Modified On-Demand Multicasting Routing Protocol for Ad Hoc Networks

AMJAD HUDAIB
Department of Computer Information Systems
KASIT
University of Jordan
Amman 11942 Jordan
ahudaib@ju.edu.jo

KHALID KAABNEH
Department of Computer Information
Arab Academy for Banking and Financial Sciences
Dr_kaabneh@yahoo.com

MOHAMAD QATAWNEH
Department of Computer Science
KASIT
University of Jordan
Amman 11942 Jordan
info@mazarco.com

Abstract: - This paper proposes and simulates a new ad hoc multicasting routing protocol called Modified On-Demand Multicast Routing Protocol (MODMRP). The MODMRP is based on On-Demand Multicasting Routing Protocol (ODMRP). MODMRP suggests two approaches aimed to reduce the service traffic; the local detection of routes and the information usage on the channels condition during the route information update timer values. The goal of MODMRP is to improve packet delivery efficiency. Through a course of simulation experiments, the MODMRP is compared to the ODMRP in reference to number factors such as Ratio of Packets Delivery and transmission delays. The Simulation results show an increase in the percentage of delivered multicast datagram on an average of 2% and a routing overhead costs decreased on average of 20.5% when compared to ODMRP.

Key-Words:- Ad hoc Network, MODMRP, ODMRP, Routing Protocol, On-Demand Multicasting

1 Introduction

The basic description of an ad hoc network is a wireless network without fixed infrastructure or centralized administration. Its layout consists of mobile nodes, which acts as routers to forward the traffic of other nodes. Each mobile node in an ad hoc network is responsible for sending and receiving its own data. Multicasting in ad hoc networks can be described in such a way that a single mobile node transmits the same data to multiple recipients[13]. The use of multicasting in such way offers many advantages; it reduces the communication cost for such applications by sending the same data to many recipients such as TV conferences, video conferencing, location and communications [5,6,10,12,14,15,16,17]. Several multicast routing protocols for ad hoc networks have been proposed such as the On-Demand Multicasting Routing protocol [1,9] (ODMRP), the ad hoc multicast routing protocol[11] (AMRoute) and the Core-Assisted Mesh Protocol [2,4,7,8] (CAMP). These protocols can be generally grouped into two categories: tree-based protocols and mesh-based protocols. Tree-based protocols are generally more efficient in terms of data transmission than mesh-based protocols, but they are not robust against topology changes because there is no alternative path between a source and a destination. Meanwhile, mesh-based multicast protocols such as ODMRP will always provide an alternative link failure path.

This paper proposes a more efficient multicast routing protocol referred to as MODMRP for a mobile ad hoc wireless network based on ODMRP. The goal of the proposed approach is to improve the ratio of packets delivery and reduce the service traffic. The rest of the paper is organized as follow: section 2 presents ODMRP, our proposed MODMRP is presented in section 3. Section 4, presents our simulation results and finally section 5, conclusion and future work.

2 On-Demand Multicast Routing Protocol (ODMRP)

Several On-Demand Multicast Routing Protocols for ad hoc wireless networks have been proposed [1,2,4,7,8,9,11]. These protocols are not robust against topology changes. ODMRP is a routing protocol designed for ad hoc networks. It creates a mesh of nodes aimed to forward multicast packets using flooding approach, and group membership is established and updated by the source on demand. ODMRP uses the concept of forwarding group[9] (FG), which is a set of nodes responsible for forwarding multicast data on shortest paths between any pair of nodes, to build a forwarding mesh for each multicast group. The nodes that are on the path of the mesh are selected as the forwarding group nodes.

When configuring the forwarding mesh for a multicast group, the ODMRP uses two types of control packet: JOIN_QUERY and JOIN_REPLY. Each of the sources of the multicast group periodically generates a JOIN_QUERY, and floods it throughout the network. If an intermediate node receives JOIN_QUERY, it stores the source ID and the sequence number in its message cache to detect a potential duplication and rebroadcast it.

When a JOIN_QUERY reaches a receiver of the multicast group, it creates and broadcast a JOIN_REPLY to its neighbors. The receiver sets the next hop field of the JOIN_REPLY as the next hop to the source of the JOIN_QUERY. When node receives a JOIN_REPLY, it checks if the next hop address of one of the entries matches its own address. If it does, the node realizes that it is on the path of the source and thus it is part of the FG. Then it sets the FG_FLAG (Forwarding Group Flag), and broadcasts its own JOIN_REPLY based upon its routing table entries. Using this approach, the JOIN_REPLY is propagated by each FG node until it reaches the multicast source via the selected path. This process constructs (or updates) the routes from sources to receivers and builds a mesh of nodes, the forwarding group.

Each FG node keeps a forwarding group table which contain entries consisted of multicast group address and a timer. The entries of forwarding group table are refreshed and updated whenever the node relays the JOIN_REPLY. When the timer in corresponding forwarding group table entry is expired, the node resets FG_FLAG of the multicast group, which makes it no longer the FG node of the multicast group.

After the mesh construction process, a source can transmit multicast packets to the receivers via selected routes and FG nodes. While outgoing data packets exist, the source sends JOIN_QUERY every REFRESH_INTERVAL. When receiving the multicast data packet, a node forwards it only if it is not a duplicate and the setting of the FG_FLAG for the multicast group has not expired.

3 Modified On-Demand Multicast Routing Protocol (MODMRP)

The message header and routing table structures that are used in MODMRP is shown in Fig.1 and Fig.2.

Type	No. of hops	No. of forwarding groups	Group's address	Source address	Previous hop	Order number

Fig.1. Message Header Structure

Group's address	Junction Forwarding Flag	Junction Forwarding time-out	Junction Stand-by Flag	Junction Stand-by time-out

Fig. 2. Routing Table Structure

- **Type** - This field (in Fig.1) determines the type of a given message. There are five types of the message used:
  - **NETWORK_JOIN_QUERY**: Total possible routes for a message sent by the group datagrams sender and distributed in a flooding way among all the network junctions.
  - **LOCAL_JOIN_QUERY:** Local route search for a message sent by a sender of group and distributed among the junctions positioned at a distance no more than two hops from the message group delivery mesh.
  - **RECEIVER_JOIN_QUERY**: Route search for a message sent by the group datagrams for new receiver.
  - **JOIN_REPLY**: Reply message on request for a route search.
  - **DATA**: The Data need to be transmitted.

Each junction contains the routing table as shown in Fig. 2. When a junction becomes a forwarding group member, it sets the forwarding group to FW_FLAG flag and when becoming a stand-by junction of the Multicast group it sets the stand-by junction to SB_FLAG flag. Both the forwarding junction time-out and the stand-by junction time-out determine the time after which they forfeit their functions correspondingly. Each junction has cache-memory aimed to determine if there is a duplicate message.

When the junction is attempting to connect to a group or be disconnected from it, the junction will wait for some time to receive a LOCAL_JOIN_QUERY message. If the junction is positioned at a distance no more than two hops from the message group delivery mesh, it receives such message. In case the new recipient does not receive the LOCAL_JOIN_QUERY message for a specified time period, then it transmits a RECEIVER_JOIN_QUERY message in a broadcasting way. Once the RECEIVER_JOIN_QUERY is received, the junctions act in the same manner as in the NETWORK_JOIN_QUERY when receiving a message.

The MODMRP suggests a balance between the routing construction efficiency and tolerance to links breaks, giving a priority to routes containing the greater number of the forwarding junctions during the information delivery route selection. While setting the routes the multicast datagrams recipient receives as a rule more than one route search message. After the recipient receives the first route search message, it saves this message in its memory and waits for some time period the other routes search messages reception.

4 Construction of Information Multicast Delivery Mesh

Any developed algorithm of the multicast routing should be related to a class of on-demand routing algorithm. Particular features of such algorithms are based on the fact that the mobile junctions do not exchange the routing information to follow changes in network topology. When the mobile junction has data to transmit to multicast group, it generates and transfers in a broadcasting manner a request for connection to NETWORK_JOIN_QUERY group in the network. When an intermediate junction receives such a request, it will immediately check if this request is a duplicate one. Each request contains the order number which is used by the intermediate junction for a duplicate verification. This set up will make sure there is no duplicate transmission using the same requests.

In the case when receiving a non-duplicated request, the junction saves the address of the junction generated the NETWORK_JOIN_QUERY, in addition to the address of junction for the sender of this message (in previous hop field). The same action is performed in the case of reverse way determination of the direction to junction- source of a request. If the message time to live (TTL) is greater than zero, then the intermediate junction changes the address in the field previous hop setting it to home address and transmits it farther in the network.

When NETWORK_JOIN_QUERY receives datagrams of the group specified in the table, it begins the reply process, which includes the following steps:

- For each datagrams source of multicast group, the receiver selects its neighbor (the first junction to transmit NETWORK_JOIN_QUERY), which will be the sender of data from this source.
- Then the receiver generates and transmits a JOIN_REPLY in a broadcasting way into the network. The JOIN_REPLY will contain a table of a pair of addresses for each multicast datagrams source (source, the next hop), where the next hop is the address of junction which will be the sender of data from the specified source. The junction receiving the JOIN_REPLY will read the attachment table contained in this message. If the field the next hop of a record matches with the junction home address, then it sets the forwarding flag FW_FLAG for a specified message group, then transmits it in a broadcasting way with its own attachment table. In case the table has no junction address, then such junction will not transmit JOIN_REPLY farther.

The end result of information delivery mesh construction procedure for multicast group is basically combining the meshes from multicast datagrams sources to their receivers. The junctions which have set forwarding flag are called the forwarding junctions and the set of forwarding junctions is called the forwarding group. Only the junctions entering the forwarding group can transmit multicast datagrams in a broadcasting way and junctions that do not enter the forwarding group ignore such datagrams. This process is called the limited flooding.

The procedure of mesh construction for multicast information delivery is illustrated in Fig. 3. Let us assume that there are two multicast group receivers (junctions 9 and 23). When junction 7 tends to join the group as the datagrams sender, it will transmit the message NETWORK_JOIN_QUERY in a broadcasting way. Once this message is received, then junction 8 transmits it farther in a broadcasting way. When junction 9 receives NETWORK_JOIN_QUERY, it generates a JOIN_REPLY message and sends it back to junction 8. When junction 8 receives JOIN_REPLY, it notifies the membership of forwarding group, sets the forwarding flag FG_FLAG and transmits JOIN_REPLY farther to junction 7. In the same manner junction 23 sends JOIN_REPLY to junction 7, while junctions 18 and 13 become the members of forwarding group. Stand-by junctions are connected directly (located in the covering range) at least with one junction of multicast group message delivery mesh. In Fig. 3, the stand-by junctions are 3, 4, 5, 6, 10, 12, 14, 17, 22, 24 and 27. The forwarding junctions and stand-by junctions will lose their functions if their status was not updated till the time-out termination.

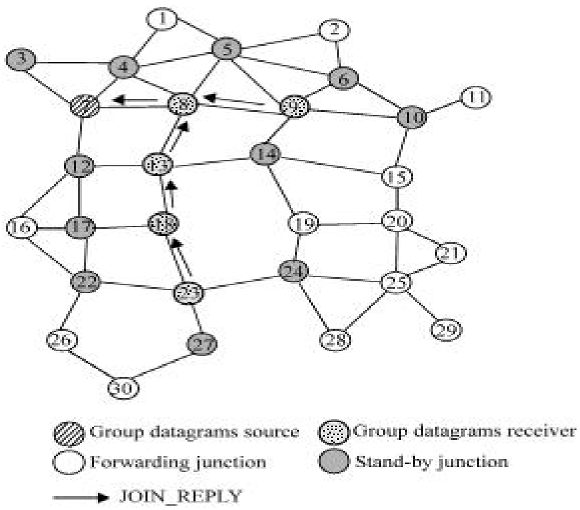

Fig. 3. Construction of Multicast Message delivery Mesh

4.1 Routing Support

The mobile junctions in ad hoc network are not restricted by any infrastructure and can have a high mobility. Thus, it can raise the existing routes support problem stimulated by displacement of the junctions entering multicast information delivery mesh. To solve this problem in on-demand multicast protocols, there is normally an applied method of periodical broadcasting dispatch to all messages routes update. For example, in ODMRP protocol, all multicast datagrams sources periodically distribute the requests of attachment to JOIN_QUERY group. Such method of routing support has significant disadvantages:

- The routes support message flooding in the entire network creating high-usage service traffic. The junctions which are not the members of multicast group and forwarding group have to retranslate such messages.
- At short time interval for the routes support messages dispatch the excess service traffic is created.

In MODMRP, there are two suggested methods aimed to reduce the service traffic substantially, where those are necessary to routes support and recovery (the local detections of routes and information usage on the channels condition during the route information update timer values selection).

4.2 Local Routes Detection (LRD)

When there is a Local Routes Detection, each multicast datagrams source transmits LOCAL_JOIN_QUERY request within some time intervals. In contrast to ODMRP protocol, for routes support, the NETWORK_JOIN_QUERY messages are distributed periodically throughout the entire network, and in case of members of the multicast information delivery and the stand-by junctions group, they only distribute messages in a broadcasting way. Thus, LOCAL_JOIN_QUERY can receive only the junctions positioned at a distance not greater than two hops from Multicast mesh. Meanwhile, MODMRP detects the service traffic and allows recovering most links broken due to junction's displacement. As a response to LOCAL_JOIN_QUERY message, the multicast group receivers transmit JOIN_REPLY messages as in a case of NETWORK_JOIN_QUERY. Using Fig.3, assuming there is a cutoff between junctions 18 and 23. At the same time, junction 7 in a broadcasting way sends the message LOCAL_JOIN_QUERY since the every source performs the local detection of the routes. Junctions 12, 17 and 22 receive this message and transmit it farther in a broadcasting way. When junction 23 receives LOCAL_JOIN_QUERY, it generates and sends JOIN_REPLY message back to source. It is necessary to note that 43% of junctions (13 from 30) don't send the message LOCAL_JOIN_QUERY.

The LRD provides a low overhead

costs evolving from transmission of the control messages, but nevertheless this method can not guarantee a recovery of all possible broken links. Thus there is a need to dispatch requests for attachment to group using flooding through the entire network remains, but in the contrary, when applying the routes local detection method such sending will be carry out less frequently and it will provide a decrease in the serving traffic. Also, to join new receivers to a multicast group, it is necessary to perform a periodical multicast mesh construction procedure. The NETWORK_JOIN_QUERY requests flooding the entire network should be performed in the following cases:

- When the junction becomes a new source of the multicast datagrams, it sends NETWORK_JOIN_QUERY for initial setting of the multicast dispatch mesh.
- Each group source periodically sends NETWORK_JOIN_QUERY to recover the links that can not be recovered by means of LOCAL_JOIN_QUERY.

A receiver being at a distance greater than two hops from the messages delivery mesh can send the message RECEIVER_JOIN_QUERY in order to be connected to mesh.

4.3 The Route Information Updated Timers

The route update interval and the junction update interval in forwarding group can significantly influence the multicast on-demand routing algorithm capacity. It is evident that these intervals should be adaptive with respect to network environment (e.g. Traffic type, traffic loading, mobility model, junction velocity, carrying capacity) and vary in dynamical manner. Small magnitude of interval values of the routes upgrade and of membership in the group can create the service traffic greater than what is required and thus be a cause of network overload.

The update interval in forwarding groups should be selected carefully. In the networks with a large loading traffic, it is better to select the small interval values in order to provide the conditions when the disconnected junctions may leave the group and to prevent excess redundancy. Whereas junctions with high mobility, it is necessary to select a greater interval values to create the possible alternative paths. As it was shown above, the route information update interval has an effect on the multicast routing algorithm productivity.

In this paper, we suggest a method designed to adapt the update interval to junction's displacement mobility and velocity. Information obtained by means of the channel state prediction mechanism is used in the following way. When multicast datagrams source sends the request LOCAL_JOIN_QUERY or NETWORK_JOIN_QUERY, it sets the channel breakage time B_Time in compliance with some value MAX_B_Time when the source has no information on the previous hop. The MAX_B_Time value determines the route information update maximum interval. The junction that received request for attachment predicts the link breakage time LB_Time between itself and the previous hop. If LB_Time < CB_Time, then the junction replaces the CB_Time value in request with LB_Time, otherwise it would stay unchanged. After this step, the junction transmits farther in a broadcasting way.

It is evident that the composite channel breakage time is determined by the minimum time of its components breakage. When the multicast group member receives the request for attachment, it calculates the breakage time LB_Time of the last link. The minimum value between LB_Time and CB_Time for request represents the channel breakage time. This value is introduced into the message JOIN_REPLY which is transmitted back to the source in a broadcasting way. If the forwarding group junction receives a number JOIN_REPLY messages with different CB_Time values (meaning that it is on the routes from one source to several receivers) it will select the minimum CB_Time value and sends JOIN_REPLY with its attachment table and this value. When the source receives JOIN_REPLY, it selects the minimum CB_Time value from all messages. Then the source supports the routs sending JOIN_QUERY before the CB_Time termination.

4.4 The Route Selection

In ODMRP protocol, the multicast datagrams receiver selects a route based on the minimum delay, thus route is selected based on the first to receive a JOIN_QUERY. When using the channel state prediction, another criterion of the route selection is applied. In MODMRP, we suggest using the most stable route and not the route with the minimum delay (with the maximum CB_Time value) should be selected. When selecting the datagrams receiving route, the receiver will wait for a time interval after the first JOIN_QUERY received, giving the opportunity to select one route from the several ones. After the route selecting id completed, the receiver transmits the message in a broadcasting way. As a result, in comparison to ODMRP, the suggested routing selection using a stable route offers a smaller frequency in route breakage and in the number of JOIN_REPLY.

4.5 The Data Transmitting

After the creation of groups and routes construction, the multicast datagrams sources can transmit data to group receivers using the selected routes and forwarding groups. When the junction receives multicast datagram, it transmits this datagram farther in a broadcasting way if the datagram is not a duplicate and the FG_FLAG flag is set for given multicast group. Using this approach, it minimizes traffic and prevents data transmission using the "stale" routes. Knowing the broadcasting nature of wireless networks used, data is not transmitted in unicast mode in series to all nearby junctions but simultaneously step-by-step to all neighbors.

4.6 The Attachment of Junction to Multicast Information Delivery Mesh

If a new multicast datagram source desires to join the multicast information delivery mesh, a NETWORK_JOIN_QUERY request is distributed in a flooding way throughout the entire network. Using MODMRP, if the new multicast datagram receiver desires to join the information delivery mesh, then it should wait for the NETWORK_JOIN_QUERY or LOCAL_JOIN_QUERY messages.

4.7 The Junction Detachment from Multicast Information Delivery Mesh

The MODMRP is based on multicast routing class with flexible links. This means that when entering the multicast group, there is no need to send explicit messages containing detachment from the multicast information delivery mesh (e.g. PRUNE message in ODMRP protocol).If a multicast datagram source desires to leave the group, it will stop sending the JOIN_QUERY requests, meaning this source has no data transmission to this group. If the receiver does not desire to receive datagrams from any group, it stops sending JOIN_REPLY messages for this group. The forwarding groups will have a time-out termination if they do not receive JOIN_REPLY messages.

4.8 The Increasing Routing Usage Efficiency

When selecting the appropriate routes, the choice should be given to routes containing the greatest number of forwarding junctions. The selection of route criteria is an important parameter since it determines the pepper balance between the route efficiency and the route resistance to links breakage. In Fig. 3, assuming that junction 27 becomes a new receiver of multicast group, subsequently, it received two route search messages, (route one 7-8-13-18-23-27 and route 7-12-17-22-23-27) both having the same length. The first route uses an existing route, meanwhile, the second route requires the determination of additional three forwarding junctions (junction 23 becomes the forwarding one in any case). In respect to stability of messages delivery, it is more effective apply route 7-12-17-22-23-27, but from the point of view of the links usage it is best to apply the second route.

5. Simulation Results

In order to test MODMRP, Network Simulator 2 (ns-2) was used. Our simulation model consists of a network of 50 mobile junctions move in an area of 1000 m2. Radio propagation range for each junction is 250 meters and the channel capacity is 2 Mbit/sec. Each simulation was executed for 900 seconds of simulation time. To precisely model the attenuation of radio waves between junctions close to the ground, radio engineers typically used a model that attenuates the power of a signal as 1/d2 for short distances and as 1/d4 for longer distances(where d is the distance between junctions). The junction's displacement is described by the random waypoint model [3]. The fundamental nature of this model is as follows:

- The junction selects the final point of motion and velocity from some range and begins to move according to selected parameters in a random way;
- After the final point selection, the junction makes a pause *p* and then repeats the process in the same way. In this work, simulation used a random waypoint module without any pauses $p = 0$.

Multicast datagrams sources generate a 512-byte data batches with a constant bit rate (CBR) set to 2 batches per second. The junctions perform a batch exchange in compliance with UDP protocol. To test the MODMRP further, a test-bed was used with random motions and group membership scenarios were generated and used as the basic data. Each motion scenario determines the motion of 50 mobile junctions at a rate uniformly distributed within a range from zero to maximum value.

The group membership scenario determines what junctions are the sources of multicast datagram's and what junctions are the receivers and also the time when they join or leave the group. The receiver will randomly join the group within 0 and 100 second and leaves it within 800 and 900 second time intervals. The sources of multicast datagram's start and end transmitting packets using the same mode. Throughout the simulation, the MODMRP is compared with ODMRP. The comparison was performed with respect the following key ingredients:

- Packet Delivery Ratio (PDR): The ratio of the actual number of packets delivered to distention (with no errors) to number of packets that should be received.
- The ratio of transmitted packets to number of delivered packets.
- The average delay of the packets transmission.

Fig. 4 shows the PDR at the various velocities of junctions motion. Both the protocols show a high efficiency even under the high dynamic conditions. In addition, both were providing excess routes due to usage of forwarding groups. The probability of successful delivery is high even in an event of main route fault. The routes excess ensures a low percentage of the data packets losses and makes the MODMRP stable in respect to the junction's mobility. The packets delivery efficiency using the MODMRP is higher than what ODMRP protocol offers. This is due to the fact that the route selection criteria in the MODMRP is based on the stability (the selected routings have the most breakage-free predicted operational time) of routes. In addition, the routes update interval (JOIN_QUERY dispatch message) in MODMRP varies in a dynamic way depending on the medium, meanwhile the ODMRP uses a static routes update period.

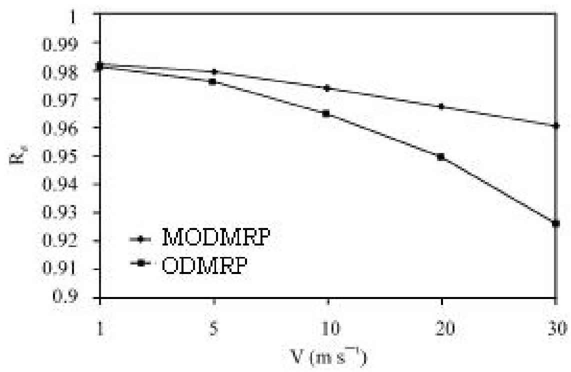

Fig. 4. Packets Delivery Factor (R_d) vs. Junctions Velocities (V).

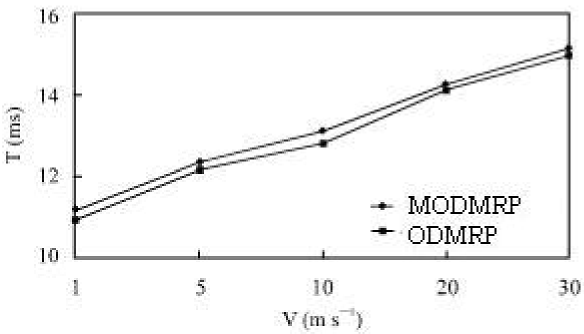

Fig. 5. Average Data Packets Transmission Delay vs. Junctions Velocities

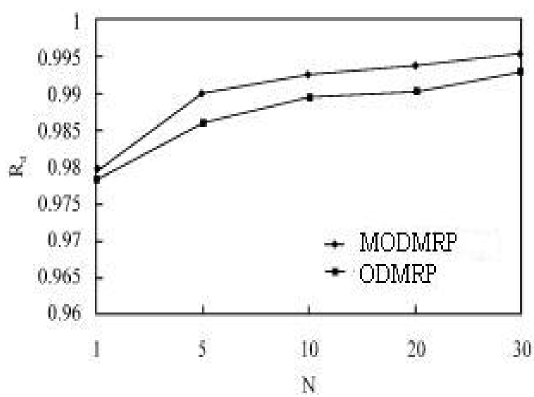

Fig. 6. The Ratio of Packets Delivery.

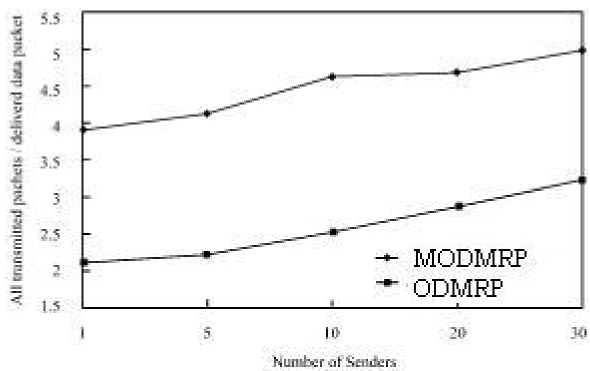

Fig. 7. Transmitted Packets vs. Multicast Datagrams Senders.

The MODMRP considerably exceeds the ODMRP in reference to packet delivery factor (as seen in Fig. 4). At a lower velocity, both protocols have close values for the packet delivery factor. Increasing the velocity of service traffic, the MODMRP exceeds ODMRP. That is because MODMRP applies a dynamically updating and varying period of delivered data bytes, in addition to the updating mechanism of local route support, where flooding to support the routes is not applied on the entire network as it takes place in ODMRP.

Fig. 5 plots the average delay of data packets transmission in respect to various velocities of junctions in motion. It is clear that the average of transmission delay is higher for the MODMRP (since the modified algorithm selects more stable routes); however this difference does not exceed 2.5%. A series of experiments were carried out to investigate the influence of a number of multicast group senders on metrics of the MODMRP and ODMRP. Multicast group constructed of 20 junctions with a velocity of 10 m/s. The number of senders varies from 1 to 20. The case was tested on 20 multicast datagrams senders simulating an interactive video conferencing lecture.

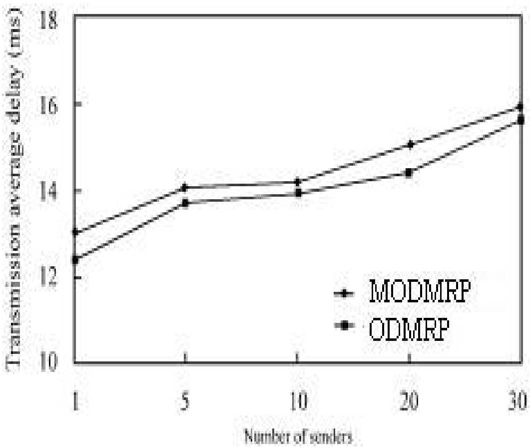

Fig. 8. Transmission Average Delay vs. Number of Multicast Senders.

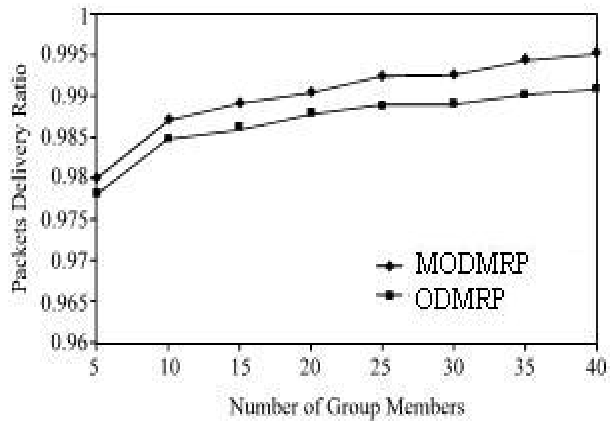

Fig. 9. Packets Delivery Ratio at Different Number of Group Members.

The Ratio of Packets Delivery is shown in Fig. 6; we can see that as the number of senders increases, the ratio of packet delivery increases. This is due to the fact that the number of forwarding junctions will increase too. The Transmitted Packets vs. Multicast Datagrams Senders is shown in Fig. 7, we can see that both MODMRP and ODMRP the overhead cost increases as there is an increase in the number of senders since both MODMRP and ODMRP use the same method of route construction from the sources. In addition, increasing the number of multicast datagrams sources causes a service traffic increase (there is more communications using JOIN_QUERY and JOIN_REPLY). In this case, the difference between ODMRP and MODMRP is virtually constant due to use of routes local support mechanisms and criterion of stability while selecting the routes (velocity does not change).

Fig. 8 indicates an increase in the number of multicast datagrams senders which result an increase in the transmission delay. The transmission delay includes the waiting in the sending queue, the interface delay, and delay caused by the packet transmission at different carrying capacity.

The determination of the scaling degree was carried out by a series of experiments showing the influence of the number of multicast group members on different scenarios, using 5 group senders and the constant junction's motion velocity is set to 10 m/s, meanwhile the number of the group members varied from 5 to 40.

The Packet Delivery Ratio at different Number of Group Members is shown in Fig. 9, we can see that any increase in the number of the group members would increases the packet delivery ratio. This is explained by the fact that, increasing the number of the group members would increase proportionally the number of forwarding junctions. This proves that the MODMRP has the good scaling property.

In Fig. 10, the overhead costs dependent of the number of the group members is presented. We can notice that the overhead costs would not increase much when increasing the number of the group members.

Finally, Fig. 11 shows the dependence transmission average delay vs. number of group members. It is clearly shown that an increase in the number of group members would increase the average delay proportionally. This can be explained by the appearance of conflicts during the packets transmission and by delays caused due to packets buffering at the junctions.

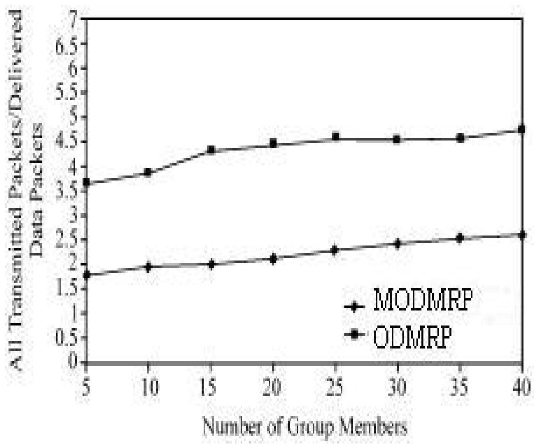

Fig.10. Transmitted Service Packets vs. Number of Group Members.

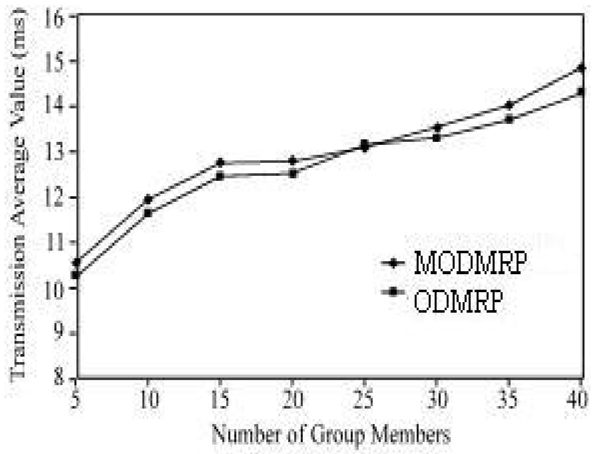

Fig. 11. Transmission Average Delay vs. Number of Group Members

The Packet Delivery Ratio at different Number of Group Members is shown in Fig. 9, we can see that any increase in the number of the group members would increases the packet delivery ratio. This is explained by the fact that, increasing the number of the group members would increase proportionally the number of forwarding junctions. This proves that the MODMRP has the good scaling property.

In Fig. 10, the overhead costs dependent of the number of the group members is presented. We can notice that the overhead costs would not increase much when increasing the number of the group members.

Finally, Fig. 11 shows the dependence transmission average delay vs. number of group members. It is clearly shown that an increase in the number of group members would increase the average delay proportionally. This can be explained by the appearance of conflicts during the packets transmission and by delays caused due to packets buffering at the junctions.

6. Conclusions and Future Work

This paper proposes and simulates a new Modified On-Demand Multicast Routing Protocol (MODMRP) for a mobile ad hoc wireless network based on ODMRP. Simulation results show that:

- There is an increase in the percentage of delivered multicast datagrams on average of 2% (average value equals 96%) comparing with ODMRP.
- The routing overhead costs decrease on average of 20.5%.

- The MODMRP will dynamically be adapted to the network mobility.
- At the low junction mobility (about 1-5 meters/second) the routing overhead costs decrease on average of 32%.
- Scalability to a large number of nodes.

The proposed MODMRP was tested on 50 mobile junctions. As a future work, a new multicasting routing protocol in which different mobile junctions are considered. To further investigate the optimality of the protocols, the experimental results of the two protocols will be compared.

References:

[1] S. H. Bae, S. J. Lee, W. Su, and M. Gerla. (2000). The Design, Implementation and Performance

Evaluation of the On-Demand Multicast Routing Protocol in Multihop Wireless Networks, IEEE Network Magazine, Vol. 14, No. 1, pp. 70-77.

[2] T. Ballardie, P. Francis and J. Crowcroft. (1993). Core Based Meshes (CBT) Architecture for Scalable Interdomain Multicast Routing, In SIGCOMM, pp.85-95.

[3] J. Broch, , D. A. Maltz, D. B. Johnson, Y. C. Hu, and J. Jetcheva. (1998). A Performance Comparison of Multi-Hop Wireless Ad-Hoc Network Routing Protocols, in Proc. of the 4th Annual ACM/IEEE International Conference on Mobile Computing and Networking (MOBICOM'98), USA, pp. 85-97.

[4] K. L. Calvert and E. W. Zegura. (1995). Core Selection Methods for Multicast Routing. Technical Report, GITCC-95/15.

[5] M. Chiang, M. Gerlar, and L. Zhang. (1998). Forwarding Group Multicast Protocol (FGMP) for Multihop, Mobile Wireless Networks, ACM/Baltzer Journal of Cluster Computing: Special issue on Mobile Computing, Vol. 1, No. 2, pp. 187- 196.

[6] S. E. Deering and D. R. Cheriton. (1990). Multicast Routing in Datagram Internetworks and Extended LANs, ACM Trans. On Computer System, 8(2), pp.85-111.

[7] S. Deering, D. Estrin, D. Farinacci, V. Jacobson, C. G. Liu and L. Wei. (1996). The PIM Architecture for Wide-Area Multicast Routing, IEEE/ACM Trans. on Networking, 4(2), pp. 153-162.

[8] J. J. Garcia-Luna-Aceves, and E. L. Madruga. (1999). The Core-Assisted Mesh Protocol, IEEE Journal on Selected Areas in Communications, Vol. 17, No. 8, pp. 1380-1394.

[9] S. J. Lee, M. Gerla, and C. Chiang. (1999). On-Demand Multicast Routing Protocol, In Proc. Of the IEEE Wireless Communications and Networking Conference, WCNC '99, pp. 1298-1304.

[10] S. J.Lee, W. Su, J. Hsu, M. Gerla, and R. Bagrodia. (2000). **A** Performance Comparison Study of ad-Hoc Wireless Multicast Protocols, in Proc. of 19th Annual Joint Conference of the IEEE Computer and Communications (INFOCOM'00), pp. 565-574.

[11] M. Lui, R. Talpade, A. McAuly, and E. Bommaiah. (1999). AMRoute: Ad-Hoc Multicast Routing Protocol, Center for Satellite and Hybrid Communication Networks. Technical Report: CSHCNT.R 99-1.

[12] K. Obraczka, G. Tsudik, and K. Viswanath.(2001). Pushing the Limits of Multicast in Ad-Hoc Networks, The 21st International Conference on Distributed Computing Systems (ICDCS'2001), USA, pp. 719-722.

[13] E. M. Royer and C. K. Toh. (1999). A Review of Current Routing Protocols for Ad-Hoc Mobile Wireless Networks, IEEE Personal Communications Magazine, pp. 46-55.

[14] K. Thomas, (2002). Multicasting: From Fixed Networks to Ad-Hoc Networks, In Handbook of Wireless Networks and Mobile Computing, I. Stojmenovic (Ed.), pp.495-507.

[15] F. Barsotti, A. Caruso, S. Chessa, The Localized Vehicular Multicast Middleware: a Framework for Ad Hoc Inter-Vehicles Multicast Communications, WSEAS Transaction on Communication, Issue 9, Volume 5, 2006, pp.1763-1768.

[16] L. Pomante, P. Di Felice, Ad-hoc HW/SW Architectures for DBMSs: a Co-Design Approach. Proc. of the 6th WSEAS Int. Conf. on Artificial Intelligence, Knowledge Engineering and Data Bases, Corfu Island, Greece, February 16-19, 2007. pp. 153-158.

[17] T. Shih and H. Yen, Location-Aware Cluster-Based Routing Protocol for Mobile Ad Hoc Networks, WSEAS Transaction on Communication, Issue 9, Volume 5, 2006, pp. 1711-1718.