Information Delivery System for Early Forest Fire Detection Using Internet of Things

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Abstract. The frequency of occurrence of forest fires have increased exponentially in India in the past few decades. This can be attributed to the increasing human settlements and involvement in the forest area. Forest fires can be controlled if proper information about them is being made available to appropriate authorities at the right time so that they can take timely action to prevent it from turning into a major disaster. We propose an information delivery system along with its associated algorithm which uses different parameters, wireless technologies, sensors and Internet of Things along with cloud computing so as to deliver real time information about the forest fire occurrences. The probability of fire occurrence is transmitted to the user in the form of interactive charts and images along with latitude, longitude of the location. The system will have a Service Oriented Architecture and will transmit information to the local as well as central authorities.

Keywords: Sensors · Wireless Sensor Networks · Cloud computing · Internet of Things · Service oriented architecture

1 Introduction

Forest fire refers to the act of witnessing uncontrolled fire which causes a devastating loss to resources, both human as well as natural. In recent times, the total incidents of forest fires have increased due to multidimensional reasons. Forest fire is one scenario where early detection and prevention can be very helpful if the appropriate authorities are informed about it. In this paper we will primarily focus upon the in-time acknowledgment of the occurrence of forest fire and the design of the information delivery system for faster delivery of information so that quick and prompt action can be taken in minimum possible time in order to minimize the loss of resources.

There are two terms generally used for forest fires. One is surface fire [1] which only burns at the surface level igniting the senescent leaves falling on the floor. This type of fire occurs primarily in autumn season when dry leaves availability is quite high than normal. Surface fires are also helpful in natural regeneration of forests and increase the overall microbial activity of the soil. The other one is known as crown fire [1] where the surface fire increases in density and burns the entire suburbs of trees and shrubs. It is a very dangerous type of fire and spreads fast uphill than downhill.

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The causes leading to forest fires can be either man-made or natural. Factors such as lightning, favorable environmental conditions that may lead to ignition of fire etc. all come under the category of natural causes of forest fire whereas anthropogenic factors include electricity sparks, cigarette, man-made flames etc. Indian forests have been affected by fires but in recent times with increased human settlement in and around the forests, have led to increased cases of forest fires being caused by manmade factors. After ignition, factors such as air pressure, wind, moisture level etc. all lead to an increase in the intensity of forest fires in the affected area.

Forests account for nearly 22% [1] of the total land area of India and one of the major reasons of degradation and reduction of forest cover in India is forest fires. The forests in the northern India are more prone to fire incidents as compared to our south and north eastern forests. The months of April, May and June experience the most fierce of forest fires due to present of dry leaves and increased temperature of forests in the daytime. Mostly, such incidents are initiated by human error which soon turns into the worst nightmares for the most of us. The historic fires of Uttarakhand [2] are still fresh in the hearts of most of us. On an average, nearly 20 thousand fire incidents are reported yearly in India.

There are varied impacts of forest fire on the environment as it leads to forest degradation and other damages which can be in the social, ecological and economic dimensions. Fires lead to loss of timber, biodiversity, vegetation and extinction of flora and fauna in the affected area. It leads to soil erosion, decrease in forest cover and carbon sink and correspondingly also leads to an increase in global warming and the percentage of harmful gases in the environment such as carbon monoxide, carbon dioxide etc. In some cases, it also affects the livelihood of the people residing in the area, mostly tribal and rural population.

Currently helicopters [3] are used to spray water and fire restricting materials to bring fire under control. However such methods are highly expensive and uneconomical for the country in the long run. Another method is to contain the fire within a restricted area by making barriers [3] around it which are beforehand cleaned so that they become devoid of vegetation. One more method used is to set a counter fire in response to the fire, when both the fires meet at a point, the fire is extinguished.

There are major health effects of forest fire on people who go close to it in order to contain it. Lack of breathable oxygen in the near vicinity of fire leads to asphyxia [3]. Especially in the people who are involved in the process of extinguishing it. Asphyxiation combined with dehydration may lead to fatal effects on the person.

The Forest Survey of India [4] states that we have nearly 63 million hectares of forest out of which 38 million hectare are dense forests. Considering the Indian demography, we are currently using our 1% of world's resources to satisfy the day to day needs of 16% of world's population along with the needs of 19% of world's cattle population which we account for. This clearly represents the level of pressure under which we currently are as a country to save our forests.

In this paper, we will deploy the latest technologies to develop such a model which can be implemented in Indian scenario with an effective integration of forest personnel in the process [17]. The use of wireless technology will enable the effective dissemination of information to the appropriate authorities in real time. The authorities will then be able to take care of the situation before it gets out of hand and turns into a disaster [18].

The rest of the paper is divided as: Sect. 2 gives a brief introduction of the latest technologies being leveraged in the paper which form a background of the paper. Section 3 will give the detailed description of our proposed system along with the architecture of the system. Section 4 showcases the proposed algorithm and describe the implementation of the model in the Indian administrative scenario. Section 5 will elaborate upon the security considerations of the system, after which the paper is concluded.

2 Background

With the onset of a technology oriented world, now these days almost every field is leveraging the reach of latest technologies in order to benefit themselves and achieve their means in the best possible manner [11]. As for the same case, the following technologies are used in the implementation of our project and a brief introduction of each of these technologies is provided as:

(a) *Cloud computing:* Cloud computing [7] provides a paid on the go service of computing to the user on a dynamic and subscription basis. It has revolutionized the aspect of computing as a service and has made computing ability a resource which is easily available through an online service portal and is most affordable compared to other means. We use cloud computing resources so as to generate graphs, charts and other visual data based on the information received.
(b) *Wireless Sensor Networks:* A wireless sensor network [6] is a network consisting of automated nodes in form of sensors which are primarily targeted at observing and exchanging data about the physical environment surrounding the sensors at any given point of time [9].
(c) *Communication technologies:* There are various communication protocols which are now available to be used while using wireless communication [5, 10]. Many such technologies are there such as General Packet Radio Service used to communicate via packets over a 2G, 3G or 4G connection of Global System for Mobile communication, protocols and standards such as ZigBee and IEEE 802.11 are the most affordable, efficient and reliable technologies available for wireless communication [13].
(d) *Internet of Things:* Internet of Things [8] refers to a network of sensors where sensors acts as nodes in the network and these nodes are capable of small computation and communication. They work on reception of some particular input and generate signals based on the results obtained by the computation carried on the input [21]. Recently, sensors have been used in all the trending fields so as to obtain real time on the go information about the environment in which they are deployed.

3 Proposed System

Many systems have been proposed for forest fire detection in near past [4, 5] but most of them suffer from the anomaly of raising false alarms. This problem has led to wastage of resources due to false alert as well as due to negligence in cases when a forest fire has indeed occurred. In order to detect the occurrence of fire in a forest with least number of false alarms [9], we propose a system which leverages the technologies such as Internet of Things, Cloud Computing and other wireless technologies and aims at providing an efficient, smart, tracking facility for forest fires [14, 15].

The resultant model is intelligent and uses different types of sensors to detect fire. These sensors when scattered in the forest at appropriate distances, sense the data and keep on transmitting it to their master nodes. After receiving the data, it will be forwarded to the user in charge [12]. The user will be at the receiving end and will keep on getting updates about the possibility of occurrence of fire with respect to time and the rest of measured parameters [19].

Once the user is notified through the user application programs, steps can be taken in time to extinguish the fire so as to minimize the overall losses [21]. The purpose of proposing this model is to minimize the false alarms as well to as to reduce the human effort which is needed to patrol the forests, especially in the months of March, April and May [3] when the probability of forest fire occurrence is greatly increased in tropical regions [2].

The proposed system will be self-dependent and autonomous in functioning with minimum need of outside interference and support. The entire stretch of forest area to be covered will be categorized and divided into three layers. The first layer will cover the outermost area and will contain multiple sensors, which are termed as sub nodes over here. The second layer will lie in the middle of the forest and will contain multiple sensors called as nodes. Nodes will be receiving data from sub nodes and process it accordingly. The last layer will be containing master nodes which are responsible for processing of data and forwarding it to the cloud service.

Types of Sensor Nodes: The sensors being scattered over the entire area of forest are categorized on the basis of level of authority and data reporting.

(a) *Sub Nodes:* These are the most primitive nodes which will collect all the basic environmental data depending upon the type of sensors being deployed. The data about the environmental conditions such as temperature and relative humidity (DHT22), smoke, light, carbon dioxide intensity, carbon monoxide intensity is sensed by these nodes. The list of parameters being sensed can be decreased or increased depending upon the cost of infrastructure or the criticality of the forest on which they are being implemented.
(b) *Nodes:* The data being sensed and collected by the sub nodes will be forwarded to these nodes which will act as a master node for the sub nodes.
(c) *Master nodes:* Master nodes are embedded with a GSM or GPRS module along with a Wi-Fi backup in adverse situations. Master nodes will sense the information regarding the net wind speed and direction and will integrate it with the

information obtained by the other nodes so as to generate useful set of data. This data is forwarded to the could computing based services through GPRS/GSM module. The services then process the data and visualizes it in the form of graphs and charts which are then sent to the user application, so as to make it very descriptive and informative to the user.

In a normal scenario, considering the environmental conditions, there are numerous natural factors which support the sustaining forest fires. Temperature, humidity level, wind, presence of dry mass etc. all account for such factors. In [10], the rule of 30 is proposed which states that if three critical factors surpass their threshold values then there is a high probability of catching fire. The rule states that if the temperature of a forest is more than 30 °C, the humidity value or moisture content in the air is more than 30% and finally if the wind speed in that area is more than 30 km/h then there might be chances of occurrence of fire in the area.

In our proposed model, we will be using a fuzzy logic function which will take few parameters as input and will be generating the output in the form of graph. The parameters listed below will be observed and transmitted by the sensors which will be dispersed along the geographical area of the forest. Different sensors will be evaluating different parameters. Since sensors have a very limited battery life, it is proposed hereby that they should be equipped with solar panels so that they can function autonomously for as long as possible before we need to manually change their batteries which may be needed in 10 months or so [11]. To further save the battery life, we propose that sensors should remain in any of the three states:

Table 1. Power consumption of sensors

S.no.	Mode of operation	Power consumed
1.	Sleep	62 μA
2.	On	9 mA
3.	Hibernate	0.7 μA

The mean separation for deployment of sensors is proposed to be around 75 m from each other where they can communicate using ZigBee protocol [12] and in case of emergency can also use GPRS for transmission of alerts. The placement of sensors is done in such a manner so as to form a grid of sensors [16] which cover each and every section of the forest. ZigBee offers a frequency of 2.4 GHz with a −96 dBm sensitivity index and a range of 75 m. The alert probability will be calculated using the algorithm proposed in the next section. The model will be using a service oriented architecture which is briefly given as [17, 18]:

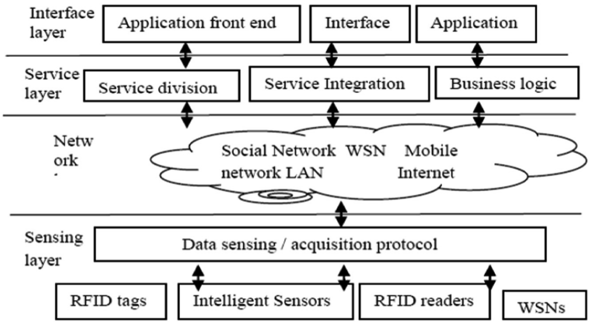

Fig. 1. Service oriented architecture

4 Proposed Algorithm

This section deals with the details of the algorithm which is being implemented for the proper functioning of the system. The algorithm takes in input in the form of data being transmitted by the sensors and then executes its function so as to provide most accurate results to the user (Table 2).

Table 2. Notations of parameters used

Parameter	Symbol
Temperature	T
Wind	W
Relative humidity	H
Air pressure	P
Smoke	S
Light	L
Sub-node	Sn
Node	N
Master node	Mn
Sn (counter, max. no.)	Sn(i,x)
N (counter, max. no.)	N(j,y)
Mn (counter, max. no.)	Mn(k,z)
Status (on, off)	(1,0)
Time (minutes)	&
Graphs and charts	Gr

The following table details out the modules being used in the model whereby every module is responsible for some or other functioning of the system.

Table 3. The list and function constituent modules

Module	Functionality
Start()	Awakes the entire system and the corresponding modules
Mobile_app()	A user interface through which information will be transferred
Sub_node_data(t,s,l,h)	This function is used to report the sensed data to the nodes in tier 2
Node_data(t,s,l,h,p,w)	This function is used to report the sensed data to the nodes in tier 3
Master_node_data(res)	It takes input and produces the output based upon a function
Sense(&, sub_node)/Sense(&, node)/Sense (&, master_node)	This function will make the parameter to sense and report data as and when the function is called
Exec_func(t,s,l,h,p,w)	A fuzzy logic based function which will predict the forest fire occurence
Status(on,off)	When invoked, all the working nodes will broadcast 1 to mark that they are alive
Send_result(res)	Sends the processed result to cloud service
Visualize(res)	The obtained result is put into graphs and charts
Notify_user(res, gr)	The user is notified via the mobile application
Cloud_service()	Data will be sent by master node to remote cloud services
Tag()	Keeps track of information such as serial number, status, product ID etc.
Sleep()	Allows the nodes to go into hibernate mode

Considering the above mentioned parameters, the algorithm which uses the parameters as well as modules is given as:

```
1) Start (&) where &={5,10} for February to May; &={10,15} for June-
October and &={20,25} for November-January
2) Start Mobile_app();
3) From (i=0 to x)
        Start_Sn(i)
        Sense (&, Sn(i));
4) From (j=0 to y)
        Start_N(j)
        Sense (&, N(j));
5) From (k=0 to z)
        Start_Mn(k)
        Sense (&, Mn(k));
6) Sub_node_data(t,s,l,h)→Node(ij);
7) Node_data(t,s,l,h,p,w)→Master_Node(jk);
8) Master_Node(t,s,l,h,p,w)→Exec_func();
9) Exec_func()=tslhpw(q)=min[µt(q),µs(q),µl(q),µh(q),µp(q),µw(q)];
10) Exec_func()→res→Master_node();
11) Master_node(res) →Cloud_service();
12) Cloud_service(res) →Visualize();
13) Visualize(gr) →Cloud_service();
14) Cloud_service(gr) →Mobile_app();
15) Repeat till &=∞;
16) End.
```

The above mentioned algorithm when implemented using a test case over the iFog simulator generates correct results for nearly 9 out of 10 cases. The data for the test cases is as provided in the table:

Table 4. Prediction of fire results

Temp	Light	Humidity	Smoke	Wind	Fire
20	300	80	30	10	27.8
80	300	80	30	10	41
20	300	80	80	15	33.8
20	900	80	30	12	39.7
20	300	100	30	20	19.3
20	300	80	30	10	30.3
80	300	80	80	8	50
80	800	80	80	50	53.6
80	800	40	80	10	63.1
100	800	40	80	20	70.1

The obtained results are in accord with our model and algorithm. The user interface and the mobile application can further be divided into two types where one user interface can be for the professionals guarding the forest and the other is for the people who are the administrators. A link to it can also be made to the emergency response services such as fire brigades, helicopters etc. which will serve as quick hand measures in action of extinguishing the fire or controlling it.

5 Security Considerations

With the rapid advancement in technology and numerous information dissemination techniques, the rate of information breach and hacking frequency has also been increased at an exponential rate [19]. The proposed system is aimed at information delivery to the appropriate authorities so as to minimize the overall loss of resources. The system does not focus ample enough to strengthen the security of its constituting components. Since the available resources that we have at our disposal are quite low therefore the computation ability is preserved to keep the system up and running for longest period of time which leads to sidelining of security. However as per the resources available, we always have an opportunity to deploy another layer which will handle the security related aspects of the system. Various encryption techniques can be used which can be expended up to 128 bits of keys [21] which can be used to encrypt and decrypt the data. This domain of security is open for future research by the aspiring researchers.

6 Conclusion

In order to effectively manage the occurrence of forest fires, it is paramount that the instant information about it is being provided to appropriate authorities on time. We propose a model along with its working algorithm whereby we predict the probability of occurrence of forest fire on the basis of some parameters. These parameters are being sensed using various sensors which will form a wireless sensor network and it will use a service oriented architecture along with leveraging the concept of Internet of Things and cloud computing. The paper concludes with the outline of the due considerations of security perspective on the system.

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