US007567791B2

(12) **United States Patent**
Laroia et al.

(10) **Patent No.: US 7,567,791 B2**
(45) **Date of Patent: Jul. 28, 2009**

(54) **WIRELESS TERMINAL METHODS AND APPARATUS FOR USE IN A WIRELESS COMMUNICATIONS SYSTEM THAT USES A MULTI-MODE BASE STATION**

(75) Inventors: **Rajiv Laroia**, Basking Ridge, NJ (US); **Pablo Anigstein**, Springfield, NJ (US); **Arnab Das**, Jersey City, NJ (US); **Sundeep Rangan**, Jersey City, NJ (US)

(73) Assignee: **QUALCOMM Incorporated**, San Diego, CA (US)

(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 592 days.

(21) Appl. No.: **11/229,847**

(22) Filed: **Sep. 19, 2005**

(65) **Prior Publication Data**

US 2007/0066273 A1 Mar. 22, 2007

(51) **Int. Cl.**
H04B 1/16 (2006.01)

(52) **U.S. Cl.** **455/343.2**; 455/418; 455/518; 455/414.1; 455/550.1

(58) **Field of Classification Search** 455/434, 455/417, 418, 518, 414.1, 420, 403, 519, 455/555, 556.1, 561, 91, 130
See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

6,584,330	B1	6/2003	Ruuska	
6,725,053	B2 *	4/2004	Rosen et al.	455/518
6,738,617	B2 *	5/2004	Rosen et al.	455/418
6,904,288	B2 *	6/2005	Rosen et al.	455/518
7,047,005	B2 *	5/2006	Kinnavy	455/434
7,403,470	B2	7/2008	Lane et al.	

FOREIGN PATENT DOCUMENTS

GB	2 366 695 A	3/2002
GB	2 398 970 A	9/2004

OTHER PUBLICATIONS

International Search Report for PCT/US2006/035930, 3 pages, dated Jan. 12, 2007.
Written Opinion of the International Searching Authority for PCT/US2006/035930, 5 pages, dated Jan. 12, 2007.
International Preliminary Report of Patentability - PCT/US06/035930, The International Bureau of Wipo - Geneva, Switzerland - Mar. 26, 2008.

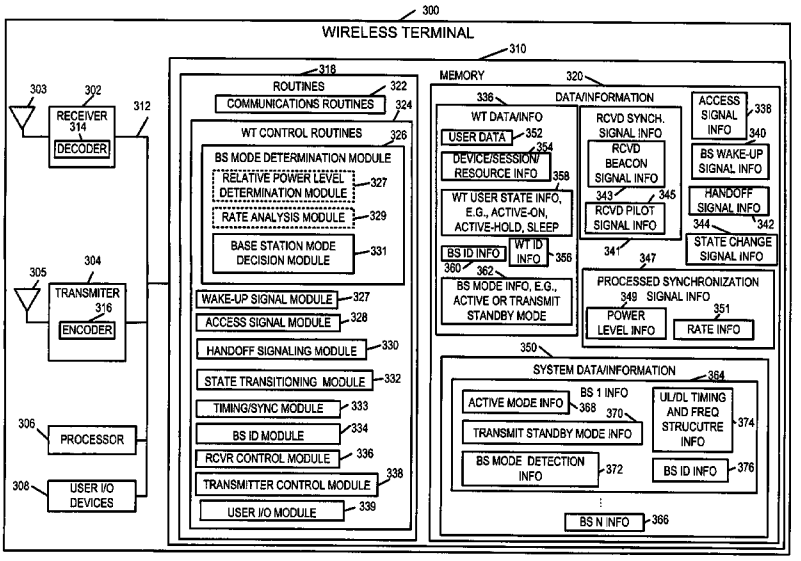
* cited by examiner

Primary Examiner—Tony T Nguyen
(74) *Attorney, Agent, or Firm*—Michael P. Straub; James K. O'Hare

(57) **ABSTRACT**

Wireless terminal for use with a multi-mode base station that supports a transmit standby mode and an active mode is described. Transmit standby mode of base station operation is a low power/low interference level of operation as compared to active mode. In transmit standby mode at least some of the synchronization signaling such as pilot tone signaling is reduced in power level and/or rate with respect to the active mode. In transmit standby mode, the base station has no active state registered wireless terminals being serviced but may have some sleep state registered wireless terminals being serviced. Mode transitions from active to transmit standby may be in response to: a detected period of inactivity, scheduling information, base station mode change signals, and/or detected wireless terminal state transition. Mode transitions from transmit standby to active may be in response to: scheduling information, access signals, wake-up signals from the wireless terminal, hand-off signals, etc.

34 Claims, 19 Drawing Sheets



VUSION-1013
11,540,216

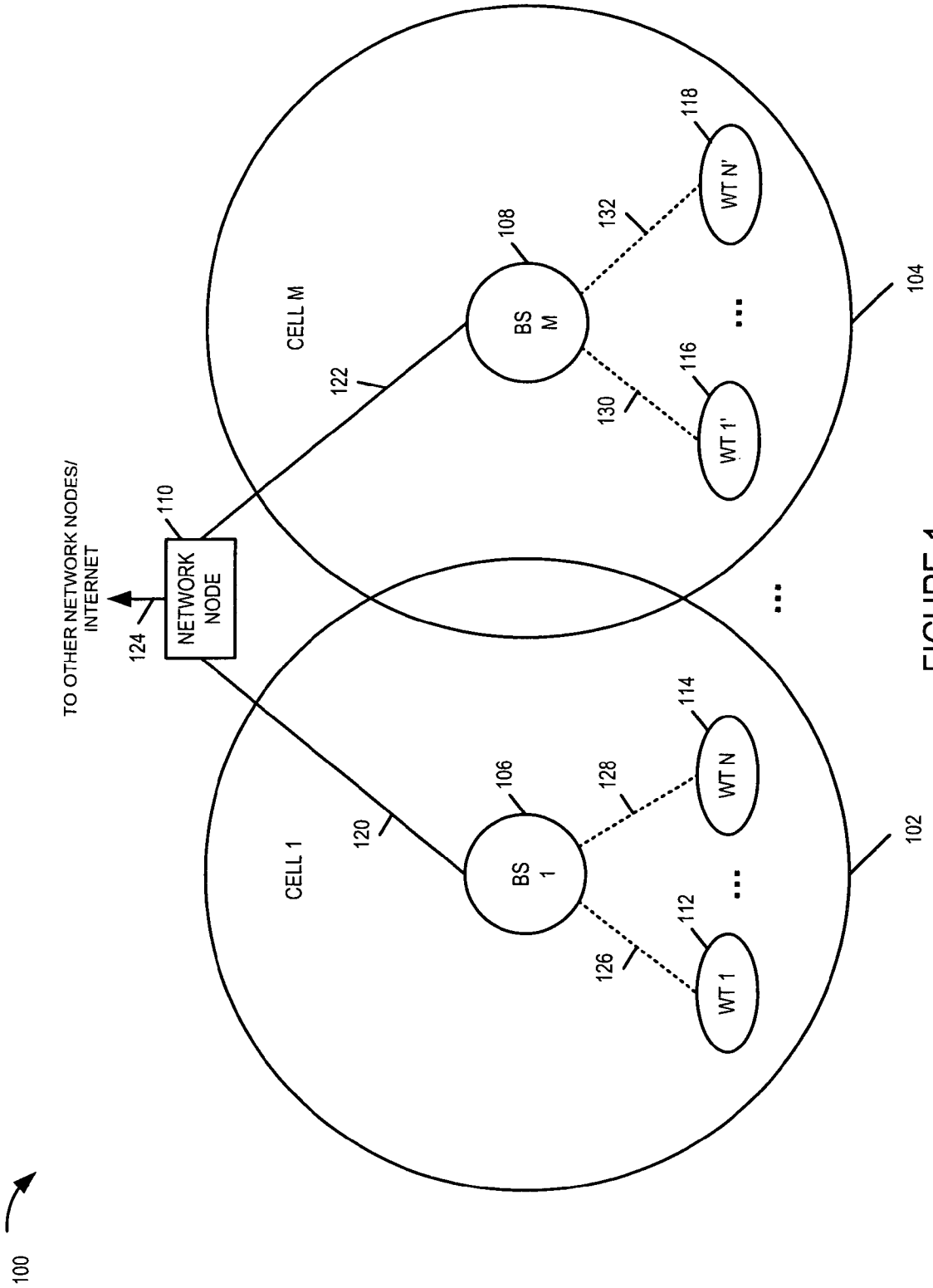

100
TO OTHER NETWORK NODES/ INTERNET
124
NETWORK NODE
110
CELL 1
CELL M
120
122
BS 1
BS M
106
108
126
128
130
132
WT 1
WT N
WT 1'
WT N'
112
114
116
118
102
104

FIGURE 1

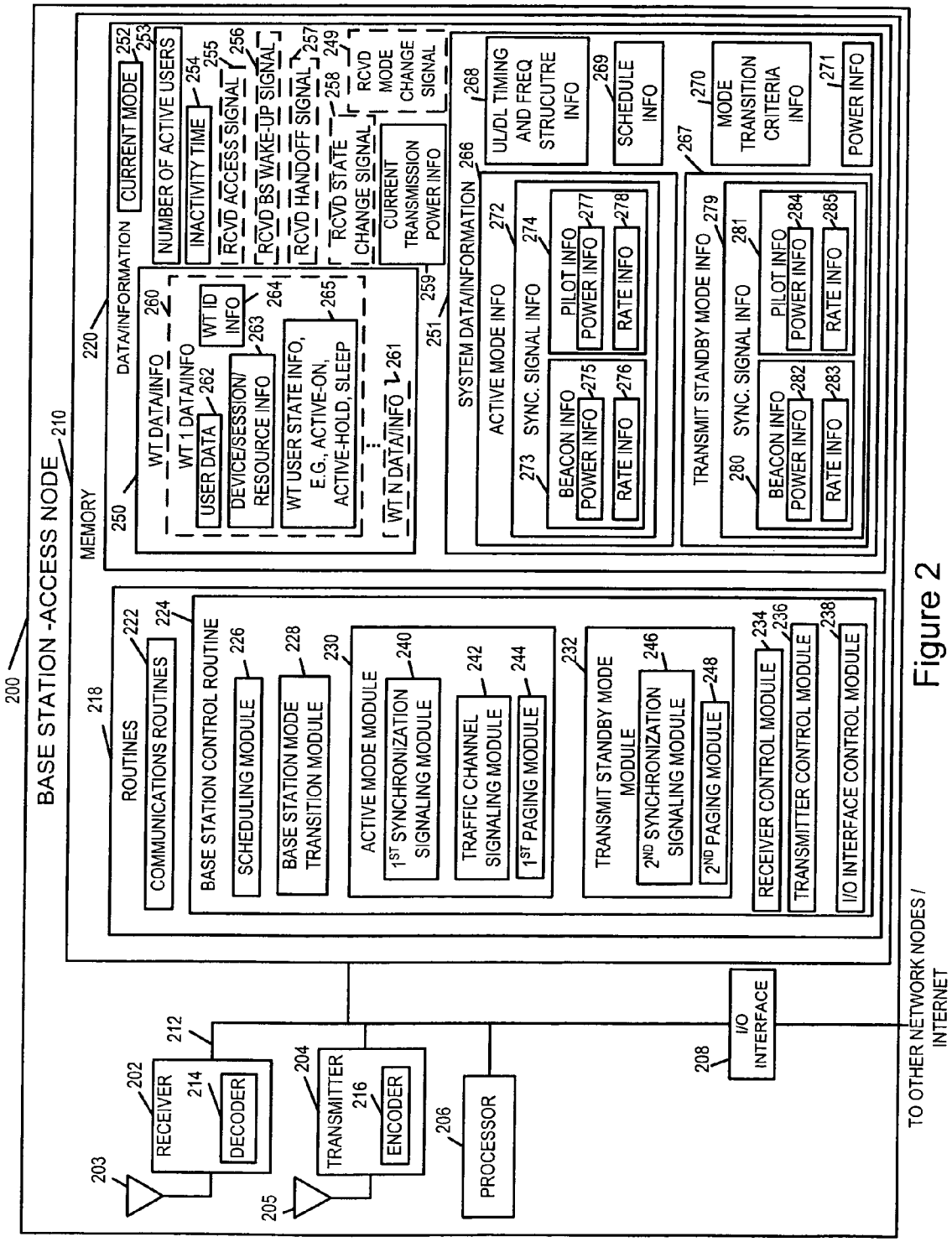

BASE STATION -ACCESS NODE
200
210
MEMORY
220
DATA/INFORMATION
CURRENT MODE
252
253
NUMBER OF ACTIVE USERS
INACTIVITY TIME
254
255
RCVD ACCESS SIGNAL
256
RCVD BS WAKE-UP SIGNAL
257
RCVD HANDOFF SIGNAL
249
RCVD STATE
258
CHANGE SIGNAL
RCVD MODE CHANGE SIGNAL
CURRENT TRANSMISSION POWER INFO
259
WT DATA/INFO
260
WT 1 DATA/INFO
USER DATA
262
DEVICE/SESSION/ RESOURCE INFO
263
WT ID INFO
264
WT USER STATE INFO, E.G., ACTIVE-ON, ACTIVE-HOLD, SLEEP
265
WT N DATA/INFO
261
250
SYSTEM DATA/INFORMATION
251
UL/DL TIMING AND FREQ STRUCUTRE INFO
268
SCHEDULE INFO
269
MODE TRANSITION CRITERIA INFO
270
POWER INFO
271
ACTIVE MODE INFO
266
SYNC. SIGNAL INFO
272
PILOT INFO
274
POWER INFO
277
RATE INFO
278
BEACON INFO
273
POWER INFO
275
RATE INFO
276
TRANSMIT STANDBY MODE INFO
267
SYNC. SIGNAL INFO
279
PILOT INFO
281
POWER INFO
284
RATE INFO
285
BEACON INFO
280
POWER INFO
282
RATE INFO
283
ROUTINES
218
COMMUNICATIONS ROUTINES
222
BASE STATION CONTROL ROUTINE
224
SCHEDULING MODULE
226
BASE STATION MODE TRANSITION MODULE
228
ACTIVE MODE MODULE
230
1ST SYNCHRONIZATION SIGNALING MODULE
240
TRAFFIC CHANNEL SIGNALING MODULE
242
1ST PAGING MODULE
244
TRANSMIT STANDBY MODE MODULE
232
2ND SYNCHRONIZATION SIGNALING MODULE
246
2ND PAGING MODULE
248
RECEIVER CONTROL MODULE
234
TRANSMITTER CONTROL MODULE
236
I/O INTERFACE CONTROL MODULE
238
RECEIVER
202
DECODER
214
212
TRANSMITTER
204
ENCODER
216
PROCESSOR
206
I/O INTERFACE
208
203
205
TO OTHER NETWORK NODES / INTERNET

Figure 2

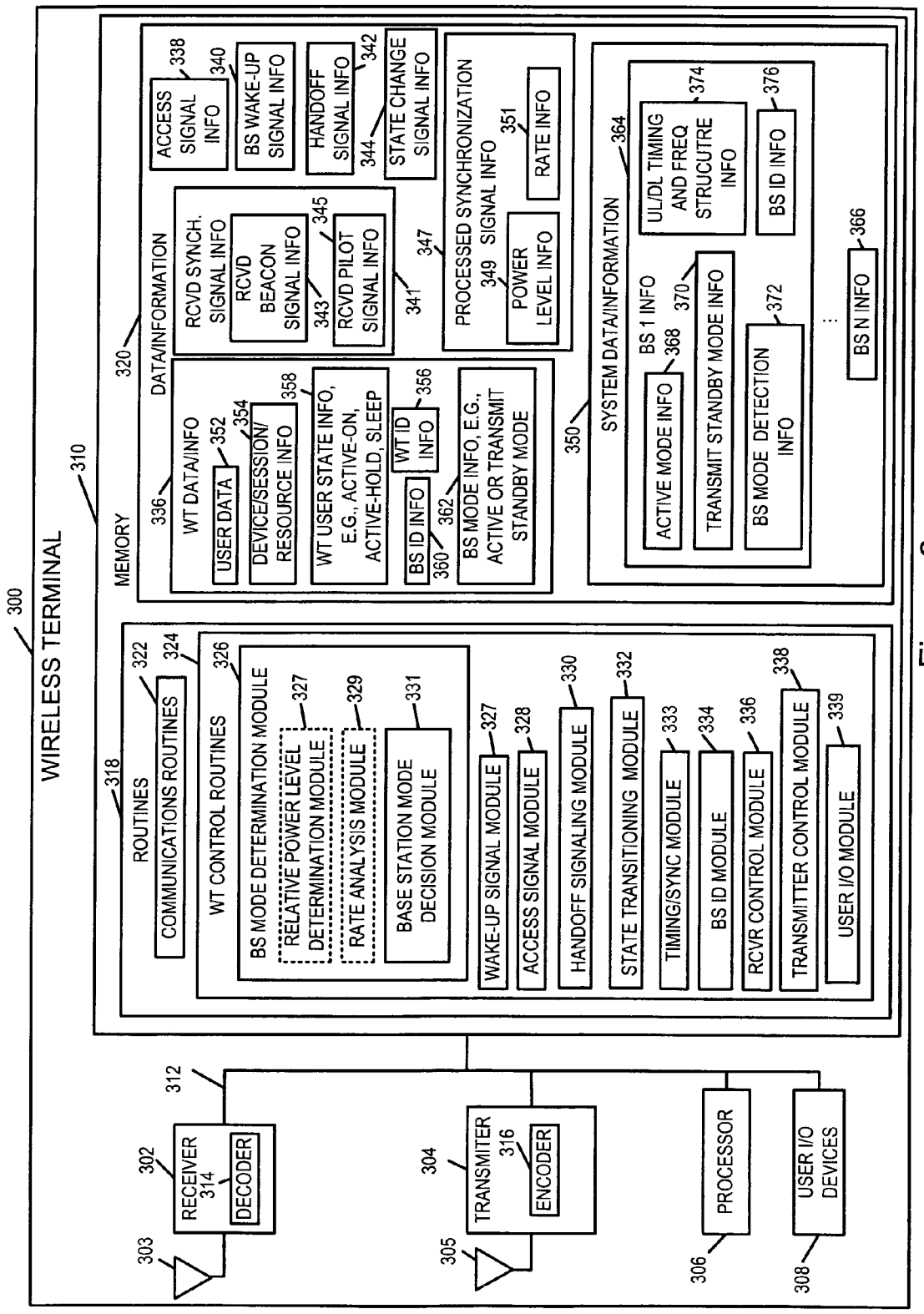

WIRELESS TERMINAL
300
MEMORY
310
DATA/INFORMATION
320
ACCESS SIGNAL INFO
338
BS WAKE-UP SIGNAL INFO
340
HANDOFF SIGNAL INFO
342
STATE CHANGE SIGNAL INFO
344
RCVD SYNCH. SIGNAL INFO
RCVD BEACON SIGNAL INFO
343
RCVD PILOT SIGNAL INFO
345
341
PROCESSED SYNCHRONIZATION SIGNAL INFO
347
349
POWER LEVEL INFO
RATE INFO
351
WT DATA/INFO
336
USER DATA
352
DEVICE/SESSION/ RESOURCE INFO
354
358
WT USER STATE INFO, E.G., ACTIVE-ON, ACTIVE-HOLD, SLEEP
WT ID INFO
356
BS ID INFO
360
BS MODE INFO, E.G., ACTIVE OR TRANSMIT STANDBY MODE
362
SYSTEM DATA/INFORMATION
350
364
UL/DL TIMING AND FREQ STRUCUTRE INFO
374
BS ID INFO
376
BS 1 INFO
368
ACTIVE MODE INFO
TRANSMIT STANDBY MODE INFO
370
BS MODE DETECTION INFO
372
BS N INFO
366
ROUTINES
318
COMMUNICATIONS ROUTINES
322
WT CONTROL ROUTINES
324
BS MODE DETERMINATION MODULE
326
RELATIVE POWER LEVEL DETERMINATION MODULE
327
RATE ANALYSIS MODULE
329
BASE STATION MODE DECISION MODULE
331
WAKE-UP SIGNAL MODULE
327
ACCESS SIGNAL MODULE
328
HANDOFF SIGNALING MODULE
330
STATE TRANSITIONING MODULE
332
TIMING/SYNC MODULE
333
BS ID MODULE
334
RCVR CONTROL MODULE
336
TRANSMITTER CONTROL MODULE
338
USER I/O MODULE
339
312
RECEIVER 314
DECODER
302
303
TRANSMITER 316
ENCODER
304
305
PROCESSOR
306
USER I/O DEVICES
308

Figure 3

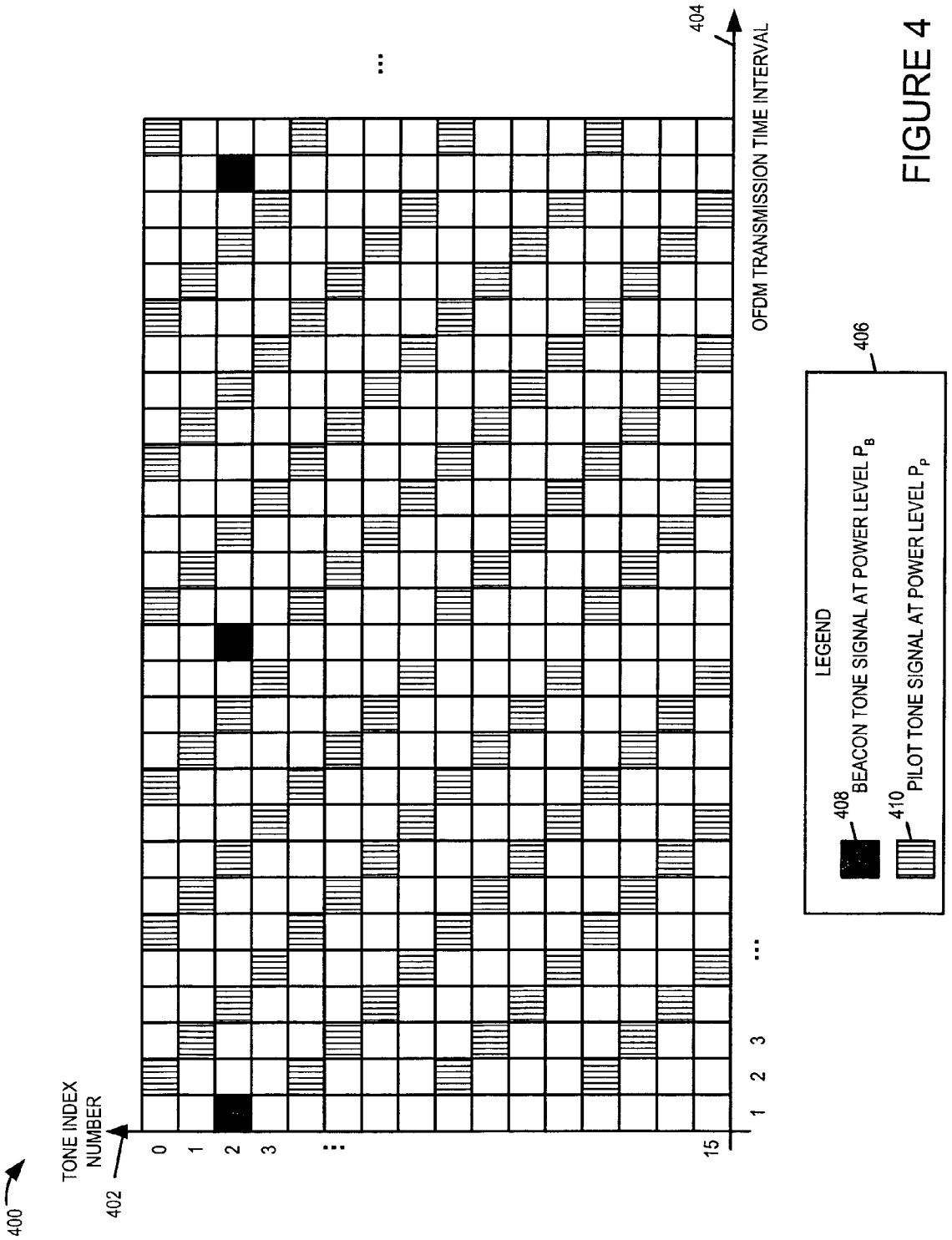

400
TONE INDEX NUMBER
402
0
1
2
3
...
15
404
OFDM TRANSMISSION TIME INTERVAL
1
2
3
...
LEGEND
408
BEACON TONE SIGNAL AT POWER LEVEL P_B
410
PILOT TONE SIGNAL AT POWER LEVEL P_P
406

FIGURE 4

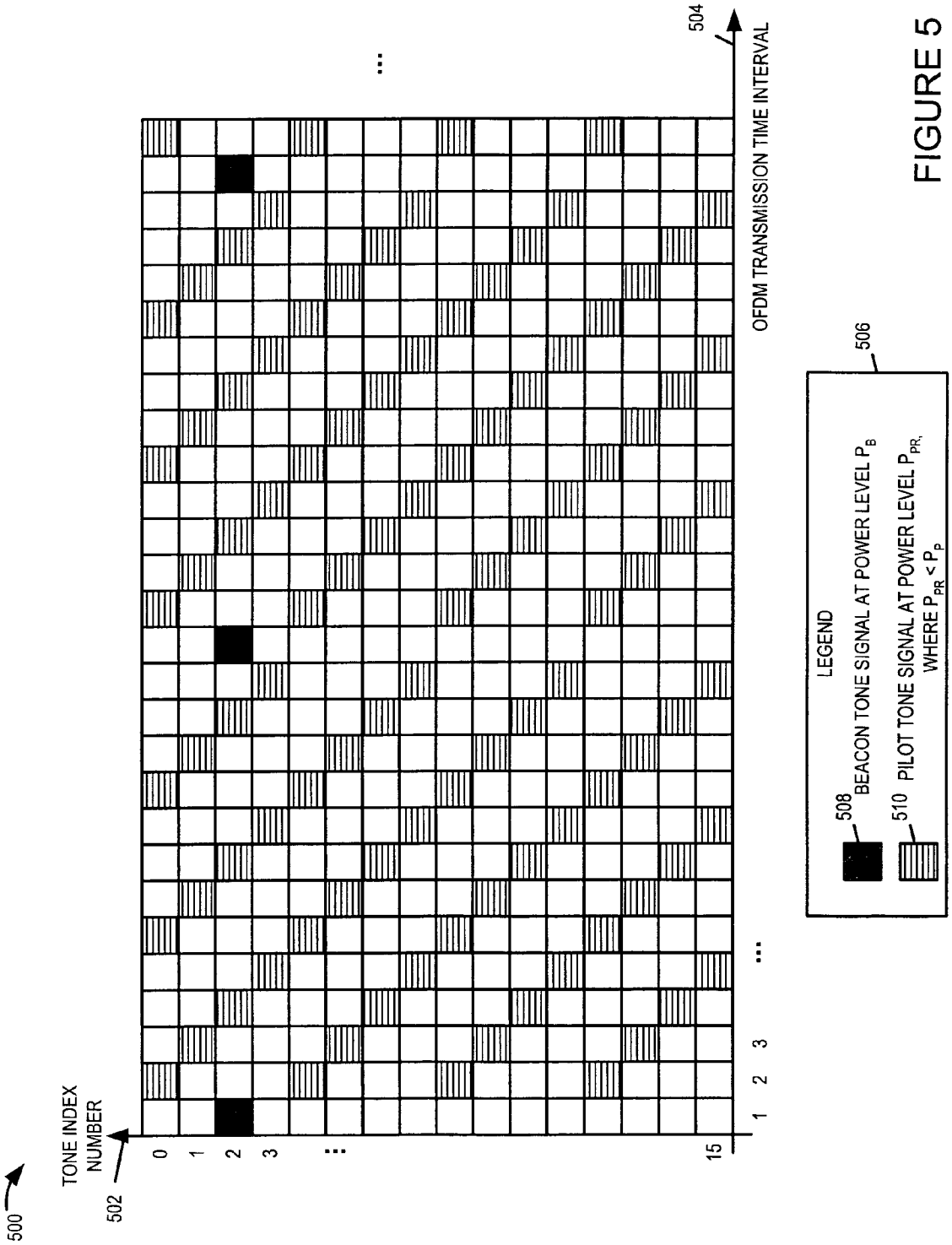

500
TONE INDEX NUMBER
502
0
1
2
3
...
15
1
2
3
...
504
OFDM TRANSMISSION TIME INTERVAL
506
LEGEND
508
BEACON TONE SIGNAL AT POWER LEVEL P_B
510
PILOT TONE SIGNAL AT POWER LEVEL P_{PR_i}
WHERE $P_{PR_i} < P_P$

FIGURE 5

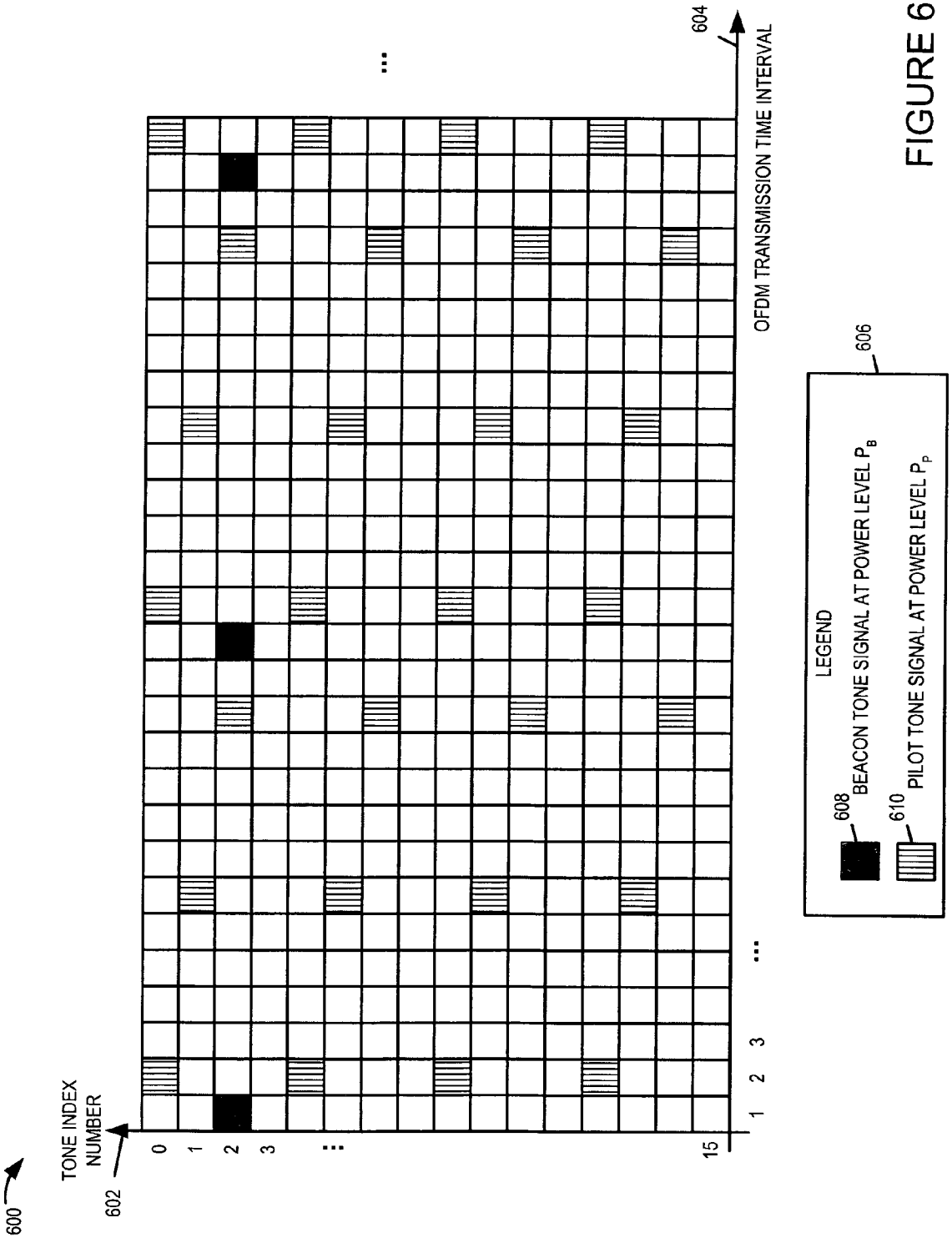

600
TONE INDEX NUMBER
602
0
1
2
3
...
15
1
2
3
...
604
OFDM TRANSMISSION TIME INTERVAL
606
LEGEND
608
BEACON TONE SIGNAL AT POWER LEVEL P_B
610
PILOT TONE SIGNAL AT POWER LEVEL P_P

FIGURE 6

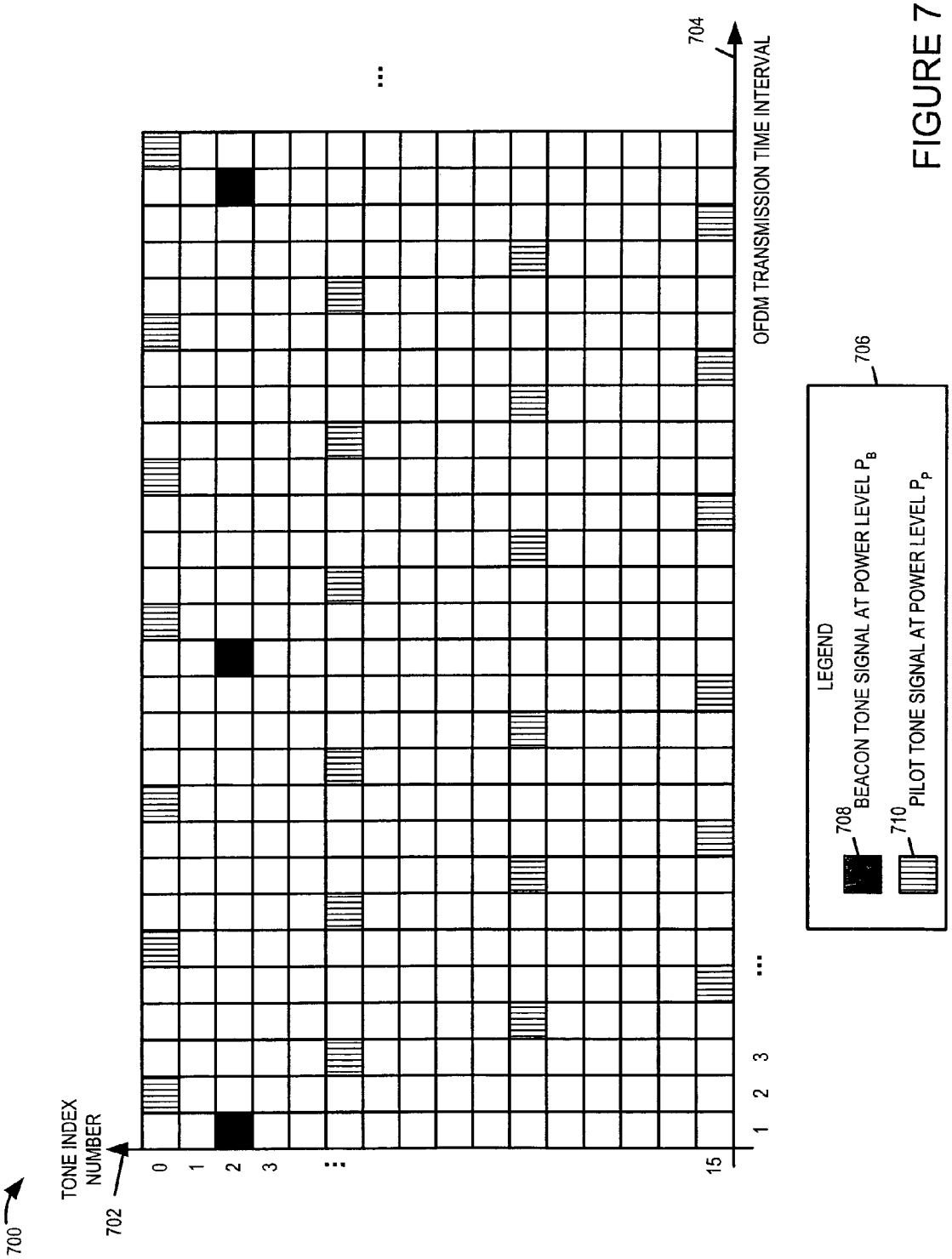

700
TONE INDEX NUMBER
702
0
1
2
3
...
15
704
OFDM TRANSMISSION TIME INTERVAL
1
2
3
...
706
LEGEND
708
BEACON TONE SIGNAL AT POWER LEVEL P_B
710
PILOT TONE SIGNAL AT POWER LEVEL P_P

FIGURE 7

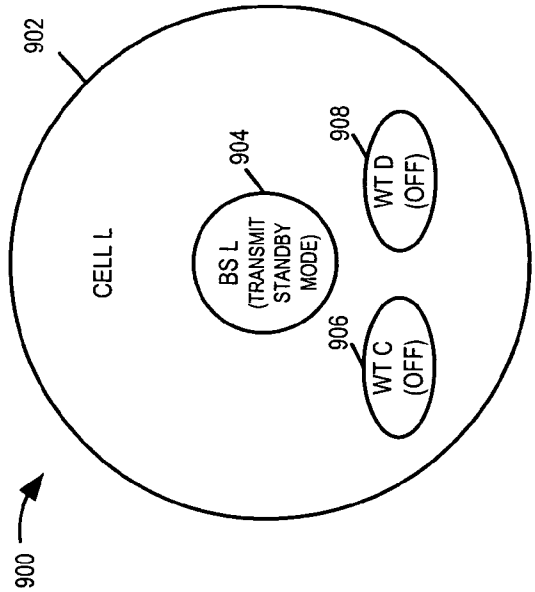


FIGURE 9

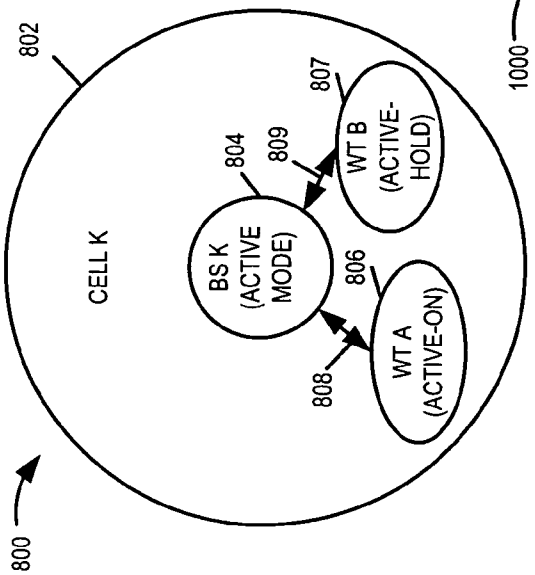


FIGURE 8

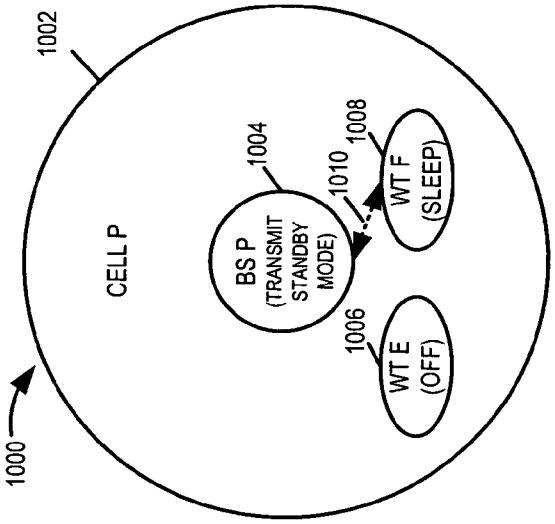


FIGURE 10

1100

	1102 BASE STATION ACTIVE MODE	1104 BASE STATION TRANSMIT STANDBY MODE
1106 SERVICED WTs	ACTIVE MODE AND SLEEP MODE	SLEEP MODE
1108 BEACON SIGNALS	YES	YES
1110 PILOT SIGNALS	YES (AT HIGH TRANSMISSION RATE AND HIGH POWER LEVEL)	YES (AT LOW TRANSMISSION RATE AND LOW POWER LEVEL)
1112 UPLINK AND DOWNLINK TRAFFIC CHANNEL DATA	YES	NO
1114 PAGING SIGNALS	YES	YES

FIGURE 11

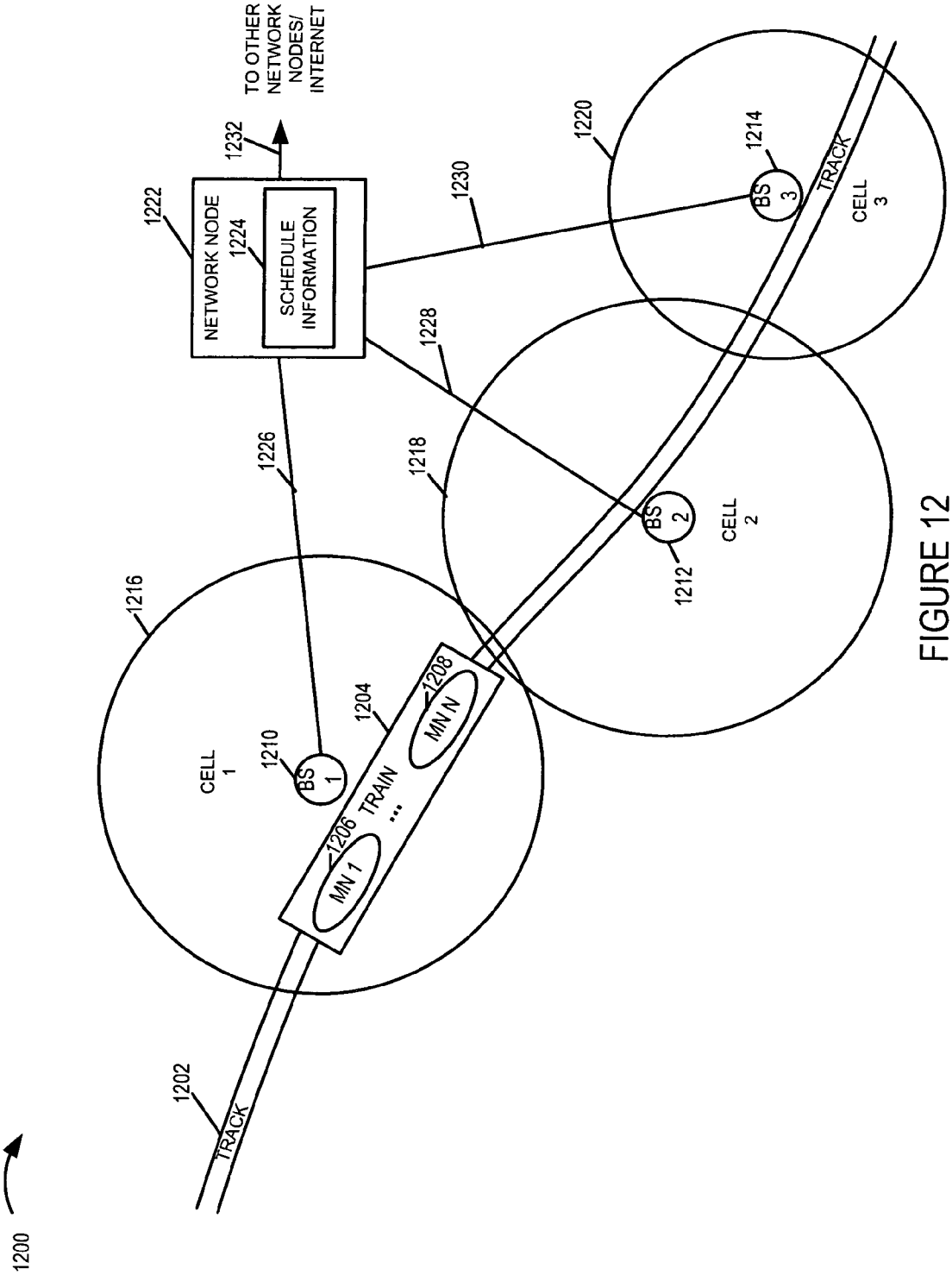

1200
1202
TRACK
1216
CELL 1
1210
BS 1
1206
MN 1
TRAIN
...
1204
1208
MN N
1226
1218
1228
1212
BS 2
CELL 2
1230
1220
1214
BS 3
TRACK
CELL 3
1222
NETWORK NODE
1224
SCHEDULE INFORMATION
1232
TO OTHER NETWORK NODES/ INTERNET

FIGURE 12

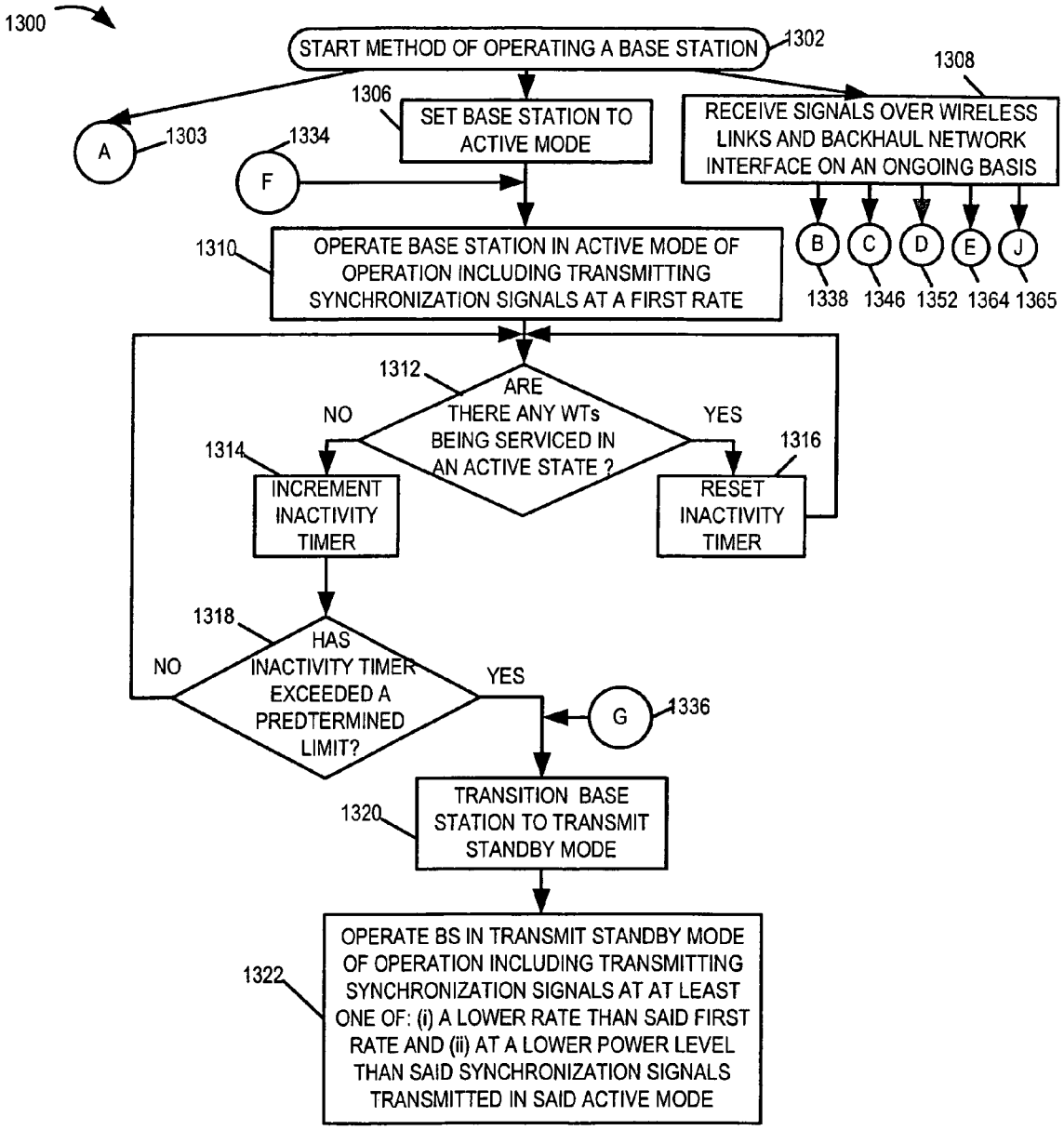


FIGURE 13A

FIGURE 13A
FIGURE 13B
FIGURE 13C

FIGURE 13

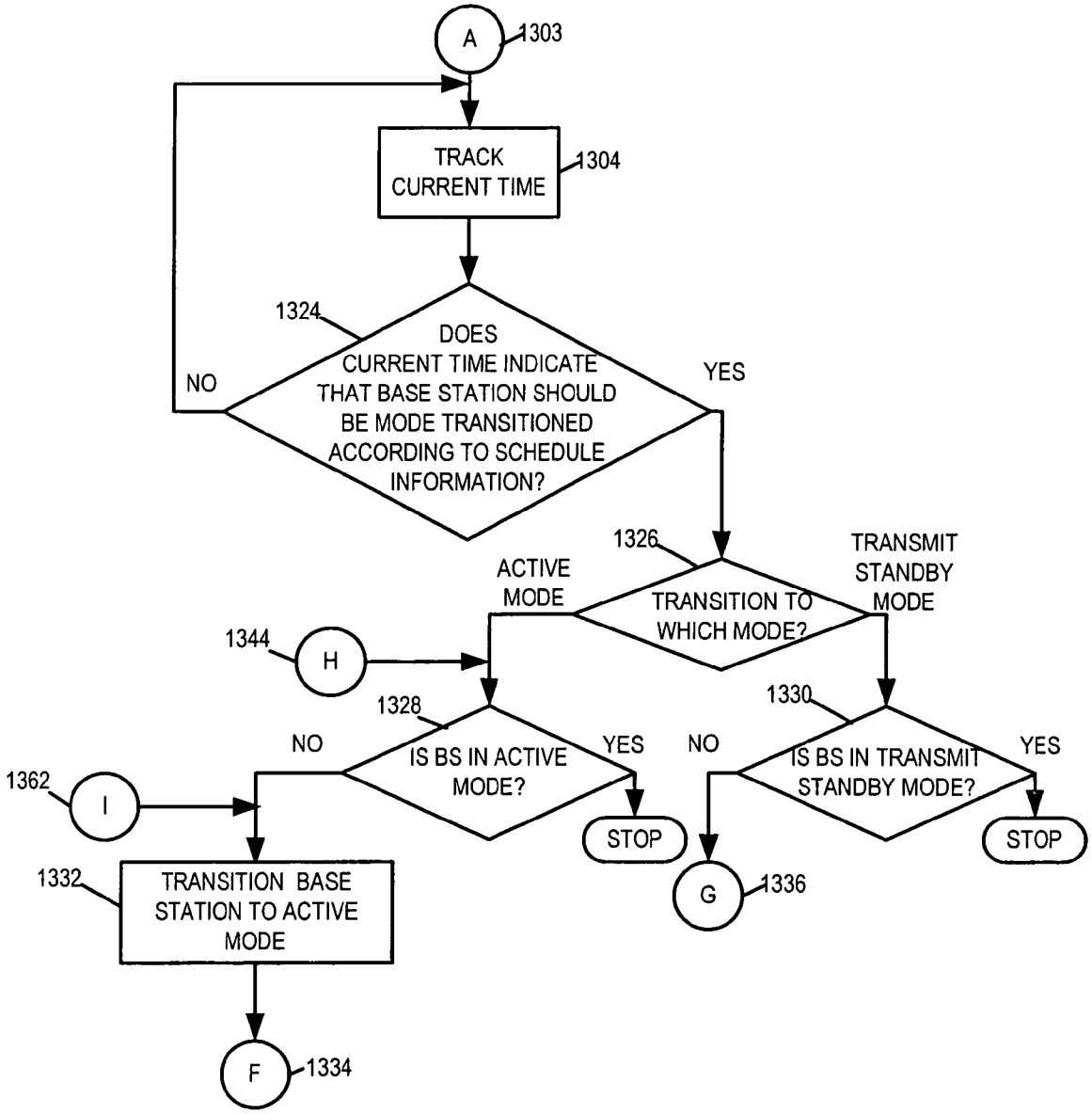

A
1303
TRACK CURRENT TIME
1304
1324
DOES CURRENT TIME INDICATE THAT BASE STATION SHOULD BE MODE TRANSITIONED ACCORDING TO SCHEDULE INFORMATION?
NO
YES
1326
TRANSITION TO WHICH MODE?
ACTIVE MODE
TRANSMIT STANDBY MODE
1344
H
1328
IS BS IN ACTIVE MODE?
NO
YES
1330
IS BS IN TRANSMIT STANDBY MODE?
NO
YES
1362
I
STOP
STOP
G
1336
1332
TRANSITION BASE STATION TO ACTIVE MODE
F
1334

FIGURE 13B

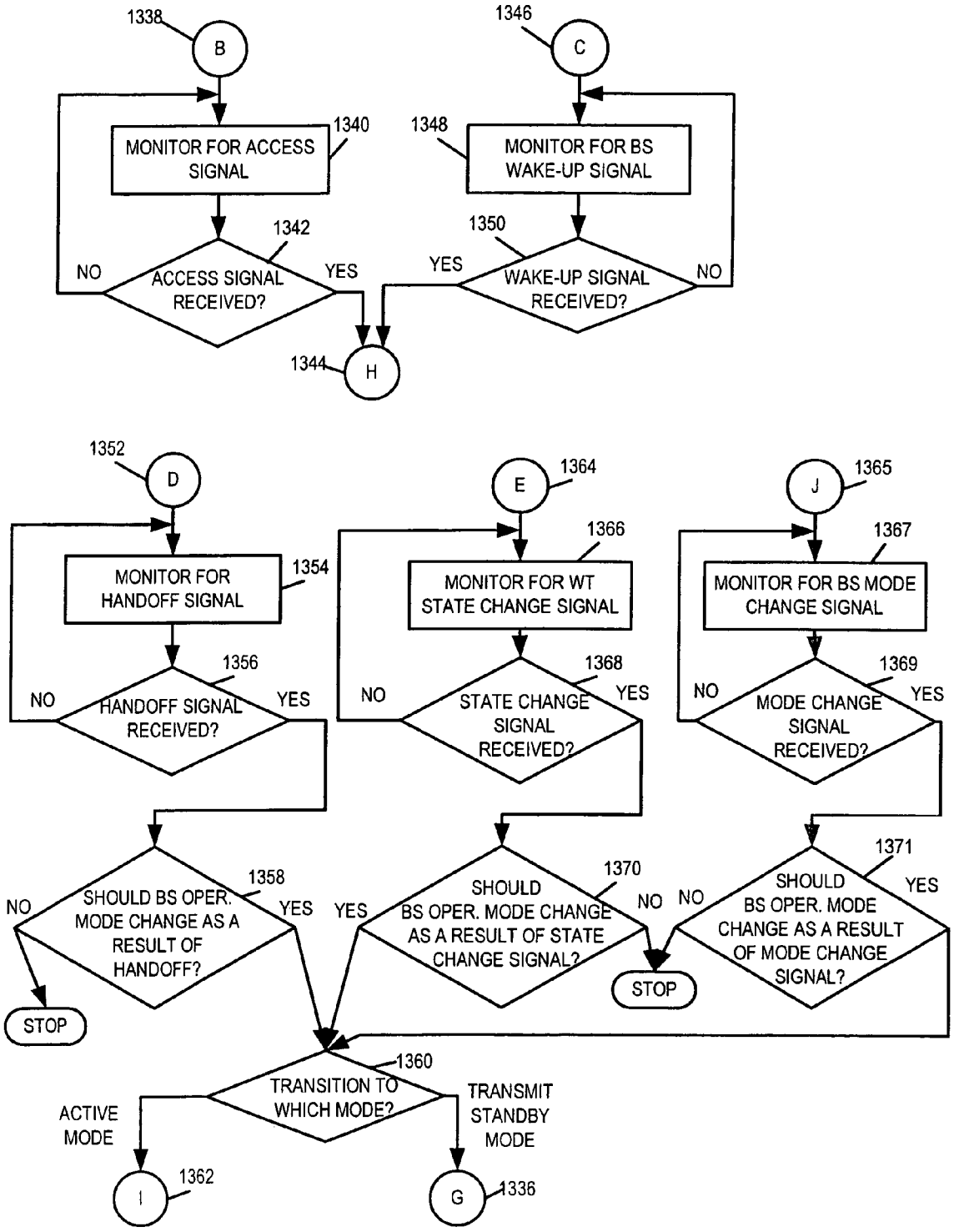

1338
B
MONITOR FOR ACCESS SIGNAL
1340
1342
ACCESS SIGNAL RECEIVED?
NO
YES
1344
H
1346
C
1348
MONITOR FOR BS WAKE-UP SIGNAL
1350
WAKE-UP SIGNAL RECEIVED?
YES
NO
1352
D
MONITOR FOR HANDOFF SIGNAL
1354
1356
HANDOFF SIGNAL RECEIVED?
NO
YES
1358
SHOULD BS OPER. MODE CHANGE AS A RESULT OF HANDOFF?
NO
YES
STOP
E
1364
1366
MONITOR FOR WT STATE CHANGE SIGNAL
1368
STATE CHANGE SIGNAL RECEIVED?
NO
YES
1370
SHOULD BS OPER. MODE CHANGE AS A RESULT OF STATE CHANGE SIGNAL?
YES
NO
STOP
J
1365
1367
MONITOR FOR BS MODE CHANGE SIGNAL
1369
MODE CHANGE SIGNAL RECEIVED?
NO
YES
1371
SHOULD BS OPER. MODE CHANGE AS A RESULT OF MODE CHANGE SIGNAL?
NO
YES
1360
TRANSITION TO WHICH MODE?
ACTIVE MODE
TRANSMIT STANDBY MODE
I
1362
G
1336

FIGURE 13C

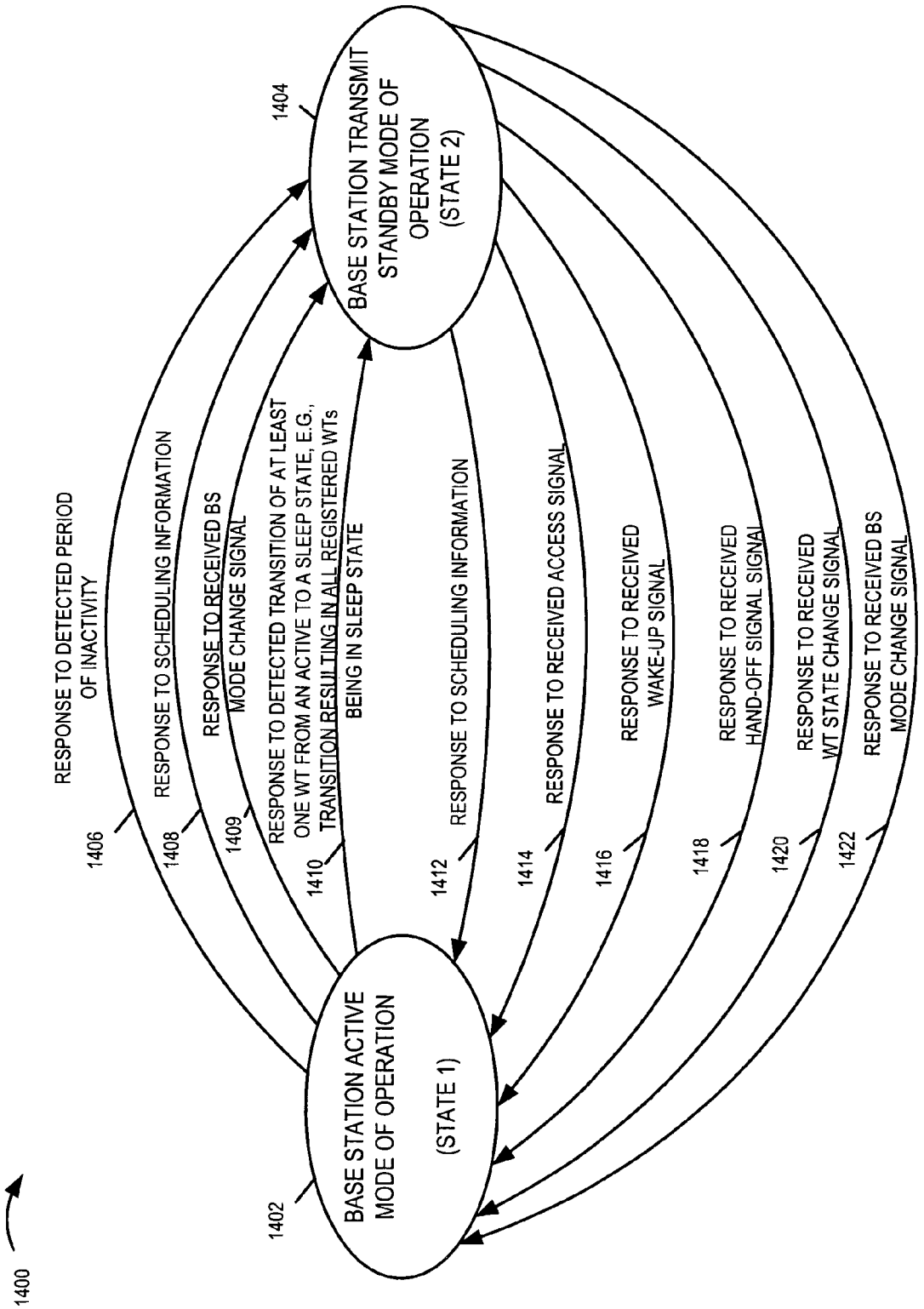

1400
1402
BASE STATION ACTIVE MODE OF OPERATION (STATE 1)
1404
BASE STATION TRANSMIT STANDBY MODE OF OPERATION (STATE 2)
1406
RESPONSE TO DETECTED PERIOD OF INACTIVITY
1408
RESPONSE TO SCHEDULING INFORMATION
1409
RESPONSE TO RECEIVED BS MODE CHANGE SIGNAL
1410
RESPONSE TO DETECTED TRANSITION OF AT LEAST ONE WT FROM AN ACTIVE TO A SLEEP STATE, E.G., TRANSITION RESULTING IN ALL REGISTERED WTs BEING IN SLEEP STATE
1412
RESPONSE TO SCHEDULING INFORMATION
1414
RESPONSE TO RECEIVED ACCESS SIGNAL
1416
RESPONSE TO RECEIVED WAKE-UP SIGNAL
1418
RESPONSE TO RECEIVED HAND-OFF SIGNAL SIGNAL
1420
RESPONSE TO RECEIVED WT STATE CHANGE SIGNAL
1422
RESPONSE TO RECEIVED BS MODE CHANGE SIGNAL

FIGURE 14

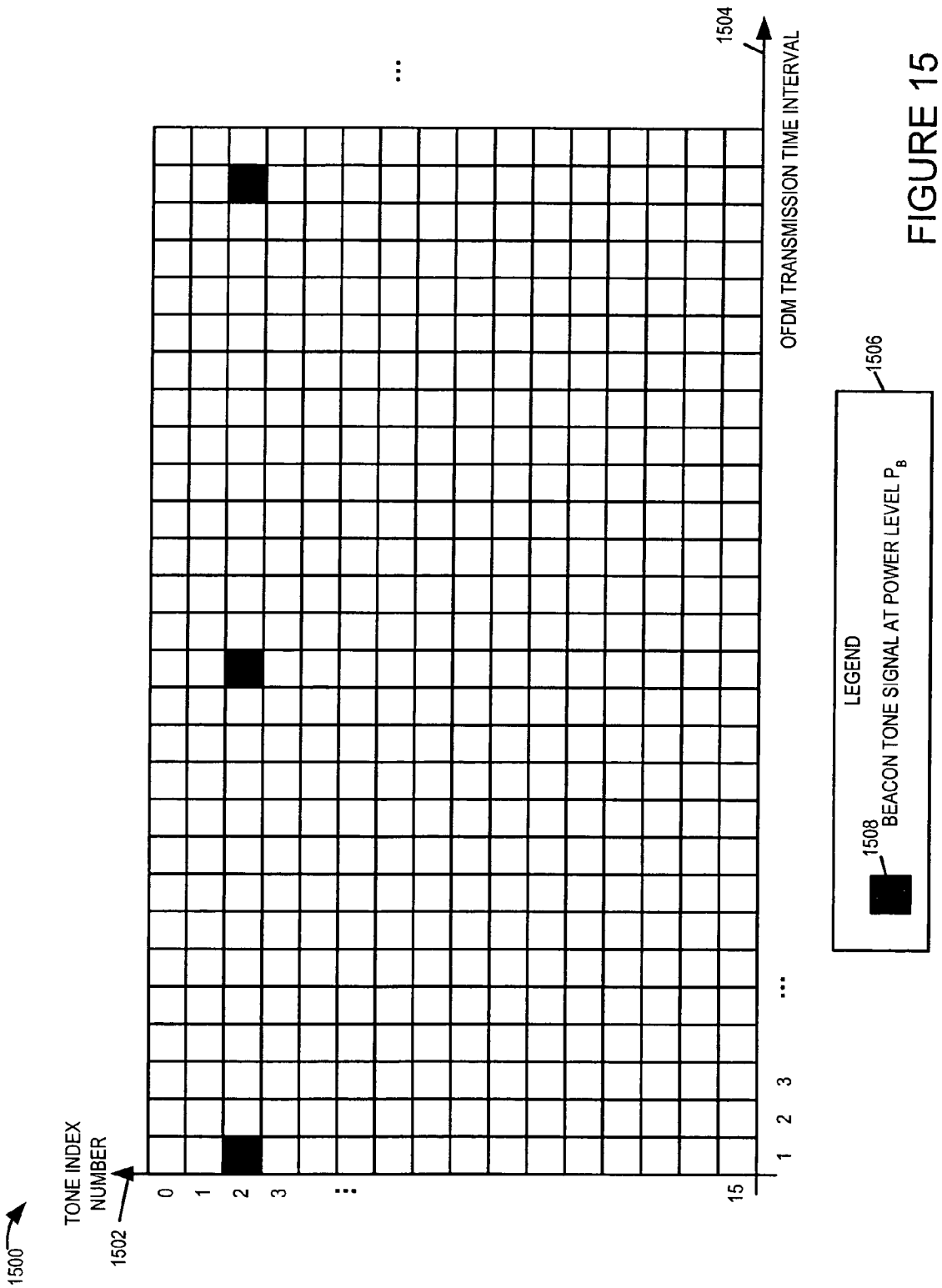

1500
TONE INDEX NUMBER
1502
0
1
2
3
...
15
1
2
3
...
1504
OFDM TRANSMISSION TIME INTERVAL
1506
LEGEND
1508
BEACON TONE SIGNAL AT POWER LEVEL P_B

FIGURE 15

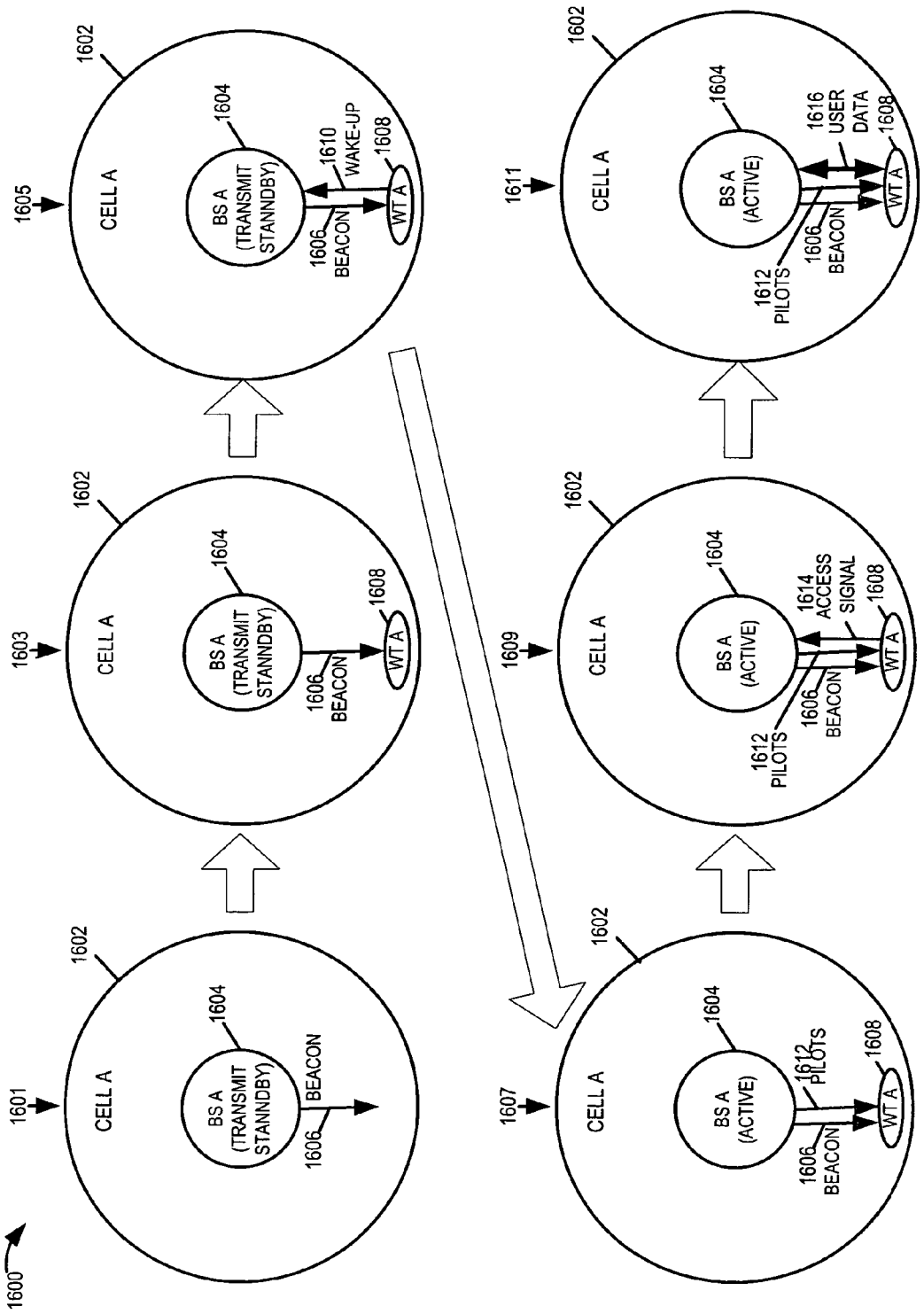

1600
1601
CELL A
1602
BS A (TRANSMIT STANNDBY)
1604
1606 BEACON
1603
CELL A
1602
BS A (TRANSMIT STANNDBY)
1604
1606 BEACON
1608 WT A
1605
CELL A
1602
BS A (TRANSMIT STANNDBY)
1604
1606 BEACON
1610 WAKE-UP
1608 WT A
1607
CELL A
1602
BS A (ACTIVE)
1604
1612 PILOTS
1606 BEACON
1608 WT A
1609
CELL A
1602
BS A (ACTIVE)
1604
1614 ACCESS SIGNAL
1612 PILOTS
1606 BEACON
1608 WT A
1611
CELL A
1602
BS A (ACTIVE)
1604
1616 USER DATA
1612 PILOTS
1606 BEACON
1608 WT A

FIGURE 16

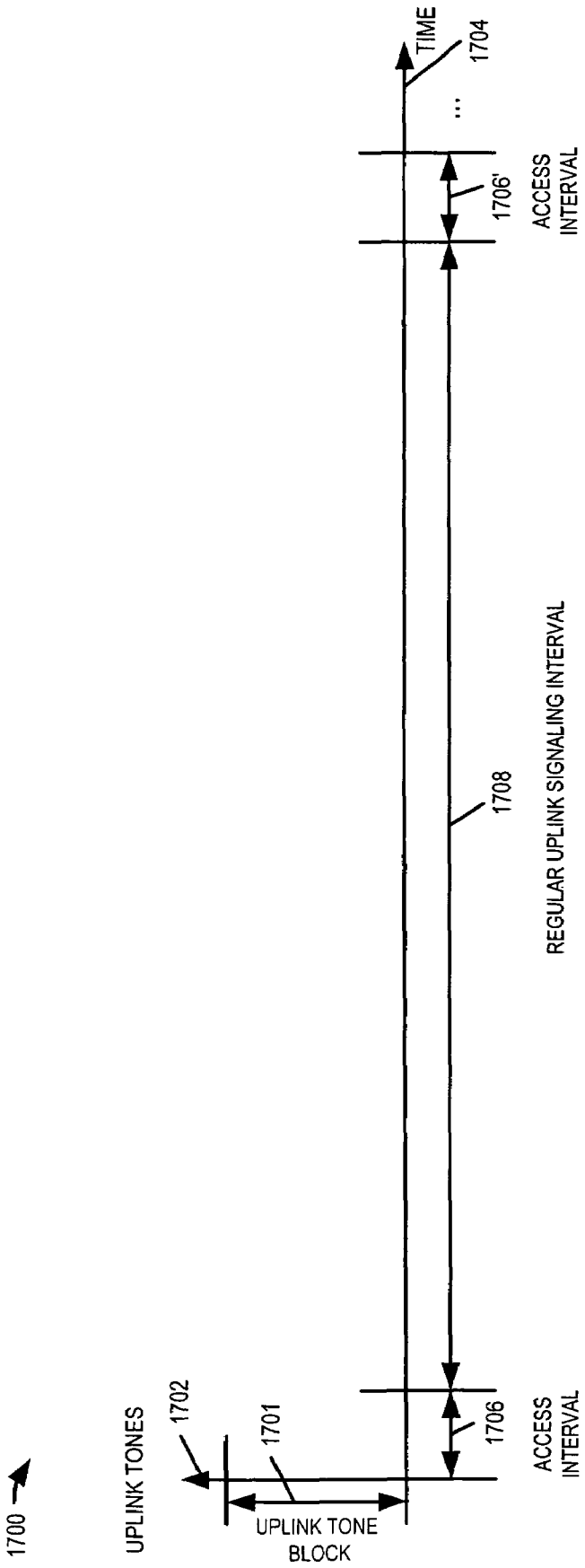

1700
UPLINK TONES
1702
1701
UPLINK TONE BLOCK
1706
ACCESS INTERVAL
1708
REGULAR UPLINK SIGNALING INTERVAL
1706'
ACCESS INTERVAL
...
1704
TIME

FIGURE 17

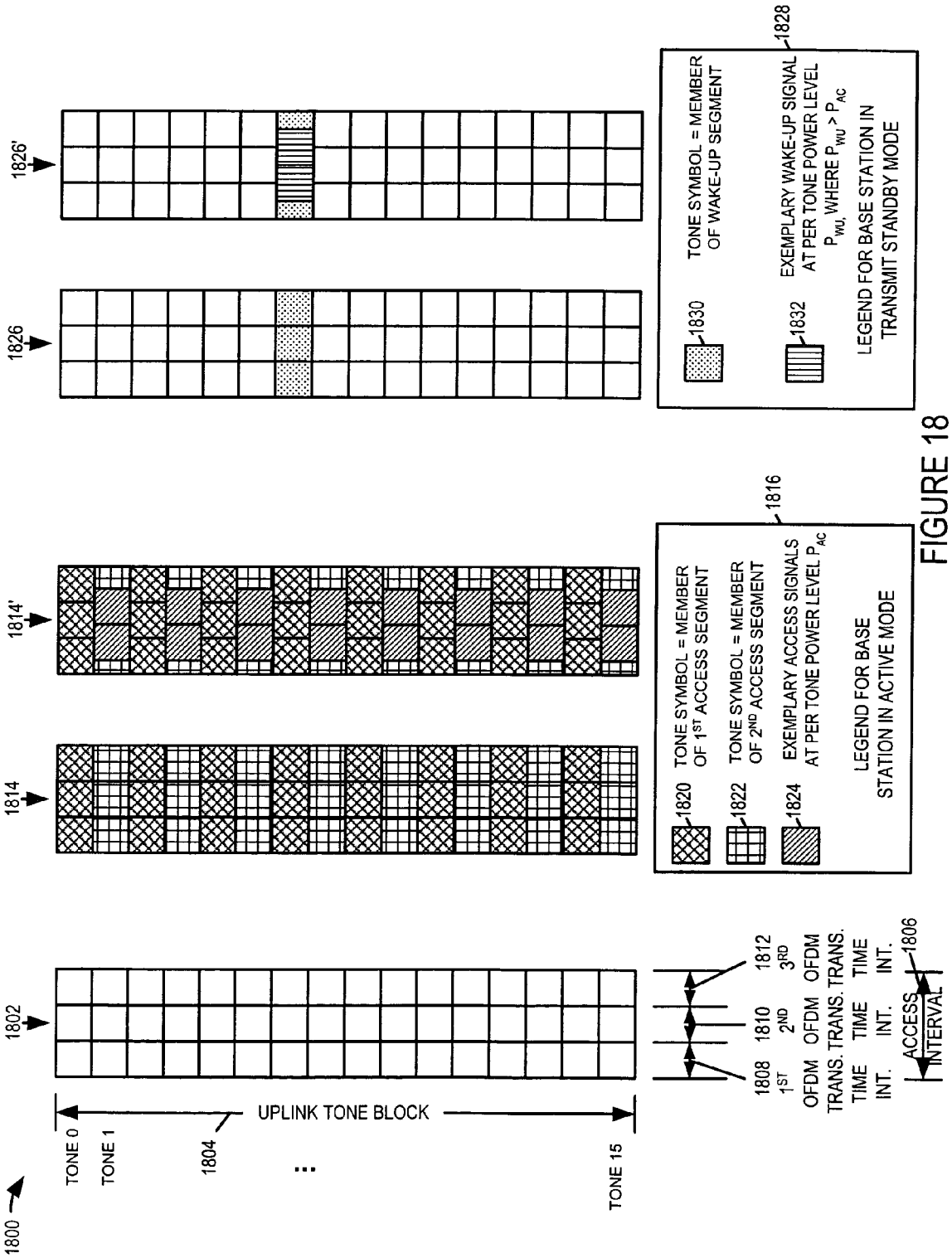

1800
TONE 0
TONE 1
1804
TONE 15
UPLINK TONE BLOCK
1802
1814
1814'
1826
1826'
1808 1ST OFDM TRANS. TIME INT.
1810 2ND OFDM TRANS. TIME INT.
1812 3RD OFDM TRANS. TIME INT.
ACCESS INTERVAL
1806
1820 TONE SYMBOL = MEMBER OF 1ST ACCESS SEGMENT
1822 TONE SYMBOL = MEMBER OF 2ND ACCESS SEGMENT
1824 EXEMPLARY ACCESS SIGNALS AT PER TONE POWER LEVEL P_{AC}
LEGEND FOR BASE STATION IN ACTIVE MODE
1816
1830 TONE SYMBOL = MEMBER OF WAKE-UP SEGMENT
1832 EXEMPLARY WAKE-UP SIGNAL AT PER TONE POWER LEVEL P_{WU}, WHERE $P_{WU} > P_{AC}$
LEGEND FOR BASE STATION IN TRANSMIT STANDBY MODE
1828

FIGURE 18

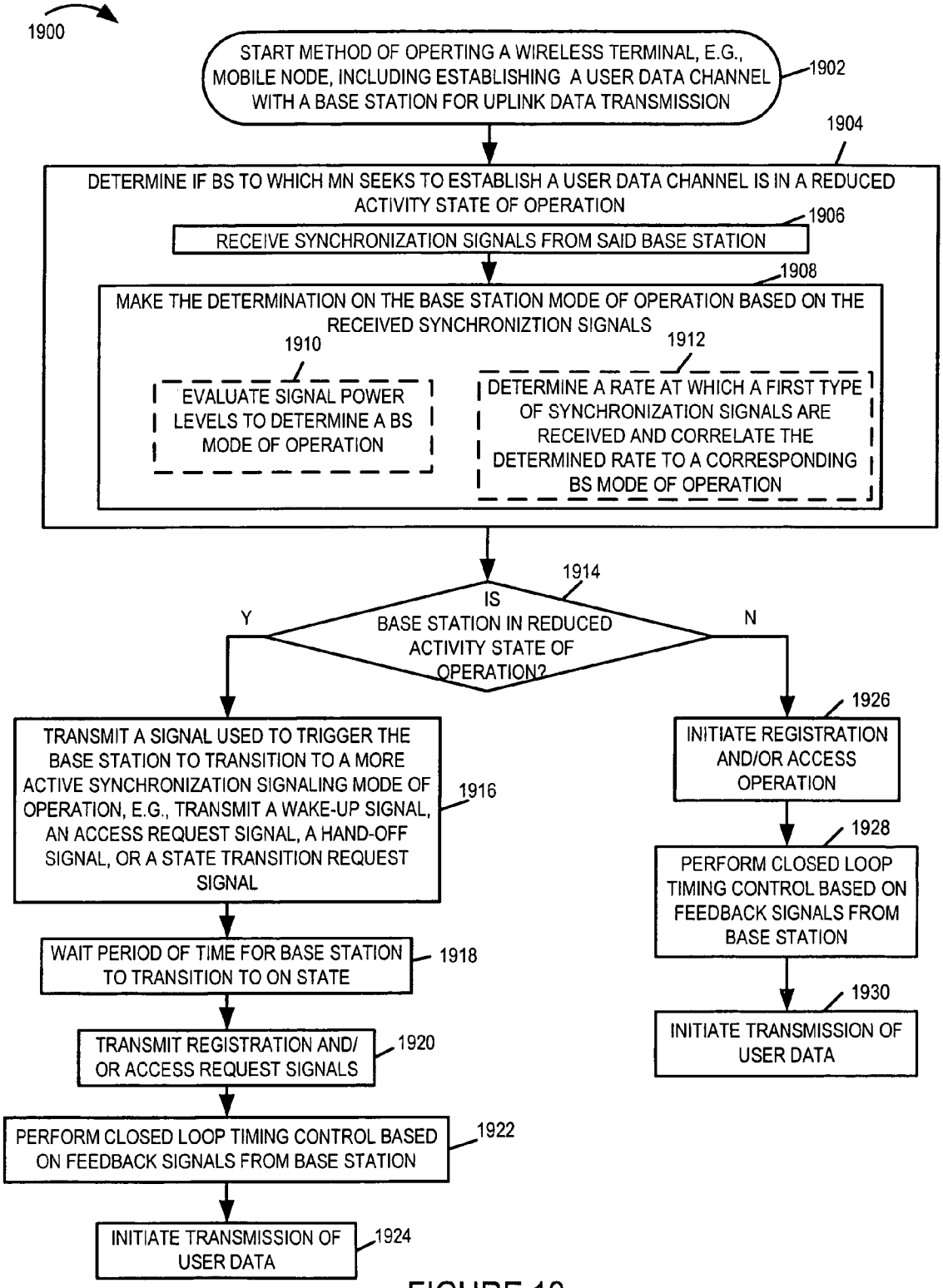

1900
START METHOD OF OPERTING A WIRELESS TERMINAL, E.G., MOBILE NODE, INCLUDING ESTABLISHING A USER DATA CHANNEL WITH A BASE STATION FOR UPLINK DATA TRANSMISSION
1902
1904
DETERMINE IF BS TO WHICH MN SEEKS TO ESTABLISH A USER DATA CHANNEL IS IN A REDUCED ACTIVITY STATE OF OPERATION
1906
RECEIVE SYNCHRONIZATION SIGNALS FROM SAID BASE STATION
1908
MAKE THE DETERMINATION ON THE BASE STATION MODE OF OPERATION BASED ON THE RECEIVED SYNCHRONIZTION SIGNALS
1910
EVALUATE SIGNAL POWER LEVELS TO DETERMINE A BS MODE OF OPERATION
1912
DETERMINE A RATE AT WHICH A FIRST TYPE OF SYNCHRONIZATION SIGNALS ARE RECEIVED AND CORRELATE THE DETERMINED RATE TO A CORRESPONDING BS MODE OF OPERATION
1914
IS BASE STATION IN REDUCED ACTIVITY STATE OF OPERATION?
Y
N
TRANSMIT A SIGNAL USED TO TRIGGER THE BASE STATION TO TRANSITION TO A MORE ACTIVE SYNCHRONIZATION SIGNALING MODE OF OPERATION, E.G., TRANSMIT A WAKE-UP SIGNAL, AN ACCESS REQUEST SIGNAL, A HAND-OFF SIGNAL, OR A STATE TRANSITION REQUEST SIGNAL
1916
WAIT PERIOD OF TIME FOR BASE STATION TO TRANSITION TO ON STATE
1918
TRANSMIT REGISTRATION AND/ OR ACCESS REQUEST SIGNALS
1920
PERFORM CLOSED LOOP TIMING CONTROL BASED ON FEEDBACK SIGNALS FROM BASE STATION
1922
INITIATE TRANSMISSION OF USER DATA
1924
1926
INITIATE REGISTRATION AND/OR ACCESS OPERATION
1928
PERFORM CLOSED LOOP TIMING CONTROL BASED ON FEEDBACK SIGNALS FROM BASE STATION
1930
INITIATE TRANSMISSION OF USER DATA

FIGURE 19

WIRELESS TERMINAL METHODS AND APPARATUS FOR USE IN A WIRELESS COMMUNICATIONS SYSTEM THAT USES A MULTI-MODE BASE STATION

FIELD OF THE INVENTION

The present invention relates to methods and apparatus for implementing wireless communications systems where the apparatus may include, for example, base stations which support multiple modes of operation and/or wireless terminals for interacting with base stations which support multiple modes of operation.

BACKGROUND OF THE INVENTION

Typically, in a wireless communications system, the base stations are powered on and continuously operated in an active mode of operation. In this active mode of operation, the base station is operated in accordance with a downlink timing and frequency structure, e.g., a repetitive timing and frequency structure. Synchronization signals, such as beacon signals and pilot signals, are transmitted on a scheduled basis at associated predetermined power levels. The power levels and rate of transmission of these synchronization signals do not typically vary regardless of the number and/or state of users being currently serviced by the base station. In high population density cellular coverage areas, this in not a significant consideration, as there is usually at least one or more active users at any given time using the base station as their network point of attachment and communicating user data. Those active wireless terminals need the full level of synchronization signals such as to maintain precise timing synchronization and maintain accurate current channel estimates.

However, in some cellular coverage areas, such as remote rural areas having low population densities and/or areas having widely varying load requirements as a function of time or a schedule, it would be advantageous if methods and apparatus were developed which allowed a base station to be operated, at certain time and/or under certain conditions, such as to reduce transmission power and/or reduce interference generated by the base station. For example, consider that a base station, e.g., a base station along a train track in a rural area, may have significant time intervals where the base station does not have any registered wireless terminals that need to communicate user data, e.g., receive and/or transmit user data. Under such a situation, during such a time interval the base station power is wasted by transmitting the full set of synchronization signals at the normal power levels. In addition, neighboring cells, which may have high population densities and typically have many active users, will be adversely affected by the interference generated from the unnecessary synchronization broadcast signaling. By reducing the interference level experienced in an adjacent cell the data throughput in that adjacent cell can be increased, e.g., by being able to increase the coding rate for a given transmission power level and modulation scheme.

It would be desirable if methods and apparatus were developed which allowed for reducing broadcast synchronization signals in response to changing system conditions. It would be beneficial if such methods and apparatus supported at least some of: rapid transitioning back to a full level of synchronization signals when required, easily detectable reactivation signaling, seamless hand-off operations, and the capability to transition between different levels of synchronization signaling as a function of schedule information. It would also be advantageous if the methods and apparatus developed to support multiple levels of synchronization signaling would still be capable of supporting registered wireless terminals in a wireless terminal sleep state irrespective of the level of synchronization signaling. In addition, it would be beneficial if the low level of synchronization signaling still provided a wireless terminal with the capability to be able to detect the presence of a base station and/or compare the base station's received signal strength with other adjacent base stations which could potentially be used as network attachment points.

In view of the above, there is a need for new methods and apparatus to implement and support multi-mode base station operations.

SUMMARY

The present invention relates to methods and apparatus for implementing wireless communications systems where the apparatus may include, for example, base stations which support multiple modes of operation and/or wireless terminals for interacting with base stations which support multiple modes of operation.

Various methods and apparatus of the invention are directed to wireless terminals that are intended for use with a base station that supports multiple modes of operation, e.g., a first mode such as a full-on mode, and a second mode such as a sleep mode. More than two modes of operation may be, and in some embodiments are, supported by the base station with each mode corresponding to, e.g., different signaling rates of at least one periodic signal and/or different power levels used to transmit some particular periodic signals such as a group of pilot tones or beacon signals.

By supporting multiple modes of operation, base station transmissions of control signals can be reduced when the higher level of signaling is not required, e.g., when there are no active wireless terminals in the cell. By reducing base station transmissions in terms of frequency and/or power level, interference with communications in neighboring cells can be reduced. This allows for improved throughput in a multi-base station system where transmissions by adjoining base stations can interfere with one another. Depending on the particular mode of operation, the base station may support downlink signaling, e.g., broadcast transmission of data but not uplink transmissions of data which may require a higher level of control signaling. Modes which support both downlink and uplink communication of user data, e.g., text data, image data, audio data and/or user application data, between wireless terminals and a base station normally correspond to one or more higher, e.g., full-on, modes of base station operation.

During different modes of base station operation, different levels and/or rates of signaling and/or transmission output power are supported depending on the mode of operation. For example, in some embodiments, pilot signals and/or various control signals which are normally transmitted at a first periodic rate in a fully on state are transmitted at a reduced rate during a sleep mode of base station operation as compared to a full-on mode of base station operation. In some embodiments the number of pilot signals transmitted during a sleep mode is reduced during individual symbol transmission time periods during the sleep mode of operation as compared to the full-on mode of operation. In some embodiments, the number of individual symbol transmission time periods during which pilot signals are transmitted during the sleep mode of operation is reduced from the number of individual symbol transmission time periods during which pilot signals are transmitted in the full-on mode of operation, with respect to the same

number of OFDM symbol transmission time periods, e.g., the same number of successive OFDM symbol transmission time periods representing a grouping in a repetitive downlink timing structure. In some embodiments, during a partial on or sleep mode of operation the power level at which particular signals are transmitted is reduced as compared to the power level used during the full-on mode of operation.

Base station transition between modes of operation can be triggered in a plurality of ways. The base station may operate in different modes according to a predetermined schedule, e.g., a train schedule, commuter schedule or other type of schedule. Such a schedule may be designed so that the base station will operate in the full-on state at particular points in time known to normally correspond to periods of wireless terminal data communications activity. Alternatively, or in addition to scheduled modes of base station operation, in some embodiments base stations monitor for wireless terminal activity in the cell which they serve and adjust the mode of operation to correspond to the detected level of communications data activity. For example, a base station may transition from a full-on state to a lower activity mode of operation with less control signaling in response to detecting a period in which no user data, e.g., text, voice or other types of user application data, have been transmitted for a predetermined period of time or when there is a determination that the cell does not include any active or registered wireless terminals.

Transitions from a base station sleep mode of operation to a full-on mode of operation are triggered, in some embodiments, by the receipt of a wake up signal from a mobile node. Wireless terminal registration signals and/or mobile node requests to transition from a sleep mode of mobile node operation to an active mode of mobile node operation in which the mobile node can transmit user data in an uplink can serve as wakeup signals and/or control signals which are used to trigger a change in base station operation from a less active to more active mode of base station operation.

The methods and apparatus of the present invention enable wireless terminals to interact with base stations which support different modes of activity. While transmission power conservation at the base stations is one benefit of supporting multiple base station modes of operation, the reduced level of signal interference achieved by supporting reduced activity modes of base station operation can increase overall system throughput by decreasing interference in neighboring cells when operating in a sleep state or other reduced activity mode of base station operation.

Numerous additional features benefits and embodiments of the present invention are discussed in the detailed description which follows.

BRIEF DESCRIPTION OF THE FIGURES

FIG. **1** is a drawing of an exemplary communications system implemented in accordance with the present invention and using methods of the present invention.

FIG. **2** is a drawing of an exemplary base station, implemented in accordance with the present invention and using methods of the present invention.

FIG. **3** is a drawing of an exemplary wireless terminal implemented in accordance with the present invention and using methods of the present invention.

FIG. **4** is a drawing of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the active mode.

FIG. **5** is a drawing of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for an exemplary embodiment.

FIG. **6** is a drawing of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for another exemplary embodiment.

FIG. **7** is a drawing of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for still another exemplary embodiment.

FIG. **8** is a drawing illustrating an exemplary base station, implemented in accordance with the present invention, currently in an active mode of base station operation, wherein the base station' cell includes active wireless terminals.

FIG. **9** is a drawing illustrating an exemplary base station, implemented in accordance with the present invention, currently operating in the transmit standby mode of operation, wherein the base station's cell includes wireless terminals that are turned off, but does not include any wireless terminals in the sleep state or active state.

FIG. **10** is a drawing illustrating an exemplary base station, implemented in accordance with the present invention, currently operating in the transmit standby mode of operation, wherein the base station's cell includes a wireless terminal that is turned off and a wireless terminal that is in the sleep state, but does not include any wireless terminals in the active state.

FIG. **11** is a drawing of a table illustrating characteristics of the base station active mode of operation and the base station transmit standby mode of operation for an exemplary embodiment, in accordance with the present invention.

FIG. **12** is a drawing illustrating an exemplary communications system including a train routed through wireless cells and schedule information used in base station operational mode switching, the communication system implemented in accordance with the present invention and using methods of the present invention.

FIG. **13** comprising the combination of FIG. **13**A, FIG. **13**B, and FIG. **13**C is a flowchart of an exemplary method of operating a base station in accordance with the present invention.

FIG. **14** is a drawing of a state diagram for an exemplary base station implemented in accordance with the present invention.

FIG. **15** is a drawing of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for still another exemplary embodiment.

FIG. **16** is a drawing illustrating a series of time sequential operations in an exemplary embodiment of the present invention, the operations including base station wake-up signaling communicated over a wireless link.

FIG. **17** is a drawing illustrating a portion of an exemplary OFDM uplink timing and frequency structure for the purpose of explaining exemplary base station wake-up signaling in accordance with various embodiments of the present invention.

FIG. **18** is a drawing illustrating exemplary access interval uplink air link resources, exemplary segments and exemplary signaling corresponding to a base station active mode of operation and a base station transmit standby mode of operation, in accordance with some embodiments of the present invention.

FIG. **19** is a flowchart of an exemplary method of operating a wireless terminal in accordance with the present invention.

DETAILED DESCRIPTION

FIG. **1** is a drawing of an exemplary communications system **100** implemented in accordance with the present invention and using methods of the present invention. Exemplary communications system **100** may be, e.g., an orthogonal frequency division multiplexing (OFDM) multiple access wireless communications system. Exemplary system **100** includes a plurality of base stations (BS **1 106**, BS M **108**), each BS (**106**, **108**) having a corresponding cellular coverage area (cell **1 102**, cell M **104**). The BSs (**106**, **108**) are implemented in accordance with the present invention, and support (i) an active mode of operation and (ii) a transmit standby mode of operation. The BSs are coupled together via a backhaul network. System **100** also includes network node **110**, e.g., a router. Network node **110** is coupled to (BS **1 106**, BS M **108**) via network links (**120**, **122**), respectively. Network link **124** couples network node **110** to other network nodes, e.g., other BSs, routers, Authentication-Authorization-Accounting (AAA) nodes, home agent nodes, etc., and/or the Internet. Network links (**120**, **122**, **124**), may be, e.g., fiber optic links, cable links, and/or high capacity radio links such as directed microwave links.

System **100** also includes a plurality of wireless terminals (WT **1 112**, WT N **114**, WT **1' 116**, WT N' **118**). At least some of the WTs (**112**, **114**, **116**, **118**), are mobile nodes, which may move throughout the communications system and establish a network point of attachment via the base station in the cell in which it is currently located. The WTs (**112**, **114**, **116**, **118**) may be, e.g., cell phones, mobile data terminals, personal digital assistants (PDAs), laptop computers, and/or other wireless communications devices supporting the communication of voice, video, text, messages, and/or files. The WTs (**112**, **114**, **116**, **118**), are implemented in accordance with the present invention, to support wireless communications signaling with the multi-mode base stations (**106**, **108**).

WTs (**112**, **114**) are currently situated in cell **1 102** and can be coupled to BS **1 106** via wireless links (**126**, **128**), respectively. WTs (**116**, **118**) are currently situated in cell M **104** and can be coupled to BS M **108** via wireless links (**130**, **132**), respectively. WTs (**112**, **114**, **116**, **118**) may operate in different states, e.g., an active state or a sleep state. In some embodiments, the active state of a WT may be further qualified with the WT supporting an active-On state and an active-Hold state.

FIG. **2** is a drawing of an exemplary base station **200**, implemented in accordance with the present invention and using methods of the present invention. Exemplary BS **200** may be any of the BSs (**106**, **108**) of the system **100** of FIG. **1**. Exemplary BS **200** includes a receiver **202**, a transmitter **204**, a processor **206**, an I/O interface **208**, and a memory **210** coupled together via a bus **212** over which the various elements may interchange data and information. Receiver **202** is coupled to a receive antenna **203** through which the base station **200** may received uplink signals from a plurality of wireless terminals. Received uplink signals may include, e.g., access signals, base station wake-up signals, handoff signals, WT state change signals, requests for resources, user data, power control information signals, timing control information signals, acknowledgement signals. Receiver **202** includes a decoder **214** for decoding received uplink signals, which have been previously encoded by a WT prior to transmission, e.g., decoding a coded block of user data communicated in an uplink traffic channel segment. Transmitter **204** is coupled to transmit antenna **205** via which the BS can transmit downlink signals to WTs. Downlink signals may include, e.g., beacon signals, pilot signals, power control signals, timing control signals, registration signals, paging signals, assignment signals, and user data signals. Transmitter **204** includes an encoder **216** for encoding downlink data/information, e.g., encoding a block of user data into a downlink traffic channel segment. In different modes of base station operation different sets of downlink signals may be communicated, different power levels may be used for the same type of downlink signal, and/or the frequency of transmission of different signals may be different. I/O interface **208** provides BS **200** with an interface to the backhaul network coupling BS **200** to other network nodes and/or the Internet. Signals communicated over the I/O interface **208** may include, e.g., scheduling information pertaining to switching the mode of operation of BS **200**, BS wake-up signals, commanded BS mode change signals, and WT handoff signals.

Memory **210** includes routines **218** and data/information **220**. The processor **206**, e.g., a CPU, executes the routines **218** and uses the data/information **220** in memory **210** to control the operation of the base station **200** and implement the methods of the present invention. Routines **218** include communications routines **222** and base station control routines **224**. Communications routines **222** implement the various communications protocols used by the BS **200**. Base station control routines **224** includes a scheduling module **226**, a base station mode transition module **228**, an active mode module **230**, a transmit standby mode module **232**, a receiver control module **234**, a transmitter control module **236**, and an I/O interface control module **238**.

Scheduling module **226**, e.g., a scheduler, schedules uplink and downlink segments to WTs. The scheduling is a function of the mode of operation of the BS **200**. In some embodiments, when the BS is in the active mode of operation the BS can schedule uplink and downlink traffic channel segments to WTs, while when the BS is in the transmit standby mode of operation, the BS does not schedule any uplink or downlink traffic channel segments to WTs.

Base station mode transition control module **228** controls the transition of the BS **200** between the active mode of operation and the transmit standby mode of operation. The base station mode transition control module **228** uses the data/information **220** in memory **220** including mode transition criteria **270**, mode transition schedule information **269**, number of active users **253**, inactivity time **254**, received access signals **255**, received wake-up signals **256**, received handoff signals **257**, received state change signals **258**, received mode change signals **249** and/or the current mode **252** in deciding whether to and at what time to transition between base station operational modes, e.g., active mode to transmit standby mode or transmit standby mode to active mode. As part of the mode transition process, mode transition module **228** activates one of active mode module **230** and transmit standby module **232**, while deactivating the other one.

Active mode control module **230** controls BS operations in the active mode of base station operation. Active mode module **230** includes a 1st synchronization signaling module **240**, a traffic channel signaling module **242**, and a 1st paging module **244**. First synchronization signaling module **240** uses the data/information **220** including active mode synchronization signal info **272** to control the power level and rate of synchronization signals, the synchronization signals including beacon signals and pilot signals. In the active mode of operation, at least some of the synchronization signals are controlled to be transmitted at at least one of: (i) a higher power level and (ii) a higher rate, then when the base station is operating in the transmit standby mode of operation. In the active mode of operation the base station **200** supports uplink and downlink traffic channel signaling with the scheduling module **226** scheduling uplink and downlink traffic channel segments to active WTs being serviced by the BS **200**, e.g., WTs currently registered with the BS **200**, operating in an active mode of operation, and currently having a BS assigned WT active user identifier. The uplink and downlink traffic channel segments are used to convey user data/information. The traffic channel signaling module **242** controls operations pertaining to the encoding, modulation and transmission of downlink traffic channel signals and controls operations pertaining to decoding, demodulation, and recovery of uplink traffic channel signals. 1st paging module **244** controls paging operations in the active mode of base station operation.

Transmit standby mode control module **232** controls BS operations in the transmit standby mode of base station operation. Transmit standby mode module **232** includes a 2nd synchronization signaling module **246**, and a 2nd paging module **244**. Second synchronization signaling module **246** uses the data/information **220** including transmit standby mode synchronization signal info **279** to control the power level and rate of synchronization signals, the synchronization signals including at least one of beacon signals and pilot signals. In the transmit standby mode of operation, at least some of the synchronization signals are controlled to be transmitted at at least one of: (i) a lower power level and (ii) a lower rate, then when the base station is operating in the active mode of operation.

Receiver control module **234** controls operations of receiver **202**; transmitter control module controls operations of transmitter **204**; I/O interface control module controls operations of I/O interface **208**. In some embodiments, modules **234**, **236**, and/or **238** operate in conjunction with either active mode module **230** or transmit standby module **232** depending upon the BS's current mode **252** of operation.

Data/information **220** includes WT data information **250** system data/information **251**, current mode **252**, number of active users **253**, inactivity time **254**, and current transmission power information **259**. At some times one or more of the following may be included in data information **220**: received access signal information **255**, received wake-up signal information **256**, received hand-off signal information **257**, received state change signal information **258**, and received mode change signal information **249**.

WT data information **250** includes different sets of information at different times depending on the WTs currently being serviced by the BS **200**. At some times, the BS may not have any users either in sleep or active state that are currently registered and being serviced. At other times, the BS may have one or more users which are being serviced by the BS **200**, and WT data/info **250** includes (WT **1** data/information **260**, . . . , WT N data/information **261**), with each set of data/information corresponding to a WT user currently being serviced. WT **1** data information **260** includes user data **262**, WT identification information **264**, device/session/resource information **263**, and WT user state information **265**. User data **262** includes, e.g., voice, video, text, data file data and information intended for WT **1** and/or intended to be sent to a peer node of WT **1** in a communications session with WT **1**. WT identification information **264** includes identifiers associated with WT**1**, e.g., a unique device identifier, a base station assigned registered user identifier, and/or a base station assigned active user identifier. Device/session/resource information **263** includes information identifying the type of WT device, e.g., mobile phone, data terminal, model, class, tier, etc., session information including, e.g., routing information, peer node identification information, session time information, etc., and resource information including, e.g., assigned uplink and/or downlink traffic channel segments, assigned dedicated control channel segments, assigned resources for a page directed to WT**1**, etc. WT user state information **265** includes information identifying the current state of operation of WT **1**, e.g., sleep state, active-hold ON state, or an active hold-state.

Current mode **252** includes information identifying the current mode of operation of BS **200**, active mode or transmit standby mode. Number of active users **253** identifies the number of WTs currently registered with BS **200** in an active state of operation. Inactivity time **254** is a time counter maintained by BS **200** of the amount of time since at least one WT was active from the perspective of the BS **200**. When, the inactivity time **254** exceeds a threshold in mode transition criteria **270**, the mode transition module **228** transitions the BS from active mode to transmit standby mode.

Received access signal information **255** represents a detected received request for access by a WT, e.g., a registration request. In some embodiments, under certain conditions, the received access signal **255** may be used by transition module **228** to trigger a transition from transmit standby mode to an active mode of operation. For example, the a WT may have entered BS **200**'s cell and desires to communicate user data, the BS may be in a transmit standby mode, the WT may send an uplink access signal during a contention based access interval, and this received signal may be used a trigger by transition module **228** to activate transition of the BS **200** into active mode.

Received wake-up signal information **255** represents a detected received request to transition the base station from transmit standby mode to active mode. For example, a wireless terminal, by monitoring the power level and/or rate of downlink broadcast synchronization signals determines that the BS **200** is in transmit standby mode, but decides that it desires to become an active user; therefore, the WT sends a wake-up signal to the BS. For example, in some embodiments a tone or tones at predefined times, within the timing/frequency structure, may be reserved to receive the wake-up signal. In some embodiments, the same air link resources reserved for access signals may also be used for wake-up signals. In some embodiments, the wake-up signal has a different characteristic than an access signal. In some embodiment, the wake-up signal is the same as the access signal, with the BS **200** treating the received signal differently depending upon its current mode **252**.

Received handoff signal **257** includes information associated with a handoff operation. In some embodiments at some times, the handoff signal may be communicated via a wireless link with a WT. In some embodiments at some times, the handoff signal may be communicated via the backhaul network through I/O interface **208**, e.g., allowing for more seamless and/or faster handoff operations. Received handoff signal information **257** may be used by BS **200** to update the WT

data/information and the number of active users **253**. For example, if the received handoff signal information **257** indicates that the last current active user is being handed off to an adjacent base station, the information may be used to update number of active users **253** and trigger the start of inactivity timer **254**. As another example, if the received handoff signal information **257** indicates that the last currently registered user at BS **200**, e.g., a user in sleep state, is being handed off to an adjacent base station, the handoff signal information **257** may be used to trigger a transition from active mode to transmit standby mode without waiting for the inactivity delay timer to reach a transition criteria. As still another example, if the received handoff information **257** indicates that an active WT is to be handed off from an adjacent BS to BS **200**, and BS **200** is currently in transmit standby mode, the information may be used to trigger a transition of the base station **200** to active mode, e.g., such that the BS **200** will be operating in active mode when the WT executes the handoff, providing a more seamless handoff operation.

Received mode change signal information **249** includes information received in a commanded mode change message, e.g., from a central management command node, directing that a base station mode change be executed. For example, a central management node may be directing mode changes in accordance with a schedule or in accordance with overall interference levels, load patterns, priority issues, emergency considerations, etc. As another example, an adjacent base station may send a commanded mode change message to BS **200**.

Received state change signal information **258** includes received information from a WT indicating a request for a change in state, e.g., from sleep to active or from active to user. The BS's mode of operation is affected accordingly. For example, if the BS is currently in transmit standby mode and the BS receives a signal indicating that one of the WTs currently registered but in sleep state requests to be transitioned to active state, the transition module **228** may transition the base station **200** to active mode. As another example, if the BS is currently in active mode, with only one active WT, and that active WT requests to transition to sleep state, then the BS sets the number of active users **253** to zero and starts the inactivity counter, which can result in a transition of the base station to transmit standby mode if no other WT becomes active before a timeout criteria is reached.

Current transmission power information **259** is information pertaining to the current transmission of the BS. In accordance with the invention, the BS the average transmission power associated with the transmission of non-traffic channel signals during the transmit standby mode of operation is reduced when compared to the average transmission power associated with the transmission of non-traffic channel signals during the active mode of operation. For example, by reducing the power level of each pilot signal during the transmit standby mode of operation, average transmission power is reduced. Alternately, by reducing the number of pilot signal tones per OFDM symbol transmission time interval, e.g., from four to one, average transmission power is reduced. Alternately, by skipping OFDM symbol transmission time intervals during which pilot signals are conveyed, average transmission power is reduced.

System data/information **251** includes active mode information **266**, transmit standby mode information **267**, uplink/downlink timing and frequency structure information **268**, schedule information **269**, mode transition criteria information **270**, and power information **271**.

Active mode information **266** includes synchronization signal information **272** including characteristic information associated with the synchronization signals which are generated and transmitted by the BS while in the active mode of operation. Synchronization signal information **272** includes beacon signal information **273** and pilot signal information **274**. Beacon information **273** includes power information **275**, e.g., a reference power level associated with the beacon tone or tones of each beacon signal, and rate information **276**, e.g., information identifying the transmission rate of the beacon signal, while in the active mode. Pilot information **274** includes power information **277**, e.g., a reference power level associated with pilot tones, and rate information **278**, e.g., information which identifies which OFDM transmission time intervals are used to transmit pilot tones, and how many pilot tones are communicated simultaneously in each of the OFDM transmission time intervals in which pilot tones are communicated, while in active mode.

Transmit standby mode information **267** includes synchronization signal information **279** including characteristic information associated with the synchronization signals which are generated and transmitted by the BS while in the transmit standby mode of operation. Synchronization signal information **279** includes beacon signal information **280** and pilot signal information **281**. Beacon information **280** includes power information **282**, e.g., a reference power level associated with the beacon tone or tones of each beacon signal, and rate information **283**, e.g., information identifying the transmission rate of the beacon signal, while in the transmit standby mode. Pilot information **281** includes power information **284**, e.g., a reference power level associated with pilot tones, and rate information **285**, e.g., information which identifies which OFDM transmission time intervals are used to transmit pilot tones, and how many pilot tones are communicated simultaneously in each of the OFDM transmission time intervals in which pilot tones are communicated, while in transmit standby mode. In accordance with the present invention, at least some of the synchronization signals transmitted by the base station in the transmit standby mode of operation are transmitted at least one of: (i) a reduced power level and (ii) a reduced rate, with respect to the active mode of operation. This results in a lower transmission average power output by the base station while in the transmit standby mode of operation which results in reduced levels of interference from the perspective of adjacent cells which are using the same frequencies.

Uplink/downlink timing and frequency structure information **268** includes, e.g., uplink carrier frequency, uplink tone block, downlink carrier frequency, downlink tone block, uplink tone hopping information, downlink tone hopping information, segment definitions in a repetitive timing and frequency structure, beacon information, pilot information, OFDM symbol transmission timing information, and grouping of OFDM symbols into, e.g., half-slots, slots, superslots, beaconslots, utraslots, etc. Schedule information **269** includes stored schedule information identifying when to transition the base station between active and transmit standby mode. In various embodiments, schedule information **269** includes data, time, and corresponding mode information for a plurality of different times. Schedule information **269** may include predetermined schedules and/or schedules which can be adjusted. For example, BS **200** may be located in a remote low density population region and schedule information **269** may be based on a train schedules or schedules coordinated to result in the base station being in an active mode coinciding with the expected presence of a train in the base station's cell. Adjustment information may be communicated to account for delays, cancelled trains and/or added unscheduled trains.

Mode transition criteria information **270** includes information such as inactivity time limits utilized by the base station mode transition control module **228** in determining if and when to perform a mode switch. Power information **271** includes BS power information, e.g., a reference BS nominal baseline power level, and specific power levels or offsets from the baseline level associated with each of the different types of signals to be transmitted by the BS, e.g., beacon, pilot, flash assignment, regular assignment, paging, traffic channel at various data transmission rates, etc.

FIG. **3** is a drawing of an exemplary wireless terminal (WT) **300** implemented in accordance with the present invention and using methods of the present invention. Exemplary WT **300** may be any of the WTs (**112**, **114**, **116**, **118**) of exemplary system **100** of FIG. **1**.

Exemplary WT **300** includes a receiver **302**, a transmitter **304**, a processor **306**, user I/O devices **308**, and a memory **310** coupled together via a bus **312** over which the various elements may interchange data and information. Receiver **302** is coupled to receive antenna **303** via which the WT **300** can receive downlink signals from BSs **200**.

When the base station **200** is in the transmit standby mode of operation, the downlink signals include synchronization signals, e.g., beacon signals and pilot signals at a reduced rate and/or power level. When, the base station **200** is in the active mode of operation the downlink signals include the synchronization signals, e.g., beacons signals and pilot signals at a higher rate and/or higher power level in comparison to the transmit standby mode. In the active mode of BS operation, uplink and downlink traffic channel signaling is supported and the downlink signals typically also include assignment signals and traffic channel signals. Receiver **302** includes a decoder **314** which decodes received downlink signals which have been encoded by the base station prior to transmission.

Transmitter **304** is coupled to transmit antenna **305** through which WT **300** can transmit uplink signals to BSs **200**. In some embodiments, the same antenna is used for both the receiver and transmitter. Uplink signals can include access signals, BS wake-up signals, WT state change request signals, requests for uplink traffic channel segment resources, handoff signals, power and timing control signals, and user data signals. Transmitter **304** includes encoder **316** which encodes at least some of the uplink signals prior to transmission.

User I/O devices **308** includes, e.g., switches, microphone, speaker, display, keypad, keyboard, touch-screen, mouse, camera, etc., and provides an interface for inputting user data/information and outputting received user data/information. User I/O devices **308** also allow the operator of WT **300** to control at least some operations of the WT, e.g., initiating a call, initiating a request for a mode change, access stored information, powering off, power off, etc.

Memory **310** includes routines **318** and data/information **320**. The processor **306**, e.g., a CPU, executes the routines **318** and uses the data/information **320** in memory **310** to control the operation of the wireless terminal and implement methods of the present invention. Routines **318** include communications routines **322**, which implements the communications protocols used by the WT **300**, and wireless terminal control routines **324**. The WT control routines **324** includes a base station mode determination module **326**, a wake-up signaling module **327**, an access signaling module **328**, a handoff signaling module **330**, a WT state transitioning module **332**, a timing/synchronization module **333**, a base station identification module **334**, a receiver control module **336**, a transmitter control module **338**, and a user I/O module **339**.

Base station mode determination module **326** uses the data information **320** in memory **310** to determine the mode of operation that the BS which transmitted the received synchronization signals being evaluated, e.g., beacon and/or pilot signals, is currently operating in, e.g., transmit standby mode or active mode. For example, in some embodiments, a reduced rate of pilot tone signaling indicates that the BS is in transmit standby mode, and detected rate of received pilot tones is used by module **326** to determine the mode of the BS. As another example, in some embodiments, a reduced power level of pilot signal indicates that the base station is in transmit standby mode, and the level of the received pilot signals may be compared to the level of the received beacon signals in performing the determination. In some embodiments, a detected level shift in received pilot tones may be indicative of a base station mode change. BS mode determination module **326** includes one of more of a relative power level determination module **327** and a rate analysis module **329**. The BS mode determination module **326** processes received synchronization signals to evaluate at least one of synchronization signal power levels and a rate of at least some synchronization signals. Relative power level determination module **327** determines the relative power level between at least two types of received synchronization signals, e.g., pilot tone signals and beacon signals. The rate analysis module **329** distinguishes between received synchronization signal rates corresponding to different modes of operation. For example, in some embodiments, the base station uses a different rate of pilot tone signals for the transmit standby mode and active mode of base station operation, and rate analysis module **329** measures the received pilot tone rate and identifies the received pilot tone rate with a mode of base station operation. In some embodiments, a precise measurement of pilot tone rate is not performed, but received signals are processed by rate analysis module **329** such as to be able to associate a level of synchronization signaling with one of the different modes of base station operation. Relative power level determination module **327** and/or rate analysis module **329** uses as input received synchronization signal information **341** and generate as output processed synchronization signal information **347**.

Base station mode decision module **331** determines the mode of the base station operation based on the relative power level of at least two different synchronization signals and/or the rate of at least one type of synchronization signal. For example, processed synchronization signal information **347** output from the relative power level determination module **327** and/or the rate analysis module **329** is used by base station mode decision module **331** in conjunction with BS mode detection information **372** to determine the base station's current mode of operation.

In some other embodiments, the base station mode determination module **326** determines the mode of operation based on a level of downlink signaling and/or the omission of one or more of certain types of signals. For example, in some such embodiments, the base station mode determination module **326** determines the mode of base station operation based on the presence or lack thereof of assignment signals corresponding to uplink traffic channel segments.

Wake-up signaling module **327** controls the generation and transmission of wake-up signals to a BS **200**, e.g., a BS **200** detected by determination module **326** to be in a transmit standby mode of operation, when WT **300** wishes to wake-up the base station, e.g., to register with the base station, to change to active state from sleep so that the WT may send uplink traffic channel data, etc.

Access signal module **328** controls the generation and transmission of access signals to a BS **200**, e.g., during predetermined access intervals using predetermined tones in the uplink timing and frequency structure, the access signals not requiring precise timing synchronization and being used for initiating a registration request with a base station. Handoff signaling module **330** controls handoff operations pertaining to WT **300** including the control of the generation and transmission of handoff request signals to a BS. State transitioning module **332** controls WT **300** state transition operations and requests for transitions which are communicated to BS **300**, e.g., transitions from WT sleep state to WT active state, and WT active state to WT sleep state. In some embodiments, the WT active state is further qualified as including an active-hold and an active on state. Request for state transitions may include state change request signals and requests for air link uplink resources which may be considered, in some embodiments, as a state change request. In some embodiments, WT state transitions are tracked by the BS and used by the BS in determining BS mode transitions.

Timing/synchronization module **333** performs timing synchronization and frequency synchronization operations, e.g., synchronizing the WTs uplink transmissions to arrive in synchronization with other WT transmissions in accordance with an uplink timing and frequency structure being maintained by the BS and being referenced with respect to downlink signaling synchronization signals. In some embodiments, the WT obtains a coarse level of synchronization based on received beacon and/or pilot signals and communicates BS wake-up signals and/or access signals without the need for a high level of timing synchronization. Timing/synchronization module **333** achieves a high level of synchronization, e.g., to within a cyclic prefix duration, for regular uplink signaling, including uplink traffic channel signals, communicated while the base station is in an active mode of operation. Base station identification module **334** identifies the base station transmitting the synchronization signals, e.g., beacon signals, and the identification can involve determining a network point of attachment associated with a base station, sector, and/or carrier frequency. Receiver control module **336** controls receiver **302** operations; transmitter control module **338** controls transmitter **304** operations, and user I/O module **339** controls user I/O devices **308**. Some of the WT control modules may operate in conjunction to perform a specific operation. For example, the transmitter control module **338** may operate in conjunction with wake-up signaling module **327** at certain times.

Data/information **320** includes wireless terminal data/information **336**, access signal information **338**, base station wake-up signal information **340**, handoff signal information **342**, state change signal information **344**, received synchronization signal information **341**, processed synchronization signal information, and system data/information **350**. WT data/information **336** includes user data **352**, device/session/resource information **354**, WT identification information **356**, WT user state information **358**, base station identification information **360**, and base station mode information **362**.

User data **352** includes, e.g., data corresponding to voice, video, text, files to be communicated to peers of WT **300** or received from peers of WT **300**. Device/session/resource information **353** includes identification information of a peer of WT **300** in a communication session with WT **300**, routing information, and air link resources information corresponding to WT **300**, e.g., information identifying downlink and uplink traffic channel segments assigned to WT **300**, while its presently connected BS is in active mode of operation. WT identification information **356** includes identifiers associated with and/or assigned to WT **300** including, e.g., a base station assigned registered user identifier, a base station assigned active user identifier, paging identifier information, and/or group identifier information. WT user state information **358** includes information identifying whether the WT is a sleep state or an active state. WT user state information **358**, in some embodiments, also includes information further identifying whether the WT is in an active-On state or an active-Hold state. Base station identification information **360** includes information identifying the base station being used as the WT's current point of network attachment and/or information identifying a BS that the WT desires to register with and use as a point of network attachment. For example, base station ID information **360** may be derived from received beacon signals and/or received pilot signals. Base station mode information **360** includes information identifying the mode of operation for base stations, e.g., for identified base stations. For example, at any given time, a base station may be in transmit standby mode of operation, e.g., a sleep mode of operation having reducing output signals, lower output power and producing less interference, or the base station may be in an active mode of operation, e.g., representing a full-up operational mode and supporting uplink and downlink traffic channel signaling.

Access signal information **338**, including access signal specifications such as, e.g., signal characteristics including power level information, modulation signal value information and extension portion information, is used by the access signal module **328** to generate access signals used for registering WT **300** with a base station. BS wake-up signal information **340**, including wake-up signal specifications such as, e.g., signal characteristics including power level information, modulation signal value information and extension portion information, is used by the wake-up module **328** to generate wake-up signals used for waking-up a base station which is in a transmit standby mode of operation. Hand-off signal information **342**, includes information used to generate handoff signals and information extracted from received hand-off signals. State change signal information **344** includes information pertaining to WT **300** state changes, e.g., information for state change request messages and information indicating that the BS has authorized a WT state change, e.g., allocating the WT an active user identifier.

Received synchronization signal information **341** includes received beacon signal information **343** and received pilot signal information **345** corresponding to received downlink synchronization signals received by receiver **302**. Received synchronization signal information **343** is used an input to the relative power level determination module **327** and/or the rate analysis module **329**. Processed synchronization signal information **347** includes power level information **349** and rate information **351**. Processed synchronization signal information **347** includes information output from the relative power determination module and/or the rate analysis module **329**, which is used as input by the base station mode decision module **331**. Power level information **349** includes, e.g., a determined power level associated with received beacon signal, a determined power level associated with received pilot tone signals, and a relative power ratio between the two types of received signals. Rate information **351** includes, e.g., a determined rate of a received type of signals. In some embodiments a determined rate of pilots tone signals is, e.g., an identified number of pilot tone signals communicated simultaneously in one OFDM symbol transmission time interval. Another example of a determined rate of pilot tone signals is, e.g., a ratio of a first number of OFDM transmission time

intervals including pilot tone signals to a second number of OFDM transmission time intervals during which no pilots tone signals are transmitted.

Received beacon signal information **343** in combination with processed synchronization signal information **347** includes information pertaining to and/or derived from received beacon signals, e.g., power level of the received signal, tones associated with the received beacon, time within a timing structure associated with the received beacon signal, base station, sector and/or carrier associated with the received beacon. Received pilot signal information **345** in combination with processed synchronization signal information **347** includes information pertaining to and/or derived form received pilot signals, e.g., power level of the received pilots, rate of received pilot signaling including number of pilots per OFDM symbol transmission time interval and/or fraction of OFDM symbol transmission time intervals including pilots, relative power of received pilots with respect to received beacons, and/or base station identification information derived from pilots, e.g., a base station identifier derived from a pilot slope.

System data/information **350** includes a plurality of sets of base station information (BS **1** information **364**, BS N information **366**). BS **1** information **364** includes active mode information **368**, transmit standby mode information **370**, base mode detection information **372**, uplink/downlink timing and frequency structure information **374**, and base station identification information **376**.

Uplink/downlink timing and frequency structure information **374** includes, e.g., uplink carrier frequency, uplink tone block information, uplink tone hopping sequence information, uplink segment information, downlink carrier frequency, downlink tone block information, downlink tone hopping sequence information, OFDM symbol transmission time interval information, grouping information of OFDM symbol transmission time intervals into half-slots, slots, superslots, beaconslots, ultraslots, etc. Active mode information **368** includes information pertaining to segments, signals, and functions relevant to the active mode, e.g., traffic channel segments and signals, dedicated control channel segments and signals. Transmit standby mode information **370** includes information pertaining to segments, signals, and functions relevant to the transmit standby mode, e.g., signals associated with base station wake-up signaling and wake-up operations. Base station mode detection information **372** includes information used by base station determination module **326** to evaluate received beacons and/or pilots to determine the BS mode of operation. BS mode detection information **372** includes, e.g., rate information and/or power level information associated with each mode of BS station operation which may be used to distinguish between the different modes of base station operation. For example, information **372** may include the rate of pilot signals in each mode and/or the relative power level of pilot signals with respect to beacon signals in each mode. Base identification information **376** includes information which allows the BS ID module **334** to determine the BS corresponding to received signals, e.g., a set of beacon tones occurring at predefined frequencies and/or times within the downlink timing and frequency structure associated with BS **1** and identifying BS **1** from among a plurality of base stations in the system. Identification may include identification of cell, sector and/or carrier frequency used.

FIG. **4** is a drawing **400** of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the active mode. Vertical axis **402** represents tone index number (**0**, **1**, **2**, . . . **15**) in the tone block utilized for downlink signaling by the base station. Horizontal axis **404** represents time, with each unit representing one OFDM symbol transmission time interval. Each small square in the grid represents a basic transmission unit, an OFDM tone-symbol, corresponding to one tone for the duration of one OFDM symbol transmission time interval. A modulation symbol may be conveyed corresponding to each OFDM tone-symbol of the grid. Legend **406** indicates that full shading of a grid square, as shown in legend element **408**, signifies that a beacon tone signal at power level P_B occupies the tone-symbol. Legend **406** also indicates that vertical line shading of a grid square, as shown in legend element **410**, signifies that a pilot tone signal at power level P_P occupies the tone-symbol.

FIG. **5** is a drawing **500** of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for an exemplary embodiment. The base station may be the same base station corresponding to the description of FIG. **4**, but now operating in the transmit standby mode rather than the active mode. Vertical axis **502** represents tone index number (**0**, **1**, **2**, . . . , **15**) in the tone block utilized for downlink signaling by the base station. Horizontal axis **504** represents time, with each unit representing one OFDM symbol transmission time interval. Each small square in the grid represents a basic transmission unit, an OFDM tone-symbol, corresponding to one tone for the duration of one OFDM symbol transmission time interval. A modulation symbol may be conveyed corresponding to each OFDM tone-symbol of the grid. Legend **506** indicates that full shading of a grid square, as shown in legend element **508**, signifies that a beacon tone signal at power level P_B occupies the tone-symbol. Legend **506** also indicates that horizontal line shading of a grid square, as shown in legend element **510**, signifies that a pilot tone signal at power level P_{PR} occupies the tone-symbol, where $P_{PR}<P_P$. In this exemplary embodiment, by reducing the power level of each pilot signal communicated the overall average transmission power of the base station is reduced in the transmit standby mode of operation with respect to the active mode of operation.

FIG. **6** is a drawing **600** of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for another exemplary embodiment. The base station may be the same base station corresponding to the description of FIG. **4**, but now operating in the transmit standby mode rather than the active mode. Vertical axis **602** represents tone index number (**0**, **1**, **2**, . . . , **15**) in the tone block utilized for downlink signaling by the base station. Horizontal axis **604** represents time, with each unit representing one OFDM symbol transmission time interval. Each small square in the grid represents a basic transmission unit, an OFDM tone-symbol, corresponding to one tone for the duration of one OFDM symbol transmission time interval. A modulation symbol may be conveyed corresponding to each OFDM tone-symbol of the grid. Legend **606** indicates that full shading of a grid square, as shown in legend element **608**, signifies that a beacon tone signal at power level P_B occupies the tone-symbol. Legend **606** also indicates that vertical line shading of a grid square, as shown in legend element **610**, signifies that a pilot tone signal at power level

P_P. In FIG. **4**, 28 successive OFDM symbol transmission time intervals are shown. In FIG. **4**, three of the OFDM symbol transmission time intervals include one beacon tone signal and no pilot signals, while the other 25 OFDM symbol transmission time intervals each include 4 pilot tone signals. In comparison in FIG. **6**, the three beacon signal OFDM symbol transmission time intervals remain unchanged; however, the pilot signaling has been reduced. In FIG. **6**, seven OFDM symbol transmission time intervals include 4 pilot signals each, while the other 18 OFDM symbol transmission time intervals include zero pilot signals. In this exemplary embodiment, by reducing the rate of pilot signaling, the overall average transmission power of the base station is reduced in the transmit standby mode of operation with respect to the active mode of operation.

FIG. **7** is a drawing **700** of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for still another exemplary embodiment. The base station may be the same base station corresponding to the description of FIG. **4**, but now operating in the transmit standby mode rather than the active mode. Vertical axis **702** represents tone index number (**0**, **1**, **2**, . . . , **15**) in the tone block utilized for downlink signaling by the base station. Horizontal axis **704** represents time, with each unit representing one OFDM symbol transmission time interval. Each small square in the grid represents a basic transmission unit, an OFDM tone-symbol, corresponding to one tone for the duration of one OFDM symbol transmission time interval. A modulation symbol may be conveyed corresponding to each OFDM tone-symbol of the grid. Legend **706** indicates that full shading of a grid square, as shown in legend element **708**, signifies that a beacon tone signal at power level P_B occupies the tone-symbol. Legend **706** also indicates that vertical line shading of a grid square, as shown in legend element **710**, signifies that a pilot tone signal at power level P_P. In FIG. **4**, 28 successive OFDM symbol transmission time intervals are shown. In FIG. **4**, three of the OFDM symbol transmission time intervals include one beacon tone signal and no pilot signals, while the other 25 OFDM symbol transmission time intervals each include 4 pilot tone signals. In comparison in FIG. **7**, the three beacon signal OFDM symbol transmission time intervals remain unchanged, however, the pilot signaling has been reduced. In FIG. **7**, 25 OFDM symbol transmission time intervals include only one pilot tone signal each. In this exemplary embodiment, by reducing the rate of pilot signaling, the overall average transmission power of the base station is reduced in the transmit standby mode of operation with respect to the active mode of operation.

FIG. **15** is a drawing **1500** of an exemplary time frequency grid representing downlink air link resources available to a base station, implemented in accordance with the present invention, and indications of timing synchronization signals transmitted by the base station using those resources while operating in the transmit standby mode, for still another exemplary embodiment. The base station may be the same base station corresponding to the description of FIG. **4**, but now operating in the transmit standby mode rather than the active mode. Vertical axis **1502** represents tone index number (**0**, **1**, **2**, . . . , **15**) in the tone block utilized for downlink signaling by the base station. Horizontal axis **1504** represents time, with each unit representing one OFDM symbol transmission time interval. Each small square in the grid represents a basic transmission unit, an OFDM tone-symbol, corresponding to one tone for the duration of one OFDM symbol transmission time interval. A modulation symbol may be conveyed corresponding to each OFDM tone-symbol of the grid. Legend **1506** indicates that full shading of a grid square, as shown in legend element **1508**, signifies that a beacon tone signal at power level P_B occupies the tone-symbol. In FIG. **4**, 28 successive OFDM symbol transmission time intervals are shown. In FIG. **4**, three of the OFDM symbol transmission time intervals include one beacon tone signal and no pilot signals, while the other 25 OFDM symbol transmission time intervals each include 4 pilot tone signals. In comparison in FIG. **15**, the three beacon signal OFDM symbol transmission time intervals remain unchanged, however, the pilot signaling has been eliminated. In this exemplary embodiment, by reducing the rate of pilot signaling to zero, the overall average transmission power of the base station is reduced in the transmit standby mode of operation with respect to the active mode of operation.

FIGS. **4**-**7** and **15** have been provided to explain the concepts of synchronization signaling power and/or rate reduction in accordance with the present invention. The characteristics of the air link resources, types of synchronization signaling, amounts of power reduction, and/or amounts of rate reduction may vary depending upon the type of system, and specifications of the system.

In one exemplary OFDM wireless communications system for a base station operating in the active mode, e.g., an OFDM symbol transmission time interval is approximately 100 micro-sec, a downlink tone block comprises 113 contiguous tones, a beacon signal occupies one tone for two successive OFDM symbol transmission time intervals, beacon signals occur once during a beacon slot of 912 OFDM symbol transmission time intervals and 4 pilot tone signals may be communicated during each of 896 OFDM symbol transmission time intervals during a beacon slot, and the pilot signals account for approximately 18% of the base station transmission power. In some such exemplary systems, a base station operating in a transmit standby has a reduced level of pilot signaling, e.g., one pilot tone signal for every eight OFDM symbol transmission time intervals where, in the active mode, there were previously pilot tone symbols transmitted. This exemplary transmit standby mode of base station operation corresponds to one pilot tone signal for each of 112 OFDM symbol transmission time intervals in a beacon slot. In some such exemplary embodiments, beacon signaling is unaltered between the two modes of base station operation. Although the beacon signal is typically transmitted at a much higher power level than a pilot signal, it is communicated much less frequency and the energy is concentrated on one or a few tones, thus limiting the interference damage. However, pilots are communicated much more frequently and consume a significant portion of the base station transmit power while in the active mode; therefore, reducing or limiting pilot signaling in the transmit standby mode can achieve more beneficial interference reductions. In addition, in some such embodiments, the base station does not transmit downlink traffic signals while operating in the transmit standby mode of operation, thereby additionally decreasing base station transmit power and interference levels.

In another type of wireless communication system, e.g., a CDMA system, spreading codes synchronization signals may be used, and the power level and/or number of spreading code synchronization signals are reduced when operating in the transmit standby mode of operation as compared to the active mode of operation.

FIG. **8** is a drawing **800** illustrating an exemplary base station, BS K **804**, with cellular coverage area, cell K **802**.

Cell K **802** includes two exemplary wireless terminals (WT A **806**, WT B **807**) coupled to BS K **804** via wireless links (**808**, **809**), respectively. BS K **804** may be in accordance with exemplary BS **200** of FIG. **2**, while WT A and WT B may be in accordance with exemplary WT **300** of FIG. **3**. BS K **804** is currently in an active mode of base station operation; WT A **806** is in an active-On state of WT operation; WT B **807** is in an active-Hold state of WT operation.

FIG. **9** is a drawing **900** illustrating an exemplary base station, BS L **904**, with cellular coverage area, cell L **902**. Cell L **902** includes exemplary two wireless terminals (WT C **906**, WT D **908**). BS L **904** may be in accordance with exemplary BS **200** of FIG. **2**, while WT C **906** and WT D **908** may be in accordance with exemplary WT **300** of FIG. **3**. WT C **906** and WT D **908** are currently in an off state. There are no WTs in cell L currently being serviced by BS L **904**, and the base station L **904** is currently operating in the transmit standby mode of operation.

FIG. **10** is a drawing **1000** illustrating an exemplary base station, BS P **1004**, with cellular coverage area, cell P **1002**. Cell P **1002** includes exemplary two wireless terminals (WT E **1006**, WT F **1008**). BS P **1004** may be in accordance with exemplary BS **200** of FIG. **2**, while WT E **1006** and WT F **1008** may be in accordance with exemplary WT **300** of FIG. **3**. BS P **1004** is currently operating in a transmit standby mode of operation. WT E **1006** is currently off and is not being serviced by BS P **1004**. WT F **1008** is currently in a sleep state of operation and is coupled to BS P **1004** via wireless link **1010**. There are currently no WTs in cell P **1002** being serviced by BS P **1004** that are in an active state of operation.

FIG. **11** is a drawing of a table **1100** illustrating characteristics of base station active mode of operation and the base station transmit standby mode of operation for an exemplary embodiment, in accordance with the present invention. First information column **1102** lists information pertaining to the base station active mode of operation. Second information column **1104** lists information pertaining to the base station transmit standby mode of operation. First row **1106** identifies that in the base station active mode the BS can service WTs in the active mode and WTs in the sleep mode, while in the BS transmit standby mode of operation the BS can service WTs in the sleep mode of operation.

Second row **1108** identifies that beacon signals are communicated in both the active mode of operation and the transmit standby mode of operation in this exemplary embodiment. In this embodiment, the beacon signaling is the same regardless of the base station mode of operation. In some embodiments, the beacon signal is a relatively high power signal occupying one or a few, e.g., two or three or four, tones for a few, e.g., one or two or successive OFDM symbol transmission time intervals. In some such embodiments, the other tones of the downlink tone block are left unused during the beacon signal transmission. In some embodiments, the beacon signaling may be different in the two modes such that the power and/or rate is reduced in the transmit standby mode as compared to the active mode. In some embodiments, a beacon signal may include one or a few high power tones and a larger number of low power tones, e.g., 25 to 75 tones out of a tone block of 113 tones, being communicated during the same OFDM symbol transmission time interval or intervals. In some such embodiments, in the transmit standby mode of operation the high power tone may unaffected, but the rate and/or power level of the lower power tones may be reduced with respect to active mode.

Third row **1110** identifies that pilot signals are communicated in both the active mode and the transmit standby mode of operation; however, the transmission rate of the pilot signals and power level of the pilot signals is reduced in the transmit standby mode with respect to the active mode, in this exemplary embodiment. In some embodiments, one of: (i) pilot signal power level and (ii) rate of pilot signaling is reduced in the transmit standby mode of operation with respect to the active mode of operation.

Fourth row **1112** indicates that uplink and downlink traffic channel data is communicated in the base station active mode, but not in the base station transmit standby mode of operation, in this exemplary embodiment.

Fifth row **1114** indicates that paging signals are communicated in both the active mode and transmit standby mode of operation. In some embodiments, the paging signaling may be communicated at different rates and/or have different characteristic depending upon the mode of base station operation. For example, in active mode, paging opportunities may occur more frequently than in the transmit standby mode. In addition, in some embodiments paging signals in the active mode may convey more information and/or be structured to allow for a more rapid response by the WT to which the page is directed.

FIG. **12** is a drawing **1200** illustrating an exemplary communications system, implemented in accordance with the present invention and using methods of the present invention. FIG. **12** includes a plurality of base stations (BS **1 1210**, BS **2 1212**, BS **3 1214**), each with a corresponding cellular coverage area (cell **1 1216**, cell **2 1218**, cell **3 1220**), respectively. Train track **1202** is shown with exemplary train **1204** situated on the track **1202**. In general, more than one train may be operating in the area covered by the communications system at the same time. Exemplary train **1204** includes a plurality of mobile nodes (MN **1 1206**, MN N **1208**).

The exemplary communications system also includes a network node **1222** coupled to (BS **1 1210**, BS **2 1212**, BS **3 1214**) via wireless links (**1226**, **1228**, **1230**), respectively. Network node **1222** is coupled to other network nodes and/or the Internet via network link **1232**. Network links (**1226**, **1228**, **1230**, **1232**) may be, e.g., fiber optic links, cable link, and/or high capacity wireless links such as directed microwave links. Network node **1222** includes schedule information **1224**.

The schedule information **1224** includes train schedule information, e.g., identifying when a train or trains will be within each BS's cellular coverage area. The network node **1222** by communicating schedule information and/or information derived from the schedule information to the BSs, can affect the switching of the base stations from transmit standby to active mode and from active mode to transmit standby mode. For example, the network node **1222** can send schedule information to each BS and the BS can switch accordingly. Alternatively, the network node can use to the schedule information to determine when to issue mode switch command signals to each base station to command base station mode switching operations.

In some embodiments, information derived from train tracking and/or train position detection mechanisms such as track sensors, e.g., already in place and used to prevent collisions, is used in controlling the transitioning of base stations from active to transmit standby mode and from transmit standby mode to active mode. In some embodiments, there is a controlled base station mode transitioning of base stations along the track **1202**, e.g., directed by network node **1222** taking into account the current position of train **1204**, the direction of train **1204**, and the speed of train **1204**.

Consider, as an example, that the area of track **1202** which runs through cells **1216**, **1218**, and **1220** is a rather remote

rural area, with a very low population density. In such an embodiment, when train **1204** is not in a cell (**1216**, **1218**, **1220**), it may be advantageous to put the base station (**1210**, **1212**, **1214**) in a transmit standby mode of operation, thus reducing transmit power and reducing interference; however when the train is about to enter or is in the cell (**1216**, **1218**, **1220**) it may be advantageous to have the base station operating in active mode. In some embodiments, there can be a linkage along the track with adjacent base stations transitioning between modes as the trains MNs (**1206**, **1208**) are handed off from one base station to the next. The reduced interference may be particularly beneficial in cell boundary areas, e.g., in a cell boundary area bordering on a higher population region where another adjacent base station may be typically operated continuously in the active mode of operation.

In some embodiments, under some conditions base stations are commanded into transmit standby mode when a train is at or near a specific location, e.g., a bridge or tunnel, e.g., for security purposes.

The methods described with respect to the train embodiment of FIG. **12** are also applicable to other transportation networks. For example base stations may be situated along flight paths and base station mode operation transitioning may be coordinated with flight schedule information.

FIG. **13** comprising the combination of FIG. **13**A, FIG. **13**B, and FIG. **13**C is a flowchart **1300** of an exemplary method of operating a base station in accordance with the present invention. The exemplary base station may be base station **200** of FIG. **2**. The exemplary method starts in step **1302**, where the base station is powered on and initialized. Operation proceeds from step **1302** to step **1306**, step **1308**, and via connecting node A **1303** to step **1304**.

In step **1306**, the base station is set to active mode, and then in step **1310**, the base station is operated in the active mode of operation. The operations of step **1310** include during a first period of time transmitting synchronization signals at a first rate. For example, the synchronization signals may include a combination of beacon signals and pilot signals. In some embodiments, the active mode of operation may be considered a base station full-up operational state of operation capable of supporting one or more active users and supporting uplink and downlink traffic channel signaling. The first rate of synchronization signaling may be such to support relatively fast synchronization and channel estimation for WTs being serviced by the. base station. Operation proceeds from step **1310** to step **1312**.

In step **1312**, the base station is operated to check as to whether there are any WTs being serviced in an active state. For example, WTs may register with a base station that it wishes to use as its point of network attachment. An exemplary registered wireless terminal may be in different states at different times, e.g., a sleep state or an active state; the active state may be further qualified to include an active-Hold state and an active-On state. The BS may control the WTs transitioning into the active state, and the control operations may include assigning WTs active user identifiers. The BS may track the number of users currently in active state. If in step **1312**, it is determined that there are no WTs being serviced in an WT active state, e.g., no WTs currently registered with the BS being serviced are currently in the active state, then operation proceeds to step **1314**; otherwise, operation proceeds to step **1316**. In step **1316**, the base station having determined that there is at least one registered WT in the active state, resets the inactivity timer. Operation proceeds from step **1316** back to step **1312**, where the base station again checks to see if there are any WTs being serviced in the active state.

In step **1314**, an inactivity timer is incremented. Operation proceeds from step **1314** to step **1318**. In step **1318**, the base station checks as to whether the inactivity timer has exceeded a predetermined limit. If the timer has exceeded the predetermined limit, operation proceeds to step **1320**; otherwise, operation returns to step **1312**, where the base station again checks as to whether or not there are any WTs being serviced in an active state.

In step **1320**, the base station is operated to transition the base station to a transmit standby mode of operation. The transmit standby mode of operation is a state of base station operation in which the base station is not servicing active users, but may be servicing users in a sleep state, and in which the base station is operated to have a lower average output power than in the active mode, thus creating less interference in the system. Operation proceeds from step **1320** to step **1322**. In step **1322**, the base station is operated in a transmit standby mode of operation which includes during a second period of time during which synchronization signals are transmitted, the synchronization signals are transmitted at least one of: (i) a lower rate than in the active mode of operation, and (ii) a lower power level, than the synchronization signals transmitted in the active mode. In some embodiments, some of the synchronization signals, e.g., beacon signals, may be the same in both modes of base station operation, while other synchronization signals, e.g., pilot signals, may be reduced in power level and/or rate while in the transmit standby mode of operation.

Returning to step **1304**, in step **1304**, the base station is operated to track current time. Operation proceeds from step **1304** to step **1324**. In step **1324**, the base station checks as to whether the current time indicates that the base station should be mode transitioned according to schedule information. For example, the BS may be located in a remote rural area and may be transitioned between modes depended upon whether or not a train including mobile wireless terminals is currently within the vicinity of its cellular coverage area based upon train schedule information either stored and/or communicated to the base station. If the current time does not indicate that the base station should be mode transitioned, operation proceeds from step **1324**, back to step **1304**. However, if the current time indicates that a mode transition should be performed based upon schedule information, then operation proceeds from step **1324** to step **1326**.

In step **1326**, the base station is operated to determine whether the transition should be to an active mode in which case operation proceeds to step **1328** or to a transmit standby mode in which case operation proceeds to step **1330**. In step **1328**, the base station checks as to whether the BS is already in an active state in which case no further action is needed with regard to this transition. However, if in step **1328**, it is determined that the BS is not in an active mode, then operation proceeds from step **1328** to step **1332**, where the base station is operated to transition to an active mode. Operation proceeds from step **1332** via connecting node F **1334** to step **1310**, where the base station is operated in active mode.

Returning to step **1330**, in step **1330**, the base station checks as to whether the BS is already in a transmit standby mode in which case no further action is needed with regard to this transition. However, if in step **1330**, it is determined that the BS is not in an transmit standby mode, then operation proceeds from step **1330** via connecting node G **1336** to step **1320**, where the base station is operated to transition to the transmit standby mode.

Returning to step **1308**, in step **1308** the base station is operated to receive signals over wireless links and the backhaul network interface on an ongoing basis. Operation pro-

ceeds from step **1308** via connecting nodes (B **1338**, C **1346**, D **1352**, E **1364**, J **1365**) to steps (**1340**, **1348**, **1354**, **1366**, **1367**), respectively.

In step **1340**, the base station monitors for access signals from WTs seeking to register with the BS to use the base station as its point of network attachment. Operation proceeds from step **1340** to step **1342**, where the base station checks as to whether or not an access signal has been received. If an access signal has not been received operation returns to step **1340**; otherwise operation proceeds via connecting node H **1344** to step **1328**, where the BS checks as to whether of not the BS is currently in active mode.

Returning to step **1348**, in step **1348**, the base station monitors for wake-up signals, e.g., via wireless links from WTs and/or via the backhaul network. A wake-up signal via the backhaul network may originate from a WT, from a centralized command node or from another network node such as an adjacent base station. For example, a wireless terminal currently connected to another adjacent BS, expecting to shortly implement hand-off operations resulting in a hand-off to the base station that it is seeking to wake-up, may initiate the wake-up signal and communicate the signal via its current point of network attachment. The WT may initiate this wake-up signal so as to obtain uninterrupted user data communications, and the wake-up signal information is ultimately communicated to the BS in transmit standby mode via the backhaul network. As another example, a centralized network control node may send the BS a wake-up signal via the backhaul, e.g., the centralized control node implementing control in accordance with train schedule information. As another example, another base station, e.g., an adjacent base station, being aware of active mobile users approaching the BS's outer cell perimeter may send the BS a wake-up signal via the backhaul, so that the BS can be transitioned into the active mode and ready for the active mobile users when they arrive in its cell. As still another example, a WT in the base stations cellular coverage area either recently powered on or in the sleep state may have detected that the BS is in a transmit standby mode, and the WT generates and sends a wake-up signal to the BS via a wireless channel. Operation proceeds from step **1348** to step **1350**, where the base station checks as to whether or not a wake-up signal has been received. If a wake-up signal has not been received operation returns to step **1348**; otherwise operation proceeds via connecting node H **1344** to step **1328**, where the BS checks as to whether of not the BS is currently in active mode.

Returning to step **1354**, in step **1354**, the base station monitors for hand-off signals, e.g., via wireless links from WTs and/or via the backhaul network. Operation proceeds from step **1354** to step **1356**, where the base station checks as to whether or not a hand-off signal has been received. If a handoff signal has not been received operation returns to step **1354**; otherwise operation proceeds to step **1358**. In step **1358** the base station determines whether or not an operational mode change should be implemented as a result of the received handoff signal. For example, consider that the received handoff signal is via a wireless link from the last currently registered wireless terminal being serviced by the base station, then after completing the handoff the base station can be transitioned into the transmit standby mode of operation. However, if such a received handoff signal was received while other registered WTs were still in an active state within the cell, a base station mode change would not be appropriate. As another example, consider that the handoff signal is via the backhaul network, indicating that an active wireless terminal is seeking to be handed off to the base station and that the base station is currently in a transmit standby mode of operation. Under such conditions it would be appropriate to transition the base station into active mode. However, if the base station was already in an active mode when such a handoff signal was received via the backhaul network no base station mode transition would be needed. If in step **1358** the base station determines that a mode change should result, operation proceeds to step **1360**; otherwise, no further operations are performed to initiate a mode change in response to this received handoff signal.

In step **1360**, the base station proceeds depending upon which mode transition direction. If the mode transition is to the active mode, operation proceeds from step **1360** via connecting node **1 1362** to step **1332**. If the mode transition is to the transmit standby mode, operation proceeds from step **1360** via connecting node G **1336** to step **1320**.

Returning to step **1366**, in step **1366**, the base station monitors for state change signals, e.g., via wireless links from currently registered WTs. For example a registered WT may request to be transitioned from sleep state to active state so that it may transmit and receive user data. Operation proceeds from step **1366** to step **1368**, where the base station checks as to whether or not a state change request signal has been received. In some embodiments, a request for additional air link resources, e.g., a request for a traffic channel segment may be viewed as a state change request signal. If a state change signal has not been received operation returns to step **1366**; otherwise operation proceeds to step **1370**. In step **1370** the base station determines whether or not an operational mode change should be implemented as a result of the received WT state change signal. For example, consider that the state change signal is from a currently registered wireless terminal being serviced by the base station in sleep state requesting a change to active state, and the base station is currently in transmit standby mode, then the BS should implement a mode change to active. However, if such a received WT state change signal was received while the base station was already in the active mode, a base station mode change would not be necessary. If in step **1370** the base station determines that a mode change should result, operation proceeds to step **1360**; otherwise, no further operations are performed to initiate a base station mode change in response to this received WT state change request signal.

Returning to step **1367**, in step **1367**, the base station monitors for mode change signals, e.g., a command via the backhaul network indicating that the BS should change its operational mode. For example a network control mode or adjacent base station node may have decided to temporarily command the BS out of active mode and into transmit standby mode due to any of a number of conditions such as interference testing, load conditions, schedule, security considerations, etc. Operation proceeds from step **1367** to step **1369**, where the base station checks as to whether or not a mode change request signal has been received. If a mode change signal has not been received operation returns to step **1367**; otherwise operation proceeds to step **1371**. In step **1371** the base station determines whether or not an operational mode change should be implemented as a result of the received base station state change signal. For example, different criteria for a mode change may apply depending upon the source of the mode change signal and or the current conditions of the base stations. Some received mode change signals are considered commands which the base station implements without further consideration, while other received mode change signals are considered requests, in which the base station has discretion regarding the mode change. For example, if the mode change command was by a centralized control node and issued for security reasons, the mode change may be implemented with-

out further consideration. Alternatively, if the mode change signal was a suggestion to transition to transmit standby mode, based upon a schedule, e.g., a train schedule, and there happens to be additional registered active users outside the train, the command may be ignored by the base station. If in step **1371** the base station determines that a mode change should result, operation proceeds to step **1360**; otherwise, no further operations are performed to initiate a mode change in response to this received BS mode change signal.

FIG. **14** is a drawing **1400** of a state diagram for an exemplary base station implemented in accordance with the present invention. The exemplary base station may be base station **200** of FIG. **2**. The exemplary base station includes an exemplary state **1 1402**, otherwise referred to as the base station active mode of operation, and an exemplary state **2 1404**, otherwise referred to as a base station transmit standby mode of operation. The arrows indicate conditions for causing a transition of state. A state transition from the base station active mode of operation **1402** to the base station transmit standby mode of operation **1404** can be a response to: a detected period of inactivity **1406**, scheduling information **1408**, a received base station mode change signal **1409**, a detected transition of at least one wireless terminal from an active to a sleep state **1410**, e.g., the transition resulting in all wireless terminal currently registered with the base station being in a sleep state. A state transition from the base station transmit standby mode of operation **1404** to the base station active mode of operation **1402** can be a response to: scheduling information **1412**, a received access signal **1414**, a received wake-up signal **1416**, a received hand-off signal **1418**, a received WT state change signal **1420**, e.g., state change request signal, or a received base station mode change signal **1422**.

FIG. **16** is a drawing **1600** illustrating a series of time sequential operations in an exemplary embodiment of the present invention. Diagrams (**1601**, **1603**, **1605**, **1607**, **1609**, and **1611**) each represent successive time sequential operations for exemplary cell A **1602**. Diagram **1601** illustrates that cell A **1602** includes exemplary base station A **1604**, operating in a transmit standby mode of operation, sometimes referred to a sleep mode of base station operation. For this exemplary BS **1604**, while operating in the transmit standby mode of operation, the BS **1604** transmits beacon signals **1606**, but does not transmit pilot signals.

Diagram **1603** illustrates that WT A **1608** has entered the cell or powered on in the cell and has received the beacon signal **1606**. The WT **1608** identifies BS A **1604** from recovered beacon signal information and recognizes that the BS **1604** is in transmit standby mode, e.g., from a lack of pilot signals.

Diagram **1605** illustrates that the WT **1608** sends a wake-up signal **1610** to BS A **1604**. Wake-up signal **1610** is implemented for easy detection without the need for precise timing synchronization, e.g., a relatively high power signal at a known location in the uplink timing and frequency structure with a duration of two OFDM symbol transmission time intervals. In some embodiments, wake-up signal **1610** is implemented for easy detection without the need for any timing synchronization between the WT **1608** and the BS **1604**, e.g., with the BS in transmit standby mode continuously monitoring certain predetermined tones for a wake-up signal. In some embodiments, the wake-up signal **1610** has the same characteristics as an access signal typically used for registration with an active base station.

Diagram **1607** indicates that the base station **1604** has recognized the wake-up signal **1610** and transitioned into the active mode of operation, e.g., reactivating the normal channels used for control and user data signaling including pilot signals **1612**. Diagram **1609** indicates that the WT **1608** has recognized that the BS **1604** is in the active mode of operation, and the WT **1608** has transmitted an access request signal **1614**, e.g., during one of the access intervals in the uplink timing and frequency structure using a contention based access segment. Diagram **1611** indicates that conventional registration of WT A **1608** has completed and the WTA **1608** has been accepted as an active user by BS A **1604**. BS A **1604** is assigning WT A uplink and downlink traffic channel segments via which user data signals **1616** are being communicated.

FIG. **17** is a drawing **1700** illustrating a portion of an exemplary OFDM uplink timing and frequency structure. At the base station, the uplink timing can be referenced with respect to the downlink timing, e.g., with respect to a downlink beacon signal. Vertical axis **1702** indicates uplink tones and includes an uplink tone block **1701**, e.g., of 113 contiguous tones. Horizontal axis **1704** represents time. The uplink timing structure includes access intervals **1706**, **1706'** and regular uplink signaling intervals **1708**. The access intervals, e.g., access interval **1706**, can be used for access signals, e.g., registration request signals, and base-station wake-up request signals. In some embodiments, depending upon the base station mode of operation, at least some of the tone-symbols of the access interval are used for different purposes. At least some of the signals transmitted by a WT during the access interval need not be precisely timing synchronized with respect to the base station, while signals transmitted by a WT during the regular uplink signaling interval **1708** typically have precise timing synchronization, e.g., to within a cyclic prefix duration. In some embodiments, signaling during the access interval uses contention based segments, while signaling during the regular uplink signaling interval uses allocated or assigned segments. The regular uplink signaling intervals can be used for various signaling including assigned uplink traffic channel segment signaling and uplink dedicated control channel signaling.

FIG. **18** is a drawing **1800** illustrating exemplary access interval uplink air link resources, exemplary segments and exemplary signaling corresponding to a base station active mode of operation and a base station transmit standby mode of operation, in accordance with some embodiments of the present invention. Time frequency grid **1802** includes 48 tone-symbols, each tone-symbol represented by a small square block and each tone-symbol representing the uplink air link resources of one tone for one OFDM symbol transmission time interval. Time frequency grid **1802** includes a uplink tone block **1804** of 16 contiguous tones (tone **0**, tone **1**, . . . , tone **15**), and has a time duration of an access interval **1806**, where the access interval includes three consecutive OFDM symbol transmission time intervals (**1808**, **1810**, **1812**). In some embodiments, the access interval has a different duration, e.g., 8 consecutive OFDM symbol transmission time intervals.

Time frequency grid **1814** represents time frequency grid **1802** partitioned, during the base station active mode of operation, to include two access segments. In some embodiments a portion of the uplink air link resources during the access interval is reserved for access segments. Legend **1816** indicates that tone-symbols which are a member of the 1st access segment are indicated by cross-hatched shading **1820**, while tone-symbols which are a member of the 2nd access segment are indicated by vertical and horizontal line shading **1822**. During the base station active mode of operation, a wireless terminal seeking to register with the base station and use the base station as its point of network attachment uses

one of the access segments to transmit an access request signal. In some embodiments, the WT randomly selects one of the access segments to use to communicate its uplink access registration request signal. Time frequency grid **1814'** represents time frequency grid **1814**, but also includes an additional access request signal represented with diagonal line shading **1824**. The access request signaling is transmitted at per tone power level P_{AC}, and the WT need not be precisely timing synchronized with respect to the base station, e.g., timing synchronization error may be greater than an OFDM symbol cyclic prefix duration, but is sufficiently small such that the access request signal can be recognized by the base station and should be received at the base station within the time constraints of the access segment.

Time frequency grid **1826** represents time frequency grid **1802**, during the base station transmit standby mode of operation; grid **1826** includes at least one wake-up segment. Legend **1828** indicates that tone-symbols which are a member of the wake-up segment are represented by dotted shading **1830**. During, the base station transmit standby mode of operation, a wireless terminal seeking to wake-up the base station, resulting in the base station transitioning from transmit standby mode to active mode, uses the wake-up segment to transmit a wake-up signal. Time frequency grid **1826'** represents time frequency grid **1826**, but also includes an additional wake-up signal represented with vertical line shading **1832**. The wake-up signaling is transmitted at per tone power level P_{WU}, where $P_{WU}>P_{AC}$ for the same WT, at the same location with the same detected beacon signal, and having the same amount of remaining battery power. The WT need not be precisely timing synchronized with respect to the base station, e.g., timing synchronization error may be greater than an OFDM symbol cyclic prefix duration, but sufficiently small such that the wake-up signal can be recognized by the base station and should be received at the base station within the time constraints of the wake-up segment. In accordance with some embodiments of the present invention, the number of tones used concurrently for the wake-up signal is reduced, e.g., to one, from the number of tones used concurrently for an access request signal, allowing the WT to significantly increase the per tone transmission power of a wake-up signal increasing the likelihood that a base station will successfully detect a wake-up signal.

In some embodiments in the transmit standby mode of operation, the base station turns off all transmission signaling except a minimum set of signaling that the wireless terminals may use to detect the presence of the base station and/or determine a coarse level of synchronization. In some such OFDM embodiments this minimum set of signaling is the beacon signaling, and the beacon signals may be communicated at the same or reduced power levels with respect to the active mode of operation. In some OFDM embodiments, this reduced set of signals can be beacons and pilots with the pilots being transmitted at reduced power and/or rate with respect to signaling in the active mode. In some embodiments, a wireless terminal after detecting the base station, e.g., via a received beacon, and desiring to wake-up the base station sends a wake-up signal to the base station; the base station upon detecting the wake-up signal reactivates the normal channels transitioning the base station into an active mode of operation. In various embodiments, the wake-up signal is designed for easy detection without the need for timing synchronization or precise timing synchronization. For example, in an exemplary OFDM embodiment, the wake up signal can be a double symbol tone at a known location in the uplink timing and frequency structure. In some embodiments, the wake-up signal can be a signal communicated at a relatively high uplink transmission power level, the signal being longer in duration than the normal modulation symbol value intended for a single OFDM tone-symbol, and the signal being communicated in two or more consecutive OFDM symbol transmission time intervals. In some embodiments, a regular access signal can be considered a wake-up signal if the base station receiving the signal is in a transmit standby mode of operation. In some embodiments, the same air link resources reserved for access signals may be reserved and used for wake-up signals. In some such embodiments, the access signals may be distinct from the wake-up signals.

FIG. **19** is a flowchart **1900** of an exemplary method of operating a wireless terminal, e.g., mobile node, in accordance with the present invention. The exemplary method of operation including establishing a user data channel with a base station for uplink data transmission starts in step **1902**. For example, a wireless terminal may have powered on and initialized in step **1902** and desires to establish an uplink communications link with a base station network attachment point corresponding to the cellular coverage area in which it is located. As another example, a wireless terminal may be currently registered with a base station in whose cell it is located, but may be in a WT sleep state, and in step **1902** its starts to initiate operations to transition to a WT active state. As another example, a wireless terminal may be currently an active user with a different base station point of network attachment, located adjacent to the new base station that it seeks to establish a user data channel, and the wireless terminal enters a boundary region. Operation proceeds from start step **1902** to step **1904**.

In step **1904**, the wireless terminal determines if the base station to which it seeks to establish a user data channel is in a reduced activity state of operation. Step **1904** includes sub-step **1906** and sub-step **1908**. In sub-step **1906**, the wireless terminal receives synchronization signals from the base station. Then, in sub-step **1908**, the wireless terminal makes the determination of the base station mode of operation based on the received synchronization signals.

In some embodiments, sub-step **1908** includes sub-step **1910**, where the wireless terminal evaluates signal power levels to determine a base station mode of operation. In some embodiments, higher signal power levels of at least some types of synchronization signals are indicative of a full on mode of base station operation, while lower signal power levels of the same type of synchronization signals are indicative of a reduced synchronization signaling mode of operation, e.g., a base station sleep mode of operation. In various embodiments, the synchronization signals include at least two types of signals and the relative power of the two types of signals is indicative of a base station mode of operation. In some such embodiments, the at least two types of signals includes a first type of signal which is an OFDM beacon signal and a second type of signal which is a pilot tone signal, and the beacon tone signal has a per tone power at least three times the per tone signal power of a pilot tone signal. In some such embodiments the OFDM beacon per tone transmission power level is the same in both the base station sleep mode and the base station active mode; however the pilot signal per tone transmission power is reduced in the base station sleep mode of operation with respect to the base station active mode of operation.

In some embodiments, sub-step **1908** includes sub-step **1912** in which the wireless terminal determines a rate at which a first type of synchronization signals are received and correlates the determined rate to a corresponding base station mode of operation. In some such embodiments, the first type of synchronization signals are pilot tone signals. In some such

embodiments, the base station is determined to be in a reduced synchronization signaling mode of operation, e.g., a sleep mode of base station operation, when the determined rate is below a predetermined threshold.

Operation proceeds from step **1904** to step **1914**. In step **1914**, the wireless terminal operation proceeds along different paths depending upon whether or not the base station is in a reduced activity state of operation. If the base station is in a reduced state of activity, e.g., a sleep state of base station operation, then operation proceeds from step **1914** to step **1916**; however, if the base station is not in a reduced state of activity, e.g., the base station is in a full-on active mode of base station operation, then operation proceeds from step **1914** to step **1926**.

In step **1916**, the wireless terminal transmits a signal used to trigger the base station to transition to a more active synchronization signaling mode of operation, e.g., transmits a wake- up signal, an access request signal, a hand-off signal, or a state transition request signal.

In some embodiments, a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation is a wake-up signal. In some such embodiments the characteristics of the wake-up signal are such to provide easy detection by a base station in sleep mode. In some embodiments, the wake-up signal includes less than 5 OFDM tones. In some such embodiments, the wake-up signal uses a single OFDM tone. In various embodiments, the wake-up signal is transmitted for a continuous period of time lasting more than one OFDM symbol transmission time period. In various embodiments, the wake-up signal is transmitted such that the signal occupies greater than a single OFDM transmission time interval, e.g., 2 successive OFDM symbol transmission time intervals, and the wireless terminal need not be precisely timing synchronized with respect to the base station, e.g., timing synchronization error may be greater than an OFDM cyclic prefix but is small enough such that the wake-up signal can be detected by the base station, e.g., the wireless terminal is synchronized with the base station to within an OFDM symbol transmission time interval. In some embodiments, a predetermined set of tones is used for the wake-up signal. In some embodiments, the predetermined set of tones includes at most one tone. In various embodiments, the wake-up signal is transmitted by the wireless terminal at a per tone power level that is higher than the average power level used by the wireless terminal to transmit user data. In some such embodiments, the wake-up signal is transmitted by the wireless terminal at the highest per tone power level used by the wireless terminal. In some embodiments, the wake- up signal is communicated using one of the tones utilized for access request signaling.

In some embodiments, a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation is an access request signal, and the wireless terminal operates differently following transmission of the access request signal if the transmission of the access request signal was to a base station in a reduced synchronization mode of signaling operation than if the transmission was to a base station in a full-on mode of synchronization signaling operation. In such an embodiment, the base station implements different processes in response to the received access request signal depending upon the base station's current mode of operation.

In some embodiments, wherein the wireless terminal is currently connected as an active user via a wireless link to a current base station located adjacent to the base station to which the wireless terminal seeks to wake-up and establish a user data channel, a signal used to trigger the base station to transition into a more active synchronization mode of operation is transmitted through the current base station as part of a handoff operation. For example, a wireless terminal may be in a sector or cell boundary region and anticipate switching base station points of network attachment, and thus transmit such a signal to its current point of network attachment, and the signal may be forwarded, e.g., via the backhaul network to the base station that needs to be woke-up. In this manner, hand-off delays may be minimized.

In some embodiments, wherein the wireless terminal is already registered with the base station that the wireless terminal seeks to cause to transition to a more active mode of synchronization signaling and the wireless terminal is in a wireless terminal sleep mode of operation in which the wireless terminal does not transmit user data, the signal used to trigger the base station to transition into a more active synchronization mode of operation is a state transition request signal, e.g., a request by the wireless terminal to transition from a WT sleep mode to a WT active mode.

Operation proceeds from step **1916** to step **1918**. In step **1918**, the wireless terminal waits a period of time for the base station to transition to an ON state. In some embodiments, the wireless terminal monitors for a change in base station signaling, e.g., in terms of rate and/or power level of base station signaling to confirm that the base station has transitioned into the active state of operation. In some embodiments, the wireless terminal repeats the signal intended to cause the transition if a base station mode transition is not observed within a predetermined amount of time, e.g., within a number of OFDM symbol transmission time intervals, or at an expected point within the timing structure, e.g., the start of the next slot in the downlink timing structure after allowing for signaling transmission times and base station mode transitioning operations.

Then, in step **1920**, the wireless terminal transmits registration and/or access request signals to the base station, e.g., an access request signals using a contention based access segment in an uplink timing and frequency structure associated with the base station. For example, for a wireless terminal new to the cell, a complete sequence of registration and access request signaling may occur. However, for a wireless terminal currently registered with the base station, but in WT sleep mode, the WT may have a registered user identifier but may seek to acquire an active user identifier and may initiate closed loop timing synchronization.

Operation proceeds from step **1920** to step **1922**, where the wireless terminal performs closed loop timing control based on feedback signals from the base station. In some embodiments, wherein the wireless terminal is being handed-off between two base station network attachment points corresponding to the same cell, e.g., two sector attachment points of the same base station or two carrier frequency attachment points corresponding to the same sector of the same base station, some or all of the timing synchronization operations may be omitted. In some embodiments, closed loop power control pertaining to the wireless terminal transmission power level is also performed.

Then, in step **1924**, the wireless terminal initiates the transmission of user data to the base station. For example, the wireless terminal may have been previously assigned a base station active user identifier, e.g., in step **1920**, the base station scheduler may have assigned one or more uplink traffic channel segments to the wireless terminal, and the wireless terminal transmits user data using the assigned uplink traffic channel segments.

Returning to step **1926**, in step **1926**, the wireless terminal initiates registration and/or access operations, and then in step

1928, the wireless terminal performs closed loop timing control based on feedback signals from the base station. Operation proceeds from step 1928 to step 1930. In step 1930, the wireless terminal initiates the transmission of user data to the base station.

While described in the context of an OFDM system, many of the methods and apparatus of the present invention, are applicable to a wide range of communications systems including many non-OFDM and/or non-cellular systems.

In various embodiments nodes described herein are implemented using one or more modules to perform the steps corresponding to one or more methods of the present invention, for example, transitioning between two base station modes of operation, operating in an active base station mode of operation, operating in a transmit standby base station mode of operation, determining a base station mode of operation, signaling to cause a mode transition, processing mode transition related signaling, deciding whether or not to implement a mode transition, etc. In some embodiments various features of the present invention are implemented using modules. Such modules may be implemented using software, hardware or a combination of software and hardware. Many of the above described methods or method steps can be implemented using machine executable instructions, such as software, included in a machine readable medium such as a memory device, e.g., RAM, floppy disk, etc. to control a machine, e.g., general purpose computer with or without additional hardware, to implement all or portions of the above described methods, e.g., in one or more nodes. Accordingly, among other things, the present invention is directed to a machine-readable medium including machine executable instructions for causing a machine, e.g., processor and associated hardware, to perform one or more of the steps of the above-described method(s).

Numerous additional variations on the methods and apparatus of the present invention described above will be apparent to those skilled in the art in view of the above description of the invention. Such variations are to be considered within the scope of the invention. The methods and apparatus of the present invention may be, and in various embodiments are, used with CDMA, orthogonal frequency division multiplexing (OFDM), and/or various other types of communications techniques which may be used to provide wireless communications links between access nodes and mobile nodes. In some embodiments the access nodes are implemented as base stations which establish communications links with mobile nodes using OFDM and/or CDMA. In various embodiments the mobile nodes are implemented as notebook computers, personal data assistants (PDAs), or other portable devices including receiver/transmitter circuits and logic and/or routines, for implementing the methods of the present invention.

What is claimed is:

1. A method of operating a wireless terminal, the method comprising:

determining if a base station to which the wireless terminal is seeking to establish a user data channel is in a reduced synchronization signaling mode of operation; and

when said wireless terminal determines that said base station is in a reduced synchronization signaling mode of operation, transmitting a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation.

2. The method of claim 1, wherein said determining includes:

receiving synchronization signals from said base station; and

making said determination based on the received synchronization signals.

3. The method of claim 2, wherein said making of said determination based on the received synchronization signals includes evaluating signal power levels to determine a base station mode of operation.

4. The method of claim 3, wherein higher signal power levels are indicative of a full on mode of base station operation than lower signal power levels which are indicative of a reduced synchronization signaling mode of operation.

5. The method of claim 4, wherein said synchronization signals include at least two types of signals and wherein the relative power of the two types of signals is indicative of the base station mode of operation.

6. The method of claim 5, wherein said at least two types of signals includes a first type of signal which is an OFDM beacon signal and a second type of signal which is a pilot tone signal; and

wherein said beacon signal has a per tone power at least three times the per tone signal power of said pilot tone signal.

7. The method of claim 2, wherein making said determination based on the received synchronization signals includes:

determining a rate at which a first type of synchronization signals are received.

8. The method of claim 7, wherein the first type of synchronization signals are pilot tone signals.

9. The method of claim 7, wherein said base station is determined to be in a reduced synchronization signaling mode of operation when said determined rate is below a predetermined threshold.

10. The method of claim 2, wherein said signal used to trigger the base station to transition into a more active synchronization signaling mode of operation is a wakeup signal.

11. The method of claim 10, wherein said wakeup signal includes less than 5 OFDM tones.

12. The method of claim 11, wherein said wakeup signal is transmitted for a continuous period of time lasting more than one OFDM symbol transmission time period.

13. The method of claim 12, wherein a predetermined set of tones is used for said wakeup signal.

14. The method of claim 13, wherein said predetermined set of tones includes at most one tone.

15. The method of claim 2, wherein said signal used to trigger the base station to transition into a more active synchronization signaling mode of operation is a wakeup signal which is transmitted by said wireless terminal at a per tone power level that is higher than the average per tone power level used by the wireless terminal to transmit user data.

16. The method of claim 15, wherein said wakeup signal is transmitted at the highest per tone power level used by said wireless terminal.

17. The method of claim 2, wherein said signal used to trigger the base station to transition into a more active synchronization signaling mode of operation is an access request signal, and

wherein said wireless terminal operates differently following transmission of the access request signal if the transmission was to a base station in a reduced synchronization mode of signaling operation than if the transmission was to a base station in a full-on mode of synchronization signaling operation.

18. The method of claim 1, wherein said wireless terminal is connected by a wireless link to a current base station located adjacent to said base station; and

wherein transmitting a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation includes transmitting said signal through said current base station as part of a handoff operation.

19. The method of claim **2**, wherein said wireless terminal is already registered with said base station and said wireless terminal is in a sleep mode of operation in which said wireless terminal does not transmit user data; and

wherein said signal used to trigger the base station to transition into a more active synchronization signaling mode of operation is a state transition request signal.

20. A wireless terminal for communicating with a base station which supports a reduced synchronization signaling mode of operation and a full on synchronization mode of operation, the wireless terminal comprising:

a transmitter;

a base station mode determination module for determining if said base station is operating in said reduced synchronization signaling mode of operation; and

a wakeup signal module, coupled to said base station mode determination module, for controlling said transmitter to transmit a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation.

21. The wireless terminal of claim **20**, further comprising:

a receiver for receiving synchronization signals from said base station; and

wherein said base station mode determination module processes received synchronization signals to evaluate at least one of i) synchronization signal power levels and ii) a rate of at least some synchronization signals.

22. The wireless terminal of claim **21**, wherein said base station mode determination module includes:

a relative power level determination module for determining the relative power levels of at least two different types of received synchronization signals.

23. The wireless terminal of claim **21**, wherein said at least two different types of received synchronization signals are pilot tone signals and OFDM beacon signals.

24. The wireless terminal of claim **21**, wherein said base station mode determination module further includes a base station mode decision module for determining the mode of base station operation based on the relative power level of at least two different synchronization signals.

25. The wireless terminal of claim **21**, wherein said base station mode determination module determines the mode of base station operation based on the rate of at least one type of synchronization signal; and

wherein said base station mode determination module includes a rate analysis module for distinguishing between received synchronization signal rates corresponding to different modes of base station operation.

26. The wireless terminal of claim **25**, wherein said synchronization signals are pilot tone signals.

27. A wireless terminal for communicating with a base station which supports a reduced synchronization signaling mode of operation and a full on synchronization mode of operation, the wireless terminal comprising:

means for transmitting signals;

means for determining if said base station is operating in said reduced synchronization signaling mode of operation; and

means for controlling said means for transmitting to transmit a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation when said means for determining that said base station is operating in said reduced synchronization mode of operation.

28. The wireless terminal of claim **27**, further comprising:

means for receiving synchronization signals from said base station; and

wherein said means for determining processes received synchronization signals to evaluate at least one of i) synchronization signal power levels and ii) a rate of at least some synchronization signals.

29. The wireless terminal of claim **28**, wherein said means for determining includes:

means for determining the relative power levels of at least two different types of received synchronization signals.

30. The wireless terminal of claim **28**, wherein said at least two different types of received synchronization signals are pilot tone signals and OFDM beacon signals.

31. The wireless terminal of claim **28**, wherein said means for determining if said base station is operating in said reduced synchronization signaling mode farther includes means for determining the mode of base station operation based on the relative power level of at least two different synchronization signals.

32. A computer readable medium including machine executable instructions, for use in a wireless terminal, the computer readable medium comprising:

instructions for causing the wireless terminal to determine if a base station to which the wireless terminal is seeking to establish a user data channel is in a reduced synchronization signaling mode of operation; and

instructions for causing the wireless terminal to transmit a signal used to trigger the base station to transition into a more active synchronization signaling mode of operation, when said wireless terminal determines that said base station is in a reduced synchronization signaling mode of operation.

33. The computer readable medium of claim **32**, wherein the computer readable medium further comprises:

instructions for causing the wireless terminal to receive synchronization signals from said base station; and

instructions for causing the wireless terminal to make said determination based on the received synchronization signals.

34. The computer readable medium of claim **33**, wherein the instructions for causing the wireless terminal to make said determination based on the received synchronization signals includes instructions for causing the wireless terminal to evaluate signal power levels to determine a base station mode of operation.

* * * * *

UNITED STATES PATENT AND TRADEMARK OFFICE

CERTIFICATE OF CORRECTION

PATENT NO. : 7,567,791 B2
APPLICATION NO. : 11/229847
DATED : July 28, 2009
INVENTOR(S) : Laroia et al.

It is certified that error appears in the above-identified patent and that said Letters Patent is hereby corrected as shown below:

Column 34, line 27, claim 32: “farther includes” to read as --further includes--

Signed and Sealed this
Twelfth Day of July, 2011

David J. Kappos

David J. Kappos
Director of the United States Patent and Trademark Office