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Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Proposed TG3 MAC Document**
Date Submitted	**2001-05-17**
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Re:	
Abstract	Output of TG3 MAC group after Session #13
Purpose	This document is for adoption as baseline MAC text by TG3
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802.16a Amendment to the 802.16 Standard Air Interface for Fixed Broadband Wireless Access Systems

Draft Document

Table of Contents

45

46   Editor's comments

1
2   <<<
3
4   This document was assembled from several contributions submitted to TG3 MAC Group
5   according to the decision of the joint TG3/TG4 MAC Group meeting at Session #12 . The
6   table of contents is not synchronized yet with baseline 802.16 Air Interface document (it will
7   be done after the decision of what are the numbers of the new MAC topics).
8
9   Some parts of the submissions will not be included into the text of document, for example,
10 because of usage of expressions like "in this submission …", etc. Such parts appear in red .
11 Editor's comments appear in blue, both of them are marked by <<< >>>
12
13 >>>
14

15 # 1. <u>Introduction</u>

16
17   802.16a MAC and PHY have to support point-to-multipoint applications in the range
18 2 to 11 GHz. Radio communications in the above range may be possible in near- and non-
19 line-of-sight situations between a base station and subscriber station. Operation may include
20 partial blockage by foliage, which contributes to signal attenuation and multipath effects.
21 802.16a compliant systems shall be deployable in multiple- cell frequency reuse systems and
22 single cell frequency reuse systems. The range of 802.16.3 radios varies with transmit power,
23 channel characteristics, availability requirement, local regulations and atmospheric conditions
24 (see IEEE 802.16.3-00/02r4 "Functional Requirements for the 802.16.3 Interoperability
25 Standard").
26   All the above features request implementation of such PHY functions as support of
27 non-line-of-sight communication, advanced power management, smart antennae support.
28 These functions are absent or insufficient in the baseline 802.16 standard and this is why the
29 802.16a amendment is focused on the definition of the above PHY and MAC functions.
30   For MAC it means that first of all it has to support the abovementioned PHY features
31 and implement the proper interface to PHY. On the other hand, some of these problems may
32 be completely or partially fixed in MAC sublayer using such tools as ARQ, advanced
33 packing, additional scheduling flexibility.
34
35

36 # 2. <u>ARQ</u>

37 ## 2.1.   <u>Formats and Data Structures</u>

38   [Editorial Group: Vladimir, Subbu, Jacob, Subir, Chet, Demos, Huan Chun]
39   ### 2.1.1. <u>General</u>
40 •   The ARQ implementation is obligatory
41 •   The ARQ invocation is optional, per connection. ARQ can be enabled only for the
42   unicast transmissions
43 •   Sequential Numbers are used to identify the retransmitted potions of data
44 •   ARQ operations are defined in the scope of 802.16 MAC connection including:

- o ARQ invocation (thus presence of ARQ Sub-header). Decision on ARQ invocation should be done at the step of the connection creation/change
- o ARQ parameters
- o ARQ state variables
- o Sequential Numbers are unique (within the transmission window) as considered within the scope of the connection

2.1.2. <u>Block Numbering Based Retransmission Scheme</u>

2.1.2.1. 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.

2.1.2.2. 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 MAC Messages. 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). The following are the restrictions:
   - Only contiguous Block Sequential Numbers may appear within a single MAC Message
   - An incomplete block may be placed only at the end of a MAC Message or at the end of partial payload in the case of packed MAC Message

4. 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 2.1.2.3). Note that according to MAC rules, if a payload (partial

1   payload) of a MAC message contains a MSDU fragment, it should be described
2   correspondently in the Fragmentation Sub-header of Packing Sub-header.
3
4   It is a matter of transmitter's policy whether the set of blocks once transmitted as a single
5   MAC Message, will be retransmitted also as a single MAC Message.
6
7   The following picture figures examples of MSDUs, fragments, block numbering and MAC
8   Messages.
9
10
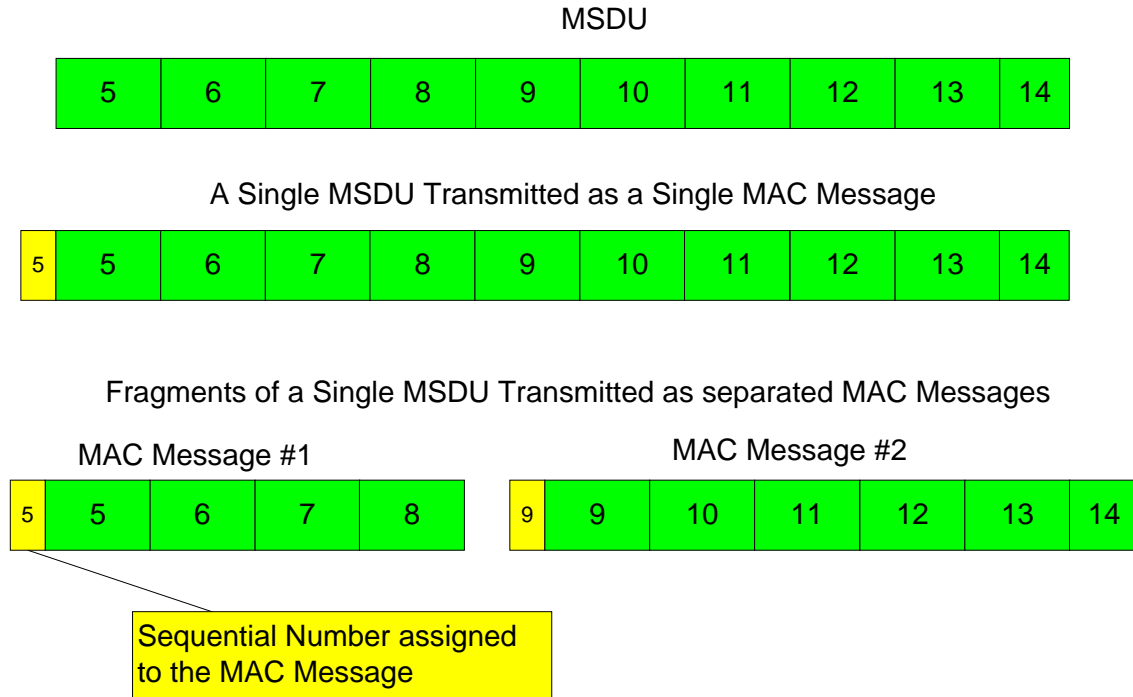
Figure 1. Options for the MSDU transmission

14   The following is an example of retransmission with and without the rearrangement of
15   MAC Messages. Note the MAC Message #2 that contains two incomplete blocks: 11 and 14.
16   Note that the incomplete blocks appear only at the end of either MAC Message or partial
17   payload.
18
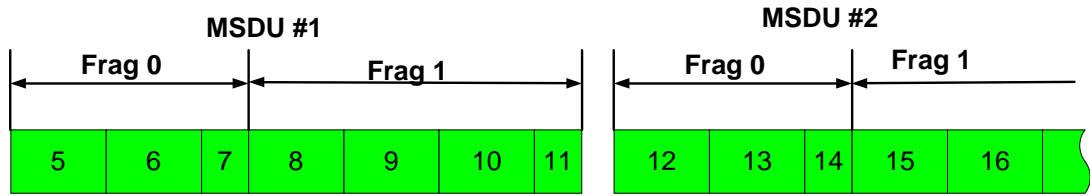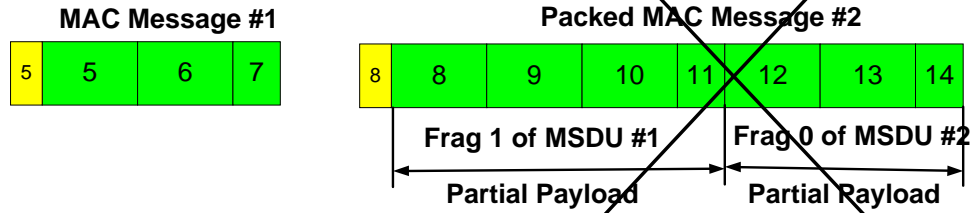
MSDU #1

Frag 0	Frag 1

5	6	7	8	9	10	11

MSDU #2

Frag 0	Frag 1

12	13	14	15	16

Original Transmission

MAC Message #1

5	5	6	7

Packed MAC Message #2

8	8	9	10	11	12	13	14

Frag 1 of MSDU #1   Frag 0 of MSDU #2

Partial Payload   Partial Payload

Retransmission with rearrangement of MAC Messages

MAC Message #3

8	8	9	10	11

Frag 1 of MSDU #1

MAC Message #4

12	12	13	14

Frag 0 of MSDU #2

Retransmission without rearrangement of MAC Messages

Packed MAC Message #3

8	8	9	10	11	12	13	14

Frag 1 of MSDU #1   Frag 0 of MSDU #2

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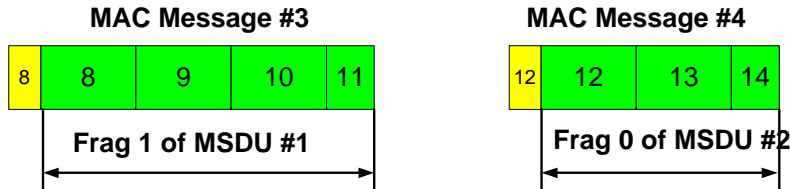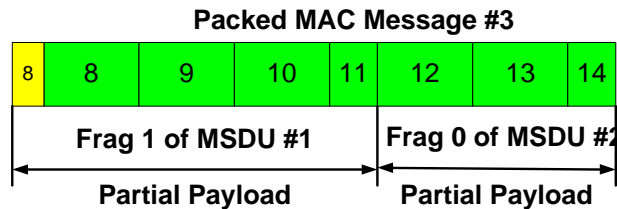
Figure 2. Retransmission with and without the rearrangement of MAC Messages

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 composes a single incomplete block. Such a definition of block size
provides especially simple numbering.
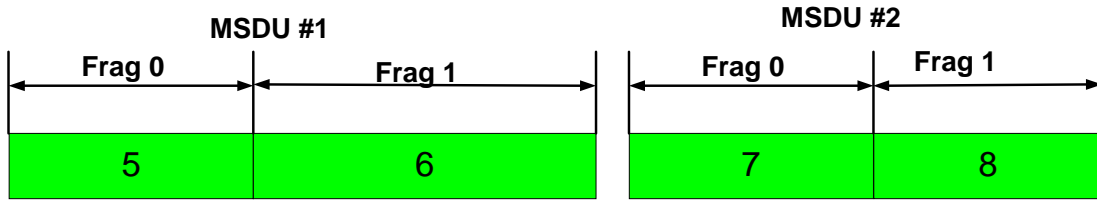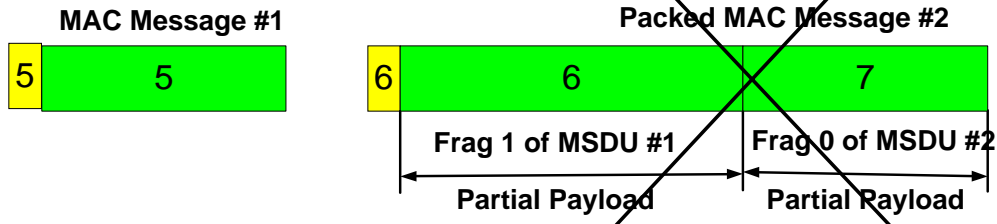
MSDU #1

Frag 0	Frag 1

| 5 | 6 |

MSDU #2

Frag 0	Frag 1

| 7 | 8 |

Original Transmission

MAC Message #1

| 5 | 5 |

Packed MAC Message #2

| 6 | 6 | 7 |

Frag 1 of MSDU #1   Frag 0 of MSDU #2

Partial Payload   Partial Payload

Retransmission with rearrangement of MAC Messages

MAC Message #3

| 6 | 6 |

MAC Message #4

| 7 | 7 |

Retransmission without rearrangement of MAC Messages

Packed MAC Message #3

| 6 | 6 | 7 |

Frag 1 of MSDU #1   Frag 0 of MSDU #2

Partial Payload   Partial Payload
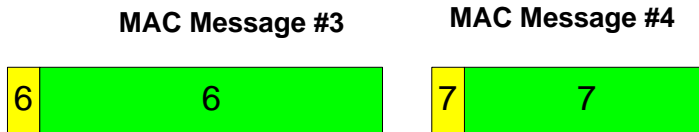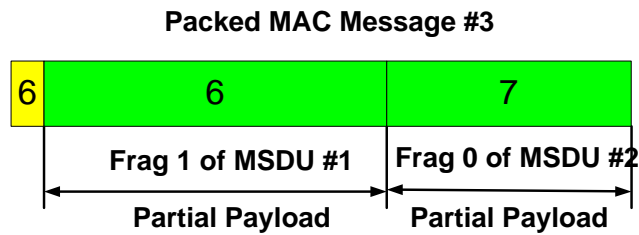
1
2   **Figure 3. Retransmission with and without the rearrangement of MAC Messages**

3

4   The following picture explains the interaction between the ARQ numbering and
5   fragmentation signaling:
6

MSDU #1

Frag 0	Frag 1	Frag 2

MSDU #2

Frag 0	Frag 1

5	6	7	8	9	10	11	12	13	14	15	16

MAC Messages

MAC Message #1

5	5	6	7

Frag 0 of MSDU #1
FC = 10

Packed MAC Message #2

8	8	9	10	11	12	13	14

Partial Payload
Frag 1 of
MSDU #1
FC = 01

Partial Payload
Frag 2 of
MSDU #1
FC = 11

Partial Payload
Frag 0 of
MSDU #2
FC = 10

Figure 4. Interaction between the ARQ numbering and fragmentation signaling

2.1.2.3.   Receiver Operations

At the Receiver side, after the successful reception of a MAC Message, the 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 5, 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 2.1.3.

Finally, MAC assembles as many MSDUs as possible, according to the Sequential Numbers and FC information.

MAC MAY decide after receiving Discard message or [TBD] that certain blocks will never arrive.

Then MAC supplies some of assembled MSDUs to the Convergence Sublayer following the best efforts policy to deliver them in order.

MSDU #1		MSDU #2	
Frag 0	**Frag 1**	**Frag 0**	**Frag 1**
5	6	7	8

Transmission

MAC Message #1

5	5

Packed MAC Message #2

6	6	7

Frag 1 of MSDU #1	**Frag 0 of MSDU #2**
Partial Payload	**Partial Payload**
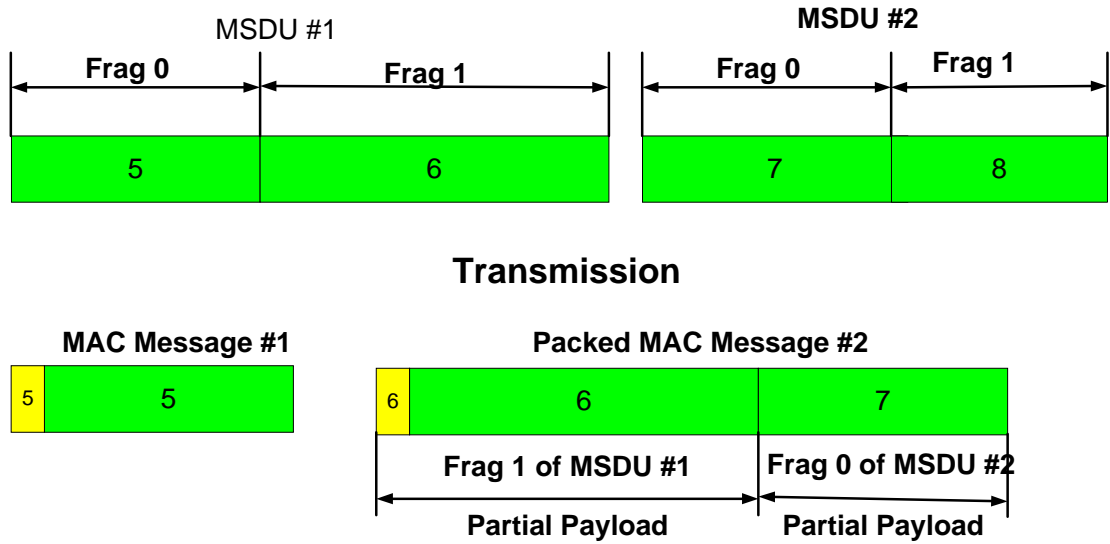
Figure 5. Block Numbering in the Case when the Block Size Exceeds the Maximum MSDU Length

2.1.3. MPDU Numbering Base Retransmission Scheme

2.1.3.1. Transmitter Operations: MAC Message Creation and Numbering

- Each MPDU is assigned a sequence number irrespective of the number of bytes in the MPDU
- Unit of retransmission is MPDU

The following picture shows an example of MAC PDU numbering.

MSDU 0 (40 bytes)	MSDU 1 (120 bytes)		*Gap.....*	MSDU 2 (40 bytes)	*Gap.....*
Block 0 (64 bytes)	*Block 1 (64 bytes)*	*Block 2 (32 bytes)*		*Block 3 (40 bytes)*	

MPDU 0 (MSN = 0)	MPDU 1 (MSN = 1)	MPDU 2 (MSN = 2)

MPDU 0
(132 bytes[Blocks 0 and 1 + 2 PSH of 2 bytes each] of payload + MAC header)

MPDU 1
(32 bytes [Block 2] of payload + MAC header)

MPDU 2
(40 bytes [Block 3] of payload + MAC header)
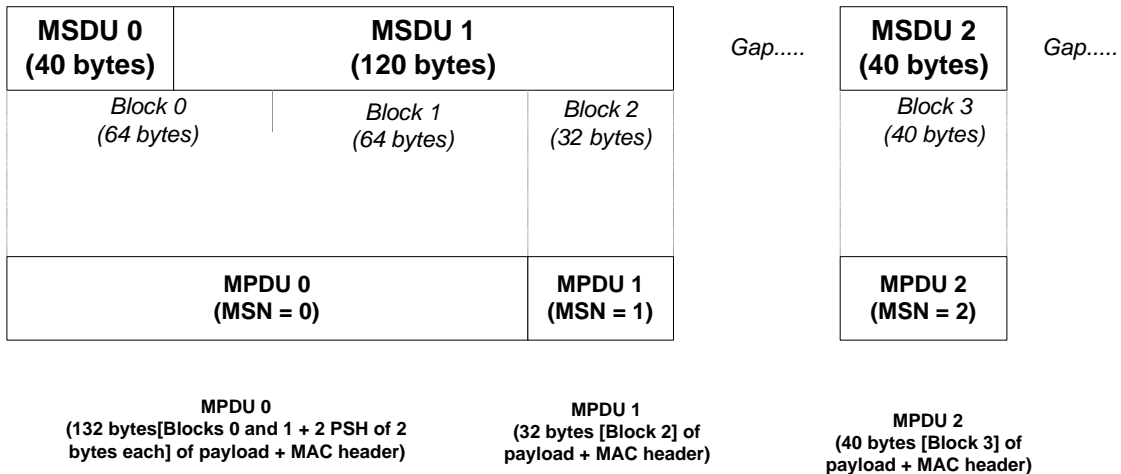
<<< To be extended >>>

2.1.3.2.   Receiver Operations

The next expected MPDU number is calculated as the last received MPDU sequence number + 1

<<< To be extended >>>

2.1.4. Formats of ARQ Related Signaling

2.1.4.1.   Encoding of the Sequential Number

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

2.1.4.1.1.   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] in the case when the MAC message carries a MSDU fragment as a payload.
<<< Seems that there is no need in the Fragmentation Sub-header as described in TG1 draft. Technically, it is suggested to replace the TG1 definition of the Fragmentation Sub-header format with 2.1.4.1.2**Error! Reference source not found.**. The new formats definitively may be used even with ARQ disabled to avoid ambiguity in the assembling of MSDUs >>>

2.1.4.1.2.   ARQ Sub-header Formats

The following picture figures formats of the ARQ sub-headers with the short and long Sequential Numbers.

<<< Actually there are two options of "long" SN. Choice is TBD at the step of finalization of the ARQ Feedback format >>>

Short Number

FC(2)	SN (6)

Long Number: 14 bits

FC(2)	SN (6)
BSN (8) - Cont.	
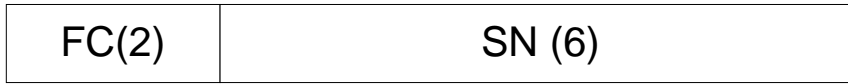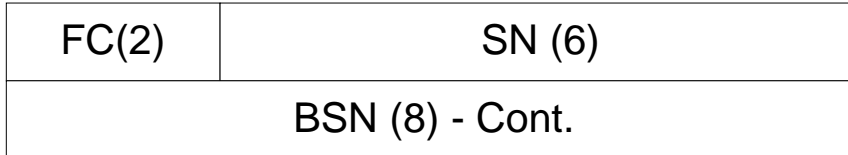
Long Number: 11bits

FC(2)	Rsvd(3)	SN (3)
BSN (8) - Cont.		
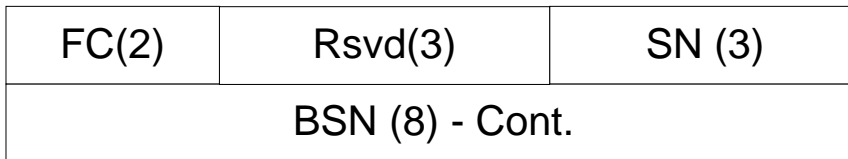
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2

2.1.4.2.   Encoding of the ARQ Feedback in Sub-headers and Partial Payloads

<<< This section suggests 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. >>>

2.1.4.3.   ARQ Feedback Information Elements used in Sub-headers and Partial Payloads

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 >>>

1   Usage of short/long ACKs is negotiated during the connection creation/change.
2   <<< Same way we may handle the presence / absence of CID >>>
3
4   These elements may be used in
5   •   ARQ feedback piggybacked onto MAC header, particularly in standalone
6   ACK/NACK message
7   •   Partial payload within a packed MAC message
8
9   In the formats below the following fields are mentioned:
10 •   The **Last** bit is used to mark the last ARQ IE in the Sub-header.
11 •   **BM** = 1 means presence the BM field
12 •   The **BSN** value means acknowledging all the blocks with the Sequential Number <
13   BSN within the transmission window.
14 •   **BM** means the bitmap that contains '1' for NACK and '0' for ACK for the blocks
15   from BSN*8 to (BSN*8+7)
16
17   *2.1.4.3.1.1.   Cumulative ACK-Short*
18

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

19

20   *2.1.4.3.1.2.   Cumulative ACK/NACK-Short*
21
22
23

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

24

25   *2.1.4.3.1.3.   Cumulative ACK-Long*
26 <<< Option #1 >>>

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

27
28
29 <<< Option #2 >>>
30

Cumulative ACK-Long

Last	BM Flag=0	ACK / NACK	F	Rsvd
SN(8)				
SN(8) - Cont.				
CID(8)				
CID (8) - Cont.				

1
2
3
4
5   <<< These formats should be revisited >>>
6

7   *2.1.4.3.1.4.   Cumulative ACK/NACK-Long*
8

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

9
10

11   2.1.4.3.2.   ARQ Feedback Sub-header
12   The following is the structure of MAC Message, which is a standalone ACK if the
13   payload is absent. The ARQ Feedback Sub-header consists of variable number of ARQ IEs.
14

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

1   **Figure 6. ARQ Feedback Sub-header**

2   2.1.4.3.3.   ARQ Feedback as Partial Payload
3   In the packed MAC Message (case of the "variable size SDUs") the following is the
4   structure of Packing Header in the case when the payload is an ARQ Feedback IE.
5   "Last" fields are not used.
6

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

7
8
9
10
11
12   The whole MAC Message structure is the following
13

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

14
15   <<< This requires change in the definition of Packing Sub-header comparatively to TG1
16   draft. Technically such a change may be done by replacing (for TG3) the correspondent
17   pictures in [1], 6.2.3.3 . The following might be a picture
18

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

19
20   Type is encoded according to the following table
21

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

1
2   >>>
3

2.1.4.4.   Encoding of the ARQ Feedback in MAC Messages

5   2.1.4.4.1.   Encodings used in the ARQ related MAC Messages
6
7   ARQ Control Message Fields
8   • CID: ID of Connection for which the message was generated
9   • Type: the type of the message. For ACK/NACK Type = 001
10   • CACK Flag = '1' if Cumulative Acknowledgement
11   • ACKC Flag – ACK congestion flag
12   • Length = number of ACK maps
13   • ACK MAP = BBN (Bitmap Block Number) + BM (bitmap)
14

15   2.1.4.4.2.   ARQ MAC Header
16
17

HT=1 (1)	EC=0 (1)	Type = "ACK"	Rsvd	ACK/NAC	SN(6)
SN (8)			CID (8)		
CID - cont (8)			HCS (8)		

18
19
20

21   2.1.4.4.3.   ACK Message
22
23

0	8		15

Connection ID			
TYPE (3)	CACK / ACKC	RSVD	Length
BBN 1		BM 1	
BBN 2		BM 2	

BBN *n*	BM *n*
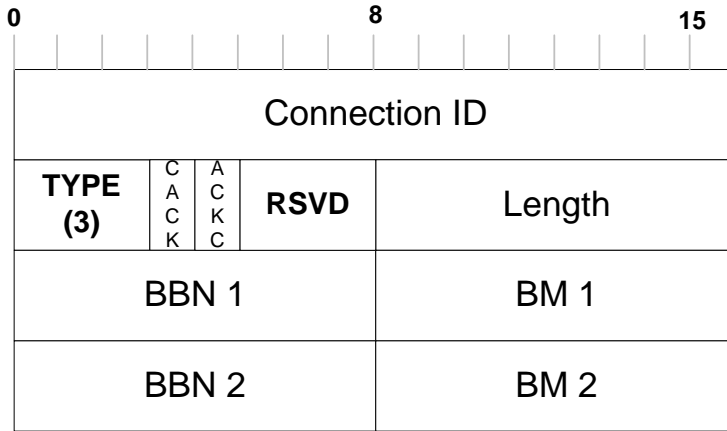
2.1.5. Additional Operations

2.1.5.1. Format of Discard and Reset Messages

0	8		15

Connection ID		
TYPE (3)	RSVD (2)	SN (11)
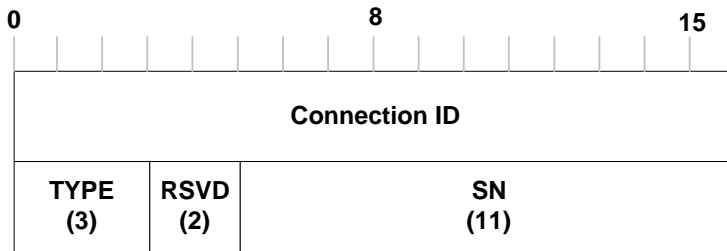
2.1.5.2. Discard

<<< To be added >>>

2.1.5.3. Reset

<<< To be added >>>

2.1.6. Retransmission Algorithms

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

2.1.7. Examples of ARQ Schemes

2.1.7.1. 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 MAC Messages 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 MAC Messages (see **Error! Reference source not found.**)

2.1.7.2. 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.

2.1.7.3. 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.

2.1.8. ARQ Related Operations at the Connection Creation/Change

<<< To be added >>>

2.2. ARQ Algorithm

<<< Specify up to minimal extent ARQ related operations of Transmitter and Receiver >>>

3. Advanced Packing

[Editorial Group: Vladimir, Subbu, Subir, Demos]
<<< Pending because of disagreement between the initial contributors >>>

4. MAC-PHY Interface for Single Carrier PHY

[Editorial Group: Subir, Vladimir, Itzik, Huan Chun, Subbu, Demos]

<<< Submission "MAC-PHY Interface" by Subir. Possibly, we need here some references to the correspondent PHY options >>>

4.1. MAP Messages

4.1.1. Downlink MAP (DL-MAP) Message

The Downlink MAP (DL-MAP) message defines the access to the downlink information
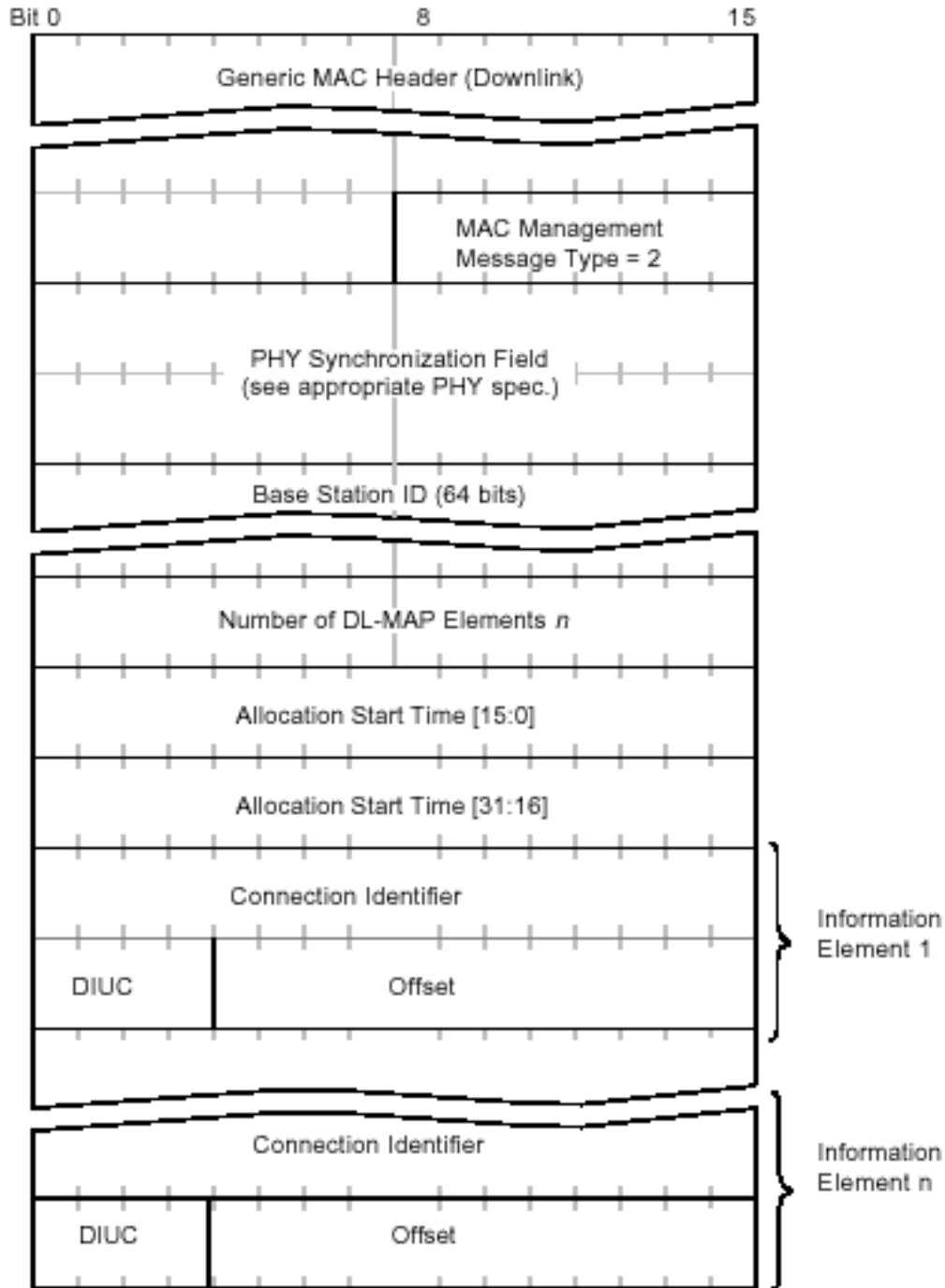
Figure 7

6   A BS shall generate DL-MAP messages in the format shown in Figure 1, including all
7   of the following parameters:

- **Length**

If the length of the DL-MAP message is a non-integral number of bytes, the Length field in the MAC header is rounded up to the next integral number of bytes. The message must be padded to match this length but the SS must disregard the 4 pad bits.

- **PHY Synchronization**

The PHY Synchronization field is dependent on the PHY layer used. The encoding of this field is given in each PHY separately.

- **Base Station ID**

The Base Station ID is a 64 bit long field identifying the BS. The Base Station ID may be programmable.

- **Alloc Start Time**

Effective start time of the uplink allocation defined by the DL-MAP in units of mini-slots. The start time is relative to the start of a frame in which DL-MAP message is transmitted.

- **Number Of Elements**

The number of Information Elements that follows.

- **MAP Information Elements**

Each Information Element (IE) consists of three fields:
1) Connection Identifier
2) Downlink Interval Usage Code
3) Offset

The encoding of remaining portions of the DL-MAP message is PHY dependent and may not be present. Refer to the appropriate PHY specification.

4.1.2. Uplink MAP (UL-MAP) Message

The Uplink MAP (UL-MAP) message allocates access to the uplink channel. The UL-MAP message shall be as shown in the following figure

Figure 8

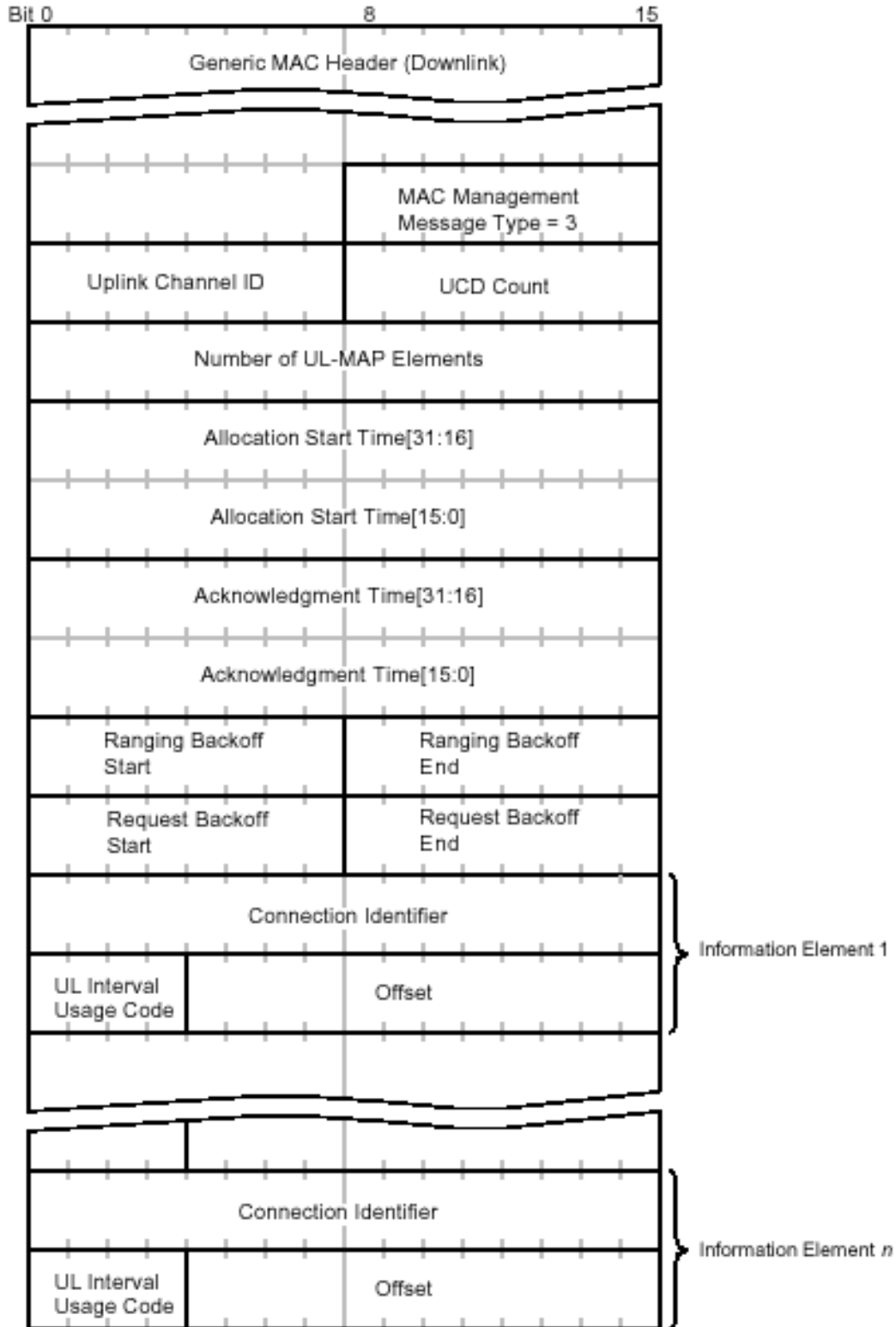The BS shall generate the UL-MAP with the following parameters:

- **Uplink Channel ID**

The identifier of the uplink channel to which this Message refers.

- **UCD Count**

Matches the value of the Configuration Change Count of the UCD which describes the burst parameters which apply to this map.

- **Number of Elements**

Number of information elements in the map.

- **Alloc Start Time**

Effective start time of the uplink allocation defined by the UL-MAP in units of mini-slots. The start time is relative to the start of a frame in which UL-MAP message is transmitted (PHY Type = {0,1}) or from BS initialization (PHY Type = 2).

- **Ack Time**

Latest time processed in uplink in units of mini-slots. This time is used by the SS for collision detection purposes. The ack time is relative to the start of a frame in which UL-MAP message is transmitted (PHY Type = {0,1}) or from BS initialization (PHY Type = 2).

- **Ranging Backoff Start**

Initial back-off window size for initial ranging contention, expressed as a power of 2. Values of n range 0–15 (the highest order bits must be unused and set to 0).

- **Ranging Backoff End**

Final back-off window size for initial ranging contention, expressed as a power of 2. Values of n range 0–15 (the highest order bits must be unused and set to 0).

- **Request Backoff Start**

Initial back-off window size for contention data and requests, expressed as a power of 2. Values of n range 0–15 (the highest order bits must be unused and set to 0).

- **Request Backoff End**

Final back-off window size for contention requests, expressed as a power of 2. Values of n range 0–15 (the highest order bits must be unused and set to 0).

- **MAP Information Elements**

Each Information Element (IE) consists of three fields:

1) Connection Identifier
2) Uplink Interval Usage Code
3) Offset

Information elements define uplink bandwidth allocations. Each UL-MAP message shall contain at least one Information Element that marks the end of the last allocated burst. The Information Elements are strictly order within the UL-MAP, as shown in Figure 8.
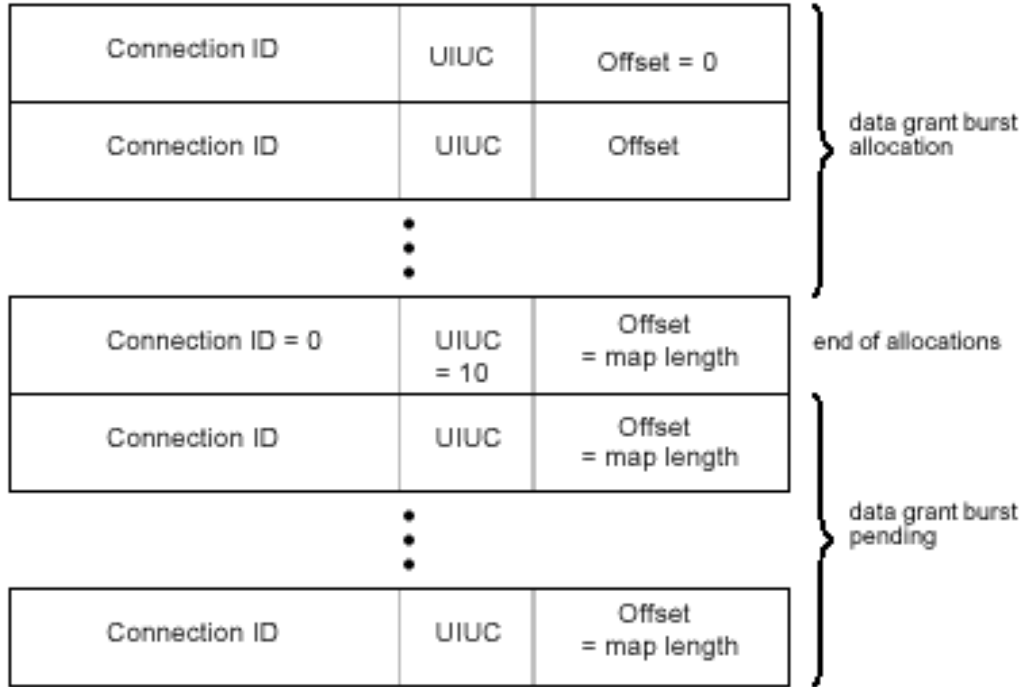
1
2   **Figure 9**
3
4
5   The Connection Identifier represents the assignment of the IE to either a unicast, multicast, or
6   broadcast address. When specifically addressed to allocate a bandwidth grant, the CID may
7   be either the Basic CID of the SS or a Traffic CID for one of the connections of the SS. A
8   four-bit Uplink Interval Usage Code (UIUC) shall be used to define the type of uplink access
9   and the burst type associated with that access. A Burst Descriptor shall be included for each
10   Interval Usage Code that is to be used in the UL-MAP. The Interval Usage Code shall be one
11   of the values defined in Table 1. The offset indicates the start time, in units of minislots, of
12   the burst relative to the Allocation Start Time given in the UL-MAP message. Consequently
13   the first IE will have an offset of 0. The end of the last allocated burst is indicated by
14   allocating a NULL burst (CID = 0 and UIUC = 10) with zero duration. The time instants
15   indicated by the offsets are the transmission times of the first symbol of the burst including
16   preamble.
17

Table 1—Uplink Map Information Elements

IE Name	Uplink Interval Usage Code (UIUC)	Connection ID	Mini-slot Offset
Reserved	0	NA	Reserved for future use
Request	1	any	Starting offset of REQ region
Initial Maintenance	2	broadcast	Starting offset of MAINT region (used in Initial Ranging)
Station Maintenance	3	unicast	Starting offset of MAINT region (used in Periodic Ranging)
Data Grant Burst Type 1	4	unicast	Starting offset of Data Grant Burst Type assignment. If inferred length = 0, then it is a Data Grant Burst Type pending.
Data Grant Burst Type 2	5	unicast	Starting offset of Data Grant Burst Type assignment. If inferred length = 0, then it is a Data Grant Burst Type Pending
Data Grant Burst Type 3	6	unicast	Starting offset of Data Grant Burst Type 2 assignment. If inferred length = 0, then it is a Data Grant Burst Type pending.
Data Grant Burst Type 4	7	unicast	Starting offset of Data Grant Burst Type 2 assignment. If inferred length = 0, then it is a Data Grant Burst Type pending.
Data Grant Burst Type 5	8	unicast	Starting offset of Data Grant Burst Type 3 assignment. If inferred length = 0, then it is a Data Grant Burst Type pending.
Data Grant Burst Type 6	9	unicast	Starting offset of Data Grant Burst Type 3 assignment. If inferred length = 0, then it is a Data Grant Burst Type pending.
Null IE	10	zero	Ending offset of the previous grant. Used to bound the length of the last actual interval allocation.
Empty	11	zero	Used to schedule gaps in transmission
Reserved	11-14	any	Reserved
Expansion	15	expanded UIUC	# of additional 32-bit words in this IE

1
2
3
4   ### 4.1.3. Uplink + Downlink MAP
5

6   For TDD and Burst FDD systems, a single MAP message is defined, that covers both uplink
7   and downlink directions.

8

Bit 0	8	15
Generic MAC Header (Downlink)		
	MAC Management Message Type = 28	
Channel ID	UCD Count	
PHY Synchronization Field (see appropriate PHY spec.)		
Base Station ID (64 bits)		
Number of DL-MAP Elements n		
Number of UL-MAP Elements m		
Allocation Start Time[31:16]		
Allocation Start Time[15:0]		
Acknowledgment Time[31:16]		
Acknowledgment Time[15:0]		
Ranging Backoff Start	Ranging Backoff End	
Request Backoff Start	Request Backoff End	

1

1
2   **Figure 10**
3

4   ## 4.2.   <u>MAP Relevance and Synchronization</u>

5   ### 4.2.1. <u>MAP Relevance for Burst PHY Systems</u>
6

7
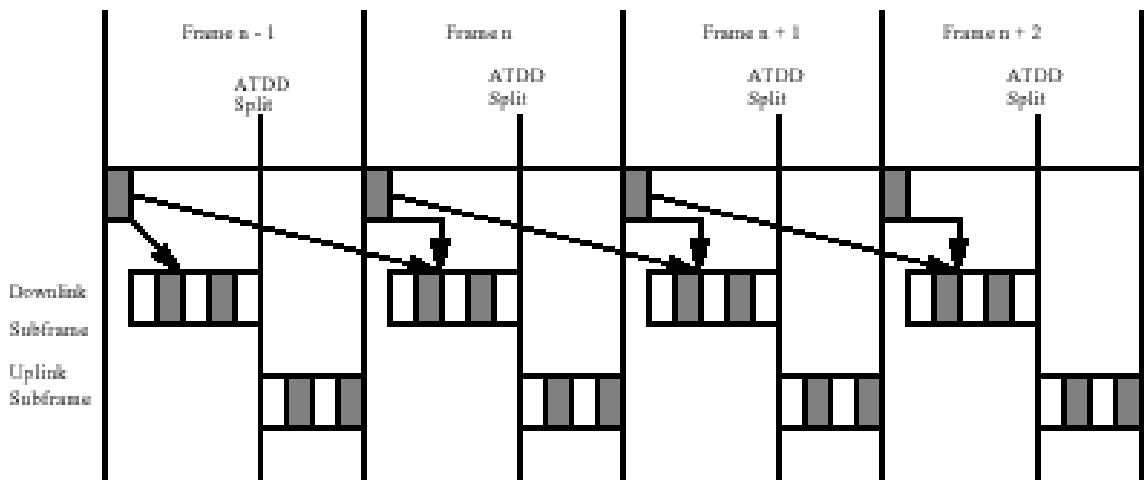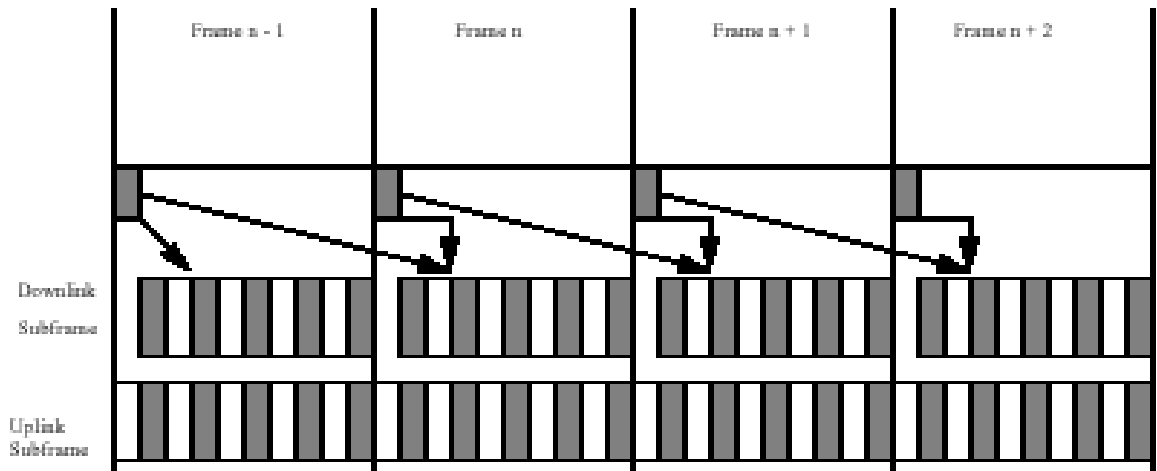8   **Figure 11. Maximum Time Relevance of PHY and MAC Control Information (TDD)**
9
10

Figure 12. Maximum Time Relevance of PHY and MAC Control Information (FDD)

As shown in Figure 5 and 6, the portion of the time axis described by the MAP is a contiguous area whose duration is equal to the duration of a frame. In the example shown in Figure 5, it consists of a portion of the downstream time of the frame in which the MAP is contained, the upstream time in this frame, followed by a portion of the downstream time in the next frame. The fraction of the downstream time in the current frame (or alternatively, the Allocation Start Time), is a quantity that is under the control of the scheduler.

4.2.2. <<< Physical Layer for TG3 Systems >>>

<<< This section does not clearly fit the TOC agreed at the meeting of TG3/4 MAC Groups (the agreed title was "MAC-PHY interface"). Editor recommends to consider changing the title and removing this stuff to another section. In 802.16_D3d1 similar data is placed in the section "6.2.7 MAC support of PHY layers" In this case some work should be done to compare the content of this section with the content of 802.16_D3d1/6.2.7 so that we'd have to figure only the difference >>>

4.2.2.1. Overview

Two modes of operation have been defined for the point-to-multi-point downlink channel:
one targeted to support a continuous transmission stream format, and
one targeted to support a burst transmission stream format.
 Having this separation allows each format to be optimized according to its respective design constraints, while resulting in a standard that supports various system requirements and deployment scenarios.
In contrast, only one mode of operation is defined for the upstream channel:
        one targeted to support a burst transmission stream format.
This single mode of operation is sufficient for the upstream, since the upstream transmissions are point-to-point burst transmissions between each transmitting subscriber station (SS) and each receiving base station (BS).

1   ### 4.2.2.2.   Downlink and Uplink Operation

2   Two different downlink modes of operation are defined: Mode A and Mode B. Mode A
3   supports a continuous transmission format, while Mode B supports a burst transmission
4   format. The continuous transmission format of Mode A is intended for use in an FDD-only
5   configuration. The burst transmission format of Mode B supports burst-FDD as well as TDD
6   configurations.
7   The A and B options give service providers choice, so that they may tailor an installation to
8   best meet a specific set of system requirements. Standards-compliant subscriber stations are
9   required to support at least one (A or B) of the defined downlink modes of operation.
10   A single uplink mode of operation is also defined. This mode supports TDMA-based burst
11   uplink transmissions. Standards-compliant subscriber stations are required to support this
12   uplink mode of operation.
13

14   ### 4.2.2.3.   Mode A (Continuous Downlink)

15   Mode A is a downlink format intended for continuous transmission. The Mode A downlink
16   physical layer first encapsulates MAC packets into a convergence layer frame as defined by
17   the transmission convergence sublayer. Modulation and coding which is adaptive to the needs
18   of various SS receivers is also supported within this framework.
19   Data bits derived from the transmission convergence layer are first randomized. Next, they
20   are block FEC encoded. The resulting FEC-encoded bits are mapped to QPSK, 16-QAM, or
21   64-QAM signal constellations. Detailed descriptions of the FEC, modulation constellations,
22   and symbol mapping formats can be found within the FEC and modulation sections.
23   Following the symbol mapping process, the resulting symbols are modulated, and then
24   transmitted over the channel.
25   In Mode A, the downstream channel is continuously received by many SSs. Due to differing
26   conditions at the various SS sites (e.g., variable distances from the BS, presence of
27   obstructions), SS receivers may observe significantly different SNRs. For this reason, some
28   SSs may be capable of reliably detecting data only when it is derived from certain lower-
29   order modulation alphabets, such as QPSK. Similarly, more powerful and redundant FEC
30   schemes may also be required by such SNR-disadvantaged SSs. On the other hand, SNR-
31   advantaged stations may be capable of receiving very high order modulations (e.g., 64-QAM)
32   with high code rates. Collectively, let us define the adaptation of modulation type and FEC to
33   a particular SS (or group of SSs) as 'adaptive modulation', and the choice of a particular
34   modulation and FEC as an 'adaptive modulation type.' Mode A supports adaptive modulation
35   and the use of adaptive modulation types.
36   A MAC Frame Control header is periodically transmitted over the continuous Mode A
37   downstream, using the most robust supported adaptive modulation type. So that the start of
38   this MAC header may be easily recognized during initial channel acquisition or re-acqustion,
39   the PHY inserts an uncoded, TBD (but known) QPSK code word, of length TBD symbols, at
40   a location immediately before the beginning of the MAC header, and immediately after a
41   Unique Word. (See PHY framing section for more details on the Unique Word). Note that
42   this implies the interval between Frame Control headers should be an integer multiple of F
43   (the interval between Unique Words).
44   Within MAC Frame Control header, a PHY control map (DL_MAP) is used to indicate the
45   beginning location of adaptive modulation type groups which follow. Following this header,
46   adaptive modulation groups are sequenced in increasing order of robustness. However, the
47   DL_MAP does not describe the beginning locations of the payload groups that immediately
48   follow; it describes the payload distributions some MAC-prescribed time in the future. This
49   delay is necessary so that FEC decoding of MAC information (which could be iterative, in

1   the case of turbo codes) may be completed, the adaptive data interpreted, and the
2   demodulator scheduling set up for the proper sequencing.
3   Note that adaptive modulation groups or group memberships can change with time, in order
4   to adjust to changing channel conditions.
5   In order that disadvantaged SNR users are not adversely affected by transmissions intended
6   for other advantaged SNR users, FEC blocks end when a particular adaptive modulation type
7   ends. Among other things, this implies that the FEC interleaver depth is adapted to
8   accommodate the span of a particular adaptive modulation type.
9

10   4.2.2.3.1.   Mode B (Burst Downlink)
11
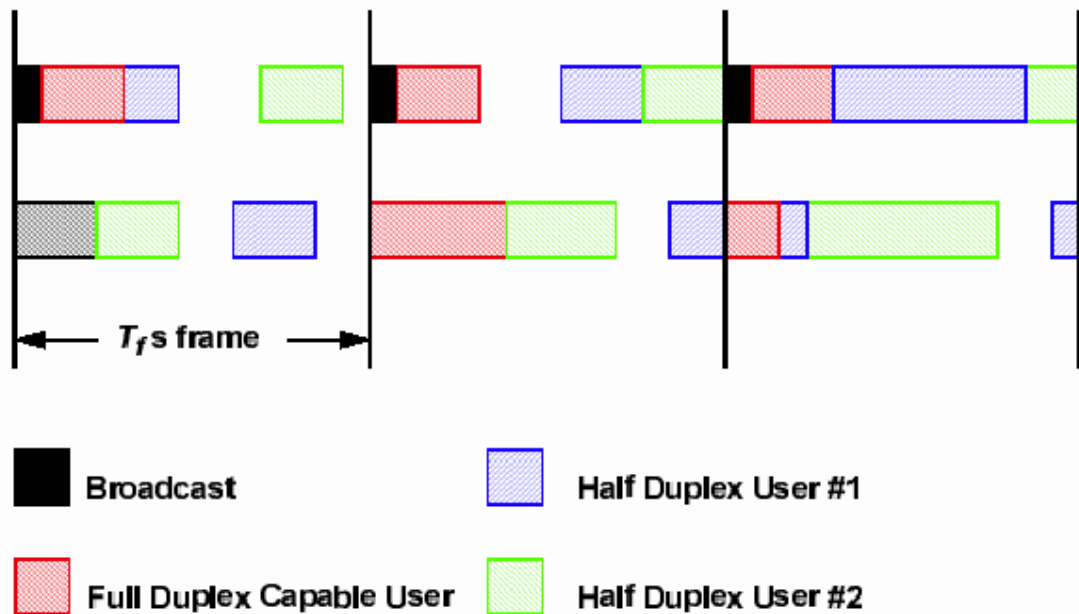
12
13   **Figure 13. Example of burst FDD Bandwidth Allocation**

14
15   Mode B is a downlink format intended for burst transmissions, with features that
16   simplify the support for both TDD systems and half-duplex terminals. A Mode B compliant
17   frame can be configured to support either TDM or TDMA transmission formats; i.e., a Mode
18   B burst may consist a single user's data, or a concatenation of several users' data. What's
19   more, Mode B supports adaptive modulation and multiple adaptive modulation types within
20   these TDMA and TDM formats.
21   A unique (acquisition) preamble is used to indicate the beginning of a frame, and
22   assist burst demodulation. This preamble is followed by PHY/MAC control data. In the TDM
23   mode, a PHY control map (DL_MAP) is used to indicate the beginning location of different
24   adaptive modulation types. These adaptive modulation types are sequenced within the frame
25   in increasing order of robustness (e.g., QPSK, 16-QAM, 64-QAM), and can change with time
26   in order to adjust to the changing channel conditions.
27   In the TDMA mode, the DL_MAP is used to describe the adaptive modulation type in
28   individual bursts. Since a TDMA burst would contain a payload of only one adaptive
29   modulation type, no adaptive modulation type sequencing is required. All TDMA format

1 payload data is FEC block encoded, with an allowance made for shortening the last codeword
2 (e.g., Reed Solomon codeword) within a burst.
3   The Mode B downlink physical layer goes through a transmission convergence
4 sublayer that inserts a pointer byte at the beginning of the payload information bytes to help
5 the receiver identify the beginning of a MAC packet.
6   Payload data bits coming from the transmission convergence layer are first
7 randomized. Next, they are block FEC encoded. The resulting FEC-encoded bits are mapped
8 to QPSK, 16-QAM, or 64-QAM signal constellations. Detailed descriptions of the FEC,
9 modulation constellations, and symbol mapping formats can be found within the FEC and
10 modulation sections. Following the symbol mapping process, the resulting symbols are
11 modulated, and then transmitted over the channel.

12   *4.2.2.3.1.1.   Uplink*

13   The uplink mode supports TDMA burst transmissions from an individual SSs to a BS.
14 This is functionally similar (at the PHY level) to Mode B downlink TDMA operation. As
15 such, for a brief description of the Physical Layer protocol used for this mode, please read the
16 previous section on Mode B TDMA operation.
17   Of note, however, is that many of the specific uplink channel parameters can be
18 programmed by MAC layer messaging coming from the base station in downstream
19 messages. Also, several parameters can be left unspecified and configured by the base station
20 during the registration process in order to optimize performance for a particular deployment
21 scenario. In the upstream mode of operation, each burst may carry MAC messages of variable
22 lengths.

23   **4.2.2.4.   Multiplexing and Multiple Access Technique**

24   The uplink physical layer is based on the combined use of time division multiple
25 access (TDMA) and demand assigned multiple access (DAMA). In particular, the uplink
26 channel is divided into a number of 'time slots.' The number of slots assigned for various uses
27 (registration, contention, guard, or user traffic) is controlled by the MAC layer in the base
28 station and can vary over time for optimal performance.
29   As previously indicated, the downlink channel can be in either a continuous (Mode A)
30 or burst (Mode B) format. Within Mode A, user data is transported via time division
31 multiplexing (TDM), i.e., the information for each subscriber station is multiplexed onto the
32 same stream of data and is received by all subscriber stations located within the same sector.
33 Within Mode B, the user data is bursty and may be transported via TDM or TDMA,
34 depending on the number of users which are to be borne within in burst.
35

36   4.2.2.4.1.   Duplexing Techniques
37 Several duplexing techniques are supported, in order to provide greater flexibility in spectrum
38 usage. The continuous transmission downlink mode (Mode A) supports frequency division
39 duplexing (FDD) with adaptive modulation; the burst mode of operation (Mode B) supports
40 FDD with adaptive modulation or time division duplexing (TDD) with adaptive modulation.
41 Furthermore, Mode B in the FDD case can handle (half duplex) subscribers incapable of
42 transmitting and receiving at the same instant, due to their specific transceiver
43 implementation.
44

45   *4.2.2.4.1.1.   Mode A: Continuous Downstream for FDD Systems*

1   In a system employing FDD, the uplink and downlink channels are located on separate
2   frequencies and all subscriber stations can transmit and receive simultaneously. The
3   frequency separation between carriers is set either according to the target spectrum
4   regulations or to some value sufficient for complying with radio channel transmit/receive
5   isolation and de-sensitization requirements. In this type of system, the downlink channel is
6   (almost) "always on" and all subscriber stations are always listening to it. Therefore, traffic is
7   sent in a broadcast manner using time division multiplexing (TDM) in the downlink channel,
8   while the uplink channel is shared using time division multiple access (TDMA), where the
9   allocation of uplink bandwidth is controlled by a centralized scheduler. The BS periodically
10   transmits downlink and uplink MAP messages, which are used to synchronize the uplink
11   burst transmissions with the downlink. The usage of the mini-slots is defined by the UL-MAP
12   message, and can change according to the needs of the system. Mode A is capable of adaptive
13   modulation..

14   *4.2.2.4.1.2.   Mode B: Burst Downstream for Burst FDD Systems*
15   A burst FDD system refers to a system in which the uplink and downlink channels are located
16   on separate frequencies but the downlink data is transmitted in bursts. This enables the
17   system to simultaneously support full duplex subscriber stations (ones which can transmit and
18   receive simultaneously) and, optionally, half duplex subscriber stations (ones which cannot
19   transmit and receive simultaneously). If half duplex subscriber stations are supported, this
20   mode of operation imposes a restriction on the bandwidth controller: it cannot allocate uplink
21   bandwidth for a half duplex subscriber station at the same time that the subscriber station is
22   expected to receive data on the downlink channel.
23   Frequency separation is as defined in 3.2.1.1.1. Figure 139 describes the basics of the burst
24   FDD mode of operation. In order to simplify the bandwidth allocation algorithms, the uplink
25   and downlink channels are divided into fixed sized frames. A full duplex subscriber station
26   must always attempt to listen to the downlink channel. A half duplex subscriber station must
27   always attempt to listen to the downlink channel when it is not transmitting on the uplink
28   channel.

29   *4.2.2.4.1.3.   Mode B: Burst Downstream for Time Division Duplexing*
30   *(TDD) Systems*
31

M Mini Slots

Downlink Subframe   **Uplink Subframe**

Guardband

MS n   **MS (n+M)**
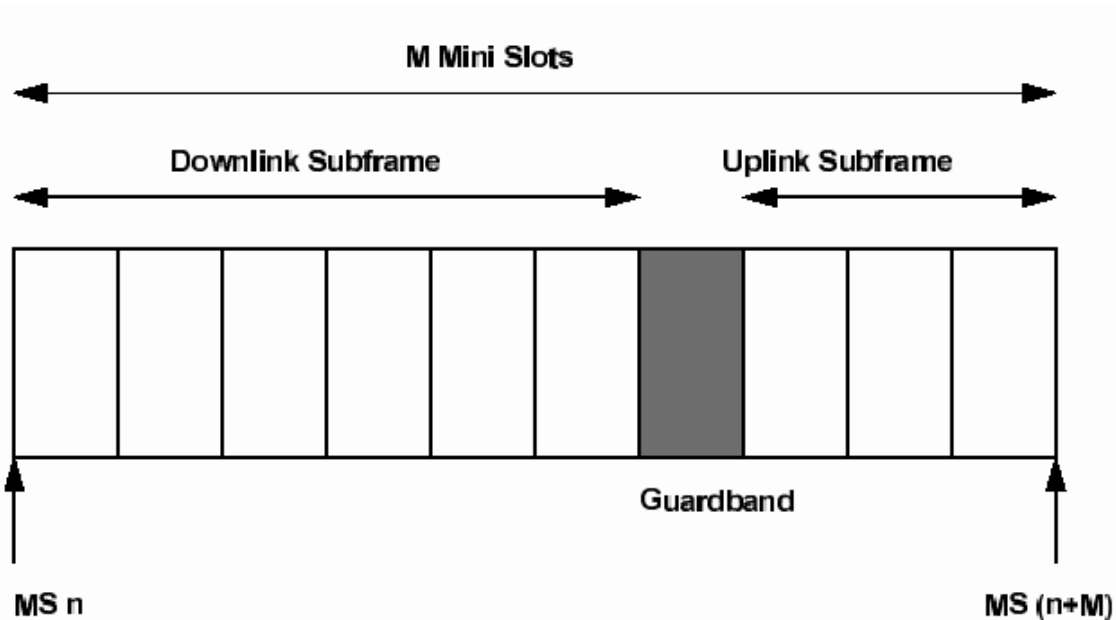
1
2   **Figure 14**
3
4
5
6   In the case of TDD, the uplink and downlink transmissions share the same frequency,
7   but are separated in time (Figure 140). A TDD frame also has a fixed duration and contains
8   one downlink and one uplink subframe. The frame is divided into an integer number of 'mini
9   slots' (MS), which facilitate the partitioning of bandwidth. These mini slots are in turn made
10 up of a finer unit of time called 'ticks', which are of duration 1 us each. TDD framing is
11 adaptive in that the percentage of the bandwidth allocated to the downlink versus the uplink
12 can vary. The split between uplink and downlink is a system parameter, and is controlled at
13 higher layers within the system.

14   4.2.2.4.1.3.1.   Tx / Rx Transition Gap (TTG)
15   The TTG is a gap between the Downlink burst and the Uplink burst. This gap allows
16 time for the BS to switch from transmit mode to receive mode and SSs to switch from receive
17 mode to transmit mode. During this gap, the BS and SS are not transmitting modulated data,
18 but it simply allows the BS transmitter carrier to ramp down, the Tx / Rx antenna switch to
19 actuate, and the BS receiver section to activate. After the TTG, the BS receiver will look for
20 the first symbols of uplink burst. The TTG has a variable duration, which is an integer
21 number of mini slots. The TTG starts on a mini slot boundary.

22   4.2.2.4.1.3.2.   Rx / Tx Transition Gap (RTG)
23   The RTG is a gap between the Uplink burst and the Downlink burst. This gap allows
24 time for the BS to switch from receive mode to transmit mode and SSs to switch from
25 transmit mode to receive mode. During this gap, BS and SS are not transmitting modulated
26 data but simply allowing the BS transmitter carrier to ramp up, the Tx / Rx antenna switch to
27 actuate, and the SS receiver sections to activate. After the RTG, the SS receivers will look for
28 the first symbols of QPSK modulated data in the downlink burst. The RTG is aninteger
29 number of mini slots. The RTG starts on a mini slot boundary.
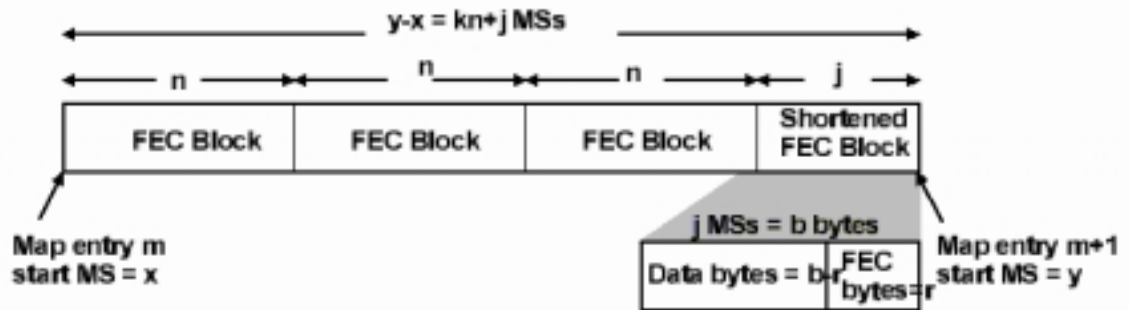30

1   *4.2.2.4.1.4.   Mode B: Downlink Data*

2

3

4   **Figure 15. Downlink MAP usage and shortened FEC blocks**

5

6   The downlink data sections are used for transmitting data and control messages to specific
7   SSs. This data is always FEC coded and is transmitted at the current operating modulation of
8   the individual SS. In the burst mode cases, data is transmitted in robustness order in the TDM
9   portion. In a burst TDMA application, the data is grouped into separately delineated bursts,
10   which do not need to be in modulation order. The DL-MAP message contains a map stating
11   at which mini slot the burst profile change occurs. If the downlink data does not fill the entire
12   downlink sub-frame and Mode B is in use, the transmitter is shut down. The DL-MAP
13   provides implicit indication of shortened FEC (and/or FFT) blocks in the downlink.
14   Shortening the last FEC block of a burst is optional (see 11.1.2.2). The downlink map
15   indicates the number of MS, p allocated to a particular burst and also indicates the burst type
16   (modulation and FEC). Let n denote the number of MS required for one FEC block of the
17   given burst profile. Then, $p = kn + j$, where k is the number of integral FEC blocks that fit in
18   the burst and j is the number of MS remaining after integral FEC blocks are allocated. Either
19   k or j, but not both, may be zero. j denotes some number of bytes b. Assuming j is not 0, it
20   must be large enough such that b is larger than the number of FEC bytes r, added by the FEC
21   scheme for the burst. The number of bytes available to user data in the shortened FEC block
22   is b - r. These points are illustrated in Figure 141. Note that a codeword may not possess less
23   than 6 information bytes.
24   In the TDM mode of operation, SSs listen to all portions of the downlink burst to which they
25   are capable of listening. For full-duplex SSs, this implies that a SS shall listen to all portions
26   that have a adaptive modulation type (as defined by the DIUC) which is at least as robust as
27   that which the SS negotiates with the BS. For half-duplex SSs, the aforesaid is also true, but
28   under an additional condition: an SS shall not attempt to listen to portions of the downlink
29   burst that are coincident---adjusted by the SS's Tx time advance---with the SS's allocated
30   uplink transmission, if any.
31   In the burst TDMA mode of operation, bursts are individually identified in the DL_MAP.
32   Hence, a SS is required to turn on its receiver only in time to receive those bursts addressed
33   to it. Unlike the TDM mode, there is no requirement that the bursts be ordered in order of
34   increasing robustness.

35   4.2.2.4.2.   Uplink Burst Subframe Structure

36
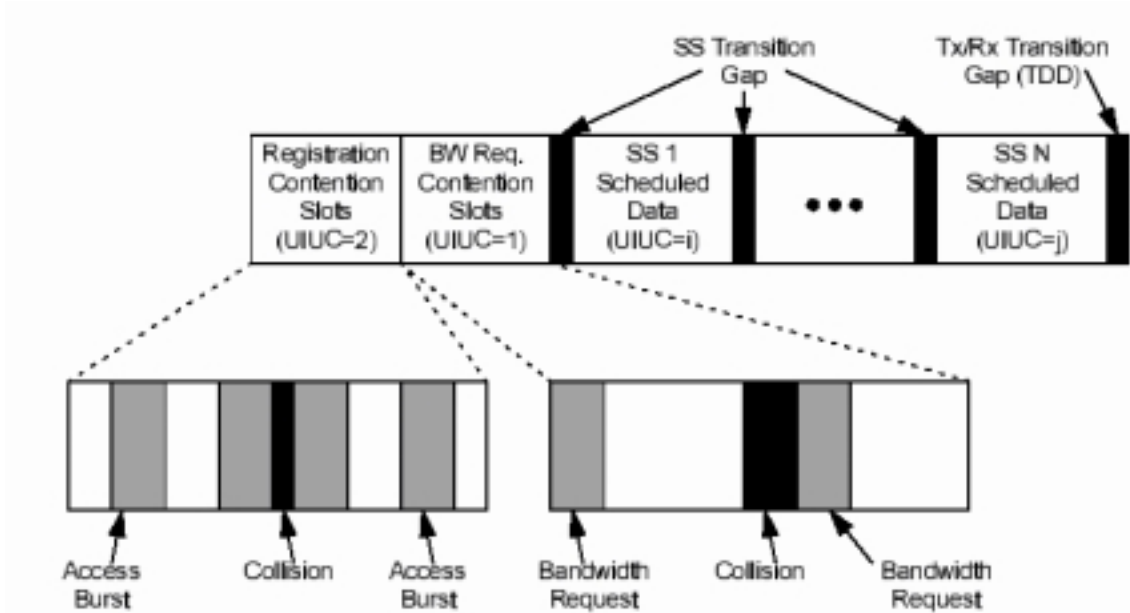
Figure 16. Uplink Subframe Structure

The structure of the uplink subframe used by the SSs to transmit to the BS is shown in Figure
142. There are three main classes of bursts transmitted by the SSs during the uplink
subframe:
a) Those that are transmitted in contention slots reserved for station registration.
b) Those that are transmitted in contention slots reserved for response to multicast and
broadcast polls for bandwidth needs.
c) Those that are transmitted in bandwidth specifically allocated to individual SSs.

4.2.2.4.2.1.   Mode A and Mode B: Uplink Burst Profile Modes

The uplink uses adaptive burst profiles, in which different SSs are assigned different
modulation types by the base station. In the adaptive case, the bandwidth allocated for
registration and request contention slots is grouped together and is always used with the
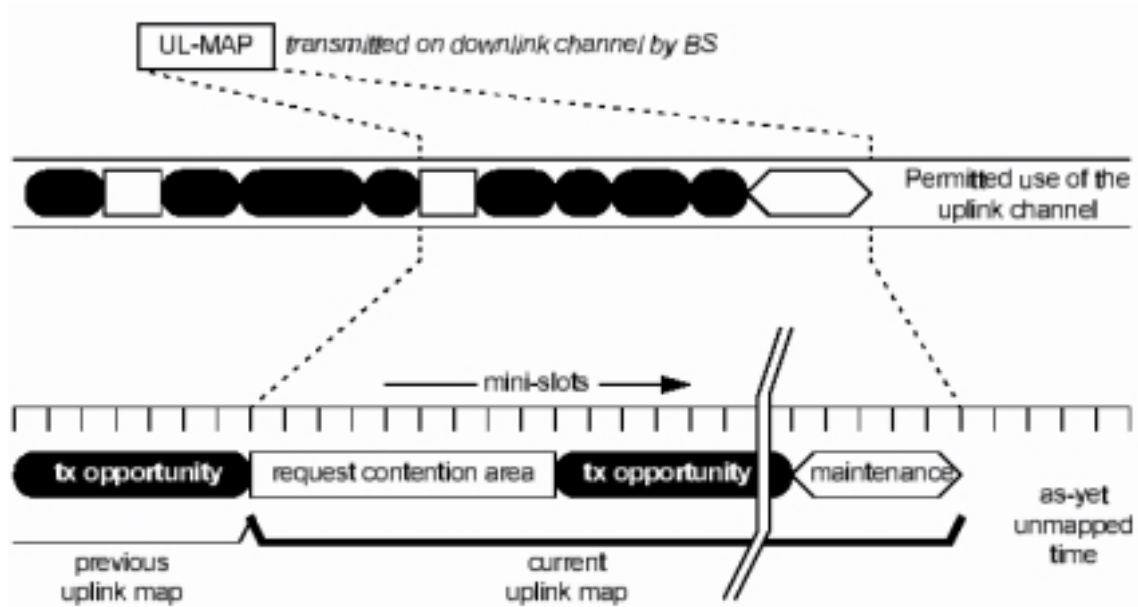
Figure 17. Uplink Mapping in the Continuous Downstream FDD Case

parameters specified for Request Intevals (UIUC=1) (Remark: It is recommended that
UIUC=1 will provide the most robust burst profile due to the extreme link budget and
interference conditions of this case). The remaining transmission slots are grouped by SS.
During its scheduled bandwidth, an SS transmits with the burst profile specified by the base
station, as determined by the effects of distance, interference and environmental factors on
transmission to and from that SS. SS Transition Gaps (STG) separate the transmissions of the
various SSs during the uplink subframe. The STGs contain a gap to allow for ramping down
of the previous burst, followed by a preamble allowing the BS to synchronize to the new SS.
The preamble and gap lengths are broadcast periodically in the UCD message. Shortening of
FEC blocks in the uplink is identical to the handling in the downlink as described in 3.2.2.1.4.

4.2.2.4.3.   PHY SAP Parameter Definitions
TBD

4.2.2.4.4.   Downlink Physical Layer
This section describes the two different downlink modes of operation that have been adopted
for use in this proposal. Mode A has been designed for continuous transmission, while a
Mode B has been designed to support a burst transmission format. Subscriber stations must
support at least one of these modes.

4.2.2.4.4.1.   *Physical layer type (PHY type) encodings*
The value of the PHY type parameter (X.X.X) as defined must be reported as shown
in the Table 1.

1   **Table 1. PHY type parameter encoding**

Mode	Value	Comment
Mode B (TDD)	0	Burst Downlink in TDD Mode
Mode B (FDD)	1	Burst Downlink in FDD Mode
Mode A (FDD)	2	Continuous downlink

2
3

4   *4.2.2.4.4.2.   Mode A: Continuous Downlink Transmission*

5   This mode of operation has been designed for a continuous transmission stream, using a
6   single modulation/coding combination on each carrier, in an FDD system. The physical
7   media dependent sublayer has no explicit frame structure. Where spectrum resources allow,
8   multiple carriers may be deployed, each using different modulation/coding methods defined
9   here.

10   *4.2.2.4.4.3.   Downlink Mode A: Message field definitions*

11   4.2.2.4.4.3.1.   Downlink Mode A: Required channel descriptor
12   parameters
13   The following parameters shall be included in the UCD message:
14   TBD
15

16   4.2.2.4.4.3.2.   Mode A: Required DCD parameters
17   The following parameters shall be included in the DCD message:
18   TBD
19

20   *4.2.2.4.4.3.2.1.   Downlink Mode A: DCD, Required burst*
21   *decriptor parameters*
22   TBD.

23   4.2.2.4.4.3.3.   Mode A: DL-MAP
24   For PHY Type = 2, no additional information follows the Base Station ID field.

25   *4.2.2.4.4.3.3.1.   Mode A: DL-MAP PHY Synchronization*
26   *Field definition*
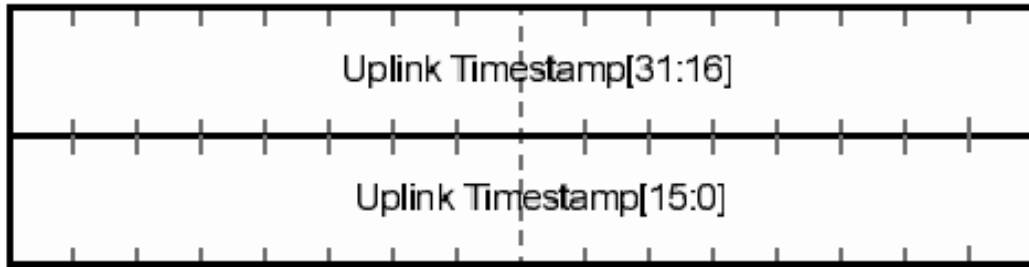27
28

Figure 18. PHY Synchronization Field (PHY Type = 2)

The format of the PHY Synchronization field is given in Figure 144. The Uplink Timestamp jitter must be less than 500 ns peak-to-peak at the output of the Downlink Transmission Convergence Sublayer. This jitter is relative to an ideal Downlink Transmission Convergence Sublayer that transfers the TC packet data to the Downlink Physical Media Dependent Sublayer with a perfectly continuous and smooth clock at symbol rate. Downlink Physical Media Dependent Sublayer processing shall not be considered in timestamp generation and transfer to the Downlink Physical Media Dependent Sub-layer. Thus, any two timestamps N1 and N2 (N2 > N1) which were transferred to the Downlink Physical Media Dependent Sublayer at times T1 and T2 respectively must satisfy the following relationship:

(N2 – N1)/(4 x Symbol Rate) – (T2 – T1) < 500 ns

The jitter includes inaccuracy in timestamp value and the jitter in all clocks. The 500ns allocated for jitter at the Downlink Transmission Convergence Sublayer output must be reduced by any jitter that is introduced by the Downlink Physical Media Dependent Sublayer.

4.2.2.4.4.3.4.   Mode A:UL-MAP Allocation Start Time definition
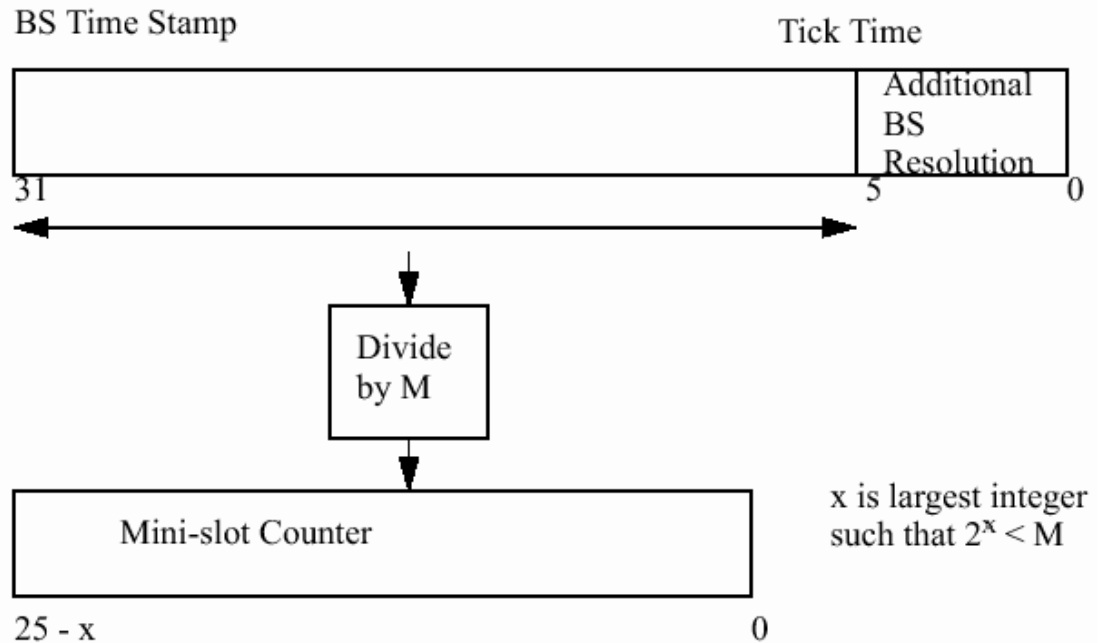
The Alloc Start Time is the effective start time of the uplink allocation defined by the UL-MAP or DL_MAP in units of mini-slots. The start time is relative to the time of BS initialization (PHY Type = 5). The UL-MAP/DL_MAP Allocation Start Time is given as an

1   offset to the Time Stamp defined in 3.2.4.3.3.1. Figure 145 illustrates the relation of the Time
2   Stamp maintained in the BS to the BS Mini-slot Counter. The base time unit is called a tick
3   and is of duration 1 us, independent of the symbol rate, and is counted using a 26 bit counter.
4   The additional BS resolution is of duration (1 tick/ 64) = 15.625 ns. The Mini-Slot count is
5   derived from the tick count by means of a divide by M operation. Note that the divisor M is
6   not necessarily a power of 2.
7   For arbitrary symbol rates, the main constraint in the definition of a mini slot, is that
8   the number of symbols per mini slot be an integer. For example given a symbol rate of R
9   Symbols/tick, and M ticks/mini-slot, the number of symbols per mini-slot N, is given by N =
10 MR. In this situation, M should be chosen such that N is an integer. In order to accommodate
11 a wide range of symbol rates, it is important not to constrain M to be a power of 2. Since the
12 additional BS resolution is independent of the symbol rate, the system can use an uniform
13 time reference for distance ranging.
14   In order to show that the time base is applicable to single carrier and OFDM symbol
15 rates, consider the following examples: (a) Single Carrier System - Given a symbol rate of
16 4.8 Msymbols/s (on a 6MHz channel), if the mini-slot duration is chosen to be 10 ticks (i.e.,
17 M = 10), then there are 48 symbols/mini-slot. Given 16QAM modulation this corresponds to
18 a granularity of 24 bytes/mini-slot (b) OFDM System - Given an OFDM symbol time of 50
19 us, the mini-slot duration is also chosen to be 50 ticks (i.e., M = 50). In this case there is only
20 a single symbol per mini-slot.

21   4.2.2.4.4.3.5.   UL-MAP Ack Time definition

22   The Ack Time is the latest time processed in uplink in units of mini-slots. This time is
23 used by the SS for collision detection purposes. The Ack Time is given relative to the BS
24 initialization time.
25

26   *4.2.2.4.4.4.   Mode B: Burst Downlink Transmission*

27 This mode of operation has been designed to support burst transmission in the downlink
28 channel. In particular, this mode is applicable for systems using adaptive modulation in an
29 FDD system or for systems using TDD, both of which require a burst capability in the
30 downlink channel. In order to simplify phase recovery and channel tracking, a fixed frame
31 time is used. At the beginning of every frame, a preamble is transmitted in order to allow for
32 phase recovery and equalization training. A description of the framing mechanism and the
33 structure of the frame is further described in 3.2.4.5.1.

34   4.2.2.4.4.4.1.   Mode B: Downlink Framing

35 In the burst mode, the uplink and downlink can be multiplexed in a TDD fashion as described
36 in 3.2.2.1.3, or in an FDD fashion as described in 3.2.2.1.2. Each method uses a frame with a
37 duration as specified in 3.2.5.1. Within this frame are a downlink subframe and an uplink
38 subframe. In the TDD case, the downlink subframe comes first, followed by the uplink
39 subframe. In the burst FDD case, uplink transmissions occur during the downlink frame. In
40 both cases, the downlink subframe is prefixed with information necessary for frame
41 synchronization.
42 The available bandwidth in both directions is defined with a granularity of one mini slot
43 (MS). The number of mini slots within each frame is independent of the symbol rate. The
44 frame size is selected in order to obtain an integral number of MS within each frame. For
45 example, with a 10 us MS duration, there are 500 MS within a 5-ms frame, independent of
46 the symbol rate.
47

1 The structure of the downlink subframe used by the BS to transmit to the SSs, using Mode B,
2 is shown in Figure 156. This burst structure defines the downlink physical channel. It starts
3 with a Frame Control Header, that is always transmitted using the most robust set of PHY
4 parameters. This frame header contains a preamble used by the PHY for synchronization and
5 equalization. It also contains control sections for both the PHY and the MAC (DL_MAP and
6 UL_MAP control messages) that is encoded with a fixed FEC scheme defined in this
7 standard in order to ensure interoperability. The Frame Control Header also may periodically
8 contain PHY Parameters as defined in the DCD and UCD.
9
10 There are two ways in which the downstream data may be organized for Mode B systems:
11
12   • Transmissions may be organized into different modulation and FEC groups, where the
13   modulation type and FEC parameters are defined through MAC layer messaging. The
14   PHY Control portion of the Frame Control Header contains a downlink map stating
15   the MSs at which the different modulation/FEC groups begin. Data should be
16   transmitted in robustness order. For modulations this means QPSK followed by 16-
17   QAM, followed by 64-QAM. If more than 1 FEC is defined (via DCD messages) for
18   a given modulation, the more robust FEC/modulation combination appears first. Each
19   SS receives and decodes the control information of the downstream and looks for
20   MAC headers indicating data for that SS.
21   • Alternatively, transmissions need not be ordered by robustness. The PHY control
22   portion contains a downlink map stating the MS (and modulation/ FEC) of each of the
23   TDMA sub-bursts. This allows an individual SS to decode a specific portion of the
24   downlink without the need to decode the whole DS burst. In this particular case, each
25   transmission associated with different burst types is required to start with a short
26   preamble for phase re-synchronization.
27
28 There is a Tx/Rx Transition Gap (TTG) separating the downlink subframe from the
29 uplink subframe in the case of TDD
30
31
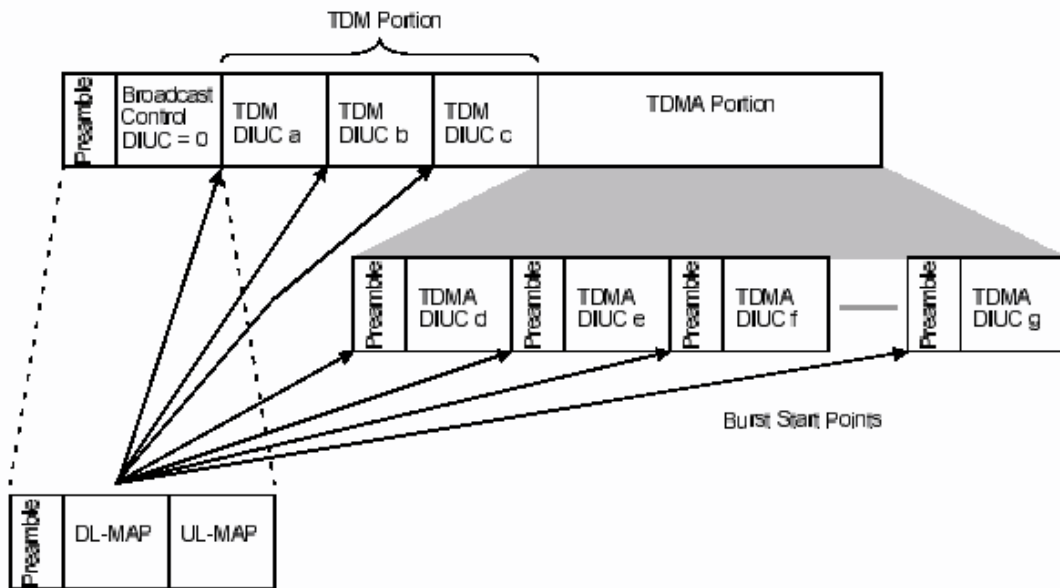
32
33   **Figure 19. Mode B Downlink Subframe Structure**

1   4.2.2.4.4.4.2.   Frame Control
2   The first portion of the downlink frame is used for control information destined for all
3   SS. This control information must not be encrypted. The information transmitted in this
4   section is always transmitted using the well known DL Burst Type with UIUC=0. This
5   control section must contain a DL-MAP message for the channel followed by one UL-MAP
6   message for each associated uplink channel. In addition it may contain DCD and UCD
7   messages following the last UL-MAP message. No other messages may be sent in the
8   PHY/MAC Control portion of the frame.

9   4.2.2.4.4.4.3.   Downlink Mode B: Required DCD parameters
10   The following parameters shall be included in the DCD message:
11 TBD
12

13   *4.2.2.4.4.4.3.1.   Downlink Mode B: DCD, Required burst*
14   *decriptor parameters*
15 Each Burst Descriptor in the DCD message shall include the following parameters:
16 TBD
17

18   4.2.2.4.4.4.4.   Downlink Mode B: Required UCD parameters
19 The following parameters shall be included in the UCD message:
20 TBD
21

22   4.2.2.4.4.4.5.   Downlink Mode B: DL-MAP elements
23 For PHY Type = {0, 1}, a number of information elements as defined as in Figure 27 follows
24 the Base Station ID field. The MAP information elements must be in time order. Note that
25 this is not necessarily IUC order or connection ID order.
26

27   4.2.2.4.4.4.6.   Allowable frame times
28 Table 3 indicates the various frame times that are allowed for the current downlink Mode B
29 physical layer. The actual frame time used by the downlink channel can be determined by the
30 periodicity of the frame start preambles
31

1   **Table 2. Allowable Frame Times**

Frame Length Code	Frame time (T_F)	Units
0x01	0.5	ms
0x02	1	ms
0x03	1.5	ms
0x04	2.0	ms
0x05	2.5	ms
0x06	3.0	ms
0x07	3.5	ms
0x08	4.0	ms
0x09	4.5	ms
0x0A	5.0	ms

2
3
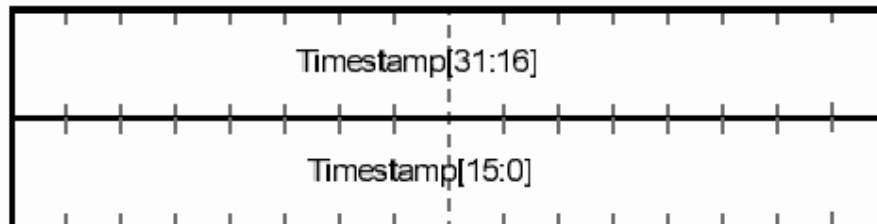4

5   4.2.2.4.4.4.7.   Mode B: DL-MAP PHY Syncronization Field
6   definition

7

8
9   **Figure 20. PHY Synchronization Field (PHY Type = {0,1})**

10
11   The format of the PHY Synchronization field is given in Figure 158. The Uplink Timestamp
12   jitter must be less than 500 ns peak-to-peak at the output of the Downlink Transmission
13   Convergence Sublayer. This jitter is relative to an ideal Downlink Transmission Convergence
14   Sublayer that transfers the TC packet data to the Downlink Physical Media Dependent
15   Sublayer with a perfectly continuous and smooth clock at symbol rate. Downlink Physical
16   Media Dependent Sublayer processing shall not be considered in timestamp generation and
17   transfer to the Downlink Physical Media Dependent Sub-layer. Thus, any two timestamps N1
18   and N2 (N2 > N1) which were transferred to the Downlink Physical Media Dependent
19   Sublayer at times T1 and T2 respectively must satisfy the following relationship:
20   (N2 – N1)/(4 x Symbol Rate) – (T2 – T1) < 500 ns
21
22   The jitter includes inaccuracy in timestamp value and the jitter in all clocks. The 500ns
23   allocated for jitter at the Downlink Transmission Convergence Sublayer output must be
24   reduced by any jitter that is introduced by the Downlink Physical Media Dependent Sublayer.

1   4.2.2.4.4.4.8.   UL-MAP Allocation Start Time definition
2   The Alloc Start Time is the effective start time of the uplink allocation defined by the UL-
3   MAP or DL_MAP in units of mini-slots. The start time is relative to the time of BS
4   initialization (PHY Type = 5). The UL-MAP/DL_MAP Allocation Start Time is given as an
5   offset to the Time Stamp defined in 3.2.4.3.3.1. Figure 145 illustrates the relation of the Time
6   Stamp maintained in the BS to the BS Mini-slot Counter. The base time unit is called a tick
7   and is of duration 1 us, independent of the symbol rate, and is counted using a 26 bit counter.
8   The additional BS resolution is of duration (1 tick/ 64) = 15.625 ns. The Mini-Slot count is
9   derived from the tick count by means of a divide by M operation. Note that the divisor M is
10 not necessarily a power of 2.
11 For arbitrary symbol rates, the main constraint in the definition of a mini-slot, is that the
12 number of symbols per mini-slot be an integer. For example given a symbol rate of R
13 Symbols/tick, and M ticks/mini-slot, the number of symbols per mini-slot N, is given by N =
14 MR. In this situation, M should be chosen such that N is an integer. In order to accommodate
15 a wide range of symbol rates, it is important not to constrain M to be a power of 2. Since the
16 additional BS resolution is independent of the symbol rate, the system can use an uniform
17 time reference for distance ranging.
18 In order to show that the time base is applicable to single carrier and OFDM symbol rates,
19 consider the following examples: (a) Single Carrier System - Given a symbol rate of 4.8
20 Msymbols/s (on a 6MHz channel), if the mini-slot duration is chosen to be 10 ticks (i.e., M =
21 10), then there are 48 symbols/mini-slot. Given 16QAM modulation this corresponds to a
22 granularity of 24 bytes/mini-slot (b) OFDM System - Given an OFDM symbol time of 50 us,
23 the mini-slot duration is also chosen to be 50 ticks (i.e., M = 50). In this case there is only a
24 single symbol per mini-slot.
25

26   4.2.2.4.4.4.9.   UL-MAP Ack Time definition
27 The Ack Time is the latest time processed in uplink in units of mini-slots. This time is used
28 by the SS for collision detection purposes. The Ack Time is given relative to the BS
29 initialization time.
30

5. MAC-PHY Interface for OFDM PHY

32
33   [Editorial Group: Subir, Vladimir, Itzik, Huan Chun, Subbu, Demos]
34

5.1. OFDM PHY Burst Definition and MAP Messages

36 <<< Contribution "OFDMA\OFDM Considerations in TG3 and TG4" by Itzik Kitroser
37 Yossi Segal, Zion Hadad >>>
38
5.1.1. Introduction
40   This section <<< contribution >>> describes the MAC-PHY considerations and
41 MAC-PHY information exchange needed for support OFDMA/OFDM based PHY layer.
42
43   The OFDMA access scheme presented in [1] defines an access scheme of a two
44 dimensional grid that combines time and frequency division access technique.

<<< The 802.16.1 MAC layer needs to be enhanced\updated to support OFDMA\OFDM access scheme while saving the main working principles of the MAC layer. >>>

In a MAC protocol that supports OFDMA PHY layer (like one presented in [1]), the concept of a sub-channel should be supported, as presented in [4], mini-slot duration should last for the time duration of a full OFDM symbol and should be used as a time symbol reference. In addition, for each time symbol reference, a sub-channel reference should be provided for an OFDMA access resolution.

Each of the Uplink and Downlink symbols are built from subcarriers, which are divided statically into sub-channels that are groups of 53 (48 useful) sub-carriers. A sub-channel does not necessarily contain consequent subcarriers.

The OFDMA defines a slot as a pair {N,m} that represents a combination of an OFDM time symbol (N) and number of a sub-channel (m).
In each cell a single FFT size is used

5.1.2. Basic Parameters

This section defines OFDMA related basic terminology and relevant parameters.

5.1.2.1.   Region and PHY Burst

For both Uplink and Downlink transmissions, several consequent sub-channels may be aggregated for several consequent symbol duration intervals (OFDM Symbols). Such an aggregation is figured by a rectangle Region at the Subcarrier(frequency)-Time domain.

Figure 21 illustrates an allocation pattern instance of a Region
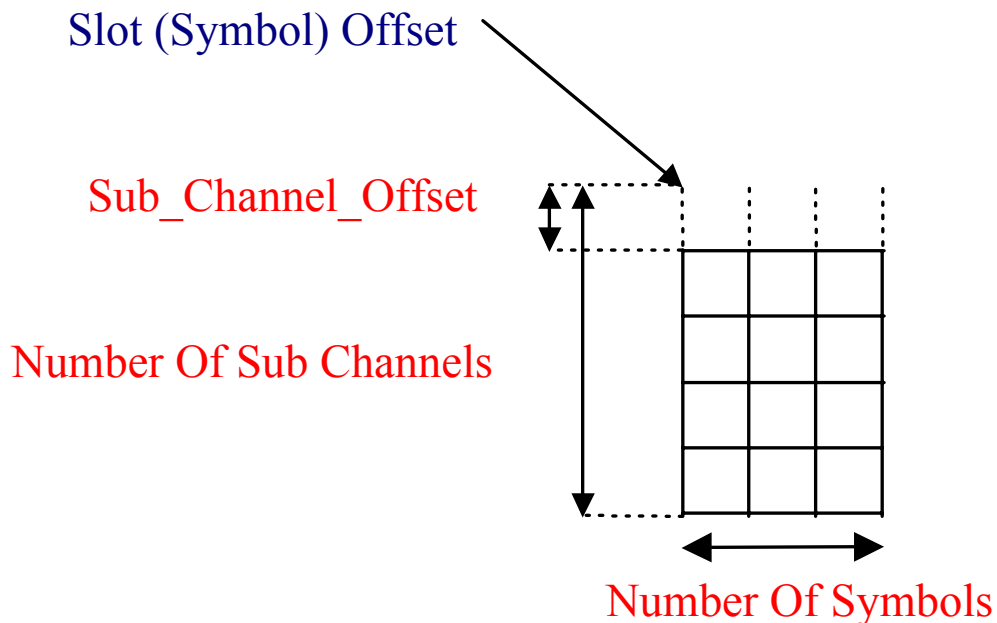
Example of allocated rectangle

Slot (Symbol) Offset

Sub_Channel_Offset

Number Of Sub Channels

Number Of Symbols

1
2   **Figure 21. Example of a Two dimensional Pattern**
3
4   A Region can be assigned in the UL to a specific SS (or a group of subscribers) or can be
5   transmitted in the DL by the BS as a transmission to a (group of) SS.
6
7   The SS's transmission at the Region is called UL PHY Burst.
8   The BS's transmission at the Region is called DL PHY Burst.
9

10   **5.1.2.2.   UL Transmission**
11
12   The PHY Burst properties will be figured:
13   • In the MAC-PHY interface primitives
14   • In UCD message within Burst Profile TLV encodings
15   • In UL-MAP message, implicitly identified by UIUC.
16   The BS learns each of SS's specific working parameters (during the SS's UL maintenance
17   Ranging and data transmission) and assigned internally UL PHY Burst profile for each SS.
18
19   <<<<<<<<<<<<<<
20
21   The following paragraph is clearly a part of OFDM PHY
22
23   The parameters the BS uses are:
24   • The CIR <<< SIR? >>> of the channel (which can be achieved when using the
25   CDMA synchronization approach [6])
26   • The C/n of the user (by measurement from a user message)
27

1   The basic suggested (partial) profiles for the uplink transmission can be summarized in the
2   following table:
3

Profile	0	1	2	3	
C/n dB	3-6	6-9	9-12	12-17	
Modulation+ code Rate	QPSK 1/2	QPSK 3/4	QAM16 1/2	QAM16 3/4	

4
5   The defined values are used for a reference, bad CIR can cause the BS to chose lower profile
6   or allocation of fewer Sub-Channels enables the BS to choose higher profile.
7   >>>>>>>>>>>>>>>>>>>>>>>
8
9   The UL MAP IEs shall have the UIUC that represent the relevant profile that determined by
10 the BS.
11
12 Figure 22 describes the logical structure of UL PHY Burst.
13
14 <<< **Note**: for the next figures, the size (number of symbols) of the preamble is still under
15 discussion of the PHY group. >>>

16
17
18   **Figure 22. UL PHY Burst example**
19
20
21 Figure 23 describes two different subscribers with different PHY Burst structures and
22 profiles.
23

1

Figure 23. UL Burst Definition Example #1

3 Figure 24 describes two different subscribers with similar PHY Burst structure and with
4 different profiles
5

6

7   **Figure 24. UL Burst Definition Example #2**

8

9   ### 5.1.2.3. DL Transmissions

10   The DL PHY Burst properties will be figured:
11   •   In the MAC-PHY interface primitives
12   •   In DCD message within Burst Profile TLV encodings
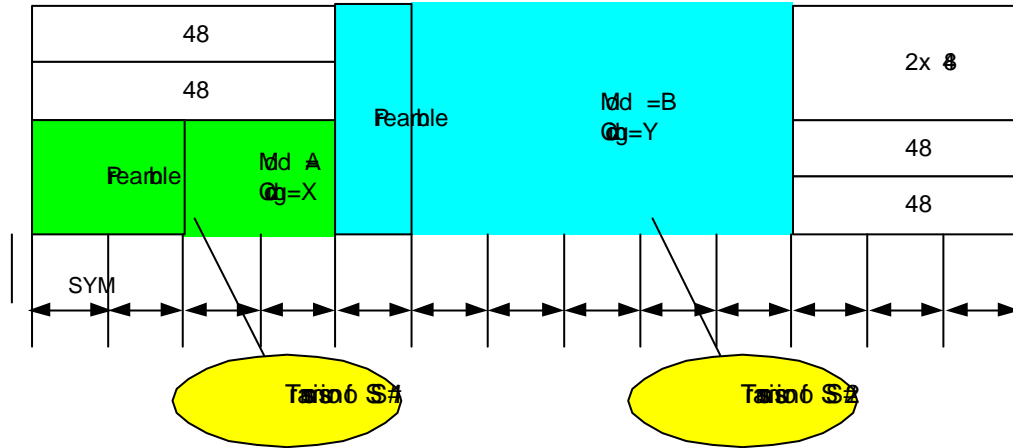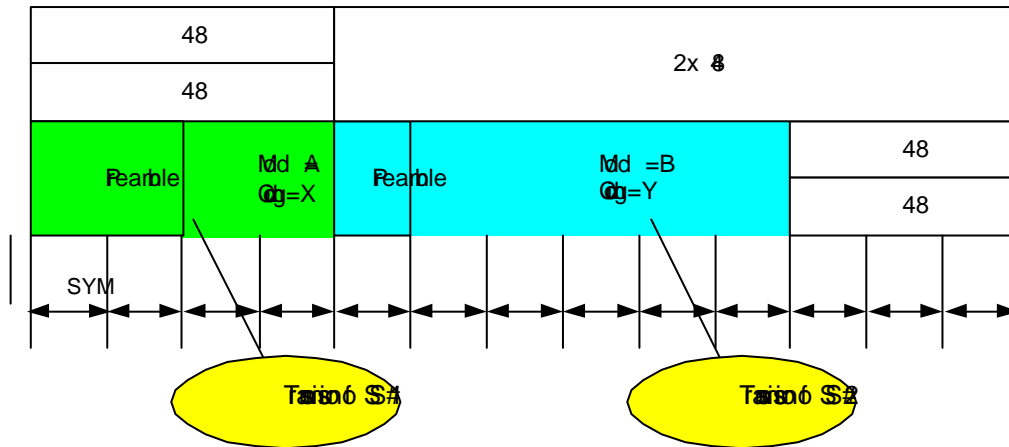13   •   In DL-MAP message, implicitly identified by DIUC.
14   •   In the RNG-RSP or DBTC-RSP messages, implicitly identified by the Downlink Burst
15   Type.
16
17   The set of DL PHY Burst parameters is specified in <Reference to OFDM PHY
18   relevant section> and includes at least:
19   •   Modulation type
20   •   FEC type
21   •   Tx Power
22

46

1   The forward adaptive profiles are relevant in the Bursty working modes (FDD-B and
2 TDD).
3
4   The SS requests from the BS a specific DL PHY Burst type (using the DBTC-REQ or
5 RNG-REQ messages), the BS will acknowledge the user with a downstream working mode
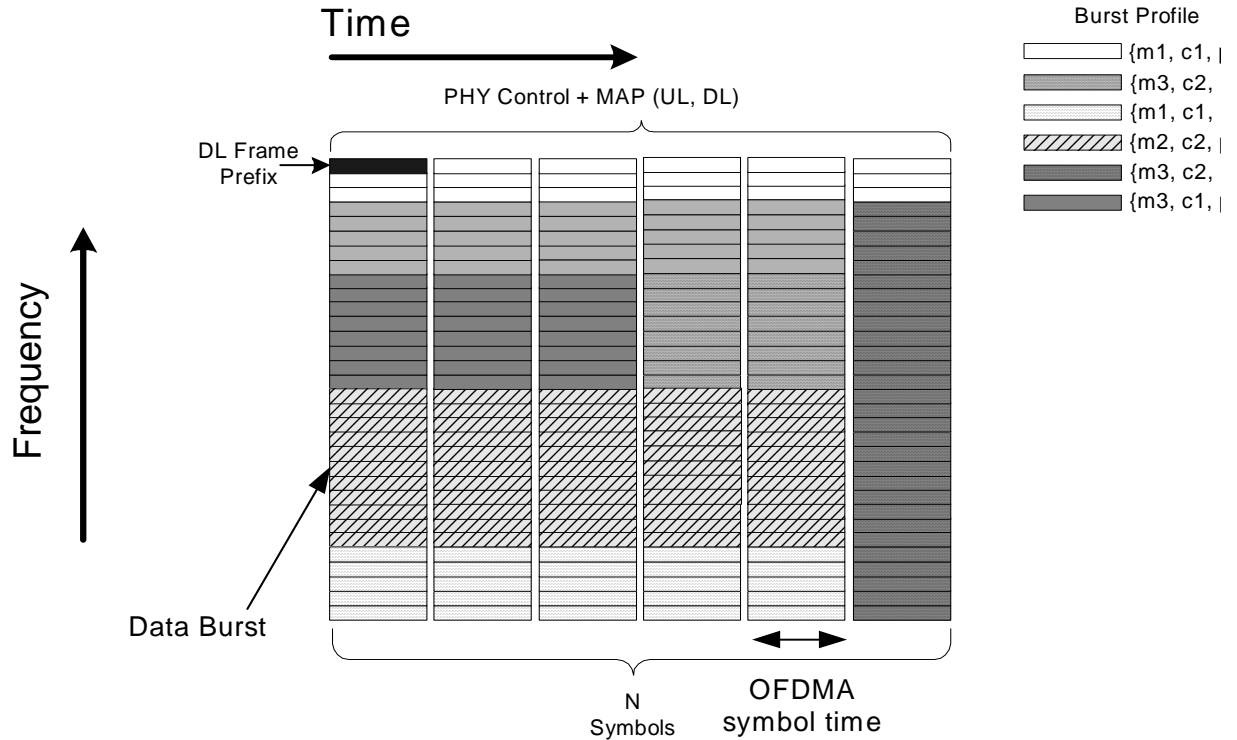6 (using the DBTC-RSP or RNG-RSP messages).
7
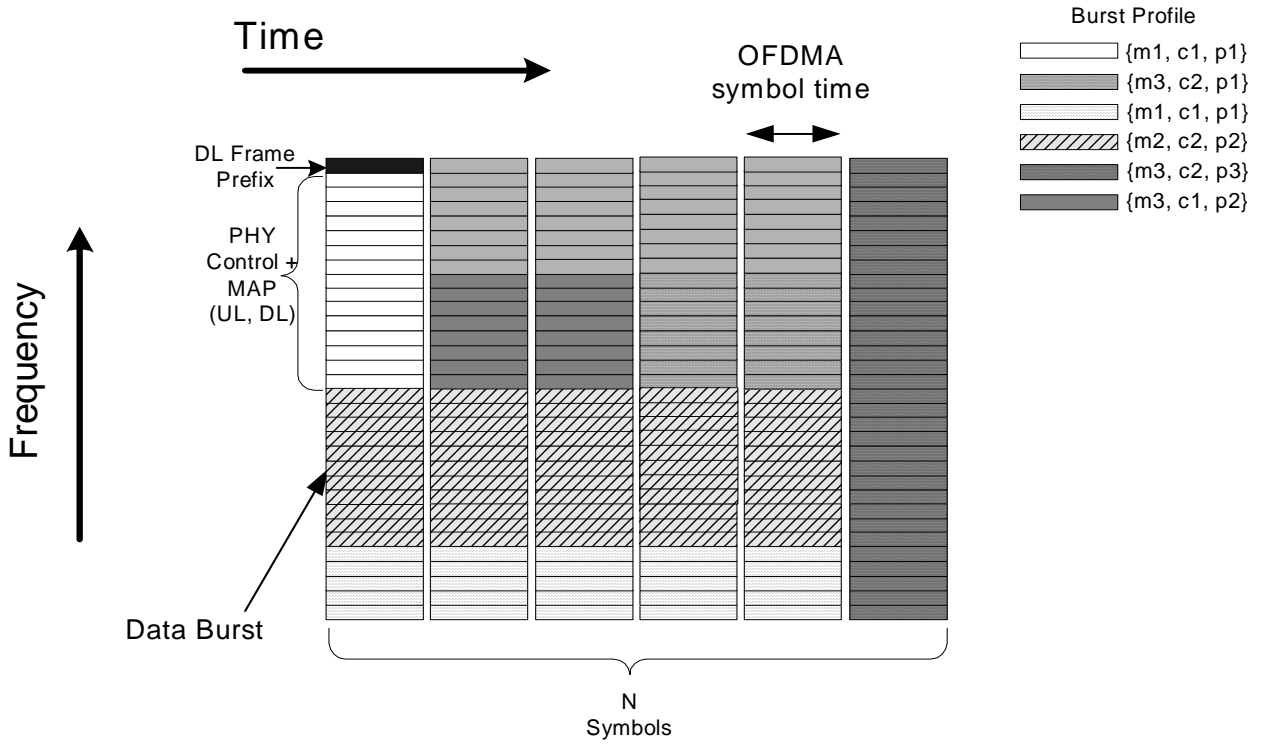
8
9

10   **Figure 25. DL Period example #1**

11

Figure 26. DL Period example #2

Figure 25 and Figure 26 describe two scenarios of DL OFDMA allocation with two options of sending DL MAP.

In the OFDM working modes (small FFT sizes), TDM\TDMA working model is used. This means that the unit of allocation is a full OFDM symbol. In those modes, the frame control information (DL/UL MAP) shall be sent on the first Symbol(s).

In the high FFT sizes modes, OFDMA working model is used. This means that the unit of allocation is a Burst (which is a combination of a sub-channels and time symbols). In those modes, there are two possibilities to transmit the DL\UL MAP:

- To take advantage of the option of forward power control, and robust transmission of frame control information, the transmission of the DL\UL MAP can be done by using 1-2 sub-channels for the duration of the whole frame while power boosting the used carriers (see Figure 6)
- To use the basic method of the OFDM case, but with size optimization. This means that the DL\UL MAP shall be transmitted at the beginning of the frame, using all or part of the sub-channels.

The frame control information should be transmitted in a deterministic pre-defined (and robust) configuration, therefore indication about the frame control information should be defined.

To be able to support a generic formation of frame control message in the downlink in the context of OFDMA\OFDM PHY modes, we propose the notion of *DL Frame prefix*.

1   **DL Frame Prefix** is one symbol long; it is transmitted at the well-known
2   modulation/coding and occupies the well-known set of sub-carriers, e.g. the first N x 48 (for
3   the FFT-64 always N = 1, for FFT-256 OFDM always N = 4 or For FFT-2048 OFDMA
4   always N=1 etc.).
5   It contains the information on the modulation/coding and formation of the DL frame
6   control information (DL\UL MAP messages) relevant to the next frame or to the same frame.
7   Figure 1 describes the structure of DL Frame Prefix:
8

0   23

| Rate_ID (4) | Symbols (6) | Sub_Channels (6) | HCS(8) |
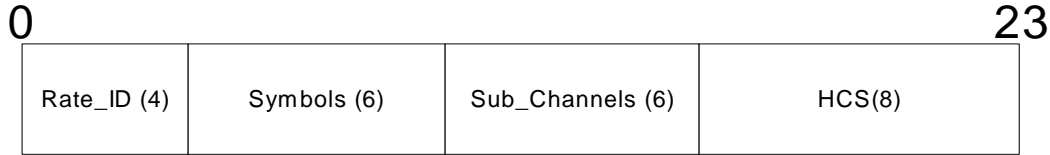
9

10   **Figure 1. DL Frame Prefix Structure**

11   **Rate_ID:** Enumerated field that describes the transmission parameters of the DL\UL
12   MAP messages.
13   **Symbols:** Number of time symbols dedicated to the DL\UL MAP message.
14   **Sub_Channels:** Number of sub-channels dedicated to the DL\UL MAP message.
15   **HCS:** An 8-bit Header Check Sequence used to detect errors in the DL Frame Prefix.
16   The generator polynomial is $g(D)= D^8 + D^2 + D + 1$
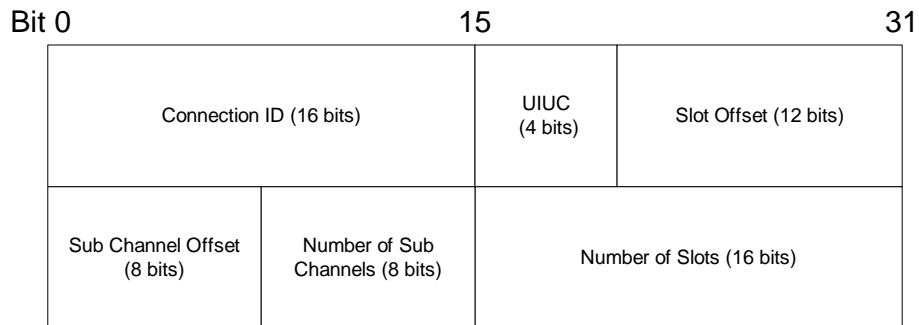17
18   DL Frame Prefix can contain also MAP message(s) (for FFT-512 for example, the full
19   first symbol will contain the DL Frame Prefix and beginning of the DL\UL MAP messages)
20   and the "MAP" PHY burst may contain also the data.
21   For the lowest modulation it is exactly 3 bytes.
22
23   The Combination of the fields *Symbols* and *Sub_Channels* defines the structure of the
24   MAP message and position (relative to the top left entry of the DL frame). In the small FFT
25   cases (OFDM modes) *Sub_Channels* field will always indicate full OFDM symbol.
26

27   **5.1.2.4.   <<< Proposed >>> Modifications in the MAP Message**
28   **<<< to the 802.16.1 MAC >>>**

29   In order to support a two dimensional allocation scheme, a pattern MAP IE should be
30   defined using the basic structure presented in Figure 2:
31

Bit 0   15   31

| Connection ID (16 bits) | | UIUC (4 bits) | Slot Offset (12 bits) |
| Sub Channel Offset (8 bits) | Number of Sub Channels (8 bits) | Number of Slots (16 bits) | |

32

Figure 2. Two dimensional pattern MAP IE

The pattern MAP IE shall define a two-dimensional allocation pattern by using the following parameters:

Slot Offset: Provides an OFDM symbol time reference.

Sub Channel Offset: Provides Initial Sub Channel offset from the start of the OFDM symbol

Number of Sub Channels: Provides the "width" of the allocation pattern, i.e. the number of consecutive sub-channels used for this allocation pattern.

Number of Symbols: Provides the number of time Symbols to be used for the allocation pattern.

5.1.2.5.   SS Rx HW Capabilities Parameters

The following Capability should be added to the SS's Capabilities TLVs (chapter 11.4.5):

DL_PHY Bursts: describes the ability of SS to Rx simultaneously N PHY Bursts.

It is on BS (Scheduler's) responsibility to avoid situation an SS is assigned at the DL more than N bursts.

5.1.2.6.   DIUC\UIUC size

The DIUC and the UIUC sizes should be increased to be able to facilitate more Burst profiles. <<< We support the proposal to increase>>> The size of DIUC and UIUC should be increased to 5 bits in the following messages:

Take one bit from Slot_Offset\PS_Start in the UL_MAP\DL_MAP.

Take one bit from reserved bits in: DBTC-REQ, DBTC-RSP, DCD and UCD messages.

5.1.2.7.   References

[1] Y.Segal, Z.Hadad, I.Kitroser. Initial OFDMA Proposal for the 802.16.3 PHY Layer. January 2001.

[2] IEEE 802.16.1/D2. Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems. January 2001.

[3] IEEE 802.16.3-00/02r4. Functional Requirements for the 802.16.3 Interoperability Standard. September 2000.

[4] IEEE 802.16.4c-01/02. Modifications to the TG1 MAC for use in TG4 Systems. January 2001

[5] DVB-RCT v.116 standard approved draft, April 2001.

[6] IEEE 802.16.3c-01/54. OFDM based Ranging Enhancement for the TG3 and TG4. April 2001

5.2.   Bandwidth Request Using CDMA Codes in OFDMA(OFDM) Base PHY <<<for TG3 & TG4>>>

[Itzik Kitroser, Yossi Segal, Zion Hadad]

5.2.1. Introduction

<<< This contribution is a complementary contribution to [6] and describes an option for fast bandwidth reservation mechanism.

The functional requirements [3] and several contributions about the expected nature of the traffic of TG3 and TG4 context, describe an IP centric environment, with dynamic and bursty traffic that requires option of fast bandwidth reservation mechanisms.
The two main access techniques in centralized systems that are most commonly used are: Contention Access (also Random Access) and Polling.
The Polling methods are best for systems with short propagation delays, small number of subscribers and small overhead for polling messages but usually are less efficient with bursty traffic.
The Contention methods usually well fit for bursty scenarios, increase the statistical multiplexing gain, supply short delay for the bursty packets but reduces the channel efficiency with high risk of collisions and potentially high jitter.>>>
The <<<proposed>>> described mechanism takes advantage of the OFDMA based PHY <<<as proposed in [1]>>> to provide a CDMA code based bandwidth reservation tool. <<< This mechanism has all the advantages of Contention scheme for bursty traffic but with much higher success percentage (90% Vs 10% for 20 simultaneous requests with window size of 10 slots, see Simulation Results) and better channel utilization >>>.

5.2.2. Description of the <<< proposed>>> Bandwidth Request mechanism
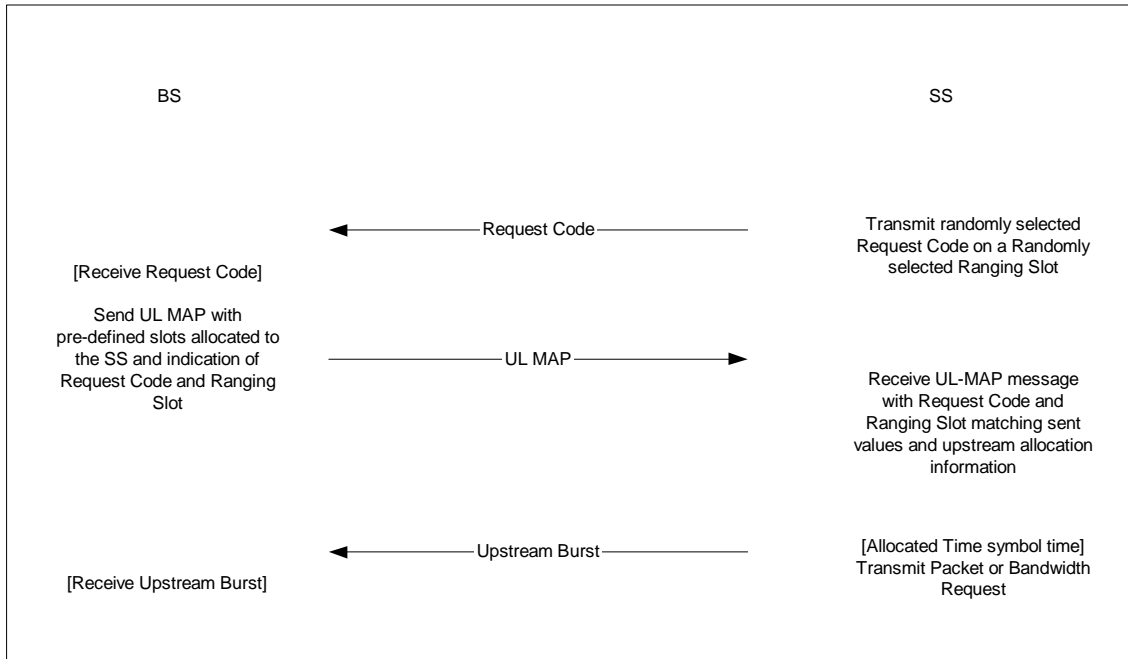
<<< As described in [6] and in [1],>>> several PHY configurations <<< are proposed, especially,>> exist.

The 1K and 2K modes define the concept of sub-channels as a subset of the frequencies transmitted in one OFDM symbol, those two modes define a unique ranging slots that co-exists with data slots for each OFDM symbol.

The SS may use the ranging slots to send CDMA codes from a three domains of codes: Initial Ranging, Maintenance Ranging and bandwidth requests. The CDMA codes used for bandwidth request are defined as Request Codes.

The <<< proposed >>> Bandwidth Request mechanism defines usage of the Request Code by the SS to request fast bandwidth allocation on a bursty basis.

Figure 27 describes the messages sequence for CDMA bandwidth request:

```
BS                                                                                    SS


                                    ───────Request Code───────                Transmit randomly selected
                            ◄───────────────────────────────                 Request Code on a Randomly
                                                                                  selected Ranging Slot
[Receive Request Code]

Send UL MAP with
pre-defined slots allocated to
the SS and indication of          ───────UL MAP───────►                      Receive UL-MAP message
Request Code and Ranging                                                       with Request Code and
Slot                                                                         Ranging Slot matching sent
                                                                             values and upstream allocation
                                                                                     information


                                  ───────Upstream Burst───────               [Allocated Time symbol time]
                            ◄───────────────────────────────                 Transmit Packet or Bandwidth
[Receive Upstream Burst]                                                               Request
```
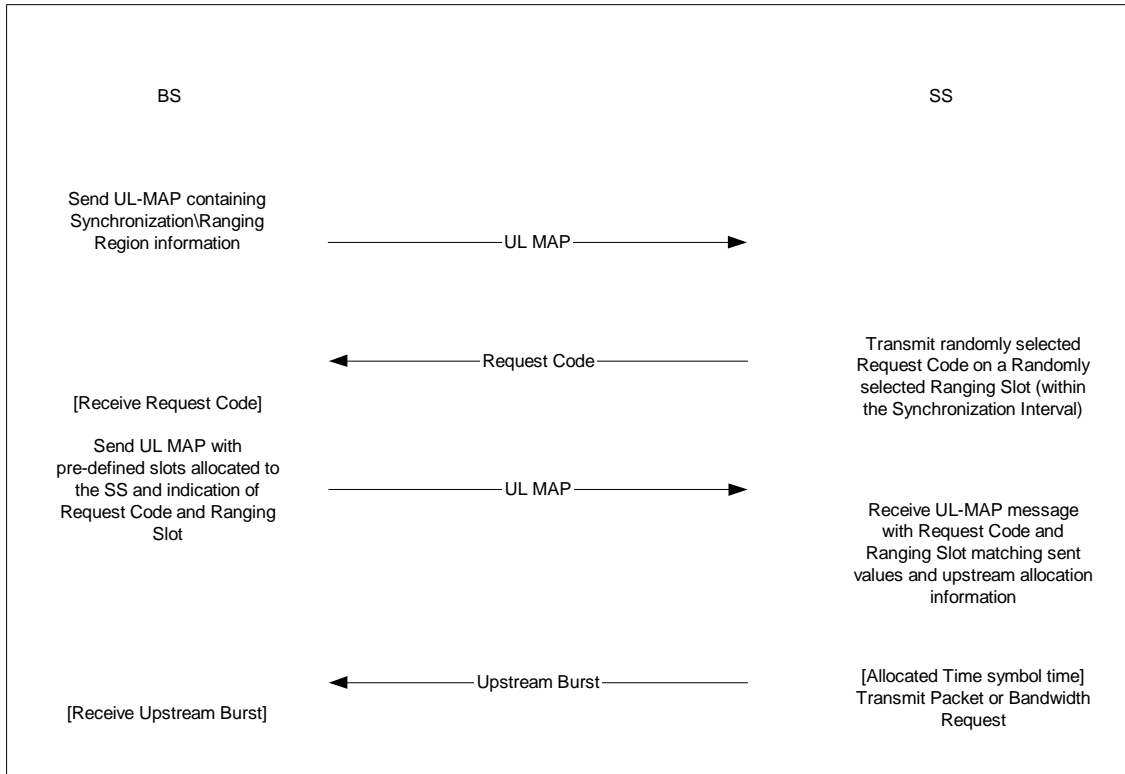
Figure 27. Bandwidth Request in high FFT modes

The SS, upon a need to request for transmission slots, shall access the air interface without the need to be polled and with reduced collision risk by transmitting a Request Code. Several request codes sent by several SS can be transmitted simultaneously without collision <<< actually there may be a collision but the data is believed to survive due to separation by CDMA codes >>> (with limitation on the number of parallel codes). The BS, when demodulating the ranging slots, and when receiving a request code, shall allocate a pre-defined (and configurable) number of bytes to the SS, the addressing of the allocation shall be done by attaching the indication of the Ranging Slot and Request Code.

The SS will use the unique allocation either to send packet or bandwidth request.

In the case of small FFT size (Access Scheme 1 in [6]), the UL MAP message shall have indication of the synchronization interval size and time (full OFDMA symbols carrying only CDMA codes with one or two sub-channels), the SS shall send the request codes in this interval.

Figure 28 describes the messages sequence for this case:

Figure 28. Bandwidth Request in small FFT modes

<<< The advantage of the proposed mechanism is the fairly safe request indication by the SS and transmitting bandwidth request in a unique allocated slot, or the option for fast requests for small allocation that can be used to send bursty based packets (like TCP Acks) in a highly dense cells. >>>

5.2.3. Request Code Grant Interval

When using the Request Code, the BS allocates a pre-defined number of slots to the sending SS whose Request code and Ranging slots are provided in the upstream MAP IE.

The value of such allocation is defined by the BS and can be optimizes according to the traffic behavior.

The minimum value of the grant interval should be big enough to accommodate at least upstream bandwidth request message.

The Unsolicited Grant Size parameter (section 11.4.12.19 page 356) can be used for this purpose.

5.2.4. New UIUC Addition

New UIUC value should be added in order to identify allocation as reaction to Request Code.

The following UIUC value should be added to section 6.2.2.2.4 Table 5 page 67:

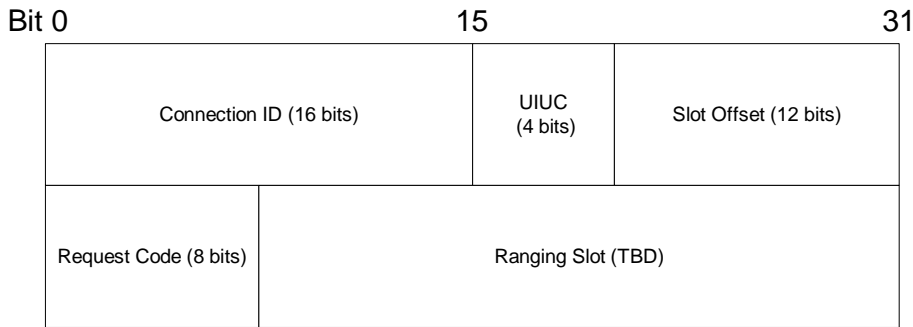1   **Table 3. Request Code UIUC value**

IE Name	UIUC	Connection ID	Mini-slot Offset
Request Code Allocation	12	Broadcast	TBD – According to OFDMA/OFDM allocation schemes

2

3   In this proposal, we adopt the Upstream MAP IE structure presented in [4] to provide
4   enhancements with full backward compatibility.
5

6   Figure 29 shows the proposed Upstream MAP IE for the proposed new UIUC (as defined in
7   Table 3)
8
9

Bit 0   15   31

| Connection ID (16 bits) | UIUC (4 bits) | Slot Offset (12 bits) |
| Request Code (8 bits) | Ranging Slot (TBD) | |

10
11   **Figure 29. Proposed Upstream MAP IE structure for Request Code UIUC**

12

13   **Ranging Slot**: A required parameter if the SS used CDMA Ranging Slot for bandwidth
14   request, in this case the UL-MAP IE element will use broadcast CID, and the combination of
15   Ranging Slot and Request Code shall be used to address the requesting SS.
16   The Ranging Slot value shall indicate a combination of OFDMA time symbol and Sub-
17   Channel number
18

19   **Request Code**: A required parameter if the SS used CDMA Request Code for bandwidth
20   request, in this case the UL-MAP IE element will use broadcast CID, and the combination of
21   Ranging Slot and Request Code shall be used to address the requesting SS.

22

23   <<< <<<<<<<<<<
24   The following section, though important, is not a normative text and thus should be deleted or
25   removed to the informative part

26

27   # Simulation Results
28   The following section describes results of a simulation done to compare the proposed
29   technique with classical contention based bandwidth request.
30   The simulation was done for period of 10 OFDMA symbols with one sub-channel allocated
31   for Request Codes.
32   Each user randomly selects (with uniform distribution) time symbol and Request code, the
33   number of available codes was 16, with cross correlation factor of 8 – meaning that if more
34   then 8 users selected the same opportunity (bucket) then all of them are lost, also if two or
35   more users selected the same code, they are considered as failed.

1   The conditions for the normal contention access assume that each request requires exactly
2   one slot (if preamble should be required for each request, then the number of the transmission
3   opportunities should have cut by half, and the results for the contention case would be worst).
4   The simulation deals with one attempt (with window size of 10 slots), retransmission will
5   improve both of the scenarios, better for the CDMA case.
6   Figure 30 describes the simulation results:
7
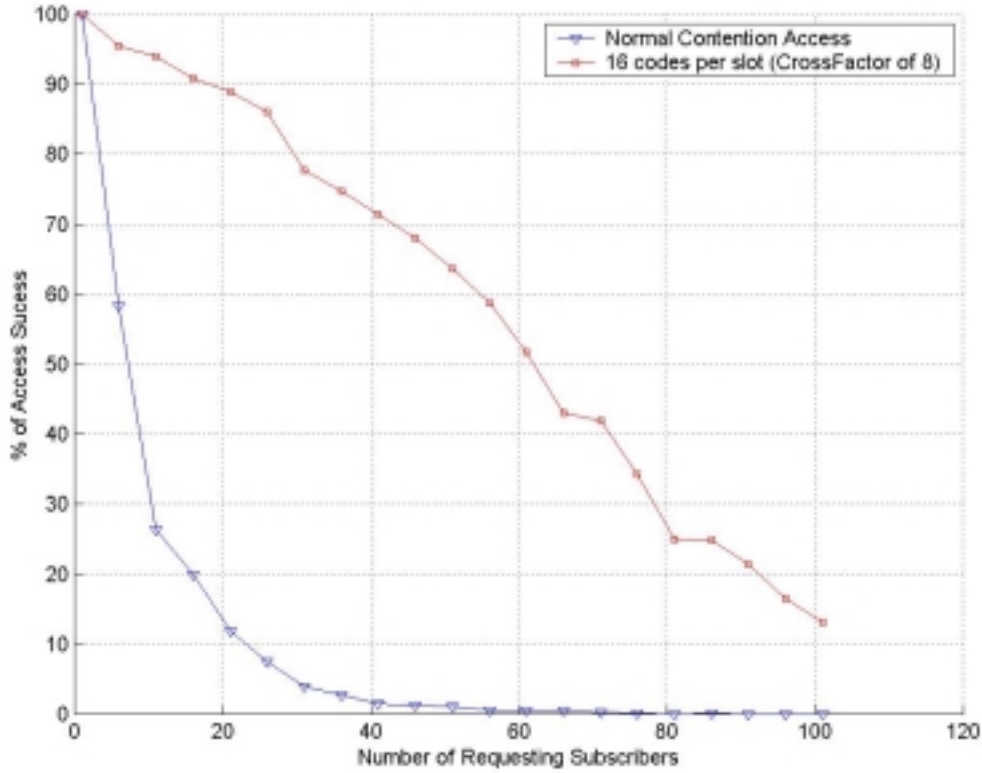
8

9   **Figure 30.CDMA Request Vs. Contention Request for 10 time symbols**

10

11   The X-axis defines the number of users sending requests, the Y-axis defines the
12   access success in percentage.
13   As can be seen, for 10 users the contention access results with ~35% of success while
14   the CDMA scheme results with ~95% of success. For 50 users the contention access drops
15   down to only 1% of success while the CDMA access results with ~63% of success. The
16   results clearly show that for one access attempt, the CDMA scheme is much better than the
17   normal Contention scheme, adding backoff exponential retry algorithm will improve the
18   results for both cases but will introduce side effects such as latency and jitter.
19   The results show that for dense cells with more then 20 simultaneous contention
20   requests, in normal Random Access window of 10 slots, the probability to fail at first request
21   is about 90% while in the CDMA access with same conditions, the probability to fail is about
22   10%.
23
24   >>>
25
26

5.2.5. References

[1] Y.Segal, Z.Hadad, I.Kitroser. Initial OFDMA Proposal for the 802.16.3 PHY Layer. January 2001.

[2] IEEE 802.16.1/D2. Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems. January 2001.

[3] IEEE 802.16.3-00/02r4. Functional Requirements for the 802.16.3 Interoperability Standard. September 2000.

[4] IEEE 802.16.4c-01/02. Modifications to the TG1 MAC for use in TG4 Systems. January 2001

[5] DVB-RCT v.116 standard approved draft, April 2001.

[6] I.Kitroser, Z.Hadad and Y.Segal. OFDMA/OFDM based Ranging Enhancement for TG3 & TG4. April 2001.

[7] 802163p-01_27.pdf. Traffic Models for Broadband Wireless Access Systems. January 2001

5.3.   Ranging Enhancement

<<< Submission "OFDM/OFDMA based Ranging Enhancement for TG3 & TG4" by Itzik Kitroser, Yossi Segal, Zion Hadad >>>

5.3.1. Introduction

<<< This document describes proposed enhancements to the TG1 MAC's ranging mechanism for the TG3 and TG4 MAC. >>>
The goal of the enhancements is to use the advantages of the OFDM/OFDMA based PHY to facilitate simpler and safer synchronization of the user with the base station.

The physical part of the proposed enhancements are described in the PHY proposals [1] <<< submitted several times to the TG3 & TG4 groups.

 The proposed mechanism is fully integrated in the approved (since April 2001) DVB-RCT standard (that is based on an OFDMA return channel) as a mature and well-defined improvement technique of the classical Ranging algorithms.>>>

The contribution describes full description of the Ranging enhancements, proposed changes to the TG1 MAC to accommodate the proposed mechanism.

5.3.2. Background

The OFDMA (OFDM) upstream physical layer access method is based on the use of a combination of time and frequency division access technique.

The <<< proposed >>> described synchronization technique is based on several sub-carriers that are spread on the entire bandwidth and are collected in CDMA form. This allows several users to perform synchronization simultaneously <<<; those special carriers within an OFDMA (OFDM) <<< time symbol are allocated for synchronization purpose and shall be referred as Ranging slots. – the definition is done below>>>

1   The basic allocation unit (e.g. slot) is a combination of a time symbol and a sub-channel. The
2   <<< current >>> OFDMA (OFDM) based PHY <<< proposals >>> define several working
3   modes, those modes define two upstream access schemes:
4   1. Each OFDMA (OFDM) symbol will carry either data or ranging slots
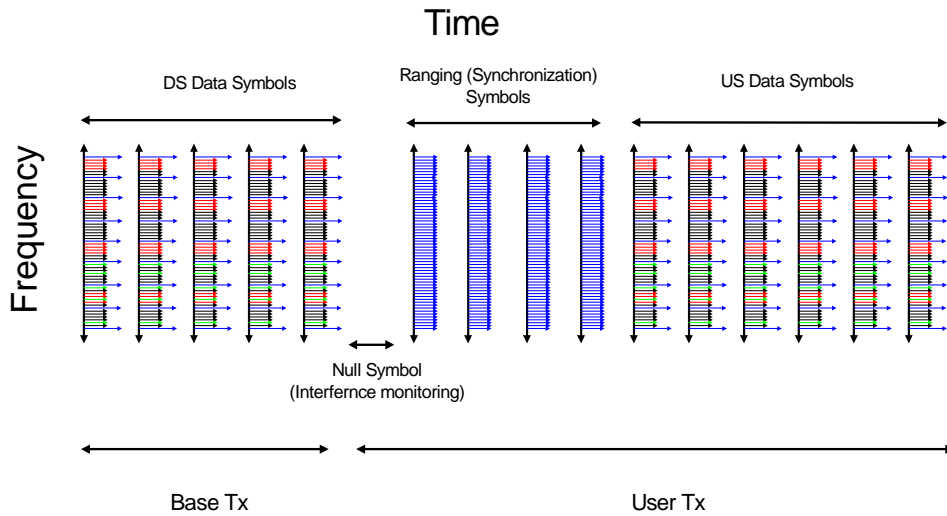5   2. Each OFDMA (OFDM) symbol will carry both data and ranging slots
6
7   Figure 31 and Figure 32 illustrate the concept of access scheme 1
8
9
10
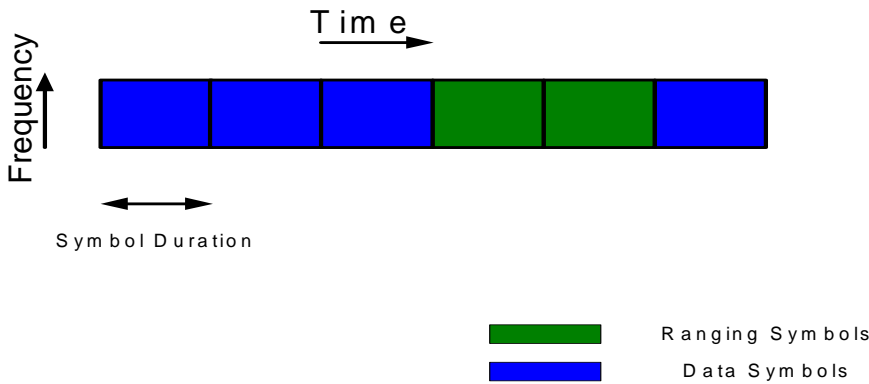
11
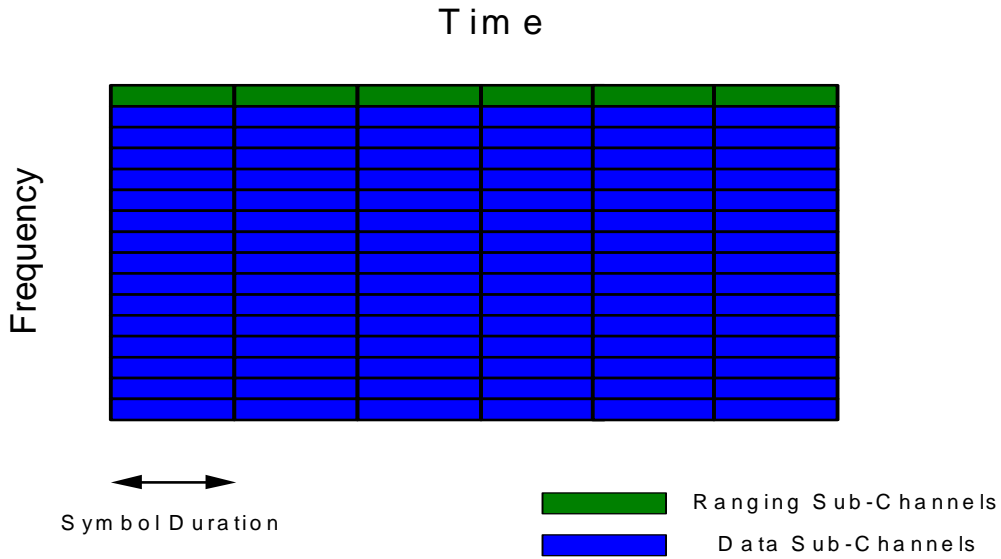12   **Figure 31. OFDMA Symbols carrying either Ranging or Data slots – General Concept**

13
14

15
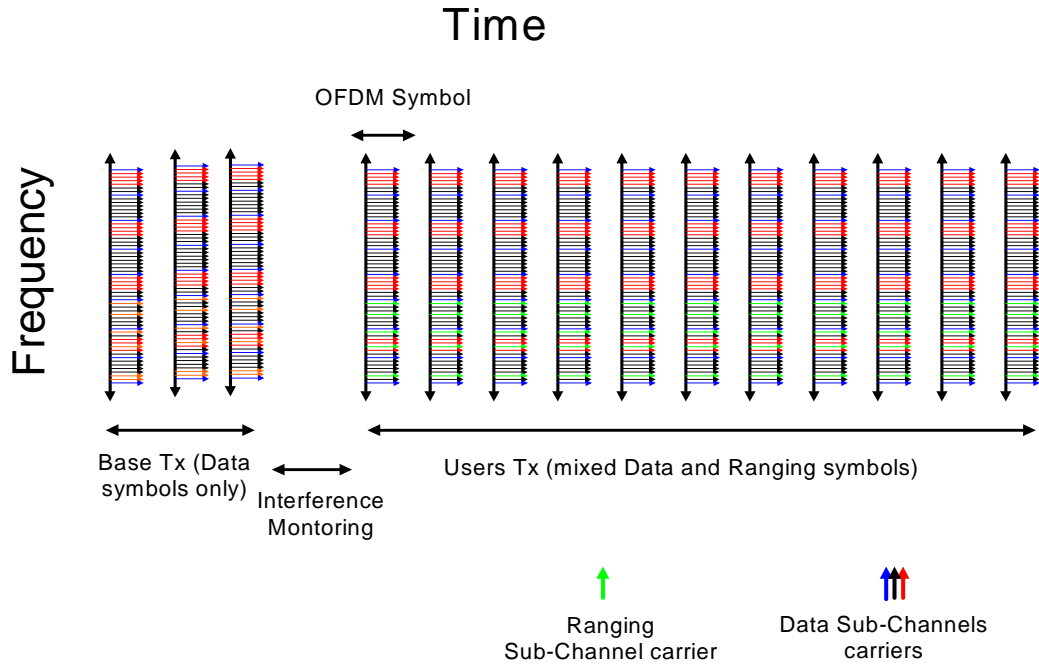16   **Figure 32.OFDMA Symbols carrying either Ranging or Data slots – In TDD mode**

17
18
19
20
21
22
23

1

2   Figure 33 and Figure 34 illustrate the concept of access scheme 2

3

T i m e

Frequency

Ranging Sub-Channels

Data Sub-Channels

Symbol Duration

4

5   **Figure 33. OFDMA Symbols carrying both Ranging and Data slots – General Concept**

6

7

Time

OFDM Symbol

Frequency

Base Tx (Data
symbols only)
                    Interference
                    Montoring

Users Tx (mixed Data and Ranging symbols)

Ranging
Sub-Channel carrier

Data Sub-Channels
carriers

8

9

10   **Figure 34. OFDMA Symbols carrying both Ranging and Data slots – In TDD mode**

11

12

13   Each user that wants to perform ranging will choose randomly a PN sequence from a

14   pre-defined set of PN sequences (16 different sequences) and will modulate (with a pre-

1   defined robust modulation scheme, i.e. BPSK) it on a pre-defined set of carriers. The
2   randomly chosen PN is referred as *Ranging Code*.

3

5.3.3. <<< Proposed >>> Ranging Mechanism Overview

5   The ranging is the process of acquiring the correct timing offset and power corrections such
6   that the SS's transmissions are aligned to a symbol that marks the beginning of a burst(s)
7   boundary with the required power.

8

9   The proposed ranging technique is mostly similar to the one presented in [2]:

10

11 • The SS, after acquiring downstream synchronization and upstream transmission
12   parameters, shall choose randomly a Ranging Slot (with use of a binary truncated
13   exponent algorithm to avoid of possible re-collisions) as the time to perform the
14   ranging, then it chooses randomly a Ranging Code (from the Initial Ranging domain)
15   and sends it to the BS (as a CDMA code).

16

17 • The BS upon successfully receiving a Ranging Code sends a Ranging Response
18   message that addressed the sending SS by supplying the Ranging Code and Ranging
19   Slot in the message. The Ranging Response message contains all the needed
20   adjustment (e.g. time, power and possibly frequency corrections) and a status
21   notification.

22

23 • Upon receiving Ranging Response message with continue status, the SS shall
24   continue the ranging process as done on the first entry.

25

26 The main points of difference with the <<< classical >>> 802.16 MAC ranging process are:

27

28 • In modes with number of carriers $\geq$ 1K, a specific set of carriers shall be used for
29   ranging, hence deduce that each OFDM symbol will always contain a pre-defined and
30   fixed ranging slot.
31 • In modes with number of carriers < 1K, a full symbol(s) shall be used for ranging, this
32   means that the base station shall define an Initial Maintenance region in the same way
33   it defined in [2].
34 • The entry to the system is anonymous and remains so for the whole ranging process,
35   the SS is identified by the indication of the sent ranging slot and sent ranging code.
36 • In modes with number of carriers $\geq$ 1K, the BS does not need to allocate a specific
37   ranging region, this allow the SS to choose when to initiate the system entry.
38 • Several SS can send ranging code simultaneously without colliding (due to the
39   CDMA technique).

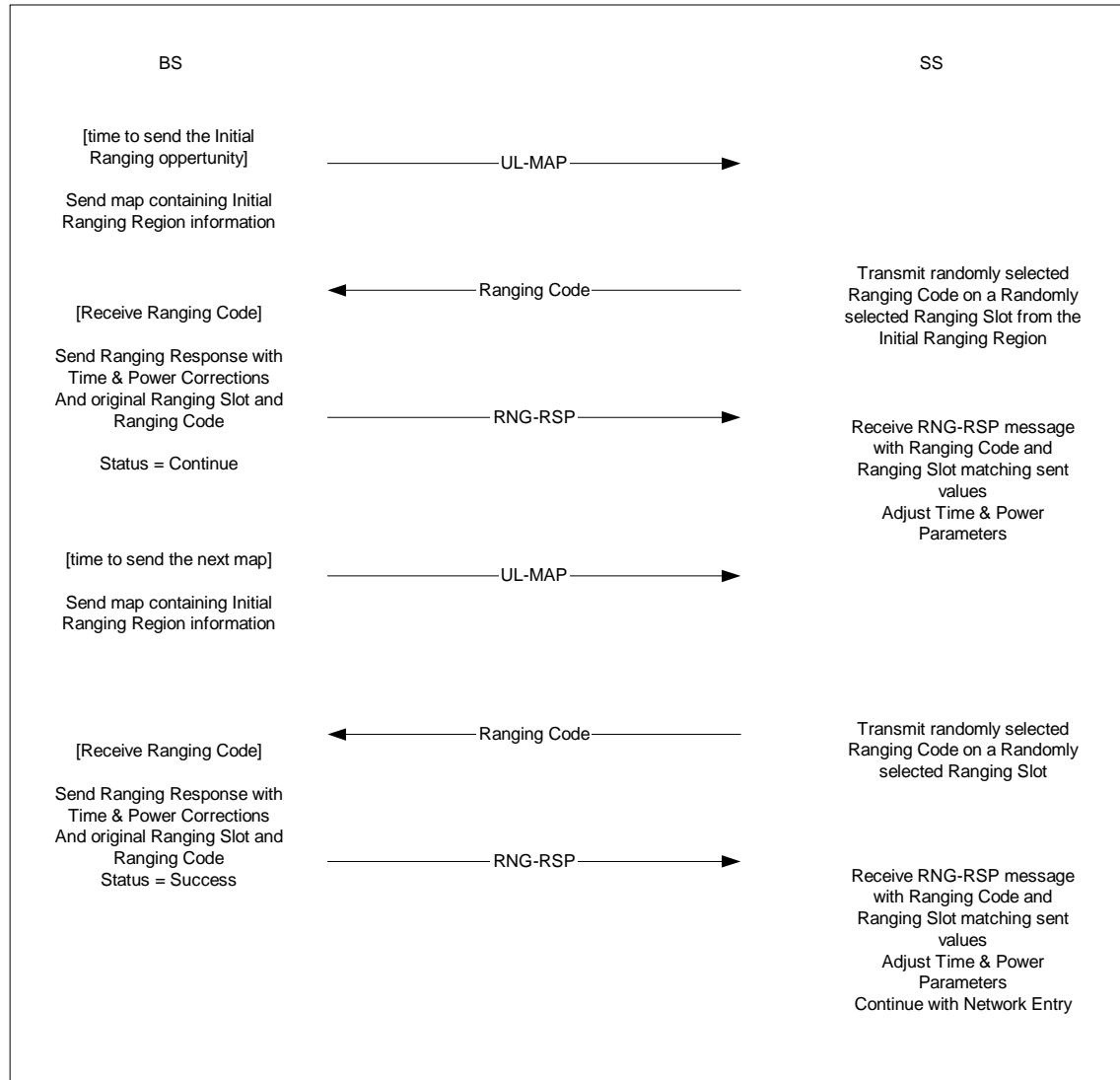40

41

42 The following message flow charts (Figure 35 and Figure 36) describe the ranging
43 adjustments process in the two access mode.

44

45 <<<Is it an "overview"? Seems more like detailed definition >>>

46
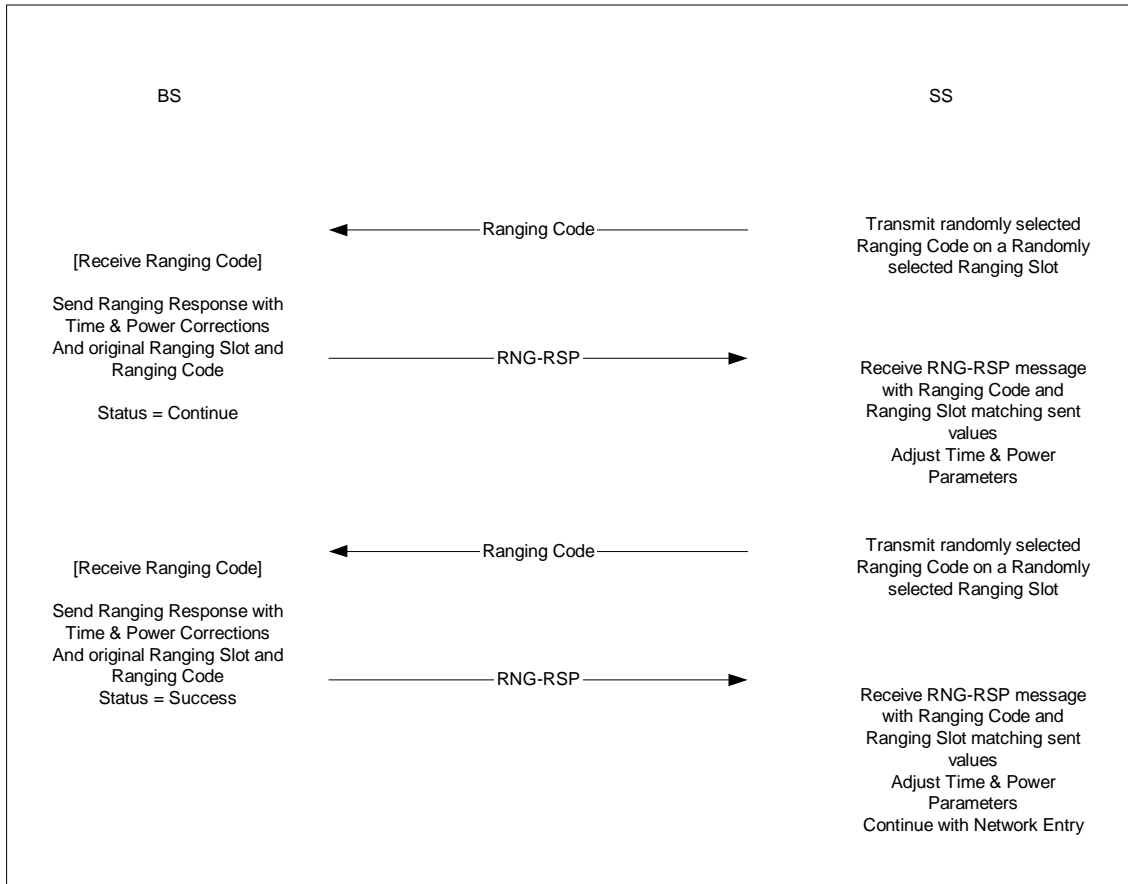
1
2   **Figure 35. Ranging and Automatic Adjustments procedure for Access Scheme 2**
3
4

1
2

Figure 36. Ranging and Automatic Adjustments procedure for Access Scheme 1

4   .
5   <<< Proposed Modifications to the 802.16.1 MAC >>>

6
7   The following sections define the detailed modifications need to done to the 802.16.1 MAC
8   in order to accommodate the proposed CDMA ranging technique assuming that the PHY
9   layer supports the required features (e.g. ranging slots, ranging codes etc.)

10   5.3.3.1.   Ranging region <<< indication >> Definition

11   For the modes with number of carriers < 1K, the ranging slots shall use full OFDM symbols,
12   therefore the initial ranging interval shall be allocated in the same way it is done in [2].
13   For the modes with number of carriers ≥ 1K, the ranging slots shall use one (or more) sub-
14   channels of an OFDMA symbol and will exists for each OFDMA symbol, therefore no
15   indication about initial maintenance region is required
16

5.3.3.2.   Update to 6.2.2.2.6 Section

The following addition should be done to the RNG-RSP Message description in section
6.2.2.2.6 line 61 page 69:

Ranging Slot: A required parameter if the SS used CDMA ranging code for initial ranging,
in this case the RNG-RSP message will be sent using broadcast CID, and the combination of
Ranging Slot and Ranging Code shall be used to address the sending SS.
The Ranging Slot value shall indicate a combination of OFDMA time symbol and Sub-
Channel number

Ranging Code: A required parameter if the SS used CDMA ranging code for initial ranging,
in this case the RNG-RSP message will be sent using broadcast CID, and the combination of
Ranging Slot and Ranging Code shall be used to address the sending SS.

5.3.3.3.   Change in the RNG-RSP Message

The following TLV values should be added to the RNG-RSP message encoding table,
section 11.1.4 page 318:

Table 4. RNG-RSP TLV Addition

Name	**Type** (1 byte)	Length (1 byte)	Value (Variable Length)
Ranging Slot	13	TBD	Used to indicate the OFDMA (OFDM) time symbol and Sub-Channel reference that was used to transmit the ranging code. This TLV is used in conjunction with the Ranging Code value to identify the sending SS.
Ranging Code	14	1	Used to indicate the ranging code that was sent by the SS (unsigned 8-bit). This TLV is used in conjunction with the Ranging Slot value to identify the sending SS.

5.3.3.4.   References

[1] Y.Segal, Z.Hadad, I.Kitroser. Initial OFDMA Proposal for the 802.16.3 PHY Layer.
January 2001.
[2] IEEE 802.16.1/D2. Draft Standard for Air Interface for Fixed Broadband Wireless
Access Systems. January 2001.
[3] IEEE 802.16.3-00/02r4. Functional Requirements for the 802.16.3 Interoperability
Standard. September 2000.
[4] IEEE 802.16.4c-01/02. Modifications to the TG1 MAC for use in TG4 Systems. January
2001
[5] DVB-RCT v.116 standard approved draft, April 2001.

6. <u>Power Control (Subir, John)</u>

[Editorial Group: Subir, John]

7. <u>Ease of Installation Support in MAC <<< Pending >>></u>

<<< E.g. Dynamic Frequency Selection. Editorial Group: John, Chet, Demos]

8. <u>Support for Advanced Antenna Technology</u>

[Editorial Group: Einan, Huan Chun, John]

<<< Support for Adaptive Antenna Arrays – title of the submission >>>

8.1. <u>Architectural Overview</u>

Adaptive Antenna Arrays are elements of the BWA system that are used in conjunction with the PHY, to enhance the performance of the system. Adaptive Arrays can improve range and system capacity. From the MAC point of view, the PHY can be equipped with an Adaptive Array element or not, depending on the system implementation. In the context of this standard, adaptive array support in the MAC sub-layer is defined by a set of services supplied by the underlying PHY, and by MAC protocol functions controlled by the CS. The main functions affected by Adaptive Array Support are:

a)   MAC control functions- Uplink/Downlink MAP distribution, Channel Description

b)   MAC utility function- PHY related information provided by MAC

c)   Registration functions- Initial Synchronization/Ranging

The main purpose of Adaptive Array Support is to enable the MAC to use any PHY that may have Adaptive Array capabilities, independent of the PHY type, or the type of Adaptive Array in use. Adaptive Array Support can be implemented in the SS MAC (which then will be able to interoperate with the MAC of any BS that have Adaptive Array Support at the MAC layer), or in the BS MAC (Which will be able to interoperate with any SS that have this capability, at the MAC layer).

8.2. <u>Definitions</u>

The following definitions apply to Adaptive Array support:

<<< It is a list of the terms, that still need definitions >>>

- AAS- Adaptive Array Support
- Broadcast Coverage
- Unicast Coverage
- Reciprocal Matrix Channel Estimation
- Feedback Matrix Channel Estimation
- AAS Ranging interval

8.3.   Compatibility model

The Adaptive Array Support (AAS) is an optional component of the 802.16.3 standard MAC.

<<< An 802.16.3 compliant system may implement this option. In the case AAS option is implemented in an 802.16.3 system, it must comply with all specifications as specified in this chapter. The AAS option, if present must not prevent the system from interoperating with other 802.16.3 MAC compliant systems at the MAC level, when operating without AAS option. – all this is contained in the first sentence >>>

8.4.   MAC Control functions to support Adaptive Arrays

The main difference between a system with Adaptive Array Processing capabilities, and a system that do not have these, are related to differences in capacity and range that is offered to each of the individual SSs. One property, inherent to FBWA system with AAS is that the Broadcast Coverage is in general, smaller then the Unicast Coverage. The MAC control functions related to AAS are aimed to compensate for this property, as to enable the MAC to work seamlessly with respect to the Adaptive array.

The following messages are used to provide AAS MAC control functions
- P-DUCD (Private Uplink/Downlink Channel Descriptor) used as an alternative to UCD and DCD
- P-MAP (Private MAP) used as an alternative to UL-MAP and DL-MAP.

8.4.1.   Private Uplink/Downlink Channel Descriptor (P-DUCD) message

A Private Uplink/Downlink Channel Descriptor message shall be transmitted by the BS to each SS that did not receive the last DCD or UCD. The P-DUCD message should contain all information contained in the DCD and UCD messages that is relevant to the addressed SS.

The MAC header and Downlink/Uplink channel ID are identical to the type-0 (UCD) packet format. The Type field value is TBD. The Configuration Change Count field is the sum of the values of Configuration Change Count fields in both corresponding UCD and DCD messages, to allow each SS to track changes and discard the P-DUCD message, in case no changes made since last update.

All TLV information that describe Uplink and Downlink channel and burst profiles are identical to their corresponding fields in the original DCD/UCD messages (the final TLV encodings should be updated after determination of the final channel encodings and DCD/UCD fields content for 802.16.3). A SS receiving a P-DUCD will ignore the message, if it had received the UCD and DCD containing the same information. This can be verified easily by comparing the Configuration Change Count field.

8.4.2.   Private MAP (P-MAP) message

The BS shall generate a Private MAP (P-MAP) message for each SS that had not received the last UL-MAP or DL-MAP. The P-MAP message defines the access to Downlink and Uplink information and contains all information relevant to the addressed SS, contained in the UL-MAP and DL-MAP messages.

The MAC header and Downlink/Uplink channel ID are identical to the type-2 (DL-MAP) packet format. The Type field value is TBD. The P-MAP contains the same fields of UL-MAP and DL-MAP, in a single message. Unlike the typical UL-MAP, which has a large

number of information elements (one for each connection for several SSs), the P-MAP shall have only few information elements, since only connections relevant to the addressed SS are informed. A SS receiving a P-MAP will ignore the message, if it had received the MAP of the current frame correctly.

8.5. MAC Utility functions to support Adaptive Arrays

Adaptive Arrays use channel state information that are measured by the receiver at one end of the link. When channel state of the downlink is required at the BS, there are two ways to obtain it:

1. By relying on reciprocity, thus using the uplink channel state estimation as the downlink channel state.

2. By using feedback, thus transmitting the estimated channel state from the SS to BS.

While the first method seems to be more elegant, it will not fit FDD systems, where reciprocity does not apply (due to the large frequency separation between uplink and downlink channels).

Adaptive Array Support for FDD systems contains two MAC control messages: Request for estimation and a reply. The reply contains channel state information, obtained at the SS. The channel state information shall be computed periodically during Channel Estimation Interval (CEI). The CEI is time allowed from the arrival of the signal that the SS uses for channel estimation, to the reply send by the SS. The value of CEI shall be determined by the BS and broadcasted to all SSs at registration.

8.5.1. CSF-REQ message

The Channel State Feedback Request (CSF-REQ) message shall be sent by the BS from time to time, to signal the SS that channel state information should be updated. The time between requests is an internal parameter of the BS MAC, and should not be limited to any specific value. The SS should perform channel estimations on a regular time basis, in order to be able to provide up-to-date estimations upon request.
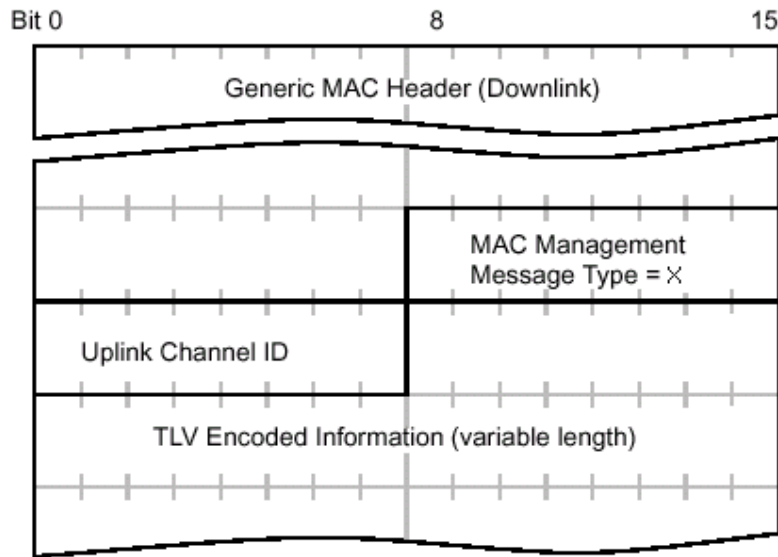
1
2   Figure 3: CSF-REQ message

3   The CID used in the header will be the basic CID of the SS that is addressed.

4   The following parameters may be included in the TLV encoded information of the message:

5   • Frequency adjust information
6   • Power adjust information
7   • Timing adjust information
8

9

10

11   **8.5.2. CSF-REP message**
12   The Channel State Feedback Reply (CSF-REP) message shall be sent by the SS as a response
13   to a CSF-REQ sent by the BS. The SS reply shall be the most up-to-date estimation of the
14   channel, obtained during a **Channel Estimation Interval** (CEI). The Channel Estimation
15   Age field shall be used to indicate the number of CEI periods elapsed since the channel
16   estimation was performed. Any value of Channel Estimation Age field, greater then zero,
17   indicates to the BS that the channel information send by SS is not up to date.

18   *Note:*

19   *The value of CEI shall be predefined according to channel stability over time (a typical value*
20   *is 20 msec), The BS is responsible to determine the actual value of CEI, and for the*
21   *distribution of this value to all SSs.*
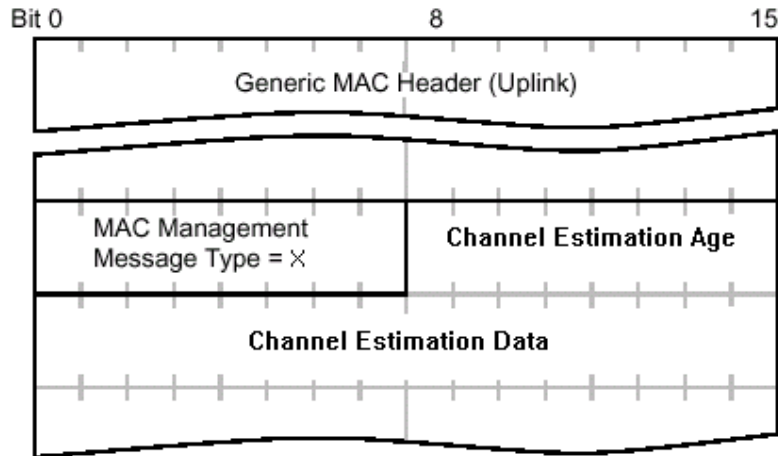
1
2   Figure 4: CSF-REP message
3

4   The Channel Estimation Data is a stream of data bits captured by the SS PHY. The definition
5   of this stream is left to the PHY, since it may be different for different PHY types. As an
6   example only, this data stream may represent 64 consecutive complex samples (of 8 bits I and
7   Q) of the received preamble or synchronization signal.

8
9