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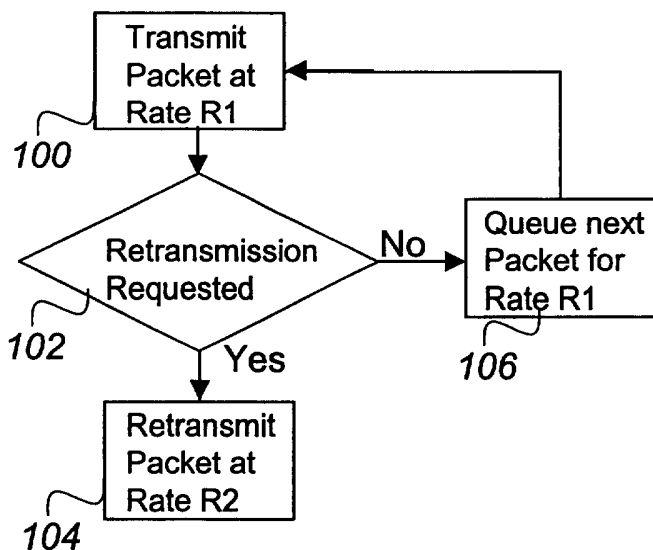
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(54) Title: RETRANSMISSION METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS SYSTEMS



(57) Abstract: A wireless communications system method and apparatus transmits packet data at a first rate ( $R_1$ ) selected to provide an acceptable packet error rate (PER) for a given wireless channel. Upon receipt of a request for retransmission of a data packet, the method and apparatus switch to a second rate ( $R_2$ ), lower than the first rate, for retransmitting the data packet. The overall transmission rate becomes  $R_1/(1+PER_1R_1/R_2)$ , which is only slightly lower than that of the single rate retransmission  $R_1/(1+PER_1)$ , but the resulting  $PER=PER_1PER_2$  is much smaller than  $PER_1^2$  for the case of single rate retransmission.

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## RETRANSMISSION METHOD AND APPARATUS FOR WIRELESS COMMUNICATIONS SYSTEMS

### Field of the Invention

5           The present invention relates to a method of and apparatus for retransmission in wireless communications systems and is particularly concerned with packet retransmission.

### Background of the Invention

10           The application of paradigms developed in wire line data transmission directly to wireless data transmission may lead to inefficient use of the limited bandwidth resources available in the wireless medium. One example of this is packet retransmissions. In wire line communications, such low error rates are available that packet retransmission involves relatively few packets and hence does not significantly  
15           impact throughput or result in unacceptable packet delays.

### Summary of the Invention

          An object of the present invention is to provide an improved method and apparatus for wireless communications systems packet retransmission.

20           In accordance with an aspect of the present invention there is provided a method of wireless data communications comprising the steps of: transmitting the data packet at a first rate; and upon receipt of a request to retransmit the data packet, transmitting the data packet at a second rate lower than the first rate.

### Brief Description of the Drawings

Figs. 1a, 1b, 1c, 1d illustrate in block diagrams a wireless communications system;

5           Fig. 2 illustrates in a block diagram a wireless communications system with forward error detection (FED);

          Fig. 3 illustrates in a block diagram a wireless communications system with forward error detection (FED) and retransmissions according to prior art;

10

          Fig. 4 illustrates in a flow chart a method of wireless communication in accordance with an embodiment of the present invention; and

          Fig. 5 illustrates in a block diagram a wireless communications system for  
15           implementing the method of Fig. 4.

### Detailed Description of the Preferred Embodiment

Referring to Fig. 1a, there is illustrated a wireless communications system 10. For simplicity, the wireless communications system 10 includes two wireless stations  
20           (terminals) 12 and 14. Fig. 1b illustrates a wireless station of the wireless communications system 10 in further detail. The wireless station 12 (or 14) includes a data input 16 and a data output 18, a transmit path 20 and a receive path 30 and an antenna port 40.

          Fig. 1c illustrates the transmit path of the wireless station of the wireless  
25           communications system 10 in further detail. The transmit path 20 typically includes a data randomization block 22, a forward error correction (FEC) coding block 24, a modulation block 26 and an RF conversion & amplification block 28. In operation, the typical transmit path 20 for a wireless communication system uses the data randomization block 22 to ensure that the modulated signal will have a uniform

spectrum. The FEC coding block 24 improves the communication robustness to noise or channel imperfections. Examples of FEC schemes are Reed-Solomon, convolutional or turbo coding. Depending on the FEC schemes this block may include one or more data interleaving schemes to improve the FEC performance. The modulation block 26 transforms data bits in base-band digital or analog signals. Modulation schemes may (but they are not limited to) be single carrier or multi-carrier (e.g. OFDM) with different constellation mappings (e.g. BPSK, QPSK, QAM) and may include spectrum spreading techniques such as direct sequence spread-spectrum (DSSS) or frequency hopping (FH). The RF conversion and amplification block 28 includes but is not limited to all the necessary functional blocks to convert the signal from baseband to RF and amplify it to the desired transmission level.

Fig. 1d illustrates the receive path of the wireless station of the wireless communications system 10 in further detail. The receive path 30 typically includes an RF amplification conversion block 32, a FEC decoding block 34, a demodulation, equalizer & slicer block 36 and a data de-randomization block 38. These functions operate in reverse fashion to the corresponding blocks in the transmit section, with the exception of the equalizer which is necessary to compensate for the channel impulse response.

Most wireless communication systems can operate with several different combinations of coding and/or modulation. Herein a combination of coding and modulation is referred to as a "rate", since the overall data rate (coding rate multiplied by the number of bits per symbol and by the symbol rate) describes the system outcome.

Typically, wireless communication systems can automatically change the "rate" with which they operate in order to compensate for changes in the channel, i.e. attenuation, multipath, natural noise and interference, changes in channel are perceived by the wireless system as changes in the overall signal-to-noise-ratio (SNR). For a given SNR, there is a tradeoff between data rate and the link bit-error-rate (BER) or packet-error-rate (PER). The higher the data rate, the higher the error probability. Wireless communication systems that are capable of adapting their "rate"

to the channel characteristics, set their “rate” enough low such that the overall BER or PER falls within quality requirements for the link. Typical requirements for overall BER are in the order  $10^{-4}$  to  $10^{-12}$  depending on the application.

5 In a wireless communication system with no retransmission, each data packet is sent only once. If transmission encountered errors (detected either at the level of the wireless system or at a higher level in the protocol) the corresponding data is discarded or, in other words, is lost. For such systems, the “rate” is set enough low so that the BER/PER meets the quality requirements for the link. Such a strong condition on BER/PER leads to poor usage of the wireless channel since the “rate” is  
10 significantly reduced below the potential rate (by 20% to 50%) to meet  $10^{-4}$  to  $10^{-12}$  BER/PER requirements.

Referring to Fig. 2 there is illustrated another form of wireless station of the  
15 wireless communications system 10 in further detail. In addition to the functional blocks shown in Fig. 1b, Fig. 2 includes a forward error detection (FED) function 50 that includes a FED add block 52, a FED check block 54 and a data valid/invalid output 56. Many wireless systems monitor the BER/PER to ensure proper operation. This is usually performed using error-detection techniques. At transmission the FED  
20 redundant information is appended or inserted in the data stream by the FED add block 52. At reception the FED information is extracted from the data stream by the FED check block 54 and used to verify if the received data is valid or not. Invalid data packets are eventually removed from the received data stream.

25 Typical forward-error-detection (FED) techniques add some redundancy at transmission, like parity check bits or cyclic-redundant-codes (CRC) that can be verified at reception, in order to validate/invalidate packets. Alternatively, error detection may be combined with error correction like with Reed-Solomon FEC/FED or other error detecting and correcting cods. Without any loss of generality, the  
30 presentation discusses the case of separate FEC and FED.

In some wireless systems, results of the error detection are exchanged between terminals systems in the form of acknowledge (ACK) and not-acknowledge (NACK) messages. This is to enable the sender of the packet to know if the packet was received properly. For simplicity and clarity, the present application refers only to packet-by-packet ACK/NACK messages but embodiments of the present invention  
5 can be applied to systems that employ group or multi-packet ACK/NACK.

Often, systems that implement both FED and ACK/NACK, also employ packet retransmission. In communication system with retransmission, the sender of a  
10 packet stores data until an ACK or a NACK is received for that packet or, in other words, until it knows if the packet was or was not properly transmitted to the receiver. If the sender receives ACK, it proceeds with the next packet. If the sender receives NACK, it tries to retransmit the stored packet. Depending of the system, one or more retransmissions may be allowed. Again, for the simplicity the document refers only to  
15 packet-by-packet retransmissions but the invention can be applied to group selective or group non-selective retransmissions like "selective-repeat", "go-back-N" or others.

Referring to Fig. 3 there is illustrated a further form of wireless station of the wireless communications system 10 in further detail. In addition to the functional  
20 blocks shown in Fig. 2, Fig. 3 includes an ACK/NACK Extractor 60 coupled to the output of the Rx path 30 and an ACK/NACK Generator 62 coupled to the input of the Tx path 20. Fig. 3 also includes a transmit data buffer 64 and a switch 66. The ACK/NACK extractor 60 is coupled to the switch.

25 In operation, each packet sent is buffered in the transmit data buffer 64. When a packet is not acknowledged either by not receiving an ACK within a specified time or receiving a NACK, the ACK/NACK Extractor causes the switch 66 to switch from a transmit position to a retransmit position to cause the missing packet to be resent. Similarly, the ACK/NACK generator 62, based on output from the FED check  
30 block 54 appends the appropriate ACK or NACK to transmitted packets.

In a wireless communication system with retransmission, the transmitted data is grouped in packets (also called frames, bursts, etc) and the receiving station acknowledges each received data packet (implicitly or explicitly) to the transmitting station. The transmitting station can then retransmit the erroneous packets. 5  
Retransmission improves exponentially the overall BER/PER for the same channel with a little decrease in the overall data rate. If  $PER_1$  and  $R_1$  are the PER and, respectively, the "rate" without retransmission then if  $n$  retransmissions are allowed and the channel characteristics are constant, the overall PER with retransmissions is  $PER_0 = PER_1^{n+1}$  and the overall rate is  $R_0 = R_1(1 - PER_1)/(1 - PER_1^{n+1})$ . The loss in rate 10  
between  $R_1$  and  $R_0$  is very small (less than PER) but the improvement from  $PER_1$  to  $PER_0$  is significant. For example allowing up to 3 retransmissions improves the BER/PER from  $10^{-4}$  to  $10^{-16}$  and from  $10^{-2}$  to  $10^{-8}$ . Therefore, wireless systems with retransmission can operate with higher  $PER_1$  which in terms means increased "rate". The rate back off in wireless systems with retransmission can theoretically be much 15  
smaller (e.g. 5-10%) that in systems without retransmission. The increase in rate facilitated by retransmission is much higher than the difference between  $R_0$  and  $R_1$ , and thus systems with retransmission utilize more efficiently the channel.

However, systems with retransmissions still have several drawbacks. The 20  
more retransmissions are allowed the higher the potential packet delay is. One retransmission is often not enough to improve the BER to the desired level with a rate back off of less than 20%.

The improvement in systems with retransmission from  $PER_1$  to  $PER_0 = PER_1^{n+1}$  25  
takes place only if the channel does not change. However, wireless channels are generally not constant. Path loss varies slowly at least with the environment changes (temperature, humidity, clouds, rain/snow, seasons) but can vary quickly in mobile and/or multi-path environments. In unlicensed bands, the interference level can show rapid changes, for example, transmission bursts from interfering station. Rapid 30  
changes in SNR cannot be tracked by the adaptation algorithm typically used to establish the "rate" in variable rate systems. Therefore, with or without retransmissions there might be periods when no packet can be correctly transmitted

unless the rate is a priori backed off enough to cover the minimum SNR case. During such periods, the communications link is effectively lost and packets accumulate at both stations until either the channel returns to normal or the “rate” adaptation algorithm reacts. This further increases the packet delay to a degree, which in many cases, may be unacceptable (i.e. the accumulated packets must be discarded and thus they are lost).

Due to delay and adaptation issues discussed above, more than one retransmission is rarely used in practice. Also, in many practical situations, systems with retransmission are used with similar “rate” back-off as those without retransmission.

Referring to Fig. 4, there is illustrated, in a flow chart a method of packet transmission for a wireless communications system, in accordance with an embodiment of the present invention. The method includes a step of initially transmitting a data packet at a first rate,  $R_1$  and represented by a block 100. The first rate  $R_1$  being a rate, chosen to provide a predetermined level of packet error-ratio (PER). If a request for retransmission is received, as represented by a decision block 102, then resending the packet at a second rate,  $R_2$ , which is lower than the first rate  $R_1$ . Otherwise, transmitting the next packet.

The retransmission method of Fig. 4 limits the number of retransmissions to one but retransmissions are performed with a lower “rate” ( $R_2 < R_1$ ). If the channel is constant and the PER for rate  $R_2$  is  $PER_2$ , then the overall PER of a system using the retransmission method of Fig. 4 is:  $PER_0 = PER_1 PER_2$  and the overall data rate is:  $R_0 = R_1 / (1 + PER_1 R_1 / R_2)$ .

When compared with a typical system with one retransmission, the system with dual-rate retransmission it has slightly lower overall rate, i.e.  $R_1 / (1 + PER_1 R_1 / R_2)$  instead of  $R_1 / (1 + PER_1)$ , however this is more than offset by a much better PER, i.e.  $PER_1 PER_2 < PER_1^2$ . This occurs because  $PER_2 / PER_1$  is typically  $10^{-4}$  to  $10^{-8}$  for a

20% decrease in rate. Therefore the system using the retransmission method of Fig. 4 has overall BER and rate characteristics that are similar to systems with multiple retransmissions in constant channels.

5           Referring to Fig. 5, there is illustrated a wireless communications station incorporating the method of Fig. 4. The wireless communications station of Fig. 5 is similar to that of Fig. 3, except the data buffer 64' provides data for retransmission at a second rate  $R_2$  that is lower than the transmission rate  $R_1$ . This is accomplished by connection 68 that takes the output of the ACK/NACK Extractor 60 and passes as  
10           control input to the Tx Path 20 for the purpose of switching between rates  $R_1$  and  $R_2$ .

          With a proper choice of  $R_2$  and consequently of  $BER_2$ , the system with dual-rate transmission can achieve BER and rate characteristics of a system with  $n$  retransmissions while maintaining a maximum delay similar to that of a system that  
15           allows only one retransmission at the same rate as the initial transmission.

          In variable channels, the second rate  $R_2$  can be further reduced so that it provides an acceptable overall BER for the worst case. Thus, with a very small decrease in the overall average rate, the dual rate system of Figs. 4 and 5 can  
20           automatically avoid extreme packet loss and/or packet delays during accidental (rare) SNR drops without any intervention from a "rate" adaptation algorithm. When compared to standard retransmission, the dual-rate system gains link margin via  $R_2$  instead of  $R_1$ , thus it can insure higher immunity to channel variations at very little expense in the overall rate.

25           A wireless system using the dual-rate retransmission algorithm of Fig. 4 has the advantage of providing performance similar to multiple retransmission algorithms, while incurring a delay similar to that of single-retransmission algorithms.

30           A further advantage to the dual-rate retransmission algorithm of Fig. 4 is that it can operate with very little back-off for  $R_1$  and very large back-off for  $R_2$ . Thus it optimizes the overall rate while it optimizes the immunity to channel variations.

Some implementations may measure PER over a predetermined number of packets or a combination of both.

Numerous modifications, variations and adaptations may be made to the particular embodiments of the invention described above without departing from the scope of  
5 the claims, which is defined in the claims.

**What is claimed is:**

1. A method of wireless data communications comprising the steps of:
  - a) transmitting a data packet at a first rate;
  - b) upon receipt of a request to retransmit the data packet, retransmitting the data packet at a second rate lower than the first rate.
2. A method as claimed in Claim 1 wherein the first rate is selected in dependence upon an average packet error rate (PER) as determined for packets sent at the first rate and the second rate is selected in dependence of the average PER to achieve a desired overall PER/BER, whereby the first rate is selected to maximize the data throughput and the second rate is selected.
3. A method as claimed in Claim 1 wherein the first rate is selected in dependence upon an average packet error rate (PER) as determined for packets sent at the first rate and the second rate is selected in dependence upon the peak PER measured for the packets sent with the first rate to achieve a desired overall PER/BER, whereby the first rate is selected to maximize the data throughput.
4. A method as claimed in Claim 1 wherein the first rate is selected in dependence upon an average packet error rate (PER) determined for packets sent at the first rate and the second rate is selected in dependence upon an average PER measured for the packets sent at the second rate to achieve a desired overall PER/BER, whereby the first rate is selected to maximize the data throughput.
5. A method as claimed in Claim 1 wherein the first rate is selected in dependence upon an average packet error rate (PER) determined for packets sent at the first rate so as to maximize the data throughput and the second rate is selected in

dependence upon the average PER determined for packets sent at the second rate to achieve the desired overall PER/BER.

5        6.        A method as claimed in Claim 1 wherein the first rate is selected in dependence upon an average packet error rate (PER) determined for packets sent at the first rate so as to maximize the data throughput and the second rate is selected in dependence upon a peak PER determined for the packets sent at the second rate so as to obtain the desired overall PER/BER.

10        7.        A method as claimed in Claim 6 wherein the request to retransmit the data packet is a not-acknowledge message.

8.        A method as claimed in Claim 6 wherein the request to retransmit the data packet is a result of not receiving an acknowledge message.

15        9.        A method as claimed in Claim 7 wherein the request to retransmit is generated a predetermined time after transmitting the data packet.

10.        A method as claimed in Claim 8 wherein the request to retransmit is generated a predetermined time after transmitting the data packet.

20        11.        Apparatus for wireless data communications comprising the steps of:

- c)        transmitting a data packet at a first rate;
- d)        upon receipt of a request to retransmit the data packet, retransmitting the data packet at a second rate lower than the first rate.

12. Apparatus as claimed in Claim 11 wherein the first rate is selected in dependence upon an average packet error rate (PER) as determined for packets sent at the first rate and the second rate is selected in dependence of the average PER to achieve a desired overall PER/BER, whereby the first rate is selected to maximize the data throughput and the second rate is selected.

13. Apparatus as claimed in Claim 11 wherein the first rate is selected in dependence upon an average packet error rate (PER) as determined for packets sent at the first rate and the second rate is selected in dependence upon the peak PER measured for the packets sent with the first rate to achieve a desired overall PER/BER, whereby the first rate is selected to maximize the data throughput.

14. Apparatus as claimed in Claim 11 wherein the first rate is selected in dependence upon an average packet error rate (PER) determined for packets sent at the first rate and the second rate is selected in dependence upon an average PER measured for the packets sent at the second rate to achieve a desired overall PER/BER, whereby the first rate is selected to maximize the data throughput.

15. Apparatus as claimed in Claim 11 wherein the first rate is selected in dependence upon an average packet error rate (PER) determined for packets sent at the first rate so as to maximize the data throughput and the second rate is selected in dependence upon the average PER determined for packets sent at the second rate to achieve the desired overall PER/BER.

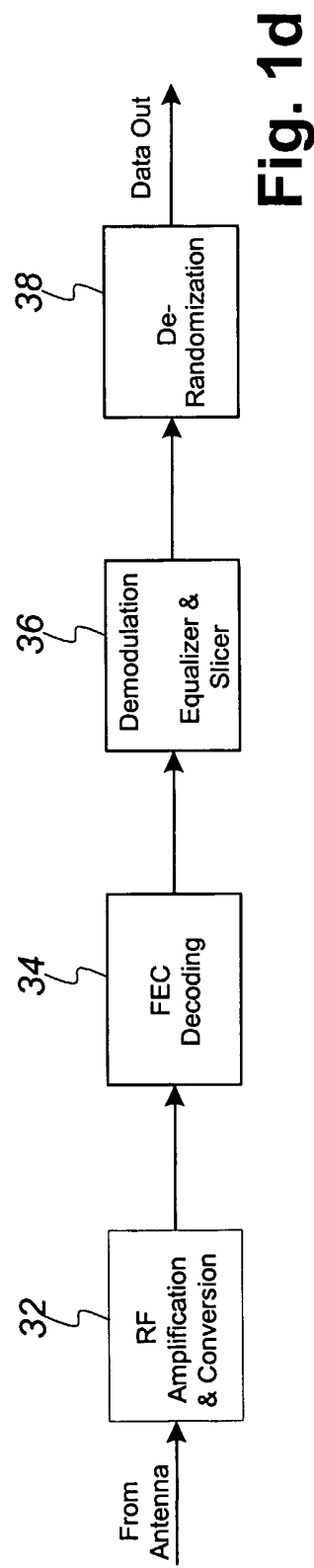
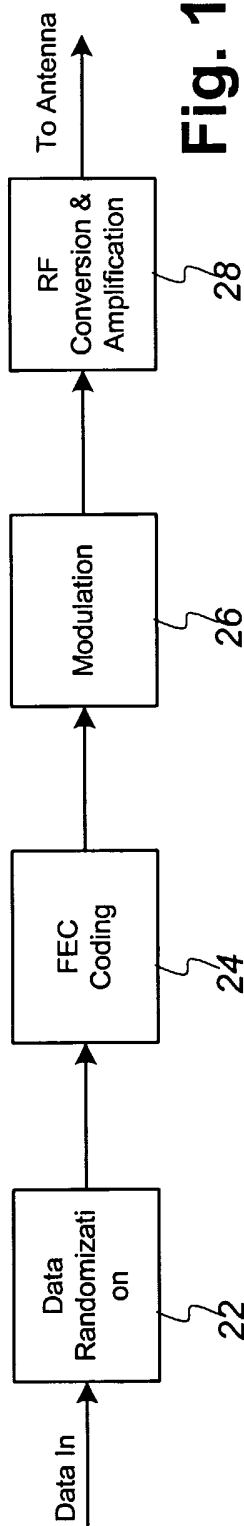
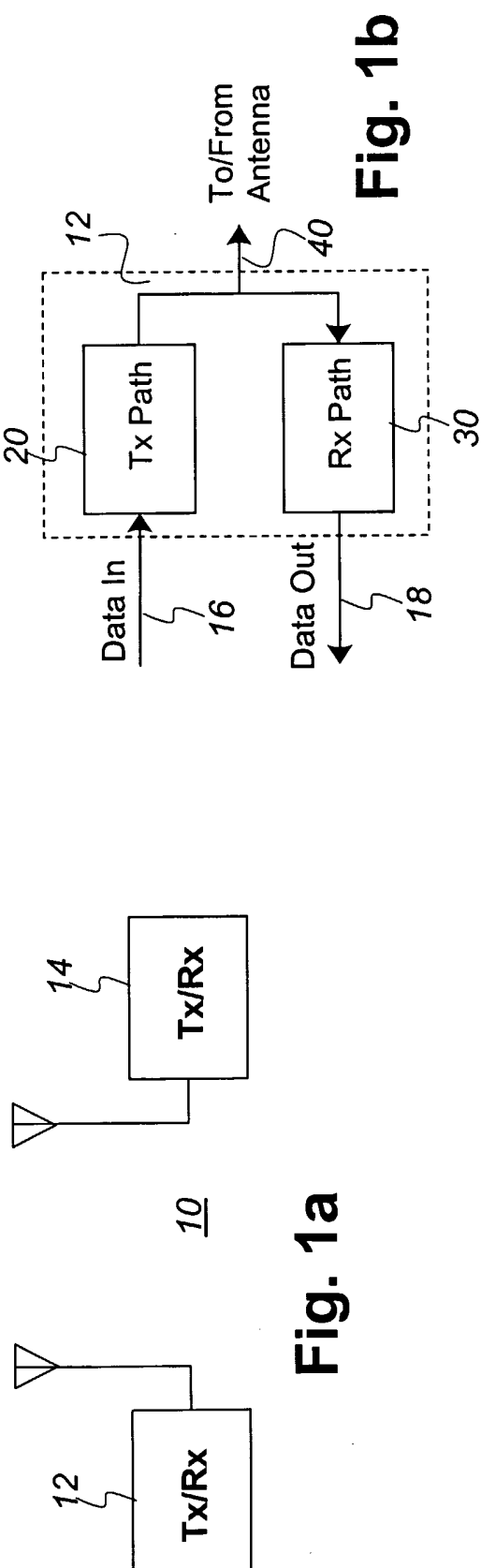
16. Apparatus as claimed in Claim 11 wherein the first rate is selected in dependence upon an average packet error rate (PER) determined for packets sent at the first rate so as to maximize the data throughput and the second rate is selected in dependence upon a peak PER determined for the packets sent at the second rate so as to obtain the desired overall PER/BER.

17. Apparatus as claimed in Claim 16 wherein the request to retransmit the data packet is a not-acknowledge message.

18. Apparatus as claimed in Claim 16 wherein the request to retransmit the data packet is a result of not receiving an acknowledge message.

19. Apparatus as claimed in Claim 17 wherein the request to retransmit is generated a predetermined time after transmitting the data packet.

20. Apparatus as claimed in Claim 18 wherein the request to retransmit is generated a predetermined time after transmitting the data packet.



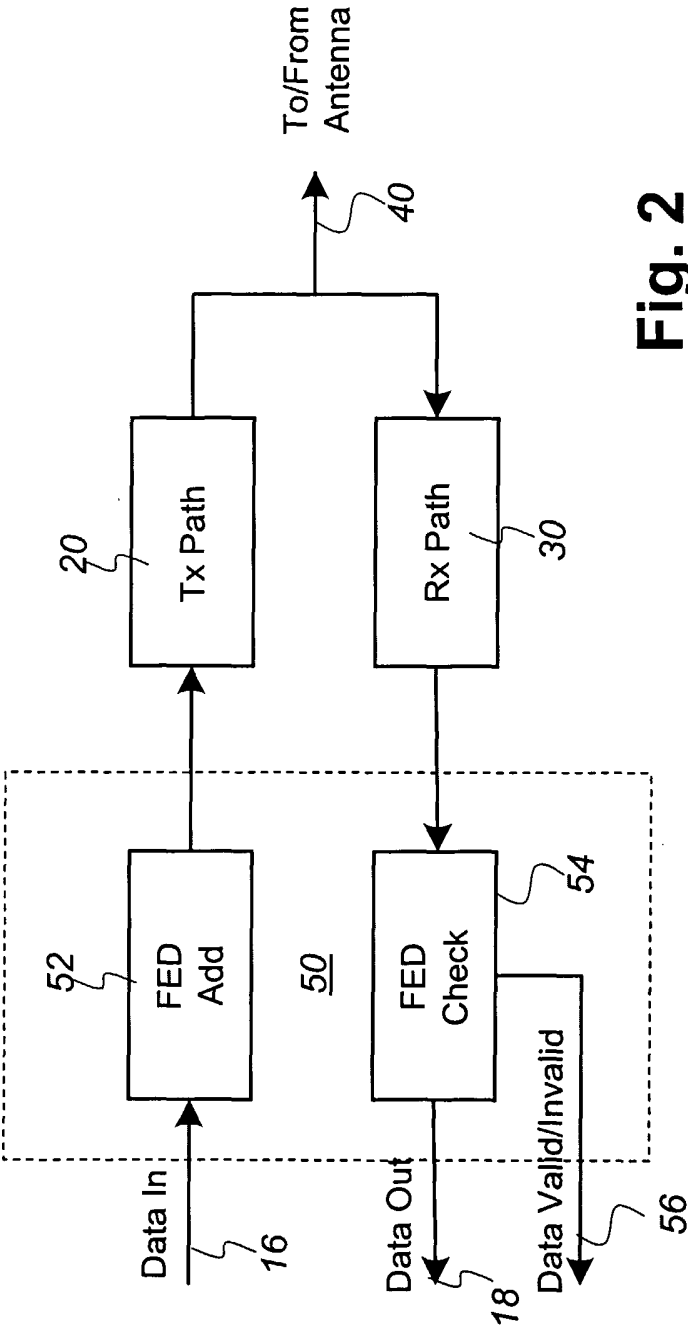


Fig. 2

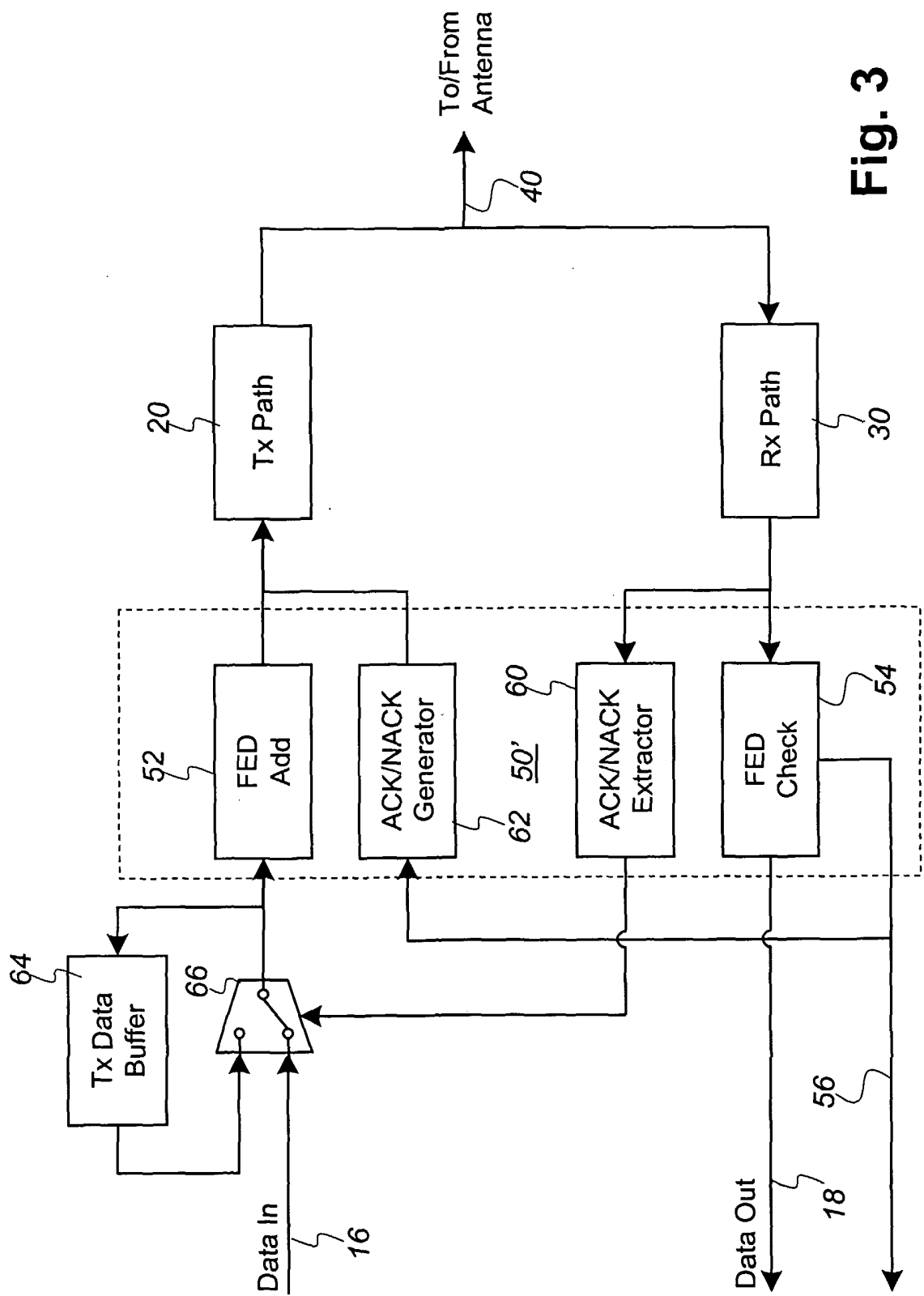


Fig. 3

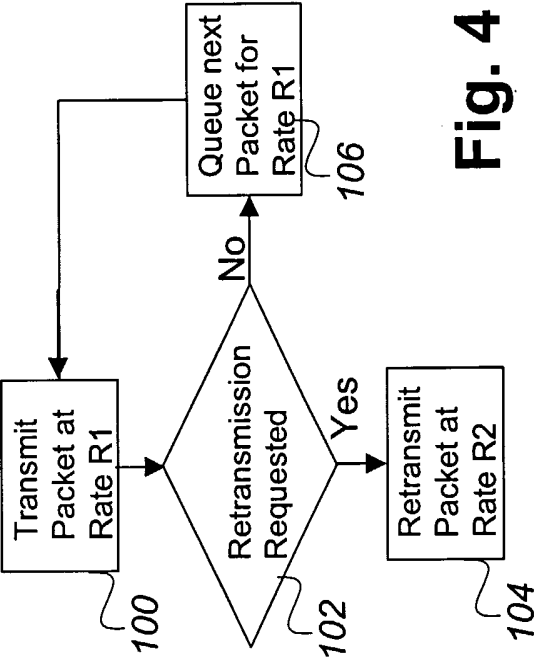


Fig. 4

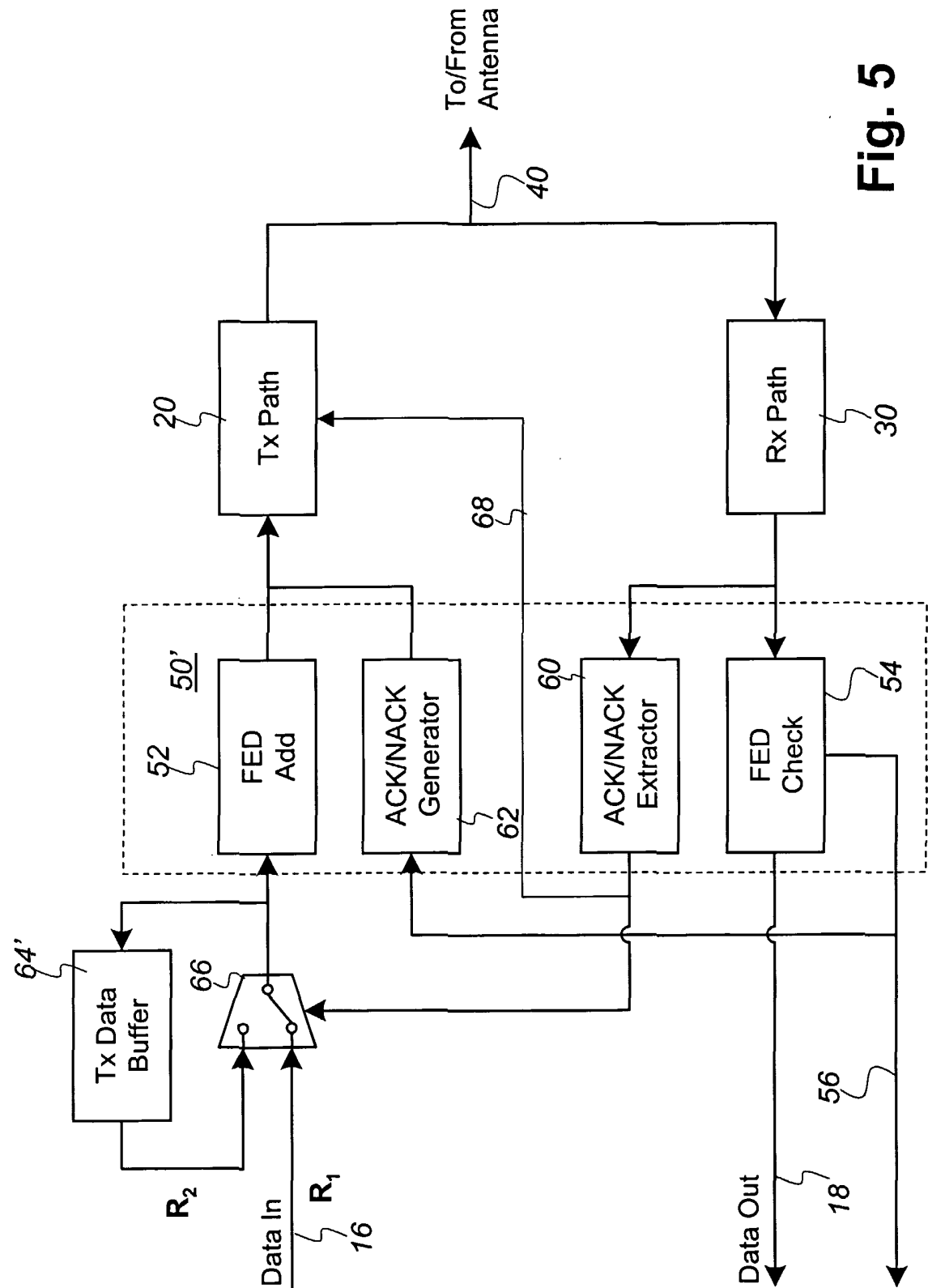


Fig. 5

## INTERNATIONAL SEARCH REPORT

International Application No

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## A. CLASSIFICATION OF SUBJECT MATTER

IPC 7 H04L1/00 H04L1/18

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

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 7 H04L

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

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

EPO-Internal, INSPEC, COMPENDEX

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

| Category ° | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                                  | Relevant to claim No. |
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| X          | WO 00 21236 A (ERICSSON TELEFON AB L M)<br>13 April 2000 (2000-04-13)<br>abstract<br>page 4, line 28 -page 5, line 27<br>page 9, line 15 -page 11, line 25<br>---                                                   | 1-20                  |
| X          | WO 01 54339 A (NORTEL NETWORKS LTD ;ROYER<br>CLAUDE (CA); TONG WEN (CA); PERIYALWAR)<br>26 July 2001 (2001-07-26)<br>abstract<br>figure 2<br>page 8, line 17 -page 9, line 19<br>page 12, line 25-34<br>---<br>-/-- | 1-20                  |

☒ Further documents are listed in the continuation of box C.☒ Patent family members are listed in annex.

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Date of the actual completion of the international search

10 January 2003

Date of mailing of the international search report

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# INTERNATIONAL SEARCH REPORT

International Application No  
PCT/CA 02/01252

## C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT

| Category * | Citation of document, with indication, where appropriate, of the relevant passages                                                                                                                          | Relevant to claim No. |
|------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------------|
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# INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No

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