(54) Title: METHOD AND ARRANGEMENT FOR IMPROVED RE-TRANSMISSION IN A WIRELESS COMMUNICATION SYSTEM
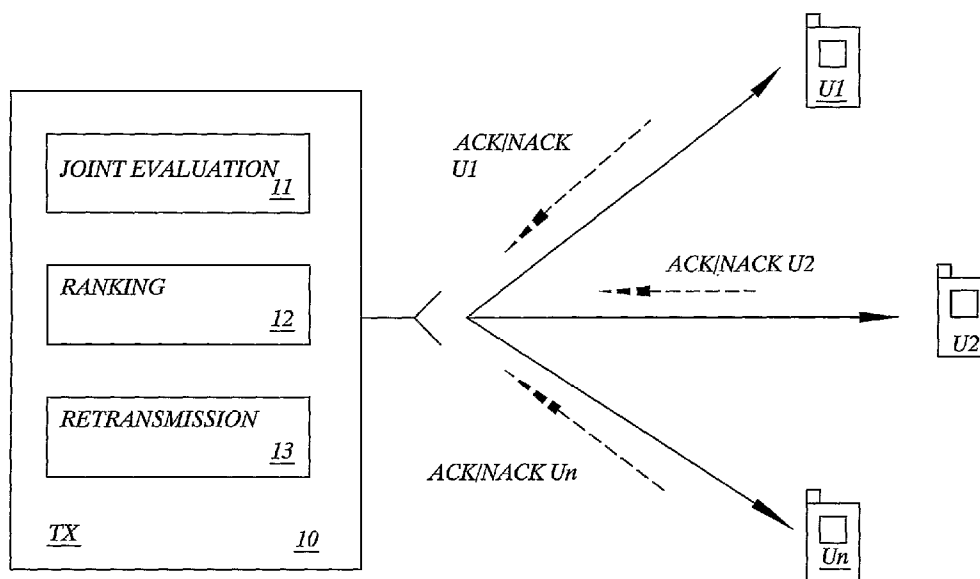
(57) Abstract: In a method of retransmission in a wireless communication system, comprising a transmitting node communicating (S0) a plurality of data blocks to multiple user nodes on a common radio channel, and in response to receiving reports (S1) of successful/unsuccessful reception of said data blocks from each of the multiple users, jointly evaluating (S2) the reception results based on the reports, ranking (S3) the data blocks for retransmission based at least on the joint evaluation, and, selectively retransmitting (S4) data blocks to the multiple users based at least on the ranking to limit the bandwidth used for retransmissions.

METHOD AND ARRANGEMENT FOR IMPROVED RE-TRANSMISSION IN A WIRELESS COMMUNICATION SYSTEM

TECHNICAL FIELD

5   The present invention relates to multimedia broadcast/multicast services (MBMS) in general, specifically to retransmissions systems supporting such services.

BACKGROUND

10   At present, there is a rapid increase in the demand for providing multimedia services such as video and audio in communication systems such as GSM and UMTS. The so called Multimedia Broadcast/Multicast (MBMS) service is an example of a solution on this subject, which provides the possibility to utilize an uplink channel for interactions between the service and its users.

15   MBMS is a unidirectional, point-to-multipoint service in which data is transmitted from a single source to a group of users in a specific area. The service in practice has two modes: broadcast mode and multicast mode.

In general, a broadcast service is a unidirectional point-to-multipoint service
20   in which data is transmitted from a single source to multiple terminals, or users in the associated broadcast service area. In other words, broadcast services can be called push-type services. On the other hand, a multicast service is a unidirectional point-to-multipoint service in which data is transmitted from a single source to a multicast group in the associated
25   multicast service area. Only users that subscribe to the specific multicast service and have joined the multicast group associated with that service can receive the multicast services. As a difference, a broadcast service can be received without separate indication from the customers. In practice, multicast users as well as broadcast users in MBMS need a return channel
30   for the interaction procedures in order to be able to subscribe to the desired services.

At present, MBMS is in the process of standardization in the 3GPP (Third Generation Partnership Project). MBMS enables offering a complete set of Multicast and Broadcast services over GSM/EDGE as well as WCDMA. MBMA is an example of the previously described Broadcast/Multicast operation (or service) where the same payload data is transmitted to multiple end users in a cellular network. Hereafter, this type of Broadcast/Multicast operation (service) in cellular networks is referred to as Multicast operation. In order to provide nearly error-free data transmissions for Multicast operation, multiple transmissions (or retransmissions) is an efficient means, compared to providing a radio environment with high enough quality to completely avoid retransmissions.

One problem regarding retransmissions in MBMS is that a single data block can generate as many retransmission requests as there are users in the systems. As the number of users increase, the likelihood of retransmission requests increases drastically. Since no separate channel exists for retransmissions, the occurrence of retransmissions limits the bandwidth available for the actual primary transmissions. At one extreme, for a system with a large number of users, this could in a worst case scenario prevent any primary transmissions from being sent.

Consequently, for the standardized MBMS [1] two different re-transmission strategies are specified:

Blind Block Repetition (BBR) – In this mode of operation, multiple transmissions (of identical data) are made a specified number of times, not considering the number of users or the current radio quality (received signal strength and/or interference level)

Packet Downlink ACK/NACK (PDAN) – In this mode of operation, re-transmissions are based on requests (ACK/NACK reporting) from up to 16 users in one cell.

3

To meet requirements on guaranteed bit rate, the number of re-transmissions must be limited (or controlled), such that sufficient transmission time is spent on sending new data (primary transmissions). A typical requirement is that each RLC block is sent at least once. This requirement, together with the arrival bit rate of new data, specifies the bit rate that must be reserved for "primary transmission" (i.e., first transmission attempts).

The primary purpose of re-transmitting data units (e.g., RLC blocks) is to provide an error-free transmission over the radio interface. However, the amount of retransmission (absolute or relative) must be restricted since retransmissions share the radio link with primary transmissions. For broadcast type of transmission, some residual errors may be preferred, rather than no errors, since the correctly received data may be obsolete by arrival.

SUMMARY

An object of the present invention is to provide improved MBMS in a cellular radio network and to keep the quality at an acceptable level for as many users as possible.

A further object is to provide retransmission strategies for MBMS.

Another object is to provide improved retransmission strategies for MBMS to limit the bandwidth used for retransmissions.

Yet another object is to provide selective retransmissions for MBMS.

A further object is to provide selective retransmissions based on ACK/NACK reports from multiple users.

4

These and other objects are achieved in accordance with the attached claims.

Briefly, the present invention comprises evaluating the reception success of a data block for multiple users, ranking the transmitted data blocks based at least on the evaluation and selectively retransmitting requested data blocks based on the ranking.

Specifically, the evaluation is performed based on received ACK/NACK reports, i.e., potentially retransmission requests, from the respective users. Additionally, the ranking can be performed based on the user priority for the set of users, the age of the requested data blocks, or some other quality requirement.

According to another specific embodiment, the available bandwidth for transmissions (and retransmissions) is divided into one minimum section reserved for primary transmission, and one remaining section for retransmission, thus, ensuring a minimum guaranteed bitrate for the users.

Advantages of the present invention comprise:
      Enabling more efficient retransmission strategies
      Enabling providing a minimum guaranteed bitrate for transmissions
      Reducing total number of retransmissions

BRIEF DESCRIPTION OF THE DRAWINGS

The invention, together with further objects and advantages thereof, may best be understood by making reference to the following description taken together with the accompanying drawings, in which:

Fig. 1 is a schematic flow diagram of an embodiment of a method according to the invention;

5

Fig. 2 is a schematic illustration of the known sliding window principle;

Fig. 3 is a diagram illustrating the effect of various embodiments according to the invention;

Fig. 4 is a diagram illustrating the effect of various embodiments according to the invention;

Fig. 5 is a diagram illustrating the effect of various embodiments according to the invention;

Fig. 6 is a diagram illustrating the effect of various embodiments according to the invention;

Fig. 7 is a schematic illustration of a system according to the invention.

ABBREVIATIONS

MBMS	Multimedia Broadcast/Multicast Service
BBR	Blind Block Repetition
PDAN	Packet Downlink ACK/NACK
RLC	Radio Link Control
MCS	Modulation and Coding Scheme
BLEP/BLER	Block Error Probability/Rate
TTI	Transmit Time Interval

DETAILED DESCRIPTION

The present invention will be described in the context of MBMS in a GSM/EDGE communication system. However, it is equally applicable to any other packet based communication system utilizing a common channel for transmissions and retransmissions, where retransmission requests are typically sent from each user on dedicated channels in the uplink.

As stated in the background, one major disadvantage of MBMS in GSM/EDGE is the sheer number of retransmission requests and correspondingly number of retransmissions necessary in a system with many users. Regarding for example one cell in a GSM/EDGE system utilizing MBMS, the capacity available for retransmissions can be analytically calculated.

Assuming a fixed MCS (Modulation and Coding Scheme) for MBMS in a cell, the total available bit rate r_{MCS} for MBMS is well defined. Assuming that the MBMS bit stream has the (average) bit rate r_1, the bit rate available for retransmissions is $r_{MCS} - r_1$. In other words, the proportion $(1 - r_1/r_{MCS})$ of the data blocks can be used for retransmissions without starving the primary bit stream.

Since the capacity available for primary transmissions and re-transmissions is limited, there might be situations when not all RLC (Radio Link Control)

blocks reported as erroneous can be re-transmitted, at least not without jeopardizing the required primary bit rate. Thus, it may be necessary to limit the total load of primary transmissions and retransmissions. In particular, a re-transmission strategy will then be necessary for how to determine which data blocks to retransmit.

Moreover, if re-transmissions are handled efficiently, resources for primary transmissions are freed and it may be possible to offer higher data rates or, alternatively, more (parallel) users or Multicast sessions.

As stated previously, the current MBMS standard does not specify strategies for how to accomplish efficient retransmission strategies. In fact, there is a risk that a large number of retransmissions would lower the available capacity for primary transmissions below the required. This will occur when retransmissions are prioritized over primary transmissions, the number of multicast users in a cell is large and their combined error probability is larger than what is possible to support by traditional unlimited retransmissions.

For example, if the error probability for each of 10 users is 10%, their combined error probability is 65%, meaning that several retransmissions might be necessary before all 10 users have received the data block correctly. Thus, even with relatively low error probabilities, the capacity required for retransmissions may become large in comparison with the capacity required for primary transmissions.

Consequently, basic requirements for MBMS should:

    -Ensure capacity for primary transmissions;
    -Aim at providing "good quality for as many users as possible" in situations when not all users can be fully supported.

The limitation to implement and to consider is that it will not always be possible to retransmit a radio block every time a user reports an error. Therefore, a careful selection of which requested retransmissions to serve will be necessary. The basic approach, according to the present invention, is therefore to prioritize all or a limited number of primary transmissions, and for the remaining capacity or bandwidth select data blocks for retransmission based on a retransmission priority scheme taking the selection of primary transmissions into account. The selection is generally based on the probability that a retransmission will keep the quality at a high level for as many users as possible.

In order to ensure capacity for primary transmissions (first transmission attempts), the idea is further to use an approach to regulate retransmission attempts. This can be accomplished by a "leaky bucket" flow control that ensures an average bit rate for primary transmissions but allows for short periods with many retransmissions.

To be efficient, retransmission strategies could be based on, but not limited to, quality requirements and current radio conditions such as the ones mentioned below:

Radio quality metric example: (residual) block error rate (BLER) per user, i.e. expected fraction of RLC blocks not correctly received.

User quality requirement example: residual BLER not exceeding a specified limit, e.g. 1%.

Basically, with reference to Figure 1, the invention comprises transmitting S0 a plurality of data blocks to a plurality of users on a common channel (it is understood, due to the inherent nature of MBMS, that the same data blocks are transmitted to all users), the users respond to the transmission by reporting S1 successful and unsuccessful reception of each data block to the transmitting node e.g. ACK/NACK reports. Subsequently, the received reports from all users are evaluated S2 together or jointly and the

transmitted data blocks are sorted or ranked S3 accordingly. Finally, retransmissions are selectively effected S4 based on the previous ranking.

Some key elements for the principles of the invention thus comprise the following:

ACK/NACK reporting (or retransmission requests) of users (which is already specified in [1]);

Ranking or prioritizing data blocks for retransmission using a score function based on ACK/NACK reports;

Retransmission of data blocks with predetermined e.g. highest rank.

The above mentioned ranking or prioritizing based on the reception success/failure reports can be performed based on some predetermined function or relation. Optionally, also the age of the data blocks can be taken into account, e.g. by discarding old data blocks in favor of new data blocks or vice versa. Another possible parameter is a user priority for each user. The priority could be based on subscriber data, or the time the user has been in the system.

In order to provide a specified or guaranteed bit rate, an additional step comprises initially allocating a predetermined fraction of the total available bandwidth to primary transmissions and allocating the remaining fraction for retransmissions.

A few specific embodiments will be described below:

Consider a system wherein time is measured as the number of basic transmit time intervals (TTI:s). The amount of data sent during a TTI is referred to as a data block (e.g. RLC block). It is also assumed that reception reporting e.g. ACK/NACK reporting is performed by each user for each such data block. Each user needs one TTI exclusive uplink channel time to send such a report comprising up to a number M of data blocks.

Decisions on new primary transmissions and retransmissions are taken after each period of K block transmissions (primary transmissions and retransmissions). Alternatively, after K time steps. To guarantee reporting from up to M users before any new decisions are taken, assume that the period between decisions is long enough, i.e. K equal to or larger than M. Typically; $K=M$ to keep retransmission delays fairly low.

An RLC ACK/NACK sliding window, illustrated in Figure 2, is used to limit the range of RLC blocks that may be retransmitted. In the Figure 2 a window of size W=5 is illustrated, where the window is slid after each transmitted new data block. Typically, the window spans the most recent data block and a fixed number of data blocks preceding the last block. Any data block within the range of the window and which has been reported as NACK is a candidate form retransmission. The window is slid forward at a pace corresponding to the rate of transmitting new data blocks. In embodiments according to the invention, the ACK/NACK report history contained in the current window is used for prioritization decisions.

When considering which data blocks are to be retransmitted, each data block within the range of the current ACK/NACK window is considered as a candidate for retransmission. As mentioned before, decisions on which data block to retransmit are based at least on the ACK/NACK reports from all users within the current window.

The number of retransmissions on the common channel is limited, according to the invention, by in the first place reserving capacity or bandwidth for primary transmissions (so that a guaranteed bit rate is achieved). This means that for each period of K transmissions, a subset is reserved for new data blocks (however, not more than necessary). The capacity or bandwidth that remains is available for selected retransmissions.

A basic way of taking block age into account is by using an ACK/NACK window that limits the number of previous blocks that may be considered for

retransmission. The ACK/NACK window is slid in accordance with the number of new data blocks transmitted (primary transmissions). Old blocks that thereby fall outside the window are discarded with respect to further retransmissions, meaning that retransmissions of these blocks are stopped.

Subsequently, each data block in the window is assigned a ranking based on the following factors:

ACK/NACK reports from all users for that particular data block. Blocks that have not yet been reported by all users may be considered for retransmission if there is spare transmission time after considering blocks with complete reports;

Current user scores or rankings (based on e.g. ACK/NACK history for each user);

Optionally, the age of the data block (or block number).

The ACK/NACK reports from each user indicate to what extent retransmissions of a certain data block is requested, whereas the scores or rankings indicate which users are already close to a good quality and also indicate the radio link quality for each user.

The scoring or ranking strategy can, according an embodiment of the present invention, be represented by a predetermined function, hereinafter referred to as a score function, and calculated for each block. The decisions on which blocks to retransmit are made based on ranking blocks with respect to at least the current scores, and how optionally on how many retransmissions that are allowed for the next retransmission period (i.e. number of retransmissions during a period of K transmissions).

The choice of score function determines which quality requirements will be best met. As exemplary embodiments of the present invention, three different score functions or strategies will be described below:

Basically, the three different embodiments according to the invention can be referred to and summarized as follows:

Fair. Retransmit most requested blocks;

Throughput: Aims at maximizing the expected number of users to successfully receive a requested block (factors: number of users requesting a block, link quality of user) and thereby gives priority to users experiencing better radio conditions;

User quality: Aims at increasing the fraction of satisfied users (FSU) by retransmitting primarily to selected users. Also, this strategy gives priority to users experiencing better radio conditions.

An exemplary first score function is defined as:

$$s_1(b) = \sum_u I_u(b)$$

where b is the data block number, u is the user and $I_u(b)$ equals 1 if block b is reported as NACK (Negative ACKnowledgement) by user u. (Consequently, a reported ACK (ACKnowledgment) results in a score function value = 0).

This so called *Fair*-strategy in some aspect assumes that a frequently requested block is caused by some error at the transmitting node, thereby enabling frequently requested blocks to be retransmitted

The second exemplary score function is defined by:

$$s_2(b) = \sum_u I_u(b) \cdot (1 - p_1(u))$$

where $p_1(u)$ is an estimate of the block error probability (BLEP) for user u. BLEP can, e.g., be estimated by the recursion $p_1(u) = a \cdot p_{err}(u; M) + (1-a) \cdot p'_1(u)$ where $p'_1(u)$ is the previous estimate used

(initially set to 0), and a is between 0 and 1. The quantity $p_{err}(u;M) = N_{err}(u;M)/M$ is the fraction of NACKs in the last report of M blocks and $N_{err}(M)$ is the number of errors for the last report.

Finally, an exemplary third score function is defined by:

$$s_3(b) = \sum_u I_u(b)/p_\infty(u)$$

where $p_\infty(u)$ is an estimate of the residual block error probability (BLEP) for user u (0/0 should be interpreted as 0). It is here estimated by the recursion $p_\infty(u) = a \cdot p_{err}(u;W) + (1-a) \cdot p'_\infty(u)$ where $p'_\infty(u)$ is the previous estimate used, and a is between 0 and 1. The quantity $p_{err}(u;W) = N_{err}(u;W)/W$ is the fraction of NACKs for user u in the current window of size W. Note that there may be better functions of the ACK/NACK history to estimate the residual BLEP.

A retransmission strategy that employs e.g. score function 1 will in the following be called strategy 1. Strategies 2 and 3 are defined correspondingly.

Although time is omitted in the score functions, they are (at least inherently) functions of the time since the ACK/NACK window changes between retransmission decisions.

Ranking of all current data blocks in the window is done with respect to the value of the score function and optionally the age of the block. For the described strategies, the age of a block (age=number of last transmitted block minus block number of considered block) is only used to rank among blocks with equal scores so that newer blocks are prioritized ("last in, first served"). However, it is equally possible to use the age of the block as an

integral part of the actual score function. It is purely a mathematical action to include age of a block into the score function.

Strategies 2 and 3 both give a higher score to users with low BLEP values, residual or not.

The strategies described can be modified by the way the block age is used when ranking blocks for retransmission. This can be important for certain real-time broadcast transmissions.

An additional factor to consider when ranking blocks for retransmission is the time spent in the broadcast session by the user requesting a specific block.

Further examples visualizing the effect of applying the previously described different score functions to a system will be discussed in relation to Fig. 3 to Fig. 6.

For the exemplary embodiments, the following assumptions are made:

The media i.e. data blocks are sent with constant bit rate.
Data blocks are numbered in ascending order as they are transmitted the first time. If a block is retransmitted at a later time, it keeps the original number. (Alternatively, it could re-numbered so that it is considered as a more recent block.)

ACK/NACK reporting is scheduled cyclically among n users so that each user is scheduled each M:th transmitted block (alternatively: each M:th time step). The number of reporting users (n) may vary in time but must be less than or equal to M. A special case is that M equals the current number of users and is changed whenever n changes.

Each user reports the *M* least recent receptions among the received but not yet reported blocks (ACK for a correctly received block, NACK for an incorrectly received block).

The transmitting node has a retransmission window of size *W*. The window is sliding as time is stepped, meaning that at time *t* the window covers ACK/ANCK reports for the *W* most recent blocks, i.e. those from time *t-x*, where *x>= W*+1, up to and including time *t*. Time is here assumed to be measured in units of number of transmission time intervals (TTIs).

Block error rates for the different users are assumed to be uniformly distributed within the given interval, unless otherwise stated. Below referred to as the simplified radio link model.

There are no gains from combination of different (re-)transmission attempt, i.e., no so called incremental redundancy has been considered.

The calculations for a simplified system scenario with three users are shown in Table 1 below. Table 1 shows results for an RLC ACK/NACK window of size *W* = 9 (more typically *W*=128-256) at some arbitrary time *t*. In this case, the BLER and residual BLER estimates used for strategy 2 and 3 respectively are for simplicity both set to the fraction of NACKs in the present window. The 3 blocks with largest scores (and least block age) are marked for each strategy. Although the calculations are performed for a simplified system scenario with only three users, the same strategy can be implemented for any number of users.

Block no: age:	n(t)-8 8	n(t)-7 7	n(t)-6 6	n(t)-5 5	n(t)-4 4	n(t)-3 3	n(t)-2 2	n(t)-1 1	n(t) 0	Sum NACK
user 1	NACK	ACK	ACK	NACK	NACK	NACK	NACK	NACK	ACK	6
user 2	ACK	ACK	NACK	ACK	ACK	ACK	ACK	NACK	ACK	2
user 3	ACK	NACK	ACK	ACK	ACK	NACK	ACK	NACK	ACK	3
Sum NACK	1	1	1	1	1	2	1	3	0	
Block score strat. 1	1	1	1	1	1	**2**	1	**3**	0	
strat. 2	0.33	0.67	**0.78**	0.33	0.33	1	0.33	**1.789**	0	
strat. 3	1.5	3	**4.5**	1.5	1.5	**4.5**	1.5	9	0	

Table 1:   Calculations for a simplified system scenario with three users and three alternative strategies

The effects of different retransmission strategies, according to the invention, in simulations (with a simplified radio link model) with corresponding calculations are shown in Figure 3 (16 users with different link quality) and Figure 4 (16 users with equal link quality). The simulations comprise 30000 data blocks transmitted (broadcast or multicast) during 48000 TTIs. The primary bitrate is supported if 10 out of 16 TTIs are spent on primary transmissions. The capacity available for retransmissions in these examples is 6 out of 16 TTIs ($K=M=16$ and $W=256$).

As a comparison, a few reference strategies are added to the diagrams, in addition to the above described three exemplary strategies. One reference strategy is the so called "Retransmission prio" where each data block is retransmitted until all users have received it correctly. In this case, the ACK/NACK window may stall the flow of primary transmissions since the window may not be moved until the block at the back end has been acknowledged by all users. In this case, data blocks that are not sent during the simulation are counted as lost and included in the residual BLER statistics. The high residual BLER should in this case be interpreted as a failure to reach the required primary bit rate. E.g., with an average residual

BLER of 22%, only 78% of the required primary bit rate has been reached. See also the analysis of Figure 5 and 6 below.

Another reference strategy is so called "Random", where the data blocks to retransmit are drawn randomly among requested retransmissions within the current window. The window is advanced by 10 data blocks per period of 16 TTIs for this and the other strategies.

The Figures show that the retransmission strategy affects the BLER distribution. For strategy 3, the distribution is tilted so that the number of users with very low BLER is increased.

Strategy 1 yields least quality dispersion among users. Strategy 3 yields a quality distribution that is between strategy 1 and 3 with respect to dispersion when there is dispersion of link quality to different users (Figure 2). However, when all links are equal, strategy 2 yields results close to strategy 1 (Figure 3).

The important difference between strategy 2 and 3 is that strategy 2 estimates and schedules retransmissions with respect to link quality. Strategy 3 in addition takes into account which users have already received much service (they are prioritized so that they stay satisfied).

The core of the invention is to use specific score functions for ranking, and in particular use a score function that aims at maximizing the fraction of satisfied users. More generally, the score functions correspond to different objectives of broadcast/multicast retransmissions.

Figures 5 and 6 show the fraction of satisfied users (i.e. max 1% residual BLER) for different numbers of users and for different strategies. The simulations comprise 10000 blocks offered over a time of 16000 TTIs. Without any limitation of retransmissions, the user quality breaks down (for all users) when the load (number of simultaneous users) becomes high

enough. Limiting the number of retransmissions maintains the quality for more users. The choice of strategy becomes increasingly important as more users are present.

In these examples, strategy 3 is always best for variable link quality, see Figure 5. For fixed link quality, strategy 1 yields a higher FSU at a specific number of present users, see Figure 6. However, strategy 3 generally yields the highest FSU when resources get very scarce.

The analysis and simulation results indicate that:

     -It is necessary to limit retransmissions in order to guarantee primary transmissions;

     -The choice of retransmission strategy affects user quality when the number of users is so large that retransmissions must be limited;

     -A score based strategy, utilizing the ACK/NACK history for each user, is clearly advantageous.

Some advantages of the invention include:

The proposed solution to regulate the number of retransmissions when resources become scarce and to employ a "score function" (together with information on the age of a given data block) will solve the basic and initial problems of wireless multicast transmission:

     -How to keep the number of retransmissions at a reasonable level?

     -How to decide which data units (e.g., RLC blocks) should be retransmitted (if retransmissions need to be limited)?

     -How to prioritize between re-transmission requests from different users (to maintain user quality) (if retransmissions need to be limited)?

In other words, with re-transmission strategies as described according to the invention, it is possible to provide required bit rates with better "guarantees"/higher probability. The bit rate required for "primary transmissions" can be guaranteed by (explicitly or implicitly) limiting the

number of retransmissions. (However, it is not guaranteed that the primary transmissions are correctly received by a large enough fraction of users.)

Figure 7 illustrates an exemplary embodiment of a system according to the invention. Accordingly, the system comprises a transmitting node 10 configured for broadcasting or multicasting data blocks to n users U1...Un. The users respond to the transmitted data blocks by sending ACK/NACK reports ACK/NACK U1...ACK/NACK Un indicating correctly received or incorrectly received data blocks. Further, the system comprises an evaluation unit 11 for jointly evaluating the received ACK/NACK reports from all users, a ranking unit for ranking or prioritizing among the data blocks based on the received reports. Finally, the transmitting node 10 comprises a retransmission unit 13 for retransmitting data blocks based on a resulting ranking from the ranking unit 13.

Even though the various units 11, 12, 13 are depicted as included in the transmitting node 10, it is implied that the actual units can be located elsewhere in the system and only supply the necessary information for actuating the selective retransmissions in the transmitting node 10.

Although embodiments of the present invention are described as implemented to handle retransmissions to users within one network cell, it is equally possible, with appropriate modifications, to use for retransmissions to users in multiple cells. One possibility could be to perform the method of the invention in multiple cells, one at a time. Another possibility could be to exploit the possibility of macrodiversity by having some functionality which coordinates the ranking of data blocks for different cells, i.e. by identifying data blocks suitable for macrodiversity and coordinating retransmissions of theses blocks in suitable cells (together providing macrodiversity). As an example, if the data block is requested for retransmission from multiple users distributed over a plurality of cells.

In summary, the invention comprises the following advantages:

Enabling more efficient retransmission strategies
Enabling providing a minimum guaranteed bitrate for transmissions
Reducing total number of retransmissions

5   It will be understood by those skilled in the art that various modifications and changes may be made to the present invention without departure from the scope thereof, which is defined by the appended claims.

REFERENCES

[1]   3GPP TS 43.246, Multimedia Broadcast Multicast Service (MBMS) in the GERAN, V6.5.0 (2005-09).

CLAIMS

1. A method of retransmission in a wireless communication system, said system comprising a transmitting node communicating a plurality of data blocks to multiple user nodes on a common radio channel, and said transmitting node receiving reports of successful/unsuccessful reception of said data blocks from each of said multiple users, **characterized by:**

jointly evaluating the reception results from said multiple users based on said reports;

ranking said data blocks for retransmission based at least on said joint evaluation, and

said transmitting node selectively retransmitting data blocks to said multiple users based at least on said ranking to limit the bandwidth used for retransmissions.

2. The method according to claim 1, **characterized by** ranking said data blocks based on a predetermined function.

3. The method according to claim 1, **characterized by** ranking said data blocks based on at least one of block error probability for a user, residual block error probability for a user, fraction of negative acknowledgements in for a user.

4. The method according to claim 2, **characterized in that** said predetermined function is represented by:

$$s_1(b) = \sum_u I_u(b)$$

where b is the data block number, u is the user and $I_u(b)$ equals 1 if block b is reported as NACK by user u.

5. The method according to claim 2, **characterized in that** said predetermined function is represented by:

$$s_2(b) = \sum_u I_u(b) \cdot (1 - p_1(u))$$

where $p_1(u)$ is an estimate of the block error probability for user u.

6. The method according to claim 5, **characterized in that** the block error probability is estimated by the recursion $p_1(u) = a \cdot p_{err}(u;M) + (1-a) \cdot p'_1(u)$ where $p'_1(u)$ is the previous estimate used (initially set to 0), and a is a value between 0 and 1. The quantity $p_{err}(u;M) = N_{err}(u;M)/M$ is the fraction of NACKs in the last report of M blocks and $N_{err}(M)$ is the number of errors for the last report.

7. The method according to claim 2, **characterized in that** said predetermined function is represented by:

$$s_3(b) = \sum_u I_u(b)/p_\infty(u)$$

where $p_\infty(u)$ is an estimate of the residual block error probability for user u.

8. The method according to claim 7, **characterized in that** the residual block error probability for user u $p_\infty(u)$ is estimated by the recursion $p_\infty(u) = a \cdot p_{err}(u;W) + (1-a) \cdot p'_\infty(u)$ where $p'_\infty(u)$ is the previous estimate used, and a is between 0 and 1. The quantity $p_{err}(u;W) = N_{err}(u;W)/W$ is the fraction of NACKs for user u in the current window of size W.

9. The method according to any of claims 2-8, **characterized by** additionally ranking said data blocks based on the age of the data blocks.

10. The method according to any of claims 2-9, **characterized by** additionally ranking said data blocks based on user priority.

11. The method according to claim 1, **characterized by** the further step of allocating at least a predetermined minimum fraction of the available bandwidth on said common radio channel to transmissions and any remaining fraction to the selective retransmissions.

12. A wireless communication system, said system comprising a transmitting node (10) configured for communicating a plurality of data blocks to multiple user nodes (U1, ..., Un) on a common radio channel, and said transmitting node (10) is further configured for receiving reports of successful/unsuccessful reception of said data blocks from each of said multiple users (U1,...,Un), **characterized by:**

   means (11) for jointly evaluating the reception results from said multiple users based on said reports;

   means (12) for ranking said data blocks for retransmission based at least on said joint evaluation, and

   means (13) for selectively retransmitting data blocks to said multiple users based at least on said ranking to limit the bandwidth used for retransmissions.

13. The system according to claim 12, **characterized in that** said ranking means (12) are adapted for ranking said data blocks based on a predetermined function.

14. The method according to claim 12, **characterized in that** said ranking means (12) are adapted for ranking said data blocks based on at least one of block error probability for a user, residual block error probability for a user, fraction of negative acknowledgements in for a user.

15. The system according to claim 13, **characterized in that** said predetermined function is represented by:

$$s_1(b) = \sum_u I_u(b)$$

where b is the data block number, u is the user and $I_u(b)$ equals 1 if block b is reported as NACK by user u.

16. The system according to claim 13, **characterized in that** said predetermined function is represented by:

$$s_2(b) = \sum_u I_u(b) \cdot (1 - p_1(u))$$

where $p_1(u)$ is an estimate of the block error probability for user u.

17. The system according to claim 16, **characterized in that** the block error probability for user u is estimated by the recursion $p_1(u) = a \cdot p_{err}(u;M) + (1-a) \cdot p'_1(u)$ where $p'_1(u)$ is the previous estimate used (initially set to 0), and a is a value between 0 and 1. The quantity $p_{err}(u;M) = N_{err}(u;M)/M$ is the fraction of NACKs in the last report of M blocks and $N_{err}(M)$ is the number of errors for the last report.

18. The system according to claim 13, **characterized in that** said predetermined function is represented by:

$$s_3(b) = \sum_u I_u(b) / p_\infty(u)$$

where $p_\infty(u)$ is an estimate of the residual block error probability for user u.

19. The system according to claim 18, **characterized in that** the residual block error probability $p_\infty(u)$ is estimated by the recursion $p_\infty(u) = a \cdot p_{err}(u;W) + (1-a) \cdot p'_\infty(u)$ where $p'_\infty(u)$ is the previous estimate used, and a is between 0 and 1. The quantity $p_{err}(u;W) = N_{err}(u;W)/W$ is the fraction of NACKs for user u in the current window of size W.

20. The system according to any of claims 13-19, **characterized in that** said ranking means are further adapted for additionally ranking said data blocks based on the age of the data blocks.

21. The method according to any of claims 13-20, **characterized in that** said ranking means are further adapted for additionally ranking said data blocks based on user priority.

26

22. The system according to claim 12, **characterized by** further means for allocating at least a predetermined minimum fraction of the available bandwidth on said common radio channel to transmissions and any remaining fraction to the selective retransmissions.
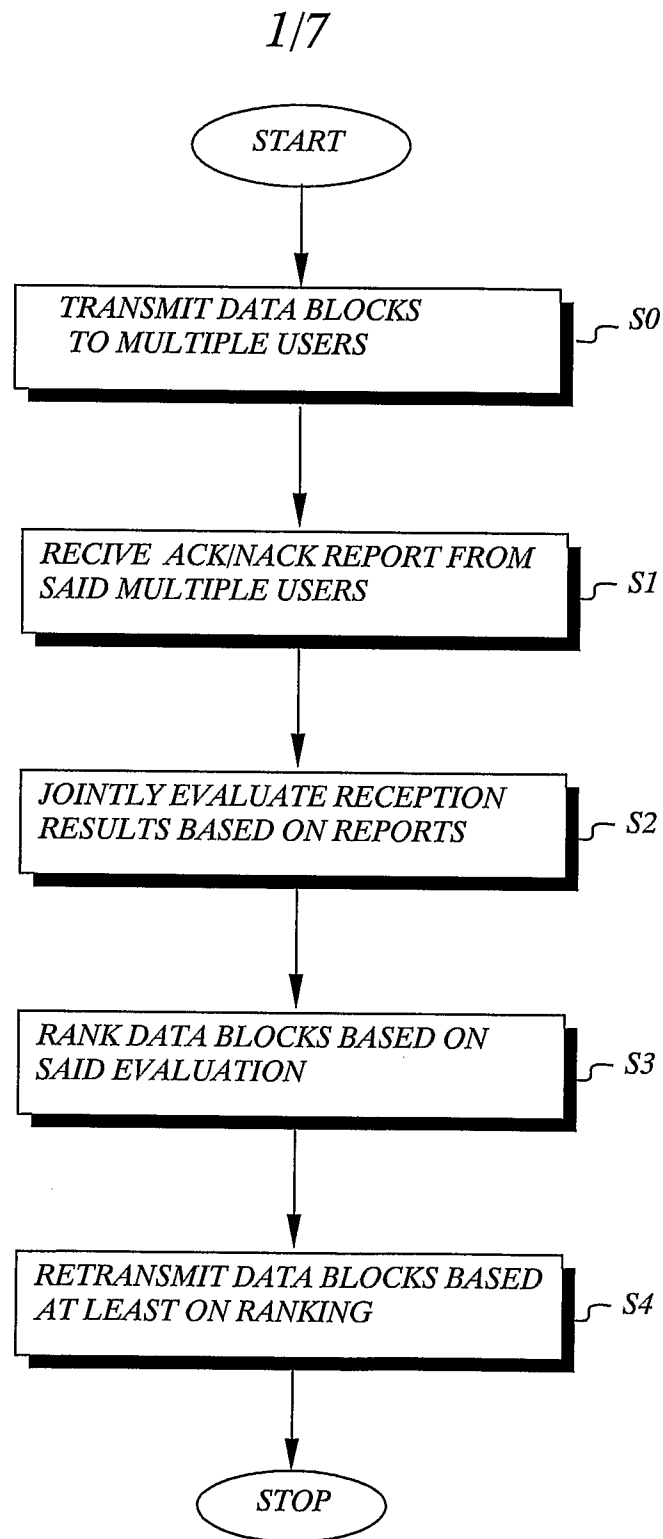
23. A node in a wireless communication system, said node is adapted for communicating a plurality of data blocks to multiple user nodes on a common channel, and said node is further adapted to receive reports of successful/unsuccessful reception of said data blocks from each of said multiple users, **characterized by:**

   means (11) for jointly evaluating the reception results from said multiple users based on said reports;

   means (12) for ranking said data blocks for retransmission based at least on said joint evaluation, and

   means (13) for selectively retransmitting data blocks to said multiple users based at least on said ranking to limit the bandwidth used for retransmissions. .

24. The node according to claim 15, **characterized by** further means for allocating at least a predetermined minimum fraction of the available bandwidth on said common radio channel to transmissions and any remaining fraction to the selective retransmissions.
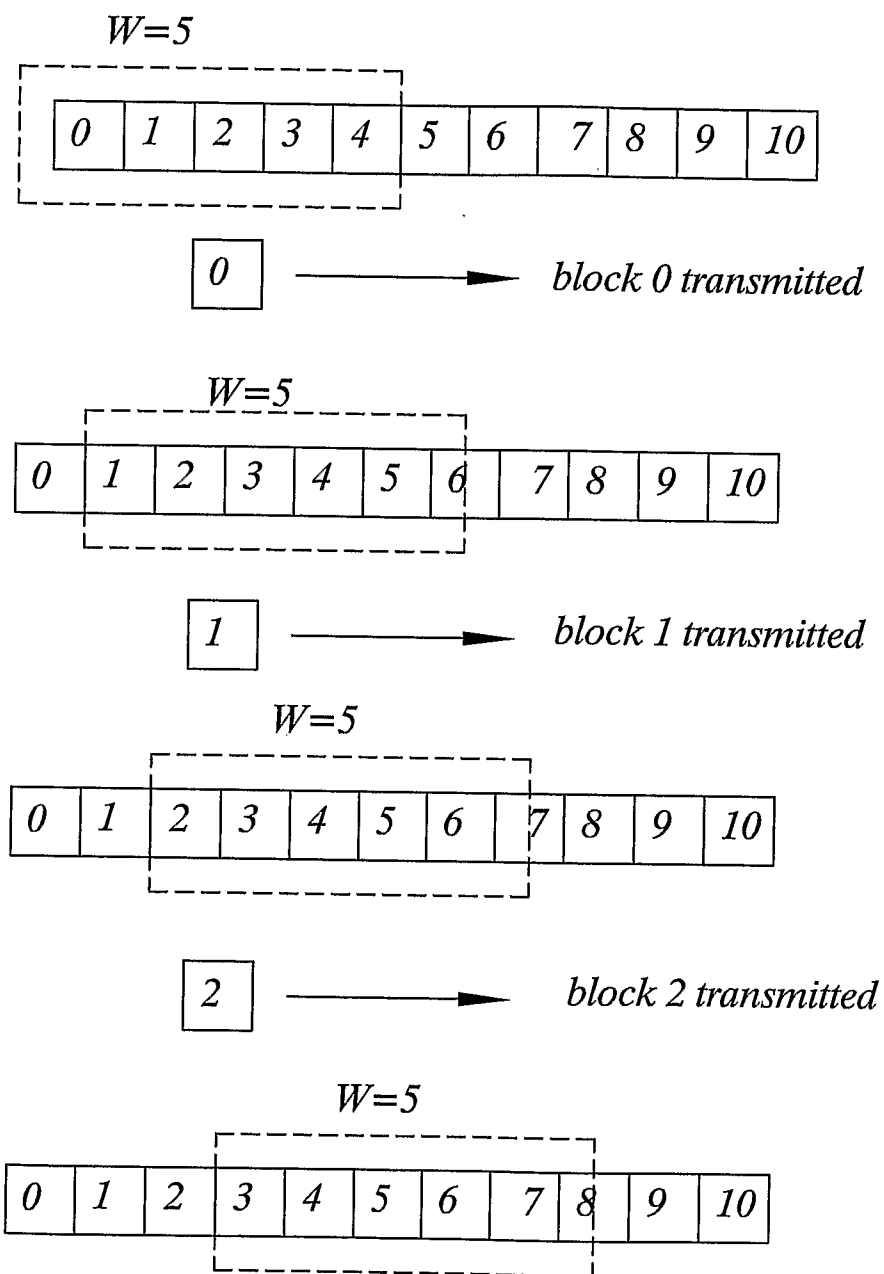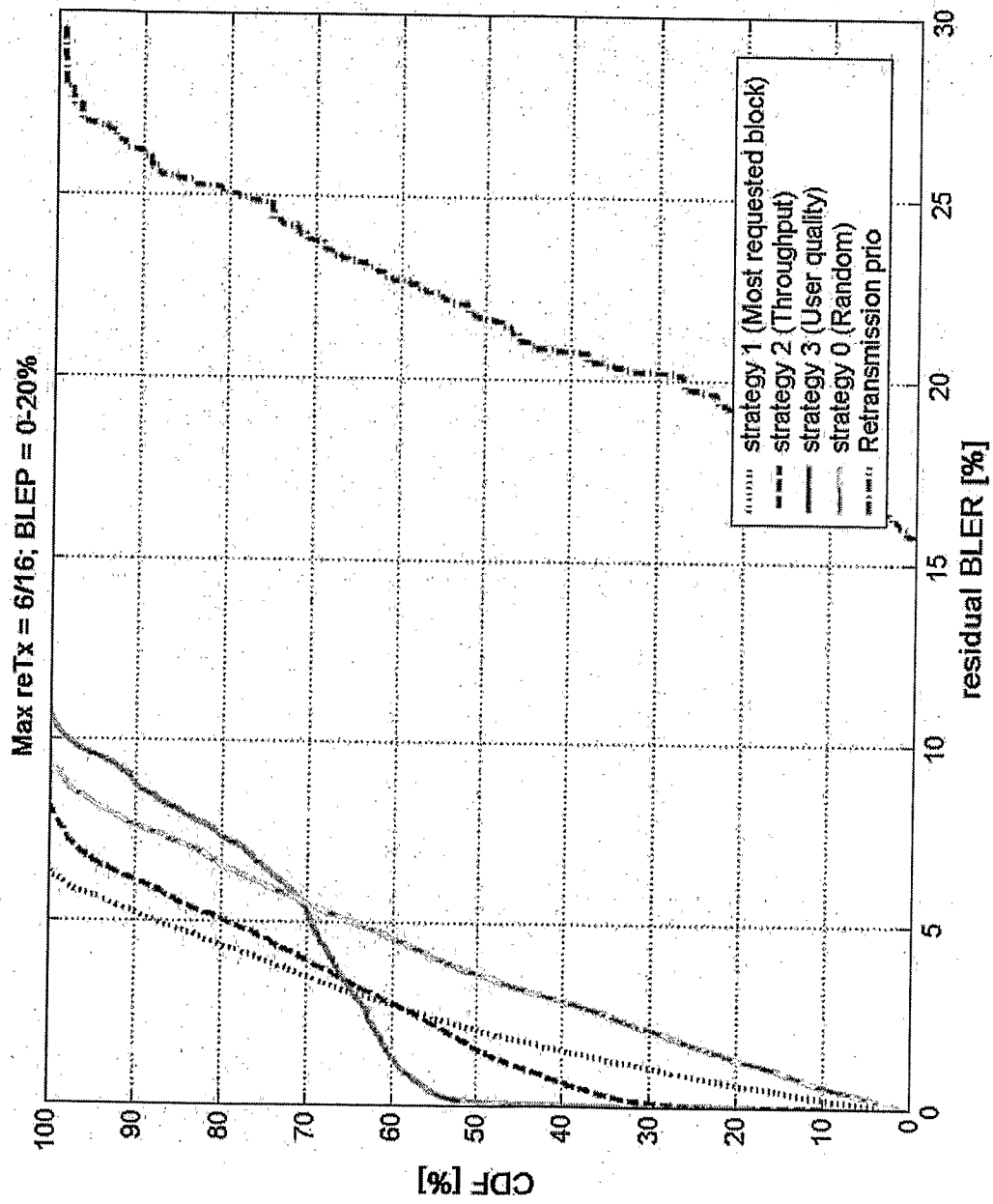

1/7

FIG. 1

$W=5$

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| 0 | ⟶ block 0 transmitted

$W=5$

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| 1 | ⟶ block 1 transmitted

$W=5$

| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

| 2 | ⟶ block 2 transmitted

$W=5$

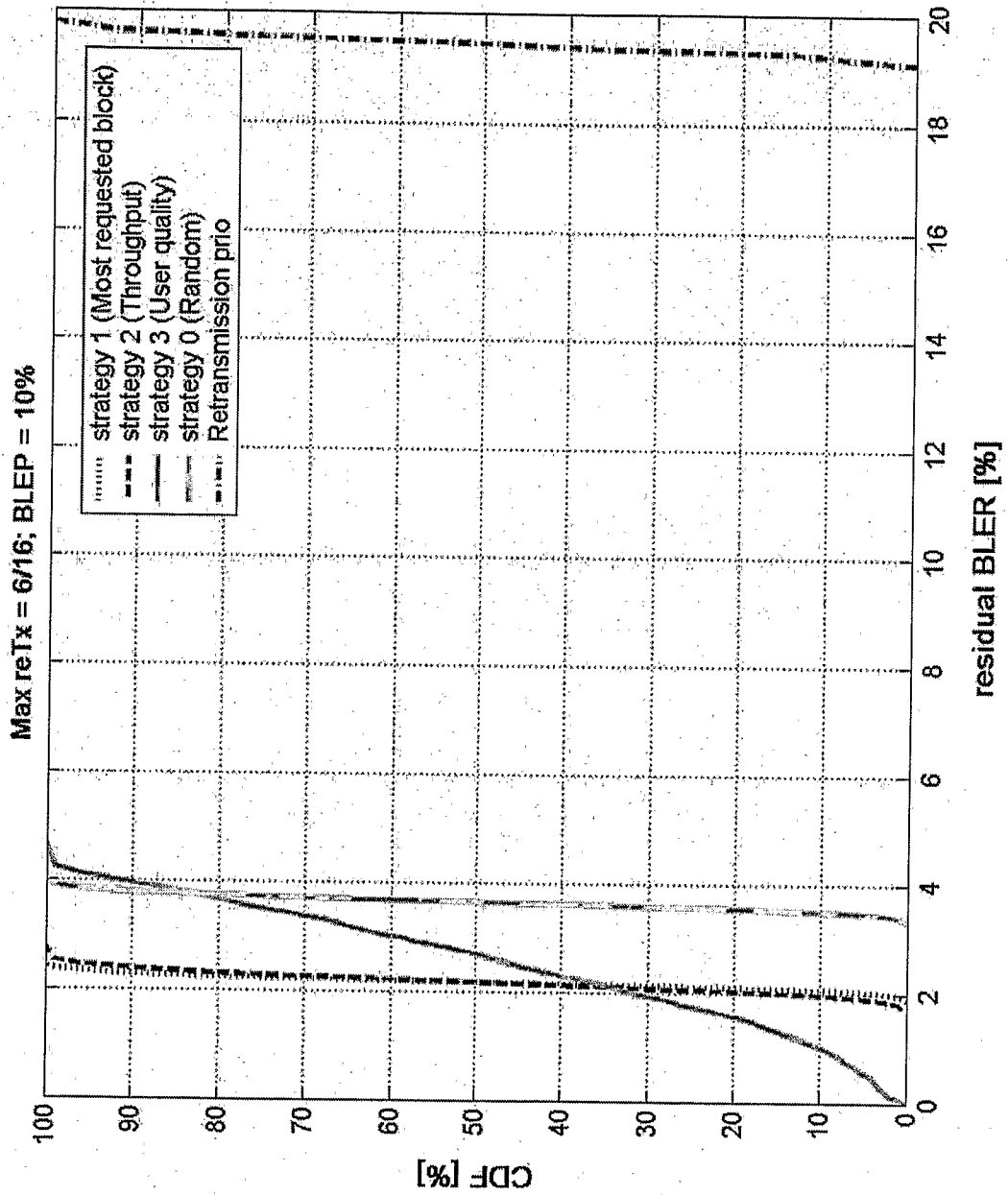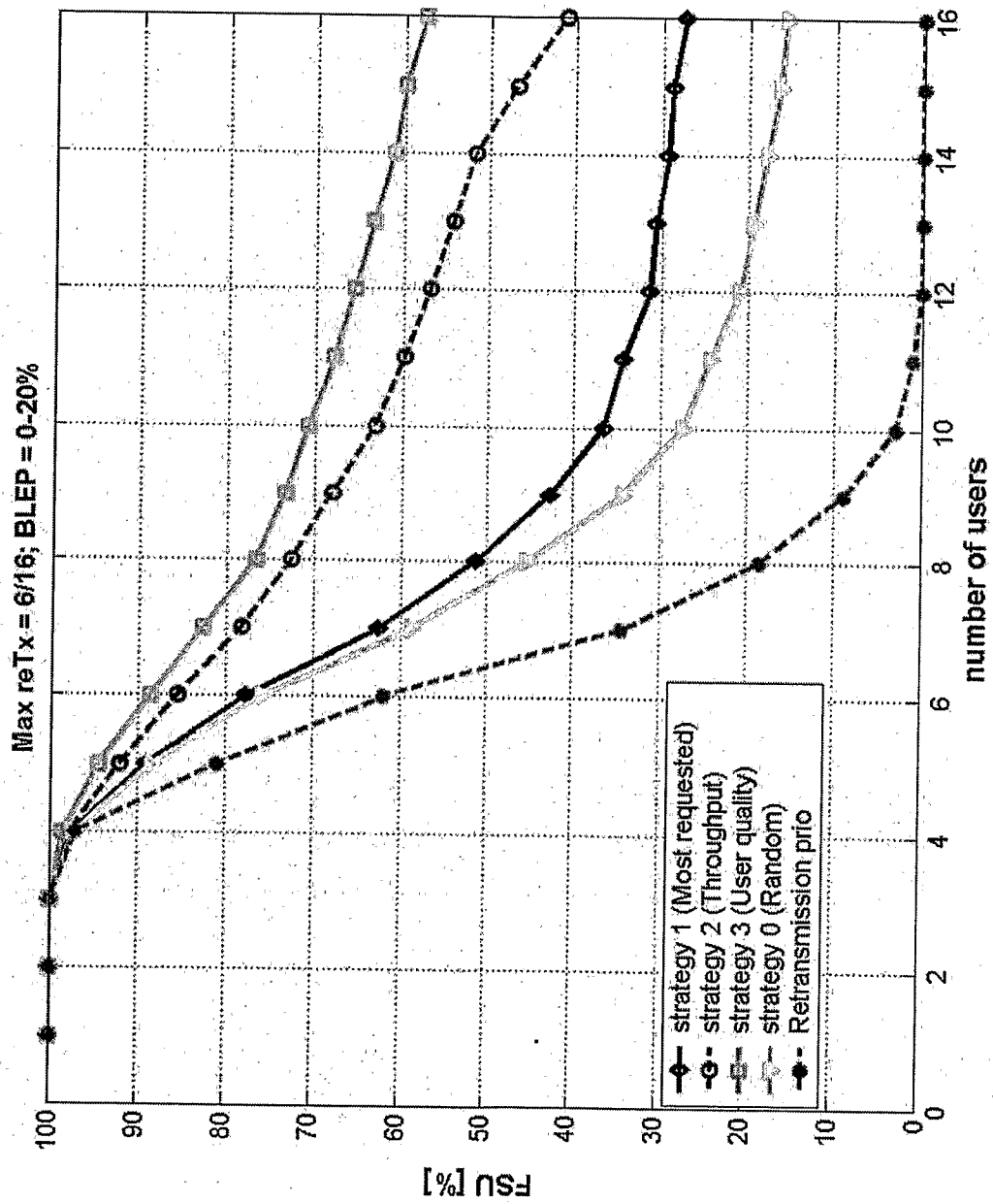| 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |

FIG. 2

FIG. 3

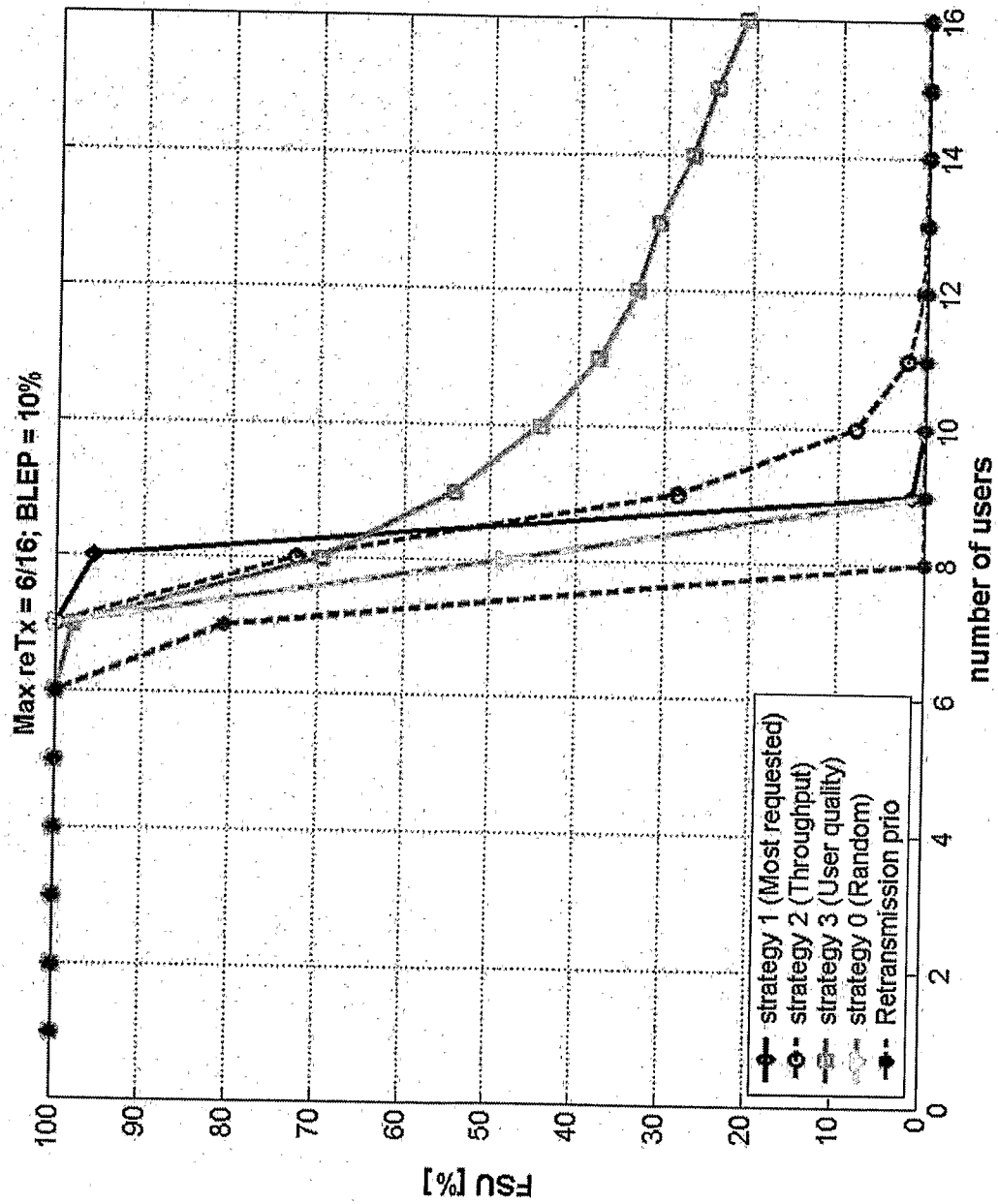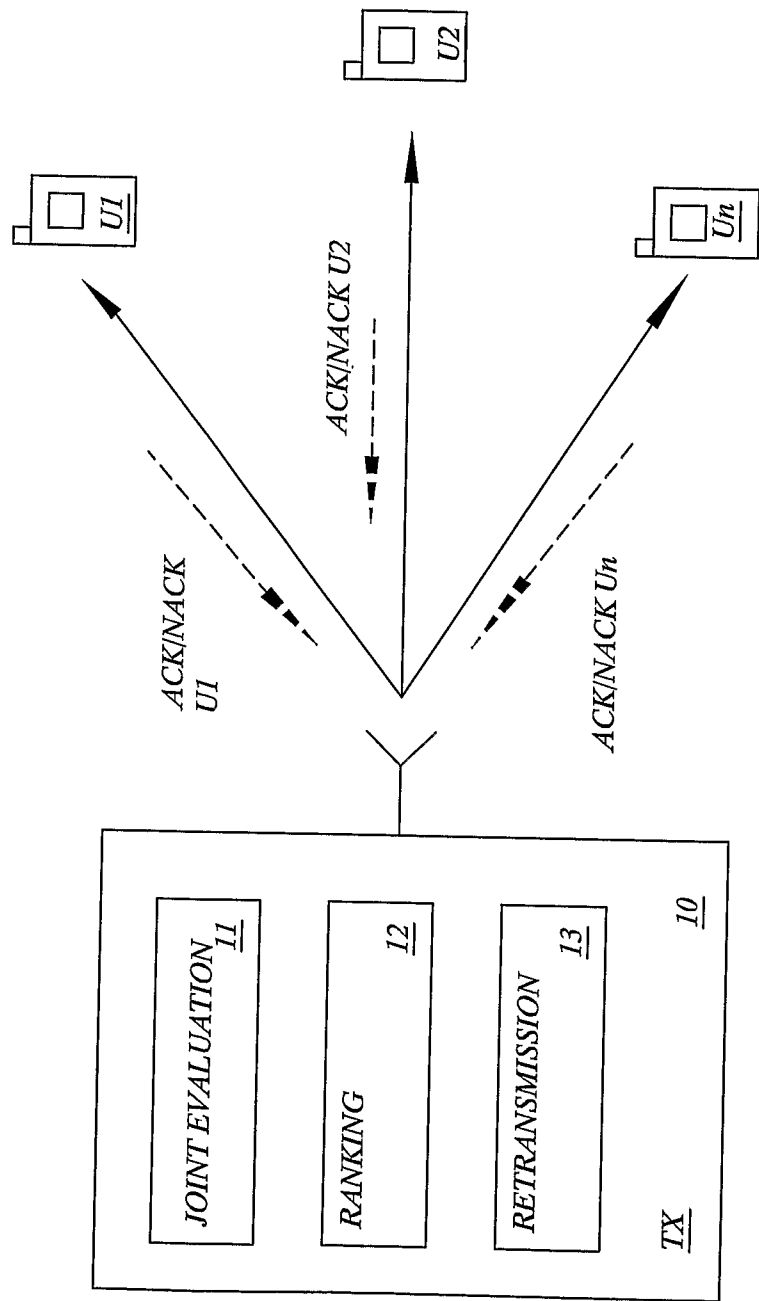*FIG. 4*

5/7

FIG. 5

FIG. 6

FIG. 7

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2005/001951

A. CLASSIFICATION OF SUBJECT MATTER

IPC: see extra sheet

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: H04L

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

SE,DK,FI,NO classes as above

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

EPO-INTERNAL, WPI DATA, PAJ

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	US 20050129058 A1 (LORENZO CASACCIA ET AL), 16 June 2005 (16.06.2005), [0011],[0028], [0041]-[0044]	1-24
	--	
A	US 20050259643 A1 (MOOI CHOO CHUAH ET AL.), 24 November 2005 (24.11.2005), [0005], [0014]-[0016]	1-24
	--	

[X] Further documents are listed in the continuation of Box C.   [X] See patent family annex.

* Special categories of cited documents:	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"A" document defining the general state of the art which is not considered to be of particular relevance	
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance: the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
"L" document which may throw doubts on priority claim(s) or which is cited to establish the publication date of another citation or other special reason (as specified)	
	"Y" document of particular relevance: the claimed invention cannot be considered to involve an inventive step when the document is combined with one or more other such documents, such combination being obvious to a person skilled in the art
"O" document referring to an oral disclosure, use, exhibition or other means	
"P" document published prior to the international filing date but later than the priority date claimed	"&" document member of the same patent family

Date of the actual completion of the international search	Date of mailing of the international search report
4 Sept 2006	1 4 -09- 2006

Name and mailing address of the ISA/	Authorized officer
Swedish Patent Office Box 5055, S-102 42 STOCKHOLM Facsimile No. + 46 8 666 02 86	Patrik Rydman / itw Telephone No. + 46 8 782 25 00

Form PCT/ISA/210 (second sheet) (April 2005)

International patent classification (IPC)
H04L 1/18 (2006.01)

Download your patent documents at www.prv.se
The cited patent documents can be downloaded at www.prv.se by following the links:
- In English/Searches and advisory services/Cited documents (service in English) or
- e-tjänster/anförda dokument(service in Swedish).

Use the application number as username.
The password is   .

Paper copies can be ordered at a cost of 50 SEK per copy from PRV InterPat (telephone number 08-782 28 85).

Cited literature, if any, will be enclosed in paper form.

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE2005/001951

Box No. II   Observations where certain claims were found unsearchable (Continuation of item 2 of first sheet)

This international search report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:
   because they relate to subject matter not required to be searched by this Authority, namely:

2. ☐ Claims Nos.:
   because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:

3. ☐ Claims Nos.:
   because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

Box No. III   Observations where unity of invention is lacking (Continuation of item 3 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

1: Claims 1-10, 12-21 and 23 directed to rank data blocks intended for retransmission using a predetermined function in order to schedule the retransmission of data blocks, i.e. determine the order in which the data blocks are retransmitted.

.../...

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.

2. ☒ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.

3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:

4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest
   ☐ The additional search fees were accompanied by the applicant's protest and, where applicable, the payment of a protest fee.
   ☐ The additional search fees were accompanied by the applicant's protest but the applicable protest fee was not paid within the time limit specified in the invitation.
   ☐ No protest accompanied the payment of additional search fees.

Form PCT/ISA/210 (continuation of first sheet (2)) (April 2005)

Box III

2: Claims 11, 22 and 24 directed to limit the number of data blocks intended for retransmission by limiting the available bandwidth for retransmissions.

INTERNATIONAL SEARCH REPORT

International application No.

PCT/SE2005/001951

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.

A	Anders Furuskär
	    Radio Repsource Sharing and Bearer Service
	    Allocation for Multi-Bearer Service,
	    Multi-Access Wireless Networks
	    May 2003
	    ISRN KTH/RST/R--03/02--SE
	    ISSN 1400-9137
	    page 19-21
	
	        --
	        -------- 	
		5-8,16-19

US	20050129058	A1	16/06/2005	AU	2004306766	A	21/04/2005
				CA	2542273	A	21/04/2005
				EP	1678981	A	12/07/2006
				WO	2005036917	A	21/04/2005
US	20050259643	A1	24/11/2005	NONE			