AOMDV Routing Algorithm for Wireless Mesh Networks with Local Repair (AOMDV-LR)

Uday Singh Kushwaha, P. K. Gupta

***Abstract*— One of the main challenges of Wireless Mesh Network is the design of robust routing algorithms that adapt to the frequent and randomly changing network topology and provide various alternate routes from source to destination. Several Multipath routing protocols have been proposed to efficiently transmit data among the participating nodes that enables data transmission over alternate paths when active path is failed. The Ad hoc On Demand Multipath Distance Vector (AOMDV) Routing Protocol is one of the most commonly used reactive protocols for multipath routing in Wireless mesh networks. AOMDV performs well, but it does not has local repair capabilities such as it uses backup route for further transmission during the failure but when no back-up route is available it restart route discovery from source to destination that degrades throughput and increases end to end delay. To overcome this problem, we present an AOMDV protocol with local repair capabilities (AOMDV-LR). In this approaches intermediate nodes in the existing paths try to find new path to the destination in the event of link failure and when no alternate route available.**

***Index Terms*— Wireless Mesh Networks, Ad-hoc routing, Routing Protocols, Back-up routes, RREQ, RREP, RERR, AOMDV with Local Repair (AOMDV-LR)**

I. Introduction

Wireless Mesh Networks (WMNs) has recently gained popularities due to their fast and economical ways to access to the Internet. WMNs integrate both ad hoc and infrastructure operation modes and interwork with other wired and wireless networks. WMNs are comprised of two types of nodes: mesh clients and mesh routers as shown in figure 1[1]. The mesh routers have least mobility that can establish a backbone network and connect to public internet that offers the wireless access to the clients [2]. Several nodes in the WMNs can operate not only as a host but also as a router, that forward the packets on behalf of other nodes that may not in direct wireless transmission range of their destinations, and produce a wireless multi-hop environment. By multi-hop communications, the WMNs can cover a broad area with much low transmission power [3][4].

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WMNs offer ubiquitous and high-speed broadband access to both mobile and fixed users, with low operation and management costs. WMNs are most promising application to provide access to information where wired infrastructure is difficult or economically infeasible to deploy specifically in rural area. WMN in the context of rural areas is suitable for its features such as high scalability, cheap-to-deploy and ease-of-maintenance [5]. In the WMNs mostly ad hoc routing algorithms are used due to some similarities between them. The routing protocols in the ad hoc network can be classified into two approaches: proactive and reactive algorithms [6].

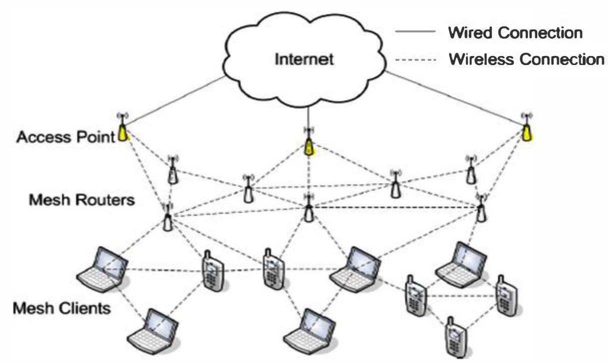

Figure 1: Wireless Mesh Network [1]

Proactive routing algorithms are also called table driven approach, the routers preserve consistent, up-to-date routing information to each other node in the network regardless of whether these routes are needed or not. Routing tables are updated every time the topology changes [7]. Destination-Sequenced Distance Vector (DSDV) [8][9] and Optimized Link State Routing, (OLSR) [9][10] are the best known proactive protocol. The routing table will maintain all the possible routes to every other node in the network. It may waste the bandwidth of the network since control messages are sent out unnecessarily when there is no data traffic. Reactive routing protocols are known as On-demand approach, when new packets needs to be delivered to the destination and there is not a valid route to carry out this delivery, a new route is discovered [11] and the routing table will not be maintained if the route is no longer in use. This type of protocols has low routing overhead and power consumption, but relatively high route latency . Dynamic Source Routing (DSR) [12], Ad-hoc On-demand Distance Vector (AODV) [13] and AOMDV [14] [15] are the best known reactive protocol.

According to the connectivity or propagation state, the network topologies are changed dynamically and may fluctuate from time to time. Because of these regular changes of the network topologies, formation and maintenance of the network is to be difficult. The main reason of topology changes is the mobility of nodes. As in WMNs nodes can move freely, the resulting of the topology alteration in the network must be acknowledged to the other nodes so that outdated topology information should be removed or updated. Many reactive and proactive routing protocols have been proposed that is based on single path and multiple paths to solve this problem. Due to the mobility of nodes, single path algorithms are not sufficient for routing.

Several multipath algorithms have been proposed for this purposed. It maintains various alternate routes to support the ongoing connections, when primary path of route is broken then alternate route is used for sending packets towards the destination and thus lowers the packet drop rate [16]. In cases where no alternate paths are available at any node during failure, route discovery has to restart from source. Since WMNs nodes are either fixed or independent to move in any direction; there may be frequent link breakage. Due to frequent link failure WMNs protocols should have mechanism to repair path locally to reduce latency for route recovery.

This paper proposes an improved AOMDV routing algorithm in WMNs with local repair capability (AOMVD-LR). It is typically proposed in order to increase the reliability of the data transmission by applying local repair capabilities to failure sensed node in the entire route that reduces Average End-to-End delay of data packets and Routing overhead. Because the recovery of route is done by failure sensed node, source does not need to re-discover the route, and route recovery will be done only between intermediate nodes from failure sensed node to next available alternate path or destination. Thus, the End-to-End delay and Routing overhead are reduced.

The rest of the paper is organized as follows: section II presents related work, section III finds the improvement potential and proposes AOMDV with local repair method and Section IV presents the conclusion and plans for future work.

II. Related Work

A. *Ad-hoc On-demand Distance Vector routing (AODV):*

AODV is a reactive, single path and loop-free distance vector protocol based on hop count. Whenever a source node wishes a route to the destination, it begins the route discovery by flooding the route request (RREQ) and then waits for the route reply (RREP) from the destination. If any intermediate node receives the first copy of RREQ and if it knows the destination node, it may unicast a route reply (RREP) to the source node via the reverse path; otherwise, it further re-broadcasts the RREQ packet to its neighbors. The forward path to the destination is established when the source receives the RREP. When any node finds out a link break or successor node failure, the node stars the local repair if the destination is nearby. If the destination is far away it broadcasts the RERR packet to the source. The source then tries to search the route to the destination again if the path is still needed .

B. *Dynamic Source Routing DSR*

Likewise AODV, DSR is based on RREQ/RREP packets. However, RREQ collect the addresses of the 'visited' nodes and preserve information regarding the complete path from the source to the destination node, not just the next hop. Every node keeps information in a route cache instead of the routing table [11][12].

C. *Ad-hoc On-demand Distance Vector – Backup Routing (AODV-BR)*

Ad hoc On Demand Distance Vector Routing with Backup Route (AODV-BR) protocol is an extensive version of AODV protocol with a reserve route. AODV-BR route construction process is based on AODV by flooding route request (RREQ) packet. When an intermediate node obtain a RREQ packet from its neighbor, it records the preceding hop info and the source node info and then further broadcast the packet or if a route to the desired destination is known it sends a route reply (RREP) packet to the source. The destination replies through a RREP packet via the selected route when it receives the first RREQ or later RREQs that examine a better route with less number of hops. It maintains two routing table i.e. primary and alternate.

The alternate path is established during the RREP stage. When a node that is not part of the primary route listens a RREP packet that is not directed to it, records the sending neighbor as the next hop to the destination in its alternate route table. In this way a node may receive several RREPs for the same route, select a route with less number of hops among them and insert it into the alternate route table. Once the RREP reaches at the source of the route, a primary route between source and destination has been constructed. All nodes that have an alternate route to the destination in their alternate route table configure a fish bone [17].

D. *Ad-hoc On-demand Multipath Distance Vector routing (AOMDV)*

Ad-hoc On-demand Multipath Distance Vector routing (AOMDV) is a multipath reactive protocol, utilize the fundamental AODV route construction process like AODV-BR. It offers link-disjoint, multiple loop-free paths. AOMDV decrease packet loss and end to end delay but routing overhead may be increased. The main idea in AOMDV is to discover multiple paths throughout route discovery process. RREQ broadcast from the source to destination construct multiple reverse paths both at intermediate nodes and the destination. Multiple route replies form several forward paths and navigate these reverse paths back toward the destination at the source and the intermediate nodes. Routing process is divided into three phase: route discovery, route maintenance, and transmission of data packet. During the route construction it uses flooding RREQ method as AODV but AOMDV uses duplicate RREQ for forming alternate route. RREP is produced either by destination in response to every RREQ copy via the reverse route or by intermediate node if it has at least one valid forward path to the destination. A node generates or forwards RERR to the source when no alternate path is available to the destination. For route maintenance HELLO packets are also generated frequently. Because of several paths the possibility of paths becoming stale is more likely. Thus, AOMDV uses a TTL (Time to Live) and as well as use HELLO messages to proactively remove stale entries. Once route is constructed, node having one or more paths to the destination and forward data packets using primary path. When it fail, switched to an alternative path .

E. Ad-hoc On-demand Multipath Distance Vector routing with Backup Route Update Mechanism (AOMDV-BU)

Ad-hoc On-demand Multipath Distance Vector routing with Backup Route Update Mechanism (AOMDV-BU) is an extensive version of AOMDV protocol, which comprise an additional method of backup route update, using a more active route discovery mechanism. The proposed AOMDV-BU performs better than the original AOMDV, reduces both average delay and loss ratio, with the weakness of a larger overhead. AOMDV-BU maintains atleast one valid backup path for any route, therefore when the active path breaks down, there is always a backup path waiting. This is attained by revoking route discovery when the number of paths for any route is less than two, while original AOMDV revokes route discovery only when there is no path available to the destination. Backup path can be constructed while the active route is still working by applying this new rule. New nodes that entered in the transmitting range after the last route discovery process could be considered as new neighbors and they may join the discovery of new paths. Thus, backup paths can be discovered and stored in routing table even if the new nodes do not exist at the time of forming the active path. AOMDV-BU algorithm adopts a more active route discover route, which may boost the route overhead [18].

III. PROPOSED WORK

The efficient Multipath Ad hoc On-Demand Distance Vector (AOMDV-LR) is multipath routing protocol is intended for efficient local route repair. Numerous configuration parameters used by AOMDV-LR are based on AODV and AOMDV. It discovers the route only when requisite i.e., on demand or need basis. AOMDV-LR nodes use different types of message like route request (RREQ), route reply (RREP), route error (RERR), and HELLO messages to communicate among each other. Among these, route request (RREQ) and route reply (RREP) messages are used for route discovery.

When a node required a route to the destination node, the originating node broadcasts a RREQ message towards its neighboring nodes, which broadcast the message towards their neighbors, and the process, is continuing till destination node get this RREQ. A RREQ message is begun with time to live (TTL) and a specified hop number by the originating node. RREQ receiving node can send RREP message with entire route information to the originating rote if any or multiple route is found in its cache. When the destination node receive a RREQ that is intended for it, replies a RREP message to the originating node. The destination node is supposed to be unreachable and the messages queued for this destination are thrown out if the TTL values in the RREQ have reached a definite threshold and still no RREP messages have been received. Each node in the Wireless Mesh network maintain a monotonically increasing sequence number and the protocol guarantee that the node only update routes with fresher ones by using sequence numbers. It guarantees loop-freedom for all routes to the destination in the network. Nodes along with the path can update entries of their routing table with the latest destination sequence number. RREQ and RREP messages include this latest destination sequence number during route discovery.

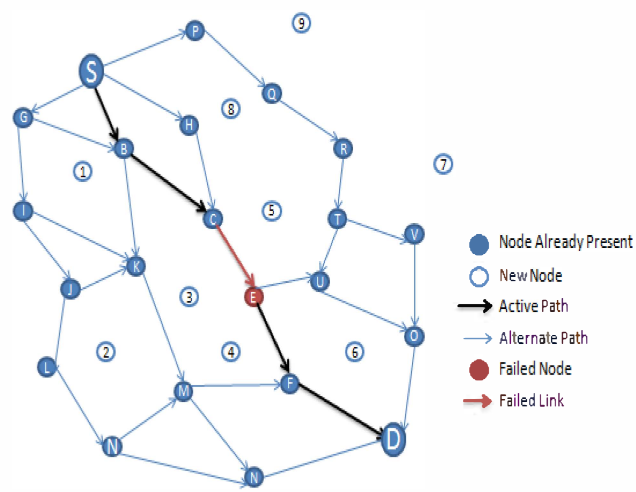

Figure 2: Node or link break in the active route

AOMDV-LR uses proactive and reactive both approaches within local area to decrease the route discovery delay in the network. As a proactive protocol it finds another route from its routing table and as a reactive protocol it search route on-demand basis when no alternate route is found. The node is supposed to be no longer available in the network, if a node has not received any message from some outgoing nodes for a specified period of time. If any node senses that next node has become unavailable then precursor node attempts to repair the broken node itself or tries to find another route to the destination when no alternate route is available, instead of sending REER message to the source.

If the precursor node attempts to repair the broken node itself, fewer number of data packets will be lost and the route may be re-establish with a lower overhead. Also, the source node is not at all worried with another Route Discovery procedure.

Local Repair is not expected to show much advantage for smaller routes, but for larger routes, especially with 10 or more than 10 hops, Local Repair is awfully beneficial. This is because in larger routes, there are more probability to breakage of links and if the intermediary nodes always carry on sending Route Error message to the source which in turn carry on initiating Route Discovery, vast number of control message are devoted and the performance will deteriorate.

Local Repair makes the precursor node of the break to effort a repair of the route. This is done through broadcasting a Route Request (RREQ) with a time to live (TTL) set to the last known distance of the destination plus an increment value. This TTL value is used with a supposition that the destination is not likely to be distant away from where it was before the break.

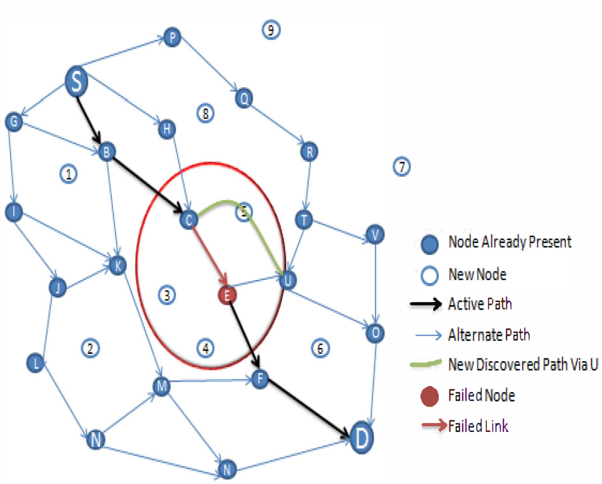

Figure 3: Local repair by intermediate route

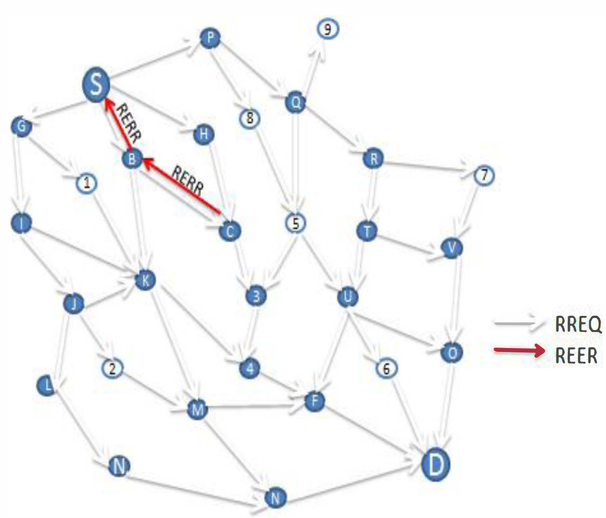

Figure 4: Source restart route discovery after receiving RERR

This precursor node increments the sequence number of the destination in its RREQ message by 1 before broadcasting it. This avoids the nodes further precursor of this node from respond to the RREQ. Thus, this mechanism prevents loop construction. End-to-end delay is improved because loss can be recovered within the neighboring nodes instead of original source node. This approach gets better consistency in term of packet release ratio as compared with AOMDV.

Note that this RREQ broadcast by intermediate node is done only once. If no node replies to this broadcast within a specified TTL, the intermediate node simply sends a RERR back to the originating node by listing all the destinations which have become unreachable due to the break.

According to above scenarios AOMDV-LR follows this algorithm:

Step 1: Proactive Multipath routing: have one active and multi alternate routes for one destination in its routing table at each node as shown as table I.

Step 2: In figure 2, a node or link goes down in the active route i.e. C-E link. If intermediate node C has other sub routes to destination D in its routing table, it will select the sub route with the least hop count and send packet via this route.

But if it has no sub-route to destination D, node C does not send any RERR message to the source. Instead, it attempt to reach destination node D via another hop. It investigates again to reach to node D by sending a RREQ message to its neighbor only by incrementing sequence number of the destination by 1 before to prevent loop construction. And when it finds any node along its new path node 5 and starts sending packets via node 5 to D (1) as in figure 3.

TABLE I

ROUTING TABLE FOR NODE B

DESTINATION	DEST. SEQ. NO	NEXT HOP	HOP COUNT	PRIORITY NOTICE
D	2	C	2	ACTIVE ROUTE
D	2	K	3	SUB ROUTE

Step 3: If the node C could not investigate a new path to destination D, it will send out a RERR packet to the source node S via its precursor node B. If the routing table of node B has another sub-route to destination D, B will select a new sub-route to D according to step-2. If B does not found any sub route to D it again send RERR to its precursor node and this process is repeated till source S if no alternate path is found in the precursors node. Intermediate node will send further packets via these new / old sub-route if found. If source S had only one route to destination D, it will restart route discovery for this destination as in figure 4.

IV. ANALYSIS AND RESULT

The proposed protocol gives better result in various network conditions. Following metric are chosen where AOMDV-LR performs better than other protocol such as AOMDV-BU and AOMDV.

A. Delivery ratio (packet delivery ratio):

AOMDV-LR increases packet delivery ratio because once route has been established it start transmission of packets. Once failure is occurred it recovers those failures locally that reduces the time of route rediscovery and increases delivery ratio. Delivery ratio defined as the ratio of the total number of data packets received at the destination and the total number of data packets sent by the source nodes:

$$D_R = (dp_r/dp_s) * 100\% \quad (1)$$

Where D_R=Delivery Ratio, dp_r= Data packet Received and dp_s=Data Packet Sent.

B. Normalized routing Load (NRL):

Routing load is reduced because every failure sensed node try to repair failed route locally instead of sending RERR to source that reduces the flooding of multiple control message (RREQ, REEP, RERR) from the network. Normalized routing load (NRL) defined as the fraction of all routing packets sent and forwarded to the successfully received data packets:

$$NRL=(cps+cpf)/dpr)*100\% \quad (2)$$

Where NRL=Normalized Routing Load, cp_s=Control packet sent, cp_f=Control packet forwarded and dpR=Data packet received

C. Throughput (aggregate throughput):

AOMDV-LR gives higher throughput due to smaller end to end delay and fast recovery of failure route. Throughput expressed as the sum of the packets delivered to all the nodes in the network in a given time unit/interval:

$$T_P=B/T[kbps] \quad (3)$$

Where Tp=Throughput, B=No. of bits transmitted and T= Time unit

D. Average End-to-End (e2e) delay:

AODMV-LR has a better average delay than AOMDV due to the fact if a link break occurs in the primary route, AOMDV would try to find an alternate path from among the backup routes between the source and the destination node pairs but when no alternate path is available it send RERR to the source that restart route discovery resulting in additional delay to the packet delivery time. If a link break occurs in AOMDV-LR, failure sensed node try to find new alternate path instead by sending RERR to the source that reduces the end to end delay. Average delay (end-to-end delay) defined as the average time required for a data packet to be transport from the source node to the destination node, i.e. a single delay is [18]:

$$e2e= D_{trans}+D_{prop}+D_{proc}+D_{queue} \quad (4)$$

Where e2e=End-to-End Delay, D_{trans}=Transmission delay, D_{prop}=Propagation delay, D_{proc}=Processing Delay and D_{queue}=Queuing Delay

V. Conclusion

In this paper, we have proposed modified AOMDV protocol with local repair process i.e. AOMDV-LR. Local Repair helps to increase the number of data packets that reach its destination. As the network size increases, the path length of these routes increases and when no alternate route is available, AODMV-LR initiate local repair at all the preceding nodes of failure which are nearer to the destination than the source, i.e. not only precursor node participate in local repair but all the preceding node participate for local repair, hence routes are expected to get repaired quickly, with slighter overhead. The ratio of number of control messages RREQ, RREP and RERR are reduced, therefore control overhead of the protocol is also reduced. Due to local route recovery source node is not bothered at all about route re-discovery, thus end to end delays are reduced.

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