ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 9, September 2016

Comparative Study on Different Energy Efficient Routing Protocols in Wireless Sensor Networks

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Abstract: **Wireless Sensor Network (WSN) is a special type of wireless network, consists of hundreds to thousands low power sensor nodes and one or may be more than one Base Station (BS). Each node is defined with limited energy. Since this is a wireless network that fully depends upon the batteries thus energy efficiency is a key design issue. It is very important to minimize the total energy consumed by the whole system, so that the life span of such network may be maximized. Lots of energy efficiency routing protocols have been proposed to maximize network life time. In this paper, a survey on various types of energy efficient routing protocol is discussed.**

***Keywords*—Wireless Sensor network; energy efficiency; routing protocol; energy consumption; network life time;**

I. INTRODUCTION

Wireless sensor network comes under personal area network (PAN), consisting of very tiny sensor nodes called motes with sensing, processing, and wireless communication capabilities over very short distances. Each sensor node collects information from the specified area and then it sends the information back to the sink node called base station (BS). The placement of sensor node in the sensor field depends on the determined condition.

A WSN is used for information gathering, performing data intensive tasks such as habitat monitoring, seismic monitoring, terrain, surveillance etc. Sensor networks are a giant leap towards "proactive computing", a paradigm where computers anticipate human needs and if necessary, act on their behalf. Sensor networks and proactive computing has the potential to improve our productivity and enhance safety, awareness and efficiency at the societal scale [1,2]. Due to various limitations arising from inexpensive nature, limited size, weight and ad hoc method of deployment, each sensor has limited energy. Since nodes may be deployed in unattended environment, so recharge of battery is inconvenient.

The logical distinction between wireless sensor network and the traditional wireless network is that sensors are very sensitive to energy consumption. The performance of the sensor network application highly depends on the lifetime of the network. Thus, energy conservation is very crucial in designing wireless sensor network. [19]

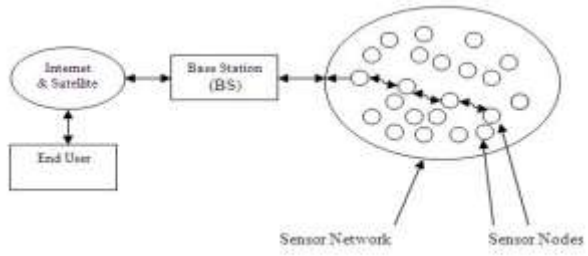

Fig-1: Wireless Sensor Network

Sensor Node and its Architecture

It is the basic unit in sensor network and is capable of performing some processing, gathering sensory information, and communicating with other connected nodes in the network [3]. Sensor nodes can be used in military application, health care monitoring , industrial processing and disaster relief scenarios.

The architecture of a sensor node mainly composed of

A) Sensing unit
B) Processing unit
C) Communication unit
D) Power unit

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
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Sensing unit

It consists of two sub units, the sensors and the (ad – c) analog – to digital converters. Actually the information sensed by the sensor are analog in nature, therefore it needs to be converted to digital for processing. Analog – to digital converter is used to convert these analog signal based information.

Processing unit

It forms the core of sensor node. This unit is composed of a micro controller and memory. It makes the sensor node collaborate with the other node to carry the sensing tasks.

Communication unit

The transceiver is used for communication of wireless sensor node. Radio frequency (rf), laser and infrared are the various choices of wireless transmission, but rf based communication is very well suits to most of wsn application. A transceiver operates mainly as transmit, receive, idle and sleep. The conversion of bit stream (that arrives from processing unit) to electromagnetic radio waves is the main task of a transceiver. Mica2 mote uses two kinds of rf radios: rfm tr1000 and chipcon cc1000 [21]

Power unit (battery)

This is the more important part of sensor node. All three process (sensing, communication and data processing) consumes power the most energy in consumed in data communication power can be stored in either battery or capacitor. But in sensor node batteries are the main source of power supply.

Batteries have the most important impact on sensor network life time. As long as the battery lives, the wireless sensor network live.

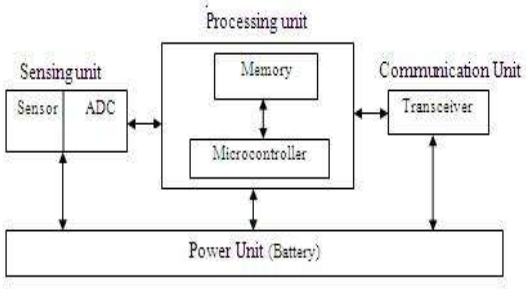

Fig-2: components of sensor node

1. *Issues and challenges*

Instead of numerous applications of WSNS, there are several restrictions in such network. Since sensor nodes are operated in three phases i.e. Sensing, processing and communicating, and all of these consume energy. Maximum energy is expended for the communication process. Here some of the challenging factors and design issue that effect routing process are discussed**.**

Security: WSNS will not be successfully deployed if security, dependability and privacy issues are not addressed adequately. [4][5] these issues become more important because WSNS are usually used for very critical applications. Furthermore, WSNS are very vulnerable and thus attractive to attacks because of their limited prices and human-unattended deployment[5].

Node deployment: Node deployment in WSNS is application dependent and affects the performance of the routing protocol. The deployment can be either deterministic or randomized Inter-sensor communication is normally within short transmission ranges due to energy and bandwidth limitations. Therefore, it is most likely that a route will consist of multiple wireless hops [6].

Fault Tolerance: In WSN nodes are deployed in harsh environment and thus nodes are usually exposed to risk of malfunction and damage. Tolerating the failure of nodes or Cluster Head (CH) is necessary in such conditions. Whenever a Cluster Head fails, re-electing of CH will not be efficient rather than we can assign a backup CH [7]

Data Aggregation**:** Since sensor nodes may generate significant redundant data, similar packets from multiple nodes can be aggregated so that the number of transmissions is reduced. Data aggregation is the combination of data from deferent sources according to a certain aggregation function, e.g., duplicate suppression, minima, maxima and average. This technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols [6].

Topology Control: Topology control deals with Coverage and Connectivity. Since, WSNS are deployed in unattended region and in ad hoc fashion, where nodes are responsible to identify its connectivity and distribution. The redundant nodes must be put to off mode and must be determined carefully so that Coverage and Connectivity is not affected [8].

Energy Efficiency: One of the most important factors that affect WSNS system is energy efficiency. Since sensor nodes are usually operated by limited and irreplaceable batteries, however energy is a scarce resource for such

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 9, September 2016

sensor systems and has to be managed wisely in order to extend the lifespan of the nodes. Energy consumption in a sensor node can be due to either "useful" or "wasteful" sources [19]

It can be observe that major wasteful energy consumption is due to

a) idle listening to the channel
b) retransmitting due to packet collision
c) over hearing
d) communication from base station to a particular node

2. Different types of energy efficient protocols.

LEACH (Low energy adaptive clustering heirarchy)

It is the most common and popular clustering technique proposed by W.R.Heinzelman, A.P. Chandrakasan and H. Balakrishnan [9]. It is self organizing and adaptive clustering protocol which evenly distributes the energy expenditure among the sensors. It is a clustered based hierarchy protocol that follows clustering techniques. This protocol is divided into two main phase.

Set-up Phase: In this phase, the formation of Cluster Head (CH) takes place. A sensor node selects randomly between 0 and 1. If this no. is not greater than threshold T (n), then the node becomes CH. T(n) can be computed as

$$T(n) = \begin{cases} \dfrac{P}{1 - P * (r * \bmod 1/P)} & \text{if } n \in G \\ 0 & \text{else} \end{cases}$$

Where , P is the desired percentage to become CH; r is the current round; and G is the set of nodes that haven't been elected as CH in the last 1/p rounds [7] [9]

Steady- state Phase: Continuing from previous state, nodes are therefore organized as CH, however in this phase, data transmission begins. Nodes send their data (packets) during their allocated TDMA slot to the CH. This transmission uses a minimal amount of energy. The radio of each non-CH nodes cannot be turned on until the nodes allocated TDMA slot, thus minimizing energy dissipation in these nodes.When all the data (packets) has been received, the CH aggregate these data and send it to the BS [10].

Although LEACH protocol has the ability to distribute energy dissipation evenly throughout the sensors, and doubling the useful system lifetime for the network, it still has problems. The CHs are elected randomly, so the optimal no. of CH cannot be ensured. It cannot be well suited for large- scale network that require single-hop communication.

II. MODLEACH (Modified Leach)

D Mahmood, N. Javaid, S. Mahmood, S. Qureshi, A.M. Memon and T. Zaman proposed the modified version of Leach[9], called MODLEACH, by introducing efficient cluster head replacement scheme and dual transmitting power levels. According to the nature of transmission, they also introduced two different levels of Power to amplify signals in cluster formation .They implemented Hard and Soft threshold on Modified Leach (MODLEACH) that boasts the performance even more. MODLEACH tends to minimize network energy consumption by efficient cluster head replacement after very first round and dual transmitting power levels for intra cluster and cluster head to Base Station communication. In MODLEACH, a cluster head will only be replaced when its energy falls below certain threshold minimizing routing load of protocol. Hence, cluster head replacement procedure involves residual energy of cluster head at the start of each round. Further, Soft and Hard thresholds are implemented on MODLEACH to give comparison on performances of these protocols considering throughput and energy utilization [11].

PEGASIS (Power-efficient Gathering in Sensor information System)

S. Lindsey and C. Raghavendra [12] proposed Power efficient Gathering in Sensor information Systems, a near optimal chain- based protocol that is an improvement over existing clustered based protocol LEACH. The sensor network of PEGASIS has the following properties.

- The Base Station is fixed at a far distance from the sensor nodes.
- The sensor nodes are homogeneous and energy constrained with uniform energy.
- No mobility of sensor nodes [12]

Formation of chain and data fusion is the two main characteristics in PEGASIS. It is assumed that all sensor nodes are static and uniform energy that may die at the same time. Since all the nodes are static they are well aware about the network, so they can easily form chain by Greedy Algorithm technique.

Although PEGASIS outperforms LEACH by somehow, but it has also some drawbacks, nodes may die early. It is assumed in this technique that each node is able to communicate directly with the sink node so there is a sure chance of energy wasting due to communication at long distance between sensor nodes and sink node.

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 9, September 2016

PEDAP (Power Efficient Data Gathering and aggregation Protocol)

Huseyin Ozgur Tan and Ibrahim Korpeoglu [13] proposed PEDAP, which is based on near optimal minimum spanning tree (MST) routing technique. In PEDAP, it is assumed that the locations of all sensor nodes are well known by Base Station (BS). Defining Base Station as the root, the routing information is computed using the technique of Prim's minimum spanning tree algorithm. Initially a node in the tree is assumed to be Base Station. In each iteration, minimum weighted edge is selected from a vertex in the tree to a vertex which is not in the tree, and then the edge is joined to the tree. It is also assumed in PEDAP, that the vertex which is just included in the tree will send its packets (data) through that edge. This procedure is been repeated until all nodes are added to the tree. By computing, it is seen that according to this minimum spanning tree technique, minimum energy is consumed. It can also seen that this technique performs well both in systems where base station is at distance from and where it is in the centre of the network field [13].

HEED (Hybrid energy efficient distributed clustering protocol)

O. Younus and S. Fahmy [14] proposed (HEED) Hybrid Energy Efficient Distributed Clustering Protocol. This protocol is developed as an improvement over LEACH. Instead of selecting Cluster Head (CH) randomly as in LEACH, HEED selects CH on the basis of residual energy and node degree as a main parameter.

In this technique, each node may have C_{prob} of becoming a CH as follows.

$$CH_{prob} = C_{prob} \cdot \frac{E_{residual}}{E_{\max}}$$

Where, C_{prob} is the initial percentage of CH required in the network, $E_{residual}$ is the current energy of the node and $E_{\max}$ is the maximum energy of the fully charged battery [7] [14]. It works in multi-hop network. In HEED, the proposed algorithm periodically chooses CHs depend upon the combination of two clustering parameters. One is residual energy of each sensor node and second one is the intra- cluster communication cost act as the node degree (i.e. no. of neighbors). Since, this protocol is a distributed clustering technique and energy is also distributed, thus it enhance the life time of the node within the network [14]. Though it is an improvement over LEACH still it has some disadvantages like more CH are generated than expected and it is not aware of heterogeneity [7].

F. TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol)

Arati Manjeshwar and Dharma P. Agarwal [15] proposed (TEEN) Threshold Sensitive Energy Efficient Sensor Network Protocol, a reactive protocol for for time-critical application. It is also based on clustering tachnique where clusters are formed by set of nodes led by head of the member called cluster head (CH) which broadcasts two types of threshold values to the nodes in the cluster namely Hard Threshold (HT) and Soft Threshold (ST). The parameters in the attribute set of the node reaches its HT value, the node switches on its transmitter and sends its data if the current value of the sensed attribute differs from sensed value by an amount equal to or greater than the ST. One of the major drawbacks of this protocol is that if threshold values are not reached, the node will not be able to communicate and not even come to know if the entire nodes are alive or dead [7].

APTEEN (Adaptive Periodic Threshold-sensitive Energy Efficient Sensor Network Protocol)

Arati Manjeshwar and Dharma P. Agarwal [20] proposed the modified version of TEEN [15], called APTEEN, which is also a hybrid routing protocol that allows for comprehensive information retrieval. The nodes in such networks react to time- critical situations as well as give an overall picture of the network at periodic intervals in suitable energy efficient manner. The user can request past, present and future data from such network in the form of historical, one –time and persistent queries respectively. In TEEN [15], a classification methodology i.e., Proactive networks and Reactive networks had proposed, however both methods have restrictions. In APTEEN, they proposed to combine the best feature of both proactive and reactive networks by creating a Hybrid network that will send data periodically and can respond to sudden changes in attribute value. They introduced TDMA schedule to avoid the collision in the close- by nodes that fall in the same cluster. Main feature of this schemes are

- It gives the user a complete view of the network
- It allows the user to set the time interval (Tc) and the threshold values for the attributes
- Time count and threshold value can control energy consumption.

Although, it is very energy efficient, it also has some drawback. The main one of this scheme is the

ISSN (Online) 2395-2717

International Journal of Engineering Research in Electrical and Electronic Engineering (IJEREEE)
Vol 2, Issue 9, September 2016

additional complexity required to implement the threshold functions and count time [20].

IV. COMPARATIVE STUDY

In this section we compare the above mentioned routing protocols according to their performance depending on different parameters. Table 1 and Table 2 shows the comparison.

Table.1 Comparison of different routing protocols

Protocols	Category	Data Delivery Model	Mobility	Multipath
LEACH	Clustering	Cluster based	Fixed BS	No
MODLEACH	Clustering	Cluster based	Fixed BS	No
PEGASIS	Reactive/ Clustering	Chain based	Fixed BS	No
PEDAP	Tree Based	Tree based	Fixed BS	No
HEED	Clustering	Cluster based	Fixed BS	Yes
TEEN	Reactive/ Clustering	Active threshold	Fixed BS	No
APTEEN	Hybrid	Active threshold	Fixed BS	No

BS: Base Station

Table.2 Comparison of different routing protocols

Protocols	Scalability	Data aggregation	Energy Efficiency	Network lifetime
LEACH	Limited	Yes	Poor	Good
MODLEACH	Limited	Yes	Poor	Good
PEGASIS	Good	No	High	Very good
PEDAP	Good	Yes	High	Very good
HEED	Limited	Yes	Medium	Good
TEEN	Good	Yes	Very high	Very good
APTEEN	Good	Yes	Very high	Very good

V. CONCLUSION

Deploying sensor nodes, especially in unattended region, is specially a complex task. Since sensor nodes rely upon the batteries and have limited amount of energy. Energy saving should be prior goal. The protocol design for such networks must be energy efficient so as to extend the life time of such network. In this paper, we presented different types of energy efficient routing protocols, and also discussed brief comparison between them. Each and every routing protocols that have been discussed, have the same objective of energy saving and extending the life time of the network. Although some of these routing techniques look good for energy saving, there are still some issues that need to be solved. We just highlighted those issues and kept those for future research work.

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