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A Technical Review on Variants of Stable Election Protocol (SEP): SEP-E, TSEP and ETSSEP in Heterogeneous Wireless Sensor Networks (HWSNs)

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Abstract: Wireless sensor networks (WSNs) are presently equipped to handle more complex functions. The main challenges in wireless sensor network include enhancement of stability, conservation of energy, the lifetime of the node and the throughput of the network and its node. To improve the stability of the network as well as to reduce the energy consumption clustering is used. In a cluster, efficient routing protocol plays a vital role in maintaining the stability and also helps in saving energy. In this paper we have surveyed some variants of Stable Election Protocol (SEP): SEP-E, TSEP and ETSSEP, they all are heterogeneous aware protocols i.e. sensor nodes are equipped with different amount of energy levels. These variants of SEP have three levels of heterogeneity in terms of normal, intermediate and advanced nodes.

Keywords: Wireless sensor networks, clustering, heterogeneous environment, stable election protocol.

I. INTRODUCTION

The Wireless sensor networks (WSNs) consists of small sensor nodes that are battery powered to monitor the physical or environmental conditions such as pressure, vibrations, sound, motion and temperature at different locations [1,4].These sensor nodes are scattered in the sensor field as depicted in Fig. 1. They have the capability to collect data and route them back to the sink. The data is routed back to the sink through multihop infrastructure-less architecture. The sink may communicate with the task manager/user via the internet or satellite or any type of wireless network like Wi-Fi, edge networks, cellular systems, WiMAX.

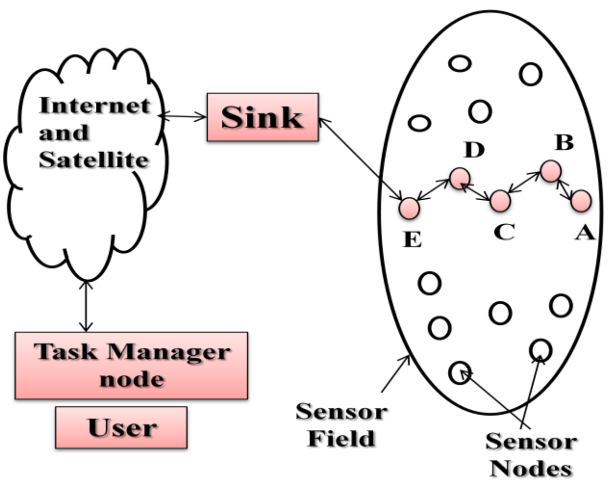

Fig.1. Architecture of Wireless Sensor Network (WSN)

In this network, node senses the data from inaccessible area and sends their report to the base station (BS) which is also called as the sink [11]. The nodes in wireless sensor networks can be mobile or stationary and are deployed in an area through proper or random deployment mechanism.

Sensor nodes have various characteristics like energy consumption, network lifetime, size, power level etc. WSNs are used in various applications like military, medical diagnoses, industries, and home automation [2].

As sensor nodes are battery operated their network lifetime depends on battery's power level. Thus energy conservation has been a key issue in wireless sensor networks.

The paper aims to survey some variants of stable election protocol in wireless sensor networks which reduce energy consumption and increase stability and throughput of the network.

The paper is organized as follows in Section II the radio energy dissipation model is described. Section III gives overview of clustering in WSN.

Section IV illustrates the related work and the motivation. Section V describes the stable election protocol (SEP). Section VI has review on some variants of SEP: SEP-E, TSEP and ETSSEP. Section VII describes the future research area and in Section VIII we conclude the paper.

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II. THE RADIO ENERGY DISSIPATION MODEL

The radio energy dissipation model is illustrated in Fig. 2. [2]. The energy expended in transmitting messages of K bits over a distance d is given by (1):

$$E_{Tx}(K,d)=\begin{cases} K.E_{elec}+K.E_{fs}*d^{2} & \text{if } d\le d_0 \\ K.E_{elec}+K.E_{amp}*d^{4} & \text{if } d\ge d_0 \end{cases} \quad (1)$$

where, E_{elec} is the energy expended per bit to run the transmitter or receiver circuitry and d_0 is the threshold distance and is calculated as (2):

$$d_0=\sqrt{\frac{E_{fs}}{E_{amp}}} \quad (2)$$

The free space model (E_{fs}) and the multipath fading channel model (E_{amp}) are two different radio models which are used. The distance between the transmitter and the receiver is denoted as d. If d is less than d_0 then the free space model is used, otherwise multipath fading channel model is used. E_{Rx} is the energy expended for receiving K bits and is calculated as (3):

$$E_{Rx}(K)=K.E_{elec} \quad (3)$$

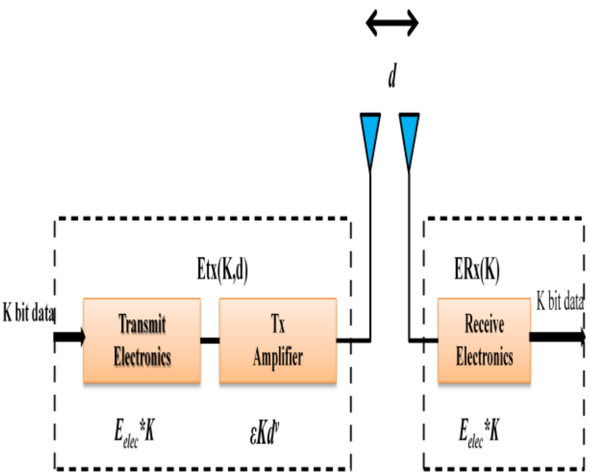

Fig.2. The **Radio** energy dissipation Model

III. OVERVIEW OF CLUSTERING IN WSN

Sensor nodes are battery powered hence to conserve energy in wireless sensor networks clustering is used. In clustering, the sensor nodes are distributed into some clusters and then some nodes are selected to be the cluster head of each cluster based on its probability to be a cluster head(CH). The nodes sense the field and send their data to the CH then after gathering and aggregating the data, the CH transmits them to the base station (sink) as shown in Fig. 3. Thus, with the help of clustering energy consumption is reduced and provides many other benefits that include reduction in routing delay and increasing the scalability [12]. Clustering's primary objective includes fault-tolerance, increasing scalability and lifetime, aggregating data and balancing load and secondary objectives are collision avoidance, increasing connectivity and to use sleeping schemes.

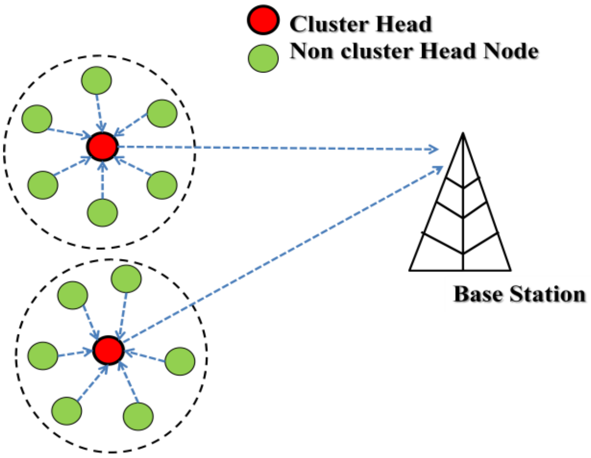

Fig.3. Cluster formation in a wireless sensor network

IV. RELATED WORK AND MOTIVATION

Homogeneous and Heterogeneous wireless sensor networks are the two categories in which clustered WSNs can be divided [10, 13]. All the nodes are equipped with an identical amount of energy in a homogeneous network. Whereas in a heterogeneous network, sensor nodes equipped with different amount of energy levels are used. Reduction in energy consumption and improvement in the network lifetime is achieved through Clustering. There are different protocols that use clustering technique to minimize energy consumption. These protocols should judiciously use energy in such networks as the nodes have irreplaceable batteries.

According to the application these protocols are classified into two categories that are proactive and reactive protocols. In the proactive protocol, sensor nodes sense the data from different locations and continuously transmit that data to the CH, then cluster head transmits to the base station whether it is required or not. Therefore, it is suitable for applications where information is required on a regular basis. While in later, if there is a drastic change in the sensed value, only then transmission occurs. Thus, it is suitable for the applications that are time critical. In routing protocols, electing a cluster head in a cluster leads to reduction in energy consumption and enhancement of the network lifetime.

The energy load distribution of the sensor nodes is not guaranteed in classical approaches such as in the case of the direct transmission (DT) and minimum energy transmission (MTE) [5]. In case of DT approach, data are directly transmitted to the base station (BS) by the sensor nodes, and thus the nodes that are far away from the sink

will die sooner than others. Whereas in the case of MTE, there are minimum cost routes over which data is routed, here cost reflects the transmission power. Under MTE, nodes close to the base station have higher probability to act as relays than the nodes that are far away from the BS. Hence, nodes that are close to the sink will die first.
In both cases, a portion of the field will not be monitored. The LEACH [2] protocol is a solution to this problem, which guarantee well distribution of energy load by creating clusters in a dynamic manner.
The Low Energy Adaptive Clustering Hierarchy (LEACH) protocol was proposed by Heinzelman et al. [2]. LEACH was the first hierarchical and reactive routing protocol for the wireless sensor networks. It is a protocol, which performs well in homogeneous networks, where all the sensor nodes have identical amount of energy.
In this protocol sensor nodes are divided into some clusters then cluster heads are elected from these clusters that aggregate data from the sensor nodes and finally transfers the data to the base station (BS). Hence, in the network only cluster head transmits the data to the base station instead of all the sensor nodes thus, energy consumption is low.
In this protocol, it is assumed that the base station or the sink is fixed. The crux of this protocol is to form clusters of sensor nodes [8]. Energy consumption is uniform as it randomly selects a cluster head for each cluster. A node is randomly selected as a cluster head and it is executed in such a way that each node becomes a cluster head once in an epoch [3,9]. The node itself makes this decision.
At the beginning, every node, choose a random number which is between 0 and 1, and then determines a threshold T(s). For the current round the node becomes a cluster head if the picked number is less than the threshold T(s), it is calculated as shown in (4):

$$T(s) = \begin{cases} \dfrac{p}{1 - p\left[r \bmod \left(\dfrac{1}{p} \right) \right]} & \text{if } s \in G \\ 0 & \text{otherwise} \end{cases} \qquad (4)$$

Where, p is the probability of a node to become a cluster head, r is the number of current round and G is the set of nodes that have not been cluster heads in the last 1/p rounds.

After the cluster formation each cluster head broadcasts a time division multiple access (TDMA) schedule for the associated nodes. Time slots are assigned to nodes for sensing and then transmitting data to the associated cluster heads. When each node in a cluster had sent the data, then the frame is repeated. LEACH is a protocol which is simple and distributed, for cluster head selection, low overhead is generated. But it is not suitable for heterogeneous wireless sensor networks. Due to energy constraint, it is not used in large areas. In this protocol once the attributes are selected, they cannot be changed.

V. STABLE ELECTION PROTOCOL (SEP)

The Stable Election Protocol (SEP) was proposed by Smaragdakis et al. [5] for the heterogeneous wireless sensor network [7] which increases network's reliability. It is an extension to the LEACH protocol in assignment of election probabilities for the nodes to become cluster heads, depending on the initial energy of a node.
The Stable Election Protocol is based on the weighted election probability and it provides improvement in the stable region of the clustering hierarchy process using the typical parameters of heterogeneity, which are the fraction of advanced nodes denoted as m and also the additional energy factor between the advanced and normal nodes denoted as α.The weighted election probabilities for the normal and the advanced nodes are shown in (5), (6), respectively:

$$P_{nrm} = \frac{P_{opt}}{1 + \alpha . m} \qquad (5)$$

$$P_{adv} = \frac{P_{opt}}{1 + \alpha . m} \times (1 + \alpha) \qquad (6)$$

Where, P_{opt} denotes the optimal probability of each node to become cluster head. The cluster heads election is done randomly based on the probability for each type of node like in the LEACH protocol. The sensed data is transmitted to the associated cluster head which then transmits it to the base station (BS). Increasing the advanced nodes denoted as m or P_{adv} can provide further improvement in the system. Therefore, it provides the increment of stability period and network lifetime due to advance nodes.

In this protocol, sensor nodes do not need any global knowledge of energy at each round. In SEP protocol, when the advanced nodes and normal nodes energy remains same, it again selects advance nodes as cluster heads rather than the normal nodes. Therefore, energy of advanced nodes drains more quickly than normal nodes and hence lifetime of the network is reduced.

VI. REVIEW ON VARIANTS OF SEP

In this section we have reviewed some variants of SEP: SEP-E,TSEP and ETSSEP.

A. Enhanced Stable Election Protocol(SEP-E)

The Enhanced Stable Election Protocol (SEP-E) was proposed by Aderohunmu et al. [6]. It is an extension to stable election protocol, in which there are three types of nodes that are referred as three tiers in the clustering process, in a two level hierarchy network. In this protocol, the relative distance of the advance nodes positions to the normal nodes position in a network determines the selection of intermediate nodes, or by the threshold of energy level between the advanced nodes and normal

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nodes. In SEP-E protocol, cluster heads selection depends on the probability of each type of node to become a cluster head. As there are three levels of heterogeneity, energy consumption is reduced to some extent. SEP-E protocol depends on the probability model thus the elected cluster heads may be very close to each other.
As in SEP-E the energy remains of each node are not considered so the nodes those have comparatively small energy remains can be the cluster heads. Therefore, the network's lifetime is reduced. At the edge of the network or in places which have very low density of nodes, cluster head may be located. Hence, many nodes in that cluster inefficiently utilize energy while communicating with the cluster head.

B. Threshold –sensitive Stable Election Protocol(TSEP)
The Threshold Sensitive Stable Election Protocol (TSEP) was proposed by Javaid et al. [9]. In the TSEP protocol, the cluster heads are selected on the basis of threshold. This protocol considers three types of nodes that have different energy levels, called as advance, intermediate and normal nodes. This protocol increases the stability and lifetime of the network because of three levels of heterogeneity. As it is a reactive routing protocol, thus throughput of the network also increases.

In the TSEP protocol, at the time of cluster change, following parameters are broadcasted by the cluster head, which are as follows: report time (TR), attributes (A), hard threshold (HT), soft threshold (ST).

The TSEP protocol increases the stability, lifetime of the network because of three levels of heterogeneity and it also increases the throughput of the network. As TSEP is a reactive routing protocol, thus the nodes keep on sensing continuously, but the transmission is not done in a frequent manner.

Therefore, energy consumption is much more less than that of networks that are proactive. As per requirement, the user can change the attributes because these attributes are broadcasted at the cluster change time. As the energy levels are not calculated for cluster head selection. Therefore, in TSEP the cluster head selection is still based on probability.

C. Enhanced Threshold Sensitive Stable Election Protocol for Heterogeneous Wireless Sensor Networks(ETSSEP)
The Enhanced Threshold Sensitive Stable Election Protocol (ETSSEP) was proposed by Kumar et al. [11]. This protocol is based on the TSEP protocol [9]. The ETSSEP protocol is a reactive routing protocol which is cluster based and has three levels of heterogeneity.

As ETSSEP has three levels of heterogeneity thus, the nodes with different energy levels are as follows: advance, intermediate and the normal nodes. Advance nodes have energy greater than all other nodes and a fraction of nodes that have energy more than the normal nodes and less than advance nodes are known as intermediate nodes. The rest of the nodes are known as normal nodes. In this protocol, the intermediate nodes and the advance nodes have 'β' times and 'α' times more energy than the normal nodes respectively. In this protocol, it is assumed that β = α/2.

In ETSSEP, the calculated probability depends on the node's residual energy and network's average energy at round r. Network's average energy at round r is estimated as (7):

$$\overline{E}(r) = \frac{1}{N} E_{total} \left(1 - \frac{r}{R}\right) \qquad (7)$$

where, r denotes the current round, N is the total number of nodes, E_{total} is the total of the initial energy of a heterogeneous network and R denotes the total rounds of the network, which is calculated as (8):

$$R = \frac{E_{total}}{E_{round}} \qquad (8)$$

In this protocol, for the selection of the cluster head the value of the threshold is adjusted that is based on the node's residual energy, network's average energy and the optimal number of clusters per round. Therefore, only the node that has the highest energy will become the cluster head, the threshold is set as (9):

$$T(s) = \begin{cases} \dfrac{p}{1 - p\left(r \cdot \bmod \dfrac{1}{p}\right)} * \dfrac{\textit{residual} \text{ energy of the node}}{\text{Average energy of network} * k_{opt}} & \text{if } s \in G \\ 0 & \text{otherwise} \end{cases} \qquad (9)$$

where, G is the set of nodes that have not become cluster heads in the last 1/P rounds, K_{opt} denotes the optimal number of clusters per round. It performs well in terms of stability, network lifetime and throughput and builds more stable routing environment.

VII. FUTURE WORK

In order to improve the stability and network's lifetime, adjustment in the mobility of the sink according to the cluster head location and increasing the level of classification of nodes in term of energy level can be done.

VIII. CONCLUSION

We have described some variants of Stable Election Protocol (SEP). Our aim is to provide a general idea of the existing SEP variants for heterogeneous wireless sensor networks (HWSNs). Many issues will remain open and we would like to see more research activities on these topics in the future.

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