Lightweight Multicast Routing Based on Stable Core for MANETs

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Abstract

Mobile ad hoc networks (MANETs) have recently gained increased interest due to the widespread use of smart mobile devices. Group communication applications, serving for better cooperation between subsets of business members, become more significant in the context of MANETs. Multicast routing mechanisms are very useful communication techniques for such group-oriented applications. This paper deals with multicast routing problems in terms of stability and scalability, using the concept of stable core. We propose LMRSC (Lightweight Multicast Routing Based on Stable Core), a lightweight multicast routing technique for MANETs, in order to avoid periodic flooding of the source messages throughout the network, and to increase the duration of multicast routes. LMRSC establishes and maintains mesh architecture for each multicast group member by dividing the network into several zones, where each zone elects the most stable node as its core. Node residual energy and node velocity are used to calculate the node stability factor. The proposed algorithm is simulated by using NS-2 simulation, and is compared with other multicast routing mechanisms: ODMRP and PUMA. Packet delivery ratio, multicast route lifetime, and control packet overhead are used as performance metrics. These metrics are measured by gradual increase of the node mobility, the number of sources, the group size and the number of groups. The simulation performance results indicate that the proposed algorithm outperforms other mechanisms in terms of routes stability and network density.

Keywords: MANET, LMRSC, stability, scalability, multicast routing

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1. Introduction

MANETs are wireless networks that are characterized by frequent changes, with no fixed infrastructure. They are a collection of mobile nodes that act as a host, or router for forwarding packets from source to destination in a contention fashion. Mobile nodes that operate as routers usually can be multihop, due to a limited radio propagation range. In MANETs, all mobile nodes can move randomly and unpredictably. As such, they may join, or leave the network at any time. In recent years, group communication applications in MANETs have become a popular research subject in areas spanning public safety systems, battlefield communications, as well as commercial and civilian environments. Multicasting technique is an effective way of performing group communications. It allows a mobile node to send the same control and data packets to a specific group of mobile nodes identified by a single destination address as a single structure. Multicasting technique in MANETs has several advantages. It reduces bandwidth consumption of available routes, saves communication costs, and reduces the processing time, as well as delay in data transmission [1-5].

In the past decade, several multicast routing strategies have been proposed for MANETs. Generally, these strategies can be classified into tree-based, and mesh-based multicast routing strategies [6]. The tree-based strategy offers one route for data packets to transmit from source node to the receiver. Some tree-based strategies include multicast ad hoc on-demand distance vector routing protocol (MAODV) [7], multicast zone routing protocol (MZRP) [8], ad hoc multicast routing utilizing increasing ID-numbers protocol (AMRIS) [9], and ad hoc multicast routing protocol (AMRoute) [10]. On the other hand, the mesh-based strategy offers redundant routes. Some mesh-based strategies include on-demand multicast routing protocol (ODMRP) [11], dynamic core-based multicast protocol (DCMP) [12], core assisted mesh protocol (CAMP) [13], and forwarding group multicast protocol (FGMP) [14]. Multicast routing protocols, which are based on a tree structure are more efficient in the utilization and maintenance of network resources, but its route is easily broken. By contrast, the mesh-based variants present greater resilience to route breakages, and have a high packet delivery ratio. At the same time, however, they have a higher forwarding overhead. In the mesh-based strategy, multiple routes are maintained between senders and receivers, leading to increase in the number of mobile nodes that work as multicast data relays, as necessary. Moreover, in high contention environments with a high density of sources and relays, these strategies have poor performance because of flooding mechanism.

Therefore, there is a great difficulty in building large scale networks. This is because, the transmitted control packets are sharply increased by the number of mobile nodes, groups and permanent change in network topology. The control packets are used to manage and maintain the multicast group membership.

In order to support more scalable and stable multicast routing protocols, our design decisions must be made to reduce the higher forwarding overhead, and breakages in the links. LMRSC is an efficient technique that is proposed for reducing the impact from unstable redundancy routes and frequent changes in topology structures. Three key components briefly describing the LMRSC technique are outlined below.

Stable core: A set of mobile nodes with high residual energy and low mobility elected by the multicast members of the network in order to establish multicast mesh. Each core node maintains the local architecture of the multicast members in its zone, and also performs route calculation in order to help members in the selection of the best route. The best stable core would lead to the minimization in the impact of flooding mechanism.

Stable route: A route in LMRSC that connects two mobile nodes for a longe period of time. It leads to a reduction in the lost data caused by frequent breakage of the routes.

Lightweight multicast routing: In LMRSC it provides multicasting services for large scale mobile ad hoc networks, with a reduction in the number of control packets overhead.

2. Related Work

In this section, we provide an overview of multicast routing mechanisms in MANETs. Many studies have been conducted in this area during the last decades [15-19]. Wireless Adaptive Mobility (WAM) Laboratory developed an on-demand routing mechanism in ad hoc network called ODMRP. This is a source-initiated multicast mesh routing mechanism, which depends on a forwarding group concept where a set of mobile nodes are responsible for sending multicast control, and data packets between multicast sources and receivers, using the shortest routes. ODMRP is very robust to route failures, which improves scalability and reduces the control overhead of network, using restricted flooding of control, and data packets. Flooding mechanism of control packets improves the establishment of routing paths, but increases routing cost and packet collisions. Also, when the network size grows, ODMRP mechanism will produce high control packets overhead, and the wastage of network resource [17].

MAODV is another reliable multicast routing mechanism proposed as an extension of the unicast routing mechanism AODV [20]. MAODV is a source-initiated shared trees multicast routing mechanism where a unique address is used to identify multicast groups. The group leader is responsible for establishing and maintaining the multicast group. A mobile node that joins the multicast group as the first member will be elected as the leader of that group. MAODV is a maximal bandwidth utilization mechanism that achieves a high packet delivery ratio in a low mobility environment. But in a high mobility environment, more frequent link breakages occur, which lead to poor packet delivery, and increased control overhead [17].

Protocol for Unified Multicasting through Announcements (PUMA) [21] is a receiver-initiated multicast mesh routing mechanism. PUMA uses the core node concept to establish multicast mesh. It uses only one node (core node) to broadcast the control, and data packets to the whole network, which reduces the network overhead. Multicast receivers join a creation group, using the core address of that group. The first receiver in a multicast group will be elected as the core of that group. The core node floods a multicast announcement to the multicast group periodically. As a result, a connectivity list is established at every mobile node in the network. The connectivity list is used to build the multicast routes between network members. Thus, data packets are forwarded hop by hop from source to multicast receivers, using the best route, depending on the best multicast announcement that is received. When multicast data packets get to multicast members, they will flood within the established mesh. PUMA discards duplicate packets by using the packet ID cache at each mobile node. The main weakness in PUMA is that problems will arise if the core node fails. This is because the energy and mobility ratio of multicast receivers are not considered during the election of a core.

Robust and Scalable Geographic Multicast Protocol (RSGM) [22] was proposed to scale both network size and group size. RSGM is a location-zone based multicast routing mechanism that works in a high mobility environment, providing robust multicast packet transmissions. Mobile nodes in this mechanism are equipped with a positioning system like GPS. Multicast data packets are transmitted along bi-directional multicast trees, using geographic routing. It uses a virtual zone structure constructed as geographic squares in order to achieve high packet delivery, more efficient membership management, and reduced control overhead. RSGM introduces Source Home in order to avoid the effects of the wide periodic flooding in the whole network by source information. Source Home is an efficient source tracking mechanism used to track the address and location of all multicast sources in the network. However, RSGM does not consider some stability parameters such as battery life, mobility, and data transmission rate, when it defines Source Home.

Long Lifetime Multicast Routing Protocol (LLMRP) [23-24] is a routing mechanism derivative of ODMRP. LLMRP tries to improve the performance of ODMRP in terms of route lifetime, control overhead, and packet delivery ratio. In LLMRP, multicast data, and control packets that are being forwarded between multicast sources, and multicast receivers use the most stable routes among the available routes. A stable route is the route that works for the longest possible period of time. Route stability in LLMRP is based on three parameters namely, distance between mobile nodes, the coverage area of each mobile node, and overall packet delay. Thus, the route discovery process, and the flooding data packets in ODMRP are modified by using the LLMRP mechanism. The necessity for multicast route maintenance in LLMRP will reduce, compared to ODMRP. The main drawback in this mechanism relates to redundant routes that affect the performance of the network, when the network size and group members increase.

Unlike previous work, this paper proposes a lightweight multicast routing mechanism for MANETs in which the multicast packets are forwarded along the most stable route using stable core concept. The proposed mechanism is made to reduce the higher forwarding overhead in large scale networks. In this mechanism the network divides into multiple zones, each of which elects its core from multicast members based on high residual energy and low mobility. Each node would select its route to the core based on the route's stability factor. Several simulation scenarios are conducted and the obtained results are compared with ODMRP and PUMA to show the performance of the proposed mechanism. performance metrics (such as packet delivery ratio, multicast route lifetime and control packet overhead) are compared by varying speeds, node density and group size.

3. Lightweight Multicast Routing Based on Stable Core

In this section, we describe our proposed protocol (LMRSC) in detail, giving the approach used to manage the flooding mechanism in order to support a stable, dense environment, and achieve a high packet delivery ratio with low control overhead. LMRSC is a mesh-based protocol that uses a receiver-initiated mechanism in which every receiver connects to the elected core along the most stable routes between the receiver and that core. The process of electing the core will be explained later in this section. LMRSC offers an efficient mechanism for treating the group membership management by dividing the network into multiple routing zones, each of which elects its core. Mobile nodes that work as a core preform some tasks, including the establishment and maintenance of the routing topology in its zone, and the management of the exchange of data between sources, and other zone members. LMRSC has only one type of control message, as opposed to two in ODMRP, and three in MAODV. A mesh structure is formed from each mobile node, which is located in the stable routes between any receiver and the core.

3.1 Messages and Tables Formats

This section presents the structure of control message , neighbors table , and message cache that is used to establish multicast mesh, and stable routes between zone members.

3.1.1 Control message (CM)

CM consists of many fields as follows:

Core ID: represents the address of the mobile node that is elected as the core in each zone.

Group ID: represents the address of the multicast group (G) (a set of multicast receivers that are interested in a particular data stream).

Previous Hop ID: represents the neighbor address of the multicast member from which it received the best control message.

Sequence Number: is designated by the core to uniquely identify the CM and data packets.

Hop Count (hc): represents the distance from the current mobile node to its core.

Node Stability Factor (NSF): this field stores the value that represents the amount of the current node stability. It does this calculation based on two other factors - mobile node velocity (v), and residual energy (Er). In our proposed mechanism, every mobile node in the network is equipped with a positioning system like GPS. Therefore, the mobile node velocity can be obtained by GPS. In a MANET, increase in the velocity of multicast member nodes will affect performance, leading to decrease in the stability of routes between these members. Thus, the velocity of multicast member nodes will be inversely proportional to the node stability factor.

$$NSF \propto 1/v \tag{1}$$

The residual energy of multicast member nodes is important in determining the lifetime of the members, and the route stability between these members. So, increasing residual energy for these members will lead to increasing the route stability between them. As a result, residual energy will be directly proportional to the node stability factor.

$$NSF \propto Er \tag{2}$$

Practically, the residual energy of each mobile node can be measured by using interfaces such as Advanced Power Management (APM), or Advanced Configuration and Power Interfaces (ACPI) [25].

Hence, node stability factor can be calculated by the following equation:

$$NSF = Er / v \tag{3}$$

Route Stability Factor (RSF): the value stored in this field is the overall value of route stability between the current node and its core. It is calculated as shown in the following equation:

$$RSF = (\sum_{i=1}^{i=hc} NSF_i) / hc \tag{4}$$

3.1.2 Neighbors Table (NT)

Mobile nodes that work as the core for specific zones, periodically transmit the CM to their respective zones. As the CM broadcasts through its zone, the core node establishes the NT at every mobile node in that zone. So, each multicast member maintains the NT that stores the information about current neighbors, and one or more routes that exist to the core within its zone. Therefore, mobile nodes are able to build a multicast mesh, and route data packets from senders to receivers, depending on the NT.

As shown in **Fig. 1**, the core node produces the CM, and broadcasts this message to all parts of its zone. As a result, the NT is built in every mobile node in that zone. The dash arrows indicate the wireless connection between mobile nodes, while the solid arrows show the neighbor from which a node receives its best CM. For example, mobile node 17 has three neighbors, 4, 9, and 10. When it receives the CM from those neighbors, it starts building its NT as shown in **Table 1**. The NT has seven fields, which are arranged as follows: Neighbor ID, Previous Hop ID, Core ID, Hop Count, Grop ID, Route Stability Factor, and Route Status. The route status field shows the status of the route between the current node, and the cores in the three cases. In the first case, when route status = 1, it means that this route represents the main route to the core. In the second case, when route status = 2, it means that this route represents an alternative route to the core.

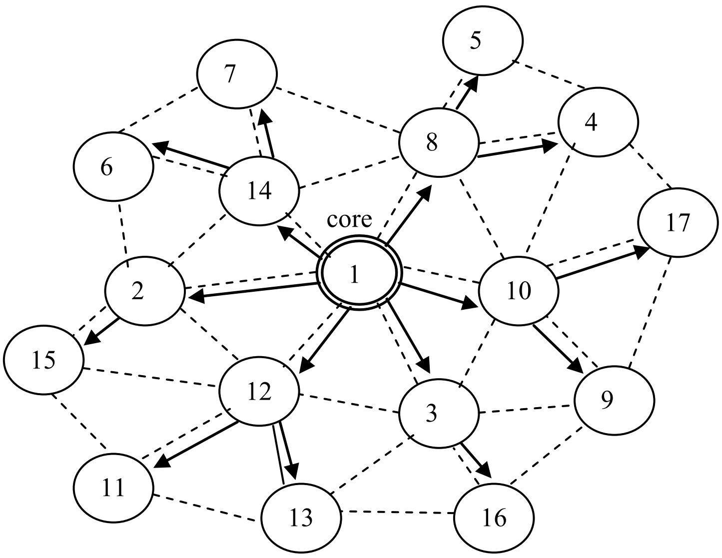


Fig. 1. Broadcast control message inside zone area

Table 1. Neighbors table at mobile node 17

Neighbor ID	Previous Hop ID	Core ID	hc	Group ID	RSF	Route status
4	8	1	3	1	3.4	2
4	10	1	3	1	2.8	2
9	10	1	3	2	3.7	2
9	3	1	3	2	3.0	2
10	1	1	2	2	4.4	1

In the last case, when route status = 3, it means that this route is used to connect this mobile node to another core in a different zone. This will help the current core to connect other cores in different zones. In each zone, core node will know information about all multicast receivers in its zone as discussed in section 3.1.2. Moreover, every core nodes in neighboring zones will contact using its sharing border node (in neighboring zones, mobile node is located at a distance of less than or equal to three hops from core nodes). So core nodes will know about all receivers in the neighboring zone. When border node fall down or move away, the other border node that has the best NSF value works as link between that core nodes.

Mobile node 17 has five entries in its NT, two from neighbor 4, two from neighbor 9, and one from neighbor 10. Anywise, it selects the best entry, based on the least hop count to the core. If two entries have the same hope count, it chooses the entry that has the highest RSF value as the best entry. Therefore, mobile node 10, which has the least hop count (shortest distance) to the core will be chosen as the best entry. This is thus the main route to the core (Route status = 1). Other entries will be alternative entries (Route status = 2). In a situation where the route is broken between mobile node 10 and mobile node 17, or where mobile node 10 moves away (out of range) from mobile node 17, all entries that use mobile node 10 will be neglected, and removed from the NT in the next receiving CM. As a result, there will be only two entries to the core with the same hop count. Mobile node 4 that has the highest RSF value will be chosen as the best entry to the core, and its route status field will be equal to 1.

3.1.3 Message Cache

Message cache is maintained by each mobile node in the network. It is used to identify and eliminate duplicate data packets. The message cache entry consists of the source ID, the packet ID, and the packet reception time of all packets that have been recently received as shown in **Fig. 2**. The content of message cache will affect the performance of the network if it is maintained permanently. So, the First In First Out (FIFO) mechanism is used to delete the old entries, leading to a lack of mobile node memory consumption.

Source ID	**Packet ID**	**Packet reception time**
13	4	2.342
13	3	2.223
13	2	2.114
6	7	2.089
13	1	1.976
. .	. .	. .

Fig. 2. Message cache at mobile node 17

3.2 Core Election

LMRSC uses an algorithm based on the election of one of the receivers as the core in each zone. Initially, any receiver node that wants to join a multicast group will have to indicate if it has received any CM from that group or not, in order to decide whether to work as a core, or a receiver. In the first case, if the mobile node has already received CM, it organizes it to follow the current core specified in that message. In this case, receivers join a multicast group by unicast CM to its core, without the need of flooding the CM to the entire network. However, LMRSC remains the current core of that zone without changing. On the other hand, the proposed algorithm adopts the new receiver to work as a core for that zone, and it periodically broadcasts a CM to its neighbors. As explained previously, each CM specifies the core ID, the previous hop ID, the multicast group ID, the sequence number, the hop count, and the NSF. It adjusts the hop count as a 0, and the previous hop id field is set to an invalid address because it is the organizer of CMs. Algorithm 1 and algorithm 2 show the pseudo codes of joining a multicast group and receiving a CM in LMRSC respectively .

Algorithm 1: Pseudo code of joining a multicast group in LMRSC

```
N wants to join a G                                   // N:Node
NSF = Er/v
RSF = 0
if N's receive CMs then
  perform algorithm 2
else C ← N for Z                                      // Z: zone
    h.c = 0
    Previous Hop ID = invalid ID
  CM interval = 3sec
  C periodically broadcasts a CM to its Z every CM interval   // Z: zone
```

Algorithm 2: Pseudo code of receiving a CM in LMRSC

```
if current node N receive CMs then
CM that has the lowest value of h.c will be selected
  if more than one CM has the same value of h.c then
    CM that has the greatest value of NSF will be selected
    if h.c ≤ 3 and TTL ≥ 0 in selected CM then          // TTL: Time to live
      N organized to follow the current C specified in CM   // C: core
      NT built in current node N
      RSF_{h.c} = ((RSF_{h.c-1} × h.c-1)+ NSF_{h.c})/ h.c
      check all h.c entries in NT
      entry with fewest h.c to C is the best route and its RS=1   // RS: Route status
      N unicast CM to its C using RS=1 and CID specified in received CM   // CID: core ID
      if more than one entry has the same h.c value then
        entry with greatest RSF value choose as the best route and its RS =1
        RS =2 in other entries with CM from same C
  if CM's received from different C's in other Z's then
    N organized to follow C with lowest h.c and greatest NSF in CM
    RS =3 in entries that refer to CM's from other Z's
```

Briefly put, each zone has only one core, and if any receiver in that zone joins a multicast group before the other receivers, it works as the core for that zone. If more than one receiver in a specific zone joins the multicast group at the same time, then the one with the highest NSF becomes the core of that zone. Moreover, if core failed or move away from its zone, the mobile node which has the greatest NSF value work as core in that zone. Algorithm 3 shows the pseudo code of cores and routes maintenance in LMRSC.

3.3 Zone Structure

In the proposed algorithm, the range of zone (a specific geographic area with a certain number of hops from the core to the zone border) can be calculated, based on the hop count field in the received CM. Any mobile node can belong to the zone if the distance between that node and the current core of that zone is not more than a specific number of hops. In LMRSC, the number of hops can be determined, based on some network environment factors, including network members density, mobility speed, and traffic load. In our simulation, we will justify the maximum number of hops between core and mobile nodes in the same zone by 3 hops. If more than one CM with the same hop count from different cores is received by any receiver, it will belong to the zone whose own core has the highest NSF. If the receiver does not receive any CM for a period of time corresponding to 3 X CM interval, or the received hop counts more than 3 hops, it becomes the new core for that zone. The value of CM interval also depends on some network environment factors as in hop counts. In our simulation, we will justify the value of the CM interval by 3 seconds.

Algorithm 3: Pseudo code of core and route maintenance in LMRSC

1. **for** each N in G
2. a. **if** (no CM's recived during 3×*CM interval*) ***OR*** (*h.c* >3 in all received *CM's*) **then** // means *C* failed or move away from its *Z*
3. all *NT* entries referring to *C* will be deleted
4. **if** max(NSF) = NSF_N **then**
5. C ← N for Z
6. b. **if** *NT* entry with RS =1 broke down **then**
7. this entry will be deleted from *NT*
8. *NT* entry with *RS* =2 ***AND*** greatest *RSF* value will be set to1

3.4 Delivery of Multicast Data Packet

A multicast source needs to send the multicast data packets to the group of members along the shortest and most stable path. In the proposed algorithm, a mobile node that receives a multicast data packet from its neighbors will forward it to the previous hop node, based on its neighbors table. When multicast data packets reach the multicast members, they will be flooded within the mesh inside the current zone by using the best routes, as we discussed in Neighbors Table. If there are still other multicast receivers in other zones, multicast data packets will be sent by zonal borders within a unicast packet to other cores in targeted zones. This process will be carried out through the use of route status field in multicast members that are located in zonal borders. When multicast data packets reach the cores in targeted zones, they will be flooded to all multicast members in that zone.

Algorithm 4: Pseudo code of delivery multicast data packet in LMRSC

1. N has D_Pkt to send (whether the packet is originated from or forwarded by N) //D_Pkt**:** Data packet
2. **if** route available to C **then**
3. D_Pkt is sent to C using the NT entry which RS =1
4. C floods D_Pkt within its zone using established mesh
5. all N belong to G in current Z & specified in its Group ID will received D_Pkt
6. **if** border N with RS = 3 in its NT received D_Pkt **then**
7. D_Pkt unicast to the neighbor C's using the chosen entry
8. Perform steps 3-5
9. **else** perform Algorithm 1
10. **if** any N in G receive duplicate D_Pkt with same S_ID and P_ID **then** // S_ID**:** Source ID; **//** P_ID**:** Packet ID
11. N discard one and delete the old entry with the oldest PRT from message cache // PRT**:** Packet reception time

---

In Fig. 1 suppose node 17 wants to send multicast data packet to group 2 (6,9,10,15). It uses the shortest and the most stable path to these members as in its NT. Nodes 9 and 10 will receive multicast data packet by one hop because they are in node 17 NT. Nodes 6 and 15 receive the multicast data packets through the routes 17-10-1-14-6 and 17-10-1-2-15, respectively using the entry with route status =1. If there are still other multicast receivers that belong to group 2 in other zones, core 1 unicast a data packets to these zones. Core 1 uses the entries with route status =3 in multicast members that are located in zonal borders. When multicast members receive the duplicate data packet from the same source, they discard it and delete the old entry with oldest packet reception time from its message cache. Algorithm 4 shows the pseudo code of delivery multicast data packet in LMRSC.

4. Simulation and Performance Evaluation

In this section, the performance of the proposed mechanism is evaluated in several simulation scenarios under different conditions. In order to illustrate its efficiency, the results of the proposed mechanism are compared with those of different multicast routing mechanisms such as ODMRP and PUMA. PUMA and ODMRP represent the state-of-the-art in multicast routing protocols for MANETs and are a well known mesh-based multicast routing protocols. ODMRP is a classic mesh-based protocol that is widely used as a robust protocol over a dynamic network. While PUMA was designed to improve the scalability of mesh-based multicast routing. Simulation environment is carried out by network simulator version 2 (NS-2) [26].

4.1 Simulation Environment

All mobile nodes in the simulated environment are distributed randomly using the random waypoint mobility model (RWP) [27-28] within a 1500 x 1500 m^2 area. In RWP, each mobile node chooses its waypoint randomly, and starts moving to a new location, using random speed. When it reaches a new location, it will choose another random destination after a pause time. These processes will be repeated until the end of the simulation.

Table 2. Simulation Parameters

Parameters	NS2 Values
Simulation time	700 second
Number of nodes	100
Simulation size	1500m x 1500m
Routing mechanism	LMRSC, ODMRP, PUMA
Physical layer protocol	IEEE 802.11 DCF
Antenna	Omni directional
Radio propagation model	Free space
Data rate	11Mbits/s
Queuing type	DropTail/PriQueue
Maximum queue size	50
Packet size	512 bytes
Mobility model	RWP
Traffic type	CBR
Transport layer protocol	UDP

In our simulation environment, the mobility of node changes from 0 to 10 m/s with various numbers of senders, receivers, and multicast group for 700s of simulation time. Senders generate Constant Bit Rate (CBR) as a traffic model to transmit packets with constant size set to 512 bytes. IEEE 802.11DCF with CSMA/CA was used as the MAC layer protocol [29]. It is the most commonly used technique in MANETs to decrease the effects of collisions at the MAC layer [22][30-31]. **Table 2** summarizes all the details about the simulation environment parameters.

Four different scenarios have been simulated in our simulation environment in order to evaluate the effect of node mobility, number of group members (receivers), number of senders, and number of multicast groups.

Each simulation scenario was run ten times with different seed values in order to give the average values of the measured data. Each scenario is configured as follows:

Scenario 1: Speed of the nodes (mobility) 0, 2, 4, 6, 8, 10 m/s. Number of Senders = 5, Number of multicast receivers (in each group) = 10, Number of multicast groups = 1.

Scenario 2: Speed of the nodes (mobility) 6 m/s. Number of Senders = 1, 2, 4, 6, 8, 10. Number of multicast receivers (in each group) = 10, Number of multicast groups = 1.

Scenario 3: Speed of the nodes (mobility) 6 m/s. Number of Senders = 5. Number of multicast receivers (in each group) = 5, 10, 15, 20, 30, 40, 50. Number of multicast groups = 1.

Scenario 4: Speed of the nodes (mobility) 6 m/s. Number of Senders = 5. Number of multicast receivers (in each group) = 10, Number of multicast groups = 1, 2, 3, 4, 5.

4.2 Performance Metrics

In order to evaluate the efficiency of the proposed mechanism (LMRSC), it is compared with different routing mechanisms such as PUMA and ODMRP. The performances of these mechanisms are measured in terms of packet delivery ratio, multicast route lifetime, and control packet overhead.

4.2.1 Packet Delivery Ratio (PDR)

This metric reflects the stability of routing mechanism in a multicasting protocols. Moreover, PDR evaluates the efficiency and level of the discovered route in routing mechanism to manage the traffic and deliver packets to the multicast receivers. It can be calculated from the following equation:

$$PDR = P_r /(P_s * N_r) \tag{5}$$

where: P_r is the total number of receiving packets in multicast receivers; P_s is the total number of packets sent out by the multicast source; and N_r is the total number of receivers.

So, the PDR value represents the average of the PDRs of each multicast receiver.

4.2.2 Multicast Route Lifetime

The network structure of MANETs changes frequently because of the random motion of mobile nodes. This will lead to a decrease in the duration of the link between neighboring mobile nodes. In certain cases, the duration of the link between two neighboring mobile nodes remains the longest period of time because these mobile nodes remain within the transmission range of each other.

Let us take, for example, two mobile nodes, N_1 and N_2 within the transmission range of each other at time t_1. The duration of the link (N_1:N_2) at time intervals [t_1, t_2] can be calculated from the following equation:

$$LD(N_1 : N_2) = t_2 - t_1 \tag{6}$$

where: $LD(N_1: N_2)$ is the duration of the link between two neighboring nodes N_1 and N_2; t_1 is the route initiation time between the two neighboring nodes, and t_2 is the route breaking time between both of them.

In general, the multicast route lifetime between sender and receiver can be calculated by taking the lowest value of $LD(N_{i-1}: N_i)$ along the path from the sender to the receiver as the maximum route duration of that path. So, in our simulation, the multicast route lifetime between sender and receiver can be calculated from the following equation:

$$MLR(Sender : \mathrm{Re}ceiver) = \min_{1 \le i \le hc} LD(N_{i-1} : N_i) \tag{7}$$

where: MRL(Sender: Receiver) is the length of multicast route lifetime between sender and receiver of creation route.

4.2.3 Control Packet Overhead

Control packet overhead in multicast routing mechanism can be calculated by the following equation:

$$ControlOverhead = P_c / P_{c+d} \tag{8}$$

where : P_c is the total number of control packets that are transmitted in the network; and P_{c+d} is the total number of control and data packets transmitted across the network.

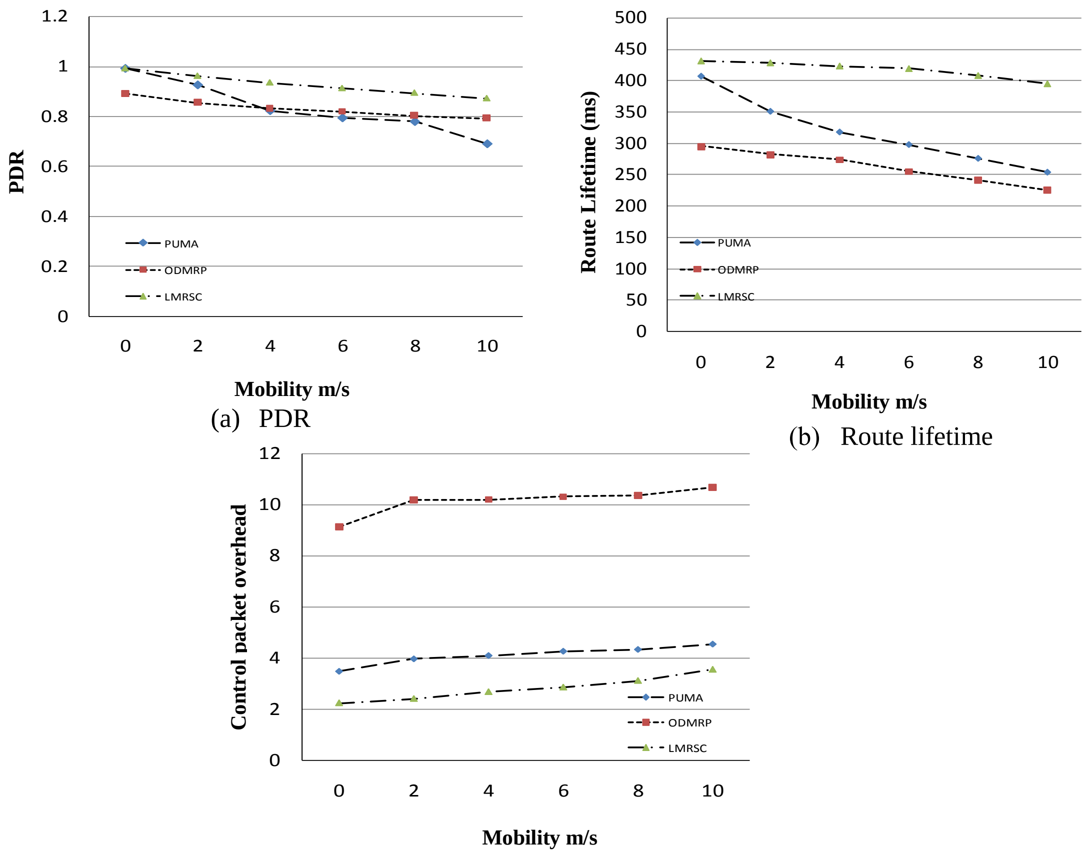
5. Simulation Results and Discussion

In this section, we discussed the effect of increasing the node mobility, the number of sources, the group size and the number of groups on multicast route lifetime which represent the stability of route (which in its turn is based on node stability) in LMRSC, PUMA, and ODMRP. On the other side, we also discussed the effect of increasing the number of sources, the group size and the number of groups on the network performance using some parametres like packet delivery ratio and control packet overhead. That effect reflects the network scalability (which is based on node density in the network) of LMRSC, PUMA, and ODMRP.

5.1 The Effect of Node Mobility

In this scenario, the mobility speed changes from 0 to 10 m/s with an increment step of 2. The number of sources is 5, and the multicast group size is put at 10 receivers.

Fig. 3a shows the effect of the node mobility speed on the packet delivery ratio. The results shown in this figure illustrate that when node mobility speed increases, the packet delivery ratio in all multicast routing mechanisms decreases. The main reason for this is the increase in routes breakage, resulting from the increase in node mobility speed. Comparing the results obtained from Figure 3, the LMRSC mechanism is found to be superior to the other mechanisms, and to produce a greater packet delivery ratio. This is because the stability of routes is not treated in PUMA and ODMRP. Thus, the hop length between mobile nodes that construct the routes will be increased, leading to an increase in packet drop rate. By contrast, the LMRSC mechanism considers route stability during the election of cores, and route selection. This makes the mechanism to have the highest packet delivery ratio. In their route selection, PUMA and ODMRP depend only on the number of hops, and this reduces the probability of selecting the route that remains connected for the longest duration of time. Moreover, as can be seen, LMRSC produces a greater packet delivery ratio than ODMRP. This is because ODMRP periodically floods route requests in order to establish and maintain the multicast structure of this mechanism, leading to increase in network congestion, and thus, the dramatic degrading of network throughputs.



(a) PDR

(b) Route lifetime

(c) Control packet overhead

Fig. 3. The effect of node mobility speed.

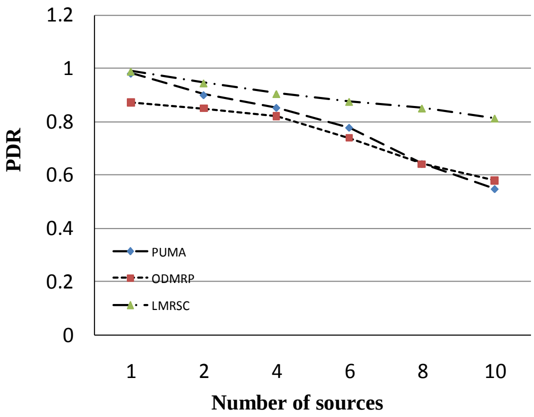
Fig. 3b illustrates the effect of this factor more clearly. It shows the impact of node mobility speed on the route lifetime. As shown in that figure, the lifetime of multicast routes reduces when mobility speed increases. LMRSC outperforms the other mechanisms because a mobile node that works as a core in PUMA, for example, changes frequently, leading to a decrease in its route lifetime. Also, ODMRP chooses its multicast routes based on the minimum delay (the least number of hops), instead of using the most stable route. That increases the amount of routing breaks.

Fig. 3c displays the effect of node mobility speed on the control packet overhead. The obtained results show that the control packet overhead of all the mechanisms increases as the node mobility speed increases. This is because when the mobile node moves faster, there is more link breakage. Therefore, all the mechanisms require more control packets for frequent route reconstruction. ODMRP produces more control packets compared to LMRSC and

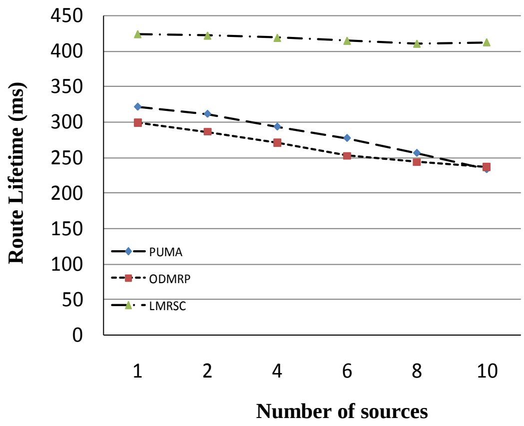
PUMA. This is because every sender in ODMRP frequently floods the control packet, whereas in LMRSC and PUMA, only the core floods its control packet. However, LMRSC outperforms the other mechanisms in terms of control packet overhead because it considers stability when choosing its core and routes.

5.2 The Effect of Sources Number

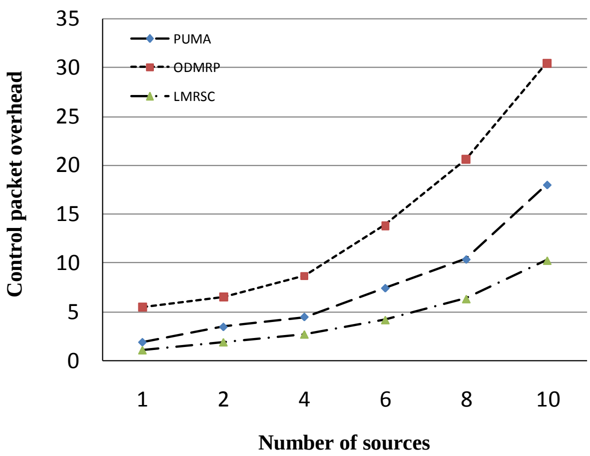
In this scenario, the number of sources changes from 1 to 10, with an increment step of 2. Multicast group size is put at 10 receivers, and node mobility speed is 6 m/s.



(a) PDR



(b) Route lifetime



(c) Control packet overhead

Fig. 4. The effect of increasing the number of sources.

Fig. 4a shows the effect of increase in the number of sources on the packet delivery ratio. The results shown in that figure illustrate that, when node mobility speed increases, the packet delivery ratio in all the multicast routing mechanisms decreases. The results further show that the packet delivery ratio of all the mechanisms decreases as the number of sources increases. This is because of the increase in the number of packet drops due to network congestion. This effect is evident in ODMRP and PUMA, respectively because of flooding mechanism from every source, and a very fast core change. As shown in that figure, the stability routing mechanism applied in LMRSC enables it to outperform the other mechanisms in terms of increasing the number of sources.

Fig. 4b shows the effect of increasing the number of sources on the multicast route lifetime. Multicast route duration is an important factor in measuring the multicast routing mechanism against node mobility. Because the node mobility in this scenario is set to 6 m/s, network topology will change continuously. As shown in that figure, LMRSC still outperforms the other mechanisms because of its routing stability mechanism.

Fig. 4c shows the effect of increasing the number of multicast sources in a single multicast group on the control packet overhead. In that figure, it can be seen that when multiple multicast sources generate their multicast control and data packets, the multicast traffic gets intensively high. This leads to increased congestion, and packet loss in the network environment. As shown in that figure, the control packet overhead increases when the number of multicast sources increases. However, LMRSC still outperforms the other mechanisms because of its strong stability mechanism. LMRSC floods only one kind of control message from the core, while ODMRP generates two kinds of control messages, and a folding mechanism is frequently applied by every multicast source. Moreover, LMRSC elects its core based on stability factors, compared to PUMA that elects its core based on the time of joining a multicast group only.

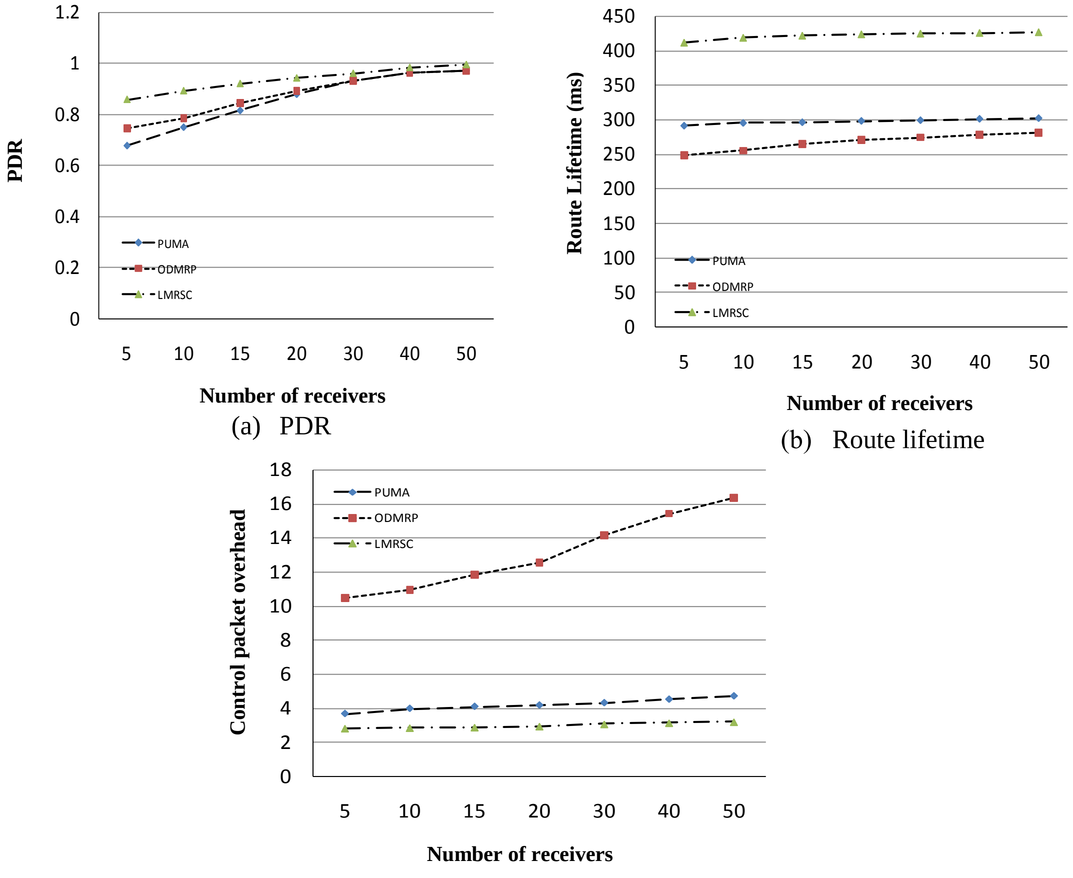
5.3 The Effect of Group Size

This scenario explains the three routing mechanisms in terms of the packet delivery ratio, route lifetime, and control packet overhead as a function of the number of multicast receivers in the multicast group. The number of multicast receivers changes from 5 to 50, the number of sources is 5, and node mobility speed is 6 m/s.

Fig. 5a shows the effect of increasing the number of receivers in a multicast group on the packet delivery ratio. The results indicate that all the multicast routing mechanisms produce a similar packet delivery ratio as group size increases. Compared to the other mechanisms though, LMRSC produces a higher rate of packet delivery ratio. This is because ODMRP and PUMA produce a greater number of control messages, leading to increasing congestion and loss of packets due to node mobility speed and large queuing delay.

Fig. 5b illustrates the effect of increasing the number of receivers in a multicast group on the multicast route lifetime. As shown in that figure, multicast route lifetime increases as the multicast group size grows. This is because as the multicast group size increases, more multicast members are incorporated as forwarding nodes. Hence, the multicast routes between sources and receivers will improve by using redundant routes. LMRSC shows a better multicast route lifetime due to its more stable and efficient forwarding mechanisms, leading to increase in the duration of multicast routes.

Fig. 5c shows the effect of increasing the number of receivers in a multicast group on the control packet overhead. Comparing the results, control packet overhead in all the routing mechanisms increases as the multicast group size grows. The control packets that require creating and reconstructing the multicast routes will increase as the group size increases, and this is more clearly seen in ODMRP. However, LMRSC trumps the other mechanisms in terms of increasing the number of multicast receivers in the multicast group.



(a) PDR

(b) Route lifetime

(c) Control packet overhead

Fig. 5. The effect of increasing the number of receivers.

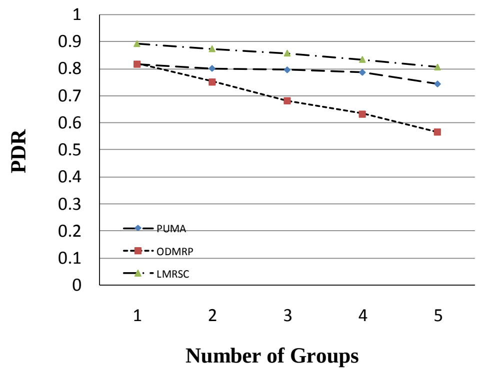
5.4 The Effect of Groups Number

This is the last scenario that illustrates the three routing mechanisms in terms of the packet delivery ratio, route lifetime, and control packet overhead, as a function of the number of multicast groups. The number of multicast group changes from 1 to 5, the number of sources is 5, the number of multicast receivers is10 in each group, and node mobility speed is 6 m/s.

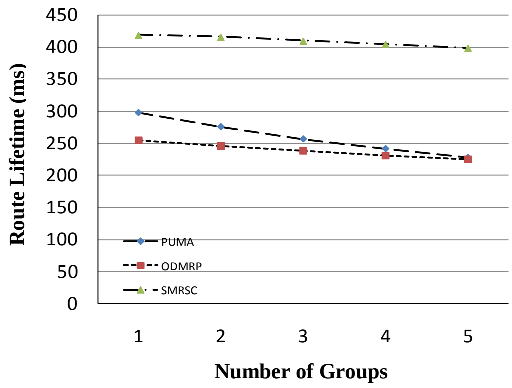
Fig. 6a shows the effect of increasing the number of multicast groups on the packet delivery ratio. In that figure, as the number of multicast groups increases, the packet delivery ratio achieved by LMRSC and PUMA is close to an order of magnitude larger than the one achieved by ODMRP. Again, this is due to the extra control packets incurred by ODMRP, as shown in **Fig. 6c**, which displays the effect of increasing the number of multicast groups on the control packet overhead. An increasing number of multicast groups leads the packet drops in ODMRP and PUMA because of the unstable mesh architecture employed. Thus, LMRSC is able to consistently maintain a higher multicast route lifetime as seen in **Fig. 6b**, which shows the effect of increasing the number of multicast groups on the multicast route lifetime.

5.5 LMRSC Robustness

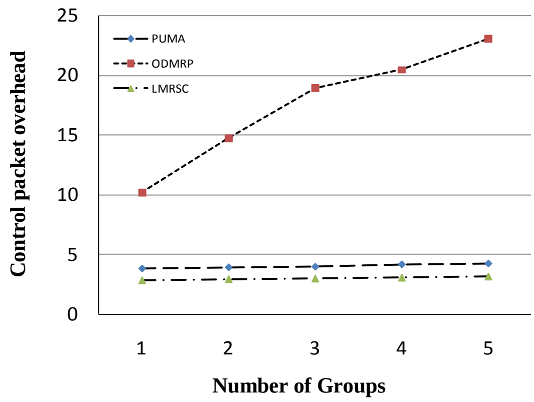
The robustness of a core node is significant for the effective performance of LMRSC. To measure the robustness of LMRSC, the average number of cores leaves its zones in simulation environment will be measured during each scenario we carried out. The simulation result of average number of cores leaves will be compared with the multicast routing mechanism which operates on the core concept "PUMA". The simulation results are shown in **Fig. 7**.



(a) PDR



(b) Route lifetime



(c) Control packet overhead

Fig. 6. The effect of increasing the number of groups.

	LMRSC						PUMA					
Mobility	**0**	**2**	**4**	**6**	**8**	**10**	**0**	**2**	**4**	**6**	**8**	**10**
Avg. N. of cores leaves	**0**	**1.23**	**1.41**	**1.65**	**1.82**	**1.94**	**0**	**1.57**	**1.86**	**2.30**	**2.64**	**2.85**
Number of Sources	**1**	**2**	**4**	**6**	**8**	**10**	**1**	**2**	**4**	**6**	**8**	**10**
Avg. N. of cores leaves	**1.65**	**1.65**	**1.65**	**1.65**	**1.65**	**1.65**	**2.30**	**2.30**	**2.30**	**2.30**	**2.30**	**2.30**
Number of receivers	**5**	**10**	**20**	**30**	**40**	**50**	**5**	**10**	**20**	**30**	**40**	**50**
Avg. N. of cores leaves	**1.46**	**1.65**	**1.78**	**1.95**	**2.32**	**2.58**	**2.13**	**2.30**	**2.84**	**3.25**	**3.73**	**4.17**
Number of Groups	**0**	**1**	**2**	**3**	**4**	**5**	**0**	**1**	**2**	**3**	**4**	**5**
Avg. N. of cores leaves	**0**	**1.65**	**1.78**	**1.95**	**2.32**	**2.58**	**0**	**2.30**	**2.84**	**3.25**	**3.73**	**4.17**

Fig. 7. Average Number of core leaves in different scenario.

Fig. 7 indicates that the cores nodes leave its zones only if nodes are mobile. So, the average number of cores nodes leaves are equal to zero for all scenarios with no mobility. Increasing the average number of cores nodes leaves will lead to the increase of the number of packet drops and control overhead. This is because of, multicast routing mechanisms always needs reconstruction multicast routes and election new cores. In the other hand, the increasing number of receivers will affect the robustness of multicast routing mechanism. When the number of multicast receivers under mobility environment increase, the average number of cores nodes leaves will increase. This is because, increasing the number of multicast receivers will lead to the increase of the zone numbers, which increase the number of cores. This will lead to the increase of the number of mobile nodes transfer between different zones and also increase average number of cores nodes leaves its zones. However, as shown in **Fig. 7**, LMRSC outperform PUMA in term of robustness, because it elects its cores and its routes based on stability factors as has been explained previously.

6. Conclusion

In this paper, we proposed a lightweight multicast routing mechanism (LMRSC) for MANETs, which could be used to reduce the effect of periodic flooding in the previous mechanisms, based on core concept. LMRSC supports a more scalable and stable multicast routing environment by reducing the higher forwarding overhead, and increasing the duration of the routes. It divides the network into different zones, and establishes a mesh topology between and within those zones. Multicast receivers in every zone elect the most stable node as the core of that zone, based on NSF, on receiving control messages. The performance of the proposed mechanism was evaluated in four scenarios, including the effect of node mobility, the number of multicast group members, the number of senders, and the number of multicast groups in terms of the packet delivery ratio, route lifetime, and control packet overhead. Simulation environment was carried out by NS2, and different multicast routing mechanisms, including ODMRP and PUMA were compared with our proposed mechanism in order to assess their relative efficiency. The simulation results showed that the proposed mechanism outperformed the other mechanisms by producing a greater packet delivery ratio, and a lower amount of control packet overhead. This is because the proposed mechanism treats the stability of routes when choosing its zonal cores, and routes. For future work, we would like to propose a new multicast routing mechanism that depends on geographic routing topology over directional antennas to scale a large network size with a dynamic mobility environment.

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