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Survey on Wireless Sensor Networks for Reliable Life Services and Other Advanced Applications

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Abstract

Wireless is an old technology; however with the advancement of science and technology it has enabled us to send signals to one or more devices without tangible wire connections and reduced complexity. The increasing human needs have lead to the integration of different technologies into a single unit and Wireless Sensor Network (WSN) is one such integration where sensors are integrated with wireless system to form a network. This network is used for a plethora of applications in sectors like defence, agriculture, medical, environment and industry. This paper is intended to be a resource for students and researchers interested in the state-of-the-art in various application areas of Wireless Sensor Networks (WSNs).

Keywords: *Wireless sensors, sensor node, network, next generation networks, MSNs, BSNs.*

1. Introduction

WSN occupy a very important place in creating persistent environment that would have profound influence on the society in the coming years and will serve as next generation networks. The wireless communication technologies and devices have reached a point that allows the creation of large and pervasive services in a trustworthy manner. With the advances in hardware, the wireless technologies have placed us at the doorstep of a new era where small wireless devices will provide access to information anytime, anywhere as well as actively participate in creating smart environments. Currently, wireless sensor networks are beginning to be deployed at an accelerated swiftness. It is not irrational to expect that in 10-15 years that the world will be covered with wireless sensor networks with access to them via the Internet. This can be considered as the Internet becoming a physical network. This new technology is exciting with unlimited potential for numerous application areas including environmental, medical, military, transportation, entertainment, crisis management, homeland defense, and smart spaces. Sensor networks would permit distributed monitoring and control through their insidious presence in even the remotest locations and in smart surroundings and are expected to play a key role in sensing, collecting, and disseminating information about the environmental phenomena. Sensing applications represent a new hypothesis for network operation and include detection, tracking and monitoring. This paper presents an overview of some of the key areas of research and development in wireless sensor networks. We have discussed current examples and application are

as of recent work to portray the state of art and show how sensor networks are likely to provide solutions in other distributed systems Figure 1 highlights some expanding application areas of WSNs.

Figure 1. Application domains of WSNs

2. Sensor Node

WSNs are formed when a set of small untethered sensor nodes are deployed in an ad-hoc fashion to cooperate on sensing a physical phenomenon. These multi functional miniature sensor nodes are battery operated and have limited processing and storage capabilities. The main components of sensor nodes are processor, transceiver, external memory, power source and sensing unit. The sensed information is converted digitally by an analog to digital converter and thereafter processed by the processing unit and sent by the transceiver to central unit through wireless links. The sensor node may be used to sense more than one phenomenon and can also be programmed as per the needs. Each sensor node has a sensing range within which it can sense the required environmental phenomena. In general sensor nodes combine sensing, low power computing and wireless networking. The sensor nodes hold the promise of revolutionizing sensing in a wide range of application domains because of their reliability, accuracy, flexibility, cost-effectiveness, and ease of deployment. Inside five years, it is expected that sensor nodes and network technologies will be the most dominant means of data collection and would bridge the gap between real and virtual world besides providing communication services in a ubiquitous manner. Figure 2 provides a view of the sensor node used for various sensing applications.
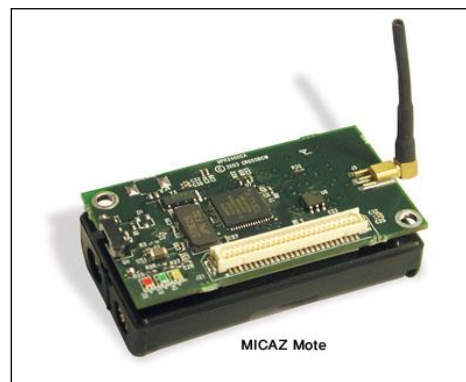

Figure 2. Wireless sensor node

3. Military Sensor Networks (MSNS)

One of the first applications of sensor network is military sensing and currently sensor networks are an integral part of military command, control, communication, intelligence, surveillance, reconnaissance and targeting systems. Sensor networks are applied very successfully in defence for monitoring of friendly forces, equipments, ammunition, battlefield

surveillance, nuclear, biological and chemical attack detection. Besides this terrain, paths and roads could also be monitored to sense the presence of opposing forces. Human teams can be replaced by sensor networks in places affected by biological and chemical warfare or incidents in order to perform nuclear reconnaissance and prevent humans to be exposed to radiations. It is desired that, MSNs must spontaneously create impromptu network, assemble the network themselves, dynamically adapt to device failure and degradation manage movement of sensor nodes, and react to changes in task and environment for specific defence applications. To summarize, in the battlefield context, rapid deployment, self-organization, fault tolerance, reconfiguration and self-awareness are essential requisites for MSNs. An example of MSNs is shown in Figure 3.
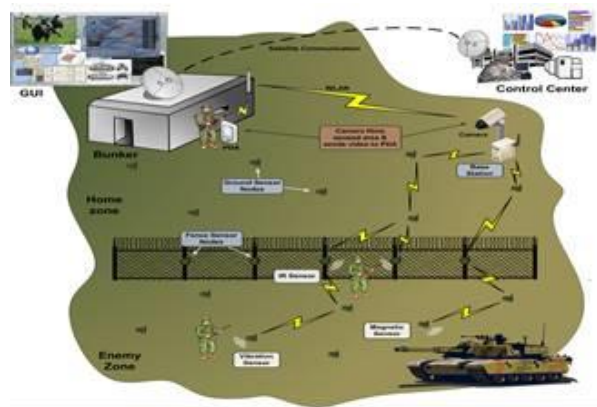

Figure 3 Military sensor networks

4. Under Water Acoustic Sensor Network (UW-ASN)

The earth is a water planet and around 70% of the surface of earth is covered by water. This is largely an unexplored area and recently it has trapped humans to explore it. Underwater acoustic networking is the enabling technology for applications such as oceanographic data collection, pollution monitoring, off shore exploration, disaster prevention, assisted navigation and tactical surveillance. Moreover, unmanned or autonomous underwater vehicles (UUVs, AUVs) equipped with sensors, enable the exploration of natural undersea resources and gathering of scientific data. UW-ASN consists of a variable number of sensors and vehicles that are deployed to perform collaborative monitoring tasks over a given area. To achieve this objective, sensors and vehicles self-organize in an autonomous network and adapt to the characteristics of the ocean environment. However underwater sensors are prone to failures because of fouling, high bit error rates, multi-path fading and limited battery power since solar energy cannot be exploited.

5. Health Sensor Network

The last decade has witnessed a rapid surge of interest in new sensing and monitoring devices for healthcare facilitating sensor networks to be widely used in this area. In some modern hospitals sensor networks are constructed to monitor patient physiological data, drug administration and long term nursing of old people. Besides this, pressure sensors and orientation sensors can be exploited for detection of muscle activity and unconsciousness. These applications reduce personnel cost and rapid the reaction of emergence situation. Other application area extends to Body Sensor Networks (BSNs), consisting of a network of sensors carried by the patient for mobile monitoring in hospitals and has lead to the development of a number of prototypes.

6. Body Sensor Networks (BSNS)

BSNs are a specific category of wireless sensors intended to operate in a pervasive manner for on-body applications. Much of the theory relating to general wireless sensors relates

also to BSNs. One key development in this area is wireless wearable and implantable in vivo monitoring jacket. Several promising prototypes are starting to emerge for managing patients with acute diabetes, for treatment of epilepsy and other debilitating neurological disorders along with monitoring the patients with chronic cardiac diseases. However issues in regard to power optimisation, battery life performance, long-term stability and biocompatibility still need to be addressed. Figure 4 presents an idea for sensors being used to monitor the health of a patient
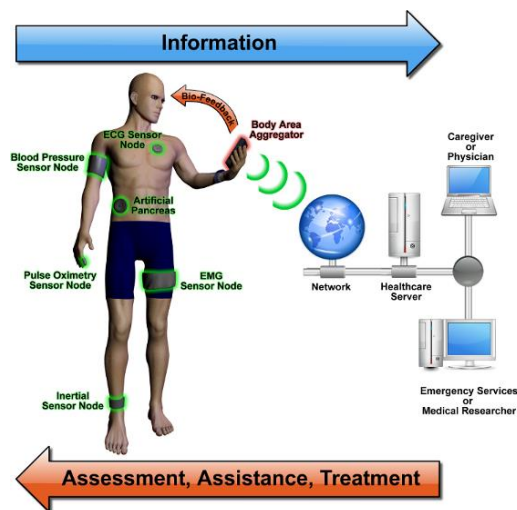

Figure 4. Body sensor networks

7. Environmental Sensor Networks

Sensor networks can be used to monitor environment, objects in that environment, and the interactions of objects with each other in their encompassing environments. Environmental sensor networks offer an exciting research opportunity for designing sustainable sensor networks for the natural environment, since communication, power management, deployment, weatherproofing, stability, and remote diagnostics present difficult technical challenges. An integrated network of sensors combining on the ground sensors monitoring local moisture levels, humidity, wind speed and direction, together with satellite imagery and meteorological forecasting can enable the determination of fire risk levels in targeted regions as well as valuable information on probable fire direction. Such network can provide valuable understanding of the environment and most importantly assist authorities in organizing a coordinated disaster response (wind sensors can be deployed along a river bank, issuing automatic warnings in the case of possible flooding) that will save lives and property. Other uses for these networks include monitoring of eco-system, water catchment, habitat, condition-based equipments, disaster management and emergency response. They can be deployed in some inhospitable environments such as volcanoes or hurricanes or can be deployed to track workers in dangerous work-environments such as mines or off shore platforms.

8. Agriculture Meteorology Sensor Network

The agriculture meteorology uses smart sensors to record microclimate and plant data in the field in an effort to select new plant varieties suited to difficult growing conditions. The sensor network system uses a range of different micro-climate sensors such as automatic weather stations, solar radiation or photo synthetic sensors, soil temperature sensors, and infrared thermometers to measure leaf temperature. In field experiments, different kinds of sensors are combined to serve the scientific objectives such as, different soil moisture sensors can be used to record the soil moisture at different depths or a master weather station can be used in conjunction with less expensive temperature sensors to record the temperature in several locations. Information gathered by the sensor network could guide farmers to improve quality, thus providing better return on their yields.

9. Precision Agriculture and Animal Tracking Sensor Network

Sensor networks are also an important component of precision agriculture which aims at "maximum production efficiency with minimum environmental impact". Few of the major concerns of precision agriculture are soil compaction, erosion, salinity and declining water quality. Therefore sensor networks could play a critical role in monitoring the health of the soil, water quality and insect-disease-weed from pre- to post-production. Sensors also contribute to real-time monitoring of variables such as soil fertility, water availability and soil compaction. Currently wireless sensors have been developed to gather data on leaf temperature, measure chlorophyll content and plant water status. Based on these data, farmers can detect problems at an early stage and implement real-time solutions. In the field of animal tracking, the movement and location of herds, the health of animals and the state of the pasture can also be controlled via sensor networks.

10. Smart Grids and Energy Control Sensor Network

The smart grid is an innovation that has the potential to revolutionise the transmission, distribution and conservation of energy. It employs digital technology to improve transparency, reliability and efficiency, further such systems can also turn on and off automatically. Sensor networks play a major role in turning traditional grids into smart grids; they are only one group of key components of the smart grid and major benefits arise from the interaction between these components. Examples include automated panels managed by sensors to track sun rays to ensure that solar power is gathered in a more efficient manner.

11. Smart Building and Home Sensor Network

Smart buildings are closely linked to smart grids; they rely on a set of technologies that enhance energy-efficiency and user comfort besides monitoring the safety of the buildings. The concept includes a combination of efficient building materials and information communication technologies (ICTs). These systems can be both found at household and office level an example to this is the second concealment of glass for skyscrapers at the headquarters of the New York Times Company having an advanced ceramic sunscreen consisting of ceramic tubes which reflect daylight and thus prevent the skyscraper from collecting heat. Sensor networks can be used to provide multiple applications in smart buildings such as, monitoring of structural health, heating, lighting, shading and ventilation.

Along with commercial applications of sensor networks it is not so hard to imagine that home applications will also step into our normal life in near future. Let's see the concept "the intelligent home", after one day hard work you come back home, at the front door the sensor detects you are opening the door, then it will tell the electric kettle to boil some water and the air conditioner to be turned on. While you sit in the sofa the light and the television on the table automatically gets on because the pressure sensor under the sofa has detected your weight and one sensor has monitored that you are sitting in front of it.

12. Industrial Sensor Network

The variety of sensor applications across industry are immense as sensor networks are broadly used for process control, control of physical properties during the production process and equipment management and. Sensors deliver real-time data on the production process and are able to detect variations in the process. Control can thus be moved from the finished product after the completed production run to the production process itself. Furthermore, a continuous monitoring of processes allows efficient use of energy during production processes. Industrial sensor networks are helpful in minimizing the faults and find extensive use in factory automation, real-time monitoring of machinery and inventory, detection of liquid/gas leakage and remote monitoring of contaminated areas.

13. Intelligent Sensor Network

Researchers have worked hard on combining surveillance systems with WSNs for various applications. Each system focuses on a specific function and has the ability to handle heterogeneous data under adverse conditions. The intelligent sensor network contains wireless sensors that trigger cameras to detect any moving object to calculate the coarse image features for object recognition. Wireless sensors serve as guarders to detect the directional, magnetic, and seismic information of any moving object in a secured area by transmitting a few bits of data to the server. The surveillance system enacts cameras to monitor the desired areas based on the signals provided by wireless sensors. Since the sensors can sense the coordinates of moving objects, the cameras can be adjusted to track them for object classification and recognition. If there is no signal from wireless sensors, the cameras will periodically rotate for traditional surveillance. On the other hand, the system can be extended to some unique applications, for example, an ID verification system can be designed by combining with the radio frequency identification (RFID) to distinguish unauthorized intruders from authorized people i.e., a person is permitted to enter a secured area if he/she carries an ID card or badge with a RFID tag from which RFID reader can read the identification of the person.

14. Transport and Logistics Sensor Network

Transport and logistics sensor network can be defined as the application of advanced emerging technologies (computers, sensors, communications, and electronic devices) in transportation to save lives, time, money, energy and environment. Sensor networks in particular can contribute to increased efficiency in freight and passenger transport by avoiding freight and passenger transport through a higher degree of virtualisation, digitisation and tele-working. These networks can be categorised into intelligent infrastructure and intelligent vehicles equipped with sensors for multiple purposes. Examples include driverless trains and buses outfitted with door sensors to detect whether doors are open. Other applications include environmental sensors on buses and tramways that detect weather conditions, analyse traffic conditions and give alerts via on-board mini-computers.

15. Mobile Sensor Networks

Modern smart phones can be termed as sophisticated computing platforms with sensing capabilities to detect user location, recording high-quality audio, measuring ambient light, sensing geomagnetic strength, and sensing orientation. Due to widespread use of smart phones, it is possible to develop large-scale sensor networks using cellular network technology and deploy applications on end-user devices to collect and report sensor readings back to servers. End-users also often have a keen interest in maintaining their phones, including repairing broken hardware, re-installing faulty software, and maintaining data synchronization with servers. This end-user maintenance helps ease of the maintenance burden from operators and other network administrators. The smart phones with sensors are likely to achieve more dispersion and adoption per unit than the conventional mobile phones towards the development of mobile sensor networks.

16. Wireless Integrated Network Sensors (WINS)

The revolution in integrated circuit design has enabled construction of more capable and inexpensive sensors, radios, and processors to allow mass production of sophisticated systems linking the physical world to digital data networks. The WINS network represents a new monitoring and control capability for applications in transportation, manufacturing, health care, safety and security. WINS are likely to provide a distributed network and internet access to sensors deeply embedded in equipments for combining micro sensor technology with low-power signal processing, computation and low-cost wireless networking in a compact system. WINS opportunities depend on development of scalable, low-cost sensors with a low bit rate through low-power transceivers. Applications of WINS can extend to security, factory automation, and condition-based maintenance in near future.

17. Embedded Sensor Networks (ESNS)

ESNs are a network of embedded computers placed in the physical world to interact with the environment. These embedded computers have a set of sensors or actuators and are physically placed in the environment near the objects to be sensed. The networked sensors communicate and cooperate with each other to monitor the environment and possibly effect changes to it. Current sensor networks are usually stationary, although sensors may be attached to moving objects or may even be capable of independent movement. These characteristics define a new field of sensor networking and differentiate it from remote sensing, mobile computing and traditional centralized sensing systems.

18. Visual Sensor Network

Visual sensor network is a type of wireless sensor network constituting of spatially distributed smart camera devices capable of processing and fusing images of a scene from a variety of viewpoints into some more useful form than the individual images. The network generally consists of the cameras having some local image processing, communication and storage capabilities, and at least one central computer, where image data from multiple cameras can be fused and processed further. Visual sensor network can provide some high-level services to the user so that the large amount of data can be distilled into information of interest using specific queries. These types of networks are most useful in applications involving area surveillance, telecommunications and tracking.

19. Cognitive Radio Sensor Network (Crsn)

CRSN is a distributed network of cognitive radio sensors which sense an event signal and collaboratively communicate the readings over dynamically available spectrum bands in a multi-hop manner. CRSN is a recently emerging paradigm that aims to utilize the unique features provided by Cognitive Radios (CR) to incorporate additional capabilities into sensor networks for operating over unlicensed bands. Today, significant increase in the applications brings the coexistence problem in these bands, hence it is promising to arm wireless sensors with CR technology to combat the interference incurred from other applications.

Conclusion

The emerging WSN technology holds vast scope for various futuristic applications both for mass community and military. The sensing technology combined with wireless communication makes it lucrative for being exploited in profusion in near future. Despite their versatility and their broad range of applications, sensor networks offer countless challenges in terms of circuits and systems and require development of low-power communication hardware, microcontrollers, efficient analog to digital converters, and power efficient devices. Finally, with tens, hundreds, or even thousands of sensors, the network as a whole must be self-configuring in order to enhance the potential and performance.

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