Umudike Journal of Engineering and Technology (UJET); Vol. 8, No. 2, December 2022, pp. 31 – 38; Michael Okpara University of Agriculture, Umudike, Print ISSN: 2536-7404, Electronic ISSN:2545-5257; http://ujetmouau.net; https://doi.org/10.33922/j.ujet_v8i2_4

THE EFFECT OF ORIGINATING CALL AND HANDOFF CALL FOR TWO SELECTED DIFFERENT ENVIRONMENTS

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ABSTRACT

In cellular networks, the signal strength and interference at various locations differs within a cell and this affects the quality of the on-going call including handoff calls. This may require the transfer of the on-going call to another cell with a better signal strength. This research evaluates cellular channel performance in terms of probability of blocking. It examines the queuing system that will be more suitable when either or both priority is given preference. It was observed that, for cell sites with traffic intensity to channel ratio of 0 – 0.75 which is considered as not congested, a system of either queuing the originating calls or the handoff calls can be employed. For a congested system in which the traffic intensity to channel ratio is 0.76 – 1 there should be separate queuing of both the originating calls and the handoff calls to provides the best network optimization. At the queue size of 2 in the site located at Umudike, the probability of blocking was approximately at 0.022. This effect was insignificant since it does not really make any difference due to the initial probability of blocking. Thus, system of either queuing the originating calls or the handoff calls can be employed. For a very efficient system like the site at Lodu Ndume, it was seen that the maximum blocking probability that can ever be offered to an originating call when handoff calls are queued was 0.000419 (4.19 x 10^{-4}). This probability was very small; which means queuing handoff calls will hardly have any effect on the originating calls as the blocking probability of the originating calls rises only by a very small margin. The research concludes that, the blocking probability decreases with increasing number of channels and decreasing amount of loads.

Keywords: *Handoff calls, Originating calls, probability of blocking, traffic intensity*

1.0 INTRODUCTION

The rapid adoption of cell phones and, especially the spread of internet connected smart phones are changing people's communications with others and their relationships with information. User's ability to access data immediately through applications and web browsers is creating a new culture of real-time information seekers and problem solvers. Recently the number of mobile users equipped with wireless devices capable of video streaming on the go has increased immensely. The trend follows the ever expanding choice of multi-access wireless technologies to which they connect and the growing popularity of mobile video applications. Increasingly more users use mobile devices to watch videos streamed over mobile wireless networks and they demand more content at better quality (Elzen, *et al.,* 2013).

The bottleneck at the base station controller (BSC) in allocating channels amongst originating calls and handoff calls remains vital and must be resolve in cellular communication. An allocated channel remains to a mobile user until, either its call is completed in the cell or it crosses the cell boundary, requiring a new channel frequency to continue (Pahlavan, *et al*., 2011). An originating call in a cell and likewise a handoff call seeking for channel may be blocked and cleared up from the system, if all the channels portioned to the related base station are all in use. This means, both the originating calls and the handoff calls are blocked/dropped once the target cell and the adjacent cell does not have resource to serve the call connection. In order to reduce such forced call termination, call arrivals (new calls and handoff calls) have to be treated differently, which leads to the call admission control (CAC) and resource management in wireless cellular networks (Mohammed, *et al.,* 2013). The new calls are those ones, which are just starting, and handoffs calls are those calls already ongoing but have moved onto a new cell and need to connect to a new base station (Lin and Huang, 2011).

The limitation of transmission channels in mobile communication system poses great problems in the number of subscribers that can access the mobile communication network at a particular period of time. A channel is used to convey an information signal. It has a certain capacity for information transmission, often measured by bandwidth (in Hertz) or data rate (in bit per second). These transmission channels, often experience congestion (block calls) in the mobile communication network interface due to high traffic generated by the number of subscribers using or try to gain access to the mobile network. Once the number of subscribers in network exceeds the maximum network capability, many subscribers will not receive response from the network, which may result to congestion or block calls. Analysing the effect of originating call and handoff call for cellular channel performance is aimed at making subscribers satisfied with the Quality of Service (QOS) rendered by the mobile communication network operators. Analysing the effect of originating call and handoff call for cellular channel performance is a significant stage for developing successful preventive congestion control schemes. These schemes target to avoid network congestion by distributing the network resources with respect to the forecasted traffic. The predictability of network traffic is of important benefits in many areas, such as dynamic bandwidth allocation, network security and network planning and predictive congestion control and so on. Though many researches' has been carried out in this area, they are largely conducted in advanced countries where the weather conditions, the terrain, the contour of the earth and so on are totally different from that in Africa particularly West Africa and in Nigeria as well.

However, the competition for channel access by handoff requests and originating calls results in call drops, this is undesirable to a subscriber. Nevertheless, there is no any perfect system so far available in tackling this bottleneck. Appropriate systems which are suitable in managing this bottleneck are made available in this paper, thus the need for this research.

2.0 CELLULAR HANDOFF FUNDAMENTALS

Handoff is the key operation in cellular mobile communication systems. It is the means through which a call is enable to proceed uninterrupted when MS moves from one cell area to another. Handoff can be defined as the process of transferring a mobile station from one base station or channel to another. The channel change due to handoff occurs through a change in time slot, frequency band, codeword or a combination of these. In Time Division Multiple Access (TDMA) the time slot is changed, whereas in Frequency Division Multiple Access (FDMA) the frequency is changed and code Division Multiple Access (CDMA) the code is changed. Figure 1 shows a Handoff Mechanism.

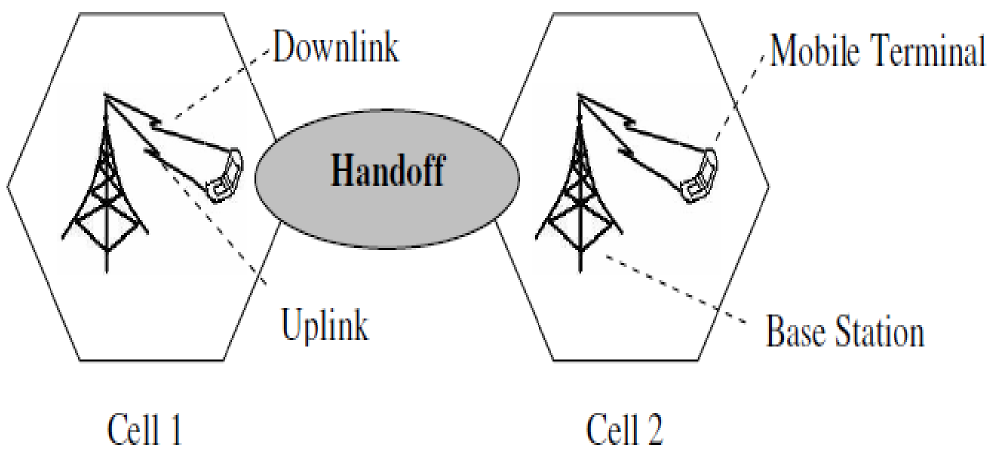

Figure 1: Handoff Mechanism, (Alagu and Meyyappan, 2011)

2.1 Handoff Prioritization Scheme

Dropping of on-going call is undesirable to subscriber than blocking of a new call and therefore, worth implementing schemes that mitigates call drops. A keyway to reduce handoff failure rate is to prioritize handoff (Abd and Lizos, 2012). Prioritization scheme reduce the forced termination probability by assigning more channel to handoff calls. The two known prioritization schemes are: Guard channels and Queuing of handoff calls (AggelikiSgora and Dimitrios, 2009).

2.1.1 Guard Channels

This scheme prioritizes handoff calls by reserving some of the total channels available in a cell for handoff calls only. N channels out of C total channels are reserved for handoff calls. The rest of the channels are used by new and handoff calls, therefore, handoff calls are better served and a new call is blocked if the number of channels available is less than (C – N). Hence, less number of channels is available for originating call. This process increases the call blocking probability and decreases the call dropping probability (Al-Saedi and Maddallah, 2012).

2.1.2 Queuing Handoff

The process of delaying handoff call when the available channels allocated to the target BS are occupied is called queuing of handoff. The MSC queues the handoff requests instead of denying access if the candidate BS is busy. Queuing is possible due to time interval between handoff initiation and receiver threshold, (Alkhawlani, *et al.,* 2011). The probability of a successful handoff can be improved by queuing handoff requests when the channels are used up. When a channel is released, it is assigned to the handoff calls in the queue. It is worth noting that, queuing does not guarantee zero forced termination probability, (Chandralekha and Behera, 2009).

3.0 SYSTEM MODEL

Consider a geographical area divided into cluster of cells, each cell has a base station which is allocated a set of channels C, and the channels are given to subscriber on demand for both handoff calls and originating calls.

When a subscriber requests service, a channel is allocated and remains dedicated for the entire duration (holding time) of the call, H. The service rate, μ, which is the frequency of the allocation of C to a subscriber, is the reciprocal of H. Therefore, the average calling time or holding time per subscriber is given by:

$$\mathrm{H} = 1/\mu \quad (1)$$

Let consider subscribers requesting for C for either originating calls or handoff calls. The frequency at which these requests arrive at the MSC is known as call arrival rate, λ. For originating calls it is denoted λ_1 and λ_2 for handoff calls. Assuming the number of call request at the mobile switching centre comes in batches and all the available channels are occupied, any call request is blocked or access to the system is denied. A queue is employed to hold the requesting user until a channel become available. M_1 refer to the size of queue for originating calls and M_2 refer to the size of queue for handoff calls. Therefore, at a particular cell site, the total traffic intensity due to originating calls and handoff call is given by:

$$a = (\lambda_1 + \lambda_2)/\mu \quad (2)$$

As a result, the traffic intensity due originating call is given by:

$$b_1 = \lambda_1/\mu \quad (3)$$

The traffic intensity due handoff calls is also given by:

$$b_2 = \lambda_2/\mu \quad (4)$$

Queuing spring up when the short term demand for service exceeds the available capacity.

Queuing is possible due to the overlap region between the adjacent cells in which MS can communicate with more than one BS. If handoff requests occur uniformly, queuing is not needed; queuing is effective only when handoff requests arrive in batches. Successful handoff probability can be improved by queuing handoff requests at the cost of increased new call blocking probability and a decrease in the ratio of carried to admitted traffic since new calls are not assigned a channel until all the handoff requests in the queue are served. The purpose of creating two request handoff levels is to provide more opportunity for a successful handoff. A handoff could be delayed if no available BS could take the call. The probability of a call not having immediate access to a channel and the call getting delayed for any period of time greater than zero is determined by the Erlang C formula given in (Hamad, 2016), as:

$$P_r = [delay > 0] = \frac{A^C}{A^C + C!\left(1-\frac{A}{C}\right)\sum_{k=0}^{C-1}\frac{A^k}{k!}} \quad (5)$$

Assuming all the channels are occupied the call is delayed, and the probability that the delayed call is forced to wait more than t seconds is given by the probability that a call is delayed, multiplied by the conditional probability that the delay is greater than t seconds. The grade of service of a trunked system where blocked calls are delayed is hence given in (Mahardhika, *et al.,* 2013) as:

$$P_r[delay > t] = P_r[delay > 0]P_r[delay > t]delay > 0$$

$$= P_r[delay > 0]e^{\frac{-t(C-A)}{H}}(-(C-A)t/H) \quad (6)$$

The average delay D for all calls in a queue system is given by:

$$D = P_r[delay > 0]\frac{H}{C-A} \quad (7)$$

Where the average delay for those calls which are queued is given by

$$\frac{H}{C-A} \quad (8)$$

3.1 New Call and Handoff Call Blocking Probability

When a mobile station wants to communicate with a base station, it must first obtain a channel from one of the base stations that hears it the best. When a new call (NC) is attempted and a channel is available, it is granted to the user. In the case that all the channels are occupied, the NC is blocked. This kind of blocking is called new call blocking. Similarly, if an idle channel exists in the target cell, the handoff call (HC) continues nearly transparently to the MS, otherwise, the HC is dropped (Dvir*, et al.,* 2010). The performance of the probability of blocking when there is no queue employed, when there is queuing of originating calls only and when there is queue for handoff calls only are considered in each case below.

Case I: Probability of blocking (no queue)

The Erlang B formula which determines the probability that a call is blocked is the assessment of the grade of service (GoS) for a trunk system which provides no queuing for blocked, these Erlang B model call is based on the following assumptions:

There are memoryless arrivals of call requests, implying that all users, including blocked users, may request a channel at any time.

a. All free channels are fully available for servicing calls until all channels are occupied.

b. The probability of a user occupying a channel (called the service time) is exponentially distributed. Longer calls are not or are less likely to happen as described by an exponential distribution.

c. The trunking pool has finite number of available channels.

d. Traffic requests are described by a Poisson distribution which implies exponentially distributed call inter-arrival times.

e. Inter-arrival times of call requests are independent of each other.

f.The number of busy channels is equal to the number of busy users.
The Erlang B formula is the probability of blocking either the originating calls or handoff calls when there is no queuing of neither calls is given by:

$$P_b = \frac{A^C}{C!} P(O) \quad (9)$$

Where,

$$P(O) = \left(\sum_{k=0}^{C} \frac{A^k}{k!}\right)^{-1} \quad (10)$$

C is the number of channels, **A** is the offered traffic.
Therefore, from equations 9 and 10 we obtain;

$$P_b = \frac{\frac{A^c}{C!}}{\sum_{k=0}^{c} \frac{A^k}{k!}} \quad (11)$$

The vice versa of this instance is where excess calls are not blocked but queued based on the assumption that;
i. Callers never hang off whilst in queue.
ii. All calls start and end in the same time period being estimated for.
iii. Callers never try to call back after having hanged up while in queue.
The probability of blocking with queuing is written in (Dvir*, et al.,* 2010);

$$P_{bq}(0) = \left[C! \sum_{i=0}^{C-1} \frac{A^{c-C}}{c!} + \frac{1 - \frac{b_1}{C}^{M_1+1}}{1 - \frac{b_1}{C}}\right]^{-1} \quad (12)$$

Where, M_1 is the originating calls queue size, b_1 is the traffic offered by the originating calls.

Case II: Probability of Blocking (when Originating Call is Queued)
In case when only the originating calls but not the handoff calls are queued, the blocking probability for originating calls is written as:

$$B_{oq} = \left(\frac{b_1}{C}\right)^{M_1} P_{bq}(0) \quad (13)$$

The resulting blocking probability for handoff calls is given by:

$$B_{hq} = \frac{1 - \left(\frac{b_1}{C}\right)^{M_1+1}}{1 - \left(\frac{b_1}{C}\right)} P_{bq}(0) \quad (14)$$

***Case III:* Probability of Blocking (when Handoff Call is Queued)**
When the handoff calls are queued but not the originating calls, the blocking probability for handoff calls is given as:

$$B_{oq} = \left(\frac{b_2}{C}\right)^{M_2} P_{bq}(0) \quad (15)$$

And the blocking probability for origination calls is also given:

$$B_{hq} = \frac{1 - \left(\frac{b_2}{C}\right)^{M_2+1}}{1 - \left(\frac{b_2}{C}\right)} P_{bq}(0) \quad (16)$$

3.2 Proposed Queuing Scheme for Queuing both Originating Calls (OC) and Handoff Calls (HC)
In Dvir*, et al.,* (2010), a system of queuing both originating calls and handoff calls together in a single queue was not considered. However, the study from this research proved that, for cell sites with very low traffic intensity per channel ratio and approximately equal arrival rates for originating and handoff calls, there is the need to queue both originating and handoff call.
In this research, a system of queuing both originating calls and handoff calls together in a single queue was will be considered. The delay probability can be written as;

$$P_{bq}(0) = \left[C! \sum_{i=0}^{C-1} \frac{1 - \left(\frac{b_1+b_2}{C}\right)^{M_1+M_1}}{1 - \left(\frac{b_1+b_2}{C}\right)}\right]^{-1} \quad (17)$$

The blocking probability for originating calls for this system is given as;

$$B_{oq}(0) = \left(\frac{b_1+b_2}{C}\right)^{M_1+M_1} P_{bq}(0) \quad (18)$$

And finally the blocking probability of handoff calls is given by:

$$B_{hq} = \frac{1 - \left(\frac{b_1+b_2}{C}\right)^{M_1+M_1}}{1 - \left(\frac{b_1+b_2}{C}\right)} \quad (19)$$

4.0 SIMULATION RESULTS AND DISCUSSION
In this section, by means of simulation, we show the probability of blocking OC and HC when OC is given priority, also, the probability of blocking OC and HC when priority is given to HC. Simulations in this work are implemented using MATLAB2 version R2012a.
The simulation focuses on two randomly selected cell sites of MTN cellular communication operator located at Umudike and Lodu Ndume, Abia State Nigeria. Each cell site has different traffic to channel intensity. The cell sites are grouped according to their channel occupancy; site with traffic intensity per channels ratio range of 0 – 0.75 channel occupancy, and site with traffic intensity per channels ratio ranging from 0.76 - 1 channel occupancy. This eases the study of the scenarios of interest.

4.1 Results for Umudike
Case I
The analysis of site with traffic intensity to channel ratio of 0 – 0.75 is considered.
Here, the originating call arrival rate, $\lambda_1 = 0.0172$ per sec, the handoff call request arrival rate, $\lambda_2 = 0.08$ per sec. The mean holding time is 49.85 sec, the number of channels allocated to the cell site is 13. The traffic intensity generated from the stated data is 4.8454 Erlang while the blocking probability at 0 queue size is 0.001.
Figure 2 shows the probability of blocking Originating Calls (OC) and Handoff Calls (HC) when OC is given priority.
Case II
Here, we consider the opposite of the case I where priority is given to the handoff calls. Figure 3 shows the result of the simulation.

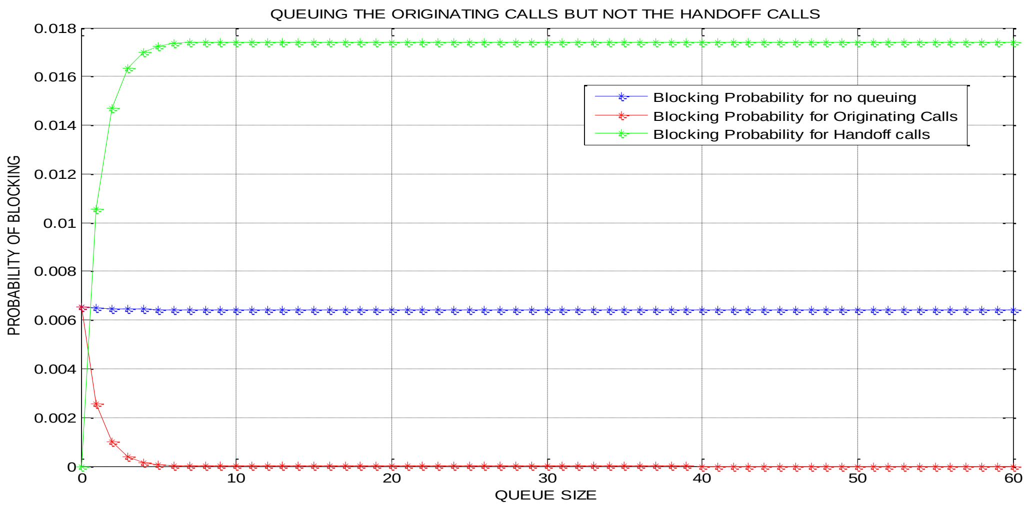

Figure 2: The probability of blocking Originating Calls (OC) and Handoff Calls (HC) when OC is given priority.

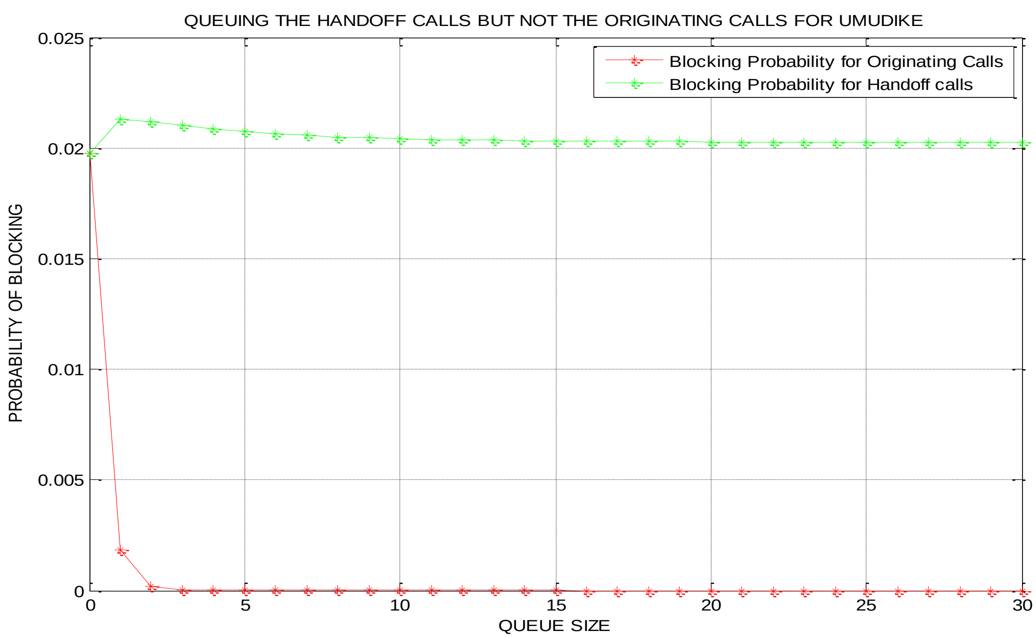

Figure 3: Queuing the handoff calls not the originating call

4.2 Result for Lodu Ndume site

Case I

In order to substantiate the previous claims, we further analyse Lodu Ndume cell sites which also have traffic intensity to channel ratio of 0.76 -1. The originating call arrival rate, $\lambda_1 = 5.219$ per seconds, handoff arrival rate $\lambda_2 = 0.314$ per seconds and a mean holding time of 16.43 seconds. Number of allocated channels, N= 121 and total traffic intensity of 90.91 Erlang.

Figure 4 shows the probability of blocking Originating Calls (OC) and Handoff Calls (HC) when OC is given priority,

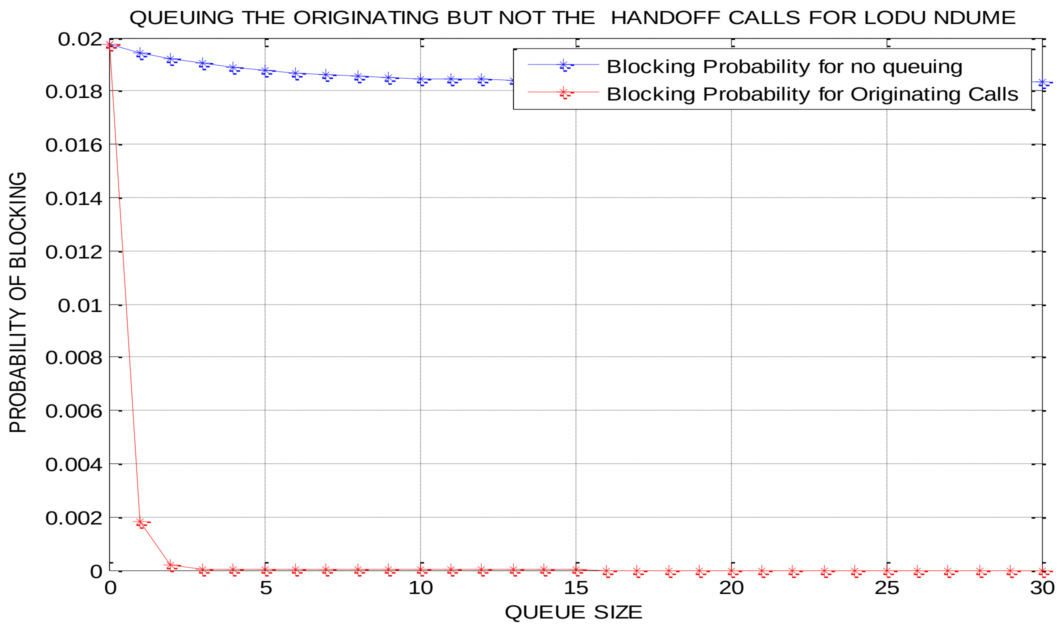

Figure 4: The probability of blocking Originating Calls (OC) and Handoff Calls (HC) when OC is given priority

Case II

This case considers the vice versa of *case I* that is, queuing the handoff calls and not the originating calls. Figure 5 shows the result of the simulation.

Also the blocking probability with increasing number of channels and decreasing amount of loads was shown in Figure 6.

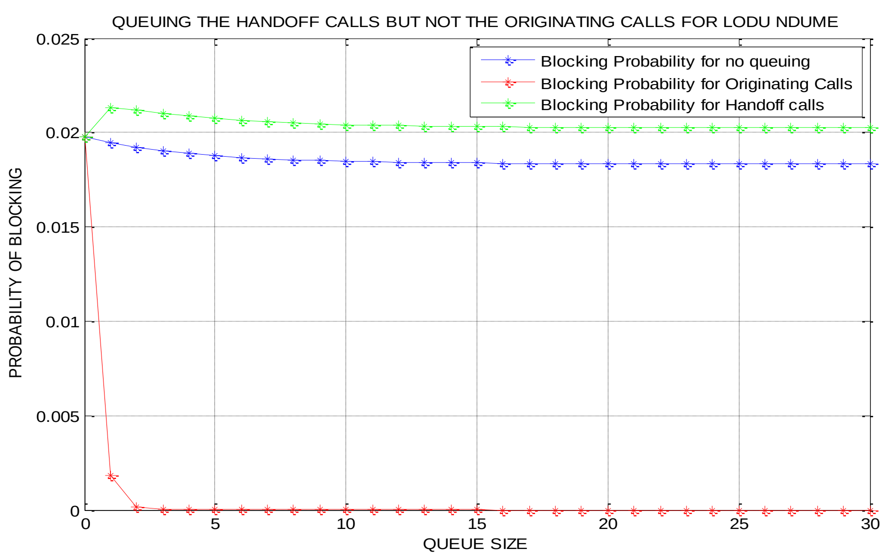

Figure 5: The probability of blocking Originating Calls (OC) and Handoff Calls (HC) when HC is given priority

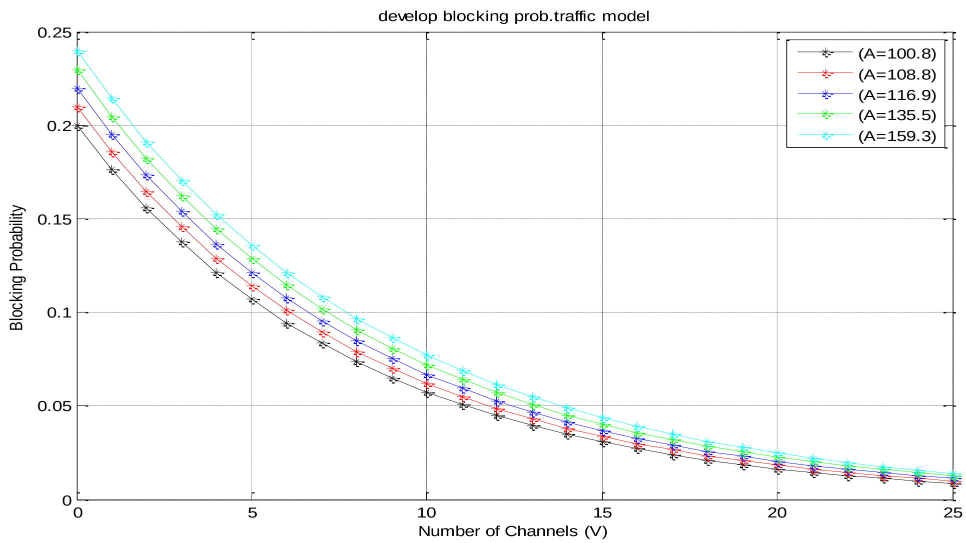

Figure 6: The blocking probability with increasing number of channels and decreasing amount of loads

4.3 Discussions

Case I for Umudike

We noticed from the figure above a significant decrement in the blocking probability of the originating calls. Since the originating calls are given the priority, the calls are queued when there is no available channel and they are granted channel as soon as an idle channel exists.

0.06 blocking probability at 0 queue size reduced to 0 at 5 queue size.

Now considering the impact of queuing originating calls has on handoff calls. Since priority is given to originating calls, handoff requests are dropped when available channels are occupied. It was seen that the blocking probability of the handoff increases as the queue size of the originating calls increases. From figure 2, it was deduced that the blocking probability decrease as the queue size increases, yet, it does not conform to the general concept of blocking probability of 0.000419 (4.19 x 10^{-4}).

Case II for Umudike

It was seen from figure 3 that even at queue size of 0 the probability of blocking is approximately 0 and it further decreased to 0 at queue size of 5. The parameters used in analyzing the blocking probability of blocking probability when Originating calls are queued are same as used here. From Figure 3, it is observed that, queuing Handoff calls have an effect on the blocking probability of originating calls. At the queue size of 2, the probability of blocking is approximately at 0.022. This effect is insignificant since it does not really make any difference due to the initial probability of blocking. Thus, system of either queuing the originating calls or the handoff calls can be employed.

Case I for Lodu Ndume site

From the figure 4 it was observed that the blocking probability at queue size 0 was 0.0018 which is very low, therefore, it's very uncommon for this cell site to cause blockage of originating calls when originating calls are queued.

However, it is seen from the figure that, queuing originating calls only does have an effect on handoff calls, which means that the handoff blocking probability increases as compared to the delay probability.

Case II

It was seen that the blocking probability of handoff calls reduces as compared to the delay probability with queuing. Figure 5 shows that even at queue size of 0, the blocking probability of hand off calls is 0.0004 (4 x 10-4) which is very small. This can be attributed to the low handoff arrival and the high number of channels available. After a handoff calls queue size of 2, the blocking probability of handoff calls falls abruptly to 0 which implies that for the cell site at Lodu Ndume, a total of 5 queue size for handoff request is more than enough to prevent any blockage at the cell site.

As expected of a very efficient system like the site at Lodu Ndume, it was seen from the figure that, the maximum blocking probability that can ever be offered to an originating call when handoff calls are queued is 0.000419 (4.19 x 10^{-4}). This probability is very small; which means queuing handoff calls will hardly have any effect on the originating calls as the blocking probability of the originating calls rises only by a very small margin. The implication is that at Lodu Ndume site, system of either queuing the originating calls or the handoff calls can be employed.

As shown in Figure 6, the blocking probability decreases with increasing number of channels and decreasing amount of loads.

5.0 CONCLUSION

This research has evaluated cellular channel performance in terms of probability of blocking, which queuing system is more suitable when either or both priority are given and when no priority is given. From the research, it was observed that for cell sites with traffic intensity to channel ratio of 0 – 0.75 which is considered as not congested, a system of either queuing the originating calls or the handoff calls can be employed. For a congested system in which the traffic intensity to channel ratio is 0.76 – 1 there should be separate queuing of both the originating calls and the handoff calls to provides the best network optimization. At the queue size of 2 in the site located at Umudike, the probability of blocking was approximately at 0.022. This effect was insignificant since it does not really make any difference due to the initial probability of blocking. Thus, system of either queuing the originating calls or the handoff calls can be employed. For a very efficient system like the site at Lodu Ndume, it was seen that the maximum blocking probability that can ever be offered to an originating call when handoff calls are queued was 0.000419 (4.19×10^{-4}). This probability was very small; which means queuing handoff calls will hardly have any effect on the originating calls as the blocking probability of the originating calls rises only by a very small margin. The research concludes that, the blocking probability decreases with increasing number of channels and decreasing amount of loads.

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