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Partitioning Multicast MANETs

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Abstract: MANETs (Mobile Ad-hoc Networks) are autonomous networks operating either in isolation or as stub networks connected to a fixed network. They do not necessarily rely on existing infrastructures. When the mobile nodes need one-to-many or many-to-many communication then multicasting is employed. Two of the best multicast protocols, MAODV (Multicast Ad-hoc On-demand Distance Vector Routing Protocol) and ODMRP (On Demand Multicast Routing Protocol), are compared. The performance measures to be evaluated are the PDR (Packet Delivery Ratio) and the Latency. This paper investigates two problems: i) does nodes partitioning into sub-groups improve performance? and ii) what is the best number of sub-groups? Three different movement scenarios are examined: i) Random movement, where all nodes move unpredictably in the area, ii) Directed movement, where the nodes move freely along the x-axis but directionally from y(0, 0) to y(0, 2000) along the y-axis, and iii) Directed II, where the nodes move as in the Directed movement and the subgroup leaders communicate with each other. Two different speed values are also examined: i) 1 m/s (average walking speed), and ii) 10 m/s (slow vehicle speed).

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 from 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.

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.

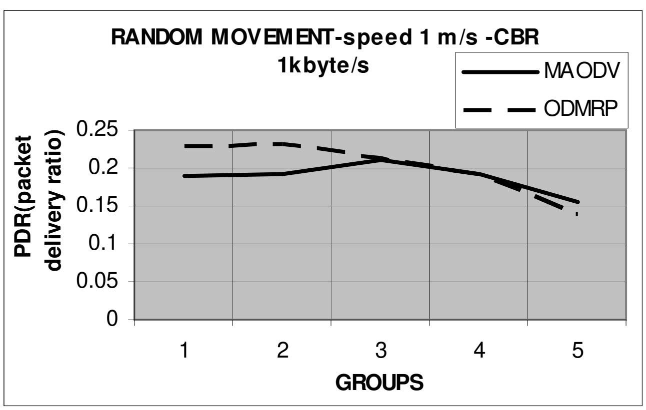
Latency is the average end-to-end packet delay. We have tested the credibility of our NS-2 simulator by running the same experiments as other researchers and validated the results. Finding the same results confirms that our simulation is correctly implemented, and that the results of our experiments 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

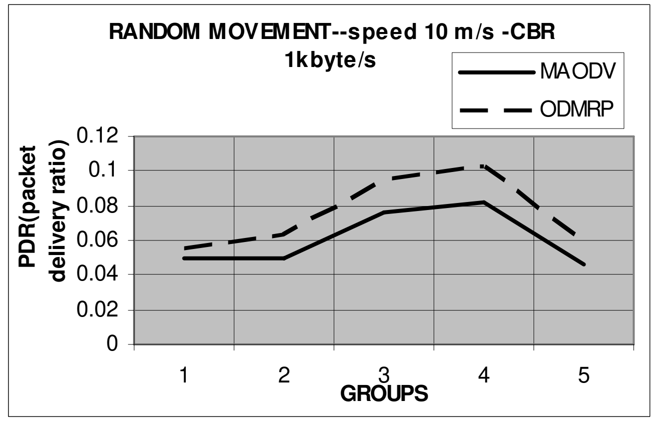
Table1. Simulation parameters

4. Simulation Results

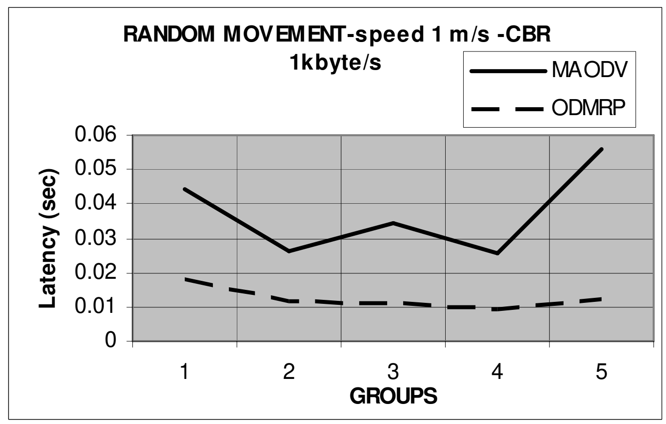
4.1 Random Movement results



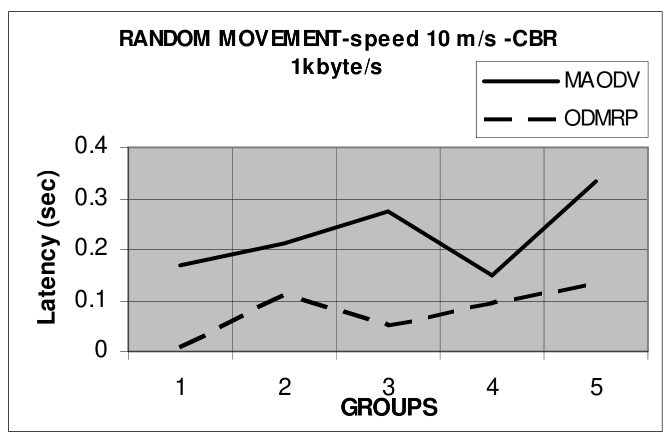
Graph 1. PDR versus number of groups with random movement and 1 m/s speed



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

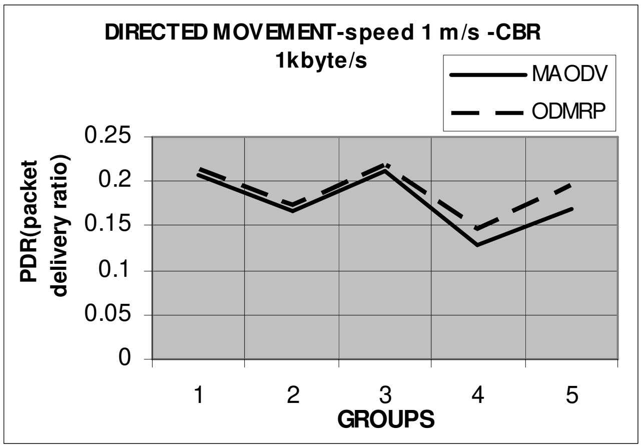


Graph 4. Latency versus number of groups with random movement and 1 m/s speed

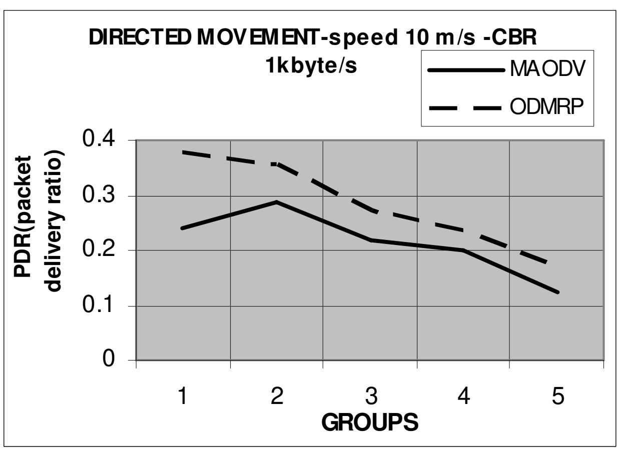
Graph 1 and Graph 2 show the PDR values for various numbers of groups. When the node speed is 1 m/s, the ODMRP achieves the best PDR value for 2 groups. When the node speed is 10 m/s, the ODMRP clearly outperforms the MAODV, achieving the best PDR value for 4 groups.

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.

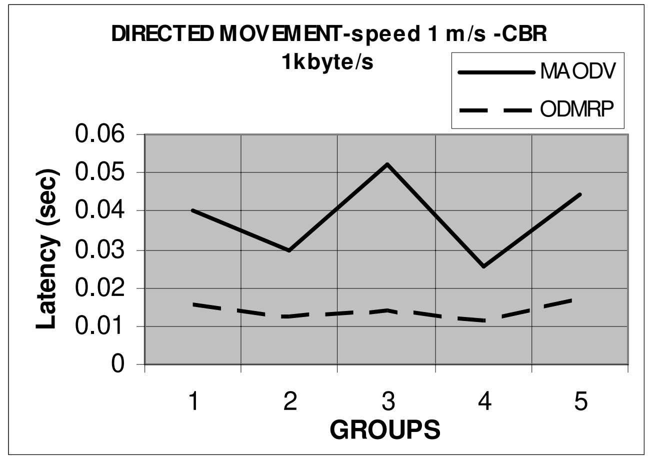
4.2 Directed Movement results



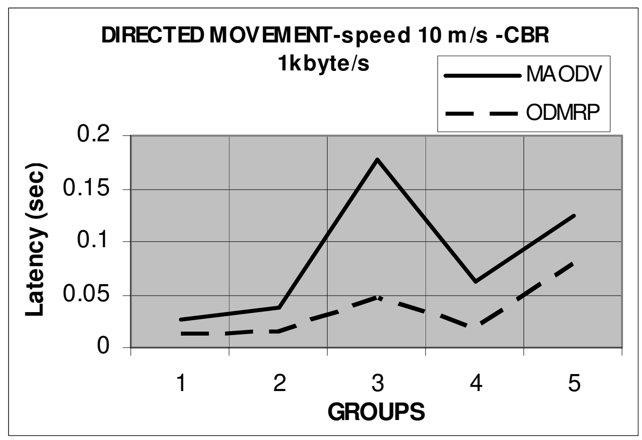
Graph 5. PDR versus number of groups with directed movement and 1 m/s speed



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



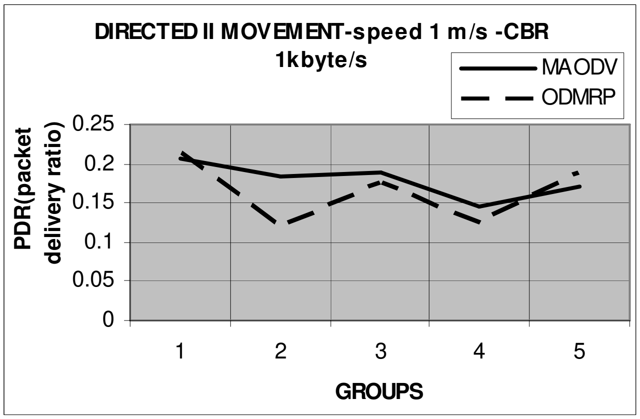
Graph 7. Latency versus number of groups with directed movement and 1 m/s speed



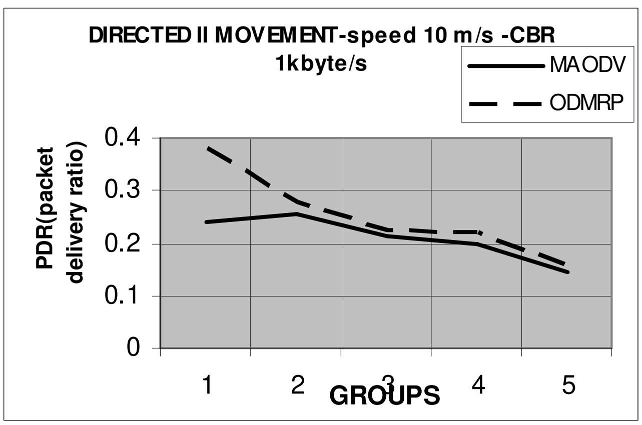
Graph 8. Latency versus number of groups with directed movement and 10 m/s speed

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).

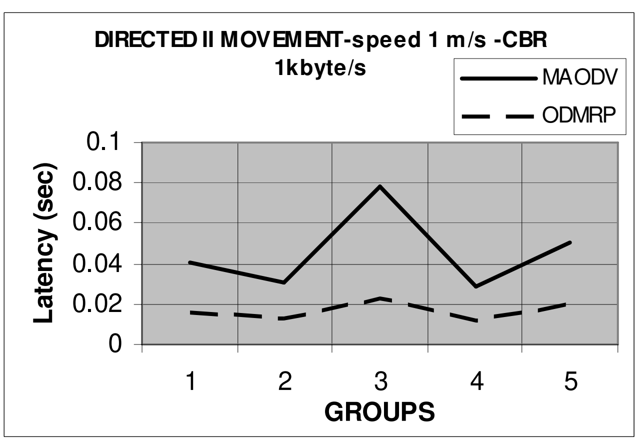
4.3 Directed II Movement results



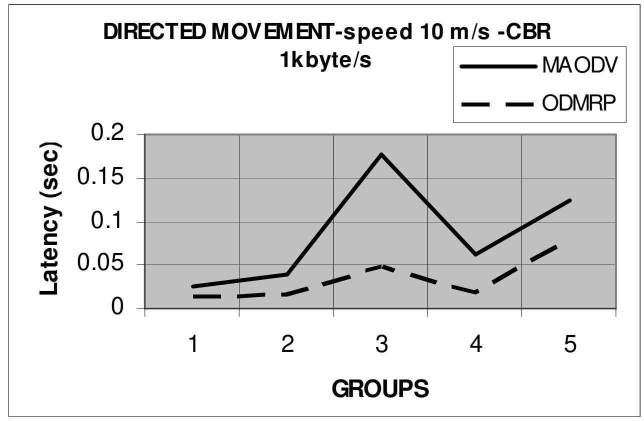
Graph 9. PDR versus number of groups with directed II movement and 1 m/s speed



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. 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.

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