An energy efficient protocol in Wireless Sensor Networks: A Survey

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Abstract: Wireless sensor network (WSN) are composed of a large number of sensor nodes which have limited energy. Replacing these energy sources in the field is usually not practicable, and simultaneously, a WSN must operate at least for a given mission time or as long as possible. Hence, the lifetime of a WSN is one of the most critical issues. Maximizing the network lifetime is always a main challenge ahead of WSN. Clustering and routing has been proved to be energy-efficient strategies for extending the network lifetime. The paper reviews the traditional energy efficient protocols to improve cluster head selection approach.

Keywords: Wireless Sensor Networks, Cluster head, Protocols, Energy Efficiency, Clustering

I. INTRODUCTION

A wireless sensor network is a highly complex distributed system comprising huge number of tiny wireless sensor nodes and base station (BS). Each wireless sensor node consists of sensor, processor, memory, RF transceiver (radio), peripherals, and power supply unit (battery) [1]. The basic components [1] of a node are a sensor unit, an ADC (Analog to Digital Converter), a CPU (Central processing unit), a power unit and a communication unit. Sensor nodes are micro-electro-mechanical systems [2] (MEMS) that produce a measurable response to a change in some physical condition like temperature and pressure. Sensor nodes sense or measure physical data of the area to be monitored. The continual analog signal sensed by the sensors is digitized by an analog-to-digital converter and sent to controllers for further processing. Sensor nodes are of very small size, consume extremely low energy, are operated in high volumetric densities, and can be autonomous and adaptive to the environment. The spatial density of sensor nodes in the field may be as high as 20 nodes/m3.As wireless sensor nodes are typically very small electronic devices, they can only be equipped with a limited power source [3]. Each sensor node has a certain area of coverage for which it can reliably and accurately report the particular quantity that it is observing. Several sources of power consumption in sensors are: (a) signal sampling and conversion of physical signals to electrical ones; (b) signal conditioning, and (c) analog-to-digital conversion.

There are three categories of sensor nodes:

- Passive, Omni Directional Sensors: passive sensor nodes sense the environment without manipulating it by active probing. In this case, the energy is needed only to amplify their analog signals. There is no notion of “direction” in measuring the environment.

- Passive, narrow-beam sensors: these sensors are passive and they are concerned about the direction when sensing the environment.

- Active Sensors: these sensors actively probe the environment.

  Potential applications of sensor networks include

  - Video surveillance
  - Traffic monitoring
  - Medical device monitoring
  - Monitoring of weather conditions
  - Air traffic control
  - Robot control

Since a sensor node has limited sensing and computation capacities, communication performance and power, a large number of sensor devices are distributed over an area of interest for collecting information (temperature, humidity, motion detection, *etc.*). These nodes can communicate with each other for sending or getting information either directly or through other intermediate nodes and thus form a network, so each node in a sensor network acts as a router [4] inside the network. In direct communication routing protocols (single hop), each sensor node communicates directly with a control center called Base Station (BS) and sends gathered information. The base station is fixed and located far away from the sensors. Base station(s) can communicate with the end user either directly or through some existing wired network.

The topology of the sensor network changes very frequently. Nodes may not have global identification. Since the distance between the sensor nodes and base station in case of direct communication is large, they consume energy quickly. In another approach (multi hop), data is routed via intermediate nodes to the base station and thus saves sending node energy. A routing protocol [5] is a protocol that specifies how routers (sensor nodes) communicate with each other, disseminating information that enables them to select routes between any two nodes on the network, the choice of the route being done by routing algorithms. Each router has *a* priori knowledge only of the networks attached to it directly. A routing protocol shares this information first among immediate neighbors, and then throughout the network. This way, routers gain knowledge of the topology of the network.

There are mainly two types of routing process: one is static routing and the other is dynamic routing. Dynamic routing [6] performs the same function as static routing except it is more robust. Static routing allows routing tables in specific routers to be set up in a static manner so network routes for packets are set. If a router on the route goes down, the destination may become unreachable. Dynamic routing allows routing tables in routers to change as the possible routes change. In case of wireless sensor networks dynamic routing is employed because nodes may frequently change their position and die at any moment.

Local groups or clusters of nodes can be formed; the "controllers" of such groups are often referred to as cluster heads (CH) and remaining sensor nodes are called as cluster nodes (CN). The role of each CH is to carry out the following three tasks. The first task is to gather sensed data from the cluster nodes periodically and aggregates the data in an effort to remove redundancy among

correlated values. The second task of the cluster head is to generate a Time Division Multiple Access (TDMA) schedule through which sensor nodes receive a time slot for data transmission. The third task is to transmit the aggregated data to nearby CH or directly to the base station. Hence the lifetime of CH would be a very short span of time if the fixed node performs all the three tasks and it becomes essential to shift the cluster head periodically in a well-structured manner. In this work a new CH selection mechanism was proposed for the two tiered WSN architecture based on residual energy and communication distance between the sensor nodes.

II. PROBLEM STATEMENT

In many scenarios, nodes will have to rely on a limited supply of energy (using batteries). Replacing these energy sources in the field is usually not practicable, and simultaneously, a WSN must operate at least for a given mission time or as long as possible. Hence, the lifetime of a WSN becomes a very important figure of merit. Evidently, an energy-efficient way of operation of the WSN is necessary. As an alternative or supplement to energy supplies, a limited power source (via power sources like solar cells, for example) might also be available on a sensor node. Typically, these sources are not powerful enough to ensure continuous operation but can provide some recharging of batteries. Under such conditions, the lifetime of the network should ideally be infinite. The lifetime of a network also has direct trade-offs against quality of service: investing more energy can increase quality but decrease lifetime [18].

III. OVERVIEW OF ENERGY EFFICIENT OPERATION

Energy Efficient Operation proposed for WSNs, cluster-based algorithms are more effective in meeting WSNs requirements, mainly energy consumption [2-5]. By clustering of sensor nodes into some groups called clusters, SNs of each cluster send their data to specific SNs in the cluster called Cluster Heads (CH).

Then, CH nodes transmit gathered information to the BS. Since CH nodes play an important role in the performance of cluster-based routing algorithms, the policy of CH node selection deeply affects network parameters i.e., network lifetime, energy consumption rate. Figure 1 shows a generalized view of WSNs, which consists of a base station, cluster heads and sensor nodes or a cluster member deployed in a geographical region. LEACH, Low-Energy Adaptive Clustering Hierarchy, is one of the most popular cluster-based routing protocols in WSNs.[5][18]

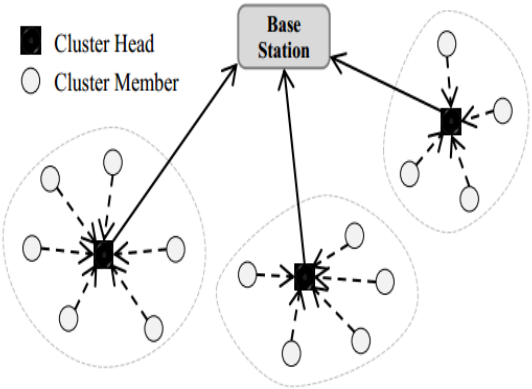

Figure 1 Cluster-based Mode

The goal of LEACH is to lower the energy consumption required to create and maintain clusters in order to improve the life time of a WSN. The operation of LEACH is partitioned into rounds and each round is partitioned into two phases namely as: setup phase and steady state phase. Steady-state phase is always long than the setup phase to minimize the overhead [2].

In LEACH protocol, time is divided into fixed intervals with equal length, which is called round or topology update interval. At the beginning of each round, each SN becomes a CH with some predetermined probability. During the CH selection, each SN selects a random number between 0 and 1 and compares it with a calculation threshold value (1). If the random number is lower than the threshold value, then that SN will become the CH in the current round. The CHs then broadcast messages to their neighbors. Other sensor nodes receive messages from the CHs and join a cluster by choosing the nearest CH (based on the received signal strength). Each non-CH transmits a join-request message back to its chosen CH using a code division multiple access (CSMA) MAC protocol. CH node sets up a time division multiple access (TDMA) schedule for data transmission coordination within the cluster [9].

IV. OUTCOMES OF A SURVEY

A *Distance based cluster head (DBCH) Algorithm*

In distance based cluster head (DBCH) Algorithm [11] new clustering algorithm which is based on LEACH. It establishes a new Threshold which includes the node energy and distance between node and base station and distance between cluster head and base station for measuring the threshold value. Simulation results show that proposed algorithm is better than LEACH in balancing the node energy and thus enhancing the network lifetime.

B *Tier Based Energy Efficient Protocol (TBEEP) and Cluster Based Energy Efficient Protocol (CBEEP)*

In TBEEP, [7] nodes are divided into three different areas depending upon their distance from Base station, commonly known as tires. Energy is distributed homogeneously in a network among all sensor nodes and minimum spanning tree is generated. After that, a head node is chosen from each tier based on the maximum energy that can send sensed aggregated data to the Base station. In CBEEP, relay nodes which are FFD (Fully Functional Device) are treated as cluster head which will perform the job (sending data to the base station) through other relay nodes which are closer to Base station. In this paper, simulation results calculate lifetime of a network and energy consumed and results are compared between the proposed protocols and LEACH using random and uniform deployment.

C *An Improved Cluster Head Selection Approach*

In An Improved Cluster Head Selection Approach,[12] considers the sensor nodes residual energy to select optimal cluster head for next round of cluster head selection algorithm. The algorithm guarantees the entire network stays alive for longer time than the other existing energy efficient techniques. The proposed technique thus improves the overall performance of wireless sensor networks in terms of increasing the lifetime of sensor nodes, reducing the bandwidth consumption and latency of WSNs. Also balancing energy distribution among all nodes of the network increases the round number at which the first node dies which reduces the energy holes in WSNs.

D *Cluster based energy efficient routing algorithm (CBER)*

In cluster based energy efficient routing algorithm (CBER)[2], CBER elects CH based on nodes near to the optimal cluster head distance and residual energy of the nodes. In WSNs energy is mostly consumed for transmission and reception, it is a non linear function of transmission range. In this paper, the optimal cluster head distance which links to optimal energy consumption is derived. In addition, residual energy is considered in the CH election in order to increase the network lifetime. Furthermore, the energy consumption of being a CH is equally spread among the cluster members. Performance results show CBER scheme reduces the end to end energy consumption and prolong the network lifetime of multi hop network compared to the well-known clustering algorithms LEACH and HEED.

E *Distance Based –LEACH (DB-LEACH) and Distance-Based Energy Aware-LEACH (DBEA-LEACH)*

In Distance Based –LEACH (DB-LEACH) selects a cluster head node by considering geometric distance between the candidate nodes to the base station. To further improve DB-LEACH, DBEA-LEACH (distance-based energy aware) additionally selects a cluster head not only based on distance, but also by examining residual energy of the node greater than the average residual energy level of nodes in the network.

F *Energy Delay Index for Trade-off (EDIT)*

In Energy Delay Index for Trade-off (EDIT) [15] is used to optimize both objectives— energy and delay. The EDIT is used to select cluster heads and "next hop" by considering energy and/or delay requirements of a given application. Proposed approach is derived using two different aspects of distances between a node and the sinks named Euclidean distance and Hop-count, and further prove using realistic parameters of radio to get data closest to the test bed implementation. The results aspire to give sufficient insights to others before doing test bed implementation.

G *An Energy Efficient and Optimal Randomized Clustering (EEORC)*

In An Energy Efficient and Optimal Randomized Clustering (EEORC) [9] decides optimal number of clusters by employing a new approach for setting threshold value, including the probability of optimum number of cluster heads and residual energy of the nodes. We also introduce a new approach maximize the network lifetime by tree construction in each cluster. Computer simulation shows that the proposed scheme effectively reduces and balances the energy consumption among the nodes, and thus significantly extends the network lifetime compared to the existing schemes.

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Ethical statement: I declare that I have followed ethical responsibilities

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