A Survey of Energy Consumption Routing Protocols in Wireless Sensor Networks

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Abstract **- Wireless Sensor Networks (WSN) is networks which consist of large number of low cost sensing nodes disseminating in the geographical region. The energy of sensing nodes is restricted for sensing various kinds of network data and then transmitting the data to other nodes or the destination. WSN are accruing much more attention in handling complex situations and functions. Wireless sensor networks are used for large number of purposes in military surveillance, habitat monitoring, forest-fire detections, landslide detections etc. The processing of sensor nodes requires battery power to use the energy in order to increase the effective network lifetime in heterogeneous topology. This paper presents the various routing protocols focuses on both the static and mobile nodes for heterogeneous wireless sensor networks to reduce the energy consumption and hence focusing on stability period, network lifetime, increasing energy efficiency and number of alive nodes. The comparison study of various WSN protocols is also presented in this paper which mainly focuses on the energy consumption parameter in the wireless network.**

Keywords **- Clustering, Energy Consumption, Network Lifetime, Stability, Wireless Sensor Network.**

INTRODUCTION

Wireless Sensor Network is a collection of thousands of nodes in the geographical area. Each node is connected with sensor nodes. These sensor nodes are used for monitoring temperature, humidity, vibrations and seismic events in geographical regions. The size of sensing nodes varying from very small to very large [1]. The more complex network of the sensing nodes, the more expensive these nodes are. Thus the cost and size are the main constraints of the wireless sensor network. The size and cost of the sensor nodes will depends on the energy consumed in transmitting the data from source node to sink node or the destination. Also memory resources, speed and bandwidth are the factors with will affect the cost and size of the network of sensing nodes. Sensor nodes may be static (fixed) or mobile nodes. Sensor nodes are based on battery powered devices, so main focus here is to reduce the energy consumption of sensor nodes in the wireless network. Thus lifetime of the sensor nodes will be increased which further enhance the stability of network nodes. Thus in WSN energy conservation is the main issue. In wireless network, the data is transmitted from sensor node to the sink or Base Station (BS). In this transmission a lot of energy is consumed. The network consists of homogeneous as well as heterogeneous nodes based on energy level of each node. The various routing protocols are designed which aimed at minimizing the energy consumption of nodes during transmission activities because replacement of batteries is very difficult once the nodes have been installed in the network. Fig. 1 shows the main components of sensor node. Sensor nodes mainly perform three main functions in the network: (a) Sensing subsystem senses the nodes using analog to digital converter. (b) Processing subsystem processes the local data for transmission containing the micro-controller and memory units. (c) Communication subsystem provides communication between the radio nodes. Power supply subsystem provides the battery functions. The various routing protocols designed for WSN are [2]: LEACH (Low energy Adaptive Clustering Protocol) is the first clustering routing protocol having self-organizing capability which distributes the energy between nodes using randomization. All nodes are assumed to be of same energy and homogeneous. In LEACH-C (LEACH- Centralized) each node gives information about energy level and location to BS. This produces better cluster requiring less energy for transmission. SEP (Stable Election Protocol) is the modification of LEACH protocol. SEP introduces the concept of heterogeneity of nodes where LEACH assumes that energy of all nodes is same, defining the homogeneous nodes.

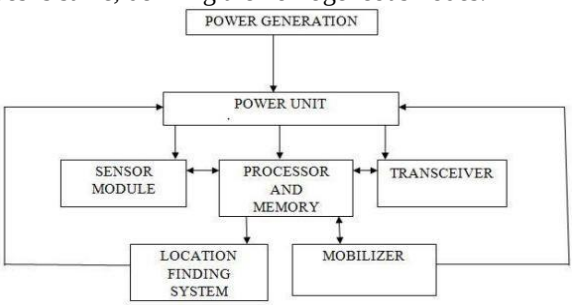

Fig.1. Components of sensor node

TERMINOLOGIES USED

In this paper the basic terminologies are used to evaluate the performance of various clustering protocols. These terminologies are:

- Stability Period: it is the time interval from the start of network operation until the death of first sensor node. Stability period also referred as stable region.
- Instability Period: it is the time interval from the death of first node to the death of last sensor node. Also referred as unstable region.
- Network Lifetime: time interval from the starting operation until the death of last alive node.
- Throughput: the measure of total rate data which is transfer over the network, data rate transfer from cluster heads to base station as well as the rate of data transfer from the nodes to their respective cluster heads.
- Data Aggregation: it is a way to reduce the energy consumption in the network. Data is aggregated by eliminating the redundant data in different messages.
- Epoch: after how many number of rounds a node becomes eligible to be selected as cluster head is known as epoch.
- Number of cluster heads per round: the number of nodes which collects the aggregated data from their respective cluster members and sends directly to the base station.

RELATED WORK

WSN routing protocols has been classified as Non- architecture based and Architecture based routing protocols. Non-architecture based routing protocols in WSN are suitable for smaller networks where data is simply transmitted from sensor nodes to the sink using Multi-hop routing mechanism. Architecture based routing protocols using the clustering techniques to transmit data to the base station and well suited for larger areas. Clustering techniques are designed to deal with energy conservation in WSN. These clustering techniques are designed for both homogeneous and heterogeneous wireless sensor networks to deal with energy management.

A. Power Efficient Gathering in Sensor Information System (PEGASIS)

PEGASIS is Non-architecture based routing protocol. In this protocol, all the nodes on the network form a chain or sequence considered by nodes or base station. All the data is aggregated by only one node of the sequence and then sent to the sink. This protocol requires the global knowledge of the network to calculate the complexity factor. Since all the nodes are in sequence and if one node fails, then new route discovery becomes very difficult because fixed path is defined for transmission of aggregated data to the sink before it starts a new route. This protocol conserves energy in much better way if compared to the LEACH protocol. The drawback of this protocol is that it does not focus on the Quality of Services (QoS) factor and also not perform well as the network size increases [3].

B. Low Energy Adaptive Clustering Protocol (LEACH)

LEACH was the first protocol introducing the clustering technique for utilization of energy in efficient way. It is a self-organizing clustering protocol which distributes energy between nodes using randomization. Sensor nodes are grouped into clusters and all nodes are assumed to have initially same energy and homogeneous. The data is aggregated in the form of clusters bye the cluster heads from their cluster members. This data is then sent to the base station. Cluster head election process is initiated in every round. Communication between cluster heads and non-cluster head nodes are making the energy dissipation very large. LEACH does not support mobile sensor nodes [4].

C. LEACH-Centralized (LEACH-C)

In this protocol each node gives the information about the energy level and the location to the base station. BS has the knowledge of location and energy of all the nodes in the network, thus LEACH-C provides 40% more data per unit energy than LEACH. Hence it provides better cluster than LEACH requiring less energy for data transmission to BS. LEACH-C does not support large networks well because BS is fixed and also directs communication between cluster head and BS [5].

D. Hybrid Cluster Head Selection LEACH (LEACH-H)

This protocol selects the cluster head at the first round and for further rounds; the cluster head for cluster is selected by current cluster head which eliminated the dependence issue on base station as in LEACH-C. It improves the network lifetime and load-balancing of the network. LEACH-H protocol has two phases. First, cluster initialization and second cluster reconstruction which is done by current cluster head [6].

E. E.Hybrid Energy-Efficient Distributed Clustering Approach (HEED)

In this protocol cluster head is selected by combination of residual energy of the node called primary parameter and network topology features
such as node degree, distance to neighbor nodes etc. as secondary parameter. Clustering of sensor nodes is done through iteration process. The maximum number of iterations takes place at any sensor node is
12. In HEED six iterations are required to terminate the ranges for all clusters. The nodes which are not in the range of cluster head doubles their probability of becoming cluster head in each iteration. The major drawback of HEED is that it does not provide guarantee for optimal slot of cluster head elected and also it does not enhance itself from two-level hierarchy [7].

F. Dynamic/Static Clustering (DSC)

This protocol is the extension of LEACH-C protocol. In this scheme, Global Positioning System (GPS) is used to get the location of each node and then location and energy status information is sent to the base station. Based on this information BS forms the cluster of the sensor nodes in the network and selects the cluster heads for each cluster. The remaining non cluster head nodes

send their data to their respective cluster heads in their allocated timeslots. These non- cluster head nodes save their energy in other timeslots by turning off their communication subsystems. After certain number of iterations, new cluster s are formed instead of forming clusters in every round. Thus the number of messages from cluster head to base station is reduced in DSC. The main drawback of DSC protocol is that this protocol also incompatible to support mobility of sensor nodes [8].

G. LEACH-Mobile (LEACH-M)

This protocol allows the mobility of both the cluster head and non-cluster head nodes. The nodes with minimum mobility are selected as cluster head. The selected cluster heads send their status to all the nodes in their transmission range. The non-cluster head nodes select the cluster head with maximum residual energy. In steady phase, if the nodes are not in the range of cluster head and vice-versa, LEACH provides handover mechanism which allows the nodes to move to the new cluster head, leaving the current cluster head. With handover mechanism nodes send DIS-JOIN message to current cluster head and JOIN-REQ message to the new cluster head. After the handoff mechanism, cluster head-reschedule the transmission process. Since the cluster head keeps on moving before selecting new cluster head for next round, the efficiency of LEACH-M protocol is not good in terms of energy consumption and number of packets are lost thus data delivery of packets is also inefficient.

H. LEACH-Mobile-Enhance (LEACH-ME)

In this scheme all the cluster head and non-cluster head nodes are mobile. The cluster head is selected by encapsulating the factors of mobility and residual energy of sensor node in the network. Node is selected as cluster head whose residual energy is maximum and mobility is minimum. Since all energy in consumed in calculation mobility factor hence LEACH-ME is not energy efficient.

I. Stable Election Protocol (SEP)

This protocol is the modification to LEACH protocol.

In this scheme, two level of hierarchy and two types of nodes (normal and advance nodes) are proposed. It is heterogeneity aware protocol having higher stability of nodes. SEP maintains the energy consumption balance in well-mannered. SEP is based on weighted election probability of each node to become cluster head according to remaining energy in each node. The energy of advance nodes is higher than the normal nodes thus chances to become cluster head is more for advance nodes. The shortcoming of SEP is that the selected cluster head is not dynamic; hence nodes away from cluster head will die first. Also the energy of higher level of nodes is not efficiently utilized in SEP [9].

J. Enhanced Stable Election Protocol (E-SEP)

This is the extension of SEP protocol. This scheme introduces three-tiers in clustering with two level of hierarchy. In addition to advance nodes and normal nodes as in SEP, intermediate nodes are introduced by E-SEP. these nodes are selected by relative distance of advance node to normal node position or by threshold energy level between advance and normal nodes. The aim of this protocol is to send the concise information to the sink, by ensuring minimum communication cost and maximum recourse utilization.

K. Energy Efficient Stable Election Protocol (EE- SEP)

This algorithm uses the initial energy of the node for calculating optimal threshold value T(s). This T(s) value reduces the cluster head selection process. This results in increasing the life time of alive nodes. Thus for data aggregation and data transmission, alive nodes uses their own energy. This reduces the amount of energy consumption and maximizing the energy efficiency, stability period and network lifetime [10].

L. Zonal-Stable Election Protocol (Z-SEP)

In this algorithm data is transmitted to the base station either by direct transmission or transmission via cluster heads. The network is divided into three zones: zone 0, head zone 1 and head zone 2. The architecture of these zones is shown in fig. 2. In zone 0, normal nodes transmit data directly to the base station to reduce the energy consumption. Half of the advance nodes are deployed in head zone 1 and remaining half in head zone 2. In these zones transmission of data is done through clustering techniques. Thus stability of nodes is increased [11]

M. Heterogeneity-aware Stable Election Protocol (H-SEP)

This protocol has two-levels of energies. This hierarchical clustering technique minimizes the distance between cluster-head and base station. Two types of cluster heads are used primary and secondary cluster head. The primary cluster head transmits data to those cluster heads which are at
minimum distances. These minimum distance cluster heads are secondary cluster heads.

N. Deterministic Stable Election Protocol (D-SEP)

In this protocol the cluster heads are elected in two, three and multi-level hierarchy. The goal is to improve the network lifetime and stability of heterogeneous nodes. The cluster heads receiving and sensing the data from component nodes consumes higher energy than their cluster members for transferring the aggregated data to base station. D-
SEP improves the network lifetime by 4.4 times over SEP. this results in longer stability period of D-SEP as compared to SEP [12].

COMPARISON OF ROUTING PROTOCOLS

In this section, the various routing protocols discussed above are classified and their features are compared. The characteristics of these routing protocols are based on their node infrastructure, position awareness of sensor nodes with their neighboring nodes; data aggregation by nodes to their cluster heads and further to the base station, GPS based location awareness of sensor nodes in the wireless network, QoS provided by nodes and the main focus is on energy consumed by each sensor node in the network. The comparison study of routing protocols in terms of their energy level is shown in table 1.

Protocols	Year	Node infrastructure	Position awareness	Data aggregation	Localization	QoS	Energy consumption
LEACH	2000	Static	No	Yes	Yes	No	Maximum
LEACH-C	2012	Static	No	Yes	Yes	No	Maximum
LEACH-H	2009	Static	No	No	Yes	Good	Maximum
HEED	2004	Static	Yes	No	Yes	No	Maximum
DSC	2008	Static	No	No	Yes	Yes	Average
PEGASIS	2002	Static	No	No	Yes	No	Maximum
LEACH-M	2006	Mobile node with static cluster head	Yes	No	Yes	Yes	Maximum
LEACH-ME	2009	Mobile	Yes	No	Yes	Yes	Average
SEP	2004	Mobile	Yes	Yes	Yes	Yes	Maximum
E-SEP	2005	Mobile	Yes	Yes	Yes	Yes	Average
EE-SEP	2005	Mobile	Yes	Yes	Yes	Yes	Low
Z-SEP	2006	Static and Mobile	Yes	Yes	Yes	Yes	Average
D-SEP	2006	Mobile	Yes	Yes	Yes	Yes	Maximum

Table 1. Comparison of Routing Protocols in WSN

CONCLUSIONS AND FUTURE WORK

In this paper, various routing protocols in wireless sensor networks are summarized based on homogeneity and heterogeneity of sensor nodes and classification of these routing protocols is done based on various features of protocols. Various routing protocols focuses on both the static and mobile nodes for heterogeneous wireless sensor networks to reduce the energy consumption and hence focusing on stability period, network lifetime, increasing energy efficiency and number of alive nodes. The traffic pattern of sensor nodes in heterogeneous routing protocols is constant bit rate (CBR). Future work will be intended to variable bit rate (VBR) traffic pattern for application specific systems which deals with compressed video streams. Also research in integration of wireless networks with wired network. All research in these routing protocols done with the assumption that the nodes are static. Further research will require exploring nodes dynamically.

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