US 20060282518A1

(19) **United States**

(12) **Patent Application Publication** (10) **Pub. No.: US 2006/0282518 A1**

Karaoguz et al. (43) **Pub. Date: Dec. 14, 2006**

(54) **MULTI-MODE CONTROLLER**

(76) Inventors: **Jeyhan Karaoguz**, Irvine, CA (US); **Nambi Seshadri**, Irvine, CA (US)

Correspondence Address:
MCANDREWS HELD & MALLOY, LTD
500 WEST MADISON STREET
SUITE 3400
CHICAGO, IL 60661

(21) Appl. No.: **11/505,745**

(22) Filed: **Aug. 17, 2006**

Related U.S. Application Data

(63) Continuation of application No. 09/866,546, filed on May 25, 2001, now Pat. No. 7,114,010.

(60) Provisional application No. 60/214,620, filed on Jun. 28, 2000. Provisional application No. 60/238,833, filed on Oct. 6, 2000.

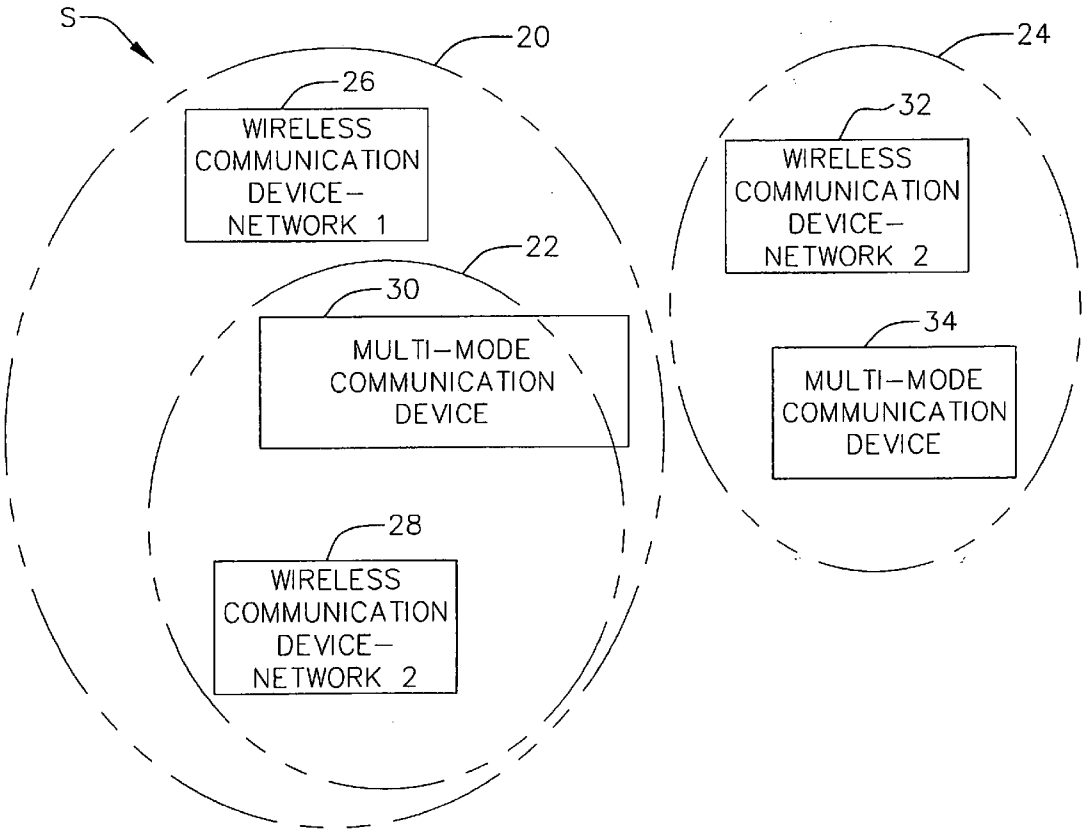
Publication Classification

(51) **Int. Cl.**
G06F 15/177 (2006.01)

(52) **U.S. Cl.** **709/221**

(57) **ABSTRACT**

A method and system for wireless communication is provided and may include, scanning by a wireless communication device, a plurality of radio frequencies for beacon messages from a plurality of master communication devices, in order to identify whether establishment of communication with at least one of said plurality of time-synchronous RF networks is possible. Each of the plurality of master communication devices may be associated with one of a plurality of time-synchronous RF networks. A network associated with one of the beacon messages may be selected based on predefined criteria. The selected network may be one of the plurality of time-synchronous RF networks. Communication may be established with said selected network by the wireless communication device. The plurality of time-synchronous RF networks may comprise a Bluetooth network and/or IEEE 802.11 Wireless Local Area (WLAN) network.



APPLE 1056

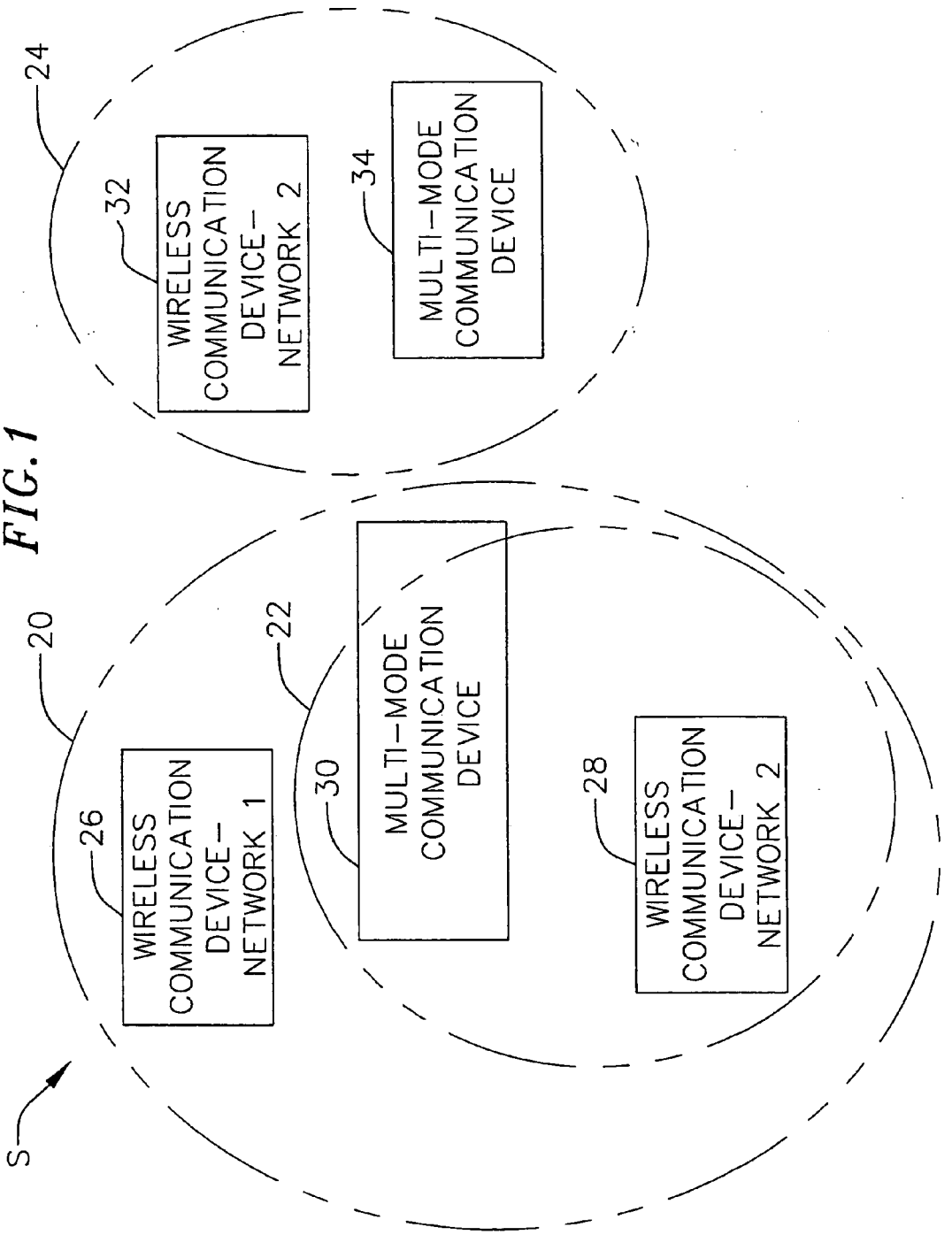

24
32
WIRELESS COMMUNICATION DEVICE– NETWORK 2
34
MULTI–MODE COMMUNICATION DEVICE
20
22
MULTI–MODE COMMUNICATION DEVICE
26
WIRELESS COMMUNICATION DEVICE– NETWORK 1
30
28
WIRELESS COMMUNICATION DEVICE– NETWORK 2
S

FIG. 1

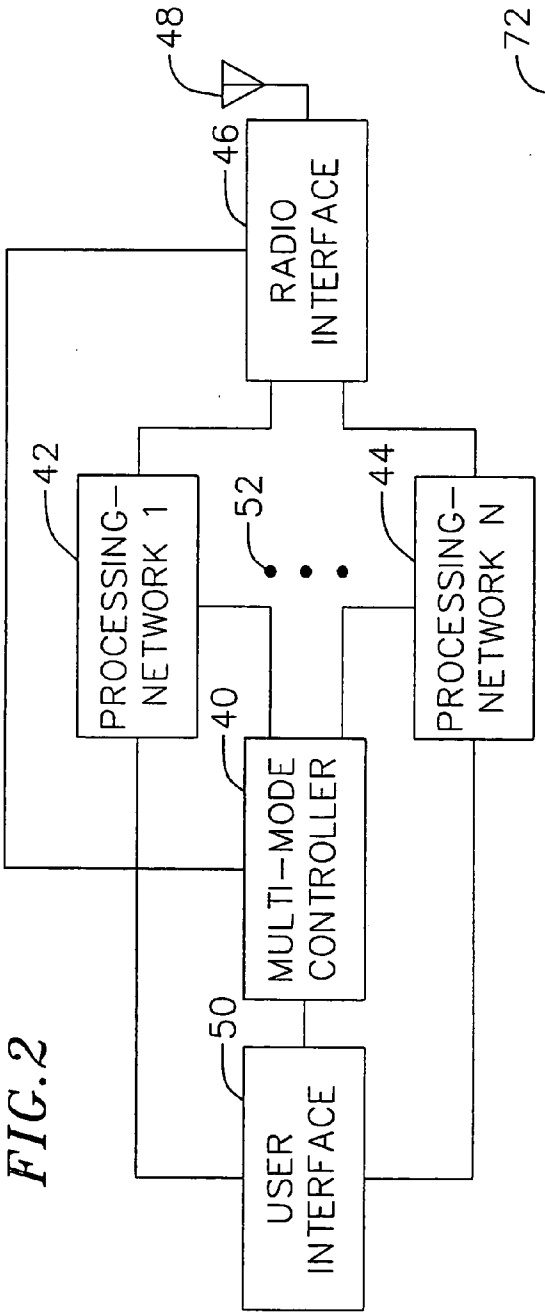

48
46
RADIO INTERFACE
42
PROCESSING-NETWORK 1
52
44
PROCESSING-NETWORK N
40
MULTI-MODE CONTROLLER
50
USER INTERFACE

FIG. 2

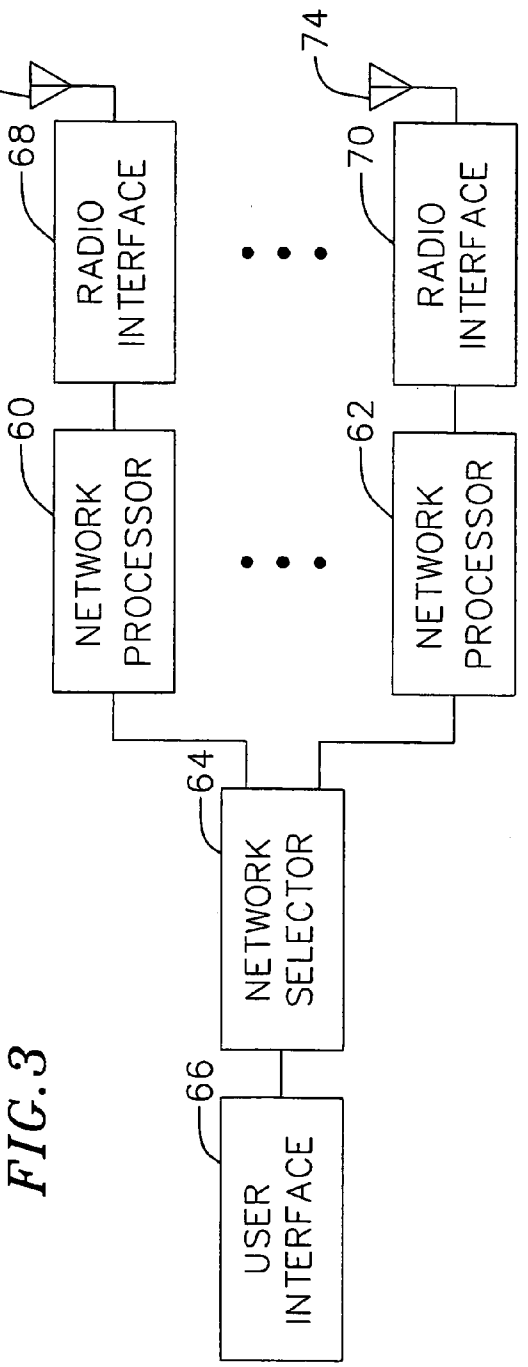

72
68
RADIO INTERFACE
74
70
RADIO INTERFACE
60
NETWORK PROCESSOR
62
NETWORK PROCESSOR
64
NETWORK SELECTOR
66
USER INTERFACE

FIG. 3

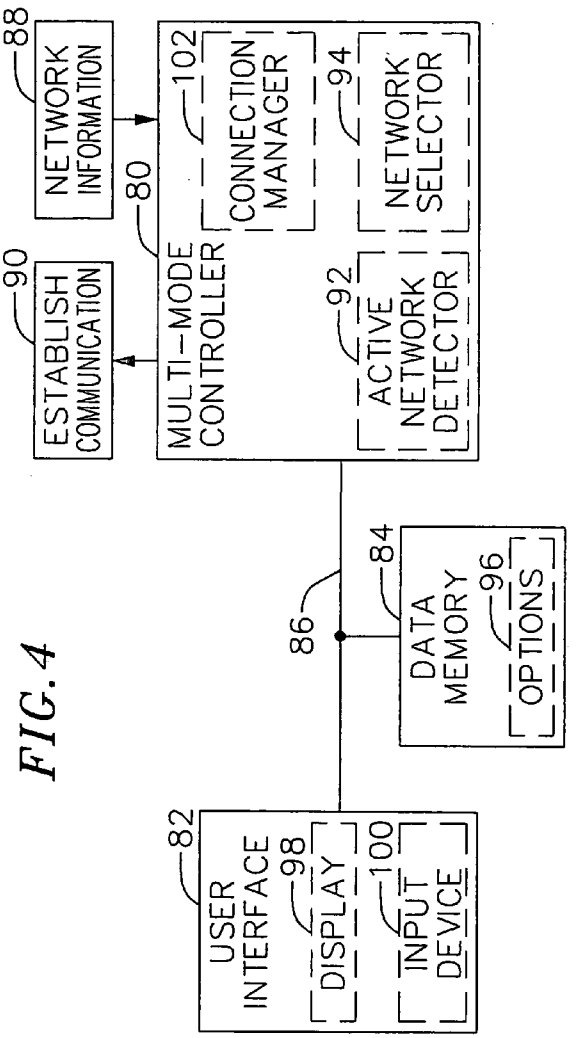

88
NETWORK INFORMATION
90
ESTABLISH COMMUNICATION
80
MULTI-MODE CONTROLLER
102
CONNECTION MANAGER
94
NETWORK SELECTOR
92
ACTIVE NETWORK DETECTOR
86
84
DATA MEMORY
96
OPTIONS
82
USER INTERFACE
98
DISPLAY
100
INPUT DEVICE

FIG. 4

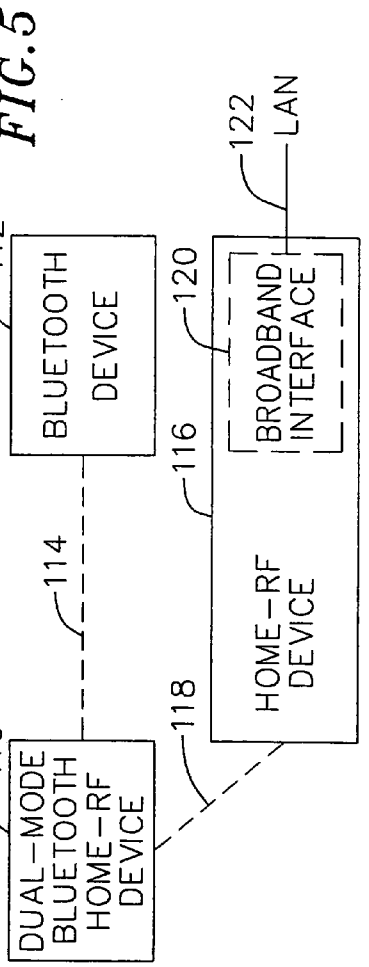

112
BLUETOOTH DEVICE
114
110
DUAL-MODE BLUETOOTH HOME-RF DEVICE
118
116
HOME-RF DEVICE
120
BROADBAND INTERFACE
122
LAN

FIG. 5

FIG. 6

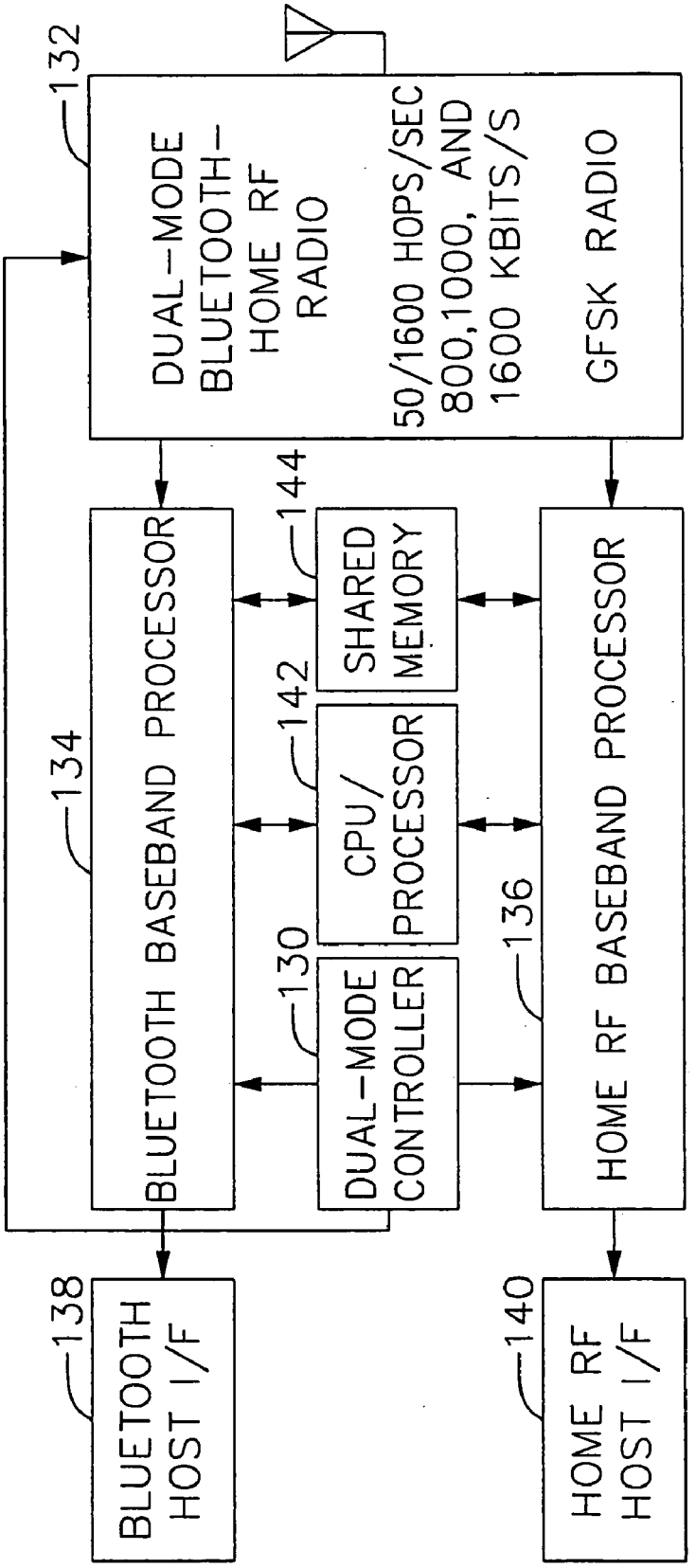

132
DUAL-MODE BLUETOOTH-HOME RF RADIO
50/1600 HOPS/SEC 800,1000, AND 1600 KBITS/S
GFSK RADIO
144
SHARED MEMORY
134
BLUETOOTH BASEBAND PROCESSOR
142
CPU/ PROCESSOR
130
DUAL-MODE CONTROLLER
136
HOME RF BASEBAND PROCESSOR
138
BLUETOOTH HOST I/F
140
HOME RF HOST I/F

FIG. 7

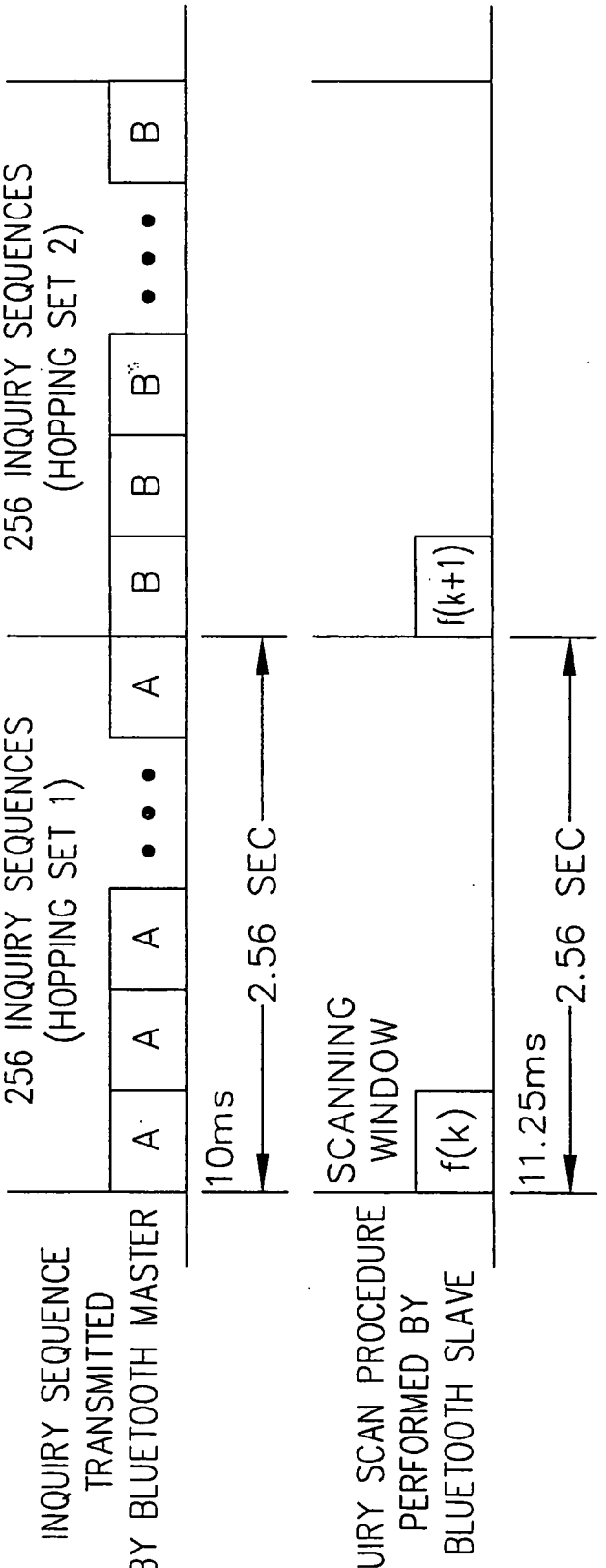

INQUIRY SEQUENCE TRANSMITTED BY BLUETOOTH MASTER
256 INQUIRY SEQUENCES (HOPPING SET 1)
256 INQUIRY SEQUENCES (HOPPING SET 2)
A
A
A
A
B
B
B*
B
10ms
2.56 SEC
INQUIRY SCAN PROCEDURE PERFORMED BY BLUETOOTH SLAVE
SCANNING WINDOW
f(k)
f(k+1)
11.25ms
2.56 SEC

FIG.8

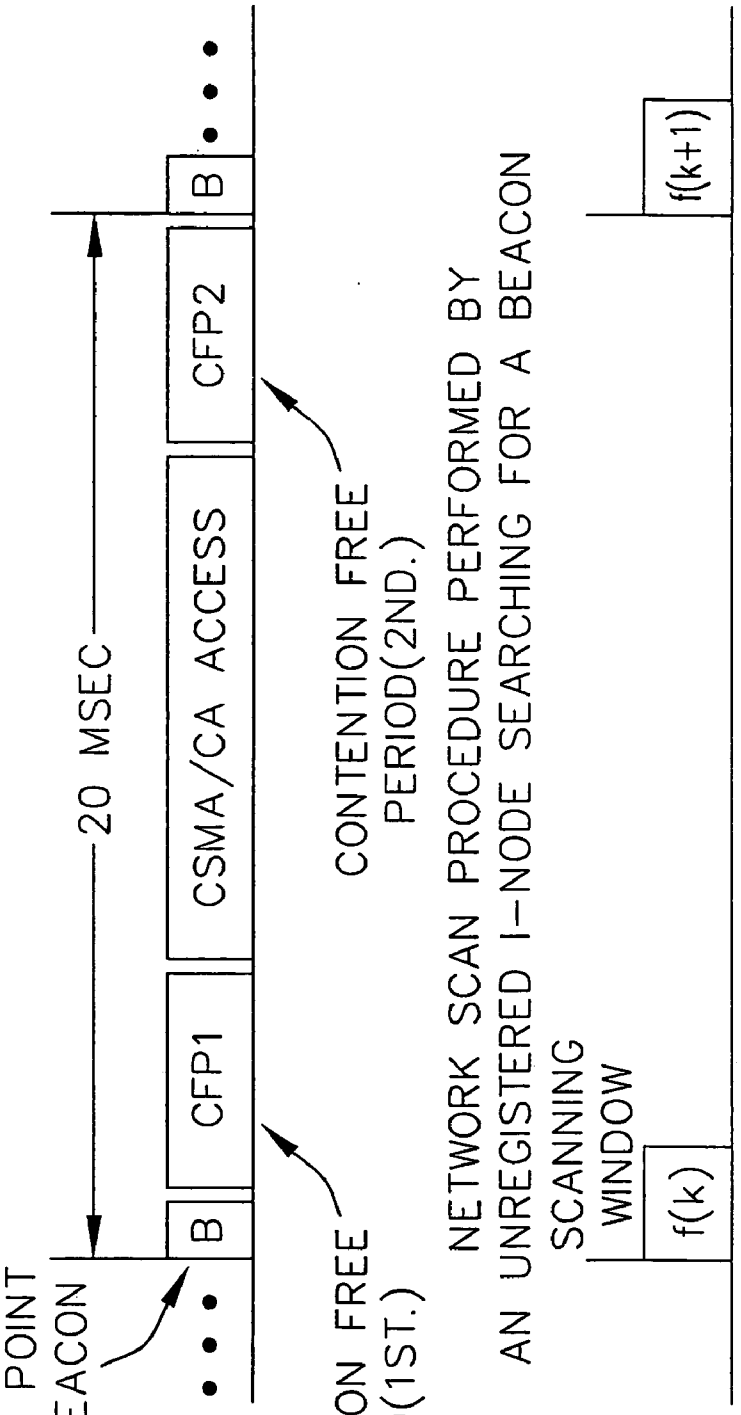

HOME RF ON-AIR SUPERFRAME STRUCTURE
UNDER CONTROL POINT MANAGEMENT
20 MSEC
CONTROL POINT
TDMA BEACON
B
CFP1
CSMA/CA ACCESS
CFP2
B
CONTENTION FREE
PERIOD(1ST.)
CONTENTION FREE
PERIOD(2ND.)
NETWORK SCAN PROCEDURE PERFORMED BY
AN UNREGISTERED I-NODE SEARCHING FOR A BEACON
SCANNING
WINDOW
f(k)
f(k+1)

FIG. 9

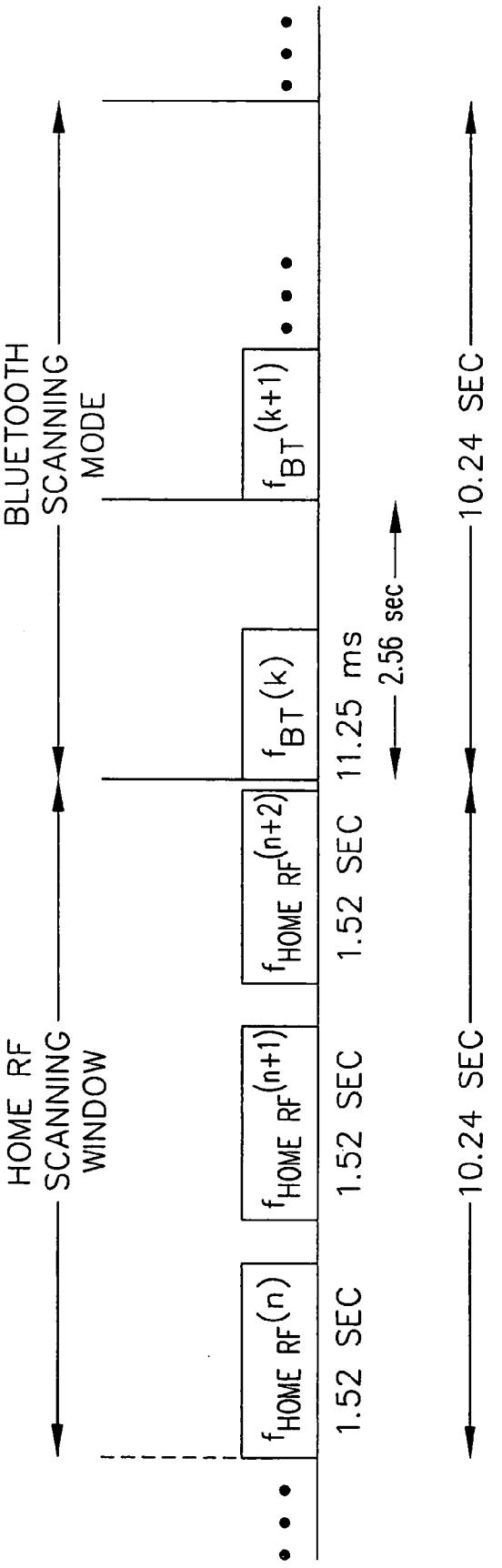

HOME RF SCANNING WINDOW
BLUETOOTH SCANNING MODE
$f_{HOME\ RF}(n)$
$f_{HOME\ RF}(n+1)$
$f_{HOME\ RF}(n+2)$
$f_{BT}(k)$
$f_{BT}(k+1)$
1.52 SEC
1.52 SEC
1.52 SEC
11.25 ms
2.56 sec
10.24 SEC
10.24 SEC

FIG. 10

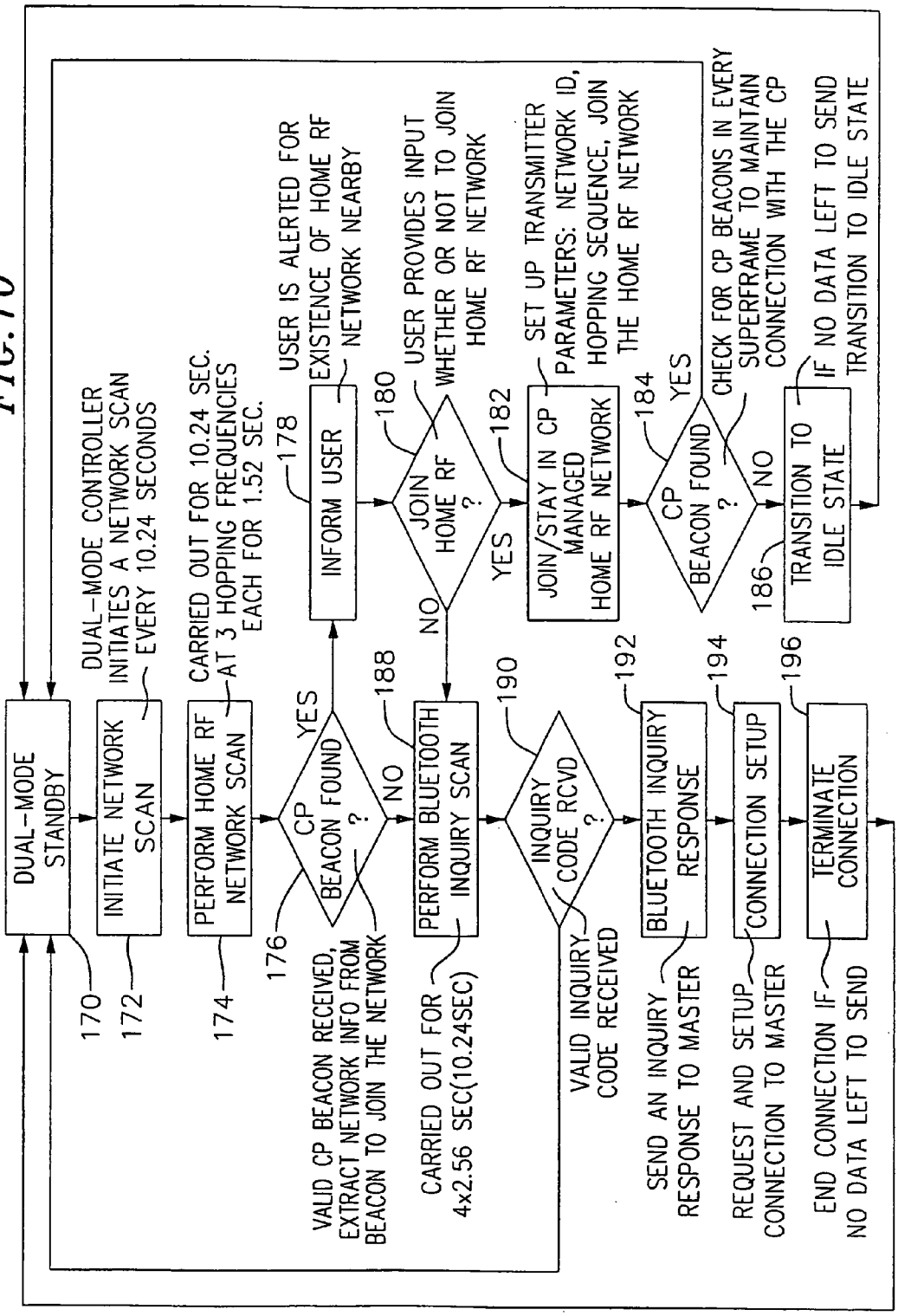

DUAL-MODE STANDBY
170
INITIATE NETWORK SCAN
172
DUAL-MODE CONTROLLER INITIATES A NETWORK SCAN EVERY 10.24 SECONDS
PERFORM HOME RF NETWORK SCAN
174
CARRIED OUT FOR 10.24 SEC. AT 3 HOPPING FREQUENCIES EACH FOR 1.52 SEC.
CP BEACON FOUND ?
176
YES
VALID CP BEACON RECEIVED, EXTRACT NETWORK INFO FROM BEACON TO JOIN THE NETWORK
INFORM USER
178
USER IS ALERTED FOR EXISTENCE OF HOME RF NETWORK NEARBY
JOIN HOME RF ?
180
NO
USER PROVIDES INPUT WHETHER OR NOT TO JOIN HOME RF NETWORK
188
PERFORM BLUETOOTH INQUIRY SCAN
CARRIED OUT FOR 4x2.56 SEC(10.24SEC)
YES
182
JOIN/STAY IN CP MANAGED HOME RF NETWORK
SET UP TRANSMITTER PARAMETERS: NETWORK ID, HOPPING SEQUENCE, JOIN THE HOME RF NETWORK
184
CP BEACON FOUND ?
YES
CHECK FOR CP BEACONS IN EVERY SUPERFRAME TO MAINTAIN CONNECTION WITH THE CP
NO
186
TRANSITION TO IDLE STATE
IF NO DATA LEFT TO SEND TRANSITION TO IDLE STATE
INQUIRY CODE RCVD ?
190
VALID INQUIRY CODE RECEIVED
192
BLUETOOTH INQUIRY RESPONSE
SEND AN INQUIRY RESPONSE TO MASTER
194
CONNECTION SETUP
REQUEST AND SETUP CONNECTION TO MASTER
196
TERMINATE CONNECTION
END CONNECTION IF NO DATA LEFT TO SEND

FIG. 11

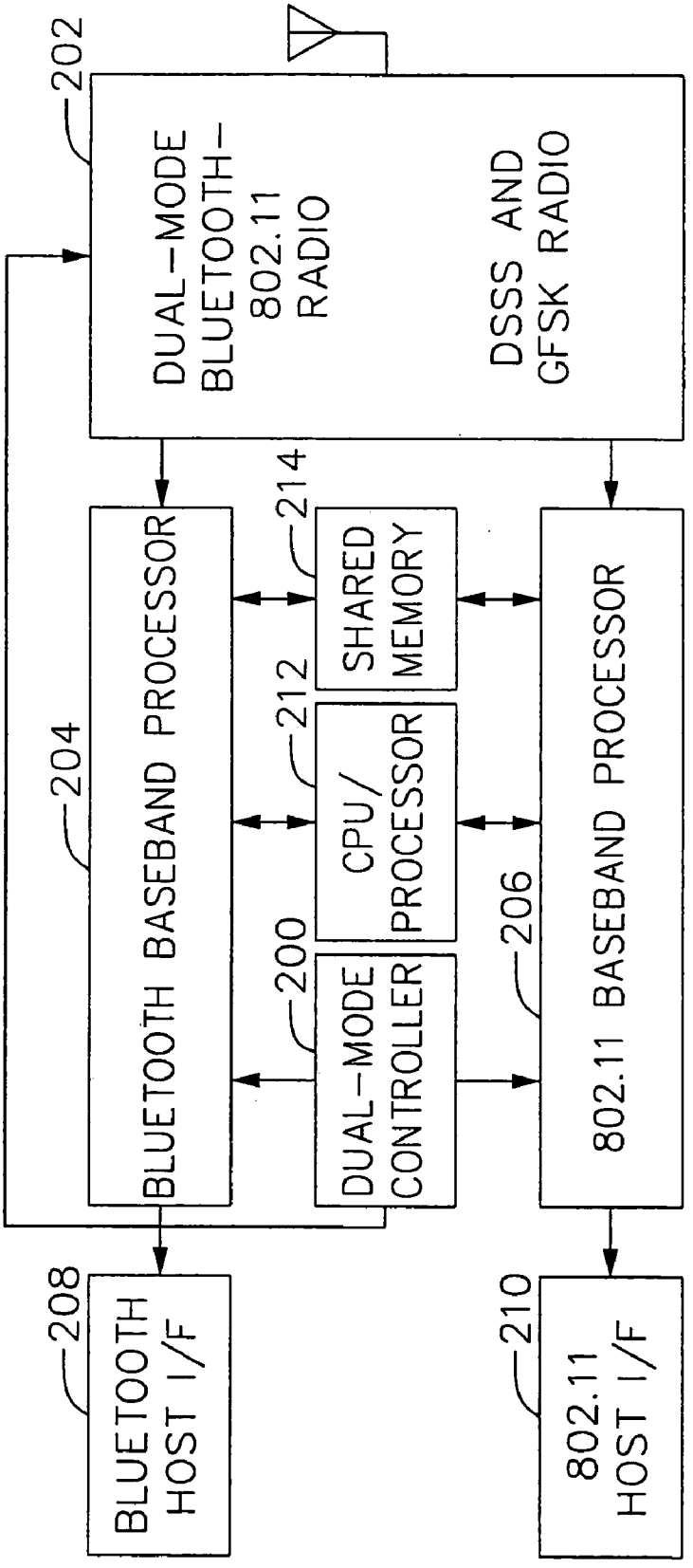

202
DUAL-MODE BLUETOOTH-802.11 RADIO
DSSS AND GFSK RADIO
214
SHARED MEMORY
204
BLUETOOTH BASEBAND PROCESSOR
212
CPU/ PROCESSOR
200
DUAL-MODE CONTROLLER
206
802.11 BASEBAND PROCESSOR
208
BLUETOOTH HOST I/F
210
802.11 HOST I/F

FIG. 12

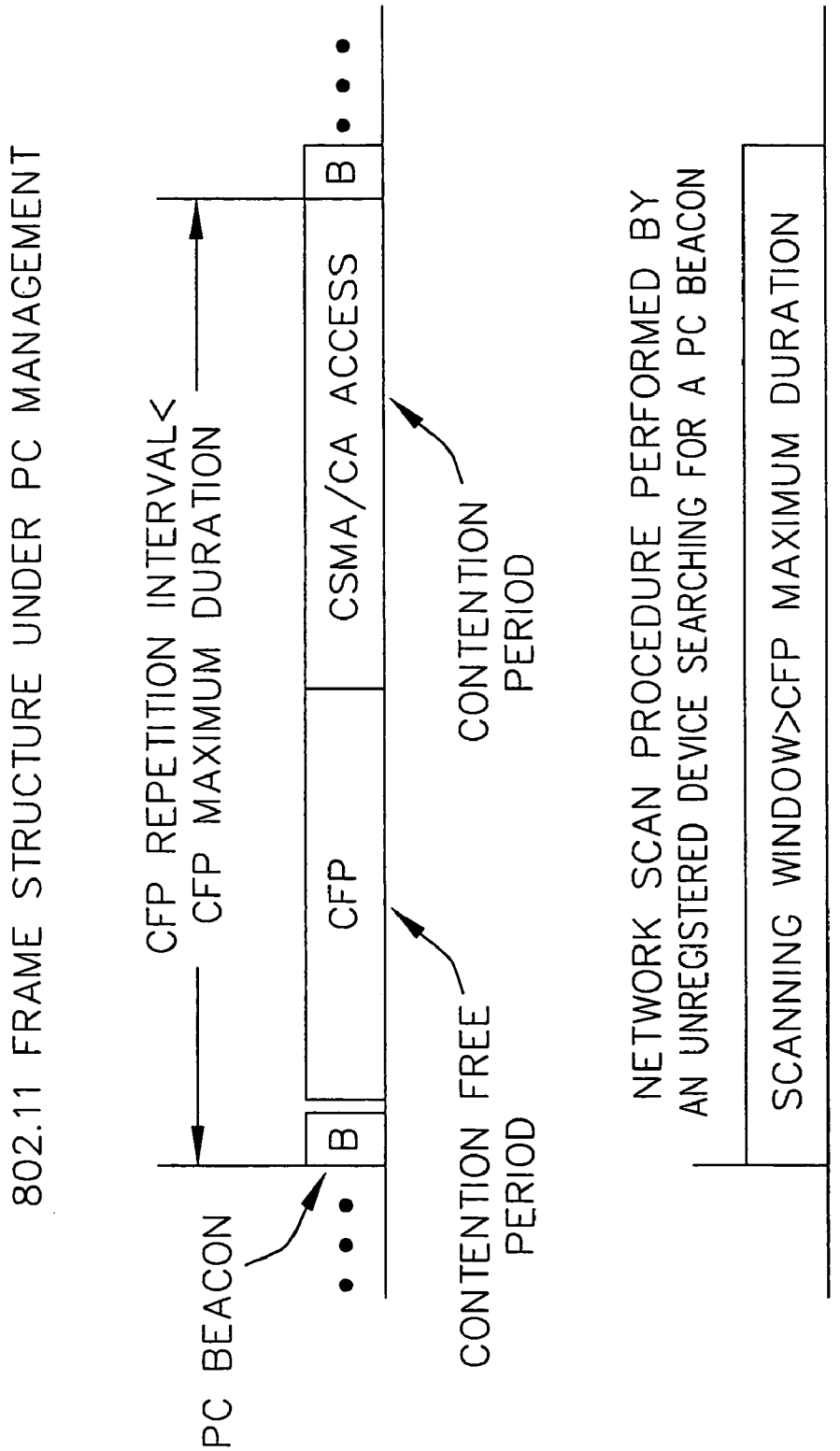

802.11 FRAME STRUCTURE UNDER PC MANAGEMENT
CFP REPETITION INTERVAL<
CFP MAXIMUM DURATION
PC BEACON
B
CFP
CONTENTION FREE PERIOD
B
CSMA/CA ACCESS
CONTENTION PERIOD
NETWORK SCAN PROCEDURE PERFORMED BY AN UNREGISTERED DEVICE SEARCHING FOR A PC BEACON
SCANNING WINDOW>CFP MAXIMUM DURATION

FIG. 13

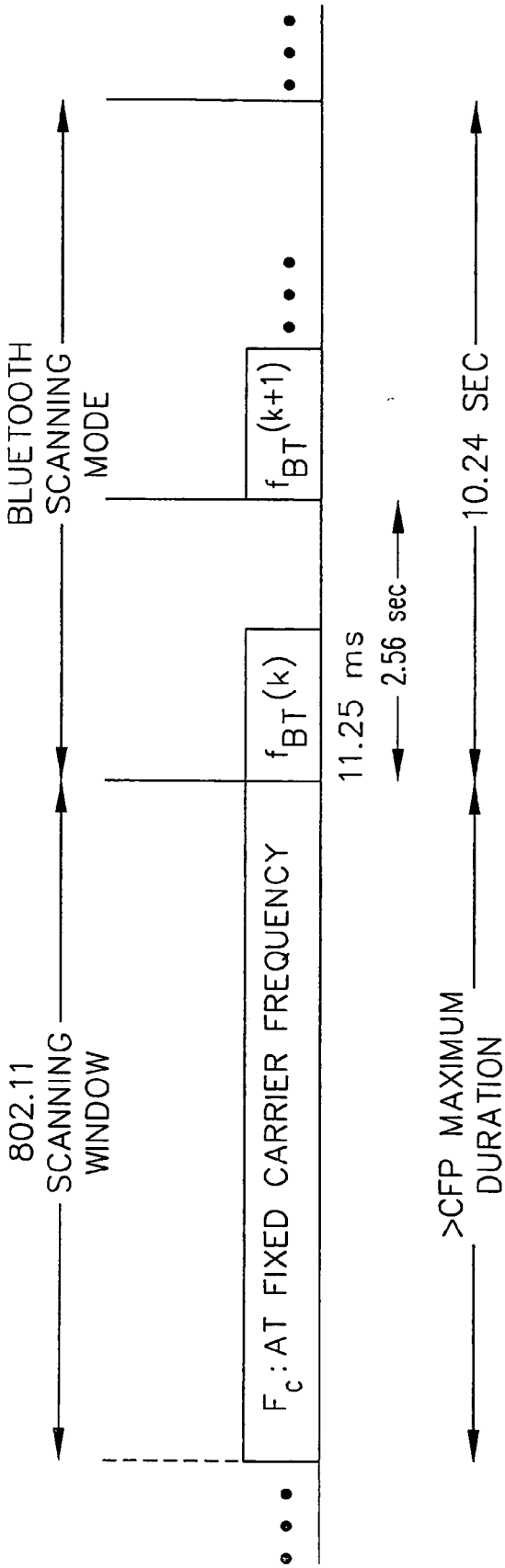
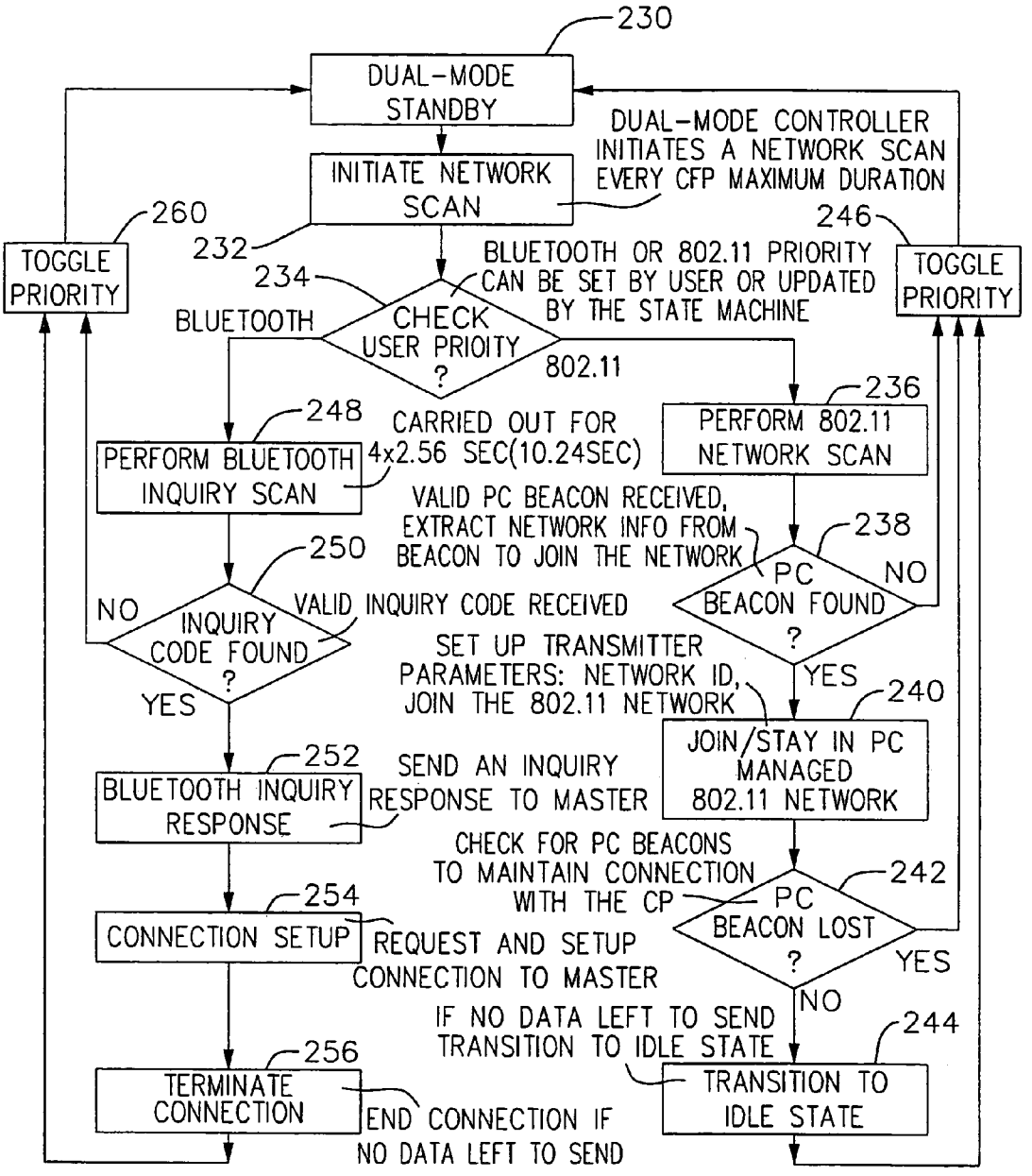

802.11
SCANNING
WINDOW
BLUETOOTH
SCANNING
MODE
F_c: AT FIXED CARRIER FREQUENCY
$f_{BT}(k)$
$f_{BT}(k+1)$
11.25 ms
2.56 sec
>CFP MAXIMUM
DURATION
10.24 SEC

FIG. 14


230
DUAL-MODE STANDBY
DUAL-MODE CONTROLLER INITIATES A NETWORK SCAN EVERY CFP MAXIMUM DURATION
INITIATE NETWORK SCAN
260
232
246
TOGGLE PRIORITY
TOGGLE PRIORITY
234
BLUETOOTH OR 802.11 PRIORITY CAN BE SET BY USER OR UPDATED BY THE STATE MACHINE
BLUETOOTH
CHECK USER PRIOITY ?
802.11
236
248
CARRIED OUT FOR 4x2.56 SEC(10.24SEC)
PERFORM BLUETOOTH INQUIRY SCAN
PERFORM 802.11 NETWORK SCAN
VALID PC BEACON RECEIVED, EXTRACT NETWORK INFO FROM BEACON TO JOIN THE NETWORK
238
250
NO
VALID INQUIRY CODE RECEIVED
PC BEACON FOUND ?
NO
INQUIRY CODE FOUND ?
SET UP TRANSMITTER PARAMETERS: NETWORK ID, JOIN THE 802.11 NETWORK
YES
YES
240
JOIN/STAY IN PC MANAGED 802.11 NETWORK
252
SEND AN INQUIRY RESPONSE TO MASTER
BLUETOOTH INQUIRY RESPONSE
CHECK FOR PC BEACONS TO MAINTAIN CONNECTION WITH THE CP
242
254
PC BEACON LOST ?
YES
CONNECTION SETUP
REQUEST AND SETUP CONNECTION TO MASTER
NO
IF NO DATA LEFT TO SEND TRANSITION TO IDLE STATE
244
256
TERMINATE CONNECTION
TRANSITION TO IDLE STATE
END CONNECTION IF NO DATA LEFT TO SEND

MULTI-MODE CONTROLLER

CROSS-REFERENCE TO RELATED APPLICATION(S)

[0001] This application claims the benefit of U.S. Provisional Application No. 60/214,620, filed Jun. 28, 2000 and U.S. Provisional Application No. 60/238,833, filed Oct. 6, 2000.

FIELD OF THE INVENTION

[0002] The invention relates generally to data communications and, more particularly, to systems and methods for controlling and managing network access in wireless communication systems.

BACKGROUND OF THE INVENTION

[0003] Demand for wireless information services had led to the development of an ever increasing number of wireless network standards. For example, cellular and PCS networks, to name just two, provide wide area wireless telephone and data services. As the demand for these services increases, portable communication devices such as personal digital assistants (PDAs) are evolving to support integrated voice, data, and streaming media while providing seamless network coverage from personal area networks (PAN) to wide area networks (WAN). On the wireless WAN side, the prevailing standards are 2G+, 3G and 4G, among others. On the wireless PAN and local area networks (LAN) side, Bluetooth, HomeRF, and IEEE 802.11b standards are emerging as important standards. A Bluetooth network may provide data connectivity between devices such as personal computer and personal digital assistants (PDAs) that are in relatively close proximity to one another. A HomeRF network may provide wireless services at relatively high data rates over a small area of coverage such as a person's home.

[0004] Boundaries between wireless WANs (including cellular networks) and LANs (e.g., home wireless LANs and other small pockets of wireless networks) are essentially disappearing as customers demand seamless continuation of service for their mobile communication device as they travel from their PAN to home network and further into the WANs.

[0005] However, in general, devices that are compatible with one wireless network are incompatible with other wireless networks. This is due, in part, to each network's use of its own unique set of protocols for facilitating communication between compatible devices.

[0006] Moreover, each network typically provides a unique set of services. Networks may provide different data transmission rates, for example, a GSM cellular telephone network typically supports data transfer rates of 64 kilobits per second (kbit/s) while a HomeRF network may support data transfer rates of 2-10 megabits per second. Networks also may provide service having different areas of coverage. For example, cellular networks provide coverage on a continental scale while Bluetooth networks typically provide coverage over the range of approximately 10 meters. Networks also may provide different information content to a user of the network. Legacy cellular telephone networks simply provided voice services. Newer networks such as PCS networks may support voice, data and other information services.

[0007] In effect, these disparate networks have created a series of islands of wireless service throughout the geographical landscape, each with its own unique set of protocol standards, data rates, areas of coverage and services. Yet there are no single wireless technologies or standards that effectively satisfy the requirements of desired coverage area (from PAN to WAN) and quality of service (high bandwidth data, voice, and streaming media) for mobile multimedia devices.

SUMMARY OF THE INVENTION

[0008] The invention is directed to systems and methods for enabling a wireless communication device to communicate with a variety of wireless networks. In particular, a portable communication device constructed according to the invention can communicate with different networks as the device is moved through the areas of coverage supported by the different networks. To this end the invention provides techniques for controlling and managing network access to several networks. As a result, a device constructed according to the invention can take advantage of services provides by a particular network when the device is within the area of coverage provided by that network. For example, when the device is within the area of coverage of a network that provides high speed Internet access, the device may switch from the network with which it was connected to the network with the high speed Internet access. Similarly, the device may, for example, connect to networks that provide different quality of service, low cost service and/or different services (e.g., voice, data, multimedia, etc.).

[0009] In one embodiment, the invention relates to systems and methods for implementing multi-mode wireless communication devices such as PDAs or multi-function (e.g. data, voice, and multimedia) mobile phones that best take advantage of the wireless networks in their proximity. That is, in the case where a nearby wireless network (WAN, LAN, or PAN) happens to provide more data bandwidth and/or better quality of service (QoS), a multi-mode wireless device may switch to that particular wireless network to access these services. Several network coverage scenarios include, for example:

[0010] (1) a PDA or a multi-function mobile phone connected to a low bandwidth internet service while located within a WAN could take advantage of a broadband internet service while located at home through a wireless LAN;

[0011] (2) a cellular phone could switch to a cordless telephone mode when at home to make calls over the wired infrastructure to avoid air-time charges;

[0012] (3) a PDA or a multi-function cell phone traveling through a WAN may encounter an island of high bandwidth wireless coverage (Bluetooth, HomeRF, 802.11b, etc.) in which case it could switch to a Bluetooth, HomeRF, or 802.11b mode to access the provided services;

[0013] (4) A Bluetooth enabled mobile WAN device may recognize and establish connection with a nearby HomeRF network; and

[0014] (5) A Bluetooth enabled mobile WAN device WAN device may recognize and establish connection with a nearby IEEE 802.11b network.

[0015] One embodiment of a system constructed according to the invention consists of a multi-mode controller that, in effect, simultaneously processes communication signals for several wireless networks. The multi-mode controller processes signals to detect the presence of network services and, in the event services are detected, selectively establishes communications between the device and the network.

[0016] One embodiment of a system constructed according to the invention consists of a dual-mode Bluetooth and HomeRF controller. The dual-mode controller, in effect, simultaneously generates polling signals and scans for polling signals to detect the presence of Bluetooth and HomeRF network services. In the event such services are detected, the device selectively establishes communications between the device and one of the two networks.

[0017] One embodiment of a system constructed according to the invention consists of a dual-mode Bluetooth and IEEE 802.11b controller. The dual-mode controller, in effect, simultaneously generates polling signals and scans for polling signals to detect the presence of Bluetooth and IEEE 802.11b network services. In the event such services are detected, the device selectively establishes communications between the device and one of the two networks.

BRIEF DESCRIPTION OF THE DRAWINGS

[0018] These and other features, aspects and advantages of the present invention will be more fully understood when considered with respect to the following detailed description, appended claims and accompanying drawings, wherein:

[0019] **FIG. 1** is a graphical representation of one embodiment of wireless communication networks defining different areas of coverage wherein a device constructed according to the invention may establish communication with one or more of the wireless communication networks;

[0020] **FIG. 2** is a block diagram of one embodiment of a multi-mode radio transmitter/receiver constructed in accordance with the invention;

[0021] **FIG. 3** is a block diagram of one embodiment of a multi-mode radio transmitter/receiver constructed in accordance with the invention;

[0022] **FIG. 4** is a block diagram of one embodiment of a multi-mode controller and user interface in accordance with the invention;

[0023] **FIG. 5** is a graphical representation of one embodiment of a communications system including Bluetooth and HomeRF networks wherein a device constructed according to the invention may establish communication with the Bluetooth and HomeRF networks;

[0024] **FIG. 6** is a block diagram of one embodiment of a dual mode Bluetooth and HomeRF radio transmitter/receiver constructed in accordance with the invention;

[0025] **FIG. 7** is a graphical representation of a Bluetooth network access procedure;

[0026] **FIG. 8** is a graphical representation of a HomeRF network access procedure;

[0027] **FIG. 9** is a graphical representation of one embodiment of a dual-mode Bluetooth and HomeRF network access procedure in accordance with the invention;

[0028] **FIG. 10** is a flowchart representative of one embodiment of a Bluetooth and HomeRF dual-mode controller state transition diagram in accordance with the invention;

[0029] **FIG. 11** is a block diagram of one embodiment of a dual mode Bluetooth and IEEE 802.11b radio transmitter/receiver constructed in accordance with the invention;

[0030] **FIG. 12** is a graphical representation of a IEEE 802.11b network access procedure;

[0031] **FIG. 13** is a graphical representation of one embodiment of a dual-mode Bluetooth and IEEE 802.11b network access procedure in accordance with the invention; and

[0032] **FIG. 14** is a flowchart representative of one embodiment of a Bluetooth and IEEE 802.11b dual-mode controller state transition diagram in accordance with the invention.

DETAILED DESCRIPTION OF THE INVENTION

[0033] The invention is described below, with reference to detailed illustrative embodiments. It will be apparent that the invention can be embodied in a wide variety of forms, some of which may be quite different from those of the disclosed embodiments. Consequently, the specific structural and functional details disclosed herein are merely representative and do not limit the scope of the invention.

[0034] **FIG. 1** is a simplified graphical representation of a communications system S defined by several wireless networks. Dashed lines **20**, **22** and **24** represent hypothetical areas of coverage for a few representative wireless networks. In this embodiment, wireless communication device **26** is associated with one network (designated network **1**) and its associated area of coverage **20**. Similarly, wireless communication devices **28** and **32** are associated with another type of network (designated network **2**) where each wireless communication device **28** and **32** is associated with a distinct area of coverage **22** and **24**, respectively.

[0035] In accordance with one embodiment of the invention, multi-mode communication devices **30** and **34** may communicate with one or more of the wireless communication devices **26**, **28** and **32**. Essentially, each multi-mode communication device **30** or **34** determines whether it is within the area of coverage of a type of network that is supported by the multi-mode communication device. For example, as multi-mode communication device **30** moves from a location outside of area **22** to a location within area **22**, the device **30** may selectively establish communications with a device in the wireless network represent by area **22** (e.g., device **28**).

[0036] Depending on the location of a multi-mode communication device **30** or **34**, the device **30** or **34** may be in an area of coverage for zero, one, two or more networks. Hence, in some situations the device **30** or **34** may need to select a network to which it will connect. As will be discussed in detail below, the decision to connect to a network may be based on different factors including, for example, the data transfer rates provided by the networks.

[0037] Typically, the devices depicted in **FIG. 1** and discussions in the sections that follow are portable devices.

However, it should be understood that the teachings of the invention may be applied to stationary devices in some applications.

[0038] **FIG. 2** is a simplified block diagram illustrating certain components of a multi-mode communication device that may operate with two or more wireless networks. A multi-mode controller **40** controls and manages network access to the wireless networks for the communication device. Processing elements **42** and **44** perform the signal processing associated with a given network. As represented by ellipses **52**, any number of processing elements for any number of networks may be supported, consistent with the teachings of the invention. Thus, the designation "N" for processing element **44** may represent the Nth network supported by the communication device.

[0039] The multi-mode controller **40** and the processing elements **42** and **44** communicate with the network via a radio interface **46**. The radio interface transmits and receives signals (e.g., radio frequency signals such as microwave signals and those in the cellular and PCS bands) to other devices in a network via an antenna **48**.

[0040] A user interface **50** enables a user (not shown) to transmit and receive information to and from a selected network via the corresponding processing elements **42** or **44** and the radio interface **46**.

[0041] **FIG. 3** is a block diagram that represents network selection operations that may be performed in accordance with the invention. In some instances, a multi-mode communication device will select one of two or more available networks. To this end, the device may selectively route information to/from a user interface **66** from/to another device in the selected network. Thus, information will be routed to/from an appropriate network processor element **60** or **62**. This selection may be based on many factors. The device may select a network with, for example, 1) a higher bandwidth; 2) a broader area of coverage; 3) less expensive connection costs; 4) different QoS; or 5) better services (e.g., Internet access, multi-media access, etc.).

[0042] In one embodiment, a network selector **64** may consist of a hard switch (e.g., a multiplexor) that routes signals from one component to another. In another embodiment the functions of the network selector **64** may be accomplished using routing software that routes the information to an appropriate hardware component or a software subroutine. In the latter case, the network processing operations may take the form of software routines, whereby the multi-mode controller may control execution of the appropriate routine for the selected network. In this case, the information would then be routed to the enabled routine. Such an embodiment typically would be used in an implementation where the multi-mode controller and network processing functionality is performed by a common processing element such as a digital signal processor.

[0043] **FIG. 3** also illustrates that in some embodiments different radio interfaces **68** and **70** may be use for interfacing with different networks. Also, several antennae may be used in some applications.

[0044] **FIG. 4** further illustrates operations related to selecting a network. A multi-mode controller **80** receives network information **88** indicative of whether the device is within range of a supported network. An active network detector **92** processes the received network information to determine whether the device is within range of a supported network. In some embodiments, network detection involves sequentially sending and/or scanning for network polling information associated with each network.

[0045] A network selector **94** may be used to determine whether to connect to a detected network. In some instances the device may be configured to only connect to certain types of networks. In other instances the device may be configured to choose between two or more detected networks.

[0046] In practice, the decision to select a particular network may be based on a variety of factors. A given network may provide better quality of service than another network. One network may provide faster rates of data transfer. One network may provide less congestion. A network may be less expensive to use. A network may provide content (e.g., Internet access) that another network does not provide. One network may provide information services (e.g., voice, data, multimedia) that are not provided by another network.

[0047] Many different schemes may be used to connect to a given network. For example, a device constructed according to the invention may query the user so that the user can decide whether to connect to a particular network. For example, the multi-mode controller may send a message that is displayed on a display **98** in the user interface **82**. The user may then use an input device **100** to send instructions to the multi-mode controller **80** regarding the user's selection.

[0048] Alternatively, a device constructed according to the invention may automatically connect to a network. In the embodiment of **FIG. 4**, a data memory **84** may include information **96** that indicates, for example, that the device should: 1) never connect to a particular network; 2) always connect to a particular network if that network is detected; 3) prompt the user of the device for input as to whether the user wishes to connect to the network; and/or 4) connect to the network depending on other options. Examples of options in the last category (number four) include a switch on the device indicative of the user's preference under certain conditions or comparison of the service (e.g., available bandwidth, quality of service, networks costs) available from each network.

[0049] Once a network has been selected, a connection manager **102** establishes communication with the network by, for example, causing the appropriate network processor **60** or **62** (**FIG. 3**) to send the necessary signals to another device in the network (as represented by block **90**).

[0050] One embodiment of the invention relates to a method for a multi-mode wireless communication device to access and take advantage of the proximity wireless network that best satisfies its service needs. In particular, this embodiment includes a dual-mode wireless network chip set architecture that combines wireless PAN and LAN functions. The dual-mode operation is achieved by a device called a dual-mode controller (DMC) which controls and manages network access to a nearby PAN or a LAN.

[0051] **FIG. 5** depicts one embodiment of the invention that enables a device to utilize Bluetooth and HomeRF networks. Central to this embodiment is a Bluetooth and HomeRF dual mode controller as discussed in more below.

[0052] A Bluetooth network is categorized as a personal area network (PAN). PANs such as Bluetooth typically have a range on the order of ten meters. Conventionally, Bluetooth devices support data transfer rates in the range of 1 Mbit/s. Current Bluetooth specifications include Bluetooth versions 1.0 and 1.1.

[0053] In some instances, Bluetooth networks may be used in ad hoc peer-to-peer communications. Examples of communications over a Bluetooth network may include data transfers between a PDA and a nearby laptop computer or between a digital camera and a personal computer. In addition, an MP3 player may communicate with a computer or "juke box" over a Bluetooth network.

[0054] A HomeRF network is categorized as a local area network (LAN) and, as such, typically supports communications over a area of coverage of approximately 100 meters. Conventional HomeRF devices support data transfer rates on the order of two to ten Mbit/s. Current HomeRF specifications include the Shared Wireless Access Protocol Specification, versions 1.3 and 2.0.

[0055] Typically, a wireless PAN connects to a backbone that provides data connectivity to other networks. For example, a wireless PAN interface may connect to a T1 line to provide Internet connectivity. Alternatively a cable modem may include a wireless PAN interface that provides LAN connectivity to wireless devices that are within close proximity to the cable modem.

[0056] Significantly, both Bluetooth and HomeRF incorporate frequency hopping. Thus, in this embodiment of the invention a portion of the RF front end may be effectively shared by the two networks. That is, some of the same circuits in the RF front end are used when the device is communicating with other Bluetooth devices or with other HomeRF devices.

[0057] Referring now to **FIG. 5**, for purposes of explanation, an embodiment of a dual-mode mobile communication device **110** capable of accessing either Bluetooth network devices **112** or HomeRF network devices **116** will be described in the context of a residential gateway (e.g. a cable modem with a HomeRF wireless LAN interface **120**). The residential gateway may provide a multi-user broadband internet access service and multi-channel cordless telephony via HomeRF interface. A PDA or a mobile phone with a dual-mode Bluetooth-HomeRF capability could switch to a HomeRF mode upon entering a home to take advantage of the broadband internet access service, or multi-channel cordless telephony service to avoid airtime charges while making a call.

[0058] In **FIG. 6**, a chip architecture that provides this dual-mode functionality is illustrated. A dual-mode radio front-end **132** can be shared with different frequency hopping and modulation rate parameters between Bluetooth and HomeRF modes of operation. To achieve a dual-mode operation, a new timing mechanism (and respective state machines) is used since both Bluetooth and HomeRF are time-synchronous networks. A dual-mode controller **130** implements this timing mechanism and the state machines to achieve the dual-mode operation.

[0059] The dual-mode controller **130** has the following operational modes:

[0060] Bluetooth-only mode

[0061] HomeRF-only mode

[0062] Dual Bluetooth-HomeRF mode

[0063] In this embodiment, all three modes are set by an external user command. In the Bluetooth-only or HomeRF-only mode, the device operates in the native Bluetooth or HomeRF mode, respectively, i.e., whichever mode the device is in the other mode would be turned off. In the dual Bluetooth-HomeRF mode, Bluetooth and HomeRF baseband processors **134** and **136**, respectively, time-share the dual-mode radio front-end **132** under the time-synchronous management of the dual-mode controller **130**.

[0064] The role of the dual-mode controller **130** may be better understood by first explaining the native Bluetooth and HomeRF network access mechanisms. **FIG. 7** illustrates what is called "inquiry scan procedure" used by new Bluetooth devices to access a nearby Bluetooth network. A Bluetooth master device (by default the first device that formed a Bluetooth network) sends a train of special inquiry sequences to probe if there are any new Bluetooth devices in the vicinity. The special inquiry sequences denoted by "A" and "B" each contain 8 frames where each frame is of time duration 1.25 ms and consists of a master-to-slave transmission slot (0.625 msec) and a slave-to-master transmission slot (0.625 msec). In every master-to-slave transmission slot, the master sends an inquiry access code on two consecutive hopping frequencies, thereby, covering 16 hopping frequencies for every 8 frames that make up the inquiry sequence "A." As shown in **FIG. 7**, the inquiry sequence "A" is repeated 256 times. There are a total of 32 predetermined hopping frequencies allocated to the inquiry procedure. In the event that no inquiry response is received by the master during the first 2.56 sec interval, the remaining set of 16 hopping frequencies are used in transmitting another train of inquiry sequences denoted by "B" as shown in **FIG. 7**.

[0065] New devices entering a Bluetooth network scan for inquiry sequences transmitted by a master device. The inquiry scan mechanism is also shown in **FIG. 7**. A new device scans the RF spectrum at a single hopping frequency for 11.25 ms in every 2.56 seconds interval. For each new scanning window, a new hopping frequency is selected based on a predetermined frequency hopping sequence. Upon receiving a valid inquiry code sequence, the new unit picks a random number N<64 and continues to search for inquiry messages on the same hopping frequency. The unit then transmits an inquiry response message (containing the unit's access ID and other parameters) in the Nth slave-to-master slot corresponding to the master-to-slave slot that carried a valid inquiry code. Sending an inquiry response message at a randomly chosen slave-to-master slot reduces the probability of collision for transmissions by multiple new units responding to the same inquiry access code. The bound on the random number N is chosen such that the inquiry response message is sent to the master unit within the same train of inquiry code sequences "A" or "B". Once the master unit receives an inquiry response message, the actual connection set up procedure is performed.

[0066] **FIG. 8** describes the HomeRF network scan procedure for a new isochronous device (called I-node) to join

a HomeRF network managed by a Control Point (CP). In this case, the CP transmits a distinctive TDMA beacon every 20 msec at the beginning of each superframe. The superframe duration (20 msec) is based on the frequency hopping rate (50 hops/sec), i.e., each superframe is sent at a different hopping frequency. The beacon contains specific information about joining the HomeRF network. A new I-node performs a network scan procedure to search for a CP beacon on one of the three predetermined network scan frequencies for 1.52 seconds.

[0067] Unless a beacon is received, all three scan frequencies are tried (each for 1.52 sec) in search of a CP beacon. If a TDMA beacon is received within the scanning window, the new I-node then extracts the network identity information and the timing information from the beacon to join the HomeRF network.

[0068] HomeRF network access mechanism for a new device is somewhat similar to the Bluetooth network access mechanism. In both cases, the new device seeking admission into the network starts a network scan procedure searching for a special message from a master unit (for a HomeRF network, the master is the CP). This similarity establishes the basis for the operation of the dual-mode controller device. For a dual-mode Bluetooth-HomeRF communication device, the dual-mode controller manages the network access mechanism for both Bluetooth and HomeRF networks in a synchronous manner. A general illustration of the time interleaved access procedure is shown in **FIG. 9**.

[0069] The dual-mode controller (DMC) device includes a new synchronous state machine that combines the standby, inquiry scan, network scan, and connection procedures carried out by Bluetooth and HomeRF devices. The dual-mode Bluetooth-HomeRF devices interoperate with standards based on Bluetooth-only or HomeRF-only devices. Network scan and connection setup procedures for a dual-mode device should follow the same rules as specified in the Bluetooth or HomeRF standards. In other words, dual-mode operation of the described embodiment should not alter the synchronous time flow of interdependent states (idle, network scan, scan response, etc.) that accomplish the respective network access procedures for Bluetooth or HomeRF networks. The exemplary dual-mode controller is configured such that Bluetooth and HomeRF network access state machines are combined without individually altering their functionalities. Detailed description of the dual-mode controller state machine is illustrated in **FIG. 10**.

[0070] The default state for the dual-mode controller is the standby mode. In the absence of any network connection, the dual-mode controller initiates a new network scan request every 10.24 seconds. The very first network scan performed by the dual-mode controller searches for a HomeRF network. In this state, a new device performs a network scan procedure on one of the three HomeRF network scan frequencies for 1.52 sec searching for a CP beacon. Unless a beacon is received, all three scan frequencies are tried (each for 1.52 sec) in search of a CP beacon as shown in **FIG. 9**. Total duration of the HomeRF network scan procedure is 10.24 seconds. If a TDMA beacon is received within the scanning window, the new unit extracts the network identity information and the timing information from the beacon to join the HomeRF network. However, before the new device attempts to join the HomeRF network based on the beacon information, the user is informed via a display message etc. about the existence of a HomeRF network and the types of services that are available. Accordingly, the user may either approve or disapprove joining the HomeRF network for the specified services. If the user directs the dual-mode controller to establish a connection with the HomeRF network, the dual-mode device then joins the HomeRF network and maintains connection until the device transitions into an idle mode or until the CP beacon is no longer received by the unit. In both cases, the dual mode device goes into the dual-mode standby mode. If the user does not approve connecting to a HomeRF network, the dual-mode controller automatically starts an inquiry scan procedure to search for the existence of a Bluetooth network **188**. As illustrated in **FIG. 10**, the dual-mode controller jumps to the same state, that is, starting a Bluetooth inquiry scan if the initial HomeRF network scan fails to find a CP beacon. In this case, the Bluetooth inquiry scan procedure is also run for 10.24 seconds. This time duration is divided into four inquiry scan periods of each 2.56 seconds. As shown in **FIG. 9**, the inquiry scan procedure involves searching for a valid inquiry code for 11.25 msec (covering 16 inquiry frequencies) in a 2.56 second interval at a single hop frequency. The same procedure is repeated at different hop frequencies until an inquiry code is received, but no more than 3 times. If a valid Bluetooth inquiry code is not received within the 10.24 second interval, the dual-mode device goes back to the dual-mode standby mode **170**. In case the unit receives a valid inquiry code **190**, it goes into an inquiry-response mode **192** followed by the connection set up procedure **194** with the master as described earlier in the text. Finally, if there is no more data to be sent, the Bluetooth connection is terminated **196**, and the dual-mode device goes back into the dual-mode standby mode **170**.

[0071] The embodiment described above typically would be implemented in one or more integrated circuits. For example the section including the baseband processors, **134** and **136**, the central processing unit **142** and the host interfaces **138** and **140** may be implemented in a single CMOS integrated circuit and the RF section may be implemented in a single integrated circuit. It should be appreciated, however, that the teachings of the invention may be implemented using a wide variety of electronic components and, typically, software programs.

[0072] As in the embodiments of **FIGS. 2-5**, the operations of the dual mode controller may be implemented using various combinations of hardware and software. Hence, operations of the state machine of **FIG. 10** may be implemented using software code running on a processor or as hardware-based logic. For example, a network scanner component or routing may be used for the network scan operations. A connection manager component or routine may be used for the connection procedure. Note that these two operations may correspond with the network detector **92** and the connection manager **102** of **FIG. 4**.

[0073] In addition, a dual-mode communication device incorporating this embodiment may include various optional user interfaces such as an audio interface and a visual interface for textual, graphical and video presentations. The device also includes an interface for user input (e.g., a keypad). The host interface may interface to a broadband backbone including, for example, an ethernet connection, satellite connection, wireless broadband, cable or the public

switched telephone network (PSTN). Typical implementations of such a device may include, for example, PDAs, cellular telephones, MP3 players, still and video cameras and video recorders.

[0074] **FIG. 11** depicts one embodiment of the invention consisting of a dual-mode mobile communication device that is capable of accessing either a Bluetooth or a Point-Controller (PC) controlled IEEE 802.11b network. 802.11b networks fall under the category of a local area network (LAN). Conventional 802.11b devices support data transfer rates on the order of 5.5 Mbits/s and 11 Mbit/s.

[0075] This embodiment is described in the context of a residential gateway (e.g. a cable modem with an 802.11b wireless LAN interface) providing a multi-user broadband internet access service and multi-channel cordless telephony via an 802.11b interface. A PDA or a mobile phone with a dual-mode Bluetooth-802.11b capability could switch to an 802.11b mode upon entering a home to take advantage of the broadband internet access service, or multi-channel cordless telephony service to avoid air-time charges while making a call.

[0076] In **FIG. 11**, a chip architecture that provides this dual-mode functionality is illustrated. A dual-mode radio front-end **202** can be shared with different RF front-end and modulation rate parameters between Bluetooth and 802.11b modes of operation. To achieve a dual-mode operation, a new timing mechanism (and respective state machines) is required since both Bluetooth and 802.11bsystems are time-synchronous networks. A dual-mode controller **200** as shown in **FIG. 11** implements this timing mechanism and the state machines to achieve the dual-mode operation.

[0077] The dual-mode controller **200** has the following operational modes:

[0078] Bluetooth-only mode

[0079] 802.11b-only mode

[0080] Dual Bluetooth-802.11b mode

[0081] In this embodiment, all three modes are set by an external user command. In the Bluetooth-only or 802.11b-only mode, the device operates in the native Bluetooth or 802.11b mode, respectively, i.e., whichever mode the device is in the other mode would be turned off. In the dual Bluetooth-802.11b mode, Bluetooth and 802.11b baseband processors **204** and **206**, respectively, time-share the dual-mode radio front-end **202** under the time-synchronous management of the dual-mode controller **200**.

[0082] **FIG. 12** describes the 802.11b network scan procedure for a new device to join an 802.11b network managed by a Point Controller (PC) device. In this case, the PC transmits a distinctive "beacon" every "CFP(Contention Free Period)RepetitionInterval" that is bounded by "CFP-MaximumDuration" parameter per IEEE 802.11b MAC specification. Unlike in an HomeRF network, 802.11b transmissions take place at the same fixed carrier frequency, i.e., no frequency hopping is allowed. The beacon contains specific information about the existing 802.11b network.

[0083] A new device with an intention to join the 802.11b network performs a network scan procedure to search for a PC beacon. Search for the PC beacon is repeated every "CFPMaximumDuration" interval per IEEE 820.11 MAC specification at the same carrier frequency. If a PC beacon is received within the scanning window, the new device then extracts the network identity information and the timing information from the beacon to join the 802.11b network.

[0084] For a dual-mode Bluetooth-802.11b communication device, the dual-mode controller **200** manages the network access mechanism for both Bluetooth and 802.11b networks in a synchronous manner. A general illustration of the time interleaved access procedure is shown in **FIG. 13**.

[0085] The dual-mode controller **200** includes a synchronous state machine that combines the standby, inquiry scan, network scan, and connection procedures carried out by Bluetooth and 802.11bdevices. It is important that dual-mode Bluetooth-802.11b devices interoperate with standards based Bluetooth-only or 802.11b-only devices. Network scan and connection setup procedures for a dual-mode device should follow the same rules as specified in the Bluetooth or 802.11b standards. In other words, dual-mode operation should not alter the synchronous time flow of interdependent states (idle, network scan, scan response, etc.) that accomplish the respective network access procedures for Bluetooth or 802.11b networks. Consequently, the objective of this invention disclosure is to devise a dual-mode controller such that Bluetooth and 802.11b network access state machines are combined without individually altering their functionalities. A description of one of the embodiments of the dual-mode controller state machine is illustrated in **FIG. 14**.

[0086] The default state for the dual-mode controller is the standby mode **230**. In the absence of any network connection, the dual-mode controller initiates a new network scan request **232** every "CFPMaximumDuration" per 802.11b MAC specification. The very first network scan performed by the dual-mode controller searches for an 802.11b network. In this state, a new device performs a network scan procedure **236** searching for a 802.11b PC beacon. Total duration of the HomeRF network scan procedure is "CFP-MaximumDuration". If a TDMA beacon is received within the scanning window (block **238**), the new unit extracts the network identity information and the timing information from the beacon to join the 802.11b network. However, before the new device attempts to join the 802.11b network based on the beacon information, the user is informed via a display message etc. about the existence of the 802.11b network and the types of services that are available. Accordingly, the user may either approve or disapprove joining the 802.11b network for the specified services (block **240**). If the user directs the dual-mode controller to establish a connection with the 802.11b network, the dual-mode device then joins the 802.11b network and maintains connection until the device transitions into an idle mode **244** or until the PC beacon is no longer received by the unit **242**. In both cases, the dual mode device goes into the dual-mode standby mode. If the user does not approve connecting to the 802.11b network, the dual-mode controller automatically starts an inquiry scan procedure to search for the existence of a Bluetooth network **248**. As illustrated in **FIG. 14**, the dual-mode controller jumps to the same state, that is, starting a Bluetooth inquiry scan if the initial 802.11b network scan fails to find a PC beacon. In this case, the Bluetooth inquiry scan procedure is run for 10.24 seconds. This time duration is divided into four inquiry scan periods of each 2.56 seconds. As shown in **FIG. 13**, the inquiry scan procedure

involves searching for a valid inquiry code for 11.25 msec (covering 16 inquiry frequencies) in a 2.56 second interval at a single hop frequency. Same procedure is repeated at different hop frequencies until an inquiry code is received but no more than 3 times. If a valid Bluetooth inquiry code is not received within the 10.24 second interval, the dual-mode device goes back to the dual-mode standby mode. In case the unit receives a valid inquiry code **250**, it goes into an inquiry-response mode **252** followed by the connection set up procedure **254** with the master as described earlier in the text. Finally, if there is no more data to be sent, the Bluetooth connection is terminated **256**, and the dual-mode device goes back into the dual-mode standby mode.

[**0087**] While the embodiments described above generally have described portable devices, the invention may be incorporated in non-portable devices. For example, a multi-mode controller may be implemented in a stationary device in an area where the wireless services may change over time. Typical scenarios may include where the quality of service or effective data rate of a given wireless service varies over time. In general, in many applications wireless networking may be used in place of non-wireless connections. Hence, it should be understood that the teachings of the invention may be applied to virtually any connectivity application where there is a need to selectively utilize the services of more than one wireless network.

[**0088**] In summary, the invention described herein teaches improved techniques for managing and controlling network connectivity in wireless systems. While certain exemplary embodiments have been described in detail and shown in the accompanying drawings, it is to be understood that such embodiments are merely illustrative of and not restrictive of the broad invention. It will thus be recognized that various modifications may be made to the illustrated and other embodiments of the invention described above, without departing from the broad inventive scope thereof. In view of the above it will be understood that the invention is not limited to the particular embodiments or arrangements disclosed, but is rather intended to cover any changes, adaptations or modifications which are within the scope and spirit of the invention as defined by the appended claims.

1-32. (canceled)

33. A method for wireless communication, the method comprising:

scanning by a wireless communication device, a plurality of radio frequencies for beacon messages from a plurality of master communication devices, each of said plurality of master communication devices associated with one of a plurality of time-synchronous RF networks, to identify whether establishment of communication with at least one of said plurality of time-synchronous RF networks is possible;

selecting in accordance with a predefined criteria, a network associated with one of said beacon messages, wherein said selected network is one of said plurality of time-synchronous RF networks; and

establishing communication with said selected network by said wireless communication device.

34. The method according to claim 33, wherein said plurality of time-synchronous RF networks comprises a Bluetooth network.

35. The method according to claim 33, wherein said plurality of time-synchronous RF networks comprises a Wireless Local Area (WLAN) network.

36. The method according to claim 33, comprising configuring said wireless communication device to scan a first of said plurality of radio frequencies for a first network during a first scanning window and scan a second of said plurality of radio frequencies for a second network during a second scanning window.

37. The method according to claim 36, wherein said first scanning window comprises a first predefined time period and said second scanning window comprises a second predefined time period.

38. The method according to claim 37, wherein said first predefined time period is equal to said second predefined time period.

39. The method according to claim 37, comprising performing multiple scans during said first scanning window.

40. The method according to claim 39, comprising performing each of said multiple scans during said first scanning window for a predefined time period.

41. The method according to claim 37, comprising performing multiple scans during said second scanning window.

42. The method according to claim 41, comprising performing each of said multiple scans during said second scanning window for a predefined time period.

43. The method according to claim **22**, wherein said predefined criteria comprises a user preference.

44. The method according to claim 33, wherein said predefined criteria comprises relative bandwidth.

45. The method according to claim 33, wherein said predefined criteria comprises relative quality of service (QoS).

46. The method according to claim 33, wherein said predefined criteria comprises relative content.

47. The method according to claim 33, comprising configuring said wireless communication device to use a common portion of an RF radio front end to communicate with said plurality of time-synchronous RF networks.

48. The method according to claim 33, comprising sequentially scanning said plurality of radio frequencies for said beacon messages.

49. The method according to claim 33, comprising sequentially scanning said plurality of radio frequencies for said beacon messages using different radio interfaces.

50. The method according to claim 33, comprising sequentially scanning said plurality of radio frequencies for said beacon messages using different protocols for at least a portion of said plurality of time-synchronous RF networks.

51. The method according to claim 33, comprising sequentially scanning said plurality of radio frequencies for said beacon messages using different frequency hopping and modulation rate parameters.

52. The method according to claim 33, comprising sequentially scanning said plurality of radio frequencies for said beacon messages using different baseband processors.

53. The method according to claim 52, wherein said different baseband processors use a common RF radio front end to communicate with different ones of said plurality of time-synchronous RF networks.

54. The method according to claim 33, comprising sequentially scanning for an inquiry sequence from at least one of said plurality of time-synchronous RF networks.

55. A system for wireless communication, the system comprising:

at least one circuit for use in a wireless communication device that enables scanning of a plurality of radio frequencies for beacon messages from a plurality of master communication devices, each of said plurality of master communication devices associated with one of a plurality of time-synchronous RF networks, to identify whether establishment of communication with at least one of said plurality of time-synchronous RF networks is possible;

said at least one circuit enables selection of a network associated with one of said received beacon messages, in accordance with a predefined criteria, wherein said selected network is one of said plurality of time-synchronous RF networks; and

said at least one circuit enables establishment of communication with said selected network by said wireless communication device.

56. The system according to claim 55, wherein said plurality of time-synchronous RF networks comprises a Bluetooth network.

57. The system according to claim 55, wherein said plurality of time-synchronous RF networks comprises a Wireless Local Area (WLAN) network.

58. The system according to claim 55, wherein said at least one circuit enables configuration of said wireless communication device to scan a first of said plurality of radio frequencies for a first network during a first scanning window and scan a second of said plurality of radio frequencies for a second network during a second scanning window.

59. The system according to claim 58, wherein said first scanning window comprises a first predefined time period and said second scanning window comprises a second predefined time period.

60. The system according to claim 59, wherein said first predefined time period is equal to said second predefined time period.

61. The system according to claim 59, wherein said at least one circuit performs multiple scans during said first scanning window.

62. The system according to claim 61, wherein said at least one circuit performs each of said multiple scans during said first scanning window for a predefined time period.

63. The system according to claim 59, wherein said at least one circuit performs multiple scans during said second scanning window.

64. The system according to claim 63, wherein said at least one circuit performs each of said multiple scans during said second scanning window for a predefined time period.

65. The system according to claim 55, wherein said predefined criteria comprises a user preference.

66. The system according to claim 55, wherein said predefined criteria comprises relative bandwidth.

67. The system according to claim 55, wherein said predefined criteria comprises relative quality of service (QoS).

68. The system according to claim 55, wherein said predefined criteria comprises relative content.

69. The system according to claim 55, wherein said at least one circuit enables configuration of said wireless communication device to use a common portion of an RF radio front end to communicate with said plurality of time-synchronous RF networks.

70. The system according to claim 55, said at least one circuit enables sequential scanning of said plurality of radio frequencies for said beacon messages.

71. The system according to claim 55, wherein said at least one circuit enables sequential scanning of said plurality of radio frequencies for said beacon messages using different radio interfaces.

72. The system according to claim 55, wherein said at least one circuit enables sequential scanning of said plurality of radio frequencies for said beacon messages using different protocols for at least a portion of said plurality of time-synchronous RF networks.

73. The system according to claim 55, wherein said at least one circuit enables sequential scanning of said plurality of radio frequencies for said beacon messages using different frequency hopping and modulation rate parameters.

74. The system according to claim 55, wherein said at least one circuit enables sequential scanning of said plurality of radio frequencies for said beacon messages using different baseband processors.

75. The system according to claim 52, wherein said different baseband processors use a common RF radio front end to communicate with different ones of said plurality of time-synchronous RF networks.

76. The system according to claim 55, wherein said at least one circuit enables sequential scanning for an inquiry sequence from at least one of said plurality of time-synchronous RF networks.

* * * * *