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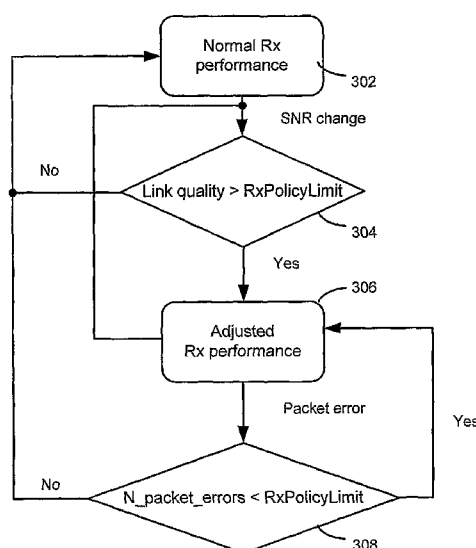


FIG. 3

(57) **Abstract:** Method, apparatus, and computer program product example embodiments are disclosed to enable reduced performance modes of operation between wireless devices. Example embodiments reduces performance in wireless devices by controlling sensitivity levels for a wireless receiver in a module of the device in response to a performance profile and/or by controlling transmission power for a wireless transmitter in the module of the device in response to the performance profile.

TITLE: WIRELESS COMMUNICATION USING PERFORMANCE POLICY**FIELD:**

[0001] Example embodiments relate to wireless communication, and for example, to performance reduction in wireless communication devices.

BACKGROUND:

[0002] Modern society has quickly adopted, and become reliant upon, handheld devices for wireless communication. For example, cellular telephones continue to proliferate in the global marketplace due to technological improvements in both the communication quality and device functionality. These wireless communication devices have become common for both personal and business use, allowing users to transmit and receive voice, text and graphical data from a multitude of geographic locations. The communication networks utilized by these devices span different frequencies and cover different transmission distances, each having strengths desirable for various applications.

[0003] Cellular networks facilitate wireless communication over large geographic areas. These network technologies have commonly been divided by generations, starting in the late 1970s to early 1980s with first generation (1G) analog cellular telephones that provided baseline voice communication, to modern digital cellular telephones. Global System for Mobile Communications (GSM) is an example of a widely employed 2G digital cellular network. This network provides voice communication and also supports the transmission of textual data via the Short Messaging Service (SMS). SMS allows a wireless communication device (WCD) to transmit and receive text messages. The Multimedia Messaging Service (MMS), an enhanced messaging system allowing for the transmission of sound, graphics and video files in addition to simple text, has also become available in certain devices. Emerging technologies, e.g., Digital Video Broadcasting for Handheld Devices (DVB-H), will make streaming digital video, and other similar content, available via direct transmission to a WCD. While long-range communication networks like GSM are a well-accepted means for transmitting and receiving data, due to cost, traffic and legislative concerns, these networks may not be appropriate for all data applications.

[0004] Short-range wireless networks provide communication solutions that avoid some of the problems seen in larger cellular networks. Bluetooth™ is an example of a short-range wireless technology quickly gaining acceptance in the marketplace. A 1 Mbps Bluetooth™ radio may transmit and receive data at a rate of 720 Kbps within a range of 10 meters, and may transmit up to 100 meters with additional power boosting. Enhanced Data Rate (EDR) technology, which is also available, may enable maximum asymmetric data rates of 1448 Kbps for a 2 Mbps connection and 2178 Kbps for a 3 Mbps connection. In addition to Bluetooth™, other popular short-range wireless networks include, for example, IEEE 802.11 Wireless LAN, Wireless Universal Serial Bus (WUSB), Ultra Wideband (UWB), ZigBee (IEEE 802.15.4), wherein each of these example wireless mediums have features and advantages that make them appropriate for various applications.

[0005] The IEEE 802.11 Wireless LAN Standards describe two major components, a wireless device, called a station (STA), and a fixed device, called an access point (AP). The AP may perform the wireless-to-wired bridging from STAs to a wired network. The basic network is the basic service set (BSS), which is a group of wireless devices that communicate with each other. An infrastructure BSS is a network that has an AP as an essential node. In an independent basic service set (IBSS) mode, also known as ad-hoc between two STAs, the basic approach is similar to the infrastructure BSS case whereas one STA is operating as an access point.

[0006] Currently, Wireless LAN (WLAN) devices use only a standard doze state based power saving, wherein the device goes into a sleep state if the device knows that there will be no data available from the AP or host. In an active mode, the device consumes power at a constant rate regardless of any required link budget and signal to noise ratio. In many cases radio specifications have a significant amount of performance overhead, which leads to higher energy consumption.

SUMMARY:

[0007] Method, apparatus, and computer program product example embodiments are disclosed to enable one or more modes of operation between wireless devices. Example embodiments may decrease performance in wireless LAN devices by utilizing a reconfigurable radio modem, which is reconfigured in response to information in both the modem and a host of the subsystem. The modem may include performance reduction logic.

An interface connects the modem to the host's control logic. The interface enables the host to control several different implementations of adjustable modem structures.

[0008] The host sets a performance profile / policy based approach for the modem's control logic. The performance profile /policy describes how sensitive the local control should be in cases of lost packets, detected changes in environment, or other parameters that may affect performance. The performance profile / policy may describe the threshold at which a lower energy state should transition back to a normal operating state where the receiver resumes listening with full sensitivity. The performance profile may be an index number. The performance profile may have one or more other parameters, e.g., how many missed packets may occur or by how much radio channel quality metrics may change before state change.

[0009] Example embodiments are disclosed to adjust performance in a transmitter by adjusting transmission power. Example embodiments are based on a performance profile / policy based approach, which may be a power save abstraction layer. In reducing transmission power, transmission power levels are adjusted, depending on the current performance profile and the related parameters, e.g. a transmit-policy signal-to-noise ratio limit and/or a transmit-policy error limit. The performance profile / policy based approach may define the allowable packet error rate and/or an allowable signal-to-noise (SNR) value. The performance profile is controlled by the host and the execution of the performance adjustment mechanism is performed autonomously in the modem based on the performance profile.

[0010] Example embodiments are disclosed to adjust performance in a receiver by changing sensitivity in the receiver, for example, by adjusting the analog to digital converter (ADC) portion of the receiver. A bit-width of the ADC may be reduced to change sensitivity. The sensitivity change may be based on the performance profile / policy based approach, different settings / reconfigurations are performed depending on the current performance profile and the related parameters. The parameters may define an allowable packet error rate and/or an allowable signal-to-noise ratio (SNR) value or other receiver parameters. The performance profile is controlled by the host and the execution of the performance adjustment mechanism is performed autonomously in the modem based on the performance profile.

[0011] Example embodiments may include three parts: the modem, the interface, and/or the host. The modem, which may be a separate chipset, has an inbuilt, sensitivity adjustment based, performance reduction scheme, which is controlled by the host via the common interface. Performance adjustment may be implemented in various ways. An example embodiment may include an analog-to-digital converter (ADC) resolution-based approach wherein fewer converted bits results in less consumed power. Another example embodiment may include reducing the noise figure of the radio frequency (RF) front-end. Still another example embodiment may place the more primary ADCs into a sleep state while the channel state is monitored before packet transmission. The above performance adjustment implementations may be used in combination. The modem may include one or more modules including the control for the control for receiver sensitivity, the control for transmission power, the receiver, and/or the transmitter.

[0012] Example embodiments separate the control into real-time control (or run-time control) of the modem and overall performance policy control by the host. The host will set guidelines via the interface as to how the real-time logic in the modem is to operate. The local control at the modem requires usage dependent knowledge. An example is two devices connected via an ad hoc connection. Channel state estimation in a conventional WLAN system may be relatively inaccurate and there may be a lag in communication between the modem and the host. However, example embodiments may improve accuracy and decrease lag through local control at the modem, which adapts independently and more rapidly to faster changes in the radio environment.

[0013] According to an example embodiment, a method may include receiving a performance profile in a module. Receiver sensitivity levels for a wireless receiver in the module may be determined in response to the performance profile. Sensitivity levels for the wireless receiver in the module may be controlled in response to the determined receiver sensitivity levels.

[0014] According to an example embodiment, a method may include receiving a performance profile in a module. A transmission power for a wireless transmitter in the module may be determined in response to the performance profile. Transmission power for the wireless transmitter in the module may be controlled in response to the determined transmission power.

[0015] An apparatus may include a module and/or a processor. The module may include a wireless receiver and/or be configured to receive a performance profile. The processor may be configured to determine receiver sensitivity levels for the wireless receiver in response to the performance profile and to control sensitivity levels for the wireless receiver in response to the determined receiver sensitivity levels.

[0016] An apparatus may include a module and/or a processor. The module may include a wireless transmitter and/or be configured to receive a performance profile. The processor may be configured to determine a transmission power for the wireless transmitter in response to the performance profile and to control transmission power for the wireless transmitter in response to the determined transmission power.

DESCRIPTION OF THE FIGURES:

[0017] Fig. 1 illustrates an external view and a functional block diagram of an example embodiment of a wireless device;

[0018] Fig. 2 illustrates a block diagram of control logic of a device according to an example embodiment;

[0019] Fig. 3 shows an example state diagram of receiver control in response to a receive policy;

[0020] Fig. 4 shows an example state diagram of transmitter control in response to a transmit policy;

[0021] Fig. 5 illustrates an external view and a functional block diagram of an example embodiment of a modem;

[0022] Fig. 6 illustrates a block diagram of an example interface between a host and a modem according to an example embodiment;

[0023] Fig. 7 shows an example state diagram for setting parameters of receiver control; and

[0024] Fig. 8 shows an example state diagram for setting parameters of transmitter control.

DISCUSSION OF EXAMPLE EMBODIMENTS:

[0025] Fig. 1 illustrates an external view and a functional block diagram of an example embodiment of a wireless device 100A. The wireless device 100A may be a communications device, PDA, cell phone, mobile terminal, laptop or palmtop computer, or any other apparatus. The wireless device 100A may include a control module 220, which includes a central processing unit (CPU) 260, a random access memory (RAM) 262, a read only memory (ROM) 264, and/or interface circuits 266 to interface with a radio transmitter 212, receiver 214, battery and other power sources, key pad, touch screen, display, microphone, speakers, ear pieces, camera or other imaging devices, etc. in the device 100A. The central processing unit 260 may be a complex logic module, an ASIC, or an instruction processor. The RAM 262 and ROM 264 may be removable memory devices, e.g., smart cards, subscriber identification modules (SIMs), wireless identity modules (WIMs), semiconductor memories, (e.g., RAM, ROM, programmable read only memory (PROM), flash memory devices), etc. The wireless device 100A includes, for example, an internet protocol stack that includes a user's application program 203 at the top, and from the application program 203 to the bottom of the stack a Transmission Control Protocol (TCP) transport layer 204, an Internet Protocol (IP) layer 205, an upper Media Access Control (MAC) layer 206, an interface 208, a lower Media Access Control (MAC) layer 210, and/or the radio physical layer comprising the transmitter (TX) 212 and the receiver (RX) 214 at the bottom of the protocol stack. The Media Access Control (MAC) layers 206 and 210 may be an IEEE 802.11 MAC layer, for example, which provides functionality to allow reliable data delivery for the upper layers over the wireless medium. The device may support other upper layer protocols, e.g., User Datagram Protocol (UDP). The wireless device might operate as station (STA) or as access point in a WLAN network.

[0026] Fig. 2 illustrates a block diagram of control logic of a device according to an example embodiment. Example embodiments of the device 100A may include: modem 202, interface 208, and/or host 200. The host 200 of the wireless device 100A may include communication layers from the upper media access control (MAC) layer 206 upwards to the application layer 203 as shown by Fig 1.

[0027] Fig. 5 illustrates an external view and block diagram of an example embodiment of the modem 202. The modem 202, which may be a separate chipset, may have a vendor specific implementation of the lower MAC layer 210, and/or the radio physical layer comprising at least one transmitter 212 and/or at least one receiver 214 at the bottom of

the protocol stack. The modem 202 may include a CPU 560, a RAM 562, and/or a ROM 564. The CPU 560 may be a complex logic module, an ASIC, or an instruction processor. The ROM may be a removable ROM, flash memory or EPROM. The interface 208 connects the modem 202 part to the host's 200 control logic. The interface 208 enables the host 200 to control various different implementations of adjustable modem 202 structures or may be used for any other data communication. For example, the modem 202 may have inbuilt transmission power adjustment and receiver sensitivity adjustment, which are controlled by the host 200 of Fig 1 via the interface 208. For example, the modem 202 may include a transmission module including the transmission power adjustment control and/or the transmitter 212, a receiver module including the receiver sensitivity adjustment control and/or the receiver 214, or a transmitter/receiver module including the transmission power adjustment control, the receiver sensitivity adjustment control, and/or the transmitter 212 and receiver 214. Fig. 5 illustrates an example embodiment of the modem 202; however, example embodiments are not limited thereto and the modem 202 may have various other configurations.

[0028] Referring again to Fig. 2, the control logic of host 200 may include an input-to-output mapping algorithm. The host 200 may assign parameters or parameter ranges to independent local control entities at the modem 202, e.g., in the module or modules of the modem 202. For example, parameter groups may include transmission rate, transmission power, scheduler control, scanning/handover control, and/or receiver dynamic range. The host 200 may set the parameter groups based on information that is available to the host 200 from a terminal energy manager, applications, location information, sensors, (e.g., acceleration sensor), and/or information from the modem 202. The host 200 and the modem 202 may exchange information via the interface 208, which may be a WLAN HAL application program interface (API).

[0029] The modem 202 may include various local functions, for example, a rate algorithm (RA_Modem), scan/handover control (S/HC_Modem), transmission power control (TPC_Modem), receiver dynamic range control (RDR_Modem), and/or a scheduler (SCH_Modem). The local functions/control entities in the modem 202, which may be flexibly controlled and optimized depending on an operating context and environment, may be implemented with separate and/or different run-time controls. The various local functions in the modem 202 may make independent decisions, and parameter changes by one of the local functions in the control logic of the modem 202 need not affect other local functions in

the modem 202. However, the control logic may make parameter changes to some, all, or none of the local functions. The local control logic in the modem 202 may have input parameters, which may be common, and the input parameters may be used to make operating decisions at run-time. Cross optimization of parameters may be performed by the host 200, and the host 200 may set a separate policy that is a guideline for local control in the modem 202. After the local control in the modem 202 receives a policy from the host 200, the local control changes internal decision limits or similar parameters according to the policy.

Alternatively, cross-optimized operating modes in the modem 202 may be selected using a performance profile / policy based approach (PerformID) as a group selection parameter. Accordingly, the modem 202 sets each control parameter of the local functions as specified in the PerformID. Fig. 2 illustrates example embodiments of control logic for the device 100A; however, example embodiments are not limited thereto and the device 100A may include various other types of control logic / functions and/or interfaces between host 200, interface 208, and modem 202.

[0030] Fig. 6 illustrates a block diagram of an example interface between a host and a modem according to an example embodiment. An interface 608 between a modem 602, which may have a hardware platform specific access interface, and the host 600, which may be a WLAN host driver, may be based on adaptation layer software, which may be specific to the modem 602. The adaptation layer software, for example a WLAN HAL API (WHA) layer, may run on the host 600, and the host 600 may implement the WHA layer as the interface 608. The host 600 may receive the device specific adaptation layer software from the modem 602. The interface 608 may convert the logical operations defined by the host 600 to device specific operations of the modem 602 and transport the converted logical operations to the modem 602. The interface 608 may convert the device specific operations of the modem 202 to the logical operations defined by the host 600 and transport the converted device specific operations to the host 600. The interface 608 may hide the device specific messaging, e.g., the real-time control, of the modem 602 from the host 600, which may allow the host 600 to handle only the logical operations, (e.g., host 600 needs only to set guidelines via the interface 608 as to how the real-time logic is to operate). Fig. 6 illustrates example embodiments for a WLAN system; however, example embodiments are not limited thereto and may be employed in other networks or systems.

[0031] Referring again to Fig. 1, the control module 220, internet protocol stack layers 204 to 210, and/or application program 203 and transmitter 212 and/or receiver 214

may be embodied as program logic stored in the RAM 262 and/or ROM 264 in the form of sequences of programmed instructions which, when executed in the CPU 260, carry out the functions of example embodiments. The program logic may be delivered to the writeable RAM, programmable read-only memory (PROM), flash memory devices, etc. 262 of the wireless device 100A from a computer program product or article of manufacture in the form of computer-usable media, e.g., resident memory devices, smart cards or other removable memory devices, or in the form of program logic transmitted over any transmitting medium which transmits programs. Alternately, the control module 220, internet protocol stack layers 204 to 210, application program 203, and/or transmitter 212 and/or receiver 214 may be embodied as integrated circuit logic in the form of programmed logic arrays or custom designed application specific integrated circuits (ASIC). Each part may be combined in one or several integrated circuits or using CPUs. The radio transmitter 212 and receiver 214 in wireless device 100A may be configured to handle one or multiple channels in a relatively high speed, time and frequency multiplexed manner in response to the control module 220.

[0032] The control in device 100A may be divided into two parts. Real-time control may be located at the modem 202, and the host 200 may set guidelines via the interface 208 as to how the real-time logic is to operate, to avoid performance drawbacks. The local control at the modem may be included in the one or more modules of the modem, which may also include the transmitter 212 and/or the receiver 214. The local control at the modem 202 may require usage dependent information. An example is two devices connected via an ad hoc connection. Channel state estimation in a WLAN system may not be very accurate and a lag in communication between the modem 202 and the host 200 may exist. Therefore, local control at the modem 202 is able to adapt independently and faster to rapid changes in the radio environment.

[0033] The host 200 sets a performance profile / policy based approach (PerformID) in a policy register 215 for the modem 202's control logic. Combined or dedicated policy registers may be available for the transmitter 212 and/or receiver 214. Combined or dedicated registers per each receiver and/or transmitter may be available if more than one receiver 214 and/or transmitter 212 are available. For example, PerformID describes how sensitive the local control at the modem 202 should be in cases of lost packets, detected changes in environment, and/or other parameters that may affect to performance, before the local control abandons a lower performance state and starts to listen with full sensitivity. PerformID may be an index number or PerformID may have additional parameters, e.g., how

many missed packets may occur or by how much radio channel quality metrics may change before state change. In another example PerformID may include parameters related to transmission rate, transmission power, scheduler control, scanning/handover control, and/or receiver dynamic range.

[0034] For example, the host 200 may set the PerformID, which defines transmission power and/or receiver parameter ranges which should be used in run-time control of the modem 202. Accordingly, the PerformID allows application usage, and environment dependent running of the modem 202. For example, the PerformID set by the host 200 may indicate an amount of packet retransmissions required before a state change, a WLAN mode (e.g., infrastructure, ad-hoc) and/or the connectivity of the device (e.g., active data sources in different access categories (AC)). Any other or further indications might be used. The modem 202 may have a control entity, e.g., in the one or more modules of the modem 202, separate from the host 200 and the control logic of the host 200 which configures transmitter 212 and/or receiver 214 parameters according to different PerformIDs. For example, the modem 202 may determine the signal and noise strength (e.g., RSSI) and/or packet error ratio (e.g., errors in received packets), etc. for received packets, (e.g., on a packet-by-packet basis). The modem 202 may detect parameters, (e.g., movement, external radio transmissions (e.g., Bluetooth or some other radio), etc.), and/or control real-time operations of transmission power, transmission rate, receiver sensitivity, etc.

[0035] The host 200 may set any number of various PerformIDs. The PerformIDs may have parameters including traffic load (e.g., type and amount allowed), transmission/receive mode optimization curve (e.g., for power, throughput, errors) and/or movement of the device, etc. For example, the device 200 may be in communication using a safe mode PerformID. The safe mode may maximize link margin at a first phase. Channel and application analysis may begin, and after connection is established the host 200 may set a usage specific PerformID for the modem 202 to continue operation in a throughput or power optimized manner. Throughput optimization may target maximum capacity and reduce delays during connection. If there are enough link margins, lower transmission power may be used; however, the modem 202 may generally use maximum transmission power and a highest supported rate. If capacity requirements are lower, the host 200 may set a PerformID to improve power operation at modem 202. The modem 202, e.g., the transmission module, may use a lower transmission rate and/or power depending on channel statistics. The modem 202 may operate in the safe mode, (e.g., after notification to the host 200), if errors are

detected or the link margin drops below a desired, or alternatively, a predetermined level. Accordingly, the host 200 may set a safe mode and/or one or more various other PerformIDs to control the state of the modem 202.

[0036] Fig. 7 shows example state diagram for setting parameters of receiver control of the modem. The host 200 may alter receiver performance policy RxPerformPolicy of receiver by setting a RxPerformPolicy command with an index parameter, e.g., in the PerformID. The index parameter may describe a set of parameters that are used for performance management in receiver control. If the receiver 214 receives a RxPerformPolicy command, the receiver 214 determines if the index parameter differs from the parameter set for the safe mode (or normal operation mode or any other mode), e.g., 1 in Fig. 7. The receiver 214 may change run-time operation parameters based on the altered RxPerformPolicy. For example, as illustrated in Fig. 7, a receive policy limit RxPolicyLimit for link quality may be set to a minimum signal-to-noise ratio (SNR) rate plus a desired, or alternatively, a predetermined margin, and a receive policy limit RxPolicyLimit for packet errors may be set in accordance with a value corresponding to the altered receive performance policy RxPerformPolicy. Fig. 7 illustrates examples embodiments having a PerformID including an index number; however, example embodiments are not limited thereto and the PerformID may include other or additional parameters.

[0037] Fig. 8 shows example state diagram for setting parameters of transmitter control of the modem. The host 200 may alter transmission performance policy TxPerformPolicy of the transmitter 212 by setting a TxPerformPolicy command with an index parameter, e.g., in the PerformID. If the transmitter 212 receives a TxPerformPolicy command, the transmitter 212 determines if the index parameter differs from the safe mode (or normal operation mode), e.g., 1 in Fig. 8. The transmitter 212 may change run-time operation parameters based on the altered TxPerformPolicy. For example, as illustrated in Fig. 8, a transmit policy limit TxPolicyLimit for link quality may be set to a minimum signal-to-noise ratio (SNR) rate plus a desired, or alternatively, a predetermined margin, and/or a transmit policy limit TxPolicyLimit for missed acknowledgements (ACKs) may be set in accordance with a value corresponding to the altered receive power policy TxPerformPolicy. Fig. 8 illustrates examples embodiments having a PerformID including an index number; however, example embodiments are not limited thereto and the PerformID may include other or additional parameters.

[0038] Example embodiments are disclosed to save power in a WLAN transmitter by adjusting transmission power. Example embodiments are based on a performance profile / policy based approach (PerformID), which may be a performance abstraction layer. In adjusting transmission power, the power levels are adjusted, depending on the current performance profile and the related parameters, e.g. a transmit-policy signal-to-noise ratio limit and/or a transmit-policy error limit stored in a transmit policy partition 218 of the at least one policy register 215. The performance profile / policy based approach (PerformID) defines the allowable packet error rate and an allowable signal-to-noise (SNR) value. The performance profile is controlled by the host 200 and the execution of the performance mechanism is performed autonomously in the modem 202 based on the allowable packet error rate and the allowable SNR value defined by the PerformID.

[0039] Example embodiments are disclosed to reduce performance in a WLAN receiver by adjusting the sensitivity in the receiver, for example, the analog to digital converter (ADC) portion of the receiver. An example embodiment may reduce bit-width of the ADC. The bit-width reduction method may be based on the performance profile / policy based approach (PerformID). Example embodiments may include analog and/or digital modules or elements for processing of the received signal. If the PerformID is used, different settings / reconfigurations are performed depending on the current profile and the related parameters stored in a receive policy partition 216 of the policy register 215. The parameters may define the allowable packet error rate and/or allowable SNR value or other receiver parameters. The performance profile PerformID is controlled by the host 200 and the execution of the performance adaption mechanism is performed autonomously in the modem 202.

[0040] Example embodiments may also employ movement tracking to create more accurate channel estimations. If movement of the device 100A is detected, a less aggressive scheme may be used at the modem 202 depending on the PerformID. If no movement is detected, the modem 202's control logic may assume that channel estimation is valid for a longer period of time, (e.g., a RX and TX Policy Timeout parameter may be extended in response to information received at the modem 202 from the host 200 via the interrupt signal).

Modem Control In Response To A Receive Policy

[0041] Fig. 3 shows example real-time operation state diagram of the modem 202 control of the receiver 214 in response to a receive policy stored in the receive policy

partition 216. In the exemplary embodiment presented parameters are receive policy signal-to-noise ratio limit (RxPolicySNRLimit) and receive policy error limit (RxPolicyErrorLimit). The presented parameters are described by the PerformID and stored in the receive policy partition 216 of the at least one policy register 215. Alternately, the parameters may be modified using a separate overrun parameter. Channel quality and/or missed packets metrics are one example of parameters which modem 202 may utilize if modem 202 is determining an improved way to utilize a selected energy saving method. Accordingly, instead of setting a full range of different parameters using different commands, the PerformID command indicates how the local control in the modem 202 may be adapted to the different usage. The PerformID scheme may be modified according to modem 202 implementation. In an example embodiment there may also be a separate fast signal (interrupt) between host 200 and modem 202, which in case of a sudden change in operating environment is used to reset performance saving features of the modem 202, e.g., modem 202 goes to "safe mode" in Fig. 2.

[0042] As WLAN energy consumption is receiver dominated, e.g. modem 202 will generally spend more active time receiving a packet or listening to a channel, even moderate reduction in average power in a receive or listening state will cause a proportional effect on overall energy consumption. Example estimated average energy saving for an example embodiment as compared to a conventional implementation may be substantial for both receiver functions and transmission functions if WLAN standard doze state based power saving is utilized for the conventional implementation. However, if the doze state is not used for the conventional implementation, estimated gains of an example embodiment as compared to the conventional implementation are much larger.

[0043] The example state diagram of receiver control of Fig. 3 includes state 302, which is a safe mode with normal performance of the receiver 214. For example, according to an example embodiment, the safe mode may allow for any type of data/traffic load, any movement of the device 100A, and/or a maximum link margin (e.g., maximum RX sensitivity). However, the safe mode is not limited thereto and may include any number of desired parameters and parameter values. If a signal-to-noise (SNR) change is detected by the modem 202, e.g., in the one or more modules of the modem 202, a decision 304 is made by the modem 202 to determine whether the link quality is greater than the receive policy limit RxPolicyLimit in partition 216 of policy register 215. If decision 304 is NO, the state remains in state 302. If decision 304 is YES, the state changes from state 302 to state 306 for an adjusted, e.g., reduced, performance of the receiver 214. An amount of RX performance

adjustment in state 306 may be proportional to a difference between measured link quality and receive policy limit RxPolicyLimit depending on an implementation of receiver 214. If a packet error is detected by the modem 202, a decision 308 is made by the modem 202 to determine whether the detected number of packet errors N_packet_errors is less than the receive policy limit RxPolicyLimit in partition 216 of policy register 215. If decision 308 is YES, the state remains in state 306 and the link quality is periodically rechecked at 304 to decide if the state should return to state 302. If decision 308 is NO, the state changes from state 306 to state 302 for the safe mode with normal performance of the receiver 214. Alternatively, a state transition from state 306 to 302, e.g., to safe mode, may occur if a time period from a last link quality measurement is violated, (e.g., a received packet exceeds RxPolicyTimeout parameter value set by host 200). For example, according to an example embodiment, the adjusted RX performance mode may be used for connection maintenance like beacon reception in a WLAN infrastructure, ad-hoc and/or mesh networks.

[0044] Although example embodiments are described with regard to a single adjusted performance state / mode of the receiver 214, example embodiments are not limited thereto. Example embodiments may include a plurality of adjusted performance states / modes having different performance aspects, (e.g., parameters), for the receiver 214. For example, example embodiments may include a plurality of modes having receiver performance levels different than a safe mode with normal performance of the receiver 214. Accordingly, example embodiments may switch between the plurality of adjusted performance states / modes to increase or decrease receiver performance, (e.g., receiver sensitivity), without needing to return to the safe mode.

[0045] In an example embodiment receiver performance reduction methods may include a less bits approach, less performance approach, a reduction in noise figure of RF front end approach, and/or an approach putting main ADC's into a sleep state. However, example embodiments are not limited thereto, and various methods of reducing receiver performance and/or sensitivity may be implemented by example embodiments. For example, ADC operation in the receiver 214 may use fewer bits, e.g., 6 bits instead of 8 bits. If the modem 202 detects that there is available link margin and allowance from host 200, the modem 202 may set reconfigurable ADCs in a lower performance mode. For example, in a case of a sigma-delta ADC, an iteration loop is run by a slower clock. In a case of flash ADCs, a switch may be used to drop part of a resistor tree out of operation with some modifications to used voltages. However, example embodiments are not limited thereto, and

a reduction in a number of bits for ADC operation in the receiver 214 may be implemented in various ways.

[0046] In an example embodiment receiver performance may be reduced by a reduction in the noise figure of the RF front end of the receiver 214. The modem 202 may use a reconfigurable design block to control channel adaptive front-end. Noise figure reduction may be performed by shutting off a low noise amplifier (LNA) of the receiver chain of the receiver 214. According to another example embodiment, RF front-end circuitry of the receiver 214 may include separate operating points which may be selected using switches such that performance parameters, (e.g., gain, noise figure, linearity or the like), may be lowered. Active RF components may be adjusted by controlling the bias current which determines an operating point, e.g., an applicable input power region (dynamic range) and sensitivity of the receiver 214. In another example embodiment, analog baseband circuits in the receiver 214 may be modified to trade-off dynamic range for power. However, a reduction in the noise figure of the RF front end of the receiver 214 may be implemented in various other ways.

[0047] In an example embodiment, receiver performance may be reduced by putting main ADC's into a sleep state. For example, received signal strength indication (RSSI) measurement may be implemented in an analog front end of the receiver 214. ADCs of a mixed signal receiver RX chain in the receiver 214 may be kept in a sleep state until a received frame start is detected. A reduced performance mode may be implemented solely in a digital domain of a transmitter and/or receiver chain, or in both the analog and digital domains. For example, the reduced performance mode may be implemented by reducing the bit width of functional modules used in the transmitter and/or receiver chains or by using special lower performance modules in the transmitter 212 and/or receiver 214. For the digital domain, signal-to-noise ratio (SNR) may be estimated before receiving a frame, and frames having higher error probability, (e.g., error probably above a threshold level), may be discarded. Each of the digital blocks in the receiver 214 may operate symbol by symbol, and if errors are detected in any phase, the following blocks are not turned on and the remainder of the packet is discarded. For example, ADCs may be put into a sleep state in the digital domain through asynchronous logic. Any of the presented examples for receiver performance adjustments may be used alone or may be combined with any other of the above presented adjustments methods.

Modem Control In Response To A Transmit Policy

[0048] The WLAN channel access scheme requires that all stations in the network detect each other. If transmission power is reduced, there is a likelihood of a hidden terminal that will cause collisions. More effective utilization of transmission power adjustment requires more efficient channel estimation. However, the WLAN standard may not support two-directional link margin measurements or link state knowledge exchange. Therefore, additional information may be needed if transmission power adjustment-based performance features are to be utilized in a WLAN chipset.

[0049] However, there are some cases where additional information is not necessary. For example, in an ad-hoc point-to-point connection, a station may make a reasonable assumption that there are no additional stations operating and, thus, the station's transmission power may be changed according to an estimated path loss. However, a host in the station may have delayed information concerning the path loss. A modem may not utilize transmission power-based energy save efficiently because the modem does not have a usage or service requirement-based information as to when to use transmission power adjustments.

[0050] Example embodiments may reduce power consumption of the WLAN equipped terminal by utilizing a modular system architecture. The modem 202, e.g., the one or more modules in the modem 202, may have real-time channel monitoring information that may be combined to control transmission power. The modem 202 may have internal control logic that adjusts the transmission power according to a detected path loss and/or link quality. The host 200 may set different policies as to how the modem 202 should use transmission power control to reduce energy consumption via the interface 208 and commands. The interface 208 and a division of the functions performed by the host 200 and the modem 202 are aspects of example embodiments.

[0051] Fig. 4 shows example state diagram of the transmitter control. In the presented example parameters transmit policy signal-to-noise ratio limit (TxPolicySNRLimit) and transmit policy error limit (TxPolicyErrorLimit) are stored in the transmit policy partition 218 of the PerformID policy register 215. Alternately, the parameters may be modified using separate overrun parameters. Channel quality and number of missed ACKs are one example of parameters, which modem 202 may utilize if modem 202 is determining an improved way to utilize selected energy saving methods. The PerformID command to the modem 202 indicates to the modem 202 how the local control in the modem 202 may be adapted to the different usage situations, instead of setting a full range of different parameters using different commands. PerformID scheme may be modified according to modem 202

implementation. For example, if there is a transmission buffer of several packets or some packet aggregation scheme is used, the host 200 may sleep to save power; however, the modem 202 may still independently adjust link SNR of each packet if the host 200 sleeps. There may also be a separate fast signal (interrupt) between host 200 and modem 202 which, in case of a sudden change in operating environment, is used to reset performance adjustment features of the modem 202, for example, the modem 202 goes to "safe mode" as in Fig. 4.

[0052] The example state diagram of Fig. 4 includes state 402, which is the safe mode with normal performance of the transmitter 212. If a signal-to-noise (SNR) change is detected by the modem 202, a decision 404 is made by the modem 202 whether the link quality is greater than the transmit policy limit TxPolicyLimit in partition 218 of policy register 215. If decision 404 is NO, the state remains in state 402. If decision 404 is YES, the state changes from state 402 to state 406 for adjusting, (e.g., dropping), the transmit power of transmitter 212. The size of the adjustment may be proportional to a difference between link quality metrics and TxPolicyLimit. If an acknowledgement (ACK) is missed as detected by the modem 202, a decision 408 is made by the modem 202 whether the detected number of missed ACKs (N_missed_ACKs) is less than the transmit policy limit TxPolicyLimit in partition 218 of policy register 215. If decision 408 is YES, the state remains in state 406, but TX power may be increased by one step and the link quality is periodically rechecked at 404 to decide if the state should return to state 402. If decision 408 is NO, the state changes from state 406 to state 402 for the safe mode with normal performance of the transmitter 212. State transition from state 406 to 402 safe mode may happen when a time limit expires from last link quality measurement for example received packet exceeds TxPolicyLimit parameter value.

[0053] Although example embodiments are described with regard to a single adjusted performance state / mode of the transmitter 212, example embodiments are not limited thereto. Example embodiments may include a plurality of adjusted performance states / modes having different performance aspects, (e.g., parameters), for the transmitter 212. For example, example embodiments may include a plurality of modes having transmitter performance levels different than a safe mode with normal performance of the transmitter 212. Accordingly, example embodiments may switch between the plurality of adjusted performance states / modes to increase or decrease transmitter performance, (e.g., transmission power), without needing to return to the safe mode.

[0054] In an example embodiment, the one more transmitter modules in the modem 202, may adjust transmission power based on a current PerformID through energy scalable amplification. A power amplifier may consume almost half of the total transmission mode energy. Transmission power may be scaled according to channel attenuation, and may be adjusted step by step using an amplifier with variable gain and compression point. Adjustments may be performed at run-time with digital control, and digital back-off may be changed according to changed amplifier properties.

[0055] In an example embodiment, an adjustable amplification chain of a transmission chain in transmitter 212 may include a variable gain amplifier (VGA), current buffer, power amplifier driver, and/or external power amplifier. Each amplifier may be digitally adjustable. The amplifiers may be adjusted through tunable degeneration resistance to impact gain and linearity, tunable load resistance to impact amplification gain, tunable bias current or voltage to affect direct current (DC) power consumption and overall performance, and/or tunable supply voltage to impact the DC power and performance. However, example embodiments are not limited thereto, and transmission power may be adjusted in various other ways.

[0056] Using the description provided herein, example embodiments may be implemented as a machine, process, or article of manufacture by using standard programming and/or engineering techniques to produce programming software, firmware, hardware or any combination thereof.

[0057] Any resulting program(s), having computer-readable program code, may be embodied on one or more computer-usable media such as resident memory devices, smart cards or other removable memory devices, or transmitting devices, thereby making a computer program product or article of manufacture according to the embodiments. As such, the terms "article of manufacture" and "computer program product" as used herein are intended to encompass a computer program that exists permanently or temporarily on any computer-usable medium or in any transmitting medium which transmits such a program.

[0058] As indicated above, memory/storage devices include, but are not limited to, disks, optical disks, removable memory devices such as smart cards, SIMs, WIMs, semiconductor memories such as RAM, ROM, PROMS, etc. Transmitting mediums include, but are not limited to, transmissions via wireless communication networks, internet, intranets, telephone/modem-based network communication, hard-wired/cabled communication network,

satellite communication, and other stationary or mobile network systems/communication links.

[0059] Although specific example embodiments have been disclosed, a person skilled in the art will understand that changes can be made to the specific example embodiments without departing from the spirit and scope thereof. For example, the features described herein may be employed in any other wired or wireless communication networks other than Wireless LAN networks.

CLAIMS:

What is claimed is:

1. A method, comprising:

receiving a performance profile in a module;

determining receiver sensitivity levels for a wireless receiver in the module in response to the performance profile; and

controlling sensitivity levels for the wireless receiver in the module in response to the determined receiver sensitivity levels.

2. The method of claim 1, wherein said determining sensitivity levels is in response to comparing link quality detected by the module to a receive policy limit of the performance profile.

3. The method of claim 2, wherein if said detected link quality violates said receive policy limit, changing the receiver from a normal receive state to a reduced performance state.

4. The method of claim 3, wherein said determining sensitivity levels is further in response to comparing packet errors detected by the module to the receive policy limit of the performance profile.

5. The method of claim 4, wherein if said detected packet errors violates said receive policy limit, changing the receiver from said reduced performance state to said normal receive state.

6. A method, comprising:

receiving a performance profile in a module;

determining a transmission power for a wireless transmitter in the module in response to the performance profile; and

controlling transmission power for the wireless transmitter in the module in response to the determined transmission power.

7. The method of claim 6, wherein said determining transmission power is in response to comparing link quality detected by the module to a transmit policy limit of the performance profile.

8. The method of claim 7, wherein if said detected link quality violates said transmit policy limit, changing the transmitter from a normal performance state to a reduced performance state.

9. The method of claim 8, wherein said controlling transmission power is further in response to comparing missed acknowledgements determined by the module to the transmit policy limit of the performance profile.

10. The method of claim 9, wherein if said missed acknowledgements violates said transmit policy limit, changing the transmitter from said reduced performance state to said normal performance state.

11. An apparatus, comprising:

a module including a wireless receiver;

said module configured to receive a performance profile; and

a processor configured to determine receiver sensitivity levels for the wireless receiver in response to the performance profile and to control sensitivity levels for the wireless receiver in response to the determined receiver sensitivity levels.

12. The apparatus of claim 11, wherein said sensitivity levels are determined in response to comparing link quality detected by the module to a receive policy limit of the performance profile.

13. The apparatus of claim 12, wherein if said detected link quality violates said receive policy limit, changing the receiver from a normal receive state to a reduced performance state.

14. The apparatus of claim 13, wherein said sensitivity levels are further controlled in response to comparing packet errors detected by the module to the receive policy limit of the performance profile.

15. The apparatus of claim 14, wherein if said detected packet errors violates said receive policy limit, changing the receiver from said reduced performance state to said normal receive state.

16. An apparatus, comprising:

a module including a wireless transmitter;

said module configured to receive a performance profile; and

a processor configured to determine a transmission power for the wireless transmitter in response to the performance profile and to control transmission power for the wireless transmitter in response to the determined transmission power.

17. The apparatus of claim 16, wherein said transmission power is determined in response to comparing link quality detected by the module to a transmit policy limit of the performance profile.

18. The apparatus of claim 17, wherein if said detected link quality violates said transmit policy limit, changing the transmitter from a normal transmit state to a reduced performance state.

19. The apparatus of claim 18, wherein said transmission power is further changed in response to comparing missed acknowledgements determined by the module to the transmit policy limit of the performance profile.

20. The apparatus of claim 19, wherein if said missed acknowledgements violates said transmit policy limit, changing the transmitter from said reduced performance state to said normal transmit state.

21. A computer program product, comprising:

a computer readable medium configured to store program instructions, which when executed by a computer processor, perform the steps of:

receiving a performance profile in a module;

determining receiver sensitivity levels for a wireless receiver in the module in response to the performance profile; and

controlling sensitivity levels for the wireless receiver in the module in response to the determined receiver sensitivity levels.

22. A computer program product, comprising:

a computer readable medium configured to store program instructions, which when executed by a computer processor, perform the steps of:

receiving a performance profile in a module;

determining a transmission power for a wireless transmitter in the module in response to the performance profile; and

controlling transmission power for the wireless transmitter in the module in response to the determined transmission power.

23. An apparatus, comprising:

means for receiving a performance profile in a module; and

means for determining a transmission power for a wireless transmitter in the module in response to the performance profile; and

means for controlling transmission power for the wireless transmitter in the module in response to the determined transmission power.

24. An apparatus, comprising:

means for receiving a performance profile in a module;

means for determining receiver sensitivity levels for a wireless receiver in the module in response to the performance profile; and

means for controlling sensitivity levels for the wireless receiver in the module in response to the determined receiver sensitivity levels.

25. The method of claim 1, wherein said controlling sensitivity levels is in response to a change in signal-to-noise ratio detected by the module.

26. The method of claim 6, wherein said controlling transmission power is in response to a change in signal-to-noise ratio detected by the module.

27. The apparatus of claim 11, wherein said controlling sensitivity levels is in response to a change in signal-to-noise ratio detected by the module.

28. The apparatus of claim 16, wherein said controlling transmission power is in response to a change in signal-to-noise ratio detected by the module.

29. The method of claim 1, wherein the sensitivity levels for the wireless receiver are controlled by adjusting a bit width of an analog-to-digital converter in the wireless receiver.

30. The method of claim 1, wherein the sensitivity levels for the wireless receiver are controlled by adjusting a noise figure of a RF front end of the wireless receiver.

31. The method of claim 1, wherein the sensitivity levels for the wireless receiver are controlled by putting at least a portion of analog-to-digital converters in the wireless receiver in a sleep state before the receiver receives a frame.

32. The apparatus of claim 11, wherein the sensitivity levels for the wireless receiver are controlled by adjusting a bit width of an analog-to-digital converter in the wireless receiver.

33. The apparatus of claim 11, wherein the sensitivity levels for the wireless receiver are controlled by adjusting a noise figure of a RF front end of the wireless receiver.

34. The apparatus of claim 11, wherein the sensitivity levels for the wireless receiver are controlled by putting at least a portion of analog-to-digital converters in the wireless receiver in a sleep state before the wireless receiver receives a frame.

35. A system, comprising:
a host configured to provide a performance profile;
a module including a wireless receiver; and
an interface coupled to the module and the host, configured to transfer at least a portion of the performance profile from the host to the module;
said module configured to determine receiver sensitivity levels for the wireless receiver in response to the performance profile and to control sensitivity levels for the wireless receiver in response to the determined receiver sensitivity levels.

36. A system, comprising:
a host configured to provide a performance profile;

a module including a wireless transmitter; and

an interface coupled to the module and the host, configured to transfer at least a portion of the performance profile from the host to the module;

said module configured to determine a transmission power for the wireless transmitter in response to the performance profile and to control transmission power for the wireless transmitter in response to the determined transmission power.

37. A method, comprising:

generating a performance profile in a host; and

providing the performance profile to a module including a wireless receiver to determine sensitivity levels in response to the performance profile, wherein the module is configured to control sensitivity levels in the wireless receiver in response to the determined sensitivity levels.

38. The method of claim 37, wherein said performance profile relates to link quality for receiving wireless messages.

39. The method of claim 37, wherein said performance profile relates to packet errors for receiving wireless messages.

40. A method, comprising:

generating a performance profile in a host; and

providing the performance profile to a module including a wireless transmitter to determine transmission power in response to the performance profile, wherein the module is configured to control transmission power of the wireless transmitter in response to the determined transmission power.

41. The method of claim 40, wherein said performance profile relates to link quality for transmitting wireless messages.

42. The method of claim 40, wherein said performance profile relates to packet errors for transmitting wireless messages.

43. An apparatus, comprising:

a host;

said host configured to generate a performance profile; and

a processor configured to provide the performance profile to a module including a wireless receiver to determine sensitivity levels in response to the performance profile, wherein the module is configured to control sensitivity levels in the wireless receiver in response to the determined sensitivity levels.

44. The apparatus of claim 43, wherein said performance profile relates to link quality for receiving wireless messages.

45. The apparatus of claim 43, wherein said performance profile relates to packet errors for receiving wireless messages.

46. An apparatus, comprising:

a host;

said host configured to generate a performance profile; and

a processor configured to provide the performance profile to a module including a wireless transmitter to determine transmission power in response to the performance profile, wherein the module is configured to control transmission power of the wireless transmitter in response to the determined transmission power.

47. The apparatus of claim 46, , wherein said performance profile relates to link quality for transmitting wireless messages.

48. The apparatus of claim 46, wherein said performance profile relates to packet errors for transmitting wireless messages.

49. A computer program product, comprising:

a computer readable medium configured to store program instructions, which when executed by a computer processor, perform the steps of:

generating a performance profile in a host; and

providing the performance profile to a module including a wireless receiver to determine sensitivity levels in response to the performance profile and controlling sensitivity levels in the wireless receiver in the module in response to the determined sensitivity levels.

50. A computer program product, comprising:

a computer readable medium configured to store program instructions, which when executed by a computer processor, perform the steps of:

generating a performance profile in a host; and

providing the performance profile to a module including a wireless transmitter to determine transmission power in response to the performance profile and controlling transmission power of the a wireless transmitter in the module in response of the determined transmission power.

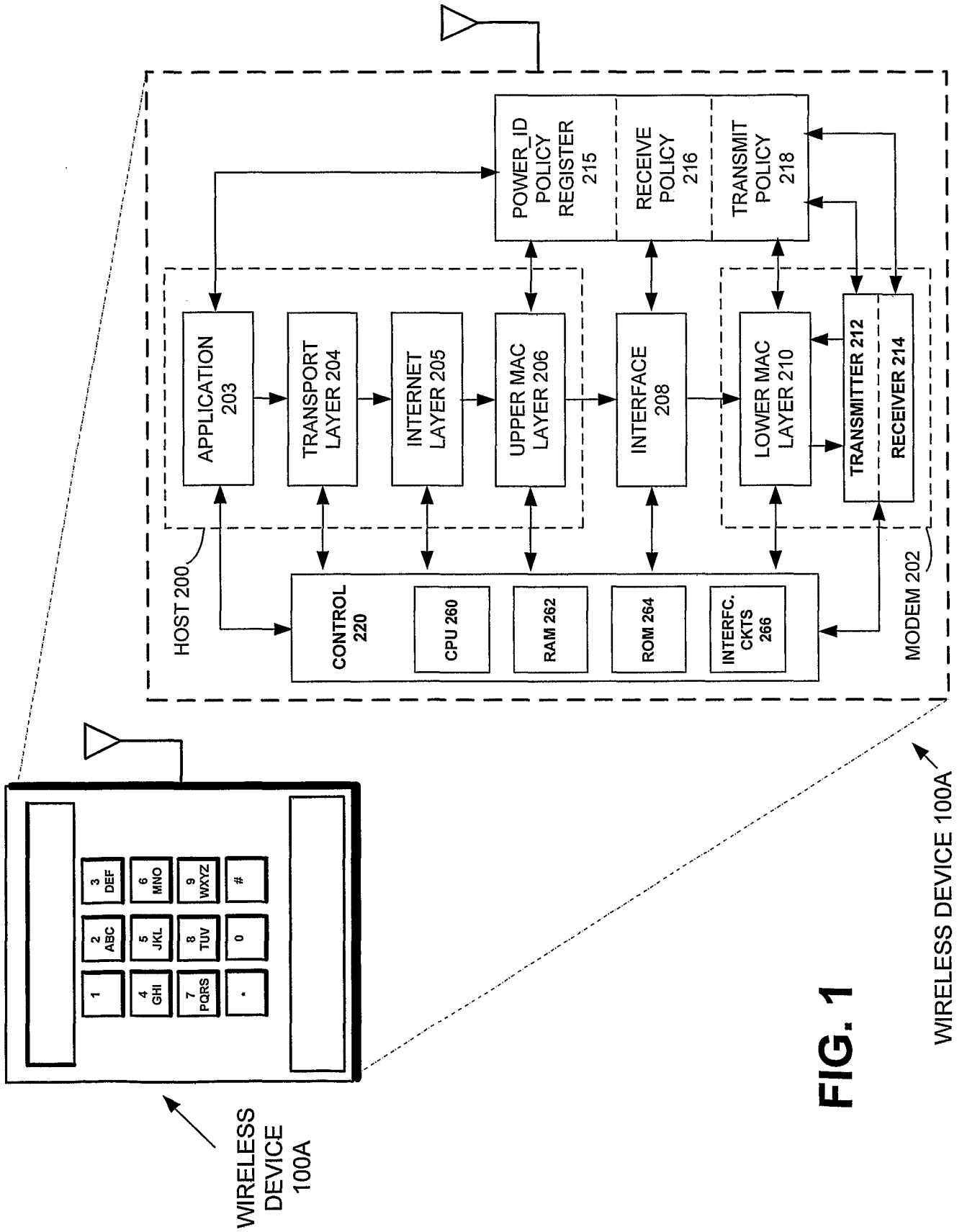


FIG. 1

100A

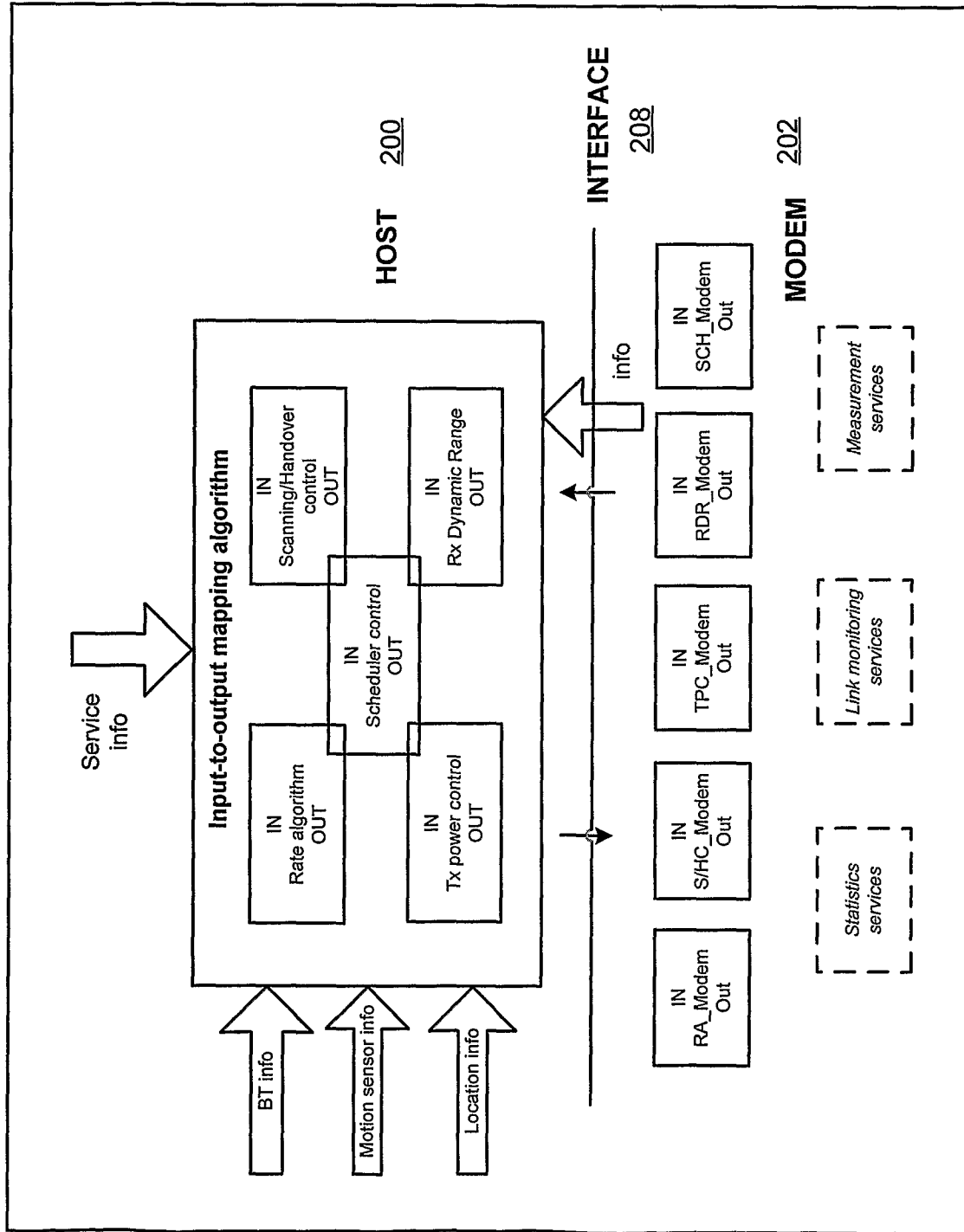
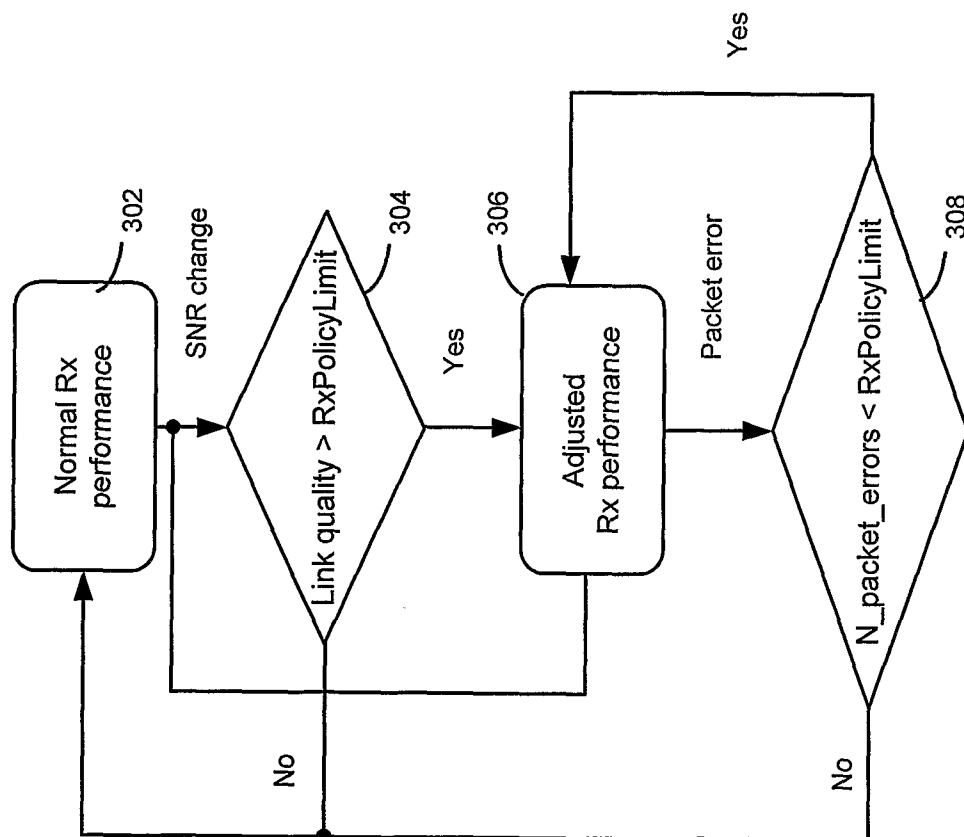
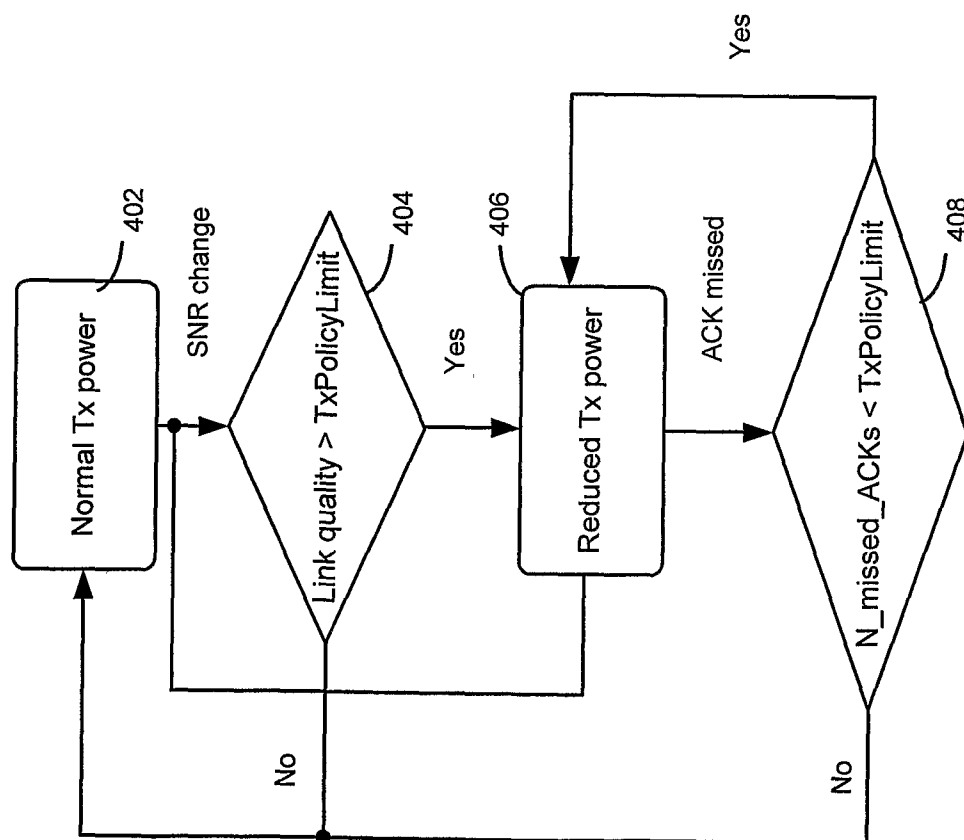


FIG. 2

**FIG. 3**

**FIG. 4**

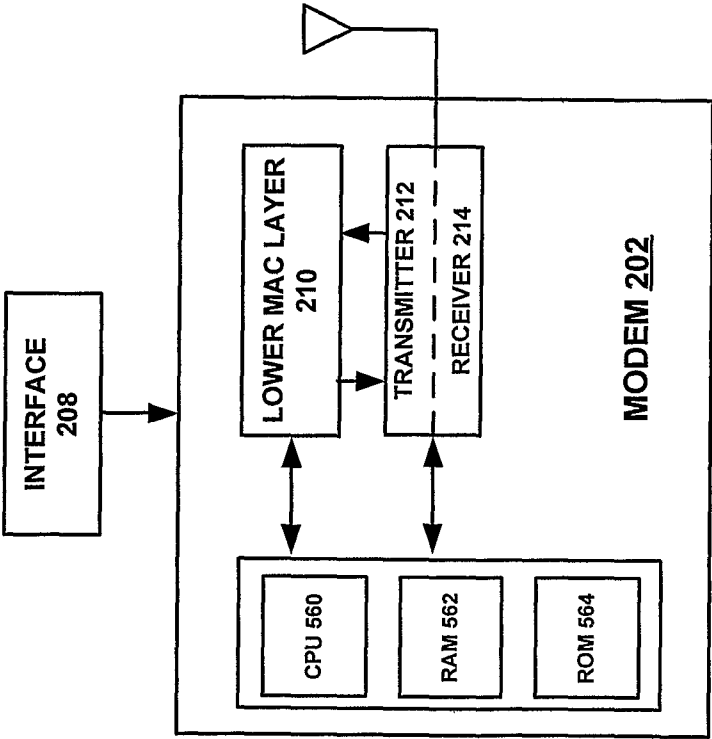


FIG. 5

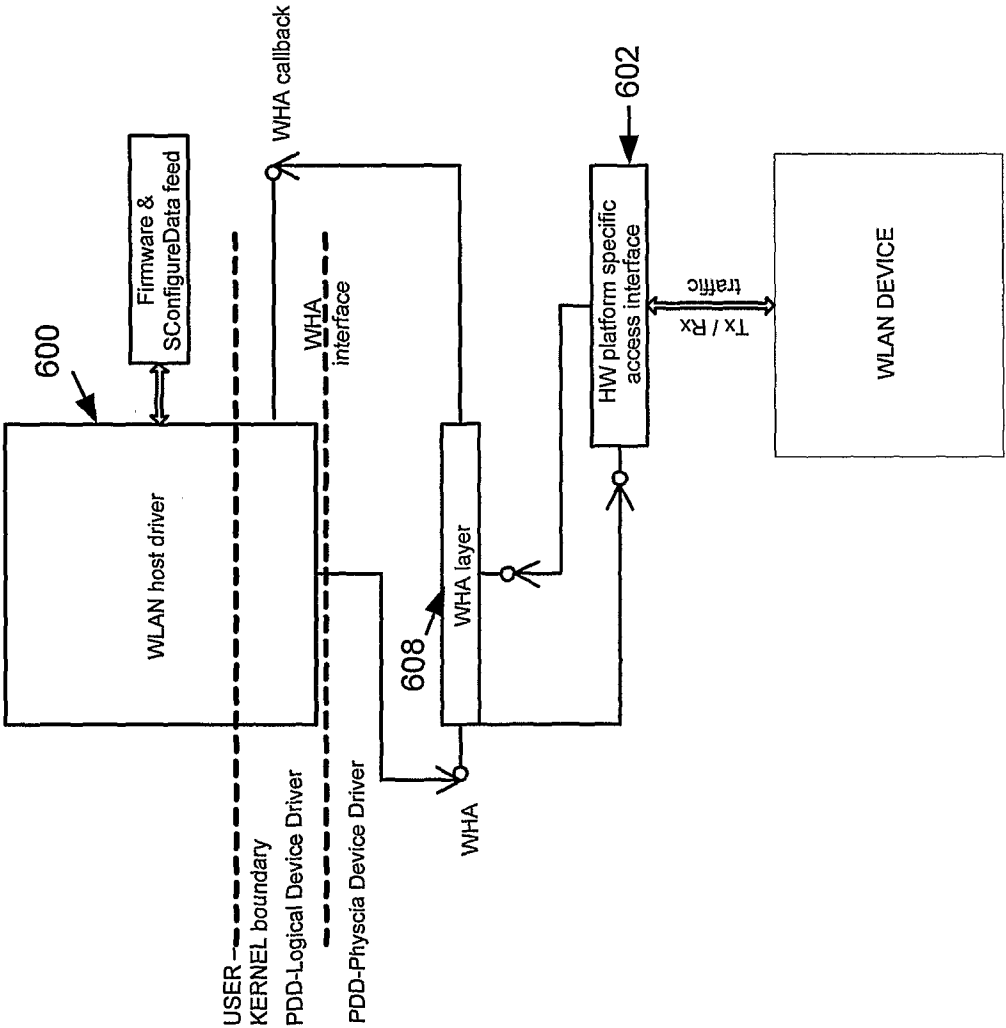


FIG. 6

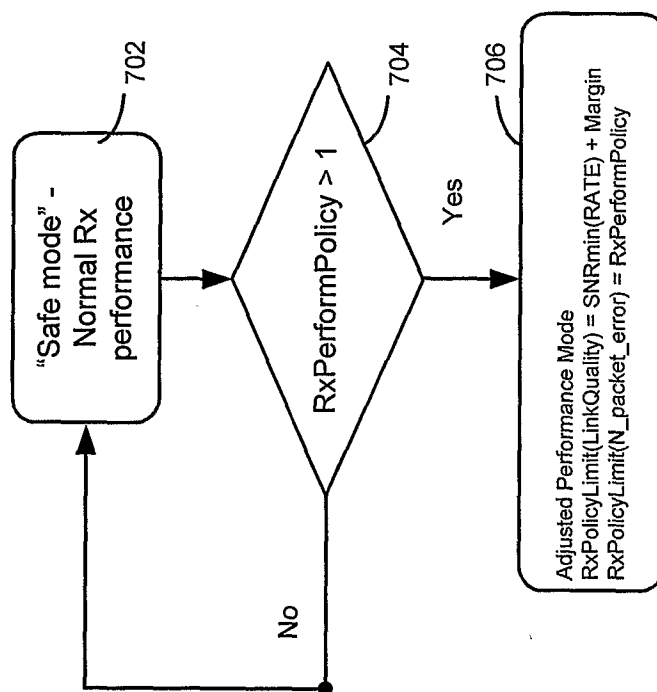
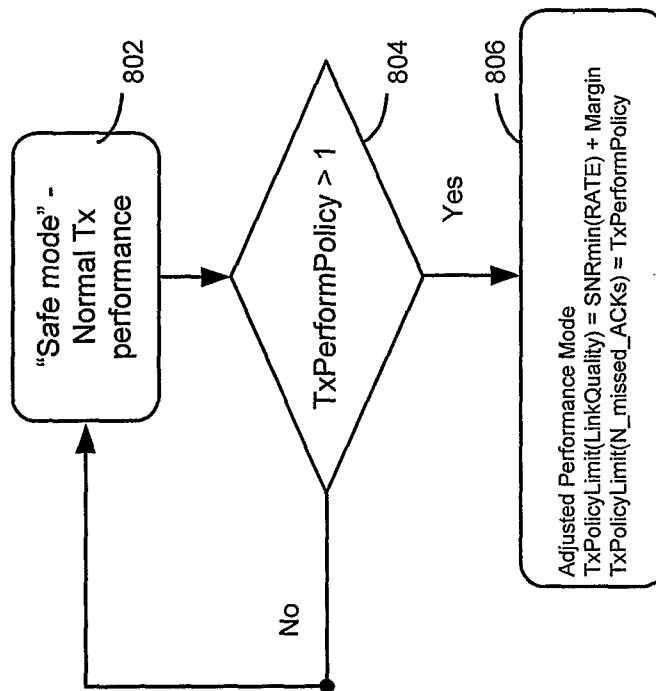


FIG. 7

**FIG. 8**

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2008/002580

A. CLASSIFICATION OF SUBJECT MATTER

INV. H04W52/02

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

H04W H04L

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

EPO-Internal, WPI Data

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 2005/048960 A1 (YAMAUCHI MASAHIRO [JP] ET AL) 3 March 2005 (2005-03-03) paragraph [0029] - paragraph [0032] paragraph [0071] paragraph [0089] paragraph [0151] - paragraph [0152] figures 1,2,4,5,16	1-50
X	US 2006/019723 A1 (VORENKAMP PIETER [US] ET AL) 26 January 2006 (2006-01-26) paragraph [0009] paragraph [0019] - paragraph [0032]; figure 1	1-50
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☒ Further documents are listed in the continuation of Box C.☒ See patent family annex.

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Date of the actual completion of the international search

22 July 2009

Date of mailing of the international search report

30/07/2009

Name and mailing address of the ISA/

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Grimaldo, Michele

INTERNATIONAL SEARCH REPORT

International application No

PCT/IB2008/002580

C(Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

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