SNR/RP Aware Routing Model for MANETs

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Abstract—Design a service-quality aware routing algorithm in mobile ad hoc network (MANET) is difficult due to the nature of the environment where nodes are mobile and connectivity is intermittent that change topology rapidly. In this work, we propose cross-layer design to attain a reliable data transmission in MANET. In MANET environment challenge is to design a mechanism that can provide high quality of service with a high level of performance or to achieve service quality in terms of high delivery rate, low latency and low bit error. The key components of our approach include a cross-layer design (CLD) to improve information sharing between network and physical layers. We present a model that allows the network layer to adjust its routing protocol dynamically based on signal noise ratio (SNR) and received power (RP) along the end-to-end routing path for each transmission link to improve the end-to-end routing performance in MANET. We evaluate our model using well known MANET - routing protocols: AODV, DSR, OLSR to illustrate that our CLD improved their performances with respect to service quality. We analyze their performance in terms of: packet delivery rate, average end-to-end delay and overhead.

Index Terms—Cross Layer Design, MANET, Routing Protocols, QoS, SNR & OPNET.

I. 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 to build a route selection. Examples of MANET protocols are Ad hoc On Demand Distance Vector (AODV) [3], Dynamic Source Routing (DSR) [4], and Optimized Link State Routing Protocol (OLSR) [5]. However, the routes selected based on hop count alone may be characterized with 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 taking into account: 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 AODV, DSR and OLSR as common MANET routing protocols to demonstrate our two models, Signal to noise Ratio (SNR) and Received Power (RP), to enhance the quality of service of those protocols. We evaluate how the protocols differ in the methods they use 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 overhead. We show that the performances of AODV, DSR, and OLSR protocols improved by using the proposed model.

The rest of this paper is organized as follows: Section II discusses related work. Section III gives background about selected routing protocols. Section IV presents the proposed cross layer design and model optimization. Section V discusses simulation environment setup. Section VI discusses simulation results and finally Section VII concludes the paper and Section. VIII presents our future work.

II. 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.

In [18] work proposes using of link lifetime and channel quality as metrics in the selection of routes. They applied the model to the Optimized Link State Routing (OLSR) routing protocol and focused on multipoint relay (MPR) selection method, to find the most optimal routes between any pair of nodes.

III. MANET ROUTING PROTOCOLS

In MANET the entire network is mobile where nodes move freely and topology is changing rapidly because of weather, terrain, highly variable delay links and error rate links. Nodes may not be able to communicate directly and have to rely on each other in order to deliver packets. The contacts between nodes in the network do not occur very frequently that makes routing difficult because the network graph is episodically connected. A lot of routing algorithms have been proposed for MANET environment and some of them have been widely used. [19-20].

In this section we review AODV, DSR and OLSR as selected MANET routing used in our design evaluation.

Ad Hoc On-demand Distance Vector Routing (AODV) protocol [3] is a reactive routing protocol. As a reactive routing protocol, it maintains only routing information about the active paths. Every node uses hello messages to notify its existence to its neighbors and maintains routing information in their routing tables to keep a next-hop routing table that contains the destinations to which it has a route. In AODV, when a source node wants to send packets to the destination but no route is available, it initiates a route discovery operation. In the route discovery operation, the source broadcasts route request (RREQ) packets. A RREQ includes addresses of the source and the destination, the broadcast ID, the last seen sequence number of the destination as well as the source node's sequence number. OLSR uses sequences numbers to ensure loop-free and up-to-date routes. Each RREQ has Time-to-Live (TTL) and nodes maintain a cache to keep track of RREQs it has received and discards any RREQ has seen before. When intermediate or destination node receives RREQ, it checks destination sequence numbers to what it knows. Then, the node creates a route reply (RREP) packet and forwards back to the source node only if the destination sequence number is equal to or greater than the one specified in RREQ. The RREP follows the reverse path of the respective RREP and intermediate nodes update their next-hop table entries with respect to the destination node. When a node discovers a link disconnection, it broadcasts a route error (RERR) packet to its neighbors, which in turn propagates the RERR packet towards nodes whose routes may be affected by the disconnected link. Then, the affected source can re-initiate a route discovery operation if the route is still needed. [20]

Dynamic Source Routing (DSR) [4] stands as one of the common representatives of reactive routing protocols like all On-Demand routing algorithms, 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. 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. 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. More clearly, in DSR routing protocol to send route reply packet, when current route breaks, destination seeks a new route. [14, 19- 21].

The Optimized Link State Routing protocol (OLSR) [5, 18] is a proactive routing protocol and operates as a table driven protocol. In OLSR, each node exchanges its link state information to all other nodes in the network and transmits its neighbor list regularly so nodes can know their two hops neighbors. Each node selects its multipoint relay (MPR) and the MPR nodes announce this information periodically using Topology control (TC) messages. When a node broadcasts a message, its neighbors will receive the message. The protocol uses MPRs to facilitate flooding of control messages and only the MPRs that have not seen the message before, rebroadcast the message in the network periodically. MPRs are used as intermediate nodes to route packets. Then, each node floods the link state information of its MPRs through the network and it obtains network topology information and constructs its routing table through link state messages. [20].

In this work we try to change route selection mechanism. We define a signal to noise ratio (SNR0 and received power (RP) parameters as new metrics in which those values are considered in constructing routes. 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) not number of hops or shortest path. In this work our aim is improving the Quality of Service (QoS) and the performance of the routing protocols in MANET environment.

IV. SNR/RP AWARE ROUTING MODEL

Routing in MANET is difficult due to 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.

In our work we used OPNET simulator [15]. We modified the packet formats in OPNET simulator of AODV (figure 1), DSR (figure 2) and OLSR (figure 3) and added two extra fields 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.

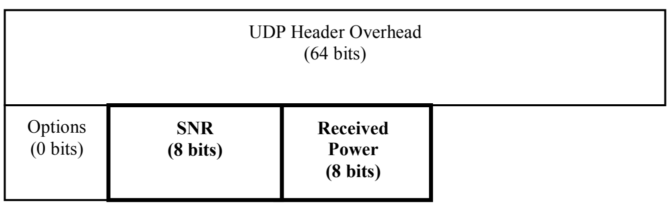

Figure 1: Modified Route Reply packet format in OPNET of AODV including metrics of SNR and RP.

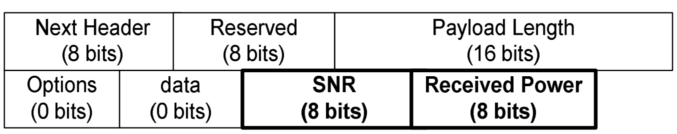

Figure 2: Modified Route Reply packet format of DSR including metrics of SNR and RP.

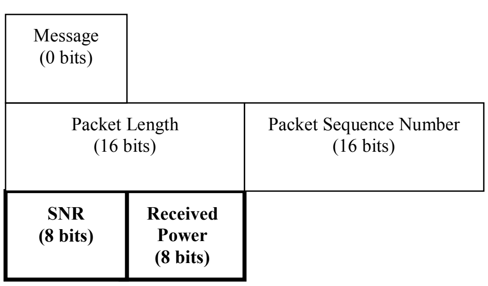

Figure 3: Modified packet format of OLSR to include metrics of SNR and RP.

Section 3 illustrated how original AODV, DSR and OLSR work. We modified also the mechanism of those routing protocols processes to include our SNR/RP model.

A. Modification in AODV and DSR (Reactive routing)

In case of DSR and AODV, the new mechanism will work 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 and AODV routing protocols work after implementing the SNR/RP model. Dotted-line areas in the figure represent new process. [21].

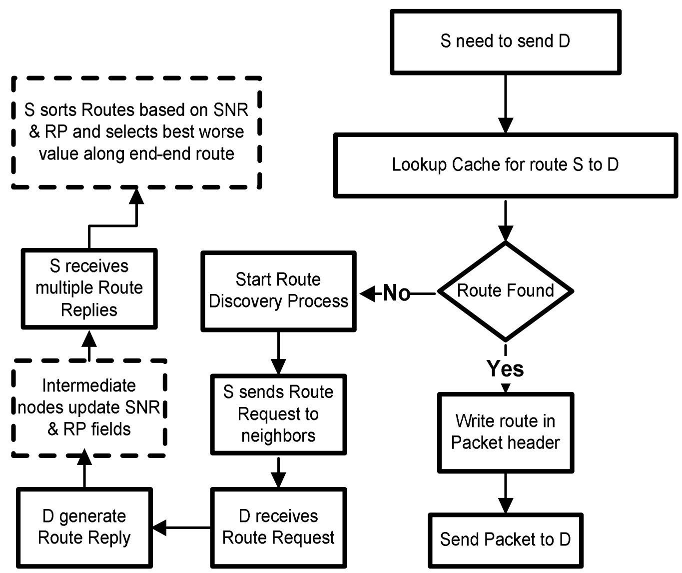

Figure 4. Flow chart shows how SNR/RP model works with DSR and AODV.

B. Modification in OLSR (Proactive routing)

Original OLSR uses hello and Topology Control (TC) messages to discover and exchange link state information throughout the network. Nodes compute next hop destination by using topology information received by neighbors considering shortest hop forwarding paths. OLSR makes use of "Hello" messages to find its one hop neighbors and its two hop neighbors through their responses. The sender node can then select its MPR based on the one hop node that offers the best routes to the two hop nodes.

In our SNR and RP model, we modified the selection process of MPR and makes nodes select MPR based on the SNR and RP values of each link connected to those MPR instead of the shortest paths. Modified OLSR constructs routing table for each node using the SNR/RP to guarantee the quality of service in the network.

Figure 5 illustrates the mechanism of our new approach, SNR/RP aware routing algorithm when it applies to DSR, AODV and OLSR routing protocols. 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, AODV and OLSR protocols will select Path 2 that has minimum number of hops eventhough the path has low-quality of service.

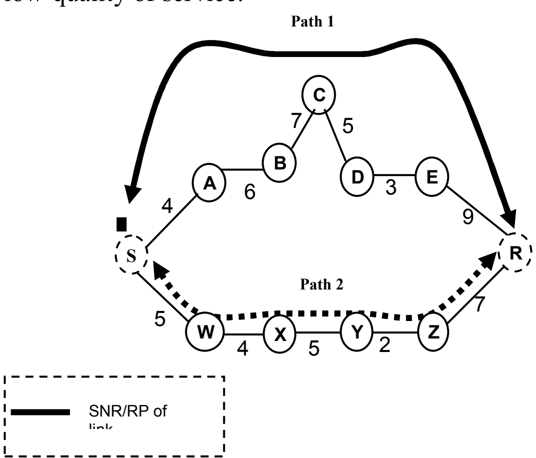

Figure 5: Scenario shows that modified DSR and AODV with SNR/RP will select path 1 (High QoS) rather than path 2 (minimum number of hops).

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 cannot 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.

V. Simulation Environment

Our cross-layer model described above was implemented and evaluated in OPNET v 14.5 simulator [15]. Figure 6 shows snapshot of our model used in OPNET simulator. 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 consider in our network topology to include fading, Doppler Effect, various speed mobility.

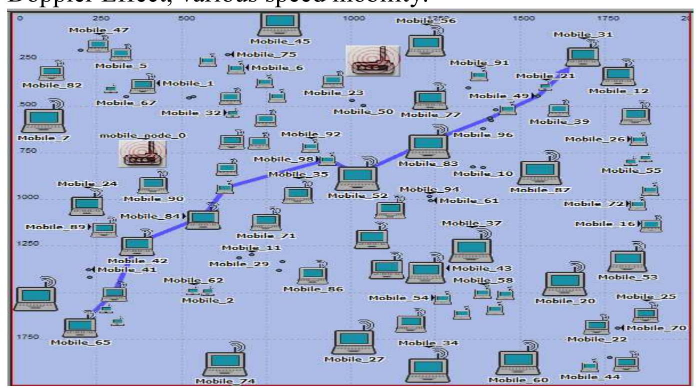

Figure 6. Snapshot of network design in OPNET simulator.

TABLE I
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	AODV, DSR, OLSR
Carrier frequency	2.4 GHz
Nodes number	100
Transmission Range	300 - 400 m
Speed of nodes	3, 6, 9, 12 m/s

VI. Results

Simulation results evaluate the performance of AODV, DSR and OLSR respectively, in terms of delay, traffic received, routing traffic received (overhead), throughput and retransmission attempts.

A. AODV evaluation

Figure7.1 shows that traditional AODV and AODV-SNR model provide good performance in terms of delay. Figure 7.2 illustrate that the RP model enhance the performance of traditional AODV and increase packet delivery in the network. 7.3 shows that overhead reduced in the network with implementing the SNR and RP model separately with AODV. In terms of MAC layer throughput performance, figure 7.4 shows that traditional AODV, SNR model and RP model provide same performance. Finally, figure 7.5 shows that the SNR model and RP model reduce the retransmission attempt in layer 2.

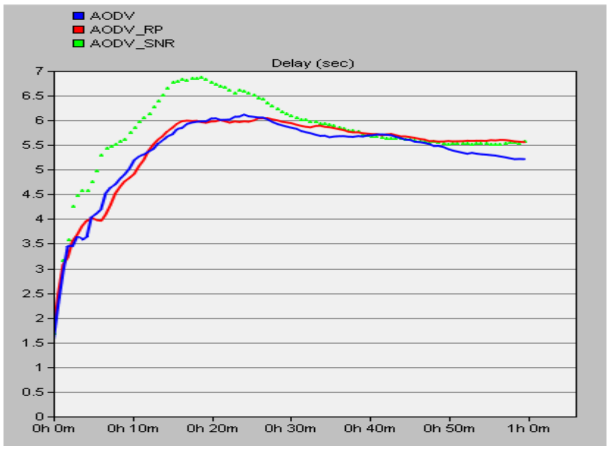

Figure 7.1. AODV and SNR model provide low delay in the network.

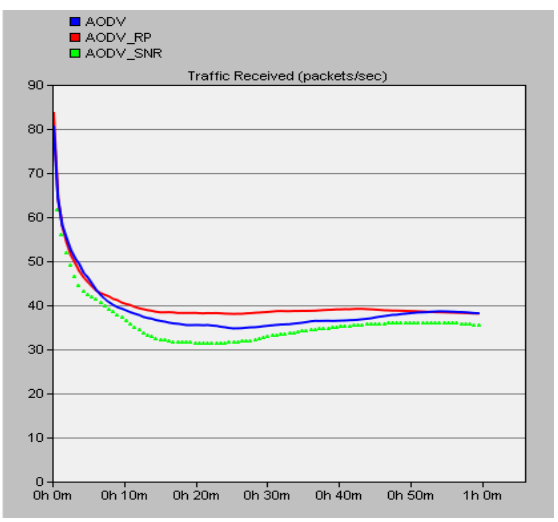

Figure 7.2. RP model increases the packet delivery.

B. DSR evaluation

It is immediately evident from the results given in figure 8.1 that delay reduced when SNR or RP models used. Figure 8.2 shows that the traditional DSR and RP model perform equally with respect to packet delivery in the network. 8.3 illustrates that overhead reduced in the network with implementing the SNR and RP model separately with DSR. In terms of MAC layer throughput performance, figure 8.4 shows that traditional RP model provide excellent performance. Finally, figure 8.5 illustrates that the SNR model and RP model reduce the retransmission attempt in layer 2.

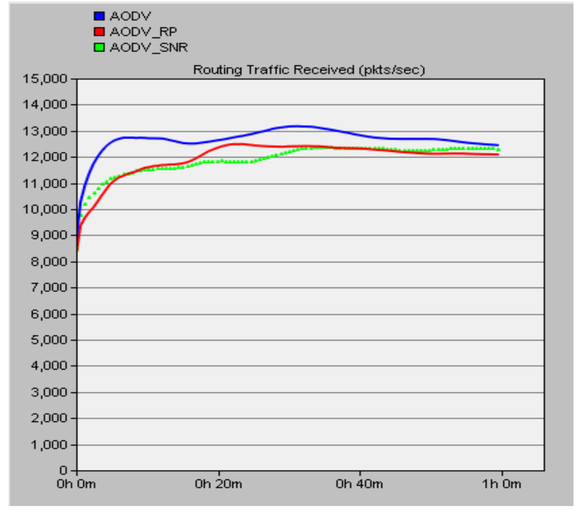

Figure 7.3. RP & SNR models reduce overhead

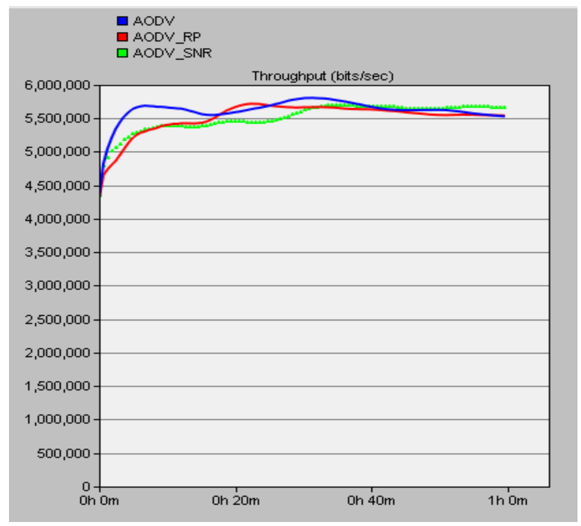

Figure 7.4. Traditional AODV, SNR and RP models have same throughput performance

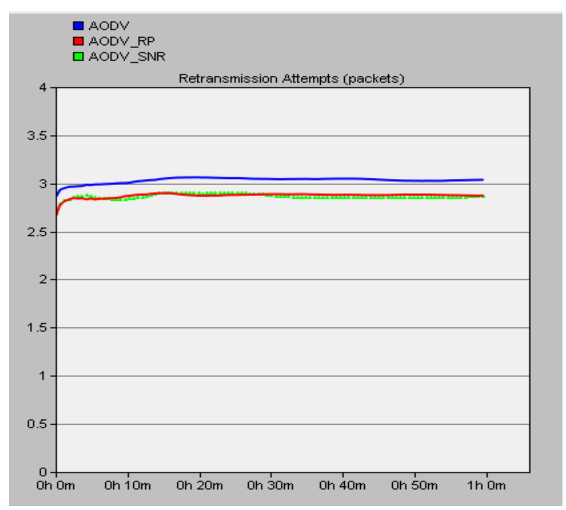

Figure 7.5. SNR & RP models improve numbers of destination's repliers

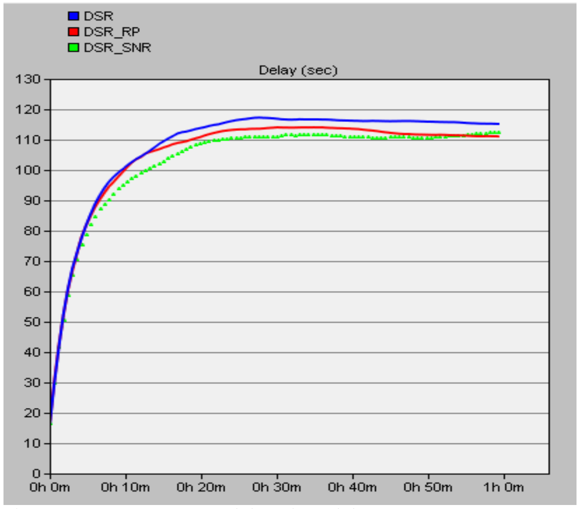

Figure 8.1. SNR & RP models reduce delay

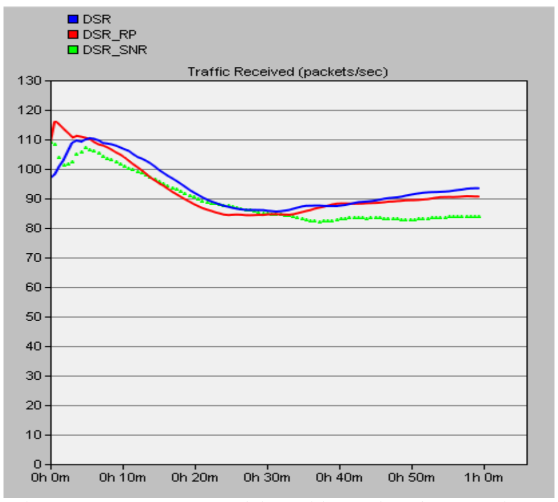

Figure 8.2. DSR & RP model provide good performance in terms of packet delivery

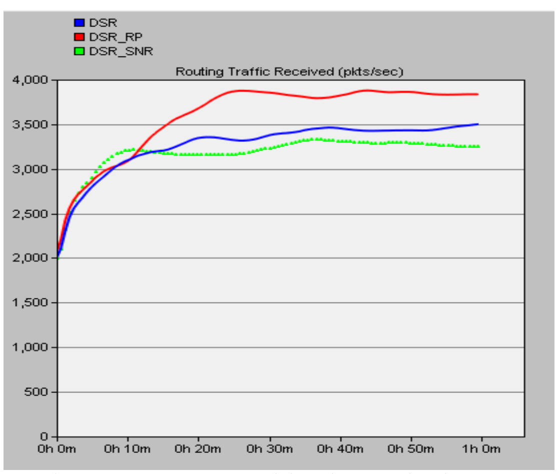

Figure 8.3. SNR & RP models reduce overhead

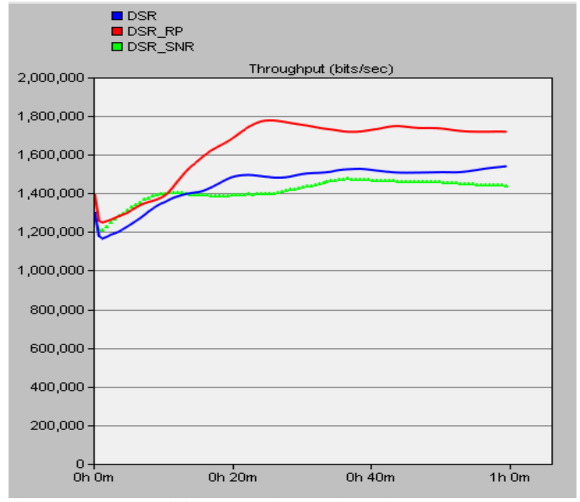

Figure 8.4. RP model increase layer 2 throughput

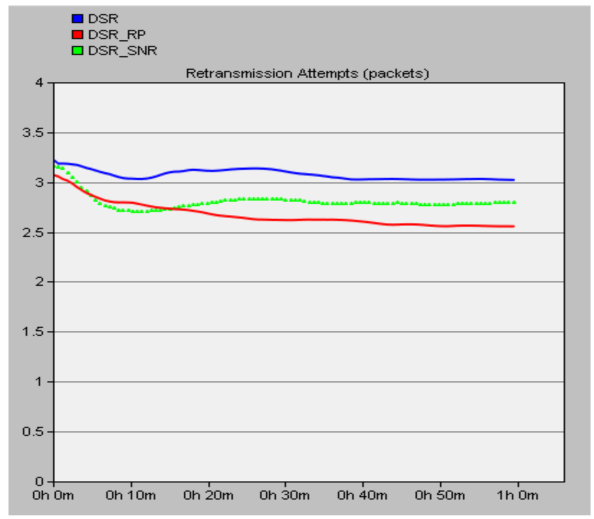

Figure 8.5. SNR & RP models reduced number of errors sent

C. OLSR evaluation

Figures 9.1, 9.2 and 9.3 show that traditional OLSR outperforms OLSR-SNR model and OLSR-RP in terms of delay, packet delivery and overhead. For MAC layer throughput performance, figure 9.4 shows that traditional OLSR, SNR model and RP model provide better performance than OLSR. Figure 9.5 shows that OLSR, SNR model and RP model same performance in terms of retransmission attempt.

D. General evaluation

We evaluate the performance of AODV, DSR and OLSR in terms of delivery rate with respect to time and number of nodes.

Figure 10.1 shows that AODV-RP increases the delivery rate. In figure 10.2, SNR and RP models enhance the delivery rate when time increases. Figure 10.3 illustrates that OLSR delivery rate is higher than the models.

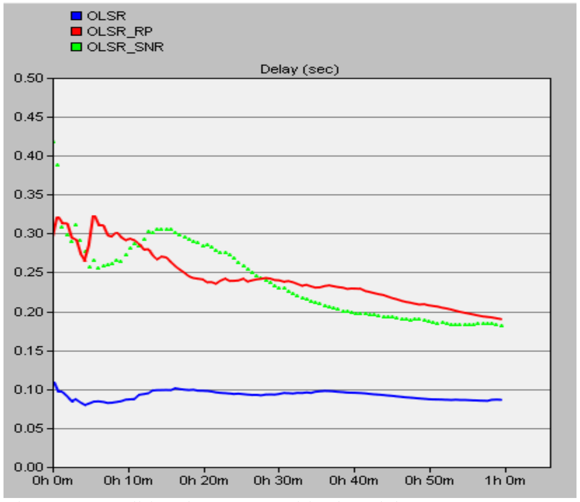

Figure 9.1. traditional OLSR provides low delay

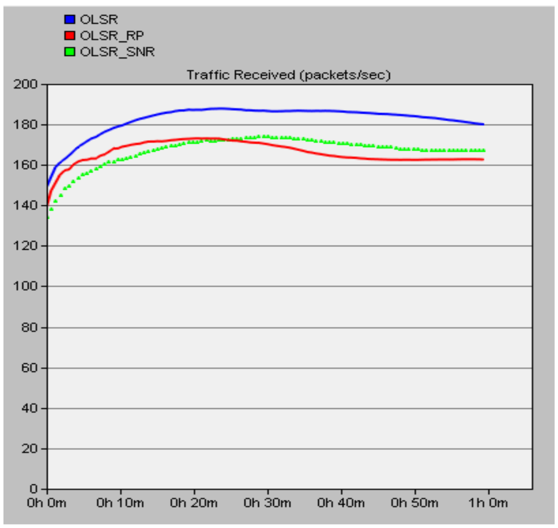

Figure 9.2. traditional OLSR delivers more traffic

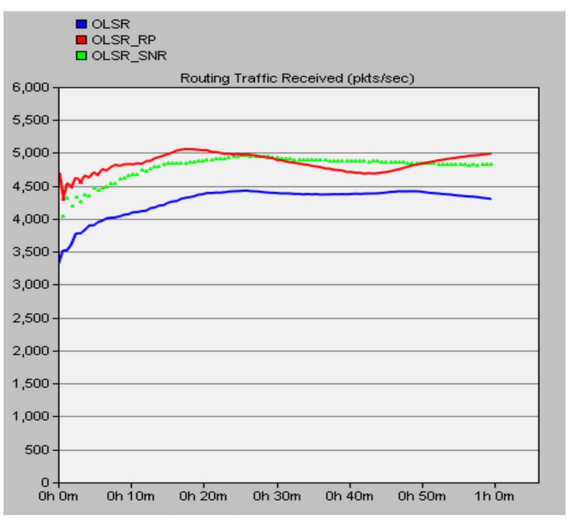

Figure 9.3. overhead in traditional OLSR is low

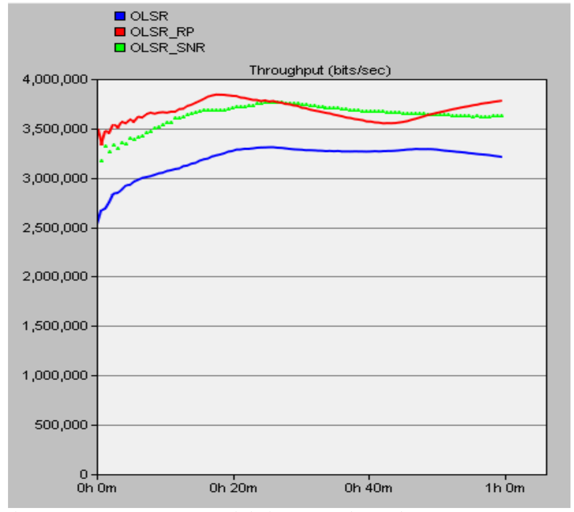

Figure 9.4. SNR & RP models increase throughput

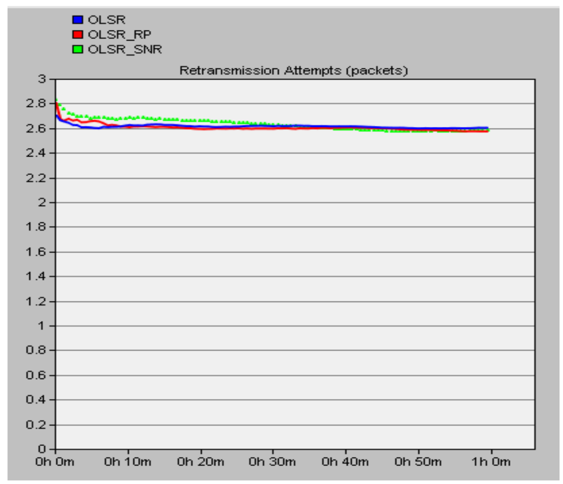

Figure 9.5. Identical performance in terms of retransmission attempts

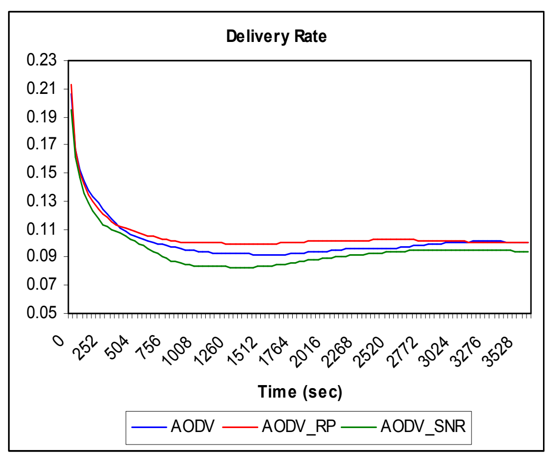

Figure 10.1. APDV-RP model increases delivery rate

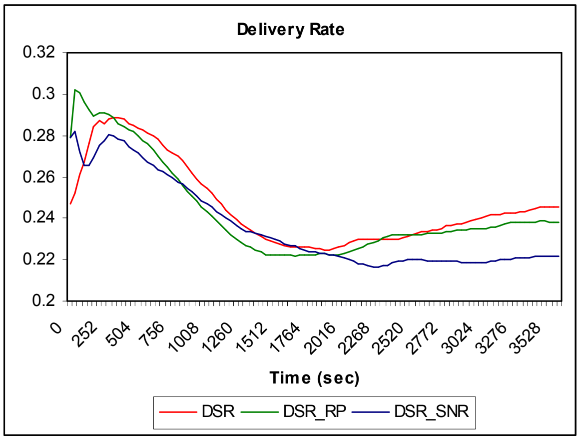

Figure 10.2. SNR & RP models presents better performance than traditional DSR

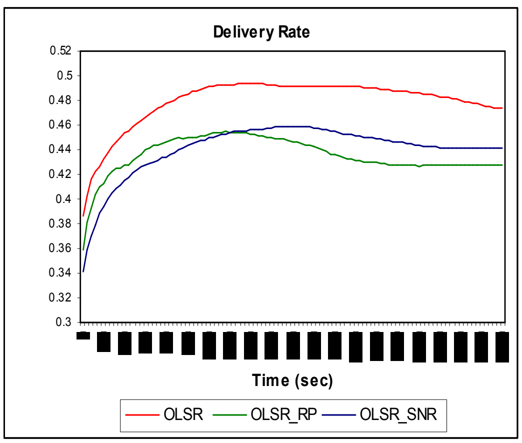

Figure 10.3. Traditional OLSR delivers more packets

Figures 11.1, 11.2 and 11.3 evaluate delivery rate with respect to number of nodes. In figure 11.1 when number of nodes increases AODV-SNR model increases delivery date and outperforms traditional AODV. Figure 11.2 shows that DSR and models achieve approximately same performance. In figure 11.3, OLSR-RP presents high performance than other with small number of nodes.

Figure 11.1. AODV-RP model increases delivery rate when No. nodes increases.

Figure 11.2. when No. nodes increases DSR and models have same performance

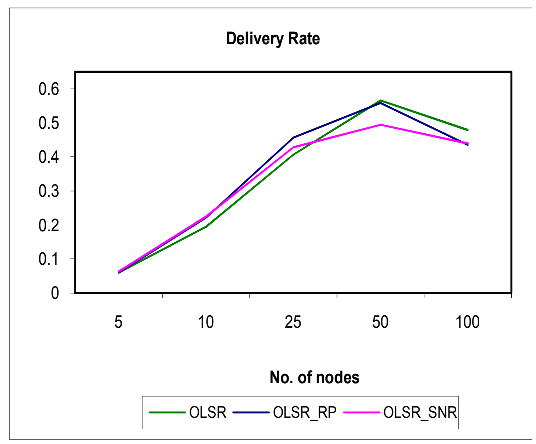

Figure 11.3. OLSR-RP presents good performance with small group of nodes

VII. Discussion and Conclusions

In this work, we present our Cross-Layer Design (CLD) to improve the performance of well known MANET routing protocols, AODV, DSR and OLSR. We modified the protocols 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 present performance evaluation of the protocols with our CLD model. The evaluation illustrates how those protocols act in the network with and without our CLD model in terms of various network behaviors.

VIII. 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 GRP and TORA.

Also, we will implement Delay/Disruption Tolerant Network (DTN) in our Model in OPNET simulator to study and analyze the impact of the physical layer parameters on the performance of DTN routing protocols. Also, our future work will complete the research by implement DTN based routing algorithms in Aerial/terrestrial Airborne Network environment.

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