
Shalini, Sangeeta Vhatkar
Department of Information Technology
Thakur College of Engineering & Technology, Mumbai
shalinivikrant@yahoo.co.in, vhatkarsangeeta@gmail.com

Abstract - A wireless sensor network (WSN) has gained tremendous importance in terms of research and application. This has been possible due to the availability of sensors that are smaller cheaper and intelligent. These sensors are equipped with wireless interfaces with which they can communicate with one another to form a network. The design of a WSN depends significantly on the application, and it must consider factors such as the environment, the application’s design objectives, cost, hardware, and system constraints. In this paper, we present a survey of the state-of-the-art routing protocols in WSNs. We study the energy concerns in WSNs and how LEACH protocol could address to these concerns in effective way. The paper concludes with possible future research areas.

Keywords- Wireless Sensor Networks, Routing Protocols, Cluster Head.

I. INTRODUCTION

Wireless sensor networks (WSNs) have gained worldwide attention in recent years, particularly with the proliferation in Micro-Electro-Mechanical Systems (MEMS) technology which has facilitated the development of smart sensors. These sensors are small, with limited processing and computing resources, and they are inexpensive compared to traditional sensors. These sensor nodes can sense, measure, and gather information from the environment and, based on some local decision process, they can transmit the sensed data to the user. Smart sensor nodes are low power devices equipped with one or more sensors, a processor, memory, a power supply, a radio, and an actuator. (An actuator is an electro-mechanical device that can be used to control different components in a system. In a sensor node, actuators can actuate different sensing devices, adjust sensor parameters, move the sensor, or monitor power in the sensor node.)

A variety of mechanical, thermal, biological, chemical, optical, and magnetic sensors may be attached to the sensor node to measure properties of the environment. Since the sensor nodes have limited memory and are typically deployed in difficult-to-access locations, a radio is implemented for wireless communication to transfer the data to a base station (e.g., a laptop, a personal hand held device, or an access point to a fixed infrastructure). Battery is the main power source in a sensor node. Secondary power supply that harvests power from the environment such as solar panels may be added to the node depending on the appropriateness of the environment where the sensor will be deployed. Depending on the application and the type of sensors used, actuators may be incorporated in the sensors.

WSNs have great potential for many applications in scenarios such as military target tracking and surveillance [1, 2], natural disaster relief [3], biomedical health monitoring [4, 5], and hazardous environment exploration and seismic sensing [6]. In military target tracking and surveillance, a WSN can assist in intrusion detection and identification. Specific examples include spatially-correlated and coordinated troop and tank movements. With natural disasters, sensor nodes can sense and detect the environment to forecast disasters before they occur. In biomedical applications, surgical implants of sensors can help monitor a patient’s health. For seismic sensing, ad hoc deployment of sensors along the volcanic area can detect the development of earthquakes and eruptions. Unlike traditional networks, a WSN has its own design and resource constraints. Resource constraints include a limited amount of energy, short communication range, low bandwidth, and limited processing and storage in each node. Design constraints are application dependent and are based on the monitored environment.

II. NETWORK CHARACTERISTICS AND DESIGN OBJECTIVES

The characteristics of sensor networks which have key impact on the network design objectives in term of network capabilities and network performance [7].

A. Network Characteristics-
As compared to the traditional wireless communication networks such as mobile ad hoc network (MANET) and cellular systems, wireless sensor networks have the following unique characteristics and constraints:

Battery-powered sensor nodes: Sensor nodes are usually powered by battery and are deployed in a harsh environment where it is very difficult to change or recharge the batteries.

Self-configurable: Sensor nodes are usually randomly deployed and autonomously configure themselves into a communication network.

Application specific: A sensor network is usually designed and deployed for a specific application. The design requirements of a sensor network change with its application.

Many-to-one traffic pattern: In most sensor network applications, the data sensed by sensor nodes flow from multiple source sensor nodes to a particular sink, exhibiting a many-to-one traffic pattern.

Dense sensor node deployment: Sensor nodes are usually densely deployed and can be several orders of magnitude higher than that in a MANET.

Severe energy, computation, and storage constraints: Sensors nodes are having highly limited energy, computation, and storage capabilities.

Unreliable sensor nodes: Since sensor nodes are prone to physical damages or failures due to its deployment in harsh or hostile environment.

Data redundancy: In most sensor network application, sensor nodes are densely deployed in a region of interest and collaborate to accomplish a common sensing task. Thus, the data sensed by multiple sensor nodes typically have a certain level of correlation or redundancy.

Frequent topology change: Network topology changes frequently due to the node failures, damage, addition, energy depletion, or channel fading.

B. Network Design Objectives-
Most sensor networks are application specific and have different application requirements. Thus, all or part of the following main design objectives is considered in the design of sensor networks:

Small node size: Since sensor nodes are usually deployed in a harsh or hostile environment in large numbers, reducing node size can facilitate node deployment. It will also reduce the power consumption and cost of sensor nodes.

Low power consumption: Since sensor nodes are powered by battery and it is often very difficult or even impossible to charge or recharge their batteries, it is crucial to reduce the power consumption of sensor nodes so that the lifetime of the sensor nodes, as well as the whole network is prolonged.

Channel utilization: Since sensor networks have limited bandwidth resources, communication protocols designed for sensor networks should efficiently make use of the bandwidth to improve channel utilization.

Fault tolerance: Sensor nodes are prone to failures due to harsh deployment environments and unattended operations. Thus, sensor nodes should be fault tolerant and have the abilities of self-testing, self-calibrating, self-repairing, and self-recovering.

QoS support: In sensor networks, different applications may have different quality-of-service (QoS) requirements in terms of delivery latency and packet loss. Thus, network protocol design should consider the QoS requirements of specific applications in terms of scalability, reliability, self-configurability, adaptability and security.

C. Network Design Challenges and Routing Issues-
The design of routing protocols for WSNs is challenging because of several network constraints.
WSNs suffer from the limitations of several network resources, for example, energy, bandwidth, central processing unit, and storage [8,9]. The design challenges in sensor networks involve the following main aspects [7,8,9]:

**Limited energy capacity:** Since sensor nodes are battery powered, they have limited energy capacity. Energy poses a big challenge for network designers in hostile environments, for example, a battlefield, where it is impossible to access the sensors and recharge their batteries. Furthermore, when the energy of a sensor reaches a certain threshold, the sensor will become faulty and will not be able to function properly, which will have a major impact on the network performance. Thus, routing protocols designed for sensors should be as energy efficient as possible to extend their lifetime, and hence prolong the network lifetime while guaranteeing good performance overall.

**Sensor locations:** Another challenge that faces the design of routing protocols is to manage the locations of the sensors. Most of the proposed protocols assume that the sensors either are equipped with global positioning system (GPS) receivers or use some localization technique [10] to learn about their locations.

**Limited hardware resources:** In addition to limited energy capacity, sensor nodes have also limited processing and storage capacities, and thus can only perform limited computational functionalities. These hardware constraints present many challenges in software development and network protocol design for sensor networks, which must consider not only the energy constraint in sensor nodes, but also the processing and storage capacities of sensor nodes.

**Massive and random node deployment:** Sensor node deployment in WSNs is application dependent and can be either manual or random which finally affects the performance of the routing protocol. In most applications, sensor nodes can be scattered randomly in an intended area or dropped massively over an inaccessible or hostile region. If the resultant distribution of nodes is not uniform, optimal clustering becomes necessary to allow connectivity and enable energy efficient network operation.

**Network characteristics and unreliable environment:** A sensor network usually operates in a dynamic and unreliable environment. The topology of a network, which is defined by the sensors and the communication links between the sensors, changes frequently due to sensor addition, deletion, node failures, damages, or energy depletion. Also, the sensor nodes are linked by a wireless medium, which is noisy, error prone, and time varying. Therefore, routing paths should consider network topology dynamics due to limited energy and sensor mobility as well as increasing the size of the network to maintain specific application requirements in terms of coverage and connectivity.

**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 technique has been used to achieve energy efficiency and data transfer optimization in a number of routing protocols.

**Diverse sensing application requirements:** Sensor networks have a wide range of diverse applications. No network protocol can meet the requirements of all applications. Therefore, the routing protocols should guarantee data delivery and its accuracy so that the sink can gather the required knowledge about the physical phenomenon on time.

**Scalability:** Routing protocols should be able to scale with the network size. Also, sensors may not necessarily have the same capabilities in terms of energy, processing, sensing, and particularly communication. Hence, communication links between sensors may not be symmetric, that is, a pair of sensors may not be able to have communication in both directions. This should be taken care of in the routing protocols.

### III. ROUTING PROTOCOLS IN WSN

Routing in wireless sensor networks differs from conventional routing in fixed networks in various ways. There is no infrastructure, wireless links are unreliable, sensor nodes may fail, and routing protocols have to meet strict energy saving requirements [11]. Many routing algorithms were developed for wireless networks in general. All major routing protocols proposed for WSNs may be divided into seven categories.

#### A. Location-based Protocols

In location-based protocols, sensor nodes are addressed by means of their locations. Location information for sensor nodes is required for sensor networks by most of the routing protocols to calculate the distance between two particular nodes so that energy consumption can be estimated. Some of the representative routing protocols in this category are:

- Minimum Energy Communication Network (MECN)

- Small Minimum-Energy Communication Network (SMECN)
- Geographic Adaptive Fidelity (GAF)
- Geographic and Energy-Aware Routing (GEAR)
- Coordination of Power Saving with Routing (Span)
- Trajectory-Based Forwarding (TBF)
- Bounded Voronoi Greedy Forwarding (BVGF)
- Geographic Random Forwarding (GeRaF)

B. Data Centric Protocols

Data-centric protocols differ from traditional address-centric protocols in the manner that the data is sent from source sensors to the sink. In address-centric protocols, each source sensor that has the appropriate data responds by sending its data to the sink independently of all other sensors. However, in data-centric protocols, when the source sensors send their data to the sink, intermediate sensors can perform some form of aggregation on the data originating from multiple source sensors and send the aggregated data toward the sink. This process can result in energy savings because of less transmission required to send the data from the sources to the sink. Some of the representative routing protocols in this category are:

- Sensor Protocols for Information via Negotiation (SPIN)
- Directed Diffusion
- Rumour Routing
- Cougar
- Active Query Forwarding in Sensor Networks (ACQUIRE)
- Energy-Aware Data-Centric Routing (EAD)

C. Hierarchical Protocols

Many research projects in the last few years have explored hierarchical clustering in WSN from different perspectives [12]. Clustering is an energy-efficient communication protocol that can be used by the sensors to report their sensed data to the sink. In this section, we describe a sample of layered protocols in which a network is composed of several clumps (or clusters) of sensors. Each clump is managed by a special node, called cluster head, which is responsible for coordinating the data transmission activities of all sensors in its clump. A hierarchical approach breaks the network into clustered layers [13]. Nodes are grouped into clusters with a cluster head that has the responsibility of routing from the cluster to the other cluster heads or base stations. Data travel from a lower clustered layer to a higher one. Although, it hops from one node to another, but as it hops from one layer to another it covers larger distances. This moves the data faster to the base station. Clustering provides inherent optimization capabilities at the cluster heads. Some of the representative routing protocols in this category are:

- Low-energy adaptive clustering hierarchy (LEACH)
• Power-Efficient Gathering in Sensor Information Systems (PEGASIS)
• Hybrid, Energy-Efficient Distributed Clustering (HEED)
• Threshold Sensitive Energy Efficient Sensor Network Protocol (TEEN)

D. Mobility-based Protocols:
Mobility brings new challenges to routing protocols in WSNs. Sink mobility requires energy efficient protocols to guarantee data delivery originated from source sensors toward mobile sinks. Some of the representative routing protocols in this category are:
• Joint Mobility and Routing Protocol
• Data MULES Based Protocol
• Scalable Energy-Efficient Asynchronous Dissemination (SEAD)
• Dynamic Proxy Tree-Based Data Dissemination

E. Multipath-based Protocols
Considering data transmission between source sensors and the sink, there are two routing paradigms: single-path routing and multipath routing. In single-path routing, each source sensor sends its data to the sink via the shortest path. In multipath routing, each source sensor finds the first k shortest paths to the sink and divides its load evenly among these paths. Some of the representative routing protocols in this category are:
• Sensor-Disjoint Multipath
• Braided Multipath
• N-to-1 Multipath Discovery

F. Heterogeneity-based Protocols
In heterogeneity sensor network architecture, there are two types of sensors namely line-powered sensors which have no energy constraint, and the battery-powered sensors having limited lifetime, and hence should use their available energy efficiently by minimizing their potential of data communication and computation. Some of the representative routing protocols in this category are:
• Information-Driven Sensor Query (IDSQ)
• Cluster-Head Relay Routing (CHR)

G. QoS-based Protocols
In addition to minimizing energy consumption, it is also important to consider quality of service (QoS) requirements in terms of delay, reliability, and fault tolerance in routing in WSNs. Some of the representative routing protocols in this category are:
• Sequential Assignment Routing (SAR)
• Energy-Aware QoS Routing Protocol
• SPEED

Although many of these routing techniques look promising, there are still many challenges that need to be solved in the sensor networks.

IV. ENERGY CONCERNS IN WIRELESS NETWORKS
One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors.

For any wireless node there are three major modes of operation: transmitting, receiving and listening. When the node is in listening mode the energy expenditure is minimal. However, if the node spends most of the time listening then this mode is responsible for a large portion of the consumed energy (as is the case in sensor networks). In multi hop wireless networks it is energy efficient to choose long paths along a series of short hops rather than short paths along a series of long hops. However, even though energy efficiency is our paramount interest it is not the only one. Communication performance is also very important. By choosing many short hops we may lower the energy expenditure, but only to a certain degree, since delay increases, processing energy increases and control overhead increases. Therefore, the choice of how to incorporate energy is not as clear as it seems.

In this section, we review a sample of hierarchical-based routing protocols for WSNs, i.e. LEACH Protocol.

Low-energy adaptive clustering hierarchy (LEACH): LEACH [14, 15] is the first and most popular energy-efficient hierarchical clustering algorithm for WSNs that was proposed for reducing power consumption. In LEACH, the clustering task is rotated among the nodes, based on duration. Direct communication is used by each cluster head (CH) to forward the data to the base station (BS). It uses clusters to prolong the life of the wireless sensor network. LEACH is based on an aggregation (or fusion) technique that combines or aggregates the original data into a smaller size of data that carry only meaningful information to all individual sensors. LEACH divides the a network into several cluster of sensors, which are constructed by using localized coordination and control not only to reduce the amount of data that are transmitted to the sink, but also to make routing and data dissemination more scalable and robust. LEACH uses a randomize rotation of high-energy CH position rather than selecting in static manner, to give a chance to all sensors to act as CHs and avoid the battery depletion of an individual sensor and dying quickly. The operation of LEACH is divided into rounds having two phases each namely (i) a setup phase to organize the network into clusters, CH advertisement, and transmission schedule creation and(ii) a steady-state phase for data aggregation, compression, and transmission to the sink. LEACH is completely distributed and requires no global knowledge of network. It reduces energy consumption by (a) minimizing the communication cost between sensors and their cluster head sand (b) turning off non-head nodes as much as possible [16]. LEACH uses single-hop routing where each node can transmit directly to the cluster-head and the sink. Therefore, it is not applicable to networks deployed in large regions. Furthermore, the idea of dynamic clustering brings extra overhead, e.g. head changes, advertisements etc., which may diminish the gain in energy consumption. While LEACH helps the sensors within their cluster dissipate their energy slowly, the CHs consume a larger amount of energy when they are located farther away from the sink. Also, LEACH clustering terminates in a finite number of iterations, but does not guarantee good CH distribution and assumes uniform energy consumption for CHs.

V. SOME OPEN RESEARCH ISSUES

Considerable work and effort has focused on designing communication protocols for sensor networks. However, no single protocol has emerged as a major contender and research on this issue is very much active and ongoing.

A. Development of an Evaluation Framework for Sensor Networks-

It would be useful to have comprehensive guidelines for evaluating a specific protocol and compare it against others. A primary goal for such a framework would be to provide a handful of models to classify sensor networks so that most of the anticipated uses of such networks are covered in an organized fashion. The framework should evaluate the goodness of the network as a whole and provide metrics to measure the effects of the design on the operation of the network (by evaluating, for example, energy efficiency, communication performance, etc).

B. Collaborative Information Gathering Networks-

The main task of a sensor network is to gather and disseminate information. However, the WSN model makes implicit assumptions about the nature and capabilities of the agents (nodes) which do not relate directly to the problem at hand.

C. Development of a new Transport Protocol-

As pointed out in [17], which proposes a reliable transport protocol for wireless sensor network, there has been little work on the design of efficient transport protocols in this setting. New transport schemes need to be introduced which will focus on energy efficiency and take advantage of the collaborating nature of sensor networks. For example, one strategy would be to design a transport protocol that can receive feedback about a variety of attributes (energy state of
the node, quality of wireless link, etc). Furthermore, the transport protocol could be aware of or allow the use of intermediate transport proxies (at the border of networks with different characteristics and feedback), thus enabling the transport of data between heterogeneous networks. The usefulness of such a transport protocol would not be limited to sensor network; most wireless networks that communicate with a fixed network would be benefited.

D. Groups of sensor networks-

Most attention has been focused on a variety of design issues for a single sensor network. The interaction with the outside world is not considered and assumed to be application specific and handled by the base station(s) on the edge of the sensor network. Therefore, interaction with other networks as well as cooperation among sensor networks (creating groups of different sensor networks) could be an area worth looking into.

VI. CONCLUSION

One of the main challenges in the design of routing protocols for WSNs is energy efficiency due to the scarce energy resources of sensors. The ultimate objective behind the routing protocol design is to keep the sensors operating for as long as possible, thus extending the network lifetime. The energy consumption of the sensors is dominated by data transmission and reception. Therefore, routing protocols designed for WSNs should be as energy efficient as possible to prolong the lifetime of individual sensors, and hence the network lifetime. In this paper, we have surveyed LEACH routing protocols by taking into account the Energy concerns in wireless networks.

REFERENCES


