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An Optimized Handover Model for GSM Networks using Regression Analysis

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Abstract- The goal of handover models and schemes in communication networks is to provide an efficient process for transfer of connection between adjacent cells when necessary. This is aimed at ensuring call continuity and sustainable Quality of Service. Moreover, the performance of a communication network system revolves around efficient allocation of resources. Against this background, this work presents a Resource Reservation Model involving an analytical process that starts with the derivation of the call blocking and call dropping probabilities using the Markov chain state equations based on a physical model. In this work, regression analysis is carried out on a simulation data which captures the total system capacity under test. A more reliable function for the determination of optimum reservations required in a system is thus derived.

Index Terms- Call blocking probability, Call drop probability, Handover, Regression Analysis, Resource Reservation.

I. INTRODUCTION

The original intention of telecommunications as it evolved towards personal communication networks is to make communication services available anytime, anywhere, to anyone, by a single identity number and a pocketable communication terminal. This has passed through many processes and stages that have led to the evolution of different generations occasioned by the desire to have improved services and technology. In a typical cellular network, the radio and fixed links required are not permanently allocated for the duration of a call. Handover, which is also referred to as handoff in North America, is the switching of an on-going call to a different channel or cell. It refers to the procedure that transfers an ongoing call from one cell (or base station) to another as the user moves through the coverage area of a cellular system [1]. Handover has also been defined as a process of changing some of the radio parameters of a channel (frequency, time slot, spreading code, or combination of them) associated with an existing connection [2]. Generally, what happens in a handover process is that a cellular network automatically transfers a call from one radio channel to another radio channel to maintain quality of services (QoS) of a call [3]. One of the basic functions of the Radio Resource layer in the GSM architecture is the execution of handover as well as making measurements required for handover. In cellular network, both the mobile station and the Base Transceiver Station, (BTS) regularly measure the radio signal strength. The mobile station also transmits its measurements reports continuously to the BTS [4].

In literature, there are four known categories of handover in the GSM system, which involve transferring a call within channels (time slots) in the same cell; cells (Base Transceiver Stations) under the control of the same Base Station Controller (BSC); cells under the control of different BSCs, but belonging to the same Mobile services Switching Center (MSC); and cells under the control of different MSCs. The first two types of handover, known as internal handovers, involve only one Base Station Controller (BSC). To save signaling bandwidth, they are managed by the BSC without involving the Mobile services Switching Center (MSC), except to notify it after the execution of the handover. The last two types of handover, known as external handovers, are handled by the MSCs involved in the communication process. A very important aspect of GSM is that the original MSC, the *anchor MSC*, remains responsible for most call-related functions, with the exception of subsequent inter-BSC handovers under the control of the new MSC, called the *relay MSC* [5].

It is typical of cellular mobile network systems to have a design that ensures that the coverage region is divided into smaller cells in order to achieve high system capacity [6]. Each cell is covered by an individual base station [7]. However, the most serious problem that arises in this architectural design is the handover issue. This problem becomes more

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pronounced for 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.

From the technical point of view, the steadily growing number of mobile users and their demand for diversity of services places a great challenge on the bandwidth utilization. Currently, the research work on radio channel allocation in cellular mobile systems focuses mainly on two aspects, one with the objective of improving the user admission capability and the other with the target of protecting the connection continuity. This work thus aims at developing a handover protection model that takes into consideration acceptable new call admission.

There are a number of mobility management schemes developed to handle handover issues which have been proposed by researchers such as the use of reserved channel schemes (RCS), probabilistic channel reservation (PCR), queuing priority schemes (QPS), preemptive and non-preemptive channel borrowing handover scheme and the intelligent channel reservation (ICR) scheme [8, 9, 10, 11, 12].However, these schemes come with various shortcomings. For instance, insufficient reservation implies that handover connections will compete for free channels with new connections and consequently lead to a higher handover blocking rate. On the other hand, prodigal reservation might increase the number of idle channels in a system. A channel is classified as an idle channel if it is reserved but has not been assigned to any connections. Obviously, new-connection blocking rate increases with the number of the idle channels. Thus, determining an appropriate number of guard channels for handover connections is an essential issue for handover management.

II. THE PROPOSED HANDOVER MODEL

The diagram in figure 1 shows the physical representation of the proposed model while figure 2 shows the Markov Chain equivalent.

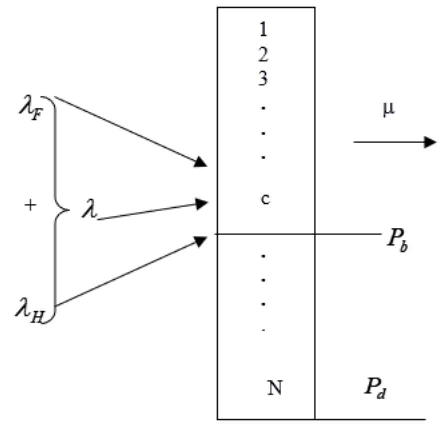

Figure 1: The Proposed Physical Model

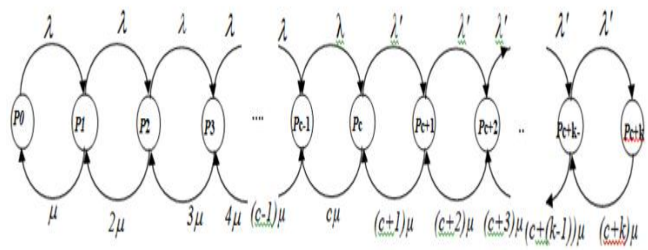

Figure 2: The Graphical Markov Chain Representation of the Model

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; $\rho = \lambda/\mu$ = traffic intensity of both fresh and handover calls; $\rho' = \lambda'/\mu$ = traffic intensity of handover calls.

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To develop the model, the state (fluid-flow) equations for the corresponding Markov chain representation are:

$$S_0:\ \lambda P_0 = \mu P_1 or P_1 = \frac{\lambda}{\mu} P_0 \quad (1)$$

$$S_1:\ \lambda P_1 + \mu P_1 = \lambda P_0 + 2\mu P_2 \quad (2)$$

$$S_{c-1}:\ \lambda P_{c-2} + c\mu P_c = \lambda P_{c-1} + (c-1)\mu P_{c-1} \quad (3)$$

$$S_c:\ \lambda' P_c + c\mu P_c = \lambda P_{c-1} + (c+1)\mu P_{c+1} \quad (4)$$

$$S_{c+1}:\ \lambda' P_{c+1} + (c+1)\mu P_{c+1} = \lambda' P_c + (c+2)\mu P_{c+2} \quad (5)$$

$$S_{c+(k-1)}:\ \lambda' P_{c+(k-1)} + \big(c+(k-1)\big)\mu P_{c+(k-1)} = \lambda' P_{c+(k-2)} + (c+k)\mu P_{c+k} \quad (6)$$

$$S_{c+k}:\ \lambda' P_{c+(k-1)} = (c+k)\mu P_{c+k} \quad (7)$$

Solving recursively, we can establish that:

$$P_i = \frac{1}{i!}\left(\frac{\lambda}{\mu}\right)^i P_0 \quad (8)$$

Hence

$$P_c = \frac{1}{c!}\left(\frac{\lambda}{\mu}\right)^c P_0 \quad (9)$$

Beyond state S_c, a new arrival rate λ' (= λ_H), is defined for handover calls only, which can be served by k reserved resources. Hence the state equations from that state are:

$$S_c:\ \lambda' P_c + c\mu P_c = \lambda P_{c-1} + (c+1)\mu P_{c+1} \quad (10)$$

With appropriate substitution of terms previously defined, we obtain:

$$P_{c+1} = \frac{1}{(c+1)\mu}\lambda P_c \quad (11)$$

Generally,

$$P_{c+k} = \prod_{n=1}^{k}\left(\frac{1}{c+k}\right)\left(\frac{\lambda'}{\mu}\right)^k P_c = \frac{c!}{(c+k)!}\left(\frac{\lambda'}{\mu}\right)^k P_c \quad (12)$$

Recalling the boundary condition:

$$\sum_{i=0}^{\infty} P_i = 1 \quad (13)$$

and carrying out further analysis, we obtain:

$$P_0 = \left[\sum_{i=0}^{c}\frac{\rho'}{i!} + \sum_{n=1}^{k}\frac{c!}{(c+n)!}(\rho')^n\frac{\rho^c}{c!}\right]^{-1} \quad (14)$$

(This is the probability of having 100% resource availability and is associated with state. So. This is the state at which any call that arrives finds the system completely idle. In other words, this first call is assured of service).

Therefore, the call blocking probability for originating/fresh calls, P_c is obtained by substituting this value into equation (9) as:

$$P_c = \frac{\rho'}{c!}\left[\sum_{i=0}^{c}\frac{\rho'}{i!} + \sum_{n=1}^{k}\frac{c!}{(c+n)!}(\rho')^n\frac{\rho^c}{c!}\right]^{-1} \quad (15)$$

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Also, the call dropping probability for handover calls, P_d is obtained by substituting P_c into equation (12) as:

$$P_d = \frac{c!}{(c+k)!}(\rho')^k \frac{\rho^c}{c!}\left[\sum_{i=0}^{c}\frac{\rho'}{i!} + \sum_{n=1}^{k}\frac{c!}{(c+n)!}(\rho')^n\frac{\rho^c}{c!}\right]^{-1} \quad (16)$$

III. RESULTS FROM THE RESOURCE RESERVATION MODEL (RRM)

The approach adopted in testing the model was to observe and record the behavior (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) of the model for varying number of reserved resources, k in a system. The traffic intensities ρ and ρ´ as previously defined were assigned values of 0.9 and 0.7 respectively. The behavior of the model was then noted and recorded for number of resources, N = 10, 15, 20, 25, and 30 respectively.

Figure 3 shows the behaviour of the model with respect to the call blocking probability, Pc and the call dropping probability, Pd. It is obvious that for zero reservation (k = 0), both Pc & Pd have a value of 3.91E-8.

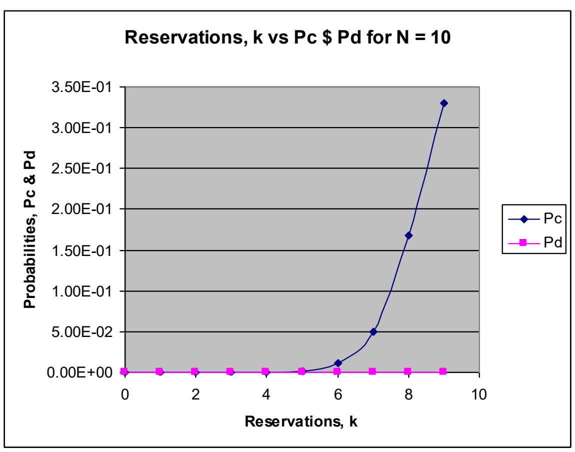

Figure 3: Probabilities, Pc and Pd versus Reservations, k (N = 10)

This is expected because at this point, no reservation is made yet for the handover calls hence both fresh and handover calls should have the same chance of being served or blocked. With k = 1, the values change as Pc slightly increases to 4.34 E-7 and Pd slightly decreases to 3.04 E-8. Further reservations continue to show progressive decrease in Pd and a simultaneous progressive increase in Pc. However, it is observed that beyond four reservations, (k = 4), there is a significant increase in Pc. This becomes the optimum reservations, R for N = 10. Note that the points appear to be zero progressively only because of the very gradual manner in which call drop probabilities change. The same procedure was followed to obtain the optimum reservations for the remaining system capacities, 15, 20, 25, and 30 and the results obtained are as shown in figures 4 to 7.

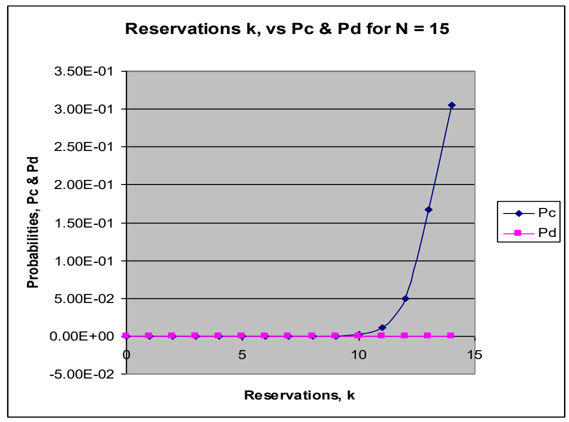

Figure 4: Probabilities of Pc and Pd versus Reservations, k

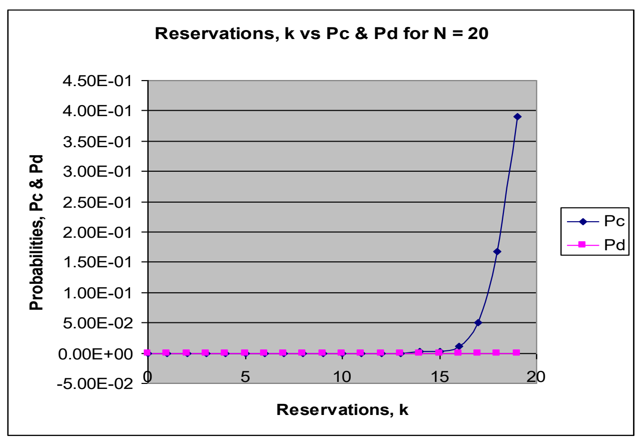

Figure 5: Probabilities, Pc and Pd versus Reservations, k (N = 20)

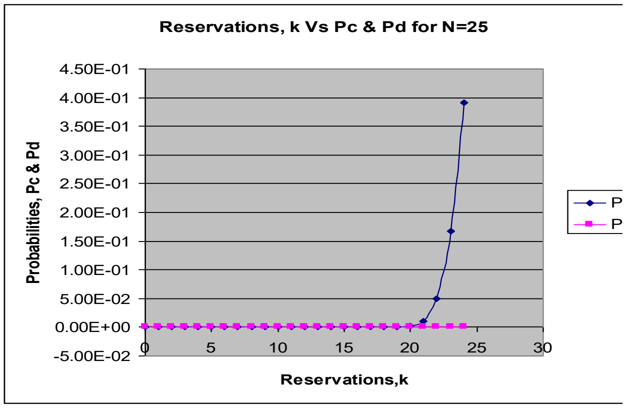

Figure 6: Probabilities, Pc and Pd versus Reservations, k (N = 25)

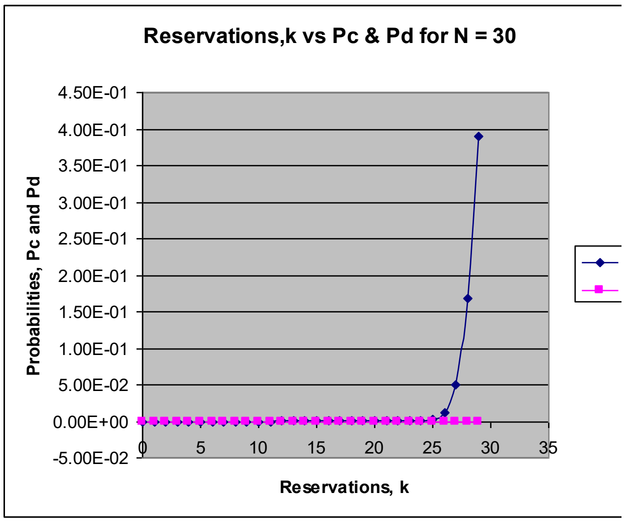

Figure 7: Probabilities, Pc and Pd versus Reservations, k (N = 30)

IV. DISCUSSION OF RESULTS

The following observations were made and the implications are as given:
The actual values of Pc and Pd are influenced by the choice of the arrival rate, λ and the service rate, μ. The ratio λ/μ is however used in this work and it represents the traffic intensity, ρ. When there is no reservation of resources for handover calls (that is, k = 0), the two categories of connection requests, the fresh calls and the handover calls, compete for channels with equal chances of being served. This is expected because with no priority given to handover calls, the call blocking probability should be the same for both classes of calls. From figure 3, with N = 10, the number of reservations is 4 (that is the point at which the fresh call blocking probability begins to rise significantly). From figure 4, the number of reservations is 9 with N = 15. Also, with N = 20 in figure 5, we have 13; from figure 6 with N = 25, we have 18 and with N = 30 in figure 7, we have 24. These numbers tend to increase with increasing number of resources because from literature, handover call requests (which should be given priority), arrive in the system at an alarming rate and in a much higher proportion than the fresh calls.

Firstly, handover calls come from mobile stations crossing their cell boundary into another cell due to its mobility (inter-system handover requests). Secondly, handover requests come from mobile stations in points of weak signal below a specified threshold within the cell referred to as hole (intra-system handover requests). These requests are made to a Base Station Controller (BSC) asking for a change of channel. Thirdly, the MSC may find that some cells are too congested while others are not. Then it would request cell sites to create early handovers for those congested cells. The wired infrastructure (MSC, BSC) may decide that the traffic in one cell is too high and shift some mobile stations to other cells with a lower load (referred to as load balancing). Moreover, Jochen Schiller had noted that about forty reasons for handover have been identified in the GSM standard [13]. Once a single space is reserved for handover calls, the call drop probability, Pd is seen to improve (that is decrease) while the call blocking probability, Pb increases slightly. It is important to recall however that from literature, handover protection and prioritization strategies incur negative impact on the new user admission. Further increase in reservations results in increased improvement albeit at the expense of new call admission. Reservation of Resources for handover calls results in the depreciation of the QoS for fresh calls while improving QoS for ongoing handover calls [14].

Unlike the queuing model, the improvement in call drop probability in this reservation model continues indefinitely. This is desirable as it allows the network system designer to define the tradeoff point. In other words, it gives the designer the chance to choose what level of fresh call blocking he is willing to accept in order to obtain a particular quality of service (which is a function of handover success rate).

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V. DETERMINATION OF THE OPTIMUM RESERVATIONS USING REGRESSION ANALYSIS

The optimum number of resources to be reserved for handover calls in any system can be estimated by taking a close look at the results obtained above and carrying out a mathematical analysis. The optimum reservation, R was determined and found to be 4, 9, 13, 18, and 24 for each of the system capacities, N = 10, 15, 20, 25, 30 respectively. Then these values were plotted and a curve was obtained as shown in figure 8.

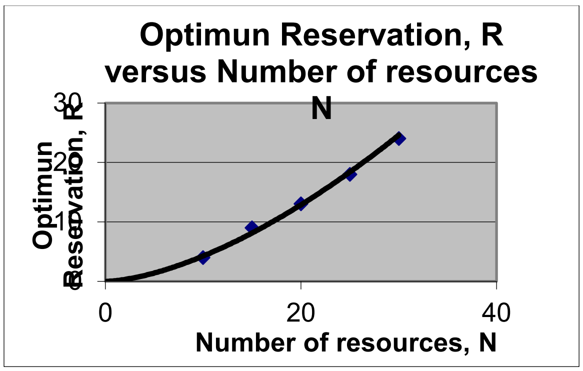

Figure 8: Optimum Reservation versus Number of Resources, N.

We can determine the expression for the maximum reservations, R, to be made for a given network with system capacity, N, by carrying out a regression analysis of the result from simulation as shown in Figure 8. Regression analysis is an important predictive modelling technique which investigates the relationship between a dependent variable say R, and an independent variable such as N. Looking at the curve in figure 8, we can find through regression analysis the function that relates the system capacity, N to the optimum reservations, R using the Generalized Power Law given by:

$$R = \propto N^{\beta} \quad (18)$$

To obtain the values of the constants α and β, equation (18) can be linearized as follows:

$$\ln R = \ln \alpha + \beta \ln N \quad (19)$$

Let $\ln R = y, \ln \propto = k,$ and $\ln N = x$

Then $y = k + \beta x$

We need to find the slope, β and the intercept, k of the entire points in the curve. To do this, we know that:

$$\sum y = nk + \beta \sum x \quad (20)$$

$$\sum yx = k\sum x + \beta(\sum x^2) \quad (21)$$

where n = number of data points considered.

Using equations (20) and (21), we substitute the values in Table 1 to obtain two equations with two unknown parameters:

$$12.217 = 5k + 14.627\beta \quad (22)$$

$$36.9391 = 14.627k + 43.5395\beta \quad (23)$$

Solving simultaneously, we have that:

$\beta = 1.6$ and $k = -2.2372$

Now $\ln \propto = k$, hence $\propto = \exp(-2.2372) = 0.1068$

Therefore

$$\boldsymbol{R = 0.1068N^{1.6}} \quad (24)$$

Table 1: Values required for the Regression Analysis

N	R	x = ln N	y = ln R	xy	x^2
10	4	2.3026	1.3863	3.1921	5.3020
15	9	2.7081	2.1972	5.9502	7.3338
20	13	2.9957	2.5650	7.6839	8.9742
25	18	3.2189	2.8904	9.3037	10.3613
30	24	3.4012	3.1781	10.8092	11.5682
	Σ =	14.627	12.217	36.9391	43.5395

VII. CONCLUSION

In this paper, the expression for the optimum number of resources to be reserved, R for handover call connections in a GSM network of a given system capacity N, was derived using regression analysis. This expression for handover call ensures optimal reservation that will guarantee call continuity which in turn is responsible for maintaining acceptable quality of service (QoS). All the points in the curve are captured to truly represent an efficient analytical model for estimating the optimum reservations, R that should be made for handover calls in a system with given capacity, N. Further work could look at investigating the impact of varying the arrival rates of both fresh calls and handover calls, as they were assumed constant in this work. In addition, a model to handle larger system capacities should be developed.

REFERENCES

[1] K. Jahangir, "Handover management in GSM cellular system," *International Journal of Computer Applications (0975–8887)*, vol. 8, no. 12, Oct. 2010. International Journal of Computer Applications

[2] K. Ioannou, S. Louvros, I. Panoutsopoulos, S. Kotsopoulos, and G. K. Karagiannidis, "Optimizing the Handover Call Blocking Probability in Cellular Networks With High Speed Moving Terminals," *IEEE Communication Letters.*, vol. 6, no. 10, Oct. 2002, p. 1.

[3] Chi Wan Sung, Member, IEEE, "Analysis of Fade Margins for Soft and Hard Handoffs in Cellular CDMA Systems," *IEEE Transactions on Wireless Communications*, vol. 2, no. 3, May 2003, p. 432.

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

[5] John Scouriars, "Overview of the Global Systems for MobileCommunication"; http://jscouria@www.shoshin.uwaterloo.ca

[6] A. Bhuvaneswari and Dr. E. George Dharma Prakash Raj, "Survey on Handoff Techniques," *Journal of Global Research in Computer Science*, vol. 2, no. 6, Jun. 2011, p. 140.

[7] G. P. Pollini, "Trends in Handover Design," *IEEE Communications Magazine*, Mar. 1996, pp. 82–90. IEEE

[8] W. Li and A. S. Alfa, "Channel reservation for handoff calls in a PCS network," *IEEE Trans. Veh. Technol.*, vol. 49, Jan. 2000, pp. 95–104. IEEE

[9] Kee Chaing Chua and S. Y. Choo, "Probabilistic Channel Reservation Scheme for Mobile Pico/Microcellular Networks," *IEEE Communication letters*, vol. 2, no. 7, Jul. 1998, pp. 195–196.

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

[11] Dharma P. Agrawal *et al.*, "Performance Analysis of Handoff Schemes with Preemptive and Nonpreemptive Channel Borrowing in Integrated Wireless Cellular Networks," *IEEE Transactions on wireless communications*, vol. 4, no. 3, May 2005, pp. 1222–1233.

[12] Ming-Hui Jin *et al.*, "An Intelligent Handover Scheme for the Next Generation Personal Communication Systems," *Journal of Communications and Networks*, vol. 6, no. 3, Sep. 2004, pp. 245–257. IEEE

[13] Jochen Schiller, *Mobile Communications*, 2nd ed. Addison Wesley, 2003, p. 117.

[14] F. I. Onah, M. O. Ezeja, and C. I. Ani, "Resource Reservation Technique for Handover Calls using Integrated Modeling Technique," *8th IEEE Design and Test Symposium*, Morocco, Dec. 16–18, 2013, pp. 1–6. IEEE