An Efficient Quality of Service Based Routing Protocol for Mobile Ad Hoc Networks

T K Godder[1], M. M Hossain[2], M M Rahman[1] and Md. Sipon Miah[1]

[1] Dept. of Information & Communication Engineering, Islamic University, Kushtia, 7003, Bangladesh

[2] Dept. of Applied Physics & Electronic Engineering, Rajshahi University, Rajshahi University, 6205, Bangladesh

Abstract

Ad-hoc network is set up with multiple wireless devices without any infrastructure. Its employment is favored in many environments. Quality of Service (QoS) is one of the main issues for any network and due to bandwidth constraint and dynamic topology of mobile ad hoc networks, supporting Quality of Service (QoS) is extremely a challenging task. It is modeled as a multi-layer problem and is considered in both Medium Access Control (MAC) and routing layers for ad hoc networks. Ad-hoc On-demand Distance Vector (AODV) routing protocol is one of the most used and popular reactive routing protocols in ad-hoc networks. This paper proposed a new protocol 'QoS based AODV' (QAODV) which is a modified version of AODV.

Keywords: *QoS, Ad Hoc Network, Routing Protocol, AODV.*

1. Introduction

A Mobile Ad Hoc Networks (MANET) is a collection of mobile nodes that can communicate with each other using multi-hop wireless links without utilizing any fixed based-station infrastructure and centralized management. Each mobile node in the network acts as both a host generating flows or being destination of flows and a router forwarding flows directed to other nodes. With the popularity of ad hoc networks, many routing protocols have been designed for route discovery and route maintenance. They are mostly designed for best effort transmission without any guarantee of quality of transmissions. Some of the most famous routing protocols are Dynamic Source Routing (DSR), Ad hoc On Demand Distance Vector (AODV), Optimized Link State Routing protocol (OLSR), and Zone Routing Protocol (ZRP). In MAC layer, one of the most popular solutions is IEEE 802.11. At the same time, Quality of Service (QoS) models in ad hoc networks become more and more required because more and more real time and multimedia applications are implemented on the network. In MAC layer, IEEE 802.11e is a very popular issue discussed to set the priority to users. In routing layer, QoS are guaranteed in terms of data rate, delay, and jitter and so on. By considering QoS in terms of data rate and delay will help to ensure the quality of the transmission of real time media. For real time media transmission, if not enough data rate is obtained on the network, only part of the traffic will be transmitted on time. There would be no meaning to receiving the left part at a later time because real time media is sensitive to delay. Data that arrive late can be useless. As a result, it is essential for real time transmission to have a QoS aware routing protocol to ensure QoS of transmissions. In addition, network optimization can also be improved by setting requirements to transmissions. That is to say, prohibit the transmission of data which will be useless when it arrive the destination to the network. From the routing protocol point of view, it should be interpreted as that route which cannot satisfy the QoS requirement should not be considered as the suitable route in order to save the data rate on the network. In this paper, we describe a QoS-aware modification of the AODV reactive routing protocol called QoS Aware AODV (Q-AODV). This serves as our base QoS routing protocol.

2. Proposed Topology

In this section I would like to show the difference between the QAODV and the AODV routing protocols during transmission with the following simple topology. There are four nodes in this network, and the initial topology is a grid as shown in Figure: 1. The scenario is designed as in Table 1. According to the scenario, at the beginning of the transmission of nodes, the two pairs are not interference with each other. At 10s, Node 2 moves towards the direction of Node 0 with a speed of 10 m/s. The distance between Node 0 and Node 2 becomes smaller and smaller, and at time 15 s, these two nodes begin to be in each others carrier sensing range, which means that these two nodes begin to share the same channel. The maximum bandwidth of the channel is around 3.64 Mbps. In AODV, where there is no QoS requirement, when Node 2 is in the interference range of Node 0, traffics are kept on and some packets are lost during the transmission, whereas, in QAODV, the QoS is ensured. When the promised data rate cannot be satisfied any more, traffic of Node 2 is stopped at once. From this case, we could see that the QAODV achieved the function of ensuring the QoS not only at the route discovery stage, but also during the transmission. Once the QoS is not satisfied, the traffic is stopped [1].

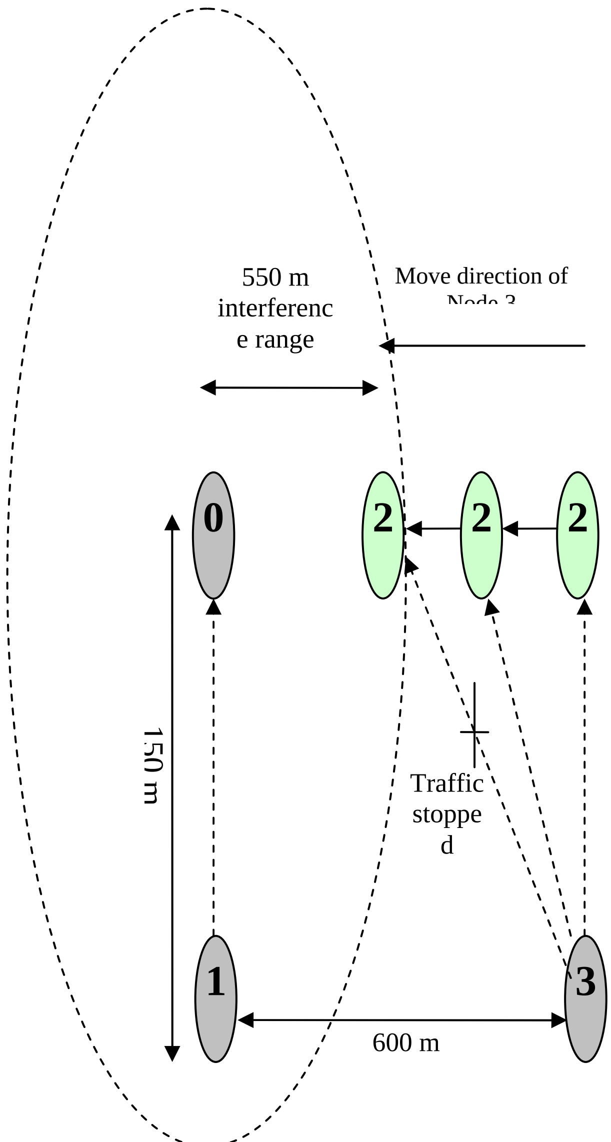

Fig. 1 A simple topology of four nodes

Table 1: Scenario descriptions for proposed topology

Node position	**Node 0 (50, 250)**	**Node 1 (50, 100)**	**Node 2 (650,250)**	**Node 3 (650, 100)**
Traffic	Traffic direction	Duration	Required data rate	Traffic Type
	Node1 ->Node 0	6s - 18 s	1.8 Mbps	CBR
	Node2 ->Node 3	6 s - 18 s	2 Mbps	CBR
Node Movement	Node ID	Time that the node begins to move	Movement Speed	Movement Direction (move toward a point)
	Node 2	10 s	10 m/s	(550, 250)

In the topology there were 20 nodes and the simulation environment was as described in Table1. The area size is 670 m * 670 m, and 20 nodes are in this area. 50 s is added at the beginning of each simulation to stabilize the mobility model. Every simulation runs 500 s in total. Each data point in the results represents an average of ten runs with same traffic models but different randomly generated mobility scenarios. For fair comparisons, same mobility and traffic scenarios are used in both the AODV and the QAODV routing protocols . The screenshot of NAM (Network Animator) at 0 second is given in figure 2.

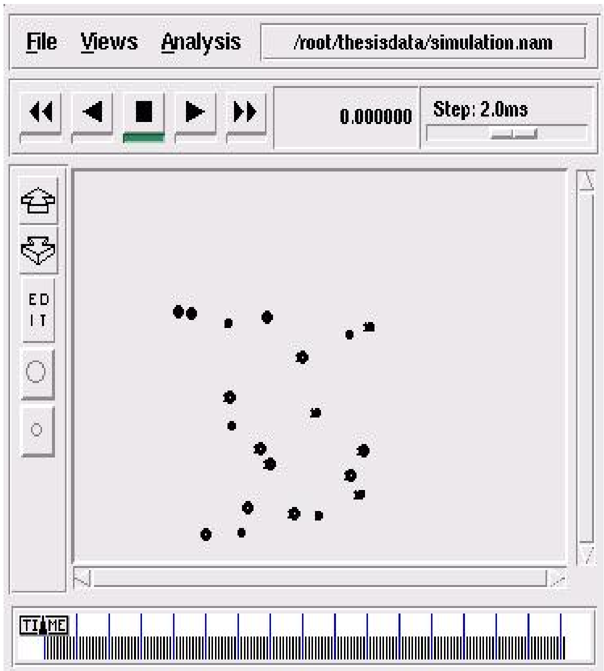

Fig. 2 NAM screenshot of the topology at 0 second

3. Simulation Traffic Pattern

The Random Waypoint model provided by NS2 is used as the mobility model. The traffic type in the application layer is CBR with packet size of 512 bytes and in transport layer User Datagram Protocol (UDP) is used. The traffic pattern that used in the simulation is shown in Table 2. It is the same as what the Reference [2] uses.

Table 2. Simulation traffic pattern

Traffic flow	**Source and destination node**	**Start time (s)**	**End time (s)**
Session 1	3 -> 4	53	174
Session 2	7 -> 8	144	280
Session 3	4 -> 5	290	315
Session 4	5 -> 7	305	475
Session 5	5 -> 6	445	483

Setting the traffic flow in such a manner aims at greater interference impact when sessions overlap. The source node and the destination node of each traffic flow are chosen by using function *cbrgen.tcl* randomly.

4. Simulation Results and Analysis

For comparing various routing protocols using UDP transport layer protocol, we have chosen three performance metrics Average End to End delay, Packet Delivery Ratio, Normalized Routing Load which are commonly used in the literature to evaluate the performance of the AODV and the QAODV routing protocols.

4.1 Data Rate

In this set of simulations, a group of data rates ranging from 50 kbps to 1800 kbps is applied. The mobility scenario is with a pause time of 30 seconds and the maximum node speed is 10 m/s. Three parameters defined above are calculated. The results are shown in the following figures (figure. 3, figure.4, figure.5).

4.1.1 Average end to end delay

From figure.3, it can be seen that AODV routing protocol performs better than QAODV routing protocol when data rate is low (below 600 kbps). The QAODV routing protocol got higher average end to end delay at the low data rate than the AODV because intermediate nodes are not allowed to perform local route repairs in case of link failures with the QAODV routing protocol, thus, there is higher route recovery latency which results in higher end-to-end delay compared with the AODV routing protocol at low data rate.

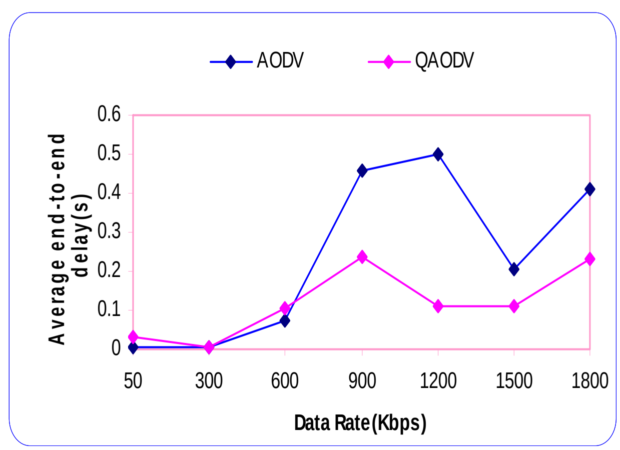

Fig. 3 Average End to End delays with different data rates

Another reason could be that, with the QAODV routing protocol, the number of transmitted routing packets is larger than the number of routing packets transmitted in the AODV routing protocol. In the QAODV routing protocol, all nodes use Hello messages to exchange information with their neighbors. Routing packets including Hello messages which have higher priority always transmitted firstly and data packets are queued nodes. With the AODV routing protocol, when the traffic is low in the network, no matter which route the traffic flow chose, the route chosen can provide enough data rate at most of the time. As a result, the end to end delay with the AODV routing protocol is not high and can be lower than the QAODV routing protocol at low data rate. If we can take more time for simulation for each data rate comparatively accurate results can be found. For these above reasons, end to end delay in QAODV is higher than the AODV at low data rate. The average end to end delay of the QAODV is always below 240ms ,whereas, the end to end delay of the AODV increases badly when the data rate of each traffic flow increases from 600 kbps to 1200 kbps. It shows that networks with the QAODV routing protocol can provide lower end to end delay for traffic flows than the AODV since the QAODV always choose to find a route with satisfying data rate. During the transmission, the QoS of the traffic is monitored in the QAODV routing protocol. Once the QoS is not satisfied as it promised, the traffic stopped. All in all, with the QAODV routing protocol, the average end to end delay is low even the load on the network increases to very high which is not true for the AODV routing protocol. This performance is very significant for real time traffic transmissions.

4.1.2 Normalized Routing Load

In figure.4, the routing overload in AODV and QAODV decreases with the increase of the data rate. In QAODV with the increase of data rate, total number of packets sent increases. For this reason routing overload is relatively high in QAODV at the low data rate. In AODV, routing overload is always low because routing packets are only

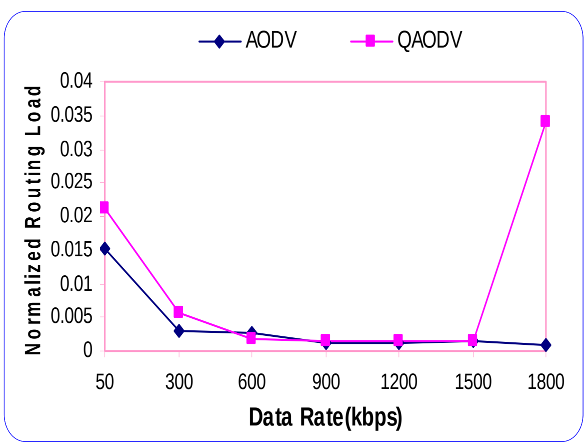

Fig. 4 Normalized routing load at different data rate

sent during the routing searching and maintenance periods without exchanging Hello messages**.** The Hello messages are needed in the QAODV routing protocol in order to exchange the precisely consumed data rate information of nodes who are sharing the same channel. It is hard to explain why the routing overload badly increase when data rate increases from 1500 kbps to 1800 kbps .

4.1.3 Packet Delivery Ratio

From figure.5 we see that, either we use the QAODV routing protocol or the AODV routing protocol, the packet delivery ratio decreases with the increase of the data rate of traffic flows.

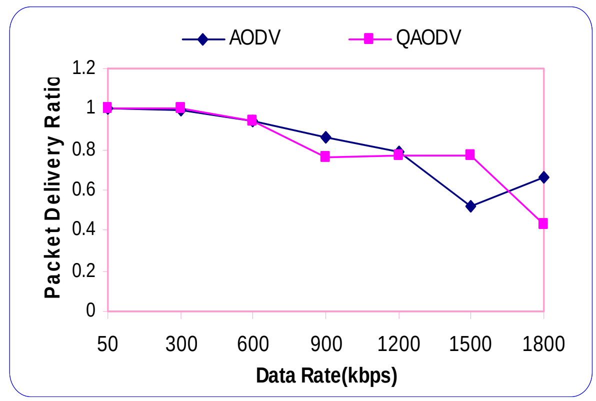

Fig. 5 Packet delivery ratio with different data rates

That is because the increasing data rate of flows increases traffic in the network. When the maximum throughput of nodes cannot satisfy the on-going traffic, queues at nodes begin to be full; the packets in the end of queues of nodes are dropped both at source nodes and at intermediate nodes.

The packet delivery ratio with the QAODV always lower than the AODV because the source node takes more time to find a suitable route in QAODV and during this period of time, the source which keeps on sending packets from the application layer of the node, it cause drops of packets at the end of the queue when the queue is full. Also, the traffic session can be paused anytime when the local available data rate of nodes in the path is not satisfied during the transmission in the QAODV routing protocol.

There are strict requirements in terms of data rate for traffic flow with access admission control. When data rate increases from 1500 kbps to 1800 kbps, only paths with hop count 1 or 2 can be admitted. As a result, there is more decrease in PDR with the QAODV than in AODV when the data rate increases from 1500 kbps to 1800 kbps. It is hard to explain why the PDR increase in AODV when data rate increases from 1500 kbps to 1800 kbps .

For the above reason, the packet delivery ratio with the QAODV routing protocol is lower than the one with the AODV routing protocol is that QAODV routing protocol has more restrictions to the route for transmission. Actually, the packets which are not delivered and dropped at the source node because of the delay for searching for a more suitable route in the QAODV routing protocol should be dropped. The reason is that if these packets are sent, and the route chosen is not satisfying the requirements, packets have more probability to be dropped at the intermediate node or packets may arrives at the destination node late because of the long duration of wait at the intermediate node. In other words, the QAODV routing protocol also helps to prohibit the packets, which have more probability to be dropped during the transmission or that arrived the destination node late, to be transmitted on the network. It helps to save the data rate as well.

4.2 Maximum Node Moving Speed

In the following simulations, the data rate is fixed at 1200 kbps. The maximum node moving speed is increased to see the behaviors of the AODV and the QAODV in a fairly high mobility mode. Maximum node moving speed is changing in the range 1 m/s to 20 m/s. The results are shown in terms of average end to end delay, packet delivery ratio and normalized routing load shown in figure:6, figure:7, and figure:8.

4.2.1 Average end to end delay

As shown in figure:6, with the increase of the maximum moving speed, the average end to end delay does not increase much in QAODV as compared with the AODV routing protocol, it means that, this protocol is quite suitable for scenarios with different moving speeds.

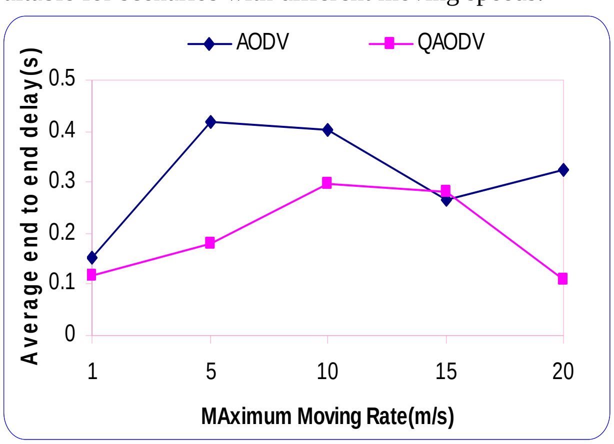

Fig. 6 Average end to end delay with different Max. moving speeds

In comparison, with the AODV routing protocol, the end to end delay varies a lot with the increase of the maximum moving speed . It can be obviously seen that, the end to end delay in QAODV is always much lower than the one in the AODV routing protocol. The low end to end delay of packets ensures the on time transmissions required by real time traffic transmissions.

To sum up, the QAODV routing protocol does decrease end to end delay significantly when the data rate of traffic flows is high.

4.2.3 Normalized Routing Load

The routing overload of AODV and QAODV almost zero at minimum speed. This is because once a route discovery process is completed; there is no need to perform the discovery process again. As shown in fig:7 the routing overload increases in AODV and QAODV with the increase of maximum moving speed. In higher mobility networks, a node which is on the route for transmitting traffic flow has higher possibility to move out of the transmission range of the upstream or the downstream nodes. The upstream nodes are nodes that transmit the packets to the considered moving node and the down stream nodes are those that receive packets from the considered moving node.

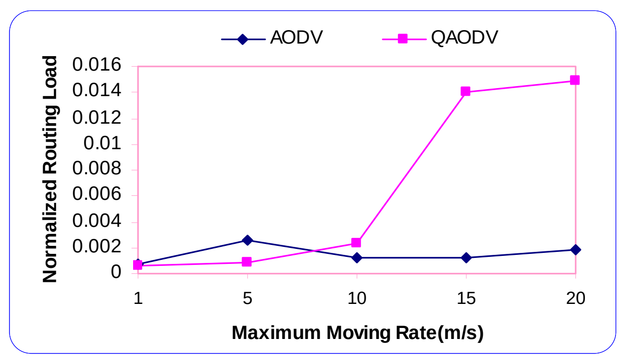

Fig. 7 Normalized routing load with different Max. moving speeds

In order to alert source nodes that there is a lost of one of the intermediate nodes on the route and to find a new route, more and more route discovery and route maintenance packets are sent with the increase of the maximum moving speed of nodes. Normalized routing load which is the number of routing packets divided by the number of successfully delivered packets, in general, increases with the maximum moving speed of nodes. The routing load in the QAODV routing protocol is always much higher than the one in the AODV routing protocol. Thus, we could see that, the QAODV routing protocol improves the performance at the expense of sending more routing packets on the network. These packets are used to exchange the network information to help assure QoS.

4.2.4 Packet Delivery Ratio

In figure. 8 with low max moving speed the packet delivery ratio in QAODV is higher than the AODV but with the increase of mobility speed the performance is lower than AODV. When the maximum moving speed is up to 20 m/s, almost half of the packets are dropped in QAODV. The reason that why more packets are dropped in QAODV and how they are dropped has been explained in the previous part of this section.

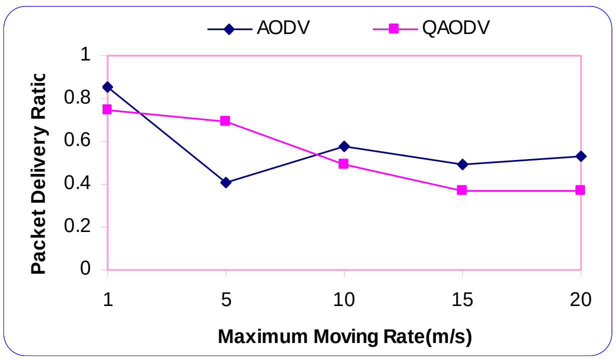

Fig. 8 Packet delivery ratio with different Max. moving speeds.

5. Conclusion

In this research, we described the importance of QoS routing in Mobile Ad-Hoc networks, the challenges we met, and the approach we took. We discussed in detail our idea of adding support for QoS into the AODV protocol. After observing the simulation and analyzing the data, it is found that packets could get less end to end delay with a QoS based routing protocol when the traffic on the network is high. This low end to end delay is meaningful for real time transmissions. When the traffic is relatively high on the network, not all the routes that are found by the AODV routing protocol have enough free data rate for sending packets ensuring the low end to end delay of each packet. As a result, the QAODV protocol works well and shows its effects when the traffic on the network is relatively high. People who work on the area of ad hoc networks with the aim of improving the QoS for ad hoc networks can get benefit from this QAODV protocol.

References

[1] Shane Bracher, "*A MECHANISM FOR ENHANCING INTERNET CONNECTIVITY FOR MOBILE AD HOC NETWORKS*", Proceedings of the Second Australian Undergraduate Students' Computing Conference, 2004.

[2] Ronan de Renesse, Mona Ghassemian, Vasilis Friderikos, A. Hamid Aghvami, "*Adaptive Admission Control for Ad Hoc and Sensor Networks Providing Quality of Service*" Technical Report, Center for Telecommunications Research, King.s College London, UK, May 2005.

[3] H. Badis and K. Al Agha, "*Quality of Service for Ad hoc Optimized Link State Routing Protocol (QOLSR)*", IETF-63 Meeting, Internet Engineering Task Force, draftbadis-manet-qolsr-02.txt, Vancouver, Canada, November 2005. Draft IETF.

[4] NS manual, available at: http://www.isi.edu/nsnam/ns/ns-documentation.html.

[5] Mario Joa Ng, "*ROUTING PROTOCOL AND MEDIUM ACCESS PROTOCOL FOR MOBILE AD HOC NETWORKS*", Ph.D. Thesis (Electrical Engineering), Polytechnic University, Hong Kong, January-1999.

[6] R. Ramanathan and M. Steenstrup, "*Hierarchically organized multihop mobile wireless networks for quality-of-service support*", ACM/Baltzer Mobile Networks and Applications, 3(1):101–119, 1998.

[7] Z. J. Haas and S. Tabrizi, "*On some challenges and design choices in ad hoc communications*", Proceedings of IEEE MILCOM'98, 1998.

[8] S. Murthy and J. J. Garcia-Luna-Aceves, "*An efficient routing protocol for wireless networks*", ACM Mobile Networks and App. J. Special Issue on Routing in Mobile Communication Networks, 1(2):183–197, 1996.

[9] C. E. Perkins, E. M. Royer, and S. R. Das, "*Multicast operation of the ad hoc on-demand distance vector routing*", Proceedings of Mobicom'99, pages 207–218, 1999.

[10] D. B. Johnson and D. A. Maltz, "*The dynamic source routing protocol for mobile ad hoc networks*", In Tomasz Imielinski and Hank Korth, editors, Mobile Computing, chapter 5, pages 153–181. Kluwer Academic Publishers, 1999.

[11] V. D. Park and M.S. Corson, "*A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks*," Proceedings of INFOCOM, pp. 1405-1413, 1997.

[12] Z. Haas, "*A new routing protocol for the reconfigurable wireless networks*", In Proc. of the IEEE Int. Conf. on Universal Personal Communications, 1997.

[13] P. Bose, P. Morin, I. Stojmenovic and J. Urrutia, "*Routing with guaranteed delivery in ad hoc wireless networks*", ACM DIALM 1999, 48- 5; ACM/Kluwer Wireless Networks, 7, 6, 609-616, November-2001.

[14] Palaniappan Annamalai, "*Comparative Performance Study of Standardized Ad-Hoc Routing Protocols and OSPF-MCDS*", Virginia Polytechnic Institute and State University, October-2005.

[15] L Xue, M S Leeson and R J Green, "*Internet Connection Protocol for Ad Hoc Wireless Networks*", Communications & Signal Processing Group, School of Engineering, University of Warwick, Coventry CV4 7AL-2004.

[16] Yuan Sun Elizabeth M. Belding-Royer, "*Internet Connectivity for Ad hoc Mobile Networks*",

Communications System Laboratory Nokia Research Center-2003.

[17] Anne-Marie Kerrnarrec, Frederic Le Mouel, FranCj:oise Andre, “*Improvement of the QoS via an Adaptive and Dynamic Distribution of Application in Mobile Environment*”, Proceedings of the 19th IEEE Symposium on Reliable Distributed Sustems (SRDS'00) 1060-9857/00 $10.00 © 2000 IEEE, January-2000.

[18] Gonzalo Camarillo, “Quality *of Service routing in mobile wireless networks*”, Advanced Signalling Research Laboratory Ericsson, FIN-02420 Jorvas, Finland-2005.

[19] Michael Gerharz, Christian Vogt, Christian de Waal, “*Current Approaches towards Improved Quality-of-Service Provision in Mobile Ad-hoc Networks*”, Technical article, Computer Science Department IV Communications Systems, Rheinische Friedrich Wilhelm University at Bonn, Germany, March-2003.

[20] C. E. Perkins, “*Ad hoc Networking*”, Addison Wesley, 2001.

[21] Gu, D; Zhang, J., "*QoS Enhancement in IEEE802.11 Wireless Local Area Networks*", IEEE Communications Magazine, ISSN: 0163-6804, Vol. 41, Issue 6, pp. 120-124, June 2003

[22] L. Hanzo (II.) and R. Tafazolli, “*Quality of Service Routing and Admission Control for Mobile Ad-hoc Networks with a Contention-based MAC Layer*”, Centre for Communication Systems Research (CCSR), University of Surrey, UK.-2005.

[23] Bracha Hod, “*Cooperative and Reliable Packet-Forwarding On Top of AODV*”, Master of Science Thesis, School of Engineering and Computer Science The Hebrew University of Jerusalem Israel December 8, 2005.

[24] Luiz Carlos Pessoa Albini, “*Reliable Routing in Wireless Ad Hoc Networks: The Virtual Routing Protocol*”, Ph.D. Thesis, Via Buonarroti 2, 56127 Pisa, Italy, July-2006.

[25] Rajarshi Gupta, “*Quality of Service in Ad-Hoc Networks*”, PhD thesis, UNIVERSITY OF CALIFORNIA, BERKELEY, Spring-2005.

Authors

Tapan Kumar Godder received the Bachelor’s, Master’s and M.Phil degree in Applied Physics & Electronics from Rajshahi University, Rajshahi. In 1994, 1995 and 2007, respectively. He is courrently Associate Professor in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. He has twenty one published papers in international and national journals. His areas of interest include internetworking, AI & mobile communication.

M M Hassain is professor in the department of Applied Physics and Electronics Engineering, Rajshahi University, Rajshahi 6205, Bangladesh. He Is currently honorable Vice-Chancellor in Pabna Science and Technology University, Pabna, Bangladesh.

M. Mahbubur Rahman received the Bachelor’s and Master‘s Degree in Physics, Rajshahi University, in 1983, 1994 and PhD degree in Computer Science & Engineering in 1997. He is courrently Professor in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. He has twenty four published papers in international and national journals. His areas of interest include internetworking, AI & mobile communication.

Md. Sipon Miah received the Bachelor’s and Master‘s Degree in the Department of Information and Communication Engineering from Islamic University, Kushtia, in 2006 and 2007, respectively. He is courrently Lecturer in the department of ICE, Islamic University, Kushtia-7003, Bangladesh. Since 2003, he has been a Research Scientist at the Communication Reasearch Laboratory, Department of ICE, Islamic University, Kushtia, where he belongs to the spread-spectrum research group. He is pursuing research in the area of internetworking in wireless communication. He has seven published paper in international and one national journals in the same areas. His areas of interest. include Wireless Communications, optical fiber communication, Spread Spectrum and mobile communication.