WSN – a Technology for Natural Resource Monitoring and Conservation- a Review

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***Abstract*- With rapid increase in globalization, the human activities have gradually affected the environment. So, environment monitoring is a vital issue and has attracted a lot of attention. A wireless sensor network (WSN) consists of a large number of tiny sensor nodes spread over a large geographical area (sensing field) where each node is a low-power device that incorporates computing, wireless communication, and sensing abilities. The WSNs are designed and implemented in a manner that they can withstand harsh environments and keep working for a long period of time. WSNs are very useful for monitoring and preserving the environment. These are used for various applications such as habitat monitoring and control, glacier monitoring, agricultural conservation, disaster forecasting, forest fire detection and detection of acid rains, computing of various activities in mines, plant protection for sustainable crop protection, water quality monitoring, ocean sensing and monitoring, earthquake detection etc. This paper presents a survey of applications of WSNs that contribute to the monitoring and conservation of environment.**

***Keywords—WSN; Environment monitoring; glacier monitoring; habitat monitoring*.**

I. INTRODUCTION

Wireless Sensor Networks consist of randomly or spatially distributed sensors over a wide geographical area for measuring various environmental parameters like temperature, humidity, sound, pressure etc. The units collecting this data are called sensing nodes. The sensing nodes transmit this data to the sinks using single hop or multiple hop communication. The sink either uses the information locally or sends it to other networks through gateways [1].

The architecture of a wireless sensor node is shown in Fig. 1. Each node is equipped with a sensing unit, a transceiver, a processing unit and a power supply. A WSN node may also have some additional application-dependent equipment attached, such as the location finding system and mobilizer. These devices when combined into a small unit make it multi-functional. In other words, the structure and characteristics of sensor nodes depend not only on their electronic, mechanical and communication limitations but also on their application-specific requirements.

The fact that WSN comprises a large number of wireless sensing units that are scattered over a wide area and work in collaboration with each other to provide information about the entire area, makes them naturally suitable for monitoring wide geographical areas. The geographical area can be a farm field, a forest, a glacier, a mine etc. This paper presents a survey of the applications of WSN that contribute towards monitoring and conservation of natural resources.

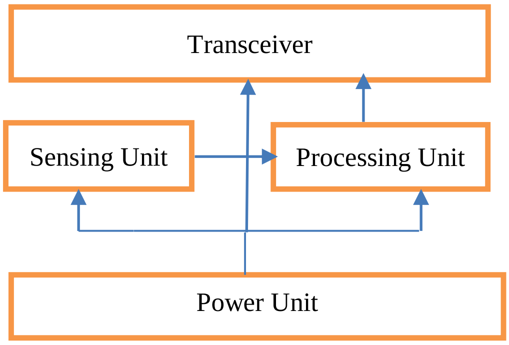

Fig.1. Architecture of a Wireless Sensor Node

The rest of the paper is organised as follows. Section II lists the design objectives for a WSN based environment monitoring system. The various characteristic features of WSNs are listed in section III. Section IV presents the various applications of WSN developed for environmental monitoring like agricultural monitoring, various methods for water and air quality monitoring etc. Finally, the paper is concluded in Section V.

II. DESIGN OBJECTIVES FOR A WSN BASED ENVIORNMENT MONITORING SYSTEM

A WSN based system designed for environmental monitoring must should the following objectives:

Autonomy: The system should be autonomous in terms of operation and control. It should have the capability of self-evaluating, self-calibrating and self-healing.

Reliability: It is important to maintain reliability in order to prevent packet loss during bad weather conditions.

Robustness: The network has to be robust to encounter problems related to hardware failure, and poor signal connectivity.

Flexibility: The system should be highly flexible so that the user may be able to add, move or change stations depending on the requirements of the stations.

III. CHARACTERSTIC FEATURES OF WIRELESS SENSOR NETWORKS

The wireless sensor networks are a special type of wireless networks. The characteristics that make them different from other wireless networks are listed below:

1) Lifetime: This is the most critical factor since the nodes are energy consuming. Energy efficient routing should avoid the loss of a node due to battery depletion. Many protocols were proposed to minimize the energy consumption on the forwarding paths, but if some nodes happen to be displaced, their lifetime will be reduced.
2) Maintenance: The desired form of maintenance in a network is the complete update of the program codes in the sensor nodes over the channel. All the sensor nodes should be updated.
3) Resilience: The sensor nodes in the network should be able to cope up with the node failures, if any.
4) Fault tolerance: The network functionality should be maintained even though the built in dynamic nature and failure of the nodes due to harsh environment, depletion of batteries, or external interference make networks prone to errors.
5) Security: The need for security in WSNs is evident, especially in health maintenance, safety and military applications. Most of the applications relay data that contain private or confidential data.
6) Production Cost: The number of nodes in WSNs is very high, and once the batteries of the nodes run out they are to be replaced by new ones. So, in order to make the deployments possible, the nodes should be of low cost.

IV. APPLICATIONS OF WSNs

In early times analogy mechanisms were used to measure physical environmental parameters. The old mechanisms included human help to download the recorded data. Then came digital data loggers. They were easy to operate but they had certain drawbacks. The digital data loggers solution, usually provided monitoring at one point only and in many cases multiple points were needed to be monitored. There was not a standard to store data and to communicate with the data logger, so several different solutions were used. Then came wireless sensors which made the work easier. Using a WSN, a number of sensors continuously monitor factors like temperature and luminosity, humidity and will process, store and transmit data co-operatively and wirelessly with other sensors to produce data that can then be collected and made accessible to users virtually anywhere on the globe.

A. Agriculture monitoring

WSN system [2] is made up of four fragments: sensor node, the sink, transmission networks and monitoring terminal. The data from the sensors can be stored, analyzed and transmitted via wireless radio channel to manager vehicle. In order to monitor agricultural activities we need environmental parameter sensors like humidity sensor, temperature sensor, CO_2 sensors etc. Based on this information the various parameters can be controlled and rectified. WSN can be used to determine the quantity of fertilizers to be used for crops, to determine the leaf chlorophyll content, leaf temperature, leaf area index, soil compaction, soil fertility, yield of grain, plant water status. WSN can be used to determine the optimum conditions for each crop, management of crop cultivation to know the exact condition in which plants are growing from your own home.

Various studies have been provided in the literature which provide us a great knowledge about the various advancements in the field of monitoring the agricultural environment.

In [3],Y. Zhu presented an agricultural environment monitoring system which included the sensor nodes design hardware and software which consist of the software flowchart. From the test performed, the system verified for consuming low power but provides high reliability, which can control real time monitoring for unprotected agriculture and environment

In [4], the authors presented a Zigbee-based agriculture monitoring system which proved to be a reliable and efficient system for efficiently monitoring the environmental parameters. Wireless monitoring of field not only allowed users to reduce the human power, but it also allows user to see accurate changes in it. This research focused basically on developing devices and tools for managing, displaying and alerting the weather/disaster warnings.

In [5],Yu et al. proposed a mixed architecture including WSN and wireless underground sensor networks (WUSN). An enactment framework was then developed for monitoring the real-time properties of soil. The influence of parameters of soil, depth of nodes, signal frequency and attenuation on transmission were studied. During data transmission reflection, scattering and diffraction may occur in the soil and at the soil–air interface. The research revealed that the frequency of the electromagnetic signals and the water content of soil affect the path loss. These system used a wireless transceiver chip based on ZigBee which was developed to gather soil terrestrial information.

In [6], the authors monitored a potato field in order to observe the climate: humidity, temperature and weather. This was done to reveal when the crop is at risk due to a disease called phytophtora.

In [7], Kim et al. developed a sensor network that used an independent robots with beacons to monitor and detect fires and air pollution in fields. The authors used a network tree topology with RF transceivers and microcontroller in order to monitor the temperature, gas, smoke, humidity and illumination.

In [8], the authors described the deployment of WSNs in an apple orchard with the main aim to monitor the moisture in top soil to analyse interaction with plant physiology. Numerous homogeneous sensors were deployed in a multi-hop mesh topology in order to minimize energy consumption.

In [9], the authors proposed a system to monitor crop fields where the system could detect and identify procedures of a WSN video surveillance system. The so designed system was able to monitor, detect, identify and transmit data over long distances. The system integrated video transmission to networks for only monitored crops. The system was, therefore, quite useful in cost reduction, increasing the lifetime of the devices and networks, and avoiding duplicate infrastructure.

1. Irrigation management

In the present era, people are working on effective irrigation techniques so as to preserve our water resources [10]. So, several efforts has been done for the preservation and effective use of water for irrigation and to provide some help in doing so, WSN are used. In [11], Peng proposed an intelligent irrigation system based on a WSN and neural fuzzy control. The objective was to solve issues of soil fertility loss and water wastage during irrigation. The system was composed of sensor nodes and the controller node. They consist of soil moisture sensors along with irrigation pipes, spray irrigation and irrigation control valves for deployment. The ZigBee network was adopted in the mesh network topology.

In [12], NesaSudha et al. proposed an automatic irrigation system with energy-efficient TDMA-based algorithm, a network with a star single- hop topology along with a MAC protocol was used to control energy consumption.

In [13], Zhang et al. proposed a WSN-based system to monitor the moisture of soil and to analyse the temporal and spatial variability of soil moisture for variable irrigation. The position of the deployed sensor nodes and the moisture sensors were measured with a GPS and both the sensors were waterproof to withstand harsh conditions. These sensors provided valuable information which further became the basis to make irrigation decisions.

In [14], a WSN soil moisture mapping and monitoring method was developed to provide irrigation scheduling information. In this the data in digital format was incorporated into VRI controlling software. The irrigation was by a centre pivot (CP) irrigator with VRI modification. Each sprinkler was controlled independently by digital maps that were uploaded to the dominant controller.

In [15], the authors presented a system that was intended to automate the irrigation process. The variability in the soil moisture was calculated and was used by the irrigation controller to initiate the irrigation actions. The sensor nodes deployed for this system were composed of ZigBee end devices (ZED) and ZigBee co-ordinator (ZC), where ZED collected soil moisture and temperature data and send it to ZC which in turn was sent to the Remote monitoring station (RMS) via cellular network. The opening and closing of irrigation valves depend on the values stored in the co-ordinator node.

2. Greenhouse management

The greenhouse effect occurs when solar radiation from sun are imprisoned by the gases in the earth’s atmosphere and reflected back from the earth. Thus, it heats the surface of earth and hints to global warming. Therefore, greenhouse monitoring system is important to guarantee the stabilization of the environment. Monitoring and control of greenhouse can be divided into three main parts: Measuring, calculating and adjusting. The measured parameters of the greenhouse climate are first converted from analog to digital and then transmitted to the computer which is normally located outside because of the large moisture content in the greenhouse. Signals provided by the sensors are normally weak. Without signal amplifier, cabled sensor units cannot transmit the data correctly. Wireless sensor networks does not have such problems. Measured data can be sent directly to the gateway node which are inserted in to the computer or it can be transferred in a multi-hop means via router nodes, if the distance between the measuring nodes and the computer extends the length of a single radio link. Besides data collection and control calculation, the computer also represents the climate variable values and statistics on the screen for the user. The computer runs the algorithm for greenhouse climate control, and the new values for the control signals are computed in every 15-60 seconds. Each output is linked to electronic relay, which switches the tools under its control on or off via the second relay, which gives the input voltage needed for the device. A modern greenhouse system can consist of several parts which have their own local climate variable settings.

Various technologies has been emerged since now that are presented in the literature as below:

In [16], a greenhouse management system using a base platform, TinyOS to measure and monitor various environmental parameters including temperature, light and humidity. The parameter information is automatically collected and send to the system which ensures the system to become highly efficient.

A Greenhouse environment monitoring system based on ZigBee was implemented in [17] which use oretical analysis and experimental test methods to ensure system efficiency. The various greenhouse monitoring parameters are collected by the system, and the system demonstrate the nodes and network coordinator communications, perform network stabilization, and agree between theoretical data and real situations.

In [18], the author proposed a method to monitor greenhouse environment for various distances. It consists of various sensor and repeat nodes and a single main node, PC terminal, MYSQL database system, an alarm system and a web service. The system senses and monitors the temperature and humidity parameters and compare them with the values stored at the database and web service. A curve is drawn by the web server which depicts the differences from the sensing module. An alarm is triggered if the curve shows the abnormal changes in the temperature and the humidity which in turn helps to take a desired action.

In [19], the authors presented an automatic monitoring system for preventing dew condensation in greenhouse environment. The system consists of sensor nodes, base nodes and relay nodes for collecting, processing the data and for driving the devices inside the greenhouse environment respectively, for data storage and processing. They constructed a physical model which resembles the typical greenhouse to verify the performance of system with regard to control of dew condensation.

B. Water and air quality monitoring

Water quality monitoring includes analyzing the properties of water in dams, rivers, lakes & oceans, as well as underground water reserves. The use of these sensors helps in proper calculation of the status of water, its levels, the various elements like minerals or toxic compounds which are harmful for human as well as for animals and plants. WSN are also helpful in the measurement of the pollution level in the air. This can be done by collecting the readings from the nodes and transmitting them to a gateway and then by visualizing the collected data using statistical and user friendly methods like tables and line graphs, reports can be generated on daily or monthly basis that represents the seriousness of air pollution. Various techniques are been laid in the literature for control of pollution levels in air and water.

The solution to the monitoring of indoor air quality is provided in [20]. In this search, various environmental parameters like temperature, humidity, pollutants, aerosols were determined to check the health of indoor space and represents them in Air Quality Index (AQI) and provides this as an input to the HVAC (Heating, Ventilation and Air Conditioning) System. A toolkit was developed to keep a check on the air quality of the deployed regions in form of graphs and numbers.

A multisensory system, SmartCoast for monitoring the quality of water is presented in [21]. This system aimed at providing a platform that aimed at meeting the monitoring requirements of Water Framework Directive (WFD) across EU. The various parameters included temperature, phosphate, dissolved oxygen, conductivity, pH, turbidity and water level. In this system, the WSN enabled the 'plug and play' capabilities at Tyndall for the integration of the sensors.

In [22], the authors proposed a group of intelligent sensors for observing the water level of the sea. In this system the authors used humidity sensors for accessing the water quality and the sea level. This system was also capable of measuring the humidity level of the sea water at the shores.

C. Glacier environment monitoring

With the constant advancements in wireless technology and miniaturization have made the deployment of sensor networks to monitor various aspects of the environment increasingly realistic. Unfortunately, due to the inventive nature of the technology, there are currently very few environmental sensor networks in operation that validate their value. Various methods or technologies has been developed which has provided a great share in the monitoring of the glaciers like NASA/JPL's project in Antarctica [23], and Huntington Gardens [24], Berkeley's habitat monitoring at Great Duck Island [25],Columbian river estuary described by CORIE project [26], deserts [27], volcanoes [28] and glaciers [29]. GlacsWeb, a sensor network was developed for operation in the hostile conditions underneath a glacier. The main aim of this system was to understand glacier dynamics in response to climate changes. Since the nodes are to be laid down in the glacial environment, they are subjected to constant immense strain and pressure from the moving ice. Therefore, a robust sensor design, integrated with high levels of fault tolerance and network reliability has to be developed

A research project for glacial monitoring, PermaSense which investigates the effect of climate changes on permafrost is well explained by the authors in [32]. It mainly aims at understanding the heat transport in frozen rock walls and its effects on the stability and large scale movements. The system consists of tiny nodes placed on the surface and a computer as a base station running on Linux OS.

N. Burriin [31] provided a MAC Layer (TDMA), topology control and a routing protocol, Dozer which provided nodes with precised wake-up schedules for all communications that only rely on local synchronization. In dozer, the clock drift compensation is the responsibility of receiver node and worst case guard times were used to guarantee a prior wake up of receiver before the transmission is started by the sender.

Elsaify introduced GWMAC, a centralized TDMA protocol in [32] especially designed for networks where contention is completely eliminated and control packets are minimized. This protocol reduces the duty cycle of the nodes to almost zero, allowing only few minutes for communication per day. It is used to synchronize the entire network during booting and each time a command packet is received.

D. Marine environment monitoring

With rapid development of economy and habitat and with their increasing human activities like tourism, urban development, industry, the marine environment has been gradually deteriorating. It is of vital importance and has attracted a great deal of research and development. For the past few decades, various marine environmental monitoring systems has been developed which used oceanographic research vessel which was quite expensive and time consuming. So, WSN has been considered as an alternative for monitoring the environment as it has numerous advantages like easy deployment, unmanned deployment, low cost and real time monitoring. In this deployment, various kinds of sensors are used to monitor and measure various physical and chemical parameters such as water temperature, pressure, wind direction and speed, salinity, turbidity, pH, chlorophyll levels and oxygen density. Various projects has been offered in the literature which aimed at monitoring the marine ecosystem with the use of different protocols like with the use of ZigBee ocean sensing and monitoring was carried out that included various parameters like temperature, pressure, salinity, nitrates, velocity with the use of LabVIEW based user interface using google maps. Some specific efforts has been also made for fish farm monitoring, coral beef monitoring, marine shellfish monitoring.

In [33], the authors presented a system that demonstrated the deployment of novel fiber optic based sensing platform which is capable of monitoring the minute changes in the impurity level of the water. Firstly, the system was validated for the oil in water and then with chlorophyll. Then this system was interfaced with SHIMMER mote to test whether the system was capable of alarming the user of the presence of pollutant in the water.

In [34], the authors proposed adaptive time piecewise constant vector quantization (ATPCVQ) compression algorithm to monitor the environment near the harbor so as to make nearby ships out of danger area. The system was capable of lowering the budget and increasing the lifetime of the sensors.

E. Wildlife

With growing population and search for new habitat, over exploitation of wildlife and forests is carried out. For covering a huge area like forests, we use mobile agents with WSN for multi hop communication. WSN can collect, transmit and store large volumes of environmental data which may be used in research or to refine wildlife management or monitoring. They can also be used in decreasing operational cost of terrestrial wildlife trapping. WSN system provides detailed tracks of targets inside the observed area. These can be used to study animal behavior in some crucial areas with the help of not only cameras but also sensor networks deployed in the surrounding area. An example of WSN application is Zebra Net, used to track zebras on the fields by gathering dynamic data about zebra positions in order to understand their mobility patterns. WSN can be used for monitoring endangered birds in their habitat, to analyze the actual life time of the different species etc.

A. Tovarin [35], reports the study of applying a WSN using DTN (Delay Tolerant Network) to find the current status of White Tail Deer in WMU Area Ontario, North of Parry Sound District of Canada. System is so designed that it is able to obtain highest range with least number of sensors. Further the author simulated the system on Planet Lab Environment to create a DTN network for monitoring the wildlife habitat.

In [36], S. Gaikwad contributes mainly towards the devastating effect of smuggling or theft of forest trees especially sandal woods on the environment. The authors proposed a microcontroller along with WSN based anti-poaching system which is capable of monitoring the theft based on the vibrations produced during cutting of trees. A low power MSP430F5529 microcontroller is used along with Xbee RF modules based on Zigbee to communicate to a central server from a remote place. The data produced due to vibrations by various tests on trees and simulated using Labview.

S. A. Seboin [37] proposed dielectric caps used for wildlife protection. In this work, Fog chamber tests were used to check and to estimate the performance of six different wildlife protection caps, which were positioned on their insulators, and outfitted with the suitable connecting cables. During the evaluation phase, the insulators were exposed to salty fog which used deionized water with appropriate amount of salt added to it. The results showed that only two caps out of six satisfied the expectations.

F. *Radiation sensor networks*

Radiation Sensor Networks helps in radiation prevention by helping authorities and security forces to measure the levels of radiations due to mining activities, nuclear power plants High doses of radiations can be devastating for the environment. In animal's radiations cause's molecules to lose electrons, kill enzymes in the body, damages the DNA, and may even increase the chances of cancer. These radiations also adversely affect the marine life. High levels of UV can cause reduction in reproduction capabilities, reduce the amount of food and oxygen that the plankton produce, can result changes in pollination patterns etc.

In [38], a WSN was designed using a group of radiation detectors with different types of sensors. These sensors were scattered in different areas and each sensors transmits data through to the main control station. The design included Gsm module and GSM modem to determine the location of mobile and fixed station and to transmit the data respectively. In the main control system, GUI software was designed to show the information and status of stations to report any radiation leakages.

G. *Habitat monitoring*

Habitat monitoring is one of the essential part of environment monitoring. Habitat is a place where animals and plants reside and grow. So, habitat monitoring ensures that the species grow without any turbulences in their habitat so that there is no ecological disturbance for plants and animals due to pollution. Various studies show how a system can monitor the pollution affecting the lives of species.

In [39], they proposed a system architecture for seabird nesting and behaviour monitoring. The authors used wireless sensor nodes instead of performing their research physically, to collect the data online without disturbing the birds' life and routine.

In [40], the authors presented a new approach, a tonal region detector (TRD) using sigmoid function. This offered flexibility since the slope and the mean of the sigmoid function can be adjusted independently. After tonal region detection, recognition performance, noise immunity and energy consumption can be improved.

An experimental test-bed for real world Habitat Monitoring System (HMS) was presented in [41], that consist of stationary sensor nodes which were combined with Wi-Fi to collect the physical data of the environment. The test- bed described data monitoring, handling and storing. The sensors can be replaced with the test bed to calculate and monitor air population, forest fire detection, health care and water quality monitoring.

H. *Natural environment protection*

Wireless sensor nodes deployed in the environment helps in detection of forest fires. These nodes detect the flames, heat and gases which are used to identify the molecules of chemical compounds that are generated due to combustion. The networks can also acquire the daily values for temperature and humidity to determine the likelihood of fire. These send an alarm indicating the status of fire, the level and the area under fire.

In study [42], by J. Lloret proposed a fire detection system that uses a wireless local area network (WLAN) together with sensor node technology. The system fixed in wireless mesh network uses multi-sensor nodes with cameras which are IP based to detect the presence of fire. When a fire is discovered by the nodes, the sensor alarm propagate via wireless network to a central server. The closest wireless camera to the multi sensor is selected by the central server, and it transmits a message to it to retrieve real-time figures from the area under detection. The main benefit from this study is that it integrates sensory data with images.

In [43], K. Trivedi presented a technique for the faster detection of forest fires using a mobile agent with the minimum consumption of energy.

V. CONCLUSION

A review of various applications of the wireless sensor networks that contribute towards the monitoring and conservation of the environment and natural resources has been presented. Many such wireless sensor networks based applications have been developed and are contributing to satisfy the cause. The inherent properties of the WSNs make them naturally suitable for such applications. Hence, in future many more such applications shall be coming up.

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