Hierarchical Multicast Protocol for Multicasting over Mobile Ad Hoc Networks

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Abstract - In mobile ad hoc networks, an application scenario requires mostly collaborative mobility behavior. The key problem of those applications is scalability with regard to the number of multicast members as well as the number of the multicast group. To enhance efficiency and scalability with group mobility, we have proposed a multicast protocol based on a new framework for hierarchical multicasting that is suitable for the group mobility model in MANET. The key design goal of this protocol is to solve the problem of reflecting the node’s mobility in the overlay multicast tree, the efficient data delivery within the sub-group with group mobility support, and the scalability problem for the large multicast group size. The results obtained through simulations show that our approach supports scalability and efficient data transmission utilizing the characteristic of group mobility.

Keywords— Mobile ad hoc network, Group Mobility, Scalability.

1. Introduction

An application uses a multicasting and broadcasting for sending the data to more than one node, because it is more cost-effective than unicast. A mobile ad hoc network (MANET) is a wireless network in which nodes can communicate without infrastructure. Each node operates as a router to forward data. The design of the multicast scheme in MANET is more complex because of the dynamic change in the network topology and the limited bandwidth availability.

Many applications require group-based communications among mobile nodes. Examples include conference seminar sessions, conventional events, disaster relief operations, and battlefield training. To support these applications, many research projects have been studied for group communication in MANET. One of the characteristics of these applications is that the nodes are divided into several sub-groups. That is, nodes that have the same mission achieve it by moving together in the same direction at a fixed distance. For those mobile ad hoc network applications, the mobile ad hoc network requires effective and efficient support for group communications with group mobility using multi-hop and one-to-many nature. [1] introduced an efficient and scalable multicast protocol called the Multicast-Enabled Landmark Ad hoc Routing Protocol (M-LANMAR). M-LANMAR uses LANMAR [2] as the unicast routing protocol to support the group mobility model. It has an advantage in that the multicast protocol can use the unicast protocol’s factors, but M-LANMAR also has the following drawbacks. M-LANMAR uses the proactive mode causing relatively more control overhead in cases where data transmission is paused or where the number of multicast members is lower. It uses inefficient simple scoped flooding for data transmission to the members within the group. In addition, each group receives data directly from the multicast source.

In order to achieve the multicasting with the group mobility, easy deployment, scalability, and low control overhead, a new hierarchical multicasting approach is required. Recent protocols have adopted overlay,
location-based, stateless, hierarchy approaches. Multicast protocols [3] require multicast member and non-member nodes to participate in multicast operations, which increase control and data transmission overhead. But, it is possible to participate in environments where some nodes do not support multicast operations. In such situations, an application-layer multicast protocol [4] can be deployed easily; it is also flexible and easy to implement. The application-layer multicast monitors only group dynamics, while the underlying unicast protocols track network dynamics, resulting in more stable protocol operation and low control overhead even in a highly dynamic environment [5]. But, the movement of physical nodes cannot affect the update action of the overlay multicast tree because there is no multicast event such as join or leave. A few application-layer multicast protocols such as LGT have tried to solve the transmission overhead resulting from the mismatch between the physical plane and the virtual plane. Also, stateless multicast routing for small groups is proposed to eliminate an overhead of creating and maintaining the delivery tree. [6] has proposed two classes of hierarchical multicasting approaches to enhance performance and enable scalability. In [6], the first approach, domain-based hierarchical routing, divides a large multicast group into sub-groups, each with a node assigned as a sub-root. The second approach, overlay-driven hierarchical routing, uses the overlay multicast as the upper layer multicast protocol, and stateless small group multicasts as the lower layer multicast protocol.

In this paper, we propose another approach that is suitable for the group mobility model. We have developed a new multicast routing protocol based on another framework for hierarchical multicasting [6] in MANET. A variety of techniques are adopted for effective multicasting to support group mobility. Our approach, that of overlay group-based hierarchical routing, has a static mission group (MG) which moves to the same directional point at a predefined distance among the mission group members (MGM). It uses an LGD-like overlay multicast among the mission group leaders (MGL) as the upper layer multicast protocol, and the stateless small group multicast or a various flood methods as the lower layer multicast protocol.

### 2. Group Mobility Model

In the ad-hoc network applications scenarios, the mobile nodes show collaborative mobility behavior. A group mobility model can generate such a collaborative mobility behavior. Some researchers have proposed several group mobility models [7][8], for the purpose of simulating an ad-hoc network with group motion. The Reference Point Group Mobility (RPGM) [7] model is a more general group mobility model. Mobile hosts are organized by groups according to their logical relationships. The center’s motion defines the entire group’s motion behavior, including location, speed, direction, acceleration, and so forth. Usually, nodes are uniformly distributed within the geographic scope of a group. The reference point scheme allows independent random motion behavior for each node, in addition to the group motion.

The Reference Velocity Group Mobility (RVGM) [8] model extends the RPGM model by proposing a velocity representation of the mobility groups and the mobile nodes. Each mobility group has a characteristic group velocity. The member nodes in the group have velocities that are close to the characteristic group velocity, although they deviate slightly from it. The Reference Region Group Mobility (RRGM) [9] model uses a reference region. A reference region defines an area towards which nodes will move, and once they are within the region, the nodes will move around within that region while waiting for other nodes to arrive. The locations of a reference region define the intermediate points where a group will move along its way to the destination. The reference region moves gradually towards the destination with its path.

### 3. Multicast Routing Protocol

Multicast routing which adopts a clustering scheme has been studied for a long time. Several multicast protocols have been proposed for the ad hoc networks. The Multicast routing protocol based on Zone Routing (MZR) [10] is a source-initiated on-demand protocol. It uses the zone routing mechanism to create and maintain multicast trees. A proactive protocol runs inside each zone to maintain an up-to-date zone routing table. The node constructs a zone around itself with a pre-configured zone radius. The protocol reaction to the changes in topology is localized to a zone. Only the nodes within the given zone are affected. As the zone’s radius is smaller, the cost of learning the zones’ topologies is higher. The Hierarchical DDM (HDDM) [6] adopts a topology-aware approach. The problem of HDDM is how to partition the multicast group into sub-groups. Within each sub-group, a sub-root is selected. Because the number of members enveloped in the packet header is significantly reduced, this scheme solves the scalability problem of basic DDM. However, the sub-groups are frequently changed according to the movement of the nodes.
The Hierarchical region-based Overlay Multicast Architecture (HOMA) [11] uses GPS and a geographical static region. HOMA solves the scalability problem for the large-sized multicast group by dividing the total multicast tree into a region-based global overlay multicast tree for the whole network. The drawback of HOMA is that multicast operations are inefficient when several nodes move to another region together. M-LANMAR [1] uses LANMAR [2] as the unicast routing protocol to support the group mobility model. The drawback of M-LANMAR is that the LANMAR protocol itself is not used generally in a mobile ad hoc network, but it has the advantage that the multicast protocol can use the factors of the unicast protocol just as it is because the unicast protocol supports group mobility. It aggregates unicast routing table updates and multicast routing maintenance. Thus, it maintains a low multicast protocol overhead because it uses the aggregated unicast routing tables. Because the group membership and multicast routes of M-LANMAR are regularly updated, it achieves constant control overhead regardless of the number of members and multicast groups. In cases where there is no M-LANMAR data transmission or where the number of the multicast group's numbers is few, it has control overhead constantly.


We propose an HMMP (Hierarchical Mission groupbased Multicast Protocol) in this paper. The key design goal of HMMP is to solve the problem of reflecting the node’s mobility in the overlay multicast tree, the efficient data delivery in the sub-group with group mobility, and the scalability problem for the large multicast group size. In Fig. 1, HMMP is based on two-tiered multicast routing architectures, which can divide the total multicast tree into a stateless overlay multicast tree (OMT) composed of mission group leaders and a mission group-based multicast tree (MMT) within the mission group. The mainly assumed conditions are that all nodes use GPS, and that any node which wants to be a multicast group member has to send a joint request message with the unicast to the multicast source or leader of the mission groups.

The multicast source divides the multicast group leaders into sub-groups according to the direction, inserts a list of other leader’s information in the same direction into the header of the packet, and sends the packet to the nearest leader in each direction. If the leader receives the packet, it delivers the packet to all multicast members within the mission group through the intra-domain multicast protocol. Each mission group leader recursively performs the above process using the node information in the header of the packet. Multicast membership is maintained by the multicast tree between the source and the leader of the mission group with a Join/Leave packet and a location report packet. Each member of the mission group sends a Join/Leave packet and a location report packet to the leader of the mission group.

4.1. Overlay Multicast Protocol

The OMT can be constructed with the leader of the mission groups. It can logically reduce the number of multicast member nodes through the hierarchical structure. So, it became easy to compose OMT by applying a suitable, stateless, multicast protocol to a small-sized group. The stateless overlay multicast protocol can eliminate large overhead due to the dynamic network topology, decrease an overhead of creating and maintaining the delivery tree and remove the routing overhead of the non-member nodes. [12] suggests that the overlay multicast is an effective, efficient and practical solution for group communication in MANET using the Location-Guided Tree (LGT) [8], because [12] concluded that LGD has the best balance between bandwidth cost, distribution delay and computational complexity among all the LGT algorithms. We also applied an LGD algorithm to construct an OMT in the upper layer multicast protocol.

In OMP, multicast data is encapsulated in a unicast packet. It is only transmitted to the leaders of the mission groups. A list of leader addresses and geometric locations is explicitly included in the header of the multicast packet to minimize the overall bandwidth cost of the multicast tree. OMP uses only the geometric location information of the leaders of the
mission groups. So, OMT does not need to know the global network topology. The transmission of the data packet can be conducted by an underlying unicast routing protocol such as AODV, because [12] discovered that LGD performs better when location information is not accurate. The leader of the mission groups reports a new geometric location only when the current location passes by the predefined boundary from the previous reported location. Such a policy reduces the number of control packets without degrading OMT. The multicast source divides the multicast member nodes into 4 sub-groups according to 4 directions, establishes the nearest node in each direction by the child node, inserts a list of other nodes’ addresses and locations in the same direction into the header of the data packet, and sends the packet to the child node of each direction. Each child node recursively performs the above process with the node information in the header of the data packet. This process stops when a data packet has an empty destination list. Here, OMP selects four as the number of direction because of its convenience regarding directional decisions and the simulation results of [12]. To reduce computational overhead, the leader caches the previously computed tree.

4.2. Group Membership Join

The multicast joining process can be divided into two steps: global and local joining. When a multicast source wants to generate a multicast group, it broadcasts an advertisement message to the whole network with its physical location information and multicast group ID. All nodes in the network learn who the source of the multicast group is. The mission group members with the same mission select a mission group leader and sub-leader. All of the mission group members memorize the leader and sub-leader’s address of their mission group. If the request to join is the first from the mission group to a multicast group, the leader of the mission group sends a request to join packet to the source of the multicast group. The mission group’s leader maintains a multicast group member list within the mission group, and learns about the location information of the multicast group members. In the event that the leader gives up his role, the sub-leader becomes the leader of the mission group. Thus, the leader sends the multicast group member list information to the sub-leader periodically. For the up-to-date membership, the multicast source uses the location report as the multicast membership refreshments to detect the blind leave node. The leader of the mission group also uses the above process. This process reduces the control message for the multicast membership.

4.3. Group Membership Leave

The multicast leaving process can be divided into two steps: global and local leaving. If a member of the mission group wants to leave the multicast group, it sends a request to leave packet to the leader of the mission group. When the leader receives a request to leave packet from the member of the mission group, it checks the multicast group member list. If the multicast member list is empty, it sends a request to leave packet to the multicast source. There is no leave reply packet in the multicast leaving process. The node sending a request to leave packet must stop in order to send the location report message to the leader or multicast source. Then, the leader or multicast source which does not receive a leave message will exclude the node from the multicast member list after a certain period of time.

4.4. Multicast Tree Maintenance

It is common that groups can be overlapped if they meet each other while moving according to the group mobility. One group can be divided into several groups. But here, in the proposed multicast architecture, the characteristic of the nodes performing the task allocated to the group does not need to consider a merge or a split between groups because one group can only be divided into several temporarily, and two groups can meet for a short time. If the leader of the mission group dies, none of the mission group members can receive data from the multicast source. So, the sub-leader of the mission group checks if the HELLO message has arrived within a threshold of latency. If the sub-leader does not receive a HELLO message within a certain period of time, it assigns itself as the leader of the mission group, advertises this fact to the members of the mission group, and sends a change of leader request message to the multicast source.

5. Conclusion

In this paper, we developed a scalable multicast protocol with group mobility support in the mobile ad hoc network to improve the performance and protocol efficiency. A new protocol, known as HMMP, constructs a pre-defined mission group with group mobility and a stateless overlay multicast tree among mission group leaders to reduce the routing overhead. Through the simulation experiments, we demonstrated that HMMP performs well with regard to the packet
delivery ratio, the packet latency, the control and data forwarding overhead, and the scalability for the number of groups with group mobility. Within the mission group with group mobility, we propose using the overlay broadcast scheme and counter-based 1-hop scheme rather than the multicast and common broadcasting methods. HMMP is based on overlay group-based hierarchical routing, which is suitable for the group mobility model in MANET. It uses the LGD-like stateless overlay multicast as the upper layer multicast protocol, and the counter-based 1-hop virtual flooding as the lower layer multicast protocol.

References


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