SIMULATION AND PERFORMANCE ANALYSIS OF MULTI HOP CELLULAR NETWORKS (MNCS) OVER SINGLE HOP CELLULAR NETWORKS (SCNS): A QUEUEING MODEL APPROACH

Neeta Singh[1, 2], R. L. Sharma[1] and Poonam Verma[2]
[1]School of ICT, Noida International University, Greater Noida, India
[2]School of ICT, Gautam Buddha University, Greater Noida, India

ABSTRACT
Multi-hop Cellular Network (MCN) [1] possesses the unique feature of having a fixed infrastructure of Base Station (BS) along with the flexibility of ad-hoc networks. This feature of MCN makes it more suitable for upcoming requirement of cellular network but at the time it increases the overheads required for communication, thus increasing the overall delay. In this paper, a queuing model has been developed to analyze the current cellular network and MCN in terms of Average Waiting Time (AWT) and Channel Utilization. Both the networks consider two types of traffic, namely, voice and data, each prioritizing the voice calls over data traffic. The simulations result is carried out using MATLAB-Simulink. Discrete Event Systems (DES) has been proven to be an effective tool for the study of large and complex systems. The simulation results clearly depict the significance of each network with respect to time.

KEYWORDS: *Single hop Cellular Network (SCN); MCN;, DES; Channel Utilization; Delay; Routing; Simulink.*

I. INTRODUCTION

Cellular system is the one that provides the service in a small area, which is divided into number of cells. The capacity of cellular mobile communication system depends upon the assignment of the radio channels to the BS situated in each cell. There are number of conditions which govern the use of channels in the cells. In a cellular system each cell receives two types of calls: new calls and handoff calls. Since dropping a call in progress is more annoying than blocking a new call request, handoff calls are typically given higher priority than new calls in access to the wireless resources. This preferential treatment of handoffs increases the blocking of new calls and hence degrades the bandwidth utilization [1]. A fixed number of radio channels called Guard Channels (GC) at each BS are reserved for the use of handoff calls in a prioritized scheme to give priority to handoff attempts. It is of interest to learn how these schemes can be solved in a broad variety of situations, in particular, the solution of many practical congestion problems of cellular system. This kind of problems is usually evaluated via queuing theory [2]. Queuing theory, by definition, is the mathematical study of waiting lines or queues. It was developed to analyze the telephone networks [3].
Since then, queuing theory has been applied for several purposes as telecommunications, computing, business, medicine, industry and transportation [4,5]. Queueing of handoff requests, when there is no channel available, can reduce the dropping probability at the expense of higher new call blocking. Queueing can be done for any combination of new and handoff calls. The queue can itself be finite [6] or infinite [7]. Hong and Rappaport are the first who systematically studied the performance evaluation of cellular networks [8]. Various researchers have worked on the cellular mobile radio

[1] MCN- Multi hop Cellular Networks, BS-Base Station, AWT Average Waiting Time, DES- Discrete Event System, SCN- Single hop Cellular networks

telephone system with prioritized and non-prioritized scheme [9]. These strategies can be implemented by selecting any one of the channel assignment schemes, namely Fixed Channel Assignment (FCA) [10], Dynamic Channel Assignment (DCA) etc.

The high data rate and Quality of Service (QoS) requirements of multimedia applications may not be fully supported over the current cellular networks. Thus, there are interests on investigating next-generation cellular network structures for higher data rates and coverage. With the advancement of technology, the numbers of cellular users are increasing day by day. In order to cope up with the requirement, more flexible cellular network is required. SCN lacks in the context of flexibility, as one has to connect to a particular BS within its respective cell for initiating any sort of communication. MCN is a cellular network possessing a unique feature of acquiring adhoc networks characteristics along with a fixed infrastructure BS, both simultaneously [11,12]. MCN-type system is considered as a promising candidate of fourth generation (4G) wireless network for future mobile communications [13]. Various researchers have worked on the performance of ad hoc with integrated services [14].

With MCN, a user in cell A can connect to BS of cell B for communication via intermediate nodes within cell A and cell B. The architecture of MCNs consists of cellular and ad hoc relaying components as shown in Figure 1. In this paper, the model is simulated for providing a comparative view between SCN and MCN and also to indicate the characteristics of both the network consecutively. For depicting the significance of MCN, shortest path routing technique is used in the model.

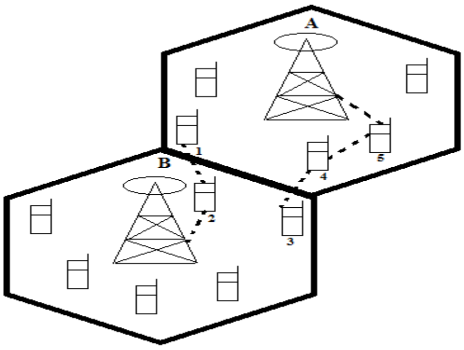


Figure 1: Architecture of MCN

In such *hybrid* network architecture, MCNs combines the benefits of SCN and ad hoc networks. The most important factor in MCNs is multi-hop routing [15], topology control, the design of Radio Resource Management (RRM) protocols, particularly for the management of the Inter-cell interference (ICI) and Load Balancing Schemes (LBS) [16]. In Figure 2, we represent the protocol stack signifying where each of those functions is to be found. Routing is a major issue in MCNs because it affect packet delay and system throughput. The approach for effective coordination of routing and packet scheduling in packet-based MCNs is addressed in [17].

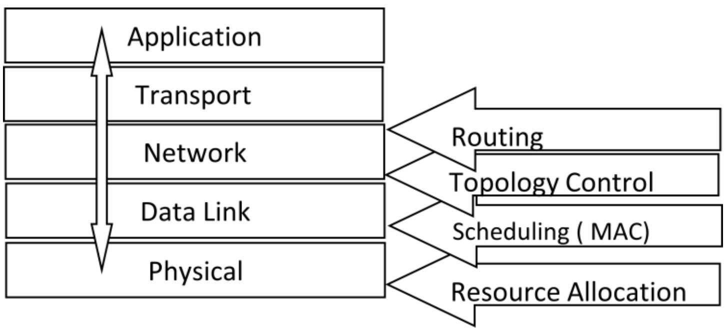


Figure 2: Protocol Stack and Design Issues Factors MCNs.

The rest of this paper is structured as follows: Section 2 describes the architecture in detail. Section 3 presents the modeling and analysis. Section 4 summarizes the simulation and results. Section 5 discussed the performance measures, indicating that the channel utilization of MCN is better than that of SCN. Finally, conclusion and areas for future research are given in section 6.

II. ARCHITECTURE

In multi hop cellular network a user in cell A approaches the base station of cell B in either of the two circumstances: a) all the channels corresponding to the base station of cell A is occupied or b) user in cell A is closer to base station of cell B. The former condition requires the introduction of multi hop communication to enable user in cell A to reach the base station of cell B. However, the use of multiple hops to transmit data has been shown to improve network capability [18,19], and may be essential due to cabling limitations in many environment. The joint scheduling and admission control problem is required in MCN to make assumption about both the network statistics i.e. multihop statistics and call level statistics. To achieve efficient use of network resources for QoS provision traffic control architecture has been developed [20] [21]. The architecture of joint routing, flow control and buffer management is shown in Figure 3. In this paper we have focused on routing and admission control, the task of these two modules and there interrelationship. The routing controls the high speed flow through the switch. The dynamic database is temporarily stored. The data abstractions filter flow information and continuously update the statistical database. The task of the admission control is to accept and reject calls so as to maximize the utilization.

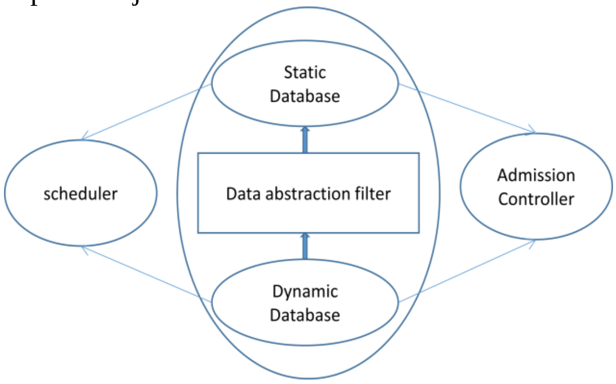


Figure 3: Architecture of Joint Routing and Admission Control

III. MODELING AND ANALYSIS

With the purpose of evaluating the MCN, a DES has been developed through Sim-Events, a Mathworks tool for simulating, modeling and analyzing dynamic systems. The model presented in the paper consist of two sub model, namely single hop and multi hop cellular network. Each of the sub models comprises of three basic phases: a) assigning priority to incoming traffic; b) managing system queue; and c) forwarding call to server so as to complete the call. It is shown in Figure 4, the model is composed of different blocks that could be described below. Each call that arrives into the terminal is represented by an entity.

a) ***Priority Assignment:*** The system prioritizes the incoming traffic based on the voice/data. Since the voice calls are the call in process, these are given higher priority over data.

b) ***System Queue Management*:** The queue of the model manages two kind of inputs, namely, voice or data calls and previously preempted calls the system. Based on the application requirement, one of the inputs is served to the channel for the completion of call.

c) ***Call Complete:*** Based on the occupancy of the channel, the calls are queued in the system queue before it has been served to the channel. This section also redirects the preempted calls to system queue, so that it can be re-transmitted through the channel for call completion.

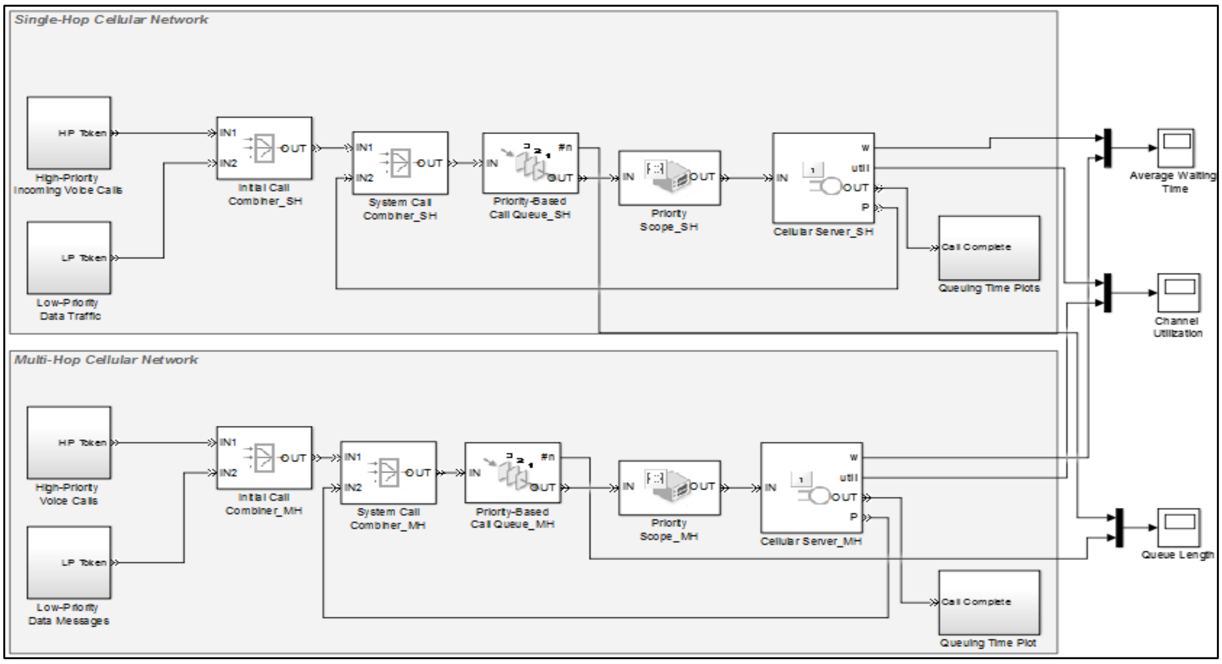


Figure 4: System Model

An additional phase of routing is introduced in the MCN sub model, so as to enable shortest path selection for the current user. The Simulink model for the shortest path selection criterion is shown in Figure 5. Based on the FIFO queue and server queue length, the shortest path is determined for routing the calls through MCN.

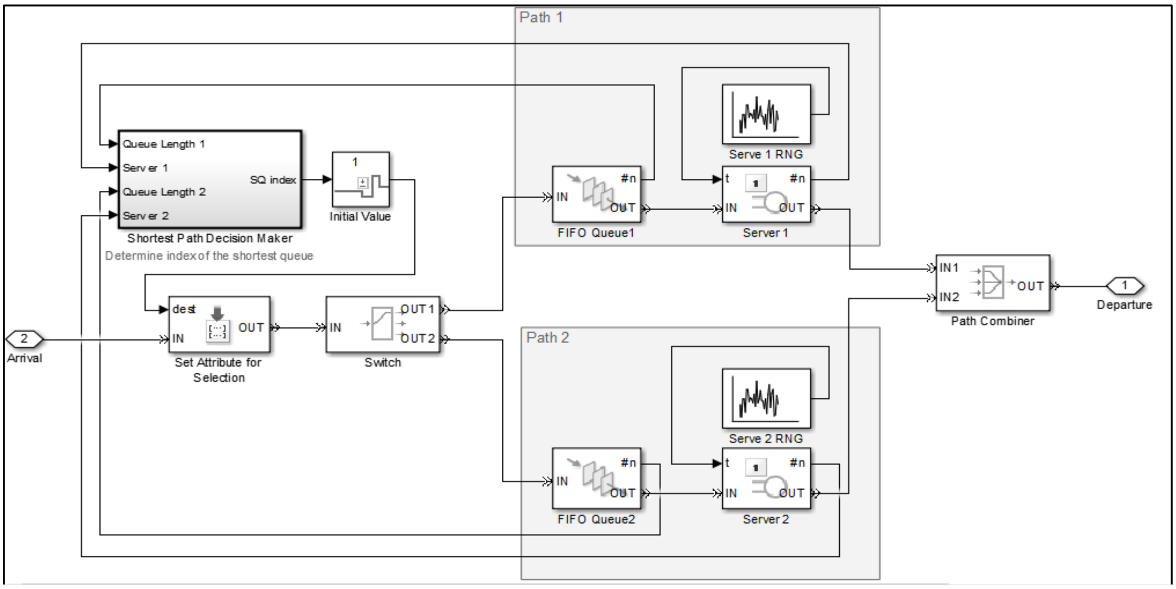


Figure 5: Model for Shortest Path Routing Technique

IV. SIMULATION AND RESULTS

Analysis and simulation results for system throughput of SCN and MCN are presented as follows. For simulation results, the SCN and MCN environments are simulated by Simulink [22]. The parameter set for the simulation is listed in Table 1. As we are considering traffic to be voice or data, the data type here taken is arbitrary continuous. The size of the queue is infinite in length. For MCN, shortest path routing protocol is considered in the model.

Table 1: Simulation Parameters

S. No.	Parameter	Values
1.	Routing Protocol	Shortest Path
2.	Simulation Time	100sec
3.	Incoming calls	Arbitrary Continuous
4.	Queue Length	Infinite (∞)
5.	Message Type	Voice; Data Messages
6.	IEEE Layer	MAC and Network Layer

V. PERFORMANCE MEASURES

5.1 Average Waiting Time

The Figure 6 shows the AWT for both the SCN and MCNs system in order to provide characteristics of each network. The simulation results illustrate that the AWT for MCNs is greater than that of the SCN as multi hop communication requires the determination of routing technique to be followed, before transmitting every single call. Here in the model, the user determines the shortest path prior to call served to the server.

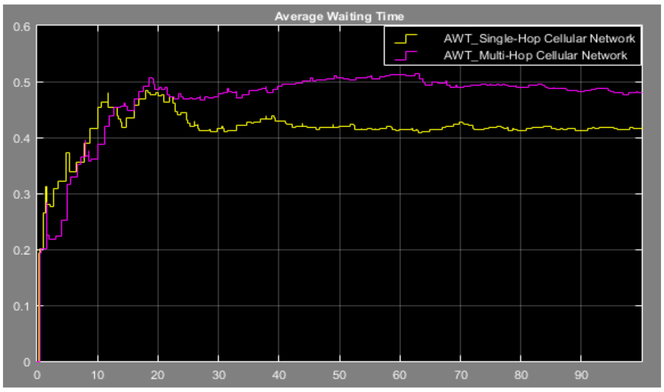


Figure 6: Average Waiting Time of SCN and MCN

5.2 Channel Utilization and Delay

Two important performance measures i.e. channel utilization and delay is depicted in Figure 7 and Figure 8, respectively. As SCN works regardless of any kind of decision making, initially channel utilization for SCN is greater than that of MCN. But as the simulation proceeds, multi hop channel utilization approaches toward maximum limit. Figure 8 provides an illustration to the queue length each for single hop and multi hop networks.

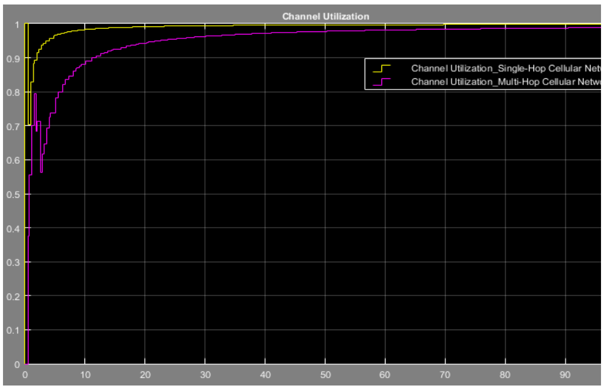


Figure 7: Channel Utilization for SCNs and MCNs

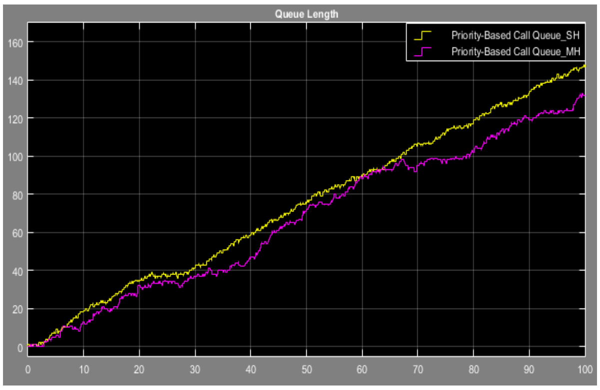
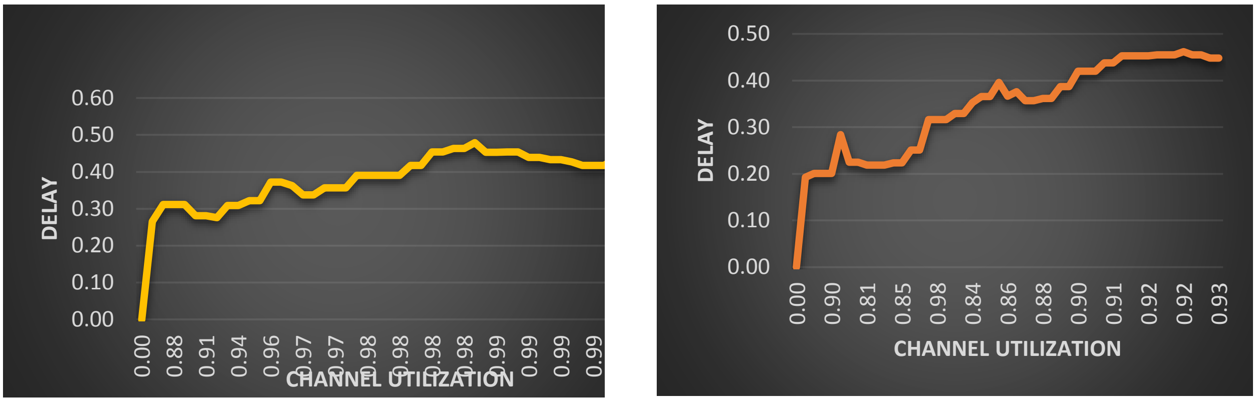


Figure 8: Queue Length for SCN and MCN

5.3 Effect of Routing

The effect of good routing is to increase throughput for the same value of average delay per packet under high offered load conditions and to decrease average delay per packet under low and moderate offered load conditions. Figure 9 (a-b) shows the graphical representation of channel utilization vs delay.



(a) Without Routing (SCN) (b) With Routing (MCN)

Figure 9: Channel Utilization vs Delay (a) single hop cellular networks (b) multi hop cellular networks

It is evident that, multi hop networks outperforms in terms of introduced delay with respect to the channel utilization as any communication within a network should be operated so as to keep average delay per packet as low as possible for any given level of offered load.

VI. Conclusion and Future Scope

Queuing model simulations are very useful to analyze a wide range of systems, such as in present study. Besides this it has the advantage of modeling different scenarios at minimum cost with the purpose of deciding best investment. In conclusion the paper presents a comparative view between SCNs i.e., the current cellular network and MCNs, 4G in terms of AWT and channel utilization. The simulation results depict the significance of each network with respect to time.

Finally, this model can be used to plan and design new facilities of services in the communication networks. In the future, we plan to design systems for MCNs which can both enhance the throughput and minimize the delay and improve the routing schemes of MCNs.

References

[1]. Valkó, András Gergely, and Andrew T. Campbell. "An efficiency limit of cellular mobile systems." *Computer Communications* 23.5 (2000): 441-451.

[2]. Van Woensel, Tom, and Nico Vandaele. "Modeling traffic flows with queueing models: a review." Asia-Pacific Journal of Operational Research24.04 (2007): 435-461.

[3]. Erlang, Agner Krarup. "The theory of probabilities and telephone conversations." Nyt Tidsskrift for Matematik B 20.33-39 (1909): 16.

[4]. Denning, Peter J., and Jeffrey P. Buzen. "The operational analysis of queueing network models." ACM Computing Surveys (CSUR) 10.3 (1978): 225-261.

[5]. Floyd, Sally, and Van Jacobson. "Random early detection gateways for congestion avoidance." Networking, IEEE/ACM Transactions on 1.4 (1993): 397-413.

[6]. Chang, Chung-Ju, Tian-Tsair Su, and Yueh-Yiing Chiang. "Analysis of a cutoff priority cellular radio system with finite queueing and reneging/dropping." IEEE/ACM Transactions on Networking (TON) 2.2 (1994): 166-175.

[7]. Hong, Daehyoung, and Stephen S. Rappaport. "Traffic model and performance analysis for cellular mobile radio telephone systems with prioritized and nonprioritized handoff procedures." Vehicular Technology, IEEE Transactions on 35.3 (1986): 77-92.

[8]. Zhang, Ming, and Tak-Shing P. Yum. "Comparisons of channel-assignment strategies in cellular mobile telephone systems." Vehicular Technology, IEEE Transactions on 38.4 (1989): 211-215.
[9]. Katzela, Irene, and Mahmoud Naghshineh. "Channel assignment schemes for cellular mobile telecommunication systems: A comprehensive survey."Personal Communications, IEEE 3.3 (1996): 10-31.
[10]. Lin, Ying-Dar, and Yu-Ching Hsu. "Multihop cellular: A new architecture for wireless communications." INFOCOM 2000. Nineteenth Annual Joint Conference of the IEEE Computer and Communications Societies. Proceedings. IEEE. Vol. 3. IEEE, 2000.
[11]. Li, Xue Jun, Boon-Chong Seet, and Peter Han Joo Chong. "Multihop cellular networks: Technology and economics." Computer Networks 52.9 (2008): 1825-1837.
[12]. Son, Kyuho, Song Chong, and G. D. Veciana. "Dynamic association for load balancing and interference avoidance in multi-cell networks." Wireless Communications, IEEE Transactions on 8.7 (2009): 3566-3576.
[13]. Liu, Yajian, et al. "Integrated radio resource allocation for multihop cellular networks with fixed relay stations." Selected Areas in Communications, IEEE Journal on 24.11 (2006): 2137-2146.
[14]. Rao, Meena, and Neeta Singh. "Performance Evaluation of AODV nth BR Routing Protocol under Varying Node Density and Node Mobility for MANETs." Indian Journal of Science and Technology 8.17 (2015).
[15]. Rao, Meena, and Neeta Singh. "An Improved Routing Protocol (AODV nthBR) for Efficient Routing in MANETs." Advanced Computing, Networking and Informatics-Volume 2. Springer International Publishing, 2014. 215-223.
[16]. Kleinrock, Leonard, and John Silvester. "Optimum transmission radii for packet radio networks or why six is a magic number." Proceedings of the IEEE National Telecommunications Conference. Vol. 4. 1978.
[17]. Gupta, Piyush, and Panganmala R. Kumar. "The capacity of wireless networks." Information Theory, IEEE Transactions on 46.2 (2000): 388-404.
[18]. Toumpis, Stavros, and Andrea J. Goldsmith. "Capacity regions for wireless ad hoc networks." Wireless Communications, IEEE Transactions on 2.4 (2003): 736-748.
[19]. Mazumdar, Subrata, and Aurel A. Lazar. "Monitoring integrated networks for performance management." Communications, 1990. ICC'90, Including Supercomm Technical Sessions. SUPERCOMM/ICC'90. Conference Record., IEEE International Conference on. IEEE, 1990.
[20]. Haung, Yieh-Ran, Yi-Bing Lin, and Jan-Ming Ho. "Performance analysis for voice/data integration on a finite-buffer mobile system." Vehicular Technology, IEEE Transactions on 49.2 (2000): 367-378.
[21]. Rao, M. and N. Singh. "Quality of service enhancement in MANETs with an efficient routing algorithm." Advance Computing Conference (IACC), 2014 IEEE International. IEEE, 2014.
[22]. Simulink, Matlab, and M. A. Natick. "The Mathworks." (1993).

AUTHORS BIOGRAPHY

Neeta Singh was born in Agra, India, in 1979. She earned her Master degree (M.C.M) in Computers and Management from Dr. B. R. Ambedker university, Agra, India, in 2003 and Ph.D. in Computer Science from Agra University, Center for Information and Decision Sciences in 2007. She has got best paper award in Bharat Ganita Parsad for the applied Mathematics category. She has been with the Department of Computer Science, School of ICT, Gautam Buddh University, Greater Noida since 2009, where she is currently an Assistant Professor. She has published more various papers in refereed international journals and in refereed international conferences. She was technical program committee member in IACC 2013 and various other conferences. Recently, she has published a book entitled “Traffic Management Models For Wireless Communication Network" in LAP Lambert Academic Publishing.

R. L. Sharma was born on 1st January 1950 in the state of Uttar Pradesh of INDIA. He is a retired Deputy Inspector General from Border Security Force He served for 35 years in the BSF in various positions and in various difficult areas and was responsible for the installation, maintenance, repairs and evaluation of wireless and other communication equipment. He relinquished his charge of DIG on 31st July 2008. From 1st August 2008 he is a Professor in various engineering colleges and is, now, a professor and head in the department of Electronics & communication engineering. He is Ph.D. from Singhania University and in teaching B.Tech. and M.Tech students and is guiding research in the field of optical sensors, optical communication.

Poonam Verma received the M.Tech, degree in Electronics & Communication Engg. from DCRUST, Murthal, Haryana, India in 2013 and is pursing Ph.D. in Electronics & Communication Engg. from Gautam Buddha University, Greater Noida, Uttar Pradesh, India.