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Re:	IEEE 802.16m-07/047 – Call for Contribution on Project 802.16m System Description Document (SDD); Proposed 802.16m Frame Structure
Abstract	This contribution proposes a base frame structure framework for 802.16m.
Purpose	Adopt concept and proposed text into SDD
Notice	
Release	
Patent Policy	

Base Frame Structure for IEEE 802.16m

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1.0 Introduction

Requirements for the development of the 802.16m amendment to the IEEE 802.16 standard, as captured in the 'IEEE 802.16m System Requirements' document [1], stipulate many improvements in performance over the WirelessMAN-OFDMA Reference System and operation in many different deployment environments. Improvements in performance include reductions in latency across the air interface, increases in user and sector throughput, and reductions in system overhead. Operation is also required in the presence of varying levels of mobility from stationary up to 350 km/h and beyond, and in sectors and cells with drastically different coverage ranges from micro-cells and even femto-cells with coverage ranges in the 10's to 100's of meters to large urban macro-cells with coverage ranges greater than 5 kilometers.

It is impossible to maximize the achievable performance under such diverse deployment and operational conditions within the relatively rigid frame structure that currently exists in IEEE 802.16 operating with the OFDMA physical layer. Therefore, a new more flexible frame structure is proposed that allows maximal performance to be more readily achieved under the given deployment and operational conditions.

An added constraint on the system design of IEEE 802.16m is the requirement to support legacy Mobile Stations (MS) that conform to the WirelessMAN-OFDMA Reference System on the same radio frequency carrier simultaneously with IEEE 802.16m MSs. In this mixed mode of operation, the legacy MSs must be able to operate as if it were being served by a Base Station (BS) that conforms only to the WirelessMAN-OFDMA Reference System. The proposed IEEE 802.16m frame structure provides such support to legacy MSs.

2.0 Design Approach for IEEE 802.16m Frame Structure

In order to maximize the advantages for 802.16m, the design approach taken is to design a frame structure that gives the most flexibility to meet 802.16m requirements and then to add legacy support as independently as possible into this new structure. Approaching the 802.16m frame structure design in this way provides several advantages over starting from the legacy frame structure and adding 802.16m support into that structure including:

- minimizing the impact of the legacy frame structure on the 802.16m frame structure

- minimizing the degradation to the 802.16m performance while serving legacy MSs on the same carrier
- allowing 802.16m operation to be consistent whether operating with or without legacy support enabled
- allowing an 802.16m MS to operate in the same manner when being served by an 802.16m BS whether legacy support is enabled or not.

In designing the 802.16m frame structure, care was taken to not tightly couple parameters that should be controlled independently. Such parameters include:

- maximum time for opportunity to transmit in opposite direction
- minimum time between frame synchronization opportunities
- scheduling relevance timeframe

A further design objective was to achieve a consistent base frame structure and frame structure elements that can be applied to all required radio carrier operating scenarios: TDD, FDD and half-duplex FDD (H-FDD), and multi-carrier.

3.0 Proposed IEEE 802.16m Frame Structure

Guided by the design considerations and approach as described in Section 2.0, a flexible base frame structure for IEEE 802.16m is proposed as described in the Proposed Text for the SDD below.

As a starting point, it is important to arrive at the best general model for the IEEE 802.16m frame structure that provides the appropriate degrees of freedom of configurability in order to satisfy the diverse requirements of IEEE 802.16m within the one solution. Later as the design matures, some of the flexibility may be sacrificed as a reasonable tradeoff to reduce frame control overhead.

4.0 Proposed Text

The following description of the base frame structure for IEEE 802.16m is put forth for adoption into the SDD.

-- Start of Proposed SDD Text ---

11.x Frame Structure

11.x.1 Overview of Frame Structure and Frame Structure Elements

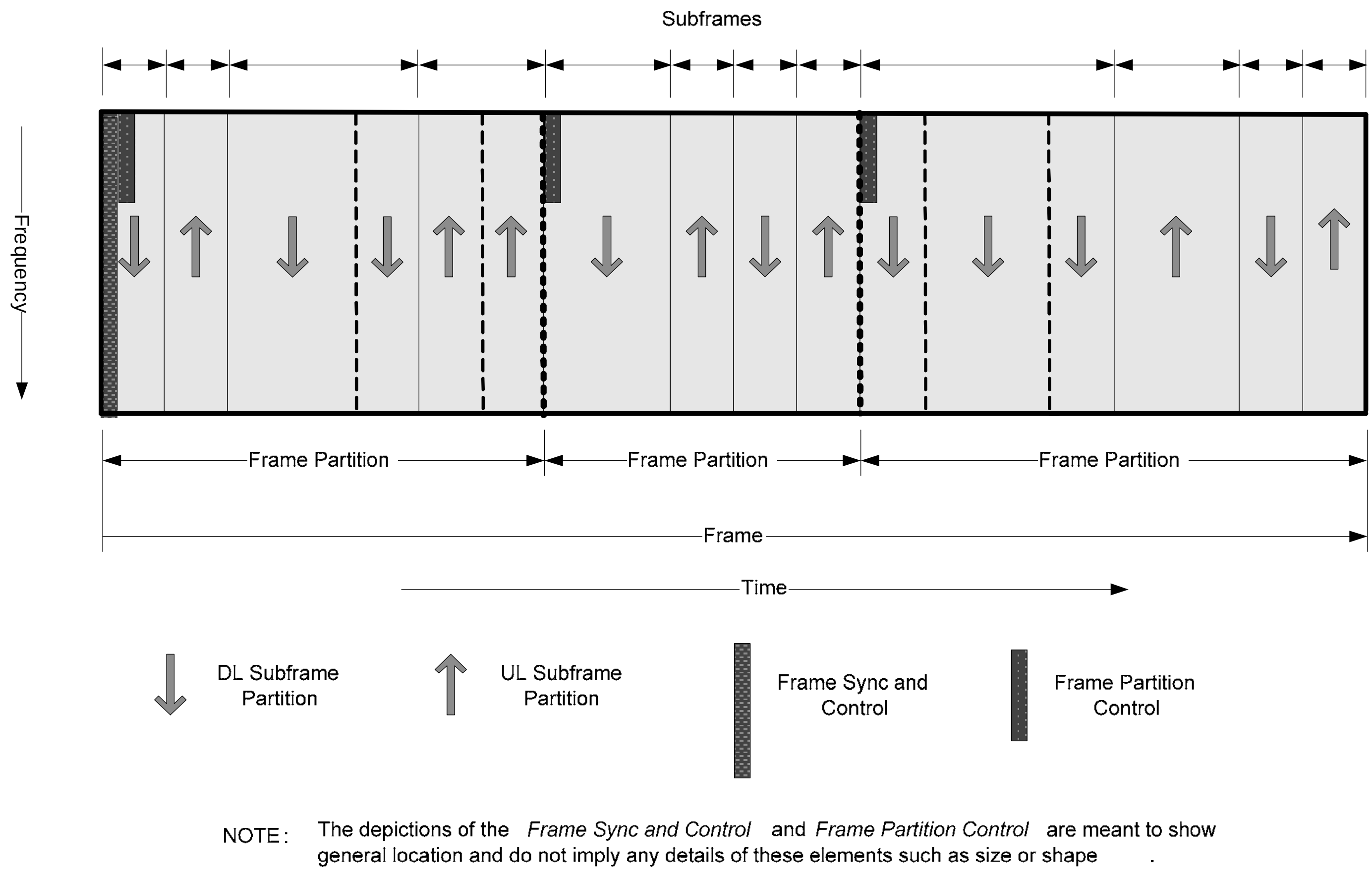

Figure 1 General Format of IEEE 802.16m Frame

Figure 1 illustrates the basic format and major elements of the proposed IEEE 802.16m frame. This format provides sufficient flexibility to allow this base frame definition to be catered to various operating scenarios, such as to meet varying minimum traffic QoS requirements or for different radio carrier configurations, different duplexing modes or multi-carrier operation.

The base frame definition comprises five major elements:

- unit subframe

  A *unit subframe* is defined as a continuous time interval of radio resources across the entire bandwidth (i.e. all subcarriers) of a radio carrier that possesses a particular physical-layer structure, such as pilot and data subcarrier organization, radio resource allocation structure, OFDM symbol structure, and idle time length and location. Units of radio resource allocations by the Medium Access Control (MAC) are always defined within the boundaries of a unit subframe and therefore, a unit subframe also represents the largest individually addressable radio resource allocable unit. A unit subframe may be subdivided into smaller units of radio resources that are individually addressable.

The nature of the physical layer parameter settings that may be set on a unit-subframe basis is a topic for further study and will be governed by the possible physical layer radio resource configurations to be defined.

A unit subframe is comprised of one or more (typically several) contiguous OFDM symbol periods and one or more idle times across all subcarriers of the a radio carrier.

The unit subframe is the smallest time-unit building block of the IEEE 802.16m frame structure.

- subframe

A *subframe* is defined as a contiguous number of time units of radio resources within a frame that has the same direction property – i.e either downlink or uplink. Therefore, a subframe is characterized by two parameters: 1) a direction (downlink or uplink) and 2) a length or duration. This definition essentially retains the definition of subframe from the WirelessMAN-OFDMA Reference System.

The granularity with which the length of subframes can be set is governed by the unit subframe since a subframe always contains an integer number of unit subframes, with the minimum length being 1 unit subframe and the maximum length being governed by the length of the frame partition in which the subframe belongs.

Since the length of subframes govern the rate of change of link direction in TDD operation, the subframe configuration has a direct impact on air interface transfer latency and therefore, on QoS and on signaling response latency.

- subframe partition

A subframe is comprised of one or more *subframe partitions*. Different subframe partitions may operate with different physical layer settings that may be better suited for communications with a certain set of MSs. This is analogous to the concept of permutation zone of the WirelessMAN-OFDMA Reference System, but with an important distinction since there may be other parameters that can be set differently between subframe partitions than subcarrier permutations.

A subframe partition is comprised of one or more unit subframes of identical or compatible configurations, and therefore, is always an integer number of unit subframes in length.

The number and lengths of subframe partitions are set on a subframe by subframe basis based on what may be the best configuration for the MSs and traffic being serviced at a particular time.

A subframe partition is characterized by a length and properties of its constituent unit subframe(s).

The radio resource allocation for a specific burst transmission may be comprised of a set of one or more individually addressable radio resource allocable units within the unit subframes of a subframe partition. Burst transmissions do not occur across subframe partition boundaries.

- frame

A *frame* provides the main outer structure that governs how quickly MSs can acquire synchronization with the frame boundaries and begin communications with a BS. Therefore, a frame is primarily characterized by a length, the presence of a synchronization signal, which is typically a Preamble at the beginning of the frame, and control information that pertains to the frame.

The frame length is therefore set as a tradeoff between how quickly MSs can acquire or re-acquire synchronization and how often the overhead of the frame synchronization and control information is incurred. Considerations for synchronization delay include time to begin or re-acquire communications with a BS, such as on initial network entry or on recovery after synchronization loss, or time to perform rudimentary signal measurements on the BS, such as during neighbor scanning to support handover.

- frame partition

  A frame partition is a sub-slice of the frame that provides a shorter timeframe for scheduling relevance. This means that decisions on radio resource structures for a frame partition are made at the beginning of the frame partition and generally cannot be altered. These are communicated to MSs via the Frame Partition Control signaling that appears at the beginning of the frame partition as shown in 0. The frame partition control defines the sub-frame structure of the frame partition. This sub-frame structure definition includes at least the following control information: 1) the time location of the start of each sub-frame that follows the first downlink sub-frame within the frame partition, 2) the directionality of each sub-frame (i.e. whether the sub-frame is used for downlink or uplink transmissions) that follows the first downlink sub-frame within the frame partition, 3) the time duration of each sub-frame, and 4) the start of the next frame partition in the frame.

  A frame partition is comprised of one or more subframes, where the first subframe must be a DL subframe in order to accommodate the Frame Partition Control signaling.

  The length of a frame partition is generally dynamically set on a frame partition by frame partition basis based on the available queued DL traffic and outstanding UL data requests and the available DL and UL radio resources in the next subframes in the frame. In this way, the scheduling horizon and the frequency of Frame Partition Control signaling adapts with the traffic load (i.e. becomes longer and less frequent as the traffic load increases). A maximum length of a frame partition is governed by the maximum tolerable delay for emergency signaling and may become relevant if this maximum length is shorter than the length of a frame. This maximum length is TBD.

  There are one or more frame partitions in a frame.

Using the definitions above, and the provided flexibility, many frame configurations are provided. For example, a frame can be defined as 20 msec, frame partitions can be defined as being of fixed lengths at 5 msec, and each frame partition can be comprised of 4 fixed-length subframes with each subframe being comprised of two subframe partitions containing a single unit subframe of 6 OFDM symbols. Such an instantiation of a frame structure is shown in **Figure 2**.

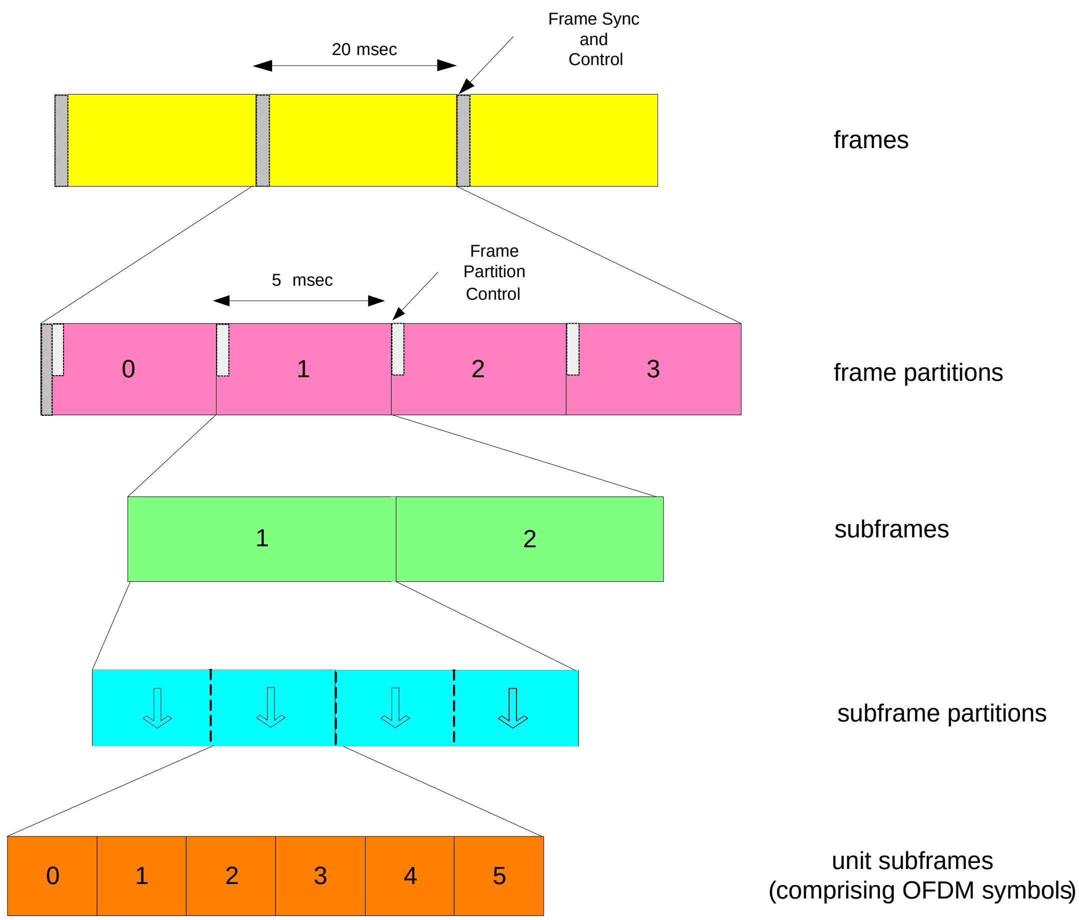

Figure 2 Example Frame Configuration for IEEE 802.16m

11.x.1.1 Unit Subframe Structures

A unit subframe may contain one or more (typically several) OFDMA symbols periods and one or more idle times across all subcarriers. **Figure 3** provides some illustrative examples of unit subframe formats that can be applied to DL subframe partitions. Example (a) in the figure shows a unit subframe which is maximally filled with OFDM symbol periods (that is, with ideally no idle time). This type of subframe would typically be used in all cases except as the last unit subframe of the last subframe partition in a DL subframe for the case of Time Division Duplex (TDD) operation or as the first unit subframe in the first DL subframe partition in the first subframe of a frame. The format of example (b) in the figure contains sufficient idle time for direction switching at the end of the unit subframe to be used as as the last unit subframe in the last subframe partition of a DL subframe in TDD mode. The format of example (c) would be one that can be applied where a synchronization signal is required in a subframe partition.

A similar set of unit subframe structures for UL is to be defined.

The exact set of unit subframe formats will depend on the definition of the OFDMA symbol parameters and unit subframe length as this will determine the fit of whole symbol periods within the unit subframe.

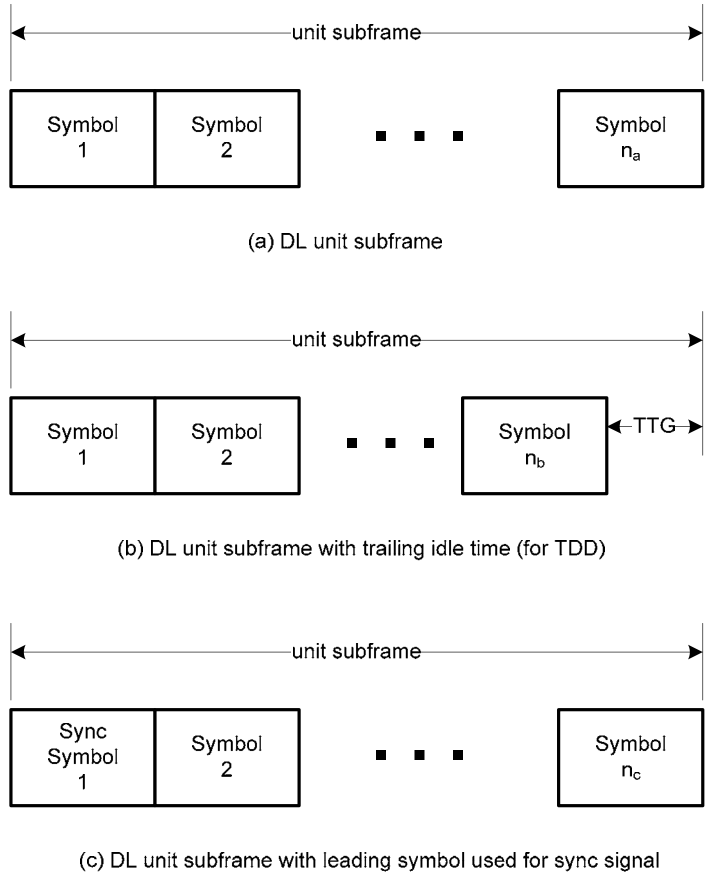

Figure 3 Illustrative Examples of DL Unit Subframe Formats

11.x.2 TDD Frame Structure

The base frame structure illustrated in **Figure 1** is directly applicable to TDD operation.

The main additional consideration for TDD operation is that the frame and subframe boundaries and subframe directions should be aligned between BSs in the neighborhood in order to minimize interference issues.

11.x.2.1 Legacy Support in TDD Mode

Support for MSs that conform to the WirelessMAN-OFDMA Reference System by an IEEE 802.16m BS is provided by the time-division multiplexing of subframe partitions of the 802.16m frame with sections of DL and UL subframes of the legacy 16e OFDMA frame. An example of the way this is done is depicted in **Figure 4**.

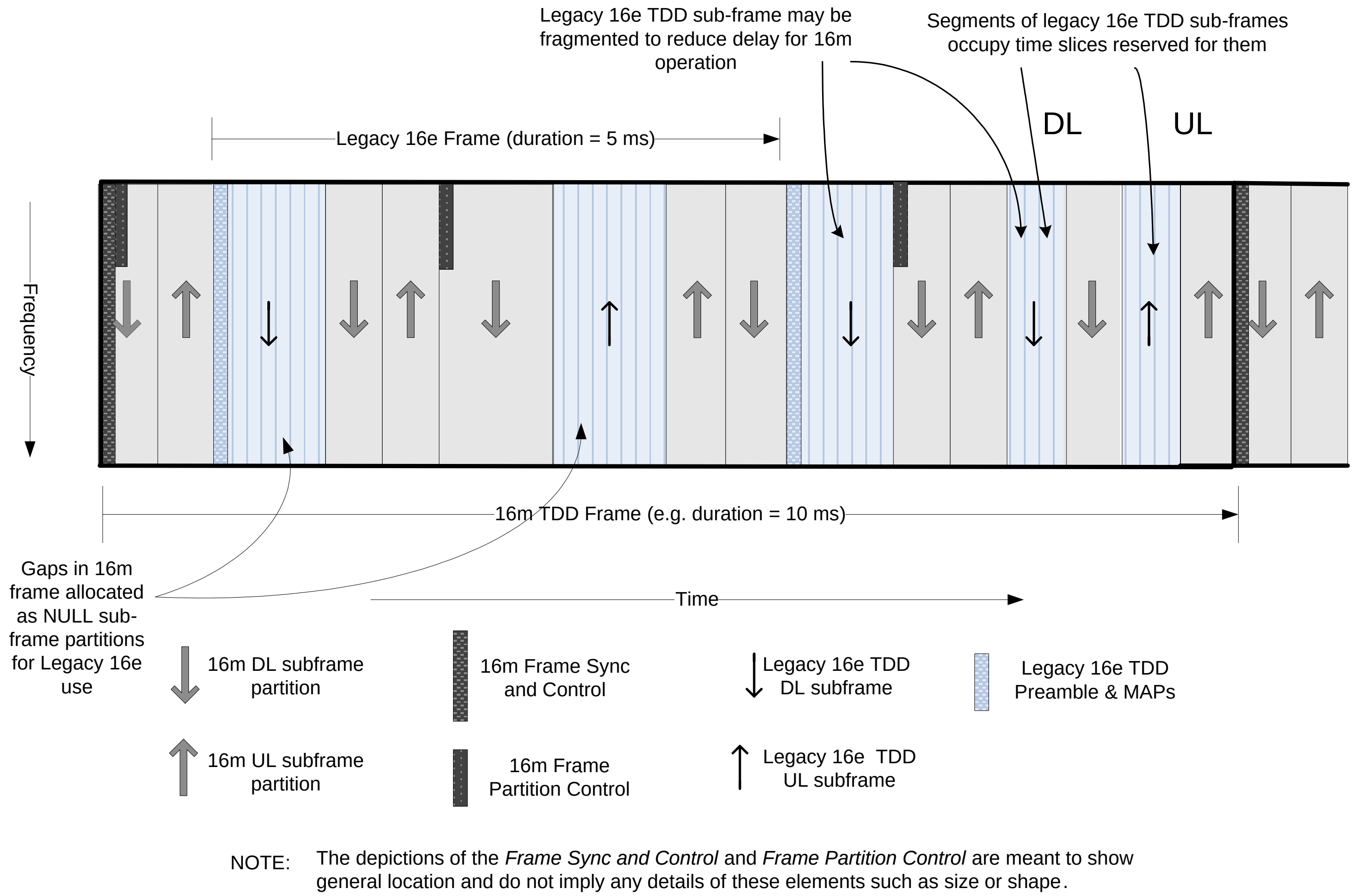

Figure 4 Support for Legacy 16e Frame via TDM – 16m Perspective

Some key aspects of the TDM operation with legacy support are:

- the existence of a separate Preamble for IEEE 802.16m operation that is orthogonal to the legacy WirelessMAN-OFDMA Preamble in order to achieve transparent operation between MSs operation in IEEE 802.16m mode versus those operating according to the WirelessMAN-OFDMA Reference System. The detailed definition of the new Preamble is described in Section 11.x.4.
- the setting of the length of the IEEE 802.16m frame to be an integer multiple of the legacy WirelessMAN-OFDMA frame length of 5 milliseconds. This allows a fixed offset to be maintained between the start of the IEEE 802.16m frame and the starts of one or more legacy WirelessMAN-OFDMA frames that overlap within the IEEE 802.16m frame.
- the use of NULL subframe partitions in the IEEE 802.16m frame to reserve parts of the frame for the legacy WirelessMAN-OFDMA frame. A NULL subframe partition is defined to be one in which no IEEE 802.16m transmissions are generated either by the BS or MS.
- the use of existing mechanisms provided by the legacy WirelesssMAN-OFDMA Reference System to notify legacy WirelessMAN-OFDMA MSs of gaps in the DL and UL subframes that are reserved for use by the IEEE 802.16m frame. Such gaps may be located at any symbol offset within a DL or UL subframe including being inserted in the middle of a DL or UL subframe to reduce the delay impact on IEEE 802.16m operation. An example of this is shown in **Figure 4** where the DL subframe of the

second legacy WirelessMAN-OFDMA frame is fragmented into two by the insertion of a pair of IEEE 802.16m subframes within the legacy DL subframe timeframe.

11.x.3 FDD Frame Structure

An extension of the base frame structure of **Figure 1** for operation on multiple simultaneous carriers on a BS provides the FDD frame structure as a specific sub-case. This extended multi-carrier frame structure with specific application to FDD is illustrated in **Figure 5**.

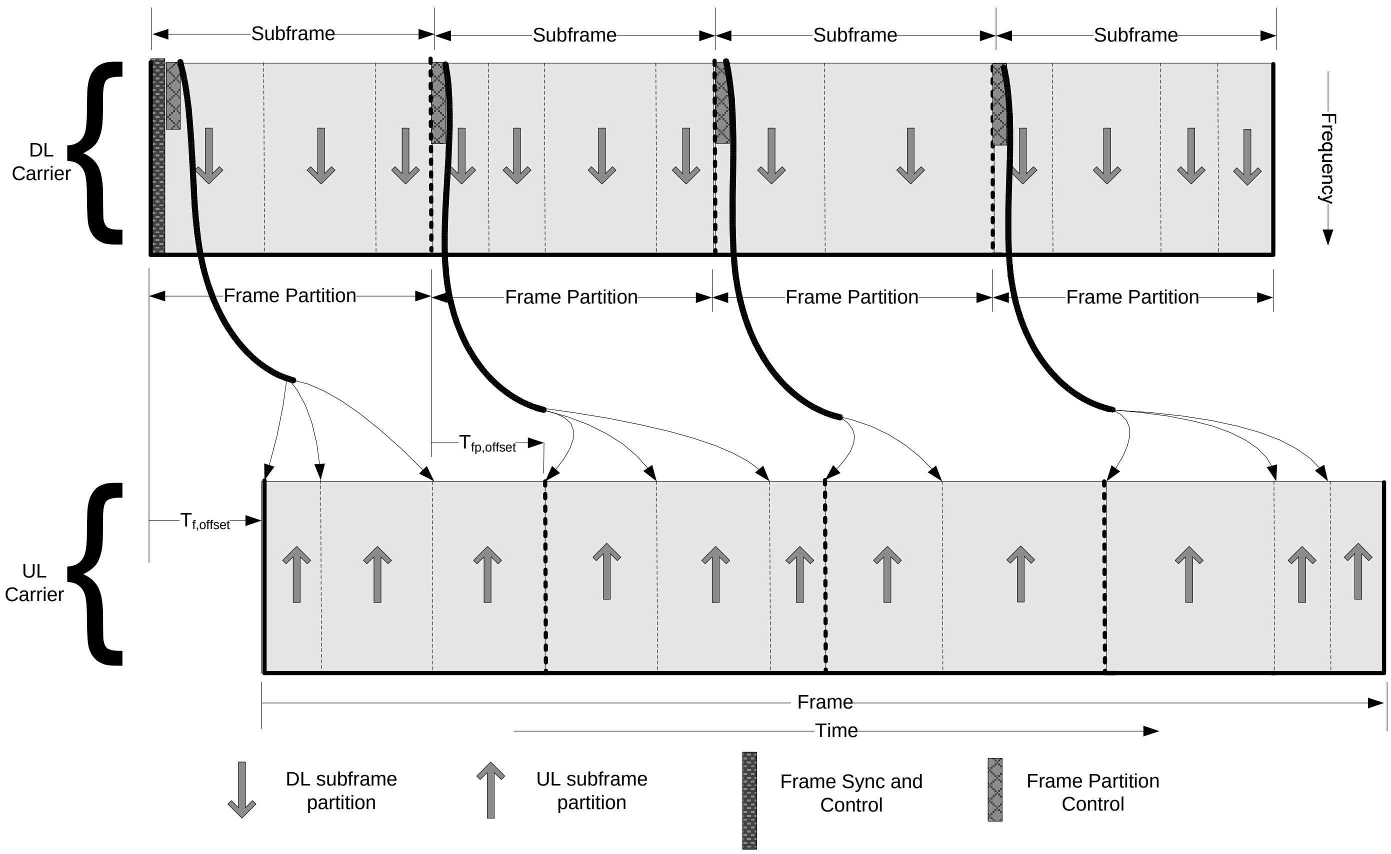

Figure 5 General format of FDD IEEE 802.16m frame

The FDD frame structure shares the same frame structure elements as the TDD frame structure with the identical elements and control appearing in the DL carrier, which is considered the primary control carrier. Besides providing control of the frame structure and radio resource allocation within the DL carrier itself, as a primary control carrier, it also provides the frame structure and radio resource allocation control for the UL carrier, which is considered a secondary carrier that is bound to the primary control carrier.

The type of control information provided by the primary control DL carrier pertaining to the secondary UL carrier may be grouped into two categories: 1) semi-static and 2) dynamic. The semi-static control information may be configurable and generally remains constant for extended periods of time (generally until some system configuration is changed) and so may be communicated as system broadcast information. The dynamic control information generally changes from one instance of the element to the next to which the control information pertains.

Included in the semi-static information are the following FDD frame control data:

- the location and size of the secondary UL carrier and possibly mapping the carrier to a carrier identifier
- the time offset, $T_{f,offset}$, from the start of the frame at the primary control DL carrier to the start of the same frame at the secondary UL carrier. This offset provides some allowance for the MS to receive and process control information at the primary carrier before it needs to be applied at the secondary UL carrier. To support half-duplex FDD (H-FDD) operation, this offset may also include allowance for channel switching from the primary control DL carrier to the secondary UL carrier and for ensuring sufficient non-overlap time between the frame partition at the primary control DL carrier and the same frame partition at the secondary UL carrier.

  There is a separate $T_{f,offset}$ for each secondary carrier.

The dynamic control information is primarily associated with each frame partition and so to support FDD (and generally multi-carrier) operation, a new set of control data for the associated frame partition at the secondary UL carrier is included in the *Frame Partition Cont*rol sent by the primary control DL carrier for each frame partition. Included in this frame partition control for the secondary UL carrier are:

- the subframe configuration within the frame partition

  For FDD sub-case of multi-carrier operation, all subframes on the primary control carrier are downlink and all subframes on the secondary carrier are uplink. Because of this, there is generally no need for more than one subframe per frame partition since the primary characteristic of a subframe is its directionality.

- the subframe partition configuration within each subframe in the frame partition
- the configuration and assignment of data allocations within each subframe partition
- the time offset, $T_{fp,offset}$, that specifies the offset of a frame partition on the primary control DL carrier to the associated frame partition at the secondary UL carrier. Having separate time offsets for each frame partition allows the frame partitions at the secondary carrier to be a different length from the associated frame partition at the primary control DL carrier.

11.x.4 16m Preamble

For 802.16m a new preamble is defined. The existence of a separate Preamble for IEEE 802.16m operation that is orthogonal to the legacy WirelessMAN-OFDMA Preamble is provided in order to achieve transparent operation between MSs operation in IEEE 802.16m mode versus those operating according to the WirelessMAN-OFDMA Reference System.

As shown in **Figure 6**, the 16m frame preamble in the *Frame Sync and Control* signal is located at the start of the 16m frame.

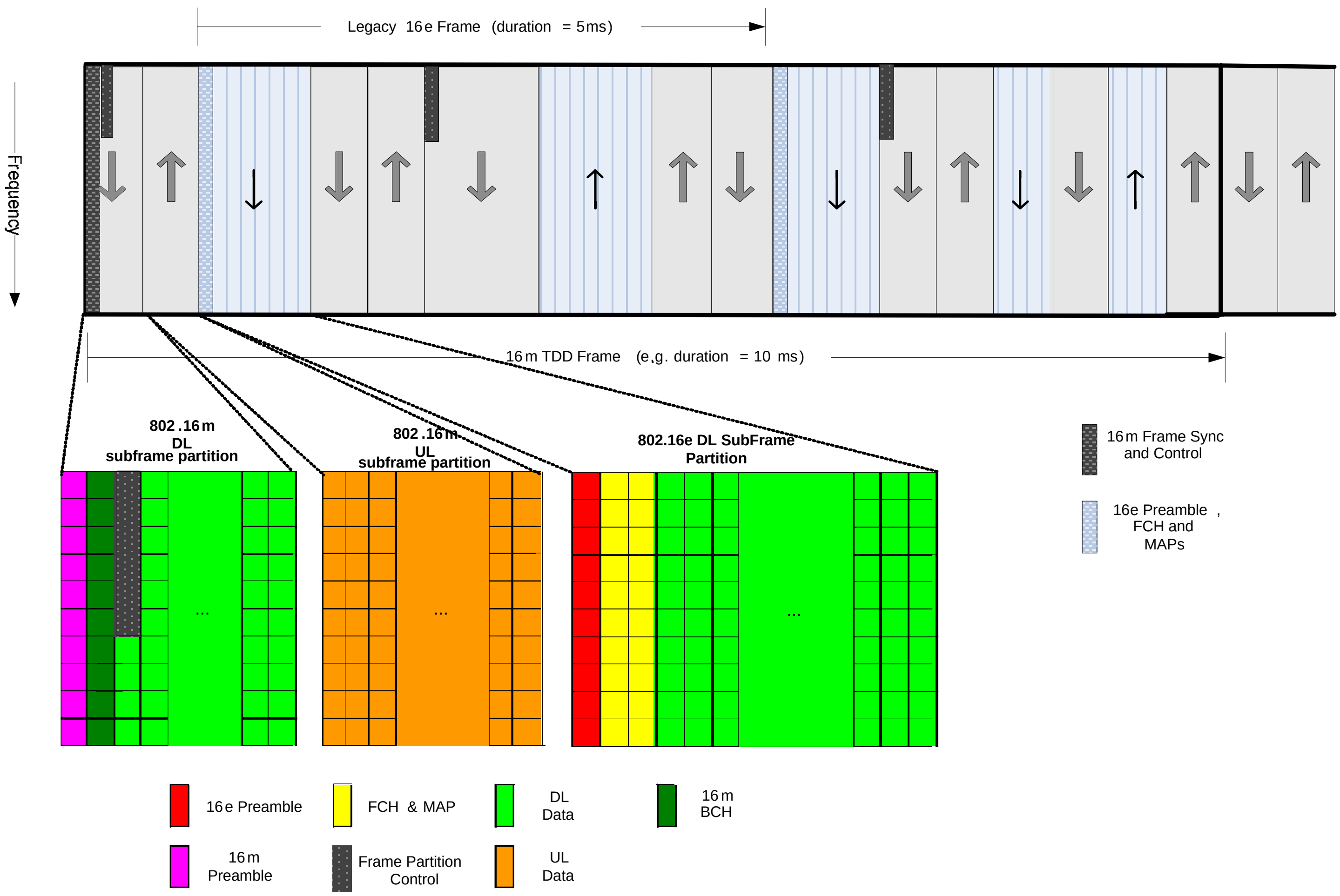

Figure 6 16m Frame Preamble (option 1)

Another alternative location example of the 16m *Frame Sync and Control* signal is showed in **Figure 7**.

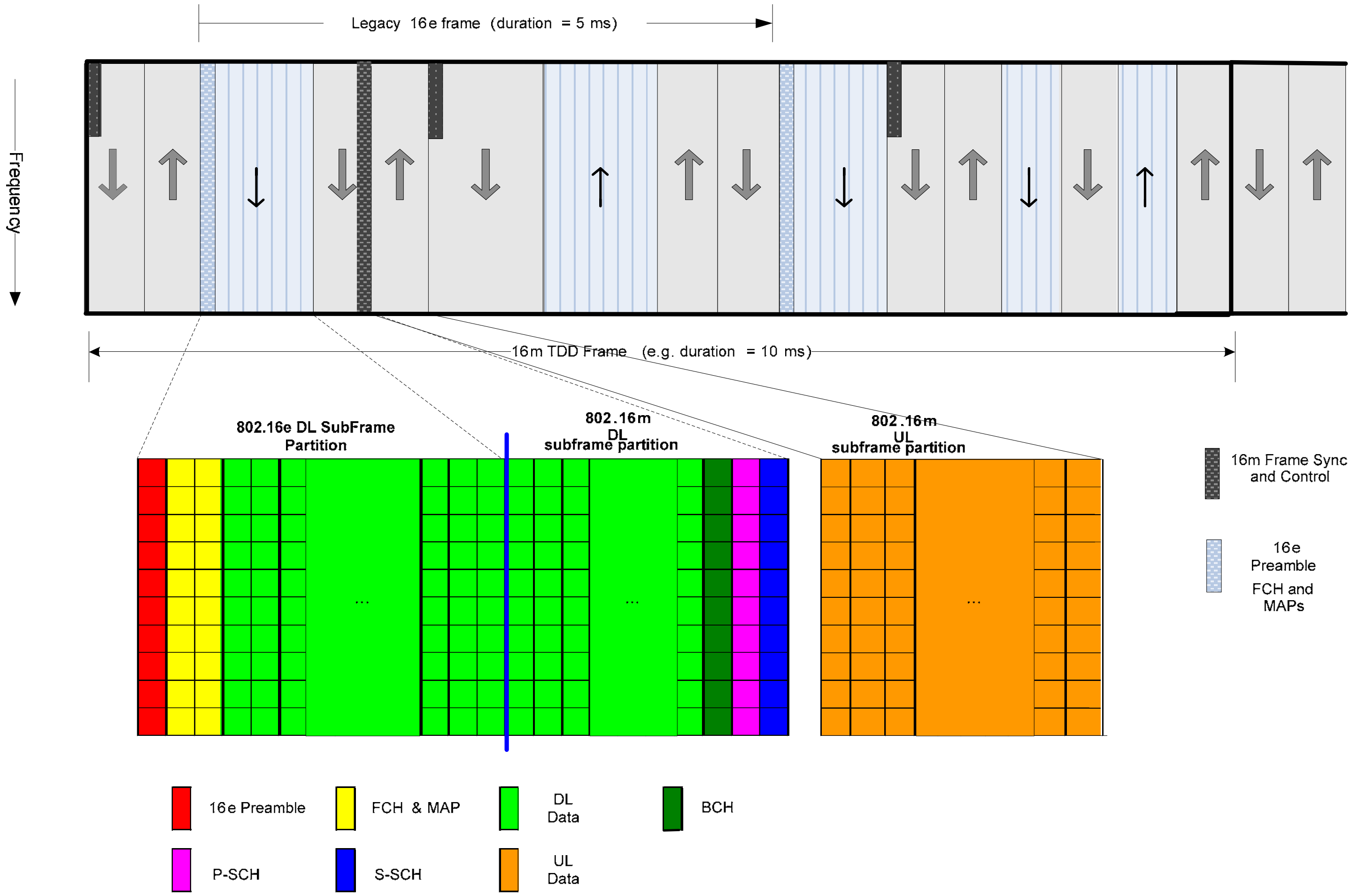

Figure 7 16m Frame Preamble (option 2)

In **Figure 7**, the frame preamble consists of three OFDM symbols, which are located at the end of a DL subframe, which precedes an UL subframe. The first OFDM symbol is the broadcast channel (BCH), which contains system parameters such as cyclic prefix length. The second OFDM symbol is the primary synchronization channel (P-SCH), which is used for coarse timing and frequency correction. The P-SCH is located in the center of the traffic bandwidth and occupies 5 MHz bandwidth (around the center frequency when bandwidth is above 5MHz). The third OFDM symbol is the secondary synchronization channel (S-SCH), which is used for fine timing and frequency correction, as well for sector identification. The cyclic prefix length of the P-SCH and S-SCH is fixed.

11.x.5 Unit Subframe Control

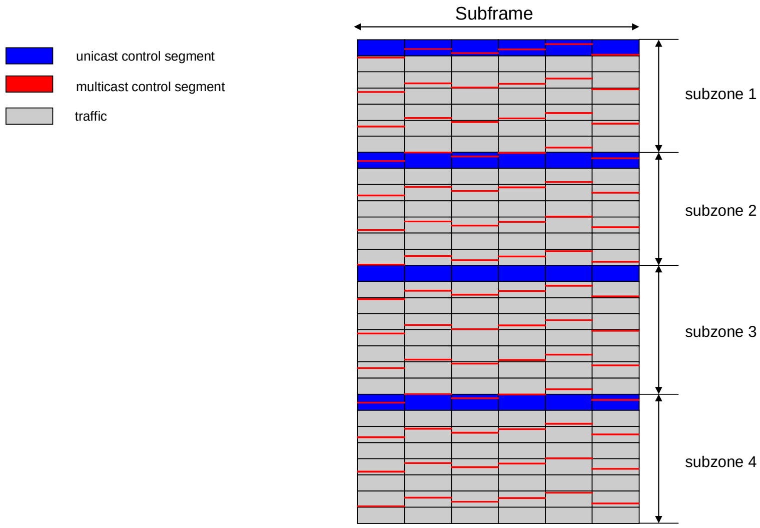

Figure 8 Unit Subframe Control

Each unit subframe has its own control segment to minimize HARQ turnaround times and CQI delay. The control segment is divided into two pieces, denoted the unicast control segment and the multi-cast control segment as depicted in **Figure 8**. The multicast control segment contains the following information, which is jointly encoded:

- Indication of the division of the frequency domain into multiple subzones, where a subzone is defined as a subset of the frequency domain
- Subcarrier permutation
- Other content for further study

Multiple unicast control segments are defined, where each segment contains one assignment. The unicast assignments are located at the beginning of each subzone. The assigned time-frequency resource is not restricted to the corresponding subzone

11.x.6 Resource Allocation

To reduce control channel overhead, a channel tree is defined for within each subframe partition. A channel tree is defined by its base-nodes, which is the smallest assignable time-frequency resource.

Two channel tree options are under consideration:

- Option 1: an annular channel tree structure is introduced. The base nodes are located on the outmost circle. The channel tree maintains a triangular structure for the outmost three levels and then switches to a power of two structure for the remaining levels. Such a structure results in a balance between the overhead associated with making time-frequency resource assignments and flexibility in the assignments. The levels of annular channel tree can be extended with the number of base nodes increasing. For the systems supporting the number of base nodes in the range of 2^n and 2^{n+1} （n>2）, the structures of annular channel tree are similar, except the number of null base nodes(null base node does not map to physical time-frequency resources).

Take example base node is defined as 14 subcarriers (data + pilot) × 6 OFDM symbols, which results in 60 base nodes for 10 MHz bandwidth and 30 base nodes for 5 MHz bandwidth. **Figure 9** shows the annular channel tree structure with two null base nodes.

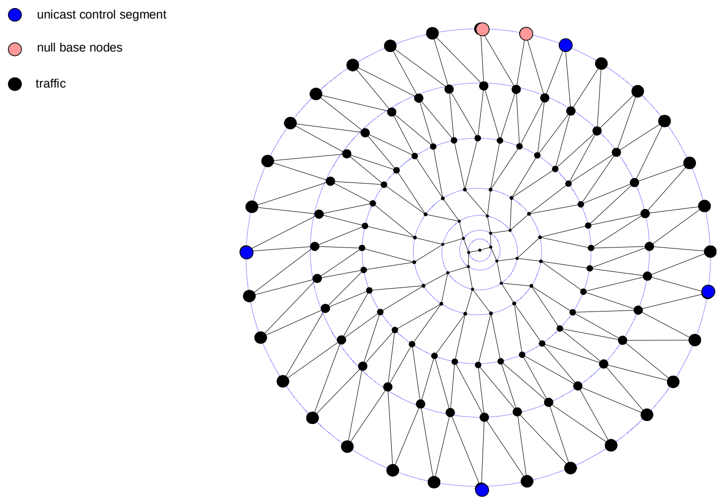

Figure 9 Channel Tree Option 1

- Option 2: a hybrid of a power of two channel tree and bitmap based assignments is designed. The parent node is signaled using the power of two channel tree, while the child nodes are signaled using a bitmap, where each bit corresponds to one channel tree node. The delineation between the power of two signaling and the bitmap signaling is a system parameter, thereby making the assignment overhead flexible. Take example that the number of base nodes is 16. **Figure 10** shows the power of two channel tree. The following are examples for allocations with bitmap indication.
  - Example 1: Parent Node 6 + bitmap '1000' = base node 27
  - Example 2: Parent Node 4 + bitmap '1110' = base nodes 19, 20, 21
  - Example 3: Parent Node 0 + bitmap '1100' = channel tree nodes 3, 4

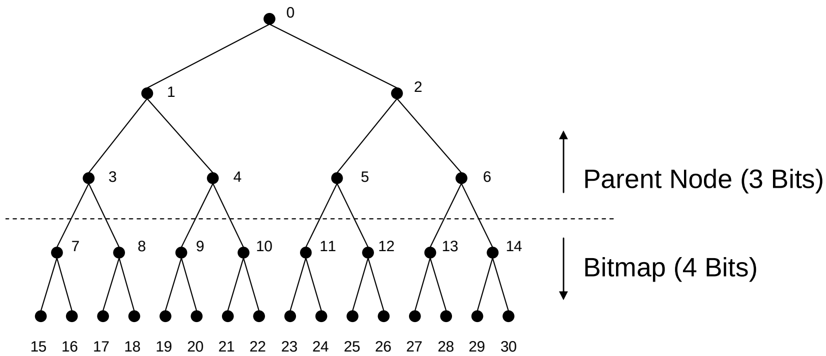

Figure 10 Channel Tree Option 2

Other resource assignment methods are under consideration

--- End of Proposed SDD Text ---

5.0 References

[1] IEEE 802.16m System Requirements, IEEE 802.16m-07/002r4, October 19, 2007.