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Title	**MAC-PHY Interface for TG3**	
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Re:	This document is contributed to the TG3 and TG4 MAC drafting teams	
Abstract	This document proposes enhancements to the TG1 MAC-PHY interface, in order to make it more suitable for use in TG3 systems.	
Purpose	Update the TG3 and TG4 MAC draft	
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MAC-PHY Interface

1.0 Choice of Time Base

The time base definition in the TG1 specification is as follows (Section 6.2.2.3.1 of 802.16.1/D1):

The available bandwidth in both directions is defined with a granularity of one PHY slot (PS), which is at a multiple of 4 modulation symbols each. The upstream bandwidth allocation MAP (UL_MAP) uses time units of mini-slots . The size of the mini-slot is specified as a number of PHY slots (PS) and is carried in the Physical Channel Descriptor for each upstream channel. One mini-slot contains N PHY slots, where $N = 2^m$*, (where m = 0...7). The additional BS time resolution (that is needed for distance ranging), is given by (Symbol Time/4)*

There are several issues that arise with this definition of the time base:

¥ As has been pointed out in [1], a single OFDM symbol can carry hundreds of bytes of data. Hence by specifying that the smallest time unit is 4 symbols, it forces the smallest transmission unit to contain a large amount of data, and also forces a very coarse level of granularity on all transmissions. This leads to waste of bandwidth and system in-efficiency.

¥ The size of the additional BS time resolution is a function of the symbol time. Once again, for OFDM systems this scheme does not work very well. For example, if the symbol time is 50 us, then the time resolution is 12.5 us, which is too coarse to do any meaningful distance ranging.

In order to resolve these issues, we propose the following alternative time base definition:

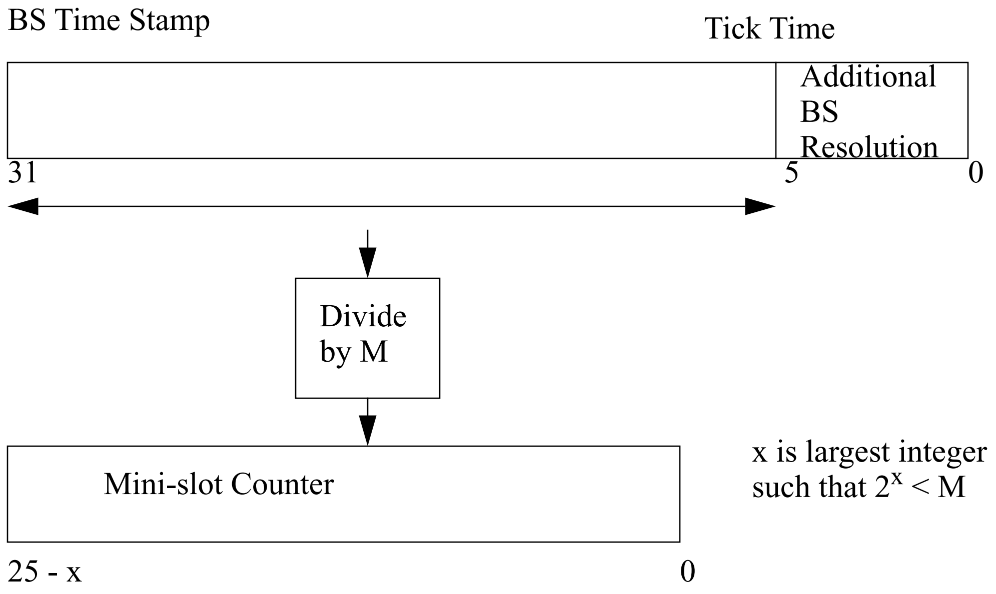


FIGURE 1.

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 BS uses a 32 bit counter, of which the most significant 26 bits are used to count the ticks. 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 accomodate a wide range of symbol rates, it is important not to contrain M to be a power of 2.

This new definition of time base resolves the problems mentioned above:

¥ 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.

2.0 Minislot Numbering and Flexible Scheduling

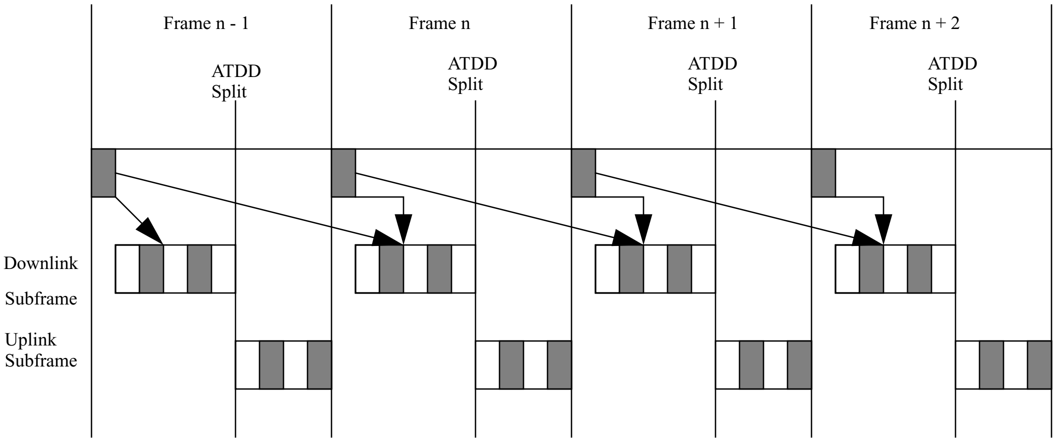


FIGURE 2. MAP relevance for burst PHY systems

In order to synchronize the clocks in the BS and the CPEs, the BSC periodically broadcasts a timestamp to all SSs. For the FDD case in the current TG1 specification, the timestamp is inserted in the DL-MAP message. The SS recovers the BS clock using this timestamp, and this also enables it to synchronize its mini-slot count with that of the BS. Note that the mini-slot count spans multiple frames in this case.

However for the TDD and HD-FDD case, there is no mechanism specified for sending the timestamp. Also the mini-slot count is reset at the start of every frame. The implication of this design is that it should be possible for the SS to achieve clock synchronization with ths BS, without the use of periodic timestamps from the BS. This design should work in principle (albeit with a different PLL implementation at the CPE), however it leads to a loss of scheduling flexibility in certain cases, for example:

- The UL-MAP and DL-MAP packets are restricted to describing the frame in which they are sent: If the mini-slot count is not reset in every frame, then the MAP packets can describe parts of the next frame as well. Such a design can reduce the real time processing requirement at the CPE.
- The Acknowledgement Time field in the UL-MAP is restricted to refer to a time instant in the previous frame: This also imposes a real time constrant on the BS scheduler that it be invoked in the previous frame. If the scheduler is implemented in software, then this requirement may be difficult to meet. If the mini-slot count is not reset in every frame, then the ACK Time can describe a time instant that is further in the past, which will remove this constraint.

We propose that TDD and HD-FDD systems employ the same timestamp based synchronization scheme that is employed by FDD systems. These timestamps are broadcast by the BS to all the SS, in a special SYNC packet, rather than in the DL_MAP packet. We also propose that the TDD and HD-FDD systems employ a running mini-slot count, rather than resetting it in every frame. These changes will lead to a common PLL design for FDD and TDD systems, and also increase the scheduling flexibility of the system.

As shown in Figure 4, the portion of the time axis decribed by a MAP is a contiguous area whose duration is equal to the size of a frame. In the example shown in Figure 4, it consists of a portion of the downstream time of the frame in which 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, and when set to zero, corresponds to the Minimum Time Relevance scenarion in Figure 56 of the TG1 specification. Note that with this design, it is no longer necessary to use a pre-defined set of frame sizes, but it can be changed under the control of the scheduler.

3.0 MAP Packet Related Issues

The TG1 specification defines downstream MAP IEs for the TDM case (Figure 15 of the TG1 specification), but not for the TDMA case. We complete the picture by defining MAP IEs for the TDMA case in Figure 13 of this contribution.

The TG1 specification uses 2 different MAP packets, namely the DL-MAP to describe the downstream and the UL-MAP to describe the upstream portions of the frame. This main advantage of this structure is that it allows FDD systems in which there is a single downstream channel coupled with multiple upstream channels.

For TDD and HD-FDD systems, there is currently an assymetry in the specification of the downstream and upstream bursts. Upstream bursts are defined in the UL-MAP message , while downstream bursts are defined in the DL-MAP message. This design has the following drawbacks:

- The location of upstream bursts is specified using mini-slot numbering, while the location of the downstream bursts is specified using physical slot (PS) numbering. This forces the MAP parser to use two different techniques for locating bursts. It would simplify things if the mini-slot based numbering was used to locate both upstream and downstream bursts.
- The identity of the Connection ID is specified only for upstream bursts, but not for downstream bursts. This forces the SS to receive and decode every downstream burst, which means that the BS is forced to transmit every downstream burst with maximum power so that it gets to every SS. This situation can be improved if the connection ID is also specified for downstream bursts. Thus the SS can then turn on its receiver only when it needs to receive a burst that is addressed to it. This will also allow the BS to vary the downstream power as a function of the SS to which the burst is going to, thus reducing the amount of interference.

If the above suggestions are accepted, then there is no need to have two different MAP, messages, indeed the UL-MAP and DL-MAP messages can be consolidated into a single MAP message. Thus will avoid the extra overhead associated with the transmission of two packets vs one.

Specific Changes to the TG1 Draft

4.0 MAP Messages

4.1 Downlink MAP (DL-MAP) Message

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

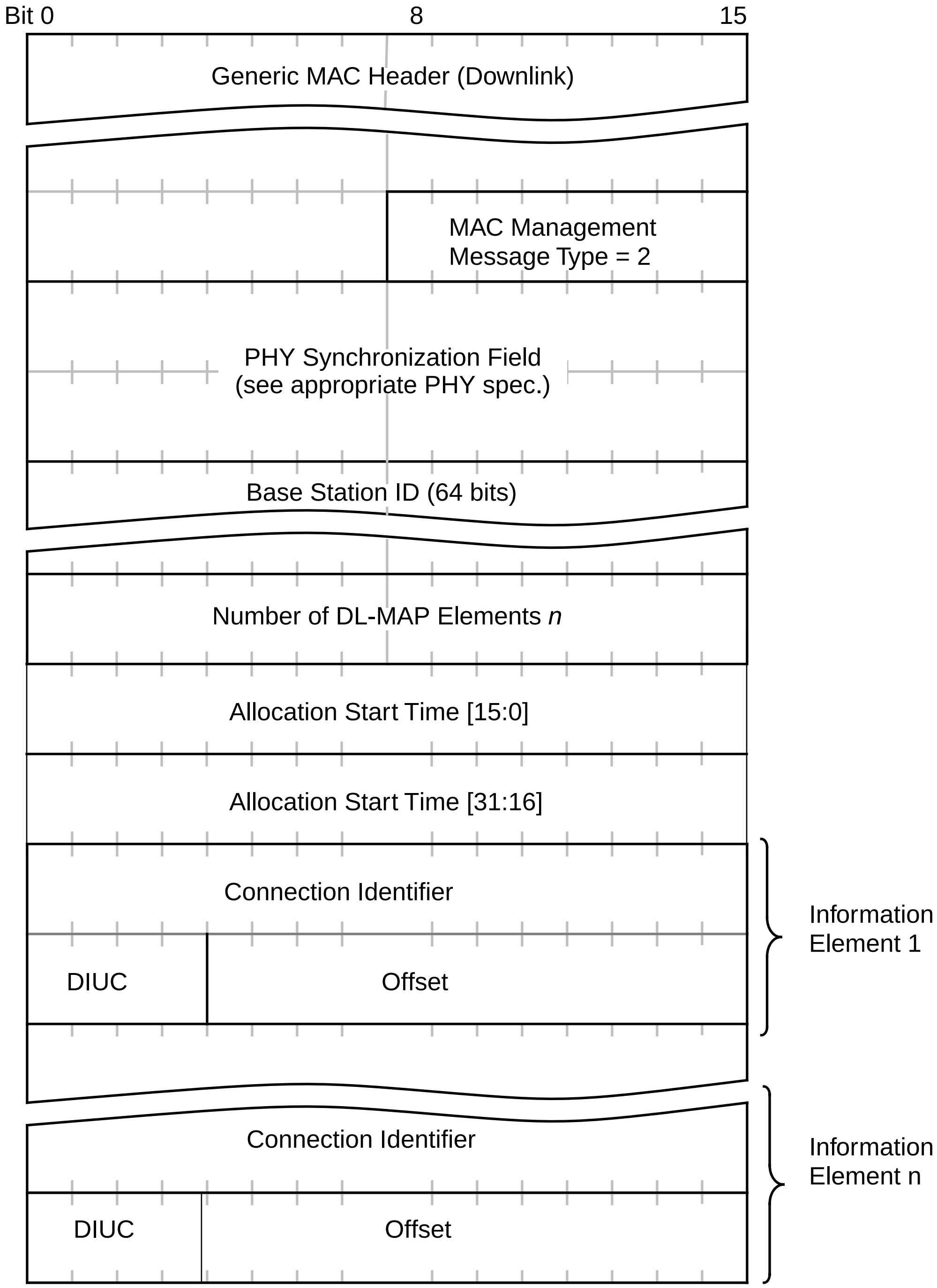

Bit 0
8
15
Generic MAC Header (Downlink)
MAC Management Message Type = 2
PHY Synchronization Field (see appropriate PHY spec.)
Base Station ID (64 bits)
Number of DL-MAP Elements *n*
Allocation Start Time [15:0]
Allocation Start Time [31:16]
Connection Identifier
DIUC
Offset
Information Element 1
Connection Identifier
DIUC
Offset
Information Element n

FIGURE 3.

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.

4.2 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 Figure 28.

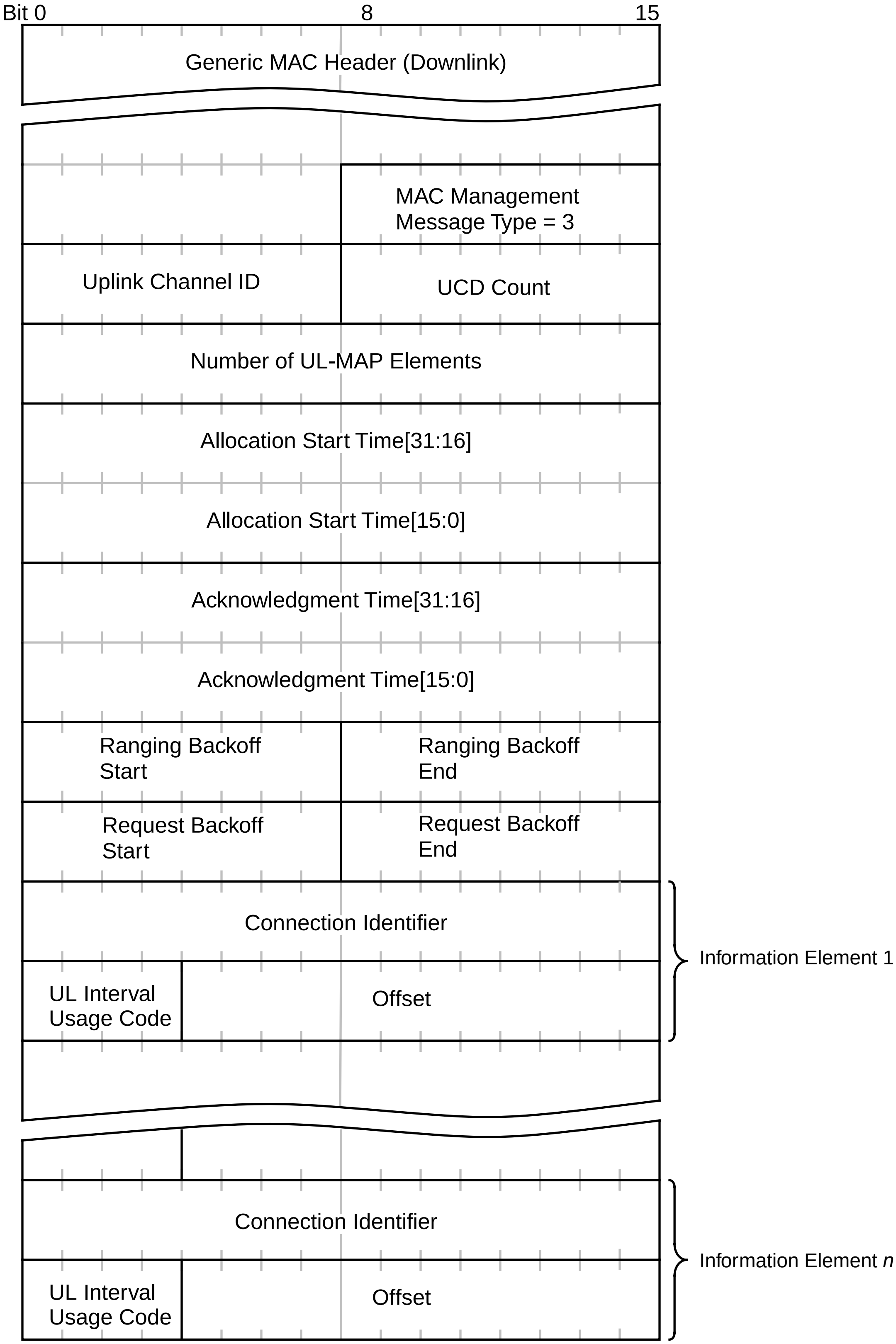

Bit 0
8
15
Generic MAC Header (Downlink)
MAC Management Message Type = 3
Uplink Channel ID
UCD Count
Number of UL-MAP Elements
Allocation Start Time[31:16]
Allocation Start Time[15:0]
Acknowledgment Time[31:16]
Acknowledgment Time[15:0]
Ranging Backoff Start
Ranging Backoff End
Request Backoff Start
Request Backoff End
Connection Identifier
UL Interval Usage Code
Offset
Information Element 1
Connection Identifier
UL Interval Usage Code
Offset
Information Element *n*

FIGURE 4.

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.

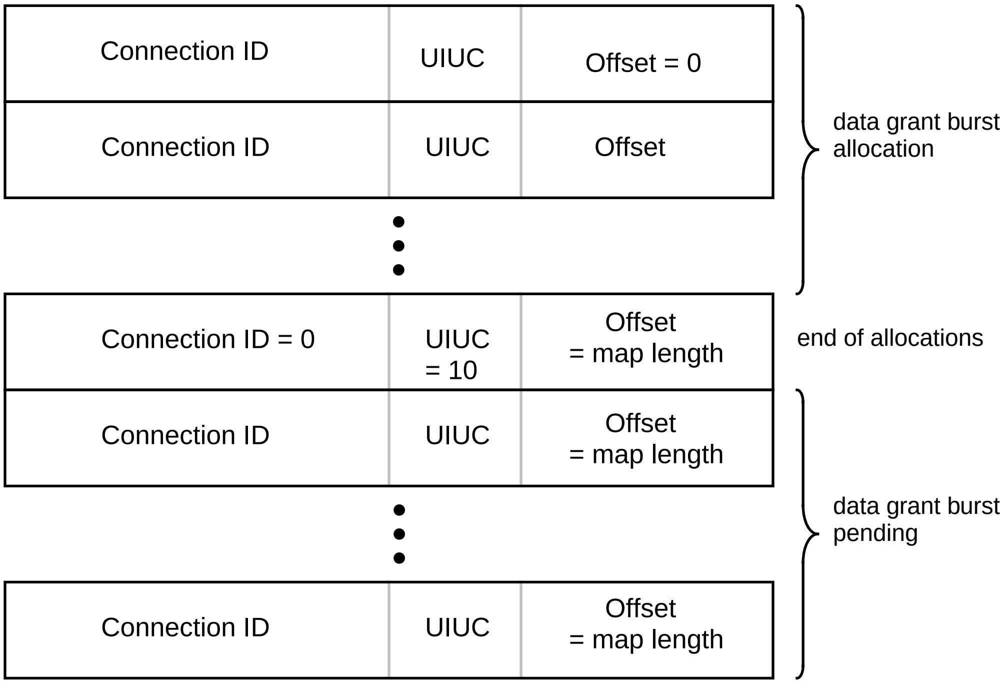


FIGURE 5.

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

4.3 Uplink + Downlink MAP

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

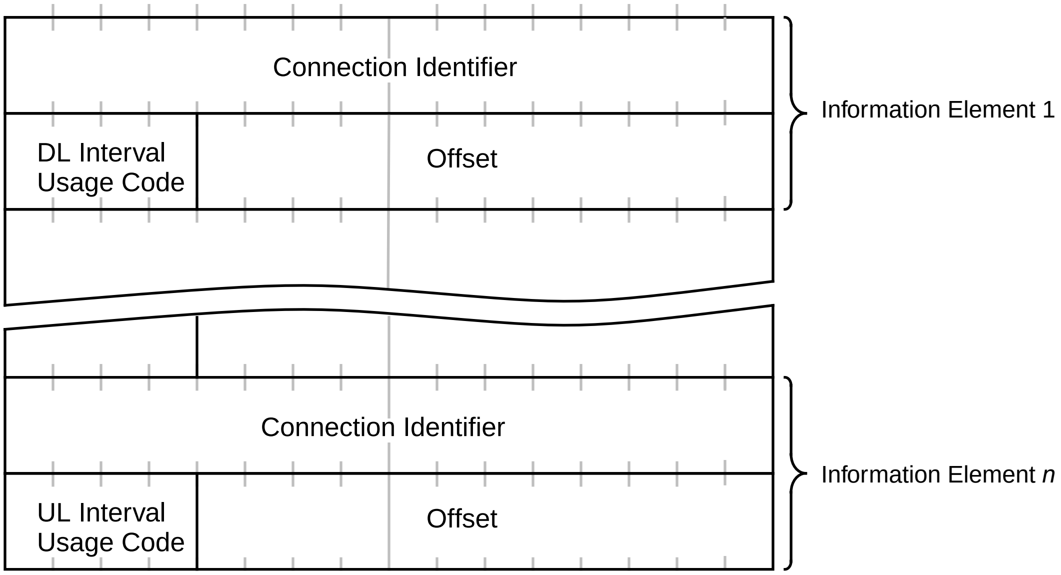


FIGURE 6.

5.0 MAP Relevance and Synchronization

5.1 MAP Relevance for Burst PHY Systems

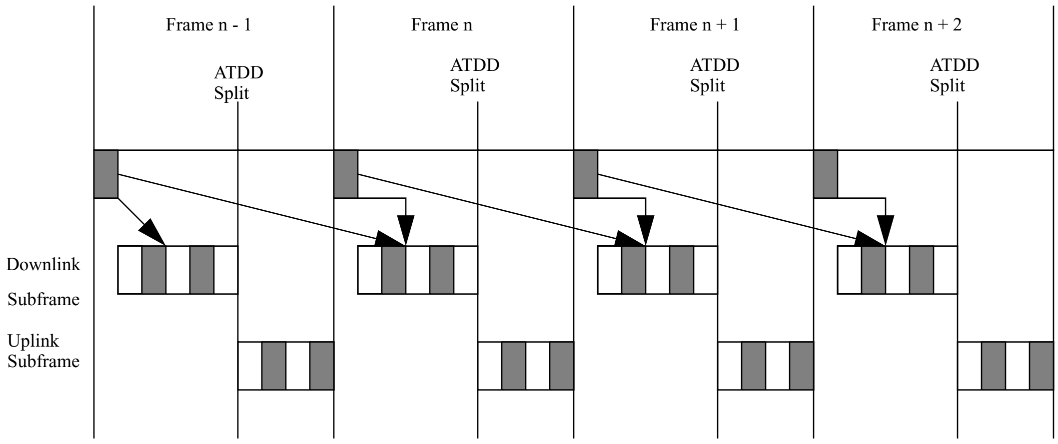


FIGURE 7. Maximum Time Relevance of PHY and MAC Control Information (TDD)

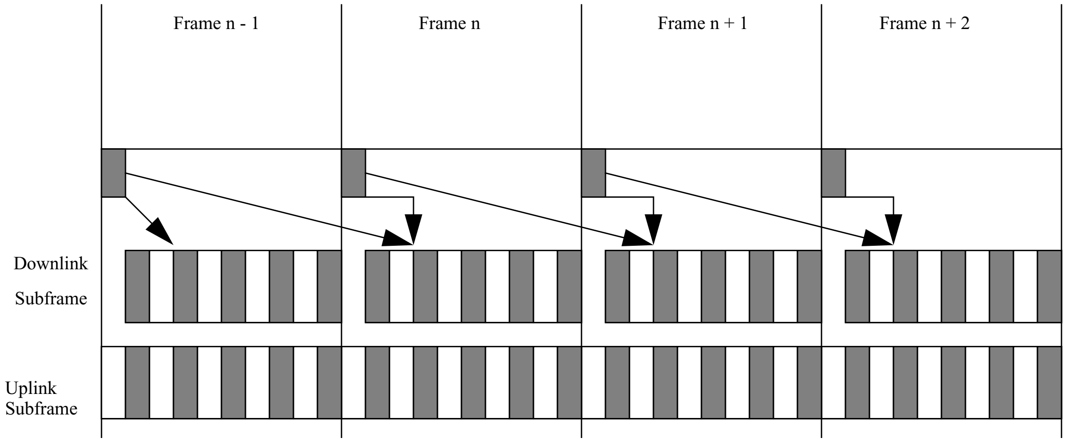


FIGURE 8. Maximum Time Relevance of PHY and MAC Control Information (FDD)

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.

6.0 Physical Layer for 10 - 66 GHz: Data/Control Plane

6.1 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).

6.1.1 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.

6.1.1.1 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.

6.1.1.2 Mode B (Burst Downlink)

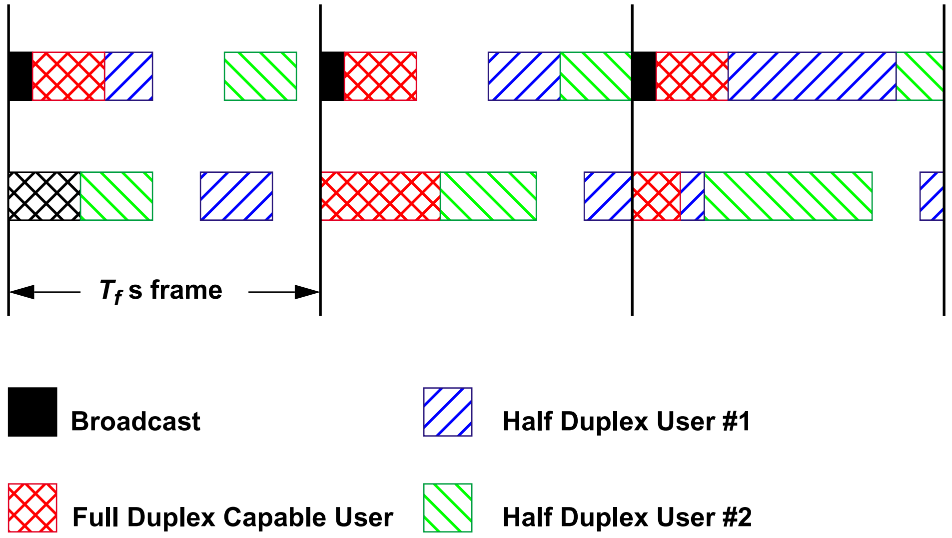


Figure 9—Example of Burst FDD Bandwidth Allocation

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.

6.1.1.3 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.

6.2 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.

6.2.1 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.

6.2.1.1 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 minislots is defined by the UL-MAP message, and can change according to the needs of the system. Mode A is capable of adaptive modulation..

6.2.1.2 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.

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

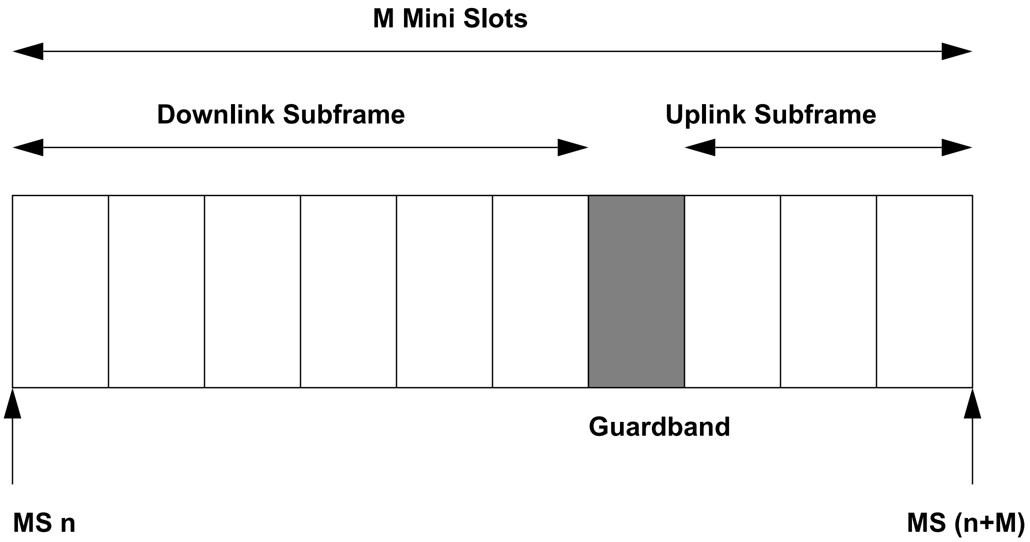


FIGURE 10.

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.

6.2.1.3.1 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.

6.2.1.3.2 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.

6.2.1.4 Mode B: Downlink Data

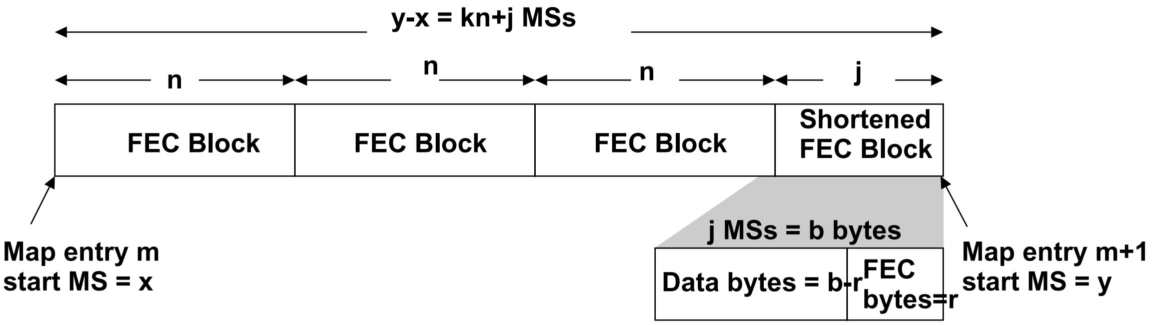


Figure 11—Downlink Map Usage and Shortened FEC Blocks

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.

6.2.2 Uplink Burst Subframe Structure

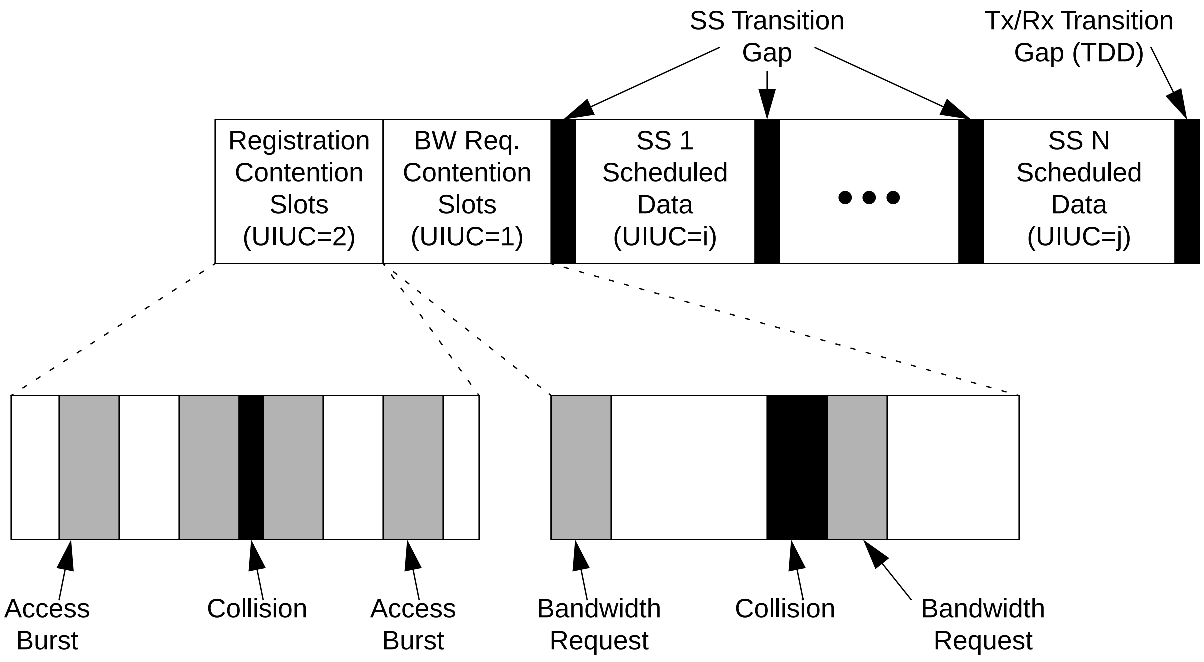


Figure 12—Uplink Subframe Structure

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.

6.2.2.1 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 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

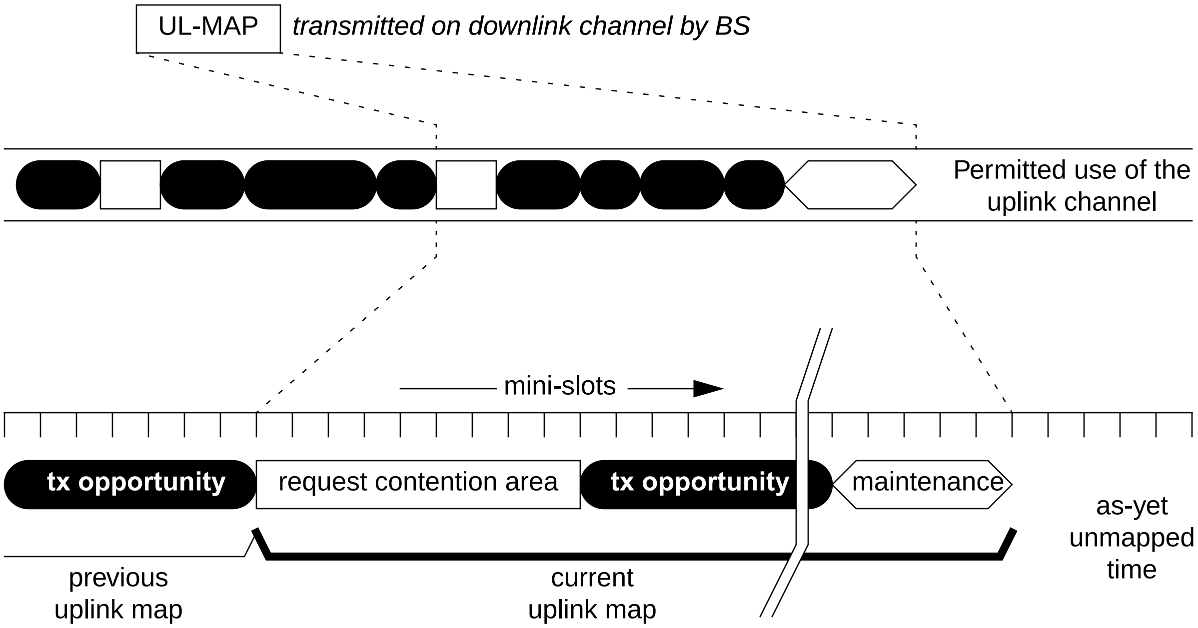


Figure 13—Uplink Mapping in the Continuous Downstream FDD Case

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.

6.2.3 PHY SAP Parameter Definitions

TBD

6.2.4 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.

6.2.4.1 Physical layer type (PHY type) encodings

The the value of of the PHY type parameter (11.1.2.1) as defined must be reported as shown in Table 2.

Table 2—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

6.2.4.2 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.

6.2.4.3 Downlink Mode A: Message field definitions

6.2.4.3.1 Downlink Mode A: Required channel descriptor parameters

The following parameters shall be included in the UCD message:

TBD

6.2.4.3.2 Mode A: Required DCD parameters

The following parameters shall be included in the DCD message:

TBD

6.2.4.3.2.1 Downlink Mode A: DCD, Required burst decriptor parameters

TBD.

6.2.4.3.3 Mode A: DL-MAP

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

6.2.4.3.3.1 Mode A: DL-MAP PHY Synchronization Field definition

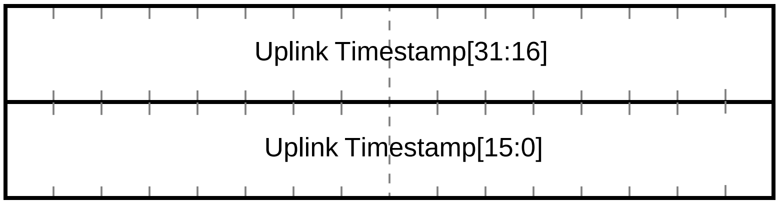


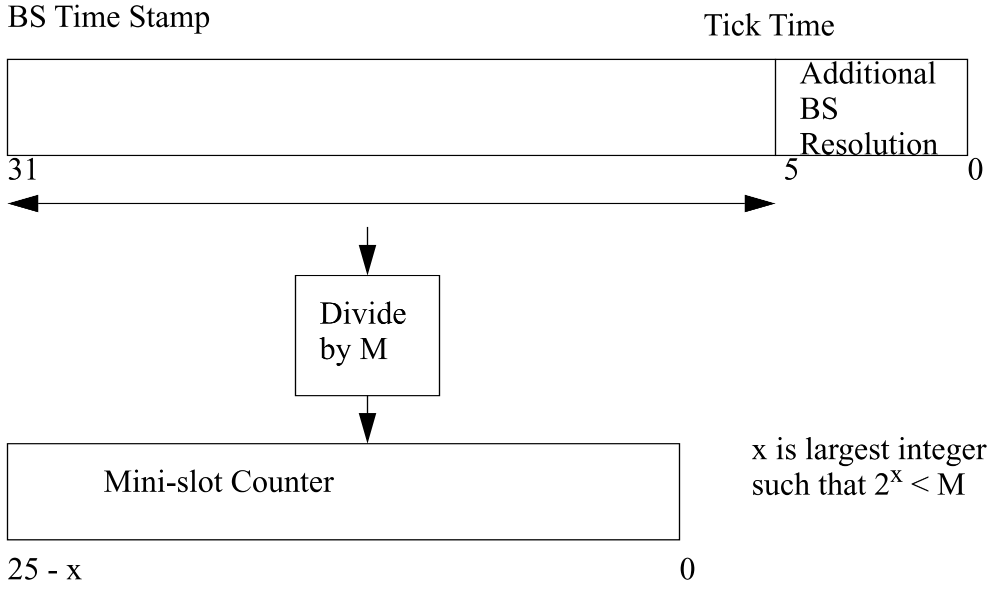
Figure 14—PHY Synchronization Field (PHY Type = 2)

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:

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

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.

6.2.4.3.4 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.

6.2.4.3.5 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.

6.2.4.4 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.

6.2.4.4.1 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.

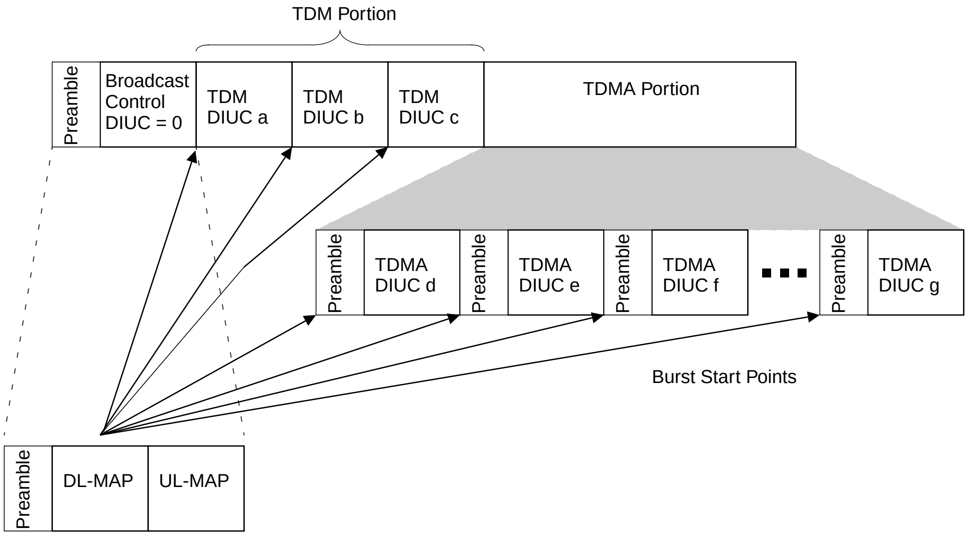


Figure 15—Mode B Downlink Subframe Structure

6.2.4.4.2 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.

6.2.4.4.3 Downlink Mode B: Required DCD parameters

The following parameters shall be included in the DCD message:

TBD

6.2.4.4.3.1 Downlink Mode B: DCD, Required burst decriptor parameters

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

TBD

6.2.4.4.4 Downlink Mode B: Required UCD parameters

The following parameters shall be included in the UCD message:

TBD

6.2.4.4.5 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.

6.2.4.4.6 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 3— 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

6.2.4.4.7 Mode B: DL-MAP PHY Syncronization Field definition

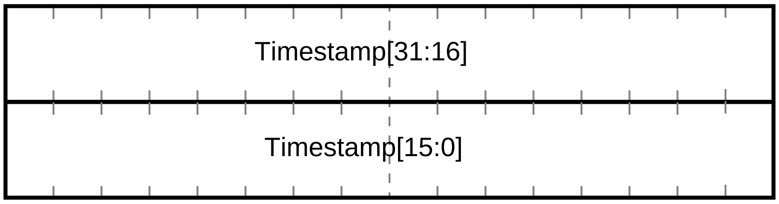


Figure 16—PHY Synchronization Field (PHY Type = {0,1})

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:

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

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6.2.4.4.8 UL-MAP Allocation Start Time definition

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6.2.4.4.9 UL-MAP Ack Time definition

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