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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 mechanism 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).
Notice	
Release	
Patent Policy	

Dynamic Inter-Cell Interference Coordination and Signaling

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1. Introduction

The radio spectrum is a scarce resource in wireless communications. To maximize the spectral efficiency, a frequency reuse factor of one is preferred in OFDMA cell deployment, i.e., the same spectrum is reused by each BS in each and every cell. Unfortunately, this high spectrum efficiency also unavoidably leads to grave inter-cell interference (ICI). Therefore, a good inter-cell interference coordination (ICIC) scheme is needed.

ICIC technique can effectively reduce ICI in cell-edge regions by letting neighboring BSs coordinate among themselves and allocating disjoint channel resources to those MSs who otherwise will experience severe interference. Since MSs at cell edge are most prone to high ICI, the overall ICI can be substantially reduced by coordination of channel allocation among neighboring BSs for these MSs.

In order to achieve ICIC, two different approaches can be pursued:

- Fixed approach: disjoint subchannels are dedicated to different cell-edge sectors. An example of ICIC using fixed approach is provided in Figure 1, wherein MS1 and MS2 are assigned with different channel resources to avoid serious interference. The fractional frequency reuse (FFR) technique introduced in IEEE 802.16e/WiMAX follows such an approach.

- Dynamic approach: subchannels are allocated to cell-edge MSs according to the similar principle as the fixed approach but in a more dynamic manner to manage interference. Apparently, dynamic approach would enjoy more flexibility than fixed approach, at the cost of additional signaling overhead.

In order to enable dynamic ICIC, following procedures may be taken by BSs in a network.

- **Over the air**
  Each BS learns the potential interference level perceived at the MSs associated with it.

- **Via the backbone**
  Each BS informs its neighboring BSs of interference information via the backbone. In addition, the BS can inform its neighboring BSs of the resource allocated to these MSs that are susceptible to high interference. Thus, the neighboring BSs can allocate the resource to its own MSs accordingly to avoid interference.

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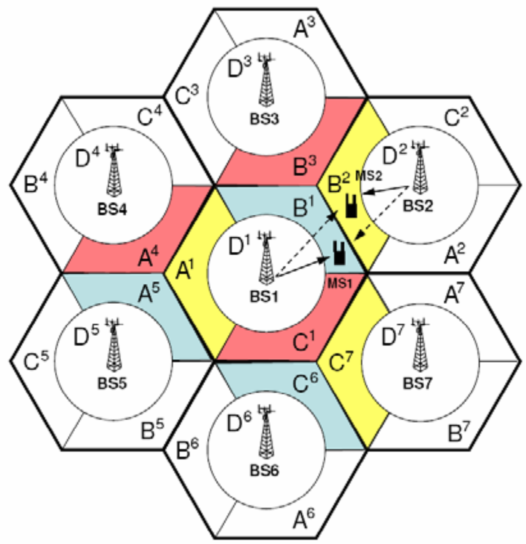

Figure 1: Illustration of resource management in a multi-cell cellular network using fixed ICIC technique, where the same/different colors represent the use of the same/different OFDMA resources.

Since the signaling via the backbone is considered out-of-scope for IEEE 802.16m, this contribution will solely concentrate on over-the-air signaling for dynamic ICIC. IEEE 802.16e does not explicitly provide support for dynamic ICIC. Nevertheless, the existing mechanisms and signaling defined for handover can be extended in a straightforward manner to enable dynamic ICIC, which will be shown in Sections 3 and 4.

The remainder of this document is organized as follows. The performance gains achievable via dynamic ICIC are demonstrated in Section 2. The extension of the current IEEE 802.16e standard is explained in Section 3. Proposed text changes are provided in Section 4.

2. Performance Gains of ICIC

We demonstrate the performance benefits of performing ICIC by computer simulation. Here we consider the downlink (DL) scenario. However, the principle of ICIC is also applicable in the UL scenario.

Table 1 summarizes the parameters used in the simulation. Figure 2 shows the SINR performance improvement due to the employment of ICIC. In Figure 2, ICI-blind is the traditional OFDMA scheme where no ICI-aware mechanism is employed; i.e., each cell performs its own channel allocation independently without coordination. We see that ICIC scheme has a remarkable improvement on the SINR performance as compared to the ICI-blind scheme. We see a particularly high gain in low SINR regime, which constitutes predominantly the cell-edge MSs. For instance, at the 10%-tile of CDF, ICIC achieves an improvement of over 5 dB. This reveals the effectiveness of ICIC scheme for ICI-prone cell-edge MSs.

Figure 3 shows the average SINR gains of ICIC with respect to the ICI-blind scheme under various traffic loads. Besides, three different inter-cell distance deployment scenarios (ρ=1, 0.9, or 0.8) are compared to show how the real-world deployment of cells can affect the performance of ICIC. Several observations can be drawn from Figure 3. First, we see that the gain provided by ICIC generally decreases as traffic load increases. Particularly, the ICIC gain drops significantly in very high load situations. This is because the inevitable channel collision in the presence of a large number of MSs has rendered the ICIC strategy ineffective. Second, comparing these three curves, we see that when cells are closer to each other (smaller ρ), ICIC gain is higher.

This is because denser deployment (smaller ρ) creates potentially higher ICI and consequently, employment of an ICIC scheme is more beneficial, as revealed by the higher gain in Figure 3. For instance, in a medium traffic load situation (15 MSs per cell), ICIC achieves a gain of 2.5 dB for ρ=1, 3.5 dB for ρ=0.9, and 4.5 dB for ρ=0.8.

Table 1: Simulation Parameters

Cell Parameters	
Number of Cells	19, wrap-around
Cell Radius	750 m
Cell-center Radius	500 m
Inter-cell Distance Ratio, ρ*	0.9
Antennas	$N_T = 4$, $N_R = 2$
Frequency Reuse Factor	1
OFDMA Parameters	
FFT Size	1024
Carrier Frequency	2.5 GHz
Sampling Frequency	11.2 MHz
Number of Subchannels	30
Number of Subcarriers Per Subchannel	28
DL Permutation Type	PUSC
Channel Model	
Path Loss (dB)	$130.62 + 37.6*\log_{10}(d)$, d in km
Fast Fading	ITU Pedestrian B
Power Control Parameters	
Cell-center Trans. Power	40 dBm
Cell-edge Trans. Power	46 dBm
Thermal Noise Power Density	-174 dBm/Hz

* Inter-cell distance may be shortened or expanded to control cell overlapping area. The ratio shown here is relative to the back-to-back hexagon cell deployment.

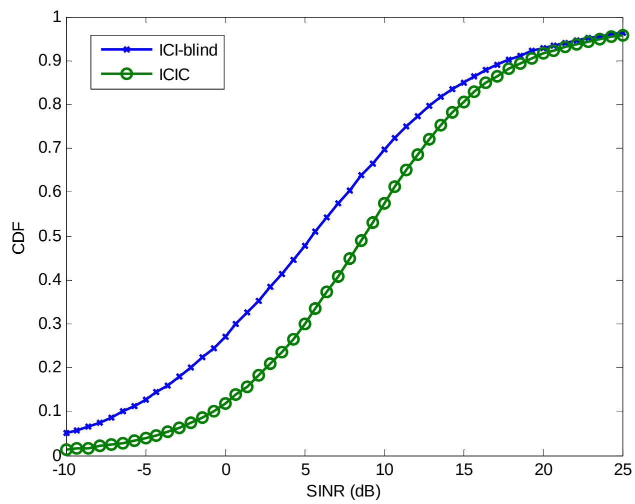

Figure 2: The SINR distribution for ICI-blind and ICIC schemes, under traffic load of 15 uniformly distributed MSs per cell.

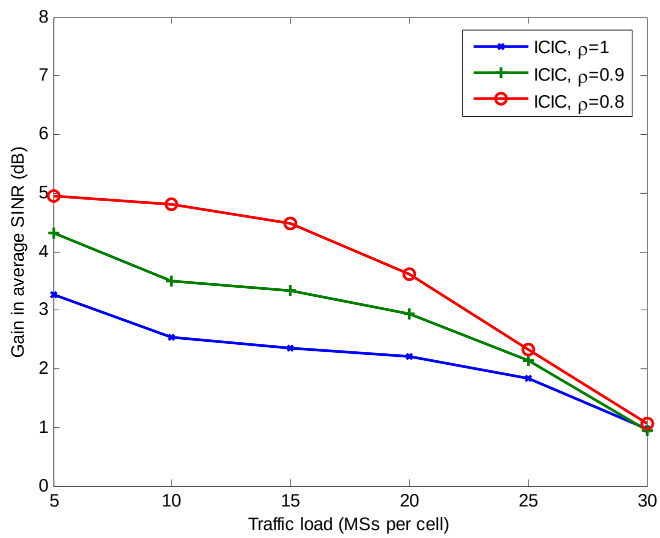

Figure 3: The average SINR gains with respect to the ICI-blind scheme under different traffic loads for different inter-cell distance deployment scenarios.

Figure 4 draws the contour plot of the SINR level in a cell plane as shown by the circle to represent the coverage. The "heights" in the plot represent the SINR in dB. Each concentric circle shows an SINR value after averaging over several MSs located at that particular distance away from the BS. Two schemes are compared under the same traffic load of 25 MSs per cell. We see from Figure 4 (a) and (b) that ICI-blind and ICIC achieve equally high SINR in the cell center but differ significantly in the cell edge. In particular, the cell-edge SINR value is low for ICI-blind, but high for ICIC. This shows that ICI management is particularly helpful to cell-edge MSs. This figure also reveals the geographical relationship of the SINR distribution.

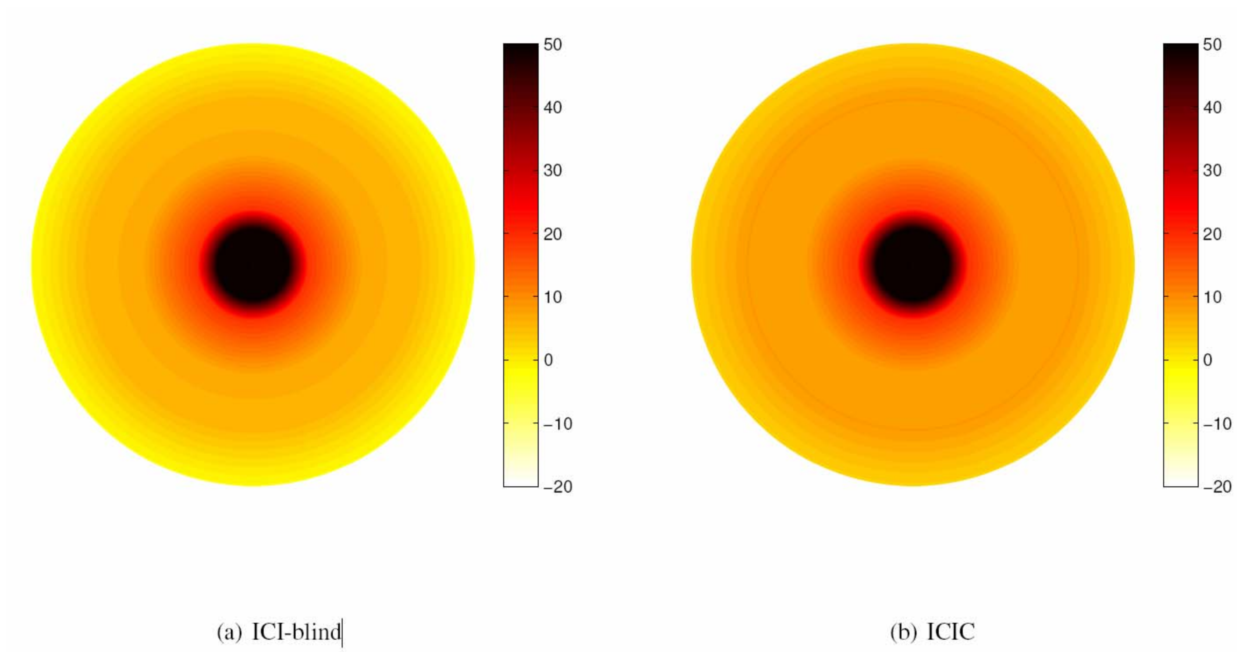

Figure 4: The contour plot of SINR (dB) in a cell, with 25-MS traffic load per cell.

3. Standardized Mechanism to Support ICIC

Naturally, a cell can be divided into three logical zones, namely, Zone 1 for cell center, Zone 2 for ICIC, and Zone 3 for handover (HO), as illustrated in Figure 5. An MS located in Zone 2 or Zone 3 can consider using one of the two available signaling procedures defined for handover in IEEE 802.16e, namely MOB_MSHO-REQ and MOB_SCN-REP, to enable ICIC operation.

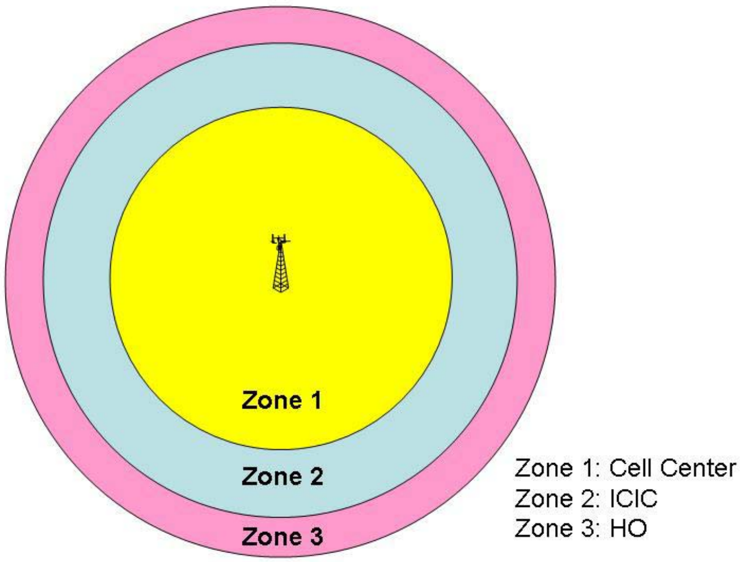

Figure 5: Interference zones in a cell.

3.1 MOB_MSHO-REQ based approach

As defined in the IEEE 802.16e standard, the MS transmits a MOB_MSHO-REQ message when it wants to initiate an HO. More specifically, MOB_MSHO-REQ message serves two purposes: 1) MS requests an HO, and 2) MS requests an Anchor BS update or Diversity Set update if MDHO/FBSS is supported.

- **MS in Zone 3**

  The MS can inform its serving BS, through the MOB_MSHO-REQ message, of its neighboring BS information, as well as the CINR or RSSI associated with each particular BS. If MDHO/FBSS is supported, additional information about BSs that are currently in the Diversity Set, and the CINR or RSSI associated with each of these BSs, will also be communicated from the MS to the BS.

- **MS in Zone 2**

  A modification to the standard on when the MOB_MSHO-REQ message can be initiated is needed. Specifically, the MOB_MSHO-REQ message needs to serve a new purpose of requesting an ICIC reporting, in addition to the existing two described above. In this case, the BS should know that there is no need to respond with the MOB_BSHO-RSP message.

3.2 MOB_SCN-REP based approach

In IEEE 802.16e, the MS can transmit a MOB_SCN-REP message to request a scanning interval for the purpose of seeking available BSs and determining their suitability as targets for HO. The MS in any cell region may transmit the MOB_SCN-REP message, periodically or event-triggered, to the BS. Through this message, the MS informs its serving BS the neighboring BSs, as well as the CINR or RSSI associated with each particular BS. If MDHO/FBSS is supported, additional information about BSs that are currently in the

Diversity Set, and the CINR or RSSI associated with each of these BS, will also be communicated from the MS to the BS.

For MSs in both Zone 2 and Zone 3, this message can be used directly to serve the ICIC purpose, without the need of any modification to the standard.

4. Proposed Text Changes

6.3.2.3.48 MOB_MSHO-REQ (MS HO request) message

[Modify the paragraph as follows]

The MS may transmit a MOB_MSHO-REQ message when it wants to initiate an HO or an ICIC. The message shall be transmitted on the Basic CID (Table 150).

[Change Table 150 as follows]

Table 150 – MOB_MSHO-REQ message format

Syntax	Size (bit)	Notes
MOB_MSHO-REQ_Message_format() {		
Management Message Type = 57	8	
Report metric	6	Bitmap indicating presence of metric in message Bit #0: BS CINR mean Bit #1: BS RSSI mean Bit #2: Relative delay Bit #3: BS RTD; this metric shall be only measured on serving BS/anchor BS. Bits #4-5: *Reserved*; shall be set to zero.
ICIC Indication	*1*	*0: If the MS is not requesting ICIC.* *1: If the MS is requesting ICIC.*
Arrival Time Difference Indication	1	0: If the MS is transmitting this message to request HO. 1: If the MS is transmitting this message to send MDHO/FBSS request (i.e., Anchor BS update or Diversity Set update).

[Insert a new subclause 6.3.28]

6.3.27 MAC support for interference management

For interference coordination purpose, MS can use both MOB_MSHO-REQ and MOB_SCN-REP to inform the serving BS of the channel condition between the MS and the neighboring BSs. When the ICIC indication field in MOB_MSHO-REQ message is set to 1, no MOB_MSHO-RSP from BS is needed as a response.