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모바일 Ad-hoc 네트워크에서 효율적인 멀티캐스트 서비스를 지원하기 위한 메쉬구조

A Mesh Scheme for Efficient Multicast Service in Mobile Ad-hoc Networks

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요 약 본 논문에서는 모바일 Ad-hoc 네트워크에서 효율적인 멀티캐스트 서비스를 지원하기 위한 메쉬구조를 제안한다. 제안된 메쉬구조를 위한 두 개의 전략, 포워딩 노드들을 위한 어답티브 업그레이딩 및 포워딩 노드들을 위한 어답티브 다운그레이딩, 이 소개된다. 제안된 메쉬구조는 모바일 Ad-hoc 네트워크에서 노드들의 이동성과 데이터 전송률이 높을 때 심각한 혼잡문제를 해결할 수 있을 뿐만 아니라, 낮은 중복데이터를 가지고 높은 페킷 전송률을 지원할 수 있는 멀티캐스트 서비스를 지원할 수 있다. 본 논문의 성능평가는 OPNET을 사용한 시뮬레이션을 통해서 이루어진다.

Abstract In this paper, we propose an evenly distributed mesh scheme to support services in mobile ad-hoc networks. Two strategies, the adaptive upgrading of forwarding nodes and the adaptive downgrading of forwarding nodes. are presented in the scheme. Our proposed scheme can support construction of better multicast mesh that can give higher packet delivery ratio with lower duplicate data as well as solve the problem of serious congestion especially when node mobility and data transmission rate are high in mobile ad-hoc networks. The performance evaluation is performed via simulation using OPNET.

Key Words : Mobile ad-hoc networks, Multicast routing, Mesh, Congestion

Ⅰ. Introduction

A mobile ad-hoc network consists of many mobile nodes that can work without the aid of any fixed network infrastructure such as a base station. Each mobile node has limit radio transmission range and the communicating routes are often multi-hop. Moreover, the network topology can be changed dynamically to adapt to arbitrarily moving nodes. Nodes also have limit bandwidth and battery power. Therefore, multicast routing schemes can be very different compared with fixed networks. And the design of efficient multicast routing schemes for mobile ad-hoc wireless networks is extremely challenging.

Recently, various new multicast routing protocols have been proposed. Depending on their characteristics, they can be categorized into two main groups such as table-driven and source initiated or proactive and reactive [1, 2]. And each group also can be categorized into two subgroups such as tree-based and mesh-based [1, 2]. In [2] the performance of many

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multicast routing protocols for mobile ad-hoc networks are evaluated in detail and compared. In tree-based multicast routing protocols data are delivered through only single shortest path from sources to receivers, whereas in mesh-based multicast routing protocols data are often delivered through more than one path. The mesh provides richer connectivity among mobile nodes compared to tree-based routing protocol. For this reason, frequent network reconfiguration may not be required and mesh-based multicast routing protocols are more robust against high node mobility. AMRoute [3], AMRIS [4], and AODVM [5] are examples of tree-based multicast routing protocols. While the examples of mesh-based multicast routing protocol are CAMP [6], ODMRP [7], and Geocast [8].

Control overheads are generated to keep track the routes among mobile nodes in mobile ad-hoc networks. The number of control overheads increases as the node mobility increases. Moreover, high data transmission rate also contributes to congestion in these networks. Congestion may make it difficult to select optimal route in mobile ad-hoc networks. Especially accumulated congestion degrades the performance of network remarkably.

To provide multicast services for mobile ad-hoc networks, many approaches have been proposed. Their mechanisms are different but they aimed to achieve the same goals: effective and reliable multicast services. However, there is a tradeoff between the reliability and efficiency of data forwarding mesh. Reliabilty is defined in terms of percentage of group members successfully receive the data and efficiency is considered as minimum number of control overheads and duplicated data.

Some approaches try to reduce congestion by optimizing the route refresh interval. In [9], average PDR is used with specific value of control parameter to determine the probability of broadcasting control overhead packet to refresh routes. They suppose that average PDR decreases due to increased control overheads. Thus the lower the average PDR, the less likely the source will broadcast route refresh packets. On the other hand, the higher the average PDR, the greater the chance of sender broadcasting control overheads to establish routes. But besides that reason, average PDR decrease may be caused by high node mobility that makes route breaks, then reducing the chance of sender broadcasting control overheads may make the situation worse. In [10] authors evaluated the effect of using Multipoint Relays (MPRs) for optimized flooding of control overheads (i.e. reducing the number of redundant re-transmission while diffusing flooding packet throughout the entire network). Each node N in the networks select some neighbors as its MPRs. Only MPRs are allowed to rebroadcast the flooding packets broadcasted by node N. Since leaf nodes cannot be MPRs, the number of nodes taking part in flooding reduces. But [10] uses the selected MRPs only for optimization of control packets (i.e. Join Query packets).

Other approaches focus on reducing the number of duplicate data packets by reducing the number of forwarding nodes because data is more bandwidth consuming than control overheads. In [11] a node will not choose a node as its forwarding node if it already has a forwarding node. In [12] the effect of using Multipoint Relays (MPRs) can reduce forwarding mesh members. The simulation results in [12] show that the mesh with MRPs results in reduced number of forwarding nodes but at the same time it results in reduced packet delivery ratio. In [13] a multicast mesh is built upon shared trees (Steiner trees). By using an algorithm, a low cost multicast mesh is built as an approximation Steiner trees. As the number of Steiner trees increases the number of forwarding node increases, but the increasing rate is not linear as the probability that Steiner trees have the same nodes is higher. A mechanism to adaptively control the redundancy for mesh is also used in [13]. A node will select the shortest path or minimize the number of forwarding node by using probabilistic path selection.

This paper is organized as follows. Section II presents the proposed evenly distributed mesh scheme. Section III evaluates the performance of the proposed scheme while the paper is concluded in Section IV.

II. Proposed evenly distributed mesh scheme

1. Motivation: Adaptive strategy

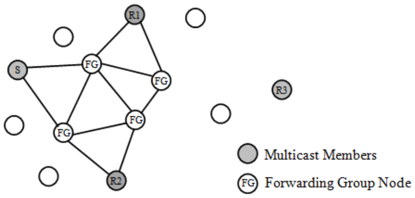
Mesh-based multicast routing protocols deliver data through meshes which can offer redundant paths among nodes in mesh group. Therefore, mesh-based multicast routing protocols rarely have communication disruptions compared with tree-based multicast routing protocols. However, additional redundant traffics due to redundant paths may be generated in the networks. When node mobility and data transmission are high, more control overheads and duplicated data are generated. This makes the nodes to be congested and reduces the performance of the multicast routing in mobile ad-hoc networks.

Some approaches have been proposed to reduce congestion in mobile ad-hoc networks such as evaluating average PDR to determine the probability of broadcasting control overhead packet to refresh routes [9], or not choosing a node as forwarding node if it already has a forwarding node [10]. In both [9] and [10], fixing route break and minimizing number of forwarding nodes are performed only when the Route Request packets are broadcasted. If route refresh time is long, mesh structure may not keep pace with high node mobility, causing local route breaks. Moreover, if forwarding group timeout value is large, the number of forwarding nodes increases. The increase in forwarding nodes provides more alternative paths but it may create local congestion. Therefore, mesh should be more adaptive to network environment to support efficient multicast services with reduced route breaks and local congestion especially when node mobility and data transmission rate are high.

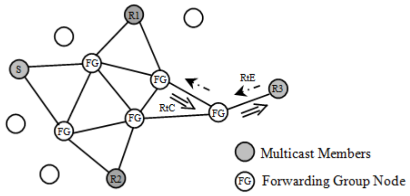
In this paper, we present two adaptive strategies to support efficient multicast services with reduced route breaks and local congestion in mobile ad-hoc networks.

2. Proposed strategy 1: The Adaptive Upgrading of Forwarding Nodes

In mesh-based multicast routing protocol, specifically the ODMRP due to node mobility the structure of mesh changes frequently. Therefore, sometimes receivers may not reach the mesh to get data from the source. These problems occur more often as node mobility increases.



(a) ODMRP



(b) Proposed strategy

그림 1. 어답티브 업그레이딩 전략의 기본 개념
Fig. 1. The basic concepts of adaptive upgrading of forwarding nodes

In this paper, we propose an adaptive upgrading of forwarding nodes in order to ensure that the source and receivers are always connected regardless of node mobility. Instead of waiting for next route refresh to build a route, receivers can begin the process of finding the nearest forwarding node which is toward the source and create a temporary route to made receivers connected to mesh structure if receivers detect that they no longer receive data from source.

In order to find the nearest forwarding node in mesh, we use two packets such as Route Explore (RtE) and Route Construct (RtC). Route Explore is used to find the shortest path from receivers to the nearest forwarding nodes of mesh and is sent from receivers. The RtE Source ID and RtE Sequence Number are used to check duplicate RtE. The Prehop ID is used to build reverse shortest path later. The Hop Count stores number of hops from source to the node sending this packet. The TTL of this packet is set to small value (i.e. 2) to prevent this packet from flooding through many nodes.

RtE Source ID	Prehop ID	RtE Sequence Number	Hop Count	TTL

그림 2. Route Explore (RtE) 페킷의 포멧
Fig. 2. Format of Route Explore (RtE) packet

RtC is used to build shortest path from receiver to mesh. It is sent from the nearest forwarding node to receiver right after RtE reaches this forwarding node. When a node receives RtC, if this is not a duplicate packet, it checks whether the next hop ID in this packet matches its ID. If it does, this node realizes that it is on the shortest path to receiver and upgrades to forwarding node.

RtC Source ID	Next hop

그림 3. Route Construct (RtC) 페킷의 포멧
Fig. 3. Format of Route Construct (RtC) packet

To forward RtE toward the source, we add a field named Hop Count to Message Cache. When a node receives a RtE, it checks whether the value of Hop Count field in this packet is less than that in Message Cache. If it does, this node continues to broadcast the packet.

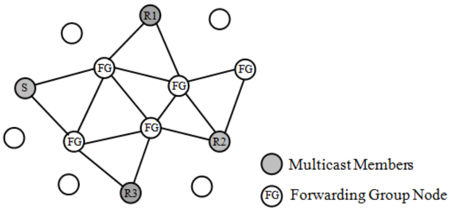
Source ID	JREQ sequence number	Hop count

그림 4. New message cache의 포멧
Fig. 4. Format of new message cache

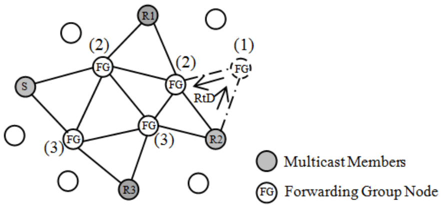
3. Proposed strategy 2: The Adaptive Downgrading of Forwarding Nodes

In ODMRP [7] the Join Request and Join Reply are used to build shortest paths between source and multicast receivers. Shortest paths are formed by forwarding nodes. A forwarding node is downgraded to normal node if not refreshed before they timeout. The forwarding group timeout impacts on the network performance. If forwarding group timeout is small, unnecessary forwarding nodes can timeout quickly and not create excessive redundant traffics. However, there may not enough forwarding nodes to provide alternate paths which may cause route disconnection. Otherwise, if forwarding group timeout is large, more alternative paths can be provided. But the number of forwarding node increases. Unnecessary forwarding nodes roam around the network and create excessive redundant traffics.

Our proposed strategy can reduce number of forwarding nodes between source and multicast receivers adaptively.



(a) ODMRP



(b) Proposed strategy

그림 5. 어답티브 다운그레이딩 전략의 기본 개념
Fig. 5. The basic concepts of adaptive downgrading of forwarding node

If a receiver detects there are more than two forwarding nodes as its neighbors, it will send Route Destruction (RtD) packet to downgrade these forwarding nodes before their timeout. The RtD packet has the following format.

Downgraded node ID	Sequence number of JREQ built this FWD node

그림 6. Route Destruction (RtD) 페킷의 포멧
Fig. 6. Format of Route Destruction (RtD) packet

Since each route refresh session uses Join Request packet with different sequence number, a node is distinguished by each sequence number of Join Request packet received before it becomes forwarding node.

We add one field called Sequence Number of received Join Request packet to Routing Table of each node as in Figure 7. Routing Table has limit size. Whenever a node receives a non-duplicate Join Request packet, it inserts the information of this packet into the top of Routing Table. The information of older Join Request packets is in the under entries. If a receiver detects there are more than two forwarding nodes as its neighbors, it sends RtD packet with Downgraded node ID of node which has oldest Sequence number of receiving JREQ in the Routing Table. A forwarding node receiving RtD packet checks whether its own ID matches the Downgraded ID. If it does, this forwarding node downgrades to normal node and rebroadcasts RtD packet with Prehop ID at the top of its Routing Table.

Source ID	Prehop ID	Sequence number of received JREQ

그림 7. New routing table의 포멧
Fig. 7. Format of new routing table

4. The combination of two strategies: strategy 1 and strategy 2

Figure 8 illustrates the combination of two strategies. Due to node mobility, certain receiver (e.g. receiver R1) may not receive data packets from source (i.e. local route break) because there are no forwarding nodes between the receiver and multicast mesh. The strategy 1 will work in this case. Meanwhile, other receiver (e.g. receiver R2) may receive same data packets from many forwarding nodes (i.e. local congestion). The strategy 2 will work in this case.

The combination of these two strategies provides adaptive multicast mesh solving local route break and local congestion. Therefore, it offers higher packet delivery ratio with lower duplicate data packets.

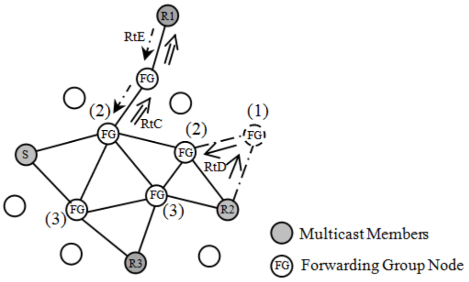


그림 8. 제안된 두 전략의 조합
Fig. 8. The combination of proposed two strategies

III. Performance evaluation

1. Simulation environment

The performance of our scheme is evaluated via simulation using Optimized Network Engineering Tool (OPNET). A mobile ad-hoc networks consisting of 50 mobile nodes that are placed randomly within a rectangular region of 1000m×1000m is modeled in the simulation. Each mobile node has constant radio propagation range of 250m. The channel capacity is 2Mbits/sec.

We assume that in our simulation mobile nodes communicate with each other in a free space propagation model in which transmission power loss is directly proportional to d where d is the distance between two nodes. When a packet arrives at the receiver of a mobile node, it is accepted if its signal strength is bigger than a threshold. Otherwise it is considered as interference and dropped. The IEEE 802.11 Distributed Coordination Function (DCF) is used as the medium access control protocol.

We simulate one multicast group which has one multicast source and varying number of receiver members. Multicast receiver members are chosen randomly. Source node sends packet with constant rate of 20 packets per second. Each data packet has 512 bytes. Random waypoint is used to model moving behavior of mobile nodes. According to this mobility model, the speed and the direction of each move are uniformly distributed within the speed range of [0, 60] km/h and direction range of [0, 2π] respectively. Each node uses these random values and moves for a period of time, called time tick of 5 seconds. After reaching a new location, it will stay there for a pause time between 0 and 10 seconds then repeats the same process. When mobile node reaches the simulation region boundary, it bounces back and continues to move.

Members join the multicast group at the start of simulation and remain as members during the simulation. Source begins to send data right after it receives the first Join Reply and continues to send the data throughout the simulation.

2. Simulation results

We run the simulation with different route refresh intervals and forwarding group timeout, and take the average values to evaluate how multicast mesh can efficiently support the multicast routing services by using following metrics:

- PDR: the ratio of the number of data packets received at multicast receivers to the number of data packets transmitted at a source node.
- The number of duplicate data packets: the number of duplicate data packets received at every mobile node in mobile ad-hoc network.
- The average number of forwarding nodes: average number of forwarding nodes in the networks.

Figure 9 and Figure 10 present PDR and number of duplicate packets (i.e. congestion) as a function of mobility speed of node respectively. As we can see in Figure 9 and Figure 10, our proposed scheme provides a mesh which can support higher PDR but lower number of duplicate data packets even under high node mobility. Under every node mobility circumstance, the mesh in our proposed scheme adapts to mobile node displacement to distribute forwarding nodes in mesh appropriately. This can help to solve local congestion and maintain higher PDR.

Figure 11 and Figure 12 show PDR and number of duplicate packets (i.e. congestion) as a function of number of multicast member nodes respectively. As we can see in Figure 11 and Figure 12, our proposed scheme also provides higher PDR but lower number of duplicate data packets even if the number of multicast member nodes is changed. When the number of multicast member nodes is small and the possibility that multicast receivers move away from mesh is high, our proposed scheme shows better performance by giving higher PDR. When the number of multicast member nodes is bigger and the possibility that multicast receivers move away from mesh, local congestion may happen more often because the number of forwarding nodes increases. In such cases, our proposed scheme can eliminate unnecessary forwarding nodes to solve local congestion and still provides higher PDR.

Figure 13 and Figure 14 show average number of forwarding nodes as a function of node mobility and multicast member nodes respectively. As we can see in Figure 13 and Figure 14, our proposed scheme optimizes number of forwarding nodes while still keeps packet delivery ratio high.

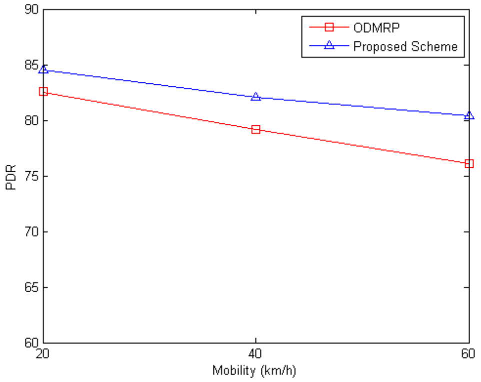


그림 9. 노드 이동성 함수로서의 PDR(페킷전달효율)
Fig. 9. PDR (Packet Delivery Ratio) as a function of node mobility

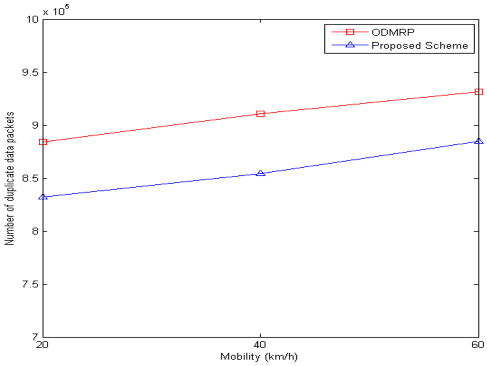


그림 10. 노드 이동성 함수로서의 혼잡성
Fig. 10. Congestion as a function of node mobility

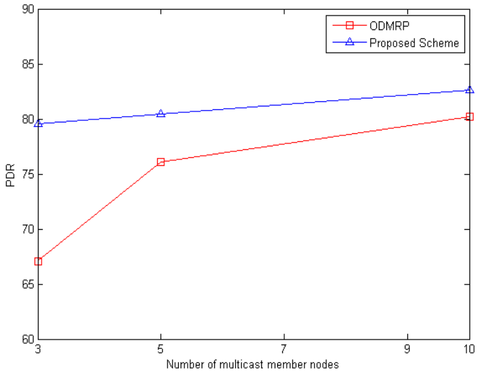


그림 11. 멀티캐스트 멤버노드 함수로서의 PDR(페킷전달효율)
Fig. 11. PDR (Packet Delivery Ratio) as a function of number of multicast member nodes

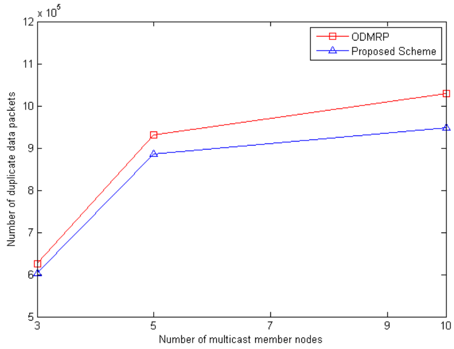


그림 12. 멀티캐스트 멤버노드 함수로서의 혼잡성
Fig. 12. Congestion as a function of number of multicast member nodes

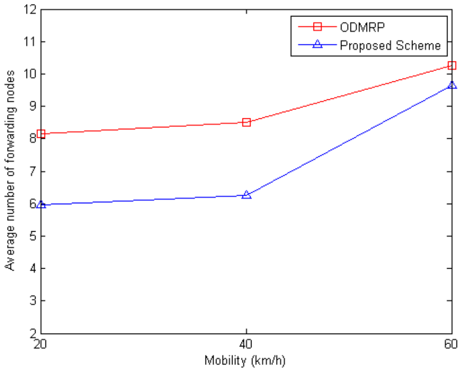


그림 13. 노드 이동성 함수로서의 평균 포워딩 노드 수
Fig. 13. Average number of forwarding nodes as a function of node mobility

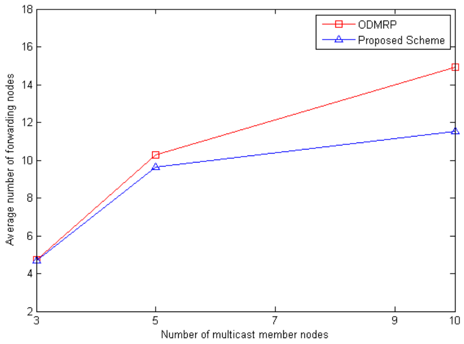


그림 14. 멀티캐스트 멤버노드 함수로서의 평균 포워딩 노드 수
Fig. 14. Average number of forwarding nodes as a function number of multicast member nodes

Ⅳ. Conclusion

In this paper, we propose an adaptive mesh-based scheme to support multicast services in mobile ad-hoc networks. The main contribution and feature of the proposed scheme are as follows. First, it provides higher packet delivery ratio by creating a temporary shortest path from multicast receivers to multicast mesh if multicast receivers cannot receive data from source for several data packets' duration. This strategy avoids great data packet loss when data are transmitted at very high rate and node mobility is also high. Second, it reduces number of duplicate data packets by reducing number of forwarding nodes sending the same data from source node to multicast receivers before these forwarding node timeout to become normal nodes. This strategy helps to eliminate redundant forwarding nodes, leading to reduced local congestion while still maintaining high packet delivery ratio. The combination of these two strategies above creates a multicast mesh which efficiently adapts to local route breaks and local congestion.

The performance evaluation using OPNET simulation shows that our proposed scheme can offer higher PDR with lower number of duplicate data packets in every case compared with conventional multicast routing protocol.

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