Chapter 2

Wireless Sensor Network Applications

Introduction

Real-life events become data by means of sensors, and data can then be processed, saved, or used in various applications. Sensors may be placed in differing environments based on how they are to be used. One example is the requirements for sensors used in the marine purpose (Albaladejo et al., 2010). The cascade of sensors should be designed such that they are waterproof and can withstand the effects of salinity and moisture. Similarly, sensors installed underground should have a high transmission power transceiver to overcome noisy channel attenuation due to being underground. The environmental changes noted by these sensors are communicated to the main server in order to make decisions in real time. Continuous monitoring of sensors means catastrophic failure can be prevented (Dargie and Poellabauer, 2010).

Solving technical issues of WSNs has widened the area of their applications. Issues like high power consumption have been improved with the reduction in the size of electronic devices so making it beneficial for large-scale remote installations. Wireless sensor networks sense the changes in the surrounding environment by means of sensor nodes, and through various methods relay the information collected to remote control centers for further action. In a wireless sensor network, there is a sink node that gathers data from all the other sensor nodes that collect information as per the requirements of the network. Sink nodes can have the same specifications as other sensors nodes or they can consist of customized devices like a PDA or laptop. They can be connected to other networks or consist of a base station that can be linked to network data by means of the internet to the remote control or monitoring center for the desired output.

With the flexibility provided by WSN technology in various fields of application, our way of thinking about life has been changed. WSNs have been successfully applied in various domains (Bharathidasan et al., 2001; Akyildiz et al., 2002, a,b; Sohraby et al., 2007; Yick et al., 2008; Boukerche, 2009; Buratti et al., 2009; Verdone et al., 2008) such as military, area monitoring, transportation, health, and environmental.

Applications and use of wireless sensor networks include intelligent monitoring of temperature, water level, humidity, pressure, and remote health monitoring of patients (Akyildiz et al., 2002; Yick et al., 2008). WSN deployment is dependable and can be modified based on the type of installation. Where there is a harsh environmental impact on sensors, the mechanical and electronic design should be robust. In the case of urban, rural, and suburban areas, the type of distortion in rural and suburban situations is lower as compared to the urban environment. This is due to increasing population density in urban areas that results in congestion and noise pollution. Due to continuous innovation in wireless sensor networks, the use of networks in unconventional applications has increased. Now a WSN can be used for monitoring sewage flooding, methane and other hazardous gases in sewers, disaster relief strategy, surveillance of criminal activities, and infrastructure monitoring (Lim et al., 2005; See et al., 2010).

Literature Review

Losilla et al. (2007) in their research have implemented WSNs for transportation purposes. Yang et al. (2007) deployed the WSN for a power delivery system–based application in order to measure sag in overhead conductors within the entire transmission line. He et al. (2004) integrated wireless sensor network technology for use in surveillance missions. This integrated system acquires and verifies information on enemy capabilities and positioning of hostile targets. It deploys an unmanned surveillance system using wireless sensor networks which have proven to be beneficial in military operations. Moturu et al. (2011) deal with the issue of improving the performance of wireless sensor networks by means of association control, and this is achieved by means of associating intelligent users with the network's access points. This provides an innovative and optimal solution for utilization of the reinforcement learning (RL) algorithm which is known as Gaussian processes temporal differences (GPTD). Wang et al. (2010) discuss supervised learning within wireless sensor networks. In their research they propose a new approach towards routing, optimization, and reliability. Routing is used in order to maintain information about neighbor states and other factors. Wang et al. focus on challenges in performing accurate and adaptive information discovery and also processing and analysis of extracted data for use in features such as co-relations. In order to achieve this, the authors propose use of supervised learning techniques for making informed decisions within wireless sensor networks.

Pawa et al. (2011) classify the routing protocols of wireless sensor networks into flat-based, hierarchical, and location-based. Low energy adaptive clustering hierarchy (LEACH) is an example of a hierarchical routing protocol which is energy efficient and works within parameters like network lifetime and stability period. It uses random rotation of nodes to find the cluster head within a cluster of wireless sensors so that energy can be evenly distributed.

WSN Applications

We can say that the range of applications for wireless sensor networks is very wide and broad, ranging from environmental to industrial to medical to military to habitat monitoring and many others, as can be seen in the following:

Area of application of wireless sensor network	Use
Asset management	Tracking of shipping containers
Air traffic control	Controlling air traffic pattern
Home automation	Multiple home system controls like conservation, convenience, safety, electric, water, and gas utility usage data, Home security
Military	Battlefield management, battlefield reconnaissance, surveillance, management, combat field surveillance, detecting structural faults in aircraft, detecting structural faults in ships, detection of enemy vehicles
Electricity management	Automatic meter reading, smart grid management, electricity load management
Biological field	Biological monitoring for agents, detecting toxic agents.
Medical	Biomedical applications, smart ambulance, real time monitoring of patients, wireless body area networks, collecting clinical data, heart beat sensor, telemedicine
Road safety and management	Bridge and highway monitoring and management

Construction	Building and structure monitoring, building automation, building energy control and monitoring, detecting structural faults in buildings
Disaster management	Earthquake detection, tsunami detection and response, disaster emergency response
Business	E-money applications, kiosks, monitoring and controlling workspaces, intruder detection
Habitat	Habitat monitoring, sensing
Industry	Industrial and building monitoring and automation, manufacturing monitoring and automation, asset management, process control, inventory management, manufacturing control, material processing systems
Power system	Monitoring of electrical distribution systems, smart grid sensor and actor network application, automated remote meter reading, thermal rating monitoring of conductors in power systems, monitoring sag clearance in overhead conductors
Transportation	Traffic monitoring, transportation-based application, vehicular ad hoc network (VANET)-based application, road-based application, car parking, underground railway tunnel monitoring,
Gas monitoring	Sewage gas monitoring, gas pipeline monitoring, gas meter monitoring, air pollution monitoring
Others	Commercial applications, consumer applications, consumer electronics and entertainments, tracking of belongings like pets, heating control

Initially wireless sensor network usage was only meant for military applications, but with advancements in wireless sensor technology areas of application have expanded.

Medical: WSNs can be used for supporting interfaces for the disabled. They can also be used for monitoring and diagnosing patients in real time. WSN technology can be used for drug administration in hospitals. One application of WSNs in medical care is tele-monitoring of physiological data.

Another application is the smart ambulance (Dumka, 2018) which will enable doctors to monitor and start their procedures for treatment in the ambulance. The smart ambulance allows for heartbeat monitoring and other medical procedures.

Power system: WSNs can be used for setting up a smart grid that is helpful in providing low-cost, flexible, low-power dissipation, and self-organized power. WSN technology can be useful in power systems for smart metering, distributed bus protection of power networks, and fault location.

Smart grid is one of the major contributions to the field of power systems that can be used with non-conventional and conventional sources of energy. WSN technology can be used for remote monitoring and controlling of a smart grid and can be used for maintenance and avoidance of major faults (Dumka, 2017). A power sensing module can be designed for calculating the power of any kind of load. The information can be communicated to the sink on regular intervals, where the data can be processed and used for deciding on suitable actions like detection of power theft, energy efficient building design, smart metering, and smart automation.

Geo sensing: With the advancement of technology and the introduction of IoT technology, the requirement for long-range wireless networks has increased. WSNs can be used to get information on a moving object and send over the network. This information is collected by GPS and LoRA (long-range) modules.

WSN technology can be used to track animals, humans, objects, and vehicles in order to get real-time data on these objects. This information can be sent to a remote base station by means of WSN technology, and the data can be processed by means of certain other tools and technologies for taking appropriate decision on such data.

Water Pipeline Monitoring

Pipeline leakage is a major issue in water wastage. WSN technology supplies a solution in this respect by decreasing leakage and conserving water. The WSN solution can be used to detect pipeline leakage and can also be used for monitoring leakage within a large pipeline system. Several leak detection and localization algorithms can be used with an efficient wireless sensor node system on chip (SoC) used in real time. Leaks can be detected using fluid mechanics and kinematics physics based on the harnessed water flow rate obtained using flow liquid meter sensors and microcontrollers.

The use of this technology means human patrolling along the pipes looking for visual leaks and use of ultrasound or acoustics equipment to search for the leaks is no longer needed. Water pipeline monitoring systems use sensors to collect data and analytics tools and techniques for processing data in an efficient manner. There are various methods provided by various researchers, such as Kim et al. (2016), in this direction as non-intrusive, autonomous water monitoring system (NAWMS).

Pipe probe, proposed by Chang et al. (2011), describes a prototype for a mobile sensor network system with a hydro molecular form. This prototype uses pressure sensors MS5541C and EcoMote. It gathers measurement from the pipe and saves information in flash memory where the readings are analyzed and suitable solution provided that require human interactions.

Sensor-based pipeline autonomous monitoring and maintenance system (SPAMMS) was proposed by Kim et al. (2016) and uses static and mobile sensors for leakage detection within the pipeline system. Pressure sensors, chemical sensors, CCD sensors, and sonar sensors can be used. This system uses robot technology for maintenance and monitoring of a pipeline system. The robot technology consists of a MiCA1 mobile sensor mote, an EM 4001 ISO radio-frequency identification (RFID), and a robot agent. This system uses high processing technologies like image processing and signal processing algorithms.

Solid Waste Management

Waste management is one of the biggest problems in keeping a city or a country clean and disease free. The waste management cycle includes waste generation by industry, markets, and houses in which garbage is collected by municipal corporations that dump it in landfill sites.

Solid waste management using WSNs focuses on waste management automation where waste bins are attached with proximity sensors that trigger an event as and when the bins are full of garbage. This full bins information can be sent to the municipal authorities by means of WSN technology, enabling them to reach a particular bin position as soon as it is full. Thus, WSN-based solid waste management provides an automated solution enabling municipal authorities to have immediate knowledge of full bins so that they can take empty the bins in a timely fashion.

There are several researchers who propose some solutions for WSN solid waste management. Chaudhary et al. (2011) in their paper propose an RFID and load cell sensor–based waste management system for detection of waste in real time. Hanan et al. (2012) in their paper propose a model with a framework consisting of RFID and communicating devices like GSM, GIS, and GPRS for garbage monitoring and management activities.

Temperature Monitoring

A WSN can be used for monitoring multiple environmental conditions such as temperature. A WSN infrastructure can be used for setting up communication among sensors. These sensors can be used to gather information and data on various environmental parameters like temperature and humidity.

Different researchers have adopted different approaches to extracting temperature data from the environment and performing analytics. Bin et al. (2011) used WSN-based Zigbee technology for extracting temperature data using thermocouples as temperature sensors. Peng and Wan (2013) used infrared-based temperature sensors for extracting data from environmental variables and this data is transferred to a system by means of RS232. Mainwaring et al. (2002) used WSN technology for real-world habitat monitoring to extract environmental data including temperature.

Structural Monitoring

WSN technology can be used in civil work such as buildings and infrastructure. WSN enabled engineering practices can be applied to bridges, flyovers, tunnels, and embankments for monitoring progress of work being done without having to visit the site. Thus, WSN can be used for remote monitoring of any civil work.

Air Pollution Monitoring

Rapid urbanization and industrialization degrade environmental quality parameters. Tracking of environmental indices in order to develop realistic models and take appropriate decisions. There are many WSN-based air quality monitoring systems being proposed by many scientists to track and fix increased air pollution levels.

There are a number of sensors that can be used for monitoring environmental conditions. Some examples are MQ-7 and MQ-2 sensors which can be used for monitoring carbon dioxide and carbon monoxide levels in the atmosphere. There are certain ARM processors such as LPC 2148 that can be used for interfacing with these sensors. Zigbee technology like Tarang F4 can be used for wireless processing of data according to conditions. Applications can be developed to retrieve data as and when required. The data retrieved can be used to make decisions for taking suitable action to prevent further pollution.

Gas Monitoring

Monitoring gases is an important use for a WSN. WSN technology by means of sensors can detect gas leaks within a system, and the same information can be sent to any remote location user by means of WSN technology or integrated with IoT can be sent to any user on their phone. Thus, any user can get information for a gas leak in their home, shops, or any other place on a real-time basis and take appropriate action.

WSN technology can be used in different applications for gas monitoring:

1. Gas meter monitoring
2. Gas pipeline monitoring
3. Sewage gas monitoring

Intruder Detection

A WSN can be used for intruder detection. Sensors are used to detect intruders within a system and send notification by means of WSN technology to a controller and then raise an alarm. Intruder detection system can be of two types: rule-based intruder or anomaly-based.

The rule-based intruder detection system is based on a signature type which works via a built in signature. This detection system has high detection rates for already known types of attacks, but does not work as well for any new types of attacks. The anomaly-based intruder detection system works by matching traffic patterns or resource utilizations. This type of intruder detection system works well for new types of attacks.

Disaster Management System

A wireless sensor network can be used for early detection of disasters in certain land masses so that people can take action. This WSN consists of sensors which detect any incoming disaster events and communicates with the base station to send data to the main station. Sensors sense the environmental surroundings within parameters like temperature, pressure, and frequency, and they generate a signal accordingly. This signal is compared with threshold values of that normal attribute, and if it exceeds the threshold value, then the signal is transmitted to the base station from where it goes to the appropriate authority for taking necessary action. Messaging can be used to send information to every individual in the case of an earthquake or tsunami type of emergency.

A disaster management system can be used for:

1. Emergency response system
2. Tsunami detection and response system
3. Disaster surveillance

Transportation

There are many applications for WSNs in transportation systems. WSN technology can be used for detection of traffic at any point in the system and can send early warning messages to all incoming traffic to that location to take a different route. Various types of sensors such as proximity and image can be used for detecting traffic. These can detect the number of vehicles at a certain point and send signals to the base station where this number is compared to the threshold value. If the number exceeds the threshold value, this triggers a message to all other incoming vehicles, preventing heavy traffic and congestion (Dumka, 2018).

Various WSN technology has been developed in recent years like mobile ad hoc networks (MANETs) and VANETs that have made for tremendous changes in traffic patterns and changed the way of thinking about using WSN in transportation systems. Some ways to using WSNs:

1. Traffic monitoring
2. Transportation-based application

3. VANET-based application
4. Road side assistance

Power System

Power system problems include power theft, power outage, and grid failure. WSNs have provided a major relief for these types of problems by providing real-time-based applications that detect power usage patterns, and this data in combination with concepts like big data can provide solutions.

Smart meters use sensor-based technology that senses power usage in real time, sending that information to a near base station that then sends the information to a main base station. The data can be processed and managed by means of a big data application and can provide solutions such as the real-time value of meter reading, real-time data based on location, user-based segmentation, area-based segmentation, and usage-based segmentation (Dumka, 2018). Some of the applications of WSN in power systems are as follows:

1. Electrical distribution system
2. Smart grid
3. Remote meter reading

Home Control

A wireless sensor network can be used for the controlling, conservation, convenience, and safety of home appliances and applications. A wireless sensor network can be used for heating, lighting, and cooling a home from a remote location. Wireless sensor networks can be used for controlling, various home systems. They can be used for capturing data on electric, water, and gas utilities. In combination with embedded intelligence, wireless sensor networks can be used for optimizing the consumption of natural resources. Thus, by means of wireless sensor technology we can remotely control all home appliance and applications. This technology will also enable users at remote location to detect or receive notifications of any unusual events occurring in the home.

Building Automation

Wireless network technology with technology like Zigbee can be used for controllable light switches, resulting in energy savings. Energy management in hotels is also an application. Centralized HVAC management saves energy by turning off cooling in empty rooms. Thus, using wireless sensor network technology, we can integrate and centralize management of lighting, cooling, heating, and security, controlling multiple systems from a centralized system, reducing energy by means of HVAC management, reconfiguring lighting systems for adaptable workspaces, upgrading building infrastructure with minimal effort, integrating and storing data from different sensors for analysis and future use.

Industrial Automation

Industrial automation can be used for the controlling, conservation, safety, and efficiency of industrial equipment in multiple ways. Automation by means of wireless sensor networks can be used for automation of manufacturing and process control systems, improving asset management, identification of faulty operations in real time, acquisition of data through remote sensors to reduce human intervention, and monitoring of networks for enhancing safety of the public and employees. Industrial automation can use RFID technology, a technology that increased world industrial revenue by $2.8 billion in 2009. In 2009 many industries adopted the technology to make their business processes more efficient.

Military Applications

Wireless sensor technology can be used in many military applications like surveillance and border monitoring. There are many new technologies and equipment developed by many companies which provide suitable military applications. Being smaller in size and having more capabilities in terms of features like robustness, self-organization, and networking than existing systems, make WSNs a better solution for surveillance in the military. WSNs by means of distributed sensing technology can be used for redundant and reliable information on threats and for localizing threats among distributed sensor nodes. WSNs can be used for monitoring large areas and perimeters to achieve goals of self-protection.

Habitat Monitoring

Many projects have been implemented for protecting and monitoring habitat. One example is Intel Research Laboratory in Berkeley in collaboration with the College of the Atlantic in Bar Harbor who set up a project that deploys a wireless sensor network on Great Duck Island in Maine. This project aims to monitor microclimates in and around nesting burrows used by Leach's storm petrel. This project's aim is to develop a habitat-monitoring kit which can be used by researchers worldwide for non-intrusive and non-disruptive monitoring of sensitive wildlife and habitat (Intel Research Laboratory). In order to achieve this, three dozen nodes are deployed on the island. These nodes monitor the nesting habits of the Leach storm petrel and send the data to the satellite link which allows retrieval of data from anywhere in the world. Habitat monitoring can also be achieved by means of taking data on temperature, humidity, and pressure so that appropriate decisions can be made for habitat preservation and prevention.

Conclusion

This chapter reviewed different applications of WSN that focus on environmental variables, disaster systems, power systems, habitat monitoring, power systems, and others. The thrust of this chapter is to open up an area of thinking of applications of WSNs in different areas, as these can be unlimited.

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