Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**ARQ Proposal for 802.16 TG3/4 MAC**
Date Submitted	**2001-03-07**
Source(s)	Vladimir Yanover et al. [Company] [Address Line 1] [Address Line 2]	Voice: +972-36457834 Fax: +972-36456222 mailto: vladimiry@breezecom.co.il
Re:	This document is submitted in response to IEEE 802.16.3-01/06 "802.16 Task Group 3 CALL FOR CONTRIBUTIONS: PROPOSED MAC ENHANCEMENTS" and IEEE 802.16.4-01/07 "Call for Comments on IEEE 802.16.4 Strawman Proposal(IEEE 802.16.4-01/05 and 06)."
Abstract	The document contains ARQ Proposal for 802.16.3/4 MAC
Purpose	The authors want 802.16 to approve the document as an addition to the 802.16 Air Interface Standard in the parts specific to 802.16.3 / 4 PARs
Notice	This document has been prepared to assist IEEE 802.16. It is offered as a basis for discussion and is not binding on the contributing individual(s) or organization(s). The material in this document is subject to change in form and content after further study. The contributor(s) reserve(s) the right to add, amend or withdraw material contained herein.
Release	The contributor grants a free, irrevocable license to the IEEE to incorporate text contained in this contribution, and any modifications thereof, in the creation of an IEEE Standards publication; to copyright in the IEEE's name any IEEE Standards publication even though it may include portions of this contribution; and at the IEEE's sole discretion to permit others to reproduce in whole or in part the resulting IEEE Standards publication. The contributor also acknowledges and accepts that this contribution may be made public by IEEE 802.16.
Patent Policy and Procedures	The contributor is familiar with the IEEE 802.16 Patent Policy and Procedures (Version 1.0) <http://ieee802.org/16/ipr/patents/policy.html>, including the statement IEEE standards may include the known use of patent(s), including patent applications, if there is technical justification in the opinion of the standards-developing committee and provided the IEEE receives assurance from the patent holder that it will license applicants under reasonable terms and conditions for the purpose of implementing the standard. Early disclosure to the Working Group of patent information that might be relevant to the standard is essential to reduce the possibility for delays in the development process and increase the likelihood that the draft publication will be approved for publication. Please notify the Chair <mailto:r.b.marks@ieee.org> as early as possible, in written or electronic form, of any patents (granted or under application) that may cover technology that is under consideration by or has been approved by IEEE 802.16. The Chair will disclose this notification via the IEEE 802.16 web site <http://ieee802.org/16/ipr/patents/notices>.

ARQ Proposal for 802.16 TG3/4 MAC

Vladimir Yanover, Naftali Chayat, Inbar Anson

BreezeCOM Ltd.

1. Acronyms

AFB	ARQ FeedBack (information or Sub-header or record)
ARQ	Automatic Repeat reQuest
FC	Frame Control
FSN	Fragment Sequence Number
MPDU	MAC Protocol Data Unit
MPDU-SN	MPDU Sequential Number
MSDU	MAC Service Data Unit
MSDU-SN	MSDU Sequential Number
PPT	Partial Payload Type (field)
SN	Sequential Number
SR	Selective Repeat (retransmission algorithm)

2. References

[1] IEEE 802.16/D2-2001. Draft Standard Air Interface for Fixed Broadband Wireless Access Systems

3. The Document s Goal

This document is to suggest the changes to be done in [1] to add the ARQ functionality to the 802.16 MAC Protocol. There will be changes concentrated in the section 6.2.3.4 ARQ Mechanism. The ARQ functionality

The following are the sections where the changes are needed.

Related section of this document	Section in [1] and the changes needed
4- 11	The content of these sections should be inserted into [1] as the sections 6.2.3.4.1- 6.2.3.4.8
9.1	A reference to this section should be added in 6.2.2
9.4	A reference to this section should be added in 6.2.3.3
11.1.2.1	A change should be done in 6.2.3.3 in the format of Packing Sub-header. A reference should be added from this section to 6.2.3.3 in the format of Packing Sub-header
6	In 6.2.3.2 the restriction should be added that for the connections with ARQ enabled, there should not be more than 16 fragments of each MSDU

4. General

Decision on ARQ invocation (thus presence of ARQ Sub-header) is to be done per connection. ARQ may be enabled / disabled as a result of certain procedure that includes transfer of the new value of ARQ Indicator, see [1] , 11.4.12.25.

The following processes may be used to identify that ARQ will be enabled at the given connection

Process	Message(s) Carrying the ARQ Indicator Parameter
Configuration File encoding	N/A
Dynamic Service Addition	DSA-REQ
	DSA-RSP
Dynamic Service Change	DSC-REQ
	DSC-RSP

5. Interaction with Fragmentation and Packing Functions

Decision on the fragmentation of any MSDU is performed by the transmission side. The non-fragmented MSDUs should be transported in the MAC messages with FC and FSN fields set to 0 and 000, respectively.

For a connection carrying variable length SDUs, it is at full discretion of the transmitting side whether to merge a group of SDUs in a single MAC message.

So typically at the connection with ARQ enabled may the following types of MPDUs may appear:
- MPDU with a single complete MSDU as a payload
- MPDU carrying a fragment of an MSDU
- MPDU with several complete MSDUs and / or MSDU fragments packed

6. Retransmission Units and Sequential Numbers

The retransmission units are complete MSDUs or fragments of MSDUs. Such a unit is identified by the Sequential Number that is a pair {MSDU-SN, FSN}. It is assumed that for the connections with ARQ enabled, MSDUs should not be fragmented into more than 16 fragments. A non-fragmented MSDU always has FSN = 0. The 8 bits MSDU-SN number is assigned when the MSDU arrives to MAC from the Convergence Layer and never changes. The partitioning of an MSDU into fragments may be done only once in the lifetime of the MSDU. For example, an MSDU once transmitted as a whole might be then divided into two fragments when retransmitted. If needed, afterwards the same MSDU may be transmitted again as a whole.

7. ARQ Operations

7.1.   Regular Operations

The Receiver supports the (cyclic) **Next_Expected_MSDU-SN** and **Next_Expected _FSN** variables. Their values are updated with arrival of any valid MPDU to note that all the MSDUs and the fragments of MSDUs with less sequential numbers were received correctly.

The Receiver then has to send AFB information of the format defined in 11. The way of decision when this information should be sent and in which format (if there is a choice) is out of scope of this standard.

7.2.   Discard Operation

In the case when the Transmitter decides (e.g. to keep the QoS parameters) to discard a set of MSDUs, it sends to the Receiver the discard message in the format specified in 11. Such a message requires an acknowledgement specified in the same section.

8. Acknowledgment Window

The size of the Acknowledgment window (Transmission window) is defined by the correspondent Service Flow parameter optionally negotiated between the peers during the DSA/DSC operations. To keep the consistency of the sequential numbers, the size of this window should not exceed 127.

9. Transmission of the MPDUs

All the cases listed in 5 are considered here for the case of ARQ enabled. In any case an ARQ sub-header should be appended to the Generic MAC Header.
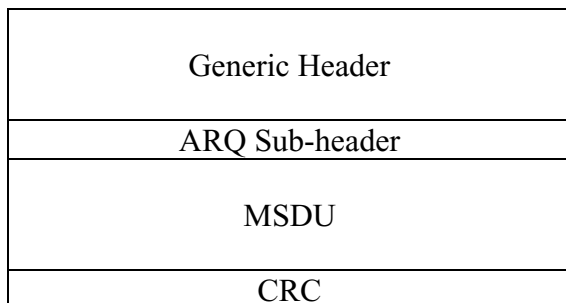
9.1.   The Format of ARQ Sub-header

The ARQ sub-header consists of a single MSDU Sequential Number field. The format of ARQ sub-header is defined by the following picture.
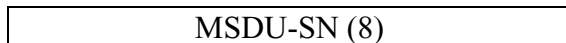
MSDU-SN (8)

Figure 1 . The Format of the ARQ Sub-header

9.2.   MPDU with a Single Complete MSDU as a Payload

In this case an ARQ sub-header (MSDU-SN) should be appended to the Generic Header.

Generic Header
ARQ Sub-header
MSDU
CRC

Figure 2. Format of an MPDU with a Single Complete MSDU as a Payload

9.3.   MPDU Carrying a Single MSDU Fragment

In this case Fragmentation sub-header and ARQ sub-header should be appended to the Generic Header.

Generic Header
Fragmentation Sub-header
ARQ Sub-header
MSDU Fragment
CRC

Figure 3. Format of an MPDU Carrying a Single MSDU Fragment

Fragmentation Sub-header format is identical to described in [1]

FC (2)	FSN (3)	Reserved (3)

Figure 4. Fragmentation Sub-header Format

9.4.   Multiple MSDUs and Fragments Packed in a Single MPDU

9.4.1. The Rule of Packing with the ARQ Enabled

The following is the rule for the assembling of the packed MPDUs for connections with ARQ enabled.

- The MPDU should contain consequent MSDUs / Fragments

This rule actually is not restrictive. Suppose that a packed MPDU (built according to this rule) failed. Then, for the retransmission, the MPDU may be divided into parts according to the rule (simply keeping the order of MSDUs / fragments).

9.4.2. MPDU Format

The following is the MPDU format.

Generic Header
ARQ Sub-header
Packing Sub-Header
MSDU / Fragment
Packing Sub-Header
MSDU / Fragment
..

ARQ Sub-header format

MSDU-SN Base (8)

MSDU-SN Base means the SN of the first MSDU (Fragment) that appears in the given MPDU. According to the rule, this number defines completely all the SNs of all the following MSDUs / Fragments.

Format of the Packing Sub-Header (PSH) for the complete MSDU or Fragment:

FC (2)	FSN (3)	Length (11)

10.   Transmission of the MPDUs: MPDU-SN Based ARQ

11.   ARQ Feedback Format

11.1. ARQ Feedback Transmission

ARQ Feedback information for a connection is transmitted at arbitrary connection of the opposite direction.
There are two options for the AFB (ARQ Feedback) format:
- Based on the Packing mechanism
- Based on the usage of AFB (ARQ Feedback) Sub-header

11.1.1.Option 1: Usage of ARQ Feedback Sub-header

11.1.1.1. Usage of Type Field

The following are the possible Type field values

00000b = normal payload, no sub-headers or special interpretation
00001b = Grant Management sub-header present (UL only, code may be reused for some DL only purpose)
00010b = packing sub-header present
00011b = both grant management and packing sub-headers present (UL only, code may be reused for some DL only purpose)

00100b = Grant Management and AFB sub-headers present (UL only, code may be reused for some DL only purpose)
00101b = packing and AFB sub-headers present
00110b = grant management, packing and AFB sub-headers present (UL only, code may be reused for some DL only purpose)

11.1.1.2. ARQ Feedback Format

The AFB Sub-header consists of one or several ARQ feedback records (AFB records). The AFB records have Last bit set to 1 for the last AFB record in the AFB sub-header and 0 for all other records.
The AFB records are used for encoding the results of integrity check performed on the MPDUs. These fields are inserted into the MAC messages transferred in the direction

opposite to the direction of the connection. The ARQ feedback is transferred using one or several AFB records that may serve different data connections.

The AFB record has the following formats: **Short, Medium, and Long**:

Table 1. AFB Short Format, total = 8 bits

Last	Mode	Reserved
1	3	4

Table 2. AFB Medium Format, total = 32 bits

Last	Reserved	Mode	FSN	MSDU-SN	CID
1	1	3	3	8	16

Table 3. AFB Long Format, total = 48 bits

Last	Mode	Reserved	MSDU-SN	Mask	CID
1	3	4	8	16	16

Bits in the **Mask** correspond to MSDUs or Fragments (depend on Mode value) with the value 1 meaning a positive acknowledgement.

Mode defines the presence and the meaning of another sub-fields:

Mode value	Meaning	AFB Format
000	Appears in AFB Short format only. Being used by the SS, this AFB means that this SS has successfully received all the DL MAC headers within the latest frame and all the MAC messages addressed to the given connection were received successfully Being used by the BS, this AFB means that the BS has successfully received all the UL MAC headers from all the SSs within the latest frame and all the MAC messages were received successfully	Short
001	The **Sequential Number** value means that all the MSDUs / Fragments with all the sequential numbers < {MSDU-SN, FSN} were successfully received	Medium
010	The value of MSDU-SN = M defines the interval M M+15 of the MSDU-SNs being acknowledged. The positive acknowledgements for these MSDUs are provided by the correspondent **Mask** bits	Long
011	The value of MSDU-SN means the Sequential Number of a fragmented MSDU so that the acknowledgements for the fragments are provided by the correspondent **Mask** bits	Long
100	Same as above plus indication that all MSDUs with the Sequential Numbers < MSDU-SN were successfully received.	Long

101	ARQ Discard Acknowledgment Record (see 11.1.1.3 below)	
110-111	Reserved	

Thus the AFB record may contain 1, 4 or 6 bytes.

11.1.1.3. Discard Related Signaling

Discard decision is to be done by the transmitter according to the QoS requested for the given Service Flow (SF) associated with the given connection and the ARQ status of the connection. Such a decision concerns a single MSDU or a group of MSDUs. The exact algorithm of the decision is out of scope of the standard.

The transmitter MAY inform the receiver on the discard decision by sending the discard acknowledgment (DA) record. Such an acknowledgment should be sent as a part of MAC message not necessarily through the same connection as the data itself. DA format is a particular case of the AFB format (though functionally they are different)

Table 4. DA Format, total = 32 bits

Last	Mode = 101	MSDU-SN
1	3	8

The DA record is transmitted at the same connection as the data itself.

This record means that all the MSDUs with the Sequential Numbers < MSDU-SN were discarded by the transmitter. The receiver MUST answer to this information by sending the Medium AFB with Mode = 001, the same MSDU-SN value and FSN= 000.

11.1.2. Option 2: Usage of Packing Mechanism

11.1.2.1. MPDU Format

The following is the MPDU format.

Generic Header
[Optional Sub-headers]
Packing Sub-Header
MSDU / Fragment
Packing Sub-Header
MSDU / Fragment
..

This option needs a change in the format of the Packing Sub-Header (PSH) for the complete MSDU or Fragment with new 2 bits Partial Payload Type (PPT) field:

FC (2)	FSN (3)	Partial Payload Type (2)	Length (9)

Figure 5. Packing Sub-Header Format

The following are the possible values for the Partial Payload type

Value	Meaning
00	The payload is an SDU
01	The payload is a set of AFB records
10-11	Reserved

For the case when the payload is a set of AFB records, FC = 00, FSN = 000.

11.1.2.2. ARQ Feedback Information Encoding

The ARQ Feedback information is encoded in the form of AFB records, in the same form as in 11.1.1.2-11.1.1.3 with the difference that the Last field is not used.