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Performance Improvement of 3D WSNs using Mobile Super Nodes

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Abstract: Mobility is an important research area in Wireless Sensor Networks (MWSNs).The feasibility of mobile nodes is further facilitated by low cost and high energy efficiency. Energy consumption by nodes is an important performance parameter to increase the lifetime of any network. Many protocols for MAC layer have been designed to make efficient energy use by assigning sleep mode in the nodes. WSN deployments were never visualized to be static. Mobility was initially regarded to have many challenges that were needed to overcome including connectivity, coverage, and energy consumption, etc. In this paper, an energy-efficient multi-layer Medium Access Control (ML-MAC) protocol is analyzed with the use of mobile super nodes for 3-Dimensional wireless sensor networks. The results are validated through extensive simulations. Simulation results prove that use of mobile super nodes in ML-MAC outperforms original ML-MAC protocol in terms of throughput, network lifetime, packets dropped, and end to end delay.

Keywords: 3D Wireless sensor networks (WSNs), mobile super nodes , ML-MAC, QualNet 6.1, energy efficiency

1. INTRODUCTION

Wireless Sensor Networks (WSNs)[1]have been extensively studied in the last decade for academic, military and civilian applications[2,3]. Sensors in a WSN are deployed over a region of interest to sense events, collect data and transmit [4] it to a sink node for further processing operations [5].In the work done so far, only 2D networks were considered for simulations. Following their success in 2-D environments, sensor networks have drawn growing interest among the researchers for the 3-D emerging applications in building, surveillance, underwater survey, atmospheric monitoring, and many more.

Different approaches are used for reduction of energy consumption [6] in WSNs and all these approaches [2,3] can be divided into three general groups:

- Duty Cycling based approaches
- Data Driven approaches, and
- Mobility based approaches

This paper presents a mobility based multi-layering MAC technique simulated in QualNet 6.1 to achieve energy efficiency leading to prolonged network lifetime. Mobile wireless sensor networks is an emerging field of research which is very close to the dynamic coverage because in both cases the goal is to monitor a wide area by a few number of mobile sensors [7].However, most of them are restricted to 2Dwork spaces and not applicable for 3D environments [8].

In this paper, a 3D clustering using mobile super nodes is proposed for random distribution of sensor nodes. In addition, ML-MAC protocol is used to prolong network lifetime. The mobility model is compared to the existing ML-MAC protocol based network.

In this paper ML-MAC protocol is also used to reduce energy consumption which increases the lifetime of network.

This paper is organized as follows: Section II illustrates the related work in this area where with multilayer highly energy efficient network was achieved. Section III describes the network model. Section IV describes simulation scenario where proposed plan of mobile sensor (MS) nodes in the network is discussed which proves to be an edge ahead of ML-MAC. Section V discusses the results obtained by simulation followed by conclusion in section VI.

2. RELATED WORKS

Sensor deployment is one important issue in WSNs because it directly affects the detection capability of a sensor network. Several researchers have proposed different mobility-based deployment schemes to help form a WSN. They considered a large amount of mobile sensors randomly deployed in a sensing field. Then, different strategies are employed to make these sensors to cover the maximal target area by automatically organizing a connected network. The existing work is mostly done using random deployment [2, 9] of sensor nodes in 2D scenario and without using ML-MAC protocol. Ranjana Thalore *et al.*[10] an energy-efficient multi-layer MAC (ML-MAC) simulated in QualNet 5.2. This protocol was designed to get low duty cycle, prolonged network lifetime and decrease the number of collisions. Ranjana Thalore et al. [11] evaluated the performance of IEEE 802.15.4 (Zigbee), in 2D and 3D terrains on the basis of QoS parameters like network lifetime, throughput, delay, and packets dropped. The work concentrated on the fact that a more practical way to analyze monitoring applications of WSNs includes designing a 3D network scenario. Hari Prabhat Gupta et al. [12] proposed a distributed protocol to schedule redundant sensors to sleep to minimize energy consumption.

The layered structure of ML-MAC protocol is shown in figure 1 in which total simulation time is divided in three different time slots assigned to different layers. Nodes in each layer are activated for that particular time slot. In this paper, a comparative study of 2D and 3D networks is presented to show the impact of mobile super nodes.

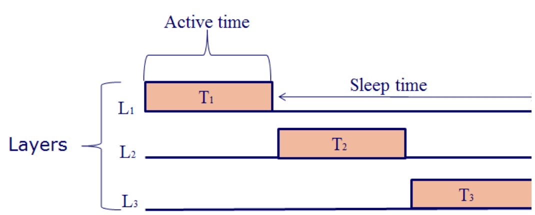

Figure 1. Layer structure in ML-MAC

3. NETWORK MODEL

In this paper, an energy efficient 3D clustering using mobile super nodes is proposed for random deployment of sensor nodes. Mobile super nodes are elected in such a way that they are not directly connected to the sink node but cover the entire geographic area. Some of the mobile sensors can be relocated to the "weakest" points of a WSN to strengthen the connectivity. In addition, ML-MAC protocol is used to prolong network lifetime. Figure 2 shows the proposed model in which there are four clusters are connected to the sink node through cluster heads. This network model is compared to the existing ML-MAC protocol based network. The nodes are randomly deployed in the network and clusters are formed. Some mobile super nodes are suitably selected from each cluster and maintain the required connectivity between the clusters and PAN coordinator.

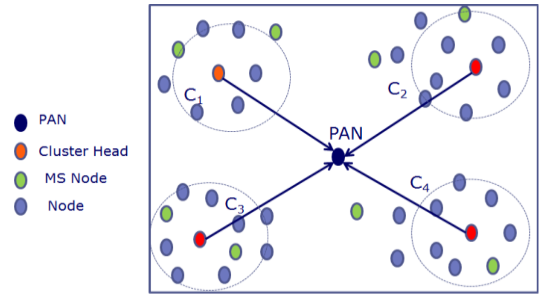

Figure 2. System Model for Proposed Network

4. SIMULATION SCENARIO

The simulations have been done using QualNet version 6.1 software that facilitates scalable simulations of WSN. In the scenario, there are two scenarios with 100 and 400 nodes distributed randomly in a 3D network. The terrain area is taken as 200m×200m in case of 100 nodes and 400m×400m in case of 400 nodes. The scenario is simulated for 1500s.The traffic type used for data application is TRAF-GEN (traffic generator). The scenario has one PAN (Personal Area Network) coordinator and four cluster heads where all the data gets collected from different nodes which are designated as Reduced Function Devices (RFDs) in the network. The packet size used is 38 bytes and message inter-arrival time between two packets is 1second.

In each scenario the nodes are divided into three layers, one third of all nodes are included in one layer and it communicates for $\left(\frac{1}{3}\right)^{rd}$ of simulation time. When one layer is communicating, other layers remain in sleep mode. Figure 3 shows a 3-D network scenario in QualNet 6.1 network simulator.

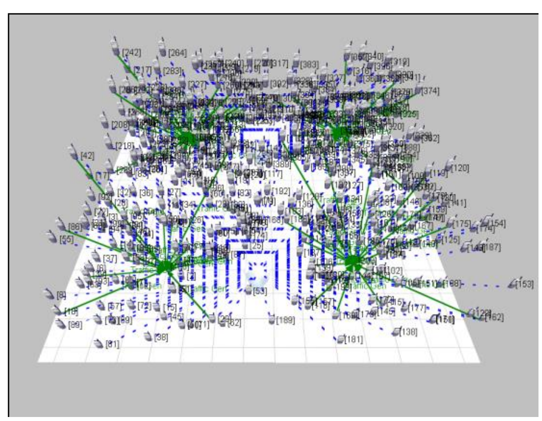

Figure 3. 3D Simulation Scenario

5. ANALYSIS OF RESULTS

For all the scenarios, the analysis is done using QualNet 6.1. The results are evaluated in terms of throughput, end-to-delay, packets dropped and network lifetime.

Network Lifetime (NL) is defined in terms of days. It is defined as the surviving time of node in network which is calculated by using the residual battery capacity.

Figure 4 shows the network lifetime of the simulated scenario. The Network Lifetime while using mobile super nodes proves to be better than a network without super nodes.

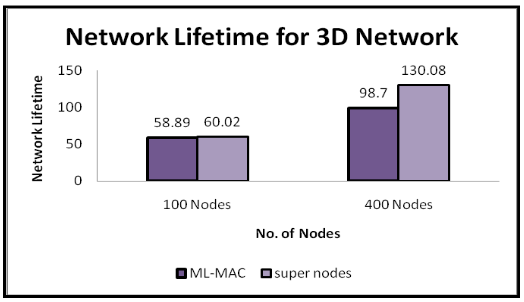

Figure 4. Network Lifetime

Figure 5 shows the performance of network in terms of throughput. Throughput of a network is defined as fraction of channel capacity which is used for useful data transmission. The use of mobile nodes to collect the data from sensing stationary nodes increases the amount of data received at the PAN coordinator.

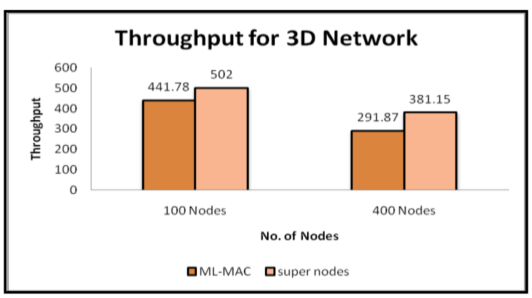

Figure 5. Throughput

The duration between the generation of data packet and the arrival of last bit at the destination is termed as End-to-End delay. The performance of the two networks in terms of End-to-End delay is shown in figure 6. Since mobile supernodes are used as data forwarding nodes in the network, the delay of data packets to reach the sink node decreases.

Number of packets dropped during transmission from source to destination while data communication is shown in figure 7.These are the data packets which are sent by the sensing node but are not able to reach the destination. A network with mobile super nodes has comparatively less dropped packets.

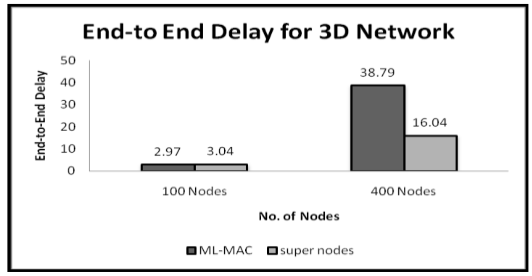

Figure 6. End-to-End Delay

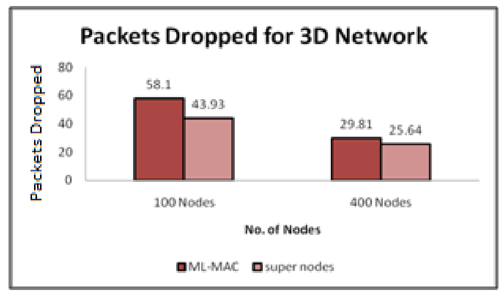

Figure 7. Packets Dropped

6. CONCLUSION

The simulation results are found better in case of mobile super nodes as compared to a network without super nodes. Though both the networks use concept of multi-layering, but use of mobile super nodes improves the overall performance of the network. The results are analyzed in terms of throughput, end-to-end delay, packets dropped and network lifetime.

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