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Wireless Sensor Network for Forest Fire Detection and behavior Analysis

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Abstract

Forests are considered an essential part from the nature and the environmental system since it forms the key ecological contributor in the balance of the nature. Unfortunately, this balance is greatly affected by forest fires that regularly happen in all forest all over the world. These fires have a long-term effect on money, environmental and social aspects. There is usually a loss in human lives besides properties' destruction and hence uninterrupted effect on individual or collective level occur. A great deal of attention was recently given for developing the suitable systems that can reactively and proactively act against these fires. In fact, WSNs is considered one of the promising solution to be used in detecting and mentoring the forest fires efficiently. Different schemes for forests fire detection based on WSNs was proposed in the literature. our proposed system has a distinctive benefit since it gathers between detection and fire behavior prediction analysis. The early detection before its too late using novel designed system for sensor coverage and fire detection with a reduced faulty alarm and distinguishing ability between argent alarm and no action required alarms. Our techniques extended the network life time almost 3 times in comparison with other techniques.

Keywords: *Forest Fire System, Forest Fire detection, Wild Fire, Fire behavior Prediction, Wireless Sensor Network, WSN, Fire behavior analysis*

1 Introduction

Forest has a critical and essential role in recreational, global, environmental and ecological system. It has a great and large effect on the quantity of "Green House Gases (GHGs)", the absorption of atmospheric carbon besides reducing the erosion of the soil. The temperature is also moderated and the rainfall is regulated. In fact, Forest Fires are considered one of the most hazardous accidents of nature that happen almost in all cities and countries. Forest fire forms the major factor of disruption within nearly practically all the vegetation areas in forests all over the world. Forest fires usually forms probable danger that results in environmental, biological and physical consequences. Moreover, forest fire may result in adverse societal effects nevertheless it has been result from human activities or natural forces.

Natural causes and the human activities are the two major reasons for the forests fire. The tree coverage is reduced due to forests fire and the emission of gases is increased in the earth, around 20% from the emissions of CO2 are caused due to forests fire (Bouabdellah et al, 2012). The natural causes involves the fire results from lava and lighting, while the human activities varies from cigarettes that are carelessly discarded, unattended campfires besides the random burning for debris to make forest fire intentionally. In fact, forest fires could be detected only once it has already covered a substantial area. However, it is very difficult to control the forest fires once it has covered a considerable forests' portion (Chowdary et al, 2018). It has been found that when if the fire lasts burning for a minute, then it can be beaten or overcome using one liter of water, once the time of burning is doubled, then the required water is ten time more (i.e. 10 liters here) (Alkhatib, 2014)..

2 Types of Forest Fires

In general, the fires that occur in the forest are classified into three major types, which are; ground fire, surface fire and crown fire. In case of ground fire, only heat is usually produced deprived of much flames as Figure 1 below illustrates. It occurs in case that the ignition of the fire happens underground with only smoke can be seen above the ground deprived of any flames. So, sensors of high accuracy are usually needed in order to detect this type of forest fires. These sensors should be able to detect even the small temperature changes even 1^° C. As it was stated by (Chowdary and Gupta, 2018), radiation and thermal sensors are sensitive enough to record the ground fires. (Sahin, 2007) also stated that the reptiles that are prepared with suitable sensor could also be used for ground fire detection.

Figure 1: Ground Fire (Chowdary et al, 2018).

The second type is surface fire that creates the smoke that occurs on the forest's surface. The ignition takes place due to the spread leaves on the forest's surface. This is usually results in visible flames besides some smoke. The flame's height at early stages is in its minimum levels, but when the fire growths, the flame's height increases and the density of the smoke is reduced. Usually, smoke sensors are used to detect this type of forest fires (Chowdary et al, 2018). This type of forest fires is illustrated in Figure 2 below.

Figure 2: Surface Fire (Chowdary et al, 2018).

The third type is the crown fire that occurs when the surface fires are not detected and controlled in its initial stage. In case of crown fires, heavy flames are usually generated. In this case, the overall forest area is burnt and the flame's height could be observed from a long distance and the fire here could not be controlled unless being stopped naturally. Unfortunately, there is no sensor that is able to tolerate the very high temperature that is created via crown fire (Chowdary et al, 2018). This type is shown below in Figure 3.

Figure 3: Surface Fire (Chowdary et al, 2018).

3 Wireless Sensor Network

“Wireless Sensor Networks (WSNs)” is a type of networks that is self-organized and it consists from different energy-limited sensor nodes that communicate among other via wireless communication. It has the benefits of low-power, high precision, low-cost, large-coverage and real-time. It is appropriate and effective to be used in large-scale, long-distance and long-time environmental mentoring (Zhu and Lingqing, 2013).

WSNs consist from different components including, PC, sensors, power module and wireless communication modules. These components together forms the monitoring system that could show the data in sensor characteristics form that is used later to take the benefit of wireless media. There are different types of sensors that can be used based on the application like, temperature, humidity, pressure, radiation, Acoustic and optic sensors (Hariyawan et al, 2013). The communication in WSNs is achieved using the gathered information via monitored field using wireless links. The transmission of the information is performed via forwarding it between multiple sensor nodes (Lakshmi and Premalatha, 2019).

In a line with the sensor technology developments, WSNs have been adopted to be employed in different field recently. Right now, the technology of WSNs is treated to be one of the most ten emerging technologies that impact the future life of the humanity. WSNs has a wide range of applications in almost life fields including; aviation, industry, medicine, military, agriculture, environmental mentoring besides disaster fighting (Zhu and Lingqing, 2013).

4 Detection Technique for Forest Fires

There are several techniques that were proposed in the literature for the purpose of detecting the forest fires and monitoring it, these techniques can be categorized into the major five types listed below (Chowdary and Gupta, 2018):

- The methods that depend on the animals or their behaviors and use them as sensor for forest fires detection.
- Forest fire detection methods using WSNs.
- Forest fires detection and monitoring methods using image processing.
- Forest fire detection methods that depend on the visual interpretation of the camera.
- Method based-"Unmanned Aerial Vehicles (UAVs)" for forest fire detection.

The conventional methods for forest fires measurements involve, satellite monitoring, ground patrolling and the watch tower. However, these methods faces different challenges and drawbacks. One critical problem is the difficulty of monitoring the forest fires accurately at all time. For instance, the level of the real-time remote mentoring for satellite images considered not high because the forest fire is not able to be observed all day where the sky clouds' thickness besides other factors decreases the fire positioning accuracy. A great deal of attention is now given to using WSNs in almost fields including forest fires detection and monitoring (Peter et al, 2017).

WSNs could be effectively used in detecting the forest fires. This can be achieved via deploying various sensor nodes all over the forest for the purpose of gathering different data types including pressure, temperature, solar radiation and humidity to be then delivered wirelessly to sink station in ad-hoc manner. The collected data could be further processed and analyzed in order to make suitable decisions once fire occurs. However, WSNs deployment is limited by different major challenges and issues regarding to the WSNs' nature. The consumption of the energy for limited power nodes is a key concern in case of aiming to achieve continuous and long-term surveillance of the overall forest region (Sun et al, 2018).

5 The Structural Design for Basic Fire Detection System

This section presents the structural design for the basic detection system of forest fires that is usually seems to be like the practical forest fire detection system employing any one of the detection methods mentioned in the previous section. There are usually two main cases, the detection of forest fire for the entire forest or only for particular part (Chowdary et al, 2018). The structural design for the detection system of forest fire in case of limited area of interest is shown in Figure 4 below.

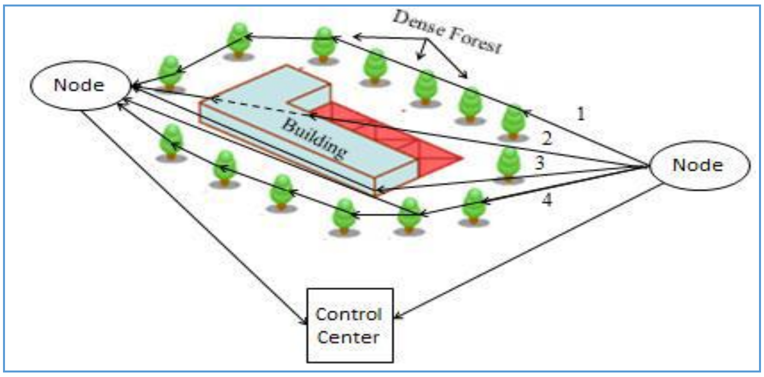

Figure 4: Forest Fire detection for limited areas (Chowdary et al, 2018)

Limited area of interest includes a building that is bounded by lot of trees or a village that is located inside the forest. This case is usually treated in this way, the fire is considered to be like an intrusion among two static points, and the nodes are then fixed orthogonally to these two points. Barriers are then created among these two nodes as Figure 1.4 illustrated. In case that any intrusion occurs from these fixed points, barrier network could detect it accordingly. The located nodes on orthogonal points refer to the virtual nodes. The created path among two virtual points is obtained from the communication among physically located nodes through the paths (Chowdary et al, 2018).

The second type of structural designs, where the overall forest area is considered as shown in Figure 1.5 below. In this case, a cluster-based network is adopted. This network consists of different sensor nodes that creates a cluster in addition to central unit or node that performs as the cluster head for that cluster. The range of communication ability for these sensors is limited and the cluster head node could directly communicate with the main control center that is placed near the considered forest or even far away from the considered forest and controlled remotely (Chowdary et al, 2018).

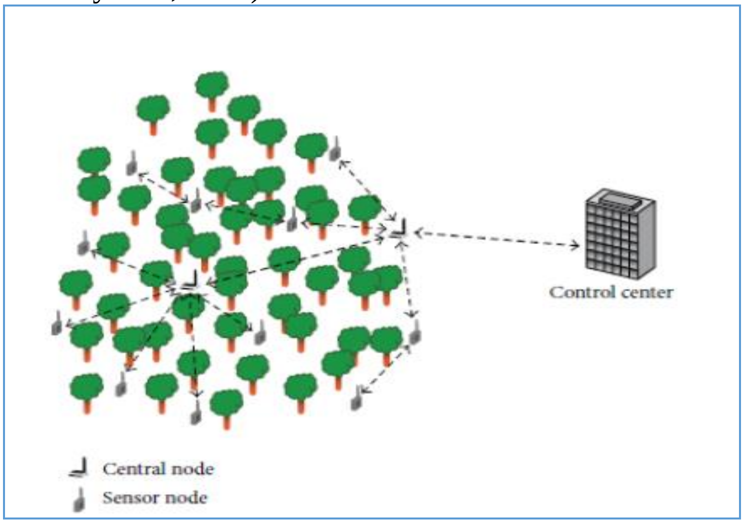

Figure 5: Forest Fire detection for the entire forest (Chowdary et al, 2018)

6 Coverage

'Coverage' is defined as how well a sensor network monitors a certain field of interest, and its corresponding Quality of Service (QoS). Coverage involves the need for connectivity between nodes and the ability to communicate with other nodes in the network and reach the network sink.

Wireless sensor network coverage generally has two types: static and dynamic. Static coverage uses fixed nodes which are usually deployed in a predefined shape. Overlap between each node's coverage range and those of adjacent nodes must be provided for an efficient static coverage. The K-coverage method has been developed to establish high quality coverage in various environmental applications. Dynamic coverage is characterized by nodes have the ability to move. The method is used when optimal deployment can't be determined due to an uncertain environment. Nodes are randomly placed; one method is air-dropping sensors from aircraft. Random deployment does not provide effective coverage and require more complicated algorithms. Various methods have been developed to address the lack of effectiveness in coverage, such as the virtual force algorithm (VFA). VFA is an algorithm for optimising sensor deployment to improve coverage after the random placement initially (Chuan et al ,2011). Dynamic coverage is popular in military applications.

Sensing range and communication range are different concepts. Sensing range describes the range at which the device can sense the events that it is designed for, while Communication Range is defined as the range at which two nodes can communicate with each other.

Nodes that are capable of communicating over a few hundred meters include Libelium-Waspmote. Nodes can communicate from 1 m (XBee 802.15.4) to thousands of km (Libelium Technichal Guid, 2020). Sensing range is variable, ranging from less than 1 m up to 80 km in very advanced and expensive sensors such as FireWatch (FireWatch, 2020).

The importance of sensing range and communication range is variable according to the application. Regarding forest fire detection, Sensor range is very important because it plays a major role in determining the distance between nodes and node density. Sensing range is much lower than communication range; thus in order to detect fire within a short time after initiation, sensing coverage must not have much gaps. This condition limits the distance between sensors due to the sensing range distance. on the other hand, using large sensing range nodes might reduce accuracy and increase detection times. Small distance sensing ranges are more accurate and produce less delay. Small distance sensors are deployed at a little bit larger distances than their sensing range, being is acceptable to have small sensing gaps between nodes.

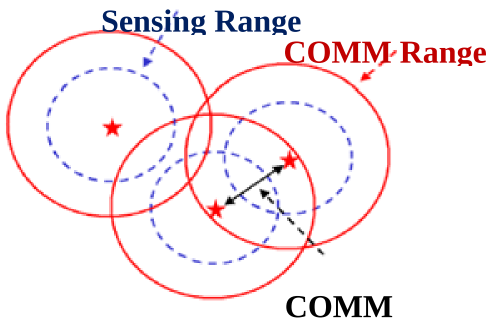

Figure 6. Sensing range and communication range

The coverage algorithm proposed by (Alkhatib, 2016) was deployed in this research. The network is divided into a number of sub-networks according to node position. In the present study, analysis is limited to division of the network into three sub-networks that shall be turned on every 10 minutes. Thus, this method allows each sub-system, instead of all nodes, to be turned on every 10 minutes for 30 seconds, it senses the environment and then go back to sleep. In the next 10 minutes, the second sub-network wakes up, and so on. So sub-networks 1, 2, and 3 work for 30 seconds every 30 minutes. Overall, all nodes wake up for 30 seconds every 30 minutes Instead of making all nodes wake up three times for 90 seconds.

fewer nodes are deployed Through this method. Also less traffic is present in the network, and the resources are fully utilised. This method is tested in NS2 and applied in three stages:

1. The network is divided into three sub-networks according to their distances from the node (R), where:

 Sub-network 1 is composed of nodes located between (0 + 15n) ≤ R < (5 + 15n)

 Sub-network 2 is composed of nodes located between (5 + 15n) ≤ R < (10 + 15n)

 Sub-network 3 is composed of nodes located between (10 + 15n) ≤ R < (15 + 15n)

Where n = {0, 1, 2 ….. [a + 15n ≤ (distance from sink to the edge of coverage area)]}

2. Each node has to check that there is at least one node in the communication range, even when borrowing from another sub-network is required. The communication range is reduced to 20 meters in the simulator to make sure that most of the nodes have more than one connection.

3. To ensure full connectivity between nodes, the check partner function is created to make sure that each node in the sub-network has at least one connection. Otherwise, an appropriate node from another sub-network is selected to be used as a partner. The solution is to borrow nodes from other sub-networks and to keep the power balanced in the network. The sub-network keeps a list of alternative

candidates, that represents all nodes that can be borrowed from other networks to cover its gaps. Every time the sub-network wakes up, a different alternative node is used.

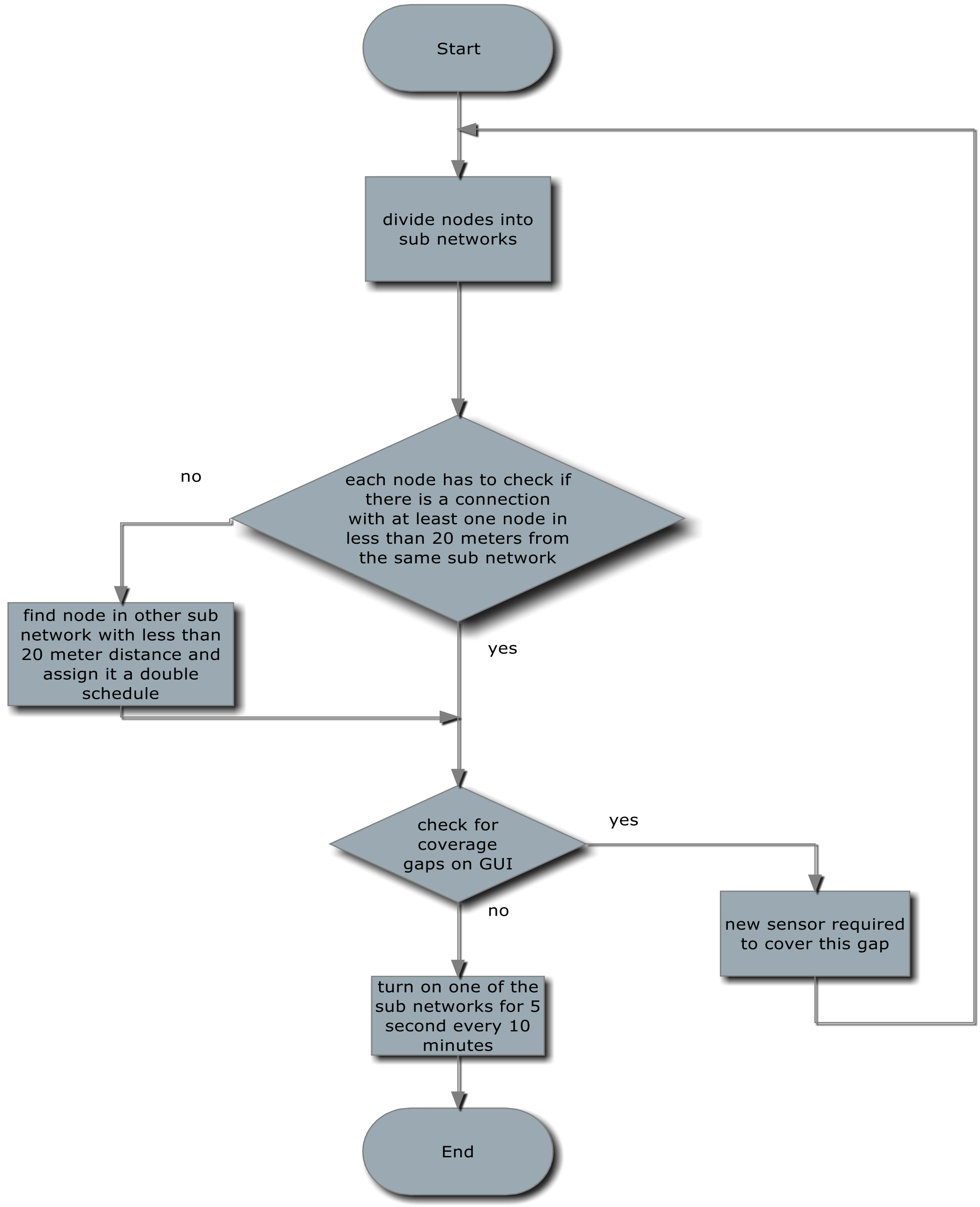

Figure 7. Network Coverage

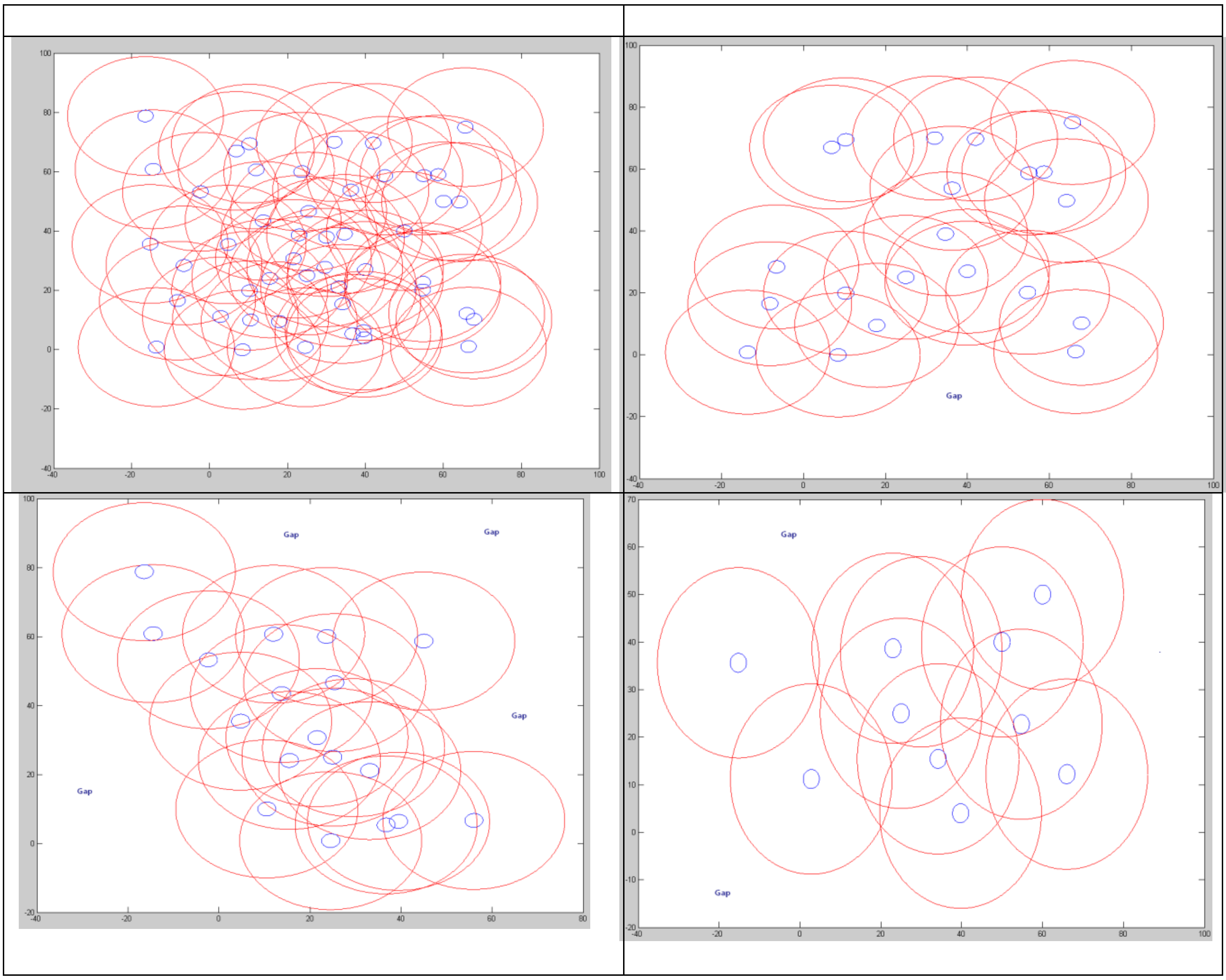

Figure 8: Nodes Coverage

7 Forest Monitoring

All fire monitoring systems rely on images or databases such as weather and fuel index models, gas boards and intelligent sensors. In this study, all nodes have known locations. Nodes only use temperature sensors and are programmed for a certain threshold temperature. Above this, the node will send an alarm message to the sink. This concept relies solely on node behaviour to alert of possible fires. Simple node components provide fire detection and information on whether it is a peaceful fire or the beginning of a wildfire. The key to this method is in making decisions by tracking the fire propagation and checking the logic behind it rather than using complicated databases or imaging technologies. The most convenient method is to monitor forests by using a GUI to represent the events and displaying alert messages on the monitoring screen using logical evaluation to come to a decision. Fifty nodes were tested in NS2, to verify the proposed algorithm.

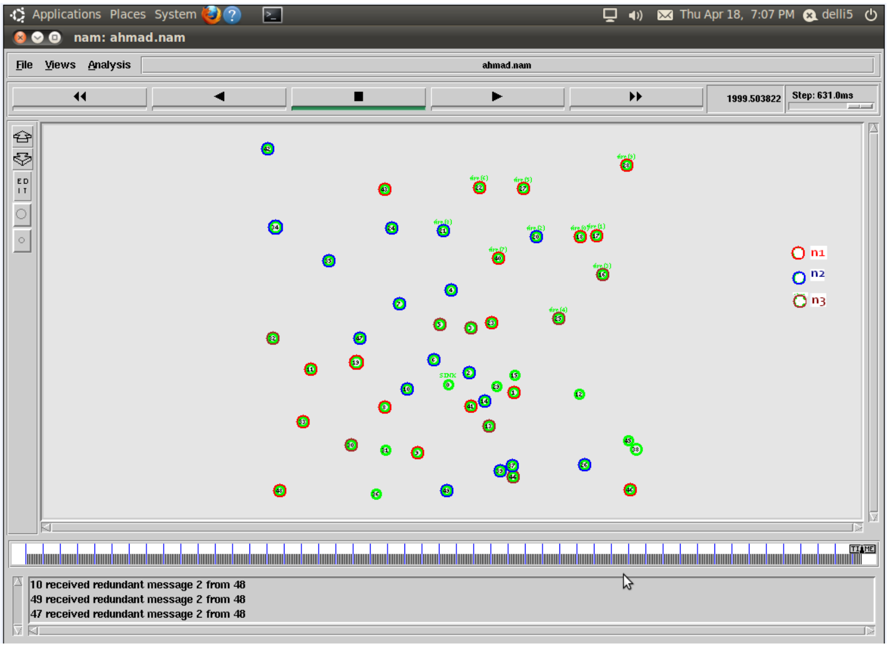

Figure 9. Randomly Distributed Nodes

We assumed that all nodes can localize themselves based on (Alkhatib et al, 2020) to recognize events locations. The moment one of the nodes detects the fire, all nodes in range of ±45 degree wakes up and starts working as a router and a sensor, if they can do any sensing at that stage, every minute is used to track the fire propagation. The fire propagation is the key logical parameter used in this simulator. If the fire started at X node then an alert will appear on the GUI at that node, a minute later the network will sense the place again to see if there are any other nodes providing alerts as well, and so on for 15 times. The risk assessment depends on the nodes alert messages and their locations. By calculating the distances between the alerted nodes we can find the size of the fire, the fire propagation or spread speed and fire direction. If the nodes readings indicate fire size above (threshold value)/2, 2.5 meters on the monitoring screen for example, and a reasonable fire propagation, which known from nodes reading, an alarm to the fire fighters to be prepared, once the fire size reach the threshold size and the propagation still continuous, the fire fighters must take an action immediately, otherwise, if the fire has no reasonable propagation or still not equal the threshold size within the 15 readings, no action is required. Without going into details of fire propagation models, this study describes all possible cases for fire propagation as follows:

Table 1: Fire Types

Camping Fire	node *x* provides a fire alert at time *t*. After *t* + 1, another nodes provides an alarm, then nothing at *t* + 2…10. This indicates there is a peaceful fire such as a camp fire, and no action is required
Medium propagation fire	node *x* send a fire alert at time *t*. After *t* + 1, another node sends an alarm, then at *t* + 5 another node sends an alarm. At this stage, the risk increases. At *t* + T, the propagation rang is bigger than a threshold value which means the fire is dangerous and requires immediate action.
Fast Propagation fire	the fire is propagating over a large distance, has a small width, and low fire density. This type is very easy to detect because it will increase the temperature in the area and will propagate over a large distances, triggering many sensors
Slow Propagation fire	slow propagation fire which is a tricky type to predict. It might be extinguished on its own because fire growth is very slow and stops at certain times. On the other hand, it might grow and become dangerous. In that case, the nodes keep tracking the fire growth until it is larger than the threshold value.
Sunny Days	a very hot sunny day might raise the temperature over the threshold value, as in figure 21. Since it’s a sunny day, temperatures will be almost the same everywhere, causing all sensors to provide alarms at once. In this case, the threshold value must be increased to a more suitable value.
Sensors under direct sun shine and under shadows	During hot days, sensors might be under trees or directly in sunlight. Therefore, some sensors might give alarms and others do not, but the apparent propagation is not logical. The alarm will come from many different discrete nodes at the same time, which does not indicate any fire propagation or growth.
Cold days	during a cold day where there is a reduced risk of fires, the temperature threshold might be reduced to a suitable value.

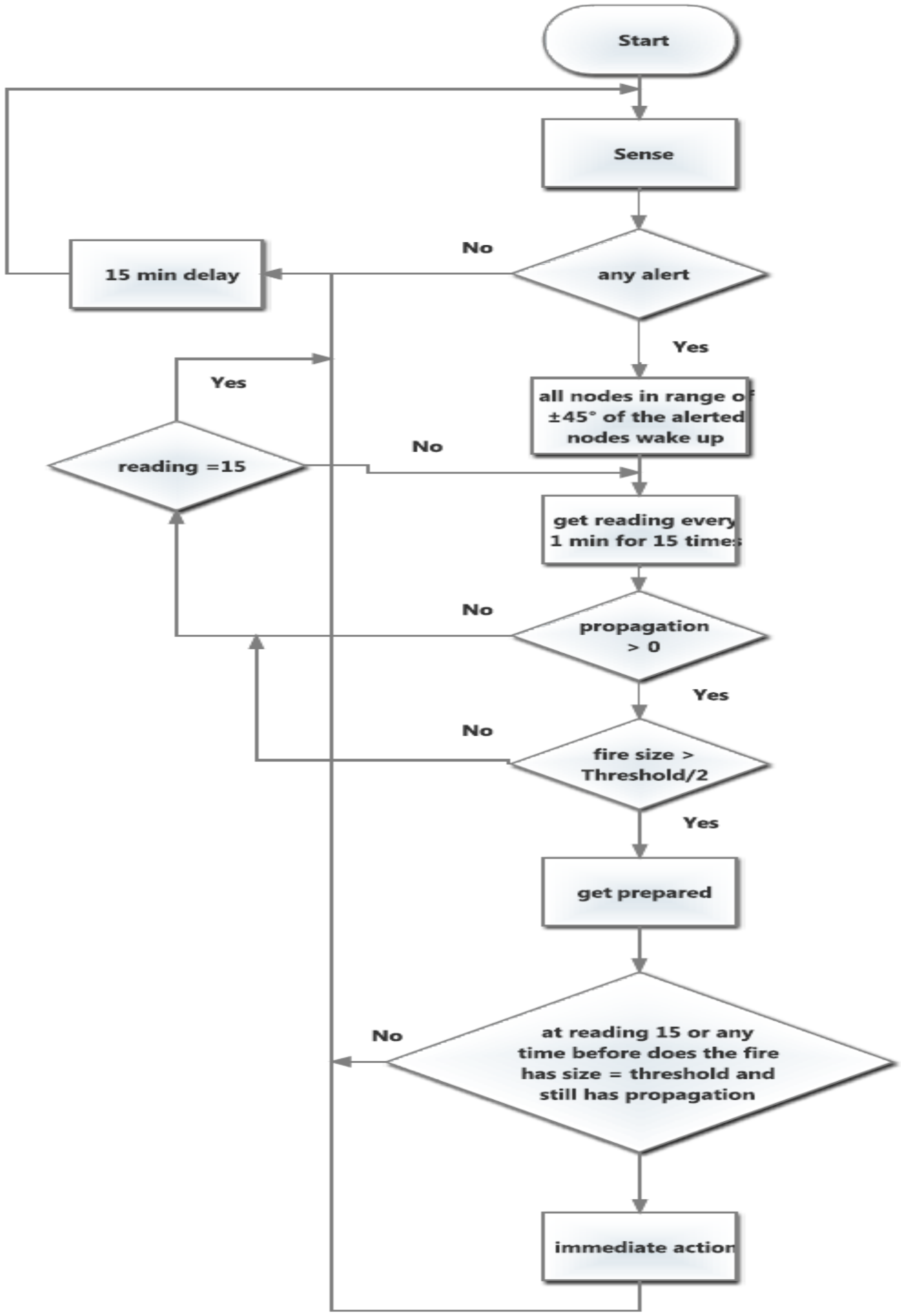

Figure 10: Fire Detection Algorithm

Relationship between the sensor deployment scheme and early detection: When the early detection goal is considered, again, regular and moderate density deployment schemes are more successful. In random deployment cases, the average distance between a fire ignition location and the closest sensor node decreases as density increases. This means it will take less time until a sensor node detects increased temperature due to fire ignition. Additionally, the distribution among the sensor nodes provides a difference in sensing performance. Also, when the number of nodes increases, fire detection is much faster because of overlapped coverage with short gaps between sensing ranges.

The distance between sensor nodes affects the time required for heat waves to reach them. It is observed that it takes more than 1 minutes for sensor nodes to sense a fire thread when the distance between the fire ignition location and the sensor node is more than 20 meters. This experiment shows that the distance between the sensor nodes should be kept to less than 20 meters to achieve successful early detection. This is what is applied in the coverage method.

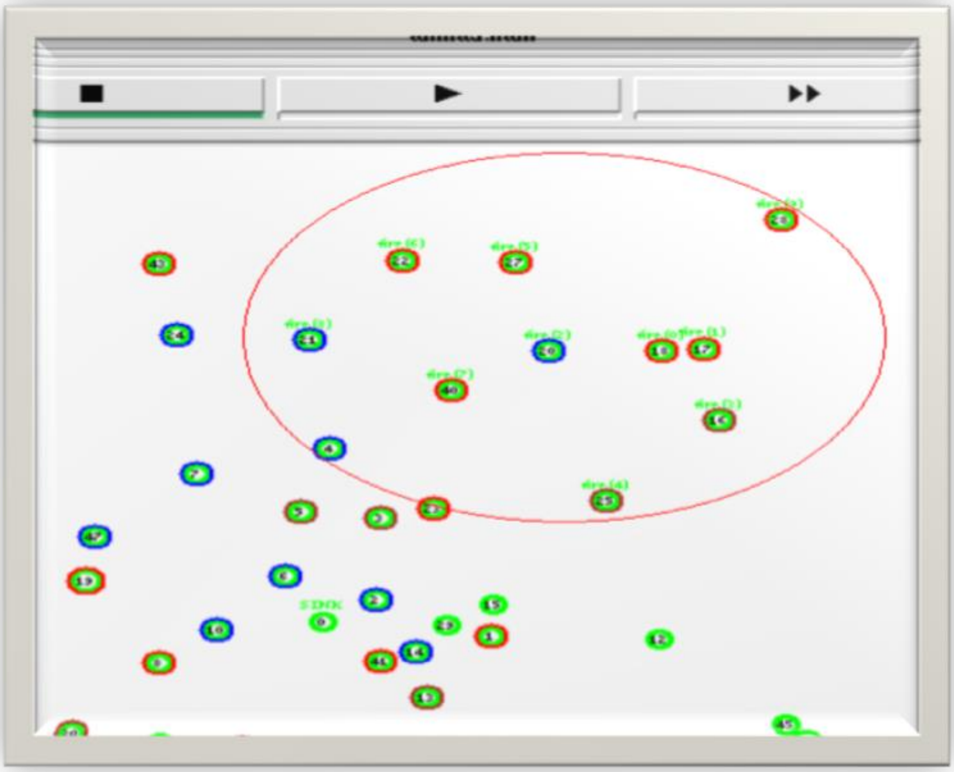

Figure 11 : Fire detection Alarm

An environment-aware scheme's performance is much better in terms of this metric. During the non-fire season months, the fire threat level is low, so the period of sleep time can be set longer. However, in fire season, the average fire detection time of the environment-aware model is too short, since the fire threat during that period is taken into account.

By using the sensing result, simple information can be provided for the firefighters about the fire's behavior, such as its ignition point, fire spread speed and direction of maximum spread. The simple simulation result for fire behavior can improve firefighter safety and fire extinguishment.

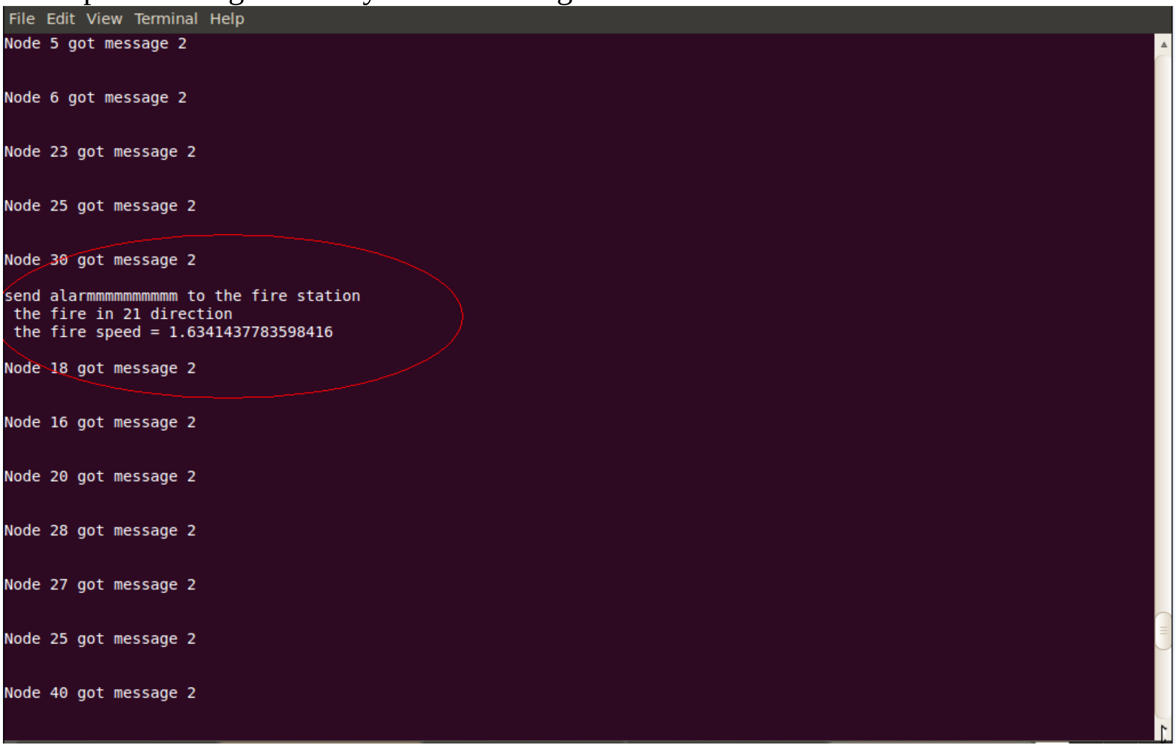

Figure12: Fire detection result

The teamwork of firefighters can be organized according to these results. For example, if the fire spreads toward an inhabited area or precious properties, the team's target is to stop the spreading in that direction. Hence, more firefighters can be deployed to the flame front in the spread direction. In the contrary, if the fire needs to be extinguished as soon as possible, more firefighters can be deployed to the back of the fire to weaken the flame front, reduce the fire intensity, limit spreading, reduce danger and make it easier to extinguish.

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Figure13: Fire management example

8 Power saving

. The proposed system power consumption will be calculated based on LibeliumTmWaspmote nodes and XBee-802.15.4. Tables 3 to 5 summarise the parameters extracted from the Waspmote datasheet (Libelium Technichal Guide, 2020).

Table 2: Wapmote parameters

Waspmote	
ON	15mA
Sleep	55µA
Deep Sleep	55µA
Hibernate	0.06µA

Table 3: XBee 802.15.4 parameters

XBee- 802.15.4	
ON	50.36mA
Sleep	0.1mA
OFF	0
Sending	49.56mA
Receiving	50.26mA

Table 4: Other Parameters

Other Parameters	
Temperature sensor	Build in internal temperature sensor in Waspmote (no need to consider sensing energy)
XBee-802.15.4 tx Power	1mW
Battery	4.2V
Battery current (Li-Ion rechargeable)	6600mA

Energy consumption calculations for a 'Waspmote node' are divided into two parts: the XBee and Waspmote device.

$$E_{total} = E_{XBee} + E_{Waspmote} \quad \text{(A1)}$$

$$E_{total} = \underbrace{[E_{tx} + E_{rx} + E_{on} + E_{sleep}]}_{E_{XBee}} + \underbrace{[E_{on} + E_{sleep}]}_{E_{Waspmote}} \quad \text{(A2)}$$

$$E_{total} = [P_{tx} * t_{send} + P_{rx} * t_{recieve} + P_{on} * t_{on} + P_{sleep} * t_{sleep}] + [P_{on} * t_{on} + P_{sleep} * t_{sleep}] \quad \text{(A3)}$$

According to the above tables' parameters, the power can be calculated for each part as follows:

$$P = I * V \quad \text{(A4)}$$

XBee-802.15.4 power consumtion

P_{tx}= 1 mW

P_{rx} = 20.172 mV * 50.25 mA = 1.014~1 mW

P_{on} = 50.36 mA * 20.172 mV = 1.016~1 mW

P_{sleep} = 0.1 mA * 20.172 mV = 2.0172 μW

Waspmote

P_{on} = 4.2 V * 15 mA = 63 mW

$P_{sleep} = P_{deep\ sleep}$ = 4.2 V*55 µA = 0.231 mW

$P_{hibernate}$ = 4.2 V * 0.06 µA = 0.252 µW

The following calculations for power consumption for one full year listed in the below table.

Table 5: power consumption calculations

1- The node is continuously working and has to provide feedback every second. Since it employs a broadcasting network, it is assumed that a reception occurs every second as well.
t = 1 year = (3600 * 24 * 365)s. $E_{total} = [E_{tx} + E_{rx} + E_{on} + E_{sleep}] + [E_{on} + E_{sleep}]$ E_{total} = [1 mW * (3600 * 24 * 365) + 1 mW * (3600 * 24 * 365) + 1 mW * (3600 * 24 * 365) + 0] + [63 mW * (3600 * 24 * 365) + 0] = 2081.376 KJ
2- Nodes observe the environment and send results continuously to the base station for 30 s every 10 min, instead of continuous observation for the whole year.
t_{on} = 30 s/10 min $\rightarrow$ 180 s/hr $\rightarrow$ 1576800 s/year. t_{sleep} = 10 * 60 – 30 = 570 s/hr $\rightarrow$ 29959200 s/year $E_{total} = [E_{tx} + E_{rx} + E_{on} + E_{sleep}] + [E_{on} + E_{sleep}]$ E_{total} = [(3 mW * 1576800) + (2.0172 µW * 29959200)] + [(63 mW * 1576800) + (0.231 mW * 29959200)] = 111.1398089 KJ ΔE = (2081.376 KJ - 111.1398089 KJ /2081.376 KJ) * 100% = 94.66027%
Using this technique, energy performance is improved by 94.66%. The energy consumed in one year is reduced by 18.7 times compared with Scenario 1.
3- This is similar to Scenario 2 but assumes that there is no transmission unless there is an event to report (according to the fire detection method). Assuming no events occurred during the network lifetime and only data packets are taken into account in this calculation, any other messages such as ARP, routing messages, etc. are ignored
t_{on} = 1576800 s/year t_{sleep} = 29959200 s/year $E_{total} = [E_{tx} + E_{rx} + E_{on} + E_{sleep}] + [E_{on} + E_{sleep}]$ E_{total} = [0 + 0 + (1 mW * 1576800) + (2.0172 µW * 29959200)] + [(63 mW * 1576800) + (0.231 mW * 29959200)] = 107.8962089 KJ ΔE = (111.1398089 KJ - 107.8962089 KJ/111.1398089 KJ) * 100% = 2.92%
Energy performance is improved by 2.92% compared to Scenario 2, which means that energy consumption is reduced by 1.03 times.

4- Similar to Scenario 3 but applying the subnetwork coverage method.

t_{on} = 30 s/30 min ➔ 60s/hr ➔ 525600 s/year.

t_{sleep} = 3600 - 60 = 3540/hr ➔ 31010400 s/year.

$E_{total} = [E_{tx} + E_{rx} + E_{on} + E_{sleep}] + [E_{on} + E_{sleep}]$

E_{total} = [zero + zero + (1 mW * 525600) + (2.0172 µ * 31010400)] + [(63 mW * 525600) + (0.24 mW * 31010400)] = 41.1435 KJ

ΔEs3 - s4 = 61.87%

ΔEs2 - s4 = 63%

The most common scenario in WSNs in forest fire applications is Scenario 2, where the whole network wakes up every 10 minutes to sense the environment and send the data to the base station. The sub-network coverage method makes improvements in the energy performance by 63%. It reduces energy consumption by 2.7 times compared to the normal routine, which means the power used in one year can be used to deliver the same functionality for 2.7 years. Most of the nodes used in forest fire applications can work between one year (as in Waspmote) to three years. The present study can increase this dramatically to 2.7—8.1 years.

Other Factors to Consider in Energy Consumption such as; the activity levels can be high in months when the risk of fire is higher (i.e. summer). When the activity level is increased in summer, the sensor nodes will consume more energy, but this is compensated for by lower activity levels and lower energy consumption during winter and at night.

There is a relationship between the sensor deployment scheme and energy consumption. The regular or random deployment modes greatly affect the network's energy consumption as well as fire detection reaction times.

Machine Learning – Supervised learning – classification is one of the potentials for fire prediction. In the last decades, software engineers tried to create softwares to make our life simpler. These applications enabled us to use online documents instead of paper in managing our work [Kanan & Fox, 2015].

classification is the process of labeling testing items using training data. It has wide applications in various domains such as news categorization, online libraries, author authentication, and many others. Even though many works have been applied on classification, there is a lack of works proposed for forest fire detection [Kanan et, al. 2015]. In order to evaluate the improvement, we collected a dataset of 5,000 records. As for the evaluation measurements, we used recall, precision, and F1 measurement, which are commonly used in evaluating classifiers. Upon the use of the stemming

ML studies the capability of supporting computers to have self-learning without programming it directly [Tarek et, al 2019]. It does so through exploring algorithms and making predictions about data.

Supervised Learning-Classification: is well-defined as an approach of generous response examples to the machine; and it includes the human's needed outputs.

9 Conclusion and Future Work

In fact, the forests nowadays form an essential part form the vital resources for social development and human survival that keep the earth ecosystem balance. Unfortunately, and due to uncontrolled activities of human and irregular conditions of the nature, forests fire frequently occur. The monitoring and detection of forest fires has attained a great deal of importance recently since it has a direct negative effect on the nature and the humanity and it may help in avoiding or at least reducing the human and nature losses.

Despite of the current achieved progress in fighting the wildfire throughout the lase decades, the need is still urgent for reinforcing the response capacity of this disaster involving the systems of early warning and the enhancement in real-time data exchange at different levels and stages from the scheme of forest monitoring. Actually, the recent achieved developments in communication and information technologies having a great effect in this field especially the recent proposed methods for forest fire detection using WSNs.

Using WSN to provide data for detection algorithm, then observing sensors behavior and reading during fire to provide analysis of fire behavior and finally the sensors readings with some other factors and inputs will help fire fighters to handle the fire in an organized fashion. The sub-network coverage method can convert networks with a random distribution into an organised deployment. Dividing the network into three sub-networks to reduce the number of used nodes can increase network lifetime by 2.7% and increases energy performance by 63% compared to normal fire detection networks.

The fire detection and decision-making systems do not require complicated gas boards and specialised devices, connection of the network to databases, or application of complicated models. Only a simple, cheap, temperature sensor is required at each node. It helps in decision-making by distinguishing between peaceful fires, false alarms and potential danger that requires an immediate reaction. Plus, the low possibility of false alarms and information about fire behaviour can improve the performance of firefighting teams.

Future work will target Machine learning techniques in order to provide more predictions for fire incidents as well as the fire behaviour and fire fighters team work organization.

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