

LETSRP: A Secure Routing Protocol for Manets

Gopal Singh, Harish Rohil, Rahul Rishi, Virender Ranga

Abstract: *Reliable link between the nodes plays vital role during the transmission of data in the routing protocols of Mobile Ad-hoc Networks (MANETs). In this research paper, a routing protocol Link named Expiration Time based Routing Protocol (LETSRP) is proposed which uses Winternitz One-time Signature Scheme to check the authentication of transmitted data in the network. The packet sending node calculates maximum LET (MaxLET), minimum LET (MinLET) and average LET (AvgLET) using greedy algorithm in our proposed solution. The number of sent packets depend on the available bandwidth. Various steps in implementation are repeated until all the packets reach the destination node. Simulations are done with variable number of nodes between 10-20 nodes with mobility setting from 10 m/s to 20 m/s.*

Keywords: *Link expiration time (LET), MaxLET, MinLET, AvgLET, LETSRP, AODV.*

I. INTRODUCTION

MANET is a network without any infrastructure at large scales. In dynamic mobility, MANET has a predetermined topology. As a result devices/nodes in MANET can travel freely and therefore the network may change its topology over and over again. Node mobility and frequent topological changes are the important characteristics of the MANETs. These characteristics lead to frequent link disconnections in a network. The proposed routing protocol emphasizes to design a reliable protocol to make effective routes which are chosen by data packets. Route maintenance process is initiated during link failures or disconnections. MANETs' routing protocols may be categorized on the base of topology-based [1, 13, 18] and position-based [11, 10, 6, 2]. Information transmits in different ways between these protocols over the network depend on many factors. To shrink the consequence of link breakage on the network service leads to enhance the routing performance. There are three proposed link expiration time metrics to make stable link. The remaining part of the paper is structured as follows: Section 2 discusses the related works of the existing link lifetime estimation mechanism to make reliable link between various nodes in the scenario. Our proposed LET based Secure Routing Protocol is described in Section 3. Section 4 presents detail working of our proposed scheme. Section 5 shows the pseudo code of LETSRP. In section 6, conclusion is shown followed by references.

II. RELATED WORKS

In [9], a new routing metric has been proposed for MANETs.

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The coverage area of scenario where the nodes travel is considered so that the link expiration information may be used. The objective is to get routes that are longer with few hops may be considered. The authors proposed a routing protocol which works on speed-aware known as (SARP) to decrease the effects of high mobility of nodes so that the route may not be disconnected. This protocol mainly works to find the nodes which maintain high mobility in the coverage area using LET [3]. There are three prediction algorithms, proposed by authors on the bases of Global Positioning System as well as Signal Strength or both [15]. The mobile nodes participate in the scenario of network to predict the connectivity using time to avoid disconnection. Nodes were used self-motivated as well as changes to enable them in combination of reliable link [14, 19]. An approach called RORP is proposed which is known as reliable on-demand routing protocol. The authors considered period for nodes, so the prediction of link between the nodes can be determined by using GPS [21]. Several paths between the sources to the destination node have been considered which selects longest duration of time for selected path during the transmission of packets as well as route maintenance. In [7] information of path availability and link between the nodes is found using probability during the investigation by the author in the paper. Every node randomly moves at one place to other by using selected velocity as well as an arbitrary vector with direction. The authors in [12] proposed an approach called Multi-constrained Quality of Service routing with mobility prediction protocol uses GPS to collect the location information of moving nodes and the path which having maximum Route Expiration Time (RET) is selected, if the nodes have sufficient resources to send data packets. Path discovery and route repairs process is being used to set static and mobile agents. Here RET is the minimum of the LETs along the path. An algorithm, LET-CDS, to determine and consider connected dominating sets (CDS) which is based on Link Expiration Time is proposed in [8]. Here, edge weights are represented by predicted LET. The result of simulation shows that LET-CDS has maximum life time compared to MaxD-CDS during the moderate and high density in networks.

III. OUR PROPOSED SCHEME

In this section, we suggest a Link Expiration Time based Routing Protocol (LETSRP) which uses a greedy algorithm approach for sending the packets. In this, the source node uses LET and available bandwidth of the neighbor nodes for calculating the MaxLET and MinLET. The source node transmits the packets to the neighbor nodes using either MinLET or MaxLET. This process is repeated by other nodes until the packets reach the destination. Here, the packets are distributed among nodes, so when the packets reach the destination, it is used by the upper layers to reorder them before passing on to the application layer. The Winternitz One-time Signature Scheme [17] has been applied for authenticating the data whether the actual data is received by destination node.

The neighbor node applies Winternitz One-time Signature Scheme over LET and bandwidth available fields in LET_REP packet. Then the receiver of LET_REP packet verifies it and source node sends the LET_REQ (Link Expiration Time Request) packets to its neighbor nodes. LET_REQ packet contains nodes position, velocity and available bandwidth. The neighbor node sends the LET_REP (Link Expiration Time Reply) packet to the source node containing its position, velocity, bandwidth available and LET. The source node computes the MinLET, MaxLET and AvgLET and then decides whether to send the packets or not. The neighbor nodes when received packets from the source node, they again send the LET_REQ packet to its neighbor nodes and do all the computation as done by the source node.

A. General Assumptions

- The nodes when forwarding the packets will not send the packets again to the node from which they are coming. The node will only send the packets to that node if the links with other nodes get disconnected before sending all the packets. In other words, number of received packets by the node < number of sent packets then the node sends the left packets to the node from which they are coming.
- The node connected to the destination node will send the packets directly to the destination node without calculating the MaxLET and MinLET.
- If the neighbor nodes are able to receive only few packets and sender node has some packets left with it then the sender node will not send any packet to the neighbor nodes and will wait for connection again i.e., number of packets to send > total number of packets received by all the neighbor nodes. The source node will wait or monitor the link with its neighbor nodes.
- All the nodes within specific interval of time send its new position and velocity to their neighbor nodes. Those nodes which are waiting for sending the packets, when sending their position and velocity will also send the size of data they want to send. The neighbor nodes then send the acknowledgement to those nodes whose data they can receive within available bandwidth.

B. Security Assumptions

- Applying Winternitz One-time Signature Scheme over LET takes time. So, it is assumed that the time of one second would be taken for applying this scheme.
- The node receiving LET and bandwidth available will also take time to verify the received LET. It is assumed that it also takes one second.
- Total Time=1+1=2 seconds
- The sender node when calculating the *number of packets received* by another node, it will reduce the value of LET to 2 seconds because overall 2 seconds are used for applying cryptographic hash functions by both the nodes (sender and receiver).
- Here, we will take LET as LET after applying Winternitz One-time Signature Scheme (i.e. by subtracting 2 from actual value of LET).

IV. DETAIL WORKING OF PROPOSED SCHEME

The source node calculates the number of packets received by the neighbor nodes then it calculates the ratio v_i/w_i , where, v_i is the LET and w_i is the number of packets received. Here, knapsack size is the number of packet send

by the node. The ratio is then sorted either in decreasing order for calculating the MaxLET or in increasing order for calculating MinLET.

$$AvgLET = (MaxLET + MinLET)/2 \tag{1}$$

The source node sends the packet to the neighbor nodes using either MaxLET or MinLET. The neighbor nodes also use this approach for sending the packets and the assumptions described above. Here we discuss our proposed scheme through an example in which, packets are sent from source node (NODE 1) to destination node (NODE 10). Here it is assumed that the node 1 sends 150 packets to the destination node 10 and the size of each packet is 100kb and $BW_{Max}=1Mbps$. When the neighbor node sends the LET_REP packet it applies Winternitz One-time Signature over LET. For key generation: Choose $x_1, x_2, \dots, x_t \in \mathbb{R} \setminus \{0, 1\}$ at random. Set $X = (x_1, \dots, x_t)$. Let any node sends the LET_REP packet to the other node. Node sending the LET_REP packet applies the Winternitz One-time Signature Scheme over LET. It is done in this way: Key Pair Generation. Let $w=2$ LET=23

$H(d)=10111, s=5$
 $t = \lceil [5/2] + \lceil (\lceil \log_2 [5/2] \rceil + 1 + 2)/2 \rceil \rceil = 5$
 $X = (x_1, x_2, x_3, x_4, x_5)$
 $Y = H(H^3(x_1) H^3(x_2) H^3(x_3) H^3(x_4) H^3(x_5))$
 Signature Generation
 Blocks = $\lceil [5/2] \rceil = 3$
 Blocks are b_1, b_2, b_3
 $(b_1, b_2, b_3) = (01, 01, 11)$
 Checksum $C = (4-1) + (4-1) + (4-3) = 7 = (111)_2$
 Blocks = $\lceil (\lceil \log_2 [5/2] \rceil + 1 + 2)/2 \rceil = 2$
 Blocks are b_4, b_5
 $(b_4, b_5) = (01, 11)$
 $b_1=1, b_2=1, b_3=3, b_4=1, b_5=3$
 $\sigma_1 = H^1(x_1) \sigma_2 = H^1(x_2) \sigma_3 = H^3(x_3) \sigma_4 = H^1(x_4) \sigma_5 = H^3(x_5)$
 Signature of LET = $(H^1(x_1), H^1(x_2), H^3(x_3), H^1(x_4), H^3(x_5))$
 When node received LET, BW_{Av} , Signature of d from another node then it can verify the signature.

1. Verification of Signature
 LET=23 $H(d)=10111 s=5 w=2$
 Blocks = $\lceil [5/2] \rceil = 3$
 $(b_1, b_2, b_3) = (01, 01, 11)$
 Checksum $C = (4-1) + (4-1) + (4-3) = 7 = (111)_2$
 Blocks = $\lceil (\lceil \log_2 [5/2] \rceil + 1 + 2)/2 \rceil = 2$
 $(b_4, b_5) = (01, 11)$
 $b_1=1, b_2=1, b_3=3, b_4=1, b_5=3$
 $\phi_1 = H^{4-1-1}(\sigma_1) = H^2(H^1(x_1))$
 $\phi_2 = H^{4-1-1}(\sigma_2) = H^2(H^1(x_2))$
 $\phi_3 = H^{4-1-3}(\sigma_3) = H^0(H^3(x_3)) = H^3(x_3)$
 $\phi_4 = H^{4-1-1}(\sigma_4) = H^2(H^1(x_4))$
 $\phi_5 = H^{4-1-3}(\sigma_5) = H^0(H^3(x_5)) = H^3(x_5)$
 $\Phi = H(H^3(x_1) H^3(x_2) H^3(x_3) H^3(x_4) H^3(x_5))$
 Here $\Phi = Y$

So, signature is verified, LET is not altered. Similarly, all nodes compute and apply the Winternitz One-time Signature over LET. The given approaches are shown in the various steps which are also shown in the flowchart as depicts in Fig. 2. Here, first determining the number of node along with their coordinates and velocities then calculating available bandwidth. In the next step, calculating the Link Expiration Time (LET). In the last, signature is verified to check the actual data is received or not.



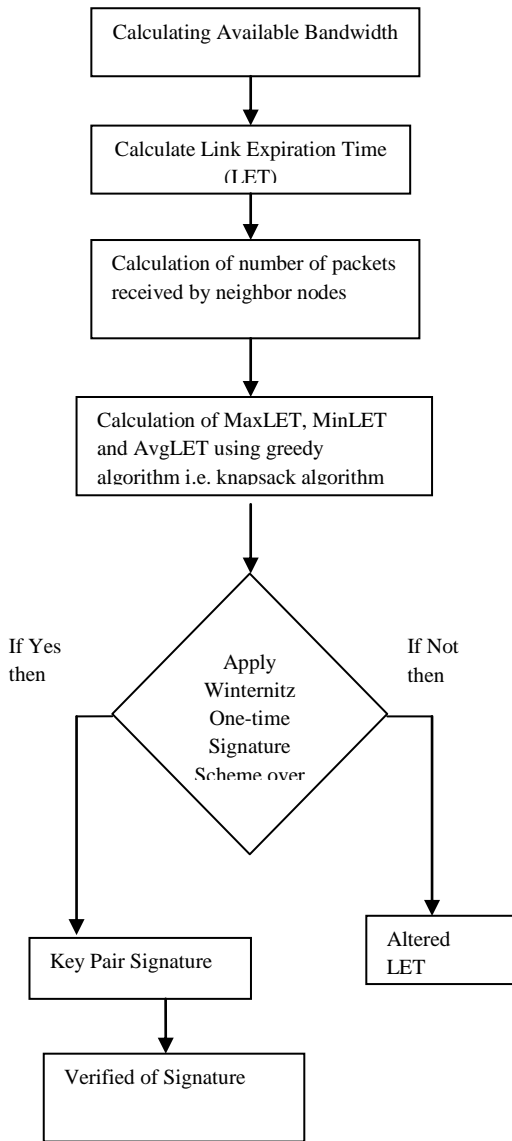


Figure 1.Flowchart to verify the Packets received by destination node. In the Table 1 for source node 1, the node 1 either uses MinLET or MaxLET for sending the packets. Suppose the node uses MaxLET for sending the packets. So, node 1 sends 14 packets to node 5 and 136 packets to node 3. Now, node 5, and node 3 calculate all the values and find MinLET and MaxLET and send the packets to their neighbor nodes. These steps are repeated until all packets reach to the destination node. The above mechanism is applied on the remaining node 2,3,4,5,6,7,8,9,10, but here we are taking few of them, i.e. Tables 2, 3, 4, 5. In Table 2. communication take place between source node 1 and destination node 5.

Table 1. For Node 1 (Source)

| Neighbor node | Actual LET (seconds) | LET' (v _i) (seconds) | BW _{Av} (kbps) | Number of packets received (w _i) | v _i /w _i |
|---------------|----------------------|----------------------------------|-------------------------|--|--------------------------------|
| 1 | 7 | 5 | 400 | 20 | 0.25 |
| 3 | 68 | 66 | 333 | 219 | 0.301 |
| 4 | 19 | 17 | 500 | 85 | 0.2 |
| 5 | 9 | 7 | 200 | 14 | 0.5 |

| Neighbor node | Actual LET (seconds) | LET' (v _i) (seconds) | BW _{Av} (kbps) | Number of packets received (w _i) | v _i /w _i |
|---------------|----------------------|----------------------------------|-------------------------|--|--------------------------------|
| 2 | 7 | 5 | 400 | 20 | 0.25 |
| 3 | 68 | 66 | 333 | 219 | 0.301 |
| 4 | 19 | 17 | 500 | 85 | 0.2 |
| 5 | 9 | 7 | 200 | 14 | 0.5 |

Table 2. For Node 2

| Neighbor node | Actual LET (seconds) | LET' (v _i) (seconds) | BW _{Av} (kbps) | Number of packets received (w _i) | v _i /w _i |
|---------------|----------------------|----------------------------------|-------------------------|--|--------------------------------|
| 1 | 7 | 5 | 400 | 20 | 0.25 |
| 5 | 45 | 43 | 285 | 122 | 0.35 |

Table 3. For Node 3

| Neighbor node | Actual LET (seconds) | LET' (v _i) (seconds) | BW _{Av} (kbps) | Number of packets received (w _i) | v _i /w _i |
|---------------|----------------------|----------------------------------|-------------------------|--|--------------------------------|
| 1 | 29 | 27 | 500 | 135 | 0.2 |
| 6 | 2 | 0 | 500 | 0 | 0 |
| 7 | 22 | 20 | 383 | 76 | 0.26 |

Table 4. For Node 4

| Neighbor node | Actual LET (seconds) | LET' (v _i) (seconds) | BW _{Av} (kbps) | Number of packets received (w _i) | v _i /w _i |
|---------------|----------------------|----------------------------------|-------------------------|--|--------------------------------|
| 1 | 28 | 26 | 500 | 135 | 0.2 |
| 6 | 11 | 9 | 500 | 0 | 0 |

Table 5. For Node 5

| Neighb or node | Actua l LET (seconds) | LET' (v_i) (seconds) | BW _{Av} (kbps) | Number of packets received (w_i) | v_i/w_i |
|----------------|-----------------------|--------------------------|-------------------------|--------------------------------------|-----------|
| 1 | 9 | 7 | 250 | 17 | 0.411 |
| 2 | 45 | 43 | 333 | 143 | 0.300 |
| 7 | 9 | 9 | 222 | 19 | 0.473 |
| 8 | 7 | 7 | 142 | 9 | 0.77 |

Every node in the scenario receives packets and forwards the packets to their neighbor nodes by using either MaxLET or MinLET. Every time when nodes receive packets, they need to calculate the MinLET and MaxLET for sending the packets and each time there might be different LET and BW_{Av}. Route from source node to destination node, assume that all the nodes have same table for sending the packets when they received the packets from their neighbor nodes as well no change in LET and BW_{Av}. So, total times taken by nodes for the packets to the destination may be used i.e.

MaxLET=217.53 seconds

MinLET=196.92 seconds

A. Pseudo Code of LETSRP

This section describes the pseudo code of LETSRP for sending the packets to the neighbor nodes using greedy approach.

Procedure to Verification of Signature _VOS ()
 1:Generate key pair
 $w=2$ to LET= 23, H (d) =10111, $s=5$
 {w represent word length, s represent no. of bits}
 2:Find t
 3:Calculate x and y
 4:Generate Signature Φ
 5: if $\Phi=Y$
 {Corrected data is received by destination node}
 6:Signature is verified
 7:end

Procedure Link Expiration Time based Secure Routing Protocol LETSRP ()

1:for $i=1$ to $n-1$
 2:no_of_packets_received[i]=
 (LET[i]*BW_AVAILABLE[i])/Packet_size
 3:ratio[i]=LET[i]/no_of_packets_received[i]
 4:end for
 5: Verification of signature _VOS ()
 6:sort_decreasing (ratio, n)
 7:knapsack_Max_LET (m, n, no_of_packets_received)
 8:sort_increasing (ratio, n)
 9:knapsack_Min_LET (m, n, no_of_packets_received)
 10:if (MinLET<MaxLET)
 11:for $i=1$ to $n-1$
 12:Send packets to node $i=no_of_packets_send_MIN[i]$
 13:end for
 14:else
 15:for $i=1$ to $n-1$
 16:Send packets to node $i=no_of_packets_send_MAX[i]$
 17:end for

18:end if
 19:end procedure
 Procedure LETSRP()
 In this procedure in lines 1-4, the sender node calculates the number of packets received by the neighbor nodes and the ratio of LET to number of packets received. According to the calculated ratio, the sender node sends the packets to the neighbor nodes. In line 5, verification of signature _VOS () procedure is called to verify the signature key. In lines6-9 procedures are called. In these procedures, MaxLET and MinLET's are calculated. In lines10-19 packets are sent to the neighbors using either MaxLET or MinLET.

Procedure sort_decreasing(ratio, n)
 In this procedure, the calculated ratios are arranged in decreasing order so that the LET corresponding to it are used for calculating the MaxLET.

Procedure sort_increasing(ratio, n)
 In this procedure, the calculated ratios are arranged in increasing order so that the LET corresponding to it are used for calculating the MinLET.

Procedure knapsack_Max_LET (m, n, no_of_packets_received)

This procedure calculates the MaxLET. The value of m (knapsack size) is the number of packets the sender wants to send. If the node sends the packets to the node which is calculating the MaxLET, then LET of that sending node is not taken until needed.

V. PERFORMANCE EVALUATION OF LETSRP AND AODV ROUTING PROTOCOL

To evaluate the performance of routing protocols four parameters to calculate different matrices as per the literature review [16], [4], [5] and [20] are evaluated. These are Packet Delivery Ratio (PDR), End to End Delay (Davg), Routing Load, and Throughput. Network SimulatorQualnet 7.3.1 is used for analyzing the given parameters. However, it is fact to mention here thatit is very hard to blueprint a routing protocol, which gives best performance.

A.Results Discussion

In this paper, two routing protocols are compared and analysed by using four parameters. These two protocols are LETSRP and AODV and different type of variations are done with varying the number of nodes and mobility of nodes.

B.Apply Effect of Node Density and Packet Length

Tables 6 and 7 contain the parameters,i.e. Routing Load, End to End Delivery, Packet Delivery Ratio and Throughput. Whereas in Figs. 4, 5AODV is represented by solid line and LETSRP representedwith bluedash line. Table 6. Scenario= 1500X1500, No of Nodes=10, Packets=100, Size= 512 Bytes

Table 7. Scenario= 1500X1500, No of Nodes=20, Packets=100, Size= 512 Bytes



| Parameter | AODV | LETSRP |
|-----------------------|---------|---------|
| Routing Load | 0.27976 | 0.53889 |
| End to end delivery | 0.18914 | 0.41327 |
| Packet Delivery Ratio | 200 | 250 |
| Throughput | 337 | 397 |

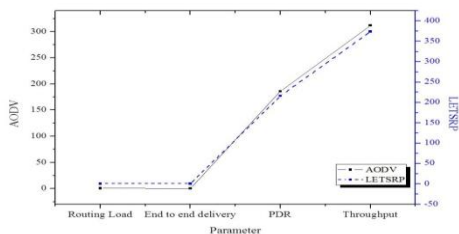


Figure 2. Scenario= 1500X1500, No of Nodes=10, Packets=100, Size= 512 Bytes

In figure 2, 1500×1500 dimensional area is used which

| Parameter | AODV | LETSRP |
|-----------------------|----------|----------|
| Routing Load | 0.666667 | 0.225434 |
| End to end delivery | 0.161402 | 0.298717 |
| Packet Delivery Ratio | 186 | 216 |
| Throughput | 312 | 374 |

includes 100 packets and each packet has size 512 bytes and packets are transmitted between the nodes in scenario of MANETs. Total number of 10 nodes are used in the scenario. When the maximum number of packets travels in the given scenario, then routing load, end to end delivery parameters are found to give best performance in LETSRP protocol. AODV shows best effective result in case of packet delivery ratio and throughput but the routing load is shown to be not so good. It provides a fast alteration in dynamic link condition in networks scenario so that routing load get lowest.

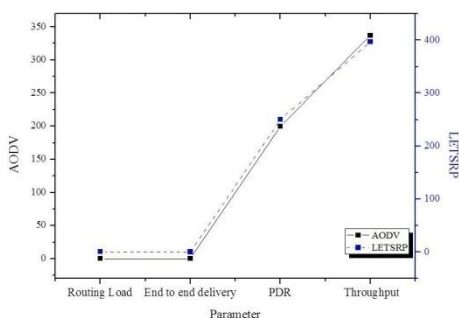


Figure 3. Scenario= 1500X1500, No of Nodes=20, Packets=100, Size= 512 Bytes

In Fig.3, total 20 nodes are used in the scenario with dimensions 1500×1500 having 100 packets and each packet has size 512 bytes. LETSRP is shown by using blue and dash line to show the results where solid line represents the AODV routing protocol in the MANETs. AODV allows mobile unit to get path fast for new destinations and does not allow nodes to maintain the routes for destinations. The result of routing load, end to end delivery and packet delivery ratio parameters show best performance in case of LETSRP protocol where throughput parameter has best performance in case of AODV routing protocol. Here it is observed that when the number of nodes changes from 10 to 20, then packet delivery ratio gives best performance in LETSRP routing protocol, however, AODV routing protocol reduce packet delivery ratio. There is not any affect in throughput when the number of nodes increases in case of AODV.

C. Apply Effect of Node Density and Mobility

In Tables 8 and 9, four parameters values, i.e. Routing Load, End to End delivery, PDR and Throughput are used. In Figs.4 and 5, AODV is represented by solid line and LETSRP is represented with blue and dash line.

Table 8. Scenario= 1500X1500, No of Nodes=10, Packets=100, Size= 512 Bytes, Mobility=10 m/s

| Parameter | AODV | LETSRP |
|-----------------------|----------|----------|
| Routing Load | 0.256579 | 5.477833 |
| End to end delivery | 0.119913 | 0.278334 |
| Packet Delivery Ratio | 139 | 230 |
| Throughput | 39 | 60 |

Table 9. Scenario= 1500X1500, No of Nodes=20, Packets=100, Size= 512 Bytes Mobility=20 m/s

| Parameter | AODV | LETSRP |
|-----------------------|------------|------------|
| Routing Load | 2.23809523 | 9.42173913 |
| End to end delivery | 0.20098246 | 9.42173913 |
| Packet Delivery Ratio | 226 | 153 |
| Throughput | 380 | 351 |

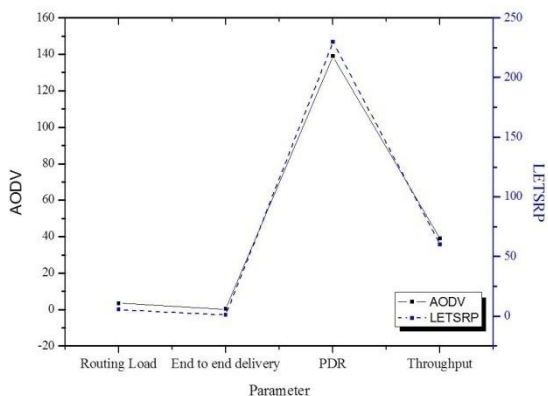


Figure 4. Scenario= 1500X1500, No of Nodes=10, Packets=100, Size= 512 Bytes, Mobility=10 m/s

In Fig. 4, 1500×1500 dimensional area is used which contains 100 packets and each packet has size 512 bytes. Mobility 10 m/s is used to get transmitted between the nodes available in scenario of MANETs. Total number of 10 nodes are used in the scenario. In Fig.4, AODV routing protocol shows best result for routing load, end to end delivery parameters whereas LETSRP shows best result for packet delivery ratio (PDR) but again throughput which is important parameter has best result for AODV which is possible when the mobility speed get increases from 10 m/s to 20 m/s. Here we observed that when the speed of transmission by the packets is high then the result of all parameters except PDR will be best for the AODV protocol but when the mobility speed is static then the result of LETSRP shows best results.

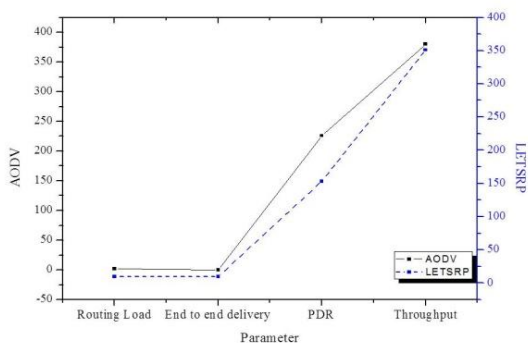


Figure 5. Scenario= 1500X1500, No of Nodes=20, Packets=100, Size= 512 Bytes, Mobility=20 m/s

In Fig. 5, 1500×1500 dimension areas is used in Qualnet networks simulation. We have set 100 packets and each packet has size 512 bytes, Mobility 20 m/s used to transmit between the nodes available in scenario of MANETs, total number of node 20 is used in the scenario. When the number of nodes varies from 10 to 20 and mobility speed also varies from 10 m/s to 20 m/s then AODV routing protocol has overall good performance in term of routing load, end to end delivery, packet delivery Ratio and Throughput. LETSRP routing protocol has worst performance in when number of nodes and mobility speed are high.

VI. CONCLUSIONS AND FUTURE SCOPE

This paper proposed a routing protocol in which Winternitz One-time Signature Scheme is used to check the authenticity of data. Routing protocol sends the data packets to the destination using different paths at the same time and this protocol was based on link expiration time. Algorithm for various functions performed within the protocols has developed. The protocol has three ways for sending the packets- MinLET, MinLET MaxLET. Qualnet 7.3.1 version has been used to implement and analysis wherever LET is used as a parameter to study whether the link is reliable or not. So here two routing protocols has been compared and analyzed by using four parameters. In future, different scenario can be used to compare the availability of link between the nodes. There are other routing protocols which may be used to compare on different size of packets and mobility models.

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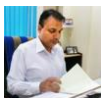
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