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Title	**Detailed ARQ Proposal for 802.16a and 802.16b MAC**
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Re:	This document is submitted to figure the details of the 802.16.3p - 01/52 “Merger of ARQ Proposals for 802.16 TG3 and 802.16 TG4” (Vladimir Yanover, 01/03/14)
Abstract	This document figures the addition needed in the TG1 MAC to achieve ARQ functionality
Purpose	The document is submitted as a part of development of 802.16a and 802.16b MAC sections. It represents author s view on the ARQ implementation. The members of 802.16a and 802.16b MAC Groups (TG3 and TG4) and especially authors of the ARQ proposals 802.16.3c-01/38, 802.16.3c-01/40 and 802.16.4c-01/21 are welcomed to share this view and suggest changes that would improve the proposed ARQ mechanism
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0. Foreword

The approach defined in this document is enough flexible to allow such a different ARQ schemes as

- SR and GBN
- byte based numbering and retransmission with granularity of one byte
- MPDU oriented when the unit of retransmission is an MPDU
- MSDU oriented when the unit of retransmission is either an MSDU or MSDU segment

Acronyms and Definitions

GBN	Go Back N
SR	Selective Repeat
SN	Sequential Number

The following sections are intended to form a separated ARQ section (6.2.3.4 in 802.16a document). The author s comments are marked by <<< >>>.

Note that there are two options of encoding of the ARQ feedback described in 5.2.2 and 5.2.3. Either one of them or both may be accommodated by the standard.

References

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

1. General

- The ARQ implementation is obligatory
- The ARQ invocation is optional
- Sequential Numbers are used to identify the retransmitted potions of data
- ARQ operations are defined in the scope of 802.16 MAC connection including:
    - ARQ invocation (thus presence of ARQ Sub-header). Decision on ARQ invocation should be done at the step of the connection creation/change
    - ARQ parameters
    - ARQ state variables
    - Sequential Numbers are unique (within the transmission window) as considered within the scope of the connection

2. ARQ Blocks

An **ARQ Block** is employed as an identifiable logical unit. The transmitted MSDUs and the MSDU fragments are logically divided into blocks that never change but MAY be assembled differently when retransmitting the data.

The parameter **ARQ_BLK_SIZE** should be of the form 2^N . It defines the block size in bytes. It is negotiated between the peers during the connection creation/change. **ARQ_BLK_SIZE** may vary from 1 to TBD bytes.

The block size MAY be more than the maximum MAC Message size. Then the only incomplete blocks appear.

Another parameter is acknowledgment window size **ACK_WIN_SIZE** that limits the amount of the blocks, transmitted but not acknowledged.

3. Transmitter Operations: MAC Message Creation and Numbering

The following is the sequence of MAC operations at the transmitting side with ARQ enabled

1. MSDU arriving from the CS MAY be fragmented. For the retransmission, further re-fragmentation might be performed, but without any change of existing blocks. It means that each original fragment may be splitted into smaller fragments with their boundaries aligned to the boundaries of the existing blocks.
2. The complete MSDUs and fragments are logically divided into portions (***ARQ blocks***) of the given size **ARQ_BLK_SIZE**. The last block in the MSDU/fragment MAY be smaller than **ARQ_BLK_SIZE,** such a block is called incomplete block . Once defined as a piece of data, block never changes (split or recombined)
3. A set of blocks is selected for the transmission and aggregated into MPDUs. This set may include also the blocks selected for the retransmission. At this step a Sequential Number should be assigned to any block not having yet such a number. Sequential Numbers, taken in the order of their assignment, form a sequence of numbers 0 .. 2^N-1 where N is the number bits (with wrap-around at 2^N). ***Only contiguous Block Sequential Numbers may appear within a single MAC Message***.
4. It is a matter of transmitter s policy whether the set of blocks once transmitted as a single MAC Message, will be retransmitted also as a single MAC Message**.**
5. Each MAC Message gets a Sequential Number, which is the Sequential Number of the FIRST, block in the MAC Message. This number is encoded in the ARQ sub-header (see section 4). Note that according to MAC rules, if a payload (partial payload) of a MAC message contains a MSDU fragment, it should be marked correspondently in the Fragmentation Sub-header of Packing Sub-header.

The following picture figures the examples of MSDUs, fragments, block numbering and MPDUs.
<<< MAC Message Sequential Numbers / Packed Payload Sequential Numbers appear in yellow >>>

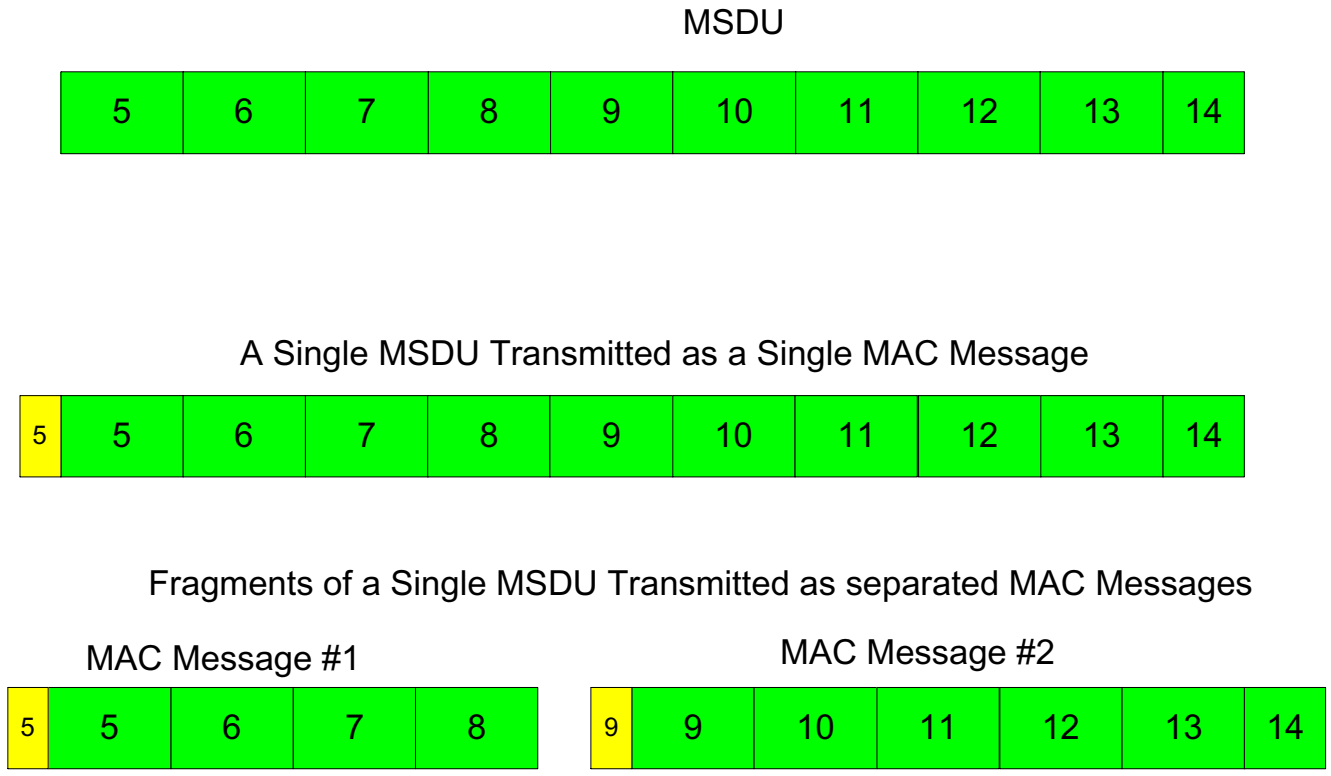

Figure 1. Options for the MSDU transmission

The following is an example of retransmission with and without the rearrangement of MPDUs. Note the MAC Message #2 that contains two incomplete blocks: 11 and 14.

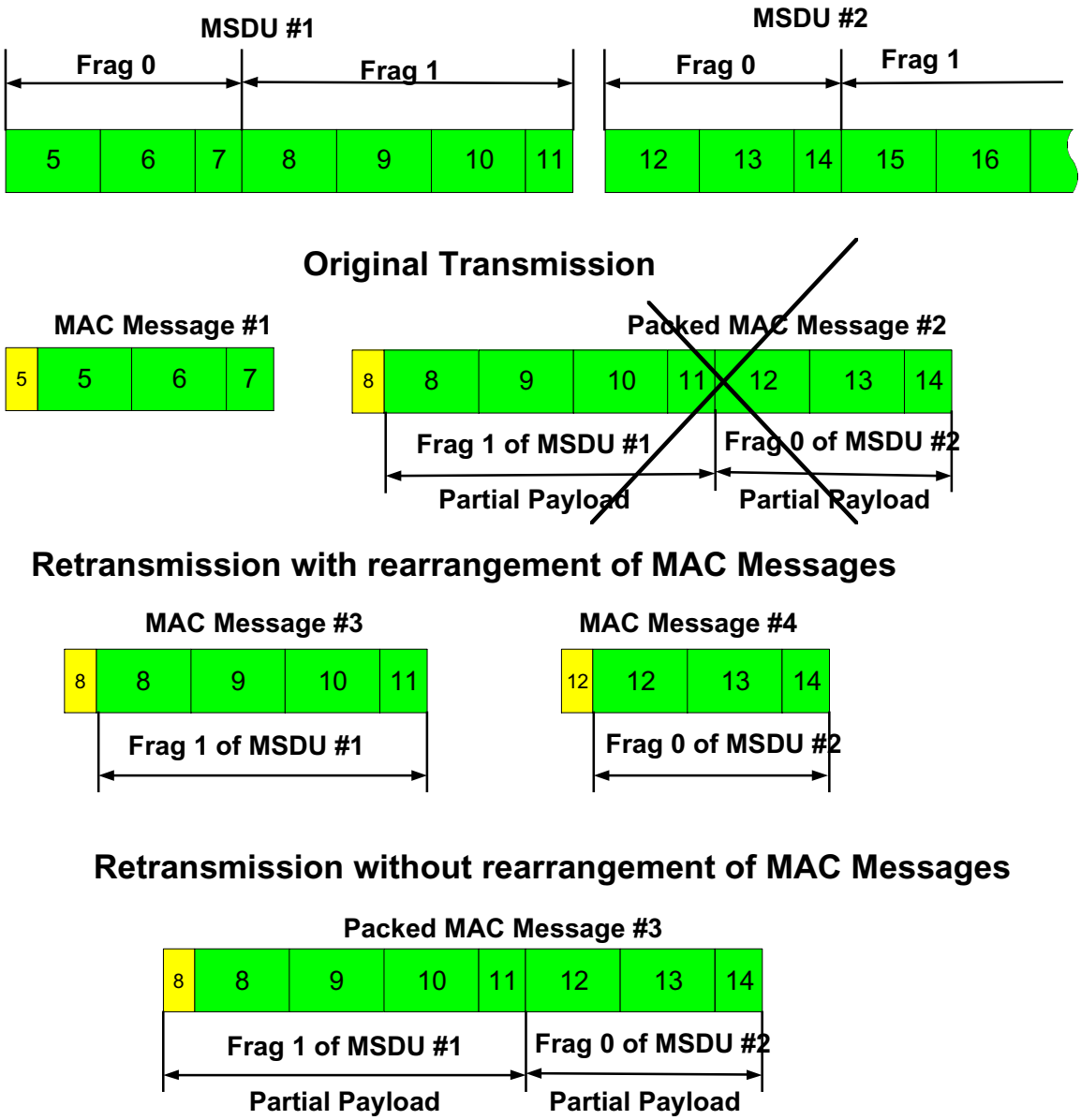

Figure 2. Retransmission with and without the rearrangement of MAC Messages

The following picture provides an important example of numbering and retransmission with a block size that exceeds the maximum of possible fragment size and therefore each fragment figures a single incomplete block. Such a definition of block size provides especially simple numbering.

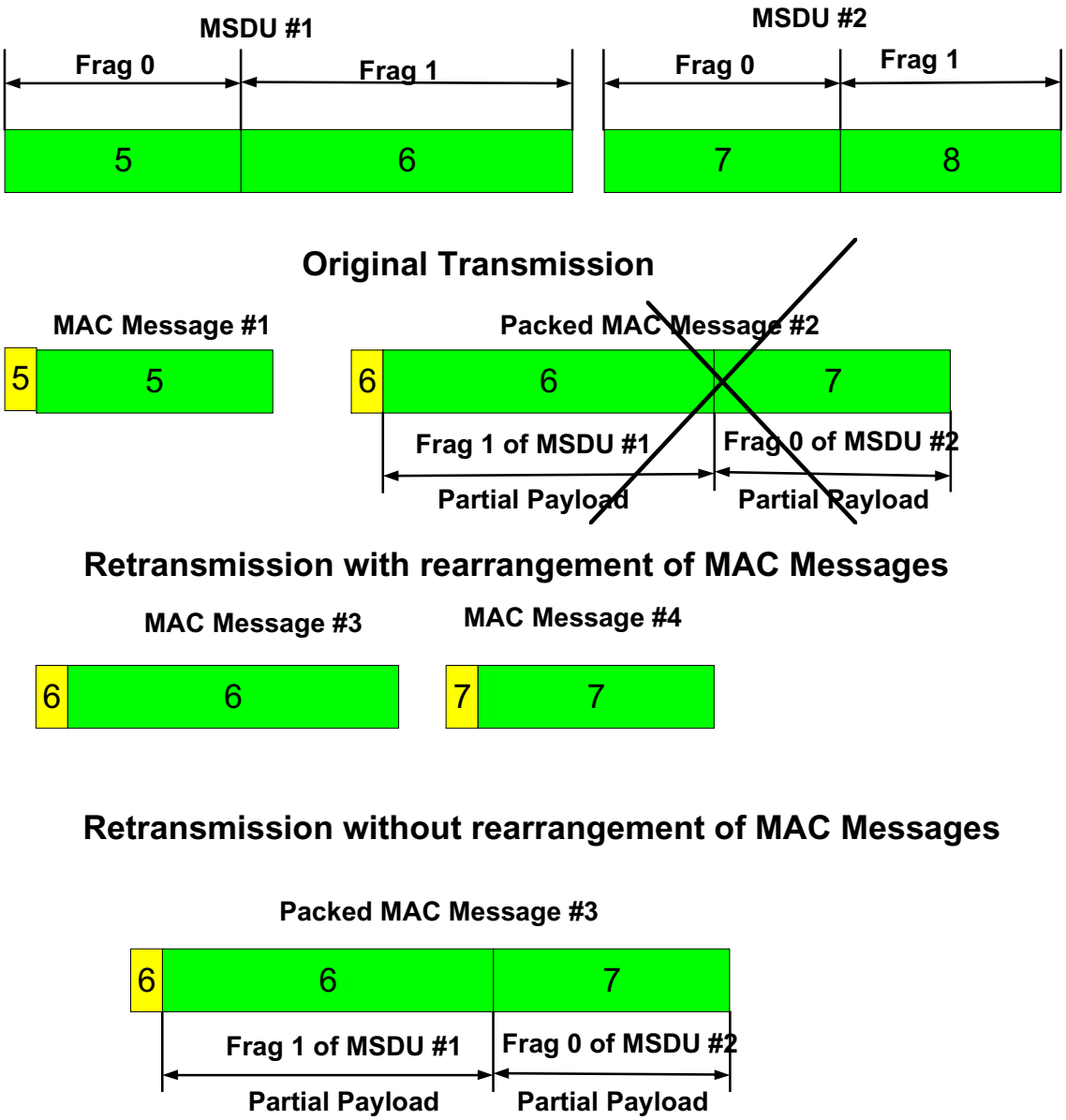

Figure 3. Retransmission with and without the rearrangement of MAC Messages

4. Receiver Operations

At the Receiver side, after the successful reception of an MAC Message, each MAC Message is decoded including parsing of MAC Header, ARQ Sub-header (containing the Sequential Number), Fragmentation Sub-header (if present), Packing Sub-headers (if present). MAC compares the Sequential Number with the expected value and decides whether the MAC Message is out of order (and then MAY be rejected).

Then Receiver calculates the number of blocks in the payload or, in the case of packed MAC Message, in each partial payload.

In the case when the block size exceeds the maximum MSDU length, the number of blocks simply is equal to the number of fragments contained in the given MAC Message. For example, at the Figure 3, after the reception of packed MAC Message #2, the next expected BSN is calculated as 6 + 2 = 8.

Having the number of blocks and the BSN of the first block, MAC may decide what range of Block Sequential Numbers is present in the received MAC Message.

According to that, MAC calculates the next BSN expected to receive and generates the ARQ Feedback information. This information identifies the status of the blocks constituting the MAC Message, e.g. blocks 126 to 143 have been received successfully . This information may be accumulated by MAC and then it should be sent back to Transmitter. See the format of ARQ feedback in 5.

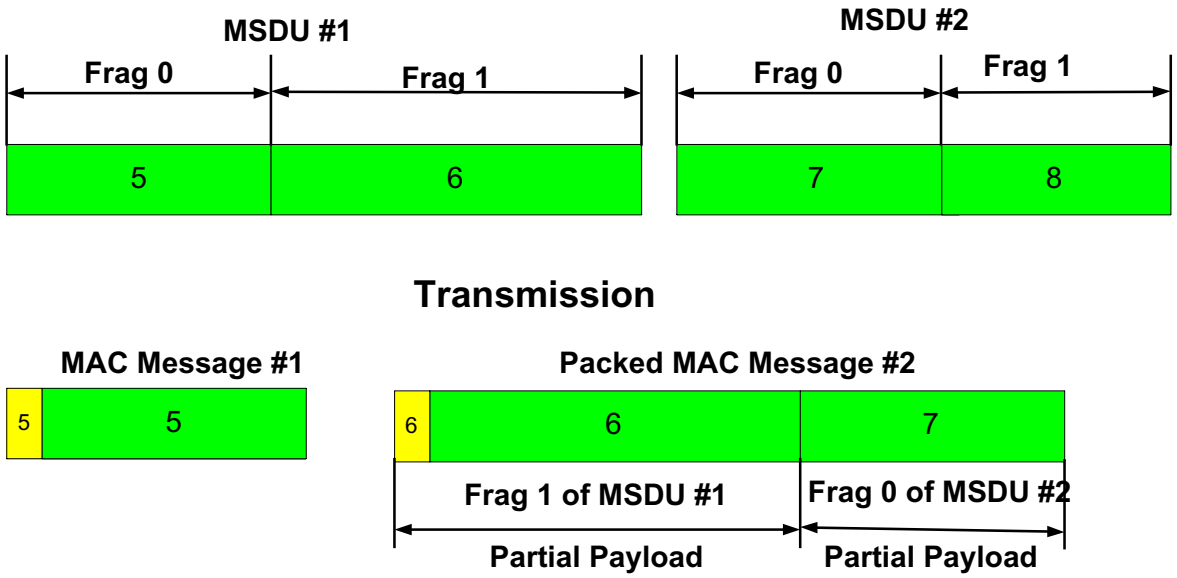

Figure 4. Block Numbering in the Case when the Block Size Exceeds the Maximum MSDU Length

5. Formats of ARQ Related Signaling

5.1. Encoding of the Sequential Number

The Sequential Number is encoded in the ARQ sub-header.

5.1.1. ARQ Sub-header Presence and Formats

ARQ Sub-header is placed after the MAC Header of the MAC Message. The presence of the ARQ Sub-header and its type (Short or Long) is defined by the Payload Type value:

<<< TBD Specification of the Type values >>>

There are two formats for Sequential Numbers: Short (6 bits) and Long (14 bits) and correspondently Short and Long formats of ARQ Sub-header.

In the pictures below **FC** stands for the Fragmentation Control (see the definition of this field in [1], 6.2.3.2). **BSN** stands for the Block Sequential Number referencing to the FIRST ARQ Block in the MAC Message.

<<< These formats of the ARQ Sub-header combine the functions of ARQ control and Fragmentation Control. So this type of sub-header will be used instead of the Fragmentation Sub-header described in [1]. This requires a change in the Packing Sub-header format comparatively to TG1 draft. Technically, it is suggested to replace the TG1 definition of the Fragmentation Sub-header format with 5.1.25.1.3. The new formats possibly may be used even with ARQ disabled >>>

5.1.2. ARQ Sub-header Short Format

FC (2)	BSN (6)

5.1.3. ARQ Sub-header Long Format

The following is the Long Format:

FC (2)	BSN (14)

5.2. ARQ Feedback Signaling

<<< This section two options for the ARQ feedback. The first option is based on the usage of yet another sub-header. The second is based on the enhanced packing.

The Information Elements carrying the ARQ feedback may be embedded either into the ARQ Feedback Sub-header or into a packed MAC Message as a partial payload. This option requires a change in the Packing Sub-header format comparatively to TG1 draft.

One more assumption is that the ARQ feedback for the given connection may be transmitted at arbitrary connection in opposite direction. >>>

5.2.1. ARQ Feedback Information Elements

The following types of Feedback Information Elements are employed

- Cumulative ACK-Short
- Cumulative ACK/NACK-Short
- Cumulative ACK-Long
- Cumulative ACK/NACK-Long

<<< There is no non-cumulative ACKs because of lack of bits in the type. If we don t implement ARQ feedback sub-header, the Last bit may be changed to Cumulative flag >>>

Usage of short/long ACKs is negotiated during the connection creation/change.
<<< Same way we may handle the presence / absence of CID >>>

These elements may be used in

- ARQ feedback piggybacked onto MAC header, particularly in standalone ACK/NACK message
- Partial payload within a packed MAC message

In the formats below the following fields are mentioned:

- The **Last** bit is used to mark the last ARQ IE in the Sub-header.
- **BM** = 1 means presence the BM field
- The **BSN** value means acknowledging all the blocks with the Sequential Number < BSN within the transmission window.
- **BM** means the bitmap that contains 1 for NACK and 0 for ACK for the blocks from BSN*8 to (BSN*8+7)

5.2.1.1. Cumulative ACK-Short

Last	BM = 0	BSN (6)
CID (8)		
CID-cont. (8)		

5.2.1.2. Cumulative ACK/NACK-Short

Last	BM= 1	BSN (6)
BM (8)		
CID (8)		
CID-cont. (8)		

5.2.1.3. Cumulative ACK-Long

Last	BM = 0	BSN (6)
BSN-cont. (8)		
CID (8)		
CID-cont. (8)		

5.2.1.4. Cumulative ACK/NACK-Long

Last	BM = 1	BSN (6)
BSN-cont. (8)		
BM (8)		
CID (8)		
CID-cont. (8)		

5.2.2. ARQ Feedback Sub-header

The following is the structure of MAC Message, which is a standalone ACK if the payload is absent. The ARQ Feedback Sub-header consists of variable number of ARQ IEs.

Generic Header Payload type points to the presence of ARQ Feedback Sub-header
Other Sub-Headers
ARQ Feedback IE with Last = 0
ARQ Feedback IE with Last = 0
.
ARQ Feedback IE with Last = 1
Payload (optional)
CRC

Figure 5. ARQ Feedback Sub-header

5.2.3. ARQ Feedback as Partial Payload

In the packed MAC Message (case of the variable size SDUs) the following is the structure of Packing Header in the case when the payload is an ARQ Feedback IE.

Last fields are not used.

Type (3) = 001 or 010	FC (2)	Length (11)

The whole MAC Message structure is the following

Generic Header Payload type points to the presence of Packing Sub-headers and partial payloads
Packing Sub-Header
ARQ Feedback IE
Packing Sub-Header
ARQ Feedback IE
.
Packing Sub-Header
SDU
Packing Sub-Header
SDU
.
CRC

<<< This requires change in the definition of Packing Sub-header comparatively to TG1 draft. Technically such a change may be done by replacing (for TG3) the correspondent pictures in [1], 6.2.3.3 . The following might be a picture

Type (3)	FC (2)	Length (11)

Type is encoded according to the following table

Type	Meaning
000	Data payload
001	ARQ Feedback with BM
010	ARQ Feedback without BM
011-111	Reserved

>>>

6. Additional Operations

6.1. Discard

<<< To be added >>>

6.2. Reset

<<< To be added >>>

7. Retransmission Algorithms

The signaling defined here is sufficient for implementation of classic SR and GBN algorithms.

8. Examples of ARQ Schemes

8.1. MSDU/Fragment- oriented Scheme

ARQ_BLK_SIZE may have any reasonable value. A 6 bit or 14 bit Sequential Number is attached to any MAC Message. The MPDUs may be rearranged when retransmitted, for example, if two subsequent MSDU fragments were initially transmitted as a single MAC Message, in the retransmission they may be arranged as two separated MPDUs (see Figure 2)

8.2. Byte pointer-based Scheme

In this case the **ARQ_BLK_SIZE** = 1. The GBN algorithm and Long numbering format are used. Thus each MAC Message has a 14 bit Sequential Number attached that expresses the number of the last data byte present in the transmission. The ACKs are encoded in the Sub-header and figure the 14 bit number of the next byte expected from the transmitter.

8.3. MAC Message-oriented Scheme

In this case the **ARQ_BLK_SIZE** may have any reasonable value. A 6 bit or 14 bit Sequential Number is attached to any MAC Message. The blocks comprising the MAC Message are not rearranged when retransmitted.

9. ARQ Related Operations at the Connection Creation/Change

<<< To be added >>>