# Design and Simulation of a Quality of Service (QoS) Guaranteed Model for Mobile Ad Hoc Networks (MANets)

[1]John B. Oladosu, *GSM, IEEE* (johnoladosu@yahoo.com), [1]Akinwale O. Alao,
[2]Matthew O. Adigun, [2]Justice O. Emuoyibofarhe, *Member, IEEE*
`profmatthewo@gmail.com`, eojustice@justice.com
[1]Computer Science and Engineering Department, Ladoke Akintola University of Technology, Ogbomoso, Nigeria,

[2]Computer Science Department, University of Zululand, South Africa

**Abstract – Mobile Ad Hoc Networks (MANets) are self organizing wireless networks. Many applications of MANets require a distinction in the quality of connections being supported in terms of bandwidth availability, end-to-end delay and jitter. The QoS model for this type of network must have the ability to distinguish flows based on their QoS needs and have mechanisms that work to meet those requirements. Also, since all nodes are peers, the QoS model must operate in a fully distributed manner without relying on a central infrastructure. Such requirements combined with the hostile working conditions of an ad hoc network make the task of designing such a model very challenging. This work simulates a novel QoS model that differentiates flows into classes and attempts to provide bandwidth and delay guarantees to flows of highest priority class. The model implements an independent QoS layer and mechanisms which provide tighter QoS guarantees to high priority flows than the results obtained from existing similar models. Our simulation was carried out in OMNET ++ 2.3 and Visual C++ 6.0.**

**Index Terms— Layer Independent Model, Mobile Ad Hoc Networks (MANets), OMNET ++, QoS Guaranteed Model**

## I. INTRODUCTION

The United Nations Consultative Committee for International Telephony and Telegraphy (CCITT) Recommendation E.800 defines QoS as "The collective effect of service performance which determines the degree of satisfaction of a user of the service."[19] Wireless Ad hoc Networks otherwise know as MANets are dynamic self-created and self-managed networks established by multi-hop wireless paths in a peer-to-peer fashion each node serving as a router (see Fig. 1). Quality of Services has been applied in the area of wired networks in the recent past. Its application to MANets is fast gaining popularity as well.

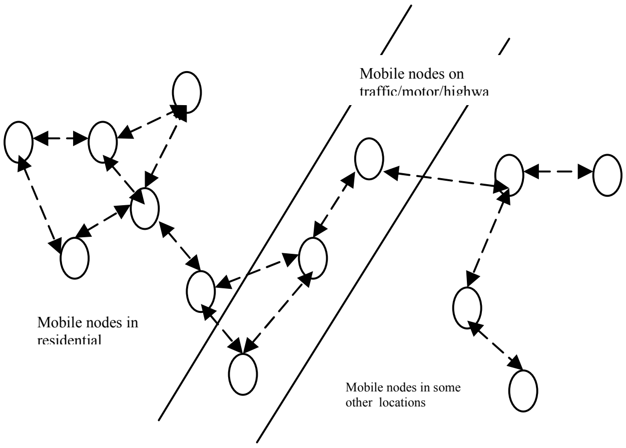

***Fig. 1: Each node of a MANet acts as a Router and is able to communicate with any adjacent node in a multi-hop***

MANets are applied in battlefields and disaster recovery mission, rural and suburban area to provide communication and Internet access due to limited provision of this facility in those settlements. They are also applicable in universities and other research centers where freedom of location and mobility may be of paramount importance. MANets are different from the conventional Internet as a result of the following characteristics: dynamic topology, limited wireless bandwidth, limited power of the nodes, limited storage capacity of the nodes as well as strictly peer-to-peer interconnection demanding that each node has routing capacity to transmit information. These characteristics make QoS provisioning in MANets a challenging task.

## II. REVIEW OF QoS MODELS FOR MANETS

QoS models specify the architecture in which certain services could be provided in the network. A QoS model for MANets should first consider the challenges of MANets, i.e. dynamic topology and time-varying link capacity. In addition, the potential commercial applications of MANets require seamless connection to the Internet. Thus the QoS model for MANets should also consider the existing QoS architectures in the Internet. In this section, QoS models for the Internet, such as lntServ [7] and DiffServ [8], are first introduced, before discussing QoS models proposed for MANETs.

### *A. Integrated Services (IntServ)*

The Integrated Services (IntServ) model was the first standardized model for the Internet developed by IETF (RFC 1633) [7]. The model offers two kinds of services: Guaranteed QoS and Controlled Load QoS. Guaranteed QoS ensures the requested bandwidth and delay bounds for the duration of the connection, while Controlled Load QoS is a better than best effort service for applications that can tolerate some amount of delay but is sensitive to congestion in the network. RFC 2212 provides specification of guaranteed quality of service, while RFC 2211 defines specifications of the controlled-load network element service.

In implementing Guaranteed QoS service, IntServ provides hard guarantees to the flows by performing admission control and making reservations along the nodes before the flow commences. The framework includes four components: packet scheduler, admission control routine, classifier and reservation setup protocol. The functionality of each of these is described briefly in [1].

Several issues hinder the direct applicability of the IntServ framework to MANets[1].

### *B. Differentiated Services*

The Differentiated Services (DiffServ) model [9] was designed to overcome the inherent demerits of the IntServ model. Many RFCs have been developed to standardize various aspects of the model such as definition of per hop behavior identification codes (RFC 3140) [10] and behaviour of the nodes to different classes of traffic (RFC *2597* [11], RFC 3246 [12]).

DiffServ appears as a potential model for a MANet environment, because of its merits such as low per node complexity, low control overhead due to the absence of an external signaling mechanism and no per flow reservation requirement. However, the model as defined for wired networks cannot be directly applied to a MANet. There are several issues that need to be resolved, such as distinction between the edge and the core nodes. Intuitively, the source nodes play the role of edge routers and the relaying nodes act as core nodes. Then, each node must have the capability to act as an edge node and a core node, resulting in an increased complexity at each node. Also, the concept of a SLA does not exist in a MANet. Each node itself must be responsible for not overwhelming the network with traffic. This leads to security concerns.

### *C. Flexible QoS Model for MANET (FQMM)*

A Flexible QoS Model for MANet (FQMM) has been proposed which considers the characteristics of MANets and tries to take advantage of both the per-flow service granularity in IntServ and the service differentiation in DiffServ [13].

FQMM is the first attempt at proposing a QoS model for MANets. However, some problems still need to be solved. First, how many sessions could be served by per-flow granularity? Without an explicit control on the number of services with per-flow granularity, the scalability problem still exists. Secondly, just as in DiffServ, the interior nodes forward packets according to a certain PHB in the DS field. It is arguable that it is difficult to code the PHB in the DS field if the PHB includes per-flow granularity, considering that the DS field is at most 8 bits without extension. Finally, making a dynamically negotiated traffic profile is very difficult.

### *D. Service Differentiation in Wireless Ad hoc Networks (SWAN)*

The SWAN model was developed by the Comet team at Columbia University [15]. The model differentiates traffic into real time UDP traffic and best effort TCP traffic. It is a stateless and fully distributed model that provides soft QoS assurances to real-time traffic. It uses admission control for real-time traffic, rate control of TCP traffic and ECN congestion control mechanisms to ensure that real-time packets meet QoS bounds.

Each node comprises an admission controller that maintains information about the status of the outgoing link in terms of the available bandwidth and amount of congestion. It does this by promiscuously listening to all packet transmissions within its range.

The admitted real-time traffic bypasses the rate controller and has a scheduling priority over best-effort traffic. The admitted real-time flows only have soft QoS assurances, so that some of the flows may be dropped or downgraded to best effort if network traffic conditions change due to rerouting of traffic.

## III. RATIONALE FOR THE RESEARCH

The peculiar nature of MANets and their relevant application scenarios where conventional Internet usage is impracticable make them important.
Motivations for this research work include:

- The unsuitability of conventional networks for places like battlefields and hill stations and during natural and man-caused catastrophes.
- The enormous cost and time consuming implementation of infrastructure-based networks especially when such networks are not to be used on a large scale.
- The poor level of service offered by many existing protocols proposed for MANets.
- The need for modification of existing layers required by most QoS protocols proposed for MANets.

## IV. METHODOLOGY

In order to achieve the aforementioned objectives of this study, the methodology employed is as stated below.

We ensured that the flows belonging to the highest priority class get preemptive priority over traffic of any of the other two classes. After the initiation of any new flow belonging to this class, the network detects and stops any interfering flow belonging to the lower classes *provided that the path to the destination is available*. Flows belonging to best-effort traffic are preempted (or delayed) before preempting any flows of medium priority class. In order not to drastically reduce the overall network throughput, only flows that interfere with the highest priority flow to the extent that they lower the resource availability of highest priority flows to less than their requirements are preempted.

We attempted to maintain end-to-end delays of less than 200 ms for any flows belonging to medium priority class *provided that the path to the destination is available*. This is done at the expense of the rate control of UDP and TCP flows belonging to the best-effort traffic. However, the guarantees to the flows of this class are soft and may be void in the event of changes in network traffic conditions or topology. Some of the flows may be preempted or demoted to best-effort to accommodate flows belonging to the highest priority class and flows belonging to the same class.

OMNET++ (Object Modular Network Testbed in C++) version 2.3 and Visual C++ Version 6.0 were used to simulate the new model.

## V. THE NEW QoS MODEL

The QoS model in this work implements a new independent layer between the network and link layers (Figure A).

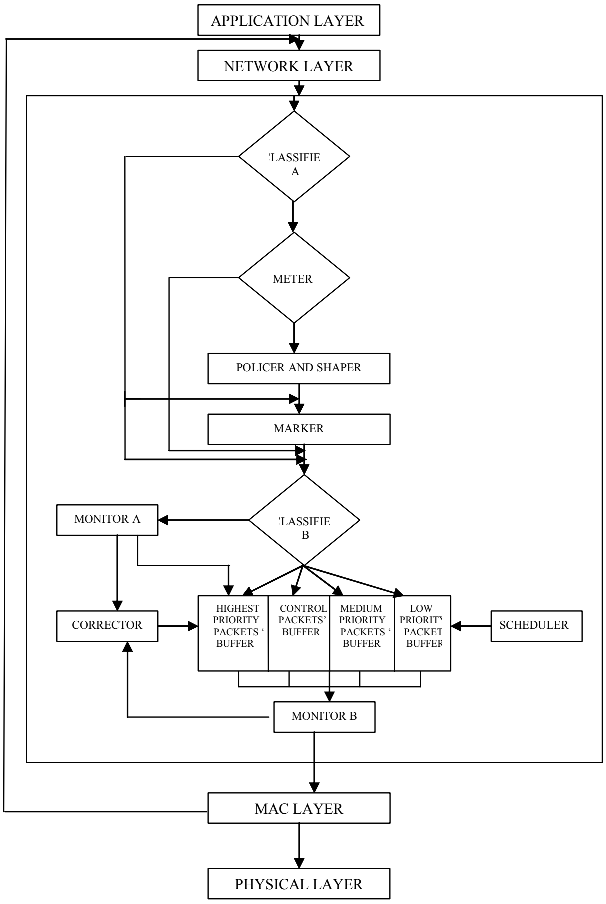

**Figure A: The QoS Model**

The model is DiffServ-based, consisting of classifiers, policer, meter, marker, a separate queue for each class of traffic, and a scheduler which schedules packets out of the queues.

Since DiffServ cannot satisfactorily provide tight QoS guarantees to flows of highest priority class, however, the model is bolstered with additional mechanisms for monitoring the activity of the highest priority flows, and taking actions to maintain tight bounds on the latency and bandwidth of the flows.

Arora [1] showed through simulations using Network Simulator (NS-2) that a similar QoS model outperformed DiffServ and SWAN in the provisioning of tight QoS guarantees to the flows of highest priority class, and in power utilization by keeping the control overhead relatively low.

Simulation results however showed that the QoS model had lower overall network throughput than DiffServ and SWAN. In this work, some mechanism modifications are introduced in order to improve the overall network utilization of the QoS model.

## VI. RESULTS

### *A. Mobility Models*

The scenario consists of 50 nodes placed randomly in a 1500m X 300m rectangular area as shown in Figure 2. Two cases were considered: static and mobile. For the mobile scenario, six different mobility models were employed viz.: Pursuit model, Random Direction model, Random Waypoint model, Random Walk model, Restricted Random Walk model, and the Normal Markovian model. The static scenario was considered as a form of the mobile scenario with a maximum speed of zero. The work of Nicola Concer [18] on MANETs was of invaluable help.

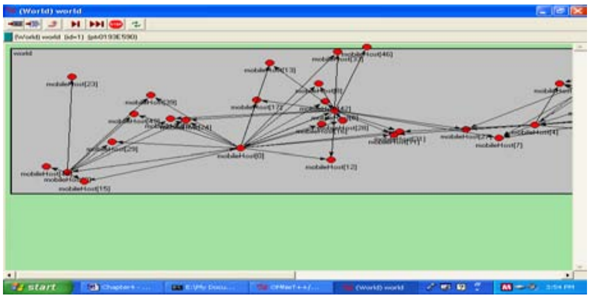

**Figure 2: Snapshot of the Network with 50 Hosts Moving on a Map of 1500m X 300m**

### *B. Analysis of Results*

Figure 3 shows the percentage of Highest Priority Flow packets received with an end-to-end delay of less than 100 ms. The result shows that the QoS model is capable of providing bounds on the end-to-end delay of H flows, and by extension, capable of providing QoS guarantees to H flows.

Figure 4 shows the control overhead of the QoS model. Compared with the control overhead of models like SWAN and DiffServ in a similar work done by Arora [1], it can be seen that the new model's control overhead is low with respect to the level of QoS guarantees it provides. This is because; by broadcasting s*quelch* packets at points of heavy congestion, the model acts as a congestion control agent thereby reducing false link breaks. Moreover, from Figure 5, it can be seen that the number of s*quelch* packets created by the model is negligible.

Figure 6 shows the overall network throughput of the QoS model. The leniency of the corrective action taken by nodes causing interference, and the novel method employed in exchanging information about the level of congestion along a route, among others, caused a significant increase in the overall network utilization compared to the one obtained by Arora as shown in the figure.

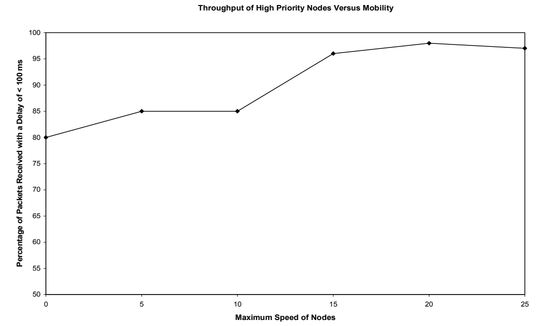

**Figure 3: Throughput of High Priority Nodes Versus Mobility (Delay <100ms)**

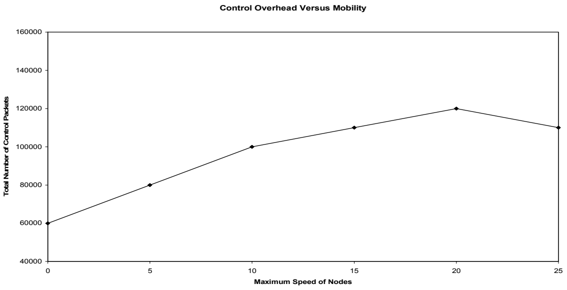

**Figure 4: The Total Number of Control Packets Sent Versus Maximum Speed of Nodes**

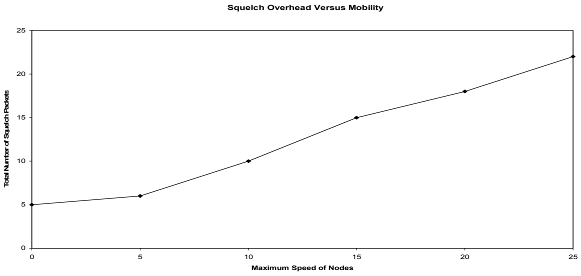

**Figure 5: Total Number of Squelch Packets Versus Maximum Speed of Nodes**

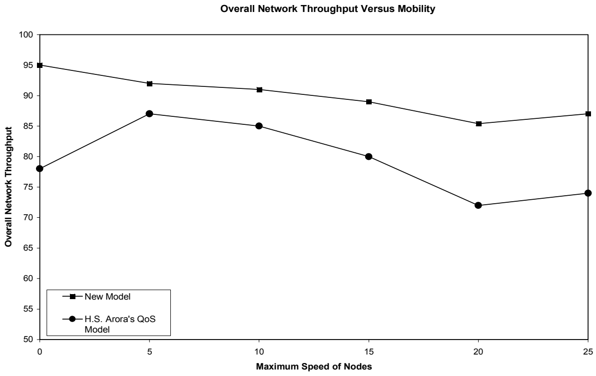

Figure 6: Overall Network Throughput Versus Maximum Speed of Nodes

## VII. CONCLUSION AND FURTHER WORK

In this work, a layer-independent QoS model was simulated using OMNeT++ version 2.3. In solving this challenging problem, a thorough review of many QoS protocols was done which cuts across many QoS routing protocols, MAC layer protocols, and QoS models.

Moreover, novel modifications and additions were made to the QoS model developed by Arora [1] resulting in a model with higher overall network utilization. The model, essentially, is DiffServ-based, but it is bolstered with certain mechanisms which enable it to provide tight QoS guarantees to high priority flows.

Additionally, the model is designed such that the "QoS layer" is independent of the network and MAC layers, meaning that it can work with any combination of QoS protocols in these layers with little or no modifications. By keeping the control overhead low, the design objective of making the QoS model power-aware was also realized.

### *A. Direction for Further Work*

The model, though capable of providing tight QoS guarantees to high priority flows while also achieving a high utilization of network resources, is still far from perfect. Following are further direction on this research which we believe will help improve the performance of the model, and the confidence of the MANet community in it.

Firstly, there is need for a comparative analysis of the model with other QoS models like SWAN and DiffServ using OMNeT++ as the simulator. This will provide a better understanding of the performance of our QoS model relative to others.

In addition, we decided to use OMNeT++ version 2.3 because of the frequency with which new releases emerged during the course of building the simulation. Due to the great number of modifications that have been made in the simulator since the release of version 2.3 in 2003, it will be worthwhile and rewarding to implement the model using the most recent version of the simulator available.

Moreover, instead of demoting or preempting flows belonging to low and medium priority traffic, it is possible to selectively enforce corrective action on certain nodes of the H-Node to promiscuously listen to transmissions of neighboring nodes. Besides, rerouting interfering flows around congested paths, r-paths along which H-Flows are being transmitted is possible – though a very challenging task. If these optimization schemes are well implemented, they may further improve the overall network utilization of the model.

Furthermore, since a number of parameters were employed in the model e.g. HFlowMax, txThreshold, rxThreshold, window, $\text{rate}_{\text{th}}$, etc., there is need for a study of the degree of dependence of the performance of the model on these parameters, and a tuning of the parameters to obtain optimal results. Lastly and most importantly, a thorough theoretical analysis of the model is indispensable so as to present bounds on the level of QoS guarantees that can be realized with the model.

## REFERENCES

[1] H. Arora, "Towards achieving QoS guarantees in Mobile Ad hoc Networks," M. Sc Thesis, Drexel University, October 2003.

[2] V. András, "OMNeT++ Discrete Event Simulation System Version 2.3 User Manual", June 2003.

[3] Z. Haas and S. Tabrizi, "On Some Challenges and Design Choices in Ad-Hoc Communications," in *Proceedings of Military Communications Conference,* Oct. 1998, vol. 1, pp. 187-912.

[4] S. Chakrabati and A. Mishra, "QoS Issues in Ad Hoc Wireless Networks," *IEEE Communications Magazine*, vol. 39, no. 2, pp. 142-148, February 2001.

[5] S. Papavassiliou, S. Tekinay, K. Malick, and K. Walker, "Performance Evaluation Framework and Quality of Service Issues for Mobile Ad Hoc Networks in the Mosaic Atd," in *Proceedings of 21st Century Military Communications Conference*, October 2000, vol. 1, pp. 297-303.

[6] IEE WG, "Part 11: Wireless LAN Medium Access Control (MAC) and Physical Layer (PHY) Specifications," *IEE 802.11 Standard*, 1999.

[7] R. Braden, D. Clark, and S. Shenker, "Integrated Services in the Internet Architecture – an Overview," *IETF RFC1663*, June 1994.

[8] S. Blake, "An Architecture for Differentiated Services," *IETF RFC2475*, December 1998.

[9] K. Nichols, V. Jacobson, and L. Zhang, "A Two-Bit Differentiated Services Architecture for the Internet," *RFC2638, ftp://ftp.rfc-editor.org/in-notes/rfc2638.txt*, July 1999.

[10] D. Black, S. Brim, B. Carpenter, and F. Le Faucheur, "Per Hop Behaviour Identification Codes," RFC3140, *ftp://ftp.rfc-editor.org/in-notes/rfc3140.txt,* June 2001.

[11] J. Heinanen, F. Baker, W. Weiss, and J. Wroclawski, "Assured Forwarding PHB Group," RFC2597, *ftp://ftp.rfc-editor.org/in-notes/rfc2597.txt,* June 1999.

[12] B. Davie, A. Charny, and J.C.R. Bennet et. al., "An Expedited Forwarding Per-Hop Behaviour," RFC3246, *ftp://ftp.rfc-editor.org/in-notes/rfc3246.txt,* March 2002.

[13] K. Wu and J. Harms, "QoS Support in

Mobile Ad Hoc Networks," *Crossing Boundaries – an interdisciplinary journal*, vol. 1, no. 1, pp. 92-104.

[14] G. Ahn, A. Campbell, A. Veres, and L. Sun, "Supporting Service Differentiation for Real-time and Best-Effort Traffic in Stateless Wireless Ad Hoc Networks (SWAN)," *IEEE Transactions on Mobile Computing*, vol. 1, no. 3, pp. 192-207, July-Sept. 2002.

[15] R. Sivakumar, P. Sinha, and V. Bharghavan, "CEDAR: A Core-Extraction Distributed Ad Hoc Routing Algorithm," *IEEE Journal on Selected Areas in Communication*, vol. 17, no. 8, pp. 1454-1465, August 1999.

[16] C. Perkins and E. Belding-Royer, "Quality of Service for Ad Hoc On-Demand Distance Vector Routing," *http://www.ietf.org/html.charters/manet-charter.html*, October 2003.

[17] S. Chen and K. Nahrstedt, "Distributed Quality-of-Service Routing in High-Speed Networks Based on Selective Probing," *23rd Annual Conference on Local Area Networks (LCN'98)*, October 1998.

[18] N. Concer, "AdHocSim: MANET Simulation with OMNeT++2.2," Retrieved April 7, 2005, from http://www.cs.unibo.it/~concer

[19] Zeinalipour-Yazti Demetrios, "A Glance at Quality of Services in Mobile Ad-Hoc Networks," Seminar in Mobile Ad hoc Networks, Department of Computer Science, University of California-Riverside, November 19, 2001.

[20] Guahong Cao et al, "Cooperative Cache-Based Data Access in Ad Hoc Networks," IEEE Computer Society Journal, February 2004, pp. 32-39.

**John B. Oladosu** holds a Bachelor of Technology in Computer Engineering from Ladoke Akintola University of Technology, Ogbomoso, Nigeria as well as Master of Science in Computer Science of University of Ibadan, Ibadan, Nigeria. He is a Graduate Student Member (GSM) of IEEE. His research interest is in the area of Grid Computing and Mobile Ad Hoc Networks. He has designed and implemented Computer networks for many reputable organizations including the faculty-wide (200-node) Internet facility at Ladoke Akintola University of Technology, Ogbomoso, Nigeria; where he is a faculty member. You may reach him at johnoladosu@ieee.org or johnoladosu@yahoo.com.