Performance Improvement in a Multi-band GSM Network by Appropriate Frequency Allocation in BCCH and TCH Bands

by

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The Project titled **"Performance Improvement in a Multi-band GSM Network by Appropriate Frequency Allocation in BCCH and TCH Bands"** Submitted by **Harun-Or-Rashid,** Roll NO: **1009062004 P,** Session **October 2009** has been accepted as satisfactory in partial fulfillment of the requirement for the degree of **Master of Engineering in Electrical and Electronic Engineering** on **5th October 2013.**

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DECLARATION

It is hereby declared that this thesis or any part of it has not been submitted elsewhere for the award of any degree or diploma.

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Abstract

To meet the increasing traffic demand and requirements for an improved Radio Quality in a GSM network, the various new technologies have been introduced. Multiband Cell or MBC is such a technology where two co-located 900-MHz and 1800-MHz cells share the same BCCH. Normally, each cell requires one BCCH for signaling. When 900-MHz and 1800-MHz cells were used simultaneously for the first time, those cells had different BCCHs with different signaling channels. To meet more traffic demand and to improve the radio network quality, MBC was implemented where both the cells shared the same BCCH. In such MBC cells, BCCH was used from the 900-MHz frequency band and TCHs were used from both the 900-MHz and 1800-MHz frequency bands. However, to ensure acceptable network quality in highly dense areas, the design requires a very low site to site distance (BTS to BTS distance of 250-300 meters) with an average antenna height of 20m. As a result, in the 900-MHz band, an operator has very limited spectrum of only 12 channels for BCCH use. Consequently, the operators have to use 4/12 re-use scheme and thus the co-channel re-use distance becomes very low creating a higher co-channel interference even with the application of aggressive down-tilt. Also, this scheme has other limitations inherent in it. For example, additional sites cannot be installed for unacceptable co-channel interference due to overshooting and further coverage area cannot be improved by reducing the antenna height, which is limited by the average height of buildings. To overcome these problems, it has been proposed in the current research to use BCCH from the 1800-MHz band and TCH from both the 900-MHz and 1800-MHz bands. As path loss in the 1800-MHz is more compared to that of the 900-MHz band, interference due to overshooting is reduced in the proposed scheme. On the other hand, available spectrum in the 1800-MHz band is comparatively more, therefore, use of more relaxed frequency reuse schemes have been made possible. Thus the overall radio Quality, like the Carrier to Interferer Ratio (C/I), Bit Error Rate (BER), Received Signal Quality (Rx Qual) have been improved.

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Abbreviations

ACCH	Associated Control Channel
AGCH	Access Grant Channels
ARFCN	Absolute Radio Frequency Channel Number
BBH	Base Band Hopping
BCH	Broadcast Channels
BER	Bit Error Rate
BSC	Base Station Controler
BTS	Base Transeiver Station
BW	Bandwidth
C/I	Carrier to Interferer Ratio
CBCH	Cell Broadcast Channel
CCCH	Common Control Channels
CCI	Co-channel Interference
CDPD	Cellular Digital Packet Data
DCCH	Dedicated Control Channels
DCS	Digital Communications System
DECT	Digital European Cordless Telephone
DL	Downlink

DLPC	Downlink Power Control
E-GSM	Extended GSM
FACCH	Fast Associated Control Channel
FCH	Frequency Correction Channels
GMSK	Gausian Minimum Shift Keying
GSM	Global System for Mobile Communication
IUO	Intelligent Underlay Overlay
MBC	Multiband Cell
MS	Mobile Station
MSK	Minimum Shift Keying
PCH	Paging Channels
PCS	Personal Communications System
pdf	Probability Density Function
Qos	Quality of service
RACH	Random Access Channels
Rx Qual	Received Signal Quality
Rxlev	Received Signal Level
SACCH	Slow Associated Contro Channel
SCH	Synchronization Channels
SDCCH	Standalone Dedicated Control Channels
SFH	Synthesized Hopping

SIR	Signal to Interferer Ratio
TCH	Traffic Channel
TCH/F	Full Rate TCH
TCH/H	Half Rate TCH
TDMA	Time Division Multiple Access
TRx	Transmitter and Receiver Unit
TS	Time Slot
UL	Uplink

CHAPTER 1

INTRODUCTION

1.1 Present Scenario

In a single band GSM network, such as a GSM 900 MHz network, there are two types of channels: BCCH (Broadcast common control channel) and TCH (Traffic channel), which are allocated from the total frequency band assigned by the regulatory body [1]. It is a standard practice to use 12/15/18 channels as BCCH and the remaining channels are used as TCH. Generally, TCH is used for carrying the intelligence signal and BCCH is used for signaling. However, in a BCCH channel, in most of the cases a few time slots are used for signaling and the remaining time slots are used for carrying traffic signals. The same approach is used for the 1800 MHz band network as well.

To increase the network capacity in densely populated area, frequencies of both the 900 MHz and 1800 MHz band can be used. Thus a multi-band network may consist of cells from different frequency bands [1], for example 900 MHz and 1800 MHz bands. By combining these frequency bands in the same cell with only one common BCCH, the network is further integrated with improved radio performance and traffic capacity. As the 900 Band cells have larger coverage than 1800 MHz Band cells [2], BCCH is usually used from 900 MHz band. The 1800 MHz band is used generally for increasing capacity of traffic channels.

1.2 Problems In Dense City Areas

In highly dense area (metropolitan cities), to ensure acceptable network quality the design requires a very low site to site distance (BTS to BTS distance of 250-300 meters) with an average antenna height of 20m. As a result, in 900 MHz band, an operator has very limited spectrum of only 12 channels for BCCH. Consequently, the operators have to use 4/12 reuse scheme and thus co-channel reuse distance becomes very low creating a higher co-channel interference even with the application of aggressive down-tilt. As there is no provision for down link power control in the BCCH TRxs, it is not possible to reduce the coverage of 900 band cells with the existing physical parameters of the antenna [3]-[5]. The 900 band coverage can also be reduced if the antenna height is reduced. However, in highly dense cities, average building height is 18m. If the antenna height is reduced further, all the antennas will be blocked by the buildings of standard height, which will significantly decrease the overall radio coverage. Further, the new site planning has also become impossible due to very close site to site distance, which may create overshooting of the cells. On the other hand, in the 1800 MHz band, each operator has sufficient spectrum (2 to 3 times of 900 MHz Band) which can be used as BCCH to overcome such problems. The cell radius of 1800 MHz band is less than that of the 900 MHz band [6] and reuse distance can be increased by using 18 channels as BCCH (6/18 reuse).

1.3 Possible Solutions

To overcome such problems in dense urban areas the following techniques may be used:

a) Lowering the Antenna Height
b) Using more Tilt
c) Reversing Channel allocation in Multiband cells

It should be noted here that the third technique has been proposed by us and the effect of implementing this will be investigated.

a) Lowering The Antenna Height:

If Antenna height is reduced, coverage area of a cell is also reduced proportionately. In fact, antenna height can be reduced up to a certain limit. It cannot be less than the average building height of a dense urban area. In areas, where antenna height is already close to the average building height, it cannot be reduced further.

b) Using More Tilting

The coverage area of a cell can also be reduced using more tilt to the antenna. However this has also some lower limits beyond which it cannot be reduced. Normally mobile operators use the maximum tilt in urban areas.

c) Reversing Channel Allocation In Multiband Cells

A multi-band network may consist of cells from different frequency bands [1], for example 900 MHz and 1800 MHz bands. By combining these frequency bands in the same cell with only one common BCCH, the network is further integrated with improved radio performance and traffic capacity. As the 900 Band cells have larger coverage than 1800 MHz Band cells [2], BCCH is usually used from 900 MHz band. The 1800 MHz band is used generally for increasing capacity of traffic channels. If BCCH and TCH bands are interchanged, that means BCCH is used from 1800 MHz band and TCH from both 900 MHz and 1800 MHz bands, BCCH will face less interferences due to less coverage in 1800 MHz bands. Interferences in TCH TRxs are controlled by using downlink power control aggressively using various available techniques. However, in the BCCH TRxs there is no provision for power control. As a result, it is not possible to reduce the interferences in BCCH TRxs using the 900 MHz band. As the 1800 MHz band has not been used anywhere as BCCH for multi band GSM network, there as is a scope for investigating the effect of using BCCH from the 1800 MHz for the densely populated area.

1.4 Objectives and Possible Outcomes

Objectives:

The objectives of the current research are as follows:

(a) To investigate present status and measure various cellular mobile parameters such as radio coverage, interference level, overshooting cases of BCCH and TCH channels.

(b) To investigate the causes of severe interference under the existing frequency plan and to suggest possible interference reduction schemes.

(c) To perform computer simulations using a professional software (Planet EV) for the proposed frequency plan.

Possible Outcomes:

It is expected that using BCCH from the 1800MHz band will cause less interference in the traffic channels than using from the 900MHz band, as in the former the propagation loss is about 6 to 7 dB higher [10]. Also, a higher reuse distance can be used in the proposed strategy as it has higher frequency band available compared to the 900MHz band.

1.5 Organization Of This Dissertation

This dissertation contains following chapters

1. **Introduction:** In this chapter problem definition, present scenario of the problem, Problems in the dense city areas, Possible Solutions to the problems, Objectives and possible outcomes and organization of dissertation have been discussed.

2. **Existing GSM system and its Frequency Allocation:** In this chapter the different features and characteristics of GSM system will be discussed. Later current practice of Frequency Allocation will also be discussed in a greater detail.

3. **Proposed Frequency Allocation for Performance Improvement:** In this chapter the proposed Frequency Allocation will be discussed in details. It will also describe how this Allocation strategy will improve the performance of existing GSM system.

4. **Simulation Results and Discussions:** In this chapter simulation for proposed Frequency Allocation Strategy will be conducted using the Planning Tool Planet EV. Later Simulation results will be discussed and explained to get clear idea how to improve the overall quality of the GSM system.

5. **Conclusions and Suggestions for Future Work:** This chapter will have conclusions of this dissertation and suggestions how to implement this Frequency Allocation Strategy. Then it will comment on future work to improve the overall quality of GSM system based on this dissertation.

6. **References:** This chapter will include the references used in this dissertation and then the Appendixes.

In this chapter problem definition, present scenario of the problem, Problems in the dense city areas, Possible Solutions to the problems, Objectives and possible outcomes and organization of dissertation have been discussed. In the next chapter the different features and characteristics of GSM system will be discussed. The current practices of Frequency Allocation will also be discussed in a greater detail.

CHAPTER 2

EXISTING GSM SYSTEM AND ITS FREQUENCY ALLOCATION

2.1 Frequency in GSM System

The frequency bands that are used in Mobile communications are shown in the following table:

Table 2.1: Parameters related to GSM Frequency bands

SYSTEM	GSM-R	E-GSM 900	GSM 1800	GSM 1900
Frequencies UL	876-880	880-915	1710-1785	1850-1910
Frequencies DL	921-925	925-960	1805-1880	1930-1990
Wavelength	~ 33 cm	~ 33 cm	~ 17 cm	~ 16 cm
Bandwidth	35 MHz	35 MHz	75 MHz	60 MHz
Duplex Distance	45 MHz	45 MHz	95 MHz	80 MHz
Carrier Separation	200 kHz	200 kHz	200 kHz	200 kHz
Radio Channels	175	175	375	300
Radio Bearer Rate	270 kb/s	270 kb/s	270 kb/s	270 kb/s

In Asia and Europe both 900 MHz and 1800 MHz frequency bands are used. The following terms are very important in discussing frequency usage.

2.1.1 Bandwidth

Bandwidth is the term used to describe the amount of frequency range allocated to one application, e.g. GSM. The amount of bandwidth available is an important factor in determining the capacity of a mobile system, i.e. the number of calls that can be handled [4].

2.1.2 Radio Channel/Carrier

Another important factor in determining the capacity of a mobile system is the channel. A channel is a frequency or set of frequencies that can be allocated for the transmission, and possibly the reception of information [5]. A simplex channel, such as an FM radio music station, uses a single frequency in a single direction only. A duplex channel, such as that used during a mobile call, uses two frequencies: one to the MS and one from the MS. The direction from the MS to the network is referred to as UPLINK. The direction from the network to the MS is referred to as DOWNLINK.

2.1.3 Duplex Distance

The use of full duplex requires that the uplink and downlink transmissions must be separated in frequency by a minimum distance [5]. This is the duplex distance. Without it, uplink and downlink frequencies would interfere with each other.

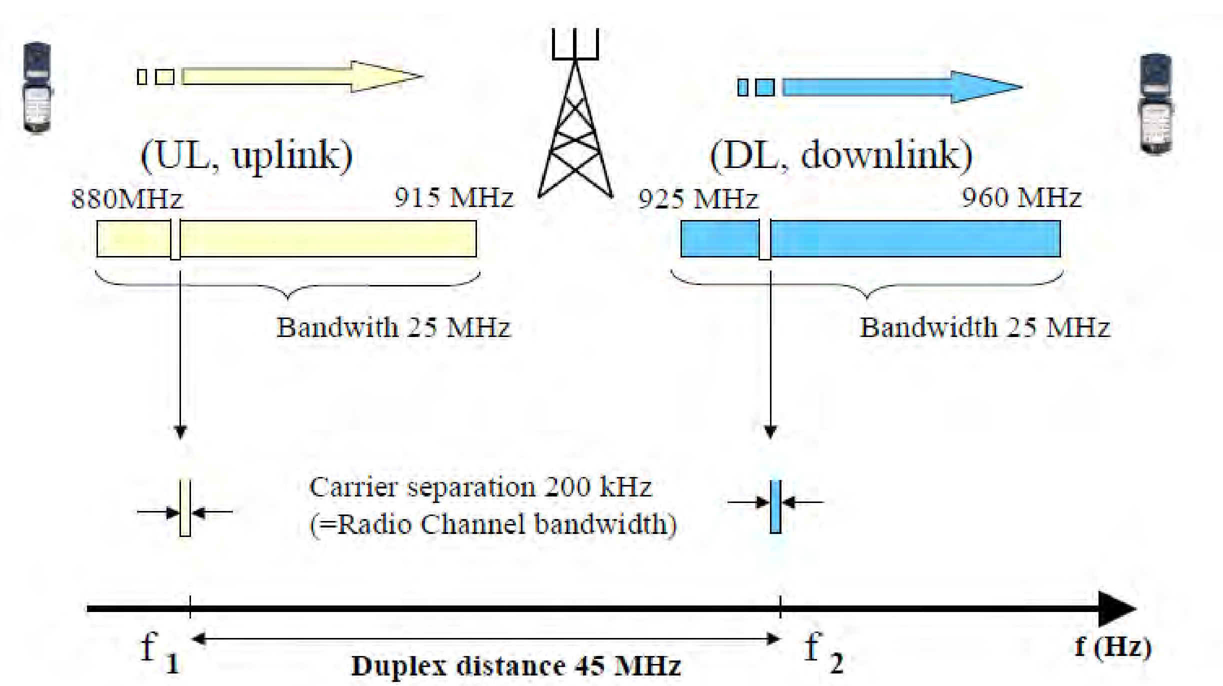


Fig. 2.1: Frequency range for E-GSM 900 system

2.1.4 Carrier Separation

In addition to the duplex distance, every mobile system includes a carrier separation. This is the distance on the frequency band between channels being transmitted in the same direction [5]. This is required in order to avoid the overlapping of information in one channel into an adjacent channel.

2.1.5 Radio Bearer Transmission Rate

The amount of information transmitted over a radio channel over a period of time is known as the transmission rate. Transmission rate is expressed in bits per second or bit/s. In GSM the net bit rate over the air interface is 270kbit/s [4].

2.1.6 Adjacent- and Co-Channel Interference

It is the number of radio channels, carriers, in a cell, which determine the capacity of a cell. Each licensed operator of a mobile network is allocated a limited number of such carriers. It is important when allocating frequencies to carriers that interference is avoided. Interference can be caused by a variety of factors. A common factor is the use of similar frequencies in neighbouring cells.

Often, the level of interference is described as a ratio between the wanted signal and the total signal including the interference. The picture shows the definition of C/A, interference caused by adjacent channel (using next frequency) and C/I, interference caused by co-channels (using identical frequency) [9]. The higher the interference, the lower the C/A and C/I ratio and thus the lower the call quality.

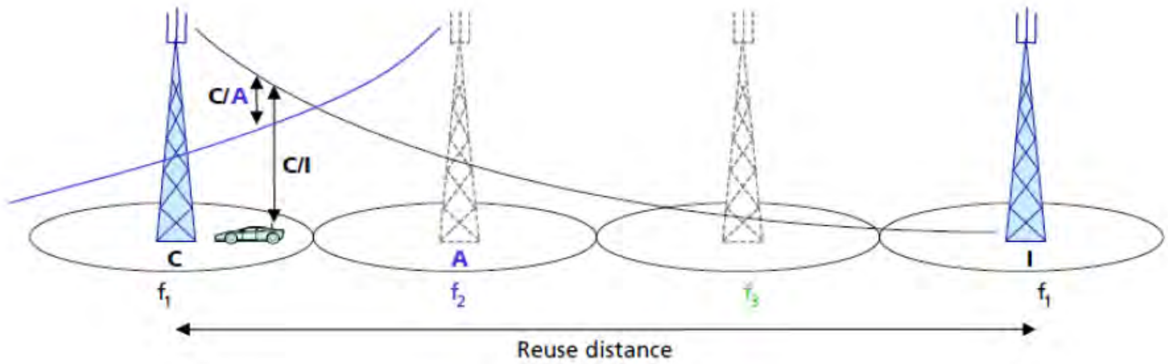
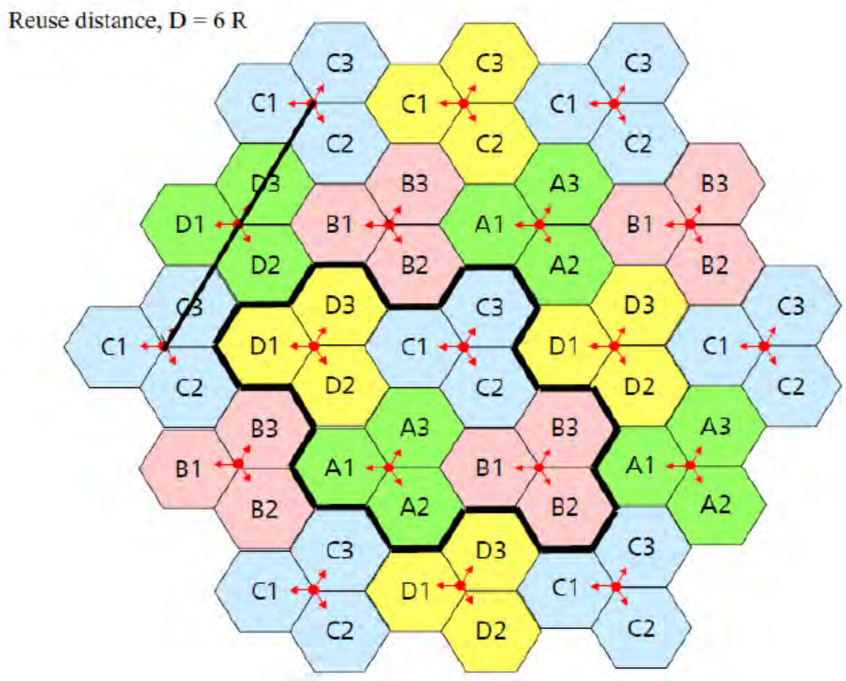


Fig. 2.2: Adjacent and Co-channel interferences

2.1.7 Frequency Reuse

To cover an entire country, for example, frequencies must be reused many times at different geographical locations in order to provide a network with sufficient capacity. The same frequencies can not be reused in neighbouring cells as they would interfere with each other. Therefore special patterns of frequency usage are determined during the planning of the network. The term “frequency reuse distance” is used to describe the distance between two identical frequencies in a reuse pattern. Shorter frequency reuse distance gives higher network capacity, but higher co-channel interference (C/I ratio) [9].

By arranging the cells in clusters we can easily ensure a sufficient reuse distance between two cells that use the same frequencies. The picture illustrates a 4/12 cell pattern, a common method for reusing frequencies. In 4/12, the available number of frequencies are divided into 4 groups, A to D. Each group consists of three cells, and all available frequencies are allocated among the cells on all 4 groups. The four groups can then define the cluster consisting of 12 cells. Adding more clusters then creates a larger network. The cells are dimensioned so that the distance between a group in a cluster and the corresponding group in the neighbouring cluster meets the requirement for C/I, Carrier to co-channel Interference ratio [11].



12 cells	Frequency f_0	f_1	f_2
A1	1	13	25
B1	2	14	26
C1	3	15	27
D1	4	16	
A2	5	17	
B2	6	18	
C2	7	19	
D2	8	20	
A3	9	21	
B3	10	22	
C3	11	23	
D3	12	24	

Fig. 2.3: Frequency Reuse example

2.1.8 Channel Structure in GSM Radio part

The GSM networks are assigned special operating frequency ranges. These frequency ranges are in turn subdivided into radio channels, 200 kHz wide channel separation). Duplex mode is employed for traffic over radio access; meaning that the base stations and the mobiles must be capable of simultaneous transmission and reception, requiring two frequency ranges sufficiently separated from one another. The separation between them is referred to as the duplex separation [12]. The combination of two frequencies constitutes a duplex radio channel.

2.1.9 Physical – Logical Channels in GSM

The channels of a mobile network are of two types:

- Control channels
- Traffic channels

Control channels are used for signalling, e.g. paging the mobiles, broadcasting system information to the mobiles and conveying mobility management and call set up information between mobiles and the network.

Traffic channels are used to carry traffic between the mobile and the network.
Control channels and traffic channels are also referred to as logical channels. These logical channels are mapped onto physical channels (time slots).
A physical channel is a time slot (TS) on a particular frequency. It may carry information from one or more logical channels, such as a paging logical channel, PCH, or a traffic channel, TCH [12].

Every cell needs at least one (physical) channel as a control channel, on which the base station continuously transmits downlink control channel information. On the uplink, there is a similar physical channel reserved as control channel. It carries the control information from the mobiles to the network. By default, the first time slot (TS0) is reserved for these purposes. The remaining 7 timeslots (TS1-TS7) are used as traffic channels to carry end-user traffic [13].

2.2 Channels and Frame Structures in GSM

2.2.1 Channel Types

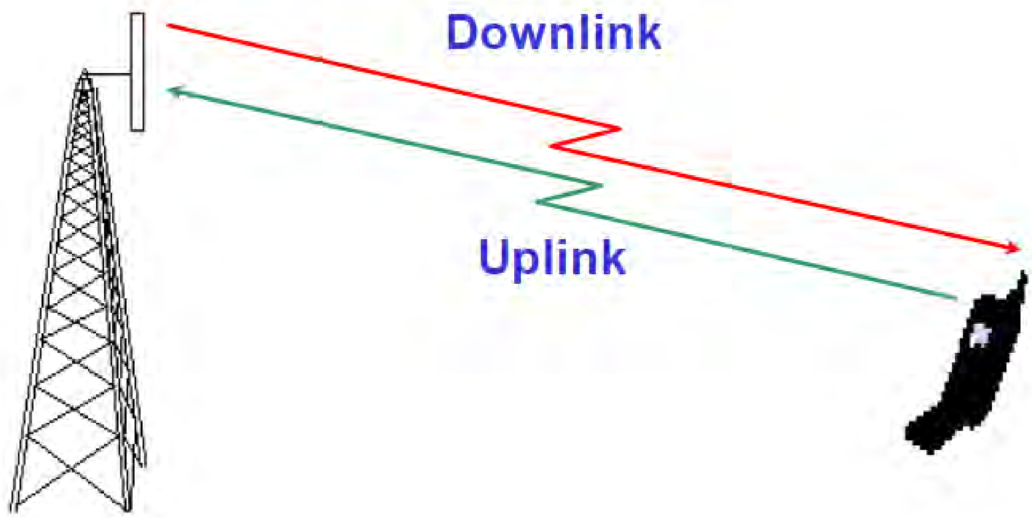


Fig. 2.4: Uplink and Downlink channels

Physical Channel

Each timeslot on a carrier is referred to as a physical channel. Per carrier there are 8 physical channels.

Logical Channel

A great variety of information must be transmitted between the BTS and the MS, specifically, user data and control signaling. Depending on the kind of information transmitted, we refer to different logical channels. These logical channels are mapped onto the physical channels (slots). Digital speech is sent on a logical channel, named traffic channel (TCH), which during the transmission can be allocated a certain physical channel, say channel Timeslot 7 (TS 7) [1]-[2]. In a GSM system no RF carrier and no slot is dedicated a priori to the exclusive use of anything. In other words, just about any slot of any RF carrier can be used for a number of different usage.

Logical channels are divided into the two categories, TCH and control channels.

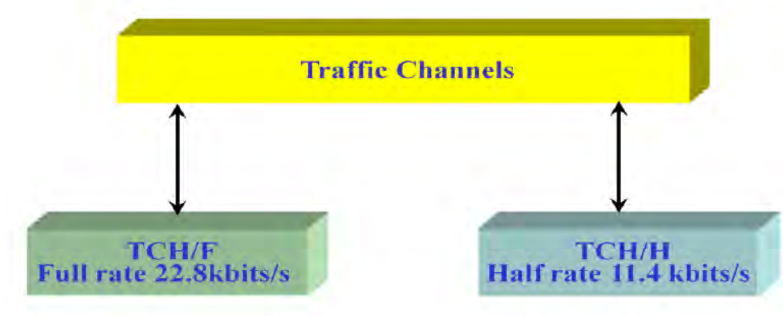


Fig. 2.5: Traffic channels

Logical TCHs

TCHs are intended to carry either encoded speech or user data both in the up and downlink directions in a point-to-point communication. There are two types of TCHs that are differentiated by their traffic rates and are defined as follows. A full rate TCH (TCH/F) carries information (encoded speech or data) at a gross rate of 22.8 Kbps. The raw data rate for each TCH is 13 Kbps for speech and 12 Kbps, 6 Kbps, and 3.6 Kbps for data. The actual user data rates are 9.6 Kbps, 4.8 Kbps, and 2.4 Kbps, which are padded to bring up the rates to 12 Kbps, 6 Kbps, and 3.6 Kbps [3]-[4].

A half rate TCH (TCH/H) carries information (encoded speech or data) at half of the full rate channel or at the gross rate of 11.4 Kbps. The user data rate associated with the half rate TCH are as follows. 4.8 Kbps and 2.4 Kbps. The allowed combinations of user data rate with full and half rate speech are as follows.

- Full rate speech (TCH/F);
- Half rate speech (TCH/H);
- 9.6 Kbps full rate data (TCH/F9.6);
- 4.8 Kbps full rate data (TCH/F4.8);
- 2.4 Kbps full rate data (TCH/F2.4);
- 4.8 Kbps half rate data (TCH/H4.8);
- 2.4 Kbps half rate data (TCH/H2.4).

Logical Control Channels

Control channels are intended to carry signaling or synchronization data. Three kinds such channels are defined below.

- Broadcast Control Channel (BCCH);
- Common Control Channel (CCCH);
- Dedicated Control Channel (DCCH).

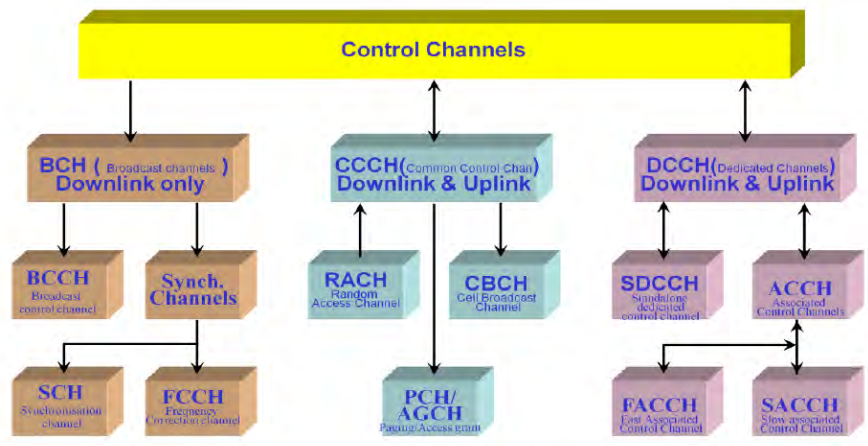


Fig. 2.6: Control channels

The Fig. 2.5 and Fig. 2.6 above show the details of different logical channels. The BCCH is a point-to- multipoint unidirectional control channel from the fixed subsystem to the MS that is intended to broadcast a variety of information to MSs, including information necessary for the MS to register in the system.

The BCCH includes a Frequency Correction Channel (FCCH), which is used to allow an MS to accurately tune to a BS, and the Synchronization Channel (SCH), which is used to provide TDMA frame oriented synchronization data to an MS [5]. When mobile recovers both FCCH and SCH signals, we consider the synchronization to be complete.

A CCCH is a point-to-multipoint (bidirectional control) channel that is primarily intended to carry signaling information necessary for access management functions (e.g., allocation of dedicated control channels). The CCCH can include the following: (1) paging channel (PCH), which is a down channel used to page MSs; (2) random access channel (RACH), which is an uplink channel used for request assignment of a DCCH; and (3) access grant channel (AGCH), which is a downlink channel used to assign a MS to a specific DCCH.

A DCCH is a point-to-point, directional control channel. Two types of DCCHs are used:

1. Stand alone dedicated control channel
2. Associated control channel (ACCH).

Stand alone SDCCH is a DCCH whose allocation is not linked to the allocation of a TCH. This channel is used before the MS is assigned a TCH. The SDCCH is used to provide authentication to MS and for location updates and assignment to TCHs [3].

A DCCH whose allocation is linked to the allocation of a TCH has ACCHs (that is, FACCH and SACCH). A FACCH or burst stealing is a DCCH obtained by preemptive dynamic multiplexing on a TCH. A SACCH, also known as a continuous data stream, is allocated together with a TCH or a SDCCH [4].

2.2.2 BCH Channels

BCCH (Broadcast Control Channel)

The BCCH provides general information on a per-BTS basis (cell-specific information) including information necessary for the MS to register in the system, including: local area code, PLMN code, RF channels used within the cell where the mobile is located, neighbour cells, hopping sequence number, cell selection parameters and RACH description and more.

One of the important messages on a BCCH channel is CCCH-CONF, which indicates the organization of the CCCHs.

The BCCH broadcasts general information of the serving cell called "System Information". BCCH is transmitted on time slot zero of the BCCH carrier [3].

SCH (Synchronization Channel)

• Downlink only
• Carries information for frame synchronization. Contains TDMA frame number and BSIC

FCCH (Frequency Correction Channel)

• Downlink only.
• Enables MS to synchronize to the frequency.
• Also helps mobiles of the ncells to locate TS 0 of BCCH carrier.

2.2.3 CCCH Channels

RACH (Random Access Channel)

• Uplink only
• Used by the MS to access the Network.

AGCH (Access Grant Channel)

• Downlink only
• Used by the network to assign a signaling channel upon successful decoding of access bursts.

PCH (Paging Channel)

- Downlink only.
- Used by the Network to contact the MS.

2.2.4 DCCH Channels (Dedicated Control Channels)

DCCHs consist of a SDCCH and the ACCH. The SDCCH is used for system signaling during idle periods and call setup before allocating a TCH. For example, MS registration, authentication, and location update takes place through this channel.

When a TCH is assigned to the MS, this channel is released. It uses 1/8 rate TCH data rate. This is achieved by transmitting data over this channel once every eighth frame [5]. The channel is used for both up/downlink and is meant for point-to-point usage.

SACCH can be linked to a TCH or an SDCCH. It is a continuous data channel carrying information, such as measurement reports, from the mobile of received signal strength for a serving cell as well as adjacent cells. This is used for the mobile-assisted handover function. The channel is also used for power regulation of the MS and time alignment and is meant for both the up and downlink. It is used for point-to-point communication between mobile and BS.

A FACCH is associated to a TCH. FACCH works in a stealing mode. This means that if suddenly during a speech transmission it is necessary to exchange signaling information with the system at a rate much higher than the SACCH can handle, then 20-ms speech (data) bursts are stolen for signaling purposes. This is the case at handover. The interruption of speech will not be heard by the user since it lasts only for 20 ms and cannot be sensed by human ears.

We shall now take up details of how the data is actually arranged within a physical channel for the logical speech and control channels.

2.2.5 Multiframe Structures for Traffic and Control Channels

Traffic Channel Multiframe Structure

The multiframe structure of a traffic channel is shown in Fig. 2.7. MS on busy mode using a TCH will synchronize to a 26-TDMA frame multiframe structure. Frame 0-11 and 13-24 used to carry traffic. Frame 12 used as SACCH to carry control information from and to MS to BTS. Frame 25 is idle and is used by mobile to decode the BSIC of neighbor cells.

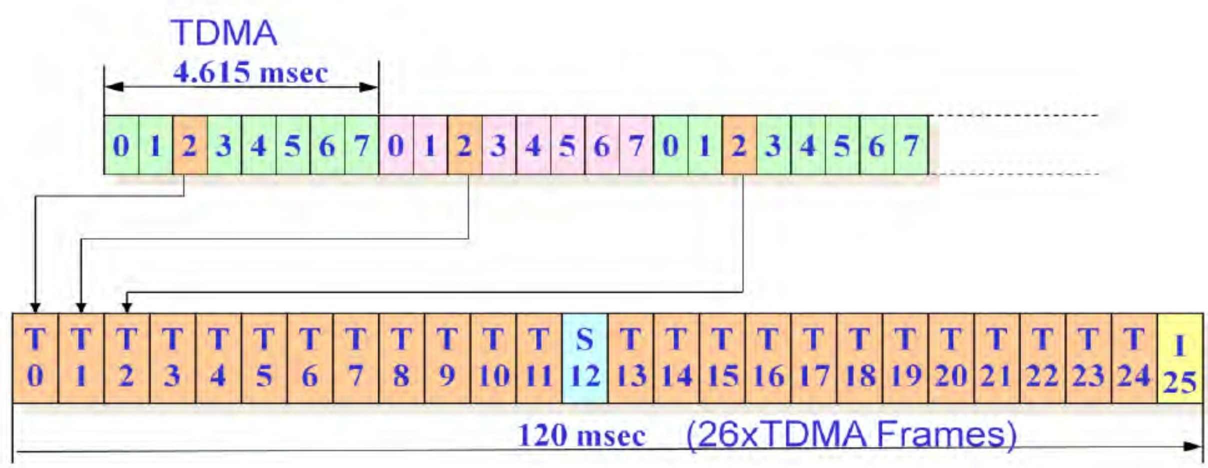


Fig. 2.7: Traffic channel multiframe structure

2.2.6 Control Channel CCH Multiframe

The control channel multiframe consists of 51 TDMA frames. It is not by accident that the control channel multiframe is not a direct multiple of the TCH multiframe. The arrangement means that the timing of the TCH multiframe is always moving in relation to that of the control channel multiframe, and this enables a receiver to receive and decode all the control channels (i.e. BCCH) along with TCH [4]-[5].

This relationship is particularly important, for a MS that needs to monitor, measure and report RSSIs of up to six target cells (it needs to be able to see all the BCCHs of surrounding cells in order to do this).

In Fig. 2.8, 2.9 and 2.9, different configuration options of the control channels are shown on the basis of the 51x TDMA multiframe.

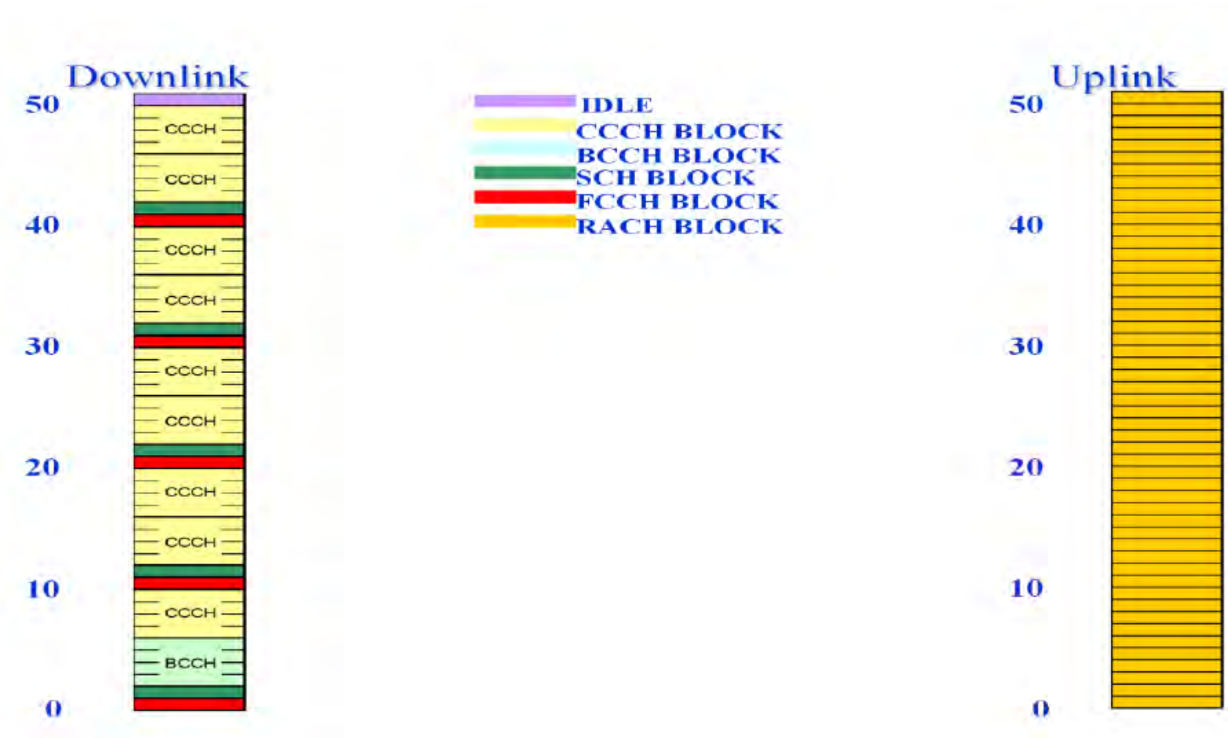


Fig. 2.8: BCCH/CCCH non-combined multiframe

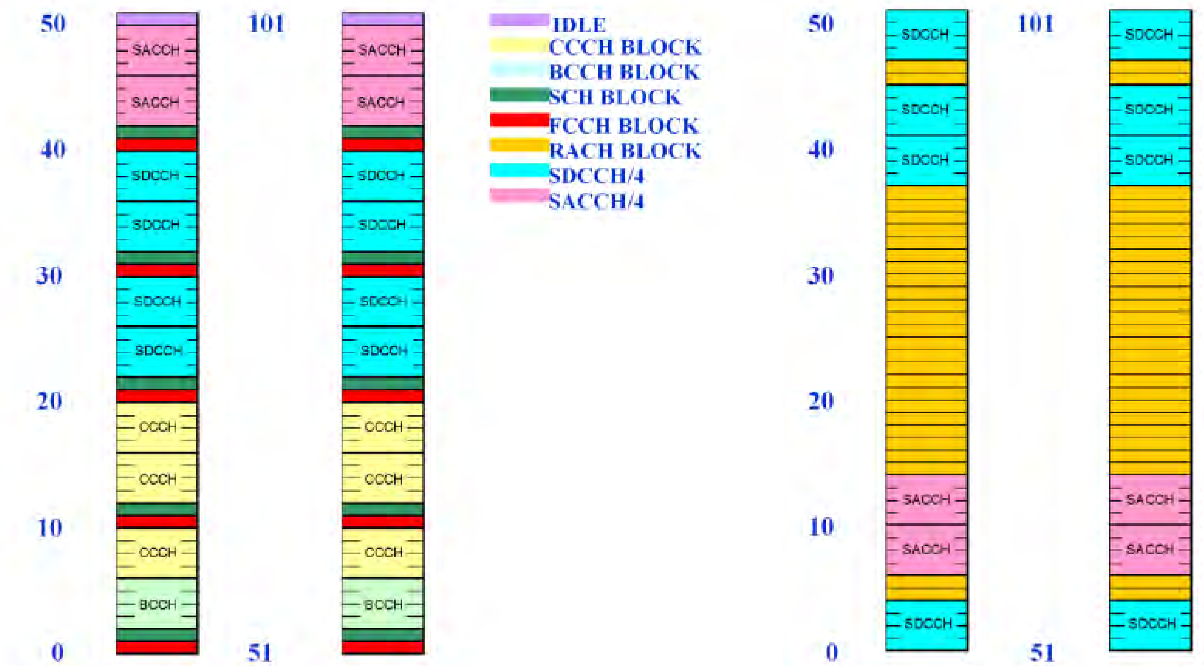


Fig. 2.9: BCCH/CCCH combined multiframe

DCCH/8 Multiframe

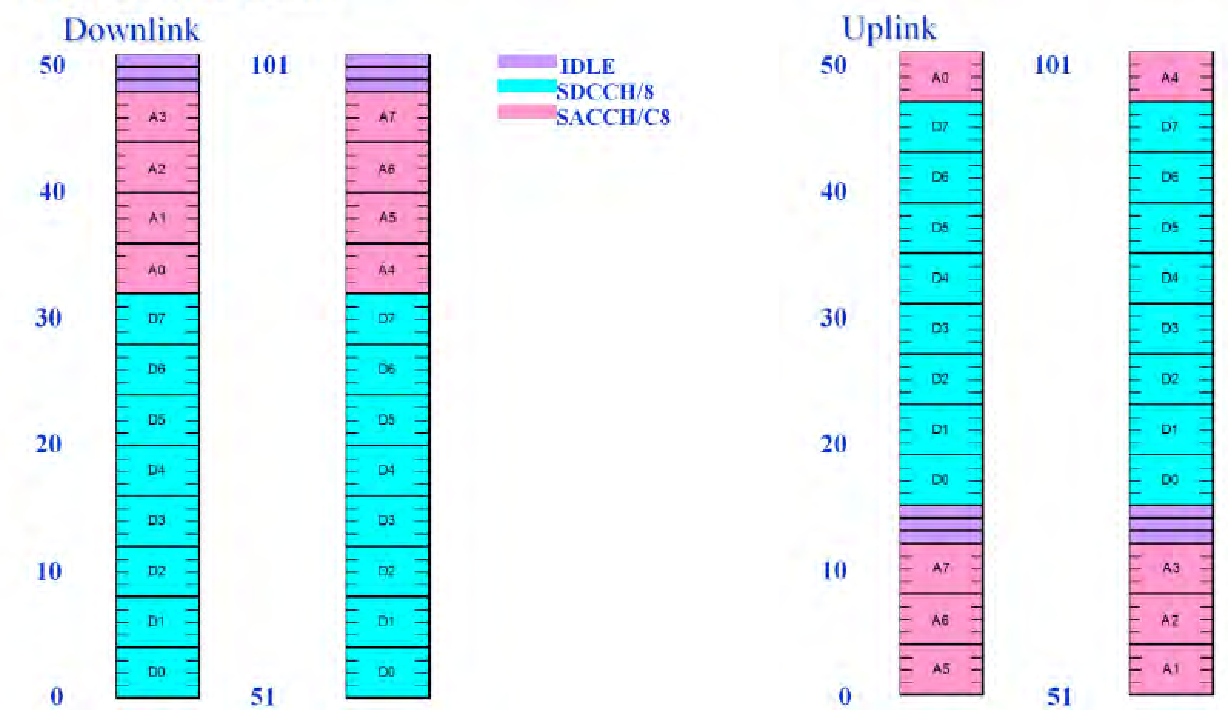


Fig. 2.10: DCCH/8 multiframe

2.2.7 Superframe and Hyperframe Structure

Fig. 2.11 shows Hyperframes, Superframes and TDMA frames. A Superframe is composed of multiple Multiframes. A superframe for Control Channels and one for Traffic Channels.

Control Channel Superframe is composed of 26 Control Channel (CCH) multiframes with a duration of 6.12 seconds.

Traffic Channel Superframe is composed of 51 Traffic Channel (TCH multiframes with a duration of 6.12 seconds.
Each superframe, whether it is a CCH or TCH frame, consists of 1326 TDMA frames (51 * 26). The CCH and TCH frame sequences will synchronize every superframe.

Hyperframes are composed of 2048 superframes with a duration of 3h 28m 53s 76ms (12,533.76 seconds). Each hyperframe consists of 2,715,648 TDMA frames.
Each TDMA frame is numbered according to its sequence within the hyperframe, starting from 0 and ending at 2,715,647.
The TDMA frame number within a hyperframe is abbreviated FN. The FN is one of the variables used in GSM encryption algorithms.

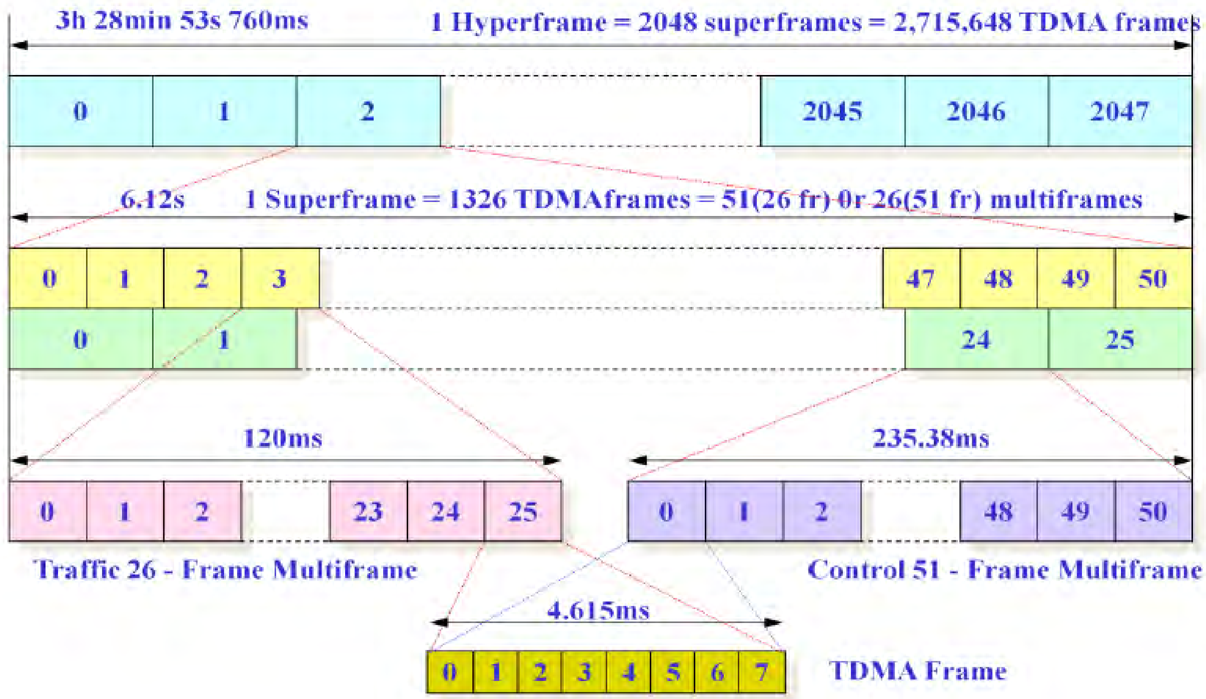


Fig. 2.11: Hyperframe, Superframe and TDMA frames

2.3 Multiband GSM Network and Current Frequency Allocation

2.3.1 Multiband GSM Network

In a GSM network two frequency bands can be used simultaneously. In Asia and Europe normally 900 MHz and 1800 MHz frequency bands are used. In other areas of the world 850 MHz and 1900 MHz frequency bands are used. In 850 MHz or 900 MHz frequency bands the available spectrum is small compared to the 1800 MHz and 1900 MHz frequency bands [5]. Therefore 850 MHz and 1900 MHz frequency bands are used for coverage issues, while 1800 MHz and 1900 MHz frequency bands are used for capacity purposes [9]. As path loss is directly proportional to the frequency used, 1800 MHz frequency bands have more losses than 900 MHz frequency bands. These two frequency bands may, however be used at a time in a site/cell. It can be achieved in the following two ways:

a. **Co-located 900 MHz and 1800 MHz independent cells:** In this configuration 900 MHz and 1800 MHz cells are individual entities with their own signaling and traffic channels [5]. Two cells have individual BCCH channels. The two cells have same physical parameters like height, azimuth or tilt. This can be done using two separate antennas of 900 MHz and 1800 MHz bands or a single antenna that is designed for both 900 MHz and 1800 Mhz bands. In this configuration number of signaling channels and number of neighbor relations are increased as in each site normally there are 3 number of 900 MHz cells and 3 number of 1800 MHz cells. Therefore in a dense urban area average number of neighbors for each cell is about 25 to 30.

b. **Using 900 MHz and 1800 MHz in the same cell:** In this configuration both 900 MHz and 1800 MHz bands can be used in the same cell. Here signaling is done in one channel of one band and the remaining channels are used as traffic channel. As both 900 MHz and 1800 MHz frequency bands are used in one cell, total nos of cells per site remains 3. So average nos of neighbors per cell in dense urban area with this configuration is reduced to 12 to 15. As BCCH is used from one band, some signaling channels are saved in this configuration.

When a single cell is designed with both 900 MHz and 1800 MHz frequency bands with a single BCCH the cell is called multiband cell (MBC). When this technology is used in GSM system, the cell is called multiband GSM cell. Sometimes it is also called Co-BCCH cell as both 900 MHz and 1800 MHz bands are sharing same BCCH.

2.3.2 Current Frequency Allocation in MBC System

According to current practice of GSM Multiband cells, BCCH is used from the 900 MHz bands and TCH is used from both the 900 MHz and 1800 MHz bands [5]. The 900 MHz frequency bands have more coverage than the 1800 MHz frequency bands. Therefore to overcome any coverage gap for signaling, the 900 MHz band is used for BCCH and 1800 MHz is used for capacity issue.

To ensure acceptable network quality in a highly dense area (metropolitan cities), the design requires a very low site to site distance (BTS to BTS distance of 250-300 meters) with an average antenna height of 20m. As a result, in the 900 MHz band, an operator has very limited spectrum of only 12 channels for BCCH. Consequently, the operators have to use a 4/12 reuse scheme and thus co-channel reuse distance becomes very low creating a higher co-channel interference even with the application of aggressive down-tilt. As there is no provision for down link power control in the BCCH Transceivers, it is not possible to reduce the coverage of the 900 band cells with the existing physical parameters of the antenna [3]-[5]. The 900 MHz band coverage can also be reduced if the antenna height is reduced. However, in highly dense cities, the average building height is 18m. If the antenna height is reduced further, all the antennas will be blocked by the buildings of standard height, which will significantly decrease the overall radio coverage. Further, the new site planning has also become impossible due to very close site to site distance, which may create overshooting of the cells. On the other hand, in the 1800 MHz band, each operator has sufficient spectrum (2 to 3 times that of the 900 MHz Band), which can be used as BCCH to overcome such problems. In an 1800MHz band, the cell radius is less than that of the 900 MHz band [6] and the reuse distance can be increased by using 18 channels as BCCH (in 6/18 reuse scheme).

In this chapter the different features and characteristics of a Multiband GSM system have been discussed. The current practices of Frequency Allocation in a Multiband GSM network are also discussed. In the next chapter, the proposed Frequency Allocation for the Multiband GSM cells will be discussed in greater details. It will also describe how this Allocation strategy will improve the performance of an existing GSM system

CHAPTER 3

PROPOSED FREQUENCY ALLOCATION STRATEGY

3.1 Proposed Frequency Allocation

For any GSM cell there are several number of Transmitters and Receivers TRxs which are physically installed in the BTS. Those TRxs are also logically defined in the BSC also. Each TRx requires an Absolute Radio Frequency Number (ARFCN) which is a combination of both uplink and downlink channels of 200 KHz bandwidth. The first TRx is called BCCH TRx and its ARFCN is called BCCH Frequency. The remaining TRxs are called TCH; TRxs and corresponding ARFCNs are termed as TCH Frequencies. Each TRx (BCCH or TCH) has 8 time slots which can be reallocated to the users [2]-[3]. The configurations of a Multiband GSM cell with TRxs are shown in Fig. 3.1.

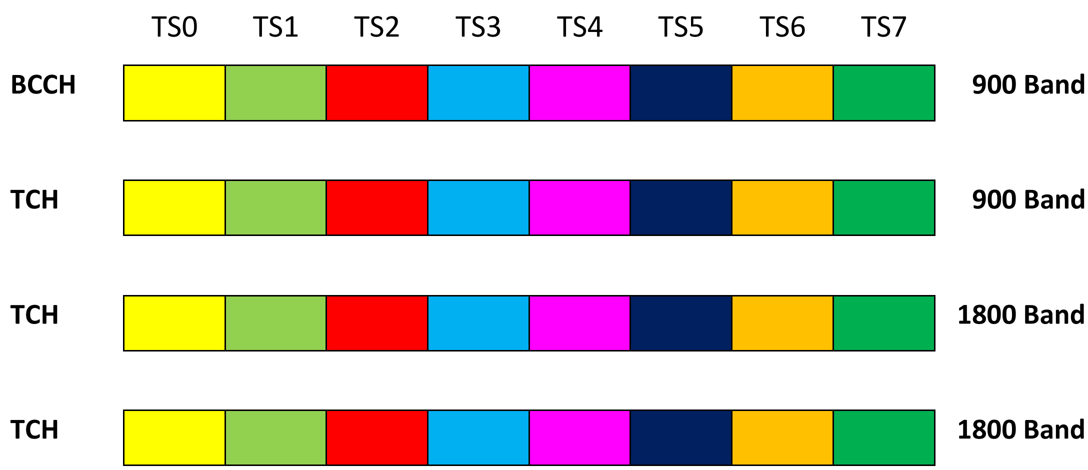


Fig. 3.1: Configurations of a Multiband GSM cell

In normal practice few time slots from BCCH TRx are used for Broadcast and Control channels. The remaining time slots can be used as traffic channels. All the time slots of TCH TRxs are used as traffic channels [2]-[3]. Thus in a Multiband GSM cell same BCCH TRx is shared by both the 900 MHz and 1800 MHz TRxs. So it is called multiband GSM cell [5].

To ensure acceptable network quality in a highly dense area (metropolitan cities), the design requires a very low site to site distance (BTS to BTS distance of 250-300 meters) with an average antenna height of 20m. As a result, in the 900 MHz band, an operator has very limited spectrum of only 12 channels for BCCH. Consequently, the operators have to use a 4/12 reuse scheme and thus the co-channel reuse distance becomes very low creating a higher co-channel interference even with the application of aggressive down-tilt. As there is no provision for down link power control in the BCCH TRxs, it is not possible to reduce the coverage of the 900 band cells with the existing physical parameters of the antenna [3]-[5]. The 900 MHz band coverage can also be reduced if the antenna height is reduced. However, in highly dense cities, the average building height is 18m. If the antenna height is reduced further, all the antennas will be blocked by the buildings of standard height, which will significantly decrease the overall radio coverage. Further, the new site planning has also become impossible due to very close site to site distance, which may create overshooting of the cells. On the other hand, in the 1800 MHz band, each operator has sufficient spectrum (2 to 3 times that of the 900 MHz Band) which can be used as BCCH to overcome such problems. The 1800MHz band cell radius is less than the 900 band cell radius [6] and reuse distance can be increased by using 18 channels as BCCH (6/18 reuse).

Therefore to overcome these problems, it has been proposed to use BCCH from the 1800 MHz band and TCH from both 900 MHz and 1800 MHz in the current research. The proposed configuration is shown in Fig. 3.2.

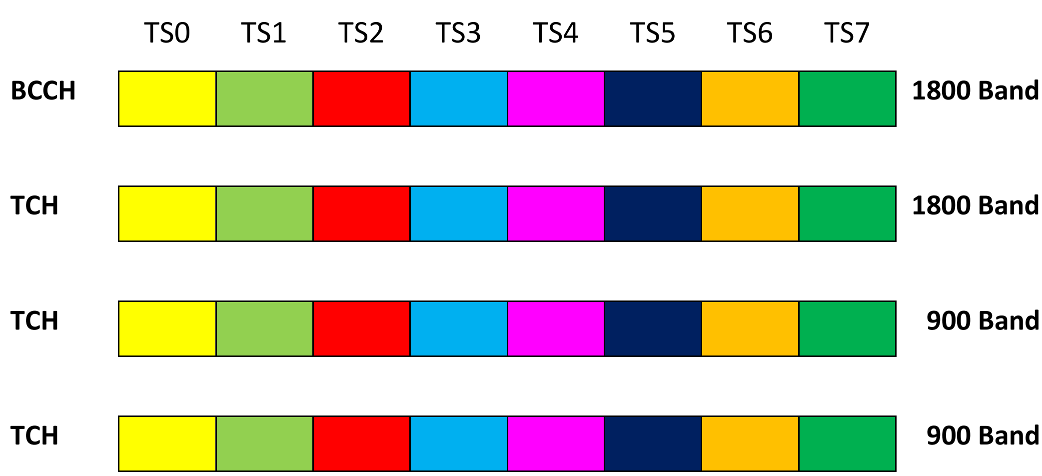


Fig. 3.2: Configuration of the Proposed Multiband GSM cell

According to the proposed strategy, all the broadcast and control channels will be assigned in BCCH TRx, which will be from the 1800 MHz band. For Traffic channels both the 900 MHz and 1800 MHz bands will be used as shown in Fig. 3.2. In the 900 MHz frequency band, cell coverage is comparatively more than that in the 800 MHz band [6]-[7]. However, in dense urban area it is almost same with respect to the coverage. Though there will be some differences with the received level as in the 1800 MHz band path loss is comparatively more.

3.2 Improvement in Proposed Allocation Strategy

If BCCH is assigned from the 900 MHz band in a GSM Multiband cell in a highly dense area, where the average site to site distance is about 250 meters to 300 meters, BCCH is interfered by reuses of ARFCNs in the neighboring clusters. Normally, 4/12 reuses are used in a GSM network for BCCH planning. As a result BCCH reuse distance becomes about 500 to 600 meters. In such distances, the co-channel interference occurs due to overshooting [5]. Due to average building height of 18 meters, antenna height cannot be further reduced. Therefore interference has become an unavoidable situation in using BCCH from the 900 MHz even with aggressive down tilt.

If P_t is transmitting power from an isotropic source, then the Power Flux (P watts per square meter), at distance d is given by

$$P = \frac{Pt}{4\pi d^2} \quad \text{......(3.1)}$$

If there is a propagation without any obstacle ,

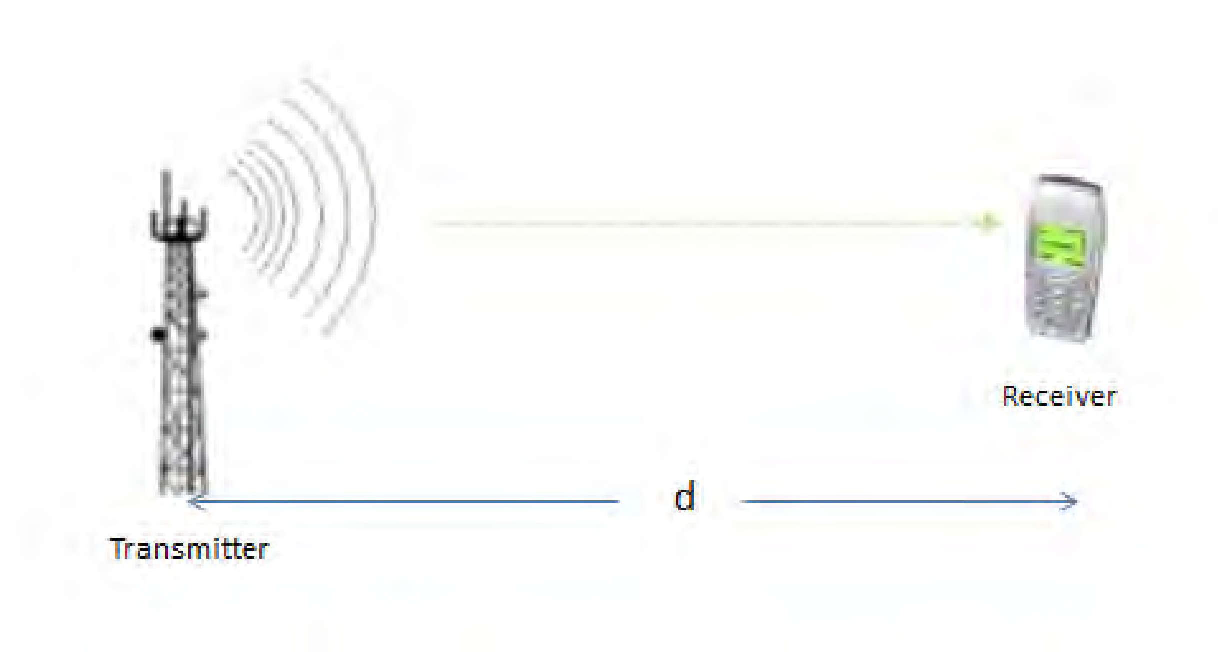


Fig. 3.3: Transmitter and Receiver at distance d

then received power P_r is given by

$$P_r = \frac{Pt.Gt.Gr}{d^2}\left(\frac{\lambda}{4\pi}\right)^2 \quad \text{................(3.2)}$$

Where

P_r = Received Power

Pt = Transmitting Power

Gt = Transmitting Antenna Gain

Gr = Receiving Antenna Gain

d = Tx – Rx distance

λ = Wavelength

So free space path loss is given by

$$\frac{Pt}{Pr} = \left(\frac{4\pi d}{\lambda}\right)^2 \text{................(3.3)}$$

The free space path loss L is represented by

$$L = 32.5 + 20\log d + 20\log f \text{ dB} \quad \ldots\ldots\ldots\ldots\ldots\ldots(3.4)$$

Where,

d is in km and f in MHz

Therefore, at a particular distance d, path loss L is proportional to f. That is in fixed pixel which is in a fixed distance from Transmitter, the received power depends on frequency band used [8].

3.2.1 GSM Cell Structure

The design objective of early mobile radio systems was to achieve a large coverage area using a single, high powered transmitter with an antenna mounted on a tall tower. The cellular concept is a system-level idea which calls for replacing a single, high power transmitter (large cell) with many low power transmitters (small cells) each providing a coverage to only a small portion of the service area. While it might seem natural to choose a circle to represent the coverage of a BS, adjacent circles cannot be overlaid upon a map without leaving gaps or creating overlapping regions. Thus when considering geometric shapes which cover an entire region without overlap and with equal area, there are three sensible choices – a square, an equilateral triangle and a hexagon [4]. The actual radio coverage of a cell is known as footprint and is determined from field measurements or propagation prediction models.

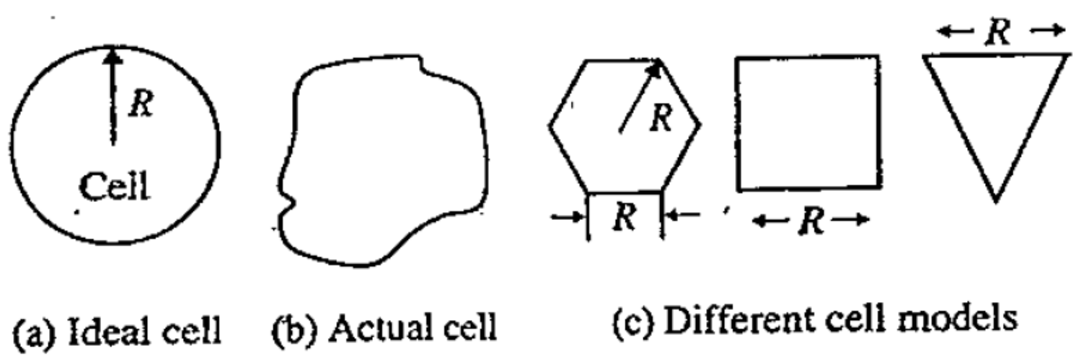


Fig. 3.4: (a) Ideal Coverage (b) Actual Coverage (c) Different cell models

For a given distance between the center of a polygon and its farthest perimeter points, the hexagon has the largest area of the three. Thus by using hexagon geometry, the fewest number of cells can cover a geographic region, and hexagon closely approximates a circular radiation pattern which would occur for an omnidirectional BS antenna and free space propagation [7]. When using hexagons to model a coverage areas, BS transmitters are depicted as either being in the center of the cell (center-excited cells) or on the three of the six cell vertices (edge-excited cells). Normally omnidirectional antennas are used in center-excited cells and directional antennas in corner-excited cells. Fig. 3.5 shows the center-excited cells with omnidirectional antennas.

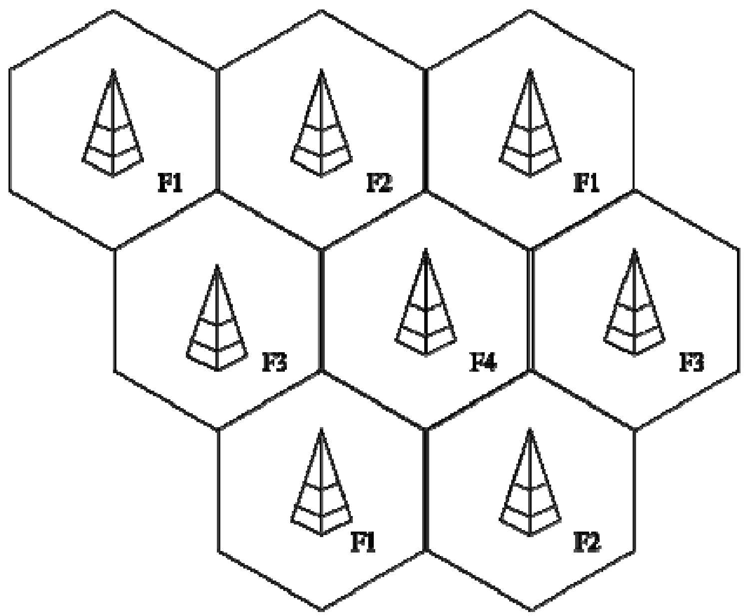


Fig. 3.5: Center-excited cells with omnidirectional antennas

Cellular system provides the following advantages

- Solves the problem of spectral congestion.
- Reuse of radio channel in different cells.
- Enable a fixed number of channels to serve an arbitrarily large number of users by reusing the channel throughout the coverage region.

3.2.2 Frequency Reuse

Each cellular BS is allocated a group of radio channels to be used within a small geographic area called cell. BS in adjacent cells are assigned channel groups which contain completely different channels than from those of the neighboring cells [3]. By limiting the coverage area to within the boundaries of a cell, the same groups of channels may be used to cover different cells that are separated from one another by distances large enough to keep the interference levels within tolerable limits. The design process of selecting and allocating channel groups for all of the cellular BSs is called frequency reuse or frequency planning. Fig. 3.6 shows an illustration of the cellular frequency reuse concept.

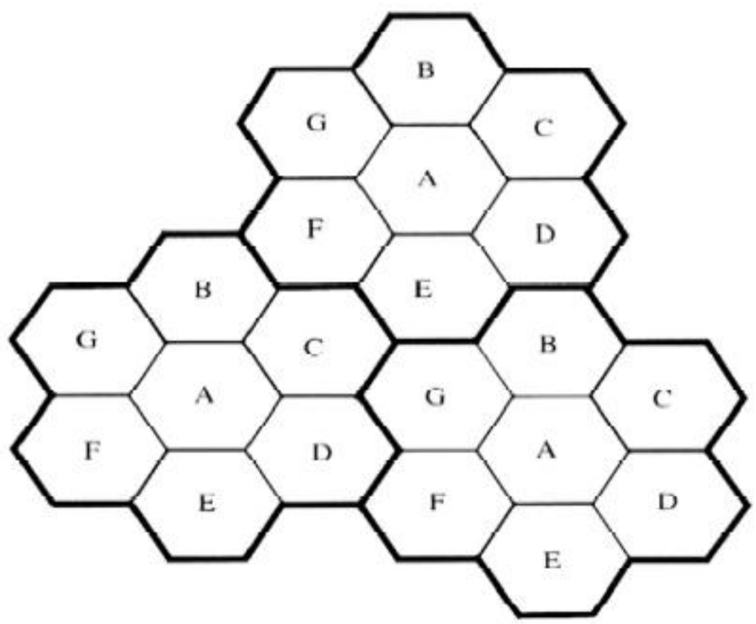


Fig. 3.6: Illustration of the cellular frequency reuse concept. Cells with the same letter use the same set of frequencies. A cell cluster is outlined in bold. In this example, the cluster size is N equal to 7 and frequency reuse factor is 1/N=1/7.

3.2.3 Cluster and Capacity

Let us consider a cellular system which has a total of S duplex channels available for use. If each cell is allocated a group of k channels (k<S), and if the S channels are divided among N cells and disjoint channel groups which each have same number of channels, the total number of available radio channels can be expressed as S=kN. N cells which collectively use the complete set of available frequencies is called a cluster [4]. Fig. 3.7 shows the arrangement of cells for various cluster sizes.

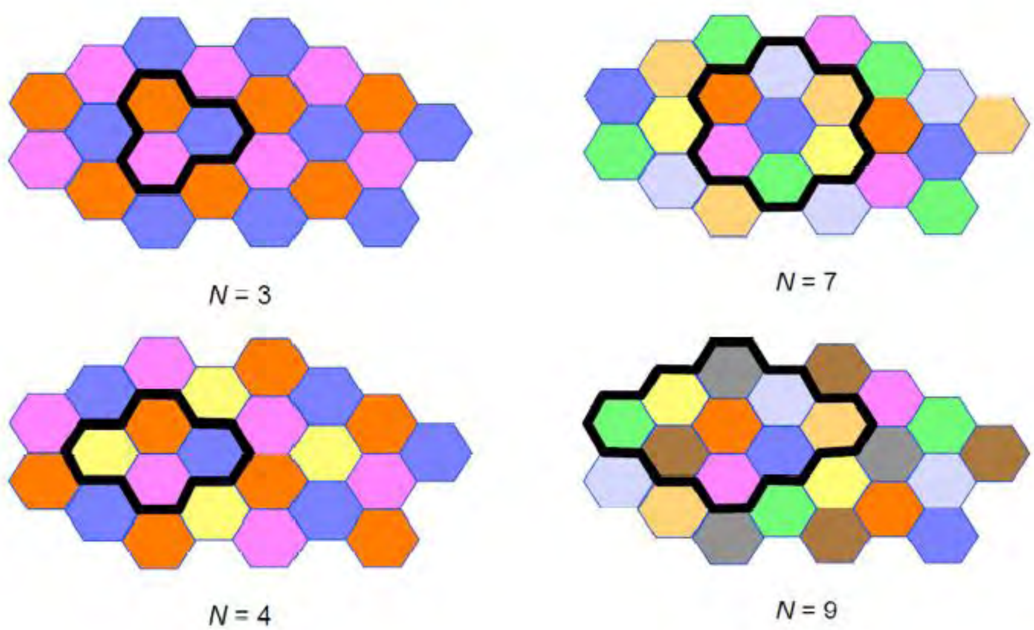


Fig. 3.7: Cluster size of 3, 4, 7 and 9.

If a cluster is replicated M times within the system, the total number of duplex channels, C, can be used as a measure of capacity and may be given by C=MkN=MS…(3.5).

Therefore the capacity of a cellular system is directly proportional to the number of times a cluster is replicated in a fixed service area. A larger cluster size causes the ratio between the cell radius and the distance between the co-channel cells to decrease, leading to weaker co-channel interference. Conversely a small cluster size indicates the co-channel cells are located much closer together. From a designer's point of view, the smallest possible value of N is desirable in order to maximize the capacity over a given coverage area. In order to tessellate – connect without gaps between adjacent cells – the geometry of the hexagon is such that number of cells per cluster N can have values which satisfy $N=i^2+ij+j^2$….(3.6). where i and j are non-negative integers.

To find the nearest co-channel neighbors of a particular cell, one must do the following: (a) move i cells along any chain of hexagons and (b) turn 60 degrees counter-clockwise and move j –cells. Fig. 3.8 illustrates the method of locating co-channel cells in a 19-cell cluster.

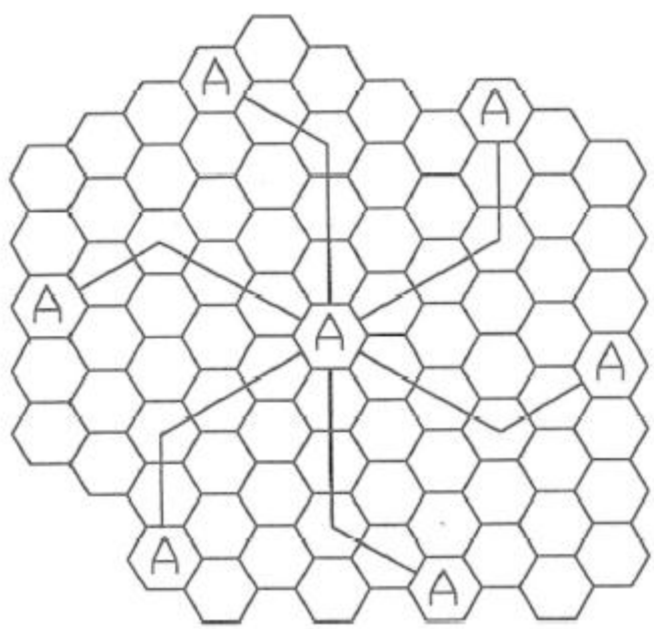


Fig. 3.8: Method of locating co–channel cells (Example for *N*=19, *i*=3, *j*=2).

Fig. 3.9 defines the reuse distance for a 7-cell cluster, and Fig. 3.10 illustrates the method of calculating the reuse distance for such a cluster.

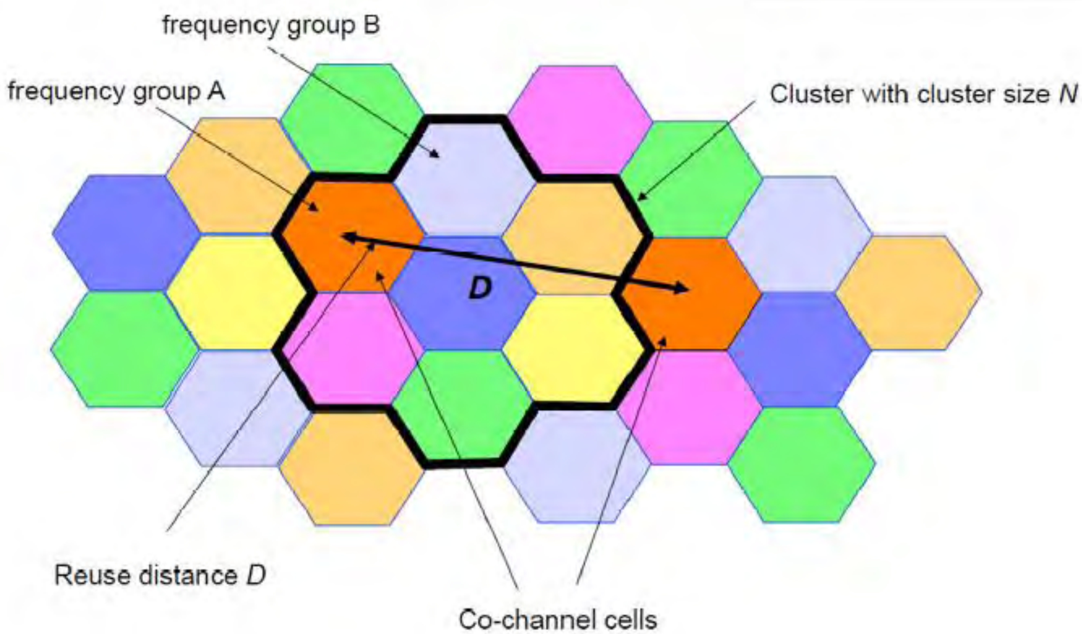


Fig. 3.9: Reuse Distance

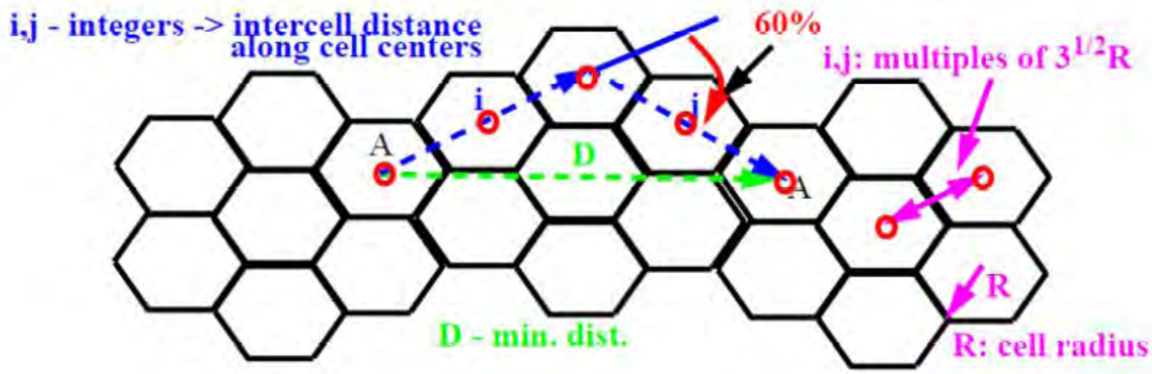


Fig. 3.10: Reuse Distance Calculation

Fig. 3.11 illustrates the method of locating the co-channel cell in a neighboring cluster in a 3-cell cluster.

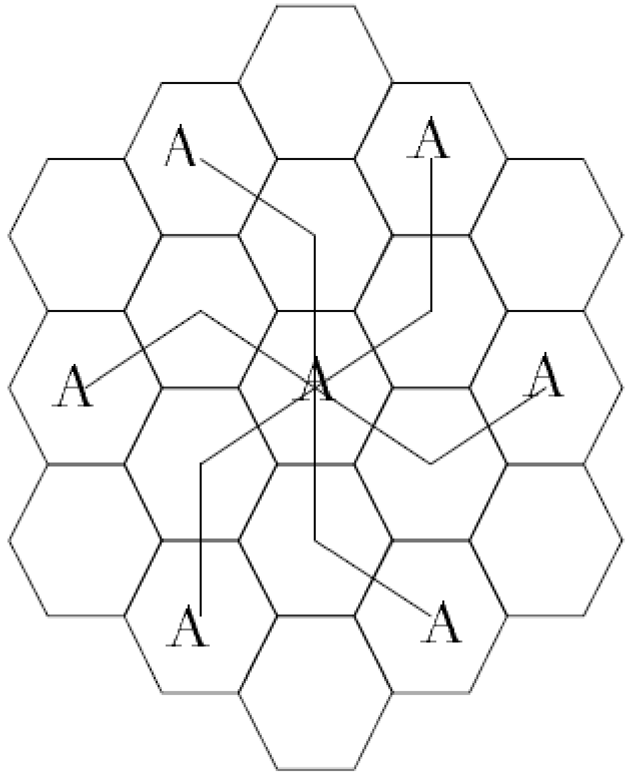


Fig. 3.11: Method of locating co-channel cells in a cellular system (in this case N=3, i.e., i=1 and j=1).

Here, the reuse distance is given by

$$D = \sqrt{3}\sqrt{\left(iR+\cos(60^0)\, jR\right)^2+\left(\sin(60^0)\, jR\right)^2}$$

$$=\sqrt{3}\sqrt{(iR)^2+\{\cos(60^0)\, jR\}^2+2\,iR\cos(60^0)\, jR+\{\sin(60^0)\, jR\}^2}$$

$$= \sqrt{3}\sqrt{(iR)^2+(jR)^2+ijR^2} = \sqrt{3N}R \quad \text{……………(3.7)}$$

3.2.4 CCI and System Capacity:

Some of the vital information related to Co-Channels Interferences and System Capacity are enumerated below:

- Frequency reuse implies that in a given coverage area there are several cells that use the same set of frequencies.
- These cells are called *co-channel cells* and interference between signals from these cells is called *co-channel interference.*
- Unlike thermal noise which can be overcome by increasing SNR, co-channel interference cannot be combated by simply increasing the carrier power of a transmitter.
- To reduce co-channel interference, co-channel cells must be physically separated by a minimum distance to provide sufficient isolation due to propagation.
- When the size of each cell is approximately the same and the BSs transmit the same power, the co-channel interference ratio is independent of the transmitted power and becomes a function of the radius of the cell (R) and the distance between the centers of the nearest co-channel cells (D).
- The parameter Q is called the co-channel reuse ratio and is related to the cluster size.
- For a hexagonal geometry $Q=D/R=\sqrt{(3N)}$…..(3.8)
- A small value of Q provides larger capacity since the cluster size is small; whereas a large value of Q improves the transmission quality, due to smaller level of co-channel interference.

Table 3.1 shows the co-channel reuse ratio for various cluster sizes.

Table 3.1: Co-channel reuse ratio at different Cluster size

	Cluster size (N)	Co-channel reuse ratio (Q=D/R)
i=1,j=1	3	3
i=1,j=2	7	4.58
i=0,j=3	9	5.20
i=2,j=2	12	6

3.2.5 Signal to Interferer Ratio (SIR):

Some of the vital information related to Signal to Interferer Ratio are enumerated below:

- Let I_0 be the number of interfering cells
- Then the SIR for a mobile receiver which monitors a forward channel (down link) can be expressed as S/I where S is the desired signal power from the desired BS and Ii is the interference power caused by the ith interfering cochannel cell BS

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i} \qquad \ldots\ldots\ldots\ldots\ldots(3.9)$$

- If D_i is the distance of the ith interferer from MS, the received power at a given MS due to the ith interfering cell will be proportional to (D_i)-n.
- n is in the range 2-4 for urban cellular systems.
- When the transmit power of each BS is equal and path loss exponent is the same throughout the coverage area, SIR for a MS can be approximated as

$$SIR = \frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}} \cong \frac{\left(\frac{D}{R}\right)^n}{i} \cong \frac{\left(\sqrt{3N}\right)^n}{i} \quad \text{................(3.10)}$$

- In the above equation (3.10)we have considered only the first layer of interfering cells and all interfering BSs are equidistant at a distance of D.
- Using exact cell geometry layout for a seven cluster cell, with MS at the cell boundary, the MS is at a distance D-R from the two nearest co-channel interfering cells, and is exactly D and D+R from the other two interfering cells in the first tier.
- Assuming n=4 , the SIR for the worst case scenario can be approximated as

$$SIR = \frac{S}{I} = \frac{R^{-4}}{2(D-R)^{-4}+2(D+R)^{-4}+2(D)^{-4}} \quad \text{................(3.11)}$$

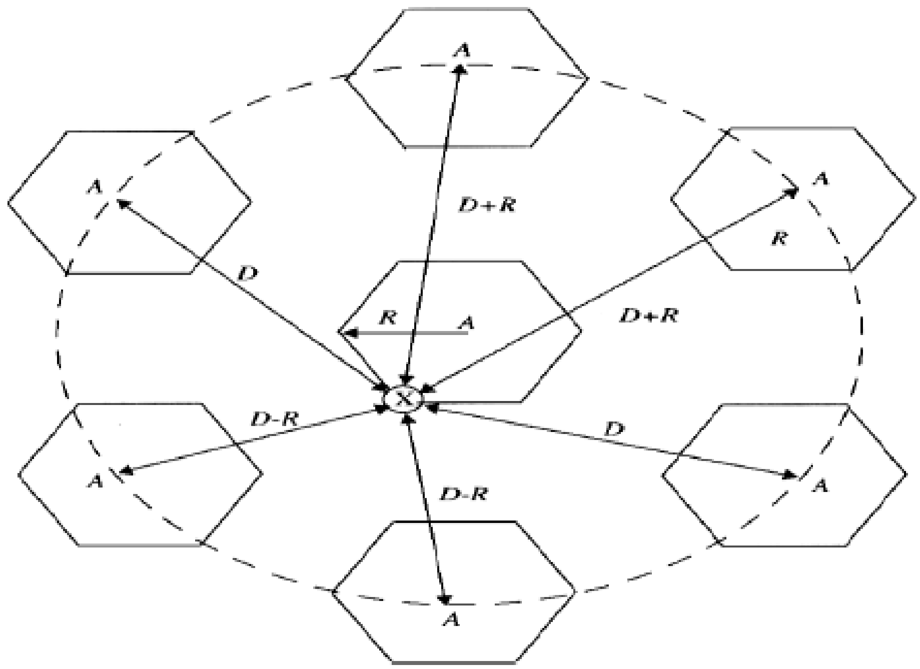


Fig. 3.12: Illustration of the first tier of co-channel cells for a cluster of N. An approximation of the actual geometry is shown here.

When the mobile is at the cell boundary, it experiences the worst case co-channel interference on the forward channel.

Sectoring is a very common method that is employed in cellular systems to improve the SIR performance, whereby cells are divided into radial sectors with wide-beam directional antennas. Cellular systems are quite often deployed with 120^0 and sometimes 60^0 cell sectors. As shown in Fig. 3.13, 120^0 cell sectoring reduces the number of first tier co-channel interferers from six to two. The two first tier interferers are located at a distance of approximately D and D+0.7R, respectively from the original cell [4]-[5].

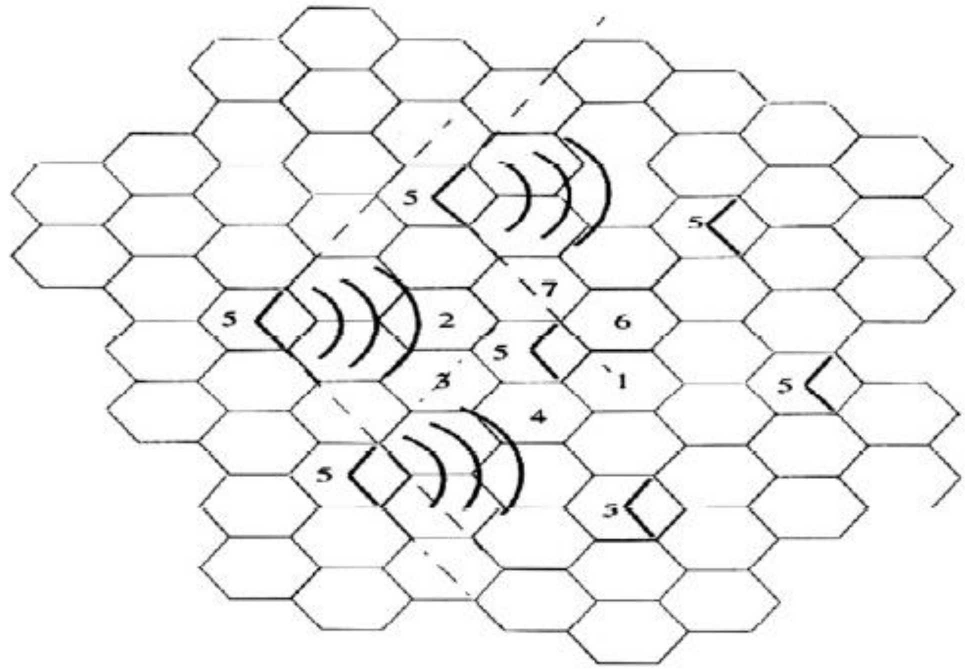


Fig. 3.13: Sectoring reduces the co-channel interferers

Fig. 3.14 shows the worst case CCI situation on the forward channel with 1200 cell sectoring

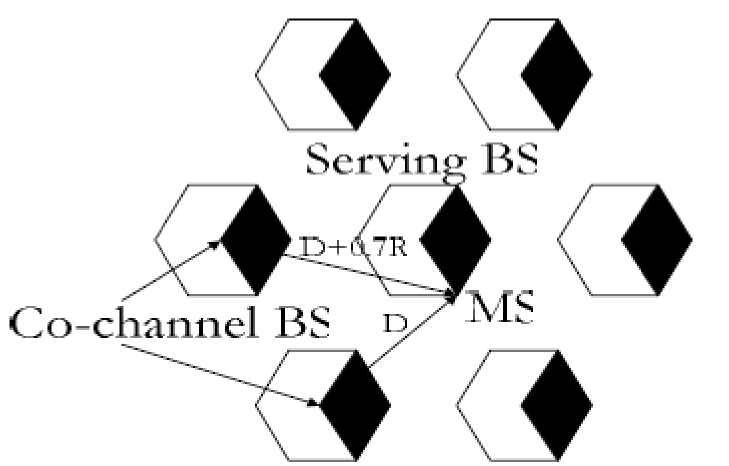


Fig. 3.14: Worst case CCI situation on the forward channel with 120^0 cell sectoring.

3.2.6 BER in GMSK

Gaussian Minimum Shift Keying (GMSK) is particularly important because it is used in some of the most prominent standards around the world. Global System for Mobile Communication (GSM), Digital European Cordless Telephone (DECT), Cellular Digital Packet Data (CDPD), DCS-1800 (Digital Communications System in the 1800 MHz band) in Europe, and GSM-based PCS-1900 (Personal Communications Services in the 1900 MHz band) in the U.S. all use GMSK as their modulation format. With GSM emerging as a dominant global standard for cellular communications, further improvements are being constantly investigated to provide optimum cellular system performance. Better GMSK demodulators can improve systems such as GSM, DECT, CDPD, and PCS with the potential of making a huge economic impact because of the enormous capital expenditure (billions of dollars) and market potential of these technologies. Considering the present market and the predicted volume, small improvements in GMSK receivers can amount to millions of dollars in savings.

Mobile radio operators have generally adopted a cellular network structure, allowing frequency reuse. The primary driving force behind this has been the need to operate and grow almost indefinitely within the limited allocated spectrum. Cellular radio can be described as a honeycomb network set up over the required operating region, where frequencies and power levels are assigned in such a way that the same frequencies can be reused in cells some distance apart. Inherent to this configuration is the problem of co-channel interference (CCI), which limits the system performance. The rejection of CCI is also of particular interest to intelligence agencies who would like to be able to separate co-channel signals as they engage in surveillance [4]-[5].

In digital communications systems, transmitter, channel and receiver imperfections corrupt an ideal digital communications signal so that the digital information is corrupted. Bit error rate (BER) provides a fundamental measure of the system performance in digital communications systems. For ideal assessment of the system performance, it is desirable to estimate BER in real-time. If accurate BER estimation can be performed in real-time, various techniques can be employed to combat the sources of bit errors and thus minimize the BER. This, of course, translates into benefits such as better quality of service (QOS), greater capacity, and/or less power requirements. The following paragraphs outline the techniques for performing real-time BER estimation [14].

BER can be measured by counting the number of errors that occur within a given sequence of bits. This method becomes impractical for small BERs of interest. For example, one would have to transmit a known training sequence of 10,000 bits and receive one error out of that known sequence to calculate a very crude BER=10^{-4} (and the variance of the estimator would still be quite high). BERs on the order of 10^{-6} or 10^{-7} require training sequences of 1,000,000 or 10,000,000 bits, respectively.

Measured BER based on one error is unreliable, since BER is a random variable with some probability density function (pdf). For more accurate BER estimates, the BER pdf should be taken into account. Even for known data, received communications signals are random processes (since the channel conditions are random), and thus, BER is a random variable. In a binary system, the decision statistic is that quantity (usually a sample) by which a decision is made at the receiver as to whether a +1 or a -1 (i.e., zero) was sent.

GMSK, as its name suggests, is based on MSK and was developed to improve the spectral properties of MSK by using a pre-modulation Gaussian filter. The filter impulse response is expressed as

$$h(t) = \frac{1}{\sqrt{2\pi}\sigma T} \exp\left(\frac{-t^2}{2\sigma^2 T^2}\right) \quad \text{...............(3.12)}$$

where $\sigma = \dfrac{\sqrt{\ln(2)}}{2\pi B_b T}$

The Gaussian filter is characterized by its B_bT product (B_b is the -3dB bandwidth of the Gaussian pre-filter and T is the symbol period.) The lower the B_bT product, the narrower the modulation bandwidth. In this paper, we use $B_bT = 1.0$ and $B_bT = 0.5$ for the uncoded system [14]. For transmission in an AWGN channel, the bit error rate of GMSK is given by

$$p = \frac{1}{2} erfc\left(\sqrt{\frac{d_{min}^2 E}{2N_0}}\right) \quad \text{...............(3.13)}$$

Where, d_{min} is the normalized minimum Euclidean distance between the signal representing "0" and the signal representing "1", E is the energy per transmitted bit and N_0=2 is the power spectral density of the AWGN.

In GSM both 900 MHz and 1800 MHz bands are used. However, the path loss is higher in the 1800 MHz than that in the 900 MHz. As in 1800 MHz frequency band the GSM cells have less coverage than the 900 MHz frequency bands, the received power level after 500 to 600 meters, where co-channels are used, will be comparatively low. The co-channel interference at a particular point of pixel is the difference in the received power levels for the serving cell and the interfering cell. Thus in a particular pixel Carrier to Interference ratio will be less in 1800 MHz band compared to a 900 MHz BCCH.

3.3 Challenges in Implementing Proposed Allocation Strategy

The main challenges in implementing proposed frequency allocation strategy are:

- Coverage problem in the 1800MHz band BCCH
- Interference problems in the 900MHz band TCH

Coverage Problem in the 1800 MHz Band BCCH: As in the 1800 MHz band cells, the coverage area is comparatively less than 900 MHz band cells, if BCCH is used from the 1800 MHz band, the cell experiences less coverage [6]. Therefore this strategy can be used only in highly dense areas, where site to site distance is very low. In a dense area, where site to site distance is about 200-300 meters, this approach can be deployed. Normally in such areas, signal strength is sufficient. However, new sites are installed to meet additional traffic demand rather than to compensate for the coverage gaps.

Interferences in 900 Band TCH: Though the 900 MHz frequency band will be shifted from the BCCH, it will still be used as the TCH. Therefore the 900 MHz TCH TRxs will experience the same type of interferences as the BCCH would due to a very low frequency reuse distance. Interferences in the 900 MHz TCH can be handled using the Downlink Power Control (DLPC), Synthesized Frequency Hopping (SFH), Intelligent Underlay Overlay (IUO) etc [4].

Downlink Power Control (DLPC): Power control is to change the transmission power of MS or BTS (or both) in radio mode within certain area. Power control can reduce the system interference and improve the spectrum utilization and prolong the service time of an MS battery. When the Relev and quality is good, the transmission power of the peer end can be reduced to lower the interference to other calls [4]. In GSM, power control can be used in uplink and downlink respectively. The downlink power control range is decided by equipment manufacturer. Although whether to adopt uplink or downlink power control function is decided by network operators, all MSs and BTS equipment must support this function. BSS manages the power control in the two directions. To facilitate BCCH frequency pull-in and the measurement of Relev (including the Rxlev of neighbor cell BCCH frequency), GSM protocol specifies that no power control is allowed for the timeslots in the downlink of BCCH TRX.

BTS power control is an optional function. It is similar to MS power control, but it only uses stable power control algorithm. The required parameters are Rxlev threshold (lower limit), and the maximum transmission level can be received (upper limit). The Relev is divided into 64 levels ranging from 0 to 63 [5]. Level 0 is the lowest Rxlev; level 63 is the highest Rxlev. BTS power control is divided into static power control and dynamic power control. Dynamic power control is the fine tuning based on static power control. There are six steps (2 dB/step) of static power control according to Protocol 0505. If the maximum output power is 46 dBm (40W), the step 6 is 34 dBm.
Static power control step is defined in the cell distributes list of data management system, which specifies the maximum output power (suppose this value is P_n) of static power control. For step 15 of dynamic power control, the corresponding value range is P_n dB – P_n -30dB. When the maximum power control still cannot satisfy the requirement, static power control step is adjusted to improve the maximum output power of the dynamic power control P_n.

Synthesized Frequency Hopping (SFH): Frequency hopping means that multiple frequencies are used for the transmission of speech, signaling or data in a single connection. Each burst for the connection is transmitted on a fixed frequency, but the frequency is changed between bursts. A burst can easily be lost when the mobile station happens to be located in a fading dip for that particular frequency, or if it is subjected to interference. The next burst, if on a different frequency, has a good chance to come through. The coding and interleaving scheme in GSM is constructed so that loss of a single burst have minimal influence on the speech quality. A predefined set of frequencies is used in each cell. The mobile station and the base station can change frequency between every burst, i.e. 217 times per second [2]-[4]. The Frequency Hopping feature is implemented in the Base Station Controller (BSC).

Advantages of Frequency Hopping

Frequency Diversity: Frequency hopping can reduce the influence of signal strength variations caused by multipath propagation. This effect is often referred to as frequency diversity.

Multipath fading is frequency and location dependent. This implies that the fading dips appear at different spatial locations for different frequencies [3]. Thus a slowly moving mobile station using frequency hopping will typically not remain in a specific fading dip for a longer time than one single burst. Thereby signal strength variations are broken up into pieces of a duration short enough for the interleaving and speech coding process to correct errors. Multipath fading dips, causing low signal strength, are thus apparently leveled out, and the slowly moving mobile stations (and cars stuck at a red light) will perceive a more even radio environment.

Interference Diversity: Frequency hopping can also break up persistent interference into periodic occasions of single burst interference. This will improve performance as further described below.

Changing frequency at each burst offers a way to improve the interference situation. The co-channel interference will change at every burst, which is beneficial for the connection that otherwise might suffer from a severe interference during the entire connection. Likewise, the interference that one connection is causing, is spread out to a number of connections in single bursts [2]. This effect is called interference averaging. The radio environment, in terms of interference characteristics, will be more even. Occasionally there will be frequency collisions causing strong interference, but with very short durations. Again, the coding and interleaving will get a chance to deal with the situation. The time varying interference increases coding and interleaving efficiency and a coding gain is achieved. The transmission link will thereby become less sensitive to interference.

These two considerations also apply to other types of interference such as, adjacent channel, intermodulation products etc. Frequency hopping thus introduces an interference diversity. The cell planning margin for the interference can be reduced which makes it possible to implement a tighter frequency plan.

From a subscriber point of view, frequency hopping gives an improved speech quality in many situations. From an operator point of view, the benefits are:

- a possibility to decrease the cell planning margin, which might be used to employ a tighter frequency reuse yielding a capacity increase,
- a more robust radio environment,
- a possibility to give the subscribers a more uniform speech quality.

The effects increase with the number of frequencies used for hopping sequence, but the relative benefit of adding yet another frequency will diminish,

Synthesizer hopping means that one transmitter handles all bursts that belong to a specific connection. The bursts are sent “straight on forward” and not routed by the bus, in contrast to baseband hopping. The transmitter tunes to the correct frequency at transmission of each burst. Fig. 3.15 shows the schematic of sending the bursts from the TRX to the transmitter at synthesizer hopping.

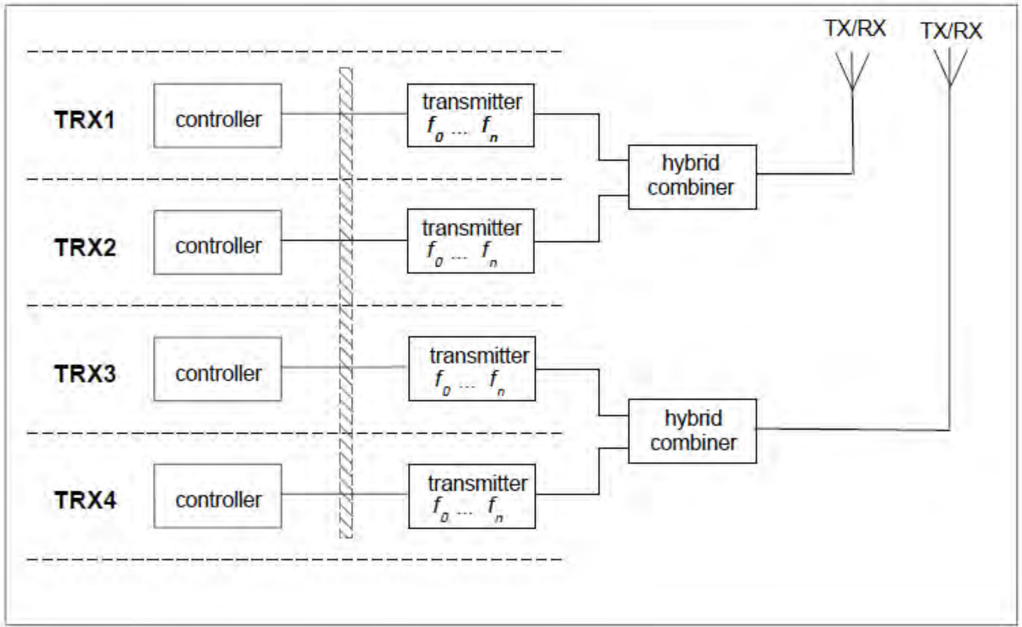


Fig 3.15: Schematic of sending the bursts from the TRX to the transmitter at synthesizer hopping.

The advantage is that the number of frequencies that can be used for hopping is not dependent on the number of transmitters. It is possible to hop over a lot of frequencies even if only a few transceivers are installed.

Intelligent Underlay Overlay (IUO): Intelligent Underlay-Overlay (IUO) is an application software in the base station controller (BSC). It allows you to reuse frequencies very intensively and hence achieve a higher radio network capacity. To avoid interference caused by an increased level of frequency reuse, the BSC estimates the degree of interference on different frequencies and directs the mobile stations to those frequencies that are 'clean' enough to sustain a good radio connection quality [4]. The interference estimation that the BSC makes is based on the measurement results that the mobile station (MS) reports via the base transceiver station (BTS) and on various adjustable parameters.

To achieve a higher radio network capacity with Intelligent Underlay- Overlay, the operating spectrum of the network is divided into regular frequencies and super-reuse frequencies. The regular frequencies are intended to serve mobile stations mainly at cell boundary areas and other locations where the carrier-to-interference (C/I) ratio is the worst. Super-reuse frequencies compose the underlay network where frequencies are reused very intensively to produce extended capacity [4]. To avoid the interference caused by the increased level of frequency reuse, the super-reuse frequencies should serve mobile stations that are close to the BTS, inside buildings and other locations where the radio conditions are less vulnerable to the interference.

The parameter TRX frequency type (FRT) controls the division into regular and super-reuse frequencies within a cell on a transceiver to transceiver basis. The transceivers (TRXs) of the cell are identified as either regular TRXs or super-reuse TRXs:

- Regular TRX: the radio frequency of the transceiver belongs to regular frequencies
- Super-reuse TRX: the radio frequency of the transceiver belongs to super-reuse frequencies

CHAPTER 4

SIMULATION RESUTLS AND DISCUSSIONS

Before simulation, a Project area was chosen in densely populated area. Then the simulation is done to obtain the various performance criteria for different reuse schemes. These are discussed from section 4.1 to 4.3 for the existing frequency plan as well as for the proposed one.

4.1 Project Area

The project area has been selected in Motijhil where site to site distance is very low (200 to 250 meters). Building density in this area is very high. Due to very low site to site distance in this area, further site planning has become impossible due to overshooting. A total of 60 sites having 180 sectors have been included in the project. The snapshot of the project area has been shown below:

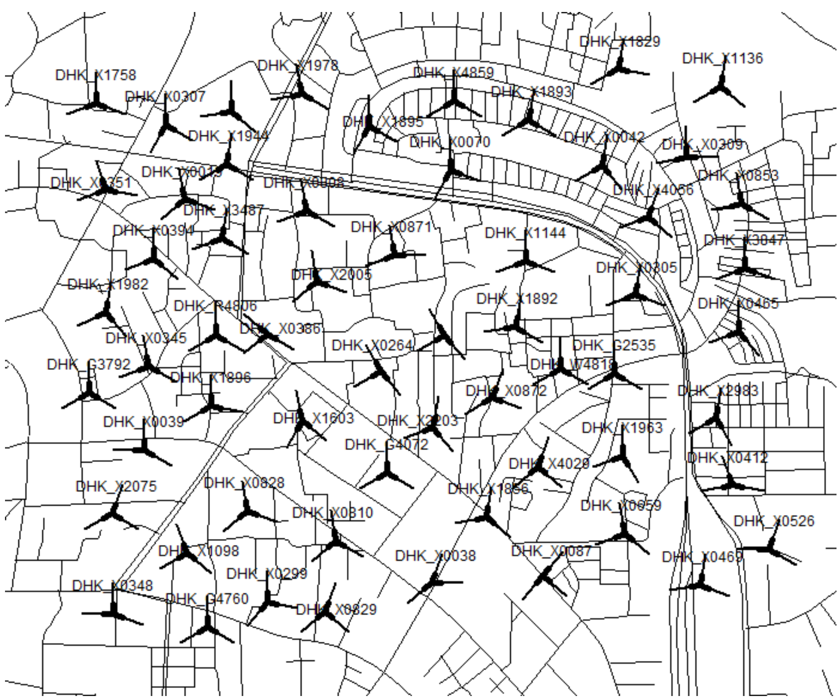


Fig. 4.1: The selected Project Area (Motijheel area, Dhaka)

4.2 Simulation

According to the proposed frequency allocation strategy, BCCH will be used from 1800 MHz band and TCH will be used from both 900 MHz and 1800 MHz bands. The simulations have been made only for BCCH TRxs for both existing and proposed frequency allocations. Simulation for TCH will ignored as it is not so important for the quality network. The interferences in TCH bands will be handled using some quality features like Synthesized Hopping (SFH), Downlink Power Control (DLPC), Discontinuous Transmission (DTX), Orthogonal sub channel (OSC), Intelligent Underlay Overlay (IUO) etc [4]. For the simulation Radio Design Tool Planet EV has been used. It used a digital clutter map of 25 meter resolution and height map with 50 meter resolution for the selected area Motijhil. Based on antenna height, antenna type, azimuth, tilt and clutter information, the tool l calculated received signal strength at every pixel. The project area along with digital map has been shown in Fig. 4.2.

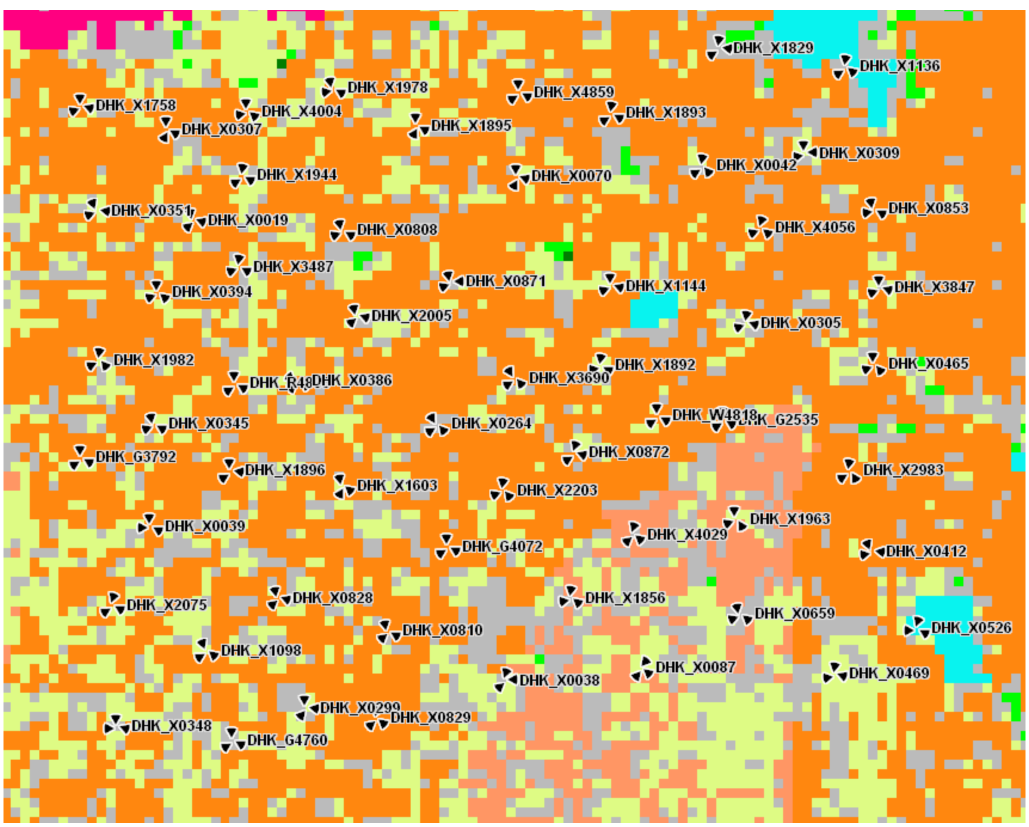


Fig. 4.2: Clutter information for the selected project area

Fig. 4.3 shows the clutter information represented by various colors.

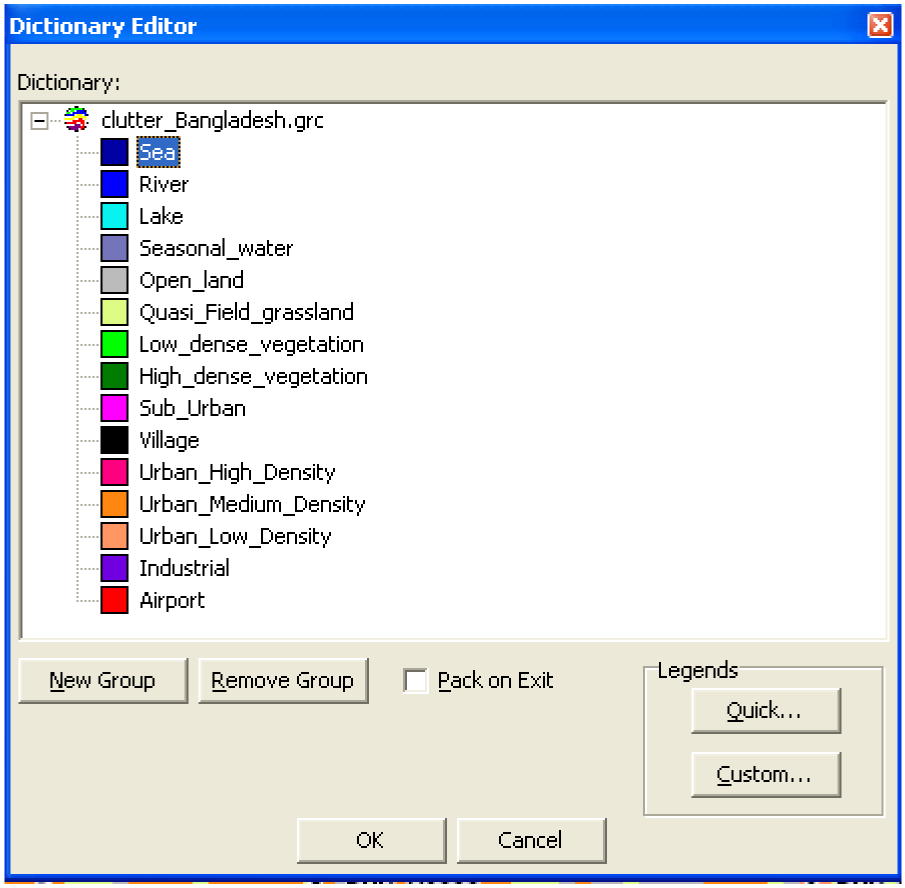


Fig. 4.3: Clutter information represented by color legends

Fig. 4.4 shows the height information of each pixel in meters.

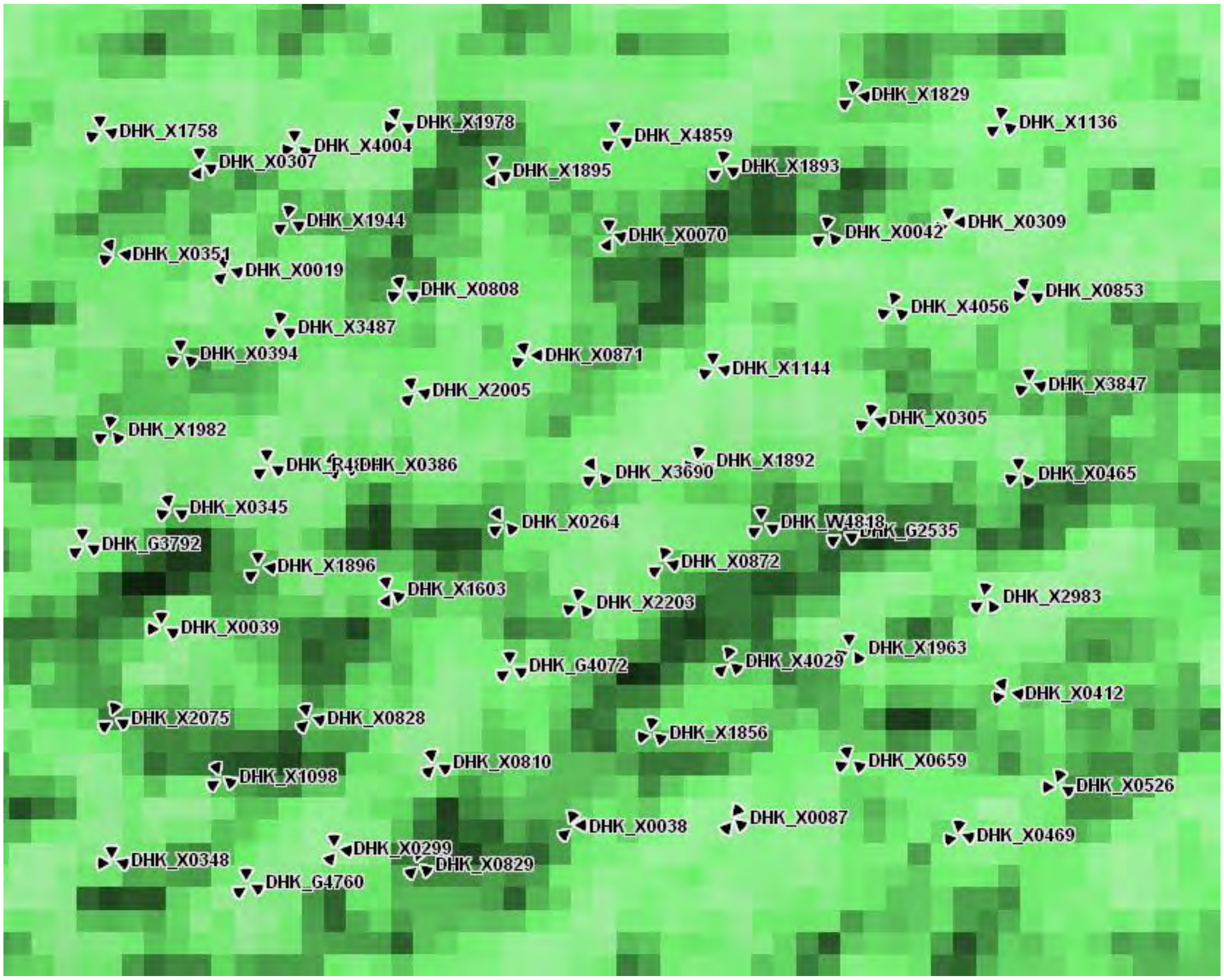


Fig. 4.4: Height information for the pixels project area

4.3 Results

The simulations have been performed at various frequency reuse criteria for both the existing and the proposed frequency allocation strategy. The 3/9, 4/12, 5/15, 6/18 and 7/21 frequency reuse schemes are used. For each analysis, Carrier to Interference Ratio (C/I), Bit Error Rate (BER) and Received signal Quality have been measured.

4.3.1 3/9 Reuse

In 3/9 frequency reuses, each cluster contains 3 sites with 9 sectors. Therefore, the whole project area will contain 20 clusters as shown in the Fig. 4.5.

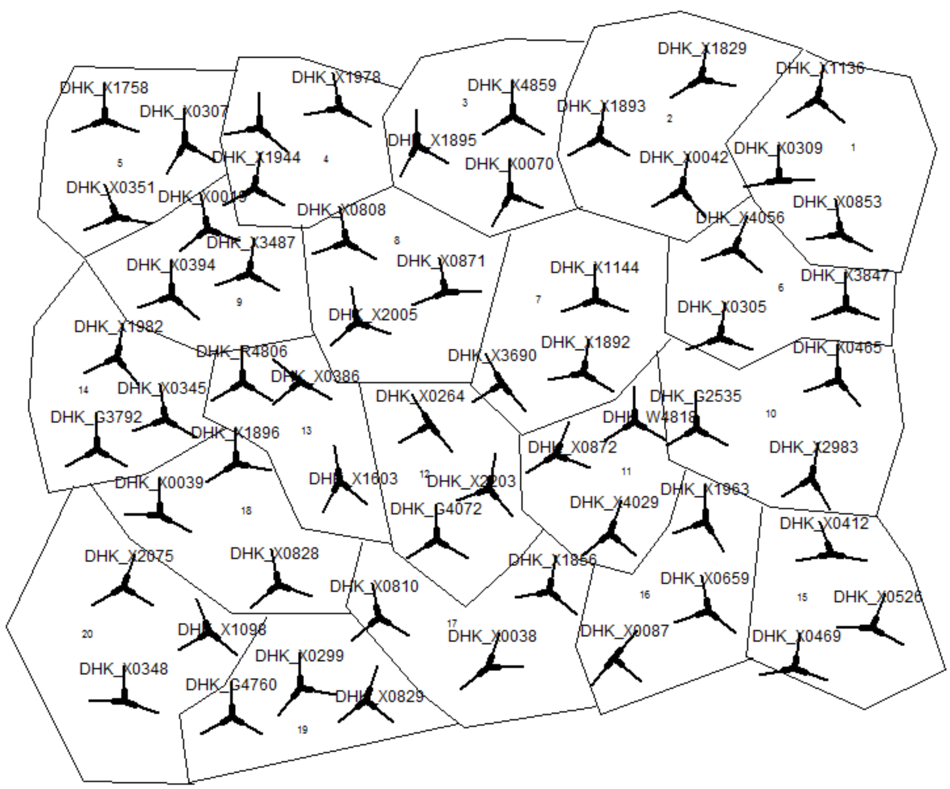


Fig. 4.5: Clusters of the 3/9 frequency reuse scheme for the project area

As the site to site distance is not uniform and orientation of all the sites are not same, the cluster size becomes irregular. In a hypothetical network it may be of regular size, but in a practical network it is always of irregular shape.

4.3.1.1 Best Server Signal Strength

Signal strength from the best server at each pixel has been calculated for both the existing and the proposed strategies and shown in Fig. 4.6 and 4.7 respectively. For the existing strategy, the signal strength at each pixel is comparatively better than proposed strategy. This is because in the 1800 MHz band path loss is more than that in the 900 MHz band [7]. This received signal strength is calculated by deducting path loss from the transmitter signal strength. Therefore, in the proposed strategy, signal strength in each pixel is still within acceptable range. From the plots of signal strength for both the strategies, it is found that in the proposed strategy signal strength at each pixel lies within -70 dBm.

Fig. 4.6: Received signal strength with the existing strategy

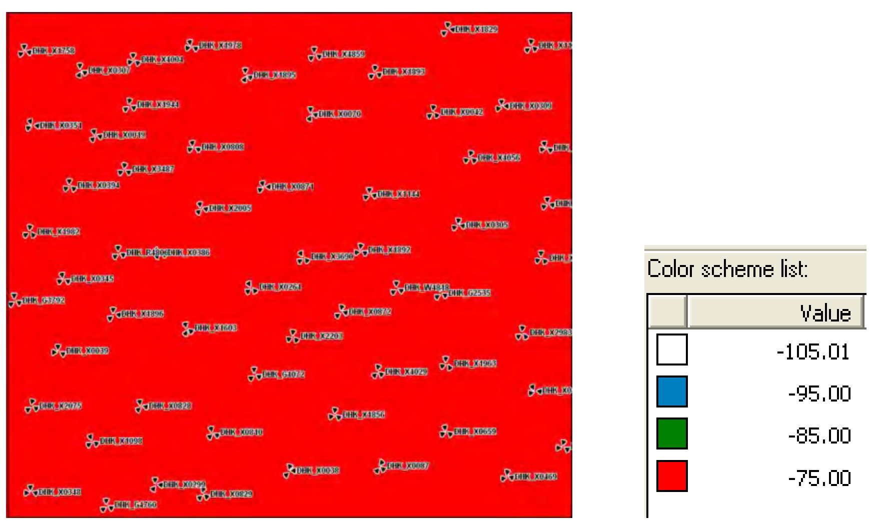


Fig. 4.7: Received signal strength with the proposed strategy

4.3.1.2 Carrier to Interferer Ratio

At each pixel of the project, the received signal strength from the serving cell and the summation of the received signal strength from the surrounding co-channel cells are measured. The ratio of those two measurements is recorded as Carrier to Interferer Ratio or C/I. The signal strength in a pixel is calculated by deducting the path loss from the transmitting power. This path loss depends on frequency and the clutter information between the transmitter and the receiver [4]-[6]. Two models are used to calculate this C/I at each pixel; one for the existing strategy and another for the proposed strategy. The C/I plot for the two strategies for 3/9 reuses are shown in the Fig. 4.8 and 4.9.

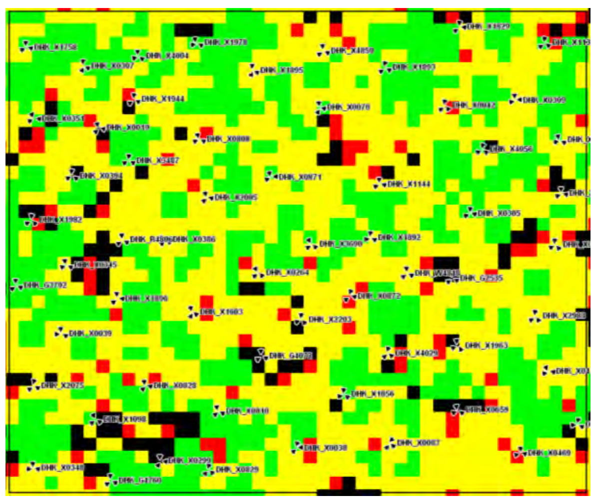


Fig. 4.8: C/I with the existing strategy

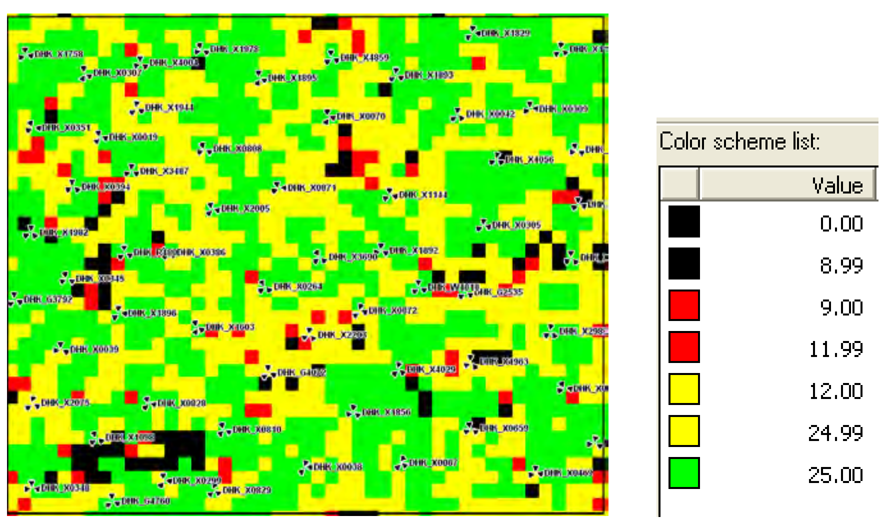


Fig. 4.9: C/I with the proposed strategy

Worse samples are reduced in the whole area in the proposed strategy.

4.3.1.3 Bit Error Rate

The Bit Error Rate (BER) at any pixel is calculated by measuring number of bits received when compared to the number of bits transmitted. It represents the measure of lost bits during transmission due to interferences [5]. The BER for existing and proposed strategies have been shown in Fig. 4.10 and 4.11 respectively.

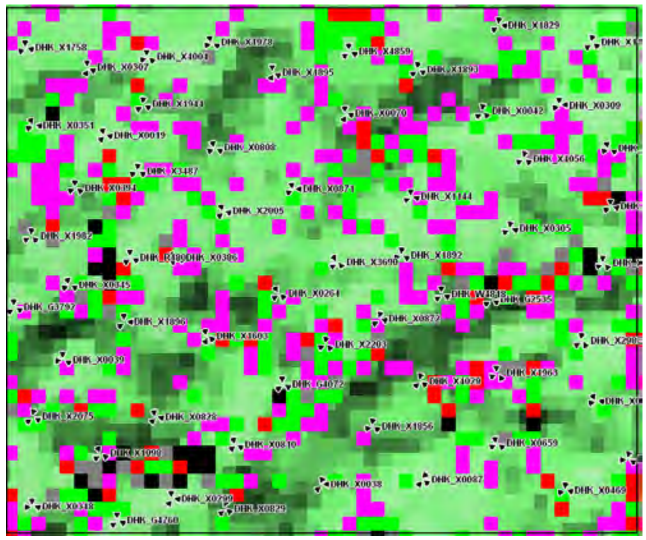


Fig. 4.10: BER with the existing strategy

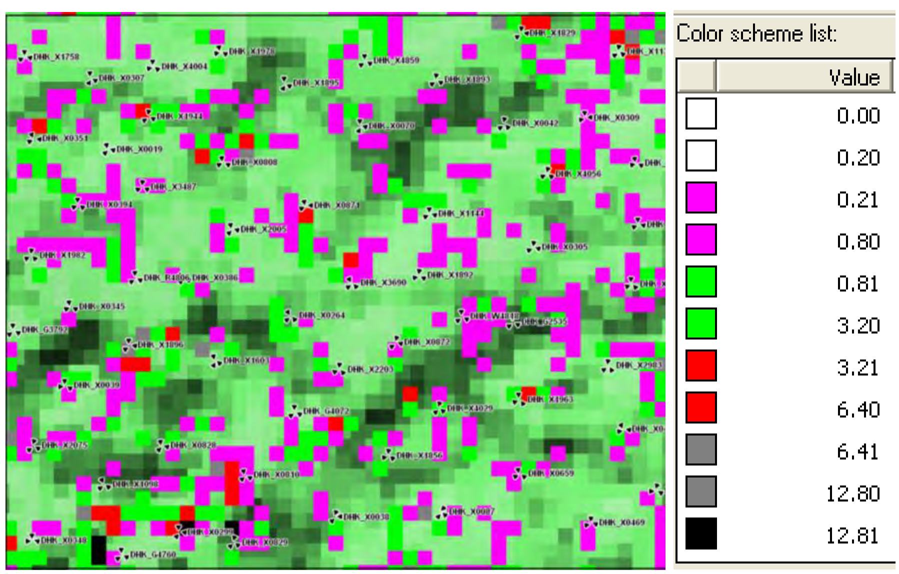


Fig. 4.11: BER with the proposed strategy

BER is improved in the lower part in the proposed strategy.

4.3.1.4 Received Signal Quality

It is the measure of quality of the received signal at each pixel. It is classified into 8 categories. Rx Qual from 0 to 4 represent good signal quality. Rx Qual from 5 to 7 represent bad signal quality [4]. This signal quality depends on the level of interferences faced by a sector at a particular pixel. Rx Quality for the both existing and proposed strategies have been shown in Fig. 4.12 and 4.13 respectively.

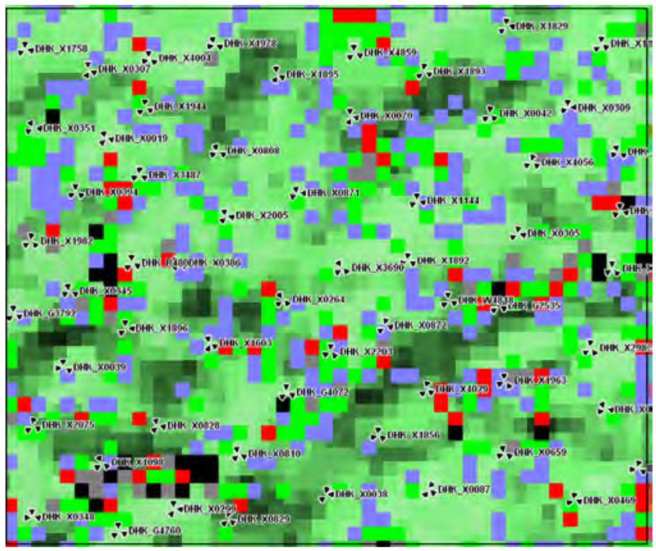


Fig. 4.12: Rx Qual with the existing strategy

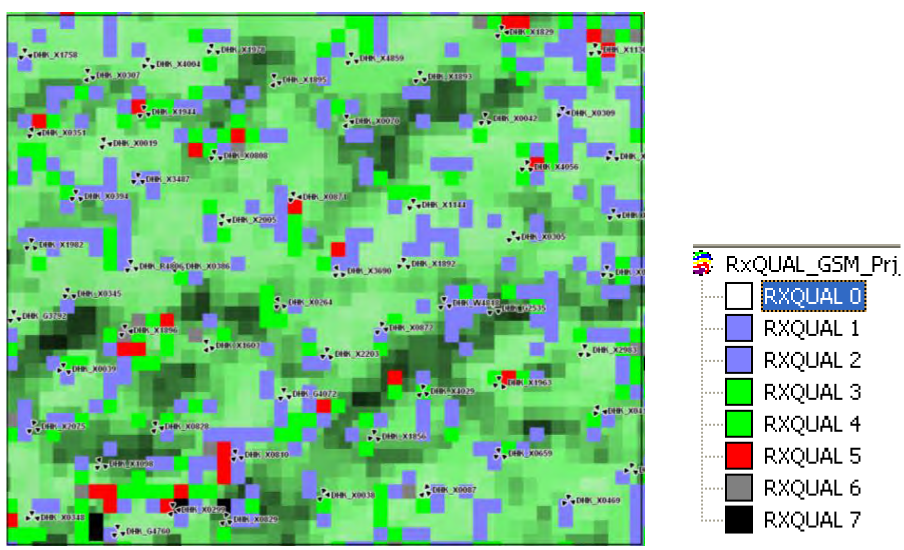


Fig. 4.13: Rx Qual with the proposed strategy

Worse Rx Qual samples are improved in the lower part in the proposed strategy.

4.3.2 4/12 Reuses

In 4/12 frequency reuses, each cluster contains 4 sites with 12 sectors. Therefore, the whole project area will contain 15 clusters as shown in Fig. 4.14.

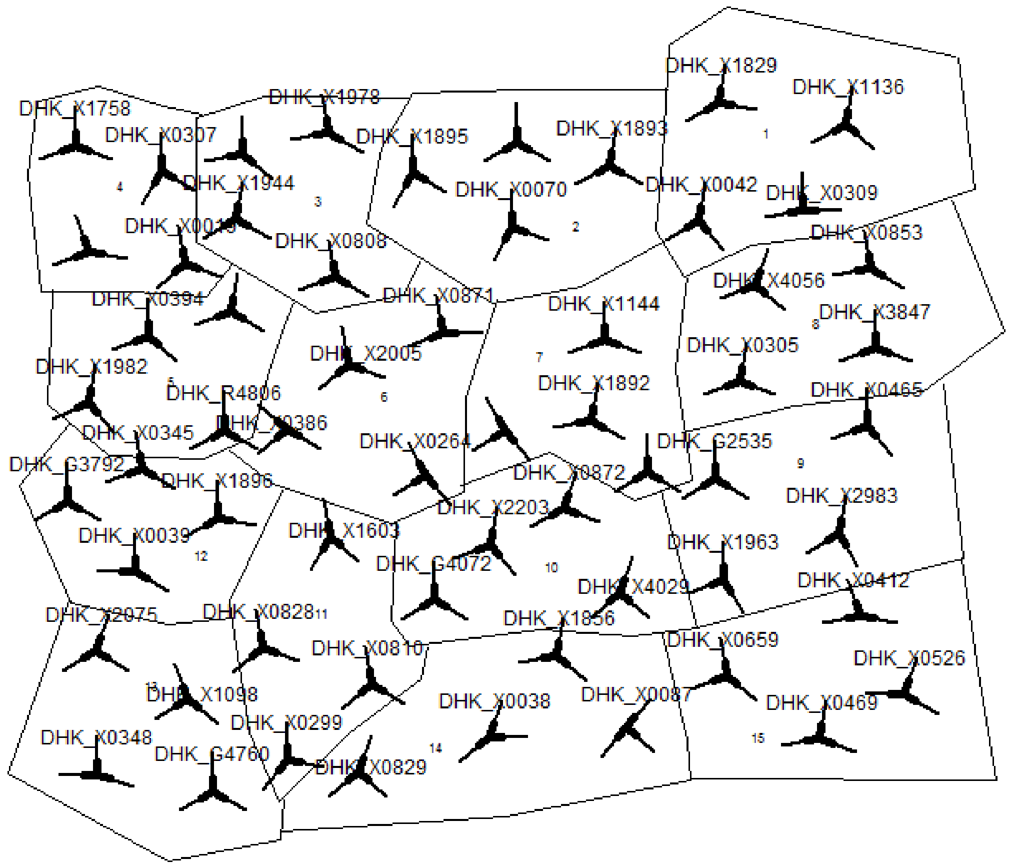


Fig. 4.14: Clusters of the 4/12 frequency reuse scheme for the project area

As the site to site distance is not uniform and orientation of all the sites are not same, the cluster size becomes irregular. In a hypothetical network it may be of regular size, but in a practical network it is always of irregular shape.

4.3.2.1 Carrier to Interferer Ratio

At each pixel of the project, the received signal strength from the serving cell and the summation of the received signal strength from the surrounding co-channel cells are measured. The ratio of those two measurements is recorded as Carrier to Interferer Ratio or C/I. The signal strength in a pixel is calculated by deducting the path loss from the transmitting power. This path loss depends on frequency and the clutter information between the transmitter and the receiver [4]-[6]. Two models are used to calculate this C/I at each pixel; one for the existing strategy and another for the proposed strategy. The C/I plot for the two strategies for 4/12 reuses are shown in the Fig. 4.15 and 4.16.

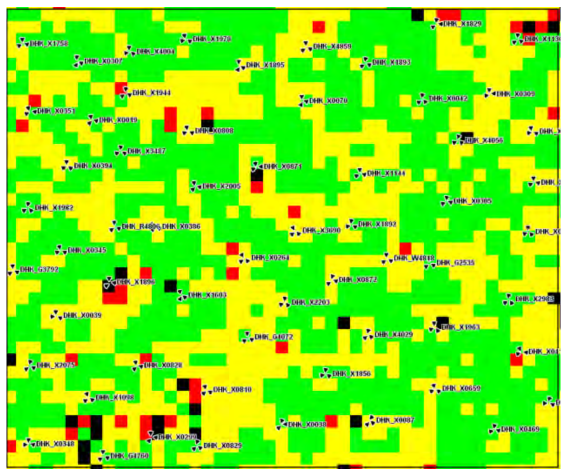


Fig. 4.15: C/I with the existing strategy

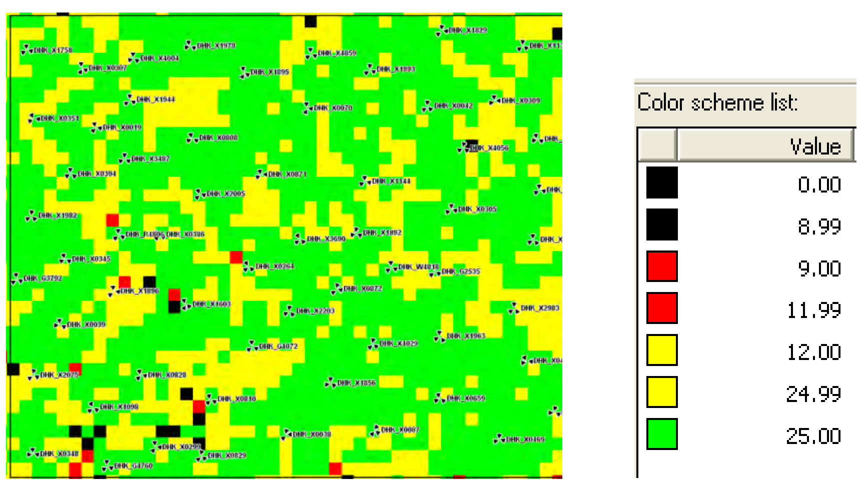


Fig. 4.16: C/I with the proposed strategy

Worse samples are reduced in the whole area in the proposed strategy.

4.3.2.2 Bit Error Rate

The Bit Error Rate (BER) at any pixel is calculated by measuring number of bits received when compared to the number of bits transmitted. It represents the measure of lost bits during transmission due to interferences [5]. The BER for existing and proposed strategies have been shown in Fig. 4.17 and 4.18 respectively.

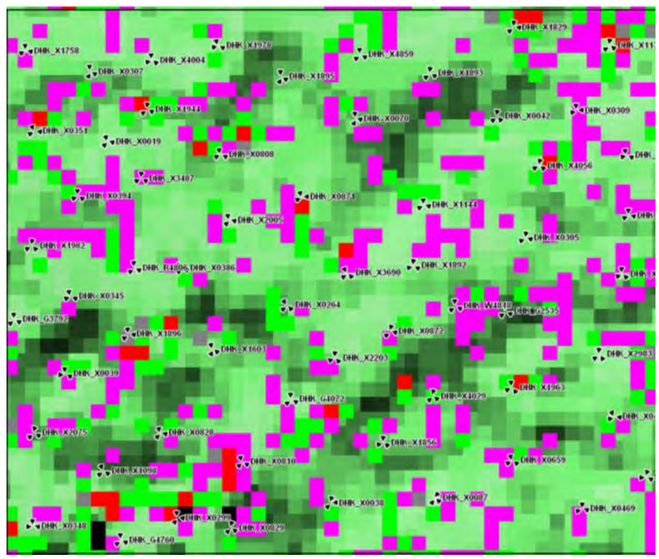


Fig. 4.17: BER with the existing strategy

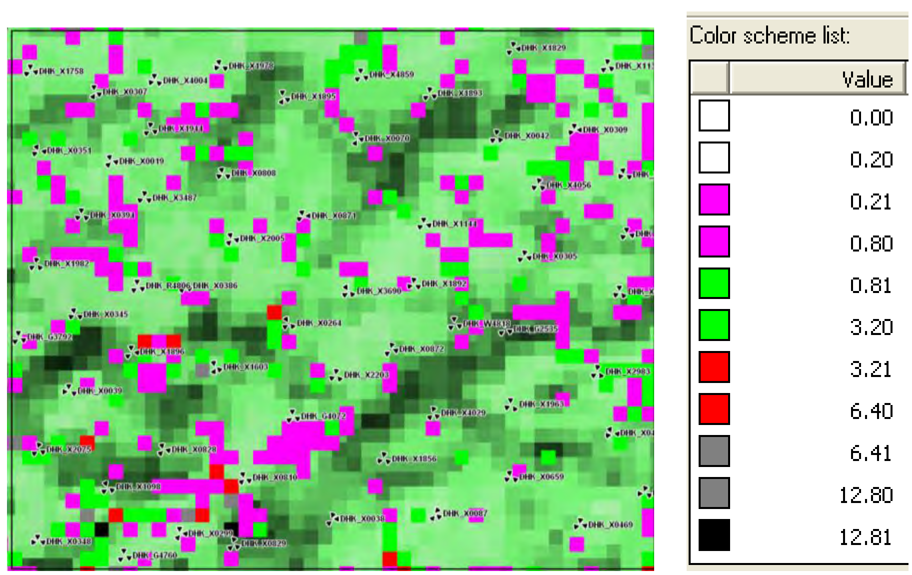


Fig. 4.18: BER with the proposed strategy

BER is improved in the lower part in the proposed strategy.

4.3.2.3 Received Signal Quality

It is the measure of quality of the received signal at each pixel. It is classified into 8 categories. Rx Qual from 0 to 4 represent good signal quality. Rx Qual from 5 to 7 represent bad signal quality [4]. This signal quality depends on the level of interferences faced by a sector at a particular pixel. Rx Quality for the both existing and proposed strategies have been shown in Fig. 4.19 and 4.20 respectively.

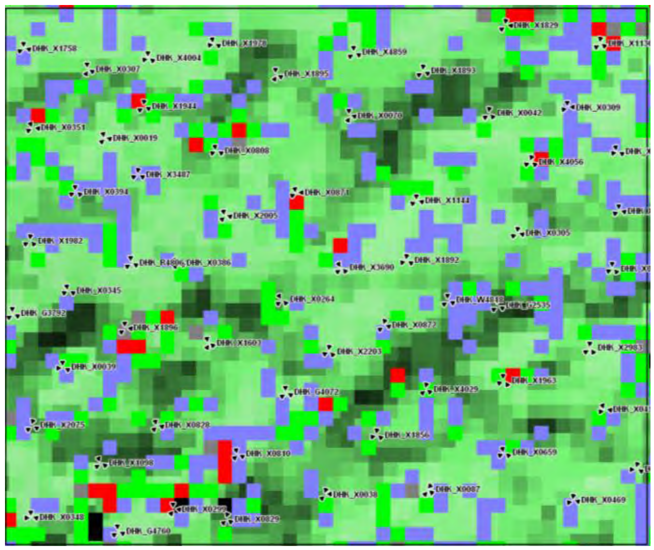


Fig. 4.19: Rx Qual with the existing strategy

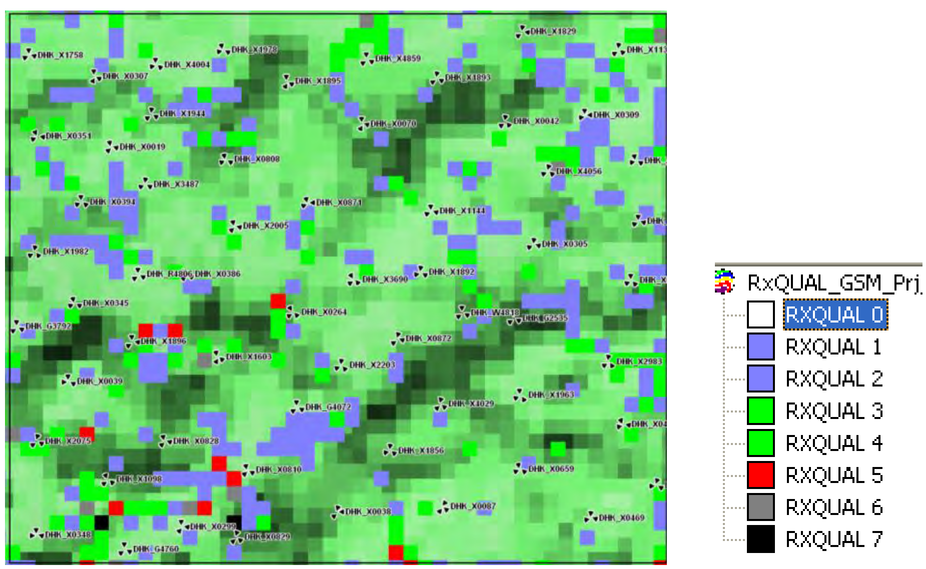


Fig. 4.20: Rx Qual with the proposed strategy

Worse Rx Qual samples are improved in the lower part in the proposed strategy.

4.3.3 5/15 Reuses

In5/15 frequency reuses, each cluster contains 5 sites with 15 sectors. Therefore, the whole project area will contain 12 clusters as shown in Fig. 4.21.

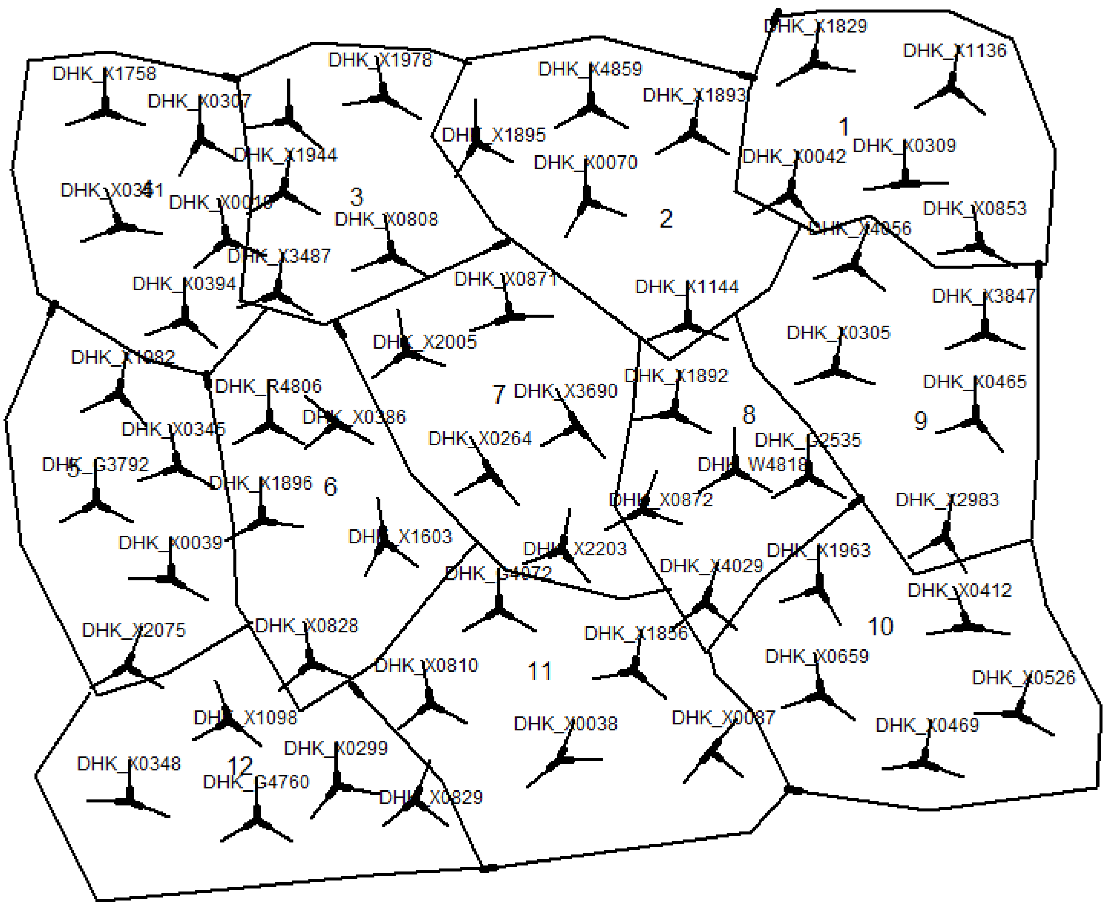


Fig. 4.21: Clusters of 5/15 frequency reuses

As the site to site distance is not uniform and orientation of all the sites are not same, the cluster size becomes irregular. In a hypothetical network it may be of regular size, but in a practical network it is always of irregular shape.

4.3.3.1 Carrier to Interferer Ratio

At each pixel of the project, the received signal strength from the serving cell and the summation of the received signal strength from the surrounding co-channel cells are measured. The ratio of those two measurements is recorded as Carrier to Interferer Ratio or C/I. The signal strength in a pixel is calculated by deducting the path loss from the transmitting power. This path loss depends on frequency and the clutter information between the transmitter and the receiver [4]-[6]. Two models are used to calculate this C/I at each pixel; one for the existing strategy and another for the proposed strategy. The C/I plot for the two strategies for 5/15 reuses are shown in the Fig. 4.22 and 4.23.

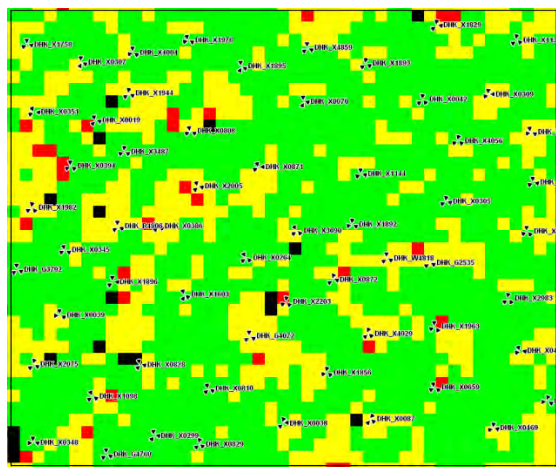


Fig. 4.22: C/I with the existing strategy

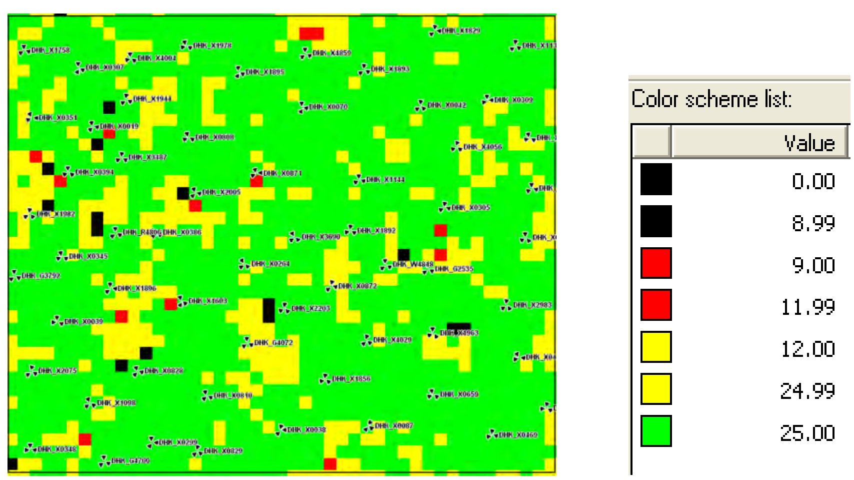


Fig. 4.23: C/I with proposed strategy

Worse samples are reduced in the whole area in the proposed strategy.

4.3.3.2 Bit Error Rate

The Bit Error Rate (BER) at any pixel is calculated by measuring number of bits received when compared to the number of bits transmitted. It represents the measure of lost bits during transmission due to interferences [5]. The BER for existing and proposed strategies have been shown in Fig. 4.24 and 4.25 respectively.

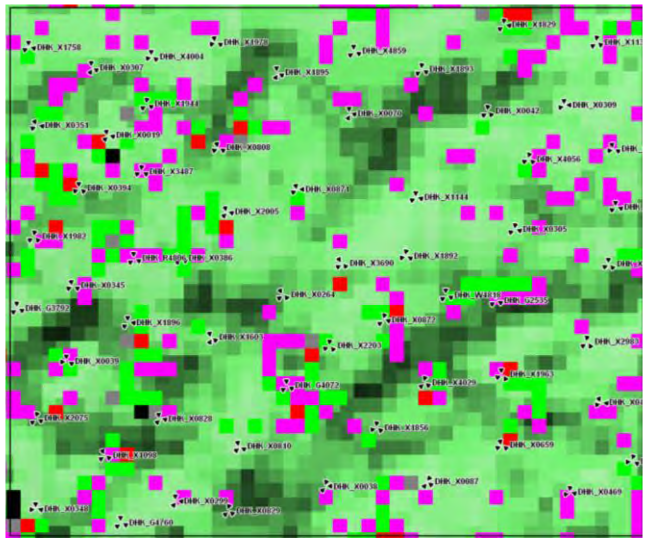


Fig. 4.24: BER with the existing strategy

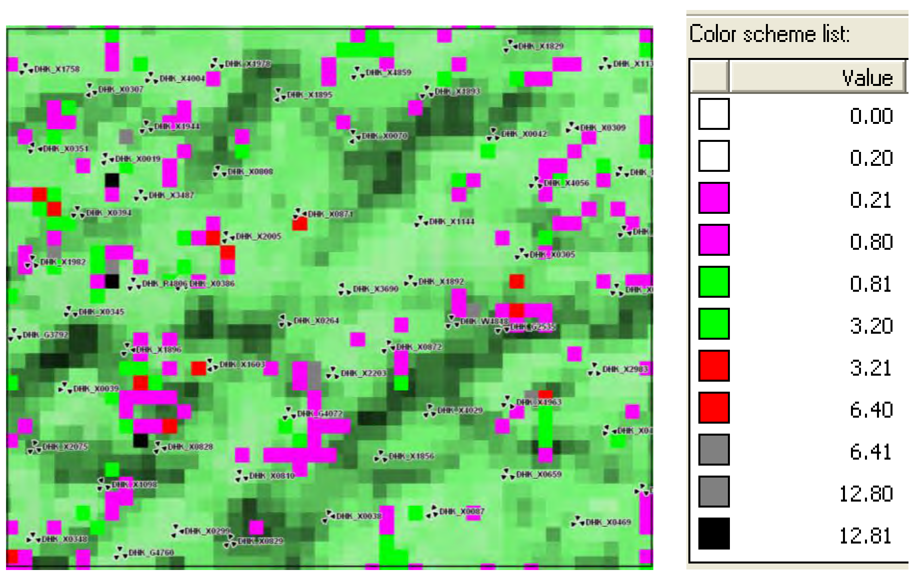


Fig. 4.25: BER with the proposed strategy

BER is improved in the lower part in the proposed strategy.

4.3.3.3 Received Signal Quality

It is the measure of quality of the received signal at each pixel. It is classified into 8 categories. Rx Qual from 0 to 4 represent good signal quality. Rx Qual from 5 to 7 represent bad signal quality [4]. This signal quality depends on the level of interferences faced by a sector at a particular pixel. Rx Quality for the both existing and proposed strategies have been shown in Fig. 4.26 and 4.27 respectively.

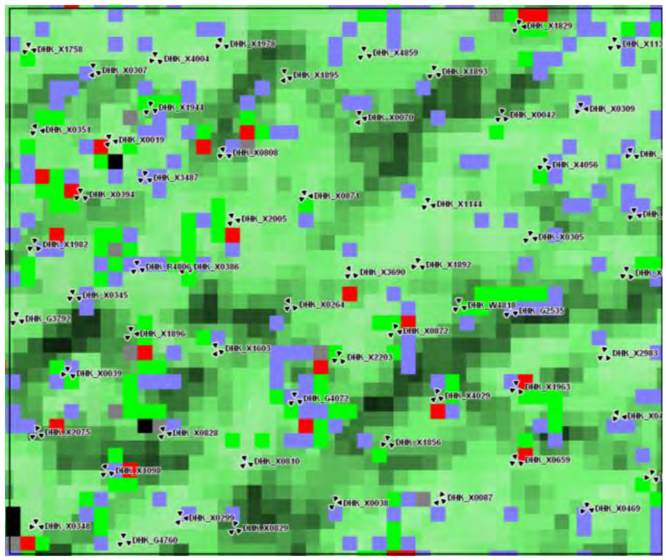


Fig. 4.26: Rx Qual with the existing strategy

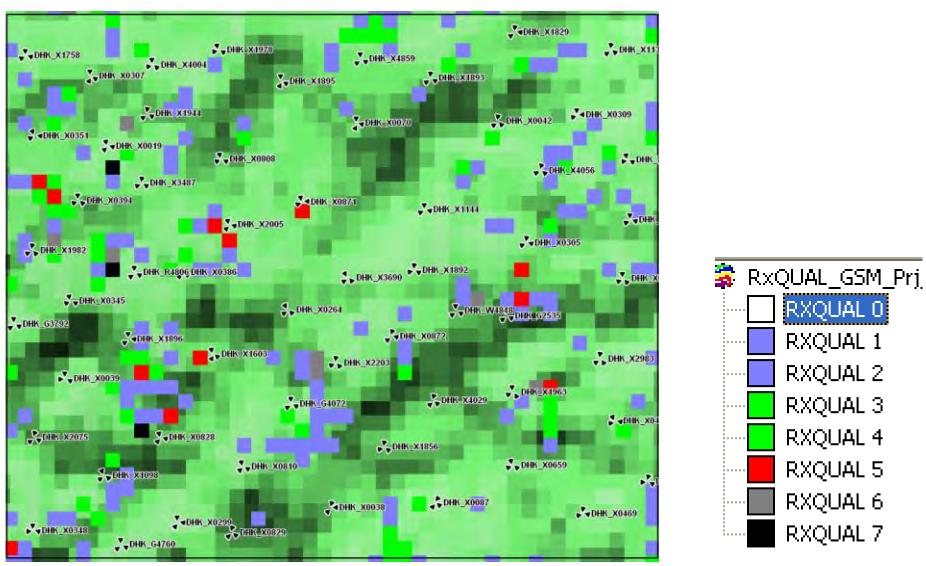


Fig. 4.27: Rx Qual with the proposed strategy

Worse Rx Qual samples are improved in the lower part in the proposed strategy.

4.3.4 6/18 Reuses

In 6/18 frequency reuses, each cluster contains 6 sites with 18 sectors. So the whole project area will contain 10 clusters as shown in Fig. 4.28.

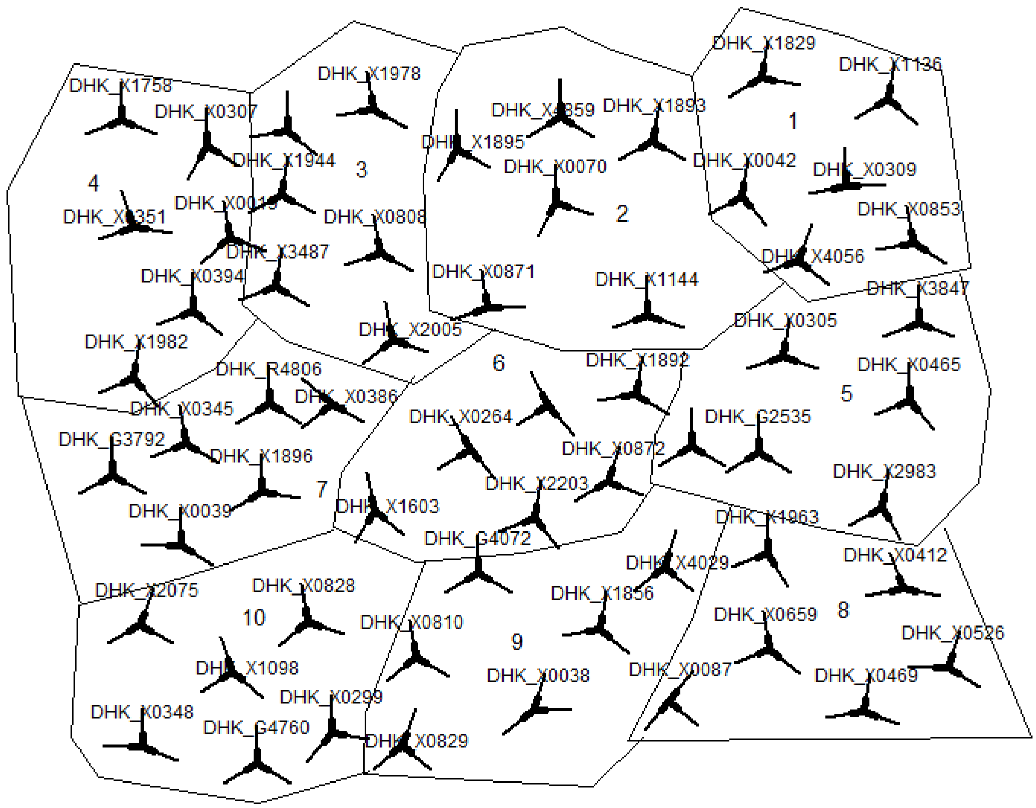


Fig. 4.28: Clusters of 6/18 frequency reuses

As the site to site distance is not uniform and orientation of all the sites are not same, the cluster size becomes irregular. In a hypothetical network it may be of regular size, but in a practical network it is always of irregular shape.

4.3.4.1 Carrier to Interferer Ratio

At each pixel of the project, the received signal strength from the serving cell and the summation of the received signal strength from the surrounding co-channel cells are measured. The ratio of those two measurements is recorded as Carrier to Interferer Ratio or C/I. The signal strength in a pixel is calculated by deducting the path loss from the transmitting power. This path loss depends on frequency and the clutter information between the transmitter and the receiver [4]-[6]. Two models are used to calculate this C/I at each pixel; one for the existing strategy and another for the proposed strategy. The C/I plot for the two schemes for 6/18 reuses are shown in the Fig. 4.29 and 4.30.

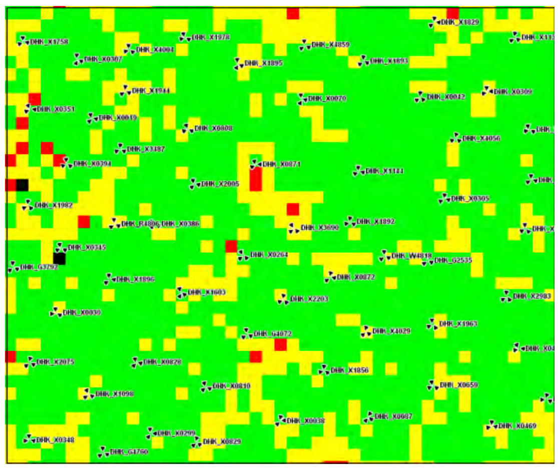


Fig. 4.29: C/I with the existing strategy

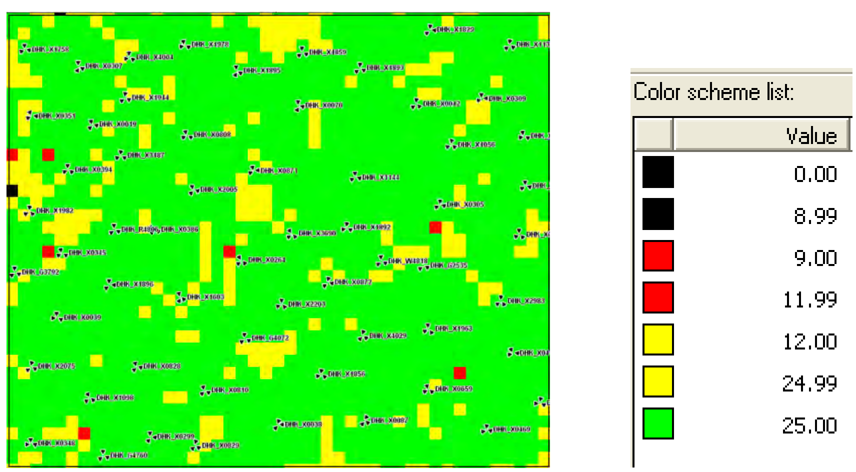


Fig. 4.30: C/I with the proposed strategy

Worse samples are reduced in the whole area in the proposed strategy.

4.3.4.2 Bit Error Rate

The Bit Error Rate (BER) at any pixel is calculated by measuring number of bits received when compared to the number of bits transmitted. It represents the measure of lost bits during transmission due to interferences [5]. The BER for existing and proposed strategies have been shown in Fig. 4.31 and 4.32 respectively.

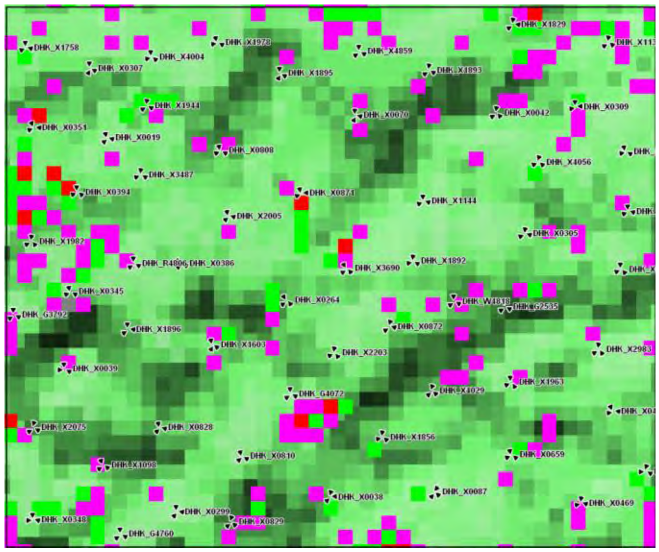


Fig. 4.31: BER with the existing strategy

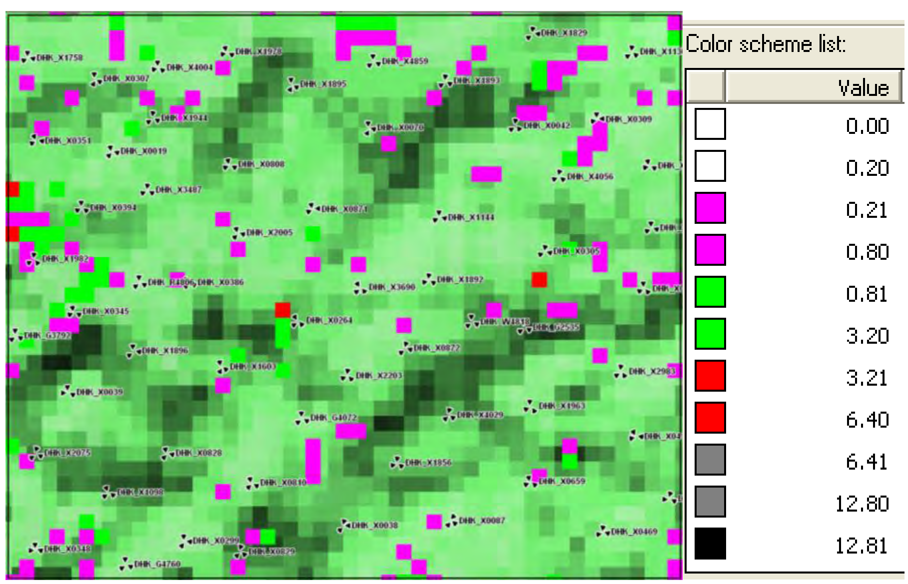


Fig. 4.32: BER with the proposed strategy

BER is improved in the lower part in the proposed strategy.

4.3.4.3 Received Signal Quality

It is the measure of quality of the received signal at each pixel. It is classified into 8 categories. Rx Qual from 0 to 4 represent good signal quality. Rx Qual from 5 to 7 represent bad signal quality [4]. This signal quality depends on the level of interferences faced by a sector at a particular pixel. Rx Quality for the both existing and proposed strategies have been shown in Fig. 4.33 and 4.34 respectively.

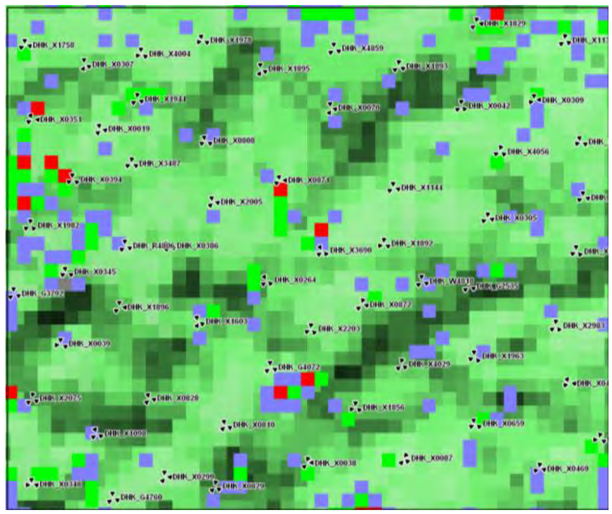


Fig. 4.33: Rx Qual with the existing strategy

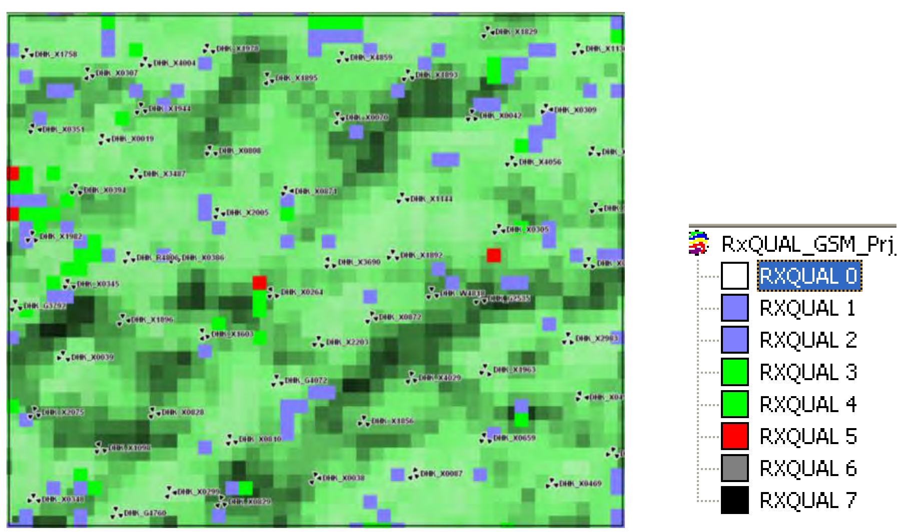


Fig. 4.34: Rx Qual with the proposed strategy

Worse Rx Qual samples are improved in the lower part in the proposed strategy.

4.3.5 7/21 Reuses: In 7/21 frequency reuses, each cluster contains 7 sites with 21 sectors. Therefore, the whole project area will contain 9 plus clusters as shown in Fig. 4.35.

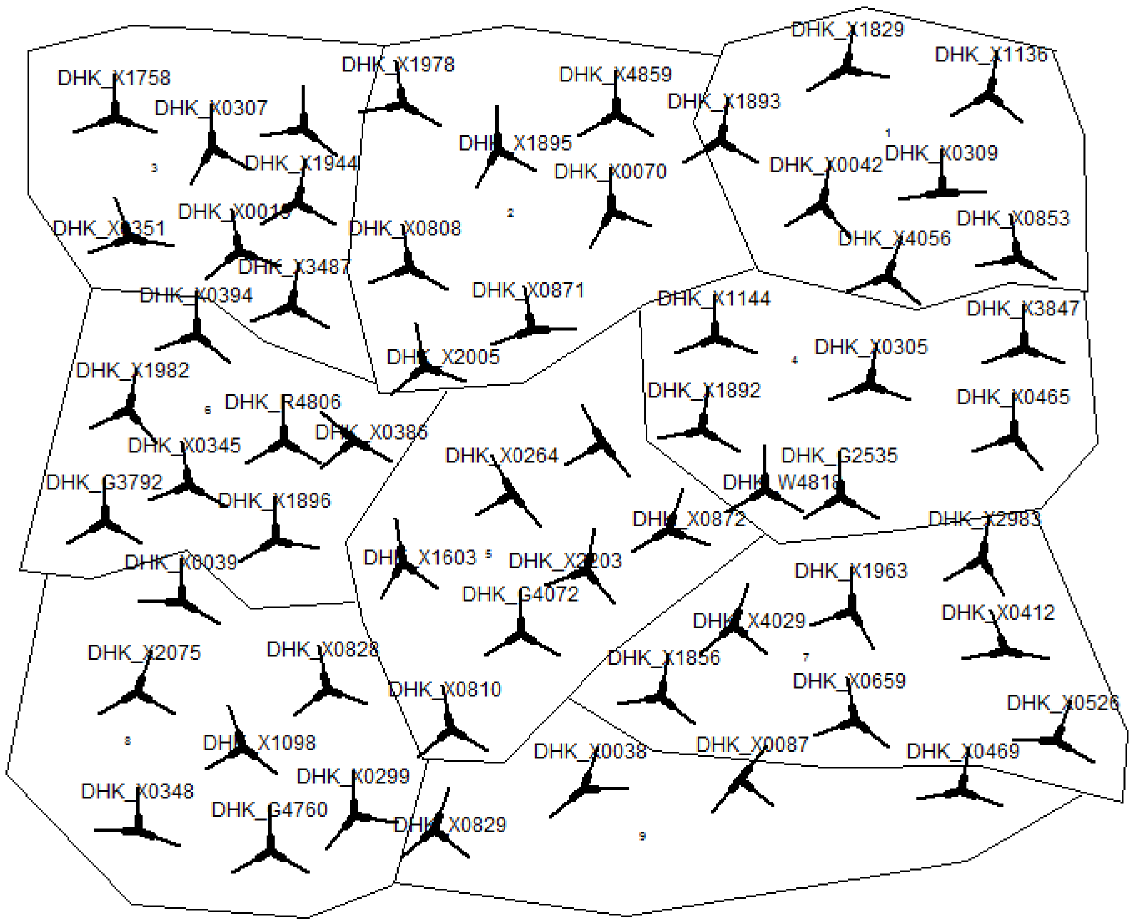


Fig. 4.35: Clusters of 7/21 frequency reuses

As the site to site distance is not uniform and orientation of all the sites are not same, the cluster size becomes irregular. In a hypothetical network it may be of regular size, but in a practical network it is always of irregular shape.

4.3.5.1 Carrier to Interferer Ratio

At each pixel of the project, the received signal strength from the serving cell and the summation of the received signal strength from the surrounding co-channel cells are measured. The ratio of those two measurements is recorded as Carrier to Interferer Ratio or C/I. The signal strength in a pixel is calculated by deducting the path loss from the transmitting power. This path loss depends on frequency and the clutter information between the transmitter and the receiver [4]-[6]. Two models are used to calculate this C/I at each pixel; one for the existing strategy and another for the proposed strategy. The C/I plot for the two strategies for 7/21 reuses are shown in the Fig. 4.36 and 4.37.

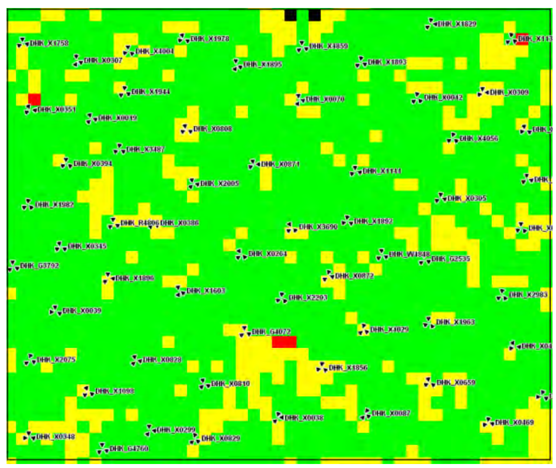


Fig. 4.36: C/I with the existing strategy

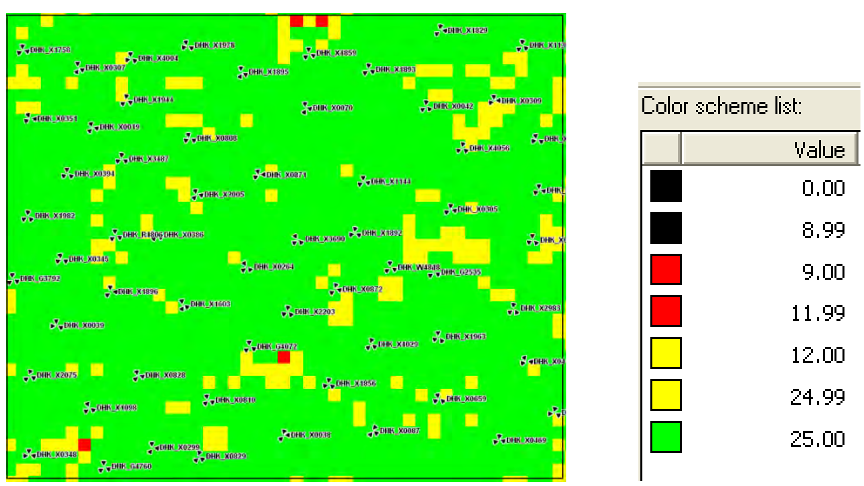


Fig. 4.37: C/I with the proposed strategy

Worse samples are reduced in the whole area in the proposed strategy.

4.3.5.2 Bit Error Rate

The Bit Error Rate (BER) at any pixel is calculated by measuring number of bits received when compared to the number of bits transmitted. It represents the measure of lost bits during transmission due to interferences [5]. The BER for existing and proposed strategies have been shown in Fig. 4.38 and 4.39 respectively.

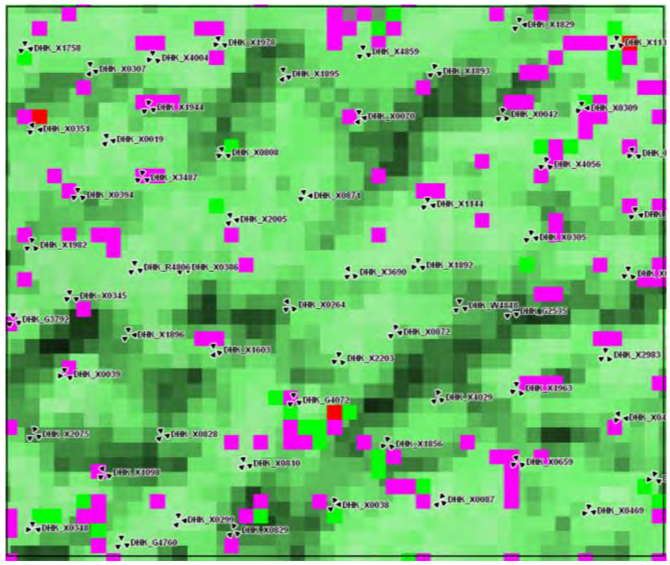


Fig. 4.38: BER with the existing strategy

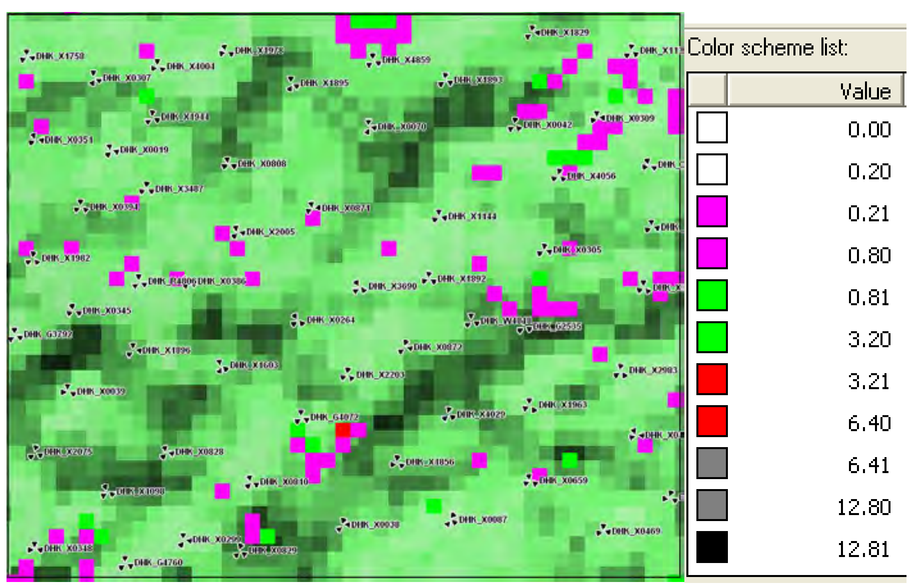


Fig. 4.39: BER with the proposed strategy

BER is improved in the lower part in the proposed strategy.

4.3.5.3 Received Signal Quality

It is the measure of quality of the received signal at each pixel. It is classified into 8 categories. Rx Qual from 0 to 4 represent good signal quality. Rx Qual from 5 to 7 represent bad signal quality [4]. This signal quality depends on the level of interferences faced by a sector at a particular pixel. Rx Quality for the both existing and proposed strategies have been shown in Fig. 4.40 and 4.41 respectively.

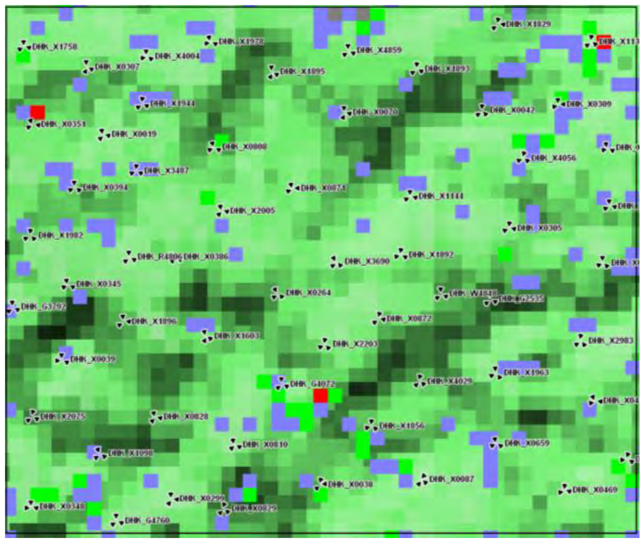


Fig. 4.40: Rx Qual with existing configuration

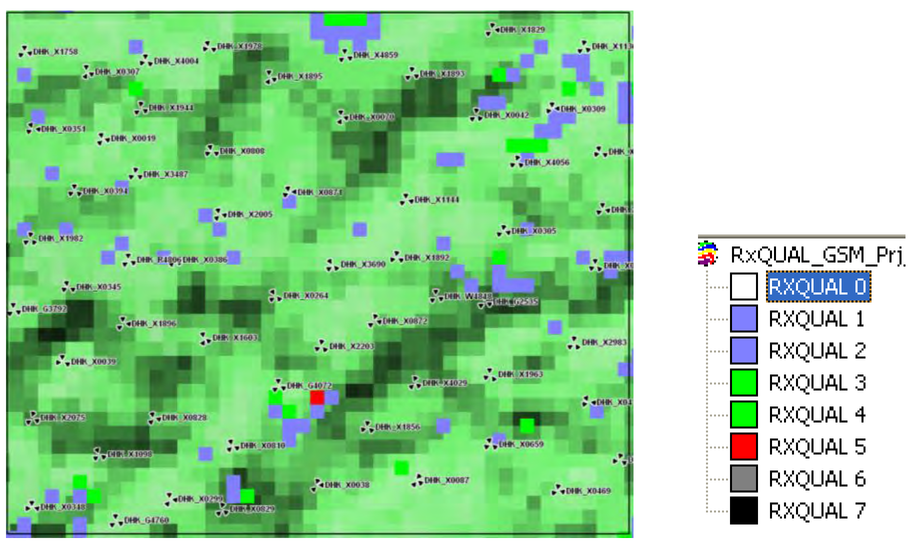


Fig. 4.41: Rx Qual with proposed configuration

Worse Rx Qual samples are improved in the lower part in the proposed strategy.

4.4 Comparative Study of the Results

The simulation results for the existing and proposed strategies have been summarized here for C/I, BER and Rx Qual. The total area of the project under discussion is 4.275 square km.

4.4.1 C/I Ratio

Table 4.1 and a graph in Fig. 4.42 show the comparison of carrier to interferer ratio within the 9 dB range.

Table 4.1: C/I ratio at various reuse schemes for the existing and the proposed strategies

	Percentage of area (%)		Amount of area (sqr km)	
Reuses	Existing Configuration	Proposed Configuration	Existing Configuration	Proposed Configuration
3_9	6.432748	4.736842	0.275	0.2025
4_12	1.578947	0.9324009	0.0675	0.04
5_15	1.052632	0.877193	0.045	0.0375
6_18	0.1169591	0.05847953	0.005	0.0025
7_21	0.1169591	0	0.005	0

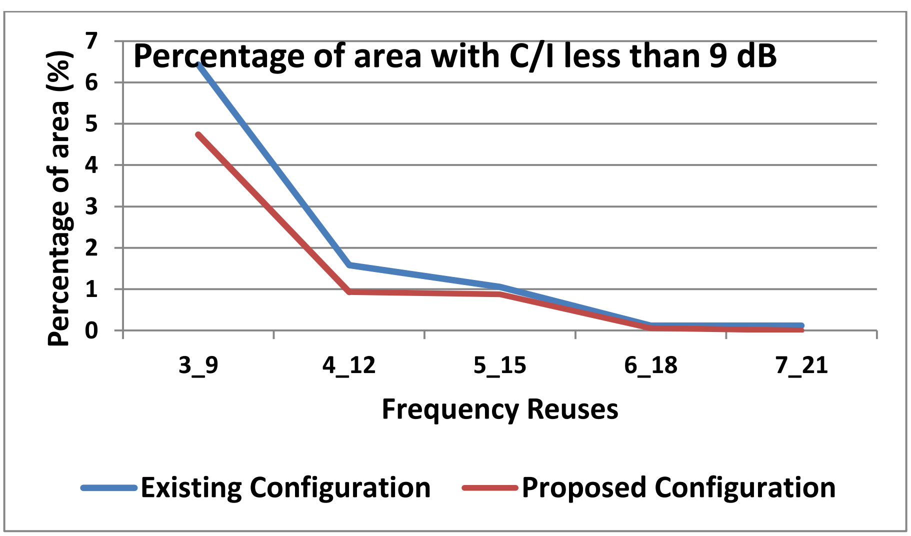


Fig. 4.42: C/I ratio at various reuse schemes for the existing and the proposed strategies

Discussion on C/I

Table 4.1 and the red curve in Fig. 4.2 represent the percentage of area where C/I is less than 9 dB for the proposed frequency allocation strategy. The blue curve in Fig. 4.2 represents the same for the existing frequency allocation strategy for various frequency reuse schemes. For any frequency reuse scheme, the proposed strategy shows improved C/I compared to the existing strategy.

Now, if the frequency reuse distance is increased from the current values, the simulation results show better performances for both the existing and the proposed frequency allocation strategies. However, there is no scope of increasing the reuse distance in the existing strategy owing to spectrum unavailability and as such, there is no scope of performance improvement any further. On the other hand, as there is scope for increasing the reuse distance in the proposed strategy, performance improvement can be realized. In the last two points of the curves, it is found that the improvement rate is less, compared to the previous cases because of the greater cluster size. For the 7/21 frequency reuse scheme, number of clusters becomes fractional and therefore exact benefit of using a higher reuse distance cannot be achieved. For a project with more sites, this improvement will be more noticeable.

Similar improvements are noticed for the BER and Rx Qual as the reuse distance is increased.

4.4.2 BER

Table 4.2and the graph in Fig. 4.43 show the BER less than 5% for both the existing and the proposed frequency allocation strategies.

Table 4.2: BER (<5%) at different frequency reuse schemes for the existing and the proposed Strategies

	Percentage of area (%)		Amount of area (sqr km)	
Reuses	Existing Configuration	Proposed Configuration	Existing Configuration	Proposed Configuration
3_9	93.508765	95.204681	3.9975	4.07
4_12	98.362575	99.064329	4.205	4.235
5_15	98.947368	99.122812	4.23	4.2375
6_18	99.181294	99.9415244	4.24	4.2725
7_21	99.8830467	99.9999976	4.27	4.275

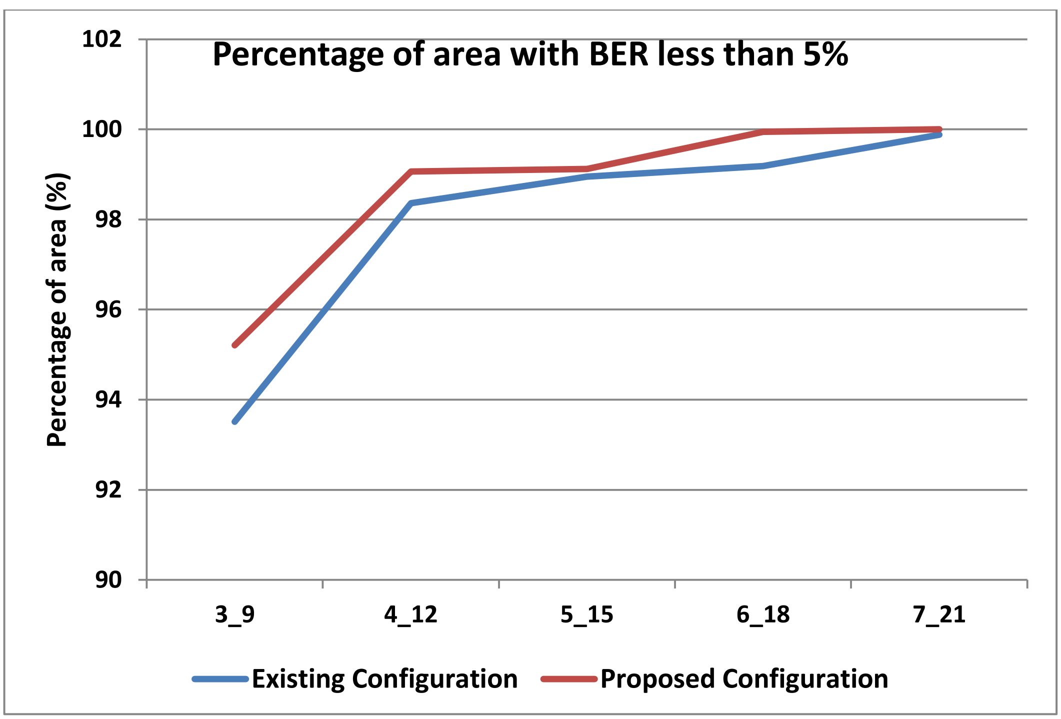


Fig. 4.43: BER (<5%) at different frequency reuse schemes for the existing and the proposed strategies

Discussion on BER

Table 4.2 and the curves in Fig. 4.43 represent percentage of area where BER is less than 5%. The blue curve represents the characteristic for existing frequency allocation strategy at different frequency reuse schemes, and the red curve represents the same for the proposed frequency allocation strategy. For any frequency reuse scheme, the proposed strategy shows improved BER compared to that of the existing strategy. If the frequency reuse distance is increased for the current values, the simulation shows better performances for both the existing and the proposed frequency allocation strategies. However, unlike the existing strategy, as there is scope for increasing the reuse distance in the proposed strategy, improved BER performance can be achieved in reality; whereas it is not possible in the existing strategy.

4.4.3 Rx Qual

Table 4.3 and the graph in Fig. 4.44 show the Rx Qual less than 5 for the existing and the proposed strategies.

Table 4.3: Rx Qual (0-4) at different frequency reuse schemes for the existing and the proposed strategies

	Percentage of area (%)		Amount of area (sqr km)	
Reuses	**Existing Configuration**	**Proposed Configuration**	**Existing Configuration**	**Proposed Configuration**
3_9	90.52632	92.865497	3.87	3.97
4_12	97.4269	98.654969	4.165	4.2175
5_15	97.894741	98.713448	4.185	4.22
6_18	99.181287	99.7660861	4.24	4.265
7_21	99.707598	99.9415156	4.2625	4.2725

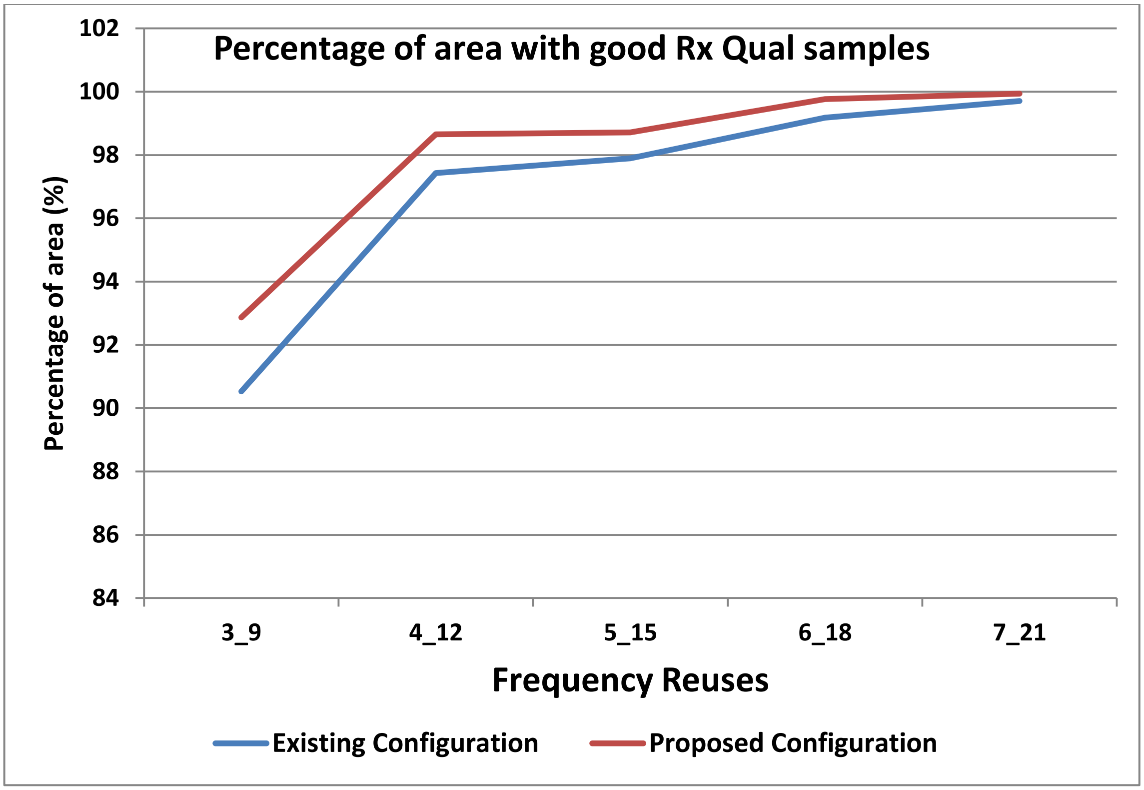


Fig. 4.44: Rx Qual (0-4) at different frequency reuse schemes for the existing and the proposed strategies

Discussion on Rx Qual

Table 4.3 and the curves in Fig. 4.44 represent the percentage of area, where Rx Qual is less than 5. The blue curve represents the characteristic for the existing frequency allocation strategy at different frequency reuse schemes. The red curve represents the same for the proposed frequency allocation strategy. For any frequency reuse scheme, the proposed strategy shows improved Rx Qual compared to the existing strategy. If frequency reuse distance is increased for current values, the simulation shows better performances for both the existing and the proposed frequency allocation strategies. However, unlike the existing strategy, as there is scope for increasing the reuse distance in the proposed strategy, improved Rx Qual performance can be achieved in reality; whereas it is not possible in the existing strategy.

CHAPTER 5

CONCLUSIONS AND SUGGESTIONS FOR FUTURE WORK

In the current research it has been proposed to use BCCH from the 1800 MHz band and TCH from both the 900 MHz and 1800 MHz bands instead of the traditional option of using BCCH from the 900 MHz band and TCH from both the 900 MHz and 1800 MHz bands. The following tasks were carried out in this regard:

The present status and measurement of various parameters such as Carrier to Interferer Ratio (C/I), Bit Error Rate (BER), Received Signal Quality (Rx Qual) and Received Signal Strength (Rx level) of the existing GSM system have been investigated.

The causes of severe interference have also been investigated under the present frequency plan and possible interference reduction schemes are suggested.

Computer simulations were also carried out using a professional software (Planet EV) for the proposed frequency plan. The conclusions of findings are discussed in section 5.1 and the scope of further research as an extension to the current research have been suggested in section 5.2.

5.1 Conclusions

The study of the current research shows that after implementing the proposed strategy in the existing GSM system, Radio KPIs (Call Drop Rate, SDCCH Drop Rate, Handover Success Rate, TCH Assignment Failure Rate due to Radio) that depend on signaling channel have been improved significantly.

The proposed approach can be applied only in highly dense areas like Dhaka, Chittagong, Sydney, London, Mumbai, Kolkata, New York and other similar cities. However, it cannot be applied in suburban areas due the presence of coverage gaps in the 1800-MHz frequency bands.

According to this approach, higher number of channels are available for BCCH. Therefore adoption of higher frequency reuse schemes are possible. It is recommended to use a 6/18 frequency reuse scheme for the BCCH to be used from the 1800 MHz band. For the TCH, the 4/12 or even the 3/9 frequency reuse scheme can be used.

To implement this strategy, no hardware installation and software up-gradation is required. It can be implemented in the existing GSM system by changing the configuration within the software and the hardware would be able to support the necessary frequency allocation and the required signaling.

While implementing this frequency allocation strategy, there are some challenges that have to be overcome. Though the 900 MHz frequency band will be removed from using the BCCH, it still will be used as the TCH to meet traffic demand. Therefore the same degree of interference will be experienced while using this as the TCH. This interference may be reduced using the downlink power control, where the BTS will transmit only the required amount of power; which is not in excess of what had been required earlier. This will reduce the interference.

This interference can also be handled using some interference tolerable radio features, like, synthesized frequency hopping, intelligent underlay overlay, discontinuous transmission etc. As TCH is used only to carry the traffic only, a call can survive even a higher interfering environment. On the other hand, all types of signaling, call set up, handovers etc. are done through the BCCH TRx. Therefore it is more important to keep the BCCH TRx less interfered than the TCH TRxs. Using the proposed strategy the interference in the BCCH TRx will be reduced, which will improve the overall radio quality as well. This will directly influence the radio KPIs, like, call drop rate, handover success rate, SDCCH drop rate, SDCCH success rate, TCH assignment failure rate, call setup success rate etc.

5.2 Suggestions for Future Work

In this study the proposed frequency allocation strategy has been studied, which may be considered as a theoretical one. Practically it has not been applied for any live network yet. In future, a further studied can be carried out by implementing the proposed scheme in a live network. While implementing this strategy in a live network, some problems may arise. Therefore, future research can be directed towards developing solutions for overcoming the following problems:

- Due to high penetration loss in very dense building areas, using BCCH from the 1800 MHz band may cause some indoor coverage gap. Researchers can work to make a balance between BCCH TRx power and TCH TRx power to overcome such problems.
- New techniques can be identified and developed to use the 1800 MHz band TRxs to carry traffic with maximum efficiency. The 900 MHz TRxs have to be used only for emergency cases or as a backup for the 1800 MHz band.
- New techniques can be developed to use this strategy or the semi-dense urban areas by increasing power in the 1800 MHz BCCH to overcome additional path loss compared to the path loss suffered in the 900 MHz frequency bands.

CHAPTER 6

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