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Scalable Multiple Team Cooperation using MANET Multicasting

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Abstract:

This paper investigates the scalability and communication among multiple rescue teams. A number of rescuers have to scan an area for airplane crash survivors. The rescuers are divided into a number of teams. Each team has to scan a specific sub-area. A commander coordinates the leaders of the teams and each team leader coordinates the members of his team. Thus, there is localization of communication inside each team. A MANET (Mobile Ad Hoc Network) is deployed in the area and multicasting is used to support the coordination and communication. The PDR (Packet Delivery Ratio) and the Latency of two multicast protocols are measured via simulation with respect to the number of teams, the rescuers' speed and the antenna range. The ODMRP protocol is better. For the given scenario of 120 rescuers scanning an area of 4Km * 3Km, it is preferable to create 4 teams. Each team is composed from 30 rescuers and scans a sub-area of 2Km *1.5Km. The rescuers may use antenna range of 500m.

Keywords:

Collaboration, Cooperation, Emergency, Group Communication, Localized Communication, Mobile Ad Hoc Networks, Multicasting, Rescue, Scalability, Team Communication.

1. Introduction

Wireless technology can offer communication in rural areas without fixed wired communication infrastructure. However, there are still some remote and isolated areas without even the simple infrastructure of a wireless network antenna. In these desert and wilderness areas there are emergency cases where the need for communication is urgent and very important. For example, several rescue teams are scanning a sierra forest to find survivors from a plain crash. It is obvious that in this scenario, no antenna could be found in this backwater area. It is crucial for the members of such teams, to communicate and coordinate among themselves without the need of pre-existing infrastructure. Mobile Ad Hoc Networks (MANETs) can support their communication needs.

MANETs are self organizing networks. They compose an autonomous self-sufficient network of mobile hosts connected by wireless links. Their most important advantage is that they do not depend on pre-installed infrastructure, such as base stations. This is implemented by giving a triple role to every mobile node. Each mobile node is acting as a sender, as a router, and as a receiver.

If two nodes want to communicate with each other and they are in transmission range, then they communicate directly. If they cannot communicate directly, then they communicate using other stations as intermediate nodes to forward their packets (multihop communication).

MANETs can be deployed in several applications:

- Military operations (battlefields, maneuvers)
- Disaster relieves (rescue teams, special forces, fire fighters)
- Personal areas networking
- Traffic control
- Mobile learning

However, MANETs have serious constrains too. Because the nodes are moving randomly, the topology of the network is changing unpredictably. In a given moment two nodes can communicate with each other, but after a while this communication is lost because the route between them has been broken. A very clever algorithm is necessary to discover new routes. A power limit constrain exists too, because all the nodes are using mobile devices (laptops, PDA, cell phones) with limited battery lifetime. There is also a bandwidth limit, because wireless channels have less bandwidth than wired ones.

In this paper, we consider several rescue teams that scan a forest to find survivors from an airplane crash. The leader of each team needs to coordinate the members of his team and all team members need to communicate among themselves. Also, all leaders need to communicate among themselves. These communication needs may be supported by multicasting protocols. In MANET multicasting protocols, there are two basic architectures for building the routes between the nodes; tree architecture and mesh architecture. In both architectures, the mobile nodes have localized information and are interested only for their neighborhood nodes ignoring the total network topology. In this paper we evaluate two of the most discussed MANET multicast protocols in the rescue scenario. MAODV [Mohapatra et al , 2004], [Royer - Perkins , 1999], [Kunz - Cheng , 2001], [Lundberg, 2004], [Kunz , 2003] with tree based architecture and ODMRP [Mohapatra et al , 2004], [Lee et al , 1999], [Kunz - Cheng , 2001], [Lundberg, 2004], [Bagrodia et al , 2000] a protocol based in mesh architecture.

This paper is very near to a real scenario of a rescue procedure. Each rescue team is moving randomly in a specific sub-area that was assigned to that team. Splitting the area in local sub areas where groups are moving, we try to find with how many sub-areas we succeed better performances. To our knowledge, this is the first paper that investigates the performance of MANET multicasting protocols, where multiple multicast groups are covering an area and each multicast group is moving locally in its sub-area.

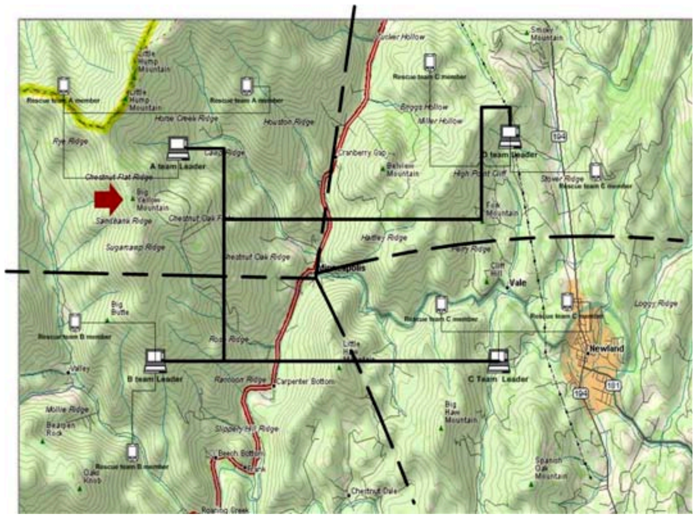


Figure 1. Plan of a rescue operation with 4 rescue teams (Location Near Elk Park North Carolina).

The rest of the paper is organized as follows In section 2, we describe the realistic scenario of a rescue operation. In section 3, we present the results of the experiments, and in section 4 we draw conclusions.

2. Rescue operation scenario

In this section, we describe a rescue operation. An airplane crashes in a forest area and a rescue team is ready to scan the area for any survivors. The rescue team is composed from 120 persons with their supplies. In order to be more effective, we split the area in some sub-areas. We also split the rescuers into teams. The number of the teams is the same with the number of the sub-areas. Every team has a leader that is also the sender of the multicast packets. All the leaders join the leaders' team, with the leader of the first group as the commander of the rescue operation.

The goal of our experiments is to find out the number of teams that will achieve better communication performance. We measure the PDR (packet delivery ratio) which represent the communication's reliability. PDR is the percentage from the send messages that are actually delivered. We also measure the Latency that is the average time a message takes to arrive at its destination. It is a measure of the amount of time between the send of a packet and its reception.

We evaluate the two multicasting protocols with 2 teams (and the leaders' team), 4 teams (and the leaders' team), and 6 teams (and the leaders' team). The total area is 4000m * 3000m. When there are 2 teams, every team is moving in a 2000m*3000m sub-area. When there are 4 teams, every team is moving in a 2000m*1500m sub-area. When there are 6 teams, every team is moving in a 2000m*1000m sub-area.

We also investigate various antenna ranges: 250m, 500m, 1000m. Finally, we investigate various moving speeds: 1m/sec, 10m/sec, 15m/sec. In every team only the leader may multicast messages. The following Tables 1, 2, and 3 show the parameters of the simulations.

Number of nodes	120
Number of teams	2 (and the leader team)
Nodes/team	60
Sub-area	2000m*3000m
Speed	1m/sec, 10m/sec, 15m/sec

Table 1. Simulation parameters for 2-teams scenario.

Number of nodes	120
Number of teams	4 (and the leader team)
Nodes/team	30
Sub-area	2000m*1500m
Speed	1m/sec, 10m/sec, 15m/sec

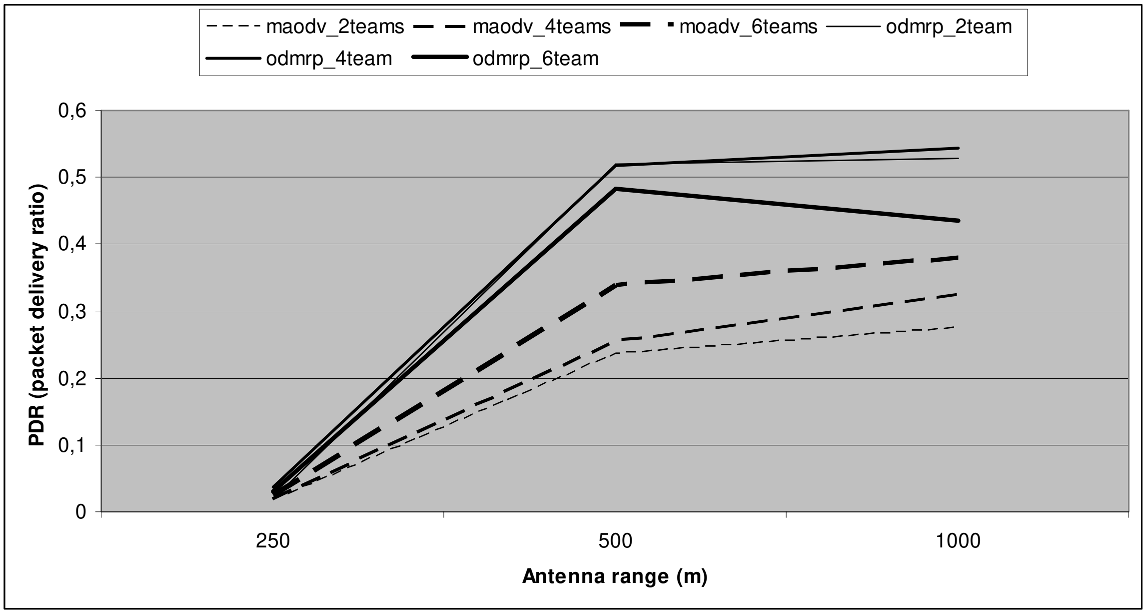
Table 2. Simulation parameters for 4-teams scenario.

Number of nodes	120
Number of teams	6 (and the leader team)
Nodes/team	20
Sub-area	2000m*1000m
Speed	1m/sec, 10m/sec, 15m/sec

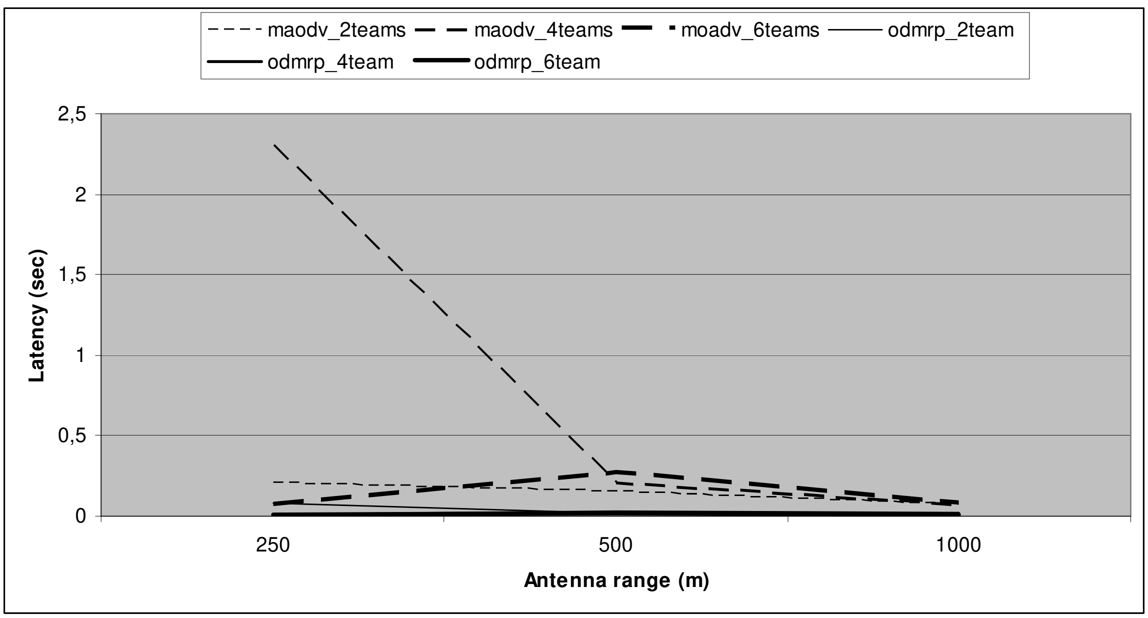
Table 3. Simulation parameters for 6-teams scenario

3. Simulation Results

We use the Ns-2 simulator with Monarch multicast extensions for the ODMRP protocol [monarch project], and the Ns MAODV implementation by Zhu and Kunz [2004]. We run the experiments many times for 180 seconds and present the average values.



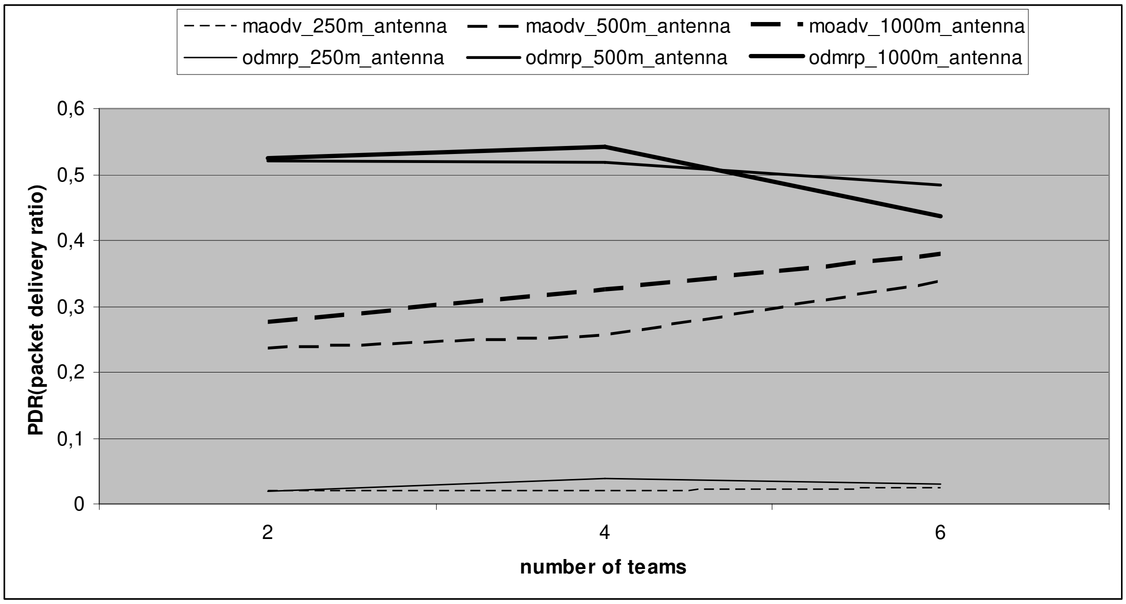
Graph 1.PDR versus antenna range with various numbers of teams and speed 1m/sec



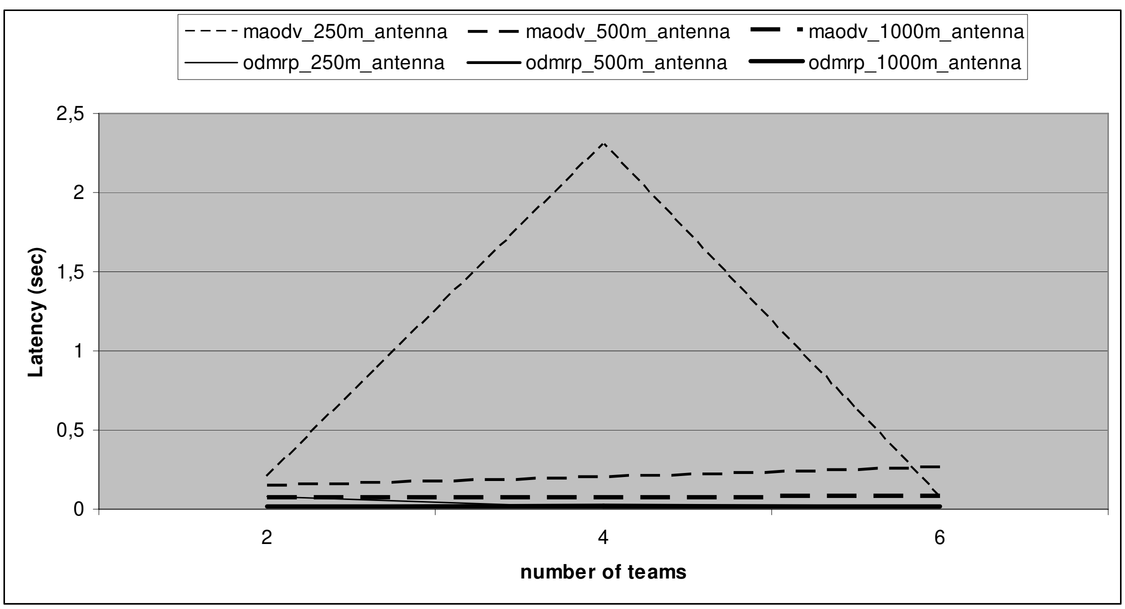
Graph 2.Latency versus antenna range with various numbers of teams and speed 1m/sec

In Graph 1 we measure the PDR with respect to the antenna range. When the antenna range is 250m, the PDR values are very low. In all the experiments, the ODMRP outperforms the MAODV protocol. As we observe from the graph 500m antenna range and 1000m antenna range have minor difference in their values. Considering that as the antenna range grows battery consumption raise too, we choose 500m antenna range as the best choice to our experiments.

In Graph2, we measure the latency with respect to the antenna range. Again, ODMRP performs better.



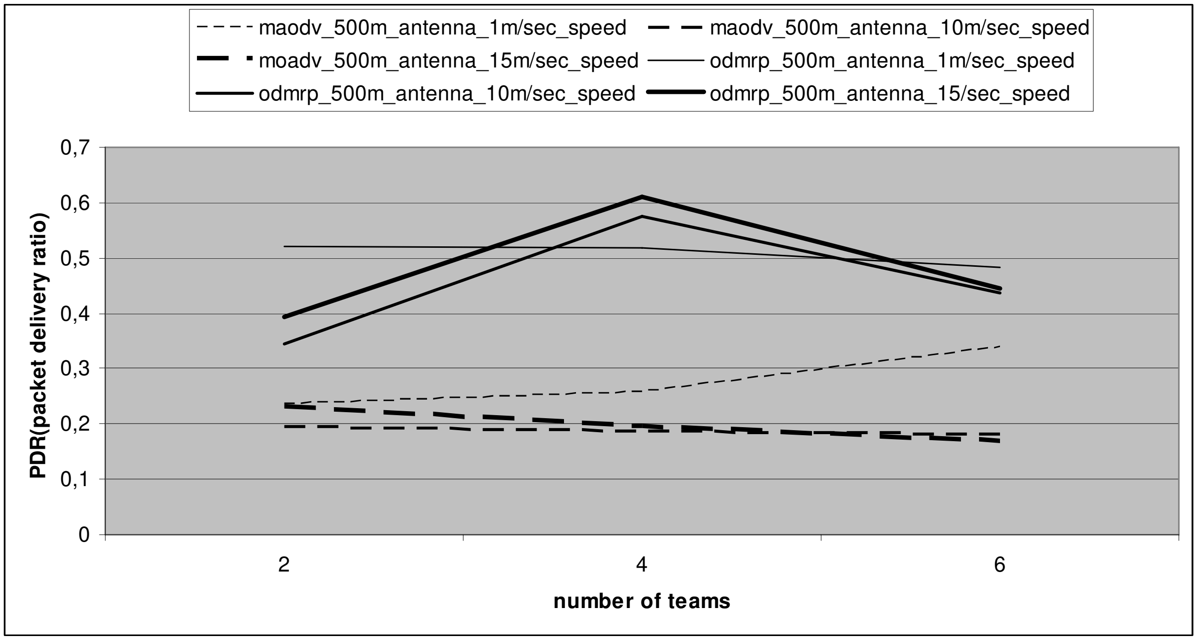
Graph 3.PDR versus number of teams with various numbers of antenna ranges and speed 1m/sec



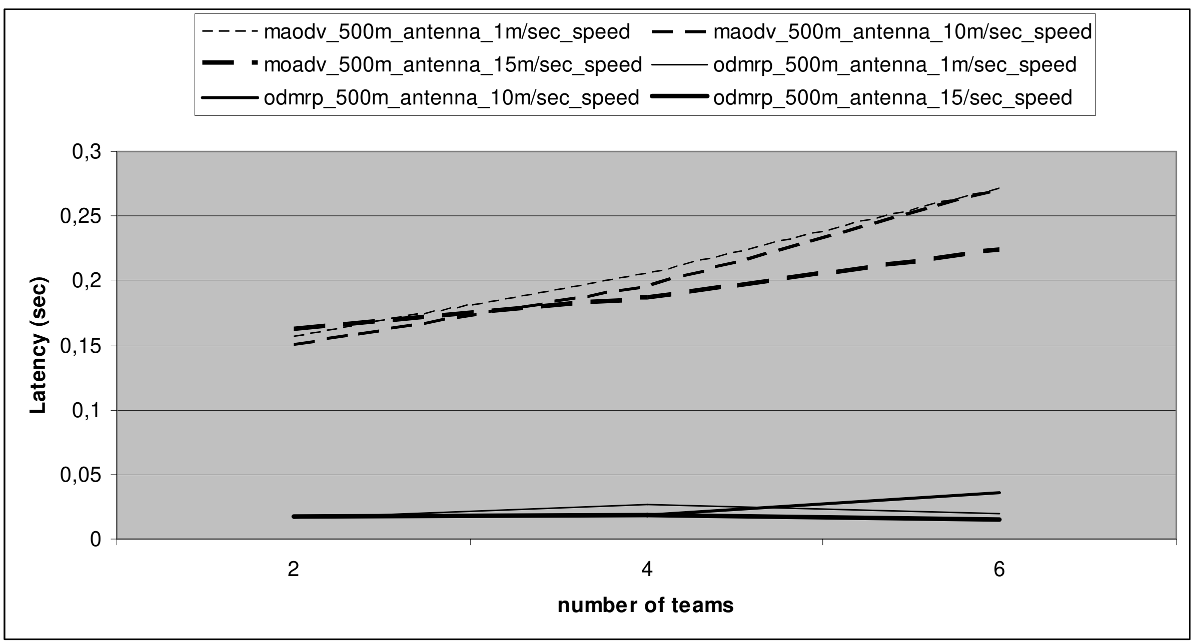
Graph 4.Latency versus number of teams with various numbers of antenna ranges and speed 1m/sec

In Graph3, we measure the PDR with respect to the number of teams. ODMRP outperforms in all experiments. As we observer from the Graph 3 , the use of 4 teams gives the best PDR results for the ODMRP protocol

In Graph4, we measure the latency with respect to the number of teams. ODMRP outperforms in all experiments, and the use of teams gives the best latency results.



Graph 5.PDR versus number of teams for the two protocols with different values of speed



Graph 6.Latency versus number of teams for the two protocols with different values of speed

Choosing 500m antenna range, we further investigate how the two protocols react with different speed values. As we observe from Graph 5 , ODMRP outperforms . When speed is

1m/sec, ODMRP gives very stable PDR values regardless the number of teams. As the speed changes ODMRP seems to be more unstable, but also gives the best PDR values when the number of teams are 4. Using 4 teams, the speed factor has a positive effect to the ODMRP protocol. In Graph 6 , ODMRP shows again very low latency values.

4. Conclusions

In all experiments the ODMRP protocol outperforms. This means that mesh architecture is better for our experiments. The first two graphs help us decide what the most appropriate antenna range for our experiments is. With respect to battery consumption we choose 500m antenna rage. . Graph 3,4 show us that the use of 4 teams is the most efficient choice. Graph 5,6 confirm that the use of 4 teams is the most appropriate. Speed factor has a positive influence to ODMRP protocol. Concluding, the best PDR is achieved for 4 teams with 30 rescuers in every team.When the antenna range is 250m, the PDR values are very low making the protocols unreliable. The antenna range should be between 500m and 1000m. It is preferable to use 500m antenna range for low energy consumption. Finally, the ODMRP seems to be very tolerant to different mobility speeds.

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