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Re:	IEEE 802.16m-07/040 (call for contributions on 802.16m SDD)	
Abstract	This document describes a proposal for inclusion of channel aggregation in the 802.16m SDD.	
Purpose	To be discussed and adopted by TGm for the 802.16m SDD.	
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Proposal to include Channel Aggregation in 802.16m SDD

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1 Introduction

In [1] a method was shown to take advantage of adjacent channels to support greater peak rates for a service. The following describes channel aggregation and is derived from a contribution [2] accepted by IEEE 802.22. The concept is very similar to the channel bonding currently being applied in various forms of 802.11. Two B MHz channels (B = 5, 10, etc.) are combined to form the equivalent of a single 2B MHz channel, with approximately double the system throughput, and peak data throughput rates approaching twice the single channel throughput for properly enabled devices. The extension to aggregating more than two channels is readily apparent, although more complicated. Note that channels being aggregated by the procedure described below need not be contiguous in frequency, which is a benefit given expected spectrum availability.

Since it defines the cell or network, the BS would necessarily operate in the channel bonded mode, providing two single B MHz channels. These two channels would look to the outside world as two independent, properly formed B MHz 802.16m channels. But properly configured devices could send on both channels simultaneously and receive on both channels simultaneously. The CPE devices could be available in two configurations. Legacy or inexpensive devices that do not support services that peak above the bandwidth of a single channel and, therefore, do not need the additional bandwidth, would operate using a standard B MHz profile, just as if they were communicating with a BS that merely produced a single B MHz channel. The legacy devices would generally remain on that one channel (there could be some load leveling or handoff function). Multi-channel CPE devices would be able to communicate with the BS on both channels simultaneously, potentially with an instantaneous bandwidth peaking at the combined peak bandwidth of both channels. For reference, a typical 802.16 OFDMA frame might look as shown in Figure 1 or in any of the contributions on frame structure.

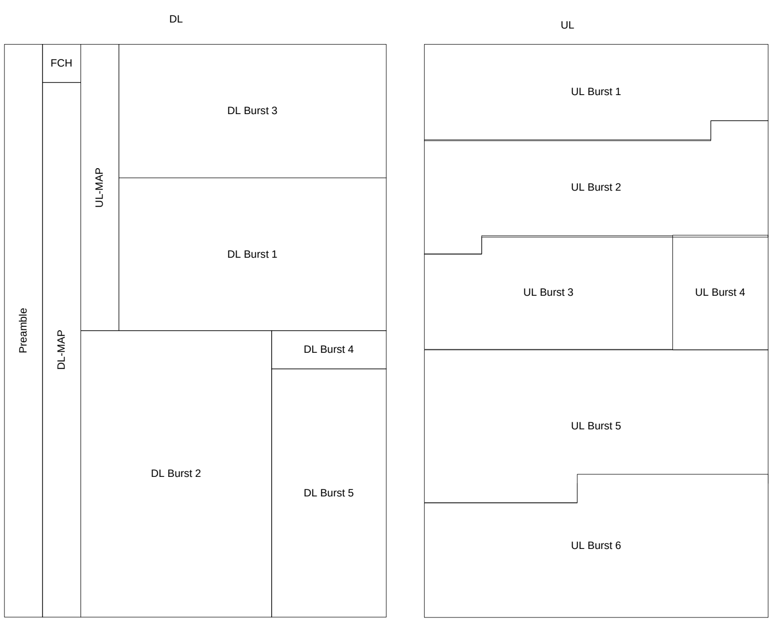

Figure 1: Basic OFDMA Frame

The goal would be to distribute data as shown in Figure 2, where CPEs 3 and 6 are enabled for 2B MHz operation, and CPEs 1, 2, 4, 5, 7, and 8 are only enabled for B MHz operation.

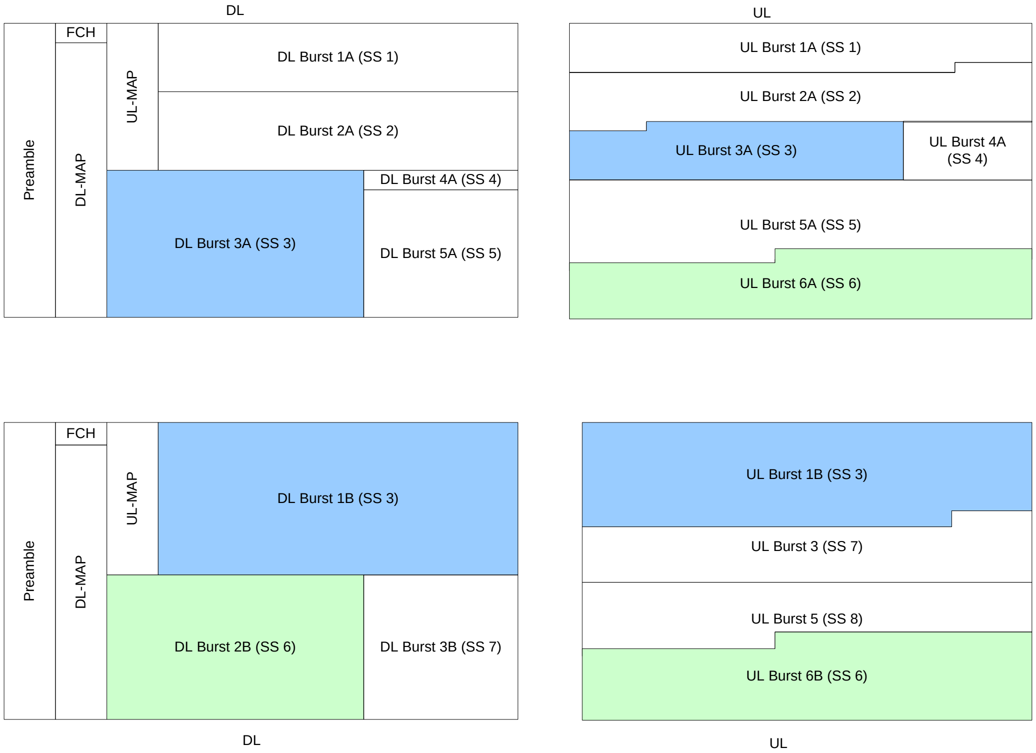

Figure 2: OFDMA Frame in Two Aggregated Channels

As can be seen, there can be substantial variability in the mapping of data due to the bursty nature of today's IP traffic. For instance, some CPEs may not receive data in every frame, or may have asymmetric UL and DL needs, not only on the average but more importantly, instantaneously on a frame by frame basis.

The BS or AP device must schedule the bandwidth taking these issues into account. In the DL, it does this by scheduling the transmission of actual data packets. In the UL, it schedules logical demand, but the algorithm is very similar to scheduling actual packets. The BS scheduling algorithm must divide the CPEs into 3 groups. The group 1 is comprised of those legacy CPEs that are only capable of B MHz operation and have accessed the network on channel A. The group 2 is comprised of those CPEs that are only capable of B MHz operation and have accessed the network on channel B. The group 3 is comprised of those multi-channel CPEs that are capable of 2B MHz operation.

As an **example** of how the scheduler would work, data for the separate groups has separate class queues within the QoS engine as shown in Figure 3. Each of these is fed by per-service queues, but since this is the same as without channel aggregation, it is not shown. The QoS engine runs initially over the 3 groups of queues, pulling the data based on the fairness algorithms implemented. However, data from group 1 must always be allocated to channel A, and data from group 2 must always be allocated to channel B. Data from group 3 can be allocated to either channel A or B or a combination of both.

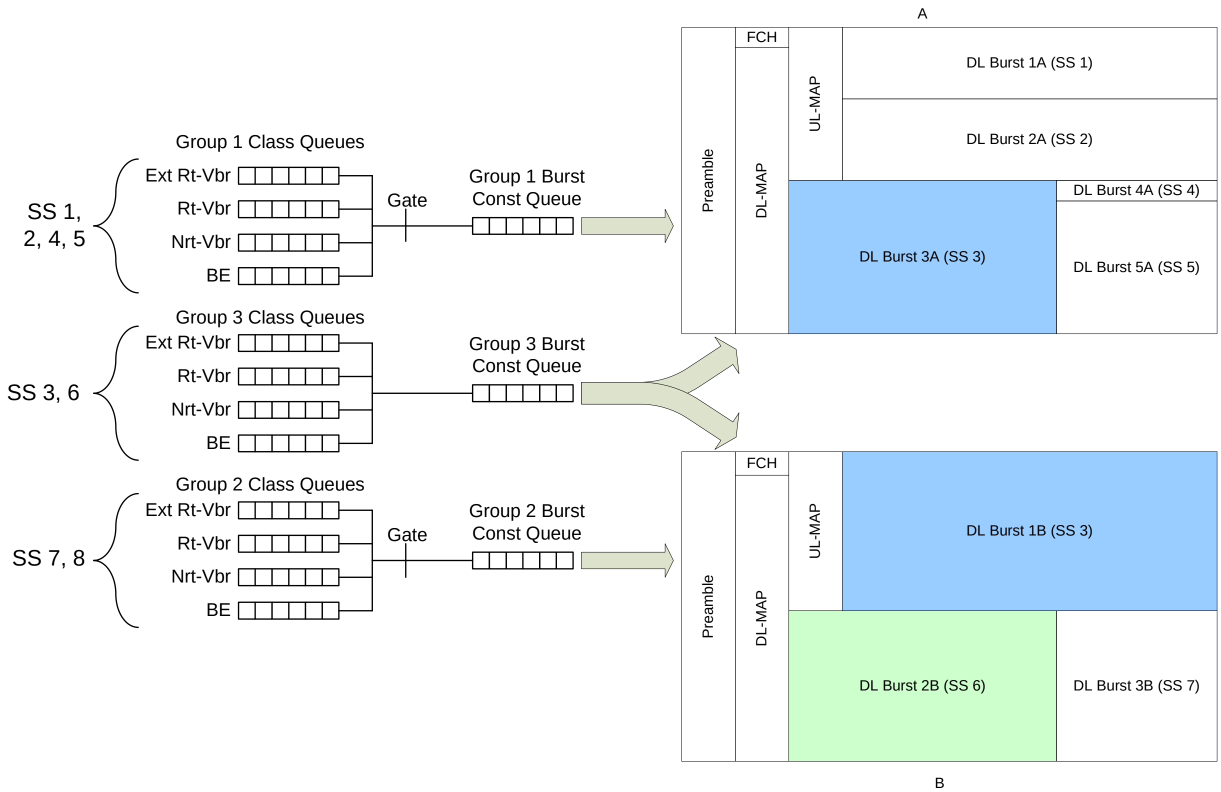

Figure 3: DL construction

Occasionally (or often in some systems), the current DL subframe on channel A or B may individually fill up before the combination of A+B is full. At this point, the QoS engine must close a gate for the group (1 or 2) that can only have its data allocated to the channel which is already full. The QoS engine continues until the combination of data from all three groups fills both channels or until the time limit for filling the frame has occurred. The result is a frame with data for group 1 in channel A, data for group 2 in channel B, and data for group 3 spread across both channels. Block numbering, as used in MAC level ARQ, can be used to guarantee in order delivery of data.

With data for one SS split simultaneously across two or more bonded channels, the issue of preservation of data order arises. There are a few possible methods for preservation of data order.

1) Simply declare one channel to be earlier in time than the other(s). For example, with two bonded channels A & B. Data in the same frame received on channel A could be viewed as earlier data than the data received on channel B, even though the data is technically received at the modem simultaneously or in the opposite order.
2) Take advantage of the block numbering and order preservation built into the MAC level ARQ in 802.16. This would imply using ARQ, but with no retransmissions on connections where we don't really want to apply ARQ.
3) Use a block/packet numbering scheme similar to what's used for ARQ and fragmentation. This has the benefit of independence from the other two functions, but it would add extra overhead.

2 Overview of specific ideas and associated amendment of the base standard

This section provides an overview of the broad concepts supporting Channel Aggregation (CA) and the resulting amendment to the 802.16 standard in support of this work. The changes are explained in turn covering the following areas:

- RF and PHY issues,
- OFDMA zone and permutation definition,
- Single MAC for multiple PHYs concept: load balancing and scheduling,
- Supporting mechanisms.

It should be noted that much of the basic messaging to support CA is already included within the base standard (i.e., 802.16); this section presents discussion of where enhancement can be made and how the CA concept can be realized in the standard.

2.1 RF and PHY issues

For simplicity, it is envisioned that channels being aggregated will retain their individual PHY layers (i.e., there will be as many PHYs as channels being aggregated, up to a maximum of three). The relationship between these PHY layers and a single MAC is addressed in Section 2.3 below.

2.2 OFDMA zone and permutation definition

This section discusses MAC support for the OFDMA PHY implementation of the CA scheme.

2.2.1 Permutation definition

The 802.16 OFDMA PHY provides a number of permutations. The permutation of user data ensures a narrow allocation of bandwidth given to a CPE is spread across a wide proportion of the available channel bandwidth; thus ensuring good frequency diversity, interference spreading and averaging. The use of CA provides a means of further benefiting from frequency diversity by performing permutation across all available channel supported by the multi-channel CPE. CA permutation undertaken in frequency across the aggregated channels ensures frequency diversity is maximized.

It is intended that a CA permutation will provide enhancement to the multi-channel CPEs, and at the same time not degrade the service of legacy CPEs. Within a CA zone existing permutations can be used by legacy CPEs with the CA specific permutations benefiting multi-channel CPEs. The CA permutation is intended to work with data allocations of different shapes. This has the obvious benefit of not compromising the performance of legacy CPE through the restriction of data region allocations. In addition there is no reduction in efficiencies of the system as a whole from either legacy or multi-channel CPEs. Assignment and control of permutations is untaken by MAC layer messaging.

2.3 Single MAC – Multiple PHYs concept: Load balancing and scheduling

The concept of single MAC with multiple PHYs is shown in Figure 5.

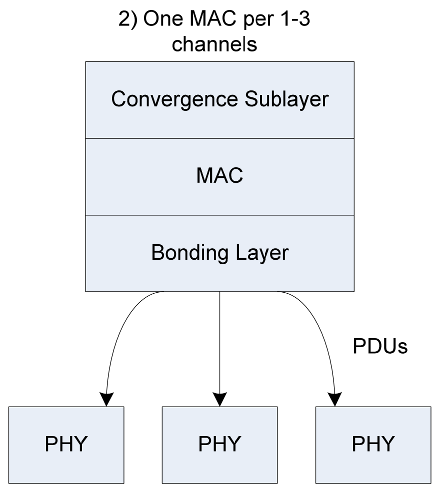

Figure 5   Single MAC – Multiple PHY Channel Aggregation Implementations

There are clear performance benefits obtained by CA from load balancing and scheduling optimization. These benefits are derived from the additional degrees of freedom provided by CA data region allocation. These enhancements are described in turn. Much of the ability to provide load balancing and scheduling enhancements through CA is left to implementation, however the basic elements of such solutions are provided via existing MAC messages.

2.3.1 Scheduling

Figure 3 in section 1 provides an illustration of how legacy and multi-channel CPEs are managed by a scheduler implementation. For a fully flexible approach it is important that allocations can be used in a fully dynamic manner. For example, in Figure 3, unused allocations for group 1 and 2 can be used by group 3 for CA-capable CPE, and in the same way, unused allocations for group 3 users can be used by group 1 and 2 users in their respective channel bandwidths.

Having a single MAC for the multiple PHYs allows the data to and from an individual CA-capable SS to be spread across the two channels as needed for maximum efficiency in scheduling. In particular, it allows individual services to peak at the combined data rate of the two channels.

The CA proposal is supported in both the downlink and the uplink. However, in the case of asymmetric traffic demands, it would be possible to provide CA in only the downlink, with the uplink remaining in single channel mode. As the downlink and uplink are managed independently, then it is also possible to provide CA in the uplink, but not in the downlink.

2.3.2 Load balancing

The concept of load balancing is centered on the ability for the scheduler to switch traffic loading between B channels for legacy users. For example if a BS device was supporting two channels with legacy devices on each channel and multi-channel devices receiving transmission on both channels, a scheduler may choose to switch a particular legacy user to the other channel in order to balance traffic on both channels.

2.4 Supporting mechanisms

This section provides information on the peripheral support aspects of the CA concept.

2.4.1 Capability negotiation/reporting

CPE capability negotiation:

CPE support multi-channel operation.
Aggregated channels supported by the CPE: 0 (default – no support for CA), 2, and 3.
CPE supports: DL, UL, or DL **and** UL CA.

BS capability statement:

Aggregated channels supported by the BS: 0 (default – no support for CA), 2, or 3 channels.
BS supports: DL, UL, or DL **and** UL CA.

2.4.2 Control/Management

Changes to the operating channel of a CPE for load balancing purposes.

3 Proposed Changes

As suggested in [3], include a Channel Aggregation section in the SDD:

Channel Aggregation

The system shall allow the aggregation of multiple adjacent or non-adjacent channels. Each of the aggregated channels shall appear individually as a normal, properly-formed channel that can support subscriber stations not capable of channel aggregation, including legacy subscriber stations. For subscriber stations capable of channel aggregation, the services implemented are allowed to peak at the sum data rate achievable on the set of aggregated channels.

There will be a capability negotiation so the BS can determine which subscriber stations are capable of channel aggregation. To preserve backwards compatibility, the default in the negotiation is for no channel aggregation.

4 References

[1] IEEE C802,16m-07/242: *TDD Frame Structures for Legacy Support in 16m*; Dong Li, Liyu Cai, Hongwei Yang, Jimin Liu, Joerg Schaepperle, Krishna Balachandran; 6 Nov 2007.

[2] IEEE 802.22-06/0133r0: *NextWave Channel Aggregation Proposal Outline*; Ramon Khalona, Kenneth Stanwood, Paul Piggin; 17 July 2006.

[3] IEEE C802.16m-07/262: *Proposed 802.16m SDD Table of Contents;* Lei Wang, Yair Bourlas, William Burchill, and Kenneth Stanwood; 7 Nov 2007.