Minimization of Call Congestion in Telecommunication Network Using OFDM Optimization Model

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Abstract—The level of patronage being experienced in Global Systems for Mobile communication (GSM) in Nigeria is overwhelming. This is as a result of freedom of calling from anywhere at any time and clarity of the voice enjoyed since it is on a digital technology platform. As the number of subscribers continues to increase at a very high rate, there is a consequential increase in network congestion. Aftermath of this is the reduction in the quality of services delivered to customers. This paper, therefore, looked at the various causes of call congestions with special emphasis to Nigeria as well as possible solution approaches. The application of Orthogonal Frequency Division Multiplexing (OFDM) Optical Wireless Communications technique for GSM congestion reduction in Nigeria is proposed. OFDM was suggested for adoption because of its inherent advantages such as high spectra efficiency, cross talk elimination and simplified channel coding, etc.

Keywords: Congestion, GSM, OFDM, Network, Communication, Subscriber.

I. INTRODUCTION

It has been observed that calls across different networks are always difficult to connect and at times diverted. This creates room for users to be confused as how much is deducted from their call credits and are compelled to having multiple GSM lines. As the network increases, more users make call across different networks and there is need to record the call time, call network, and line identification and be able to put calls across the networks without much congestions. The transmission of calls without much congestion in the network using OFDM optical wireless network, is the bases for this paper. The purpose of this research work is to establish an OFDM Optical Wireless Communication (OWC) model that will serve and improve signals congestion control system for multi-user telecommunication networks in Nigeria. This study will help to determine the status of GSM network resource allocation in Nigeria with a view to knowing areas to be addressed for congestion reduction.

A. Brief History of Nigeria's Telecommunication Industry

The journey to success in Nigeria's telecommunication has been long and tortuous. The British colonial administration in Nigeria established telecommunication facilities first in 1886[1]. At independence in 1960, with a population of roughly 40 million people, the country only had about 18,724 phone lines for use [2]. During this period, the service was very unsatisfactory. The telephone system was unreliable, congested, expensive and customer unfriendly.

Postal and Telecommunication Divisions merged with NET in 1985 to form Nigerian Telecommunications Limited (NITEL), a limited liability company[2].The main objective of establishing NITEL was to harmonies the planning and co-ordination of the internal and external telecommunications services, rationalize investments in telecommunications development and provide accessible, efficient and affordable services. After some years, the Nigerian Telecommunication Plc, NITEL had roughly half a million lines available to over 100 million Nigerians. NITEL the only national carrier had a monopoly on the sector and was synonymous with epileptic services and bad management. On assumption of office on May 29, 1999 the then President Olusegun Obasanjo administration swung into action by making it a reality, the complete deregulation of the telecom sector. Most especially the much touted granting of licenses to GSM service providers and setting in motion the privatization of NITEL. This proactive approach by the government to the telecom sector has made it possible for over 10 million Nigerians to clutch GSM phones today [2].

B Problems of the Existing System

Due to the Radio Frequency (RF) spectrum being used by the service providers in Nigeria, GSM congestion had been a big problem affecting the quality of service in the country. This is due to the fact that the RF spectrum is not enough to accommodate over 10 million subscribers in Nigeria owing to its frequency range. This however causes problem of GSM congestion in Nigeria [3].

C Justification for the New System

The new system is designed to solve congestion problem affecting Nigeria's telecommunication system. It is designed to use OFDM optical wireless systems thereby relieving the problems of spectrum deficit. The optical wireless system uses a large spectrum with multipath propagation, which can accommodate all the subscribers in Nigeria, thereby reducing GSM congestion. The OFDM creates multicarrier signals, which are orthogonal to one another [4].

The OWC employs light emitting diodes (LEDs) as transmitters and photodiodes (PDs) as receivers, which secure communication in areas where the RF transmission is physically impossible or prohibited. The data transmission in OWC is achieved through intensity modulation and direct detection. Optical OFDM with multilevel quadrature amplitude modulation (M-QAM) delivers very high data rates, because it has inherent robustness to inter-symbol interference [5].

D Network Congestion

Data networking and queuing theory has that network congestion occurs when a link or node is carrying so much data that its quality of service deteriorates. Typical effects include queuing delay, packet loss or the blocking of new connections. A consequence of these is that incremental increases in offered load lead either only to small increase in network throughput, or to an actual reduction in network throughput.

Congestion is the overcrowding of route, leading to slow and inefficient flow. In computing, it is a situation in which the amount of information to be transferred is greater than the amount that data communication path can carry [6]

Telecommunication devices are systems that transmit electronic or optical signals across long distances. Telecommunication enables people around the world to contact one another to access information instantly, and to communicate from remote areas [6].

II THEORY OF CONGESTION CONTROL

The modern theory of congestion control was pioneered by Frank Kelly [7], who applied microeconomic theory and convex optimization theory to describe how individuals controlling their own rates can interact to achieve an "optimal" network-wide rate allocation.

Congestion control then becomes a distributed optimization algorithm for solving the above problem. Many current congestion control algorithms can be modeled in this framework. A major weakness of this model is that it assumes all flows observe the same price, while sliding window flow control causes "burstiness". This makes different flows to observe different loss or delay at a given link. Congestion control algorithms are classified by the type and amount of feedback received from the network; loss; delay; single-bit or multi-bit explicit signals [8].

By the aspect of performance, it aims at improving high band width-delay product networks, lossy links, fairness, advantage to short flows and variable-rate links [3], [8].

A. Areas of Congestion On GSM Network

Four areas of congestion in the GSM network are:

(i) Common Control Channels (CCCH): This is a group of control channels that support the establishment and maintenance of communication links between the mobile Stations and Base [9]. It consists of Random Access Channel (RACH) used to make request for network assignment, Paging Channels (PCH) used to alert the mobile stations of incoming calls and Access Grant Channel (AGCH) used to assign Mobile Station to a specific Dedicated Control Channel Congestion (DCCH) or Stand-alone Dedicated Control Channel (SDCCH) for onward communication. On these Common Control Channels, congestion occurs under three conditions:

- *RACH Congestion (RACHC):* occurs when there is no free Random Access Channel to use to either make a call or respond to a call. In this case, there is total blocking to either in-coming or outgoing call.
- *PCH Congestion (PCHC):* occurs when there is no free PCH to use in alerting the mobile station of an incoming message.
- *AGCH Congestion (AGCHC***):** occurs when there is no free Access Grant channel to authenticate the responding Mobile station .

When any of these three control channels is congested call establishment does not exist between the sender and receiver. This is called a "Call Establishment Failure"[9].

*(ii) Dedicated Control Channel Congestion (DCHC***):** This is the failure to allocate Stand-alone Dedicated Control Channel (SDCCH) to provide authentication to mobile stations, location updating and assignments to traffic channels during idle periods. The messages on SDCCH channel include short message service. When making a call or responding to paging message for the allocation of an SDCCH for authentication, if vacant SDCCH exists not to use at that time, the call will be terminated[9][10].

(iii) Traffic channels congestion (TCHC): This failure occurs when an Access Grant Channel cannot get any free traffic channel (TCH) to allocate to the request of the mobile terminal through the random access channel. TCH is used to transfer voice, data, and control information and when there is no vacant TCH, the voice communication on the GSM network cannot be established [9][10].

(iv) Pulse Code Modulation Congestion (PCMC): Pulse Code Modulation (PCM) is the link required to connect together the Base station (BS) and Mobile-switching center (MSC).Each PCM can carry between 1 and 32 calls. When there is no free PCM to carry the call signals between the BS and MSC, then Pulse Code Modulation Congestion (PCMC) takes place. This type of congestion can either occur within the network or between networks [9][10].

B. Other Causes of Congestion in GSM Network in Nigeria:

(i) Inadequate Base Station.

(ii) Inadequate Channels for users.

(iii) Competition for subscribers among the Network Operators.

(iv) Lack of good communication among the Network operators.

(v) Inadequate of End to End Systems.

(vi) Marketing strategies and pricing schemes also affect traffic behavior since these could increase the number of subscriber on the network schemes [11].

(vii) Lack of good /quality phones.

(viii) Redialing by subscribers when they experience blocking [9][10].

B. Factors affecting smooth flow of transmission in Nigeria

(i) Malfunction of the electronics/equipments

(ii) Power failures, though there are provisions for redundant machines for automatic take over

(iii) Vandalization from human beings

III CONGESTION MINIMIZATION MODELS

A. Orthogonal frequency-division multiplexing (OFDM):

This is a method of encoding digital data on multiple carrier frequencies. it has developed into a popular scheme for wideband digital communication whether wireless or over copper wires used in applications such as digital television and audio broadcasting, DSL broadband internet access, wireless networks, and 4G mobile communications.

The primary advantage of OFDM over single-carrier schemes is its ability to cope with severe channel conditions attenuation of high frequencies in a long distance, narrowband interference and frequency-selective fading due to multipath without complex equalization filters. Channel equalization is simplified because OFDM may be viewed as using many slowly modulated narrowband signals rather than one rapidly modulated wideband signal.

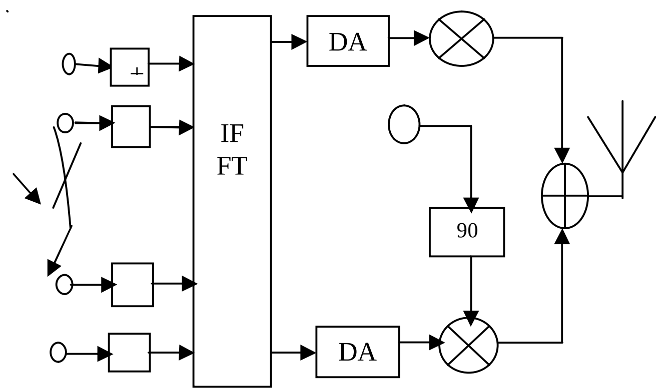


Fig 1: OFDM Transmitter with Data Buffer in the IFFT.

The low symbol rate makes the use of a guard interval between symbols affordable, making it possible to eliminate inter-symbol interference (ISI) [3],[12],[13]. An OFDM OWC carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using quadrature amplitude modulation (QAM) An inverse FFT is computed on each set of symbols, giving a set of complex time-domain samples.

These samples are then quadrature-mixed to pass band in the standard way [13]. The real and imaginary components are first converted to the analogue domain using digital-to-analogue converters (DACs); the analogue signals are then used to modulate cosine and sine waves at the carrier frequency fc, respectively. These signals are then summed to give the transmission signal, S(t).

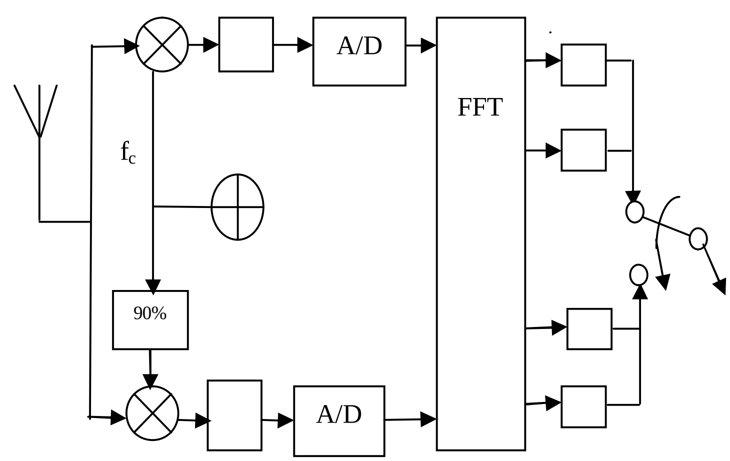


Fig. 2: OFDM Receiver with Data Buffer in the FFT

The receiver picks up the signal r(t) which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency. This also creates signals centered on $2f_c$, so low-pass filters are used to reject these. The baseband signals are then sampled and digitized using analog-to-digital converters (ADCs), and a forward FFT is used to convert back to the frequency domain [14].

This returns N parallel streams, each of which is converted to a binary stream using an appropriate symbol detector. These streams are then re-combined into a serial stream, S[n], which is an estimate of the original binary stream at the transmitter [12]. Coded inputs bits are mapped onto complex – valued symbols in order to modulate the information – carrying frequency domain subcarrier.

(i) Implementation steps:

a) A cyclic prefix is appended at the beginning of every OFDM symbol to mitigate inter – symbol interference and inter – carrier interference.

b) The pre – distorted OFDM symbol is subjected to a parallel – to – serial (P/S) conversion, and it is passed through the digital – to – analog (D/A) converter[5].

c) A pulse shaping filter is applied to obtain the continuous – time signal.

d) The optical OFDM systems employ the inverse fast Fourier transform (IFFT) as a multiplexer technique at the transmitter, and the Fast Fourier transform (FFT) as a de-multiplexer at the receiver.

e) An OFDM carrier signal is the sum of a number of orthogonal sub-carriers, with baseband data on each sub-carrier being independently modulated commonly using some type of quadrature amplitude modulation (QAM).

f) Input and output data buffering is used so that the congestion can be minimized. The buffer temporary stores multicarrier signals that arrived simultaneously and allows them to be sent without congestion [5].

(g) The receiver picks up the signal, which is then quadrature-mixed down to baseband using cosine and sine waves at the carrier frequency.

(ii) Mathematical Description

If N sub-carriers are used, and each sub-carrier is modulated using M alternative symbols, the OFDM symbol alphabet consists of M^N combined symbols. The OFDM signal is expressed as:

$$V(t) = \sum_{K=0}^{N-1} X_K \; e^{j2\pi kt/T} \; 0 \le t < T \qquad (1)$$

Where X_K are the data symbols, N is the number of sub-carriers, and T is the OFDM symbol time. The sub-carrier spacing of 1/T makes them orthogonal over each symbol period; this property is expressed as:

$$r(t) = \frac{1}{T}\int_0^T e^{\frac{j2\pi(k_1+k_2)t}{T}} dt = \delta k_1 k_2 \qquad (2)$$

To avoid inter-symbol interference in multipath fading channels, a guard interval of length T_g is inserted prior to the OFDM block [7]. During this interval, a *cyclic prefix* is transmitted such that the signal in the interval $-T_g \le t < 0$ equals the signal in the interval $(T- T_g) \le t < T$.

The OFDM signal with cyclic prefix is thus:

$$V(t) = \sum_{k=0}^{N-1} X_k e^{\frac{j2\pi kt}{T}}, \text{ for } -T_g \le t < T \qquad (3)$$

The low-pass signal is typically complex-valued; the transmitted signal is up-converted to a carrier frequency F_c.

In general, the transmitted signal can be represented thus,

$$S(t) = \sum_{k=0}^{N-1} | X_k | \cos\left(2\pi\left[f_c + \frac{k}{T}\right] t + \arg\left[X_k\right]\right) \qquad (4)$$

(iii) Using the FFT algorithm

The orthogonality allows for efficient modulator and demodulator implementation using the FFT algorithm on the receiver side, and IFFT on the sender side [14]. Although the principles and some of the benefits have been known since the 1960s, OFDM is popular for wideband communications today by way of low-cost digital signal processing components that can efficiently calculate the FFT [5],[13].

(iv) Guard intervals for elimination of inter-symbol interference.

One key principle of OFDM is that since low symbol rate modulation schemes (i.e., where the symbols are relatively long compared to the channel time characteristics) suffer less from inter-symbol interference caused by multipath propagation [15]. It is advantageous to transmit a number of low-rate streams in parallel instead of a single high-rate stream. Since the duration of each symbol is long, it is feasible to insert a guard interval between the OFDM symbols, thus eliminating the inter-symbol interference [16].

B Optimization Models for minimization of congestion problems[16], [17].

i*) Involvement of Government and Corporate bodies*: This is to enable operators procure some of the costly equipments needed to build base stations and carry-out total maintenance.

With the help of these bodies in GSM operations, more attentions will be given to operations and better outputs gotten which would support less congestion in the network[10][11].

ii) Dynamic Half Rate: This involves assigning only half of the normal data rate to users operating on a communication channel. by doing this, the number of users that can share the channel will be doubled, GSM can be designed to accommodate a half rate speed coder which produces speech at half of the present bit rate of the present full rate speed coder[9].

iii*) National Roaming agreement*: This is the ease of moving from one wireless carrier's system coverage area to another for service. Subscribers do not need to drop their SIMS while changing from locations of different network coverage. When implemented, this will enhance GSM operation and minimize congestion[9],[10]&[11].

iv*) Regionalization*: This refers to allocating a particular region to a given operator and she making sure that the region in particular has quality network coverage .this will enhance the performance in that area because they will do their best to see that they are allowed to extend the coverage to other regions of interest in view of having more subscribers[10],[11]. For this model to work optimally, the national roaming model must have been put in place to allow users to make calls anywhere anytime within the country especially when moving out of their present region. When this approach is implemented it will enhance congestion greatly.

v) *Merging two operator*: This involves pulling together two separately existing network in to a simple homogenous structure using the already existing infrastructure to harness the potentials of individuals networks [11]. The well established service brands of both operators being retained regardless of any optimization of the underlying infrastructure.

C Other methods of congestion improvement

With evaluation to the issues that attributed to poor quality of services by operators, the following measures are suggested towards improving network performance.

i) Operators should properly upgrade and optimize all existing base stations. Because doing this will reduce call set up failures due to rise in traffic volumes [9].

ii) Installing additional base stations across the country. This would provide rooms for the networks to handle more traffic than it used to before [9],[10]&[17].

iii) Build additional switching centers across the country and increase capacity to handle more traffic.

iv) If a particular base station is to be taken "offline" (either for schedule maintenance, repairs, upgrades etc.), all neighboring base stations should have their power level beefed up. This will make the effects of offline station unnoticed and increase their coverage area, thereby reducing congestion and dropped calls [10].

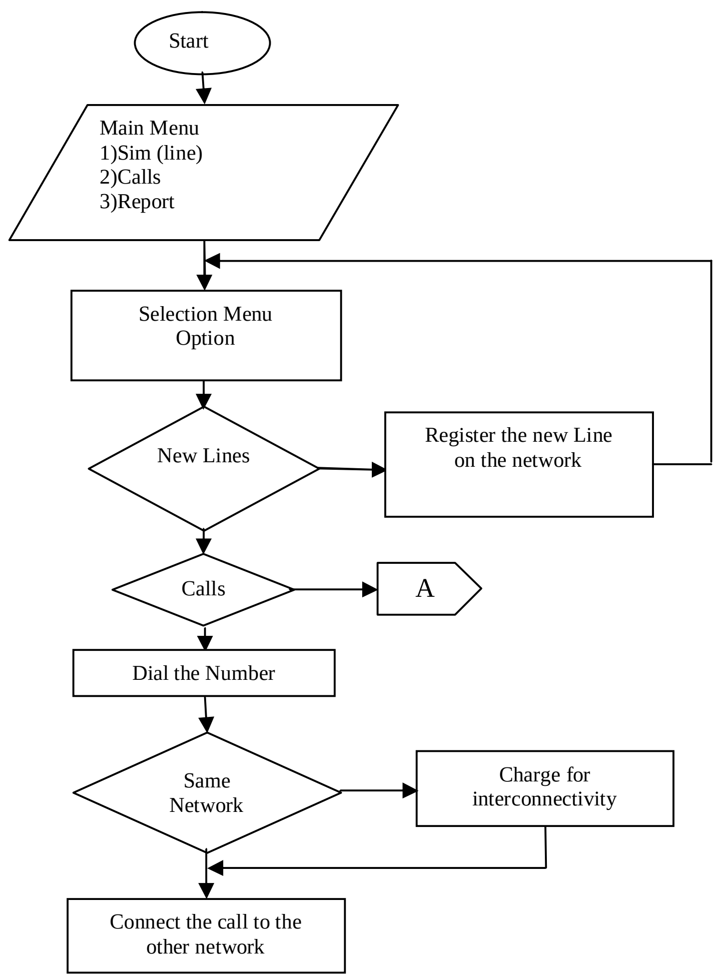
v) Operators should invest heavily in transmission network development and have a proper radio planning. This would ensure increased network resilience, improved bandwidth utilization and alleviation of capacity bottlenecks.

vi) Operators should try to give back to the society what aims at enhancing social security. This is because no amount of security personnel can deter hoodlums from attacking base station sites. Also, if government can create more jobs for its citizens, poverty level would be reduced and a lot roaming youths will be taken off streets. Hence we would have a secured environment.

vii) Consistence power failures should be addressed by the government. This will stop the over-dependence on generators for power supply and the money spent on generators using channeled to other useful things, call tariff would drastically go down when this is done.

D. Flowchart for congestion minimization by priority allocation technique

The implementation procedure consists of Main Menu which presents the subscriber with options to be chosen and when that is done, other actions and sequences are carried out using the flowchart scheme outlined in Figure 3.



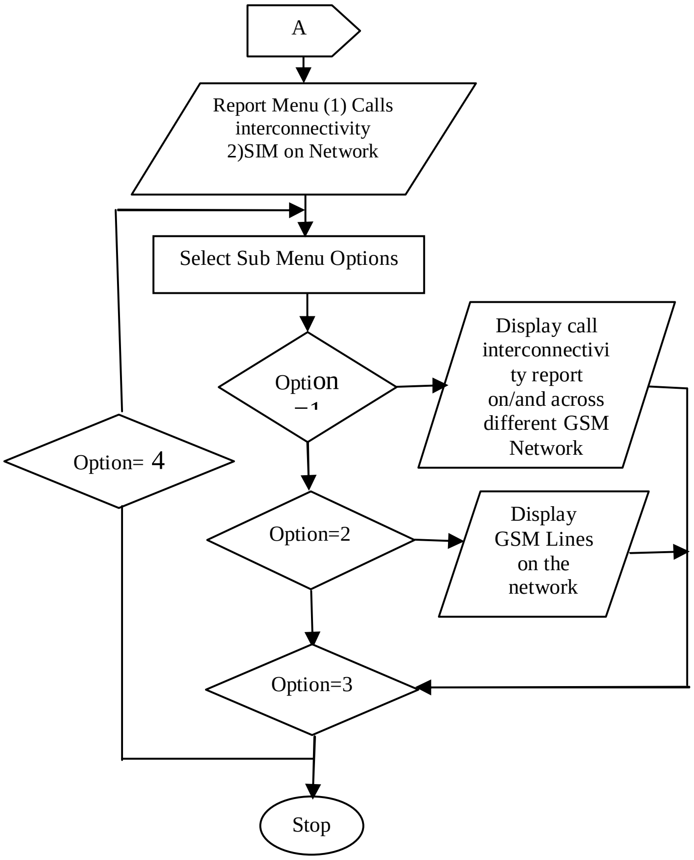


Fig 3: OFDM implementation flowchart

IV. CONCLUSION

The use of Orthogonal Frequency Division Multiplexing (OFDM) based Optical wireless communication and other Optimization Models in call congestion reduction in Nigeria was studied. OFDM specifically was elaborated because of its inherent characteristic like allowing several carriers of different frequency range to share a common physical transmission medium. It has a radio frequency which operates at $3KH_Z$ -$300GH_Z$ only.

This measure was adopted because it has been considered as another useful approach in proffering solutions to lot of challenges congestion has imposed on communication systems in Nigeria despite various mitigation efforts. Guard interval is needed in multipath propagation to eliminate inter-symbol-interference (ISI).

OFDM is necessary in our communications system because when adopted, it will go a long way in congestion minimization owing to its mode of propagation.

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