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| Project | **IEEE 802.16 Broadband Wireless Access Working Group <**<http://ieee802.org/16>**>** | |
| Title | **System Requirements on Interference Management for IEEE 802.16q Multi-Tier Networks** | |
| Date Submitted | **2012-09-17** | |
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| Re: | “IEEE 802.16-12-0507-02-Shet,” in response to Call for Contributions: Multi-Tier Networks IEEE 802.16 Working Group on System Requirmeent of Multi-Tier Networks | |
| Abstract | Proposal regarding System Requirements of Multi-Tier Networks | |
| Purpose | To discuss and adopt the proposed texts in the System Requirements Document (SRD) on IEEE P802.16q Multi-Tier Networks | |
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# System Requirements on Interference Management for IEEE 802.16q Multi-Tier Networks

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# Introduction

Recently, a multi-tier network architecture, which allows overlay deployments of several different types of cells (e.g., typically, overlay of a macro cell and several small cells (including micro, pico, femto cell)), has been vigorously studied and several standard development bodies such as IEEE 802.16 [1] have adopted this as a project item due to its potential benefits increment of areal capacity, coverage, and client quality of service (QoS) and also to decrease cost per bit. In order to accomplish those advantages, interference to/from overlaid/adjacent macro cells and adjacent small cells shall be well managed.



Figure 1 – Examples of downlink interference from overlaid/adjcent cells in a 2-tier multi-tier network



Figure 2 – Examples of uplink interference from overlaid/adjacent cells in a 2-tier multi-tier network

A 2-tier architecture composed of multiple small cells overlaid by a macro cell is a quite simple, but mostly considered scenario as a multi-tier network. In this architecture, mobile stations (MSs) connected to an overlaid small/macro cell may significantly suffer from interference from overlaying macro/small cell(s) in downlink as shown in Figure 1 – (a). Similarly, in uplink, MSs connected to an overlaying small/macro cell may generate strong interference to overlaid macro/small cell(s) as shown in Figure 2 – (a). In practice, regular hexagonal deployment of base stations (BSs) may not be made, and a large number of small cells could be deployed in a hotspot area, so the effect of interference from adjacent cells becomes severer as shown in Figure 1 – (b) and Figure 2 – (b). Also, strong interference from overlaying macro cell(s) can degrade the performance of an overlaid small cell when traffic offloading from a macro BS to a small BS even though received signal strength (RSS) from the macro BS is higher than that from the small BS. Accordingly, reliable transmission of control channels may not be guaranteed due to such interference from overlaying/adjacent cells, so there would be MSs given under coverage hole. To overcome this problem, coordinated resource (time, frequency, power) management on control channels with overlaying/adjacent BSs shall be supported. As well, in data transmission perspectives, coordinated resource management on data channels also shall be provided to enhance network capacity. It is widely accepted to take into account resource multiplexing, (soft) fractional frequency reuse (FFR), dynamic coordinated scheduling, downlink power setting/control of BSs, and uplink power control of MSs as coordinated resource management schemes for multi-tier networks, and their details are given below.

* A simple approach to discard interference is time/frequency division multiplexing (TDM/FDM), which exclusively dedicates resource (time, frequency) to a specific cell rather than reuses it among mutually overlaying/adjacent cells. It is suitable for the robust transmission such as control channels and data channels requiring high target (bit/block) error rate.
* On the other side, (soft) fractional frequency reuse (FFR) allowing more power on primary partition(s) and less power on the rest of partitions is more efficient than TDM/FDM in terms of resource reuse while permitting not-strong interference from overlaying/adjacent cells. Its gain can be improved when it is configured depending on the amount of load and the strength of interference by adapting the number of partitions, size of each partition, and (maximum) power of each partition. In the baseline standard [2], partial usage of subchannels (PUSC) is used as a sort of (hard) FFR with 3 of the number of partitions and equal partition size, but its efficacy may not be feasible if the number of adjacent cells is larger than 3 and each cell would serve different amount of load or be exposed by different level of interference. Thus, FFR with support of varied settings on the number of partitions, size of each partition, and (maximum) power of each partition is required.
* Typically, the configuration of TDM/FDM or FFR stated above statically changes without or with less consideration of small-scale channel variation, but as increase of the number of overlaying/adjacent cells, interference fluctuation becomes more dynamic due to the small-scale channel variation and unpredictable scheduling of other cells. Therefore, link reliability or transmission efficiency decreases, and then network capacity also declines. Those problems can be mitigated using dynamic coordinated scheduling jointly performed by mutually nearby BSs.
* Another approach to suppress interference to MSs connected to overlaid/adjacent cells is downlink transmit power setting/control of small BSs. For example, in downlink, small BSs can increase transmit power to exploit traffic offloading from macro BSs to them, but this may cause strong interference to MSs connected to macro BSs and located near the edge of small cells. In this case, small BSs would decrease or limit transmit power on part of resource(time, frequency) by coordination with overlaid macro BSs.
* In uplink, MSs can suppress interference to BSs in overlaid/adjacent cells by means of uplink transmit power control, by which maximum power level can be constrained not to generate significant level of interference to overlaid/adjacent BSs in a more dynamic fashion by compensating relatively rapid channel variation.

As increase of the number of cells due to deployment of small cells to support abrupt data explosion, the number of cell-edges also increases, so the probability that an MS suffers from strong interference at the cell-edge can increase, which may limit or decrease client QoS. It is well known that cooperative transmission such as coordinated beamforming and collaborative MIMO is a essential way to resolve those problems. It enhances cell-edge performance by avoiding interference from overlaying/adjacent cells or accomplishing diversity/multiplexing/array gain by joint transmission by multiple BSs in overlaing/adjacent cells.

The interference management schemes stated above can be applied not only solely but also jointly depending on how interference mutually affects the performance of overlaying/adjacent cells or is likely to do.

Coordinated resource management and cooperative transmission can work well under good synchronization conditions between an MS and its overlaid/adjacent BSs as well as between an MS and its serving BS. However, due to different coverage between small cells and their overlaying macro cell, difference of propagation delay between an MS and its serving small BS and that between the MS and its overlaying macro BS is not negligibly small. Therefore, the arrival time of signals from/to small BSs can be much shorter than that from/to overlaying macro BS, so it gives rise to frame misaligned at the receive side. It inherently generates inter-symbol/carrier interference nonetherless how well interference management works. Therefore, synchronization of frames operated by a macro BS and its overlaid small BSs shall be provided to prevent from being impaired by inter-symbol/carrier interference.

In order to realize such varied interference management schemes, BSs and MSs need to determine their feasibility or gain when enabling them, and some schemes necessitate knowledge of interference channel as well as desired channel. Therefore, how to measure and report interference channel from overlaid/adjacent cells or its side information shall be provided to exploit those interference management schemes.

As mentioned above, most of interference management schemes require close coordination and cooperation among overlaid/adjacent cells, so it is quite significant to provide which/when/how management information is exchanged among mutually nearby BSs.

# References

1. IEEE 802.16-12-0394-05-Gdoc, PAR and Five Criterias for P802.16q on a Multi-tier Amendment to IEEE Std 802.16, July 2012.
2. IEEE Std 802.16-2012, IEEE Standard for Air Interface for Broadband Wireless Access Systems, Aug. 2012.

# Proposed Texts on Interference Management as Part of System Requirement Document (SRD) for IEEE 802.16q Multi-Tier Networks

[-------------------------------------------------------Start of Text Proposal-------------------------------------------------------]

# X. Functional Requirements

## X.1 Interference Management in Multi-tier Networks

### The 802.16q system shall support interference management by coordination and cooperation among BSs for multi-tier networks.

### X.1.1 The 802.16q system shall provide mechanisms for coordinated resource (time, frequency, power) management to mitigate inter-cell interference between macro cells, between small cells, and between macro cells and small cells.

### X.1.1.1 The 802.16q system shall provide mechanisms for resource(time, frequency) multiplexing, which limits reuse of resource by overlaying/adjacent cells and exclusively dedicates resource to a specific cell among overlaying/adjacent cells.

### X.1.1.2 The 802.16q system shall provide mechanisms for fractional frequency reuse (FFR) with support of varied settings on the number of frequency partition, size of each partition, and (maximum) power of each partition.

### X.1.1.3 The 802.16q system shall provide mechanisms for dynamic coordinated scheduling to alleviate small-scale interference variation.

### X.1.1.4 The 802.16q system shall provide mechanisms for downlink transmit power setting/control of small BS to suppress interference to MSs connected to overlaid/adjacent cells.

### X.1.1.5 The 802.16q system shall provide mechanisms for uplink power control of MSs to suppress interference to BSs in overlaid/adjacent cells.

### X.1.2 The 802.16q system shall provide mechanisms for cooperative transmission by multiple macro BSs, by multiple small BSs, or by macro BS(s) and small BS(s) to enhance cell-edge performance such as cell-edge throughput and client quality of service (QoS) (e.g., coordinated beamforming, collaborative MIMO).

### X.1.3 The 802.16q system shall provide mechanisms for synchronization of frames operated by a macro BS and its overlaid small BS(s) to prevent from being impaired by inter-symbol/carrier interference.

### X.1.4 The 802.16q system shall provide mechanisms for inter-cell interference channel measurement and report to support interference management with coordination and cooperation among BSs.

### X.1.5 The 802.16q system shall provide mechanisms for management information exchange among BSs to support interference management with coordination and cooperation among BSs.

[--------------------------------------------------------End of Text Proposal--------------------------------------------------------]