NAMP: Neighbor Aware Multicast Routing Protocol for Mobile Ad Hoc Networks

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Abstract: *A Mobile Ad Hoc Network (MANET) represents a system of wireless mobile nodes that can freely and dynamically self-organize into arbitrary and temporary network topologies without the presence of any fixed communication infrastructure. Reliable routing and robustness of the network are two important issues for MANETs. In this paper we propose Neighbour Aware Multicast Routings Protocol (NAMP), which is a tree based, hybrid multicast routing protocol for ad hoc networks. Our routing protocol aims at achieving robustness in the ad hoc networks as well as the improvement of the end-to-end delivery of data packets. For route creation, the protocol uses neighboring information and dominant pruning approach. It uses secondary forwarder method for route maintenance.*

Keywords: *Ad hoc networks, dominant pruning, secondary forwarder list, multicasting, NAMP.*

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1. Introduction

With the recent proliferation of mobile computers like laptops and palmtops the idea of ad hoc networking is gaining popularity day by day. Ad hoc networks are self-organizing, dynamic topology networks formed by a collection of mobile nodes through radio links. Minimal configuration, absence of infrastructure and quick deployment make them convenient for emergency situations like armed conflicts, earthquakes, cyclones or any other natural or human induced disasters. Since host mobility causes frequent and unpredictable topological changes, the formation and maintenance of ad hoc networks is a nontrivial task and different from the conventional wired networks.

As ad hoc networks do not make use of any router for routing mechanism, every host plays the role of a router. When a host tries to communicate with other host(s), the host(s) in between the source and the destination(s) should be involved to make the connection.

This paper presents a new tree-based multicast routing protocol which aims at achieving robustness as well as reliable data packet delivery in the ad hoc networks. It reduces the control overhead and the end-to-end delay by using the neighborhood information and dominant pruning [1] flooding method.

As ad hoc networks are often envisioned to be deployed in the critical environments (e.g., emergency situations like disaster situation, military reconnaissance scenario), robustness is one of the paramount concerns [2]. For ensuring robustness our protocol maintains a secondary forwarder list (SFL) at the time of creating the tree structure.

The rest of the paper is organized as follows. Section 2 presents the related works, Section 3 presents the details of NAMP, and Section 4 points out some future works and Section 5 concludes the paper.

2. Related Work

Many routing protocols have been proposed for ad hoc networks. They can be broadly classified into two major categories namely, proactive routing protocols and reactive routing protocols. Proactive protocols continuously learn the topology of the network by exchanging topological information among the network nodes. Thus, when there is a need for a route to a destination, such route information is available immediately. DSDV [3], WRP [4], DBF [5], etc. are some of the proactive routing protocols.

The main concern regarding using a proactive routing protocol is; if the network topology changes too frequently, the cost of maintaining the network might be very high. Moreover, if the network activity is low, the information about the actual topology might even not be used and the investment of limited transmission and computing resources in maintaining the topology is lost. The reactive routing protocols on the other hand, are based on some sort of "query-reply" dialog. Reactive protocols proceed for establishing route(s) to the destination only when the need arises or on demand basis. DSR [6], AODV [7], ABR [8], RDMAR [9] etc. are the examples of reactive protocols.

In the recent days several hybrid protocols are also proposed. A hybrid protocol is a combination of both the reactive and proactive protocols. It includes some of the characteristics of reactive protocols and some of the characteristics of proactive protocols. Example of a hybrid protocol is TORA [10]. In addition to the unicast routing protocols, several multicast routing protocols have been also proposed like ODMRP [11], MAODV [12], CAMP [13] etc. The multicast routing protocols for ad hoc networks can be classified into two categories: tree-based and mesh-based protocol. Mesh-based routing protocols use several routes to reach a destination while the tree-based protocols maintain only one path. Tree-based protocols ensure less end-to-end delay in comparison with the mesh-based protocols.

Besides all of these, in the recent times, some geocast routing protocols are proposed which aim to send messages to some or all the wireless nodes within a particular geographic region [14]. LBM [15], GeoTORA [16], voronoi-diagrams-based routing protocols [17] etc. are some of them. Our proposed protocol NAMP is a tree based, hybrid multicast routing protocol that has proactive nature for collecting neighbor information but a route is created from a sender to a destination based on demand (reactive nature).

3. A New Multicast Routing Protocol

3.1. Overview of NAMP

NAMP is an efficient tree-based multicast routing protocol which also includes the neighboring concept. The routes are built and maintained using the traditional request and reply messages. A hard state approach is used for multicast group maintenance.

NAMP uses neighbor information of two-hops away for transmitting the packets to the receiver(s). If the receiver(s) is not within this range, then it searches the receiver(s) using dominant pruning flooding method and forms the multicast group using the replies along the reverse path. Although the mesh structure is known to be more robust against topological changes, the tree structure is better in terms of packet transmission. NAMP targets to achieve less end-to-end delay of packets by using a tree structure and it uses the secondary forwarder list method for robustness.

3.2. Neighbor Awareness in NAMP

Each node v_i keeps the information of all of its neighbors of one-hop distance in a neighbor table. A node periodically transmits HELLO packet (containing its own neighbor table information) to all of its neighbors. If there is already an existing neighbor node v_j, it gets the HELLO packet of v_i, in which its v_j own ID is included. Consequently, node v_i also gets the HELLO packet from node v_j that is, the neighboring information of node v_j. If a neighbor node v_j moves out of the range of node v_i, NAMP uses a soft-state approach (e.g., a time out value is assigned to each entry of the neighbor table) to detect the topological change. If a node comes within the neighbor range of another node for the first time, it gets the HELLO packet of that node and finds that its own ID is missing but as it is now within the neighbor range, it informs about its presence by sending a HELLO_REP packet and eventually the neighbor table of each node is updated.

3.3. Multicast Tree Creation

When a source wants to send a data packet, it initializes a FLOOD_REQ packet with data payload attached. This packet is flooded throughout the network based on dominant Pruning method. We first state the dominant pruning approach and then show how it is used in NAMP. Dominant pruning approach extends the range of neighborhood information into two-hop apart nodes. This two-hop neighborhood knowledge can be obtained by exchanging the adjacent node lists with neighbors. In dominant pruning, the sender node selects adjacent nodes that should relay the packet to complete broadcast. The IDs of selected adjacent nodes are recoded in the packet as a forward list. An adjacent node that is requested to relay the packet again determines the forward list. This process is iterated until broadcast is completed.

In Figure 1 and throughout the paper, *N (v)* implies the set of adjacent nodes of node *v* while *N (N (v))* is the set of nodes at most two-hops apart from node *v*. Both sets include the node *v* itself.

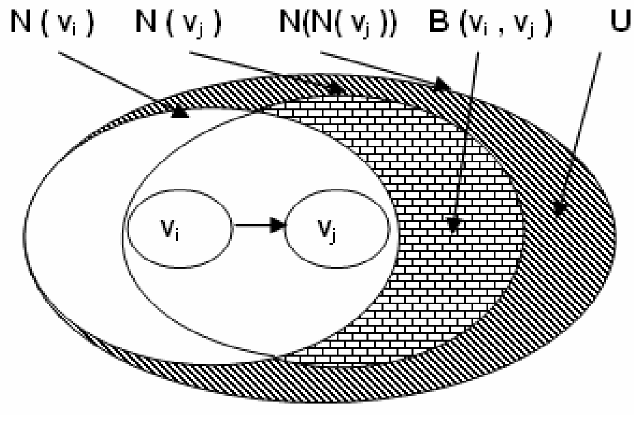

Figure 1. Dominant pruning method.

Let us examine how each node determines the forward list. Suppose, node v_j receives a packet from v_i and v_j is in the forward list. Node v_j should determine its own forward list so that all nodes within two-hop distance from v_j receive the packet. The forward list should be minimized to decrease the number of transmissions. Among nodes in $N(N(v_j))$, v_i, v_j, $N(v_i)$ have already received the packet, and $N(v_j)$ will receive the packet when v_j forwards the packet.

Therefore, a node v_j determines its forward list so that all nodes in $U = N(N(v_j)) - N(v_i) - N(v_j)$ receive the packet 1. Figure 1 shows the set U. Let $B(v_i, v_j) = N(v_j) - N(v_i)$. Then a set of $\subseteq$ nodes $F = \{f_1, f_2, \dots f_m\}$ $B(v_i, v_j)$ is selected such that $\cup_{f_i \in F} (N(f_i) \cap U) = U$.

Finding a minimum F is the set cover problem which is NP-complete [18]. Thus, approximation algorithms are used to determine the forward list. Dominant pruning flooding uses greedy set cover algorithm [19]. The algorithm which finds the set F is as follows:

Let $F = 0$, $K = \{S_1, S2 \dots S_n\}$ *where,* $S_k = N(v_k) \cap U (I \leq k \leq n)$, $Z = 0$
Find the set S_k *whose size is maximal in a set K.*
$F = FU \{v_k\}$, $Z = ZU\, S_k$, $K = K - \{S_k\}$, $S_t = S_t - S_k$ *for all* $S_t \in K$
If $Z = U$*, complete the algorithm*
Otherwise, repeat from 2 again.

This algorithm repeats selecting v_k in which the number of neighbor nodes that is not covered yet is maximum. It has been proved that, this approximation algorithm has the approximation ratio of ($ln\ |U| + 1$) [19].

Let us explain dominant pruning with an example shown in Figure 2. In the figure, node 4 is the source node. Blind flooding needs eight packets forwarding because all the nodes that receive the packet should forward the packet.

Now, consider the dominant pruning method. Node 4 should determine the forward list among the neighboring nodes. In the example, $N(N(4)) = \{1, 2, 3, 4, 5, 6, 7, 8\}$. Among these nodes, $N(4) = \{1, 2, 3, 4, 5, 7\}$ receives the packet directly from node 4. We should determine the forward list such that $N(N(4)) - N(4) = \{6, 8\}$ are covered.

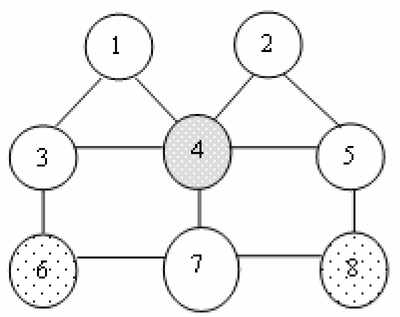

Figure 2. An example scenario.

The optimal forward list would be {7}. Based on the same method, we can determine the forward list of node 7 to be 0. Consequently, only two nodes 4, 7 need to forward the packet in order that all the nodes get the packet [1].

When the destination node(s) gets the FLOOD_REQ packet it sends a REPLY packet to the source backtracking the path through which it has received the FLOOD_REQ packet. The backward knowledge is obtained by using the following technique. When the source sends the FLOOD_REQ packet to the destination(s) each intermediate node between the source and destination(s) updates the source address field of the FLOOD_REQ packet with its own address but before that it caches the content of the source address field of the packet which is actually the upstream node address. So, the FLOOD_REQ packet always contains only one address as the source address which is changed at each hop. Thus, this backward information is used to send the REPLY packet back to the originator of the FLOOD_REQ packet. The REPLY packet eventually reaches the original source node creating the multicast tree. So, the multicast tree of a group contains the originator, destination(s) and the nodes in between them. The nodes that are involved in transmitting packets from the source to the destination(s) are called the forwarding nodes. They are not necessarily the members of the same multicast group.

3.4. Multicast Tree Maintenance

Maintaining a multicast tree is an important task. As any node can be drifted off from its current position at any time in ad hoc network, the routing protocol should also have the mechanism for maintaining the multicast tree.

In this regard, NAMP uses the secondary forwarder list scheme. In dominant pruning approach, only those nodes are selected for forwarding the FLOOD_REQ packet, which could be used to flood the packet throughout the whole network with minimum effort. It actually makes an efficient flooding of the FLOOD_REQ packet. Now, to form the Secondary Forwarder List (SFL) for each node along a route, the one-hop neighbor nodes those are also the neighbors (one-hop distance) of the next forwarder node are selected. Each node forming the multicast tree keeps its own SFL and also sends its own SFL to the selected next forwarder along that particular route. The selected forwarder node makes the nodes in that particular SFL know about the next selected forwarder node (e.g., the selected forwarder after it along the route). In this way, some neighbor nodes get the knowledge about which node to connect, if there is any link failure.

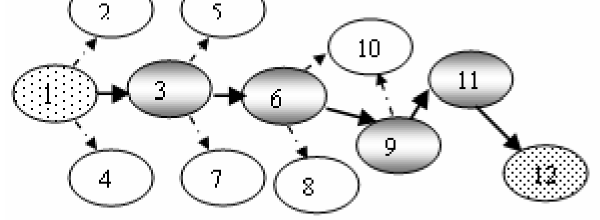

Figure 3. Formation of SFL.

Let us explain the formation of SFL with an example. Figure 3 shows how the secondary forwarder list is created. In this figure, node 1 is the source and node 12 is the destination. The selected forwarders in this route are {3, 6, 9, 11}. Each of these nodes and the source keep the SFLs. The SFL of node 1 contains 2 and 4, SFL of node 3 contains 5 and 7, SFL of node

6 contains 8 and 10, SFL of node 9 contains 10 and the node 11 does not have any secondary forwarder node in its SFL. Now, node 1 sends its own SFL to node 3 and node 3 in turn informs the nodes in the SFL of node 1 about the node 6. So, 2 and 4 gets the information that, node 6 should be communicated if node 3 fails. Likewise, node 6 informs nodes 5 and 7 about node 9; node 9 informs 8 and 10 about node 11 and finally node 11 informs node 10 about the node 12.

Every forwarder node as well as the source can detect any link failure if it finds no information of the downstream node in its neighbor table within a certain interval. If any link failure is detected within the multicast tree, the upstream forwarder of the failed link tries to find out the destination(s) through the nodes in its SFL. As the SFL nodes for that upstream node knows about the next-next forwarder, any of the SFL nodes is selected as a new forwarder to take the place of the failed forwarder. This newly selected forwarder tries to communicate with the known (what it knows previously) next forwarder node to keep the previously established route to reach the destination or for the repairing process.

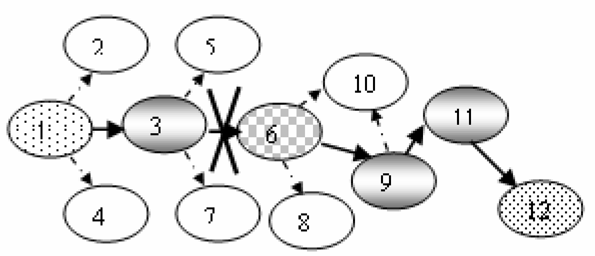

Figure 4. Failure of a link.

If these approaches fail to recover the link, NAMP uses the previously described method for route creation. Let us explain the link failure recovery process with an example. Suppose, in our previous example in Figure 3, link between 3 and 6 failed as the node 6 failed accidentally. The situation is shown in Figure 4. In this case, node 3 tries to find out the destination through its SFL nodes. In our example, node 3 checks its own SFL to randomly select a new forwarder which could be used for repairing the link. We see that, the SFL nodes of node 3; node 5 and node 7 knows about the node 9. This information could be enough to repair and keep the previously established link. Eventually, node 7 and node 8 could be used in our case to reach node 9. The neighboring information from node 8 helps for the repairing process. The resulting route is shown here in Figure 5.

3.5. Joining and Leaving a Group

As ad hoc networks support high mobility, any node(s) can leave or join a multicast group at any time. For handling the departure of a multicast group member two approaches are applicable: *Soft-state approach* and *Hard-state approach*. In the *Soft-state approach* the multicast group membership and associated routes are refreshed periodically. But, in the *Hard-state approach*, when a node wants to leave the multicast group, it informs all the group members about its departure.

In case of NAMP, by sending the REPLY packet a node joins the multicast group. The leaving of a node is maintained by using a hard state approach; that is the node floods a LEAVE packet to all of its group members and the route is reconfigured.

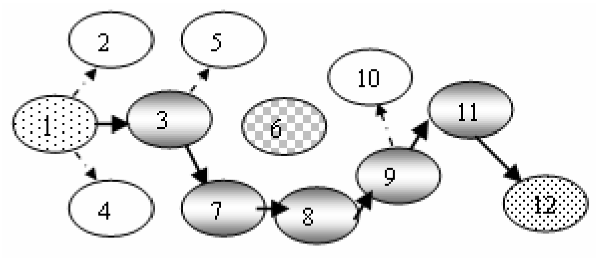

Figure 5. Failure of a link.

4. Future Work

In future, our aim is to implement the protocol using mobile computers to prove practically its robustness and performance increase for end to end delivery of data packets. We are also trying to increase the robustness by devising a method for creating an underlying mesh structure at the time of route creation. We believe that, these works will surely improve its performance and reliability.

5. Conclusion

In this paper, we proposed an efficient routing protocol for mobile ad hoc networks named Neighbour Aware Multicast Routing Protocol (NAMP). We expect that, NAMP improves the performance of the network by taking less time to transfer packets from the source to the destination(s). The tree based protocol also ensures robustness in the network by employing the Secondary Forwarder List (SFL) method. The neighborhood awareness improves the routing mechanism. By using the dominant pruning method for flooding of packets and route creation, it is expected to utilize the bandwidth available for the network.

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