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Performance Evaluation of Mobile Cellular Networks in Nigeria

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ABSTRACT

The aim of this paper is to evaluate the performance of mobile networks such as MTN, GLO, and ETISALAT in Nigeria and suggest ways the performance of digital cellular networks can improve to minimize some of its present short comings or limitations. This paper discusses the performance improvement of digital cellular networks. A non- CDMA cellular network is use in an overall wireless environment for the purpose of this paper. This paper also discusses the performance assessment of three mobile network operators. In addition, ways to minimize the limitations in other to improve the performance of digital mobile networks was also discussed. Finally, suggestions were made to improve QoS of mobile networks.

Keywords: *mobile networks, MTN, GLO, ETISALAT, Cellular Networks, Performance Evaluation*

1. INTRODUCTION

The mobile phone has become a fashionable and every day object. In this information age most businessmen find it necessary to access data (such as files) while on the rather than use a fixed terminal, which might not be available at the time, portable computer connected to a cellular network will be more convenient for those who do a lot of traveling. These portable computers could be use to send and receive data in form of faxes, e-mails and other forms of data [10].

Modern cellular networks not only need to provide high quality voice for customers, but a large amount of data transfer service as well, such as wireless internet, multimedia, file transfer and downloading. These concerns lead to the new demand to enhance the throughput and high data rate coverage for future cellular networks. However, conventional cellular networks cannot offer the Signal to Interference and Noise Ratio (*SINR*) that is high enough to meet the new requests. Theoretical difficulties will be encountered if the future 4G networks are constructed purely based on conventional network architecture. First, the transmission rate for the future 4G networks is much higher than that of 3G networks, which will adversely affect the *SINR* at the receiving end, since *SINR* is in inverse proportion to the transmission rate. Second, the spectrum allocated for 4G networks could be well above 2 GHz when compared with 3G networks. Under the operation of such a high band, the received signal will decrease tremendously according to the radio propagation model [10].

Performance issues in digital cellular networks are so prevalent that they involve all aspects of the wireless communication system design and operation and technology platforms. But there is a general misconception that performance requirements for one type of technology platform are significantly different from others. However, all systems have to deal with capacity, coverage requirements, lost calls, call quality etc

PERFORMANCE EVALUATION OF MOBILE CELLULAR NETWORKS

In this section, we evaluate the performance of some of the digital cellular network operators in Nigeria to justify the need for improvement of the system. Three GSM operators were selected for the purpose of assessment and Oyo State was also chosen for the case study. For the purpose of performance evaluation, the GSM operators evaluated were MTN, GLO, and ETISALAT.

Analysis of the data

The data was analyzed using Microsoft excel package. The Drop call rate call drop rate and the Grade of service were the criteria used in evaluating the performances of the operators are:

2. Drop call rate call drop rate:

$$\text{Call drop rate} = \frac{\text{Number of call drops}}{\text{Number of successful seizures}} \times 100\%$$

3. Grade of service

Formula for calculating grade of service

$$\text{GoS } (p) = \frac{\text{Number of lost calls}}{\text{Total number of calls}}$$

Justification for the improvement

Going by the overall grade of service (GoS) analysis result summarized in table 1 below, obviously there is an urgent need for capacity and performance improvement of the system in order to meet the recommended quality of service (QoS) objective of achieving a grade of service of 1% - 2%. Glo has the best quality of service with an overall grade of service of 26.15% followed by MTN with an overall (GoS) of 28.73% and lastly ETISALAT with an overall grade of service of 33.88%. The (GoSs) of the network operators is still very much higher than the recommended value of 1%-2% which implied a poor quality of service (QoS) on a general note. Also, the call drop rate for each of the operators is still on the high side therefore, there is need for performance improvement of these networks.

Table 1: Table Showing Overall Percentage GoS of the operators

Operators	**Overall % Avg GoS**	**Recommended**
MTN	28.73	1 – 2 %
GLO	26.15	1 – 2 %
ETISALAT	33.88	1 – 2 %

Table 2: Table Showing Overall Percentage Drop Call Rate of the operators

Operators	**Overall Avg DCR**
MTN	46.00
GLO	35.54
ETISALAT	47.85

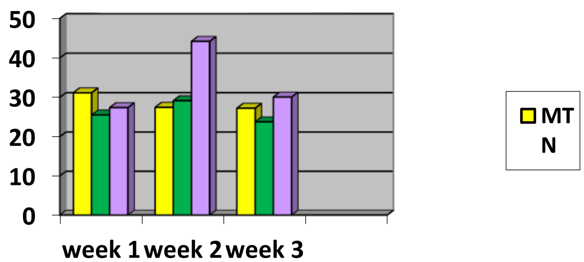

Fig 1: Bar chart showing weekly (QoS) of the operators

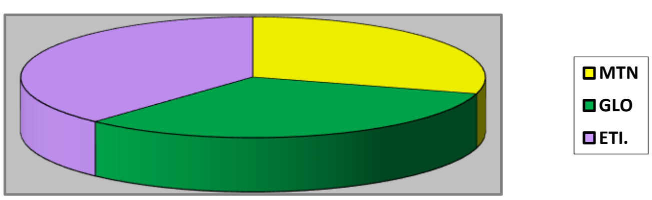

Fig 2: Pie chart showing overall grade of service (QoS)

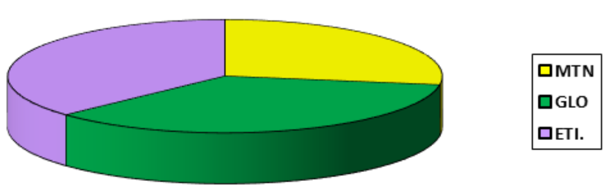

Fig 3: Pie chart showing overall percentage drop call rate

PERFORMANCE IMPROVEMENT

Solutions to Transmission Problems

This section describes some solutions to the problems described in previous sections. Although many of these do not entirely solve all problems on the radio transmission path, they do play an important part in maintaining call quality for as long as possible

1. Diversity—A Technique to Mitigate the Effects of Fading and Dispersion

In this section frequency and space diversity will be discussed. There is a third diversity scheme called time diversity, which can be applied to digital cellular radio systems. In principle, such techniques can be employed at the base station and/or at the mobile unit, although different problems have to be solved for each. The basic concept behind diversity is that when two or more radio paths carrying the same information are relatively uncorrelated, when one path is in a fading condition, often the other path is not undergoing a fade. These separate paths can be developed by having two channels, separated in frequency. The two paths can be separated in space. Also, the two paths can be separated in time. When the two (or more) paths are separated in frequency, we call this frequency diversity. However, there must be at least 2% or greater frequency separation for the paths to be comparatively uncorrelated. Because, in the cellular situation, there is shortage of spectrum, using frequency diversity (i.e., using a separate frequency with redundant information) is essentially out of the question, and it will not be discussed further except for its implicit use in CDMA[2],[8].

Space Diversity

Space diversity is commonly employed at cell sites, and two separate receive antennas are required, separated in either the horizontal or vertical plane. Separation of the two antennas vertically can be impractical for cellular receiving systems. Horizontal separation, however, is quite practical. Increased received signal strength at the BTS may be achieved by mounting two receiver antennae instead of one. If the two Rx antennae are physically separated, the probability that both of them are affected by a deep fading dip at the same time is low. There is a set of rules for the cell site, and there is another for the mobile unit [2], [8].

Space Diversity on a Mobile Platform: both vertically separated and horizontally separated antennas on a mobile unit. For the vertical and horizontal separation cases, 1.5λ and 0.5λ, respectively, are recommended. At 850 MHz, $\lambda = 35.29$ cm. Then $1.5\lambda = 1.36$ ft or 52.9 cm. For the 0.5λ, the value is 0.45 ft or 17.64 cm [2].

Justification

At 900 MHz, it is possible to gain about 3 dB with a distance of five to six meters between the antennae. At 1800MHz the distance can be shortened because of its decreased wavelength.

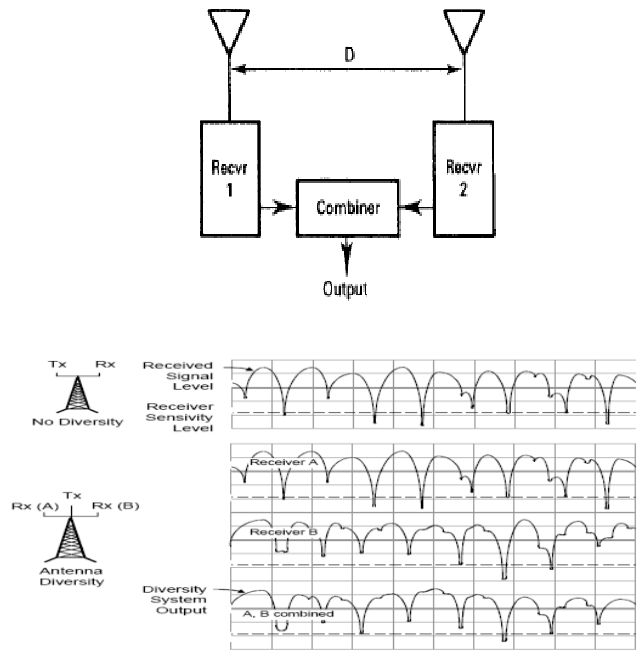

Figure 4: Space diversity

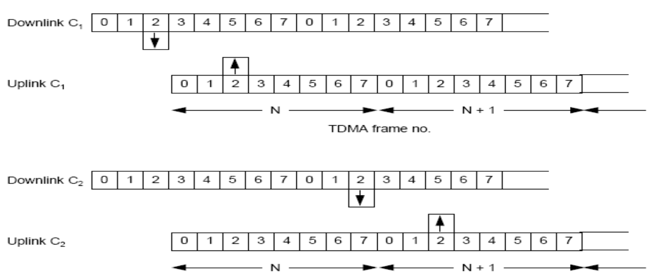

Figure 5: Frequency Hoping

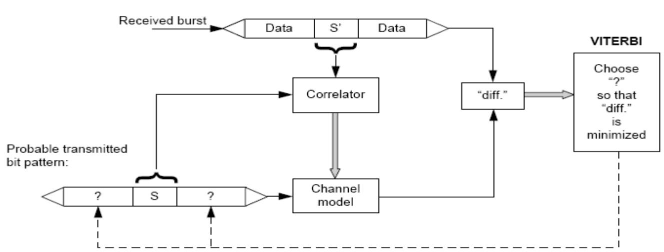

Figure 6: Adaptive equalization

Frequency Diversity

It was pointed out that conventional frequency diversity was not a practical alternative in cellular systems because of the shortage of available bandwidth. However, with CDMA (direct sequence spread spectrum), depending on the frequency spread, many frequency diversity paths are available, and in most CDMA systems we have what is called *implicit diversity*; and multipath can be resolved with the use of a RAKE filter. This is one of the many advantages of CDMA [2].

2. Forward Error Correction—A Form of Time Diversity*:* Forward error correction (FEC) can be used on digital cellular systems not only to improve *bit error rate* but to reduce fading. To reduce the effects of fading, an FEC system must incorporate an *interleaver*.

Justification

An interleaver pseudo randomly shuffles bits. It first stores a span of bits and shuffles them using a generating polynominal. The span of bits can represent a time period. The rule is that for effective operation against burst errors, the interleaving span must be much greater than the typical fade duration. The deinterleaver used at the receive end is time-synchronized to the interleaver incorporated at the transmit end of the link.

3. Frequency Hopping

As mentioned previously, Rayleigh fading is frequency dependent. This means that the fading dips occur at different places for different frequencies. To benefit from this fact, it is possible for the BTS and MS to hop from frequency to frequency during a call. The frequency hopping of the BTS and MS is synchronized. In GSM there are 64 patterns of frequency hopping, one of which is a simple cyclic or sequential pattern. The remaining 63 are known as pseudo-random patterns which an operator can choose from.

Justification

At every frame, the system can hop to a new frequency, thus spreading the signal out. This serves the purpose of fighting frequency-specific fades. It also helps fight co channel interference, as it keeps hopping from channel to channel and only stays on one particular channel for a fraction of the time.

Thus, if two mobiles are assigned the same channel in their frequency-hopping pattern, they will seldom use that same frequency at the same time—and even if they do meet, it is only for one frame [8].

4. Adaptive Equalization

Adaptive equalization is a solution specifically designed to counteract the problem of time dispersion. Due to the signal dispersion caused by multipath signals the receiver cannot be sure exactly when a burst will arrive and how distorted it will be [8]. To help the receiver identify and synchronize to the burst, a Training Sequence is sent at the centre of the burst [8].

Justification

When a burst of information is received, the equalizer searches for the training sequence code. When it has been found, the equalizer measures and then mimics the distortion which the signal has been subjected to. The equalizer then compares the received data with the distorted possible transmitted sequences and chooses the most likely one. There are eight different Training Sequence codes numbered 0–7. Nearby cells operating with the same RF carrier frequency will use different Training Sequence Codes to enable the receiver to discern the correct signal. Because some assumptions are made about the radio path, adaptive equalization may not result in a 100% perfect solution every time. However, a "good enough" result will be achieved. A viterbi equalizer is an example of an adaptive equalizer.

5. Channel Coding

In digital transmission, the quality of the transmitted signal is often expressed in terms of how many bits are incorrect, this is called the Bits Error Rate (BER).BER defines the percentage of the total number received bits which are incorrectly detected.

Transmitted Bits: 1 1 0 1 0 0 0 1 1 0
Received Bits: 1 0 0 1 0 0 1 0 1 0
↑ ↑ ↑
3/10 = 30% BER

This percentage should be as low as possible. It is not possible to reduce the percentage to zero because the transmission path is constantly changing. This means that there must be an allowance for a certain amount of errors and at the same time an ability to restore the information, or at least detect errors so the incorrect information bits are not interpreted as correct. This is especially important during transmission of data, as opposed to speech, for which a higher BER is acceptable [8].

Justification

Channel coding is used to detect and correct errors in a received bit stream. It adds bits to a message. These bits enable a channel decoder to determine whether the message has faulty bits, and to potentially correct the faulty bits

6. Sectorization

The problem with employing omni-directional cells is that as the number of MSs increases in the same geographical region, we have to increase the number of cells to meet the demand. To do this, we have to decrease the size of the cell and fit more cells into this geographical area. Using omni-directional cells we can only go so far before we start introducing co-channel and adjacent channel interference, both of which degrade the cellular network's performance [5].

To gain a further increase in capacity within the geographic area we can employ a technique called "sectorization". Sectorization split a single site into a number of cells, each cell has transmit and receive antennas and behaves as an independent cell.

Justification

In using sectorization technique each cell uses special directional antennas to ensure that the radio propagation from one cell is concentrated in a particular direction. This has a number of advantages:

- ❖ Firstly, as we are now concentrating all the energy from the cell in a smaller area 60, 120, 180 degrees instead of 360 degrees, we get a much stronger signal, which is beneficial in locations such as "in-building coverage".
- ❖ Secondly, we can now use the same frequencies in a much closer re-use pattern, thus allowing more cells in our geographic region which allows us to support more MSs.

By dividing the cell geographically, usually into 120° sectors, an operator can increase its coverage and improve the overall quality of the service of the (QoS) system, as directional antenna systems are usually better performers [11].

8. Combining Call Admission Control with buffer in controlling Congestion

Call admission control (CAC) and network resource allocation are the key issues of concern. CAC determines the condition for accepting or rejecting a new call based on the availability of sufficient network resources to guarantee the QoS parameters without affecting the existing calls. On the other hand, the network resource allocation decides how to accept incoming connection requests.

The major call-level qualities of service parameters based on cellular concept are: new call blocking and handoff call blocking probabilities

When a mobile user tries to communicate with another user or a base station, it must first obtain a channel from one of the base stations that hears it. If a channel is available, it is granted to the user otherwise the new call is blocked. The user releases the channel either when the user completes the call or moves to another cell before the call is completed. The procedure of moving from one cell to another while a call is in progress is called handoff.

While performing handoff, the mobile unit requires that the base station in the cell that it moves into will allocate it a channel. If no channel is available in the new cell, the handoff call is blocked. Instead of blocking such call, a buffer is introduced which stores the call until a channel is available to transmit the call.

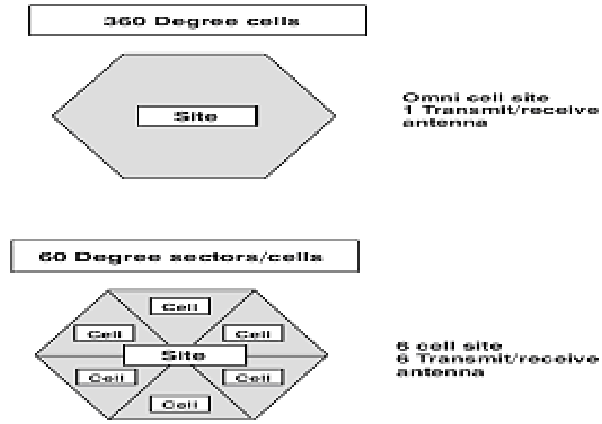

Fig 7: Site Sectorization

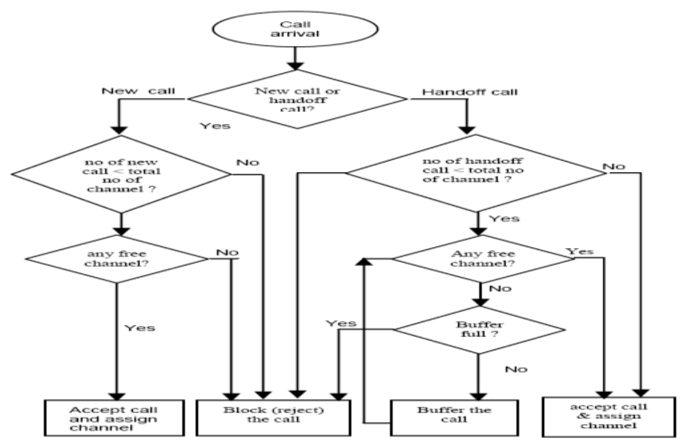

Figure 8: flow chart for the scheme

Development of a Congestion Control Scheme Model

The proposed scheme considers a multiple class of calls (multimedia system) that differ in their QoS requirements and traffic parameters, allowing for call transitions among classes. The model is structured over users moving along an arbitrary topology of cells. Each cell has the same number of channels, due to the fact that wireless network resources are limited. During call establishment, a call is assumed to declare its priority.

The call processing entities of the system (e.g. the processing elements of the Base station or Base Station Controller) are able to identify the call type at any moment. The available resources are the maximum number of channels in a cell and the buffer size that is used to queue handoff call in case no channel is available. The buffer size could be adjusted depending on the input traffic rate [15].

Channel Allocation

There are many ways to allocate channels to call requests in mobile networks. This proposed model focuses on the use of dynamic channel allocation method [3] which is adjusted depending on the input rate. The algorithm is shown

Buffer Management

Typically a customer waits in a queue with other customers awaiting service, but it is possible for the seller to provide higher priority to certain, presumably higher spending customers. Computational resources could be done in the same manner. Handoff call would be buffered if no free channel is available rather than rejecting them. This would be allocated channel any time either of the following occurs:

(i) user completes the call

(ii) The user moves to another cell before the call is completed

However, what determines the handoff that will be allocated channel first depends on the priority attached to it. This policy makes us determine whether delay sensitive handoff should be buffered, or allowed to be initiated again based on its dwelling time.

Algorithm of the proposed model

If (incoming request is new call or handoff call)
If (there is a free channel) then
Allocate the free channel
Else
If (handoff call)
Put in a buffer
If (there is free channel again)
    Allocate the free channel to handoff call
Else
Ignore request
End if
Else
    Ignore request
End if
    Ignore request
End if
End if

End

Justification of the Model

This proposed model presents the analysis of a new policy of congestion control in wireless mobile networks. Although research efforts have been trying to address this issue, but most of them did not put into consideration buffering handoff calls as a way of reducing the number of handoff call block. Instead of deteriorating the quality of service of handoff calls in the presence of new calls, a buffer is introduced to take care of this and the total throughout of the network will increase considerably. The proposed scheme if implemented would provide a quality of service guarantee to both new and handoff calls and at the same time the exploitation of buffer resources to accommodate blocked handoff in order to improve the performance of the network.

CONCLUSION

Due to the rapid growth in the cellular communication industry, there is an urgent need for greater system capacity. Code division multiple access (or CDMA) is the new technology and it does not need a cellular structure. CDMA is a 'spread spectrum' technology; it spreads the information contained in a particular signal over the entire bandwidth allocated for the mobile communication. With CDMA, unique digital codes, rather than radio frequencies or channels, are used to differentiate the different signals. These codes are shared by both the transmitter and receiver; and hence the receiver (the mobile phone) receives all the signals but can only recognize the one with the same codes. CDMA has many advantages over the existing cellular systems

- Increases capacity and improves quality of the signal.
- Simplified system planning through the use of the same frequency all over the covered area.
- Enhanced privacy

The legacy networks 2G and 3G are on the brink of their capacity limit therefore, the deployment of a technology that can bring more capacity and meet requirement for effective data transfer which is a definitely a spread spectrum technology (CDMA) which a spread spectrum offers justifies its deployment in order to have better performance.

RECOMMENDATIONS

The following recommendations are given to digital cellular operators in order to have better QoS

- With network expansion and subscriber growth, it becomes necessary to review the engineering in order to use the frequency spectrum efficiently.
- Visiting a site on air is a good opportunity to update the planning database and obtain newer panoramic pictures. A complete audit of the site is done (re checking coordinates, azimuths, heights, tilts, antenna types, etc.). Urban changes affect the cellular network in the sense that a new building, for example, recently built in front of an existing antenna generates a signal propagation obstruction.
- Spectral efficiency is the key word in TDMA based networks. The frequency resource is rare and expensive, so it should be efficiently used. Frequency planning is an operation that is necessary each time it becomes difficult to find new frequencies for integrating new sites.
- Operators should have QoS monitoring schedule in order to know actual state of the performance of their networks.
- At the deployment phase, operators tend to use standard parameter templates, as thousands of GSM parameter exist. However, due to differences between cells (propagation and interference environment), it is necessary to fine-tune some parameters on a cell-by-cell or adjacency-by-adjacency basis in order to get *optimum* performance.
- Due also to lack of coverage, site physical re-engineering can be proposed. This is one way of optimizing antenna coverage in order to improve site performance

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