Link stable routing with minimal delay nodes for MANETs

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Abstract: Multi-hop routing in mobile ad hoc networks (MANETs) requires good resource managing protocols. The efficient route from source to destination in the network is identified by determining the level of signal strength from intermediate hops. The link quality between the intermediate nodes is determined by calculating the signal strength level. The received signal strength is one method to estimate the medium characteristics and distance between the intermediate nodes which is one of the quality of service required by the network. The nodes with high signal strength and high bandwidth are identified as minimal delay nodes so as to determine the reliable path. The data is sent through minimal delay nodes in the shortest path from source to destination. The better link quality improves the performance metrics such as packet delivery ratio, throughput and simultaneously reduces the control message overheads, average and end-to-end delay compared to some of the existing routing protocols. The experimental study shows that the proposed routing protocol is 30% better in packet delivery ratio, throughput, reduced control message overheads, average and end-to-end delay than the existing stable and delay constrained routing protocol.

Keywords: routing; minimal delay nodes; signal strength; mobile ad hoc network; MANET.

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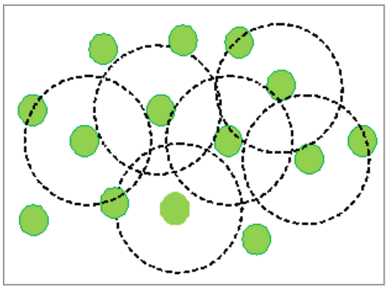
1 Introduction

Mobile ad hoc network (MANET) is a wireless ad hoc network used to exchange information and it is established quickly anytime and anywhere with dynamic changes in location. Here, nodes are free to move in any direction within its transmission range and each node is equipped with the transceiver. Base station and backbone infrastructure support is not required and the nodes communicate with each other by forming a multi-hop network in a decentralised manner.

The link failures in MANET are caused due to several reasons such as high mobility (Karuppiah, 2016), interference, occurrence of congestion due to low channel capacity, poor signal strength, nodes out of transmission range, etc. MANET face many challenges such as resource constraint, bandwidth management and packet broadcast overhead, thus making it complicated to design routing protocols. Routing protocols are categorised as proactive and reactive protocols (Karuppiah et al., 2016). Proactive protocols such as DSDV periodically send routing control packets to neighbours for updating routing tables. Reactive routing protocols such as ad hoc on-demand distance vector (AODV) and DSR send control packets only when route discovery or route maintenance is done. When a route is created or repaired, the control packets, particularly route request (RREQ) packets flooded by source across the network (Li et al., 2016). Moreover, the number of control packets increased rapidly with network size and topology changes.

Figure 1 MANET architecture (see online version for colours)



The congestion occurs when the amount of data sent to the network exceeds the available channel capacity. Such situation leads to increased buffer space usage in intermediate nodes, leading to data losses. In cellular network, signal to noise ratio (SNR) of connection between mobile phone (Kumari et al., 2016) and base stations is monitored to determine when to switch from one base station to another. Contrast to it in MANET current routing protocols do not predict when a link's SNR will fall below a threshold. Periodic hello messages in AODV denote the presence or absence of neighbours. The general architecture of the MANET is shown in Figure 1. The green coloured circles are indicated as nodes in the network and the dashed circles around the nodes indicates their maximum transmission range. The transmission range implies that the nodes can communicate with each other within the range.

2 Related work

Several methods were proposed for determining efficient route for data transmission (Li et al., 2017), among them some of the protocols were discussed here. The protocol uses RREQ message for route discovery and ROUTE REPLY message for route maintenance and finalises the route for data transmission.

The primary protocol considered in the MANETs is AODV (Perkins et al., 2003) routing and the performance of this protocol is good but the hop counts was alone considered during the route selection. High packet drops occurred due to link failure, this is solved by using local repair mechanism, and the upstream intermediate nodes send route error message to the source and tries to establish the new route segment. However, local repair mechanism has heavy control overhead messages and suffers from frequent link breaks.

To establish stable and sustainable paths between all pairs of mobile nodes a link state QoS routing protocol was proposed (Moussaoui et al., 2014). The link availability is estimated according to the probability calculation, the link stability values of the neighbour nodes are measured depending on the variance of signal power of message exchanged between them. Stability of nodes (SN) and fidelity of nodes (FN) are the two metrics derived in this mechanism. The function of stability of nodes can be determined by calculating the stability of a neighbour B by a node A. The fidelity of nodes is termed as the degree of reachability with only the stable node.

To overcome the disadvantage of AODV protocol AODV-HPDF (Marina and Das, 2001) was proposed to reduce the control overheads and frequent link failures. Several multipath approaches have been proposed to enhance the AODV protocol and to reduce the frequent link breakages caused due to dynamic ad hoc networks. In single path for every route break, a new route discovery is needed in response to that route break and this leads to large overheads. This inefficiency is avoided by the proposed ad hoc on-demand multicast routing protocol (AOMDV) (Wu et al., 2008). Multiple redundant paths are created here.

Temporally ordered routing algorithm (TORA) (Pandey et al., 2013) a loop free routing protocol have been proposed for multi-hop networks to minimise the overheads occurred due to topological changes. TORA is based on link reversal algorithm, which reduces the control messages in ad hoc networks. However, overheads in the network have been controlled by choosing longer routes from source to destination.

Efficient power aware routing (EPAR) protocol was proposed (Suresh et al., 2014) to increase the network lifetime and to reduce the expected energy level used for the packet transmission over a specific link. To minimise the amount of energy consumption the proposed protocol traces the amount of energy spent for packet transmission between each and every nodes on the route. Minimum energy consumption nodes are selected to route the packets from source to destination. Based on the transmission and receiving power, energy is determined for each node.

On-demand reliable routing mechanism (Pandey et al., 2013) has been proposed, based on received signal strength (RSS). Newton interpolation polynomial is constructed for the selection of middle value from the several sample values in order to calculate the signal strength, link lifetime and velocity of nodes. Link failure prediction QoS routing (LFPQR) protocol (Satyanarayana and Rao, 2007) was proposed, this protocol was designed for the prediction of future state of the node to decide whether the node is a good selection for the router or not. The future state prediction of the node depends on mobility and power level.

A cross-layer distributed algorithm called interference-based topology control algorithm (Zhang et al., 2015) was proposed for delay-constrained (ITCD). Here the constraints which lead to the occurrence of delay such as transmission delay over intermediate links, contention delay over nodes and queuing delay due to heavily channelled conditions are taken into consideration. Using these constraints the unstable links are determined and removed from the network. By increasing the transmission power end to end delay can be reduced but leads to more interference to other active receiving nodes. The transmission power of node is controlled to minimise the interference and the topology control algorithms adjust the transmission power by considering the SNR threshold to facilitate successful transmission of packets.

Stable and delay constrained routing (SDCR) (Yang and Huang, 2008) protocol was proposed for the QoS and it consists of two phases. In route discovery phase the path meeting, delay requirement with great link stability factor was introduced. The changes occurred in network topology are continuously monitored and perform rerouting if any delay occur in route maintenance phase. Due to high mobility of nodes the information used for traditional routing protocols become obsolete. To avoid this situation (Shah and Nahrstedt, 2002) a location delay prediction scheme was proposed to predict end to end delay for the data packet sent from source to destination and information are updated in the update table. Hence, re-routing could be done before the link failure based on the updated table information.

Bandwidth aware on demand multipath routing protocol (Sharma and Kumar, 2014) was proposed to improve the network performance by selecting the available channel bandwidth. Many routes are discovered and the best route is identified based on the minimum hop distance, the available bandwidth between the nodes and then the data is forwarded.

Reliable multicast routing protocol (RMRP) was proposed for multicast routing system with link stability and database maintained at every node. Based on the selection of stable forwarding and high link connectivity of nodes stable routes are found. The received power and the distance between the nodes calculate the link stability among the nodes. However, these schemes suffered from network unbalancing, frequent route failures and high overhead. To provide a robust data transmission, a stable method for data delivery is required to support an unpredictable network topology.

Jayalakshmi and Saravanan (2018) proposed a protocol (CRIN), where selection of next hop based on the speed of movement of nodes and transmission range: reduces overall energy consumption, link failures and delay constraints. The weights of the link quality between the nodes present in the network can be estimated by cost metrics such as distance and travelling speed of the node. Semi-Markov smooth and mobility model with fewer complexions was designed for providing stable routing. Smooth mobility and link reliability-based OLSR (SMLR_OLSR) efficiently designs the reliability-based multi point relay and this identifies the realistic behaviours of node. Selecting signal strength-based link stability estimation (SSLSE) was proposed for selecting the stable links by transmitting the data over multiple receivers during the route construction process.

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However the crucial challenge in building a MANET is equipping each device to continuously maintain the information required to properly route traffic. Such networks may operate by themselves or might be associated with the bigger internet. They may contain one or numerous and distinctive transceivers between nodes. This result in a highly dynamic, autonomous topology MANETs are a kind of Wireless ad hoc network that usually has a routable networking systems administration condition on top of a link layer impromptu or ad hoc network. Mobility causes startling link or connectivity breakages since the nodes move out-of-range of each other. There is a delay brought on in the network due to reconfiguration of links progressively. Most routing schemes in the related schemes focus mainly on data transmission and often use shortest path, however the stable routing and link reliability between the nodes present in the shortest path has not been addressed properly.

3 Detecting stable routes using minimal delay nodes

In mobile ad hoc network, the homogeneous nodes are considered in this proposed link stable minimal delay node routing (LSMDNR) method. Source node broadcasts RREQ message to find the active nodes in the network. Once the RREQ reach the destination node, it passes the RREP messages via the reverse path. During the reception of RREP message, the signal strength is computed to prevent average end-to-end delay due to the occurrence of link or route failures in the intermediate nodes.

The predefined threshold value for the signal strength is set. For each node-to-node link, the signal strength is determined and compared with the predefined threshold value. If the RSS is greater than the threshold value, then the node is added in to the group of minimal delay nodes. The RSS from one node to the other node is determined by using the formula,

$$S_r = S_t \left(\frac{\lambda}{4\pi r} \right)^2 \tag{1}$$

where

S_r RSS

S_t transmitted signal strength

λ wavelength of signal in metres

d distance between the transmitting and receiving nodes.

The predefined threshold value of the nodes is determined by computing the average threshold value for all the nodes coming under the network by using the formula,

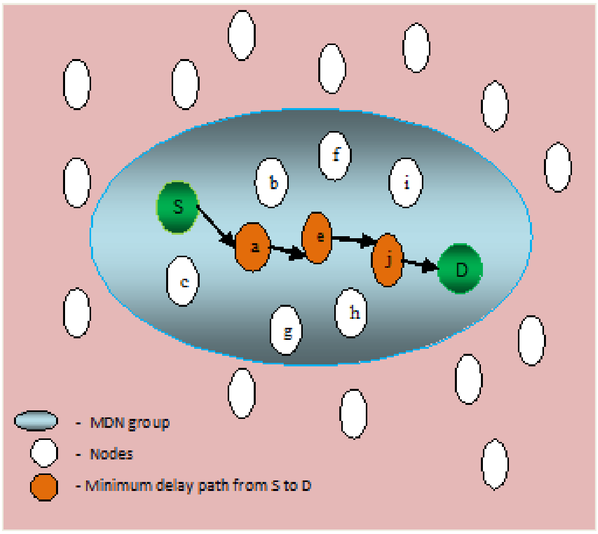
$$V_{THRESH} = \left(\frac{SNR}{t}\right) \tag{2}$$

where

SNR SNR at time 't'.

From the group of minimal delay nodes, the intermediate nodes with the shortest path $S - a - e - j - D$ from source to destination are selected and their processing rate is calculated. Here *a*, *e* and *j* are considered as relay or intermediate nodes. *S* and *D* are taken as source and destination nodes. The nodal processing rate includes the time taken by the packet to arrive at the corresponding node, time taken to process the packet and time taken to relay the packet to the next node. This includes the overall processing delay of the information.

Figure 2 LSMDNR illustration (see online version for colours)



The average processing rate of all minimal delay nodes is determined and set as threshold value. The intermediate nodes with the high processing rate are selected from the MDN group, and the data is sent from source to destination. The minimum delay nodes are picked based on the nodal delay value. It includes packet processing time and queuing time. The nodal processing delay is calculated by using the formula in equation (3)

$$\delta(n) = t_p + t_q \tag{3}$$

where

δ nodal delay

t_p processing time

t_q queuing time.

The processing time (t_p) is termed as processing delay and this can be defined as time it takes nodes to process the packet header. It is a key component in the network. After nodal processing the router directs the data or packet to the queue which causes additional delay and this is termed as queuing delay (t_q).

The average threshold value for all the nodes coming under the network is calculated by using the formula,

$$\delta_{Thresh} = \left(\frac{S_{proc}}{t} \right) \tag{4}$$

where

S_{proc} processing speed of the node

t time.

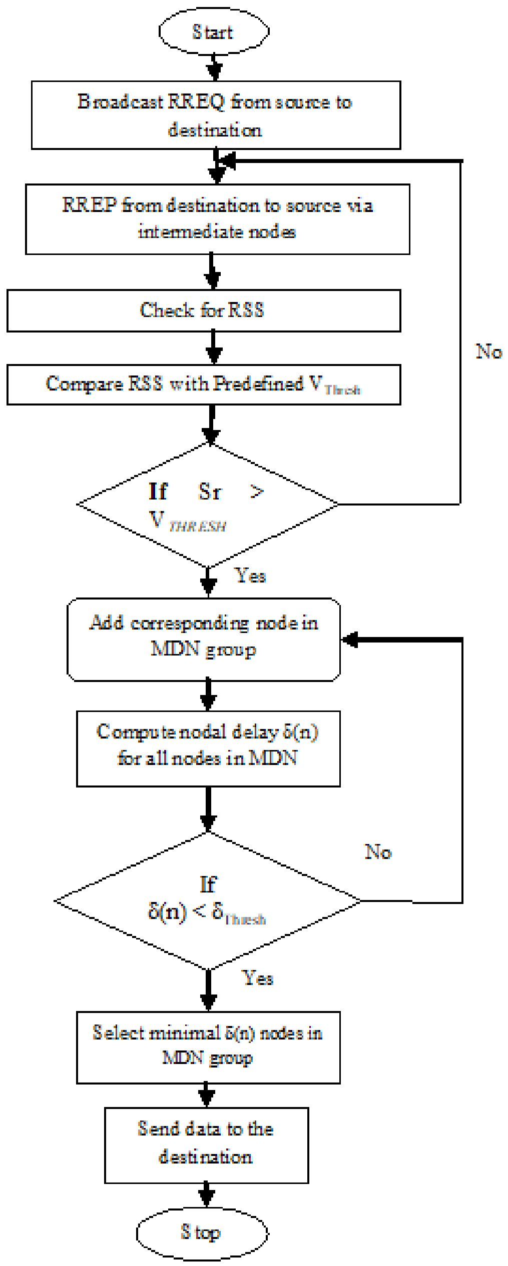
By determining the RSS and the nodal processing delay between the nodes present in the network or the relay nodes between the source and destination the stable routes can be determined.

Algorithm 1 LSMDNR algorithm

1 current_node ← source node;
2 source broadcasts → RREQ
3 Receive RREP ← Destination
4 **for** all *n* neighbours (current_node) **do**
5   Compute $S_r(n)$
6   Set V_{Thresh}
7   Compare V_{Thresh} with received $S_r(n)$
8   **if** $S_r(n) > V_{Thresh}$ **then**
9   Append *n* into *MDN* list;
10   Calculate δ for each node $MDN(n)$
11   Set average threshold δ_{Thresh}
12   **if** $\delta(n) < \delta_{Thresh}$ of MDN(n) **then**
13   append $\delta(n)$ to shortest path
14   Send data from *src* to *dest*
15   **else**
16   GOTO → *MDN* list
17   Repeat step 11
18   Until finding *MDN* nodes
19   **end if**
20:     **else**
21   GOTO step 1 → Re-route from *src* to *dest*
        until data reaches destination;
22   **end if**
23 **end for**

LSMDNR algorithm describes the intelligent routing in MANETs. Intelligent routing can be done by selecting the minimal delay nodes in the network. The shortest path is calculated among the minimal delay nodes and the data is sent via the shortest path. Dijkstra's algorithm is used to find out the shortest path from the source node to the destination node. The weights of the node's edges are calculated to find the shortest and reliable nodes in the MDN group.

Figure 3 Flowchart for LSMDNR



The proposed method LSMDNR is explained in the flow chart and in the algorithm. The flowchart is shown in Figure 3 which describes the working flow of LSMDNR protocol.

RSS is calculated through the distance between the nodes. The nodes which have higher S_r is taken and nodal processing delay is calculated. Minimum delay nodes are selected and the data is sent through these nodes that move towards the destination.

Table 1 Simulation parameters

Parameter	*Values*
Channel type	Wireless channel
Simulation time	20 seconds
Number of nodes	50
MAC type	802.11
Traffic model	CBR traffic
Simulation area	1,300 × 700
Transmission range	250 m
Network interface type	Wireless phy

4 Simulation analysis

The simulation scenario for the proposed method is shown in Figure 2. The simulation parameters used for the simulation analysis is shown in Table 1. The simulated results are obtained using network simulator (NS-2.34) tool. An object oriented discrete event simulator is used to identify the performance of the proposed scheme. The backend language is C++ and the front end is tool command language (TCL), which is described as string-based command language.

User datagram protocol (UDP) is the communication protocol through which the nodes communicated with each other. The nodes moved arbitrarily within the simulation area by utilising the mobility model random way point (RWP). The radio wave is proliferated by utilising two ray ground propagation models. The activity in the network system is dealt with utilising the movement of constant bit rate (CBR). The nodes or hubs in the network receive the signal from all direction by means of the Omni directional antenna. The execution of the proposed routing protocol is accessed by using the parameters packet delivery rate, packet loss rate, average delay, throughput, residual energy and network lifetime.

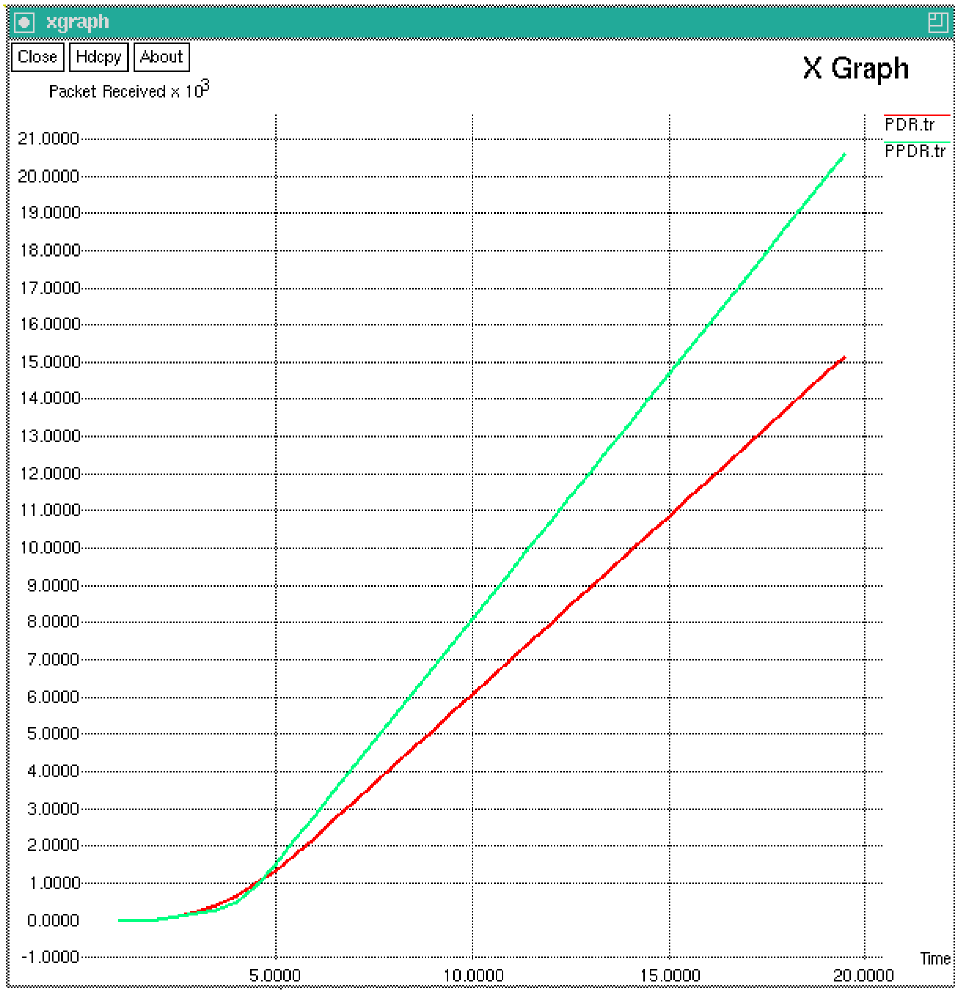
4.1 Packet delivery rate

It is defined as the ratio of packets received by the destination node to the total number of packets sent. Equation (5) is used for *PDR* calculation,

$$PDR = \frac{Total\ no\ of\ \ pkts\ received\ by\ dest\ node}{Total\ no\ of\ \ pkts\ sent\ by\ src\ node} \tag{5}$$

The packet delivery rate for the proposed scheme is higher comparing to the existing system SDCR that is shown in Figure 4. The unit of packet delivery rate is measured in bits per second and time is measured in seconds.

Figure 4 PDRs of SDCR and LSMDNR (see online version for colours)



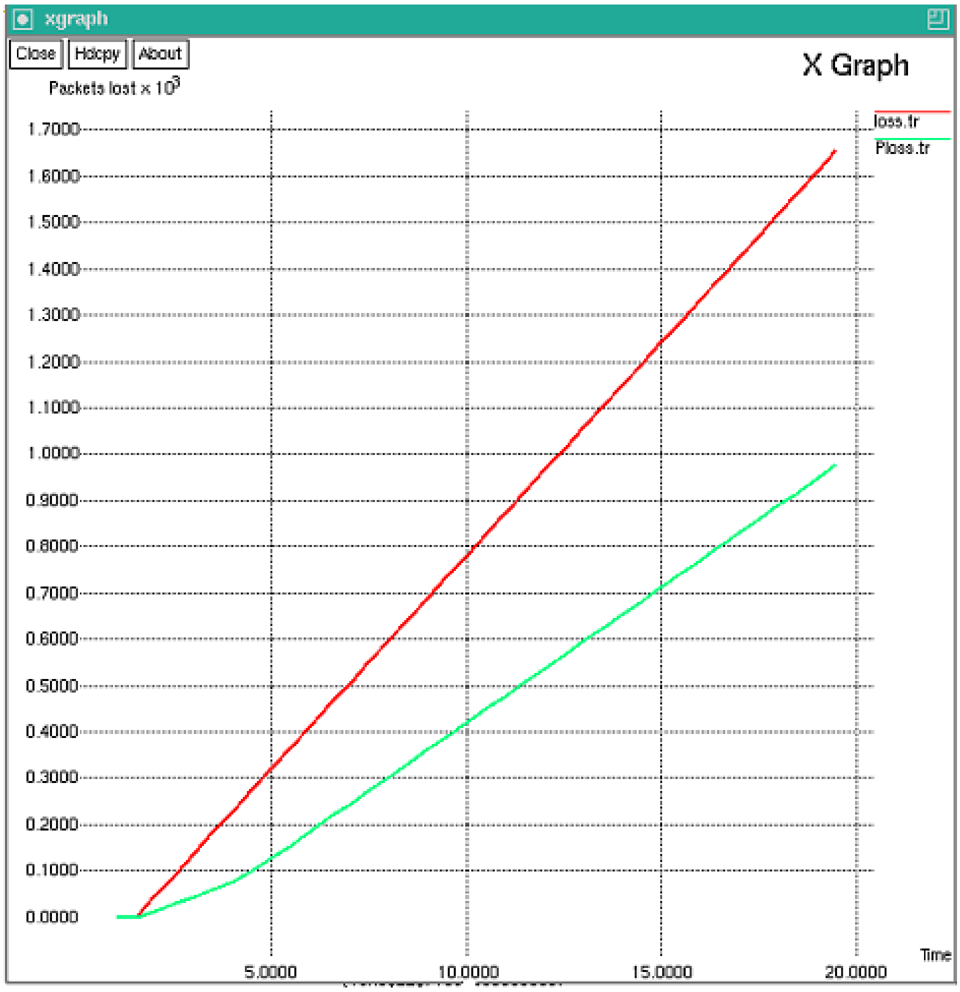
4.2 *Packet loss ratio*

Packet loss ratio is defined as the ratio of number of packets dropped by the nodes in the network to the total number of packets sent as given in equation,

$$PLR = \frac{Total\ \ pkts\ lost}{Total\ \ pkts\ sent} \tag{6}$$

Figure 5 shows that the packet loss ratio of the proposed LSMDNR mechanism remains low when compared to that of the SDCR protocol. *Ploss* describes packet received rate for proposed scheme and *loss* depicts the packet received rate for the conventional scheme. Time is measured in seconds. *PPDR* describes packet received rate for proposed scheme and PDR depicts the packet received rate for the conventional scheme.

Figure 5 PLR of SDCR and LSMDNR (see online version for colours)



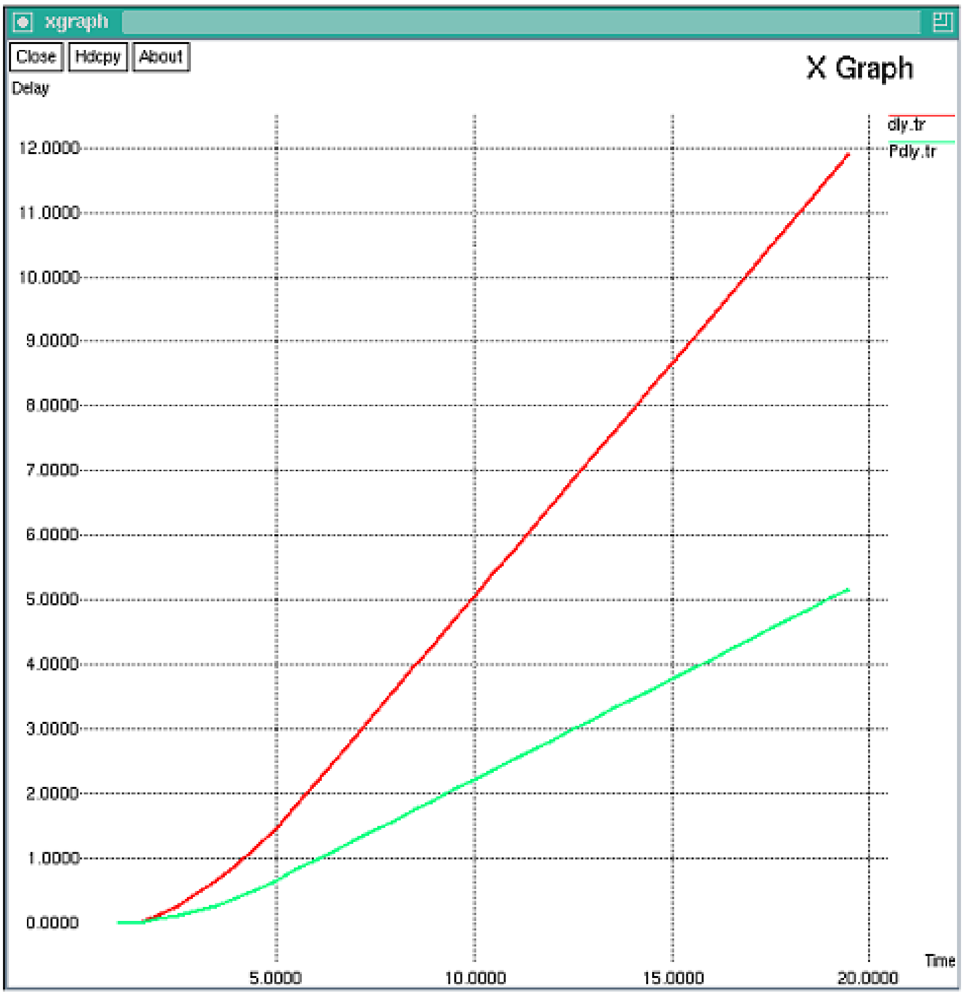
4.3 *Average delay*

Average delay can be estimated by evaluating the nodal processing and queuing time during data transmission and reception as given in equation (7)

$$Delay = \frac{(Pkts\ rcvd\ time - Pkts\ sent\ time)}{Total\ time} \tag{7}$$

Delays of SDCR and proposed method LSMDNR are measured and plotted in Figure 6. It can be observed that the delay of the LSMDNR is minimum since they are the averages of each node to process data. The decrease in delay of the proposed method reflects the efficiency of the bandwidth routing in the proposed method. The unit of time is measured in seconds. *Pdly* describes delay or time taken for sending or receiving the packets from one end to other for proposed scheme and *dly* depicts the delay rate for the conventional scheme.

Figure 6 Delay of SDCR and LSMDNR (see online version for colours)



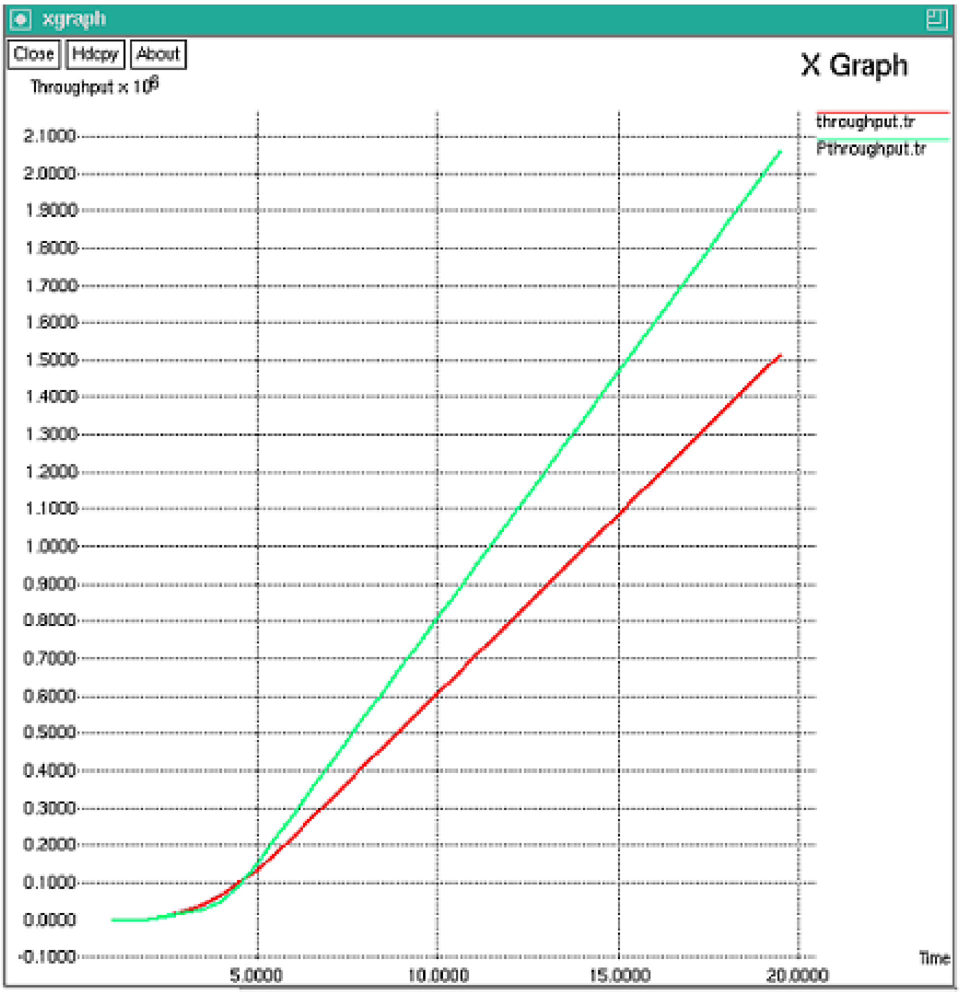
4.4 Throughput

Throughput evaluation is commonly done for judging the network performance and it is defined as the rate of successful delivery of information over a preferred network. It is given in the equation (8)

$$Throughput = \left(\frac{Total\ no.\ of\ \ pkts\ rcvd \times 8}{t} \right) \text{s} \tag{8}$$

Figure 7 shows the proposed method LSMDNR have greater throughput compared to the existing one. *Pthroughput* describes throughput for proposed scheme and *throughput* depicts the packet received rate for the conventional scheme.

Figure 7 Throughput of SDCR and LSMDNR (see online version for colours)



5 Conclusions

The efficient and reliable route for data transmission is discovered by this proposed LSMDNR method. Link breakages among the nodes are avoided by signal strength computation process. Higher RSS with high processing rate nodes are chosen in the MDN group then the data is sent through the shortest route formed by the Dijkstra's algorithm. Throughput increase indicates the efficiency improvement in the proposed method when compared to the existing method. Selecting nodes based on signal strength by minimising delay to avoid congestion and thereby giving high packet delivery ratio.

These factors increase the communication efficiency by 30% in MANETs. The reliability of the path is increased and it is mostly based on the availability of link among the nodes in the network.

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