MAXIMIZATION OF THROUGHPUT IN 3G NETWORKS USING CELL SECTORING TECHNIQUE

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Abstract- **This research work aimed at the maximization of throughput in a 3G network. The researcher utilized cell sectoring technique in achieving the goal of throughput maximization. Signal-to-interference ratio of a system is a major parameter in determining the throughput of the system, hence this research work used this parameter for its analysis. The use of 120^0 and 60^0 sectorial antenna were deployed alongside the use of omnidirectional antenna in a cell. Cell radius of 20 units and Frequency reuse distances of 50, 60, 70, 80, 90 and 100 units were used in the model. The signal-to-interference ratio of the network for the different Frequency reuse distance were determined for the three categories. This was achieved by modeling the parameters for checking the signal-to-interference ratio of a network (radius of the cell was kept constant while Frequency reuse distance was varied) and analysis using Matlab. The combined analysis of the three sectoring techniques showed that the use of 60^0 sectorial antenna produced the highest signal-to-interference ratio for all reuse distances while the use of omnidirectional antenna produced the least. From this analysis, the researcher concluded that in a congested cellular system where there is high number of request leading to increased traffic, appropriate cell sectoring technique when applied has the capability of increasing the signal-to-interference ratio of the system thereby leading to a maximized throughput.**

1. INTRODUCTION

Wireless communication is the transfer of information between two or more points that are not connected by an electrical conductor (Muthukumara Sonya, 2017). Mobile wireless communication is the use of technology that allows us to communicate with others in different locations without the use of cables. This method of communication has experienced a remarkable change over the past decades. These changes are referred to as generations, G.

The 1G, first generation mobile wireless communication system was introduced in 1980's. This 1G technology was an analog system which was based on a standard known as Advance Mobile Phone Service (AMPS). The AMPS system was frequency modulation radio system using frequency division multiple access (FDMA). The channel capacity of 1G is 30 KHz and frequency band was 800-900 MHz. The main service given is VOICE only.(Kruthik M.S 2018)

2G is the Second-Generation wireless telecommunication technology, based on digital technologies. In 1991, 2G was launched in Finland. The digital mobile access technology such as TDMA and CDMA are used by 2G system. At first, TDMA divides signal in different time slots then CDMA allocates each user a special code to communicate over a multiplex physical channel(Abdullah A et al 2017,). There are different TDMA technologies such as GSM (Global System for Mobile), PDC (Personal Digital Cellular), iDEN (Integrated Digital Enhanced Network). Again, IS-95 is CDMA technology. GSM was first 2G system and has origin from Europe in the late 1980s. It utilizes digital signals for voice transmission. Fundamental concentrate of this technology was on digital signals and gives services to convey content and provide picture message at low speed (in kbps). It utilized the bandwidth of 30 to 200 KHz. Three types of developments took place in second generation wireless communication system, IS-54(TDMA) in 1991, IS-95(CDMA) in 1993, and IS-136 in 1996(Yadav S.S. 2018,). 2G technology used digital signals for voice transmission and had a speed up to 64 kbps. It helps mobile batteries to last long because, the digital signals consume less battery power. Digital coding improves the voice clarity and reduces noise in the line. The use of digital data service assists mobile network operators to introduce short message service (SMS) over the cellular mobile phones. 2G also provides services such as text message, picture messages, Multimedia message service (MMS), cordless telephone (DECT, PACS), Private mobile radio (TETRA), Wireless Local Loop (WLL) cellular systems (GSM, D-AMPS, PDC etc.), Mobile Satellite Systems (IRIDIUM, ICO, GLOBALSTAR) (Abdullah A et al 2017,). This technology offers greater security for both sender and receiver. All text messages are digitally encrypted, which allows for the transfer of data in such a way that only intended receiver can receive and read it.

The extension of existing 2G network is General packet radio service (GPRS) which have the capacity of launching packet based services with enhanced the data rates. This system is described by the term "Second and a half generation" as this technology is developed in between its predecessor, 2G, and its successor, 3G.(Abdullah Al-Mamun Bulbul , Sagor Biswas , Md. Bellal Hossain , Saibba Biswas 2017,) GPRS provided data rates from 56 Kbps up to 115 Kbps by using database of HLR, VLR, AUC with HSCSD, GPRS and EDGE technologies. It provides services such as wireless application protocol (WAP) access, multimedia messaging service (MMS) and for internet communication services such as e-mail and worldwide wireless web (WWW) access. 2.5G technology has enlarged the data rates for GSM evolution (EDGE) networks with the introduction of 8PSK encoding (Abdullah Al-Mamun Bulbul , Sagor Biswas , Md. Bellal Hossain , Saibba Biswas 2017,). EDGE technology is an extended version of GSM. EDGE which is preferred over GSM for its flexibility to carry packet switch data and circuit switch data. The EDGE technology is faster technology GPRS. For example, a typical text file of 40KB is transferred in only 2 seconds while the GPRS technology takes 6 seconds. EDGE is characterized by 3rd Generation Partnership Project (3GPP) which provides a potential three-fold increase in capacity of GSM/GPRS networks. Here, higher data rates (up to 236.8 Kbits/s) is achieved by switching to more sophisticated methods of coding (8PSK), within existing GSM timeslots (Abdullah A et al 2017,). GPRS and EDGE are sometimes referred to as 2.5 and 2.75G respectively. The main advantage of using EDGE technology is any additional hardware and software installation is not needed.

3G technology usually referred as universal mobile telecommunications standard (UMTS) is found to be 3 times better than GSM, with maximum date rate of 8Mbps(M.Benisha, R.Thandaiah Prabu, Thulasi Bai,2019). It assigns low data rate channel for voice calls and large data rate channel for video calls. To frame the International standard for 3G cellular networks, international telecommunication union (ITU) signed the international mobile telecommunications 2000 (IMT 200) in the year 1999. Thereby the 3G was supported by 2 main technologies UMTS and CDMA2000 with the support of 3GPP and 3GPP2 respectively (Peral-Rosado JA, Raulefs R, López-Salcedo JA, SecoGranados,2017). UMTS uses the air interface as wideband CDMA (WCDMA) often called as universal terrestrial radio access (UTRA). It is configured to support up to 2Mbps data rate with frequency division duplexing (FDD) and time division duplexing (TDD), whereas CDMA 2000 uses multiple narrowband CDMA carriers.(M. Benisha et al,2019) It requires higher bandwidth that becomes the drawback of the technology.

3.5G uses a wireless telecommunication protocol named High-speed downlink packet access (HSDPA) which provides higher data transfer speeds. HSDPA is a packet-based data service in W-CDMA downlink and it provides data transmission up to 8-10 Mbit/s over a 5MHz bandwidth in W-CDMA downlink.(Abdullah A et al 2017,) Also for MIMO (multiple-input multiple-output) systems data transmission is up to 20 Mbit/s. 3.5G technologies acquirement includes adaptive modulation and coding (AMC), multiple-input multiple-output (MIMO), hybrid automatic request (HARQ), fast cell search and advanced receiver design. Another technology, High-speed uplink packet access (HSUPA) called 3.75G has similar data rate with HSDPA but with higher uplink speed.

The mobile communication networks have witnessed remarkable research development in the areas of power control, handover procedures, frequency hopping, discontinuous transmission, spectrum efficiency, multiple access technology, cluster size and frequency re-use. These techniques were developed to increase the network capacity, hence increase the number of subscribers that can access the limited transmission channels in the mobile communication networks.

In recent years, there has been an increasing demand in mobile communication with limited spectrum bandwidth. A simplified approach to the throughput optimization problem is to assume continuous rate and power assignments, instead of practical discrete system parameters, at the expense of an approximate solution. This method is valid because throughput is continuously distributed over time and improves with continuous power assignments. CDMA has been considered and recognized as a viable alternative to both FDMA and TDMA. CDMA schemes have many advantages, but these advantages are hindered by the increasing interference caused by other active terminals, since all signals in the CDMA system share the same transmission bandwidth. Blocking occurs when the tolerance limit to interference is exceeded. Hence, in CDMA, the level of interference is a limiting factor.

Let us consider a receiver and two terminals (transmitters) with one closer to the receiver and the other farther away. If they transmit simultaneously at equal powers, then the receiver will receive more power from the near transmitter. Since one's transmission signal is the other's noise, the signal-to-noise ratio (SNR) for the farther transmitter is much lower. If the nearer transmitter transmits a signal of magnitude higher than the farther transmitter, then the SNR for the latter may be below detectability and may as well not transmit. This effectively jams the communication channel. This problem is commonly solved by dynamic output power adjustment of the transmitters. That is, the nearer transmitter uses less power so that the SNR for all transmitters at the receiver is roughly the same. This sometimes can have a noticeable impact on handset battery life, which varies depending on distance from the base station. In high-noise situations, closer transmitters may boost their output power, which forces distant transmitters to boost their output to maintain a good SNR, and other transmitters react to the rising noise floor by increasing their output. This process continues, and eventually, distant transmitters lose their ability to maintain a usable SNR and drop from the network. If there are optimum numbers of active terminals, when noise and out-of-cell interference are negligible, then the transmitter power levels should be controlled to achieve power balancing. With power balancing, all signals arrive at the base station with equal power.

Throughput maximization and power control is very important in any communication system in order to improve the quality of service. It is therefore recommended that as there are now many networks in the country, their engineers should try to maintain the SNR level as low as possible when designing their network so that quality of service will be improved.

1.1 Statement of the Problem

The benchmark of what a system is capable of doing or its maximum performance is what the user or designer is interested on. To enhance the quality of the system, there is a need to optimize the network.

Throughput is, therefore, a good measure of the channel capacity of a communication link. The message or information delivery may be over a physical or logical link, or over a wireless channel, passing through a certain network node such as data passed between two specific computers. Throughput is usually measured in bits per second (bps) and sometimes data packets per second or data packets per time slot. The throughput of a wireless data communication system depends on a number of variables which include: packet size, transmission rate, the number of overhead bits in each packet, received signal power, received noise power spectral density, modulation technique, and channel conditions. The key to maximizing throughput is maintaining the signal-to-interference-and-noise ratio (SINR) at an optimum level. Users of telecommunication devices, system designers, and researchers involved in communication theory are often interested in knowing the expected performance of a system. The performance long-term achievable data transmission rate a network can support, could be measured in terms of efficiency, timeliness, and cost. Modern technologies like 4G LTE and 4G LTE-A tend to offer improved quality of Service through increased network capacity, high data rate and improved throughput but due to cost implication, these technologies are yet to be deployed in some undeveloped cities. Hence, the need to seek more solutions to maximize 3G network throughput so as to offer improved quality of service in those areas.

1.2 Aim and Purpose of the study

The aim of this study is to enhance the quality of the system, by maximizing the network throughput, given a number of terminals transmitting simultaneously in a 3G network.

The specific objectives of the research are:

1. To show different sectoring technique in a 3G network
2. To analyze co-channel interference for different sectoring techniques
3. To show the effect of cell sectoring on Signal-to-Interference ratio of a network

1.3 SCOPE OF THE STUDY

This thesis will consider a system in which all the terminal operate with equal priorities. One possible path for future work is the application of this research in progressive image coding techniques in which the most significant bits of the image are given. In this thesis, it will be assumed that constant transmission rate is employed by the different terminals and hence it would be interesting to analyze the effects on throughput for variable sectoring technique.

2. LITERATURE REVIEW

2.1 Conceptual Framework

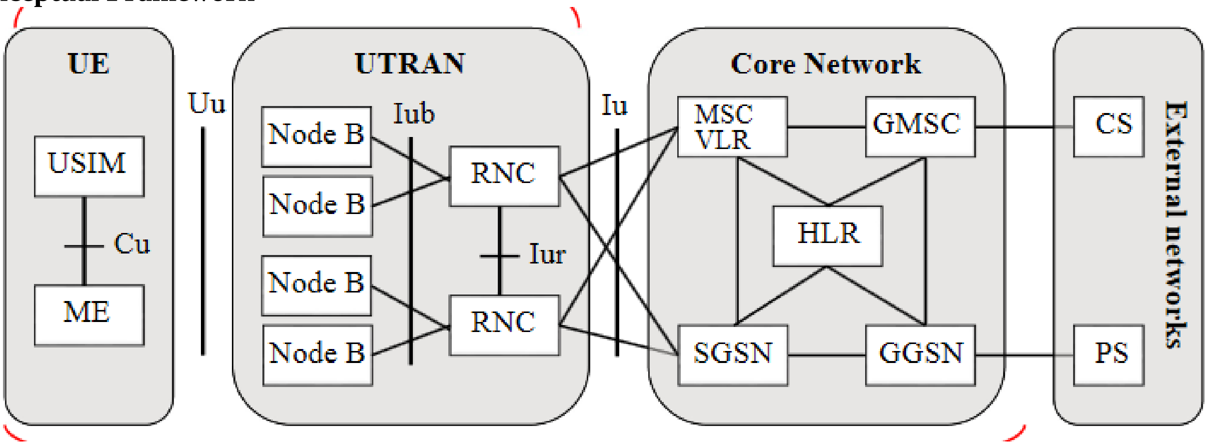

Fig 2.1: The Architecture of a 3g Network

Functionally the network elements are grouped into the

- ✓ Radio Access Network (RAN/UTRAN) that handles radio-related functionalities
- ✓ Core Network (CN), which is responsible for switching and routing calls and data connections to external networks.
- ✓ User Equipment (UE) that interfaces with the user.
- ✓ From standardization point of view, both UE and UTRAN are fully different from GSM. Part of the definition of Core Network (CN) is adopted from GSM. This supports, for example, cost effective introduction of new radio technologies and global roaming.
- ✓ UTRAN = UMTS Terrestrial Radio Access Network

User Equipment (UE)

This contains

- Mobile equipment (ME) which handles Radio communication over Uu interface
- UMTS Subscriber Identity Module (USIM) which manages the the subscriber identity, execution of authentication algorithms, storing of authentication and encryption keys and some subscription information that is needed at the terminal

UTRAN

UTRAN consists of Node B's and RNC's Node B (Base Station): Handles/manages the traffic between Uuand Iub interfaces. Basic tasks like coding, interleaving, rate adaptation, modulation, spreading etc. Handles also some mobility management tasks. Radio Network Controller (RNC): Control radio resources of Node B's in its operation area. Provide services for Core Network (CN). Load and congestion control, admission control, code allocation, radio resource management tasks. In addition RNC terminates the RRC (Radio Resource Control) protocol that defines the messages and procedures between the UE and UTRAN. The RNC controlling one Node B (i.e. terminating the Iub interface towards the Node B) is indicated as the Controlling RNC (CRNC) of the Node B. The Controlling RNC is responsible for the load and congestion control of its own cells, and also executes the admission control and code allocation for new radio links to be established in those cells.

CORE NETWORK

The core network contains the following:

- ✓ **HLR (Home Location Register):** Database that is located in the user's home system. Stores the master copy of the user's service profile. The service profile consists of, for example, information on allowed services and forbidden roaming areas. It is created when a new user subscribes to the system, and remains stored as long as the subscription is active.
- ✓ **MSC/VLR (Mobile Services Switching Centre/Visitor Location Register**): The switch (MSC) and database (VLR) that serves the UE for Circuit Switched (CS) services. The MSC function is used to switch the CS transactions
- ✓ **The VLR** function holds a copy of the visiting user's service profile, as well as more precise information on the UE's location within the serving system. The part of the network that is accessed via the MSC/VLR is often referred to as the CS domain.
- ✓ **GMSC (Gateway MSC):** The switch at the point where UMTS PLMN is connected to external CS networks. All incoming and outgoing CS connections go through GMSC. SGSN (Serving GPRS (General Packet Radio Service) Support Node): Functionality is similar to that of MSC/VLR but is used for Packet Switched (PS) services. The part of the network that is accessed via the SGSN is often referred to as the PS domain. Similar to MSC, SGSN support is needed for the early UE handling operation.
- ✓ **GGSN (Gateway GPRS Support Node):** Functionality is close to that of GMSC but is in relation to PS services.

2.2 Overview of Network Throughput

Network throughput refers to how much data can be transferred from source to destination within a given timeframe. **It measures how many packets arrive at their destinations successfully.** Throughput may also be referred to as the overall effective transmission rate, taking into account things like transmission overhead, protocol inefficiencies and perhaps even competing traffic (Peter L,2017). Throughput capacity **is measured in bits per second,** but it can also be measured in data per second. Throughput can be affected by factors some of which are mentioned below:

- **Transmission Medium Limitation:** Network bandwidth which is the maximum transfer throughput capacity of a network can also be referred to as a measure of the maximum amount of data that can be sent and received at a time. Bandwidth is measured in bits, megabits, or gigabits per second. (www.dnsstuff.com,2019)

Bandwidth (or the theoretical capacity) of a particular transmission medium will limit the throughput over that medium. For example, a FastEthernet interface provides a theoretical data rate of 100 Mbps. Therefore, no matter how much traffic needs to be sent over that interface, they cannot go over the 100 Mbps data rate. In reality, the practical data rate over such an interface will be about 95% of the theoretical capacity.

- **Enforced Limitation**: Let's assume an organization wants to purchase a 3 Mbps link capacity from an ISP, through what medium will the ISP deliver this capacity to the organization? The likelihood, based on current technologies, is that the ISP will use a medium that can theoretically deliver more capacity than the 3 Mbps being requested (e.g. MetroEthernet on 100 Mbps interface).

As such, the ISP will use other features to enforce the 3 Mbps capacity on the link which will, in turn, affect the throughput on that link. (www.dnsstuff.com,2019)

- **Network Congestion:** The degree of congestion on a network will also affect throughput. For example, the experience of a single car on a 4-lane highway is much better than when there are 100 cars on the same highway. As a general rule, the more congested the network is, the less throughput will be available on that network (when viewed from the perspective of a single source-destination set). (www.dnsstuff.com,2019)

- **Latency:** Latency (or delay) is the time it takes for a packet to get from sender to destination. For some types of traffic, the higher the latency on the network, the lower the throughput. Let's take TCP for example: before another stream of packets can be sent from source to destination, the previous stream must be acknowledged.

Therefore, if the acknowledgment is delayed, the average throughput measured over time will also reduce. The throughput of other kinds of traffic such as UDP is not necessarily affected by latency. (www.dnsstuff.com,2019)

- **Packet Loss and Errors:** Similar to latency, the throughput of certain kinds of traffic can be affected by packet loss and errors. This is because bad/lost packets may need to be retransmitted, reducing the average throughput between the devices communicating. Both latency and packet loss can be affected by a host of factors including bottlenecks, security attacks, and damaged devices. (www.dnsstuff.com,2019)
- **Protocol Operation:** The protocol used to carry and deliver the packets over a link can also affect the throughput. Examples include the flow control and congestion avoidance features in TCP, which can impact when and how much data can be sent between two devices.(www.dnsstuff.com,2019)

2.3 Preview of throughput parameters in wireless communication system

Despite this upgrade in mobile communication (GSM and CDMA2000) technology from second Generation to third Generation (2G to 3G) and their enormous advantages, Nigerian GSM subscribers are still unsatisfied with the quality of service (QOS) provided by these operators (network providers), especially during busy hours as a result of frequent blocked calls or unsuccessful calls. These blocked calls are expressed in terms of blocking probability, which is a major factor used to determine the QOS experience in mobile networks

Goodman and Marantz (Goodman et. al, 2003) in their paper explained that a data source generates packets of length L bits at each terminal of a CDMA system. A forward error correction (FEC) encoder, if present and a cyclic redundancy check (CRC) encoder together expand the packet size to M bits at each terminal of a CDMA system. The data rate of the coded packed is Rs b/s. the digital modulator spreads the signal to produce Rc chips/s. the CDMA processing gain is

$$G = W/Rs \qquad (2.1)$$

Where W (Hz) is the system bandwidth

Rs is the data rate of the coded packets

Terminal i also contain a ratio modulator and a transmitter radiating power pi watt. The path gain from transmitter i to the base station is hi and the signal from terminal i arrives at the base station at a received power level of

$$Q_i = P_i h_i \text{ (W)} \qquad (2.2)$$

Where P_i is the radiating power

hi is the path gain from transmitter i to base station

The base station also receives noise and out-of-cell interference with a total power of O^2W. The base station has N receivers, each containing a demodulator, a correlator for de-spreading the received signal, and a cyclic redundancy check decoder. Each receiver also has a channel decoder if the transmitter includes forward error correction.

In this analysis, the details of the transmission system are embodied in a mathematical function f (y), which is the probability that a packet arrive at the CRC decoder without errors. The dependent variable Y is the received SINR. For terminal i,

$$\gamma i = G \frac{Pihi}{\sum_{\substack{j=1 \\ j\neq i}}^{N} Pjhj + \sigma^2} \qquad 2.3$$

Substituting equation 2.2 into 2.3, obtain

$$\gamma i = G \frac{Qi}{\sum_{\substack{j=1 \\ j\neq i}}^{N} Qi + \sigma^2} \qquad 2.4$$

Massages acknowledged from the receiver inform the transmitter of errors detected at the CRC decoder that have not been corrected by the channel decoder. The transmitter employs selective-repeat retransmission of packets received in error. It is assumed in parts of this analysis that intra-cell interference dominates the total distortion and study of system performance when $\sigma^2 = 0$. When $\sigma^2 > 0$, the signal-to-noise ratio of the receiver is defined as

$$S_i = Q_i / \sigma^2 \qquad (2.5)$$

Substituting this into (2.4) gives

$$\gamma i = G \frac{Si}{\sum_{\substack{j=1 \\ j\neq i}}^{N} Si + 1} \quad 2.6$$

If the probability of undetected error at the CRC decoder is negligible, the throughput of signal I, defined as the number of information bits per second received without error is

$$T_i = \frac{L}{M} R_s f(\gamma) b/s \quad (2.7)$$

Where T_i is the throughput of terminal i (b/s)
L is the packet length (bit)
M is the packet size expanded by both FEC encoder and the CRC encoder (bit)
Rs is the packet data rate (b/s)
f (ﻻ) is the probability function that a packet arrives at the CRC decoder without errors.
The aggregate throughput, $T_{total,}$ is the sum of the N individual throughput measures. Assuming that L, M, and Rs are system constants, the normalized throughput, U, is analyzed and defined

$$U = \frac{M}{LR} T_{total} = \sum_{\substack{j=1 \\ j\neq i}}^{N} f(y)$$

(2.8)
Where U is dimensionless and bounded by $0 \le U \le N$,

2.4 CELL SPLITTING

Cell splitting is the process of subdividing a congested cell into smaller cells each with its own base station and a corresponding reduction in antenna height and transmitter power (Abhinav Kumar & Vinay Verma, 2014). Cell splitting is done by defining and installing new cells which have a smaller radius than the original cells (microcells). Cell splitting increases the capacity of a cellular system since it increases the number of times that channels are reused. By defining new cells which have a smaller radius than the original cells and by installing these smaller cells (called microcells) between the existing cells, capacity increases due to the additional number of channels per unit area. The consequence of the cell splitting is that the frequency assignment has to be done again, which affects the neighboring cells. It also increases the handoff rate because the cells are now smaller and a mobile is likely to cross cell boundaries more often compared with the case when the cells are big Cell splitting preserves the geometry of the architecture and therefore simply scales the geometry of the architecture. The increased number of cells would increase the number of clusters which in turn would increase the number of channels reused, and capacity (T. Rappaport,2002). A typical example of cell splitting is shown in Figure 2.1. Here, it is assumed that the cell cluster is congested and as a result, the call blocking probability has risen above an acceptable level. Imagine if every cell in the cluster was reduced in such a way that the radius, R of every cell was cut in half, (R/2). In order to cover the entire service area with smaller cells, approximately four times as many cells would be required. The increased number of cells would increase the number of clusters over the coverage region, which in turn would increase the number of channels, and thus capacity, in the coverage area. In the example shown in Figure 2.1, the smaller cells were added in such a way as to preserve the frequency reuse plan of the system. In this case, the radius of each new microcell is half that of the original cell.

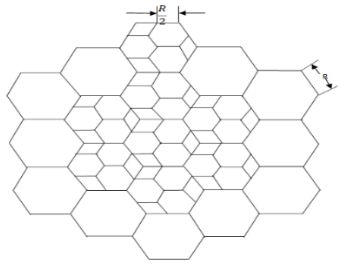

Figure 2.2: Each cell in a cluster is split into approximately four smaller cells by reducing R by half

By following cell splitting, the new small cells are reassigned new frequencies that do not cause co-channel interference with adjacent cells.

2.5 CELL SECTORING

Cell sectoring technique increases the capacity via a different strategy. In this method, a cell has the same coverage space but instead of using a single Omni-directional antenna that transmits in all directions, either 3 or 6 directional antennas are used such that each of these antennas provides coverage to a sector of the hexagon. When 3 directional antennas are used, 120° sectoring is achieved (each antenna covers 120°), and when 6 directional antennas are used, 60° sectoring is achieved (each antenna covers 60°).

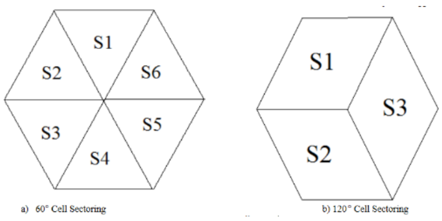

Fig 2.5 Cell Sectoring

Dividing the cells into sectors actually reduces the network capacity because the channels allocated to a cell are now divided among the different sectors (C.-L. I and P.-H. Chao,1993). In fact, handoff takes place when a cell phone moves from one sector to another in the same cell. The gain in network capacity is achieved by reducing the number of interfering co-channel cells. If sectoring is done in a way that channels assigned to a particular sector are always at the same direction in the different cells (i.e., group A of channels is assigned to the sector to the left of the tower in all cells, and group B of channels is assigned to the sector at the top of all cells, and so on), each sector causes interference to the cells that are in its transmission angle only. Unlike the case of no sectoring where 6 interfering co-channel cells from the first-tier co-channels cells cause interference, with 120° sectoring, 2 or 3 co-channel cells cause interference and with 60° sectoring, 1 or 2 co-channel cells cause interference. The number of co-channel interfering cells depends on the cluster shape and size. By having less than 6 interfering first-tier co-channel cells causing interference, the SIR is increased for the same cluster size. This allows us to reduce the cluster size and achieve the same original SIR, which directly increases the network capacity.

2.6 Power control in a sectored cell

Power control is the intelligent selection of transmitter power output in a communication system to achieve good performance within the system. Transmit power control is a technical mechanism used within some networking devices in order to prevent too much unwanted interference between different wireless networks.

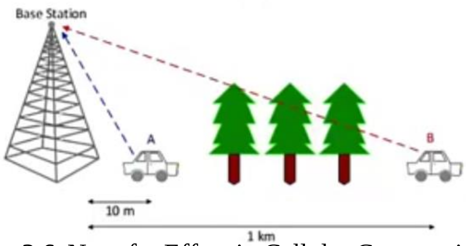

Fig 3.6 Near-far Effect in Cellular Communication

Consider user A and B at different distances from the base station, if they both transmit at the same power level, the base station receives a less quality signal from user B due to constraints like fading, path loss, e.t.c. Consequently, the base station requests for user B to transmit at a higher power so as to maintain uniformity in the received power. This implies that the farther UEs transmit at higher power than UEs closer to the base station.

3. RESEARCH METHODOLOGY

3.1 Cell Sectoring Model

The design process of selecting and allocating channel groups for all of the cellular base stations within a system is called frequency planning. The same set of frequency is reused after a specific distance to ensure increase in capacity and coverage. In cell sectoring, a cell has the same coverage space but instead of using a single Omni-directional antenna that transmits in all directions, directional antennas are used to transmit to different sectors of the cell. Several cells that use the same set of frequencies are called co-channels. The figure below is a diagrammatical example of co-channels. The cells bearing the same number are co-channel cells. The nearest co-channel cells are separated by a distance called Frequency Reuse Distance, labelled D in the diagram below.

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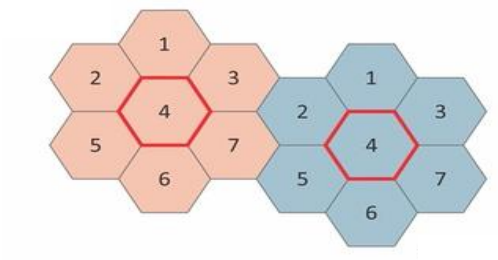


Fig 3.1 Co-channel description

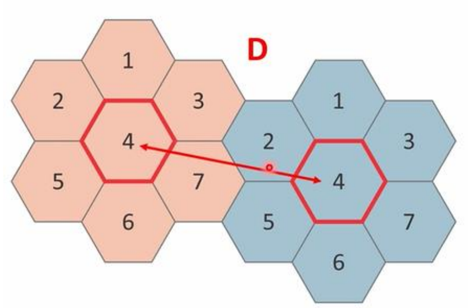


Fig 3.2 Frequency Reuse distance

Frequency reuse distance, D is given by **D = √3NR**
Where R is the cell radius; N is the number of cells per clusters also referred to as cluster size.
Frequency reuse factor Q is given by D/R = **√3N**
This thesis will consider a seven cell cluster, that is N = 7. For a seven cell cluster, the co-channel reuse ratio, Q is 4.58

3.2 Interference in a sectored cell

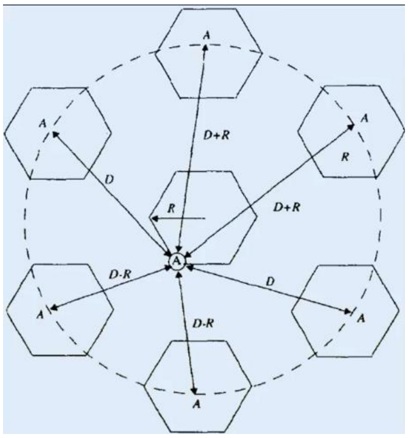
Interference is a major limiting factor in the performance of cellular radio system. Sources of Interference include: Another mobile in the same cell, a call in progress in a neighboring cell, other base stations operating in the same frequency band or any non cellular system which inadvertently leaks energy into the cellular frequency band.
The two major types of system generated interferences are Co-channel interference and Adjacent channel interference. Co-channel cells use the same set of channels, hence, there is always a possibility of interference in these cells. Interference between the co-channel cells is known as Co-channel interference. Adjacent Channel Interference is an interference resulting from signals which are close in frequency to the desired signal. Adjacent channel interference results from imperfect receiver filters which allow nearby frequencies to leak in to pass band.
The signal to interference ratio of a cellular system is given by

$$\frac{S}{I} = \frac{S}{\sum_{i=1}^{i_0} I_i}$$

where S – desired signal power Ii – Interference power caused by the interfering co-channel cell base station
Assuming that the transmitting power of each base station is equal and the path loss exponent same throughout the coverage area,

$$\frac{S}{I} = \frac{R^{-n}}{\sum_{i=1}^{i_0} (D_i)^{-n}} \quad \text{----3.2}$$

Where i_o is the number of Co-channels and S/I is the Signal to interference ratio at the desired mobile receiver.
For the case where the mobile unit is at the cell boundary in a 7-cell cluster (the worst case).



The distances from the co-channel interfering cells are approximated to D-R, D and D+R . Assuming n= 4
The signal-to-interference ratio is given by

$$\frac{S}{I}=\frac{R^{-4}}{2(D-R)^{-4}+2(D+R)^{-4}+2D^{-4}} = \frac{1}{2(Q-1)^{-4}+2(Q+1)^{-4}+2Q^{-4}} \quad \text{------3.3}$$

For a 120^{0} sectored cell where there are 2 cells with co-channel interference,

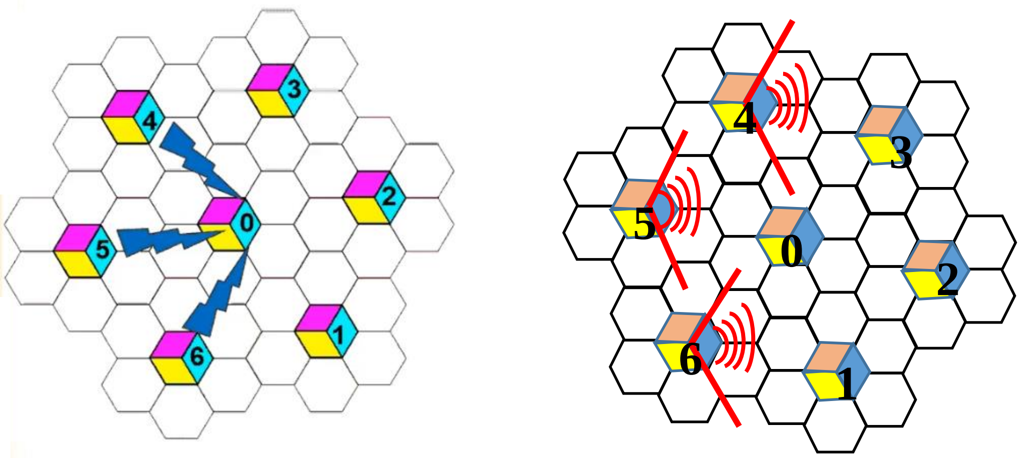


Fig. 3.4 Co-channel interference in 120^{0} Sectored cell

The signal-to-interference ratio is given by

$$\frac{S}{I}=\frac{R^{-4}}{D^{-4}+(D+0.7R)^{-4}} = \frac{1}{q^{-4}+(q+0.7)^{-4}} \quad \text{-----------3.4}$$

For a 60^{0} sectored cell there is one cell generating co-channel interference,

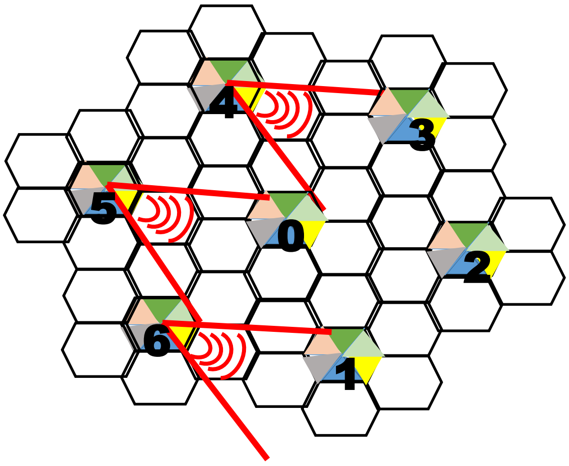


Fig. 3.5 Co-channel interference in 60^0 Sectored cell

$$\frac{S}{I} = \frac{R^{-4}}{(D + 0.7R)^{-4}} = (q + 0.7)^4 \qquad \text{-----------3.5}$$

3.3 Model presentation and Simulation

Model 1: Signal to interference ratio for an Omni-Directional Antenna in the Cell.

The radius of the cell R was kept constant while the Reuse distance D was varied

Simulation parameters are:

R = Cell Radius = 20

D = Reuse distance; 50, 60, 70, 80, 90, 100

$$\frac{S}{I} = \frac{R^{-4}}{2(D-R)^{-4} + 2(D+R)^{-4} + 2D^{-4}}$$

The simulation was done using the following matlab codes: Reuse distance vs Signal-to-interference ratio graph generated after the simulation will be seen in chapter 4

Model 2: Signal to interference ratio for a 120^0 sectored Antenna in the Cell

The radius of the cell R was kept constant while the Reuse distance D was varied.

Simulation parameters are:

R = Cell Radius = 20

D = Reuse distance; 50, 60, 70, 80, 90, 100

$$\frac{S}{I} = \frac{R^{-4}}{D^{-4} + (D + 0.7R)^{-4}}$$

The simulation was done using the following matlab codes: Reuse distance vs Signal-to-interference ratio graph generated after the simulation will be seen in chapter 4

Model 3: Signal to interference ratio for a 60^0 sectored Antenna in the Cell

The radius of the cell R was kept constant while the Reuse distance D was varied.

Simulation parameters are:

R = Cell Radius = 20

D = Reuse distance; 50, 60, 70, 80, 90, 100

$$\frac{S}{I} = \frac{R^{-4}}{(D + 0.7R)^{-4}}$$

The simulation was done using matlab codes: Reuse distance vs Signal-to-interference ratio graph generated after the simulation will be presented in part 4

4. ANALYSIS AND PRESENTATION OF RESULTS

4.1: Signal to interference ratio for an Omni-Directional Antenna in the Cell

The simulation of model 1 in chapter 3 was done and the data's gotten were tabulated in the table below. The graph that resulted from the simulation is in fig. 4. Below

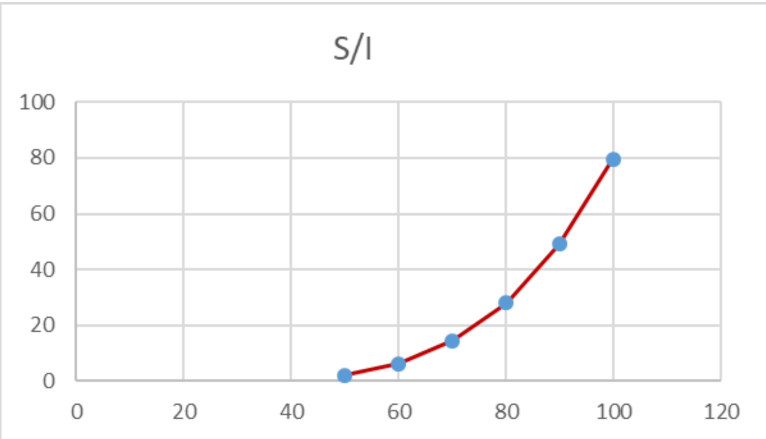
D	S/I
50	2.175855
60	6.349051
70	14.40817
80	28.00818
90	49.0419
100	79.64504

Table 4.1: Signal to interference ratio vs Frequency reuse Distance for an Omni-Directional Antenna in the Cell

From fig 4.1 above, while the frequency reuse distance was increased from 50 to 100 the signal to interference ratio improved from 2.18 to 79.65.
This analysis shows that Signal-to-interference ratio is directly proportional to the Frequency reuse distance of the network. This means that when the reuse distance of a network is increased, there will be an increased signal-to-

Fig 4.1: Signal to interference ratio against Frequency reuse Distance for an Omni-Directional Antenna in the Cell

interference ratio which implies an increased network throughput.



4.2: Signal to interference ratio for a 120^0 sectored Antenna in the Cell
The simulation of model 2 in chapter 3 was done and the data gotten tabulated in the table below. The graph that resulted from the simulation is in fig. 5. Below

D	S/I
50	28.46024
60	56.55661
70	101.2395
80	167.9102
90	262.7196
100	392.5681

Table 4.2: Signal to interference ratio vs Frequency reuse Distance for 120^0 sectored Antenna in the Cell

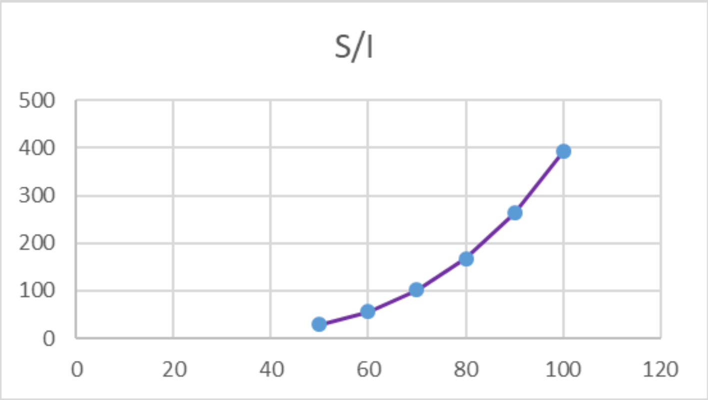


Fig 4.2: Signal to interference ratio against Frequency reuse Distance for 120^0 sectored Antenna in the Cell

From fig 4.2 above, while the frequency reuse distance was increased from 50 to 100 the signal to interference ratio improved from 28.46 to 392.57.

This analysis shows that for a 120^0 sectored cell, Signal-to-interference ratio increases as the Frequency reuse distance increases. This increase implies that the maximum data transmitted in the communication system is higher when the frequency reuse distance is increased.

4.3: Signal to interference ratio for a 60^0 sectored Antenna in the Cell

The simulation of model 3 in chapter 3 was done and the data gotten tabulated in the table below. The graph that resulted from the simulation is in fig. 5. Below;

D	S/I
50	104.8576
60	187.4161
70	311.1696
80	487.9681
90	731.1616
100	1055.6

Table 4.3: Signal to interference ratio vs Frequency reuse Distance for 60^0 sectored Antenna in the Cell

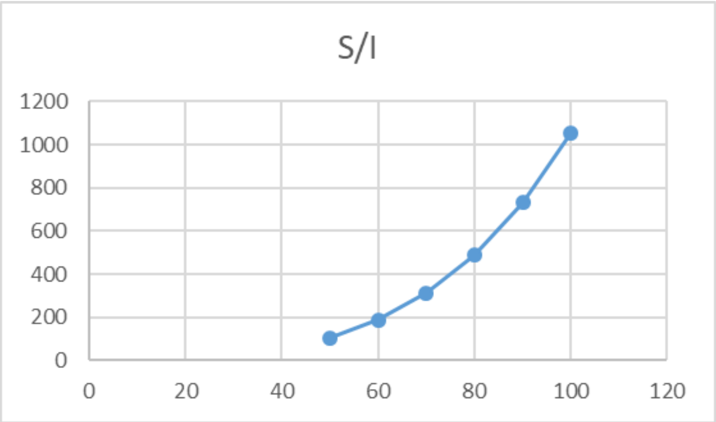


Fig 4.3: Signal to interference ratio against Frequency reuse Distance for 120^0 sectored Antenna in the Cell

From fig 4.3 above, while the frequency reuse distance was increased from 50 to 100 the signal to interference ratio improved from 104.86 to 1055.6.
This analysis shows that for a 60^0 sectored cell, Signal-to-interference ratio increases as the Frequency reuse distance increases. This increase implies that the maximum data transmitted in the communication system is higher when the frequency reuse distance is increased.

4.4: Comparative analysis of Ominidirectional mode, 120^0 Sector and 60^0 sector.

D	S/Ia	S/Ib	S/Ic
50	104.8576	28.46024	2.175855
60	187.4161	56.55661	6.349051
70	311.1696	101.2395	14.40817
80	487.9681	167.9102	28.00818
90	731.1616	262.7196	49.0419
100	1055.6	392.5681	79.64504

Table 4.4: Signal to interference ratio vs Frequency reuse Distance for omnidirectional mode, 120^0 and 60^0 sectored cell

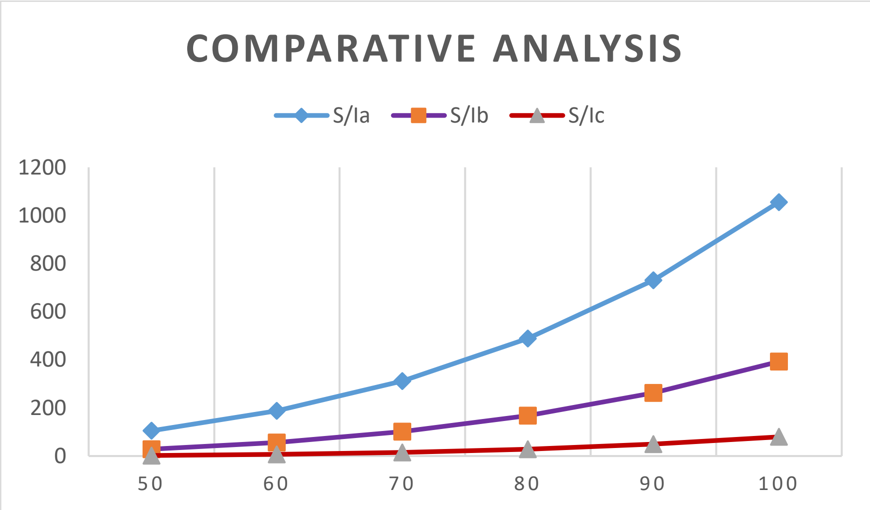


Fig 4.4: Signal to interference ratio vs Frequency reuse Distance for omnidirectional mode, 120^0 and 60^0 sectored cell

The comparative analysis of the three case scenarios are shown on table 4.4 and figure 4.4 above. S/Ia represents the signal-to-interference ratio of the 60^0 sector, S/Ib represents the signal-to-interference ratio of the 120^0 sector while S/Ic represents the Omnidirection antenna mode.
From the analysis, the Signal-to-interference ratio for the 60^0 sector produced the highest Signal-to-interference ratio while the omnidirectional mode produced the least signal-to-interference ratio. Since a high signal-to-interference ratio leads to a maximized throughput, it then implies that the throughput of the network will be higher when a smaller sectoring is used.

5.1 SUMMARY OF FINDINGS

Throughput is a key measure of the quality of a wireless data link and its maximization is a major concern in cellular communication. Signal-to-interference ratio of a network plays an important role in determining maximum data transmitted in the communication system. This thesis made use of cell sectoring technique in achieving a goal of throughput maximization. Different sectoring techniques were deployed to be able to analyze the signal-to-interference ratio of the network for different Frequency reuse distance. From the combined analysis presented in table 4.4 and figure 4.4, it is clear that smaller the angle of the sectorial antenna used in a cell, the higher the signal-to-interference ratio and hence the higher the throughput of the communication system.

5.2 CONCLUSION

This analysis of this thesis showed that in a congested cellular system where there is high number of request leading to increased traffic, appropriate cell sectoring technique when applied has the capability of increasing the capacity of a system thereby leading to a maximized throughput.

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