Project	**IEEE 802.16 Broadband Wireless Access Working Group <http://ieee802.org/16>**
Title	**802.16m basic frame structure for improved intra-system coexistence**
Date Submitted	**2008-01-16**
Source(s)	Mariana Goldhamer Alvarion ltd. 21A, Ha Barzel Street Tel Aviv E-mail: mariana.goldhamer@alvarion.com
Re:	Call for Contributions IEEE 802.16m-07/047 - Proposed 802.16m Frame Structure with special attention to legacy support
Abstract	Proposed 802.16m Frame Structure for compliance with the new requirements of traffic performance at cell margin and of cell higher spectral efficiency
Purpose	Actions: 1. Modification of ToC 2. Capture of the text in the SDD
Notice	
Release	
Patent Policy	

802.16m basic frame structure for improved intra-system coexistence

Mariana Goldhamer
Alvarion Ltd.

Introduction

System Requirements

The 802.16m System Requirements relevant to this contribution specify:

6.4.2 Interference management

IEEE 802.16m shall support interference mitigation schemes.

7.1.1 Relative performance

The targets for average user-throughput and cell-edge user throughput of downlink/uplink for data only system for baseline antenna configuration are shown in Table 6. Both targets should be achieved relative to WirelessMAN-OFDMA Reference System performance as per antenna configuration defined above.

Table 6–Relative throughput of a data only system

Metric	DL data (xWirelessMAN-OFDMA Reference System)	UL data (xWirelessMAN-OFDMA Reference System)
Average user throughput	> 2x	>2x
Cell edge user throughput	> 2x	>2x

7.4 Cell coverage

IEEE 802.16m shall provide significantly improved coverage with respect to the WirelessMAN OFDMA Reference System.
Based on the same configuration, the link budget of the limiting link (e.g. DL MAP, UL bearer) of IEEE 802.16m **shall be improved by at least 3 dB compared to the WirelessMAN-OFDMA Reference System**.

7.5 Enhanced multicast-broadcast service

As outlined in Section 6, IEEE 802.16m shall support enhanced multicast-broadcast service for IMT Advanced multimedia multicast broadcast services in a spectrally efficient manner.
The IEEE 802.16m enhanced multicast-broadcast service may support large cells (**e.g. 50 km**).
Minimum performance requirements for E-MBS, expressed in terms of spectral efficiency over 95% coverage area, appear in Table 14.

Table 14–MBS minimum spectral efficiency vs. inter-site distance

Inter-site distance (km)	Min. spectral efficiency (bps/Hz)
0.5	4
1.5	2

The following notes apply to Table 14:
1. The performance requirements apply to a wide-area multi-cell multicast broadcast single frequency network (MBSFN).
2. The specified spectral efficiencies neglect overhead due to ancillary functions (such as synchronization and common control channel) and apply to both mixed unicast-broadcast and dedicated MBS carriers, where the performance is scalable with carrier frequency bandwidth.

Elements of the solution

In order to address the above requirements, we propose a 16m Frame solution to address:

- Frame structure, including both Reuse 1 and Reuse 3 approaches, to increase the C/I at cell margin and to enable the inter cell/sector interference management
- Multiple MCH/MAP transmissions to increase C/I per transmission
- Dedicated Reuse-1 zone to form a single frequency network for broadcast traffic
- Coordinated UL sub-channel selection zone for pro-active opportunistic scheduling
- Coordinated UL sounding
- More flexible ZONE approach.

This contribution will address the basic Fame Structure in relation with the improved coexistence and spectral efficiency.

Inter cell/sector interference management

Interference problem in Reuse 1 scenario

There are two problems in the Reuse 1 scenario: inter-cell interference and inter-sector interference. The following figure shows the interference problem for DL (downlink) at cell margin, where the two adjacent cells, including the more far cells can interfere with the wanted signal and create in the worst case an average negative SIR (Signal to Interference Ratio) of –(5…6) dB per some subcarriers (3dB from adjacent sectors, and another aprox. 2dB from the more remote interfering sectors). If we consider the channel fluctuations and the Doppler effects the interference levels on specific sub-carriers might be worse.
Fig. 1 shows the deployment problem with Reuse 1, for the areas in which the inter-cell or inter-sector interference are dominant. In this figure the inter-cell interference areas are shown as green islands (see also the pointer indicating the problematic area) and the inter-sector interference areas are shown as red islands. The wished signal direction is marked with thick lines, while the interfering links are marked with thinner interrupted lines. This simplified scenario is suitable to rural area.

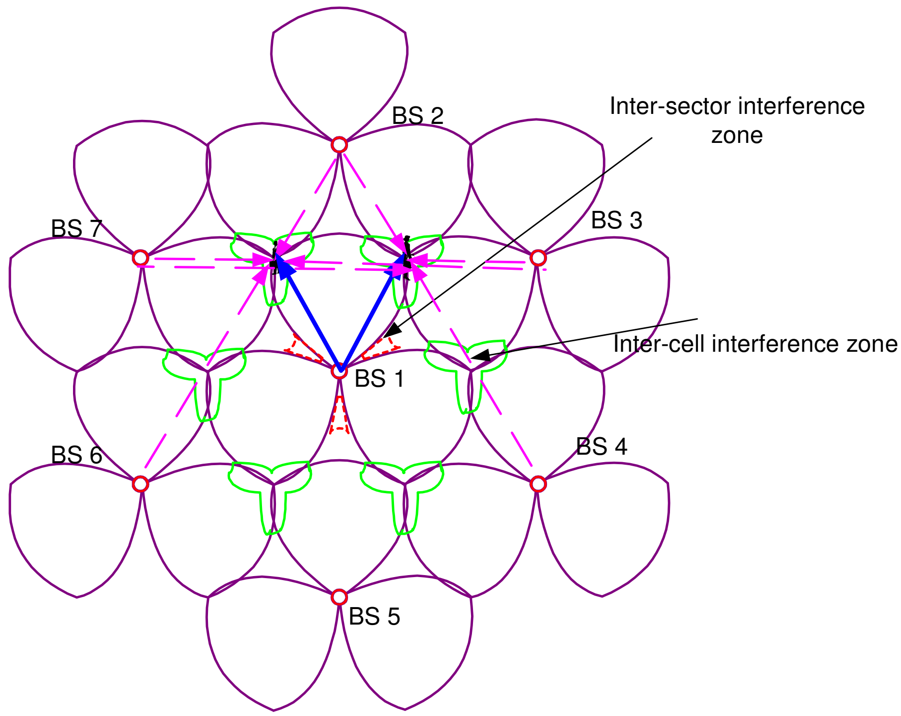

Fig. 1 Down-link inter cell/sector interference

The DL permutations in PUSC allow mitigating the gravity of the problem for relatively narrow data transmissions, occupying one channel. However there are cases in which there is a penalty of lower spectral efficiency due to the lack of an appropriate solution that is able to reduce the SIR for:
- MAP (control information) transmissions;
- More demanding traffic, as IP-Video or Internet browsing, for which the probability of collisions between sub-carriers of adjacent cells may become too high
- Broadcast traffic transmissions, for which the collisions between sub-carriers of adjacent cells create a serious disadvantage, due to the expected QoS.

Due to the above problems, the Reuse 1 significantly reduces the peak data rate and is avoided in practical deployment solutions. Instead in many deployments the Reuse 3 solution is preferred. In other words, a Reuse 3 solution is more adequate for addressing the coexistence problems at cell margins. No solution is provided for broadcast (separate single-frequency channel) support inside a frequency channel.

A similar problem occurs in the UL (up-link), as shown in Fig. 2:

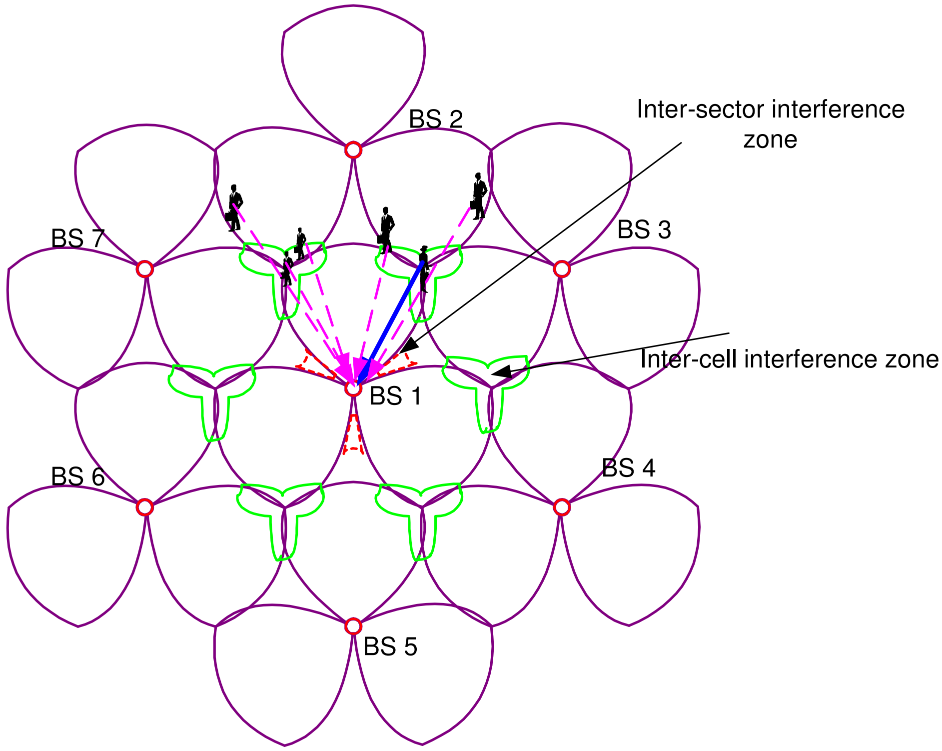

Fig. 2 Up-link inter cell/sector interference

Coverage and MAP efficiency

Due to the fact that the MAP starts always at the same time/sub-channel location, uses all the sub-carriers in a segment and the same permutations are applied to all the sectors during its transmission, simulations show that even for Reuse 3, in areas with high shadowing probability, we can still have a relatively large percentage of low SIR situations.

Solution

In order to address these requirements, under the constraint of 95% cell coverage, namely the improvement of the cell edge user throughput, spectral efficiency and cell coverage for both UL and DL, increased spectral efficiency and broadcast traffic support, an adequate 802.16m FRAME should be used.
The basic Frame type is explained in this contribution, while the additional possible Frame types are explained in a different contribution.

Start text for SDD

Frames for TDD operation

Frame type 1 – OFDMA domain

The 802.16m frame combines the Reuse 1 and Reuse 3 operations, inside a frequency channel, using the OFDMA domain. The “Reuse 1” implies that all the sectors in a Base Station will use the same frequency partition, while the “Reuse 3” implies that each frequency partition is used by a single sector. Such partitions, each including a number of sub-channels are call DLSET and ULSET, for respectively DL and UL.

Downlink sub-frame

Partition in SETs

The 802.16m Frame is partitioned between Reuse 1 and Reuse 3 SETs. For example, in the case of 3 sectors deployment, the Reuse 1 SETs will be used by all the sectors, while every one of the Reuse 3 SETs are allocated to a specific sector. Every SET used in Reuse 3 is assigned with a number of sub-channels, such that there is **no collision between sub-channels used in the same SET (sector) but in different BS.**

A TDD Frame example is shown in Fig. 3, which includes possible sub-channel partitions between SETS, every SET is transmitted with its own preamble, MCH (MAP Control Header) and MAP. The MCH contains the MAP Control Prefix data structure which clarifies how the MAP messages shall be decoded. The MCH and the MAP (including both DL MAP and UL MAP) may be considered as a “Control Channel”.

The DLSET0, intended for Reuse 1, is further split in multiple sub-sets, which can use different maximum sub-carrier power levels, like the data sub-set – DLSET01 and the broadcast sub-set – DLSET02.

The broadcast zone, intended for the E-MBS (Enhanced broadcast-multicast service), includes its own MCH02 and MAP and can use much higher powers than used for all the other SETs or sub-sets. Due to the adjacent sub-carrier interference, the carriers allocated for the Broadcast sub-set should be separated by one or more guard carriers from the carriers allocated to the other zones. A dedicated number of sub-channels are dedicated to the Broadcast zone. The duration of the Broadcast Zone is programmable and is included in its private MAP.

Possible variants of this approach are:

- Separation from the beginning of the Preamble, MCH and MAPs for broadcast and unicast allocation of respectively DLSET01 and DLSET02 (Fig. 4). The approach offers best performance, with the disadvantage of more parallel processing requirements; in continuation we have chosen to show only the variant in Fig. 3.
- Transmission of the Broadcast Preambles, MCH and MAP first, over the full DLSET0, and continue with the unicast MCH and MAP over the DLSET01.

The SETS intended for Reuse 3 are named SET1, SET2 and SET3. These sets include their own Preambles, MCH and MAPs and can be transmitted using the maximum sub-carrier power assigned for the unicast services.

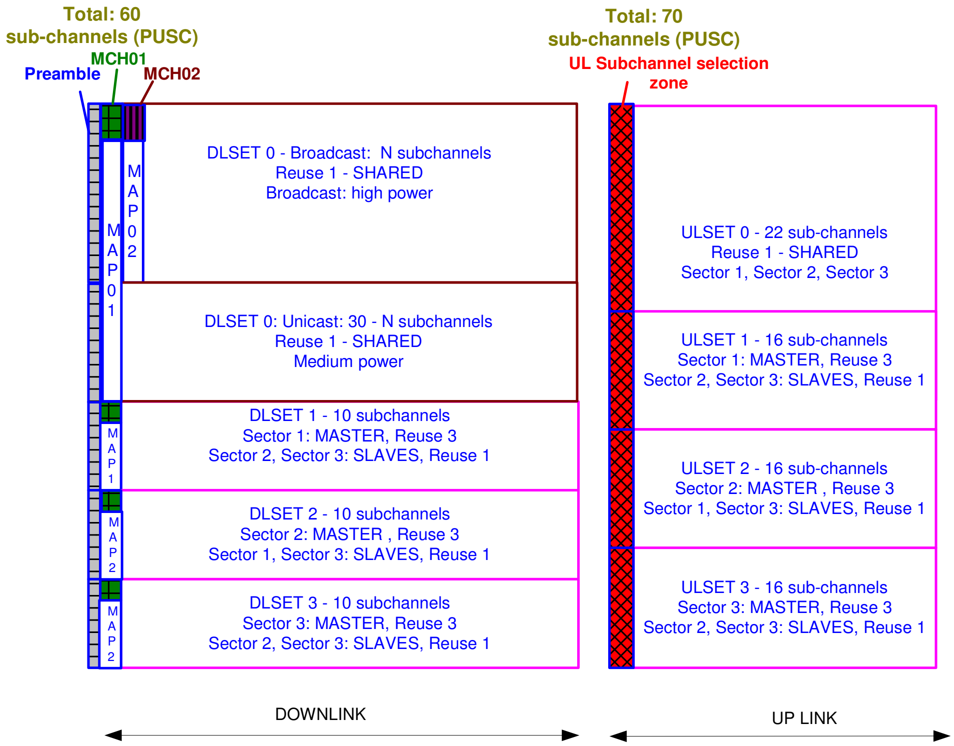

Fig. 3 Frame structure suitable to 3 sectors deployments

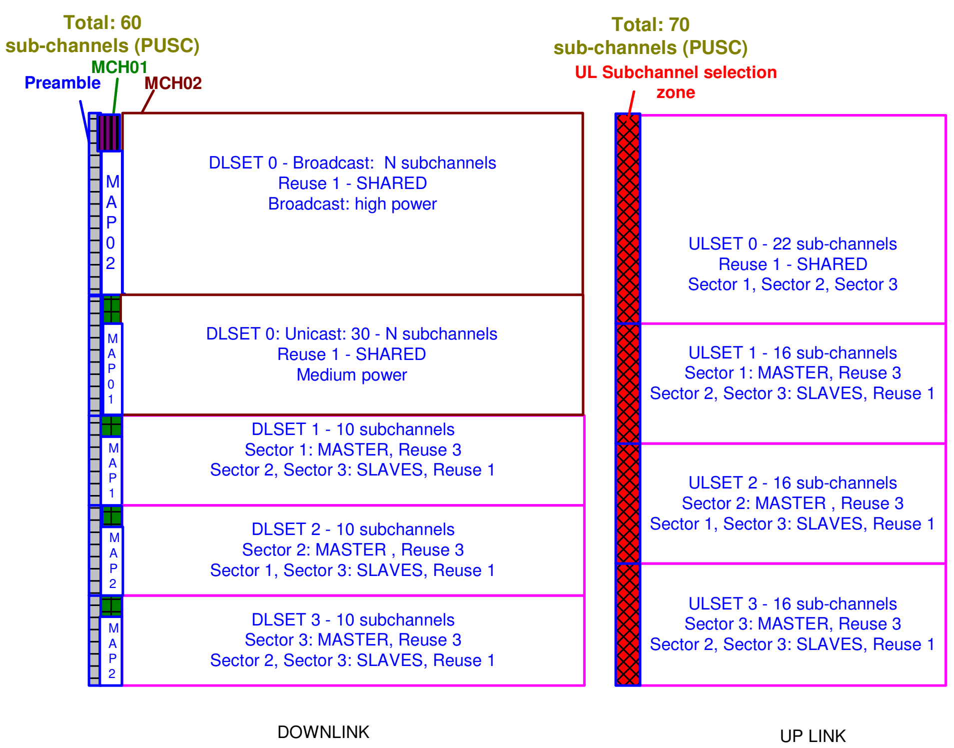

Fig. 4 Frame structure suitable to best Reuse 1, DL efficiency, 3 sectors deployments

Flexible SET allocation

The split between all the sets may differ based on a number of factors, like the amount of broadcast traffic, rural/sub-urban/urban deployment, etc. In order to address these variations, but still operate in a robust mode, the 16m Frame should start in a pre-determined mode, with the possibility that the MCH and/or the MAP will determine the actual sub-channel/sub-carrier allocation to the different SETS. Fig. 5 shows a more flexible approach, with data transmission using different allocation relative to the initial MCH/MAP transmission.

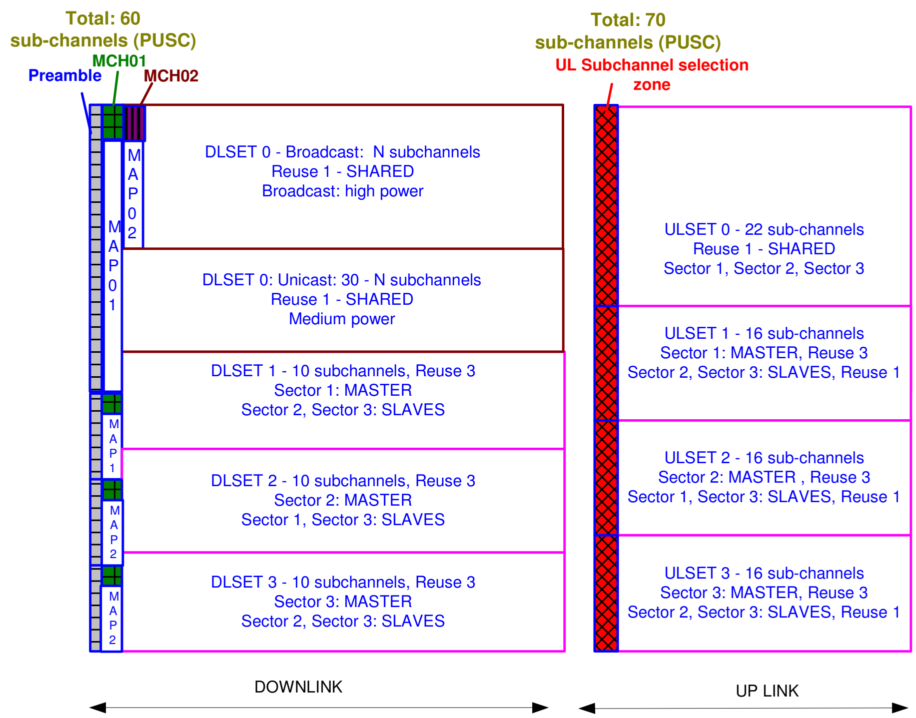

Fig. 5 Frame structure suitable to flexible SET allocations

In this approach the MCH at the start of the Frame has pre-known allocated sub-carriers and it is transmitted with pre-known parameters, as modulation, coding, cell_id, permutation, etc. The Map Prefix transmitted during the MCH may include the parameters to correctly decode the associated MAP (coding, duration) and a pointer to the start of the zone in which the MAP is transmitted. The MCH can also indicate the structure of the zone and point to one or more other MCHs.

Power Rules

A sector may use the entire available bandwidth, but each SET had its own rules of maximum power usage for the included sub-channels.

Fig. 6 shows an example, for the BS Sector 2, of the channel BW allocation between sets, for a 20MHz channel using 2k FFT, 60 DL subchannels and 70 UL sub-channels.

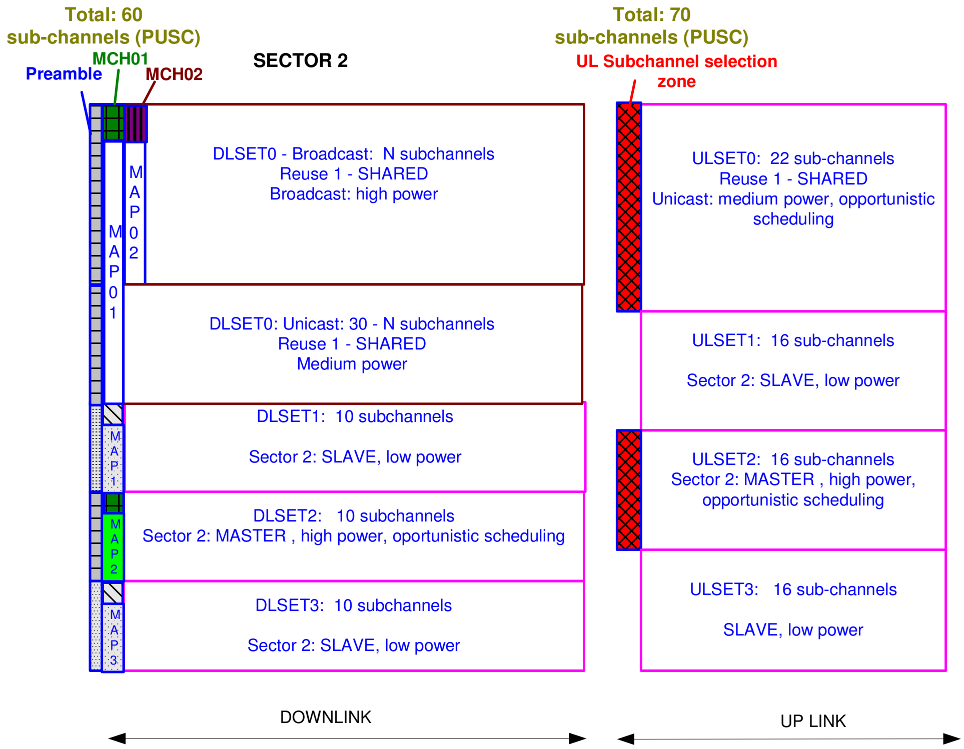

Fig. 6 Example of Frame structure as seen by Sector 2 (North)

The 2nd sector could typically use part of the Reuse 1 area for broadcast and another part for unicasts. In order to limit the inter-cell interference between the DLSET01 allocations, the transmitted power inside this SET is lower than the maximum unicast power allowed in DLSET2. DLSET2 is called the Master set, due to the fact that can transmit the BS unicasts at the maximum sub-channel power.

Fig. 7 shows an example of maximum power density levels (per sub-channel) between sets for the same BS sector.

The sub-channels assigned to DLSET1 and DLSET3, called Slave SETS, can be also used, however the power limitation should be such to not create interference to the sectors using the DLSET1 or DLSET3 as Master allocations. A practical approach may limit the transmitted power of the Slave systems to a certain level, as 12dB lower than the maximum BS transmission power in Master state.

The SLAVE sub-channels transmit their preambles, at the attenuated power per sub-carrier. They may use their own MCH and MAP, however in order to reduce the receiver complexity a more practical approach may be that the MAPs relevant to the SLAVE SETs are transmitted as part of the Reuse 1 Unicast (MAP01) and/or part of the MASTER Unicast (MAP2 in this example).

According to the example, Sector 2 can use 50% of its sub-channels in Reuse 1. The remaining 50% is equally split between the three SETs used in Reuse 3, every SET getting 16.7% from the channel bandwidth. So Sector 2 gets 67% of the channel in the Reuse 1 and MASTER SETs. This is equivalent with the fractional frequency Reuse percentage (2/3) used today for Reuse 1 simulations, however the inter-cell interference is drastically reduced.

Fig. 8 shows the power distributions per SETs in Sector 3. It can be seen that the sub-channels using the Master power level (maximum power per sub-channel) applied for the DLSET3 use a different sub-channel partition (SET) from the subchannels using the MASTER allocation in Sector 2.

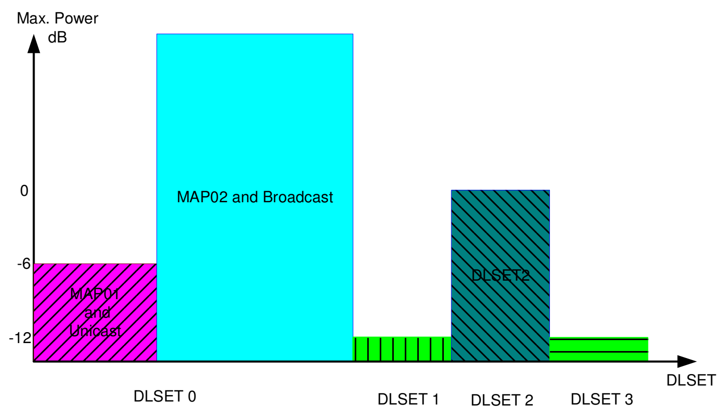

Fig. 7 Example of power limitations for different SETs in Sector 2

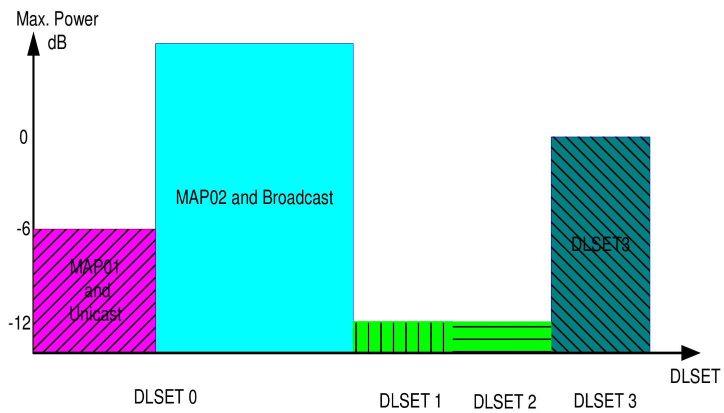

Fig. 8 Example of power limitations for different SETs in Sector 3

Up-link

The up-link subchannels, used for unicasts, are also split in Reuse 1 usage (ULSET0) and Reuse 3 usage (ULSET1, ULSET2 and ULSET3). The UL power rules are similar with the DL power rules. In Reuse 3 mode, the SSs transmitting in the Master ULSET can use the maximum power, while those transmitting in the Slave SETS are limited in power. The SSs transmitting in the Reuse 0 mode have the power limited by the inter-cell interference criteria.

The UL Frame includes a special zone, to be used in conjunction with the pro-active opportunistic scheduling (detailed in another contribution) and eventually with the UL sounding. This zone, named “UL sub-channel selection zone”, is used for the determination of the “best available channel”. A sector will use this zone for the sub-channels included in Reuse 1 mode and for those included in the MASTER Reuse 3 SET. The scope of this zone is to assess the best available UL-subchannel for opportunistic scheduling and to increase the UL cell data throughput by using the best available sub-channel.

Fig 9 shows the frame structure for a combined frequency Reuse for deployments using 4 sectors, combining Reuse 1 and Reuse 4 allocations. An additional Master SET was introduced for matching the Reuse 4 deployment.

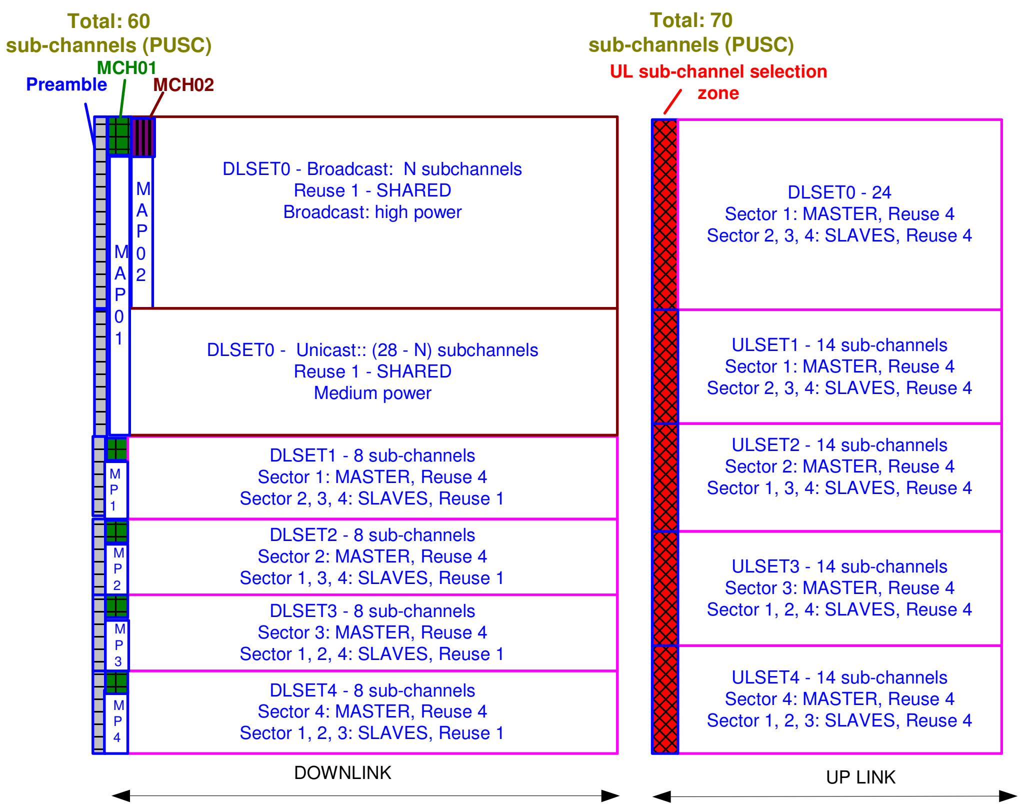

Fig. 9 Frame structure suitable to 4 sector deployments

Selection of the appropriate SET

We suppose that the BSs are managed and able to know the general sub-channel allocation to different DL sets. However, in a given deployment situation, using a non-regular grid, it is necessary to determine the least interfered of the SETS allocated for the Reuse 3 operation of each sector.
Because no SSs are connected in the initial phase, each BS sector shall measure the UL interference created by the other Base Stations and claim the ULSET enjoying the minimum interference experience.

End text for SDD

Benefits of the using SETS inside the frame structure

The usage of the Reuse 3 at cell margin and the reduction of the power for the sub-cannels using Reuse 1 operation dramatically reduce the inter-cell interference. The interferer picture in the cellular deployment shows the improved situation at the cell boundary, however we still have some interference from the other cells. The next level of interferers is shown, for the DL transmission, in Fig. 14.

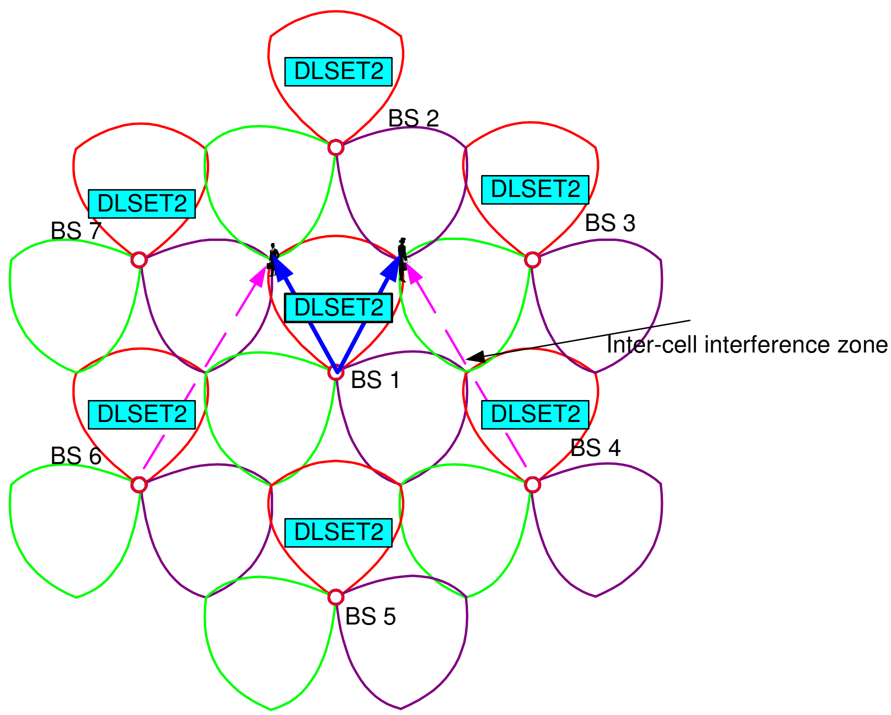

Fig. 14 DL inter cell interference with the new approach

The strongest interferers are the Sectors 1 from BS 5 and BS 4, which may contribute together 8dB S/I. The aggregated remote interferers can decrease the S/I around 6dB. However, we have drastically improved the S/I from -5dB to aprox. +6dB. This improvement will be translated into both cell size and throughput.

A simpler calculation shows that with the assumption that 50% of the available spectrum will be use in Reuse 1 and the rest in Reuse 3, for downlink, we have:

- Every sector uses more than 67% of the available channel in guaranteed mode
- Additional 33% can be used if the scheduling and power levels will be such to not create interference to the Master allocations;
- Data rate in the areas using the Reuse 3 is improved according to the 11dB difference, which means at least 9 times:
    - 7dB go to from QPSK1/2 rep. 6 to QPSK1/2 (6 times)
    - 3dB go from QPSK ½ to QPSK ¾ (1.5 times).

Fig. 15 shows the results of a deployment simulation, showing the SIR for Reuse 3 in a cellular deployment, rural propagation model, interference limited, outdoor SS, on a DLSET.

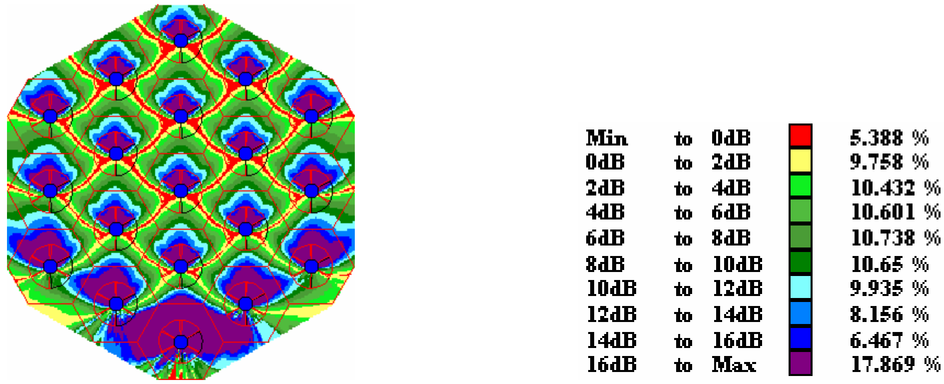

Fig. 15 – Reuse 3 for rural deployment environment

It is possible to see that the cell margin is covered at SIR of 6..8 dB, which corresponds to the calculation above.

Legacy support

The approach most suitable is the legacy frame split in time domain, such that the legacy systems and the 16m systems will occupy different sub-frames.

A number of contributions presented in the November 802.16 session already addressed the support of legacy systems. One of the contributions presenting the split in time domain is the contribution IEEE C802.16m-07/263 [1]. We consider that the approach in this contribution is suitable for the implementation of the new frame structure proposed in this contribution.

Required Actions

TOC

In order to address the new frame structure in SDD, it is needed a clause related to this issue.
We propose to add a sub-clause to the Physical Layer Chapter, named "High-level frame structure". This will permit to address the changes at lower level in a different clause.

Text in SDD

There are two possibilities:

1. If there are other contributions presenting the Frame Structure, **we suggest forming an Ad-Hoc for the harmonization of this proposal with other proposals related to the frame structure** in order to include in SDD a consolidated text.
2. If this contribution is accepted as it is, the Text for SDD contained between the Title "Frame type 1 – OFDMA domain" on page 5 and ends on page 11 before the Title "Benefits of the using SETS inside the frame structure".

References

[1] Roger Marks, Lei Wang, Yair Bourlas, Srikanth Gummadi, Kenneth Stanwood, "802.16m Frame Structure to Enable Legacy Support, Technology Evolution, and Reduced Latency", contribution IEEE C802.16m-07/263.