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Nevo et al.

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(54) MULTIPLE WIRELESS COMMUNICATION PROTOCOL METHODS AND APPARATUSES INCLUDING PROACTIVE REDUCTION OF INTERFERENCE

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(*) Notice: Subject to any disclaimer, the term of this patent is extended or adjusted under 35 U.S.C. 154(b) by 0 days.

(21) Appl. No.: **09/560,672**

(22) Filed: **Apr. 27, 2000**

Related U.S. Application Data

(63) Continuation-in-part of application No. 09/439,946, filed on Nov. 12, 1999, which is a continuation-in-part of application No. 09/408,725, filed on Sep. 29, 1999, and a continuation-in-part of application No. 09/436,458, filed on Nov. 8, 1999.

(51) **Int. Cl.**[7] **H04J 1/12**

(52) **U.S. Cl.** **370/480**; 370/395.5; 370/515; 370/201; 370/338; 370/350; 375/132; 375/140

(58) **Field of Search** 370/480, 395.5, 370/503, 513, 201, 338, 350, 278, 343, 465, 469, 478; 375/132, 140

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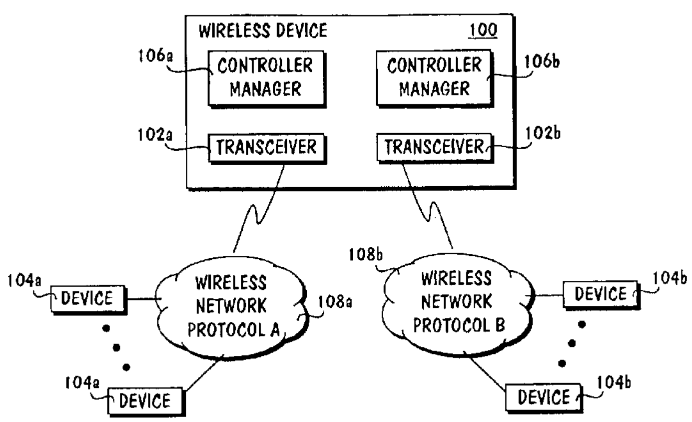
(57) **ABSTRACT**

A collection of wirelessly networked devices including first devices wirelessly networked together using a first wireless protocol that is a frequency hopping protocol, and second devices wirelessly networked together using a second wireless protocol, are operated in a coordinated manner, including proactive reduction of interference between the networked devices. In one embodiment, the first devices include at least a first and a second subset operating with a first and a second frequency hopping pattern respectively. The proactive reduction effort includes synchronized operations of the first and second subsets of the first devices, and the second devices operate in a manner complementary to the synchronized operations of the first devices. In one embodiment, the collection of wirelessly networked devices includes at least one wireless device that operates in both wireless networks in accordance with both wireless protocols. The multi-protocol device is equipped to at least facilitate prospective anticipation of whether transmission of a long packet that spans multiple ones of successive frequencies by a device of the first wireless network will cause interference with devices of the second wireless network.

26 Claims, 14 Drawing Sheets



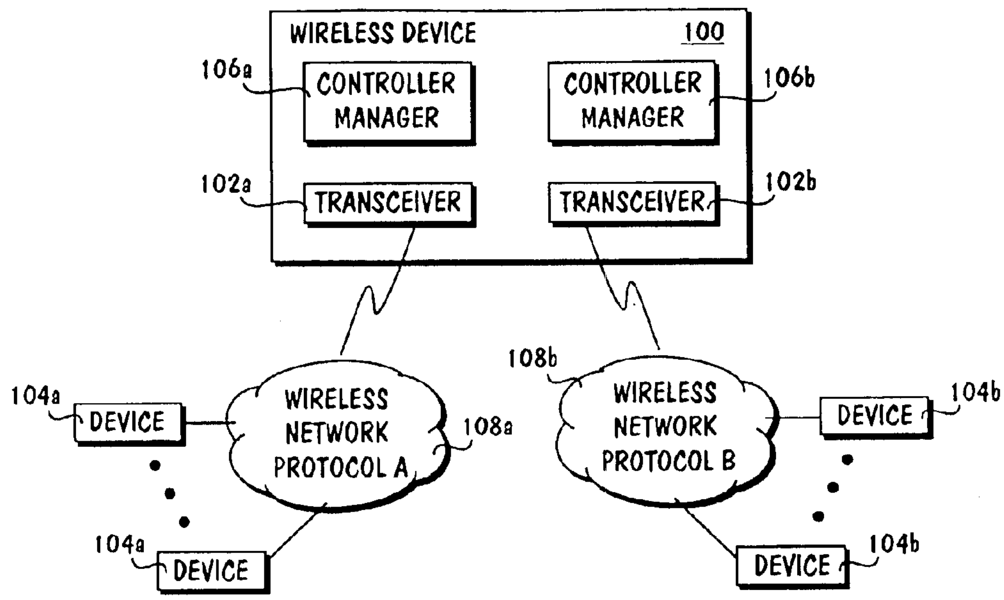

WIRELESS DEVICE
100
106a
CONTROLLER MANAGER
CONTROLLER MANAGER
106b
102a
TRANSCEIVER
TRANSCEIVER
102b
108b
104a
DEVICE
WIRELESS NETWORK PROTOCOL A
108a
WIRELESS NETWORK PROTOCOL B
DEVICE
104b
104a
DEVICE
DEVICE
104b

FIG. 1

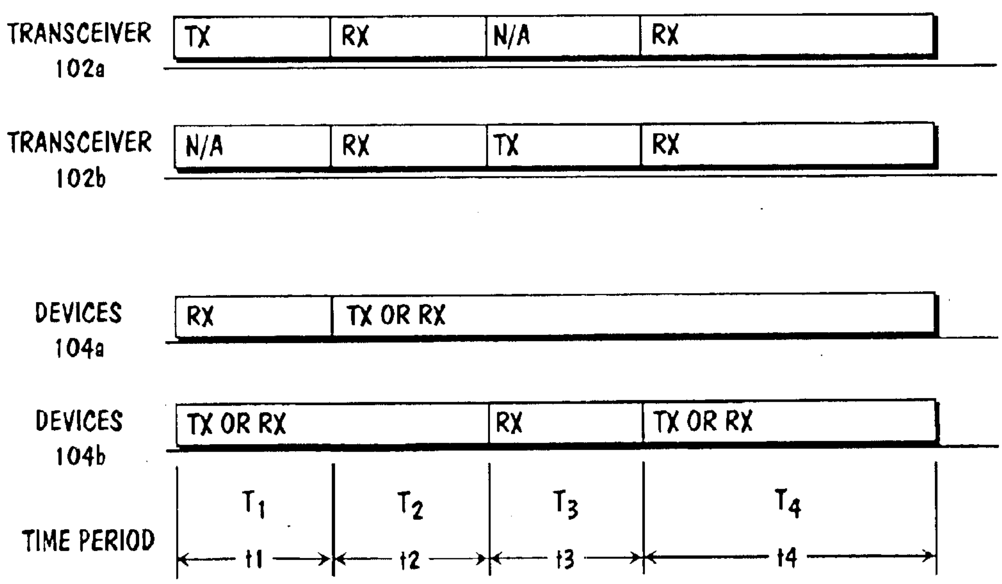

TRANSCEIVER 102a
TX
RX
N/A
RX
TRANSCEIVER 102b
N/A
RX
TX
RX
DEVICES 104a
RX
TX OR RX
DEVICES 104b
TX OR RX
RX
TX OR RX
TIME PERIOD
T_1
T_2
T_3
T_4
t1
t2
t3
t4

FIG. 2

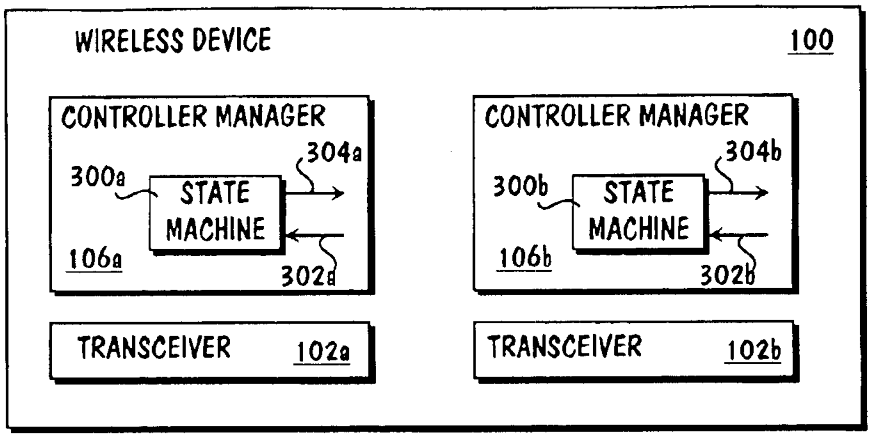

WIRELESS DEVICE
100
CONTROLLER MANAGER
300a
STATE MACHINE
304a
106a
302a
TRANSCEIVER
102a
CONTROLLER MANAGER
300b
STATE MACHINE
304b
106b
302b
TRANSCEIVER
102b

FIG. 3

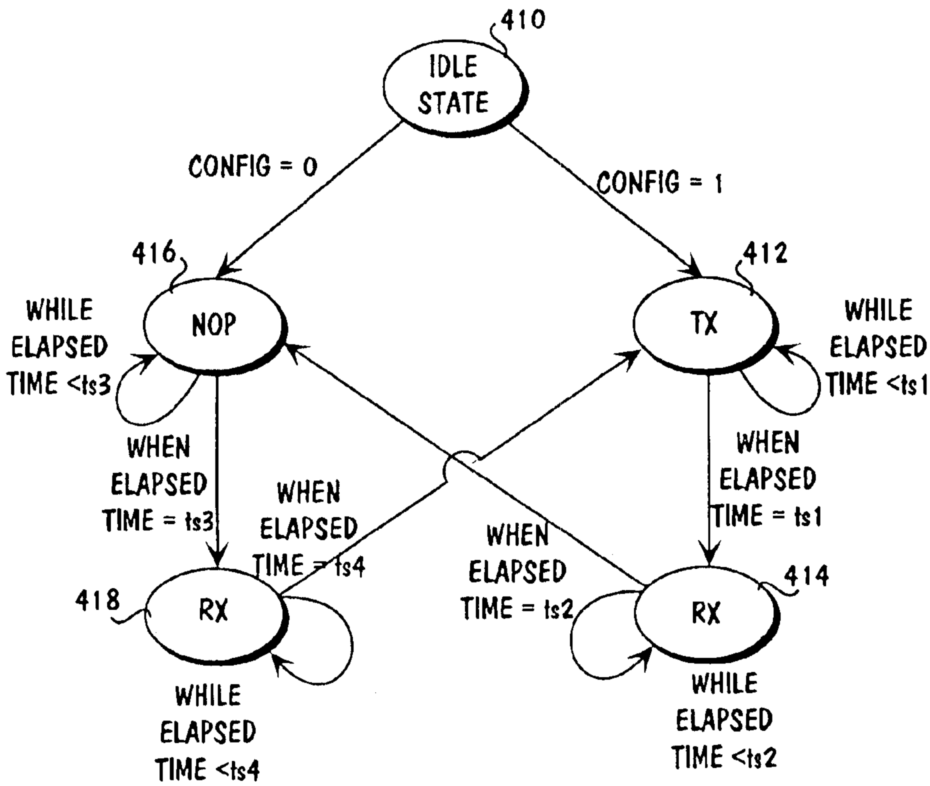

410
IDLE STATE
CONFIG = 0
CONFIG = 1
416
NOP
412
TX
WHILE ELAPSED TIME <ts3
WHILE ELAPSED TIME <ts1
WHEN ELAPSED TIME = ts3
WHEN ELAPSED TIME = ts4
WHEN ELAPSED TIME = ts2
WHEN ELAPSED TIME = ts1
418
RX
414
RX
WHILE ELAPSED TIME <ts4
WHILE ELAPSED TIME <ts2

FIG. 4

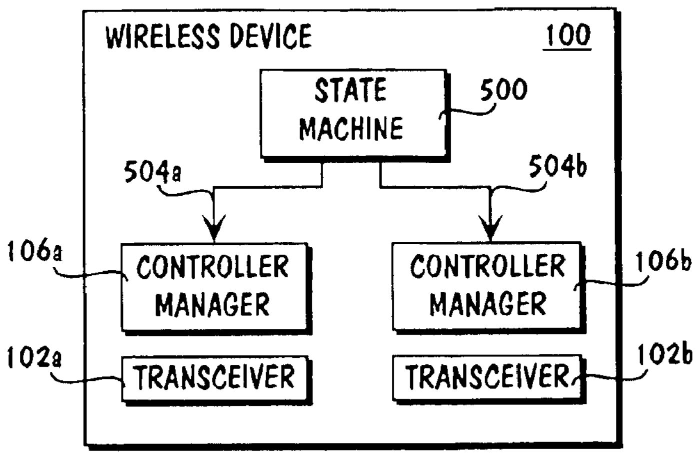

WIRELESS DEVICE
100
STATE MACHINE
500
504a
504b
106a
CONTROLLER MANAGER
CONTROLLER MANAGER
106b
102a
TRANSCEIVER
TRANSCEIVER
102b

FIG. 5

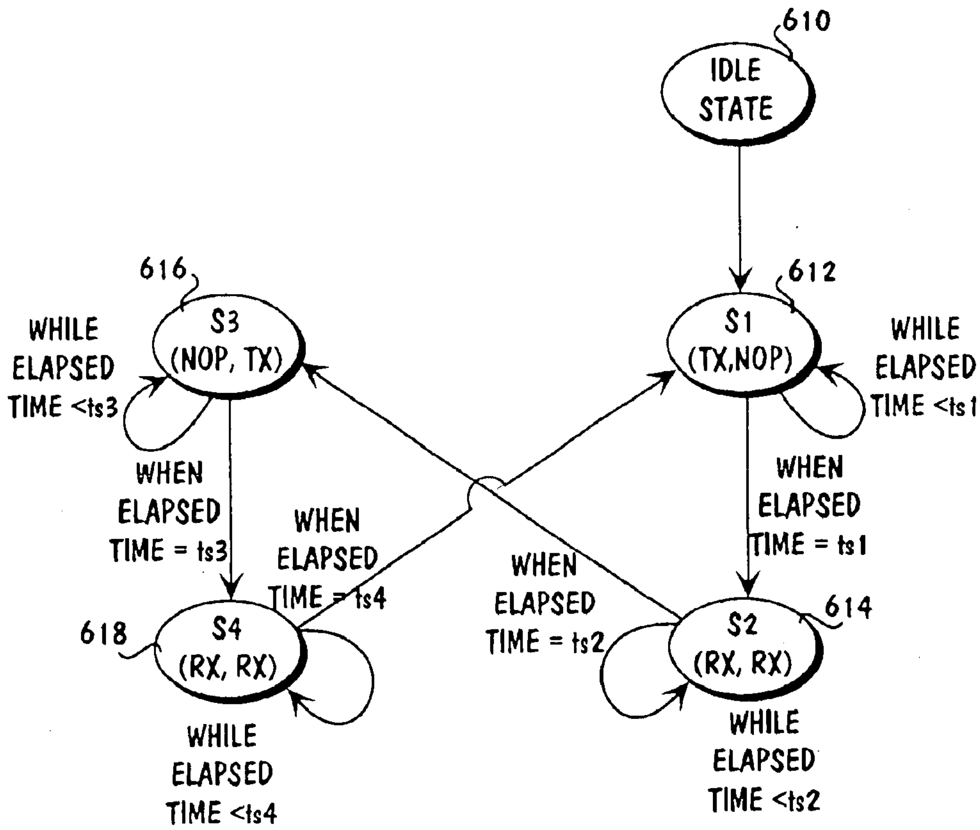

610
IDLE STATE
616
S3 (NOP, TX)
612
S1 (TX,NOP)
WHILE ELAPSED TIME <ts3
WHILE ELAPSED TIME <ts1
WHEN ELAPSED TIME = ts3
WHEN ELAPSED TIME = ts4
WHEN ELAPSED TIME = ts2
WHEN ELAPSED TIME = ts1
618
S4 (RX, RX)
S2 (RX, RX)
614
WHILE ELAPSED TIME <ts4
WHILE ELAPSED TIME <ts2

FIG. 6

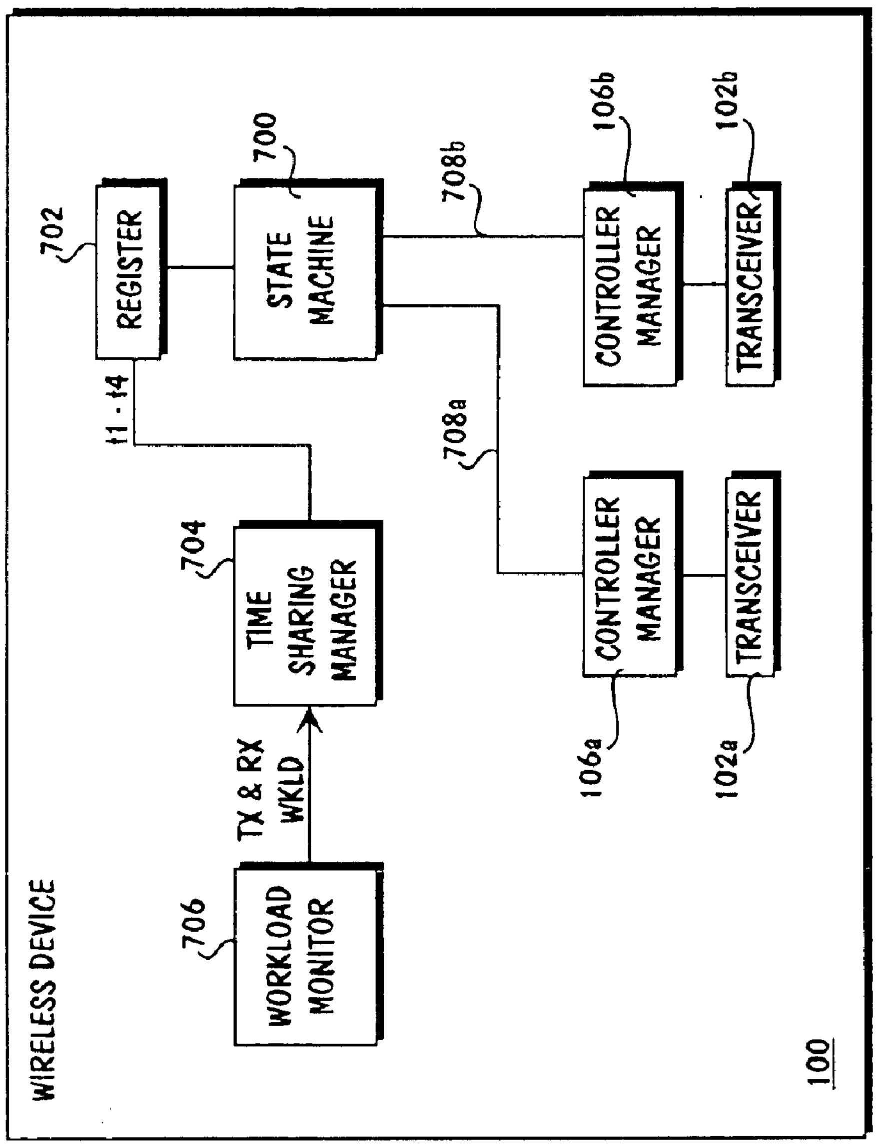

WIRELESS DEVICE
WORKLOAD MONITOR
706
TX & RX WKLD
TIME SHARING MANAGER
704
t1 - t4
REGISTER
702
STATE MACHINE
700
708a
708b
CONTROLLER MANAGER
106a
CONTROLLER MANAGER
106b
TRANSCEIVER
102a
TRANSCEIVER
102b
100

FIG. 7

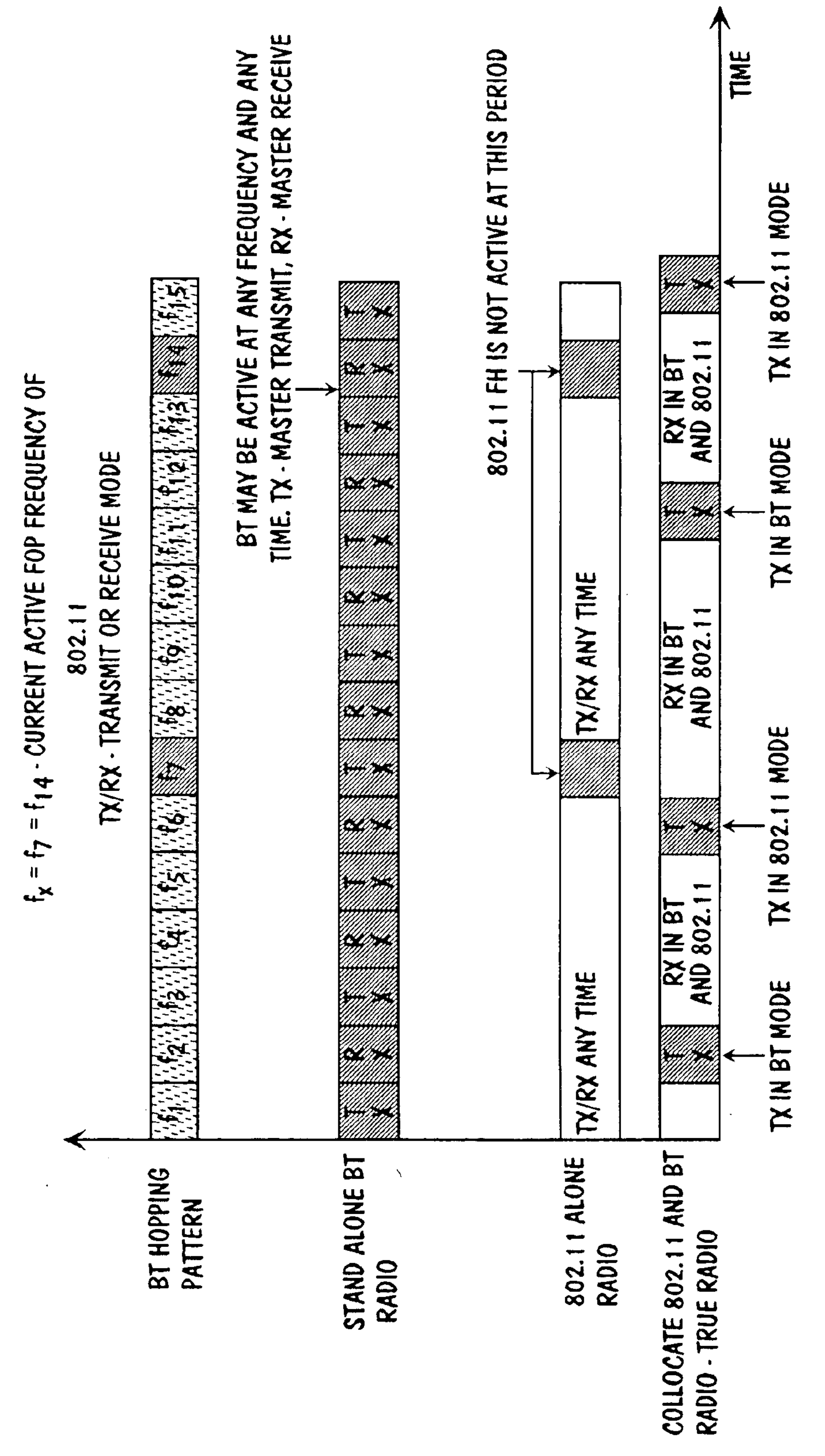
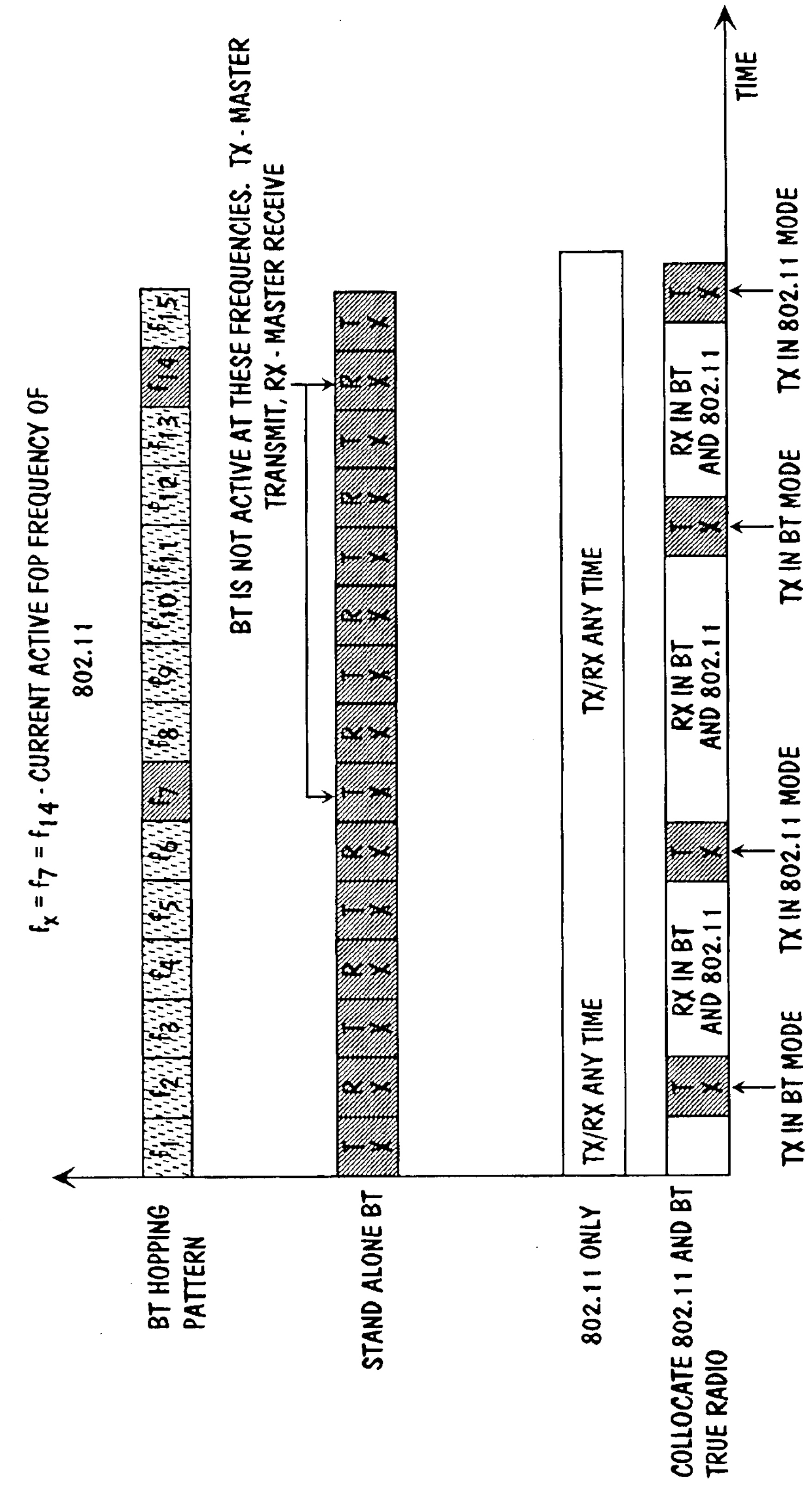

$f_x = f_7 = f_{14}$ - CURRENT ACTIVE FOP FREQUENCY OF 802.11
TX/RX - TRANSMIT OR RECEIVE MODE
BT HOPPING PATTERN
f_1 f_2 f_3 f_4 f_5 f_6 f_7 f_8 f_9 f_{10} f_{11} f_{12} f_{13} f_{14} f_{15}
STAND ALONE BT RADIO
BT MAY BE ACTIVE AT ANY FREQUENCY AND ANY TIME. TX - MASTER TRANSMIT, RX - MASTER RECEIVE
TX RX TX RX TX RX TX RX TX RX TX RX TX RX TX
802.11 ALONE RADIO
TX/RX ANY TIME
TX/RX ANY TIME
802.11 FH IS NOT ACTIVE AT THIS PERIOD
COLLOCATE 802.11 AND BT RADIO - TRUE RADIO
TX
RX IN BT AND 802.11
TX
RX IN BT AND 802.11
TX
RX IN BT AND 802.11
TX
TX IN BT MODE
TX IN 802.11 MODE
TX IN BT MODE
TX IN 802.11 MODE
TIME

FIG. 8A



$f_x = f_7 = f_{14}$ - CURRENT ACTIVE FOP FREQUENCY OF 802.11
BT IS NOT ACTIVE AT THESE FREQUENCIES. TX - MASTER TRANSMIT, RX - MASTER RECEIVE
BT HOPPING PATTERN
f_1 f_2 f_3 f_4 f_5 f_6 f_7 f_8 f_9 f_{10} f_{11} f_{12} f_{13} f_{14} f_{15}
STAND ALONE BT
TX RX TX RX TX RX TX RX TX RX TX RX TX RX TX
802.11 ONLY
TX/RX ANY TIME
TX/RX ANY TIME
COLLOCATE 802.11 AND BT TRUE RADIO
TX
RX IN BT AND 802.11
TX
RX IN BT AND 802.11
TX
RX IN BT AND 802.11
TX
TX IN BT MODE
TX IN 802.11 MODE
TX IN BT MODE
TX IN 802.11 MODE
TIME

FIG. 8B

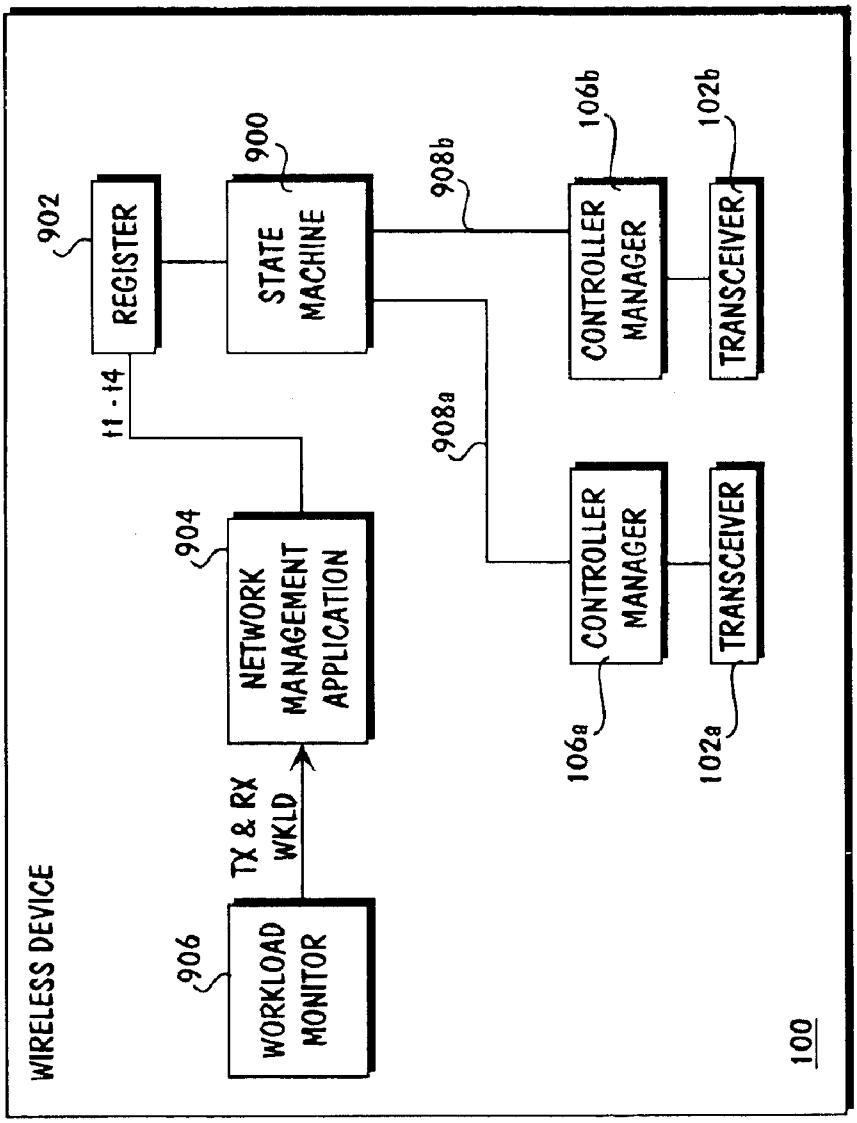

WIRELESS DEVICE
100
WORKLOAD MONITOR
906
TX & RX WKLD
NETWORK MANAGEMENT APPLICATION
904
t1 - t4
REGISTER
902
STATE MACHINE
900
908a
908b
CONTROLLER MANAGER
106a
CONTROLLER MANAGER
106b
TRANSCEIVER
102a
TRANSCEIVER
102b

FIG. 9A

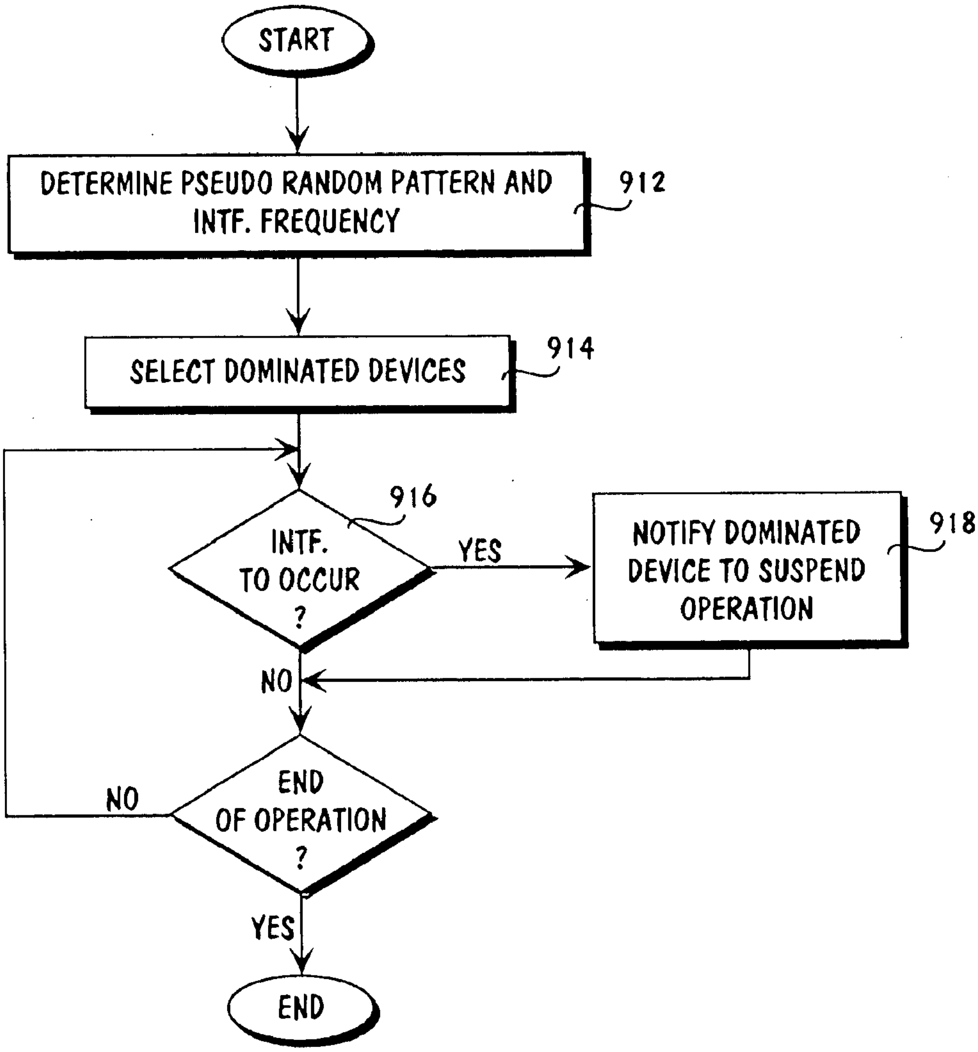
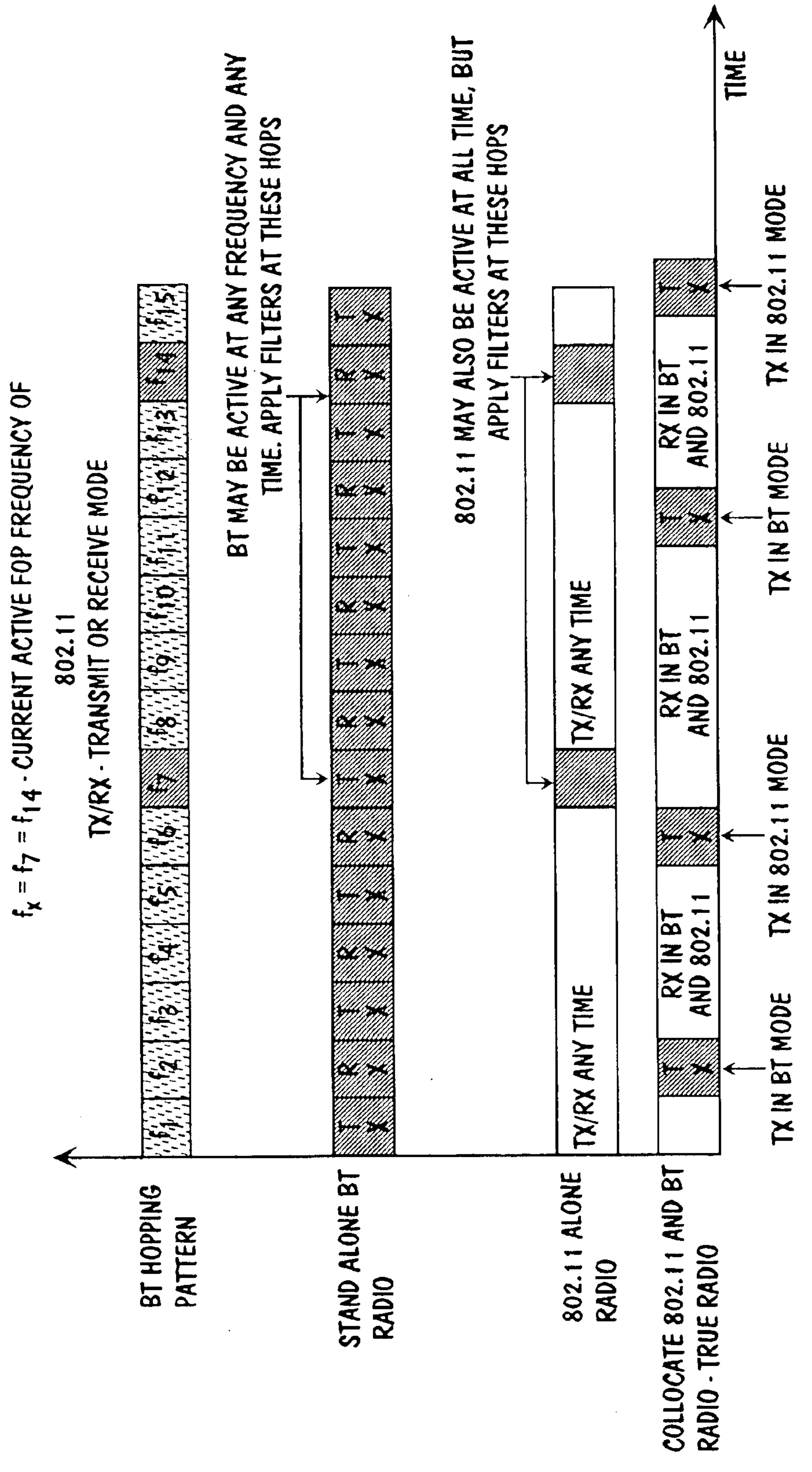

START
DETERMINE PSEUDO RANDOM PATTERN AND INTF. FREQUENCY
912
SELECT DOMINATED DEVICES
914
916
INTF. TO OCCUR ?
YES
NOTIFY DOMINATED DEVICE TO SUSPEND OPERATION
918
NO
END OF OPERATION ?
NO
YES
END

FIG. 9B



$f_x = f_7 = f_{14}$ - CURRENT ACTIVE FOP FREQUENCY OF 802.11
TX/RX - TRANSMIT OR RECEIVE MODE
BT MAY BE ACTIVE AT ANY FREQUENCY AND ANY TIME. APPLY FILTERS AT THESE HOPS
802.11 MAY ALSO BE ACTIVE AT ALL TIME, BUT APPLY FILTERS AT THESE HOPS
TIME
BT HOPPING PATTERN
STAND ALONE BT RADIO
802.11 ALONE RADIO
COLLOCATE 802.11 AND BT RADIO - TRUE RADIO
TX/RX ANY TIME
TX/RX ANY TIME
RX IN BT AND 802.11
RX IN BT AND 802.11
RX IN BT AND 802.11
TX IN BT MODE
TX IN 802.11 MODE
TX IN BT MODE
TX IN 802.11 MODE

FIG. 10

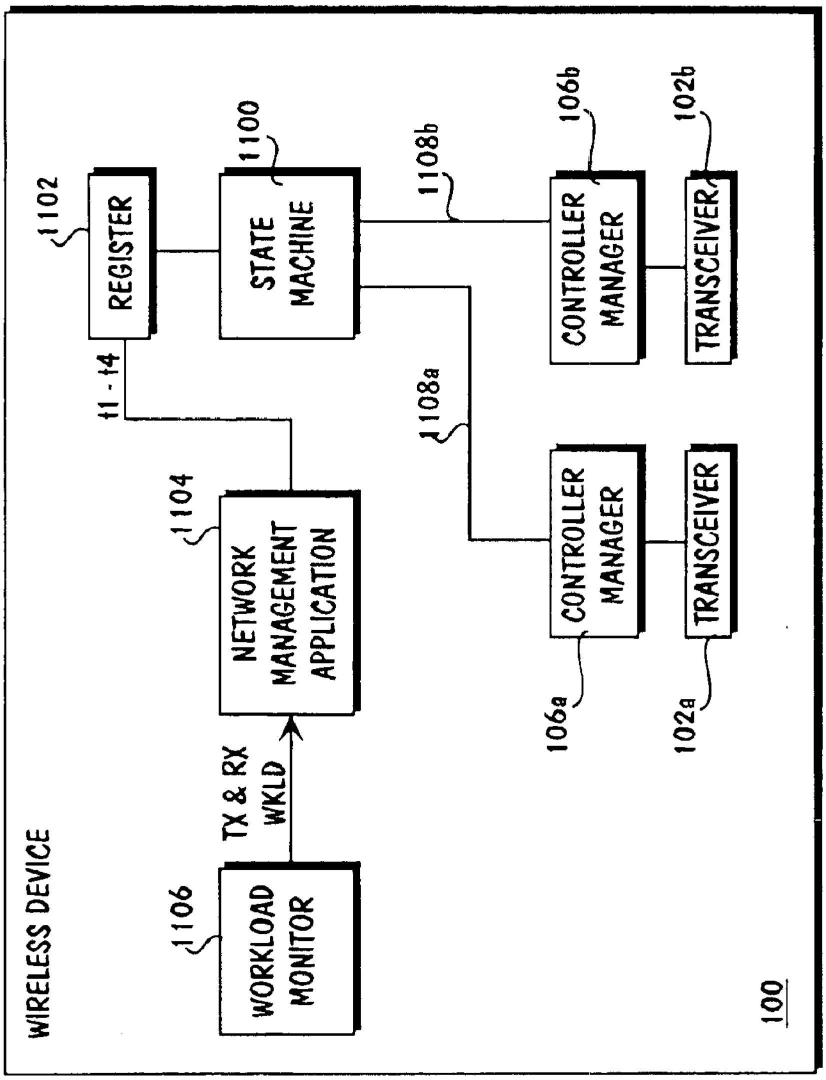

WIRELESS DEVICE
100
WORKLOAD MONITOR
1106
TX & RX WKLD
NETWORK MANAGEMENT APPLICATION
1104
I1 - I4
REGISTER
1102
STATE MACHINE
1100
1108a
1108b
CONTROLLER MANAGER
106a
CONTROLLER MANAGER
106b
TRANSCEIVER
102a
TRANSCEIVER
102b

FIG. 11A

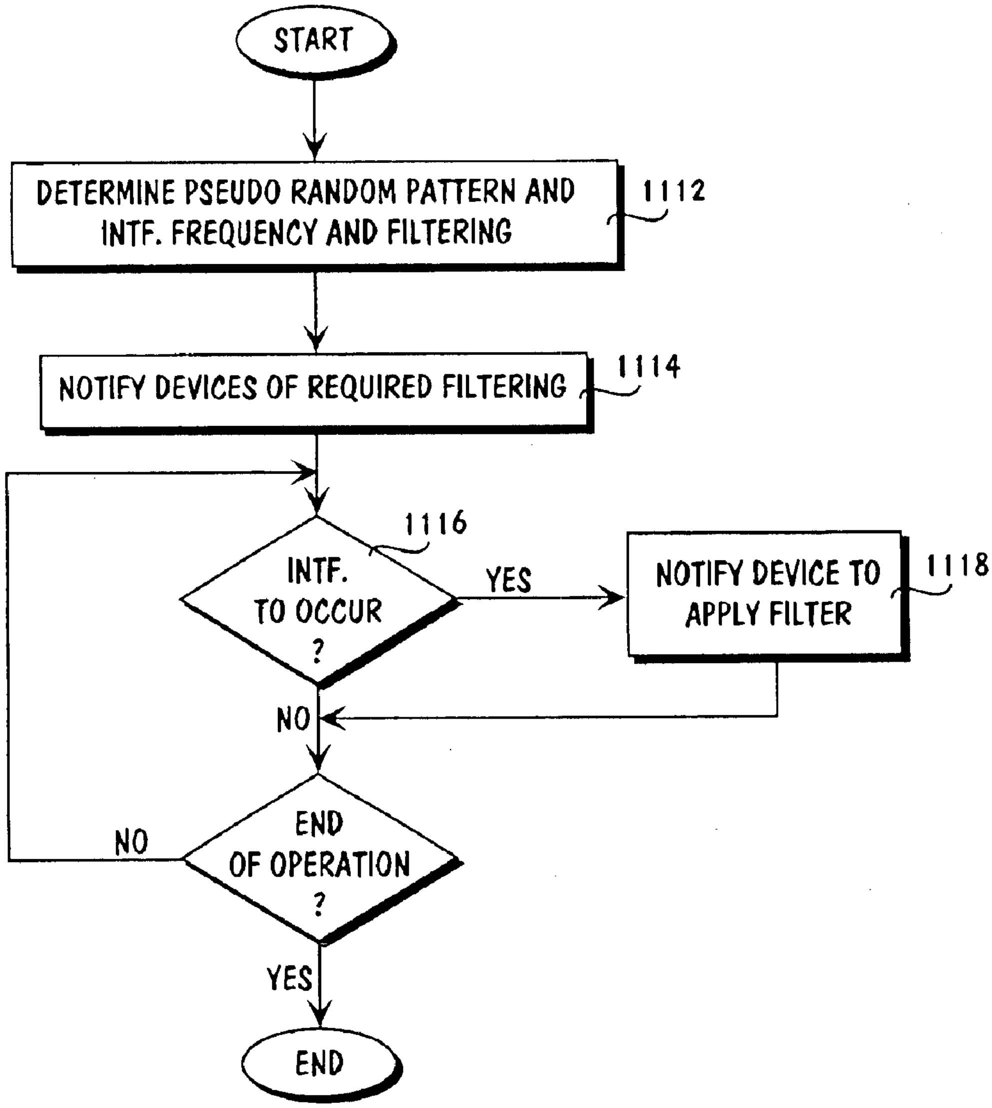

START
DETERMINE PSEUDO RANDOM PATTERN AND INTF. FREQUENCY AND FILTERING
1112
NOTIFY DEVICES OF REQUIRED FILTERING
1114
INTF. TO OCCUR ?
1116
YES
NOTIFY DEVICE TO APPLY FILTER
1118
NO
END OF OPERATION ?
NO
YES
END

FIG. 11b

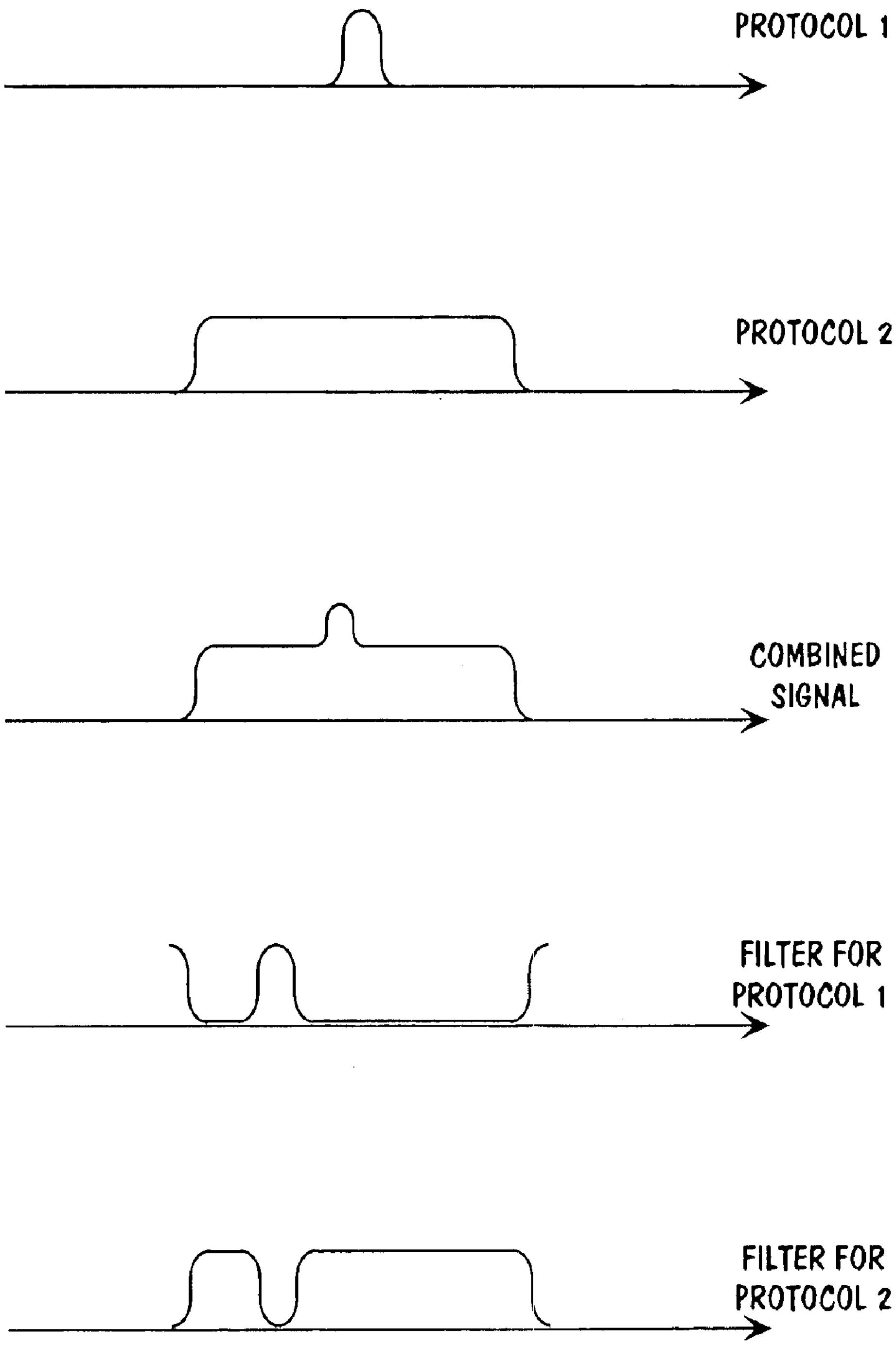
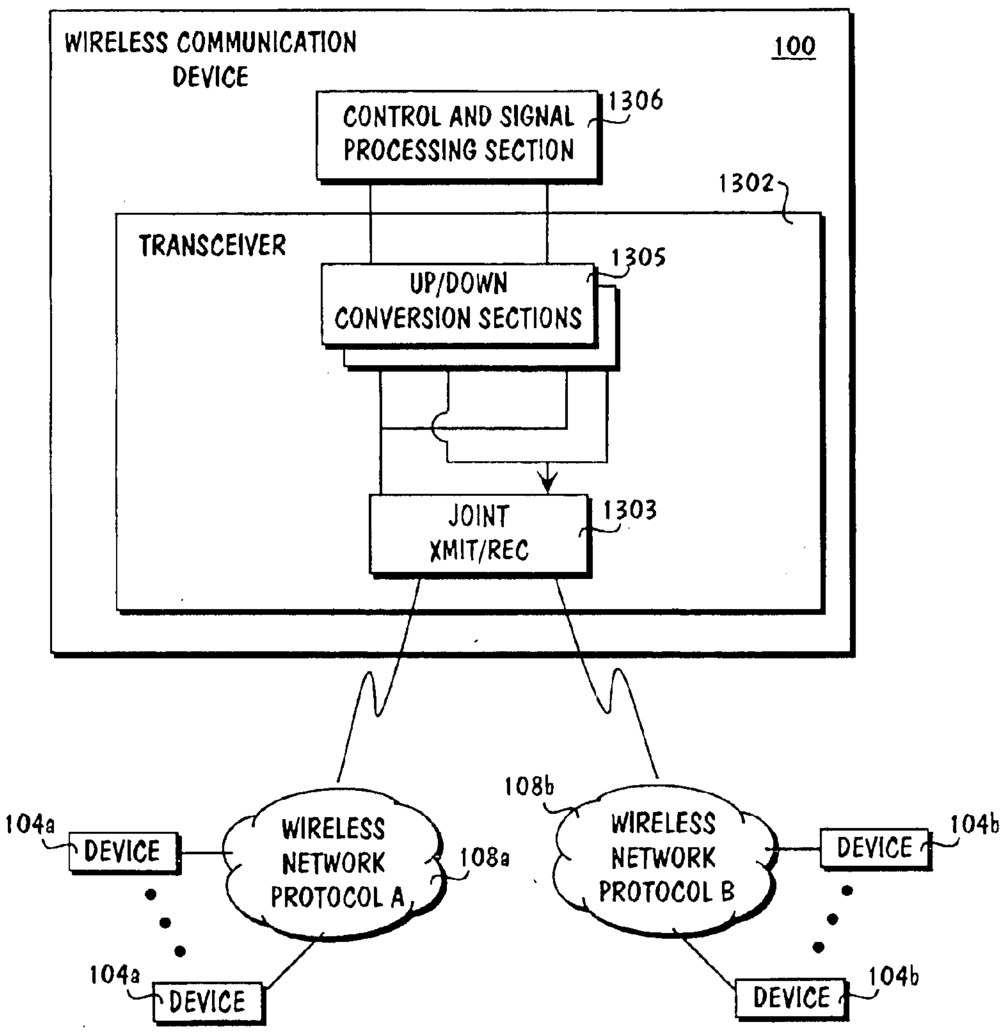

PROTOCOL 1
PROTOCOL 2
COMBINED SIGNAL
FILTER FOR PROTOCOL 1
FILTER FOR PROTOCOL 2

FIG. 12



WIRELESS COMMUNICATION DEVICE
100
CONTROL AND SIGNAL PROCESSING SECTION
1306
1302
TRANSCEIVER
UP/DOWN CONVERSION SECTIONS
1305
JOINT XMIT/REC
1303
108b
104a
DEVICE
WIRELESS NETWORK PROTOCOL A
108a
WIRELESS NETWORK PROTOCOL B
DEVICE
104b
104a
DEVICE
DEVICE
104b

FIG. 13

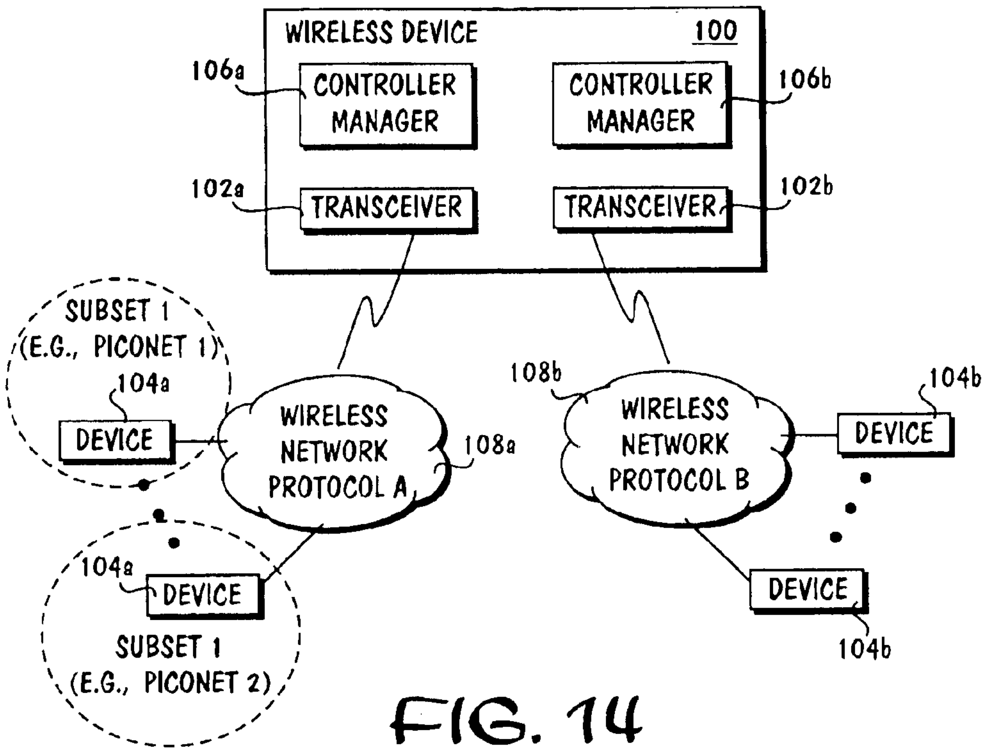

WIRELESS DEVICE
100
106a
CONTROLLER MANAGER
CONTROLLER MANAGER
106b
102a
TRANSCEIVER
TRANSCEIVER
102b
SUBSET 1
(E.G., PICONET 1)
104a
DEVICE
WIRELESS NETWORK PROTOCOL A
108a
108b
WIRELESS NETWORK PROTOCOL B
104b
DEVICE
104a
DEVICE
SUBSET 1
(E.G., PICONET 2)
DEVICE
104b

FIG. 14

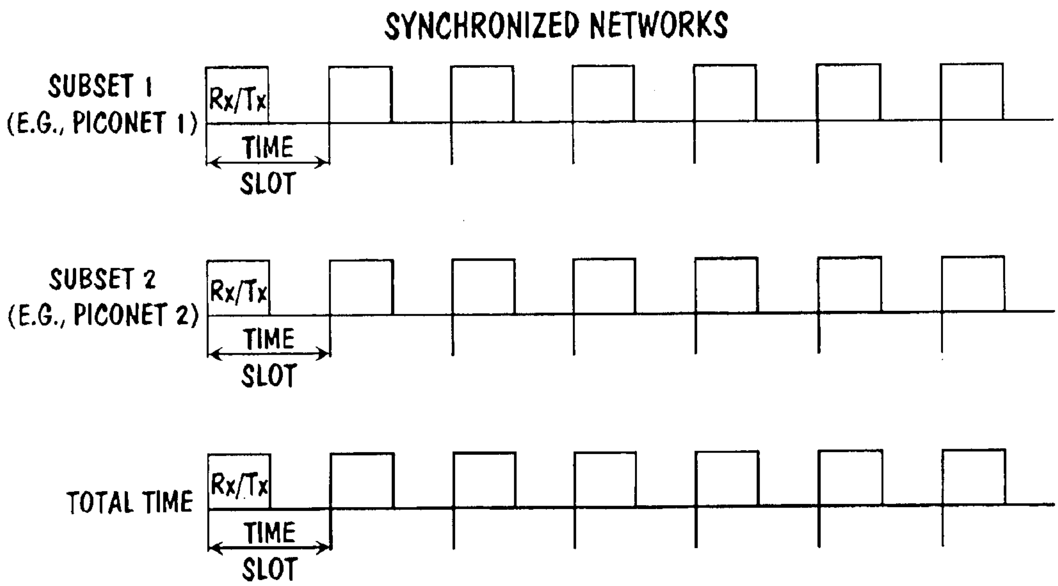

SYNCHRONIZED NETWORKS
SUBSET 1
(E.G., PICONET 1)
Rx/Tx
TIME SLOT
SUBSET 2
(E.G., PICONET 2)
Rx/Tx
TIME SLOT
TOTAL TIME
Rx/Tx
TIME SLOT

FIG. 15

MULTIPLE WIRELESS COMMUNICATION PROTOCOL METHODS AND APPARATUSES INCLUDING PROACTIVE REDUCTION OF INTERFERENCE

RELATED APPLICATION

This application is a continuation-in-part application of U.S. patent application Ser. No. 09/439,946, filed on Nov. 12, 1999, entitled Multiple Wireless Communication Protocol Methods and Apparatuses, which itself is a continuation-in-part application of (a) U.S. patent application Ser. No. 09/408,725, filed on Sep. 29, 1999, entitled "A Wireless Apparatus Having Multiple Coordinated Transceivers For Multiple Wireless Communication Protocols", and (b) U.S. patent application Ser. No. 09/436,458, filed Nov. 8, 1999, entitled "A Wireless Apparatus Having A Transceiver Equipped To Support Multiple Wireless Communication Protocols".

BACKGROUND OF THE INVENTION

1. Field of the Invention

The present invention relates to the field of wireless communication. More specifically, the present invention relates to the problem of concurrent wireless communication with multiple communication partners of different wireless communication protocols.

2. Background Information

Advances in microprocessor and communication technology have led to the increase in popularity of wireless communication. Once confined to the privileged, wireless voice communication have become affordable and available to the masses. Today, various efforts are under way to apply wireless communication to replace attachment cables used for attaching peripheral devices, such as printers, scanners and the like, as well as networking cables used for connecting clients, servers and the like. A leading candidate to accomplish the former is commonly known to those skilled in the art as the Bluetooth technology or Bluetooth protocol. Examples of technology to accomplish the later include the different variants of the IEEE 802.11 Standard published by the Institute of Electrical and Electronic Engineers, 802.11 (Frequency Hoping, Direct Sequence), 802.11a, 802.11b, as well as Home RF, also known as Shared Wireless Access Protocol (SWAP) to those skilled in the art.

A need has emerged in a number of applications that it is desirable for a device to be able to operate "concurrently" in multiple wireless protocols. One such applications is having a notebook computer being able to communicate with peripheral devices such as a phone, a printer, a scanner and the like, in accordance with the Bluetooth protocol; and with other computing devices, such as other peer computers or servers, communication devices, such as modems or adapters, and networking devices, such as gateways, routers, switches and the like, in accordance with one of the 802.11 protocols or Home RF.

However, the need cannot be met by simply providing the device with multiple transmitters, one for each protocol. The reason is because if multiple ones of these transmitters were to transmit at the same time. The transmitters are going to interfere with each other, resulting in corruption and/or loss of data, as well as degradation in performance.

As will be described in more detail below, the present invention substantially address this need in a very efficient and low cost manner. This and other advantages of the present invention will be readily apparent from the description to follow.

SUMMARY OF THE INVENTION

A collection of Tirelessly networked devices including first devices Tirelessly networked together using a first wireless protocol that is a frequency hopping protocol, and second devices Tirelessly networked together using a second wireless protocol, are operated in a coordinated manner, including proactive reduction of interference between the networked devices. In one embodiment, the first devices include at least a first and a second subset operating with a first and a second frequency hopping pattern respectively. The proactive reduction effort includes synchronized operations of the first and second subsets of the first devices, and the second devices operate in a manner complementary to the synchronized operations of the first devices. In one embodiment, the collection of Tirelessly networked devices includes at least one wireless device that operates in both wireless networks in accordance with both wireless protocols. The multi-protocol device is equipped to at least facilitate prospective anticipation of whether transmission of a long packet that spans multiple ones of successive frequencies by a device of the first wireless network will cause interference with devices of the second wireless network.

BRIEF DESCRIPTION OF DRAWINGS

The present invention will be described by way of exemplary embodiments, but not limitations, illustrated in the accompanying drawings in which like references denote similar elements, and in which:

FIG. **1** illustrates an overview of the wireless device of the present invention, in accordance with one embodiment;

FIG. **2** illustrates a period of operation of the wireless devices of FIG. **1**, in accordance with one embodiment;

FIG. **3** illustrates the wireless device of FIG. **1** in further detail, in accordance with one implementation;

FIG. **4** illustrates the operational states and flow of the state machine of FIG. **3** in further detail, in accordance with one implementation;

FIG. **5** illustrates the wireless device of FIG. **1** in further detail, in accordance with another implementation;

FIG. **6** illustrates the operational states and flow of the state machine of FIG. **5** in further detail, in accordance with one implementation;

FIG. **7** illustrates the wireless device of FIG. **1** in further detail, in accordance with yet another implementation;

FIGS. **8***a*–**8***b* illustrate a period of operation of the wireless devices of FIG. **1**, in accordance with each of two alternate embodiments;

FIGS. **9***a*–**9***b* illustrate the architecture and operational flow of the wireless device **100** of FIG. **1** for practicing a selected one of the methods of operation of FIGS. **8***a*–**8***b*, in accordance with one embodiment;

FIG. **10** illustrates a period of operation of the wireless devices of FIG. **1**, in accordance with another embodiment;

FIGS. **11***a*–**11***b* illustrate the architecture and operational flow of the wireless device **100** of FIG. **1** for practicing the method of operation of FIG. **11**, in accordance with one embodiment;

FIG. **12** illustrates the concept of notch filtering;

FIG. **13** illustrates an overview of the wireless device of the present invention, in accordance with another embodiment;

FIG. **14** illustrates another overview of the multi-protocol wireless device of the present invention, along with other wireless devices, in accordance with yet another embodiment; and

FIG. **15** illustrates the concept of synchronized operation of two subsets of devices employing a frequency hopping protocol in accordance with two corresponding frequency hopping patterns.

DETAILED DESCRIPTION OF THE INVENTION

In the following description, various aspects of the present invention will be described. However, it will be apparent to those skilled in the art that the present invention may be practiced with only some or all aspects of the present invention. For purposes of explanation, specific numbers, materials and configurations are set forth in order to provide a thorough understanding of the present invention. However, it will also be apparent to one skilled in the art that the present invention may be practiced without the specific details. In other instances, well known features are omitted or simplified in order not to obscure the present invention.

Parts of the description will be presented using software terminology commonly employed by those skilled in the art to convey the substance of their work to others skilled in the art. As well understood by those skilled in the art, these software quantities take the form of electrical, magnetic, or optical signals capable of being stored, transferred, combined, and otherwise manipulated through mechanical and electrical components of a digital system; and the term digital system includes general purpose as well as special purpose processors, systems, and the like, that are standalone, adjunct or embedded.

Various operations will be described as multiple discrete steps performed in turn in a manner that is most helpful in understanding the present invention, however, the order of description should not be construed as to imply that these operations are necessarily order dependent, in particular, the order the steps are presented. Furthermore, the phrase "in one embodiment" will be used repeatedly, however the phrase does not necessarily refer to the same embodiment, although it may.

Referring now to FIG. **1**, wherein an overview of the present invention, in accordance with one embodiment, is shown. As illustrated, wireless device **100** is provided with wireless transceivers **102***a* and **102***b* to transmit and receive signals wirelessly in accordance with a first and a second wireless communication protocol, to enable device **100** to be communicatively coupled to devices **104***a* and devices **104***b* of wireless networks **108***a* and **108***b* respectively. Wireless device **100** further includes controller managers **106***a* and **106***b* to control the operation of wireless transceivers **102***a* and **102***b* respectively. As will be described in more detail below, controller managers **106***a* and **106***b* control transmits and receives by wireless transceivers **102***a* and **102***b*, in a coordinated manner, in accordance with the present invention, to allow wireless device **100** to operate with devices **104***a* and devices **104***b* of wireless network **108***a* and **108***b* in accordance with the respective wireless communication protocols at the same time.

In one embodiment, controller managers **106***a* and **106***b* control transmits and receives by wireless transceivers **102***a* and **102***b* (hereinafter, simply transceivers), in a coordinated manner. More specifically, in this embodiment, controller managers **106***a* and **106***b* control transceivers **102***a* and **102***b* to alternate between transmits by one of the two transceivers and receives by both of the two transceivers. FIG. **2** illustrates a period of operation in accordance with this embodiment. As shown, in time period T1, for duration t1, control manager **106***a* controls transceiver **102***a* to perform transmit of signals to devices **104***a* of wireless network **108***a* (hereinafter, simply network) in accordance with the first wireless communication protocol (hereinafter, simply protocol), while control manager **106***b* controls transceiver **102***b* to neither perform transmit nor receive of signals to and from devices **104***b* of network **108***b*. In time period T3, for duration t**3**, the reverse is performed. Control manager **106***b* controls transceiver **102***b* to perform transmit of signals to devices **104***b* of network **108***b* in accordance with the second protocol, while control manager **106***a* controls transceiver **102***a* to neither perform transmit nor receive of signals to and from devices **104***a* of network **108***a*. In time periods T2 and T4, for duration t**2** and t**4** respectively, control managers **106***a* and **106***b* control both transceivers **102***a* and **102***b* to perform receive of signals from devices **104***a* and **104***b* of network **108***a* and **108***b* in accordance with the respective protocols respectively.

Since all wireless protocols operate on either a carrier sense or contention free protocol, devices **104***a* are able to receive in time period T1, and transmit when there are packets to transmit, but otherwise receive, in time periods T2–T4. Likewise, devices **104***b* are able to receive in time period T3, and transmit when there are packets to transmit, but otherwise receive, in time periods T1–T2 and T4.

Accordingly, wireless device **100** is able to operate with devices **104***a* and **104***b* of networks **108***a* and **108***b* in two wireless protocols at the same time.

Note that time periods T1–T4 may or may not be equal in duration. That is, numerically t**1**–t**4** may or may not be equal. As will be described in more detail below, in different variants of this embodiment, duration t**1**–t**4** of time periods T1–T4 are dynamically and adaptively set. In particular, in some variants, duration t**1**–t**4** of time periods T1–T4 are adaptively set based at least in part of transmit and receive workloads of networks **108***a* and **108***b*.

Referring back to FIG. **1**, except for the teachings of the present invention incorporated in wireless device **100** to effectuate the above described coordinated manner of operation of transceivers **102***a* and **102***b*, transceivers **102***a* and **102***b* as well as controller managers **106***a* and **106***b* are otherwise intended to represent a broad range of these elements known in the art. Accordingly, except for the teachings of the present invention, which will be further described below, transceivers **102***a* and **102***b* and controller managers **106***a* and **106***b* will not be otherwise further described.

Wireless device **100** is intended to represent a wide range of devices that can benefit from having the ability to wirelessly operate with other wireless devices in two or more wireless communication protocols at the same time. Examples of device **100** include but not limited to computers of various form factors, such as desktop, notebook, palm size and so forth, controller devices (i.e. master devices) to manage and control the operation of networks **108***a* and **108***b*, and gateway devices to facilitate communication between devices **104***a* and devices **104***b*.

Likewise, devices **104***a* and **104***b* are intended to represent a broad range of devices that can benefit from being able to communicate wirelessly. Examples of devices **104***a* include but not limited to phones, video cameras, speakers, modems, printers and scanners equipped to wireless communicate in accordance with the Bluetooth protocol. Examples of devices **104***b* include clients and servers, as well as gateways, modems, hubs, routers, and switches equipped to wireless communicate in accordance with a selected variant of the IEEE 802.11 protocols or Home RF.

For ease of understanding, only two groups of devices **104***a* and **104***b*, communicating in accordance with the first and second wireless communication protocols are shown in FIG. **1**. However, from the description to follow, it will be readily apparent to those skilled in the art, the present invention may be practiced with more than two transceivers (as long as the transceivers are likewise coordinated).

Referring now to FIGS. **3** and **4**, wherein a block diagram and a state diagram illustrating wireless device **100** of FIG. **1** in further detail, in accordance with one embodiment, are shown. As illustrated, each controller manager **106***a*/**106***b* of wireless device **100** is endowed with a state machine **300***a*/**300***b* to complementarily assist the controller manager **106***a*/**106***b* to control its transceiver **102***a*/**102***b* in the above described coordinated manner. More specifically, each state machine **300***a*/**300***b*, in addition to idle state **410**, has four operating states **412**–**418** (TX, RX1, NOP, and RX2) to output a signal **304***a*/**304***b* denoting a selected one of a transmit (TX) operation, a receive (RX) operation and no-op (NOP) for its controller manager **106***a*/**106***b*.

Upon power-on or reset, each state machine **300***a*/**300***b* either transitions from idle state **410** to TX state **412** or NOP state **416**, depending on the state of configuration (config) signal **302***a*/**302***b*. One state machine, e.g. **300***a*, is configured to transition from idle state **410** to TX state **412**, while the other state machine, e.g. **300***b*, is configured to transition from idle state **410** to TX state **412**. Config signal **302***a*/**302***b* may be set e.g. via a jumper or other equivalent means, as well as through software.

While in TX state **412**, state machine **300***a*/**300***b* remains in the state for duration ts**1**, outputting signal **304***a*/**304***b* denoting TX operation for its controller manager **1026***a*/**106***b*. In one embodiment, where t**1** and t**3** may take on different values, one state machine, e.g. **300***a*, is configured with ts**1** set to t**1**, while the other state machine, e.g. **300***b*, is configured with ts**1** set to t**3**. Ts**1** may be selectively set in any one of a number of techniques known in the art, e.g. through separate registers or multiplexing circuitry. Upon expiration of ts**1**, state machine **300***a*/**300***b* transitions from TX state **412** to RX1 state **414**.

While in RX1 state **414**, state machine **300***a*/**300***b* remains in the state for duration ts**2**, outputting signal **304***a*/**304***b* denoting RX operation for its controller manager **106***a*/**106***b*. In one embodiment, where t**2** and t**4** may take on different values, one state machine, e.g. **300***a*, is configured with ts**2** set to t**2**, while the other state machine, e.g. **300***b*, is configured with ts**2** set to t**4**. Ts**2** may likewise be selectively set in any one of a number of techniques known in the art. Upon expiration of ts**2**, state machine **300***a*/**300***b* transitions from RX1 state **414** to NOP state **416**.

While in NOP state **416**, state machine **300***a*/**300***b* remains in the state for duration ts**3**, outputting signal **304***a*/**304***b* denoting NOP for its controller manager **106***a*/**106***b*. In one embodiment, where t**1** and t**3** may take on different values, one state machine, e.g. **300***a*, is configured with ts**3** set to t**3**, while the other state machine, e.g. **300***b*, is configured with ts**3** set to t**1**. Ts**3** may likewise be selectively set in any one of a number of techniques known in the art. Upon expiration of ts**3**, state machine **300***a*/**300***b* transitions from NOP state **416** to RX2 state **418**.

While in RX2 state **418**, state machine **300***a*/**300***b* remains in the state for duration ts**4**, outputting signal **304***a*/**304***b* denoting RX operation for its controller manager **106***a*/**106***b*. In one embodiment, where t**2** and t**4** may take on different values, one state machine, e.g. **300***a*, is configured with ts**4** set to t**4**, while the other state machine, e.g. **300***b*, is configured with ts**4** set to t**2**. Ts**4** may likewise be selectively set in any one of a number of techniques known in the art. Upon expiration of ts**4**, state machine **300***a*/**300***b* transitions from RX2 state **418** to TX state **412**.

From TX state **412**, state machine **300***a*/**300***b* continues operation as described earlier.

Referring now to FIGS. **5** and **6**, wherein a block diagram and a state diagram illustrating wireless device **100** of FIG. **1** in further detail, in accordance with another embodiment, are shown. As illustrated, for this embodiment, instead of having each controller manager **106***a*/**106***b* of wireless device **100** be endowed with a state machine to complementarily assist the controller manager **106***a*/**106***b* to control its transceiver **102***a*/**102***b* in the above described coordinated manner, wireless device **100** is endowed with a single state machine **500** to assist both controller managers **106***a* and **106***b*. Similarly, state machine **500**, in addition to idle state **610**, has four operating states **612**–**618** (S1–S4) to output a pair of signals **504***a*–**504***b* denoting a selected combination of operations, TX with NOP, both RX, and NOP with TX for controller managers **106***a* and **106***b*.

Upon power-on or reset, state machine **500** transitions from idle state **610** to S1 state **612**. While in S1 state **612**, state machine **500** remains in the state for duration ts**1**, outputting signal **504***a*–**504***b* denoting TX and NOP for controller managers **106***a* and **106***b*. Ts**1** is set to t**1**. Upon expiration of ts**1**, state machine **500** transitions from S1 state **612** to S2 state **614**. While in S2 state **614**, state machine **500** remains in the state for duration ts**2**, outputting signal **504***a*–**504***b* denoting RX for both controller managers **106***a* and **106***b*. Ts**2** is set to t**2**. Upon expiration of ts**2**, state machine **500** transitions from S2 state **614** to S3 state **616**.

While in S3 state **616**, state machine **500** remains in the state for duration ts**3**, outputting signal **504***a*–**504***b* denoting NOP and TX for controller managers **106***a* and **106***b*. Ts**3** is set to t**3**. Upon expiration of ts**3**, state machine **500** transitions from S3 state **616** to S4 state **618**. While in S4 state **618**, state machine **500** remains in the state for duration ts**4**, outputting signal **504***a*–**504***b* denoting RX for both controller managers **106***a* and **106***b*. Ts**4** is set to t**4**. Upon expiration of ts**4**, state machine **500** transitions from S4 state **618** to S1 state **612**.

From S1 state **612**, state machine **500** continues operation as described earlier.

Referring now to FIG. **7**, wherein a block diagram illustrating wireless device **100** of FIG. **1** in further detail, in accordance with yet another embodiment, is shown. As illustrated, for this embodiment, in addition to having wireless device **100** be endowed with a single state machine **700** to assist both controller managers **106***a* and **106***b* as described earlier (with signals **708***a*—**708***a* denoting TX-NOP, RX-RX or NOP-TX), wireless device **100** is further endowed with register **702**, time sharing manager **704**, and workload monitor **706** operatively coupled to each other and state machine **700** as shown. Register **702** stores t**1**–t**4** for state machine **700**. Time sharing manager **704** dynamically adjusts t**1**–t**4** to enable state machine **700** be able to adaptively assist controller managers **106***a* and **106***b* in controlling transceivers **102***a* and **102***b*. For the illustrated embodiment, time sharing manager **704** dynamically adjusts t**1**–t**4** based at least in part on transmit and receive workloads of networks **108***a* and **108***b*. Transmit and receive workloads are monitored by workload monitor **706** and provided to time sharing manager **704**.

Register **702** may be constituted with any storage circuitry known in the art. Time sharing manager **704** and workload monitor **706** may be implemented with any combinatorial logic or in software.

Referring now to FIGS. **8***a*–**8***b*, wherein a period of operation for the wireless devices of FIG. **1** in accordance with each of two alternate embodiments are shown. In each of these two alternate embodiments, first protocol of wireless devices **104***a* of network **108***a* is assumed to be a frequency hopping protocol as shown, i.e. wireless devices **104***a* hop from frequency to frequency in accordance with a pseudo random pattern to transmit signals. For ease of understanding, second protocol of wireless devices **104***b* of network **108***b* is assumed to be a constant frequency protocol (although in alternate embodiments, it may also be a frequency hopping protocol). In any event, to illustrate the present invention, at least one of the frequencies of the first protocol is the same frequency of the second protocol. Thus, if some of devices **104***a* and **104***b* are located sufficiently close to each other, and when one of devices **104***a* selects the same frequency for transmission, interference (or collision) between these devices will occur, resulting in one or more transmission failures. For the illustrated example, frequency interference (or collision) is shown to occur at the 7^{th} and 14^{th} hop (f_7 and f_4). That is, in accordance with the pseudo random pattern, in each of these two hops, devices **104***a* transmit in the same frequency employed by devices **104***b*. An example of a frequency hopping protocol is the Bluetooth protocol, and an example of a protocol having an interfering frequency with Bluetooth is the 802.11 protocol. [Note that the example interference at the 7^{th} and 14^{th} hop is not intended to suggest that the interference occurs at every 7^{th} hop. The interference pattern is dictated by the intersection of the pseudo random pattern followed by the frequency hopping devices **104***a* and the frequency employed by devices **104***b*.]

To further improve the operating efficiencies of both network, instead of just letting the interfering devices **104***a* and **104***b* resolve each of the frequency interference, after it occurred, through conventional collision detection, back off and retry approaches, wireless device **100** coordinates the operation of devices **104***a* and **104***b* to proactively reduce actual occurrence of interference. More specifically, for the illustrated embodiments, either devices **104***a* or devices **104***b* are selected to be the "dominant" devices. The non-selected devices are considered to be the dominated devices. The dominated devices are notified, from time to time, to suspend operation to pro-actively avoid interference with the dominant devices, allowing the dominant devices to continue to operate without interference. As result, the time consuming collision detection, back off and retries are substantially reduced, and experience has shown that the overall operating efficiencies of both networks improve, the dominated network as well as the dominant network.

FIG. **8***a* illustrates a period of operation when devices **104***a*, the frequency hopping devices, are selected to be the dominant devices, while FIG. **8***b* illustrates a period of operation when devices **104***b* are selected to be the dominant devices. That is, under FIG. **8***a*, devices **104***b*, upon informed, will temporarily suspend operation to proactively avoid interference, whereas under FIG. **8***b*, devices **104***a*, upon informed, will temporarily suspend operation to proactively avoid interference.

Under either one of these embodiments, wireless device **100** basically operates as earlier described. Except wireless device **100** assumes the additional responsibilities of determining the pseudo random frequency hopping pattern of devices **104***a* (in one embodiment, including the interfering frequency), selecting either devices **104***a* or **104***b* to be the dominated devices, predicting the occurrence of interference, and preemptively notifying the dominated devices to suspend operation to avoid interference (in one embodiment, conditionally suspending operation).

Referring now to FIGS. **9***a*–**9***b*, wherein the architecture and operational flow of wireless device **100** having these added responsibilities are shown. As illustrated in FIG. **9***a*, wireless device **100** is basically the embodiment earlier described referencing FIG. **7**, except wireless device **100** is further provided with network management application (or network manager) **904** to proactively managing network devices **104***a* and **104***b* to reduce actual occurrence of interference. Network manager **904** also subsumes the earlier described responsibilities of time sharing manager **704**, i.e. monitoring the workloads of the two protocols, and adaptively setting the values of **t1**–**t4** for time period T1–T4.

Operationally, as illustrated in FIG. **9***b*, upon initialization, network manager **904** monitors the operation of devices **104***a* and **104***b* for an observation period, and determines the pseudo random frequency hopping pattern followed by devices **104***a* (and in one embodiment, the interfering frequency with devices **104***b*), **912**. This may be accomplished using any one of a number of techniques known in the art. Next, network manager **904** selects either devices **104***a* or devices **104***b* to be the dominant devices, **914**. In one embodiment, network manager **904** makes the selection in accordance with configuration information programmed in configuration register **902**. In alternate embodiments, other configuration registers, or other techniques known in the art, such as jumpers, may also be employed to assist network manager **904** in making the selection.

Then, on an on going basis, network manager **904**, predicts when interference will occur, using the determined pseudo random pattern and interference frequency, **916**. Whenever, an interference is to occur, network manager **904** preemptively notifies the dominated devices to suspend operation accordingly, thereby allowing the dominant devices to operate without interference, 918. [In one embodiment, if the dominated devices are devices **104***a*, the notification includes the interfering frequency, and the suspension is conditional, only if the predicted frequency is indeed the interfering frequency.] The process continues, as long as there are wireless devices of both types **104***a* and **104***b* operating.

In one embodiment, network manager **904** repeats the calibration periodically. In yet another embodiment, network manager **904** monitors actual interference between devices **104***a* and **104***b*, and tracks the mean time between interference. Network manager **904** repeats the calibration, whenever the tracked mean time between interference drops below certain given performance level.

Note that in embodiments where the number of devices **104***a* and **104***b* present in networks **108***a* and **108***b* are relatively small, including in particular, the simplest case where there is only one device **104***a* and one device **104***b* in networks **108***a* and **108** respectively, network manager **904** may make the selection of the dominated devices in a dynamic and individualized manner, when an interference is predicted to occur. That is, different device or devices **104***a* and **104***b* are dynamically and individually selected for different predictions of interference. Such dynamic, individualized manner of selection may also be made in view of the workloads of the two protocols.

As those skilled in the art would appreciate, the above described improved manner of operation (including the embodiment, where suspension is to be conditionally made by devices **104**a) may be practiced with minimal or no change to devices **104**,a and **104**a, as virtually all network devices are capable of temporarily suspending operation responsive to a request. As to the embodiment where suspension is to be conditionally made by devices **104**a, the conditional performance may be effectuated through addition of simple frequency testing combinatorial logic.

Additionally, in yet other embodiments, upon selecting the dominated devices at **914**, wireless device **100** notifies devices **104**a and **104**b of their respective roles, i.e. whether they are the dominating devices or dominated devices. Further, at least the dominated devices are also provided with a collision map, for the dominated devices to self determine whether interference is to occur. In other words, operation **916** is distributed to the dominated devices, and operation **918** is eliminated.

In yet other embodiments where the wireless protocol is a frequency hopping protocol successively employing a number of frequencies in a pseudo random manner, independent of whether the interference determination is performed by wireless device **100** or the dominated devices, the determination of interference further includes prospectively anticipating whether the transmission of a long packet by a dominated device operating in accordance with such frequency hopping protocol will cause interference with the dominating devices. A long packet is a packet whose transmission spans multiple ones of the frequency hops. The dominated devices either self-determine or instructed by wireless device **100** (depending on implementations) to refrain from starting such transmission of a long packet unless interference will not occur.

Referring now to FIG. **10**, wherein a period of operation for the wireless devices of FIG. **1** in accordance with another embodiment is shown. Again, first protocol of wireless devices **104**a of network **108**a is assumed to be a frequency hopping protocol, and second protocol of wireless devices **104**b of network **108**b is assumed to be a constant frequency protocol (although it may also be a frequency hopping protocol). Nevertheless, for illustrative purpose, it is suffice that at least one **4**: of the frequencies of the first protocol of wireless devices **104**a conflicts with the frequency of the second protocol of wireless devices **104**b as shown, and earlier described. Thus, in like manner, if some of devices **104**a and **104**b are located sufficiently close to each other, and devices **104**a select to transmit in the same frequency, interference (or collision) will occur, resulting in one or more transmission failures. To further improve the operating efficiencies of both network, instead of just letting the interfering devices **104**a and **104**b resolve each of the frequency interference, after it occurred, through conventional collision detection, back off and retry approaches, wireless device **100** coordinates the operation of devices **104**a and **104**b to proactively reduce actual occurrence of interference. More specifically, under this embodiment, devices **104**a and **104**b are correspondingly notified of the filtering to be employed to correspondingly cancel the respective interfering signals, and when to apply the filtering. As will be described in more detail below, in one embodiment, the filtering to be employed is a notch filter inversely formed in accordance with the other devices' signal. As a result, the time consuming collision detection, back off and retries are also substantially reduced, and experience has shown that the overall operating efficiencies of both networks also improve.

As illustrated in FIG. **10**, at each predicted occurrence of interference, both devices **104**a and **104**b apply the corresponding required filtering to correspondingly cancel the respective interfering signals. As before, the basic operations of wireless device **100** remain substantially unchanged, except, wireless device **100** assumes the additional responsibilities of determining the pseudo random frequency hopping pattern of devices **104**a, the interfering frequency, the corresponding filtering to be employed to cancel the respective interfering signals, and preemptively notifying devices **104**a and **104**b of the determined filtering as well as when to apply them.

Referring now to FIGS. **11**a–**11**b, wherein the architecture and operational flow of wireless device **100** having these added responsibilities are shown. As illustrated in FIG. **1**a, wireless device **100** is basically the embodiment earlier described referencing FIG. **9**a. That is, wireless device **100** is also additionally provided with network manager **1104**, except the additional responsibilities assumed by network manager **1104** to proactively reduce interference are slightly different.

As illustrated in FIG. **11**b, upon initialization, network manager **1104** monitors the operation of devices **104**a and **104**b for an observation period, and determines the pseudo random frequency hopping pattern followed by devices **104**a, and the interfering frequency with devices **104**b, **1112**. This again may be accomplished using any one of a number of techniques known in the art. Next, network manager **1104** determines the corresponding filtering to be employed by devices **104**a and **104**b to correspondingly cancel their respective interfering signals of "the other devices", and provides the determined information to devices **104**a and **104**b, **1114**. In one embodiment, as alluded to earlier, the corresponding filtering to be employed are notched filters inversely constructed in accordance with the other devices' signals (see FIG. **12**). That is, devices **104**a are to apply a notch filter, inversely formed in accordance with transmit signals of devices **104**b, whereas, devices **104**b are to apply a notch filter, inversely formed in accordance with transmit signals of devices **104**a. [Notch filters in general are known in the art, and will not be further described.]

Then, on an on going basis, network manager **1104**, predicts when interference will occur, using the determined pseudo random pattern and interference frequency, **1116**. Whenever, an interference is to occur, network manager **1104** preemptively notifies devices **104**a and **104**b to correspondingly apply their corresponding filtering, thereby allowing both devices **104**a and **104**b to operate without interference, **1118**. The process continues, as long as there are wireless devices of both types **104**a and **104**b operating. [Likewise, the application of filtering by devices **104**a may also be conditionally performed, only if the frequency is indeed the same as the interfering frequency.]

As before, in one embodiment, network manager **1104** repeats the calibration periodically. In yet another embodiment, network manager **1104** monitors actual interference between devices **104**a and **104**b, and tracks the mean time between interference. Network manager **1104** repeats the calibration, whenever the tracked mean time between interference drops below certain given performance level.

As those skill in the art will appreciate, the immediately described improved manner of operation may also be practiced with minimal change to devices **104**a and **104**a, by equipping both types of network devices with the ability to responsively apply notch filtering. [Likewise, devices **104**a may be additionally provided with simple combinatorial logic to effectuate the conditional application of notch filtering.]

Similar to the embodiments described with references to FIGS. **8a–8b** and **9a–9b**, in yet other embodiments, in addition to notifying the devices of the required filtering at **1114**, wireless device **100** provides the devices with a collision map, such that the devices can self determine whether interference is to occur, and the appropriate filtering to be applied. In other words, operation **1116** is distributed to the devices, and operation **1118** is eliminated.

Skipping now to FIG. **14**, wherein another overview of wireless device **100** of the present invention, along with devices **104a** and **104b** of wireless networks **108a** and **108b** are shown, in accordance with another embodiment. In this embodiment, the devices additionally operate in a complementary manner to proactively reduce interference among the devices. For illustrative purpose, wireless devices **104a** are assumed to employ a frequency hopping protocol. Moreover, wireless devices **104a** are subdivided into at least two subsets, with the devices of the two subsets employing successive frequencies in accordance with at least two corresponding pseudo random patterns. [In one embodiment, where the frequency hopping protocol is Bluetooth, each subset corresponds to a "piconet". Note that even though for ease of understanding, only one device **104a** is illustrated in each of the subset, the present invention may be practiced with each subset having one or more devices.]]

In accordance with the present invention, to effectuate the desired proactive reduction of interference, the various subsets of devices **104a** are operated in a synchronized manner (see FIG. **15**). In one embodiment, the synchronization is effectuated by synchronizing-transmit and receive operations of the various subsets to a reference signal. In one embodiment, the reference signal is provided by one of devices **104b**. In other embodiments, the reference signal is provided by yet another device (not shown). Complementarily, devices **104b** are also operated with transmit and receive operations aligned to the reference signal.

For this embodiment, in addition to having been incorporated with one or more of the novel features earlier described, wireless device **100** is further equipped to operate in a manner that is complementary to the synchronized operation of devices **104a** and the aligned operation of devices **104b**, to effectuate the desired reduction of interference among the devices. In particular, one or both controller managers **106a** and **106b** are equipped to enable the two controller managers **106a** and **106b** to operate with aligned control clocks for the two protocols.

More specifically, in one embodiment, controller manager or managers **106a** and/or **106b** are equipped such that when wireless device **100** joins wireless network **108b** after having begun communication with devices **104a** of at least one of the subsets, wireless device **100** would cause the two control clocks for the two protocols to be aligned incrementally. In one embodiment, the incremental alignment is effectuated in a dependent manner, depending on the amount of misalignment with respect to a transmission time slot. In one embodiment, the incremental alignment is effectuated by decrementing the start time of a transmission time slot by a predetermined amount for m successive transmission time slots if the amount of misalignment is less than half of the transmission time slot size, or by incrementing the start time of a transmission time slot by a predetermined amount for n successive transmission time slots if the amount of misalignment is less than half of the transmission time slot size.

In other words, if the transmission periods for the protocol employed by devices **104b** are 0, B, 2B, . . . , kB ($0<=k<2^{64}$), and the transmission time slots of the protocol employed by devices **104a** start at d, d+S, d+2S, . . . , d+mS etc ($0<=d<S$), the start time of a transmission time slot of the protocol of network **108a** can be adjusted successively by t micro seconds for m or n successively transmission time slots, depending on whether d is less than or equal to S/2 or greater than S/2. In one embodiment, S is 625 micro seconds, and t is set to 8 micro seconds. For this embodiment, if d is less than or equal to S/2, m is set to the largest integer smaller than d/8, whereas if d is greater than S/2, n is set to the largest integer smaller than S−d/8.

In other embodiments, other criteria and/or parameters, even other incremental approaches may be employed instead. In one embodiment, the incremental alignment is repeated; however only after waiting for at least predetermined number of transmission time slots to "dampen oscillations" In one embodiment, the predetermined number of transmission time slots waited is **10**. In other embodiments, different waiting periods may be used instead.

Referring now to FIG. **13**, wherein an overview of the present invention, in accordance with another embodiment, is shown. Similar to the embodiment of FIG. **1**, wireless device **100** is communicatively coupled to devices **104a** and devices **104b** of wireless networks **108a** and **108b** respectively. Wireless device **100** performs transmits and receives of the two protocols, in a coordinated manner, to allow wireless device **100** to operate with devices **104a** and devices **104b** of wireless network **108a** and **108b** in accordance with the respective protocols at the same time. However, unlike all the earlier described embodiments, wireless device **100** is provided with a single wireless transceiver **1302**, which includes joint signal transmit/receive section **1303**, and a number of transmit and receive signals up/down conversion sections **1205** sharing joint signal transmit/receive section **1303**. Wireless device **100** further includes controller/signal processing (C/SP) section **1306** to process data for transmission by wireless transceiver **1302**, to process signals received by wireless transceiver **1302**, and to control the data/signal processing operations as well as the operation of wireless transceiver **1302**. The constitution and operations of wireless device **100** is the subject of the second parent application Ser. No. 09/436,458, which is hereby fully incorporated by reference. Additionally, in some embodiments, wireless device **100** is endowed with a network manager equipped with the capabilities earlier described referencing FIGS. **8a–8b** and **9a–9b**, with or without the prospective interference anticipation for long packets. In other embodiments, wireless device **100** is endowed with a network manager equipped with the capabilities earlier described referencing FIGS. **110** and **11a–11b**. In yet other embodiments, wireless device **100** is endowed with the capabilities earlier described referencing FIGS. **14** and **15**. In one words, the capabilities and methods of operations described referencing FIGS. **8a–8b** and **9a–9b**, FIGS. **10** and **11a–11b**, and FIGS. **14–15**, may be practiced with the multiple protocol wireless apparatus of the first parent application Ser. No. 09/408,725, or the multiple protocol wireless apparatus of the second parent application.

Thus, a wireless device equipped to substantially operate currently with multiple wireless communication protocols, and various associated methods of operations, including proactive reduction of interference, have been described. While the present invention has been described in terms of the above illustrated embodiments, those skilled in the art will recognize that the invention is not limited to the embodiments described. The present invention can be practiced with modification and alteration within the spirit and scope of the appended claims. The description is thus to be regarded as illustrative instead of restrictive on the present invention.

What is claimed is:

1. A collection of networked apparatuses comprising:

a first plurality of apparatuses including first and second subsets wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a first frequency hopping protocol, with the first and second subsets operating in accordance with a first and a second frequency hopping pattern based on a first and a second pseudo random pattern;

a second plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a second protocol;

wherein said first and second subsets of said first plurality of apparatuses are operationally synchronized and in wireless communication with a common wireless device, and said second plurality of apparatuses are operated in a manner complementary to said synchronized operation of said first and second subsets of said first plurality of apparatuses, to proactively reduce interference between said first and second plurality of apparatuses and wherein the common wireless device comprises a multi-protocol apparatus equipped with a first and a second transceiver to communicate wirelessly with said first and second plurality of apparatuses in accordance with said first and second protocols respectively, and in a manner that is complementary to said synchronized operation of said first and second subsets of said first plurality of apparatuses to proactively reduce interference with said first and second plurality of apparatuses;

wherein said first and second subsets are operationally synchronized to a reference signal, and said second plurality of apparatuses are operationally aligned to the same reference signal and said multi-protocol apparatus includes control logic to operate in a manner that is complementary to said synchronization as well as said alignment with respect to said reference signal, to effectuate said proactive reduction of interference among said apparatuses; and

wherein said control logic includes logic to effectuate said alignment to said reference signal incrementally, and in a selected one of at least a first and a second manner depending on an amount of misalignment with a transmission time slot.

2. The apparatuses of claim 1, wherein said logic decrements a transmission time slot starting time by a predetermined amount for m successive transmission time slots if the amount of misalignment is less than half of a transmission time slot size.

3. The apparatuses of claim 1, wherein said logic increments a transmission time slot starting time by a predetermined amount for n successive transmission time slots if the amount of misalignment is greater than half of a transmission time slot size.

4. An apparatus comprising:

a plurality of wireless transceivers to transmit and receive signals in accordance with a first and a second protocol, to and from first and second network devices of a first and a second wireless network communicatively coupled to the apparatus, the first network devices comprising first and second subsets that transmit and receive in accordance with a first and a second frequency hopping pattern based on a first and a second pseudo random pattern in a synchronized manner wherein the first and second subsets are in wireless communication with a common wireless device, the first protocol being a frequency hopping protocol;

at least one controller manager coupled to the wireless transceivers to control and coordinate operation of said wireless transceivers in a manner that complements said synchronized operation of said first and second subsets of said first network devices to reduce interference among said apparatus and said first and second network devices;

wherein the at least one controller manager includes logic to align transmit and receive operations of said wireless transceivers to a reference signal against which said first and second subsets of said first network devices synchronize operations; and

wherein said logic effectuates said alignment to said reference signal incrementally in a selected one of at least a first and a second manner depending on an amount of misalignment with a transmission time slot.

5. The apparatus of claim 4, wherein said logic decrements a transmission time slot starting time by a predetermined amount for m successive transmission time slots if the amount of misalignment is less than half of a transmission time slot size.

6. The apparatus of claim 4, wherein said logic increments a transmission time slot starting time by a predetermined amount for n successive transmission time slots if the amount of misalignment is greater than half of a transmission time slot size.

7. In an apparatus having a first and a second wireless transceiver, a method of operation comprising:

controlling said first wireless transceiver to transmit and receive data to and from first and second subsets of first network devices of a first wireless network in accordance with a first protocol which is a frequency hopping protocol, and in a manner that is complementary to a synchronized manner of operation of the first and second subsets of said first network devices in accordance with first and second frequency hopping patterns based on first and second pseudo random patterns respectively;

controlling said second wireless transceiver to transmit and receive data to and from second network devices of a second wireless network in accordance with a second protocol, and in a manner that is complementary to an aligned manner of operation of said second network devices to said synchronous operation of the first and second subsets of said first network devices;

wherein said complementary manners of controlling comprise aligning transmit and receive operations of said first and second wireless transceivers to a reference signal against which said first and second subsets of said first network devices synchronize operations; and

wherein said alignment to said reference signal is effectuated incrementally in a selected one of at least a first and a second manner depending on an amount of misalignment with a transmission time slot.

8. The method of claim 7, wherein said incremental alignment comprises decrementing a transmission time slot starting time by a predetermined amount for m successive transmission time slots if the amount of misalignment is less than half of a transmission time slot size.

9. The method of claim 7, wherein said incremental alignment comprises incrementing a transmission time slot

starting time by a predetermined amount for n successive transmission time slots if the amount of misalignment is greater than half of a transmission time slot size.

10. A collection of networked apparatuses comprising:

a first plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a first frequency hopping protocol comprising a plurality-of frequencies successively employed based on a pseudo random pattern;

a second plurality of apparatuses wirelessly networked together, with each apparatus being equipped to communicate wirelessly in accordance with a second protocol; and

a multi-protocol apparatus equipped to communicate wirelessly with said first and second plurality of apparatuses in accordance with said first and second protocols respectively, wherein the multi-protocol apparatus further at least facilities reduction of interference among said apparatuses, including at least facilitating prospective anticipation of whether interference will occur during transmission of a long packet by a selected one of said first plurality of apparatuses in accordance with said first protocol, said transmission of a long packet spanning multiple ones of said successive frequencies.

11. The collection of networked apparatuses of claim **10**, wherein the multi-protocol apparatus includes a network manager equipped to determine the pseudo random frequency hopping pattern of said first network devices of said first wireless network.

12. The collection of networked apparatuses of claim **11**, wherein the network manager is further equipped to predict when interference will occur between said first and second network devices of said first and second wireless networks, based on said determined pseudo random frequency hopping pattern.

13. The collection of networked apparatuses of claim **12**, wherein the network manager is further equipped to provide said first/second network devices with collision maps.

14. The collection of networked apparatuses of claim **12**, wherein the network manager is further equipped to inform said first/second network devices of anticipated interference.

15. An apparatus comprising:

at least one wireless transceiver to transmit and receive signals in accordance with a first and a second protocol to and from first and second network devices of a first and a second wireless network respectively, said first protocol being a frequency hopping protocol comprising a plurality of frequencies successively employed in accordance with a pseudo random pattern; and

at least one controller manager coupled to the at least one wireless transceiver to control and coordinate performance of said transmits and receives, including at least facilitation of proactive reduction of interference among said apparatus and said network devices, by at least facilitating prospective anticipation of whether interference will occur during transmission of a long packet by a selected one of said first network devices in accordance with said first protocol, said transmission of a long packet spanning multiple ones of said successive frequencies.

16. The apparatus of claim **15**, wherein the apparatus further includes a network manager equipped to determine the pseudo random frequency hopping pattern of said first network devices of said first wireless network.

17. The apparatus of claim **16**, wherein the network manager includes logic to predict when interference will occur between said first and second network devices of said first and second wireless networks, based on said determined pseudo random frequency hopping pattern.

18. The apparatus of claim **17**, wherein the network manager is further equipped to provide said first/second network devices with collision maps.

19. The apparatus of claim **17**, wherein the network manager is further equipped to inform said first/second network devices of anticipated interference.

20. The apparatus of claim **15**, wherein the first protocol is a version of Bluetooth, and the second protocol is a protocol selected from a group consisting of a version of 802.11 frequency hopping, 802.11 direct sequence, 802.11a, 802.11b, and Home RF.

21. The apparatus of claim **15**, wherein the apparatus is a computer having a form factor selected from a group consisting of a desktop type, a notebook type, and a palm sized type.

22. In an apparatus having at least one wireless transceiver and at least one controller manager; a method of operation comprising:

controlling said at least one wireless transceiver to transmit and receive signals in accordance with a first and a second protocol to and from first and second network devices of a first and a second wireless network respectively, said first protocol being a frequency hopping protocol comprising a plurality of frequencies successively employed in accordance with a pseudo random pattern; and

at least facilitating proactive reduction of interference among said apparatus and said network devices, by at least facilitating prospective anticipation of whether interference will occur during transmission of a long packet by a selected one of said first network devices in accordance with said first protocol, said transmission of a long packet spanning multiple ones of said successive frequencies.

23. The method of claim **22**, wherein said at least facilitating includes determining the pseudorandom frequency hopping pattern of said first network devices of said first wireless network.

24. The method of claim **23**, wherein said at, least facilitating further includes predicting when interference will occur between said first and second network devices of said first and second wireless networks, based on said determined pseudo random frequency hopping pattern.

25. The method of claim **24**, wherein said at least facilitating further comprises providing said first/second network devices with collision maps.

26. The method of claim **24**, wherein said at least facilitating further comprises informing said first/second network devices of anticipated interference.

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