Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Proposed 802.16m Frame Structure Baseline Content Suitable for Use in the 802.16m SDD**
Date Submitted	**2008-03-03**
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Re:	IEEE 802.16m-08/006 ("Charter and Scope of TGm Rapporteur Groups")
Abstract	The contribution proposes the 802.16m frame structure baseline content suitable for use in the 802.16m SDD.
Purpose	To be discussed and adopted by TGm for use in the 802.16m SDD.
Notice	
Release	
Patent Policy	

Proposed 802.16m Frame Structure Baseline Content Suitable for Use in the 802.16m SDD

1 Introduction

This contribution proposes an initial text to be included in the 802.16m System Description Document (SDD) under the frame structure section. The proposed text fairly captures the membership inputs on frame structure and provides for some key attributes of IEEE 802.16m frame structure as required by the IEEE 802.16m system requirement document [1], such as legacy support, while allowing for the introduction of advanced transmission technology in advanced BSs and MSs, relay support, coexistence with other radio access technologies, data and control plane latencies, etc.

2 Editor Notes

We propose to include the 802.16m frame structure specification as a subsection in the “Physical Layer” section in the 802.16m SDD; i.e., Section 11 in the current 802.16m SDD draft (80216m-08/003). The frame structure section provided includes several subsections that we believe directly impact on the 802.16m frame structure; e.g., duplex schemes, OFDMA parameters, etc.

In the proposed baseline content, there are duplicated section/subsection numbers, Figure numbers, and Table numbers, which are meant to capture multiple proposals as expressed in the combined spreadsheet [2], for the same topic.

Text in brackets indicates either an editorial note or a text proposal for which no consensus has been established, but for which strong interest if not substantial consensus was exhibited in the combined spreadsheet [2].

Text without brackets indicates a text proposal for a frame structure concept that exhibited substantial consensus in the combined spreadsheet [2].

The following provides an overview of the proposed content given in section 3 of this document:

11.1 Duplex Schemes

11.2 Downlink and Uplink Multiple Access Schemes

11.3. OFDMA Parameters
[Table 11.3-1: OFDMA parameters for IEEE 802.16m] → proposal-1
[Table 11.3-1: OFDMA parameters for IEEE 802.16m] → proposal-2

11.4 Frame Structure

11.4.1 Basic Frame Structure (proposal-1)
11.4.1.1 Super-frame Header

3 Proposed 802.16m Frame Structure Baseline Content

11.1 Duplex Schemes

IEEE 802.16m supports TDD, FDD, and H-FDD duplex schemes in accordance with IEEE 802.16m system requirements document [1]. Unless otherwise specified, the frame structure attributes and baseband processing are common for all duplex schemes.

11.2 Downlink and Uplink Multiple Access Schemes

[IEEE 802.16m uses OFDMA as the multiple access scheme in the downlink. Determination of the UL multiple access method is pending the output of the Uplink Access Techniques Rapporteur Group and further action by TGm]

11. 3 OFDMA Parameters

The OFDMA parameters for the IEEE 802.16m are specified as follows:

<table>
<tr><th colspan="2">Nominal Channel Bandwidth (MHz)</th><td>5</td><td>7</td><td>8.75</td><td>10</td><td>20</td></tr>
<tr><th colspan="2">Over-sampling Factor</th><td>28/25</td><td>8/7</td><td>8/7</td><td>28/25</td><td>28/25</td></tr>
<tr><th colspan="2">Sampling Frequency (MHz)</th><td>5.6</td><td>8</td><td>10</td><td>11.2</td><td>22.4</td></tr>
<tr><th colspan="2">FFT Size</th><td>512</td><td>1024</td><td>1024</td><td>1024</td><td>2048</td></tr>
<tr><th colspan="2">Sub-Carrier Spacing (kHz)</th><td>10.94</td><td>7.81</td><td>9.77</td><td>10.94</td><td>10.94</td></tr>
<tr><th colspan="2">OFDMA Useful Symbol Time Tu (µs)</th><td>91.4</td><td>128</td><td>102.4</td><td>91.4</td><td>91.4</td></tr>
<tr><th>Cyclic Prefix (CP)</th><th>symbol Duration Ts (µs)</th><th colspan="4">Number of OFDM Symbols per Frame</th><th>Idle Time (µs)</th></tr>
<tr><td rowspan="3">Tg=1/8 Tu</td><td>91.4 + 11.42=102.82 (for 5, 10, 20 MHz)</td><td colspan="4">48 (for 5, 10, 20 MHz)</td><td>64.64</td></tr>
<tr><td>128+16=144 (for 7 MHz)</td><td colspan="4">34 (for 7 MHz)</td><td>104</td></tr>
<tr><td>102.4+12.8=115.2 (for 8.75 MHz)</td><td colspan="4">43 (for 8.75 MHz)</td><td>46.40</td></tr>
</table>

[Table 11.3-1: OFDMA parameters for IEEE 802.16m] → proposal-1

Parameter		Unit	Parameter Values					
Channel Bandwidth (BW)		MHz	5	7	8.75	10	14	20
Sub-carrier Spacing (△f)		kHz	12.5					
Sampling Frequency (Fs)		MHz	6.4	12.8	12.8	12.8	25.6	25.6
FFT size			512	1024	1024	1024	2048	2048
Useful Symbol Time (T_u)		us	80					
CP Length (T_{CP})	**Short CP**	us	T_u /32 =2.5					
	Normal CP	us	[9.375], [T_u /8 =10]					
	Long CP	us	[16.875], [T_u /4= 20]					
Symbol Time	**Short CP**	us	82.5					
	Normal CP	us	[89.375], [90]					
	Long CP	us	[96.875], [100]					

[Table 11.3-1: OFDMA parameters for IEEE 802.16m] → proposal-2

11.4 Frame structure

[<Editor note: Start of proposal-1 of “11.4.1 Basic Frame Structure”>

11.4.1 Basic Frame structure (Proposal-1)

The IEEE 802.16m basic frame structure is illustrated in Figure 11.4-1. Each 20 ms super-frame is divided into four equally-sized 5ms radio frames. When using the same OFDMA parameters as the reference system, each 5 ms radio frame further consists of eight sub-frames. Each sub-frame can be assigned for either downlink or uplink transmission/reception depending on the duplexing scheme. There are two types of sub-frames in case of a CP length of 1/8 Tu: 1) the regular sub-frames which consist of six OFDMA symbols and 2) the irregular sub-frames that consist of five or less OFDMA symbols.

The basic frame structure is applied to FDD, TDD, and H-FDD duplexing schemes. The number of switching points in each radio frame in TDD systems ranges from two to four.

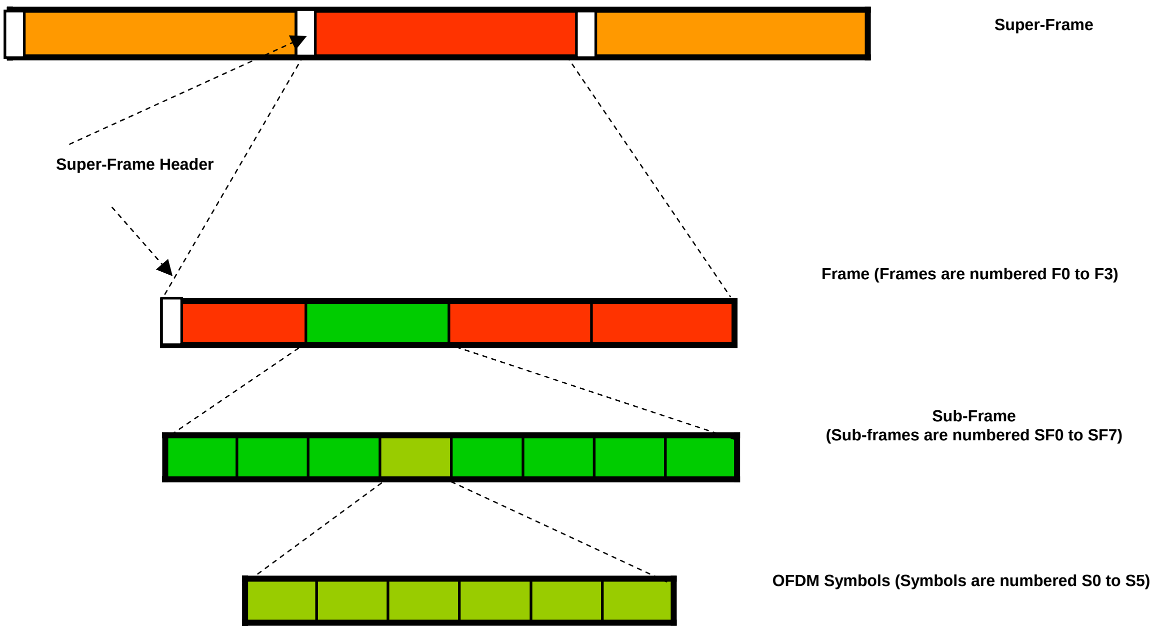


Figure 11.4-1: Basic frame structure

Figure 11.4.-2 illustrates an example TDD frame structure with DL to UL ratio of 3:5. Assuming OFDMA symbol duration of 102.82 us, the length of regular and irregular sub-frames are 0.617 ms and 0.514 ms, respectively. Other OFDMA parameter sets may result in a different number of sub-frames per frame and symbols within the sub-frames. Figure 11.4-3 shows the frame structure in FDD mode.

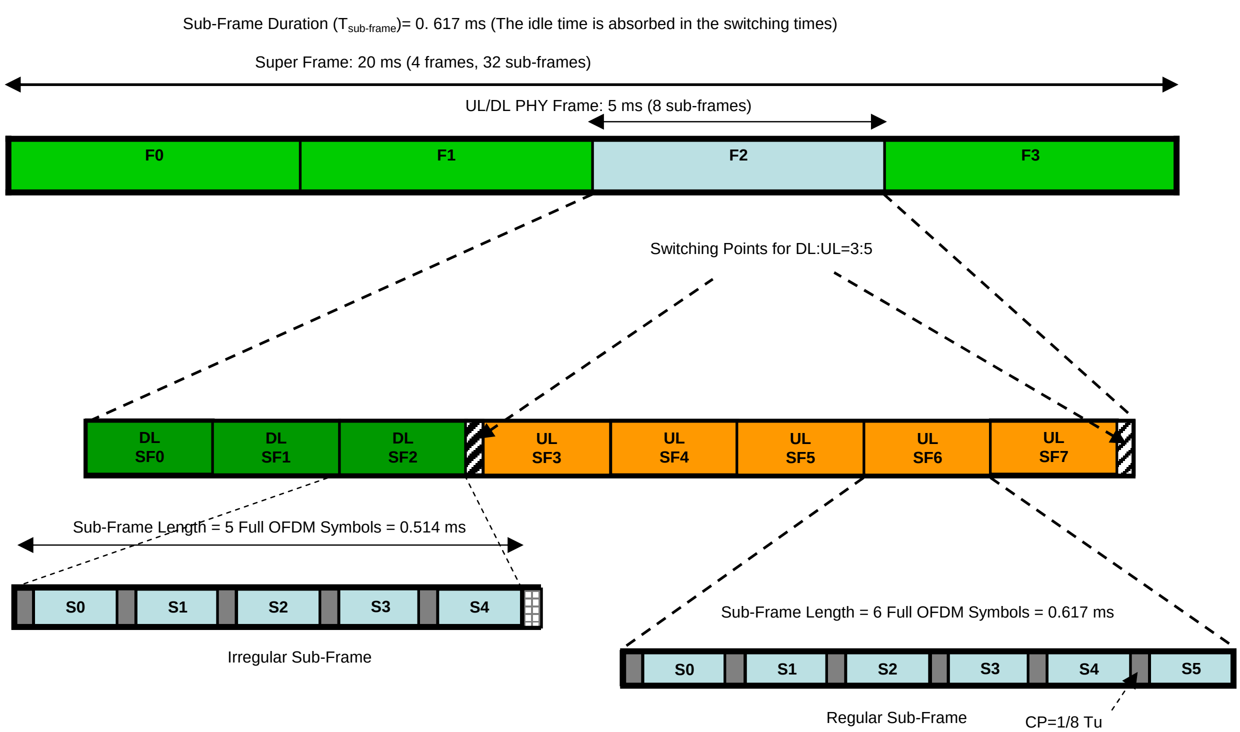


Figure 11.4-2: Regular and irregular sub-frames in TDD duplex scheme

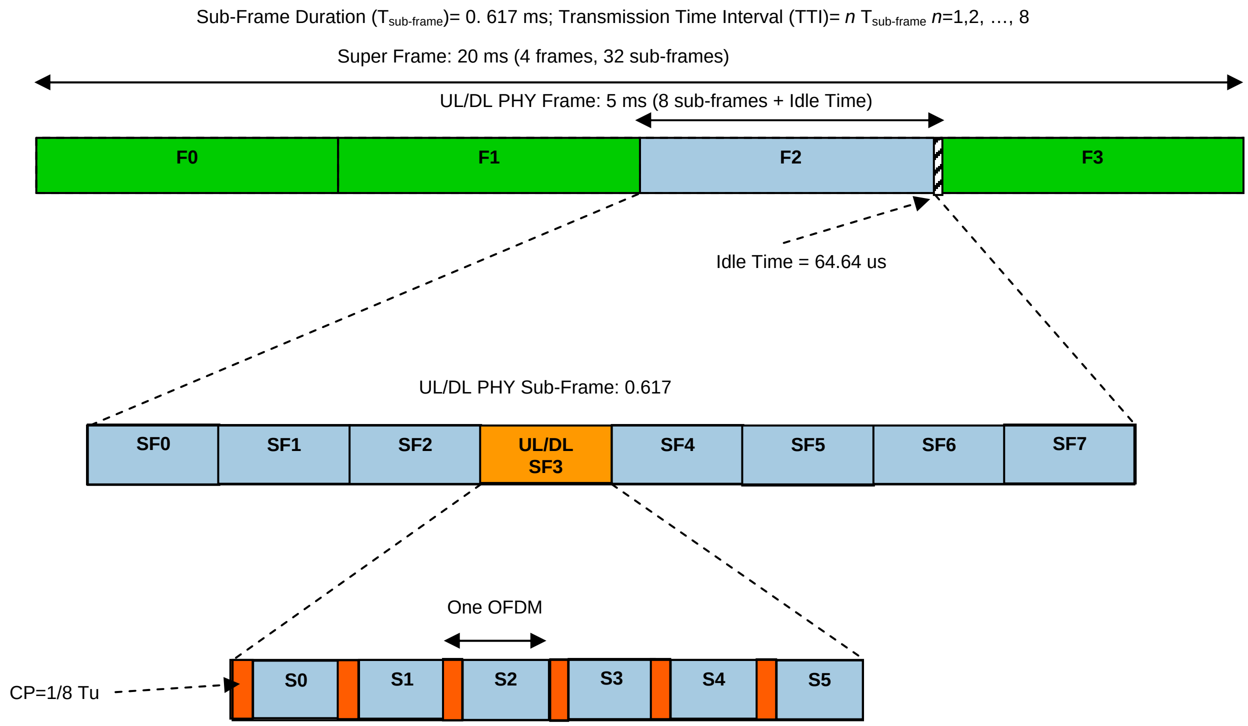


Figure 11.4-3: Frame structure in FDD duplex scheme (regular sub-frames)

11.4.1.1 Super-frame Header

As shown in Figure 11.4-1, each super-frame shall begin with a super-frame header which fully or partially occupies the first downlink sub-frame of each super-frame.

11.4.1.2 Transmission Time Interval

The transmission time interval is the minimum transmission time of physical layer data units over the radio air-interface and is equal to an integer number of sub-frames (default one sub-frame).

] <Editor note: end of proposal-1 of “11.4.1 Basic Frame Structure”>

[<Editor note: Start of proposal-2 of “11.4.1 Basic Frame Structure”>

11.4.1 Basic Frame structure (Proposal-2)

The IEEE 802.16m basic frame structure is illustrated in Figure 11.4-1 (proposal-2). In the time domain, the 802.16m air link consists of equally-sized super-frames. A super-frame is defined as the interval between two consecutive BS DL synchronization signals. A super-frame consists of integer number of equal-sized radio frames.

A radio frame is defined as the minimal repeated time interval for radio resource control, e.g., the repeated pattern for the Downlink (DL) and Uplink (UL) split in TDD systems, and the radio resource allocation decisions cycle. In TDD systems, a radio frame consists of two or more subframes, where the first subframe within a radio frame must be a DL subframe. In FDD or HFDD systems, a radio frame consists of one or more subframes.

A subframe is defined as contiguous time allocation with a fixed directionality i.e. downlink or uplink. Therefore, there are two types of subframes: DL subframe and UL subframe. A subframe consists of one or more permutation zones and may include the subsequent idle time to accommodate direction switching.

A permutation zone is defined as contiguous time allocation with consistent PHY properties, e.g. sub-carrier arrangements, resource block definitions, etc. A permutation zone consists of one or more mini-frames.

A mini-frame is defined as the unit of transmission that is determined by the rudimentary PHY structures e.g. pilot patterns, etc. A mini-frame consists of one or multiple OFDMA symbols.

An OFDMA symbol is defined in the OFDMA PHY section (provide the reference here).

[In addition, Hyper-Frame is defined as the repeated time interval defining location in which longer-term system information occurs, e.g., the channel descriptors, neighbor lists, security information, etc.]

The basic frame structure as shown in Figure 11.4-1 (proposal-2) is applied to FDD, TDD, and H-FDD duplexing schemes.

In the frequency domain, the 802.16m air link consists of subchannels. The 802.16m subchannels are defined in the OFDMA PHY section (provide the reference here).

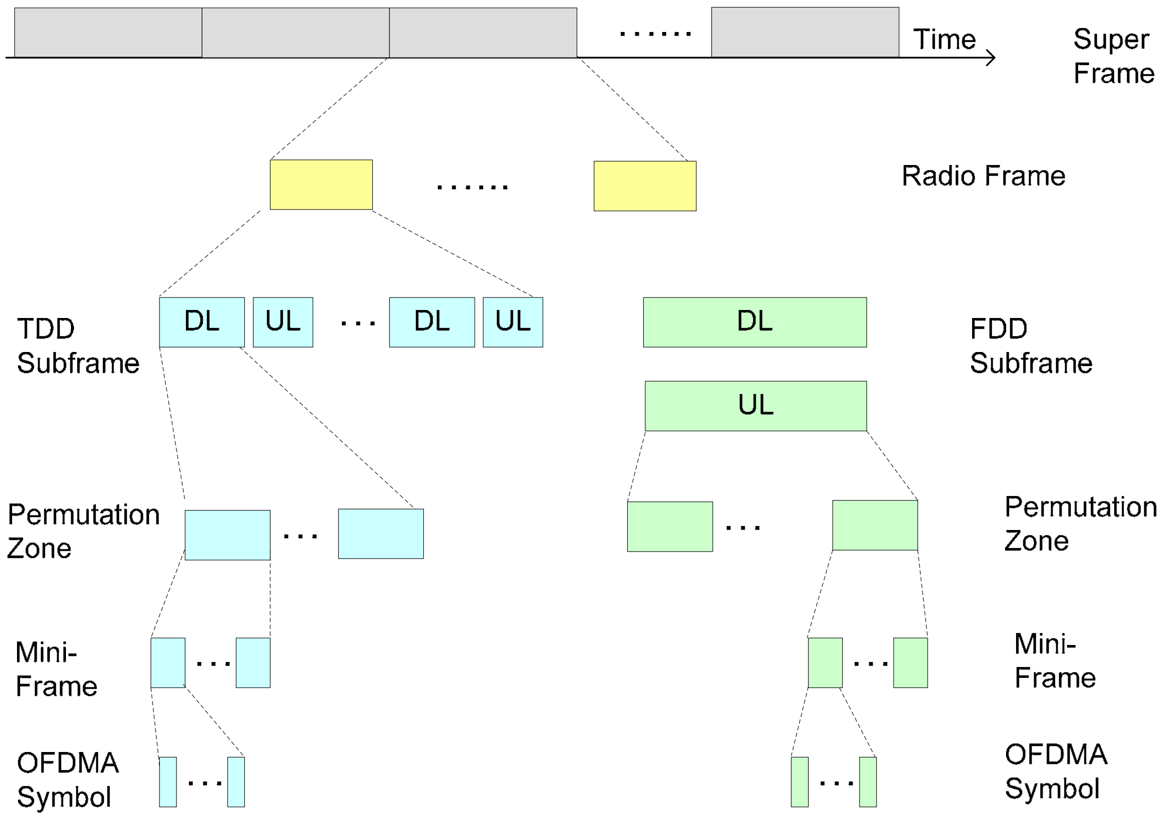


Figure 11.4-1: Basic frame structure → proposal-2

] <Editor note: end of proposal-2 of “11.4.1 Basic Frame Structure”>

[<Editor note: start of proposal-1 of “11.4.2 Frame Structure Supporting Legacy Frames”>

11.4.2 Frame Structure Supporting Legacy Frames (Proposal-1)

The legacy and new frames are offset by a fixed number of sub-frames to allow accommodate of new features such as new synchronization channel (preamble), broadcast channel (system configuration information), and control channels, as shown in Figure 11.4-3 (proposal-1). The FRAME_OFFSET is an integer number of sub-frames (default value is two sub-frames).

There shall be only two switching points in each TDD radio frame when supporting legacy systems.

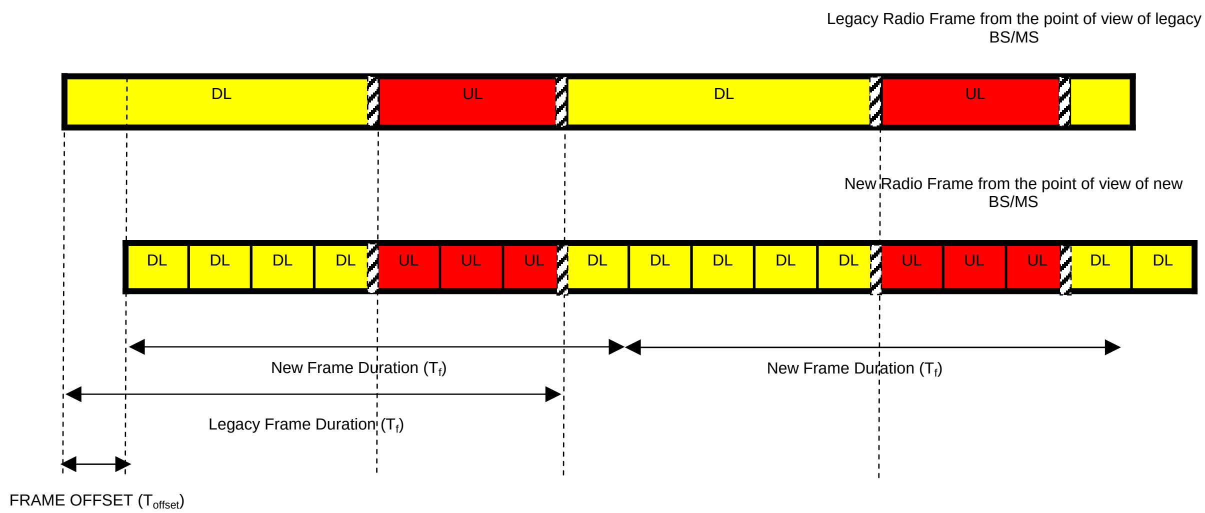


Figure 11.4-3: Relative position of the new and legacy radio frames (example TDD duplex scheme) → proposal-1

] <Editor note: end of proposal-1 of “11.4.2 Frame Structure Supporting Legacy Frames”>

[<Editor note: start of proposal-2 of “11.4.2 Frame Structure Supporting Legacy Frames”. Note that the basic idea of proposal-1 and proposal-2 of the legacy support frame structure are similar, i.e., both use TDM between 16m and legacy in both DL and UL. However, they differ regarding the usage and definitions of the terminology specified in the Basic Frame Structure section. >

11.4.2 Frame Structure Supporting Legacy Frames (proposal-2)

When legacy support is enabled, the legacy frames and the 802.16m frames are offset by a fixed integer number of mini-frames to allow accommodate of new designs for 802.16m such as system synchronization signal. As shown in Figure 11.4-3 (proposal-2), the 802.16m frame structure supports the legacy frames by having the legacy portion and the 802.16m portion sharing the 802.16m air link in a time-division manner. Such a legacy frame support scheme is applied to TDD, FDD, and H-FDD duplexing schemes, although Figure 11.4-3 (proposal-2) illustrates the scheme in TDD.

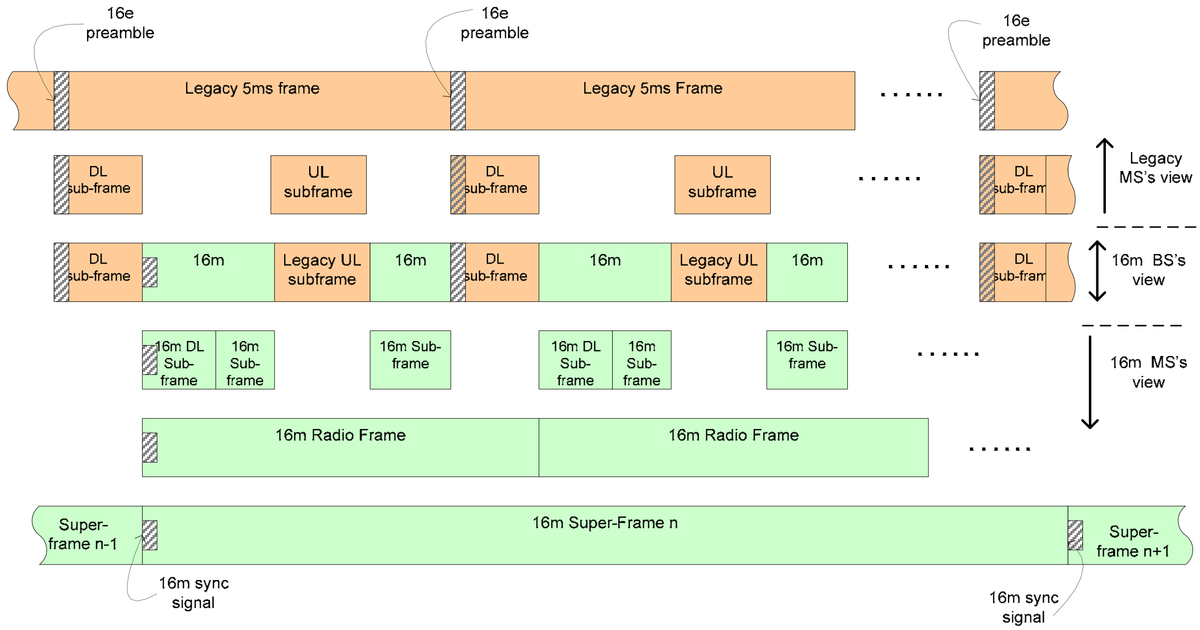


Figure 11.4-3: Frame Structure Supporting Legacy Frames (TDD) → proposal-2

] <editor note: end of proposal-2 of “11.4.2 Legacy Support Frame Structure”>

[Editor’s note: start of proposal-3 of “11.4.2 Frame Structure Supporting Legacy Frames”, the difference between proposal-3 and proposal-2 of “11.4.2. Frame Structure Supporting Legacy Support Frames” is the UL TDM vs. FDM between legacy portion and 16m portion.>

11.4.2 Frame Structure Supporting Legacy Frames (proposal-3)

When legacy support is enabled, the legacy frames and the 802.16m frames are offset by a fixed integer number of mini-frames to allow accommodate of new designs for 802.16m such as system synchronization signal. As shown in Figure 11.4-3 (proposal-3), the 802.16m frame structure supports the legacy frames by having the legacy portion and the 802.16m portion sharing the 802.16m air link in a time-division manner in DL and in a frequency-division manner in UL. Such a legacy frame support scheme is applied to TDD, FDD, and H-FDD duplexing schemes, although Figure 11.4-3 (proposal-3) illustrates the scheme in TDD.

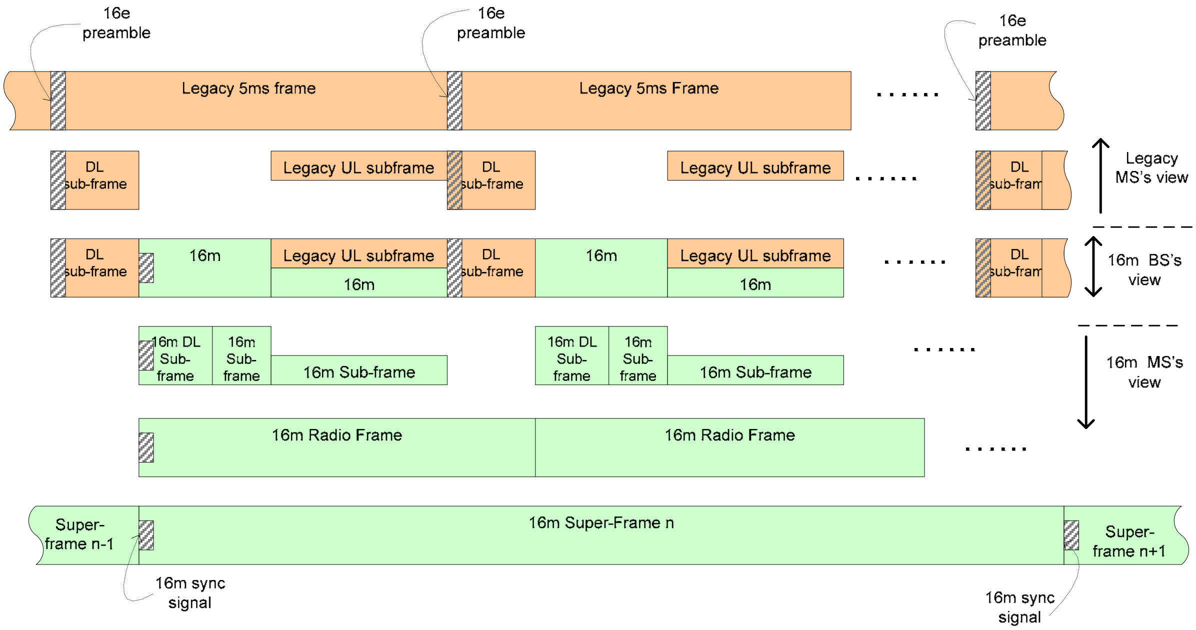


Figure 11.4-3: Frame Structure Supporting Legacy Frames → proposal-3

] <Editor note: end of proposal-3 of "11.4.2 Frame Structure Supporting Legacy Frames">

[<Editor note: When 802.16m uses a wider contiguous channel than the corresponding legacy system, there are three proposals: a] legacy portion is in the middle of the wider channel; b) the legacy portion is on one side of the wider channel; and c) two legacy channels are accommodated in one wider 802.16m channel. Those three proposals are illustrated by the following three subsections, named as 11.4.3 (proposal-1), 11.4.3 (proposal-2), and 11.4.3 (proposal-3), respectively. Note that the content of this section is subject to change based on the ultimate decision on the multi-carrier and multi-bandwidth support in IEEE 802.16m>]

[<Editor note: start of proposal-1 of "11.4.3 Frame Structure Supporting Legacy Frames with a wider channel for 802.16m">

11.4.3 Frame Structure Supporting Legacy Frames with a Wider Channel for 802.16m (proposal-1)

When legacy support is enabled and the 802.16m system uses a wider contiguous channel, the legacy channel is embedded in the middle of the wider 802.16m channel, as illustrated in Figure 11.4-4 (proposal-1).

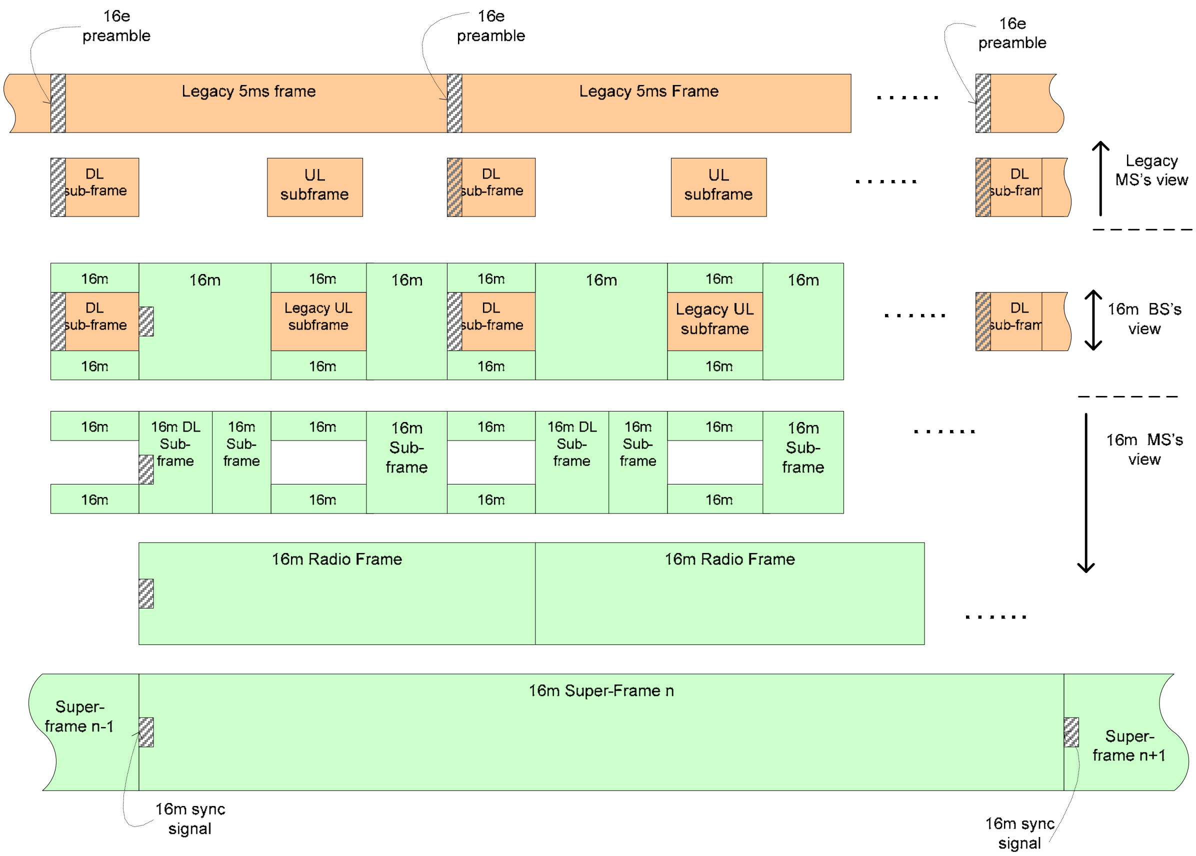


Figure 11.4-4: Frame Structure Supporting Legacy Frames with a wider channel for 16m → proposal-1

[<Editor note: end of proposal-1 of "11.4.3 Frame Structure Supporting Legacy Frames with a wider channel for 802.16m">

[<Editor note: beginning of proposal-2 of "11.4.3 Frame Structure Supporting Legacy Frames with a wider channel for 802.16m">

11.4.3 Frame Structure Supporting Legacy Frames with a Wider Channel for 802.16m (proposal-2)

When legacy support is enabled and the 802.16m uses a wider contiguous channel, the legacy channel is on the one side of the wider 802.16m channel, as illustrated in Figure 11.4-4 (proposal-2).

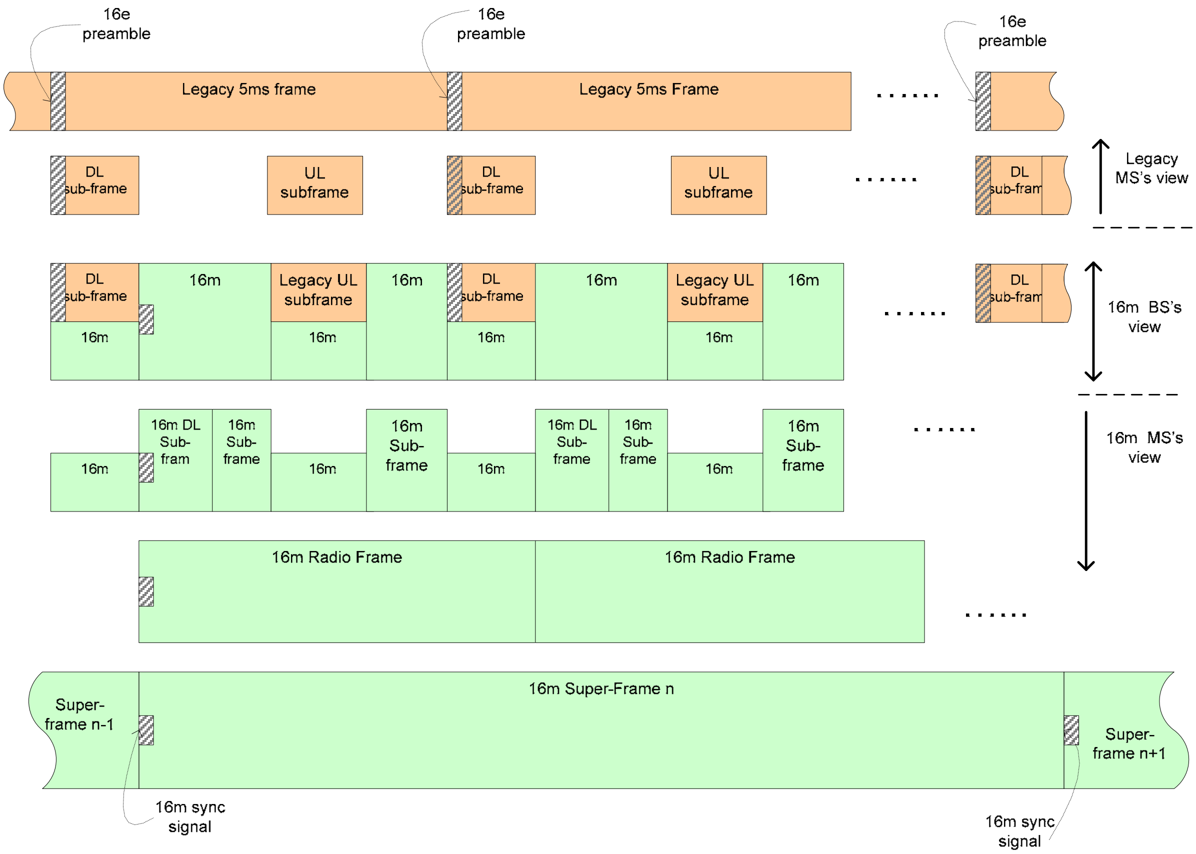


Figure 11.4-4: Frame Structure Supporting Legacy Frames with a wider channel for 16m → proposal-2

[<Editor note: end of proposal-2 of "11.4.3 Frame Structure Supporting Legacy Frames with a wider channel for 802.16m">

[<Editor note: beginning of proposal-3 of "11.4.3 Frame Structure Supporting Legacy Frames with a wider channel for 802.16m">

11.4.3 Frame Structure Supporting Legacy Frames with a Wider Channel for 802.16m (proposal-3)

When legacy support is enabled and the 802.16m uses a wider contiguous channel that is twice the width of the legacy channel, two legacy channels are accommodated by the one wider 802.16m channel, as illustrated in Figure 11.4-4 (proposal-3).

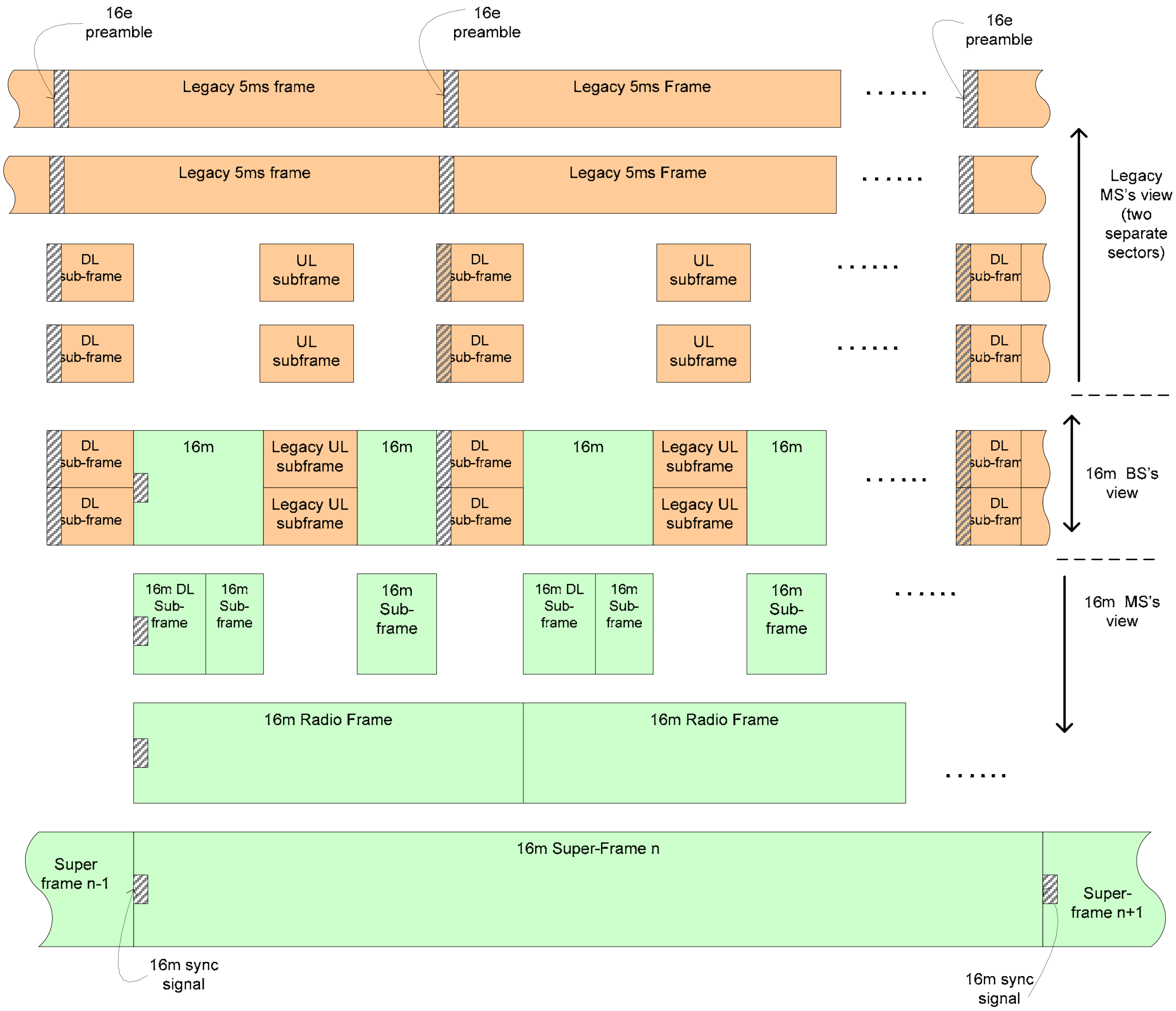


Figure 11.4-4: Frame Structure Supporting Legacy Frames with a wider channel for 16m → proposal-3

]<Editor note: end of proposal-3 of “11.4.3 Frame Structure Supporting Legacy Frames with a wider channel for 802.16m”>

11.4.4 Relay Support in Frame Structure

[In accordance with the IEEE 802.16m system requirements (IEEE 802.16m-07/002r4), the 802.16m should provide mechanisms to enable multi-hop relays including those that may involve advanced antenna technique transmission.

When the relay support is enabled, in order to support relay operations, the definition of IEEE 802.16m DL and UL time zones is expanded to support communications with RSs as well as communications with MSs. An example relay-enabled TDD frame structure is illustrated in Figure 11.4-5. The top half of the figure shows the frame structure from the perspective of the BS and the bottom half shows the frame structure from the perspective of the RSs. In order to support relay operations, an additional IEEE 802.16m DL relay zone and an additional IEEE 802.16m UL relay zone are introduced to the frame structure. Receive/transmit transmission gaps are required between IEEE 16e DL zone and the IEEE DL relay zone and between the two consecutive IEEE 802.16m DL relay/access zones and between the IEEE 802.16m UL relay/access zones to allow the RSs to transition from receive to transmit operation and vice versa. These gaps are required only for the RSs and thus appear only in the RS frame structure. The BS may transmit to MSs or receive from MSs during these gaps.

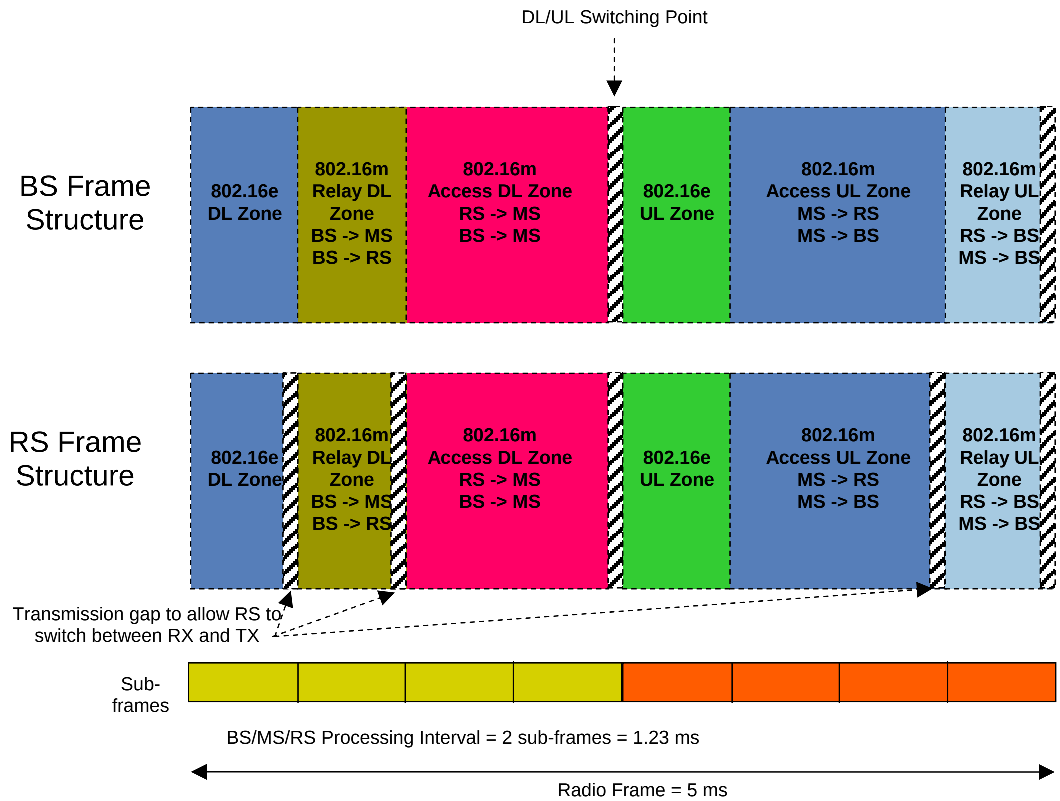


Figure 11.4-5: Relay Support in TDD Frame Structure

The FDD frame structure is the same as the TDD frame structure except that the DL and UL transmission are in separate frequency bands shown as F_1 and F_2 in Figure 11.4-6. The dotted lines between the DL and UL transmissions indicate the DL zone in which MAPs may be transmitted for the associated UL zone. Note that the relay and access time zones must be located at least two sub-frames apart to account for the BS/RS/MS processing time.

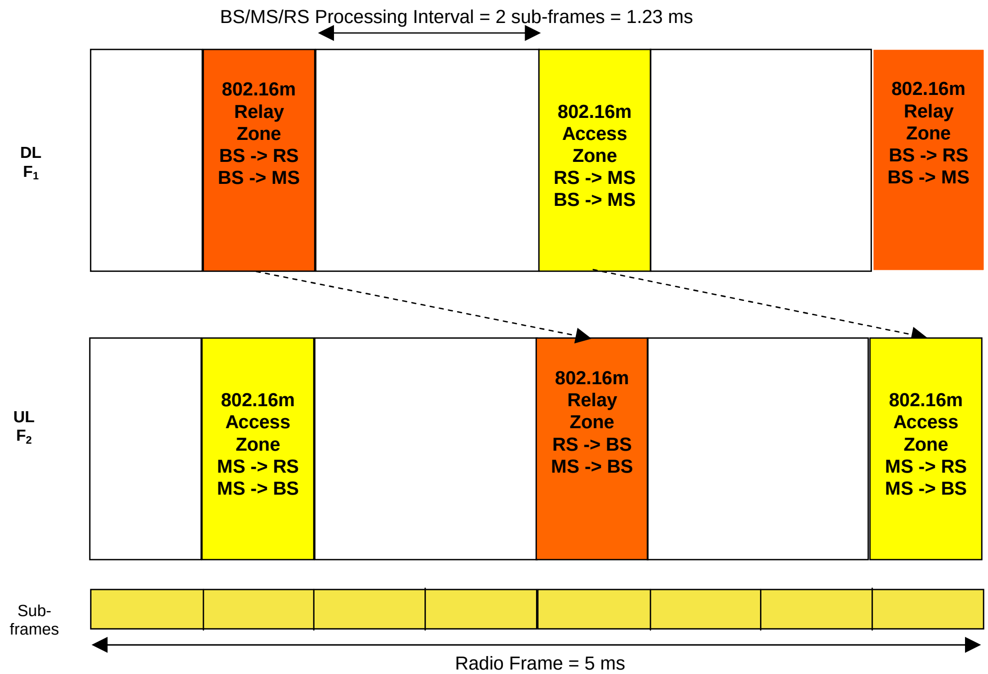


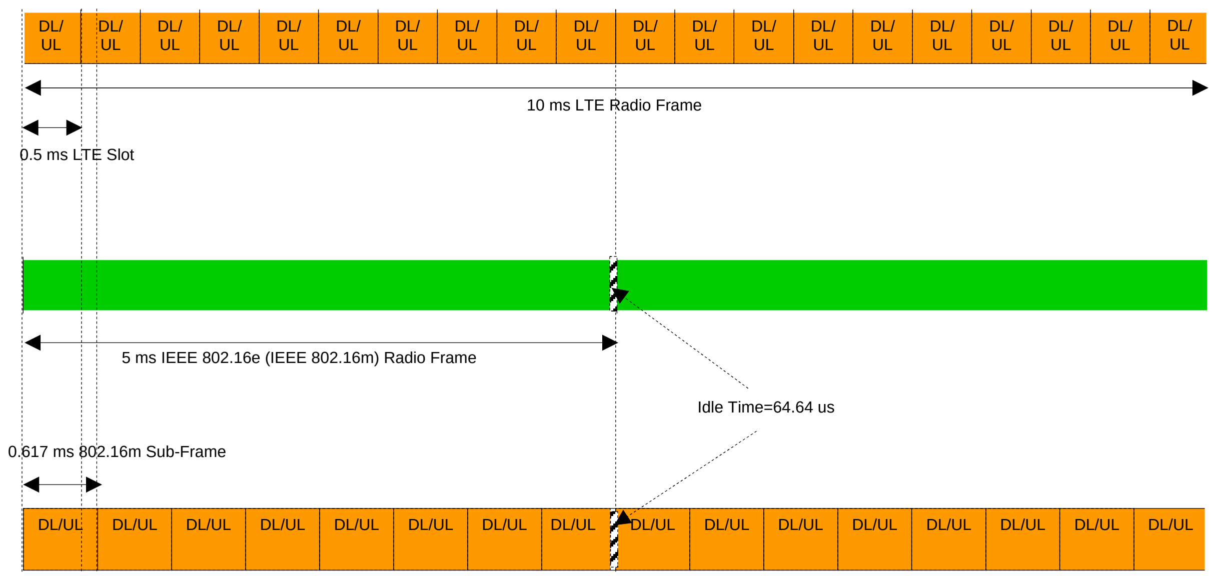
Figure 11.4-6: Relay Support in FDD Frame Structure

]

11.4.5 Coexistence Support in Frame Structure

11.4.5.1 Coexistence with E-UTRA (LTE)

[Coexistence between IEEE 802.16m and E-UTRA in TDD duplex scheme may be facilitated by inserting either idle symbols within the IEEE 802.16m frame or idle sub-frames. Applying a delay or offset between the beginnings of the IEEE 802.16m frame and the E-UTRA TDD frame may allow the time allocated to idle symbols or idle sub-frames to be minimized. Figures 11.4-7 and 11.4-8 demonstrate how coexistence between IEEE 802.16m and E-UTRA can be achieved in both FDD and TDD modes, respectively to minimize the inter-system interference.



Notes: Each 10 ms LTE radio frame is equivalent to two 5 ms 802.16m radio frames.
5 LTE Sub-Frames are equivalent to 8 802.16m Sub-Frames (**5:8 Sub-Frame Ratio**).

Figure 11.4-7: Alignment of IEEE 802.16m frame with E-UTRA frame in FDD mode

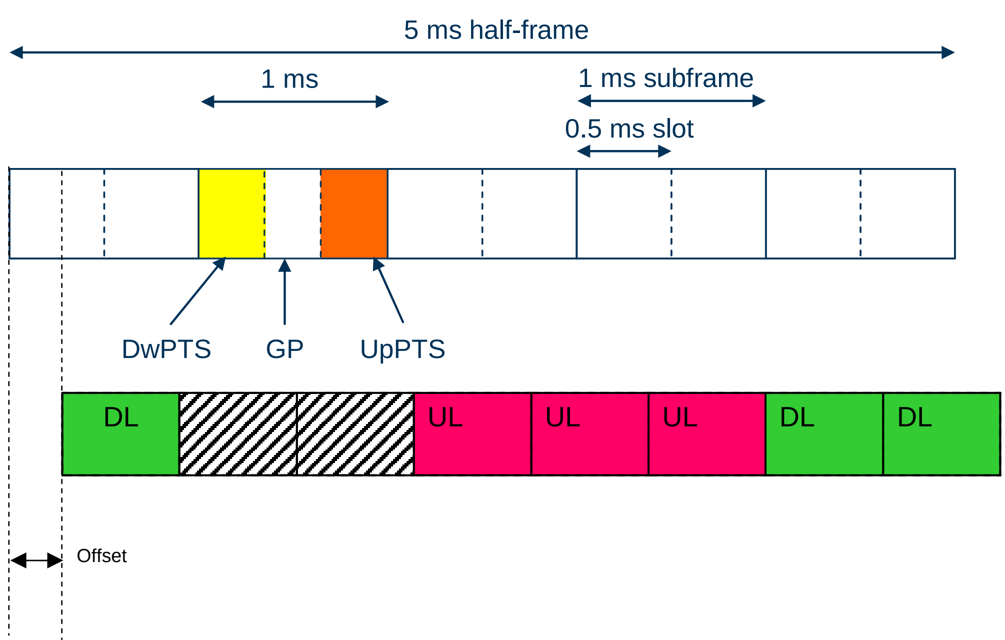


Figure 11.4-8: Alignment of IEEE 802.16m frame with E-UTRA frame in TDD mode

11.4.5.2 Coexistence with UTRA LCR-TDD (TD-SCDMA)

Coexistence between IEEE 802.16m TDD and UTRA LCR-TDD (TD-SCDMA) may be facilitated by inserting either idle symbols within the IEEE 802.16m frame or idle sub-frames. Figure 11.4-9 shows how coexistence between IEEE 802.16m with a 4:4 DL:UL ratio and TD-SCDMA can be facilitated.

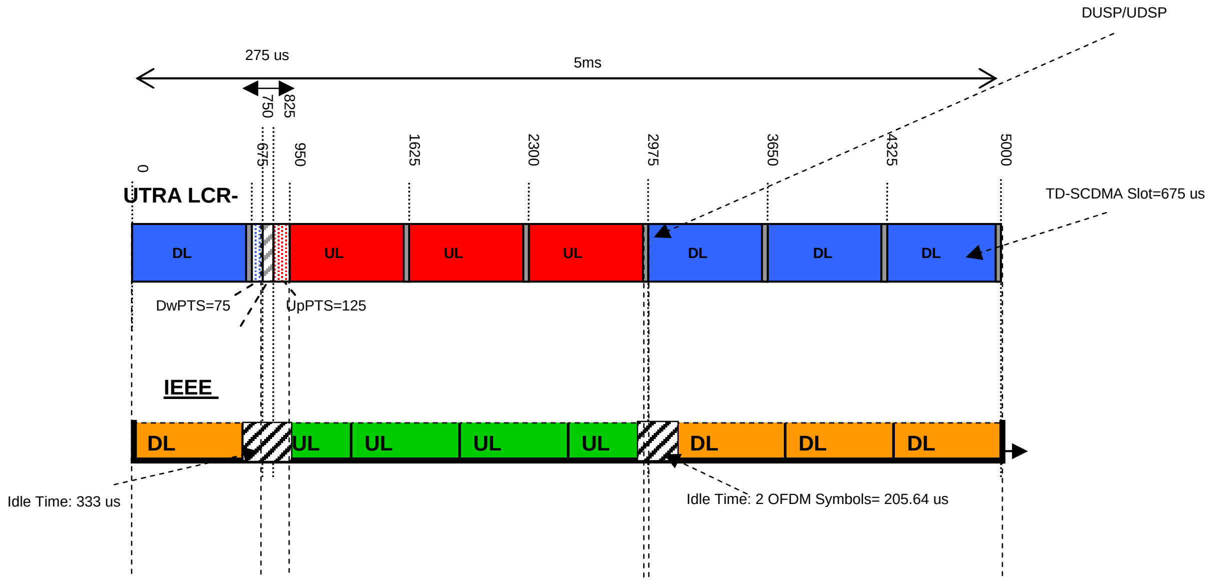


Figure 11.4-9: Alignment of IEEE 802.16m frame with UTRA LCR-TDD frame in TDD mode

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[Editor note: the following text has been generated based on minority opinion and the TBD responses from a large number of members to latency attributes of the frame structure in the Excel Sheet [2] and the necessity to demonstrate the frame structure compliance with the IEEE 802.16m SRD [1]. The content of the following tables will be updated based on the ultimate decisions that will be made in the group on the frame structure parameters.]

11.5 Data Plane and Control Plane Access Latencies

[In order to justify the choice of parameters for the proposed frame structure, it is imperative to demonstrate that the frame structure and associated parameters satisfy the IEEE 802.16m system requirements. In the following sections, the break down of the data and control planes access latencies is provided for the reference and the IEEE 802.16m systems.

11.5.1 Data Plane Access Latency

The break down of the components of data plane access latency is shown in Table 11.5-1. The access latency with 30% frame error rate over the airlink is 4.67 ms which is less than 10 ms limit specified by the IEEE 802.16m SRD.

Step	Description	IEEE 802.16e Value	IEEE 802.16m Value
0	MS wakeup time	Implementation Dependent	Implementation Dependent
1	MS Processing Delay	2.5 ms	1.23 ms
2	Frame Alignment	2.5 ms	0.31 ms
3	TTI for UL DATA PACKET (Piggy back scheduling information)	5 ms	0.617 ms
4	H-ARQ Retransmission (FER = 30%)	0.3*20 ms	0.3* 4.3 ms
5	BS Processing Delay	2.5 ms	1.23 ms
6	R6 Transfer delay	T_{R6}	T_{R6}
7	ASN-GW Processing delay	T_{ASN_GW}	T'_{ASN_GW}
	Total one way access delay	18.50 ms + T_{ASN_GW}+T_{R6}	4.67 ms + T'_{ASN_GW}+T_{R6}

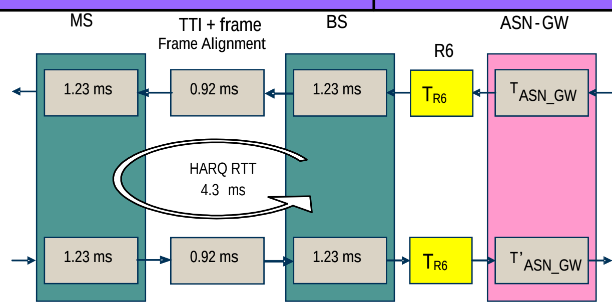

Table 11.5-1: Data plane access latency

11.5.2 Control Plane Access Latency

The break down of system entry procedure from DL scanning and synchronization to the point where the radio resource control (RRC) connection is established is shown in Table 11.5-2. Note that the use of super-frame header, that encompasses the system configuration information, would significantly reduce the time spent in step 1. Also, since the probability of error required for transmission of some of the MAC control messages is typically 10^{-3}, H-ARQ is used to ensure more reliability. The use of shorter TTI and faster transmissions would enable shorter H-ARQ retransmission, consequently reducing the total time for IDLE_STATE to ACTIVE_STATE transition.

In addition, we assume that the base station, relay station, or mobile station processing time is approximately 2*TTI = 1.23 ms, that further reduces the total delay budget. It is shown that the IDLE_STATE to ACTIVE_STATE transition time of less than 80 ms is achievable through the use of proposed frame structure which is less the 100 ms value specified by the SRD.

It must be noted that some of the radio resource control and management messages require probability errors in the order of 10^{-6}; ARQ is used in conjunction with H-ARQ to achieve higher transmission reliability.

Step	Description	IEEE 802.16e Value	IEEE 802.16m Value
0	MS wakeup time	Implementation dependent	Implementation dependent
1	DL scanning and synchronization + DL MAP acquisition + DCD/UCD acquisition	> 300 ms (Assuming 0.5 s DCD/UCD interval)	20 ms
2	Random Access Procedure (UL CDMA Code + BS Processing + DL CDMA_ALLOC_IE)	> 15 ms	< 5 ms
3	Initial Ranging (RNG-REQ + BS Processing + RNG-RSP)	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ
4	Capability Negotiation (SBC-REQ + BS Processing + SBC-RSP) + H-ARQ Retransmission @ 30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
5	Authorization and Authentication/Key Exchange (PKM-REQ + BS Processing + PKM-RSP + …) +H-ARQ Retransmission @30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
6	Registration (REG-REQ + BS/ASN-GW Processing + REG-RSP) + H-ARQ Retransmission @30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
7	RRC Connection Establishment (DSA-REQ + BS Processing + DSA-RSP + DSA-ACK) + H-ARQ Retransmission @30%	> 15 ms (0.3*20 ms for H-ARQ ReTX)	< 5 ms (0.3* 4.3 ms for H-ARQ ReTX)
	Total C-plane connection establishment Delay	> 80 ms	< 30 ms
	Total IDLE_STATE –> ACTIVE_STATE Delay	> 380 ms	< 80 ms

Table 11.5-2: Control plane access latency

]

4 References

[1] IEEE 802.16m-07/002r4 (“IEEE 802.16m System Requirements”)

[2] IEEE C80216m-08/096r10

[3] Frame structure contributions, all available at http://ieee802.org/16/tgm ; also as listed in FrameStructList_r1.doc at http://groups.google.com/group/dot16m/files?hl=en