Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**Backward Compatible FDD 802.16m Frame Structure for Full-Duplex and Half-Duplex MS Operations**
Date Submitted	**2008-01-16**
Source(s)	Pei-Kai Liao, I-Kang Fu, Chih-Yuan Lin, Ciou-Ping Wu, Paul Cheng MediaTek Inc. No.1, Dusing Road 1, Science-Based Industrial Park, Hsinchu, Taiwan 300, R.O.C. pk.liao@mediatek.com peikai_liao@hotmail.com paul.cheng@mediatek.com
Re:	IEEE 802.16m-07/047, “Call for Contributions on Project 802.16m System Description Document (SDD)” for the following topic: 1. Proposed 802.16m Frame Structure with special attention to legacy support
Abstract	This contribution proposes a backward compatible FDD frame structure to support full-duplex and half-duplex MS operations for 802.16m systems.
Purpose	Propose to be discussed and adopted by TGm for the use in Project 802.16m SDD.
Notice	
Release	
Patent Policy	

Backward Compatible FDD 802.16m Frame Structure for Full-Duplex and Half-Duplex MS Operations

Pei-Kai Liao, I-Kang Fu, Chih-Yuan Lin, Ciou-Ping Wu, and Paul Cheng

MediaTek Inc.

I. Introduction

This contribution proposal is to propose an FDD (Frequency Division Duplex) 802.16m frame structure for legacy support. According to IEEE P802.16m System Requirement Document (SRD) [1], 802.16m systems shall support high system performance as well as backward compatibility. However, these two requirements actually contradict with each other. Backward compatibility usually confines the potential of system performance improvement due to the outdated architecture of legacy systems. Therefore, finding a good way to support backward compatibility without confining the potential of performance improvement at the same time is essential in the 802.16m system.

In "Section 5.6 Duplex Schemes" of SRD, it says:

- *IEEE 802.16m shall support both Time Division Duplex (TDD) and Frequency Division Duplex (FDD) operational modes. The FDD mode shall support both full-duplex and half-duplex MS operation. Specifically, a half-duplex FDD (H-FDD) MS is defined as an FDD MS that is not required to transmit and receive simultaneously.*

This means that, in addition to TDD duplex scheme, 802.16m system is also required to support FDD, including full-duplex and half-duplex MS operation schemes. In this contribution, we will focus on solutions for the design of FDD frame structure (including full-duplex and half-duplex MS operation schemes). The major concern of the proposed frame structure is to provide a smooth migration from legacy systems to 802.16m systems without performance degradation of both systems. Proposed FDD frame structure designs for the coexistence with legacy systems are discussed in this contribution. Both full-duplex and half-duplex MS operation schemes are considered. In section II, the FDD case of full-duplex MS operation is discussed and a backward compatible design is proposed. According to SRD, FDD frame structures for half-duplex MS operation is also required. To support half-duplex MS operation, a spectrum-efficient frame structure design is proposed in section II and III. In Section IV, the frame structure to co-exist with the legacy TDD system is illustrated. Finally, a short summary of the proposed designs is shown in the last section.

II. FDD Frame Structure with Full-duplex MS Operation

For the case where both BS and MSs support full-duplex FDD, the major design problem is how to allocate the spectrum resources for 802.16m and legacy systems over an overlapped spectrum appropriately without performance degradation while also considering that downlink and uplink can be conducted simultaneously. In this section, we use the case where the channel bandwidth of 802.16m systems is larger than that of legacy systems as an example to illustrate our design ideas. For the case where the channel bandwidths of two systems are the same, frame structure design can be easily obtained from the ideas illustrated with this example. Note that the values of channel bandwidths shown in the following figures are just used for illustration. Practical applications are not limited to them.

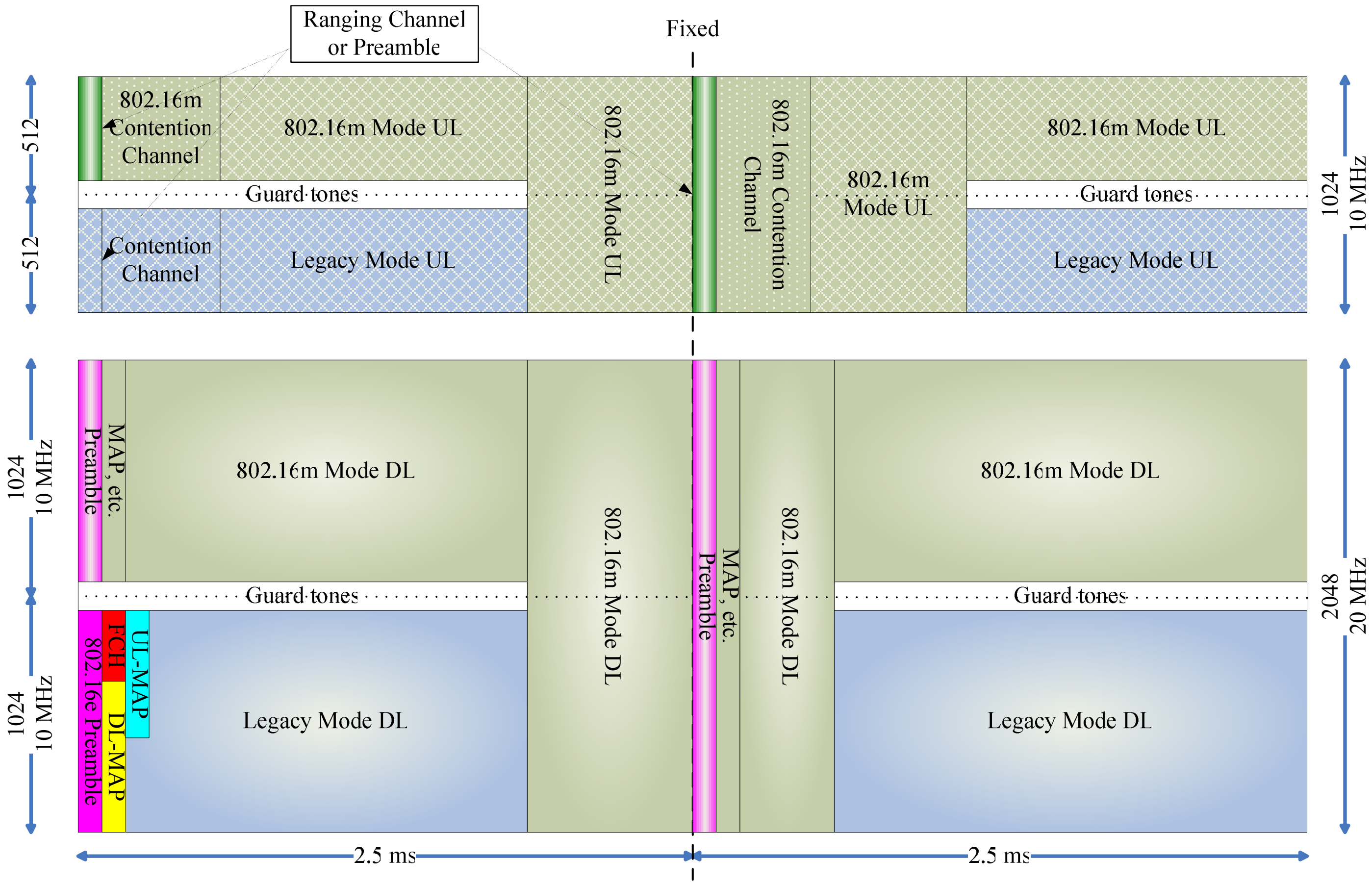

Figure 1 – Proposed FDD frame structure over different channel bandwidths with sub-frame length of 2.5 ms when the spectrum of legacy systems is at the edge of 802.16m spectrum

Fig. 1 shows the proposed FDD frame structure over different channel bandwidths with sub-frame length of 2.5 ms when the spectrum of legacy systems is at the edge of 802.16m spectrum. The upper part of the figure shows the uplink band while the lower part shows the downlink band. The 5-ms frame is divided into two 2.5-ms sub-frames. This sub-frame length may become the new time length of an 802.16m frame to enhance the support of high mobility. Though 2.5-ms sub-frame length is shown in Fig. 1, it does not mean that 2.5 ms is the only sub-frame length that can be used in this design. It is just a special case and other sub-frame lengths can be easily applied to the proposed design as well. Important features of this design are described as follows. Note that we only focus on the frame structure design for 802.16m systems. For legacy systems, regions shown here do not represent any required modification to current legacy system.

1. Preamble or ranging channel: For downlink band, a preamble is inserted in the first OFDM symbol of each sub-frame for synchronized time slot structure and channel estimation. Since downlink and uplink are in different bands, channel and timing information can not be shared and a preamble or ranging channel is needed for BS to obtain the information in uplink band. The preamble can be a new design or a legacy one if it is decided to have a preamble in uplink band as well. Different designs only affect the performance of synchronization and channel estimation.
2. Compatibility of different channel bandwidths: When a larger channel bandwidth is applied to 802.16m systems, larger FFT size is required in order to keep subcarrier spacing the same as legacy systems. This may increase demodulation difficulties when two MSs of different FFT sizes communicate with BS over

an overlapped spectrum simultaneously. Fortunately, we found, after further analysis, that the data for legacy systems still can be recovered perfectly even though they are modulated together with those of 802.16m systems using 2048 FFT in downlink. However, it is required to insert guard tones between two spectrum regions to avoid possible interferences due to imperfect effects of RF filters and the using of different preambles for each system. With this frame structure design, 802.16m BS can easily serve any fraction of legacy systems without performance degradation.

3. Contention channel: For full-duplex FDD scheme, downlink and uplink can be conducted at the same time. This largely reduces the data latency when comparing to TDD scheme. However, one problem may occur. If 802.16m MAP information in downlink band is not decoded completely, MSs can not know which sub-channels they are allowed to transmit their data. Thus, the first several OFDM symbols may be wasted due to this problem in uplink band. One possible solution is to delay the valid time of MAP information for one 2.5-ms su-bframe so that MSs can transmit their data based on the MAP information decoded in previous sub-frame. However, this solution can not reflect immediate sub-channel allocation. The proposed solution is to create a contention channel in the beginning OFDM symbols after preamble or ranging channel. MSs thus still can transmit their data without knowing MAP information on the basis of contention.

III. FDD Frame Structure with Half-duplex MS Operation (H-FDD)

For the case where only BS supports full-duplex FDD and MSs support half-duplex FDD (H-FDD), the design problem becomes more complicated. In this subsection, we also take the case where the channel bandwidth of 802.16m systems is larger than that of legacy systems as an example for explanation. In addition to compatibility issue of different channel bandwidths, efficiency of spectrum utilization also needs to be considered. In order to use the limited spectrum resource more efficiently, MSs attached to the 802.16m BS is divided into three groups – legacy users, 802.16m user group A, and 802.16m user group B. Fig. 2 illustrates the proposed FDD frame structure for different channel bandwidths when MSs are assumed all H-FDD and 802.16m BS is assumed full duplex FDD. For the case where the channel bandwidths of two systems are the same, frame structure design can be easily obtained from the ideas illustrated with this example. 2.5-ms sub-frame length is assumed in this design but the proposed idea is not limited to this sub-frame length only. Important features of this design are described as follows. Note that we only focus on the design of 802.16m systems. For legacy systems, regions shown here do not represent any required modification to current legacy system.

1. Improved spectrum utilization: Since half-duplex FDD scheme may induce many idle spectrum holes and thus decreases the spectral efficiency if the spectrum resource allocation is not designed based on the aspect of cell throughput, staggered sub-frames are utilized to enhance cell throughput. Similar idea is introduced in [2] though it is used in TDD frame structure. In Fig. 2, a 5-ms frame is divided into 4 sub-timeslots. Detailed mode switches of MSs in each sub-slot are explained as follows.
    1) In the first sub-timeslot, user group A of 802.16m MSs and legacy MSs receive downlink data from 802.16m BS while user group B of 802.16m MSs transmit uplink data to the BS.
    2) In the second sub-timeslot, user group A enters uplink mode and user group B switches to downlink mode, beginning a new 2.5-ms sub-frame cycle while legacy users remain in downlink mode.
    3) In the third sub-timeslot, user group A switches back to downlink mode, beginning a new 2.5-ms sub-frame cycle and user group B enters uplink mode while legacy users remain in downlink mode.
    4) In the fourth sub-timeslot, user group A enters uplink mode and user group B switches to downlink mode, beginning next new 2.5-ms sub-frame cycle while legacy users change mode to uplink.

Though the proposed frame structure may increase the complexity of radio resource allocation for 802.16m BS, the cell throughput is increased and spectral efficiency is improved as well. Since the length of each sub-timeslot is fixed, no further information is required in 802.16m MAP. For legacy systems, the unknown data zones will be skipped without any system failure.

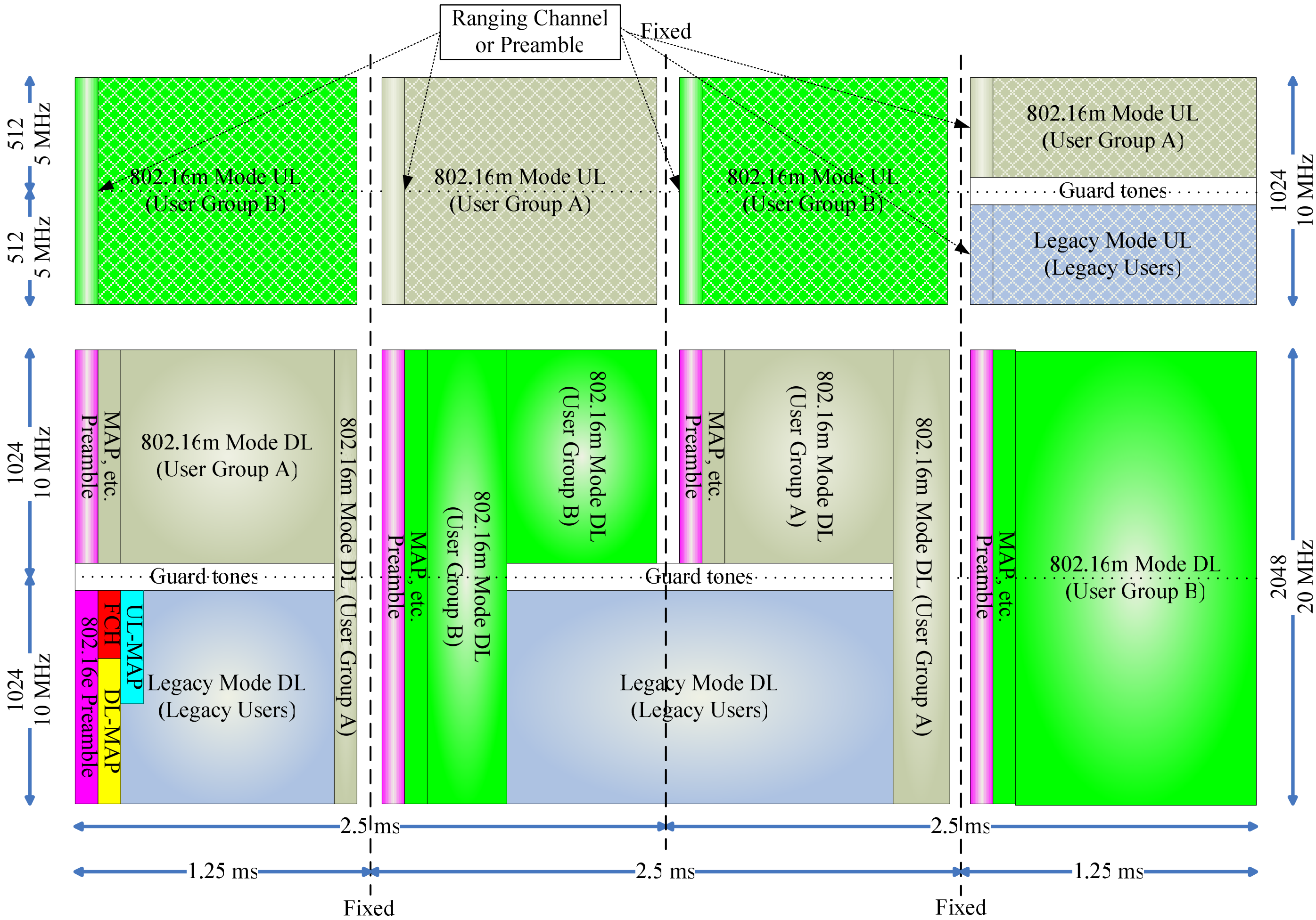

Figure 2 – Proposed FDD frame structure for different channel bandwidths when MSs are assumed all H-FDD and 802.16m BS is assumed full duplex FDD

2. Preamble and ranging channel: Similar to full-duplex scheme, a preamble or ranging channel is inserted in uplink band for synchronization and channel estimation. For downlink band, the preamble is inserted at the beginning of each user group's sub-frame.

3. Transition period: Transition time is still needed for half-duplex MSs to switch between downlink mode and uplink mode even though downlink and uplink are in different bands. Therefore, a transition period is inserted at each uplink-to-downlink switch and downlink-to-uplink switch. No specific time length is proposed here. It is to be decided after further analysis.

IV. Coexistence with TDD Legacy Frame Structure

Since most of legacy OFDMA systems are of TDD frame structure, the frame structure for the migration from TDD-based legacy systems to FDD-based advanced systems may be the one that most of people pay attention to. In the following subsections, the ideas for both full-duplex and half-duplex MS operations is proposed and illustrated by figures.

A. For Full-duplex MS Operation (F-FDD)

Fig. 3 shows an example for the proposed F-FDD frame structure for 802.16m system when it coexists with TDD-based legacy systems over different channel bandwidths. The idea is similar to that shown in Fig. 1. The difference is that TDD-based legacy systems coexist with 802.16m system in uplink band instead of downlink band. This is because downlink traffic is usually heavier and requires more radio resources. By having a dedicated frequency band only for 16m DL, the format of preamble, FCH, MAP, sub-carrier permutation and other control message may be different than 16e. This may be beneficial for TGm to develop more efficient MAC for 16m DL.

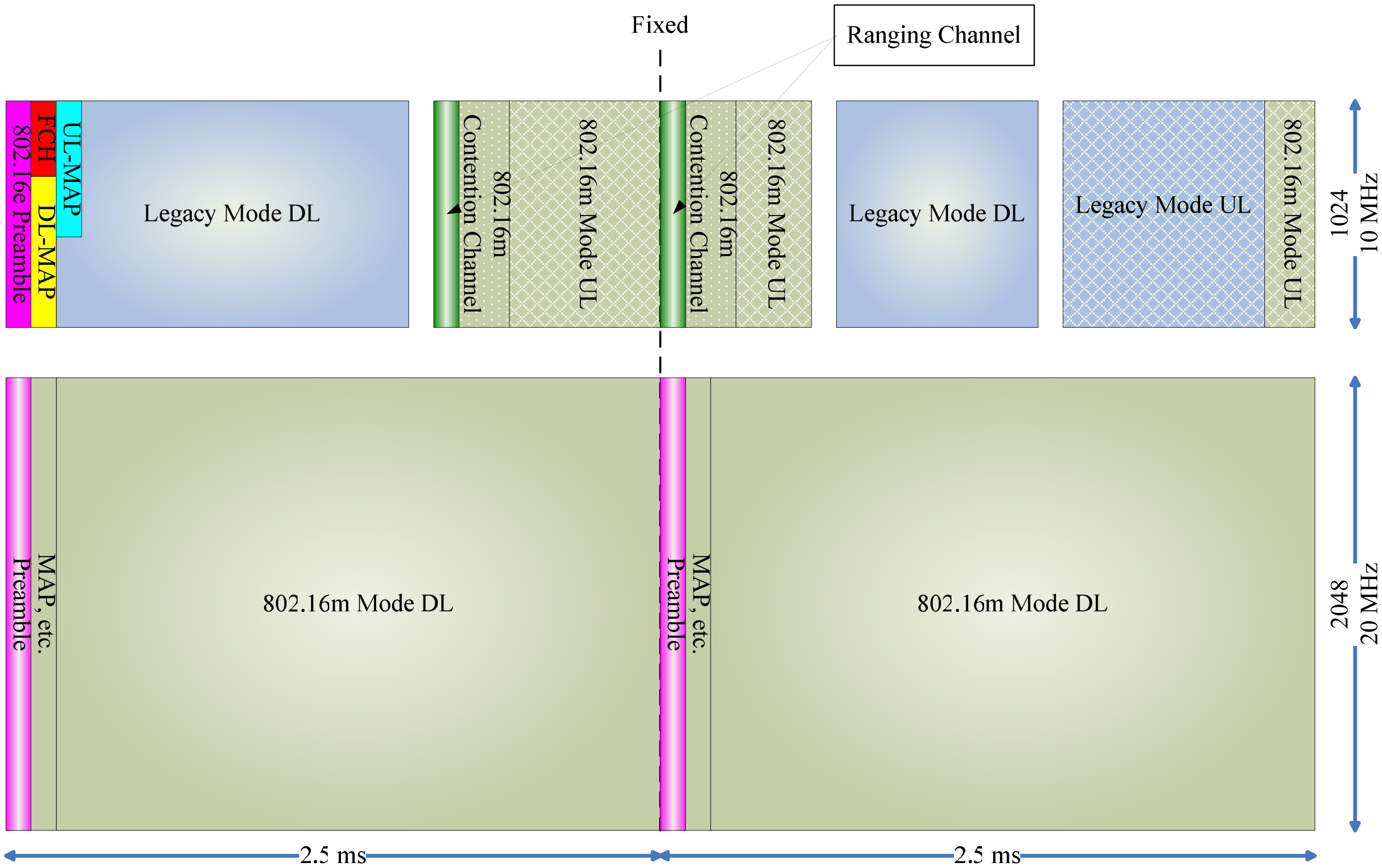

Figure 3 – Proposed F-FDD frame structure for 802.16m system when it coexists with TDD legacy systems over different channel bandwidths

For the MS supporting 16m only, it can scan the 16m preamble and control message to acquire system information and frame boundary in 16m DL channel. Then it may perform ranging over 16m UL ranging channel, where its location can be indicated from 16m DL. Note that the BS needs to determine the range of 16m UL based on the requirement from 16e legacy mode to ensure the backward compatibility. In addition, since the channel is not reciprocal between 16m DL and UL, 16m MS may need to transmit some reference signal in 16m UL for channel estimation or other purpose. A simple idea is provided in Fig. 3 by locating UL ranging channel (or similar contention channel) over frequency domain in 16m UL channel. So that 16m MS may transmit some reference signal (e.g. ranging code) over such contention channel.

B. For Half-duplex MS Operation (H-FDD)

Fig. 4 shows an example for the proposed H-FDD frame structure for 802.16m system when it coexists with TDD legacy systems over different channel bandwidths. For half-duplex MS operation, similar ideas in previous subsection can be applied. The difference is that TDD-based legacy systems coexist with 802.16m system in uplink band instead of downlink band. Just like F-FDD case, 802.16m BS is allowed to enable this mode if the migration from TDD-based service to H-FDD-based service is necessary.

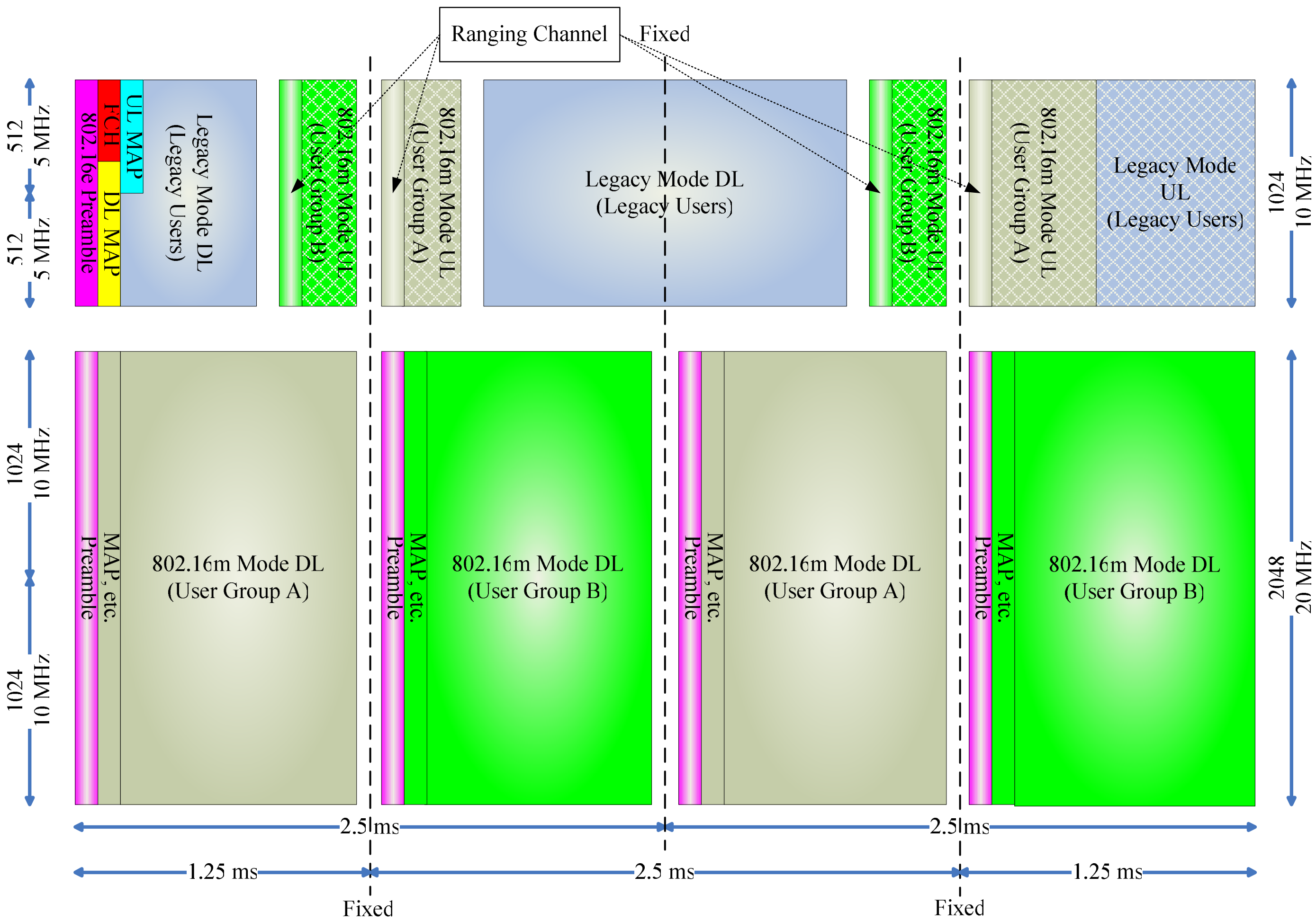

Figure 4 – Proposed H-FDD frame structure for 802.16m system when it coexists with TDD legacy systems over different channel band widths

IV. Conclusion and Summary

In this contribution proposal, several frame structure designs for FDD duplex schemes are proposed to resolve problems induced by the requirement of backward compatibility. To coexist with legacy systems as well as support high system performance, the frame structure for 802.16m systems has to be carefully designed. It is suggested to discuss and adopt the proposed ideas for future 802.16m frame structure design. Content of this contribution proposal is summarized as follows.

1 FDD Frame Structure with Full-duplex MS Operation

2 FDD Frame Structure with Half-duplex MS Operation (H-FDD)

3 Coexistence with TDD Legacy Frame Structure

- Important Features:
  - Allow smaller sub-frame length to meet strict high mobility support after legacy systems fade out gradually.
  - Allow smooth migration from legacy systems to 802.16m systems without large performance degradation.
  - Contention channel is utilized to avoid possible spectrum waste in uplink band due to the late decoding results of MAP information when full-duplex MS operation scheme is adopted.
  - Mechanisms of user group separation and staggered sub-frames are utilized to increase cell throughput and improve spectral efficiency when half-duplex MS operation scheme is adopted.
  - Allow the migration from TDD-based legacy systems to FDD-based advanced system if the special zone for legacy downlink in uplink band is enabled.

REFERENCES

[1] IEEE 802.16m-07/002r4, "IEEE 802.16m System Requirements."

[2] IEEE C802.16m-07/0242r1, "TDD Frame Structures for Legacy Support in 16m."