A DEEP INSIGHT INTO HETEROGENEOUS ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

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Abstract: Wireless Sensor Network (WSN) deals with various wireless sensor nodes that are deployed in the targeted areas for sensing the surrounding. The sensed data is forwarded to the sink or base station for further required operation. The one of the significant concern that WSN suffers from is the limited battery constraints. Therefore, in this paper, various heterogeneous protocols are discussed that enhances the efficiency of the network to a great level. This paper aims to study the various methods that are adopted by some important studies available in the literature so far. As we know, it is the routing that decides the fate of the wireless senor node; therefore, the extensive review of these studies given in this paper will help the researchers to develop a new technique. While discussing about various routing protocols, the important concern of clustering is highlighted. Clustering proliferates the scalability of the network and also reduces the number of transmission from the sensor nodes. Therefore, this paper also aims to highlight the cluster head selection methods existing in the heterogeneous WSN. Furthermore, a significant insight to the various optimization methods is also being discussed to give a new direction to the researchers for developing new energy efficient protocol.

Keywords: Wireless Sensor Network, heterogeneous routing protocols, Clustering, Cluster head selection, optimization.

I. INTRODUCTION

Wireless Sensor Network (WSN) deals with various wireless nodes that are deployed mostly in the remote areas to collect critical information from that area. There are numerous applications for which WSNs are used namely tracking the target, detection of earthquake, health monitoring, industrial sector, and predominantly in agricultural sector [1]. There are of Sensor Nodes (SNs) which are efficient enough to monitor data and thereby sending to the sink [2].

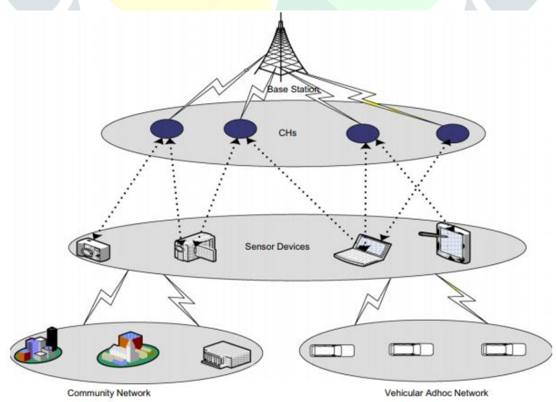

Fig. 1 Architecture of WSN [3]

WSNs generally comprises of small devices that are involved in communication mainly due to single hop or multi hop communication. Every node of WSN is termed as sensor node (SN). It has basically four main components, microcontroller, transceiver, antenna and the most important one is battery [4]. Sensor node senses the data and forwards it after aggregating the data to the sink. The general representation of WSN architecture is shown in Fig. 1. Clustering is basically employed for acquiring energy efficiency in WSN. The numerous applications are show in Fig. 2.

Fig. 2 Applications of WSN [5]

The first protocol that introduced the clustering to the research area of sensor network is Low Energy Adaptive Clustering Hierarchy (LEACH) [4]. The protocol undergoes through two phases of selecting the CH; set up phase and the other one is steady state phase.

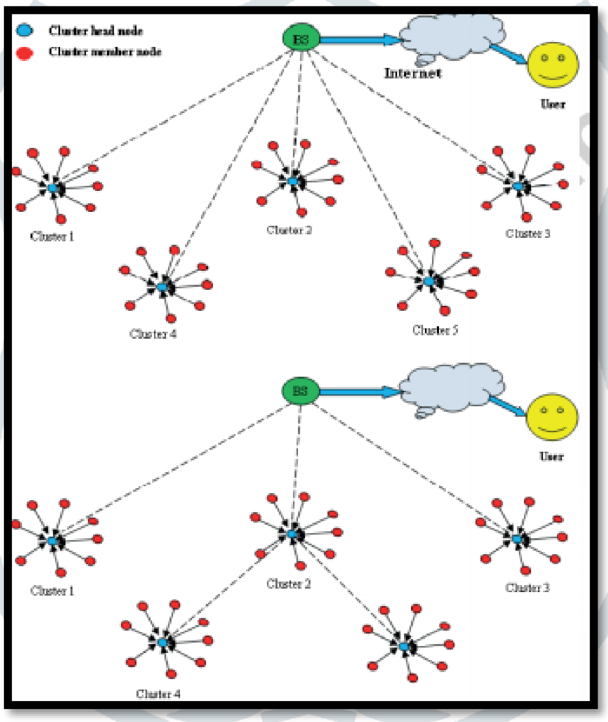

Fig. 2 Single hop and multiple hop routing in WSN

The set-up phase deals with the network formation and Cluster head (CH) selection. Similar to the setup phase, the steady-state phase is always long to minimize the overhead. The SNs arrange themselves into regional clusters in LEACH protocol, with one node serving as the chief and recognized as the cluster head (CH), and the majority of the nodes functioning as normal nodes. LEACH involves randomly generated high-energy CH rotation to lengthen the survival period of the network and conducts local data synthesis to communicate the quantity of data sent by the CHs to the BS. If the sink/BS is placed quite far from the CH node, then the energy consumption of the nodes will be higher. It is always observed about the energy of the nodes which becomes the deciding factor for selecting it as CH.

The single hop and multi hop communication is shown in Fig. 2.

The heterogeneous protocols exploits CH selection based on the different formulae for the threshold computation. The probability is computed for each node and later the same probability is utilized in the threshold computation. Finally, the computed value is compared with the random number. It is further analyzed that if the random number exceeds the threshold value, then that node is said to be ordinary node otherwise it is termed as CH. The threshold computation is done as follow in eq. (1).

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

In above eq. (1), the symbol used are defined as follow. The probability of each node is represented by *p*. The round value is denoted by *r*. *G* defines the group of nodes that are selected as CH. In this expression, the different routing protocols exploits different attributes for the selection of CH. That is where they all differs with each other. The parameters that define the performance of the network are stated as follow.

a) Stability Period: It is the first node dead in other words the completion of given number of rounds till first node of the network is dead.
b) Network Lifetime: The rounds completed till all nodes of the network are exhausted of their energies
c) Throughput: Successful transmission of data packets to the sink is termed as throughput.

Based on these parameters, the network performance is decided. Some papers have defined that the stability period gets lower in case if network lifetime is enhanced. But it is all up to the application for which the sensor network is designed.

In next session the deep study about the different heterogeneous routing protocols is reported.

II. HETEROGENEOUS ROUTING PROTOCOLS

There have been various routing protocols that have worked for the network performance. Heterogeneous routing protocols are described as follow.

A. SEP (Selection Election Protocol)

Smaagdakis et al. in [7] presented Stable Election Protocol that made use of two types of heterogeneous nodes; normal and advanced nodes. The normal nodes were kept lesser in energy as compared to the advanced nodes. The CH selection for the SEP protocol involved through the following probabilistic formulae as given in eq. (2).

$$p=\begin{cases}\frac{p_{opt}}{1+am} & \text{for normal nodes;}\\ \frac{p_{opt}\ (1+a)}{1+am} & \text{for advance nodes;}\end{cases} \qquad (2)$$

The SEP protocol suffered from the drawback that it selects CH based on weight value but it doesn't give any weightage to the residual energy of the nodes. Furthermore, it also doesn't consider the distance factor for the CH selection.

B. DEEC (Distributed Energy-Efficient Clustering)

Qing et al. in [6] proposed the better version of SEP protocol in terms of the selection of CH. It also followed the concept of the two heterogeneous level of nodes deployed in the network but the selection of CH differs in some context. Here the proposed protocol is termed as DEEC and the selection of CH is done based on the ration of residual to the average energy of the network. It helps in the selection of CH of those nodes which are in higher stock of energy as compared to the other nodes.

However, it suffered from the fact that the selection of high energy nodes as CH was done repeatedly. Eventually, the moment comes when the nodes are completely exhausted of their energies. Therefore, the penalization effect should be mitigated to resolve this concern. The probabilities of normal, advance and super nodes are given by equation (3):

$$p=\begin{cases}\frac{p_{opt}\,E_i(r)}{(1+am)\,\bar{E}(r)} & \text{for normal nodes;}\\ \frac{p_{opt}\,(1+a)\,E_i(r)}{(1+am)\,\bar{E}(r)} & \text{for advance nodes;}\end{cases} \qquad (3)$$

In eq. (3), $E_i(r)$ denotes the residual energy of the node at round value *r*. $\bar{E}(r)$ represents the average energy of the node.

It is observed through its finding that DEEC overcomes the SEP protocol in terms of different performance metrics.

C. DDEEC (Developed Distributed Energy-Efficient Clustering)

Elbhiri et al. in [7] reported this protocol which helped in balancing the energy of the nodes in the network. It basically worked in saving the nodes from the penalization of the high energy nodes. The nodes follow the same formula until the energy of the rest of the nodes gets lower to the threshold value. The probability for the DDEEC is given by equation (4):

$$p=\begin{cases}\frac{p_{opt}\,E_i(r)}{(1+am)\,\bar{E}(r)} & \text{for normal nodes if } E_i(r) > Th_{rev};\\ \frac{p_{opt}\,(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{for advance nodes if } E_i(r) > Th_{rev};\\ c\,\frac{p_{opt}\,(1+a)E_i(r)}{(1+am)\bar{E}(r)} & \text{for normal, advance nodes if } E_i(r) \le Th_{rev}\end{cases} \qquad (4)$$

where Th_{rev} is the threshold value of the energy. Similarly, at three level heterogeneity was introduced was EDEEC [8] which was further considered in EDDEEC [9] to mitigate the penalization effect. BEENISH [10] was introduced at four level of heterogeneity. The various other protocols were taken into consideration for the network enhancement and DRESEP and SEECP protocols worked for dual hop communication. While doing so, they suffered from the hot-spot problem.

III. COMPARISON OF VARIOUS HETEROGENEOUS ROUTING PROTOCOLS

The comparison of various heterogeneous protocols is discussed in Table 1 which mostly covers the cost analysis, network lifetime and highlights the drawbacks as given.

Table1: Comparison of heterogeneous routing protocols

Protocols	**Number of levels of Heterogeneity**	**Cost analysis**	**Network lifetime**	**Drawback**
SEP	2	L	L	Global Status required
DEEC	2	L	L	Penalizing Effect
DDEEC	2	L	M	Only for 2 level
EDEEC	3	M	High	Penalizing Effect
EDDEEC	3	M	High	For 3 level
BEENISH	4	H	High	Penalizing Effect
DRESEP	3	M	High	Hot-Spot Problem
SEECP	3	M	High	Hot-Spot Problem

**L, M and H are abbreviated for Low, Medium and High, respectively*

Table 2 Cluster head selection in heterogeneous WSN

Study reference	Name of Protocols	Heterogeneity level	Mode of Communication	Cluster Head selection				
				Initial Energy	Residual Energy	Average Energy	Distance	Node Density
Smaragdakis et al. (2004) [11]	SEP	2	single hop	✓	×	×	×	×
Qing et al. (2006) [12]	DEEC	2	single hop	×	✓	✓	×	×
Kumar et al. (2009) [13]	EEHC	3	single hop	×	×	×	×	×
Elbhiri et al. (2010) [14]	DDEEC	2	single hop	×	✓	✓	×	×
Javaid et al. (2013) [15]	EDDEEC	3	single hop	×	✓	✓	×	×
Qureshi et al. (2013) [16]	BEENISH	4	single hop	×	✓	✓	×	×
Kashaf et al. (2012) [17]	TSEP	3	single hop	×	×	×	×	×
Kumar et al. (2015) [18]	DRESEP	3	dual hop	×	✓	×	✓	×
Kumar et al. (2016) [19]	SEECP	3	dual hop	×	✓	✓	×	×
Paola et al. (2017) [20]	P-SEP	2	single hop	×	×	×	×	×
Kumar et al. (2017) [21]	EHDT	3	dual hop	×	✓	×	×	×
Verma et al. (2018) [4]	MRA	3	Single hop	×	✓	×	✓	✓
Verma et al. (2019) [3]	GAOC	3	Single hop	×	✓	×	✓	✓

It can be seen that some of the protocols are higher in cost due to the greater number of levels in the network. The network lifetime is acquired with respect to their performance. Penalizing effect is cajoling the high energy nodes to be CH more frequently for a given number of rounds. While doing so, the energy of the nodes is highly consumed therefore the network optimal performance is disturbed heavily.

The table 2 shows the CH selection methods in heterogeneous WSN. It could be seen that the different parameters are used for the CH selection.

IV. CONCLUSION

In this paper, we have given overview of the various heterogeneous routing protocols that acquire the common objective of elongated network lifetime and stability period. The main concern that is observed through the review of the protocols is the Cluster head selection. Most of the heterogeneous protocols have considered residual energy and distance factors for the selection of CH among the nodes of cluster. However, the CH selection seems to be a NP-Hard (Non-Polynomial) problem therefore, the inclusion of significant numbers of factors must be performed. Another important concern is the optimization of the routing schemes that are implemented in the WSN. There the main focus must be given to the fitness function which is to be designed as it tends to incorporate various fitness parameters. While considering the above issues and facts, we have given a study for various routing protocols in heterogeneous environment.

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