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INVESTIGATION AND SIMULATION OF ENERGY-SAVING METHODS FOR WIRELESS SENSOR NETWORKS

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Abstract - The expeditious advances in the field of networking and communication technologies, have made wireless sensor networks (WSNs) a very important technology of recent times. The range of applications in which WSN is used has only broadened over the years. Since the sensor nodes are battery operated and they are generally deployed in a harsh environment, therefore replenishment or replacement of sensor nodes is almost impossible. Hence design of energy efficient techniques has remained as the most important challenge for researchers. A sensor node consumes maximum energy in communication i.e. transmission/reception. Many researchers proposed energy efficient clustering and routing algorithm and neglected the aspect of energy balancing. Therefore, clustering and routing protocols designed for WSNs should be energy efficient as well as energy balanced for long run of WSNs. By observing the drawbacks of existing techniques, in this research work effective solutions for the existing clustering and routing problems were developed.

Key Words: Wireless Sensor Networks (WSNs), Energy-efficient techniques, Clustering algorithm, Routing protocol, Load balancing.

1. INTRODUCTION

Wireless sensor networks (WSN), are geographically distributed autonomous sensors which are deployed either arbitrarily or using some predefined provision. It is used to monitor the physical or environmental characteristics such as temperature, pressure, humidity, sound etc. shown in figure 1.1. The collected data is cooperatively forwarded to the base station for application specific decisions. WSNs have gained enormous attention and are currently being used in various sectors from structural monitoring, health, military (Akyildiz *et al*., 2002; Yick *et al*., 2008) etc. The functioning of WSN is shown in Figure 1.1. Furthermore, sensor nodes have serious limitations in terms of battery lifetime, memory constraints and computational and communication capabilities.

In general a wireless sensor network contains thousands of sensor nodes. The sensor nodes can communicate between themselves by means of radio signals. A wireless sensor node is outfitted with sensing and computing devices, radio transceivers and power components. The individual nodes in a wireless sensor network are intrinsically resource constrain: they have constrained processing speed, storage capacity, and communication bandwidth. The sensor nodes are responsible for self-organizing an appropriate network infrastructure frequently with multi-hop communication and they are responsible for collecting information of interest. Wireless sensor devices also act in response to queries sent from a sink site to act upon specific instructions and deliver sensing samples. A sensor node uses Global Positioning System (GPS) and local positioning algorithms to obtain location and positioning information. Wireless sensor devices contain actuators to proceed upon certain conditions. These networks are occasionally referred as Wireless Sensor and Actuator Networks (Akkaya *et al*., 2005).

I. WSN Applications

Classic applications of wireless sensor network consist of monitoring, tracking, and controlling. Some of the precise applications of WSN include environment monitoring, object tracking, nuclear reactor controlling, fire detection system, traffic monitoring and management etc. In a usual purpose, a WSN is scattered in an area for the collection of data all the way through its sensor nodes.

II. Architecture of the sensor node

A sensor node is identified as a mote. A sensor node is responsible for processing, gathering and communicating with other connected sensor nodes in the network. The major components within a sensor node include controller, transceiver, external memory, power source and sensors. The Architecture of the sensor node is shown in Figure 1.2.

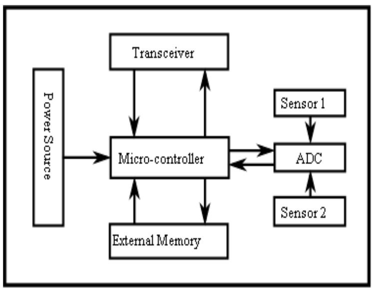

Figure 1.2: Architecture of the sensor node (Akyildiz *et al*., 2002)Communication in wireless sensor network

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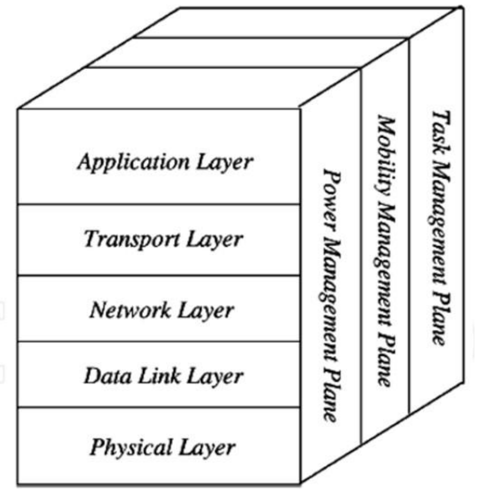
Every scattered sensor nodes has the capability to gather data and route data back to the sink node. Data are routed back to the end user through a multi-hop infrastructure-less architecture all the way through the sink nodThe physical layer handles the operations at the radio interface such as, frequency selection, modulation scheme, transmit power, signal detection and coding. Wireless Sensor Network works on the ISM (Industrial, scientific and medical) band. With the purpose of energy minimization, physical layer balances the transmit power and number of retransmissions. In the MAC (Medium Access Control) layer it addresses channel access, frame detection and error control. A number of MAC layer protocols for WSNs are S-MAC, B-MAC Z-MAC etc. provide unique features such as limited memory, battery power, processing capability etc. The Network layer provide best path from source to sink for transporting data and apply



data aggregation process to handle data centric nature of WSNs because most of the energy is exhausted in transmission and reception. So, an energy efficient network layer protocols is the requirement.

Figure 1.4: Wireless Sensor Network protocol stack (Akyildiz et al., 2002)

2.1 ROUTING AND CLUSTERING

Over the years numerous clustering and Routing algorithms (Heinzelman et al., 2000; Raghavendra et al., 2001; Manjeshwar et al., 2001; Gupta & Younis., 2003; Younis et al., 2004; Amgoth & Jana,2013; Kumar & Kumar, 2017; Kumar & Kumar, 2018) have been proposed, the main aim of which were minimization of energy consumption of the nodes.

A popular technique named LEACH (Heinzelman et al., 2000) uses a distributed algorithm to form clusters. For balancing the load amongst the sensor nodes it dynamically rotates the load of the Cluster Head to the nodes. But the main disadvantage with this approach is that it may select a node as CH with low energy which may eventually die quickly. Also, in this approach BS receives the packet from the CH via single hop communication which is not a practical scenario for WSNs that may have large coverage area. Hence, this lead to development of more

In comparison to LEACH, TEEN reduces energy consumption but the main drawback with TEEN is that if threshold will not reach the nodes will never communicate and in the event of node failure the user will never know about it. PEGASIS improves network lifetime. PEGASIS uses a method of chain formation with nodes such that each node communicates with the neighbor and only a single node selected as group head will transmit data to the BS. But this approach is also unsuitable for large networks as it constantly requires adjustment of topology and the data delay is also very high. HEED is a distributed clustering scheme which selects CHs based on residual energy and intra-cluster distance. The main disadvantage of HEED is several iterations needs to be performed for forming clusters which results in significant overhead which leads to reasonable amount of energy consumption.

3. RELATED WORK

Lots of works have been proposed in the field of clustering and energy efficiency for WSNs. Liu X (2012) proposed a survey on clustering routing protocols in wireless sensor networks. Here, we are presenting some of the review and research work on this topic.Low Energy Adaptive Clustering Hierarchy (LEACH) protocol (Heinzelman, 2000) is a popular TDMA based MAC protocol which improves the lifespan of WSN. LEACH protocol uses two phases namely set-up phase and steady phase. It balances the load of routing by dynamically rotating the workload of the CHs between the sensor nodes. On the other hand, the limitation of this approach is that it selects a node as CH without considering its residual energy. In addition to that in LEACH a CH communicates with the base station in a single hop.Some of the algorithms (Liu et al., 2008; Ali et al., 2008; Al-Refai et al., 2011; Tyagi & Kumar, 2013; Kulia & Jana, 2012; Gupta et al., 2017; Han et al., 2017; Nayak & Vathasavai, 2017) have been proposed for clustering and routing to improve clustering protocol but it has serious connectivity issues with CHs.

Huruiala et al. (2010) have presented a GA based clustering and routing algorithm designed to extend the life of the network. It minimizes the energy consumption and latency by choosing the best nodes as cluster-heads. This algorithm uses a multi-objective genetic algorithm on the base station and then communicates with the network.

Kong et al. (2017) proposed a genetic algorithm based energy-aware routing protocol for a middle layer oriented wireless sensor network. The proposed design has two phases, selecting candidate middle layer phase and genetic algorithm phase. The author claims that the design lowers the traffic of the relay stations with full coverage.

Yuan et al. (2017) proposed a GA based, self-organizing network clustering (GASONeC) method that introduces a framework for dynamic optimization of wireless sensor node clusters. GASONeC uses residual energy, expected energy expenditure, distance to the base station, and the number of nodes for searching an optimal and dynamic network structure. This method enhances network life up to 43.44 % because node density greatly affects the network longevity.

Kumar & Rai (2017) proposed an energy efficient and optimized load balanced localization method using CDS with one-hop neighborhood and genetic algorithm in WSNs. The proposed algorithm uses genetic algorithm for balancing and calculating the computational load among anchor nodes for location calculation. They have used an optimized

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backbone to locate the unknown nodes. This algorithm improves the network lifetime because it distributes the computational load efficiently among the anchor nodes.

Kulia et al. (2013) proposed a GA based clustering algorithm to solve load balancing problem. In this work they have used GA for minimizing the maximum load of each gateway. The proposed algorithm differs from the traditional GA because it generates children chromosomes that ensures better load balancing where as in traditional GA in which mutation point is selected randomly. Thus, the proposed strategy of generating initial population makes the proposed algorithm converges faster than the traditional GA. We have used this paper.

3.1 PROPOSED ARCHITECTURE

The proposed design is very simple and efficient, and meets the requirements of wireless micro sensor networks. This work involves a set of nodes (micro sensors) deployed manually or randomly into the target area. In our proposed WSN model there are there are two types of nodes in the network, sensor nodes and less energy constraint cluster heads. Sensor nodes are accountable to sense local data and send it to their respective CHs. While, the CHs receive the data from their member sensor nodes, aggregate the received data and forward them to their next-hop Cluster Head (CH) or towards the Base Station (BS). We are assuming the all sensor nodes are stationary after deployment. A scenario of the proposed architecture is given in Figure 3.2. In WSN individual nodes data are correlated to obtain a meaningful result using a high-level function of the data that describes the events occurring in the environment.

4.5 EXPERIMENTAL RESULT

4.5.1 Simulation setup

In this section, we evaluate and compare our algorithm with some existing popular algorithms. The simulation was performed on MATLAB version R2012b. We created a simulation environment in which nodes where randomly deployed in the target area of 300m × 300m and the base station was located outside the target region.

5.1. NETWORK MODEL AND TERMINOLOGIES

We assume that all the sensor nodes and gateways are deployed randomly. The sensor nodes and gateways become stationary after their deployment. The sensor nodes can only be assigned to that gateway that falls within the communication range of the sensor node.

6.1.1 Simulation Setup

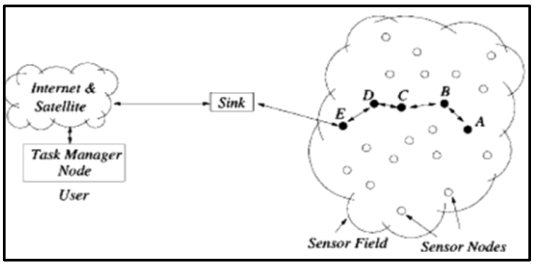
We performed simulation using MATLAB R2012b. The parametric values used in performing simulation are shown in Table 6.2. In the simulation run different WSN scenarios were created by varying the number of sensor nodes and gateways ranging from 200-600 and 30-70 respectively. The experiment results were obtained by considering the clustering and routing in a combined manner. But, in the comparisons made on the basis of number of hops and distance covered in round only routing is considered.

6.1 Simulation Result

For the sake of comparison, various other popular algorithms were simulated. The results obtained were compared with PSO-based approach for energy-efficient and energy-balanced routing and clustering algorithm developed by Azhar et al, (2017) another PSO based approach given by Kuila et al, (2014) , a GA based algorithm GALBCA (Kuila et al., 2013) and LDC by (Bari et al.,2008)

In view of comparison we have used following performance metrics.

Network Lifetime- The lifetime of a network for WSNs can be defined in numerous ways. In our simulation we have defined the network lifetime as total number of rounds till the first gateway depletes its energy fully and dies. In order to increase the network lifetime the depletion of energy among the gateways should be balanced. The proposed algorithm builds a trade-off between inter-cluster distance and total number of hops. In the simulation the number of sensor nodes were varied from 200-800 and the number of gateway used were 50. The comparison of the proposed algorithm with other existing algorithms with respect to network lifetime can be seen in Fig.6.8. The lifetime of the proposed algorithm is better than LDC, GALBCA and PSO based algorithms presented by Kuila and Azhar respectively.For the experiment we assumed that the sensor nodes are randomly deployed in 400×400 square meter area and the position of the sink is taken at the co-ordinate (200,200) i.e. at the centre of the region. The deployed sensors are heterogeneous in nature i.e. their initial energy varies from 0.5J to 2J. The round assumed in the experiment is same as LEACH. The proposed algorithm was evaluated based on two performance metrics, namely lifetime of the network and energy consumption. Figure 7.2 and Figure 7.3



compares EADCA with BDCP (Amgoth & Jana, 2013) and LEACH (Heinzelman et al., 2000). The result shows our algorithm outperforms the other two algorithms.

9.1 CONCLUSION

In this thesis various new clustering and routing techniques have been designed. The main focus of our research has been development of energy efficient protocols for WSNs.

Chapter One provides the basic understanding of WSNs. The scope of this chapter has been fulfilled by providing a wide background for WSNs. This chapter includes the motivation of designing energy efficient WSNs and also lists the objectives of the research. Chapter Two contains the review of literature for WSNs. In this chapter numerous popular energy efficient techniques has been discussed and the gap in research has been identified. On the basis of

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different approaches used this chapter is divided into three sections namely clustering and routing, sink mobility and heuristics.

9.2 FUTURE WORK

Our work can be extended in following ways:

- Fault tolerance issue can also be considered while designing clustering techniques.
- For solving optimization problems other heuristic and meta-heuristic algorithms can also be explored
- Novel routing protocols can be designed by taking the mobility of sensor nodes into consideration.
- The proposed techniques can be tested on real hardware and their performance can be evaluated.

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