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MANETs for environmental monitoring

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Abstract: **Environmental monitoring is important for life sustainability. Continuous measurements of environmental parameters may help to prevent and cope with environmental damages. Sensors that measure environment's conditions may be placed at appropriate locations and transmit environmental data. In a case of emergency, environmentalist rush to the affected area to analyze the problem and take appropriate actions. They have to communicate among themselves and collect data from the sensors. This paper proposes the use of MANETs (Mobile Ad Hoc Networks) to support the communications among sensors and environmentalists. Simulation results show that MANETs can support reliable communications.**

Index Terms: **communications, environmental monitoring, mobile networks, simulation, wireless networks.**

I. INTRODUCTION

As pollution on planet earth grows rapidly, the need for monitoring the environment has become crucial. Places with reach biota are now protected as biosphere reserves and national parks. European Union (EU) expresses sensitivity towards pollution issues and institutes ecological laws. In the 7th Framework Programme (7FP), EU is interested in developing innovative methods, tools and technologies for monitoring, prevention and mitigation of environmental pressures and risks, as well as for the conservation of the natural and man-made environment [1].

Monitoring the environment can be achieved using synchronous sensors and portable devices that measure moisture, temperature, pollution etc. Companies like APC [2] have developed very reliable devices which can monitor the environment. The purpose of these devices is to sense the pollution of the environment and confront several ecological threats. There are sensor networks that monitor national parks. A sensor network is a computer network of many spatially distributed sensor devices that monitor conditions such as temperature, sound, vibration, pressure, motion, or pollutants at various locations. Usually these devices are small and inexpensive, so that they can be produced and deployed in large numbers. Hence, their resources in terms of energy, memory, computational speed or bandwidth are severely constrained.

Each device is equipped with a radio transceiver, a small microcontroller, and an energy source, usually a battery [3]. Furthermore, each device has special sensors to measure specific environmental parameters. These devices are placed once at a specific location and usually never moved again. So, the position is extremely crucial. A sensor device is placed in a specific place manually or is dropped for example by an aeroplane. In the last case, its exact position can be found using GPS (Global Positioning Systems) or by the position of other known sensors [4]. There are several papers about how sensors can communicate with each other and report to a base station. Most of these papers consider that the sensors do not move. However, in environmental monitoring, there are not only unmoved sensors but also humans with portable devices that monitor environmental parameters too. This means that we have to build a network with still sensors and moving humans which should communicate efficiently. This can be easily constructed using Wi-Fi technology. This wireless networking technology assumes that there is a pre-installed infrastructure (e.g. antenna, electricity). However, there are places without infrastructure that need environmental monitoring not continuously but occasionally. Our proposal in this paper is to create an infrastructure-independent team with sensors and portable devices that can easily move to any place and communicate efficiently. This autonomous portable system will collect data and process them on location and on time. This paper focuses on establishing efficient communications among the units of the team. We propose to use MANETs (mobile ad hoc networks). Moreover, we use unicast and multicast connections among the units. We investigate the feasibility, reliability and efficiency of the communications among the units using simulation. MANETs are self organizing mobile ad hoc networks without the need for a pre-existing infrastructure. Every network node is acting as a sender, as a receiver and as a router at the same time. Devices such as laptops, PDAs (Personal Digital Assistants), mobile phones, pocket PC with wireless connectivity are commonly used. 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 [5]. However in MANETs, routing and multicasting are extremely challenging. Nodes in these networks move unpredictably, thus the network topology changes frequently. Furthermore, there is a power limit due to the batteries of the node devices. Bandwidth limit is another serious constrain. Multicast is the transmission of data in a group of nodes which is recognized by one and unique address [6].

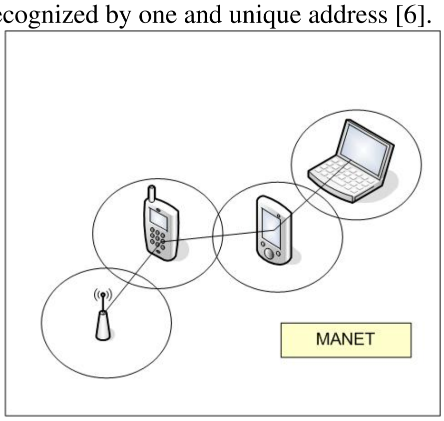

Fig 1. MANET

In cooperation with the Environment Protection Agency we design a realistic environmental monitoring scenario. We use MANETs in order to establish communication among sensors and environmentalists. Then, we try to determine if the sensors and environmentalists can communicate among themselves reliably. We use the ODMRP protocol, because it supports unicast and multicast transmissions and has shown very good results in many experiments [5, 7, 8]. We investigate the reliability and efficiency of the communications via several simulations with respect to the number of sensors (5 or 10), the participating humans (5 or 10) and the different areas (500m*100m, 1000m*1000m, 1000m*2000m). This paper is organised as follows. In section II, we describe the ODMRP protocol. In section III, we describe the environmental monitoring scenario. In section IV, we show the results from our experiments. Finally, in section V we draw conclusions.

II. ODMRP (On-demand multicast routing protocol)

ODMRP is an On-Demand protocol so it discovers the routes only when it has something to send [9, 10, 11]. It is a mesh architecture protocol, so it has multiple paths from the sender 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.

III. Environmental monitoring scenario

Our purpose is to create an environmental mobile team, consisting of humans and sensors resources, which will be ready to be deployed to any emergency place and establish reliable communications without any fixed infrastructure. Most of the environmental sensors have wireless connectivity so the data can be transferred without the use of any cable. Our scenario takes place into a National Park where several animals are sick due to unknown reasons. A number of researchers immediately hasten to the area. Every member of the team has a mobile device such as a laptop with camera and video recorder as well as environmental sensors to measure, record and analyze environmental parameters. For example, these sensors may measure pollution, temperature, moisture, etc. In addition, there are sensors installed in several places. In our experiments, there are either 5 or 10 sensors installed at symmetrical positions in the area that they cover. We simulate three different areas: 500m*1000m, 1000m*1000m, and 1000m*2000m. The sensors will continuously send data to the mobile researchers. So, increasing the number of sensors will increase the traffic too. We want to evaluate how different traffic conditions affect the communications. Our researchers comprise a multicast team that accepts data continuously from the sensors. We employ multicasting in order to reduce the total traffic into the network. This multicast team will be the receiver in our experiment. We also consider that there are either 5 or 10 researchers. The node speed plays an important role in MANETs but not in our scenario. The sensors are still and the researchers are moving randomly on foot, so a maximum speed of 1m/sec satisfies our scenario. The traffic will be continuous, so CBR (constant bit rate) is choosen. Traffic of 1kbps is enough, because the sensors will only send few data. Varying the number of senders, the number of receivers and the area, we try to find if MANETs can support reliable communication and under what conditions. We also vary the antenna range in order to examine how it affects the reliability of the network. The next Table 1 shows the simulation parameters.

TABLE 1. SIMULATION PARAMETERS

Number of senders (sensors)	5 or 10
Number of receivers (humans)	5 or 10
area	500m*100m or 1000m*1000m or 1000m*2000m
speed	1m/sec
CBR	1kbp
Antenna range	250m or 500m
Simulation Time	900 sec

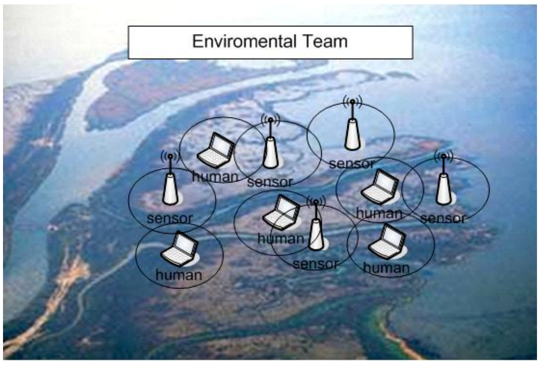

Fig 2. Enviromental team at Axios Delta, Greece

We use the NS-2 simulator with the implementation of the monarch project [12] for simulating the ODMRP protocol. Several studies confirm the reliability of the NS-2 simulator [13]. We measure the PDR (packet delivery ratio) and the latency. PDR represents the percentage of the packets that was received in relation to the packets that were sent. It reflects the communication reliability. The Latency is the average delay of the packets from source to destination and reflects the communication performance.

IV. SIMULATION RESULTS

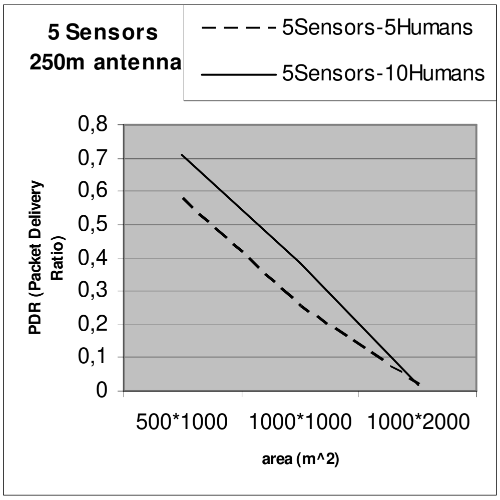

Fig 3. PDR versus area with 5 sensors and 250m antenna range

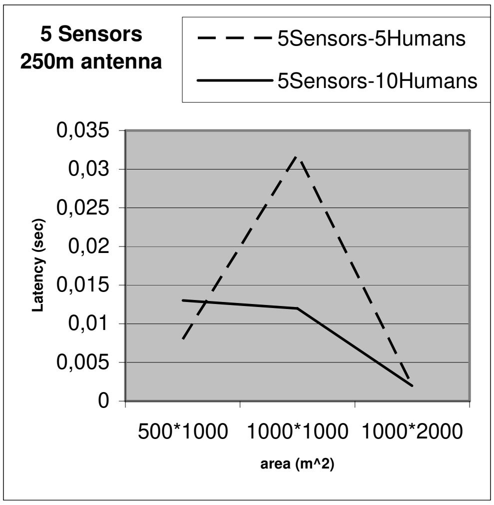

Fig 4. Latency versus area with 5 sensors and 250m antenna range

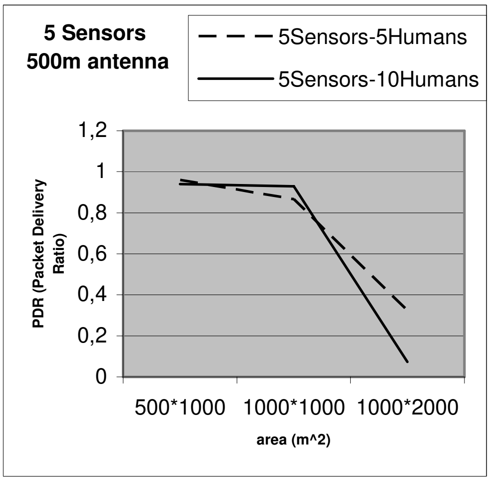

Fig 5. PDR versus area with 5 sensors and 500m antenna range

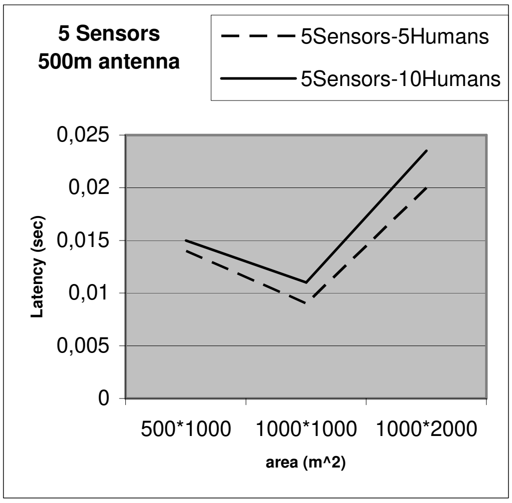

Fig 6. Latency versus area with 5 sensors and 500m antenna range

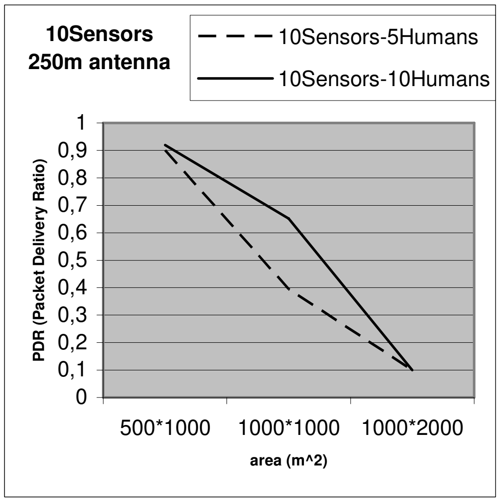

Fig 7. PDR versus area with 10 sensors and 250m antenna range

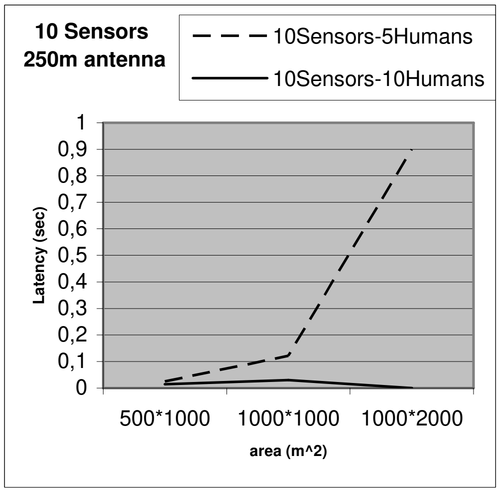

Fig 8. Latency versus area with 10 sensors and 250m antenna range

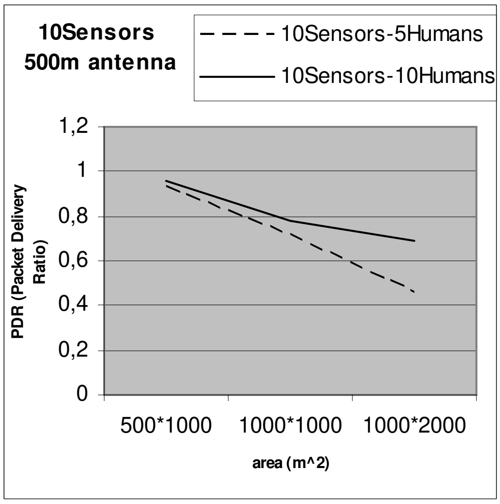

Fig 9. PDR versus area with 10 sensors and 500m antenna range

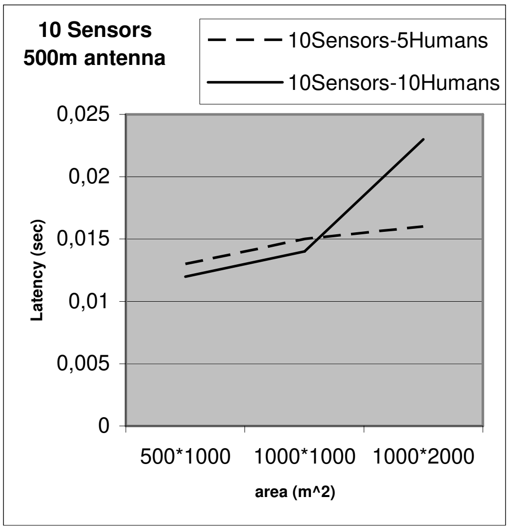

Fig 10. Latency versus area with 10 sensors and 500m antenna range

V. DISCUSSION AND CONCLUSIONS

Let that there are 5 sensors in the area transmitting environmental data (Figures 3 to 6). Using 250m antenna range (Figure 3), communications are reliable for an area 500m*1000m, not so reliable for an area 1000m*1000m and unreliable for an area 1000m*2000m. The PDR values are better when there are 10 humans than when there are 5 humans. The explanation is that when there are more nodes into the network there are more possibilities for a packet to find a good route to its destination, so the packet delivery ratio increases. ODMRP proofs against increased traffic. Also, the latency is low (Figure 4). If we consider that the packets are generated every 0.25 sec, the latency values are below this point. This means that the packets may arrive in the same order as they were generated. Increasing the antenna range to 500m, the network connectivity is increased. So, the PDR values are much better (Figure 5), making the network reliable for areas 500m*1000m and 1000m*1000m. Similarly, the latency improves and all values are below 0.025 sec (Figure 6). However, we have to consider that increasing the antenna range more battery energy is consumed.

Next, we consider that there are 10 sensors in the area (Figures 7 to 10). This means that there are more senders that generate packets, increasing the totally traffic and the chance for collisions and packet drops. Again ODMRP proofs against traffic, and gives better PDR values comparing to the same experiments with 5 sensors. As was mention above, this happens because more nodes are participating into the network. Let investigate the mix of sensors and humans in the network. Considering that there are 15 nodes in the network, we either have 5 sensors and 10 humans (Figure 1) or 10 sensors and 5 humans (Figure 7). We see that is better to have more sensors than humans. This happens because the network becomes more stable since the sensors are not moving. This stability results to more reliable communication. Figure 8 shows that for areas 500m*500m and 1000m*1000m the latency values are extremely low. However, further increase in the area results to dramatic increase of the latency. Increasing the antenna range to 500m (Figure 9), we achieve better PDR values. Our network is reliable for areas 500m*1000m and 1000m*1000m. Also, increasing the number of humans (receivers), we achieve better PDR values. Finally, all latency values are very low (Figure 10).

Synopsizing the simulation results we notice:

Increasing the number of sensors, the communications reliability is increasing too.

Increasing the number of humans, the communications reliability is increasing too, but in a smaller degree than increasing the number of sensors.

For low CBR, the network seems to be very proof against traffic.

For 10 to 15 nodes with 250m antenna range, we achieve very reliable communication in an area of 500m*1000m. For 20 nodes with 250 antenna range, we achieve reliable communication in areas of 500m*1000m and 1000m*1000m. Increasing the antenna range to 500m, we achieve reliable communication in areas of 500m*1000m and 1000m*1000m regardless of the number of nodes.

Concluding, we can say that MANETs can efficiently support the communications in this environmental monitoring scenario. We can create an environmental team that can easily move and communicate at any place. In our experiments, reliable communications can be achieved for areas of 500m*1000m and 1000m*1000m. Also, increasing the number of sensors or humans, larger areas can be reliably covered.

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