| | |
|---|---|
| Project | **IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>** |
| Title | **Backward Compatible TDD 802.16m Frame Structure with Reduced Latency over Same or Different Channel Bandwidths** |
| Date Submitted | **2008-01-16** |
| Source(s) | Pei-Kai Liao, Chih-Yuan Lin, Ciou-Ping Wu, Paul Cheng<br>MediaTek Inc.<br>No.1, Dusing Road 1,<br>Science-Based Industrial Park,<br>Hsinchu, Taiwan 300, R.O.C.<br>pk.liao@mediatek.com<br>peikai_liao@hotmail.com<br>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:<br>1. Proposed 802.16m Frame Structure with special attention to legacy support |
| Abstract | This contribution proposes a TDD frame structure to provide backward compatibility as well as reduced latency 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 TDD 802.16m Frame Structure with Reduced Latency over Same or Different Channel Bandwidths

*Pei-Kai Liao, Chih-Yuan Lin, Ciou-Ping Wu, and Paul Cheng*

*MediaTek Inc.*

## I. Introduction

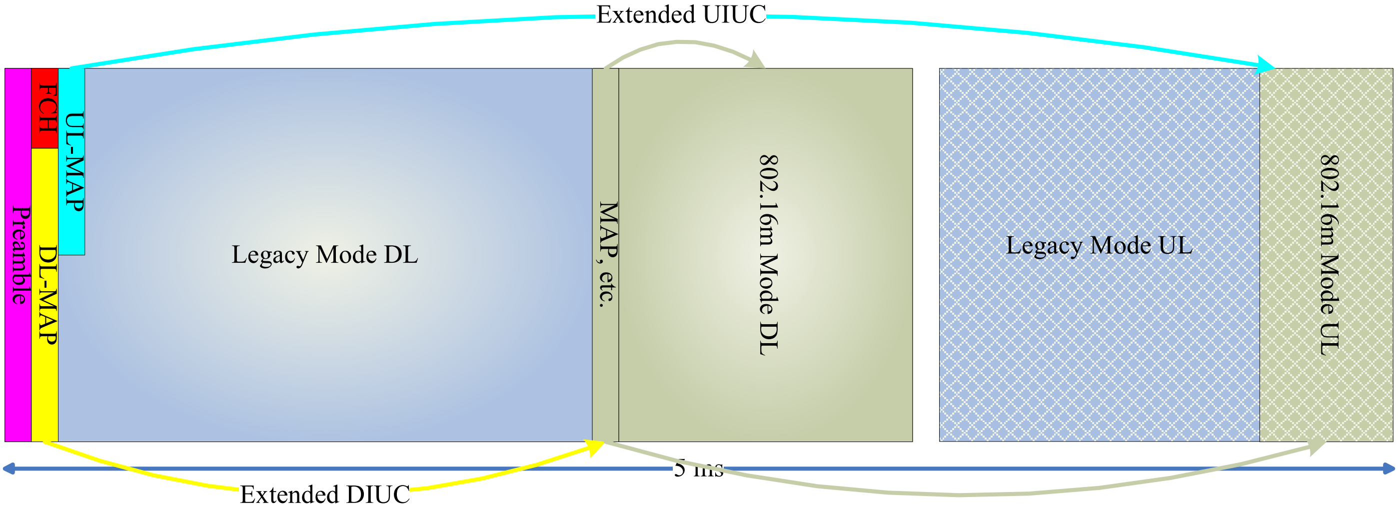
This contribution proposal is to propose a TDD (Time Division Duplex) 802.16m frame structure for legacy support with reduced latency. According to IEEE P802.16m System Requirement Document (SRD) [1], 802.16m systems shall support high system performance as well as backward compatibility. However, these 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 Backward compatibility usually confines the potential of system performance improvement due to the outdated architecture of legacy systems. Finding a good way to support backward compatibility without confining the potential of performance improvement at the same time requires a lot of efforts.

Based on SRD [1], legacy support and reduced latency (including data latency and handover latency) are two important issues for consideration of 802.16m frame structure design. In last meeting, there are already a lot of good ideas about TDD frame structure. In this contribution proposal, we will focus on solutions for several overlooked design problems of TDD frame structure. 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 TDD frame structure designs for the coexistence with legacy systems with same/different bandwidths and low latency support are discussed in the following two sections. In section II, several cases of TDD frame structure are discussed and solutions to overlooked problems are proposed. A short summary of the proposed designs is shown in the last section.

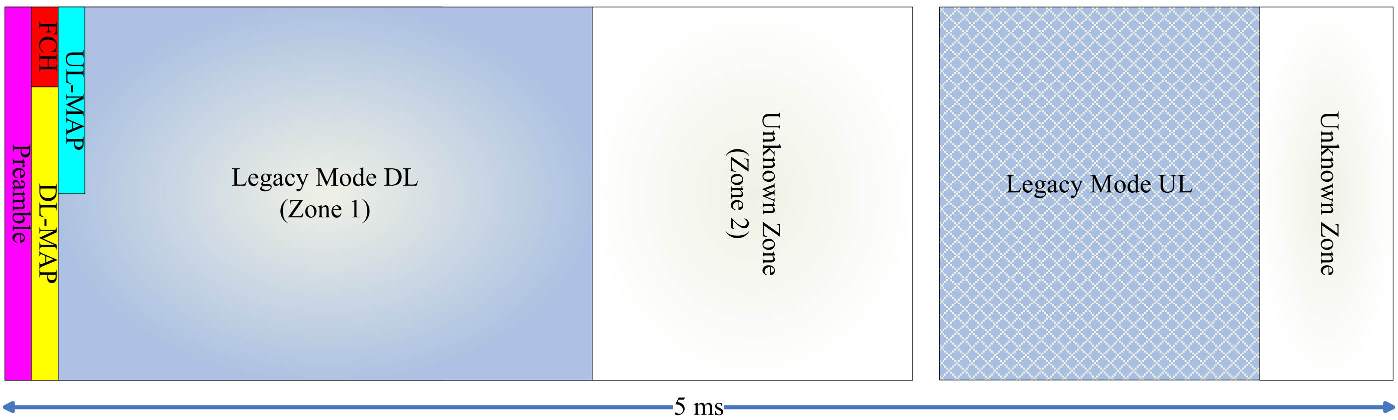
## II. TDD Frame Structure

In this section, TDD frame structures with legacy support for different system requirements are proposed for discussion. Due to the scarce of frequency band resource, 802.16m may be required to coexist with legacy systems on the same RF carrier over the same or different channel bandwidths during the migration period from legacy systems to advanced systems. In "Section 5.1 Legacy Support" of SRD [1], the second and fifth backward compatibility requirements also say:

- *Systems based on IEEE 802.16m and the WirelessMAN-OFDMA Reference System shall be able to operate on the same RF carrier, with the same channel bandwidth; and should be able to operate on the same RF carrier with different bandwidths.*
- *An IEEE 802.16m BS shall be able to support a legacy MS while also supporting IEEE 802.16m MSs on the same RF carrier, at a level of performance equivalent to that a legacy BS provides to a legacy MS.*




(a) From 802.16m Equipments Side



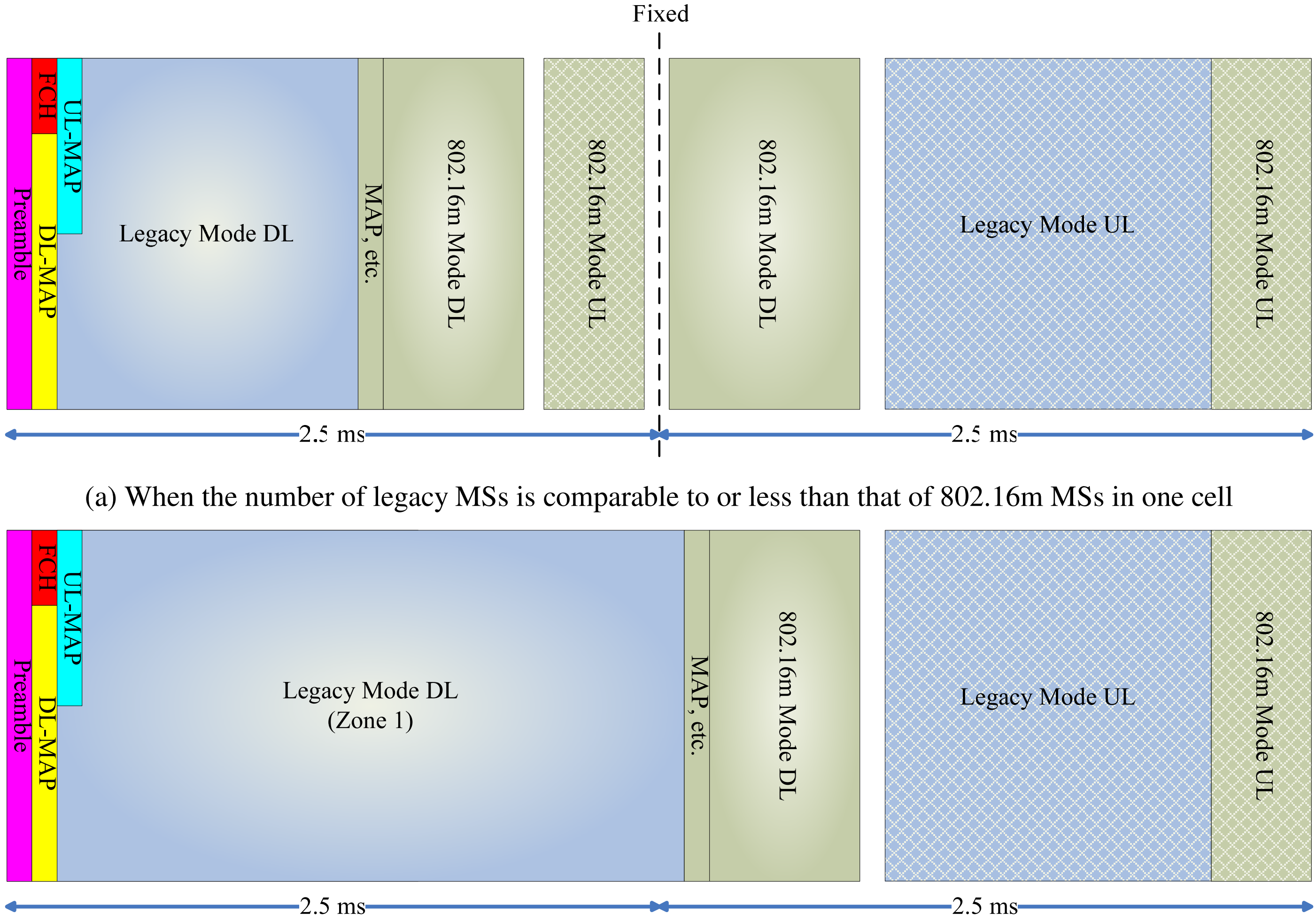

(b) From Legacy Equipments Side

Figure 1 – Basic idea of TDD frame structure proposed in [2]

This means the proposed 802.16m frame structure not only has to accommodate legacy systems on the same RF carrier but also has to keep their system performance the same. Since 802.16m has high performance requirements [1], designing a frame structure to provide a certain level of system design flexibility as well as legacy support is not an easy task, especially when different channel bandwidths are applied. Note that the values of channel bandwidths shown in the following figures are just used for illustration. Practical applications are not limited to them.

### A. Coexistence with Legacy Systems on the Same RF Carrier with Same Channel Bandwidth

In this subsection, we first consider the case where same channel bandwidth is applied to both 802.16m and legacy systems on the same RF carrier. In session #52, many contributions have proposed good ideas to meet the aforementioned requirements. A common view of these contributions is to utilize TDD zone separation to accommodate two systems in one frame though no consensus decision is made in the meeting. Fig. 1 shows the basic idea proposed in [2]. They proposed to make use of zone switches supported by legacy systems and reserved extended DIUC/UIUC codes to separate a new zone for 802.16m system. This not only gives a certain level of system design flexibility for 802.16m systems but also keep the performance of legacy systems unaffected. However, 5-ms frame can not meet the latency requirement described in "Section 6.2.1 Data Latency" of SRD [1]. For 802.16m systems, maximum data latency is 10 ms. So if more than one retransmission are needed, it will cause more than 10-ms latency and thus exceed the aforementioned latency requirement. Hence, several contributions proposed the concept of sub-frames to enhance the low latency support.




(a) When the number of legacy MSs is comparable to or less than that of 802.16m MSs in one cell



(b) When the number of legacy MSs is much larger than that of 802.16m MSs in one cell

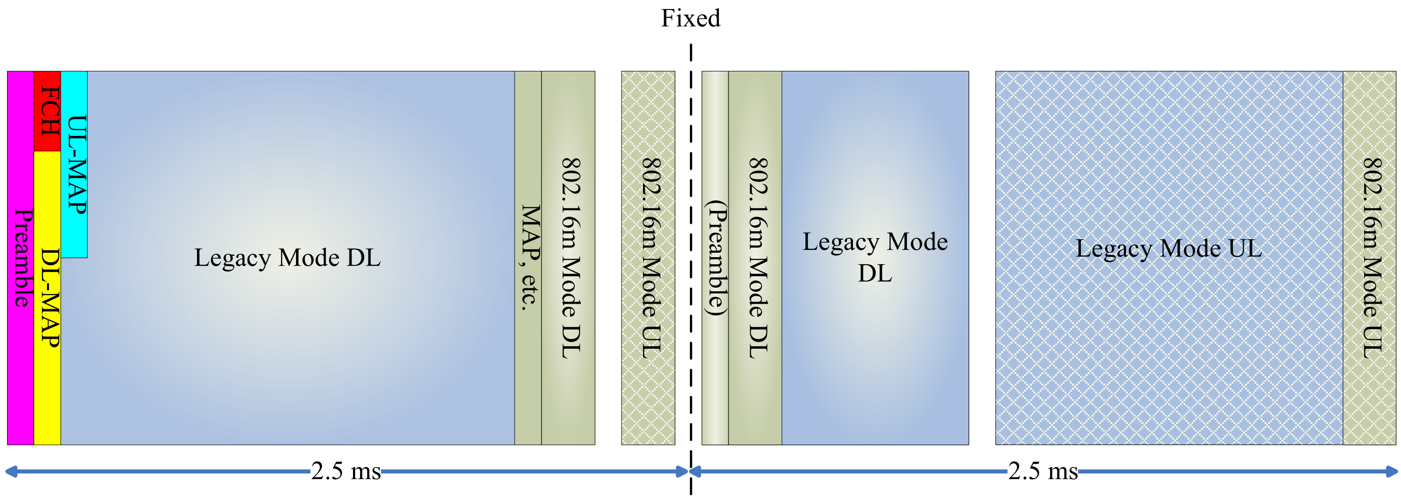
Figure 2 – TDD frame structure for low latency support proposed in [2]

### A.1 TDD Frame Structure for Low Latency Support with Sub-frame Length of 2.5 ms –

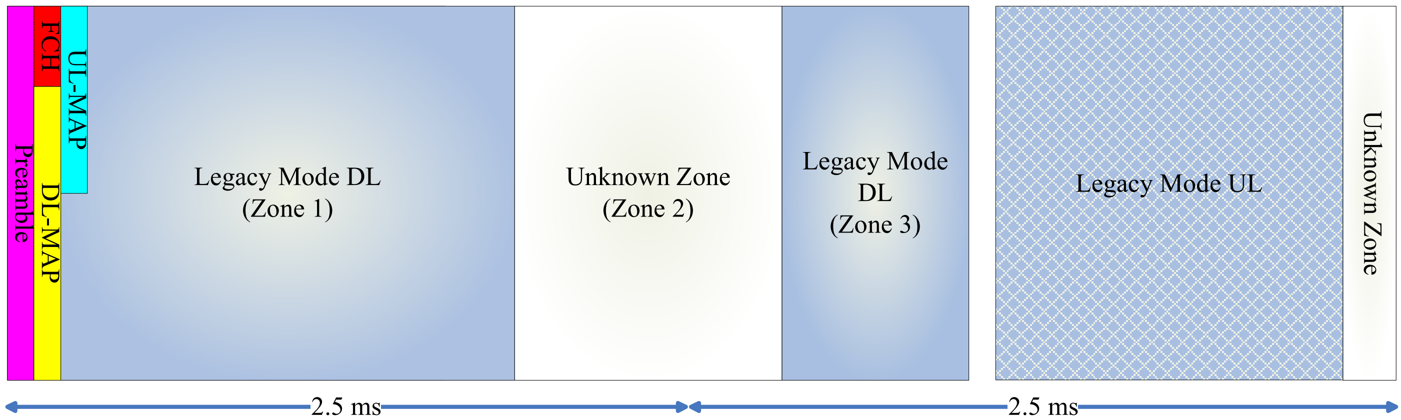
Fig. 2(a) shows the solution proposed by [2]. To enable low latency support, 5-ms frame is divided into two 2.5-ms sub-frames. In each 2.5-ms sub-frame, it consists of one 802.16m DL zone and one 802.16m UL zone. The sub-frame length is fixed while the portion of DL or UL zone reside in each sub-frame is configurable. Thus, two retransmissions can be easily completed in 10 ms. However, this solution has one shortcoming. Frame structure for low latency support can not be enabled if there is large fraction of legacy MSs. Fig. 2(b) shows the case where the number of legacy MSs is much larger than that of 802.16m MSs in one cell. In order to meet the performance requirement of legacy support, radio resources for legacy MSs can not be suppressed to fit 2.5-ms sub-frame structure. In other words, 2.5-ms sub-frame structure has to be disabled when there is large fraction of legacy MSs and thus may degrade the system performance of 802.16m, especially for data latency. This case usually happens at the beginning stage of the migration from legacy systems to 802.16m and it should be fixed.

Here, we proposed a modified scheme to resolve this problem. Fig. 3 shows the proposed scheme and important features are described as follows.

1. Accommodation of more legacy MSs: Just like the idea proposed in [2], one 5-ms frame is divided into two 2.5ms sub-frames. Nevertheless, in the second 2.5-ms sub-frame, one more zone for legacy downlink is assigned. With this scheme, it can support more legacy MSs while 2.5-ms sub-frame structure remains enabled. Hence, both performance requirement of legacy support and low latency requirement of 802.16m systems can be easily met. Fig. 3(b) shows the frame structure seen by legacy MSs. Legacy MSs will find there are three zones in downlink sub-frame and skip the second unknown zone.
2. Solution to possible transmission collision: However, with this scheme, transmission collision between 802.16m MSs and neighboring BSs may happen if the frame structures are not synchronized. One possible solution is to allow 802.16m BS communicating with neighboring BSs to allocate appropriate sub-channels to 802.16m MSs attached to it so as to avoid possible transmission collisions.
3. Preamble: During the period of system migration, legacy preambles are used for time slot synchronization and channel estimation. However, for the second sub-frame, it is allowed to insert a preamble (new design or a legacy one) at the beginning of the sub-frame for high mobility support though this may require 802.16m MSs to understand two preamble structures if new preamble design is applied to 802.16m system.




(a) From 802.16m Equipment Side



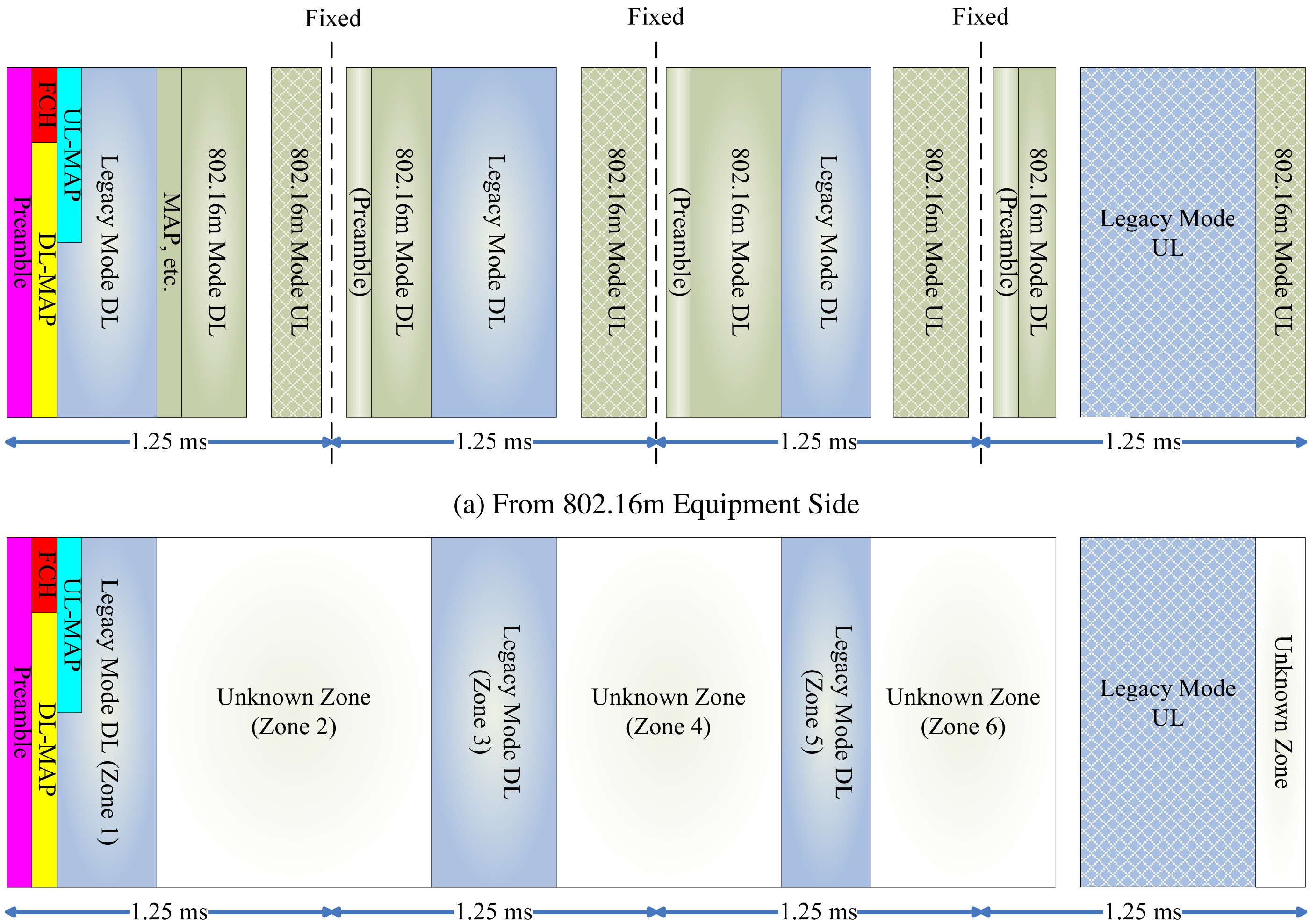

(b) From Legacy Equipment Side

Figure 3 – Proposed modified TDD frame structure for low latency support when the number of legacy MSs is much larger than that of 802.16m MSs

A.2 TDD Frame Structure for Low Latency Support with Other Sub-frame Lengths –

With the proposed modified scheme, we can also further decrease the length of sub-frame for better latency support (including both data latency and handover latency) if the fraction of 802.16m MSs grows to a certain level. This also meets the third requirement in "Section 5.1 Legacy Support" of SRD [1], which says:

- *An IEEE 802.16m BS shall support a mix of IEEE 802.16m and legacy MSs when both are operating on the same RF carrier. The system performance with such a mix should improve with the fraction of IEEE 802.16m MSs attached to the BS.*




(a) From 802.16m Equipment Side



(b) From Legacy Equipment Side

Figure 4 – Proposed TDD Frame structure composed of four 1.25-ms sub-frames for low latency support when the number of legacy MSs is comparable to that of 802.16m MSs

Fig. 4 shows an example with 1.25-ms sub-frame length. Note that both 2.5-ms and 1.25-ms sub-frame length are special cases of the proposed ideas and the sub-frame length is not limited to these two numbers only. Which sub-frame length to be used is to be decided based on system performance requirement. Important features are described as follows.

1. Support of lower latency: This scheme can support much more retransmissions without exceeding 10-ms data latency, compared to previous schemes. From 802.16m equipment side, it will identify four 1.25-ms sub-frames and each one consists of one 802.16m DL zone, one 802.16m UL zone and one legacy system DL/UL zone. From legacy equipment side, it will identify three only out of six zones in the downlink sub-frame. The system provider may decide when the 802.16m BS will support shorter sub-frame length and the fraction of legacy MSs it will support. Due to the maximum limit of zone switches (8 zones at most in downlink sub-frame) in WirelessMAN-OFDMA Reference System [4], the smallest sub-frame length is 1 ms, which is equal to the transmission time interval (TTI) in 3GPP LTE [5].
2. Solution to possible transmission collision: Similar to the proposed idea in Fig. 3, transmission collision between 802.16m MSs and neighboring BSs may be a serious interference problem if the frame structures are not synchronized. Since this scheme is suggested to be enabled after most of legacy systems fade out, the interference from neighboring legacy BSs will be small and it can also be avoid via mutual communication between 802.16m BS and other neighboring legacy BSs. For the interferences from other neighboring 802.16m BSs, advanced antenna technique can also be applied to reduce the possibility of transmission collision.
3. Support of higher mobility: Since 802.16m shall support better system performance in high mobility, compared to legacy systems, smaller time slot structure will help better synchronization and timely channel state information update in high mobility. With the proposed scheme, it allows to insert a preamble (new design or a legacy one) at the beginning of each sub-frame. This also keeps the flexibility for the future enhancement for the support of high mobility.

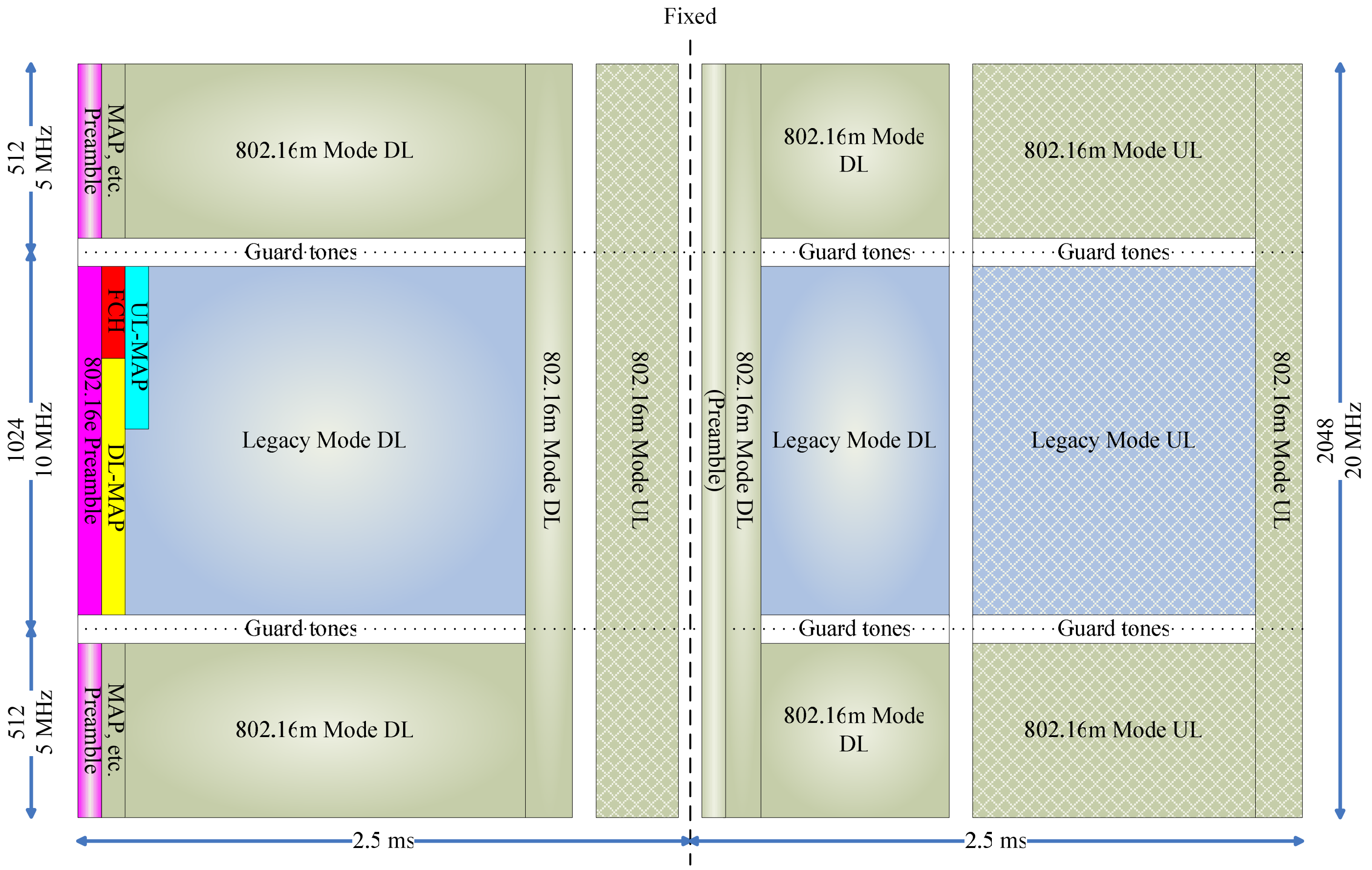



Figure 5 – Proposed TDD frame structure for different channel bandwidths with sub-frame length of 2.5 ms

when the spectrum of legacy systems is at the center of 802.16m spectrum

### B. Coexistence with Legacy Systems on the Same RF Carrier with Larger Channel Bandwidth

In this subsection, we consider the case where different channel bandwidths are applied to 802.16m and legacy systems on the same RF carrier. Though [3] has proposed a good idea for the support of different channel bandwidths in last meeting, we focus on low latency support and several overlooked problems to seek solutions and detailed discussion in this contribution proposal.

B.1 TDD Frame Structure for Low Latency Support with Sub-frame Length of 2.5 ms –

Since 802.16m system may use larger channel bandwidth than legacy system over the same RF carrier, it is important to consider the compatibility issues of two systems.

1. 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 induce demodulation difficulties when MSs of two systems communicate with BS by different FFT sizes over an overlapped spectrum simultaneously. Fortunately, we found, after further analysis, that the data for legacy systems still can be recovered correctly even though they are modulated together with those for 802.16m systems by 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 use separate preambles for each system.

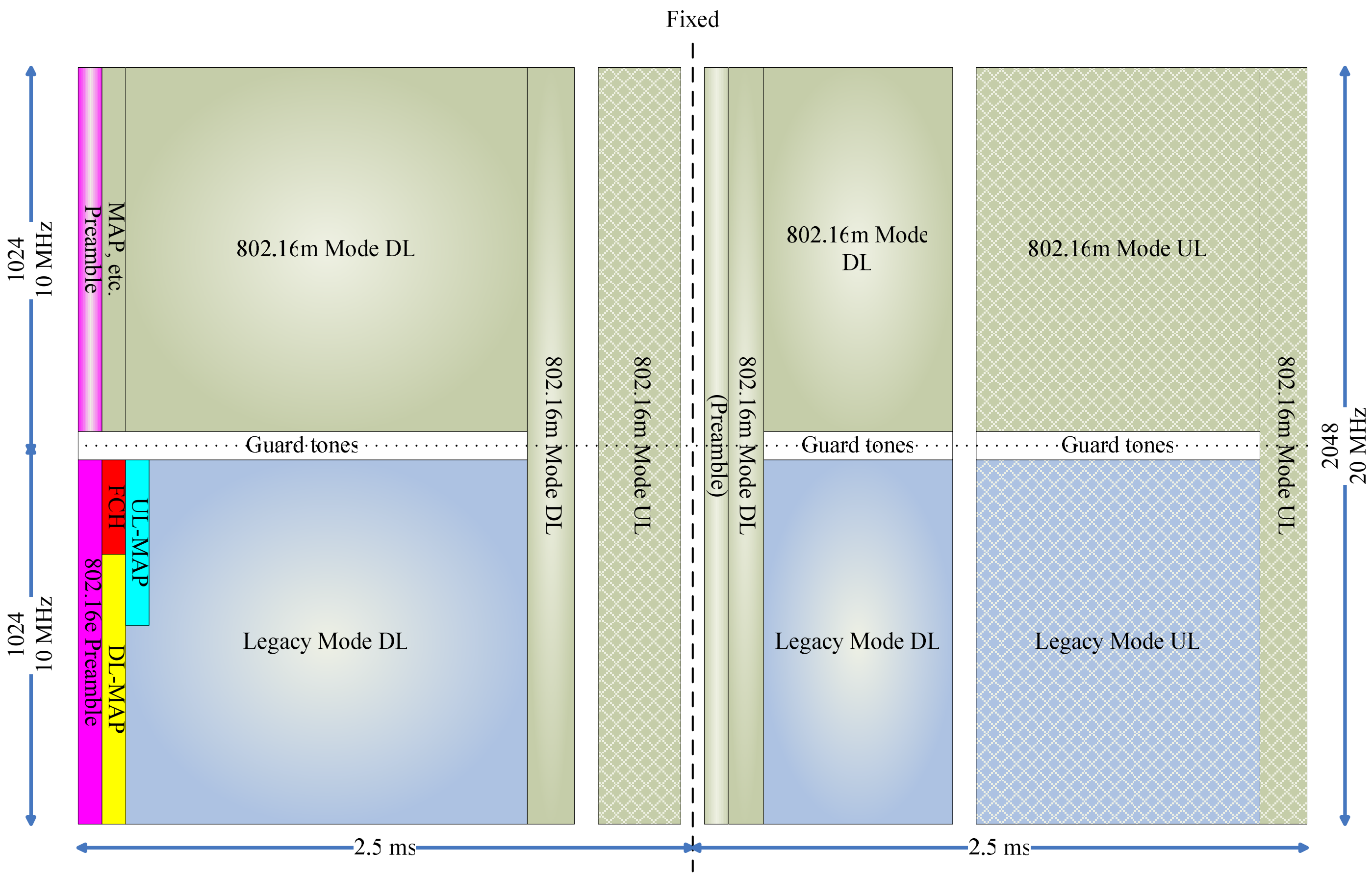



Figure 6 – Proposed TDD frame structure for different channel bandwidths with sub-frame length of 2.5 ms

when the spectrum of legacy systems is at the edge of 802.16m spectrum

2. Low latency support: To meet the requirement of maximum data latency (10 ms) and maximum handover interruption time (30 ms for intra-frequency) in SRD [1], smaller frame duration is preferred. [3] proposed a frame structure to accommodate two different frame durations at the same time slot over an overlapped spectrum but it also has similar problem as [2]. The frame structure proposed in [3] can not support large fraction of legacy systems in one cell, which usually occurs at the beginning stage of system migration. Fig. 5 and Fig. 6 illustrate examples of the proposed frame structure with sub-frame length of 2.5 ms to resolve aforementioned problems. Fig. 5 shows the case when the spectrum of legacy systems is at the center of 802.16m systems while Fig. 6 shows the case when the spectrum of legacy systems is at the edge. Since legacy MSs will skip unknown zones, which will be determined in DL/UL-MAP, and proceed to the next legacy zone, backward compatibility requirement can be met.
3. Preamble design: As for 802.16m preamble shown in Fig. 5 and Fig. 6, legacy preambles and new developed one are all possible options. After legacy systems fade out, the frame structure will migrate smoothly to the one of 802.16m systems with new timeslot duration of 2.5 ms and wider channel bandwidth to provide better system performance without any system modification. By then, if necessary, preamble can be added in the first OFDM symbol of the second 2.5-ms sub-frame for high mobility support.

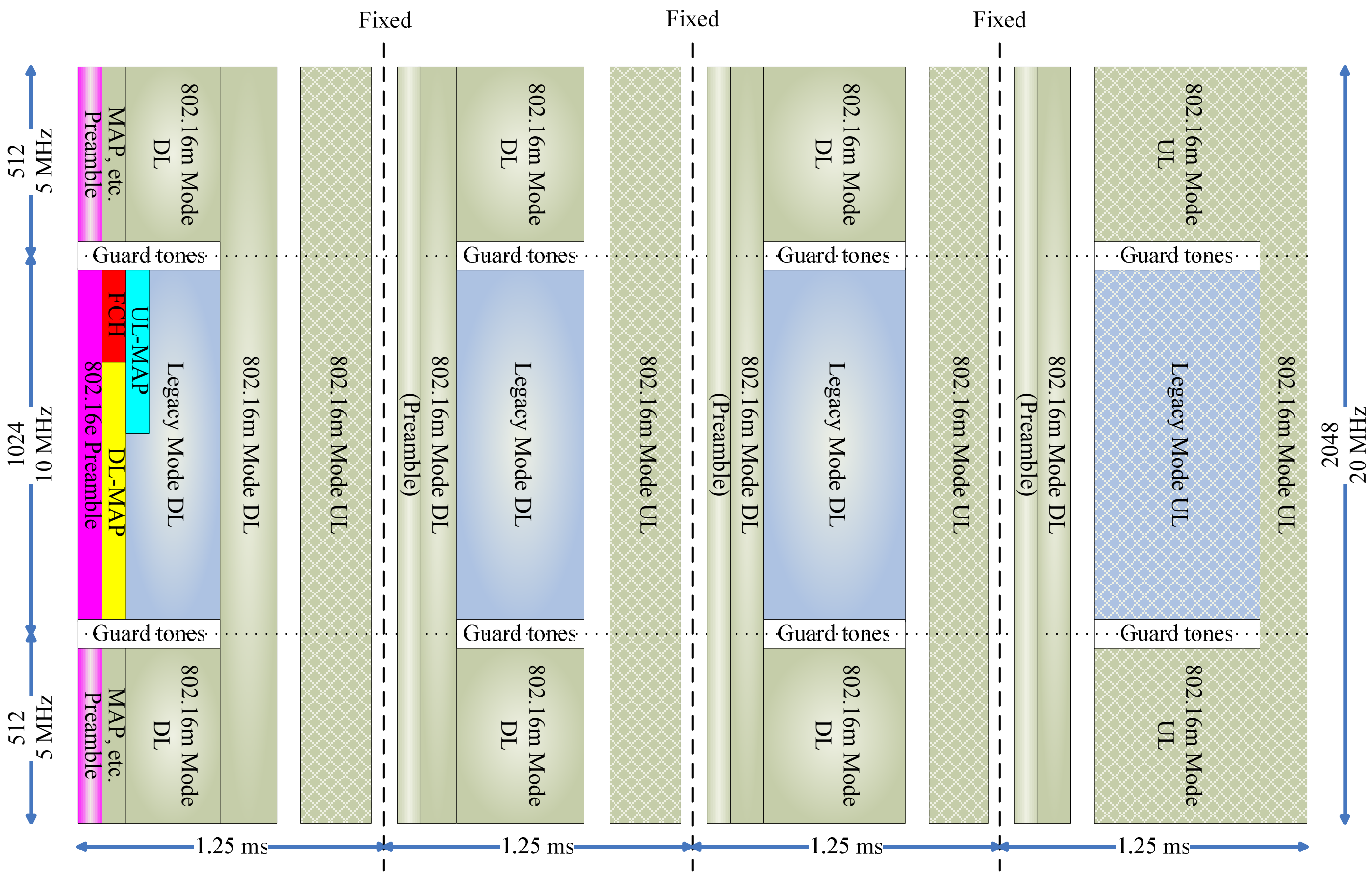



Figure 7 – Proposed TDD frame structure for different channel bandwidths with sub-frame length of 1.25 ms when the spectrum of legacy systems is at the center of 802.16m spectrum

B.2 TDD Frame Structure for Low Latency Support with Other Sub-frame Lengths –

Similar concepts can be applied to frame structures with other sub-frame lengths. However, one requirement has to be met. Smaller sub-frame length can be applied only when the fraction of legacy systems decreases to a certain level so that the performance of legacy systems will not be affected and the interferences due to transmission collision can be mitigated. Fig. 7 and Fig. 8 illustrate examples of the proposed frame structure with sub-frame length of 1.25 ms when the legacy spectrum is at different locations. Just like the case with 2.5-ms sub-frame, legacy MSs will skip unknown zones and proceed to the next legacy zone so backward compatibility requirement can be met and preamble can be added in the first OFDM symbol of the following 1.25-ms frames for synchronization for high mobility support or after legacy systems fade out. Note that both 2.5-ms and 1.25-ms sub-frame length are special cases of the proposed ideas and the sub-frame length is not limited to these two numbers only. Which sub-frame length to be used is to be decided based on system performance requirement.

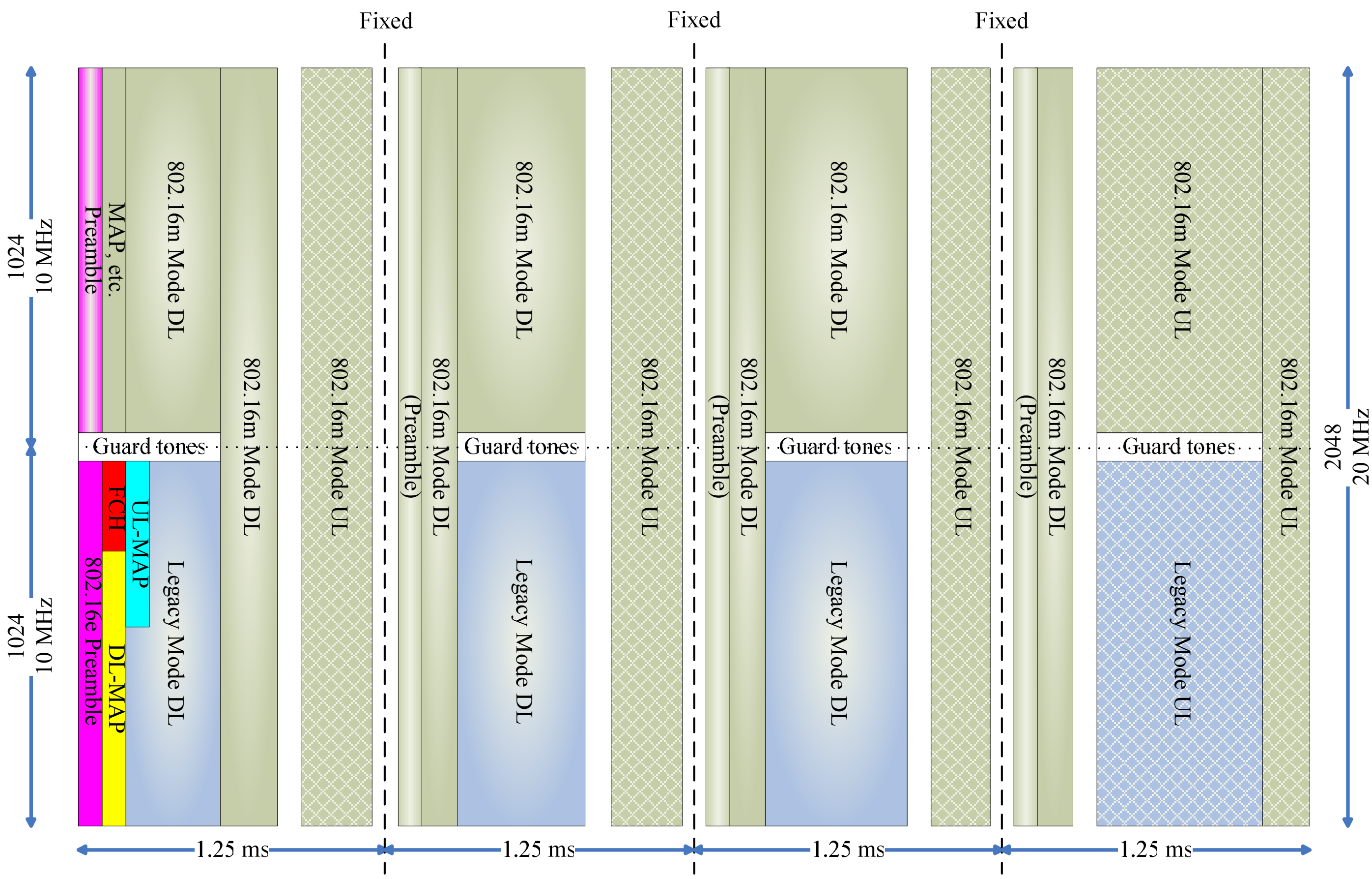



Figure 8 – Proposed TDD frame structure for different channel bandwidths with sub-frame length of 1.25 ms when the spectrum of legacy systems is at the edge of 802.16m spectrum

## III. Conclusion and Summary

In this contribution proposal, several frame structure designs for TDD 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 Coexistence with Legacy Systems on the Same RF Carrier with Same Channel Bandwidth

1.1 Sub-frame Length of 2.5 ms

1.2 Other Sub-frame Lengths (take 1.25 ms as an example)

2 Coexistence with Legacy Systems on the Same RF Carrier with Larger Channel Bandwidth

2.1 Sub-frame Length of 2.5 ms

2.2 Other Sub-frame Lengths (take 1.25 ms as an example)

- Important Features:
  - 802.16m BS can support large fraction of legacy MSs in one cell with low latency support.
  - Allow smaller sub-frame length to meet more strict latency and mobility requirement described in 802.16m SRD after legacy systems fade out gradually.
  - Allow smooth migration from legacy systems to 802.16m systems without large performance degradation.
  - The time length of a sub-frame is configurable based on system performance requirement.

**REFERENCES**

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

[2] IEEE C802.16m-07/263, "802.16m Frame Structure to Enable Legacy Support, Technology Evolution and Reduced Latency."

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

[4] IEEE Std 802.16Rev2/D2, "Air Interface for Broadband Wireless Access Systems."

[5] http://www.3gpp.org/Highlights/LTE/LTE.htm