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Source(s)	Subir Varma Aperto Networks 1637 South Main Street Milpitas, CA 95035 Voice: (408) 719 9977 Fax : (408) 719 9970 mailto:svarma@apertonet.com
Re:	IEEE 802.16.1/D1-2000, December 2000
Abstract	The objective of this contribution is to comment on certain aspects of the TG1 MAC protocol, from the point of view of its suitability for TG4.
Purpose	
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Modifications to the TG1 MAC for Use in TG4 Systems

Subir Varma

Aperto Networks

1.0 Introduction

The proposed TG1 Wireless MAC protocol [2], has two main parts:

- The Wireless Transport Layer which is responsible for the actual transfer of bits from one end of the wireless link to the other. Topics such as encapsulation of higher layer packets, ARQ, Request-Grant mechanisms in the upstream time base management and frame level control fall within its boundaries.
- The Wireless Link Management Protocol, which is responsible for overall control of the wireless link itself. Topics such as system initialization, encryption, flow management, registration, security etc. fall within its boundaries.

The current TG1 MAC protocol is quite adequate for TG3 in the area of the Link Management Protocol, but lacks several features that are essential for a wireless transport operating in the lower frequency bands. The sub-11 GHz bands have the following characteristics that are not found in the higher bands:

- The wireless link is subject to larger delay spreads and thus a higher degree of multipath related fading, as opposed to the higher bands that are affected more due to longer term fading caused by environmental factors. This has obvious implications on the PHY layer, but even the MAC layer needs to be more agile, and have the ability to recover quickly from transient channel error conditions.
- There is a greater degree of co-channel interference due to the fact that the wireless signals propagate farther in the lower bands. The actions taken by the wireless transport layer have a profound effect on the amount of interference that is caused by a transmitter, as well as techniques that the system can use to recover from interference.
- The system is oriented more towards residential and SOHO markets, so that each wireless channel has to support a large number of users, each of whom may be generating sporadic traffic, with low long term average bit rate. Web Surfing would be dominant application running on these systems, so the protocol should be able to handle the traffic generated by TCP applications efficiently.

The suggestion made in this contribution is to adopt the current TG1 Wireless Link Management protocol for TG3, but enhance the TG1 Wireless Transport Protocol in the following areas:

- Provide for greater link robustness: Transient link error conditions should be hidden from higher layer protocols, and the system should be able to recover from them in a transparent manner.
- Provide for greater link agility: The system should have the ability to control and modify a number of MAC and PHY level parameters, in a very dynamic manner.
- Provide for the ability for the system to efficiently handle bursty traffic of the type generated by TCP based applications.
- Choice of time base that allows for both single carrier as well as multi-carrier modulation.
- Choice of mini-slot numbering scheme that allows for flexible scheduling

2.0 TG4 MAC Transport Layer

2.1 Encapsulation

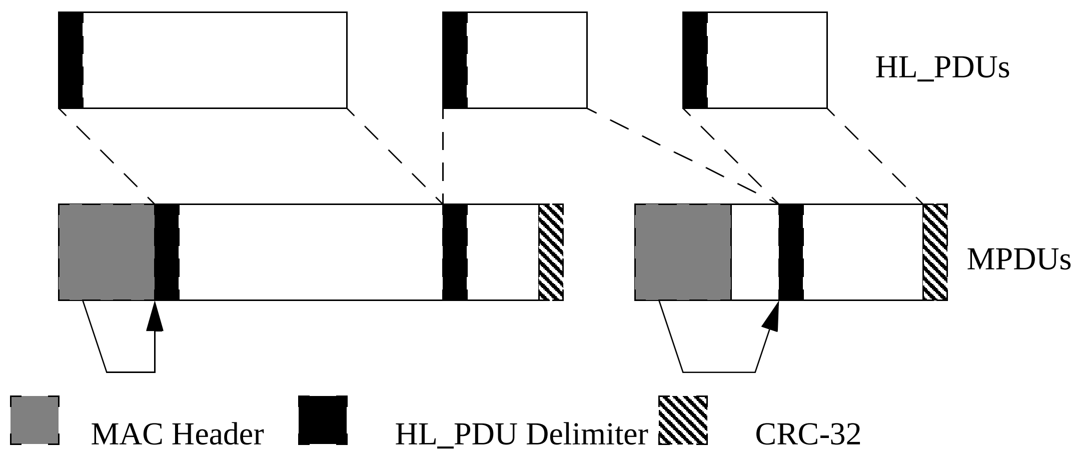

FIGURE 1. Encapsulation of HL_PDUs into MPDUs

The MAC Transport Layer encapsulates all Higher Layer PDUs (CS-PDUs) into MAC layer PDUs (MPDU) at the transmitter. At the receiver, the CS-PDUs s are extracted by means of pointer fields that are inserted into the header of the MPDU, as well as length indicator fields at start of each CS-PDU. The size of an MPDU is not fixed, but is subject to a maximum which is a function of current link conditions.

The proposed transport layer design decouples the MAC layer from higher layers, so that the MAC layer control entity is able to control the size of the MPDU as a function of the current link conditions, and independent of the PDU sizes of the higher layer protocols it is actually carrying. This ability is especially important with the addition of ARQ, since in low error rate environments the optimal MPDU size is larger as compared to high error rate environments, and vice-versa (note that re-transmissions are made at the MPDU level). In the current TG1 MAC scheme, the MPDU size can reduced under control of the BS, but it cannot be increased, since an MPDU cannot contain more than one CS-PDU.

Note that the MAC Header overhead appears only once per MPDU in the proposal, as opposed to once per CS-PDU, thus reducing link overhead. The scenario under which there are a large number of small IP packets waiting for upstream transmission, is quite common, as the following example illustrates: In a TDD based system, for any downstream traffic that uses the TCP protocol, such as FTP or HTTP, there are a large number of 60 byte ACK packets that are generated in the upstream direction (TCP sends one ACK back for every 2 packets that it receives). Under the current TG1 protocol, the BS can give a large grant that can accommodate a large number of these ACK packets, but each of them will have to have their own MAC header. Under the scheme proposed above on the other hand, a large number of ACK packets can be packed in the same MPDU, thus simplifying the protocol and making it more efficient. Since TCP is the most common protocol running in data networks, treating TCP ACKS inefficiently will have a negative effect on system efficiency. In general, since the BS does not know the sizes of the individual CS-PDUs at the SS, the situation in which more than one MAC header appears in an upstream burst can be quite common under the current TG1 protocol.

Another benefit of this approach, which will become more apparent when we discuss the ARQ scheme, is that the proposed encapsulation scheme enables the size (and contents) of the MPDU to change between re-transmissions, thus enabling the protocol to carry varying number of bytes of the CS-PDUs from one transmission to another. The size of an MPDU can change for various reasons in between re-transmissions, for example if the link parameters change, or because of the constraints of the framing structure, the MPDU will not fit within the space left in the frame etc. The current TG1 protocol rigidly constraints the contents of the MPDU to remain the same between re-transmissions, thus reducing the flexibility that the scheduler has in efficiently utilizing the available frame space. Also combined with the point made above, that the BS does not have complete control over the MPDU size in the TG1 MAC, it may mean that there are a lot of smaller size MPDUs being re-transmitted, that the BS has to keep track of.

Note that the proposed scheme does not prevent the BS from giving Grants per Terminal, the only difference is that each MPDU may now contain several CS-PDUs, as opposed to a single one.

2.2 Request-Grant Mechanism

The following Request/Grant mechanism is proposed:

- The SS communicates its current backlog in bytes, to the BS, by means two fields in the MPDU header, namely the reqWinOff and the curWinOff. The reqWinOff counter is updated when a higher layer packet arrives for transmission, and is a running count of the total number of bytes that have arrived into the queue. The curWinOff counter is updated when a MPDU is transmitted and is a running count of the total number of bytes that have been transmitted so far. Both these fields are present in the REQ packet as well as every MPDU sent from the SS. The BS computes the current SS backlog as the difference between these two fields.

- The BS gives grants to the SS, also in bytes, by means of fields in the MAP packet. When the SS receives a grant, it generates an MPDU, with the number of bytes in the payload portion of the MPDU, equal to the grant size.

The curWinOff and reqWinOff fields are used in the Request-Grant process, as well as in the ARQ mechanism, as described in the next section. The proposed Request-Grant mechanism differs from TG1 Request-Grant mechanism in the following ways:

- Due to the presence of the full size piggyback fields in each MPDU, the BS has complete knowledge of the current number of backlogged bytes in each upstream flow. In the TG1 scheme, the SS has limited ability to convey its current backlog to the BS due to the small size (8 bits) of the piggyback field, and has to make a new REQ to do so in most cases. As an example consider the case when the SS makes an initial request for 1500 bytes, and the BS proceeds to give it three grants over the course of the next few frames in order to satisfy this request. If 1000 additional bytes arrive before the final grant, then under the current TG1 MAC, the SS will have to generate an additional REQ packet and then steal some BW from one of the grants, in order to transmit it. This ends up consuming extra BW for the REQ packet, as well as leads to the creation of an additional packet fragment. Under the proposed scheme, the request for the additional 1000 bytes can be piggybacked with one of the MPDUs that are sent upstream.
- The BS gives grants to the SSs not only in terms of number of time units allocated, but also in terms of number of payload bytes in the MPDU. This allows the BS and the SS to maintain very tight control over the transfer of data across the channel, and enables the ARQ mechanism to work. Having a byte based grant mechanism also simplifies the design of the hardware on both the BS and SS ends, since it does not have to do any sophisticated calculations to figure out how much data it can transmit within a certain time interval, since that information is readily available in the MAP.

2.3 ARQ

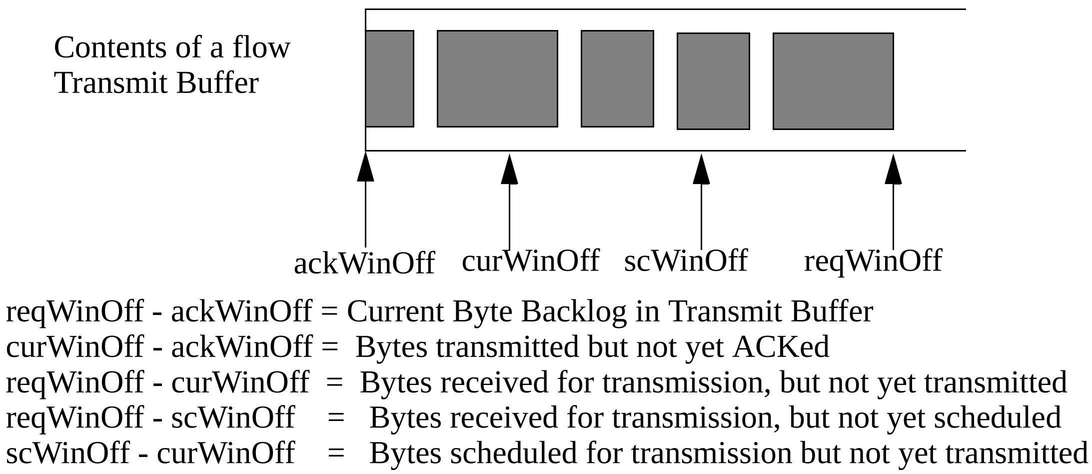

FIGURE 2. Counters Maintained at the Transmitter on a per flow basis

Objectives of the ARQ protocol:

- It should be possible to support different levels of ARQ on a per flow basis, for example:

1. No ARQ for voice traffic
2. Limited ARQ for TCP traffic - limited number of re-transmissions, such that the number of re-transmissions can be changed.

- The ARQ protocol should not un-necessarily constrain the peak BW for the flow (by limiting the number of MPDUs per frame, for example).
- The ARQ protocol should avoid the use of timers to control re-transmissions.
- The ARQ protocol should enable the link layer parameters and/or size of the MPDU to change between re-transmissions.
- The ARQ protocol should be robust and recover from various error events, such as loss of ACK packets etc.

2.3.1 Downstream ARQ Protocol

- The BS maintains the reqWinOff, scWinOff, curWinOff and the ackWinOff counters for each flow, at the transmitting end. The reqWinOff counter is incremented when a new CS-PDU arrives, the scWinOff counter is incremented when bytes from the transmit buffer are scheduled, the curWinOff counter is incremented when the bytes actually get transmitted and the ackWinOff counter is incremented when an ACK is received from the receiver. When an CS-PDUs gets scheduled for transmission, the BS creates the MPDU and inserts the curWinOff field into the MPDU header.

- The SS maintains an ackWinOff counter, on a per flow basis. The value of this counter is set to the sequence number of the next byte that the SS expects to receive. If a MPDU is received correctly, then this counter is incremented by the number of bytes contained in the MPDU. If the MPDU is lost or received in error, then the counter is not incremented.
- As long as there are bytes in the flow transmit queue that have not been acked, the BS schedules a special ACK packet in the upstream (on a per flow basis). The SS returns the ackWinOff value in the ACK packet. The SS also indicates in the ACK packet whether the last MPDU in the downstream frame was received correctly or in error.
- If an MPDU is lost, then the SS drops all subsequent MPDUs on that flow, until it receives the one with the expected sequence number. When the BS receives a NACK, it re-transmits all the bytes in the queue with sequence numbers of ackWinOff and greater.
- If one or more MPDUs are not able to get across after N re-transmissions, then the BS drops the first CS-PDU in its transmit queue. It then continues by sending the next HL-PDU, with the same Sequence Number (curWinOff) as the on that the SS is expecting. When the SS starts receiving a new CS-PDU, it drops the incomplete CS-PDUs that it was trying to re-assemble.

2.3.2 Upstream ARQ Protocol

The upstream ARQ protocol that is described in this section has the desirable property that all re-transmissions are controlled directly by the BS. This facilitates the operation of the ARQ protocol, since the BS can allocate upstream BW for re-transmissions, without having to be prompted to do so by the SS.

- The BS updates its own copy of the reqWinOff field by examining the MAC header of REQ and data packets coming from the SSs. It gives upstream data slot allocations in the MAP packet, and updates the scWinOff counter with every grant allocation, by the number of bytes in the payload portion of the grant.
- On receiving an allocation, the SS creates and transmits the MPDUs, and increments its own copy of the curWinOff counter by the number of bytes in the transmission payload. On receiving an CS-PDU, it increments its copy of the reqWinOff counter by the size of the HL_PDU. It puts the curWinOff and reqWinOff counters in the appropriate fields in the MPDU header.
- If an MPDU is lost, then the BS detects this and sends a NACK back to the SS. It also allocates BW for re-transmission of the lost MPDUs. When the SS receives a NACK, it rolls back its curWinOff counter and sets it equal to the ackWinOff counter value received from the BS, and re-transmits the data.
- If an MPDU is not able to get across after N re-transmissions, then the BS sets the flush flag in the ACK. When the SS gets the flush, it drops the CS-PDU at the head of its transmit queue. If there are additional packets in the transmit queue, then it requests BW for them by using the REQ slots.

3.0 Link Layer Parameter Control

The wireless link is subject to greater number of impairments, as compared to wired transmission media. One of the objectives of the MAC and PHY layers is to protect the applications running in the higher layers from these problems. The link layer ARQ scheme described in the previous section offers a first level protection against errors, but does not work very well under extreme conditions. In such situations, the system should have the ability to appropriately change other parameters, at the MAC, PHY or Radio layers, in order to increase the robustness of the transmissions. Among the various parameters that can be varied, the TG1 specification incorporates the ability to control two, namely the modulation and the FEC. However, in general the protocol should have the flexibility to be able to control more than these parameters. An example of a parameter that can be controlled in a more dynamic manner is Transmit Power level. Others include various diversity related parameters such an polarization, antennae etc.

We propose that the MAP packet incorporate a separate field in each IE, upstream and downstream, that describes the set of parameters that are applicable for that burst. This field can be parsed by both the transmitter as well as the receiver, and can be used to appropriately set the link parameters, on a burst by burst basis. The presence of this field will enable the link control algorithms in the BS to react very quickly to changing link conditions, and vary link parameters without the need to exchange messages in advance of doing so.

4.0 Choice of Time Base

The current 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:

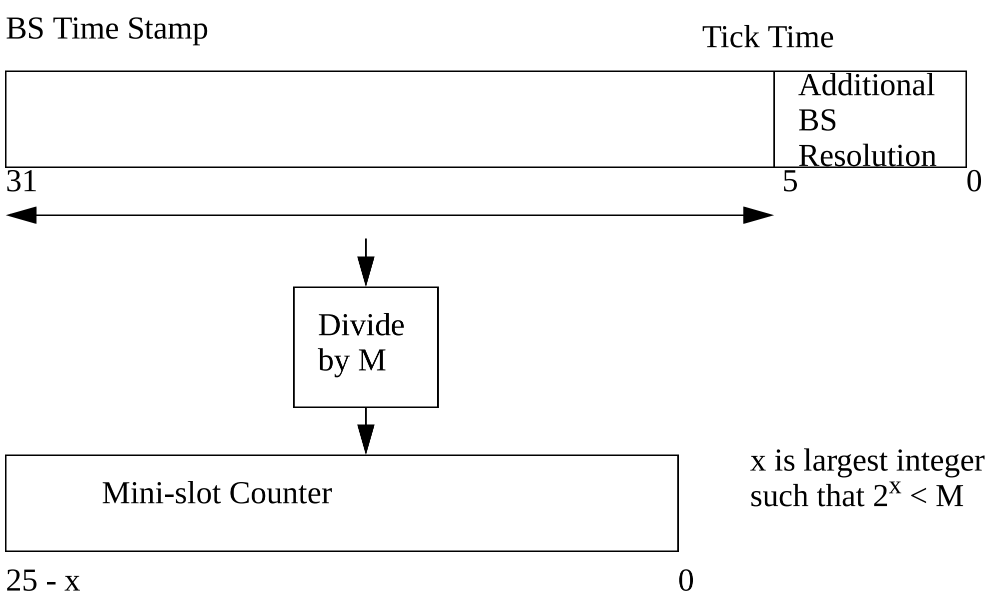

FIGURE 3.

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 acco-modate 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.

5.0 Minislot Numbering and Flexible Scheduling

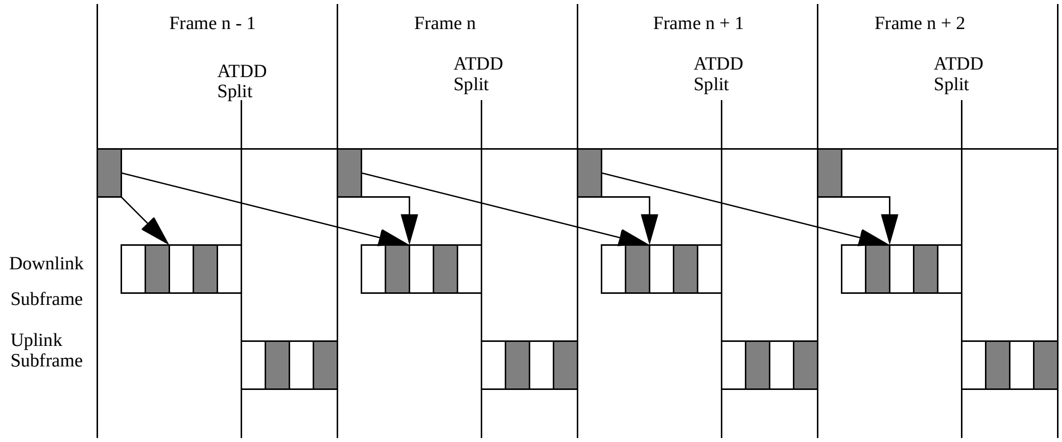

FIGURE 4. MAP relevance for burst PHY systems

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.

6.0 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 si plify 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.

7.0 Specific Comments on Section 6.2.1

Replace the contents of Section 6.2.1 by the contents of Section 8.1 of this document.

7.1 MAC Header Formats

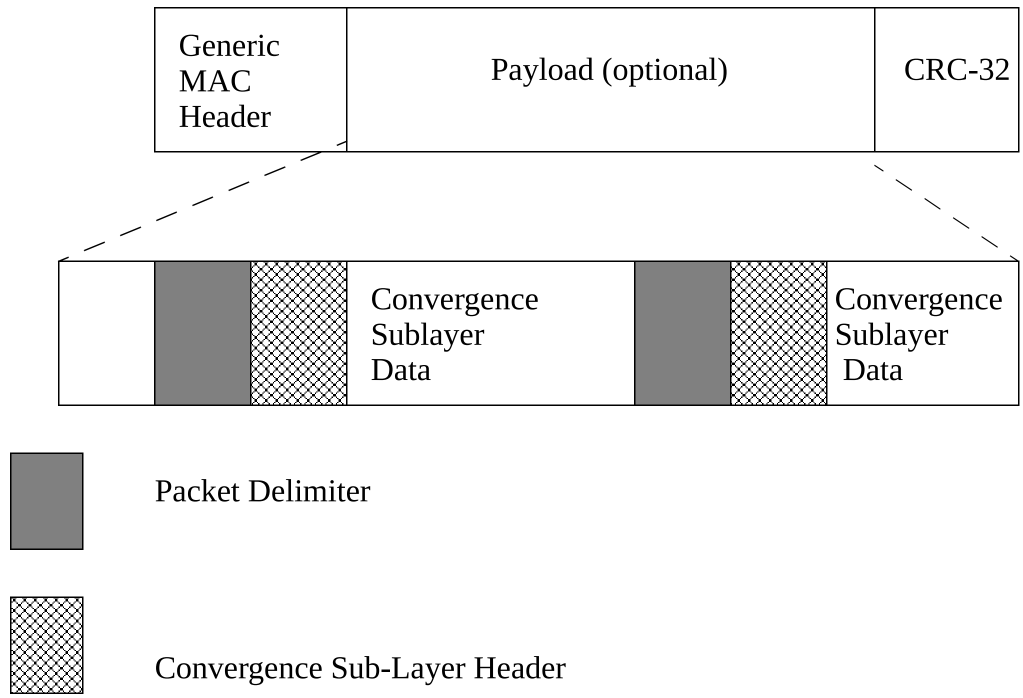

FIGURE 5. MAC PDU Format

MAC Protocol Data Units (PDU) shall be of the form illustrated in Figure 3. Each PDU is preceded by a fixed length generic MAC header. The PDU may contain optional payload information. The payload information can vary in length, so that a MAC PDU will represent a variable number of bytes. The payload information is divided into three parts: A two byte packet delimiter field (Figure 4), an yet to be defined convergence sublayer header and the data portion. This allows the MAC to tunnel various higher layer traffic types without knowledge of the formats or bit patterns of those messages.

A 32-bit CRC is appended to the MAC PDU if the payload size is non-zero. Messages are always transmitted in order: Most-Significant-Byte first with the Most-Significant-Bit first in each byte.

Five MAC Header formats are defined. The first two are generic headers that precede each MAC data message, while the other headers precede MAC management, Bandwidth

Request and Upstream ACK messages respectively. There is a bit field in the Frame Control Byte that is used to distinguish between the various MAC message types.

FIGURE 6. Packet Delimiter field

All Higher Layer PDUs (CS-PDUs) are preceded by a two byte delimiter field, whose format is shown in Figure 4. The size of the CS-PDU, in bytes, is inserted into this field.

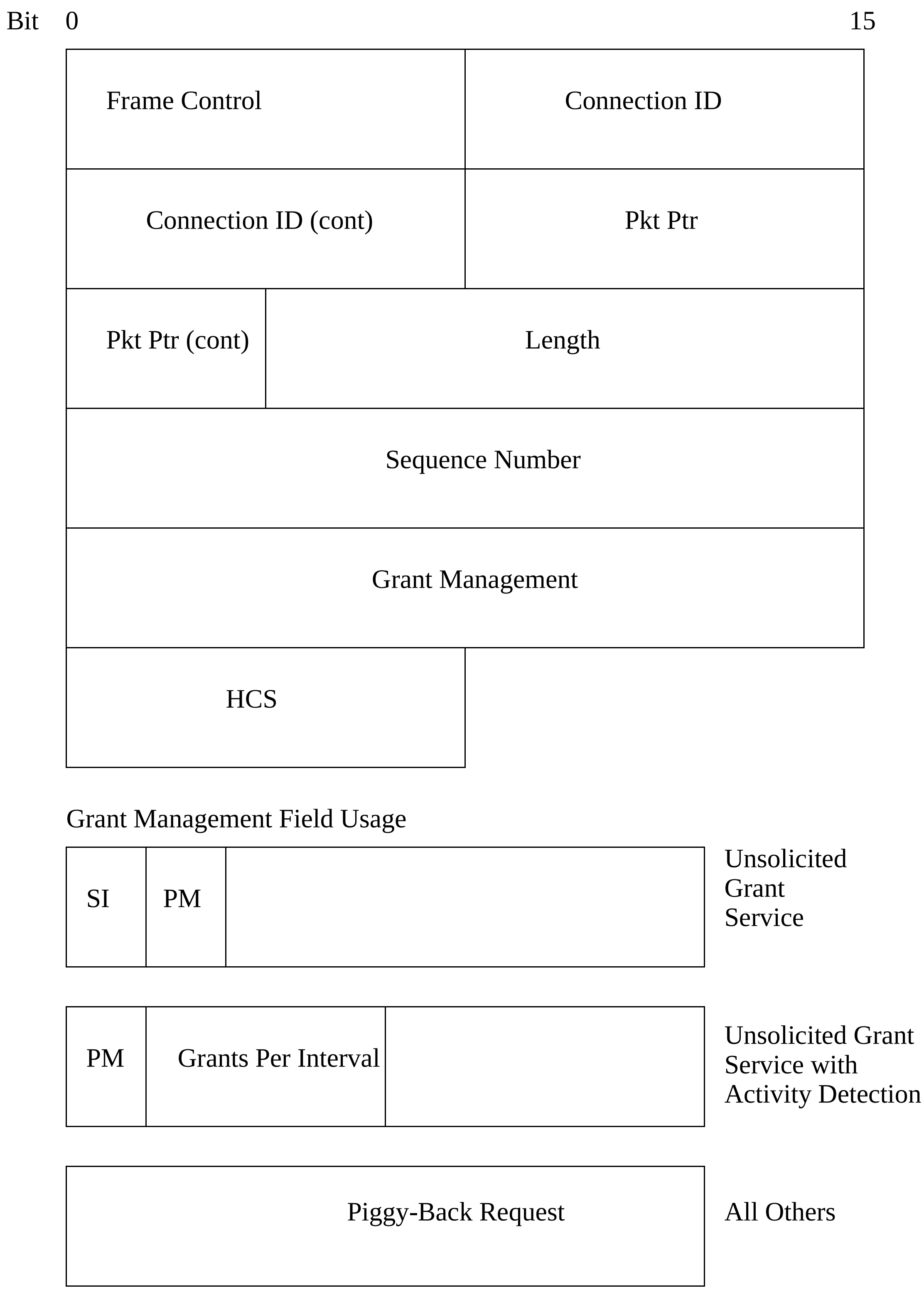

FIGURE 7. Upstream MAC Header

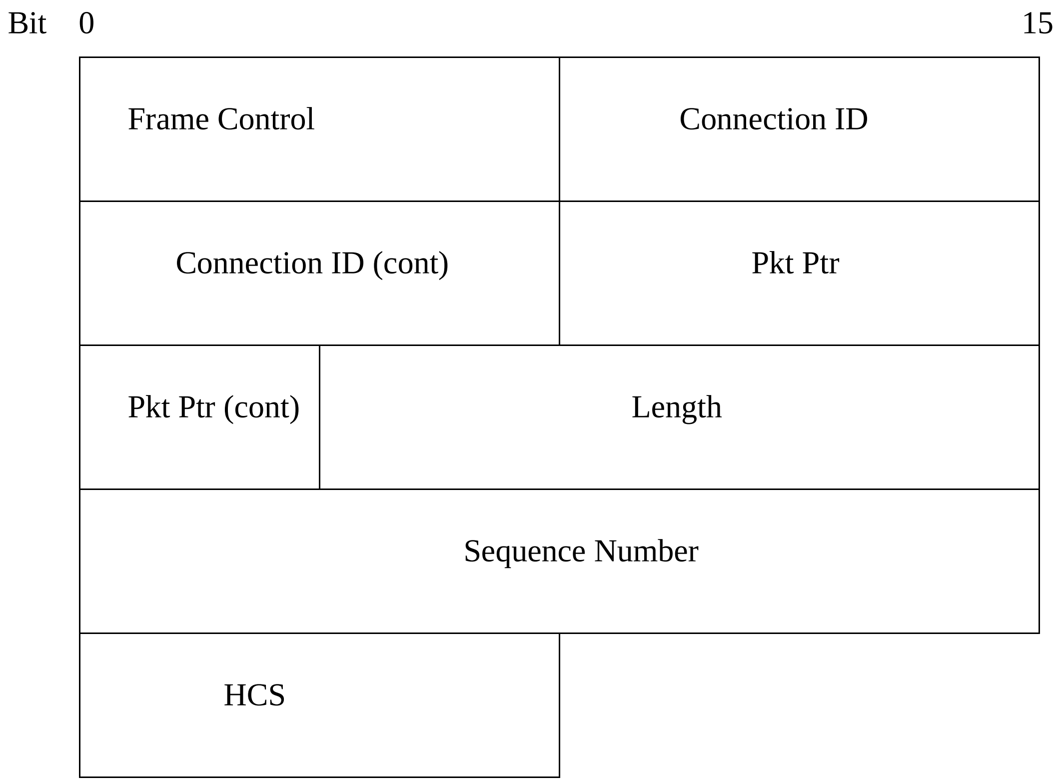

FIGURE 8. Downstream MAC Header

The format shown in Figure 5 shall be used for all PDUs transmitted by the SS to the BS in the uplink direction. For the downlink transmissions, the format shown in Figure 6 shall be used. These two generic header formats are equivalent with the exception of the Grant Management field, which is only present in uplink transmissions.

The Grant Management field is 2 bytes in length and is used to by the SS to convey bandwidth management needs to the BS. This field is encoded differently based upon the type of connection (as given by the Connection ID). The use of this field is defined in Section 2.10.

The format and contents of the Frame Control field is described in Table 1.

Bit 0 15

Frame Control	Connection ID
Connection ID (cont)	Sequence Number
Sequence Number (cont)	BW Request
BW Request (cont)	HCS

FIGURE 9. Bandwidth Request Packet Header Format

The third header is a special format used by a SS to request additional bandwidth. This header shall always be transmitted without a PDU. The format of the Bandwidth Request Header is given in Figure 7.

Bit 0 15

<table>
<tr><td>Frame Control Byte</td><td colspan="2">Connection ID</td></tr>
<tr><td>Connection ID (cont)</td><td>Reserved</td><td>Length</td></tr>
<tr><td>Length (cont)</td><td colspan="2">HCS</td></tr>
</table>

FIGURE 10. MAC Management Packet Header Format

The fourth header shown in Figure 8, is a special format used for MAC Management messages.

Bit 0	15
Frame Control	Connection ID
Connection ID (cont)	Sequence Number
Sequence Number (cont)	ACK/NACK Status
Link Status	
HCS	

FIGURE 11. Upstream ACK Packet Header Format

The fifth and final header format, shown in Figure 9, is used for upstream ACK packets.

TABLE 1. MAC Frame Control Field Usage

Name	Length (bits)	Description
FC_TYPE	2	MAC Frame Control Type Field 00: Data Packet 01: MAC Control Packet
FC_PARM	5	Parameter bits, use dependent on FC_TYPE Data Packet x x x x 0/1: Encryption Key Sequence x x x 0/1 x : Encryption Not Used/Encryption Used x x 0/1 x x : CRC not appended/CRC appended x 0/1 x x x : Convergence Sublayer Indication 0/1 x x x : ARQ OFF/ON MAC Control Packet 0000 : Ranging Packet 0001 : Bandwidth Request Packet 0010 : Upstream ACK Packet
RSVD	1	

TABLE 2.

Name	Length (bits)	Description
Frame Control	8	See Table 1
Connection ID	16	Connection Identifier
Pkt Ptr	12	Points to the first encapsulated HL_PDU, which beginning falls within this MAC packet.
Length	12	Length in bytes of the MAC payload, excluding the MAC header and CRC-32 fields
Sequence Number	16	The value of the curWinOff counter is inserted here for data packets. The value of the ackWinOff field is inserted here for ACK packets.
Piggyback Request	16	The value of the reqWinOff counter is inserted in this field

7.2 Specific Comments on Section 6.2.1.2

In Table 2, replace Types 2 and 3 by a single Type 2 MAP packet, and add a new Type 3 for SYNC packets.

TABLE 3.

Type	Message Name	Message Description
2	MAP	Downlink and Uplink Access Definition
3	SYNC	System Time Stamp Reference
4	RNG-REQ	Upstream Ranging Request
5	RNG-RSP	Upstream Ranging Response

7.3 Specific Comments on Section 2.5.2.2

Add the following row to Table 11.

TABLE 4.

Burst Type	DIUC	Comments
Downstream ACK	7	Used for Downstream ACK (of upstream data)

7.4 Specific Comments on Section 6.2.1.2.3

Replace the contents of Section 6.2.1.2.3 by the following:

2.5.3 MAP Message

The MAP message allocates access to the upstream channel for FDD systems, and to both downstream and upstream slots for TDD and HD-FDD systems.

0	8	16	24 31
MAC Management Header			
Channel ID	CD Count	PHY Type	Frame Length
Base Station ID[0:31]			
Base Station ID[32:63]			
Number of Downstream IEs		Number of Upstream IEs	
Allocation Start Time			
Acknowledgement Time			
Ranging Backoff Start	Ranging Backoff End	Request Backoff Start	Request Backoff End
Downstream IE #1			
⋮			
Downstream IE #n			
Upstream IE #1			
⋮			
Upstream IE #m			

FIGURE 12. MAP Message Format

Channel ID

For FDD systems, the identifier of the uplink channel to which this message refers. For TDD systems, the identifier of the uplink and downlink channel to which this message refers.

CD Count

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

PHY Type

0 = TDD
1 = HD-FDD
2 = FDD

Frame Length

Number of Downstream IEs

For FDD systems this field is not used. For TDD systems this field contains the number of downstream IEs in the map.

Number of Upstream IEs

This field contains the number of upstream IEs in the MAP.

Allocation Start Time

For FDD systems, the effective start time of the uplink allocation defined by the MAP, in units of mini-slots. For TDD or HD-FDD systems, the effective start time of the downlink + uplink allocation, in units of mini-slots. In both cases, the start time is relative to the time of BS initialization.

Ack Time

Latest time processed in uplink, in units of mini-slots. This time is used by the SS for collission detection purposes. The ack time is relative to the time of BS initialization.

Ranging Backoff Start

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

Ranging Backoff End

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

Request Backoff Start

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

Request Backoff End

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

Downstream MAP IEs

These are shown in Figures 13 and 14 and 15.

Bit 0 15 31

Connection ID (16 bits)	DIUC (4 bits)	Slot Offset (12 bits)
MPDU Payload Size (12 bits)	Link Control (16 bits)	RSVD

FIGURE 13. Downstream MAP IE Format for Downstream Data (DIUC = 8, 9, 10, 11, 12 or 13)

Bit 0 15 31

Connection ID	DIUC	ACK/NACK Status
Sequence Number	RSVD	

FIGURE 14. Downstream MAP IE Format for ACKs for Upstream Data (DIUC = 7)

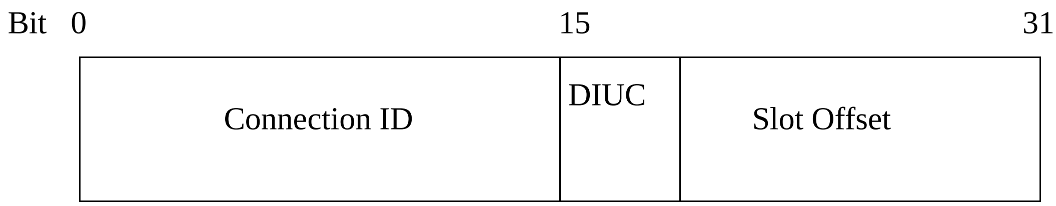

FIGURE 15. Downstream MAP IE Format for Control Packets (DIUC = 6)

Upstream MAP IEs

These are shown in Figures 16 and 17.

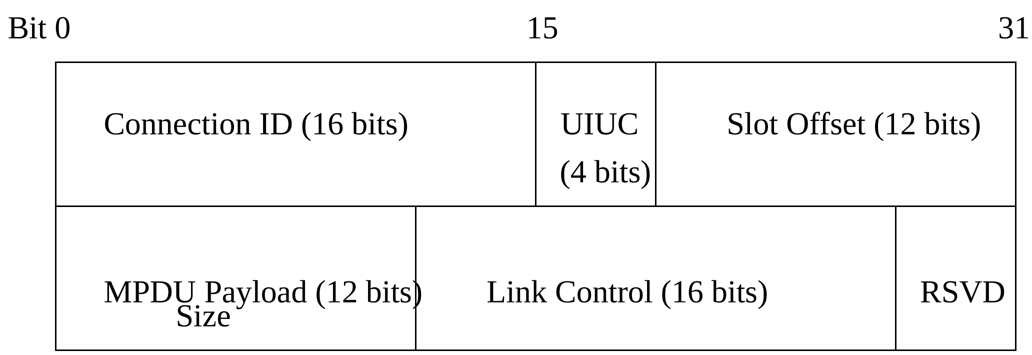

FIGURE 16. Upstream MAP IE Format for Upstream Data Grants (UIUC = 4, 5, 6, 7, 8 or 9)

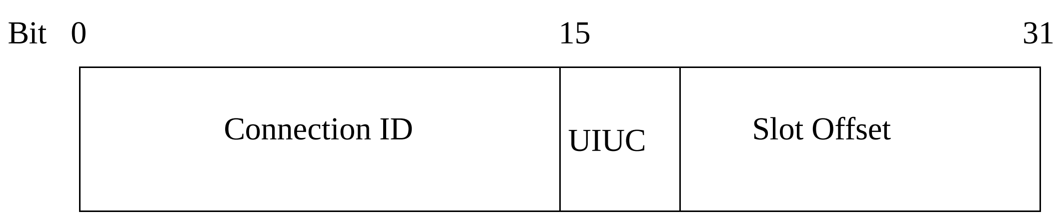

FIGURE 17. Upstream MAP IE Format for Upstream Control Packets (UIUC = 1, 2, 3)

Add the following row to Table 4

TABLE 5.

IE Name	UIUC	Connection ID	Mini-slot Offset
ACK	12	unicast	Starting Offset of ACK region

7.5 Specific Comments on Section 6.2.1.2.4

Replace the contents of Section 6.2.1.2.4 by the following:

2.5.4 SYNC Message

The SYNC packet carries the 32-bit timstamp from the BS to each of the SS. The SYNC message format shall be as shown in Figure 15

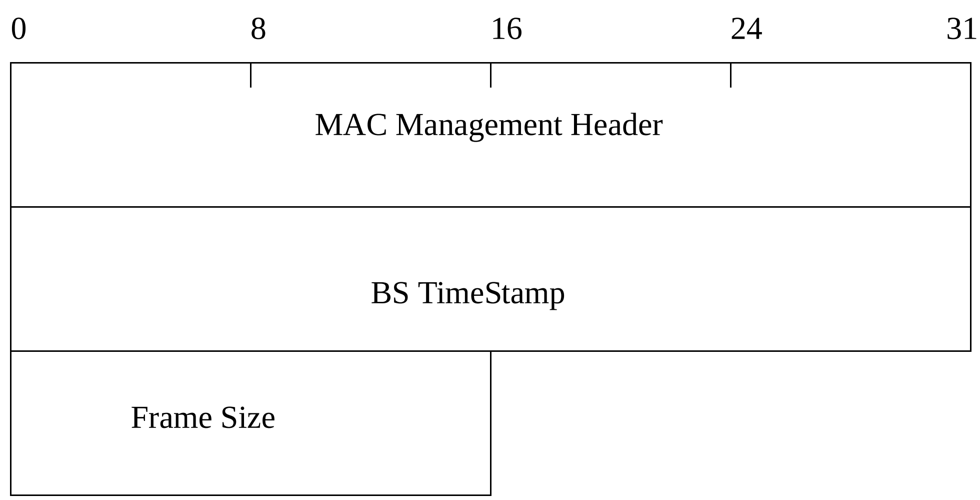

FIGURE 18. SYNC Message Format

The parameters are defined below:

BS Timestamp. The count state of an incrementing 32 bit binary counter clocked with the BS 64 MHz master clock.

Frame Size. The Frame Size that the scheduler is currently using, in units of ticks. This information is used by the SS during initialization, to start receiving the MAP packets.

The BS timestamp represents the count state at the instant that the first byte of the SYNC message is transferred from the MAC layer to the PHY layer.

8.0 Specific Comments on Section 6.2.2.3.1

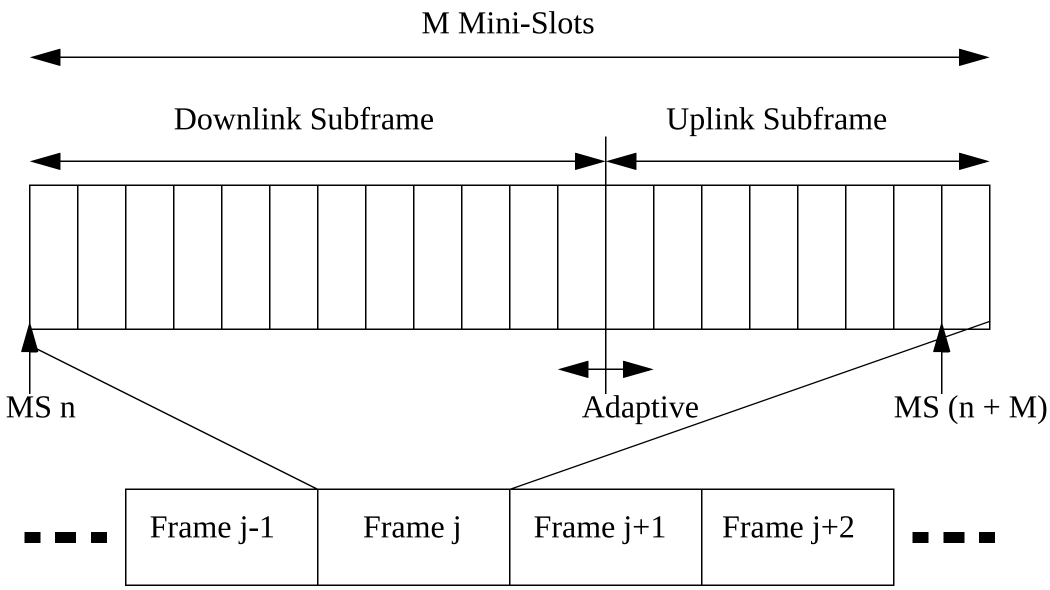

FIGURE 19. TDD Frame Structure with M mini-slots per frame

Replace Figure 121 by Figure 19 above. Replace thecontents of Section 6.2.2.3.1 with the following:

The available bandwidth in both directions is defined with the granularity of one tick, which is of duration equal to one microsecond. The number of ticks with each frame is independent of the modulation rate. 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. The frame size should be selected so that the number of mini-slots per frame is an integer.

9.0 Specific Comments on Sections 6.2.2.3.1.1 and 6.2.2.3.1.2

Delete Sections 6.2.2.3.1.1 and 6.2.2.3.1.2 and replace the contents of Section 6.2.2.3.1.2 (re-named to System Timing) by the following:

6.2.2.3.1.2 System Timing

The system timing is based on the System Time Stamp reference, which is a 32-bit counter that increments at a rate of 64 MHz. The 26 most significant bits of this counter increment at a rate of 1 MHz, and count the 1 us ticks, while the 6 least significant bits are used to provide additional time resolution that equals 1/64th of a tick.This allows the SS to track the BS with a small time offset.

The BS maintains a separate System Time Stamp for each port in the TDD case, or for each upstream/downstream port pair, in the FDD case. The value of the BS System Time Stamp is broadcast to all the SS using the SYNC message. Each SS maintains its own System Time Stamp so that it is synchronous with the BS Time Stamp for the channel that it is using. The SS Time Stamp must change at the same rate as its BS counterpart, but all upstream transmissions are offset from it so that the upstream bursts arrive at the BS at the correct time. Similarly for TDD and HD-FDD systems there is an offset for receiving the downstream transmissions. In general these two offsets are different. The upstream offset is a function of the fixed PHY delays plus the variable propagation delay between the BS and the SS and is set by the BS using the RNG-RSP message. The downstream offset is a function of the fixed PHY delay.

10.0 Specific Comments on Section 6.2.2.3.2

Replace the contents of Section 6.2.2.3.2 by the following:

6.2.2.3.2 Mini-Slot Definition

The bandwidth allocation MAP uses time units of “mini-slots” for allocating bandwidth in the upstream for FDD systems and for allocating BW in both upstream and downstream in TDD and HD-FDD systems. The size of the mini-slot (M) is dpecified as a number of ticks and is carried in the Channel Descriptor for each channel. One mini-slot contains M ticks, where M is not necessarily a power of 2. The value of M should be chosen so that the number of symbols per mini-slot (N) is an integer. The frame size should be chosen so that the number of mini-slots per frame is an integer.

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.

A mini-slot is the unit of granularity for data transmissions. There is no implication that any PDU can actually be transmitted in a sigle mini-slot.

Figure 3 (of this contribution) illustrates the mapping of the System Time Stamp maintained in the BS to the BS mini-slot counter. The BS and SS base their transmit or receive allocations on a 32-bit counter that normally counts to 2^{32}-1 and then wraps back to zero. The 26 most signficant bits of this counter are subject to a Divide-by-M operation, to derive the mini-slot counter.

11.0 Specific Comments on Section 6.2.2.4.1

Replace Figures 53 and 56 in the TG1 specification by Figure 4 of this contribution. Replace the text in Section 6.2.2.4.1 by the following:

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 59 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.

REFERENCES

1. V. Yanover, S. Varma and H. Ye, ‘‘Using the TG1 MAC for TG3 Purposes,” *Contribution Number 802.16.3p-00/56*, November 2000.
2. ‘‘Draft Standard for Air Interface for Fixed Broadband Wireless Access Systems”, *Document Number IEEE 802.16.1/D1-2000*, December 2000.