Abstract

Due to the increased attention in the potential use of Wireless Sensor Networks (WSNs) in the applications such as disaster management, border protection, security surveillance etc., sensors are supposed to be placed in large numbers and to operate independently in inaccessible environment where some phenomenon is to be monitored. Wireless Sensor Networks consist of one or more small nodes with wireless sensing, and data networking capabilities. Sensor networks consisting of wireless sensor nodes with limited battery power are deployed in the field to collect useful information. Collecting sensed information in an energy efficient manner is critical to operate the sensor network for a long period of time. So, many routing, power management and data dissemination protocols have been specially designed for WSNs which have energy awareness issues. In this paper, the WSNs model and its components are studied. Then, the different protocols such as LEACH, PEGASIS and TEEN are surveyed.

Keywords: Clustering, Routing Protocols, Wireless Sensor Network, WSN Model, WSN Components, Zigbee

1. Introduction

Due to the growth in emerging fields like microelectronics, wireless communication and digital electronics, new sensor nodes with low cost and low power consumption have been developed. A Wireless Sensor Network (WSN) with spatially distributed autonomous sensors is used to monitor physical or environmental conditions, such as temperature, sound, pressure, etc., and to cooperatively send their information through the network to the user. The development of wireless sensor networks was motivated by military applications such as battlefield surveillance; in industrial and consumer applications, such as industrial process monitoring and control, machine health monitoring. While measuring the ambient conditions of the surrounding, sensor transforms them into an electric signal processing. Such a signal exhibits some properties about objects which are located or events happening in the vicinity of the sensor.

One of the advantages of Wireless Sensors Networks (WSNs) is their ability to operate unnoticed in an environment where survival is difficult. In such a harsh condition, contemporary human-in-the-loop monitoring schemes are risky, inefficient and sometimes infeasible. Therefore, sensors are expected to be placed randomly for a particular purpose by an uncontrolled means (thrown by a helicopter) to form a network.

As shown in the Figure 1, the sensor nodes are dispersed in a sensor field and each of it collects data and route data back to the end users by multihop infrastructure architecture through the sink or Base Station (BS). The BS may communicate with the task manager node via internet or satellite.

Figure 1. Wireless sensor network model.

*Author for correspondence
As shown in Figure 2, a sensor node is made up of four basic components: a processing unit, a sensing unit, a communication unit and a power unit. ADC in sensing unit converts the analog signals produced by the sensors based on the observed phenomenon to digital signals, and then processes using the processing unit having small storage unit, which makes the sensor node jointly work with the other nodes to carry out the assigned sensing tasks. A transceiver unit connects the node to the network. One of the most important components of a sensor node is the power unit. Power units may be supported by a power scavenging unit such as solar cells. WSN Applications are categorized into military, environment, health, home and other commercial areas.

The network design challenges, advantages, disadvantages and characteristics of WSNs are presented in the following subsections. Also, the overview of IEEE 802.15.4 and Zigbee is given.

1.1 Network Design Challenges
- Limited energy constraints.
- Hardware resources constraints.
- Enormous and Random Deployment.
- Dynamic and Unreliable Environment.
- Diverse Applications.

1.2 Advantages of WSNs
- Ease of deployment: Can be dropped from a plane or placed in a factory, without any prior organization, thus reducing the installation cost and time, and increasing the flexibility of deployment.
- Extended range: One huge wired sensor (macro-sensor) can be replaced by many smaller wireless sensors for the same cost.
- Mobility: Since these wireless sensors are equipped with battery, they can possess limited mobility (e.g., if placed on robots).

1.3 Disadvantages of WSNs
- Fault tolerant: Failure of one node have no effect on the network operation.
- Computational capabilities: Sensor nodes have low power and therefore may run simple versions of routing protocols.
- Energy limitation: Sensor nodes can use up their limited energy supply carrying out computations and transmitting information.
- Communication range: The wireless links connecting sensor nodes have often limited bandwidth, thereby constraining inter-sensor communication.
- QoS: In military applications, the information should be conveyed within a certain period of time from the moment it is sensed.
- Control Overhead: Due to collisions, the number of retransmissions in wireless medium increases which further increases the latency and energy consumption.
- Security: Besides physical security, both authentication and encryption should be feasible while complex algorithm needs to be avoided.
- Transmission media: Traditional problems related with a wireless channel (e.g., high error rate, fading) have an effect on the network operation.

1.4 Characteristics of WSNs
- Sensor nodes are battery powered.
- Sensor nodes have limited energy, computation and storage facility.
- Sensor nodes are application specific.
- Sensor nodes are unreliable as they are prone to failures and physical damages.
- Network topology changes frequently.
- No global identification.
- Many-to-one traffic pattern.

1.5 Zigbee and 802.15.4 Overview
Low-power consumption and low-cost communication are the key points that lead to the specification of the IEEE 802.15.4 standard. The process of standardization in the field of WSNs is very active in the last years and
an important outcome is represented by IEEE 802.15.4 which is a short-range communication system intended to provide applications with relaxed throughput and latency requirements in Wireless Personal Area Networks (WPAN). The key features of 802.15.4 wireless technology are low complexity, low cost, low power consumption, low data rate transmissions, to be supported by cheap either fixed or moving devices. The main field of application of this technology is the implementation of WSNs.

ZigBee is an IEEE 802.15.4-based specification for a suite of high-level communication protocols used to create personal area networks with small, low-power digital radios. The technology defined by the ZigBee specification is intended to be simpler and less expensive than WPANs such as Bluetooth Wi-Fi.

2. Background of WSNS

The design and operation of large size network requires scalable architectural and management strategies. In addition, sensors in such conditions are energy constrained as their batteries cannot be recharged. Therefore, an important factor for extending the lifetime of sensors is in designing energy-efficient algorithms.

In clustering, nodes are partitioned into a number of small groups called clusters. In each cluster, one node is selected as a cluster head which aggregates data from its cluster members and then transmits it towards the base station. The selection of CH is done by the sensors in a cluster or the network designer.

Homogeneous are those in which nodes have same initial energy while heterogeneous networks have different initial energy. Figure 3 shows classification of Clustering. A literature survey of published distributed algorithms for clustering WSNs is presented in the following section.

2.1 LEACH (Low-Energy Adaptive Clustering Hierarchy)

A hierarchical clustering-based protocol which lessens the energy dissipation in sensor network algorithm for sensor networks, called LEACH was introduced by. The definition of LEACH is to randomly select sensor nodes as cluster-heads, so the high-energy dissipation in sharing with the base station is spread to all sensor nodes in network. It is divided into two phases, the set-up phase and the steady phase. After the cluster heads are selected, the cluster-heads publicize to all sensor nodes in the network to tell that they are the new cluster-heads. Once this is done, based on the signal strength of the advertisement from the cluster-heads to the sensor nodes, the cluster is determined which sensor node wants to belong and they inform the appropriate cluster-heads that they will be a member of the cluster. Afterwards, based on a TDMA approach, the cluster-heads allocate the time on which the sensor nodes can send data to the cluster-heads.

2.2 PEGASIS (Power-Efficient Gathering in Sensor Information Systems)

An enhancement over the LEACH protocol was proposed by. The main aim in PEGASIS is to receive and transmit the data from each node to close neighbors and being the leader take turns for transmission to the sink or BS which will pass the energy load evenly among the sensor nodes in the network. For passing data in each round, each node receives data from one neighbor, combines with its own data, and passes to the other neighbor on the chain. As shown in Figure 4, node c2 is the leader, and it will pass the token along the chain to node c0. Node c0 will transfer its data towards node c2. Node c2 will pass the token to node c4 as soon as it receives data from node c1, and node c4 will pass its data towards node c2.

2.3 TEEN (Threshold-Sensitive Energy Efficient Protocol)

Hierarchical routing protocol called TEEN is proposed in. It is the first protocol developed for reactive net-
work. In reactive networks, the sensor nodes respond immediately to sudden changes in the value of a sensed attribute. In this protocol, in addition to the attributes, the cluster-head broadcasts to its members with every cluster change time,

- **Hard Threshold (HT):** It is the absolute or threshold value of the sensed attribute beyond which, the node must activate its transmitter and report to its cluster head.
- **Soft Threshold (ST):** It is the small change in the value of the sensed attribute which activate the node to transmit. These nodes sense their location continuously.

When a parameter from the attribute set has its hard threshold value, the node switches on its transmitter and transmits the sensed data. This value is stored in an internal variable in the node, called the Sensed Value (SV). The nodes will next pass data in the current cluster period, only when both the following conditions are true:

- The current value of the sensed attribute is larger than the hard threshold.
- The difference between the current value of the sensed attribute and SV is same or greater than the soft threshold.

### 2.4 APTEEN (Adaptive Periodic Threshold-Sensitive Energy Efficient Sensor Network Protocol)

In APTEEN\textsuperscript{14}, in each cluster period, the cluster head first transmits the following parameters as soon as CHs are selected:

- **Attributes (A):** A set of physical parameters which the user is interested in obtaining information about.
- **Thresholds:** Threshold is of two types: Hard Threshold (HT) and Soft Threshold (ST). A specified value of an attribute beyond which a node can be stimulated to pass on the data is called HT. A small change in the value of an attribute which can trigger a node to pass on the data again is called ST.
- **Schedule:** It is based on TDMA in which each slot is assigned to each node.
- **Count Time (TC):** It is the maximum time period between two successive reports forward by a node. It can be a multiple of the TDMA schedule length which is used for the proactive component and each node in the cluster is assigned a transmission slot. In a sensor network, neighbor nodes comes under same cluster, sense similar data and try to pass their data simultaneously, causing possible collisions.

### 3. Research Issues

WSN has been the most developing area in the field of sensing technology. The one of the prominent concern in this field is the replacement of battery resources. Once the sensor node is deployed, its battery cannot be replaced. So it has to be utilized as efficiently as possible. Also, there are many challenging issues that need to be addressed in image applications in wireless sensor networks. Distributed Wireless Smart Camera (DWSC)\textsuperscript{8} network is a special type of WSNs that processes captured images in a distributed manner. In addition to the limitations of conventional WSNs, image processing on DWSCs requires more computational power, bandwidth and deployments. So, the aim is to develop a number of algorithms that are highly scalable, portable, energy efficient and performance efficient\textsuperscript{8}. Communication among the nodes is one of the factors which are responsible for the consumption of energy. So routing among the nodes really becomes significant. Farther the data is to be routed, the more it will be consuming energy. So in order to make the energy consumption as minimum as possible, various routing protocols have been developed\textsuperscript{6–8}.

### 4. Conclusion

With the backdated study of literature in WSN specifically in routing techniques, it has been found out that, the main aim have been to enhance the network lifetime in terms of number of rounds with the given number of nodes. Battery which can't be replaced has to be used efficiently as possible. In addition, sensors in sensitive environments have energy limitations and their batteries cannot be recharged. So, designing energy-conservation algorithms becomes an important task for increasing the lifetime of sensors. Many power management, data dissemination and routing protocols have been specially made for WSNs which have energy awareness issues. Also, other challenging issues that need to be addressed in many advanced image, video and multimedia applications on WSNs include the effective image and video capturing, image aggregation in sensor nodes, image processing and editing, taking into account domain knowledge such as location and angle information.

In WSN network there is a sink or BS (placed anywhere in the target area) which conveys all information to the
end user. The nodes which are nearer to the sink easily transmit their message to it but the nodes which are at farther place from it cannot directly pass their data to the sink; they have to send their data to the intermediate node which is closer to it than its neighbor passes its data to sink. So, their energy is used in sending their data along with the data of farther nodes which leads to depletion of energy. Hence the problem called HOT SPOT problem arises. The nodes near the sink get depleted faster in terms of their energy which might creates holes in the network thus resulting in network isolation. The nodes around the mobile sink always changes, thus reducing the energy consumption in the network. This has modified the problem of network isolation to a significant extent by reducing the energy consumption of the network. Besides this it has also improved the throughput, efficiency of the network.

5. References

1. Akyildiz IF, Su W, Sankarasubramaniam Y, Cayirci E. A survey on sensor networks. IEEE Communications Magazine. 2002 Aug; 40(8):102–14.
2. Sohraby K, Minoli D, Znati T. Wireless sensor networks. John Wiley and Sons Inc Publication; 2007. p. 1–25.
3. Hill JL. System architecture for wireless sensor networks [A dissertation]. Berkeley: University of California; 2003.
4. Sohrabi K, Gao J, Ailawadhi V, Pottie GJ. Protocols for self-organization of a wireless sensor network. IEEE Personal Communications. 2000; 7(5):16–27.
5. Min R, et al. Low power wireless sensor network. Proceedings of International Conference on VLSI Design; Bangalore, India. 2001 Jan.
6. Abbasi, Younis M. A survey on clustering algorithms for wireless sensor networks. Computer Communications. 2007; 30:2826–41.
7. Heinzelman WR, Chandrakasan A, Balakrishnan H. Energy-efficient communication protocol for wireless microsensor networks. IEEE Proceedings of the International Conference on System Sciences; Hawaii. 2000 Jan. p. 1–10.
8. Liu J, Beng. Distributed low-power image processing in wireless sensor network for intelligent video surveillance applications [PhD thesis]. Queensland University of Technology. Jun 2012.
9. Edmund YL, Lui K-S, Tam VWL. Image and video processing in wireless sensor networks. Multidimensional Systems and Signal Processing. Springer Science; 2009 Mar.
10. Bandyopadhyay S, Coyle EJ. An energy efficient hierarchical clustering algorithm for wireless sensor networks. IEEE Conference INFOCOM; 2003. p. 189–200.
11. Jamal NA, Kamal AE. Routing techniques in wireless sensor networks: A survey. IEEE Journal on Wireless Communication. 2004; 11(6):6–28.
12. Lindsey S, Raghavendra CS. PEGASIS: Power–Efficient Gathering in Sensor Information Systems. IEEE Aerospace Conference Proceedings; 2002. DOI: 10.1109/AERO.2002.1035242.
13. Manjeshwar A, Agarwal DP. TEEN: A routing protocol for enhanced efficiency in wireless sensor networks. 1st Int’l Wksp on Parallel and Distrib Comp Issues in Wireless Networks and Mobile Comp; 2001 Apr.
14. Manjeshwar A, Agarwal DP. APTEEN: A hybrid protocol for efficient routing and comprehensive information retrieval in wireless sensor networks. Proc Int’l Parallel and Distrib Proc Symp; 2002. p. 195–202.