SNR/RP AWARE ROUTING ALGORITHM: CROSS-LAYER DESIGN FOR MANETS

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ABSTRACT

Routing in MANET is complex due to the fact that the network graph is episodically connected and nodes get only intermittently connected because of nodes mobility, terrain, weather, and jamming that change topology rapidly. In this paper, we propose cross-layer design to achieve a reliable data transmission in MANET. A key challenge is to create a mechanism that can provide good delivery performance and high quality of service in intermittent networks. The key components of our approach include a cross-layer design (CLD) to improve information sharing between different protocol layers. In order to improve the end-to-end performance of MANET, we present mechanism that allows the network layer to adjust its routing protocol dynamically based on SNR and Received Power along the end-to-end routing path for each transmission link. We evaluate our approach using one of common MANET routing protocols, DSR, to illustrate that our CLD improved the performance of DSR.

KEYWORDS

Cross Layer Design, Mobile Ad-Hoc Networks, Routing Protocols, QoS, SNR & OPNET.

1. INTRODUCTION

A Mobile Ad hoc Network (MANET) is a dynamic wireless network with or without fixed infrastructure. Nodes may move freely and arrange themselves randomly. The contacts between nodes in the network do not occur very frequently. As a result, the network graph is rarely, if ever, connected and message delivery required a mechanism to deal with this environment [1] Routing in MANET using the shortest-path metric is not a sufficient condition to construct high-quality paths, because minimum hop count routing often chooses routes that have significantly less capacity than the best paths that exist in the network. [2]

Most of the existing MANET protocols optimize hop count as building a route selection. Examples of MANET protocols are Ad hoc On Demand Distance Vector (AODV) [3], Dynamic Source Routing (DSR) [4], and Destination Sequenced Distance Vector (DSDV) [5]. However, the routes selected based on hop count alone may be of bad quality since the routing protocols do not ignore weak quality links which are typically used to connect to remote nodes. These links usually have poor signal-to-noise ratio (SNR), hence higher frame error rates and lower throughput. [6], [7].

The wireless channel quality among mobile nodes is time varying due to fading, Doppler Effect and pathloss. Known that the shortest-path metric does not take into account the physical channel variations of the wireless medium, it is desirable to choose the route with minimum cost based on some other metrics which are aware of the wireless nature of the underlying physical channel. In MANET, there are many other metrics to be considered: Power, SNR, Packet Loss, Maximum available bandwidth etc. These metrics should come from a cross-layer approach in order to make the routing layer aware of the local issues of the underling layers. [8].

The ability of MANET to provide acceptable quality of service (QoS) is restricted by the ability of the underlying routing protocol to provide consistent behavior despite the inherent dynamics of a mobile computing environment. [9] [10].

Cross-Layer Design has enormous potential in wireless communication systems. By using Cross Layer Design (CLD) we try to offer dedicated QoS for dedicated applications.

Our objective is to design a mechanism to provide an efficient QoS routing protocol to enhance the performance of existing routing protocols in Mobile ad hoc network environment.
In this paper we select DSR as one of the common MANET protocols to demonstrate our two models, Signal to noise Ratio (SNR) and Received Power (RP), to enhance the quality of service of the DSR. We evaluate how the protocol differ in the methods it uses to select paths, detect broken links, and buffer messages during periods of link outage. Our new approach is called Signal to Noise Ratio/Received Power Aware Routing Algorithm (SNR/RP). We computed differences in terms of packet delivery ratio, throughput, end-to-end latency, and mechanism overhead. We show that the performance of DSR protocol improved by using the proposed model.

The rest of this paper is organized as follows: Sec. 2 discusses related work. Sec. 3 gives background about DSR. Sec. 4 presents the proposed cross layer design and model optimization. Sec. 5 discusses simulation environment setup. Sec. 6 discusses simulation results and finally Sec. 7 concludes the paper and Sec. 8 presents our future work.

2. RELATED WORK

Many proposals and models addressed quality of service (QoS) among mobile nodes of the wireless networks and considered the link quality in their designs and architectures. Wisitpongphan and et al. [11] proposed a bit error rate (BER)-based routing design, where the chosen route is the one which guarantees the lowest BER at the ending node. They considered providing QoS in terms of BER at the destination node.

[12] presented a mechanism to improve both the routing and data forwarding performance of DSR, with lesser power consumption. This mechanism involves intelligent use of the route discovery and route maintenance process thereby providing faster routing and reduced traffic as compared to the basic DSR. This mechanism enables faster data forwarding and reduced collisions with lesser power consumption.

In [8] authors modified DSR to work as three-state Markov model of the wireless channel instead of two-state Markov model (Gilbert-Elliot model) by applying a higher order of Markov chains. They applied their model to the Dynamic Source Routing protocol (DSR). In their proposed modified DSR, both the route discovery and route selection are based on physical layer parameter and the link monitoring function located at each node.

Authors in [13] proposed a simple extension of DSR. They presented a model to reduce routing overhead in request process and the anycast group management protocol is discussed.

3. BACKGROUND

DSR stands as one of the common representatives of reactive routing protocols like all On-Demand routing algorithms, Ad Hoc On-Demand Distance Vector (AODV), Dynamic MANET On-demand (DYMO). DSR applies source routing rather than hop-by-hop routing, in which each packet to be routed carrying in its header the full ordered list of nodes through which the packet should pass. The key benefits of source routing is that intermediate nodes do not need to maintain up-to-date routing information in order to route the packets they forward, since the packets themselves already contain all the routing decisions. This fact, coupled with the on-demand nature of the protocol, eliminates the need for the periodic route advertisement and neighbor detection packets present in other protocols. [14]

In DSR source node generates a route request packet when it has a new route to a destination. The route request is flooded through the network until it reaches some nodes with a route to that destination. See figures 1 and 2.

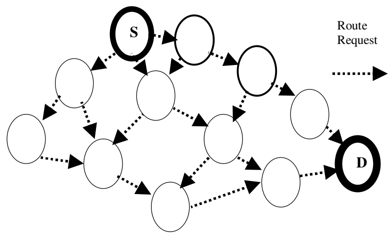

Figure 1. S sends Route Request to D

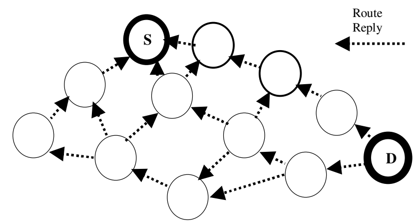

Figure 2. D sends Route Reply to S

Each route request packet holds the information of the route it has propagated. When the route request packet arrives at the destination or an intermediate node with a route to the destination, a route reply packet will be generated. This reply packet is then sent back to the source node following the reverse route contained in the route request packet. While transmitting the data traffic, the complete path is added to each data packet according to the routing table of the source node. The intermediate nodes forward packets according to the path provided in the packet. See figure (1.b).

More clearly, in DSR routing protocol to send route reply packet, when current route breaks, destination seeks a new route. In this paper we try to change route selection mechanism. We also define a signal to noise Ratio and received power parameters as new metrics in which those values are added to the route reply packet. Given those features, source node can select the best and more stable route out of various available routes based on Signal to Noise Ratio (SNR) or Received Power (RP). Therefore we can improve the Quality of service (QoS) and the performance of the routing protocols in MANET environment.

4. SNR/RP AWARE ROUTING ALGORITHM (BEST OF WORSE END-TO-END ROUTING PATH)

Routing in MANET is difficult as a result of the dynamic nature of network topology and the resource constraints. The issue of Link reliability in mobile ad hoc networks is a main problem to transmit messages through the wireless channels. Routing in multi-hop wireless networks using the shortest-path metric is not an adequate condition to build good quality paths, because minimum hop count routing often selects paths that have significantly less capacity than the best paths that exist in the network. [2]

Physical-layer limits of wireless channel because of: time-varying fading, multipath, co-channel interference, hostile jamming, mobility, dynamic network topology.

In technicality, information from the transmission links, such as Signal to Noise Ratio (SNR) and Received Power (RP), can furnish valuable information to the source node about the transmission paths as far as routing is concerned. Each wireless node can communicate with any other node within its transmission range, which depends on SNR and RP at the receiver node.

We modified the route reply packet format and added two extra fields in the packet format to store the worst value of power strength (received power strength) and worst value of SNR (signal-to-noise ratio) along the route from destination to source. See figure 3.

<table>
<tr><td>Next Header
(8 bits)</td><td colspan="2">Reserved
(8 bits)</td><td colspan="2">Payload Length
(16 bits)</td></tr>
<tr><td>Options
(0 bits)</td><td>data
(0 bits)</td><td colspan="2">SNR
(8 bits)</td><td>Received Power
(8 bits)</td></tr>
</table>

Figure 3: Modified Route Reply packet format of DSR including metrics of SNR and RP.

Section 3 illustrated how original DSR works. We modified also the mechanism of DSR process to include our SNR/RP model. The new mechanism will works as follows: when the route request packet arrives at the destination or an intermediate node with a route to the destination, a route reply packet will be generated. This reply packet is then sent back to the source node following the reverse route contained in the route request packet. Each intermediate node will update the SNR and RP values if its link values of SNR and RP lower than the existing recorded values in the route reply packet. If SNR/RP values of its link are greater than recorded value, the node will not update the value. The process will continue until the route reply packet reach the source node. Now, at the source node there are many of available routes with different values of SNR and RP. The Source node will select the route based on the value of best of worse available values of SNR or RP. Figure 4 demonstrates the flow chart of how modified DSR routing protocol works after implementing the SNR/RP model. Dotted-line areas in the figure represents new process.

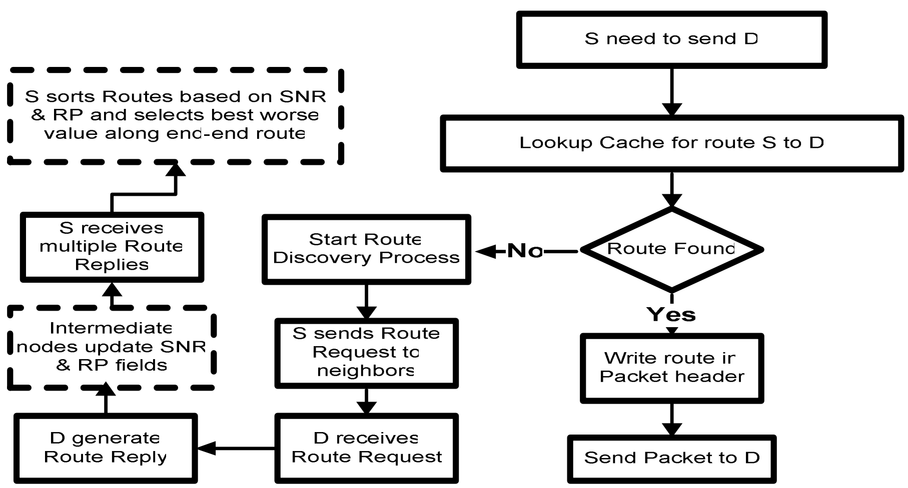

Figure 4. Flow chart shows how SNR/RP model works with DSR.

Figure 5 illustrates the mechanism of our new approach, SNR/RP aware routing algorithm when it applies to DSR routing protocol. The values on links represent the values of Signal to Noise Ratio of the link or values of received power of the link. When node S needs to send a packet to node R. Node S sends 2 route request packets along path 1 and path 2. Node R generates 2 route reply packets to node S along the reverse routes of paths 1 and 2. Now, at node S there 2 available routes to destination R, path 1 with 5 hops but the lowest value of SNR or RP found in the end-to-end path is 3, and path 2 with 4 hops but the lowest value of SNR or RP found in the end-to-end path is 2. Source node S will sort the two routes and select path 1 based on our new mechanism since the best worse value of path 1 is 3 is grater than the worse value of the other path which is 2. Traditional DSR protocol will select Path 2 that has minimum number of hops eventhough the path has low-quality of service.

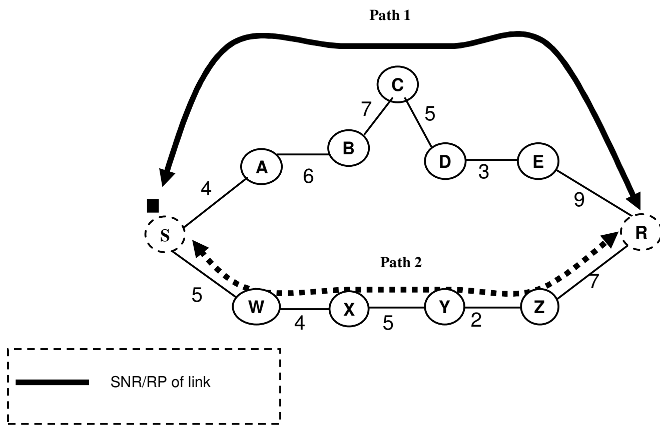

Figure 5: Scenario shows that modified DSR with SNR/RP will select path 1 (High QoS) rather than path 2 (minimum number of hops).

Wireless channels have high channel bit error rate and limited bandwidth. The high bit error rate degrades the quality of transmission and the network performance. A routing protocol that can not quickly recover from link breakage caused by mobility renders a QoS model incapable of meeting delivery requirements. [9]. Implementing our model will guarantee the Quality of service in the environment of MANET where is QoS is low. Any routing protocol should be smart enough to pick a stable and good quality communication route in order to avoid any unnecessary packet loss.

Routing in MANET is challenging due to the dynamic nature of network topology and the resource constraints. In our model, we create a mechanism that can provide good delivery performance and high quality of service in MANET environment that characterized with intermittent network and episodically connected and nodes get intermittently connected because of nodes mobility, terrain, weather, and jamming to reach a reliable data transmission.

5. SIMULATION ENVIRONMENT

The cross-layer algorithm described above was implemented and evaluated in OPNET v 14.5 simulator [15]. Table 1 shows the parameters used in our simulation.

The fading modules contributed in [16] are included into account. The modulation, BPSK, compute the BER under fading condition from the loop-up tables. We calculate the Doppler shift velocity according to the ground speed, pitch, and yaw of the transmitting node and the receiving node. Look up the fading amplitude according to the Rician K=5 factor. [17]. We considered in our network topology to include fading, Doppler effect, various speed mobility.

Table 1: simulation setup

Parameters	**Value**
Network Size	3 x 3 Km
Modulation Scheme	BPSK
Traffic rate	11 Mbps
Transmit Power	35 mW
Packet Reception-Power Threshold	-75 dBm
Mobility model	Random-Waypoint
Propagation–Path loss	Free space
Propagation fading model	Rayleigh, Rician
Rician K Factor	5
MAC protocol	802.11
Packet size	1024 bits
Routing protocol	DSR
Carrier frequency	2.4 GHz
Nodes number	80
Transmission Range	300 - 400 m
Speed of nodes	3, 6, 9, 12 m/s

6. RESULTS

Simulation results show that according to the channel quality, the delay, received data and throughput show significant improvement in performance when compared to traditional DSR. Our results indicate that the cross-layer design using the model of Signal to Noise Ratio SNR aware routing algorithm provides a better improvement in the Quality of Service when compared to the traditional DSR routing protocol and the Received Power (RP) aware routing algorithm improved the performance of traditional DSR.

It is immediately evident from the results given in figures 6-11 that our SNR/DSR model improved the performance of traditional DSR.

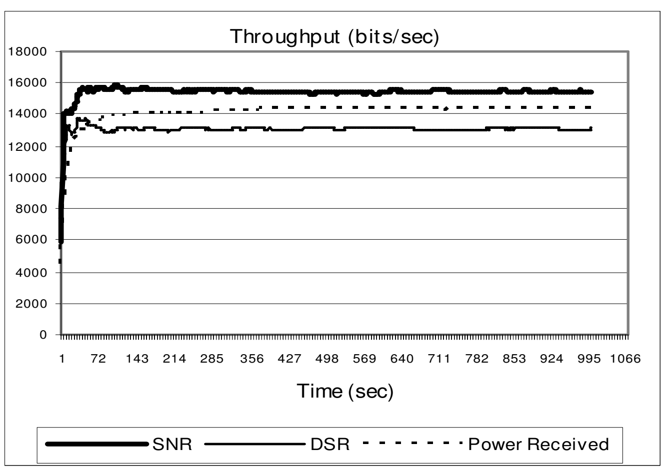

Figure 6. SNR & RP models improve the throughput

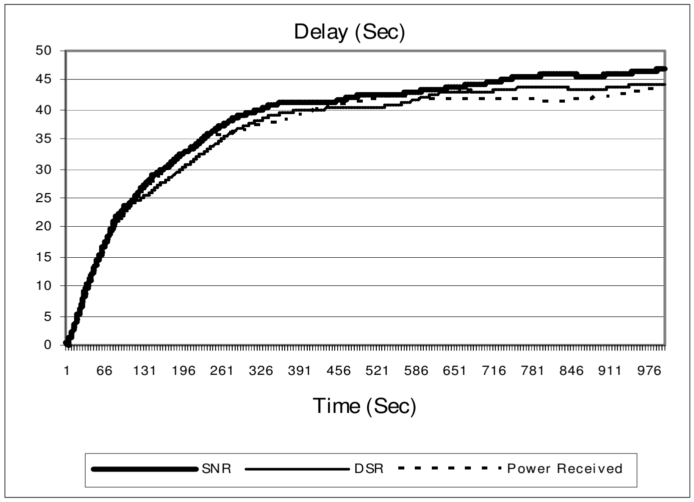

Figure 7. RP model reduces the delay

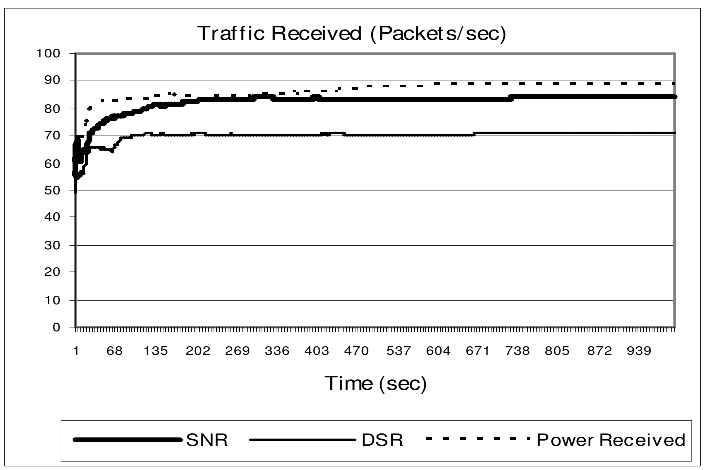

Figure 8. RP & SNR models improve the delivery rate

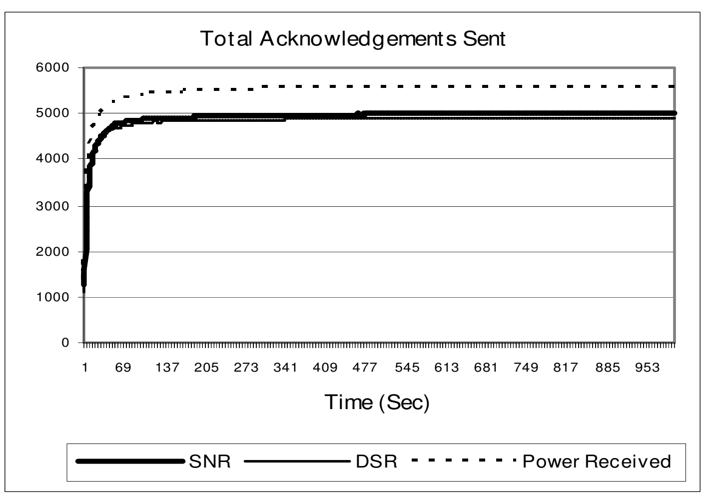

Figure 9. RP & SNR models increase number of ACKs sent

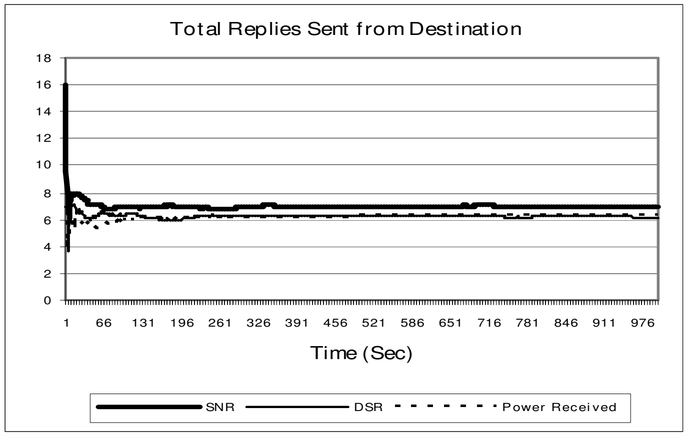

Figure 10. SNR & RP models improve numbers of destination's repliers

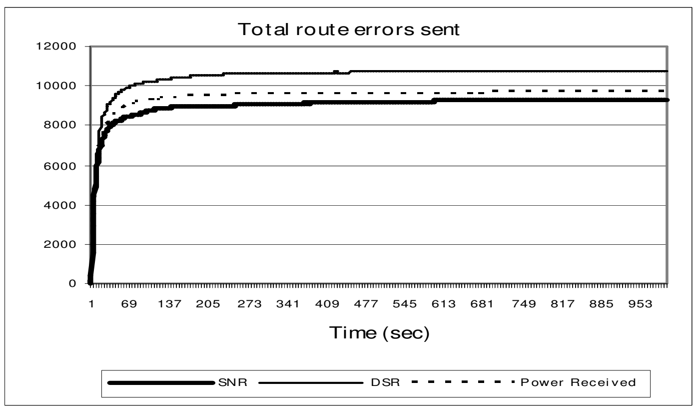

Figure 11. SNR & RP models reduced number of errors sent

7. DISCUSSION AND CONCLUSIONS

In this work, we modified the DSR protocol to choose routes according to the Signal to Noise Ratio (SNR) or a Received Power (RP) criterion which is characterized with the best value of SNR or RP of the weakest link along the route from destination to source to eliminate the routes with bad links that has very low SNR and to improve QoS. We have presented our recent results of the SNR/RP aware routing design to achieve reliable communication in networks associated with intermittent connectivity. The challenge was to find a routing design that can deal with dynamic environment causing networks to split and merge, considering nodes mobility, fading, and Doppler Effect. Simulation results show that our model achieved better performance than traditional DSR protocol in terms of delivery rate, delay, throughput over intermittent network.

8. FUTURE WORK

We intend to continue on developing the proposed model and provide a detailed analytical as well as simulation-based study. Our future work will complete the research to implement SNR/RP aware routing design on AODV, GRP, TORA and OLSR. Also, we will study and analyze the impact of the physical layer parameters on the performance of the Delay Tolerant Network (DTN)-based probabilistic routing protocols. We will design a cross-layer frame assists information exchanges between different network layers, expedites upper layers' response to quick changes of physical links and outside environment, and helps to optimize link selections in MANET using DTN routing protocols. Our future work will complete the research by implement DTN based routing algorithms in Aerial/terrestrial Airborne Network environment.

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REFERENCES

[1] Fuad Alnajjar, Tarek Saadawi, “Social-stratification Probabilistic Routing Algorithm in Delay-Tolerant Networks”, The International Conference on Wireless Algorithms, Systems and Applications (WASA'09), Boston, MA, August 2009, Pages: 579–591.

[2] Wing Ho Yuen, Heung-no Lee and Timothy D. Andersen “A Simple and Effective Cross Layer Networking System for Mobile Ad Hoc Networks”, in: PIMRC 2002, vol. 4, September 2002, pp. 1952-1956

[3] C. E. Perkins and E. M. Royer, “Ad-hoc on-demand distance vector routing,” in Proc. IEEE Workshop on Mobile Comp. Sys.and Apps., Feb. 1999, pp. 90-100.

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

[5] C. E. Perkins and P. Bhagwat, “Highly dynamic destinationsequenced distance-vector routing (DSDV) for mobile computers“, Computer Communications Review, pp. 234-244, Oct.1994.

[6] H.M. Tsai, N. Wisitpongphan, and O.K. Tonguz, “Link-Quality Aware AODV Protocol,” in *Proc. IEEE International Symposium on Wireless Pervasive Computing (ISWPC) 2006*, Phuket, Thailand, January 2006

[7] E. Royer and C.-K. Toh, "A Review of Current Routing Protocols for Ad Hoc Mobile Wireless Networks," IEEE Personal Communications Magazine, vol. 6, No. 2, April 1999.

[8] Merlinda Drini & Tarek Saadawi .”Modeling Wireless Channel for Ad-Hoc Network Routing Protocol”, ISCC Marakech Marocco, July 2008, Page(s): 549-555

[9] John Novatnack , Lloyd Greenwald & Harpreet Arora, “Evaluating ad hoc routing protocols with respect to quality of service”, Wireless And Mobile Computing, Networking And Communications, 2005. Volume 3, 22-24 Aug.2005, Pages: 205-212

[10] Frank Aune “Cross-Layer Tutorial” NTNU 2004

[11] N. Wisitpongphan, G. Ferrari, S. Panichpapiboon, J.S. Parikh, and O.K. Tonguz, "QoS provisioning using BER-based routing for ad hoc wireless networks", IEEE Vehicular Tech. Conf. (VTC Spring 2005), PP. 2483-2487.

[12] Arun kumar .B.R, C. Lokanatha Reddy and P.S. Hiremath, “High performance Modified DSR with Power Consumption Optimization for Mobile Adhoc Networks.” IJCSNS International Journal of Computer Science and Network Security, VOL.7 No.5, May 2007.

[13] Vivek Gulati, Aman Garg and Nitin Vaidya, “Anycast in Mobile Ad Hoc Networks,” Technical Report, Texas A&M University, April 2001.

[14] Josh Broch, David A. Maltz, David B. Johnson, Yih-Chun Hu, Jorjeta Jetcheva, "A Performance Comparison of Multi-HopWireless Ad Hoc Network Routing Protocols", Proc. of the Fourth Annual ACM/IEEE International Conference on Mobile Computing and Networking (MobiCom'98),October 25–30, 1998, Dallas, Texas, USA.

[15] The OPNET simulator www.opnet.com

[16] R. J. Punnoose, P. V. Nikitin, and D. D. Stancil. "Efficient simulation of ricean fading within a packet simulator". September 2000. Code available at http://www.ece.cmu.edu/wireless/downloads/ns2 ricean dist.tgz.

[17] Theodore Rappaport, Wireless Communications: Principles and Practice, Prentice Hall PTR, Upper Saddle River, NJ, 2001

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