

Project	IEEE 802.16 Broadband Wireless Access Working Group < http://ieee802.org/16 >	
Title	ARQ Rewrite Based on MAC Group Comment Resolution For Letter Ballot #7	
Date Submitted	2002-07-11	
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Re:	Comment Resolution for Working Group Letter Ballot #7 “Draft Amendment to IEEE Standard for Local and Metropolitan Area Networks –Part 16:Air Interface for Fixed Broadband Wireless Access Systems – Medium Access Control Modifications and Additional Physical Layer Specifications for 2-11 GHz ”	
Abstract	Revised text for ARQ based on the results of Letter Ballot #7 comment resolution. The text was adopted under Comment 60 to supercede Comments 60 through 97.	
Purpose	Provide readable version of ARQ text for review.	
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Page 67 Line 16**6.2.4 ARQ - 2-11 GHz bands only**

Note: ARQ shall not be used with the PHY specification defined in clause 8.2.

The ARQ mechanism is an optional part of the MAC layer and can be enabled on a per-connection basis. The per-connection ARQ and associated parameters shall be specified and negotiated during connection creation or change. A connection cannot have a mixture of ARQ and non-ARQ traffic. Similar to other properties of the MAC protocol the scope of a specific instance of ARQ is limited to one unidirectional connection.

The ARQ feedback information can be sent as a standalone MAC management message on the appropriate basic management connection, or piggybacked on an existing connection. ARQ feedback cannot be fragmented. The implementation of ARQ is optional.

Page 68 Line 1**6.2.4.1 ARQ Feedback Information Element format**

Table 184 defines the ARQ Feedback IE used by the receiver to signal positive or negative acknowledgments.

A set of IEs of this format may be transported either as a packed payload ("piggybacked") within a packed MAC PDU or as a payload of a standalone MAC PDU.

Table 184—ARQ Feedback Information Element

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6.2.4.2 ARQ parameters

6.2.4.2.1 ARQ_FSN_MODULUS

ARQ_FSN_MODULUS is equal to the number of unique FSN values, i.e. 2^{11} .

6.2.4.2.2 ARQ_WINDOW_SIZE

ARQ_WINDOW_SIZE is the maximum number of the unacknowledged ARQ fragments at any given time. An ARQ fragment is unacknowledged if it has been transmitted but no acknowledgement has been received.

ARQ_WINDOW_SIZE must be less than or equal to half of the **ARQ_FSN_MODULUS**.

6.2.4.2.3 ARQ_FRAGMENT_LIFETIME

ARQ_FRAGMENT_LIFETIME is the maximum time interval beyond which a transmitter shall discard unacknowledged ARQ fragments.

6.2.4.2.4 ARQ_RETRY_TIMEOUT

ARQ_RETRY_TIMEOUT is the minimum time interval a transmitter shall wait before retransmitting an unacknowledged ARQ fragment.

6.2.4.2.5 ARQ_SYNC_LOSS_TIMEOUT

ARQ_SYNC_LOSS_TIMEOUT is the maximum time interval **ARQ_TX_WINDOW_START** or **ARQ_RX_WINDOW_START** shall be allowed to remain at the same value before declaring a loss of synchronization of the sender and receiver state machines when data transfer is known to be active. The ARQ receiver and transmitter state machines manage independent timers. Each has its own criteria for determining when data transfer is “active” (see sections 6.2.4.5.2 and 6.2.4.5.3).
(Replaces comment 60)

6.2.4.2.6 ARQ_RX_PURGE_TIMEOUT

ARQ_RX_PURGE_TIMEOUT is the time interval the receiver shall wait after successful reception of a fragment that does not result in advancement of **ARQ_RX_WINDOW_START**, before advancing **ARQ_RX_WINDOW_START** (see section 6.2.4.5.3).
(Addition, no comment number)

6.2.4.3 ARQ procedures

6.2.4.3.1 ARQ state machine variables

All the ARQ state machine variables are set to 0 at connection creation or by an ARQ reset operation.
(Comment 61)

6.2.4.3.1.1 Transmitter variables

ARQ_TX_WINDOW_START: All FSN up to (**ARQ_TX_WINDOW_START** - 1) have been acknowledged.

ARQ_TX_NEXT_FSN: FSN of the next fragment to send. This value shall reside in the interval **ARQ_TX_WINDOW_START** to (**ARQ_TX_WINDOW_START** + **ARQ_WINDOW_SIZE**), inclusive.

(Comment 62)

6.2.4.3.1.2 Receiver variables

ARQ_RX_WINDOW_START: All FSN up to (**ARQ_RX_WINDOW_START** - 1) have been correctly received.

ARQ_RX_HIGHEST_FSN: FSN of the highest fragment received, plus one. This value shall reside in the interval **ARQ_RX_WINDOW_START** to (**ARQ_RX_WINDOW_START** + **ARQ_WINDOW_SIZE**), inclusive.

(Comment 63)

6.2.4.4 ARQ-enabled connection setup and negotiation

Connections are set up and defined dynamically through the DSA/DSC class of messages. CRC-32 shall be used for error detection of PDUs for all ARQ-enabled connections. All the ARQ parameters

(Comment 64)

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6.2.4.2) shall be set when an ARQ-enabled connection is set up. The transmitter and receiver variables (defined in subclause 6.2.4.3.1) shall be reset on connection setup.

6.2.4.5 ARQ operation

6.2.4.5.1 Sequence number comparison

Transmitter and receiver state machine operations include comparing fragment sequence numbers and taking actions based on which is larger or smaller. In this context, it is not possible to compare the numeric sequence number values directly to make this determination. Instead, the comparison shall be made by normalizing the values relative to the appropriate state machine base value and the maximum value of sequence numbers, ARQ_FSN_MODULUS, and then comparing the normalized values. Normalization is accomplished by using the expression:

$$\text{fsn}' = (\text{fsn} - \text{FSN_base}) \bmod \text{ARQ_FSN_MODULUS} \quad (\text{Comment 65 \{indent line\}})$$

The base values for the receiver and transmitter state machines are ARQ_TX_WINDOW_START and ARQ_RX_WINDOW_START, respectively.

6.2.4.5.2 Transmitter state machine (Comment 66, 67, 68)

The transmitter is responsible for choosing the appropriate fragment size on a per-fragment basis. Determining fragment size is outside the scope of this standard. Unlike non-ARQ connections, where a single MAC PDU would not normally have two consecutive fragments from the same MAC SDU, this is likely for ARQ-enabled connections, since such fragmentation can facilitate retransmission. MAC SDU fragment structure shall be maintained for retransmissions. An ARQ fragment may be in one of the following four states, not-sent, outstanding, discarded and waiting-for-retransmission. Any ARQ fragment begins as not-sent. After it is sent, it becomes outstanding for a period of time termed ACK_RETRY_TIMEOUT. While a fragment is in outstanding state, it either is acknowledged and discarded, or transitions to waiting-for-retransmission after ACK_RETRY_TIMEOUT or NACK. An ARQ fragment can become waiting-for-retransmission before the ACK_RETRY_TIMEOUT period expires if it is negatively acknowledged. An ARQ fragment may also change from waiting-for-retransmission to discarded when an ACK message for it is received or after a timeout ARQ_FRAGMENT_LIFETIME.

For a given connection the transmitter shall first handle (transmit or discard) fragments in 'waiting-for-retransmission' state and only then fragments in 'non-sent' state. Fragments in 'outstanding' or 'discarded' state shall not be transmitted. When fragments are retransmitted, the fragment with the lowest FSN shall be retransmitted first. (Comment 71)

The ARQ transmit fragment state sequence is shown in Figure 139.

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Figure 139—ARQ transmit fragment states

MAC PDU formation continues with a connection's 'not-sent' MAC SDUs. The transmitter builds each MAC PDU using the rules for fragmentation and packing as long as the number of fragments to be sent plus the number of fragments already transmitted and awaiting retransmission does not exceed the limit imposed by ARQ_WINDOW_SIZE. As each 'not-sent' fragment is formed and included in a MAC PDU, it is assigned the current value of ARQ_TX_NEXT_FSN, which is then incremented. (Comment 72)

When an acknowledgement is received, the transmitter shall check the validity of the FSN. A valid FSN is one in the interval ARQ_TX_WINDOW_START to ARQ_TX_NEXT_FSN-1 (inclusive). If FSN is not valid, the transmitter shall ignore the acknowledgement.

When a cumulative acknowledgement with a valid FSN is received, the transmitter shall consider all fragments in the interval ARQ_TX_WINDOW_START to FSN (inclusive) as acknowledged and set ARQ_TX_WINDOW_START to FSN+1.

When a selective acknowledgement is received, the transmitter shall consider as acknowledged all fragments so indicated by the entries in the bitmap for valid FSN values. As the bitmap entries are processed in increasing FSN order, ARQ_TX_WINDOW_START shall be incremented each time the FSN of an acknowledged fragment is equal to the value of ARQ_TX_WINDOW_START.

A bitmap entry not indicating acknowledged that has an FSN lower than a bitmap entry which does indicate acknowledged shall be considered a NACK for the corresponding fragment. A not acknowledged bit map entry may also be considered a NACK if sufficient time elapsed before the feedback IE was transmitted to allow the receiver to receive and process the corresponding fragment.

When a cumulative with selective acknowledgement with a valid FSN is received, the transmitter performs the actions described above for cumulative acknowledgement, followed by those for a selective acknowledgement.

All timers associated with acknowledged fragments shall be cancelled.

A Discard message shall be sent following violation of ARQ_FRAGMENT_LIFETIME. The message may be sent immediately or may be delayed up to ARQ_RX_PURGE_TIMEOUT + ARQ_RETRY_TIMEOUT. Following the first transmission, subsequent discard orders shall be sent to the receiver at intervals of ARQ_RETRY_TIMEOUT until an acknowledgement to the discarded FSN has been received. Discard orders for adjacent FSN values may be accumulated in a single Discard message. (Comment 73)

The actions to be taken by the transmitter state machine when an ARQ Reset Message is received are provided in Figure 140. The actions to be taken by the transmitter state machine when it wants to initiate a reset of the receiver ARQ state machine are provided in Figure 141.

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On receiver side, [\(Comment 76\)](#)

change ARQ_TX_WINDOW_START=0 to - ARQ_RX_WINDOW_START=0

Replace [\(Comment 79\)](#)

"Enable transmission" at the right column with "Enable reception"

Replace the sentence by the following: [\(Comment 81\)](#)

"Discard all SDUs from which one or more fragments has reached the 'discarded' state"

Figure 140—ARQ Reset message dialog - receiver initiated

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Receiver side (Comment 82)

change ARQ_TX_WINDOW_START=0 to - ARQ_RX_WINDOW_START=0

(Comment 85)

The text in a box in the bottom left side of figure 141, reading 'Discard all fragments held by the transmitter from SDUs where one or more fragments have been discarded', seems a little circular

Replace the sentence by the following:

"Discard all SDUs from which one or more fragments has reached the 'discarded' state"

Figure 141—ARQ Reset message dialog - transmitter initiated.

Synchronization of the ARQ state machines is governed by a timer managed by the transmitter state machine. Each time ARQ_TX_WINDOW_START is updated, the timer is set to zero. When the timer exceeds the value of ARQ_SYNC_LOSS_TIMEOUT the transmitter state machine shall initiate a reset of the connection's state machines as described in Figure 140. (Comment 86)

6.2.4.5.3 Receiver state machine

When a PDU is received, its integrity is determined based on the CRC-32 checksum. If a PDU passes the checksum, it is unpacked and de-fragmented, if necessary. The receiver maintains a sliding-window defined by ARQ_RX_WINDOW_START state variable and the ARQ_WINDOW_SIZE parameter. When an ARQ fragment with a number that falls in the range defined by the sliding window is received, the receiver shall accept it. ARQ fragment numbers outside the sliding window shall be rejected as out of order. The receiver should discard duplicate ARQ fragments (i.e. ARQ fragments that were already received correctly) within the window.

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Comment 90, Itzik to provide revised diagram

Figure 142—ARQ receive fragment states

The sliding window is maintained such that the *ARQ_RX_WINDOW_START* variable always points to the lowest numbered ARQ fragment that has not been received or has been received with errors. When an ARQ fragment with a number corresponding to the *ARQ_RX_WINDOW_START* is received, the window is advanced (i.e. *ARQ_RX_WINDOW_START* is incremented modulo **ARQ_FSN_MODULUS**) such that the *ARQ_RX_WINDOW_START* variable points to the next lowest numbered ARQ fragment that has not been received or has been received with errors. **The timer associated with ARQ_SYNC_LOSS_TIMEOUT shall be reset.** (New comment, delete this sentence)

As each fragment is received, a timer is started for that fragment. When the value of the timer for a fragment exceeds **ARQ_RX_PURGE_TIMEOUT**, the timeout condition is marked. When this occurs, *ARQ_RX_WINDOW_START* is advanced to the FSN of the next fragment not yet received after the marked fragment. **Timers for delivered fragments remain active and are monitored for timeout until the FSN values are outside the receive window.**

When *ARQ_RX_WINDOW_START* is advanced, any FSN values corresponding to fragments that have not yet been received residing in the interval between the previous and current *ARQ_RX_WINDOW_START* value shall be marked as received and the receiver shall send an ARQ Feedback IE to the transmitter with the updated information. Any fragments belonging to complete SDUs shall be delivered. Fragments from partial SDUs shall be discarded. (Comment 92)

When a discard message is received from the transmitter, the receiver shall discard the specified fragments, advance **ARQ_RX_WINDOW_START to the FSN of the first fragment not yet received after the FSN provided in the Discard message, and mark all not received fragments in the interval from the previous to new ARQ_RX_WINDOW_START values** as received for ARQ feedback IE reporting. (New comment)

For each ARQ fragment received without errors (including duplicates), an acknowledgment message may be sent to the transmitter. Acknowledgments may be either for specific ARQ fragments (i.e. contain information on the acknowledged ARQ fragment numbers), or cumulative (i.e. contain the highest ARQ fragment number below which all ARQ fragments have been received correctly) or a combination of both (i.e., cumulative with selective). Acknowledgments shall be sent in the order of the ARQ fragment numbers they acknowledge. The frequency of acknowledgement generation is not specified here and is implementation dependent. (Comment 95)

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A MAC SDU is ready to be handed to the upper layers when all of the ARQ fragments of the MAC SDU have been correctly received within the time-out values defined.

When ARQ_DELIVER_IN_ORDER is enabled, a MAC SDU is handed to the upper layers as soon as all the ARQ fragments of the MAC SDU have been correctly received within the defined time-out values and all fragments with sequence numbers smaller than those of the completed message have either been discarded due to time-out violation or delivered to the upper layers.

When ARQ_DELIVER_IN_ORDER is not enabled, MAC SDUs are handed to the upper layers as soon as all fragments of the MAC SDU have been successfully received within the defined time-out values. (Comment 96, new paragraph)

The actions to be taken by the receiver state machine when an ARQ Reset Message is received are provided in Figure 141. The actions to be taken by the receiver state machine when it wants to initiate a reset of the transmitter ARQ state machine are provided in Figure 140.

Synchronization of the ARQ state machines is governed by a timer managed by the receiver state machine. Each time ARQ_RX_WINDOW_START is updated, the timer is set to zero. When the timer exceeds the value of ARQ_SYNC_LOSS_TIMEOUT the receiver state machine shall initiate a reset of the connection's state machines as described in Figure 141. (Comment 97)

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11.4.8.18.7 ARQ_RX_PURGE_TIMEOUT

The BS shall set this parameter. The DSA-REQ or DSA-RSP messages shall contain the value of this parameter as set by the BS. If this parameter is set to 0, then the ARQ_RX_PURGE_TIMEOUT value shall be considered infinite.

Table ???— ARQ_RX_PURGE_TIMEOUT TLV

Type	Length	Value	Scope
[24/25].????	2	0 – 655350 (10 us granularity)	DSA-REQ DSA-RSP

(New comment)