A Brief Overview of Application Domains and Real-Time Applications of Wireless Sensor Networks

[1]Sachin R. Jain, [2]Nileshsingh V. Thakur

[1]Department of Information Technology, Yeshwantrao Chavan College of Engineering, Nagpur, India
[2]Principal, Nagpur Institute of Technology, Nagpur, India
sachinjain98440@rediffmail.com[1], thakurnisvis@rediffmail.com[2]

Abstract*— One of the main reasons of popularity of the Wireless Sensor Networks (WSNs) is its wide area of application domains. There are a large number of real-time applications available that witnesses the wide development in field of wireless sensor networks in the recent era. Some of main application domains of WSNs include environmental monitoring, health monitoring, traffic monitoring, industrial process control, automation and monitoring, space exploration, military applications, home automation etc. These types of networks are consisting of application specific sensor nodes, which are designed to sense, acute, compute and route the sensed data to the destination, where it can be analyzed, examined, processed and monitored to take necessary actions. The sensors used in these types of networks are generally automated, cooperative, and small in size. These devices are battery operated which cannot be recharged or removed. The sensors used in these types of networks are geographically fixed or sometimes moveable in nature. In this paper, a brief overview of the application domain of WSNs and some real-time applications of static and mobile WSN is discussed.

***Index Terms*—Wireless Sensor Networks, WSN, Sensors, Applications of WSN, Static Nodes, Mobile Nodes.**

I. INTRODUCTION

In recent years the Wireless Sensor Networks (WSNs) [1-4] are become more popular, growing and one of the blazing topics of research because of its wide variety of real-time application areas. Such type of networks are basically composed of tiny, low powered, low cost, non-rechargeable, non replaceable, small battery driven, autonomous, self-cooperative, self organized, distributed sensors that are designed for a dedicated and specific application. The sensors are deployed very closely in a large numbers, sometimes hundreds to thousands in number, in a region of interest as shown in Figure 1, from where the information is to be collected and transferred to the base station or sink which is located away from this region and then the collected data can be further processed. In such systems, there is no fixed network infrastructure, so the nodes must cooperate to accomplish communication, global control and information aggregation.

The applications of wireless sensor networks can be broadly classified into two categories. The first category is the wireless sensor networks consisting of only static nodes, i.e. the WSNs consisting of sensor nodes which can move from one location to other, they are fixed at one position once they are deployed in the network. In the second category the sensor nodes deployed in the WSNs may be mobile in nature, the mobile nodes can move from one location to the other while working, performing operations during its lifetime. The mobility of the nodes in WSNs introduces new challenges and issues in the network, because the topology of the network changes continuously and dynamically in the network.

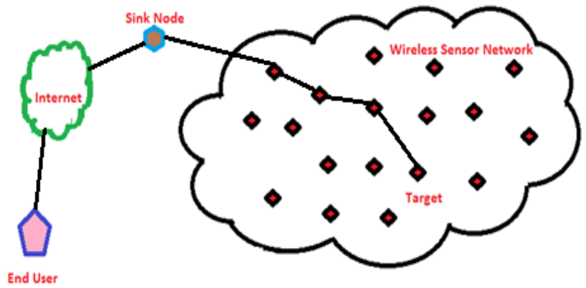

Figure1: Sample Scenario of Wireless Sensor Networks

II. ISSUES IN WIRELESS SENSOR NETWORKS

A wireless sensor network (WSN) design can be affected by many factors. The issues discussed in [5] influences the WSN includes: scalability, hardware constraints, power consumption, fault tolerance, production costs, environmental constraints, topology of the network, and communication medium. Different architectures and network design constraints [6] have been considered for designing of sensor networks depending on the applications. The performance of the application is strongly related to the architectural and network design model used in the application. Some of these issues include node deployment strategy, network dynamics, network topology, data delivery model, node capabilities, data aggregation policy, etc.

Scalability

Depending on the application, the number of sensor nodes deployed in the WSN may be in order of hundreds or thousands or many more than that or sometimes, even very few in number. The network must be able to occupy and handle small as well as a big number of sensor nodes, so the network must be highly scalable in nature, so that it fits to almost every requirement of the application. The nodes must also exhibit the high density characteristic of WSNs. In such networks [7], the density of sensor nodes can range from few to few hundred in a region of interest that can be less than even 10 meter in diameter.

Hardware Constraints

A sensor node is composed up of four basic components: a sensing unit for data acquisition, a processing unit for sensed data processing, a wireless communication unit for transmission of sensed data and a power unit containing a non rechargeable limited energy battery. It may also have some additional components like mobilizer, a global positioning system (GPS), power generator etc., which can be integrated in the basic model of sensor node depending on the type of applications. All of these components should be fitted into small sized module like a matchbox [8] or even smaller than that [9]. Apart from the size of the sensor node, there are some other rigorous constraints [10] like, the nodes should consume extremely low power, operate in high volumetric densities, should have low production cost, should be autonomous and adaptive in nature etc.

Topology of Network

A large number of autonomous, self localizing sensor nodes are deployed densely in the region of interest. These nodes are prone to frequent failures because of some uncertain and unexpected reasons, which results in a more challenging job of maintaining topology of the network [11, 12]. So, deploying such a large number of nodes densely in the region of interest requires careful handling of topology maintenance in the network. Some issues regarding the topology maintenance are studied and categorized in three phases: Pre-deployment phase and deployment phase, Post-deployment phase, and Re-deployment of additional nodes phase.

Energy Considerations

Energy optimization is one of the important issues in WSN, as the sensor nodes are low powered, non-removable, non-rechargeable battery driven devices. So, during the formation of the infrastructure, energy consumption must be considered for the process of setting up the path for routing. The transmission power of a wireless radio is generally proportional to the square of the distance; sometimes it is even higher in the presence of obstacles or hurdles in the network.

If all the sensor nodes are very closer to the sink node, the direct routing method is preferable, otherwise multi-hop routing should be considered, as it consumes less energy than direct method [13]. If the nodes are scattered randomly in the sensor network, multi-hop routing becomes more energy efficient than direct communication with the sink node.

III. APPLICATION DOMAIN OF WSN

The WSNs application areas in general can be divided into two main classes [14] depending on their type of use. The classes are monitoring and tracking of a domain specific application. These classes are briefly described in the Figure 2. The tracking class comprised of application like, enemy tracking for military applications, traffic tracking in the industrial applications, animal tracking in habitat applications, human tracking in business applications, etc.

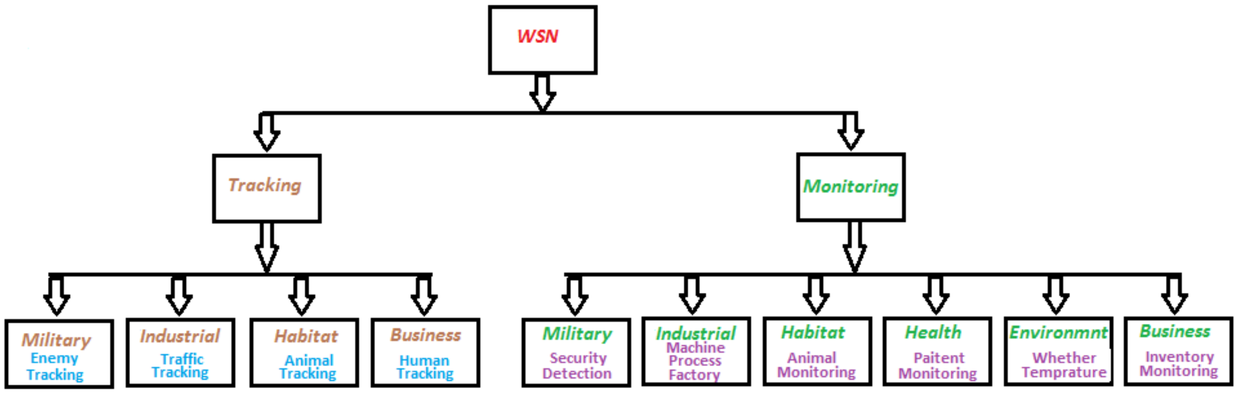

Figure 2: Application classification in WSNs

Whereas, the second class i.e. monitoring class comprised of applications like, security and detection in military applications, machine process and factory monitoring in industries applications, animal monitoring in habitat applications, patient health monitoring in health applications, whether, temperature, air monitoring in environmental applications, inventory, material monitoring in business applications.

As discussed earlier, the WSNs can be divided into static and mobile WSNs. In static network, the sensor nodes which are deployed in the region of interest are fixed in nature; they cannot move from one location to other. These types of WSNs normally have a fixed type of network topology and it is less complex in nature in comparison with the WSNs having mobile nodes. Due to the simplicity and ease of use, there are a very large number of applications developed using the static WSNs. Some real time applications developed and implemented using static WSN are discussed below. Some of the applications of static and mobile WSNs are described in the following section.

IV. APPLICATIONS OF STATIC WSN

The dominating applicability of WSNs has motivated researchers to explore the area of precision agriculture. Delicately designed and developed sensors for the agricultural field provide more correct, perfect and exact prediction of crop performances with help of WSNs. Authors in [15] have proposed a new network structure by installing four dissimilar types of sensor nodes in the region of interest. The network basically comprised of soil sensors, environment sensors, water sensors and gateway sensors, which are used to sense, acute, compute and processed for recording, observing and analyzing different attributes periodically like, temperature in the field, moisture level, salinity, water level, etc. the proposed approach was deployed, implemented and tested on various parameters on cabbage crop successfully.

A different case study of WSN using static sensor nodes is proposed by authors in [16], which is developed to record and monitor costal redwood trees nearby Sonoma, California. The application specific sensor nodes were fixed on redwood trees, which monitor periodically, the data like temperature, humidity photo synthetically active solar radiation. The proposed system collects all data regarding the micro climate around the costal redwood trees with help of the deployed sensor nodes, which then will be sent to the base station for further processing and analysis done by the skilled professional for further studies, actions and investigations to be carried out.

In [17] G. Werner-Allen et al. have proposed a novel Volcanic monitoring system, which comprised of 16 application specific sensor nodes deployed on Volcàn Reventador in northern Ecuador. It uses a typical WSN system in which the sensor nodes are placed at a distance of around a range of 200 meter to 400 meter from each other. The sensor nodes sense, acute, compute, process the desired data from the region of interest and then sends the processed data with the help of multi-hop routing strategy to the sink, which is actually a gateway node. The gateway node aggregates the collected data from all the nodes and then sends it to the base station which is located far away. The proposed system was tested, observed and monitored and the collected data was later studied and analyzed.

M. Rahimi et al. [18] proposed Cyclops, which provides sensor technology with CMOS imaging. It has programmable logic and memory with high speed data transfer rate. To interact with outside world, a micro-controller is used. Cyclops is very useful in applications, where high speed processing or high resolution images are required.

V. APPLICATION OF MOBILE WSN

In real-time scenarios, it is needed in many applications, that the sensor nodes should have a capability to move from one location to another or the sensor nodes are deployed in such a manner that they move from location to other, to sense the desired data. In such situations the topology of the network is not fixed due to mobility of nodes, it changes as any of the sensor nodes moves from one place to other. These types of networks are more complex and complicated compared to pure static WSN. The network in such application must be able to handle the mobility of the nodes, so that the desired goals would not defer. Some of the real-time applications implemented using mobile WSN are discussed below.

An underwater wireless sensor network system is discussed by the authors I. Vasilescu et al. [19] to observe and monitor coral reefs and fisheries. The proposed system uses static as well as mobile sensor nodes which are deployed underwater. It uses different application specific sensor nodes for monitoring temperature, pressure and other different underwater environmental conditions. A special high speed optical communication channel which works underwater is established which also uses an acoustic protocol for broadcasting purpose. The mobile sensor nodes are located above the static nodes, to collect the data from the specified environment. The proposed system performs various additional operations like network maintenance, relocation, deployment and recovery.

A blood pressure and heart rate tracking and observing system is developed by authors in [20], called “Heart@Home”. The proposed system makes use a SHIMMER mote, which is located inside the wrist cuff, connected to a pressure and heart rate monitoring sensor. The task of SHIMMER mote is to transmit the observed data to the sink node periodically, which is located away. The collected data at the sink are analyzed, processed and using this data, a graph of the blood pressure and heart rate are generated.

For monitoring the infants, the SHIMMER mote is used by the authors in [20]. The proposed system has a three axis accelerometer sensor which senses the body position, relativity and gravity of the infant. The task of the SHIMMER mote is to transmit the data packets periodically to the sink node. The data collected at the sink then can be processed and analyze to monitor the position of the infant.

A different system called as “iMouse” proposed by Yu-Chee Tseng et al. in [21]. The developed system is an integrated mobile WSN, which is used for the purpose of surveillance, where mobile nodes move to various event locations. They have the ability to exchange the data with each other and they also have ability to take snapshots of event scenes. The data is collected from the sensors and transmitted to the base station located away from the deployment region, which is then further analyzed and processed.

The authors in [22] have proposed a system called as "ZebraNet" which uses the mobile nodes to observe the movements of the animals at the Sweetwaters game reserve in central Kenya. In proposed system, the sensor nodes are deployed in collar of the zebra, which is consist of a microcontroller, a flash memory, a radio device, and a GPS device. The GPS device is used to take the current geographical location of the zebra. The readings collected from the sensors are sent to the sink node which is then processed and analyzed for further operations.

To check the surface conditions of the roads, a different type of mobile WSN application called "Pothole Patrol" is proposed in [23] by Jakob Eriksson. The system proposed, makes use of the mobility of the vehicles and collects the real-time data by using vibrations and GPS sensors. The collected data from the sensors are sent to the sink node where they are analyzed and processed to the assessment of the surface conditions of the roads.

A system called "TrueMobile" is discussed in [24] by David Johnson et al. is deployed for public use. The authors tried to build the first remotely accessible mobile wireless and sensor test-bed. In "TrueMobile" the robots carry motes and single board computers using a fixed field of sensor equipped motes. In real-time, using "TrueMobile", remote users can point out the location of the robots, control all the computers, network interfaces, and log data through it. "TrueMobile" offer simple path planning, vision based tracking system, which provides very accurate result, live maps and web-cams.

A system known as "FireLine" is a wireless heart rate sensing system, which is used to monitor a fire fighter's heart rate to detect any abnormality and stress in real-time [25]. It consists of a T-mote, a heart rate sensor board, and three re-usable electrodes, which are embedded into a shirt that a fire fighter will wear. The T-mote will send the readings to the base station, which are then processed, analyze and an alert is raised if the fire fighter's heart rate is increasing too high. Another system known as "LISTSENse" that enables the hearing impaired people to be informed of any audible information. In this system, the person using the system has to carry the base station T-mote with him, which consists of LEDs and a vibrator. The transmitters motes consist of an omni-directional condenser microphone are place near objects that can be listened e.g., alarm bell, smoke alarm, doorbell, and siren. These transmitters sample signals periodically. At any moment if the signal is greater than the reference signal, it will send an encrypted activation message to the base station, and the T-mote at the base station actives the LEDs and vibrator to warn the person using it.

A system for human-centric search of the physical world, "MAX" is discussed in [26] which permit people to search and locate physical objects when needed, by providing location information reference to identifiable landmarks. It uses a hierarchical architecture design that requires objects to be tagged, sub stations as landmarks, and BS to locate these object. Crossbow motes were used to show implementation of MAX, and a room of physical objects was used to take trials of the system.

VI. CONCLUSION

Due to less cost, feasibility, scalability, and usefulness, the wireless sensor networks have a wide variety of application areas. In this paper, a brief overview of the static and mobile wireless sensor networks and the issues and challenges that arises in WSNs is discussed. The domain specific applications and their general classification depending on the type of application, like tracking and monitoring is also discussed in the paper. It also focuses on the real-time application examples of static and mobile sensor networks.

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