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(54) METHOD AND SYSTEM FOR VOIP OVER WLAN TO BLUETOOTH HEADSET USING ACL LINK AND SNIFF FOR ALIGNED ESCO TRANSMISSION

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(57) **ABSTRACT**

A system and method are disclosed for reducing interference in simultaneous wireless LAN (WLAN) and wireless personal area network (PAN) signal handling in mobile wireless terminals having both a WLAN and a PAN interface. The wireless terminal includes a first transceiver operating in the PAN network in a communications band and a first communications protocol transmitting first data units. The wireless terminal also includes a second transceiver operating in the WLAN network in substantially the same communications band and a second communications protocol transmitting second data units. The wireless terminal further includes a controller coupled to the first and second transceivers, assigning a higher transmission priority to the second data units than to the first data units when transmission of the second data units overlaps a first occurring transmission of the first data units, to abort transmission of the first occurring data unit. The controller assigns a higher transmission priority to the aborted first data unit than to the second data units when transmission of the second data units overlaps the retransmission of the aborted first data unit, to transmit the aborted first data unit.

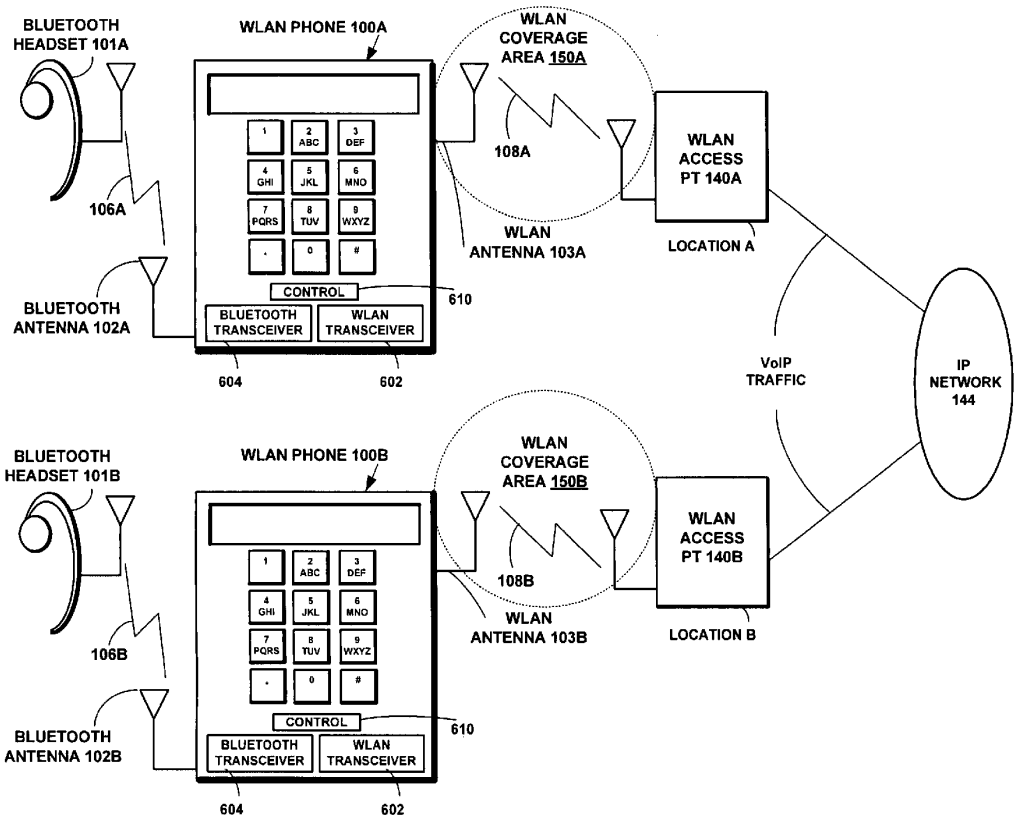


FIG. 1

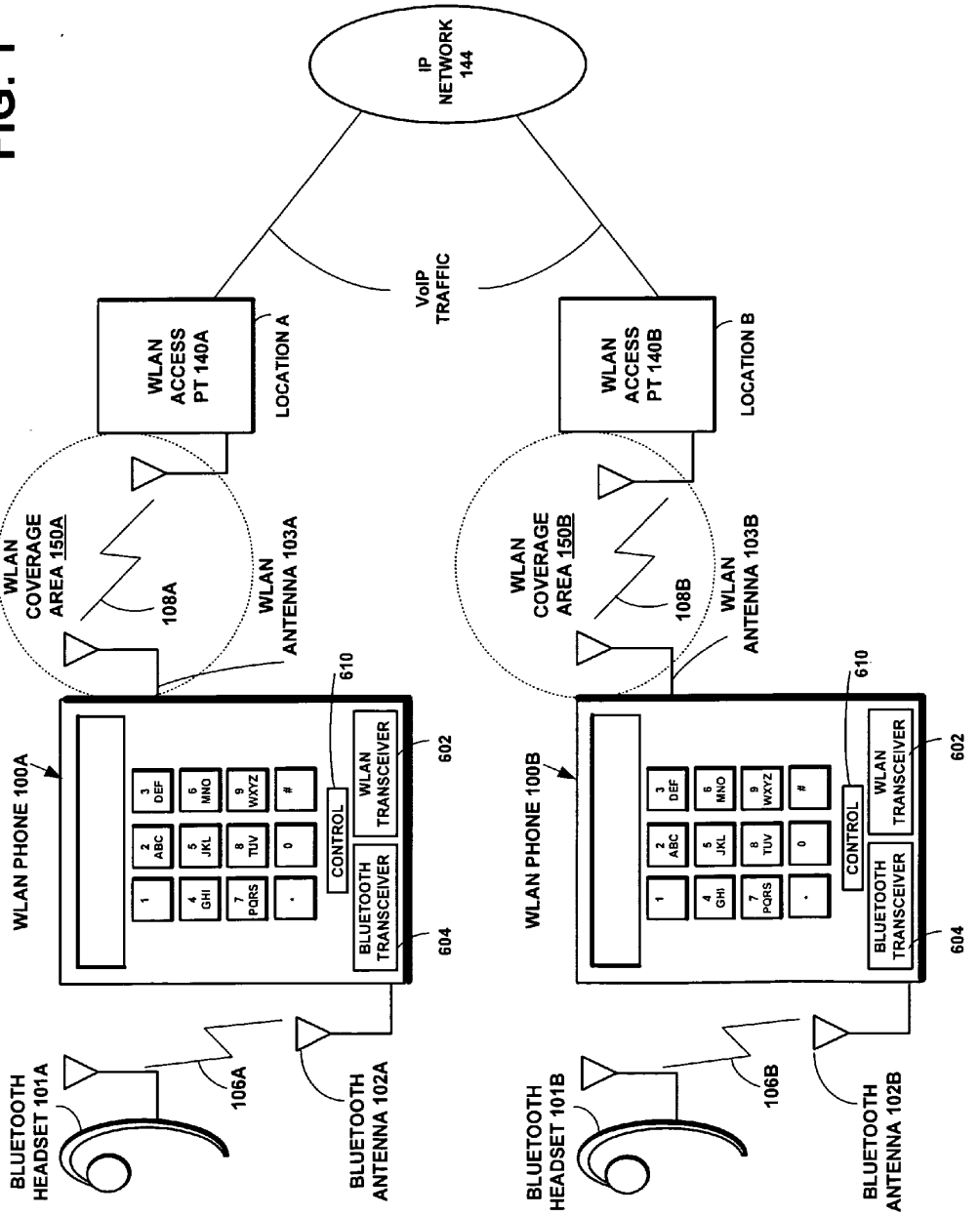
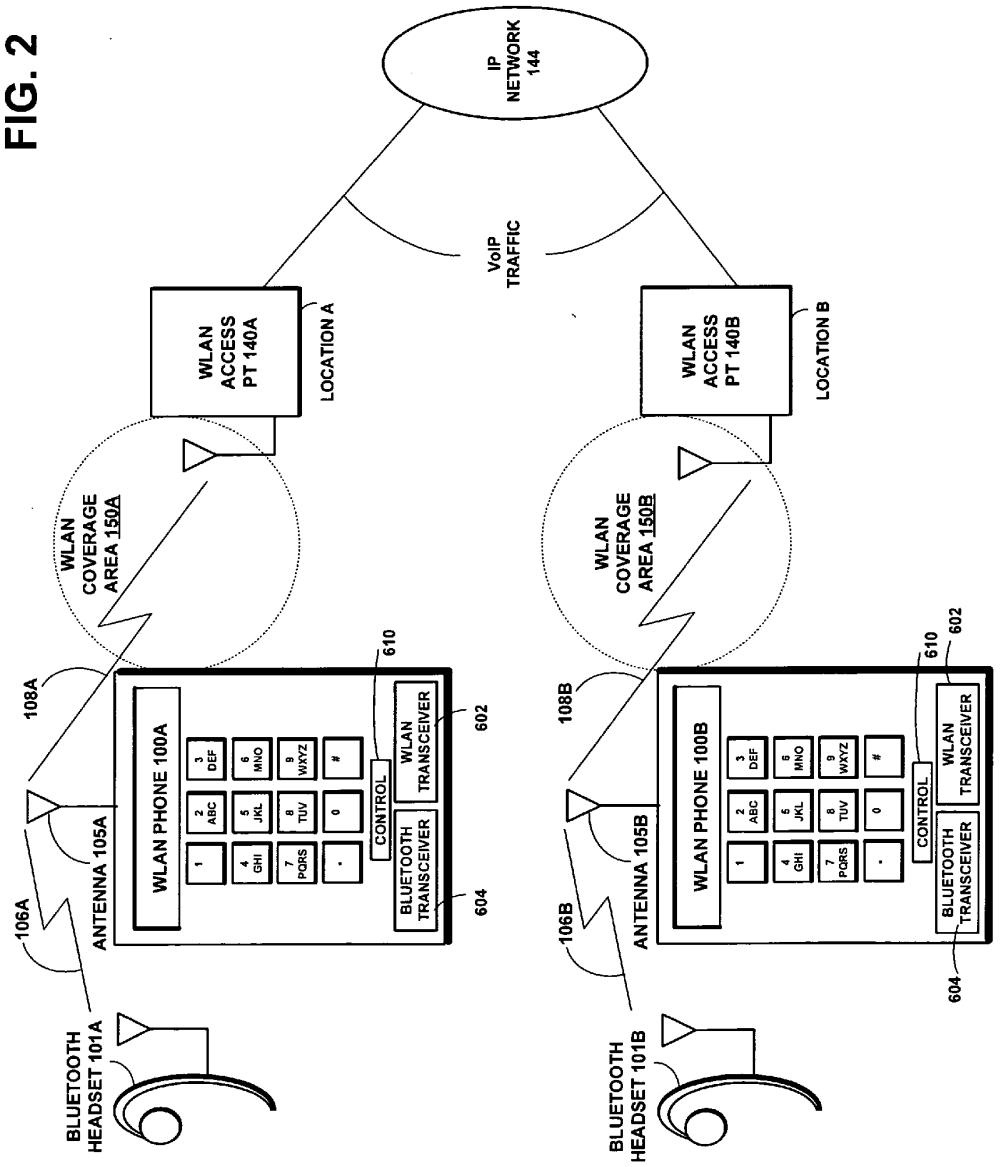

IP NETWORK 144
VoIP TRAFFIC
WLAN ACCESS PT 140A
LOCATION A
WLAN ACCESS PT 140B
LOCATION B
WLAN COVERAGE AREA 150A
WLAN COVERAGE AREA 150B
108A
108B
WLAN ANTENNA 103A
WLAN ANTENNA 103B
WLAN PHONE 100A
WLAN PHONE 100B
610
602
604
CONTROL
WLAN TRANSCEIVER
BLUETOOTH TRANSCEIVER
BLUETOOTH HEADSET 101A
BLUETOOTH HEADSET 101B
106A
106B
BLUETOOTH ANTENNA 102A
BLUETOOTH ANTENNA 102B

FIG. 2


IP NETWORK 144
VoIP TRAFFIC
WLAN ACCESS PT 140A
LOCATION A
WLAN ACCESS PT 140B
LOCATION B
WLAN COVERAGE AREA 150A
WLAN COVERAGE AREA 150B
108A
108B
106A
106B
ANTENNA 105A
ANTENNA 105B
WLAN PHONE 100A
WLAN PHONE 100B
CONTROL
WLAN TRANSCEIVER
BLUETOOTH TRANSCEIVER
602
604
610
BLUETOOTH HEADSET 101A
BLUETOOTH HEADSET 101B

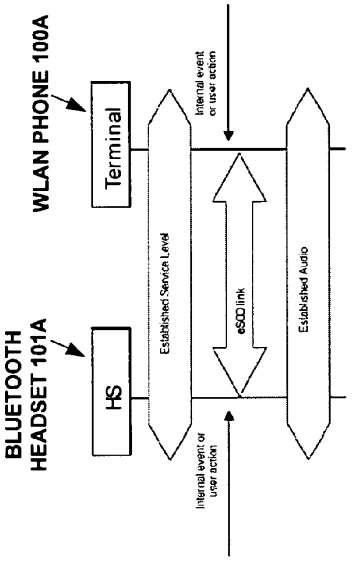


FIG. 3

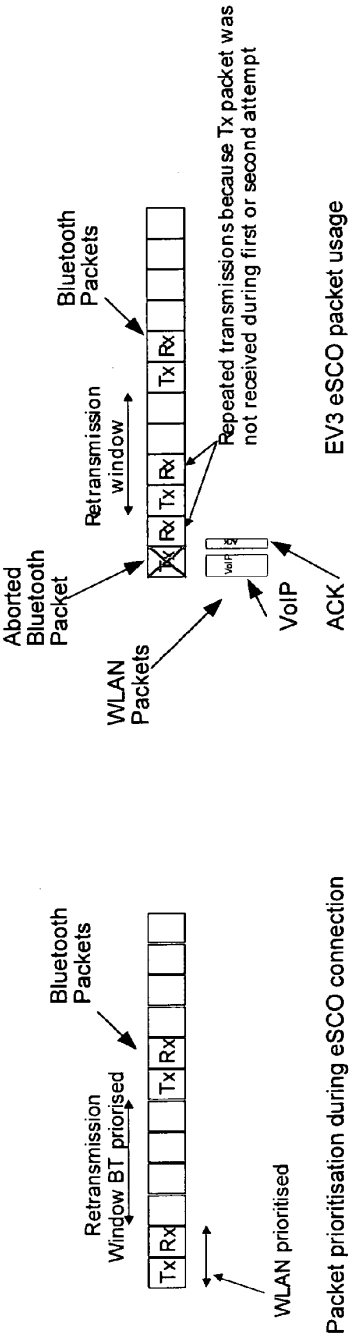


FIG. 4

FIG. 5

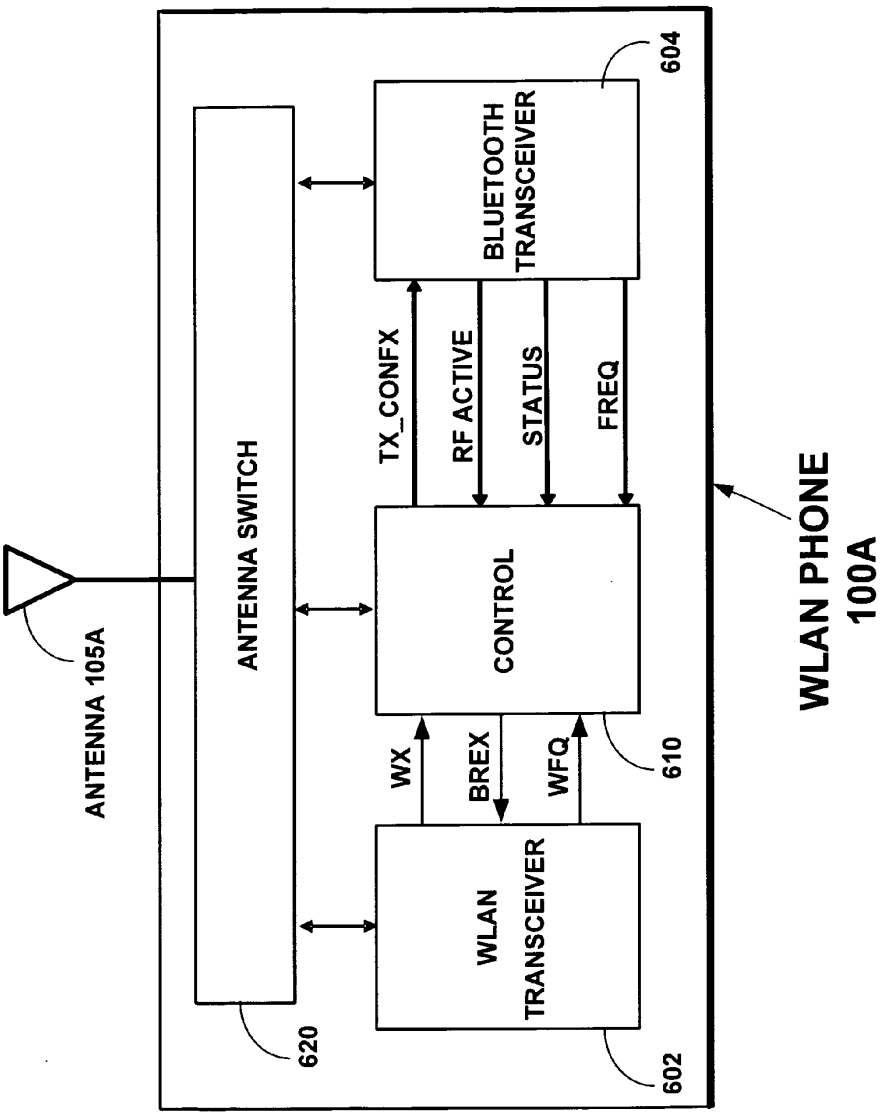

WLAN PHONE
100A
ANTENNA 105A
ANTENNA SWITCH
620
BLUETOOTH
TRANSCEIVER
604
TX_CONFX
RF ACTIVE
STATUS
FREQ
CONTROL
610
WX
BREX
WFQ
WLAN
TRANSCEIVER
602

FIG. 6

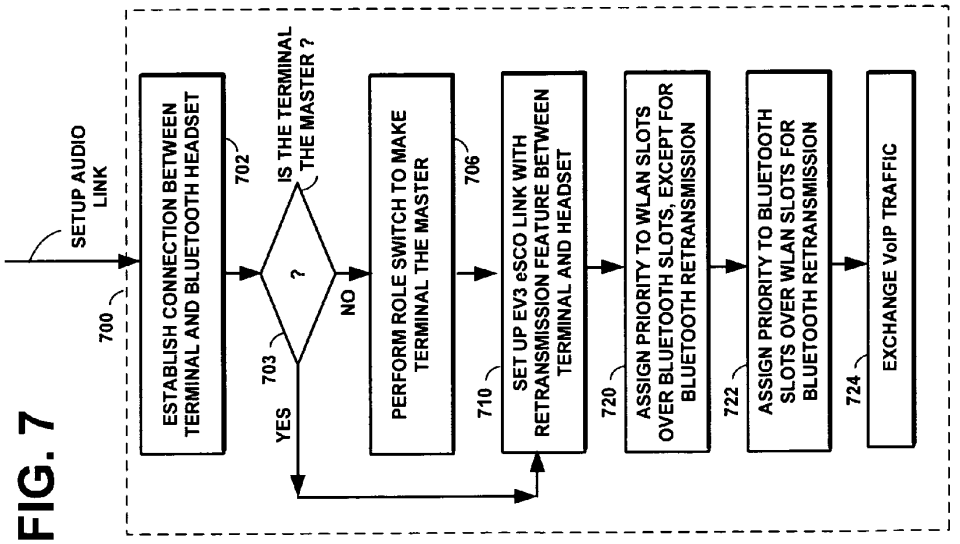

SETUP AUDIO LINK
700
ESTABLISH CONNECTION BETWEEN TERMINAL AND BLUETOOTH HEADSET
702
IS THE TERMINAL THE MASTER ?
703
YES
NO
PERFORM ROLE SWITCH TO MAKE TERMINAL THE MASTER
706
SET UP EV3 eSCO LINK WITH RETRANSMISSION FEATURE BETWEEN TERMINAL AND HEADSET
710
ASSIGN PRIORITY TO WLAN SLOTS OVER BLUETOOTH SLOTS, EXCEPT FOR BLUETOOTH RETRANSMISSION
720
ASSIGN PRIORITY TO BLUETOOTH SLOTS OVER WLAN SLOTS FOR BLUETOOTH RETRANSMISSION
722
EXCHANGE VoIP TRAFFIC
724

FIG. 7

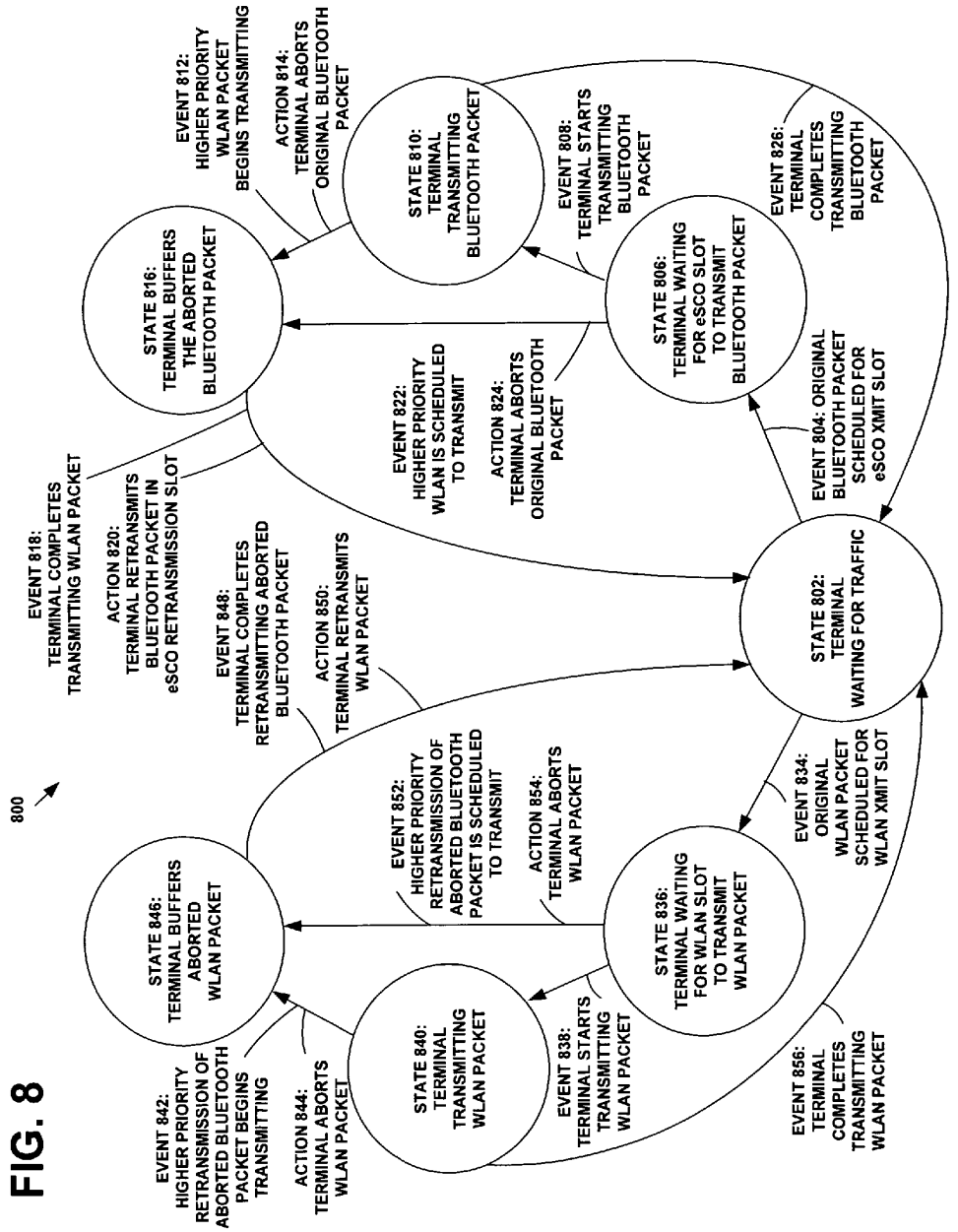

800
STATE 802: TERMINAL WAITING FOR TRAFFIC
STATE 806: TERMINAL WAITING FOR eSCO SLOT TO TRANSMIT BLUETOOTH PACKET
STATE 810: TERMINAL TRANSMITTING BLUETOOTH PACKET
STATE 816: TERMINAL BUFFERS THE ABORTED BLUETOOTH PACKET
STATE 836: TERMINAL WAITING FOR WLAN SLOT TO TRANSMIT WLAN PACKET
STATE 840: TERMINAL TRANSMITTING WLAN PACKET
STATE 846: TERMINAL BUFFERS ABORTED WLAN PACKET
EVENT 804: ORIGINAL BLUETOOTH PACKET SCHEDULED FOR eSCO XMIT SLOT
EVENT 808: TERMINAL STARTS TRANSMITTING BLUETOOTH PACKET
EVENT 812: HIGHER PRIORITY WLAN PACKET BEGINS TRANSMITTING
ACTION 814: TERMINAL ABORTS ORIGINAL BLUETOOTH PACKET
EVENT 818: TERMINAL COMPLETES TRANSMITTING WLAN PACKET
ACTION 820: TERMINAL RETRANSMITS BLUETOOTH PACKET IN eSCO RETRANSMISSION SLOT
EVENT 822: HIGHER PRIORITY WLAN IS SCHEDULED TO TRANSMIT
ACTION 824: TERMINAL ABORTS ORIGINAL BLUETOOTH PACKET
EVENT 826: TERMINAL COMPLETES TRANSMITTING BLUETOOTH PACKET
EVENT 834: ORIGINAL WLAN PACKET SCHEDULED FOR WLAN XMIT SLOT
EVENT 838: TERMINAL STARTS TRANSMITTING WLAN PACKET
ACTION 844: TERMINAL ABORTS WLAN PACKET
EVENT 842: HIGHER PRIORITY RETRANSMISSION OF ABORTED BLUETOOTH PACKET BEGINS TRANSMITTING
EVENT 848: TERMINAL COMPLETES RETRANSMITTING ABORTED BLUETOOTH PACKET
ACTION 850: TERMINAL RETRANSMITS WLAN PACKET
EVENT 852: HIGHER PRIORITY RETRANSMISSION OF ABORTED BLUETOOTH PACKET IS SCHEDULED TO TRANSMIT
ACTION 854: TERMINAL ABORTS WLAN PACKET
EVENT 856: TERMINAL COMPLETES TRANSMITTING WLAN PACKET

FIG. 8

FIG. 9A

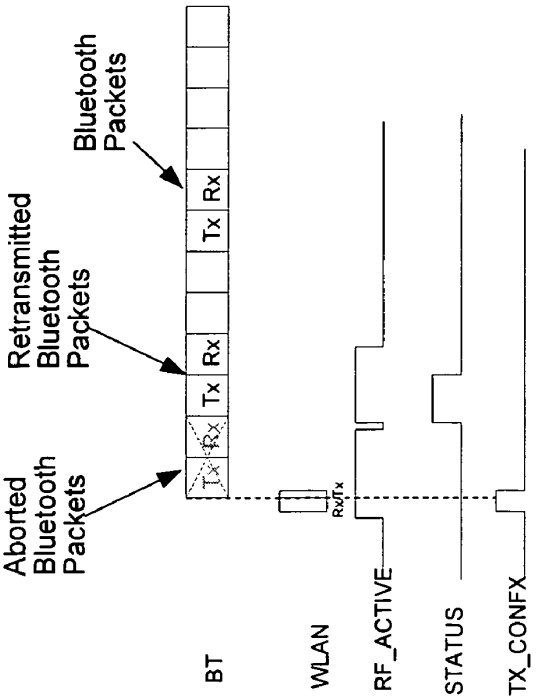
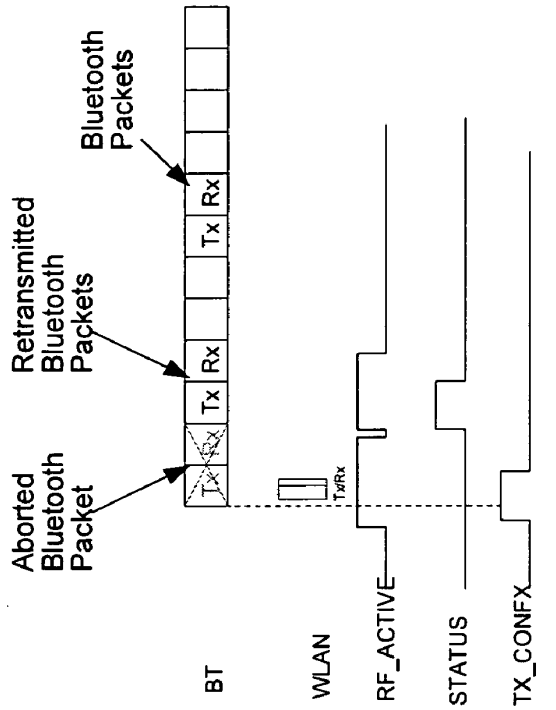


FIG. 9B



Status Signal Protects the Bluetooth Retransmission Window by Preventing WLAN Transmission from the Terminal

FIG. 10

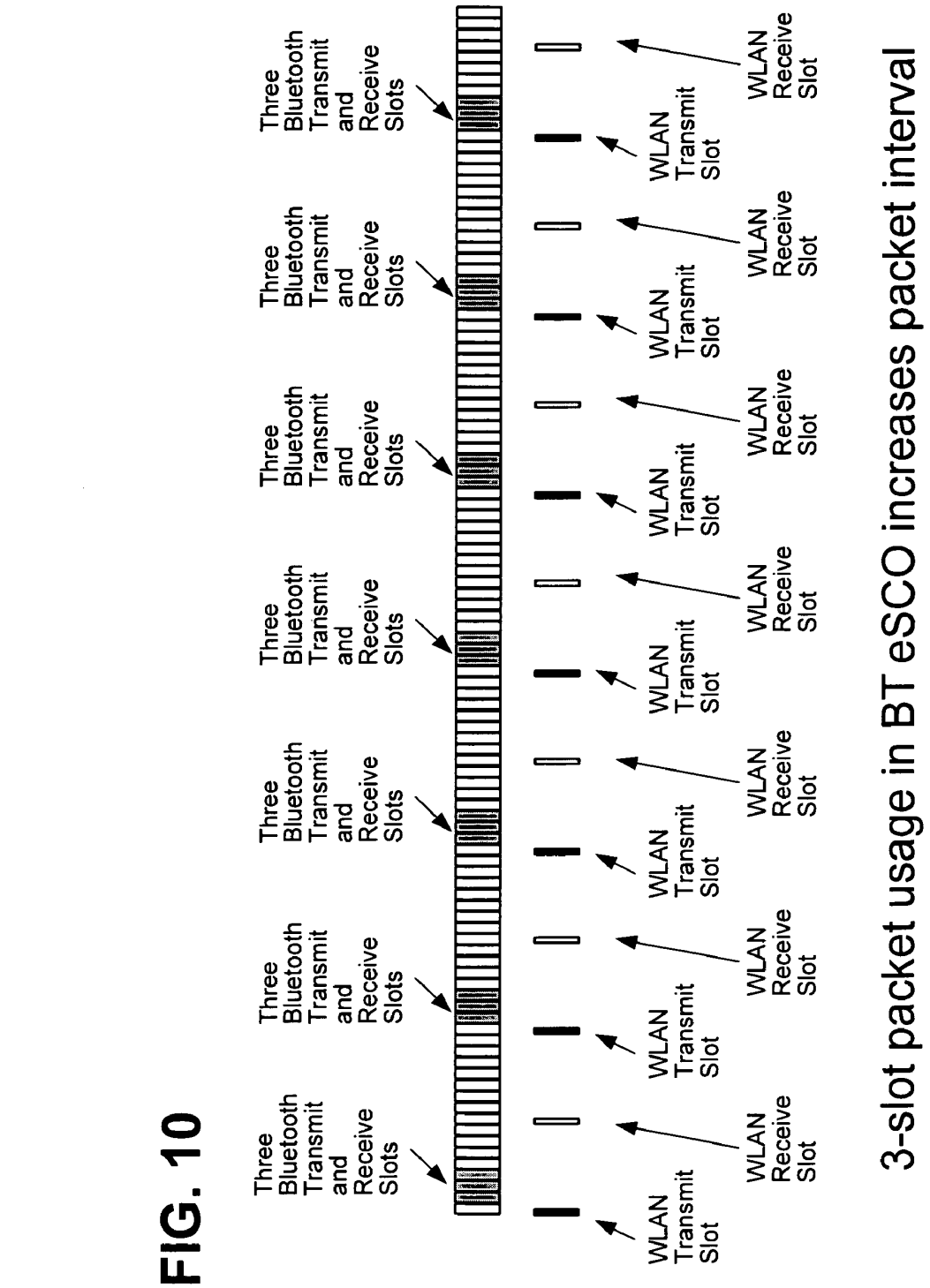
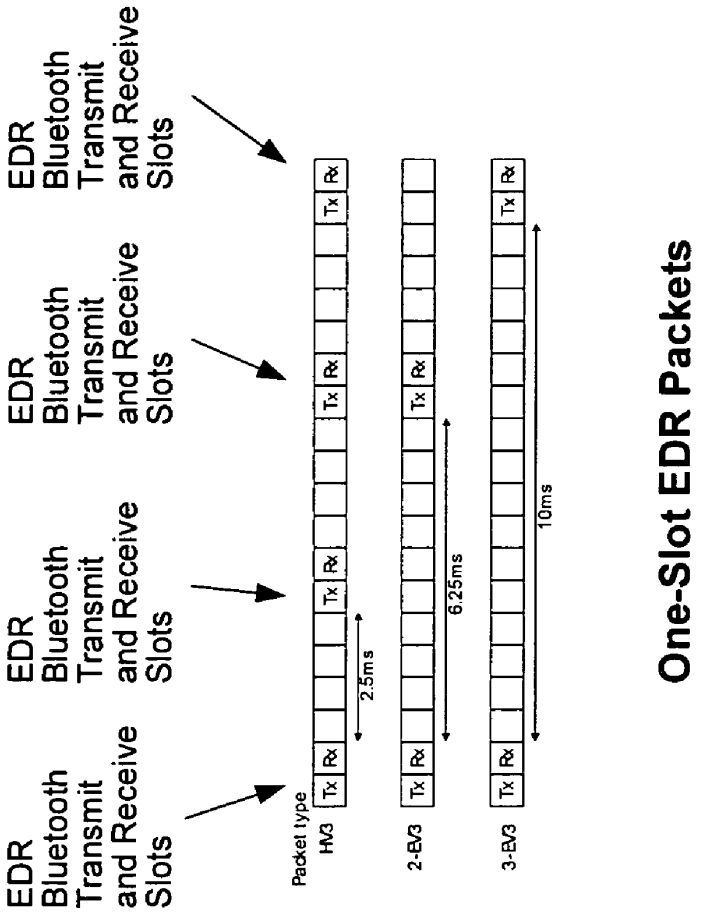

Three Bluetooth Transmit and Receive Slots
WLAN Transmit Slot
WLAN Receive Slot
3-slot packet usage in BT eSCO increases packet interval

FIG. 11


EDR Bluetooth Transmit and Receive Slots
EDR Bluetooth Transmit and Receive Slots
EDR Bluetooth Transmit and Receive Slots
EDR Bluetooth Transmit and Receive Slots
Packet type
HV3
2-EV3
3-EV3
Tx
Rx
2.5ms
6.25ms
10ms
One-Slot EDR Packets

METHOD AND SYSTEM FOR VOIP OVER WLAN TO BLUETOOTH HEADSET USING ACL LINK AND SNIFF FOR ALIGNED ESCO TRANSMISSION

FIELD OF THE INVENTION

[0001] The invention disclosed broadly relates to improvements in mobile wireless terminals having more than one short-range communication interface, for reducing interference in simultaneous signal handling. The invention more particularly relates to reducing interference in voice over IP (VoIP) communications in wireless terminals having both wireless local area network (WLAN) and Bluetooth interface.

BACKGROUND OF THE INVENTION

[0002] The best-known example of wireless personal area network (PAN) technology is the Bluetooth Standard, which operates in the 2.4 GHz ISM band. Bluetooth is a short-range radio network, originally intended as a cable replacement. Bluetooth devices are designed to find other Bluetooth devices and Bluetooth access points within their roughly ten meter radio communications range. Bluetooth is a time division multiplexed (TDM) system, where the basic unit is a slot of 625 microsecond duration. Each Bluetooth device may be either a master or a slave at any one time, but not simultaneously. The master device initiates an exchange of data by sending a packet in a slot and the slave device must respond to the master with a packet in the next slot indicating whether it successfully received the prior packet. The slave will not transmit again until the master again transmits to it. The Bluetooth Special Interest Group, *Bluetooth Specification Including Core, Volume* 1.2, Nov. 5, 2003, (hereinafter "Bluetooth v1.2 Specification") describes the principles of Bluetooth device operation and communication protocols. The Bluetooth v1.2 Specification is available from the Bluetooth Special Interest Group at the web site www.bluetooth.com.

[0003] A recent specification published by the Bluetooth Special Interest Group, *Specification of the Bluetooth System, Volume* 2.0+EDR, Nov. 4, 2004, (hereinafter "Bluetooth v2+EDR Specification") describes the Enhanced Data Rate (EDR) Bluetooth, which permits speeds up to 2.1 Mbps, which while maintaining backward compatibility. The Bluetooth v2+EDR Specification is available from the Bluetooth Special Interest Group at the web site www.bluetooth. com.

[0004] One application of the Bluetooth technology is to carry audio information, which enables designing devices such as wireless headsets. Audio data is carried via Synchronous Connection-Oriented (SCO) packets using coding schemes such as Continuously Variable Slope Delta (CVSD) modulation or a Pulse Code Modulation (PCM). When a SCO link is established, the packets are exchanged over the air between the master and a slave device by alternately transmitting and receiving the encoded audio data in consecutive SCO slots. An example of a Bluetooth wireless headset and a Bluetooth-enabled telephone terminal is shown in **FIG. 1**. The telephone terminal **100**A includes a Bluetooth transceiver module **604** connected to the Bluetooth antenna **102**A. The wireless headset **101**A also includes a Bluetooth transceiver module connected to its own Bluetooth antenna. Either the headset or the telephone terminal can initially assume the role of the master device, depending on how the connection was initiated. When a SCO link **106**A is established between the telephone terminal **100**A and the wireless headset **101**A, packets are exchanged over the air between the master and slave device by alternately transmitting and receiving the encoded audio data in consecutive SCO slots.

[0005] Wireless local area networks (WLAN) cover a larger radio communications range of up to one hundred meters. Examples of wireless local area network technology include the IEEE 802.11 Wireless LAN Standard. The 802.11b standard for wireless local area networks (WLANs), also called Wi-Fi, is part of the 802.11 series of WLAN standards from the Institute of Electrical and Electronics Engineers (IEEE). Networks employing 802.11b operate at radio frequencies in the 2.4 GHz ISM band, the same as that for Bluetooth. Like other 802.11 standards, 802.11b uses the Ethernet protocol and CSMA/CA (carrier sense multiple access with collision avoidance) for path sharing. The modulation method used in 802.11b is complementary code keying (CCK), which allows higher data speeds and is less susceptible to multipath-propagation interference. An example of a WLAN is shown in **FIG. 1**, where the telephone terminal **100**A is a mobile device, which includes an IEEE 802.11b transceiver **602** connected to a WLAN antenna **103**A. The WLAN access point **140**A shown at location A in **FIG. 1** also has an IEEE 802.11b transceiver connected to its own WLAN antenna. When an RF communications link **108**A conforming to the IEEE 802.11b Standard is established between the telephone terminal **100**A and the access point **140**A, data frames containing encoded audio data are exchanged over the WLAN coverage area **150**A between the telephone terminal **100**A and the access point **140**A. The access point **140**A is shown connected by wireline to the IP Network **144**, to exchange data frames containing voice over internet (VoIP) encoded audio data in a IP network.

[0006] **FIG. 1** shows a second WLAN access point **140**B shown at location B in **FIG. 1** connected by wireline to the IP Network **144**, establishing a second WLAN coverage area **150**B. The WLAN access point **140**B has an IEEE 802.11b transceiver connected to its own WLAN antenna. The second WLAN access point **140**B communicates with a second telephone terminal **100**B, which includes an IEEE 802.11b transceiver connected to a WLAN antenna **103**B. When an RF communications link **108**B conforming to the IEEE 802.11b Standard is established between the telephone terminal **100**B and the access point **140**B, data frames containing voice over internet protocol (VoIP) encoded audio data are exchanged over the WLAN coverage area **150**B between the telephone terminal **100**B and the access point **140**B. The telephone terminal **100**B includes a Bluetooth transceiver module connected to the Bluetooth antenna **102**B. The wireless headset **101**B also includes a Bluetooth transceiver module connected to its own Bluetooth antenna. Either the headset or the telephone terminal can initially assume the role of the master device, depending on how the connection was initiated. When a SCO link **106**B is established between the telephone terminal **100**B and the wireless headset **101**B, packets are exchanged over the air between the master and slave device by alternately transmitting and receiving the encoded audio data in consecutive SCO slots. In this manner, voice conversations can be established between users of the wireless headsets **101**A and **101**B.

[0007] The 802.11g specification is another standard for wireless local area networks (WLANs) that offers transmission over relatively short distances at up to 54 megabits per second (Mbps), compared to the 11 Mbps theoretical maximum with the earlier 802.11b standard. Networks employing 802.11g operate at radio frequencies in the 2.4 GHz ISM band, the same band as for Bluetooth and for 802.11b. But, the 802.11g specification employs orthogonal frequency division multiplexing (OFDM) to obtain higher data speed than that for 802.11b. Computers or terminals set up for 802.11g can fall back to speeds of 11 Mbps. This feature makes 802.11b and 802.11g devices compatible within a single network. The IEEE 802.11 Wireless LAN Standard is available from the IEEE, Inc. web site http://grouper.ieee-.org/groups/802/11.

[0008] Combining the short range PAN (e.g., Bluetooth) and the longer range WLAN (e.g., IEEE 802.11g) features in a unitary, mobile terminal enables a user to tap into area-wide WLAN access points and to operate local I/O devices without a cable connection. An example of such a mobile terminal is the wireless telephone **100**A of **FIG. 1** that includes both a Bluetooth transceiver and a WLAN transceiver, enabling the user to receive a voice over internet (VoIP) telephone call from a WLAN access point **140**A and to converse with the caller using the wireless headset **101**A via the Bluetooth connection **106**A between the headset and the telephone. A significant problem with a wireless telephone that includes both a Bluetooth transceiver and a WLAN transceiver is that the Wireless LAN and the Bluetooth networks both operate in the 2.4 GHz ISM band and therefore can interfere with each other.

[0009] The VoIP telephone call is established over Internet Protocol (IP) by using User Datagram Protocol (UDP) and Real Time Protocol (RTP). VoIP packets carry real time data in the Voice Payload. The standard for transmitting real time data in packet switched networks is ITU standard H.323, which uses RTP/UDP/IP encapsulation. Real-Time Transport Protocol (RTP) supports end-to-end delivery services of applications transmitting real-time data over IP networks. The RTP packet includes an RTP header and the Voice Payload. User Datagram Protocol (UDP) is a connectionless protocol that, like TCP, runs on top of IP networks. The UDP packet includes a UDP header and the RTP packet. UDP/IP offers a direct way to send and receive packets over an IP network. The IP packet includes an IP header, the UDP packet, and a CRC trailer field. The VoIP packet typically delivers 20 ms of speech and the size of the IP packet depends on the voice codec used in encoding the speech stream. The VoIP packet is sent to the mobile terminal **100**A using the WLAN link **108**A. In mobile terminal the VoIP packet is decoded and then re-encoded with a Bluetooth codec, which is a Continuously Variable Slope Delta (CVSD) modulation codec or a Pulse Code Modulation (PCM) codec described in the Bluetooth v1.2 Specification. In the receiving mode, the coded packet is delivered to the Bluetooth headset **101**A and converted to voice. The sequence is reversed in the transmitting mode, although the processing capacity of the headset may limit applicable encoding schemes and hence also technical solutions to the interference problem.

[0010] The WLAN frame structure for the IEEE 802.11b standard carries the VoIP packet in the frame body field of the Medium Access Control (MAC) frame defined in the IEEE Standard. Each wireless station and access point in an IEEE 802.11 wireless LAN implements the MAC layer service, which provides the capability for wireless stations to exchange MAC frames. The MAC frame transmits management, control, or data between wireless stations and access points. After a station forms the applicable MAC frame, the frame's bits are passed to the transceiver for transmission. The WLAN data frame carrying a VoIP packet+ACK frame includes several additional components that give it an average duration of approximately 622 microseconds, which is approximately the same duration as a Bluetooth slot. The WLAN data frame begins with an interframe DIFS space of 50 microseconds, which ensures the previous transmission has completed and that it is safe to access the medium again. Next is a back-off wait interval averaging 80 microseconds to allow sharing the medium. Next is a 192 microsecond interval for the synchronization preamble. Next is the MAC frame payload of approximately 87 microseconds, which includes the VoIP packet. This is followed by the SIFS gap of ten microseconds between the data frame and its acknowledgement. This is followed by the WLAN acknowledgement (ACK) frame, which is 203 microseconds duration. The WLAN data frame is transmitted, on average, every twenty milliseconds in both the send and the receive directions.

[0011] Interoperability problems arise when WLAN transceivers and Bluetooth transceivers having their own separate antennas **102**A and **103**A are located in the same terminal **100**A and have limited antenna isolation, as shown in **FIG. 1**. From an integration perspective, it is beneficial to utilize the same antenna and RF filter in a mobile terminal to reduce manufacturing cost and form factor, since both transceivers use the same 2.4 GHz band. In this case the access to the antenna for the WLAN and Bluetooth transceivers is arranged using a switch to connect one or the other of the transceivers to the antenna port at a time. An example of this is shown in **FIG. 2** where the single antenna **105**A of the terminal **100**A is shared by both the Bluetooth transceiver and the WLAN transceiver. Similarly, the single antenna **105**B of the terminal **100**B is shared by both the Bluetooth transceiver and the WLAN transceiver. This arrangement requires that the Bluetooth and the WLAN transceivers in a terminal operate at different instants, requiring a coordinating control between the transceivers. Such a coordinating control must decide which transceiver can use the channel.

[0012] There are different requirements for the control, depending on whether the link is operating in real time for an interactive application, such as telephony, or whether the link is operating in a data transfer mode, such as file transfer protocol (FTP).

[0013] The WLAN access point is basically autonomous of the terminal, which has limited capabilities to affect downlink timing. Hence, the WLAN traffic cannot be reliably estimated by the terminal. Thus, when the access point is transmitting to the terminal, potentially many of the WLAN packets can be lost due simultaneous Bluetooth activity or a wrong switch position. To maintain speech integrity, retransmissions are required.

[0014] The Bluetooth v1.2 Specification defines different types of logical transports between the master and slave. Five logical transports have been defined:

[0015] 1. Synchronous Connection-Oriented (SCO) logical transport, described above,

[0016] 2. Extended Synchronous Connection-Oriented (eSCO) logical transport,

[0017] 3. Asynchronous Connection-Oriented (ACL) logical transport,

[0018] 4. Active Slave Broadcast (ASB) logical transport, and

[0019] 5. Parked Slave Broadcast (PSB) logical transport.

[0020] The Synchronous Connection-Oriented (SCO) transports are point-to-point logical transports between a Bluetooth master and a single slave in the piconet. The synchronous logical transports typically support time-bounded information like voice or general synchronous data. The master maintains the synchronous logical transports by using reserved slots at regular intervals. Four packets are allowed on the SCO logical transport: HV**1**, HV**2**, HV**3** and DV. The HV**1** packet has 10 information bytes. The HV**2** packet has 20 information bytes. The HV**3** packet has 30 information bytes. The DV packet is a combined data and voice packet. On each SCO channel, n-bits are sent and received in consecutive SCO slots once every T_{SCO} slots.

[0021] In addition to the reserved slots, the Extended Synchronous Connection-Oriented (eSCO) logical transport provides a retransmission window after the reserved slots. EV packets are used on the synchronous eSCO logical transport. The packets include retransmission if no acknowledgement of proper reception is received within allocated slots. eSCO packets may be routed to the synchronous I/O port. Three eSCO packets have been defined for Bluetooth. The EV**3** packet has between 1 and 30 information bytes and may cover up to a single time slot. The EV**4** packet has between 1 and 120 information bytes and may cover to up three time slots. The EV**5** packet has between 1 and 180 information bytes and may cover up to three time slots. On each eSCO channel, n-bits are sent and received in consecutive eSCO slots once every period of T_{eSCO} slots. Each packet header includes a one-bit acknowledge indication, ARQN, which indicates that the last prior packet was correctly received. With an automatic repeat request scheme, EV packets are retransmitted until acknowledgement of a successful reception is returned by the destination (or timeout is exceeded). As opposed to SCO links, eSCO links can be set up to provide limited retransmissions of lost or damaged packets inside a retransmission window of size W_{eSCO} slots.

[0022] The Asynchronous Connection-Oriented (ACL) logical transport is also a point-to-point logical transport between the Bluetooth master and a slave. In the slots not reserved for synchronous logical transport, the master can establish an ACL logical transport on a per-slot basis to any slave, including the slaves already engaged in a synchronous logical transport.

[0023] The Active Slave Broadcast (ASB) logical transport is used by a Bluetooth master to communicate with active slaves. The Parked Slave Broadcast (PSB) logical transport is used by a Bluetooth master to communicate with parked slaves.

[0024] The Bluetooth link between the terminal and the headset in the prior art typically uses the SCO transport and HV**3** packet. Due to the synchronous nature of that transport, Bluetooth traffic can be estimated fairly accurately by the terminal. However, in the SCO transport, there are no retransmissions and therefore if the medium is reserved by the WLAN transceiver in the terminal at a particular moment or if the WLAN transceiver in the terminal is connected to the antenna, the SCO packet is permanently lost. For a VoIP packet received by the terminal from the WLAN access point and intended to be forwarded to the Bluetooth headset, a collision or packet loss will likely occur once every 16 Bluetooth SCO slots, increasing the SCO packet loss by approximately 6%. If HV**2** or HV**1** packets are used instead of HV**3**, collisions will occur even more often. Instead, if the medium is being used by the Bluetooth transceiver in the terminal when the WLAN transceiver in the terminal tries to access the medium, the WLAN packet is not permanently lost, but can be retransmitted as provided by the IEEE 802.11 standard. On the average, the WLAN transceiver in the terminal will have to retransmit once every 3rd packet, which increases WLAN retransmissions by 30%.

[0025] The interference problem of WLAN and Bluetooth transceivers operating in the same terminal has been recognized in the prior art. The IEEE has developed a recommended practice to handle this problem, which is published in the IEEE Standards 802, Part 15.2: *Coexistence of Wireless Personal Area Networks with Other Wireless Devices Operating in Unlicensed Frequency Bands.* This IEEE recommended practice is based on establishing a control block between the WLAN and Bluetooth transceivers in a terminal. The control block assigns a higher priority to Bluetooth transmissions than to WLAN transmissions and selects which one of those transceivers is to be operating at a particular instant.

[0026] The first problem with the IEEE recommended practice is that it is only a recommendation and thus it cannot be known whether and how different WLAN transceiver manufacturers will implement this recommendation for access points and mobile terminals. Secondly the IEEE recommended practice assigns the WLAN acknowledgement (ACK) packet to have priority over the Bluetooth packet during WLAN retransmissions of interrupted WLAN packets. This will directly cause some permanent packet losses for the Bluetooth transceiver. Additionally, the IEEE recommended practice does not utilize the more enhanced functionality provided by the later Bluetooth v1.2 Standard, such as the Extended Synchronous Connection-Oriented (eSCO) logical transport or Bluetooth adaptive frequency hopping (AFH). The AFH feature included in the Bluetooth v1.2 Specification could be used to alleviate WLAN and Bluetooth collisions by controlling Bluetooth to avoid hopping on those frequencies that are currently being used by WLAN transmissions. However, the AFH does not help in cases where the antenna isolation is small (i.e. where WLAN and Bluetooth transceivers are integrated into the same terminal, but have separate antennas) or the single antenna is shared between transceivers. Transmission from either of the transceivers over any part of the ISM band will bring the receiver portion of the other transceiver into saturation so that nothing can be received.

[0027] What is needed in the prior art is a method to reduce interference in simultaneous WLAN and Bluetooth signal handling, especially in voice over IP communications via a WLAN telephone to a Bluetooth headset.

SUMMARY OF THE INVENTION

[0028] The invention solves the problem of reducing interference in simultaneous WLAN and Bluetooth signal handling, especially in voice over IP communications via a WLAN telephone to a Bluetooth headset. The invention provides a new mode of operation for the control block between the WLAN and Bluetooth transceivers in a terminal, which assigns a higher priority to WLAN transmissions than to Bluetooth transmissions and selects which one of those transceivers is to be operating at a particular instant. The invention uses the Extended Synchronous Connection-Oriented (eSCO) logical transport in the Bluetooth protocol and exploits its retransmission window that is available after the reserved slots. The EV packets used on the synchronous eSCO logical transport include retransmission of aborted packets within the retransmission window if the transmission of the last prior Bluetooth packet has been interrupted by a higher priority transmission of WLAN packets. The new control block assigns to the Bluetooth retransmission packet a higher priority over the WLAN packets, to assure retransmission of the interrupted Bluetooth packet.

[0029] Further in accordance with the invention, if the headset is initially the master, then after the headset connection has been established, the terminal will perform a role switch to assume the master role. Alternately, the terminal will be the initial master and will retain the role. As the master device, the terminal will set up an EV**3**-type eSCO link with headset, which enables the headset to use the retransmission feature. After an ACL link has been established by the terminal, one or more eSCO links are set up to the headset. The eSCO links are similar to SCO links using timing control flags and an interval of T_{eSCO} slots in duration. The eSCO link with the headset is set up to provide limited retransmissions of lost or damaged packets inside the retransmission window of size W_{eSCO} slots. (For example, the headset is configured to support the Hands Free Profile 1.2 with an eSCO repetition period of T_{eSCO}=6 slots and an eSCO window size of W_{eSCO}=2 slots using the EV**3** packet format and CVSD compression encoding.)

[0030] During operation of the invention, the WLAN traffic is assigned a higher priority than the Bluetooth eSCO traffic so that the first-time transmission of a Bluetooth packet is suppressed or interrupted when a WLAN packet is simultaneously either being received or transmitted or when it is known that WLAN transmission or reception will happen during a Bluetooth first-time transmission. This can happen, for example, with the RTS (Request to Send) signal or the CTS (Clear to Send) signal to control station access to the WLAN medium, or with the CTS-to-self protection mechanism. The CTS-to-self protection mechanism method sends a CTS message using an 802.11b rate to clear the air, and then immediately follows with data using an 802.11g data rate. To assure that the suppressed or interrupted Bluetooth eSCO packet is eventually retransmitted successfully, the Bluetooth retransmission packet is assigned a higher priority than the WLAN traffic. Any WLAN packet known to have started transmission during the retransmission of a Bluetooth eSCO packet is interrupted. The existing WLAN protocol will later retransmit the interrupted WLAN packet. In effect, collision with WLAN traffic can be reduced by scheduling the Bluetooth eSCO transmission later, if necessary. In this manner WLAN packet retransmissions are used less often than in the prior art, thus imposing less of an encumbrance on the WLAN traffic.

[0031] From the headset point of view, when the terminal is in receive mode, the headset can transmit the eSCO packet to the terminal during an eSCO slot. If the headset did not receive the previous eSCO packet from the terminal in the scheduled master-to-slave slot because of a WLAN transmission, the headset will recognize the omission and set the acknowledge indication ARQN bit='0' in its reply eSCO packet. Although the terminal may not receive the reply eSCO packet because of the WLAN transmission, it does not matter because the terminal knows that its last prior eSCO transmission was preempted and it will use the eSCO retransmission window to retransmit the eSCO packet. An advantage of the invention is that it does not require a change to the WLAN or Bluetooth standard, but merely a proprietary change to the Bluetooth and WLAN control logic of the terminal. The headset, itself, operates according the hands free profiles for headsets, which support eSCO.

[0032] The resulting invention is particularly advantageous in areas of high WLAN traffic, such as in a business office, where frequent retransmission of interrupted WLAN packets would significantly impair WLAN traffic capacity. A further advantage of the invention is the ability of the terminal to predict the need to transmit Bluetooth packets because SCO and eSCO packets are transmitted at known fixed intervals. Still another advantage of the invention is that it does not require a change to the WLAN or Bluetooth standard, but merely a proprietary change to the Bluetooth and WLAN control logic of the terminal.

[0033] In an alternate embodiment of the invention, after the headset connection has been established by the terminal and the terminal is in the master role, the terminal will set up an EV**5** eSCO link with headset. The EV**5** packet type enables power consumption in the headset to be reduced because the packets are sent less frequently and the protocol-to-packet overhead is smaller. The parameters for the eSCO connection with EV**5** packets are T_{eSCO}=32 slots and W_{eSCO}=2 using EV**5** and CVSD voice coding.

[0034] The reason to select T_{eSCO}=32 slots is that with this value the EV**5** eSCO packet is aligned at every 32 slots, which is the same time interval as the average interval of 20 ms for the VoIP WLAN packet. It should also be noted that with these parameters and the maximum EV**5** packet data of 180 bytes, the average data rate is 72 kbps, which means that roughly every 12th packet does not have to be sent. Alternately, if a steady 64 kbps data rate is desired, a 160 byte payload can be used. This is not limited to any particular voice coding scheme, but can be used as long as the required data rate is below 72 kbps.

[0035] Although establishing the Bluetooth connection with the terminal as the master device is the preferred way to operate the invention, retaining the headset in the role of the master device can also be used to establish the Bluetooth connection. In this alternate embodiment, the terminal and headset are programmed so that the headset remains the master device in establishing the Bluetooth connection. As the master device, the headset will set up the EV**3**-type eSCO link with the terminal, which enables the headset to use the retransmission feature as described above.

[0036] In another alternate embodiment of the invention, the Enhanced Data Rate (EDR) Bluetooth packets can be

used, as provided in the Bluetooth EDR protocol. The EDR packets make it possible to increase the Bluetooth voice packet interval and thus also leave more time for WLAN packets to be transmitted. The EDR eSCO packets have the same retransmission feature as the eSCO packets discussed above for the Bluetooth v1.2 Specification and they have the advantage of transmitting at a raw data rate of from 2 Mbps to 3 Mbps. Both one-slot and three-slot EDR packets are available; the one-slot packet is preferred to keep latency to a minimum.

[0037] The resulting invention solves the problem of reducing interference in simultaneous WLAN and Bluetooth signal handling, especially in voice over IP communications via a WLAN to a Bluetooth headset.

DESCRIPTION OF THE FIGURES

[0038] **FIG. 1** is a network diagram according to an embodiment of the present invention showing a voice over IP (VoIP) communications network via a WLAN telephone to a Bluetooth headset. The telephone terminal includes a Bluetooth transceiver module connected to a Bluetooth antenna and a WLAN transceiver connected to a separate WLAN antenna.

[0039] **FIG. 2** is a network diagram according to an embodiment of the present invention showing a voice over IP (VoIP) communications network via a WLAN telephone to a Bluetooth headset. The telephone terminal includes a Bluetooth transceiver module and a WLAN transceiver connected to the same antenna.

[0040] **FIG. 3** is a diagram according to an embodiment of the present invention showing the Basic level audio link setup between the terminal and the Bluetooth headset.

[0041] **FIG. 4** is a timing diagram according to an embodiment of the present invention showing the Packet prioritisation during the Bluetooth eSCO connection. The WLAN transmissions have a higher priority during normal Bluetooth slots and the Bluetooth retransmissions have a higher priority during Bluetooth retransmission slots.

[0042] **FIG. 5** is a timing diagram according to an embodiment of the present invention showing the Bluetooth EV**3** eSCO packet usage. Bluetooth packets that were interrupted in a prior occurring normal slot are assigned a higher priority and are retransmitted in the following Bluetooth retransmission slots.

[0043] **FIG. 6** is a functional block diagram according to an embodiment of the present invention showing the WLAN telephone with a control module that coordinates the operation of the Bluetooth transceiver and the WLAN transceiver.

[0044] **FIG. 7** is a flow diagram according to an embodiment of the present invention showing the process of establishing a connection between the Bluetooth terminal and the Bluetooth headset to exchange voice packets that have been exchanged with the WLAN access point.

[0045] **FIG. 8** is a state diagram according to an embodiment of the present invention showing the operating states established by the controller to assign a higher priority to the WLAN transmissions during normal Bluetooth slots and assign a higher priority to the Bluetooth retransmissions during Bluetooth retransmission slots.

[0046] **FIGS. 9A and 9B** are timing diagrams according to an embodiment of the present invention showing the control signals of the controller for Bluetooth EV**3** eSCO packet usage. Bluetooth packets that were aborted because they were scheduled to begin when an existing WLAN transmission was occurring in **FIG. 9A** or that were aborted because they were interrupted by a WLAN transmission in a prior occurring normal Bluetooth slot in **FIG. 9B** are assigned a higher priority for retransmission and are retransmitted in the following Bluetooth retransmission slots.

[0047] **FIG. 10** is a timing diagram according to an embodiment of the present invention showing Bluetooth eSCO three-slot packets, which provide a reduced power consumption.

[0048] **FIG. 11** is a timing diagram according to an embodiment of the present invention showing one-slot EDR packets, which can transmit at a data rate of up to 3 Mbps.

DISCUSSION OF THE PREFERRED EMBODIMENT

[0049] **FIG. 1** is a network diagram according to an embodiment of the present invention showing a voice over IP (VoIP) communications network via a WLAN telephone **100**A to a Bluetooth headset **101**A. The telephone terminal **100**A includes a Bluetooth transceiver **604** connected to a Bluetooth antenna **102**A and a WLAN transceiver **602** connected to a separate WLAN antenna **103**A. The Bluetooth transceiver **604** operates in the Bluetooth network **106**A to communicate with the wireless headset **101**A using the ISM band of 2.4 GHz and the Bluetooth v1.2 Specification communications protocol to exchange Bluetooth packets. When a Bluetooth link **106**A is established between the telephone terminal **100**A and the wireless headset **101**A, packets are exchanged over the air between the terminal **100**A and the wireless headset **101**A by alternately transmitting and receiving the encoded audio data in consecutive Bluetooth slots.

[0050] **FIG. 2** shows the same voice over IP (VoIP) communications network as shown in **FIG. 1**, but with the WLAN telephone terminal **100**A having its Bluetooth transceiver **604** and WLAN transceiver **602** connected to the same antenna **105**A.

[0051] **FIG. 3** shows the basic level audio link setup between the WLAN terminal **100**A and the Bluetooth headset **101**A. The WLAN terminal **100**A and the Bluetooth headset **101**A exchange inquiry and paging packets to establish a connection and a service level. Then by means of an internal programmed event or user action, the eSCO link is established. After this stage, the basic level audio link is established.

[0052] The WLAN access point **140**A at location A in **FIG. 1** also has an IEEE 802.11b transceiver connected to its own WLAN antenna. When an RF communications link **108**A conforming to the IEEE 802.11b Standard is established between the telephone terminal **100**A and the access point **140**A, data frames containing encoded audio data are exchanged over the WLAN coverage area **150**A between the telephone terminal **100**A and the access point **140**A. The RF communications link **108**A can also conform to the IEEE 802.11g Standard. The access point **140**A is shown connected by wireline to the IP Network **144**, to exchange data frames containing voice over internet (VoIP) encoded audio data in a telephone network.

[0053] **FIG. 1** shows a second WLAN access point **140**B at location B connected by wireline to the IP Network **144**, establishing a second WLAN coverage area **150**B. The WLAN access point **140**B has an IEEE 802.11b transceiver connected to its own WLAN antenna. The second WLAN access point **140**B communicates with a second WLAN telephone terminal **100**B, which includes an IEEE 802.11b transceiver connected to a WLAN antenna **103**B. When an RF communications link **108**B conforming to the IEEE 802.11b Standard is established between the telephone terminal **100**B and the access point **140**B, data frames containing voice over internet (VoIP) encoded audio data are exchanged over the WLAN coverage area **150**B between the telephone terminal **100**B and the access point **140**B. The RF communications link **108**B can also conform to the IEEE 802.11g Standard. The telephone terminal **100**B includes a Bluetooth transceiver module connected to the Bluetooth antenna **102**B. The wireless headset **101**B also includes a Bluetooth transceiver module connected to its own Bluetooth antenna. When a Bluetooth link **106**B is established between the telephone terminal **100**B and the wireless headset **101**B, packets are exchanged over the air between the terminal **100**B and the wireless headset **101**B by alternately transmitting and receiving the encoded audio data in consecutive Bluetooth slots. In this manner, voice conversations can be established between users of the wireless headsets **101**A and **101**B. **FIG. 2** shows the WLAN telephone terminal **100**B having its Bluetooth transceiver **604** and WLAN transceiver **602** connected to the same antenna **105**B.

[0054] The invention provides a new mode of operation for the control module or controller **610** shown in **FIG. 1** and in greater detail in **FIG. 6**, between the WLAN transceiver **602** and the Bluetooth transceiver **604** in the terminal **100**A, which assigns a higher priority to WLAN transmissions or to channel reservations, for example, with RTS and CTS signaling, than to original Bluetooth transmissions, i.e., a first attempt at transmitting a Bluetooth packet. The control module **610** selects which one of those transceivers is to be operating at a particular instant. The invention uses the Extended Synchronous Connection-Oriented (eSCO) logical transport in the Bluetooth v1.2 Specification, as shown in **FIG. 4**. **FIG. 4** shows the packet prioritisation during the Bluetooth eSCO connection. The WLAN transmissions have a higher priority during normal Bluetooth slots and the Bluetooth retransmissions have a higher priority during Bluetooth retransmission slots. The invention exploits the retransmission window feature in the eSCO logical transport that is available after the reserved slots. EV packets used on the synchronous eSCO logical transport include retransmission of aborted packets within the retransmission window if the transmission of the last prior Bluetooth packet has been interrupted by a higher priority transmission of WLAN packets. Of course this retransmission is utilized also in the case of error in Bluetooth eSCO packet. The control module **610** assigns to the aborted or retransmitted Bluetooth packet a higher priority for its retransmission over the WLAN packets, to assure retransmission of the aborted Bluetooth packet. **FIG. 5** shows the Bluetooth EV**3** eSCO packet usage. Bluetooth packets that were interrupted in a prior occurring normal slot are assigned a higher priority than WLAN packets and are retransmitted in the following Bluetooth retransmission window.

[0055] Further in accordance with the invention, if the headset is initially the master, then after the headset connection **106**A has been established, the terminal **100**A will perform a role switch to assume the master role. Alternately, the terminal will be the initial master and will retain that role. As the master device, the terminal **100**A will set up an EV**3**-type eSCO link with headset **101**A, which enables the headset **101**A to use the retransmission feature. **FIG. 7** is a flow diagram showing the process **700** of establishing a connection between the Bluetooth terminal **100**A and the Bluetooth headset **101**A to exchange voice packets that have been exchanged with the WLAN access point **140**A. Step **702** establishes a Bluetooth connection between the terminal **100**A and the headset **101**A. Step **703** determines if the terminal is the initial master. If it is, then the steps flow to step **710**. Alternately, if the terminal is not the initial master, then the steps flow to step **706**. In Step **706** the terminal **100**A performs a role switch with the headset **101**A to make the terminal the master. In Step **710** the terminal **100**A sets up an EV**3** eSCO link with the retransmission feature between the terminal and the headset. In Step **720** the control module **610** assigns priority to WLAN slots over Bluetooth slots, except for Bluetooth retransmissions. In Step **722** the control module **610** assigns priority to Bluetooth slots over WLAN slots for Bluetooth retransmissions. In Step **724** the terminal **100**A, headset **101**A, and access point **140**A can then begin to exchange VoIP traffic.

[0056] After an ACL link has been established by the terminal **100**A, one or more eSCO links are set up to the headset **101**A. The eSCO links are similar to SCO links using timing control flags and an interval of T_{eSCO} slots in duration. The eSCO link with the headset is set up to provide limited retransmissions of lost or damaged packets inside the retransmission window of size W_{eSCO} slots. (For example, the headset is configured to support the Hands Free Profile 1.2 with an eSCO repetition period of T_{eSCO}=6 slots and an eSCO window size of W_{eSCO}=2 slots using the EV**3** packet format and CVSD compression encoding.)

[0057] During operation of the invention, the WLAN traffic is assigned a higher priority than the Bluetooth eSCO traffic so that the first-time transmission of a Bluetooth packet is suppressed or interrupted when a WLAN packet is simultaneously either being received or transmitted or when the channel is reserved to a WLAN access point and a station transmits for example, the RTS (Request to Send) signal, CTS (Clear to Send) signal, or the CTS-to-self protection signal. To assure that the suppressed or interrupted Bluetooth eSCO packet is eventually retransmitted successfully, the Bluetooth retransmission packet is assigned a higher priority than the WLAN traffic. Any WLAN packet known to have started transmission during the retransmission of a Bluetooth eSCO packet is interrupted. The existing WLAN protocol will later retransmit the interrupted WLAN packet. In effect, collision with WLAN traffic can be reduced by scheduling the Bluetooth eSCO transmission later, if necessary. In this manner WLAN packet retransmissions are used less often than in the prior art, thus imposing less of an encumbrance on the WLAN traffic.

[0058] **FIG. 6** shows the WLAN telephone **100**A with the control module **610** that coordinates the operation of the Bluetooth transceiver **604**, the WLAN transceiver **602**, and the antenna switch **620** that selectively connects one or the other transceiver to the antenna **105**A. **FIG. 8** is a state

diagram showing the operating states established by the control module **610** to assign a higher priority to the WLAN transmissions during normal Bluetooth slots and assign a higher priority to the Bluetooth retransmissions during Bluetooth retransmission slots. **FIGS. 9A and 9B** show the control signals of the control module **610** for Bluetooth EV**3** eSCO packet usage. Bluetooth packets that were aborted because they were scheduled to begin when an existing WLAN transmission was occurring in **FIG. 9A** or that were aborted because they were interrupted by a WLAN transmission in a prior occurring normal Bluetooth slot in **FIG. 9B** are assigned a higher priority by the control module **610** for retransmission and are retransmitted in the following Bluetooth retransmission slots.

[**0059**] The WLAN transceiver **602** in **FIG. 6** signals to the control module **610** with the WX signal when it is scheduled to transmit or is transmitting WLAN packets. The Bluetooth transceiver **604** signals to the control module **610** with the STATUS signal whether it has an aborted Bluetooth packet ready for retransmission. The control module **610** signals to the Bluetooth transceiver **604** with the TX_CONFX signal if it is to abort any transmission of an original Bluetooth packet. The control module **610** signals to the WLAN transceiver **602** with the BREX signal if it is to abort any scheduled WLAN packet transmission or abort transmitting any WLAN packets. The Bluetooth transceiver **604** also signals to the control module **610** with the RF_ACTIVE signal whether it is transmitting a Bluetooth packet. The Bluetooth transceiver **604** in **FIG. 6** signals to the control module **610** with the FREQ signal to provide information when Bluetooth is hopping into restricted channel. The WLAN transceiver **602** signals to the control module **610** with the WFQ signal to provide its timing.

[**0060**] If the STATUS signal is low, then there is no aborted Bluetooth packet ready for retransmission. In response to when the WLAN transceiver **602** signals to the control module **610** with the WX signal that it is scheduled to transmit or is transmitting WLAN packets in combination with the STATUS signal being low, indicating that there is no aborted Bluetooth packet ready for retransmission, the control module **610** raises the TX_CONFX signal to the Bluetooth transceiver **604** causing it to abort any transmission of an original Bluetooth packet. This is shown in the state diagram of **FIG. 8** and the timing diagrams of **FIGS. 9A and 9B**.

[**0061**] If the STATUS signal is high, indicating that there is an aborted Bluetooth packet ready for retransmission, then in response the control module **610** signals to the WLAN transceiver **602** with the BREX signal to abort any scheduled WLAN packet transmission or abort transmitting any WLAN packets. This enables the Bluetooth transceiver **604** to retransmit the aborted Bluetooth packet. This is shown in the state diagram of **FIG. 8** and the timing diagrams of **FIGS. 9A and 9B**.

[**0062**] The control module **610**, the WLAN transceiver **602**, and the Bluetooth transceiver **604** of **FIG. 6** can be a set of LSI circuit chips. The control module **610** can be implemented as a programmed microcontroller chip that contains all the components comprising a controller, including a CPU, RAM, some form of ROM to store program code instructions, I/O ports, and timers. The control module **610** can also be implemented as an Application-Specific Integrated Circuit (ASIC). Alternately, the control module **610** circuitry can be integrated into the LSI circuit chip of the Bluetooth transceiver **604** or integrated into the LSI circuit chip of the WLAN transceiver **602**.

[**0063**] From the headset **101**A point of view, when the terminal **100**A is in receive mode, the headset **101**A can transmit the eSCO packet to the terminal **100**A during an eSCO slot. If the headset **101**A did not receive the previous eSCO packet from the terminal **100**A in the scheduled master-to-slave slot because of a WLAN transmission by the terminal **100**A, the headset **101**A will recognize the omission and set the acknowledge indication ARQN bit='0' in its reply eSCO packet. Although the terminal **100**A may not receive the reply eSCO packet because of the WLAN transmission, it does not matter because the terminal **100**A knows that its last prior eSCO transmission was preempted and it will use the eSCO retransmission window to retransmit the aborted eSCO packet. An advantage of the invention is that it does not require a change to the WLAN or Bluetooth standard, but merely a proprietary change to the Bluetooth side of the terminal **100**A. The headset **101**A, itself, operates according the hands free profiles for headsets, which support eSCO.

[**0064**] The state diagram **800** of **FIG. 8** shows the operating states established by the control module **610** to assign a higher priority to the WLAN transmissions during normal Bluetooth slots and assign a higher priority to the Bluetooth retransmissions during Bluetooth retransmission slots. The state diagram **800** for terminal **100**A begins in the quiescent State **802**: where the terminal is waiting for traffic. In State **802**, if Event **804** occurs where an original Bluetooth packet is scheduled for an eSCO transmission slot, then the state transitions to State **806** where the terminal is waiting for the eSCO slot to begin to enable transmitting the Bluetooth packet. In State **806**, if Event **808** occurs where the terminal starts transmitting the Bluetooth packet, then the state transitions to State **810** where the terminal is actively transmitting the Bluetooth packet. In State **810**, if Event **812** occurs where a higher priority WLAN packet begins transmitting, then Action **814** is taken where the terminal aborts transmitting the original Bluetooth packet and the state transitions to State **816** where the terminal buffers the aborted Bluetooth packet. In State **816**, if Event **818** occurs where the terminal completes transmitting the WLAN packet, then the Action **820** is taken where the terminal retransmits the aborted Bluetooth packet in an eSCO retransmission slot and the state transitions back to the quiescent State **802** where the terminal is waiting for traffic. There is a second possible event that can occur in State **806**. In State **806**, if Event **822** occurs where a higher priority WLAN packet is scheduled to transmit, then Action **824** is taken where the terminal aborts the original Bluetooth packet and the state transitions to State **816**. There is a second possible event that can occur in State **810**. In State **810**, if Event **826** occurs where terminal completes transmitting the Bluetooth packet, then the state transitions back to the quiescent State **802**: where the terminal is waiting for traffic.

[**0065**] In State **802** of **FIG. 8**, if Event **834** occurs where an original WLAN packet is scheduled for a WLAN transmit slot, then the state transitions to State **836** where the terminal is waiting for the WLAN slot to begin to enable transmitting the WLAN packet. In State **836**, if Event **838** occurs where the terminal starts transmitting the WLAN packet, then the

state transitions to State **840** where the terminal is actively transmitting the WLAN packet. In State **840**, if Event **842** occurs where a higher priority retransmission begins of an aborted Bluetooth packet, then Action **844** is taken where the terminal aborts the WLAN packet and the state transitions to State **846** where the terminal buffers the aborted WLAN packet. In State **846**, if Event **848** occurs where the terminal completes retransmitting the aborted Bluetooth packet, then Action **850** is taken where the terminal retransmits the aborted WLAN packet and the state transitions back to the quiescent State **802** where the terminal is waiting for traffic. There is a second possible event that can occur in State **836**. In State **836**, if Event **852** occurs where a higher priority retransmission of an aborted Bluetooth packet is scheduled to transmit, the Action **854** is taken where the terminal aborts the WLAN packet and transitions to State **846**. There is a second possible event that can occur in State **840**. In State **840**, if Event **856** occurs where the terminal completes transmitting the WLAN packet, then the state transitions back to the quiescent State **802** where the terminal is waiting for traffic.

[**0066**] The control module **610**, the WLAN transceiver **602**, and the Bluetooth transceiver **604** of **FIG. 6** can include programmed microcontroller chips that contain all the components comprising a controller, including a CPU processor, RAM storage, some form of ROM to store program code, I/O ports, and timers.

[**0067**] The Bluetooth transceiver **604** of **FIG. 6** can include a programmed microcontroller chip that stores in its ROM program code for execution by its processor for operating the Bluetooth transceiver in the Bluetooth network. The WLAN transceiver **602** of **FIG. 6** can include a programmed microcontroller chip that stores program code in its ROM for execution by its processor for operating the WLAN transceiver in the WLAN network.

[**0068**] The control module **610** of **FIG. 6** can include a programmed microcontroller chip that stores in its ROM program code for execution by its processor. The program code implements the method of the invention, for example as represented by the state diagram **800** of **FIG. 8**. The program code in the control module **610**, when executed by its processor, assigns a higher transmission priority to WLAN packets than to Bluetooth packets when transmission of WLAN packets overlaps a first occurring transmission of Bluetooth packets, to abort transmission of the first occurring Bluetooth packets. The program code in the control module **610**, when executed by its processor, assigns a higher transmission priority to the aborted Bluetooth packet than to the WLAN packets when transmission of the WLAN packets overlaps the retransmission of the aborted Bluetooth packet, to transmit the aborted Bluetooth packet.

[**0069**] In an alternate embodiment of the invention, after the headset connection has been established by the terminal and it performs a role switch to assume the master role, the terminal will set up an EV**5** eSCO link with headset. The EV**5** packet type enables power consumption in the headset to be reduced because the packets are sent less frequently and the protocol-to-packet overhead is smaller. The example parameters for the eSCO connection with EV**5** packets are T_{eSCO}=32 slots and W_{eSCO}=2 using EV**5** and CVSD voice coding.

[**0070**] The reason to select T_{eSCO}=32 slots is that with this value the EV**5** eSCO packet is aligned at every 32 slots, which is the same time interval as the average interval of 20 ms for the VoIP WLAN packet. It should also be noted that with these parameters and the maximum EV**5** packet data of 180 bytes, the average data rate is 72 kbps, which means that roughly every 12th packet does not have to be sent. Alternately, if a steady 64 kbps data rate is desired, a 160 byte payload can be used. This is not limited to any particular voice coding scheme, but can be used as long as the required data rate is below 72 kbps.

[**0071**] Although establishing the Bluetooth connection **106**A with the terminal **100**A as the master device is the preferred way to operate the invention, retaining the headset **101**A in the role of the master device can also be used to establish the Bluetooth connection **106**A. In this alternate embodiment, the terminal and headset are programmed so that the headset remains the master device in establishing the Bluetooth connection. As the master device, the headset will set up the EV**3**-type or EV**5**-type eSCO link with the terminal, which enables the headset to use the retransmission feature as described above.

[**0072**] In another alternate embodiment of the invention, the Enhanced Data Rate (EDR) Bluetooth packets can be used, as provided in the Bluetooth v2+EDR Specification. The EDR packets make it possible to increase the Bluetooth voice packet interval and thus to leave more time for WLAN packets to be transmitted. The EDR eSCO packets have the same retransmission control as described above for the Bluetooth v1.2 Specification eSCO packets and they have the advantage of transmitting at a raw data rate of from 2 Mbps to 3 Mbps. Both one-slot and three-slot EDR packets are available; the one-slot packet is preferred to keep latency to a minimum. The Bluetooth transceiver **604** in **FIG. 6** signals to the control module **610** with the FREQ signal that BT is about to transmit on a restricted channel.

[**0073**] **FIG. 10** shows the timing diagram of Bluetooth eSCO three-slot packets, which provide a reduced power consumption. **FIG. 11** shows the timing diagram for one-slot EDR packets, which can transmit at a raw data rate of up to 3 Mbps.

[**0074**] The resulting invention solves the problem of reducing interference in simultaneous WLAN and Bluetooth signal handling, especially in voice over IP communications via a WLAN to a Bluetooth headset.

[**0075**] The resulting invention is particularly advantageous in areas of high WLAN traffic, such as in a business office, where frequent retransmission of interrupted WLAN packets would significantly impair WLAN traffic capacity. A further advantage of the invention is the ability of the terminal to predict the need to transmit Bluetooth packets because SCO and eSCO packets are transmitted at known fixed intervals. Still another advantage of the invention is that it does not require a change to the WLAN or Bluetooth standard, but merely a proprietary change to the Bluetooth side of the terminal.

[**0076**] Although specific embodiments of the invention have been disclosed, a person skilled in the art will understand that changes can be made to the specific embodiments without departing from the spirit and scope of the invention. For example the wireless terminal **100**A can exchange with the wireless access point **140**A IEEE 802.11 protocol data units containing data for other types of I/O devices, such as

a printer or a bar code scanner, for example. The wireless terminal **100**A can exchange encoded data in Bluetooth eSCO packets with a wireless I/O device such as a Bluetooth-enabled printer or a Bluetooth-enabled bar code scanner, for example. Additionally, the wireless PAN **106**A connecting the terminal **100**A to the headset **101**A can operate in either a radiofrequency band, an infrared band, or an optical band.

1. A wireless terminal, comprising:

a first transceiver operating in a wireless PAN network for communicating first data units in accordance with a first communications protocol and operating in a wireless communications band;

a second transceiver operating in a wireless LAN network for communicating second data units in accordance with a second communications protocol and operating in a band substantially the same as said wireless communications band;

said first transceiver establishing predefined slot times to listen for traffic for timing an assignment of relative priorities to the first data units and the second data units; and

a controller coupled to said first and second transceivers, assigning a higher priority to said second data units if one of said second data units is sensed during one of said predefined slot times, to abort transmission of one of said first data units;

said controller assigning a higher priority to said aborted first data unit than to said second data units if one of said second data units is sensed while attempting to retransmit said aborted first data unit in a slot following said one of said predetermined slots, to retransmit said aborted first data unit.

2. The wireless terminal of claim 1, further comprising:

said first communications protocol is a Bluetooth standard and said first data units are Bluetooth ACL packets.

3-6. (canceled)

7. The wireless terminal of claim 1, further comprising:

said wireless terminal exchanging voice over internet (VoIP) packets as said second data units with a wireless access point using IEEE 802.11 Wireless LAN Standard as said second communications protocol; and

said wireless terminal exchanging encoded audio data in Bluetooth ACL packets as said first data units with a wireless headset using a Bluetooth standard as said first communications protocol.

8. The wireless terminal of claim 7, further comprising:

said wireless terminal establishing a connection with said headset and performing a role switch to assume a master role to set up an ACL link with said headset in a sniff mode.

9. The wireless terminal of claim 7, further comprising:

said ACL packets transporting voice data between the terminal and the headset having time-based characteristics that may be retransmitted until received or expired;

said terminal being programmed to automatically flush aborted ACL voice packets after the packets have expired because of waiting too long for an available slot for retransmission;

said terminal determining if a frequency of occurrence of flushed ACL voice packets is greater than a predetermined value; and

said terminal increasing a duration of a listening window following said predefined slot times if said frequency of occurrence is greater than said predetermined value.

10. The wireless terminal of claim 1, further comprising:

said wireless PAN band being selected from the group consisting of radiofrequency band, infrared band, and optical band.

11. A method in a wireless terminal, comprising:

operating a first transceiver in a wireless PAN network for communicating first data units in accordance with a first communications protocol and operating in a wireless communications band;

operating a second transceiver in a wireless LAN network for communicating second data units in accordance with a second communications protocol and operating in a band substantially the same as said wireless communications band;

establishing with said first transceiver predefined slot times to listen for traffic for timing an assignment of relative priorities to the first data units and the second data units;

assigning a higher priority to said second data units if one of said second data units is sensed during one of said predefined slot times, to abort transmission of one of said first data units; and

assigning a higher priority to said aborted first data unit than to said second data units if one of said second data units is sensed while attempting to retransmit said aborted first data unit in a slot following said one of said predetermined slots, to retransmit said aborted first data unit.

12. The method in a wireless terminal of claim 11, further comprising:

said first communications protocol is a Bluetooth standard and said first data units are Bluetooth ACL packets.

13-16. (canceled)

17. The method in a wireless terminal of claim 11, further comprising:

said wireless terminal exchanging voice over internet (VoIP) packets as said second data units with a wireless access point using IEEE 802.11 Wireless LAN Standard as said second communications protocol; and

said wireless terminal exchanging encoded audio data in Bluetooth ACL packets as said first data units with a wireless headset using a Bluetooth standard as said first communications protocol.

18. The method in a wireless terminal of claim 17, further comprising:

said wireless terminal establishing a connection with said headset and performing a role switch to assume a master role to set up an ACL link with said headset in a sniff mode.

19. The method in a wireless terminal of claim 17, further comprising:

transporting voice data in said ACL packets between the terminal and the headset having time-based characteristics that may be retransmitted until received or expired;

automatically flushing aborted ACL voice packets after the packets have expired because of waiting too long for an available slot for retransmission;

determining if a frequency of occurrence of flushed ACL voice packets is greater than a predetermined value; and

increasing a duration of a listening window following said predefined slot times if said frequency of occurrence is greater than said predetermined value.

20. The method in a wireless terminal of claim 11, further comprising:

said wireless PAN band being selected from the group consisting of radiofrequency band, infrared band, and optical band.

21. A system, comprising:

a wireless terminal;

a wireless headset;

a first transceiver in said wireless terminal operating in a wireless PAN network for communicating first data units in accordance with a first communications protocol and operating in a wireless communications band to communicate with said wireless headset;

said first transceiver establishing predefined slot times to listen for traffic for timing an assignment of relative priorities to the first data units and the second data units;

a wireless access point;

a second transceiver in said wireless terminal operating in a wireless LAN network for communicating second data units in accordance with a second communications protocol and operating in a band substantially the same as said wireless communications band to communicate with said wireless access point; and

a controller in said wireless terminal coupled to said first and second transceivers, assigning a higher priority to said second data units if one of said second data units is sensed during one of said predefined slot times, to abort transmission of one of said first data units;

said controller assigning a higher priority to said aborted first data unit than to said second data units if one of said second data units is sensed while attempting to retransmit said aborted first data unit in a slot following said one of said predetermined slots, to retransmit said aborted first data unit.

22. The system of claim 21, further comprising:

said first communications protocol is a Bluetooth standard and said first data units are Bluetooth ACL packets.

23-26. (canceled)

27. The system of claim 21, further comprising:

said wireless terminal exchanging voice over internet (VoIP) packets as said second data units with a wireless access point using IEEE 802.11 Wireless LAN Standard as said second communications protocol; and

said wireless terminal exchanging encoded audio data in Bluetooth ACL packets as said first data units with a wireless headset using a Bluetooth standard as said first communications protocol.

28. The system of claim 27, further comprising:

said wireless terminal establishing a connection with said headset and performing a role switch to assume a master role to set up an ACL link with said headset in a sniff mode.

29. The system of claim 27, further comprising:

said ACL packets transporting voice data between the terminal and the headset having time-based characteristics that may be retransmitted until received or expired;

said terminal being programmed to automatically flush aborted ACL voice packets after the packets have expired because of waiting too long for an available slot for retransmission;

said terminal determining if a frequency of occurrence of flushed ACL voice packets is greater than a predetermined value; and

said terminal increasing a duration of a listening window following said predefined slot times if said frequency of occurrence is greater than said predetermined value.

30. The system of claim 21, further comprising:

said wireless PAN band being selected from the group consisting of radiofrequency band, infrared band, and optical band.

31. A chipset for a wireless terminal, comprising:

a first transceiver circuit chip operating in a wireless PAN network for communicating first data units in accordance with a first communications protocol and operating in a wireless communications band;

a second transceiver circuit chip operating in a wireless LAN network for communicating second data units in accordance with a second communications protocol and operating in a band substantially the same as said wireless communications band;

said first transceiver establishing predefined slot times to listen for traffic for timing an assignment of relative priorities to the first data units and the second data units; and

a controller circuit chip coupled to said first and second transceivers, assigning a higher priority to said second data units if one of said second data units is sensed during one of said predefined slot times, to abort transmission of one of said first data units;

said controller assigning a higher priority to said aborted first data unit than to said second data units if one of said second data units is sensed while attempting to retransmit said aborted first data unit in a slot following said one of said predetermined slots, to retransmit said aborted first data unit.

32. The chipset for a wireless terminal of claim 31, further comprising:

said first communications protocol is a Bluetooth standard and said first data units are Bluetooth ACL packets.

33-36. (canceled)

37. The chipset for a wireless terminal of claim 31, further comprising:

said wireless terminal exchanging voice over internet (VoIP) packets as said second data units with a wireless access point using IEEE 802.11 Wireless LAN Standard as said second communications protocol; and

said wireless terminal exchanging encoded audio data in Bluetooth ACL packets as said first data units with a wireless headset using a Bluetooth standard as said first communications protocol.

38. The chipset for a wireless terminal of claim 37, further comprising:

said wireless terminal establishing a connection with said headset and performing a role switch to assume a master role to set up an ACL link with said headset in a sniff mode.

39. The chipset for a wireless terminal of claim 37, further comprising:

said ACL packets transporting voice data between the terminal and the headset having time-based characteristics that may be retransmitted until received or expired;

said terminal being programmed to automatically flush aborted ACL voice packets after the packets have expired because of waiting too long for an available slot for retransmission;

said terminal determining if a frequency of occurrence of flushed ACL voice packets is greater than a predetermined value; and

said terminal increasing a duration of a listening window following said predefined slot times if said frequency of occurrence is greater than said predetermined value.

40. The chipset for a wireless terminal of claim 31, further comprising:

said wireless PAN band being selected from the group consisting of radiofrequency band, infrared band, and optical band.

41. A program product for a wireless terminal, comprising:

program code for execution in a wireless terminal for operating a first transceiver in a wireless PAN network for communicating first data units in accordance with a first communications protocol and operating in a wireless communications band;

program code for execution in a wireless terminal for operating a second transceiver in a wireless LAN network for communicating second data units in accordance with a second communications protocol and operating in a band substantially the same as said wireless communications band;

program code for execution in a wireless terminal for establishing with said first transceiver predefined slot times to listen for traffic for timing an assignment of relative priorities to the first data units and the second data units;

program code for execution in a wireless terminal for assigning a higher priority to said second data units if one of said second data units is sensed during one of said predefined slot times, to abort transmission of one of said first data units; and

program code for execution in a wireless terminal for assigning a higher priority to said aborted first data unit than to said second data units if one of said second data units is sensed while attempting to retransmit said aborted first data unit in a slot following said one of said predetermined slots, to retransmit said aborted first data unit.

42. The program product for a wireless terminal of claim 41, further comprising:

said first communications protocol is a Bluetooth standard and said first data units are Bluetooth ACL packets.

43-46. (canceled)

47. The program product for a wireless terminal of claim 41, further comprising:

said wireless terminal exchanging voice over internet (VoIP) packets as said second data units with a wireless access point using IEEE 802.11 Wireless LAN Standard as said second communications protocol; and

said wireless terminal exchanging encoded audio data in Bluetooth ACL packets as said first data units with a wireless headset using a Bluetooth standard as said first communications protocol.

48. The program product for a wireless terminal of claim 47, further comprising:

said wireless terminal establishing a connection with said headset and performing a role switch to assume a master role to set up an ACL link with said headset in a sniff mode.

49. The program product for a wireless terminal of claim 47, further comprising:

program code for execution in a wireless terminal for transporting voice data in said ACL packets between the terminal and the headset having time-based characteristics that may be retransmitted until received or expired;

program code for execution in a wireless terminal for automatically flushing aborted ACL voice packets after the packets have expired because of waiting too long for an available slot for retransmission;

program code for execution in a wireless terminal for determining if a frequency of occurrence of flushed ACL voice packets is greater than a predetermined value; and

program code for execution in a wireless terminal for increasing a duration of a listening window following said predefined slot times if said frequency of occurrence is greater than said predetermined value.

50. The program product for a wireless terminal of claim 41, further comprising:

said wireless PAN band being selected from the group consisting of radiofrequency band, infrared band, and optical band.

51. A program product for a wireless terminal, including program code which, when executed, performs the steps comprising:

operating a first transceiver in a wireless PAN network for communicating first data units in accordance with a first communications protocol and operating in a wireless communications band;

operating a second transceiver in a wireless LAN network for communicating second data units in accordance with a second communications protocol and operating in a band substantially the same as said wireless communications band;

establishing with said first transceiver predefined slot times to listen for traffic for timing an assignment of relative priorities to the first data units and the second data units;

assigning a higher priority to said second data units if one of said second data units is sensed during one of said predefined slot times, to abort transmission of one of said first data units; and

assigning a higher priority to said aborted first data unit than to said second data units if one of said second data units is sensed while attempting to retransmit said aborted first data unit in a slot following said one of said predetermined slots, to retransmit said aborted first data unit.

52. The program product for a wireless terminal of claim 51, further comprising:

said first communications protocol is a Bluetooth standard and said first data units are Bluetooth ACL packets.

53-56. (canceled)

57. The program product for a wireless terminal of claim 51, further comprising:

said wireless terminal exchanging voice over internet (VoIP) packets as said second data units with a wireless access point using IEEE 802.11 Wireless LAN Standard as said second communications protocol; and

said wireless terminal exchanging encoded audio data in Bluetooth ACL packets as said first data units with a wireless headset using a Bluetooth standard as said first communications protocol.

58. The program product for a wireless terminal of claim 57, further comprising:

said wireless terminal establishing a connection with said headset and performing a role switch to assume a master role to set up an ACL link with said headset in a sniff mode.

59. The program product for a wireless terminal of claim 57, including program code which, when executed, performs the steps further comprising:

transporting voice data in said ACL packets between the terminal and the headset having time-based characteristics that may be retransmitted until received or expired;

automatically flushing aborted ACL voice packets after the packets have expired because of waiting too long for an available slot for retransmission;

determining if a frequency of occurrence of flushed ACL voice packets is greater than a predetermined value; and

increasing a duration of a listening window following said predefined slot times if said frequency of occurrence is greater than said predetermined value.

60. The program product for a wireless terminal of claim 51, further comprising:

said wireless PAN band being selected from the group consisting of radiofrequency band, infrared band, and optical band.

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