A New Approach of Extendable Multicast Routing Protocol in Mobile Ad Hoc Networks

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March, 2010

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A thesis submitted in partial fulfillment of the requirements for the degree of Bachelor of Science in Computer Science and Engineering (CSE) at Khulna University.

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Abstract

Multicasting is a useful operation that facilitates group communications among the nodes using the most efficient strategy to deliver the messages over each link of the network. It is a challenging task due to the fact that the topology may change frequently, multicast group size may increase, and communication links may be broken because of the mobility of network hosts. Efficient and extendable multicast routing in Mobile Ad Hoc Networks (MANETs) is a difficult issue. To enhance performance and to enable scalability, we have proposed a domain-based protocol named EMRP (Extendable Multicast Routing Protocol) for hierarchical multicasting in MANET environments. Each domain has a sub-source in order to reduce the path length between the original source and intended receiver and solute the scalability issue. We have considered a variety of approaches that are suitable for different mobility speed and group sizes. Results obtained through simulations demonstrate enhanced performance in packet delivery ratio and end-to-end delay of the proposed technique as compared to the existing ones.

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Chapter I

Introduction

The uses of mobile and wireless devices are becoming ubiquitous. Thus, the need for efficient intercommunication among these devices is becoming critical. In addition to the infrastructure-based cellular wireless network, the study and developments of infrastructure less wireless networks have been very popular in recent years. Mobile Ad hoc networks (MANETs) belong to this class. An ad hoc network refers to a collection of mobile hosts with wireless communication capability which builds a temporary network without the help of any established infrastructure or centralized administration. Mobile Ad-hoc networks are self-organizing and self-configuring multihop wireless networks where the structure of the network changes dynamically [13]. Two nodes can communicate if they are within each other's transmission range, otherwise intermediate nodes can serve as routers if they are out of range (multi-hop routing).

Multicast is a mechanism to efficiently support multi-point communications [12]. It involves the transmission of a datagram to a group of zero or more hosts identified by a single destination address, and so is intended for group-oriented computing. A multicast datagram is delivered to all members of its destination host group with reliability.

1.1 Motivation

- Multicast is a technique which is used to deliver data only to the interested receivers and saves bandwidth.
- Multicast provides the most efficient use of resources and becomes more popular.
- Multicast provides energy saving techniques aimed at minimizing the total power consumption of all nodes in the multicast group.

1.2 Objectives

The objectives to develop a multicast routing protocol involves the following-

- The path traveled from the source to each destination must be optimal (the shortest or minimum cost path).
- Multicast group should be extendable if necessary.

- There must be no loops in routing; that is, packet must not visit a router more than once.
- The data packet delivery ratio must be sufficiently high.
- The data transmission delay must be as minimum as possible.
- Lower number of control bytes transmitted per data byte delivered.

1.3 Application Area

In multicasting, data are delivered to interested hosts. Links, which are connected to uninterested hosts, do not carry traffic unless such hosts are on the path from the sender to the interested receivers. Thus, multicast provides the most efficient use of resources, and it is becoming more popular, especially the following areas-

(a) **Military battlefield:** Military equipment now routinely contains some sort of computer equipment. MANET multicast networking would allow the military to take advantage of commonplace network technology to maintain an information network between the soldiers, vehicles, and military information headquarters. The basic techniques of ad hoc network came from military battlefield [11].

(b) **Commercial sector:** Ad hoc multicast can be used in emergency or rescue operations for disaster relief efforts, e.g., in fire, flood, or earthquake. Emergency rescue operations must take place where non-existing or damaged communications infrastructure and rapid deployment of a communication network is needed. Information is relayed from one rescue team member to another over a small handheld. Other commercial scenarios include e.g., ship-to-ship ad hoc mobile communication, law enforcement, etc.

(c) **Local level:** Ad hoc multicast networks can autonomously link an instant and temporary multimedia network using notebook computers or palmtop computers to spread and share information among participants at a conference or classroom. Another appropriate local level application might be in home networks where devices can communicate directly to exchange information.

(d) **Civil applications:** Civil application of MANET multicast includes audio and video conferencing, telematics applications (traffic), sports etc.

(e) **Personal Area Network (PAN):** Short-range MANET can simplify the intercommunication between various mobile devices. Tedious wired cables are replaced with wireless connections. Such an ad hoc network can also extend the access to the Internet or other networks by mechanisms e.g., Wireless LAN, GPRS, and UMTS. The PAN is potentially a promising application field of MANET in the future pervasive computing context.

1.4 Multicast Routing Protocol Design Issues and Challenges

The particular features of MANETs make the design of a multicast routing protocol a challenging one. These protocols must deal with a number of issues, including high dynamic topology, limited and variable capacity, limited energy resources, a high bit error rate, a multi-hop topology, and the hidden terminal problem. The requirements of multicast routing protocols and the issues associated with these protocols that should be taken into consideration are listed below-

(a) **Topology, Mobility, and Robustness:** In MANETs, nodes are free to move anywhere, any time and at different speeds. The random and continued movement of the nodes leads to a highly dynamic topology, especially in a high-mobility environment. A multicast routing protocol should be robust enough to react quickly to the mobility of the nodes and should adapt to topological changes in order to avoid dropping a data packet during the multicast session, which would create a low packet delivery ratio. It is very important to minimize control overhead while creating and maintaining the multicast group topology, especially in an environment with limited capacity.

(b) **Capacity and Efficiency:** Unlike wired networks, MANETs are characterized by scant capacity caused by the noise and interference inherent in wireless transmission and multi-path fading. Efficient multicast routing protocols are expected to provide a fair number of control packets transmitted through the network relative to the number of data packets reaching their destination intact, and methods to improve and increase the available capacity need to be considered.

(c) **Energy Consumption:** Energy efficiency is an important consideration in such an environment. Nodes in MANETs rely on limited battery power for their energy. Energy-saving techniques aimed at minimizing the total power consumption of all nodes in the multicast group (minimize the number of nodes used to establish multicast connectivity, minimize the number of overhead controls, and so on) and at maximizing the multicast life span should be considered.

(d) Quality of Service and Resource Management: Providing quality of service (QoS) assurance is one of the greatest challenges in designing algorithms for MANET multicasts. Multicast routing protocols should be able to reserve different network resources to achieve QoS requirements such as, capacity, delay, delay jitter, and packet loss. It is very difficult to meet all QoS requirements at the same time because of the peculiarities of ad hoc networks. Even if this is done, the protocol will be very complex (many routing tables, high control overhead, high energy consumption, etc.). As a result, doing so will not be suitable for these networks with their scarce resources, and resource management and adaptive QoS methods are more convenient than reservation methods for MANETs.

(e) Security and Reliability: Security provisioning is a crucial issue in MANET multicasting due to the broadcast nature of this type of network, the existence of a wireless medium, and the lack of any centralized infrastructure. This makes MANETs vulnerable to eavesdropping, interference, spoofing, etc. Multicast routing protocols should take this into account, especially in some applications such as military (battlefield) operations, national crises, and emergency operations. Reliability is particularly important in multicasting, especially in these applications, and it becomes more difficult to deliver reliable data to group members whose topology varies.

(f) Scalability: A multicast routing protocol should be able to provide an acceptable level of service in a network with a large number of nodes. It is very important to take into account the nondeterministic characteristics (power and capacity limitations, random mobility, etc.) of the MANET environment in coping with this issue.

1.4 Organization of the Report

Our report has been organized into five chapters; each chapter gives a distinct concept as mentioned bellow.

Chapter I (*Introduction*): This Chapter describes introductory concept and a brief overview of mobile ad hoc network and multicast, objective of multicast, application area and multicast protocol design issues.

Chapter II (*Literature Survey)*: This chapter describes some existing research works related to multicast routing protocol and their drawbacks.

Chapter III (*Proposed Method)*: This chapter represents our proposed multicast routing protocol towards the fulfillment of our objectives.

Chapter IV *(Experimental Results and Analysis)*: This chapter shows the results of performance evaluation of our thesis work.

Chapter V (*Concluding and Recommendation*): This chapter contains conclusion, limitation of our works and recommendation.

Chapter II

Literature Survey

2.1 Introduction

There are several algorithms which have been proposed by different persons in order to enhance multicast routing protocol for mobile ad hoc networks. These algorithms are based on several application areas such as dynamic network topology, limited bandwidth, power etc. The main issues which have been used for these algorithms are bandwidth, constrained power, mobility of network hosts and link disruption.

2.2 Related Concepts

Computer Network

A computer network is a group of interconnected computers that are connected through a cable or some types of wireless connection in order to share resources such as data, hardware and software.

Mobile Ad-Hoc Network (MANET)

An ad-hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any stand-alone infrastructure or centralized administration. Mobile Ad-hoc networks are self-organizing and self-configuring multihop wireless networks where the structure of the network changes dynamically. Ad hoc networking can be applied anywhere where there is little or no communication infrastructure or the existing infrastructure is expensive or inconvenient to use.

Routing

Routing is the process of selecting paths in a network along which to send network traffic. Routing is performed for many kinds of networks, including the telephone network, electronic data networks (such as the Internet), and transportation networks. The routing concept basically involves, two activities: firstly, determining optimal routing paths and secondly, transferring the information groups (called packets) through an internetwork.

Unicast

In computer networking, unicast transmission is the sending of information packets to a single network destination. It is one to one communication system. Here sender transmits data to the intended receiver only.

Multicast

Multicast addressing is a network technology for the delivery of information to a group of destinations simultaneously using the most efficient strategy to deliver the messages over each link of the network only once, creating copies only when the links to the multiple destinations split.

Broadcast

In computer networking, broadcasting refers to transmitting a packet that will be received (conceptually) by every device on the network. In practice, the scope of the broadcast is limited to a broadcast domain.

Topology

Network topology is the physical or logical arrangement and interconnections of the elements of a computer network. There are several network topologies such as mesh, ring, bus, and star.

Protocol

A protocol is a common set of rules which is used by computers to communicate with each other's across a network. A protocol is a convention or standard that controls or enables the connection, communication, and data transfer between computing ends points.

Hop Count

In networking, the hop count represents the total number of devices a given piece of data passes through. Generally speaking, the more hops data must traverse to reach their destination, the greater the transmission delay incurred.

2.3 Related Work

2.3.1 ODMRP

The On-Demand Multicast Routing Protocol (ODMRP) was proposed S.J. Lee, M. Gerla, and C. C. Chiang [9], which is a mesh-based, rather than a conventional tree based, multicast scheme and uses a forwarding group concept. It applies on-demand procedures to dynamically build routes and maintain multicast group membership. There is a request phase and a reply phase that comprises the protocol. While a multicast source has packets to send, it periodically broadcasts to the entire network a member advertising packet, called a JOIN REQUEST. It refreshes the membership information and updates the route as follows. The message broadcasts another node and updates their table entry accordingly. This process constructs or updates the routes from sources to receivers and builds a mesh of nodes, the *forwarding group*. Periodic control packets are sent only when outgoing data packets are still present. When receiving a multicast data packet, a node forwards it only if it is not a duplicate and the setting of the FG Flag for the multicast group has not expired.

Drawbacks

- The main disadvantage of ODMRP is high control overhead while maintaining current forwarder groups and all network request package flooding.
- Another disadvantage is that the same data packet propagates through multiple paths to a destination (duplicate packets), which reduces multicast efficiency. In addition, ODMRP provides non scalable group size.
- Network hosts running ODMRP are required to maintain member table, routing table, forwarding group table and message cache.
- In ODMRP, no explicit control packets are sent to leave the multicast group. In order to ensure the presence of a node JOIN REQUEST packets are needed to send periodically.
- More maintenance cost is required in order to maintain the mesh-based structure.

2.3.2 AMRoute: Ad Hoc Multicasting Routing Protocol

AMRoute [6] creates a multicast shared tree over mesh. It creates a bidirectional shared multicast tree using unicast tunnels to provide connections between multicast group members. Each group has at least one logical core. Each core periodically floods *JREQs* to discover other disjoint mesh segments for the group. Any member, either core or non-core in the mesh segment, can respond to the *JREQ* message to avoid adding many links to a core. . After the mesh has been created, the logical core periodically transmits *TREECREATE* packets to mesh neighbors in order to build a multicast shared tree. Receiving *TREECREATE* from one of its mesh links, it forwards the packet to all other mesh links. If a duplicate *TREECREATE* packet is received, a *TREE CREATE-NAK* is sent back along the incoming link. The nodes wishing to leave the group send the *JNAK* message to the neighbors and do not forward any data packets for the group.

Drawbacks

- AMRoute suffers from loop formation.
- It creates non optimal trees and requires higher overhead to assign a new core.
- AMRoute suffers from a single point of failure of the core node.

2.3.3 DDM Algorithm

Differential Destination Multicast (DDM) [8] is a receiver-initiated multicast routing protocol. It operates in two modes: Soft-State and Stateless. In Stateless mode, source nodes insert the destination address into the field, called the DDM block of the data packet, and unicast it to the next node, using the underlying unicast routing protocol. Every such node that receives the DDM block data packet acquires the address of the following node and unicasts the DDM block data packet. Finally, the data packet reaches its destinations. In soft-state mode, each node along the forwarding path remembers the destination address by sorting it in the forwarding set. Therefore, by caching this information, there is no need to list all the destination addresses in every packet, which is why it is called the Differential Destination Multicast protocol. This protocol is best suited for applications with small multicast groups in a dynamic MANET environment.

Drawbacks

- DDM consumes a significant bandwidth since each destination periodically sends *Join* control packets to the source to show its interest in the multicast session.
- The size of the DDM block data packet becomes larger as the number of receivers increases, which means that it is not extendable.

2.3.4 PAST-DM Algorithm

The PAST-DM algorithm was proposed by C. Gui and P. Mohapatra [4], which is a new overlay multicast protocol for MANET. It uses the frequently updated link states to maintain the virtual mesh and develops a novel *source-based steiner tree* algorithm to construct the upper source-based tree infrastructure. All the member nodes periodically exchange *GroupReq* messages to discover and keep track of the neighbors. The group members can form a dynamic virtual mesh. Each source of the group will construct its own source-based data delivery tree based on its local link table using the *source-based steiner tree* algorithm. If we denote the distance between the source node s and node n as $ds(n)$, then the distance between source node to a virtual link $(n1, n2)$ can be defined as $ds(n1, n2) = min[ds(n1), ds(n2)]$. If $c(n1, n2)$ denotes the cost of virtual link $(n1, n2)$, then the *'adaptive cost'* of this link to the source is given as $ac(n1,n2) = ds(n1,n2).c(n1, n2)$. The source can create its steiner tree by selecting the smallest *'adapted cost'* links. Adaptive cost determines the level of children of the tree.

Drawbacks

- Each member node starts a neighbor discovery process using an expanded ring search (ERS) technique. The maximum radius of the ring is limited to a very small value.
- The link cost calculation may be incorrect since PAST-DM does not explicitly consider node mobility prediction in the computation of the *adaptive cost*.
- The overlay is constructed and maintained even if no source has multicast data to transmit.
- Exchanging link state information with neighbors and the difficulty of preventing different unicast tunnels from sharing the same physical links may affect the efficiency of the protocol.

2.3.5 MANHSI Algorithm

Multicast for Ad hoc Network with hybrid Swarm Intelligence (MANHSI) protocol was proposed by Z. M. Alfawaer, G. Hua, and N. Ahmed [1], which relies on swarm intelligence, based optimization technique to learn and discover efficient multicast connectivity. MANHSI creates a multicast connection among group members by determining a set of forwarding nodes. The protocol exploits a core-based technique where each member joins the group via the core node to establish a connection with the other group members. The core announces its existence to the others by flooding the network with a COREA ANNONCE packet. Other nodes establish initial connectivity by sending a JOIN Request packet. Nodes who receive a JOIN Request addressed to themselves become forwarding nodes. To maintain connectivity and allow new members to join, the core floods CORE ANNOUNC periodically as long as there are more data to be sent.

Drawbacks

- The path between the multicast member and forwarding set to the designated core is not always the shortest.
- The cost associated with each node can represent different measurements, depending on the desired properties of the forwarding set. So cost calculation per node is difficult.
- The maintenance of forwarding sets is more complex.
- More routes exist to reach a single node which causes more traffic overhead.
- It is not robust enough to be used in highly dynamic environment.

2.4 Identification of Problems

We present a survey of the existing multicast routing protocols designed for MANETs.

- DDM [8], ODMRP [9], PAST-DM [4] and MANHSI [1] do not provide the scalability of the multicast group size. They work only when the multicast group size is sufficiently small.
- MANHSI [1], PAST-DM [4], AMRoute [6] suffer from high end-to-end transmission delay.
- The disadvantage of ODMRP [9], MANHSI [1] is high control overhead while maintaining current forwarder groups and all network request package flooding.

A multicast protocol can hardly satisfy all requirements. But in multicast extendibility is a high challenging issue. An efficient protocol for multicast that works well in large group is badly needed. Moreover, proper, and shortest route selection causes less traffic cost and minimum data transmission delay. So, our target is to design an efficient extendable multicast protocol.

Chapter III

Proposed Method

3.1 Details of Problem Specification

The extendibility problems of previously discussed protocols are analyzed. In this section, we have proposed a hierarchical multicast scheme which is extendable if necessary. This protocol is reliable for large group and is a topology-aware approach. The key issue in extendable multicast routing protocol (EMRP) is the optimal route selection, the sub source maintenance, which involves how to optimally partition the multicast group into the sub-groups. In the worst case when the distant members are put into one sub-group, the performance will degrade. Specifically, we cover the following topics:

- Optimal Path Selection Procedure.
- Partitioning procedure of the multicast group so that adjacent cluster of members can form a sub-group. Which node among the nodes in a sub-group is selected as a sub source?
- When a new member joins the group, which sub-group is it assigned to?
- An optimal partitioning conducted long ago may not represent the current network topology. How to dynamically adjust the partitioning?

The answers to all these topics are described in the next section.

3.2 Proposed Method: Extendable Multicast Routing Protocol (EMRP) in MANET

(a) Optimal Route Selection Procedure

A node *S* initiates route discovery when it has data to send to *n* but it has no available route. Node *S* floods the network with a *RREQ* (Route Request message) for *n*. When *n* receives a *RREQ*, it sends back a *RREPL* (route reply message) to *i* through some nodes that are a subset of the direct acyclic graph rooted at *S*. Every *RREQ* from *S* to *n* has a *REQP* (request priority) field, which is initialized to a positive constant by the source and decremented by one every time the message is retransmitted. When *REQP* field will be zero, the message is not be retransmitted. The first time *i* receives a *RREQ* from *S* to *n*, it initializes $MAXREQP_{ni}^{S}$ to $REQP$ and HOP_{ni}^{S} to the previous hop of the message. Every time *i* receives a request with $REQP <= MAXREQP_{ni}^{S}$ it includes the previous hop of the message inHOP_{ni}^{S} . If *i* receives a request with $REQP > MAXREQP_{ni}^{S}$ (meaning the request traversed a shorter path from *S* to this node), it resets $MAXREQP_{ni}^{S}$ to *REQP* and HOP_{ni}^{S} to the previous hop of the message. The set HOP_{ni}^{S} contains the identifiers of nodes that can receive a corresponding *RREPL* from *i*, if *i* sends one. When a destination node *n* receives a *RREQ*, it immediately sends back a *RREPL* if *REQP*>$MAXREQP_{ni}^{S}$. Every *RREPL* explicitly specifies the set of nodes *HOP* that can accept it. The destination node *n* initializes this field to the previous hop of the *RREQ*, effectively indicating that the *RREPL* is only intended for this node. Every *RREPL* also has a hop count field *HOPC* initialized to zero by the destination. A node *i* processes a *RREPL* if *i* Є *HOP*. Node *i* then accepts the route in *RREPL* if *HOPC* < *DEST* (distance to the destination). Thus, the source node *S* selects the route as well as collects the node list.

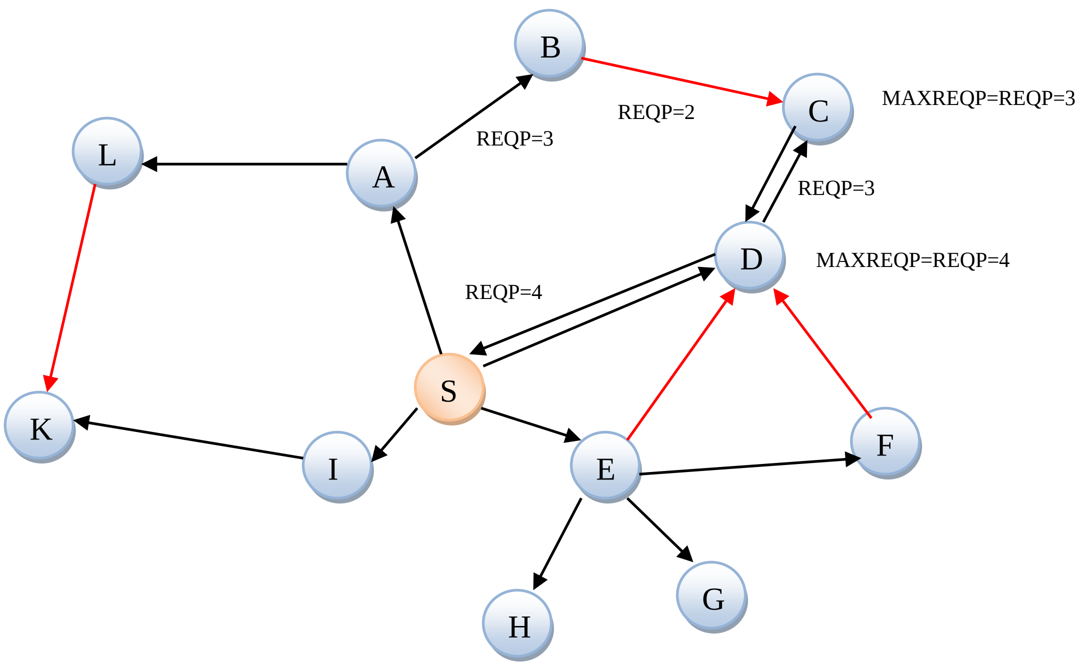

Fig 3.1: **Route Selection Mechanism**

In above figure source S transmits RREQ with REQP=4.Node D initializes MAXREQP by 4. When D retransmits the RREQ, REQP is decremented by 1. Node C gets RREQ from node D and B. But discards the B's RREQ as $REQP_D$>$REQP_B$. Red arrow indicates that the request is discarded.

(b) Sub-Source Selection Technique

The source node, denoted as S, has a list of nodes. In order to build the multicast hierarchy following the current network topology, node S generates a HREQ message. The message contains the information about the format of the partition. The most important information is the expected size of each subgroup, which is equal to or less than the number containing the REQP field. It is notable that REQP must be greater than a TRESOLD value and less than a MAX value. This message is delivered to all group members using the routing mechanism discussed earlier. Here the cost of the message delivery is mainly proportional to the group size. When a member node, denoted as r_s, receives the packet carrying this HREQ message, the header of the packet contains a list of members, to which node r_s is responsible for forwarding the packet. We can view it as the subtree in the multicast tree rooted at node r_s. Further, this member list is the result of the forwarding process from S to r_s, representing the most current topology information. If the cardinality of this list matches the intended sub-group size indicated in the HREQ message, node r_s becomes a candidate for sub-source. To become a sub-source, node r_s unicasts back to node S a HREPL message. It contains the node r_s's sub-group node list. Node S need to wait for a period to collect the HREPL messages from the member nodes that request to be sub-source candidates. S then partitions the whole member list based on the collected HREPLs. The partition calculation transforms the group member list GRLST into the form $\{GL_{ss}1,\ GL_{ss}2,\ \ldots\ldots\ldots\ldots..,\ GL_{ss}k\}$, in which $GL_{ss}k$ represents the k-th sub-group list. We denote the root of $GL_{ss}k$ *as* $RT_{sg}k$. For all the newly selected sub-source, S need to unicast to $RT_{sg}k$ an SRT_ENSURE message, carrying the subgroup member list $GL_{ss}k$. By receiving this message, $RT_{sg}k$ recognizes that it succeeds as a sub-source, and record $GL_{ss}k$ as its subgroup member list.

(c) Sub-Source Maintenance Procedure

When a sub-source dies, the entire sub-group can no longer receive data packets from the source. In order to recover this situation, the source S sends periodically a LIVE message onto a data packet at the upper layer multicast. By receiving this LIVE message, each sub-source needs to reply with a LIVE ON message. Thus, the source node can check each sub-source if the LIVE ON has arrived within a defined time. When a sub-source is identified as not functioning, the source S assigns the first node of the sub source's list as new sub root and sends the remaining nodes to the newly selected sub source as sub source listGL_{ss}

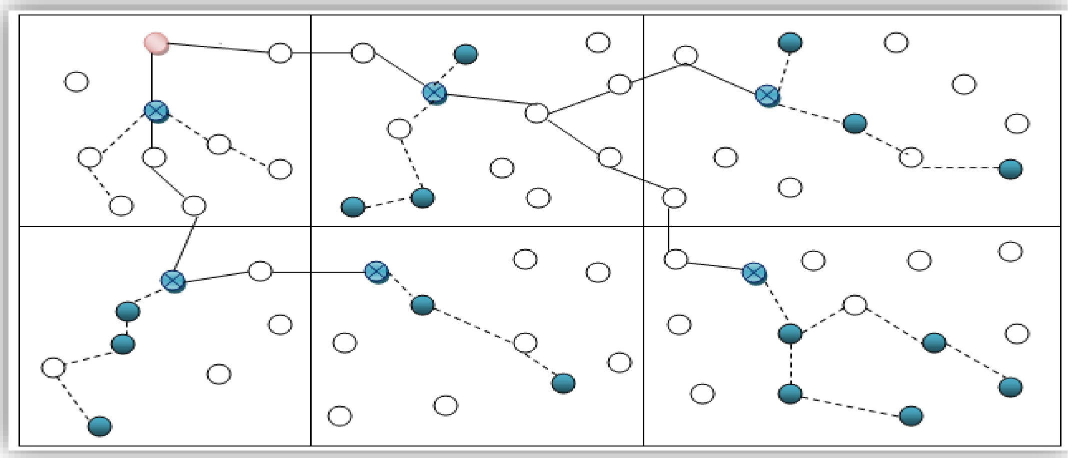

Fig 3.2: **Extendable multicast trees. Colored nodes are group members. Nodes are selected as sub sources for the domains. The solid lines form the upper-level multicast tree with node as the Source. Dotted lines are branches of the lower-level multicast trees.**

(d) Join and Leave Policy

When a new member wants to join the multicast group it unicasts a join request message to the source node. However, in order to optimally assign a subgroup for a new member to join, EMRP needs to extend this join process. When a node *n* needs to join a subgroup, it first unicasts a join request JREQ message to the source node S. According to the status of a group partition process, node S will respond a JREQ differently. If the partitioning process has finished, S will reply to node n a JSUB_SOURCE message to tell it to start finding a sub-root for itself. Otherwise, if the partitioning has not finished yet, and S still has a flat member list, S will refrain from responding. In this case, node n may try sending JREQ to S several times as if the packet is lost. When partitioning is done, node n will get a JSUB respond. When node n receives JSUB message, it starts finding its sub-group by broadcasting a SS_REQ message with a limiting time *t*. The message is flooded in the local space around node n, with a scope up to *t* hops away. Node n can start with a small timing value and gradually increase it. A sub-root $RT_{sg}k$ receiving this SS_REQ message will not forward the message, but reply to a SS_REPL message to n. When node n receives the SS_REPL, it can infer its hop distance from the sending sub-root from the unicast routing information. Node n needs to wait for a period collecting SS_REPL messages. Finally, node n can select the nearest responding sub-root, and join its sub-group by replying to a SS_ACCEPT message. For a sub-root, when its SS_LEAVE message reaches the source node, the source needs treated it as a die node and re-assign the sub-root role to the fist node of the list in the same sub-group. This is the same procedure mentioned in the sub-root maintenance part.

(e) Node Switching Control among Sub-groups

Some members of a sub-group may move far away and close to the members of another sub-group. A group member node n, of sub-group $GL_{ss}1$ could be forwarding packets for another sub-group$GL_{ss}2$. Node *n* can utilize this chance to decide if it is better to switch sub-group. Whenever node n receives or forwards a data packet, it can query from the unicast routing information to infer its current hop distance to the sub-source sending the packet. Let $HOPD_i1$ and $HOPD_i2$ denote node n's hop distances to the sub-source of $GL_{ss}1$ and $GL_{ss}2$ respectively. If $HOPD_i1 > HOPD_i2$ and their difference exceed a threshold value, node n will decide that it is better to switch to $GL_{ss}2$. In order to switch, node n needs to unicast SS_REQ message to$RT_{sg}2$, sub-source of $GL_{ss}2$. When it receives the confirming SS_REPL message from $RT_{sg}2$, node n can further unicast SS_ LEAVE message to $RT_{sg}1$. Both $RT_{sg}1$ and $RT_{sg}2$ will need to update its sub-group member list accordingly during this switch process. Note that once the partitioning is finished, the source node only takes care of the upper layer multicast. As long as the member list and the sub-rooting do not change, the source node does not need to know this switching procedure.

Chapter IV

Experimental Result and Analysis

4.1 Introduction

Development of a multicast routing protocol is successful when it can give better performance than the previously developed protocol related to this field. Our protocol is implemented using network simulator ns-2 (ns-2.33). The experiment is performed on open-source operating system-LINUX. Experiments have shown interesting and improved results in terms of packet delivery ratio, transmission delay and control bytes transmitted per data byte delivered.

4.2 Simulation Configuration

Our simulation network has 200 mobile nodes randomly roaming within a 2000m × 2000m free space. Each node has used the channel with channel capacity 4 Mbits/sec. Each simulation run lasts for 100 simulation seconds. One multicast group with a single source is simulated. We have used IEEE 802.11 Distributed Coordinate Function (DCF) as the MAC layer protocol. The interface queue is a 50-packet drop-tail priority queue. The size of data payload is 1024 bytes. Members join the multicast group at the start of the simulation and remain as members either throughout the simulation or can join another multicast group. Random waypoint is used as the mobility model.

4.3 Performance Factors

The metrics used for performance evaluations of proposed protocol with the competing multicast protocols are as follow:

- **Packet delivery ratio as a function of mobility speed:** The number of data packet delivered to multicast receivers over the number of data packets supposed to be delivered to multicast receivers varying the node mobility speed. If the total transmitted packet is P_t and total received packet is P_r then packet transmission ratio (in percentage)

$$R_{mobility\ speed} = \frac{received\ packet\ (P_r)}{transmitted\ packet(\ P_t)} \times 100\ \%$$

- **Packet delivery ratio as a function of group size (node number):** The number of data packet delivered to multicast receivers over the number of data packets supposed to be delivered to multicast receivers varying the number of nodes in a multicast group. If the total transmitted packet is P_t and total received packet is P_r then packet transmission ratio (in percentage)

$$\boldsymbol{R_{node\ number} = \frac{received\ packet\ (P_r)}{transmitted\ packet(\ P_t)} \times 100\ \%}$$

- **End to end delay:** The delay for every packet delivered. If the packet (P_n) transmission time is T_t and the packet received time is T_r (where $T_r > T_t$) then transmission delay is defined as

$$\boldsymbol{D_{pause\ time} = received\ time\ (T_r)\ -\ transmission\ time\ (T_t)}$$

- **Number of control bytes transmitted per data byte delivered**: Instead of using a pure control overhead, we choose to use a ratio of control bytes transmitted to data byte delivered to investigate how efficiently control packets are utilized in delivering data. In addition to bytes of control packets (e.g., JOIN REQUESTS, JOIN TABLES), bytes of data packet headers are included in calculating control bytes transmitted. Accordingly, only bytes of the data payload contribute to the data bytes delivered.

4.4 Performance Analysis using Experimental Results

We have considered MANHSI, PAST-DM, DDM and ODMRP in our experiments in order to justify our proposed technique. Here we have analyzed the results into different sections such as packet delivery ratio, end-to-end delay. In calculating packet delivery ratio, we have considered two criteria a. mobility speed and b. group size. We have also tested the efficient join and leave policy of a member node in the network. A member node always remains under that group which is closer than other.

Now we provide the experimental results of packet delivery ratio varying the mobility speed and multicast group size in comparison to the protocol named MANHSI [1].

Table 1: Packet Delivery Ratio as a Function of Mobility Speed.

Mobility Speed(m/sec)	MANHSI			Proposed Protocol (EMRP)		
	Sending Packets	Receiving Packets	Delivery Ratio (%)	Sending Packets	Receiving Packets	Delivery Ratio (%)
0	2432	2411	99.1365	2457	2441	99.3488
5	2429	2392	98.4767	2456	2423	98.6965
10	2429	2343	96.4594	2453	2415	98.4509
15	2423	2259	93.2315	2453	2409	98.2063
20	2421	2179	90.4172	2449	2395	97.7450
25	2418	2107	87.1381	2449	2387	97.4286
30	2418	2031	83.9950	2448	2370	96.8137
35	2417	1942	80.3475	2448	2354	96.1601
40	2417	1918	79.3545	2448	2353	96.1184

Table 2: Packet Delivery Ratio as a Function of Node Numbers in a Multicast Group.

Group Size (Node Numbers)	MANHSI			Proposed Protocol (EMRP)		
	Sending Packets	Receiving Packets	Delivery Ratio (%)	Sending Packets	Receiving Packets	Delivery Ratio (%)
5	4267	4241	99.3906	3978	3961	99.5726
10	2733	2682	98.1339	1652	2612	98.4917
15	2454	2355	95.9657	2522	2471	97.9778
20	2421	2189	90.4172	2449	2395	97.7950
25	2209	1943	87.9583	2407	2328	96.7180
30	2185	1803	82.5171	2371	2282	96.2463
35	2047	1581	77.2349	2347	2239	95.3984
40	1985	1463	73.7027	2303	2164	93.9643
45	1907	1334	69.9528	2287	2140	93.5723
50	1843	1146	62.1812	2233	2081	93.1930

4.4.1 Packet Delivery Ratio

In this experiment, each mobile node stays stationary for 10 seconds and starts moving to a selected location with a random speed uniformly distributed over 0 m/sec to 40 m/sec. 20 nodes are configured as multicast members of the same group and 1 source having 4 sub-sources transmits packets to the member nodes.

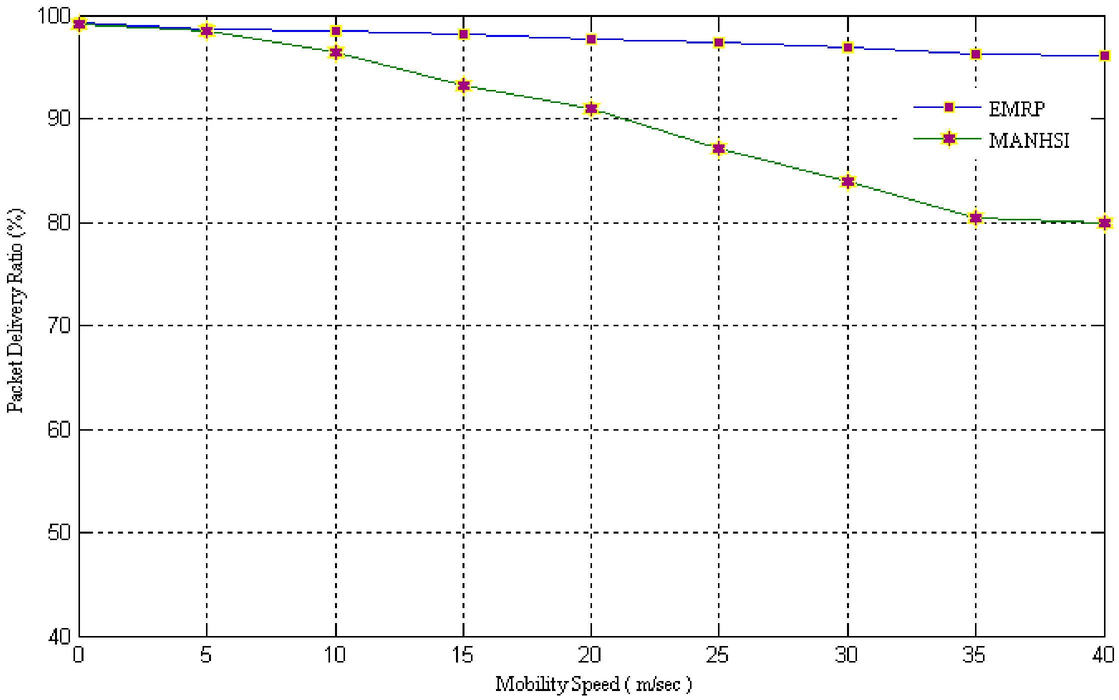

Fig. 4.1: Packet Delivery Ratio as a Function of Mobility Speed.

Fig. 4.2 depicts packets delivery ratio of the two protocols under different mobility speed [0-40 m/sec] with a constant group size. The packet delivery ratio of Extendable Multicast Routing Protocol (EMRP) is better than the MANHSI [1] when mobility speed increases. Data transmission in MANHSI mainly depends on the forwarding set and in high-speed environment the paths break randomly. Moreover, when data packets are forwarded several times, it attenuates the signal. As a result, the probability of packet lost increases. In EMRP sub-sources are responsible to retransmit the data packets to the intended receiver and slightly depends on forwarding set as the average path length between main source to sub-source and sub-source to intend receiver becomes less than MANHSI.

Fig. 4.3 represents packets delivery ratio of the two protocols under different node number [0-40 nodes] of a multicast group with a constant speed. The packet delivery ratio of Extendable Multicast Routing Protocol (EMRP) is better than the MANHSI [1] when

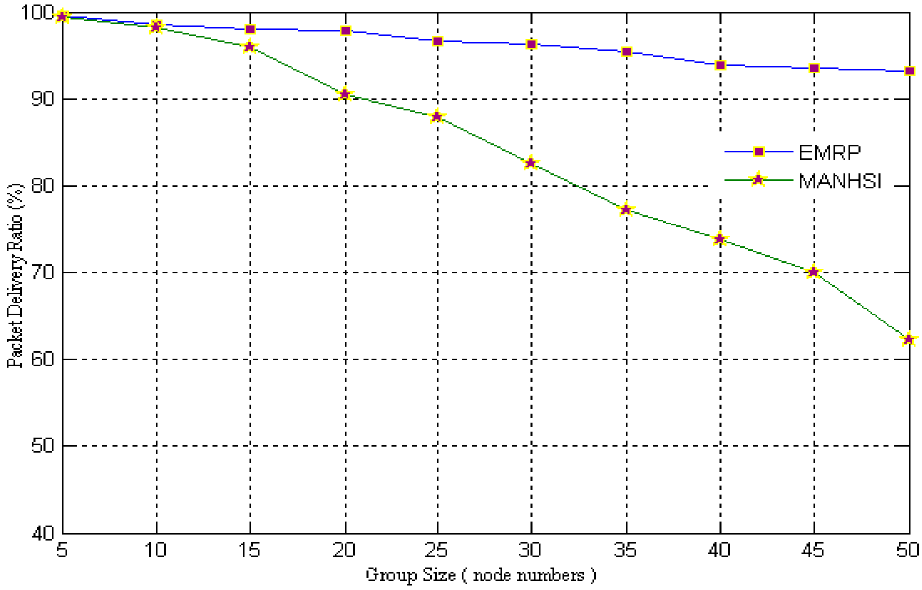

Fig. 4.2: Packet Delivery Ratio as a Function of Node Numbers in a Multicast Group.

node number increases. MANHSI does not provide scalable group size rather it provides constant group size. When group size becomes large the path length between the source and receiver becomes large. The signal weakens and lost before reaching the intended receiver. In EMRP subsources reduce this problem significantly and maintain the packet delivery ratio in an acceptance level. When group size becomes more than 20 the delivery ratio falls significantly in MANHSI.

4.4.2 End-to-End Delay

Fig. 4.3 shows the end-to-end delay of the two protocols (MANHSI and EMRP) under different pause time (sec) considering constant speed and multicast group size. The presence of more paths from source to receiver creates path confusion and significantly increases the end-to-end delay. MANHSI creates more paths to send a data packet to an intended receiver. Moreover, when multicast group size increases, MANHSI depends on a large number of forwarding nodes as well as a large number of packet retransmission which weakens the signals. EMRP depends on a few numbers of forwarding nodes and significantly reduce data packets retransmission. When new routes are established or existing routes are broken, the end-to-end delay increases a little but most of the time delay remains constant and in an acceptance level. But in high-speed environment, it grows higher in MANHSI.

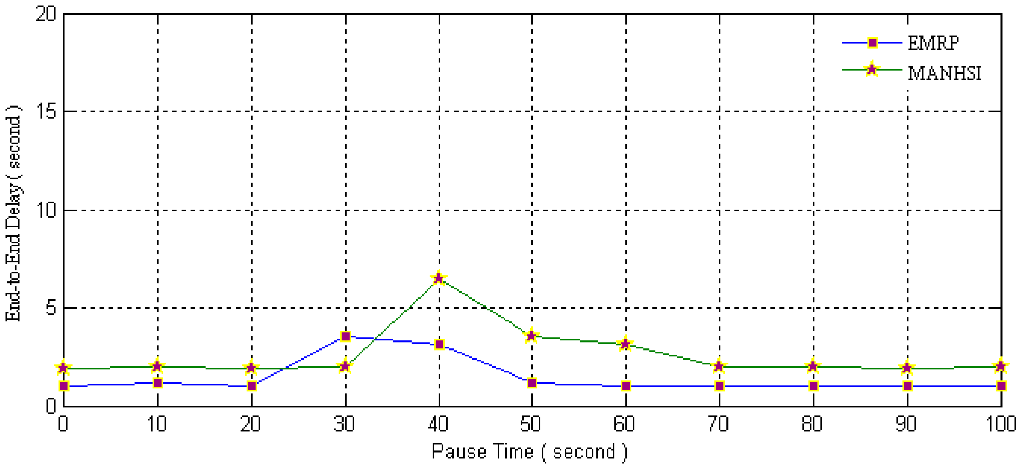

Fig. 4.3: End-to-End Delay.

Chapter V

Conclusion and Recommendation

5.1 Conclusion

We present an extendable multicast routing protocol (EMRP) aiming at solving the scalability issues of multicast group. We propose domain-based approach for hierarchical multicast tree construction. The domain-based method uses the topological vicinity of nodes to form different levels of hierarchy. At each level different nodes are configured as sub-sources in order to communicate with the neighbor nodes. By keeping the group size small at each of the levels, efficient small group multicasting protocol could be adopted.

We presented a detailed performance evaluation of the proposed extendable multicast routing technique. The simulation results have demonstrated the performance benefits, packet transmission ratio, enhanced scalability, and low transmission delay (since the tree quality is only moderately hampered when periodic update behaviors are conducted) with the proposed technique. A comparative study of variations of our techniques is also presented and the relative merits of these techniques for different mobility and size of MANETs are analyzed.

5.2 Limitation

Though tree-based technique is more reliable and robust than mesh-based technique, tree maintenance cost is relatively high. This protocol deals with the environment where a multicast group contains only one source.

5.3 Recommendation

For the future work, we identify the need to develop a light-weighted but reliable multicast protocol for large group. It can be applied to the upper-level multicast in the routing hierarchy to achieve better reliability in packet delivery.

References

[1] Z. M. Alfawaer, G.W. Hua and N. Ahmed, "A *Novel Multicast Routing Protocol for Mobile Ad Hoc Networks"*, American Journal of Applied Sciences 4 (5), pp. 333-338, 2007.

[2] Z. Liu and B. Gupta, "*A Modified Shared-tree Multicast Routing Protocol in Ad Hoc Networks*", Journal of Computing and Information Technology-CIT 13, vol. 3, pp. 177-193, 2005.

[3] M. F. Sjaugi, M. Othman and M. Fadlee, A. Rasid, "*A New Distance Based Route Maintenance Strategy for Dynamic Source Routing Protocol*", Journal of Computer Science 4(3), pp. 172-180, 2008.

[4] C. Gui and P. Mohapatra, "*Efficient Overlay Multicast for Mobile Ad Hoc Networks"*, Proc. IEEE WCNC, vol. 2, pp. 1118-1123, 2003.

[5] G. Pei, M. Gerla and T. W. Chen, "*Fisheye State Routing: A Routing Scheme for Ah Hoc Wireless Networks*", In Proceedings of IEEE/ICC'00, June 2000.

[6] J. Xie, M Liu, "*AMRoute: Ad Hoc Multicast Routing Protocol*", Mobile Networks and Applications, vol. 7, pp. 429-439, 2002.

[7] R. Vaishampavan and R. V. Department, "*Efficient and Robust Multicast Routing in Mobile Ad Hoc Networks*", In Proceedings of IEEE international conference on mobile ad-hoc and sensor, 2004.

[8] J. Lusheng and M. S Corson, *"Differential Destination Multicast: A MANET Multicast Routing Protocol for Small Groups"*, INFOCOM, vol. 2, pp 1192-1201, 2001.

[9] S. J. Lee, W. Su and M Gerla, "*On Demand Multicast Routing Protocol*", ACM, vol. 7, pp. 441-153, 2002.

[10] S. Mueller, R. Tsang and D. Ghosal, "*Multipath Routing in Mobile Ad Hoc Networks; Issue and Challenges,"* in performance tools and applications to networked systems, vol. 2965 of LNCS, pp. 209-234, 2004.

[11] J. Sun, "*Mobile Ad Hoc Networking; An Essential Technology for Pervasive Computing,* " proceeding of international conference on info-tech and info-net, vol. 3, pp. 316-321, 2001.

[12] O. Badarneh, M. Kadoch, "*Multicast Routing Protocols in Mobile Ad Hoc Networks: A Comparative Survey and Taxonomy,*"This research was supported by grant from NSERC, 2008.

Appendix

Accepted Paper in the 13th International Conference on Computer and Information Technology (ICCIT 2010), 23-25 December 2010, Dhaka, Bangladesh

A New Approach of Extendable Multicast Routing Protocol in Mobile Ad Hoc Networks

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Abstract

Multicasting is a challenging task that facilitates group communication among the nodes using the most efficient strategy to deliver the messages over each link of the network. In spite of significant research achievements in recent years, efficient and extendable multicast routing in Mobile Ad Hoc Networks (MANETs) is still a difficult issue. To enhance performance and to enable scalability we have proposed a domain-based Extendable Multicast Routing Protocol (EMRP) for hierarchical multicasting in MANET environments. In the proposed technique, each domain has a sub-source that reduces the path length between the original source and intended receiver which solute the scalability issue. We have analyzed the performance with respect to a variety of parameters for different mobility speed and group sizes. Results obtained through simulations demonstrate enhanced performance in packet delivery ratio and end-to-end delay of the proposed technique as compared to the existing ones.

Keywords: Domain Based Multicasting, Extendable Multicasting, Hierarchical Routing, Mobile Ad Hoc Networks, Tree Based Protocol.

I. INTRODUCTION

An ad hoc network is a collection of wireless mobile hosts forming a temporary network without the aid of any stand-alone infrastructure or centralized administration. Routing in mobile ad hoc network is a critical task due to the fact that the structure of the network changes dynamically and communication links may be broken because of the mobility of network hosts. Mobility, potentially in case of very large number of mobile nodes and limited resources (e.g. bandwidth, power) make routing in ad hoc networks extremely challenging [5]. Thus multicast support is a critical and a desirable feature of ad hoc networks [4].

Many multicast routing protocols have been proposed for mobile ad hoc networks addressing different challenging issues and some remarkable achievements have been reported [1], [4], [6], [8], [9]. Among the MANET multicast protocols, AMRoute [6] and PAST-DM [4] are overlay multicast protocols that constrain the protocol state within the group members. In overlay multicast protocol, only a selected subset of nodes form a virtual infrastructure and maintain it even if no source has multicast data to transmit. DDM [8] is a stateless multicasting protocol which does not maintain any protocol state at the forwarding nodes but it consumes a significant bandwidth. The size of the DDM block becomes larger as the number of receiver increases. ODMRP [9] proposed by Lee, Gerla and Chiang performs better in dynamic MANET environment but greatly suffers from scalability issue when the network size increases. MANHSI [1] relies on a swarm intelligence based technique and depends on a large number of forwarding sets. More routes exist to reach a single node and its performance degrades when the multicast group size increases.

To overcome the above problems we have proposed a domain based multicasting scheme aiming at solving the extendibility issue. Our proposed technique efficiently divides a large multicast group into sub-groups called domain. Each domain has a sub-source which acts as a source for that domain and maintains protocol state. Original source communicates only with the sub-sources that depend on a very small number of forwarding nodes and sub-sources communicate with the receivers. Thus by keeping each domain small it facilitates reduced path length between the sub-sources and receiver nodes.

The rest of the paper is organized as follows: In section II, we discuss our proposed multicast routing protocol in details. The result of performance and comparative studies are presented in section III. Finally the concluding remarks are presented in section IV.

II. PROPOSED METHOD

This section describes the proposed hierarchical multicast scheme which is reliable for large group and is a topology-aware approach. The key issues of our technique are the optimal route selection for transmitting data packets and sub-source maintenance which involves how to optimally partition the multicast group into the sub-groups.

A. Proposed Algorithm

The proposed algorithm of our multicast scheme is described below:

1. Source S initiates route selection procedure and collects node information.
2. if $(node\ number > MaxNode)$ then

   Partition the group members into k subgroups having the form $\{GL_{ss}1, GL_{ss}2, \ldots\ldots, GL_{ss}k\}$

   // k represents the total number of sub-groups and $GL_{ss}k$ represents the $k\text{-}th$ sub-group list.

   else

   a. S passes data packet to its member list.

   b. go to step 6.

3. Assign the role of sub-source to $S_s i$ for i-th sub-group $[i = 1,2,3, \ldots \ldots \ldots, k]$
4. A particular node m is under the group list $GL_{ss} i$
   for $j = 1$ to k (where $j \neq i$) do
   if(($Distance\ (m, S_s i) - Distance(m, S_s j)$) > $ThresholdValue$) then
      a. Node m leaves from sub-group $GL_{ss} i$
      b. Node m joins into sub-group $GL_{ss} j$
5. S passes data packet to sub-sources and sub-sources pass data packet to its member list.
6. End

B. Description of the Proposed Method

B.1 Optimal Route Selection Procedure

A source node *S* initiates route discovery process when it has data to send but it has no available route. Node *S* floods the network with a *RREQ* (Route Request) message for a node *n* within the network. When *n* receives a *RREQ*, it sends back a *RREPL* (Route Reply) message to *S* through some intermediate nodes *i* that are a subset of the direct acyclic graph rooted at *S*. Every *RREQ* from *S* to *n* has a *REQP* (Request Priority) field, which is initialized to a positive constant by the source

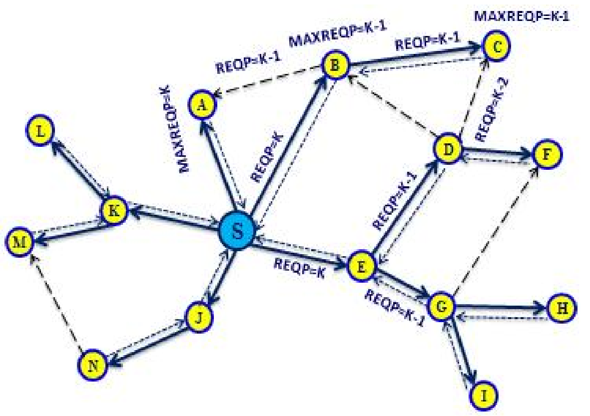

Fig. 1. Route Selection Mechanism.

and decremented by one every time the message is retransmitted. When *REQP* field will be zero, the message will not be retransmitted. It is notable that *REQP* must be greater than a *THRESOLD* (The minimum value of *REQP* field) value and less than a *MAX* (The maximum value of *REQP* field) value. The first time any node *n* receives a *RREQ* message from *S* via *i*, it initializes its $MAXREQP_{ni}^{s}$ field to *REQP* and HOP_{ni}^{s} field to the previous hop of the message. Every time *n* receives a request with $REQP > MAXREQP_{ni}^{s}$ (i.e. the request traversed a shortest path from *S* to this node), it resets $MAXREQP_{ni}^{s}$ to $REQP$ and HOP_{ni}^{s} to the previous hop of the message. When a destination node receives a *RREQ*, it immediately sends back a *RREPL* to *S*. Every *RREPL* explicitly specifies the set of nodes *NODE_SET* that can accept *RREPL* message. The destination node initializes the *NODE_SET* field to the previous hop of the *RREQ*, effectively indicating that the *RREPL* is only intended for this node. Every *RREPL* also has a hop count field *HOPC* initialized to zero by the destination. A node *i* process a *RREPL* if $i \in$ *NODE_SET*. Node *i* accepts the route in *RREPL* if *HOPC* < *DEST* (distance to the destination). Thus the source node *S* selects the route as well as collects the node list.

In the Fig. 1, source *S* transmits *RREQ* with $REQP = k$. Node B initializes *MAXREQP* by the value k. When B retransmits the *RREQ*, *REQP* is decremented by 1. Node C gets *RREQ* from node B and D with *REQP* $(k-1)$ and $(k-2)$. C discards the D's *RREQ* as $REQP_B > REQP_D$. Dashed black arrows indicate the non-optimal path, so these requests are discarded. Dotted arrows indicate the established optimal path.

B.2 Sub-Source Selection Technique

At the beginning, the main-source S_m, has a list of nodes. If $node\ number > MaxNode$, S_m generates *HREQ* message in order to build multicast hierarchy following the current network topology. The message contains the information of the expected size of each subgroup. This message is delivered to all group members using the routing mechanism discussed earlier. Here the cost of message delivery is mainly proportional to the group size. When a member node, denoted as S_s receives the packets carrying this *HREQ* message, the header of the packet contains a list of members to which node S_s is responsible for transmitting the packet. We can view it as the sub-tree in the multicast tree rooted at node S_s. If the cardinality of this list matches the intended sub-group size indicated in the *HREQ* message, node S_s becomes a candidate for sub-source. To become a sub-source, node S_s unicasts back to node S_m a *HREPL* message. Node S_m needs to wait for a period to collect the *HREPL* massages from all the member nodes that request to be sub-source candidates. S_m then partitions the whole member list based on the collected *HREPLs*. The partition calculation transforms the group member list into the form $\{GL_{ss}1, GL_{ss}2, \ldots \ldots \ldots \ldots \ldots, GL_{ss}k\}$, in which $GL_{ss}k$ represents the k-th sub-group list. We denote the root of $GL_{ss}k$ by $SS_{sg}k$.For all the newly selected sub-source, S_m needs to unicast to $SS_{sg}k$ a *SS_ENSURE* message, carrying the sub-group member list $GL_{ss}k$. By receiving this message, $SS_{sg}k$ recognizes that it succeeds as a sub-source and record $GL_{ss}k$ as its sub-group member list.

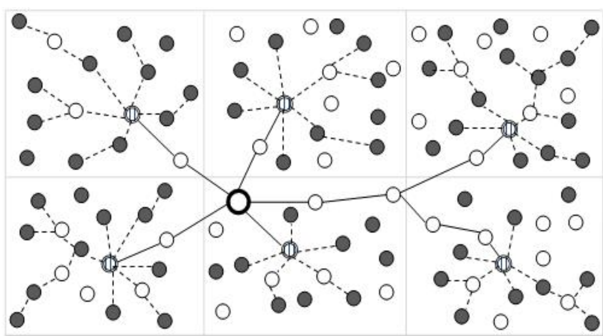

Fig. 2. Hierarchical Multicast Tree.

Fig. 2 represents the two level hierarchical multicast tree. Solid bold lines represent the upper level multicast which is responsible to maintain the communication between main source and sub-sources. Dotted lines represent the lower level multicast which is responsible to maintain the communication between sub-sources and intended receivers. Each rectangle represents a domain that contains a sub-source.

- Represents Main-Source
- Represents Sub-Source
- Represents Receiver Node
- Represents Forwarding Node

B.3 Sub-Source Maintenance Procedure

When a sub-source dies, the entire sub-group can no longer receive data packets from the source. In order to recover from this situation the main-source S_m sends periodically a *LIVE* message onto a data packet at the upper layer multicast. By receiving this *LIVE* message, each sub-source needs to reply with a *LIVE_ON* message. Thus the source node can check each sub-source if the *LIVE_ON* has arrived within a pre-defined time. When a sub-source is identified as not functioning, the main-source S_m assigns the role of sub-source to the first node of that sub-source's node list. Before assigning the role, S_m ensures that the selected node is able to transmit data packets to the remaining nodes of the node list. Then S_m sends the nodes to the newly selected sub-source as its node list. Otherwise the role is assigned to the second node and so on.

B.4 Join and Leave Policy

When a new member wants to join the multicast group it unicasts a join request message, *JREQ* to the source node. The source node S_m replies the node *n* according to the status of the group partitioning process. If the partitioning has not finished yet and S_m still has a flat member list, it includes the node to the list and replies it. When partitioning has been done, S_m sends a *JSUB* message to tell it to start finding a sub-source for itself. When node *n* receives *JSUB* message, it starts finding its sub-group by broadcasting a sub-source request message, *SS_REQ* with a limiting time *t*. Node *n* can start with a small time value and gradually increase it. A sub-source $SS_{sg}\,k$ receiving this *SS_REQ* message will not forward the message but reply a *SS_REPL* message to *n*. When node *n* receives the *SS_REPL* it can infer the hop distance from the sub-source by the help of unicast routing information. Node *n* needs to wait for a period to collect all the *SS_REPL* messages. Finally, node *n* can select the nearest responding sub-source and join its sub-group by replying a *SS_ACCEPT* message. The sub-source sends this node information to the original source. For a sub-source, when its *SS_LEAVE* message reaches to the source node, the source treats it as a die node and re-assigns the sub-source role. When a member node sends *LEAVE* message to the sub-source, all its information are deleted by the sub-source as well as the main source after waiting some period.

B.5 Node Switching Control among Sub-Group

Some members of a sub-group may move far away and close to the members of another sub-group. Whenever a member node n of sub-group $GL_{ss}\,i$ receives or forwards a data packet, it can query from the routing information to infer its current hop distance to all the sub-sources. Node *n* can utilize this chance to decide if it is better to switch to another sub-group. Let $HOPD_n i$ and $HOPD_n j$ (j=1,2,…....,k and i ≠ j) denote the hop distances from the i-th and remaining one's respectively and $ThreasoldValue$ denotes a predefined distance. If $(HOPD_n\, i - HOPD_n j) > ThreasoldValue$ node n will decide that it is better to join to $GL_{ss}\, j$. In order to switch, node n needs to unicast a $LEAVE$ message to $SS_{sg}\, i$ and a *JSUB* message to $SS_{sg} j$. Both $SS_{sg} i$ and $SS_{sg} j$ need to update its sub-group member list. Note that once the partitioning is finished, the source node only takes care of the upper layer multicast. As long as the member list and the sub-sourcing do not change, the source node does not need to know this switching procedure.

III. EXPERIMENTAL RESULTS AND PERFORMANCE EVALUATION

Now we present the simulation results and evaluate the performance through the comparative studies between the proposed technique and MANHSI [1]. To simulate the techniques we have used the network simulator ns-2 (ns-2.33). Experiments have shown improved results in terms of packet delivery ratio and data transmission delay.

A. Simulation Configuration

Our simulation network has 400 mobile nodes randomly roaming within 2000m × 2000m free space. The radio transmission range of each node is 250 meters. Each node has used the channel capacity 4 Mbits/sec. Each simulation run lasts for 100 simulation seconds. In this experiment, each mobile node stays stationary for 10 seconds and starts moving to a selected location with a random speed uniformly distributed over 0 m/sec to 40 m/sec. For the multicast session, we have chosen the group size [10-100] nodes. We have used IEEE 802.11 Distributed Coordinate Function (DCF) at the MAC layer protocol. The interface queue is a 50 packets drop-tail priority queue. The size of data payload is 1024 bytes. In our simulation, the member nodes join the multicast group at the start of the simulation and remain as members either throughout the simulation or can join another multicast group. Random waypoint is used as the mobility model.

B. Performance Factors

The metrics used for performance evaluations of the proposed protocol with the competing multicast protocol are as follow:

- **Packet Delivery Ratio:** The number of data packets delivered to multicast receivers over the number of data packets supposed to be delivered to multicast receivers. It can be defined as

$$R = \frac{received\ packet\ (P_r)}{transmitted\ packet(\ P_t)} \times 100\ \%$$

• **End-to-End Delay:** The delay for every packet delivered. If the packet transmitted at time T_t and received at time T_r (where $T_r > T_t$) then transmission delay is defined as

$$D_{pause\ time} = received\ time\ (T_r) \text{ - } transmission\ time\ (T_t)$$

C. Performance Analysis using Experimental Results

We have considered MANHSI [1] in our experiments in order to justify our proposed technique. In calculating packet delivery ratio we have considered two criteria a. mobility speed and b. group size. We have also tested the efficient join and leave policy of a member node in the network. A member node always remains under that group which is closer than other.

C.1 Packet Delivery Ratio

Fig. 3 depicts packets delivery ratio of the two protocols under different mobility speed [0-40 m/sec] with a constant group size. The packet delivery ratio of Extendable Multicast Routing Protocol (EMRP) is better than the MANHSI [1] when mobility speed increases. Data transmission in MANHSI [1] mainly depends on a large number of forwarding nodes and in high speed MANET environment the paths break randomly. Moreover when data packets are forwarded several times it attenuates the signal. As a result, the probability of packet loss increases in MANHSI [1]. In EMRP sub-sources are responsible to retransmit the data packets to the intended receiver and slightly depend on forwarding set as the average path length between main source to sub-source and sub-source to intend receiver becomes less than MANHSI [1].

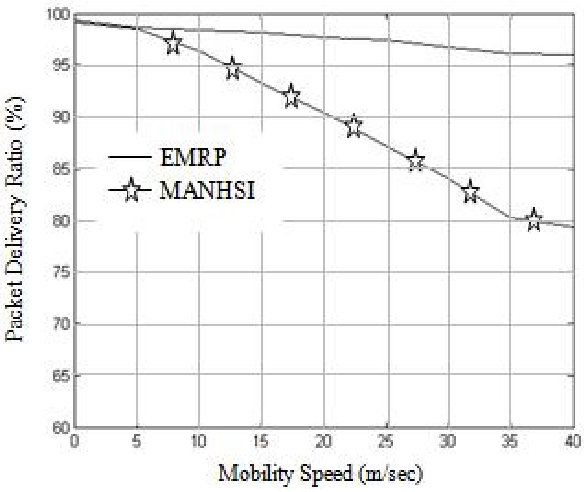

Fig. 3. Packet Delivery Ratio as a Function of Mobility Speed.

Fig. 4 represents packets delivery ratio of the two protocols under different node number [10-100] nodes of a multicast group with a constant speed. The packet delivery ratio of Extendable Multicast Routing Protocol (EMRP) is better than the MANHSI [1] when node number increases.

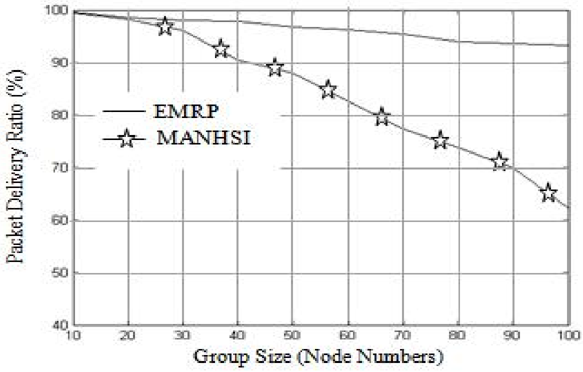

Fig. 4. Packet Delivery Ratio as a Function of Node Numbers in a Multicast Group.

MANHSI [1] does not provide scalable group size rather it provides constant group size. When group size becomes large the path length between the source and receiver becomes large. The signal weakens and lost before reaching the intended receiver. In EMRP sub-sources reduce the path length significantly and maintain the packet delivery ratio in an acceptance level. When group size becomes more than 20 the delivery ratio falls significantly in MANHSI [1].

C.2 End-to-End Delay

Fig. 5 shows the end-to-end delay of the two protocols, MANHSI [1] and EMRP, under different pause time (in second) considering constant speed and equal group size (30nodes and 50 nodes). The presence of more paths

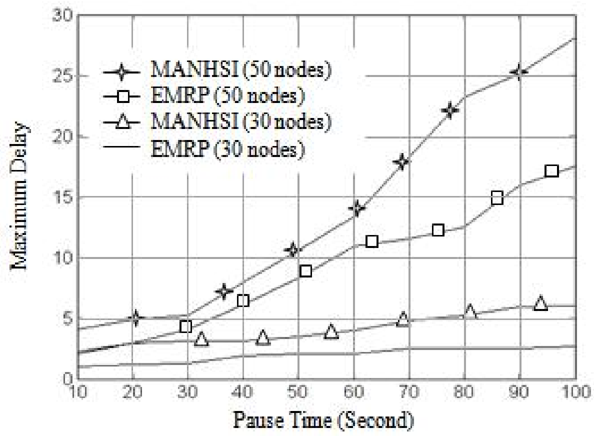

Fig. 5. End-to End Delay.

from source to receiver creates path confusion and significantly increases the end-to-end delay. MANHSI [1] creates more paths to send a data packet to an intended receiver. Moreover when a multicast group size increases, MANHSI [1] depends on a large number of forwarding nodes as well as a large number of packet retransmission which weakens the signals. EMRP depends on a few number of forwarding nodes and significantly reduce data packets retransmission. When new routes are established or existing routes are broken, the end-to-end delay increases a little but most of the time delay remains constant and in an acceptable level.

IV. CONCLUSION

In this paper, we present an extendable domain-based multicast routing protocol (EMRP) aiming at solving the extendibility issues of multicast group. The domain-based method uses the topological vicinity of nodes to form different levels of hierarchy. At each level different nodes are configured as sub-sources in order to communicate with the neighboring nodes. By keeping the group size small, efficient small group multicasting protocol could be adopted. The comparative study of our techniques shows the improved results as compared to existing ones.

Multicast tree is more reliable and robust than mesh based technique but its maintenance cost is relatively high. So we identify the need to develop a light-weighted but reliable multicast protocol for large group which can handle more than one source in a single multicast group.

REFERENCES

[1] Z. M. Alfawaer, G.W. Hua and N. Ahmed, "A Novel Multicast Routing Protocol for Mobile Ad Hoc Networks", *American Journal of Applied Sciences*, vol. 4(5), 2007, pp. 333-338.

[2] Z. Liu and B. Gupta, "A Modified Shared-Tree Multicast Routing Protocol in Ad Hoc Networks", *Journal of Computing and Information Technology-CIT*, vol. 13(3), 2005, pp. 177-194.

[3] M. F. Sjaugi, M. Othman, M. Fadlee and A. Rasid, "A New Distance Based Route Maintenance Strategy for Dynamic Source Routing Protocol", *Journal of Computer Science*, vol. 4(3), 2008, pp. 172-180.

[4] C. Gui and P. Mohapatra, "Efficient Overlay Multicast for Mobile Ad Hoc Networks", *In Proceedings of IEEE WCNC*, vol. 2, 2003, pp. 1118-1123.

[5] G. Pei, M. Gerla and T. W. Chen, "Fisheye State Routing: A Routing Scheme for Ad Hoc Wireless Networks", *In Proceedings of ICC*, 2000, pp.70-74.

[6] J. Xie and M Liu, "AMRoute: Ad Hoc Multicast Routing Protocol", *Journal of Mobile Networks and Applications*, vol. 7, 2002, pp. 429-439.

[7] R. Vaishampavan and J.J. Garcia, "Efficient and Robust Multicast Routing in Mobile Ad Hoc Networks", *In Proceedings of IEEE International Conference on Mobile Ad Hoc and Sensor Systems*,2004, pp. 304-313.

[8] J. Lusheng and M. S. Corson, "Differential Destination Multicast: A MANET Multicast Routing Protocol for Small Groups", *In Proceedings of IEEE INFOCOM*, vol. 2, 2001, pp. 1192-1202.

[9] S. J. Lee, M. Gerla and C.C. Chiang, "On Demand Multicast Routing Protocol", *In Proceedings of IEEE WCNC*, 1999, pp. 1298-1302.

[10] S. Mueller, R. Tsang and D. Ghosal, "Multipath Routing in Mobile Ad Hoc Networks: Issues and Challenges", *Performance Tools and Applications to Networked Systems*, vol. 2965 of LNCS, 2004, pp. 209-234.

[11] J. Sun, "Mobile Ad Hoc Networking; An Essential Technology for Pervasive Computing", *In Proceeding of International Conference on Info-Tech and Info-Net*, 2001, pp. 316-321.

[12] O. Badarneh and M. Kadoch, "Multicast Routing Protocols in Mobile Ad Hoc Networks: A Comparative Survey and Taxonomy", *EURASIP Journal on Wireless Communications and Networking*, vol. 209, 2009, pp. 42.