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Title	**Comments on the Time Base Structure of TG3**
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Re:	IEEE 802.16.1/D1-2000, December 2000
Abstract	The current time base structure in TG1 makes it unsuitable for use in TG3 systems. We propose a an alternative time base structure that does not have these problems.
Purpose	
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Comments on the Time Base Structure of TG3

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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:

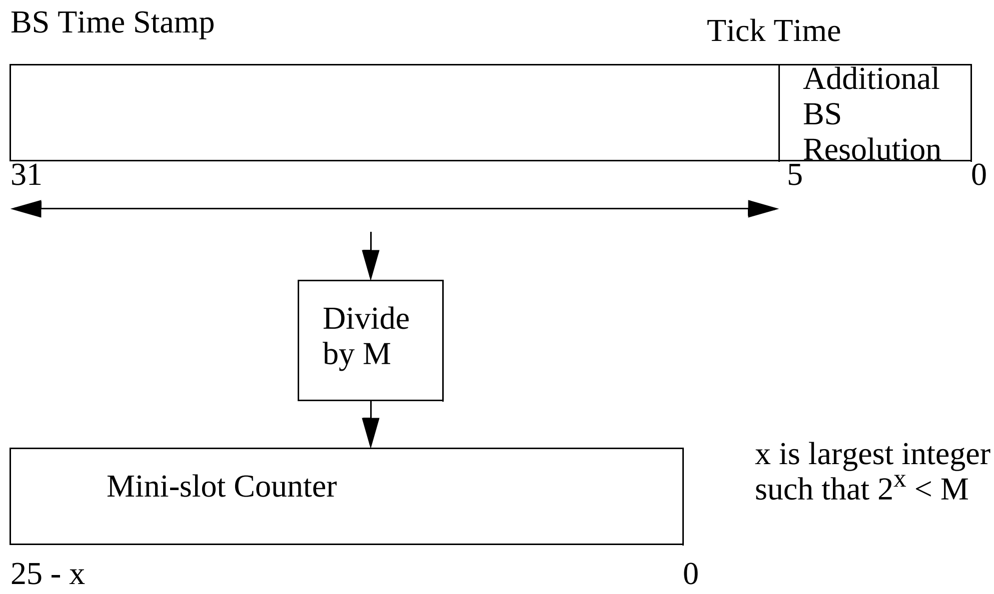

FIGURE 1.

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 accommodate 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

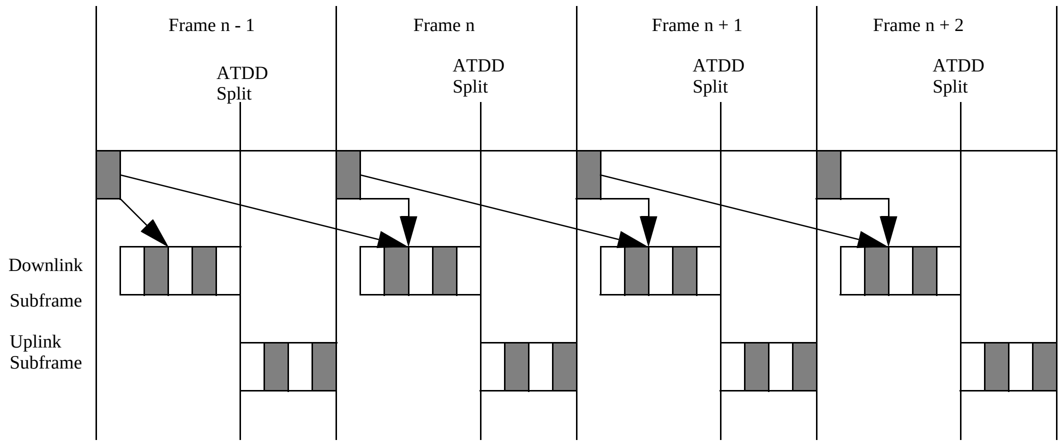

FIGURE 2. MAP relevance for burst PHY systems

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 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.

3.1 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 3. 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 4. 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 5. Downstream MAP IE Format for ACKs for Upstream Data (DIUC = 7)

Bit 0	15	31
Connection ID	DIUC	Slot Offset

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

Upstream MAP IEs

These are shown in Figures 16 and 17.

Bit 0	15		31
Connection ID (16 bits)		UIUC (4 bits)	Slot Offset (12 bits)
MPDU Payload Size (12 bits)	Link Control (16 bits)		RSVD

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

Bit 0	15	31
Connection ID	UIUC	Slot Offset

FIGURE 8. Upstream MAP IE Format for Upstream Control Packets (UIUC = 1, 2, 3)

Add the following row to Table 4

TABLE 1.

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

3.2 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

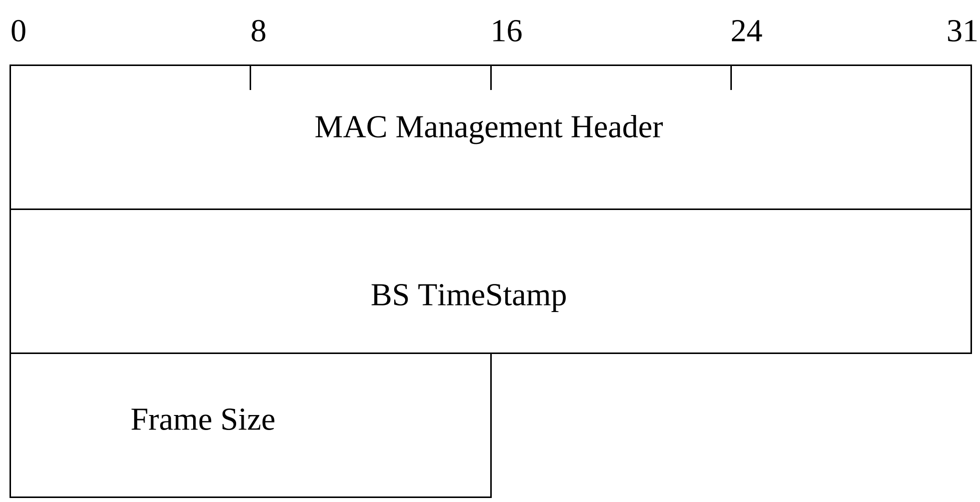

FIGURE 9. SYNC Message Format

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.

4.0 Specific Comments on Section 6.2.2.3.1

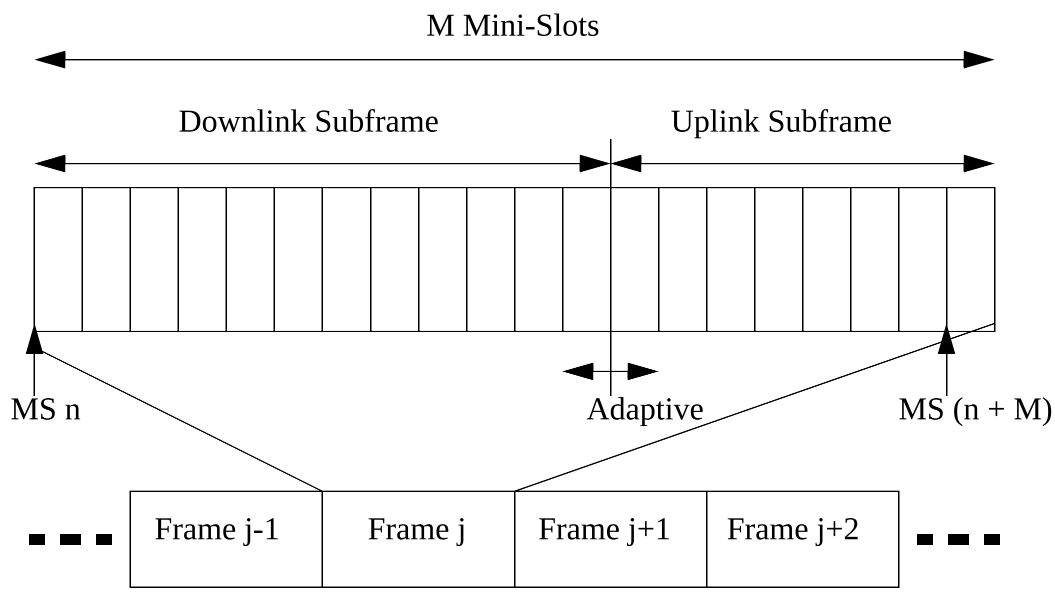

FIGURE 10. TDD Frame Structure with M mini-slots per frame

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.

5.0 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.

6.0 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.

7.0 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.