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Forest Monitoring System Using Wireless Sensor Network

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Abstract: **The Wireless Sensor Network is used in the field of automation, home appliances and security. The proposed system enables the integrated use of Mercury Tilt Sensor, vibration sensor, temperature and humidity sensor, pressure sensor and CO gas sensor incorporated into trees for the sensing of events in the natural environment. The wireless RF module enables the communication between the cluster node, the node and the control centre. This helps monitoring and detection of tree theft and disasters like forest fire protecting the natural environment. This article presents the interface and network topology of the wireless sensor network and their advantages.**

***Keywords*—Wireless Sensor Network, cluster node, Tree theft, forest fire, Mercury Tilt Sensor, vibration sensor, temperature and humidity sensor, pressure sensor, CO gas sensor.**

I. INTRODUCTION

The Wireless Sensor Network can be implemented with tree in the forest as node in a network, this approach can bring an interlinked structure with the widespread forest. Integrated sensor units can detect the environmental parameters like temperature, pressure, humidity and gas. The illegal tree cutting and theft can be detected by the combined work of Mercury Tilt Sensor and Vibration sensor. The RF communication unit established by the Zigbee module makes the system network protocol simplified. Each cluster nodes are connected together as a mesh topology and the nodes are connected to the cluster via star topology. Each sensor nodes are carefully hidden into the trunk of tree to protect from access and deactivation though it is literally enhances our detection of the node. The logger increases the recording and recapping of the alert signal developed by the sensor communication node. The use of percentage based sensor response detection also increases the identification of only the desired output neglecting the unwanted usual responses from the natural environment. The provision of alarms and display notification enhances the alerting of the forest guards rather than just video monitoring. The gateway system also increases the shortest path for the data codes to be transmitted in the network. The cc2530 is among the versatile module for the RF based wireless sensing network system. The following sections presents a brief overview of automatic detection and monitoring systems of fire and theft protection in the forest, experience with these systems in practical operation, and their evaluation in terms of efficiency, accuracy, versatility, and other key attributes[1].

II. WIRELESS SENSOR NETWORK

Sensors integrated into structures, machinery, and the environment, coupled with the efficient delivery of sensed information, could provide tremendous benefits to society.

Potential benefits include: fewer catastrophic failures, conservation of natural resources, improved manufacturing productivity, improved emergency response and enhanced homeland security. However, barriers to the widespread use of sensors in structures and machines remain. Bundles of lead wires and fiber optic “tails” are subject to breakage and connector failures.

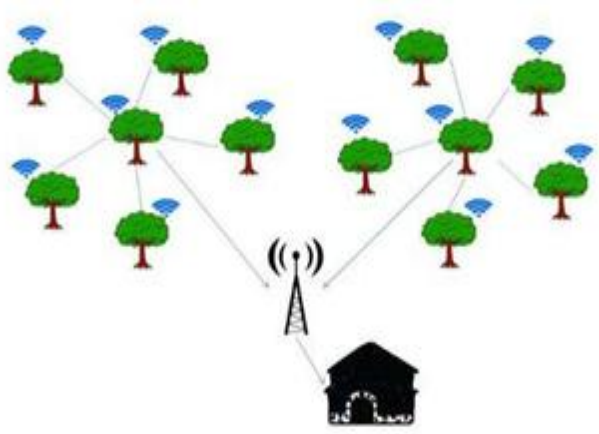

Figure1.Basic Structure of Wireless Sensor Network

Long wire bundles represent a significant installation and long term maintenance cost, limiting the

number of sensors that may be deployed, and therefore reducing the overall quality of the data reported. Wireless sensing networks can eliminate these costs, easing installation and eliminating connectors[2]. The ideal wireless sensor is networked and scalable, consumes very little power, is smart and software programmable, capable of fast data acquisition, reliable and accurate over the long term, costs little to purchase and install, and requires no real maintenance. Battery life, sensor update rates, and size are all major design considerations. Examples of low data rate sensors include temperature, humidity, and peak strain captured passively. Recent advances have resulted in the ability to integrate sensors, radio communications, and digital electronics into a single integrated circuit (IC) package. This capability is enabling networks of very low cost sensors that are able to communicate with each other using low power wireless data routing protocols, as portrayed in figure2.

III. ARCHITECTURE

The architecture of the precision Forest fire detection system based on wireless sensor networks consists of the monitoring nodes, base stations, communications systems, Internet access and the structure of monitoring hardware and software system. from figure2. It proposes a novel network structure which increase system scalability [4]. According to different functions, a large number of the different sensors can be placed in the field and constructed a self-organized network to monitor the value change including temperature, humidity, smoke or gas detector etc. The collection data is send to the sink by wireless mode. The control center can send the control information to any node in the network. Likewise, the remote data could be transmitted to the control center with the sink. The system adopts the cluster topology and hierarchical routing protocols. All sensor nodes are divided to some cluster. Each cluster is equivalent to a relatively fixed self-organizing network. The nodes are divided into the common node and cluster-head node. The common nodes will collect the data which transmitted to the cluster-head node. The data is stored to the database. Expert decision support system processes and analyzes the data at the same time. Sensor node is the basic platform of wireless sensornetworks. The sensor is made up of four parts, sensor node module, the processing module, wireless communication module and the power module. Sensor module is responsible for collecting temperature, humidity, light intensity, smoke and other parameters and data conversion module. The processor module controls the operation of the sensor nodes, stores and processes the collected data.

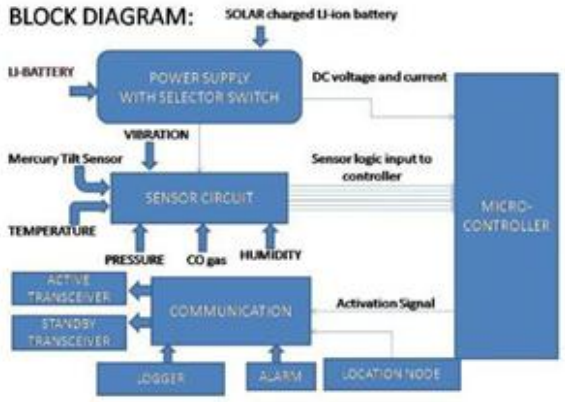

Figure2. Hardware Design

Wireless communication module communicates with other nodes, exchanges control information and sends and receive data. The power modular provides the energy to the sensor module, processing module and wireless communication module.

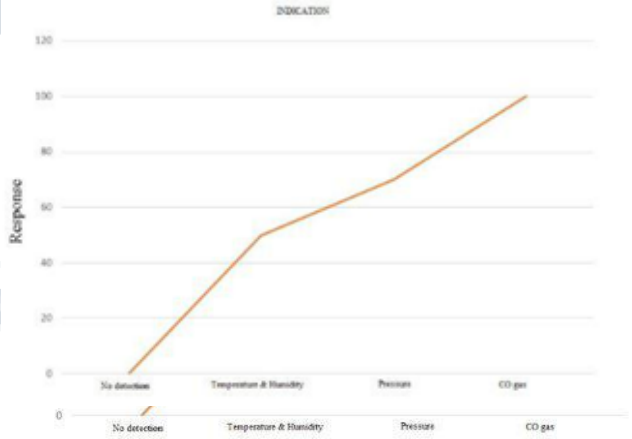

Figure3: Fire Characteristics diagram

A. Fire Hazard Response Condition:

Case1: Temperature and humidity sensor may be activated to contribute 50% of final result as shown in the graph,figure3.

Case2: When the pressure sensor detects an event, it confirms 75% of the fire detection.

Case3: The activation of the CO gas sensor gives a final 100% confirmation of fire disaster.

B. Illegal Tree Cut Response Condition:

Case1: Vibration Sensor activation indicates 50% of probability of a tree cut.

Case2: Mercury Tilt Sensor accompanies the 100% indication of a tree theft.

C. Temperature and humidity sensor

The capacitive humidity and temperature sensors provide digital and fully calibrated output which allows for easy integration without the need for additional calibration, Figure4. The excellent long term stability has been very well perceived and the cutting edge low energy consumption is unachieved and makes them the right choice for any remote application.

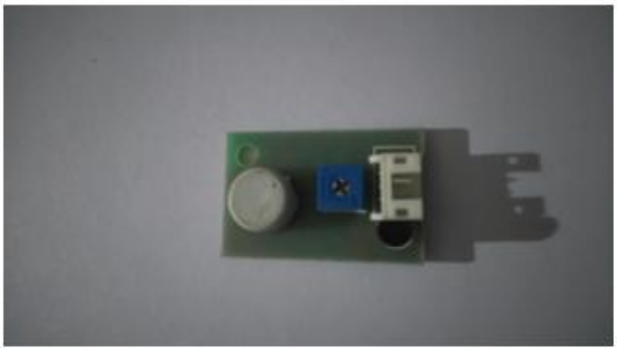

Figure4.Temperature sensor module

D. Optical smoke detector

A smoke detector is a device that detects smoke, typically as an indicator of fire, Figure5. An optical detector is a light sensor. When used as a smoke detector, it includes a light source (incandescent bulb or infrared LED), a lens to collimate the light into a beam, and a photodiode or other photoelectric sensor at an angle to the beam as a light detector. In the absence of smoke, the light passes in front of the detector in a straight line. When smoke enters the optical chamber across the path of the light beam, some light is scattered by the smoke particles, directing it at the sensor.

Figure5. CO gas sensor module

E. Pressure sensor

Pressure is proportional with the temperature and the measurement of barometric pressure improves the correctness of the fire detection. Also their calibration and efficiency is an added advantage to the sensor unit.

F. Mercury Tilt Sensor

The Liquid metal mercury, Figure6 is a good conductor of electricity and this property makes the tilt detection during illegal tree cut. By proper placement of the sensor into the tree trunk, a tilt in position is measured accurately.

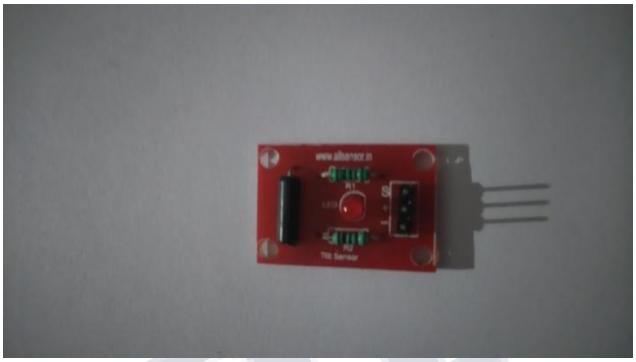

Figure6. Mercury tilt sensor module

G. Vibration Sensor

The force during tree fall if large and this causes an equal and opposite reaction on the tree. The piezoelectric property of the vibration sensor can identify such a huge vibration and indicate a tree cut effectively.

H. Microcontroller UNIT

Microcontroller like CC2530 performs tasks, processes data and control the functionality with other components in the sensor node. This also sends the data to the RF transceivers for the transmission of data to the base station. The microprocessor has a number of functions including:

1. Managing data collection from the sensors
2. Performing power management functions Interfacing the sensor data to the physical radio layer

I. RF transceivers

Zig-Bee is a Technological Standard Created for Control and Sensor Networks based on the IEEE 802.15.4 specification for wireless personal area network .It is a new wireless technology that has application in various fields. Zig-Bee benefits are low cost and Range and obstruction issues avoidance. The main features of this standard are network flexibility, low cost, very low power consumption, and low data rate in an ad-hoc self-organizing network among inexpensive fixed, portable and moving devices.

IV. THE DESIGN OF SYSTEM SOFTWARE

A. The Software Architecture

The software architecture of sensor node is divided into embedded OS kernel layer and API layer. Embedded module provides tasks, power management and communication protocol [5]. The kernel also provides a low-level node driver of all hardware devices. API layer provides sensor acquisition module and RF communication module. The software architecture of sensor node is shown in Figure 5.

Task debugging module controls the control flow throughout the operating system, which is mainly responsible for the initialization of the wireless sensor and the maintenance of the operating status.

The software architecture of sensor node is shown in Figure 7. Task debugging module controls the control flow throughout the operating system, which is mainly responsible for the initialization of the wireless sensor and the maintenance of the operating status.

The power management module supports processor, RF transceiver, sensors and other parts of the state control of energy consumption [6]. Energy management is able to ensure that nodes wake up at the right time, run in the low-power mode and maximize the use of energy.

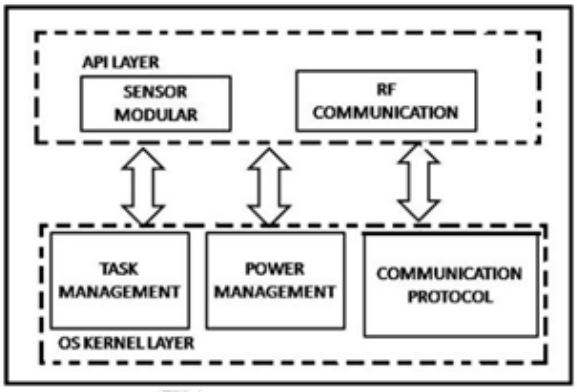

Figure7. The software architecture

B. The Function of WSN Protocol

Wireless network communication protocol provides the wireless communication standards between the cluster-head nodes and nodes [2]. It achieves registration, sleep the node, data acquisition, device controller, parameter settings and debugging.

1) ***Registration:-*** When the nodes work on, the noderegisters MAC to the cluster-head node and accesses to the network subnet number. It is assigned to a node ID.

2) ***The Node Sleep***- The cluster-head node sends a datapacket to notify the next node sleep time.

3) ***Data Collection:-*** According to testing requirements, thecluster-head node assigns the task of data collection, such as temperature, humidity, light intensity and gas concentration.

4) ***Equipment Control****:* The cluster-head node analyzes thedata and makes decision. The packet of control instructions is sent to the node

5) ***Parameter Settings:*** The cluster-head node sends themodified equipment parameters to the child nodes.

6) ***Debugging:*** It is the equipment development and debugging functions.

Since only the active transceiver is active always and the standby transceiver usually is switched only when the controller is triggered due to any event detection, such type of WSN protocol normally requires a minimal need for power supply to their working. It can be easily achieved by the use of CC2530 based Zigbee module for the process of packet transfer. Thus an effective communication is setup between the control room and the cluster nodes and simultaneously with the adjacent nodes.

C. Wireless Sensor Network Protocol Stack

Software component is the gateway and sensor nodes. The function of gateway software is processing and management data from sensor nodes [5]. It mainly consists of the serial port communications software, RF communications software, command software and task management software.

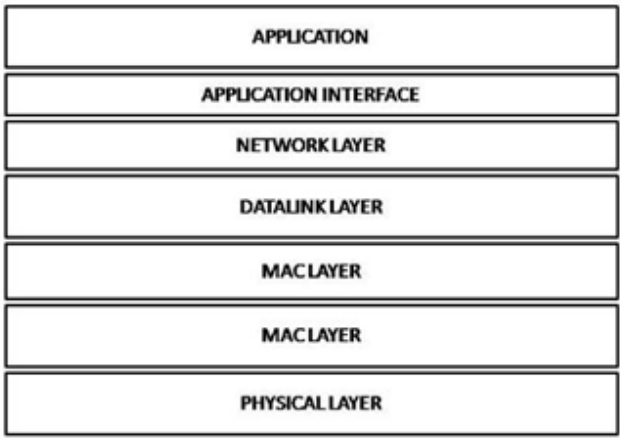

Figure8. The protocol structure

The software of sensor node is to receive the instruction from the cluster-head node and send the data to the sensor gateway [1]. In Fig.8, the wireless sensor network protocol stack consists of the physical layer, medium access control layer, network layer and other components Application interface provide a simple software interface including the application sub-layer and

device object, so the application layer achieves the management of the equipment.

V. POWER CIRCUITS

The power circuit, Figure9 for the entire network is an independent source and hence no intervention can be made by any external disturbances. An active and standby Li-ion rechargeable battery charged by the solar panel makes the system more environment friendly.

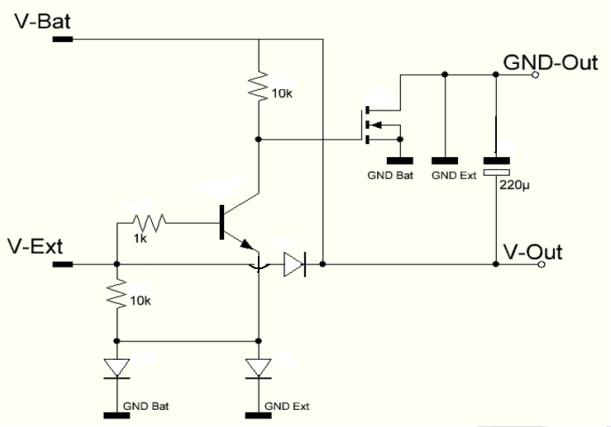

Figure9. Supply Selector Switch

A power supply selector switch is provided to help the discharged battery to be charged while the standby supply keeps the network alive. It can be understood from the diagram as shown in the figure 7 below. Since the sensors used in the system are integrated and highly manufactured for limited power consumption, the 12V output from the charged Li-ion cell can effectively contribute towards the provision of DC output to the controller, communication module, sensor modules and the accessory circuits.

VI. PROSPECT AND CHALLENGE

In the Forest fire monitoring system, all nodes always work under the adverse environmental condition, so they are different from the design of the traditional sensor network. Due to a larger monitoring area of forest , the sensor network has a large number of nodes while it ensures the cost of the network[1]. The nodes will be scattered in various regions to achieve a comprehensive monitoring on forestl field. Because the sensor node energy is limited, the possibility of node failure is very large. The monitoring system must solve the reliability problem. The lifetime of WSN depends on the failure of the sensor node. In short, the forest fire monitoring system must solve the following problem:

A. The Large-scale High-density Network Structure

The requirement of monitoring material movement in geographical space is intrinsic motivation of the sensor networks. Compared with the traditional mode base on radar or satellite, WSN has some unique technical advantages on a distributed multi-dimensional and multi-angle information processing [4]. It can significantly improve the signal noise ratio, reduce the possible exploration in the region, and eliminate shadows and blind spots. The network nodes must be a large-scale, high-density deployment method to keep monitoring the area coverage and connectivity. The availability of a disturbance or hindrance free environment is impossible under the natural environment which is to be balanced. A large number of nodes in the network will inevitably increase the cost which will affect the network in the practical application. The premise of agriculture application is to design an available and economic deployment mechanism for WSN.

B. *Data Processing and Node Energy*

Communication is the maximal energy consumption. Each node has data independent processing ability. It reduces network transmission cost by processing and extracting the original data. A well-designed network networking, data transfer and data integration algorithms are important to the lifetime of the network. The use of RF transceiver must be accurate and scalable. High consumption of the supply is an undesirable quality of any working real time system.

C. The Network Redundancy and Tolerance

The validity and accuracy of data in agricultural monitoring system is very important. The optimization of node distribution is studied to reduce the energy consumption and ensure the effective information acquisition in wireless sensor network. The error signals generated from the sensor nodes are more frequent and their detection by the control centre is one of a tedious process yet to be solved. Network fault tolerance includes node failure detection and failure recovery. If each node has the portable GPS devices, it will inevitably increase the cost of the entire network [6]. How to balance between the costs of network configuration and node failure detection is a problem to be solved. Node failure recovery adopts the replacement of the general failure of redundant nodes, but it needs to design the number and the location of redundant nodes.

VII. MESH TOPOLOGY

The Mesh topology can rely on messages using routing techniques. A Mesh network whose nodes are all connected to each other is a fully connected network. The fully connected wired networks have the advantage of security and reliability. The single data that is passed during an event to the other nodes makes the control centre easy to retrieve it from the most nearby WSN node. It can be pictorially represented as shown in the figure10.

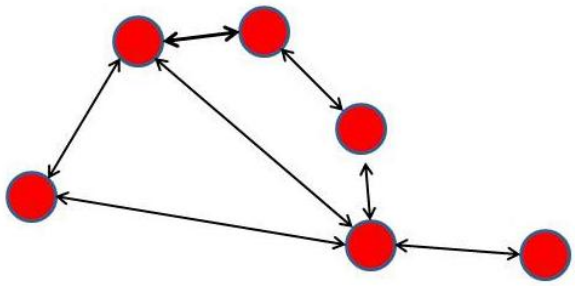

Figure10. Mesh Topology Representation

VII.STAR TOPOLOGY

A connected node is to which all other nodes are connected independently. This central node provides a common connection point for all nodes through the hub. Star topology reduces the damage caused by line failure by connecting all of the systems to a central node.

In star network, the data transfer is very reliable because even if one computer or its connections breaks, it doesn't affect the other computer and their connections. It can be understood from the representation Figure11 below.

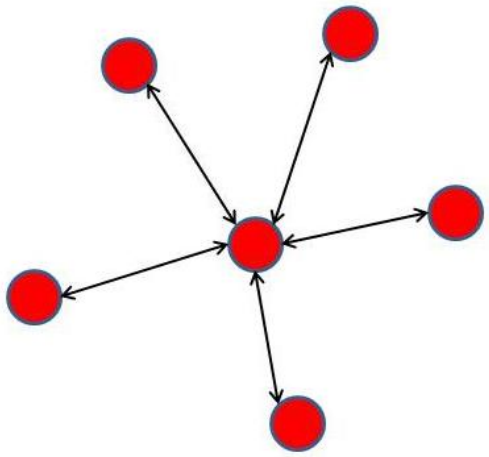

Figure11. Star topology Representation

IX. COMPUTER SIMULATION

The data representing the output from the sensor unit is efficiently passed to the adjacent nodes within its range and they terminate this specific data code from a particular node to the control centre receiver tower. This message can be interpreted in the form of a connected network with the affected node indicated by an alert color change. The pictorial representation of the healthy and the affected nodes are represented in the computer as shown in the figure10 below. A 250m square area can be effectively segregated into five equal blocks with 4 sensor nodes per 100m diameter. The 'RED' color is indication of any response from the integrated sensor action and the 'GREEN' is for normal operation of the nodes. Such an arrangement can ensure the reliability of the overall system. When a node fails in the network, it is also seen in the computer. But this does not disturb the system action, because any break in the data passed takes a diverted path through the nearby nodes and it can accurately terminate to the control center. The visual and the alarm based indication enables the system utilization by any language speaking people.

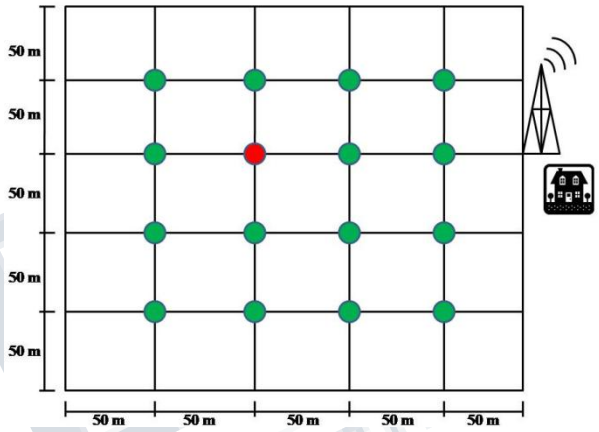

Figure12. Pictorial representation of the network

X.AREA OF INTEREST

The major area of implementation of such system of fire and illegal tree cut are more prominently requiring attention in the following reserved areas.

1. Yellow stone national Park(timber)-USA.
2. Southwestern Ghats moist forest-India.
3. Eastern Deccan Plateau forest-India.
4. Naga-Manipuri- chin hill forest.
5. Sundarban National Park.
6. Dixie National forest in Uttar Pradesh.
7. Gifford Pinchot National forest (Washington).
8. Oconee National Forest-Georgia.

It is only a few listed above, but it is there are vast region under the prone of destruction necessary to be safe guarded from the verge of extinction.

XI. RESULT

This project is designed with the hardware and software based on WSN protocol which includes Sensors such as temperature, smoke, humidity along with the processor CC2530 and Zigbee as a RF device. We have tested on field and taken reading of above parameters which is transmitted to base station where data logging is

done day -wise. Our hardware works on battery operated system, in future we will use solar power for the same. The forest fire monitoring system was developed which detects fire in the forest and the theft monitoring system to determine and inform about any probable illegal tree cut at the reserved forest area. The real time sense data is recorded in database and this is available for reference any time in the memory.

XII. FUTURE EXPANSION

The innovation will be inevitable if the system is of advantageous to the society. On further more integration with this WSN technology, we can enhance the digital automation to a next level by incorporating GSM based mobile message passing system to the concerned officials in the forest protection force. Additional sensors like light sensors and panel adjusters can also be provided for the efficient utilization of the solar power for the system operations Another research in this field is on RF to DC based power conversion and the use of much developing technique of bio- electrical which makes the system more economical, sustained and more reliable.

XIII.ADVANTAGES

The following are the major advantages in the field of WSN for forest management system.

1. Automatic Forest management system.
2. Audio and Display based alert mechanism.
3. Interlinked and enhanced connectivity over a large area.
4. Prohibiting and identifying illegal tree cut or theft.

XIV. LOGGER

A data logger is an electronic device that records data over time or in relation to locate either with a built in instrument or sensor or via external instrument and sensors.

Data loggers are implicitly stand-alone devices, while typical data acquisition system must remain tethered to a computer to acquire data. Data loggers typically have slower sample rates. One of the primary benefits of using data loggers is the ability to automatically collect data on a 24-hours basis. Upon activation, data loggers are typically deployed and left unattended to measure and record information for the duration of the monitoring period. This allows for a comprehensive, accurate picture of the environmental conditions being monitored, such as air temperature and relative humidity.

This unattended nature also dictates that data loggers must be extremely reliable. Since they may operate for long periods nonstop with little or no human supervision, and may be installed in harsh or remote locations, Its is imperative that so long as they have power, they will not fail to log data for any reason. Manufactures go to great length to ensure that the devices can be depended on in these applications. As such data loggers are almost completely immune to the problems that might affect a general-purpose computer in the same applications, such as program crashes and the instability of some operating systems.

XV. CONCLUSION

This paper has described the design and implementation of a wireless sensor network for forest fire detecting and theft monitoring system. Forest fire has multidimensional negative effects in social, economic and ecological matters. It is difficult to say that firefighting can be successful without enough data about fire such as direction and speed etc. The more data about forest fire means the more effective fire management and illegal tree cut. Firefighting is well known to be a costly task.

It is wise to invest in early warning systems which are definitely much less costly on the whole. WSNs are thus the right choice and the least costly of all surveillance and early detection systems. Solar based renewable power supply is also an developing field in research that can improve the WSN supply of remote notes. The ongoing research in wireless sensor networks is promising that cost effective systems shall immerge for forest fire sensing and detection applications. Finally, we conclude that wireless sensor network is a very powerful and suitable tool to be applied in this application.

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