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Early Detection of Forest Fire Using Wireless Sensor Network

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Abstract

Wireless sensor network have a broad range of applications in the category of environmental monitoring. In this paper, the problem of forest fire is considered and a comprehensive framework is proposed for the use of wireless sensor networks for real-time forest fire detection and monitoring. The wireless sensor network unlike that of traditional approaches, can easily forecast forest fires before the fire is spread uncontrollable. This framework includes proposal for designing of sensor node and data transmission process. Thus multiple environmental parameters like temperature, humidity and presence of flammable gas are measured & monitored here for the efficient prediction of forest fire.

Keywords—wireless sensor network, BTBee module

I. INTRODUCTION

Wireless sensor network consist of large number of sensor nodes densely deployed in the environment, which collect data and disseminate the collected data towards sink. This concept of wireless sensor network has been attracting many crucial applications where manual involvement of humans is difficult. As forests are part of the important and indispensable resources for human survival and social development that protect the balance of the earth ecology. However, because of some uncontrolled anthropogenic activities and abnormal natural conditions, forest fires occur frequently. Thus forest fire is a fatal threat throughout the world. It is reported that for last decade, each year, a total of 2000 wild fires happened in Turkey and more than 100000 in all countries [1]. However, the prevention and monitoring of forest fires has become a global concern in forest fire prevention organizations. Currently, forest fire prevention methods largely consist of observation from Lookout towers and lately satellite monitoring [2]. Although observation from Lookout towers is easy and feasible, it has several defects as difficult life condition at lookout towers and unreliability of human observations. This led the development of several technologies studied aiming to make the fire fighters aware of the forest fire as early as possible. Some important technologies and systems that are currently used towards this goal are: employing charged coupled device (CCD) cameras and Infrared (IR) detectors, satellite based monitoring systems and wireless sensor networks. In case of charged coupled device (CCD) cameras and IR detectors based system, the accuracy of the system is affected by weather conditions such as clouds, light reflection and smoke from various activities. Moreover, the unclear sight view in case of large forest fields and technical incapability restrict the effectiveness of such systems. Another alternate technology for the forest fire detection is the use of satellite based monitoring [2].Current satellite based forest fire detection system use the data gathered by two satellites; Advanced Very Resolution Radiometer(AVHRR) which was launched in 1998 and Moderate Resolution Imaging Spectroradiometer(MODIS)which was launched in 1999[3]. Given these shortcomings of traditional approaches, a sensory information technique is presented in this work. For this, BTBee wireless sensor network is discussed and explain its application as a monitoring system [4, 5]. This system can monitor environmental parameters causing forest fire, i.e. temperature, relative humidity and the presence of combustible gases and send the data immediately to the observer of the monitoring center. The collected data will be analyzed and Compared with the normal meteorological information to make a quick assessment of a potential fire danger at remote location.

Three factors compose the basis of a forest fire: the fire source, environmental elements and combustible material. A forest fire usually occurs as the result of their combined effects. According to the Canada Fire Weather Index Forecast Model [2], the moisture content of the combustible material and presence of flammable gases plays an important role in forest fires. Therefore, the moisture content of combustible materials is a major point of assessment and predicts whether a fire will take place. The moisture content has much to do with relative humidity in the atmosphere, air temperature, wind and similar factors. Water evaporation can be directly affected by relative humidity. At the same time, the physical properties of combustible materials can be changed indirectly by air temperature. Thus, relative humidity and air temperature are regarded as the two main factors which affect the moisture content of the fuel. And also the presence of flammable gases provides another measurable parameter for this system. Fig 1, represent complete system as:

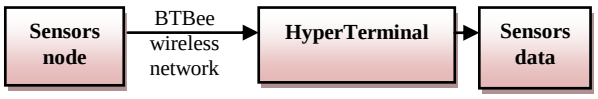

Figure 1. Proposed framework

Therefore, to reflect the moisture content indirectly, these two parameters are the main objects of our investigation, which should provide an important basis for the prediction and monitoring of forest fires. Certainly, forest fires are also caused by other factors, such as the active lightning above the forest, human factors, etc. However, these factors will be ignored in this discussion.

A. Wireless sensor network

A wireless sensor network, which combines computer and Communication technology with the technology of a sensor network, is considered to be one of the ten emerging technologies that will affect the future of human civilization. This network is composed of numerous and ubiquitous micro sensor nodes which have the ability to communicate and calculate. These nodes can monitor, sense and collect information of different environments and various monitoring objects cooperatively [6]. BTBee is a low-rate, low-cost and low-power kind of short range wireless network communication protocol. Compared with other wireless technologies, BTBee has unique advantages of safe and reliable data transmission, an easy and flexible network configuration, low equipment costs and long-lasting batteries. Thus, it has great development potential and a promising market application in the field of industrial control. By applying a wireless sensor network based on BTBee to a forest fire monitoring system, information such as temperature, humidity and presence of combustible gases at any part of the forest covered by the network could easily be collected, dealt with and analyzed at any time. In addition, the system can be extended significantly, the cost of equipment maintenance could be reduced and the whole system could be optimized.

B. Senor network communication architecture

A BTBee wireless sensor network system includes sensor nodes, gateways (routers) and a monitoring host computer. Sensors nodes are fitted with microcontroller of low processing capacity are distributed randomly in the forest and nearby areas to collect fire monitoring parameters such as combustible gases, humidity and atmospheric temperature. The Arduino Mega 2560 microcontroller board based on ATmega 2650 is used in this work for processing purpose. Then data collected from sensor field is transmitted to its own cluster head by an ordinary bottom node. Via the cluster head, data collected by ordinary bottom nodes in the cluster can be fused and transmitted to the nearest network coordinator. Routers transmit the data to the monitoring host computer via BTBee, which provides a decision-making basis for forest fire.

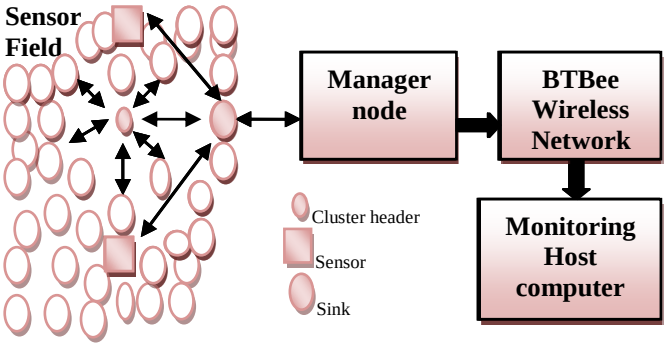

Figure 2. BTBee based wireless sensor network

C. Structure of the sensor node

The sensor node is a basic unit and platform of the wireless sensor network. A sensor node is commonly composed of four modules: sensing module, a processing module, a transceiver module and a power module [6]. In Fig 3, the structure of the sensor node for the proposed framework is shown.

The Sensing module are usually composed of two subunits: sensors and analog to digital converters (ADCs). Three sensors: Rht03, MQ-2 and Lm35 are used in the proposed framework for collecting parameters such as humidity of the atmosphere, presence of combustible gas and air temperature. Also we need not to use the analog to digital converter separately as all such functions are already assembled in single Arduino Mega 2560 microcontroller board.

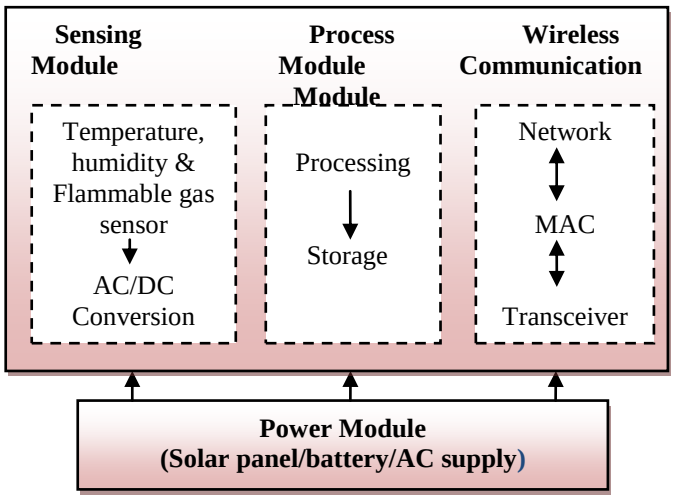

Figure 3. The components of a sensor node

Since, the processing module is responsible for controlling the operation of the whole sensor node and saving and coping with data collected by its own node. Therefore, Arduino Mega 2560 board is responsible for the processing.

The wireless communication module is responsible for communication and exchanging control information and receiving or transmitting

data. In this system Bluetooth module (BTBee) serves as wireless communication module. Since Arduino Mega 2560 microcontroller board lacks wireless transmission, thus wireless SD shield is used along with it. The wireless shield contains BTBee socket for wireless transmission of data and an additional SD card slot for storage of collected data [7].
The power module supplies power for the other three modules and drives the nodes, making it the key factor for the effective operation of the network. The power supply can be given using battery or from solar panel.

II. SYSTEM HARDWARE DESIGN

The hardware design of sensor nodes is the basis of the wireless sensor network structure. Fig 4 shows the circuit principle of a sensor node. An Arduino Mega 2560 is the core board used in the hardware design of nodes. It is a SoC CMOS chip, embedded with a high performance and low-power microcontroller chip 8051, an integrated ADC of 14-bit analog-digital conversion and a 2.4 GHz RF wireless transceiver that conforms to the IEEE802.15.4 standard. This chip has good wireless receiving sensitivity and excellent anti-interference performance.

RHT03 is a digital relative humidity and temperature sensor. It together applies digital-signal-collecting-technique and humidity sensing technology, assuring more reliability and stability. Their sensing element is polymer humidity capacitor.
It is small in size & has low consumption & long transmission distance (100m) which enable RHT03 to be suited in all kinds of harsh applications. Single-row packaged with four pins, making the connection very convenient. It operating range is humidity 0-100%RH; temperature -40~80Celsius and accuracy is about humidity +-2%RH (Max +-5%RH); temperature +-0.5Celsius [8].

LM35 are precision integrated temperature sensors whose output generates in form of Celsius. These provide accuracies of ±1⁄4°C at room temperature and ±3⁄4°C at +150°C temperature range and works on 60 µA [9].

MQ-2 is flammable gas sensor which detects the concentration of combustible gas in the air (atmosphere) and provides the output in form of voltage signal. Measures the concentration of flammable gas of 300 to 10,000 ppm. Operates at temperature range from -20 to 50°C. Sensor carrier with sensitivity-setting resistor (10kΩ) required for interfacing and working with sensor node. Resistive load between the supply voltage and ground select the sensitivity of the sensor. The main advantage of using this is low power consumption with the required current is 150 µA [10, 11].

Now for the wireless transmission of sensor node data BTBee is used, it is an easy to use Bluetooth Serial Port Profile (SPP) module compatible With existing Xbee sockets, and designed for transparent wireless serial connection. Bluetooth module (BTBee) is fully qualified Bluetooth V2.0+EDR (Enhanced Data Rate) 3Mbps Modulation with complete 2.4GHz radio transceiver and baseband. It uses CSR Blue core 04-External single chip Bluetooth system with CMOS technology and with AFH (Adaptive Frequency Hopping Feature). It transmits +40dBm RF power with typical sensitivity of -80dBm.

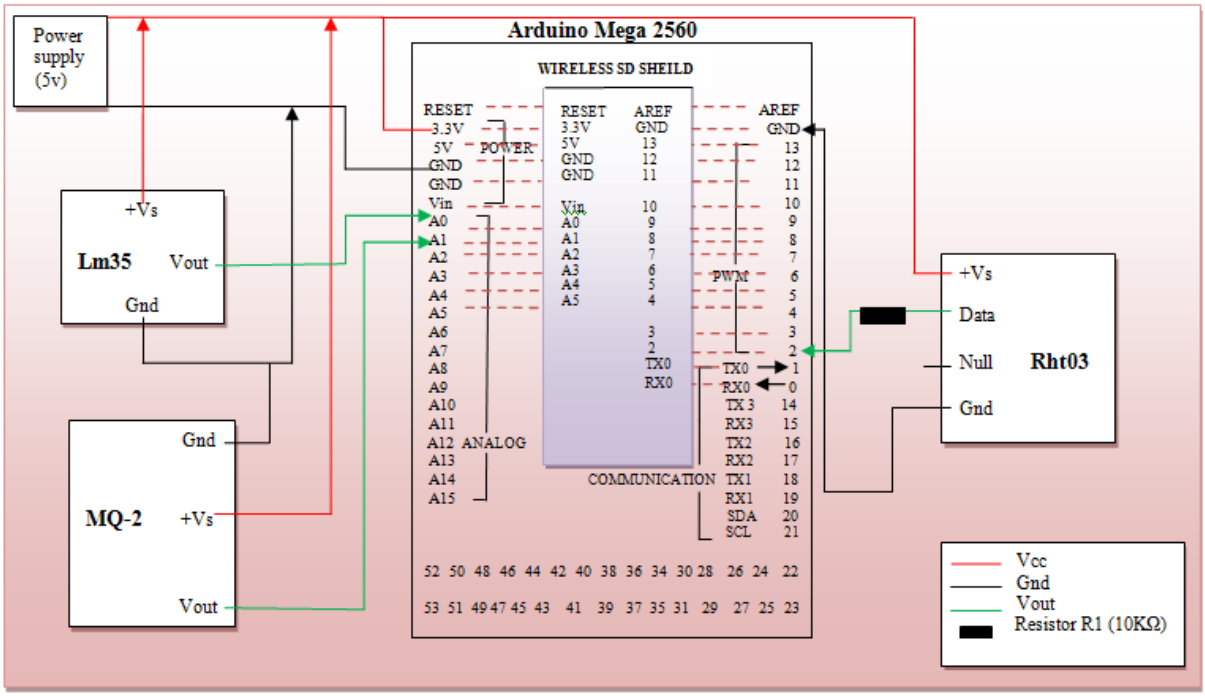

Figure 4. Circuit diagram of sensor node

III. DATA TRANSMISSION PROCESS

A sensor node is being designed with Arduino mega 2560 as a controller board and the combinations of three sensors. There is a need to transmit the sensors data wirelessly to the host computer, so BTBee module is used for this purpose.

A. Working with Arduino environment

The Arduino is different from the traditional data acquisition system and need special programming skills. It works on IDE (Integrated development environment) and required basic knowledge of embedded C [11]. Acquiring real time sensor data is a critical task or to configure the three sensors, one digital and two analog and calibration required a high skill of programming. For this wireless transmission of sensors data Arduino IDE is used for programming the controller board. Embedded C is used for programming with some dedicated commands for Arduino. Arduino provide the facility of variable baud rate, here we use the standard baud rate of 9600 and COM7 is configured for the initial configuration of Arduino and then for wireless transmission hyper terminal is used which act as virtual port. Initialization process starts with the CT command

B. BTBee based wireless data transmission

There is a requirement to transmit the data wirelessly to the remote location. So, BTBee is used here for the same. Configuring BTBee for this work requires the deep knowledge of network topologies. So For this work yet another Software HyperTerminal is used, which facilitate the virtual terminal port [12] and used as shown in Fig 5.

To deliver data transmission inside the BTBee network in this design, a system of active requests for information by the monitoring host computer and passive responses by the sensor nodes is used. Fig 6, shows the data transmission process. When the monitoring computer, operated by a authorized experience person, sends an order to inquire about the state of forest temperatures, humidity and the level of combustible gases and the order is transmitted to the router via the internet. The router then scans the routing tables according to the order and decides the target coordinator, which then broadcasts in the attached cluster branch to activate the target cluster head. After receiving the data collected and sent by the nodes, the cluster head integrates and returns the data to the monitoring host computer along the original line. If the target network is not found or not connected, the cluster head will desert the data packet and generate a report to the monitoring host computer. Most nodes in the system are in dominant state to save energy and extent the lifetime of network. Also provide by solar panel for minimum utilization of energy.

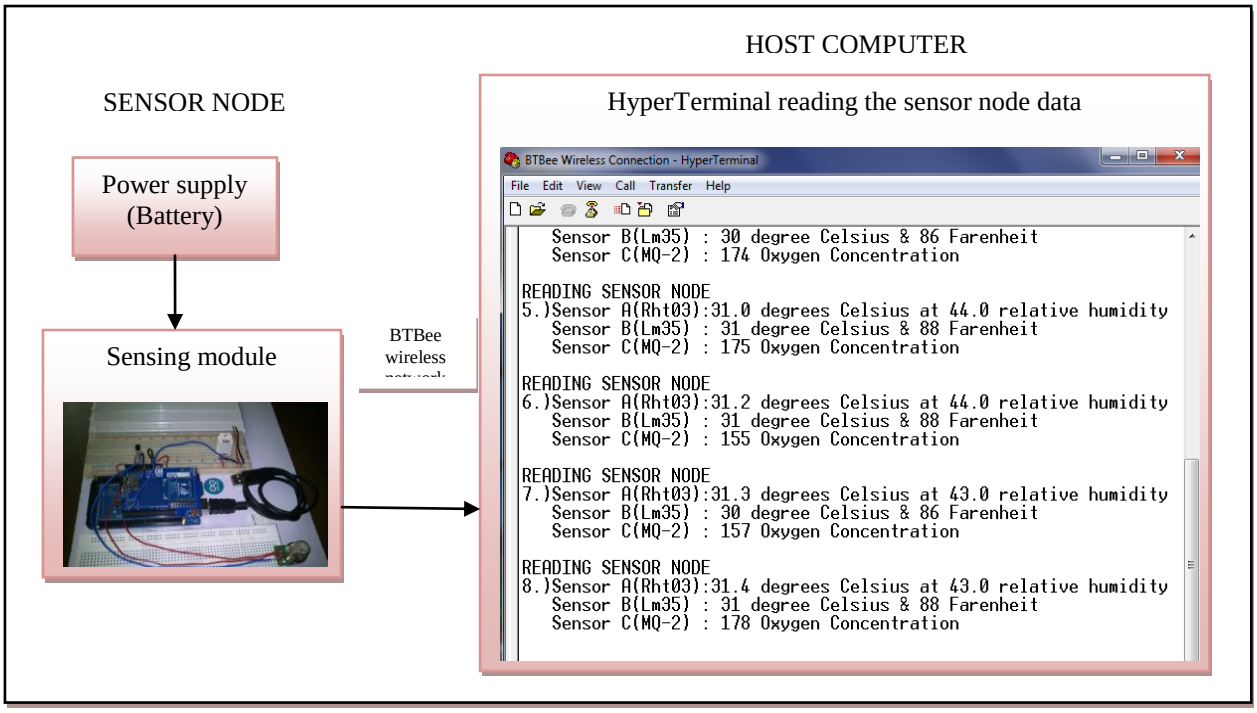

Figure 5. HyperTerminal used as virtual port

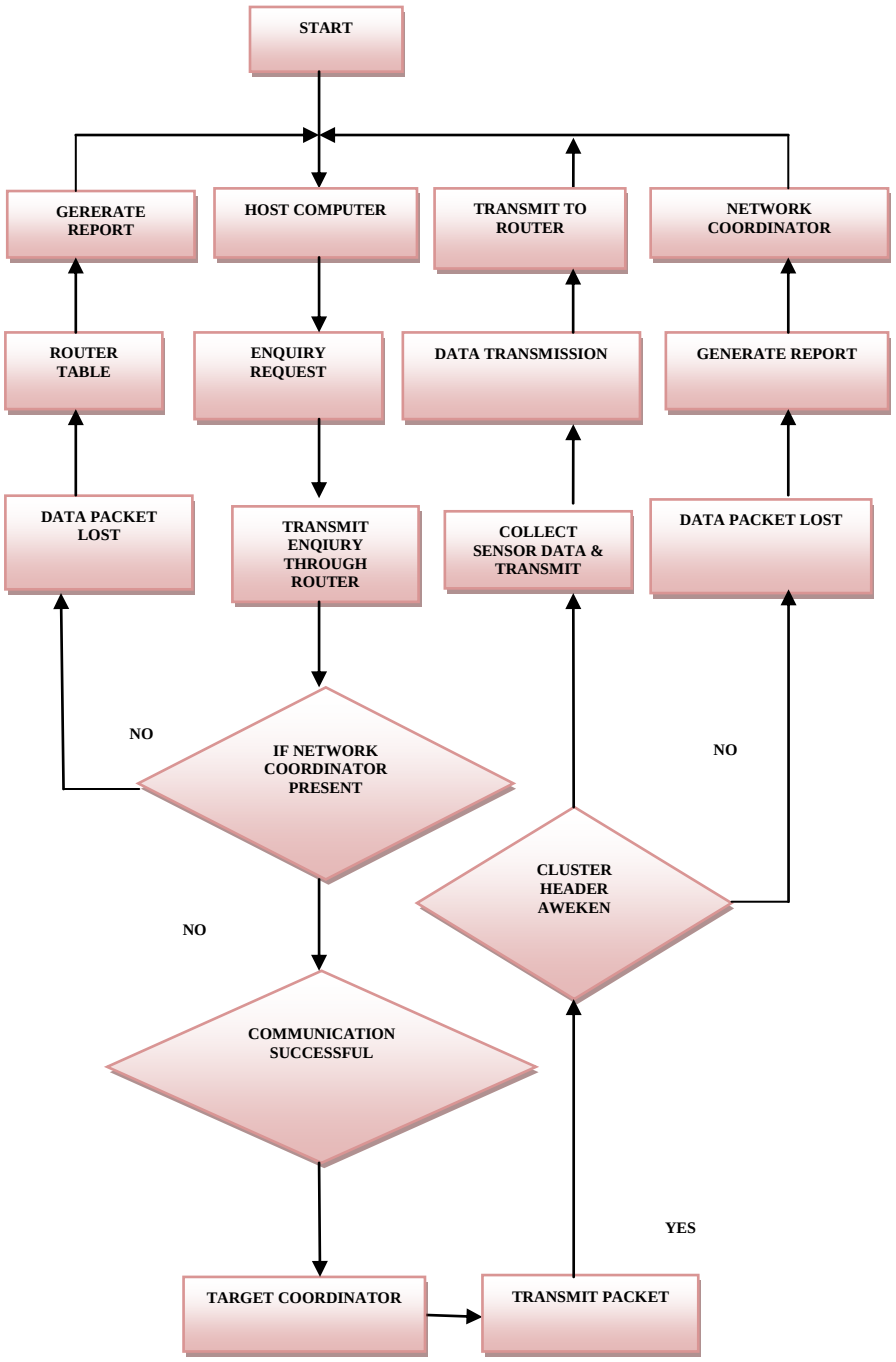

Figure 6. Flowchart for the data transmission process

IV. CONCLUSION

As per the proposed system and sensor nodes that have been designed, it is investigated that wireless sensor network can be effectively applied to the environmental and habitat monitoring. Especially they are best suited for difficult and harsh environments, disadvantages of traditional monitoring system has been overcome by the use of WSN. In addition, wireless sensor technology has a broad application in the field of real-time forest fire monitoring. To monitor temperature, humidity and the presence of combustible gases in the forest in a more timely and precise way, this work pointed out unique advantages of safety in data transmission. Flexibility in building the network, low cost and energy requirements for a forest fire monitoring system based on a BTBee wireless sensor technology that is designed here. The Network topology structure of the system is of a cluster-tree structure. In other words, here proposed system is as a first attempt and complement to existing forest

fire monitoring and prevention methods. It provides a solid basis in terms of hardware for the application of advanced wireless sensor network technology. Although it required the knowledge of network communication but once it implemented then it's easy to understand. Arduino as data acquisition board make the system more robust and facilitate the proper utilization of environmental parameters for monitoring. Use of combustible gas as a monitoring parameter provides us the different approach to predict the forest fire by estimating weather index. Overall the system can easily detect the forest fire more promptly then traditional approaches [2]. Further, the clustering of captured data can be done using ANN classifier techniques.

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