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Rescue operations using coordinated multicast MANET

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Abstract. Disaster relief and rescue operations are common situations where the need for communication is crucial. We propose the use of multicast MANETs (Mobile Ad Hoc Networks) and investigate via simulation whether they can efficiently support the communications during such operations. MANETs are suitable for such operations, since they do not need any pre-existing infrastructure. We simulate two realistic scenarios. The first one is a rescue operation to find any survivors at a mountain. We split the rescuers into four teams. The rescuers in each team are coordinated and scan an area of 1000m*4000m. The purpose of this experiment is to find out the number of the rescuers per team that achieves reliable communication. We also investigate the effect of the antenna range transmissions. The second scenario is a gas pipe explosion in an inhabited area. The damage is in an area of 1500m*1500m. A rescue group of 40 rescuers and 10 doctors scans the area for any survivors. We use two multicast groups: the rescuers and the doctors. We also use one unicast connection between the rescuer's leader and the doctor's leader. We examine the effect of the traffic on the communication reliability.

Keywords: MANET, MAODV, Mobile Ad-Hoc Networks, Multicasting, ODMRP, rescue operation, disaster relief, coordinate motion.

I. INTRODUCTION

In situations of emergency, like disaster relief, the need for communication between the rescue teams is crucial. These unexpected situations demand for a very flexible and reliable mobile communication system. We were surprised to find out from a member of the Hellenic Rescue Team, who is responsible for maintaining the communication among the rescuers, that most of the communications were established on a very low speed. Moreover, transferring photos was very complicated. Although they can establish communication everywhere, the bandwidth of their connection is very low, allowing only data and low quality of speech to be transmitted. There are traditional methods to achieve higher bandwidth, but they are not so flexible, and need extra equipment and human resource to implement them. As technology advances, new rescue methods or rescue resorts are implemented. An example is the use of robots in rescue procedures [1]. Robots can move and search for survivors in unapproachable places. They can move independently or be guided by a human. This approach demands from the network to be capable of transmitting photos and videos. Otherwise, neither the robot can alert with confidence the rescuers that there is a survivor, neither the robot can be guided by its operator. Small helicopters with remote control can also be used to scan areas. These helicopters can have cameras and videos and transmit their data to the operator. In disaster areas, the rescuers can place voice or movement sensors at selected places. These sensors will detect the nearest rescuer and will transmit data to him. Because rescue procedures are unpredictable, communications has to be area independed. In this paper, we propose Mobile Ad Hoc Networks (MANET), as the answer to all the above questionings. MANETs are self organizing networks without the need for pre-existing infrastructure. Moreover, they may use the 802.11g standard with speeds at 54 Mbps. These characteristics make MANETs suitable for rescue operations. We analyze two realistic rescue scenarios. We investigate what are the best parameters for efficient communication among the rescuers. We evaluate the communication performance and reliability for two realistic rescue scenarios for various numbers of groups, rescuers per group, antenna ranges, and communication rates. We simulate two MANET multicast protocols, ODMRP and MAODV which has shown in many simulation very good performances.[2],[3],[4].

The first rescue scenario takes place on a mountain. After a snow slide, the traces of a group of mountaineers are lost. A rescue procedure starts immediately to find any survivors. The novel to our simulation experiments is that the rescuers are not moving completely random, but they are moving towards a specific direction. In real rescue procedures, all rescue teams are scanning an area as they move towards the same direction. Furthermore, the rescuers in each team are also moving towards the same direction.

The purpose of these experiments is to find out the appropriate number of rescuers per group in order to achieve reliable communication.

The second rescue scenario takes place in a medium size city. An explosion of a gas pipe causes disaster in an area of 1500m * 1500m. Rescuers (professionals and volunteers) with doctors approach the area to find any survivors. We evaluate the performance and reliability of the communication for various communication rates.

The rest of the paper is organized as follows. In section 2, we describe the two multicasting protocols. In section 3, we describe the mountain rescue scenario. In section 4, we describe the gas pipe rescue scenario. In section 5, we present the results of the experiments. Finally, in section 6 we discuss the results and draw conclusions.

II. MULTICAST PROTOCOLS REVIEW

A. MAODV (Multicast Ad-hoc On-demand Distance Vector Routing Protocol)

MAODV is the multicast extension of the AODV protocol. As an on-demand protocol, it discovers multicast routes when it has something to send. If a mobile node wishes to join a multicast group, or does not have route to that group, it originates a Route Request (RREQ) message. This multicast group is identified by a unique group address, associated with group sequence numbers for tracing the freshness of the group situation. The nodes which are group members together with the nodes that are not group members but are critical for forwarding the multicast information compose a tree structure. When a node wants to join a multicast group that does not exist, this node becomes the multicast group leader. The multicast group leader is responsible for maintaining the multicast group sequence number and the tree structure. This is established through a Group Hello message. The nodes use the Group Hello information to update their request table. Tree nodes can be organized as upstream and downstream. The group leader has no upstream node. For every node, its upstream node is the next node which is nearer to the group leader (hop counts are less) and its downstream the next node which has more hop counts to the group leader. In MAODV, a node keeps the unicast routing table and 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 net hop information and the lifetime.

When a node sends a not join RREQ any node with fresh enough route (based on group sequence number) of the multicast group may respond. If the message is a join RREQ then only member nodes of the multicast group can answer.

MAODV keeps hard state in the routing table which means that if a node wants to terminate its group membership it must ask for it. When a node leaves the multicast group, pruning is required. MAODV also monitors link breaks. If a link brake is detected then the most downstream node from the group leader is responsible for repairing the breakage [5], [6], [8], [9], [10].

B. ODMRP (On Demand Multicast Routing Protocol)

ODMPR is an On-Demand protocol based on mesh architecture. Mesh architecture gives multiple paths from the sender to the destination. Contrary to this, MAODV (tree architecture) provides only one path from sender to destination. It is a soft state protocol, meaning that if a node wants to leave from the multicast group then it is over passing the group maintaining messages. No explicit control message is required to leave the group. When a node has packets to send and no route to the destination, it broadcasts a join Query message. The nodes that accept this message update their routing table with the appropriate node id (backward learning) from which the message was received for the reverse path back to the sender. If the TTL (time to leave) is greater than zero then the message is re-broadcasted. When a multicast receiver accepts a Join Query message, it broadcast a Join Reply message to the neighbors. When the neighbor nodes take the message, they check if their node id is the same with any of the next hop id in the Join Reply table. If it is so, then they understand that they are on the path to the source and set the FG_FLAG (Forwarding Group flag). When receiving a multicast data packet, a node forwards it only when it is not a duplicate, hence minimizing traffic overhead. [5], [7], [8], [9], [11].

III. MOUNTAIN RESCUE SCENARIO

A group of mountaineers start hiking from a lodge with destination the peak of a mountain. The last time they were seen was in the morning when they left the lodge. During the day, a snow slide runs away from the mountain and the communication with the mountaineers is broken. The last communication with the mountaineers reveals that they were about 4 km far from the lodge. Immediately a rescue team starts to scan the area to find any survivors, or any wounded people. The first plan was to scan an area of 4000m * 4000m, considering the position that the group was last seen to be the center of the scanning area. No wounded people could walk more than 2km in the specific time that the rescue procedure will take place, so it is more likely to find all the mountaineers in this area. The scanning area was divided into four sections (1000m * 4000m). The rescuers were divided into four groups too, and every group was responsible to scan one section. It is obvious that the four rescue groups will start scanning at the same time, and all the groups will be moving in parallel. The maximum speed of the rescuers is 1m/sec (average walking speed). The four rescue teams are starting from the (x,0) point and walk towards the (x,4000) point. Every member of a rescue team is communicating with the other team members using multicasting. Also, every rescue team has a leader who communicates with the other leaders using multicasting. This means that we have 5 multicast groups. The traffic in the network was chosen to be 3.2Mbit/sec, because it very likely for the rescues to communicate using audio (320 Kbit/sec near CD quality) or video (1 Mbit/sec VHS quality). Moreover, the use of small rescue helicopters demands for audio and video transmissions. The simulation time is 900sec and the multicasting protocols are either the ODMRP or the MAODV.

The purpose of this experiment is to find out for which number of the rescuers per rescue group the communication is reliable. In the simulation experiments, we use rescue groups with 3 or 5 or 10 or 15 or 20 members. We also repeat the simulations with different antenna ranges: 100m, 200m, 250m, 500m, or 1000m. We measured the PDR (packet delivery ratio) and the latency. PDR is the percentage of the delivered packets from the sent packets and shows the reliability of the communication. The latency describes the average end to end delay, an important parameter especially with multimedia applications.

Table1. Simulation parameters for the mountain rescue scenario.

Number of groups	4 rescue groups and 1 leader group
Number of nodes/rescue group	3 or 5 or 10 or 15 or 20
scanning area	4000m*4000m
Rescue group moving area	1000m*4000m
Antenna range	100m or 200m or 250m or 500m or 1000m
Simulation protocols	MAODV and ODMRP
Simulation time	900sec
Speed	1m/sec

IV. GAS PIPE RESCUE SCENARIO

In a medium size city, an explosion of a gas channel caused major damage to an inhabited area of 1500m * 1500m. Immediately a crew of 40 rescuers, professional and volunteers, and 10 doctors reached at the explosion area to find and rescue any survivors. The rescuers are moving randomly to the specific area. When a rescuer detects a survivor he sends (multicast) a message to the others. So, anyone available will come and help with the rescue operation. In the same time, he sends (unicast) a find survivor message to the leader of the doctor‘s team. The leader himself multicasts a find survivor message to all the doctors, so any available doctor will help. We choose two different multicast groups (rescuers and doctors) rather than one, because it will reduce the overload of the network. It is obvious that the doctor team will communicate with each other not only for finding survivors, but also for professional advices. If we used one multicast team, then the rescuers would receive these messages too. The same stands for the rescuers team.

In this simulation experiment, we have two multicast groups (rescuers and doctors) and one unicast connection between the two leaders of the rescuers‘ team and the doctors‘ team. One great advantage of MANET is that when there is a transmission of a message usually the nearest node gets it first. This is very crusial especially if we use sensors. Rescuers can install sensors in the smithereens, and wait if the sensors transmit any data. Except from the rescue operation, sensors are very helpful in the network topology because they are stable and help MANET algorithms to find the routes. In our experiment, we didn‘t use any sensors because we want to simulate the scenario in the heaviest circumstances. We used the MAODV and ODMRP protocols and different bit rates (5, 10, 12.5, 20, 25 packets/sec) with 256bytes packet size. We run the simulation for 900sec and measured two parameters: the PDR (packet delivery ratio) and the latency.

Table2. Simulation parameters for the gas explosion rescue scenario

Number of groups	2
Number of nodes/group	10 for the doctor’s group 40 for the rescuer’s group
Area	1500 * 1500
Antenna range	250 m
Bit rate	5 , 10 , 12.5, 20, 25 packets/sec with 256bytes packet size
Speed	1m/sec
Simulation time	900 sec

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V. RESULTS

We use the Ns-2 simulator with Monarch multicast extensions for the ODMRP protocol [12], and the Ns MAODV implementation by Zhu and Kunz [13]. We run the experiments for 900 seconds.

A.Mountain rescue scenario

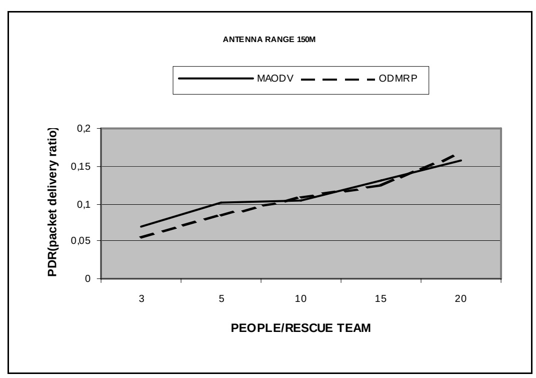

Figure1. PDR versus number of people/rescue team with 150m antenna range

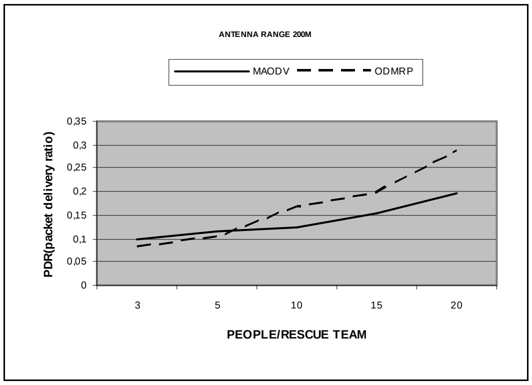

Figure2. PDR versus number of people/rescue team with 200m antenna range

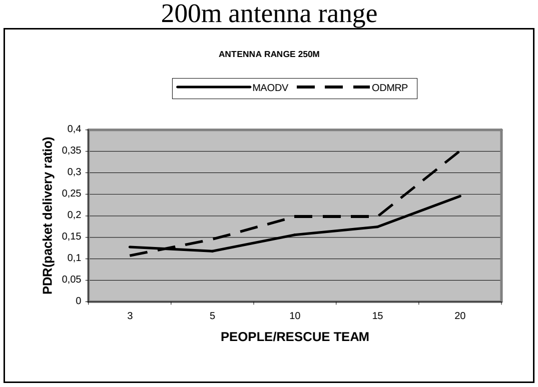

Figure3. PDR versus number of people/rescue team with 250m antenna range

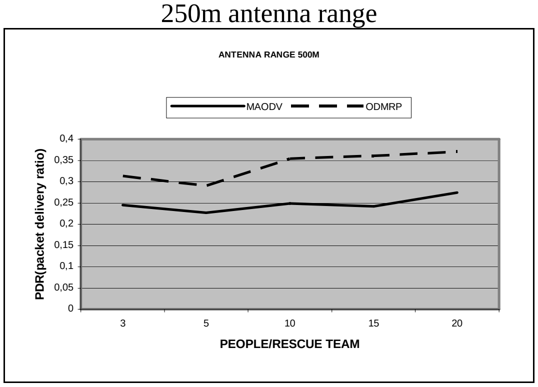

Figure4. PDR versus number of people/rescue team with 500m antenna range

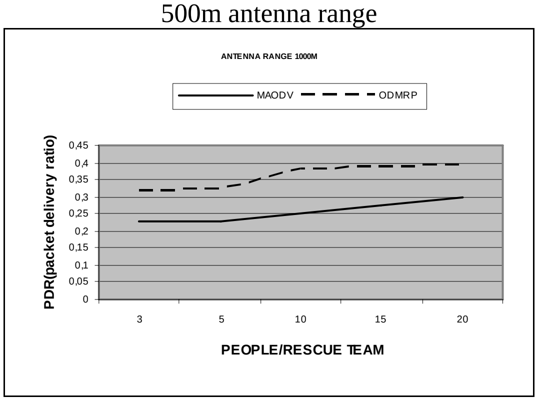

Figure5. PDR versus number of people/rescue team with 1000m antenna range

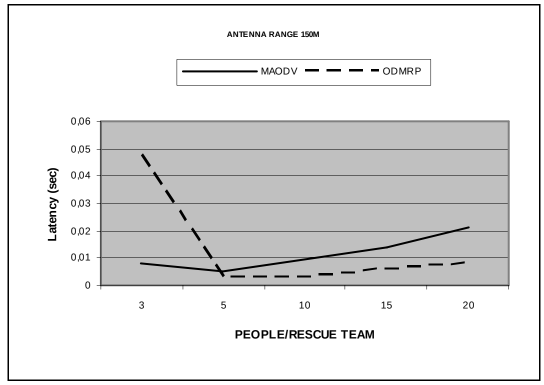

Figure6. Latency versus number of people/rescue team with 150m antenna range

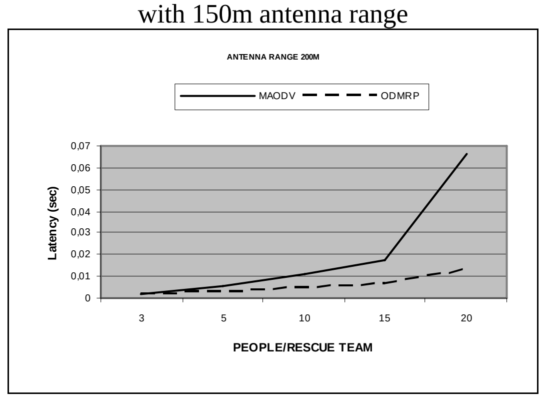

Figure7. Latency versus number of people/rescue team with 200m antenna range

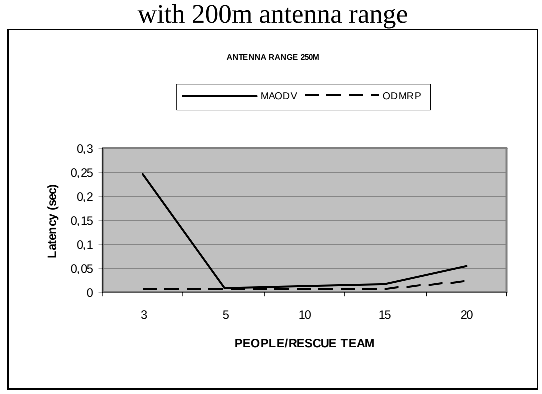

Figure8. Latency versus number of people/rescue team with 250m antenna range

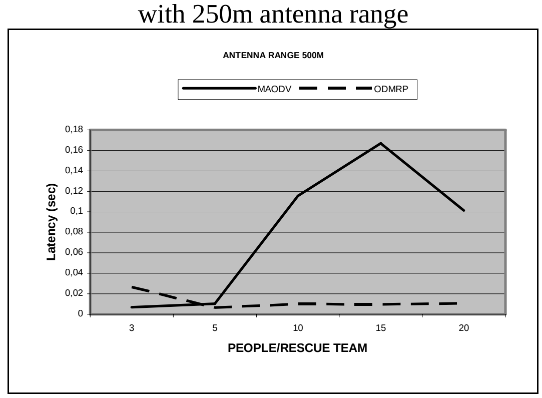

Figure9. Latency versus number of people/rescue team with 500m antenna range

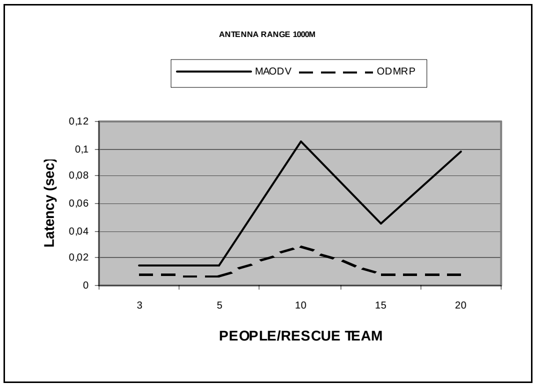

Figure10. Latency versus number of people/rescue team with 1000m antenna range

Due to space limitations, we briefly describe the simulation results.

In Figure1, we observe that no one protocol outperform. MAODV shows better values with 3, 5, 15 people/rescue team, and ODMRP better values for 10, 20 people/rescue team. The two protocols perform the same , with very low PDR values.

In Figure2 and Figure3 ODMRP shows slightly better values after the 5 people/rescue team. MAODV show better values with 3 people/rescue team.

In Figure4 and Figure5 ODMRP outperform.

In Figures 6 ,7 ,8 ,9,10 we measured the latency .

In Figure6 and Figure 9 with 3people/rescue team MAODV have better latency but after that point ODMRP outperform.

In Figure 7 and Figure 8 and Figure 10 ODMRP outperforms in all circumstances .

B.Gas explosion rescue scenario

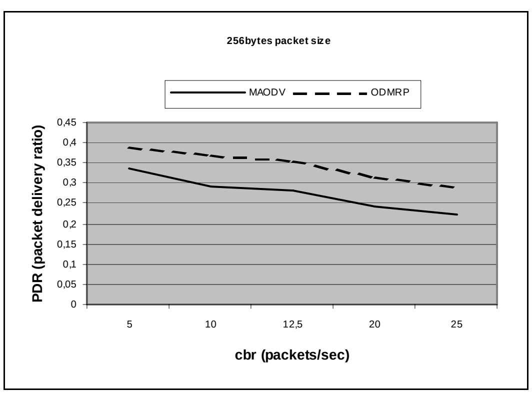

Figure11. PDR versus traffic for the gas explosion scenario

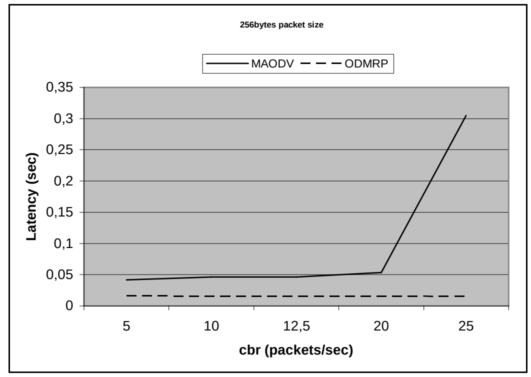

Figure12.Latency versus traffic for the gas explosion scenario

In Figure 11 ODMRP outperform in all the experiments

In Figure 12 ODMRP shows the better latency values in all the experiments

VI. CONCLUSIONS

In the simulation, we considered the worst cases with respect to traffic. We used the IEEE 802.11a standard at 5.9Mbps rate. This caused low PDR values since the rescuer‘s traffic in the first experiment is 3.2Mbps and all the rescuers transmit simultaneously. However, in reality not all the rescuers will transmit at the same time. So, the PDR will be higher and the latency lower, because not so many packets will have to be retransmitted due to collisions. Also, in the simulation, we use CBR (constant bit rate) traffic. This means that packets are transmitted continuously with the same rate. However, new compression algorithms may give excellent audio and video qualities in much lower bandwidth. In the first scenario, as the number of the rescuers per team increases, the PDR value increases too. This is very normal because we have more nodes to route the packets. But in the beginning of a real rescue operation, probably we could not gather many rescuers immediately. Also, we must consider that increasing the antenna range, we increase the battery consumption too. For the first scenario, if we have to choose between the two protocols, we would choose the ODMRP because it shows better PDR and latency values in general. In the gas explosion scenario, as the traffic increase, the PDR value falls off. It is also better to employ the ODMRP protocol. As we observe from most of the figures for the first scenario, PDR values increase sharply when we use 10 person/rescue group. A number between 10 and 15 person /rescue group will give satisfactory PDR and Latency results. Considering all the extreme into our simulations, the results are satisfactory and encouraging. MANETs can be used for reliable communication in real rescue operations.

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