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WSN based Forest Fire Detection System

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Abstract. Forest is a major part of the global, ecological, environmental, and recreational system. It has a huge impact on amount of greenhouse gases, atmospheric carbon absorption, and reduction of soil erosion. It directly modulates the temperature and regulate amount and nature of rainwater. To a large extent, forest fire is one of the most dangerous natural hazards that occur in practically in all countries worldwide affecting physical, biological, and environmental consequences. An advanced technology, Wireless Sensor Network (WSN), is nowadays getting more importance and has started application in forest fire detection. The Wireless nodes integrate on the same PCB, the sensors, the data processing, the wireless transceiver, and they all run by the same source- batteries. Unlike cell phones, WSN do not require recharging periodically. The sensors used here, are device for sensing their environment and computing data. The sensors sense physical parameters such as the temperature, pressure, and humidity, as well as chemical parameters such as Carbon Monoxide (CO), Carbon Dioxide (CO_2) and Nitrogen Dioxide (NO_2). The sensors operate in a self-healing and self-organising wireless networking environment.

Keywords. Wireless Sensor; Network; Forest; Fire

1. Introduction

Global mankind is so unfortunate that the forest fire is commonly observed only when it has already spread abruptly over a large area, making its control and stoppage arduous, and often even nearly impossible. The result is a devastating loss of enormous lives and property and additional irreparable damage to the ecology (huge amount of smoke and harmful gases such as carbon dioxide (CO2), carbon monoxide (CO), etc. in the atmosphere). Some unavoidable dreadful consequences of forest fire are such long-term devastating effects on the local weather pattern, global warming, annihilation of rare species of the flora and fauna, etc. Most important problem of forest fire control is that the forests are usually remote, abandoned, unmanaged areas full of trees, dry and parching wood, and leaves etc. which form a highly combustible agent and represent the perfect medium for fire ignition and also as fuel for later stages of the fire. The fire ignition could be caused through human actions, like smoking or barbeque parties, or by natural reasons such as; high temperature in a hot summer day, or a broken glass working as a collective lens focusing the sun light on a small spot for a length of time thus leading to fire ignition. Once ignition starts then the combustible materials may easily fuel to feed the fire central spot. The spot then grows bigger and wider. The initial stage of ignition is

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normally referred to as 'surface fire' stage. This may then lead to gulp the adjoining trees and the fire flame grows rapidly.

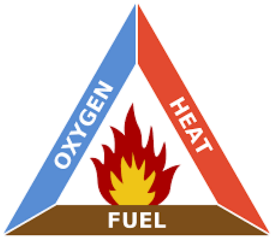

Figure 1. Fire Factors Triangle

According to Burati et al. (2009), a WSN can be defined as a network of devices, denoted as nodes, which can sense the environment and communicate the information gathered from the monitored field (e.g., an area or volume) through wireless link. The data is mostly forwarded via multiple hops, to a sink which can use it either locally or is connected to other networks (e.g., the Internet) through a gateway. The nodes may be stationary or moving and can be aware of their position or not. They can be homogeneous or heterogeneous [1]. Forest fire detection and prevention is another challenge in numerous countries. Different process for monitoring the emergence of fires have been proposed and initiated as well. The earlier methods were based on mainly watch towers, but this technique was inefficient and unsuccessful. Subsequently, camera surveillance methods and satellite imaging technologies were implemented but this also proved ineffective to efficiently monitor the ignition of the surface fire. For example camera networks can be installed in different positions in the forests but these provide only some sight pictures which again might be affected by weather situation and/or physical obstacles. Satellite images turn to be more efficient than camera surveillance, where images captured and accumulated by two satellites. The Advanced Very High Resolution Radiometer (AVHRR), launched in 1998 and the Moderate Resolution Imaging Spectro-radiometer (MODIS), launched in 1999 have been used for this purpose [2]. Unfortunately, these satellites can capture images of the regions of the earth every two days which is a bit longer time for fire scanning, besides the quality of satellite images can are dependent on present weather condition. The revolution of WSN technology in recent era has made it possible to use this technology with a potential for prior forest fire detection. These sensors required to be self organised and follow an efficient algorithm, interfaced with different technologies or networks. Several studies have been investigated using WSN in wood fire systems. Doolin et al [3] experimented with 10 sensors provided with GPS device, to sense temperature, humidity, pressure and feed these data back to the sink. The drawback of this system is that the distance between sensors is too far (approximately 1km), in case of node failure a connection between some sensors and the sink may be lost and that could leave a gap in the network. Lloret et al [4] suggested implementing a mesh network of sensors attached with internet protocol (IP) cameras. Here the sensors identify the fire at the beginning and transmit an alarm signal to the sink. The sink then sends a message to switch on the cameras in the same area of the detected fire to collect real images of the fire at any moment. Hartung et al [5] used WSN for wood fire detection in hybrid mode with web cameras. The main objective of their studies was to investigate the fire behaviour in forests. They used WSN to gather live data for weather status and web cameras to provide the real images of the fire. Son [6] proposes a project for fire detection in South Korea using Camera surveillance with WSN in hybrid. They propose a clustered topology for the whole network. Each cluster a head node to do some calculations, for example, fire risk level by measuring temperature, humidity, and some other relevant parameters. Additionally, there are routing, and data aggregation tasks included within their algorithm. In this method power consumption rate increases in each head nodes, besides they do not count the power balancing issue, which may result in some sensors deactivating before others, leading to coverage gaps. Hafeeda et al [7] presents a very smart system. They place their network action on fire weather index (FWI). This index covers the probability of fire ignition and fire spread rate as well. FWI provides the moisture content in relation with the weather observation where the fuel code explains the soil content of forest ground.

Let us concise a definition for fire forest [8]: Combustion is a complex process in which fuel is heated, ignites, and oxidizes rapidly, giving off heat in the process. Fire is a special case of combustion—self-perpetuating combustion characterized by the emission of heat and accompanied by flame and/or smoke. With fire, the supply of combustible fuel is controlled by heat given off during combustion (Scott 2012) [8].

2. Research aim

Evolving research interest is to find out the fast and low cost solution to build a network through distributed wireless sensors randomly spread in the forest and to create an automatic, self-organized and robust network between the sensors to cover larger areas.

The function of this sensor network would be to detect fire in the coverage area at regular intervals of short span of time (10-15 minutes) and to send a warning signal to a main server for further transmission to emergency services in the instant a fire is detected. When the fire is recognized, all of the sensors in the area of vicinity will become active and commence the mandatory start and routine tasks immediately. As the sensors are built up with small wireless range transmitters the data will be transmitted from one sensor to another until and unless the signal reaches the sink. After receiving the data sink will start processing a routine and check whether the fire certainly represents danger through a measurement of the fire spreading rate. If the result of processing is positive and real danger exists, then the sink determines the position of the fire. Then the sink will send an alarm signal to the fire department to inform the exact location of the fire, the temperature, fire spreading speed indicating the fire behavior. Based on the information received, the fire department will then be able to assess the extent and gravity of the situation to arrive at an optimal decision to take proper action as soon as possible. In case of real danger, subsequent preventative action can be initiated to mitigate the situation through appropriate measure before the fire turns uncontrollable. The main aim for this research can simply represented by the following picture:

Figure 2. Research goal

A fire consists of different sections burning in different environments, such as wind direction, wind velocity, slope, moisture contents, wind speed, etc. This heterogeneity of fire environment might contain a very complex shape, even if each part of the fire spreads in elliptical shape [8].

Different sections of the fire are as follows [8]:

- A finger is a long, narrow extension of the main body of fire.
- A pocket is an unburned indentation of the fire perimeter surrounded by three sides by the fire.
- An island is an unburned area within a fire which is totally surrounded by burned area
- A spot fire is a fire ignited in outer region of the main fire by a firebrand.

3. Fire detection and decision making

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The increasing demand of sensors to indicate and monitor the fire behavior has enriched the application of new technologies in the fire field. Sensors are able to sense certain dynamic and static variables such as humidity, the type of fuel, slope of the land, the direction and the speed of the wind, smoke, etc. They allow us to determine the direction and possible evolution of the flame front.

One of the popular wireless technologies is ZigBee which is a new industrial standard based on IEEE 802.15.4 radio specification and works in unlicensed bands including 2.4 GHz, 900 MHz and 868 MHz. This technology mainly emphasizes low cost battery powered application and small solar panels and is suited for low data rates and small range communications. Zigbee protocol has the ability to support mesh networking in which nodes are interconnected with other nodes so that multiple pathways connect each node. Connections between nodes are dynamically modified, updated and optimized through smart, built-in mesh routing table. Wireless Sensor Networks have gone through rapid developments in many applications. This type of technology has the potential to be applied almost everywhere; hence the research interest in sensor networks is becoming higher and higher every year.

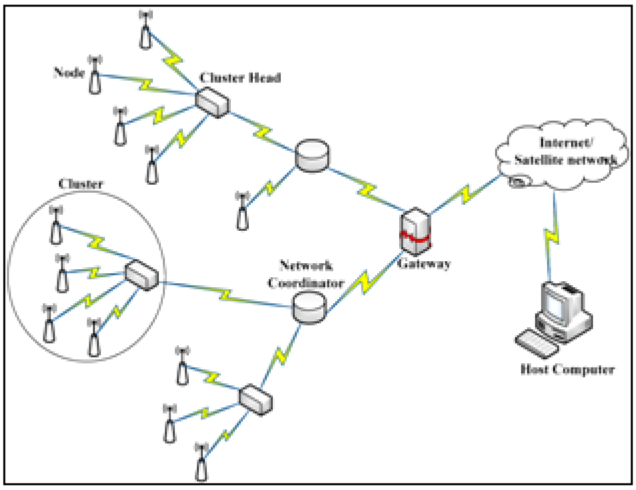

Figure 3. Sensor network for fire detection

The previous work was fully dependent upon images or databases such as Weather index, Fuel Index models, gas boards and intelligent sensors to make the decision. In this paperwork, all nodes belong to known location, and nodes only use temperature sensors, and they are programmed based on a certain threshold temperature, above it the node will send an alarm signal to the sink.

This concept solely depends on the node behaviour to alert of crises possibility using simple node components. This provides detection and information on whether this is a harmless fire, or the beginning of wild fire. The key in this method is to make decisions by tracking the fire propagation and check the logic behind it rather than using complicated databases or imaging technologies.

The most convenient solution is to monitor forests by using a GUI to represent the events and alerting signals on the monitoring screen using some logical evaluation to reach a decision as following figure 4. Once one of the nodes detect the fire all nodes in range of ±45 degrees wake up and start working as a router and a sensor, if they can do any sensing at that stage, every minute to track the fire spreading.

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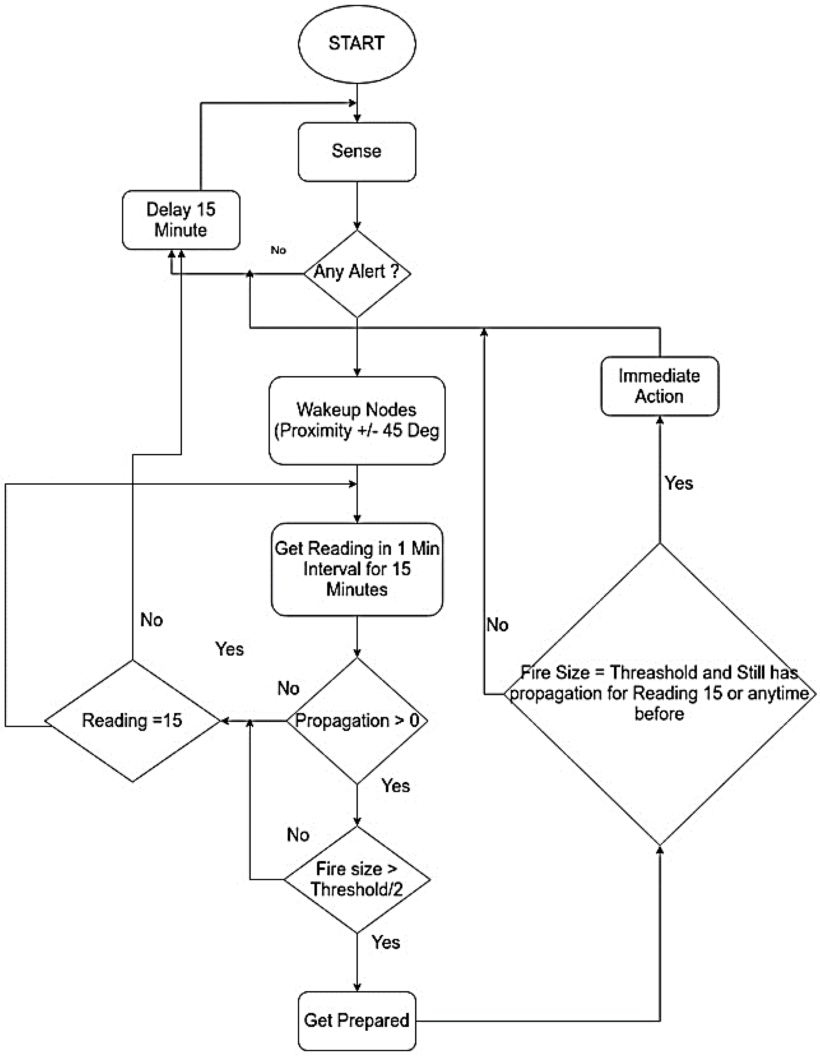

Figure 4. Fire detection method flowchart

4. Conclusion

A prototype of an advanced Forest Fire Detection system has been proposed to overcome the demerits of the Existing technologies of Forest Fire Detection. It can be ensured that the system can be implemented on a large scale due to its promising results. The system can also be improved to upgrade with low-power elements and solar power for effective application.

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