Energy Efficient Wireless Sensor Networks: A Review

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ABSTRACT
Recent advances in wireless communication and micro-electro-mechanical systems (MEMS) have led to the development of implementation of low-cost, low power, multifunctional sensor nodes. These sensor nodes are small in size and communicate themselves to transfer the data. The nodes in sensor networks have limited battery power (<0.5 Ah, 1.2 V) and it is not feasible or possible to recharge or replace the batteries, therefore power consumption should be minimized so that overall network lifetime will be increased. Mainly power dissipated during data processing, data transmission, data reception and idle listening. The power consumed during transmission is the greatest portion of energy consumption of any node. In this survey we studied various techniques and algorithms to increase the network lifetime.

Keywords
Wireless Sensor Network, Data Aggregation, Topology Control.

1. INTRODUCTION
With the recent advances in Micro Electro-Mechanical Systems (MEMS) technology, low power digital circuitry and RF designs, WSNs are considered to be one of the potential emerging computing technologies. Several useful and varied applications of WSNs include applications requiring information gathering in harsh, inhospitable environments, weather and climate monitoring, detection of chemical or biological agent threats, and healthcare monitoring. These applications demand the usage of various equipment including cameras, acoustic tools and sensors for measuring different physical parameters.

Wireless Sensor Networks (WSNs) are consists of number of typically tiny sensors called as sensor node and each sensor node consist of four parts: sensor, processor, transceiver, and battery (as energy source). The sensor node is a low-cost, low-power, and multifunctional tiny embedded system. The main aim in Wireless Sensor Networks is how to handle with their limited energy resources. The performance of Wireless Sensor Networks strongly depends on their lifetime. As a result, Dynamic Power Management approaches with the purpose of reduction of energy consumption in sensor nodes.

The sensor nodes have a limited battery power and batteries of node are difficult to replace or recharge. Ones the nodes are deployed, node sends the sensed data while the battery power is sufficient. Since the batteries of sensor nodes are small with limited power capacity, minimizing the energy consumption for maximizing the life time becomes a key challenge of the design of the WSNs. Therefore, energy conservation is a serious and critical issue in designing of WSNs with longevity. More Energy is consumed in communication than that of processing, that is consumed energy in radio modes like reception, transmit and idle or listening mode, it can be reduced at least an order of magnitude in sleep mode [2, 10, 37]. Thus it is very important to turn off the radio as early as possible and it is depends on the specific application. Many research studies around the world have been done to reduce the energy consumption in radio communications. Several energy conservation schemes have been proposed in the literature and comprehensive survey studies on them as perfect taxonomy which divides all energy efficient approaches into three main groups: duty-cycling, data reduction, and mobility based approaches [11]. Duty cycle control divided into two types one topology control, in this various topology algorithm are developed such as Low Energy Adaptive Clustering Hierarchy (LEACH), Directed Diffusion [10], Energy Efficient Sensor Routing (EESR), Adaptive Self-Configuring Sensor Network Topologies (ASCENT) [17] etc, each having advantages and disadvantages, Second type is power management which categorized into three types on-demand wakeup, scheduled wakeup, and asynchronous wakeup [18].

The hybrid approach is topology control technique that uses some form of clustering and other approach like power adjustment or power mode to increase the network lifetime [17]. There are several factors which determine the energy efficiency of a sensor network such as network architecture, the data aggregation mechanism and the underlying routing protocol [1]. Till now several techniques have been proposed and implemented for energy efficient WSNs. Our goal is to design and develop a new algorithm to increase the lifetime of Wireless Sensor Networks.

2. LITERETURE REVIEW
Wireless Sensor Networks (WSNs), are set of many sensor nodes that have some limitations of energy and dimension. Because of the energy limitation for these nodes, we must use their energy very usefully such that the network lifetime increases. Hundreds to thousands of micro nodes can be deployed in many domains including health, environment and battlefield monitoring in order to resolve specific problems that cannot be addressed by using human being, so WSN is the good solution for such situation. Some interventions can damage the WSN monitored area and thus disturb the accuracy of the observations. Once a wireless sensor network is in place, its lifetime should as long as possible based on the initially provided energy in the form of battery. Reducing the energy consumption is only the option to increase the lifetime of wireless sensor networks. There are some method such as data aggregation, routing protocol and network topology which are used to increase the lifetime of WSN.

2.1 Data Aggregation Technique
Data Aggregation is defined as process of gathering of data from multiple sensors to eliminate redundant transmission and provide fused information to based station. The main goal of data aggregation algorithms is to gather and aggregate data in an energy efficient manner so that network lifetime is enhanced. Architecture of sensor network plays important role in Data aggregation protocol [1, 13]. There are two main types of data aggregation, Structure and Structure free data aggregation, each having merits and limitation. Again

structure networks categorized into two types Hierarchical networks and Flat networks. The comparison between two is given in Table 1.

Table 1. Data Aggregation in hierarchical network versus flat networks

Hierarchical networks	Flat networks
Data aggregation performed by cluster heads or a leader node.	Data aggregation is performed by different nodes along the multi-hop path.
Overhead involved in cluster or chain formation throughout the network.	Data aggregation routes are formed only in regions that have data for transmission.
Even if one cluster head fails, the network may still be operational.	The failure of sink node may result in the breakdown of entire network.
Lower latency is involved since sensor nodes perform short range transmissions to the cluster head.	Higher latency is involved in data transmission to the sink via a multi-hop path.
Routing structure is simple but not necessarily optimal.	Optimal routing can be guaranteed with additional overhead.
Node heterogeneity can be exploited by assigning high energy nodes as cluster heads.	Does not utilize node heterogeneity for improving energy efficiency.

Power-Efficient Gathering in Sensor Information Systems (PEGASIS) [1] is the protocol in which only one node is chosen as a head node that sends the fused data to the Base Station per round. PEGASIS protocol requires the formation of a chain, which is achieved in two steps. During the chain construction phase, the extreme node from the Base Station is considered first. During the data gathering phase, a leader of each round is selected randomly. Randomly selecting the head node also provides a benefit as it is more likely for nodes to die at random locations, thus providing a robust network. When a node dies, the chain is reconstructed to bypass the dead node. After the leader is selected, it passes the token to initiate the data gathering process. Passing the token also requires energy consumption but the cost of passing the token is very small because the token size is very small. In PEGASIS, the transmitting distance is reduced for the sensor nodes. Since each node gets selected once, energy dissipation is also less.

A question in WSNs is to schedule nodes' activities to reduce energy consumption. Focus on designing energy-efficient protocol for low-data-rate WSNs, where sensors consume different energy in different radio states (transmitting, receiving, listening, sleeping, and being idle) and also consume energy for state transition. To use TDMA as the MAC layer protocol and schedule the sensor nodes with consecutive time slots at different radio states while reducing the number of state transitions.

Table 2. Energy Cost Symbols

Symbol	Meaning	Typical Value
Ptx	Energy consumption in transmitting	60 mW
Prvc	Energy consumption in receiving	40 mW
Plst	Energy consumption in listening	45 mW
Pslp	Energy consumption in sleeping	90 µmW
tp	Time needed to poll channel once	3 ms
rvi	Data packet per period by vi	Varying
Ldata	Data packet length	36 Bytes
tB	Time to transmit or receive a byte	416E-6s
T	A scheduling period (# of time- slots)	1s to 60s
ts	Slot size	30ms
Ps	# of packets transmitted in a lot	~10

In scheduling period, any sensor node needs only to weak up at most twice : one for continuously receiving all packets from its children nodes and ones for sending its own data to its parent node, proposed in [2] by Y. Wu. Table 2 summarizes some typical values of the energy cost for different operations.

Two challenges in Structure free data aggregation is defined with their solution by Kai-Wai Fan in [3] is i) no pre-defined structure and routing decision. ii) Node does not know their upstream node and they cannot wait on data from any particular node before forwarding their own data. The solution is Data Aware Any cast (DAA) and Randomized Waiting (RW) respectively to improve data aggregation.

In order to support data aggregation through efficient network organization, nodes can be partitioned into a number of small groups called clusters. Each cluster has a coordinator, called as a cluster head (CH). The member nodes report their data to the respective CHs. The CHs aggregate the data and send them to the central base through other CHs. Ossama younis in [5] proposed, classification of clustering technique based on two criteria: the parameter used for electing CHs and the execution nature of a clustering algorithm. Hongbo Jiang proposed energy efficient data collection which is clustering and prediction based, that is author use past input values from the sensor to perform prediction operation. It implies that the sensor does not need to transmit the data values if they differ from predicted values by less than certain specified threshold or error values [6].

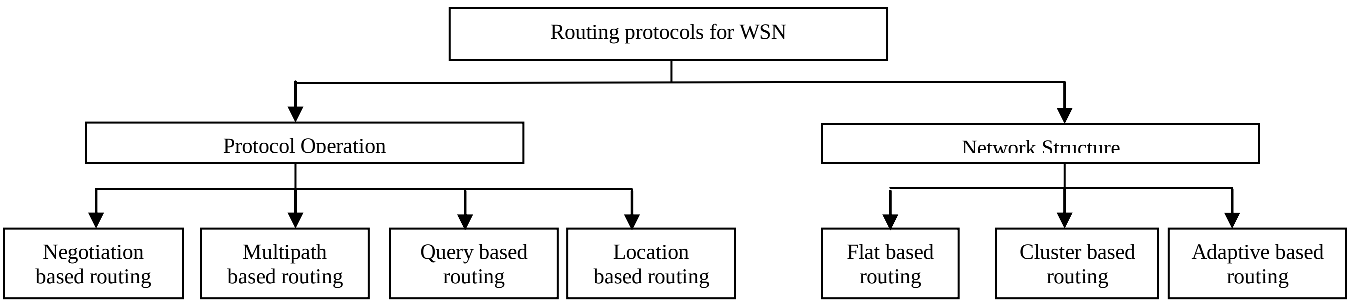

Figure. 1 Taxonomy of routing protocol for WSN

By combining cooperative Multiple Input Multiple Output (MIMO) with data aggregation to reduce the power consumption, But for this cluster size cannot be very big and sensor node should be proper clustered [4].

Flexible-Schedule-Based TDMA Protocol (FlexiTP) have been developed by Winnie Loius [7], it provides end-to-end guarantees on data delivery such as predictable throughput for gathered data, fair access to the network for all sensor nodes. FlexiTP is the first integrated protocol for sensor networks that proposes a scheduling scheme that provides a balance among end-to-end guarantees on data delivery, energy efficiency, and memory efficiency. This protocol is self healing designed for periodic data gathering application, nodes only transmit and receive packets at their own time slot(s) and sleep until their slots turns up again.

In Duty cycle control, sensor nodes dynamically create on- off schedules such that the node will be awake only when they are needed. Christophe J. [8] proposed two new approaches to control duty cycle for target rate of transmitted packets by Asymmetric Additive Duty Cycle Control (AADCC) and Dynamic Duty Cycle Control (DDCC).

2.2 Routing Protocol

One of the most important causes for energy consumption in WSN is routing protocol and it classify into two parameters. First classification is based on the protocol operation that classifies all routing algorithms to negotiation-based routing, multi-path based routing, query-based routing and Location-based routing algorithms. Second classification is based on the network structure that classifies all routing algorithms to flat, Cluster based routing and Adaptive based routing algorithms.

In flat networks, each node plays the same role and all sensor nodes collaborate together to perform the sensing task and to transmit the data packets to the base station.

Cluster based algorithms, classify all nodes to some clusters and specific number of nodes are responsible for data transmission to base station. In Cluster based routing algorithms, the role of the nodes is different from each other. In terms of network lifetime and the energy consumption over these networks show that cluster-based algorithms or hierarchical routing algorithms have the best work in contrast to other algorithms [9, 15].

Hana Khamfroush in [9] Proposed algorithm works on the nodes clustering. And it did by considering the residual energy of nodes and the distances between those nodes to Base Station. Load sharing routing algorithm is proposed in [10] by Asjd Amin which save the energy of node by changing route of data transmission with respect to power resource of each node but it increase the transmission time.

Lucia LoBello [16] introduces a novel energy balancing feature that is able to significantly increase the overall network lifetime, first provides support for both periodic and non periodic transmissions. Second, it allows for dynamic clustering set up of aggregated units, when the density of nodes is non uniform. Finally, it introduces a novel energy balancing feature that is able to significantly increase the overall network lifetime through a node exchange policy.

2.3 Topology Control

In WSN, Topology provides information about set of node and connectivity link between pair of nodes. To construct the network topology each sensor node discovers its neighbors and relative link using its maximum power and transmission power, based on this gathered information the node can make decisions to build a network. Application of topology control methods will have an impact on energy efficiency and hence battery lifetime. WSNs are also different from other networks in the following aspects: they are densely deployed, nodes are susceptible to failure, and heavily rely on broadcast communications. So they have to be properly deployed to avoid the neighboring interference.

Topology is dynamic, in which node-to-node links are established and broken quite often due to various reasons including deliberate changes to the transmission power of the nodes, node failure or mobility. Maintaining a fully connected topology for such networks is a challenge and requires careful application of topology control. Distributed topology control algorithms according to their energy conservation technique are categories into four groups: power adjustment, power mode, clustering and hybrid [18].

Power adjustment deals with a technique that reduces energy consumption by varying the transmission power of nodes. Power mode deals with switching of radio in sleep, weak up and transmission mode. Clustering approaches conserve energy by critically selecting a set of neighbor nodes to construct an energy efficient backbone in the network and challenging hybrid approaches further improve the energy saving by integrating the clustering approach with either power mode or power adjustment approaches [19].

Experimental studies show that 95% of total energy is consumed by idle listing mode searching for neighbors, the new sleep scheduling protocol, based on hierarchical arrangements proposed by Bong Jun Choi [19]. Various energy efficient approaches in WSN are proposed by Neha Enami [23], like duty cycle, mobility based, topology control, power management etc. comparison of various existing algorithm with their advantages and disadvantages is given by Alaauldin Ibrahim [10], Azrina Abd Aziz [18] and Cosmin Cirstea [16].

Recently WSN is used in various filed for continuous monitoring like industrial monitoring [36], [26], [32], real time application like smart grid monitoring [24], land slide detection [25], water quality monitoring [28],[30], warehouse [31], wind mill [34], medical [29] and in agriculture monitoring[27], [29], [35]. In the real time application there is various ways to increase the life time of sensor node by using the different transmitting method like Wi-Fi, Zigbee, UWB or Bluetooth depends on requirement of application. In some of the application sensor node consists of ARM based 32 bit microcontroller that consume less power to increase the node lifetime.

3. PROBLEM DEFINATION

By analyzing literature, it has been found that the energy efficiency issue and a comprehensive study of data aggregation, routing control and topology control techniques for extending the lifetime of battery powered WSNs.

In data aggregation technique different algorisms are used depend on the network structure like hierarchical network or flat network. We compare and contrast different algorithms on the basis of performance measures such as lifetime, latency and data accuracy. Although, many of the data aggregation techniques presented look promising, there is significant scope for future research. Combining aspects such as security, data latency and system lifetime in the context of data aggregation is worth exploring. A systematic study of the relation between energy efficiency and system lifetime is an area of future research. In future several challenges are worth exploring in the Data aggregation.

Routing is the most important cause for energy consumption in WSN. In Cluster based routing algorithms, the role of the nodes is different from each other. In terms of network lifetime and the energy consumption over these networks show that cluster-based algorithms or hierarchical routing algorithms have the best work in contrast to other algorithms.

Topology is dynamic, in which node-to-node links are established and broken quite often due to various reasons including deliberate changes to the transmission power of the nodes, node failure or mobility. Maintaining a fully connected topology for such networks is a challenge and requires careful application of topology control. Further, these algorithms are classified according into four groups: power adjustment, power mode, clustering and hybrid. Challenging hybrid approaches further improve the energy saving by integrating the clustering approach with either power mode or power adjustment approaches.

Due to the cost, time and expertise required to deploy a Wireless Sensor Networks (WSN), simulation is currently the most widely adopted evaluation method. Network simulation is well established for mobile ad hoc networks. Various simulator is used for WSN like OMNET++, OPNET, WSNsim, ns2 etc. By comparing, Network simulator 2 (NS2) is most widely used open source simulator for developing energy efficient algorithms in WSN. As a result, simulation is currently the most widely adopted method of analyzing WSNs, allowing the rapid development, evaluation and optimization to propose algorithms and protocols. In view of the above related literature review is aiming to concentrate on research activity to investigate the design and simulate new algorithms to increase the lifetime of Wireless Sensor Networks by using existing algorithms in data aggregation, topology control or hybrid approach.

4. CONCLUSION

In Wireless Sensor Networks the sensor nodes have a limited battery power and batteries of node are difficult to replace or recharge. Ones the nodes are deployed, node sends the sensed data while the battery power is sufficient. In view of the related literature review there are various methods and many algorithms are developed each having some merits and limitation. Network lifetime can also be increase by using communication medium like Wi-Fi, Zigbee, UWB or Bluetooth depends on requirement of application. Most of the power is consume in the communication than that of processing. So the new direction in this area are aiming to concentrate on research activities to investigate the design and development of new algorithms to increase the lifetime of WSNs using Data Aggregation, Topology Control or by combining these two algorithms. As a result, simulation is currently the most widely adopted method of analyzing WSNs, allowing the rapid development, evaluation and optimization to propose algorithms and protocols.

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