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Review and study paper on wireless sensor network and few advancements

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ABSTRACT

In this paper, the author aims at describing a wireless sensor network. Wireless sensor network consisting of spatially distributed autonomous devices using the sensor to monitor physical or environmental conditions. The wireless sensor network can be used in wide range of applications including environmental monitoring, habitat monitoring, various military applications, smart home technologies and agriculture. Wireless sensor networks constitute one of the promising application areas of the recently developed wireless sensor networking techniques. Various clustering Schemes have been discussed and employed in both homogenous and heterogeneous wireless sensor network.

Keywords: *Wireless underground sensor networks (WUSNS), Heterogeneous energy efficient mobile node clustering protocol (HEEMCP).*

1. INTRODUCTION

A wireless sensor network is a group of specialized transducers with a communications infrastructure for monitoring and recording conditions at diverse locations. A sensor network consists of multiple detection stations called sensor nodes, each which is small, lightweight and portable. Every sensor node is equipped with a transducer, microcomputer, transceiver and power source. The power for each sensor node is derived from a battery. Some sensors may also be provided with additional units like Global Positioning System (GPS), allowing them to accurately determine their position [1]. There are five types of wireless sensor network [2]: Terrestrial wireless sensor network, underwater wireless sensor network, Underground wireless sensor network, Multimedia wireless sensor network and mobile wireless sensor network. Terrestrial sensor networks are designed to operate on the land it needs air as communication channel for communication. Underground wireless sensor networks are specialized kind of wireless sensor network that mainly focuses on the use of sensors at the subsurface region of the soil. Electromagnetic waves function as the communication medium. In which underwater wireless sensor networks are ocean bottom sensor nodes enable application for oceanographic data collection, pollution monitoring, offshore exploration, disaster prevention, assisted navigation and tactical surveillance applications. Battery power is limited and usually batteries cannot be recharged. Multimedia sensor network has enabled tracking and monitoring of events in the form of multimedia such as audio, video, and imaging. The mobile wireless sensor network is much more versatile than static sensor networks. The advantage of mobile wireless sensor network over static wireless sensor network includes better and improved coverage, better energy efficiency, and superior channel capacity. Micro-electro-mechanical systems (MEMS) accelerometers, for instance, are ubiquitous in airbags and have recently started appearing in commodity hardware such as laptop hard disc drives. Wireless sensor networks will have a role to play for a number of military purposes like enemy movement detection and force tracking. Being equipped with suitable sensors, these networks can enable detection of enemy motion, exploration of enemy force and analysis of their movement and improvement. Environmental observation and forecasting may include volcanic studies and eruption warning system, flood detection, meteorological observation, earthquake studies and warning system, cyclone and tsunami warning system, water quality monitoring etc. Applications of wireless sensor networks focused on monitoring the health status of patients have been in demand and various projects are in the development and implementation stages [3]. Sensor networks are being researched and deployed in a wide range of applications in healthcare. Typical application scenarios could be monitoring of heart beats, body temperature, body positions, the location of the person, overall monitoring of ill

patients in the hospital and at home and so on. Sometimes this domain area is referred to as wireless body area sensor networks or Wireless Body Area Networks (WBAN). Wearable sensors can be integrated with a wireless body area network to monitor the environmental parameters and vital signs, and thus allow monitoring of elderly people or patients with instantaneous alerts to health care personal, immediate reports to the users about their current health updates. WSN technology is not considered mature enough to be widely implemented in process control applications. Even though wireless transmission of data has been utilized for over ten years in process control applications such as supervisory control and data acquisition (SCADA), industrial WSN products for process monitoring and control are not commercially available until recently due to its specific requirements and challenges. By using sensor networks, maintenance can be conducted on the basis of the condition of the equipment, which significantly reduces the cost of maintenance, increases machine life time and even saves lives. A wireless sensor network consists of a large number of unattended tiny devices equipped with different sensors to perform certain tasks. They can be used in challenging places where it is inconvenient for a human to be present. The sensors on the devices extract physical information from the environment, such as temperature through a temperature sensor, pressure through a barometer, noise through a microphone, and even an image through a camera or thermal camera. The collected data then is sent over to the control command for further processing. Heterogeneous systems with low-cost sensors and imagers can be very cost-effective in some cases. Hardware constraints, fault tolerance, scalability, production cost, WSN Topology, Transmission media, Power consumption, Security are the factor in which challenges have to be faced by the Wireless sensor network. Wireless sensor networks (WSNs) may consist of several thousands of homogeneous or heterogeneous sensors that can collect reliable and accurate information in distant and hazardous environments. Wireless Sensor Networks are generally assumed to be energy restrained because sensor nodes operate with small capacity DC source or may be placed such that replacement of its energy source is not possible Most commonly battery is used to supply electricity to the deployed nodes, so it's important to route the notes to efficiently utilize its power. A basic wireless sensor network requires very little infrastructure. In one such network, nodes can be deployed in an ad hoc fashion. Aggregating nodes in clusters has many advantages [4] as the size of the routing table stored at each node gets reduced. Communication bandwidth can be conserved since inter-cluster interactions become limited to cluster heads and hence avoid the redundant exchange of information among sensor nodes. Objectives of node clustering are dependent on the application. Some of the most common objectives of clustering are load balancing, fault tolerance, keeping cluster count to a minimum and maximum network longevity. A heterogeneous wireless sensor network consists of a large number of normal nodes and some heterogeneous nodes. The main task of normal nodes is sensing and issuing data report. However, heterogeneous nodes have advanced energy capacity or communication capability. In comparison with normal nodes, these nodes may be configured with more memory and more powerful microprocessor/microcontroller. There are three types of heterogeneity in WSNs, mainly computational, link and energy heterogeneity. Computational heterogeneity means heterogeneous node is equipped with more powerful microprocessor and more memory. Link heterogeneity means heterogeneous node has long distance network transceiver-like Ethernet and high bandwidth. This provides more reliable data communication. Energy heterogeneity means heterogeneous node is line powered or its battery can be replaced. Studies and eruption warning system, flood detection, meteorological observation, earthquake studies and warning system, cyclone and tsunami warning system, water quality monitoring etc. Applications of wireless sensor networks focused on monitoring the health status of patients have been in demand and various projects are in development and implementation stages. Sensor networks are being researched and deployed in wide range of applications in healthcare. 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A heterogeneous wireless sensor network consists of a large number of normal nodes and some heterogeneous nodes. The main task of normal nodes is sensing and issuing data report. However, heterogeneous nodes have advanced energy capacity or communication capability. In comparison with normal nodes, these nodes may be configured with more memory and more powerful microprocessor/microcontroller. There are three types of heterogeneity in WSNs are computational, link and energy heterogeneity.

2. LITERATURE REVIEW

Prasad et.al [5] presented a framework for fault revoking and homogenous distribution of randomly deployed sensor nodes, so that the cluster head within various clusters consume equal amount of energy. Deployment area was first divided into clusters of equal size. Mobile sensor nodes were deployed in the deployment area with the help of parachutes and each of the mobile sensor nodes was embedded with a static sensor node that can be used to replace the dead sensor nodes in the network. The total number of mobile sensor nodes were equal to the total number of clusters and the number of mobile sensor nodes which were required for fault revoking depends on the number of clusters and the size of deployment area. In a cluster if a sensor node gets damaged then its location id was sent to the mobile sensor node by the base station. The affected sensor node was replaced by mobile sensor node, thus increasing the lifetime of the network.

Rashed et.al [6] proposed an energy efficient routing protocol called Weighted Election Protocol (WEP). It is a scheme of combining clustering strategy with chain routing algorithm for satisfying both energy and stable period constraints under heterogeneous environment. Weight was assigned to the optimal probability for each node and this weight was kept equal to the initial energy of each node divided by initial energy of the normal node. After assigning

weight, cluster head election was done in the same way as in LEACH.

Nazir et.al [7] presented an energy efficient multi-hierarchy clustering protocol. In this protocol, in addition to normal nodes, sensor nodes with more energy called super nodes were deployed to cater hotspot problem and prolong network lifetime. The multi-level hierarchy was achieved by placing super nodes acting as a local sink at the top level, normal nodes as cluster heads at the middle level and normal nodes as cluster member at the lowest level. Both coverage and residual energy were used as selection parameter for CH. After CH selection, sleep/wakeup schedules for nodes were defined by CHs. Nodes covering the same area were made to sleep and wake alternately. TDMA scheduling was done by CHs to avoid interference in transmission. After that data was sent from cluster members to CH using single hop and from CH to BS using multi-hop communication.

Said et.al [8] proposed an improved and balanced clustering algorithm called Improved and Balanced LEACH (IB-LEACH). In this scheme, some high energy nodes called NCG nodes (normal node/cluster head/gateway) were made cluster heads to aggregate the data of their cluster members and transmit the data to the chosen gateways that requires the minimum communication energy in order to reduce energy consumption of cluster head and to decrease probability failure of nodes. It was more effective in prolonging lifetime and stability period than LEACH and Stable Election Protocol (SEP).

Elbhiri et.al [9] discussed another clustering protocol for heterogeneous wireless sensor networks called Stochastic Distributed Energy-Efficient Clustering (SDEEC) protocol. The cluster head election was based on the residual energy of the nodes. This protocol was based on DEEC with new strategies. The stochastic energy was the main idea where the intra cluster transmission was reduced. This protocol also considers two-level heterogeneity, but unlike DEEC energy consumption was reduced by making non-CH nodes sleep. The drawback in this protocol was that if non-CH nodes turn off their radios when CH is performing data aggregation, how they would come to know about the next round of CH selection.

Yassein et.al [10] presented another clustering protocol called V-LEACH in which besides having a cluster head, a vice-cluster head was also elected that performed the role of cluster head when it was dead. The advantage of this protocol was reliable data transmission to the base station and there was no need of electing new cluster head each time when a cluster head was dead.

ZhouHaibo et.al [11] analyzed a self- adaptive clustering routing protocol called EDFM. It is different from other energy efficient protocols in terms of CH election. It was based on one step energy consumption forecast method. Considering the energy consumption in sequential rounds is correlative, Energy-efficient Forecast Method (EDFM) used average power consumption of two types of CHs in the previous round as power consumptions in next round to forecast the CHs. To evaluate performance, time intervals before first node dead (stable state period) and half nodes dead (normal state period) were recorded. This protocol balanced the energy consumption in each round very well and has increased the lifetime as well as a stable period of the network.

Kumar et.al [12] presented an extension of SEP. EEHC is an energy efficient clustering protocol for heterogeneous WSNs. This scheme extended the network lifetime by introducing three degrees of heterogeneity: normal, advanced and super nodes. For each type of nodes, optimal percentage to become CH was defined. The principle of EEHC was kept same as that of SEP with the addition of one more node type. Network lifetime achieved was more than that achieved using SEP.

Varma [13] proposed a base station initiated dynamic routing protocol in which nodes possessing the higher computational capability and more power were elected as cluster heads. A reference level was defined as the distance from base station to CH. A CH was considered in low level if it was near to the base station. The base station was set at 0 level and the communication was initiated by the BS by broadcasting a packet for CHs. Level of CHs was set according to the packets received. Selected first level CHs broadcasted their level to the lower level CHs. In a similar manner, the transmitting powers of all the CHs were set according to their parents. Then sensor nodes would join their CHs according to RSS of different CH and the data transmission would take place. Communication between CH and sensor nodes was single hop while communication between CH and BS was multi-hop.

Li et.al [14] developed another clustering protocol in a heterogeneous environment called REECR. Cluster head election was done on the basis of residual energy and energy consumption rate (REECR) of the node rather than the rotation in turn. Since type-1 nodes transmitted bigger data packet than type-0 nodes, therefore energy consumption rate of two types of nodes was imbalanced. Hence energy consumption rate becomes one of the factors of electing cluster heads. At the same time, the residual energy of a node was also considered as a factor of electing cluster heads so that nodes having more residual energy were elected as cluster heads.

Qing et.al [15] described another protocol for heterogeneous wireless sensor networks. It is a distributed energy efficient clustering protocol based on clustering. Cluster heads were elected on the basis of probability based on the ratio between residual energy of each node and the average energy of the network. The epochs of being CH for each node was different depending upon its initial and residual energy. The nodes with high initial energy had more chances to become CHs than the nodes with less initial energy. DEEC had prolonged network lifetime as well as the stability period.

Loscri et.al [16] proposed another LEACH based protocol which used two-level hierarchies. In this, instead of one cluster head, two cluster heads were elected, primary and secondary. Cluster head collects data from another cluster member as in LEACH, but instead of transferring data directly to the base station, it used one of the cluster heads lying between the cluster head and the base station as a relay station. Data was sent from each sensor node to its secondary cluster head. Then aggregated data from secondary cluster head was sent to its primary cluster head. Transmit distance for nodes had been reduced, so less energy was consumed and hence it was possible to do data aggregation could be done both on primary and secondary levels to further improve the energy efficiency.

Smaragdakis et.al [17] proposed an energy-aware protocol for heterogeneous wireless sensor networks. SEP or Stable Election Protocol is used for electing cluster heads in two-

level hierarchical wireless sensor networks. This protocol is based on weighted election probabilities of each node to become cluster head according to the residual energy in each node. SEP improved the stable region of the clustering hierarchy process using the fraction of advanced nodes (m) and the additional energy factor between advanced and normal nodes (α). Since advanced nodes had more energy than normal nodes, so advanced nodes were made cluster heads more frequently than the normal nodes. This was done by increasing the epoch of the sensor network in proportion to the energy increment. However, SEP cannot be used for multi-level heterogeneous wireless sensor networks.

Younis et.al [18] presented another energy efficient clustering protocol for multi-hop networks called HEED. CHs here selected periodically according to a combination of two clustering parameters. The primary parameter was the residual energy of each sensor node which was used to probabilistically select an initial set of CHs, and secondary parameter was the intra-cluster communication cost as the function of cluster density and it was used for breaking ties. CHs selected in HEED was well distributed across the network and the communication cost was minimized.

Mhatre et.al [19] made a comparative study on homogenous and heterogeneous network for single hop communication. For homogenous networks, LEACH was used as the representative and for heterogeneous networks, a network with two types of nodes was used. A method to estimate the optimal distribution among different type of sensor nodes was proposed. The case of multi-hop routing was also studied within each cluster. For the multi-hop homogeneous network, a multi-hop variant of LEACH called M-LEACH was proposed and analyzed. Results show that M-LEACH had better energy efficiency than LEACH in many cases. A comparison based on cost was also done between multi-hop homogenous network M-LEACH and multi-hop sensor network with two types of nodes.

Heinzelman et.al [20] discussed a centralized clustering algorithm called LEACH-C. During the setup phase, each node's location and energy level was sent to the base station. The decision of node to be selected as cluster head was made by the base station on the basis of average node energy. Once the cluster heads were elected and the associated clusters were formed, data transmission was done as in LEACH. This protocol produced a better cluster distribution than LEACH as it had global knowledge about the location of all the nodes but it required nodes to be equipped with GPS (Global Positioning System) or other location finding algorithms and also if base station was far away from the network then the cost to reconfigure the network would be high.

Manjeshwar et.al [21] presented an improved version of TEEN to overcome its drawbacks. It is a hybrid clustering protocol that allows the sensor to sense the data periodically (as in LEACH) and react to any sudden change in the value of the sensed attributes (as in TEEN). The architecture of APTEEN is same as that of TEEN. APTEEN supports 3 different query types namely a) historical query, b) one-time query, to take a snapshot view of the network and c) persistent queries, to monitor an event for a period of time.

Manjeshwar et.al [22] proposed another hierarchical protocol for reactive networks called TEEN. Reactive networks are the networks in which node respond immediately to the changes in the relevant parameters. In this protocol, in addition to the attributes, CH sends a hard and a soft threshold. The nodes sense their environment continuously. The first time a parameter from the attribute set reached its hard threshold value, the transmitter of the node was switched on and data was sent. The sensed value was stored in an internal variable called sensed value (SV). The data was sent by the nodes in the current cluster period if the following conditions were true: the current value of the sensed attribute was greater than the hard threshold, and the current value of the sensed attribute differs from sensed value by an amount equal to or greater than the soft threshold. Both strategies tend to reduce the number of transmissions. The main drawback of this scheme was that, if the thresholds were not reached, the nodes would never communicate; the user would not get any data from the network at all and would not come to know even if all the nodes were dead.

Heinzelman et.al [23] proposed the first clustering protocol LEACH, based on single hop communication model. The operation of LEACH consisted of 2 phases. In the setup phase, cluster head election and cluster formation has done. Cluster head selection was done on the basis of threshold equation. During the steady state phase, data transmission was done. Data was first sent from non-cluster heads to cluster head and then to base station. Due to high energy consumption at cluster heads, they were re-elected in the next round in order to distribute the energy load among all the nodes. This protocol resulted in improved energy efficiency of the network. But this protocol had many disadvantages too, like non-uniform and unbalanced distribution of cluster heads and, random cluster head selection.

L. B. Oliveria et al. proposed FLEACH, a protocol for securing node to node communication in LEACH-based network. It used random key pre-distribution scheme with symmetric key cryptography to enhance security in LEACH. FLEACH provides authenticity, integrity, confidentiality and freshness to node-to-node communication. But it is vulnerable to node capturing attack [24].

3. PERFORM WORK

Following steps have been followed to achieve the objective:

Survey of the literature related to the proposed work.

Implementation /simulation of the cluster using MATLAB.

Implementation/simulation of LEACH protocol using MATLAB.

Implementation/simulation of the HEEMCP using MATLAB.

The channel between transmitter and receiver could be as simple as a line of sight, but mostly electromagnetic waves bounce off from objects in the environment and reach the receiver following multiple paths. This electromagnetic wave propagation can be model as a power law function of the distance between the transmitter and the receiver. For simulation of different protocols, both free space model and multipath models were used, depending on the distance between transmitter and receiver as defined by channel propagation model. If the distance between transmitter and receiver is less than a certain cross-over distance, the Fries free space model is used, and if the distance is greater than cross-over distance, Two Ray Ground Propagation Model is used. The cross-over distance is given by:

$$d_{crossover} = \frac{4\pi\sqrt{L}h_r h_t}{\lambda}$$

Before discussing step-by-step simulation of the proposed protocol, it is important to select good models for all aspects of communication. Here, a simple model is assumed where transmitter and receiver dissipate the energy to run the radio electronics in the power amplifier. The power attenuation is dependent on the distance between transmitter and receiver. For short distances, the propagation loss is inversely proportional to d2, whereas, for longer distances, it is inversely proportional to d4.

LEACH

Low Energy Adaptive Clustering Hierarchy (LEACH) is a self-organizing, adaptive clustering protocol that uses a randomized rotation of cluster heads to distribute the energy load among the sensor nodes. The main features of LEACH are:

Localized coordination and control for data transfer,

Randomized, self-configuring and adaptive formation of clusters Low energy media access, and Data processing, such as data aggregation to reduce global communication.

HEEMCP - The Proposed Protocol

In this paper, Heterogeneous Energy Efficient Mobile Node Clustering Protocol is developed and compared against LEACH. The key features of this protocol are Self-organization of sensor nodes.

Randomized rotation of cluster heads and the corresponding clusters.

Addition of hierarchical level which comprises of the master cluster head.

TDMA scheduling for energy efficiency.

Local compression to reduce global communication. Replacement of cluster heads or master cluster head with mobile nodes when their energy gets depleted. In this section, a comparison is drawn between the performance of HEEMCP with LEACH protocol, in terms of energy consumption and network lifetime. It is clear that network lifetime of HEEMCP has improved further from other existing protocols. Analysis of network lifetime in terms of the death of first node, the death of first 10 nodes, half nodes alive and all the nodes dead. Comparison result for energy consumption in each round. All the protocols are compared with HEEMCP. It can be inferred from the figure that HEEMCP is an order of magnitude more energy efficient than LEACH protocol. Data processing, such as data aggregation to reduce global communication.

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