International Journal of Scientific & Engineering Research, Volume 5, Issue 8,August-2014
ISSN 2229-5518

Comparative Analysis of Queuing and Reservation Schemes for Handover in GSM Networks

Ezeja, M. O.
E-mail: obinna.ezeja@unn.edu.ng Phone: +234(0)8030940211

Abstract: - Premature call termination takes place when a roaming user moves from its serving base station into a new one but cannot be assigned a channel in the new cell to resume its connection. This implies that the call could not be handed over to the nearest base station for connection continuity. A good number of schemes have been developed and proposed to ensure successful handover and avoid abrupt disruption. The schemes include Conventional Handover Mechanism, Guard Channel Prioritization Scheme, Call Admission Control Prioritization Scheme, Handover Queuing Prioritization and Resource Reservation Schemes. However, a comparison of the performance of queuing and reservation techniques was carried out in this work to highlight their strengths and weaknesses given predefined system parameters. The analysis showed that resource reservation schemes guarantee progressive call drop probability reduction subject only to chosen trade-off point for fresh call admission while queuing was noticeably effective only up to 25% of the queue spaces provided.

Key words: Call drop probability, handover, queuing, quality of service, reservations.

◆

1 THEORITICAL BACKGROUND:

Mobile communications systems have seen a rapid increase in the number of subscribers and this places extra demands on system capacity. This increase leads to a new network design where the cells are made increasingly smaller. There are two types of calls in such communication systems. The first is the fresh or new calls which refer to originating connection requests while the second is the handover calls which refer to requests for transfer of existing connections from one base station to another. In cellular mobile networks, the coverage region is divided into smaller cells (micro cells) in order to achieve high system capacity [1]. Each cell within the coverage region is covered by an individual base station [2]. The most serious problem that arises in this architecture however, is the issue of handover. This problem is even more serious in high speed moving terminals where the handover rate increases and the probability that an ongoing call will be dropped due to the lack of a free traffic channel is high.

Handover is a process of changing some radio parameters of a channel (frequency, time slot, or spreading code,) associated with an existing connection. It is often initiated either by crossing a cell boundary or by a deteriorated quality of received signal on a currently employed channel. Failure to carry out a successful handover results in a call drop. Since users are very sensitive to the interruption of ongoing communications, a good communication system must minimize the handover call drop probability. Handover is an expensive process to execute, so unnecessary handovers should be avoided [3].

One of the most desirable features of wireless cellular networks is to achieve continuous (uninterrupted) services using handover when mobile subscribers cross the boundaries of cells in the coverage area. Handover is the process in which a cellular phone is handed over from one cell to the next in order to maintain an existing radio connection with the network [4]. It occurs when a mobile telephone network automatically transfers a call from one radio channel to another radio channel as a mobile unit crosses a cell boundary. It is important to note however that the “boundary” may not necessarily be defined by a physical geographical distance or radius. Rather, it is determined by a certain preset signal reception threshold limit [5]. Thus, Mobile services Switching Centre sets up and monitors the reception level as the subscriber moves. Whenever it goes down below the threshold limit, it automatically switches the call to whatever idle channel at any site serving the mobile unit has the strongest received signal above the prescribed level.

For various advantages which include efficient reuse of scarce radio bandwidth, reduced transmission power requirements, and smaller, cheaper base station equipment, mobile cellular networks are increasingly adopting pico/microcellular architectures. As noted before, these smaller cell sizes lead to increased handover events as a user roames from picocell to picocell during the course of a typical call connection. In addition to increasing the signaling load on the network, frequent handover events also leads to increased probabilities of call dropping which adversely impact network quality of service. Thus it is important that efficient channel assignment schemes be designed to take care of the frequent handover events in such networks. Handover comprises two major steps. The first is handover initiation and in this phase, decision to start the handover procedure is taken. The second is handover execution and in this phase, a new channel assignment is made or if there is no channel available, the call is dropped [6].

2 REVIEW OF EXISTING HANDOVER SCHEMES

2.1 Conventional Handover Mechanism

In cellular networks, the mobile station and the BTS (Base Transceiver Station) regularly measure the radio signal strength. The mobile station transmits its measurement reports continuously to the BTS. When the BTS detects a decrease in radio signal under a specified minimal level, it initiates a handover request. The BTS then informs the BSC about the request, which then verifies if it is possible to transfer the call into a new adjacent cell. Actually the always BSC checks whether a free channel is available in the new adjacent cell or not. In this situation the BSC does not differentiate between the channel requests (either for fresh call or handover). When a free channel is available in the adjacent cell then the handover request can be satisfied, and the mobile station switches to the new cell. If there is no free channel in the adjacent cell then it increases the chances of dropping of the handover call. The disadvantage of this handover procedure is the fact that the handover request for channels is same as used for fresh calls. The conventional handover mechanism is thus very problematic from the users' quality of service perspective, since users prefer blocking a new call to a dropped call in the middle of transmission [7].

2.2 Guard Channel Prioritization Scheme

The guard channel scheme was introduced in 1980s for mobile cellular communication systems. The scheme improves the probability of a successful handover by simply reserving a number of channels exclusively for handover requests in each cell. The remaining channels can be shared equally between handover and new calls. Guard Channels are established only when the number of free channels is equal to or less than the predefined threshold. In this situation, fresh calls are bypassed and only handover requests are served by the cell until all channels are occupied. The GC scheme is feasible because new calls are less sensitive to delay than the handover calls [8].

2.3 Call Admission Control Prioritization Scheme

The call admission control scheme refers to the task of determining whether new call requests are admitted into the network or not. In the CAC the arrival of new calls is estimated continuously and when it is higher than the predefined threshold level then some calls are restricted (blocked) irrespective of whether a channel is available or not to decrease the probability of handover calls failure. In the CAC both the fresh and handover calls have access to all channels. If a new call that is generated in a cell cannot find an idle channel the call is discarded immediately. There is no queue provided for the new calls to wait [9].

The CAC scheme can be classified into different schemes that consider the local information like the amount of unused bandwidth in the cell where the user currently resides, remote information like the amount of unused bandwidth in the neighbouring cells to decide whether to accept or reject a call. CAC based on knowledge of both network and user characteristics, keeps the track of available system capacity and accommodates new call request while ensuring quality of service for all existing users. Decisions in CAC are made in each BSC in a distributed manner and there is no central coordination. The aim of the CAC schemes is to prevent congestion and to ensure stability for cellular network operations. The CAC reacts quickly to any load change that may lead to unstable control. For instance during a call all connection (channel) requests are accepted until congestion occurs and then all the requests are rejected. It is desirable for the cellular network to accommodate as many users in the system as possible to maximize the utilization of the radio resources while the QoS for each user must be maintained.

2.4 Handover Queuing Prioritization Schemes

Handover call queuing scheme queues the handover calls when all the channels are occupied in the BSC. When a channel is released in the BSC, it is assigned to one of the handover calls in the queue. The handover queuing scheme reduces the call dropping probability at the expense of the increased call blocking probability and decrease in the ratio of carried to admitted traffic since fresh calls are not assigned a channel until all the handover requests in the queue are served [10].

In the handover queuing schemes, when the received signal strength of the BSC in the current cell reaches a certain defined threshold, the call is queued for service in a neighboring cell. A new call request is assigned a channel if the queue is empty and if there is at least one free channel in the BSC. The call remains queued until either a channel becomes available in the new cell or the power by the base station in the current cell drops below the receiver threshold. If the call reaches the receiver threshold and no free channel is found, then the call is terminated. Queuing is known to be effective only when the handover requests arrive in groups and traffic is low. First in first out (FIFO) scheme is the most common queuing scheme where the handover requests are ordered according to the way they arrive. To analyze this scheme it is necessary to consider the handover procedure in detail. FIFO queuing strategy is assumed at the base station as shown in figure 1.

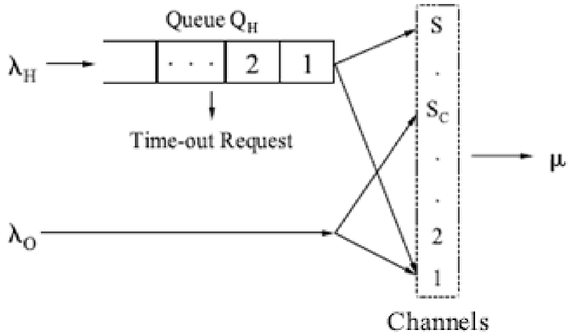

Fig. 1. Priority Queue System Model for Handover Call [11].

Originating calls represented by their arrival rate, λ_O, as well as handover calls, represented by λ_H, all seek to receive service, represented by the service rate, μ, as they arrive the system seeking channels to use. The system capacity (number of channels) ranges from 1, 2, 3…S_c…S. In this system, a queuing space, Q_H, is provided for handover requests only, such that new calls and handover calls can both be admitted into the system but only up to point S_c, beyond which only the handover calls may be served. This implies that the queue (or buffer) space is given by $S - S_c$.

A practical scheme based on the queuing model was developed by H. G. Ebersman and O. K. Tonguz, in their work "handover ordering using signal prediction priority queuing in personal communication systems". In the work, they proposed the use of queuing priority schemes (QPS). In this type of schemes, each base station provides a waiting queue for the mobile terminals with on-going connections, which enter a handover area from one of its adjacent cells. As channels become available, a free channel will be assigned to a mobile terminal that is currently in the waiting queue. When the queue is empty, the channel could be assigned to any mobile terminal which attempts to initiate a new connection. [12]

A similar scheme based on this principle was discussed by Lee, in his work titled Wireless and Cellular Telecommunications. Lee explained that an MSC will queue the requests of handover calls instead of rejecting them if the new cell sites are busy.

He arrived at the following equations for the following cases namely [5]:

1 Queuing the originating calls but not the handover calls: Here, queue spaces are provided for originating calls only, implying that priority is given to fresh calls. The blocking probability for originating calls is

$$B_{oq} = \left(\frac{b_1}{N}\right)^{M_1} P_q(0) \qquad (1)$$

and the blocking probability for handover calls is

$$B_{oh} = \frac{1-(b_1/\ N)^{M_1+1}}{1-(b_1/N)} P_q(0) \qquad (2)$$

where

$$P_q(0) = \left[N! \sum_{n=0}^{N-1} \frac{a^{n-N}}{n!} + \frac{1-(b_1/N)^{M_1+1}}{1-(b_1/N)} \right]^{-1} \qquad (3)$$

2 Queuing the handover calls but not the originating calls. Here, queue spaces are provided for handover calls only, implying that priority is given to handover calls. The blocking probability for handover calls is

$$B_{hq} = \left(\frac{b_2}{N}\right)^{M_2} P_q(0) \qquad (4)$$

where $P_q(0)$ is as expressed in equation (5). The blocking probability for originating calls will then be

$$B_{ho} = \frac{1-(b_2/N)^{M_2+1}}{(b_2/N)} P_q(0) \qquad (5)$$

The parameters used in the expressions above are defined as follows:

$1/\mu$ = average calling time in seconds including new calls and handover calls is each cell,

λ_1 = arrival rate per second for originating calls, λ_2 = arrival rate per second for handover calls

M_1 = size of queue for originating calls, M_2 = size of queue for handover calls, N = number of voice channels, $a = (\lambda_1 + \lambda_2)/\ \mu$, $b_1 = \lambda_1/\ \mu$, $b_2 = \lambda_2/\ \mu$

The queuing model proposed by Lee has the capacity to improve on either the call blocking probability or the call dropping probability depending on which of the call categories is prioritized by provision of queue spaces. This section shall examine the performance of Lee's queuing model. Two cases are considered:

(a) Determination of the call blocking probability, P_b and the call dropping probability, P_d, when queue spaces are provided for fresh calls only;

(b) Determination of the call blocking probability, P_b and the call dropping probability, P_d, when queue spaces are provided for handover calls only.

To do this, we arbitrarily assign values to the parameters in the analytical model as follows: N = 30, a = 20, $b_1 = b_2 = 1$, $M_1 = M_2 = 20$ (where the parameters retain their meanings as defined in the previous section).

(a) The behaviour of Pb and Pd with variation in Queue spaces, M_1 for Fresh calls

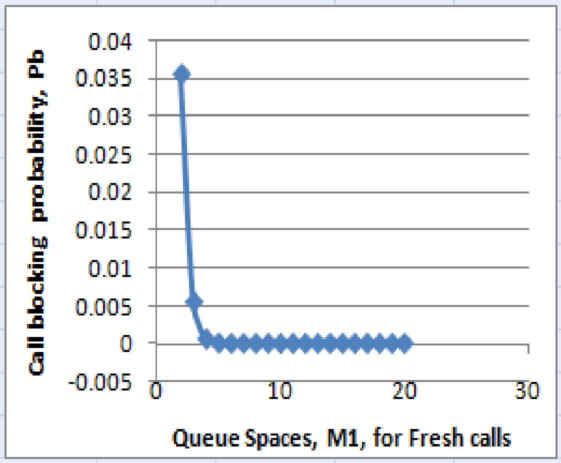

Fig. 2: P_b versus Queue spaces, M_1 for Fresh calls

From figure 2, when queue spaces, M_1 are provided for fresh calls but not for handover calls, the fresh call blocking probability is seen to decrease sharply for few of the queue spaces provided and then decrease rather insignificantly as more queue spaces are provided. Specifically, with 3 queue spaces, the call blocking probability reduces from 0.036 to 0.005. When 4 spaces are provided, it reduces to 0.00059. For 5 queue spaces and more (up to 20), there is virtually no reduction any longer in the call blocking probability. This implies that the optimum number of queue spaces that can be provided for fresh calls is 5 out of 20, representing 25% of the buffer capacity.

In the case of the call drop probability when queue spaces, M_1 are provided for new calls but not for handover calls, the handover call blocking probability (i.e. call dropping probability) is seen to decrease rather insignificantly as more queue spaces are provided (See Fig 3).

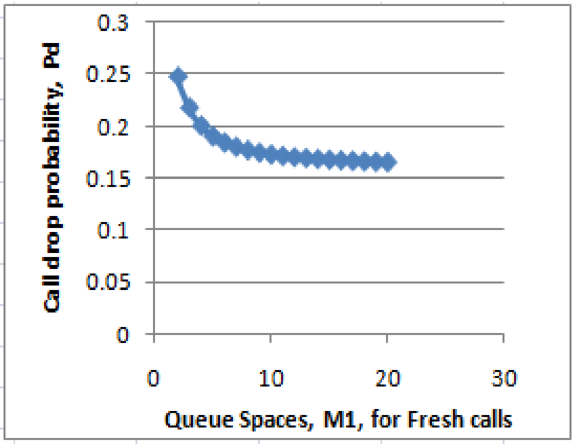

Fig. 3. P_d versus Queue spaces, M_1 for Fresh calls

Specifically, with 3 queue spaces, the call dropping probability reduces from 0.24 to 0.21. When 4 spaces are provided, it again reduces to 0.20. For 5 queue spaces and more (up to 20), there is virtually no progressive reduction any longer in the call blocking probability. What this implies is that providing queue spaces for fresh calls does very little to improve (i.e. reduce) the call dropping probability.

(b) The behaviour of Pb and Pd with variation in queue size, M_2

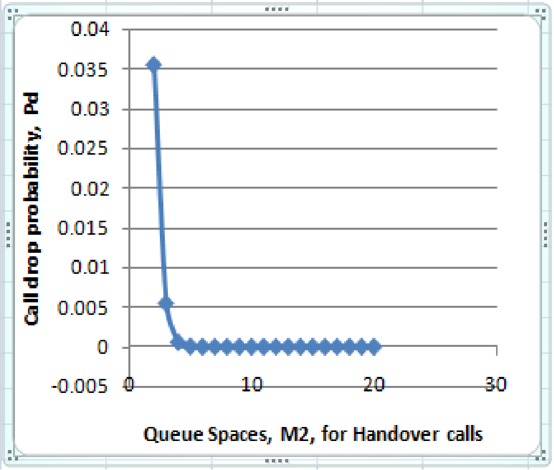

Fig. 4. P_d versus Queue spaces, M_2 for Handover calls

From figure 4, when queue spaces, M_2 are provided for handover calls but not for fresh calls, the handover call dropping probability decreases sharply for few of the queue spaces provided and then decreases rather insignificantly as more queue spaces are provided. This is similar to the observation made when queue spaces are provided for fresh calls and the fresh call blocking probability noted. Specifically, with 3 queue spaces, the call blocking probability reduces from 0.036 to 0.005. When 4 spaces are provided, it reduces to 0.00059. For 5 queue spaces and more (up to 20), there is virtually no reduction any longer in the call blocking probability. This behaviour was also noted by Lee in his work [5]. This implies that the number of optimum queue spaces that can be provided for handover calls is 5 out of 20, representing 25% of the total buffer capacity.

Moreover, when queue spaces, M_2 are provided for handover calls but not for fresh calls, the fresh call blocking probability is seen to decrease rather insignificantly as more queue spaces are provided (see Fig 5).

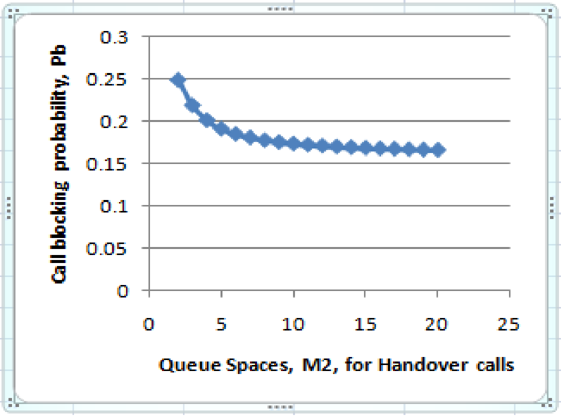

Fig. 5. P_b versus Queue spaces, M_2 for Handover calls

Specifically, with 3 queue spaces, the call dropping probability reduces from 0.24 to 0.20. When 4 spaces are provided, it reduces to 0.19. For 5 queue spaces and more (up to 20), there is virtually no progressive reduction any longer in the call blocking probability. What this implies is that providing queue spaces for handover calls does virtually nothing to improve (i.e. reduce) the call blocking probability for fresh calls.

2.5 Resource Reservation Technique

Onah F. I. et al [13] also proposed a resource reservation scheme in which a function was generated from optimum reservations made for specified system capacities. This was determined from the call drop probabilities derived from state equations using Markov's birth-death process. From the state flow equations, the call blocking probabilities, P_c for fresh calls and call drop probabilities, P_d for handover calls were derived as follows [13]:

$$P_c = \frac{\rho^c}{c!}\left[\sum_{i=o}^{c}\frac{\rho^i}{i!} + \sum_{n=1}^{k}\frac{c!}{(c+n)!}(\rho')^n\frac{\rho^c}{c!}\right]^{-1} \quad (6)$$

and

$$\mathrm{P_d} = \frac{c!}{(c+k)!}(\rho')^k\frac{\rho^c}{c!}\left[\sum_{i=o}^{c}\frac{\rho^i}{i!} + \sum_{n=1}^{k}\frac{c!}{(c+n)!}(\rho')^n\frac{\rho^c}{c!}\right]^{-1} \quad (7)$$

Definition of Parameters:

λ_F = arrival rate of the fresh calls – these are calls requesting for new connections and are also referred to as originating calls; λ_H (=λ') = arrival rate of handover calls – these come from calls which are already served but require to handover to a new channel in the same cell due to weak signal or to a new channel in another cell due to its mobility as it crosses the cell boundary; λ = combined arrival rate of both fresh calls and handover calls. In other words, $\lambda = \lambda_F + \lambda_H$ (This is captured in the schematic diagram of the Physical Model); k = reserved resources; c = the number of resources that can serve both originating and handover call requests beyond which fresh calls can no longer be served; μ = service rate; ρ = λ/μ = traffic intensity of both fresh and handover calls; ρ′ = λ′/μ = traffic intensity of handover calls.

To evaluate the model, the behaviour (that is, change in the call blocking probabilities, P_c, for the fresh calls and change in call dropping probabilities, P_d, for handover calls) for varying number of reserved resources, k in a system was observed and recorded using the analytical model in equation (7). The traffic intensities ρ and ρ´ which were defined previously were arbitrarily assigned values of 0.9 and 0.7 respectively. The behaviour of the model was then noted and recorded for system capacity, N = 20. The result is as shown in Figure 6:

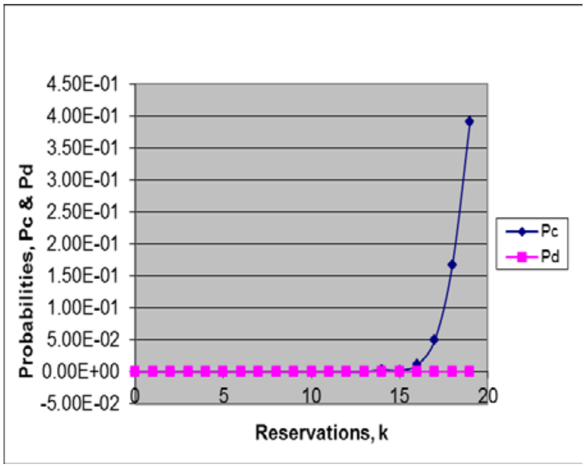

Fig. 6: Call blocking and Call drop probabilities, Pc and Pd, versus Reservations, k

From figure 6, when there is zero reservation (k = 0), both P_c & P_d have a value of 2.03 E-20. With k = 1, the values change as P_c slightly increases to 4.51 E-20 and P_d slightly decreases to 1.58 E-20. Further reservations continue to show remarkably progressive decrease in P_d and a simultaneous increase in P_c. However, it is observed that beyond thirteen reservations, (k = 13), there is a significant increase in P_c. This becomes the optimum reservations, R for N = 20. This is just to ensure that new call admission is not impaired so much otherwise increased reservation still leads to further reduction in call drop probability. There are thus different optimum reservations to be made for given system capacities.

3 COMPARISON BETWEEN QUEUING AND RESERVATION SCHEMES

This work focuses on the performance evaluation of the last two schemes which involves queuing and making reservations. Queuing and reservation schemes are designed to ensure that priority is given to handover call requests in a given cell or base station or between base stations while the user roams. Queuing schemes queue handover calls in a buffer created for them when the entire system resources are occupied. On the other hand, reservation schemes which also target handover calls prioritization, reserve certain amount of the resources (long before they are occupied) strictly for handover calls. This ensures that even when both fresh and handover calls compete for and get served by the system up to a certain threshold, handover calls can have access to system resources for a longer period. This ensures increased call continuity which is a key factor for quality of service, QoS.

4 PERFORMANCE COMPARISON

It is visible from the results above that the queuing model actually provides some reduction in call blocking and call dropping probabilities when queue spaces are provided for fresh calls and handover calls respectively. A close look at the graphs reveals, notwithstanding that beyond just a few queue spaces (about five), the rest queue spaces provided do not significantly affect the call blocking probability, P_b and the call dropping probability, P_d. Furthermore, it is also observed that when queue spaces are not provided for a particular category of call requests, there is very little impact of the model on that category. On the other hand, in reservation schemes like the Resource Reservation Scheme [13] discussed above, there is continuous reduction in the call drop probability resulting in improved call continuity (only to the detriment of fresh call connection/service). What this implies is that reservations made are subject to the designer's discretion. Consequently, the scheme allows the systems designer to set the acceptable call drop rate vis-à-vis the admission of fresh calls.

5 CONCLUSION

Successful handover in mobile communication networks like the GSM is non-negotiable for call continuity and acceptable quality of service, QoS. Queuing schemes and reservation models all reduce the call drop probability. However, in the case of the queuing technique, sharp reduction in call drop probability is observed only for a few of the queue spaces provided. In other words, beyond the first few spaces (approximately 25% of the queue spaces) provided for queuing handover calls, there is no noticeable reduction anymore in the call drop probability. The resource reservation model leaves the extent of call drop reduction in the hands of the communication network system designer since call drop probability reduces progressively up to the maximum reservations made. He only has to choose the trade-off point considering that this reduction in call drop probability results in progressive increase in call blocking probability (thereby increasing the blocking of fresh calls). Also, it is observed that there are points where the rise in call blocking probability becomes rather substantial. This point could therefore be regarded as the optimum extent of resource reservation for handover. This is an advantage over the queuing model.

6 ACKNOWLEDGEMENT

I wish to appreciate the support of the Federal Government of Nigeria for providing the department of Electronic Engineering, University of Nigeria, Nsukka with ETF Centre of Excellence in Networking for Communications Network research.

REFERENCES

[1] A. Bhuvaneswari, Dr. E. George Dharma Prakash Raj. Survey on Handoff Techniques. Journal of Global Research in Computer Science Volume 2, No. 6, June 2011, p. 140.

[2] G.P. Pollini , “Trends in Handover Design”, IEEE Communications Magazine , pp. 82 – 90, March 1996 .

[3] Dinesh Sharma and R.K.Singh. Analysis of Handover Initiation using Path Loss to Sustain QoS. International Journal of Scientific & Engineering Research Volume 3, Issue 5, May-2012 1 ISSN 2229-5518 (odd page), p. 3

[4] Shoewu, O., Edeko, F.O. Outgoing call quality evaluation of GSM network services in Epe, Lagos State. American Journal of Scientific and Industrial Research, 2(3), 2011, p. 416.

[5] William C. Y. L., Wireless and Cellular Telecommunications, McGraw-Hill Companies Inc. 2006, pp. 486-487.

[6] G.E. Corazza & Others, “Characterization of Handover Initialization in Cellular Mobile Radio Networks”, IEEE VTC 94, pp. 1869 – 1872, 1994.

[7] Mandjes, M., and Tutschku, K. Efficient Call Handling Procedures in Cellular Mobile Networks, [Online].Report No.144, 1996.

http://www3.informatik.uniwuerzburg.de/publications/reports.shtml

[8] Katzela, I and Naghshineh. Channel Assignment Scheme for Cellular Mobile Telecommunication Systems- A Comprehensive Survey, IEEE Personal Communications, 3 (3),1996, pp.10-31.

[9] Abdulova, V., and Aybay, I.) Handoff Prioritizing Schemes in Cellular Wireless Networks. IEEE Computer Networks Symposiums.16 (18), 2006, pp 1-6.

[10] Nishitd, D., Jeffrey, N and Vanlandingham, F. Handoff in Cellular Systems. IEEE Personal Communications. (1998)

http://www.comsoc.org/pci/private/1998/dec/Tripathi.html>

[11] Jahangir Khan et al, "Cellular Handover Approaches in 2.5G to 5G Technology", International Journal of Computer Applications (0975 – 8887) Volume 21, No.2, May 2011

[12] Ebersman H. G. and Tonguz O. K., "Handover ordering using signal prediction priority queuing in personal communication systems," IEEE Trans.Veh. Technol., vol. 48, pp. 20–35, Jan. 1999.

[13] Onah, F. I. et al, "Resource reservation technique for handover calls using integrated modeling technique", 8th IEEE Design and Test Symposium (IDT), Marrekesh, Morocco, Dec. 16-18, 2013. pp. 1-6.