Load Balanced and Link Break Prediction Routing Protocol for Mobile Ad Hoc Networks

Mandeep Kaur Gulati[1], Monika Sachdeva[2], and Krishan Kumar[3]
[1] Deptt. of Computer Science, KCW ASR, PTU Kapurthala, Punjab, India
[2] Deptt. of Computer Science and Engineering, IKG Punjab Technical University, Kapurthala, Punjab, India
[3]Deptt. of Information Technology, University Institute of Engineering and Technology, Panjab University, Chandigarh
Email: gulati_mandeep@rediffmail.com, {monasach1975, k.salujasbs}@gmail.com

Abstract —A Mobile Ad-hoc Network (MANET) is an infrastructure less and decentralized network which needs a robust routing protocol. With the development of the MANET applications, more importance is given to Quality of Service (QoS) routing strategy. However congestion and mobility of the nodes lead to frequent link failures and packet losses affecting the QoS performance of the protocol. We consider these issues and propose a Load balanced and Link Break Prediction Routing Protocol (LBALBP) for Mobile Ad hoc Networks. The protocol finds least loaded path based on path count metric. Link break prediction mechanism is also integrated in the route maintenance phase of the protocol. Based on the signal strength of the packets received from the neighbour, the node calculates the link break prediction time of the link and if the link is found to be broken soon, an alternate path is found before the link actually breaks. Simulation results show that the proposed protocol outperforms AODV in terms of packet delivery ratio, delay, throughput and no. of link breakages but at the cost of high routing overhead.

Index Terms—mobile ad hoc network, quality of service, stability, load balance, Load Balanced and Link Break Prediction Routing Protocol (LBALBP), cross layer weight based on demand routing protocol, stable energy efficient qos based congestion and delay aware routing protocol

I. INTRODUCTION

A Mobile Ad hoc Network (MANET) is a collection of mobile nodes that form a dynamic infrastructure-less communication network wherever it is required. The nodes in the net-work not only act as hosts but also as routers that discover and maintain routes to other nodes in the network. Therefore, finding and maintaining routes in MANET is a complicated task. Researchers proposed several routing algorithms for mobile ad hoc networks like AODV [1], DSR [2], DSDV [3], WRP [4] etc. However these protocols concentrate mainly on establishing shortest path without any attempt to provide QoS requirements. But such a selected path may not always be the best path for real-time audio and video applications which are sensitive to the Quality of Service (QoS). These applications require the underlying network to provide certain guarantees that are manifested in the support of several important QoS parameters such as throughput, delay, jitter, packet de-livery ratio, link stability, node buffer space, packet loss ratio etc. [5]. However, achieving QoS guarantees in MANETs is a challenging task due to dynamic topology, limited bandwidth and power, variable capacity, error-prone and insecure wireless channels.

The key factor which makes it difficult to develop QoS routing in ad hoc networks is congestion caused due to limited resources such as bandwidth, buffer space, battery power and memory etc. In min-hop routing protocols, nodes on the shortest path will be more heavily loaded than others since they are frequently chosen as the routing path. With the unbalanced traffic distribution, the heavily loaded nodes can exhaust their power resulting in node failures. With more failure of nodes, the connectivity of the network is reduced leading to network partitions. Furthermore, congested nodes can lead to packet loss and buffer overflow, resulting in longer end-to-end delay, degradation in throughput, and loss of transport connections. Hence, it is important for a routing protocol to have some form of load balancing so that traffic is uniformly distributed among various nodes. Load balancing can minimize traffic congestion and end to end delay, maximize node lifetime and can balance network energy consumption. Thus load balancing is emerging as a key tool to better use MANET resources and improve MANET performance. Another major problem in MANETs is the link breakage occurring due to the dynamic network topology and arbitrary movement of the nodes. This leads to the network partitioning and degradation of performance. When the route breaks, the routing protocols try to recover the connection either by repairing the route locally around the breakage or globally by informing the source node which then starts a completely new route discovery process. This kind of action taken after the route is already broken leads to increase in packet loss and the route rediscoveries. This can be avoided if the route maintenance phase of the protocol includes the link breakage prediction mechanism that predicts the link failure before its real occurring.

In this paper, we have considered these issues and proposed a Load balanced and Link Break Prediction (LBALBP) Routing Protocol for Mobile Ad hoc

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Networks which is an extension of AODV protocol. In RREQ packet, path count metric is added which counts the no. of active routes through a node. This indicates the load of a node. When a node receives RREQ packet, it adds its path count value to the RREQ packet and the destination chooses the least loaded path based on the path count metric. This approach distributes the load to the nodes having lesser no. of neighbours. The route maintenance phase of AODV is enhanced so as to predict the link failure based on average rate of change of signal strength. Link break prediction time is calculated and an alternate route is found before the link actually breaks. When the node in an active route predicts that the link with its previous hop is going to break soon, it sends warning message to the upstream node. The upstream node then finds an alternate route locally before the link breakage in order to deliver the data packets which would have lost due to link failures. The alternate route found is strong with the signal strength greater than the threshold value. If the upstream node cannot find an alternate route, weak link breaks and the link failure module of AODV works. The protocol is evaluated and compared with AODV by using NS2 simulator. The simulation results show that the proposed protocol outperforms AODV in terms of parameters like packet delivery ratio, end to end delay, throughput and no. of link breakages etc.

The rest of the paper is organized as follows. Section II presents the related work that has been done in this area. Section III explains the LBPRP protocol in detail. Section IV discusses the simulation results that have been obtained. Section V presents the conclusion and the future work.

II. Related Work

Some of the researches related to load balanced routing and link break prediction in mobile ad hoc networks have been mentioned below.

Excessive load on the network creates congestion leading to the dropping of packets and failure of nodes at times. Load balancing is required to balance the network traffic and avoids excessive end-to-end delay caused by congested nodes. Various single-path and multipath load-balancing mechanisms have been proposed in the literature. In [6], Lee and Gerla proposed a Dynamic Load-Aware Routing protocol (DLAR), in which the queue length of a node is used as a metric to discover the route. Song *et al.* [7] proposed Delay-based Load-Aware On-demand Routing (D-LAOR) protocol, in which optimal path is found based on estimated total path delay and hop count. With this definition, the queuing, contention, and transmission delays are all considered. Lee *et al.* [8] proposed a novel load-balancing technique for ad hoc on- demand routing protocols. The scheme utilizes interface queue occupancy and workload to control RREQ messages adaptively. Wang *et al.* [9] proposed load-balanced routing scheme named FDAR (Free-Degree Adaptive Routing) which uses the routing metric called free-degree of nodes. Souihli *et al.* [10] proposed novel routing metric called degree of centrality that push the traffic further from the center of the network. Their approach improves the load distribution and significantly enhances the network performances in terms of average delay and reliability. Dahab *et al.* [11] propose a cross-layer solution “Load-Aware AODV” (LA-AODV), which selects the path with the minimum MAC load based on a metric called “MAC load indicator”. Kim *et al.* [12] proposed a Load Balanced Congestion Adaptive Routing (LBCAR) protocol which selects the route with low traffic load density and maximum life time for data transmission. Some other papers compared the performance of single-path and multi-path load-balancing approaches. Though multi-path approaches have numerous advantages as high reliability and fault tolerance [13], it appears that single-path approaches are much more efficient as concerned to load-balancing. Multi-path routing is effective only when the alternate paths are disjoint, which is not so easy to achieve in mobile ad hoc networks [13], [14].

Su *et al.* [15] proposed a Distance Vector with Mobility Prediction (DV-MP) routing protocol in which route is selected based on the link predicted expiration time. Link expiration time is predicted and appended to data packets as they move to their destinations. Mobility prediction utilizes GPS location information. However the drawback of using GPS is its high cost and secondly it may not work properly because of fading. Y. Zhu [16] proposed a proactive route maintenance mechanism (AODV-PRM) for improving the performance of AODV, in which the link breakage time can be known before the links are actually broken, so that the alternate route can be found in time to avoid packet loss. He also proposed a proactive tree maintenance mechanism (MAODV-PTM) for improving the performance of Multicast AODV (MAODV). Simulations show both unicast and multicast protocols achieve higher packet delivery ratio by using proactive maintenance. Qin and Kunz [17] added a link status prediction algorithm to DSR which uses the signal power strength of the received packets to predict the link breakage time, and if the link is found to be broken soon, it sends a warning to the source node of the packet which then broadcasts a Route Request message to find the new route. In [18] Preemptive Local Route Repair (PLRR) mechanism is proposed which is an extension to AODV. When nodes predict that the link is about to break, they trigger the preemptive local route repair procedure. GPS is used to obtain the node position and motion information and using this information, nodes compute Link Expiration Time (LET) which is used to predict the time the nodes will stay in range. However the cost of using GPS and the need for synchronization between the internal clocks of nodes are some of the problems associated with this approach. Goff *et al.* [19] proposed a proactive route maintenance extension to on-demand ad hoc routing algorithms (DSR and AODV).

When the received power of the signal drops below a threshold, a warning is sent to the source which then finds an alternative path before the cost of a link failure is incurred. This significantly reduces the no. of broken paths.

Boukerche and Zhang [20] propose a Preemptive AODV (PrAODV). In this, when a node senses that the signal power of received packets is below a threshold value, it sends a hello message called “ping” to its upstream neighbours and the neighboring nodes reply with a hello packet called “pong” if they have an alternate route. If a node does not receive the pong message within a timeout, a warning message is sent back to the source. When source receives this message, it starts rediscovery of the route. Park *et al*. [21] proposed a proactive link management scheme that implements the link handover to reduce the link loss. The link handover scheme can be implemented by selecting a new link before the failure of an old link when the signal strength or the power of a node drops below a threshold level. Thus the scheme improves the link survivability without causing disconnections.

Qin *et al*. [22] presented a mathematical model for predicting the link breakage be-tween mobile nodes to support multimedia streaming. Hacene *et al*. [23] have proposed predictive preemptive AODV (PPAODV), which predicts the link failure by using Lagrange interpolation method. The method approximates the Received Signal Strength (RSS) by means of a function with past RSS information and finds a new route before the active route breaks. Choi *et al*. [24] have proposed an algorithm for vehicular ad hoc networks which predicts a link breakage possibility using the value of RSSI (Received Signal Strength Indicator). Each vehicle in the network checks the signal strength of the packets from its neighbours and uses the collected value to calculate the distance, velocity, and the acceleration of its next hop from which it receives the data packets. If a vehicle finds that link with its next hop is going to break soon, it builds an alternate route before the previous link breaks. The alternate route is found with the neighbor which has the highest value of RSSI.

Yang and Biao Huang [25] proposed Stable and Delay Constraints Routing (SDCR) protocol which can provide QoS guarantee. The protocol finds paths meeting delay requirement with great link stability factor in the route discovery phase and in the route maintenance phase, it keeps on monitoring the changes in network topology through delay pre-diction and performs rerouting in time. However, due to the extra calculation for link stability factor in SDCR, the delay increases slightly. Wang and Lee [26] proposed a reliable multi-path QoS routing (RMQR) protocol which selects a stable path based on the two parameters, the Route Expiration Time (RET) and the number of hops. Moreover, the time at which the link break occurs is also predicted based on these parameters and an alternative path is found to transmit the data before the original link breaks. Zahedi and Ismail [27] have proposed the route maintenance approach in DSR in which the node uses the Received Signal Strength Indicator (RSSI) value to predict a link breakage and sends warning to the source node if there is a possibility of link breakage. The source node then discovers a new route without using the link which is predicted to be broken soon. Rajabzadeh *et al*. [28] developed a protocol called as Multi Agent based Adaptive DSR (MA-DSR) that considers congestion and energy level of each node in order to choose a particular path. It also includes signal strength metric to predict the link failures before they actually occur. It uses cross layer approach and some modifications in the MAC layer for RERR Analysis. Srinivasan and Kamalakkannan [29] proposed "make-before-break" mechanism, to enhance the route maintenance in Route Stability and Energy Aware Routing (RSEA-AODV). This mechanism monitors the signal strength, residual energy and interface queue length at periodic intervals and if there is any possibility for link break due to mobility, energy drain and congestion, it proactively establishes an alternate route for data transfer. Kumar and Kamalakkannan [30] proposed a Cross layer scheme for wireless mobile devices to reduce the link breakage in MANETs. The scheme finds out the optimized route by prediction of link break based on Received Signal Strength (RSS) and Link Expired Time (LET) of every node in the network and thus reduces the packet loss. Srivastava and Kumar [31] proposed a Multi Metric QoS Routing Protocol for MANETs which maintains the mini-mum delay and bandwidth constraint throughout the communication process and thus provides QoS aware route discovery. It also includes the link failure prediction mechanism which estimates link expiration time (LET) with the help of signal intensity level so that an alternate route can be found for transmission of packets before route breaks up. Ahmed *et al*. [32] proposed the Cross-Layer design approach for Power control (CLPC) which helps to enhance the transmission power by averaging the RSS values and to find an effective route between the source and the destination. A dynamic transmission power control algorithm predicts a link breakage if likely to happen and discovers an alternate new route before the link actually breaks. Gulati and Kumar [33] presented Stable Energy efficient QoS based Congestion and Delay aware Routing (SEQCDR) Protocol that provides effective load balancing at the node and finds a stable path between the source and destination meeting the delay requirement. Later in [34], Cross layer Weight Based On demand Routing Protocol (CLWORP) was proposed which selects stable and energy efficient route based on three metrics: link signal strength, residual energy and drain rate. In both these protocols, link break prediction was not considered.

In the literature discussed above, focus is either on load balance in the route discovery phase or on link break prediction in the route maintenance phase but no protocol has considered these concepts together. Moreover in the protocols with link breakage prediction, focus during route reconstruction is mainly on excluding the link that has been predicted to have a link breakage. The bad links which are weak but not predicted to be broken yet may be included in the newly constructed route. These links may break during or directly after the construction of the new route which decreases the packet delivery ratio and increases the packet loss and delay. In this paper, we propose a Load balanced and Link Break Prediction (LBALBP) Routing Protocol for Mobile Ad hoc Networks which combines the concept of load balance and the link break prediction. The protocol finds the load balanced path based on the path count metric. During the route maintenance phase, the protocol predicts the link failure based on average rate of change of signal strength. When a node detects the weak link, it informs the upstream node about the link breakage. The upstream node then constructs a new route which not only excludes the soon-to-be-broken link but also avoids the use of any weak link.

III. Load Balanced and Link Break Prediction (LBALBP) Routing Protocol for Mobile Ad Hoc Networks

In this section, we propose Load balanced and Link Break Prediction (LBALBP) Routing Protocol for MANETs. Before we introduce the proposed routing protocol, we first define the following metrics which have been considered during route discovery and route maintenance phase of the protocol.

a) Path Count: No. of active routes through a node is defined as path count. It measures the load of a node. The greater the active routes through a node, the more traffic would be passing through a node.

b) Signal strength: The received signal strength is a MAC layer information used by routing layer through cross-layer interaction. It is one of the good metrics to measure the stability of the link. According to NS2 implementation, Two Ray Ground Reflection Approximation is used as radio propagation model [17]. The Received Signal Power Strength at a node is given by

$$P = \frac{P_t * G_t * G_r * (ht^2 * hr^2)}{d^4} \qquad (1)$$

P: Signal power at the receiver.
P_t: Signal power at the transmitter.
G_t: Gain for a signal to a node from the transmitter.
G_r: Gain for a signal to a node from the receiver.
ht: Height of transmitter antenna.
hr: Height of receiver antenna.
d: Distance between transmitter and receiver.

It is assumed that P_t is a constant (as in IEEE 802.11 radios). Also an omni directional antenna is used in our wireless ad hoc network simulation. Further, it is assumed that ground is flat, and that *hr* and *ht* are constants. So (1) can be simplified under the conditions of ad hoc wireless network simulation:

$$P = k\frac{P_t}{d^4} \qquad (2)$$

where $k = G_t*G_r*(ht^2 * hr^2)$ is a constant. Equation (2) shows that the signal power at the receiver node has relation ($1/d^4$) with the distance between the sender node and receiver node.

The received signal strength is calculated on Physical layer and passed onto the MAC layer as shown in Fig. 1.

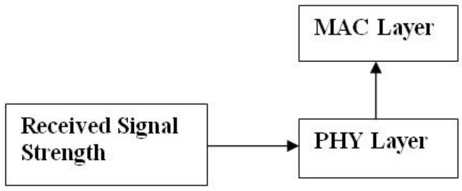


Fig. 1. Crossing the distance value (d) from physical layer to MAC layer

c) Link break Prediction time: This is the time predicted by the successor node during which the link with its predecessor node is expected to break. If this time is less than the threshold time, then the node sends the warning message to the upstream node which then finds the alternate path to the destination before the link breakage.

The proposed algorithm has two phases - Route discovery and Route maintenance which are described below:

A. *Route Discovery Phase*

When the source node wants to send packets to some destination node, it firstly checks whether the route is available in the routing table or not. If the route is already available, it starts the transmission of data immediately otherwise, it generates RREQ packet and broadcasts it to all its neighbours. An additional field of path count is added in RREQ packet which is initialized to 0 (Fig. 2). Rest of the fields are initialized as in AODV. Field of path count is also added in RREP packet and the routing table. All the intermediate nodes on receiving RREQ add their path count value in the path count field of RREQ packet. Destination receives the aggregate value of the path count in RREQ packet and it replies by adding that value in RREP packet. Since the destination does not wait for all the possible routes, the source node can quickly obtain the route information and it can immediately start data transmission without any delay. If the destination receives RREQ from the same source but through different path, it again replies with the aggregate path count. When the intermediate node receives RREP, it compares RREP's path count with the existing path count for the same source. If new path count is less than the existing value, it updates routing entry otherwise it drops RREP. This results in final selection of the best path with least path count.

0			31
Type	Flags	Reserved	Hopcount
RREQ (Broadcast) Id			
Destination IP Address			
Destination sequence no.			
Original IP address			
Original sequence no.			
RREQ_flag	Padding bits		
Path count			

Fig. 2. RREQ format

By updating the path with lower path count, the protocol rejects the nodes in the higher dense area of the network. These nodes are normally congested because they act as intermediate nodes for maximum paths of the network. Thus the load is distributed to less dense area of the network. This leads to less contention and buffer delay and more optimal utilization of the bandwidth for data transmission. The algorithm for route discovery at the source, intermediate and destination nodes is given below:

```
Source node
{
If (it has data to send)
If (the route is available in its routing table)
    Start data transmission on that route
    Else
Generate a RREQ packet for the destination
Initialize its value as in AODV
        Initialize Path count = 0
Broadcast RREQ packet to the neighbours
    End if
End if
If (it receives RREP Packet)
      If (the packet has greater sequence number or
has lesser aggregate path count for the same sequence no.
or lesser hop count for the same sequence no. and path
count or greater signal strength for same sequence no.
and path count and hopcount)
      Make forward route entry for the destination
      Start data transmission on that route
 Else
        Drop RREP Packet and exit.
      End if
End if
}

Intermediate node
{
If (it receives RREQ packet)
       If (sequence no.> stored sequence no.(||) sequence
no. = stored sequence no. and && hop count <
stored hop count)
Make reverse route entry for that source node
Add its path count value to the path count field
of RREQ packet
Broadcast the RREQ message to all its
neighbours
        Else
             Drop the packet and exit
        End if
End if
If (it receives RREP message)
If (the packet has greater sequence number than stored
or has lesser aggregate path count for the same
sequence no. or lesser hop count for the same
sequence no. and path count or greater signal strength
for same sequence no. and path count and
hopcount)
update forward route entry for the destination
unicast RREP message towards the source node
Else
         Drop RREP Packet
        End if
  End if
}

Destination node
{
If (it receives RREQ packet)
    If (sequence no. > stored sequence no. or (||)
sequence no = stored sequence no. and && hop count <
stored hop count) then
Make a temporary reverse RT entry
        Add aggregate path count value received from
RREQ packet in RREP packet
Send RREP message back to the source node
    Else
        Drop the packet
    End if
End if
```

B. Route Maintenance Phase

Once the least loaded path is discovered, data transmission starts between the source and the destination. To reduce the link failures, link breakage prediction mechanism is integrated in the route maintenance phase of AODV protocol. The algorithm uses four packets to determine the expected link breakage time. A node receiving data packets saves the arrival time and received signal strength of four packets with decreasing signal strength. The node stores the signal strength SS1 and reception time T1 of the first packet. Afterwards, it stores the next signal strength SS2 and time T2 only at the instant when SS2 becomes less than SS1. Proceeding in the same way, it stores SS3, SS4 only when the signal strength value is less than the previous stored value. The receiving node then calculates the average rate of change of the signal strength of the packets and by using this average, calculates the estimated link break time. If the link break time comes out to be less than a certain threshold, the node sends a warning message to its previous node. The warning message is a new routing packet named as “Info packet” as shown in Fig.3.

0   31
Pre-hop
Destination
Destination of the route

Fig. 3. Info packet

The Info packet contains three fields: *Prehopaddress* is the address of the node for which the warning message is issued; *Destination address* is the address of the data source; *Destination of the route* is the destination of the route for which the data packets are sent by the source.

The previous node after receiving the warning message initiates the Local Repair Request (LRR) to its neighbours to find an alternate path towards the destination. For differentiating local repair request from Route Request (RREQ) message, flag (8 bits) has been added in the RREQ packet which has been set to 1 for local repair and 0 for route request packet (Fig. 2).

The local repair uses admission control based on strong signal strength. The neighbor node which receives the local repair request with the signal strength above a threshold (Thr), replies to the upstream node confirming that only strong links are taken in the repair mechanism. Else it discards the message. In case the alternate path is not found, route is allowed to break and link failure module of AODV works. The algorithm not only avoids the use of soon-to-be-broken link but also avoids any weak link in the construction of the new path.

Let P1, P2, P3 and P4 be the four data packets with decreasing signal strengths SS1> SS2> SS3>SS4 received at the times T1, T2, T3 and T4. The receiving node then calculates Average Rate of change of Signal Strength (AVG RSS) and Link break prediction time (T_p) as:

$$\text{AVG RSS} = \left(\frac{SS2-SS1}{T2-T1} + \frac{SS3-SS2}{T3-T2} + \frac{SS4-SS3}{T4-T3}\right)/3 \qquad (3)$$

$$T_p = (RxThr - SS_{cur}) / \text{AVG RSS} \qquad (4)$$

where SS_{cur} be the current signal strength and RxThr be the threshold signal strength at the predicted time T_p. We assume that when received power level reduces to threshold power at the predicted time T_p, the link will break. The threshold signal strength RxThr is the minimum power of the signal receivable by the device at the maximum transmission range of 250m. The value of the threshold signal strength RxThr is $3.65 * 10^{-10}$ Watts (e.g. characteristic of the WaveLAN card) [10].

The algorithm for link break prediction is mentioned below:

```
Intermediate node
{
On receipt of a data packet,
Update record of (received power, time) for 4 data packets with decreasing signal strength,
Estimate the average rate of change of signal strength (AVG RSS) by using (3)
Estimate the link break prediction time Tp by using (4)
If Tp<=threshold value
 Send warning message to the upstream node
}

Upstream node
{
On receipt of warning message,
Local route repair( )
{
Send local repair request to all the neighbours
If received reply from the neighbour for the new path
{
If (sequence no > stored sequence no. || sequence no = stored sequence no. and && hop count < stored hop count || sequence no = stored sequence no. and && hop count = stored hop count and signal strength > stored signal strength)
  {
    Route the packet through the new path
    Else
    Discard the reply packet
    }
Else
Allow the weak link to break and send RERR message to the source
}
}

Neighbour node (On receipt of local repair request)
{
if (signal strength of the local repair request <Thr)
Drop the packet
Else
{
If (stored sequence no >= local repair request sequence no.)
{
Send the reply to the upstream node
Else
Broadcast the local repair message
}
}

Source (on receipt of RERR message)
{
Buffer the data
Find new path
Start the transmission of data through new path
}
```

IV. Performance Evaluation

In this section, the performance of the proposed protocol is compared to that of AODV using network simulator NS-2.34.

A. Simulation Environment

As the basic scenario, we consider a MANET with 100 mobile nodes spread randomly over an area of 1000m x 1000m. The “random waypoint” model is used to simulate the nodes movement. The simulations are performed for 400 seconds for varying mobility speed and no. of connections. The traffic sources are CBR (continuous bit – rate). The detailed description of simulation environment is presented below in Table I. The simulations evaluate the performance metrics like packet delivery ratio, end-to-end delay, throughput and normalized routing overhead by varying the mobility speed of the nodes and network load.

TABLE I: SIMULATION PARAMETERS

Simulation Parameter	Value
Simulator	Ns-2.35
Radio-propagation model	Two ray Ground
Channel type	Wireless channel
MAC Type	802.11
Network interface type	Wireless Physical
Link layer	LL
Antenna	Omni Antenna
Mobility Model	Random Waypoint
Queue Length	50
Area	1000m*1000m
Varying Mobility speed (m/s)	5, 10, 15, 20, 25
No. of nodes	100
Pause time (seconds)	10s
No. of Connections	20
Traffic	CBR(Constant bit rate)
Transmission range	250
Carrier Sensing range	550
Data rate	4 packet/second
Packet size	512 byte
Simulation time	400s
Thr	1.2*RxThr
Threshold value of time	1.0sec

B. Performance Metrics

The performance metrics evaluated are described below:

1) Packet Delivery Ratio (PDR)

It is defined as the no. of packets successfully delivered from source to destination and it can be written as

$$P = (P_r / P_s) *100$$

where P is packet delivery ratio, P_r is the total number of packet received and P_s is the total number of packets sent.

2) Average end to end delay (AD)

Average End to End Delay (AD) refers to the time taken for a packet to be transmitted from source to destination and is expressed as

$$AD = (P_s-P_r) / P_r$$

where P_s is the packet sending time and P_r is the packet received time.

3) Throughput

Throughput is defined as the number of packets received per second.

4) Normalized Routing Overhead (NRO)

It is defined as the ratio of the number of routing packets generated to the total number of data packets generated by the source.

5) No. of link failures

It is defined as the no. of links which failed to carry the data during simulation.

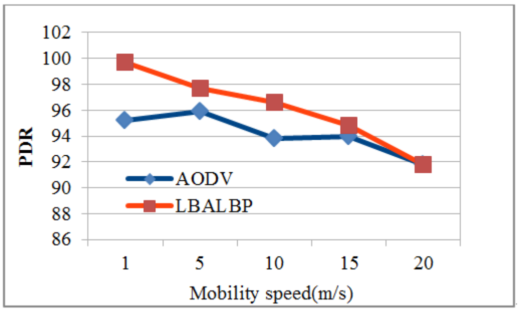
C. Simulation Results by Varying Mobility Speed of the Nodes

Fig. 4a–e show the comparison of the proposed protocol and AODV for the different values of mobility speed. Fig. 4a shows that PDR of LBALBP protocol is higher than AODV, the reason being that the proposed protocol avoids the congestion and finds the load balanced path in the route discovery phase. This reduces the packet loss and results in increased no. of packets delivered at the destination. During route maintenance, the protocol predicts the link breakage and finds an alternate path before the actual breakage and so the packets which would have lost due to breakages are prevented and sent on the alternate path found. This contributes to higher no. of packets delivered at the receiver end. Moreover, initially when the mobility of the nodes is less, the packet delivery ratio of both the protocols is high but as the mobility of the node increases, no. of link breakages increases, so PDR of both the protocols tend to fall.

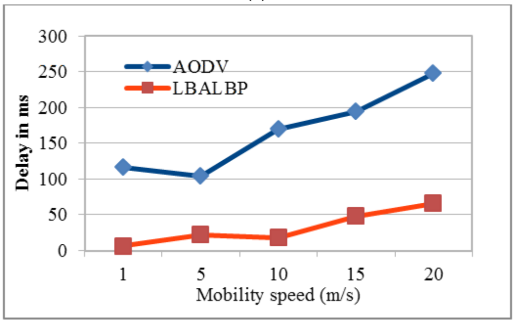
In Fig. 4b, the average end to end delay of the LBALBP protocol is much less than AODV. The reason is that AODV does not avoid congestion and large no. of packets are dropped which results in higher delay as compared to LBALBP. Moreover in AODV, when the link breaks, packets are buffered and sent later on the new route discovered. In such a case, packets are delayed in reaching the destination. LBALBP, on the other hand, avoids congestion and hence results in lesser delay. Also, the protocol predicts the link breakage and finds an alternate path before the actual breakage and so the packets which would have been delayed due to route re-discoveries are prevented and sent on the alternate path found. Thus LBALBP has much less delay than AODV. Moreover, with the increase in mobility speed of the nodes, link breakages increase which increases delay in both the protocols.

In Fig. 4c, LBALBP has higher throughput than AODV because the proposed protocol finds the load balanced path for data transmission and while transmitting data, maintains the route availability by finding alternate path before the actual link breakage. Thus it has higher throughput than AODV. Moreover, increase in speed of the nodes results in increase of link breakages which further results in decrease of throughput in both the protocols.

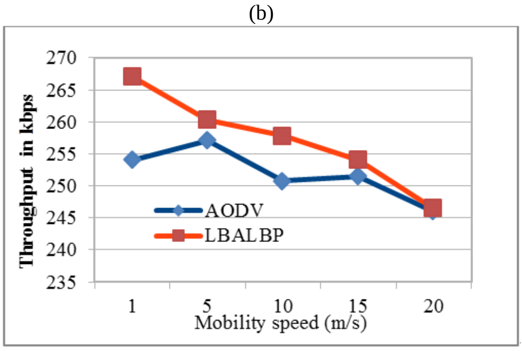
Fig. 4d shows that routing overhead of LBALBP is higher than AODV. Because of the integration of link breakage mechanism in route maintenance phase of the LBALBP protocol, warning message called “info packet” is added. When link break is predicted, this warning message is sent to the upstream node which then finds an alternate route. Due to this extra packet, routing overhead of LBALBP is more than AODV. Moreover as speed of the nodes increases, no. of link breakages increases which results in more of route re-discoveries and broadcasting of RREQ packets. This increases NRO with increase in speed of the nodes.



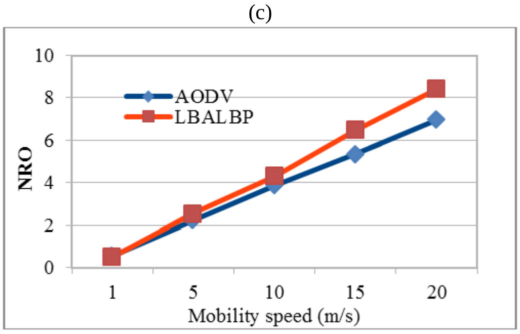
(a)



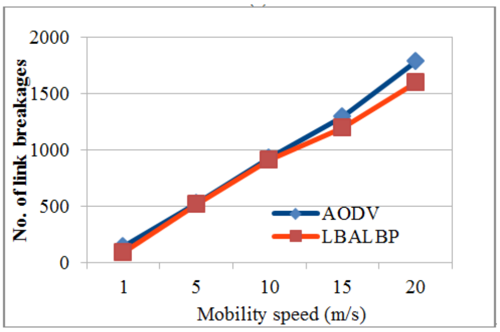
(b)



(c)



(d)



(e)

Fig. 4. Graphs with varying speed of the nodes.a) Packet delivery ratio v/s speed. b) Average end to end delay v/s speed. c) Throughput v/s speed d) Normalized Routing Overhead v/s speed. e) No. of Link failures v/s speed

Fig. 4e shows that no. of link breakages in LBALBP are less than AODV since the proposed protocol reduces the link breakage by predicting and finding an alternate route before actual breakage. As mobility of the nodes increases, changes in network topology occur frequently which increases the no. of link breakages. Thus the graph has increasing trend with the increase in speed.

D. Simulation Results by Varying no. of Connections

Fig. 5a–e shows the comparison of the proposed protocol and AODV for the varying no. of connections. Fig. 5a shows that PDR of LBALBP protocol is higher than AODV, the reason being that the proposed protocol finds the load balanced path for transmitting data and during transmission of data, finds an alternate path before the actual breakage and so the packets which would have been lost due to breakages are prevented and sent on the alternate path found. This contributes to higher no. of packets delivered at the receiver end. However, increasing the no. of connections do not have much effect on PDR of LBALBP because it balances the load increased due to increase in no. of connections. Since AODV does not balance the load, so increase in network load leads to congestion and packet loss. This tends to decrease the PDR in AODV with the increase in no. of connections.

Fig. 5b shows that delay of LBALBP is much less than AODV. This is because in AODV, congestion occurs due to which packets are delayed in reaching the destination. Whereas LBALBP avoids congestion and hence results in lesser delay as compared to AODV. Moreover, in LBALBP, delay remains almost constant with the increase in network load. But when the no. of connections increases to 40, load becomes too high which results in increased congestion and delay.

Fig. 5c shows that throughput of LBALBP is higher than AODV because LBALBP finds load balanced path and also predicts link breakage before the link actually breaks. Moreover, when the no. of connections increases, generation of data packets increases which results in higher no. of packets delivered per second. Thus throughput increases with the increase in network load.

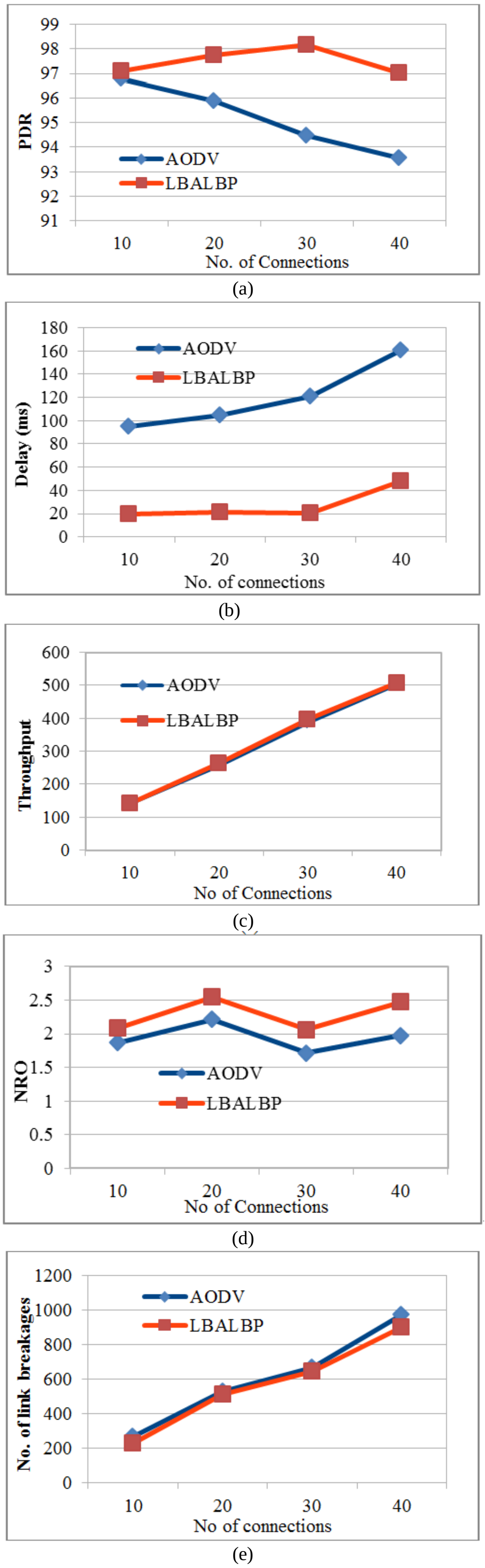


Fig. 5. Graphs with varying no. of connections. a) Packet delivery ratio v/s No. of connections. b) Average end to end delay v/s No. of connections. c) Throughput v/s No. of connections. d) NRO v/s No. of connections e) No. of Link breakages v/s No. of connections.

Fig. 5d shows that NRO of LBALBP is higher than AODV because of the extra "info packet" added.

Fig. 5e shows that no. of link breakages of LBALBP are less than AODV as LBALBP is able to find an alternate path before the link breakage. Moreover, when the no. of connections increases, more no. of links are established, more chances of link breakages are there. Thus the graph shows increasing trend with the increase in network load.

V. Conclusions

Congestion and frequent link breakages lead to packet losses occurring in mobile ad hoc networks. Due to this, quality of service support in MANETs remains a challenging issue. In this paper, we propose a Load balanced and Link Break Prediction Routing Protocol (LBALBP) for Mobile Ad hoc Networks which finds load balanced path based on the path count metric. The link break prediction mechanism is also integrated in the routing protocol to provide effective route maintenance strategy quickly in the situation of node mobility. In this mechanism, when a node receives four data packets of decreasing signal strength from the neighbour node, it calculates the link break prediction time of its link with that node and when the node finds that the link is expected to be broken soon, it sends a warning message to the upstream node. The upstream node then finds an alternate route to deliver the packets that would have been dropped because of link failure. The alternate route found is shortest and strongest route. Finally, the simulation results show that the proposed protocol outperforms AODV in terms of packet delivery ratio, delay, throughput and no. of link breakages but at the cost of little higher overhead. In this research work, the simulations are conducted by varying mobility speed of the nodes and no. of connections. In our future work, we would like to perform the simulations by varying the network size.

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Mandeep Kaur Gulati has received her BTech in Electronics and Electrical Engineering from Guru Nanak Dev Engineering College, Ludhiana, Punjab in 1997. She completed her MTech (IT) from Guru Nanak Dev University, Amritsar, Punjab in 2004. At present, she is a PhD candidate of Punjab Technical University, Kapurthala (Punjab), India. She has 15 years of teaching experience. Currently, she is working as an Assistant Professor in Department of Computer Science at Khalsa College for Women, Amritsar, Punjab, India. Her current research interests include quality of service routing in mobile ad hoc networks.

Monika Sachdeva received the B.Tech. Degree in Computer Science & Engineering from National Institute of Technology NIT, Jalandhar, Punjab **(**India**)**, in 1997 and MS Degree in Software Systems from Birla Institute of Technology and Science BITS, Pilani, Rajasthan **(**India**)**, in 2002**.** She received her Ph.D. degree in Computer Science & Engineering from Guru Nanak Dev University, Amritsar, Punjab **(**India**)**, in 2012**.** She is currently an Associate Professor in the Department of Computer Science & Engineering, Inder Kumar Gujral Punjab Technical University **(**IKGPTU**)** main Campus, Kapurthala, Punjab **(**India**).** She has more than 18 years of teaching experience.Her primary research interests are in the areas of Network Security and Wireless Sensor Networks with particular emphasis on the timely detection of Distributed Denial of Service attacks in the Wireless Networks and various related network layer attacks in Wireless Sensor Networks**.** She is also interested in the applications of sensor networks for enhancement in the lifetime of the network, Web Services and Design and Analysis of Algorithms**.** She has done two research projects and many of her publications are well cited in research community.

Krishan Kumar has received his BTech in Computer Science and Engineering from National Institute of Technology NIT, Hamirpur in 1995. He finished his MS Software Systems from BITS Pilani in 2001. He completed his PhD from Department of Electronics and Computer Engineering at Indian Institute of Technology, Roorkee in February 2008. Currently, he is Professor in Department of Information Technology, University Institute of Engineering and Technology, Panjab University, Chandigarh, India. His general research interests are in the areas of information security and computer networks. His specific research interests include intrusion detection, protection from internet attacks, web performance, network architecture/protocols, and network measurement /modeling.