Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**802.16 compatible MAC fragmentation, packing and ARQ numbering**
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Re:	IEEE 802.16 Working Group Letter Ballot #4 (P802.16a/D1-2001)
Abstract	This is a revised version of contribution C802.16a-02/10 [3]. The resolutions proposed here fully or partially address the following technical comments submitted to Letter Ballot #4: 159, 161 – 163, 165, 167 – 170, 172 – 179, 185 – 193, 197, 199, 203, and 205 – 206.
Purpose	Incorporate the changes proposed in this contribution into P802.16a/D1-2001
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1 Introduction and Summary

The ARQ sequence numbering used in the current 802.16a draft is based on the concept of ARQ blocks. The ARQ block-numbering scheme fundamentally changes the way fragmentation is done in 802.16a. Non-ARQ connections also have to implement such a complex numbering scheme, in order to avoid having two different fragmentation/reassembly mechanisms within the same system. Moreover the benefits of such a complex scheme is not proven, even for ARQ connections. If the block-numbering scheme were included in the standard, it would be very difficult to add future extensions to 802.16, considering the various incompatible and unnecessary additions in 802.16a MAC draft. Moreover, MAC hardware designers would find it difficult to make use of the common basic MAC access, fragmentation and packing functions, in designing chips that could be used in different frequency bands.

The addition of block numbering also generated quite a few technical comments in Letter Ballot #4. The questions/concerns raised in these comments are:

- Need for block oriented ARQ
- Justification for incompatibility between fragmentation and packing of baseline and 802.16a MACs
- Restrictions on the block size (granularity as well as minimum size)
- Forcing fragmentation to occur only on block boundaries
- Not supporting variable block size
- Forcing non-ARQ connections to use the same “block numbering” scheme as the ARQ connections

This contribution proposes an alternative sequence numbering scheme that addresses all these concerns. The proposed scheme is a straightforward extension of the 802.16 baseline FSN (Fragment Sequence Number) that provides almost all the benefits of the block numbering scheme, with much less complexity.

A scheme similar to the one proposed here was proposed during the early stages of standard development [1], with a slightly different fragment identification numbers. Another interesting extension to FSN was proposed in a recent contribution [2], that includes an extension to FC/FSN of 802.16 in addition to a per-fragment sequence number (TSN). While this mechanism allows the size of the fragment to be changed once, it is not clear how this would work when a fragment of a fragment is lost during the first retransmission. For example, the selective ACKs (bitmaps) as defined in the draft could only selectively acknowledge anything with only one level of numbering (e.g., BSN, TSN or FSN). However, [2] requires at least two levels of numbering to uniquely identify fragments of a originally transmitted fragment. In such a scenario, the entire original fragment has to be retransmitted, as there is no way to indicate the loss of a fragment of a fragment, unless the bitmap formats are also modified. However, sprit of contribution [2] is an ARQ numbering extension to 802.16 without breaking the fragmentation and packing defined in the baseline.

802.16 MAC implies that fragmentation should be performed only when the whole MSDU cannot be fit into a MAC PDU due to a scheduling decision or other framing constraints, as it does not make sense to fragment an MSDU, when the scheduler has allocated sufficient BW to carry the whole MSDU in a single frame. However, this restriction can be relaxed for the 802.16a ARQ connections in order to support retransmission flexibility (one of the benefits that block numbering scheme is supposed to provide). 802.16a MAC should allow multiple consecutive fragments of the same MSDU be carried within the same MAC PDU. This allows the ARQ transmitter and the scheduler to choose the optimal fragment size either statically or dynamically based on various system/modulation parameters, connection properties and link conditions.

Non-ARQ connections continue to use the baseline fragmentation and packing headers. The simple extension proposed here adds 8 bits of FSN to the existing fragmentation and packing sub-headers, effectively increasing the FSN size to 11 bits. The FSN bits are not contiguous and this would be possible if we reorder the 802.16 the fields of fragmentation and packing sub-headers (i.e., change the location of the FSN field).

The following section describes the suggested specific changes to P802.16a/D1-2001.

2 Specific Changes to P802.16a/D1-2001

Globally replace "ARQ Block" with "ARQ Fragment", "Block" with "Fragment", and "BSN" with "FSN" under all sections pertaining to ARQ

Globally replace references to "10 – 66 GHz Systems" with "Non-ARQ Connections" and references to "2 – 11 GHz Systems" with "ARQ Connections", under all sections pertaining to ARQ, fragmentation and packing.

Page 42, Remove Figure 135

Page 42, Remove the last sentence "The ARQ block numbering scheme is detailed in clause 6.2.4.1"

Page 43, Section 6.2.3.4.3.1 replace the text (lines 43 – 48) with the following:

"The ARQ Fragmentation sub-header is a simple extension of the Fragmentation sub-header defined for non ARQ connections. Table 164 shows the ARQ fragmentation sub-header."

Page 45, Section 6.2.3.4.3.1, Replace Table 164, with the following:

Table 161: Format of ARQ Fragmentation sub-header

Syntax	Size	Notes
ARQ_Fragmentation_Sub_Header_Format() {		
FC	2 bits	Fragmentation Control Indicates the fragmentation state of the payload: 00 = no fragmentation 01 = last fragment 10 = first fragment 11 = continuing (middle) fragment
FSN	3 bits	Bits 2: 0
Reserved	2 bits	
FSN	8 bits	Bits 10:3
}		

Page 45, Section 6.2.3.4.3.2 replace first paragraph (text from lines 35-44) with the following:

"In this case each PDU may contain multiple MAC SDUs or fragments thereof and ARQ feedback payload. Each of the packed MAC SDU or MAC SDU fragments or ARQ feedback payload requires its own packing sub-header as some of them may be transmissions while other are re-transmissions. The position of ARQ packing sub-header within a PDU and the contents of the packing sub-header are shown in Figure 138 and Table 165 respectively."

Page 46, Section 6.2.3.4.3.2 replace Table 165 with the following:

Table 162: Format of ARQ Packing sub-header

Syntax	Size	Notes
ARQ_Packing _Sub_Header_Format() {		
FC	2 bits	Fragmentation Control Indicates the fragmentation state of the payload: 00 = no fragmentation 01 = last fragment 10 = first fragment 11 = continuing (middle) fragment FC bits shall be ignored, if the payload followed by this packing sub-header is an ARQ feedback payload
FSN	3 bits	Bits 2: 0
Length	11 bits	The length in bytes of the MAC SDU or MAC SDU fragment or ARQ feedback payload, including the three-byte ARQ_Packing sub-header
FSN	8 bits	Bits 10: 3
}		

Page 46 - 47, Remove section 6.2.4.1.

Page 47, Table 166, Replace BSN with FSN and Block Sequence Number with Fragment Sequence Number on line 31

Page 47, Table 166, for the text in column 3, from lines 42 to 48, replace "ARQ Block" with "ARQ Fragment", "BSN" with "FSN" and "block numbers" with "Fragment Sequence Numbers"

Page 47, Remove section 6.2.4.3.1

Page 48, Section 6.2.4.3.2, replace "ARQ blocks" with "ARQ Fragments", "ARQ Block" with "ARQ Fragment" and "ARQ_MAX_BSN" with "ARQ_MAX_FSN"

Page 48, Section 6.2.4.3.3,Rename the section title to "ARQ_FRAGMENT_LIFETIME". Same for the text. Also, replace "ARQ blocks" with "ARQ Fragments"

Page 48, Section 6.2.4.3.4, Replace "ARQ block" with "ARQ Fragment"

Page 48, Section 6.2.4.4.1.1, replace "BSN" with FSN", "next block" with "next fragment" and "ARQ_TX_NEXT_BSN" with "ARQ_TX_NEXT_FSN"

Page 48, Section 6.2.4.4.1.2, replace "BSN" with FSN", "highest block" with "highest fragment" and "ARQ_TX_HIGHEST_BSN" with "ARQ_TX_HIGHEST_FSN"

Page 48-49, Section 6.2.4.6.1, replace "BSN" with "FSN", "blocks" with "fragments", "bsn" with "fsn", "BSN_base" with "FSN_base" and "ARQ_MAX_BSN" with "ARQ_MAX_FSN"

Page 49, Remove Section 6.2.4.6.2 and Figure 139

Page 50, Section 6.2.4.6.3, replace first paragraph (text from lines 3 to 11) with the following:

"The ARQ protocol is responsible for choosing the right fragment size on a per-fragment basis. The fragment size is not a fixed value that remains constant for a particular connection. Unlike non-ARQ connections, where a single MAC PDU may not have two consecutive fragments of the same MSDU in the first transmission, such fragmentation is allowed for ARQ connections. ARQ connections may send consecutive fragments of the same MSDU in a single MAC PDU. Once defined, the size of a fragment cannot be changed between retransmissions.

An ARQ fragment may be in one of the following four states, *not-sen*t, *outstandin*g, *discarded* and *waiting-for-retransmissio*n. Any ARQ fragment begins as *not-sen*t. 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 is *discarde*d, or transitions to *waiting-for-retransmission* after **ACK_RETRY_TIMEOUT**. 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_LIFETIM**E."

Page 50, Section 6.2.4.6.3 and Figure 140, replace "block" with "fragment" and "BSN" with "FSN"

Page 51, Section 6.2.4.6.4 replace "block" with "fragment" and "BSN" with "FSN"

Page 225, Remove Section 11.4.8.18.2

3 References

[1] **802.16.3c-01/16**, *Data Integrity in 802.16 MAC*, Vladimir Yanover et al., 2001

[2] **C802.16a-02/04**, *Figures accompanying ballot*, Carl Eklund, 2002

[3] **C802.16a-02/10**, *ARQ Sequence numbering for 802.16a*, Subbu Ponnuswamy, 2002