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Study and Comparative Analysis of various Energy Efficiency Techniques in Wireless Sensor Networks

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ABSTRACT

Wireless Sensors Networks with hundreds and thousands of sensor nodes are a revolutionary information gathering and transmission resources. But athe limited energy backup is one the major constraints in efficient working of WSNs. A number of energy efficient routing protocols have been developed so as to minimize the energy consumption but in this review paper we are focusing on the architecture of the Wireless Sensor Network and comparing three different (LEACH, Direct Diffusion and GEAR) protocols for energy efficiency in WSNs. Further we have presented a comparative study of these protocols on certain set of parameters.

Keywords: *Energy Efficiency, Routing Protocols, Sensor Networks.*

I. INTRODUCTION

A Wireless Sensor Network (WSN) is a network formed by a large number of sensor nodes where each node is equipped with a sensor to detect physical phenomena such as light, heat, pressure, etc. WSNs are regarded as a revolutionary information gathering method to build the information and communication system which will greatly improve the reliability and efficiency of infrastructure systems. Compared with the wired solution, WSNs feature easier deployment and better flexibility of devices [1]. WSN is a network communicating using a many-to-one model with a number of sensor nodes scattered into a target observation area with objective of collecting and routing data to the end users via a single sink node also called base station.

To ensure that the data collected from the environment is successfully relayed to the sink, Wireless Sensor Network implements a co-operative multi-hop routing scheme where each sensor may play one of the three different roles:

- Sensing node used to sense the environment.
- Relay node used as transit for the information sensed by other nodes.
- Sink node acting as a base station attached to a high energy device also referred to as gateway used to transmit the information to a remote processing place.[2]

In WSN nodes utilize disproportionate amount of energy for communication and the required energy in terms of battery power to transmit the packet will differ among the transmissions with respect to the distance between the sender and receiver nodes; therefore multi-hop communication is recommended. And by using this scheme, the data captured in the target environment is forwarded to the end users by a multi-hop infrastructureless network via the sink node which passes this information to a gateway communicating with the task manager node using the Internet, wireless communication such as WiFI, WiMax, or a satellite link as illustrated by Figure1.1 below.

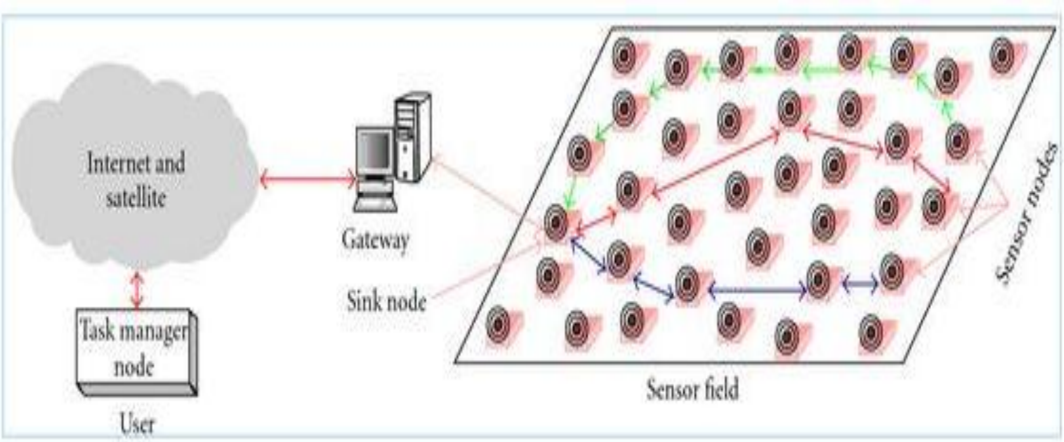

Figure:1.1 Deployment of Wireless sensors Network [2]

To enhance the network lifetime appropriately many routing protocols and cluster-based algorithms are used to fulfill the application requirements in WSN. From existing research methods, optimizing energy dissipation for communication becomes very critical. For maximizing lifetime of the WSN, part of an energy consumption of each sensor node has an important role while communicating among other sensor nodes[3].

The rest of this paper is organised as follows. In the next section, we summarizes the previous works that were carried out and discussed so as increase the energy efficiency of WSNs. Section 3 consists of our motivation to optimise the energy efficiency in WSNs. Section 4 describes the various techniques used for energy efficiency. Section 5 analyzes the efficiency of energy conservation techniques described in section 4 and section 6 describes the future scope and conclusions derived from the study.

II. RELATED WORK

Many techniques have been used in accordance to achieve and optimise the energy efficiency in WSNs. Some of which are discussed in this section starting from the year 2007 onwards.

In 2007, the effects of Rayleigh fading over AMC-based communications *(L. Xiao-Hui* et al) were analysed by using discrete-time queuing model in a Wireless Sensor Network and achieved as much as 40% reduction in energy dissipation.

In 2008, a novel real-time routing protocol with load distribution (RTLD) was proposed by *A. A. Adel* and *N. Fisal* to increase the lifetime of WSN.

In 2009, a method for efficiently and reliably routing data packets from a static information source to a mobile sink through a multi-hop Wireless Sensor Network was presented by *M. Andrea* et-al and the results demonstrated that the scheme outperformed conventional routing protocols in terms of packet transfer reliability, latency, and energy efficiency.

In 2010, a hybrid clustering method to improve the network quality within that network and in addition to that of forwarding and storage nodes was developed by *B. Ali* et-al, which helped in solving the risks of failure of sensed data and also increases the lifetime of the network.

In 2011, an improved QoS mechanism based on weighted mapping table was presented by *F. Lin* et-al, it also calculated the weight from mapping table according to the level of events, and dynamically adjusted the transmit probability of each event resulting in increased network lifetime.

In 2012, a clustering technique balancing the load among the cluster by using some backup nodes was presented by *W. Dipak* and *Dr. T. V. Nileshsingh*. In which the backup high energy and high processing power nodes replaced the cluster head after the cluster reached to its threshold limit. It resulted in increasing the network lifetime and providing high throughput. A Medium Access Control (MAC) protocol based on WTRP named WTRP-S for Wireless Sensor Networks was proposed by *Z. Fan* et-al which guaranteed the QoS and controled the energy consumption.

In 2013, energy-efficient routing techniques for two-tiered WSN using Genetic Algorithm, Particle Swarm Optimisation and A-Star algorithm based approach to enhance lifetime of the network were presented by *R. Keyur* and *Z. Mukesh. R.*

In 2014, a load balanced clustering (LBC) algorithm, 3-layer framework for mobile data collection in WSNs was developed by *Z. Miao* et-al, which included the sensor layer, cluster head layer, and mobile collector layer and it achieved over 50% energy saving per node & 60% energy saving on cluster heads.

In 2015, a decentralized routing algorithm, called Game Theoretic Energy Balance Routing Protocol (GTEB) was proposed by *M. A. Abd* et-al to extend the network lifetime by balancing energy consumption in a larger network area. Further a new cluster-based Route Optimisation and Load-balancing protocol (ROL) was presented by *H. Mohammad* and *N. Robert* to provide an inclusive solution to extend network life. So as for energy efficient multicasting a new approach called Global optimal multicast delivery was presented by *J. Dingde* et al, with the minimum energy consumption (GMEE) to minimize multicast energy consumption and prolong the lifetime of multicast connection in wireless multi-hop networks. As the WSNs do comprise of multiple sinks which often lead to more energy consumption, an energy efficient routing protocol for Wireless Sensor Network with multiple sinks (ERPWSN) was developed by *M. K. Sah* et-al, which works on the concept of optimal energy consumption and performed better.

In 2016 a novel hierarchical approach, called Hierarchical Energy-Balancing Multipath routing protocol for Wireless Sensor Networks (HEBM) was proposed by *G. Chirihane* et-al, which aimed to fulfill the purposes of decreasing the overall network energy consumption, balancing the energy dissipation among the sensor nodes and extending the lifetime of the network. It has also been stated that Energy efficiency is focused on in the traditional routing protocols, while quality of service (QoS) (i.e., delay, reliability, robustness) becomes important in practical application(*G. Teng* et al) therefore routing protocols should not only ensure the energy efficiency, but also realize QoS performances. Further for cluster basd protocols, a clustering-tree topology control algorithm based on the energy forecast (CTEF) for saving energy and ensuring network load balancing was proposed by *Z. Hong* et-al and an innovative clustering protocol of load balancing which increased network lifetime in comparison with LEACH, TCAC and DSBCA protocols by 73%, 52% and 21%, respectively and improved the energy efficiency and load balancing was presented by *S. Saman* et-al.

Recently In 2017, BeeSwarm, a SI based energy efficient hierarchical routing protocol for WSNs was presented by *M.S. Palwinder*, *S. Satvir*. Evaluation of simulation results show that BeeSwarm perform better in terms of packet delivery, energy consumption and throughput with increased network life compared to other SI based hierarchical routing protocols.

III. MOTIVATION

It is a fact that the sensor nodes are battery-powered devices, hence have limited energy. A large amount of energy is consumed during data transmission. Furthermore, a significant amount of energy is consumed during the route discovery and its maintenance phase. The lifetime of the network directly depends on the total energy consumption by each node [22]. If a sensor node's energy reaches below a certain level, it will become nonfunctional and affects the performance of the network. Therefore, it is a big challenge for a routing protocol designer to manage the energy of the sensor nodes to maximize the network lifetime.

IV. CLASSIFICATION OF ENERGY EFFICIENCY TECHNIQUES

4.1 LEACH (Low Energy Adaptive Clustering Hierarchy)

LEACH [23] is a self-organizing and adaptive clustering protocol. Randomization is used for the distribution of energy load among the sensors in the network. The following are the assumptions made in the LEACH protocol:

a. All nodes can transmit with enough power to reach the base station.

b. Each node has enough computational power to support different MAC protocols.

c. Nodes located close to each other have correlated data.

According to this protocol, the base station is fixed and located far from the sensor nodes and the nodes are homogeneous and energy constrained. Here, one node called cluster-head (CH) acts as the local base station. LEACH randomly rotates the high-energy cluster-head so that the activities are equally shared among the sensors and the sensors consume battery power equally. LEACH also performs data fusion, *i.e.* compression of data when data is sent from the clusters to the base station thus reducing energy dissipation and enhancing system lifetime. LEACH divides the total operation into rounds—each round consisting of two phases: set-up phase and steady phase.

In the set-up phase, clusters are formed and a CH is selected for each cluster. The CH is selected from the sensor nodes at a time with a certain probability. Each node generates a random number from 0 to 1. If this number is lower than the threshold node [T(n)] then this particular node becomes a CH. T(n) is given as follows:

$$T(n) = \frac{p}{1-p}\left[r \bmod (1/p)\right],\ n \in G = 0, \text{otherwise}$$

where p is the percentage of nodes that are CHs, r is the current round and G is the set of nodes that have not served as cluster head in the past $1/p$ rounds.

Then the CH allocates time slots to nodes within its cluster. LEACH clustering is shown in Figure 1.2 below:

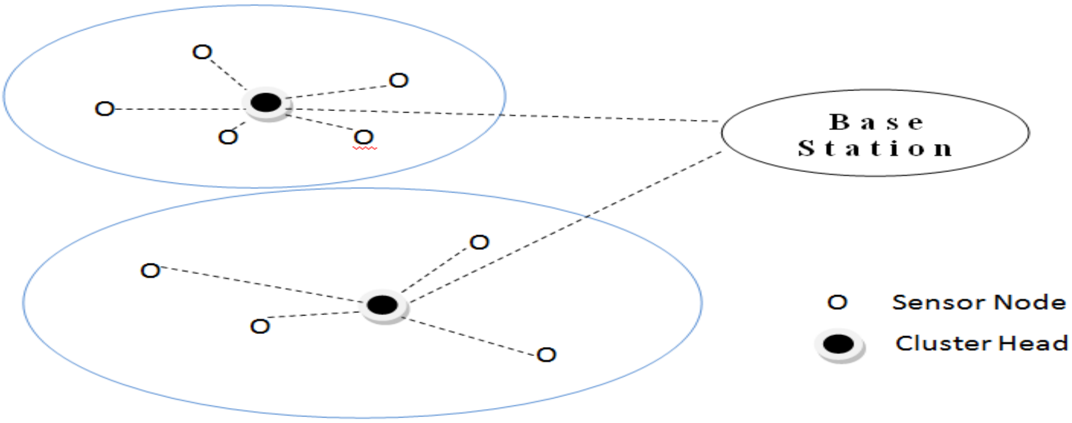

Fig: 4.1 Clustering in LEACH Protocol [23].

In steady state phase, nodes send data to their CH during their allocated time slot using TDMA. When the cluster head gets data from its cluster, it aggregates the data and sends the compressed data to the BS. Since the BS is far away from the CH, it needs high energy for transmitting the data. This affects only the nodes which are CHs and that's why the selection of a CH depends on the remaining energy of that node.

4.2 DD (Directed Diffusion)

Directed diffusion [24,25] is a data-centric (DC) and application-aware protocol in which data generated by sensor nodes is named by attribute-value pairs. It consists of four elements: [26] interests, data messages, gradients and reinforcements. An interest (a list of attribute value pairs) describes a task. Data messages are named using attribute value pairs. A gradient specifies data rate as well as the direction of event and reinforcement selects a particular path from a number of paths. In the DC protocol data coming from different sources are combined and thus eliminating redundancy, minimizing the number of transmissions, saving network energy and prolonging its lifetime. DC routing searches for a destination from multiple sources. In directed diffusion, a base station diffuses a query towards nodes in the interested region. The query or interest is diffused through the network hop-by-hop. Each sensor receives the interest and sets up a gradient toward the sensor nodes from which it receives the interest. This process continues until gradients are set up from the sources back to the BS. The sensed data are then returned to the BS along that reverse path. The intermediate nodes may aggregate their data depending on the data message (data's name and attribute value pair) thus reducing the communication cost. Since in this case data transmission is not reliable the BS periodically refreshes and resends the interest when it starts to receive data from the source(s). Directed Diffusion protocols are application specific and hence can save energy by selecting optimal paths by caching and processing data in the network. It has some drawbacks [26]. First of all, for data aggregation it needs time synchronization technique that is not very easy to achieve in WSNs. Another problem is associated with the overhead involved in recording information thus increasing the cost of a sensor node. The DD Protocol is described in figure1.3 below:

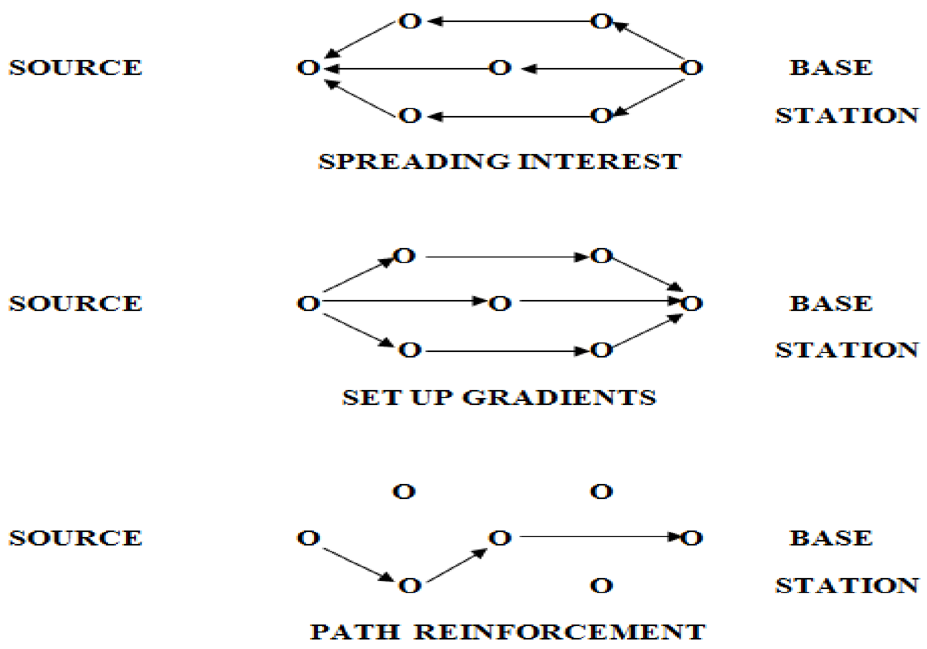

Figure: 4.2 Directed Diffusion Protocol.

4.3 Geographic and Energy-Aware Routing (GEAR)

Location based routing protocols for sensor network need location information of all the sensor nodes to calculate the distance between any two nodes. GEAR [24,27] is a location based routing protocol which uses GIS (Geographical Information System) to find the location of sensor nodes in the network. According to this protocol, each node stores two types of cost of reaching the destination: estimated cost and learning cost. The estimated cost is a combination of residual energy [28] and distance to destination. The learned cost is a modified estimated cost and it accounts the routing around holes in the network. When a node does not have any closure neighbours towards the target region, a hole occurs. In case where no holes exit, the estimated cost is equal to the learned cost. The GEAR protocol only considers a certain region rather than sending the interests to

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the whole network as happens in Directed Diffusion [25] and thus restricting the number of interests. There are two phases in this protocol:

Phase-I: In this phase, packets are forwarded towards the target region. After receiving a packet, a node searches for a neighbour which is closer to the target region then itself. The neighbour is then selected as the next hop. If there are more than one suitable nodes then there exists a hole and in this case one node is picked to forward the packet based on the learning cost function.

Phase-II: In this phase, the packets are forwarded within the region. If the packet reaches the region, it is diffused in that region by either recursive geographic forwarding or restricted flooding. If the sensors are not densely deployed, then restricted flooding is used and if the node density is high, then geographic flooding is used. In geographic flooding, the region is divided into four sub regions and four copies of the packet are created. This process continues until the regions with only one node are left.

V. COMPARATIVE ANALYSIS OF LEACH, DIRECT DIFFUSION AND GEAR

The above discussed protocols are compared on the basis of certain set of parameters. Table 1 shows the comparison.

Protocols **Parameters**	**LEACH**	**DD**	**GEAR**
Mobility	Fixed BS	Limited	Limited
Power Management	Maxi-mum	Limited	Limited
Network Lifetime	Very Good	Good	Good
Scalability	Good	Limited	Limited
Resource Awareness	Yes	Yes	Yes
Classification	Clustering	Proactive/ Flat	Location Based
Data Aggregation	No	Yes	No
Query Based	No	Yes	No
Multi Path	No	Yes	No

Table 1: Comparison of different routing protocols

LEACH have fixed infrastructure and is a cluster based routing protocol. LEACH transmits data continuously whereas In directed diffusion the base station sends queries to sensor nodes by the flooding technique. In Directed diffusion each node can communicate with its neighbours, so it does not need the total network information. LEACH doesn't use meta-data whereas direct diffusion does use it. GEAR limits the number of interests in Directed Diffusion by considering only a certain region rather than sending the interests to the whole network [23, 24]. GEAR thus complements Directed Diffusion and conserves more energy.

VI. CONCLUSION AND FUTURE SCOPE

In this paper we have discussed three different (LEACH, direct diffusion and GEAR) protocols for energy efficiency in Wireless Sensor Networks. Since WSNs are designed and used for specific applications therefore designing energy efficient protocols is considered one of the important aspects. Due to the cause that the WSNs are application specific therefore it becomes difficult to say that which of the particular protocols is better than the other. But still they can be compared on certain set of parameters depending upon their use and application. Future scope of this work shall be to study machine learning techniques and use them for better optimisation of energy efficiency.

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