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Re:	
Abstract	First draft for 802.16a MAC section
Purpose	This document is for the comments and revision by TG3 MAC Group
Notice	
Release	
Patent Policy and Procedures	

802.16a Amendment to the 802.16 Standard Air Interface for Fixed Broadband Wireless Access Systems

Draft Document

Table of Contents

Editor s comments

<<<

This document was assembled from several contributions submitted to TG3 MAC Group according to the decision of the joint TG3/TG4 MAC Group meeting at Session #12 . The table of contents is not synchronized yet with baseline 802.16 Air Interface document (it will be done after the decision of what are the numbers of the new MAC topics).

Some parts of the submissions will not be included into the text of document, for example, because of usage of expressions like in this submission , etc. Such parts appear in red . Editor s comments appear in blue, both of them are marked by <<< >>>

>>>

1. Introduction

802.16a MAC and PHY have to support point-to-multipoint applications in the range 2 to 11 GHz. Radio communications in the above range may be possible in near- and non-line-of-sight situations between a base station and subscriber station. Operation may include partial blockage by foliage, which contributes to signal attenuation and multipath effects. 802.16a compliant systems shall be deployable in multiple- cell frequency reuse systems and single cell frequency reuse systems. The range of 802.16.3 radios varies with transmit power, channel characteristics, availability requirement, local regulations and atmospheric conditions (see IEEE 802.16.3-00/02r4 Functional Requirements for the 802.16.3 Interoperability Standard).

All the above features request implementation of such PHY functions as support of non-line-of-sight communication, advanced power management, smart antennae support. These functions are absent or insufficient in the baseline 802.16 standard and this is why the 802.16a amendment is focused on the definition of the above PHY and MAC functions.

For MAC it means that first of all it has to support the abovementioned PHY features and implement the proper interface to PHY. On the other hand, some of these problems may be completely or partially fixed in MAC sublayer using such tools as ARQ, advanced packing, additional scheduling flexibility.

2. ARQ

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

<<< Pending because of disagreement between the initial contributors >>>

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

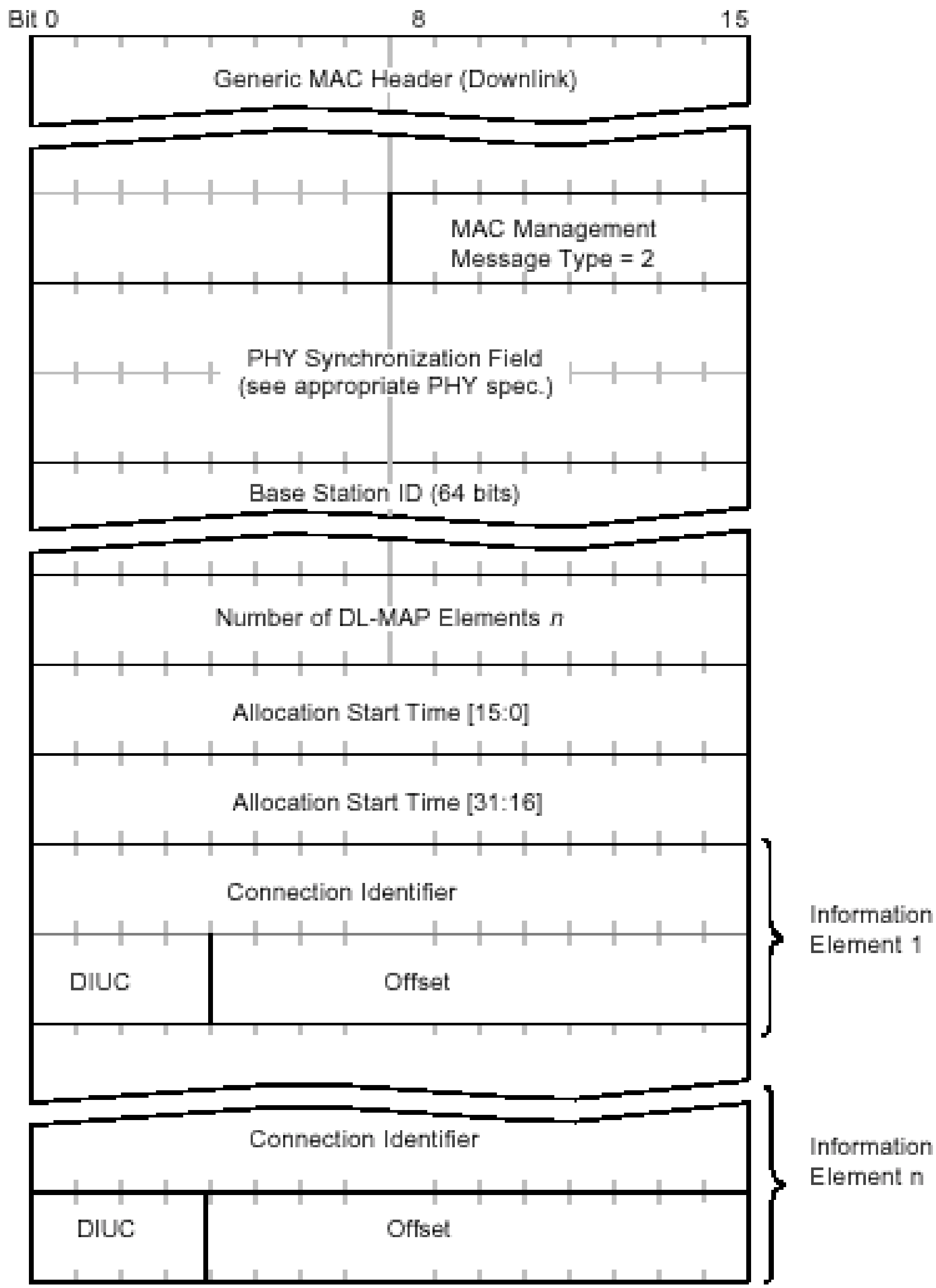


Figure 1

A BS shall generate DL-MAP messages in the format shown in Figure 1, including all 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

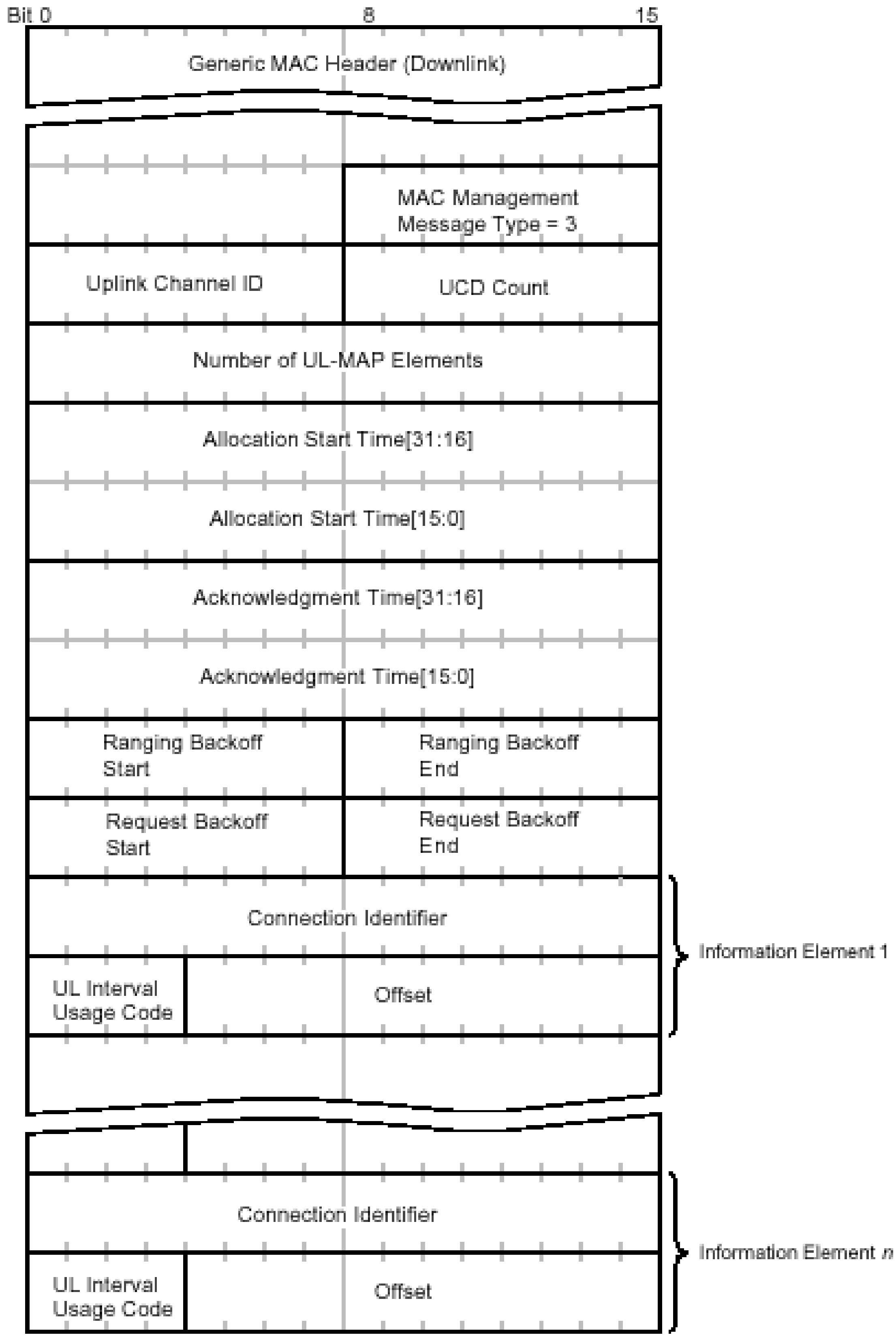


Figure 2

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 2.

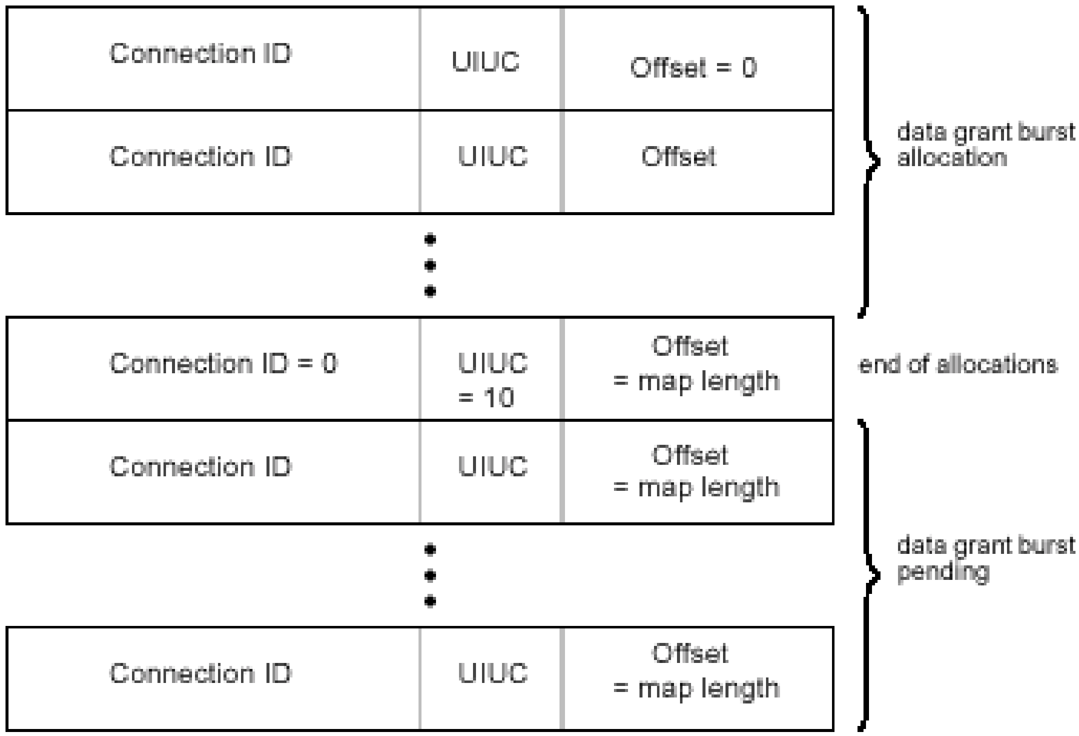


Figure 3

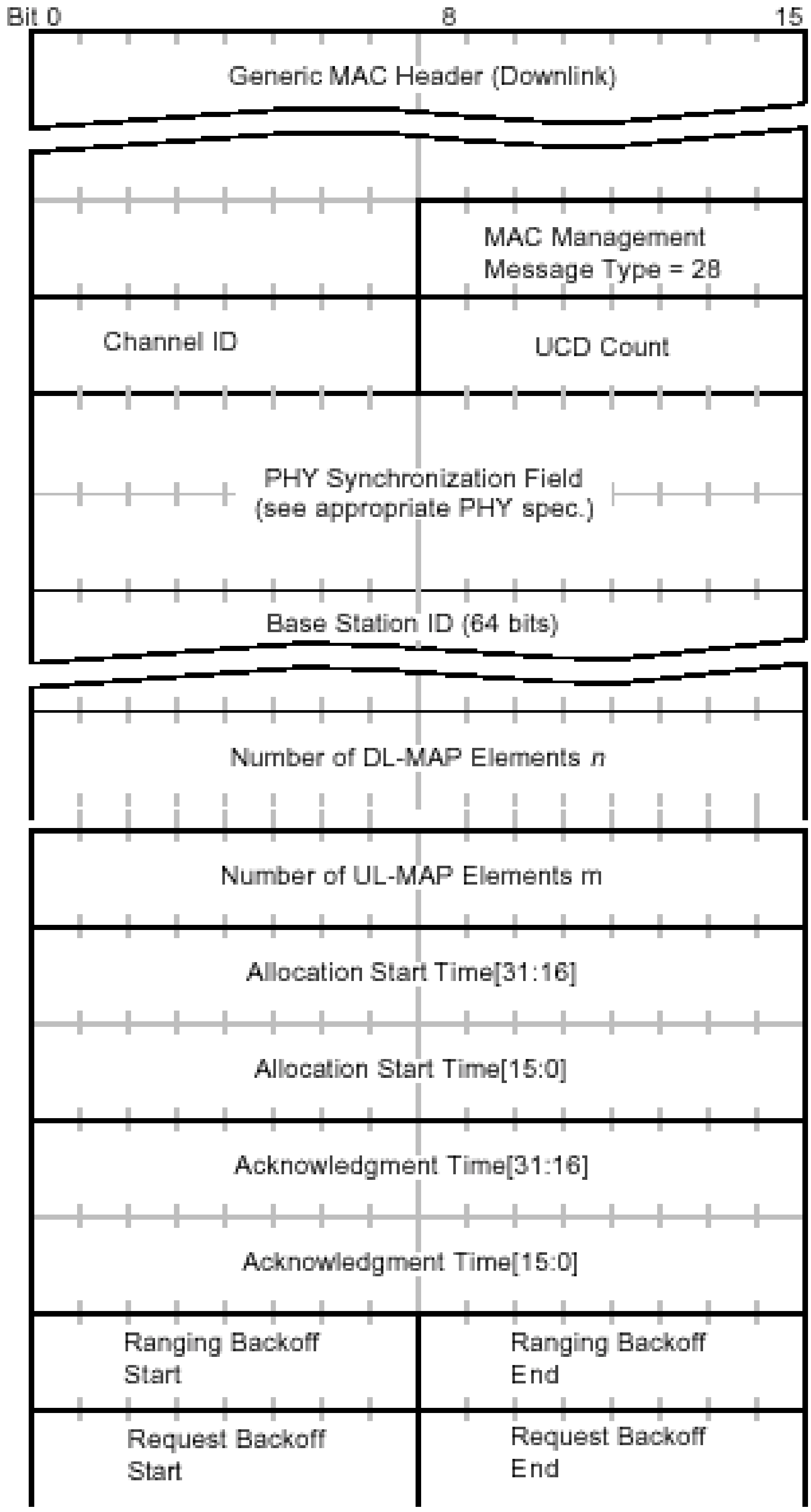
The Connection Identifier represents the assignment of the IE to either a unicast, multicast, or broadcast address. When specifically addressed to allocate a bandwidth grant, the CID may be either the Basic CID of the SS or a Traffic CID for one of the connections of the SS. A four-bit Uplink Interval Usage Code (UIUC) shall be used to define the type of uplink access and the burst type associated with that access. A Burst Descriptor shall be included for each Interval Usage Code that is to be used in the UL-MAP. The Interval Usage Code shall be one of the values defined in Table 1. The offset indicates the start time, in units of minislots, of the burst relative to the Allocation Start Time given in the UL-MAP message. Consequently the first IE will have an offset of 0. The end of the last allocated burst is indicated by allocating a NULL burst (CID = 0 and UIUC = 10) with zero duration. The time instants indicated by the offsets are the transmission times of the first symbol of the burst including preamble.

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

4.1.3. Uplink + Downlink MAP

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


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

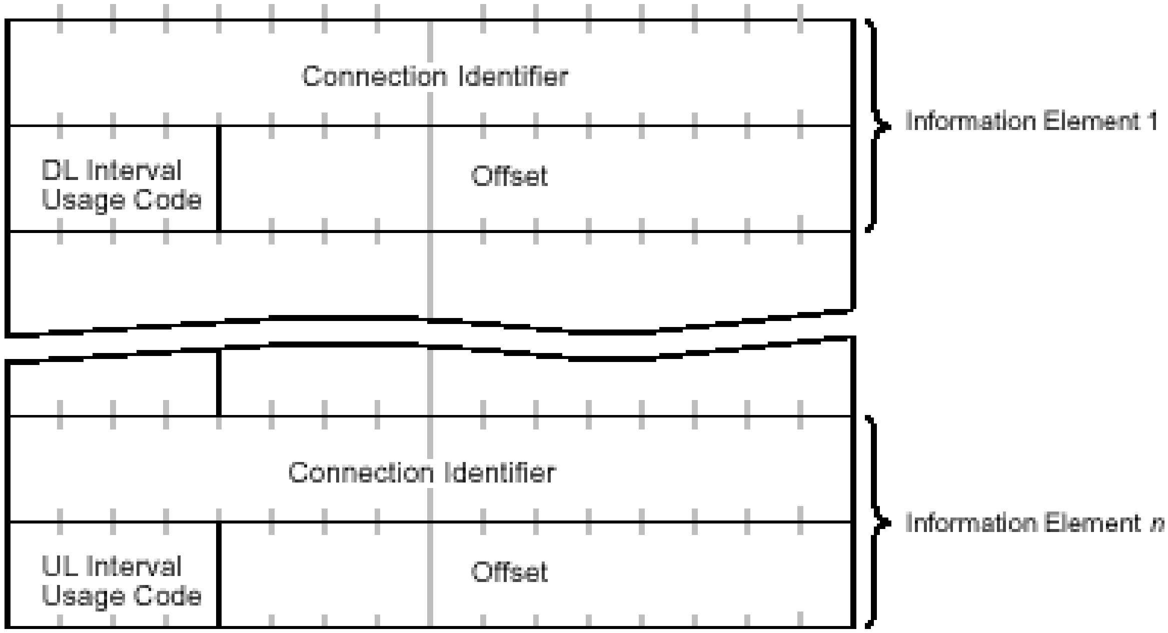


Figure 4

4.2. MAP Relevance and Synchronization

4.2.1. MAP Relevance for Burst PHY Systems

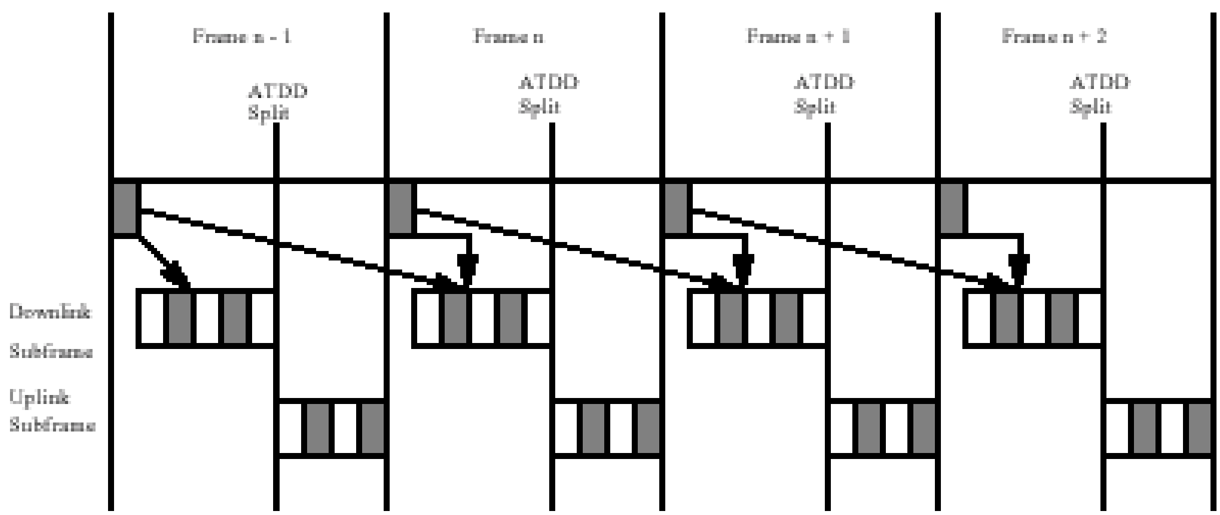


Figure 5. Maximum Time Relevance of PHY and MAC Control Information (TDD)

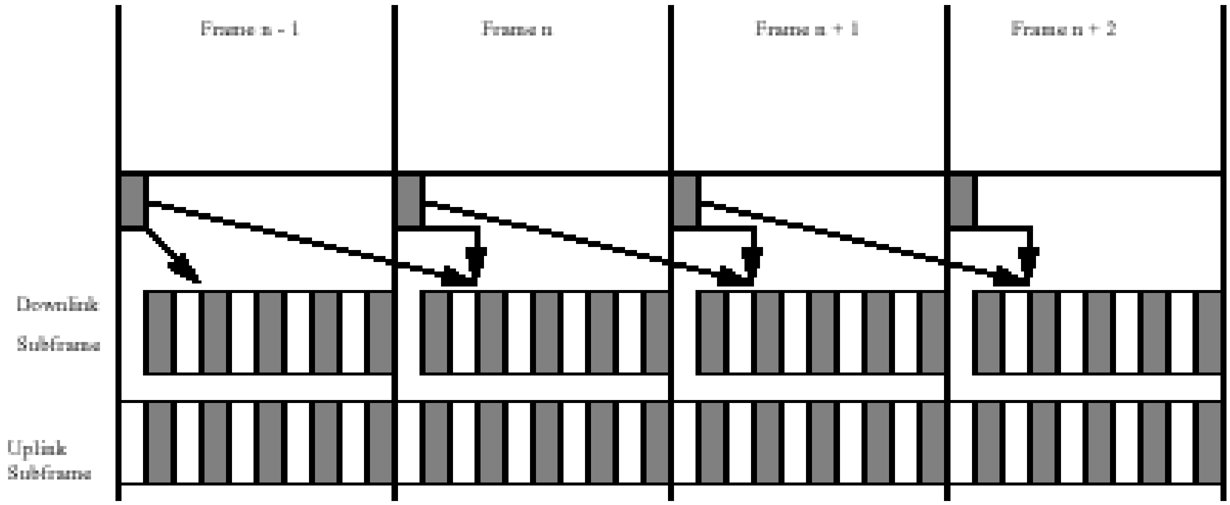


Figure 6. Maximum Time Relevance of PHY and MAC Control Information (FDD)

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).

4.2.2.2. Downlink and Uplink Operation

Two different downlink modes of operation are defined: Mode A and Mode B. Mode A supports a continuous transmission format, while Mode B supports a burst transmission format. The continuous transmission format of Mode A is intended for use in an FDD-only configuration. The burst transmission format of Mode B supports burst-FDD as well as TDD configurations.

The A and B options give service providers choice, so that they may tailor an installation to best meet a specific set of system requirements. Standards-compliant subscriber stations are required to support at least one (A or B) of the defined downlink modes of operation.

A single uplink mode of operation is also defined. This mode supports TDMA-based burst uplink transmissions. Standards-compliant subscriber stations are required to support this uplink mode of operation.

4.2.2.3. Mode A (Continuous Downlink)

Mode A is a downlink format intended for continuous transmission. The Mode A downlink physical layer first encapsulates MAC packets into a convergence layer frame as defined by the transmission convergence sublayer. Modulation and coding which is adaptive to the needs of various SS receivers is also supported within this framework.

Data bits derived from the transmission convergence layer are first randomized. Next, they are block FEC encoded. The resulting FEC-encoded bits are mapped to QPSK, 16-QAM, or 64-QAM signal constellations. Detailed descriptions of the FEC, modulation constellations, and symbol mapping formats can be found within the FEC and modulation sections.

Following the symbol mapping process, the resulting symbols are modulated, and then transmitted over the channel.

In Mode A, the downstream channel is continuously received by many SSs. Due to differing conditions at the various SS sites (e.g., variable distances from the BS, presence of obstructions), SS receivers may observe significantly different SNRs. For this reason, some SSs may be capable of reliably detecting data only when it is derived from certain lower-order modulation alphabets, such as QPSK. Similarly, more powerful and redundant FEC schemes may also be required by such SNR-disadvantaged SSs. On the other hand, SNR-advantaged stations may be capable of receiving very high order modulations (e.g., 64-QAM) with high code rates. Collectively, let us define the adaptation of modulation type and FEC to a particular SS (or group of SSs) as ’adaptive modulation’, and the choice of a particular modulation and FEC as an ’adaptive modulation type.’ Mode A supports adaptive modulation and the use of adaptive modulation types.

A MAC Frame Control header is periodically transmitted over the continuous Mode A downstream, using the most robust supported adaptive modulation type. So that the start of this MAC header may be easily recognized during initial channel acquisition or re-acqusition, the PHY inserts an uncoded, TBD (but known) QPSK code word, of length TBD symbols, at a location immediately before the beginning of the MAC header, and immediately after a Unique Word. (See PHY framing section for more details on the Unique Word). Note that this implies the interval between Frame Control headers should be an integer multiple of F (the interval between Unique Words).

Within MAC Frame Control header, a PHY control map (DL_MAP) is used to indicate the beginning location of adaptive modulation type groups which follow. Following this header, adaptive modulation groups are sequenced in increasing order of robustness. However, the DL_MAP does not describe the beginning locations of the payload groups that immediately follow; it describes the payload distributions some MAC-prescribed time in the future. This delay is necessary so that FEC decoding of MAC information (which could be iterative, in

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

4.2.2.3.1. Mode B (Burst Downlink)

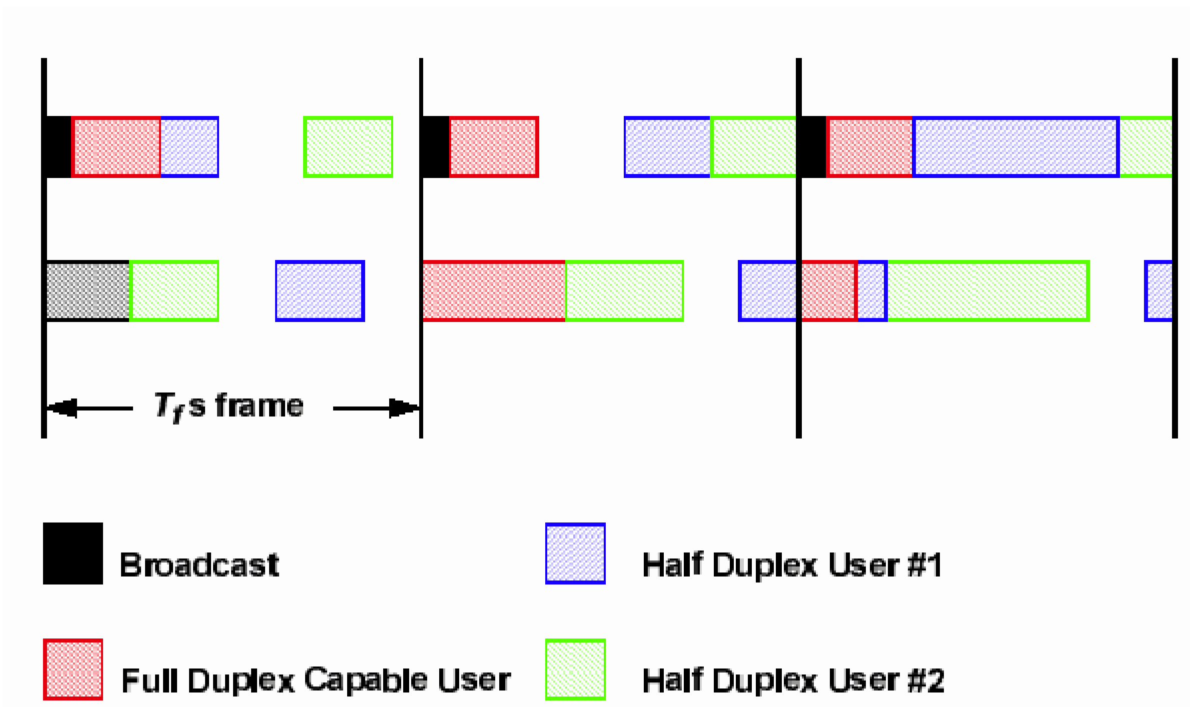


Figure 7. Example of burst FDD Bandwidth Allocation

Mode B is a downlink format intended for burst transmissions, with features that simplify the support for both TDD systems and half-duplex terminals. A Mode B compliant frame can be configured to support either TDM or TDMA transmission formats; i.e., a Mode B burst may consist a single user's data, or a concatenation of several users' data. What's more, Mode B supports adaptive modulation and multiple adaptive modulation types within these TDMA and TDM formats.

A unique (acquisition) preamble is used to indicate the beginning of a frame, and assist burst demodulation. This preamble is followed by PHY/MAC control data. In the TDM mode, a PHY control map (DL_MAP) is used to indicate the beginning location of different adaptive modulation types. These adaptive modulation types are sequenced within the frame in increasing order of robustness (e.g., QPSK, 16-QAM, 64-QAM), and can change with time in order to adjust to the changing channel conditions.

In the TDMA mode, the DL_MAP is used to describe the adaptive modulation type in individual bursts. Since a TDMA burst would contain a payload of only one adaptive modulation type, no adaptive modulation type sequencing is required. All TDMA format payload data is FEC block encoded, with an allowance made for shortening the last codeword (e.g., Reed Solomon codeword) within a burst.

The Mode B downlink physical layer goes through a transmission convergence sublayer that inserts a pointer byte at the beginning of the payload information bytes to help the receiver identify the beginning of a MAC packet.

Payload data bits coming from the transmission convergence layer are first randomized. Next, they are block FEC encoded. The resulting FEC-encoded bits are mapped to QPSK, 16-QAM, or 64-QAM signal constellations. Detailed descriptions of the FEC, modulation constellations, and symbol mapping formats can be found within the FEC and modulation sections. Following the symbol mapping process, the resulting symbols are modulated, and then transmitted over the channel.

4.2.2.3.1.1. Uplink

The uplink mode supports TDMA burst transmissions from an individual SSs to a BS. This is functionally similar (at the PHY level) to Mode B downlink TDMA operation. As such, for a brief description of the Physical Layer protocol used for this mode, please read the previous section on Mode B TDMA operation.

Of note, however, is that many of the specific uplink channel parameters can be programmed by MAC layer messaging coming from the base station in downstream messages. Also, several parameters can be left unspecified and configured by the base station during the registration process in order to optimize performance for a particular deployment scenario. In the upstream mode of operation, each burst may carry MAC messages of variable lengths.

4.2.2.4. Multiplexing and Multiple Access Technique

The uplink physical layer is based on the combined use of time division multiple access (TDMA) and demand assigned multiple access (DAMA). In particular, the uplink channel is divided into a number of 'time slots.' The number of slots assigned for various uses (registration, contention, guard, or user traffic) is controlled by the MAC layer in the base station and can vary over time for optimal performance.

As previously indicated, the downlink channel can be in either a continuous (Mode A) or burst (Mode B) format. Within Mode A, user data is transported via time division multiplexing (TDM), i.e., the information for each subscriber station is multiplexed onto the same stream of data and is received by all subscriber stations located within the same sector. Within Mode B, the user data is bursty and may be transported via TDM or TDMA, depending on the number of users which are to be borne within in burst.

4.2.2.4.1. Duplexing Techniques

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

4.2.2.4.1.1. Mode A: Continuous Downstream for FDD Systems

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

4.2.2.4.1.2. Mode B: Burst Downstream for Burst FDD Systems

A burst FDD system refers to a system in which the uplink and downlink channels are located on separate frequencies but the downlink data is transmitted in bursts. This enables the system to simultaneously support full duplex subscriber stations (ones which can transmit and receive simultaneously) and, optionally, half duplex subscriber stations (ones which cannot transmit and receive simultaneously). If half duplex subscriber stations are supported, this mode of operation imposes a restriction on the bandwidth controller: it cannot allocate uplink bandwidth for a half duplex subscriber station at the same time that the subscriber station is expected to receive data on the downlink channel.

Frequency separation is as defined in 3.2.1.1.1. Figure 139 describes the basics of the burst FDD mode of operation. In order to simplify the bandwidth allocation algorithms, the uplink and downlink channels are divided into fixed sized frames. A full duplex subscriber station must always attempt to listen to the downlink channel. A half duplex subscriber station must always attempt to listen to the downlink channel when it is not transmitting on the uplink channel.

4.2.2.4.1.3. Mode B: Burst Downstream for Time Division Duplexing (TDD) Systems

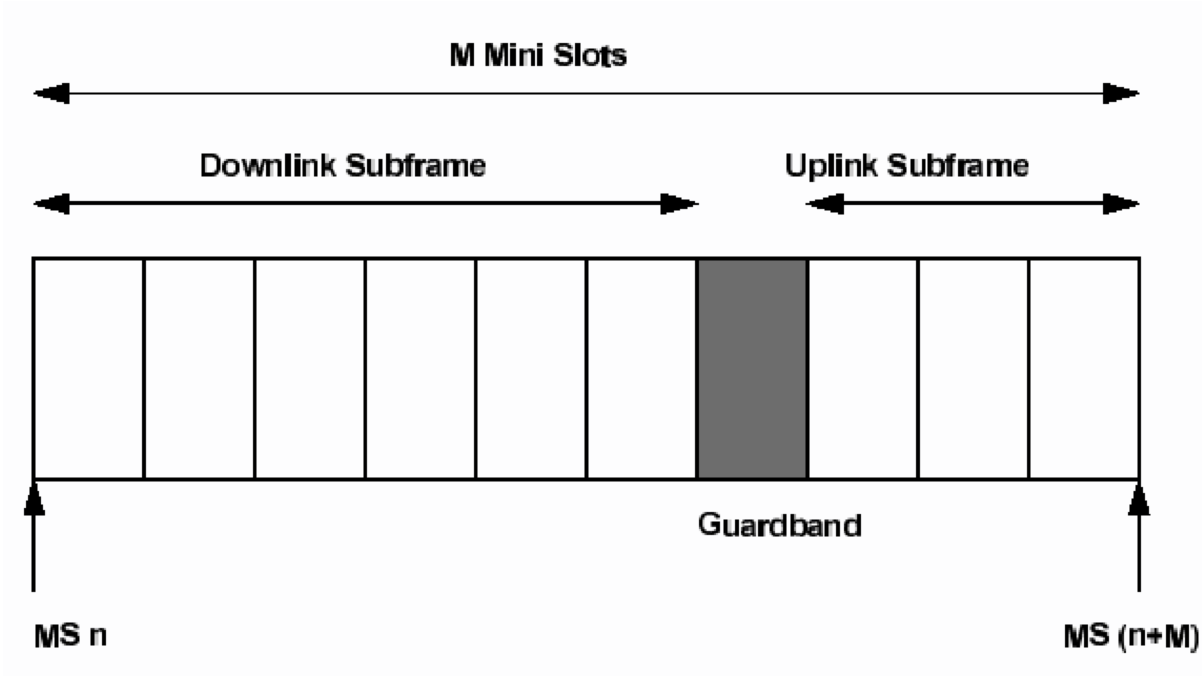


Figure 8

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

4.2.2.4.1.3.1. Tx / Rx Transition Gap (TTG)

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

4.2.2.4.1.3.2. Rx / Tx Transition Gap (RTG)

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

4.2.2.4.1.4. Mode B: Downlink Data

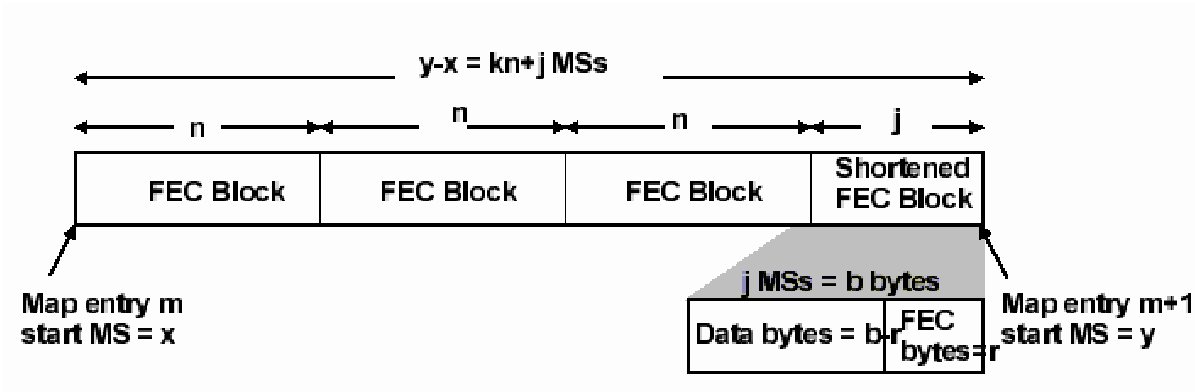


Figure 9. Downlink MAP usage and shortened FEC blocks

The downlink data sections are used for transmitting data and control messages to specific SSs. This data is always FEC coded and is transmitted at the current operating modulation of the individual SS. In the burst mode cases, data is transmitted in robustness order in the TDM portion. In a burst TDMA application, the data is grouped into separately delineated bursts, which do not need to be in modulation order. The DL-MAP message contains a map stating at which mini slot the burst profile change occurs. If the downlink data does not fill the entire downlink sub-frame and Mode B is in use, the transmitter is shut down. The DL-MAP provides implicit indication of shortened FEC (and/or FFT) blocks in the downlink. Shortening the last FEC block of a burst is optional (see 11.1.2.2). The downlink map indicates the number of MS, p allocated to a particular burst and also indicates the burst type (modulation and FEC). Let n denote the number of MS required for one FEC block of the given burst profile. Then, p= kn + j, where k is the number of integral FEC blocks that fit in the burst and j is the number of MS remaining after integral FEC blocks are allocated. Either k or j, but not both, may be zero. j denotes some number of bytes b. Assuming j is not 0, it must be large enough such that b is larger than the number of FEC bytes r, added by the FEC scheme for the burst. The number of bytes available to user data in the shortened FEC block is b - r. These points are illustrated in Figure 141. Note that a codeword may not possess less than 6 information bytes.

In the TDM mode of operation, SSs listen to all portions of the downlink burst to which they are capable of listening. For full-duplex SSs, this implies that a SS shall listen to all portions that have a adaptive modulation type (as defined by the DIUC) which is at least as robust as that which the SS negotiates with the BS. For half-duplex SSs, the aforesaid is also true, but under an additional condition: an SS shall not attempt to listen to portions of the downlink burst that are coincident---adjusted by the SS’s Tx time advance---with the SS’s allocated uplink transmission, if any.

In the burst TDMA mode of operation, bursts are individually identified in the DL_MAP. Hence, a SS is required to turn on its receiver only in time to receive those bursts addressed to it. Unlike the TDM mode, there is no requirement that the bursts be ordered in order of increasing robustness.

4.2.2.4.2. Uplink Burst Subframe Structure

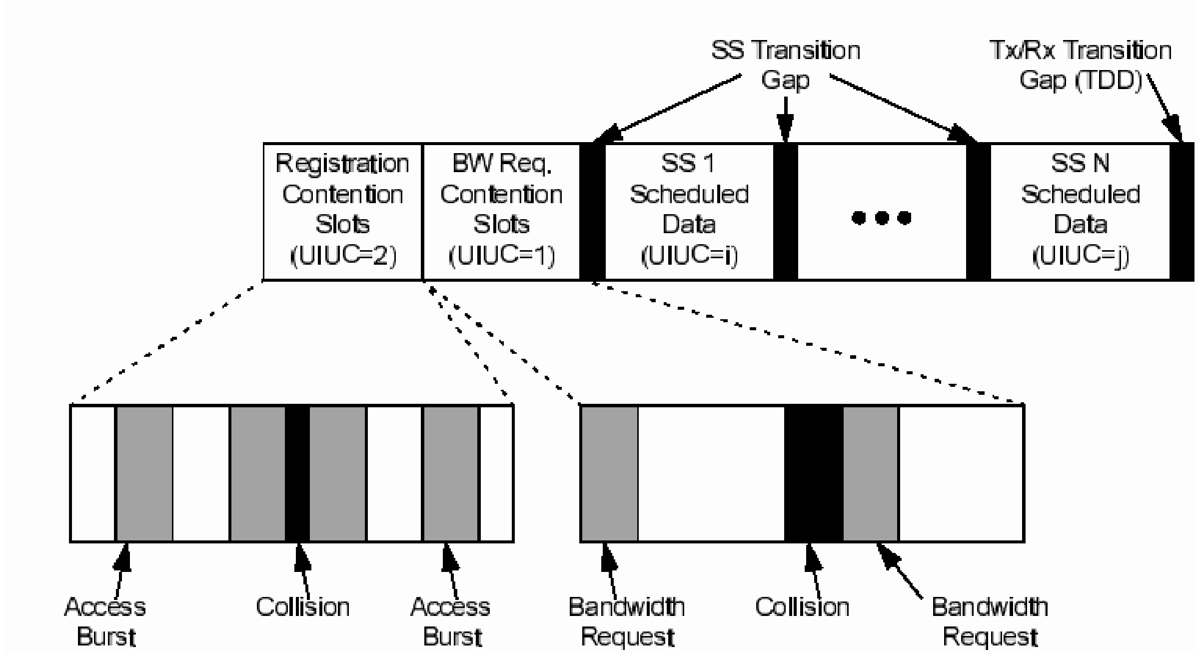


Figure 10. Uplink Subrame Structure

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

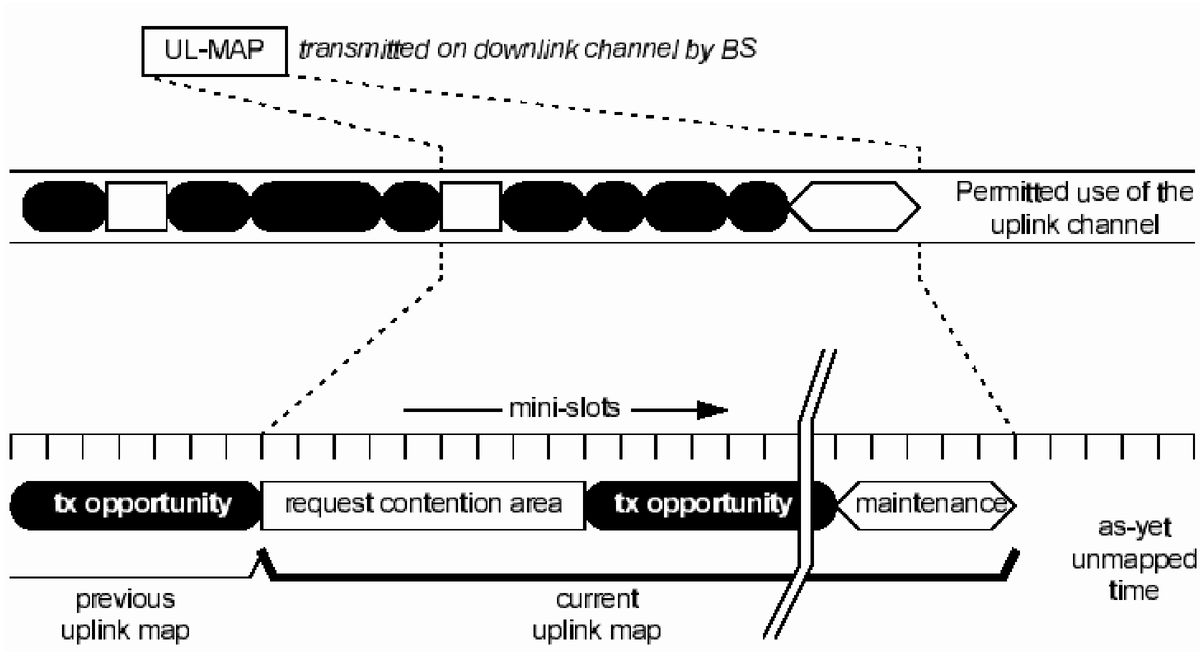


Figure 11. Uplink Mapping in the Continuous Downstream FDD Case

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.

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
ModeA (FDD)	2	Continuous downlink

4.2.2.4.4.2. Mode A: Continuous Downlink Transmission

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

4.2.2.4.4.3. Downlink Mode A: Message field definitions

4.2.2.4.4.3.1. Downlink Mode A: Required channel descriptor parameters

The following parameters shall be included in the UCD message:
TBD

4.2.2.4.4.3.2. Mode A: Required DCD parameters

The following parameters shall be included in the DCD message:
TBD

4.2.2.4.4.3.2.1. Downlink Mode A: DCD, Required burst decriptor parameters

TBD.

4.2.2.4.4.3.3. Mode A: DL-MAP

For PHY Type = 2, no additional information follows the Base Station ID field.

4.2.2.4.4.3.3.1. Mode A: DL-MAP PHY Synchronization Field definition

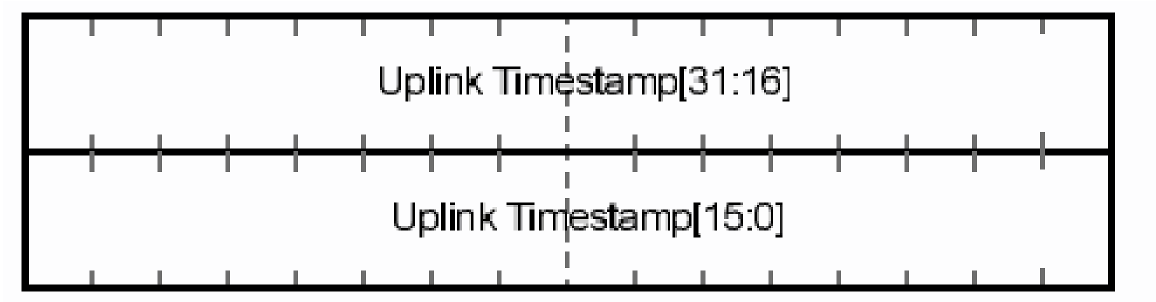


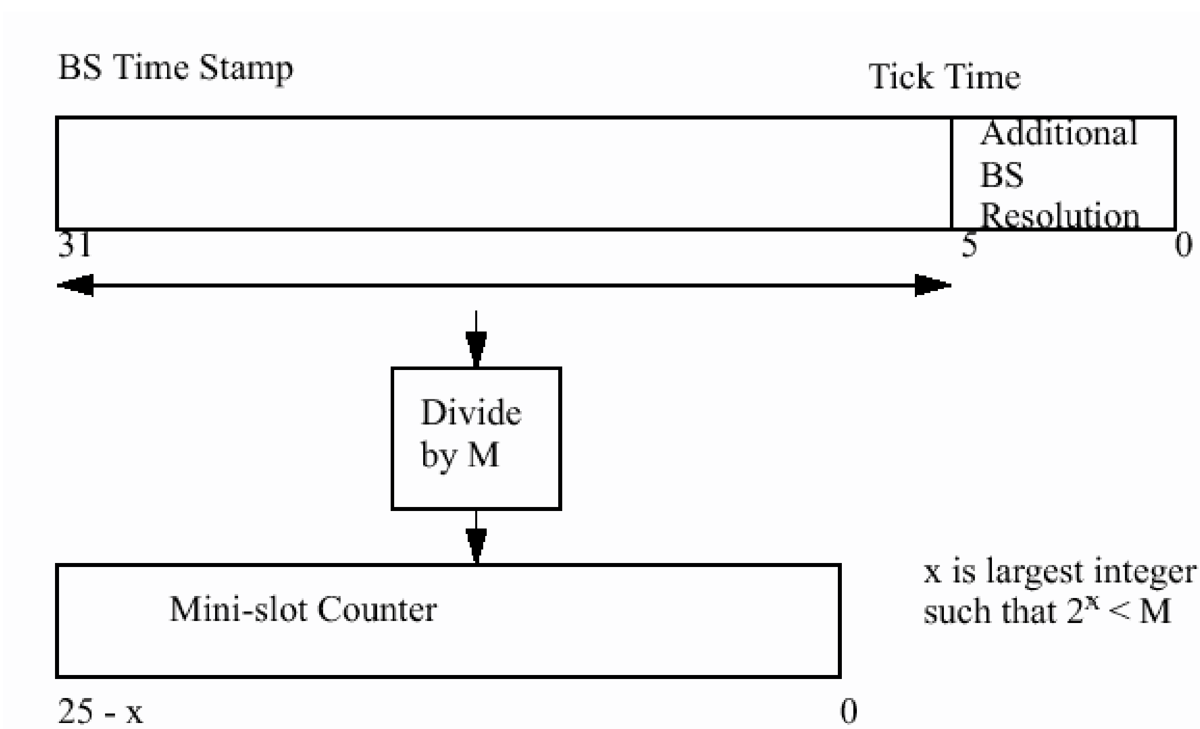
Figure 12. PHY Synchronization Field (PHY Type = 2)

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:

$(N2 — N1)/(4 \text{ x Symbol Rate}) — (T2 — T1) < 500 \text{ ns}$

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 offset to the Time Stamp defined in 3.2.4.3.3.1. Figure 145 illustrates the relation of the Time Stamp maintained in the BS to the BS Mini-slot Counter. The base time unit is called a tick and is of duration 1 us, independent of the symbol rate, and is counted using a 26 bit counter. The additional BS resolution is of duration (1 tick/ 64) = 15.625 ns. The Mini-Slot count is derived from the tick count by means of a divide by M operation. Note that the divisor M is not necessarily a power of 2.

For arbitrary symbol rates, the main constraint in the definition of a mini slot, is that the number of symbols per mini slot be an integer. For example given a symbol rate of R Symbols/tick, and M ticks/mini-slot, the number of symbols per mini-slot N, is given by N = MR. In this situation, M should be chosen such that N is an integer. In order to accommodate a wide range of symbol rates, it is important not to constrain M to be a power of 2. Since the additional BS resolution is independent of the symbol rate, the system can use an uniform time reference for distance ranging.

In order to show that the time base is applicable to single carrier and OFDM symbol rates, consider the following examples: (a) Single Carrier System - Given a symbol rate of 4.8 Msymbols/s (on a 6MHz channel), if the mini-slot duration is chosen to be 10 ticks (i.e., M = 10), then there are 48 symbols/mini-slot. Given 16QAM modulation this corresponds to a granularity of 24 bytes/mini-slot (b) OFDM System - Given an OFDM symbol time of 50 us, the mini-slot duration is also chosen to be 50 ticks (i.e., M = 50). In this case there is only a single symbol per mini-slot.

4.2.2.4.4.3.5. UL-MAP Ack Time definition

The Ack Time is the 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 given relative to the BS initialization time.

4.2.2.4.4.4. Mode B: Burst Downlink Transmission

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

4.2.2.4.4.4.1. Mode B: Downlink Framing

In the burst mode, the uplink and downlink can be multiplexed in a TDD fashion as described 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 duration as specified in 3.2.5.1. Within this frame are a downlink subframe and an uplink subframe. In the TDD case, the downlink subframe comes first, followed by the uplink subframe. In the burst FDD case, uplink transmissions occur during the downlink frame. In both cases, the downlink subframe is prefixed with information necessary for frame synchronization.

The available bandwidth in both directions is defined with a granularity of one mini slot (MS). The number of mini slots within each frame is independent of the symbol rate. The frame size is selected in order to obtain an integral number of MS within each frame. For example, with a 10 us MS duration, there are 500 MS within a 5-ms frame, independent of the symbol rate.

The structure of the downlink subframe used by the BS to transmit to the SSs, using Mode B, is shown in Figure 156. This burst structure defines the downlink physical channel. It starts with a Frame Control Header, that is always transmitted using the most robust set of PHY parameters. This frame header contains a preamble used by the PHY for synchronization and equalization. It also contains control sections for both the PHY and the MAC (DL_MAP and UL_MAP control messages) that is encoded with a fixed FEC scheme defined in this standard in order to ensure interoperability. The Frame Control Header also may periodically contain PHY Parameters as defined in the DCD and UCD.

There are two ways in which the downstream data may be organized for Mode B systems:

- Transmissions may be organized into different modulation and FEC groups, where the modulation type and FEC parameters are defined through MAC layer messaging. The PHY Control portion of the Frame Control Header contains a downlink map stating the MSs at which the different modulation/FEC groups begin. Data should be transmitted in robustness order. For modulations this means QPSK followed by 16-QAM, followed by 64-QAM. If more than 1 FEC is defined (via DCD messages) for a given modulation, the more robust FEC/modulation combination appears first. Each SS receives and decodes the control information of the downstream and looks for MAC headers indicating data for that SS.
- Alternatively, transmissions need not be ordered by robustness. The PHY control portion contains a downlink map stating the MS (and modulation/ FEC) of each of the TDMA sub-bursts. This allows an individual SS to decode a specific portion of the downlink without the need to decode the whole DS burst. In this particular case, each transmission associated with different burst types is required to start with a short preamble for phase re-synchronization.

There is a Tx/Rx Transition Gap (TTG) separating the downlink subframe from the uplink subframe in the case of TDD

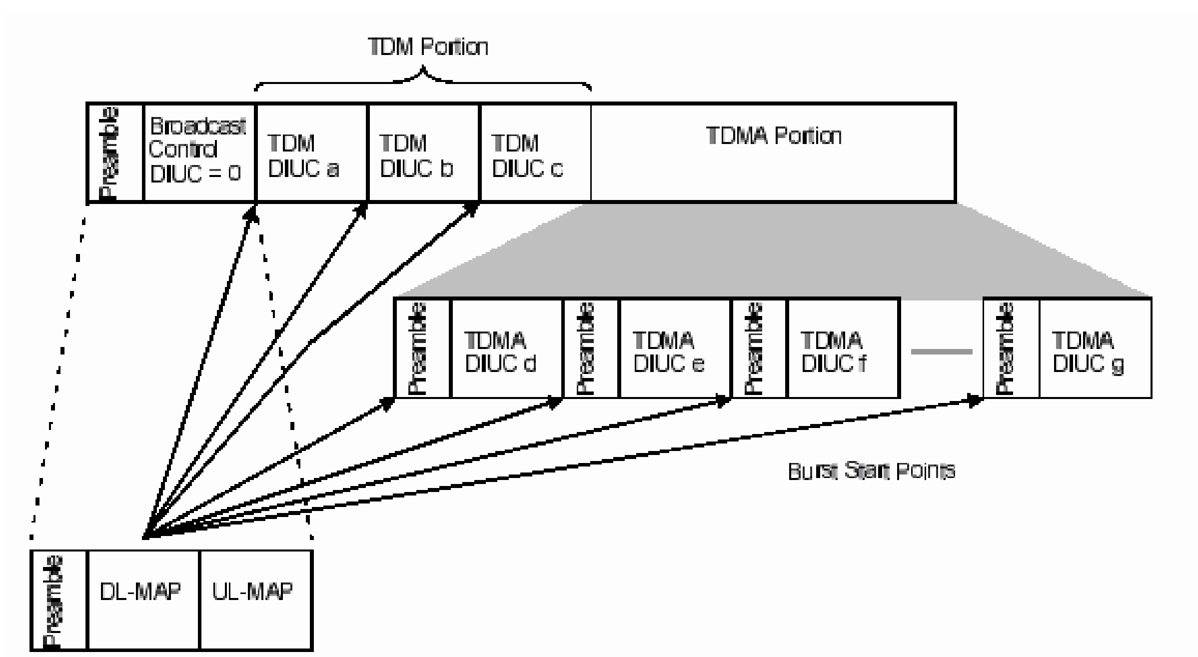


Figure 13 Mode B Downlink Subframe Structure

4.2.2.4.4.4.2. Frame Control

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

4.2.2.4.4.4.3. Downlink Mode B: Required DCD parameters

The following parameters shall be included in the DCD message:
TBD

4.2.2.4.4.4.3.1. Downlink Mode B: DCD, Required burst decriptor parameters

Each Burst Descriptor in the DCD message shall include the following parameters:
TBD

4.2.2.4.4.4.4. Downlink Mode B: Required UCD parameters

The following parameters shall be included in the UCD message:
TBD

4.2.2.4.4.4.5. Downlink Mode B: DL-MAP elements

For PHY Type = {0, 1}, a number of information elements as defined as in Figure 27 follows the Base Station ID field. The MAP information elements must be in time order. Note that this is not necessarily IUC order or connection ID order.

4.2.2.4.4.4.6. Allowable frame times

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

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

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

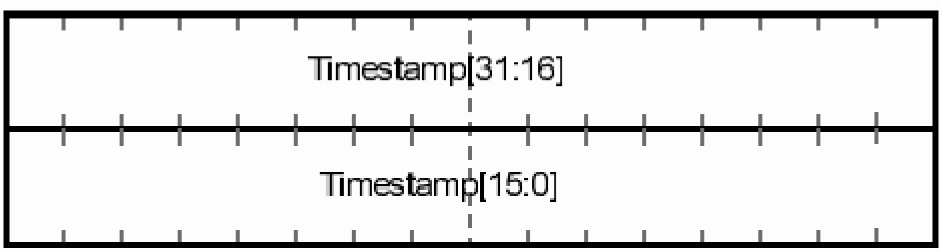


Figure 14. PHY Synchronization Field (PHY Type = {0,1})

The format of the PHY Synchronization field is given in Figure 158. 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:

$(N2 - N1)/(4 \times \text{Symbol Rate}) - (T2 - T1) < 500$ 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.

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

4.2.2.4.4.4.9. UL-MAP Ack Time definition

The Ack Time is the 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 given relative to the BS initialization time.

5. MAC-PHY Interface for OFDM PHY

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

5.1. OFDM PHY Burst Definition and MAP Messages

<<< Contribution OFDMA\OFDM Considerations in TG3 and TG4 by Itzik Kitroser Yossi Segal, Zion Hadad >>>

5.1.1. Introduction

This section <<< contribution >>> describes the MAC-PHY considerations and MAC-PHY information exchange needed for support OFDMA/OFDM based PHY layer.

The OFDMA access scheme presented in [1] defines an access scheme of a two 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 15 illustrates an allocation pattern instance of a Region

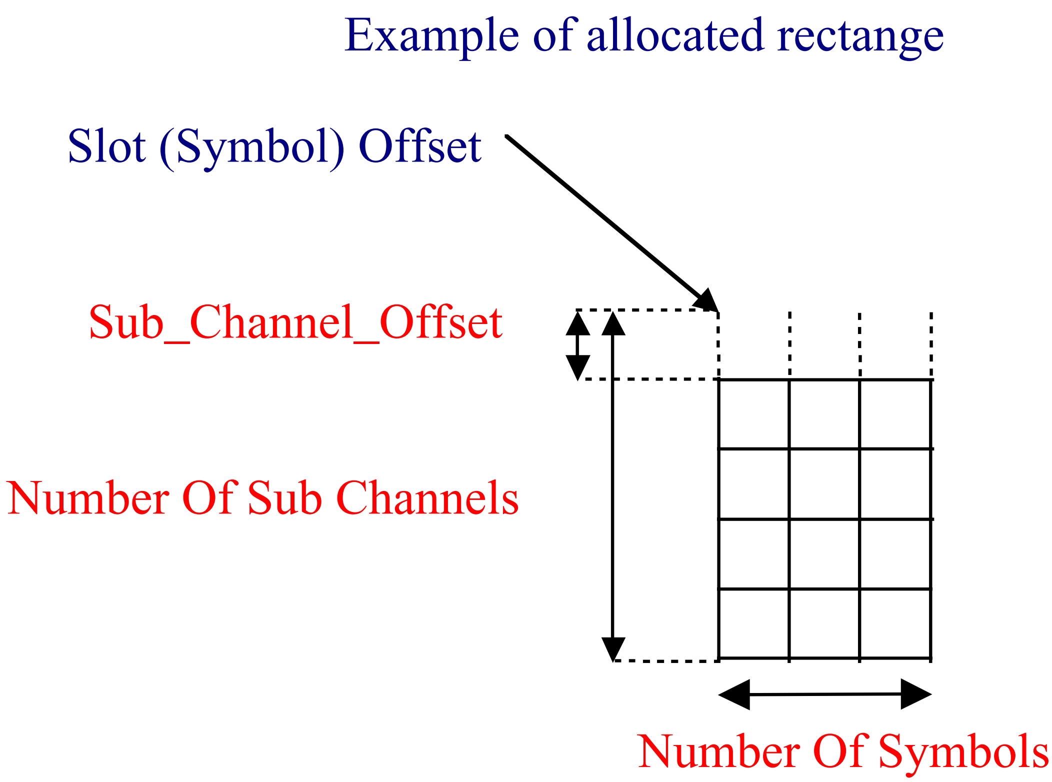


Figure 15. Example of a Two dimensional Pattern

A Region can be assigned in the UL to a specific SS (or a group of subscribers) or can be transmitted in the DL by the BS as a transmission to a (group of) SS.

The SS s transmission at the Region is called UL PHY Burst.
The BS s transmission at the Region is called DL PHY Burst.

5.1.2.2. UL Transmission

The PHY Burst properties will be figured:

- In the MAC-PHY interface primitives
- In UCD message within Burst Profile TLV encodings
- In UL-MAP message, implicitly identified by UIUC.

The BS learns each of SS s specific working parameters (during the SS s UL maintenance Ranging and data transmission) and assigned internally UL PHY Burst profile for each SS.

<<<<<<<<<<<<<<

The following paragraph is clearly a part of OFDM PHY

The parameters the BS uses are:

- The CIR <<< SIR? >>> of the channel (which can be achieved when using the CDMA synchronization approach [6])
- The C/n of the user (by measurement from a user message)

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

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

The defined values are used for a reference, bad CIR can cause the BS to chose lower profile or allocation of fewer Sub-Channels enables the BS to choose higher profile.

>>>>>>>>>>>>>>>>>>>>>

The UL MAP IEs shall have the UIUC that represent the relevant profile that determined by the BS.

Figure 16 describes the logical structure of UL PHY Burst.

<<< Note: for the next figures, the size (number of symbols) of the preamble is still under discussion of the PHY group. >>>

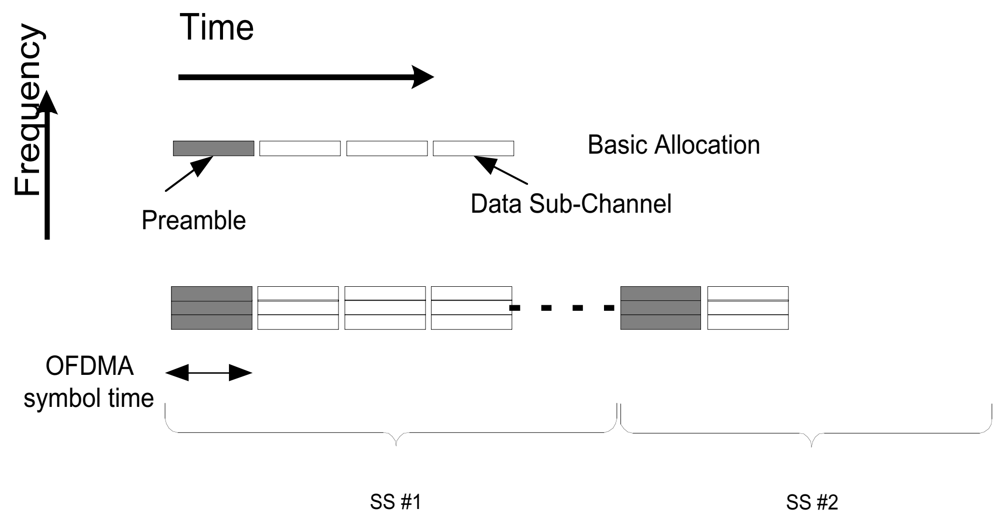


Figure 16. UL PHY Burst example

Figure 17 describes two different subscribers with different PHY Burst structures and profiles.

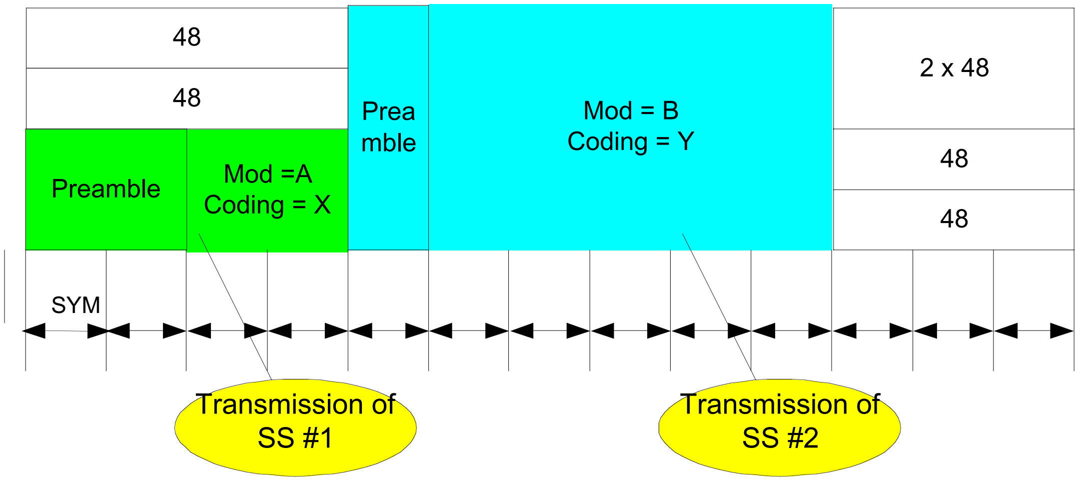


Figure 17. UL Burst Definition Example #1

Figure 18 describes two different subscribers with similar PHY Burst structure and with different profiles

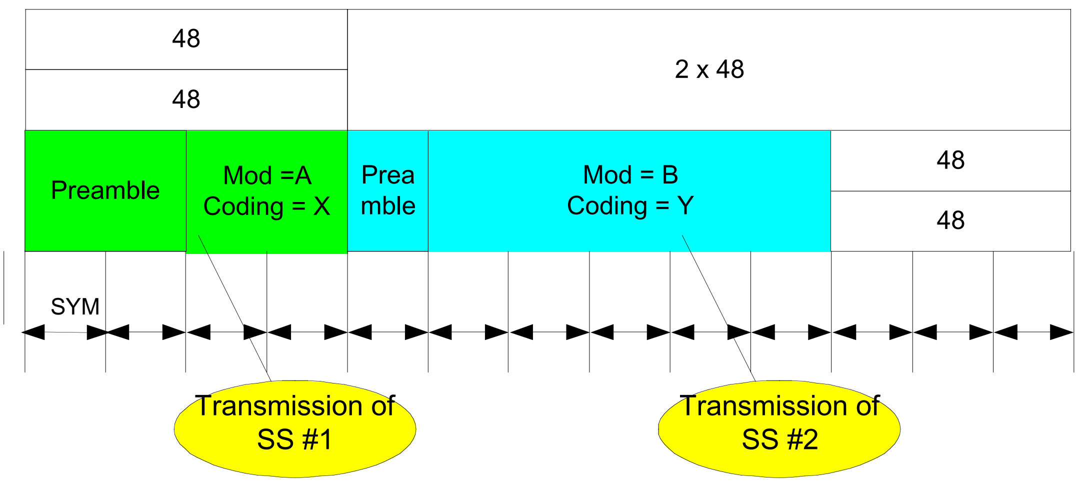


Figure 18. UL Burst Definition Example #2

5.1.2.3. DL Transmissions

The DL PHY Burst properties will be figured:

- In the MAC-PHY interface primitives
- In DCD message within Burst Profile TLV encodings
- In DL-MAP message, implicitly identified by DIUC.
- In the RNG-RSP or DBTC-RSP messages, implicitly identified by the Downlink Burst Type.

The set of DL PHY Burst parameters is specified in <Reference to OFDM PHY relevant section> and includes at least:

- Modulation type
- FEC type
- Tx Power

The forward adaptive profiles are relevant in the Bursty working modes (FDD-B and TDD).

The SS requests from the BS a specific DL PHY Burst type (using the DBTC-REQ or RNG-REQ messages), the BS will acknowledge the user with a downstream working mode (using the DBTC-RSP or RNG-RSP messages).

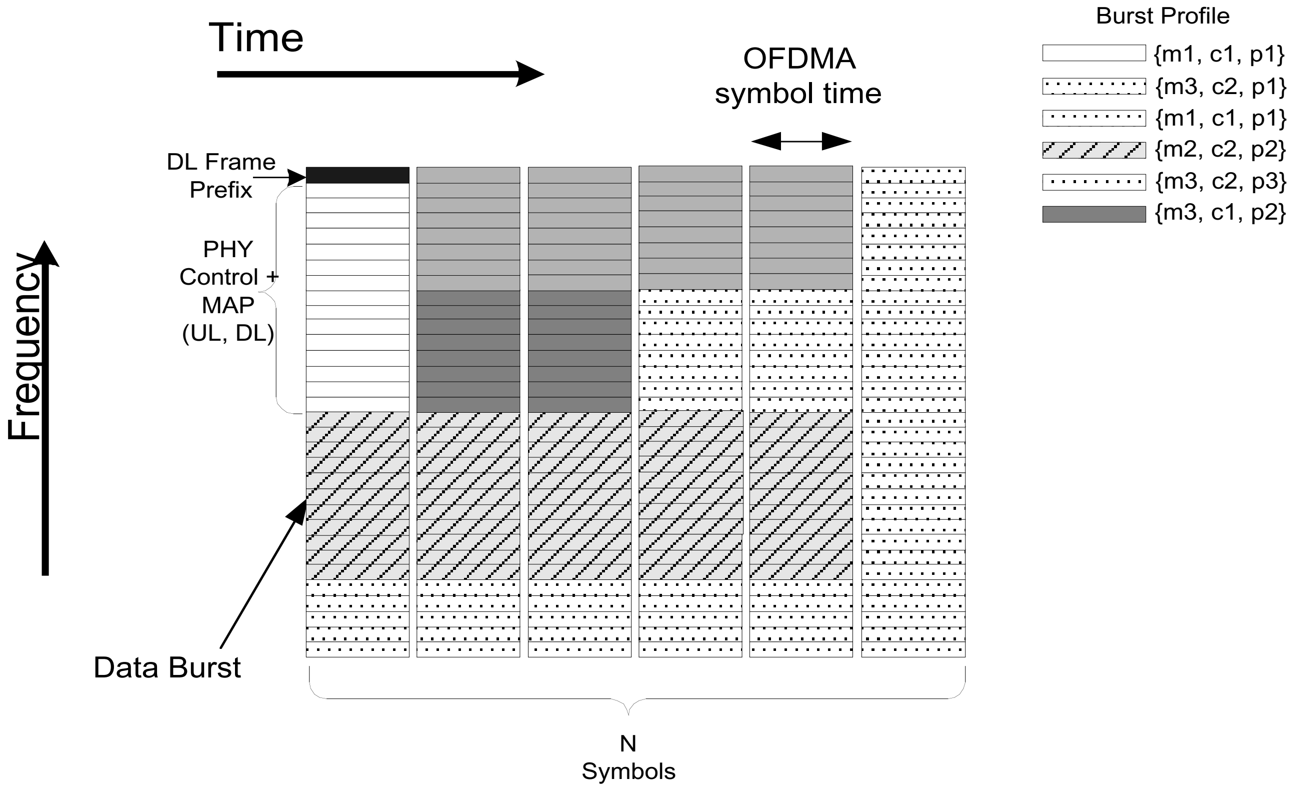


Figure 19. DL Period example #1

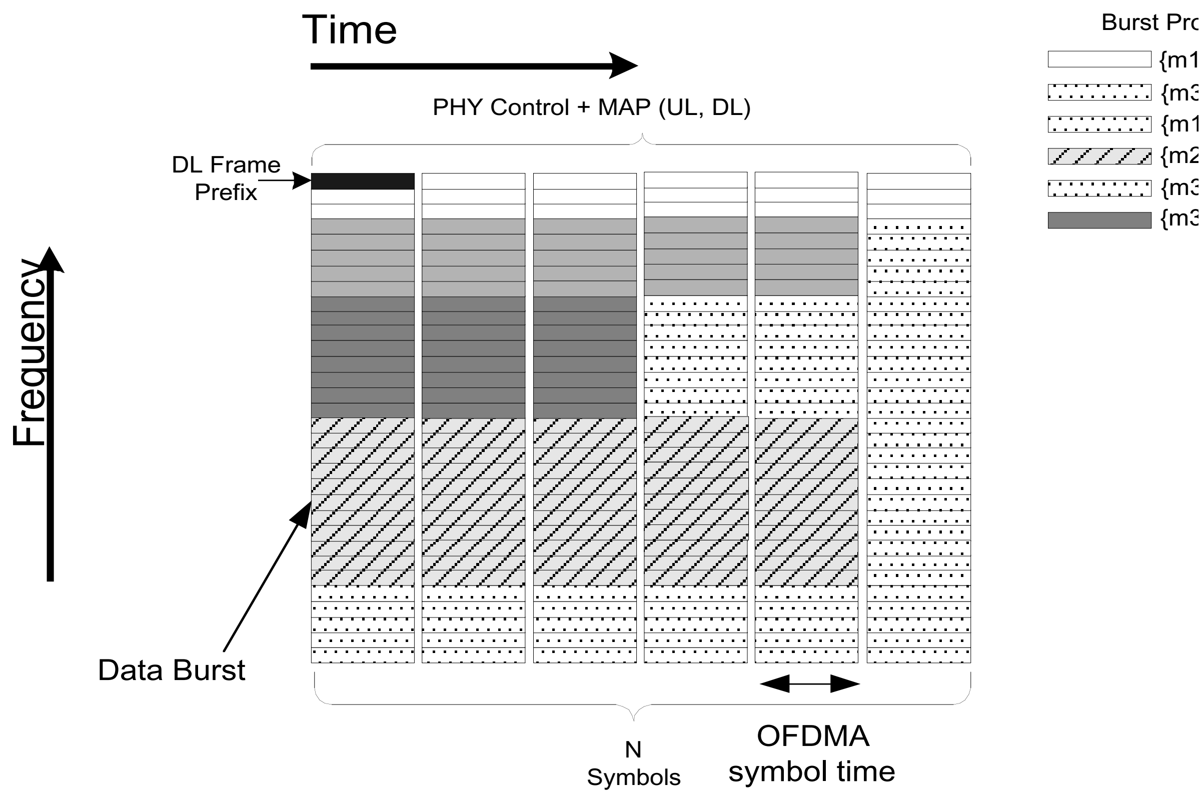


Figure 20. DL Period example #2

Figure 19 and Figure 20 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*.

DL Frame Prefix is one symbol long; it is transmitted at the well-known modulation/coding and occupies the well-known set of sub-carriers, e.g. the first N x 48 (for the FFT-64 always N = 1, for FFT-256 OFDM always N = 4 or For FFT-2048 OFDMA always N=1 etc.).

It contains the information on the modulation/coding and formation of the DL frame control information (DL\UL MAP messages) relevant to the next frame or to the same frame.

Figure 1 describes the structure of DL Frame Prefix:

0			23
Rate_ID (4)	Symbols (6)	Sub_Channels (6)	HCS(8)

Figure 1. DL Frame Prefix Structure

Rate_ID: Enumerated field that describes the transmission parameters of the DL\UL MAP messages.

Symbols: Number of time symbols dedicated to the DL\UL MAP message.

Sub_Channels: Number of sub-channels dedicated to the DL\UL MAP message.

HCS: An 8-bit Header Check Sequence used to detect errors in the DL Frame Prefix. The generator polynomial is $g(D)= D^8 + D^2 + D + 1$

DL Frame Prefix can contain also MAP message(s) (for FFT-512 for example, the full first symbol will contain the DL Frame Prefix and beginning of the DL\UL MAP messages) and the MAP PHY burst may contain also the data.

For the lowest modulation it is exactly 3 bytes.

The Combination of the fields *Symbols* and *Sub_Channels* defines the structure of the MAP message and position (relative to the top left entry of the DL frame). In the small FFT cases (OFDM modes) *Sub_Channels* field will always indicate full OFDM symbol.

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

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

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)		

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

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 21 describes the messages sequence for CDMA bandwidth request:

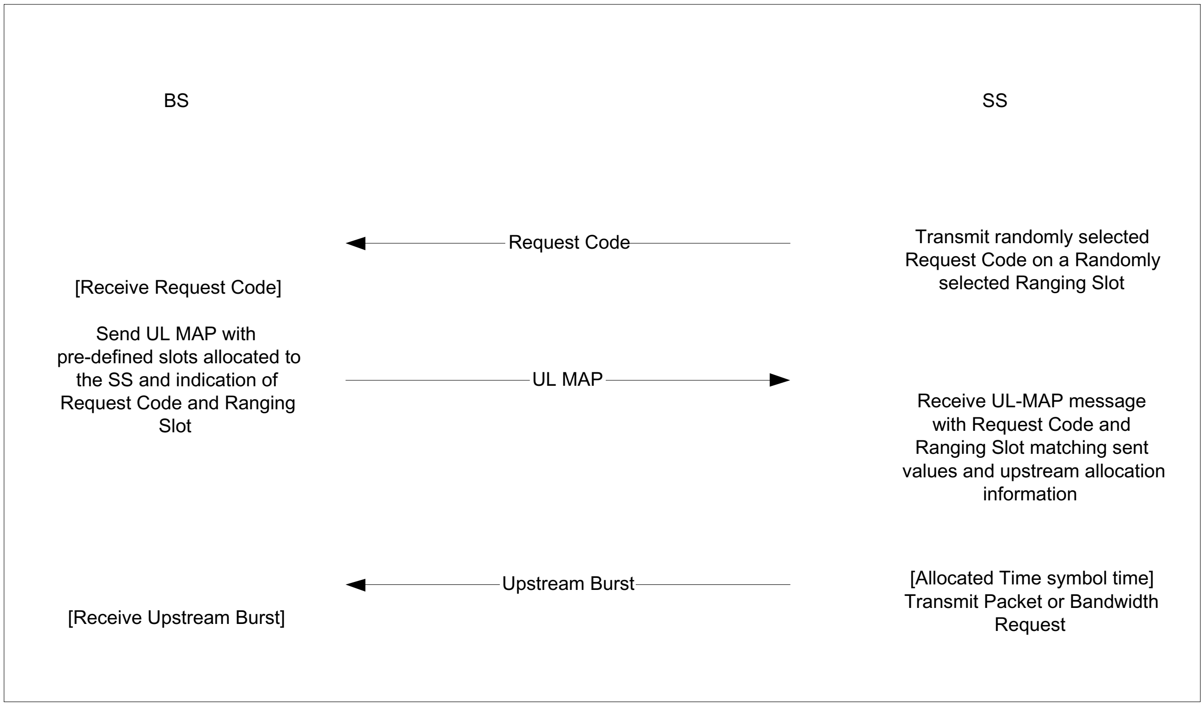


Figure 21. Bandwidth Request in high FFT modes

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 22 describes the messages sequence for this case:

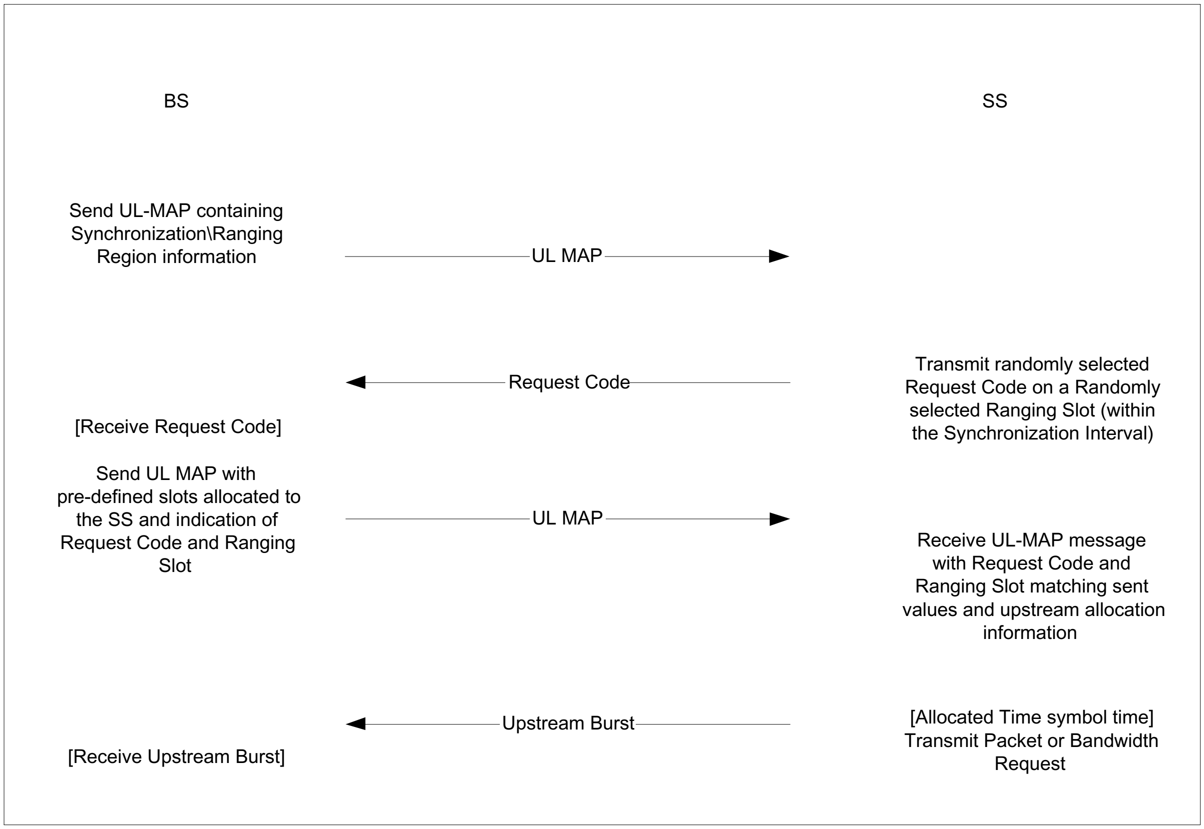


Figure 22. Bandwidth Request in small FFT modes

<<< 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:

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

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

Figure 23 shows the proposed Upstream MAP IE for the proposed new UIUC (as defined in Table 3)

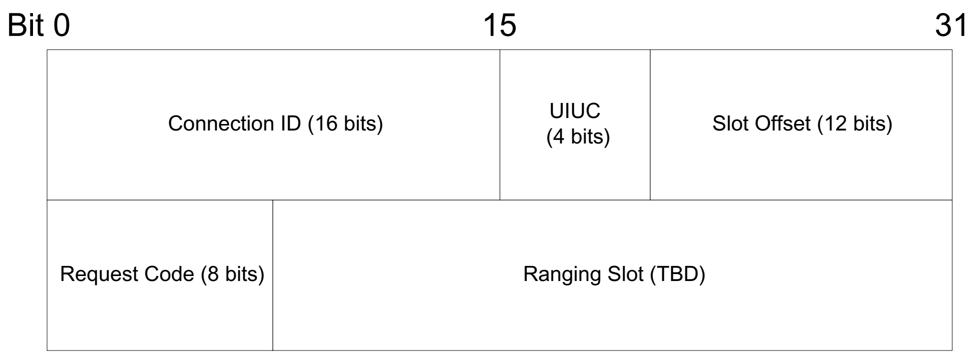


Figure 23. Proposed Upstream MAP IE structure for Request Code UIUC

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

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

<<< <<<<<<<<<<

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

Simulation Results

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

The conditions for the normal contention access assume that each request requires exactly one slot (if preamble should be required for each request, then the number of the transmission opportunities should have cut by half, and the results for the contention case would be worst). The simulation deals with one attempt (with window size of 10 slots), retransmission will improve both of the scenarios, better for the CDMA case.
Figure 24 describes the simulation results:

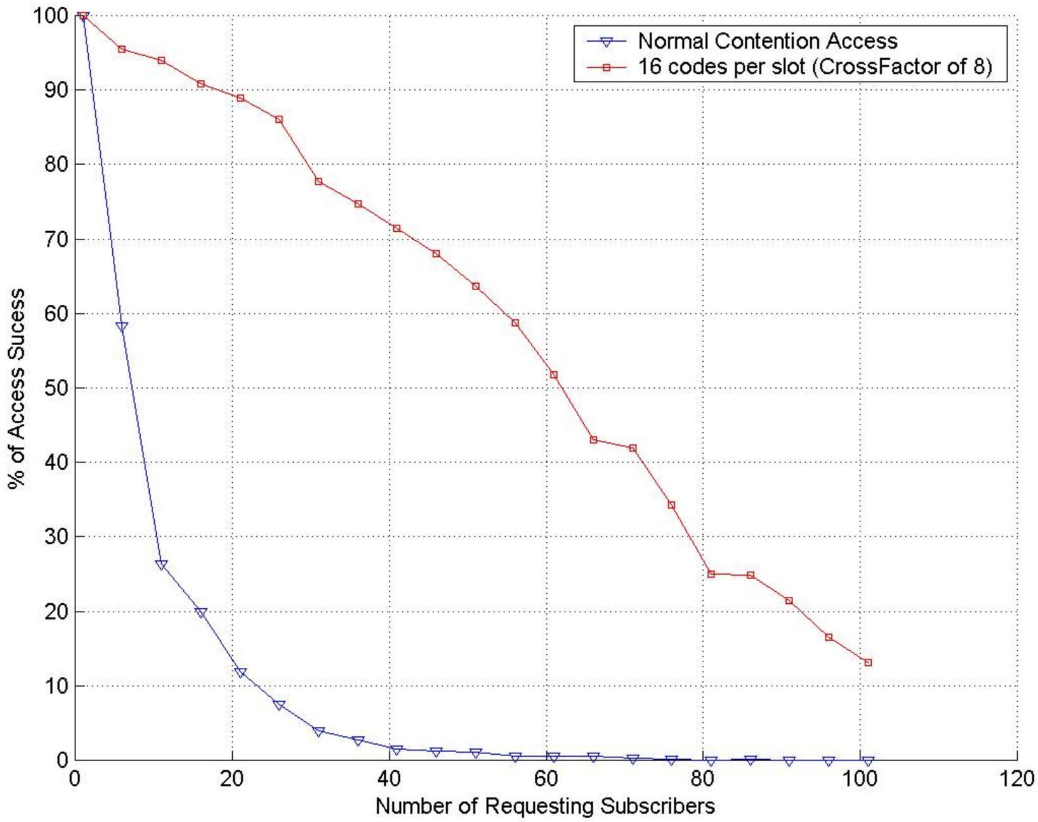


Figure 24.CDMA Request Vs. Contention Request for 10 time symbols

The X-axis defines the number of users sending requests, the Y-axis defines the access success in percentage.

As can be seen, for 10 users the contention access results with ~35% of success while the CDMA scheme results with ~95% of success. For 50 users the contention access drops down to only 1% of success while the CDMA access results with ~63% of success. The results clearly show that for one access attempt, the CDMA scheme is much better than the normal Contention scheme, adding backoff exponential retry algorithm will improve the results for both cases but will introduce side effects such as latency and jitter.

The results show that for dense cells with more then 20 simultaneous contention requests, in normal Random Access window of 10 slots, the probability to fail at first request is about 90% while in the CDMA access with same conditions, the probability to fail is about 10%.

>>

<<<<< References lists of all the sections will be integrated together >>>

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>>>

The basic allocation unit (e.g. slot) is a combination of a time symbol and a sub-channel. The <<< current >>> OFDMA (OFDM) based PHY <<< proposals >>> define several working modes, those modes define two upstream access schemes:

1. Each OFDMA (OFDM) symbol will carry either data or ranging slots
2. Each OFDMA (OFDM) symbol will carry both data and ranging slots

_ _Figure 25 and Figure 26 illustrate the concept of access scheme 1

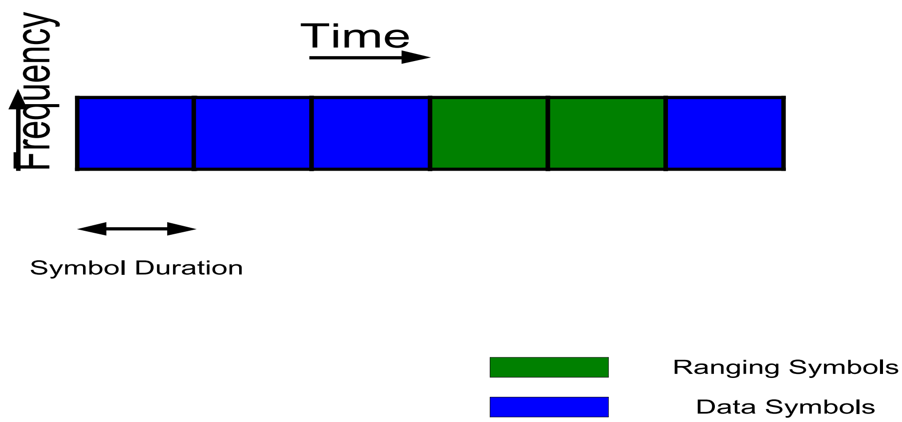


Figure 25. OFDMA Symbols carrying either Ranging or Data slots — General Concept

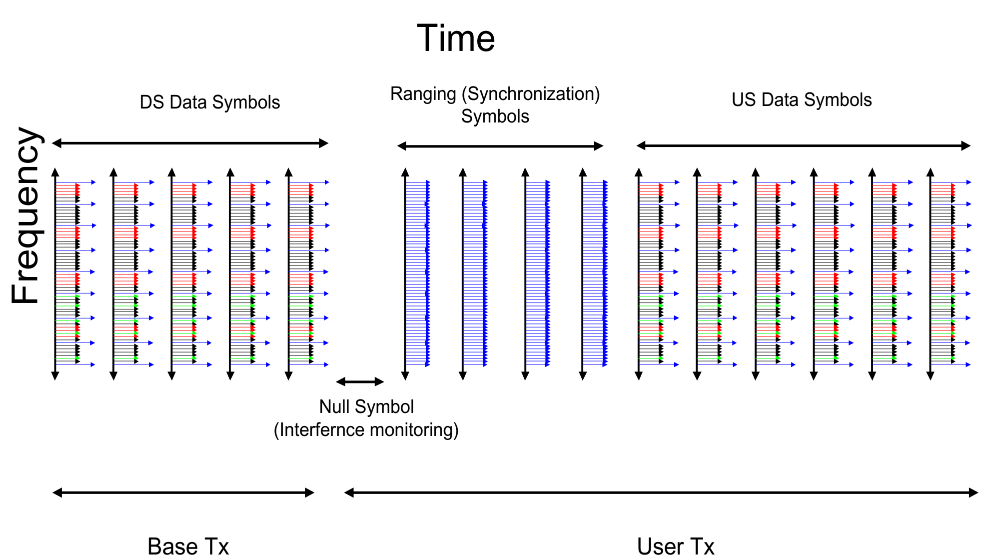


Figure 26.OFDMA Symbols carrying either Ranging or Data slots — In TDD mode

_Figure 27 and Figure 28 illustrate the concept of access scheme 2

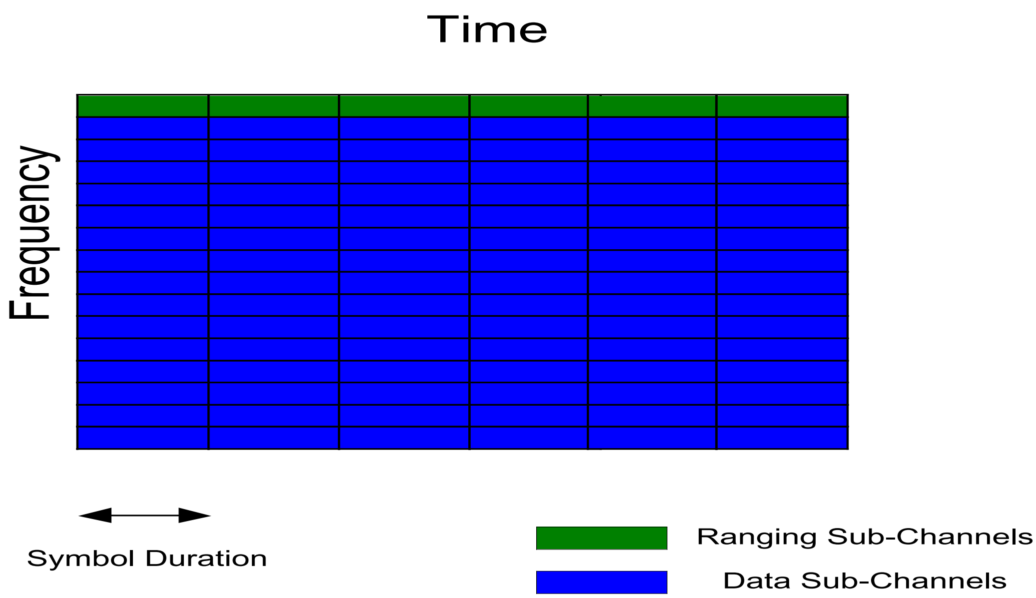


Figure 27. OFDMA Symbols carrying both Ranging and Data slots — General Concept

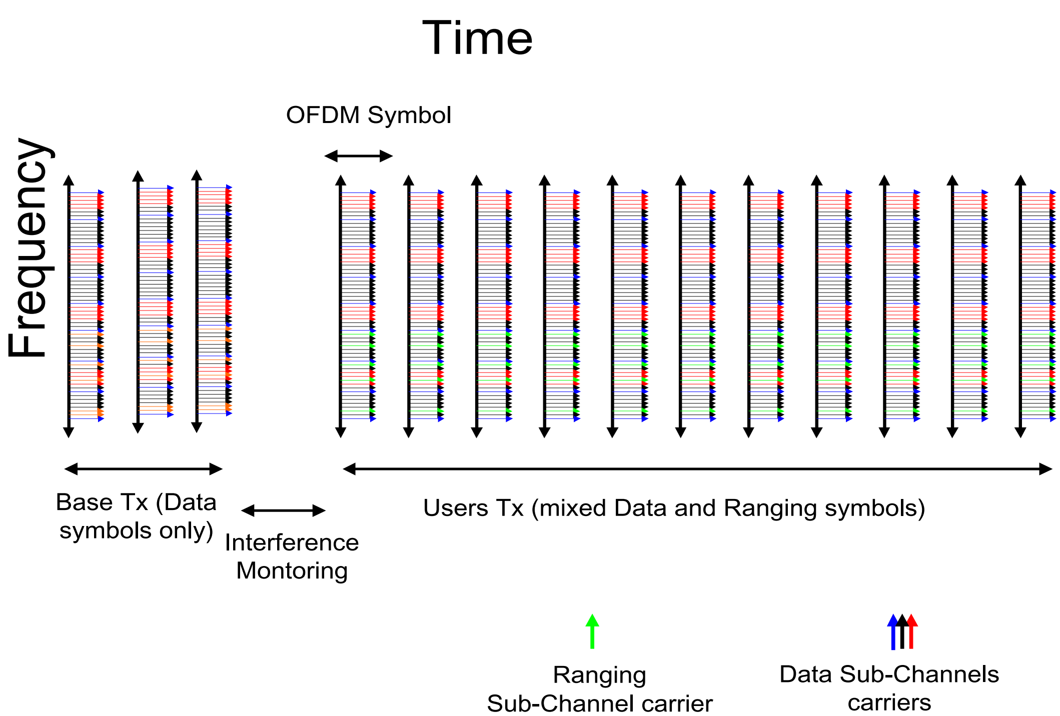


Figure 28. OFDMA Symbols carrying both Ranging and Data slots — In TDD mode

Each user that wants to perform ranging will choose randomly a PN sequence from a pre-defined set of PN sequences (16 different sequences) and will modulate (with a pre-defined robust modulation scheme, i.e. BPSK) it on a pre-defined set of carriers. The randomly chosen PN is referred as *Ranging Code*.

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

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

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

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

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

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

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

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

The following message flow charts (_Figure 29 and Figure 30) describe the ranging adjustments process in the two access mode.

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

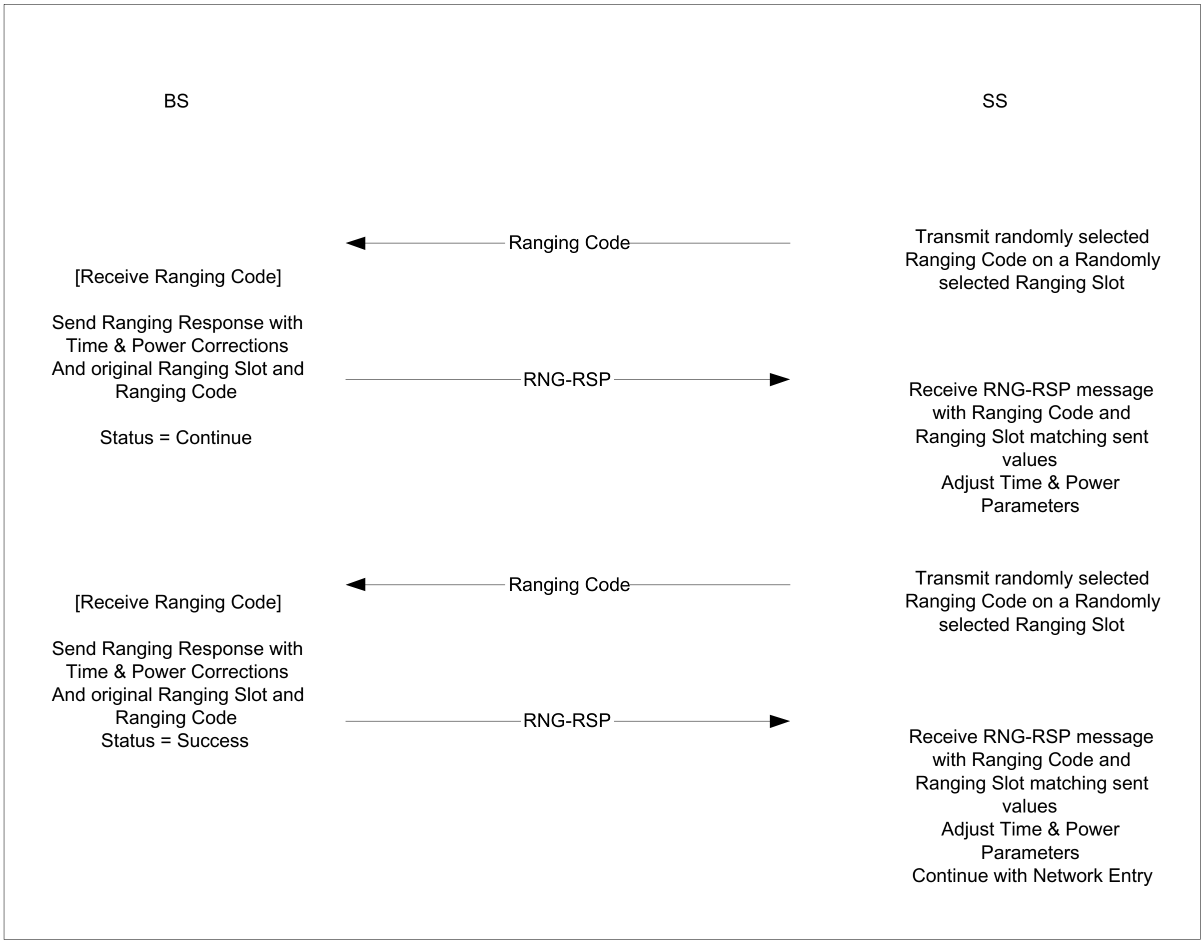


Figure 29. Ranging and Automatic Adjustments procedure for Access Scheme 2

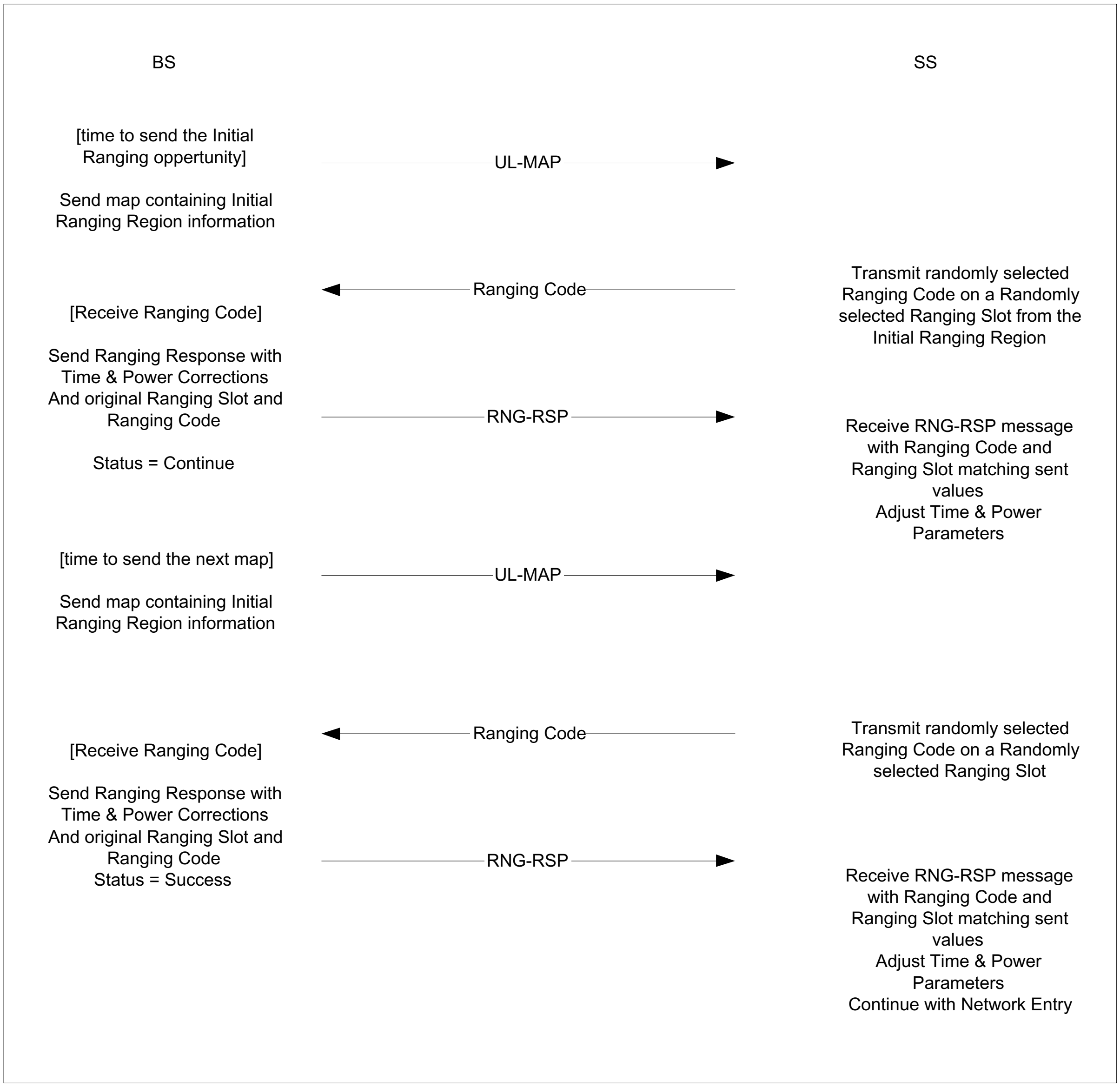


Figure 30. Ranging and Automatic Adjustments procedure for Access Scheme 1

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<<< Proposed Modifications to the 802.16.1 MAC >>>

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

5.3.3.1. Ranging region <<< indication >> Definition

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

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. Power Control (Subir, John)

[Editorial Group: Subir, John]

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

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

8. Support for Advanced Antenna Technology

[Editorial Group: Einan, Huan Chun, John]

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

8.1. Architectural Overview

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. Definitions

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.

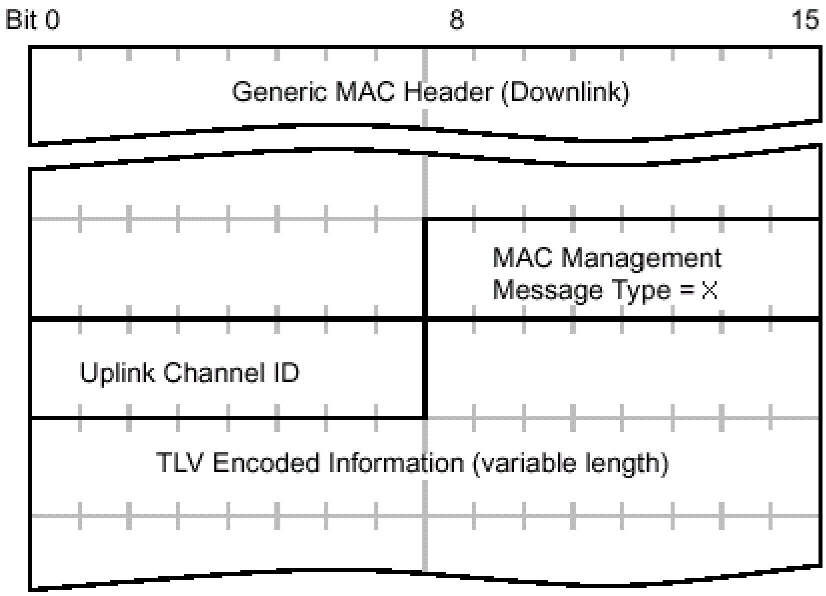

Figure 3: CSF-REQ message

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

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

- Frequency adjust information
- Power adjust information
- Timing adjust information

8.5.2. CSF-REP message

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

Note:

The value of CEI shall be predefined according to channel stability over time (a typical value is 20 msec), The BS is responsible to determine the actual value of CEI, and for the distribution of this value to all SSs.

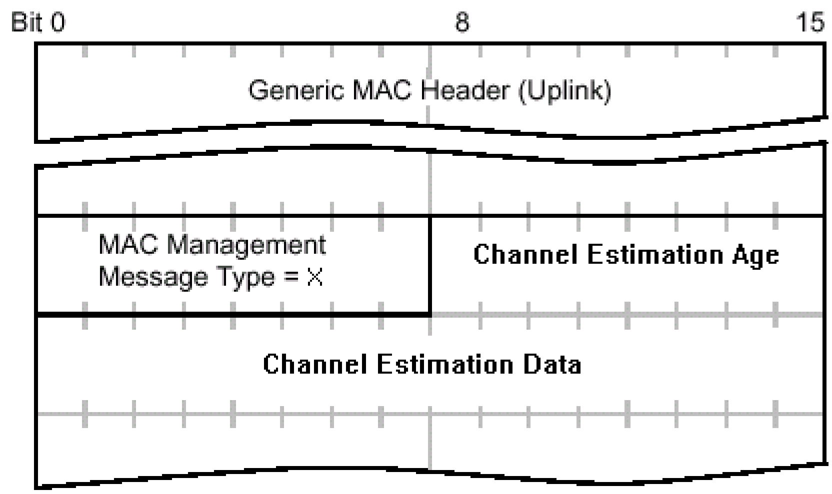

Figure 4: CSF-REP message

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