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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **Proposed MAC ARQ Mechanism for the proposed 802.16.4 Standard** |
| Date Submitted | **2001-03-04** |
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| Re: | This contribution is in response to the Call for Contributions IEEE 802.16.4 for error control and the discussions at the Session 11.5 of TG4 |
| Abstract | An Automatic Repeat Query (ARQ) is being proposed for the Proposed IEEE 802.16.4 Air Interface that provides for all traffic types over wireless channels. A common approach is to implement the ARQ in a data link controller that is separate from the media access controller. A common approach is to implement the ARQ in a data link controller that is separate from the media access controller. Implementations of this type cause delays in retransmission that make it difficult or impossible to support the fixed latency guarantees required by some real-time services.<br><br>This proposal provides a fast selective repeat ARQ that supports all traffic types over wireless channels including traffic with fixed latency requirements and can be used with Single Carrier or multi-Carrier PHY Layer Broadband Fixed Wireless Access . |
| Purpose | For TG4 to consider including this ARQ approach in the Proposed 802.16.4 Standard |
| Notice |  |
| Release |  |
| Patent Policy and Procedures |  |

## BACKGROUND

A common objective expressed by many for the proposed IEEE 802.16.4 Air Interface Broadband Wireless Access (BWA) Standard contributions, was to reach agreement on a PHY and MAC layers that result in cost-effective BWA Air Interface implementations. Among the Wireless HUMAN BWA performance enhancing techniques is ARQ.

What follows is a description of an ARQ technique that can be used alone to efficiently and cost effectively improve performance of fixed BWA systems of low bit error rate channels, or concatenated with a PHY layer FEC to effectively improve performance of BWA systems with high error rate channel.

## ARQ DETAILED DESCRIPTION

Data transmission and ARQ in only the downstream direction will be described. ARQ is applied in the upstream in an identical manner. The ARQ relevant portions of the MAC are described first, then the data structures enabling the implementation of the MAC followed by a description of the traffic scheduling and ARQ algorithms. Finally the key benefits that can result from the proposed ARQ are listed.

## RELEVANT PORTIONS OF THE MAC

The Access Point (AP) MAC through the use of a MAC frame controls access to the wireless media. Each MAC frame consists of a downstream and an upstream portion. Contained within the downstream portion are the frame descriptor header, subscriber reservation request acknowledgments, downstream cell acknowledgments and downstream data cells. The upstream portion of the MAC frame consists of a short slotted Aloha contention period in which the subscriber terminals request reservations followed by upstream cell acknowledgements and upstream data cells.

The mapping of subframes within the MAC frame is communicated by the AP to the Subscriber Terminals (STs) via the frame descriptor header. For the purposes of this description, the most important section of the frame descriptor header is the downstream burst map.

The downstream burst map includes a maximum of sixteen entries (one for each burst, thereby limiting the downstream portion of the MAC frame to no more than 16 bursts). Each burst map consists of a Subscriber Unit-Access Identifier (SU-AID), the traffic type of the burst, and the number of cells contained within the burst. The frame descriptor header and thus the downstream burst map are sent out at the beginning of a MAC frame.

## MAC DATA STRUCTURES

1. Subscriber Unit List: contains a list of actively registered SU-AIDs, with a pointer from each entry to a set of traffic queues.
2. Subscriber Unit Traffic Queues: For each SU that is actively registered with an AP, there is a set of traffic queues, one queue per traffic type.
3. Cell Acknowledgement Map: Each time a cell is sent from the AP to a ST, the AP expects to receive a positive or a negative acknowledgement of the cell's arrival. Since no more than six cells of a given traffic type for a particular SU can be sent within a single MAC frame, it is not necessary to retain the acknowledgements status for more than six cells of a given traffic queue. Each queue therefore has six bit acknowledgement state of the most recently sent six cells.
4. Pending Reservation Queue: For each traffic type, there is a circular buffer containing a single entry for each SU with traffic awaiting a reservation.

5. Downstream Frame Reservation Schedule: Contained within this structure is a map of all downstream bursts to be sent during the downstream portion of the subsequent MAC frame. Entries for each burst include the SU-AID, the traffic type of the burst, and the number of cells contained within the burst.

## TRAFFIC SCHEDULING ALGORITHMS

Cell Entry to the MAC: When a cell enters the MAC, it is de-multiplexed into the traffic queue corresponding to the SU and traffic type. If the queue had been empty upon cell arrival, the SU's SU-AID is entered into the pending reservation buffer for the corresponding traffic type.

Cell Scheduling: MAC frame burst maps are generated less than one frame in advance of the time that they are to be sent over the air. The cell scheduler first checks the pending reservation request buffer for the highest priority traffic type to see if any cells of that type are awaiting transmission. If there is an entry in the buffer (indicating that there may be traffic of that type queued-up), the scheduler reads the SU-AID from the buffer and uses it as an index into the SU list to reference the SU's traffic queue for that traffic type.

Because of the implementation of the cell scheduling algorithm, it is possible for entries to remain in the pending reservation queue even though no more traffic is pending. In that case, the scheduling controller removes the entry from the pending reservation buffer and makes no corresponding entry in the downstream schedule/burst map.

If there is traffic in the queue at the time the pending reservation is processed, the scheduling controller places the SU-AID into the tail end of the buffer, in order to keep the reservation open for potential cell retransmissions.

Cell Acknowledgment: The six bits of acknowledgment map for traffic queue corresponds to the acknowledgement state of the most recently sent cells. The data are sent to the ST during the downstream portion of the MAC frame, and are expected to be acknowledged during the upstream portion. The acknowledgment sent by a ST contains a six-bit map, with a 1 bit indicating positive acknowledgment and a 0 bit indicating negative acknowledgment. This six-bit map is transferred into the acknowledgment map for the corresponding SU-AID and traffic type.

Garbage Collection: During downstream transmission of the bursts that were scheduled in the previous frame, the MAC has time to remove positively acknowledged cells from traffic queues. The garbage collector checks each queue's acknowledgment map. Any cell with positive acknowledgment has been received correctly and thus no longer need to remain queued up. They are removed from the queue, and the count of pending cells for that particular traffic queue, is decreased by one.

ARQ Mechanism: retransmission of cells that were negatively acknowledged (or not positively acknowledged) is automatic as a result of the operations described above.

Two aspects of the MAC design force this to be true. First, only positive cell acknowledgement causes a cell to be removed from a traffic queue, thus leaving a cell in the traffic queue until its reception is confirmed. Second, Because the cell scheduler continues to add the ST access identifier to the pending reservation buffer, the reservation for that ST and traffic type is kept open until all cells have been positively acknowledged. A processor resequences acknowledged received cells. As each cell of data contains a sequence number in its header, resequencing can be performed in the MAC/ARQ layer or in a convergence sublayer without any additional complexity.

## KEY BENEFITS OF THE PROPOSED ARQ APPROACH

1. Allows a BWA system to provide error correction without requiring sending unnecessary FEC overhead to each ST.

2. Allows a fast turnaround ARQ mechanism for support of fixed bit rate and low latency traffic, by including the ARQ mechanism in the channel access mechanism.
3. Since the bandwidth for the ACKS/NACKS is always allocated within the MAC frame, the delay for receiving feedback from the far end of the link is always deterministic. Also since there need not be any contention for bandwidth for sending an ACK/NACK, the overall bandwidth efficiency of the network is improved
4. Since the ACK/NACK bits are always located in the same place in the MAC frame, there need to be no separate identifier symbols and there not be any packet sequence numbers accompanying the ACKS/NACKS.
5. The scheme is simple to implement because the six-bit ACK/NACK bitmap is stored directly on the six-bit acknowledgement bitmap of the traffic queue. This allows cells that have been successfully transmitted, to be removed from the traffic queue at some other time during the MAC frame.
6. The traffic schedule that defines all of the traffic to be sent in a MAC frame is identical to the on-air frame descriptor header. This allows the header to be assembled at the same time the control flow for the MAC is being assembled. This simplifies hardware.
7. Can be supplemented with a Physical Layer FEC to form a Hybrid ARQ-FEC to effectively improve the performance of BWA channels with high error rate.