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Re:	2nd Call for Contribution on Project 802.16m System Description Document (SDD) issued on 2007-12-17 (http://ieee802.org/16/tgm/docs/80216m-07_47.pdf)
Abstract	Proposed frame structure of 802.16m
Purpose	For discussion and approval by IEEE 802.16m TG
Notice	
Release	
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Proposal on Considerations of IEEE 802.16m Frame Structure

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1. Introduction

This document is provided in response to the 2nd Call for Contribution on Project 802.16m System Description Document (SDD) issued on 2007-12-17 (http://ieee802.org/16/tgm/docs/80216m-07_47.pdf) to propose a consideration of IEEE 802.16m frame structure together with multiple access and multi antenna techniques.

The 802.16m frame structure shall fundamentally support both basic and advanced feature to fully meet IMT-advance requirements. The 802.16m shall also support legacy system without degrading the basic requirements. Therefore, it is important to realize the basis of the 802.16m implementation.

In this contribution we propose to have a basic frame structure to support both 802.16m and legacy system but with the baseline configuration of 802.16m.

2. Major concerns on frame structure

To develop an effective frame structure, we need to identify the major issues on IEEE 802.16m. It is fully understood that the development of SDD is targeting on the next generation of global cellular mobile communication system, say IMT-Advanced next generation mobile networks [1]. This should be the major concern of system development and also the frame structure to implement an advanced air interface. As the standard is intended to be a candidate for consideration in the IMT-advanced evaluation process [2], the critical requirement should be to make WirelessMAN-OFDMA to be highly competitive to other proposed system(s).

Bearing all these in mind, we derive a priority list on development of the frame structure. The top items we propose to support the new frame structure are:

- Peak-data rate to implement future high throughput new network
- Latency to support all aspects of the new system
- Mobility for high speed in next generation cellular

These three requirements should form the basic frame structure.

3. Frame structure for basic and advanced features

For the purpose of high speed, high throughput and low latency, a frame structure can be formed as demonstrated in Figure 1 to support basic and advanced features of 802.16m.

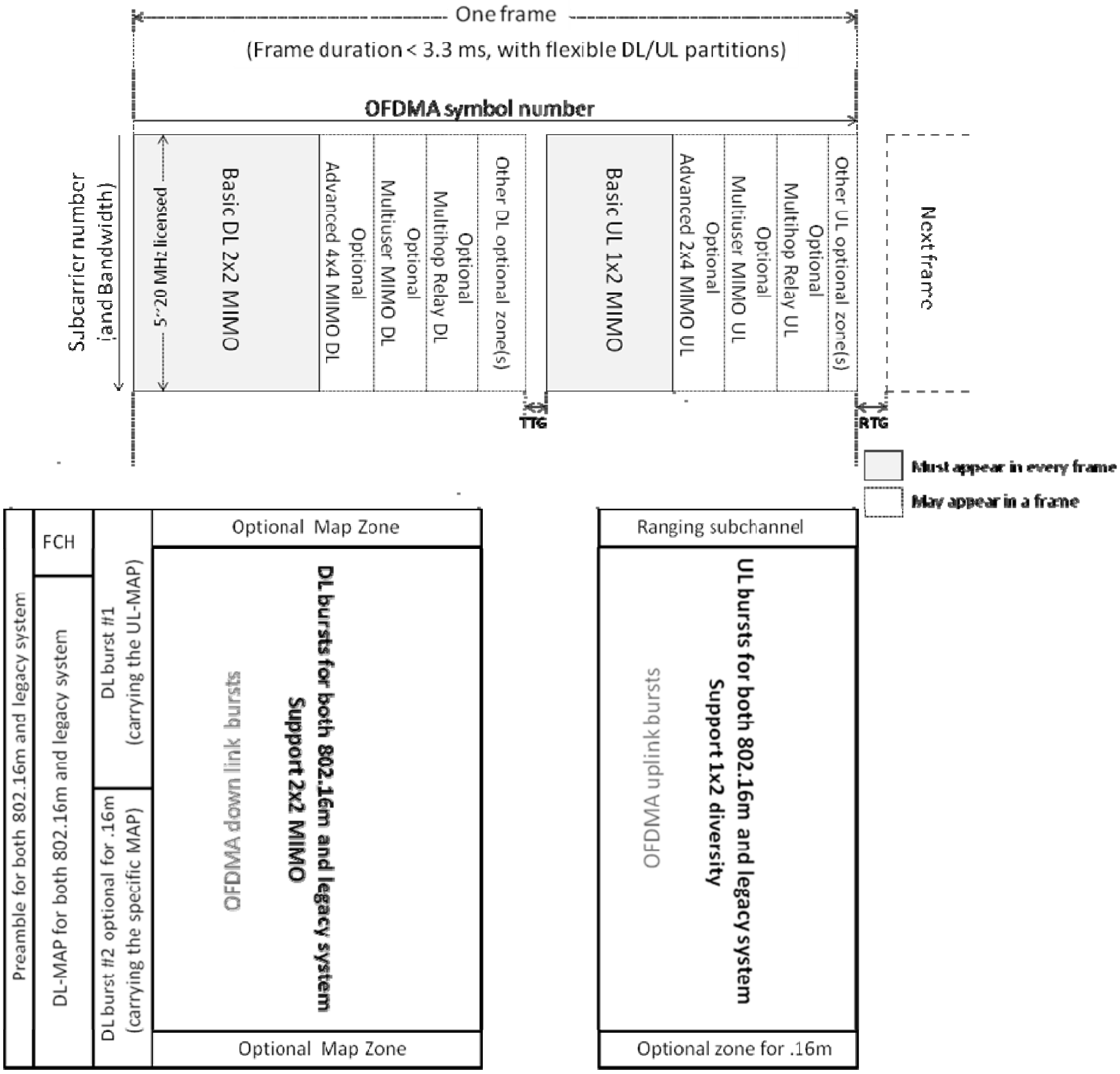


Figure 1: Frame structure for basic and advanced feature

3.1 Basic frame structure and basic features supported

As shown in the above Figure 1, the basic frame structure has specified the basic requirements of 802.16m system as follows:

- Basic operating bandwidths
- Minimum antenna requirements/configurations
- Maximum data latency

The basic operating bandwidths have been defined in SRD to support scalable bandwidths from 5 to 20 MHz. The minimum antenna configurations for the BS of 802.16m are two transmit and two receive antennas. For the MS, a minimum of one transmit and two received antennas shall be supported.

The maximum latency is defined as 10 ms for both downlink and uplink. Even though there could be other advanced techniques be/being developed in 802.16m to realize low latency with long frame duration, we suggest accepting short frame duration. In this design, we assume that if the data in the initial DL in the 1st frame fails, an NACK would be transmitted in the next frame. BS may re-transmit the data in the 3rd frame. Therefore, we might consider these DL, UL and DL within three frames (as minimum). Consequently, the maximum frame duration might not be over 3.3 ms.

Note that the length of a frame can be even shorter. A short frame is also feasible to support high mobility.

The basic frame structure should support the following basic features which could be adopted in IEEE 802.16m

- Minimum single-input single-output (SISO) basic connections
- 2x1 beamforming/diversity
- 2x2 diversity
- 2x2 spatial multiplexing

Even though it is possible to disable one antenna at the BS to support SISO transmission, it is not recommended as it is more effective to operate the available two BS antennas to support high performance, say 2x1 diversity at least. This basic structure also supports legacy compatibility and further discussion on legacy support will be presented in section 4.

3.2 Overview of advanced zone (Brief explanations)

For any other advanced features supported in 802.16m, such as 4x4 DL, 2x4 UL, Multiuser MIMO (MU-MIMO), Multihop Relay (MR), etc., frame structure should specify specific zone(s) to enable the advanced operations as also shown in Figure 1.

- 4x4-DL/2x4-UL MIMO zone
  - This zone is to support mainly on those MSs with 4 antennas (4-receive antenna, 2 transmit antenna), which is different from the basic transmission of 802.16m (2x2-DL and 1x2-UL)
- Multiuser MIMO zone:
  - This is designed specifically for implementing SDMA to achieve higher spectrum efficiency and system capacity
- Multi-hop Relay zone:
  - This zone shall be adopted for cellular extension and further performance enhancement but it is a optional feature as specified in [2] that the performance requirements shall be met without inclusion of the relay stations

There might also be other optional zone(s), such as to support very high speed mobility, some specific legacy scheme, e.g., smaller bandwidth operation which will be further discussed in latter section.

3.3 Advanced 4x4-DL/2x4-UL MIMO

This zone is to support the target requirement of MIMO configuration as specified in [2]. Different from the basic 2x2-DL/1x2-UL MIMO, this can be treated as an optional feature for higher throughput with options that the served mobile terminals shall be equipped with 4-antenna for receiving (DL) and 2-antenna for transmission.

The frame structure configuration of this zone might be similar to the basic zone if those MSs are well-estimated and scheduled at the beginning of the frame. However, for independent operation of this specific zone, we propose the following frame structure, as an example, for opration of 4x4-DL and 2x4-UL MIMO.

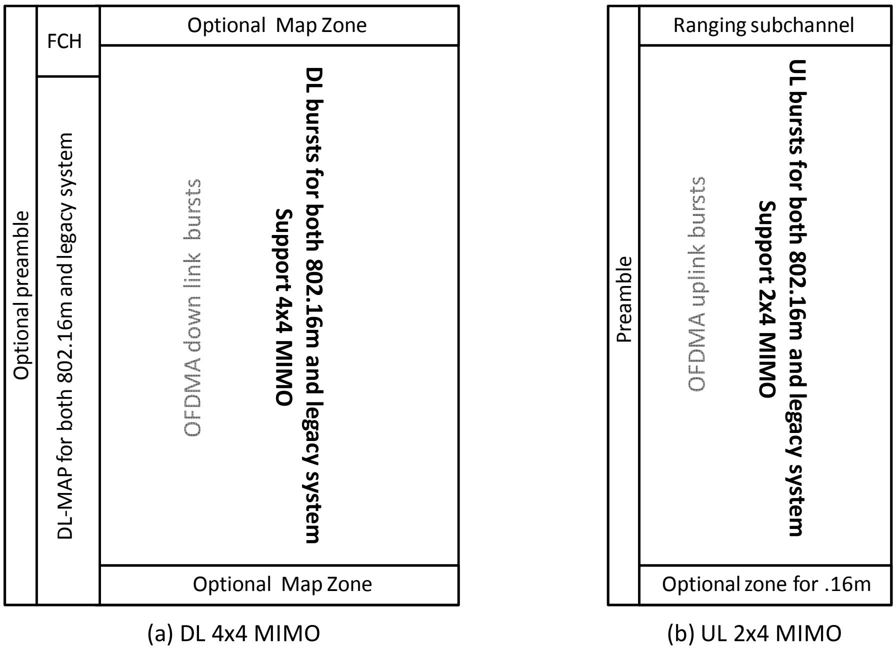


Figure 2: An example frame structure for 4x4-DL/2x4-UL zone

The DL preamble is optional if the preamble of the basic zone is transmitted on the four antennas. However, it is possible for the basic zone to transmit its preamble on only two operating antenna. The optional preamble has to be transmitted on four antennas.

The UL preamble is essential for this specific zone to form 2x4 decoding. Other optional map zones are similar to those in the basic zone.

Note that the frame structure in Figure 2 is also possible to support other MIMO antenna configurations beyond those which have been discussed previously.

3.4 Advanced Multiuser MIMO

A widely known scheme of MU-MIMO is Space-division multiple access (SDMA) that allows BS to transmit (or receive) signal to (or from) multiple users in a same band and time, simultaneously. In 802.16m, it might be worthwhile to have a clear definition on MU-MIMO.

For those MSs which are suitable and/or chosen for MU-MIMO transmission, they are grouped and operated in this specific zone. Note that a single MS could be equipped with only a single antenna or multiple antennas.

Pre-coding is a common technical term for MU-MIMO. Both linear pre-coding and non-linear pre-coding should be defined in 802.16m and operated in this zone.

To support MU-MIMO, the following items/information might be required to be exchanged/operated during one MU-MIMO zone:

- additional frame control
- both forward and reverse channel estimates
- both forward and reverse parameters/information
- mapping MS(s) on transmission/service
- mapping on-service MS(s) on feedback

- mapping non-serviced MS(s) on feedback

Base on these concerns, an example design of the MU-MIMO zone is demonstrated in Figure 3.

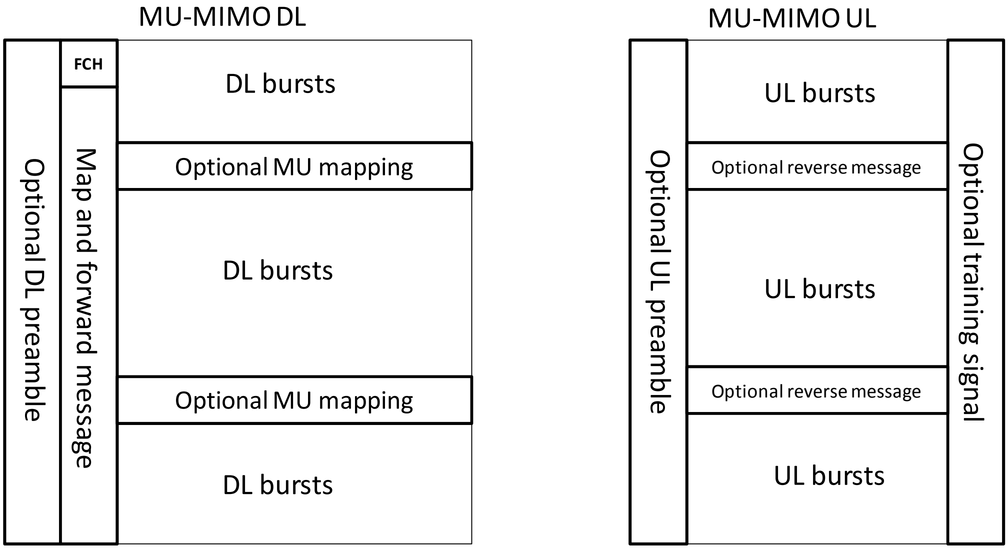


Figure 3: An example design of MU-MIMO zone

The optional DL preamble could be required for forwarding pre-coded preamble. An FCH could be required for this new frame control, which also could be applied to indicate all those optional items. The part of 'Map and forward message' shall be only for MSs under service. Additional mapping to other potential MSs could be specified by optional MU mapping zone(s) in MU-MIMO DL.

In MU-MIMO UL, the UL preamble is optional and could be also selected to be utilized by a number of MSs. The optional training signal(s) could be assigned to those MSs under service and/or other MSs which are not under service during this zone. Reverse message could be also required for MSs to report any message related to DL and/or UL.

Note that UL transmission might or might not be pre-coded.

The major concern of this design is to support continuous MU-MIMO formatting and operating.

3.5 Advanced Multi-hop Relay

It might be beneficial to support multihop relay in a separated zone, in which case it implies ability to support radio resource reuse as well. An example of the application is shown in Figure 4, where BS and RS represent Base Station and Relay Station respectively.

In the figure 4, it assumes a 2-hop relay application. Without radio resource reuse as shown in (a), the 2-hop relay could be operated by 2 frame periods. With radio resource reuse as shown in (b), the 2-hop relay could be operated in 1 frame. The operation could be left to operator upon to scenario, relay type, transparent/non-transparent support, etc. However, all kinds of operation require the optional zone for multihop relay support.

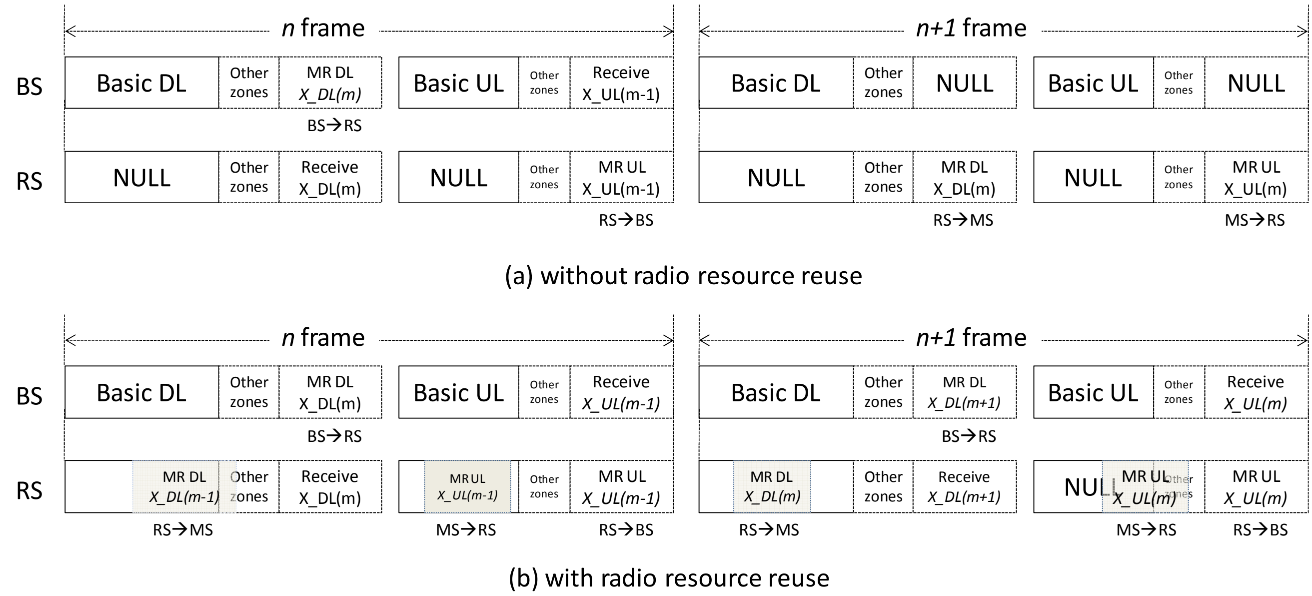


Figure 4: An application example of multihop relay zone (2-hop)

4. Frame structure for legacy support

Based on consideration and comparison which are discussed in Appendix I, we present two examples of frame structure to support legacy system with the development of 802.16m frame structure.

4.1 An example design of 802.16m basic frame structure (TDD) with basic legacy support

Based on requirements of 802.16m and its legacy support, basic frame structure of 802.16m can be designed in many ways. An example design of the basic frame structure, corresponding to Figure 218 in [3], is presented in Figure 5 (also see Figure 1 for its extension). As shown clearly that this frame structure is based on the current legacy frame structure in order to support legacy terminals inside the basic frame – note that a legacy transmission shall be allocated by one burst or more as requested by the legacy terminal.

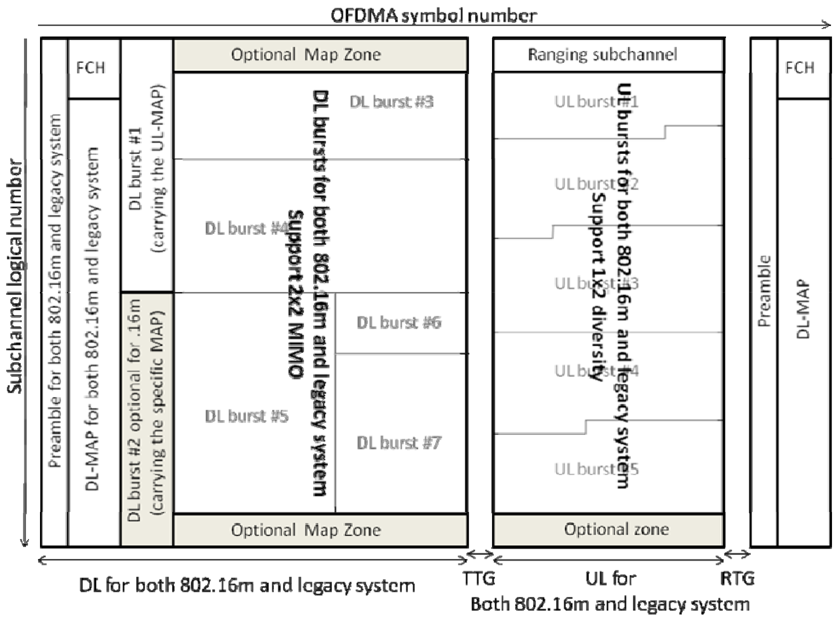


Figure 5: An example design of basic frame with legacy support (with only mandatory zone)

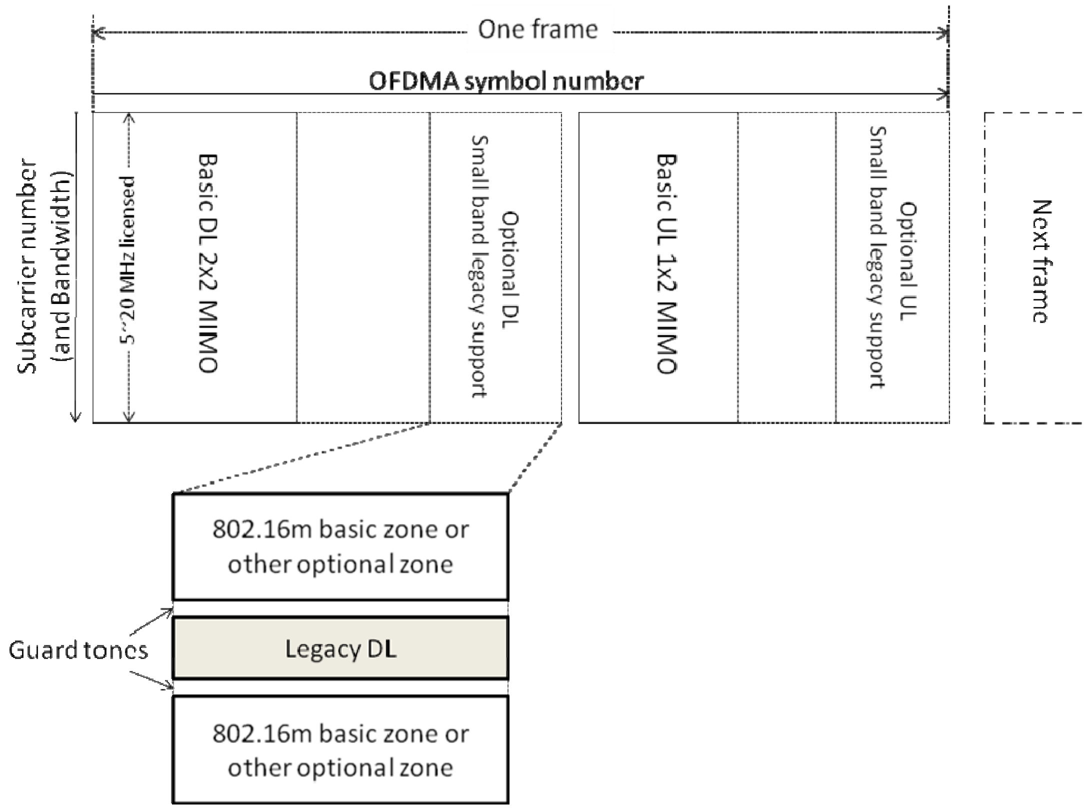
There are several optional burst/zone introduced mainly for 802.16m operation but partially for legacy terminals (optional to support legacy MIMO operation). The optional zones might not be fixed in the frame as long as they are informed to 802.16m terminals and/or legacy terminals.

With this design, there is a little modification to the existing legacy frame – only one flag (only to 802.16m terminals) is required to indicate the DL burst #2 if it is used to carry specific MAP. All other optional zones could be defined in the DL burst #2. However, for legacy terminal(s) beyond its basic transmission, such as optional 2x2 MIMO, AAS, etc., all these optional zones could be used for legacy operation and could be defined in legacy mapping as specified in [3, 4] – e.g., the optional zone in UL could be utilized for reverse link AAS control signals.

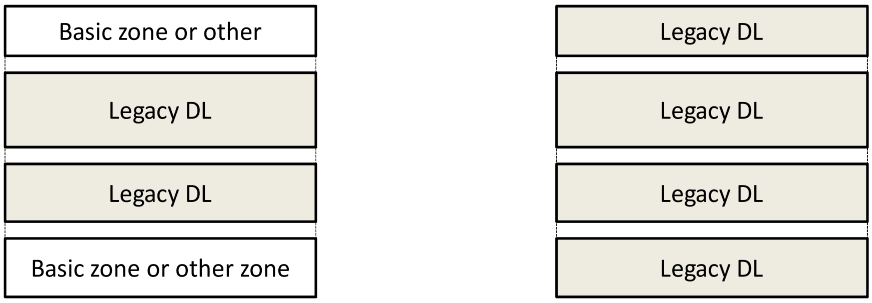
4.2 An example design of 802.16m optional zone with legacy support on smaller bandwidth operation

As we clearly showed in Table 1 (Appendix I), 802.16m and legacy within 5~20 MHz frequency band should be fully supported without legacy problem with the operation bandwidth. However, for legacy terminals which are operated with band between 1.5 and 5 MHz but in the same operating frequency, an optional zone in 802.16m frame should support this kind of legacy operation. An example design is shown in Figure 6. The major concern on this design is to make less disturbing on 802.16m frame structure but much flexible with high efficiency.

Even though the optional zone is utilized, as required, specifically for the legacy small band operation, it is not excluded any operation of basic zone and/or any other optional zone(s) of 802.16m (as already indicated in Figure 6 (a)). Furthermore, the zone could allocate more than one legacy with same or different band, as shown in Figure 6 (b) and/or the zone could be fully occupied with various legacy small bands (Figure 6 (c)).



(a) A full illustration of frame structure



(b) One than one legacy band (c) Full with legacy bands

Figure 6: An example design to support legacy small bandwidth operation

4.3 Frame duration and legacy support in multiple frames

As already discussed previously, the 802.16m frame duration should be much shorter than the legacy's. For shorter frame duration with an integer number embedded in the 5 ms duration of the legacy frame, 2.5 ms frame duration should be one option in the 802.16m frame structure implementation as already proposed in many contributions such as in [5, 6, 7]. With this option (2.5 ms), a multiple-frame implementation is shown in Figure 7, which demonstrates fully legacy support with our proposed 802.16m frame structure presented in this contribution.

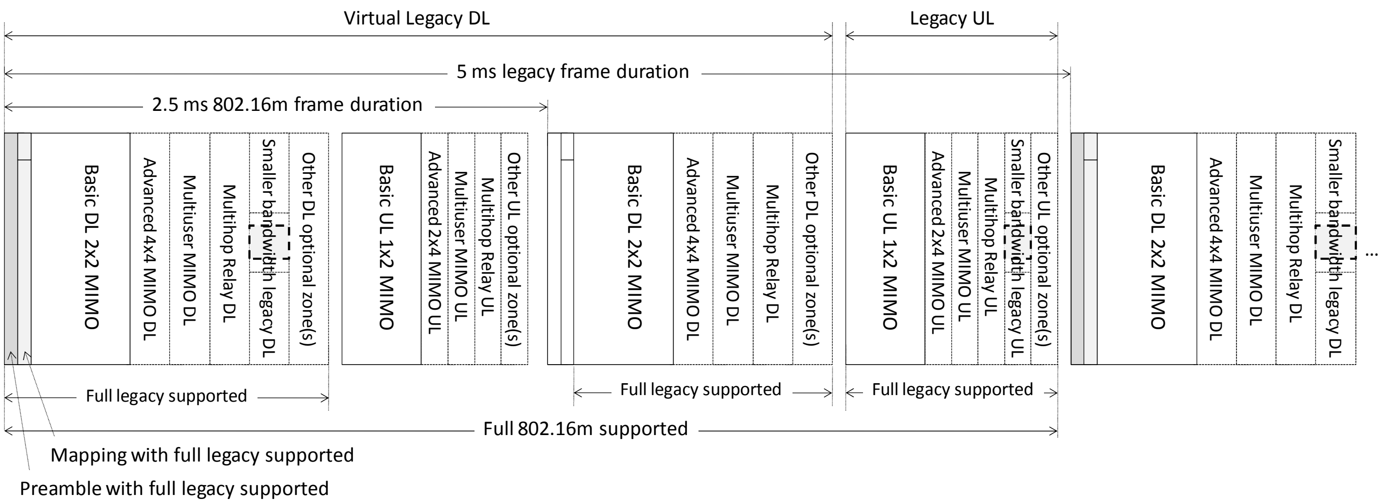


Figure 7: Frame duration with full legacy supported

As shown clearly in the above figure, the preamble and mapping message with full legacy supported would be transmitted every 5 ms. New preamble design should be allowed but with conditions that the preamble has to be recognized by legacy system.

Compared to the legacy frame duration, legacy system might have only partial duration to be supported in an 802.16m system. In contrast, 802.16m is proposed to be supported in full duration without loss of any efficiency. The partitions between 802.16m and legacy system become more effective and flexible. In the above Figure 7, the Virtual Legacy DL covers DL-UL-DL of 802.16m, where the two DLs can support legacy transmission in the new system.

5. Conclusion

In this contribution frame structure for 802.16m SDD has been discussed and proposed. We propose that the basic frame structure of 802.16m should be advanced to support baseline configurations and requirements specified in 802.16m SRD and IMT-advance. This support includes 2x2-DL MIMO and 1x2-UL diversity for high throughput and efficiency. We also propose to employ the 802.16m basic frame structure to support legacy system as well. Other advanced features in 802.16m are proposed to be supported by optional zones, including 4x4-DL/2x4-UL MIMO, MU-MIMO, Multihop Relay, etc. The example designs of each optional zone are also presented and discussed. Further to support smaller bandwidth legacy system (say 1.5~5 MHz), a specific zone is proposed to make flexible allocation of the legacy transmission.

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x.x.x Frame structure

[Insert the following text and diagram for 802.16m frame structure]

The system shall support 2x2-DL/1x2-UL baseline configuration with low latency (<10 ms) by its basic frame structure. Other advanced features of the system shall be supported by optional zones, such as MU-MIMO, Multihop Relay, etc. Example of an OFDMA frame structure , with basic zone (the mandatory zone), in TDD mode is depicted in Figure aaa.

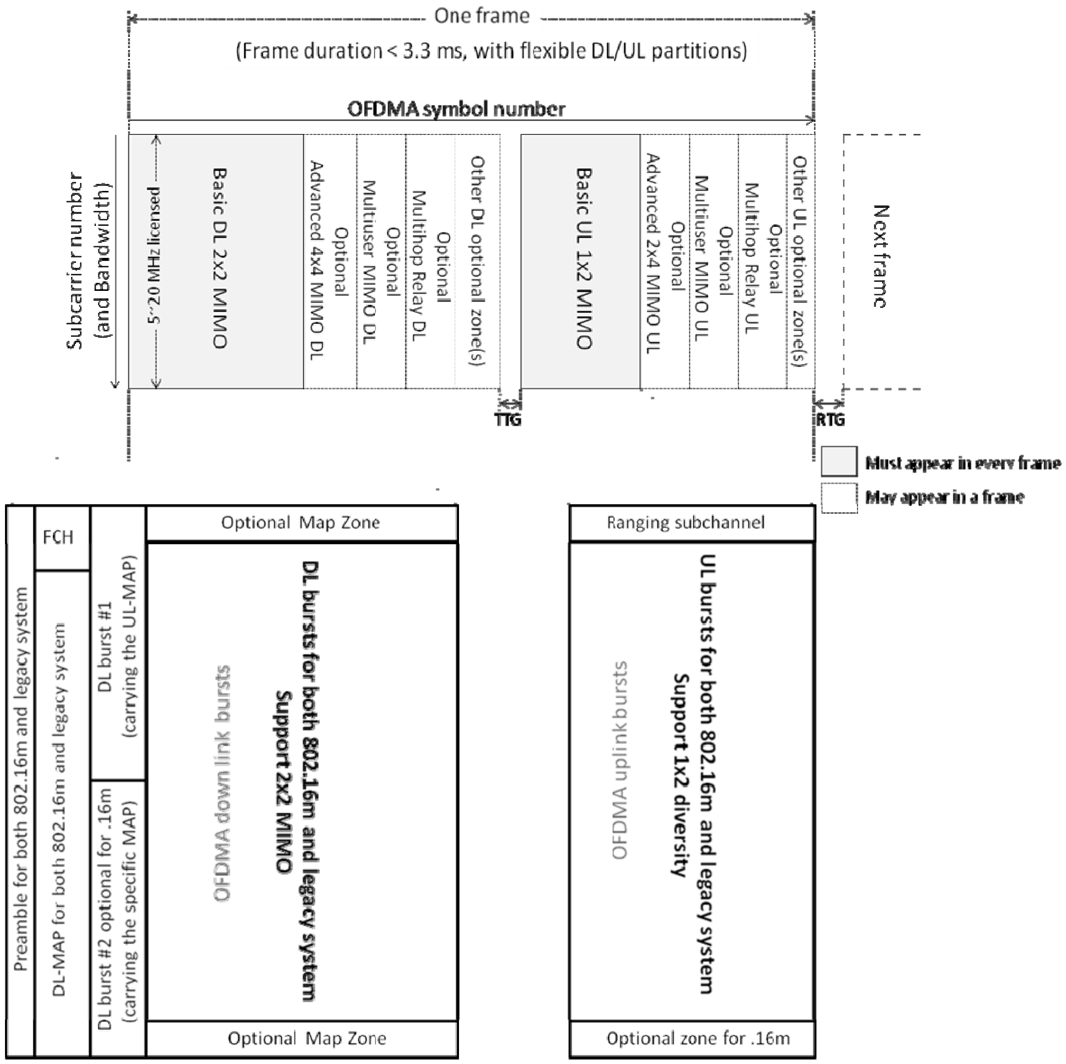


Figure aaa – Example of an OFDMA frame with basic zone (mandatory zone) in TDD mode

x.x.x.1 4x4-DL/2x4-UL zone

The advanced 4x4-DL/2x4-UL shall be implemented during one frame with capability of MIMO decoding on both downlink and uplink. A frame structure to support this feature is shown in figure bbb.

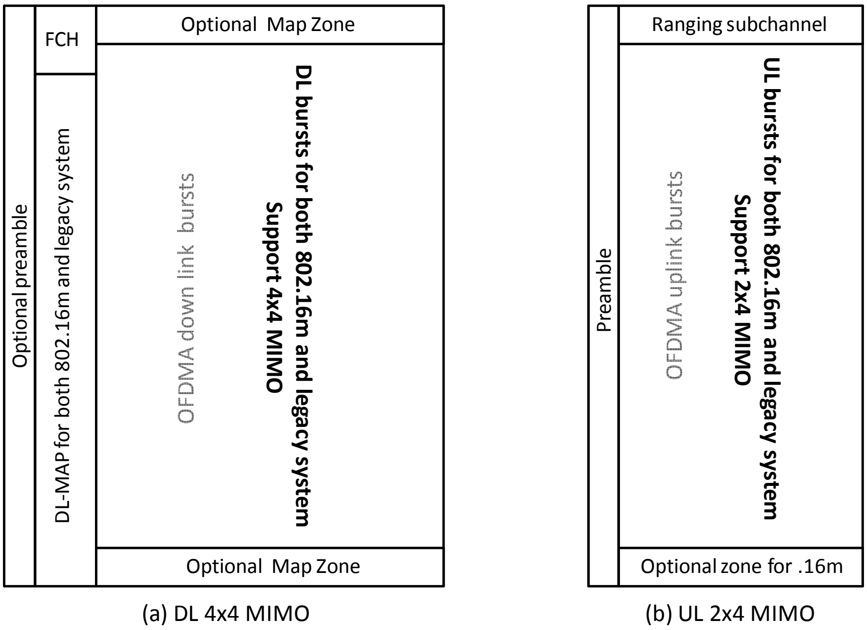


Figure bbb: An example frame structure for 4x4-DL/2x4-UL zone

x.x.x.2 Multiuser MIMO zone

An example design of the MU-MIMO zone is demonstrated in Figure ccc.

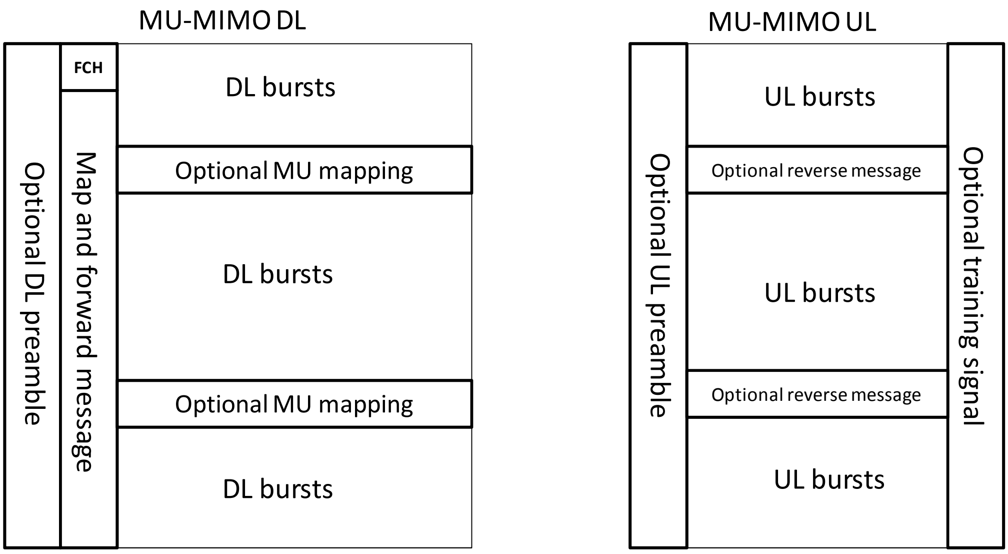
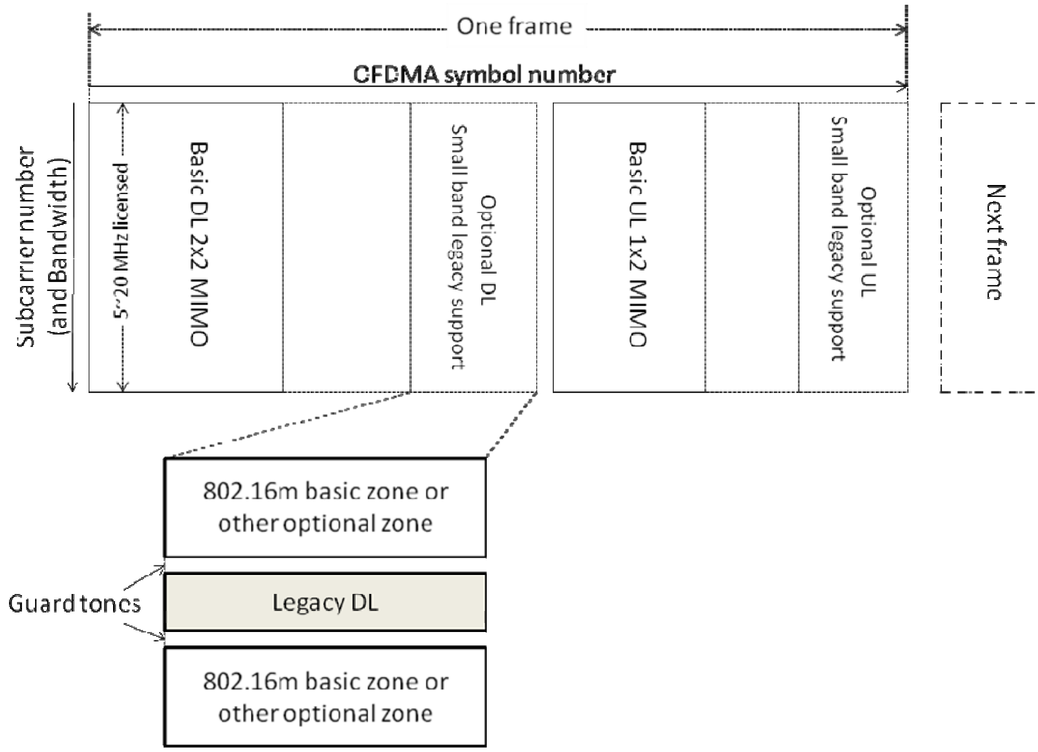


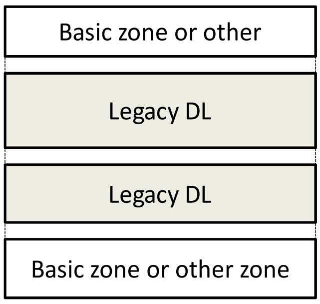
Figure ccc: An example design of MU-MIMO zone

x.x.x.3 Smaller bandwidth operation

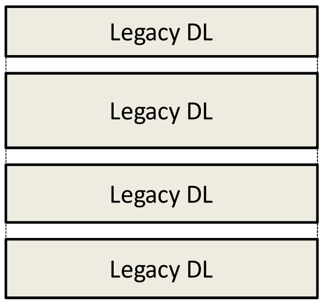
For legacy terminals which are operated with band between 1.5 and 5 MHz but in the same operating frequency, an optional zone in 802.16m frame should support this kind of legacy operation. An example design is shown in Figure ddd.



(a) A full illustration of frame structure (symmetric)



(b) One than one legacy band



(c) Full with legacy bands (asymmetric)

Figure ddd: An example design to support legacy small bandwidth operation

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References

[1] IEEE 802.16m PAR, December 2006, http://standards.ieee.org/board/nes/projects/802-16m.pdf

[2] IEEE 802.16m System Requirements, IEEE 802.16m-07/002r4, 2007-10-19, http://ieee802.org/16/tgm/docs/80216m-07_002r4.pdf

[3] IEEE Std. 802.16e-2005, IEEE Standard for Local and metropolitan area networks, Part 16: Air Interface for Fixed and Mobile Broadband Wireless Access Systems, Amendment 2: Physical and Medium Access Control Layers for Combined Fixed and Mobile Operation in Licensed Bands, and IEEE Std. 802.16-2004/Cor1-2005, Corrigendum 1, 28 February 2006
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[4] IEEE Std 802.16-2004: Part 16: IEEE Standard for Local and metropolitan area networks: Air Interface for Fixed Broadband Wireless Access Systems, June 2004

[5] C802.16m-07/242r1, “TDD frame structure for legacy support in 16m”, 2007-11-07

[6] C802.16m-07/263, “802.16m frame structure to enable legacy support, technology evolution, and reduced latency”, 2007-11-07

[7] C802.16m-07/265, “Implications of backwards compatibility on IEEE 802.16m frame structure”, 2007-11-07

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Appendix I: Legacy considerations and supports

Based on SRD, 802.16m provides continuing support for legacy WirelessMAN-OFDMA equipment. In the development of the frame structure, this can be interpreted as that it allows new 802.16m frame structure but the 802.16m frame structure provides legacy support. Consequently, we are proposing in this proposal to develop 802.16m frame structure based on SRD (inline with IMT-advanced requirements) and the developed 802.16m frame structure shall partially support legacy equipments, without dissatisfying any of IMT-advance requirements and disturbing the new system. For all these purposes, some comparisons based on multiple access and multi antenna configurations are performed as shown in Table 1.

	Legacy terminals	**802.16m terminals**	**Notes/comments**
Operating frequency	Possible 3G spectrum	Possible new spectrum for next generation cellular	Could be automatically separated by operating spectrum
Supporting channel bandwidths	scalable 1.25 to 20 MHz	scalable 5 to 20 MHz	The differences are on small bandwidth of 1.25 to 5 MHz. (The difference is not between 10 and 20 MHz)
Multiple access	TDD, FDD, SDD	TDD, FDD, SDD	
Antenna configuration baseline	DL 1x1 UL 1x1	DL 2x2 UL 1x2	Baseline is different
Multi antenna supported	BS: 1 to 4 MS: 1 to 4	BS: 2 to 4 MS: 1 to 4	Difference on the minimum BS antenna
MIMO support	Optional	Mandatory	MIMO has to be supported in 802.16m to meet requirements
AMC	Optional	Mandatory	

Table 1: Some comparison between legacy terminals and 802.16m terminals

Based on the concerns described above, we propose the development of 802.16m frame structure should target on multi antenna supports in 5 to 20 MHz as basic frame but possibly to support 1x1 legacy terminals if the legacy terminals are operated in the same operating frequency and channel band. For legacy terminals with bandwidths between 1.25 to 5 MHz, it could be further supported by 802.16m as optional feature in an optional zone.
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Note that even we say to support 1x1 legacy terminals, it does not mean we have to utilize 1x1 configurations in 802.16m. More precisely, the 802.16m basic frame structure is to support legacy terminal with 1 antenna.