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Applications and Challenges in Wireless Sensor Networks

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Abstract: Sensor networks offer a powerful combination of distributed sensing, computing and communication. They lend themselves to countless applications and, at the same time, offer numerous challenges. Energy is the scarcest resource of WSN nodes, and it determines the lifetime of WSNs. WSNs may be deployed in large numbers in various environments, including remote and hostile regions, where ad hoc communications are a key component. Wireless Sensor Networks provide capabilities that are valuable for continuous, remote monitoring for healthcare applications; they can be deployed inexpensively in existing structures without additional IT infrastructure. This paper presents an overview of the different applications of the wireless sensor networks and various Challenges. Energy management is an important parameter in increasing the network lifetime and thereby meeting user requirements to perform various applications in different fields.

Keywords: WSN Applications, Challenges, Classification.

I. INTRODUCTION

Wireless sensor networks are spatially distributed autonomous sensors to monitor physical or environmental conditions, such as temperature, sound, pressure etc. and to cooperatively pass their data through the network to a main location. The WSN is built up of "nodes" – from a few to several hundreds or even thousands, where each node is connected to one of the sensors. Each such sensor network node has typically several parts: a radio transceiver with an internal antenna, a microcontroller, an electronic circuit for interfacing with the sensors and an energy source, usually a battery. The cost of sensor nodes is similarly variable, ranging from a few to hundreds of dollars, depending on the complexity of the individual sensor nodes. Accordingly the topology of the WSNs can vary from a simple star network to an advanced multi-hop wireless mesh network. WSNs are becoming more widely adopted for commercial and scientific use and in settings where battery replacement or recharging is difficult, it is important that WSNs have long and predictable lifetimes. We thus expect energy management to play an increasingly important role in meeting user requirements.

Sensor Node: Figure-1 shows the architecture of sensor node. A sensor node, also known as a mote is a node in a sensor network that is capable of performing some processing, collecting information from the sight and communicating with other connected nodes in the network.
The microcontroller performs tasks, processes data and controls the functionality of other components in the sensor node. The functionality of both transmitter and receiver are combined into a single device known as a transceiver.

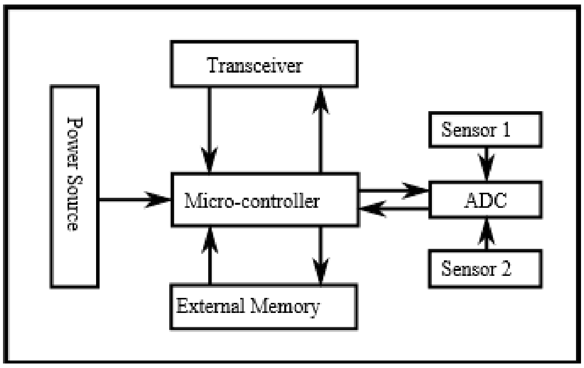

Figure-1

The sensor node takes power from power source for sensing, communicating and data processing. Memory requirements are very much application dependent. User memory is used for storing application related or personal data, and Program memory is used for programming the device. Sensors are used by wireless sensor nodes to capture data from their environment. They are hardware devices that produce a response to a change in a physical condition like temperature, humidity, light, vibration, fire or pressure. Sensors will measure the physical data of the parameter to be monitored. The continual analog signal produced by the sensors is digitized by an analog-to-digital converter and sent to microcontrollers for further processing.

II. CHARACTERISTICS OF WSN

The main characteristics of a WSN include:

- Power consumption constraints for nodes using batteries or energy harvesting.

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- Ability to cope with node failures
- Mobility of nodes
- Heterogeneity of nodes
- Scalability to large scale of deployment
- Ease of use

III. APPLICATIONS OF WSN

WSN can monitor **different physical values**: temperature, humidity, light, pressure, noise, soil composition, object motion (detection, and tracking), objects weight, size, etc. The sensors also have the ability to transmit and forward sensing data to the base station. Most modern WSNs are bi-directional, enabling two-way communication, which could collect sensing data from sensors to the base station as well as disseminate commands from base station to end sensors. The development of WSNs was motivated by military applications such as battlefield surveillance; WSNs are widely used in industrial environments, residential environments and wildlife environments. Structure health monitoring, healthcare applications, home automation, and animal tracking are some of the representative WSNs applications. Numerous applications of WSNs in different fields are:

Environmental monitoring: There are many applications in monitoring environmental parameters like Air pollution monitoring, Forest fire detection, Landslide detection, Water quality monitoring, and Natural disaster prevention. Figure-2 shows Environmental monitoring. In this various sensors are spreaded over the trees in the forest areas. These sensors report to the existing weather sensing station and the temperature of the forest is reported to the weather sensing station which continuously communicates with the satellite and the satellite is connected to the fire monitoring station. As the temperature exeeds a specific threshold value, the control centers are alerted and necessary action is taken to provide help to the required place.

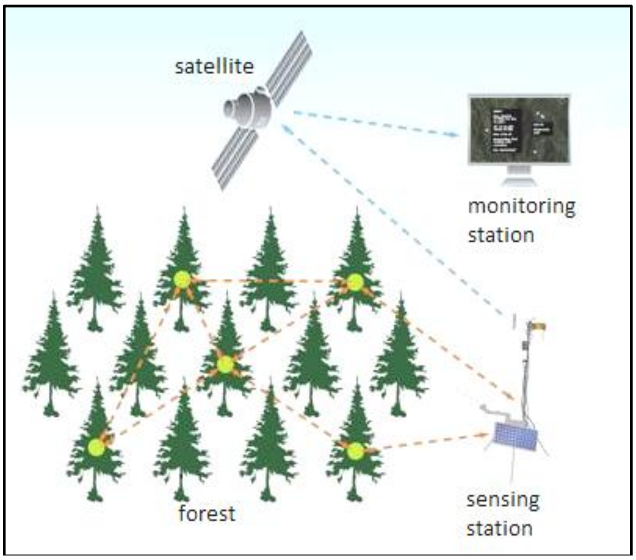

Figure-2

- Acoustic detection: is the science of using sound to determine the distance and direction of something. Location can be done actively or passively, and can take place in gases, liquids, and in solids. Active acoustic location involves the creation of sound in order to produce an echo, which is then analyzed to determine the location of the object in question. Passive acoustic location involves the detection of sound or vibration created by the object being detected, which is then analyzed to determine the location of the object in question.
- Seismic Detection: Seismic waves produced by explosions or vibrating controlled sources are one of the primary methods of underground exploration. Controlled-source seismology has been used to map salt domes, anticlines and other geologic traps in petroleum-bearing rocks, faults, rock types, and long-buried giant meteor craters. Seismometers are sensors that sense and record the motion of the Earth arising from elastic waves. Seismometers may be deployed at the Earth's surface, in shallow vaults, in boreholes, or underwater.
- Medical monitoring: The medical applications can be of two types: wearable and implanted. Wearable devices are used on the body surface of a human. The implantable medical devices are those that are inserted inside human body. Body-area networks thus formed can collect information from wearable and implanted medical devices about an individual's health, fitness, and energy expenditure.

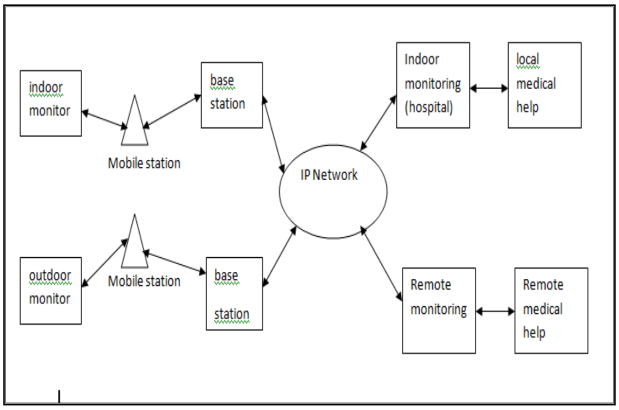

Figure-3

Figure-3 shows the role of wireless sensor networks in medical applications. In this there is indoor monitoring as well as outdoor monitoring which is done with the help of mobile stations and base station. The information from the base station is sent to the IP Network which acts as a gateway from the monitoring side to the help side. After receiving the information about the patient with the help of IP Network, medical help is given to the patient.

- Security & Surveillance: The focus of surveillance missions is to acquire and verify information about enemy capabilities and positions of hostile targets. Such missions often involve a high element of risk for human personnel. Hence, the ability to deploy unmanned surveillance missions, by using wireless sensor networks, is of great practical importance for the military. But due to the energy

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constraints of sensor devices, such systems necessitate an energy-aware design to ensure the longevity of surveillance missions. The system allows a group of cooperating sensor devices to detect and track the positions of moving vehicles in an energy efficient and stealthy manner.

IV. CLASSIFICATION OF WSN

(i) Terrestrial WSN: Consist of large no. of low-cost nodes deployed on land in given area usually in ad-hoc manner for applications like environmental sensing and monitoring, industrial monitoring and surface explorations etc.
(ii) Underground WSN: Consist of no. of sensor nodes deployed in caves or mines or underground to monitor underground conditions. They require appropriate equipments to ensure reliable communication through soil, rocks and water. Wireless communication is a challenge in such environment due to high attenuation and signal loss.
(iii) Underwater WSN: consist of sensors deployed underwater, like ocean environment. Underwater wireless communication uses acoustic waves that presents various challenges such as limited bandwidth, long propagation delay, high latency, and signal fading problems. Applications of underwater WSNs include pollution monitoring, under-sea surveillance and exploration, disaster prevention and monitoring, seismic monitoring, equipment monitoring, and underwater robotics.
(iv)Multimedia WSN: consists of low cost sensor nodes equipped with cameras and microphones, deployed in a preplanned manner to guarantee coverage. Multimedia sensor devices are capable of storing, processing, and retrieving multimedia data such as video, audio and images. They must cope with various challenges such as high bandwidth demand, high energy consumption, quality of service (QoS) provisioning, data processing, and compressing techniques, and cross-layer design.
(v) Mobile WSN: consist of mobile sensor nodes that can move around and interact with the physical environment. Mobile nodes can reposition and organize themselves in the network in addition to be able to sense, compute, and communicate. A dynamic routing algorithm must, thus, be employed unlike fixed routing in static WSN. Mobile WSNs face various challenges such as deployment, mobility management, localization with mobility, navigation and control of mobile nodes, maintaining adequate sensing coverage, minimizing energy consumption in locomotion, maintaining network connectivity, and data distribution.

V. CHALLENGES VS. REQUIRED MECHANISMS IN WSN

Both WSN and Wireless ad-hoc networks have battery powered nodes and therefore there is a big common concern on minimizing power consumption. MANETS are usually “closed” to humans, that most nodes in the network are devices used by human beings e.g., laptop computers, PDAs, mobile radio terminals etc. On the other side, sensor networks do not focus on human interaction, but on the interaction with the environment. Due to this focus of wireless sensor networks on interacting with environment, the Network is embedded in environment. Nodes in the network are equipped to sense the physical parameters then process information and communicate wirelessly.
The collaborative nature of WSNs brings several advantages over conventional wireless ad-hoc networks, including self-organization, rapid deployment, flexibility, and inherent intelligent-processing capability. However, the unique features of WSN present new challenges in hardware design, communication protocols, and application design. A WSN technology must address these challenges to realize the numerous envisioned applications. This requires modifying legacy protocols for conventional wireless ad-hoc networks or designing new effective communication protocols and algorithms. Some of the important challenges and corresponding required mechanisms to address them in WSN are mentioned below:

(i) Resource constraints are to be handled by efficient use of resources viz. energy aware routing etc.
(ii) Adaptive network operation helps in handling dynamic and extreme environment conditions
(iii) Data fusion and localized processing techniques should be implemented to eliminate data redundancy. Data aggregation is performed in some applications that are only interested in average, maximum or minimum values. In such cases, the sensor nodes do not have to transport all the sensed data, since the sampled data generated in a period of time can be aggregated by the node for some necessary processing. Finally, only the required data is transported and a large amount of energy can be saved from the reduction of communication.
(iv)Unreliable wireless communication is to be handled through reliability studies and ensuring reliability mechanisms.
(v) No global identification (ID) for sensor nodes is handled through Data-centric communication paradigm which focuses on data generated by group of sensors.
(vi)Fault tolerance is required to reduce impact of unexpected node failures.
(vii) Scalability and large scale deployment of sensors needs to be met through low-cost small-sized sensors with self-configuration and self-organization.
For these reason, algorithms and protocols need to address the following issues:

- Increased lifespan
- Robustness and fault tolerance
- Self-configuration

The energy constraints are more fundamental than the limited processor bandwidth and memory in sensor networks. The unattended nature of sensor nodes and the hazardous sensing environment prevents manual battery replacement. For these reasons, energy awareness becomes the key research challenge for sensor network. It also uses sleep mode and active mode for each sensor to save their important energy. Energy Consumption of the sensing device should be minimized and sensor nodes should be made energy efficient since their limited energy resource determines their lifetime. To conserve power, wireless sensor nodes normally power off both the radio transmitter and the radio receiver when not in use (sleep mode).

VI. CONCLUSION

In this paper, various applications of WSN along with the knowledge of classification and challenges of WSN are discussed. There is currently enormous research potential in the field of WSN. Sensors are already everywhere. But most sensors used today are large and expensive. They lack the intelligence to analyze and simply report for remote processing. Smart, wireless networked sensors will soon be all around us, collectively processing vast amount of data that will help to work on various applications such as in agriculture monitoring, medical monitoring, environmental monitoring, security and surveillance.

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