Optimization of Frequency Spectrum through Beam Replication

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Abstract - *The past couple of decades the wireless communication has experienced a phenomenal growth and it has become an integral part of the society. The spectrum available for wireless mobile communication is very less and is much costlier. So, it is essential to efficiently utilize the spectrum available prudently. After the introduction of Long Term Evolution (LTE) many subscribers had been moved from Global System for Mobile (GSM) and Wide Band Code Division multiple Access (WCDMA) technologies to LTE. The subscribers for 2G may still decrease and the GSM technology might soon get extinct at the evolving rate of wireless communication. The GSM operates on 900 MHz and 1800 MHz frequency bands. As the number of subscribers reduces, the frequency spectrum used gets wasted, since the same range of frequency is used for higher technologies. So, an idea of cannibalizing the available GSM frequency is proposed to optimize the frequency spectrum. This method includes the idea of transmitting the information as beam and its duplication at the different antennas of the same RFM (Radio Frequency Module) or at different RFM to cover the 360 degree of area under consideration, in order to do so Broadcast Control Channel (BCCH) and Transceivers (TRXs) are replicated in all the three beams. This reduces the frequency spectrum consumption compared to the conventional method of having multiple sectors of different frequencies.*

Key Words: **GSM technology, Beam Replication, Spectrum Optimization, Beam Hopping, Single Sector.**

1. INTRODUCTION

Network has deeply penetrated into our daily life, such as the communication networks, transport networks and so on. In a nutshell, transmission of specific objects to provide specific services for users is the most important function of a network. But as the volumes and the types of applications grow rapidly, the contradiction between the application demands and the limited network resources leads to the resource competition which may result in network congestion further. Thus many researchers are attracted by how to improve the optimization of the spectrum available and the traffic capacity of a network especially in recent decade. According to the survey (1) report, there are 7.8 billion mobile subscribers across the globe and they are estimated to be 8.9 billion by 2023 and there are 5.8 billion broadband subscribers were there in 2017 and are estimated to be 8.3 billion by 2023. In the past few years the subscribers for 2G technology has been drastically reduced are moving towards LTE and 5G due to the ever growing technologies, applications and its huge requirement of data rates. Since the users for GSM are much less in number, the amount spectrum used for this is getting wasted enormously. In the GSM technology a cell site consists of a Base Station Controller (BSC), Base stations (BTS) and the transceivers (TRX). The base station includes the antennas and transceivers in each cell. The size of the cell depends upon the transmitting power of an antenna. Each TRX is allocated with different frequency. In the proposed method, a single beam is replicated to cover 360 degree area and only one BTS is used with minimum number transceivers which consists of a single Broadcast Control Channel. The same Broadcast control channel is transmitted along all the beams. Depending upon the maximum signal strength measured the single beam is selected for the transmission. So in the main aim is to optimize the spectrum utilized for the GSM technology. The different elements of the GSM network are

A. Base Station

The Base Station provides the connection between the network and the Mobile station via Air interface. It performs radio related tasks. The BTS consists of Radio frequency module that has transmitters, receivers and its associated antennas. It performs the functions such as encoding and encryption of data, time and frequency synchronization, feeding radio frequency signal to the antenna. It also performs decoding, decryption and equalization of received signals.

B. Base Station Controller

The BSC takes care of all the central functions and the control functions in the Base Station Subsystem (BSS) such as handovers within the group of BTSs and manages radio resources. It also performs power management and frequency reallocation among the BTSs.

C. Mobile Station

Mobile stations are the mobile phones that are connected to the network through BTS through air interface. It has a transceiver through which it connects to the network.

The past couple of decades the wireless communication has experienced a phenomenal growth and it has become an integral part of the society. The number of users and the services provided and also its quality has been tremendously increased. The mobile wireless communication has different generations with some new advancements. Paper (1) and paper (2) gives the over view of different generations in development of mobile wireless technologies from 1G to 4G. Paper (2) discusses the disadvantages and advantages of one generation over the other and hence the evolution of wireless technologies. The GSM technology utilizes the bandwidth which lies in the range of 815-930MHz for uplink and 935-960MHz for downlink. Many methods are proposed in various papers to optimize the spectrum consumption and improve the performance of the network. The composite multisite is used increase the coverage where the antennas at different locations are merged into single cell as nodes by eliminating the inter-cell handovers. This increases the coverage of GSM network and network performance (4). The frequency reuse and cell splitting methods, & cell pattern (5) are used to increases the spectrum efficiency. When the frequency is reused co-channel interference and the adjacent channel interference are introduced which can be identified by Absolute Radio Frequency Channel Number (AFRCN). A channel with high level of frequency has to reassigned (6). The interference can also be reduced by Maximum Likelihood Sequence estimation followed by successive interference cancellation (7). The receiver decodes the strongest signal and extract the weaker signal among them which reduces the channel interference (8). Radio frequency hopping and Baseband hopping are also used to control the level of interference by frequency reuse.

II.EXISTING SYSTEM

A traditional method of multi-sector allocation of transceivers and frequency is used in cell planning. A cell site consists of multiple sectors (generally one to twelve) where TRXs are distributed among the sectors. Each TRx is allocated different frequency based on frequency planning. Allocating different frequencies to all the TRXs involved in a site consume large amount of frequency spectrum. Methods like spectrum sensing, spectrum decision, spectrum sharing, spectrum handoff, frequency reuse and cell splitting are been in use for wise spectrum utilization. Different BCCHs are transmitted through different TRXs (Time Slot 0). Radio Frequency hopping and Base Band hopping are used to eliminate the co-channel interference and adjacent channel interference due to frequency reuse or in the condition of adjacent frequencies are used.

The cell selection in the existing GSM technology has the following steps,

- The Mobile station (MS) is power ON
- The MS measures the received power level in power level from each cell which is defined.
- Then the MS compares the suitable cell based on the threshold criterion of received power level on each BCCH of the cell for Cell camping.
- Then that cell is selected for the call placement.
- When the number of full rate calls exceeds then the full rate calls are converted into half rate calls and hence increases the efficiency of time slots that is two calls are placed in one time slot.
- When the signal strength of the current cell below the received signal strength the inter-cell handover occurs by comparing the cell measurements of the neighbouring cells (9) and (10).

When the frequency resources are insufficient, the frequencies from neighbouring cells are reused due to which co channel and adjacent channel interference are occurred. So, the frequency hopping technologies are used to reduce the interference. The frequency hopping may be radio frequency (RF) hopping where the carrier frequency is changed in transmission of each bursts or Baseband hopping where one dedicated frequency is assigned for each TRX. In BB hopping. Here of all TRX the call hops between same TRX. These methods reduces the interference due to co channel and adjacent cannel interference.

When the signal strength is less or during roaming in order keep the call ongoing or to eliminate call drop handover takesplace. The handover is made based on power budget expression. PGBT compares the path loss of the MS and the service cell with the path loss and potential handover of the target cell. When the PGBT exceeds the handover threshold value, the handover will be initiated. The PGBT is given by the expression

PBGT(n) = (Min(MS_TXPWR_MAX,P)-RXLEV_DL-PWR)-(Min(MS_TXPWR_MAX(n),P) RXLEV_NCELL(n))--eq(1)

In the existing method since each cell consists of BTS and multiple number of TRxs with individual frequencies and the call is placed in any one of the sector of that BTS the remaining frequency goes unused and also each sector has the separate BCCH which will be transmitting power leads to excess power consumption. This method is suitable if the area under consideration consists of huge number of subscribers. But this can be considered as squandering of frequency where the subscribers are comparatively very less. So a coherent solution is proposed to make use of available frequency methodically.

III.PROPOSED SYSTEM

The places where the subscribers are comparatively less the proposed method seems to be acceptable. Violating the traditional method of multi-sectors only one sector is used which is called as omni sector. This sector consists of single BSC and BTS with limited number of TRXs (one to seven). The same beam is replicated into three beams to cover the whole area of a cell. All beams have the same have the same replica of BCCH and TRXs. The beam replication at the radio frequency module pipes are shown in Fig 1.

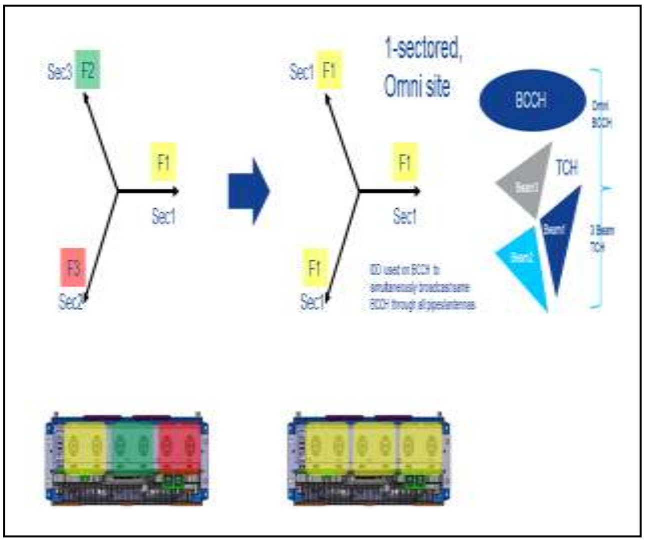

Fig-1: Transmission of information in three identical replicated beams

In the replicated three beams six regions are taken into consideration where in three are main beam regions and another three are beam hopping region. The three regions of single beam are Beam 1, Beam 2 and Beam 3 and the three beam hopping regions are Beam Hopping Region 1 – Beam1/Beam2, Beam Hopping Region 2 – Beam2/Beam3, Beam Hopping Region 3 – Beam3/Beam1. The classification of the beam regions are shown in Fig 2.

The selection of the beam consists of the following steps

- When the MS is powered ON, MS measures the Average scaled Channel Tap Energy (ASCTE) of each beam
- The beam selection process depends on the Average scaled Channel Tap Energy (ASCTE). It is the measure of required received signal energy out of total received energy.
- A single beam is selected if the beam Then that particular beam is selected for placing the call if ASCTE for given beam is greater than ASCTE of two other beams or the absolute ASCTE difference between given beam and the two other beam is greater than beam hopping threshold.
- When the number of full rate calls exceeds then the full rate calls are converted into half rate calls and hence increases the efficiency of time slots.
- If the Mobile Station (MS) is in the where two beams are overlapping, then transmission can be performed between two beams alternatively. Beam hopping will be used, when absolute difference between ASCTE of the best beam and ASCTE of second best beam is lower or equal beam hopping threshold.

Beam hopping threshold defines the threshold for BTS to compare the uplink path losses of individual beams in a Multi- Beam TRX. When the absolute difference in the uplink path losses is equal to or greater than the Beam Hopping Threshold, BTS selects for its transmission the beam with the lowest path loss in uplink. When the absolute difference in uplink path losses is smaller than the Beam Hopping Threshold, BTS selects Beam Hopping rather than an individual beam for its transmission in a Multi- Beam TRX.

Due to dense frequency reuse the network may face high interference which might not be handled easily by RF or BB hopping. When the calls on the network exceeds the limit the speech quality of the cell decreases due to high level of interference and it cannot meet the required carrier to interference (C/I) ratio. This results in call drops. Though an idle channel is available, no call can be allocated due to severe interference. This interference problem can be controlled by a method called as interference-based channel allocation (IBCA). During channel allocation the BSC measures the C/I ration of the neighboring cell channels and also C/I ratio of the new call that might cause interference to already established calls. It selects the channel with highest C/I ratio and prioritize that channel for the new calls. This way the interference due to compact frequency use can be reduced that might be caused by beam overlapping region.

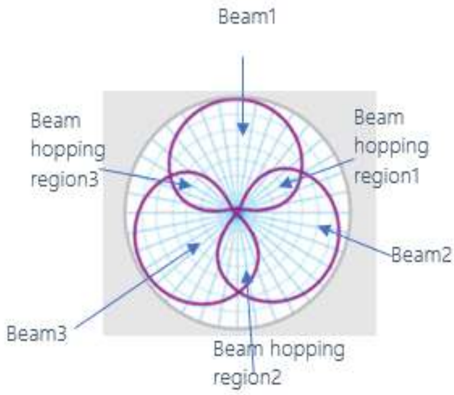

Fig-2: Replicated beams classified into six regions

IV.IMPLEMENTATION

Two cell sites, one with traditional method with three sectors say Site 1 and another with the proposed method that is with single sector say Site 2 are created using the HIT tool. Both the sites are commissioned with the Base Stations (BTSs) to integrate the BTSs as a part of the network. The implementation setup is made as shown in Fig 3.

The pipes of RFM associated with respective antenna to carry respective beam are connected to programmable variable attenuator (PVA). The attenuation power for each beam is defined and controlled by PVA. The PVA is finally connected to Radio Frequency Box where the Mobile Stations (MS) are placed. Then continuous calls are placed on both the sites through mobile phones. The calls can be made remotely using Mobile Call Generator. Then the efficiency of both the existing and the proposed methods are compared.

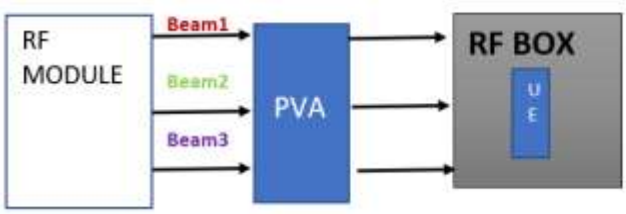

Fig-3: Implementaion setup

V. RESULTS

Continuous calls on both the sites are placed using Mobile Call Originator on both Site 1 and Site 2. The wireshark logs when the call is placed is shown in the Fig-4. It is observed that the site 2 with only one sector was able to handle the calls when compared with the calls handled by site 1 with three sectors as shown in Fig-5 and Fig-6. Therefore, the frequency used for other two sectors in site 1 could be saved by using proposed method as in site 2. Hence the spectrum is optimized. In site 1 the handovers are made from sector to sector when calls are placed at different sector or when the signal strength is weak. So, it results in the exchange of handover signaling between the BSC and the BTS. But in site to since only one sector is present the concept of inter cellular handover doesn't exist, but instead beam hopping or switching is seen which reduces the handover signaling power consumption.

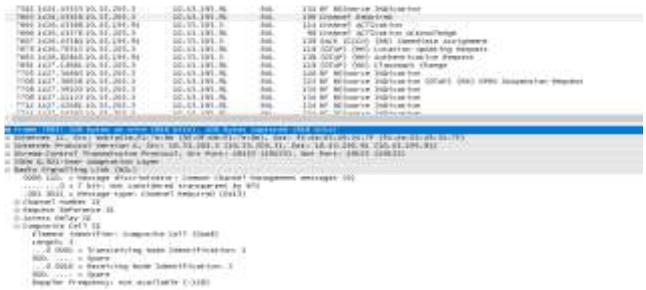

Fig-4: Wireshark log showing call placed on beam 1

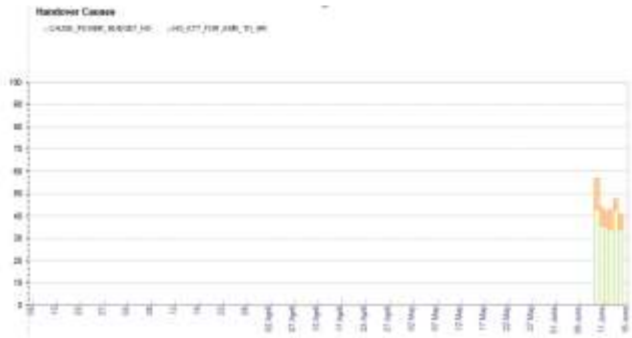

Fig-5: Call placed on site 1 with Power Budget Handover

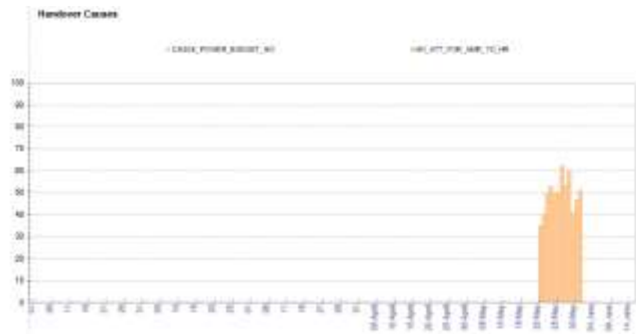

Fig-6: Call placed on site 2 without Power Budget Handover

VI. ADVANTAGES

- Frequency can be efficiently utilized by using the same number of TRXs of same frequency, yet covering the whole region of 360 degree of the cell.

- The BCCH power can be conserved, since the same BCCH is replicated and transmitted.
- Since the single BCCH is transmitted the power required in BSC is reduced.
- The BTSs can be connected to multiple antennas that are not co-located to reduce inter-cell handover.
- Signalling is reduced from BSC due to the absence of handovers and instead beam hopping/switching is used.

VII. CONCLUSION

The traditional allocation of frequencies for TRXs are reformed by a new method which uses the single sector of limited TRXs where the information is sent through identical replicated beams. This method will optimize the use of frequency spectrum of GSM band and increases its efficiency. This method is suitable where the limited number of subscribers are there in an area. This method reduces the power consumption with the same capacity as that of the conventional method. The remaining frequency can be made use for other technologies such as narrow band LTE.

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