Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Resource Allocation for Inter-Cell Interference Coordination**
Date Submitted	**2008-07-03**
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Re:	Response to IEEE 802.16m-08/024 Call for Contributions on Project 802.16m System Description Document (SDD) (i.e., ***interference mitigation***).
Abstract	This contribution proposes the OFDMA resource allocation scheme to support inter-cell interference coordination (ICIC) for 802.16m system description document (SDD).
Purpose	To adopt the inter-cell interference coordination (ICIC) scheme proposed herein into IEEE 802.16m system description document (SDD).
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Resource Allocation for Inter-Cell Interference Coordination

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1. Introduction

In a multi-cell deployment, interference management is often the most challenging problem near the cell edge, where the coverage of two or more cells overlaps. In the inter-cell interference coordination (ICIC) schemes considered thus far in academia and industry, the frequency resource allocation between cells can be static or semi-static. The latter schemes incur more signaling overhead, while the static schemes are simpler but not flexible enough to deal with changing traffic demands in each cell.

The proposed scheme in this contribution strikes a balance between the static and semi-static schemes, thereby reducing the signaling overhead. We use a combined fixed (static) and adaptive resource allocation (semi-static) technique that is valid for both the downlink and uplink scenarios. The radio resource in our scheme is divided into fixed and adaptive bands. Accordingly, we classify users as primary and secondary users (MS), depending on whether they use (or are assigned) the fixed or adaptive band radio resources. We further propose to subdivide the adaptive band into two categories, namely, the reserved and the free bands.

The remainder of this document is organized as follows. The proposed resource allocation scheme is elaborated in Section 2. The benefit of the proposed scheme is demonstrated in Section 3. Proposed text changes are provided in Section 4.

2. Proposed Resource Allocation Scheme for ICIC

In our proposal, the cell-edge radio resources of each cell consist of two parts: fixed cell-edge band and adaptive cell-edge band. In general, radio resources allocated to *fixed cell-edge band* change on a fairly static basis, and vary only over a period of several hours or days, while the radio resources allocated to *adaptive cell-edge band* vary semi-statically or semi-dynamically over a shorter timescale of the order of hundreds of seconds. Fixed cell-edge band resources could for instance be allocated for those traffics which are urgent and/or important since the likelihood for these radio resources to be interfered is minimum or negligible as they are usually assigned in the non-overlapping bands. Each cell, in general, may be allocated a fixed and an adaptive radio resource. The adaptive band can be further classified into two categories, namely, the *reserved* and the *free* band. For this contribution, we focus only on cell edge bands because it is there that the potential for interference is highest. However, this proposal does not preclude the use of fixed cell-edge band and adaptive cell-edge band by cell-center users.

Figure 1 shows an example cell deployment, on which the following discussion will be based.

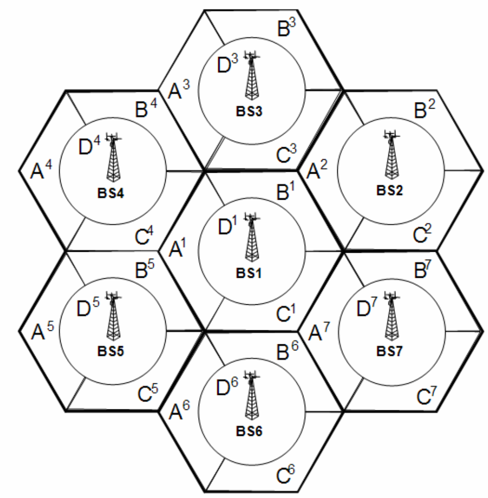

Figure 1: Example of cell deployment.

- **Fixed cell-edge band**

  This is introduced to ensure an interference free radio resource for the MSs at the cell edge. Those MSs using the allocated fixed radio resources are known as the primary MSs and the rest are secondary MSs. The advantage of being the primary users is that the BS can assign them the resource with minimum delay while not having to worry about being interfered with.

  The fraction of system bandwidth allocated to fixed cell-edge band depends on the vendor's projected service requirement, and can be small or large. The benefit of fixed cell-edge band is to reduce the network signaling overhead because each cell is given the exclusive right to use this bandwidth or the bands which are non-overlapping among neighboring cells. The cell has the right to use its fixed cell-edge band resources without having to measure interference or waiting for an interference indicator; this reduces delay and incurs a low signaling overhead. Thus, a primary MS has the advantage that the BS can assign radio resources to it with minimum delay and without having to worry about unplanned for interference.

Figure 2: Illustration of fixed cell-edge band allocation for ICIC (option 1)

- **Adaptive cell-edge band**

  The radio resources allocated to adaptive cell-edge band in a cell will depend on what is left over from the fixed band allocation and the traffic level demand for that cell. The adaptive radio resource is further classified into two categories – *reserved* and *free*. MSs in a cell have the priority on reserved adaptive radio resource. On the other hand, a free adaptive radio resource may be used by another cell, but only after it has exhausted its reserved adaptive cell-edge band radio resources.

  - The ***adaptive reserved band*** gives the owner the priority to use the band but not the overriding rights as in the case of the fixed. In other words, if the owner of the reserved radio resource wants to utilize them and they happen to be borrowed, it would have to wait for the borrowing cell to release the radio resource within a predefined time frame which could be vendor specific. Owner here means a cell that "owns" the band or radio resource which are usually allocated in non-overlapping bands to neighboring cells. A cell could borrow a reserved resource belonging to another owner (cell or sector). However, when the transmission is complete, the borrower will have to release the resource back to its rightful owner. Only upon receiving the "interference free" indicator, or after a time-out period, could the owner resume its rights to use the reserved resource. In order for the primary BS to exercise its "ownership" over the resource block it desires to use, additional backbone signaling would be needed. However, this signaling would be out of the scope of IEEE 802.16m.

- The ***adaptive free bands*** or radio resources are free for all and anyone can grab the resource as long as the interference perceived on that resource is tolerable. No one has the priority for the use of these radio resources and they are used on a competitive basis.

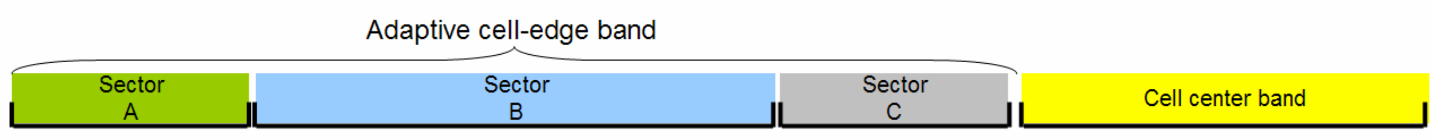

Figure 3: Illustration of adaptive cell-edge band allocation for ICIC (option 1).

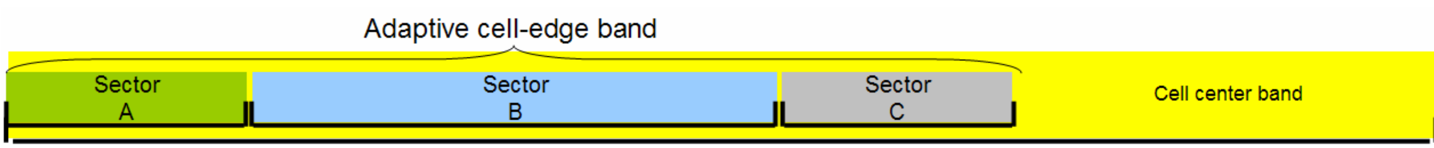

Figure 4: Illustration of adaptive cell-edge band allocation for ICIC (option 2).

- **Hybrid mode**
  The system can be configured for one or more of these options which will be vendor specific. As mentioned above, the difference between the reserved and the free adaptive resources is that the owner of the reserved resources has a higher priority to use the resource.

3. Performance Gain

We present in what follows our simulation results and their underlying assumptions. In order to evaluate the merits of the proposed ICIC schemes, we focus on the uplink of a 7-cell hexagonal layout with omni-directional antennas at the center of each cell. We assume delay sensitive traffic model for MSs, hence users which cannot be serviced due to a shortage on the available resources (according to the adopted ICIC scheme) are accounted for as contributing to the blocking probability.

We control the traffic load in each cell by uniformly dropping a number of users within each cell. We further assume that the traffic load is unevenly partitioned among the seven cells; i.e., the central cell is assumed to be fully loaded whereas the remaining cells are under-loaded. In order to show the benefits of the borrowing mechanism implemented by the proposed ICIC scheme, we make sure that the central-cell is always slightly over-loaded in terms of cell-edge traffic (coupled with the fully-loaded assumption mentioned above, this means that the central cell is under-loaded in terms of cell-center traffic). We further account for a distance-dependent path-loss model with a decay factor of 3.7. No such distinction is necessary for the full frequency reuse scheme (without ICIC which we use as a benchmark). Shadowing and small scale fading are not accounted for.

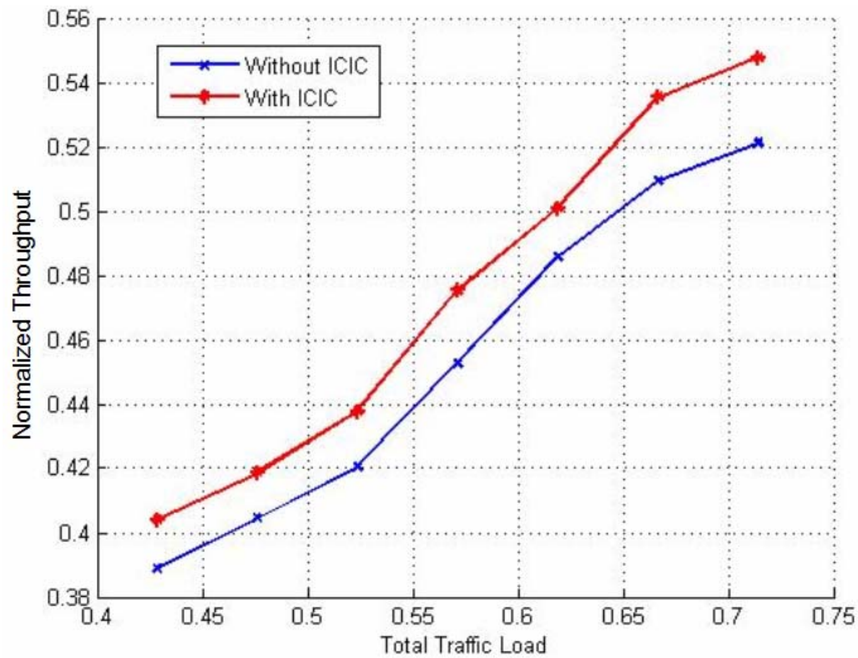

Figure 5: Normalized average cell-edge throughput versus traffic load.

Figure 5 shows the normalized average throughput for cell-edge users as function of the overall system traffic load. The normalization is with respect to the maximum achievable throughput for cell-edge users across the seven cells. As can be seen from this figure, the proposed ICIC scheme well outperforms the one without ICIC.

Figure 6 shows the average SINR per cell-edge MS for the cases with and without ICIC as function of the overall system's traffic load. It is observed that the adaptive ICIC scheme yields the best performance in terms of achievable SINR. This is expected since the resource sharing adopted by this scheme allows to serve more cell-edge users who are otherwise blocked or denied service, thereby increasing the interference level seen by each MS.

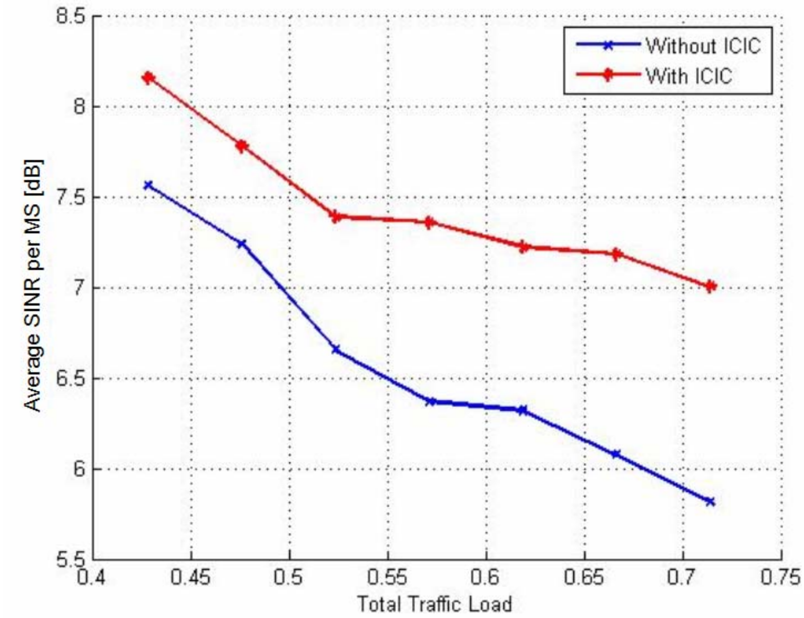

Figure 6: Average SINR per cell-edge MS in dB versus system's traffic load.

4. Proposed Text Changes

[Insert a new subclause on interference management]

x.x.x. Interference Management

Fixed cell-edge band allocation, adaptive cell-edge band allocation, and a hybrid of both can be used in an IEEE 802.16m network to mitigate interference. To enable adaptive cell-edge band allocation or hybrid band allocation, neighboring BSs need to exchange such information as the interference level of certain resource blocks, the resource allocation it has made for these MSs that are highly susceptible to interference, the desire to reclaiming the reserved resource that has been borrowed by the neighboring cell, etc.