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Method for physical layer automatic repeat request for a subscriber unit

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2002313803

(71) Applicant(s)
InterDigital Technology Corporation

(72) Inventor(s)
Kwak, Joseph A

(74) Agent/Attorney
Watermark Patent & Trademark Attorneys, 290 Burwood Road, Hawthorn, VIC, 3122

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ABSTRACT

A method and apparatus for physical automatic repeat request by a subscriber unit (38). A physical layer at the transmitter receivers data (34a) and at the transmitters (42) formats the received data into packets having a particular encoding/data modulation. The physical layer contains n channels (41) which transmit the packets and retransmits packets upon failure to receive a corresponding acknowledgment for a given packet at an acknowledgement receiver (56). The subscriber unit (38) collects retransmission statistics and adjusts the particular encoding/data modulation at the transmitters (42) using the collected statistics.

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COMPLETE SPECIFICATION

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Invention Title: **Method for physical layer automatic repeat request for a subscriber unit**

The following statement is a full description of this invention, including the best method of performing it known to us:

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METHOD FOR PHYSICAL LAYER AUTOMATIC REPEAT REQUEST FOR A SUBSCRIBER UNIT

BACKGROUND

The present invention relates to wireless communication systems. More particularly, it relates to a modification to such systems by employing a physical layer (PHY) automatic repeat request (ARQ) scheme.

Proposed broadband fixed wireless access (BFWA) communication systems, using either single carrier-frequency domain equalization (SC-FDE) or orthogonal frequency division multiplex (OFDM) plan on using a high speed downlink packet access (HSDPA) application. This application will transmit downlink packet data at high speeds. In BFWA, a building or group of buildings are connected, either wirelessly or wired, and operate as a single subscriber site. The data demand for such a system is quite high for the single site's multiple end users requiring large bandwidths.

The current proposed system employs a layer 2 automatic repeat request (ARQ) system. Data blocks unsuccessfully transmitted to the subscribers are buffered and retransmitted from layer 2. The data blocks stored in layer 2 are typically large, are transmitted for high signal to noise ratio (SNR) reception, are received with a low block error rate (BLER), and are infrequently retransmitted. Additionally, layer 2 ARQ signaling is typically slow requiring large buffers and long retransmission intervals.

Accordingly, it is desirable to have alternatives in addition to a layer 2 ARQ system.

SUMMARY

A physical automatic request repeat system comprises a transmitter and a receiver. A physical layer transmitter, at the transmitter, receives data and formats the received data into packets having a particular encoding/data modulation. The physical

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layer transmitter contains n channels which transmit the packets and retransmits packets in response to not receiving a corresponding acknowledgment for a given packet. An adaptive modulation and coding controller in the transmitter collects retransmission statistics and adjusts the particular encoding/data modulations using the collected statistics. The receiver has a physical layer n-channel receiver for receiving the packets. The receiver contains an n-channel hybrid ARQ combiner/decoder which combines packet transmissions, decodes packets and detects packet errors. The receiver contains an acknowledgment transmitter which transmits an acknowledgment for each packet, if that packet has an acceptable error rate. The receiver contains an in-sequence delivery element which delivers acceptable packets to higher layers.

BRIEF DESCRIPTION OF THE DRAWINGS

Figures 1a and 1b are simplified block diagrams of downlink and uplink physical ARQs.

Figure 2 is a flow chart for using retransmission statistics for adaptive modulation and coding.

Figure 3 is block diagram showing a multi-channel stop and wait architecture.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Figures 1a and 1b respectively show a downlink physical ARQ 10 and uplink physical ARQ 20.

The downlink physical ARQ 10 comprises a base station 12 receiving packets from the higher layer ARQ transmitter 14a provided in network 14. The packets from transmitter 14a are applied to the physical layer ARQ transmitter 12a in base station 12. The ARQ transmitter 12a encodes the data with a forward error correcting code (FEC), appends error check sequences (ECSs), modulates the data as directed by the adaptive modulation and coding (AMC) controller 12c, such as by using binary phase shift keying (BPSK), quadrature phase shift keying (QPSK) or m-ary quadrature amplitude modulation (i.e. 16-QAM or 64-QAM). Additionally, for orthogonal frequency division multiple access (OFDMA), the AMC controller 12a may vary the subchannels used to carry the packet data. The physical layer ARQ transmitter 12a transmits packets to the subscriber unit 16 through air interface 14 by way of switch, circulator or duplexor 12d and antenna 13. The transmitter 12a also temporarily stores the message for retransmission, if necessary, in a buffer memory incorporated in the transmitter 12a.

[0016] Antenna 15 of subscriber unit 16 receives the packet. The packet is input into physical layer ARQ receiver 16a through switch, circulator or duplexor 16b. At the receiver 16a, the packet is FEC decoded and checked for errors using the ECS. The receiver 16a then controls acknowledgment transmitter 16c to either acknowledge (ACK) receipt of a packet with an acceptable error rate or to request retransmission by, preferably, withholding an acknowledgment signal or transmitting a negative acknowledgment (NAK).

[0017] The ACK is sent by ACK transmitter 16c to the base station 12 through switch 16b and antenna 15. The ACK is sent via the air interface 14 to antenna 13 of base station 12. The received ACK is processed by an acknowledgment receiver 12b in the base station. The ACK receiver 12b delivers the ACK/NAKs to the adaptive modulation and coding (AMC) controller 12c and to the transmitter 12a. The AMC controller 12c analyzes the channel quality to the subscriber unit 16 using statistics of the received ACKs and may vary the FEC encoding and modulation techniques of subsequent transmissions of the message, as will be described in more detail. If the subscriber unit 16 acknowledges receipt of the packet, receipt of this ACK at base station 12 causes the original packet, which was temporarily stored in a buffer memory, to be cleared in readiness for the next packet.

[0018] If no ACK is received or a NAK is received, the physical layer transmitter 12a retransmits the original message or selectively modified version of the original message to subscriber 16. At the subscriber unit 16, the retransmission is combined with the original transmission, if available. This technique facilitates receipt of a correct message by use of data redundancy or selective repeat combining. The packets having an acceptable error rate are transferred to higher layers 16d for further processing. The acceptable received packets are delivered to the higher layers 16d in the same data order in which the data was provided to transmitter 12a in the base station (i.e. in-sequence delivery). The maximum number of retransmissions is limited to an operator-defined integer value, such as in the range of 1 to 8. After the maximum number of retransmissions are attempted, the buffer memory is cleared for use by the next packet. Decoding an acknowledgment using small packets at the physical layer reduces transmission delays and message handling time.

[0019] Since PHY ARQ occurs at the physical layer, the number of retransmission occurrences for a particular channel, retransmission statistics, is a good measure of that channel's quality. Using the retransmission statistics, the AMC controller 12c may vary the modulation and coding schemes for that channel, as shown in Figure 2. Additionally, the retransmission statistics can also be combined with other link quality measurements, such as bit error rates (BERs) and block error rates (BLERs), by the AMC controller 12c to gauge the channel quality and determine whether a change in the modulation and coding scheme is required.

[0020] To illustrate for SC-FDE, the retransmission occurrences for a particular channel are measured to produce retransmission statistics, (60). A decision on whether to change the modulation scheme is made using the retransmission statistics, (62). If the retransmissions are excessive, a more robust coding and modulation scheme is used, (64), usually at a reduced data transfer rate. The AMC controller 12c may increase the spreading factor and use more codes to transfer the packet data. Alternately or additionally, the AMC controller may switch from a high data throughput modulation scheme to a lower one, such as from 64-QAM to 16-QAM or QPSK. If the rate of retransmissions is low, a switch to a higher capacity modulation

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scheme is made, such as from QPSK to 16-ary QAM or 64-ary QAM, (66). The decision preferably uses both the retransmission rate and other link quality measurements signaled from the receiver, such as BER or BLER, (62). The decision limits are preferably set by the system operator.

[0021] For OFDMA, the retransmission occurrences are used to monitor the channel quality of each subchannel. If the retransmission rate or retransmission rate/link quality for a particular subchannel indicates poor quality, that subchannel may be selectively nulled from the OFDM frequency set, (64), in order to preclude use of such poor quality subchannels for some future period. If the retransmission rate or retransmission rate/link quality indicates high quality, a previously nulled subchannels may be added back to the OFDM frequency set, (66).

[0022] Using the retransmission occurrences as a basis for AMC provides a flexibility to match the modulation and coding scheme to the average channel conditions for each user. Additionally, the retransmission rate is insensitive to measurement error and reporting delay from the subscriber unit 16.

[0023] The uplink ARQ 20 is similar in nature to the downlink ARQ 10 and is comprised of a subscriber unit 26 in which packets from a higher layer ARQ transmitter 28a of the higher layers 28 are transferred to physical layer ARQ transmitter 26a. The message is transmitted to the base station antenna through switch 26d, subscriber antenna 25 and air interface 24. The AMC controller, likewise, may vary the modulation and coding scheme using the retransmission statistics of a channel.

[0024] Physical layer ARQ receiver 22a, similar to receiver 16a of Figure 1a, determines if the message has an acceptable error rate requiring retransmission. The acknowledgment transmitter reports status to subscriber unit 26, causing the transmitter 26a to retransmit or alternatively to clear the original message temporarily stored at transmitter 26a in readiness to receive the next message from the higher layers 28. Successfully received packets are sent to the network 24 for further processing.

[0025] Although not shown for purposes of simplicity, the system is preferably used for a HSDPA application in a BFWA system, although other implementations may be used. The BFWA system may use frequency division duplex or time division duplex SC-FDE or OFDMA. In such a system, the base station and all of the subscribers are in fixed locations. The system may comprise a base station and a large number of subscriber units. Each subscriber unit may serve multiple users within one building or several neighboring buildings, for example. These applications typically require a large bandwidth due to the large number of end users at one subscriber unit site.

[0026] A PHY ARQ deployed in such a system is transparent to the higher layers, such as the medium access controllers (MACs). As a result, PHY ARQ can be used in conjunction with higher layer ARQs, such as layer 2. In such cases, the PHY ARQ reduces the retransmission overhead of the higher layer ARQs.

[0027] Figure 3 is an illustration of an N-channel stop and wait architecture for a PHYARQ 30. The Physical Layer ARQ transmit function 38 may be located at the base station, subscriber unit or both depending on whether downlink, uplink or both PHYARQs are used. Blocks 34a of data arrive from the network. The network blocks are placed in a queue 34 for transmission over the data channel 41 of the air interface 43. An N-channel sequencer 36 sends data of the blocks sequentially to the N transmitters 40-1 to 40-n. Each transmitter 40-1 to 40-n is associated with a transmit sequence in the data channel 41. Each transmitter 40-1 to 40-n FEC encodes and provides ECS for the block data to produce packets for AMC modulation and transmission in the data channel 41. The FEC encoded/ECS data is stored in a buffer of the transmitter 40-1 to 40-n for possible retransmission. Additionally, control information is sent from the PHYARQ transmitter 38 to synchronize reception, demodulation and decoding at the receivers 46-1 to 46-n.

[0028] Each of the N receivers 46-1 to 46-n receives the packet in its associated timeslot. The received packet is sent to a respective hybrid ARQ decoder 50-1 to 50-n

(50). The hybrid ARQ decoder 50 determines the error rate, such as BER or BLER, for the received packet. If the packet has an acceptable error rate, it is released to the higher levels for further processing and an ACK is sent by the ACK transmitter 54. If the error rate is unacceptable or no packet was received, no ACK is sent or a NAK is sent. Packets with unacceptable error rates are buffered at the decoder 50 for potential combining with a retransmitted packet.

[0029] One approach for combining packets using turbo codes is as follows. If a turbo encoded packet is received with an unacceptable error rate, the packet data is retransmitted to facilitate code combining. The packet containing the same data is encoded differently. To decode the packet data, both packets are processed by the turbo decoder to recover the original data. Since the second packet has a different encoding, its soft symbols are mapped to different points in the decoding scheme. Using two packets with different encoding adds coding diversity and transmission diversity to improve the overall BER. In another approach, the identical signal is transmitted. The two received packets are combined using a maximum ratio combining of symbols. The combined signal is subsequently decoded.

[0030] The ACK for each receiver 46-1 to 46-n is sent in a fast feedback channel (FFC) 45. The fast feedback channel 45 is preferably a low latency channel. For a time division duplex system, the ACKs may be sent in idle periods between upstream and downstream transmissions. The FFC 45 is preferably a low speed, high bandwidth CDMA channel overlaying other in-band transmissions. The FFC CDMA codes and modulations are selected to minimize interference to other in-band transmissions. To increase the capacity of such a FFC 45, multiple codes may be used.

[0031] The ACK receiver 56 detects the ACKs and indicates to the corresponding transmitter 40-1 to 40-n whether the ACK was received. If the ACK was not received, the packet is retransmitted. The retransmitted packet may have a different modulation and coding scheme as directed by the AMC controller 12c, 26c.

If the ACK is received, the transmitter 40-1 to 40-n clears the previous packet from the buffer and accepts a subsequent packet for transmission.

[0032] The number of transmitters and receivers N is based on various design considerations, such as the channel capacity and ACK response time. For the preferred system previously described, a 2-channel architecture is preferably utilized, with even and odd transmitters and receivers.

[0033] The PHY ARQ technique of the preferred embodiment provides a 7 db gain in signal to noise ratio (SNR) as compared to a system using only higher layer ARQ. This occurs by operating at higher block error rates (BLERs) (5-20% BLER) and using smaller block sizes for layer 1 than is practical with higher layer ARQ alone. The decreased SNR requirement allows for: increased capacity by switching to high order modulation employing an adaptive modulation and coding (AMC) technique; lower customer premise equipment (CPE) costs by using lower grade RF (radio frequency) components with the PHY ARQ compensating for reduced implementation performance; increased downlink range which extends the cell radius; reduced downlink power in the base station (BS) to minimize cell-cell interference; and increased power amplifier (PA) back-off when employing a multi-carrier technique.

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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method for adjusting data modulation at a subscriber unit, comprising:

receiving data at a transmitter for transmission;

formatting the received data into packets for transmission, each packet having a particular type of encoding/data modulation;

transmitting the packets;

monitoring a return channel for receipt of an acknowledgment for each packet that that packet has been received;

retransmitting a packet at the transmitter, if an acknowledgment for that packet has not been received;

collecting retransmission statistics; and

adjusting each particular encoding/data modulation using the collected retransmission statistics, wherein if the collected retransmission statistics indicate a low number of retransmissions, a higher capacity encoding/modulation scheme is selected as the particular encoding/data modulation and if the collected retransmission statistics indicate a high number of retransmissions, a lower capacity encoding/data modulation scheme is selected as the particular encoding/data modulation.

2. The method of claim 1 wherein the particular type of encoding/data modulation is forward error correction (FEC).

3. The method of claim 2 wherein the packets are transmitted using an orthogonal frequency division multiple access (OFDMA) air interface and the FEC encoding/data modulation adjusting is performed in addition to selective nulling of subchannels in an OFDMA set.

4. The method of claim 1 wherein the packets are transmitted using a single carrier having a frequency domain equalization (SC-FDE) air interface.

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5. The method of claim 1 wherein the return channel is a fast feedback channel when the packets are transmitted using a code division multiple access (CDMA) air interface.

6. The method of claim 1 further comprising:

identifying a packet as having an unacceptable error rate responsive to receipt of a negative acknowledgment.

7. A method for adjusting data modulation at a subscriber, comprising:

formatting data into packets for transmission over a wireless air interface;

receiving packets of data over said air interface, each packet having a particular encoding/data modulation;

for each received packet, generating and transmitting a positive acknowledgment at the physical layer of said air interface when a received packet has an acceptable error rate; wherein a retransmission statistics of the packets are collected and the particular encoding/data modulation of each packet is adjusted using the collected retransmission statistics, wherein if the collected retransmission statistics indicate a low number of retransmissions, a higher capacity encoding/modulation scheme is selected as the particular encoding/data modulation and if the collected retransmission statistics indicate a high number of retransmissions, a lower capacity encoding/data modulation scheme is selected as the particular encoding/data modulation.

8. The method of claim 7 wherein the positive acknowledgments are transmitted on the fast feedback channel when said air interface using a code division multiple access (CDMA).

9. The method of claim 7 further comprising transmitting a negative acknowledgment if that packet has an unacceptable error rate.

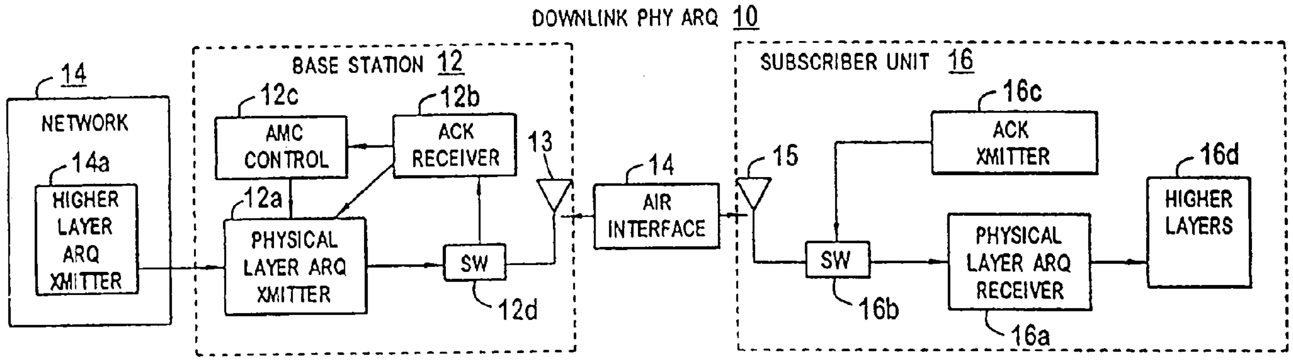
DOWNLINK PHY ARQ 10
14
NETWORK
14a
HIGHER LAYER ARQ XMITTER
BASE STATION 12
12c
AMC CONTROL
12b
ACK RECEIVER
12a
PHYSICAL LAYER ARQ XMITTER
SW
12d
13
14
AIR INTERFACE
SUBSCRIBER UNIT 16
15
SW
16b
16c
ACK XMITTER
PHYSICAL LAYER ARQ RECEIVER
16a
16d
HIGHER LAYERS

FIG. 1A

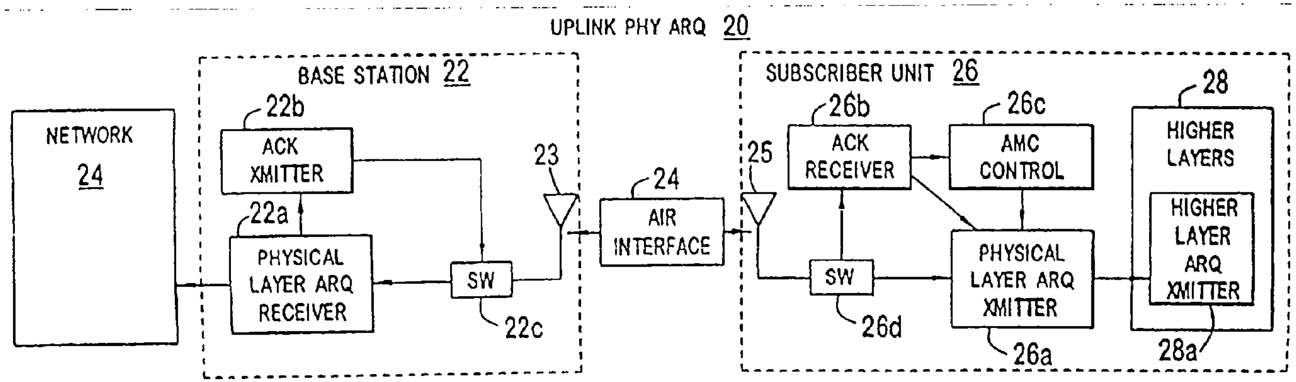
UPLINK PHY ARQ 20
NETWORK
24
BASE STATION 22
22b
ACK XMITTER
22a
PHYSICAL LAYER ARQ RECEIVER
SW
22c
23
24
AIR INTERFACE
SUBSCRIBER UNIT 26
25
26b
ACK RECEIVER
26c
AMC CONTROL
SW
26d
PHYSICAL LAYER ARQ XMITTER
26a
28
HIGHER LAYERS
HIGHER LAYER ARQ XMITTER
28a

FIG. 1B

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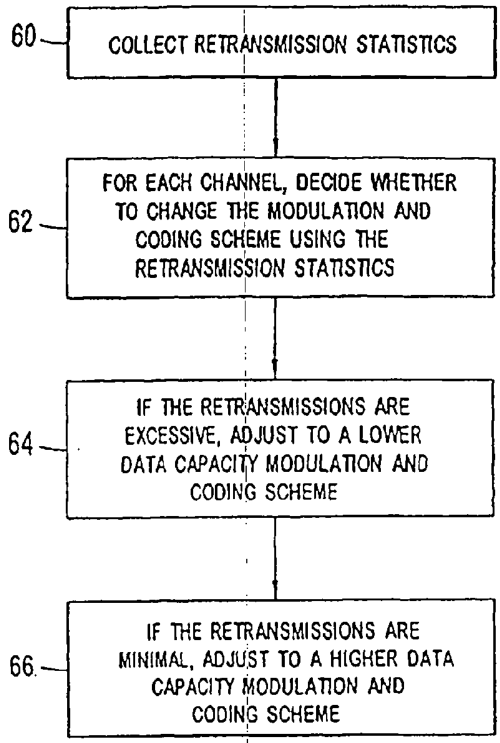

FIG. 2

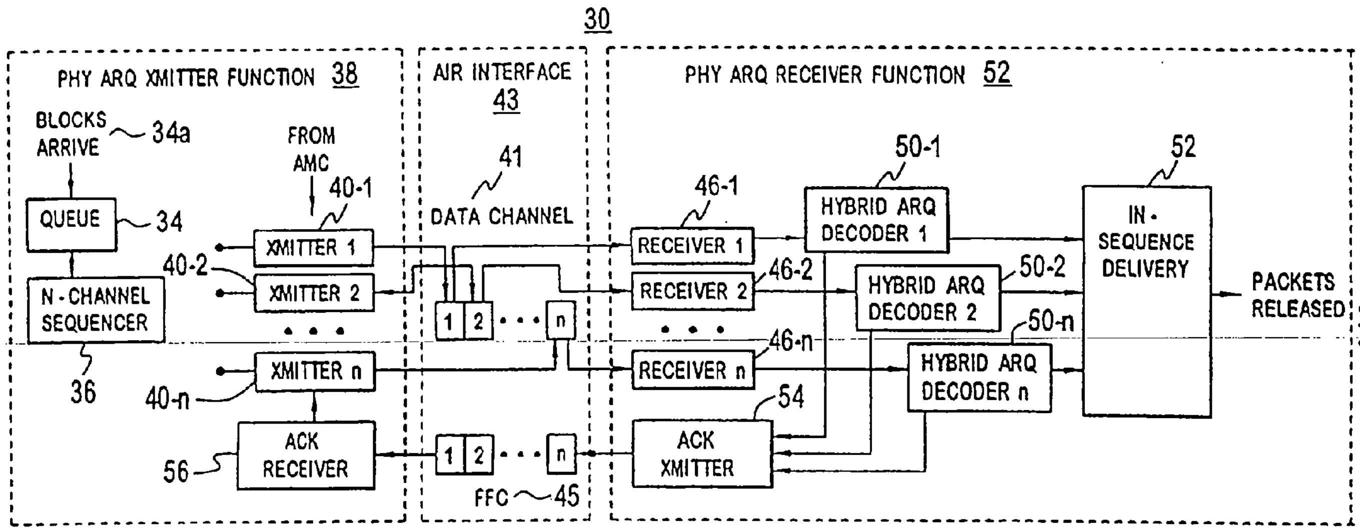
30
PHY ARQ XMITTER FUNCTION 38
BLOCKS ARRIVE
34a
QUEUE
34
N-CHANNEL SEQUENCER
36
FROM AMC
40-1
XMITTER 1
40-2
XMITTER 2
XMITTER n
40-n
ACK RECEIVER
56
AIR INTERFACE 43
41
DATA CHANNEL
1 2 n
FFC
45
PHY ARQ RECEIVER FUNCTION 52
46-1
RECEIVER 1
46-2
RECEIVER 2
46-n
RECEIVER n
54
ACK XMITTER
50-1
HYBRID ARQ DECODER 1
50-2
HYBRID ARQ DECODER 2
50-n
HYBRID ARQ DECODER n
52
IN-SEQUENCE DELIVERY
PACKETS RELEASED

FIG. 3