Vasiliou, A. & Economides, A.A.: **Multicast groups in MANETs**. *WSEAS Transactions on Communications*, Issue 8, Vol. 4, pp. 686-693, August 2005.

Multicast groups in MANETs

ALEXANDROS VASILIOU AND ANASTASIOS A. ECONOMIDES
Information Systems Department
University of Macedonia
Egnatia 156 Thessaloniki,
GREECE
{avasil, economid}@uom.gr

Abstract: **MANETs (Mobile Ad-hoc Networks) consist of autonomous self-powered mobile nodes. The usual movement scenario is to consider that these mobile nodes move randomly in the area. In this paper, we investigate three different movement scenarios: i) Random movement, where the modes move randomly in the area, ii) Directed movement, where the nodes move towards the same direction, and iii) Directed II movement, where the nodes move towards the same direction, however they also form subgroups, and the subgroup leaders communicate among themselves. We also consider that each node either moves on foot or using a slow vehicle. In MANETs, the mobile nodes communicate among themselves either directly or via their intermediate nodes. When they need one-to-many or many-to-many communication, then a multicasting protocol is employed. In this paper, we compare two of the best multicasting protocols: i) MAODV (Multicast Ad-hoc On-demand Distance Vector Routing Protocol), and ii) ODMRP (On Demand Multicast Routing Protocol). We compare them with respect to their achieved PDR (Packet Delivery Ratio) and Latency. We investigate what network partitioning into sub-groups and for what conditions is more efficient.**

Key-Words: **MANET, MAODV, ODMRP, Multicasting, Ad hoc, Performance evaluation, Grouping, Partitioning.**

1. Introduction

MANETs have a wide range of applications such as rescue operations, disaster relief, education, and crowd control. In MANETs, the mobile nodes may be laptops, PDAs (Personal Digital Assistants), mobile phones, or pocket PC with wireless connectivity. Every node acts as a sender, as a receiver and as a router at the same time. If two nodes are in the transmission range of each other then they can communicate directly. Otherwise, they reach each other via a multi-hop route. Each node may forward packets for other nodes. Since the nodes move unpredictably, the network topology is continuously changing. In addition, the nodes have limited battery life and storage capacity. Finally, the communication links are bandwidth constrained. Therefore, efficient multicasting in MANETs is extremely difficult. Multicast is the transmission of data in a group of nodes which is recognized by one and unique address [1]. Groups exist in most MANETs scenarios and the use of multicast, rather unicast reduces the bandwidth and energy cost, and the end-to-end delay [2]. However, multicasting in MANETs is an extremely challenging problem.

Two main categories of multicasting protocols are used in MANETs. Tree-based protocols, where MAODV seems to be the most discussed tree-based protocol [3], and mesh based protocols, where ODMRP is considered to be the best mesh-based protocol [4]. A hybrid category is also discussed in [5]. Technologies such as GPS (Global Position System) can be used to predict the node movement and provide universal timing. Previous studies evaluate the MAODV and ODMRP with respect to the network traffic, the node speed, the area and the antenna range for random node movement [6]. A recent paper partitions the nodes into subgroups and investigates the performance of the ODMRP with respect to the antenna range, area, speed and directionality [7]. In this paper we compare the MAODV and ODMRP protocols in various conditions. In many applications there is the need for the member nodes to be separated in groups. The first goal of this paper is to investigate how the MANET multicast protocols react with respect to the number of groups. Also, we diversify the way that the nodes move in the area. We examine three different movement variations. In the first one, named “RANDOM”, all the nodes move unpredictably. In the second, named “DIRECTED”, the nodes move randomly but in the same direction. For example, all the nodes move from y(0, 0) to y(0, 2000) with random speeds. The third, named “DIRECTED II”, is almost the same as the “DIRECTED” movement. In the “DIRECTED” movement, the groups are independent from each other. In the “DIRECTED II” movement, all the group leaders are connected among themselves. Thus, another group consisting of the sub-group leaders is created. For example, in a rescue operation the different rescue groups must be connected to each other. If we let the rescuers move freely then we have “RANDOM” movement. If all the rescuers move in the same direction, scanning an area, then we have “DIRECTED” movement. If the leaders of the rescue groups want to communicate to each other, then we use “DIRECTED II” movement. Two different speeds are also examined in the experiments: i) 1 m/s (average walking speed) and ii) 10 m/s (a slow vehicle). The performance of the two protocols is also examined with respect to the node speed. In chapter 5 we investigate farther the ODMRP protocol examining how the protocol reacts when the traffic become heavier (CBR 10kbytes/s).

2. MANET multicast protocols

2.1 MAODV

MAODV is the multicast extension of the AODV protocol. It is an On-Demand protocol, so it discovers the routes only when it has something to send. It is a hard state protocol, so if a member node of a multicast group wants to terminate its group membership, it must ask for it. When a mobile node wants to join a multicast group or wants to send a message but does not have a route to the group, a Route Request (RREQ) is originated. MAODV is a tree based protocol. All the nodes that are members of a multicast group together with the nodes that are not members of the group but their position are very critical for forwarding the multicast information, compose the tree structure. Every multicast group is identified by a unique address and group sequence numbers for tracing the freshness of the group situation. When a node sends a not join RREQ any node with fresh enough route (based on group sequence number) to the multicast group may respond. If the message is a join RREQ then only member nodes of the multicast group can answer. If a node wants to be member of a multicast group that does not exists, then this node is becoming the leader of that multicast group and is responsible for maintaining the multicast group. This is established through a Group Hello message. Nodes use the Group Hello information to update their request table. A node keeps not only the unicast routing table but also a multicast routing table for the group tree structure. This table contains the multicast group address, the multicast group leader address, the multicast group sequence number, hop count to the multicast group leader next hop information and the lifetime**.** Nodes in a tree structure are described as downstream and upstream nodes. A downstream node is a neighborhood node which is further from the group leader (more hop counts from the group leader). An upstream node is a neighborhood node which is nearer to the group leader (less hop counts from the group leader). It is obvious that a group leader has only downstream nodes. When a node leaves the multicast group, the tree structure needs pruning. When a link breaks, the most downstream node is responsible for repairing the breakage [2], [3], [9], [10], [11].

2.2 ODMRP

ODMRP is also an On-Demand protocol. It is a mesh architecture protocol, so it has multiple paths from the sender to the receivers, contrary to the MAODV which is a tree based protocol and has only one path to the receivers. When a node has information to send but no route to the destination, a Join Query message is broadcasted. The next node that receives the Join Query updates its routing table with the appropriate node id from which the message was received for the reverse path back to the sender (backward learning). Then the node checks the value of the TTL (time to live) and if this value is greater than zero it rebroadcasts the Join Query. When a multicast group member node receives a Join Query, it broadcasts a Join Reply message. A neighborhood node that receives a Join Reply consults the join reply table to see if its node id is the same with any next hop node id. If it is the same then the node understands that it is on the path to the source and sets the FG_FLAG (Forwarding Group flag). ODMRP is a soft state protocol, so when a node wants to leave the multicast group it is over passing the group maintaining messages [2], [4], [9], [10], and [12].

3. Simulation scenarios

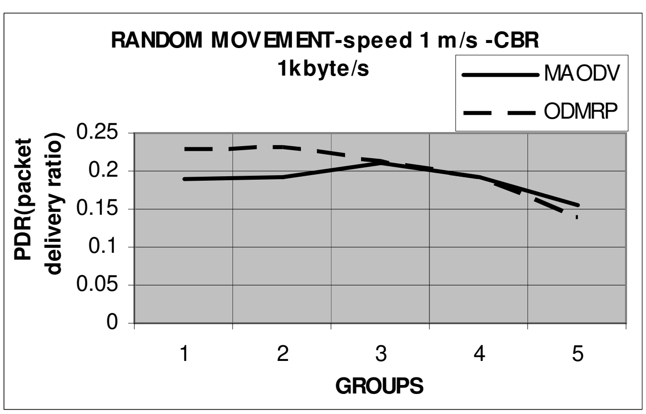
We use the NS-2 simulator with the MAODV implementation for ns-2.26 [13] and the monarch project [14] for simulating the ODMRP protocol. We measure the PDR (Packet Delivery Ratio) and the Latency for the two protocols. PDR is the ratio of the number of packets sent to the number of packets received and shows the reliability of the protocol. Latency is the average end-to-end packet delay. We have tested the credibility of our NS-2 simulator by running the same experiments as other researchers and validated the results. Finding the same results confirms that our simulation is correctly implemented, and that the results of our experiments will be accurate. We choose the NS-2 simulator, because it is freeware and many experiments show that NS-2 produces similar results to another well known simulator, the OPNET modeler [15].

Number of nodes	60
Number of groups	1, 2, 3, 4, 5
Movement scenario	Random, Directed, Directed II
Area	2000 m * 2000 m
Speed	1 m/s or 10 m/s
CBR	1 kbyte/s
Simulation time	900 seconds

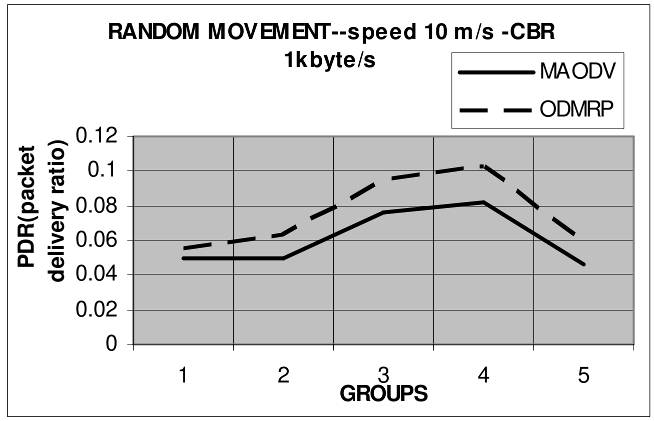
Table1. Simulation parameters

4. Simulation Results

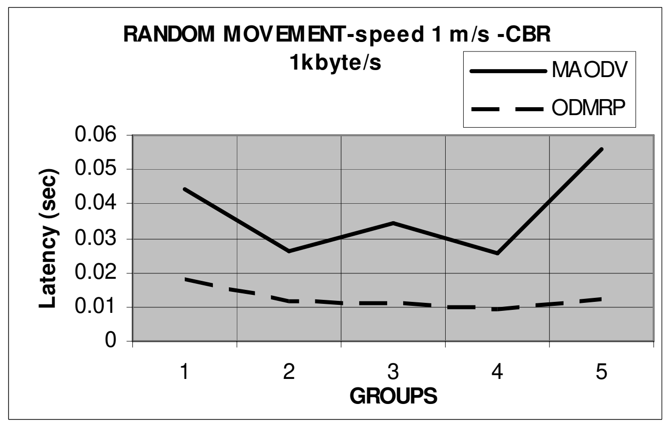
4.1 Random Movement results



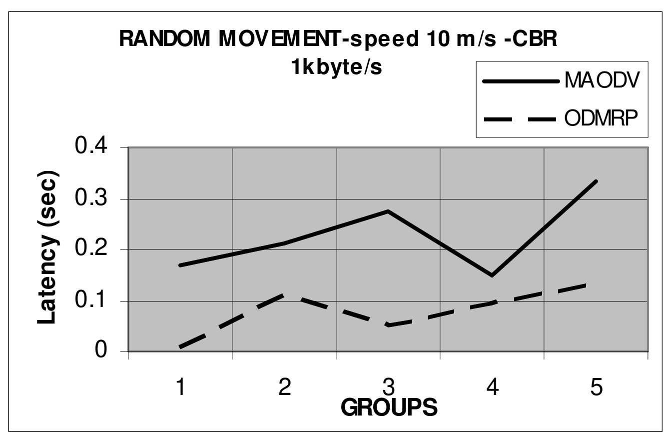
Graph 1. PDR versus number of groups with random movement and 1 m/s speed



Graph 2. PDR versus number of groups with random movement and 10 m/s speed



Graph 3. Latency versus number of groups with random movement and 1 m/s speed

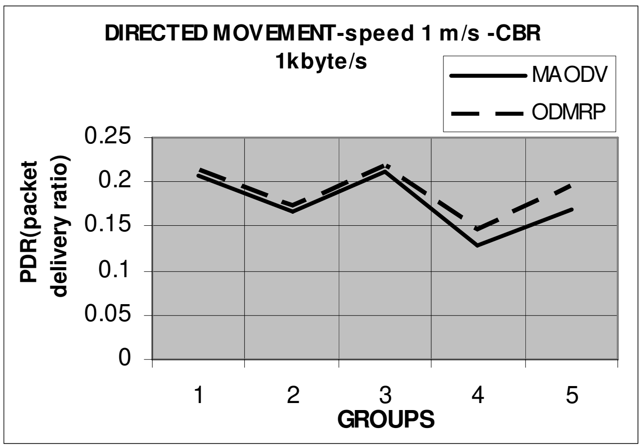


Graph 4. Latency versus number of groups with random movement and 1 m/s speed

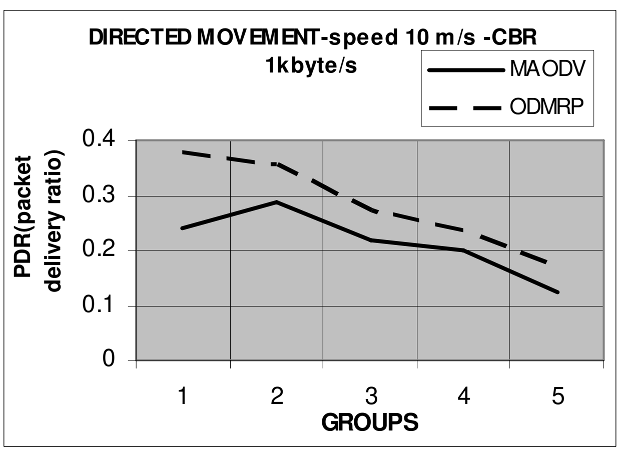
Graph 1 and Graph 2 show the PDR values for various numbers of groups. When the node speed is 1 m/s, the ODMRP achieves the best PDR value for 2 groups. When the node speed is 10 m/s, the ODMRP clearly outperforms the MAODV, achieving the best PDR value for 4 groups.

Graph 3 and Graph 4 show the latency values for various numbers of groups. The ODMRP clearly outperforms the MAODV. When the node speed is 1m/s, it achieves the lowest latency value for 4 groups. When the node speed is 10 m/s, it achieves the lowest latency value for 1 group.

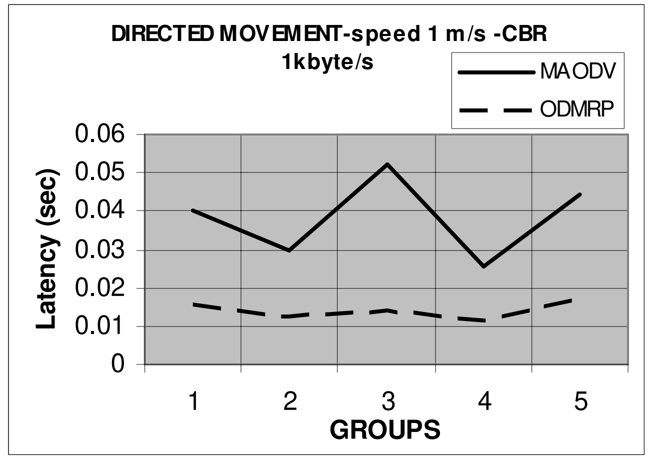
4.2 Directed Movement results



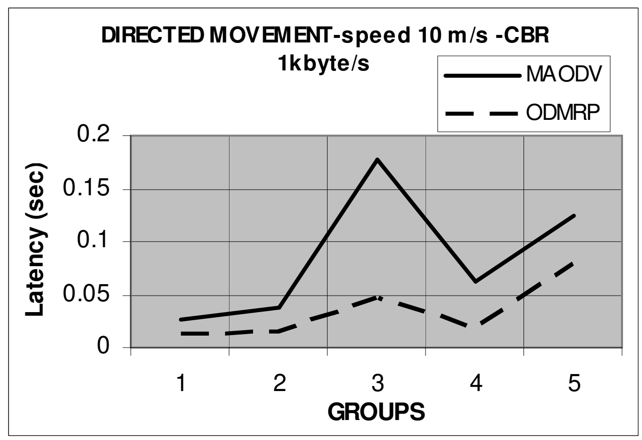
Graph 5. PDR versus number of groups with directed movement and 1 m/s speed



Graph 6. PDR versus number of groups with directed movement and 10 m/s speed



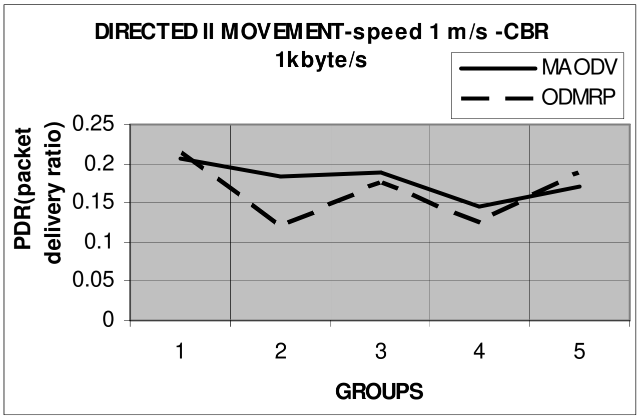
Graph 7. Latency versus number of groups with directed movement and 1 m/s speed



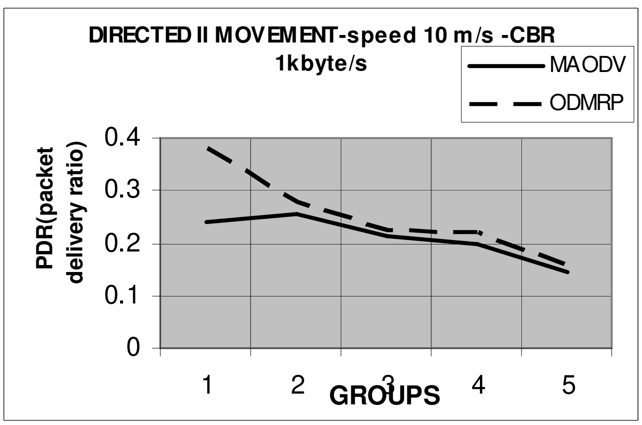
Graph 8. Latency versus number of groups with directed movement and 10 m/s speed

Graphs 5, 6, 7, and 8, show that the ODMRP clearly outperforms the MAODV when the nodes move along a direction. When the nodes move with speed=1 m/s, both protocols achieve their best PDR value for 1 and 3 groups. When the node speed increases to 10 m/s, the ODMRP superiority is even more clear (Graph 6). The ODMRP achieves the best PDR value for 1 group, while the MAODV for 2 groups. The ODMRP achieves the best latency for 2 and 4 groups (Graphs 7 and 8).

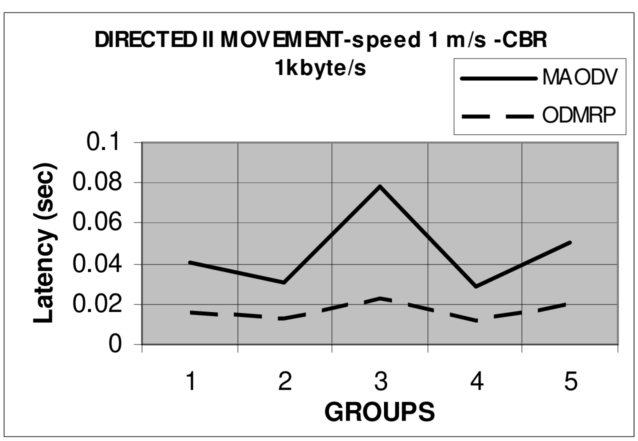
4.3 Directed II Movement results



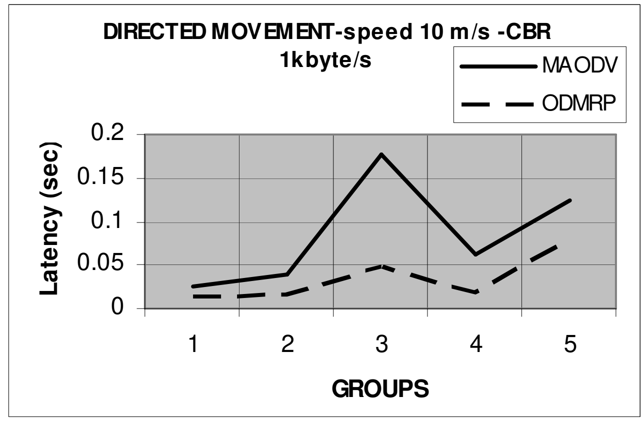
Graph 9. PDR versus number of groups with directed II movement and 1 m/s speed



Graph 10. PDR versus number of groups with directed II movement and 10 m/s speed



Graph 11. Latency versus number of groups with directed II movement and 1 m/s speed



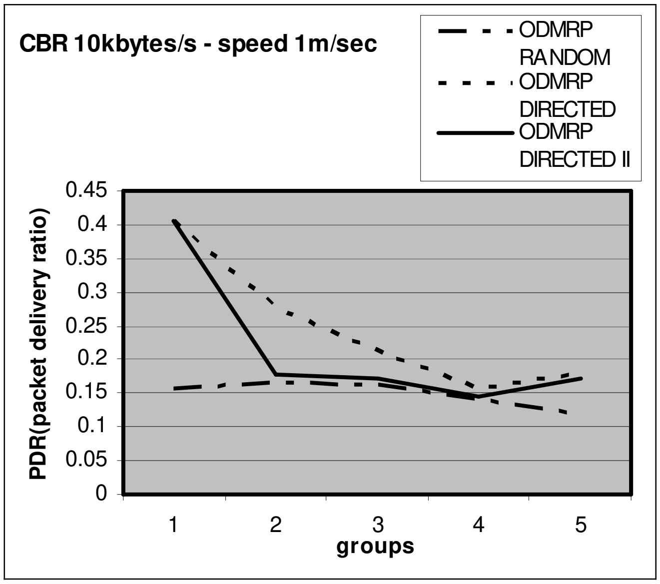
Graph 12. Latency versus number of groups with directed II movement and 10 m/s speed

In these last experiments (Graphs 9, 10, 11 and 12), the nodes move with directed II movement. The ODMRP outperforms the MAODV in all cases, except the following: the MAODV achieves better PDR than the ODMRP only when the nodes move with speed=1 m/s for 2, 3 and 4 groups (Graph 9). The ODMRP achieves its best PDR for 1 group (Graph 9, and 10). The MAODV achieves its best PDR for 1 group when the speed is 1 m/sec (Graph 9) and for 2 groups when the speed is10 m/sec (Graph 10).

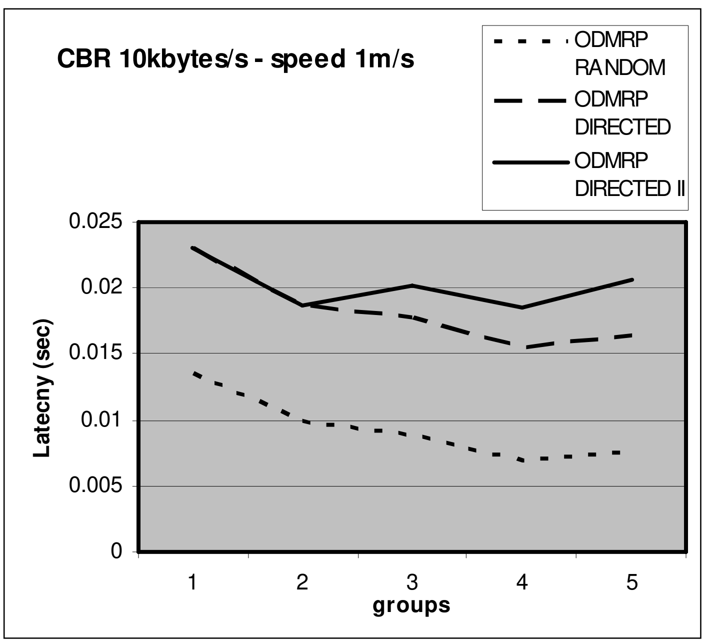
Both protocols achieve their best latency for 2 groups (Graph 11) when the node speed is 1 m/s, and for 1 group when the node speed is 10 m/s.

5. Heavier traffic for the ODMRP protocol

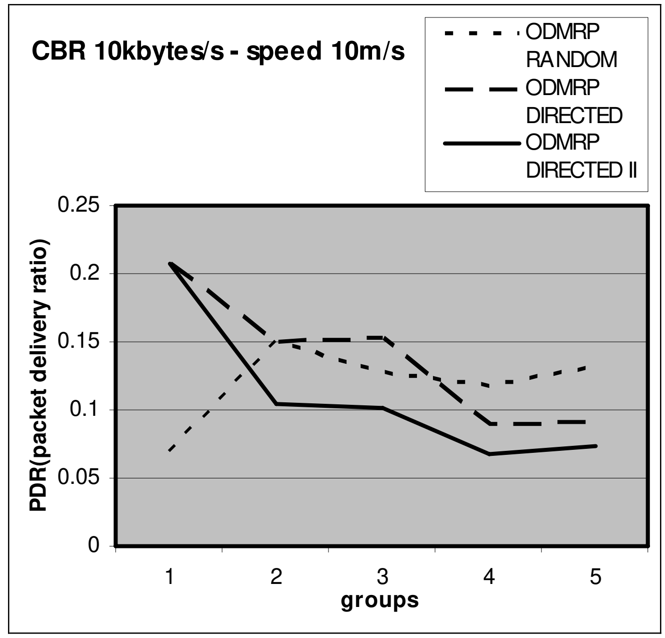
As we observe in most graphs, the ODMRP protocol seems to be the best protocol. In this section, we investigate how the ODMRP protocol reacts when the traffic becomes heavier. We use traffic CBR 10 kbytes/sec.



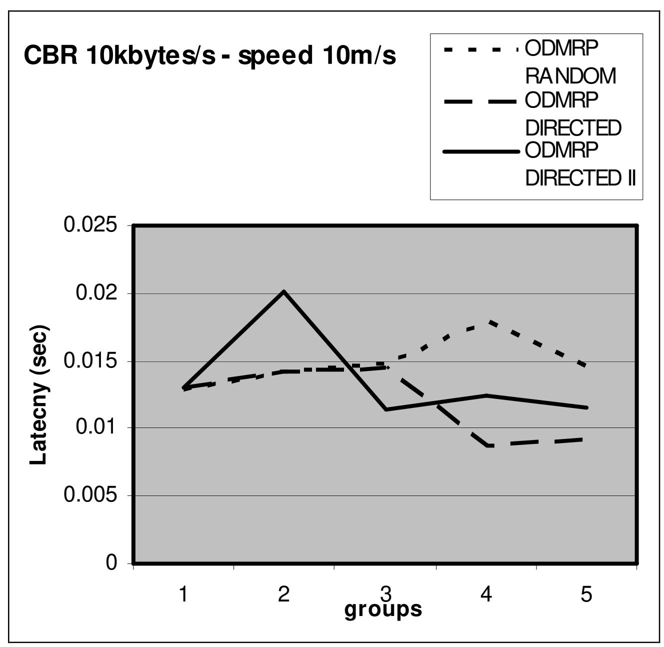
Graph 13. PDR versus number of groups for all movements with CBR 10 kbytes/s, speed 1m/s for the ODMRP protocol



Graph 14. Latency versus number of groups for all movements with CBR 10 kbytes/s, speed 1m/s for the ODMRP protocol



Graph 15. PDR versus number of groups for all movements with CBR 10kbytes/s, speed 10 m/s for the ODMRP protocol



Graph 16. Latency versus number of groups for all movements with CBR 10 kbytes/s, speed 1m/s for the ODMRP protocol

Increasing the CBR traffic to 10 kbytes/s, we investigate farther the ODMRP protocol. When the tnode speed is 1 m/s (Graph 13), the Random movement shows the worst PDR values. The best PDR value is achieved for all movements when we use 1 group.

In Graph 14, we observe that the Random movement shows the best Latency values in all groups partitioning. The best Latency values are achieved for all movements when we use 4 groups.

Using CBR 10 kbytes/s and speed 10 m/sec we see in Graph 15 that the Directed and Directed II movements achieve similar results, and the Directed movement having better results. Both movements achieve their best PDR value for 1 group. The Random movement achieves the best PDR value for 2 groups.

In Graph 16, we observe that the Latency in the various movement scenarios behaves differently. The Random movement achieves the best Latency value for 4 groups, the Directed movement for 3 groups, and the Directed II movement for 2 groups.

6. Conclusions

The main aim of this paper is to discover what network partitioning could be more efficient. In almost all the simulated experiments the ODMRP outperforms. However, both protocols show very poor PDR values. If the PDR is the most important parameter and the MANET uses the MAODV protocol, then for node moving on foot (speed= 1 m/s) the best node partitioning is to have 1 or 3 groups. If the latency is the most important parameter, then it is better to partition the network into 4 groups. If the network uses the MAODV and the nodes move randomly with speed=10 m/sec, then partitioning the network into 4 groups achieves the best PDR and latency values. If the nodes move along a direction, then 2 groups achieve the best PDR while 1 group achieves the best latency. If the network uses the ODMRP, the simulations do not clearly show what is the best network partitioning. However, we observe that it achieves almost the best values in all experiment with 1 group. This is especially true when the nodes move along a direction. In random movement, things are more indefinable. When the node speed is 1 m/s, the MAODV and the ODMRP achieve similar PDR and latency values in all movement scenarios. When the node speed is 10m/sec, the directed movement achieves 250% to 500% and more, better values. A representative example is for the ODMRP with speed=10 m/sec and 1 group. When the nodes move randomly the PDR value is 0.055, and when they move along a direction the PDR value is 0.379, 600% up.

References:

1. A.A. Baziakos, and A.A. Economides, “Multicast routing algorithms: a survey”, Proceedings ICT ’98, International Conference on Telecommunications, pp. 476-480, 1998.
2. P. Mohapatra, J. Li, and C. Gui “ Multicasting in Ad Hoc Networks”, book chapter, Kluwer Press, 2004.
3. Elizabeth M. Royer , and Charles E. Perkins, “Multicast Operation of the Ad-hoc On-demand Distance Vector Routing Protocol”, Proceedings of MobiCom '99, Seattle, WA, August 1999, pp. 207-218.
4. S.-J. Lee, M. Gerla, and C.-C. Chiang, ”On-demand multicast routing protocol” Proceedings of IEEE WCNC, 1999, pp. 1298-1302.
5. C.Chiang, M.Gerla, and L.Zhang “ Adaptive shared tree multicast in mobile wireless networks” Proceedings of IEEE Globecom '98, pp. 1817-1822.
6. A. Vasiliou, and A.A. Economides, “Evaluation of Multicasting algorithms in MANETs”, Proceedings 3rd World Enformatika Conference (WEC’05)- International Conference on Telecommunications and Electronic Commerce (TEC 2005), 2005.
7. A. Vasiliou, and A.A. Economides, “Performance of multicast groups moving towards the same direction”, Proceedings Annual Conference on Telecommunications & Multimedia, TEMU 2005.
8. X. Hong, K. Xu, and M. Gerla, "Scalable Routing Protocols for Mobile Ad Hoc Networks", IEEE Network, July-Aug, 2002, pp. 11-21.
9. Thomas Kunz, and Ed Cheng “Multicasting in Ad-Hoc Networks: Comparing MAODV and ODMRP“, Proceedings of the Workshop on Ad hoc Communications, Bonn, Germany, September 2001.
10. D.Lundberg, “ Ad Hoc Protocol Evaluation and Experiences of real world Ad Hoc networking” Uppsala University Department of Information Technology , technical report 2004-026, June 2004.
11. Thomas Kunz, “Reliable Multicasting in MANETs”, Contractor Report, Communications Research Centre, Ottawa, Canada, July 2003.
12. R. Bagrodia, M. Gerla, J. Hsu, W. Su, and S.-J. Lee, “A performance comparison study of ad hoc wireless multicast protocols”, Proc. of the 19th Annual Joint Conf. of the IEEE Computer

and Communications Societies, March 2000, pp. 565 –574.

13. Y.Zhu and T.Kunz " MAODV Implementation for NS-2.26 " Systems and Computing Engineering, Carleton University, Technical Report SCE-04-01, January 2004.
14. The Rice University Monarch Project "Wireless Multicast Extensions for ns-2.1b8"
15. Gilberto Flores Lucio, Marcos Paredes-Farrera, Emmanuel Jammeh, Martin Fleury, Martin J. Reed. "OPNET Modeler and Ns-2: Comparing the Accuracy of Network Simulators for Packet-Level Analysis using a Network Testbed" WSEAS Transactions on Computers, No.3, Vol. 2, July 2003, ISSN 1109-2750 , pp. 700-707.

Alex Vasiliou was born in Thessaloniki. He received his Diploma Degree in Electronic Engineering from the Technological Educational Institute of Thessaloniki, in 2002, and his M.Sc. in Information Systems from the University of Macedonia, Thessaloniki, in 2004. His research interests are in the area of Mobile Networks and Tele-education.

Dr. Anastasios A. Economides was born and grew up in Thessaloniki, Greece. He received the Diploma degree in Electrical Engineering from Aristotle University of Thessaloniki, in 1984. Holding a Fulbright and a Greek State Fellowship, he received a M.Sc. and a Ph.D. degree in Computer Engineering from the University of Southern California, Los Angeles, in 1987 and 1990, respectively. He is currently an Ass. Professor of Computer Networks and Vice-Chairman in the Information Systems Postgraduate Program at the University of Macedonia, Thessaloniki, Greece. He is the Director of CONTA (Computer Networks and Telematics Applications) Laboratory. His research interests are in the area of Mobile Networks and Tele-education.