Multicast Routing Architecture in Ad-Hoc Network

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Abstract – *In this paper we propose multicast (Mcast) routing architecture that uses basic trees and their neighboring MNs (NMN) in ad-hoc network. The basic trees are generated based on hop-counts from mobile nodes (MN) toward arbitrary base node (BN). The NMNs of a specific MN on a basic tree are upper, lower or peer MNs that 1-hop away from it and controlled by other basic trees. These NMNs identify only whether they have Mcast group MNs in mapping table or not, and never broadcast MNs' Mcast request. But MNs on an identical basic tree have to broadcast Mcast request to upper or lower MNs when they don't have Mcast group in mapping table. And all MNs don't have Mcast routing table but have only mapping table to convert logical address into physical IP address, also the mapping table has a tag-bit for NMNs and Mcast bit for indicating Mcast group joins or not. Thus the proposed Mcast routing architecture has effectiveness to solve shortcomings in ad-hoc and sensor networks because it can decrease effectively flooding traffic that restrict only to MNs on a basic tree and MNs don't have Mcast routing table separately.*

Keywords: Ad-hoc network, wireless network, multicast, and routing.

1 Introduction

Ad-hoc networks consist of many mobile hosts connected by wireless links. Each mobile node (MN) operates not only as an end-system, but also as a router to forward packets over the multihop ad-hoc networks. The ad-hoc network topology is dynamic one, so it may change frequently due to the nodes' movements. Routing protocols for ad-hoc networks can generally be divided into two categories. One is a proactive routing protocol that attempts to allow each MN using it to always maintain an up-to-date route to each possible destination MN in the mobile wireless network. Other is on-demand routing protocol to establish routing path when a specific MN wants to send data to destination MN [1, 2, 3, 4]. The basic concept of these protocols is flooding that overwhelming amount of packet transmission, most of them unnecessary, can quickly exhaust the battery of hosts and may hang up the entire network as a result of severe packet contention and collision [5, 6, 7].

This paper presents a new multicast routing architecture in ad-hoc network; it uses basic trees toward arbitrary or fixed BN, and on-demand tree to establish a new path for Mcast communication. For establishing basic tree, MNs send initially request packet toward BN, and then some basic trees based on hop-count toward BN and their location are established in ad-hoc network. And on-demand tree for Mcast is established through basic trees with their NMNs. Thus MN on the basic trees to join for Mcast group broadcasts join packet their upper/ lower MNs and NMNs, and then they support Mcast tree to the MN with the shortest path when the MNs received Mcast join packet are already join Mcast group. Otherwise, they determine whether it is sent from MNs on their basic tree or not. And MNs on the same basic tree broadcast it to connected MNs. This operations progress until it arrives to BN. But NMNs check only their mapping tables for identifying a specific Mcast group and they never broadcast it. If any NMN has a list for the Mcast group, it supports Mcast tree to MN to join Mcast group. Otherwise, it discards Mcast join packet. The shortest on-demand Mcast path is established if the tables have a list of a specific Mcast group, otherwise using two basic trees via BN.

This paper adopts three kinds of NMNs. The NMNs to a specific MN (HC=n) are composed of HC=n-1, HC=n or HC=n+1 MNs toward BN within its transmission range. They are not MNs on a specific MN's basic tree but are on other basic trees. Thus, each MN has a table to identify its NMNs and may use it when it wants to send data to a specific peer MN that does not know the path. In such a case NMNs check only their table for destination MN and never broadcast request packet (REQ) other MNs when they have no table for it in their table. Thus, the MNs to broadcast REQ packet are restricted to source node and MNs on its basic tree only. As a result, though the MNs manage their table for three kinds of NMNs, the overhead for on-demand routing tree toward Mcast group or destination MN may not increase but memory space is added only a few KB (kilo byte) at best for table. Therefore adopting three kinds of NMNs may contribute to establish on-demand Mcast routing tree without increasing bandwidth cost, and especially effectively use them when upper MN moves to other basic tree or is power down in ad-hoc network.

The rest of this paper is as follows: Section 2 explains creating basic tree and mapping technique converting physical IP address into logical address. Section 3 addresses on-demand Mcast routing algorithm in ad-hoc network, and Section 4 deals with simulation and analysis of the results. Finally, we discuss our conclusion.

2 Creating a Basic Tree

Creating a basic tree is initiated sending a broadcast packet (request packet; REQ) to BN from all MNs in the ad-hoc network. Some of them receive directly reply packet (REP) from BN, they are the group of the nearest 1-hop MNs. Others receive REP from 1-hop MNs directly or indirectly, the MNs which receive it directly become 2-hop MNs and MNs received indirectly from *n-1* hop MN be an *n*-hop MNs. The provision to create a basic tree is as follows,

i) All MNs request a connection to BN ➔ broadcasting request packet (REQ) including their type of MNs
ii) BN sends REP packet and logical address with location field through unicast to MNs which broadcasted REQ packet from MNs is arrived to BS
iii) MNs which receive directly REP packet from BS be a 1-hop MNs
iv) Other MNs broadcast REQ packet repeatedly
v) Other MNs excluding step (iii) receive REP packet with logical address from their upper MNs
Their hop-count is determined according to their upper MNs' hop-count and it's by adding 1 to upper MN's hop-count

All MNs on the same basic tree have the same location-field and mapping table to convert logical address into physical IP address. Although logical address needs theoretically only *k*-bit ($log_2\ n : n$ *is number of MNs*) in order to assign all MNs, this paper needs more few bits because some MNs on the same basic tree may have identical hop-count. Thus because a few MNs that have the same hop count are controlled by a upper MN, extra bits are needed to discriminate them. Also, logical address needs bit for indicating whether MNs join Mcast group or not.

Address allocation

Address allocation [6, 8, 9] is initiated by BN after BN receives connection request packet (CREQ) to establish some basic trees in ad-hoc network. As soon as BN receives CREQ, it generates location number sequentially and sends it 1-hop MN through unicast. After that, address allocation is assigned by upper MNs on its own tree due to hop-count of MNs during establishing a basic tree. Thus 1-hop MN that receives REP directly from BN identifies lower MNs and sends identical location number with peer-classifying field to lower MNs. The peer-classifying field discriminates MNs because the upper MN may have a few identical hop-count MNs on its basic tree. With this logical address, each MN has a tag-bit that indicate whether it is NMN on other basic tree or not and Mcast-bit indicates whether MN already join a specific Mcast group or not. As a result logical address that is consisted with n-bits which is divided by 4-fields as follows,

Mcast -bit	Tag	Peer classifying field	Location field

In logical address the location field is assigned by the order of BN's response for MNs' CREQ for some basic trees and it indicates the number of basic trees in ad-hoc network. The peer classifying field is assigned by the order of *hop-k* MN's response for *hop (k+1)* MNs' CREQ on an identical basic tree. It is needed because some *hop (k+1)* MNs on a basic tree may be controlled by a *hop-k* MN as explained above. Thus, location field and a part of peer classifying field are the same code to all MNs that is composing the same basic tree and has the same number of hop-counts, respectively. The hop-count is added by 1 whenever REP packet is arrived lower MN from upper MN. In this paper the hop-count is restricted 5 because the probabilistic of error increases according to longer hop-count. As a result, the length of peer-classifying field is 2-bit and this 2-bit is determined by the response sequence of upper MN. Also, Mcast-bit assigns only a few bits because mobile ad-hoc networks don't have many Mcast groups, so this paper restricts it to 2-bit. The reason is that 3-TV programs will be serviced with Mcast delivery in ad-hoc network in future works. The length of logical address is not fixed but varying the number of MNs and Mcast groups in ad-hoc network. Thus as the overhead per MN according to adopting logical address, the size of the mapping table for converting logical address into physical IP address is $n(L + P + 32)$ bits, where n is the number of MNs in ad-hoc network and $L+P = l$ is the length of logical address. And each MN has to maintain identifying table for its 3-kinds of NMNs, its size is lx bits, where x is the number of NMNs per a specific MN. And the size of overhead for each MN's managing table is indicated by $l(x + n) + 32n$. But this paper adopts tag-bit (1-bit) for indicating NMNs in order to reduce memory space of MNs. Thus tag-field in mapping table is to be set when a specific MN has NMNs that upper, lower or peer MNs of a specific MN for maintaining a basic tree. And Mcast-bits indicate whether MNs already Mcast group or not. Therefore the size of mapping table is determined to $l(x + n) + 35n$. Fig. 1 shows the delivery tree structure with basic tree that the NMNs of MN *5* is the set as{3, 4, 6, 7, 10} within its transmission range. The root MN of MNs' set {2, 3, 4, 5, 6, 7} and {9, 10, 11} are MN *1* and MN *8*, respectively. The hop count (HC) of MN *5* is 4, and its location field and peer-classifying field are 1101 and 10-01-11, respectively.

The positions of MNs on its basic tree are found from location field of logical address. The Fig. 2 shows a part of mapping table for *MN 5* that has *NMNs* {*3*, *4*,*6*, *7*, *10*}. In

Fig. 2, 1-bit Tag-field indicates NMNs of *MN 5*. The 2-bits multicast-bit (composing 3-Mcast group; 01, 10 and 11) indicates whether the MNs have already join the specific Mcast groups or not. Thus Fig. 2 shows that *NMNs* {*2, 3, 4, 6, 7*} on the same basic tree where the value of their location field is same 1101 have already joined Mcast group 11, also *NMNs* {*4*} and *NMNs* {*6*} have joined 10 and 01, respectively.

The positions of MNs on its basic tree are found from location field of logical address. Thus, a basic tree for *MN 5* from Fig. 1 includes {*3, 4, 6, 7*} and NMNs for *MN 5* are {*3, 4, 5, 7, 10*}. The reason that *NMNs* {*3, 4, 6, 7*} are on the same basic tree is that they have an identical location field, 1101. If the logical address of *MN 5* is 27D, *MN 4* have an identical hop-count (HC=4), and *MNs* {*6, 7*} are MNs that have HC = 5. The method for assigning logical address is no relation to BN except hop-1 MNs, but it depends on upper MN only. Also, Fig. 2 shows *NMNs* {*3, 7, 10*} have already join Mcast group 3, *MN 4* joins Mcast group 2 and *MN 6* has already join Mcast group 1. And specific MNs' information in mapping table is modified only when some MNs move to other basic tree or as a result change the relationship with its NMNs, join or prune of Mcast group and send only changed MNs' items to BN.

M	T	Logical Address	Pysical Address
11	1	1101-10-01 (MN 3)	12AB0CE7
10	1	1101-10-01-10 (MN 4)	2357ABCD
01	1	1101-10-01-11-10 (MN 6)	15EC03435
11	1	1101-10-01-11-11 (MN 7)	345212BC
11	0	1110-01-11 (MN 10)	6789CDAB

Fig. 1 A mapping table with neighboring MNs and join or prune of Mcast groups for MN *j*

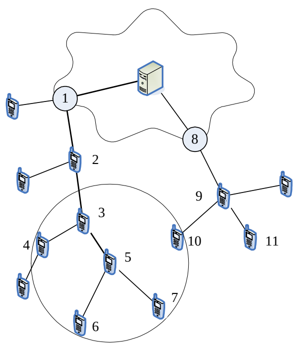


Fig. 2 The structure for generating on-demand tree using broadcast REQ packet only source and MNs on its basic tree.

3. Multicast Routing Algorithm for Ad-Hoc Network

The Prior to create a multicast routing tree in ad-hoc network, this paper generates basic trees that all MNs broadcast request packet (REQ) to BN and they receive reply packet (REP) from BN or upper MN with logical address including location field.

After establishing its basic tree, when the source MN-a wants to join a specific Mcast group, at first, the MN-a investigates its mapping table to identify MNs on its basic tree and its NMNs on other basic trees whether they manage the Mcast group or not. If the table of MN-a contains Mcast group, then the Mcast path will be established via its basic tree or NMNs. Otherwise, MN-a broadcasts JOIN packet for Mcast group to its tree and NMNs. Upper and lower MNs on the basic tree and its NMNs which received JOIN packet examine their mapping table. If any table has Mcast group MNs on basic tree or NMNs, simply it joins the Mcast group through them, otherwise only MNs on its tree broadcast Mcast JOIN packet also, and NMNs check only their table manage Mcast group or not.

When the MN-a, upper and lower MNs broadcast JOIN packet for joining Mcast group, and the some NMNs may have mapping table for requesting Mcast group. In this case MN-a may receive some routing information from MNs on its basic tree and their NMNs, then MN-a selects an on-demand Mcast routing path with minimum hop count. Otherwise, the JOIN packet to Mcast group is arrived BN, then BN supports a path using MN-a's basic tree and another basic tree which control Mcast group. Note that although all the NMNs which controlled by other trees receive Mcast JOIN packet from a specific tree they do not broadcast JOIN packet at any case but investigate only whether they have a table for a specific Mcast group or not. The procedure for creating overlay Mcast routing tree explained above is summarized as follows,

i) Source MN-a broadcasts JOIN packet with Mcast group address

ii) All MNs received Mcast JOIN packet examine their mapping table whether they have MNs that already joined Mcast group or not

iii) If any MN has joined Mcast group,,
then it sends ACK with hop-count toward source MN
else it discards Mcast JOIN packet excluding upper and lower MNs on MN-a' basic tree and go to step (v)

iv) If MN-a checks hop-counts towards Mcast-source MN via NMN and appropriates them,
then NMN sends Mcast packet to MN-a
else MN-a sends DN(deny) packet to that NMN and goto step (vi)

v) MN-a receives Mcast group packet via NMN when transmission is complete

vi) Upper and lower MNs on MN-a's basic tree broadcast Mcast JOIN packet until arrive it to BN, and if any MN on its basic tree identifies no path via its tree, then the BN sends ACK packet to MN-a with joinable basic tree via BN

vii) MN-a receives Mcast group packet via BN

viii) MN-a prunes Mcast group when transmission is complete

Fig. 2 shows the method for generating on-demand Mcast tree using broadcasting JOIN packet from source MN and other MNs within its basic tree. And NMNs check only their mapping table just likes Fig. 1 whether it has a specific Mcast-bit or not and never flooding Mcast JOIN packet to any other MNs. In this paper the number of managed lower MNs by upper MN is restricted 4-lower MNs because the load of upper MN may increase if it is more.

Logical address on MNs is shown in Fig. 2, the 1st and 2nd parts of it indicate location of its basic tree in mobile wireless network, the rests of it indicate to classify peer MNs with the same hop-count. Thus logical address 1-2-1-1-2 means that location is the 1st basic tree from BN, the 2nd among hop-2 MNs, the 1st hop-3 and hop-4 MN, and the 2nd among hop-5 MN on its basic tree. The total traffic to establish basic trees and on-demand Mcast group tree in the ad-hoc network is as follows,

$$\sum_{i=1}^{h} ba_i REQ + nREP \qquad (1)$$

where, a_i: number of i-hop MNs' tree request on a basic tree
h: number of maximum hop-count on a basic tree
b: number of basic tree in ad-hoc network
n: number of MN in ad-hoc network

Equation (1) indicates overhead for establishing basic trees in the mobile wireless network. The 1st term of equation (1) is for MNs' tree request on basic trees and the 2nd term is reply for it from upper MNs on their basic tree.

The Equation (2) indicates overhead for establishing on-demand Mcast tree via two basic trees via BN as the case of no list for a specific Mcast group in mapping table of NMNs on source MN's basic tree. The equation (2') is that via NMNs of source MN's basic tree and the added a REQ and REP are overhead for on-demand Mcast routing path between NMN and destination MN. Remember that their hop difference is only 1.

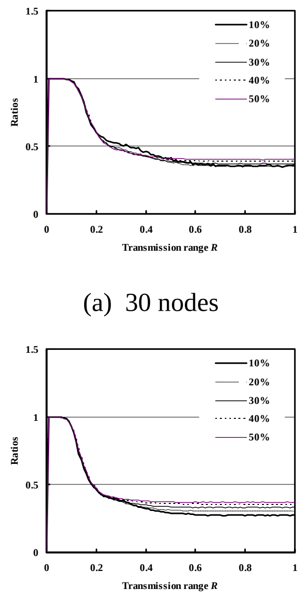
$$n(h_{ms} + h_b)(\text{JOIN} + \text{ACK}) \qquad (2)$$
$$n(|(h_s - h_u)| + 1)\ (\text{JOIN} + \text{ACK}) \qquad (2')$$

where, h_{ms}: number of hop from source MN to 1-hop MN on its basic tree
h_s: number of hop toward BN for source MN
h_b: number of hop toward BN
n: total number of MN requesting path
h_u: number of hop of issuing ACK MN on source MN's basic tree

4 Simulation and Analysis of of Performance

Our simulation network is created within a 1000m x 1000m space with 256 MNs and a random mobility model with maximum speed of 20 m/sec and pause time of 5 seconds. Each MN's and BN transmission range is selected from a uniform distribution 200 m, and the number of 1-hop MNs toward BN is selected 1 to 5 and maximum hop-count is 5. and rate of joining for a specific Mcast group is 10 – 50%.

Fig. 3 shows the comparison between source tree multicast scheme and proposed scheme. The X-axis shows the transmission range *R* while the left Y-axis shows the ratio of the number of control packets for proposed scheme over the number of control packets for conventional multicast scheme with source tree multicast scheme. Form the result, proposed scheme saves the total network bandwidth consumption compared to the conventional scheme all the time.

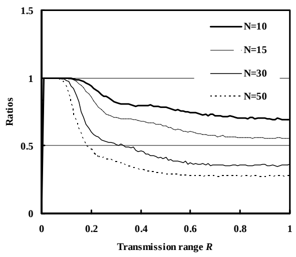


(a) 30 nodes

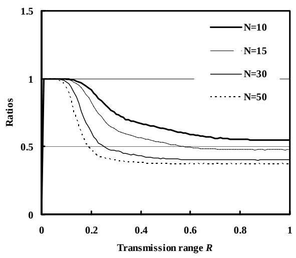
(b) 50 nodes

Fig. 3 The packet ratio compared with source tree multicast as the function of the number of nodes 30 and 50, according to the various numbers of request rates from 10% to 50%.

Fig. 4 shows the ratio in a point of view of the total number of MNs in wireless networks based on the various request rate 10% to 50%. From the simulation results, the proposed scheme can reduce the required control packet to establish multicast delivery tree. As shown in Fig. 4, the traffics are not increase or decrease uniformly according to the number of MNs and their NMNs. The reason is that hop-count is different between upper or lower-MN that managing NMN that has a list for Mcast group and source MN As shown in Fig. 4, the number of flooding for on-demand Mcast tree using NMNs is restricted less than 0.5. Thus this technique can contribute VOD service in ad-hoc network when it applies to the web-cached multicast [10].



(a) 10% reqeust rate



(b) 50% request rate

Fig. 4 The packet ratio compared with source tree multicast as the function of the request rates 50%, according to the various numbers of nodes (N) in wireless networks

5 Conclusions

In MANET, the mobility of nodes results in frequent path breaks, packet collisions, transient loops, stale routing information, and difficulty in resource reservation. Thus streaming multimedia is not easy to implement due to the frequent path broken. This paper presents Mcast routing architecture in ad-hoc network using the combination of basic trees and on-demand tree. This routing architecture can reduce effectively flooding traffic because flooding is restricted only to MNs on a basic tree, as a result this technique can reduce unnecessary power consumption by flooding. Cascading address make MNs calculate the distance from BN and estimate the existence possibility of the alternative route toward BN. The simulation results indicate that the number of MN and the request rate are the critical performance factor in order to minimize the network bandwidth consumption.

Acknowledgement

This work was supported (in part) by the Ministry of Commerce Industry and Energy(MOCIE), the Korea Institute of Industrial Technology Evaluation and Planning(ITEP) through the Multimedia Research Center at University of Incheon

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