Project	**IEEE 802.16 Broadband Wireless Access Working Group** <http://ieee802.org/16>
Title	**Frame Structure to Support Inter-cell Interference Mitigation for Downlink Traffic Channel using Co-MIMO and FFR.**
Date Submitted	**2008-01-16.**
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Re:	IEEE 802.16m-07/047: Call for Contributions on Project 802.16m System Description Document (SDD) (2007-12-17), Multiple access and multi antenna techniques, specifically as related to frame structure.
Abstract	This contribution proposes a frame structure to support inter-cell interference mitigation for downlink traffic channel using both FFR and Co-MIMO.
Purpose	Adoption of proposed text into SDD
Notice	
Release	
Patent Policy	

Frame Structure to Support Inter-cell Interference Mitigation for Downlink Traffic Channel using both FFR and Co-MIMO

Choong Il Yeh, Young Seok Song, Seung Joon Lee, Byung-Jae Kwak, Jihyung Kim, Dong Seung Kwon

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Rationale

Universal frequency reuse (frequency reuse factor = 1) is highly desirable because it makes cell planning easy and prohibits frequency reuse penalty. On the contrary, it causes very severe inter-cell interference especially in the cell boundaries and limits system capacity.

Therefore, TGm has to prepare a more precise inter-cell interference mitigation than conventional systems, which will probably employ seven-cell or even higher frequency reuse in the downlink as well as in the uplink.

In the past, most approaches to deal with inter-cell interference have relied on receiver techniques. But as the universal frequency reuse is gaining popularity, it is inevitable to invent new algorithms for cancelling interference more effectively. Recently a fractional reuse scheme (FFR) or a Co-MIMO (Network-MIMO or Collaborative-MIMO) are being proposed to deal with inter-cell interference and gaining much attention.

FFR is a frequency reuse scheme with reduced bandwidth overhead compared to traditional frequency reuse schemes. Soft FFR and hard FFR are two kinds of applicable FFR schemes. Soft FFR refers to the case where the power on some of the tones is reduced rather than not used. In the hard FFR, some of the tones belonging to the whole bandwidth are not used to mitigate inter-cell interference. Therefore, power control reflecting the overload conditions of neighboring cells can be considered as a soft FFR to mitigate inter-cell interference in the universal frequency reuse scheme.

In order to mitigate inter-cell interference in the uplink, such standardization bodies as 3GPP LTE and IEEE (802.20 MBWA) are considering power control based on Interference over Thermal (IoT) overload bit on a specific downlink channel and forward link other sector interference channel (F-OSICH), respectively. Both are considered as kinds of uplink power control taking advantage of network cooperation (soft FFR).

For the downlink inter-cell interference mitigation, FFR is also useful and therefore, being studied now in some standardization bodies [R1-072974]. Co-MIMO, which realizes a MIMO transmission from multiple BSs to one or multiple MSs through network coordination, may be a good solution to solve the interference problems in the universal frequency reuse scheme [IEEE C802.16m-07/162].

But at this point we would say that DL interference mitigation has not been as much developed as in the uplink. For these reasons, this contribution tries to solve inter-cell interference problems specifically in the downlink traffic (dedicated) channels operated under universal (or low) frequency reuse scheme by taking advantage of both FFR and Co-MIMO simultaneously.

The purpose of this contribution is to propose a frame structure to support inter-cell interference mitigation for downlink traffic channel using both Co-MIMO and FFR.

Required Parameters (Measurements)

In order to utilize both FFR and Co-MIMO to deal with inter-cell interference in the downlink, we need to define such measurements as downlink preamble CINR (DL PCINR), strong interfering cell indices, and a preferred beam index at the mobile side.

- DL PCINR: This is the ratio of the preamble power of the serving cell to the sum of preamble powers of neighboring cells. This is measured at MS side. In order to support this kind of measurement, it is recommended for MSs to identify cells using preamble.
- Strong interfering cell indices: MS automatically can recognize interfering cells in the process of measuring DL PCINR.
- Preferred beam index: We assume that each MS has the knowledge of channel information, $\mathbf{h} \in C^{1\times K}$ $(K = \text{number of transmit antennas at BS})$ and quantizes the direction of its channel $\mathbf{h}/\|\mathbf{h}\|$ to a unit norm vector $\hat{\mathbf{h}}$. The quantization is chosen from a codebook $\{\mathbf{c}_n; n = 1,2,\cdots,N\}$ of unit norm vectors according to the minimum distance criterion $\hat{\mathbf{h}} = \mathbf{c}_n$ with $n = \arg\max_{1\le n\le N} \left|\hat{\mathbf{h}}\mathbf{c}_n^*\right|$. In this case, n is the MS's preferred beam index. For this measurement, common pilots per antenna are required in the downlink.

Network Cooperation to Utilize Feedback Parameters (Measurements)

After measuring above parameters, each MS feeds back DL PCINR, strong interfering cell indices, and preferred beam index to the serving BS. Then, neighboring cells will exchange feedback information from MSs via network interface. When this process is completed, network recognizes where MSs of interest are, and understands interference conditions between cells. Fig 1 shows the inferred MS positions by the network according to feedback information of Table 1 from MSs and cooperation between BSs.

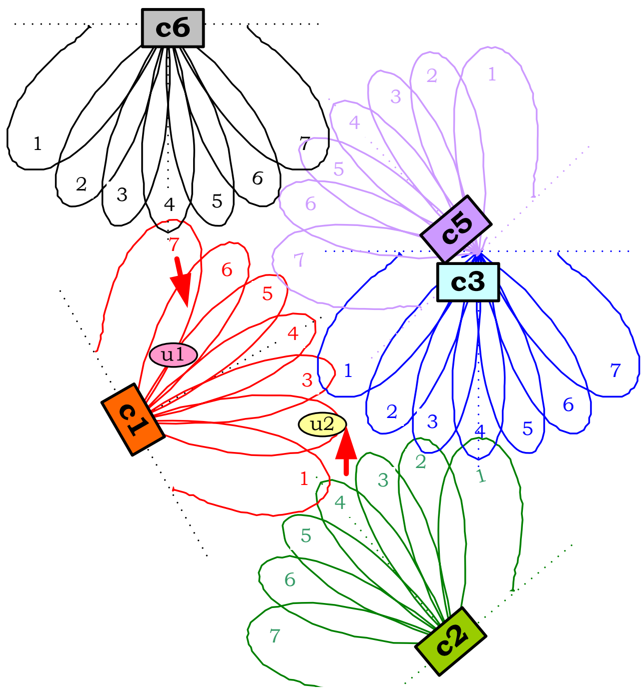

Fig 1. Mobile location example according to Table 1.

	User 1	User 2
DL PCINR	High	Low
Strong interfering cell index	None	c3
Preferred beam index	6	2

Table 1. Feedback example from user 1 and user 2 whose serving cell is c1.

MIMO and FFR classification using network cooperation

We are going to define three regions in a cell for MIMO applications.

- MU-MIMO region without network cooperation (w/o Co-MIMO and FFR): spectral reuse factor > 1
- Network cooperation region with Co-MIMO: spectral reuse factor ≅ 1
- Network cooperation region with both Co-MIMO and FFR: spectral reuse factor < 1

If we assume a wireless network consists of N cells and that the same spectrum is reused K times in the network, then the spectrum reuse factor can be defined by K/N.

MU-MIMO region without network cooperation (w/o Co-MIMO and FFR): spectral reuse factor > 1

This is applied to MSs in the center of cell. In this region, no interference from neighboring cells and high CINR are assumed. Also we assume that there is no network cooperation to share antennas with neighboring cells and FFR is not applied here. Only the serving cell is relevant to a group of selected users for MU-MIMO under which BS transmits multiple streams to the multiple selected users in the cell using the same spectrum resource. Also, multiple streams can be transmitted to a specific user for spatial multiplexing (SM).

Depending on the operator’s policy, partial transmit channel status information (CSIT)-based MU-MIMO or full CSIT-based MU-MIMO could be applicable in this region. For partial CSIT based MU-MIMO realization, we need to define codebook and MS will feed back its preferred beam index. Linear or non-linear types of full CSI based MU-MIMO schemes could also be applicable.

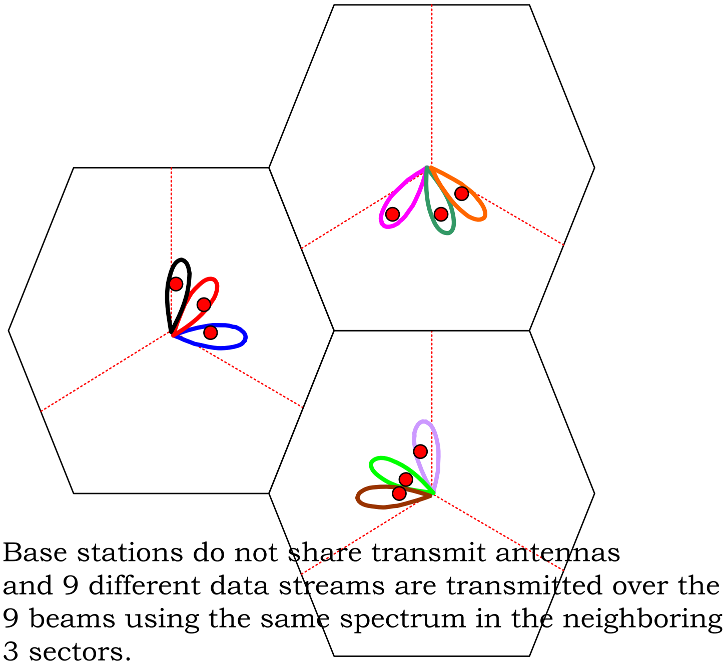

Fig. 2. MU-MIMO region without network cooperation.

Network cooperation region with Co-MIMO (spectral reuse factor ≅ 1)

This is applied to MSs in the cell boundaries. The users in this region have strong interfering cells and low CINR but should not get clustered together. Since the required CINR for MU-MIMO and/or SM is not guaranteed in the cell boundaries, we cannot use MU-MIMO in this region. But the system can still enjoy spectral reuse factor of nearly 1 by sharing transmit antennas of neighboring base stations and exchanging feedback parameters via network (Co-MIMO). The restriction for universal frequency reuse in the cell edge regions is that the corresponding users using the same spectrum should be separated enough to neglect inter-beam interference.

Fig. 3 shows the simple example of this application. In Fig. 3, some of the neighboring cells can transmit beams carrying the same data to a specific user simultaneously. And the spectrum resource is completely reused by the neighboring cells.

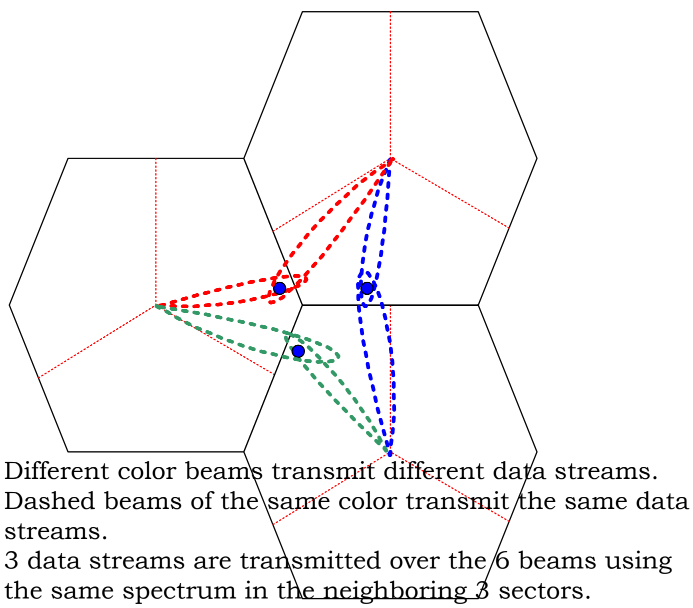

Fig. 3. An example of network cooperation with Co-MIMO.

Network Cooperation region with both Co-MIMO and FFR: spectral reuse factor < 1

If the users get together in a certain place of cell boundaries and have low CINR and strong interfering cells, the system cannot enjoy universal frequency reuse. In this case, in order to avoid inter-cell and inter-beam interference, hard (soft) FFR incorporated with Co-MIMO can be applied. The spectrum resource used to service to one of the clustered users cannot be reused by neighboring cells to service to other users being in the same place where they are clustered.

Fig. 4 shows the simple example of this application.

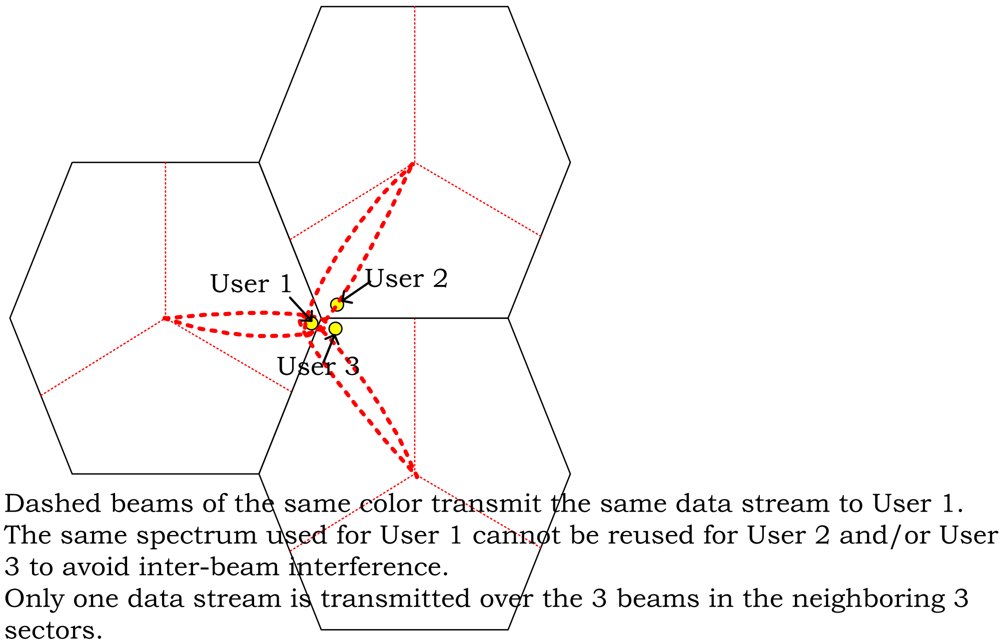

Fig. 4. An example of network cooperation with both Co-MIMO and FFR.

Frame Structure for Inter-cell Interference Mitigation

Frame Structure: In Fig.5, downlink subframe is divided by two regions; one for legacy 16e, the other for 16m advanced support. In order to mitigate inter-cell interference using MIMO and network cooperation, 16m system should allocate part of its resource to MSs having the capability of supporting inter-cell interference mitigation. The allocated resource to support inter-cell interference mitigation is called IIM Zone. Also, the IIM Zone is further subdivided into three regions; MU-MIMO region without network cooperation, Network cooperation region with Co-MIMO, and Network cooperation region with both Co-MIMO and FFR. The amounts of resource allocated to these three regions are not fixed. By the help of network cooperation, they are dynamically allocated depending on the distribution of subscribers.

Subchannel Allocation: Under universal frequency reuse scheme, legacy 16e OFDMA systems use inter-cell interference randomization to alleviate inter-cell interference. When allocating subcarriers into a subchannel, the adjacent cells of legacy system permute them differently to guarantee minimum subcarrier-hit probability between subchannels.

But when the inter-cell interference mitigation by network cooperation is applied, we don’t have to permute subcarriers to constitute a subchannel (legacy 16e PUSC Subchannelization has already this capability).

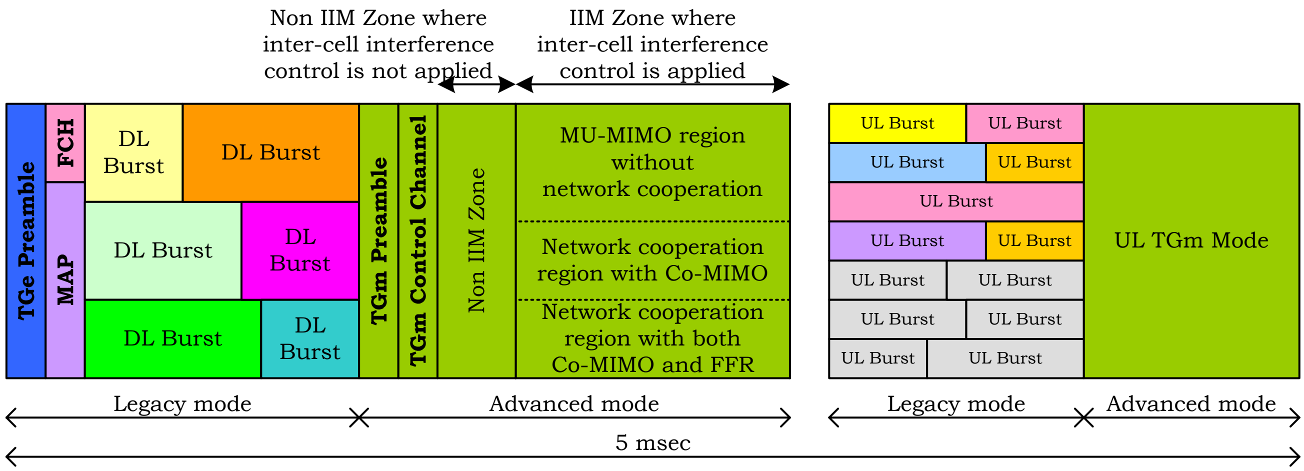

Fig. 5. Frame structure to support IIM Zone using network cooperation.

[Reflect text proposal to SDD.]

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Text Proposal

Section XXX. Frame structure to support inter-cell interference mitigation for DL traffic channels using network cooperation.

In Fig.x, downlink subframe is divided by two regions; one for legacy 16e, the other for 16m advanced support. In order to mitigate inter-cell interference using MIMO and network cooperation, 16m system should allocate part of its resource to MSs having the capability of supporting inter-cell interference mitigation. The allocated resource to support inter-cell interference mitigation is called IIM Zone. Also, the IIM Zone is further subdivided into three regions; MU-MIMO region without network cooperation, Network cooperation region with Co-MIMO, and Network cooperation region with both Co-MIMO and FFR. The amounts of resources allocated to these three regions are not fixed. By the help of network cooperation, they are dynamically allocated depending on the distribution of subscribers.

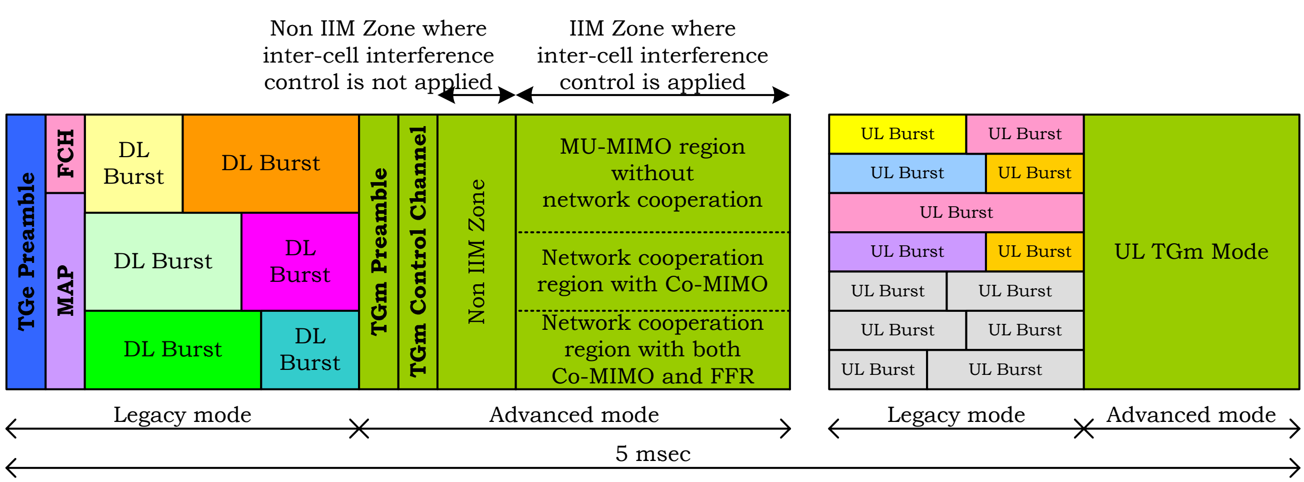

Fig. x. Frame structure to support IIM Zone using network cooperation.

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Network cooperation region with Co-MIMO (spectral reuse factor ≅ 1)

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References

[1] IEEE 802.16m-07/002r4, TGm System Requirement Document (SRD)

[2] IEEE 802.16m-07/037r2, TGm Evaluation Methodology Document (SRD)

[3] 3GPP, R1-072974

[4] IEEE P802.20/D1