An Adaptive Reliable Routing Protocol for Mobile Ad Hoc Networks

R.Vadivel[1], V. Murali Bhaskaran[2]
[1]School of Computer Science & Engineering
Bharathiar University, Coimbatore-641 046
Tamil Nadu, India
vlr_vadivel@yahoo.co.in

[2]Paavai College of Engineering
NH-7, Pachal, Namakkal-637018
Tamil Nadu, India
murali66@gmail.com

ABSTRACT: *Since the communication is based on the received power of the forwarding node, it is possible to measure the quality of the route and we can estimate the status of the link. When a node does not have enough received signal strength, then it believes that the link will break within a short period of time Based on this identified factor, we propose an Adaptive Reliable Routing protocol for ad hoc networks. In this protocol, whenever a link is likely to be broken the link failure can be determined by examining the received signal strength. When a link is likely to be broken, the previous node will cache the subsequent packets in its data buffer. When a link failure occurs, the upstream node with the cached data in its buffer can retransmit it through the next reliable link. By simulation results, we show that the proposed reliable routing protocol achieves high delivery ratio with reduced delay and overhead.*

Keywords: Routing protocols, MANET, Mobile networks

Received: 9 August 2010, Revised 11 September 2010, Accepted 16 September 2010

1. Introduction

1.1 Quality of Service (QoS) in MANET

Ad hoc wireless network is a special case of wireless network devoid of predetermined backbone infrastructure. This feature of the wireless ad hoc networks makes it flexible and quickly deployable. Nevertheless, significant technological challenges are also posed by this property. There are several challenges incorporating issues of efficient routing, medium access, power management, security and quality of service (QoS). As the nodes correspond over wireless links, all the nodes must combat against the extremely erratic character of wireless channels and intrusion from the additional transmitting nodes. These factors make it a challenging problem to exploit on data throughput even if the user-required QoS in wireless ad hoc networks is achieved.

A source node that needs to communicate with a destination node uses either a direct link or a multihop route to reach the latter. This requires that all nodes must have some basic routing capability to ensure that packets are delivered to their respective destinations. Repeated route changes cause huge complications in implementing ad hoc networks owing to the mobility of the nodes and intrusion between nodes. The high packet loss rates and recurrent topological changes lead to unbalanced transport layer and constrained amount of traffic being carried out by the network. The three eminent problems in ad hoc networks are the lack of constant packet delivery due to the intrusion and movement of nodes, incomplete bandwidth owing to the channel limitations, and constrained node life span caused as an outcome of small battery size. A major challenge in mobile ad hoc networking is how to maximize data packet delivery in the face of rapidly changing network topology without incurring a large routing overhead.

1.2 Problem Identification

Slow detection of broken links causes data packets to be forwarded to stale or invalid paths thereby decreasing the packet delivery ratio. Proactive routing protocols rely on periodic updates to determine if a link to a neighbor is still up. In a highly dynamic network topology where link changes are frequent, many packets are dropped. One solution to make proactive routing protocols quickly detect broken links is to decrease the update interval but this would entail excessive routing overhead.

In on-demand routing, quick detection of broken links is facilitated by hop-by-hop acknowledgment of data packets or the link layer feedback. This approach may however require additional overhead because of data packet acknowledgment. Another downside of using data packet acknowledgment to determine link status is that link failure is only determined after failing to forward a packet. Hence, this packet and possibly more may become undeliverable.

To avoid dropping undeliverable packets, AODV [1] incorporates an optimization known as "local route repair." DSR [2] also provides a feature for the same purpose known as "packet salvaging." However, these optimizations degrade the performance of these protocols at high network load and high mobility rates because of their limited effectiveness and undesirable side effects.

Over the last few years, several routing protocols are proposed for mobile ad hoc networks [1]-[7], [12], [13], [18]. A number of performance comparison studies [8]-[11] have revealed that the on-demand routing protocols perform better in terms of packet delivery and routing overhead than proactive routing schemes especially in the presence of node mobility. Proactive and hybrid schemes do not perform well in dynamic topologies because of the following two major factors: Slow detection of broken links and periodic exchange of route updates even when routes are not needed.

In this paper, we propose to develop an Adaptive Reliable Routing protocol for mobile ad hoc networks. In this protocol, whenever a link is likely to be broken, the link failure can be determined by examining the received signal strength. The proposed protocol finds the next reliable link before the link breakage.

2. Related Work

Hossam Hassanein and Audrey Zhou [4] have proposed a Load-Balanced Ad hoc Routing (LBAR) protocol for communication in wireless ad hoc networks. LBAR defines a new metric for routing known as the degree of nodal activity to represent the load on a mobile node. In LBAR routing information on all paths from source to destination were forwarded through setup messages to the destination. A setup message includes nodal activity information of all nodes on the traversed path. After collecting information on all possible paths, the destination then makes a selection of the path with the best-cost value and sends an acknowledgement to the source node. LBAR also provides efficient path maintenance to patch up broken links by detouring traffic to the destination.

Ihab El Kabary et al [5] have proposed the Weighted Critical Path Routing (WCPR) protocol that strives to incorporate the merits of reactive and proactive ad hoc routing schemes. The main objective of their work was to achieve low latency between highly active pairs of nodes, thus increasing the overall performance of the network without dramatically increasing the routing overhead. The genuine aspect of WCPR was that it initially starts-off as a conventional reactive Dynamic Source Routing (DSR) protocol. The network traffic was monitored in attempt to gradually discover pairs of highly interactive nodes in the network. Critical Paths are then constructed between these pairs of nodes and proactively safe guarded. The established CPs was treated differently depending on the amount of traffic consumed by each.

Lei Chen and Wendi B. Heinzelman [6] have proposed a QoS-aware routing protocol that incorporates an admission control scheme and a feedback scheme to meet the QoS requirements of real-time applications. The important part of their QoS-aware routing protocol was the use of the approximate bandwidth estimation to react to network traffic. Their approach implements those schemes by using two bandwidth estimation methods to find the residual bandwidth available at each node to support new streams.

Kaixin Xu, et. al. [7] have proposed a scalable QoS architecture. The scheme proposed by the authors draws upon the positive aspects of both Intserv and DiffServ, and extends upon the scalable LANMAR routing protocol to support QoS. Their scheme was also capable of incorporating mobile backbone networks to improve the scalability.

Duc A. Tran and Harish Raghavendra [12] have proposed CRP, a congestion-adaptive routing protocol for MANETs. CRP enjoys fewer packet losses than routing protocols that are not adaptive to congestion. This was because CRP tries to prevent congestion from occurring in the first place, rather than dealing with it reactively. Their *ns*-2-based simulation have confirmed the advantages of CRP and demonstrated a significant routing and energy efficiency improvement over AODV and DSR.

Jianbo Xue et al. [13] have proposed a QoS framework for MANETs- Adaptive Reservation and Pre-allocation Protocol (ASAP). By using two signaling messages, ASAP provides fast and efficient QoS support while maintaining adaptation flexibility and minimizing wasted reservations.

Alvin C. Valera et al [14] have proposed a new routing protocol CHAMP (Caching And Multiple Path). CHAMP uses cooperative packet caching and shortest multipath routing to reduce packet loss due to frequent route failures. From their simulation results they have shown that these two techniques yield significant improvement in terms of packet delivery, end-to-end delay and routing overhead.

B. Ramachandran and S. Shanmugavel [15] have proposed three cross-layer designs among physical, medium access control and routing layers. It is done using the Received Signal Strength (RSS) as cross layer interaction parameter for energy conservation, unidirectional link rejection and reliable route formation in mobile ad hoc networks. They have implemented their proposed designs using GloMosim, and the performance of the cross layer protocol framework were studied by them.

Yihai Zhang and Aaron Gulliver [16] have proposed a QoS routing protocol based on AODV (QS-AODV), which creates routes according to application QoS requirements. A local repair mechanism is used to improve the packet delivery ratio. They have shown that their QS-AODV provides performance comparable to AODV under light traffic conditions.

Rekha Patil and Damodaram [17], have proposed a cost based power aware cross layer design to AODV. This approach is based on intermediate nodes calculating cost based on battery capacity. Simulations are performed to study the performance of power aware cross layer AODV protocol using NS2. Their simulation results shows that the cross layer protocol improves packet delivery ratio & throughput and also nodes energy consumption is reduced by routing packets using energy optimal routes.

3. Adaptive Reliable Routing Protocol

3.1 Overview

In order to observe that a node is moving and a route is about to break, we rely on the fact that communication is based on received power of the forwarding node. Because of this fact, it is possible to measure the quality of the route and based on that guess if the link is about to break. When a receiving node receives the power less than the maximum threshold, then the link will break within a short period of time. Based on this documentation, we propose an Adaptive Reliable Routing protocol in ad hoc networks.

In this protocol, whenever a link is likely to be broken the link failure can be determined by examining the received signal strength. The protocol finds the next reliable link before the link breakage.

It contains new route discovery mechanism to reduce the packet loss due to route breakage. It uses alternative route to retransmit the data whenever an intermediate node does not able to forward it, due to link failure. Every node maintains a small buffer for storing data packets that pass through it. When a link is likely to be broken, the previous node will cache the subsequent packets in its data buffer. When a link failure occurs, the upstream node with the cached data in its buffer can retransmit it through the next reliable link.

In existing reactive routing protocols, only the node which encounters the error can salvage or retransmit a data packet. (ie) packet salvaging is centralized. Our proposed scheme enables more nodes to salvage a dropped packet, (ie) packet salvaging is distributed.

3.2 Measuring the Signal Strength

In cross layer design the received signal strength is calculated at the physical layer and it can be accessed at the top layer as shown in the figure 1. In order to transfer the measured value of received signal strength to the MAC layer along with the signal the procedures at physical layers have to be customized [15]. In MAC layer calculations this value is used if required or to pass the routing layers along with the routing control packets. This value is stored in the routing/neighbour tables and it is also used in some of the decision making process. As an interlayer interaction parameter, the received signal strength which is related to the physical layer is passed to the top layers. By adjusting the medium access and routing protocols as per the required cross layer design, the received signal strength is used to improve the performance of the mobile ad hoc networks.

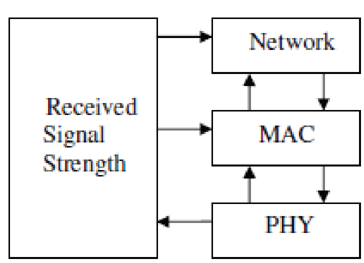

Figure 1. Cross-layer Design

The IEEE 802.11 is reliable MAC protocol. Since the received signal strength must reach every exposed node, it assumes the fixed maximum transmission power. When a sending node transmits RTS packet, it attaches its transmissions power. The receiving node measures the signal strength received for free–space propagation model while receiving the RTS packet [15].

$$P_R = P_T(\lambda / 4\pi d)^2 \, G_T G_R$$

Where, λ is wavelength of the carrier, d is distance between sender and receiver. G_T and G_R are unity gain of transmitting and receiving omni directional antennas, respectively.

3.3 Determining the Link Failure

The node status is adaptively determined based on the value of P_R as given below.

Node status is Green, if $T_{\min} > P_R < T_{\max}$

Node status is Yellow, if $P_R = T_{\min}$

Node status is Red, if $P_R < T_{\min}$

Where $T_{\min}$ and $T_{\max}$ are the maximum and minimum transmission power values.

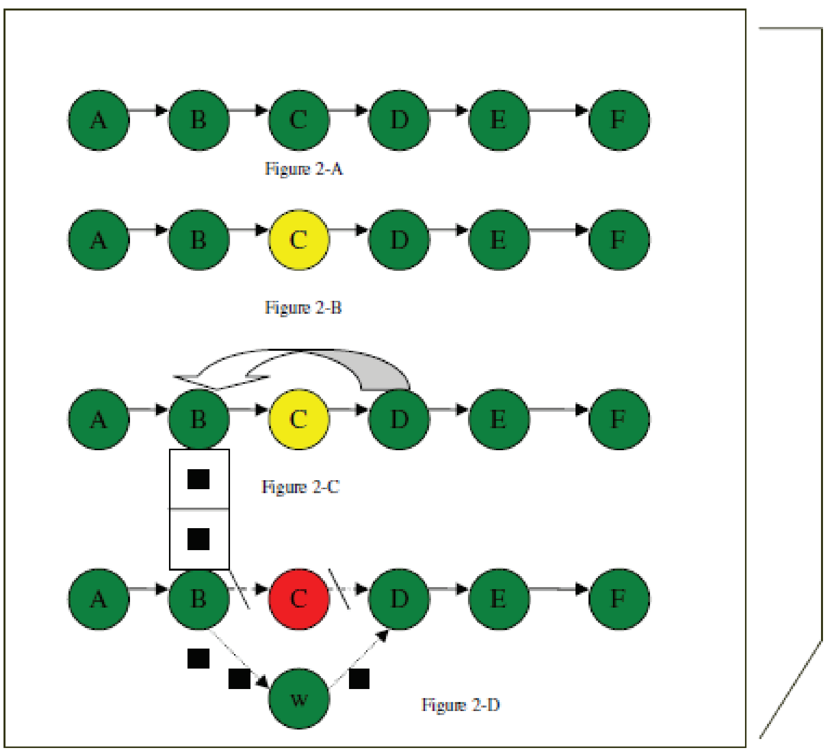

Figure 2. Status of the Nodes

Initially all the nodes are in green status (Figure 2-A). When a node D comes to know that its downstream node C is yellow (ie about to fail, shortly) (Figure 2-B) then it will inform to the previous node of the yellow node (B) about the status of C (Figure 2-C). Then B starts caching the data packets in its data buffer .When the node C becomes red (ie completely failed), then D informs B about the status of C. Then the node B salvages all packets that are still in its data cache through the bypass route (Figure 2-D) which is determined using the mechanism discussed in the next section.

3.4 Bypass Route Discovery

Every node periodically broadcasts an update packet which contains UPD (Node Status St, Destination D, Next Green Node G and Distance d to G for each destination appearing in the routing table.

Algorithm

Let ST is the current link status of the node n_k.

Let $RT[n_k]$ is the routing table of n_k .

1. For {each destination D in $RT[n_k]$}
2. Find the next node n_j.
3. If status of n_j is green or $n_j = D$
   3.1 $G = n_j$
   3.2 $d = 2$
4. Otherwise
   4.1 $G = RT[n_k].G$
   4. 2 $d = RT[n_k].d+1$
5. Add the route [St, D, G, d] to the UPD packet.

When a node n_i receives an UPD packet from its next node n_j about the destination D, n_i will come to know the failure status of n_j and the next green node of n_i. This information is used at the time of establishing a bypass route discovery.

4. Performance Evaluation

4.1 Simulation Model and Parameters

We use *NS2* to simulate our proposed algorithm. In our simulation, the channel capacity of mobile hosts is set to the same value: 2 Mbps. We use the distributed coordination function (DCF) of IEEE 802.11 for wireless LANs as the MAC layer protocol. It has the functionality to notify the network layer about link breakage.

In our simulation, the nodes are varied as 50, 75, 100, 125 and 150. The mobile nodes move in a 500 meter x 500 meter square region for 50 seconds simulation time. We assume each node moves independently with the same average speed. All nodes have the same transmission range of 250 meters. In our simulation, the speed is 10 m/s. The simulated traffic is Constant Bit Rate (CBR).

Our simulation settings and parameters are summarized in table 1.

No. of Nodes	50, 75, 100, 125 and 150
Area Size	500 X 500
Mac	802.11
Radio Range	250m
Simulation Time	50 sec
Traffic Source	CBR
Packet Size	512
Mobility Model	Random Way Point
Speed	10m/s
Pause time	5

Table 1. Simulation parameters

4.2 Performance Metrics

We evaluate mainly the performance according to the following metrics.

Control Overhead: The control overhead is defined as the total number of routing control packets normalized by the total number of received data packets.

Average End-to-End Delay: The end-to-end-delay is averaged over all surviving data packets from the sources to the destinations.

Average Packet Delivery Ratio: It is the ratio of the number .of packets received successfully and the total number of packets transmitted.

Drop: It is the average number of packets dropped.

The simulation results are presented in the next section. We compare our ARRP protocol with the congestion adaptive routing protocol (CRP) [12] and AODV [1] protocol.

4.3 Results

4.3.1 Effect of Varying Flows

Initially we vary the number of flows as 2, 4, 6 and 8.

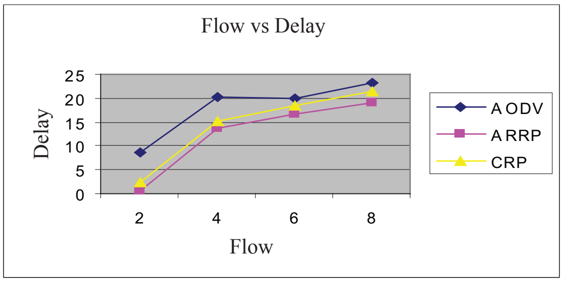

Figure 3. Flow Vs Delay

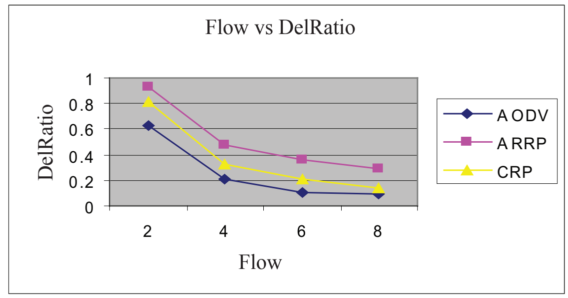

Figure 4. Flow Vs Delivery Ratio

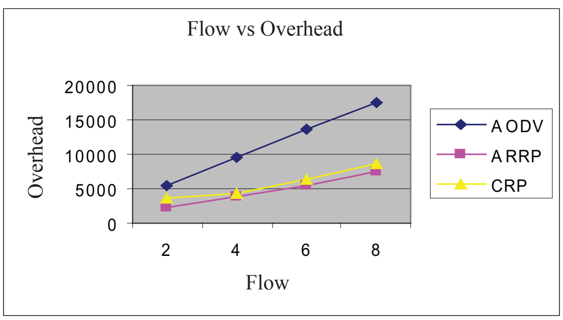

Figure 5. Flow Vs Overhead

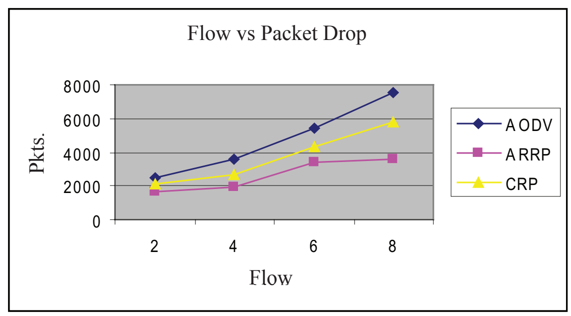

Figure 6. Flow Vs Packets Drop

Figure 3 shows the results of average end-to-end delay for the flows 2, 4….8. From the results, we can see that ARRP scheme has significantly lower delay than the other schemes CRP and AODV. Figure 4 shows the results of average packet delivery ratio for the varying flows scenario. Clearly our ARRP scheme achieves more delivery ratio than the other schemes CRP and AODV, since it has reliability features. Figure 5 shows the results of routing overhead for the flows 2, 4….8. From the results, we can see that ARRP scheme has less routing overhead than the other schemes, since it does not involve route re-discovery routines. Figure 6 shows the results of packet drop for the flows 2, 4….8. From the results, we can see that the less packets dropped in ARRP than the other schemes, since it has reliability features.

4.3.2 Effect of Varying Nodes

Initially we fix the number of nodes which vary as 50, 75, 100, 125 and 150.

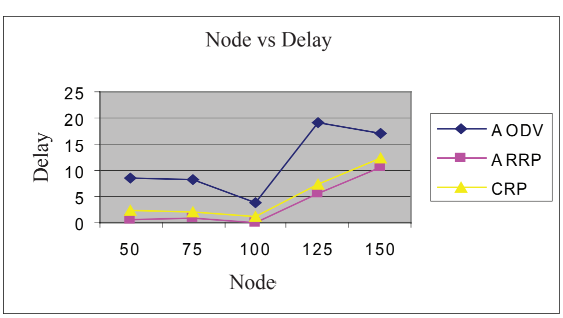

Figure 7. Node Vs Delay

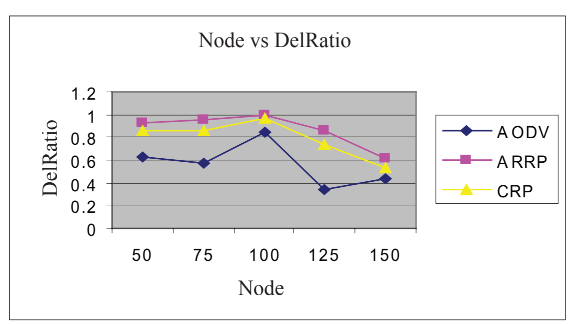

Figure 8. Node Vs Delivery Ratio

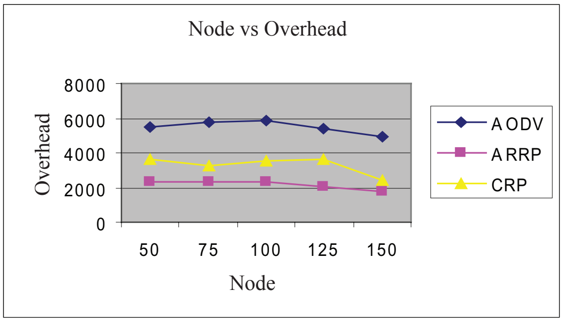

Figure 9**.** Node Vs Overhead

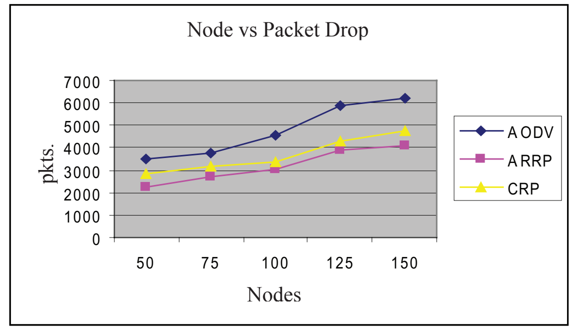

Figure 10. Node Vs Packets Drop

Figure 7 shows the results of average end-to-end delay for the nodes 50, 75….150. From the results, we can see that ARRP scheme has significantly lower delay than the other schemes CRP and AODV. Figure 8 shows the results of average packet delivery ratio for the varying nodes scenario. Clearly our ARRP scheme achieves more delivery ratio than other schemes CRP and AODV, since it has both reliability the reliability features. Figure 9 shows the results of routing overhead for the nodes 50, 75….150. From the results, we can see that ARRP scheme has less routing overhead than the other schemes, since it does not involve route re-discovery routines. Figure 10 shows the results of packet drop for the nodes 50, 75….150. From the results, we can see that the packets dropped are less in ARRP than the other schemes, since it has reliability features.

5. Conclusion

When a node does not have enough received signal strength, then it believes that the link will break within a short period of time Based on this documentation, we have proposed an Adaptive Reliable Routing protocol for ad hoc networks. When a link is likely to be broken, the previous node will cache the subsequent packets in its data buffer. When a link failure occurs, the upstream node with the cached data in its buffer can retransmit it through the next reliable link by using a bypass route. By simulation results, we have shown that the proposed reliable routing protocol achieves high delivery ratio with reduced delay and overhead. We plan to extend the study with more experimental features so that the results will yield more reliability.

References

[1] Perkins, Charles E., Royer, Elizabeth M. (1999). Ad-hoc On-Demand Distance Vector Routing, *In: Proceedings of 2nd IEEE Workshop on Mobile Computing Systems and Applications*, p: 90- 100, New Orleans, LA, USA.

[2] Johnson, David B., Maltz, David (1996). A Dynamic Source Routing in Ad Hoc Wireless Networks, *In: Proceedings of International Series in Engineering and Computer Science*, V. 353, p. 153- 181.

[3] Hou, Xiaobing., Tipper, David (1990). Impact of Failures on Routing in Mobile Ad Hoc Networks Using DSR, *In: Proc. of IEEE Journal on Selected Areas in Communications*, 8 (9) 1696-1708.

[4] Hassanein, Hossam., Zhou, Audrey (2001). Routing with Load Balancing in Wireless Ad hoc Networks, *In: Proc. of the 4th ACM International Workshop on Modeling, Analysis and Simulation of Wireless and Mobile Systems*, p. 89- 96, Rome, Italy.

[5] Kabary, Ihab El., Elnahas, Amal., Ghoniemy, Said (2006). Weighted Critical Path Routing Protocol for Mobile Ad Hoc Networks, *In: Proc. of International Conference on Wireless Information Networks and Systems*, Portugal.

[6] Chen, Lei., Heinzelman, Wendi B. (2005). QoS-Aware Routing Based on Bandwidth Estimation for Mobile Ad Hoc Networks, *In: Proceedings of IEEE Journal on Selected Areas in Communications*, 23 (3).

[7] Xu, Kaixin., Tang, Ken., Bagrodia, Rajive., Gerla Mario., Bereschinsky, Michael (2003). Adaptive Bandwidth Management and QoS Provisioning in Large Scale Ad Hoc Networks, *In: Proceedings of IEEE Conference on Military Communications*, V. 2, p. 1018- 1023, 13- 16.

[8] Gerharz, Michael., Waal, Christian de and Matthias Frank., James, Paul (2003). A Practical View on Quality-of-Service Support in Wireless Ad Hoc Network, *In: Proc. of the 3rd IEEE Workshop on Applications and Services in Wireless Networks (ASWN)*, p. 185-196, Berne, Switzerland.

[9] Geetha, Jayakumar., and Ganapathy, Gopinath (2007). Performance Comparison of Mobile Ad-hoc Network Routing Protocol, *In: Proc. of International Journal on Computer Science and Network Security*, 7 (11).

[10] Ahvar, E., Fathy, M (2007). Performance Evaluation of Routing Protocols for High Density Ad Hoc Networks based on Energy Consumption by GlomoSim Simulator, *In: Proceedings of World Academy on Science, Engineering and Technology*, 23.

[11] Liu, Changling., Kaiser, Jorg (2005). A Survey of Mobile Ad Hoc network Routing Protocols, Technical Report, University of Magdeburg.

[12] Tran, Duc A., Raghavendra, Harish (2006). Congestion Adaptive Routing in Mobile Ad Hoc Networks, *IEEE Transactions on Parallel and Distributed Systems*, 17 (11).

[13] Xue, Jianbo., Stuedi, Patrick., Alonso, Gustavo (2003). ASAP: An Adaptive QoS Protocol for Mobile Ad Hoc Networks, *In*: *14th IEEE proceedings on Personal, Indoor and Mobile Radio Communications*, V. 3, p. 2616- 2620.

[14] Valera, Alvin C., Winston, K. Seah, G., Nageswara Rao, S. V. (2005). Improving Protocol Robustness in Ad Hoc Networks through Cooperative Packet Caching and Shortest Multipath Routing, *IEEE Transactions On Mobile Computing*, 4 (5).

[15] Ramachandran, B., Shanmugavel, S (2009). Received Signal Strength-based Cross-layer Designs for Mobile Ad Hoc Networks, *IJCSNS International Journal of Computer Science and Network security*, 9 (1).

[16] Zhang, Yihai., Gulliver, Aaron (2005). Quality of Service for Ad hoc On-demand Distance Vector Routing, *IEEE International Conference on Wireless And Mobile Computing, Networking And Communications*, V. 3. p. 196.

[17] Patil, Rekha., Damodaram, A (2008). Cost Based Power Aware Cross Layer Routing Protocol for MANET, *IJCSNS International Journal of Computer Science and Network Security*, 8 (12).

[18] Venkat Reddy, E. (2010). Trustworthy Robust Routing Protocol for Mobile Ad Hoc Network, *International Journal of Engineering Science and Technology* 2 (2) 77-86.

Authours Biography

Mr. R. Vadivel is a Assistant Professor in the School of Computer Science and Engineering, Bharathiar University, Coimbatore, Tamilnadu, India. He obtained his Diploma in Electronics and Communication Engineering from State Board of Technical Education in the year 1999, B.E. Degree in Computer Science and Engineering from Periyar University in the year 2002 and M.E. degree in Computer Science and Engineering from Annamalai University in the year 2007.He is currently pursuing Ph.D degree, working closely with **Prof&Dr.V.Murali Bhaskaran**. He has published 4 papers in Conferences both at National and International level. He is a life member of ISTE, CSI and ACS, IAENG. Also he is an Associate Member of the Institution of Engineers (India) AMIE. His areas of interest include Computer Networks, Network Security, Information Security, etc.,

Dr. V. Murali Bhaskaran is a Principal of Paavai College of Engineering, NH-7, Pachal, Namakkal, Taminadu, India. He obtained his B.E. Degree in Computer Science and Engineering from Bharathidasan University in the year 1989, M.E. degree in Computer Science and Engineering from Bharathiar University in the year 2000 and secured University III rank and Ph.D in Computer Science and Engineering from Bharathiar University in the year 2008. He has published 4 papers in Journals and 12 papers in Conferences both at National and International level. He is a life member of ISTE, CSI and ACS. Also he is a fellow member in IE (FIE). His areas of interest include Computer Architecture, Computer Networks, Network Security, Information Security, etc.,