differing sizes are to be com-

1. The format of UUIDs is defined by the International Organization for Standardization in ISO/IEC 11578:1996. “Information technology – Open Systems Interconnection – Remote Procedure Call (RPC)”

pared, the shorter UUID must be converted to the longer UUID format before comparison.

2.7.2 Service Search Patterns

A service search pattern is a list of UUIDs used to locate matching service records. A service search pattern is said to match a service record if each and every UUID in the service search pattern is contained within any of the service record's attribute values. The UUIDs need not be contained within any specific attributes or in any particular order within the service record. The service search pattern matches if the UUIDs it contains constitute a subset of the UUIDs in the service record's attribute values. The only time a service search pattern does not match a service record is if the service search pattern contains at least one UUID that is not contained within the service record's attribute values. Note also that a valid service search pattern must contain at least one UUID.

2.8 BROWSING FOR SERVICES

Normally, a client searches for services based on some desired characteristic(s) (represented by a UUID) of the services. However, there are times when it is desirable to discover which types of services are described by an SDP server's service records without any a priori information about the services. This process of looking for any offered services is termed browsing. In SDP, the mechanism for browsing for services is based on an attribute shared by all service classes. This attribute is called the BrowseGroupList attribute. The value of this attribute contains a list of UUIDs. Each UUID represents a browse group with which a service may be associated for the purpose of browsing.

When a client desires to browse an SDP server's services, it creates a service search pattern containing the UUID that represents the root browse group. All services that may be browsed at the top level are made members of the root browse group by having the root browse group's UUID as a value within the BrowseGroupList attribute.

Normally, if an SDP server has relatively few services, all of its services will be placed in the root browse group. However, the services offered by an SDP server may be organized in a browse group hierarchy, by defining additional browse groups below the root browse group. Each of these additional browse groups is described by a service record with a service class of BrowseGroupDescriptor.

A browse group descriptor service record defines a new browse group by means of its Group ID attribute. In order for a service contained in one of these newly defined browse groups to be browseable, the browse group descriptor service record that defines the new browse group must in turn be browseable. The hierarchy of browseable services that is provided by the use of browse group descriptor service records allows the services contained in an SDP

server to be incrementally browsed and is particularly useful when the SDP server contains many service records.

2.8.1 Example Service Browsing Hierarchy

Here is a fictitious service browsing hierarchy that may illuminate the manner in which browse group descriptors are used. Browse group descriptor service records are identified with (G); other service records with (S).

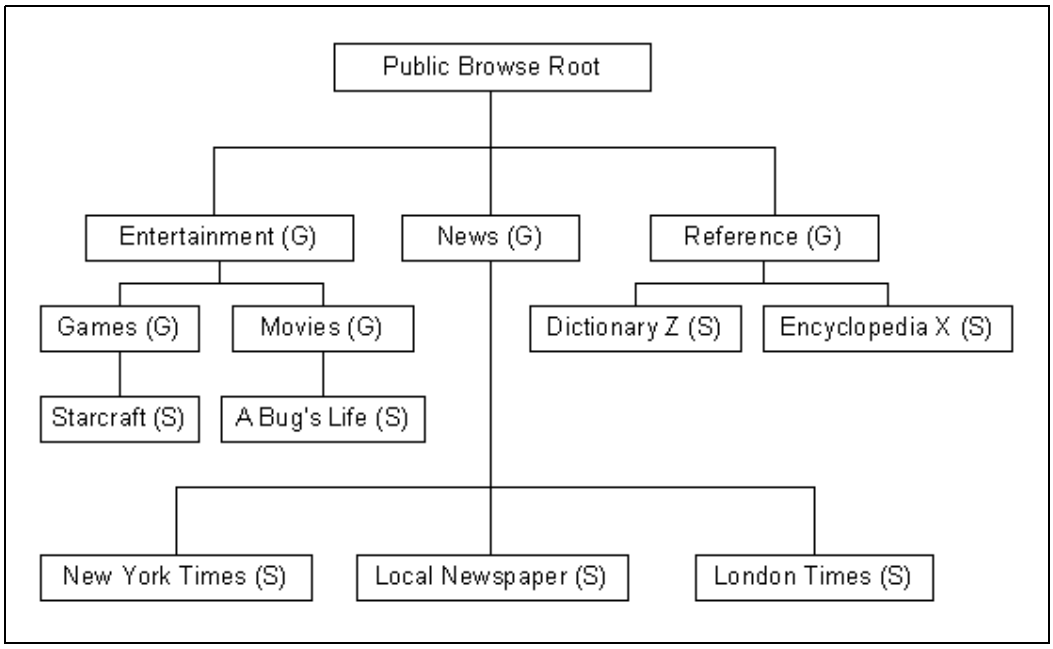


Figure 2.6:

This table shows the services records and service attributes necessary to implement the browse hierarchy.

Service Name	Service Class	Attribute Name	Attribute Value
Entertainment	BrowseGroupDescriptor	BrowseGroupList	PublicBrowseRoot
		GroupID	EntertainmentID
News	BrowsegroupDescriptor	BrowseGroupList	PublicBrowseRoot
		GroupID	NewsID
Reference	BrowseGroupDescriptor	BrowseGroupList	PublicBrowseRoot
		GroupID	ReferenceID
Games	BrowseGroupDescriptor	BrowseGroupList	EntertainmentID
		GroupID	GamesID
Movies	BrowseGroupDescriptor	BrowseGroupList	EntertainmentID
		GroupID	MoviesID
Starcraft	Video Game Class ID	BrowseGroupList	GamesID
A Bug's Life	Movie Class ID	BrowseGroupList	MovieID
Dictionary Z	Dictionary Class ID	BrowseGroupList	ReferenceID
Encyclopedia X	Encyclopedia Class ID	BrowseGroupList	ReferenceID
New York Times	Newspaper ID	BrowseGroupList	NewspaperID
London Times	Newspaper ID	BrowseGroupList	NewspaperID
Local Newspaper	Newspaper ID	BrowseGroupList	NewspaperID

Table 2.1:

3 DATA REPRESENTATION

Attribute values can contain information of various types with arbitrary complexity; thus enabling an attribute list to be generally useful across a wide variety of service classes and environments.

SDP defines a simple mechanism to describe the data contained within an attribute value. The primitive construct used is the data element.

3.1 DATA ELEMENT

A data element is a typed data representation. It consists of two fields: a header field and a data field. The header field, in turn, is composed of two parts: a type descriptor and a size descriptor. The data is a sequence of bytes whose length is specified in the size descriptor (described in section 3.3 on page 128) and whose meaning is (partially) specified by the type descriptor.

3.2 DATA ELEMENT TYPE DESCRIPTOR

A data element type is represented as a 5-bit type descriptor. The type descriptor is contained in the most significant (high-order) 5 bits of the first byte of the data element header. The following types have been defined.

Type Descriptor Value	Valid Size Descriptor Values	Type Description
0	0	Nil, the null type
1	0, 1, 2, 3, 4	Unsigned Integer
2	0, 1, 2, 3, 4	Signed twos-complement integer
3	1, 2, 4	UUID, a universally unique identifier
4	5, 6, 7	Text string
5	0	Boolean[1]
6	5, 6, 7	Data element sequence, a data element whose data field is a sequence of data elements
7	5, 6, 7	Data element alternative, data element whose data field is a sequence of data elements from which one data element is to be selected.
8	5, 6, 7	URL, a uniform resource locator
9-31		Reserved

Table 3.1: Data Element Type.

1. False is represented by the value 0, and true is represented by the value 1. However, to maximise interoperability, any non-zero value received must be accepted as representing true.

3.3 DATA ELEMENT SIZE DESCRIPTOR

The data element size descriptor is represented as a 3-bit size index followed by 0, 8, 16, or 32 bits. The size index is contained in the least significant (low-order) 3 bits of the first byte of the data element header. The size index is encoded as follows.

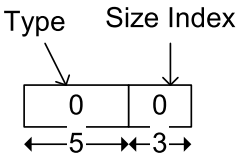
Size Index	Additional bits	Data Size
0	0	1 byte. Exception: if the data element type is nil, the data size is 0 bytes.
1	0	2 bytes
2	0	4 bytes
3	0	8 bytes
4	0	16 bytes
5	8	The data size is contained in the additional 8 bits, which are interpreted as an unsigned integer.
6	16	The data size is contained in the additional 16 bits, which are interpreted as an unsigned integer.
7	32	The data size is contained in the additional 32 bits, which are interpreted as an unsigned integer.

Table 3.2:

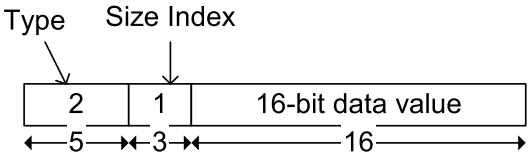
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3.4 DATA ELEMENT EXAMPLES

Nil is represented as:



A 16-bit signed integer is represented as:



The 3 character ASCII string "Hat" is represented as:

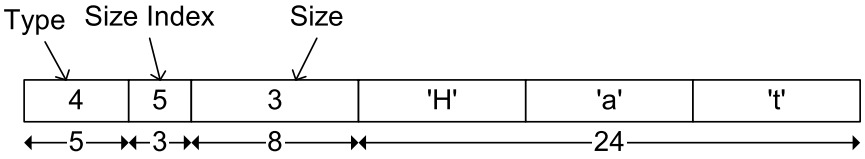


Figure 3.1:

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4 PROTOCOL DESCRIPTION

SDP is a simple protocol with minimal requirements on the underlying transport. It can function over a reliable packet transport (or even unreliable, if the client implements timeouts and repeats requests as necessary).

SDP uses a request/response model where each transaction consists of one request protocol data unit (PDU) and one response PDU. In the case where SDP is used with the Bluetooth L2CAP transport protocol, only one SDP request PDU per connection to a given SDP server may be outstanding at a given instant. In other words, a client must receive a response to each request before issuing another request on the same L2CAP connection. Limiting SDP to sending one unacknowledged request PDU provides a simple form of flow control.

The protocol examples found in Appendix B – Example SDP Transactions, may be helpful in understanding the protocol transactions.

4.1 TRANSFER BYTE ORDER

The service discovery protocol transfers multiple-byte fields in standard network byte order (Big Endian), with more significant (high-order) bytes being transferred before less-significant (low-order) bytes.

4.2 PROTOCOL DATA UNIT FORMAT

Every SDP PDU consists of a PDU header followed by PDU-specific parameters. The header contains three fields: a PDU ID, a Transaction ID, and a ParameterLength. Each of these header fields is described here. Parameters may include a continuation state parameter, described below; PDU-specific parameters for each PDU type are described later in separate PDU descriptions.

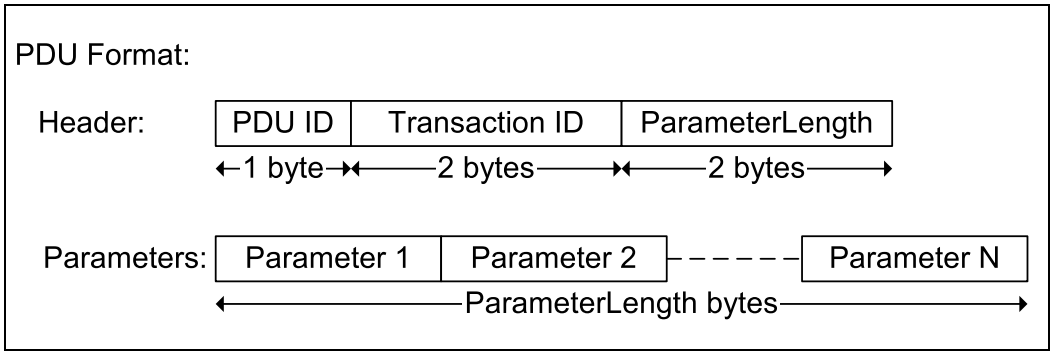


Figure 4.1:

PDU ID: *Size: 1 Byte*

Value	Parameter Description
N	The PDU ID field identifies the type of PDU. I.e. its meaning and the specific parameters.
0x00	Reserved
0x01	SDP_ErrorResponse
0x02	SDP_ServiceSearchRequest
0x03	SDP_ServiceSearchResponse
0x04	SDP_ServiceAttributeRequest
0x05	SDP_ServiceAttributeResponse
0x06	SDP_ServiceSearchAttributeRequest
0x07	SDP_ServiceSearchAttributeResponse
0x07-0xFF	Reserved

TransactionID: *Size: 2 Bytes*

Value	Parameter Description
N	The TransactionID field uniquely identifies request PDUs and is used to match response PDUs to request PDUs. The SDP client can choose any value for a request's TransactionID provided that it is different from all outstanding requests. The TransactionID value in response PDUs is required to be the same as the request that is being responded to. Range: 0x0000 – 0xFFFF

ParameterLength: *Size: 2 Bytes*

Value	Parameter Description
N	The ParameterLength field specifies the length (in bytes) of all parameters contained in the PDU. Range: 0x0000 – 0xFFFF

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4.3 PARTIAL RESPONSES AND CONTINUATION STATE

Some SDP requests may require responses that are larger than can fit in a single response PDU. In this case, the SDP server will generate a partial response along with a continuation state parameter. The continuation state parameter can be supplied by the client in a subsequent request to retrieve the next portion of the complete response. The continuation state parameter is a variable length field whose first byte contains the number of additional bytes of continuation information in the field. The format of the continuation information is not standardized among SDP servers. Each continuation state parameter is meaningful only to the SDP server that generated it.

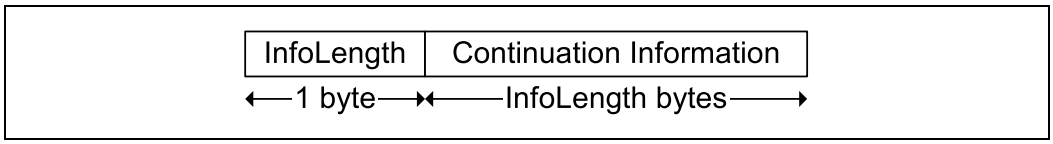


Figure 4.2: Continuation State Format

After a client receives a partial response and the accompanying continuation state parameter, it can re-issue the original request (with a new transaction ID) and include the continuation state in the new request indicating to the server that the remainder of the original response is desired. The maximum allowable value of the InfoLength field is 16 (0x10).

Note that an SDP server can split a response at any arbitrary boundary when it generates a partial response. The SDP server may select the boundary based on the contents of the reply, but is not required to do so.

4.4 ERROR HANDLING

Each transaction consists of a request and a response PDU. Generally, each type of request PDU has a corresponding type of response PDU. However, if the server determines that a request is improperly formatted or for any reason the server cannot respond with the appropriate PDU type, it will respond with an SDP_ErrorResponse PDU.

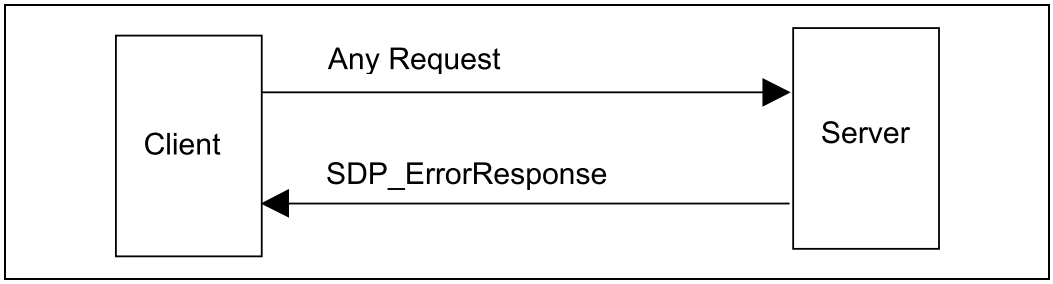


Figure 4.3:

4.4.1 SDP_ErrorResponse PDU

PDU Type	PDU ID	Parameters
SDP_ErrorResponse	0x01	ErrorCode, ErrorInfo

Description:

The SDP server generates this PDU type in response to an improperly formatted request PDU or when the SDP server, for whatever reason, cannot generate an appropriate response PDU.

PDU Parameters:

ErrorCode: *Size: 2 Bytes*

Value	Parameter Description
N	The ErrorCode identifies the reason that an SDP_ErrorResponse PDU was generated.
0x0000	Reserved
0x0001	Invalid/unsupported SDP version
0x0002	Invalid Service Record Handle
0x0003	Invalid request syntax
0x0004	Invalid PDU Size
0x0005	Invalid Continuation State
0x0006	Insufficient Resources to satisfy Request
0x0007-0xFFFF	Reserved

ErrorInfo: *Size: N Bytes*

Value	Parameter Description
Error-specific	ErrorInfo is an ErrorCode-specific parameter. Its interpretation depends on the ErrorCode parameter. The currently defined ErrorCode values do not specify the format of an ErrorInfo field.

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4.5 SERVICESEARCH TRANSACTION

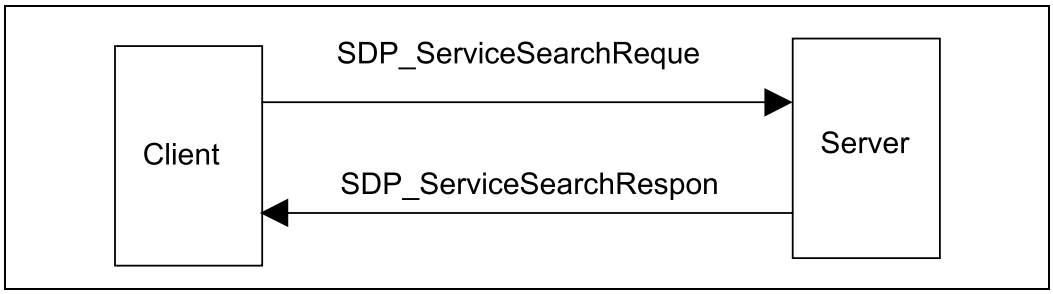


Figure 4.4:

4.5.1 SDP_ServiceSearchRequest PDU

PDU Type	PDU ID	Parameters
SDP_ServiceSearchRequest	0x02	ServiceSearchPattern, MaximumServiceRecordCount, ContinuationState

Description:

The SDP client generates an SDP_ServiceSearchRequest to locate service records that match the service search pattern given as the first parameter of the PDU. Upon receipt of this request, the SDP server will examine its service record data base and return an SDP_ServiceSearchResponse containing the service record handles of service records that match the given service search pattern.

Note that no mechanism is provided to request information for all service records. However, see section 2.8 on page 124 for a description of a mechanism that permits browsing for non-specific services without a priori knowledge of the services.

PDU Parameters:

ServiceSearchPattern: *Size: Varies*

Value	Parameter Description
Data Element Sequence	The ServiceSearchPattern is a data element sequence where each element in the sequence is a UUID. The sequence must contain at least one UUID. The maximum number of UUIDs in the sequence is 12[1]. The list of UUIDs constitutes a service search pattern.

1. The value of 12 has been selected as a compromise between the scope of a service search and the size of a search request PDU. It is not expected that more than 12 UUIDs will be useful in a service search pattern.

MaximumServiceRecordCount: *Size: 2 Bytes*

Value	Parameter Description
N	MaximumServiceRecordCount is a 16-bit count specifying the maximum number of service record handles to be returned in the response(s) to this request. The SDP server should not return more handles than this value specifies. If more than N service records match the request, the SDP server determines which matching service record handles to return in the response(s). Range: 0x0001-0xFFFF

ContinuationState: *Size: 1 to 17 Bytes*

Value	**Parameter Description**
Continuation State	ContinuationState consists of an 8-bit count, N, of the number of bytes of continuation state information, followed by the N bytes of continuation state information that were returned in a previous response from the server. N is required to be less than or equal to 16. If no continuation state is to be provided in the request, N is set to 0.

4.5.2 SDP_ServiceSearchResponse PDU

PDU Type	**PDU ID**	**Parameters**
SDP_ServiceSearchResponse	0x03	TotalServiceRecordCount, CurrentServiceRecordCount, ServiceRecordHandleList, ContinuationState

Description:

The SDP server generates an SDP_ServiceSearchResponse upon receipt of a valid SDP_ServiceSearchRequest. The response contains a list of service record handles for service records that match the service search pattern given in the request. Note that if a partial response is generated, it must contain an integral number of complete service record handles; a service record handle value may not be split across multiple PDUs.

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PDU Parameters:

TotalServiceRecordCount: *Size: 2 Bytes*

Value	Parameter Description
N	The TotalServiceRecordCount is an integer containing the number of service records that match the requested service search pattern. If no service records match the requested service search pattern, this parameter is set to 0. N should never be larger than the MaximumServiceRecordCount value specified in the SDP_ServiceSearchRequest. When multiple partial responses are used, each partial response contains the same value for TotalServiceRecordCount. Range: 0x0000-0xFFFF

CurrentServiceRecordCount: *Size: 2 Bytes*

Value	Parameter Description
N	The CurrentServiceRecordCount is an integer indicating the number of service record handles that are contained in the next parameter. If no service records match the requested service search pattern, this parameter is set to 0. N should never be larger than the TotalServiceRecordCount value specified in the current response. Range: 0x0000-0xFFFF

ServiceRecordHandleList: *Size: (CurrentServiceRecordCount*4) Bytes*

Value	Parameter Description
List of 32-bit handles	The ServiceRecordHandleList contains a list of service record handles. The number of handles in the list is given in the CurrentServiceRecordCount parameter. Each of the handles in the list refers to a service record that matches the requested service search pattern. Note that this list of service record handles does not have the format of a data element. It contains no header fields, only the 32-bit service record handles.

ContinuationState: *Size: 1 to 17 Bytes*

Value	Parameter Description
Continuation State	ContinuationState consists of an 8-bit count, N, of the number of bytes of continuation state information, followed by the N bytes of continuation information. If the current response is complete, this parameter consists of a single byte with the value 0. If a partial response is contained in the PDU, the ContinuationState parameter may be supplied in a subsequent request to retrieve the remainder of the response.

4.6 SERVICEATTRIBUTE TRANSACTION

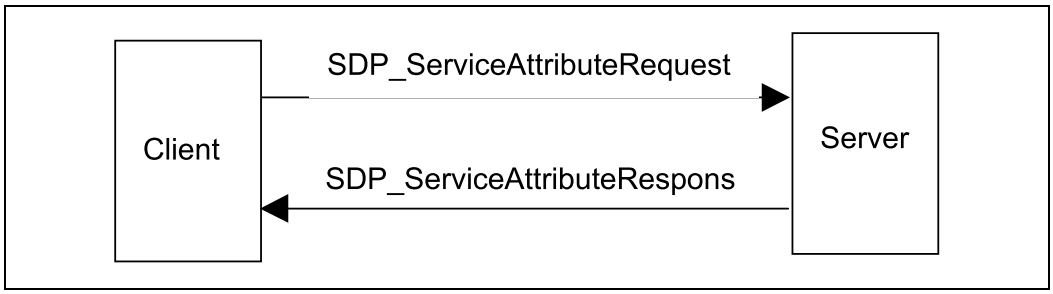


Figure 4.5:

4.6.1 SDP_ServiceAttributeRequest PDU

PDU Type	PDU ID	Parameters
SDP_ServiceAttributeRequest	0x04	ServiceRecordHandle, MaximumAttributeByteCount, AttributeIDList, ContinuationState

Description:

The SDP client generates an SDP_ServiceAttributeRequest to retrieve specified attribute values from a specific service record. The service record handle of the desired service record and a list of desired attribute IDs to be retrieved from that service record are supplied as parameters.

Command Parameters:

ServiceRecordHandle: *Size: 4 Bytes*

Value	Parameter Description
32-bit handle	The ServiceRecordHandle parameter specifies the service record from which attribute values are to be retrieved. The handle is obtained via a previous SDP_ServiceSearch transaction.

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MaximumAttributeByteCount: *Size: 2 Bytes*

Value	Parameter Description
N	MaximumAttributeByteCount specifies the maximum number of bytes of attribute data to be returned in the response to this request. The SDP server should not return more than N bytes of attribute data in the response PDU. If the requested attributes require more than N bytes, the SDP server determines how to segment the list. In this case the client may request each successive segment by issuing a request containing the continuation state that was returned in the previous response PDU. Note that in the case where multiple response PDUs are needed to return the attribute data, MaximumAttributeByteCount specifies the maximum size of the portion of the attribute data contained in each response PDU. Range: 0x0007-0xFFFF

AttributeIDList: *Size: Varies*

Value	Parameter Description
Data Element Sequence	The AttributeIDList is a data element sequence where each element in the list is either an attribute ID or a range of attribute IDs. Each attribute ID is encoded as a 16-bit unsigned integer data element. Each attribute ID range is encoded as a 32-bit unsigned integer data element, where the high order 16 bits are interpreted as the beginning attribute ID of the range and the low order 16 bits are interpreted as the ending attribute ID of the range. The attribute IDs contained in the AttributeIDList must be listed in ascending order without duplication of any attribute ID values. Note that all attributes may be requested by specifying a range of 0x0000-0xFFFF.

ContinuationState: *Size: 1 to 17 Bytes*

Value	Parameter Description
Continuation State	ContinuationState consists of an 8-bit count, N, of the number of bytes of continuation state information, followed by the N bytes of continuation state information that were returned in a previous response from the server. N is required to be less than or equal to 16. If no continuation state is to be provided in the request, N is set to 0.

4.6.2 SDP_ServiceAttributeResponse PDU

PDU Type	PDU ID	Parameters
SDP_ServiceAttributeResponse	0x05	AttributeListByteCount, AttributeList, ContinuationState

Description:

The SDP server generates an SDP_ServiceAttributeResponse upon receipt of a valid SDP_ServiceAttributeRequest. The response contains a list of attributes (both attribute ID and attribute value) from the requested service record.

PDU Parameters:

AttributeListByteCount: *Size: 2 Bytes*

Value	Parameter Description
N	The AttributeListByteCount contains a count of the number of bytes in the AttributeList parameter. N must never be larger than the MaximumAttributeByteCount value specified in the SDP_ServiceAttributeRequest. Range: 0x0002-0xFFFF

AttributeList: *Size: AttributeListByteCount*

Value	Parameter Description
Data Element Sequence	The AttributeList is a data element sequence containing attribute IDs and attribute values. The first element in the sequence contains the attribute ID of the first attribute to be returned. The second element in the sequence contains the corresponding attribute value. Successive pairs of elements in the list contain additional attribute ID and value pairs. Only attributes that have non-null values within the service record and whose attribute IDs were specified in the SDP_ServiceAttributeRequest are contained in the AttributeList. Neither an attribute ID nor an attribute value is placed in the AttributeList for attributes in the service record that have no value. The attributes are listed in ascending order of attribute ID value.

ContinuationState: *Size: 1 to 17 Bytes*

Value	Parameter Description
Continuation State	ContinuationState consists of an 8-bit count, N, of the number of bytes of continuation state information, followed by the N bytes of continuation information. If the current response is complete, this parameter consists of a single byte with the value 0. If a partial response is given, the ContinuationState parameter may be supplied in a subsequent request to retrieve the remainder of the response.

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4.7 SERVICESEARCHATTRIBUTE TRANSACTION

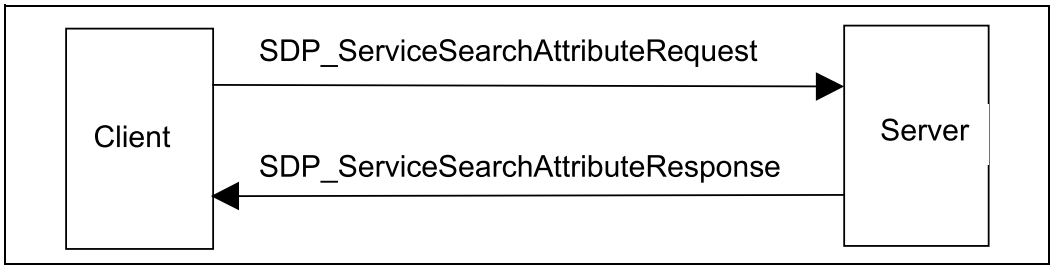


Figure 4.6:

4.7.1 SDP_ServiceSearchAttributeRequest PDU

PDU Type	PDU ID	Parameters
SDP_ServiceSearchAttributeRequest	0x06	ServiceSearchPattern, MaximumAttributeByteCount, AttributeIDList, ContinuationState

Description:

The SDP_ServiceSearchAttributeRequest transaction combines the capabilities of the SDP_ServiceSearchRequest and the SDP_ServiceAttributeRequest into a single request. As parameters, it contains both a service search pattern and a list of attributes to be retrieved from service records that match the service search pattern. The SDP_ServiceSearchAttributeRequest and its response are more complex and may require more bytes than separate SDP_ServiceSearch and SDP_ServiceAttribute transactions. However, using SDP_ServiceSearchAttributeRequest may reduce the total number of SDP transactions, particularly when retrieving multiple service records.

Note that the service record handle for each service record is contained in the ServiceRecordHandle attribute of that service and may be requested along with other attributes.

PDU Parameters:

ServiceSearchPattern: *Size: Varies*

Value	Parameter Description
Data Element Sequence	The ServiceSearchPattern is a data element sequence where each element in the sequence is a UUID. The sequence must contain at least one UUID. The maximum number of UUIDs in the sequence is 12[1]. The list of UUIDs constitutes a service search pattern.

1. The value of 12 has been selected as a compromise between the scope of a service search and the size of a search request PDU. It is not expected that more than 12 UUIDs will be useful in a service search pattern.

MaximumAttributeByteCount: *Size: 2 Bytes*

Value	Parameter Description
N	MaximumAttributeByteCount specifies the maximum number of bytes of attribute data to be returned in the response to this request. The SDP server should not return more than N bytes of attribute data in the response PDU. If the requested attributes require more than N bytes, the SDP server determines how to segment the list. In this case the client may request each successive segment by issuing a request containing the continuation state that was returned in the previous response PDU. Note that in the case where multiple response PDUs are needed to return the attribute data, MaximumAttributeByteCount specifies the maximum size of the portion of the attribute data contained in each response PDU. Range: 0x0007-0xFFFF

AttributeIDList: *Size: Varies*

Value	Parameter Description
Data Element Sequence	The AttributeIDList is a data element sequence where each element in the list is either an attribute ID or a range of attribute IDs. Each attribute ID is encoded as a 16-bit unsigned integer data element. Each attribute ID range is encoded as a 32-bit unsigned integer data element, where the high order 16 bits are interpreted as the beginning attribute ID of the range and the low order 16 bits are interpreted as the ending attribute ID of the range. The attribute IDs contained in the AttributeIDList must be listed in ascending order without duplication of any attribute ID values. Note that all attributes may be requested by specifying a range of 0x0000-0xFFFF.

ContinuationState: *Size: 1 to 17 Bytes*

Value	Parameter Description
Continuation State	ContinuationState consists of an 8-bit count, N, of the number of bytes of continuation state information, followed by the N bytes of continuation state information that were returned in a previous response from the server. N is required to be less than or equal to 16. If no continuation state is to be provided in the request, N is set to 0.

4.7.2 SDP_ServiceSearchAttributeResponse PDU

PDU Type	PDU ID	Parameters
SDP_ServiceSearchAttributeResponse	0x07	AttributeListsByteCount, AttributeLists, ContinuationState

Description:

The SDP server generates an SDP_ServiceSearchAttributeResponse upon receipt of a valid SDP_ServiceSearchAttributeRequest. The response contains a list of attributes (both attribute ID and attribute value) from the service records that match the requested service search pattern.

PDU Parameters:

AttributeListsByteCount: *Size: 2 Bytes*

Value	Parameter Description
N	The AttributeListsByteCount contains a count of the number of bytes in the AttributeLists parameter. N must never be larger than the MaximumAttributeByteCount value specified in the SDP_ServiceSearchAttributeRequest. Range: 0x0002-0xFFFF

AttributeLists: *Size: Varies*

Value	Parameter Description
Data Element Sequence	The AttributeLists is a data element sequence where each element in turn is a data element sequence representing an attribute list. Each attribute list contains attribute IDs and attribute values from one service record. The first element in each attribute list contains the attribute ID of the first attribute to be returned for that service record. The second element in each attribute list contains the corresponding attribute value. Successive pairs of elements in each attribute list contain additional attribute ID and value pairs. Only attributes that have non-null values within the service record and whose attribute IDs were specified in the SDP_ServiceSearchAttributeRequest are contained in the AttributeLists. Neither an attribute ID nor attribute value is placed in AttributeLists for attributes in the service record that have no value. Within each attribute list, the attributes are listed in ascending order of attribute ID value.

ContinuationState: *Size: 1 to 17 Bytes*

Value	Parameter Description
Continuation State	ContinuationState consists of an 8-bit count, N, of the number of bytes of continuation state information, followed by the N bytes of continuation information. If the current response is complete, this parameter consists of a single byte with the value 0. If a partial response is given, the ContinuationState parameter may be supplied in a subsequent request to retrieve the remainder of the response.

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5 SERVICE ATTRIBUTE DEFINITIONS

The service classes and attributes contained in this document are necessarily a partial list of the service classes and attributes supported by SDP. Only service classes that directly support the SDP server are included in this document. Additional service classes will be defined in other documents and possibly in future revisions of this document. Also, it is expected that additional attributes will be discovered that are applicable to a broad set of services; these may be added to the list of Universal attributes in future revisions of this document.

5.1 UNIVERSAL ATTRIBUTE DEFINITIONS

Universal attributes are those service attributes whose definitions are common to all service records. Note that this does not mean that every service record must contain values for all of these service attributes. However, if a service record has a service attribute with an attribute ID allocated to a universal attribute, the attribute value must conform to the universal attribute's definition.

Only two attributes are required to exist in every service record instance. They are the ServiceRecordHandle (attribute ID 0x0000) and the ServiceClassIDList (attribute ID 0x0001). All other service attributes are optional within a service record.

5.1.1 ServiceRecordHandle Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceRecordHandle	0x0000	32-bit unsigned integer

Description:

A service record handle is a 32-bit number that uniquely identifies each service record within an SDP server. It is important to note that, in general, each handle is unique only within each SDP server. If SDP server S1 and SDP server S2 both contain identical service records (representing the same service), the service record handles used to reference these identical service records are completely independent. The handle used to reference the service on S1 will, in general, be meaningless if presented to S2.

5.1.2 ServiceClassIDList Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceClassIDList	0x0001	Data Element Sequence

Description:

The ServiceClassIDList attribute consists of a data element sequence in which each data element is a UUID representing the service classes that a given service record conforms to. The UUIDs are listed in order from the most specific class to the most general class. The ServiceClassIDList must contain at least one service class UUID.

5.1.3 ServiceRecordState Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceRecordState	0x0002	32-bit unsigned integer

Description:

The ServiceRecordState is a 32-bit integer that is used to facilitate caching of ServiceAttributes. If this attribute is contained in a service record, its value is guaranteed to change when any other attribute value is added to, deleted from or changed within the service record. This permits a client to check the value of this single attribute. If its value has not changed since it was last checked, the client knows that no other attribute values within the service record have changed.

5.1.4 ServiceID Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceID	0x0003	UUID

Description:

The ServiceID is a UUID that universally and uniquely identifies the service instance described by the service record. This service attribute is particularly useful if the same service is described by service records in more than one SDP server.

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5.1.5 ProtocolDescriptorList Attribute

Attribute Name	Attribute ID	Attribute Value Type
ProtocolDescriptorList	0x0004	Data Element Sequence or Data Element Alternative

Description:

The ProtocolDescriptorList attribute describes one or more protocol stacks that may be used to gain access to the service described by the service record.

If the ProtocolDescriptorList describes a single stack, it takes the form of a data element sequence in which each element of the sequence is a protocol descriptor. Each protocol descriptor is, in turn, a data element sequence whose first element is a UUID identifying the protocol and whose successive elements are protocol-specific parameters. Potential protocol-specific parameters are a protocol version number and a connection-port number. The protocol descriptors are listed in order from the lowest layer protocol to the highest layer protocol used to gain access to the service.

If it is possible for more than one kind of protocol stack to be used to gain access to the service, the ProtocolDescriptorList takes the form of a data element alternative where each member is a data element sequence as described in the previous paragraph.

Protocol Descriptors

A protocol descriptor identifies a communications protocol and provides protocol-specific parameters. A protocol descriptor is represented as a data element sequence. The first data element in the sequence must be the UUID that identifies the protocol. Additional data elements optionally provide protocol-specific information, such as the L2CAP protocol/service multiplexer (PSM) and the RFCOMM server channel number (CN) shown below.

ProtocolDescriptorList Examples

These examples are intended to be illustrative. The parameter formats for each protocol are not defined within this specification.

In the first two examples, it is assumed that a single RFCOMM instance exists on top of the L2CAP layer. In this case, the L2CAP protocol specific information (PSM) points to the single instance of RFCOMM. In the last example, two different and independent RFCOMM instances are available on top of the L2CAP layer. In this case, the L2CAP protocol specific information (PSM) points to a distinct identifier that distinguishes each of the RFCOMM instances. According to the L2CAP specification, this identifier takes values in the range 0x1000-0xFFFF.

IrDA-like printer

((L2CAP, PSM=RFCOMM), (RFCOMM, CN=1), (PostscriptStream))

IP Network Printing

((L2CAP, PSM=RFCOMM), (RFCOMM, CN=2), (PPP), (IP), (TCP), (IPP))

Synchronization Protocol Descriptor Example

((L2CAP, PSM=0x1001), (RFCOMM, CN=1), (Obex), (vCal))

((L2CAP, PSM=0x1002), (RFCOMM, CN=1), (Obex), (otherSynchronisationApplication))

5.1.6 BrowseGroupList Attribute

Attribute Name	Attribute ID	Attribute Value Type
BrowseGroupList	0x0005	Data Element Sequence

Description:

The BrowseGroupList attribute consists of a data element sequence in which each element is a UUID that represents a browse group to which the service record belongs. The top-level browse group ID, called PublicBrowseRoot and representing the root of the browsing hierarchy, has the value 00001002-0000-1000-8000-00805F9B34FB (UUID16: 0x1002) from the Bluetooth Assigned Numbers document.

5.1.7 LanguageBaseAttributeIDList Attribute

Attribute Name	Attribute ID	Attribute Value Type
LanguageBaseAttributeIDList	0x0006	Data Element Sequence

Description:

In order to support human-readable attributes for multiple natural languages in a single service record, a base attribute ID is assigned for each of the natural languages used in a service record. The human-readable universal attributes are then defined with an attribute ID offset from each of these base values, rather than with an absolute attribute ID.

The LanguageBaseAttributeIDList attribute is a list in which each member contains a language identifier, a character encoding identifier, and a base attribute

ID for each of the natural languages used in the service record. The LanguageBaseAttributeIDList attribute consists of a data element sequence in which each element is a 16-bit unsigned integer. The elements are grouped as triplets (threes).

The first element of each triplet contains an identifier representing the natural language. The language is encoded according to ISO 639:1988 (E/F): “Code for the representation of names of languages”.

The second element of each triplet contains an identifier that specifies a character encoding used for the language. Values for character encoding can be found in IANA's database[1], and have the values that are referred to as MIBEnum values. The recommended character encoding is UTF-8.

The third element of each triplet contains an attribute ID that serves as the base attribute ID for the natural language in the service record. Different service records within a server may use different base attribute ID values for the same language.

To facilitate the retrieval of human-readable universal attributes in a principal language, the base attribute ID value for the primary language supported by a service record must be 0x0100. Also, if a LanguageBaseAttributeIDList attribute is contained in a service record, the base attribute ID value contained in its first element must be 0x0100.

5.1.8 ServiceInfoTimeToLive Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceInfoTimeToLive	0x0007	32-bit unsigned integer

Description:

The ServiceTimeToLive attribute is a 32-bit integer that contains the number of seconds for which the information in a service record is expected to remain valid and unchanged. This time interval is measured from the time that the attribute value is retrieved from the SDP server. This value does not imply a guarantee that the service record will remain available or unchanged. It is simply a hint that a client may use to determine a suitable polling interval to revalidate the service record contents.

1. See http://www.isi.edu/in-notes/iana/assignments/character-sets

5.1.9 ServiceAvailability Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceAvailability	0x0008	8-bit unsigned integer

Description:

The ServiceAvailability attribute is an 8-bit unsigned integer that represents the relative ability of the service to accept additional clients. A value of 0xFF indicates that the service is not currently in use and is thus fully available, while a value of 0x00 means that the service is not accepting new clients. For services that support multiple simultaneous clients, intermediate values indicate the relative availability of the service on a linear scale.

For example, a service that can accept up to 3 clients should provide ServiceAvailability values of 0xFF, 0xAA, 0x55, and 0x00 when 0, 1, 2, and 3 clients, respectively, are utilizing the service. The value 0xAA is approximately (2/3) * 0xFF and represents 2/3 availability, while the value 0x55 is approximately (1/3)*0xFF and represents 1/3 availability. Note that the availability value may be approximated as

(1 - (current_number_of_clients / maximum_number_of_clients)) * 0xFF

When the maximum number of clients is large, this formula must be modified to ensure that ServiceAvailability values of 0x00 and 0xFF are reserved for their defined meanings of unavailability and full availability, respectively.

Note that the maximum number of clients a service can support may vary according to the resources utilized by the service's current clients.

A non-zero value for ServiceAvailability does not guarantee that the service will be available for use. It should be treated as a hint or an approximation of availability status.

5.1.10 BluetoothProfileDescriptorList Attribute

Attribute Name	Attribute ID	Attribute Value Type
BluetoothProfileDescriptorList	0x0009	Data Element Sequence

Description:

The BluetoothProfileDescriptorList attribute consists of a data element sequence in which each element is a profile descriptor that contains information about a Bluetooth profile to which the service represented by this service record conforms. Each profile descriptor is a data element sequence whose first element is the UUID assigned to the profile and whose second element is a 16-bit profile version number.

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Each version of a profile is assigned a 16-bit unsigned integer profile version number, which consists of two 8-bit fields. The higher-order 8 bits contain the major version number field and the lower-order 8 bits contain the minor version number field. The initial version of each profile has a major version of 1 and a minor version of 0. When upward compatible changes are made to the profile, the minor version number will be incremented. If incompatible changes are made to the profile, the major version number will be incremented.

5.1.11 DocumentationURL Attribute

Attribute Name	Attribute ID	Attribute Value Type
DocumentationURL	0x000A	URL

Description:

This attribute is a URL which points to documentation on the service described by a service record.

5.1.12 ClientExecutableURL Attribute

Attribute Name	Attribute ID	Attribute Value Type
ClientExecutableURL	0x000B	URL

Description:

This attribute contains a URL that refers to the location of an application that may be used to utilize the service described by the service record. Since different operating environments require different executable formats, a mechanism has been defined to allow this single attribute to be used to locate an executable that is appropriate for the client device's operating environment. In the attribute value URL, the first byte with the value 0x2A (ASCII character '*') is to be replaced by the client application with a string representing the desired operating environment before the URL is to be used.

The list of standardized strings representing operating environments is contained in the Bluetooth Assigned Numbers document.

For example, assume that the value of the ClientExecutableURL attribute is http://my.fake/public/*/client.exe. On a device capable of executing SH3 WindowsCE files, this URL would be changed to http://my.fake/public/sh3-microsoft-wince/client.exe. On a device capable of executing Windows 98 binaries, this URL would be changed to http://my.fake/public/i86-microsoft-win98/client.exe.

5.1.13 IconURL Attribute

Attribute Name	Attribute ID	Attribute Value Type
IconURL	0x000C	URL

Description:

This attribute contains a URL that refers to the location of an icon that may be used to represent the service described by the service record. Since different hardware devices require different icon formats, a mechanism has been defined to allow this single attribute to be used to locate an icon that is appropriate for the client device. In the attribute value URL, the first byte with the value 0x2A (ASCII character '*') is to be replaced by the client application with a string representing the desired icon format before the URL is to be used.

The list of standardized strings representing icon formats is contained in the Bluetooth Assigned Numbers document.

For example, assume that the value of the IconURL attribute is http://my.fake/public/icons/*. On a device that prefers 24 x 24 icons with 256 colors, this URL would be changed to http://my.fake/public/icons/24x24x8.png. On a device that prefers 10 x 10 monochrome icons, this URL would be changed to http://my.fake/public/icons/10x10x1.png.

5.1.14 ServiceName Attribute

Attribute Name	Attribute ID Offset	Attribute Value Type
ServiceName	0x0000	String

Description:

The ServiceName attribute is a string containing the name of the service represented by a service record. It should be brief and suitable for display with an Icon representing the service. The offset 0x0000 must be added to the attribute ID base (contained in the LanguageBaseAttributeIDList attribute) in order to compute the attribute ID for this attribute.

5.1.15 ServiceDescription Attribute

Attribute Name	Attribute ID Offset	Attribute Value Type
ServiceDescription	0x0001	String

Description:

This attribute is a string containing a brief description of the service. It should be less than 200 characters in length. The offset 0x0001 must be added to the attribute ID base (contained in the LanguageBaseAttributeIDList attribute) in order to compute the attribute ID for this attribute.

5.1.16 ProviderName Attribute

Attribute Name	Attribute ID Offset	Attribute Value Type
ProviderName	0x0002	String

Description:

This attribute is a string containing the name of the person or organization providing the service. The offset 0x0002 must be added to the attribute ID base (contained in the LanguageBaseAttributeIDList attribute) in order to compute the attribute ID for this attribute.

5.1.17 Reserved Universal Attribute IDs

Attribute IDs in the range of 0x000D-0x01FF are reserved.

5.2 SERVICEDISCOVERYSERVER SERVICE CLASS ATTRIBUTE DEFINITIONS

This service class describes service records that contain attributes of service discovery server itself. The attributes listed in this section are only valid if the ServiceClassIDList attribute contains the ServiceDiscoveryServerServiceClassID. Note that all of the universal attributes may be included in service records of the ServiceDiscoveryServer class.

5.2.1 ServiceRecordHandle Attribute

Described in the universal attribute definition for ServiceRecordHandle.

Value

A 32-bit integer with the value 0x000000000.

5.2.2 ServiceClassIDList Attribute

Described in the universal attribute definition for ServiceClassIDList.

Value

A UUID representing the ServiceDiscoveryServerServiceClassID.

5.2.3 VersionNumberList Attribute

Attribute Name	Attribute ID	Attribute Value Type
VersionNumberList	0x0200	Data Element Sequence

Description:

The VersionNumberList is a data element sequence in which each element of the sequence is a version number supported by the SDP server.

A version number is a 16-bit unsigned integer consisting of two fields. The higher-order 8 bits contain the major version number field and the low-order 8 bits contain the minor version number field. The initial version of SDP has a major version of 1 and a minor version of 0. When upward compatible changes are made to the protocol, the minor version number will be incremented. If incompatible changes are made to SDP, the major version number will be incremented. This guarantees that if a client and a server support a common major version number, they can communicate if each uses only features of the specification with a minor version number that is supported by both client and server.

5.2.4 ServiceDatabaseState Attribute

Attribute Name	Attribute ID	Attribute Value Type
ServiceDatabaseState	0x0201	32-bit unsigned integer

Description:

The ServiceDatabaseState is a 32-bit integer that is used to facilitate caching of service records. If this attribute exists, its value is guaranteed to change when any of the other service records are added to or deleted from the server's database. If this value has not changed since the last time a client queried its value, the client knows that a) none of the other service records maintained by the SDP server have been added or deleted; and b) any service record handles acquired from the server are still valid. A client should query this attribute's value when a connection to the server is established, prior to using any service record handles acquired during a previous connection.

Note that the ServiceDatabaseState attribute does not change when existing service records are modified, including the addition, removal, or modification of service attributes. A service record's ServiceRecordState attribute indicates when that service record is modified.

5.2.5 Reserved Attribute IDs

Attribute IDs in the range of 0x0202-0x02FF are reserved.

5.3 BROWSEGROUPDESCRIPTOR SERVICE CLASS ATTRIBUTE DEFINITIONS

This service class describes the ServiceRecord provided for each BrowseGroupDescriptor service offered on a Bluetooth device. The attributes listed in this section are only valid if the ServiceClassIDList attribute contains the BrowseGroupDescriptorServiceClassID. Note that all of the universal attributes may be included in service records of the BrowseGroupDescriptor class.

5.3.1 ServiceClassIDList Attribute

Described in the universal attribute definition for ServiceClassIDList.

Value

A UUID representing the BrowseGroupDescriptorServiceClassID.

5.3.2 GroupID Attribute

Attribute Name	Attribute ID	Attribute Value Type
GroupID	0x0200	UUID

Description:

This attribute contains a UUID that can be used to locate services that are members of the browse group that this service record describes.

5.3.3 Reserved Attribute IDs

Attribute IDs in the range of 0x0201-0x02FF are reserved.

APPENDIX A – BACKGROUND INFORMATION

A.1. Service Discovery

As computing continues to move to a network-centric model, finding and making use of services that may be available in the network becomes increasingly important. Services can include common ones such as printing, paging, FAXing, and so on, as well as various kinds of information access such as teleconferencing, network bridges and access points, eCommerce facilities, and so on — most any kind of service that a server or service provider might offer. In addition to the need for a standard way of discovering available services, there are other considerations: getting access to the services (finding and obtaining the protocols, access methods, “drivers” and other code necessary to utilize the service), controlling access to the services, advertising the services, choosing among competing services, billing for services, and so on. This problem is widely recognized; many companies, standards bodies and consortia are addressing it at various levels in various ways. Service Location Protocol (SLP), Jini™, and Salutation™, to name just a few, all address some aspect of service discovery.

A.2. Bluetooth Service Discovery

Bluetooth Service Discovery Protocol (SDP) addresses service discovery specifically for the Bluetooth environment. It is optimized for the highly dynamic nature of Bluetooth communications. SDP focuses primarily on discovering services available from or through Bluetooth devices. SDP does not define methods for accessing services; once services are discovered with SDP, they can be accessed in various ways, depending upon the service. This might include the use of other service discovery and access mechanisms such as those mentioned above; SDP provides a means for other protocols to be used along with SDP in those environments where this can be beneficial. While SDP can coexist with other service discovery protocols, it does not require them. In Bluetooth environments, services can be discovered using SDP and can be accessed using other protocols defined by Bluetooth.

APPENDIX B – EXAMPLE SDP TRANSACTIONS

The following are simple examples of typical SDP transactions. These are meant to be illustrative of SDP flows. The examples do not consider:

- Caching (in a caching system, the SDP client would make use of the ServiceRecordState and ServiceDatabaseState attributes);
- Service availability (if this is of interest, the SDP client should use the ServiceAvailability and/or ServiceTimeToLive attributes);
- SDP versions (the VersionNumberList attribute could be used to determine compatible SDP versions);
- SDP Error Responses (an SDP error response is possible for any SDP request that is in error); and
- Communication connection (the examples assume that an L2CAP connection is established).

The examples are meant to be illustrative of the protocol. The format used is `ObjectName[ObjectSizeInBytes] {SubObjectDefinitions}`, but this is not meant to illustrate an interface. The `ObjectSizeInBytes` is the size of the object in decimal. The `SubObjectDefinitions` (inside of `{}` characters) are components of the immediately enclosing object. Hexadecimal values shown as lower-case letters, such as for transaction IDs and service handles, are variables (the particular value is not important for the illustration, but each such symbol always represents the same value). Comments are included in this manner: `/* comment text */`.

Numeric values preceded by “0x” are hexadecimal, while those preceded by “0b” are binary. All other numeric values are decimal.

B.1. SDP Example 1 – ServiceSearchRequest

The first example is that of an SDP client searching for a generic printing service. The client does not specify a particular type of printing service. In the example, the SDP server has two available printing services. The transaction illustrates:

1. SDP client to SDP server: SDP_ServiceSearchRequest, specifying the PrinterServiceClassID (represented as a DataElement with a 32-bit UUID value of `ppp...ppp`) as the only element of the ServiceSearchPattern. The PrinterServiceClassID is assumed to be a 32-bit UUID and the data element type for it is illustrated. The TransactionID is illustrated as `tttt`.
2. SDP server to SDP client: SDP_ServiceSearchResponse, returning handles to two printing services, represented as `qqqqqqqq` for the first printing service and `rrrrrrrr` for the second printing service. The Transaction ID is the same value as supplied by the SDP client in the corresponding request (ττττ).

```
/* Sent from SDP Client to SDP server */
SDP_ServiceSearchRequest[15] {
  PDUID[1] {
    0x02
  }
  TransactionID[2] {
    0xtttt
  }
  ParameterLength[2] {
    0x000A
  }
  ServiceSearchPattern[7] {
    DataElementSequence[7] {
      0b00110 0b101 0x05
      UUID[5] {
        /* PrinterServiceClassID */
        0b00011 0b010 0xpppppppp
      }
    }
  }
  MaximumServiceRecordCount[2] {
    0x0003
  }
  ContinuationState[1] {
    /* no continuation state */
    0x00
  }
}


/* Sent from SDP server to SDP client */
SDP_ServiceSearchResponse[18] {
  PDUID[1] {
    0x03
  }
  TransactionID[2] {
    0xtttt
  }
  ParameterLength[2] {
    0x000D
  }
  TotalServiceRecordCount[2] {
    0x0002
  }
  CurrentServiceRecordCount[2] {
    0x0002
  }
  ServiceRecordHandleList[8] {
    /* print service 1 handle */
    0xqqqqqqqq
    /* print service 2 handle */
    0xrrrrrrrr
  }
  ContinuationState[1] {
    /* no continuation state */
```

```
    0x00
  }
}
```

B.2. SDP Example 2 – ServiceAttributeTransaction

The second example continues the first example. In Example 1, the SDP client obtained handles to two printing services. In Example 2, the client uses one of those service handles to obtain the ProtocolDescriptorList attribute for that printing service. The transaction illustrates:

1. SDP client to SDP server: SDP_ServiceAttributeRequest, presenting the previously obtained service handle (the one denoted as qqqqqqqq) and specifying the ProtocolDescriptorList attribute ID (AttributeID 0x0004) as the only attribute requested (other attributes could be retrieved in the same transaction if desired). The TransactionID is illustrated as uuuu to distinguish it from the TransactionID of Example 1.
2. SDP server to SDP client: SDP_ServiceAttributeResponse, returning the ProtocolDescriptorList for the specified printing service. This protocol stack is assumed to be ((L2CAP), (RFCOMM, 2), (PostscriptStream)). The ProtocolDescriptorList is a data element sequence in which each element is, in turn, a data element sequence whose first element is a UUID representing the protocol, and whose subsequent elements are protocol-specific parameters. In this example, one such parameter is included for the RFCOMM protocol, an 8-bit value indicating RFCOMM server channel 2. The Transaction ID is the same value as supplied by the SDP client in the corresponding request (uuuu). The Attributes returned are illustrated as a data element sequence where the protocol descriptors are 32-bit UUIDs and the RFCOMM server channel is a data element with an 8-bit value of 2.

```
 /* Sent from SDP Client to SDP server */
SDP_ServiceAttributeRequest[17] {
  PDUID[1] {
    0x04
  }
  TransactionID[2] {
    0xuuuu
  }
  ParameterLength[2] {
    0x000C
  }
  ServiceRecordHandle[4] {
    0xqqqqqqqq
  }
  MaximumAttributeByteCount[2] {
    0x0080
  }
  AttributeIDList[5] {
    DataElementSequence[5] {
```

```
      0b00110 0b101 0x03
      AttributeID[3] {
        0b00001 0b001 0x0004
      }
    }
  }
  ContinuationState[1] {
    /* no continuation state */
    0x00
  }
}

/* Sent from SDP server to SDP client */
SDP_ServiceAttributeResponse[38] {
  PDUID[1] {
    0x05
  }
  TransactionID[2] {
    0xuuuu
  }
  ParameterLength[2] {
    0x0021
  }
  AttributeListByteCount[2] {
    0x001E
  }
  AttributeList[30] {
    DataElementSequence[30] {
      0b00110 0b101 0x1C
      Attribute[28] {
        AttributeID[3] {
          0b00001 0b001 0x0004
        }
        AttributeValue[25] {
          /* ProtocolDescriptorList */
          DataElementSequence[25] {
            0b00110 0b101 0x17
            /* L2CAP protocol descriptor */
            DataElementSequence[7] {
              0b00110 0b101 0x05
              UUID[5] {
                /* L2CAP Protocol UUID */
                0b00011 0b010 <32-bit L2CAP UUID>
              }
            }
            /* RFCOMM protocol descriptor */
            DataElementSequence[9] {
              0b00110 0b101 0x07
              UUID[5] {
                /* RFCOMM Protocol UUID */
                0b00011 0b010 <32-bit RFCOMM UUID>
              }
              /* parameter for server 2 */
              Uint8[2] {
                0b00001 0b000 0x02
              }
            }
```

```
            /* PostscriptStream protocol descriptor */
            DataElementSequence[7] {
              0b00110 0b101 0x05
              UUID[5] {
                /* PostscriptStream Protocol UUID */
                0b00011 0b010 <32-bit PostscriptStream UUID>
              }
            }
          }
        }
      }
    }
  }
  ContinuationState[1] {
    /* no continuation state */
    0x00
  }
}
```

B.3. SDP Example 3 – ServiceSearchAttributeTransaction

The third example is a form of service browsing, although it is not generic browsing in that it does not make use of SDP browse groups. Instead, an SDP client is searching for available Synchronization services that can be presented to the user for selection. The SDP client does not specify a particular type of synchronization service. In the example, the SDP server has three available synchronization services: an address book synchronization service and a calendar synchronization service (both from the same provider), and a second calendar synchronization service from a different provider. The SDP client is retrieving the same attributes for each of these services; namely, the data formats supported for the synchronization service (vCard, vCal, ICal, etc.) and those attributes that are relevant for presenting information to the user about the services. Also assume that the maximum size of a response is 400 bytes. Since the result is larger than this, the SDP client will repeat the request supplying a continuation state parameter to retrieve the remainder of the response. The transaction illustrates:

1. SDP client to SDP server: SDP_ServiceSearchAttributeRequest, specifying the generic SynchronisationServiceClassID (represented as a data element whose 32-bit UUID value is `sss...sss`) as the only element of the ServiceSearchPattern. The SynchronisationServiceClassID is assumed to be a 32-bit UUID. The requested attributes are the ServiceRecordHandle (attribute ID 0x0000), ServiceClassIDList (attribute ID 0x0001), IconURL (attribute ID 0x000C), ServiceName (attribute ID 0x0100), ServiceDescription (attribute ID 0x0101), and ProviderName (attributeID 0x0102) attributes; as well as the service-specific SupportedDataStores (AttributeID 0x0301). Since the first two attribute IDs (0x0000 and 0x0001) and three other attribute IDs(0x0100, 0x0101, and 0x0102 are consecutive, they are specified as attribute ranges. The TransactionID is illustrated as `vvvv` to distinguish it from the TransactionIDs of the other Examples.

Note that values in the service record's primary language are requested for the text attributes (ServiceName, ServiceDescription and ProviderName) so that absolute attribute IDs may be used, rather than adding offsets to a base obtained from the LanguageBaseAttributeIDList attribute.

2. SDP server to SDP client: SDP_ServiceSearchAttributeResponse, returning the specified attributes for each of the three synchronization services. In the example, each ServiceClassIDList is assumed to contain a single element, the generic SynchronisationServiceClassID (a 32-bit UUID represented as sss...sss). Each of the other attributes contain illustrative data in the example (the strings have illustrative text; the icon URLs are illustrative, for each of the respective three synchronization services; and the SupportedDataStore attribute is represented as an unsigned 8-bit integer where 0x01 = vCard2.1, 0x02 = vCard3.0, 0x03 = vCal1.0 and 0x04 = iCal). Note that one of the service records (the third for which data is returned) has no ServiceDescription attribute. The attributes are returned as a data element sequence, where each element is in turn a data element sequence representing a list of attributes. Within each attribute list, the ServiceClassIDList is a data element sequence while the remaining attributes are single data elements. The Transaction ID is the same value as supplied by the SDP client in the corresponding request (0xvvvv). Since the entire result cannot be returned in a single response, a non-null continuation state is returned in this first response.

   Note that the total length of the initial data element sequence (487 in the example) is indicated in the first response, even though only a portion of this data element sequence (368 bytes in the example, as indicated in the AttributeLists byte count) is returned in the first response. The remainder of this data element sequence is returned in the second response (without an additional data element header).

3. SDP client to SDP server: SDP_ServiceSearchAttributeRequest, with the same parameters as in step 1, except that the continuation state received from the server in step 2 is included as a request parameter. The TransactionID is changed to 0xwww to distinguish it from previous request.
4. SDP server to SDP client: SDP_ServiceSearchAttributeResponse, with the remainder of the result computed in step 2 above. Since all of the remaining result fits in this second response, a null continuation state is included.

```
/* Part 1 -- Sent from SDP Client to SDP server */
SdpSDP_ServiceSearchAttributeRequest[33] {
  PDUID[1] {
    0x06
  }
  TransactionID[2] {
    0xvvvv
  }
  ParameterLength[2] {
    0x001B
  }
  ServiceSearchPattern[7] {
```

```
    DataElementSequence[7] {
      0b00110 0b101 0x05
      UUID[5] {
        /* SynchronisationServiceClassID */
        0b00011 0b010 0xssssssss
      }
    }
  }
  MaximumAttributeByteCount[2] {
    0x0190
  }
AttributeIDList[18] {
    DataElementSequence[18] {
      0b00110 0b101 0x10
      AttributeIDRange[5] {
        0b00001 0b010 0x00000001
      }
      AttributeID[3] {
        0b00001 0b001 0x000C
      }
      AttributeIDRange[5] {
        0b00001 0b010 0x01000102
      }
      AttributeID[3] {
        0b00001 0b001 0x0301
      }    }
  }
  ContinuationState[1] {
    /* no continuation state */
    0x00
  }
}

/* Part 2 -- Sent from SDP server to SDP client */
SdpSDP_ServiceSearchAttributeResponse[384] {
  PDUID[1] {
    0x07
  }
  TransactionID[2] {
    0xvvvv
  }
  ParameterLength[2] {
    0x017B
  }
  AttributeListByteCount[2] {
    0x0170
  }
  AttributeLists[368] {
    DataElementSequence[487] {
      0b00110 0b110 0x01E4
      DataElementSequence[178] {
        0b00110 0b101 0xB0
        Attribute[8] {
          AttributeID[3] {
            0b00001 0b001 0x0000
          }
          AttributeValue[5] {
```

```
            /* service record handle */
            0b00001 0b010 0xhhhhhhhh
          }
        }
        Attribute[10] {
          AttributeID[3] {
            0b00001 0b001 0x0001
          }
AttributeValue[7] {
            DataElementSequence[7] {
              0b00110 0b101 0x05
              UUID[5] {
                /* SynchronisationServiceClassID */
                0b00011 0b010 0xssssssss
              }
            }
          }
        }
        Attribute[35] {
          AttributeID[3] {
            0b00001 0b001 0x000C
          }
          AttributeValue[32] {
            /* IconURL; '*' replaced by client application */
            0b01000 0b101 0x1E
            "http://Synchronisation/icons/*"
          }
        }
        Attribute[22] {
          AttributeID[3] {
            0b00001 0b001 0x0100
          }
          AttributeValue[19] {
            /* service name */
            0b00100 0b101 0x11
            "Address Book Sync"
          }
        }
        Attribute[59] {
          AttributeID[3] {
            0b00001 0b001 0x0101
          }
          AttributeValue[56] {
            /* service description */
            0b00100 0b101 0x36
            "Synchronisation Service for"
            " vCard Address Book Entries"
          }
        }
        Attribute[37] {
          AttributeID[3] {
            0b00001 0b001 0x0102
          }
          AttributeValue[34] {
            /* service provider */
            0b00100 0b101 0x20
            "Synchronisation Specialists Inc."
```

```
      }
    }
    Attribute[5] {
      AttributeID[3] {
        0b00001 0b001 0x0301
      }
      AttributeValue[2] {
        /* Supported Data Store 'phonebook' */
        0b00001 0b000 0x01
      }
    }
  }
  DataElementSequence[175] {
    0b00110 0b101 0xAD
    Attribute[8] {
      AttributeID[3] {
        0b00001 0b001 0x0000
      }
      AttributeValue[5] {
        /* service record handle */
        0b00001 0b010 0xmmmmmmmm
      }
    }
    Attribute[10] {
      AttributeID[3] {
        0b00001 0b001 0x0001
      }
                AttributeValue[7] {
      DataElementSequence[7] {
        0b00110 0b101 0x05
        UUID[5] {
          /* SynchronisationServiceClassID */
          0b00011 0b010 0xssssssss
        }
      }
      }
    }
    Attribute[35] {
      AttributeID[3] {
        0b00001 0b001 0x000C
      }
      AttributeValue[32] {
        /* IconURL; '*' replaced by client application */
        0b01000 0b101 0x1E
        "http://Synchronisation/icons/*"
      }
    }
    Attribute[21] {
      AttributeID[3] {
        0b00001 0b001 0x0100
      }
      AttributeValue[18] {
        /* service name */
        0b00100 0b101 0x10
        "Appointment Sync"
      }
    }
```

```
        Attribute[57] {
          AttributeID[3] {
            0b00001 0b001 0x0101
          }
          AttributeValue[54] {
            /* service description */
            0b00100 0b101 0x34
            "Synchronisation Service for"
            " vCal Appointment Entries"
          }
        }
        Attribute[37] {
          AttributeID[3] {
            0b00001 0b001 0x0102
          }
          AttributeValue[34] {
            /* service provider */
            0b00100 0b101 0x20
            "Synchronisation Specialists Inc."
          }
        }
        Attribute[5] {
          AttributeID[3] {
            0b00001 0b001 0x0301
          }
          AttributeValue[2] {
            /* Supported Data Store 'calendar' */
            0b00001 0b000 0x03
          }
        }
      }
    /* } Data element sequence of attribute lists */
    /* is not completed in this PDU. */
  }
  ContinuationState[9] {
    /* 8 bytes of continuation state */
    0x08 0xzzzzzzzzzzzzzzzz
  }
}

/* Part 3 -- Sent from SDP Client to SDP server */
SdpSDP_ServiceSearchAttributeRequest[41] {
  PDUID[1] {
    0x06
  }
  TransactionID[2] {
    0xwwww
  }
  ParameterLength[2] {
    0x0024
  }
  ServiceSearchPattern[7] {
    DataElementSequence[7] {
      0b00110 0b101 0x05
      UUID[5] {
        /* SynchronisationServiceClassID */
        0b00011 0b010 0xssssssss
```

```
      }
    }
  }
  MaximumAttributeByteCount[2] {
    0x0180
  }
    AttributeIDList[18] {
    DataElementSequence[18] {
      0b00110 0b101 0x10
      AttributeIDRange[5] {
        0b00001 0b010 0x00000001
      }
      AttributeID[3] {
        0b00001 0b001 0x000C
      }
      AttributeIDRange[5] {
        0b00001 0b010 0x01000102
      }
      AttributeID[3] {
        0b00001 0b001 0x0301
      }
    }
  }
  ContinuationState[9] {
    /* same 8 bytes of continuation state */
    /* received in part 2 */
    0x08 0xzzzzzzzzzzzzzzzz
  }
}

Part 4 -- Sent from SDP server to SDP client

SdpSDP_ServiceSearchAttributeResponse[115] {
  PDUID[1] {
    0x07
  }
  TransactionID[2] {
    0xwwww
  }
  ParameterLength[2] {
    0x006E
  }
  AttributeListByteCount[2] {
    0x006B
  }
  AttributeLists[107] {
    /* Continuing the data element sequence of */
    /* attribute lists begun in Part 2. */
      DataElementSequence[107] {
        0b00110 0b101 0x69
        Attribute[8] {
          AttributeID[3] {
            0b00001 0b001 0x0000
          }
          AttributeValue[5] {
            /* service record handle */
            0b00001 0b010 0xffffffff
```

```
        }
      }
      Attribute[10] {
        AttributeID[3] {
          0b00001 0b001 0x0001
        }
        AttributeValue[7] {
          DataElementSequence[7] {
            0b00110 0b101 0x05
            UUID[5] {
              /* SynchronisationServiceClassID */
              0b00011 0b010 0xssssssss
            }
          }
        }
      }
      Attribute[35] {
        AttributeID[3] {
          0b00001 0b001 0x000C
        }
        AttributeValue[32] {
          /* IconURL; '*' replaced by client application */
          0b01000 0b101 0x1E
          "http://DevManufacturer/icons/*"
        }
      }
      Attribute[18] {
        AttributeID[3] {
          0b00001 0b001 0x0100
        }
        AttributeValue[15] {
          /* service name */
          0b00100 0b101 0x0D
          "Calendar Sync"
        }
      }
      Attribute[29] {
        AttributeID[3] {
          0b00001 0b001 0x0102
        }
        AttributeValue[26] {
          /* service provider */
          0b00100 0b101 0x18
          "Device Manufacturer Inc."
        }
      }
      Attribute[5] {
        AttributeID[3] {
          0b00001 0b001 0x0301
        }
        AttributeValue[2] {
          /* Supported Data Store 'calendar' */
          0b00001 0b000 0x03
        }
      }
    }
  /* This completes the data element sequence */
```

```
    /* of attribute lists begun in Part 2.
  }
  ContinuationState[1] {
    /* no continuation state */
    0x00
  }
}
```



GENERIC ACCESS PROFILE

This profile defines the generic procedures related to discovery of Bluetooth devices (idle mode procedures) and link management aspects of connecting to Bluetooth devices (connecting mode procedures). It also defines procedures related to use of different security levels. In addition, this profile includes common format requirements for parameters accessible on the user interface level.

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FOREWORD

Interoperability between devices from different manufacturers is provided for a specific service and use case, if the devices conform to a Bluetooth SIG-defined profile specification. A profile defines a selection of messages and procedures (generally termed *capabilities*) from the Bluetooth SIG specifications and gives a description of the air interface for specified service(s) and use case(s).

All defined features are process-mandatory. This means that, if a feature is used, it is used in a specified manner. Whether the provision of a feature is mandatory or optional is stated separately for both sides of the Bluetooth air interface.

1 INTRODUCTION

1.1 SCOPE

The purpose of the Generic Access Profile is:

To introduce definitions, recommendations and common requirements related to modes and access procedures that are to be used by transport and application profiles.

To describe how devices are to behave in standby and connecting states in order to guarantee that links and channels always can be established between Bluetooth devices, and that multi-profile operation is possible. Special focus is put on discovery, link establishment and security procedures.

To state requirements on user interface aspects, mainly coding schemes and names of procedures and parameters, that are needed to guarantee a satisfactory user experience.

1.2 SYMBOLS AND CONVENTIONS

1.2.1 Requirement status symbols

In this document (especially in the profile requirements tables), the following symbols are used:

‘M’ for mandatory to support (used for capabilities that shall be used in the profile);

’O’ for optional to support (used for capabilities that can be used in the profile);

‘C’ for conditional support (used for capabilities that shall be used in case a certain other capability is supported);

‘X’ for excluded (used for capabilities that may be supported by the unit but shall never be used in the profile);

’N/A’ for not applicable (in the given context it is impossible to use this capability).

Some excluded capabilities are capabilities that, according to the relevant Bluetooth specification, are mandatory. These are features that may degrade operation of devices following this profile. Therefore, these features shall never be activated while a unit is operating as a unit within this profile.

In this specification, the word *shall* is used for mandatory requirements, the word *should* is used to express recommendations and the word *may* is used for options.

1.2.2 Signaling diagram conventions

The following arrows are used in diagrams describing procedures :

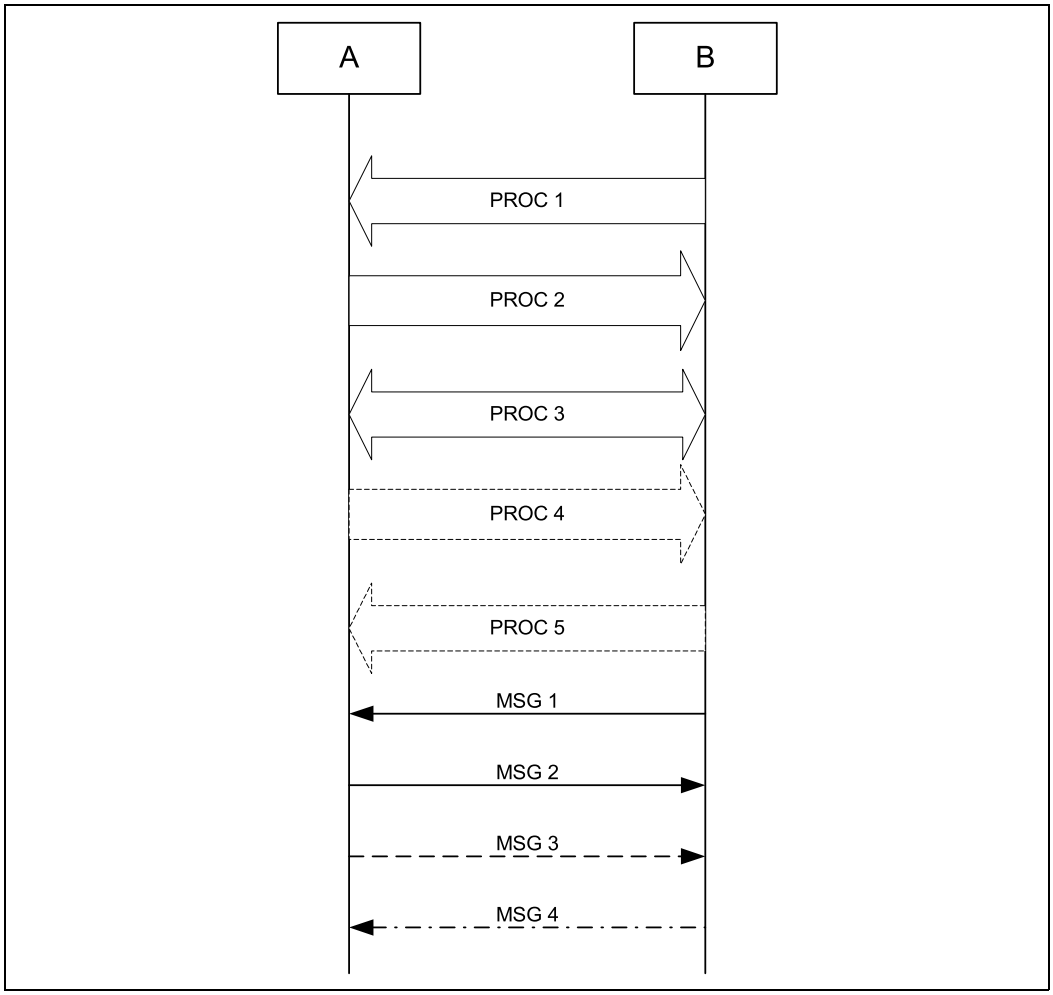


Figure 1.1: Arrows used in signaling diagrams

In the table above, the following cases are shown: PROC1 is a sub-procedure initiated by B. PROC2 is a sub-procedure initiated by A. PROC3 is a sub-procedure where the initiating side is undefined (may be both A or B). Dashed arrows denote optional steps. PROC4 indicates an optional sub-procedure initiated by A, and PROC5 indicates an optional sub-procedure initiated by B.

MSG1 is a message sent from B to A. MSG2 is a message sent from A to B. MSG3 indicates an optional message from A to B, and MSG4 indicates a conditional message from B to A.

1.2.3 Notation for timers and counters

Timers are introduced specific to this profile. To distinguish them from timers used in the Bluetooth protocol specifications and other profiles, these timers are named in the following format: '$T_{GAP}(nnn)$'.

2 PROFILE OVERVIEW

2.1 PROFILE STACK

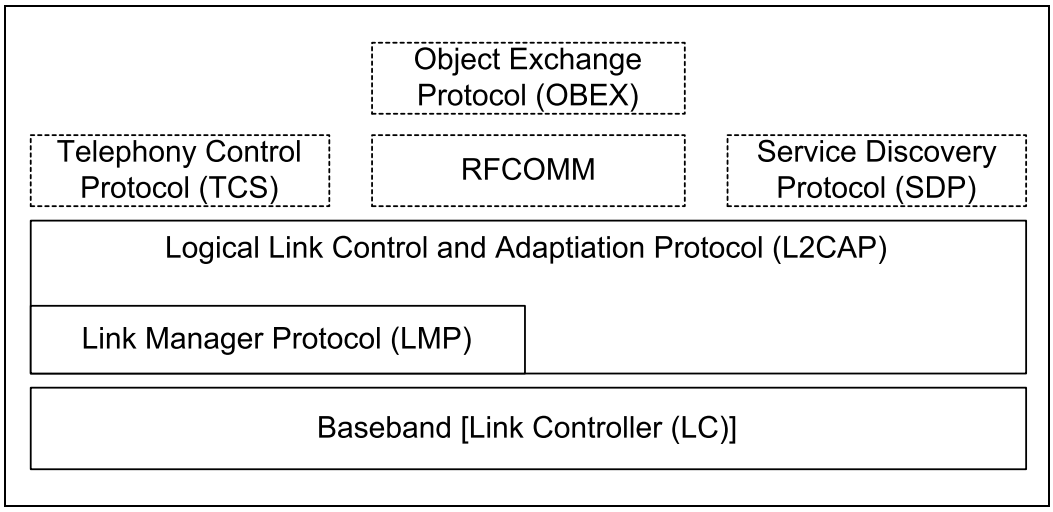


Figure 2.1: Profile stack covered by this profile.

The main purpose of this profile is to describe the use of the lower layers of the Bluetooth protocol stack (LC and LMP). To describe security related alternatives, also higher layers (L2CAP, RFCOMM and OBEX) are included.

2.2 CONFIGURATIONS AND ROLES

For the descriptions in this profile of the roles that the two devices involved in a Bluetooth communication can take, the generic notation of the A-party (the *paging device* in case of link establishment, or *initiator* in case of another procedure on an established link) and the B-party (*paged device* or *acceptor*) is used. The A-party is the one that, for a given procedure, initiates the establishment of the physical link or initiates a transaction on an existing link.

This profile handles the procedures between two devices related to discovery and connecting (link and connection establishment) for the case where none of the two devices has any link established as well as the case where (at least) one device has a link established (possibly to a third device) before starting the described procedure.

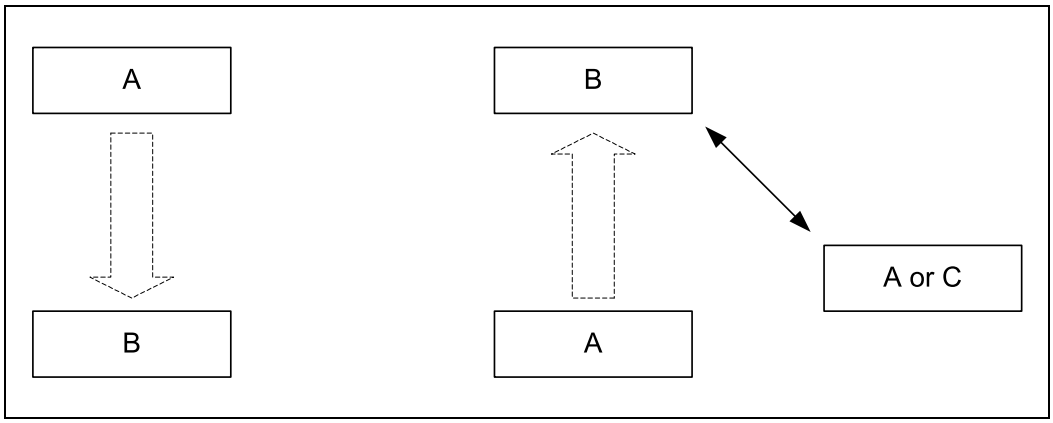


Figure 2.2: This profile covers procedures initiated by one device (A) towards another device (B) that may or may not have an existing Bluetooth link active.

The initiator and the acceptor generally operate the generic procedures according to this profile or another profile referring to this profile. If the acceptor operates according to several profiles simultaneously, this profile describes generic mechanisms for how to handle this.

2.3 USER REQUIREMENTS AND SCENARIOS

The Bluetooth user should in principle be able to connect a Bluetooth device to any other Bluetooth device. Even if the two connected devices don't share any common application, it should be possible for the user to find this out using basic Bluetooth capabilities. When the two devices do share the same application but are from different manufacturers, the ability to connect them should not be blocked just because manufacturers choose to call basic Bluetooth capabilities by different names on the user interface level or implement basic procedures to be executed in different orders.

2.4 PROFILE FUNDAMENTALS

This profile states the requirements on names, values and coding schemes used for names of parameters and procedures experienced on the user interface level.

This profile defines modes of operation that are not service- or profile-specific, but that are generic and can be used by profiles referring to this profile, and by devices implementing multiple profiles.

This profile defines the general procedures that can be used for discovering identities, names and basic capabilities of other Bluetooth devices that are in a mode where they can be discoverable. Only procedures where no channel or connection establishment is used are specified.

This profile defines the general procedure for how to create bonds (i.e. dedicated exchange of link keys) between Bluetooth devices.

This profile describes the general procedures that can be used for establishing connections to other Bluetooth devices that are in mode that allows them to accept connections and service requests.

2.5 CONFORMANCE

Bluetooth devices that do not conform to any other Bluetooth profile shall conform to this profile to ensure basic interoperability.

Bluetooth devices that conform to another Bluetooth profile may use adaptations of the generic procedures as specified by that other profile. They shall, however, be compatible with devices compliant to this profile at least on the level of the supported generic procedures.

If conformance to this profile is claimed, all capabilities indicated mandatory for this profile shall be supported in the specified manner (process-mandatory). This also applies for all optional and conditional capabilities for which support is indicated. All mandatory capabilities, and optional and conditional capabilities for which support is indicated, are subject to verification as part of the Bluetooth certification program.

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3 USER INTERFACE ASPECTS

3.1 THE USER INTERFACE LEVEL

In the context of this specification, the user interface level refers to places (such as displays, dialog boxes, manuals, packaging, advertising, etc.) where users of Bluetooth devices encounters names, values and numerical representation of Bluetooth terminology and parameters.

This profile specifies the generic terms that should be used on the user interface level.

3.2 REPRESENTATION OF BLUETOOTH PARAMETERS

3.2.1 Bluetooth device address (BD_ADDR)

3.2.1.1 Definition

BD_ADDR is the address used by a Bluetooth device as defined in [1]. It is received from a remote device during the device discovery procedure.

3.2.1.2 Term on user interface level

When the Bluetooth address is referred to on UI level, the term ’Bluetooth Device Address’ should be used.

3.2.1.3 Representation

On BB level the BD_ADDR is represented as 48 bits [1].

On the UI level the Bluetooth address shall be represented as 12 hexadecimal characters, possibly divided into sub-parts separated by’:’.
(E.g., ’000C3E3A4B69’ or ’00:0C:3E:3A:4B:69’.) At UI level, any number shall have the MSB -> LSB (from left to right) ’natural’ ordering (e.g., the number ’16’ shall be shown as ’0x10’).

3.2.2 Bluetooth device name (the user-friendly name)

3.2.2.1 Definition

The Bluetooth device name is the user-friendly name that a Bluetooth device presents itself with. It is a character string returned in LMP_name_res as response to a LMP_name_req.

3.2.2.2 Term on user interface level

When the Bluetooth device name is referred to on UI level, the term ’Bluetooth Device Name’ should be used.

3.2.2.3 Representation

The Bluetooth device name can be up to 248 bytes maximum according to [2]. It shall be encoded according to UTF-8 (i.e. name entered on UI level may be down to 82 characters outside the Unicode range 0x00-0x7F are used).

A device can not expect that a general remote device is able to handle more than the first 40 characters of the Bluetooth device name. If a remote device has limited display capabilities, it may use only the first 20 characters.

3.2.3 Bluetooth passkey (Bluetooth PIN)

3.2.3.1 Definition

The Bluetooth PIN is used to authenticate two Bluetooth devices (that have not previously exchanged link keys) to each other and create a trusted relationship between them. The PIN is used in the pairing procedure (see Section 10.2 on page 224) to generate the initial link key that is used for further authentication.

The PIN may be entered on UI level but may also be stored in the device; e.g. in the case of a device without sufficient MMI for entering and displaying digits.

3.2.3.2 Terms at user interface level

When the Bluetooth PIN is referred to on UI level, the term ’Bluetooth Passkey’ should be used.

3.2.3.3 Representation

The Bluetooth PIN has different representations on different levels. PINBB is used on baseband level, and PINUI is used on user interface level.

PINBB is the PIN used by [1] for calculating the initialization key during the pairing procedure. PINUI is the character representation of the PIN that is entered on UI level. The transformation from PINUI to PINBB shall be according to UTF-8 and decimal digits shall be within the Unicode range 0x00 - 0x7F.

According to [1], PINBB can be 128 bits (16 bytes). I.e. if a device supports entry of characters outside the Unicode range 0x00 - 0x7F, the maximum number of characters in the PINUI may be less than 16.

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Examples:

User-entered code	Corresponding PIN_{BB}[0..length-1] (value as a sequence of octets in hexadecimal notation)
’0123’	length = 4, value = 0x30 0x31 0x32 0x33
’Ärlich’	length = 7, value = 0xC3 0x84 0x72 0x6C 0x69 0x63 0x68

All Bluetooth devices that support the bonding procedure and support PIN handling on UI level shall support UI level handling of PINs consisting of decimal digits. In addition, devices may support UI level handling of PINs consisting of general characters.

If a device has a fixed PIN (i.e. PIN is stored in the device and cannot be entered on UI level during pairing), the PIN shall be defined using decimal digits. A device that is expected to pair with a remote device that has restricted UI capabilities should ensure that the PIN can be entered on UI level as decimal digits.

3.2.4 Class of Device

3.2.4.1 Definition

Class of device is a parameter received during the device discovery procedure, indicating the type of device and which types of service that are supported.

3.2.4.2 Term on user interface level

The information within the Class of Device parameter should be referred to as ’Bluetooth Device Class’ (i.e. the major and minor device class fields) and ’Bluetooth Service Type’ (i.e. the service class field). The terms for the defined Bluetooth Device Types and Bluetooth Service Types are defined in [11].

When using a mix of information found in the Bluetooth Device Class and the Bluetooth Service Type, the term ’Bluetooth Device Type’ should be used.

3.2.4.3 Representation

The Class of device is a bit field and is defined in [11]. The UI-level representation of the information in the Class of device is implementation specific.

3.3 PAIRING

Two procedures are defined that make use of the pairing procedure defined on LMP level (LMP-pairing, see Section 10.2 on page 224). Either the user initiates the bonding procedure and enters the passkey with the explicit purpose of creating a bond (and maybe also a secure relationship) between two Bluetooth devices, or the user is requested to enter the passkey during the establishment procedure since the devices did not share a common link key beforehand. In the first case, the user is said to perform ’bonding (with entering of passkey)’ and in the second case the user is said to ’authenticate using the passkey’.

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4 MODES

Procedure	Ref.	Support
Discoverability modes:	4.1	
Non-discoverable mode		C1
Limited discoverable mode		O
General discoverable mode		O
Connectability modes:	4.1.3.3	
Non-connectable mode		O
Connectable mode		M
Pairing modes:	4.2.2.2	
Non-pairable mode		O
Pairable mode		C2
C1: If limited discoverable mode is supported, non-discoverable mode is mandatory, otherwise optional.		
C2: If the bonding procedure is supported, support for pairable mode is mandatory, otherwise optional.		

Table 4.1: Conformance requirements related to modes defined in this section

4.1 DISCOVERABILITY MODES

With respect to inquiry, a Bluetooth device shall be either in non-discoverable mode or in a discoverable mode. (The device shall be in one, and only one, discoverability mode at a time.) The two discoverable modes defined here are called limited discoverable mode and general discoverable mode. Inquiry is defined in [1].

When a Bluetooth device is in non-discoverable mode it does not respond to inquiry.

A Bluetooth device is said to be made discoverable, or set into a discoverable mode, when it is in limited discoverable mode or in general discoverable mode. Even when a Bluetooth device is made discoverable it may be unable to respond to inquiry due to other baseband activity [1]. A Bluetooth device that does not respond to inquiry for any of these two reasons is called a silent device.

After being made discoverable, the Bluetooth device shall be discoverable for at least $T_{GAP}(103)$.

The speed of discovery is dependent on the configuration of the inquiry scan interval and inquiry scan type of the Bluetooth device. The Host is able to configure these parameters based on trade-offs between power consumption, bandwidth and the desired speed of discovery.

4.1.1 Non-discoverable mode

4.1.1.1 Definition

When a Bluetooth device is in non-discoverable mode, it shall never enter the INQUIRY_RESPONSE state.

4.1.1.2 Term on UI-level

Bluetooth device is ’non-discoverable’ or in ’non-discoverable mode’.

4.1.2 Limited discoverable mode

4.1.2.1 Definition

The limited discoverable mode should be used by devices that need to be discoverable only for a limited period of time, during temporary conditions or for a specific event. The purpose is to respond to a device that makes a limited inquiry (inquiry using the LIAC).

A Bluetooth device should not be in limited discoverable mode for more than $T_{GAP}(104)$. The scanning for the limited inquiry access code can be done either in parallel or in sequence with the scanning of the general inquiry access code. When in limited discoverable mode, one of the following options shall be used.

- *Parallel scanning*

  When a Bluetooth device is in limited discoverable mode and when discovery speed is more important than power consumption or bandwidth, it is recommended that the Bluetooth device enter the INQUIRY_SCAN state at least every $T_{GAP}(105)$ and that Interlaced Inquiry scan is used.

  If, however, power consumption or bandwidth is important, but not critical, it is recommended that the Bluetooth device enter the INQUIRY_SCAN state at least every $T_{GAP}(102)$ and Interlaced Inquiry scan is used.

  When power consumption or bandwidth is critical it is recommended that the Bluetooth device enter the INQUIRY_SCAN state at least every $T_{GAP}(102)$ and non-Interlaced Inquiry scan is used.

  In all cases the Bluetooth device shall enter the INQUIRY_SCAN state at least once in $T_{GAP}(102)$ and scan for the GIAC and the LIAC for at least $T_{GAP}(101)$

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When either a SCO or eSCO link is in operation, it is recommended to use interlaced scan to significantly decrease the discoverability time.

- *Sequential scanning*

  When a Bluetooth device is in limited discoverable mode, it shall enter the INQUIRY_SCAN state at least once in $T_{GAP}(102)$ and scan for the GIAC for at least $T_{GAP}(101)$ and enter the INQUIRY_SCAN state more often than once in $T_{GAP}(102)$ and scan for the LIAC for at least $T_{GAP}(101)$.

  If an inquiry message is received when in limited discoverable mode, the entry into the INQUIRY_RESPONSE state takes precedence over the next entries into INQUIRY_SCAN state until the inquiry response is completed.

4.1.2.2 Conditions

When a device is in limited discoverable mode it shall set bit no 13 in the Major Service Class part of the Class of Device/Service field [11].

4.1.2.3 Term on UI-level

Bluetooth device is ’discoverable’ or in ’discoverable mode’.

4.1.3 General discoverable mode

4.1.3.1 Definition

The general discoverable mode shall be used by devices that need to be discoverable continuously or for no specific condition. The purpose is to respond to a device that makes a general inquiry (inquiry using the GIAC).

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4.1.3.2 Conditions

When a Bluetooth device is in general discoverable mode and when discovery speed is more important than power consumption or bandwidth, it is recommended that the Bluetooth device enter the INQUIRY_SCAN state at least every $T_{GAP}(105)$ and that Interlaced Inquiry scan is used.

If, however, power consumption or bandwidth is important, but not critical, it is recommended that the Bluetooth device enter the INQUIRY_SCAN state at least every $T_{GAP}(102)$ and Interlaced Inquiry scan is used.

When power consumption or bandwidth is critical it is recommended that the Bluetooth device enter the INQUIRY_SCAN state at least every $T_{GAP}(102)$ and Non-interlaced Inquiry scan is used.

In all cases the Bluetooth device shall enter the INQUIRY_SCAN state at least once in $T_{GAP}(102)$ and scan for the GIAC for at least $T_{GAP}(101)$.

When either a SCO or eSCO link is in operation, it is recommended to use interlaced scan to significantly decrease the discoverability time.

A device in general discoverable mode shall not respond to a LIAC inquiry.

4.1.3.3 Term on UI-level

Bluetooth device is ’discoverable’ or in ’discoverable mode’.

4.2 CONNECTABILITY MODES

With respect to paging, a Bluetooth device shall be either in non-connectable mode or connectable mode. Paging is defined in [1].

When a Bluetooth device is in non-connectable mode it does not respond to paging. When a Bluetooth device is in connectable mode it responds to paging.

The speed of connections is dependent on the configuration of the page scan interval and page scan type of the Bluetooth device. The Host is able to configure these parameters based on trade-offs between power consumption, bandwidth and the desired speed of connection.

4.2.1 Non-connectable mode

4.2.1.1 Definition

When a Bluetooth device is in non-connectable mode it shall never enter the PAGE_SCAN state.

4.2.1.2 Term on UI-level

Bluetooth device is ’non-connectable’ or in ’non-connectable mode’.

4.2.2 Connectable mode

4.2.2.1 Definition

When a Bluetooth device is in connectable mode it shall periodically enter the PAGE_SCAN state. The device makes page scan using the Bluetooth device address, BD_ADDR. Connection speed is a trade-off between power consumption / available bandwidth and speed. The Bluetooth Host is able to make these trade-offs using the Page Scan interval, Page Scan window, and Interlaced Scan parameters.

R0 page scanning should be used when connection speeds are critically important and when the paging device has a very good estimate of the Bluetooth clock. Under these conditions it is possible for paging to complete within two times the page scan window. Because the page scan interval is equal to the page scan window it is not possible for any other traffic to go over the Bluetooth link when using R0 page scanning. In R0 page scanning it is not possible to use interlaced scan. R0 page scanning is the highest power consumption mode of operation.

When connection times are critical but the other device either does not have an estimate of the Bluetooth clock or when the estimate is possibly out of date, it is better to use R1 page scanning with a very short page scan interval,

$T_{GAP}(106)$, and Interlaced scan. This configuration is also useful to achieve nearly the same connection speeds as R0 page scanning but using less power consumption and leaving bandwidth available for other connections. Under these circumstances it is possible for paging to complete within $T_{GAP}(106)$. In this case the Bluetooth device shall page scan for at least $T_{GAP}(101)$.

When connection times are important but not critical enough to sacrifice significant bandwidth and/or power consumption it is recommended to use either $T_{GAP}(107)$ or $T_{GAP}(108)$ for the scanning interval. Using Interlaced scan will reduce the connection time by half but may use twice the power consumption. Under these circumstances it is possible for paging to complete within one or two times the page scanning interval depending on whether Interlaced Scan is used. In this case the Bluetooth device shall page scan for at least $T_{GAP}(101)$.

In all cases the Bluetooth device shall enter the PAGE_SCAN state at least once in $T_{GAP}(102)$ and scan for at least $T_{GAP}(101)$.

The page scan interval, page scan window size and scan type for the six scenarios are described in the following table:

Scenario	Page Scan Interval	Page Scan Window	Scan Type
R0 (1.28s)	$T_{GAP}(107)$	$T_{GAP}(107)$	Normal scan
Fast R1 (100ms)	$T_{GAP}(106)$	$T_{GAP}(101)$	Interlaced scan
Medium R1 (1.28s)	$T_{GAP}(107)$	$T_{GAP}(101)$	Interlaced scan
Slow R1 (1.28s)	$T_{GAP}(107)$	$T_{GAP}(101)$	Normal scan
Fast R2 (2.56s)	$T_{GAP}(108)$	$T_{GAP}(101)$	Interlaced scan
Slow R2 (2.56s)	$T_{GAP}(108)$	$T_{GAP}(101)$	Normal scan

Table 4.2: Page scan parameters for connection speed scenarios

When either a SCO or eSCO link is in operation, it is recommended to use interlaced scan to significantly decrease the connection time.

4.2.2.2 Term on UI-level

Bluetooth device is ’connectable’ or in ’connectable mode’.

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4.3 PAIRING MODES

With respect to pairing, a Bluetooth device shall be either in non-pairable mode or in pairable mode. In pairable mode the Bluetooth device accepts paring – i.e. creation of bonds – initiated by the remote device, and in non-pairable mode it does not. Pairing is defined in [1] and [2].

4.3.1 Non-pairable mode

4.3.1.1 Definition

When a Bluetooth device is in non-pairable mode it shall respond to a received LMP_in_rand with LMP_not_accepted with the reason *pairing not allowed*.

4.3.1.2 Term on UI-level

Bluetooth device is ’non-bondable’ or in ’non-bondable mode’ or “does not accept bonding”.

4.3.2 Pairable mode

4.3.2.1 Definition

When a Bluetooth device is in pairable mode it shall respond to a received LMP_in_rand with LMP_accepted (or with LMP_in_rand if it has a fixed PIN).

4.3.2.2 Term on UI-level

Bluetooth device is ’bondable’ or in ’bondable mode’ or “accepts bonding”.

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5 SECURITY ASPECTS

	Procedure	Ref.	Support
1	Authentication	5.1	C1
2	Security modes	5.2	
	Security mode 1		O
	Security mode 2		C2
	Security mode 3		C2
C1: If security mode 1 is the only security mode that is supported, support for authentication is optional, otherwise mandatory. (Note: support for LMP-authentication and LMP-pairing is mandatory according [2] independent of which security mode that is used.)			
C2: If secure communication is supported, then support for at least one of Security mode 2 or Security mode 3 is mandatory.			

Table 5.1: Conformance requirements related to the generic authentication procedure and the security modes defined in this section

5.1 AUTHENTICATION

5.1.1 Purpose

The generic authentication procedure describes how the LMP-authentication and LMP-pairing procedures are used when authentication is initiated by one Bluetooth device towards another, depending on if a link key exists or not and if pairing is allowed or not.

5.1.2 Term on UI level

’Bluetooth authentication’.

5.1.3 Procedure

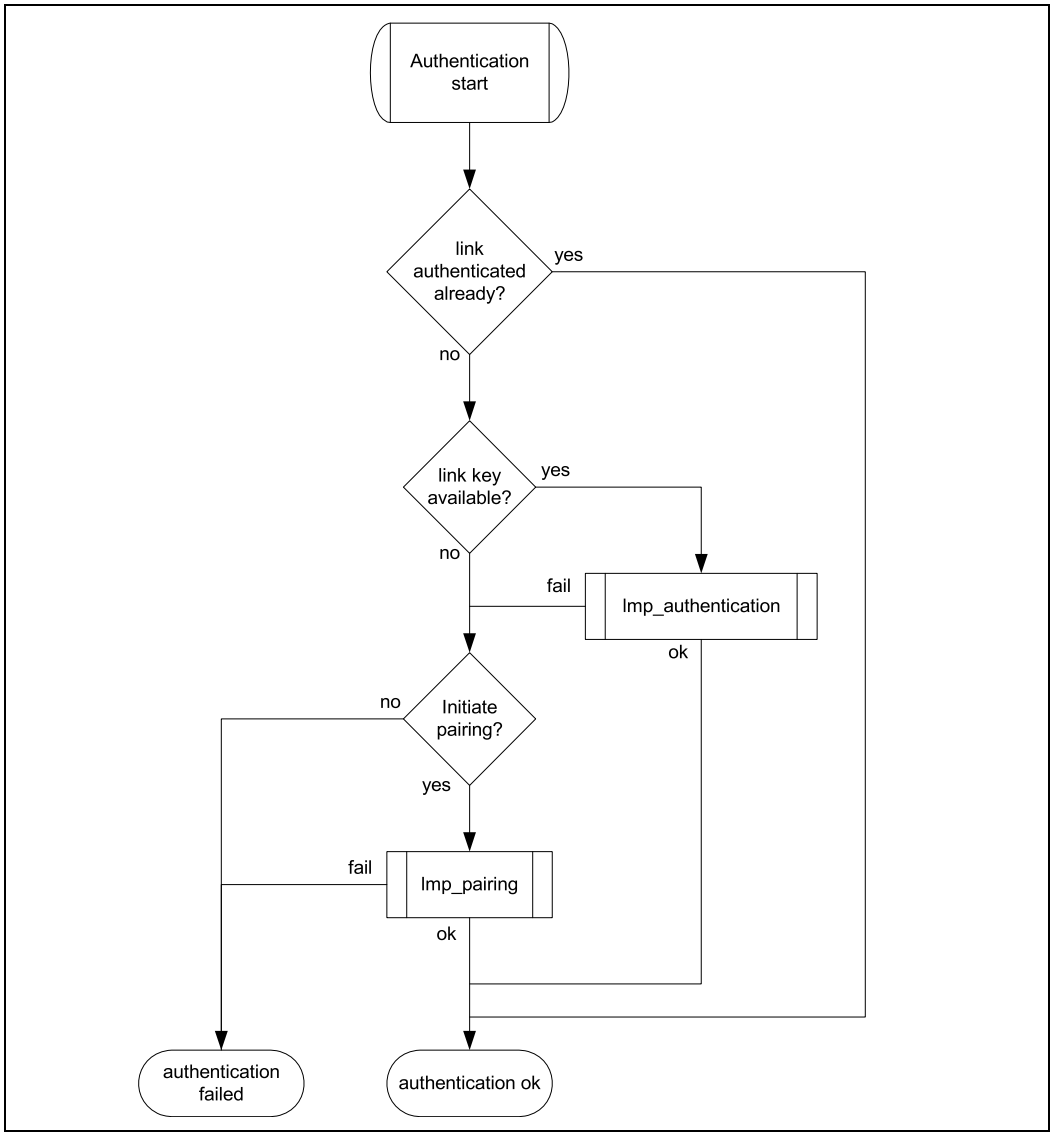


Figure 5.1: Definition of the generic authentication procedure.

5.1.4 Conditions

The device that initiates authentication has to be in security mode 2 or in security mode 3.

5.2 SECURITY MODES

The following flow chart describes where in the channel establishment procedures initiation of authentication takes place, depending on which security mode the Bluetooth device is in.

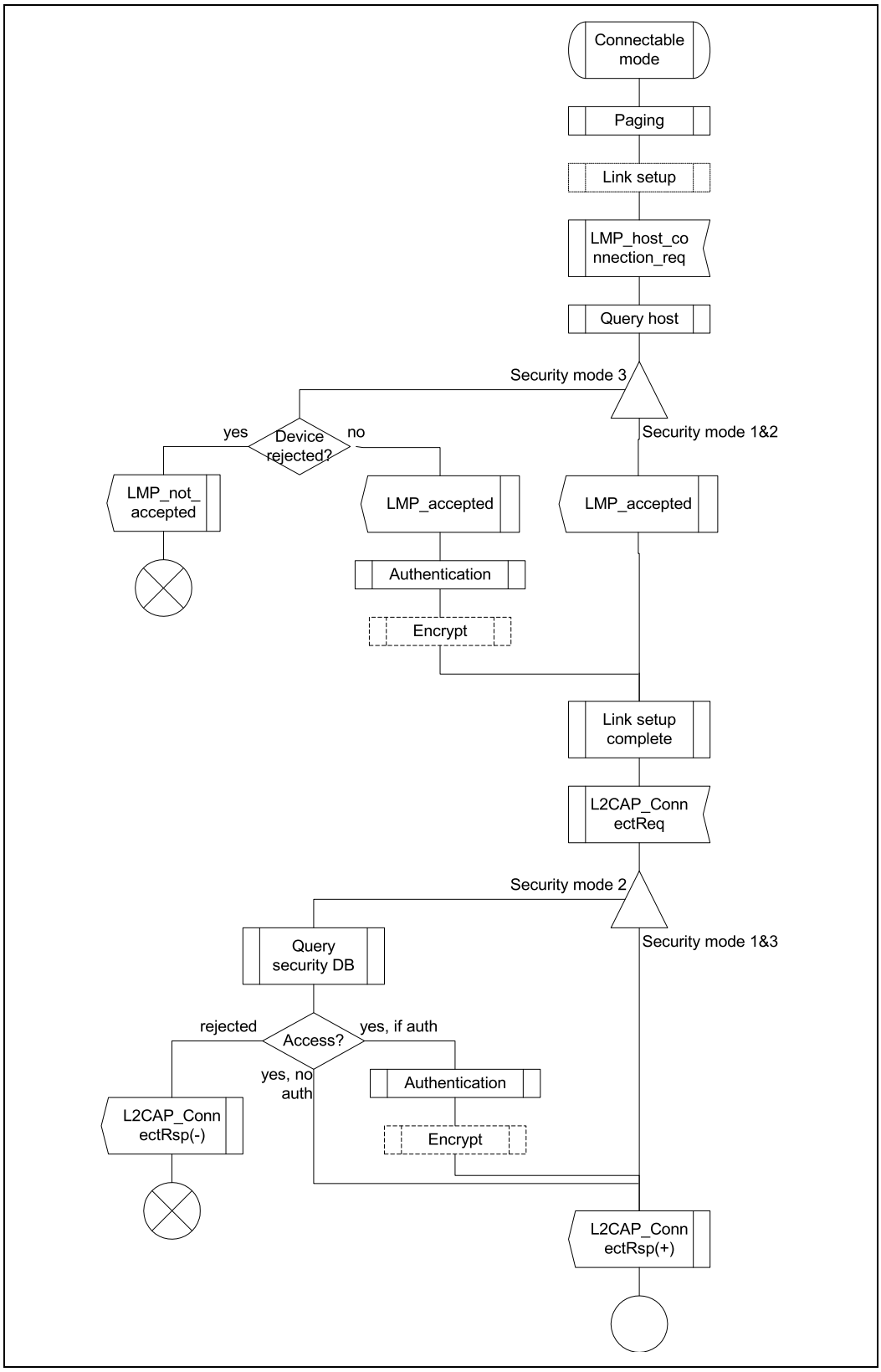


Figure 5.2: Illustration of channel establishment using different security modes.

When authentication is initiated towards a Bluetooth device, it shall act according to [2] and the current pairing mode, independent of which security mode it is in.

5.2.1 Security mode 1 (non-secure)

When a Bluetooth device is in security mode 1 it shall never initiate any security procedure (i.e., it shall never send LMP_au_rand, LMP_in_rand or LMP_encryption_mode_req).

5.2.2 Security mode 2 (service level enforced security)

When a Bluetooth device is in security mode 2 it shall not initiate any security procedure before a channel establishment request (L2CAP_ConnectReq) has been received or a channel establishment procedure has been initiated by itself. (The behavior of a device in security mode 2 is further described in [10].) Whether a security procedure is initiated or not depends on the security requirements of the requested channel or service.

A Bluetooth device in security mode 2 should classify the security requirements of its services using at least the following attributes:

- Authorization required;
- Authentication required;
- Encryption required.

Note: Security mode 1 can be considered (at least from a remote device point of view) as a special case of security mode 2 where no service has registered any security requirements.

5.2.3 Security modes 3 (link level enforced security)

When a Bluetooth device is in security mode 3 it shall initiate security procedures before it sends LMP_link_setup_complete. (The behavior of a device in security mode 3 is as described in [2].)

A Bluetooth device in security mode 3 may reject the host connection request (respond with LMP_not_accepted to the LMP_host_connection_req) based on settings in the host (e.g. only communication with pre-paired devices allowed).

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6 IDLE MODE PROCEDURES

The inquiry and discovery procedures described here are applicable only to the device that initiates them (A). The requirements on the behavior of B is according to the modes specified in Section 4 on page 189 and to [2].

	Procedure	Ref.	Support
1	General inquiry	6.1	C1
2	Limited inquiry	6.2	C1
3	Name discovery	6.3	O
4	Device discovery	6.4	O
5	Bonding	6.5	O
C1: If initiation of bonding is supported, support for at least one inquiry procedure is mandatory, otherwise optional. (Note: support for LMP-pairing is mandatory [2].)			

6.1 GENERAL INQUIRY

6.1.1 Purpose

The purpose of the general inquiry procedure is to provide the initiator with the Bluetooth device address, clock, Class of Device and used page scan mode of general discoverable devices (i.e. devices that are in range with regard to the initiator and are set to scan for inquiry messages with the General Inquiry Access Code). Also devices in limited discoverable mode will be discovered using general inquiry.

The general inquiry should be used by devices that need to discover devices that are made discoverable continuously or for no specific condition.

6.1.2 Term on UI level

’Bluetooth Device Inquiry’.

6.1.3 Description

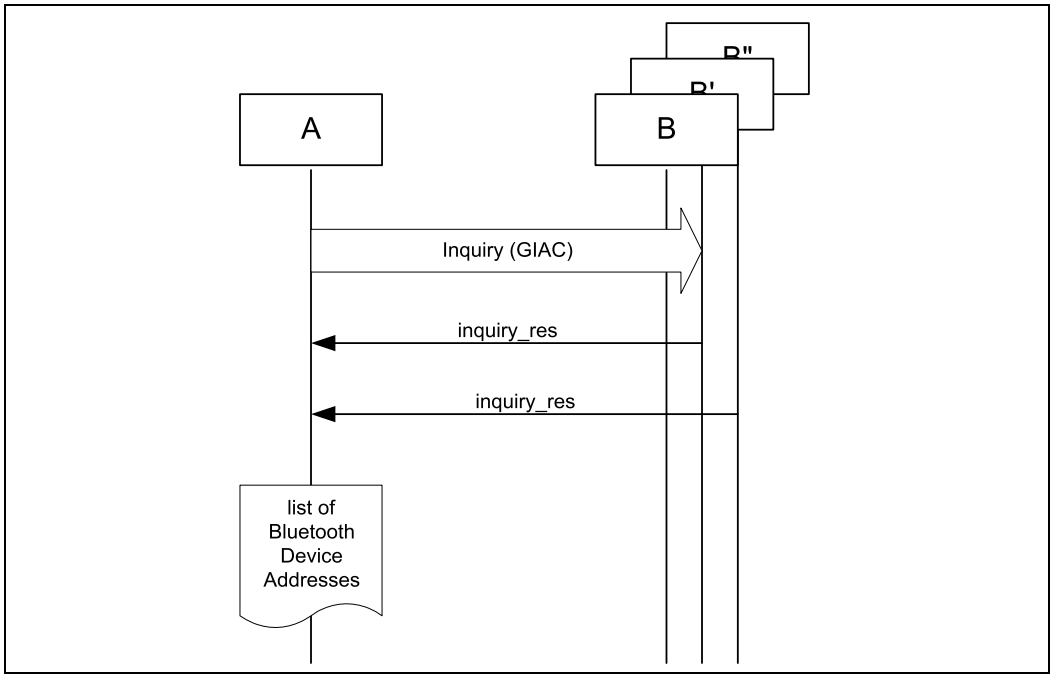


Figure 6.1: General inquiry ,where B is a device in non-discoverable mode, B´ is a device in limited discoverable mode and B" is a device in general discoverable mode. (Note that all discoverable devices are discovered using general inquiry, independent of which discoverable mode they are in.)

6.1.4 Conditions

When general inquiry is initiated by a Bluetooth device, the INQUIRY state shall last $T_{GAP}(100)$ or longer, unless the inquirer collects enough responses and determines to abort the INQUIRY state earlier. The Bluetooth device shall perform inquiry using the GIAC.

In order to receive inquiry response, the remote devices in range have to be made discoverable (limited or general).

6.2 LIMITED INQUIRY

6.2.1 Purpose

The purpose of the limited inquiry procedure is to provide the initiator with the Bluetooth device address, clock, Class of Device and used page scan mode of limited discoverable devices. The latter devices are devices that are in range with regard to the initiator, and may be set to scan for inquiry messages with the Limited Inquiry Access Code, in addition to scanning for inquiry messages with the General Inquiry Access Code.

The limited inquiry should be used by devices that need to discover devices that are made discoverable only for a limited period of time, during temporary

conditions or for a specific event. Since it is not guaranteed that the discoverable device scans for the LIAC, the initiating device may choose any inquiry procedure (general or limited). Even if the remote device that is to be discovered is expected to be made limited discoverable (e.g. when a dedicated bonding is to be performed), the limited inquiry should be done in sequence with a general inquiry in such a way that both inquiries are completed within the time the remote device is limited discoverable, i.e. at least $T_{GAP}(103)$.

6.2.2 Term on UI level

'Bluetooth Device Inquiry'.

6.2.3 Description

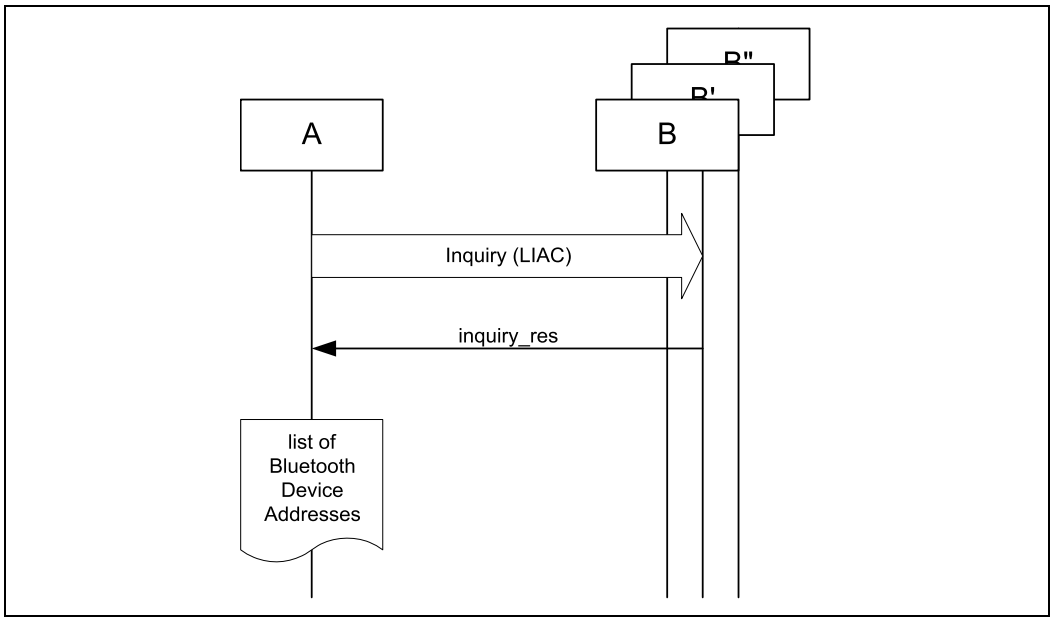


Figure 6.2: Limited inquiry where B is a device in non-discoverable mode, B' is a device in limited discoverable mode and B" is a device in general discoverable mode. (Note that only limited discoverable devices can be discovered using limited inquiry.)

6.2.4 Conditions

When limited inquiry is initiated by a Bluetooth device, the INQUIRY state shall last $T_{GAP}(100)$ or longer, unless the inquirer collects enough responses and determines to abort the INQUIRY state earlier. The Bluetooth device shall perform inquiry using the LIAC.

In order to receive inquiry response, the remote devices in range has to be made limited discoverable.

6.3 NAME DISCOVERY

6.3.1 Purpose

The purpose of name discovery is to provide the initiator with the Bluetooth Device Name of connectable devices (i.e. devices in range that will respond to paging).

6.3.2 Term on UI level

'Bluetooth Device Name Discovery'.

6.3.3 Description

6.3.3.1 Name request

Name request is the procedure for retrieving the Bluetooth Device Name from a connectable Bluetooth device. It is not necessary to perform the full link establishment procedure (see Section 7.1 on page 209) in order to just to get the name of another device.

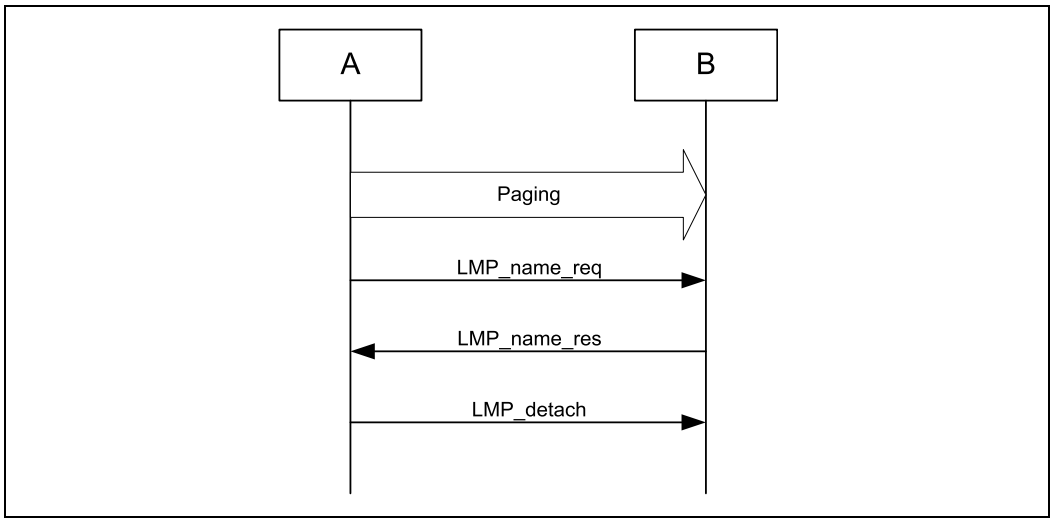


Figure 6.3: Name request procedure.

6.3.3.2 Name discovery

Name discovery is the procedure for retrieving the Bluetooth Device Name from connectable Bluetooth devices by performing name request towards known devices (i.e. Bluetooth devices for which the Bluetooth Device Addresses are available).

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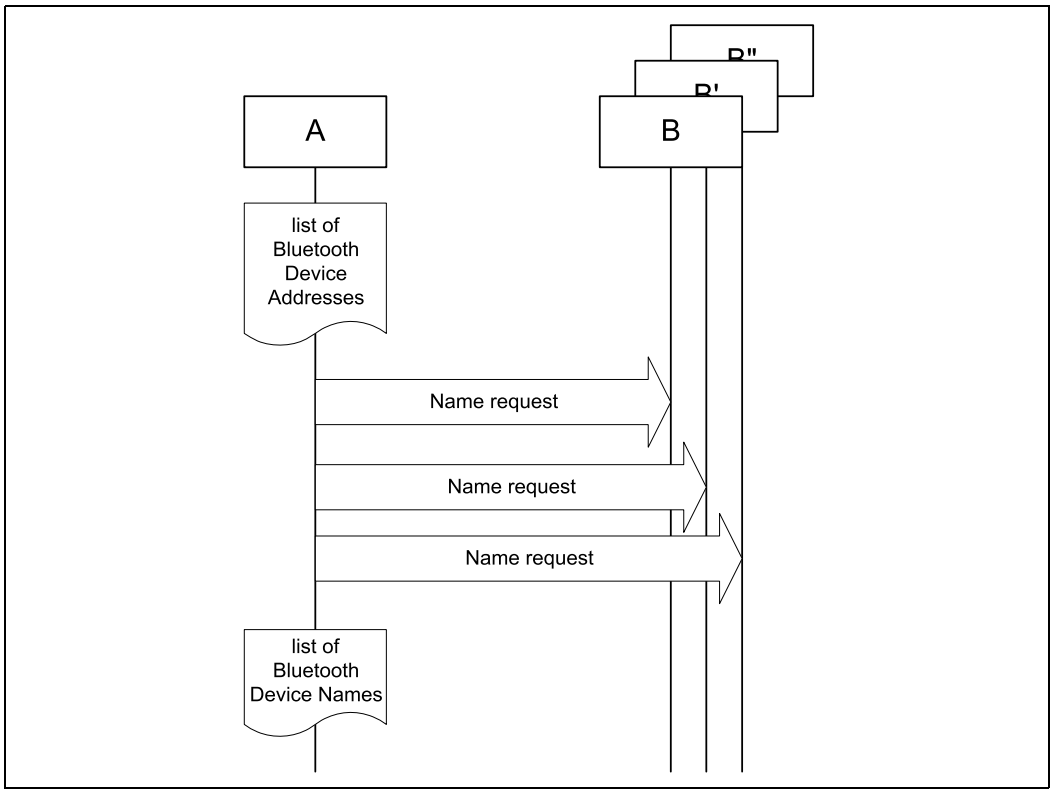


Figure 6.4: Name discovery procedure.

6.3.4 Conditions

In the name request procedure, the initiator will use the Device Access Code of the remote device as retrieved immediately beforehand – normally through an inquiry procedure.

6.4 DEVICE DISCOVERY

6.4.1 Purpose

The purpose of device discovery is to provide the initiator with the Bluetooth Device Address, clock, Class of Device, used page scan mode and Bluetooth device name of discoverable devices.

6.4.2 Term on UI level

'Bluetooth Device Discovery'.

6.4.3 Description

During the device discovery procedure, first an inquiry (either general or limited) is performed, and then name discovery is done towards some or all of the devices that responded to the inquiry.

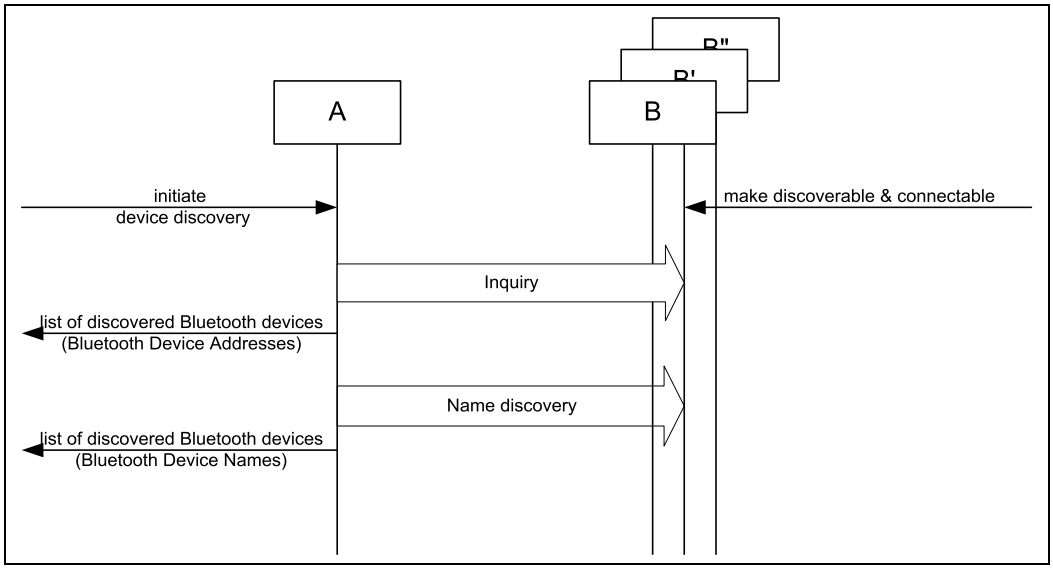


Figure 6.5: Device discovery procedure.

6.4.4 Conditions

Conditions for both inquiry (general or limited) and name discovery must be fulfilled (i.e. devices discovered during device discovery must be both discoverable and connectable).

6.5 BONDING

6.5.1 Purpose

The purpose of bonding is to create a relation between two Bluetooth devices based on a common link key (a bond). The link key is created and exchanged (pairing) during the bonding procedure and is expected to be stored by both Bluetooth devices, to be used for future authentication.

In addition to pairing, the bonding procedure can involve higher layer initialization procedures.

6.5.2 Term on UI level

'Bluetooth Bonding'

6.5.3 Description

Two aspects of the bonding procedure are described here. Dedicated bonding is what is done when the two devices are explicitly set to perform only a creation and exchange of a common link key.

General bonding is included to indicate that the framework for the dedicated bonding procedure is the same as found in the normal channel and connection establishment procedures. This means that pairing may be performed successfully if A has initiated bonding while B is in its normal connectable and security modes.

The main difference with bonding, as compared to a pairing done during link or channel establishment, is that for bonding it is the paging device (A) that must initiate the authentication.

6.5.3.1 General bonding

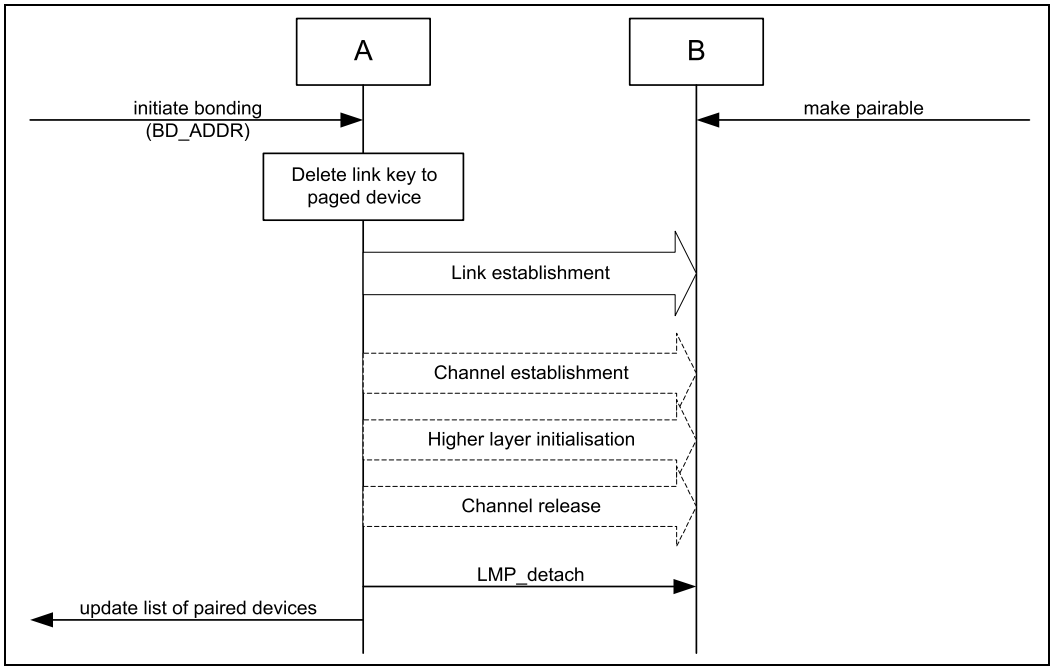


Figure 6.6: General description of bonding as being the link establishment procedure executed under specific conditions on both devices, followed by an optional higher layer initalization process.

6.5.3.2 Dedicated bonding

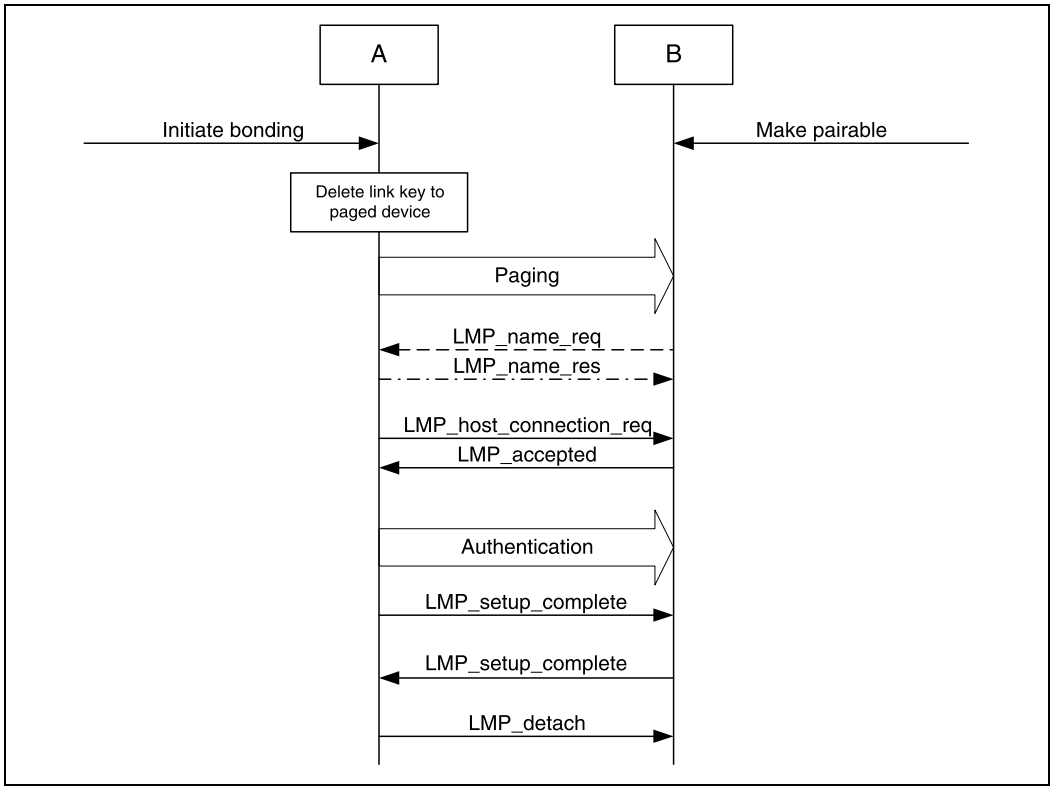


Figure 6.7: Bonding as performed when the purpose of the procedure is only to create and exchange a link key between two Bluetooth devices.

6.5.4 Conditions

Before bonding can be initiated, the initiating device (A) must know the Device Access Code of the device to pair with. This is normally done by first performing device discovery. A Bluetooth Device that can initiate bonding (A) should use limited inquiry, and a Bluetooth Device that accepts bonding (B) should support the limited discoverable mode.

Bonding is in principle the same as link establishment with the conditions:

- The paged device (B) shall be set into pairable mode. The paging device (A) is assumed to allow pairing since it has initiated the bonding procedure.
- The paging device (the initiator of the bonding procedure, A) shall initiate authentication.
- Before initiating the authentication part of the bonding procedure, the paging device should delete any link key corresponding to a previous bonding with the paged device.

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7 ESTABLISHMENT PROCEDURES

	Procedure	Ref.	Support in A	Support in B
1	Link establishment	7.1	M	M
2	Channel establishment	7.2	O	M
3	Connection establishment	7.3	O	O

Table 7.1: Establishment procedures

The establishment procedures defined here do not include any discovery part. Before establishment procedures are initiated, the information provided during device discovery (in the FHS packet of the inquiry response or in the response to a name request) has to be available in the initiating device. This information is:

- The Bluetooth Device Address (BD_ADDR) from which the Device Access Code is generated;
- The system clock of the remote device;
- The page scan mode used by the remote device.

Additional information provided during device discovery that is useful for making the decision to initiate an establishment procedure is:

- The Class of device;
- The Device name.

7.1 LINK ESTABLISHMENT

7.1.1 Purpose

The purpose of the link establishment procedure is to establish a physical link (of ACL type) between two Bluetooth devices using procedures from [1] and [2].

7.1.2 Term on UI level

’Bluetooth link establishment’

7.1.3 Description

In this sub-section, the paging device (A) is in security mode 3. The paging device cannot during link establishment distinguish if the paged device (B) is in security mode 1 or 2.

7.1.3.1 B in security mode 1 or 2

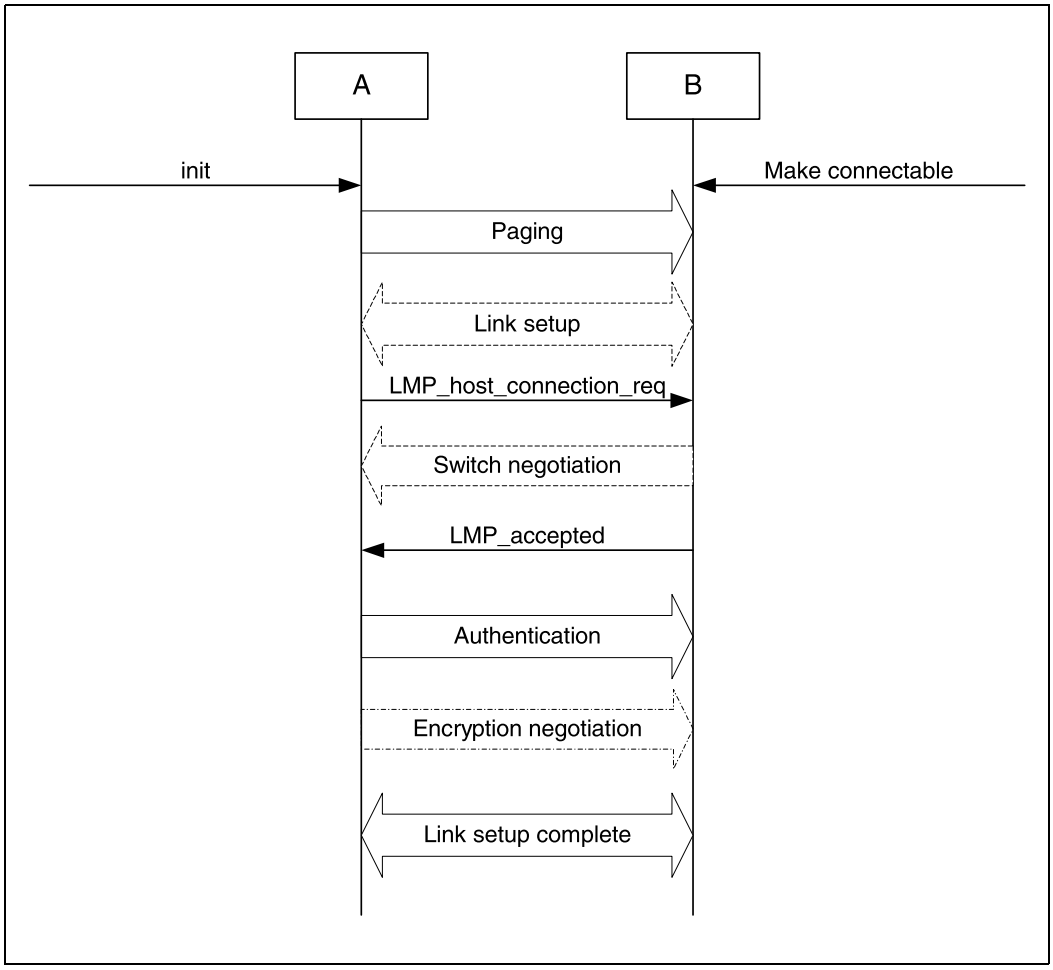


Figure 7.1: Link establishment procedure when the paging device (A) is in security mode 3 and the paged device (B) is in security mode 1 or 2.

7.1.3.2 B in security mode 3

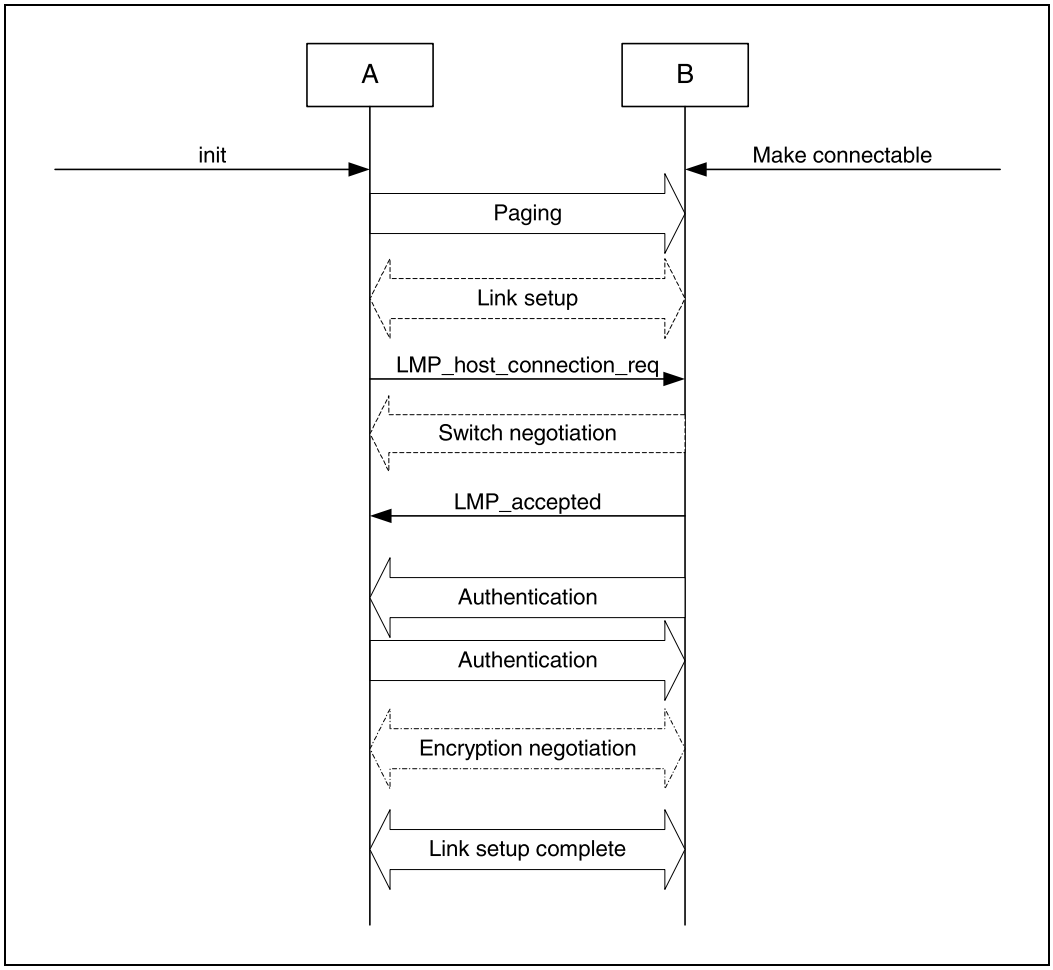


Figure 7.2: Link establishment procedure when both the paging device (A) and the paged device (B) are in security mode 3.

7.1.4 Conditions

The paging procedure shall be according to [1] and the paging device should use the Device access code and page mode received through a previous inquiry. When paging is completed, a physical link between the two Bluetooth devices is established.

If role switching is needed (normally it is the paged device that has an interest in changing the master/slave roles) it should be done as early as possible after the physical link is established. If the paging device does not accept the switch, the paged device has to consider whether to keep the physical link or not.

Both devices may perform link setup (using LMP procedures that require no interaction with the host on the remote side). Optional LMP features can be used after having confirmed (using LMP_feature_req) that the other device supports the feature.

When the paging device needs to go beyond the link setup phase, it issues a request to be connected to the host of the remote device. If the paged device is in security mode 3, this is the trigger for initiating authentication.

The paging device shall send LMP_host_connection_req during link establishment (i.e. before channel establishment) and may initiate authentication only after having sent LMP_host_connection_request.

After an authentication has been performed, any of the devices can initiate encryption.

Further link configuration may take place after the LMP_host_connection_req. When both devices are satisfied, they send LMP_setup_complete.

Link establishment is completed when both devices have sent LMP_setup_complete.

7.2 CHANNEL ESTABLISHMENT

7.2.1 Purpose

The purpose of the channel establishment procedure is to establish a Bluetooth channel (a logical link) between two Bluetooth devices using [3].

7.2.2 Term on UI level

'Bluetooth channel establishment'.

7.2.3 Description

In this sub-section, the initiator (A) is in security mode 3. During channel establishment, the initiator cannot distinguish if the acceptor (B) is in security mode 1 or 3.

7.2.3.1 B in security mode 2

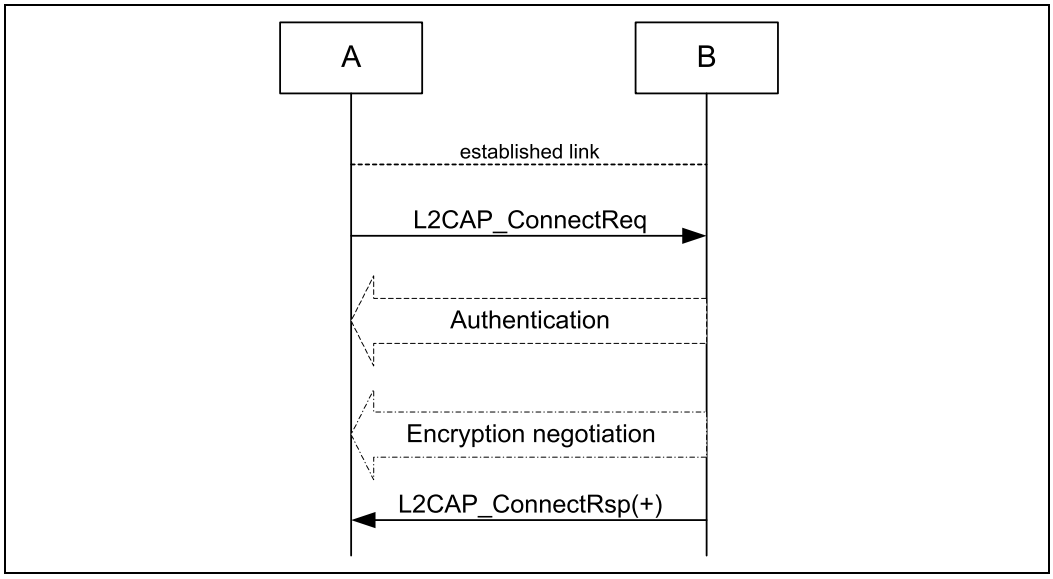


Figure 7.3: Channel establishment procedure when the initiator (A) is in security mode 3 and the acceptor (B) is in security mode 2.

7.2.3.2 B in security mode 1 or 3

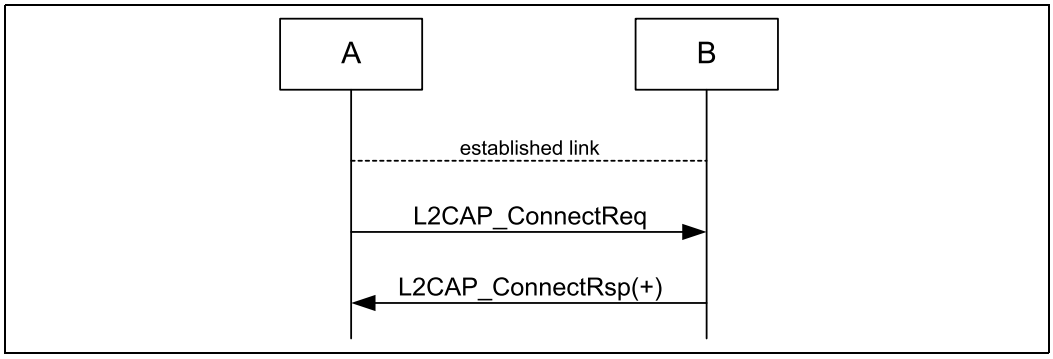


Figure 7.4: Channel establishment procedure when the initiator (A) is in security mode 3 and the acceptor (B) is in security mode 1 or 3.

7.2.4 Conditions

Channel establishment starts after link establishment is completed when the initiator sends a channel establishment request (L2CAP_ConnectReq).

Depending on security mode, security procedures may take place after the channel establishment has been initiated.

Channel establishment is completed when the acceptor responds to the channel establishment request (with a positive L2CAP_ConnectRsp).

7.3 CONNECTION ESTABLISHMENT

7.3.1 Purpose

The purpose of the connection establishment procedure is to establish a connection between applications on two Bluetooth devices.

7.3.2 Term on UI level

'Bluetooth connection establishment'

7.3.3 Description

In this sub-section, the initiator (A) is in security mode 3. During connection establishment, the initiator cannot distinguish if the acceptor (B) is in security mode 1 or 3.

7.3.3.1 B in security mode 2

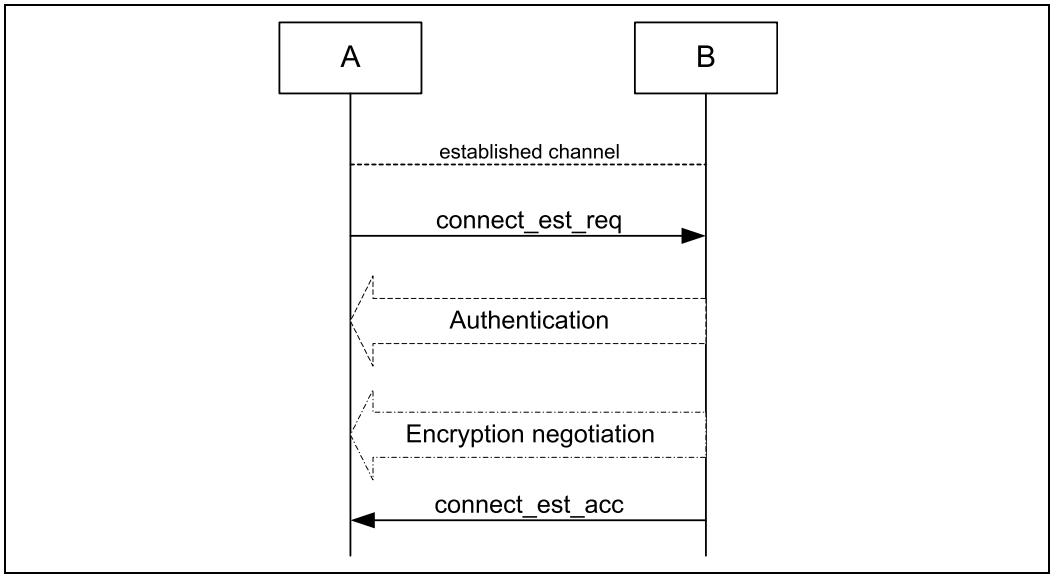


Figure 7.5: Connection establishment procedure when the initiator (A) is in security mode 3 and the acceptor (B) is in security mode 2.

7.3.3.2 B in security mode 1 or 3

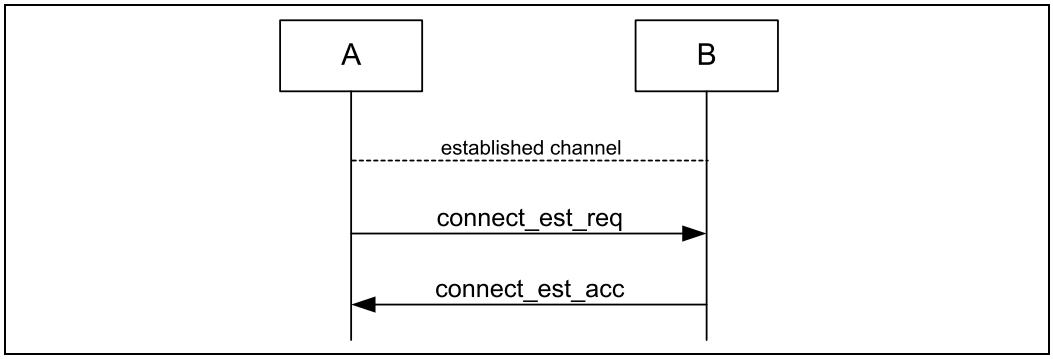


Figure 7.6: Connection establishment procedure when the initiator (A) is in security mode 3 and the acceptor (B) is in security mode 1 or 3.

7.3.4 Conditions

Connection establishment starts after channel establishment is completed, when the initiator sends a connection establishment request (’connect_est_req’ is application protocol-dependent). This request may be a TCS SETUP message [5] in the case of a Bluetooth telephony application Cordless Telephony Profile, or initialization of RFCOMM and establishment of DLC [4] in the case of a serial port-based application Serial Port Profile (although neither TCS or RFCOMM use the term ’connection’ for this).

Connection establishment is completed when the acceptor accepts the connection establishment request (’connect_est_acc’ is application protocol dependent).

7.4 ESTABLISHMENT OF ADDITIONAL CONNECTION

When a Bluetooth device has established one connection with another Bluetooth device, it may be available for establishment of:

- A second connection on the same channel, and/or
- A second channel on the same link, and/or
- A second physical link.

If the new establishment procedure is to be towards the same device, the security part of the establishment depends on the security modes used. If the new establishment procedure is to be towards a new remote device, the device should behave according to active modes independent of the fact that it already has another physical link established (unless allowed co-incident radio and baseband events have to be handled).

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8 DEFINITIONS

In the following, terms written with capital letters refer to states.

8.1 GENERAL DEFINITIONS

Mode . A set of directives that defines how a device will respond to certain events.

Idle . As seen from a remote device, a Bluetooth device is idle, or is in idle mode, when there is no link established between them.

Bond . A relation between two Bluetooth devices defined by creating, exchanging and storing a common link key. The bond is created through the bonding or LMP-pairing procedures.

8.2 CONNECTION-RELATED DEFINITIONS

Physical channel . A synchronized Bluetooth baseband-compliant RF hopping sequence.

Piconet . A set of Bluetooth devices sharing the same physical channel defined by the master parameters (clock and BD_ADDR).

Physical link . A Baseband-level connection[1] between two devices established using paging. A physical link comprises a sequence of transmission slots on a physical channel alternating between master and slave transmission slots.

ACL link . An asynchronous (packet-switched) connection[1] between two devices created on LMP level. Traffic on an ACL link uses ACL packets to be transmitted.

SCO link . A synchronous (circuit-switched) connection[1] for reserved bandwidth communications; e.g. voice between two devices, created on the LMP level by reserving slots periodically on a physical channel. Traffic on an SCO link uses SCO packets to be transmitted. SCO links can be established only after an ACL link has first been established.

Link . Shorthand for an ACL link.

PAGE . A baseband state where a device transmits page trains, and processes any eventual responses to the page trains.

PAGE_SCAN . A baseband state where a device listens for page trains.

1. The term ’connection’ used here is not identical to the definition below. It is used in the absence of a more concise term.

Page . The transmission by a device of page trains containing the Device Access Code of the device to which the physical link is requested.

Page scan . The listening by a device for page trains containing its own Device Access Code.

Channel . A logical connection on L2CAP level between two devices serving a single application or higher layer protocol.

Connection . A connection between two peer applications or higher layer protocols mapped onto a channel.

Connecting . A phase in the communication between devices when a connection between them is being established. (Connecting phase follows after the link establishment phase is completed.)

Connect (to service) . The establishment of a connection to a service. If not already done, this includes establishment of a physical link, link and channel as well.

8.3 DEVICE-RELATED DEFINITIONS

Discoverable device . A Bluetooth device in range that will respond to an inquiry (normally in addition to responding to page).

Silent device . A Bluetooth device appears as silent to a remote device if it does not respond to inquiries made by the remote device. A device may be silent due to being non-discoverable or due to baseband congestion while being discoverable.

Connectable device . A Bluetooth device in range that will respond to a page.

Trusted device . A paired device that is explicitly marked as trusted.

Paired device . A Bluetooth device with which a link key has been exchanged (either before connection establishment was requested or during connecting phase).

Pre-paired device . A Bluetooth device with which a link key was exchanged, and the link key is stored, before link establishment.

Un-paired device . A Bluetooth device for which there was no exchanged link key available before connection establishment was request.

Known device . A Bluetooth device for which at least the BD_ADDR is stored.

Un-known device . A Bluetooth device for which no information (BD_ADDR, link key or other) is stored.

Authenticated device . A Bluetooth device whose identity has been verified during the lifetime of the current link, based on the authentication procedure.

8.4 PROCEDURE-RELATED DEFINITIONS

Paging . A procedure for establishing a physical link of ACL type on baseband level, consisting of a page action of the initiator and a page scan action of the responding device.

Link establishment . A procedure for establishing a link on LMP level. A link is established when both devices have agreed that LMP setup is completed.

Channel establishment . A procedure for establishing a channel on L2CAP level.

Connection establishment . A procedure for creating a connection mapped onto a channel.

Creation of a trusted relationship . A procedure where the remote device is marked as a trusted device. This includes storing a common link key for future authentication and pairing (if the link key is not available).

Creation of a secure connection. A procedure of establishing a connection, including authentication and encryption.

Device discovery . A procedure for retrieving the Bluetooth device address, clock, class-of-device field and used page scan mode from discoverable devices.

Name discovery . A procedure for retrieving the user-friendly name (the Bluetooth device name) of a connectable device.

Service discovery . Procedures for querying and browsing for services offered by or through another Bluetooth device.

8.5 SECURITY-RELATED DEFINITIONS

Authentication . A generic procedure based on LMP-authentication if a link key exists or on LMP-pairing if no link key exists.

LMP-authentication . An LMP level procedure for verifying the identity of a remote device. The procedure is based on a challenge-response mechanism using a random number, a secret key and the BD_ADDR of the non-initiating device. The secret key used can be a previously exchanged link key.

Authorization . A procedure where a user of a Bluetooth device grants a specific (remote) Bluetooth device access to a specific service. Authorization implies that the identity of the remote device can be verified through authentication.

Authorize . The act of granting a specific Bluetooth device access to a specific service. It may be based upon user confirmation, or given the existence of a trusted relationship.

LMP-pairing . A procedure that authenticates two devices, based on a PIN, and subsequently creates a common link key that can be used as a basis for a trusted relationship or a (single) secure connection. The procedure consists of the steps: creation of an initialization key (based on a random number and a PIN), creation and exchange of a common link key and LMP-authentication based on the common link key.

Bonding . A dedicated procedure for performing the first authentication, where a common link key is created and stored for future use.

Trusting . The marking of a paired device as trusted. Trust marking can be done by the user, or automatically by the device (e.g. when in pairable mode) after a successful pairing.

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9 APPENDIX A (NORMATIVE): TIMERS AND CONSTANTS

The following timers are required by this profile.

Timer name	Recommended value	Description	Comment
$T_{GAP}(100)$	10.24 s	Normal time span that a Bluetooth device performs inquiry.	Used during inquiry and device discovery.
$T_{GAP}(101)$	10.625 ms	Minimum time in INQUIRY_SCAN.	A discoverable Bluetooth device enters INQUIRY_SCAN for at least $T_{GAP}(101)$ every $T_{GAP}(102)$.
$T_{GAP}(102)$	2.56 s	Maximum time between repeated INQUIRY_SCAN enterings.	Maximum value of the inquiry scan interval, $T_{inquiry\ scan}$.
$T_{GAP}(103)$	30.72 s	A Bluetooth device shall not be in a discoverable mode less than $T_{GAP}(103)$.	Minimum time to be discoverable.
$T_{GAP}(104)$	1 min	A Bluetooth device should not be in limited discoverable mode more than $T_{GAP}(104)$.	Recommended upper limit.
$T_{GAP}(105)$	100ms	Maximum time between INQUIRY_SCAN enterings	Recommended value
$T_{GAP}(106)$	100ms	Maximum time between PAGE_SCAN enterings	Recommended value
$T_{GAP}(107)$	1.28s	Maximum time between PAGE_SCAN enterings (R1 page scan)	Recommended value
$T_{GAP}(108)$	2.56s	Maximum time between PAGE_SCAN enterings (R2 page scan)	Recommended value

Table 9.1: Defined GAP timers

10 APPENDIX B (INFORMATIVE): INFORMATION FLOWS OF RELATED PROCEDURES

10.1 LMP-AUTHENTICATION

The specification of authentication on link level is found in [2].

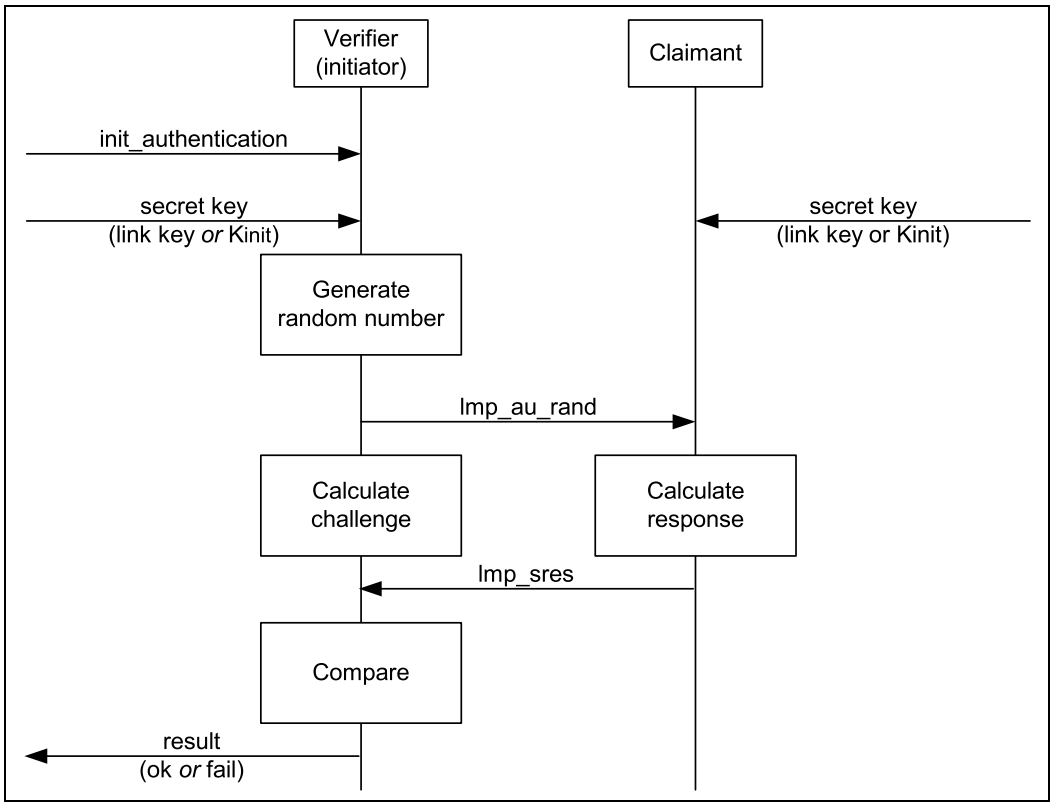


Figure 10.1: LMP-authentication as defined by [2].

The secret key used here is an already exchanged link key.

10.2 LMP-PAIRING

The specification of pairing on link level is found in [2].

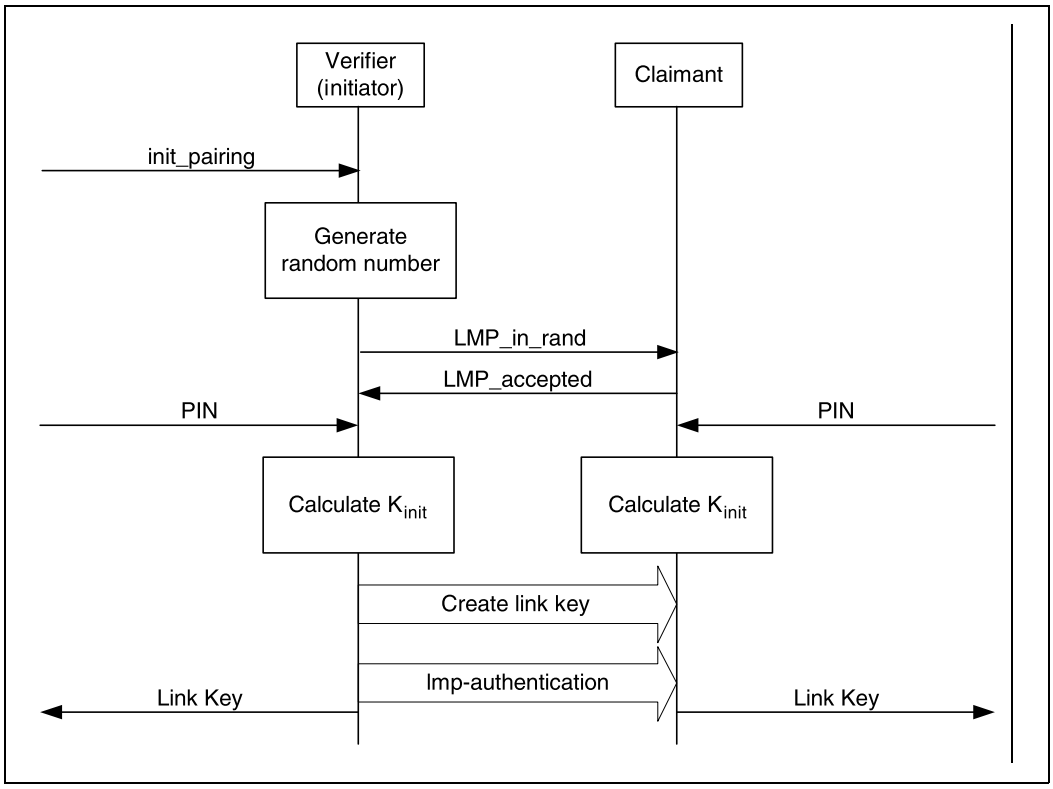


Figure 10.2: LMP-pairing as defined in [2].

The PIN used here is PN_{BB}.

The create link key procedure is described in [Vol. 2, Part C] Section 4.2.2.4 on page 228 and [Vol. 2, Part H] Section 3.2 on page 755. In case the link key is based on a combination key, a mutual authentication takes place and shall be performed irrespective of current security mode.

10.3 SERVICE DISCOVERY

The Service Discovery Protocol [6] specifies what PDUs are used over-the-air to inquire about services and service attributes. The procedures for discovery of supported services and capabilities using the Service Discovery Protocol are described in the Service Discovery Application Profile. This is just an example.

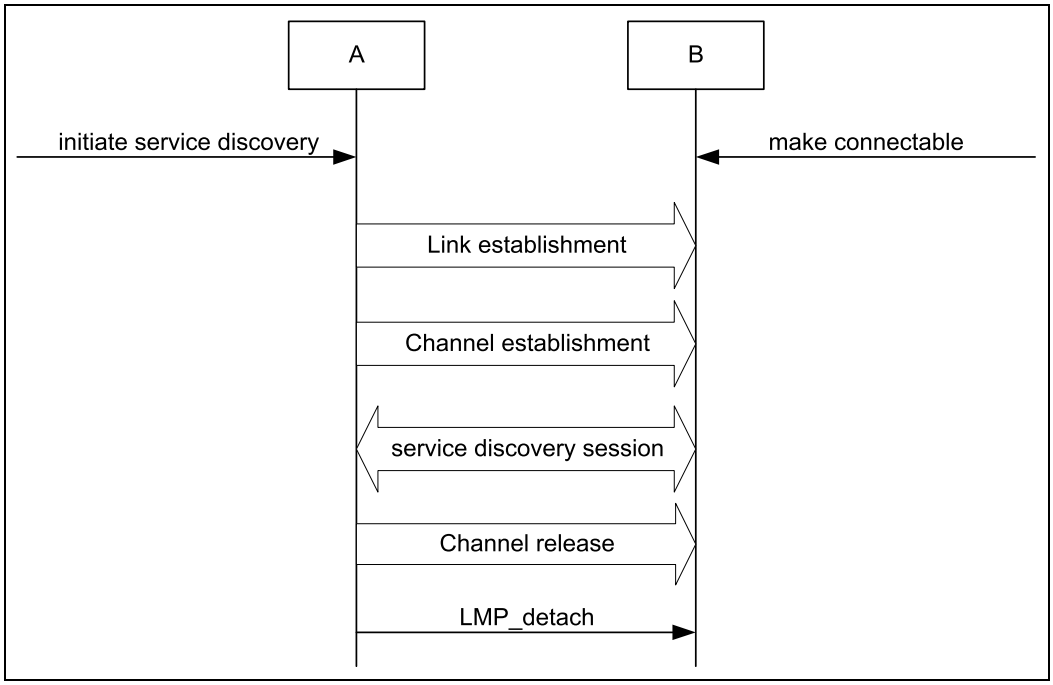


Figure 10.3: Service discovery procedure.

11 REFERENCES

[1] Bluetooth Baseband Specification

[2] Bluetooth Link Manager Protocol

[3] Bluetooth Logical Link Control and Adaptation Protocol

[4] Bluetooth RFCOMM

[5] Bluetooth Telephony Control Specification

[6] Bluetooth Service Discovery Protocol

[7] Bluetooth Service Discovery Application Profile

[8] Bluetooth Cordless Telephony Profile

[9] Bluetooth Serial Port Profile

[10] Bluetooth Security Architecture (white paper)

[11] Bluetooth Assigned Numbers
https://www.bluetooth.org/foundry/assignnumb/document/assigned_numbers

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Core System Package [Host volume]
Part D



TEST SUPPORT

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1 TEST METHODOLOGY

This section describes the test mode for hardware and low-level functionality tests of Bluetooth devices. The test mode includes transmitter tests (packets with constant bit patterns) and loop back tests.

The test mode supports testing of the Bluetooth transmitter and receiver. It is intended mainly for certification/compliance testing of the radio and baseband layer, and may also be used for regulatory approval or in-production and after-sales testing.

1.1 TEST SCENARIOS

A device in test mode shall not support normal operation. For security reasons the test mode is designed such that it offers no benefit to the user. Therefore, no data output or acceptance on a HW or SW interface shall be allowed.

1.1.1 Test setup

The setup consists of a device under test (DUT) and a tester. Optionally, additional measurement equipment may be used.

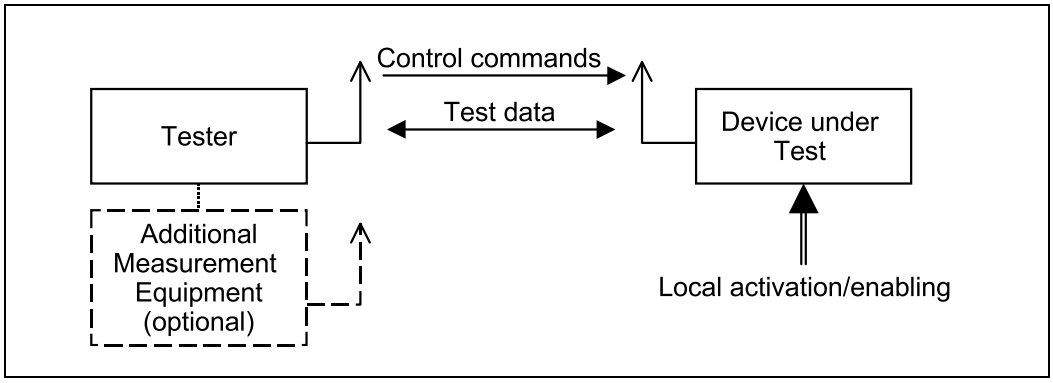


Figure 1.1: Setup for Test Mode

Tester and DUT form a piconet where the tester acts as master and has full control over the test procedure. The DUT acts as slave.

The control is done via the air interface using LMP commands (see [Vol. 2, Part C] Section 4.7.3 on page 266). Hardware interfaces to the DUT may exist, but are not subject to standardization.

The test mode is a special state of the Bluetooth model. For security and type approval reasons, a Bluetooth device in test mode shall not support normal operation. When the DUT leaves the test mode it enters the standby state. After power-off the Bluetooth device shall return to standby state.

1.1.2 Transmitter Test

The Bluetooth device transmits a constant bit pattern. This pattern is transmitted periodically with packets aligned to the slave TX timing of the piconet formed by tester and DUT. The same test packet is repeated for each transmission.

The transmitter test is started when the master sends the first POLL packet. In non-hopping mode agreed frequency is used for this POLL packet.

The tester (master) transmits control or POLL packets in the master-to-slave transmission slots. The DUT (slave) shall transmit packets in the following slave-to-master transmission slot. The tester's polling interval is fixed and defined by the LMP_test_control PDU. The device under test may transmit its burst according to the normal timing even if no packet from the tester was received. In this case, the ARQN bit is shall be set to NAK.

The burst length may exceed the length of a one slot packet. In this case the tester may take the next free master TX slot for polling. The timing is illustrated in Figure 1.2.

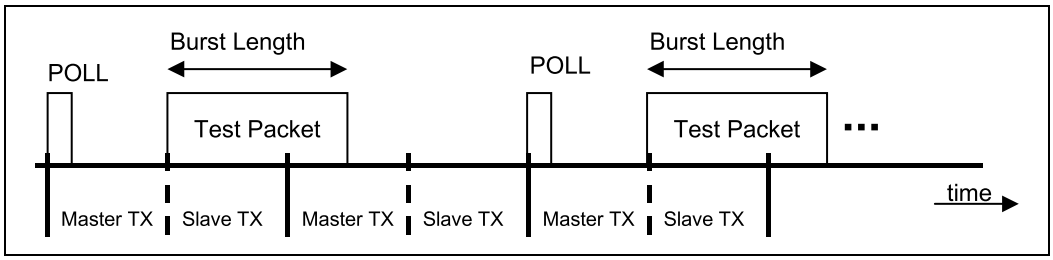


Figure 1.2: Timing for Transmitter Test

1.1.2.1 Packet Format

The test packet is a normal Bluetooth packet, see Figure 1.3. For the payload itself see below.

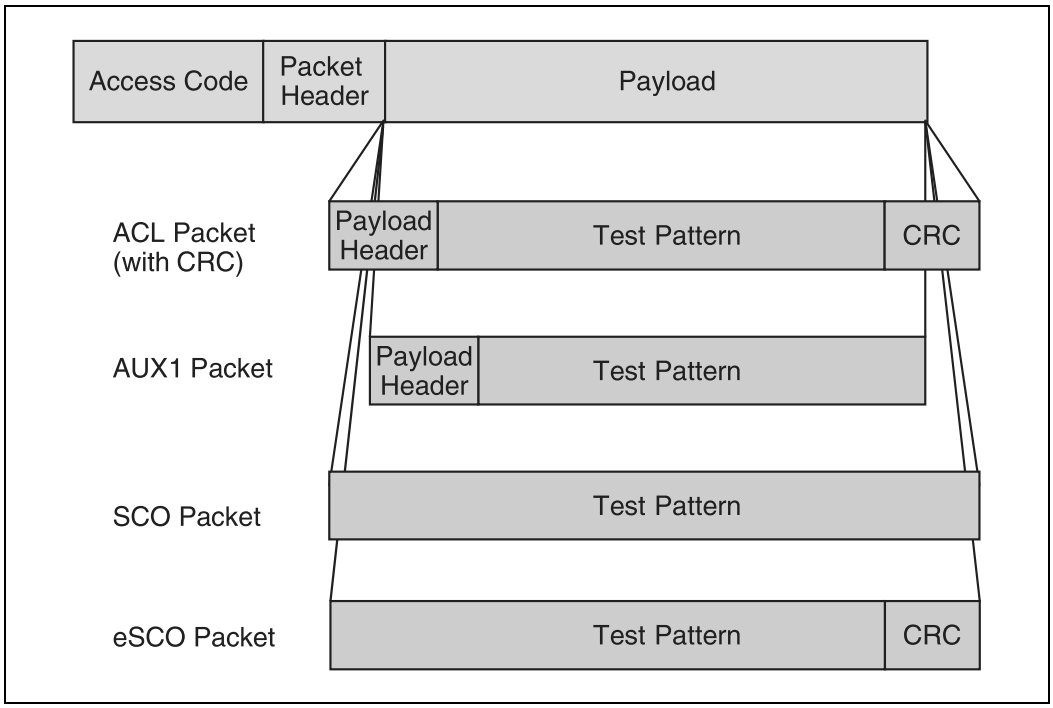


Figure 1.3: General Format of TX Packet

During configuration the tester defines:

- the packet type to be used
- payload length

For the payload length, the restrictions from the baseband specification shall apply (see “Baseband Specification” on page 45[vol. 2]). In case of ACL, SCO and eSCO packets the payload structure defined in the baseband specification is preserved as well, see Figure 1.3 on page 235.

For the transmitter test mode, only packets without FEC should be used; i.e. HV3,EV3, EV5, DH1, DH3, DH5 and AUX1packets.

In transmitter test mode, the packets exchanged between the tester and the DUT shall not be scrambled with the whitening sequence. Whitening shall be turned off when the DUT has accepted to enter the transmitter test mode, and shall be turned on when the DUT has accepted to exit the transmitter test mode, see Figure 1.4 on page 236. Implementations shall insure that retransmissions of the LMP_accepted messages use the same whitening status as used in the original LMP_accepted.

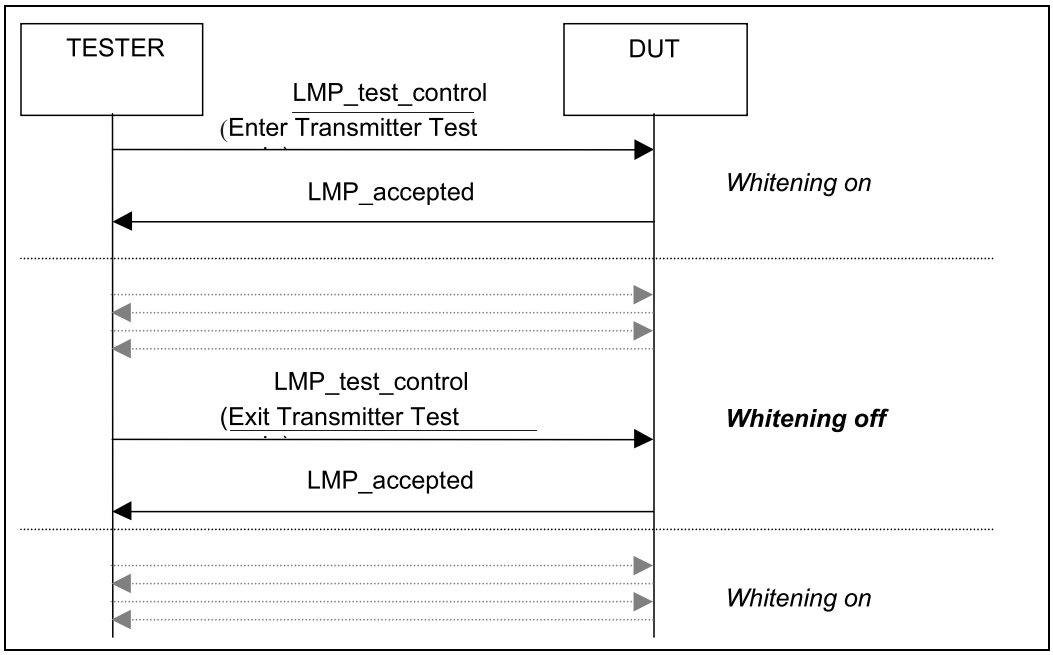


Figure 1.4: Use of whitening in Transmitter mode

1.1.2.2 Pseudorandom Sequence

The same pseudorandom sequence of bits shall be used for each transmission (i.e. the packet is repeated). A PRBS-9 Sequence is used, see [2] and [3].

The properties of this sequence are as follows (see [3]). The sequence may be generated in a nine-stage shift register whose 5th and 9th stage outputs are added in a modulo-two addition stage (see Figure 1.5), and the result is fed back to the input of the first stage. The sequence begins with the first ONE of 9 consecutive ONEs; i.e. the shift register is initialized with nine ones.

- Number of shift register stages: 9
- Length of pseudo-random sequence: 2^9-1 = 511 bits
- Longest sequence of zeros: 8 (non-inverted signal)

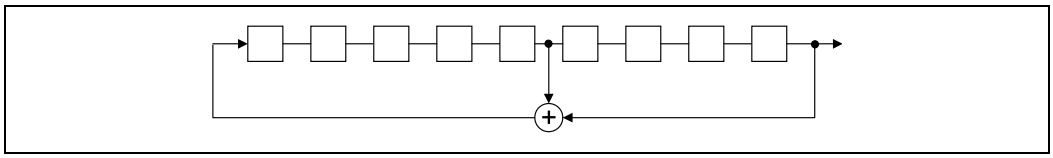


Figure 1.5: Linear Feedback Shift Register for Generation of the PRBS sequence

1.1.2.3 Control of Transmit Parameters

The following parameters can be set to configure the transmitter test:

1. Bit pattern:
   - Constant zero
   - Constant one
   - Alternating 1010...[1]
   - Alternating 1111 0000 1111 0000...[4]
   - Pseudorandom bit pattern
   - Transmission off
2. Frequency selection:
   - Single frequency
   - Normal hopping
3. TX frequency
   - k $\Rightarrow$ f := (2402 + k) MHz
4. Default poll period in TDD frames (n * 1.25 ms)
5. Packet Type
6. Length of Test Sequence (user data of packet definition in “Baseband Specification” on page 45[vol. 2])

1.1.2.4 Power Control

If adaptive power control is tested, the normal LMP commands will be used. The DUT shall start transmitting at the maximum power and shall reduce/ increase its power by one step on every LMP_incr_power_req or LMP_decr_power_req command received.

1.1.2.5 Switch Between Different Frequency Settings

A change in the frequency selection becomes effective when the LMP procedure is completed:

When the tester receives the LMP_accepted it shall then transmit POLL packets containing the Ack for at least 8 slots (4 transmissions). When these transmissions have been completed the tester shall change to the new frequency hop and whitening settings.

After sending LMP_accepted the DUT shall wait for the LC level Ack for the LMP_accepted. When this is received it shall change to the new frequency hop and whitening settings.

1. It is recommended that the sequence starts with a one; but, as this is irrelevant for measurements, it is also allowed to start with a zero.

There will be an implementation defined delay after sending the LMP_accepted before the TX or loopback test starts. Testers shall be able to cope with this.

Note: Loss of the LMP_Accepted packet will eventually lead to a loss of frequency synchronization that cannot be recovered. Similar problems occur in normal operation, when the hopping pattern changes.

1.1.2.6 Adaptive Frequency Hopping

Adaptive Frequency Hopping (AFH) shall only be used when the Hopping Mode is set to 79 channels (e.g. Hopping Mode = 1) in the LMP_test_control PDU. If AFH is used, the normal LMP commands and procedures shall be used. When AFH is enabled prior to entering test mode it shall continue to be used with the same parameters if Hopping Mode = 1 until the AFH parameters are changed by the LMP_set_AFH PDU.

The channel classification reporting state shall be retained upon entering or exiting Test Mode. The DUT shall change the channel classification reporting state in Test Mode based on control messages from the tester (LMP_channel_classification_req) and from the Host (HCI Write_AFH_Channel_Classification_Mode).

1.1.3 LoopBack test

In loopback, the device under test receives normal baseband packets containing payload *Accepted* from the tester. The received packets shall be decoded in the DUT, and the payload shall be sent back using the same packet type. The return packet shall be sent back in either the slave-to-master transmission slot directly following the transmission of the tester, or it is delayed and sent back in the slave-to-master transmission slot after the next transmission of the tester (see Figure 1.7 to Figure 1.9 on page 241).

There is no signalling to determine or control the mode. The device behavior shall be fixed or adjusted by other means, and shall not change randomly.

The tester can select, whether whitening is on or off. This setting holds for both up- and downlink. For switching the whitening status, the same rules as in Section 1.1.2 on page 234 (Figure 1.4) shall apply.

The following rules apply (for illustration see Figure 1.6 on page 240):

- If the synch word was not detected, the DUT shall not reply.
- If the header error check (HEC) fails, the DUT shall either reply with a NULL packet with the ARQN bit set to NAK or send nothing.
- If the packet contains an LMP message relating to the control of the test mode this command shall be executed and the packet shall not be returned, though ACK or NAK shall be returned as per the usual procedure. Other LMP commands are ignored and no packet is returned.
- The payload FEC is decoded and the payload shall be encoded again for transmission. This allows testing of the FEC handling. If the pure bit error rate shall be determined the tester chooses a packet type without FEC.
- The CRC is shall be evaluated. In the case of a failure, ARQN=NAK shall be returned. The payload shall be returned as received.
  A new CRC for the return packet shall be calculated for the returned payload regardless of whether the CRC was valid or not.
- If the CRC fails for a packet with a CRC and a payload header, the number of bytes as indicated in the (possibly erroneous) payload header shall be looped back.

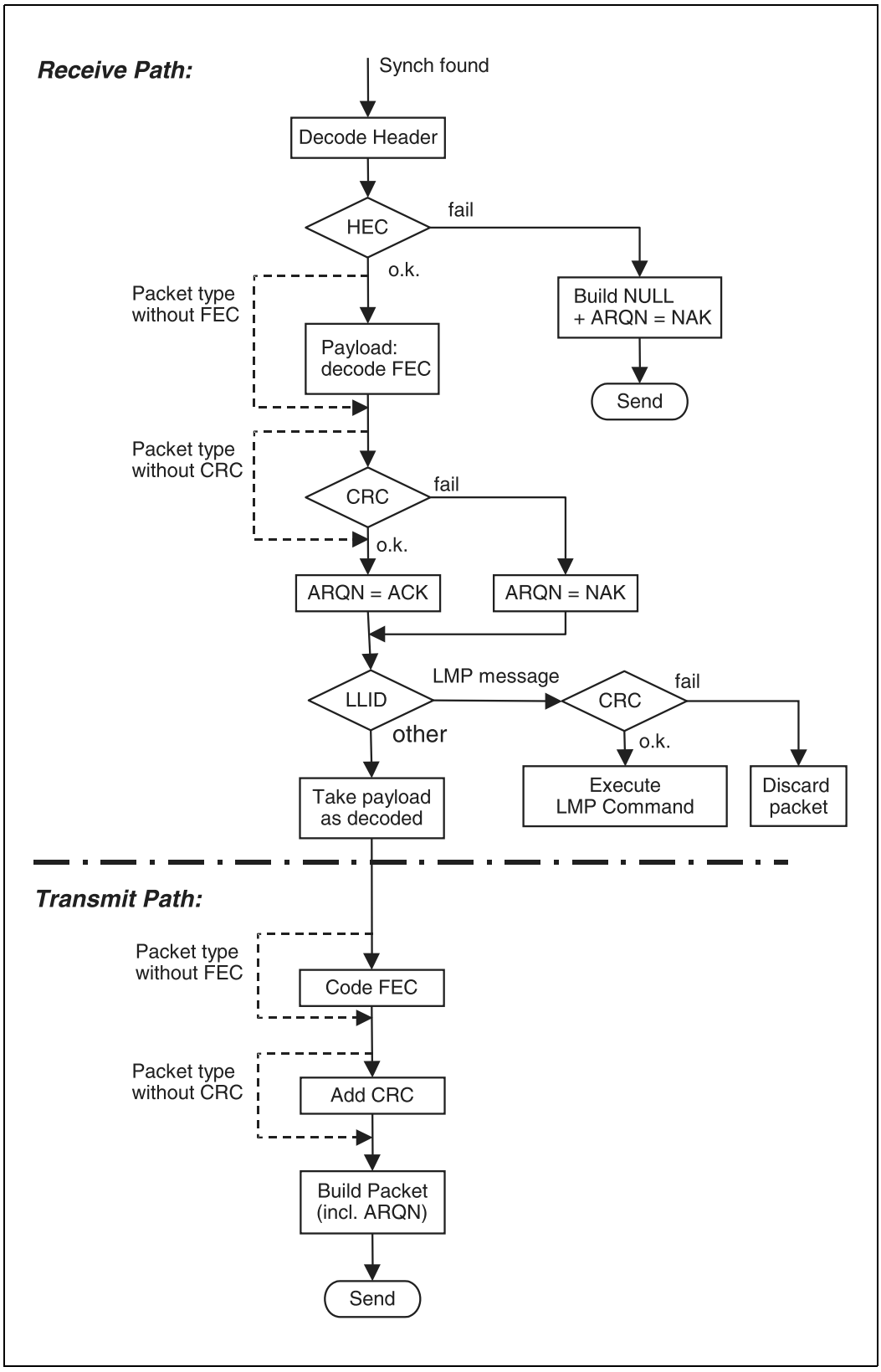


Figure 1.6: DUT Packet Handling in Loop Back Test

The timing for normal and delayed loopback is illustrated in Figure 1.7 to Figure 1.9:

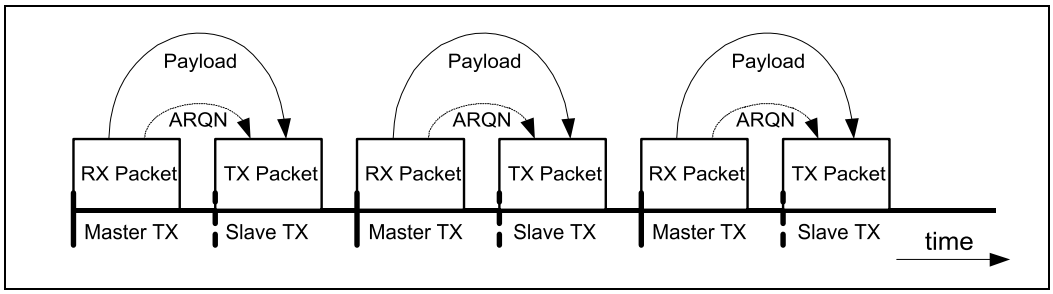


Figure 1.7: Payload & ARQN handling in normal loopback.

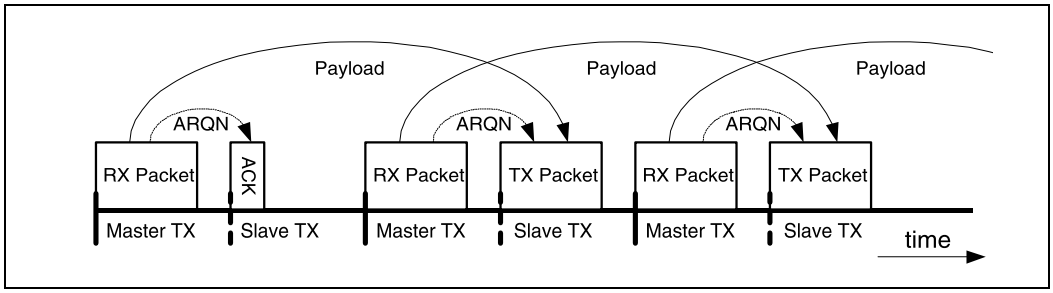


Figure 1.8: Payload & ARQN handling in delayed loopback - start.

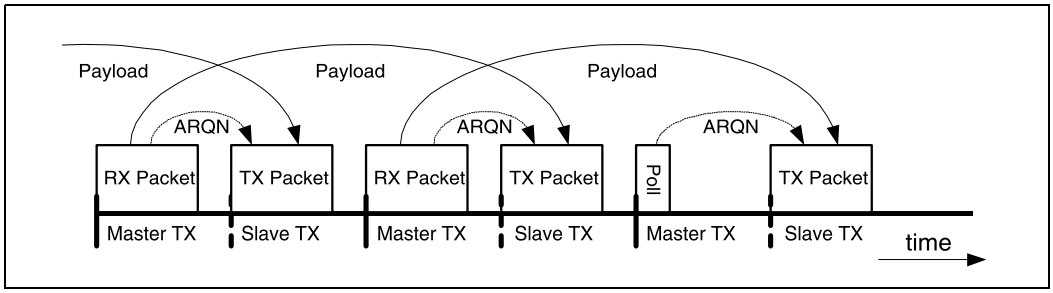


Figure 1.9: Payload & ARQN handling in delayed loopback - end.

The whitening is performed in the same way as it is used in normal active mode.

The following parameters can be set to configure the loop back test:

1. Packet Class[1]
   - ACL Packets
   - SCO Packets
   - eSCO Packets
   - ACL Packets without whitening

1. This is included because, in the future, the packet type numbering may not remain unambiguous.

- SCO Packets without whitening
- eSCO Packets without whitening

2. Frequency Selection
   - Single frequency (independent for RX and TX)
   - Normal hopping
3. Power level: (To be used according radio specification requirements)
   - power control or fixed TX power

The switch of the frequency setting is done exactly as for the transmitter test (see Section 1.1.2.5 on page 237).

1.1.4 Pause test

Pause test is used by testers to put the device under test into Pause Test mode from either the loopback or transmitter test modes.

When an LMP_test_control PDU that specifies Pause Test is received the DUT shall stop the current test and enter Pause Test mode. In the case of a transmitter test this means that no more packets shall be transmitted. While in Pause Test mode the DUT shall respond normally to POLL packets (i.e. responds with a NULL packet). The DUT shall also respond normally to all the LMP packets that are allowed in test mode.

When the test scenario is set to Pause Test all the other fields in the LMP_test_control PDU shall be ignored. There shall be no change in hopping scheme or whitening as a result of a request to pause test.

1.2 REFERENCES

[1] Bluetooth Link Manager Protocol.

[2] CCITT Recommendation O.153 (1992), Basic parameters for the measurement of error performance at bit rates below the primary rate.

[3] ITU-T Recommendation O.150 (1996), General requirements for instrumentation for performance measurements on digital transmission equipment.

[4] Bluetooth Baseband Specification.

2 TEST CONTROL INTERFACE (TCI)

This section describes the Bluetooth Test Control Interface (TCI). The TCI provides a uniform method of accessing the upper interface of the implementation being tested. This facilitates the use of a standardized interface on test equipment used for formal Qualification of implementations.

2.1 INTRODUCTION

2.1.1 Terms used

Conformance testing	Testing according to the applicable procedures given in the Bluetooth Protocol Test Specifications and the Bluetooth Profile Conformance Test Specification when tested against a test system.
HCI	Host Controller Interface
IUT	Implementation Under Test: An implementation of one or more Bluetooth protocols and profiles which is to be studied by testing. This term is used when describing the test concept for products and components equipped with Bluetooth wireless technology as defined in the PRD.
PRD	Bluetooth Qualification Program Reference Document: This document is maintained by the Bluetooth Qualification Review Board and is the reference to specify the functions, organisation and processes inside the Bluetooth Qualification program.
TCI	Test Control Interface: The interface and protocol used by the test equipment to send and receive messages to and from the upper interface of the IUT.

2.1.2 Usage of the interface

For all products and components equipped with Bluetooth wireless technology, conformance testing is used to verify the implemented functionality in the lower layers. Conformance testing of the lowest layers requires an upper tester to test the implementation sufficiently well.

In order to avoid that the tester will have to adapt to each and every product and component equipped with Bluetooth wireless technology, the use of the standardized TCI is mandated. This concept puts some burden upon the manufacturer of the IUT in terms of supplying an adapter providing the necessary conversion from/to the IUT's specific interface to the TCI. The adapter can consist of hardware, firmware and software. After qualification testing has been performed the TCI may be removed from the product or component equipped with Bluetooth wireless technology. It is the manufacturer's option to remove it from the qualified product or component equipped with Bluetooth wireless technology.

The TCI is used when qualifying the implemented functionality of the:

- Baseband layer, BB
- Link Manager layer, LM

If support of the Host Controller Interface is claimed by the manufacturer the TCI is used to qualify it.

2.2 TCI CONFIGURATIONS

This section describes the test configurations used when verifying the different Bluetooth requirements. Each layer in the Bluetooth stack is qualified using the procedures described in the layer specific test specification.

2.2.1 Bluetooth RF requirements

For qualification of the Bluetooth Radio Frequency requirements the defined Test Mode is used, see Section 1 on page 233.

Similar to TCI, the specific test mode functionality may be removed from the product or component after qualification, at the discretion of the manufacturer.

2.2.1.1 Required interfaces

For RF qualification only the air interface is required, see Figure 2.1. Depending on the physical design of the IUT it might be necessary to temporarily attach an RF connector for executing the RF tests. As stated in Section 1 on page 233, the Test Mode shall be locally enabled on the IUT for security reasons. The implementation of this local enabling is not subject to standardization.

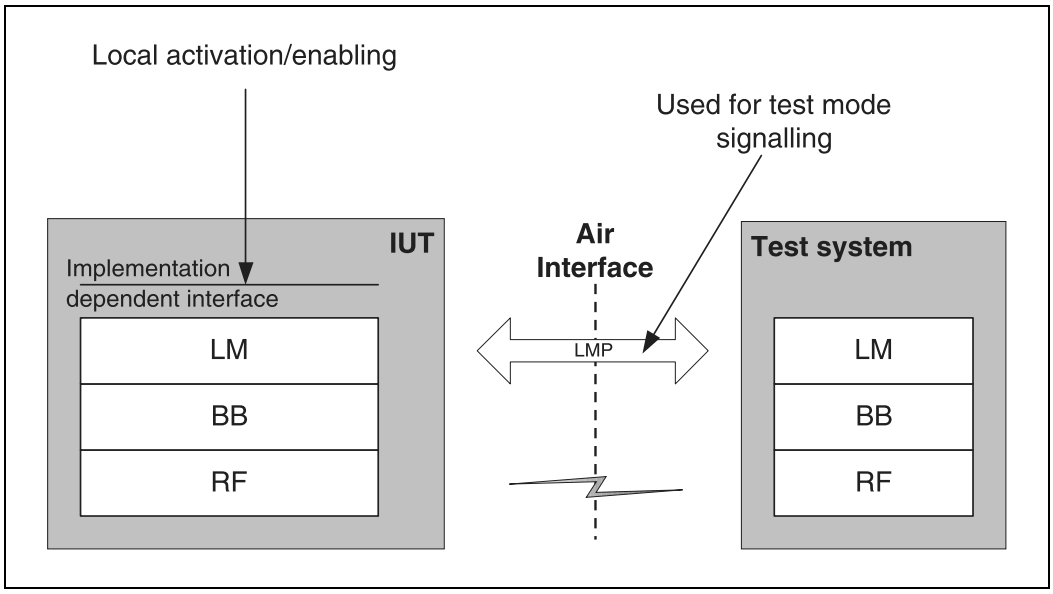


Figure 2.1: General test set-up for RF qualification

2.2.2 Bluetooth protocol requirements

Depending on which of the Bluetooth layers BB, LM or HCI are implemented in the product subject to qualification, the amount of testing needed to verify the Bluetooth protocol requirements differs. Also, the TCI used during the qualification is slightly different. The commands and events necessary for qualification are detailed in the test specifications and only those commands indicated in the test cases to be executed need be implemented.

For other protocols in the Bluetooth stack the TCI is not used. An implementation specific user interface is used to interact with the IUT's upper interface.

2.2.2.1 Required interfaces

For BB, LM and HCI qualification both the air interface of the IUT and the TCI are required. For other protocols both the air interface and the user interface are used as described in the test specification.

2.2.3 Bluetooth profile requirements

For each Bluetooth profile for which conformance is claimed, profile qualification testing is performed to verify the Bluetooth profile requirements. With higher layer protocols the TCI is not used during testing. A user interface specific to the implementation is used to interact with the IUT's upper interface.

2.2.3.1 Required interfaces

For this type of qualification both the air interface and the user interface of the IUT are used as described in the test specification.

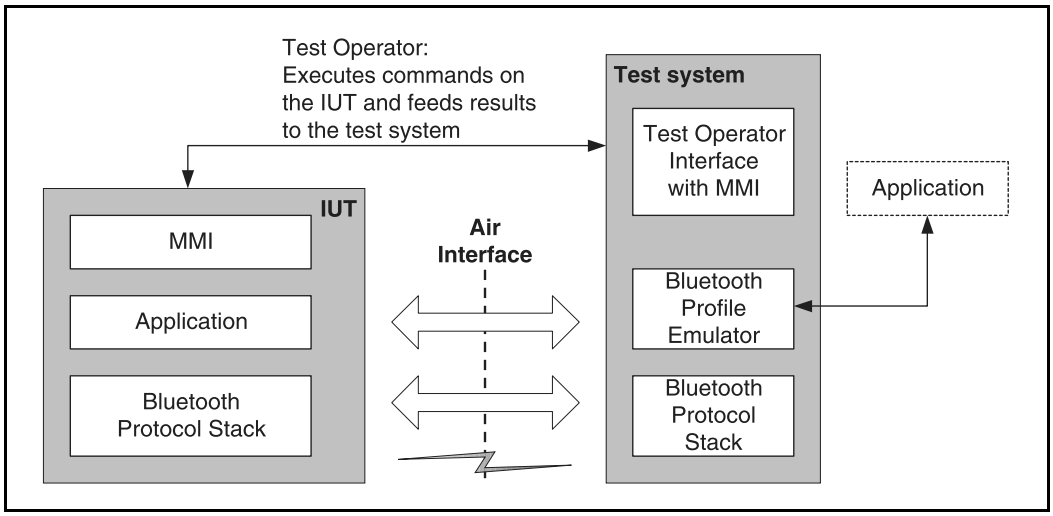


Figure 2.2: General test set-up for profile qualification

2.3 TCI CONFIGURATION AND USAGE

This interface is semantically and syntactically identical to the HCI interface described in “Host Controller Interface Functional Specification” on page 307[vol. 2]. The complete HCI interface is not required in the TCI, but the subset of HCI commands and events necessary for verifying the functionality of the IUT. The exact set of commands and events is specified in the test specifications for the layers subject to testing.

It is worth emphasizing again the TCI is an adapter, logically attached to the upper interface of the IUT. As such the TCI adapts the standardized signalling described here to the implementation specific interface of the IUT.

2.3.1 Transport layers

The method used to convey commands and events between the tester and the IUT’s upper interface can be either physical bearer or “software bearer”.

2.3.1.1 Physical bearer

It is recommended to use one of the transport layers specified for the HCI in. However, other physical bearers are not excluded and may be provided on test equipment. The use of a physical bearer is required for test cases active in category A. Please see the PRD for the definitions of test case categories. Please see the current active Test Case Reference List for the categorization of specific test cases.

2.3.1.2 Software bearer

There is no physical connection between the tester and the IUT’s upper interface. In this case, the manufacturer of the IUT shall supply test software and hardware that can be operated by a test operator. The operator will receive instructions from the tester and will execute them on the IUT. The “software bearer” shall support the same functionality as if using the TCI with a physical bearer. Use of the “software bearer” shall be agreed upon between the manufacturer of the IUT and the test facility that performs the qualification tests. The test facilities can themselves specify requirements placed on such a “software bearer”. Furthermore, the use of a “software bearer” is restricted to test cases active in one of the three lower categories B, C and D.

2.3.2 Baseband and link manager qualification

For the qualification of the link control part of the Baseband layer and for the Link Manager layer, the TCI is used as the interface between the test system and the upper interface of the IUT. The test system accesses the upper interface of the IUT by sending HCI commands and receiving HCI events from the IUT as described in the HCI specification. The required functionality on the TCI depends on the IUT's implemented functionality of the BB and LM layers, and therefore which test cases are executed.

A schematic example in Figure 2.3 shows the test configuration for BB and LM qualification of Bluetooth products which do not support HCI, and use a physical bearer for the TCI. In this example the Test Control (TC) Software represents what the manufacturer has to supply with the IUT when using an external test facility for qualification. The function of the TC Software is to adapt the implementation dependent interface to the TCI.

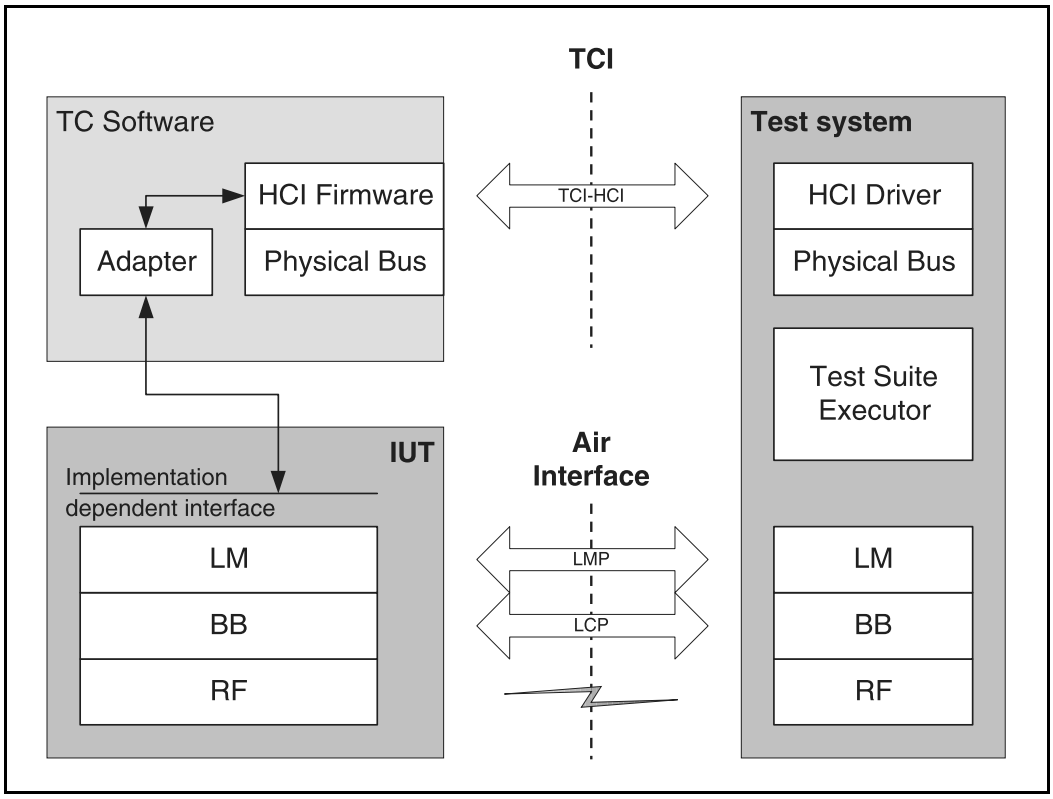


Figure 2.3: BB and LM qualification with TCI physical bearer

Figure 2.4 shows a schematic example of the test configuration for the same Bluetooth product using a “software bearer” for the TCI. Here the function of the Test Control Software is to represent the application that can be controlled by the test operator.

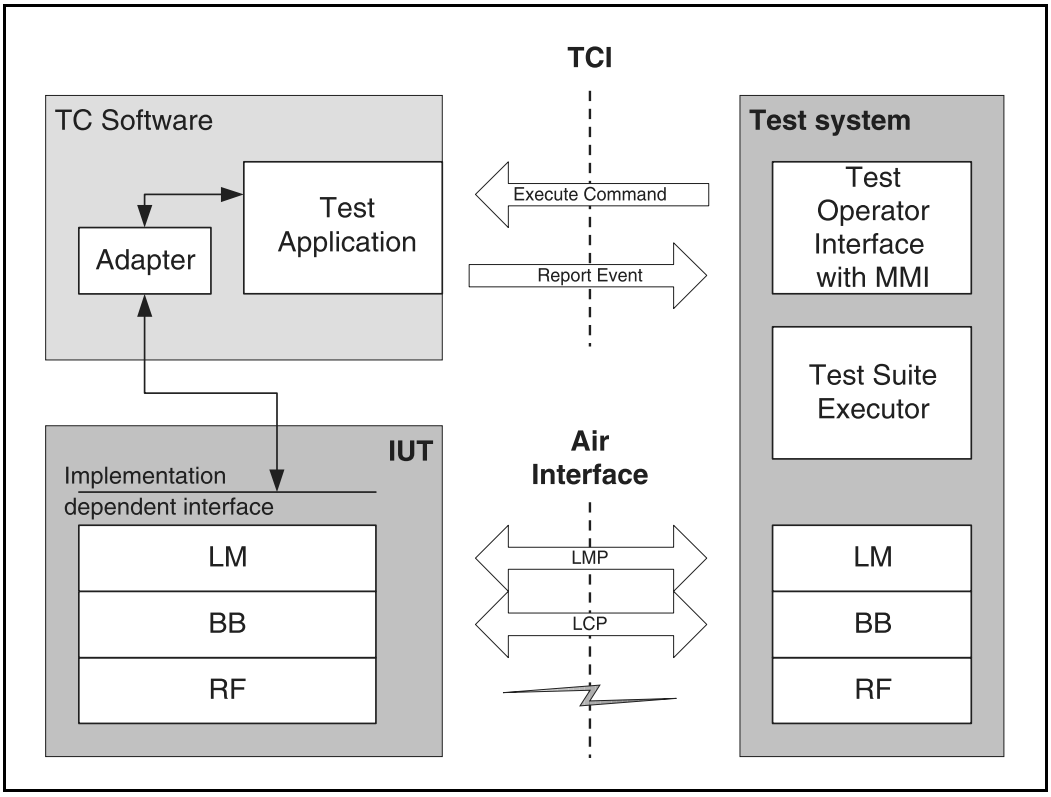


Figure 2.4: BB and LM qualification with “software bearer”

2.3.3 HCI qualification

The TCI may also be used for HCI signalling verification and qualification. The HCI signalling is only verified if support of the HCI functionality is claimed by the manufacturer.

A schematic example in Figure 2.5 shows the test configuration for HCI qualification of Bluetooth products. As can be seen in the figure the implemented HCI is used as the interface to the tester.

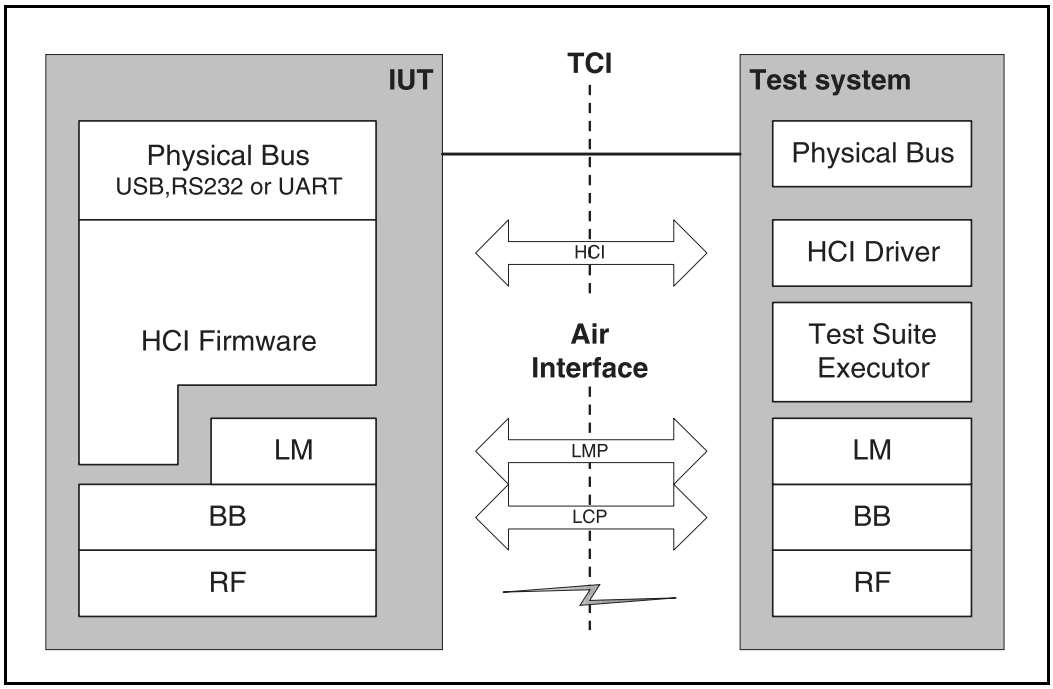


Figure 2.5: General test set-up for HCI qualification

