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Title	**Inter-Cell Interference Management in DL/UL Control**
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Re:	IEEE 802.16m-08/016r1: Call for Contributions on Project 802.16m System Description Document (SDD). Target topic: “Uplink Control Structures”.
Abstract	This contribution proposes inter-cell interference management in DL/UL control
Purpose	For discussion and approval by TGm.
Notice	
Release	
Patent Policy	

Inter-Cell Interference Management DL/UL Control

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1. Introduction

In this contribution we propose some interference management measures in the PHY Control to reduce the possible interference in the transmission between an MS and BSs. The interference can be roughly classified into three categories: 1) Cell edge interference: the co-channel interference imposed on a cell edged MS from several BSs; 2) Sector interference: an MS suffers the co-channel interference generated from different sectors on the same BS and 3) Data transmission interference: in TDD/FDD, the interference generated from the data transmission in the DL and UL. We define'cell edge zone' in the DL control channel to reduce the interference in the Cell Edge Interference while we use the orthogonal pilots in the DL and UP transmission to reduce other two kinds of interferences.

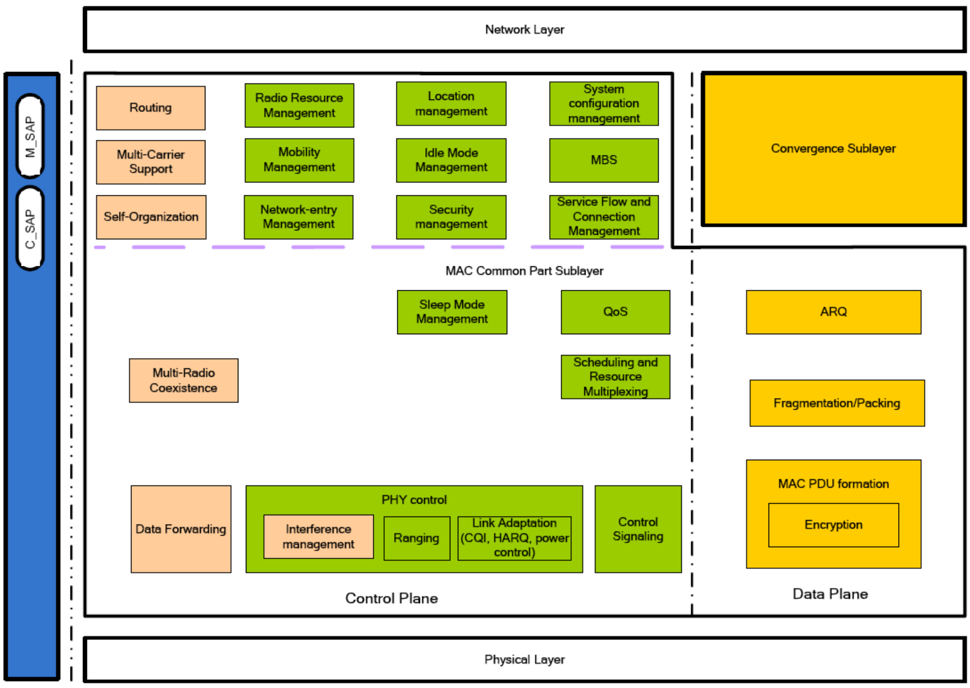


Fig. 1 The IEEE 802.16m Protocol Structure

2. Interference Types

Four types of interferences are considered and discussed in the following. From interference characteristics, it can be divided into two classes, namely, 1) the interference generated due to the location of the MS, e.g., the interference generated when the MS is located at the cell edge or sector edge and 2) the interference generated between MS and BS or between MS and MS when data is transmitted in the DL and UL.

2.1 Interference Generated Due to the MS Location

2.1.1 MS in the Cell Edge

If the MS is located in the Cell Edge, the user's signal power strength is lower, it may get another BS's interference.

As shown in Fig. 2, when the MS is located in the cell edge, its received signal level from the serving BS is low it mal suffer high power interference from other BS due to the near-far effect.

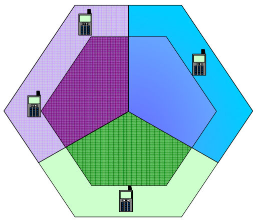


Fig. 2 The interference for MS in the BS cell edge

2.1.2 MS located at sector boundary

As shown in Fig. 3, when the MS is located at the sector edge it will suffer interference generated from other sector besides the signal it receives from the serving sector.

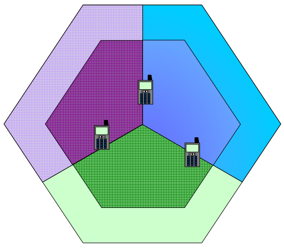


Fig. 3 The interference of MS at the BS sector edge

2.2 Interference between BS and MS or between MS and MS

2.2.1 Data Transition Interference in TDD

In Fig.4 it depicts the interference generated when data is transmitted in the TDD mode. In the same sector and when different MSs are in the data transitions and transmit data simultaneously in the DL and UL MSs may suffer interferences.

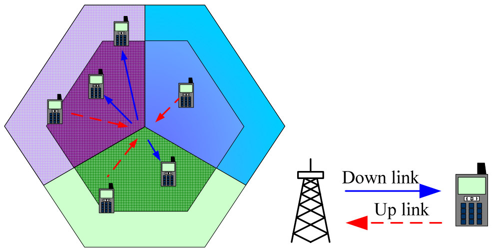


Fig. 4 Data Transition Interference in TDD

2.2.2 Data transition interference in FDD

In Fig.5 it depicts the interference generated when data is transmitted in the FDD mode. In the same sector and when different MSs are in the data transitions and transmit data simultaneously in the DL and UL MSs may suffer interferences.

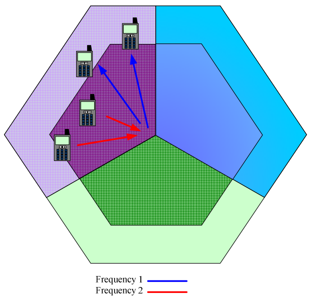


Fig. 5 Data Transition Interference in FDD

3. PHY Control for Interference Management

Based on the interferences as introduced in section 2, we will define in this section some interference management methods in the DL/UL control channel so as to reduce the interferences in the data transmission between the MS and the BS.

3.1 Frame Structure for Control Channel

The general control channel structure for 802.16m is shown in Fig. 6. There are five types of control channels:

1) **SFH (Super Frame Header)**: the SFH is used for the transmission of the information such as the synchronization, frequency reference, cell ID etc
2) **FH (Frame Header)**: the FH will identify which frame should activate an IR-Zone, and when this IR-Zone is activated the MS in this zone will receive the interference reducing service.
3) **SFM (Sub-frame Map)**: the SFM is used to designate which MSs in this zone need the interference reducing service. The MS designated can be a group of MSs or a single MS. It gives MS the information of the zone location, the orthogonal pilot pattern and it also will provide the relative location information of the UL- Zone.
4) **IR-Zone (Interference Reducing Zone)**: this zone is activated by the BS and it can be divided into UL and

DL IR-zones. The zone's size and location are designated by the FH and the SFM and it also serves those MSs that need interference reducing services.

5) **UL-IRR (Uplink–interference Reducing Request)**: the MS will send the instant interference reducing request in this frame and the BS will include this MS which sends this request in the IR-Zone in the next frame.

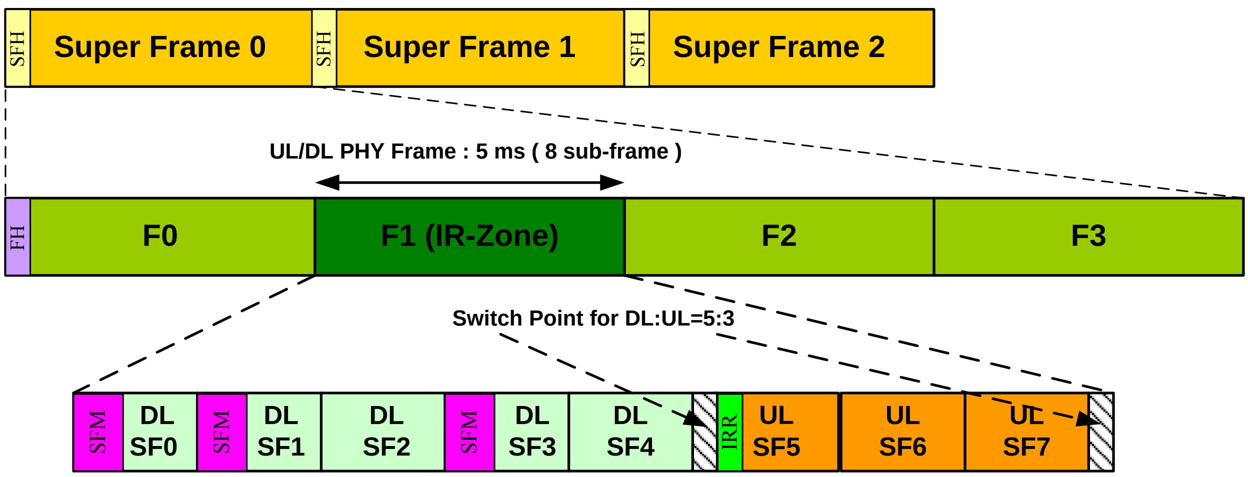
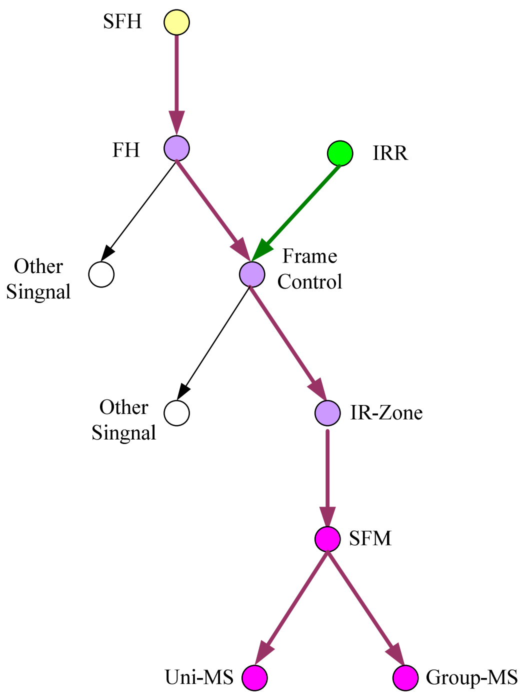
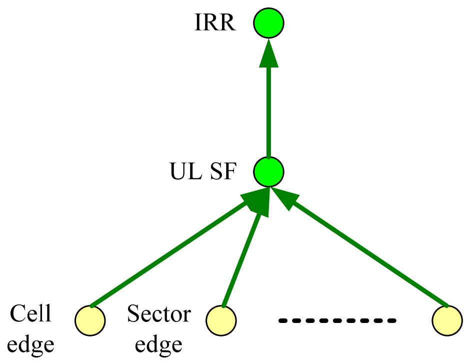


Fig. 6 Control channel structure for 802.16m

a. DL control flow for interference management



b. UL control flow for interference management



3.2 DL/UL Control Channel for Inference Management

Some extra information is included in the DL and UL control channels. As shown in Fig. 7 we include some interference management information in the DL control channel. In the DL control channel, the super frame header contains the system information elements such as the frequency reference, cell ID, system bandwidth, CP length…etc. In frame header it contains the DL and UL parameters that to locate the users position and to identify it is in the IR-Zone.

For MS locating in this IR-Zone, the MS can be an MS in a group or a unique MS. When this zone exists, it will exist a specific Sub-Frame Header. In this SFM it contains the information of SFM, and it also provides the location of the information of the MS, which has accepted this kind of service, and the pilot pattern for using in the interference reducing. Cell management information is also included in the UL control signal, as shown in Fig. 8, when the MS is in the IR-zone it will add an IRR signal in the UL control subframe. When BS receives this IRR signal it will add this MS in its designated IRR zone in the next frame and then the BS will determine from this IRR the pilot structure will be used in its data transmission.

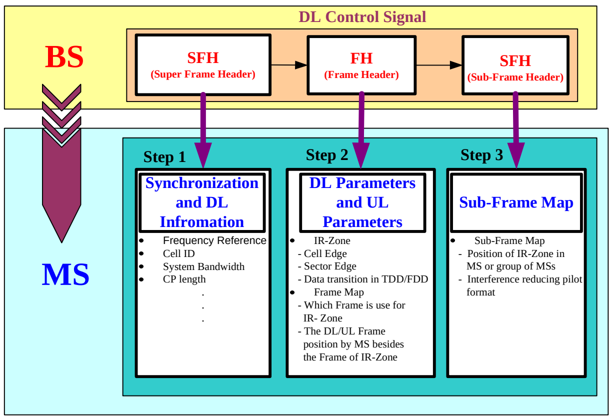


Fig. 7 Cell Management Information in the DL control Channel

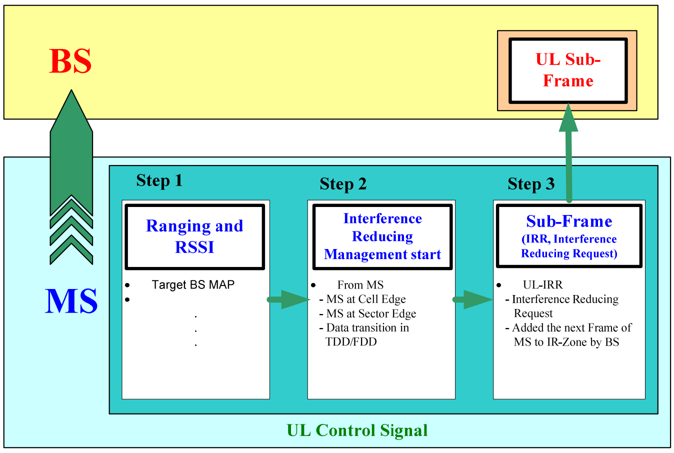


Fig 8. Cell Management Information in the UL control

1) *Example for cell edge MS Cell in using IR-Zone*

As shown in Fig. 9, it occupies the same frequency band in cell 1 and cell 2. When an MS is in the cell edge (Zone B) it will suffers the interference from cell 2, similarly the MS in the cell 2 edge, Zone B, it will have interference generated from cell 1. In this situation when the MS transmits an IRR request, this IRR request will be added into the IR-Zone in next frame and it will use a pilot pattern that is orthogonal to or has minimum interference to the pilot pattern used in cell 2. For example in Fig. 9 if the MS in SF7 has the IRR signal added and send an IRR request to cell1 then cell 1 in the next frame will add this MS in the IR-Zone, SF1 or SF2. Then in Fig. 10 this MS is in the IR-Zone then the SFM will indicate the location of this MS in the IR-Zone and also provides its pilot pattern, while an MS not in the IR-Zone, it will be controlled by the Frame MAP.

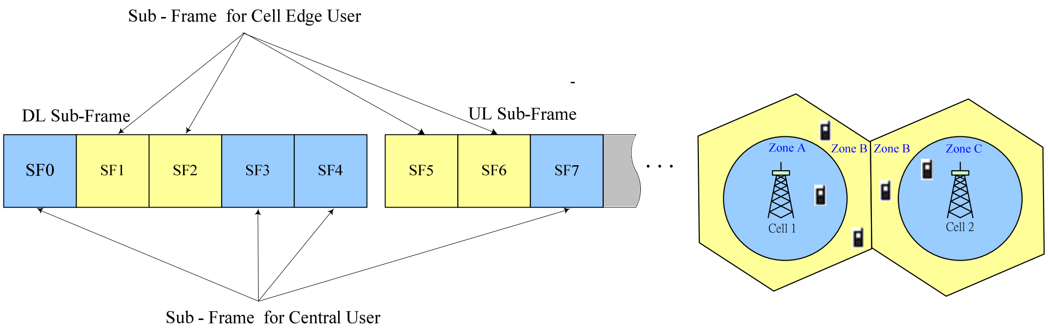


Fig 9. Different sub-frames are allocated for users with different levels of interferences

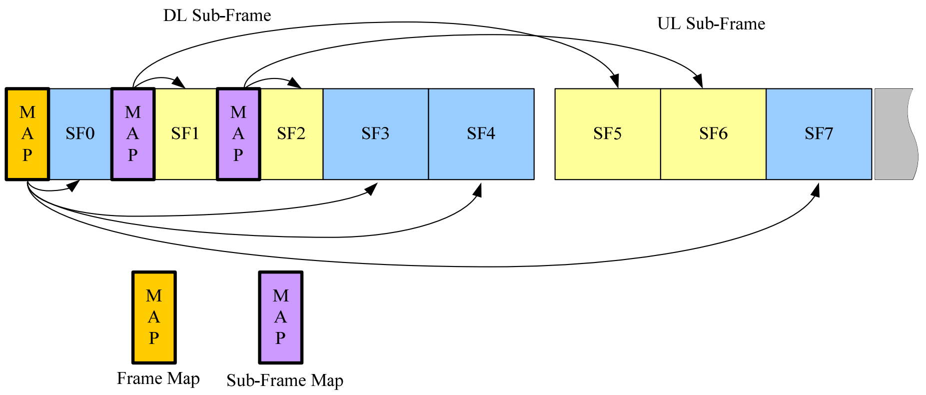


Fig 10. MAP Define for Cell Edge User and Central User

4. *Example for Interference Reducing Pilot*

Several examples will be given in this section to illustrate how the MS sends the signal to ask for the IRR request and how the BS adds this MS in the IR-Zone and then design the pilot pattern for the MS already existing in the IR-Zone.

4.1 Two Types of Interference Reducing Pilots

1) Square Type Pilot

As shown in Fig. 11, four pilots in a square are allocated for a resource block with 18 sub-carriers and 6 symbols, 18*6, and are identified with gray colors.

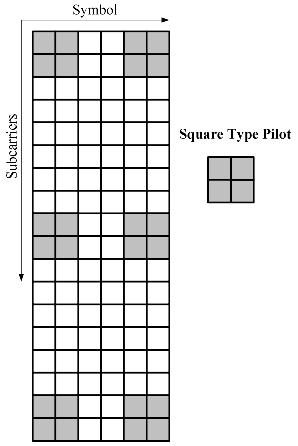


Fig 11. Square Type Pilot

2) Line Type Pilot

As shown in Fig. 12, four pilots in straight line are allocated for a resource block with 12 sub-carriers and 6 symbols, 12*6, and are identified with gray colors.

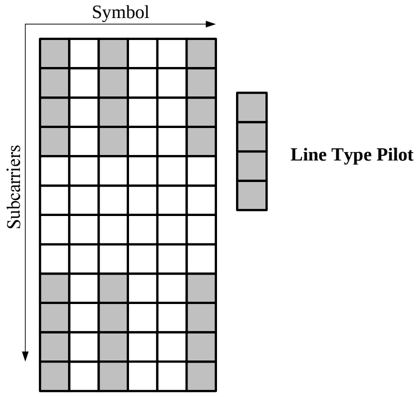


Fig 12. Line Type Pilot

4.2 Interference Reducing Pilot Pattern vs. Interference weight

With the pilot patterns considered for the two types of resource block as defined in section 4.1, we will then illustrate the relationship between the pilot pattern and the interference weight.

4.2.1 Square Type Pilot

For square type pilot the interference weight assignment for various types of pilot pattern are shown in Fig.13-A and the interference weights between pilot patterns permutated from the square type pilot are shown in Table 1-A.

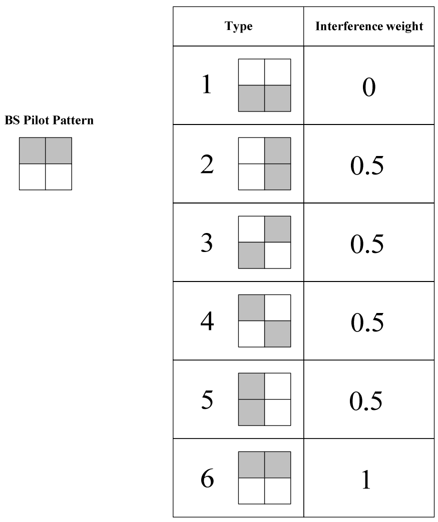


Fig. 13-A Interference weight assignment for square type pilot pattern

Table 1-A Interference weights between all pilot patterns permutated from square type pilot

IR Pilot_MT / Pilot_BS	1	2	3	4	5	6
1	1	0.5	0.5	0.5	0.5	0
2	0.5	1	0.5	0.5	0	0.5
3	0.5	0.5	1	0	0.5	0.5
4	0.5	0.5	0	1	0.5	0.5
5	0.5	0	0.5	0.5	1	0.5
6	0	0.5	0.5	0.5	0.5	1

4.2.2 Line Type Pilot

For line type pilot the interference weight assignment for various types of pilot pattern are shown in Fig.13-B and the interference weights between pilot patterns permutated from the line type pilot are shown in Table 1-B.

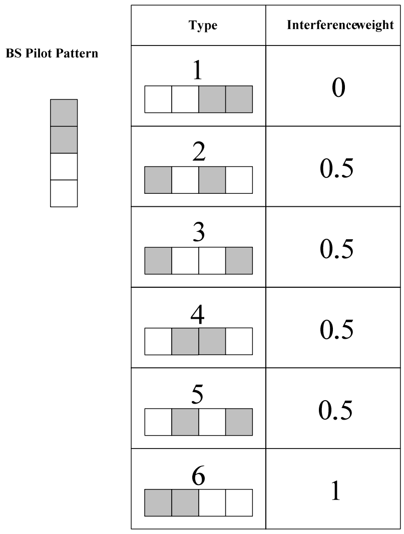


Fig. 13-B Interference weight assignment for line type pilot pattern

Table 1-B Interference weights between all pilot patterns permutated from line type pilot

IR Pilot_MT / Pilot_BS	1	2	3	4	5	6
1	1	0.5	0.5	0.5	0.5	0
2	0.5	1	0.5	0.5	0	0.5
3	0.5	0.5	1	0	0.5	0.5
4	0.5	0.5	0	1	0.5	0.5
5	0.5	0	0.5	0.5	1	0.5
6	0	0.5	0.5	0.5	0.5	1

4.3 Pilots Assignment in TDD/FDD

4.3.1 Pilots Assignment in TDD

1) In Fig 14, it shows the assignments of orthogonal pilot patterns for the down and up links in the TDD multiplexing. For example in Sector A, down link has assigned the Type 1 pilot pattern while it is assigned the pilot pattern 6 for the up link assignment, and these two pilots are orthogonal each other.

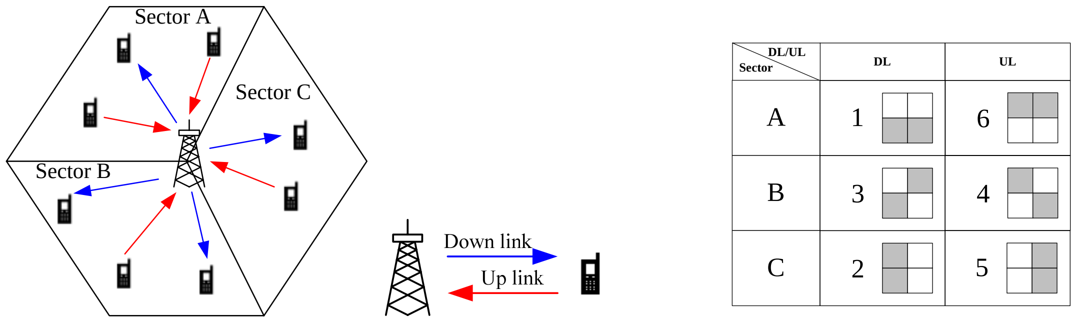


Fig. 14 Pilot assignments in TDD segments

Based on the pilot patterns assignment as illustrates in Fig. 14 we have in Fig. 15 the orthogonal pilot patterns assignment in one sector for the up and down link subframes.

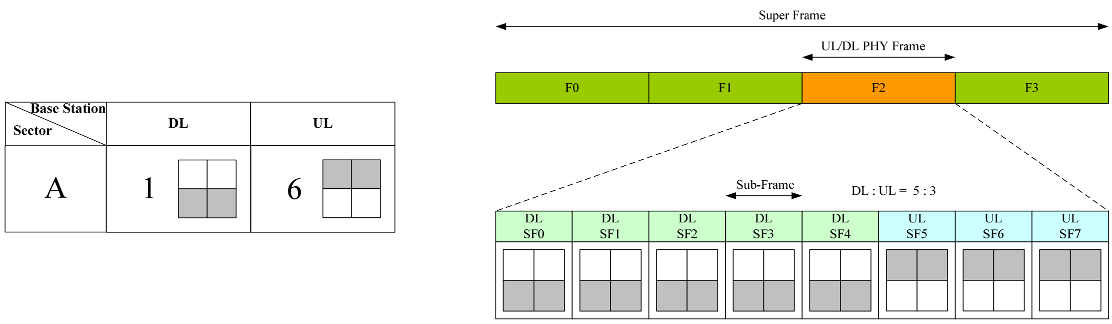


Fig. 15 Pilots assignment in TDD subframes

2) In TDD multiplexing, three groups of orthogonal pilot patterns are assigned for the down and up links in various three clusters as shown in Fig. 16. For example in Cluster 1, down link is assigned type 1 pilot pattern is assigned for the down link while it is type 6 pilot pattern assigned for the up link. In Table 3 it tabulates the interference weight between the pilot patterns assigned for the down and up links among various clusters.

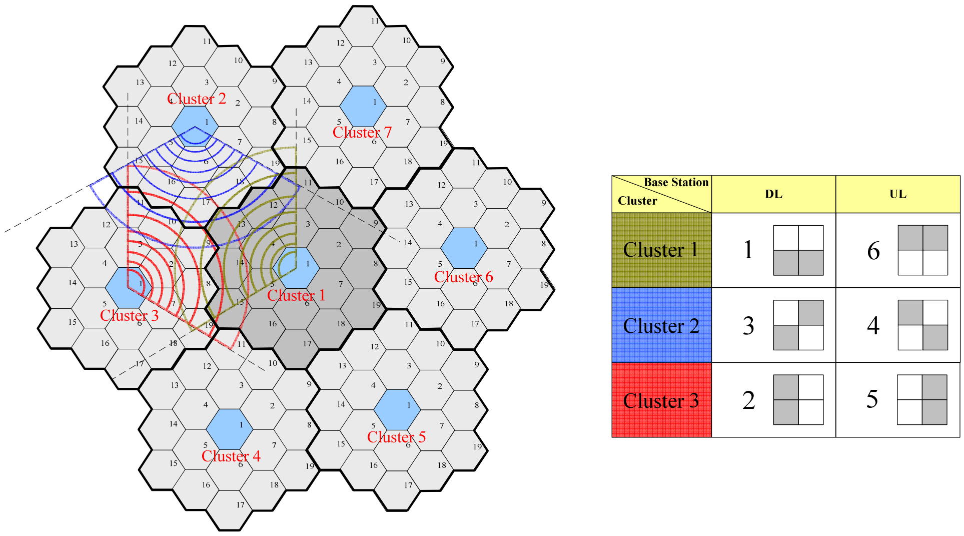


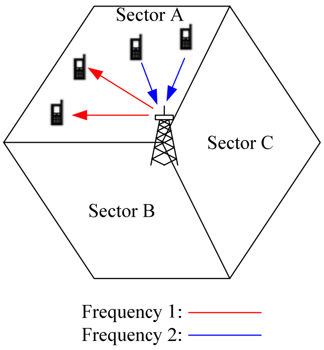
Fig 16. Pilots Assignment in TDD

Table 3 Interference weight for the pilot patterns assigned between the down and uplinks for the three clusters considered

Interference Weight		Cluster 1		Cluster 2		Cluster 3	
		DL	UL	DL	UL	DL	UL
Cluster 1	DL		0	0.5	0.5	0.5	0.5
	UL	0		0.5	0.5	0.5	0.5
Cluster 2	DL	0.5	0.5		0	0.5	0.5
	UL	0.5	0.5	0		0.5	0.5
Cluster 3	DL	0.5	0.5	0.5	0.5		0
	UL	0.5	0.5	0.5	0.5	0	

4.3.2 Pilots Assignment in FDD

In FDD structure, we assign orthogonal pilot patterns for down link, with frequency 2, and up link, with frequency 1. For example in frequency 1 (assigned for the down link, user 1 is assigned the pilot pattern 1 while user2 is assigned the type 6 pilot pattern, they are orthogonal each other.



User / Frequency	User 1	User 2
1	1	6
2	3	4

Fig.17 Pilot pattern assignment in FDD multiplexing

Based on the pilot patterns assignment as illustrates in Fig. 17 for FDD we have in Fig. 18 for frequency 1 and frequency 2 the orthogonal pilot patterns assignment for the up and down link subframes.

User / Frequency	User 1	User 2
1	1	6
2	3	4

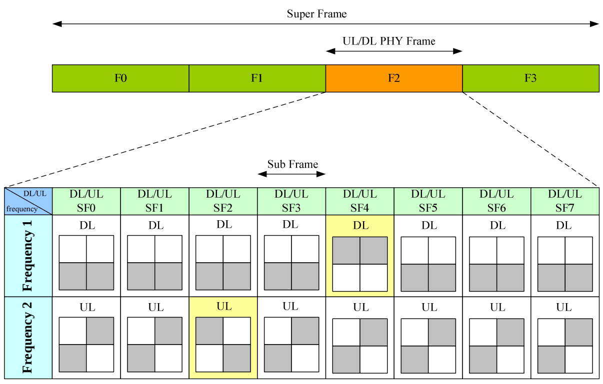


Fig.18 Pilot pattern assignment for down link and uplink subframes in FDD multiplexing

4.3.3 Cell edge interference management

In the cell edge zone as shown in Fig. 19, the MS will receive signals not only from the serving BS but also from other BS, therefore interference will be introduced. Orthogonal pilot patterns, as defined in Fig. 20, can be used to reduce this cell edge interference.

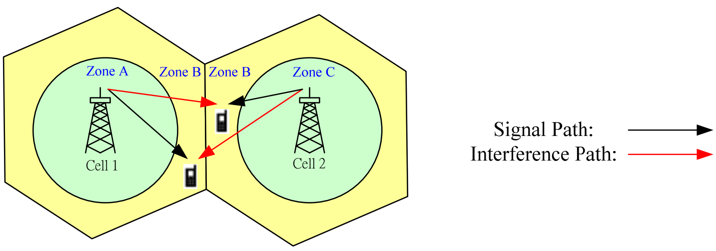


Fig 19. Cell edge interference

Base Station / Case	Cell 1	Cell 2	Interference weihgt
A	1	6	0
B	3	4	0
C	4	3	0
D	6	1	0
E	2	5	0
F	5	2	0

Fig.20 Orthogonal pilot pattern assignment for cell 1 and cell 2 when the MS is located at the cell edge

5. *Simulation Results*

Simulations will be conducted by applying the pilot patterns derived from the interference reducing effect will to the 802.16 m to study its system performance.

1) Using Interference Reducing Pilot structure by different BS

By considering seven (7) base stations with frequency reuse factor 1 we will evaluate the resulting interference performance with or without using the interference reducing pilot patterns.

Table 4: Simulation environment for frequency reuse factor = 1

Parameter	***Value***
Carrier Frequency	2.5 GHz
System BW	10 MHz
BS Antenna Gain	17dB
MS Antenna Gain	0dB
BS height	32 M
MS height	1.5 M
Path Loss model	COST231 Hata model
Cell radius	500 M
Number of BS	7
Frequency reuse factor	1

In Fig.21, No. 4 BS is the serving base station for the MS while the neighbor base station, No.1 BS, introduces the highest interference to the MS. We can use in this example the orthogonal pilots between the serving BS and this neighboring BS to reduce the interference.

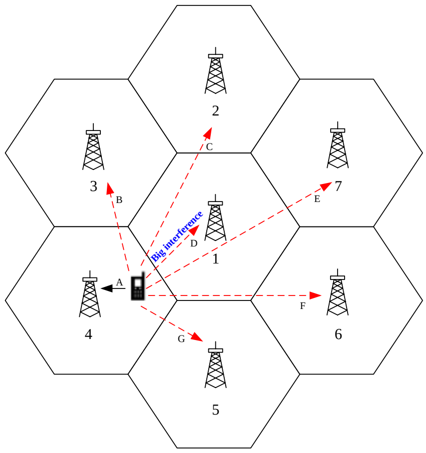


Fig. 21 Interference introduced from neighboring BSs to the MS

Table 5 Pilot assignments for different BSs

No. BS	Type	Sensitivity (dBm)
4		-119.6224
1		-131.9415
5		-135.7063
3		-135.7182
6		-143.4239
2		-143.4282
7		-145.5291

Serving BS = No. 4   Target BS = No. 1

Lets us define in Fig. 21 the signal paths A~G as the various communication paths from the base stations to the MS and with various interference weights assigned to each path:

A. Signal path, the desired signal path

B. Interference path (interference weight: 0.5)

C. Interference path (interference weight: 0.5)

D. Interference path (interference weight: 0)

E. Interference path (interference weight: 0.5)

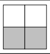
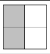
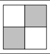
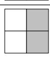
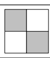
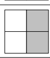
F. Interference path (interference weight: 0.5)

G. Interference path (interference weight: 0.5)

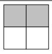
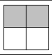
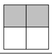
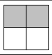
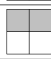
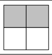
In Table 6 it tabulates the resulting interference levels when using the interference reducing pilots for the BSs and the interference levels introduced from BSs when a common pilot pattern is used for all BSs.

Table 6 Resulting Interference levels by using interference reducing pilots for BSs and by using common pilots for all BSs

IR Pilot

No. BS	Type	Sensitivity (dBm)	Interference weight
1		-131.9415	0
2		-143.4282	0.5
3		-135.7182	0.5
5		-135.7063	0.5
6		-143.4239	0.5
7		-145.5291	0.5

Common Pilot

No. BS	No. BS	Sensitivity (dBm)	Interference weight
1		-131.9415	1
2		-143.4282	1
3		-135.7182	1
5		-135.7063	1
6		-143.4239	1
7		-145.5291	1

Pattern	Serving BS interference (dBm)
IR Pilot	-132.3239
Common Pilot	-126.3570

2) Using Interference Reducing Pilot structure by different Cluster

In another example we consider the system with 19 base stations and with 19 reuse factors to compare the resulting interference levels with and without the use of interference reducing pilot patterns. The simulation parameters are listed in Table 7.

Table 7: Simulation environment for frequency reuse factor = 19

Parameter	***Value***

Carrier Frequency	2.5 GHz
System BW	10 MHz
BS Antenna Gain	17dB
MS Antenna Gain	0dB
BS height	32 M
MS height	1.5 M
Path Loss model	COST231 Hata model
Cell radius	500 M
Cluster	7
Number of BS	19
Frequency reuse factor	19

In Fig.22 the user's serving base station is assumed to be the cluster #3 and cluster #1 is considered to introduce the highest interference level to the MS. Orthogonal pilot patterns are assigned between clusters 3 and 1 while other clusters use the other remaining pilot patterns as shown in Table 8.

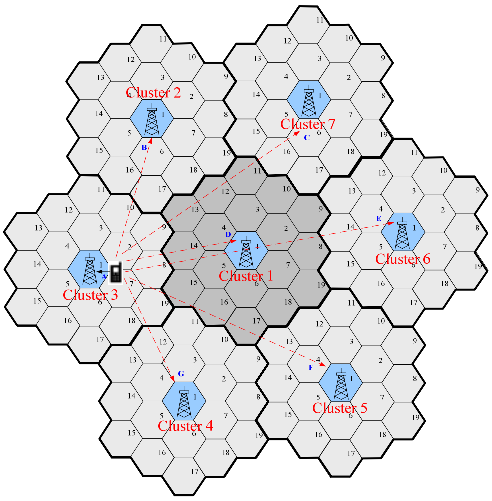
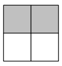
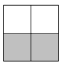
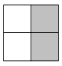
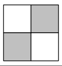
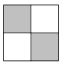
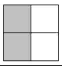
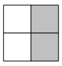


Fig. 22 MS uses the same frequency to communicate with all cluster BSs.

Table 8 Pilots assignment for different clusters

Cluster	Type	Sensitivity (dBm)
3		-135.4475
1		-156.5196
2		-158.5863
4		-158.5863
5		-166.6907
7		-166.6907
6		-168.8460

Lets us define in Fig. 22 the signal paths A~G as the various communication paths from the base stations to the MS and with various interference weights assigned to each path:

A. Signal path: the desired signal path

B. Interference path (interference weight: 0.5)

C. Interference path (interference weight: 0.5)

D. Interference path (interference weight: 0)

E. Interference path (interference weight: 0.5)

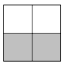
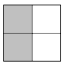
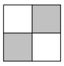
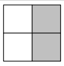
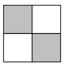
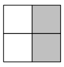
F. Interference path (interference weight: 0.5)

G. Interference path (interference weight: 0.5)

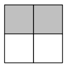
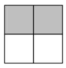
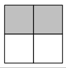
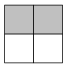
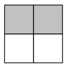
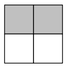
In Table 9 it tabulates the resulting interference levels when using the interference reducing pilots for the BSs and the interference levels introduced from BSs when a common pilot pattern is used for all BSs.

Table 9 Resulting Interference levels by using interference reducing pilots for BSs and by using common pilots for all BSs

IR Pilot

No. Cluster	Type	Sensitivity (dBm)	Interference weight
1		-156.5196	0
2		-158.5863	0.5
4		-158.5863	0.5
5		-166.6907	0.5
6		-168.8460	0.5
7		-166.6907	0.5

Common Pilot

No. Cluster	No. BS	Sensitivity (dBm)	Interference weight
1		-156.5196	1
2		-158.5863	1
3		-158.5863	1
5		-166.6907	1
6		-168.8460	1
7		-166.6907	1

Pattern	Cluster interference (dBm)
IR Pilot	-138.4283
Common Pilot	-135.3844

6. Conclusion

When we introduced the Interference reducing pilots for the various communication links we have the results of reducing

(a) the interference level by 6 dB when the frequency reuse factor is1, and

(b) the interference level by 3 dB when the frequency reuse factor is 19.

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