Making Ad Hoc Network Stable, Secured and Energy Efficient

Divya Sharma[1],Ashwani Kush[2]

**[1] Information Technology Department, ITM University ,
Gurgaon, Haryana 122017, India**

**[2] Computer Science Department, University College, Kurukshetra University
Kurukshetra, Haryana 134619, India**

Abstract

Mobile Ad hoc networking is a challenging task due to the lack of resources in the network as well as the frequent changes in the network topology. Although lots of research has been done on supporting QoS in the Internet and other networks, they are not suitable for mobile Ad hoc networks and still QoS support for such networks remains an open problem. In this paper, a new scheme has been proposed for achieving QoS in terms of packet delivery, multiple connections, better power management and stable routes. It offers quick adaptation to distributed processing, dynamic linking. It also offers low processing overhead and loop freedom at all times. The proposed scheme has been incorporated using AODV protocol and by extensive simulation the performance has been studied, it clearly shows that the proposed scheme performs very well**.**

Keywords: *Ad hoc network, Routing protocols, AODV, MANET.*

1. Introduction and Motivation

An ad hoc wireless network is a collection of mobile devices equipped with interfaces and networking capability. Ad hoc [1] can be mobile, stand alone or networked. Such devices can communicate with another node within their radio range or one that is outside their range by multi hop techniques. An Ad hoc network is adaptive in nature and is self organizing. In this wireless topology may change rapidly and unpredictably. A mobile ad hoc network is also called MANET [2]. The main characteristic of MANET strictly depends upon both wireless link nature and node mobility features. Basically this includes dynamic topology, bandwidth, energy constraints, security limitations and lack of infrastructure. MANET is viewed as suitable systems which can support some specific applications as virtual classrooms, military communications, emergency search and rescue operations, data acquisition in hostile environments, communications set up in Exhibitions, conferences and meetings, in battle field among soldiers to coordinate defense or attack, at airport terminals for workers to share files etc. Several routing protocols for ad hoc networks have been proposed as DSR, DDR, TORA, AODV and RDMAR. Major emphasis has been on shortest routes in all these protocols in response whenever break occurs. In this paper a new scheme the stable routing with power factor has been suggested which would allow mobile nodes to maintain routes to destinations with more stable route selection. This scheme responds to link breakages and changes in network topology in a timely manner.

Due to the frequent changes in network topology and the lack of the network resources both in the wireless medium and in the mobile nodes, mobile ad hoc networking becomes a challenging task. Routing in Ad hoc networks experiences more link failures than in other networks. Hence, a routing protocol that supports QoS for ad hoc networks requires considering the reasons for link failure to improve its performance. Link failure stems from node mobility and lack of the network resources. Therefore it is essential to capture the aforesaid characteristics to identify the quality of links. Furthermore, the routing protocols must be adaptive to cope with the time-varying low-capacity resources. For instance, it is possible that a route that was earlier found to meet certain QoS requirements no longer does so due to the dynamic nature of the topology. In such a case, it is important that the network intelligently adapts the session to its new and changed conditions. According to RFC 2386[18], quality of service means providing a set of service requirements to the flows while routing them through the network. A new scheme has been suggested which combines two basic features to achieve Qos, which are stable routing and concept of battery power. The scheme uses backbone stable nodes for stable routes and uses power factor to determine active nodes to participate in routing.

The rest of the paper is organized as follows: Section 2 takes a look at the Routing protocols classification, Section 3 analyzes new proposed scheme, Section 4 describes the simulation environment and results and Section 4 summarizes the study and the status of the work.

2. Routing Protocol Classification

A routing protocol is needed whenever a packet needs to be handed over via several nodes to arrive at its destination. A routing protocol has to find a route for packet delivery and make the packet delivered to the correct destination. Routing Protocols have been a QOS based Routing for Ad Hoc Mobile networks 2 active area of research for many years; many protocols have been suggested keeping applications and type of network in view. Routing Protocols in Ad Hoc Networks can be classified into two types:

2.1 Proactive Protocols

In Proactive or Table Driven routing protocols each node maintains one or more tables containing routing information to every other node in the network. All nodes keep on updating these tables to maintain latest view of the network. Some of the famous table driven or proactive protocols are: DBF [5], GSR [6], WRP [7], ZRP [8] and STAR [9].

2.2 Reactive Protocols

In Reactive or On Demand routing protocols, routes are created as and when required. When a transmission occurs from source to destination, it invokes the route discovery procedure. The route remains valid till destination is achieved or until the route is no longer needed. Some famous on demand routing protocols are: DSR [10], DDR [11], TORA [12], AODV [14], RDMAR [13]. The study has been concentrated for Reactive Protocols due to dynamic topology of network. Surveys of routing protocols for ad hoc networks have been discussed in [3, 17].

3. Proposed Scheme

The proposed scheme takes care of on demand routing along with a new concept of backbone nodes with power factor [28]. Many protocols have been discussed using concept of power in many existing schemes [19- 27]. In all the schemes discussed under concept of power routing, no concern has been taken for stable routing or better packet delivery. All emphasis is on concept of battery power or energy requirement for routing process. In this paper two different concepts have been merged together to make an efficient protocol. Major concentration is on the routing problem. In the proposed scheme, the backbone stable nodes help in reconstruction phase in fast selection of new routes. Selection of backbone stable nodes is made upon availability of nodes and battery status. Each route table has an entry for number of backbone stable nodes attached to it and their battery status. The protocol is divided into three phases. Route Request (REQ), Route Repair (REP) and Error Phase (ERR).

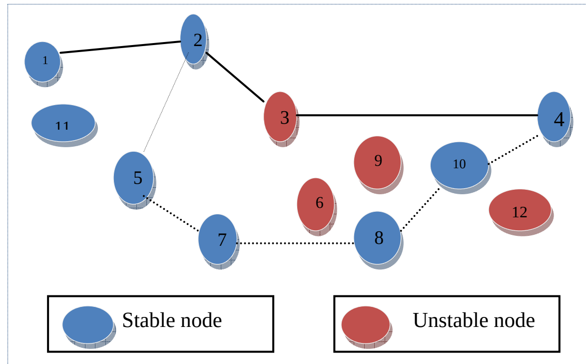

Fig1: An example of routing

The proposed scheme is explained with the help of an example shown in Figure 1. Assume that the node S is the source with index 1 while D is the destination node with index 4. Note that the route discovered using SBNRP scheme routing protocol may not necessarily be the shortest route between a source destination pair. If the node with index 3 is having power status in critical or danger zone, then though the shortest path is 1-2-3-4 but the more stable path is 1-2-5-7-8-10-4 in terms of active power status is chosen. This may lead to slight delay but improves overall efficiency of the protocol by sending more packets without link break than the state when some node is unable to process route due to inadequate battery power. The process also helps when some intermediate node moves out of the range and link break occurs, in that case backbone stable nodes take care of the process and the route is established again without much overhead. In Figure 1 if the node with index 5 moves out, the new established route will be 1-2-11-7-8-10-4. Here the node with index 11 is acting as stable node (SN) for the node with index 5 and the node with index 8.

3.1 Route Construction Phase

This scheme can be incorporated with reactive routing protocols that build routes on demand via a query and reply procedure. The scheme does not require any modification to the AODV's RREQ (route request) propagation process [13]. In this scheme when a source needs to initiate a data session to a destination but does not have any route information, it searches a route by flooding a ROUTE REQUEST (REQ) packet. REQ packet has a unique identifier so that nodes can detect and drop duplicate packets. An Intermediate node with an *active route* (in terms of power and Backbone Nodes), upon receiving a no duplicate REQ, records the previous hop and the source node information in its route table i.e. backward learning. It then broadcasts the packet or sends back a ROUTE REPLY (REP) packet to the source if it has an *active route* to the destination. The destination node sends a REP via the selected route when it receives the first REQ or subsequent REQs that traversed a better *active route*. Nodes monitor the link status of next hops in *active routes*. When a link break in an active route is detected, an ERR message is used to notify that the loss of link has occurred to its one hop neighbor. Here ERR message indicates those destinations which are no longer reachable. Taking advantage of the broadcast nature of wireless communications, a node promiscuously overhears packets that are transmitted by their neighboring nodes. When a node that is not part of the route overhears a REP packet not directed to itself transmit by a neighbor (on the primary route), it records that neighbor as the next hop to the destination in its alternate route table. From these packets, a node obtains alternate path information and makes entries of these stable nodes (SN) in its route table. If route breaks occurs it just starts route construction phase from that node. The protocol updates list of BNs and their power status periodically in the route table.

3.2 Route Error Maintaince

In this scheme data transmits continuously through the primary route unless there is a route disconnection. When a node detects a link break, it performs a one hop data broadcast to its immediate neighbors. The node specifies in the data header that the link is disconnected and thus the packet is candidate for alternate routing. Upon receiving this packet route maintenance phase starts by selecting alternate path and checking power status.

3.2.1 Local Repair (ERR Phase)

When a link break in an active route occurs, the node upstream of that break may choose to repair the link locally if the destination was no farther and there exists BNs that are active. The Time to live (TTL) of the REQ should initially be set to the following value:

TTL = max (MIN_REPAIR_TTL + SN, 0.5 * #hops) + Power status

Where the MIN_REPAIR_TTL is the last known hop count to the destination, #hops is the number of hops to the sender (originator) of the currently undeliverable packet. SN is number of stable nodes attached to the said node and Power status is power state of the node at that time. As **0.5* #hops** is always less than MIN_REPAIR_TTL+SN, so the whole process becomes invisible to the originating node. This factor is transmitted to all nodes to select best available path with maximum power.

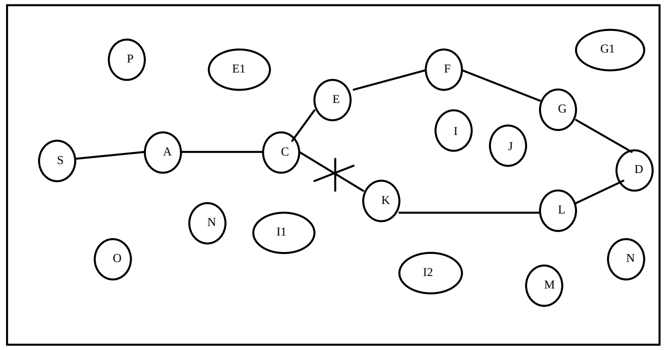

Fig 2 Local Repair

Figure 2 gives an idea of working of local route repair. Initial path from source node ‘Source’ to destination node ‘Destination’ is shown via solid lines. When link breaks at node C, route repair starts, node C starts searching for new paths, buffering packets from S-A in its buffer. Node C invokes Route Request phase for ‘Destination’. Now backbone stable nodes are selected and proper selection of nodes is done based on power factor. Path selected becomes [**C - E – F – G – Destination],** instead of [**C – I – G –Destination],** since the node I is not in active state. Even though the route may become longer, but the selected route path is far more stable and delivers more packets. Stability of route depends upon two major aspects as: Life time and Power status. The concept has been explained in Table 1. When selection has to be made between nodes I1 and E at the start of repair phase, selection of node E has the advantage over node I1. Similarly in the selection between nodes G and G1, node G has higher weight. If any SN has not been on active scale, it is rejected and a new node is searched. In addition to power factor, efforts are made to keep the path shortest. This local repair attempts are often invisible to the originating node.

Node	SN	Min TTL	#hops*.5	Power status	Total
E	3	3	1/2	9	15
F	4	2	2/2	8.5	14.5
G	3	1	3/2	8	12
I	3	1	2/2	4	8
J	3	1	3/2	3	7
I1	1	4	1/2	7	12.5
I2	2	3	2/2	7	12
G1	2	1	4/2	7.5	10.5
E1	1	3	2/2	8.0	12

Table 1: Active Life Time Estimation

During local repair data packets will be buffered at local originator. If, at the end of the discovery period, the repairing node has not received a reply message REP it proceeds in by transmitting a route error ERR to the originating node. On the other hand, if the node receives one or more route reply REPs during the discovery period, it first compares the hop count of the new route with the value in the hop count field of the invalid route table entry for that destination. Repairing the link locally is likely to increase the number of data packets that are able to be delivered to the destinations, since data packets will not be dropped as the ERR travels to the originating node. Sending a ERR to the originating node after locally repairing the link break may allow the originator to find a fresh route to the destination that is better, based on current node positions. However, it does not require the originating node to rebuild the route, as the originator may be done, or nearly done, with the data session. In AODV, a route is timed out when it is not used and updated for certain duration of time. The proposed scheme uses the same technique for timing out alternate routes.

4. Simulation and Result

Simulation study has been carried out to study the Performance study of existing different protocols. Simulation Environment used is NS-2 (network simulator) version NS-2.34 to carry out the process. The simulator NS-2 has been developed by University of California and the VINT project [15]. Simulation results have been compared with AODV, DSR and TORA. Simulation study has been performed for packet delivery ratio, Throughput and End to End delay evaluations.

Packet Delivery Ratio: The fraction of successfully received packets, which survive while finding their destination. This performance measure also determines the completeness and correctness of the routing protocol. If C is total number of flows, f is id, R is packets received from f and T is transmitted from f, then F can be determined by equation 1.

$$F = \frac{1}{C}\sum_{f=1}^{C}\frac{R_f}{T_f} \qquad \text{--- } 1$$

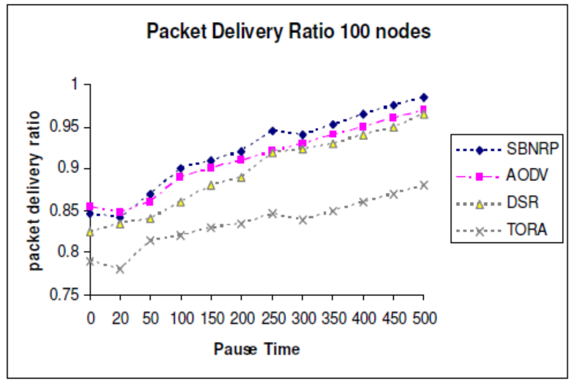

Fig 3: Packet Delivery Ratio at diff pause time.

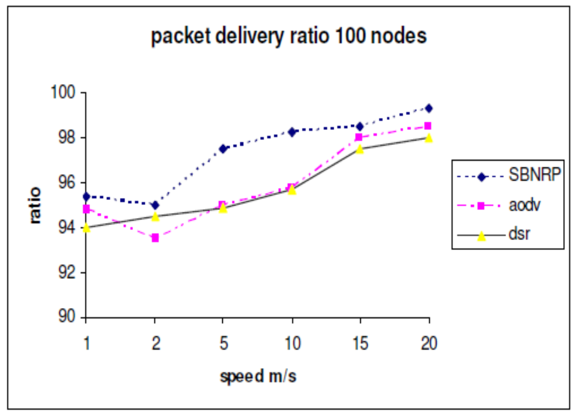

Fig 4: Packet Delivery Ratio at diff speed.

End-to-End Delay:
QOS based Routing for Ad Hoc Mobile networks 5 Average end-to-end delays is the delay experienced by the successfully delivered packets in reaching their destinations. This is a good metric for comparing protocols and denotes how efficient the underlying routing algorithm is, because delay primarily depends on optimality of path chosen denoted in equation 2.

Average end-to-end Delay= $\frac{1}{S}\sum_{i=1}^{S}(r_i - s_i)$ --- 2

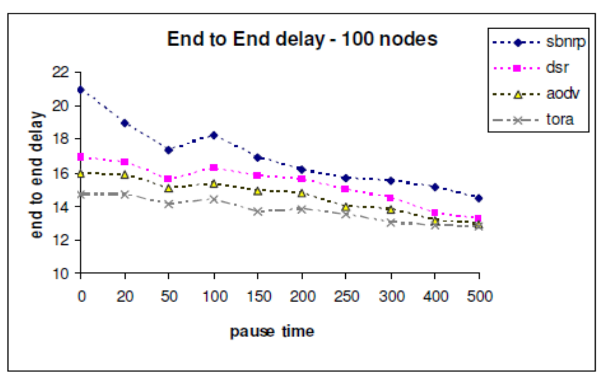

Fig 5: End to end delay at diff pause time.

Throughput

It is defined as rate of successfully transmitted data per second in the network during the simulation. Throughput is calculated such that, it is the sum of successfully delivered payload sizes of data packets within the period, which starts when a source opens a communication port to a remote destination port, and which ends when the simulation stops. Average throughput can be calculated by dividing total number of bytes received by the total end-to-end delay.

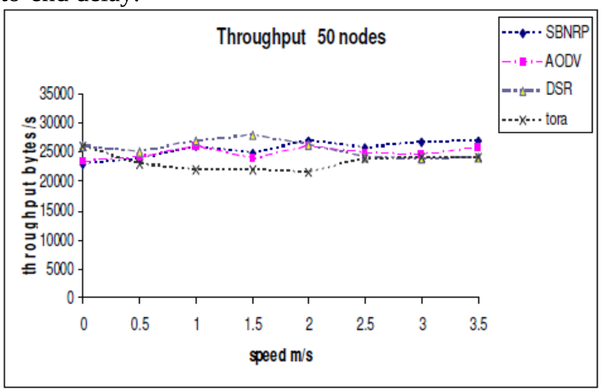

Fig 6: Throughput at different speeds.

In simulation study 100 nodes were taken in a random scenario of size 1000 × 1000. Two parameters have been takes as Pause time and speed. The study has been conducted at different pause times. Pause time of 0 means maximum mobility and 500 is minimum mobility. The sources connected are 25-34 using TCP connection. Figure 3 represents the results. TORA is not delivering more than 84% in denser mediums. It is unable to perform better in higher congestion zones. AODV outperforms DSR in congested medium. DSR drops significant packets at high speed; the reason can be use of source routing and aggressive use of cache. With higher loads the extent of cache is too large to benefit performance. Often stale routes are chosen and all this leads to more packet falls. AODV is delivering more packets to DSR in most of the cases and has an edge over it. New scheme (SBNRP) is overall best for 100 nodes. It starts with 86% and with increasing pause time gets stable and delivers more than 95% packets. Figure 4 shows the simulation results with speed as a function. AODV and DSR have performed better at all speeds. DSR cache performance has suffered a bit at higher speed in denser medium. The reason is that keeping cache for such a large network demand more storage and in turn slows packet delivery rate. DSR is able to deliver more than 94% packets all the time. AODV improves in denser mediums as it is able to support more packets. It overpowers DSR at high speed of 15 to 20 meters per second and trend is true even at higher speeds. New scheme has been the best in dense mediums, showing almost same performance at all speeds. In case of SBNRP scheme delivery ratio was nearing 98% even at higher speeds 10 to 20 and more. Proposed scheme outperforms all other schemes. This proves SBNRP scheme performs better in denser medium, as more backbone stable nodes are available for route selection and also more nodes are available with better power status.

End to end delay has been explained in Figure 5. Here it is clear that DSR has more delays than AODV. The protocol proposed has higher delays. While DSR uses source routing, it gains so much information by the source that it will learn routes to many destinations than a distance vector protocol like AODV or SBNRP. This means while DSR already has a route for a certain destination, SBNRP would have to send a specific request for that destination. The packets would in the mean while stay in the buffer until a valid route is found. This takes some time and will therefore increases the average delay. The delay for SBNRP is more and the reason is that it spends more time in QOS based Routing for Ad Hoc Mobile networks 6 calculation of stable route. SBNRP does deliver even those packets, which may have been dropped in AODV as it has better recovery mechanism and local repair system for faster recovery. All this process increases delay but not at the cost of efficiency. *Throughput* in bytes per second has been calculated and speed has been varied from 0 to 3.5 meter per second. Figure 6 shows the graphical representation. TORA can spare less bandwidth to data transmission. It has almost steady throughput. DSR, AODV and SBNRP have an increase in throughput. The throughput increase can be further explained by TCP behavior, such that, when ACK is not received back, TCP source retransmits data. With increased mobility, source may distribute several identical packets to different intermediate nodes, because of route changes at 1.5 m/s speed, AODV protocol also shows an increasing behavior with the increased network speed. This is due to increased triggered replies and requests. New scheme performance is driven using concept of AODV. It shows better performance after 1.5 m/s speed is because to two factors (i) Like AODV it triggers receives more replies and requests and (ii) the routes becomes stable with better selection of nodes. It has been observed that the end-to-end throughput for all protocols decrease for high network speeds above 10 meter per second.

5. Conclusion

A new scheme has been presented that utilizes a mesh structure and alternate paths. The scheme can be incorporated into any ad hoc on-demand unicast routing protocol to improve reliable packet delivery in the face of node movements and route breaks. Alternate routes are utilized only when data packets cannot be delivered through the primary route. As a case study, the proposed scheme has been applied to AODV and it was observed that the performance improved. Simulation results indicated that the technique provides robustness to mobility and enhances protocol performance. It was found that overhead in this protocol was slightly higher than others, which is due to the reason that it requires more calculation initially for checking backbone stable nodes. This also caused a bit more end to end delay. The process of checking the protocol scheme is on for more sparse mediums and real life scenarios and also for other metrics like Path optimality, Link layer overhead.

References

[1] National Science foundation, "Research priorities in Wireless and mobile networking", Available at www.cise.nsf.gov .

[2] E.M. Royer and C.K. Toh, "A review of current routing protocols for ad hoc mobile wireless networks". IEEE Personal Communications, pages 46–55, April 1999.

[3] Andrew TanenBaum, "Computer Networks", Prentice Hall, New Jersey, 2002.

[4] Dimitri Bertsekas, Robert Gallager, "Data Networks – 2nd Editions" Prentice Hall, New Jersey, ISBN 0-13-200916-1.

[5] Tsu-Wei Chen, Mario Gerla, "Global State Routing: A New Routing Scheme for Ad-hoc Wireless Networks"Proceedings IEEE ICC 1998.

[6]S. Murthy, J.J. Garcia-Luna-Aceves, "An Efficient Routing Protocol for Wireless Networks", ACM Mobile Networks and App. Journal, Special Issue on Routing in Mobile Communication Networks, Oct. 1996, pp. 183-97.

[7] Z.J. Hass, M.R. Pearlman, "Zone routing protocol (ZRP)",Internet draft, June 1999, at www.ietf.org.

[8] J.J. Garcia, M. Spohn and D. Bayer, "Source Tree Adaptive Routing protocol", IETF draft, October 1999.

[9] D.B. Johnson, D.A. Maltz, "Dynamic Source Routing in Ad Hoc Networks", Mobile Computing, T. Imielinski and H. Korth, Eds., Kulwer, 1996, pp. 152-81.

[10]Navid Nikaein, Christina Bonnet, "Dynamic Routing algorithm",available at Instiute Eurecom,Navid.Nikaein@eurocom.fr.

[11] V.D. Park, M.S. Corson, "A Highly Adaptive Distributed Routing Algorithm for Mobile Wireless Networks", Proceedings of the IEEE International Conference on Computer Communications (INFOCOM), Kobe, Japan, April 1997, pp. 1405-1413.

[12] G. Aggelou, R. Tafazoli, "Bandwidth efficient routing protocol for mobile ad hoc networks (RDMAR)",CCSR ,UK.

[13] C.E. Perkins, E.M. Royer, "Ad-Hoc On Demand Distance Vector Routing", Proceedings of the 2nd IEEE Workshop on Mobile Computing Systems and Applications (WMCSA), New Orleans, LA, February 1999, pp. 90-100.

[14] NS notes and documentation www.isi.edu/vint.

[15] CMU/Monarch's code from www.monarch.cs.edu

[16]Josh Broch, David A.Maltz and Jorjeta Jetcheva, "A performance Comparison of Multi hop Wireless Adhoc Network Routing Protocols", Mobicomm'98, Texas, October 1998.

[17]E. Crawley, R. Nair, B. Rajagopalan, and H. Sandick, "A framework for QoS based routing in the internet," RFC 2386, Aug. 1998.

[18]C.K. Toh, "Ad hoc mobile wireless Networks", Prentice Hall, New Jersey, 2002.

[19] M. Ettus,"System Capacity, Latency, and Power Consumption in Multihop-routed SS-CDMA Wireless QOS based Routing for Ad Hoc Mobile networks". In *Radio and Wireless Conference (RAWCON '98)*, pages 55–58, Aug. 1998.

[20]X. Lin and I. Stojmenovic," Power-Aware Routing in Ad Hoc Wireless Networks". In *SITE, University of Ottawa, TR-98- 11*, Dec. 1998.

[21] A. Chockalingam and M. Zorzi, "Energy Consumption Performance of a Class of Access Protocols for Mobile Data Networks," *Proc. IEEE VTC*, May 1998, pp. 820–24.

[22]A. Michail and A. Ephremides, "Energy Efficient Routing for Connection Oriented Traffic in Ad-hoc Wireless Networks," *Proc. IEEE PIMRC*, Sept. 2000, pp. 762–66.

[23]G. Zussman and A. Segall," Energy efficient routing in ad hoc disaster recovery networks". In Proceedings of IEEE INFOCOM, April, 2003.

[24] C. Schurgers and M. B. Srivastava," Energy efficient routing in wireless sensor networks".In Proceedings of IEEE MILCOM, pages 28–31, October 2001.

[25] C. K. Toh, "Maximum battery life routing to support ubiquitous mobile computing in wireless ad hoc networks", IEEE Comm. Mag., June 2001, pp. 138-147.

[26]S. Singh, M. Woo and C. S. Raghavendra, "Power aware routing in mobile ad hoc networks", IEEE/ACM Mobi Com, Oct. 1998, pp. 181-190.

[27] D. B. Johnson and D. A. Maltz, "Dynamic source routing in ad hoc wireless networks", Mobile Computing, Kluwer, 1996, pp. 153-181.

[28] A.Kush, R.Chauhan,C.Hwang,P.Gupta "Stable and Energy Efficient Routing for Mobile Adhoc Networks" Proceedings of the Fifth International Conference on Information Technology: New Generations, Pages 1028- 1033, 2008 ISBN:978-0-7695-3099-4 available at ACM Digital Portal.

Divya Sharma is B.Tech (Computer Science and Engineering-2005) with Hons and M.Tech.(Computer Science and Engineering-2007) from Kurukshetra University, Kurukshetra, India. Currently, she is pursuing her Ph.D. in the area of Ad Hoc Networks. From August 2007 to June 2008, she served at Pyramid IT Consulting as Software Developer. Since July 2008, she has been working as Assistant Professor at ITM University, Gurgaon, India.

Dr. Ashwani Kush is employed as Head and Associate Professor in Department of Computer Science & Applications, University College, Kurukshetra University, Kurukshetra. He has done Ph.D. in Computer Science in association with Indian Institute of Technology, Kanpur, India and Kurukshetra University, Kurukshetra, India. He is professional Member of ACM, IEEE, SCRA, CSI INDIA and IACSIT Singapore, IAENG Hon Kong. He has more than 60 research papers to his credit in various International/National Journals and Conferences. He has authored 15 books in computer science for undergraduate and school students. His research interests are in Mobile Ad hoc Networks, E-Governance and Security. Dr. Kush has chaired many sessions in International Conferences in USA and Singapore. He is member of Syllabus Committee, Time table and Quiz Contests of Kurukshetra

University, Kurukshetra, India. He is also on the panel of eminent resource persons in Computer Science for EDUSAT project, Department of Higher Education, Government of Haryana. His lectures are also broadcasted through satellite in Haryana, India.