Inter-Cell Interference Management in DL/UL PHY Control for IEEE802.16m

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Abstract—**Some interference management measures in the PHY Control to reduce possible interferences in the transmission between an MS and BSs are proposed. The design and assignment procedures to generate pilots to have lower interference levels are introduced and discussed. Based on the design process each pilot is accordingly assigned an interference weight with respect to a basic pilot and with this design in the system simulation by utilizing the generated pilots to IEEE 802.16m system it reveals that the system performance has 7.5 dB and 23 dB advantages in the interference levels for 7 BSs and 19 BSs respectively comparing with the conventional pilot design that assigns the pilots with the same interference weight for all BSs.**

Keywords- TDD (Time-division duplex), FDD (Frequency –division duplex), SFH (Super Frame Header), FH (Frame Header), FM (Frame Map), SFM (Sub-Frame Map), IR-Zone (Interference Reducing Zone), UL-IRR (Uplink-interference Reducing Request)

I. INTRODUCTION

In this paper we propose some interference management measures in the PHY Control to reduce the possible interference in the transmission between an MS and BSs [1-6]. The interference can be roughly classified into two categories: 1) Location-oriented interference: it further can be divided into two types of interferences, the cell edge interference and the sector interference. In the cell edge interference, an MS located in a cell edge zone suffers interference from several BSs. In the sector interference, an MS suffers interference from different sectors on the same BS [7-11]. 2) Cross link interference in TDD (Time-division duplex)/FDD (Frequency-division duplex): the interference generated from data transmissions between various downlinks and uplinks and also in data transmissions when they are in the transition between DL and UL or vice versa. In order to reduce various kinds of interference we introduce various interference reducing pilot types and assign interference weight for every pilot type. Then in communication paths between an MS and various BSs that it includes a desired path between the MS and the desired BS and many interference paths between the MS and other BSs, and when we assign various interference weight pilot types to the BSs, the resulting interference will be lower comparing with the interference induced in the system by using the conventional common interference weight pilots for all BSs.

II. INTERFERENCE TYPES

In general interferences can be divided into two classes, namely, 1) Location-oriented interference: the interference is generated when the MS is located at the cell edge or at the sector edge and 2) Link-oriented interference: the interference is generated between an MS and a BS when data is transmitted both in the DL and UL.

A. Interference Generated Due to the MS Location

- MS is located in the cell edge zone: when the MS is located in the cell edge its received signal level, due to the near-far effect, from the serving BS may be lower than the interferences generating from other BSs.
- MS is located at sector boundary: when the MS is located at the sector boundary it will suffer interferences generating from other sectors besides the signal from the serving sector.

B. Interference between BSs and an MS or between an MS and other MSs

- Data transition interference in TDD: When different MSs are in the same sector and transmitting and receiving data simultaneously in the UL and DL in TDD mode, they may suffer the data transition interference when those MSs are in the time transition duration.
- Data transition interference in FDD: When different MSs are in the same sector and transmitting and receiving data simultaneously in the UL and DL in the FDD mode, they may suffer the data transition interference when those MSs are in the frequency transition interval.

III. PHY CONTROL FOR INTERFERENCE MANAGEMENT

Based on the interferences as introduced in section Ⅱ, 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 an MS and a BS.

We introduce and define six types of control channels for IEEE802.16m: 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

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activate an IR-Zone (Interference Reducing Zone), and when an IR-Zone is activated then the MS in this zone will receive the interference reducing service. 3) FM (Frame Map): this FM is used to designate MSs' locations in the sub-frame for those MSs are not in the IR-Zone. 4) SFM (Sub-Frame Map): the SFM is used to designate which MSs in this IR-Zone need the interference reducing service. The MS designated can be a group of MSs or a single MS. It gives the MS the information of the zone location, the orthogonal pilot pattern and it also will provide the relative location information of the UL IR-Zone. 5) IR-Zone: this zone is activated by the BS; it can be divided into UL and DL IR-zones. The zone's size and location are described in the FH and the SFM; it also serves those MSs that need interference reducing services. 6) UL-IRR (Uplink-Interference Reducing Request): the MS will send an interference reducing request in this frame and the BS will include this MS which sends this request in the IR-Zone in the next DL frame. These control channel structure is shown in Fig. 1. The downlink message or information conveyed from the superframe to the subframe as described in the above control channel can be described schematically as in Fig.2. The uplink controls the flow of the MS sending the Interference reducing request (IRR) to the BS as described in the control channel in the above can be described schematically as in Fig.3.

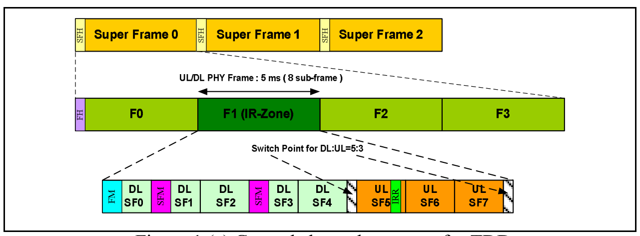

Figure 1 (a) Control channel structure for TDD

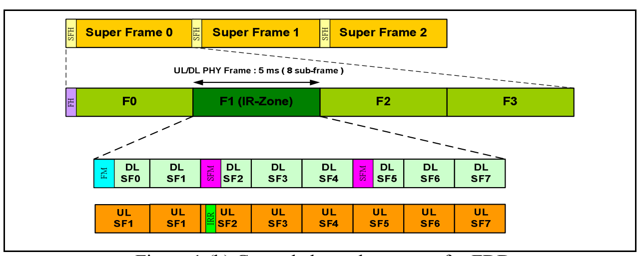

Figure 1 (b) Control channel structure for FDD

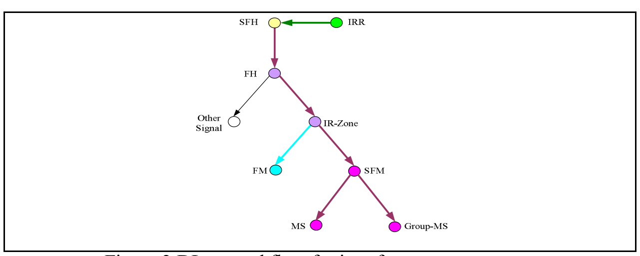

Figure 2 DL control flow for interference management

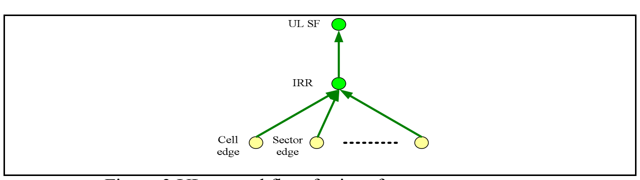

Figure 3 UL control flow for interference management

A. DL/UL Control Channel for Interference Management

Some extra message/information is included in the conventional DL and UL control channels. As shown in Fig.4 we include some interference management information in the DL control channel. In the DL control channel, the superframe header contains the system information elements such as the frequency reference, cell ID, system bandwidth, CP (Cyclic Prefix) length etc. In frame header it contains the DL and UL parameters that to locate the user's position and to identify if 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 contains a specific Subframe Header (SFH). In this SFH it contains the information of SFM, and it also provides the location information of the MS, which has been accepted for this kind of service, and the pilot pattern for the MS to use in the interference reducing management. Cell management information is also included in the UL control signal, as shown in Fig.5, 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.

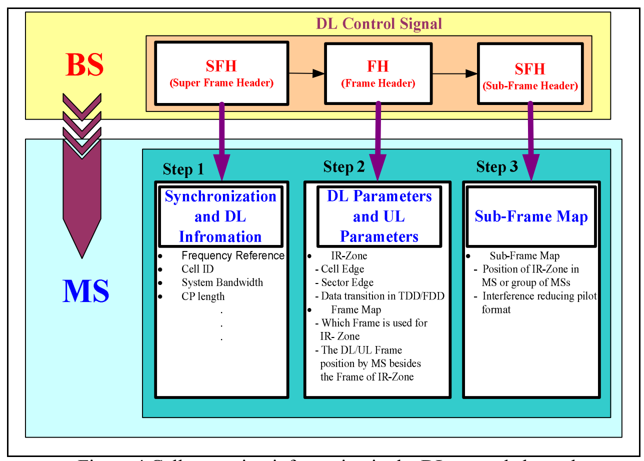

Figure 4 Cell managing information in the DL control channel

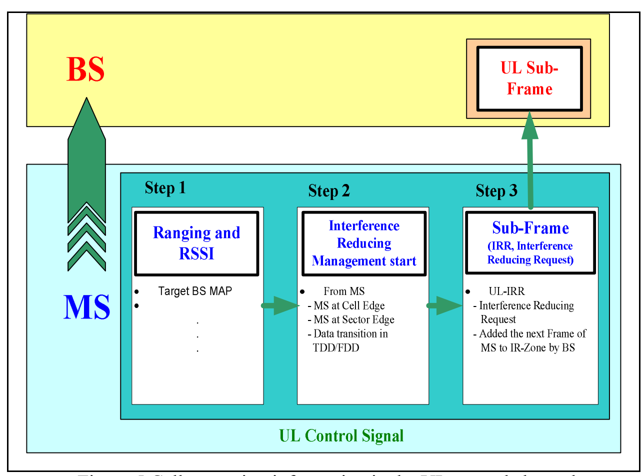

Figure 5 Cell managing information in the UL control channel

IV. Interference Reducing Pilot

A. *Two Types of Interference Reducing Pilots, Square Type Pilot and LineTypePilot,are Considered*

1) *Square type pilot:* The square type pilot, as shown in Fig.6 in gray, consisting of four pilots in the square is the basic constituent block for the 18 x 6 resource block that consists of 18 subcarriers and 6 symbols.

2) *Line type pilot:* The line type pilot, as shown in Fig.7 in gray, consisting of four pilots in a line is the basic constituent block for the12 x 6 resource block that consists of 12 subcarriers and 6 symbols.

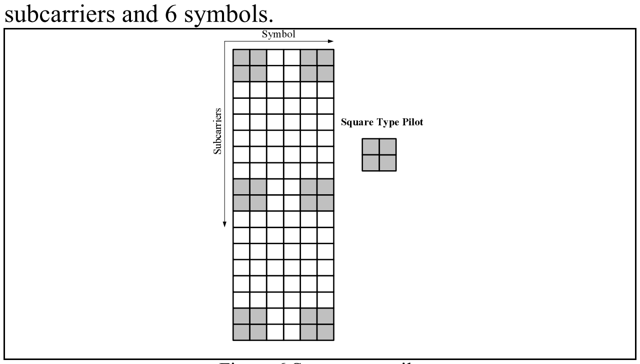

Figure 6 Square type pilot

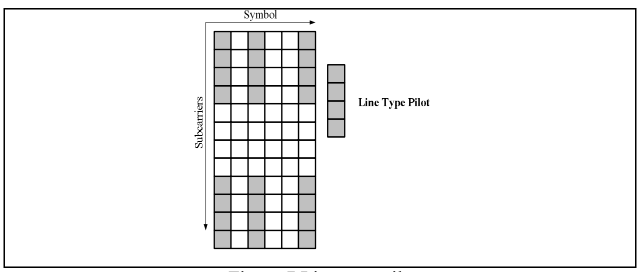

Figure 7 Line type pilot

B. *Interference Reducing Pilot Pattern vs. Interference Weight*

As shown in Fig. 8 for square type pilot we illustrate the assignment of interference weight between a pilot type and a reference pilot pattern. For example in considering the weight assignment for type 1 pilot, it has the blue stream in the same symbol and same subcarrier locations as the reference pilot it is assigned the weight 0.5 and similarly condition for the red stream therefore it has total weight of 0.5+0.5 =1. For type 2 pilot for the blue stream it has the same symbol location and the same subcarrier location with the reference pilot it has weight 0.5 while for the red stream it is in the same symbol location but in different subcarrier location with the reference pilot it is assigned the weight 0.1and consequently it has a total weight of 0.6. For type 4 pilot; for the blue and red streams they are in the same symbol location but in different subcarrier location with the reference pilot they have weight 0.4 + 0.4 = 0.8. In summary, if a pilot type has the same symbol and subcarrier locations with the reference pilot it has pilot weight 0.5; if it is in the same subcarrier location but in different symbol location it is assigned the weight 0.4; while for pilot type if it is in the same symbol location but in different subcarrier location with the reference pilot it has a weight 0.1 and finally if the pilot type has neither the same symbol location nor the same subcarrier location with the reference pilot then it is assigned the weight 0. The interference weight assignment for other pilot types in the figure can be similarly determined and then the determination of the interference weights for the line type pilot as shown in Fig. 9.

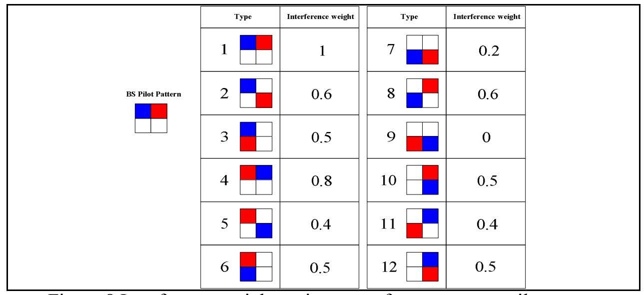

Figure 8 Interference weight assignments for square type pilot pattern

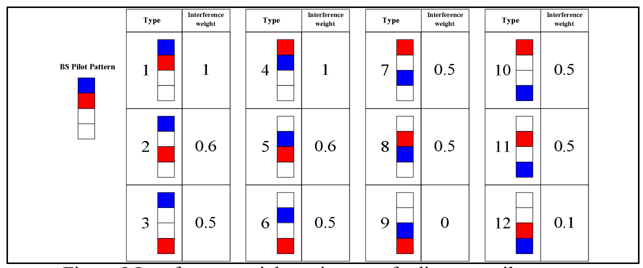

Figure 9 Interference weight assignment for line type pilot pattern

C. *Pilots Assignment in TDD/FDD*

1) *Pilot assignment in TDD:* In Fig.10, it shows the assignments of orthogonal pilot patterns for both DL and UL in the TDD multiplexing. For example in Sector A, downlink has assigned the Type 1 pilot while it is assigned the pilot Type 6 for the uplink assignment, and these two pilot types are orthogonal each other. Based on the pilot types assignment as illustrated in Fig.10 we have in Fig.11 the orthogonal pilot patterns assignment in one sector for UL and DL subframes.

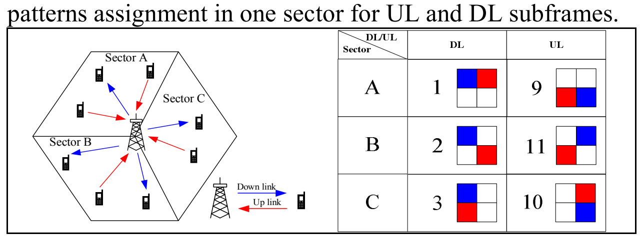

Figure 10 Pilot assignments in TDD segments

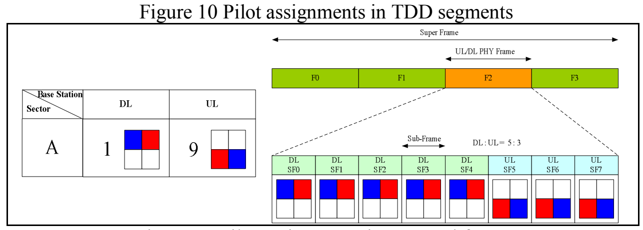

Figure 11 Pilot assignments in TDD subframes

2) *Pilot assignments in FDD:* In FDD structure, we assign orthogonal pilot pair for DL, transmitting with frequency 1, and assign another orthogonal pair of pilots for UL, transmitting with frequency 2. For example as shown in Fig.

12 in frequency 1 assignment for the DL, user 1 is assigned the pilot Type 1 while user 2 is assigned the Type 9 pilot, they are orthogonal each other. Based on the pilot type assignments as illustrated in Fig.12 for FDD and we have in Fig.13 for orthogonal pilot type assignment for the DL and UL subframes with frequency 1 and frequency 2 respectively.

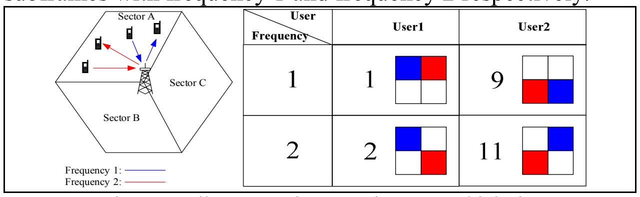

Figure 12 Pilot type assignments in FDD multiplexing

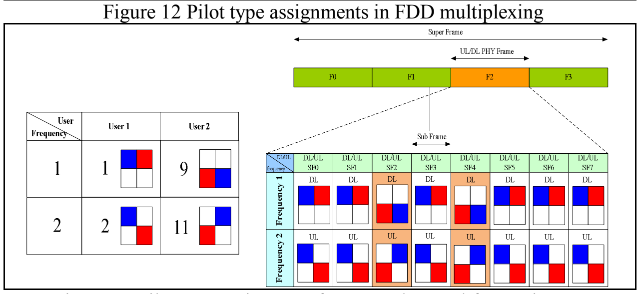

Figure 13 Pilot type assignment for DL and UL subframes in FDD multiplexing

3) *Cell edge interference management:* In the cell edge zone as shown in Fig.14, the MS will receive signals not only from the serving BS but also from other BSs, therefore interference will be introduced. Orthogonal pilot patterns, as defined in Fig.15, can be used to reduce this kind of cell edge interference.

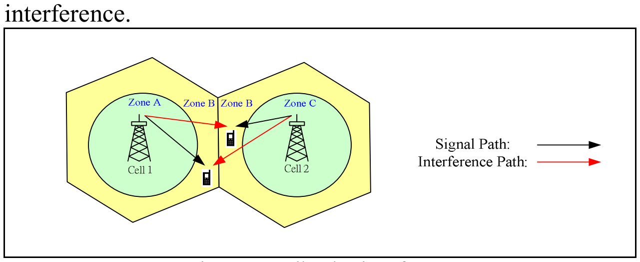

Figure 14 Cell- edge interference

Base Station / Case	Cell1	Cell2	Interference weihgt
A	1	9	0
B	2	11	0
C	3	10	0
D	4	7	0
E	5	8	0
F	6	12	0

Figure 15 Orthogonal pilot pattern assignments for cell 1 and cell 2 when the MS is located at the cell edge

V. SIMULATION

Simulations will be conducted by applying the pilot types derived from considering the interference reducing effect to the IEEE802.16 m to study its system performance.

A. Simulation for 7 BSs with Frequency Reuse Factor 1

By considering seven (7) base stations with frequency reuse factor 1 and with system simulation parameters as shown in Table□we simulate and compare the system performances by using the conventional pilots and the designed interference reducing pilots for the paths between the MS and various BSs.

TABLE I. SIMULATION PARAMETERS FOR FREQUENCY REUSE FACTOR 1

Parameter	Value
Carrier Frequency	2.5GHz
System BW	10MHz
BS Antenna Gain	17dB
MS Antenna Gain	0dB
BS Height	32M
MS Height	1.5M
Path Loss Model	COST231 Hata Model
Cell Radius	500M
Number of BS	7
Frequency Reuse Factor	1

In Fig.16, No. 4 BS is the serving base station for the MS considered while the neighboring base station, No.1 BS, introduces the highest interference to the MS. We can in this example use a pair of orthogonal pilots for the serving BS and this neighboring BS to reduce the resulting interference.

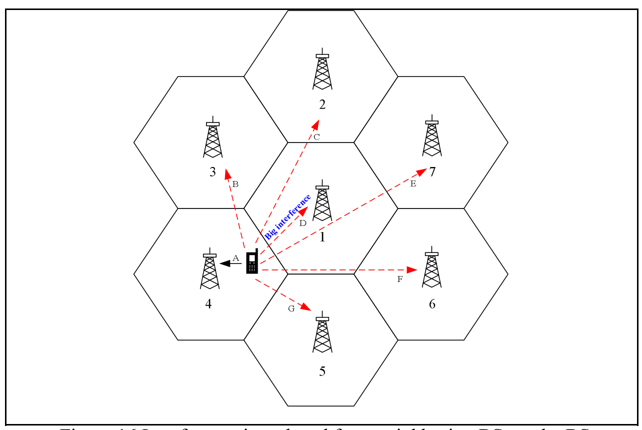

Figure 16 Interference introduced from neighboring BSs to the BS

Let us define in Fig.16 the signal paths A ~ G as the communication paths from various base stations to the MS, the resulting interference weight in each path is described in the following. The BS has the pilot type with its associated resulting interference weight assigned are shown in Table II.

- A: signal path, the desired signal path.
- B: interference path (interference weight: 0.4).

- 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: 0.6).
- G: interference path (interference weight: 0.2).

TABLE II. PILOT TYPE ASSIGNMENTS FOR 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

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

TABLE III. RESULTING INTERFERENCE LEVELS BY USING AND WITHOUT USING INTERFERENCE REDUCING PILOTS FOR BSS

IR Pilot				Common Pilot			
No. BS	Type	Sensitivity (dBm)	Interference weight	No. BS	No. BS	Sensitivity (dBm)	Interference weight
1		-131.9415	0	1		-131.9415	1
2		-143.4282	0.5	2		-143.4282	1
3		-135.7182	0.4	3		-135.7182	1
5		-135.7063	0.2	5		-135.7063	1
6		-143.4239	0.6	6		-143.4239	1
7		-145.5291	0.5	7		-145.5291	1

Pattern	Serving BS interference (dBm)
IR Pilot	-136.4793
Common Pilot	-128.8767

B. *Simulation for 19 BSs with Frequency Reuse Factor 19*

In another example we consider is a system with 19 base stations and with Frequency Reuse Factor 19 to compare the interference levels by using the conventional pilots and the designed interference reducing pilots for BSs for the paths between the MS and various BSs.

The system parameters used in the simulation are listed in Table IV.

In Fig.17 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 types are assigned between clusters 3 and 1 while other clusters use other remaining pilot types are shown in Table V.

TABLE IV. SIMULATION PARAMETERS FOR FREQUENCY REUSE FACTOR 19

Parameter	Value
Carrier Frequency	2.5GHz
System BW	10MHz
BS Antenna Gain	17dB
MS Antenna Gain	0dB
BS Height	32M
MS Height	1.5M
Path Loss Model	COST231 Hata Model
Cell Radius	500M
Cluster	7
Number of BS	19
Frequency Reuse Factor	19

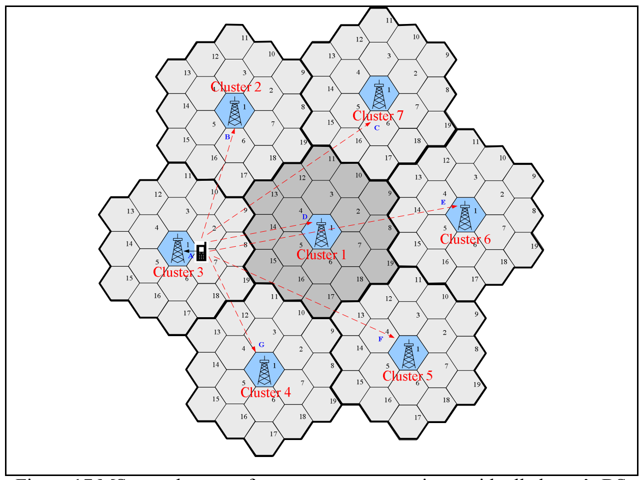

Figure 17.MS uses the same frequency to communicate with all cluster's BSs

TABLE V. PILOTS ASSIGNMENTS 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

Let us define in Fig.17 the signal paths A ~ G as the communication paths from the base stations to the MS and the resulting interference weight in each path is described in the following. The BS has the pilot type with its associated interference weight assigned as shown in the Table V.

- 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: 0.6).
- F: interference path (interference weight: 0.2).
- G: interference path (interference weight: 0.4).

In Table VI 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 VI. RESULTING INTERFERENCE LEVELS BY USING AND WITHOUT USING INTERFERENCE REDUCING PILOTS FOR BSS

IR Pilot

No. Cluster	Type	Sensitivity (dBm)	Interference weight
1		-156.5196	0
2		-158.5863	0.5
4		-158.5863	0.4
5		-166.6907	0.2
6		-168.8460	0.6
7		-166.6907	0.5

Common Pilot

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

Pattern	Cluster interference (dBm)
IR Pilot	-158.3135
Common Pilot	-135.3844

VI CONCLUSION

In this paper we introduced the interference reducing pilots for the various communication links and from this assignment we can reduce the interference level by 7.5 dB for 7 base stations with frequency reuse factor 1 and the interference level reduce by 23 dB for 19 base stations when the reuse factor is 19.

ACKNOWLEDGMENT

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