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A Survey on Energy Efficient Protocols for Wireless Sensor Network

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ABSTRACT
A wireless sensor network (WSN) consists of inexpensive power constrained sensor nodes collecting data from the sensing area and transmits data towards the base station in a synergetic way. Wireless sensor networks are appearing as an emerging need for mankind now a day. The basic goal of Wireless sensor networks is to enhance the lifetime of the network, and to use the energy of nodes efficiently. The WSN nodes are restricted by energy, storage capacity, and computing power. So it is necessity to design more effective and energy aware protocols to enhance the network lifetime and stability. Energy efficient design and implementation of WSN has become a very popular area of research in recent years. Increasing the stability and network lifetime is the major issue in WSN. This paper presents a review on different protocols of wireless sensor network.

Keywords
Sensor networks, routing protocol, energy aware routing, classification of protocol

1. INTRODUCTION
Wireless sensor network (WSN) is a collection of tiny, battery constrained sensors interconnected with each other to monitor the physical or environmental conditions, such as sound, vibration, pressure, temperature, motion or pollutants, at different locations [2]. WSN is widely used in various domains like medical diagnoses, disaster management, industrial processes, military surveillances and traffic management. In WSN each sensor node communicates with other sensor nodes within its radio communication range [3]. WSN nodes sense information from different location and send this sensed information to the base station. A wireless sensor network has thus become a very effective tool for extracting data from the environment. WSN nodes deployed in the monitoring field may be either fixed or mobile. In addition, the sensor nodes communicate to the base station through a wireless network model instead of directly communicating through a wired means. So, wireless sensor networks are more convenient and flexible for getting data from monitoring environment. The conventional wired sensor network nodes are very costly and involve large amounts of energy for the network operation.

Also, the deployment of these nodes is very expensive. Therefore, it is very good idea to replace these node with low cost nodes. It is very important that the sensor nodes be easy to deploy. The general architecture of a wireless sensor network is shown in figure 1. The protocols designed for such type of network must be energy efficient. The WSN is widely used in so many applications, so there are some constraints which affect the design of WSNs.

1.1 Limited Energy Supply:
Initially, the energy of any node in the network is very limited [2]. At the time of data transmission the node's energy is consumed. So, it is easy to drain the energy of any node in the network.

1.2 Limited transmission range:
The energy and antenna capability of node is limited, so it affects the transmission range of the node. Therefore, a large number of nodes have to deploy in a sensing area for good coverage of the network.

1.3 Small storage capacity:
sensor nodes are very tiny in size, and very small storage capacity in compared to traditional networks.

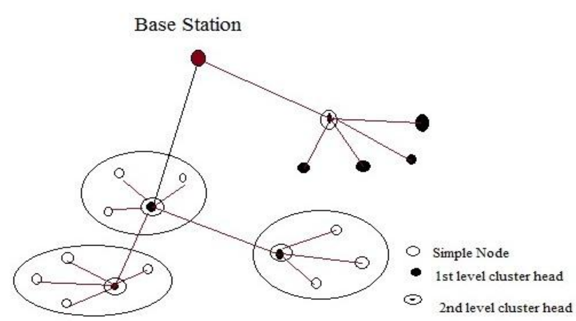

Fig 1: General architecture of wireless sensor network

Sensor networks can be classified into two types, homogeneous and heterogeneous networks. In a homogeneous network, all the nodes have identical energy. On the other hand, in a heterogeneous network, different types of nodes in terms of energy levels are used. Due to limited resource constrained like limited power computation, bandwidth, energy, storage and dynamic changing topology, wireless sensor network is unable to provide more efficiency in transmission, stability and network lifetime. These days, clustering is one of the most efficient techniques is extensively used as one of the best solutions to face up this limitation. Clustering superabundantly reduces the energy consumption. In this approach many protocols are used. Many energy efficient protocols are designed for improving the life time of network. There are different types of routing protocols in WSN. The taxonomy of routing protocol is shown in figure 2.

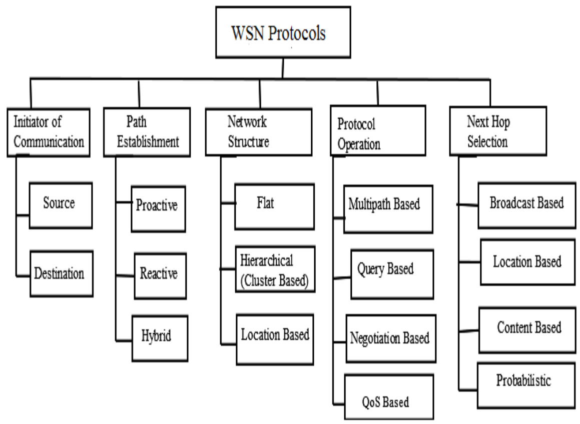

Fig 2: Taxonomy of wireless sensor network protocol

Protocols such as clustering enhance the performance of protocol in terms of energy and network organization. Clustering [13] technique is one of the most efficient techniques used in the WSN to improve the network lifetime and stability of a sensor network by belittling energy consumption [3] and provide network efficiency, scalability, and security. Clustering is dividing the whole network into small networks, which is known as clusters, and each cluster consist different number of nodes. Each cluster remains under the administration of a special type of sensor node often referred to as a Cluster Head (CH). A Cluster head may be elected by nodes itself or it may be elected by administrator. The sensor nodes sense the data from the area and transfer it to the CH, than cluster head aggregates the data referred as data aggregation, and sends this data to the base station. Figure 2 describes the general architecture of wireless sensor network. In this paper we describe some cluster based hierarchical routing protocols for WSNs.

2. ENERGY EFFICIENT PROTOCOLS IN WSN

Various routing energy efficient protocols have been developed for wireless sensor networks. Protocols such as clustering can enhance the performance of protocols in terms of energy efficiency and network organization**.** Initially, In WSN, classical approaches like direct transmission (DT) and minimum energy transmission (MTE) [9] were used to transmit the data to the base station. In direct transmission nodes senses the data from sensing area, and individually sends the sensed value to the cluster head. In DT approach, each sensor node directly transmit the sensed value to the base station, while in case of MTE, data is routed over minimum cost routes. In DT approach single hop communication [2,9] sensor nodes directly transmit their sensed data to the base station or sink, so the nodes far away from sink will die first, while in case of MTE, data is transmitted over minimum cost routes, where this cost reflects the transmission power. In the MTE, nodes near the base station passes on with higher probability than the nodes that are far from the base station. So the nodes near the base station will die first. In case of a large WSN which covers a large geographical area, direct transmission approach between the nodes and the sink is not possible. In such type of large WSN multihop communication takes place.

In DT and MTE approach, a part of the area will not be observed. A solution for this problem, called LEACH. Heinzelman et al.[2,3] proposed Low Energy Adaptive clustering Hierarchy(LEACH) protocol in 2000. LEACH is one of the oldest and first hierarchical routing protocols for WSN. It is a protocol for homogeneous network (all sensor nodes have same amount of energy). LEACH is a clustering routing protocol. It forms clusters of the sensor nodes and cluster head (CH) is elected dynamically according to the election probability, to transfer the data to the base station. A node themselves elects as a cluster head randomly and it is done in a way that each node in the network becomes a cluster head once in an epoch [1, 9, 11, 13]. This decision is made by the node itself, initially each node chooses a random number between, 0 and 1, and computes a threshold, and the threshold is computed as:

$$T(n) = \begin{cases} \frac{P}{1-P*(r \bmod \frac{1}{P})} & if\ n \in G \\ 0 & otherwise \end{cases} \qquad (1)$$

where p is the desired percentage of cluster head, r is current round and G is the set of nodes that have not become cluster head in last $\frac{1}{P}$ rounds. A node becomes a CH for the current round if the picked number is less than the threshold. LEACH is oldest and most famous protocol, but it is not as successful for heterogeneous WSN. So for heterogeneous networks, many different protocols are considered.

So to overcome this weakness of LEACH Smaragdakis et al.[4] proposed Stable election protocol (SEP) in 2004 for heterogeneous WSN which also guarantee network’s stability. Stable Election Protocol (SEP) extends LEACH in assigning election probabilities for nodes to become cluster heads according to the initial energy of a node. SEP is based on weighted election probability. Each normal node becomes a cluster head once in every $\frac{1}{P_{opt}}.(1+\alpha.m)$ round per epoch. Each advance node becomes a cluster head 1+α times every$\frac{1}{P_{opt}}.(1+\alpha.m)$ rounds per epoch. In this protocol two types of nodes are considered advance nodes and normal nodes, and advance nodes have α time more energy than normal nodes. In LEACH protocol only same energy level nodes are considered, but in SEP advance nodes are also considered with more energy than normal node, which improves the cluster head election, due to efficient cluster head election, advance nodes have more chances to be cluster head, so this mechanism improves the network lifetime and stability of network than LEACH.

Extension of SEP (ESEP) [20] is a network protocol for heterogeneous wireless sensor network. Although, the sensor nodes are power constrained so, energy optimization is most important factor and must be managed by an efficient manner to improve the lifetime of networks. it is an extension of SEP protocol, in which three types of nodes are considered with different level of energy: normal nodes, advance nodes and intermediate nodes. Advance nodes have more energy than normal and intermediate nodes; intermediate nodes have less energy than advance nodes and more energy than normal nods and rest of nodes are normal nodes. After election of cluster head, each node transmits data to associated cluster head, whereas, CH aggregates the sensed data from different nodes within cluster and send that data to BS. In ESEP, each node within a cluster chooses a random number between, 0 and 1, and this random number is compared with threshold, if the value is less than threshold, then node becomes a cluster head for current round. By increasing one more level of heterogeneity the life time of protocol is increased. In ESEP one more energy level of nodes is considered, so this improves the lifetime and stability of the network than SEP.

N.Javed et al.[21] proposed a protocol Heterogeneity-aware Hierarchical Stable Election (HSEP) protocol in 2012 for WSNs. It is a hierarchal based clustering routing protocol, which reduces the transmission cost between cluster head to base station. The energy consumption in data transmission depends on different factors. One of them is, the distance between CH and BS. If the distance between cluster head to BS will be more, then it will consume more energy for data transmission. HSEP is proposed by authors to improve this energy consumption between CH to BS. It consist two levels of nodes: normal nodes and advance nodes. Advance nodes have more energy than normal nodes. HSEP minimize this transmission cost between CH to BS, by using two types of CHs, primary and secondary. In HSEP, election probability is leaden by the initial energy of a node relative to the other nodes. In this approach, secondary cluster head can be elected from existing primary cluster heads, on the basis of probability, and only primary cluster heads can participate in process of electing secondary CHs this scheme improves the stability and life time of the network. For election of primary cluster head, each node selects a random number between, 0 and 1, if the random value is less than defined threshold then node become primary CH. Primary CHs aggregate, sensed data, and send it to the secondary CHs which further transmit data to the base station. By saving the transmission cost or energy consumption between CH and BS, lifetime and stability improves.

Threshold Sensitive Energy Efficient Protocol (TEEN) is a reactive, threshold sensitive, an event driven protocol for time critical applications. In TEEN [7] a node senses the sensing area continuously, but turns on its radio if there is a drastic change in the sensing value, and transmits that value to the base station. Every node in a cluster takes turn to become a cluster head within a cluster period. TEEN is based on two threshold values hard threshold and soft threshold. Two levels of thresholds are considered in TEEN, hard threshold and soft threshold. Whenever the currently sensed value becomes equal or greater than hard threshold, nodes turn their radio on and transmit data to the cluster head. And for the next time they transmit only when the difference between the sensed value and previously saved value at which transmission was done is greater than or equal to soft threshold. So, by using two level of threshold number of transmission is reduces, which improves energy consumption and stability of the network. The main drawback of this approach is, that the nodes will never communicate, if the threshold is not reached. So it is not suitable for such type of application where the user needs to get data on a regular basis.

Threshold sensitive Stable Election Protocol (TSEP) is proposed by N.Javed et al.[8]. TSEP is a reactive routing protocol for heterogeneous wireless sensor network. Generally transmission consumes more energy than sensing in WSN, so in TSEP transmission is done only when a specific threshold [8, 10] is reached. In TSEP we consider two levels of threshold, soft threshold and hard threshold. All nodes continuously sense the environment. As the parameter reaches hard threshold value, the transmitter is turned on and the data is transmitted to the base station. Now this sensed value is stored in a variable in the node. For the next time, and the other nodes will transmit sensed data only if the currently sensed value is greater than the hard threshold or the difference between the sensed value and previously stored value in the variable is equal or greater than soft threshold. In this approach, three levels of heterogeneity are considered, nodes with three levels of energy are: normal nodes, intermediate nodes and advance nodes. Where, advance nodes have energy greater than all the remaining nodes and a fraction of nodes which have more energy than the normal nodes and less energy than advance nodes , called the intermediate nodes, while rest of the nodes are called normal nodes. By considering two threshold and efficient cluster head election improves the lifetime and stability of the network.

Jin Wang et. Al [12] proposed a protocol name as "An Improved Stable Election based Routing Protocol with Mobile Sink for Wireless Sensor Networks (MSE)". It is reactive routing protocol with sink mobility. In the above approaches we assume that the base station or sink is stationary or fixed, but in this scheme sink is mobile with non-uniform node distribution. In this proposed scheme sink's route as the center line of the sensing field which is predictable. In this approach two types of nodes are considered: advance node and normal nodes, and advance nodes have α time more energy than normal nodes. The network is divided into several clusters, and cluster head is elected on the basis of residual energy of the node. Each cluster head collects data from different nodes into the cluster, aggregates it, and checks the distance between cluster head and sink trajectory before transmitting the data. If the distance between the normal CH to sink trajectory is greater than the distance between the normal cluster head to its nearest advance CH, it will calculate distance between advances CH to sink trajectory. If this distance is smaller, the normal CH will transfer the data to advance CH, and then advance CH to sink. If somehow advance CH die in current round, than corresponding normal CH have no next advance CH. To solve this condition, if the advance CH has no sufficient energy to transmit the data to BS, it will send a STOP-MSG to the normal CH associated with it, and remove itself from the network. Then normal CH again calculates its distance with adjacent advance node, and sets up a route, otherwise normal CH directly transmits the data to the base station.

3. MODELS USED IN CLUSTERING PROTOCOLS

Following system models are used for energy dissipation in the wireless sensor network clustering protocols:

3.1 Network Model

To develop the new protocol, the network model consists of the operating environment which consists of N number of nodes and one base station. Nodes are randomly installed in an M×M area with the base station assumed to be located at the center of the network area. The sensor nodes periodically sense the environment and send the sensed data to the base station. And on the other hand, the base station is responsible for getting data from the sensor nodes and then presented the user a condition of the environment where the nodes are sensing. Some of the characteristics of the network model are as follows:

1. All nodes have the equal capabilities of sensing, processing and communicating data;

2. The nodes are energy constrained;

3.2 Radio Energy Model

Radio energy model is used to assess the energy dissipation [1, 3]. The radio energy model has three modules i.e transmitter, amplifier and receiver. In this model the radio transmitter dissipates energy to transmit the data and receiver dissipates the energy to run the receiver for receiving the data. Radio dissipation model is shown in figure 3:

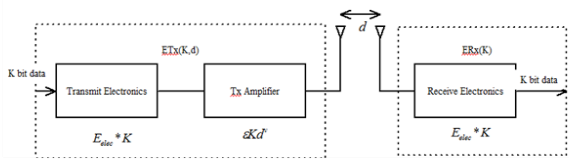

Fig 3: Radio energy dissipation model

In this model, two channel models free space model and multipath fading models are used, which depends on the distance between the transmitter and receiver. In free space model the propagation loss of transmitting power is modelled as inversely proportional to d^2, where d is the distance between the transmitter and the receiver. In the multipath fading channel model, the propagation loss of transmitting power is modelled as inversely proportional to d^4. The amplifier is used to amplify the transmitting power. Thus the energy for dissipating K bit data from transmitter to receiver at distance d is defined as:

$$E_{Tx}(K, d) = \begin{cases} K.E_{elec} + K.E_{fs} * d^2 & \text{if } d < d_0 \\ K.E_{elec} + K.E_{amp} * d^4 & \text{if } d < d_0 \end{cases} \quad (2)$$

Where E_{elec} is the energy dissipated per bit to run the circuit. E_{fs} And E_{amp} are amplifier parameters used for free space and propagation model and multipath fading model. d_0 is the crossover distance, and can be obtained from:

$$d_0 = \sqrt{\frac{E_{fs}}{E_{amp}}} \quad (3)$$

If the distance d is larger than d_0, multipath fading model is used otherwise, the free space model is considered to measure the energy dissipation.

4. CONCLUSION

The literature review on LEACH, SEP, ESEP, HSEP, TEEN, TSEP and Stable Election Protocol with Mobile Sink (MSE) in this paper. By conducting the detail study it is found that MSE protocol is much better than other protocol. MSE is more useful than other protocols in terms of their stability and lifetime also. The survey has shown that still some research is required to improve the stability of the network. Because we can further optimize the cluster head selection method. In near future we will propose a new Improved SEP protocol with sink mobility which increase the stability as well as entire lifetime of the WSN.

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