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Abstract	
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Control channel allocations for overlapping heterogeneous deployments

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Introduction

The 802.16m SRD includes requirements relative to macro cells, relays and femto cells, however the SDD does not define at least the allocation for the control channels, like the Frame Control Header (FCH) or MAPs messages, which shall be decoded in a reliable mode in all the situations, including those created by heterogeneous overlapping deployment. The specification of these allocations has a big impact on the simulation results and shall be included in SDD.
We present in this contribution an approach for the allocation of the control channels for the three cell categories covered by the SRD:

- Cat.1 – Protected cells, for example macro-cells;
- Cat.2 – Regular cells, for example micro-cells or relay cells;
- Cat.3 – Cells including BSs or MSs having the ability of creating harmful interference to the MSs of the other cells, as femto cells.

Overlapping deployment scenarios are possible between these types of cells.
A special element to be considered is the assessment of the harmful interference, created by a femto-BS to a MS belonging to Cat. 1 or Cat. 2 cell.

Resource allocation within the superframe

The resource allocation will take into account the BS-SS interference. In general the allocation of dedicated resources for the control and data channels in OFDMA (frequency) domain is sufficient to resolve the interference, but there are cases, when due to the low distance between a femto-BS and a MS belonging to a macrocell or a microcell, the interference can be separated only in the time domain.

Resource allocation in OFDMA (frequency) domain

Fractional Frequency Reuse

The FFR (Fractional Frequency Reuse) concept in 802.16m is shown in fig. 1. In this figure a given BS sector can use an OFDMA (frequency) resource, while enjoying relatively high power allowance and enjoying low interference, in tree modes:

- Alone (Reuse 1/3) - in case of Reuse 1/3, it is allocated a given frequency (OFDMA) resource, for high transmission power allowance, only to one sector in a Base Station using 3 sectors. Same kind of functionality is also named Reuse 3 in other documents.
- In the same time with another sector (Reuse 2/3). Reuse 2/3 operation is suitable only for those cases in which two sectors belonging to two different Base Stations do not interfere one with each-other, for example due to geographical separation or due to the interference nulling capability of the receivers.
- In parallel with all the other sectors (Reuse 1).

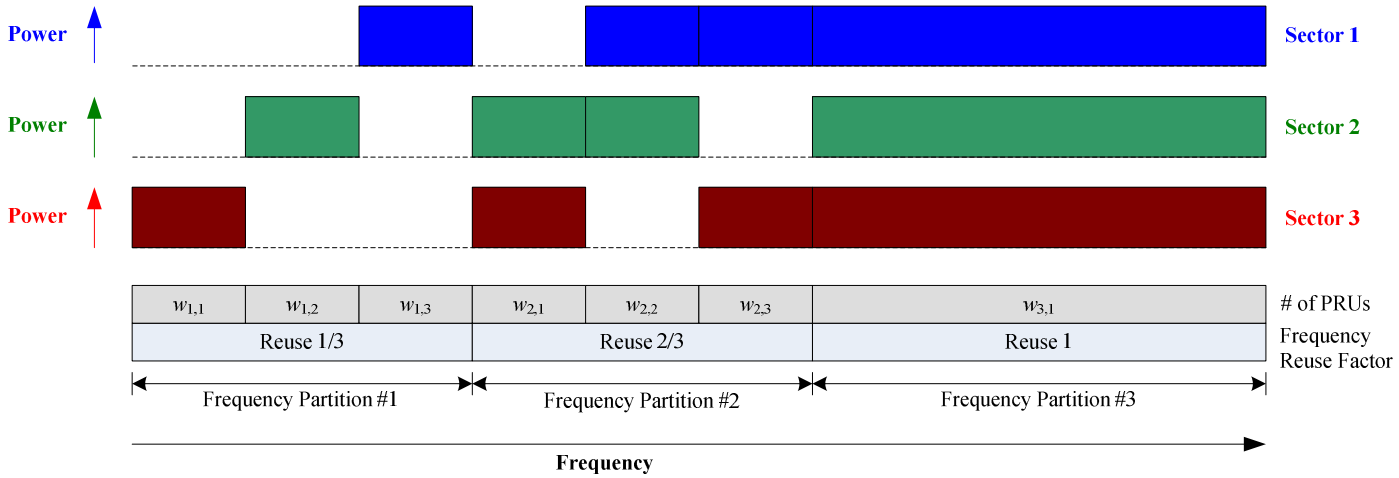

Fig. 1 FFR concept in 802.16m

Note that also single sector Base Stations can separate their interference by using one of the resources allocated to a Sector. The above solution does not cover the deployment using different cell categories which may overlap.

Resources for Control Channels

The Control Channels include transmission of information related to synchronization, control, sounding, resource allocation, etc.

The downlink (DL) and up-link (UL) resource allocation for the Control Channels of the protected cells should be reserved within the frequency channel, in those OFDMA partitions which enjoy controlled (low) interference from the adjacent cells. The size of these partitions can be different in different frames or even sub-frames of the superframe, due to the different amount of information transmitted in the first 802.16m superframe (includes the information relative to the superframe operation) and in the regular frames. A partition can contain adjacent sub-carriers (localized) or non-adjacent sub-carriers (distributed).

The OFDMA resources using Reuse 1/3 mode enjoys high link budget and minimum interference from the adjacent cells, because each sector can have a dedicated OFDMA partition. Due to these properties the OFDMA resources allocated using Reuse 1/3 are most suitable for the operation of the Control channels of the protected and regular cells.

Reuse 1 operation is suitable for those cells or part of cells which do not interfere with each other or do not have stringent cell size requirements. The Control channels of the Cat. 3 cells may fall into this category.

There are cases in which a Base Station has no active MS. The control channels are used to advertise the presence of the BS and should be active at established and synchronized time intervals, relative to the superframe timing. There are also situations when, due to the dense deployment and line-of-sight operation of the cells, more than 3 different control channels will be needed for the Cat. 2 and Cat. 3 cells.

This will create a need for a sufficient high number of Control Channels for Cat. 2 and Cat. 3 cells.

Resources for Data Channels

The resource allocation for the Data Channel should include minimum operational resources enjoying low

interference and extended operational resources. The extended operational resources are shared between Base Stations.

The data channels can use the resources function of their cell Category and the FFR split of the frequency channel. The used frames should correspond to the frames in which the Control Channels are active, but also other possibilities should be valid.

The resources in the Reuse 1/3 area should be allocated exclusively to Cat. 1 systems, if they operate on the Channel. The Reuse 1 area should be the main operational area for Cat. 3 systems, if Cat. 1 and Cat. 2 systems are operational within the channel.

Cat. 2 systems should have the ability to use either the isolation offered by Reuse 1/3 deployment, either the isolation offered by street deployment. Their Data Channels may be placed in a Reuse 3 area or in a Reuse 1 area.

Resource allocation in superframe (time) domain

There are cases where the BS-MS interference is very strong, as the case of a MS belonging to a Macro cell operating in the vicinity of a femto-BS. In a similar mode, the femto-BS is interfered by a mobile SS belonging to another cell and operating in its vicinity. Significant interference can appear also in the case of dense micro-cell deployment.

This strong interference created by femto-cells is affecting the MS receiver SINR (Signal to Interference and Noise Ratio) due to the limited adjacent channel rejection or even due to interference between different sub-carriers. Such MS transmissions will create interference to the femto-BS receive activity.

The time separation will resolve this kind of interference, but it requires reserving different time resources for the Control and Data channels transmitted by the femto-BS creating interference.

There are a number of possibilities for the allocation of these resources. The 802.16m superframe consists of 4 frames and each frame may have a number of down-link sub-frames. The 802.16m control information is transmitted at the start of every frame. It should be avoided to introduce more control sub-frames, as the downlink frame already includes legacy systems and relays.

Resource allocation in both OFDMA (frequency) and time domain

The rules address the usage of the frequency-time resources by the networks belonging to different Categories.

Category 1 systems are the only ones entitled to use:

- Dedicated frequency (OFDMA) partitions allocated for Reuse 1/3, for both Control and Data Channels.
- Dedicated time (sub-frames) partitions allocated within a superframe. In case of a superframe composed of four frames, such allocations can include the first and 3d frame, for both down-link and up-link, in both FDD and TDD operation.
- Cat. 1 systems can use all the available OFDMA/time partitions, but the interference is minimized only in the protected frequency and time intervals.

Category 3 systems, when sharing a channel with Cat.1 or Cat.2 systems, are assigned dedicated OFDMA/time partitions which do not overlap with the dedicated partitions for the Cat. 1 systems. Only the dedicated time partitions will enjoy reduced interference. For example, the Cat. 3 systems can use:

- Dedicated time partitions: second frame within the superframe
- Dedicated frequency partitions: the entire frequency channel, excluding those frequency partitions allocated to the Category 1 systems.

Category 2 systems, based on the fact that do not create harmful interference to Cat. 1 systems operating within the same frequency channel, are assigned:

- Different frequency partitions from those used by the Cat. 1 systems operating in the same frequency channel; however, some of the frequency partitions can be used by either Cat. 1 or Cat. 2 systems.
- Same time partitions as those used by the Cat. 1 systems operating in the same frequency channel.

Control Channel

Based on the analysis above, we can split the OFDMA and time domains in a number of partitions. An example is given below (see fig. 2), indicating the resources to be used for the Control channels, in case of using all the cell categories on a frequency channel.

- The Control Channel for the Cat. 1 (protected) cells should be placed within each frame, with the following restrictions:
    - Superframe domain (time):
        - First frame of the super-frame, best interference experience; allocation suitable for the superframe control channel.
        - 2nd frame of the superframe, but the reception of the downlink traffic cannot be guaranteed for the MSs affected by Femto-BS interference;
        - 3d frame of the superframe, good interference experience;
        - 4th frame of the superframe, but the reception of the downlink traffic cannot be guaranteed for the MSs affected by Femto-BS interference.
    - OFDMA domain
        - Dedicated OFDMA partition (Reuse 1/3 in fig. 1);
        - Additional possible partitions in Reuse 2/3 zones (if Cat. 2 cells are not deployed within the channel).
- The Control Channels for the Cat. 2 (regular) cells should be placed within:
    - Superframe domain
        - Same as Cat. 1 systems, but exceptions can be made to offer more resources to femto-cell Control Channels. This happens in Frames 2 and 4, where the Reuse 1 partition is used in the benefit of Cat. 3 cells.
    - OFDMA domain
        - Dedicated OFDMA partitions (within Reuse 1/3&2/3 in fig. 1).
        - Additional possible partitions in Reuse 1 area.
- The Control Channel for the Cat. 3 cells should be placed within:
    - 2nd frame of the super-frame or a well-known sub-frame inside the superframe, different from the resources allocated to Cat.1 and Cat.2 cells; this partition is suitable for the superframe Control Channels of Cat. 3 cells.
    - Shared OFDMA partitions (Reuse 1 and/or Reuse 3&2/3 in fig. 1).

Particular case:

- Cat. 2 cells could use the partitions allocated for Cat. 1 cells if there are no Cat. 1 cells on the channel;

Note that due to the potential of creating interference over different sub-carriers in the channel or on the adjacent and alternate channels, the Control Channels of the Cat. 3 cells have always to operate on a different time partition. Special preambles or control elements are useful for identifying the BS of such cells. These cells are forbidden to use the time resources allocated exclusively to the protected cells in the frame structure.

We have preferred a distribution of the Control Channels such to avoid too long delays. Priority was given to the Cat. 1 systems. A relatively high number of Control Channels were allocated for Cat. 2 and Cat. 3 systems, because these systems could have a more dense deployment and also a higher probability that not all the data channels will be fully used.

Data Channels

The data should be scheduled according to the Reuse 1/3, 2/3 and 1 rules. More flexibility related to the data traffic and resource allocations can be achieved with inter-cell coordination procedures.

Resource allocation for Relays

The frequency/time resources for the relay backhauling will be provisioned by the operator.
The Relay frame structure shall define within the time intervals in which the Relay access link is operational similar frame structure as used in the general case. The Relays can be assimilated with Cat. 2.
Any cases of harmful transmit-receive interference, which may appear between specific radio devices, can be resolved by time separation.

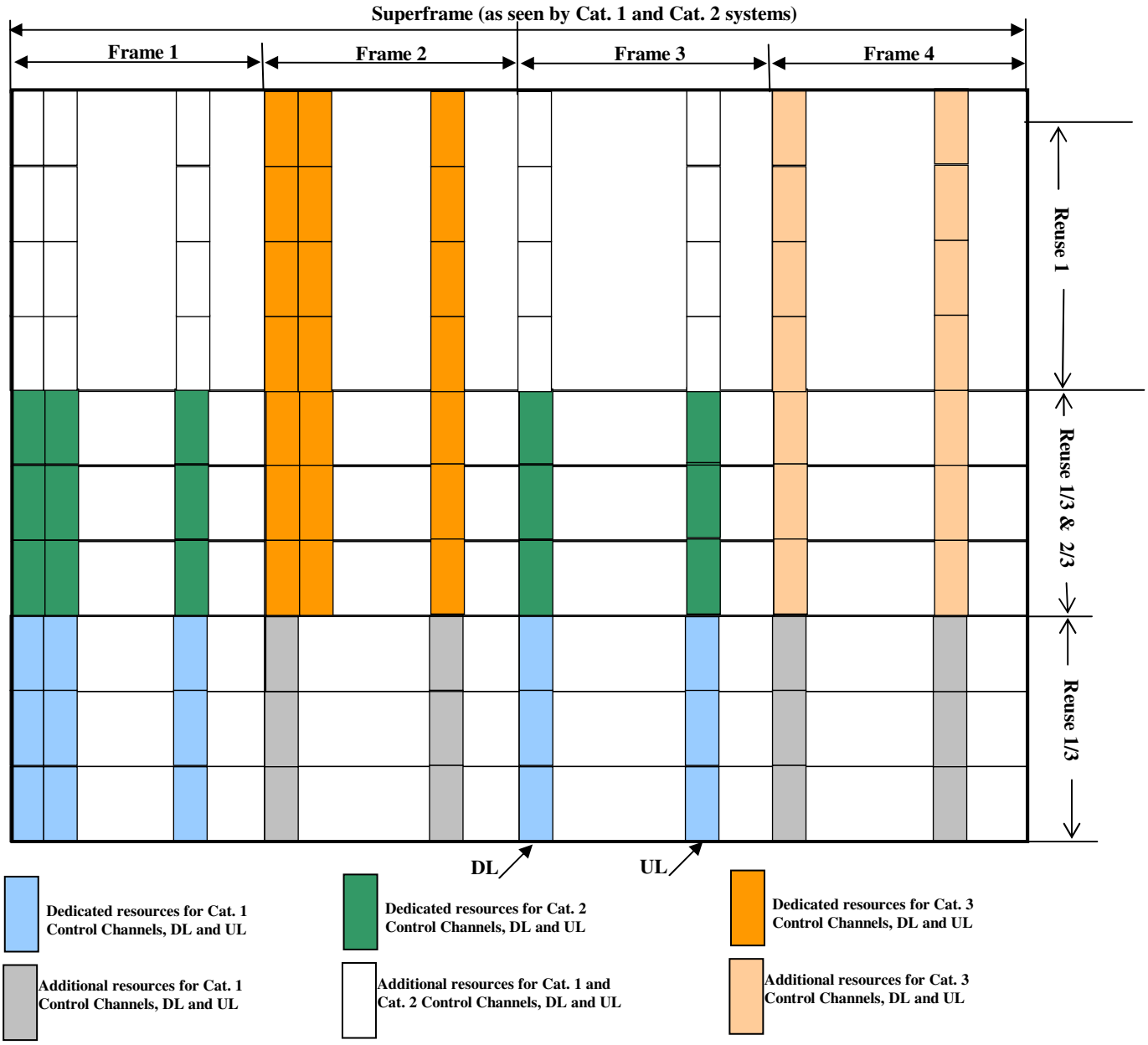

Fig. 2 Resource allocation for Control Channels

SDD TEXT

Insert new clause 11.4.5:

Support for the Control Channels of heterogeneous cells in Frame Structure

802.16m systems include three categories of heterogeneous cells, which can be deployed in overlapping geographical areas. Three categories of cells are defined:

- Cat.1 – Macro-cells;
- Cat.2 – Regular cells, for example micro-cells or relay cells;
- Cat.3 – Femto cells.

It is required to provide the assignment of the main control channels, as FCH (Frame Control Header, MAPs, sounding, etc.) such to avoid interference. The general FFR concept for avoiding interference is presented in fig. 45, SDD clause 20.1. The Superframe control channels shall be placed according to fig. xx, as follows:

- Controls channels for Cat. 1 systems is placed in the Reuse 1/3 area of the first Frame within the superframe;
- Control channels for Cat. 2 systems use reuse 1/3 and are placed in the Reuse 1/3&2/3 area; this area can be used by Cat. 1 systems in reuse 2/3 if the Cat. 2 systems are not deployed in the frequency channel.
- Control Channels for Cat. 3 systems are placed in the 2nd Frame of the Superframe, avoiding the Reuse 1/3 allocation reserved for Cat. 1 systems.

The allocation of the control channels in other frames is FFS.
Fig. xx illustrates the allocation of the control channels:

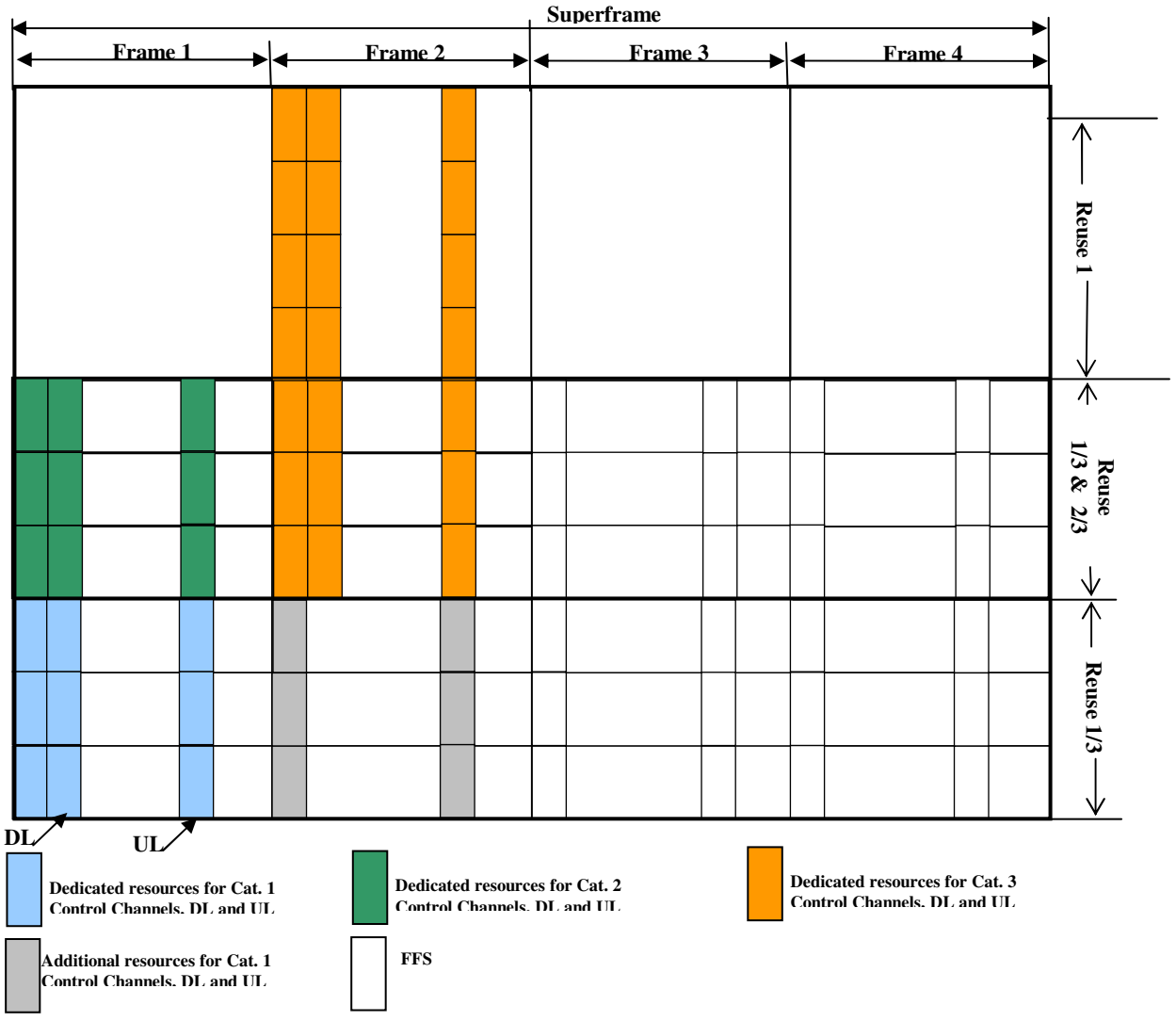

Fig. xx Allocation of the control channels in heterogeneous deployment

End text insertion