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(54) **DYNAMIC REAL-TIME QUALITY MANAGEMENT OF PACKETIZED COMMUNICATIONS IN A NETWORK ENVIRONMENT**

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(60) Provisional application No. 60/472,647, filed on May 22, 2003.

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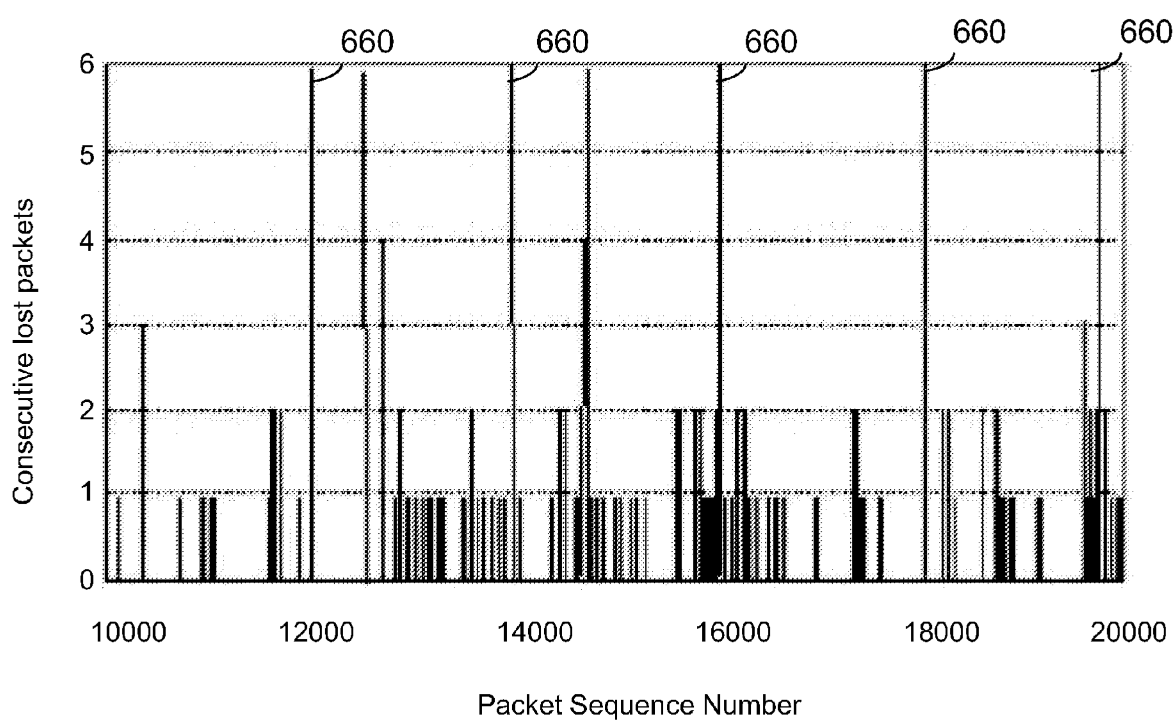
(57) **ABSTRACT**

Dynamic real-time quality management of packetized communications in a network environment. Packetized communications are monitored by and exchanged between wireless Access Points (APs) and wireless terminals or by quality monitoring modules located within network segments or at network vertices. The processing unit analyzes the packetized communications to identify communication signatures associated with the packetized communications. The processor then uses these signatures to identify network impediments to the exchange of the packetized communications. These impediments may take the form of coding problems in which case an appropriate coding scheme is employed by the programmable COder/DECoder (CODEC) to convert incoming packetized communications to incoming user communications, and outgoing user communications to outgoing packetized communications. These impediments may also take the form of communication problems along and between the various network segments. In these cases, the processor may choose a more appropriate communication pathway with which to route the packetized communications.



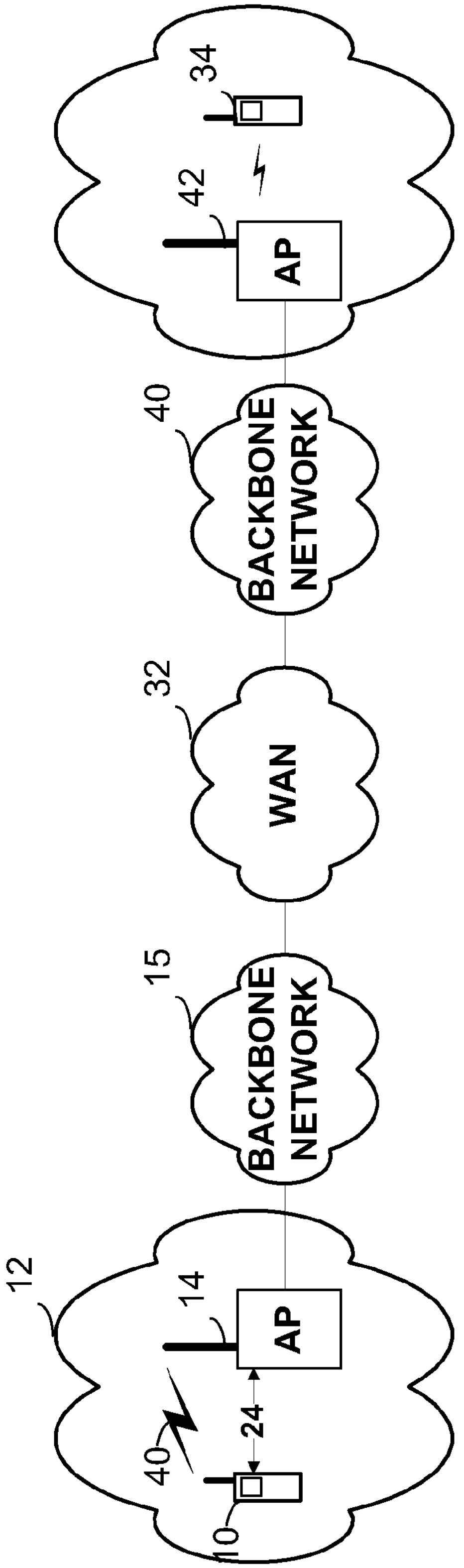

12
10
40
24
AP
14
BACKBONE NETWORK
15
WAN
32
BACKBONE NETWORK
40
AP
42
34

FIG. 1A

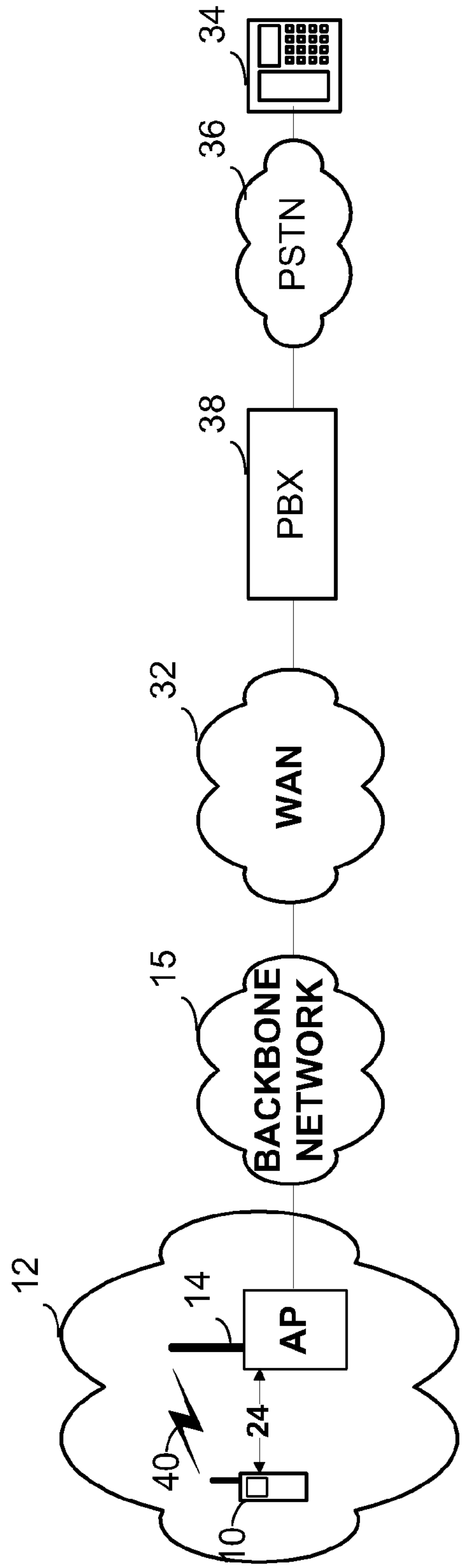

12
10
40
24
AP
14
BACKBONE NETWORK
15
WAN
32
PBX
38
PSTN
36
34

FIG. 1B

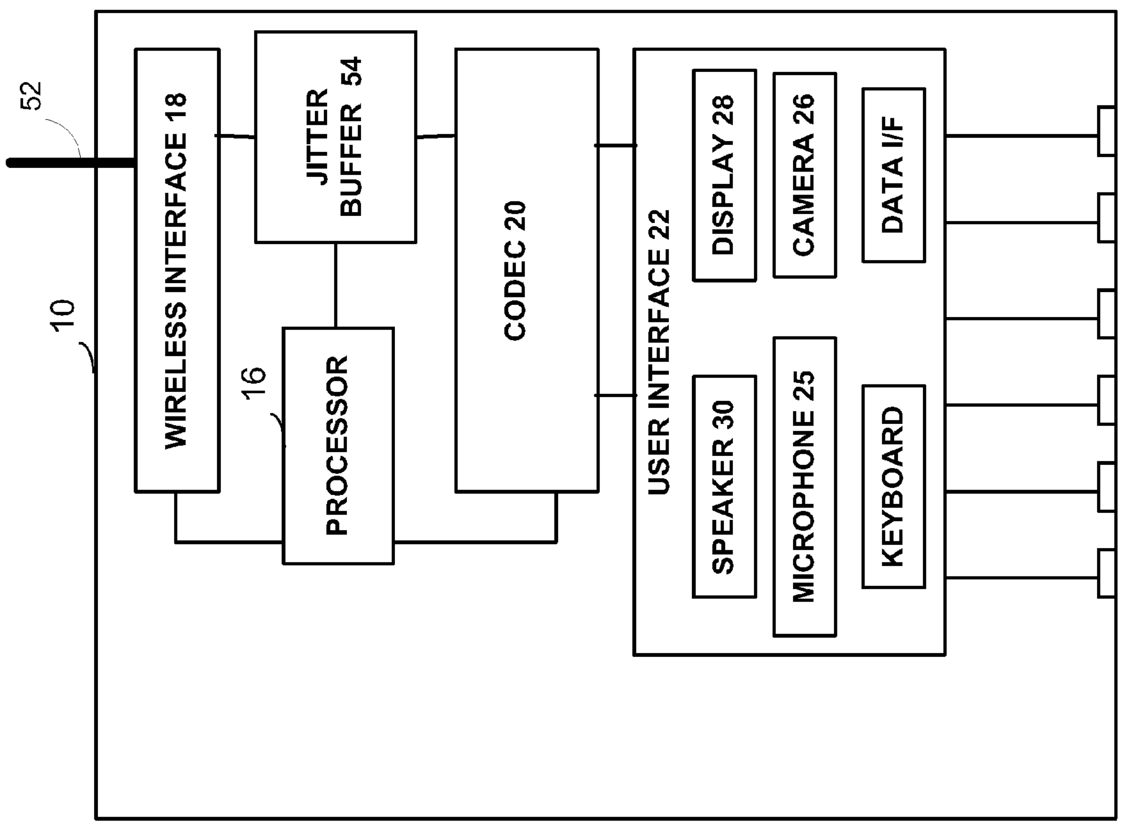

52
10
WIRELESS INTERFACE 18
JITTER BUFFER 54
16
PROCESSOR
CODEC 20
USER INTERFACE 22
DISPLAY 28
CAMERA 26
DATA I/F
SPEAKER 30
MICROPHONE 25
KEYBOARD

FIG. 2

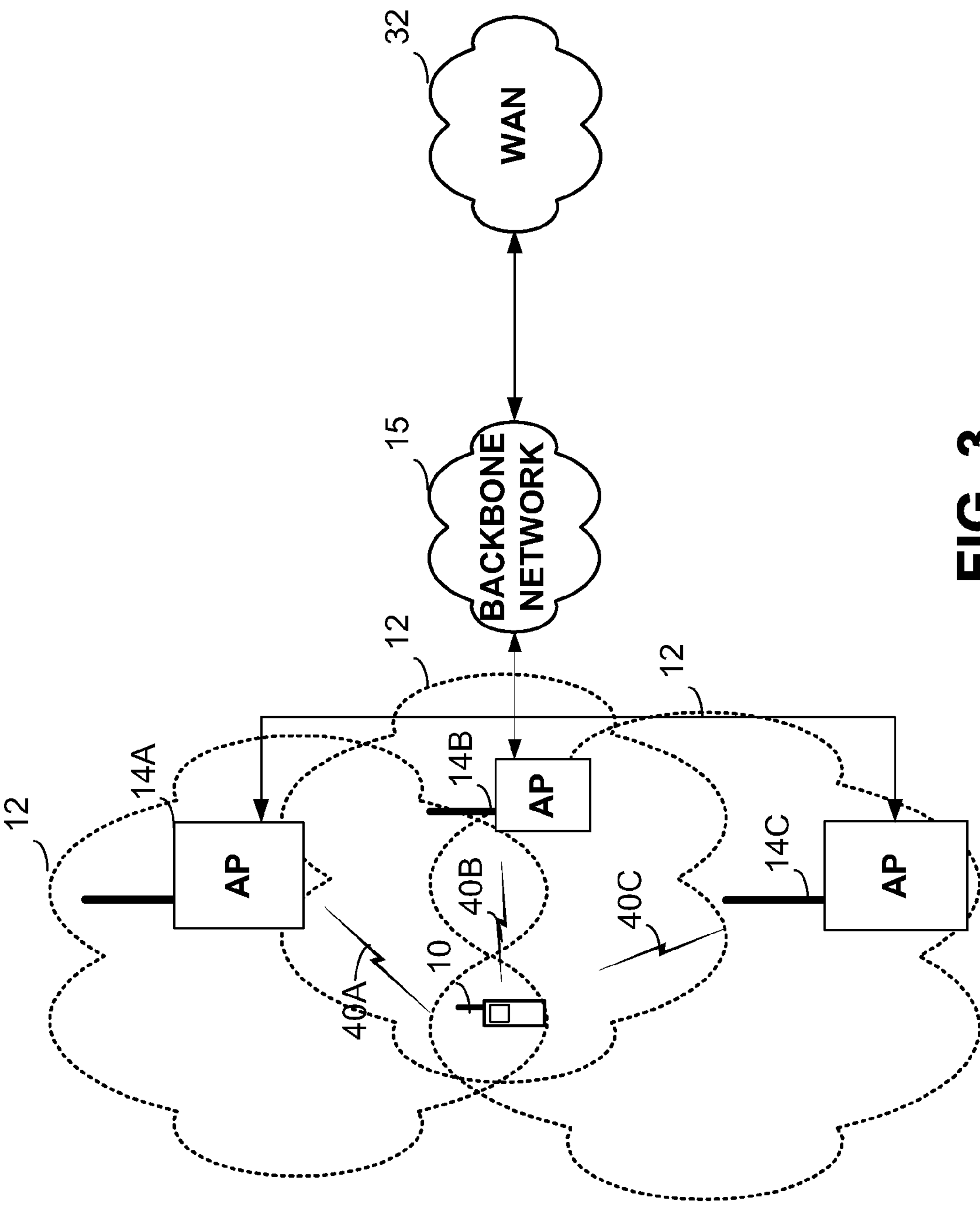

32
WAN
15
BACKBONE NETWORK
12
12
12
14A
AP
14B
AP
14C
AP
40A
40B
40C
10

FIG. 3

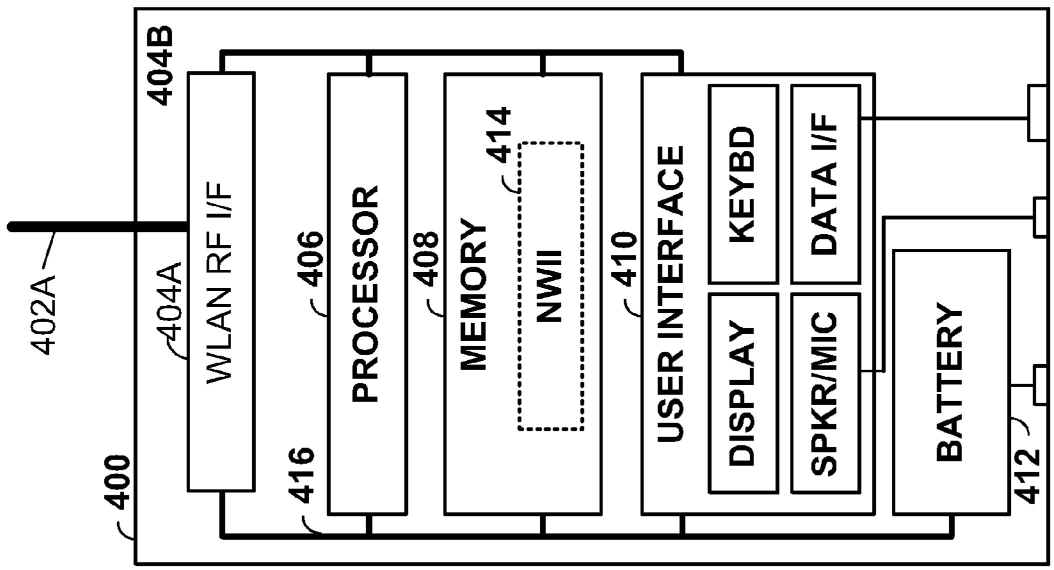

400
404B
402A
404A
WLAN RF I/F
416
406
PROCESSOR
408
MEMORY
414
NWII
410
USER INTERFACE
KEYBD
DISPLAY
DATA I/F
SPKR/MIC
BATTERY
412

FIG. 4A

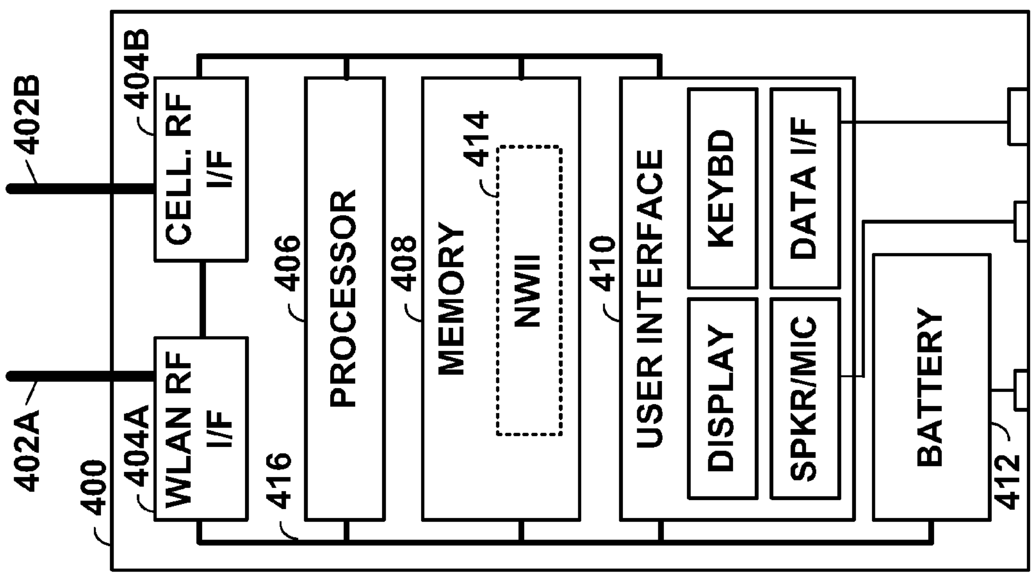

400
402A
402B
404A
404B
WLAN RF I/F
CELL. RF I/F
416
406
PROCESSOR
408
MEMORY
414
NWII
410
USER INTERFACE
DISPLAY
KEYBD
SPKR/MIC
DATA I/F
BATTERY
412

FIG. 4B

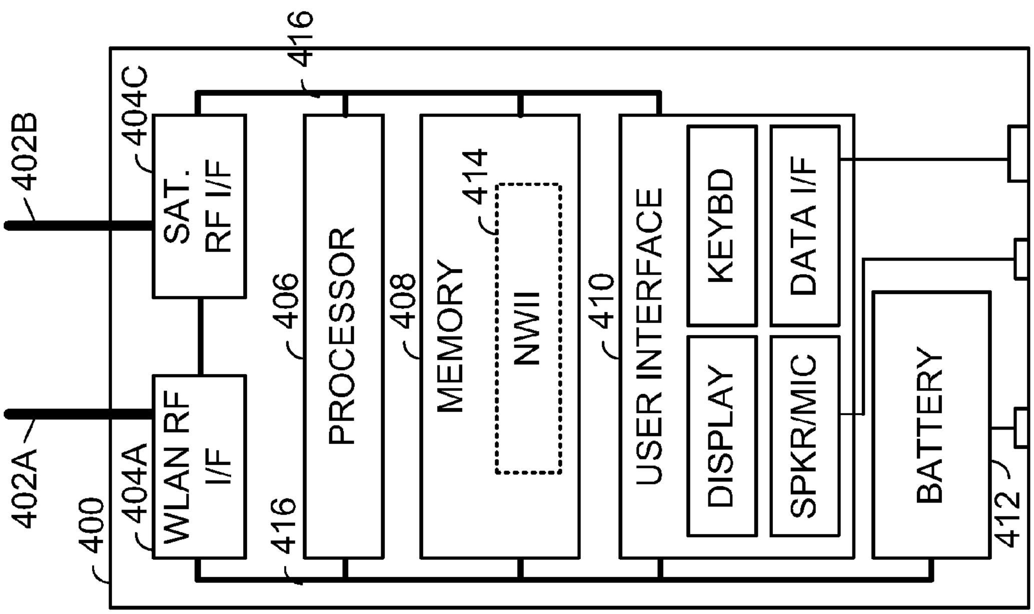
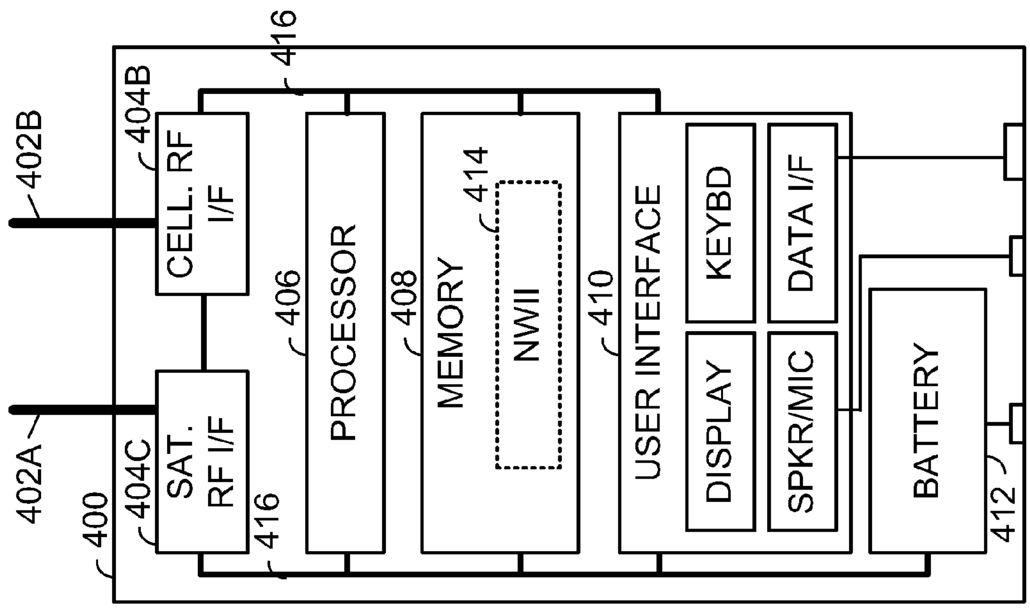
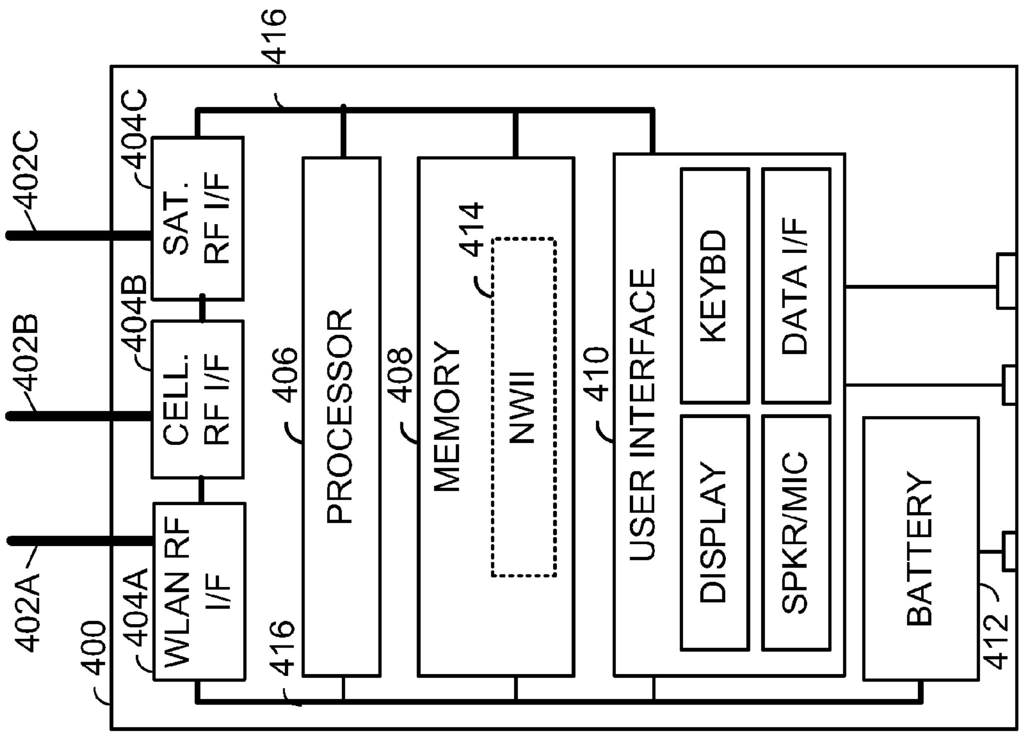

402A
402B
400
404A
WLAN RF I/F
404C
SAT. RF I/F
416
416
406
PROCESSOR
408
MEMORY
414
NWII
410
USER INTERFACE
DISPLAY
KEYBD
SPKR/MIC
DATA I/F
BATTERY
412

FIG. 4C



400
402A
402B
404C
SAT. RF I/F
404B
CELL. RF I/F
416
416
406
PROCESSOR
408
MEMORY
414
NWII
410
USER INTERFACE
DISPLAY
KEYBD
SPKR/MIC
DATA I/F
BATTERY
412

FIG. 4D



402A
402B
402C
400
404A
404B
404C
416
416
WLAN RF I/F
CELL. RF I/F
SAT. RF I/F
406
PROCESSOR
408
MEMORY
414
NWII
410
USER INTERFACE
DISPLAY
KEYBD
SPKR/MIC
DATA I/F
BATTERY
412

FIG. 4E

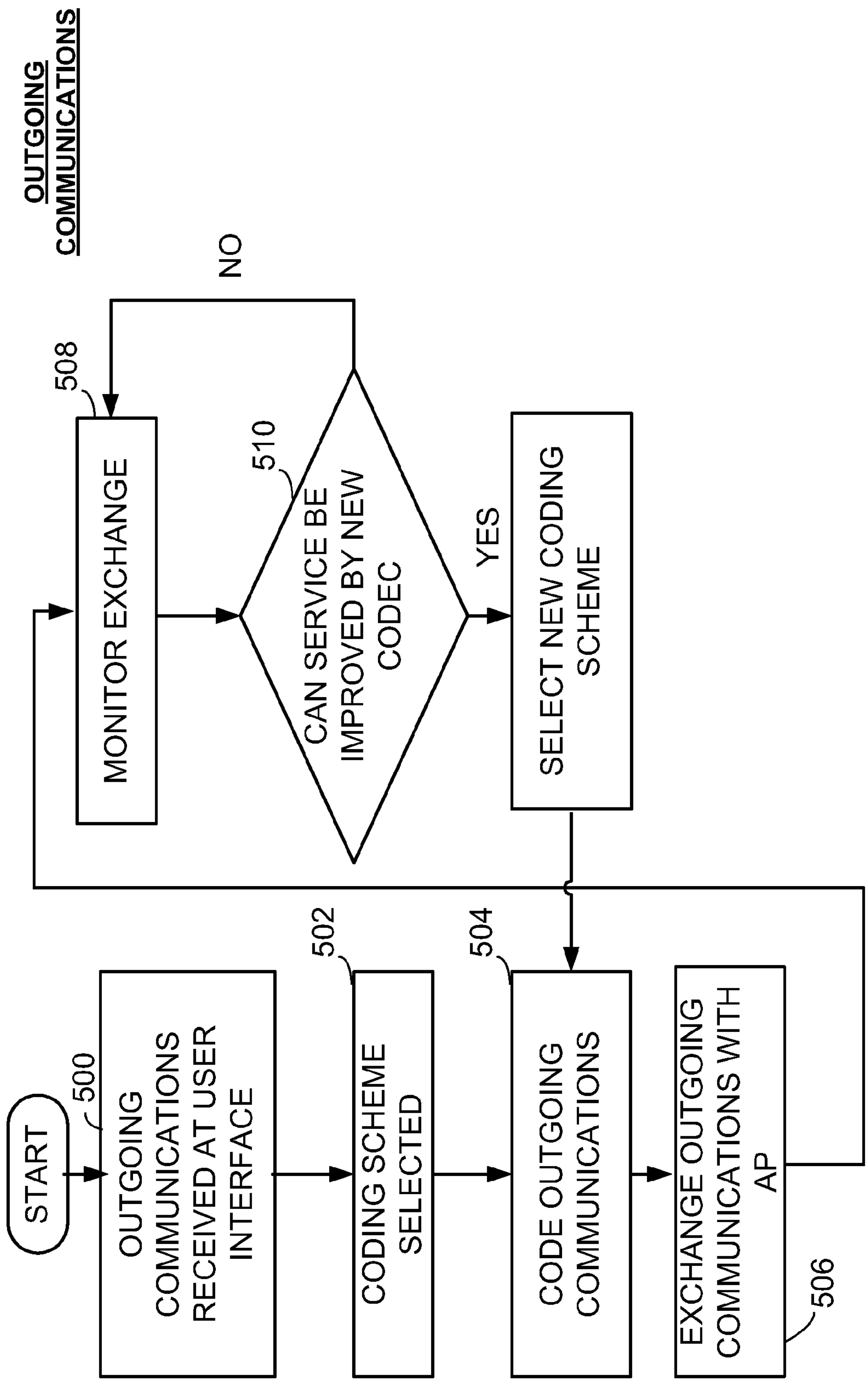

OUTGOING COMMUNICATIONS
START
500
OUTGOING COMMUNICATIONS RECEIVED AT USER INTERFACE
502
CODING SCHEME SELECTED
504
CODE OUTGOING COMMUNICATIONS
EXCHANGE OUTGOING COMMUNICATIONS WITH AP
506
508
MONITOR EXCHANGE
510
CAN SERVICE BE IMPROVED BY NEW CODEC
NO
YES
SELECT NEW CODING SCHEME

FIG. 5A

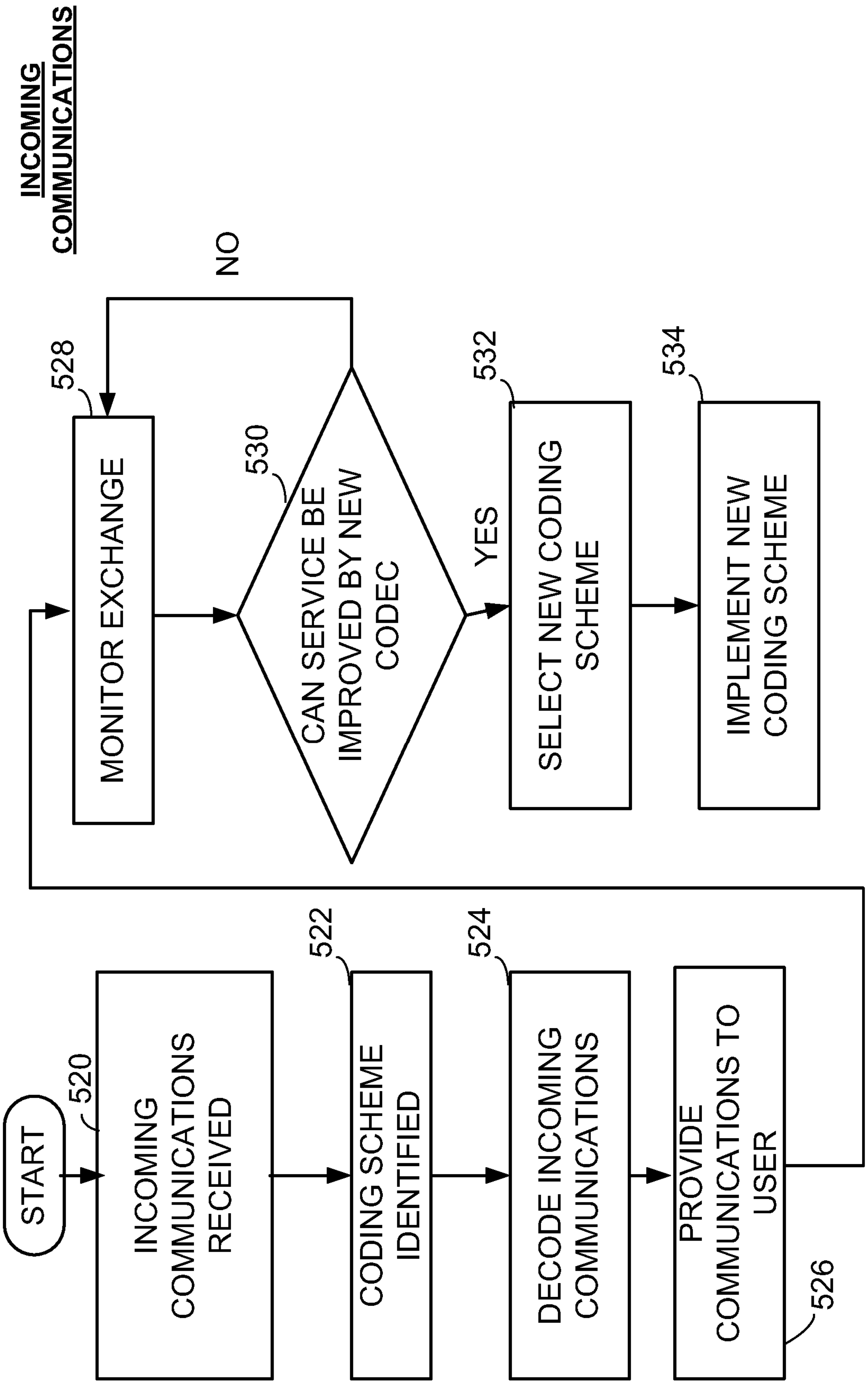

INCOMING COMMUNICATIONS
START
520
INCOMING COMMUNICATIONS RECEIVED
522
CODING SCHEME IDENTIFIED
524
DECODE INCOMING COMMUNICATIONS
526
PROVIDE COMMUNICATIONS TO USER
528
MONITOR EXCHANGE
530
CAN SERVICE BE IMPROVED BY NEW CODEC
NO
YES
532
SELECT NEW CODING SCHEME
534
IMPLEMENT NEW CODING SCHEME

FIG. 5B

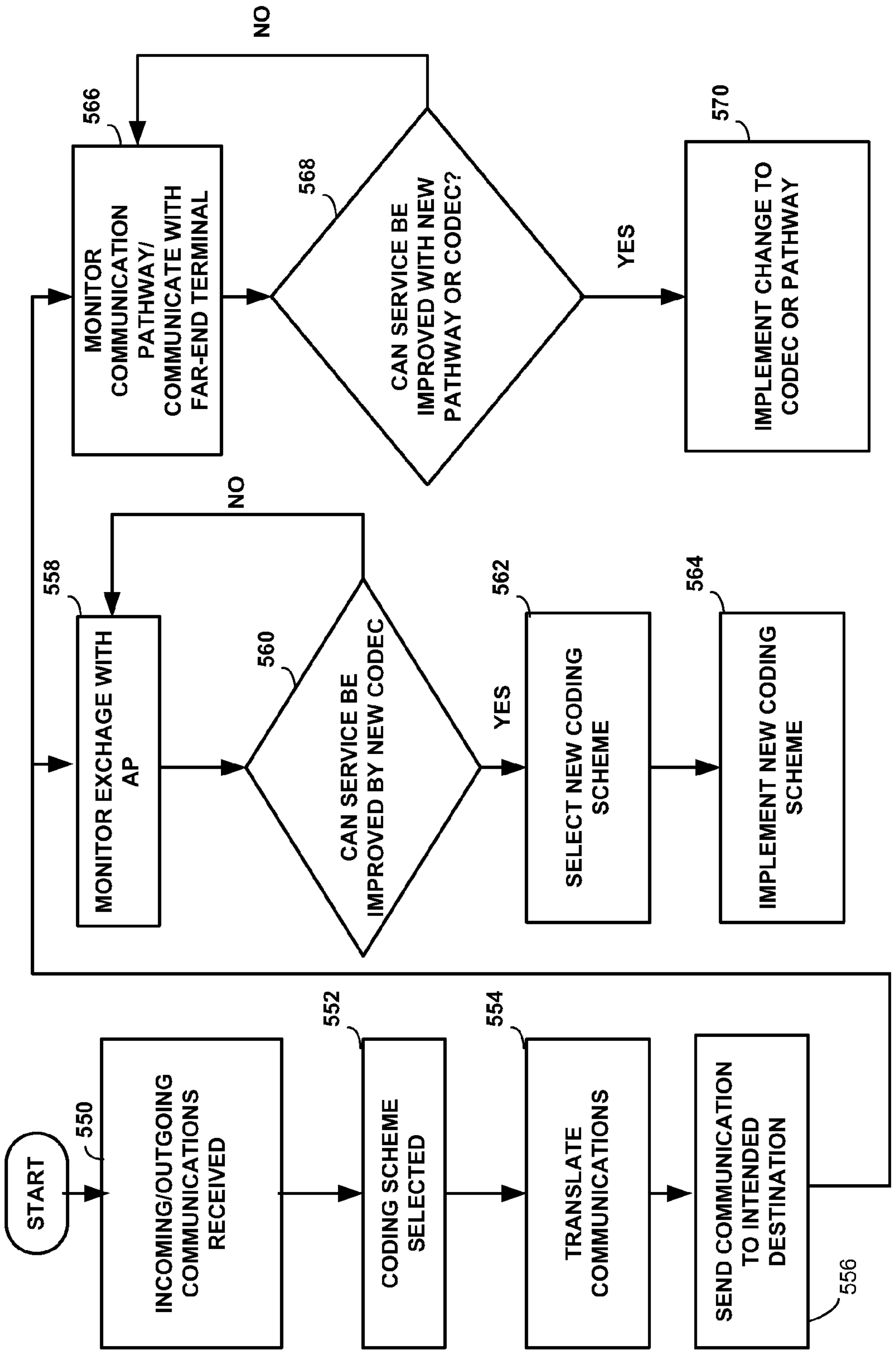

START
550
INCOMING/OUTGOING COMMUNICATIONS RECEIVED
552
CODING SCHEME SELECTED
554
TRANSLATE COMMUNICATIONS
556
SEND COMMUNICATION TO INTENDED DESTINATION
558
MONITOR EXCHAGE WITH AP
560
CAN SERVICE BE IMPROVED BY NEW CODEC
NO
YES
562
SELECT NEW CODING SCHEME
564
IMPLEMENT NEW CODING SCHEME
566
MONITOR COMMUNICATION PATHWAY/ COMMUNICATE WITH FAR-END TERMINAL
568
CAN SERVICE BE IMPROVED WITH NEW PATHWAY OR CODEC?
NO
YES
570
IMPLEMENT CHANGE TO CODEC OR PATHWAY

FIG. 5C

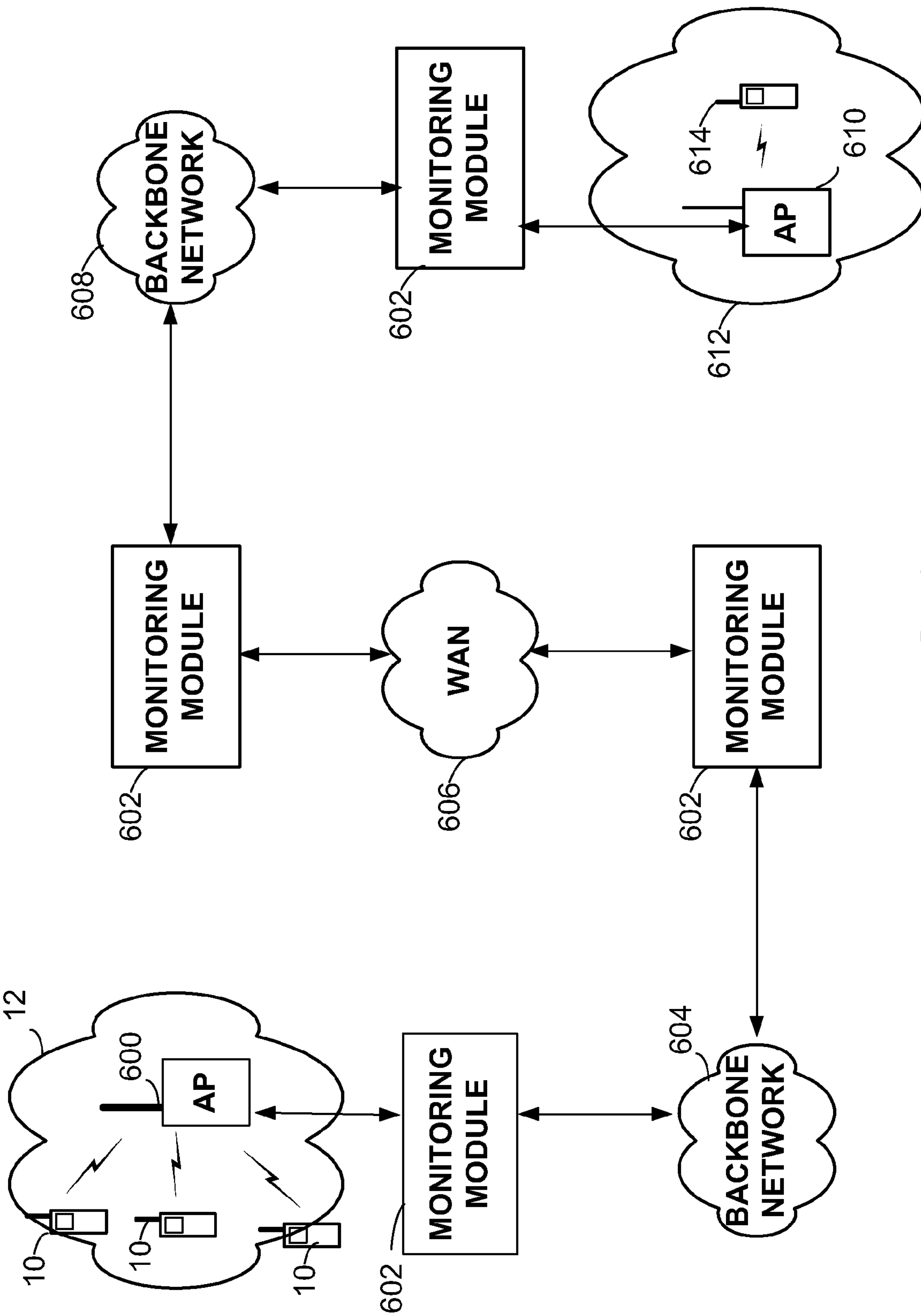

BACKBONE NETWORK
608
MONITORING MODULE
602
AP
610
614
612
MONITORING MODULE
602
WAN
606
MONITORING MODULE
602
12
AP
600
10
10
10
MONITORING MODULE
602
BACKBONE NETWORK
604

FIG. 6A

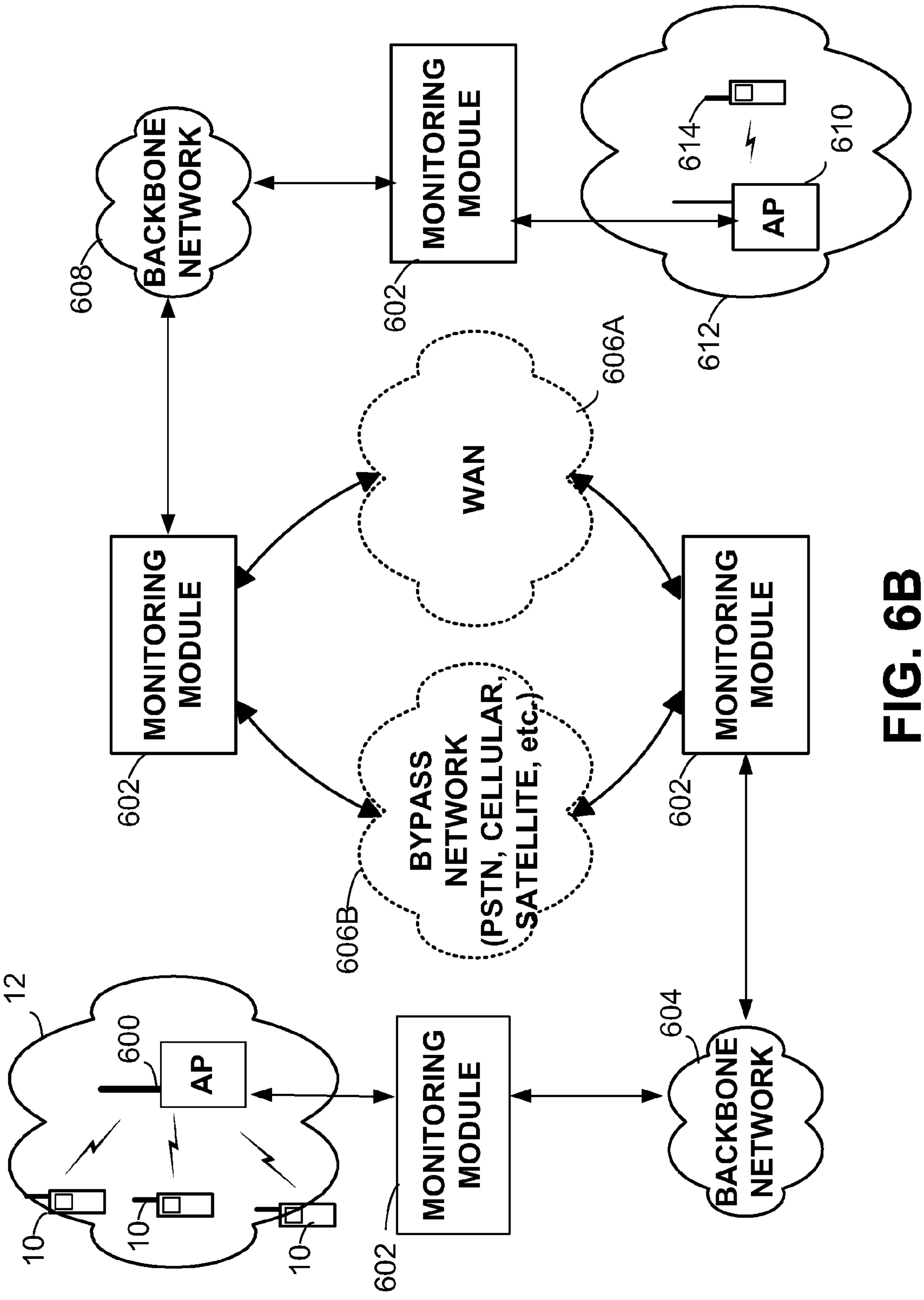
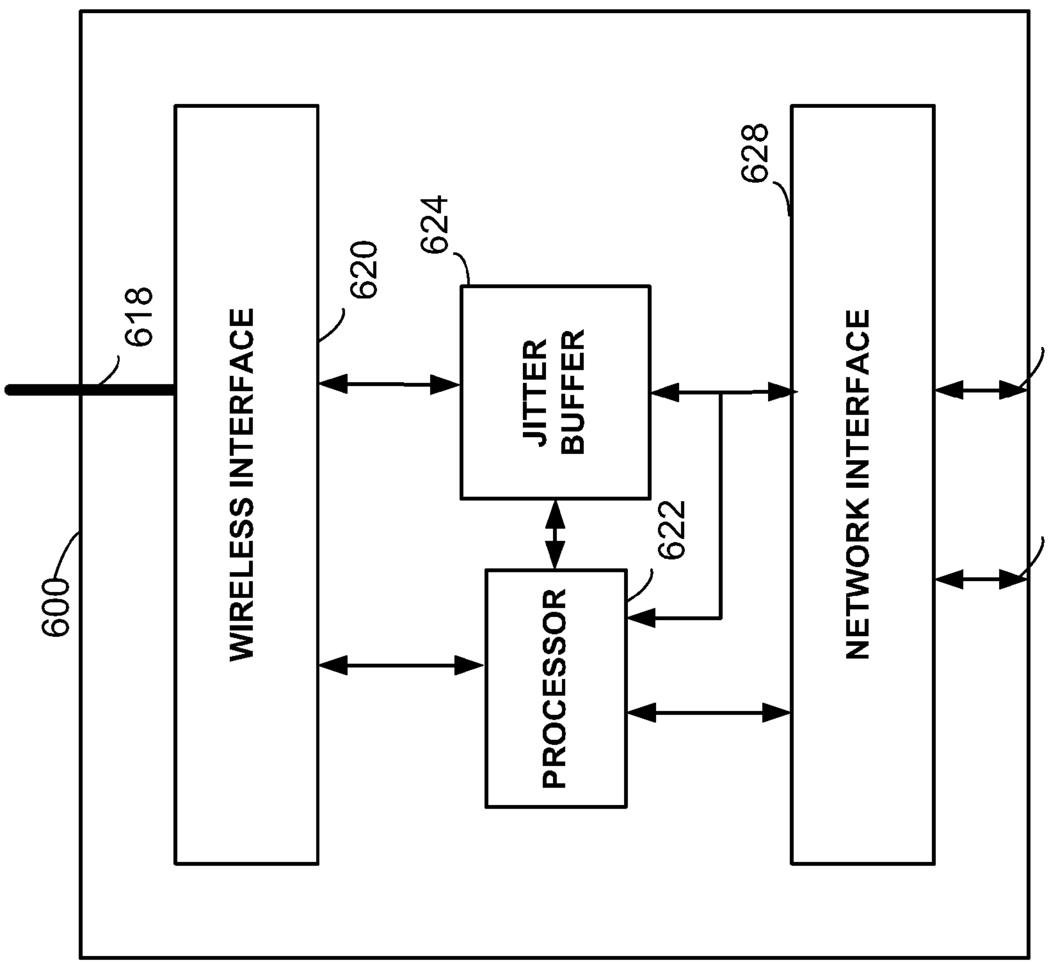

BACKBONE NETWORK
608
MONITORING MODULE
602
AP
610
614
612
WAN
606A
MONITORING MODULE
602
BYPASS NETWORK (PSTN, CELLULAR, SATELLITE, etc.)
606B
MONITORING MODULE
602
12
AP
600
10
10
10
MONITORING MODULE
602
BACKBONE NETWORK
604

FIG. 6B

FIG. 7A


600
618
620
624
628
WIRELESS INTERFACE
JITTER BUFFER
PROCESSOR
NETWORK INTERFACE
622
630
630

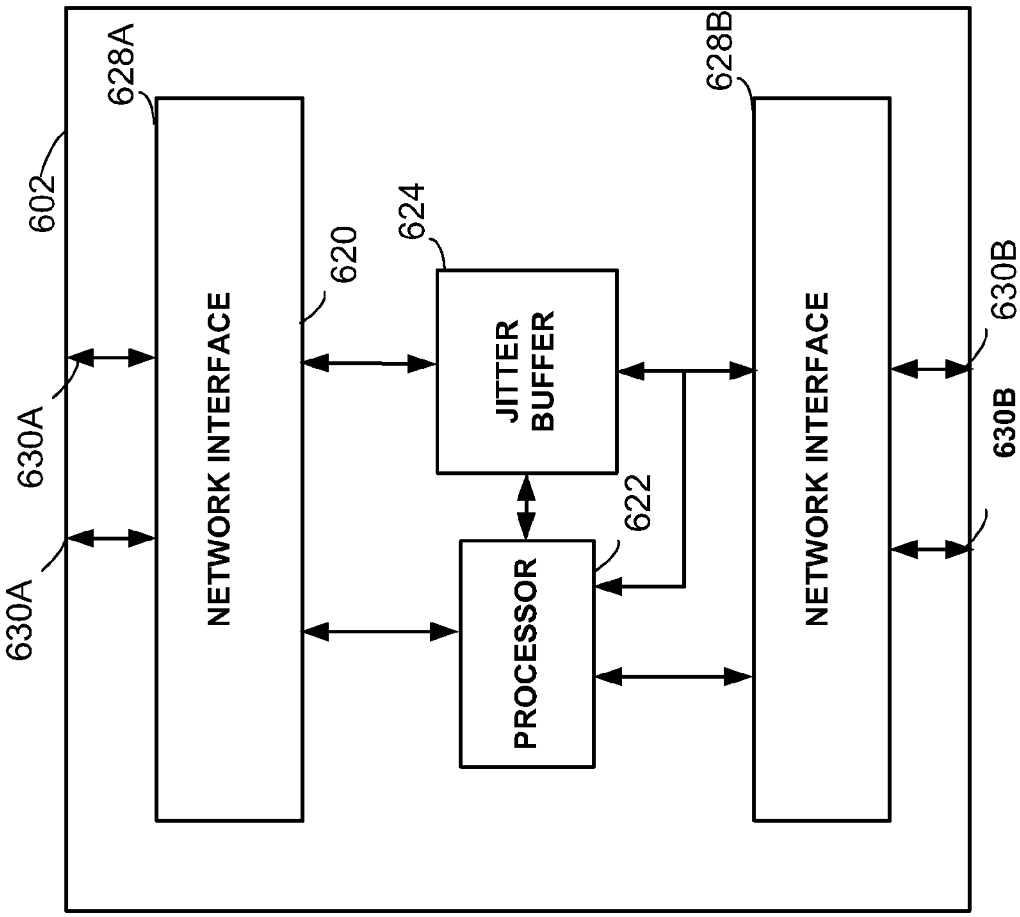

602
628A
628B
NETWORK INTERFACE
620
624
JITTER BUFFER
622
PROCESSOR
NETWORK INTERFACE
630A
630A
630B
630B

FIG. 7B

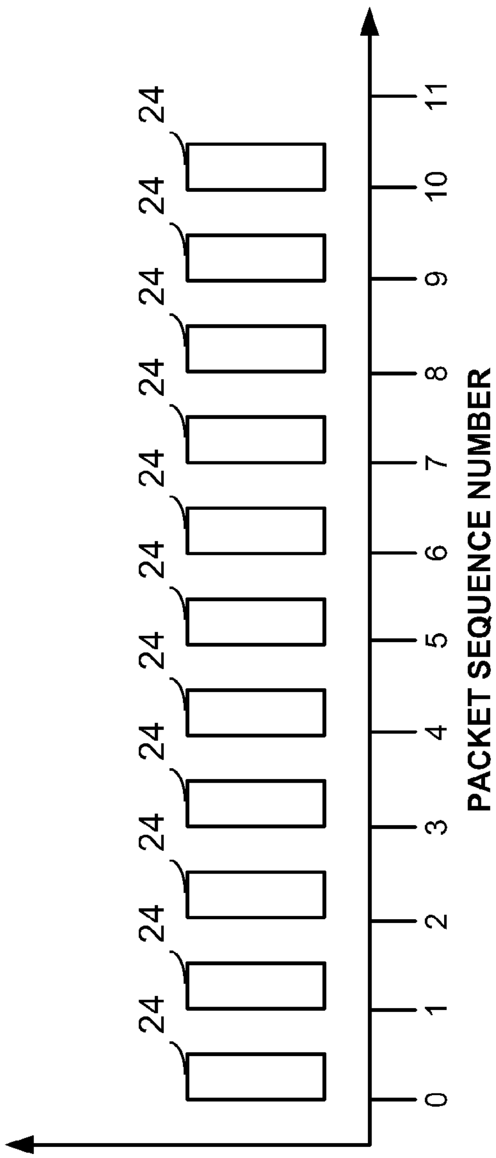

24
0
1
2
3
4
5
6
7
8
9
10
11
PACKET SEQUENCE NUMBER

FIG. 8A

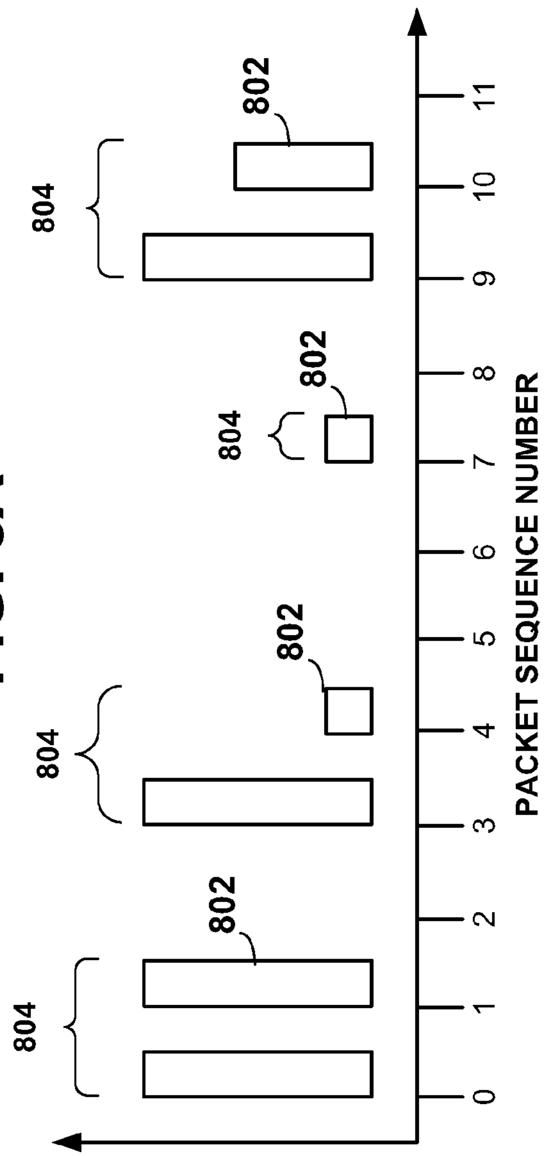

804
802
0
1
2
3
4
5
6
7
8
9
10
11
PACKET SEQUENCE NUMBER

FIG. 8B

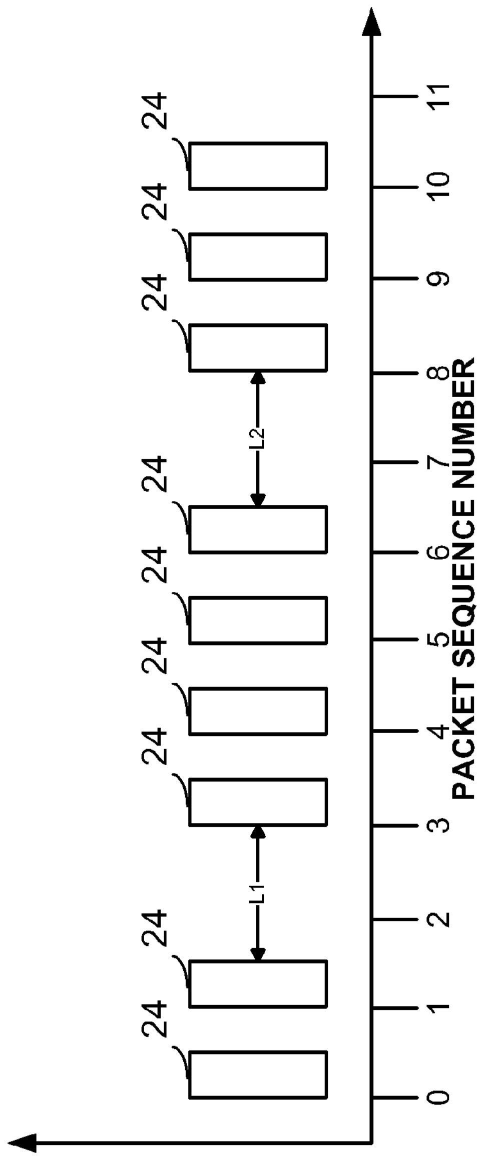

24
L1
L2
0
1
2
3
4
5
6
7
8
9
10
11
PACKET SEQUENCE NUMBER

FIG. 8C

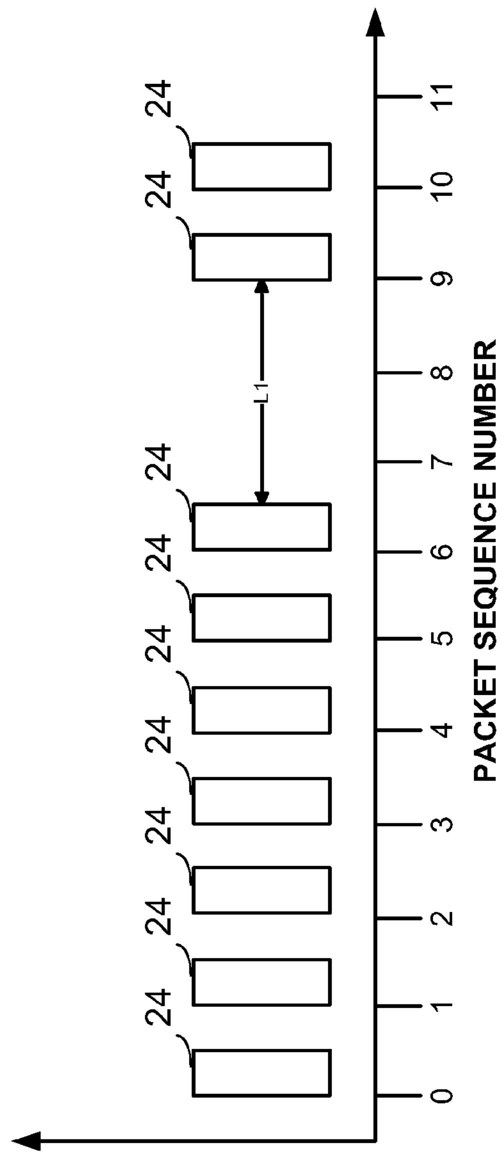
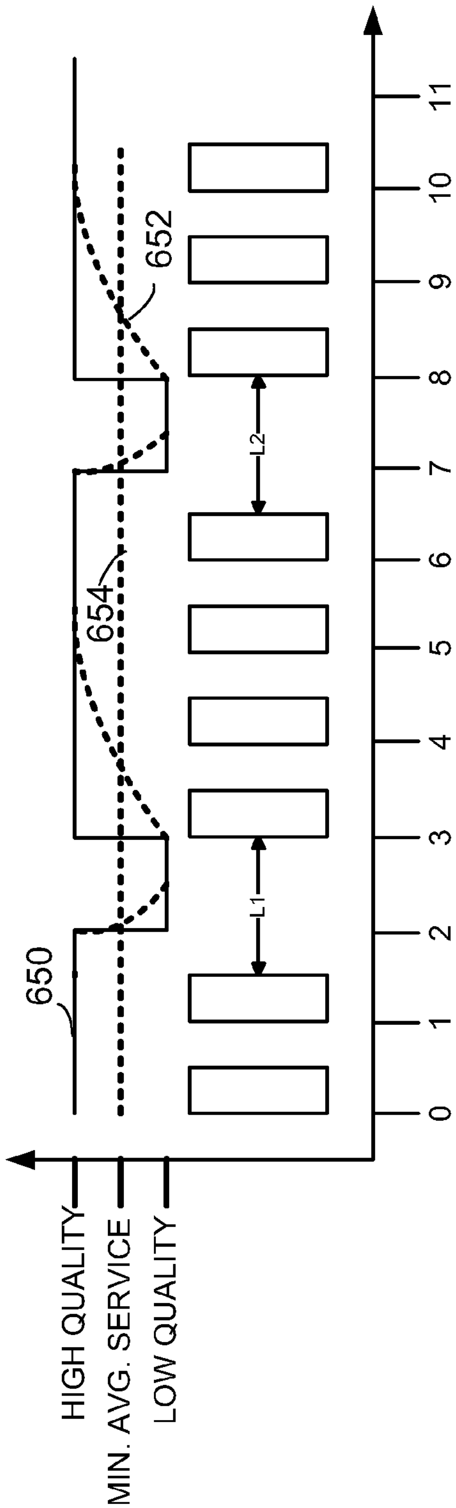
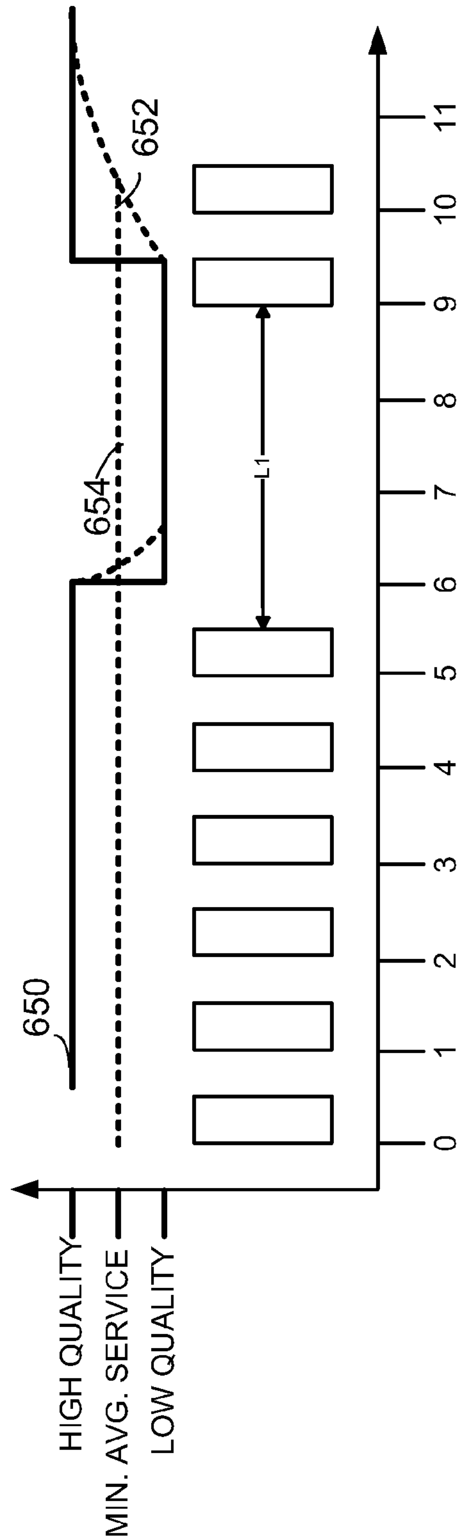

24
L1
0
1
2
3
4
5
6
7
8
9
10
11
PACKET SEQUENCE NUMBER

FIG. 8D



PACKET SEQUENCE NUMBER

FIG. 9A



PACKET SEQUENCE NUMBER

FIG. 9B

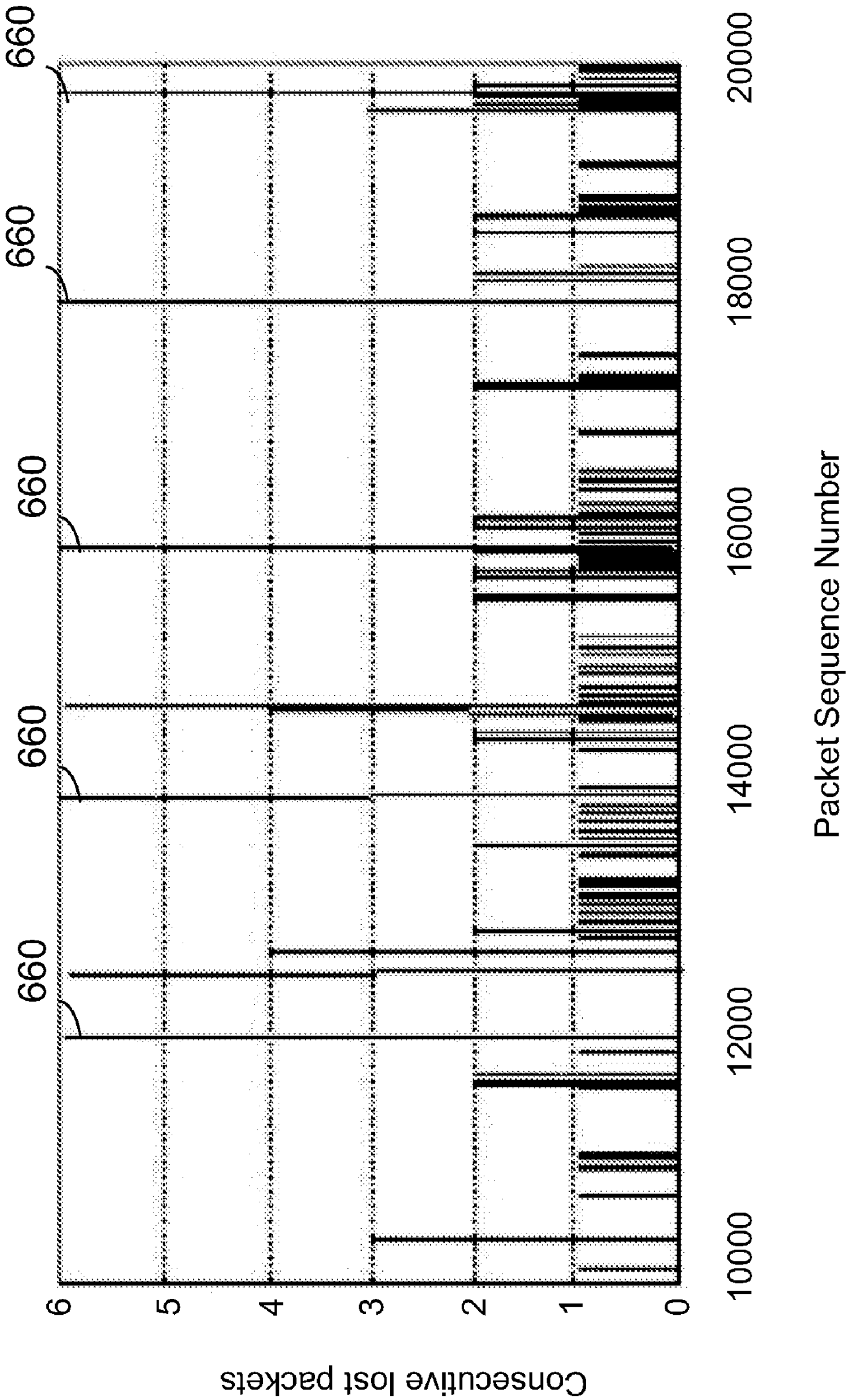

660
660
660
660
660
Consecutive lost packets
0
1
2
3
4
5
6
10000
12000
14000
16000
18000
20000
Packet Sequence Number

FIG. 10

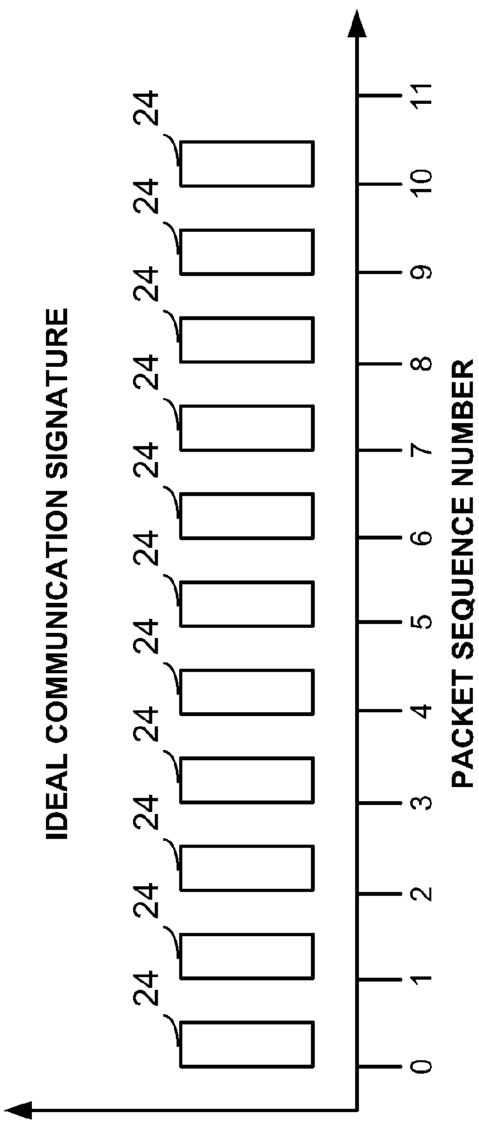


FIG. 11A

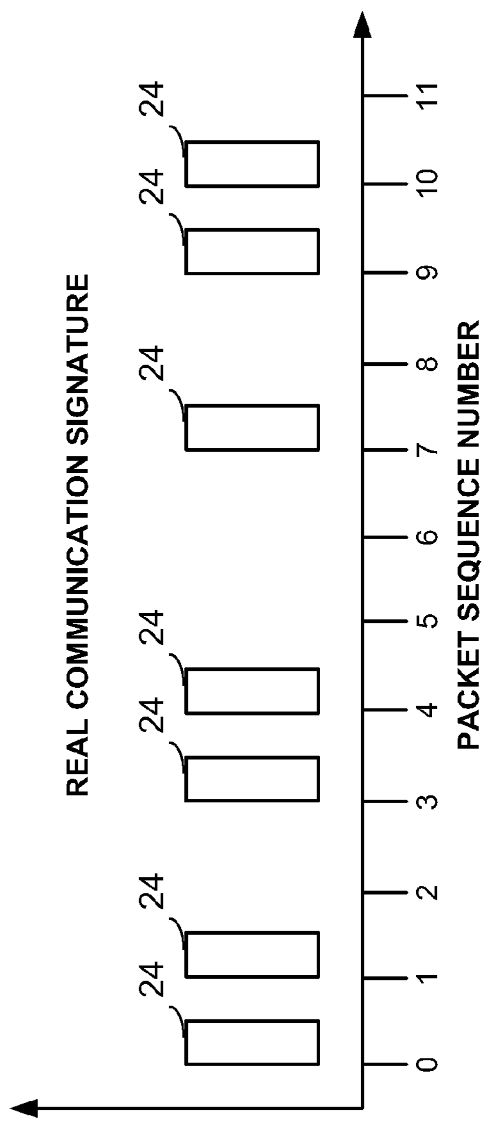


FIG. 11B

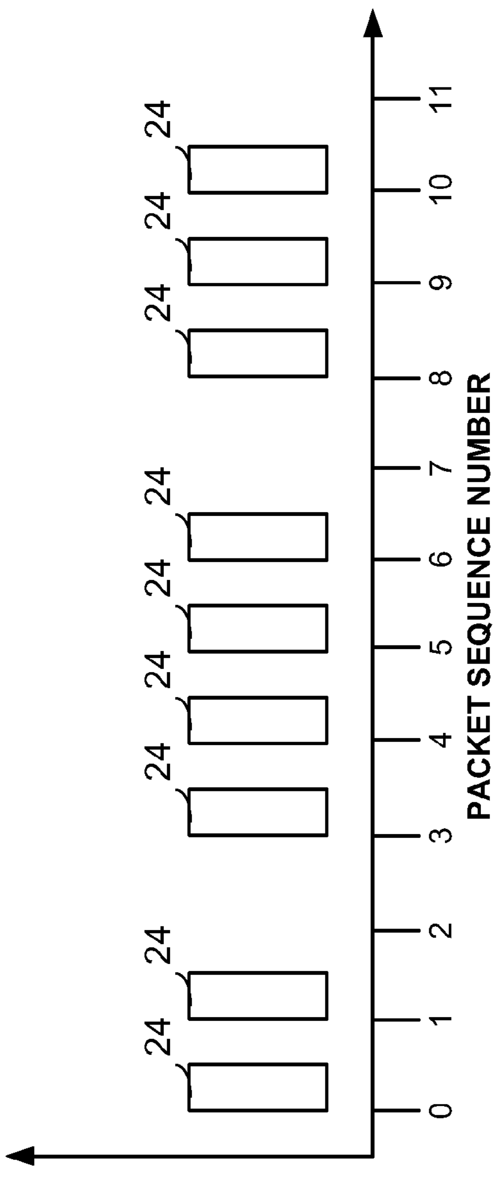


FIG. 12A

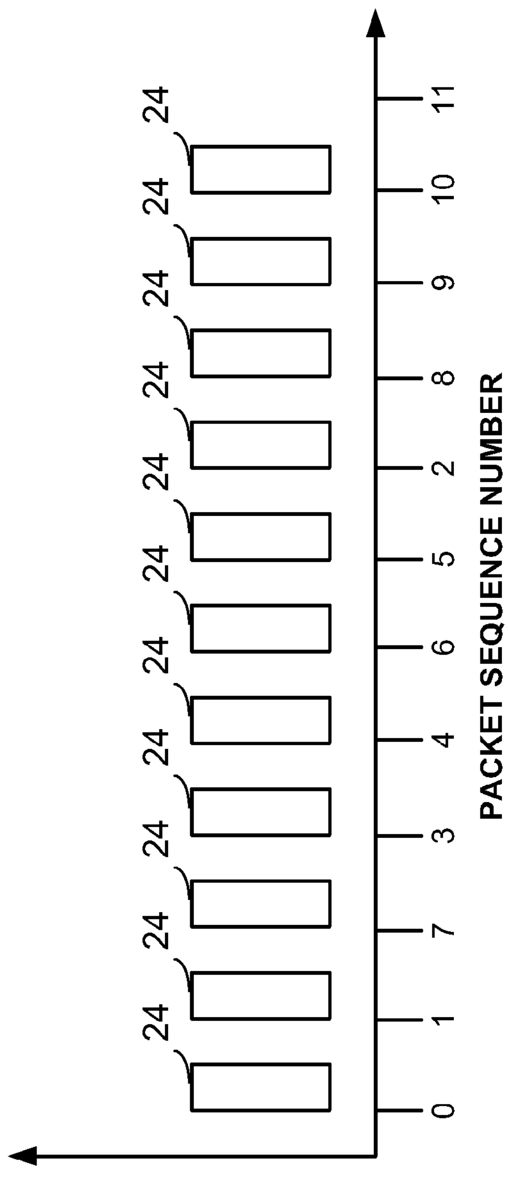


FIG. 12B

OUTGOING COMMUNICATIONS

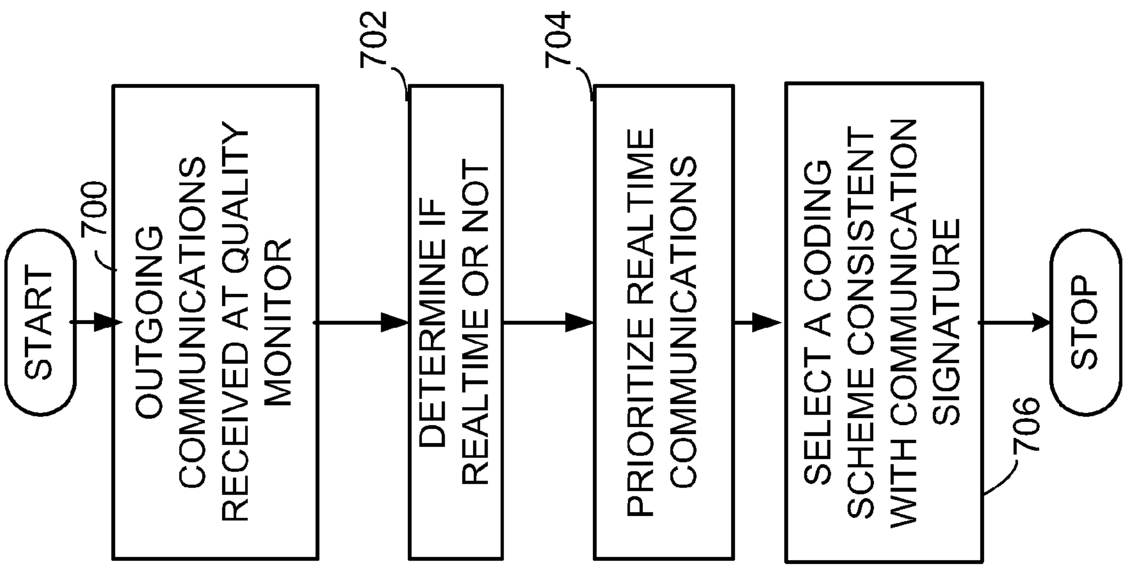


FIG. 13A

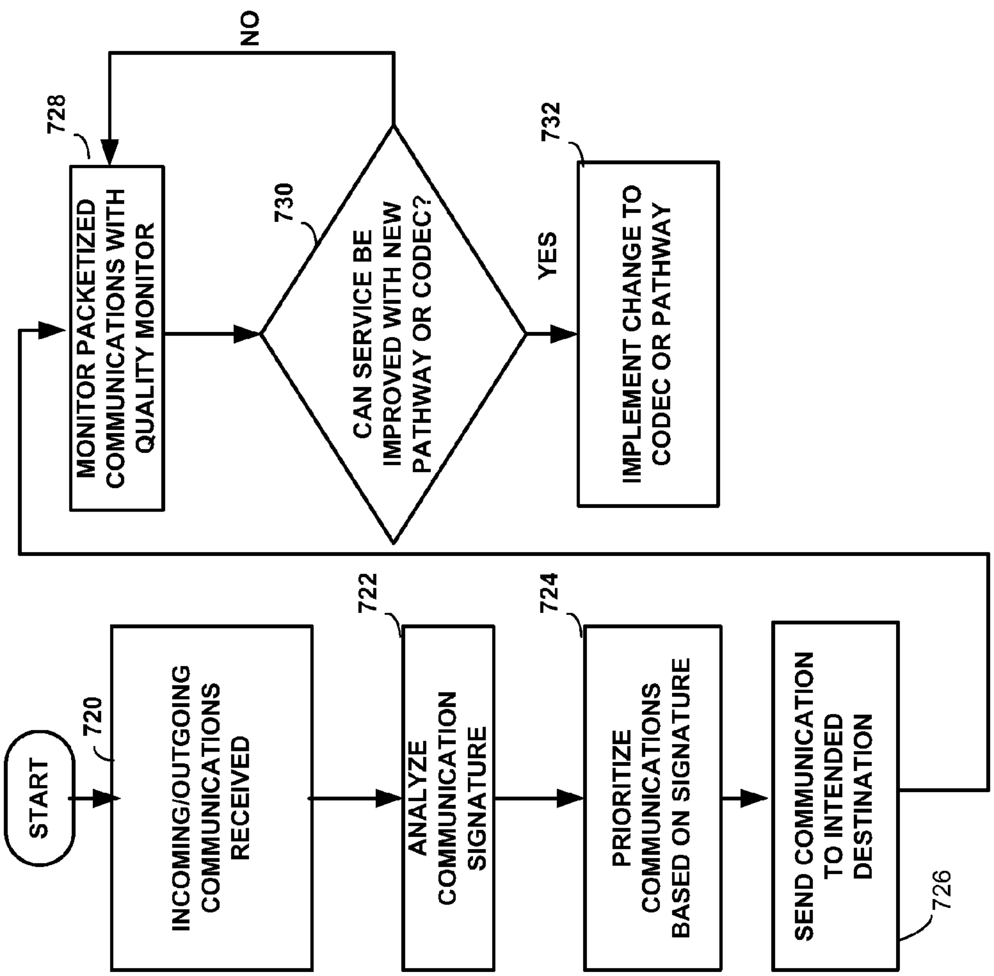

START
720
INCOMING/OUTGOING COMMUNICATIONS RECEIVED
722
ANALYZE COMMUNICATION SIGNATURE
724
PRIORITIZE COMMUNICATIONS BASED ON SIGNATURE
726
SEND COMMUNICATION TO INTENDED DESTINATION
728
MONITOR PACKETIZED COMMUNICATIONS WITH QUALITY MONITOR
730
CAN SERVICE BE IMPROVED WITH NEW PATHWAY OR CODEC?
NO
YES
732
IMPLEMENT CHANGE TO CODEC OR PATHWAY

FIG. 13B

DYNAMIC REAL-TIME QUALITY MANAGEMENT OF PACKETIZED COMMUNICATIONS IN A NETWORK ENVIRONMENT

CROSS REFERENCE TO RELATED PATENTS/PATENT APPLICATIONS

Continuation Priority Claim, 35 U.S.C. §120

[0001] The present U.S. Utility Patent Application claims priority pursuant to 35 U.S.C. §120, as a continuation, to the following U.S. Utility Patent Application which is hereby incorporated herein by reference in its entirety and made part of the present U.S. Utility Patent Application for all purposes:

[0002] 1. U.S. Utility application Ser. No. 10/779,838, entitled "Dynamic real-time quality management of packetized communications in a network environment," (Attorney Docket No. BP2970.1), filed 02-17-2004, pending, which claims priority pursuant to 35 U.S.C. §119(e) to the following U.S. Provisional Patent Application which is hereby incorporated herein by reference in its entirety and made part of the present U.S. Utility Patent Application for all purposes:

[0003] a. U.S. Provisional Application Ser. No. 60/472,647, entitled "Method for handoff of a telephone call between two different wireless networks," (Attorney Docket No. BP2970.1), filed 05-22-2003, now expired.

BACKGROUND OF THE INVENTION

[0004] 1. Technical Field of the Invention

[0005] The present invention relates generally to communication networks supporting multimedia packetized communications, and more particularly to a system for managing the quality of service provided by a wireless local area network.

[0006] 2. Description of Related Art

[0007] Communication technologies that network electronic devices are well known. Examples include wired packet data networks, wireless packet data networks, wired telephone networks, and satellite communication networks, among other networks. These communication networks typically include a network infrastructure that services a plurality of client devices. The Public Switched Telephone Network (PSTN) is probably the best-known communication network and has been in existence for many years. The Internet, another well-known example of a communication network, has also been in existence for a number of years. Communication networks like these enable client devices to communicate with one another on a global basis.

[0008] Local Area Networks (wired LANs), e.g., Ethernets, support communications between networked computers and other devices within a serviced area. These wired LANs often link serviced devices to Wide Area Networks (e.g., WANs) and the Internet. Each of these networks is generally considered a "wired" network, even though some of these networks, e.g., the PSTN, may include some transmission paths that are serviced by wireless links.

[0009] Wireless networks have come into existence more recently. Examples include cellular telephone networks, wireless LANs (WLANs), and satellite communication networks. Common forms of WLANs such as IEEE 802.11(a) networks, IEEE 802.11(b) networks, and IEEE 802.11(g) networks are referred to jointly as "IEEE 802.11 networks." In a typical IEEE 802.11 network, a wired backbone couples to a plurality of wireless Access Points (APs), each of which supports wireless communications with computers and other wireless terminals that include compatible wireless interfaces within a serviced area. The wired backbone couples the APs of the IEEE 802.11 network to other networks, both wired and wireless, and allows serviced wireless terminals to communicate with devices external to the IEEE 802.11 network. Devices that operate consistently with an IEEE 802.11 protocol may also support ad-hoc networking in which wireless terminals communicate directly to one another without the presence of an AP.

[0010] Currently, Wireless Local Area Networks (WLANs) service a wide variety of data communications, typically relating to non-real-time requirements. As the bandwidth delivered on the wireless links serviced by the WLANs increases, additional data communications may also be delivered, e.g., Voice Over Internet Protocol (VOIP), video conferencing, multi-media streaming, etc. However, when the WLAN supports many data transactions, the communications requiring continual throughput such as voice and multimedia communications may not be sufficiently serviced. The result of this shortcoming is reduced voice and video image quality, disconnection of the serviced communication, etc.

[0011] The shortcomings of the WLAN may be at the APs that service the wireless links within the WLAN. Each WLAN supports only a maximum throughput, e.g., 11 Mbps (Mega-bits per second) for IEEE 802.11b APs and 54 Mbps for 802.11a and 802.11g APs. When a particular AP cannot service all of its client devices, latency in the communications will increase. Because the AP cannot typically assign priority to its serviced communications, some or all of the serviced communications are adversely affected.

[0012] The performance of the WLAN may also be affected by the switches, routers, nodes or other elements in the backbone network of the WLAN and/or gateways that couple the WLAN to a WAN, to the Internet, to the Public Switched Telephone Network (PSTN) or to another servicing network. When these devices become overloaded, the WLAN serviced communications are also affected. Additionally, traffic within individual network segments may adversely impact communications.

[0013] WLANs often serve as terminating networks for voice communications, multimedia communications, etc. In some operations, the WLANs perform adequately but a network that couples the WLANs does not. An example of such an installation is when two offices of a major corporation each have WLAN service and a WAN couples the WLANs. In order to reduce telephony costs, voice traffic is routed across the WAN. When voice quality suffers, the WLAN administrators most likely identify the WLAN components as the problem even though the WAN itself may be the bottleneck. This troubleshooting most often occurs when reported by a user after the fact. By that time, the WAN problem may have been remedied and the system administrator can offer no solution. Such is also the case when the APs or other WLAN components are temporarily overloaded.

[0014] Thus, a need exists for intelligent systems and components that can identify network or pathway problems in real-time and effect real-time solutions.

BRIEF SUMMARY OF THE INVENTION

[0015] The present invention is directed to apparatus and methods of operation that are further described in the following Brief Description of the Several Views of the Drawings, the Detailed Description of the Invention, and the claims. Other features and advantages of the present invention will become apparent from the following detailed description of the invention made with reference to the accompanying drawings.

BRIEF DESCRIPTION OF THE SEVERAL VIEWS OF THE DRAWINGS

[0016] For a more complete understanding of various aspects of the present invention and the advantages thereof, reference is now made to the following description taken in conjunction with the accompanying drawings in which like reference numerals indicate like features and wherein:

[0017] FIGS. **1**A and **1**B depict communication pathways between wireless terminals and far end terminals;

[0018] FIG. **2** provides a block diagram that details the functions of the wireless terminal of FIGS. **1**A and **1**B;

[0019] FIG. **3** depicts an embodiment where an individual wireless terminal selects a communication pathway, selects a wireless link to an access point providing the highest level of service;

[0020] FIGS. **4**A-**4**E provide block diagrams depicting the functions of various embodiments of wireless terminals;

[0021] FIG. **5**A depicts a flow chart detailing the processes associated with selecting the appropriate coding scheme for outgoing user communications;

[0022] FIG. **5**B depicts the selection of a coding scheme associated with incoming communications at the wireless terminal;

[0023] FIG. **5**C depicts a process by which incoming and outgoing communications are received and the coding scheme and communication pathway are monitored and evaluated for potential changes which would improve the measured and perceived quality of the serviced communication;

[0024] FIGS. **6**A and **6**B depict an embodiment wherein the decision making process may be executed by a processor within either an access point or a quality monitoring module;

[0025] FIG. **7**A depicts the internal functions of a wireless AP having the ability to monitor and make quality decisions on the exchange of packetized communications through the wireless AP;

[0026] FIG. **7**B depicts a quality-monitoring module located within the network. The module is capable of monitoring, evaluating and acting on information contained within the communication signatures of packetized communications passing through the quality monitoring module;

[0027] FIG. **8**A provides an ideal communication signature of real-time packetized communications;

[0028] FIG. **8**B provides one example of a non-real-time data communication involving bursts of data;

[0029] FIGS. **8**C and **8**D depict real communication signatures wherein packets of data are dropped;

[0030] FIGS. **9**A and **9**B illustrates the perceived and measured quality level impacts of the dropped packets in FIGS. **8**C and **8**D;

[0031] FIG. **10** depicts that packets are typically lost in bursts;

[0032] FIG. **11**A provides an ideal communication signature wherein a real-time communication is received in packet sequence order;

[0033] FIG. **11**B depicts a real communication signature wherein packetized communications are dropped via the wireless link between the wireless terminal and the access point;

[0034] FIG. **12**A depicts a real communication signature wherein packetized communications are dropped within the network communication pathway;

[0035] FIG. **12**B depicts a real communication signature wherein packets are received out of order from the network; and

[0036] FIGS. **13**A and **13**B depict process flows associated with quality monitoring.

DETAILED DESCRIPTION OF THE INVENTION

[0037] Preferred embodiments and aspects of the present invention are illustrated in the figures, like numerals being used to refer to like and corresponding parts of the various drawings.

[0038] FIG. **1**A provides a diagram illustrating a wireless terminal **10** wirelessly coupled to WLAN **12** through AP **14**. FIG. **2** further details wireless terminal **10**. Processing unit **16** within wireless terminal **10** couples to and directs the functions of wireless interface **18** that communicatively couples to AP **14**. Additionally, processing unit **16** couples to and directs programmable COder/DECoder (CODEC) **20** to convert user information or communications received at user interface **22** into packetized communications. User interface **22** may take the form of a microphone **25**, camera **26**, or other like device to receive audio and/or visual input from a user. Additionally, the user interface **22** may include a display **28**, speaker **30**, or other like device to present audio and/or visual information to the user. Packetized communications **24** are exchanged between wireless terminal **10** and AP **14**.

[0039] As shown in FIG. **1**A, AP **14** broadcasts within WLAN **12** and couples to backbone network **15**. As shown, backbone network **15** couples to a wide area network (WAN) **32** that in turn relays the packetized communications to far-end terminal **34**. In this first instance, far-end terminal **34** is serviced by a remote wireless local area backbone network **40** having AP **42**. It should be noted that the far-end terminal **34** need not be limited to a wireless terminal. For example, a wire-based telephone such as that illustrated in FIG. **1**B may act as the far-end terminal. In this example, backbone network **15** couples to the public switch telephone network (PSTN) **36** via a private box exchange (PBX) **38** and delivers audio communications to a far-end terminal **34**.

[0040] Returning to wireless terminal **10** of FIG. **2**, processing unit **16** monitors the packetized communications **24** exchanged between wireless terminal **10** and AP **14** in order to determine a communication quality level delivered by the wireless link that couples wireless terminal **10** to AP **14**. Once the communication quality level delivered by wireless link **40** has been determined, processing unit **16** specifies the coding scheme to be employed by CODEC **20** to convert user communications into packetized communications **24**. Additionally, processing unit **16** may communicate with far-end terminal **34** to determine the overall delivered communication quality level along the entire communication pathway. Then processing unit **16** can select the coding scheme based on the overall delivered communication quality level.

[0041] Some example coding schemes used in audio or video coding include Huffman encoding, ITU-T G.711, u-law, A-law, CCITT G.721, CCITT G.723, ITU-T G.726, ITU-T G.723.1, ITU-T G.723.1A, ITU-T G.729, ITU-T

G.729A, ITU-T G.729AB, ITU-T G.729E, ITU-T G.728, ITU-T G.722, ITU-T G.722.1, ITU-T G.722.2, GSM-EFR, GSM AMR, IMA/DVI ADPCM, Microsoft ADPCM, LPC-10E, CELP GSM 06.10, shorten, Real Audio, MPEG, ACE and MACE, as well as others known to those skilled in the art. Wireless terminal **10** receives packetized communications **24** wirelessly via antenna **52**. Wireless interface **18** exchanges the incoming communications with jitter buffer **54**. Processing unit **16** monitors jitter buffer **54** to determine its latency. This information may be used to determine the communication quality level delivered by wireless link **40**. Based on the measurement of the communication quality level delivered, processing unit **16** may change the selected coding scheme used by CODEC **20** to convert user communications received to and from packetized communications.

[0042] Processing unit **16** may also monitor various signal pathways in its decision-making process. FIG. **3** depicts a situation wherein wireless terminal **10** has access to APs **14**A, **14**B and **14**C that each couple to wireless local area backbone network **15**. This allows processing unit **16** to choose its servicing AP based upon the expected service quality level supplied by individual APs **14**A, **14**B and **14**C. In one instance, this process involves monitoring a number of APs by querying each available AP to determine the service quality level delivered by each individual AP. Wireless terminal **10** then chooses a new AP when the service quality level provided by the new servicing AP exceeds the service level provided by the current servicing AP by a predetermined service level.

[0043] FIGS. **4**A-**4**D provide block diagrams illustrating the typical components of various wireless terminals. FIG. **4**A depicts wireless terminal **400** as having only a short-range digital radio WLAN RF unit **404**A that supports Bluetooth® or like wireless communications with the WLAN. FIG. **4**B includes a cellular RF unit **404**B that supports wireless communications with the cellular network. FIG. **4**C includes a WLAN RF unit **404**A and satellite RF unit **404**C. FIG. **4**D includes WLAN RF unit **404**A, cellular RF unit **404**B, and satellite RF unit **404**C. RF units, **404**A, **404**B and **404**C couple to antennae **402**A, **402**B and **402**C respectively. These antennae **402**A, **402**B, and **402**C may be located internal or external to the case of the wireless terminal **400**. Further, in some embodiments, a single RF unit and/or a single antenna may support communications with both the WLAN and the cellular network. Processor **406** may be an Application Specific Integrated Circuit (ASIC) or another type of processor capable of operating the wireless terminal **400** according to this disclosure. Memory **408** includes both static and dynamic components, e.g., DRAM, SRAM, ROM, EEPROM, etc. In some embodiments, the memory **408** may be partially or fully contained within an ASIC that also includes the processor **406**. A user interface **410** includes a display, indicators, a keyboard, a speaker, a microphone, and/or a data interface, and may include other user interface components known to those still in the art. RF interfaces **404**A, **404**B, and **404**C, processor **406**, memory **408**, and user interface **410** couple via one or more communication buses/links **416**. Battery **412** or power port **418** couples to and powers RF interfaces, processor, memory and the user interface.

[0044] FIG. **5**A provides a flowchart that depicts the servicing of real-time communications through a wireless terminal. At Step **500**, outgoing communications are received at the user interface of the wireless terminal. These user communications may take the form of either audio or visual communications. An initial coding scheme, selected at Step **502**, is utilized to code outgoing communications into packetized communications at step **504**. FIG. **5**B depicts incoming communications and utilizes the coding scheme to convert the incoming packetized communications to a format more readily used by the user. Outgoing packetized communications are exchanged between the wireless terminal and servicing AP at a given packetized rate in Step **506**. This exchange is monitored in Step **508** to determine the communication quality level supported between the AP and the wireless terminal. By monitoring the exchange of packetized communications between the AP and the wireless terminal, the maximum delivered communication rate between the AP and the wireless terminal may then be used at decision point **510** to determine if the measured or perceived service can be improved by selecting a new coding scheme. If an improvement can be effected, a new CODEC is selected at step **512** and used in step **504** to convert new user communications into packetized communications. Otherwise, the processor continues to monitor the exchange of packetized communications in step **508**.

[0045] FIG. **5**B provides a flow chart illustrating the processes associated with receiving incoming packetized communications at the wireless terminal via the AP. At step **520**, incoming packetized communications from the network are received at the wireless terminal. The processor identifies the coding scheme associated with these packetized communications in step **522**. These communications are converted into user communications at step **524** and provided to the user through an interface at step **526**. Simultaneously, the device monitors the communication quality level between the wireless terminal and the AP, and potentially the far-end terminal in step **528**.

[0046] During the monitoring, a continuous evaluation is made as to whether or not the measured or perceived service can be improved with an alternative coding scheme at decision point **530**. If it cannot, monitoring continues at step **528**. Otherwise, a new coding scheme is selected in step **532**, and implemented with the far-end terminal in step **534**. New communications received should then be coded in accordance with the selected coding scheme as the process begins again at step **520**.

[0047] FIG. **5**C illustrates the receipt of incoming and outgoing communications at a user interface in step **550**. An initial coding scheme, selected at step **552**, is employed in step **554** to translate between user communications and packetized communications. Packetized communications are exchanged between the wireless terminal and the APs at step **556**. As previously stated, the exchange process is monitored to determine the delivered communication quality level between the wireless terminal and APs in step **558**. At decision point **560**, a determination is made as to whether or not a need exists to revise the CODEC. The revised CODEC is selected and implemented in steps **562** and **564** respectively. Otherwise, the processor continues to monitor the exchange of packetized communications.

[0048] The monitoring process may also evaluate the communication pathways used to exchange packetized communications between the wireless terminal and the far-end terminal in step **566**. Alternatively, communications between both end points may determine the appropriate CODEC or communication pathway. The process answers this question at decision point **568** and implements changes at step **570** or continues to evaluate at step **566**.

[0049] In this embodiment, the overall communication quality level delivered across the entire communication path maybe evaluated. The decision to revise the selected CODEC at the above decision points now may consider the overall communication quality level and/or network/hardware considerations. Additionally, communications between the wireless terminal and the far-end terminal may identify a CODEC supported by both the far-end terminal and wireless terminal.

[0050] The process of monitoring packetized communications between end points may include monitoring the latency of packetized communications within the jitter buffer within the wireless terminal or VoIP terminal. As will be discussed later, this process may also be repeated or emulated at the AP or various nodes within the communication pathways that link the wireless terminal to the far-end terminal.

[0051] FIGS. **6**A and **6**B detail embodiments where the processing and decision-making process does not need to occur within wireless terminal **10**. Here, wireless terminal **10** is wirelessly linked to AP **600**. AP **600** services WLAN **12**. One embodiment of AP **600** is further detailed in FIG. **7**A.

[0052] In FIG. **7**A, a wireless connection links wireless terminal **10** to antenna **618** and wireless interface **620** of AP **600**. Processor **622** monitors and directs wireless interface **620**, jitter buffer **624**, and network interface **628**. Processor **622** identifies and examines the communication signatures of packetized communication from wireless terminal **10** to determine if the communication is a real-time communication or non-real-time communication. A priority based on the communications real-time requirements is assigned for the serviced communication. Additionally, processor **622** evaluates the coding scheme and communication pathways used between wireless terminal **10** and the intended far-end terminal. Processor **622** determines how the communication should be routed and assigns a coding scheme and communication pathway that provides a predetermined level of service for the real-time communication. Furthermore, processor **622** may communicate with wireless terminal **10** in order to direct which coding scheme is to be used by the programmable CODEC, with the terminals.

[0053] In one example, processor **622** may examine the packetized communications exchanged between wireless terminal **10** and wireless interface **620** to determine the communication quality level delivered by the wireless link. When the wireless link is limiting, processor **622** may employ a coding scheme based on the communication quality level delivered by the wireless link. Additionally, by examining jitter buffer **624**, processor **622** determines the latency associated with these buffers and assigns an appropriate coding scheme based on that latency. Processor **622** also interfaces with network interface **628** to direct the exchange of packetized communications between AP **600** and the backbone network or other network components in the communication pathway between wireless terminal **10** and the destination terminal.

[0054] These same processing functions may be achieved with a quality-monitoring module **602** further detailed in FIG. **7**B. If the WLAN AP with which the wireless terminal communicates does not have the ability to monitor and evaluate packetized communications, these functions may be supported by quality monitoring module **602**. Additionally, these modules, when located at nodes within the pathway, may supplement the functions of APs having these abilities.

[0055] FIG. **7**B shows that network communications maybe received at network interface **628**A via port **630**A. As previously stated, the network interface couples to processor **622** and jitter buffer **624**. The communications then pass from network interface **628**B and ports **630**B to the other segments in the network.

[0056] Returning to FIG. **6**A, it should be further noted that quality-monitoring modules **602** might be located within any network segment or at any network vertices such as those between backbone network **604** and WAN **606**, as well as backbone network **608** and WAN **606**. FIG. **6**A shows that wireless terminal **10** communicates with far-end terminal **614** along the communication pathway shown. It should be understood that the monitoring modules are optional as AP **600**, as configured in FIG. **7**A, has the ability to process and evaluate the packetized communications exchanged between the network and wireless terminal **10**.

[0057] FIG. **6**B includes a bypass network such as PSTN, cellular, satellite, or other like network known to those skilled in the art. In this instance, quality-monitoring modules **602** may direct that if the primary communication pathways are unable to support the real-time communications between wireless terminal **10** and far-end terminal **614**, then a bypass network **606**B, such as one or more of those identified above may be used in favor of WAN **606**A. Quality monitoring modules **602**, in addition to evaluating communication quality levels delivered by the network, and the coding schemes employed, may further direct that non-real-time communications receive a lower priority or be temporarily stored in a buffer, or be delayed to support real-time communications.

[0058] One process accomplished by processor **622** in either AP **600** or quality monitoring module **602** is to determine whether or not the communications received from wireless terminal **10** are above or below a predetermined communication quality level threshold. The determination as to whether or not the communications are real-time communications or non-real-time communications may be determined by the protocols associated with the communications. For example, RTP protocols may identify real-time communications. FIG. **8**A provides an example of an ideal packetized communication signature associated with a real-time communication from the wireless terminal. FIG. **8**B depicts one possible signature of data communications that contain large amounts of data in relatively small bursts **804**. Thus, the processor may also evaluate these communication signatures to determine which communications are real-time communications and to assign a predetermined level of service to those real-time communications. This evaluation of the communication signature is important where non-real-time protocols are used to convey real-time communications.

[0059] FIGS. **8**C and **8**D show real-time communications with some data loss. Losses of individual packets of packetized communications impact the quality that the user perceives at the wireless terminal. It is important to maintain a perceived level of quality for the end user. This results in subscriber retention and increased user satisfaction. Ideally, VoIP systems should approach or exceed the quality of traditional telephony systems.

[0060] FIGS. **9**A and **9**B depict the effects of the dropped packets in FIG. **8**C and **8**D on the user's perceived quality. FIG. **9**A shows that packet sequence **2** is lost as indicated by the gap L**1**. Gap L**2** indicates the loss of packet sequence **7**. These losses result in a reduced overall quality. Line **650** indicates the measured communication quality while dotted line **652** indicates the user's perceived communication quality. Line **650** depicts the measured communications quality as varying between a high quality and a low quality. Somewhere in between is a minimum average service to be maintained in order to ensure end user satisfaction. FIG. **9**B depicts an instance when the same number of packetized communications is lost. However the packets lost are consecutive or form a burst at gap L**1**. This loss has a much more pronounced effect on the user's perceived quality of the communications than the small non-burst losses seen in FIG. **9**A. FIG. **9**B depicts a large gap wherein the perceived quality **652** dropped below the minimum service level for the communications. The fact that lost packets typically occur in bursts is indicated by the data represented in FIG. **10** wherein consecutive lost packets versus packet sequence number are provided. Spikes **660** indicate large losses of data. These typically are large consecutive losses of packetized communications.

[0061] The time that it takes for the perceived quality of the communications to rise above a minimum acceptable level is a function of the recovery from the loss of data, and the coding scheme used. Some coding schemes may more quickly compensate for recently lost packets. FIG. **11**A depicts an ideal communication signature between a wireless terminal and an AP wherein a real-time communication having a series of packetized communications **24** are received in the proper packet sequence order and contain approximately the same amount of information. In contrast, FIG. **11**B depicts one example of a real communication signature between the wireless terminal and the AP wherein some packetized communications **24** are dropped in packet sequence order.

[0062] Thus, the quality monitor for the signatures depicted in FIGS. **11**A and **11**B may choose different coding schemes. FIG. **11**A does not require a rapid recovery from dropped packets. However, FIG. **11**B requires the processors to select the scheme that provides the highest level of perceived quality and minimizes the effect of dropped packets. Additionally, the quality monitor may seek to service a wireless terminal with an alternative AP in order to avoid dropped packetized communications if a second AP is available to provide a higher level of service.

[0063] Network communications received from the far end terminal by the quality monitor should be received in packet sequence order and in a timely fashion. However, FIG. **12**A provides the communication signature of packetized communications received from another segment in the network when packets are dropped. FIG. **12**B depicts a communication signature wherein packets are received out of packet sequence order. Both instances may affect the perceived quality of the communication; the quality monitor may evaluate these communication signatures and direct an appropriate course of action. For example, in FIG. **12**A, where packetized communications **24** that correspond to packet sequence nos. **2** and **7** are dropped in order, the quality monitor may elect a coding scheme better suited to maintain a high level of perceived quality when occasional packetized communications **24** are dropped. Additionally, when packetized communications **24** contain routing information, a determination can be made as to the network segment at which the packetized communications corresponding to the dropped packet sequence numbers. Then, the dropping network segment may be removed if possible from the communication pathway. In an instance where this is not possible, the quality monitor may direct an alternative communication pathway such as that provided by bypass network **606**B of FIG. **6**B.

[0064] FIG. **12**B indicates that while no packetized communications **24** were dropped, latency problems caused the packetized communications to be received out of sequence. As shown here, the packetized communications corresponding to packet sequence nos. **7**, **6**, **5**, and **2** were received out of order. In certain cases, these packets will be discarded. These packetized communications are analyzed to determine the root cause of their delay and the network impediment, which may be removed, if possible, or a coding scheme revised to handle packetized communications received out of order while still allowing the perceived quality of the communication to remain high. Alternatively, a bypass network may be utilized if reconfiguring the communication pathway and revising the coding scheme does not provide the desired level of service.

[0065] FIG. **13**A provides a process flow by which the quality monitors associated with either the APs or quality-monitoring modules within the network are able to receive outgoing communications at the quality monitor (processor) in step **700**. The quality monitor determines, based on the communication signature associated with the outgoing communications, whether or not the communication is a real-time communication in step **702**. In which case, real-time communications are prioritized at step **704** and non-real-time communications may be delayed dependent upon the bandwidth requirement of current communications. Then, a coding scheme consistent with the communication signature or communication pathway consistent with the communication signature may be selected at step **706**. The process continually repeats for ongoing communications in order to ensure that the highest possible levels of communications are provided to the end user.

[0066] FIG. **13**B also provides a process flow wherein communications are received by a quality monitor at Step **720**. Communications signatures are analyzed at Step **722** in order to prioritize the communications and send them to their intended destination at steps **724** and **726** respectively. The quality monitor continuously monitors these communications at step **728** and evaluates whether or not service can be improved with either a new communication pathway or coding scheme at step **730**. If service may be improved, the necessary change is implemented at step **732**. Otherwise, the evaluation process continues at step **728**.

[0067] In summary, this disclosure provides the ability to incorporate quality monitors either into wireless terminals, wireless access points, or other network modules. These quality monitoring functions monitor, in real-time, the measured and perceived quality of real-time communications. In addition to monitoring these levels of quality, communication pathways and coding schemes may be dynamically reconfigured to improve the measured and perceived level of quality. This has particular applications to VOIP and other like streaming multimedia applications. Such applications enable providers to maintain a high level of user satisfaction while minimizing the impact on network resources. Additionally, quality monitors support dynamic mixed usage of network bandwidth such that voice data and other multimedia communications are prioritized based on their immediate need when compared to other data communications. Thus, the quality monitors support dynamic bandwidth sharing amongst the different types of communications. This ability minimizes network-operating costs and provides real-time communications such as VOIP at quality levels that can reach or exceed traditional telephony levels.

[0068] In some embodiments, a system and method are operable to service real-time audio and/or visual communications in a network environment that are negatively impacted by packet delay or packet losses, such as Voice over Internet Protocol (VoIP) or wireless terminals that transmit and receive communications in a digital form having discrete packets. More specifically, various aspects of the present invention provides a dynamic real-time quality management of packetized communications in a network environment. Various solutions presented herein may involve dynamically altering coding schemes, network pathways or dynamically assigning priorities to network communications.

[0069] Packetized communications are monitored by and exchanged between wireless Access Points (APs) and wireless terminals or a wired terminal, such as a VoIP telephone, and a servicing network. Alternatively, the packetized communications are relayed by quality monitoring modules located within network segments or at network vertices. The processing unit analyzes the packetized communications to identify communication signatures associated with the packetized communications. The processor then uses these signatures to identify network impediments to the exchange of the packetized communications. These impediments may take the form of coding problems in which case an appropriate coding scheme is selected and implemented. Alternatively, the communication signatures may indicate network (traffic) or hardware problems within specific segments of the communication pathway. In this case, traffic is prioritized or rerouted.

[0070] One embodiment provides an intelligent Wireless Local Area Network (WLAN) Access Point (AP). A second embodiment provides an intelligent VoIP network interface. While, a third embodiment provides an intelligent quality-monitoring module. In the instance of a WLAN AP or intelligent VoIP network interface, the WLAN AP or intelligent VoIP network interface performs the functions of the quality-monitoring module. A wireless interface exchanges packetized communications with wireless terminals on the WLAN. A processing unit couples to the wireless interface and to the WLAN's backbone network interface, and monitors the exchange of communications serviced by the WLAN AP. The processing unit identifies the communication signature for the packetized communications. Then the processing unit determines, based upon the corresponding communication signature, when the packetized communications are real-time communications. Communications identified as real-time communications are assigned a predetermined service level. The service level assigned to non-real-time communications may be lower than that of the real-time communications.

[0071] When the real-time communications cannot be provided the predetermined service level, the processor may direct the real-time communications to be re-routed via another servicing network. Alternatively, the processor may direct that the real-time communications be prioritized over the non-real-time communications.

[0072] Each packetized communication has a pair of signatures: a receive signature corresponding to communications received from a corresponding wireless terminal via the wireless interface and a transmit signature corresponding to communications received via the WLAN backbone interface and intended for the corresponding wireless terminal. The receive signature is primarily employed to determine whether the packetized communication is a real-time communication. Problems in this signature typically indicate problems with wireless link of AP.

[0073] The transmit signature usually indicates problems (network impediments) within other portions of the communication path. Such network impediments may result in non-uniformity of receipt of the packetized communications from a near-end wireless terminal. This instance indicates problems in the wireless link. Non-uniformity or non-linearity of receipt of the packetized communications from a far-end terminal indicates problems along the various network pathways between the AP and the far-end terminal.

[0074] Another embodiment takes the form of a method of servicing real-time communications in a network environment. A WLAN AP receives outgoing user communications from a wireless terminal and incoming user communications for the wireless terminal from a WLAN backbone network interfaced with the AP. These communications are in the form of packetized communications coded according to a coding scheme with a programmable COder/DECoder (CODEC). The programmable CODEC converts incoming user communications from packetized communications and outgoing user communications to packetized communications according to the selected coding scheme.

[0075] Packetized communications are exchanged between the servicing AP, the WLAN terminal, and the WLAN backbone network, the VoIP terminal, intelligent VoIP network interface and backbone network, or other network elements known to those skilled in the art, at a communication quality level. These communications are monitored to determine the communication quality level delivered between the servicing AP, the WLAN terminal, the WLAN backbone network, and the far-end terminal. The communications quality can be monitored within switches, routers, handsets, nodes, access points or other elements within the network infrastructure known to those skilled in the art. Monitoring the packetized communications from end-to-end supports the management of the coding scheme and routing of the packetized communications. The CODEC or communication pathway may be revised to improve service by selecting one or more new coding schemes based upon the communication quality level delivered or by selecting a new pathway. This communication quality level depends on the jitter experienced by the communications, the number and frequency of lost packets, the arrival or transmission rate of the packetized communications, and other such factors known to those skilled in the art.

[0076] By monitoring the packetized communications from end-to-end, the method can intelligently manage the selected coding scheme and routing of the packetized communications. For example, in one instance, the processor communicates with a far-end terminal to identify an appropriate coding scheme. These coding schemes may include, but are not limited to audio and/or video coding schemes such as Huffman encoding, ITU-T G.711, u-law, A-law, CCITT G.721, CCITT G.723, ITU-T G.726, ITU-T G.723.1, ITU-T G.723.1A, ITU-T G.729, ITU-T G.729A, ITU-T G.729AB, ITU-T G.729E, ITU-T G.728, ITU-T G.722, ITU-T G.722.1, ITU-T G.722.2, GSM-EFR, GSM AMR, IMA/DVI ADPCM, Microsoft ADPCM, LPC-10E, CELP GSM 06.10, shorten, Real Audio, MPEG, ACE and MACE.

[0077] In another instance, real or emulated jitter buffers, at any point in the communication pathway, monitor latency. This latency is used to determine the communication quality level between the AP and WLAN terminal, VoIP terminal and intelligent VoIP network interface, or along any network segment. Additionally, the communication quality level delivered between the WLAN terminal and the far-end terminal at any point in the network may also be determined.

[0078] This information allows the processor to select the route the communications take by choosing which network segments are used to route the communications or which AP is servicing the communication. In the case of the latter, the APs are queried to determine the expected service quality level from each AP. Then, the WLAN terminal registers with a new servicing AP when the expected service quality level to be provided by the new servicing AP exceeds the expected service quality level provided by the servicing AP by a predetermined service quality level.

[0079] Although the present invention is described in detail, it should be understood that various changes, substitutions and alterations can be made hereto without departing from the spirit and scope of the invention as described by the appended claims.

What is claimed is:

1. An apparatus, comprising:
a network interface for supporting a communication with a communication device via a communication network;
a processor, coupled to the network interface, for monitoring a service level of the communication network; and
a codec, coupled to the processor, for selectively employing a first coding scheme or a second coding scheme to process the communication based on the service level.

2. The apparatus of claim **1**, further comprising:
at least one additional network interface, coupled to the processor, for supporting the communication with the communication device via at least one additional communication network; and wherein:
the processor monitoring at least one additional service level of the at least one additional communication network; and
the apparatus employing the at least one additional network interface for supporting the communication with the communication device via the at least one additional communication network based on the service level and the at least one additional service level.

3. The apparatus of claim **2**, wherein:
the codec selectively employing the first coding scheme or the second coding scheme to process the communication based on the service level and the at least one additional service level.

4. The apparatus of claim **1**, wherein:
the processor analyzing a signature associated with the communication to determine whether the communication is a real-time packetized communication;
when the communication is a real-time packetized communication, the codec firstly employing the first coding scheme to process the communication; and
when the service level is below a predetermined service level, then the codec secondly employing the second coding scheme to process the communication or at least one additional communication.

5. The apparatus of claim **1**, wherein:
the processor analyzing a signature associated with the communication to determine whether the communication is a non-real-time packetized communication; and
when the communication is a non-real-time packetized communication, the codec employing a third coding scheme to process the communication.

6. The apparatus of claim **5**, wherein:
the third coding scheme is the first coding scheme or the second coding scheme.

7. The apparatus of claim **1**, wherein:
the codec employing the first coding scheme to process the communication; and
the codec employing the second coding scheme to process at least one additional communication.

8. The apparatus of claim **1**, wherein:
the processor analyzing a signature associated with the communication in determining that the communication is a real-time packetized communication;
the processor analyzing a signature associated with at least one additional communication in determining that the at least one additional communication is a non-real-time packetized communication; and
the processor prioritizing the real-time packetized communication over the non-real-time packetized communication.

9. The apparatus of claim **1**, wherein:
the network interface is a wireless local area network (WLAN) radio frequency (RF) interface, a cellular RF interface, or a satellite RF interface.

10. The apparatus of claim **1**, wherein:
the apparatus is a wireless terminal.

11. An apparatus, comprising:
a first network interface for supporting a first communication with a communication device via a first communication network;
a second network interface for supporting a second communication with the communication device via a second communication network;
a processor, coupled to the first network interface and the second network interface, for monitoring a first service level of the first communication network and a second service level of the second communication network; and
a codec, coupled to the processor, for selectively employing a first coding scheme or a second coding scheme to process the first communication or the second communication based on the first service level and the second service level.

12. The apparatus of claim **11**, wherein:
the processor analyzing a signature associated with the first communication to determine whether the first communication is a real-time packetized communication;
when the first communication is a real-time packetized communication, the codec firstly employing the first coding scheme to process the first communication; and
when the first service level is below a predetermined service level, then the codec secondly employing the second coding scheme to process the first communication or a third communication.

13. The apparatus of claim **11**, wherein:
the processor analyzing a signature associated with the first communication to determine whether the first communication is a non-real-time packetized communication; and
when the first communication is a non-real-time packetized communication, the codec employing a third coding scheme to process the first communication.

14. The apparatus of claim **11**, wherein:
the network interface is a wireless local area network (WLAN) radio frequency (RF) interface, a cellular RF interface, or a satellite RF interface.

15. A method, comprising:
operating a network interface for supporting a communication with a communication device via a communication network;
monitoring a service level of the communication network; and
operating a codec for selectively employing a first coding scheme or a second coding scheme to process the communication based on the service level.

16. The method of claim **15**, further comprising:
monitoring at least one additional service level of at least one additional communication network for supporting the communication with the communication device; and
operating at least one additional network interface for supporting the communication with the communication device via the at least one additional communication network based on the service level and the at least one additional service level.

17. The method of claim **16**, further comprising:
operating the codec for selectively employing the first coding scheme or the second coding scheme to process the communication based on the service level and the at least one additional service level.

18. The method of claim **15**, further comprising:
analyzing a signature associated with the communication to determine whether the communication is a real-time packetized communication;
when the communication is a real-time packetized communication, firstly employing the first coding scheme to process the communication; and
when the service level is below a predetermined service level, secondly employing the second coding scheme to process the communication or at least one additional communication.

19. The method of claim **15**, further comprising:
analyzing a signature associated with the communication in determining that the communication is a real-time packetized communication;
analyzing a signature associated with at least one additional communication in determining that the at least one additional communication is a non-real-time packetized communication; and
prioritizing the real-time packetized communication over the non-real-time packetized communication.

20. The method of claim **15**, wherein:
the network interface is a wireless local area network (WLAN) radio frequency (RF) interface, a cellular RF interface, or a satellite RF interface implemented within a communication device.

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