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Jalali et al.

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(54) **METHOD AND AN APPARATUS FOR A QUICK RETRANSMISSION OF SIGNALS IN A COMMUNICATION SYSTEM**

(75) Inventors: **Ahmad Jalali**, San Diego, CA (US); **Eduardo A. S. Esteves**, S.D., CA (US); **Nagabhushana T. Sindhushayana**, San Diego, CA (US); **Peter J. Black**, San Diego, CA (US); **Rashid A. Attar**, San Diego, CA (US)

(73) Assignee: **Qualcomm Incorporated**, San Diego, CA (US)

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(52) **U.S. Cl.** **714/748**; 370/474; 375/358

(58) **Field of Search** 714/748; 370/349, 370/342, 330, 436, 469, 474; 375/224, 228, 358

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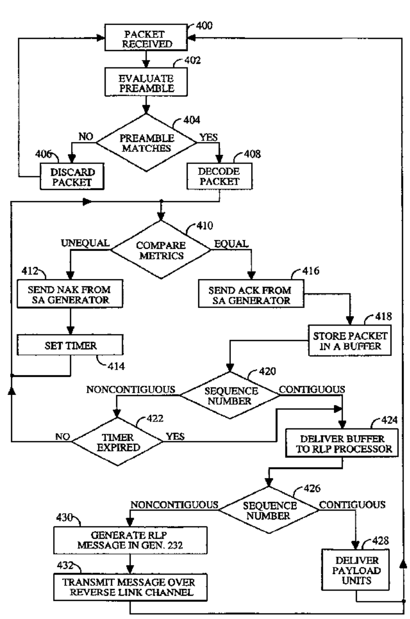
Primary Examiner—Albert Decady
Assistant Examiner—Cynthia Britt
(74) *Attorney, Agent, or Firm*—Philip Wadsworth; Kent Baker; Pavel Kalousek

(57) **ABSTRACT**

A method and an apparatus for quick retransmission of signals in a communication system are disclosed. A transmitting terminal, e.g., a base station, transmits signals in a form of packets to a receiving terminal, e.g., a subscriber station. The receiving terminal determines if the packet was intended for the receiving terminal, and if so, the receiving terminal demodulates the packet. The receiving terminal then computes a quality metric of the packet, e.g., a cyclic redundancy check, and compares the computed quality metric with a quality metric contained in the packet. If the quality metrics match, the packet is declared correctly received, and is forwarded for further processing. If the quality metrics fail to match, the receiving terminal sends a request for retransmission of the packet. The transmitting terminal determines which packet needs to be retransmitted based on the request for retransmission. The transmitting terminal then schedules the packet for retransmission. If delivery of the packet in accordance with the aforementioned description fails, retransmission in accordance with conventional sequence-number-based schemes, e.g., radio link protocol, is attempted.

37 Claims, 6 Drawing Sheets



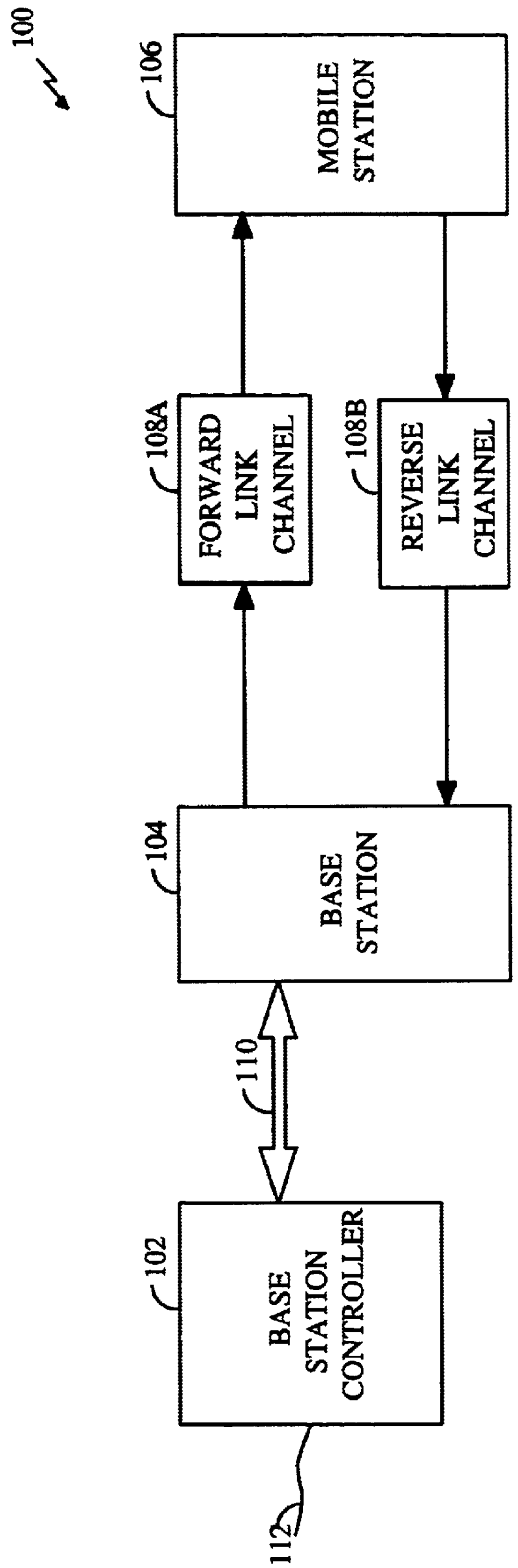

100
MOBILE STATION
106
FORWARD LINK CHANNEL
108A
REVERSE LINK CHANNEL
108B
BASE STATION
104
110
BASE STATION CONTROLLER
102
112

FIG. 1

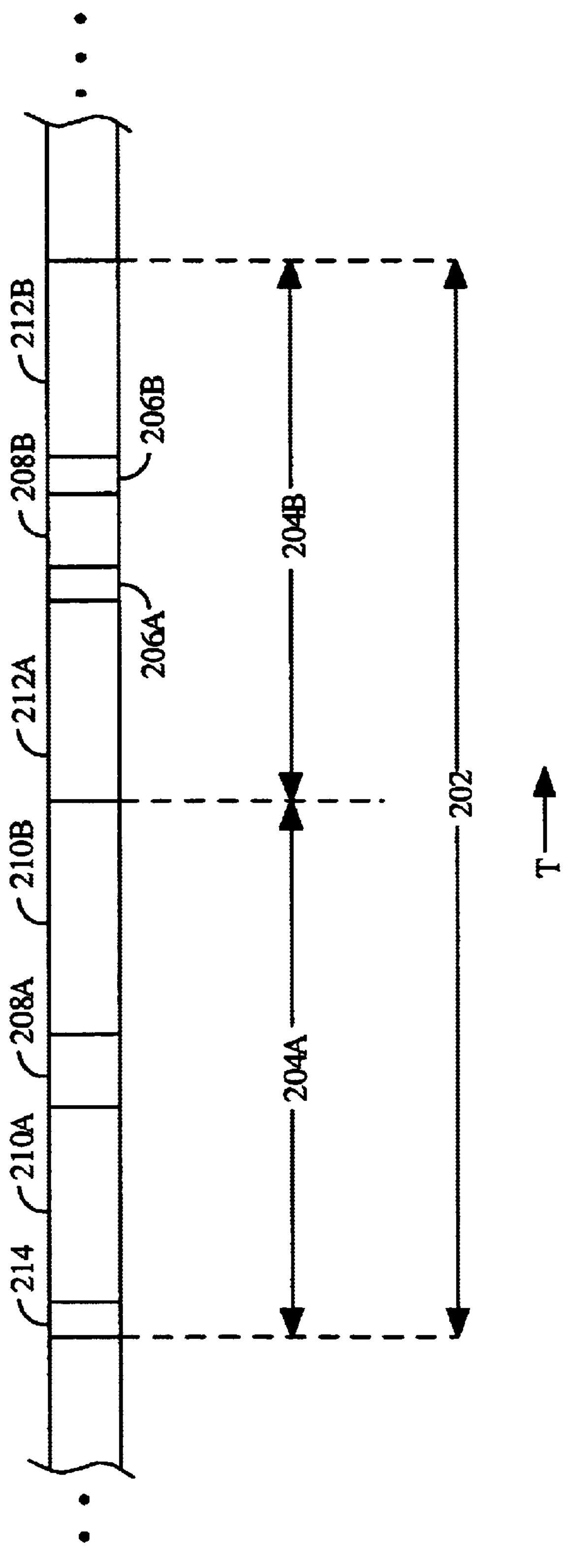


FIG. 2

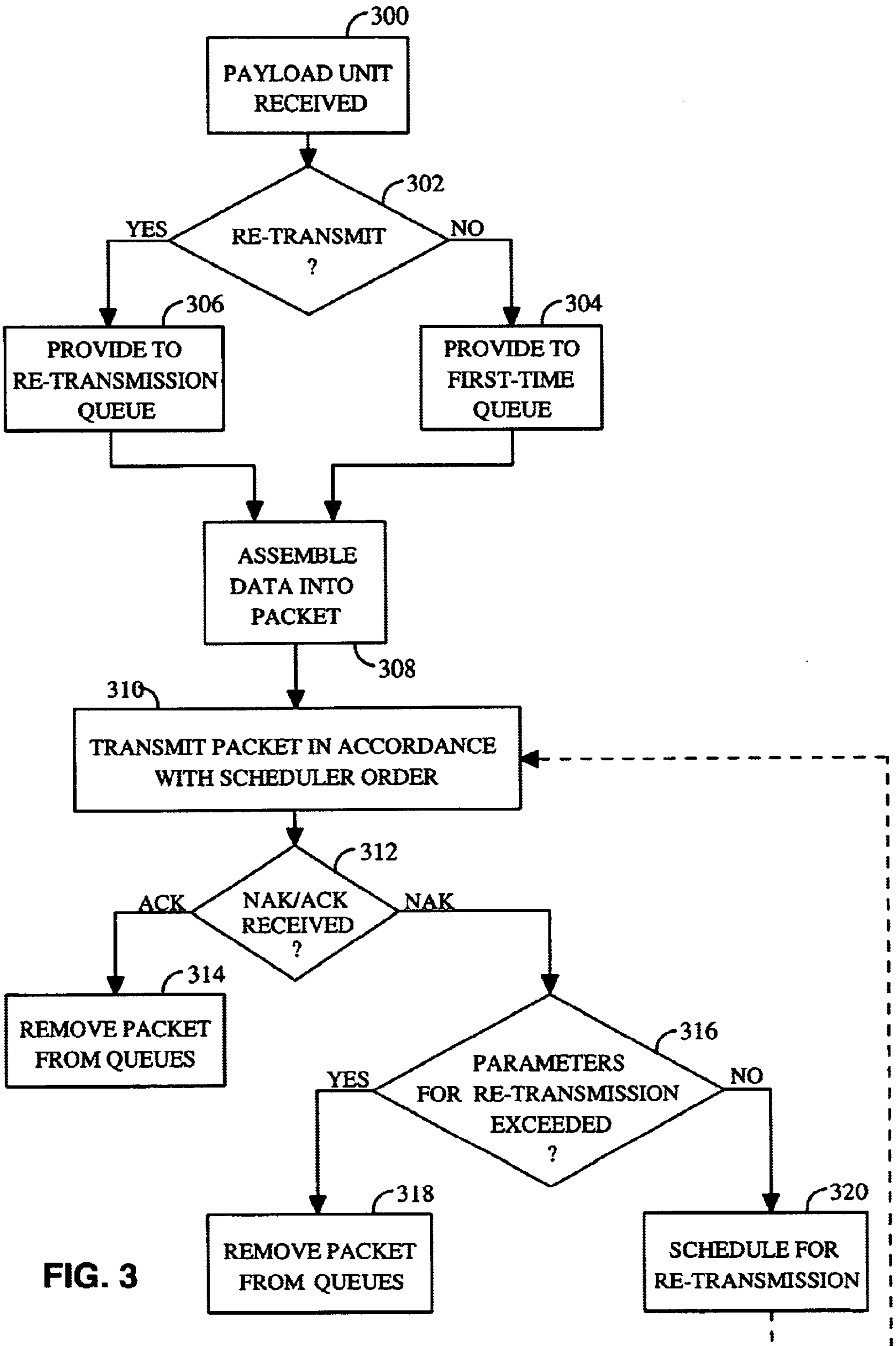

300
PAYLOAD UNIT RECEIVED
302
RE-TRANSMIT ?
YES
NO
306
PROVIDE TO RE-TRANSMISSION QUEUE
304
PROVIDE TO FIRST-TIME QUEUE
ASSEMBLE DATA INTO PACKET
308
310
TRANSMIT PACKET IN ACCORDANCE WITH SCHEDULER ORDER
312
NAK/ACK RECEIVED ?
ACK
NAK
314
REMOVE PACKET FROM QUEUES
316
PARAMETERS FOR RE-TRANSMISSION EXCEEDED ?
YES
NO
318
REMOVE PACKET FROM QUEUES
320
SCHEDULE FOR RE-TRANSMISSION

FIG. 3

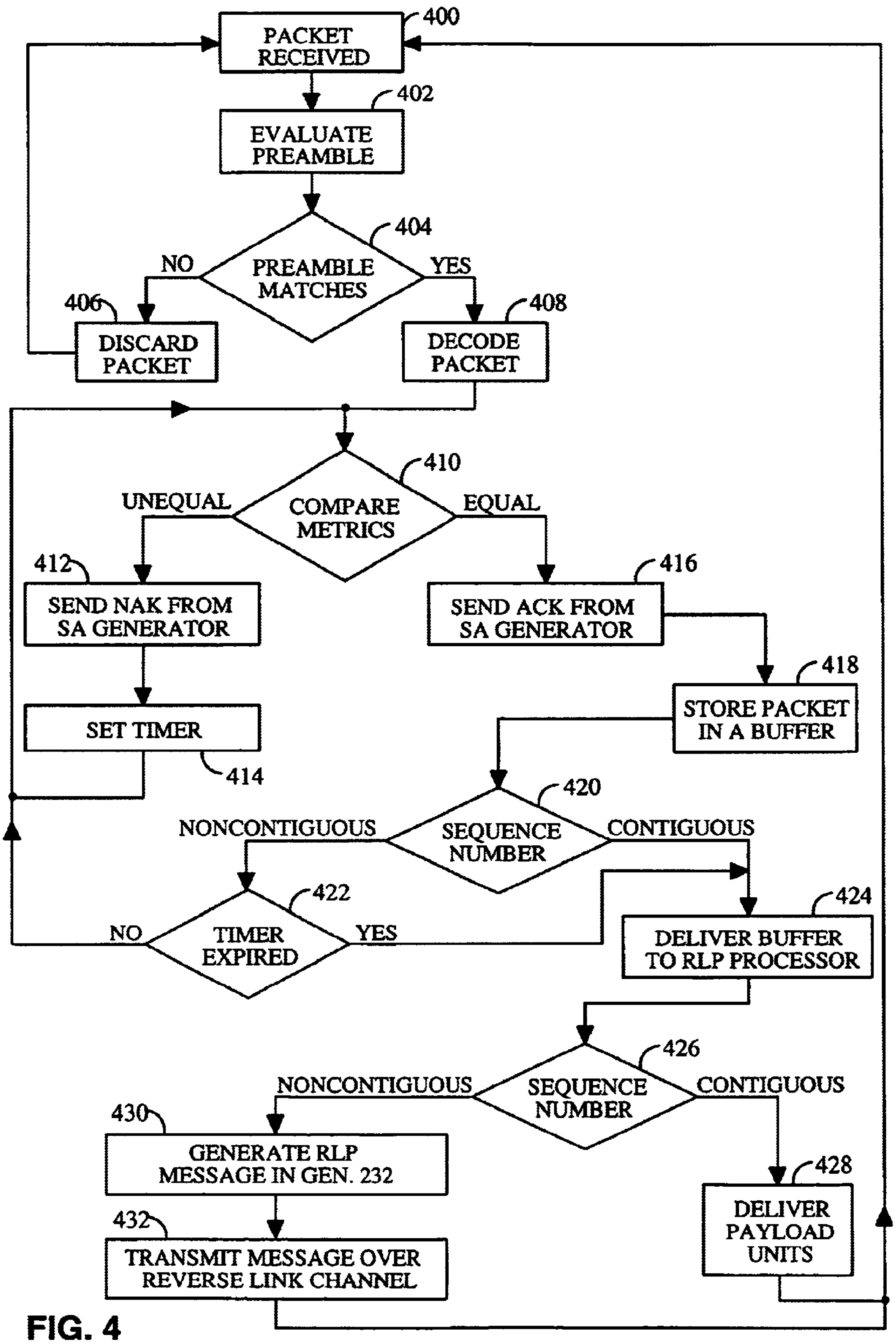

PACKET RECEIVED
400
EVALUATE PREAMBLE
402
PREAMBLE MATCHES
404
NO
YES
406
DISCARD PACKET
408
DECODE PACKET
COMPARE METRICS
410
UNEQUAL
EQUAL
412
SEND NAK FROM SA GENERATOR
416
SEND ACK FROM SA GENERATOR
SET TIMER
414
418
STORE PACKET IN A BUFFER
SEQUENCE NUMBER
420
NONCONTIGUOUS
CONTIGUOUS
TIMER EXPIRED
422
NO
YES
424
DELIVER BUFFER TO RLP PROCESSOR
SEQUENCE NUMBER
426
NONCONTIGUOUS
CONTIGUOUS
430
GENERATE RLP MESSAGE IN GEN. 232
432
TRANSMIT MESSAGE OVER REVERSE LINK CHANNEL
428
DELIVER PAYLOAD UNITS

FIG. 4

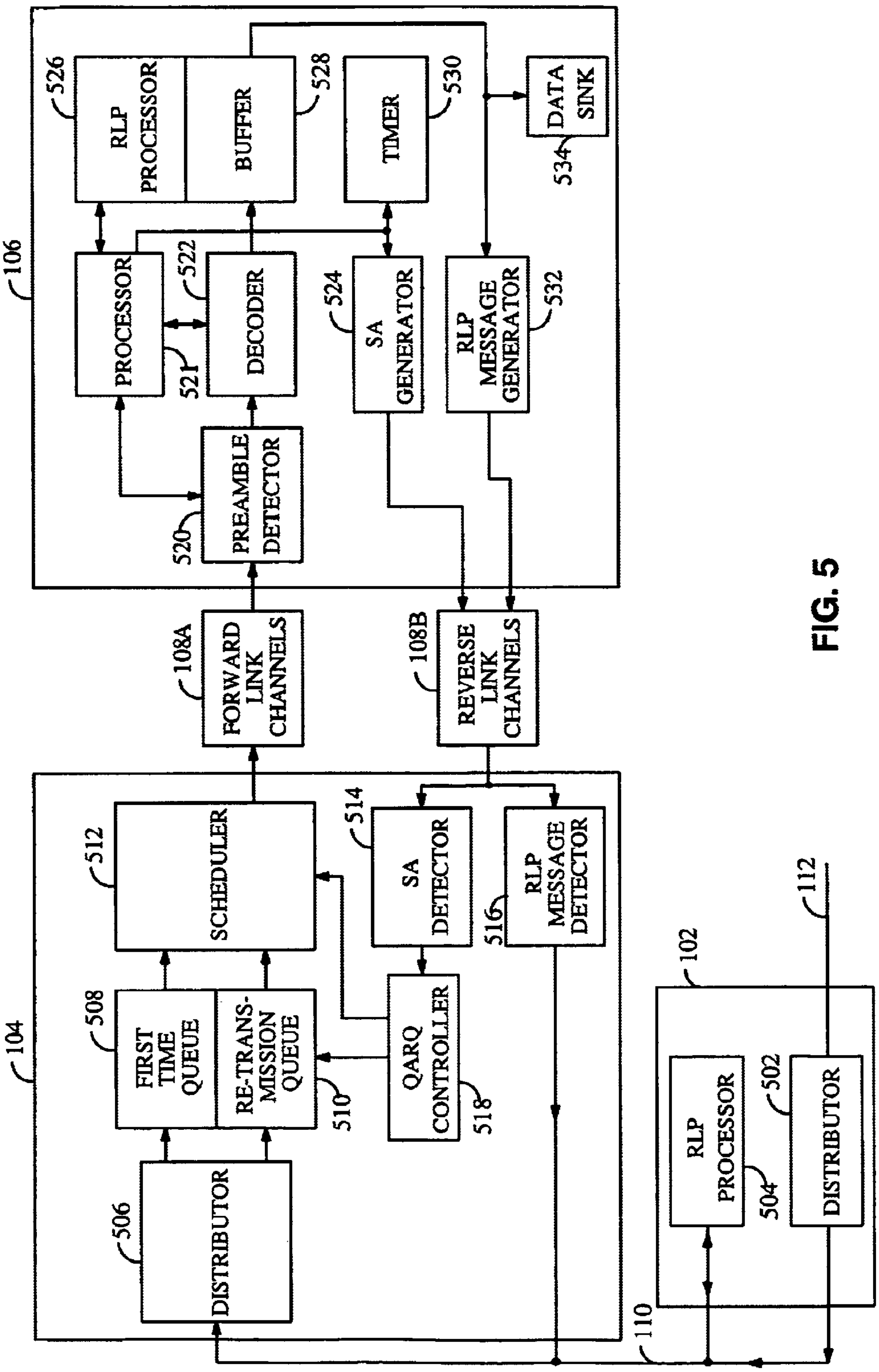

106
RLP PROCESSOR
526
BUFFER
528
TIMER
530
DATA SINK
534
PROCESSOR
521
522
DECODER
SA GENERATOR
524
RLP MESSAGE GENERATOR
532
PREAMBLE DETECTOR
520
FORWARD LINK CHANNELS
108A
REVERSE LINK CHANNELS
108B
104
SCHEDULER
512
SA DETECTOR
514
RLP MESSAGE DETECTOR
516
FIRST TIME QUEUE
508
RE-TRANS-MISSION QUEUE
510
QARQ CONTROLLER
518
DISTRIBUTOR
506
102
RLP PROCESSOR
504
DISTRIBUTOR
502
112
110

FIG. 5

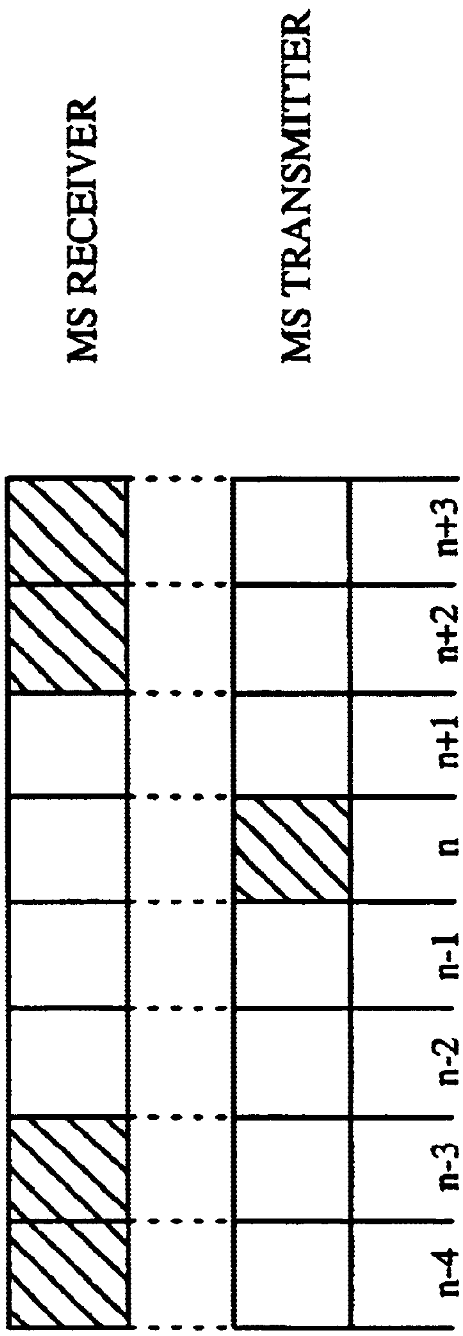


FIG. 6

METHOD AND AN APPARATUS FOR A QUICK RETRANSMISSION OF SIGNALS IN A COMMUNICATION SYSTEM

BACKGROUND OF THE INVENTION

I. Field of the Invention

The current invention relates to communication. More particularly, the present invention relates to a novel method and apparatus for quick retransmission of signals in a communication system.

II. Description of the Related Art

In a communication system, a communication channel through which signals travel between transmitting and receiving terminals is subject to various factors, changing characteristics of the communication channel. In wireless communication systems these factors comprise, but are not limited to: fading, noise, interference from other terminals, and the like. Consequently, despite extensive error control coding, certain packets are missed or received erroneously at a receiving terminal. Unless defined differently, a packet is a unit of a signal comprising a preamble, a payload, and a quality metric. Therefore, Automatic Retransmission reQuest (ARQ) schemes are often used at the link layer of communication systems to detect missing or erroneously received packets at the receiving terminal, and request retransmission of these packets at the transmitting terminal. An example of an ARQ is a Radio Link Protocol (RLP). RLP is a class of error control protocols known as NAK-based ARQ protocols, which are well known in the art. One such RLP is described in TIA/EIA/IS-707-A.8, entitled "DATA SERVICE OPTIONS FOR SPREAD SPECTRUM SYSTEMS: RADIO LINK PROTOCOL TYPE 2," hereinafter referred to as RLP2, and incorporated herein by reference.

Existing ARQ schemes achieve retransmission of missing or erroneously received packets by utilizing a sequence number unique to each packet. When a receiving terminal detects a packet with a sequence number higher than an expected sequence number, the receiving terminal declares packet(s) with sequence number(s) between the expected sequence number and the detected packet's sequence number missing or erroneously received. The receiving terminal then sends a control message requesting retransmission of the missing packets to a transmitting terminal. Alternatively, the transmitting terminal may resend the packet after a certain timeout interval if the transmitting terminal has not received a positive acknowledgement from the receiving terminal.

Consequently, existing ARQ schemes cause a large delay between the first transmission of a packet and a subsequent retransmission. The ARQ does not declare a particular packet missing or erroneously received until the next packet, containing a sequence number higher then an expected sequence number is received or until the time outinterval expires. This delay results in a large variance in the end-to-end delay statistics, which has a further detrimental effect on the network throughput. Transport layer protocols such as the transport control protocol (TCP) implement a congestion control mechanism, which reduces the number of outstanding packets in a network based on the variance of the round-trip delay estimate. In effect, larger variance of delay results in a reduction of the amount of traffic that is admitted into the network and a subsequent reduction in throughput of a communication system.

One approach to reducing the delay and the delay's variation is to avoid retransmissions by ensuring that the first

transmission is received correctly with high probability. However, this approach requires a large amount of power, which in turn reduces throughput.

Based on the foregoing, there exists a need in the art for an ARQ mechanism with low retransmission delay.

SUMMARY OF THE INVENTION

The present invention is directed to a method and an apparatus for quick retransmission (QARQ) of signals in a communication system.

In accordance with one aspect of the invention, a receiving terminal determines a quality metric of a packet of received signal. The receiving terminal immediately sends a short acknowledgement (SA) to a transmitting terminal in accordance with the quality metric of the packet. If the quality metric indicates that the packet was incorrectly received, then the SA is termed negative acknowledgement (NAK); otherwise, the SA is termed positive acknowledgement (ACK) or acknowledgement.

In another aspect of the invention, there exists a determinable relationship between a particular packet and the SA; therefore, there is no need for the SA to contain an explicit indication as to which packet is to be retransmitted.

In accordance with another aspect of the invention, the SA is a bit of energy.

In accordance with another aspect of the invention, the transmitting terminal attempts retransmission of the packet a predetermined number of times.

In accordance with yet another aspect of the invention, a conventional, sequence-number-based ARQ is employed together with the QARQ scheme.

BRIEF DESCRIPTION OF THE DRAWINGS

The features, objects, and advantages of the present invention will become more apparent from the detailed description set forth below when taken in conjunction with the drawings in which like reference characters identify correspondingly throughout and wherein:

FIG. **1** is a block diagram of an exemplary communication system.

FIG. **2** is an illustration of an exemplary forward link signal structure.

FIG. **3** is a flowchart of an exemplary method of data processing at the transmitting terminal.

FIG. **4** is a flowchart of an exemplary method of data processing at a receiving terminal.

FIG. **5** is a detailed block diagram of the communication system of FIG. **1**.

FIG. **6** is a diagram showing timing associated with packet processing at a receiving terminal in accordance with an embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

FIG. **1** illustrates an exemplary communication system **100** capable of implementing embodiments of the invention. A first terminal **104** transmits signals to a second terminal **106** over a forward link **108***a*, and receives signals from the second terminal **106** over a reverse link **108***b*. The communication system **100** can be operated bi-directionally, each of the terminals **104** and **106** operating as a transmitter unit or a receiver unit, or both concurrently, depending on whether data is being transmitted from, or received at, the terminal. In a wireless cellular communication system embodiment, the first terminal **104** can be a base station (BS), the second terminal **106** can be a mobile station (MS) such as a phone, a laptop computer, a personal digital assistant and the like. The forward link and reverse link can be electromagnetic spectra.

In general, a link comprises a set of channels carrying logically distinct types of information. These channels can be transmitted according to a time division multiplex (TDM) scheme, a code division scheme (CDM), or a combination of the two. In the TDM scheme, the channels are distinguished in time domain. The forward link consists of time slots in a periodic train of time intervals, and the channels are transmitted in the time slots. Consequently, the channels are transmitted one at a time. In the code division scheme, the channels are distinguished by a pseudorandom orthogonal sequence; consequently, the channels can be transmitted simultaneously. A code division scheme is disclosed in U.S. Pat. No. 5,103,459, entitled "SYSTEM AND METHOD FOR GENERATING SIGNAL WAVEFORMS IN A CDMA CELLULAR TELEPHONE SYSTEM" assigned to the assignee of the present application and incorporated by reference herein.

In one embodiment of the invention, a forward link comprises a set of channels, e.g., a pilot channel, a medium access channel, a traffic channel, and a control channel. The control channel is a channel carrying signals to be received by all MSs monitoring the forward link. In one embodiment of the invention, data being carried on the traffic channel, including both first time transmissions and quick retransmissions, can be demodulated without information provided on a control channel. In another embodiment, the control channel may carry information necessary for demodulation of the data being carried on the traffic channel. For a forward link signal structure of an exemplary embodiment of the invention, refer to FIG. **2**.

In one embodiment of the invention, the reverse link comprises a set of channels, e.g., a traffic channel and an access channel. The reverse traffic channel is dedicated to transmission from a single MS to the BSs comprising a network. The reverse access channel is used by the MSs to communicate with the BSs in the network when the MSs do not have traffic channel.

For simplicity, communication system **100** is shown to include one BS **104** and one MS **106** only. However, other variations and configurations of the communication system **100** are possible. For example, in a multi-user, multiple access communication system, a single BS may be used to concurrently transmit data to a number of MSs. In addition, in a manner similar to soft-handoff, disclosed in U.S. Pat. No. 5,101,501, entitled "METHOD AND SYSTEM FOR PROVIDING A SOFT HANDOFF IN COMMUNICATIONS IN A CDMA CELLULAR TELEPHONE SYSTEM," assigned to the assignee of the present application and incorporated by reference herein, a MS may concurrently receive transmissions from a number of BSs. The communication system of the embodiments described herein may include any number of BSs and MSs. Consequently, each of the multiple BSs is connected to a base station controller (BSC) **102** through a backhaul similar to backhaul **110**. The backhaul **110** can be implemented in a number of connection types including, e.g., a microwave or wire-line E1 or T1, or optical fiber. A connection **112** connects the wireless communication system **100** to a public switched data network (PSDN), which is not shown.

In an exemplary embodiment, each MS monitors signal quality metric of signals received from BSs. A MS (for

example MS **106**) receiving forward link signals from multiple BSs identifies the BS associated with the highest quality forward link signal (for (example BS **104**). The MS **106** then generates a prediction of a data rate at which the packet error rate (PER) of packets received from the selected BS **104** will not exceed a target PER. An exemplary embodiment uses a target PER of approximately 2%. The **106** then computes a rate at which a "tail probability" is greater than or equal to the target PER. The tail probability is the probability that the actual signal quality during the packet transmission period is less than the signal quality required for successful decoding of a packet correctly at a given rate. The MS **106** then sends a message on the reverse link specifically to the selected BS **104**, requesting data rate at which the specific selected base station may transmit forward link data to the MS **106**.

In one embodiment of the invention, the message is sent on a data rate control channel (DRC). DRC is disclosed in application Ser. No. 08/963,386 entitled: "A METHOD AND AN APPARATUS FOR HIGH RATE DATA TRANSMISSION," now U.S. Pat. No. 6,574,211, issued Jun. 3, 2003, assigned to the assignee of the present invention, and incorporated herein by reference.

In another embodiment of the invention, a dedicated reverse link medium access channel (R-MACCH) is utilized. The R-MACCH carries the DRC information, a reverse rate indicator (RRI) and a SA information.

In an exemplary embodiment, the BS **104** monitors the reverse channel from one or more MSs and transmits data on forward link to no more than one destination MS during each forward link transmit time slot. The BS **104** selects a destination MS (for example MS **106**) based on a scheduling procedure designed to balance the grade of service (GoS) requirements of each MS with the desire to maximize throughput of the system **100**. In an exemplary embodiment, the BS **104** transmits data to the destination MS **106** only at the rate indicated by the most recent message received from the destination MS. This restriction makes it unnecessary for the destination MS **106** to perform rate detection on the forward link signal. The MS **106** need only determine whether it is the intended destination MS during a given time slot.

In an exemplary embodiment, BSs transmit a preamble within the first time slot of each new forward link packet. The preamble identifies the intended destination MS. Once a destination MS establishes that it is the intended destination for data in a slot, the MS begins decoding the data in the associated time slot. In an exemplary embodiment, the destination MS **106** determines the data rate of the data in the forward link based on the request message the MS **106** sent. The number of forward link time slots used to transmit a packet varies based on the data rate at which the packet is sent. Packets sent at a lower rate are sent using a greater number of time slots.

Once the MS **106** determines that the data are intended for the MS **106**, the MS **106** decodes the packet and evaluates a quality metric of the received packet. Quality metric of a packet is defined by a formula in accordance with a content of the packet, e.g., a parity bit, a cyclic redundancy check (CRC), and the like. In one embodiment of the invention, the quality metric is a CRC. The evaluated quality metric and the quality metric contained in the received packet are compared, and based on the comparison an appropriate SA is generated. As discussed with reference to FIG. **5**, the SA in an exemplary embodiment can comprise only one bit.

In one embodiment, the SA is ACK based, i.e., an ACK message is sent from a MS to a BS if a packet is correctly decoded and no message is sent is the packet is incorrectly decoded.

In another embodiment the SA is NAK based, i.e., a NAK message is sent from a MS to a BS if a packet is incorrectly decoded and no message is sent is the packet is correctly decoded. An advantage of this approach is that high reliability and low noise interference with other reverse links, as well as energy saving at the MS can be achieved. As discussed, because a BS is transmitting a packet intended to only one MS, at most this MS sends NAK, thus achieving a low interference on the reverse link. In a well-designed system, the probability of the MS incorrectly decoding the packet is low. Furthermore, if the NAK is a bit of zero energy, the NAK contains low energy. Therefore, the MS can allocate large amounts of power to the infrequent transmission of the NAK bit.

In yet another embodiment, an ACK is a first value of energy and a NAK is a second value of energy.

The SA is then sent to the BS **104** over a channel on the reverse link **108***b*. In one embodiment of the invention, the reverse link channel is a DRC.

In another embodiment of the invention, a code channel orthogonal to the reverse link can be advantageously utilized. Because a BS is transmitting a packet intended for only one MS, at most this MS sends a SA, thus achieving a low interference on the reverse link. In a well-designed system, the probability of the MS incorrectly decoding the packet is low. Furthermore, if the SA is an ACK as a bit of zero energy or a NAK as a bit of zero energy, the orthogonal channel contains low energy. Therefore, the MS can allocate large amount of power to the infrequent transmission of the SA bit, guaranteeing high reliability and low interference with the reverse link.

In yet another embodiment of the invention, a dedicated reverse link medium access channel (R-MACCH) is utilized. The R-MACCH carries the DRC, the RRI and the ACK/NAK information.

The BS **104** detects the SA and determines whether a retransmission of the packet is necessary. If the SA indicates that a retransmission is necessary, the packet is scheduled for retransmission, otherwise, the packet is discarded.

In an exemplary embodiment, the aforementioned QARQ scheme cooperates with the RLP as will be disclosed in the following description.

FIG. **2** shows the forward link signal structure transmitted by each base station in an exemplary high data rate system. Forward link signals are divided into fixed-duration time slots. In an exemplary embodiment, each time slot is 1.67 milliseconds long. Each slot **202** is divided into two half-slots **204**, with a pilot burst **208** transmitted within each half-slot **204**. In an exemplary embodiment, each slot is 2048 chips long, corresponding to a 1.67 millisecond slot duration. In an exemplary embodiment, each pilot burst **208** is 96 chips long, and is centered at the mid-point of its associated half-slot **204**. A reverse link power control (RPC) signal **206** is transmitted to either side of the pilot burst in every second half-slot **204***b*. In an exemplary embodiment, the RPC signal is transmitted in the 64 chips immediately before and the 64 chips immediately after the second pilot burst **208***b* of each slot **202**, and is used to regulate the power of the reverse link signals transmitted by each subscriber station. In an exemplary embodiment, forward link traffic channel data are sent in the remaining portions of the first half-slot **210** and the remaining portions of the second half-slot **212**. In an exemplary embodiment, preamble **214** is 64 chips long and is transmitted with each packet. Because the traffic channel stream is intended for a particular MS, the preamble is MS specific.

In an exemplary embodiment, a control channel is transmitted at a fixed rate of 76.8 kbps and the control channel is time division multiplexed on the forward link. Because the control channel messages are directed to all MSs, the control channel's preamble is recognizable by all the MS.

FIG. **3** is an exemplary flowchart of a method for a BS using QARQ to transmit or retransmit a packet to a MS. At step **300**, the BS receives a payload unit intended for transmission to a MS.

At step **302** the BS determines whether the payload unit is a payload unit to be transmitted or a payload unit to be retransmitted. As discussed with reference to FIG. **1**, the retransmission request can be initiated only by the RLP at this step.

If the payload unit is to be transmitted, the method continues in step **304**, in which the payload unit is provided to a first time queue.

If the payload unit is to be retransmitted, the method continues in step **306**, in which the payload unit is provided to a first time queue.

At step **308**, the BS assembles payload units intended for a particular MS to a packet a structure of which is determined in accordance with a transmission data rate. The data rate at which the packet is sent is based on a feedback signal received over the reverse link from the destination MS. If the data rate is small, then the packet (called a multiple-slot packet) of data is transmitted in multiple forward link time slots. In an exemplary embodiment, a preamble is transmitted within a new packet. The preamble enables identification of the intended destination MS during decoding. In an exemplary embodiment, only the first time slot of the multiple-slot packet is transmitted with the preamble. The preamble could alternatively be transmitted in every forward link time slot.

At step **310**, the BS transmits the packet in accordance with a scheduler order as discussed with reference to FIG. **1**.

After the packet has been transmitted, the BS tests at step **312** if a SA corresponding to the transmitted packet was received. As disclosed with reference to FIG. **6**, the BS knows when to expect the SA.

If an ACK is received (or a NAK is not received) in the expected time slot, the method continues at step **314**. At step **314**, the packet is removed from the first time slot and the retransmission queues, and the packet is discarded.

If a NAK is received (or an ACK is not received) in the expected time slot, the method continues at step **316**. At step **316**, parameters controlling retransmission are tested. The parameters assure that a particular packet will not be retransmitted repeatedly, thus increasing buffer requirements and decreasing throughput of a communication system. In one embodiment, the parameters comprise, e.g., the maximum number of times a packet can be retransmitted and the maximum time for which a packet can remain in the first-time queue after the packet has been transmitted. If the parameters were exceeded, the packet is removed from the first time and the retransmission queues, and the packet is discarded at step **318**. In this scenario, the QARQ retransmission processing ends, and the packet may be retransmitted upon request from the RLP processor as discussed with reference to FIG. **6**. If the parameters were not exceeded, the packet is rescheduled for retransmission at step **320**.

FIG. **4** is an exemplary flowchart of a method for a MS using QARQ to generate a response to a BS. At step **400**, the MS receives a packet from the BS.

At step **402**, the preamble of the packet is extracted. The preamble is compared with a reference preamble at step **404**.

The packet is discarded if the preamble indicates that the packet is intended for another MS at step **406**, and the flow returns to step **400** to wait for another packet. If the preamble indicates that the packet is intended for the MS, the MS decodes the packet and evaluates a quality metric of the received packet at step **408**.

At step **410**, the evaluated quality metric and the quality metric contained in the received packet are compared. If the evaluated quality metric and the quality metric contained in the received packet do not match, an appropriate SA is sent at step **412**. In the exemplary embodiment, the SA is a NAK, represented by a bit of non-zero energy. A timer for the SA sent is started at step **414**. The purpose of the timer is to limit a period for which the MS waits for retransmission of the payload units of the incorrectly decoded packet. In the exemplary embodiment, if the payload units of the incorrectly decoded packet are not received within the timer expiration period for the NAK associated with the incorrectly decoded packet, the QARQ processing is aborted, and the RLP handles the missing payload units. See steps **416**–**432** and accompanying description.

If a packet was correctly decoded at step **410**, an appropriate SA is sent at step **416**. In an exemplary embodiment, the SA is a bit of no energy. The payload unit(s) contained in the packet are then stored in a buffer at step **418**.

At step **420**, the RLP sequence number of the payload units is tested against expected values of the RLP sequence number.

If the RLP sequence number indicates contiguity, it means that all the payload units of the packet transmitted to the MS were properly received. Consequently, all the payload units with contiguous sequence numbers contained in the buffer are provided to an RLP layer at step **420**.

If the RLP sequence number indicates non-contiguity, the timer, corresponding to the last NAK sent (which was started at step **414**), is checked at step **422**. If the timer has not expired, the MS waits for retransmission of the missing payload units or expiration of the timer for the last NAK sent.

If the timer for a particular NAK, and, consequently a particular set of missing payload unit expired, the QARQ scheme for these payload units is aborted. All payload units stored in the buffer with sequence number higher than the missing payload units associated with the particular NAK and lower than the missing units associated with the next NAK (if any) are provided to an RLP layer at step **424**.

At step **426**, the RLP layer checks the sequence numbers of the delivered payload units. If the sequence number indicates contiguity, the RLP layer delivers data from the buffer to a data sink at step **428**. Otherwise, the RLP layer generates RLP messages requesting retransmission of the missing units at step **430**. In one embodiment of the invention, the RLP message requests retransmission of all of the missing units in the buffer. In another embodiment, the message requests retransmission of only the latest detected missing payload units.

At step **432**, the message is transmitted over the reverse link to the serving BS.

FIG. **5** shows a detailed block diagram of the communication system **100** of FIG. **1**. Data to be delivered to the MS **106** arrive at the BSC **102** through the connection **112** from the PSDN (not shown). The data are formatted into payload units under the control of a RLP processor **504**. Although an RLP processor is shown in the embodiment, other protocols, allowing retransmission based on sequence number methods can be utilized. In one embodiment of the invention, the payload unit is 1024 bits long. The RLP processor **504** also supplies a distributor **502** with information as to which packets have been requested for retransmission. The retransmission request is delivered to the RLP processor **504** through the RLP message. The distributor **502** distributes payload units through a backhaul to the BS, which serves the MS for which the data are intended. The distributor **502** receives information about location of the MS from the BS which serves the MS through the backhaul.

The payload units that arrived at the BS **104** through the backhaul **110** are provided to a distributor **506**. The distributor **506** tests whether the payload units are new payload units or payload units provided by the RLP processor **504** for retransmission. If the payload units are to be retransmitted, the payload units are provided to a retransmission queue **510**. Otherwise, the payload units are provided to a first time queue **508**. The payload units are then assembled into packets in accordance with a data rate requested by the MS **106**, as described with reference to FIG. **1**.

Assembled packets are provided to a scheduler **512**. The scheduler **512** cooperates with a QARQ controller **518** on assigning priority between the first time packets and the packets intended for retransmission to the MS **106**. The packet transmitted to the MS **106** remains in the queues **508** and **510**, while the BS **104** waits for a SA from the MS **106**.

The packets arriving at the MS **106** over the forward link **108***a* are provided to a preamble detector **520**, which detects and decodes a preamble of the packets. The preamble is provided to a processor **521**, which compares the decoded preamble to a reference preamble. The packet is discarded if the preamble indicates that the packet is intended for another MS; otherwise, the packet is provided to a decoder **522**, which decodes the packet. The decoded packet is provided to a processor **521**, which evaluates a quality metric of the packet. The evaluated quality metric and the quality metric contained in the received packet are compared, and based on the comparison, an SA generator **526** generates an appropriate SA. Though the preamble detector **520**, the decoder **522**, and the processor **521** are shown as separate elements, one skilled in the art will appreciate that the physical distinction is made for explanatory purposes only. The preamble detector **520**, the decoder **522**, and the processor **521** may be incorporated into, single processor accomplishing the above-mentioned processing.

If a packet was incorrectly decoded, i.e., the evaluated quality metric and the quality metric contained in the received packet do not match, the SA is sent and a timer **530** for the SA is started. In the exemplary embodiment, the SA is a NAK represented by a bit of non-zero energy. The purpose of the timer **530** is to limit a period, for which the MS **106** waits for retransmission of the payload units of the incorrectly decoded packet. If the payload units of the incorrectly decoded packet are not received within the timer **530** expiration period for the NAK associated with the incorrectly decoded packet, the QARQ processing is aborted. A retransmission of the missing payload units is handled by an RLP.

If a packet was correctly decoded, the payload unit(s) contained in the packet are stored in a buffer **528**. The RLP sequence number of the payload unit(s) contained in the packet is checked by the decoder **522** against an expected value of the RLP sequence number. If the RLP sequence number indicates contiguity, all the payload units with contiguous sequence numbers contained in the buffer **528** are provided to a RLP processor **526**. Otherwise, the timer **530**, corresponding to the last NAK sent, is checked. If the time has not expired, the payload units are stored in the buffer **528**, and the MS **106** waits for retransmission of the missing payload units or expiration of the timer **530** for the last NAK sent. If the timer **530** for a particular NAK, and, consequently a particular set of missing payload unit expired, all payload units in the buffer **528** with sequence number higher than the missing units associated with the particular NAK and lower than the missing units associated with the next NAK—if any—are provided to a RLP processor **526**.

The RLP processor **526** checks the sequence numbers of the delivered payload units. If the sequence number indicates contiguity, the RLP processor **524** delivers data from the buffer **528** to the data sink **534**. Otherwise, the RLP processor **526** instructs RLP message generator **532** to generate RLP message requesting retransmission of the missing units. In one embodiment of the invention, the RLP message requests retransmission of all of the missing units in the buffer **528**. In another embodiment, the message requests retransmission of only the latest detected missing payload units. The message is then transmitted over the reverse link **108***b* to the BS **104**.

The data containing a SA and arriving at the BS **104** over the reverse link are provided to a SA detector **514** and an RLP message detector **516**.

If the received data contain an ACK, which is detected in a SA detector **514**, the QARQ controller **518** removes the packet associated with the ACK from the queues **508** and **510**.

If a NAK is received, the QARQ controller **518** checks whether parameters controlling retransmission were exceeded. In the exemplary embodiment, the parameters comprise a maximum number of times a packet can be retransmitted and a maximum time for which a packet can remain in the first-time queue **508** after the packet has been transmitted. If the parameters were exceeded, the QARQ controller **518** removes the packet form the queues **508** and **510**. Otherwise, the QARQ controller **518** instructs the scheduler **512** that the packet be rescheduled for transmission with higher priority. The packet is moved from the first-time queue **508** to the retransmission queue **510** if the QARQ controller **518** determines that the non-acknowledged packet resides in the first time queue **510**.

If the received data contain an RLP retransmission request, which is detected by an RLP message detector **516**, the RLP message detector **516** provides the RLP message to the RLP processor **504** through the backhaul **110**. The RLP processor then initiates the procedure for re-transmitting the packet in accordance with the RLP implemented.

FIG. **6** illustrates a relationship between a packet received at a MS **106** and a SA transmitted from the MS **106**. In slots n−4, n−3, a receiver at the MS **106** receives a packet over the forward channel link **108***a*, and determines if the packet was intended for the MS **106**. The MS **106** discards the packet if the packet was not intended for the MS **106**. Otherwise, the MS **106** decodes the packet, evaluates a quality metric of the packet, and compares the evaluated quality metric with the quality metric contained in the packet in slots n−2, n−1. In slot n, a transmitter at the MS **106** sends a SA back to the BS **104** over the reverse channel link **108***b*. In slot n+1, the SA received at the BS **104** is decoded and provided to a QARQ controller. In slots n+2, n+3 the BS **104** retransmits the packet if so requested. The position of the slots on the received forward link channel **108***a* and the reverse link channel **108***b* is synchronized at the MS **106**. Therefore, the relative position of slots on the forward channel link **108***a* and the reverse channel link **108***b* is fixed. The BS **104** can measure a round trip delay between the BS **104** and the MS **106**. Consequently, the time slot in which the SA must arrive at the BS **104** can be ascertained, provided that a relation between the received packet processing and the SA is determinable.

In one embodiment of the invention, the relation between the received packet processing and the SA is determinable by fixing the number of slots between receiving a packet and sending a SA back, i.e., slots n−2, n−1. Consequently, the BS **104** can associate each packet with each SA. One skilled in the art will understand that FIG. **5** is meant only to illustrate the concept. Consequently, the number of slots allocated for a particular event may change, e.g., decoding and evaluating of a packet's quality metric may occur in more or less than two slots. Furthermore, certain events are inherently variable, e.g., length of a packet, delay between the SA reception and the packet retransmission.

In another embodiment of the invention, the relation between the received packet processing and the SA is determinable by including information as to which packet is to be retransmitted into the SA.

The previous description of the preferred embodiments is provided to enable any person skilled in the art to make or use the present invention. The various modifications to these embodiments will be readily apparent to those skilled in the art, and the generic principles defined herein may be applied to other embodiments without the use of the inventive faculty. Thus, the present invention is not intended to be limited to the embodiments shown herein, but is to be accorded the widest scope consistent with the principles and novel features disclosed herein.

What is claimed is:

1. An apparatus configured to retransmit signals in a communication system, comprising:

a decoder configured to decode contents of a unit of received signal;

a first feedback signal generator configured to generate a first feedback signal; and

a first processor configured to determine a quality metric of said unit of signal, to instruct said feedback signal generator to generate a feedback signal in accordance with said quality metric, and to prevent decoding of said unit of signal if an indication received on a control channel indicates that said unit of signal is not to be decoded.

2. The apparatus of claim **1** wherein the unit of signal is a packet.

3. The apparatus of claim **1** wherein the quality metric is a cyclic redundancy check.

4. The apparatus of claim **1** wherein said decoder decodes contents of said unit of signal in accordance with information carried on a control channel.

5. The apparatus of claim **1** wherein said first feedback signal is a burst of energy.

6. The apparatus of claim **5** wherein said burst of energy is a bit.

7. The apparatus of claim **1** wherein said first feedback signal contains no energy.

8. The apparatus of claim **7** wherein said first feedback signal is a bit.

9. The apparatus of claim **1** wherein the first processor is further configured to transmit said first feedback signal at a determinable time instant.

10. The apparatus of claim **9** wherein said determinable time instant is fixedly delayed from an event time instant, said event time instant being selected from a group consisting of:

a time instant when said unit of signal is received;

a time instant when said determination if said unit of signal is to be demodulated is made;

a time instant when said unit of signal is demodulated; and

a time instant when said quality metric is computed.

11. An apparatus configured to retransmit signals in a communication system, comprising:

a decoder configured to decode contents of a unit of received signal;

a first feedback signal generator configured to generate a first feedback signal;

a first processor configured to determine a quality metric of said unit of signal; and instruct said feedback signal generator to generate a feedback signal in accordance with said quality metric; and

a preamble detector configured to detect and decode a preamble of said unit of signal; and wherein said first processor is further configured to prevent decoding of said unit of signal if said preamble indicates that said unit of signal is not to be decoded.

12. The apparatus of claim 11 wherein the unit of signal is a packet.

13. The apparatus of claim 11 wherein the quality metric is a cyclic redundancy check.

14. The apparatus of claim 11 wherein said decoder decodes contents of said unit of signal in accordance with information carried on a control channel.

15. The apparatus of claim 11 wherein said first feedback signal is a burst of energy.

16. The apparatus of claim 15 wherein said burst of energy is a bit.

17. The apparatus of claim 11 wherein said first feedback signal contains no energy.

18. The apparatus of claim 17 wherein said first feedback signal is a bit.

19. The apparatus of claim 11 wherein the first processor is further configured to transmit said first feedback signal at a determinable time instant.

20. The apparatus of claim 19 wherein said determinable time instant is fixedly delayed from an event time instant, said event time instant being selected from a group consisting of:

a time instant when said unit of signal is received;

a time instant when a determination as to whether said unit of signal is to be demodulated is made;

a time instant when said unit of signal is demodulated; and

a time instant when said quality metric is computed.

21. An apparatus configured to retransmit signals in a communication system, comprising:

a decoder configured to decode contents of a unit of received signal;

a first feedback signal generator configured to generate a first feedback signal;

a first processor configured to determine a quality metric of said unit of signal; and instruct said feedback signal generator to generate a feedback signal in accordance with said quality metric;

a second feedback signal generator for generating a second feedback signal; and

a second processor configured to instruct said second feedback generator to generate a second feedback signal in accordance with a sequence number of said unit of signal when said retransmission of said signal in accordance with said quality metric is declared a failure.

22. The apparatus of claim 21 further comprising means for declaring said retransmission of said signal in accordance with said quality metric a failure when:

said unit of signal is not received within a predetermined number of retransmissions; or

said unit of signal is not received within a predetermined period measured from a first transmission of said unit of signal; or

said unit of signal is not received within a predetermined period measured from transmission of a request signal corresponding to said unit of signal.

23. The apparatus of claim 21 wherein the unit of signal is a packet.

24. The apparatus of claim 21 wherein the quality metric is a cyclic redundancy check.

25. The apparatus of claim 21 wherein said decoder decodes contents of said unit of signal in accordance with information carried on a control channel.

26. The apparatus of claim 21 wherein said first feedback signal is a burst of energy.

27. The apparatus of claim 26 wherein said burst of energy is a bit.

28. The apparatus of claim 21 wherein said first feedback signal contains no energy.

29. The apparatus of claim 28 wherein said first feedback signal is a bit.

30. The apparatus of claim 21 wherein the first processor is further configured to transmit said first feedback signal at a determinable time instant.

31. The apparatus of claim 30 wherein said determinable time instant is fixedly delayed from an event time instant, said event time instant being selected from a group consisting of:

a time instant when said unit of signal is received;

a time instant when a determination as to whether said unit of signal is to be demodulated is made;

a time instant when said unit of signal is demodulated; and

a time instant when said quality metric is computed.

32. An apparatus for retransmission of signals in a communication system, comprising:

a data queue for storing a plurality of units of signal to be transmitted;

a scheduler for scheduling a transmission of said units of signal to a destination receiving terminal;

a first detector for detecting a first feedback signal received from the destination receiving terminal; and

a first control processor configured to receive said first feedback signal, select a unit of signal which was transmitted at a time instant preceding a time instant of receiving said first feedback signal by a sum of a round trip delay and a determinable delay, and schedule said unit of signal for retransmission, wherein the determinable delay is a difference between a first time instant of transmitting said retransmission request and a second time instant, said second time instant being selected from a group consisting of:

a time instant when said unit of signal is received;

a time instant when a determination as to whether said unit of signal is to be demodulated is made;

a time instant when said unit of signal is demodulated; and

a time instant when a quality metric of said unit of signal is computed.

33. The apparatus of claim 32 wherein the determinable delay is contained in the first feedback signal.

34. The apparatus of claim 32 wherein the first processor is further configured to determine a time instant at which to retransmit said unit of signal, said time instant being variably delayed from receipt of said first feedback signal.

35. The apparatus of claim 32 wherein the first processor is further configured to determine a time instant at which to

retransmit said unit of signal, said time instant being fixedly delayed from receipt of said first feedback signal.

36. The apparatus of claim **32** further comprising:

a second detector for detecting a second feedback signal received from the destination receiving terminal; and

a second control processor configured to receive said second feedback signal, select a unit of signal in accordance with said second feedback signal, and schedule said unit of signal for retransmission.

37. The apparatus of claim **36** wherein the second feedback signal contains sequence numbers of said unit of signal to be retransmitted.

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