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Abstract	
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Control Channels allocation for Femto cells

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Introduction

We present in this contribution an approach for self-organization of radio networks which has two main targets:

- Protection of the cell size and the associated traffic for certain cells, to be named "protected cells". Example of such cells are the macro-cells, which might experience, for example, the interference created by a femto-BS (Base Station) to a MS (mobile or fix subscriber) operating in the femto-BS vicinity;
- Operation with reduced interference of the other cells.

It is assumed that an operator can provision the different Base Stations to belong to one of the following categories:

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

Deployment in overlapping geographical areas is possible between these types of cells. With the exception of the femto-cells, which may not belong to the mobile operator, the BS-MS interference can be simply resolved by the hand-over of the MS to the BS which is creating interference to it. In case of the femtocells, the hand-over is limited to those situations where user's access is allowed by the target cell. Due to this, the most important scenario to be resolved is the overlapping between femto-cells and the other cells.

It is assumed that the operator will provision each possible operating radio channel and BS in accordance with the basic sharing scenario, indicating which categories of cells may share the radio channel.
As an example, the protected cells or regular cells may share the channel with femto cells.

For self-organization at radio level, the operator or a rule in the standard will establish the minimum OFDMA and time resources to be reserved for Control and Data channels of different cell types.

Each system will chose the operational frequency-time resources based on this simple provisioning and a set of interference assessment and avoidance rules, to be further explained. No frequency planning or inter-cell communication will be necessary for the basic operation.

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 macro-cell, 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).

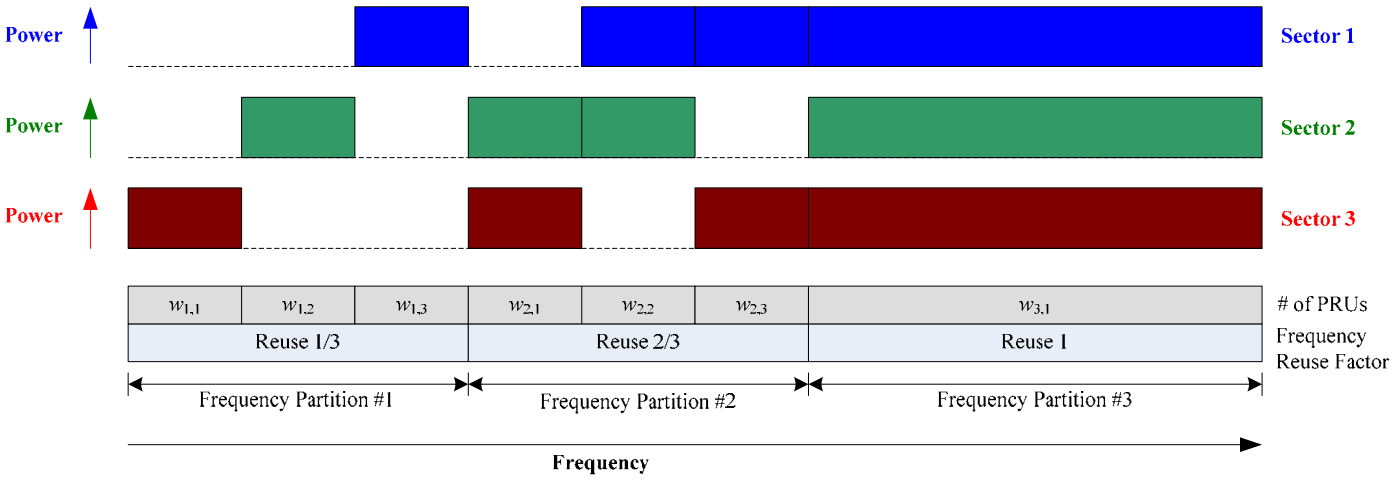

Fig. 1 FFR concept in 802.16m

Note that also single sector Base Stations can separate their interference by using one of the resources allocated to a Sector.
The above solution is not suitable for a deployment using different cell categories which may overlap. In addition, the SDD does not address the allocation of control channels for Relay and femto-cells operation.

Resources for Control Channels

The Control Channels include transmission of information related to synchronization, FCH, MAPs, sounding, 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 resource allocation for the Control Channels of the regular cells is dependent of the mode in which the frequency channel is used, for example:

- If the frequency channel is used only for regular cells, the regular cells may use all the available control channels
- If the frequency channel is used by both protected and regular cells, the regular cells will use those control channel allocations not exclusively assigned to the protected cells.

- If the frequency is used only by Cat. 1 systems, they can use the OFDMA resources reserved for regular cells in the Reuse 2/3 mode.

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 femto-cells cells may fall into this category.

There are cases in which a femto-BS 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 femto-cells.

This will create a need for a sufficient high number of Control Channels for femto-cells. 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 downlink sub-frames. The 802.16m control information is transmitted at the start of every frame. The legacy systems and the relay systems also use part of the sub-frames, such that it should be avoided introducing additional functionality by frame splitting.

Resource allocation in both OFDMA (frequency) and time domain

The rules below 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, 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 only to the Category 1 systems.

Control Channel

Based on the analysis above, and focusing on the operation of macro-cells and femto-cells in overlapping geographical areas, we can split the OFDMA and time domains in a number of partitions. An example is given in fig. 2:

- The Control Channel for the Cat. 1 (protected) cells should be placed within each frame, for allowing those MS not affected by femto-cells to operate with no restrictions. The full Cat. 1 cell, affected by the femto-cell interference, will operate 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 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 2/3 in fig. 2).

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 to the protected cells in the frame structure.

Note that a relatively high number of Control Channels were allocated for Cat. 3 systems, having a more dense deployment and also a higher probability that the data channels there will not 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.

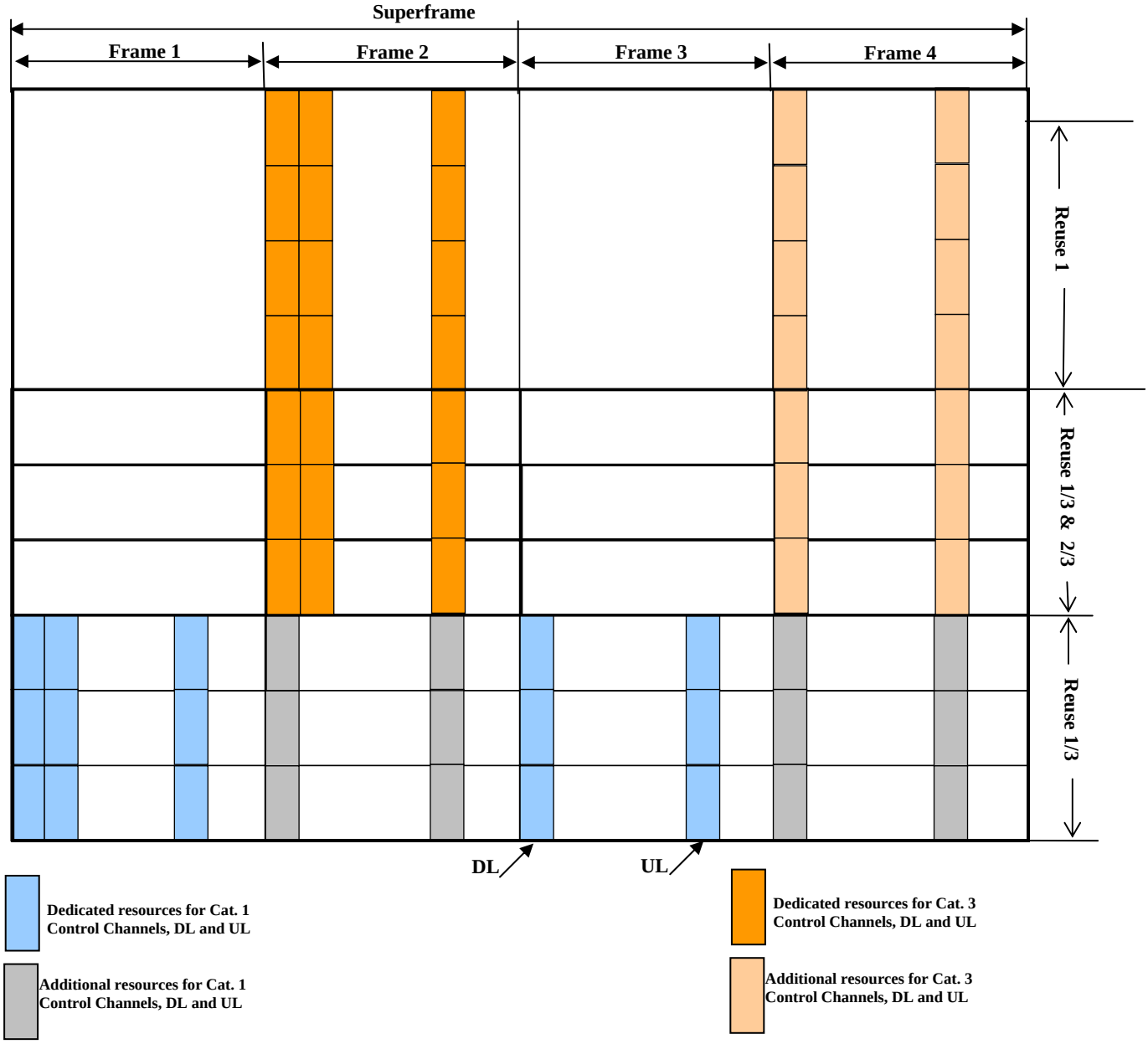

Fig. 2 Resource allocation for Control Channels

SDD Text

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The femto-cells are a special deployment category, which has potential for creating harmful interference interference to a MS associated with a macro-cell, on both co-channel and adjacent channels operation. The allocation of the Control Channels needs to be adapted for including heterogeneous deployment categories in overlapping geographical areas.

The allocation of the control channels for femto-cells, including the superframe start, will use a different frame from the frame used by the macro-cells for their superframe start. The OFDMA partitions used for the superframe control channels of the Femto-cells shall be different from the Reuse 1/3 partitions used by macro-

cells.
An example of control channel allocations, such to avoid the interference to macro-cells, is given in fig. xx.

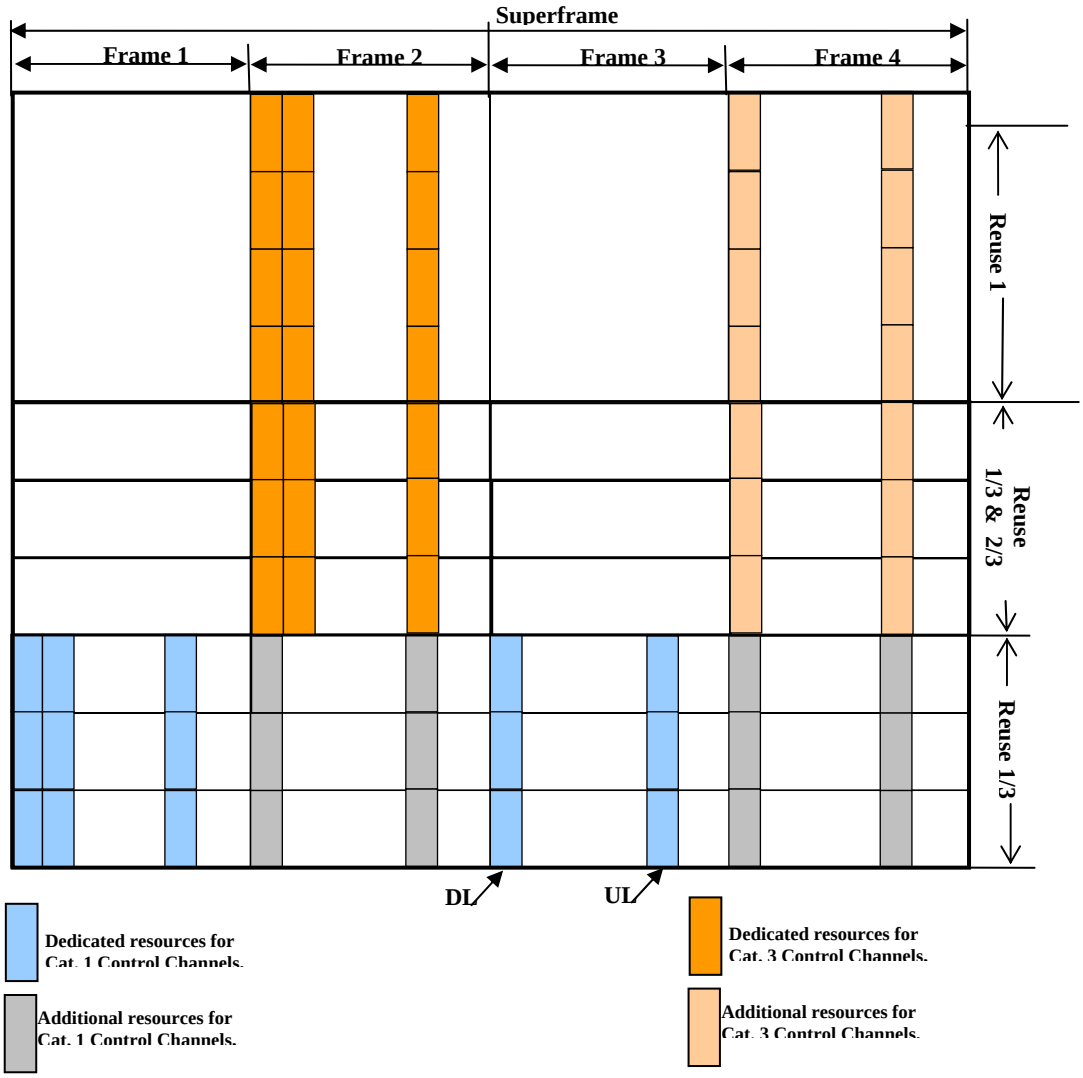

Fig. xx Control channel allocations for macro cells and femto cells

In this example, the control channels for macro-cells are active each frame, but their reception with minimum interference is provided only during the frames 1 and 3. During these frames the femto-cells refrain from the transmission of the control channels.