A STUDY ON MULTICASTING STRATEGIES OF ROUTING IN WIRELESS MOBILE AD HOC NETWORKS

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Abstract : Mobile Ad hoc Networks with large network size and highly dynamic real-time traffic for collaborative data sharing and computation in a VOIP, VoD, or P2P based communication require routing strategies to be designed in terms of different types of data, applications and MANET specific environmental challenges of node mobility, multiple users accessing shared resources, data transfer using multiple hops, and with limitations of link breakages, packet transmission delays, losses etc. In ad hoc networks, routing protocols are challenged with establishing and maintaining multihop routes in the face of mobility, bandwidth limitation and power constraints. In this paper, we study the routing strategies for ad hoc networks. Multicast routes and group membership are obtained on demand to use the network resources efficiently and effectively.

Keywords: Wireless and Mobile Ad hoc networks, routing, DSR,AODV,SMR

I.INTRODUCTION

Mobile Ad hoc networks is a wireless networking of mobile devices for communicate rapidly without any infrastructure, where there are no base stations or fixed routers for a centralized control over the nodes and the data routed. Route the traffic by acting as a sender, and receiver. The autonomous MANET network is a highly dynamic environment based on an open architecture. The examples of applications of Mobile adhoc networks are, business communication networking in specific areas and in disaster or defence mechanisms for emergency operations. The users may join in real time and communicate in multi-hops using the nodes in the MANET topology. The rapid global exposure to various kinds of information, implosion in exchange of digital information, advances in cloud based data access, and increasing demand for multimedia content have created numerous challenges of communication in MANETs. The research challenges are devising routing strategies for MANETs offering efficient services with QoS. Multicasting supports multipoint communication and the multicast based protocol development is increasing with growing demand for applications of high quality multimedia content communication. A multicast consists of many nodes which send packets to many receivers. The model has two components where the first component is called the multicast group management whereas the second component is known as the multicast routing protocols. The first component multicast group management has to take care of transmitting the multicast grouping starting at local router in the direction of the subnets which have direct connections where retransmitting of the multicast groups is not considered either within the routers else over the networks existing in the intermediary [1]. The second component multicast routing protocol determines the suitable multicasting paths of delivery towards all the receivers. The MANET topology undergoes changes recurrently and in this context multicasting and multicast routing protocol aim to provide information broadcasting competently especially for multimedia communication in terms of the bandwidth available where the transmission of data packets in multicast groups has packet forwarding starting at the sender and ending with every receiver of the group [2]. In this context multicast based protocol design is an important strategy in MANETs where network hosts implement tasks using a group based working approach.

II.LITERATURE REVIEW

Wu H and Jia X [3] Developed Multiple Parallel Paths/Trees (MPT) approach is an on-demand QoS based multicast protocol similar to the LTM approach which creates parallel paths or trees in multiple numbers between nodes for connections with assured bandwidth. A strategy is used based on the assumption of a MAC sub-layer here using a CDMA-over TDMA channel and that any node is capable of calculating the link specific free time slots. Based on this strategy three approaches of multicast routing are devised: the SPTM (shortest path tree based multiple paths) approach, the LCTM (least cost tree based multiple paths) method, and the MLCT (multiple least cost trees) approach .Here realization of the necessary bandwidth and delay minimization is the objective primarily of the algorithms. This strategy applied in the SPTM and the LCTM approaches creates between every node pair as per necessity multiple numbers of paths and with the MLCT approach similarly creates multiple trees connecting a source node and the destinations nodes. The minimization of the delay is achieved by path selection based on lesser hops and considering minimization of the costviability of the network is also achieved. The computation of the cost incurred from network is equivalent to the bandwidth times by the total number of hops or links within a tree. Here paths or the trees of multiple numbers are used in a parallel manner for improving the protocols utilization of the network resources .For all the above approaches we observe no increase in the cost of the network in terms of the distribution in the traffic, however because of maintenance of the tree there is increase in the overhead.

Ng J M, Low C P and Teo H S. [4] approach On-Demand QoS Multicast Routing and Reservation for MANETs (ODQMM) protocol is motivated from the MAODV approach and attempts to implement in the unicast protocols or the protocols of multicast routing a strategic integration with bandwidth reservation. A requirement for QoS reservation of bandwidth is implemented in the Protocol, using a fixed filter (FF) style of reservation, and a shared-bandwidth filter (SB) type of reservation. A FF based reservation style has every source not enabled for resources sharing by the other sender and so it is appropriate for implementations of streaming video. A SB based reservation style has one reservation shared with all the senders in a session, which makes it appropriate for various implementations of audio conferencing, etc. This total reserved bandwidth with SB may be given as: max(BW1, BW2, . . . ,BWn). A best effort manner may be used to send the data in case the data is insensitive to the parameters of QoS. This newer ODQMM approach attempts to enhance the process of the MAODV where the MAODV messages collection is added with the QoS Error as well as the Keep Alive control messages. The bandwidth reservation strategy is executed in case of finding a suitable path by the approach based on the strategy of reservation service integrated in it with the routing protocol. The bandwidth information is obtained from an underlying layer such as TDMA network. Here the routing requires huge storage and communication in case of maintaining multiple numbers of tables by every node consisting of the topology information of the network along with the reservation information of the bandwidth.

Layuan L and Chunlin L [5] are created QoS Multicast Routing for Clustering MANETs (QMRPCAH) design is an ad hoc network cluster based multicast protocol with QoS awareness where the quality of service is a soft QoS support without assurances. Here the strategy of the protocol QMRPCAH has the information of the local multicast maintained by a node including the information of the remaining clusters where the global network knowledge is not needed. Here the strategy of the approach has the routing tables of the intra-cluster network maintained and updated by every node whereas the routing tables of the inter-cluster are maintained by every bridge node. A mobile node for subscribing to a new domain uses remote technique of subscription to join a local multicast tree. A path best suitable is chosen using programming techniques of a discrete dynamic approach based on the factors of delay and hop count. Here links disturbing the bandwidth constraints are deleted using an algorithmic strategy of flooding based on the receiver-initiated selection. An assessment of the performance of the QMRPCAH approach is based on the metrics of delay, bandwidth, jitter, and the packet loss in terms of variance in the delay, mobility, the size of the network. The outcomes of the simulated experiments show achievement of improved control overhead including higher delivery ratio particularly for huge size multicast groups.

Tebbe H and Kassler A [6] this protocol QoS to Ad hoc Multicast Enabled Networks (QAMNET) adapts a multicast mesh topology model ODMRP to offer low delay with necessary throughput in multicast real-time flows. The approach presents the techniques differentiation of service (traffic class RT and BE),distributed resource probing, a control admission strategy, and rate control addictiveness in non-real-time traffic dependent on the feedback from the MAC layer. A scheme to regulate the mobile nodes and the variations in the bandwidth is also incorporated in QAMNET approach. The available node-based bandwidth is measured from the RT flows threshold rate difference with the present RT traffic rate in the same way as the SWAN based calculation. The dynamic pattern changes occurring in traffic directly impacts the threshold rate increasing the complexity of its accurate assessment. The regulation of the BE traffic is performed with a MAC layer back-off delay based algorithm AIMD (Additive Increase Multiplicative Decrease) in QAMNet. A probing mechanism included in the multicast routing in QAMNet offers stability in the routing together with control messages reduction. Near the shaper the regulation of the BE traffic has the RT packets average delay controlled. The simulated experiments of the approach are performed in MANETs with multicast routingand real-time data packets which demonstrates delay reduction and decrease in the rate of packet losses considering the entire mobile nodes range.

III. ROUTING PROTOCOLS ARCHITECTURE ENHANCEMENTS

A) Distributed Bellman-Ford

Distributed Bellman-Ford (DBF) algorithm was developed originally to support routing in the ARPANET. A version of it is known as RIP (Routing Internet Protocol) [7] and is still being used today to support routing in some Internet domains. It is a table-driven routing protocol, i.e., each router constantly maintains an up-to-date routing table with information on how to reach all possible destinations in the network. For each entry, the next router to reach the destination and a metric to the destination are recorded. The metric can be hop distance, total delay, or cost of sending the message. Each node in the network begins by informing its neighbors about its distance to all other nodes. The receiving nodes extract this information and modify their routing table if any route measure has changed. For instance, a different route may have been chosen as the best route or the metric to the destination may have been altered.

B) Dynamic Source Routing

Dynamic Source Routing (DSR) [8] was developed at Carnegie Mellon University. It is a direct descendant of the source routing scheme used in bridged LANs. It uses source routing instead of hop-by-hop packet routing. Each data packet carries the list of routers in the path. The main benefit of source routing is that intermediate nodes need not keep route information because the path is explicitly specified in the data packet. DSR does not require any kind of periodic message to be sent, supports uni-directional and asymmetric links, and sets up routes based on demand by the source. DSR consists of two phases: (a) route discovery and (b) route maintenance, which are explained in the following sections.

Route Discovery: When a source has a data packet to send but does not have any routing information to the destination, the source initiates a route discovery. To establish a route, the source floods a Route Request message with a unique request ID. When this request message reaches the destination or a node that has route information to the destination, it sends a Route Reply message containing path information back to the source. The \route cache" maintained at each noderecords routes the node has learned and overheard over time to reduce overhead generated by a route discovery phase. When a node receives a Route Request packet, this message is forwarded only if all of the following conditions are met: (a) the node is not the target (destination) of the Route Request packet, (b) the node is not listed in source route, (c) the packet is not a duplicate, and (d) no route information to the target node is available in its route cache. If all are satisfied, it appends its identification to the source route and broadcasts the packet to its neighbors. If condition (b) or (c) is not met, it simply discards the packet. If a node is the destination of the packet or has route information to the destination, it builds and sends a Route Reply to the source, as described above.

Route Maintenance: The main innovation of DSR with respect to bridged LAN routing is in route monitoring and maintenance in the presence of mobility. DSR monitors the validity of existing routes based on the acknowledgments of data packets transmitted to neighboring nodes. This monitoring is achieved by passively listening for the transmission of the neighbor to the next hop or by setting a bit in a packet to request an explicit acknowledgment. When a node fails to receive an acknowledgment, a Route Error packet is sent to the original sender to invoke a new route discovery phase. Nodes that receive a Route Error message delete any route entry (from their route cache) which uses the broken link. Note that a Route Error message is propagated only when a node has a problem sending packets through that link. Although this selective propagation reduces control overhead (if no packets traverse a link), it yields a long delay when a packet needs to go through a new link.

C) Associativity-Based Routing

Developed at Cambridge University, Associativity-Based Routing (ABR) [9] is a protocol that is designed for an ad hoc mobile network environment. Routes are established based on demand. The uniqueness of this scheme is the route selection criteria. By exploiting the spatial and temporal relationship of mobile hosts, ABR introduces the following new routing metrics:

- Longevity of a route based on associativity,
- Route relaying load of intermediate nodes supporting existing routes, and
- Link capacities of the selected route.

By `associativity' or `affinity' we mean the spatial, temporal, and connection relationship of a mobile host with its neighbors. Associativity is measured by recording the number of control beacons received by a node from its neighbors. For example, assume each mobile host has a transmission/reception range of ten meters in diameter and there are two mobile hosts A and B. Initially, A and B are not in radio connectivity with each other but each sends a control beacon to signify its presence once every two seconds. If A is migrating at 1 m/s and it starts to enter B's radio range and move through it diagonally, then both A and B record at most five beacons each. Hence, this is the associativity threshold. Namely, if only five or less beacons are recorded, then one can assume that the other mobile host is migrating past it, and this situation is viewed as being associatively unstable. Otherwise, if the mobile host is moving but is constantly within the radio coverage of its neighbors, then more than five beacons will be recorded and hence the node is regarded as being associatively stable. Note that associativity has an inter-locking characteristic since a node's associativity stability with its neighbors depends on the mobility profile of the neighbors. By selecting nodes with high associativity counts/ticks, the route is expected to have a long-lived characteristic. This stability could result in a route with non-shortest path, but the route can be maintained with less chance of having to perform route recovery. The detailed algorithm for route selection in ABR can be found in [10].

The following sections shall elaborate further on: (a) route discovery and (b) route reconstruction.

A) Route Discovery Phase: The route discovery process consists of Broadcast Query (BQ) and BQ-REPLY cycle. When a source demands a route, it floods a BQ message. Any Intermediate Node (IN) that receives the BQ packet checks if the message has already been processed by looking up the seen table, which will be explained in Section 2.3.5. If the BQ packet has not been seen before, it appends the following to the BQ packet: (a) its identifier, (b) associatively ticks with its neighbors, (c) route relaying load, (d) link propagation delay, and (e) hop count information. The IN then broadcasts the packet to its neighbors. When the destination node receives BQ packets, it knows all the possible routes and their qualities. The destination node then selects the best route based on longevity and other qualities (route load, minimum hop, etc.) and sends a BQ-REPLY control packet (which contains a list of INs' addresses/IDs and a summary of selected route QoS) back to the source node via the selected route. When INs of the selected route receive the BQ-REPLY packet, they update their routing tables with this new route.

B) Route Reconstruction (RRC) Phase: In circumstance where nodes' mobility invalidate the selected route, the Route Reconstruction (RRC) process is invoked to discover alternate partial routes quickly. The migration of neighbor nodes can be detected when no beacon message is received within the timeout interval. When an IN of an existing route moves away from radio range of its immediate upstream or downstream, the route is invalidated. The immediate downstream node sends a Route Notification (RN) packet towards the destination to inform the invalidity of that route. Nodes that subsequently receive such a message delete their route entry. The immediate up stream of the moved node, however, performs a Localized Query (LQ) to discover a new partial route. Unlike BQ, a LQ process performs a limited scope broadcast (i.e., the flood radius is controlled by a hop count field). However, similar to BQ, information about route metrics is appended into LQ packets as they make their way to the destination. After the destination node receives several LQ messages, it selects the best partial route (again based on associativity stability) and sends back a LQ-REPLY message to the node that invoked the LQ process. As a result, all nodes in this partial path have their routing entry updated, allowing subsequent data packets to be forwarded via this new partial path.

In the case when the node that sent the LQ message does not receive the LQ- REPLY message within the timeout period (i.e., when partial paths could not be located), it sends a RN packet to the immediate upstream node (i.e., backtrack). When a node receives a RN packet from an immediate downstream node, it recognizes the backtrack and invokes a LQ process again. The fundamental strategy here is to localize the route discovery process to a bounded region so that other parts of the route are not affected. This localization also helps in avoiding the use of full broadcast unnecessarily. For a displacement of a node along the route, LQ processes can be performed at most half the route hop distance. Thereafter, if no partial path can be located, a RN message is sent back to the source node of the route to invoke a BQ process. This quick abort mechanism is to shorten route recovery time (avoiding the possibility of backtracking all the way to the source) by limiting the number of LQ processes.

IV.MULTIPATH ROUTING WITH MAXIMALLY PATHS

A) Routing Paths

In recent years, routing has been the most focused area in ad hoc networks research. On-demand routing in particular, is widely developed in bandwidth constrained mobile wireless ad hoc networks because of its effectiveness and efficiency. Most proposed on-demand routing protocols however, build and rely on single route for each data session. Whenever there is a link disconnection on the active route, the routing protocol must perform a route recovery process. Multiple paths can be useful in improving the effective bandwidth of communication pairs, responding to congestion and bursty traffic, and increasing delivery reliability. These protocols use table-driven algorithms (link state or distance vector) to compute multiple routes. Studies show however, that proactive protocols perform poorly because of excessive routing overhead [11].

Split Multipath Routing (SMR) that establishes and utilizes multiple routes of maximally disjoint paths. Multiple routes, of which one is the shortest delay path, are discovered on demand. Established routes are not necessarily of equal length. Providing multiple routes helps minimizing route recovery process and control message overhead. We believe utilizing multiple routes is beneficial in network communications, particularly in mobile wireless networks where routes are disconnected frequently because of mobility and poor wireless link quality. Our protocol uses a per-packet allocation scheme to distribute data packets into multiple paths of active sessions. This traffic distribution efficiently utilizes available network resources and prevents nodes of the route from being congested. We evaluate the performance of our scheme by extensive simulation.

B) Route Discovery

Split Multipath Routing (SMR) is an on-demand routing protocol that builds multiple routes using request/reply cycle. When the source needs a route to the destination but no route information is known, it floods the Route Request (RREQ) message to the entire network. Because this packet is flooded, several duplicates that traversed through different routes reach the destination. The destination node selects multiple disjoint routes and sends Route Reply (RREP) packets back to the source via the chosen routes.

RREQ Propagation: The main goal of SMR is to build maximally disjoint multiple paths. We want to construct maximally disjoint routes to prevent certain nodes from being congested, and to utilize the available network resources efficiently. To achieve this goal in on-demand routing schemes, the destination must know the entire path of all available routes.

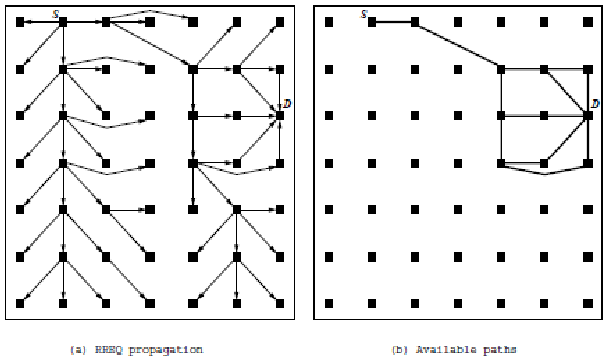

Figure 1: Overlapped multiple routes.

Therefore, we use the source routing approach where the information of the nodes that consist the route is included in the RREQ packet. Additionally, intermediate nodes are not allowed to send RREPs back to the source even when they have route information to the destination. If nodes reply from cache as in DSR and AODV , it is difficult to establish maximally disjoint multiple routes because not enough RREQ packets will reach the destination and the destination node will not know the information of the route that is formed from the cache of intermediate nodes. When the source has data packets to send but does not have the route information to the destination, it transmits a RREQ packet. The packet contains the source ID and a sequence number that uniquely identify the packet. When a node other than the destination receives a RREQ that is not a duplicate, it appends its ID and re-broadcasts the packet. During simulation experiments however, we found out that dropping all duplicate RREQs only generate multiple paths that are mostly overlapped. Figure 1 (a) shows the paths taken by RREQs from the source node S to the destination node D, and Figure 1 (b) depicts the available routes. We can observe that all five routes share the first two links.

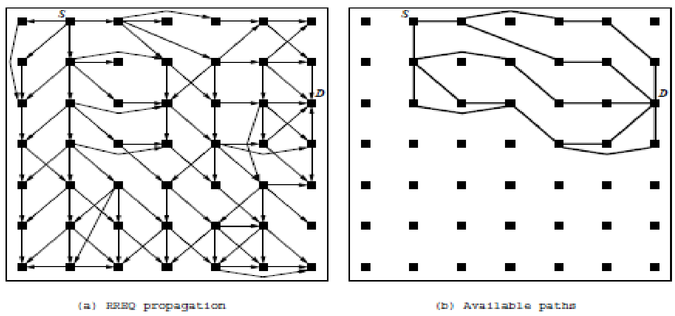

Figure 2: Multiple routes with maximally disjoint paths.

In order to avoid this overlapped route problem, we introduce a different packet forwarding approach. Instead of dropping every duplicate RREQs, intermediate nodes forward the duplicate packets that traversed through a different incoming link than the link from which the first RREQ is received, and whose hop count is not larger than that of the first received RREQ. Figure 2 (a) shows the paths taken by RREQs using this technique. We can select more disjoint paths from routes available in Figure 2 (b) than those in Figure 1 (a). Our approach has a disadvantage of transmiting more RREQ packets, but it enables us to discover maximally disjoint routes.

Route Selection Method: In our algorithm, the destination selects two routes that are maximally disjoint. More than two routes can be chosen, but we limit the number of routes to two in this study. One of the two routes is the shortest delay route; the path taken by the first RREQ the destination receives. We use the shortest delay path as one of the two routes to minimize the route acquisition latency required by on-demand routing protocols. When receiving this first RREQ, the destination records the entire path and sends a RREP to the source via this route. The node IDs of the entire path is recorded in the RREP, and hence the intermediate nodes can forward this packet using this information. After this process, the destination waits a certain duration of time to receive more RREQs and learn all possible routes. It then selects the route that is maximally disjoint to the route that is already replied. The maximally disjoint route can be selected because the destination knows the entire path information of the first route and all other candidate routes. If there are more than one route that are maximally disjoint with the first route, the one with the shortest hop distance is chosen. If there still remain multiple routes that meet the condition, the path that delivered the RREQ to the destination the quickest between them is selected. The destination then sends another RREP to the source via the second route selected. Note that two routes of the session are not necessarily of equal length.Because our protocol uses the source routing and intermediate nodes do not reply from cache, only the source nodes maintain route information to destinations. Each node hence uses less memory, but packet header size is larger because we use source routing.

C) Route Maintenance

A link of a route can be disconnected because of mobility, congestion, and packet collisions. It is important to recover broken routes immediately to do effective routing. In SMR, when a node fails to deliver the data packet to the next hop of the route (by receiving a link layer feedback from IEEE 802.11 [12] or not receiving passive acknowledgments [13]), it considers the link to be disconnected and sends a Route Error (RERR) packet to the upstream direction of the route. The RERR message contains the route to the source, and the immediate upstream and downstream nodes of the broken link. Upon receiving this RERR packet, the source removes every entry in its route table that uses the broken link (regardless of the destination). If only one of the two routes of the session is invalidated, the source uses the remaining valid route to deliver data packets.

IV. SIMULATION RESULTS

A) Packet Delivery Ratio

Figure 3 shows the throughput of each protocol in packet delivery fraction. Packet delivery ratio is obtained by dividing the number of data packets correctly received by the destinations by the number of data packets originated by the sources. We can observe from the result that both SMR schemes outperform DSR, especially when the mobility increases (i.e., the pause time decreases). In DSR, only one route is used for each session and when that route is invalidated, the source uses the cached route that is learned from overhearing packets. If no such route is available, it sends a RREQ to discover a new route. In the latter case, intermediate nodes that have cached routes to the destination provide those route to the source by sending RREPs. DSR however, does not apply any aging mechanism for cached route entries, and hence routes stored in the cache (either by the source or the intermediate nodes) may be stale.

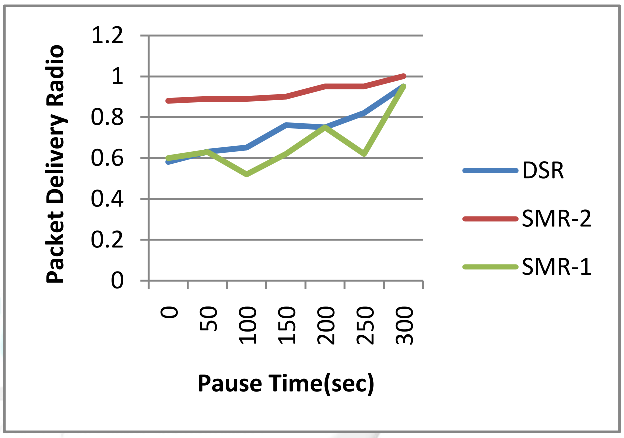

Figure 3: Packet delivery ratio.

After a route break, source nodes will use these newly acquired but obsolete routes only to learn that they are also invalid, and will attempt another route recovery. Many data packets are dropped during this process and more delay is needed to discover correct routes. Between SMR protocols, SMR-2 delivers more packets than SMR-1. We can analyze that the control packets generated by the route rediscovery processes of SMR-1 cause collision and contention with data packets. Even though SMR- 2 will have only one available route to the destination after the other route is broken, it can still deliver data packets without producing control traffic as long as the remaining route stays connected, and that leads to a good throughput performance.

Figure 4 illustrates the number of packets dropped by each protocol. Both data and control packets are measured. The reasons for packet drops can be incorrect route information, mobility, collisions, and congestion. DSR cannot maintain precise routes and drops more packets as nodes move more often (i.e., less pause time). The usage of state routes from caches is the major reason of DSR packet drops.

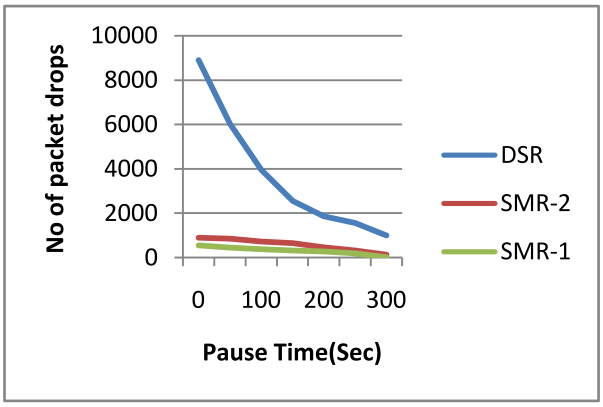

Figure 4: Number of packet drops.

Both SMR schemes have considerably fewer packet drops compared with DSR. SMR-2 has fewer packet drops because it invokes fewer route recovery processes and consequently, transmits less control messages.

B) Control Overhead

Figure 5 presents the control overhead in normalized routing load. Normalized routing load is the ratio of the number of control packets propagated by every node in the network and the number of data packets received by the destination nodes. This value hence represents the protocol efficiency. When there is no mobility, DSR has the smallest value. This result is expected because SMR protocols generate more control packets while building multiple routes. On the other hand, DSR builds single route for each session and minimizes flooding overhead by allowing intermediate nodes of replying from cache.

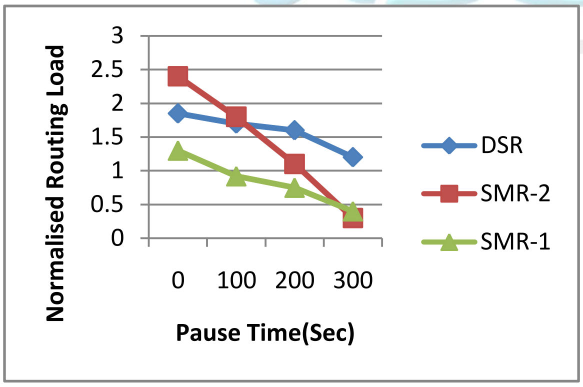

Figure 4.5: Normalized routing load.

Cached routes are useful in static networks as they remain valid for the entire duration. As mobility is increased, however, SMR-2 shows better efficiency than DSR. DSR yields less overhead in initial route discovery process, but it invokes more route reconstruction procedures than SMR-2 since DSR intermediate nodes often reply with stale routes. Additionally, DSR transmits considerably more RERR packets than SMR schemes because the former has more route disconnections and route recoveries. Furthermore, DSR sends RERR packets whenever a unicast packet (data, RREP, and RERR) fails to be delivered to the next hop. SMR sends RERR only when the data packet is undeliverable. Therefore, DSR shows higher normalized routing load than SMR-2 when mobility is present. We can also observe that SMR-1 shows less efficiency than other protocols regardless of mobility. Since the source floods the network with RREQs when any route of a session is disconnected, more control packets are transmitted than DSR and SMR-2. We can deduce from this result that excessive flooding makes the protocol inefficient.

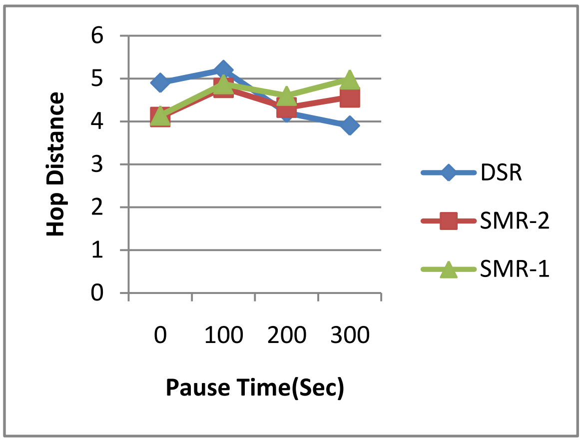

Figure 6: Hop distance.

C) Hop Length

Figure 6 reports the average hop distance of each protocol. DSR has the shortest hop distance when there is no mobility because SMR schemes' second routes may have longer distance than the first routes. With mobility however, the hop distance of DSR grows and becomes larger than those of SMR protocols. If the route is established directly from the destination, it can be the shortest route since it is built based on the most recent information and accounts for node locations after movements. DSR, however, uses cached routes from intermediate nodes. These routes may not be fresh enough and do not exploit the current network topology. DSR therefore builds longer routes than SMR protocols. Longer paths have a better chance of having route breaks since one link disconnection results in a route invalidation. Results from Figure 3 confirms our observation.

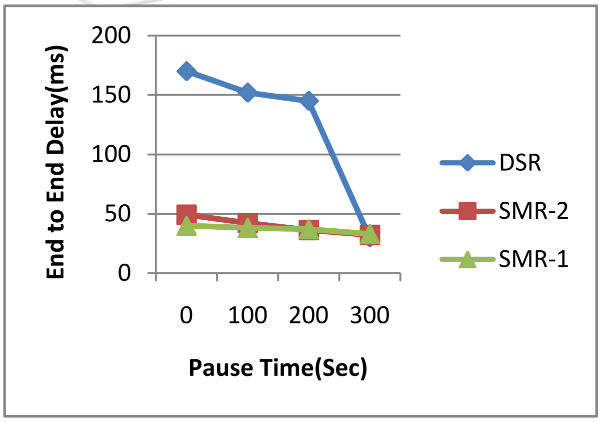

Figure 7: End-to-end delay.

D) Delay

Figure 7 shows the end-to-end delay. DSR has the longest delay in mobile scenarios because it delivers data packets on routes longer than those of SMR. In addition, DSR yields longer delays in reconstructing routes and the period of time the data packets are buffered at the source node during route recovery results in larger end-to-end delays. SMR on the other hand, uses the remaining valid route when one of the multiple route is disconnected, and hence no route acquisition latency is required.

V.CONCLUSION

In this paper presented the Split Multipath Routing (SMR) protocol for ad hoc networks. SMR is an on-demand protocol that builds maximally disjoint routes. Our scheme uses two routes for each session; the shortest delay route and the one that is maximally disjoint with the shortest delay route. We attempt to build maximally disjoint routes to avoid having certain links from being congested, and to efficiently utilize the available network resources. Providing multiple paths is useful in ad hoc networks because when one of the route is disconnected, the source can simply use other available routes without performing the route recovery process.

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