International Journal of Recent Technology and Engineering (IJRTE)
ISSN: 2277-3878 (Online), Volume-8, Issue-1, May 2019

Cross-layer and Reliable Opportunistic Routing with Location Prediction Update Vector (CBRT-LPUV) in Mobile Ad hoc Networks (MANET)

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Abstract: In the wireless network, especially in Mobile Ad hoc Networks (MANET) includes mobile nodes having no fixed infrastructure as well as not having centralized administration. In MANET, designing of Routing protocol is critical task. Cross-layer and reliable opportunistic routing algorithm (CBRT) are useful for improving the reliability of routing protocols as well as efficiency. But in CBRT, location of the nodes is identified by exchanging the probe packets periodically. However, it might fail to accurately predict the locations of nodes with increased mobility rate. So to solve the above mentioned issue, we have proposed new location prediction algorithm called Cross-Layer and Reliable Opportunistic Routing with Location Prediction Update Vector (CBRT-LPUV). It is used to predict the nodes location dynamically even with the presence of high node mobility. In this work, Fuzzy Logic System is used for fuzzy rule generation by which more reliable relay node can be selected. Here failures of the nodes are tolerated by introducing the Quality and Stability aware link failure prediction algorithm. This proposed model is implemented in the NS2 and performance as well as evaluation of proposed model is done by using network parameters viz. end-to-end delay time, packet delivery ratio and network life-time metrics.

Keywords: fuzzy logic, location prediction, node selection, opportunistic routing, topology control.

I. INTRODUCTION

MANET may not configures by its own and having no pre-defined infrastructure which has set of nodes that are connected through wireless techniques. Every device in the MANET are subjected to have a free mobility in all directions, and hence have a great chance to change its link topology with other devices frequently. In any given instance of time, any node can either join or leave from the existing network. Each and every node behaves as a router in the network and follows a specific routing mechanism to make communication with other nodes.

Revised Manuscript Received on 30 May 2019.

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The process of sending and receiving of data packets over the network is known as routing and this is possible through pre-defined path as well as on-demand path. MANETs are largely used in the recent technologies such as IoT, vehicular network [1] and so on. Due to various constraints available in MANET, designing of routing protocols are very challenging for Wireless network. There exists a couple of strategies for this purpose. The first is deterministic routing and second is Opportunistic Routing (OR) [2]. In the case of deterministic routing, one node sends data packets to its neighbour node by using any optimal routing algorithm. But in case of OR, the data packets are sent to the set of relay nodes from sender node; instead of sending to only one relay node for the improvement of packet delivery ratio throughout communication network. In this work, we have primarily focussed on OR [3]. OR is one of the promising method with an improved performance in the wireless network. In the case of OR, the sender node does not select any particular node in advance for sending unicast data packets. In lieu of, it selects a group of nodes that will act as potential forwarders and will broadcast the data packets. There are multiple receivers of the data packets which will coordinate to each other in such a way that the node having higher priority value will transmit the data packet first. By this method, OR will delay the process of selecting the transmitter (forwarder) node on receiver side that will increase the reliability as well as robustness in the multihop wireless network [3]. The OR's performance is much relied on various factors. The first is candidate selection. The process of prioritizing the candidates is the next factor that is more influential. The next comes the coordination between various receivers of a data packet for ensuring that only one node among all will transmit the data packet. In previous work, to solve the above issues scatter based fuzzy logic (SBFL) has been used [9]. In SBFL, when nodes are in mobile state, actual candidate list prepared by OR protocols, cannot work in efficient manner, since the previously calculated candidate list will not be valid as soon as the network topology changes. At the same time, location of the nodes is identified by exchanging the probe packets periodically. However, it might fail to accurately predict the locations of nodes with increased mobility rate [4].To Satisfy the above factors, we have proposed, new location prediction algorithm called Cross-layer and Reliable opportunisticouting with location update vector (CBRT-LUV).

It is used to predict the nodes location dynamically even with the presence of high node mobility. In this work, Fuzzy Logic System [9] is used for fuzzy rule generation by which more reliable relay node can be selected. These selected relay nodes are used by Cross-Layer and Reliable Opportunistic Routing with Location Prediction Update Vector (CBRT-LPUV) in MANET. Location prediction is the method of estimating the location of a mobile host's in advance. If the location of mobile host is known in advance, then such type of information may be useful in different ways for improving the overall performance of wireless network. Here failures of nodes are tolerated by introducing the link failure prediction algorithm. Link failure prediction will have done with the concern of prediction of future availability of links between the nodes forming the route [5]. Results are measured using Network Simulator-2 (NS2) [19].

This paper is classified as, in Section 2, we introduced Literature Review. Section 3 introduces proposed methodology for CBRT-LPUV. Section 4 evaluates the performance of proposed CBRT-LPUV and it compares with existing cross-layer and reliable opportunistic routing algorithm (CBRT). In last, Section 5 concludes the work in this paper.

II. LITERATURE REVIEW

Yang, et al [5] proposed LAOR with the aid of OR technique that uses the node's location information that defines the group of forwarding candidate nodes and assigning priority to the candidate nodes. The distance from their destination nodes is key aspect to determine the priority of candidate nodes, i.e. higher priority has been assigned to nearer node to the destination node. LAOR emphases on the minimum resource utilization and avoiding the duplicate transmissions by carefully selecting forwarding nodes that will avoid divergence of routes. The losses of packets are protected by the process of local recovery by the LAOR for re-transmit the packet only if Acknowledgement is not received within the expected time. Tahooni, et al [6] proposed a novel method for the mobile ad hoc network based on OR called as EMOR protocol. For the purpose of dealing with the mobility of the node, that takes into account geographical location of candidate node and count of the neighbouring nodes with link delivery are compared with EMOR (Enhanced Mobility-based Opportunistic Routing) with other five renowned routing protocols in the aspect of end-to-end delay, delivery ratio and the desired count of transmission from sender node to the receiver node. The result based on simulation shows that proposed method drastically enhances the delivery ratio and desired count of data packets transmission. Jubin Sebastian, et al [7] came with a model of Location Based Opportunistic Routing Protocol (LOR) for addressing the problems related to proper delivery of data packets in highly dynamic MANETs with increased reliability in the timely fashion. This method captures an additional benefit of being stateless property of geographically based routing and nature of broadcasting in a wireless medium. Whenever the data packet is sent, nearby nodes will act as the forwarding node by overheard the transmission and it will pass the data packets, if they do not transmit by the best forwarding node in the specified time. With the use of such backup, interruption in a communication is avoided. The latency due to local route recovery and relaying same data packet due to packet reroute are minimized in great extent. The results are simulated in the NS2 and it is confirmed that the effectivity of proposed protocol will increase and throughput will increase by 28%.

Bhorkar, et al [8] proposed the concept of adaptive OR scheme for MANET. This scheme uses the learning framework to route the data packet opportunistically when there are no sufficient knowledge of channel statistics and model used for network. This method found to have a good average per packet rewarding criterion. This proposed method also addresses the challenges of routing and learning in OR context, where the network model follows the probabilities of successful transmission of packets. Specifically, this learning framework results in new routing method which ideally searches and uses all available opportunities that are possible in the that particular network.

Chung, et al [11] proposed three models for the purpose of analysing the count of transmission for the successful delivery of the given packet in three OR based schemes. The single-forwarder OR where the topologies that are already known, the multiple-forwarder OR where the topologies that are already known and multiple forwarder OR where the topologies is not known previously. These models may be beneficial in the context of network planning. Bo, et al [12] incorporated the concept that will built a simple model for evaluation of the forwarding character of neighbour node and applying same model to OR in the MANET. An innovative and reliable model is incorporated by selecting the highest priority forwarding node and that node having a trusted minimum cost routing (MCOR) was formed and, then the correctness with its effectiveness are measured. In the last, MCOR algorithm is demonstrated by using simulation technique nsclick and its evaluation are compared with well-known protocols available: Watchdog-DSR, TAODV and ExOR [2]. Kumar, et al [13] introduced a new and novel technique for evaluation of the node's lifetime and lifetime of the links by using dynamic nature like as the rate of energy draining of node and its relative mobility. These two parameters are then integrated into the route lifetime prediction algorithm to pick the path having long lifetime with consistently data packets forwarding. Further, the process of evaluating and maintaining nodes behaviour in terms of trust is the vital in the MANET. This can be achieved by trust computational methods. Korsnes, et al [14] developed a novel method in which routes are maintained and fixed on the basis of 'ages' incorporated on the routes. With comparing with that of other routing techniques, this algorithm shows more efficiency in the aspect of reliable routes lifetime. However, the protocol overhead is minimized which gives increased throughput due to awareness of elapsed routes lifetime. This approach is applicable to military environment where the node's movement are correlative in manner.

III. PROPOSED METHODOLOGY

This section explains the architecture of the proposed Cross-Layer and Reliable Opportunistic Routing with Location Prediction Update Vector (CBRT-LPUV). In CBRT-LPUV, relay node selection will be done based on the fuzzy logic and link prediction based on link life time prediction are explained in detail in this section.

A.FUZZY LOGIC ALGORITHM

As outlined in Figure 1, fuzzy logic system is classified into three units: fuzzification, fuzzy logic inference, and defuzzification. Fuzzification is the process where the variables that are used as inputs are mapped in the fuzzy set on the basis of linguistic variables and associated membership functions. Let us assume that the universe of input is *U* and the fuzzy set of universe *U* is *A*;$\mu_A$is the membership function which maps universe *U* to fuzzy set *A*. Here membership function depicts the membership between universe *U* and fuzzy set *A*, i.e.,μ_A: u→A∈[0,1]. The fuzzy set *A* may be represented as:

A= $\{(u_i \mu_A(u_i))|u_i \in U\}$ where u_i is the element of universe *U*.

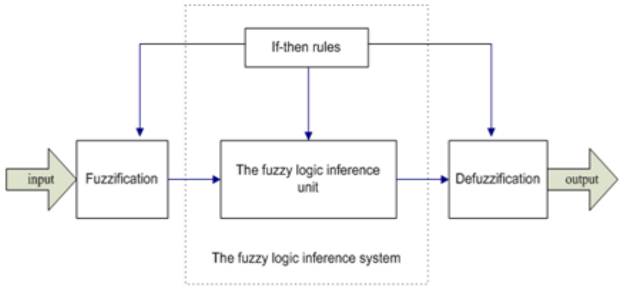

Figure1. Fuzzy Logic system

The generalized description of the membership function as

$$\begin{cases} u_A(u_i) = 1: \quad u_i \text{ belongs to } A \text{ complete;} \\ u_A(u_i) = 0: \quad u_i \text{ does not belong to } A \text{ complete;} \\ 0 < u_A(u_i) < 1: \quad u_i \text{ belongs to } A \text{ partly;} \end{cases} \quad (1)$$

The fuzzy set *A* will be input value for fuzzy inference unit that are utilized for computation of the output fuzzy set *B*. If there are more cross-layer performance available, then the fuzzy rules is as follows:

If $A_1, A_2, A_3,$ ….. A_n *then B* (2)

where A_1, A_2, A_3, ….,A_n (inputs) and *B*(output) are the fuzzy sets, u_1, u_2,u_3…..u_n, (inputs) and *U* (output), respectively. If there are more number of fuzzy rules, then it will require more memory which is impractical in the case of MANETs. To solve this, a new algorithm incorporated which can insulate all the effects of number of inputs to compute from fuzzy inference system, it means; increase in the count of fuzzy rules, it will not effects on the inputs count. This novel algorithm may be termed as scatter based balanced fuzzy logic algorithm (SBFL).

SBFL algorithm

Taking into consideration of the fact that in selecting the relay node with its priority value, the metrics for performance computation viz; residual energy, ETX, distance to the destination node. In this SBFL algorithm, we assume that there are *n* number ofinput universes, which is U= $[U_1, U_2, U_{3,\ldots} \quad U_n]$; for each universe, there are *m* elements, i.e.$U_i = [u_i^1, u_i^2, u_i^3, \ldots\ldots u_i^m]^T$. In order to reflect the rate of variation in more accurate manner, the relative variance (*rv*) will consider the average of all the metrics for evaluation of variation rate, expressed as:

$$D_i = \frac{1}{m}\sum_{j-1}^{m} \left(\frac{U_i^j - U_i}{U_i}\right), i \in [1, n] \quad (3)$$

where U_i^jmeans the *j*[th]element of U_i; $\overline{U_\iota}$ is the average value of the parameters available in U_i. In SBFL, the input universes U_1 ,U_2 ,…, U_n are exchanged by the relative variance *D* which will be the input to the fuzzy inference system. Here, fuzzy set A_D are represented by:

$$A_D = \{(d, d_A(d_i)) \mid d_i \in D\}$$
$$= [d_A(d_1), d_A(d_2), d_A(d_3), \ldots\ldots, d_A(d_n)] \quad (4)$$

where $d_A(i)$, represents membership function among scatter *D* and fuzzy set A_D . Here scatter *D* is the 1 x n matrix, so that fuzzy rules may be reprinted as: *If* A_D *then B*.

B. LOCATION PREDICTION

Location prediction algorithm is used for the prediction of the current position of the given node by using the node's location information and node mobility data that are composed at the time of flooding-based route discovery. For this purpose, here we are doing the following steps.

Route Discovery to Collect Location Update Vector

If the source node having a data packet to be transmitted to the destination node and if route to that destination node is not aware, then source node will start a flooding based route discovery. This is carried out sending the Route-Request packet (RREQ) to its neighbours nodes. The sequence number is maintained by source node for the discoveries of the flooding based route that may initiated to reach to the destination node. All of the nodes that receives the first RREQ packet will contain its related location update vector LUV. This will contain node id value, X axis, Y axis co-ordinates, current velocity and angle of movement related to X axis coordinates. The node that is present in the intermediate also will append its own id value in the field Route record of the RREQ packet [17]. RREQ packets may deliver to destination node via various paths and will collect all the LUVs information from various nodes available in the network.

C. LINK LIFE TIME PREDICTION ALGORITHM

In MANETs, nodes can move freely anywhere, due to this mobility link topology may changes repeatedly, so that the link will break easily and it cannot survive for long time [16]. The link lifetime is based on mobility of the node. Every node having a GPS device, which will compute the node's coordinate and its moving speed with the direction. Both of these two values have an impact to the link lifetime.

The node will obtain location of other nodes' by sharing their probe packet. In this algorithm, selection of candidate relay node will depend on distances of neighbour nodes. The neighbour node having smaller distance from its source node, the such sender nodes are also known as candidate relay node. The link lifetime measure is depending on the source node *s*, its relaying node *r*, and in the last, its destination node *d*. As the results of mobility of source node *s* as well as its destination node *d* from its previous positions, the coverage of survival area will change frequently. In addition to this, the connection link will be broken as the result of mobility characteristics of the relaying node *r*, moves away from its coverage of survival area.

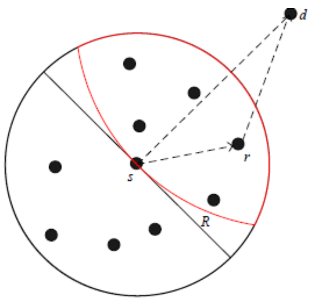

Figure 2. Geographic based relay node selection

In Figure 3, moving velocities for the node *s*, for the node *r*, and for the node *d* are $\vec{v}_s$(here speed as $\vec{v}_s$ and direction as θ_s), $\vec{v}_r$ (here moving speed as v_r and moving direction as θ_r), and $\vec{V}_d$(here moving speed as V_d and moving direction as θ_d), respectively.By assuming the destination node *d* as reference frame, then its relative velocity of source node *s* can be expressed as : $\vec{v}_{sd} = \vec{v}_s - \vec{v}_d$. As per the concept of vector synthesis theory, the relative speed and direction of $\vec{v}_{sdr}$can be expressed as :

$v_{sd} = \sqrt{v_{xsr}^2 + v_{ysr}^2}$, $\theta_{sdr} = arctan\left(\frac{v_{xsdr}}{v_{ysdr}}\right)$ $v_{xsdr} = v_r cos\theta_r + v_{sd} cos\theta_{sd}$ and

$$v_{ysdr} = v_r sin\theta_r + v_{sd} sin\theta_{sd}$$

where v_{xsdr} is the speed of v_{sdr} in *x-axis* and v_{ysdr} is the speed of v_{sdr} in *y-axis*. So that, relative velocity of relay node *r* relatives to $\vec{v}_{sd}$can be calculated as : $\vec{v}_{sdr} = \vec{v}_r - \vec{v}_{sd}$.

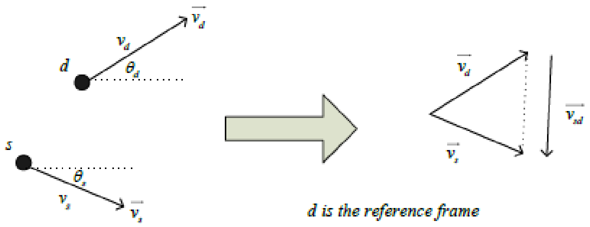

Figure 3. Principle of the velocity vector

Algorithm. The proposed CBRT-LPUV

1. sender node will broadcast RREQ packet to the its neighbournode;
2. if dst(node_X, receiver_node) < dst (sender_node,receiver_node);
3. node X*will* transmit the RREP packet to sendernode;
4. sender node computes the RND;
5. end if
6. if($U^j \geq U^{th}$)
7. node_status ←true;
8. elseif($U^j < U^{th}$)
9. node_status ←false;
10. end if
11. sender node update the candidate relay list;
12. sender node will extract cross-layer metrics fromthe RREP packet;
13. $D \leftarrow$ Dispersion(U^j);
14. $\omega_i \leftarrow$ Fuzzylogic(D_i);
15. sender node broadcastdata packet to candidate relay nodes with its prioritylist;
16. candidate relay nodes transfer the data packet as per theirhigher priority.

IV. SIMULATION AND DISCUSSION

This section discusses the experimental results of our proposed model. The model is implemented using NS2. The existing cross-layer and reliable opportunistic routing algorithm (CBRT) and proposed CBRT-LPUV are compared with respect to network parameters as end-to-end delay, network lifetime and packet delivery ratio.

The parameters used for the simulation are:

Area	1000 mtr ×1000 mtr
Transmission range	100 mtr
Traffic type	CBR
CBR rate	512 Bytes × 6 per second
Initial energy:	5J
High transmission power:	0.8W
Low transmission power	0.1W
Number of Nodes	50-200
Average moving speed:	0.2 m/s
Receiving power:	0.05W

1. Delay

By broadcasting the probe packets periodically, we can get the transmission delay of the relay node. This is equivalent to the measurement of the link's ETX. It is represented by the following notation:

$$D_t = \frac{N}{R} \text{seconds} \qquad (5)$$

where D_t: transmission delay (sec.)

N: the number of bits

R: transmission rate (bps)

2.Packet Delivery Ratio (PDR)

PDR is used to compute network performance. It is the ratio of how many data packets received by receiver node to the how many data packets broadcast by the source node.

$$PDR = \frac{P_{received}}{\sum_{i=1}^{n} p_{generated_i}} * 100 (6)$$

where,$P_{received}$ represents how many data packets received by receiver node, $p_{generated}$ is the how many data packets broadcast by the source node and n represents the number of nodes available.

3.Network Lifetime

It can be estimated as the network operational time in which it has ability to perform all the dedicated functions.

4.Throughput

It is the amount data packets transferred from the source node to the destination node in a specific time duration. The unit for throughput is bits per second (bps) / megabits per second (Mbps) / gigabits per second (Gbps).

TABLE:1. Results of End- to -End delay

Time in (m.s)	Delay values of different Methods	
	E(CBRT)	LP(CBRT-LPUV)
0	0	0
5	0.0122455	0.0062455
10	0.3221045	0.2521045
15	0.7221369	0.6121369
20	0.8442103	0.7042103

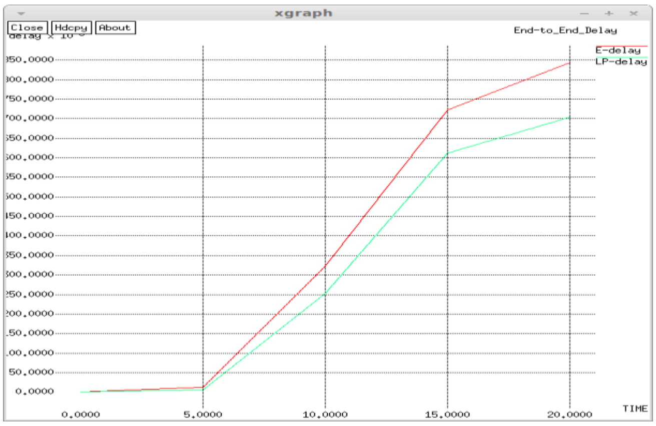

Figure 4. Simulation result of delay in seconds

Fig. 4. demonstrates the results of performance analysis of existing CBRT and proposed CBRT-LPUV model in terms of delay in seconds. It shows that the newly introduced CBRT-LPUV model renders lesser delay result than the existing CBRT model produce higher delay results.

TABLE: 2. Results of Packet delivery ratio

Time in (m.s)	Packet delivery ratio values of different Methods	
	E(CBRT)	LP(CBRT-LPUV)
0	0	0
5	0.4748	0.5891
10	0.5013	0.6940
15	0.6940	0.7738
20	0.7660	0.8611

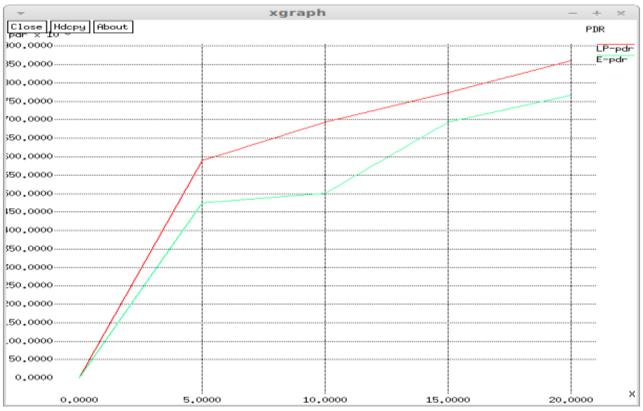

Figure 5. Simulation result of packet delivery ratio

Figure 5. demonstrates the results of performance analysis of existing CBRT and proposed CBRT-LPUV model in terms of packet delivery ratio. This depicts that the newly introduced CBRT-LPUV model renders higher packet delivery ratio result than the existing CBRT model

TABLE: 3. Results of Network lifetime

Time in (m.s)	Network lifetime values of different Methods	
	E(CBRT)	LP(CBRT-LPUV)
5	95.78	95.87
10	95.75	95.76
15	95.60	95.63
20	95.39	95.46

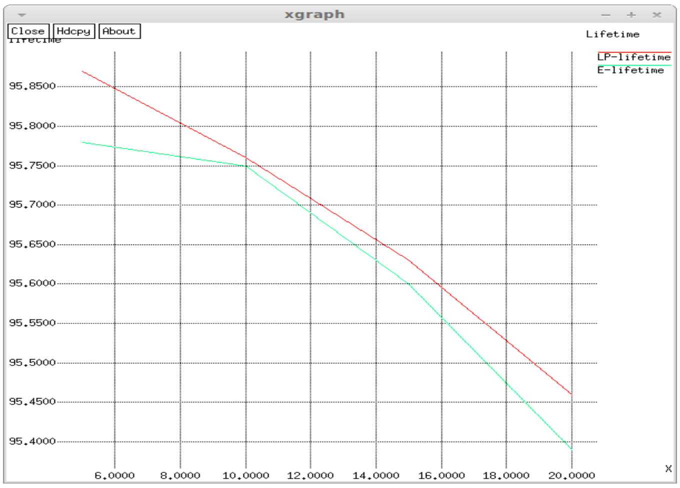

Figure 6. Simulation result of Network Lifetime (sec)

Figure 6. demonstrates the results of performance analysis of existing CBRT and proposed CBRT-LPUV model in terms of network lifetime. It shows that the newly introduced CBRT-LPUV model renders higher network lifetime result than the existing k-connection, CBRT model.

TABLE: 4. Results of Throughput

Time in (m.s)	Throughput values of different Methods	
	E(CBRT)	LP(CBRT-LPUV)
0	0	0
5	0.6230012	0.7630012
10	0.8623314	0.9823314
15	1.2000058	1.3700058
20	1.3844521	1.5344521

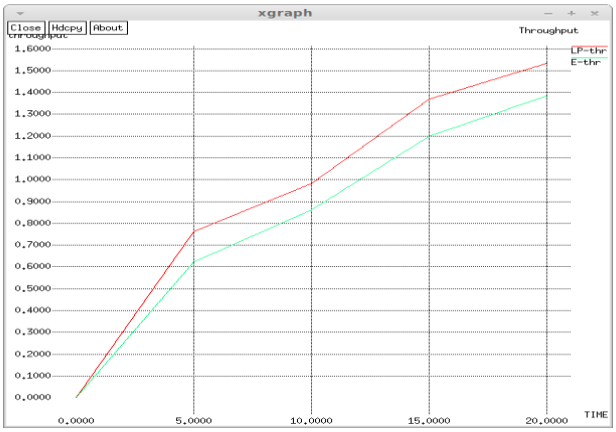

Figure 7. Simulation result of Throughput (sec.)

Figure 7. demonstrates the results of performance analysis of existing CBRT and proposed CBRT-LPUV model in terms of Throughput. It shows that the newly introduced CBRT-LPUV model renders higher Throughput result than the existing k-connection, CBRT models.

V. CONCLUSION

In this work, we have proposed the Cross-Layer and Reliable Opportunistic Routing with Location Prediction Update Vector (CBRT-LPUV) algorithmare useful forimproving the reliability of routing protocols as well as efficiency in MANET. It is used to predict the node's location dynamically even with the presence of high node mobility. Here the failures of the nodes are tolerated by introducing the link failure prediction algorithm. Link failure prediction will have done with the concern of prediction of future availability of links between the nodes forming the route. By this simulation model, the network performance of CBRT-LPUV is improved and is evaluated with respect to end-to-end delay, network life-time, packet delivery ratio and throughput metrics.

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