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Wireless Sensor Network: Architecture, Design Issues and Applications

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Abstract: ***Wireless sensor networks is composed of large number of nodes that have capabilities to sense their surroundings, perform computations and communicate wirelessly to their neighbor nodes and base station. Wireless sensor networks (WSNs) are one of the most interesting research areas and have become very popular technology. This paper surveys the architecture of WSNs according to the OSI model that having five layers and three cross planes or layers. WSN designing become more complex due to characteristics of computation, deploying nodes, coverage. This paper also represents various applications of WSNs.***

Keywords: WSNS, Sensor Networks, LEACH, Design Issues, Applications

1. Introduction

Wireless sensor network is a wireless network comprises of spatially independent distributed devices using sensors in attempt to monitor physical and environmental conditions. WSN is built of several nodes from few to hundreds or even thousands and node is connected to one or sometimes several sensors if required. A sensor node typically consists of several parts i.e. radio transceiver with an internal antenna, a microcontroller used to interface with the sensors and an energy source usually a battery. The size of a sensor node can be either small or large. The cost of sensor nodes can also range from hundreds to thousands dollars. WSN consists of a base station also called sink that communicates with sensor nodes. These large number of nodes wirelessly communicate with each other and to the base station directly or indirectly, and have capabilities to sense the data from their surroundings, store the data , pass their sensed data to their neighbor sensor nodes or to the base station and perform some computations on the sensed data. There are wide applications of WSN include: physical security, air traffic control, environment monitoring, healthcare monitoring, military and so on. Sensor networks may be quite different for various applications.

2. Literature Survey

Yazeed Al-Obaisat, Robin braun[2] introduced some recommendation and directions as guidelines that would assist and give more enhancement to the protocols and algorithms for wireless sensor networks. he finds that various power management, data routing, data dissemination protocols have been designed for wireless sensor networks that are dependent both on the applications and the network architecture that it is designed for. **Ajay jangra et al**. [7] has presented the various node characteristics and functioning of every module of WSN architecture. **Gurbhej singh, harneet arora [11]** finds that there are two major applications of the WSN are tracking based and another is monitoring based. They have covered almost all issues that affect the performance and efficiency of the wireless sensor networks and simulation tools in their paper.

3. Structure of Wireless Sensor Networks

Wireless sensor networks follows most common architecture OSI model. Basically, there are five layers in sensor network. These are application layer, transport layer, network layer, data link layer and physical layer. There are three cross layers planes added to those above five layers of OSI model i.e. power management plane, connection management plane, task management plane. These layers are used to manage the network connectivity and allows the nodes to work together to increase the overall efficiency of the network.

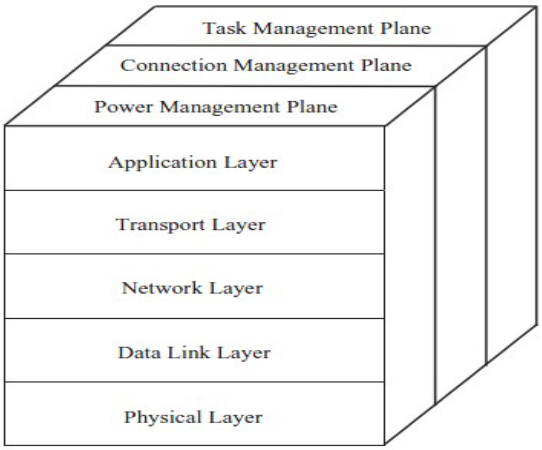

Figure 1: WSN OSI layers

1)Transport Layer

The function of this layer is to provide congestion avoidance and reliability and there are a lot of protocols designed to provide this function are either applied on downstream and upstream. This layer is particularly needed when a system is organized to access other network. The basic function of this layer is to accept data from above layers and split it up into smaller units then pass these to the network layer and ensure the delivery of all pieces at the other end. It contains a variety of protocols like TCP, UDP, SCTP, DCCP, SPX.

2) Network Layer

The major function of the network layer is routing. This layer has a lot of challenges depending upon the application but probably, the major challenges are in the limited memory and buffers, power saving, sensor does not have a global ID and have to be self organized. This is unlike computer networks with IP address and central device for controlling. The basic idea of the routing protocol is to define a reliable path and redundant paths according to a certain scale called metric, which distinct from protocol to protocol. There are various routing protocols available for this layer, they can be divide into; flat routing such as direct diffusion and hierarchal routing e.g., LEACH or can be divided into time driven, event driven and query driven. In continuous time driven protocol, the data is sent periodically and time driven for applications that need a periodic monitoring. In event driven and query driven protocols, the sensor acknowledge according to action or user query.

3) Data link layer

The data link layer is responsible to maintain the error correction and error detection mechanisms. It is also accountable for the multiplexing of data frame detection, data streams, error control and medium access.

4) Physical layer

Physical layer can provide an interface to transmit a stream of bits over physical medium. Responsible for generating carrier frequencies, frequency selection, signal detection, signals modulation and data encryption.

5) Application layer

Responsible for traffic management and provide software for different applications that translate the data in an understandable form or send queries to obtain information. Sensor networks deployed in different applications in various fields, for example; medical, military, environment, agriculture fields. It contains a variety of protocols like NNTP, SIP, SSI, DNS, FTP, GOPHER, NFS, NTP, SMTP, SMPP, ANMP and TELNET.

The three cross planes or layers are:

1) Power management plane: It is responsible for managing the power level of sensor nodes for processing, sensing and communication.
2) Connection management plane: It is responsible for configuration or reconfiguration of sensor nodes in attempt to establish or maintain network connectivity.
3) Task management plane: It is responsible for distribution of tasks among sensor nodes to prolong network lifetime and improve energy efficiency.

4. Design Issues

1.1 Energy Consumption

It is one of the major issues in wireless sensor network. Sensor nodes are equipped with battery that is used as their energy source. The sensor network can be deployed in hazardous condition so it becomes difficult recharging or changing batteries. The energy consumption depends upon major operations of the sensor nodes which are sensing, data processing, communication. The large amount of energy is consumed during communication. So, the efficient routing protocols ought to be used at each layer to prevent energy consumption.

1.2 Localization

Sensor localization is a fundamental and critical issue for network operations and management. The sensor nodes are deployed in ad-hoc manner so they do not have any information about their position. The problem of determining the physical location of the sensors after they have been deployed is called localization. This problem can be solved by beacon nodes, GPS, proximity based localization.

4.3 Coverage

It says how well an area of interest is controlled as traced by the sensor. These Sensor nodes use coverage algorithm to sense data and send them to sink using routing algorithm. For the good coverage, sensor nodes must be selected in such a manner so that whole network should be covered. There efficient technique such as minimal and maximal exposure path algorithms and coverage configuration protocol are suggested.

4.4 Clocks

Clock synchronization is a critical service in WSN. The goal of time synchronization is to provide a common timescale for local clocks of nodes in sensor networks. Clocks ought to be synchronized in some applications such as tracking and monitoring.

4.5 Computation

The amount of data proceeds by every node is called computation. The major problem in computation is that it should minimize the use of resources. If the lifetime of base station is more critical then data processing can be completed at every node before sending data to base station. In case when we have few resources at every node then entire computation must be done at sink.

4.6 Production Cost

As we know, large numbers of nodes are deployed in the sensor networks, so if the cost of a single node will be very high then we can assume the overall cost of the network will also be very high. Eventually, the cost of every sensor node has to be kept low. So cost of each sensor node in the network is a challenging issue.

4.7 Hardware Cesign

While designing any hardware of sensor network, it must be energy-efficient. Hardware such as power control, micro-controller, and communication unit should be design in such a way that it consumes less energy.

4.8 Quality of Service

QOS means data should be delivered within time period. There are some real time sensor applications that are based on time i.e. if data should not be delivered on time to the

receiver from the moment it is sensed; data will become useless. There is various quality of service issues in sensor networks such as network topology may change continually and the available state information for routing is constitutionally imprecise.

5. Applications

Wireless sensor network include different type of sensors like seismic sensors, acoustic, infrared, thermal and visual sensors etc which can monitor variety of commercial conditions that include:

- Vehicle monitoring
- Light conditions
- Temperature
- Soil conditions
- Noise levels

5.1 Vehicle Parking WSNs are used in applications such as vehicle parking for the purpose of effective usage of existing parking slots instead of making new expensive installations coupling with cheap sensor nodes that can track the vehicles effectively. Earlier solutions for parking applications use video cameras and magnetometers. The results of magnetometers are not very accurate because of environmental factors. Video cameras are very expensive and it is not feasible to transfer huge amount of data through multiple hops. The accurate vehicle detection was possible with a combination of wireless sensors and magnetometers**.** But it did not result in better parking management.

Smart parking management system (SPARK) based on WSN has been presented in [7].Parking reservation mechanism, remote parking monitoring and automated guidance are the features provided by the system.

5.2 Intra car security Wired networks and cables are replaced by wireless networks in order to ensure fuel efficiency and reduction in the weight of automotives. But the security issues of such a replacement are highly questionable. But the selection of appropriate security algorithm and using a systematic methodology the execution speed and security issues can be resolved.

5.3 Event Detection Typical characteristic of WSN is tracking, especially instant event tracking. In WSN much work has been done with sensor nodes having indistinguishable sensing nodes. A fully distributed protocol Collaborative Event Detection and Tracking (collect) for tracking and event detection for heterogeneous WSNs is presented in[10].But major issues like solutions to the sensor node deployment and routing is yet to be resolved.

5.4 Green house surveillance In order to check the automatic system in a green house it is mandatory to check the various climate parameters in various parts of a large green house. But the entire system will get inelegant and costly by using wired network. But the wireless sensor network with sensor nodes equipped with radio will be a cost effective solution for same type of problem.

5.5 Military applications WSN is an essential part of military (C4ISRT) command, communication, computing, control, intelligence, surveillance, reconnaissance and targeting. The destruction of any of the dense deployment of sensor nodes does not affect the military operations as much as the destruction of traditional sensors. Some of the applications of WSN in military applications are surveillance of friendly forces, impedimenta and cartridges, scrutiny of opposing forces, battlefield monitoring, (NBC) nuclear biological chemical attack detection.

5.5.1 Surveillance of friendly forces, impedimenta and cartridges: with the help of sensor networks, leaders can monitor the status of friendly troops, availability of impedimenta and cartridges in a battlefield. Small sensors are attached with any vehicle, troops and equipments to track their status. These reports are gathered in a base station and sent to the troop leader by aggregating with the data at different levels.

5.5.2 Battlefield monitoring: In order to prepare new operational plans new sensor networks can be deployed anytime in the battle field. Critical grounds, approach routes, paths and channel can be easily covered with sensor networks.

5.5.3 Targeting: Sensor networks can be incorporated into guidance systems of intelligent projectiles or missiles.

5.6 Environmental applications Some of the applications of WSN include trailing the movement of birds, insects and small animals. Surveillance of environmental conditions that affect crops and livestock, macro instruments for large scale earth monitoring and planetary survey. Forest fire and flood detection.

5.6.1 Forest fire detection: Sensor nodes are randomly, densely deployed in a forest. Sensor nodes can broadcast the exact origin of the fire to the users before it spread uncontrollable. Mostly sensor nodes are equipped with optical systems. Also they are equipped with power rummage methods such as solar cells. The nodes will associate with each other to perform distribute sensing and overcome many obstacles.

Figure 2: Forest fire detection

5.6.2 Definitude agriculture: Some of the benefits of wireless sensor networks is to monitor the soil erosion

level, level of air pollution in real time, and to detect the pesticide level in the drinking water.

5.7 Health Applications Some of the health applications of the WSN is diagnostics, drug management in hospital, tele-diagnosis of human physiological data, monitoring and tracking of patients and doctors inside a hospital.

5.7.1 Monitoring and tracking patients and doctors inside a hospital: Each and every patient has sensor node attached to them. Each node has its own specific task. For e.g. one node is detecting patient's blood pressure and other one is detecting patients heart rate. Doctors may also carry sensor nodes which help them to locate other doctors.

5.7.2 Drug management in hospitals: If the sensor nodes are attached to the medicines the chance of giving wrong medicine to patients will be less. As the patients will have sensor nodes attached to them so nodes can detect the patient's problem and medicine giving to them.

5.8 Home applications Smart sensor nodes can be entomb in many appliances such as microwave oven, refrigerators, and vacuum cleaners, VCR's etc. These sensor nodes inside the devices can interact with each other and with external network via satellite. The end users can manage the devices more easily and remotely.

5.9 Biological applications Wireless sensor networks have tremendous impact for biological problems. Some of the biological problems are biological task mapping and scheduling, biomedical signal monitoring etc.

5.9.1Biological task mapping: WSN have recent research going in the concept of "labs on a chip" which is supported by latest technology such as nano-techniques. Biological applications use the trend of WSN due to the advancement in technologies like Micro Electro-Mechanical systems (MEMS), embedded systems and microcontrollers etc.

Biological task mapping and scheduling is an algorithm in which a main complex application was broken down into smaller task. Assigning of resources to these tasks is known as task mapping and sequence of execution of task is known as task scheduling. Heuristic techniques are used to achieve near optimal solution for task mapping. However the simulation model built in this application was only applicable if the nodes are separated by a distance set of 150m.

5.10 Other merchandising application
Other merchandising applications are manufacturing virtual key boards, detecting product quality, building smart office spaces, interactive toys and museums, monitoring disaster areas, monitoring transport facilities, detecting car thefts, monitoring and control of factory processes, tracking and detection of vehicles, monitoring semiconductor processing chambers.

6. Future Trends

In wireless sensor network cost effective and very powerful devices should be used so that it will be used in applications such as underwater acoustic sensor networks, cognitive sensing, sensing based cyber physical system, spectrum management, time critical applications. There should be more research targeting on less resource based hardware and focusing on building intelligent systems.

7. Conclusion

Wireless sensor networks become more popular these days due to its less power requirement, low cost, performance and high potential application areas. In this paper we have presented wireless sensor network architectures, their applications and various design issues. The application of WSN in the areas of military, vehicle parking, event detection, green house surveillance, environmental, home applications have been briefed. We have analyzed and enlisted analyzed various design issues that are faced in the design of WSN monitoring strategy. In order to use wireless technology in different applications like we have presented in the paper, needs a well understanding of the network architecture. The application is not restricted to the areas elaborate in this paper. The future prospects of WSN applications are highly promising to revolutionize our everyday lives.

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