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An Improved Forest Fire Alerting System Using Wireless Sensor Network

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Abstract: Wireless Sensor Network is a self-organization network that consists of a distributed number of minor devices for performing the monitoring activities within the deployed environment. Many wildfires cause forest damages affecting a large number of living organisms. This research study discusses a system design approach to wireless sensor network (WSN) based on the monitoring of wildfire. The main goal of the proposed solution is to intelligently estimate the scale and intensity of the wildfire which is ignited in the forest. The energy efficient and priority based techniques have been implemented for the data communication between the wireless sensor networks. The dynamic routing paths can be created with the help of the proposed data communication solution. These dynamic paths are developed depending upon a number of parameters such as weight, energy, fire, weather index and security. For the sake of validation, the proposed solution designs and implements a prototype by using Microsoft Framework (tools and technologies) to accomplish an extensive number of simulation experiments. The results and evaluations clearly show the efficiency and dependability of our proposed approach based on the wireless sensor network.

Keywords: Energy, Wildfire, Landslide, Intensity, Framework

1. Introduction

The information and communication (ICT) technology has been utilized for a number of applications in the real-time monitoring, surveillance and performing many other tasks and activities. With the help of information technology, numerous tasks have been automated in performing many activities which are almost impossible for the human to perform. There is a number of key solutions which have been designed, developed and implemented with the help of advanced communication technologies. Still, a large number of research works have been conducted in the field of communication and networking. In today world, there is a number of key turn solutions which are available in the market.

Wireless Sensor Network (WSN) is a self-organization network that consists of a distributed number of minor devices. The wireless sensor networks have been utilized in a number of real-time applications. The wireless sensor networks (WSN) are also used to perform various kinds of environmental monitoring activities. The sensors are used to collect different kind of parameters from the environment and transfer the information to the sink node or base stations. There are many protocols which have been utilized for the data transfer between the wireless sensor networks (WSN). The wireless sensor networks (WSN) have few standards of data communication and coordination. The common sensor network utilized for the wireless sensor network (WSN) includes ZigBee [1], Bagheri [2] and 6LoWPAN [3]. These are the common schemes which have been utilized for the WSNs communication and coordination. The verification and authentication of the real-time application are the critical challenge especially in case of real-time application based on sensor network technology such as flood detection system, home automation [5], logistics [6], landslide detection, machine health monitoring [7], disaster prevention and monitoring of large zonal areas [8]. However, many simulations have also been designed and developed before implementing the real-time application. The proposed model can be deployed in the simulation environment like a few common wireless sensor simulators OPNET, NetSim, NetLogo, NS2, Win log C#, OMNet and many other applications [4]. In the design and development of sensor network applications, modeling and simulation of sensor network play an important role [9]. Wireless Sensor Network (WSN) also offers a number of benefits such as fast deployment, low maintenance, high coverage, lower costs, scalability, ubiquitous network access, greater resiliency, hypervisor protection against network attacks [10].

The wireless sensor networks are usually organized an ad hoc network, which is a kind of network such that each node participates in routing by forwarding data to other nodes, without relying on any centralized infrastructure such as router and base station. Nodes can join or leave at any time and are free to move around as they desire. A routing protocol is an algorithm used by nodes to determine a path for forwarding packets toward a destination. Ad hoc networks usually use distance vector routing, since centralized link state routing is not feasible due to its complexity and the significant cost of propagating the link states. In distance vector routing protocols, each node maintains the name of next hop and the number of hops to reach the destination. Ad hoc routing protocols fall into two categories: table-driven and on-demand [11]. A routing protocol is one of the most fundamental infrastructures of ad hoc networks.

Automatic and intelligent system demands are dynamically increasing in today's market and it observed that there is a high demand for decision support system. The above discussion is performed from the perspective of existing forest fires detection system that has been conducted in past. The key gaps and issues focusing on the context that how these challenges and issues can be resolved through the conceptual framework based on WSN technology. Because each system has some gaps and missing holes which might available in the said system, however, according to our analysis, there is a high probability that if these issues and challenges are resolved for a better Forest Fires Alerting System (FFAS) based on WSN can be designed and developed.

2. Literature Review

Forest fires detection and alerting system development are defined and considered as one of the complex, critical and time-consuming process [18]. It is analyzed that with the passage of time the demand of forest fire system or automation system are increasing and there are a number of developed countries in the Globe that are investing on the forest fires detection systems such as UK, US, and many others. In the context of this research that the theme of this section is to provide the deep investigation on the existing forest fires detection system and what are the key gaps or challenges that exist within the context of these systems as mentioned in [3]. According to our understanding and analysis, it is observed that every forest fires system or any system have certain types of weaknesses or gaps and there is a high probability that through the execution of the system these gaps and weaknesses can be addressed.

This is considered as the key section that has helped in developing the foundation and by the help of this foundation the key area can be identified and analyses in which the extension be needed in the forest fires detection supporting argument from [11]. In the context of this study the next section 3 the natural disasters have been covered. While in section 4 a detailed discussion about the forest fires detection systems have been discussed, after it we will also place some points about the use of traditional approaches for controlling forest fire.

During the analysis and the arguments from [19], it is observed that in developing countries have also planned to invest in the information and communication technology so that they have saved their natural resources. According to UN a number of non-governmental organizations (NGOs) working in developing countries and are quite active in the development of many projects that can help in saving the natural resources from disasters. It is also observed that during the year of 2000 to 2016 that there is estimation that millions of people are being affected and their properties have been impacted by natural disasters, hazards and many other issues supporting the argument from [19]. On the analysis, it has been observed that there are different sort of ranges that are available for the automation system detection and the most common technique is a satellite-based system as mentioned by [20]. It is also indicated that there are many of the systems have also been utilized for the disaster management and detection such as earthquake detection. According to the deep understanding and investigation, there are different ways that can be utilized for finding the natural disaster in different aspects and it has been observed that among all a common and the most recommended one is the use of technology (sensors, nodes, and networks). It has also been observed that as compared to the traditional solution an advance solution is more effective and efficient and provide better outcome if the technology is properly deployed for it [8, 11]. Because the traditional approach for the forest fires detection is also used and build but its accuracy dependability upon the vision, humidity, fog, etc can affect the line of action. The traditional approach for such task can be divided into two categories as mentioned in Figure – 1.

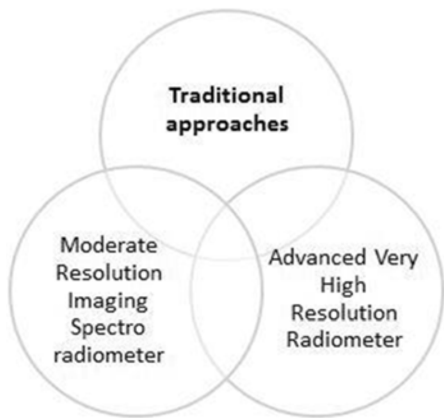

Figure 1. *Traditional Approaches.*

One of the most traditional methods includes the fire lookout tower [20]. These towers are deployed in the area near the forest. This device is equipped with special devices. The devices help in the monitoring of the forest fires. These special devices include Osborne fire finder or Night-Vision Device Aided [20]. Fire lookout towers are still in use in many countries around the world including America, Australia, and Canada [21].

2.1. Automatic Residential Fire Detection

In this section, the detail discussion in the context of Automatic Residential Fire Detection system has been presented and it is observed that these systems have the capacity to respond in the context when the forest fires have occurred supporting the argument from [8]. This study will not discuss that how the forest fires need to be responded but will be analyzing that how the forest fire is detected [9]. The smell via nose has considered as one of the terrific fire detectors and even it has the capacity to smell odors by using millions of neurons that are present in the brain of a human skull. The human body is a complex system and there is a high probability that fire can be detected but in the specific region.

Further, there are different sort of commercial products that can also be utilized for the detection of fire and mostly these products have low range capacity. The airborne smoke is one of the common application that simulate and detect using sensor including ionization and photoelectric. These systems mostly consist of an alarm and whenever the smoke is detected the alarm gets activated. All the sensors are connected with each other through wires and then solution for protecting things from fire is detected. But due to poor performance and less efficiency a new system in this regards need to design, developed and implemented in the context for improved detection [22-23].

2.2. Wireless Sensor Network Approach

Wireless Sensor Network and sensor technology offers many benefits and a lot of features in detecting fire in the forest which cannot be achieved through traditional approach. The features of Wireless Sensor Technology includes sensor deployed in the field having high coverage low costs,, scalability, ubiquitous network access, greater resiliency, hypervisor protection against network attacks and less maintainability in energy compared to the other technology [24]. It is alternative to traditional approach; WSN also has the capacity for the detection and alerting of the forest fires [20-21], requires less power, self-organized, and need less maintenance and being inexpensive [13]. In previous years, a large number of alerting applications have been developed, designed and implemented for detecting and alerting of forest fires using sensor network but most of the system are connected with web services or online alerting system. It is observed that a significant delay in sending a warning message to the emergency offices [26].

2.3. Forest Fire Surveillance System

This approach and solution architecture has been designed, developed and implemented for the South Korea Mountains. The key concept and objective development of this solution is to detect forest fires but no response applications have been currently developed for it. It utilized the wireless sensor network technologies and communication protocol for the data and information in the context transferring data among different nodes. The main components of the forest fire surveillance system are wireless sensor network, middleware and web application [27]. In this system the sensor will be deployed for detecting three main parameters for the affected area including temperature, humidity, detect smoke. But due to this multi-variables of the environment and accessing web application and not concentrated on detecting heat as well as no real time early alarm system, therefore, failed to delivered effectively for such a task.

2.4. Fire WxNet

The FireWxNet [19] is a multi-tiered portable fire sensor network to measure the weather and environmental condition considered for the region where the forest fires application has been deployed. It composed of a web camera, sensor technology and a base station that helps in long-distance communication through the deployment of the FireWxNet [19]. It collects the weather condition after half hour intervals via web camera which has been integrated to provide a continuous view of the current fire condition that may be burnt in the forest fires. This system has the capacity of providing useful data for fire behavior analysis. [28]. But one key problem is considered as the key gaps in the context of this system is the lack of continuity in data collection so failed to delivered result in the context of real-time environment.

2.5. Fire Detection in Mines

The fire detection or identification in mines is also one of the critical challenges as the growth rate of the fires in the mines is greater than the fires ignited in the forest. The wireless sensor network has also been utilized for the identification of the fires in the mines. A solution was designed and implemented by [27] in which data is collected with the help of sensors deployed in the mines and a fast and energy efficient communication protocol utilized scheduling mechanism techniques for transferring data to base station [27]. It has been observed that this scheduling mechanism technique helps in the saving of energy and overall increasing of the network performance and network optimization technique. The other component in this application includes the data processing; once the data is collected, the information is transferred to the processing components where it is processed and sends the information to the monitoring components where alert is generated from the monitoring subsystem [27].

2.6. Skyline Access

A skyline is an intelligent mechanism and a communication approach which has been utilized in the wireless sensor network for the forest fires detections. This approach is only transfers the required message to the base station or sink node, a specific criteria for each of the transmission are defined like those sensor readings with maximum temperature and high wind speed can only data on the skyline are sent to a sink to be used for the detection of fire. Meanwhile sink processes the data according to the suggested algorithm and the results are produce in a fast and energy efficient manner [24].

2.7. Fire Index System

With the passage of time, it is analyzed that there is a number of different sort of system that can be utilized for the Fire Index System. However, the most commonly utilized systems for fire indexing system (FIS) are indicated as below:

2.7.1. Fire Weather Index

It provides the calculation of relative fire potential based on the weather conditions. Based on the existing researchers work [6-8] it is analyzed that this is one of the common systems and mostly utilized for FWI system and forest fires detection and its estimation mechanism [16]. The low values of FWI are calculated not likely to be based on fired but on the calculation and the research analysis of [29] as shown in the Table – 1 below:

Table 1. *Ignition Potential versus the FFMC value [29].*

S/No	Ignition Potential	FFMC Value Range		Action Required	Priority
		High Value	Low Values		
1	Low	75	1	Send Alert	LOW
2	Moderate	85	76	Send Alert	LOW
3	High	89	86	Urgent Action Required	MEDIUM
4	Very High	92	90	Urgent Action Required	HIGH
5	Extreme	93+ (Can reached up to 130 depending upon the environmental conditions	92	Urgent Action Required	HIGH

While the high values of FWI are calculated on the basis of fire that ignited; some fires might be left to burn while others need to be extinguished immediately. The key innovation of this system is the design of a wireless sensor network application for forest fire detection and is based on FFMC, DMC, DC code and ISI, BUI, and calculation of the FWI index [16] as shown in the figure – 2 below:

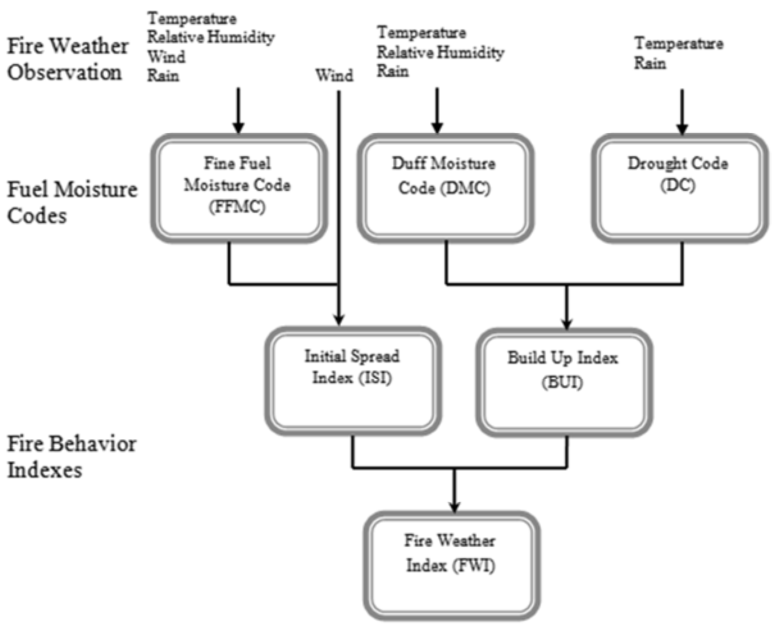

Figure 2. *Fire Weather Index System (Groot, 1998).*

2.7.2. National Fire Danger Rating System (NFDRS) Hazed Index

This approach is based on a number of Indexes such as Occurrence Index which indicates the potential of fire incidence, Burning Index which specifies the possible amount of effort required to control a single fire in a particular fuel type within a rating area, and Fire Load Index which shows the total amount of efforts needed to surround all probable fires within the rating area during a particular period of time [18].

2.8. Problems with Existing System

As discussed above one by one the problems of detections and identification in these systems are as under:

1. Delay in Response
2. High Cost of Infrared Cameras

3. Maintenance Problems
4. High False Alarm Rate
5. Low Coverage

3. Proposed System Architecture and Design

The system architecture and design is the centerpiece of attention. There are many components in which the complete system architecture is presented. Each component is integrated with the other components to perform a specific task so that the required objective of the research can be achieved. The proposed solution is based on four core components Wireless Sensor Network, Middleware, Web Application and Alerting Subsystem. All these components are coupled with each other so that the early detection of the forest fires can be achieved. In this regard these basic components are presented in the proposed solution for the design and implementation of an early alerting system for forest fire based on wireless sensor network (WSN) approach; a) a detail discussion on the system architecture, b) wild fire monitoring middleware which is a desktop application, c) fire alerting web interface that is an active server pages application, d) system components consists of base station and sensor nodes, f) a proposed architecture for communication and coordination between the sensor, g) a detailed description of index system components of Fire Weather Index including fuel code and fire index of fire weather index by [16], h) a detailed description of deployment of application in the real time environments and i) the software requirement specification including function and non-functional requirements.

3.1. System Architecture

The vision of the proposed system architecture is to design, develop and implement a proposed solution to fulfill all the functional requirements of the proposed research objectives. There are a number of the indexing systems which can be utilized for the identification of the forest fires; however, in the proposed solution fire weather indexing is utilized. The communication and coordination between the wireless sensor networks are based on the priority data packet sent and received. The sensor network area is divided into two main areas such as secure and insecure.

The data packet headers consist of a number of parameters which help in the overall decreasing of the network overhead and the energy utilized for the data transmission between sensor nodes and base stations. The Microsoft.net framework has been utilized in the design and development of the proposed solution based on middleware and web applications. The middleware is a desktop based application and web application is based on active server pages.

The proposed solution identifies the forest fires and it scales with the help of the fire weather index. The wireless sensor network is designed and deployed in the forest fires. However, in the real-time environment, the sensor can be deployed with the help of the helicopter. Once the sensor network is deployed the based station of the sink node will be selected. In the simulation environment, the web service has utilized for the data communication between the base station and middleware. The middleware is the core part of the research study in which the alerting and monitoring of the system can be performed. The alerting subsystem is initiated with the help of the web application. The system can send the email to the required administrator in case if the fire is ignited in the forest. The alerting subsystem will automatically identify the scale of the fire. This calculation of scale is based on the fire weather index. The sensor network deployed in the forest will be able to detect the following parameters from the environments. These parameters will be converted into data packets and the information will be exchanged with the help of the proposed solution.

The working principle of the proposed solution calculates the Fire Weather Index (FWI) index. Once these indexes are calculated, the information is transferred to the web services. The data packets are uploaded to the web services using Simple Object Access Protocol (SOAP). Middleware graphically presents the information relating to the sensor, current Fire Weather Index (FWI), and many other parameters. The longitude and latitude values in the simulation environments are replaced by x-axis and y-axis. The alerting subsystem sends the email in case if the fire is ignited in the forest environments. Middleware accesses the information of Fire Weather Index (FWI) from the web service deployed on the web server. The design and development purpose of the middleware is to continuously monitor the FWI and web application and it will also be integrated with the middleware. The web application can help to create a connection with all other emergency services like Fire Bridge.

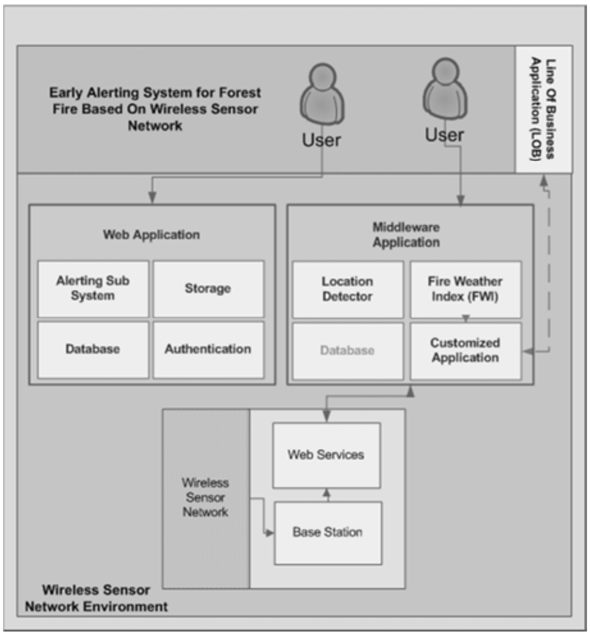

Figure 3. *Conceptual Framework.*

If the Fire Weather Index (FWI) value is on the danger scale then, the middleware sends a warning message to the web service deployed on the web server. The web application and the smartphone are also connected to the web services. This warning message contains the x-axis and y-axis location of the fire, date and time and many other parameters. The message is uploaded to the web application and also in the smartphone. This information will also be saved in the database server. Whenever there is a new message an alarm is generated by the web service. The web application is monitored and can be accessed at the offices of emergency services by providing authentication (login name and password). Whenever a message about the fire is received then they respond to the place where the fire accident has occurred. The FWI values are displayed by a different color as shown in table – 2 below:

Table 2. *Fire Weather Index (FWI) Color.*

S/No.	FWI Value	Color
1	FWI <= 10	Blue
2	FWI > 10 && FWI <= 20	Yellow
3	FWI > 20 && FWI <= 30	Brown
4	FWI > 30	Red

3.2. Fire Monitoring Middleware

It is a desktop application working between the operating system and Wireless Sensor Network (WSN). It is designed to run on a traditional desktop computer and has portable computing devices. The middleware represents graphical information retrieved from the sensor nodes. It calculates the fire weather index of the current weather conditions provided by the wireless sensor network place in the graphical window to show the user and the approximated position of the sensor coordinates. The area where there is a high value of Fire Weather Index (FWI) the color of that area will be changed. The auto message is generated by the middleware and will be sent to the web application. The middleware will continually scan the information provided by the wireless sensor network. The main goal of this middleware (Monitoring Application) is to recognize the approximate position where the fire is ignited. It will auto generate the message and calculate the fire weather index of each location and intensity of the fire.

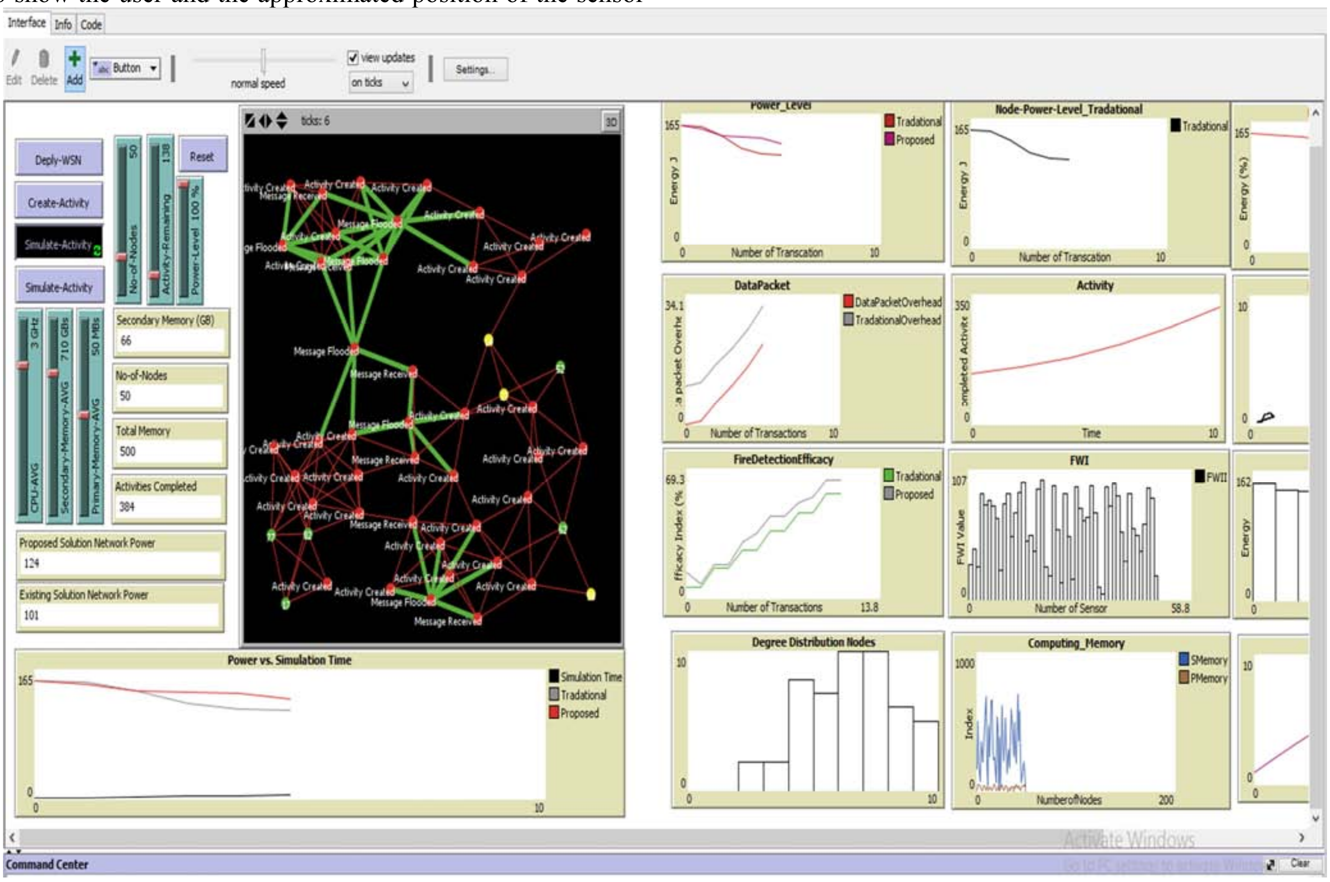

Figure 4. *Application Interface.*

3.3. Fire Alerting Web Interface

The web application can be accessed on the computers of all emergency offices. The information of the fire in the forest and the fire accident can be accessed from this application. This application will also be connected to the database of the forest PC. There will be information regarding temperature in the form of a graph. The web application will send the message about the fire accident to the officers working in the forest emergency offices. The emergency services can rapidly respond to the problems and take control of the fire.

3.4. Client Application

The front end or client end application is designed and developed using the C# and Asp.net. The application is connected with the web services to update information regarding the data retrieved from the wireless sensor network. If the fire is ignited in the forest, then the application will identify the fire, its location, index date, temperature, time and many other parameters. The information will also be uploaded to the web application. These different applications will be hosted on the web server and can be accessed anywhere with the help of the internet. These emergency services will be accessed in the web application for a specific area as mentioned below:

a) Environment

The environment is considered as the area where the sensor network is deployed. The environment contains two main components, WSN and base station. The purpose of WSN is to monitor the situation parameters such as temperature (t), relative humidity (h), wind speed (WS) and rain (r). Once the parameters are calculated, the FWI is calculated and the information then transferred to a specific node or base station. In a simulation environment, the data is sent to the web service acting as a base station.

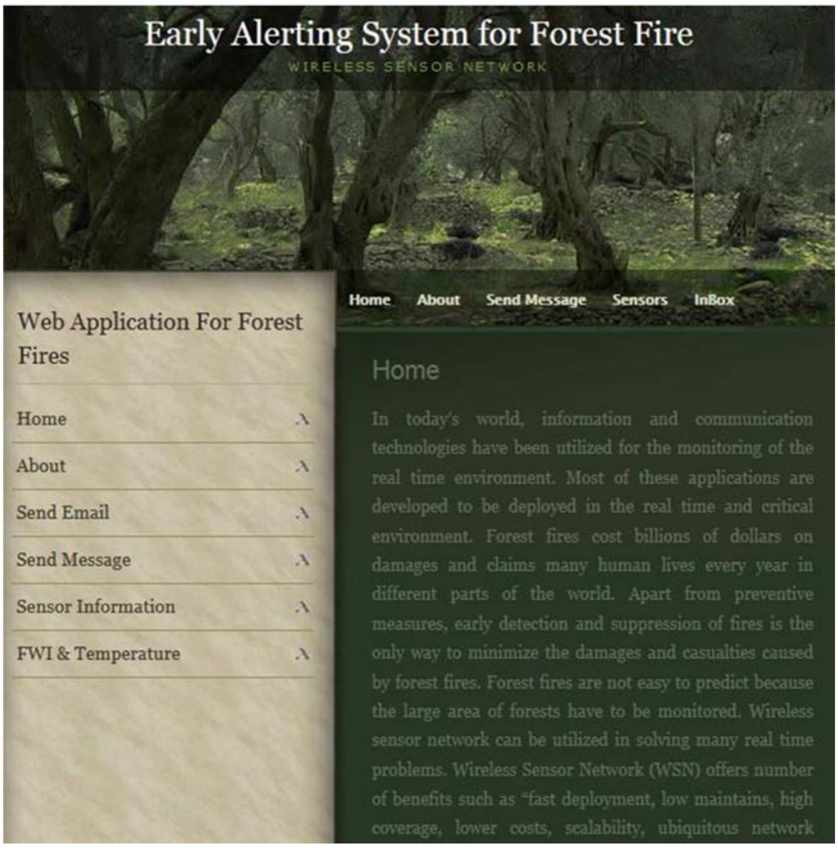

Figure 5. *Web Application.*

b) Data Communication Protocol

The communication protocol between the sensors network plays an important role in overall performance of the network. The proposed solution implements a new data communication methodology for communication between the sensor nodes or base station. There is number of parameters which have been utilized for communication such as weight, priority, security and many others. In the forest fire environment, the nodes are considered as statics. There are no specific rules for the deployment of the sensor in the forest environment. Each sensor node in the network manager has many parameters. All the nodes in the network can travel directly to the sink nodes or base station. The steps of the approach are as followed:

In the initial step, the shortest distance is calculated with the help of the Dijkstra's algorithm. The equation used for the Dijkstra's algorithm as follows:

$$Di,j = \sqrt{(Xj - Xi)^2 + (Yj - Yi)^2}$$

In the next step, the weight is calculated with the help of the residual energy and radius of a specific node. In the simulation environment, the radius is considered within the range of 5 to 10 millimeters.

$$Pi,j = \frac{Erem + R}{D\ i,j}$$

Many parameters which have been analyzed during the priorities nodes which include the factors of security, speed, FWI, and energy. The equation for it is as under:

$$Wi = (\sum(\varphi i)\ Pi,j$$

The equations perform a different type of calculation and help to set the priority of the data packet and the selection of the path on which the data is transfer. These equations have also been simulated in the customized simulation environment developed using Microsoft C#.

But with the passage of time, there are different protocols have been designed by different researchers to let the devices share data packets in the network. In the situation of this research, we will be developing the customized protocol that will be working on the standards of Wireless Application Protocol and wireless 802.11n [29].

Table 3. *Data Transmission.*

Steps	Sensor Nodes to Nodes Communication	Nodes Involved	
1	Data Packets Transmission sending a data packet from sensor node (SN) to sensor node (SN)	SN	SN
2	Data Packets Transmission	(SN) → (SN)	
3	Data Packets transmission sending message from Sensor Node (SN) to Base station (BS)	SN	BN
4	Data Packets Transmission	(SN) → (BN)	
5	New Sensor Node (NSN) Add and Transmission the message sensor node to sensor node	NSN	SN
6	Data Packets Transmission	(NSN) → (SN)	

c) Multi Dynamic Route

The proposed communication solution identifies the multi-dynamic route in the wireless sensor network. The identification of multi-dynamic route is developed with help of priorities. It is observed from the two dynamic paths that the yellow and red line represents the path built within the priority of energy and weight, whereas another path of the sensors with blue and dark blue lines represent the path built on security and weight priority. However, several multi routes can also be identified using the proposed solution utilizing for priority feature.

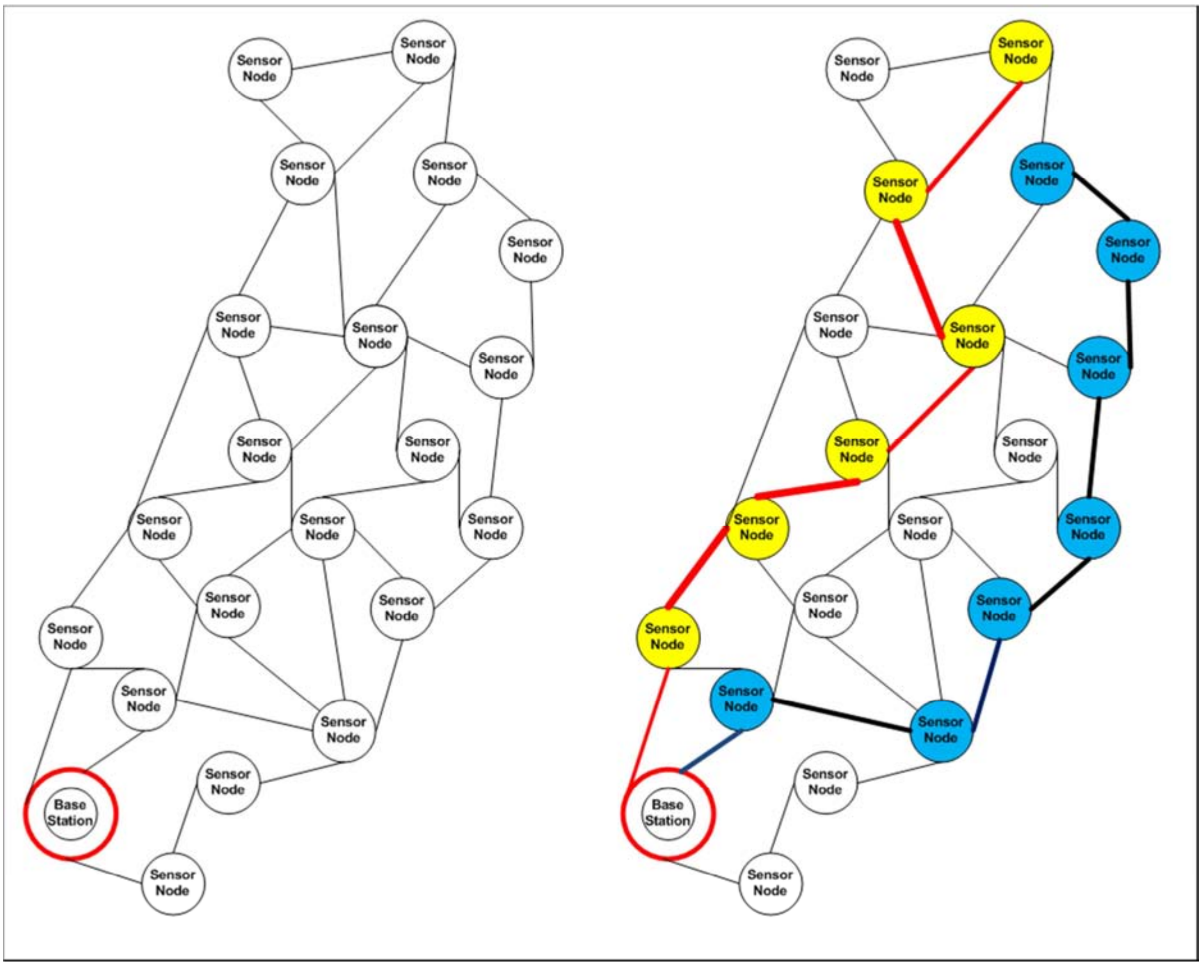

Figure 6. *Multi Dynamic Route.*

4. Verification and Validation

Verification and validation of proposed solution are a complex and time-consuming process as there are different types of parameters that are involved in the system architecture that need to be tested and verified as mentioned in [33]. It is analyzed that with the passage of time there are different types of tools, techniques, and approaches such as programming languages, simulation languages, testing techniques and many others are designed and developed for performing the testing. It is indicated that testing in the overall process is a time-consuming job because the different types of variables that linked to the context of testing are the key goal or the whole system can be tested. It is observed that there is a high probability that if the testing is properly performed for the proposed solution or architecture can be shifted from testing environment to the real-time environment as mentioned in [3-5]. It is also observed that based on the architecture of the Microsoft solution framework will be considered in the testing and in this research. However, this testing will be conducted through the utilization of simulation environment that is developed in the Java language and the procedural language NetLogo, with the passage of time and researchers [3, 4] that are different sort of tools, techniques, and approaches that are designed, developed and implemented for testing of any sort of solution. The analysis of most researchers suggested that testing must be conducted through utilization of simulation mechanism or using any programming language, so the analysis of the proposed work is also based on existing researcher's work. It is analyzed that if the proposed solution is tested in the real-time environment there is a high probability that, in case of failure of the test the cost is considered is a key factor in testing; but if the verification and validation are properly performed there is a high chance for the key objective and goals is linked to the context of an early alerting system for forest fire based on wireless sensor network can be achieved.

4.1. Testing Through Simulation Approach

The existing work of most of the researchers that are conducted under the umbrella of forest fires detection and wireless sensor network, an emphasis that simulation environment must be utilized but lack the detail of the simulation environment so need to designed and developed using Java and the testing technique from [6]. After analysis it has been observed that the results are identified in this section will let us decide that whether a proposed solution can be integrated into the context of the real-time environment or not. Because two key aspects are taken that is proposed solution architecture for the detection of forest fires and the communication protocol. There is a high probability that considering these components will directly help us to achieve the key objective and identifying the path that how the proposed solution can be integrated.

4.2. Simulation Environment

As already discussed in the perspective of this research, NetLogo is used for simulation of all the key experiment and utilizing the context of NetLogo. It is observed that the key reason for the selection of NetLogo is that, in various features and the complete parameters for each of the wireless sensor node that we need in the solution can be deployed. As already discussed in the context of this research we will also integrate the fire weather index. There are different sort of impact that can be utilized for the verification and validation of the proposed solution. However, it is indicated that there is key reason due to which the proposed solution testing was performed in the scenario using NetLogo. In the following section, we have indicated the key point that can be considered as the justification that when NetLogo is utilized for the verification and validation of an early alerting system for forest fire based on wireless sensor network:

1. Open Source Technology
   a. Net Logo is design and developer in the context of open source technology and it is observed that new module and functions can easily be design, develop and implemented through the utilization of open source programming language (technology).
2. Behavior Model
   a. It is observed that the language have one of the key aspects of the behavior model that let the key stakeholder or researcher to developer different types of variable and conduct the analysis of these variables.
3. Parameter Setting
   a. Through the utilization of the NetLogo language, it is quite easy to identify, analyze and characterization of each of the parameters for the agent that is linked in the context of this solution.
   b. It is observed that there are high chances for the better results that can be obtained if program each element of the proposed solution that is linked in the context of an early alerting system for forest fire based on the wireless sensor network.

It would be summarized that these are the key reason or justification due to which we have proposed the solution and there is a high probability that better results and outcome can be obtained if the NetLogo is properly utilized.

4.3. Simulation Design

The proposed solution of simulation design for an early alerting system for forest fire based on wireless sensor network is developed using NetLogo, parameters, and components which are linked within the context of this research are indicated below:

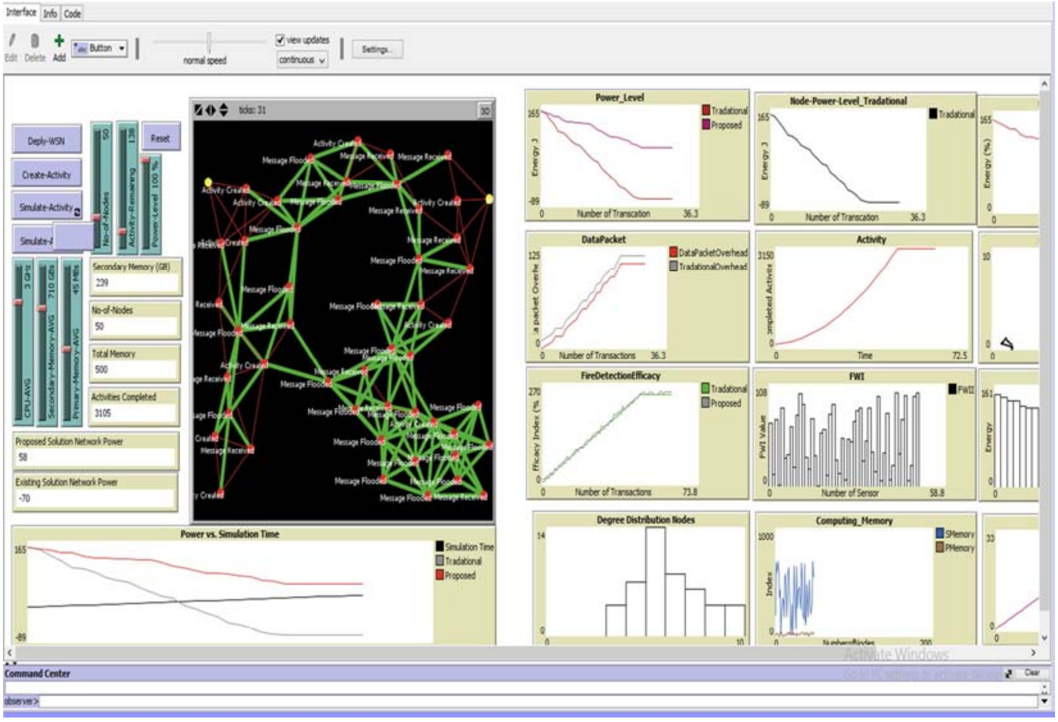

Figure 7. *Simulation Design.*

1. Setting Environment for Area

a. In the initial phase of the environment in the context of the simulation design, an early alert system for forest fire based on the wireless sensor network, the area is selected. In the context of NetLogo, the patch and key area on which the simulation environment will be conducted is 256 x 256. The model setting is indicated the in the figures below:

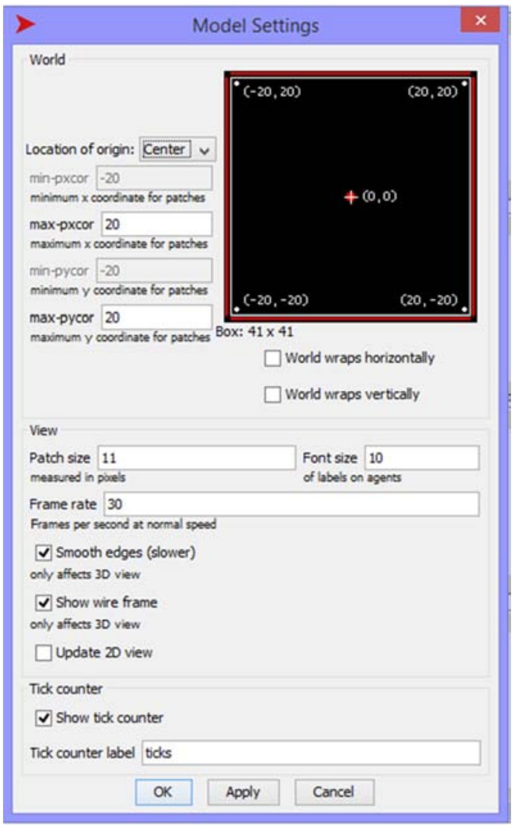

Figure 8. *Model Setting.*

2. The setting of the Wireless Sensor Network

a. In this phase, the Wireless Sensor Network will be deployed. It is observed that in each phase the analysis will be conducted so that the true performance of the proposed solution can be detected.

b. In the figure below the wireless sensor network deployed in the context of simulation environment is presented.

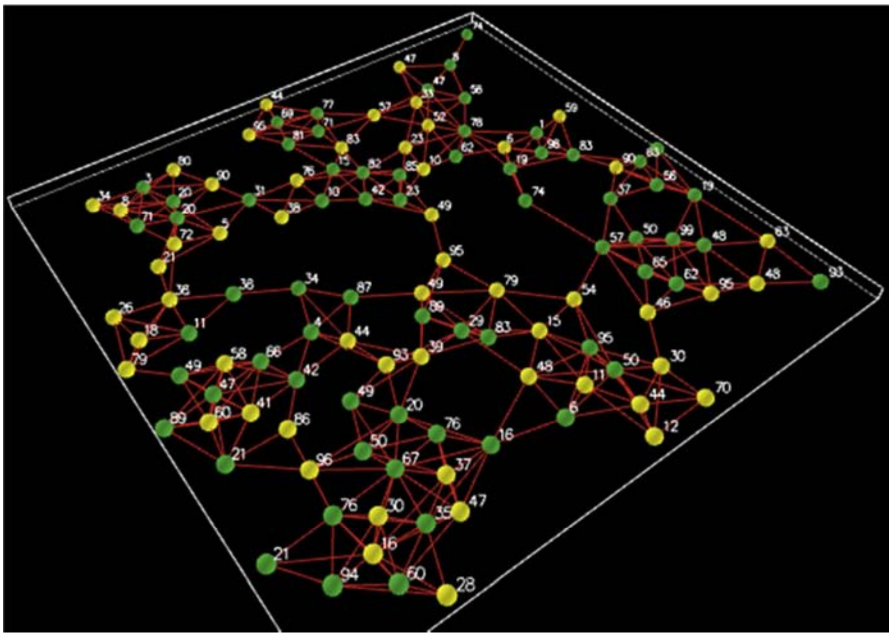

Figure 9. *3D View of Wireless Sensor Network.*

3. Linking the Wireless Sensor Network

a. As the communication and collaboration between among parameters, the wireless sensor network needs to be conducted. So it is analyzed that communication among all the nodes of a wireless sensor network that are deployed in the context of the proposed solution must be integrated.

b. In the figure below the sensor nodes deployed in the context of simulation environment shown in the 2D scenario.

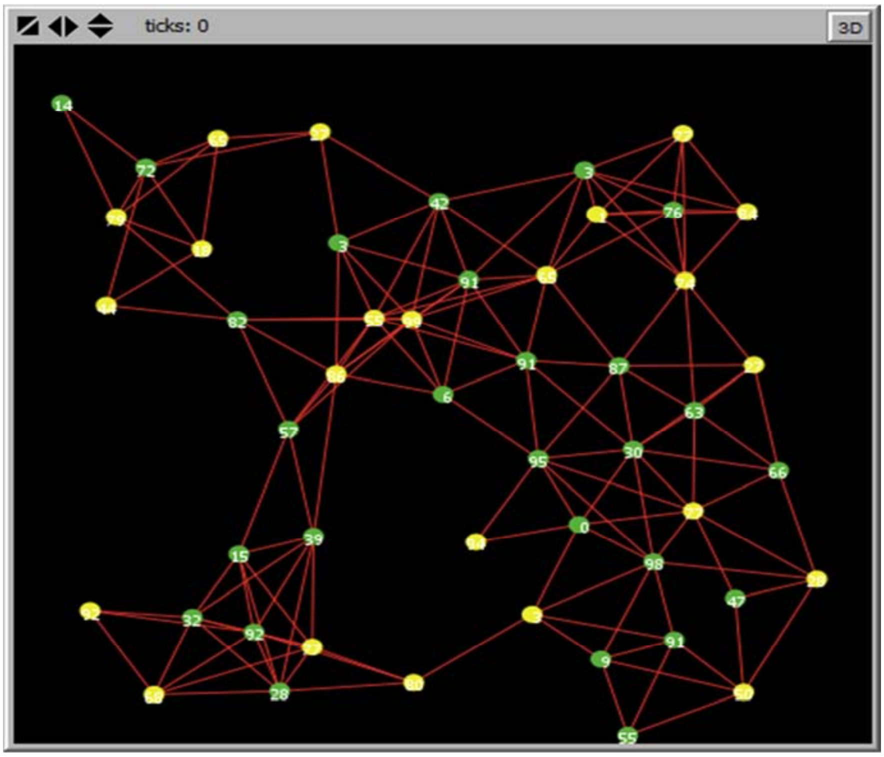

Figure 10. *2D Network Connectivity.*

4. Programming the Fire Weather Index

Once the deployment of the proposed solution is implemented than in the next phase each of the fire weather indexes is deployed on the wireless sensor network. There is a high probability that each node in the specific area may extract the key four environmental parameters. Once all these parameters are detected the objective for analyzing the Fire weather Index will be obtained.

5. Integration the communication protocol

a. In this module, the programming of the communication protocol is conducted. All the important multi-listing techniques are programmed in NetLogo so that the desired outcome can be obtained.
b. Conducting Experiment
c. Once all the above steps in the simulation design and development are completed then the experiments would be conducted.
d. The figure presented below indicates the experiment results.

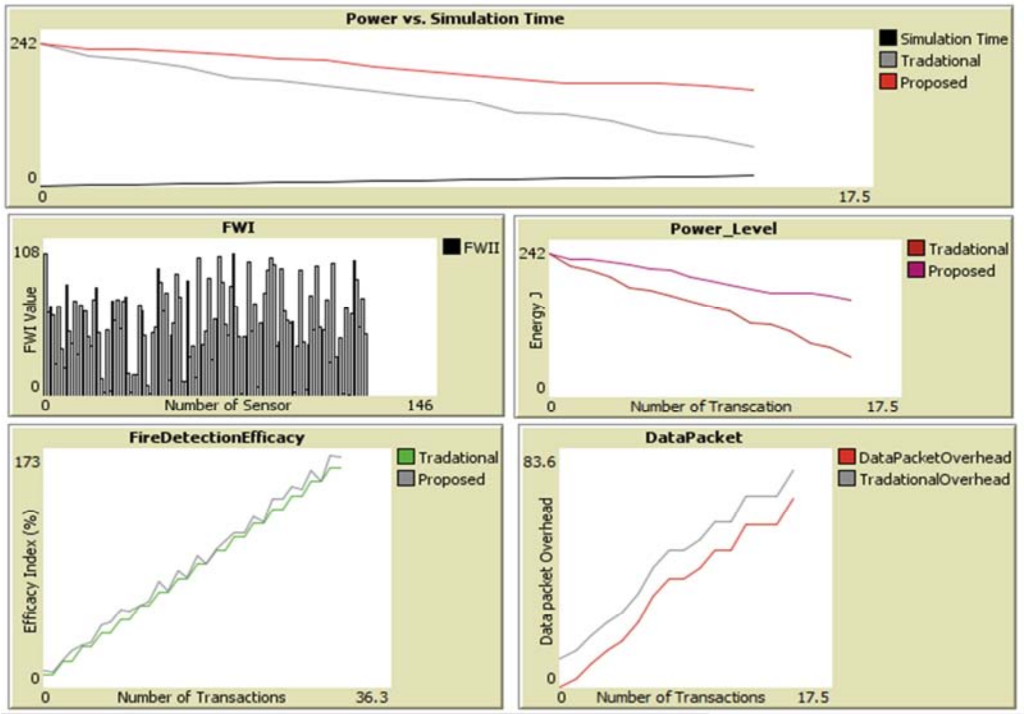

Figure 11. *Experiments.*

On the basis of the experiment, it is observed that if the simulation design of an early alerting system for forest fire is conducted then the outcome can be better.

4.4. Experimental Access

In a simple context, the experimental approach is defined as "An approach to research in which the researcher manipulates and controls one or more variables and then measures any change in other variables" [8]. It is observed that with the experimental approach NetLogo has the capacity to execute the process for a required solution.

The following experiments can be conducted in case of an early alert system for forest fire based on the wireless sensor network.

a. Network Power Analysis,
b. Fire Detection Efficacy,
c. Data Packet Analysis,
d. Fire Weather Index Analysis,
e. Simulation Time and Network Power Analysis.

Using different parameters all the above experiments led us to the solution. In the next section, the detail discussion of the solutions is presented.

4.5. Network Power Analysis

This experiment is conducted to analyze the network power and a traditional solution as presented by [9, 2] and a proposed solution that is presented as the part of this research early alerting system for forest fire based on the wireless sensor network is considered.

Based on the context of the simulation environment it is analyzed that proposed solution due to the integration of multi-listing technique is a better solution as compared to the traditional one. In the simulation environment, the proposed solution is tested around 116. Based on the simulation results, it is observed that the proposed solution that is executed in the simulation environment has better results.

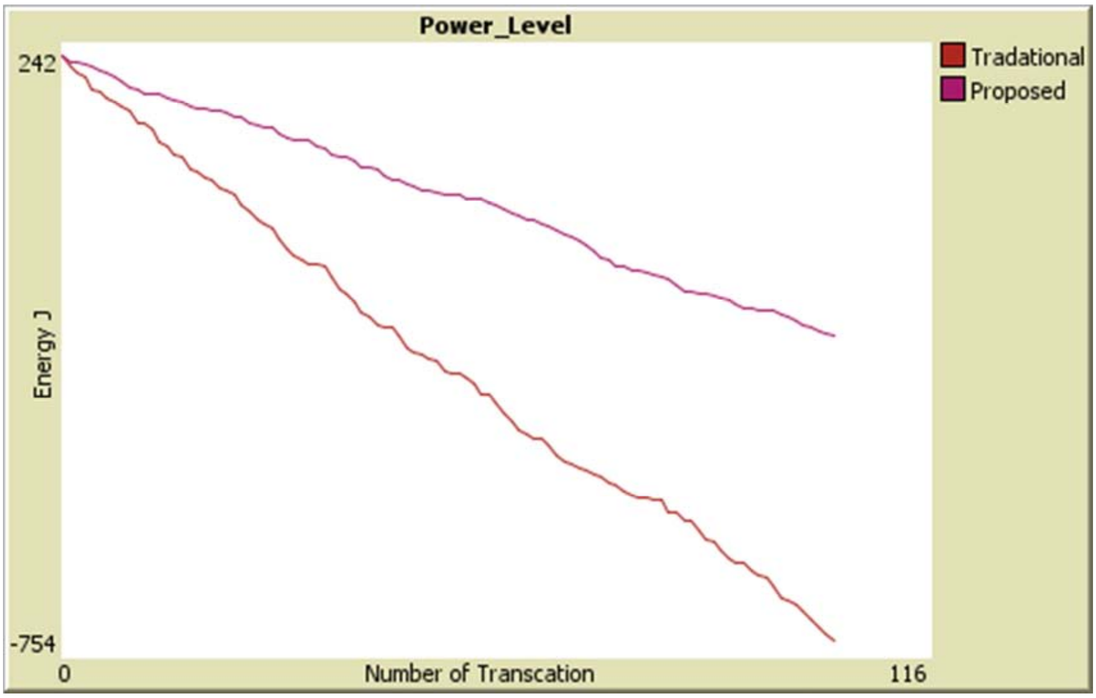

Figure 12. Network Power Analysis.

4.6. Fire Detection Efficacy

Fire detection efficacy experiment is conducted to measure the Fire Detection Efficacy in the proposed solution in the early alerting system for forest fire based on wireless sensor network and traditional solution of [10] is considered. Up to some extent, the traditional and proposed solution for fire detection efficacy is similar; however, about 5% improvement is measured in the speed and time of detection in an early alerting system for forest fire based on WSN.

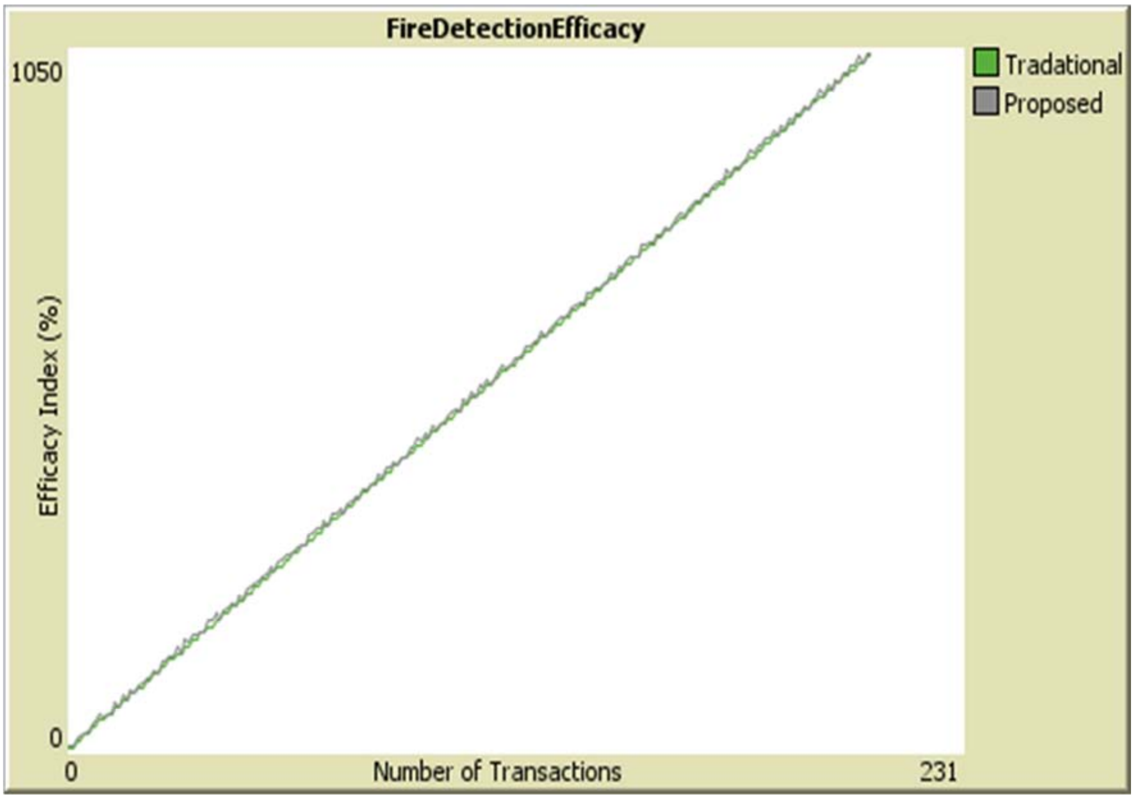

Figure 13. Fire Detection Efficacy.

4.7. Data Packet Analysis

Data packets are required to be simulated for every ad-hoc or traditional network. However, this experiment is conducted to identify and analyze the data packet overhead of traditional and proposed solution. During the simulation results, it is analyzed that traditional solution has more data packet overhead as compared to the proposed solution overhead. Further data packet analysis obtained better results due to the multi-listing technique [2].

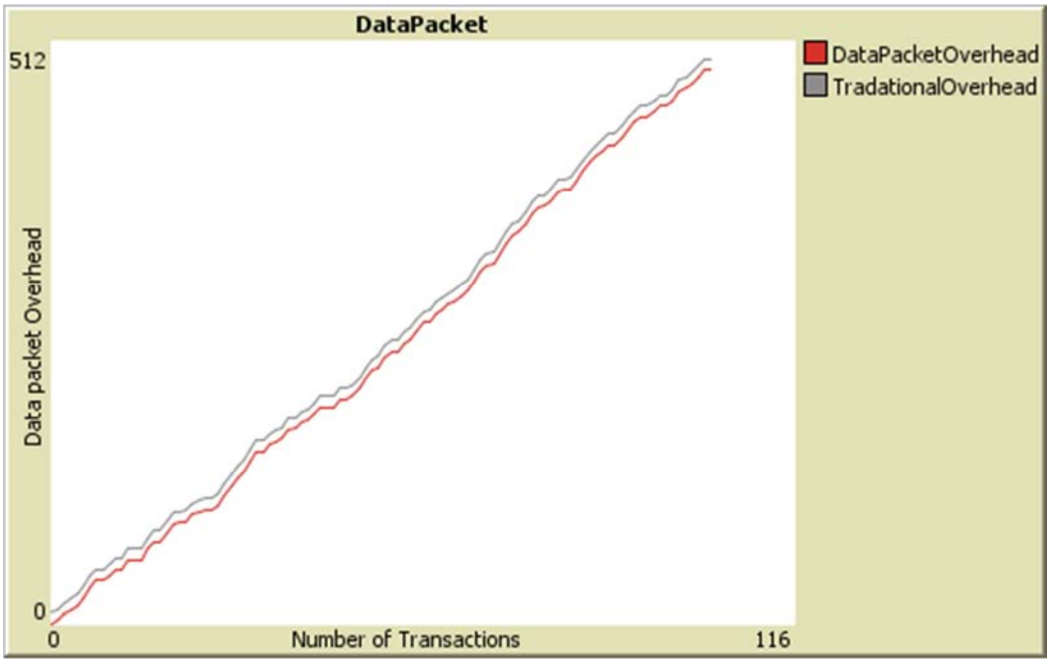

Figure 14. *Data Packet Analysis.*

4.8. Fire Weather Index Analysis

This experiment is conducted to identify and analyze the index that is collected by each sensor node as shown graphically in the figure below:

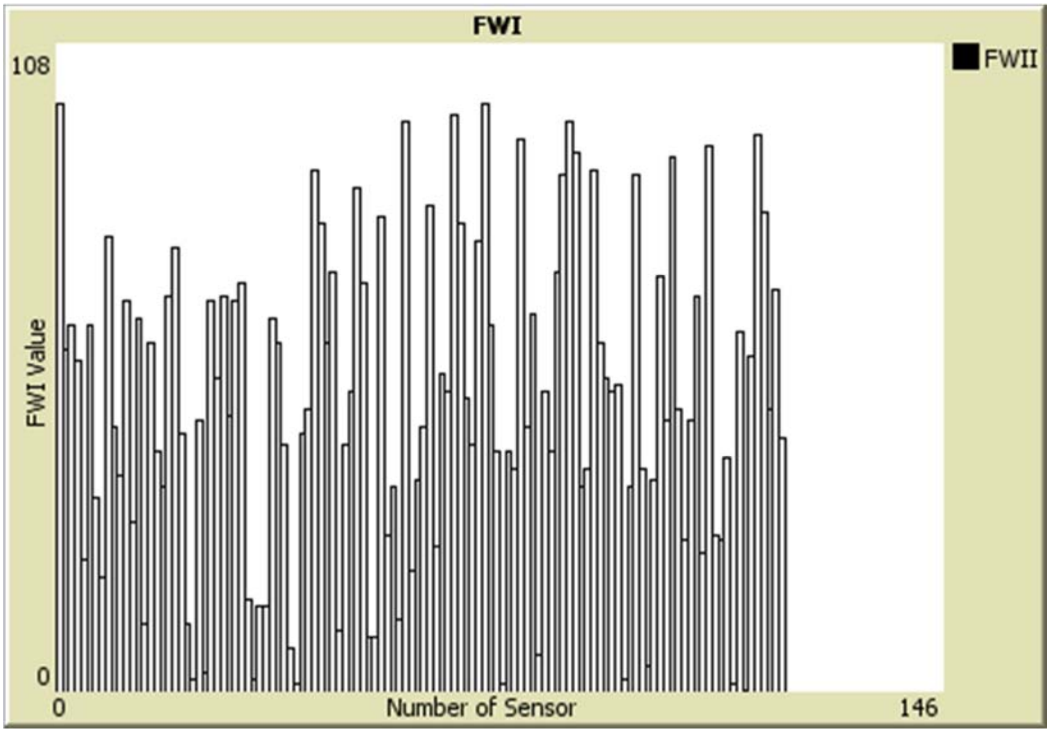

Figure 15. *Fire Weather Index Analysis.*

4.9. Relationship Between Simulation Time and Network Power

This experiment is conducted to identify and analyze the relationship between the simulation time and network power. It is analyzed that simulation time and network power move simultaneously.

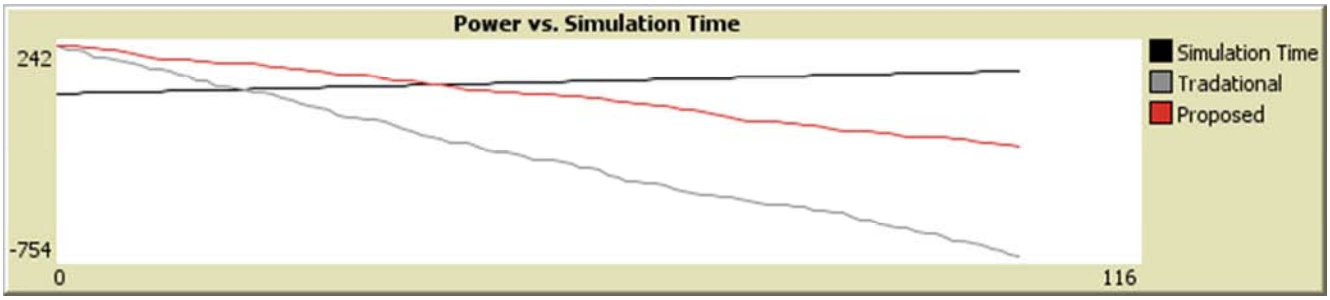

Figure 16. *Simulation Time and Network Power.*

5. Conclusion

It can be summarized that the key objectives and goals that are linked within the context of an early alerting system for forest fire, based on wireless sensor network, have been achieved. The proposed solution presented in the research has the capacity of early detection and identification of the forest fires, using sensor network technologies. In the context of the proposed solution, the FWI is integrated and it is observed that the scale and intensity can be measured through the utilization of FWI. According to analysis and understanding of the problem, there is a high probability that proposed solution can be transformed into real-time environment.

Furthermore, if proper mechanism is adopted, definitely better results and key gaps in the proposed solution of an early alerting system for forest fire based on wireless sensor network can be achieved. In this regard a proper communication and collaboration with all the stakeholders must be designed and developed. Furthermore, agent-based model be integrated and environmental factors must be considered for the betterment. However NS3 is a better communication and collaboration protocol for an early alerting system for forest fire based on wireless sensor network can provide better testing.

In the context of the future area for an early alerting system of forest fire based on wireless sensor network, the middleware application must be executed through the utilization of cloud technology. It can be summarized that if the cloud computing technology is integrated, better results and outcome can be extracted.

Appendix – A

The said system is implemented using a software toolkit NetLogo 5.3.1, which are given below:

```
breed[nodes a-node]

extensions [profiler]
globals [nodename
Services
SecondaryMemory
Activity-Rem
totpower
power
totpower_old
power_old
Datapack1
PrimaryMem
SecureNet
]
nodes-own[
visited
Security
Secure
PMemory
SMemory
CPU
Access_Control
DataPacket
UNSecurity
FWI
]
links-own[visit]

;Create and Deploy Computing Nodes
to setup
setup-Computing-Nodes
setup-spatially-clustered-network-Computing
ask links [set color red
set visit false
]
do-plotting
Plot_Computing_Memory
set PrimaryMem 1

;;create-Meters1
end

;Create Computing Nodes
to setup-Computing-Nodes
;; (for this model to work with NetLogo's new plotting features,
  ;; __clear-all-and-reset-ticks should be replaced with clear-all at
```

```
  ;; the beginning of your setup procedure and reset-ticks at the end
  ;; of the procedure.)
  __clear-all-and-reset-ticks
create-nodes No-of-Nodes
 [
   ;for visual reasons, we don't put any nodes *too* close to the edges
   setxy (random-xcor * 0.95) (random-ycor * 0.95)
   set shape "circle"
   set color green
   set visited false
   set label-color white
   set SecondaryMemory random 12
   set FWI Random 100
   set power No-of-Nodes + Power-Level
   set power_old No-of-Nodes + Power-Level

   set label FWI
   set Security random 2
;   set Visited random 1

   set PMemory random Primary-Memory-AVG
   set SMemory random Secondary-Memory-AVG
   set CPU random CPU-AVG
   set Access_Control random 1
   ;set label PMemory
;   do-plotting-SecureNodes
   ]

   ask nodes with [Security = 0]
   [
   set color yellow

   ]
   Plot_FWI

end

;Deployement of the Computing Nodes
to setup-spatially-clustered-network-Computing
let num-links (6 * No-of-Nodes) / 2

 while [count links < num-links ]
 [
   ask one-of turtles
   [
     let choice (min-one-of (other turtles with [not link-neighbor? myself])
                [distance myself])
     if choice != nobody [ create-link-with choice
      ]
   ]
 ]
 ; make the network look a little prettier
 repeat 10
 [
   layout-spring turtles links 0.3 (world-width / (sqrt No-of-Nodes)) 1
 ]
end

;Generate Message for nodes
to Create-Activity
ask one-of nodes
[
set color red
set label "Activity Created"
set Activity-Rem Activity-Remaining

]
end

to test2
let kj count nodes with [color = green]
if-else kj != 0
[
let k one-of nodes with [color = red and visited = false]
if k != nobody
[
ask k
[
set label "Sending Message"
set visited true
set nodename who
ask my-links with [visit != true]
[
set color green
set thickness 0.5
set visit  true
]
]
]
]
[
show "No Node to Send Message"
stop
]
end

to Simulate-Activity
every 1
[
do-plotting
tick
do-plotting-time
do-plotting-memory
do-plotting-Activity
do-plotting-power-level
do-plotting-power-level_Trad
do-plotting-time_Total
Power_Level
do-plotting-memory


Data_Packet
let kj count nodes with [color = green]
if-else kj != 0
```

```
[
test2
let yy a-node nodename
ask yy
[
set label "Message Flooded"
set SecondaryMemory SecondaryMemory + 10
set Activity-Rem Activity-Rem + SecondaryMemory
set power power - random 10
set power_old power_old - random 20
set DataPacket DataPacket + random 10
set Datapack1 DataPacket + Datapack1

if PrimaryMem > 0
[
set PrimaryMem PMemory + PrimaryMem
set PrimaryMem PrimaryMem - random 8
]

if-else Security > 0
[
set  SecureNet  SecureNet  + 1
do-plotting-SecureNodes-Activity
]
[
set  SecureNet 0
do-plotting-SecureNodes-Activity
]
let f1 count my-links with [color = green
]
repeat f1
[
let r (one-of link-neighbors with [color != red])
if r != nobody
[
ask r
[ set color red
set label "Message Received"
]
]
]
]
]

[stop]

]
end
to do-plotting ;; plotting procedure
  let max-degree max [count link-neighbors] of nodes
  set-current-plot "Degree Distribution Nodes"
 ; plot-pen-reset  ;; erase what we plotted before
 ; set-plot-x-range 1 (max-degree + 1)  ;; + 1 to make room for the width of the last bar
  histogram [count link-neighbors] of nodes
    set-current-plot "Degree Distribution (log-log)"

;  plot-pen-reset  ;; erase what we plotted before
  ;; the way we create the network there is never a zero degree node,
  ;; so start plotting at degree one
  let degree 1
  while [degree <= max-degree]
  [
    let matches turtles with [count link-neighbors = degree]
    if any? matches
      [ plotxy log degree 10
             log (count matches) 10 ]
    set degree degree + 1
  ]
end

to do-plotting-time
set-current-plot "Simulation-Time"
;  set-current-plot-pen "tick11"
  plot ticks
end

to do-plotting-time_Total
  set-current-plot "Power vs. Simulation Time"
     set-current-plot-pen "Simulation Time"
     plot ticks

     set-current-plot-pen "Tradational"
     plot Power_old

     set-current-plot-pen "Proposed"
     plot Power
end


to do-plotting-memory
 set-current-plot "FireDetectionEfficacy"

 set-current-plot-pen "Tradational"
 plot  SecondaryMemory

 set-current-plot-pen "Proposed"
 plot  SecondaryMemory + Random 10
  end

 to do-plotting-Activity
 set-current-plot "Activity"
 plot Activity-Rem
 end

 to  do-plotting-power-level
  set-current-plot "Node-Power-Level_Proposed"
  plot power
end

to  do-plotting-power-level_Trad
  set-current-plot "Node-Power-Level_Tradational"
  plot power_old
end

to  do-plotting-power-level_Existing
  set-current-plot "Node-power-Level"
```

```
  plot power_old
end

to Plot_Computing_Memory
  set-current-plot "Computing_Memory"
  set-current-plot-pen "SMemory"
  ask nodes[
  plot SMemory
  ]

    set-current-plot-pen "PMemory"
  ask nodes[
  plot PMemory
  ]

end

to Data_Packet
  set-current-plot "DataPacket"
  set-current-plot-pen "DataPacketOverhead"
  plot Datapack1

    set-current-plot "DataPacket"
  set-current-plot-pen "TradationalOverhead"
  plot Datapack1 + 10
  end

to do-plotting-SecureNodes-Activity
   set-current-plot "Power-Remaining"
  plot power

end

to Power_Level
  set-current-plot "Power_Level"
  set-current-plot-pen "Tradational"
  plot power_old


  set-current-plot-pen "Proposed"
  plot power
end

to Plot_FWI
  set-current-plot "FWI"
  set-current-plot-pen "FWII"
  ask nodes[
  plot FWI
  ]
end
```

References

[1] Alliance, Z. (2006). *ZigBee specification*. Document 053474r06. Retrieved from Document 053474r06, Version 1 (2006).

[2] Bagheri, M. (2007). Efficient K-Coverage Algorithms for Wireless Sensor Networks and Their Applications to Early Detection of Forest Fires. *Computing Science SIMON FRASER UNIVERSITY*, MSc:75.

[3] Bahrepour, M., Nirvana, M., & Havinga, P. J. (2008). Automatic fire detection: A survey from wireless sensor network perspective.

[4] Breejen, & E., M. B. (1998). Autonomous forest fire detection. Third International Conference on Forest Fire Research and Fourteenth Conference.

[5] Burgan, R. E. (1988). National Fire-Danger Rating System. *Asheville, NC: U.S. Department of Agriculture, Forest Service, Southeastern Forest Experiment*, Res. Pap. SE-273.

[6] Cano, A., Reig, C., Milan-Scheiding, C., & Lopez-Baeza. (2012). Automated Soil Moisture Monitoring Wireless Sensor Network for Long-Term CalVal Applications. *Wireless Sensor Network, 4* (8).

[7] Chae, M., Yoo, H., Kim, J., & Cho, M. (2006). Bridge Condition Monitoring System Using Wireless Network (CDMA and Zigbee). *23rd International Symposium on Automation and Robotics in Construction ISARC 2006, Tokyo, Japan, 3 – 5 Oct*.

[8] Chen, Z. (2013). A review of automated formal verification of ad hoc routing protocols for wireless sensor networks. *arXiv preprint arXiv*, 305.7410.

[9] Chowdhury, N., Mahabub, H., & Samiul, I. (2013). IOT: Detection of Keys, Controlling Machines, and Wireless Sensing Via Mesh Networking through Internet. *Global Journal of Researches In Engineering*.

[10] Cracknell, A. P. (1997). *The Advanced Very High-Resolution Radiometer (AVHRR)*. CRC Press.

[11] Dutta, D., Dilip, K., & Arindam, K. (2013). Analysis of IEEE 802.15. 4 MAC under low duty cycle. *arXiv preprint arXiv:1301.6532*. edition.cnn. (2013, 20 12). *http://edition.cnn.com/2013/10/20/world/asia/australia-fires/*. Retrieved from http://edition.cnn.com: http://edition.cnn.com/2013/10/20/world/asia/australia-fires/.

[12] Flannigan, M. D. (1998). Future wildfire in circumboreal forests in relation to global warming. *Journal of Vegetation Science*, 469-476.

[13] Fleming, G., & Robertson, R. (October 2003.). *Fire Management Tech Tips: The Osborne Fire Finder*. USA: Technical Report 0351 1311-SDTDC, USDA Forest Service.

[14] Forestry Division Newsdesk, N. (2008). *http://www.dfr.state.nc.us/news_pubs/*. Retrieved 01 12, 2013, from http://www.dfr.state.nc.us/news_pubs/: http://www.dfr.state.nc.us/news_pubs/.

[15] García, H., & Ana, B. (2008). *WSN Application Scenarios*. London: Springer.

[16] Gat, E. (1998, Retrieved 2008-04-06). On three-layer architectures. *Artificial Intelligence and Mobile Robots*, 195–210.

[17] Groot., W. J. (1998). Interpreting the Canadian Forest Fire Weather Index (FWI) System. *In Proc. of the Fourth Central Region Fire Weather Committee Scientific and Technical Seminar, Edmonton, Canada*.

[18] Gungor, V. C., & Gerhard, P. (2013). *Industrial Wireless Sensor Networks: Applications, Protocols, and Standards*. CRC Press.

[19] Hussain, A., & Niazi, M. (2010). A novel agent-based simulation framework for sensing in complex adaptive environments. *IEEE Sensors Journal, 11 (0), doi:10.1109/JSEN.2010.2068044.*

[20] J. San-Miguel-Ayanz, J. C. (2003). Section 2: Current methods to assess fire danger potential. In Wildland Fire Danger Estimation and Mapping The Role of Remote Sensing Data. World Scientific Publishing Co. Pte Ltd.

[21] Karali, A. (2013). Evaluation of the Canadian Fire Weather Index in Greece and Future Climate Projections. *Advances in Meteorology, Climatology and Atmospheric Physics. Springer Berlin Heidelberg*, 501-508.

[22] Knuth, D. E. (1977). A generalization of Dijkstra's algorithm. In *Information Processing Letters 6.1* (pp. 1-5).

[23] Lee, & Tsung-Han. (2013). Modeling and Performance Analysis of Route-Over and Mesh-Under Routing Schemes in 6LoWPAN under Error-Prone Channel Condition. *Journal of Applied Mathematics 2013*.

[24] Lee, S.-J., Gerla, M., & Toh, C.-K. (1999). A simulation study of table-driven and on-demand routing protocols for mobile ad hoc networks. *Network, IEEE, 13* (4), 48-54.

[25] Lim, Y.-s., & S. Lim, e. a. (2007). A Fire Detection and Rescue Support Framework with Wireless Sensor Networks. Convergence Information Technology.

[26] Milke, J. A., & McAvoy, T. J. (1995). Analysis of signature patterns for discriminating.

[27] Muller, H. C., & Fischer, A. (1995). A robust fire detection algorithm for temperature and optical smoke density using fuzzy logic. *Security Technology, Sanderstead*.

[28] Niazi, M., & Hussain, A. (2009). Agent-based tools for modeling and simulation of self-organization in peer-to-peer, ad-hoc and other complex networks. *IEEE Communications Magazine, 47 (3)*, 163 - 173.

[29] Okayama, Y. (1991). A primitive study of a fire detection method controlled by the artificial neural net. *Fire Safety Journal, 17* (6), 535-553.

[30] PAK, M. (2012, 06 06). *http://www.microsoft.com/en-pk/default.aspx*. Retrieved from http://www.microsoft.com.

[31] Pripužic, K. H. (2008). Early Forest Fire Detection with Sensor Networks: Sliding Windows Skylines Approach. Faculty of Electrical Engineering and Computing, Department of Telecommunication, White Paper.

[32] Silberschatz, A., Galvin, P. B., & Gagne, G. (2010). *Process Scheduling*. (J. (Asia), Ed.) Operating System Concepts (8th ed.).

[33] Son, B., Yong-sork, H., & J, K. (2008). A design and implementation of a forest-fires surveillance system based on wireless sensor networks for South Korea mountains. *International Journal of Computer Science and Network Security (IJCSNS), 12* (6.9), 124-130.

[34] Thuillard, M. (2000). Application of Fuzzy Wavelets and Wavelets in Soft Computing.

[35] Tiwari, A., Ballal, P., & Frank, L. (2007). Lewis Energy-efficient wireless sensor network design and implementation for condition-based maintenance. *ACM Transactions on Sensor Networks (TOSN) archive, Volume 3, Issue 1*.

[36] Tymstra, C., Bryce, R., & Wotton, B. (2009). Development and structure of Prometheus: the Canadian wildland fire growth simulation model. *Nat. Resour. Can., can. For. Serv., North. For. Cent., Edmonton, AB. Inf. Rep. NOR-X-417.*

[37] Vescoukis, V., & T. Olma, e. a. (2007). Experience from a Pilot Implementation of an "InSitu Forest Temperature Measurement Network. Personal, Indoor and Mobile Radio Communications".

[38] Viani, F., Rocca, P., Oliveri, G., & Massa, A. (2012). Pervasive remote sensing through WSNs. *Antennas and Propagation (EUCAP), 2012 6th European Conference on*, (pp. 49-50).

[39] Yu, L., & Wang. (2005). Real-time forest fire detection with a wireless sensor.

[40] Zhiping, L., & Q. Huibin, e. a. (2006). The Design of Wireless Sensor Networks for Forest Fire Monitoring System. *School of Electronics and Information, Hangzhou Dianzi University.*

Biography

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