A COMPREHENSIVE STUDY OF ENERGY EFFICIENT ALGORITHMS IN WSN

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Abstract—*Wireless sensor networks are an arrangement of devices in a network that can gather the information from the monitored field through wireless links. WSN is a wireless network that consists of base station and nodes. These nodes are also known as sensors or motes. To reduce the energy consumed by the nodes in Wireless Sensor Networks (WSNs) the Communication paths are selected in such a way that the total energy consumed along the path is minimized [1]. The whole network area is divided into clusters in order to maintain the scalability. Dividing the network into Clusters creates a hierarchical structure of WSNs which gives efficient utilization of limited resources of sensor motes and extends network life span [1]. The objective of this paper is to present, review on Energy Efficient algorithms in Wireless Sensor Networks.*

Keywords—WSNs (Wireless Sensor Networks), BASE STATION (BS), CLUSTER HEAD (CH), LEACH, TEEN, SEP, DEEC, EEEAC, CCS, TSC, DDR, EECMT, DDEEC, TL-LEACH.

1. INTRODUCTION

At present, routing protocols which are energy efficient is emerging as an extensive zone of research in WSNs. The layout of a WSN can be traced as, the network area having huge amount of sensor nodes which have limited battery lifetime and are established in the network at various locations. These kind of sensor nodes are also named as 'motes' [2]. These member nodes are required to analyze the environment such as temperature, humidity, pressure, position, vibration. A sensor is a device that reacts to the environmental circumstances and detects some sort of input such as light, heat, humidity, pressure etc [3]. The sensor node's output is an electrical signal. These sensor nodes contains the following components-

1) **Microcomputer** which is culpable for processing, storing the sensor output [3].
2) **Transducer** will generate electrical signals [3].
3) **Battery** is used as the power source.
4) **Transceiver** does the task of receiving commands from the central computer and transmitting data to that computer.

A WSN approximately contains tens to thousands of nodes [4]. These nodes gather the information and forward it to centre location.

Clustering is the method of partitioning the network into clusters. There are 2 types of Clustering-

- Static Clustering
- Dynamic Clustering

1. **Static Clustering** is where the clusters once constructed can never be changed throughout the network lifetime.[7]

2. **Dynamic Clustering** is where the clusters based on some kind of network characteristics changes time to time during network operation [7].

Each cluster is governed by a node known as cluster head (CH) and remaining nodes are referred as cluster nodes. Cluster nodes do not communicate directly with the sink node [8]. They have to pass the collected data to the cluster head. Cluster head collects the data from the respective nodes of the cluster and transmits it to the base station. Thus, this minimizes the energy consumption in a network. The basic features of wireless sensor networks are capability to self-organize, dynamic network topology, node failure limited power, multi-hop routing, short-range broadcast communication and large scale of deployment.

A WSN architecture is basically build on 2 models- Homogeneous and Heterogeneous.

In Homogeneous model all the nodes in network field are of equivalent energy while in heterogeneous model the nodes in the network are of different energy means some will be of low power and some will be of high power. When nodes are taken together for communication, the network is called Hierarchal Network otherwise the network is called a Flat Network. In Flat Network all types of nodes whether they having low power or high power or moderate power will perform the same functionalities for a sensor network.

The arrangement of nodes in a particular wireless Sensor Network can be understood by the below figure 1.This figure represents 4 clusters, A cluster head is defined in each cluster. From each cluster head data is forwarded to the sink.s

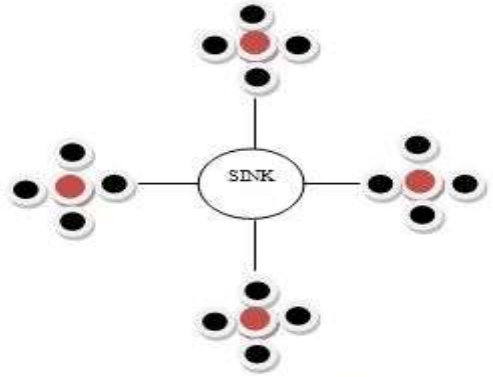

Figure1. Arrangement of clusters

Cluster Head

Cluster Member

2. APPLICATIONS OF WSNs

WSN can be commonly used to achieve military tracking and surveillance, dangerous environment exploration, natural disaster release and health monitoring, etc. Due to the flexibility of WSNs in resolving problems in various applications, these sensor networks had probably gained more popularity and have more potential to alter our lifestyle in various different ways.

1. Military Surveillance: The military can use the WSNs for various purposes such examining militant activity , force protection, nuclear, biological and chemical attack detection, battlefield surveillance etc[6]. These networks can be used with appropriate sensors to detect enemy movement, identity enemy force and analyze the movement and force.

2. Home applications: As the technology progresses, our household appliances are also making their way for running smoothly and for the brilliant performances. These sensors are found in vacuum cleaners, microwave ovens, water monitoring systems and in many more [6]. By using the WSNs we can utilize these devices locally and remotely.

3. Transportation: WSN collects the real-time traffic information which is further used as feed to the congestion and traffic models to solve problems regarding traffic.

4. Health applications: Different instruments are easily available in the market to check body changes, but there are some limitations due to heavier cost, maintenance, instrument size and the patient's mobility.

5. Nature Observing: The term Nature Observing has yielded to extend over the various uses of WSNs for research in earth sciences .This includes the inspection of volcanoes, seas, forests etc. Some major important areas listed below:

1) Forest fire detection: The nodes consisting of sensors are placed in the forest to measure various environmental activities like change in temperature, change in humidity etc. which is generated due to fire. These sensors evaluates the changes and sends an alarm accompanied by its location to BS.

2) Water quality detection: Various parameters like temperature, turbidity and pH water quality is checked in various water resources like river, lakes and oceans.

3) Land Slide Detection: By making the utilization of WSNs we can stop the occurrences of landslides long before it happens. This detection system observes the movement of soil and other various parameters.

4) Air pollution monitoring: WSN's have been deployed in various cities to keep a record of various dangerous gases, so that some precautions could be taken to save the citizens from the dangerous effect of those gases

4. Farming sector: In agriculture sector, crop management is big task and precision management is the technology implemented in this crop management. This particular management manages various parameters like soil quality, moisture consistency, wind speed, irrigation automation this will manage the water use.

3. Challenges in WSNs

Since WSNs are having certain properties yet various challenges are to be faced. The main issues are with the routing protocols which are having a great impact on the characteristics and performance of the sensor networks. Some issues are listed below-

1. Energy constraint: The first and common issue is the energy efficiency across the whole network. Extensive energy is drained during these activities- data sensing, data communication and data processing. During these 3 activities comprehensive amount of energy consumption is required.

Mainly the lifetime of the network straight forwardly relies upon the energy utilization by each node. If a sensor node's energy reaches below a certain level, it will become nonfunctional and affects the performance of network. Sometimes it becomes very hard to recharge the node batteries and these nodes are based on the energy constraint. So, for the researchers it is most difficult to develop energy efficient protocols for WSNs.

2. Security: Since, sensor networks are used in military surveillance and in many other critical applications, these applications main concern is confidentiality, integrity,

privacy etc [6]. In sensor networks each and every node should have the capability to identity that the required data or information is being send by the actual trusted sender so that the nodes should not accept the false data [6]. At the end, it should be considered that actual data should be transferred to the end user because this kind of redundant data r information can change the working of a network. Many types of threats are increasing in the WSNs so security is the main concern.

3. Scalability: Large number of sensors are placed in network area. So, the protocol should be designed in such a way that it is able to handle and operate upon such large area and these many kinds of nodes [7].

4. Fault Tolerant: In a network consisting of many nodes, any of the nodes can die because of the energy constraint or due to any other reason. If a node fails to respond, the protocols should work in such a way that dying of a node should not affect the network [7]. The protocol should be able to detect other suitable paths for further communication in the network.

4. Clustering in WSNs

The entire network of thousands of nodes is split into clusters, referred to as clustering [8] .A CH monitors each and every cluster and the other cluster nodes are known as cluster nodes. These cluster nodes do not communicate directly to the BS meanwhile these cluster nodes will firstly send their respective data to the cluster head of the cluster in which they are deployed. So, all the cluster nodes send their data to the respective cluster head (CH) [8] .CH collects, aggregates and forwards the information to the base station. This whole phenomenon requires less number of nodes in the communication as well as less number of messages in order to communicate, hence energy dissipation from the nodes can be minimized.

Benefits of Clustering-

1) Increased resource availability.

2) Reduces communication overhead.

3) Efficient energy utilization.

4) Great scalability for large numerous of nodes.

5. Related Work

Heinzelman *et al.* (2000) introduced a protocol which is known as Low Energy Adaptive Clustering Hierarchy (LEACH).It is also known as the classical clustering algorithm. It is a MAC protocol based upon TDMA[5]. This protocol was proposed to outstrip the shortcomings of the conventional algorithms. LEACH was the first energy efficient algorithm based on the hierarchy of clusters. The deployment of hundreds to thousands of nodes (sensors) in a homogeneous environment means that all nodes have same kind of energy [9] This particular protocol gave birth to multi-hop communication through which communication overhead will reduce because through this kind of communication, energy transmit will also be less. This protocol performs dynamic clustering [9]. Each cluster will contain CH and the rest of the nodes in cluster are known as cluster members. Randomization is opted for selecting the CH. The operation in this protocol is described in 2 phases-

1) Set-up phase 2) Steady phase

In set-up phase the network splits in clusters dynamically and the steady phase, which is also known as transmission phase is accountable for data transfers which is from the member to the respective cluster head and at last from CHs to BS[5]. The operation of this protocol is based upon rounds.

Manjeshwar *et al.* (2001) proposed protocol named TEEN (Threshold Sensitive Energy Efficient Sensor Network Protocol).This protocol was specially developed for reactive networks [10]. This protocol was initially used for temperature sensing applications. In proactive networks the their transmitter on and keep sensing at various time intervals while in reactive networks are the networks in which nodes responds within a fraction of second to the changes happened or keep their transmitter off. So, these protocols are good for time bounded applications [10].

Two types of threshold are defined in this particular protocol- 1) Hard threshold 2) Soft threshold.

Smaragdakis *et al.* (2004) proposed Stable election protocol (SEP) for heterogeneous WSNs and this protocol overcomes loopholes of LEACH protocol. It basically works on heterogeneous two-level hierarchy sensor networks. This protocol is useful mainly to enhance the time interval before the death of first node known as stability period .Two-level hierarchy includes 2 types of nodes the first is the normal nodes and the next is the advance nodes. Let m be the fraction of the total number of nodes n, which are equipped with α times more energy than the others. We refer to these powerful nodes as advanced nodes, and the remaining (1−m) ×n as normal nodes [11]. Here the focus is on making the advance nodes cluster head most of the times and this will play a fair constraint in energy consumption.

For cluster head selection, SEP protocol uses weighted election probabilities [11]. These election probabilities are weighted by the initial energy of a node relative to that of other nodes in the network. SEP also uses different threshold values for normal nodes and advanced nodes for the election of cluster heads [11]. The major advantage of SEP over LEACH is in choosing the advanced nodes more times cluster head because in this protocol advanced nodes are introduced and these are nodes are having a large amount of energy so they can survive more. Throughout this whole process the network lifetime will increase.

Loscri *et al. (2005)* proposed a protocol named TL-LEACH i.e two-level hierarchy for low-energy adaptive clustering hierarchy. This protocol is applicable for homogeneous environment. The CH in a particular cluster is chosen in a randomized way. In this two-level hierarchy 2 types of CH are introduced which are named as follows- Primary cluster head and secondary cluster head [12]. Firstly the primary cluster will receive the data from the sensor nodes, then the primary cluster will send the aggregated data to the secondary cluster, further it will be forwarded to the base station [12]. This particular protocol is compared to the LEACH protocol and it outperforms LEACH protocol.

Misra *et al. (2005)* suggested a protocol named EEEAC (Enhanced Energy-Efficient Adaptive Clustering Protocol) in which the whole concept revolves around the remaining energy of the node in node. In this particular protocol broadcasting is taken into consideration. In a particular cluster in each round the cluster member will broadcast their respective residual energy information to all the other nodes in that particular cluster[13]. So, in this way all the nodes in a particular cluster knows the information of residual energy of all the nodes of the cluster. The selection of CH is done in a way that the node having most amount of residual energy will become the CH. The concept of CDMA is also taken into consideration .Each cluster is assigned a CDMA code so that whenever a cluster wants to communicate the respective CDMA code for that particular cluster is used to avoid the problem of interference[13]. Finally after the simulation it is concluded that this protocol performs better than LEACH protocol hence, improve the lifetime of the network.

Qing *et al.* (2006) proposed a protocol DEEC (Distributed Energy Efficient Clustering Algorithm) which was used by the heterogeneous wireless sensor networks. In this particular protocol the selection of CH is probabilistic. In this protocol the cluster heads are selected with a probability based on the ratio between the residual energy of each node and the average energy of the network[14]. The nodes are more likely to become a cluster head, which is having a large amount of initial and residual energy. Here the advance nodes do not take into consideration, especially when their residual energy drains and soon they act like normal nodes. In this protocol specially the stability period is prolonged which will lead to better performance of the network. It is also suitable for multi-level heterogeneous networks[14]. This protocol overcomes the problem of the fact that each node should be aware about the global knowledge of the network. Here in this protocol the average energy of the network is taken as the reference energy. Thus, DEEC does not require any global knowledge of energy at every election round[14].

S.Jung *et al. (2007)* proposed a protocol named Concentric Clustering Scheme(CCS) .This protocol improves PEGASIS protocol discussed earlier and reduces the energy consumption as in compared to the PEGASIS protocol. Here the main concern is the position of the BS. The network in CCS protocol is split into concentric circular tracks, these are regarded as distinct clusters and each circular track is given a level. The track nearest to the BS is assigned as level 1 and further as the distance from the BS increases the level number also increases [15].

Similar to PEGASIS, inside the track chains are built. One node is chosen as a CH at each level and the information transfer is based on the PEGASIS system. All nodes communicate their information to the closest node along the chain at each stage. The receiving node combines its own information and transmits the information to the next node[15]. The CH node in level-n sends information to the CH node in level (n-1) and this method continues until the sending of information to the BS is finished[15]. Comparing both PEGASIS and CCS we got to know the following advantages of CCS over PEGASIS-

1) Energy consumption in CCS is reduced due to the decrease of the data transmission spectrum from CH to BS.
2) By splitting the network into concentrated clusters, CCS also saves energy.

N.Gautam *et al.(2009)* proposed a protocol named TSC(Track–Sector Clustering).According to this the network is divided into circular tracks and triangular sectors[16] .This type of arrangement of the network provides the shortest distance between the CH and the BS thus, this will reduce the duplicate data transmission and will further improve the efficiency of the network.The outline of a cluster in Track-sector clustering is described as an area created by the intersection of circular track and a triangular sector[16] . The implementation of the TSC method is split into four stages which are as follows-

1) Track setup 2) Sector setup 3) Chain Formation 4) Data transfer

In the very first phase the concentric circular paths are set up by the base station and the base station keeps itself in the center of the circular paths. Each node is allocated a specific track a level is allocated to each track. According to the location of the BS and the density of the nodes the total number of tracks is made.

During the second phase sectors are formed and cluster head (CH) selection is done in every sector. In the third phase with the intersection of a track and the sector the area which is formed normally known as cluster the nodes in the form of chain is established inside in these clusters [16]. Then at least finally the CH conducts fusion in each cluster and transmits it to the CH in the reduced level path and lastly transmits information to the BS via multi-hop communication.

SHEMSHAKI *et al. (2009)* proposed a protocol named EECMT(Energy Efficient Clustering with Multi hop transmission).This protocol main focus is on multi hop routing for transmitting the data [17].Basically, in this protocol, all nodes are having the same probability to become the cluster head. So due to this concept it will not affect the energy of only certain kind of nodes [17]. The selection of CH rotates among all the nodes. This protocol contains following two phases-

1) Set-up phase- Firstly the cluster heads are selected afterwards the clusters are created. After this the member node transfer data to their respective cluster head. Further, all the CH will transfer the data to the BS and aggregation of data is performed at BS.
2) Steady phase- It consists of 3 activities, namely transmission of data from member nodes to CH, multihop routing to send data from CH to BS and finally transmitting the data.

This particular outperforms LEACH protocol and maximizes the performance of the network.

Elbhiri *et al.(2010)* proposed a protocol named DDEEC(Developed distributed energy based clustering) which was suitable for heterogeneous networks .This will outperform SEP protocol and DEEC protocol. DDEEC works on the same scheme in which DEEC works. DDEEC requires advantage of first node dies and the prolongation of the stable moment as compared to DEEC [18]. Mostly the change in this protocol is done in the equation related to residual threshold. In DEEC, the decision always penalizes the advanced nodes when they deplete their remaining energy and become within the range of normal nodes. So, the advanced nodes will die quickly [18]. So this particular is solved in DDEEC by using the same mechanism of the normal nodes with the advance nodes when they drain energy.

Ahmed *et al.* (2013) described another protocol known as DDR (Density Controlled Divide and Conquer Scheme) for WSNs. This technique makes use of static clustering and this will overcome the problem of energy hole [19]. In this technique CHs are selected on the basis of threshold .By using this technique the distance between the member nodes and CH, CH and BS are reduced. The total number of CHs in each round is same. In every round new CH is selected in each cluster. The node having first, second, last and so on minimum distance from the central point is selected as the CH in that particular cluster. This selection procedure of CH is known a dynamic selection.

Multi-hop communication is used in this technique. DR protocol enhances the stability period, prolongs the network lifetime, and throughput [19].

6. CONCLUSION

This paper outlines the working structure of different types of energy-efficient routing algorithms which are used to save the energy of the sensor nodes which further leads to betterment of the network performance in WSNs.Other than the above discussed protocols for energy efficient algorithms many other protocols are also developed and are still being developing by the researchers in order to minimize the problem of energy constraint.

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