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Re:	IEEE 802.16m-09/0020, "Call for Contributions on the Project 802.16m Amendment Working Document (AWD) Content" Category: AWD-New contribution/ Area: Interference Mitigation
Abstract	The contribution proposes the text relevant to fractional frequency reuse to be included in the 802.16m amendment.
Purpose	To be discussed and adopted by TGm for the 802.16m amendment.
Notice	
Release	
Patent Policy	

Proposed Text of Fractional Frequency Reuse Section for the IEEE 802.16m Amendment

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1. Introduction

Fracitional frequency reuse (FFR) is one of the interference mitigation (IM) techniques which are adopted in IEEE 802.16m SDD [1]. The basic concept is to reduce interference origin by dividing total frequency resource into several partitions and by exploiting only limited partitions per BS. Since, by doing this, the number of interference sources is decreased and distance of interference is increased, interference level could be far much reduced. Though main advantage of FFR is cell edge performance enhancement, spectral efficiency reduction is inevitable. This trade-off between sector and cell edge throughput is determined by how to operate the FFR.

In this contribution, the generic FFR scheme and an enhanced FFR technique are introduced. And, for the amendment text, required signaling and operation-oriented sections are proposed to be adopted.

2. Fractional Frequency Reuse Schemes

The main objective of generic FFR is to increase cell edge performance. Figure 1 shows an example of frequency partitions for generic FFR and assignment of them to sectors. In the example the total resource is divided into 4 partitions where one is universal frequency reuse and the other three partitions are frequency reuse factor(FRF) 3. Each sector is managing one reuse-1 partition and one reuse-3 partition. Compared to FRF-1 partition, FRF-3 partitions are experiencing less number of interferences and also the distance between two closest interferers is bigger.

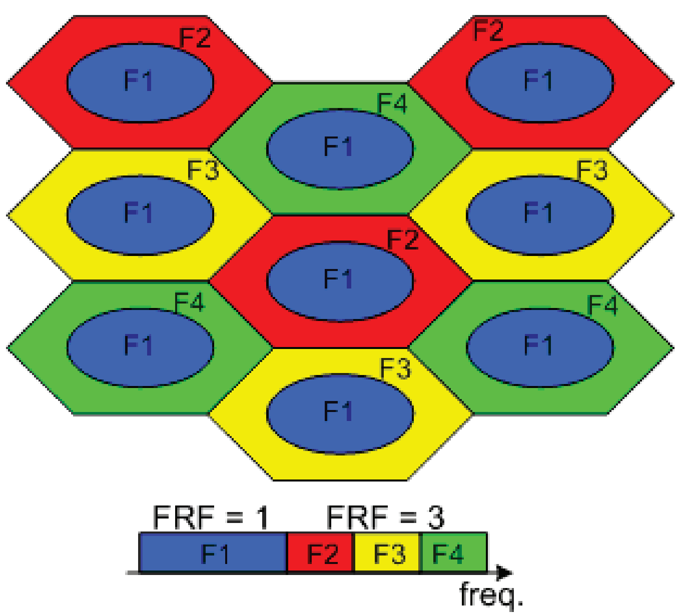

Figure 1. An example of generic FFR scenarios; four partitions and assignment

Every sector has one FRF-1 partition and one FRF-3 partition only. If a BS assigns cell edge users the FRF-3 partition, the cell edge users who suffered from high level interference can benefit from lowered interference level. This kind of basic theory makes it possible for cell edge users to increase SINR.
Note in Figure 1 that spectral efficiency loss happens since a BS exploits not all resources but parts of them. Therefore sector average throughput could be decreased while cell edge performance could be increased. Generic FFR schemes are always facing with this problem and this is why more refined techniques have been developed to compensate the spectral efficiency loss.

2.1. Enhanced FFR

As mentioned above, loss of spectral efficiency is the weakest point of generic FFR schemes. In order to overcome this problem, soft FFR schemes were developed. Soft FFR schemes exploit FRF-3 partitions additionally which is not originally intended to be assigned to a sector. Figure 2 shows what is different with generic FFR and soft FFR.

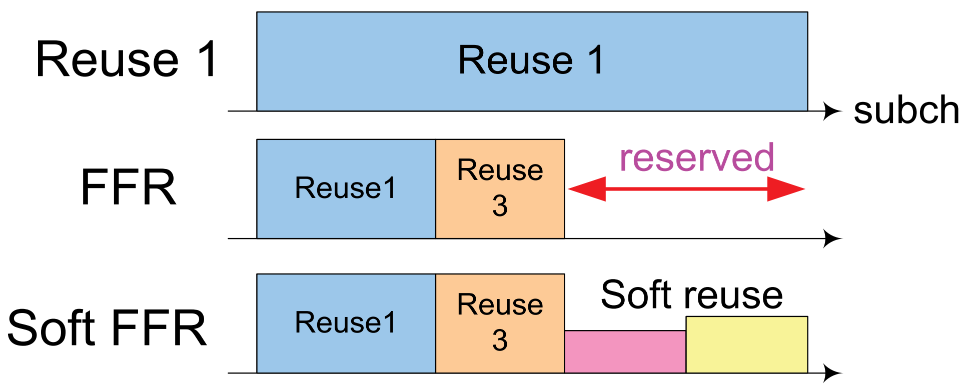

Figure 2. An example of generic FFR scenarios; four partitions and assignment

There are total 3 FRF-3 partitions in frequency domain. Compared to generic FFR which uses only two partitions, soft FFR uses total 4 partitions altogether. This makes spectral efficiency better than generic FFR. Of course cell edge users are affected and might be deteriorated by using the reserved two partitions.
Usually, the transmitted power of BS in reserved partitions is lower than that in FRF-1 or allowed FRF-3 partition. This is because BS tries to minimize the effect of using the reserved partitions on other sectors which is originally allowed to use the partitions. Therefore the transmission power of the reserved partitions should be controlled very carefully for BS's intention, and how to determine the transmission power is key point to increase soft FFR performance.

In this contribution, the algorithm of setting the transmission power for the reserved partitions are explained and the performance of this enhanced FFR (eFFR) is investigated. The main goal of the proposal is to protect the cell edge user's SINR which occupies the FRF-3 region in neighbor sector.
Figure 3 shows the three sectors which operate in soft FFR. BS1, BS2 and BS3 use F1 partition for FRF-1 and each BS uses one more FRF-3 partition mandatorily and this FRF-3 partition is protected FRF-3 partition. Besides, two more FRF-3 partitions can be utilized by the BS. For example, in BS1, F3 and F4 partitions are exploited by BS1. However, If BS1 assigns users in the reserved partitions (i.e. F3 and F4), this impacts on the users in FRF-3 partition of the neighbor sector – MS_{22} in BS2, MS_{33} and MS_{32} in BS3. In order to minimize the effect, BS1 should calculate the transmission power for F3 and F4.
In the proposed eFFR, the transmission power in the reserved partition is decided by deboosting value and

follows the Equation (1).

$$P_{\text{Tx,Max}} + L_{\text{path,interference}} - P_{\text{deboost}} \le P_{\text{Tx,Max}} + L_{\text{path,signal}} - M \qquad \text{Equation (1)}$$

$$P_{\text{Tx,Max}} - P_{\text{deboost}} \le P_{\text{Tx,Max}} + L_{\text{path,signal}} - \text{M} - L_{\text{path,interference}} = P_{\text{Tx,Max}} + RSSI_{\text{signal}} - RSSI_{\text{interference}} - M \qquad \text{Equation (2)}$$

where

- $P_{Tx,Max}$ is the maximum value of transmission power of BS
- $P_{deboost}$ is the deboosting value which is applied to the $P_{Tx,Max}$ in the reserved partition
- $L_{path,n}$ is the pathloss between the BS n and an MS
- $RSSI_n$ ($=P_{Tx,Max} - L_{path,n}$) is the received signal strength from BS n
- M is margin value to protect the nearest MS

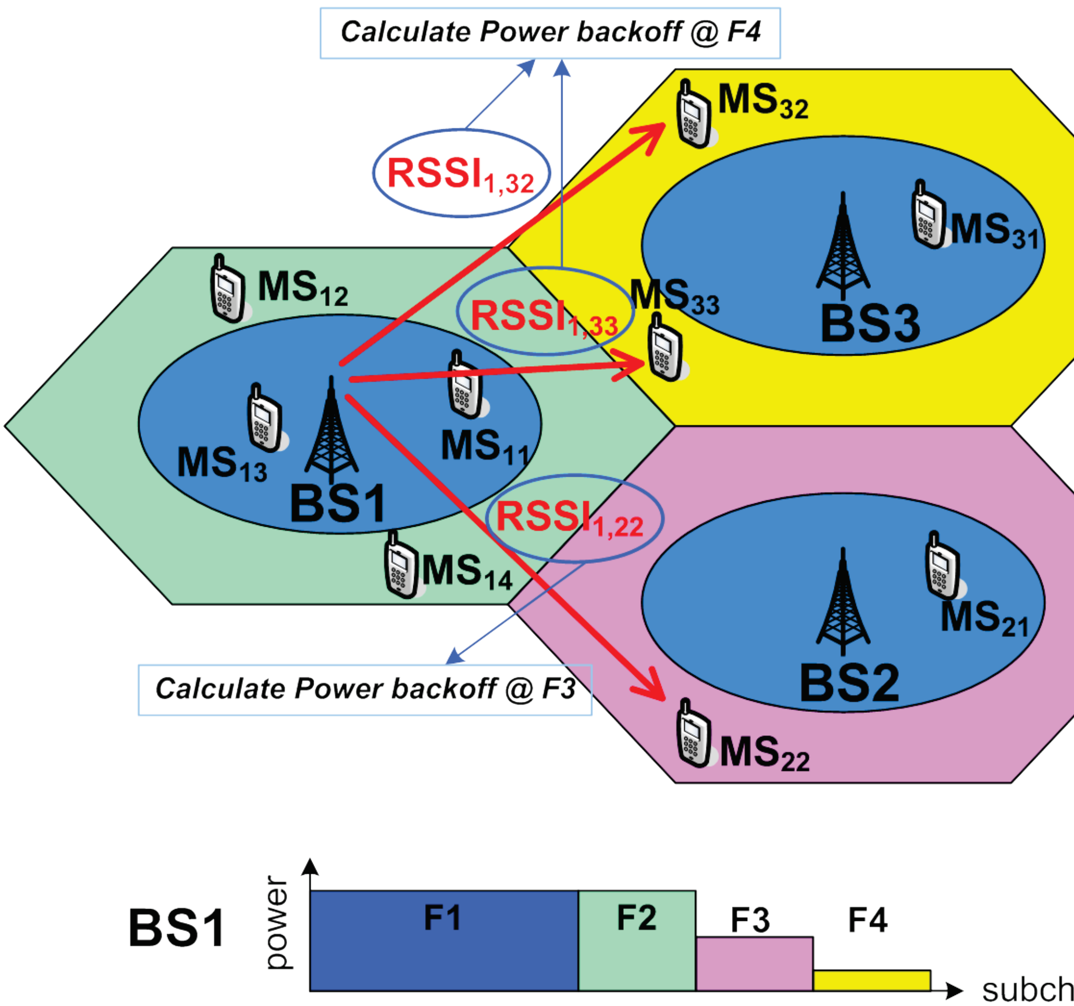

Figure 3. An example of generic FFR scenarios; four partitions and assignment

2.2. Required Signaling

In previous section, how to decide the transmit power of BS for the restricted partition is described as Equation (2). In Equation (2) $P_{deboost}$ should be optained based on other parameter as follows:

$$P_{deboost} \geq RSSI_{\text{interference}} - RSSI_{signal} + M$$ Equation (3)

Since $RSSI_n$ is used to obtain the value, BS needs to know the RSSI from interfering cell. For this reason, MS who is located at cell edge should report the RSSI of neighbor BS whose received signal strength is highest. Then, serving BS shares the information with neighbor BSs. In Figure 3, from the viewpoint of BS1, BS1 should know the RSSI values for MS_{33} for frequency partition 4 and for MS_{22} for frequency partition 3. This could be done by BS2 and BS3 sharing the information.

Besides, when BS schedules MSs, channel information of every MS for every frequency partition is required. Therefore every MS needs to report channel quality of each frequency partition. As long as diversity transmission is considered, however, the signaling overhead can be reduced by using downlink noise and interference (NI) level instead of CQI because NI statistics have long-term behavior compared to CQI.

In summary, the signalings described below are proposed for enhanced FFR operation.

- MS to serving BS
  - ■ Estimated pathloss between neighbor BS and MS (cell edge MS only)
  - ■ 1 CQI for reuse 1 frequency partition (frequently)
  - ■ noise and interference level information for each partition (infrequently)
- BS to BS
  - ■ One pathloss value which should be the highest
    - ◆E.g. BS2 needs to share the highest RSSI value (MS22's) with BS1 so that BS1 could set the Tx power of frequency partition 3.
    - ◆E.g. BS3 needs to share the highest RSSI value (MS33's) with BS1 so that BS1 could set the Tx Power of frequency partition 4.

2.3. Practical Situation

2.3.1. Large number of MSs

According to Equation (1), as $RSSI_{\text{interference}}$ (RSSI from neighbor BS) is getting higher, P_{deboost} value is getting larger. Therefore there might a concern with practical situation where too many MSs (over 100) are active so that the biggest $RSSI_{\text{interference}}$ is very high. Therefore the transmit power might be close to zero – it means this enhanced FFR is not utilizing the restricted band and becomes static FFR.

To verify this kind of situation, the required deboosting value is compared from 10MSs to 300MSs. Table 1 shows the average power backoff (deboosting) value when margin M is 5, 10, 15 and 20 dB case respectively. We assumed that only MSs whose geometry is smaller than 0dB reports the RSSI. This results implies that we can easily control the trade-off between sector throughput and cell edge throughput by controlling the power margin of restricted partition.

Eventually, if we use 10dB of power margin, even though the system becomes fully loaded situation, the gap between the average TX power of restricted region with respect to that of under loaded situation is only about 2.5dB. That is to say, by setting appropriate power margin for the restricted region, we can make use of the resources in restricted region without causing severe inter-cell interference.

Restricted partition power margin	Num AT per sector	RSSI Report Threshold: Geometry < 0dB
		Avg. TX power backoff in restricted region (dB)
5dB	10	−0.899
	20	−1.200
	50	−1.601
	100	−1.870
	200	−2.123
	300	−2.263
10dB	10	−2.623
	20	−3.351
	50	−4.190
	100	−4.605
	200	−4.862
	300	−5.129
15dB	10	−4.866
	20	−6.091
	50	−7.565
	100	−8.170
	200	−8.505
	300	−8.882
20dB	10	−7.918
	20	−9.632
	50	−12.043
	100	−12.906
	200	−13.361
	300	−13.861

Table 1. Required power deboosting value along with the number of MSs

2.3.2. NI report impairment-quant/period

For the sake of lower signaling overhead, one of proposed signaling types is NI level of each frequency partition. Since NI statistics changes based on long term, report period could be long and this results in overhead reduction. In this theory, a concern could happen – what about system performance with delayed NI information? In order to investigate the effect of NI report impairment, SLS verification is used. Table 2 shows the effect of NI report impairment on system performance in terms of average throughput and cell edge throughput. As shown in the table, throughput reduction from quantization and delay of NI report is less than 4% even though the NI report period is upto 600ms. In fact, there may exist some gap between the actual CQI and the estimated CQI using the reported NI level. But this gap can be overcame with the help of Outer-loop error rate control which modifies the amount of offset to maintain the error rate close to the target PER. Furthermore, in high mobile velocity environment, the averge SE performance deterioration by NI impairment is almost negligible because of the inaccuracy of the reported CQI but still the edge throughput can be degraded upto 10%. In mixed mobility case, the average SE performance degradation is less than 2.5% while the degradation of edge throughput is 4.2%. Consequently infrequent report of NI could be used instead of frequent CQI report with only small amount of performance loss while keeping the CQI feedback overhead as small as only 25% of full CQI report case. This is the way the signaling overhead could be reduced for enhaced FFR operation.

Table 2. Effect of NI report impairment – quantization and report period

NI Quantization	NI report period	3km/h		Mixed mobility (6:3:1)		120km/h	
		Avg SE	5%-tile edge throughput	Avg SE	5%-tile edge throughput	Avg SE	5%-tile edge throughput
Reference	Ref	100%	100%	100%	100%	100%	100%
1.0dB	50ms	96.34%	96.37%	97.87%	95.78%	100.13%	92.36%
	100ms	96.34%	95.27%	98.04%	95.98%	99.96%	91.72%
	200ms	96.10%	94.28%	97.92%	97.56%	100.13%	90.53%
	400ms	96.17%	95.88%	97.76%	97.08%	100.16%	92.86%
	600ms	96.37%	93.69%	97.47%	96.23%	100.12%	90.29%

2.4. Performance Evaluation

In this section, SLS results are provided and analyzed. The parameters and assumptions of the simulations are basically aligned with configuration in [2].

2.4.1.Parameters and assumptions for Simulation

Table 3 shows the key system parameters for simulation. Please refer to [2] for other parameters and modeling of BS and MS in details. Also, Table 4 shows the assumptions for simulation and scheduling.

Table 3. System Parameters

Parameter	Value
Carrier frequency (GHz)	2.5
Sampling frequency (MHz)	11.2
Inter site distance (m)	1500
System and frame structure	802.16m TDD, 1 frame =5ms
Number of symbols for data	30 symbols
FFT size (tone)	1024
Number of useful tone	864

Permutation	2-step random permutation (PRU unit)
Antenna configuration	2x2
PHY Abstraction	RBIR
HARQ type and Max. ReTx	CC, max 4 ReTx
Outer loop rate control	On

Table 4. Assumptions for Simulation and Scheduling

Parameter	**Value**
Traffic type	Full Buffer
Number of MCS level	10
MS channel type	Ped B 3km/h, Veh-A 120km/h, Mixed mobility (60% 3km/h, 30% 30km.h, 10% 120km/h)
Channel estimation	Ideal
Min. number of subchannel assigned for a MS	3 PRUs
FFR partial loading	50% (4 RBs for reuse1, 4 RBs for reuse3, 4 + 4 RBs for reserved partition)
Scheduling priority method	PF
PF exponent	1
Total number of users per sector	10
Max. BS Tx power	46 dBm

2.4.2. System performance with EFFR

Table 5 shows the system performance with EFFR on various conditions. Note that total 4 frequency partitions are used for FFR and EFFR case and every reuse 3 partition has same partition size. The definition of partial loading is the ratio of the restricted band among total bandwidth. For example, if partial loading is 50% the portion of reuse 1 partition is 25%. Note that for soft FFR case, -8dB deboosting is assumed in reserved partitions.

Table 5. System performance with EFFR (compared to reuse 1 and generic FFR)

Velocity	**Scheme**	**Avg SE (bps/Hz/cell)**	**5%-tile edge throughput (kbps)**
3kmph	Reuse1	4.15	352.60
	HFFR PL50	3.66	432.41
	SFFR PL50	4.48	435.00
	EFFR, Margin 10dB	4.62	488.08
	EFFR, Margin 12dB	4.66	482.18
	EFFR, Margin 15dB	4.68	462.70
Mixed (6:3:1)	Reuse1	4.08	355.00
	HFFR PL50	3.55	400.34
	SFFR PL50	4.33	445.50
	EFFR, Margin 10dB	4.47	467.44
	EFFR, Margin 12dB	4.51	481.08

	EFFR, Margin 15dB	4.53	496.13
120kmph	Reuse1	3.93	336.94
	HFFR PL50	3.30	398.87
	SFFR PL50	4.03	405.69
	EFFR, Margin 10dB	4.14	443.84
	EFFR, Margin 12dB	4.18	448.82
	EFFR, Margin 15dB	4.23	488.82

Compared to reuse 1 in 3km/h scenario, generic hard FFR could give over 22% cell edge performance enhancement (5%-tile MS throughput). However, the average sector throughput degraded by 12%. By using soft FFR the throughput gain is 8% and the edge throughput gain is 23%. Furthermore, with eFFR, the throughput gain is 12.5% and the edge throughput gain is 37% (EFFR with 12dB Margin). This enhancement is basically dependent on the use of restricted bands because utilization of restricted bands could increase sector throughput but could degrade cell edge performance. But even though we make use of the restricted bands, it does not directly degrade the performance of cell edge throughput. By allocating some MSs with good channel condition in restricted bands, then the opportunity of getting resources in reuse1 and reuse3 bands will be increased for those MSs with poorer channel condition. This is why the throughput and cell edge throughput performance is less sensitive to the margin of restricted bands. Consequently, by setting BS power to minimizing the effect on cell edge user of neighbor cell, both system throughput and cell edge throughput enhancements can be obtained.

3. References

[1] *IEEE 802.16m System Description Document (SDD),* IEEE 802.16m-08/003r7

[2] *IEEE 802.16m Evaluation methodology Document*, IEEE 802.16m-08/004r5

4. Text proposal for inclusion in the 802.16m amendment

-- Text Start --

15.2.4.x Channel Measurement REP-REQ/RSP (report request/response)

Table 1. Channel Measurement REP-REQ message format

Syntax	Size (bit)	Notes
Report_Request_Message_Format() {	-	-
Management Message Type = [TBD]	TBD	-
Report Request TLVs	variable	-
}	-	-

Table 2. Channel Measurement REP-RSP message format

Syntax	Size (bit)	Notes
Report_Request_Message_Format() {	-	-
Management Message Type = [TBD]	TBD	-
Report Response TLVs	variable	-
}	-	-

Y.Z.1 REP-REQ Management Message Encoding

Name	Type	Length	Value
Report request	1	variable	compound

Name	Type	Length	Value
Downlink Noise and Interference Level request	[TBD]	1	00 : distributed LRU 01 : contiguous LRU

Y.Z.2 REP-RSP Management Message Encoding

Name	Type	Length	Value
Report	1	variable	compound

REP-REQ report type	Name	Type	Length	Value
[TBD]	Distributed LRU	[TBD]	4	Bits 0-7: Mean of downlink noise and interference level in frequency partition 0 Bits 8-15 : Mean of downlink noise and interference level in frequency partition 1 Bits 16-23 : Mean of downlink noise and interference level in frequency partition 2 Bits 24-31 : Mean of downlink noise and interference level in frequency partition 3
[TBD]	Contiguous LRU	[TBD]	4	Bits 0-7 : Mean of downlink noise and interference level in frequency partition 0 Bits 8-15 : Mean of downlink noise and interference level in frequency partition 1 Bits 16-23 : Mean of downlink noise and interference level in frequency partition 2 Bits 24-31 : Mean of downlink noise and interference level in frequency partition 3

15.2.4.y1 AAI_SCN-REQ message
(Editor's notes : This will be defined later)

15.2.4.y2 AAI _SCN-RES message
(Editor's notes : This will be defined later in handover related function)

15.2.4.y3 AAI _SCN_REP message
(Editor's notes : This will be defined later in handover related function)

15.2.Z MAC Support PHY

15.2.Z.1 Downlink FFR

ABS can decide the transmission power of each reuse partition using the RSSI information from neighbor ABSs. The RSSI measurement can be performed over the serving BS and neighbor ABSs by an AMS in solicited/unsolicited manner.

When RSSI information is fed back from AMS information, the ABS selects the highest RSSI value and transfer the difference of RSSI value (e.g. RSSI from interfering BS - RSSI from serving BS) to neighbor ABS which is designated in the reported RSSI report.

On receiving the RSSI information from neighbor ABS(s), each ABS selects the highest RSSI value in each restricted frequency partition and determines the maximum allowed transmission power of the frequency partition. The following equation can be an example.

$P_{deboost,n} = RSSI_{difference,n,i} + M$

where n is the frequency partition index and $RSSI_{difference,n,i}$ is the RSSI difference shared from neighbor ABS i, M is the system-wide margin value.

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