Link Cost Routing For MANETs

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***Abstract*--Increasing progress of multimedia communication has increased the significant approaches to deal with the problems like unstable channel conditions, limited resources and mobility of infrastructure less wireless networks. A cross layer design is the effective approach to allow the direct communication between protocols towards non-adjacent layers or sharing variables between layers and utilizing their information to improve the performance of the mobile ad hoc network. In this paper we investigate a cross layer approach which overcomes the problem of resource constraints and simultaneously provides a reliable and QoS path for routing by exchanging the crucial QoS parameters among different layers. Our simulation study reveals a persistent improvement on various factors to analyze the performance of MANETs.**

Keyword*s*-- Mobility, Adjacent layers, Cross layer design, QoS paths, QoS parameters.

I. INTRODUCTION

In MANET, the process of routing and data packet forwarding is done by nodes themselves. If the nodes are not able to communicate directly, because of the mobility they become out of range from each other, then intermediate nodes are needed to make the connection between two unreachable nodes so as to transmit the packets indirectly. A number of ad hoc routing protocols have been suggested to certify the network connectivity. Implementing such routing algorithms pretenses a substantial technical challenge, because of the battery operated devices and the shared medium which contains noise for the signals to transmit. The devices need to be power conserving so that battery life is maximized and noise must be considered in the channel while estimating the actual strength of the signal. The shortest path based on the number of hops is the most common criteria followed by the various conventional routing protocols. The problem along with the shortest path is that the nodes might be participating in communication more often and so their batteries exhausts faster. Such situation might be one of the reasons for the network or the sub networks to become disconnected leaving disparity in the power. Therefore, the shortest path or the minimum number of hops is not the most suitable metric for the routing decision. Some other metrics that consider the power constraint for choosing the appropriate route are more useful in some scenarios.

Figure. 1 shows a traditional layered design which is the exchange of information among various layers of OSI (Open System Interconnection) reference model. Recently the researchers have developed a significant interest on cross-layer design in ad-hoc networks. The designer may design the protocols in two ways in the framework of OSI model. In the first way the protocols can be designed by following the rules of the reference architecture. In a layered architecture, such protocols would mean that a protocol on the higher-layer only works on the services at the lower layers despite of how the service is being provided. When the protocols strictly follow the architecture it means that it would not need any interface which is not given in the reference architecture. Alternatively, protocols can also be designed by adding some new services in the reference architecture, for example, the direct communication can be allowed between protocols at nonadjacent layers or these layers can share some variables or parameters. Such type of new design of a layered architecture is cross-layer design with respect to the reference architecture. A cross layer design between physical and MAC layers which is simply responsible for power saving based on transmission power mechanism is proposed in [1]. The main concept is to follow the functionalities of the original layers with allowing the coordination, communication and joint optimization of protocols crossing different layers so as to improve the overall network performance.

The physical layer mentioned in the above layered design is responsible for transmission of bits with the aim to achieve minimum Bit Error Rate (BER). The most relevant metrics that describe the physical layer features are (BER), SNR (signal-to-noise ratio), and SNIR (signal-to-noise -interference ratio) which captures the interference effect from the environment. Another important parameter is the transmission power (depends on the operation mode) and energy of the node. The upper layer solutions can influence particularly from physical layer design and information gained from physical layer conditions.

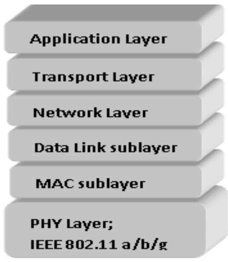

Figure 1. Layered design

The aim of this proposal is to design a mechanism to provide a capable QoS service based on cross layer design to enhance the performance of existing routing protocols in Mobile ad hoc network environment. In this paper, a cross layer based routing mechanism is proposed for route selection which is a succession of Ad- hoc on demand Distance Vector protocol (AODV) [2]. The AODV routing protocol is a popular on demand single path routing protocol for ad hoc wireless networks. The route discovery procedure is invoked by source node to locate its destination through broadcasting of request packet. A reply packet is sent by either an intermediate node if route is available or by destination node, otherwise that request is ignored. The source node selects the shortest path for sending data packet. In our proposal an optimum route is selected based on the parameters of physical and MAC layer at the network layer. The rest of this paper discusses QoS in MANET then the cross layer designs are discussed followed by the related work. Further, we present the proposed cross layer design and optimization algorithm. And then the simulation environment and parameters are given followed by simulation results and conclusion with future work.

II. QOS IN MANETS

Quality of Service (QoS) is the given assurance of the network components (Applications, host, router) to provide a guaranteed grade of communication services between the service user and the service provider. The aim of QoS provisioning proposed in [3] is to attain a more deterministic network behavior, so that the network information can be better derived and utilization of network resources can perform in better way. The important QoS parameters that provide the desired grade of service are: The link's Bandwidth, Delay, Jitter, Signal to noise ratio, Packet delivery ratio, Throughput, Security, Reliability, Resources availability, and Energy consumption.

Lots of challenges are there to establish a favorable QoS framework in MANETs that are: dynamic network topology, indefinite state information, lack of central organization, the mobility of hosts, the noisy shared channel, the inadequate accessibility of resources (i.e, bandwidth and device lifetime) and the uncertain medium. Two solutions commonly used for QoS provisioning in the MANETs are [4]:

1) QoS method based solutions:

- Communication between network protocol and QoS (QoS-aware routing).
- Communication between network protocol and the Medium Access Control (MAC) protocol.
- The routing information updates mechanism.

2) The solution for the layer at which they function:

- Medium Access Control / Data Link Layer (MAC/DLL) Solutions.
- Routing layer solutions.
- Cross-layer solutions.

In this paper the QoS provisioning for efficient and reliable routing has been given which is based on cross layer solution.

III. CROSS-LAYER DESIGN

Many cross-layer design proposals are given in the literature. The authors in [5] present a survey of various cross-layer design proposals based on the layers that are coupled for information exchange. The important issue of concern is *how* the layers are coupled in a particular cross-layer design. The possible violation of the layered architecture given in Figure 1 can be in the following basic ways:

- Creation of new interfaces between layers
- Merging of adjacent layers
- Design coupling without new interfaces
- Vertical calibration across layers

It is found that most of the cross-layer design proposals fit into one of these basic categories. Several designs require a new interface crossing the layers for communications between the adjacent layers at run time.

The violation of architecture here is the creation of a new interface not available in the layered architecture. And depending on the direction of information flow along the new interfaces this way of violation has been divided into three categories:

- Upward: From lower layer(s) to a higher layer
- Downward: From higher layer(s) to a lower layer
- Back and forth: Iterative flow between two Layers

The solution proposed in this paper for QoS provisioning is based on the Upward Information Flow in which a protocol at the higher-layer needs some data from the lower layer(s) at runtime results in the design of a new interface from the lower layer(s) to the higher layer. Such situations can alleviate by forming interfaces from the lower layers to the network layer to enable explicit notifications. When the layers are allowed to communicate with each other they are allowed for sharing runtime information. To allow the direct communication among the layers means making the variables of one layer perceptible to the other layers at runtime.

IV. **RELATED WORK**

The significant interest of researchers on cross-layer design in ad-hoc networks has been attracted [6, 7]. The information sharing between various protocol layers is the point of concern here. In [8], a routing solution for minimum energy broadcasting has been proposed by Wan et al. which is dedicated to static ad-hoc networks. A combination of simulation and experimental results presented in [9] by Laura Feeney shows that energy and bandwidth are fundamentally different metrics and the resource consumption in routing protocols is not fully addressed by bandwidth- centric analysis. C. K. Toh, in [10] presented a hybrid protocol which is a Conditional Max-Min Battery Cost Routing (CMMBCR) protocol that tries to intercede between the Minimum total transmission power routing (MTPR) and Max-Min Battery Cost Routing (MMBCR).

Authors Patil et al., in [1], proposed a cost function that considers the utilization of battery of a node. However it is assumed that power of a node at the time of transmission is fixed which is not true practically. The size of the packet transmitted gives the power loss due to transmission. Moreover, they only concentrate for battery power during routing, but it is possible that a route with nodes having better battery power can have more delay due to high congestion or more length, whereas a route with nodes having sustainable battery power can provide less delay. Further the path chosen by concentrating on battery life only may not be proficient of providing lesser bandwidth assurance to multimedia applications. So, this protocol is not appropriate for multimedia applications. The authors Enneya et al., proposed another protocol, which accounts for mobility parameter only to calculate the cost function for routing [11]. However, it is possible that a path with a bit more mobility value than the path with a less mobility value can result high bandwidth and lesser delay without considering the major restriction of inadequacy of battery power of nodes.

Veerayya et al. in [12], proposed a protocol that takes battery power available at nodes into accounts for routing. Thus, only cost function of non-delay sensitive applications is used, and the QoS requirements of applications are ignored. Pushpalatha et al., proposed a protocol which uses trust based on forwarding frequency as a cost function [13]. However, trust alone cannot guarantee QoS provisioning. The protocol proposed by Mbarushimana et al., accounts for the type of service and capacity in network while routing [14], both of these factors give the cost function conforming to delay sensitive applications like bandwidth, and ignores the limitation of battery power of nodes. In [15], a Cross- Layer Ad-hoc On-demand Distance Vector Routing protocol (CLAODV) is proposed to accomplish trustworthy data transmission in MANET. A cross-layer design is included to improve information sharing among network layer and physical layer. This mechanism employs Signal to Noise Ratio (SNR) measurements along with the routing path and chooses the path with high quality of service value rather than the shortest path.

Another cross layer design based SNR/RP model has been proposed in [16], to enhance the performance of Dynamic Source Routing protocol by offering dedicated QoS for dedicated applications, but this model considers only received power of the signal and ignores other important parameters. An adaptive Link Weight (ALW) algorithm as a succession of AODV has been proposed in [17]. To select an optimum route an adaptive route selection process is used which closely matches to the requirements of the applications. For the breakage of link and loss of network resources, a new method is proposed in [18], which works in two phases. Working of first phase is based on signal strength by measuring the signal strength between the nodes and this value is then compared with RSSI threshold value. If the value of signal strength is higher than RSSI threshold value, then it is taken for further processing otherwise it is ignored. A bandwidth aware multipath protocol is proposed in [19], which considers only one parameter through the adjacent layer of network layer as the optimizing metric for on demand protocol.

V. PROPOSED CROSS LAYER APPROACH

The performance of layered architecture is bound with the lack of coordination between layers due to the specific challenges modeled by wireless environment for the transmission links in MANET. To overwhelm such restrictions, a cross-layer design has been proposed in Figure 2. To maintain the functionalities related to the original layers, the coordination, interaction and joint optimization of layers is also allowed with the protocol crossing different layers so as to improve the performance of the network. Practically wireless communication channels in MANETs are irregular and undergo with high packet-loss due to noise present in the channel. As far as routing is concerned, data from the transmission link such as Signal to Noise Ratio (SNR) can provide valued information to the source node about the transmission paths. Each wireless node can transmit information to any other node inside its transmission range, which technically depends on SNR. In this approach, the SNR value and the lifetime of the node are communicated from the physical layer directly to the network layer and delay of the link is communicated from MAC layer to the network layer to optimize the route selection process at the source.

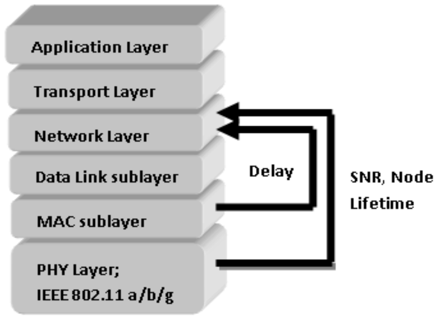

Figure 2. Proposed cross layer design

A. *Format of Packets and Route Table Entry*

As the proposed protocol is the succession of AODV routing protocol, so the route request packet is similar to the request packet of AODV and no any additional field is added with request packet but the route reply packet contains an additional field to keep the Link cost value of sending node. It finds the best route during the route discovery with QoS assurance by using these control packets. The format for route reply packet is shown in Figure 3. The format of reply packet contains source ID, destination ID, hop count, sequence number and link cost based on three QoS parameters that are SNR, delay of the link and node lifetime. And the routing table structure as shown in Figure 4, consists the entries of destination ID, sequence number, next hop ID, hop count, expiry time of the route and link cost of the selected route.

Src ID	Dst ID	Hop Count	Seq. No.	Link Cost

Figure 3. Reply packet format

Dst. ID	Seq. No.	Next hop	Hop Count	Time Out	Link Cost

Figure 4. Routing table entry

B. *QoS link cost parameters*

The path selection criterion of this protocol is based on three QoS parameters: SNR value, delay and node lifetime. Considering these QoS parameters makes the selected path as the optimum quality path.

- Signal to Noise Ratio: To investigate the effect of noise on unreliable wireless communication channel the signal to noise ratio (SNR) is considered here. In the simulation the noise has been created in the background channel so as to observe the behavior of the AODV protocol as well as our proposed protocol in the noisy environment. The SNR is defined as the ratio of signal power to the noise power and is calculated at the receiving node. A ratio higher than 1:1 indicates more signal than noise.

$$SNR= (P_{signal} \div P_{noise})$$

Where, P_{signal} and P_{noise} are the received power of the signal and received power of the noise. In decibels, the SNR is defined as

$$SNR_{dB} = 10\log_{10} (P_{signal} \div P_{noise}) = P_{signal,dB} - P_{noise,dB}$$

- Link Delay: Link delay is the accumulated delay which is the interval between the time when packet is send by the source to the time when it is received at the receiving node. The link delay is calculated after reception of every RREQ by using the RREQ packet creation time information and reception time. The overall end to end delay can be directly calculated with the delay of each link involved in the route from source to destination.
- Node Lifetime**:** The Node lifetime is an essential parameter for route choice and this implementation provides a predictable value of remaining battery lifetime in each RREQ.

In the optimal path minimum delay is expected while for Node Lifetime and SNR the maximum values are desired. Therefore, in the calculation of composite metric (ie. Link Cost) the three variables (SNR, Node lifetime and delay) are normalized.

For selecting a route each QoS parameter required a weight factor to calculate the link cost at node j. Here K_1, K_2 and K_3 weight factors are used with respect to $SNR_{i,j}$ of the link from node i to node j, $Delay_{i,j}$ of link from node i to node j and Node Lifetime (NLT_j) of node j for selecting a route using equation (1).

$$QoS\ LinkCost_j = (K_1 * SNR_{i,j}) + (K_2 * Delay_{i,j}) + (K_3 * NLT_j) \qquad (1)$$

$$Where\ K_1 + K_2 + K_3 = 1$$

C. *Route Discovery Process*

The route discovery process of the proposed protocol is as follows: When the route request packet arrives at the node, each node will calculate its link cost with the SNR of the link, delay of the link and its lifetime and store it. The intermediate receiving node will broadcast the packet further to its neighbors and generates the reverse path. When the destination receives the request it calculates the link cost, puts it in the reply packet and sends it towards the source. Each intermediate node when receives the reply will compare the stored link cost with the link cost received in the reply packet and updates the reply packet with the minimum of the two values. The replies arrived at the source will contain the link cost of the link with the minimum of the costs associated with the links in the path. The source node starts the data transmission with the first received reply. When the next reply packet arrives at the source, it compares the new path with the current path and chooses the path having the maximum link cost value. To find the quality of the path the Maximum flow- Minimum cut approach is used in this protocol. In this approach the link cost of the path is the minimum of the costs of all the links of a path. The source node chooses the path with the maximum value of link cost out of all the paths.

Referring to Figure 5, node A broadcasts RREQ to look for the destination node J. All neighbor nodes when receive the request, they calculate the link cost and store it. The relay node E when receives request from node B, discards it since it is the same request that it has already received from node A. The RREQ reaches at destination node with relaying process through nodes F, C and H. The destination node sends replies to F, C and H nodes and puts the link cost value in RREP packets respectively. The node F, C and H when receive reply, compare the stored link cost value with the link cost value received in the RREP and update the packet with minimum value of link cost. As link cost stored at node F is 5.1 and received in RREP is 5.8, node F will update the RREP with link cost value 5.1 and sends it towards the source node. When node I will receive RREP, it will update the RREP with link cost value 4.7 and sends it towards the source node. Similarly, the source node will receive the multiple RREP's from nodes I, E and B with the link cost value 4.7, 4.8 and 4.3. Suppose the first reply received at the source node is through node I, then it will start data forwarding with this route only. When the next reply received at the source node, which is from node E with link cost value 4.8, it will compare the new link cost value from node E with the current link cost value ie, 4.7. And chooses the route with maximum value of the cost among the two link costs of the paths and switch to that path for data forwarding, and ignores the previous path. Similarly, the source node will also receive the reply from node B with link cost value 4.3. It will perform comparison again among the two values of the link costs, but will not switch this time, since the value of the link cost of the new received path is less as compared to the link cost of the current path. So, in this example, the best route available at source node A is the route A-E-C-J with link cost 4.8.

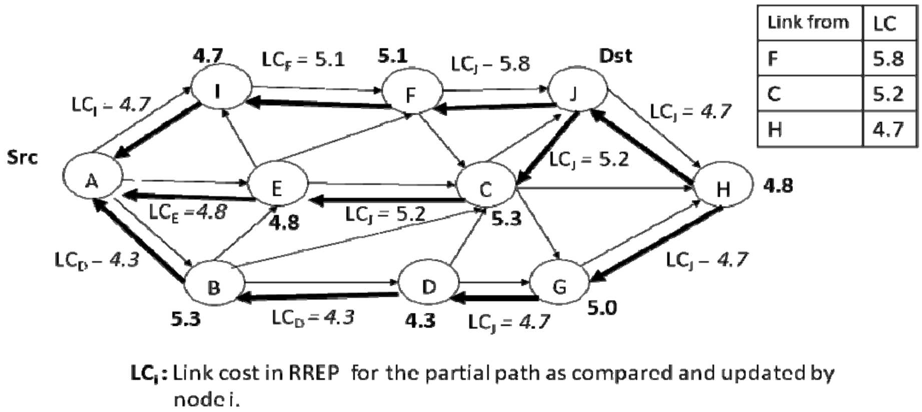

Figure 5. Route Selection of process

D. *Proposed Algorithm*

i) The source node broadcasts the RREQ to all its neighbors.

ii) If the node that receives the RREQ is not the destination then :

   a) It calculates the link cost with received SNR of the packet, delay of the packet and its node lifetime and stores the link cost in its buffer.

   b) It generates the reverse path and broadcasts the RREQ further.

   c) If it received the RREQ with the same source address and sequence number again then it discards the packet.

iii) If the node that receives the RREQ is the destination, it puts the calculated link cost in the RREP packet. And sends RREP towards the source.

iv) If the node that receives RREP is not the source, it makes the comparison between the stored link cost and the link cost received in the reply packet. And updates RREP with the minimum link cost value.

v) The source node receives RREP with the lowest available link cost of the route. It starts data forwarding with first received RREP.

vi) As the source node may receive multiple RREPs, when next RREP will arrive at the source, it will compare the link cost of the current path and the new received path, and choose the path with maximum value of the link costs of the paths for data forwarding and discard the other paths.

VI. SIMULATION ENVIRONMENT

We implement the proposed protocol with NS-2 [20] to evaluate its performance. Different scenarios were simulated to observe the performance and behavior of the protocol. The simulation Environment is shown in Table I.

TABLE I: SIMULATION PARAMETER

Parameters	Values
Area	1000*1000 m
Propagation Model	Two ray ground
Number of nodes	100
MAC	802.11
Node speed	Varying (4 m/s to 20 m/s)
Simulation time	100,150, 200, 250, 300, 350, 400, 450, 500 sec.
Traffic Pattern	Constant Bit Rate
Packet Size	512 Mb
Protocols for comparison	LCAODV, CLAODV, AODV.

A. *Performance metrics and simulation results*

Following parameters have been used for measuring the performance of the protocols and to compare the performances of the proposed protocol with AODV and CLAODV protocols. Figure 6 to 9 show the results for average end to end delay, packet delivery fraction, throughput and Packets drop.

- Average end to end delay: The average end-to-end delay of data packets is the interval between the data packet generation time and the time when the last bit arrives at the destination. Figure 6 shows that the average end to end delay of the protocols for varying simulation time in which the delay of LCAODV is 24% less than the delay due to AODV and 48% less than the delay due to CLAODV. The reason being the consideration of the minimum delay, high SNR among the links of the path chosen by LCAODV.

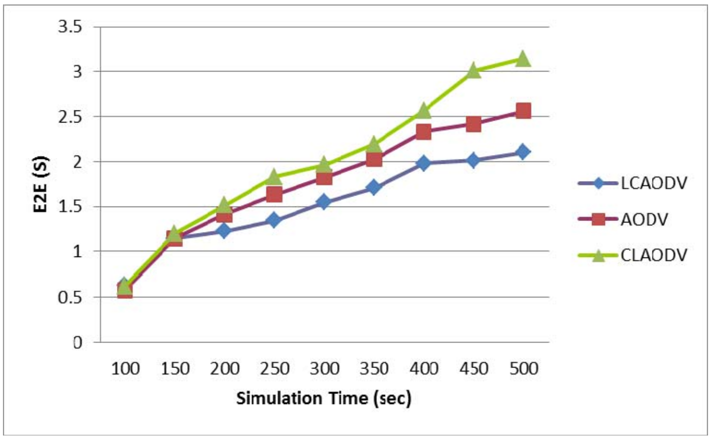

Figure 6. Average end to end delay.

- Packet delivery fraction: It is the ratio of the number of packets received by the destination to the number of data packets generated by the source. As shown in Figure 7, LCAODV gives 7.8% better packet delivery than AODV and 5% better packet delivery than CLAODV, since the route chosen in LCAODV are more reliable which assures better packet delivery towards the destination. Due to the use of SNR and node lifetime in selecting the route, LCAODV chooses the more reliable paths as compared to AODV and CLAODV.

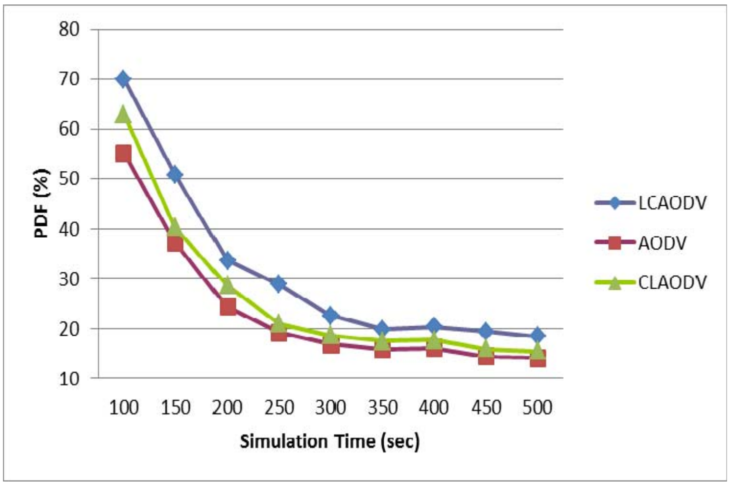

Figure 7. Packet delivery fraction

- Throughput: It is the ratio of total data received by receiver in a given time interval. Throughput is measured in kilo bits per second. Figure 8 shows that the throughput of LCAODV is 14.8% better than AODV and 8.4% better than CLAODV in our simulation experiment. Because the route chosen by LCAODV in the route discovery are of the longer period of time with the longer node lifetime so the chances of node failure get reduced, increasing the throughput by making the data packets available to the receiver in appropriate time.

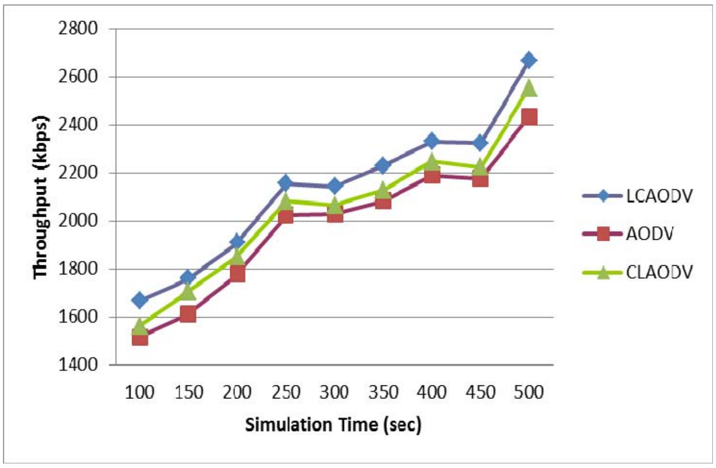

Figure 8. Throughput

- Packets Drop: It is the measure of number of packets dropped by nodes due to various reasons. Number of dropped packets shown in Figure 9, has been reduced by 9.2% than AODV and by 6% than CLAODV. The packet drop might occur due to node failure and weak signal strength, but LCAODV selects the path based on SNR and the nodes having more battery power.

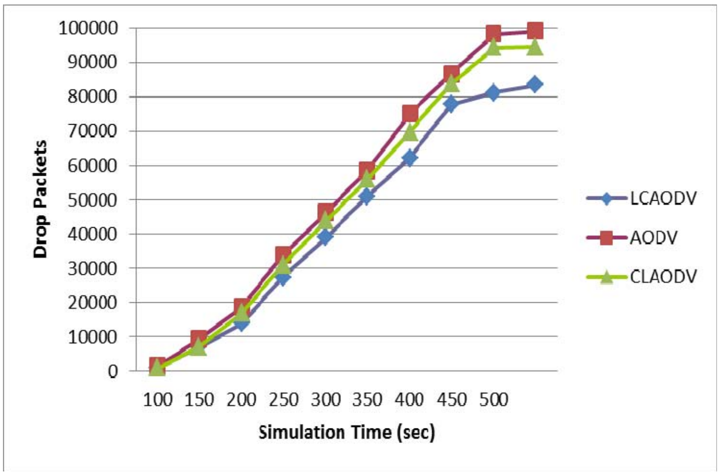

Figure 9. Packets Drop

VII. CONCLUSION

This paper presented the link cost based AODV (LCAODV) protocol for routing in MANET which is a succession of AODV protocol. The proposed routing protocol provides a significant improvement in performance as compared to traditional AODV protocol and recent CLAODV protocol. It provides an optimum quality path which in turn provides an improvement in QoS level when compared to the traditional AODV routing protocol. This protocol does not consider other network problems like congestion. This may gives a new direction for future research.

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