Position Based Mobility Adaptive Multicast Routing in MANET

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Abstract*— Group communications are essential in Mobile Ad hoc Networks (MANET). Multicast routing is an important technique to implement the group communications. The optimal multicast tree creation needs to repair the group membership management issues and link disconnections induced by the node mobility properly. It is challenging to implement the scalable multicasting in MANET due to the issues in zone membership maintenance and multicast packet routing over dynamic environment. This paper introduces an efficient zone multicast scheme, based on mobility prediction, which track the future movement of the node in a precise way for efficient data delivery. The proposed Mobility Prediction AIDed Multicast Routing Protocol (MP-AID-MRP) constructs a virtual-zone-based structure to implement scalable and efficient group membership management. In order to reduce the mobility impact on the maintenance of tree structure and packet routing, the position information of the node is utilized to conduct the zone structure building, multicast tree construction, and multicast packet forwarding. The location-aware quick group is joining and leaving technique for more reliable membership management and packet transmissions dramatically improves the scalability even under a large network. The mobility prediction based zone leader handoff and group maintenance completely reduce the redundant overhead, and thus it achieves high scalability and adaptability to the highly dynamic environment. The simulation results demonstrate that proposed MP-AID-MRP is an effective protocol in term of high packet delivery ratio and low control overhead with a high degree of node mobility. Finally, it reveals that the proposed protocol, MP-AID-MRP performs well other than the existing multicast routing protocol EGMP.

***Keywords*—MANET, Multicast, Greedy Selection, Node Mobility, Mobility prediction, Scalability, and Efficiency.**

I. INTRODUCTION

A set of mobile nodes in MANET is capable of making a direct or multi-hop communication with each other [1]. These nodes are free to move anywhere at any time. The wireless communication between mobile nodes requires routing over multiple-hop wireless paths. Much work applies unicast routing protocols over wireless communications. However, multicast is a fundamental routing service to enable communication among group of mobile nodes, where one-to-many data dissemination is in need such as disaster recovery scenarios [2] [3]. Recently, the geographical routing protocols have been proposed for more scalable and efficient routing. In geographical routing protocols, the mobile nodes are aware of their own location information using Global Positioning System (GPS) or other location services.

The local topology or geographic based routing mechanism is more scalable and robust in a dynamic network topology. Making use of position information to design the multicast routing scheme reduces the topology maintenance overhead and support more reliable routing. However, there are many challenges to implementing an efficient and reliable position based multicast routing scheme over wireless communication [4] [5]. For example, a data packet carries the destination address to guide the packet forwarding in unicast routing protocols, whereas, in multicasting the receiver is a group of nodes. A simple way to apply the geographic routing in multicast routing is to load the address of all receivers into the packet header directly, however, it increases the packet header overhead over large scale network topology [6] [7]. The multicast routing design is complex due to the dynamic network topology and the limited network capacity. It is essential to reduce the states to be maintained in the network and make the multicast routing that should not impacted by the dynamic network topology.

The proposed work, MP-AID-MRP influences the process of forwarding node selection and zone based multicast routing performance under highly dynamic network topology. This mobility prediction and fast update of the list of zone members improves the overall performance of MP-AID-MRP. The simulation results demonstrate that the proposed MP-AID-MRP provides an effective routing in terms of the high packet delivery ratio and routing overhead under highly mobile scenarios. It attains high scalability and efficiency under both group maintenance and data communication than EGMP with the high frequency of node mobility.

A. Problem Statement

The design of highly efficient and scalable multicast routing protocols has many issues such as scalability and reliability over MANET environment. The problems associated with the zone based multicast routing are group maintenance and link disconnection due to the unpredictable node mobility in the network. Frequent and hard to predict the topology changes in the network due to the node mobility is the most important issue taken into account for improving the multicast routing scalability and efficiency. A greedy routing has taken in the geographical routing for providing an adaptive routing even under dynamic network environment. However, a greedy selection is not an optimal solution for deciding the forwarding node always, as it can easily move out of the sender node's communication range. In existing multicast routing schemes, the mobility factors of the network are identified, but the prediction of these factors is difficult under real time scenarios. Determining an optimal solution to the node mobility impact on the multicast routing mechanism is challenging, since the existing multicast routing approaches take routing decision by assuming the probability distribution function of these random factors. Moreover, it significantly fell down the group membership maintenance and degrades the multicast routing performance. There is a need to propose a geographical multicast routing protocol for achieving efficient and scalable group communication over highly dynamic environment.

B. Aim and Objectives of the paper

The main aim and objectives of the paper are,

- To construct a virtual zone based structure using the location information of the mobile nodes
- To manage group membership of mobile nodes in a zone based virtual structure, under a highly dynamic network topology
- To select an efficient zone leader and route the multicast data packets using a multicast tree with the support of mobility prediction scheme
- To enhance the scalability of zone based multicast routing by reducing routing overhead, and eliminate the frequent broadcast of beacon packets among the neighboring nodes.

C. Paper Organization

The rest of this paper is organized as follows. Section 2 discusses the related work of existing multicast routing protocol. Section 3 explains a proposed highly efficient MP-AID-MRP. Finally, Section 4 demonstrates the simulation results and concludes the proposed work in Section 5.

II. RELATED WORKS

Several multicast routing protocols build distribution structure either in mesh or tree-based structure for delivering the multicast packets in a dynamic environment. In existing, tree-based multicast routing technique forwards the data packets on a single route to a particular receiver. The association of routes to all the multicast receivers forms the multicast tree, which is common for all the senders in a multicast session. However, the mesh-based routing includes multiple paths to each receiver, but this redundancy leads to increased protection against dynamic environment.

A. Multicast Routing Protocols

The conventional topology based multicast routing protocols includes tree [8-10] [11] and mesh-based protocols ([4], [12]). The tree-based protocols form a tree topology for more efficient forwarding of multicast packets to all the receivers. Mesh-based routing protocols expand the tree structure with multiple routes and these routes forward packets when the route gets failure. Even though the topology-aware tree or mesh-based routing are efficient for the MANET environment [5], the global topology maintenance is difficult to scale to a large scale network topology. It is because, the states to be maintained in the multicast routing increases the control routing overhead. The works in [13], [14] design the stateless multicast protocol [15] and it provides better scalability even to a large scale network topology.

In contrast, EGMP [16] employs a location-aware multicast routing scheme for efficient maintenance of group members and supports high scale network topology. In order to obtain the location of the nodes and maintain the group, the geographic multicast routing protocols require location service [17] [18]. The geographic multicast protocols in [19], [20] and [3] need to load entire tree information in the packet header, and this increases the routing overhead when the group size is large. In contrast, the DSM [19] allows each node to flood its location in the network. Moreover, a multicast source node builds a Steiner tree and encodes the information about the entire multicast tree into the data packets and follows the source routing to deliver the data packets. Two overlay multicast trees, LGT [20] require each group to inform their location information with the members of all other groups.

B. Mobility Impact on Multicast Routing

The node mobility incurs additional challenge to the multicast routing protocol. It results in the frequent handover process of zone leader and link failure. With the use of geographical information [21], ODMRP improves the scalability of multicast routing by restricting the flooding in a specific geographic region. In dynamic source multicast, DSM each node floods its position information and knows the location of all others in MANET. The multicast source node constructs the multicast tree from the position information of all receivers. This tree information is efficiently encoded in the packet header. By default, the multicast source node forwards the data packets in a greedy manner. When no such neighbor exists in the positive progress set, the routing scheme recovers the system from local communication hole. However, frequent link failure due to dynamic network topology impacts the multicast routing scalability and efficiency. Both, the tree and mesh-based multicast routing protocols, need to maintain state information about the distribution structure and thus they are limited to environments, where the node mobility is high.

III. OVERVIEW OF THE PROPOSED METHODOLOGY

The proposed mobility prediction aided multicast routing protocol, MP-AID-MRP is location based routing protocol, each node identifies its own position information using GPS. The location-based multicast routing performs three primary functions such as multicast structure construction, group membership maintenance, and multicast data forwarding. In our proposed MP-AID-MRP, considerable enhancements that provide adaptability for the unpredictable node mobility are carried out in three primary functions in location based multicasting.

A. Multicast structure construction with Mobility Prediction

In the proposed MP-AID-MRP, constructs the virtual zone based structure in the form of two-level hierarchy. In the lower level, each node identifies its zone id distributively, and each zone member elects a leader based on the node mobility factor. In the upper level, elected zone leaders of every zone serve as a representative for its zone and also take responsibility for a new node joining or leaving process.

B. Group membership maintenance

In order to reduce group membership maintenance overhead, MP-AID-MRP allows each node inspect only its group membership changes rather than tracking of each node movement. In the case of wrong prediction, the member node informs its new location only to its zone leader, which periodically broadcast the beacon packet including its group membership information. Hence, node movement in the routing zone is easily identified with the help of mobility prediction.

C. Mobility Adaptive Multicast packet forwarding

Towards destination zone, the multicast source node selects the next hop and forwards the multicast routing packets. Multicast source node forwards the data packets from source to destination means source node selects one of its members or ordinary node which is closer to the destination. Moreover, a frequent detection of node mobility and fast joining and leaving process of the mobile node under highly dynamic network topology improves the multicast packet forwarding.

IV. MOBILITY PREDICTION AIDED MULTICAST ROUTING PROTOCOL (MP-AID-MRP)

The main issue in multicasting is the proper selection of zone leader and group maintenance under highly dynamic environment. To enhance the performance gain of the multicasting, the MP-AID-MRP includes mobility prediction with the process of three primary functions in location based multicasting. The MP-AID-MRP form virtual zone structure using a reference point. However, the zone construction does not depend on the network structure, and this makes the proposed work easy to maintain the zone. A multicast group crosses multiple zones, and there is no need to track individual node movement. It is sufficient to track the movement of group members, and thus it reduces the routing overhead. By using the constraint virtual based zone construction and maintenance [19], the proposed work can significantly minimize the maintenance overhead and improves the efficiency of the proposed MP-AID-MRP protocol performance.

A. Zone Leader Election

In every zone, each mobile node may act as a zone member or an ordinary node. Each zone selects a node to act as a leader (Z_{ldr}) that manage the multicast group members. To initiate the process, the zone leader selection and maintenance process follows three steps. Initially, each node in the zone broadcast the hello packets including its current location with velocity and measures Acceptable Location Change (ALC) factor for itself and Zone leader, Z_{ld}. Initially, each node in each zone elects a node with less ALC value, and it should be located at the center of the zone region [19] [20]. This node is named as Zone leader, Z_{ldr}. In the second step, the Z_{ldr} selected in a distributed manner periodically broadcasts the beacon packets including the list of zone members and remaining neighboring nodes in the communication range with the measured ALC value for every i interval. In the third step, Z_{ldr} measures ALC value for all the neighboring nodes, and a node updates its location information to the Z_{ldr}, only when the measured ALC value is false. Thus, there is no need to broadcast the beacon packets frequently among the neighboring nodes, including both zone members and ordinary nodes in the zone. Moreover, each node is aware of its neighboring nodes and divides the neighbor zones into upstream and downstream zones based on its distance to the destination zone. The upstream zone supports to maintain the virtual zone, when it has no zone members.

/*Neighbor List and Zone Leader Selection*/

```
Each node in a zone do
{
    Broadcast the beacons to all nodes, n;
    Creates the neighbor's list for each node i, NH_i;
    Z_ldr election ();
    NH_i Update ();
}

Z_ldr election: each i do
{
        For( i=1; i<=n; i++)
        {
            For( j=i+1; j<=n; j++ )
            {
                If (ACL_i < ACL_j )
                {
                    Temp = ACL_i;
                }
            }
            Temp elected as Z_ldr;
        }
}
```

NH Update alg: **do**

{

Receives Zone member list, ZM_l from Z_{ldr};

Updates the NH_i:

}

Fig. 1 Algorithm for Zone Leader Election and Group Maintenance

On receiving the beacon packets, each node compares the neighboring nodes' ACL to others and select a node which is the center of the zone region. In each one, a high stability node is elected as a Z_{ldr} and the neighboring nodes send the vote message to it. To ensure its leadership, the Z_{ldr} broadcasts it for every i/2 period enabling the leader flag bit in the beacon packets. Moreover, it includes the predicted next location of neighboring nodes, and thus it minimizes the beaconing overhead, as there is no need to do the position update among all the neighboring nodes. Instead of that, Z_{ldr} includes the neighboring node list in beacons.

B. *Group membership maintenance*

This section describes the multicast group membership construction and maintenance schemes. It facilitates adaptive group joining and leaving, and empty zone handling process [EGMP]. On the node joining process, it sends the join request to Z_{ldr} when it overhears the data transmission of particular multicast session or receives the beacon message from Z_{ldr}. Each ordinary node sends the beacon packet including its Z_{ldr} information per every I interval. Thus, each Z_{ldr} is aware of its neighboring zones. Under highly dynamic environment, the measured ALC assists to maintain the zone membership efficiently.

1) Acceptable Location Change

In the proposed MP-AID-MRP, each Z_{ldr} predicts the next location of its zone members and ordinary nodes using a simple prediction scheme and measures ALC for each of its neighboring nodes. Based on the location prediction scheme, the Z_{ldr} can ensure whether the zone member or an ordinary node is still within their communication range and update their list accordingly. For every i/2 time period, the Z_{ldr} sends beacon packets including both the list of zone members and ordinary nodes. The main rule of the mobility prediction scheme is to inform the location information from node i to Z_{ldr}, when the error is identified between the predicted location information of node i and node i's actual location after its movement.

Over a relatively short period of time, one can assume that each node, i follows a linear trajectory, and its next location is a function of time and velocity as shown in the equation (1).

$$\text{Pos}\,(t+1) = \begin{Bmatrix} X_i \\ Y_i \end{Bmatrix} + \begin{Bmatrix} V_x^i \\ V_v^i \end{Bmatrix} * (t - t1) \quad -----(1)$$

$$ALC = \left(\begin{Bmatrix} X_i - X_j \\ Y_i - Y_j \end{Bmatrix} + \begin{Bmatrix} V_i^x - V_j^y \\ V_i^x - V_j^y \end{Bmatrix} * t \right) \quad -----(2)$$

If an error occurs between the original and its predicted next location, it makes an error in the ALC value. In this case, a node i send its original location information to the Z_{ldr} and it informs all the neighboring nodes using beacon packet. Note that each node measures ALC for Z_{ldr}. In case of Z_{ldr} movement prediction, the higher priority node waits to receive the handover message from Z_{ldr} and the measured ALC of Z_{ldr} is high, it sends messages to provide the leadership for higher priority node, attaching the selected node address as Z_{ldr}. Thus, it significantly minimizes the routing overhead and impact of node mobility on zone management, and moreover, it reduces the node mobility impact on the group maintenance and reduces the routing overhead.

C. *Multicast Data Forwarding*

The proposed MP-AID-MRP divides the neighboring zones into upstream and downstream zones based on its distance to the destination zone without using additional beacon packets [20] [21]. When a node i wants to forward the multicast packets to a list of multicast receivers (R1; R2;::Rn), it decides the next hop node towards each destination or select forwarders from the upstream zone as shown in the Fig. 2.

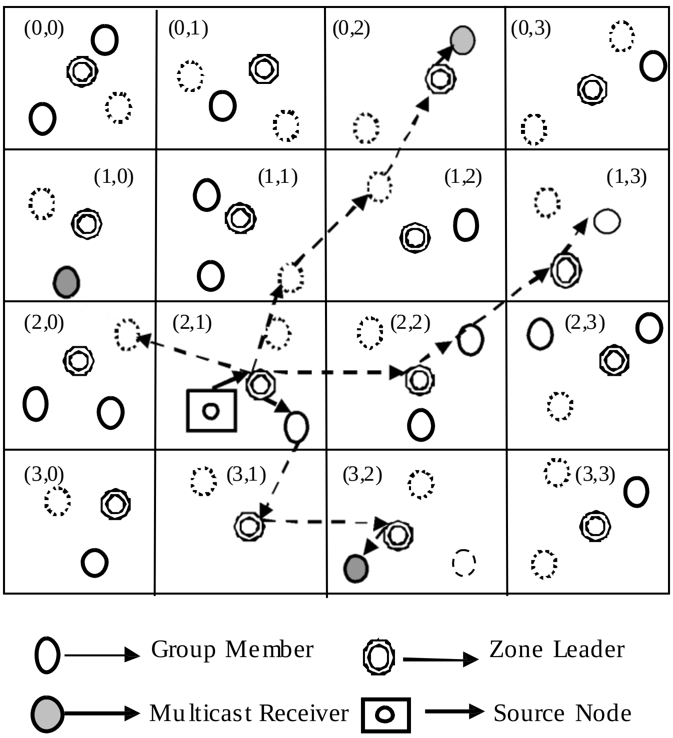

Fig. 2 MP-AID-MRP

In order to determine the nearer neighbor node to upstream stream, each node calculates the distance of its neighboring nodes in the upstream zone to reach its target zone (X_{tgt},Y_{tgt}) as follows,

$$D(i,j) = \left(\left[\frac{X_i - X_j}{Y_i - Y_j} \right] + \left[\frac{dx_i - dx_j}{dx_i - dx_j} \right] * t \right) \quad -----(3)$$

Thus, a zone with a smaller distance value is closer to the target zone is determined. The source node will forward the data packet towards the zone leader of the target zone. After determining the very nearer next hop node to reach the target zone. Zone representative forward the data packet to the destination node in the zone by exploiting the information in the membership table after arriving at the destination zone.

V. PERFORMANCE EVALUATION

The NS2 simulation is employed to evaluate the performance of proposed priority location aided scalable multicast protocol. The proposed work is simulated in the network domain consists of 100 nodes situated randomly within the flat square of area 1000m x 1000m area. Moreover, in the simulation the velocity of each node varies between 10 and 60 m/s. To show the advantage of proposed algorithm MP-AID-MRP, the performance comparison is evaluated between existing EGMP and proposed protocol.

A. Simulation Results

The following section illustrates the experimental results of the proposed protocol in terms of packet delivery ratio and routing overhead with varying node mobility.

1) Packet delivery ratio

The packet delivery ratio is defined as the ratio between the number of packets received at the destination to the number of packets sent from the source. In order to improve successful transmission of data packets from source to destination, proper zone membership maintenance is performed in accordance with dynamic mobility. The proposed work predicts the mobility of zone leader and its neighboring nodes, and hence in MP-AID-MRP, the high packet delivery ratio is achieved rather than other stateless multicast protocol, EGMP.

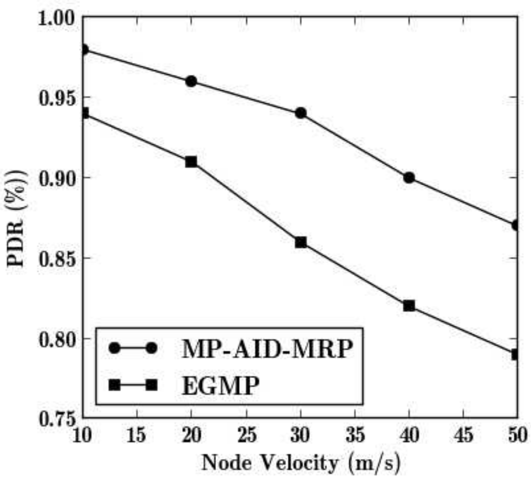

Fig. 3 Node velocity Vs Packet Delivery Ratio

2) Control Overhead

Control overhead is also the ratio between number of control messages accumulated over through each hop to the total number of data packets received at the destination. Under the dynamic mobility, high overhead is incurred to maintain group membership of all nodes in a zone. Location updation is performed in accordance with the individual node movement, but it leads to large excessive overhead in EGMP. However, in the proposed MP-AID-MRP reduces the location updation among neighboring nodes and minimizes the node mobility impact on multicast routing.

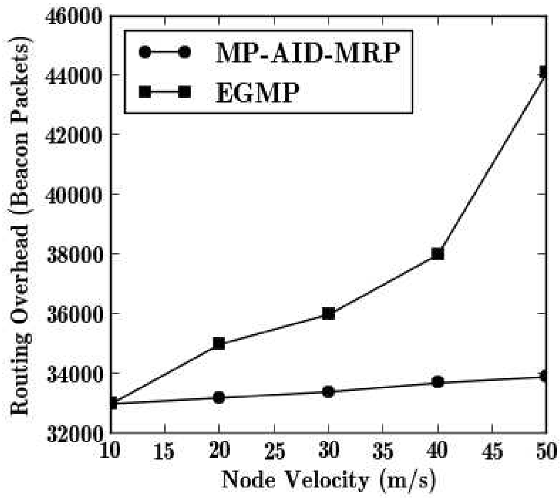

Fig. 4 Node velocity Vs Control Overhead

VI. CONCLUSION

In this paper, a zone based multicast routing protocol MP-AID-MRP for MANET is proposed. The proposed approach attains high scalability and efficiency by selecting stable forwarding members using mobility prediction scheme. Thus, the group membership maintenance and multicast data transmission successfully perform their tasks using the accurate location information that reduces the routing overhead and access delay. The use of location information for construction of the zone structure significantly reduces the group maintenance complexity. In the proposed MP-AID-MRP, the partition of neighbor zones into upstream and downstream zones handles the empty zone problem without incurring control overhead. Achieving fast tree structure adaptation under dynamic network topology and avoid redundant packet transmission, the MP-AID-MRP employs the location prediction scheme in a precise way. Thus, it influences the process of forwarding node selection and zone based multicast routing performance in MANET. Experimental results obtained from the simulation demonstrate that the proposed protocol MP-AID-MRP achieves a high packet delivery ratio and reduced control overhead under highly dynamic environment. Finally, it reveals that the proposed protocol performs well when compared to the existing EGMP.

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