Survey on Energy Utilization of Nodes in Wireless Sensor Networks

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***Abstract* - Rapid advances in Wireless Sensor Networks (WSNs) indicate that they are becoming increasingly complex. Consequently users and applications are becoming more demanding. Due to unique characteristics of WSNs, like small dimensions and limited resources and capabilities, Energy consumption is imposed as one of the key factors. WSNs are becoming the primary research field for many researchers. Because of some hardware problems, especially with respect to energy supply and miniaturization, Energy efficiency is a major concern in WSNs. As sensor nodes are typically battery powered, the energy usages has to be carefully managed in order to prolong the lifetime of the system. This paper gives an overview of Energy efficient protocol for WSNs. It can provide efficient saving of energy that appropriately takes into account. Entire sensor nodes are battery powered devices. Energy consumption of nodes during transmission or reception of packets affects the life-time of the entire network. To make routing, energy efficient protocols like LEACH and PEGASIS were developed. Different routing protocols are compared based on metrics such as mobility support, stability, overlapping sensor size, cost, power, routing and capacity of wireless networks. The study concludes with the recommendations to the future direction in the energy efficiency model for the sensor networks.**

***Keywords* - WSN, LEACH, LEACH-C, LEACH-L, PEGASIS, TEEN, APTEEN, CH, metrics, routing.**

I. INTRODUCTION

In the past few years, the field of wireless sensor networks has become a key area of research in several military as well as civilian domains. The sensor networks along with the widespread internet enable a user to remotely monitor a phenomenon of interest. Due to the adhoc nature of sensor networks and severe battery energy limitations, energy efficient protocols are required at all the layers of the protocol stack. However, in this paper we survey in greater details of one important problem in sensor networks, namely energy efficient routing network design.

Wireless Sensor Network contains a number of sensor nodes that are deployed over a geographical area to sense the desired physical phenomena [1]. WSNs are basically the collection of wireless nodes having limited energy capabilities, are deployed randomly over a dynamically changing atmosphere, may be mobile or stationary, for observing physical phenomena like humidity, temperature, health monitoring, vibrations, seismic events etc. Selecting a routing strategy is the core issue for gathering and delivering the efficient packets of useful information to the specified destination. So the routing strategy should guarantee the least energy consumption resulting in maximizing the networks Life time. WSNs on agriculture may benefit the industry frees the farmer from the maintenance and wiring in a difficult environment [2].

A sensor node is typically an ultra-small limited power device that consists of four basic components shown in Fig 1. First is the sensing part for data acquisition, then the control system for the local data processing and memory operations (storage), then a communication subsystem for transmission and reception of data from other linked devices and finally a power source that supplies the required energy for performing the desired tasks[3]. This power source usually comprises of a battery with limited energy so if a critical node stops working then it's a big and serious protocol failure. The main thing is that it could be impossible to recharge the battery because the nodes are deployed and spread randomly in a hostile environment or any other area of interest such as unapproachable areas or the disaster locations for getting the required information. So to fulfill the scenario requirements the sensor nodes should have enough and prolonged life time, even in some cases up to several months or years can be required. So the question arises that "how to elongate the lifetime of the node for such a long duration".

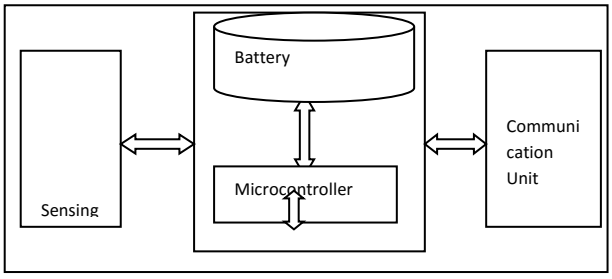

Fig. 1 Components of Sensor

The sensor nodes are small devices that consist of four basic components 1) sensing subsystem, 2) processing subsystem, 3) wireless communication subsystem 4) energy supply subsystem. The sensor nodes have limited battery power, communication

range and memory etc. In most cases, the sensors forming these networks are deployed randomly and left unattended to and are expected to perform their mission properly and efficiently. Sensor networks are also energy constrained since the individual sensors are extremely energy-constrained [5].

The most imperative consideration for a wireless sensor network is power consumption. Though the applications of WSN are extremely ample and attractive, the WSN will not be adopted in most of these applications if batteries are to be changed constantly [3]. Therefore, when the sensor node is designed, power consumption must be minimized. There are a number of strategies that can be used to reduce the average supply current of the radio, and hence the power consumption.

The problem related to the energy consumption is attempted by many methods like, providing an improved clustering algorithm, routing algorithm, data aggregation, optimizing the transmitter and receiver power, reducing data size, local data processing, etc. Among these, many of the problems could be solved by choosing an energy efficient clustering algorithm. Once deployed, the small sensor nodes are usually inaccessible to the user, and thus replacement of the energy source is not feasible. Hence, one of the most important issues that need to be enhanced in order to improve the life span of the network is energy efficiency. To overcome this demerit much research has been done to improve the lifetime of WSN [7].

It is also possible to use the energy from the external environment e.g. using the solar cells as a power source. But usually a non-continuous behavior is usually observed from the external power sources so some energy buffer is also needed.

Since a sensor network is deployed with an objective of gathering information, for a given initial battery energy, it is desired that the network continues to function and provide data updates for as long as possible. This is referred to as the maximum lifetime problem in sensor networks. During each data gathering phase, nodes spend a part of their battery energy on transmitting, receiving and relaying packets. Hence the routing algorithm should be designed to maximize the time until the first battery expires, or a fraction of the nodes have their batteries expired. In certain low bandwidth sensor networks, besides the battery energy, the channel bandwidth presents itself as another constraint, and the routing problem has to take this into account. While it is easy to show that such an energy efficient routing problem reduces to a linear programming problem, the real challenge lies in devising lightweight and efficient distributed algorithms for solving it [4]. In clustering certain nodes are selected as Cluster Heads (CHs) which had to spent more energy than rest of the nodes for a specific time frame. The information from the sensor nodes is accelerated to CHs and then these CHs are responsible to handover the information to the base station (BS) which is placed far apart from the field. Many cluster based protocols like LEACH, LEACH-C, LEACH-L, PEGASIS [8], TEEN, APTEEN etc. are proposed which enlighten the efficient usage of energy in wireless sensor networks.

This paper is structured as follows: The section II enlightens the related work in the surveys of routing protocols in WSNs. The objective of section III is to understand the sources of energy waste in WSNs. In section IV, different clustering protocols and schemes along with their advantages and disadvantages are discussed. Finally in section V concludes the paper.

II. RELATED WORK

An enormous number of current works and efforts are on the go, for the advancement of routing protocols in WSNs. These routing protocols are grounded on the application needs and the structure of the network. However, there are some issues that must be taken into consideration while mounting the routing protocols for WSNs. The most important and glittering factor is the energy efficiency of the sensors that directly influence the lifetime of the network. There are numerous surveys and Journals on routing protocols in WSNs and an effort is done to present below and discuss the dissimilarities between them.

The [4] is a survey proposed on Genetic Algorithm-Based Approach for Energy-Efficient Clustering of Wireless Sensor Networks. It used a multi-purpose algorithm named as Genetic algorithm to optimize the number of sensor nodes within a cluster and ultimately reduced transmission cost. The total transmission cost entirely concerned with the total number of cluster head taken and their location in the network. Thus the main objective is to generate an optimal clustering technique to optimize energy consumption. The performance of GA is greatly affected by a number of factors, such as the population size, the probability of mutation and crossover.

The survey in [6] studied the energy efficiency and data aggregation is key issues in wireless sensor network. Wireless sensor network consists of a large number of autonomous sensor nodes. The group of sensor nodes forms a cluster. Each cluster controlled by cluster head. The data aggregated by cluster head from all ordinary nodes within the cluster transmit data to base station. In this paper, Graph theory is used to detect the shortest path. It divided proposed work in four phases as 1.Distance calculation, 2.Energy calculation, and 3.Shortest path detection 4.Acknowledgement. The network nodes are represented by vertices and also direct connection between the nodes by edges. Finding shortest path to send data from cluster head to base station is based upon the distance calculation and energy calculation. The results show that the sensor nodes utilize less power and have long life.

The survey in [7] studied that wireless sensor network with very limited power source due to hardware constraint. The sensor nodes operated by using tinny batteries and these batteries hold a very limited amount of energy. To tackle this problem, clustering technique is used. It stated that in heterogeneous wireless sensor network, some percentage of sensor nodes is equipped with more energy than all remaining nodes in wireless sensor network. Thus sensor nodes can be classified as sensor nodes and super sensor nodes. The super sensor nodes have more energy capabilities. The cluster head are selected among super sensor nodes. Cluster head aggregate the data from all sensor nodes and further send that data to base station or user. This process continues until the entire energy drains out. In this paper energy consumption analysis is divided into two phases i.e. Energy Consumption Model analyzes the energy.

In some of the survey [10], the authors explained comprehensively the design problems and techniques for the WSNs. They define the “physical constraints of sensor nodes” and the “proposed protocols” apprehending all layers of the network stack. Other than that the potential applications of sensor networks are also discussed. But the list of discussed protocols in the paper

can't give the complete picture and the scope of the survey. My survey is more dedicated to the energy efficiency of WSNs providing the classification of the existing routing hierarchical protocols. I also discussed a number of already developed energy-efficient routing hierarchical protocols and provide guidelines to the readers to select the most suitable protocol for their network.

The [11], is a survey on "routing protocols in WSNs" presented in 2012. Flat, hierarchical, and location-based routing protocols are the three routing techniques classified in this survey based on the structure of the network. These protocols are further classified into "Multipath-based, query-based, negotiation based, and QoS-based routing techniques". In total it presents 27 routing protocols. Furthermore, this paper presents a fine number of energy efficient routing protocols which have been established for WSNs. Challenges in routing are also presented and Design Issues are also mentioned in the paper. On the other side, in my work I focused on the energy efficiency issues in WSNs. I provide some details and comparisons on energy efficient protocols that may help researchers on their work to some extent.

The survey in [16], shows a "top-down approach "of numerous applications and reviews on many features of WSNs in 2013. It organizes the problems into three different kinds: "internal platform and underlying operating system, communication protocol stack, network services, provisioning, and deployment". But the survey didn't provide a detailed comparison of the protocols. My work is a dedicated study on energy-efficient clustering protocols and provides guidelines to the readers on selecting the most appropriate protocol.

In survey [18], some energy-efficient routing techniques for "Wireless Multimedia Sensor Networks (WMSNs)" are presented in 2011. The authors also focused on the performance matters of each strategy. The design tasks of routing protocols for WMSNs are also highlighted in the paper. Furthermore, taxonomy of current routing protocols for WMSNs is also presented. This survey paper discusses few issues on energy efficiency.

III. CAUSES OF ENERGY WASTE IN WSNS

If have to save the energy then lessening data extracted from transducer is necessary. During the reporting, repetition can be arisen because of the intrinsic redundancy in "WSN". It's true that the communication subsystem is a gluttonous cause of the energy debauchery because in communication, wastage of energy occurred in those states which are useless from the application point of view. Some of them are as follows:

Collide: All the packets will be collided, when a node obtains more than one pack at the similar time. All packs that grounds the smash have to be castoff and the retransmission of these packs is obligatory.

Overhearing: P.Minet in "Adhoc and Sensor Wireless Networks" explains that "when a sender transmits a packet, all nodes in its transmission range receive this packet even if they are not the intended destination. Thus, energy is wasted when a node receives packets that are destined to other nodes."

Overloading of Control Packets: To enable data transmission, the minimal number of control packets should be used.

Listening to an idle node: it is occurred, when a node listens to an idle channel to get probable traffic. It is considered the biggest source of energy wastage.

Interference: P.Minet in"AdHoc and Sensor Wireless Networks" explains that "each node located between transmission range and interference range receives a packet but cannot decode it."

IV. CLASSIFICATION OF HIERARCHICAL ROUTING PROTOCOLS IN WIRELESS SENSOR NETWORK

Routing protocols in WSN's are classified as Data-centric, Hierarchical and Location based. These classifications are shown in Fig.2.

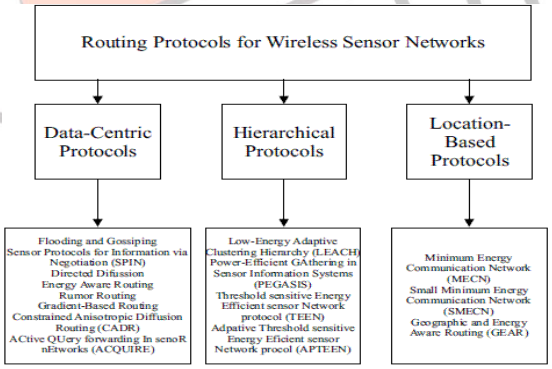

Fig.2 Routing Protocols in WSN's

In "Hierarchical Networks" protocols nodes are grouped into the clusters, as compare to flat protocols in which each node has its distinctive universal address and all the nodes are peers. In "Hierarchical Networks", each cluster owns a cluster head, of which election is established on the different election algorithm. Uses of cluster head are: *1) advanced level of communication, 2) decreasing the transportation overhead*. Having the identical level of communication thoughts in each level, the clustering can be drawn-out to the more than just two levels. Indeed, this technique also has a lot of positive points, among all of them, reducing the size of routing tables along with increasing the scalability is very dominant benefit.

Low energy adaptive clustering hierarchy (LEACH)

LEACH is the cluster based algorithm. LEACH forms the clusters based on the received signal strength and without any centralized control. The CH is determined with probability that can reach using least communication energy. CH localized the data processing of all the fusion and aggregation. The role of CH is assigned to some other node in order to balance the load. The

rotation of CH role is assigned through choosing random number between 0 and 1. A node becomes a CH for the current rotation, if the random number is less than the threshold. Data from cluster nodes to BS achieves through CH [1].

Low energy adaptive clustering hierarchy uses the clustering principle to distribute the energy consumption all along its network. Here, based on data collection, network is divided into Clusters and Cluster heads are elected randomly. The cluster head collects the information from the nodes which are coming under its cluster. Let us see the steps involved in each round in the LEACH protocol.

Advertisement phase: This is the first step in LEACH protocol. The eligible cluster head nodes will be issuing a notification to the nodes coming under its range to become a cluster member in its cluster. The notes will be accepting the offer based upon the Received Signal Strength (RSS). *Cluster set-up phase*: In this step the nodes will be responding to their selected cluster heads. *Schedule creation*: After receiving response from the nodes the cluster head have to make a TDMA scheme and send back to its cluster members to intimate them when they have to pass their information to it. *Data transmission*: The data collected by the individual sensors will be given to the cluster head during its time interval and on all other time the cluster members radio will be off to reduce it energy consumption.

Here in the LEACH protocol multi cluster interference problem was solved by using unique CDMA codes for each cluster. It helps to prevent energy drain for the same sensor nodes which has been elected as the cluster leader, using randomization for each time cluster head would be changed. The cluster head is responsible for collecting data from its cluster members and fuse it. Finally each cluster head will be forwarding the fused data to the base station. When compared with its previous protocols LEACH have shown a considerable improvement.[3]

LEACH-C "Low-Energy Adaptive Clustering Hierarchy Centralized

It involves a centralized clustering algorithm. The steady state will remain the same whereas the setup phase of the Leach-C contains each node sending information about the current location and also the energy level to the base station. The base station thus by utilizing the global information of the network produce better clusters that requires the less energy for data transmission .It needs GPS or the other location tracking method. The base station has to make sure that only nodes with enough energy are allowed to participate in the selection of the cluster head. The base station then broadcasts the information to all nodes in the network .Leach-C has a deterministic threshold algorithm which takes into account the amount of energy in the node and/or whether or not the node was recently a cluster head. The number of cluster head nodes and its placement cannot be guaranteed. The central control algorithm can be used to form the clusters which may produce better clusters through the distribution of the cluster head nodes throughout the network.

LEACH-L (Energy Balanced Low Energy Adaptive Clustering Hierarchy)

Leach-L is an advanced multihop routing protocol and considers only the distance. It is suitable for large scope wireless sensor network and the optimum hop counts are deduced. The cluster heads can communicate directly to the base station when they are located close to it. When they are located far away from the base station, they can communicate by the method of multi-hop way and the shortest transmission distance is limited. In this, the sensors are allowed to use different frequencies and gaps to communicate with base station .The clusters re re-established in each round consisting of the setup and steady state phase and in each round new cluster heads are elected and the load is distributed and balanced among the nodes in the network. Since Leach-L makes power equally distribute among all sensors.

PEGASIS "Power-Efficient Gathering in Sensor Information Systems"

It is a "chain-bases protocol" and an upgrading of the "LEACH". In "PEGASIS" every node transfers only with a close neighbor to direct and obtain information. It receipts turns communicating to the BS, thus decreasing the quantity of energy consumed per round. The nodes are in this way that a chain should be developed, which can be completed by the sensor nodes along with using an algorithm[13]. On the other hand, the BS can compute this chain and transmission of it to all the sensor nodes.

The main idea in PEGASIS is for each node to receive from and transmit to close neighbors and take turns being the leader for transmission to the BS. This approach will distribute the energy load evenly among the sensor nodes in the network. We initially place the nodes randomly in the play field, and therefore, the i-th node is at a random location. The nodes will be organized to form a chain, which can either be accomplished by the sensor nodes themselves using a greedy algorithm starting from some node. Alternatively, the BS can compute this chain and broadcast it to all the sensor nodes. For constructing the chain, we assume that all nodes have global knowledge of the network and employ the greedy algorithm. We could have constructed a loop; however, to ensure that all nodes have close neighbors is difficult as this problem is similar to the traveling salesman problem. The greedy approach to constructing the chain works well and this is done before the first round of communication. To construct the chain, we start with the furthest node from the BS. We begin with this node in order to make sure that nodes farther from the BS have close neighbors, as in the greedy algorithm the neighbor distances will increase gradually since nodes already on the chain cannot be revisited.

PEGASIS improves on LEACH by saving energy in several stages. First, in the local gathering, the distances that most of the nodes transmit are much less compared to transmitting to a cluster-head in LEACH. Second, the amount of data for the leader to receive is at most two messages instead of 20 (20 nodes per cluster in LEACH for a 100-node network). Finally, only one node transmits to the BS in each round of communication.

TEEN "Threshold sensitive Energy Efficient sensor Network protocol"

TEEN is a hierarchical clustering protocol, which groups sensors into clusters with each led by a CH. The sensors within a

cluster report their sensed data to their CH. The CH sends aggregated data to higher level CH until the data reaches the sink. Thus, the sensor network architecture in TEEN is based on a hierarchical grouping where closer nodes form clusters and this process goes on the second level until the BS (sink) is reached.

The functioning of TEEN is, Hard threshold (HT): This is a threshold value for the sensed attribute. It is the absolute value of the attribute beyond which, the node sensing this value must switch on its transmitter and report to its cluster head.

Soft Threshold (ST): This is a small change in the value of the sensed attribute which triggers the node to switch on its transmitter and transmit.

As it says in definition, only when the sensed attribute is in the range of interest the hard threshold allows the nodes to transmit data and by doing so they reduce the number of transmissions significantly. Soft Threshold also significantly further reduce the number of transmission of sensed data as it eliminates data transmission if there is little or no change in the sensed attribute.

The key benefit of "TEEN" is that it performs sound in the circumstances like unexpected variations in the identified characteristics like temperature. On the other side, in big area networks and when the number of covers in the pyramid is small, "TEEN" inclines to consume a lot of energy, because of long remoteness broadcasts. Furthermore, when the number of covers rises, the broadcasts converts into shorter and overhead in the system stage as well as the process of the system exist.

If cluster head don't seem to be within the communication range of each other, the data may be disappeared, because information transmission is completed only at CHs.

APTEEN "Adaptive Threshold sensitive Energy Efficient sensor Network"

APTEEN aims at both capturing periodic data collections (LEACH) and reacting to time-critical events (TEEN). Thus, APTEEN is a hybrid clustering-based routing protocol that allows the sensor to send their sensed data periodically and react to any sudden change in the value of the sensed attribute by reporting the corresponding values to their CHs. CHs also perform data aggregation in order to save energy. APTEEN supports three different query types namely (i) historical query, to analyze past data values (ii) one-time query, to take a snapshot view of the network (iii) persistent queries, to monitor an event for a period of time. APTEEN is a combination of both proactive policies as well as reactive policies, similar to LEACH and TEEN respectively. Energy dissipation will be lower and a large number of sensors alive in APTEEN.

V CONCLUSION

In this survey paper, we provided an overview of some of the recent work on energy and cost optimizations in wireless sensor networks. Sensor nodes are highly energy constrained, and energy efficiency is of prime importance at all the layers of protocol stack. Different network design issues surface depending on the kind of application involved. In this survey, we restricted ourselves mainly to those applications which are of data gathering type. We focused our attention on two important aspects of sensor networks, namely routing and design optimizations. In the context of routing optimizations, we looked at some of the important papers on energy efficient routing for maximizing the system lifetime.

WSNs have greatly prolonged playing a key role for the data efficient selection and delivery. The energy efficiency is a very most important issue for the networks particularly for WSNs which are described by "limited battery capabilities". Due to complexity in WSNs operations, what is required is the use of energy-efficient routing techniques and protocols, Which will assure the network connectivity and routing of Information with less required energy.

In this paper, our focus was on the energy efficient hierarchical protocols that have been developed for WSNs. If we talk about a large network, the flat protocols become "infeasible" because of link and the processing overhead. This is a problem and the hierarchical protocols try to solve it and as a result produce scalable, efficient and effective solutions. They split the network into "clusters "to proficiently maintain the energy consumption of sensor nodes and also perform "data aggregation and fusion" to lessen the number of transmitted messages to the sink. The clusters are arranged based on the energy backup of sensors and sensor's nearness to the CH. Thus, we can conclude that the hierarchical protocols are appropriate for sensor networks with the heavy load and wide coverage area. So in order to develop a scheme that will prolong the lifetime of the WSNs is needed to increase the energy consumption of the sensors within the network. Therefore, the application of the appropriate routing protocol will enhance the lifetime of the network and at the same time it will guarantee the network connectivity and effective and efficient data delivery.

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