Technical Journal, University of Engineering and Technology (UET) Taxila, Pakistan Vol. 22 No. 3-2017
ISSN:1813-1786 (Print) 2313-7770 (Online)

Middleware Application for Alerting Forest Fires using Wireless Sensor Network

Z. U. Rahman[1], A. Javed[2]

[1,2]*Software Engineering Department, University of Engineering and Technology, Taxila, Pakistan*
engr.zia146@yahoo.com

Abstract-Wireless Sensor Network (WSN) has become one of the most important aspects for environmental monitoring, i.e. wildfire monitoring, Landslide detection and many others. Many wildfires causes massive forest damages every year in different parts of the world. This paper presents an effective approach based on wireless sensor network to identify and monitor wild fires in forest. The proposed work presents an intelligent system that provides early warning of potential forest fires as well as to provide an effective evaluation of fire scale and fire intensity. The main objectives of the proposed intelligent sensor based network is to measure the environmental attributes such as temperature (t), relative humidity (h); rain (r) and wind speed (WS) etc. The data of these parameters are acquired via wireless sensor network from different geographical locations and transfer to third party application for processing. The research presented the conceptual framework to intelligently estimate "scale and intensity" of the forest fires. The proposed system is effective and reliable to identify and monitor forest fires. It can easily be integrated with third party applications.

Keywords-Conceptual Framework, Forest Fires, Intelligent, System Architecture, Wireless Sensor Network (WSN)

I. INTRODUCTION

Forest fires or wild fires cost a loss of millions of dollars each year in different parts of the world [i]. Forest fires are a major source of massive damage to houses, buildings, and human lives each year[ii]. Beside preventive measures, the identification of forest fires at early stage and its suppression are the only ways to minimize the damages and casualties cause by the wild or forest fires" [iii]. Researchers have explored this area in great deal and contributed in this domain with various solutions [iv-ix] to provide alert and monitoring services for forests fire identification and propagation. This area always keeps researchers interested to propose novel and effective solutions as human lives and nature are affecting from this problem. There exist a room to propose effective and efficient solutions to save the human lives and natural resources all over the world. Beside plenty of room for research, forest fire identification and monitoring is a challenging task [x].

There are various sources that contribute to initiate and propagate forest fires, some of them are natural but unfortunately most of the time the forest fires are caused due to the human carelessness such as Lighting, Aridity [xi].

A. Real time Application

To design and develop a real time application for forests fire monitoring is a critical and challenging task. Existing research work [xi, viii] have been proposed to design effective solutions for the detection of forest fires at early stages. Researchers have also contributed in this domain and proposed various solutions [xi] to address the problem of forest fires propagation at rapid speed. These systems are designed by using different types of information and communication technologies [xii]. Rapid advancement in technology and ease of information access has resulted in the development of effective solutions for real time environments such as "forest fires detection [xiii], building security system [xiv], and home automation [xv-xvi] etc. Even though much work has been proposed in this area but the challenging environment and nature of disasters has demanded to propose more effective solutions to meet the current real time challenges in forest fire identification and propagation [xvii].

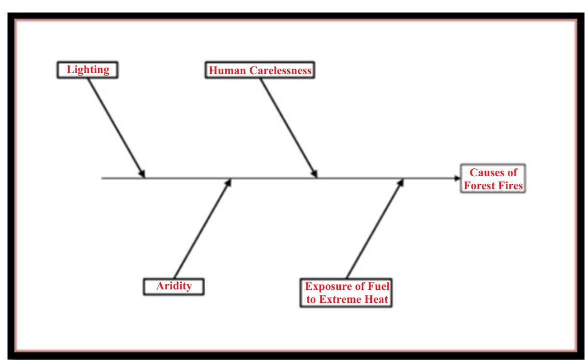

Fig. 1. Causes of Forest Fires

In past, large number of tools and techniques are being utilized for design and implementation for monitoring of the real critical environment such as Agent based forest fires [xviii], MRISR, Osborne fire finder etc.

This paper presents a solution to identify and monitor the propagation of forest fires by using wireless sensor networks (WSN) for forest fire control. The proposed solution is divided into three layers and each layer consists of specific components. These components are designed to perform specific task such as "Fire detection"[xix]. However, all the components are integrated together so that the overall performance and efficiency of the proposed solution can be increased.

Smart sensor technology has been used in various domains to propose effective solutions for real world problems [xx]. Existing research is also being conducted to achieve better performance and efficiency by using smart sensor technology. Wireless sensor network (WSN) technology has been in practice since many years in various daily life applications [xxi]. Smart sensors are part of various portable devices these days such as cell phones, PDA etc. which are used for data collection [xxii]. Sensor frequency identification devices transfer the data using wireless medium of communication. Existing systems [xxiii] have also been designed in the field of communication and information technology (ICT) specifically focusing on WSN. Wireless sensor network (WSN) is considered as a low cost inexpensive solution and can easily be integrated with any system or application in various domains [xxiv].

We have designed a sensor-based network for the identification and detection of the forest fires. However, we have presented a conceptual framework that can be integrated in various software applications. The base station of the network act as a web service. Fire Weather Index (FWI) is used for the identification of the forest fires.

Developing a real time critical system for the real time environment of forest fire is a challenging task. We have presented the system for the identification and detection of the forest fire. The following section presents the desired objectives.

1. Early detection of forest fires.
2. An intelligent estimation mechanism for scale and intensity of fire.
3. Fire Index calculation based on Fire Weather Index (FWI). Fire Weather Index model is presented in [xiv].
4. Design and development of dynamic web application for integration with alerting system

There are number of challenges which we have faced during the design and development of a system for the identification and control of forest fires. Few of the design challenges are mentioned below:

1. The identification and detection of the forest fires is based on the number of the component such as measuring temperature, Fire Intensity, Routing Path so that the estimated scales and intensity are identified.
2. The identification of the forest fires should be based on the number of parameters such as Scale, FWI, FFMC [xiv]

This paper presents a conceptual framework for the identification and control of forest fires. Wireless sensor network is used to design the proposed framework. The proposed solution implements a conceptual frame work with a capacity to identify forest fires at early stage, and intelligently estimate 'scale and intensity' of the forest fire.

Section II presents a critical analysis of existing state-of-the-art. Section III presents the architecture of the proposed framework and analysis on its core parameters. Experimental results are discussed and evaluated in Section IV. Section V presents the conclusion of the proposed system.

II. Literature Review

Most of the existing systems used nowadays for forest fire detection rely either on satellite imagery or watch towers. These systems suffer from limited operations under bad weather conditions that can result in a loss of visibility. This affects the overall performance of the detection accuracy of forest fires. This section presents the critical analysis of existing state-of-the-arts. The open research problems are also identified. The design and architecture based on different approaches, tools and techniques of existing state-of-the-arts are also elaborated in detail.

A. Forest Fire Detection Systems

The design and architecture of existing forest fire detection systems heavily rely on traditional implementation techniques such as "Digital Image Processing (DIP), satellite imagery or watch towers" [xxv]. There exist many limitations in existing systems. The existing systems have limited operations under bad weather conditions such as "Fog, Rain, Smoke etc.[xxvi]. Loss of visibility is another core issue that affects the performance of existing systems to accurately detect forest fires. Existing forest fires detection systems have a high ratio of "errors and inaccuracy" because these systems mainly depends on traditional approaches [xxvii].

B. Wireless Sensor Network

This sub-section presents the information related to existing forest fires detection systems [xvii, xxiv] based on wireless sensor network approaches. The details regarding wireless sensor networks and transmission medium are also discussed here.

Wireless Sensor Network (WSN) is considered as an alternative to the traditional approaches for forest fires detection. Existing forest fire detection systems [xix, xxii] that are based on wireless sensor networks have reported better detection accuracy to detect forest fires at early stages as compared to traditional approaches. The benefits of wireless sensor networks such as less power consumption, self-organized architecture, less effort in maintenance have been reported in [xxiv].

The skyline approach is designed by using greater values of sensor readings such as maximum temperature and high wind speed. The skyline data are sent to the sink that are then used to identify forest fires [xvii]. Sink process the data according to the recommended algorithm in [xvii] and produces an energy efficient and rapid detection solution for forest fires. Each sensor consists of the receiver and sender and transfers all the information to the receiver or sender [xxii].

The proposed framework uses wireless sensor network (WSN) technology to detect and control the forest fires. The performance of the proposed system architecture in terms of identifying issues related to the design and implementation of a conceptual framework for real time applications is also evaluated. The main objective of the proposed system is to detect forest fires at early stages and provide an accurate estimation of the scale and intensity of forest fires. The research objective is to provide forest fire detection of an effective, state of the art, service support software based on Microsoft platform and any other open source technology. For the sake of verification and validation (V&V),a couple of simulation [xviii] are performed as well.

Energy is considered as the core aspect in the real time critical applications. To increase the overall performance of the network and the other components, the energy sources must be identified so that the specific monitoring and surveillance can be performed without dropping or failing down the devices [xxix] or other components integrated with it. The energy sources can be provided to WSN sink node. These sensors are usually equipped with the battery.

C. Photovoltaic Devices

The Photovoltaic Device is considered as the source of energy. These devices can also be integrated in WSN based sensor. The elementary photovoltaic device is also commonly known as photovoltaic cell. These cells are composed of two main layers. Each layer is made of semiconductor [xxx]. These semi-conductors are separated by metal contact [xxxi]. The two adjoining layers of semiconductor are separated with the help of metal contacts that have been doped. After doping, an *n* layer is created (n = negative) with a surplus of electrons followed by a "*p*" layer (p = positive) with an electron deficiency. In the photovoltaic devices, the electron flows from *n* layer to *p*-layer and creates an "electrical field" or "space charge zone". These fields are created inside the semiconductor structures [xxxii].

D. Energy Considerations

There exist many constraints for energy or battery sources. The battery size of the WSN based sensor is directly proportional to the capacity. As the battery size increases, the capacity of the sensor also increases, or vice versa. Wireless sensor network based technology sensors are smaller in size, so they have low capacity to improve the overall network lifetime. An easy way to increase the network or battery lifetime is to use battery scheduling algorithm. The selection of the optimal transmission power is also an important parameter to consider for energy constraints.

The energy consumption is also directly proportional to the transmission power. The transmission power is functional between the communication nodes. It helps to transfer the information or data from one node to another node. As the transmission power increases, the energy consumption and the transmission power decreases. "Optimal transmission power decreases the interference among nodes, which in turn increases the number of simultaneous transmissions." [xxxiii]. The reduction in the transmission power increases the frequency to reuse the better channel utilization. Power control is considered as an important part of the CDMA-based applications or systems [xxxiv].

We have presented a framework that uses wireless sensor network based on fire weather index system to resolve the issues of energy constraints in forest fires detection systems.

III. PROPOSED SYSTEM

The proposed framework based on wireless sensor network is designed to detect the pattern, scale and intensity of forest fires at early stages. The proposed framework has many benefits as compared to existing systems. The architecture of the proposed framework is designed by using fire weather index (FWI) as compared to forest fire danger index system (FFDI) that are used in existing systems. The fire weather index uses four parameters that are, *Temperature, Humidity, rain* and *wind speed* to predict the patterns, scale, and intensity of forest fires. It also facilitates in the identification of the Initial spread index as well as the build-up index of the forest fires.

In this section, we have provided an overview of the system architecture, system components, system features, and a detailed discussion on wireless sensor networks.

A. System Architecture

The system architecture is always considered as a baseline to lay the foundation for the overall system implementation. The proposed system consists of three main components namely, wireless sensor network, middleware, and web application. Wireless sensors are used to collect and transmit the data to the detection system. Fire weather index (FWI) model [xvi] is used for data calculations. The system automatically generates an alert in case the FWI values exceeds the threshold. Moreover, the information is collectively shared with the corresponding administrator. Shown in Fig. 2 is the architecture of the proposed framework.

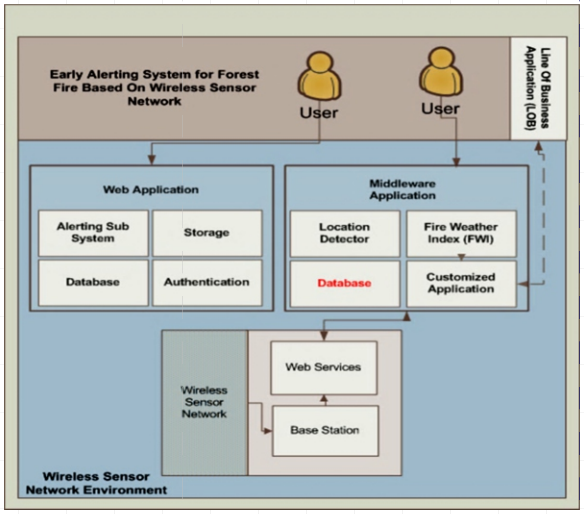

Fig. 2. Architecture of Proposed Framework

The proposed framework is more flexible and requires little effort in maintenance as compared to existing systems [viii, xx, xxiv, xxviii].The proposed system can be deployed easily. Web Application can be integrated for quick response. The application is based on the web based architecture that can easily be accessed from different locations with the internet connectivity. The system is much reliable as it is based on the Fire Weather Index. Warning alert is only generated in case if FWI level exceeds the threshold value up to 85.The minimum and maximum values of FWI as a candidate for potential ignition are presented in Table I.

TABLE I
FWI VALUES

Ignition Potential	Minimum Value	Maximum Value
Low	1	75
Moderate	76	85
High	86	89
Very High	90	92
Extreme	92	93+

False alarm rate of the proposed system for forest fire detection is significantly low as compared to existing systems [viii, xx]. The proposed system can be deployed in large zonal areas and provides an immediate response regarding indicators of fires. The proposed system is more flexible as it is based on the sub components of middleware and web application. The architecture of fire weather index is shown in Fig. 3.

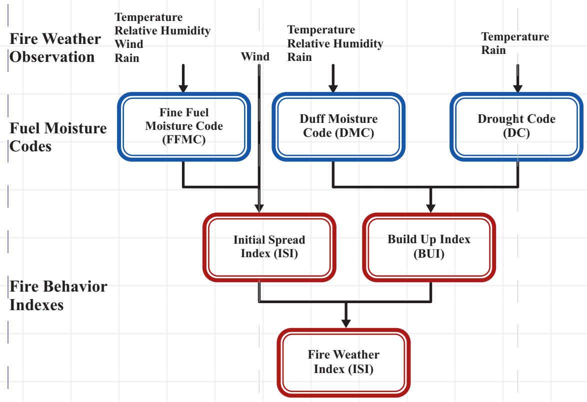

Fig. 3. Fire Weather Index System [xvi]

B. Wireless Sensor Network

Wireless sensor network is composed of a large number of tiny sensor devices that are used for specific data calculations from the environment or monitoring locations such as “wind speed, rain, humidity, temperature, heat etc. [x]. The sensor devices transform the environmental data into radio signals followed by transmission to the base station. The base station act as a wireless gateway [xiv]. Shown in Fig. 4 is the architecture of the wireless sensor node.

The significance of wireless sensor based networks cannot be denied nowadays because of their benefits in monitoring the location. These sensor instruments can be deployed in the critical and real time environment for forest fire monitoring [xxxvi]. Wireless sensor networks are more efficient to perform in real-time and challenging weather conditions. This wireless sensor requires less maintenance and has high efficiency and long life. Radio frequency identification based sensor network is normally used in various domains such as Medical application (diagnosis, physiological data), military applications (intelligent missiles, battlefield surveillance), Environmental monitoring (traffic, habitat) Industrial monitoring (factories, supply chains) etc. These radio frequency operated sensor networks continuously monitors the environment and report the data back to the base station. Radio frequency identification based sensor networks measures and obtain the coordinates of the location of fire ignition.

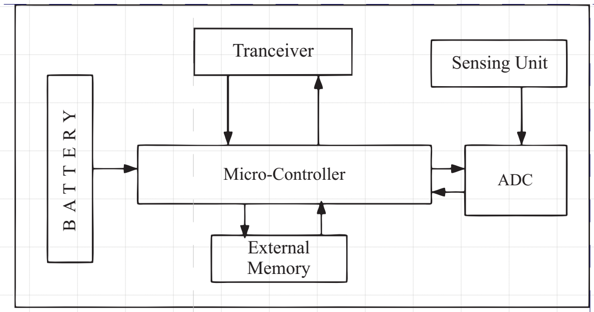

Fig. 4. Wireless Sensor Architecture

Radio frequency identification based sensor is used in many applications such as medical, military, environment and industrial monitoring etc. The sensor can be used in the form a sensor network or dynamic web. These networks can be deployed in the specific location for the environment monitoring. The entire sensor network uses the static or dynamic routing protocol depending upon the position of the sensor location [xxxv]. These routing protocol transmit the data to the designation. WSN transmits all the data to the base stations. The base station is connected with the monitoring application. WSN has many benefits such as reduction in cost monitoring by limiting the need for wires, communication channel etc.

IV. Experimental Results

Performance evaluation of the proposed system is measured via objective evaluation. We have evaluated various aspects of middleware and web application for the forest fire detection. Middleware collects the data from the nodes that are deployed in the forest. The middleware calculates the coordinate of each sensor node that facilitates accurate computation of fire ignition location. The middleware also calculates the fire weather index based on processing input data from each sensor. Shown in Fig. 5 is the accuracy comparison between the FFMC and FWI. High values of fire weather index indicates fire ignition and demands to mitigate fire ignitions by the authority. The nature of fire spread, scale, pattern of fire propagation and intensity are investigated in detail to take appropriate measures to control forest fires. This detailed study is useful to decide the outcome of either taking appropriate measures for fire mitigation.

In order to overall increase the performance and capacity the Multi-Listing technique is utilized to overall discard the repeated packages that are flooded in wireless network. However, in this research the energy efficiency goal is achieved by using agent based approach.

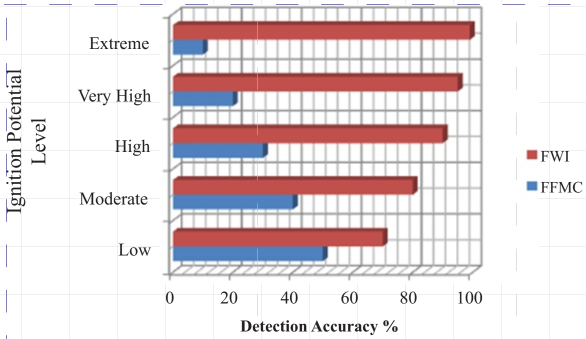

Fig. 5. Performance Comparison of FFMC and FWI

In Fig. 5 the experiment has been conducted to measure the performance of the FFMC and FWI. The detection accuracy has been measured on the five Ignitions Potential Level defined on the x-axis of the fig 5. It can be analysed from the experiment results that within the context of the detection accuracy the FWI is most accurate and efficient as compared to FWI. These values has been driven from the dataset presented in Table II

TABLE II
FFMC and FWI Value

Ignition Potential Level	Humi-dity	Temp-erature	FFMC	Humi-dity	Temp-erature	Wind-Speed	Rain	FWI
Low	30%	17 C	50	30%	17 C	5 mph	0	70
Moderate	45%	20 C	40	45%	20 C	18 mph	0	80
High	65%	25 C	30	65%	25 C	23 mph	0	90
Very High	43%	30 C	20	43%	30 C	30 mph	0	95
Extreme	32%	43 C	10	32%	43 C	50 mph	0	99

C. Relationship of Fire Intensity and FWI

Shown in Fig. 6 is the relationship between the fire intensity and fire weather index. Fire intensity indicates the energy output measured in kilowatts/meter of the frame length on the base region of the fire.

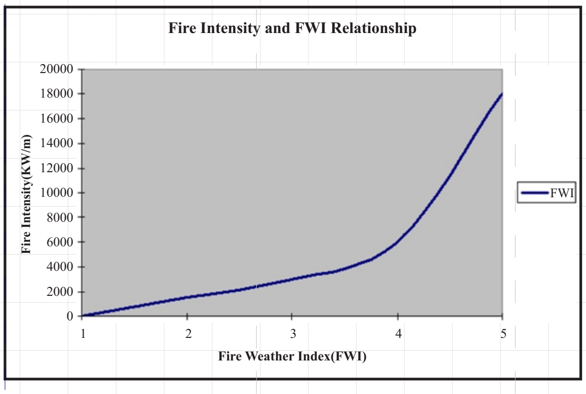

Fig. 6. Relationships between Fire Intensity

D. Measuring Time Detection

In our next experiment, we have evaluated various aspects of middleware application that has been designed to measure the effectiveness of the proposed framework. Fire detection time metric is used to evaluate the performance of the proposed system. Moreover, the detection time of the proposed system is compared with existing state-of-the-arts to signify the effectiveness of the proposed system as compared to existing systems [viii, xx, xxiv, xxviii]. Shown in Fig. 7 is the fire detection time measure of the proposed and existing state-of-the-arts. It can be observed from the results that the proposed framework successfully detect the forest fires more swiftly as compared to existing systems.

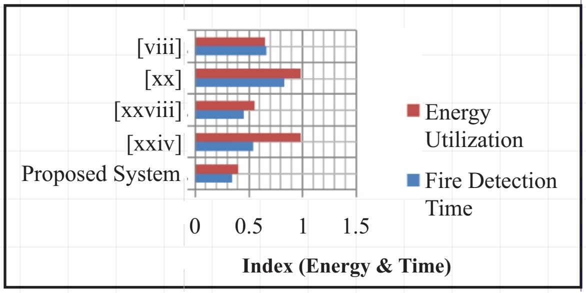

Fig. 7. Comparison between Existing Times

In Fig 7, the comparison based on the energy and time has been conducted with the existing solution [viii, xx, xxiv, xxviii] and proposed system. It can be analysed from the experimental results that the proposed system within the context of time is energy consumption is much more efficient as compared to the existing system. The dataset for the experiment has been presented in Table III.

TABLE III
PERFORMANCE COMPARISON OF FIRE DETECTION TIME

Systems	Fire Detection Time	Energy Utilization
Proposed System	0.34	0.4 J
Son et al. [xxiv]	0.54	0.98 J
Belani et al. [xxviii]	0.45	0.55 J
Estrin et al. [xx]	0.83	0.98 J
Hefeeda et al. [viii]	0.66	0.65 J

It can be analysed from Table III. that the proposed system detects fire ignition rapidly as compared to existing state-of-the-arts. The identification of forest fires at early stage is one of the main contributions of the proposed system.

E. Early Warning of Potential Forest Fires

Fine fuel moisture code (FFMC) indicates the relative ease of ignition and flaming fuel category due to exposure to extreme heat. To analyze the system we have investigated FFMC on different data inputs. The fine fuel moisture code is a positive integer with values in the range of (0 to 101)ignition rate. FFMC is the only component of the fire weather index with the open-ended scale. In general, fire ignites at around 60-70 % and it can shoot at maximum up to 96 %. High value of FFMC is an indicator of possible fire ignition and vice versa.

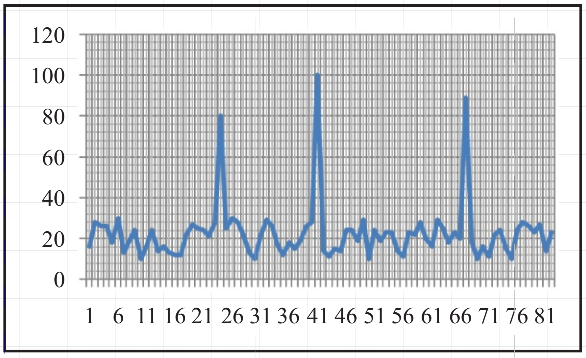

Fig. 8. Temperature Analysis

F. Estimate the scale and intensity of the fire if it is materialized

Fire weather index is used to estimate the scale and intensity of the fire, if it is materialized. FWI estimates the fire intensity by merging the rate of fire spread. Initial spread index is used to calculate the fire spread rate.

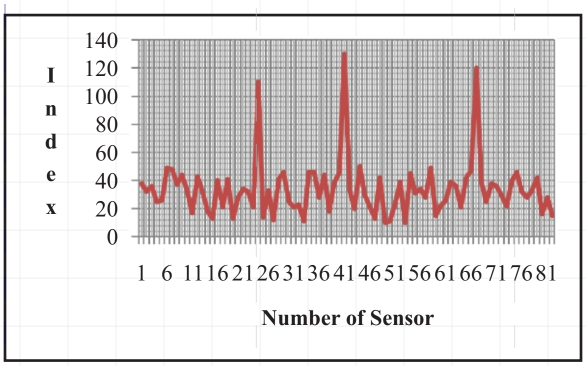

Fig. 9. Fire weather index changes as the temperature increases

A high value of the fire weather index indicates fire ignition, if value of FWI exceeds the specified threshold. FFMC and FWI are computed from the input data such as temperature, wind, relative humidity, rain etc. acquired from the sensors.

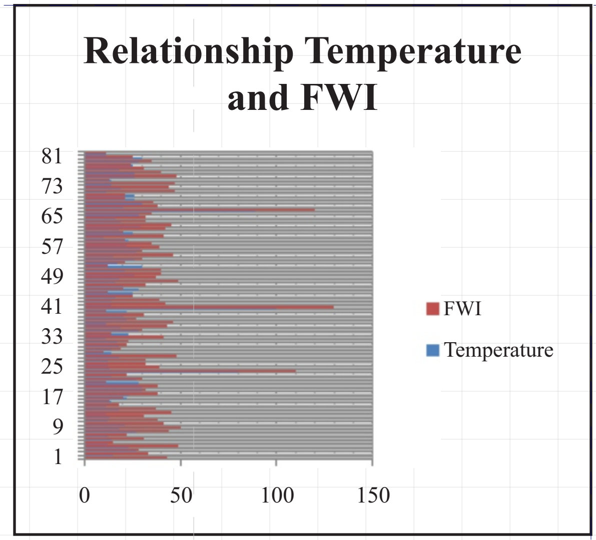

Fig. 10. Relationships between Temperature and FWI

Shown in Fig. 10 is the relationship between the temperature and FWI. The temperature values are plotted in combination of FWI values to give the indication of a direct relationship between these two parameter values. It can be observed that where the temperature is high the FWI values are also high. At some point in Fig. 10 the temperature and FWI strike rate is high. So it can be assumed from the Table IV dataset that Temperature and FWI are directly proportional to each other.

TABLE IV
RELATIONSHIP BETWEEN TEMPERATURE & FWI

T	FWI	T	FWI	T	FWI	T	FWI
13	26	27	29	21	13	29	45
18	28	80	110	13	21	30	43
19	29	21	33	20	44	29	36
15	31	30	33	16	23	10	25
27	45	29	21	12	15	89	120
15	49	20	13	16	44	29	17
24	12	15	50	13	31	18	18
11	39	20	46	25	18	14	46
19	28	10	43	28	29	23	41
14	30	28	18	29	14	17	25
21	11	21	46	19	31	20	44
11	18	13	43	29	49	18	38
24	33	17	12	25	25	16	18
10	34	11	13	15	32	18	31
30	13	25	47	21	18	17	23
19	23	16	35	26	47	19	28
15	20	21	49	11	25	29	43
29	13	14	19	18	13	23	24
24	23	100	130	18	40	11	46
25	25	17	20	18	10	26	45
15	16	27	29	21	13	29	45
22	26	80	110	13	21	30	43

The proposed research work demonstrates the utilization of wireless sensor network as opposed to traditional technologies like watch tower for forest fire detection. Database is used for storage information which can be effectively utilized for the process of operationalization and verifications. The proposed system acquires the input data from the sensors at real time and effectively identify the location of forest fire ignition and generates a warning message to administrator.

The design and implementation of the proposed framework is based on Dynamic System Development Method (DSDM). Real time application testing is the most challenging task to evaluate the performance of the proposed framework. The proposed system utilizes fire weather index and identifies the location of fire ignition. The proposed forest fire detection system consists of a large number of inexpensive and small WSN nodes. The detection accuracy of the proposed system is significantly better as compared to traditional approaches [xi]. Moreover, the proposed system can detect forest fires more rapidly. Shown in Fig. 11 is the application interface of the proposed framework.

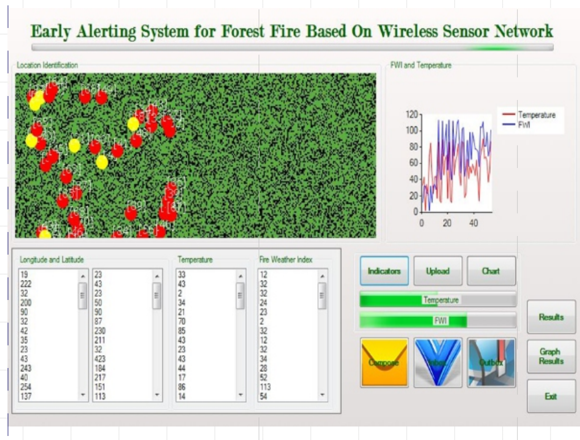

Fig. 11. Application Interface

The systems can intelligently estimate the scale and intensity of the forest fires. Existing system uses the FFMC index system. FFMC indexing systems utilizes humidity and time environmental variables, whereas the proposed framework uses four main variables (wind speed, rain, humidity, temperature). The existing system cannot be integrated with the third party open source application however the proposed solution can also be integrated with third party application. WSN identification can easily be located as compared to the [xx] sensor network. However, there still exists a demand to propose efficient real-time solutions to detect forest fires in different geographical locations around the globe.

V. CONCLUSION

The proposed system presents a middleware and web application using wireless sensor network to detect forest fires at early stage. The proposed framework calculates the scale and intensity of the forest fires. Middleware is based on the fire weather index and successfully locates the position of fire ignition. Wireless sensor network technology is found to be more efficient as compared to traditional approaches for forest fire detection and estimation. It can be observed from the results that the proposed system detects forest fire immediately, and forecast about the forest fire danger rate with better accuracy. The proposed framework can be extended by incorporating the cloud technology and software as a service facilities to the existing solution presented in this paper.

REFERENCES

[i] T. Ankit, B. Prasanna , and L. L. Frank , "Energy-efficient wireless sensor network design and implementation for condition-based maintenance," ACM Transactions on Sensor Networks (TOSN) archive, Volume 3 , Issue 1 (March),Article No.: 1, 2007.

[ii] A. Cardenas, N. Benammar, and G. Papageorgiou, "Cross-Layered Security Analysis of Wireless Ad Hoc Networks," Proc. of 24th Army Science Conference, 2004.

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

[iv] L. R. Christensen and E. Grönvall , "Challenges and Opportunities for Collaborative Technologies for Home Care Work," in Proceedings of the 12th European Conference on Computer, 2011.

[v] S. M. Kuo , B. H. Lee, and W. Tian, Real-Time Digital Signal Processing: Implementations and Applications., 2006.

[vi] M. H. Hayes, Statistical Digital Signal Processing and Modeling.: Wiley. ISBN 0-471-59431-8., 1996.

[vii] M. J. Chae, H. S. Yoo, J. R. Kim, and M. Y. Cho, "Bridge Condition Monitoring System Using Wireless Network (CDMA and Zigbee)," 23rd International Symposium on Automation andRobotics in Construction ISARC 2006, Tokyo, Japan, 3 – 5 Oct, 2006.

[viii] M. Bagheri, M. Hefeeda, "Wireless sensor Network for early detection of forest fire. ," International Conferences of Mobile Adhoc and Sensor Systems IEEE Publication, 2007.

[ix] N. Kurata, "Risk Monitoring of Buildings Using Wireless Sensor Network," in Planning Section, Kobori Research Complex, Kajima Corporation, Minato-ku, Tokyo, 2011, pp. 107-85.

[x] I. F. Su, W. Y.Sankarasubramaniam, and Cayirci, E. Akyildiz, "A survey on sensor networks. ," IEEE communications magazine, 40, 8, pp. 102-114, 2002.

[xi] D. Johnson, A. Perrig, and Y. Hu, "SEAD: secure efficient distance vector routing in mobile wireless ad-hoc networks.," Proceedings of the 4th IEEE workshop on mobile computing systems and applications (WMCSA'02). , pp. 3–13, 2002.

[xii] E. Jovanov, D. Raskovic, J. Price, and A. Moore, "Patient Monitoring Using Personal Area Networks of Wireless Intelligent Sensors," in Biomedical Sciences Instrumentation, Vol. 37, 2001, pp. 373-378.

[xiii] A. P. Cracknell, The Advanced Very High Resolution Radiometer (AVHRR).: CRC Press, 1997.

[xiv] G. X. Fleming and R. G. Robertson, "Fire Management Tech Tips: The Osborne Fire Finder.," USA, 2003.

[xv] J. Carlson, M. Alexander, K. Tolhurst,G. Morgan, and R. Sneeuwjagt. J. San-Miguel-Ayanz,.:.World Scientific Publishing Co. Pte Ltd, 2003.

[xvi] W. J. de Groot., "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, 1998.

[xvii] A. Tiwari, B. Prasanna and L. L. Frank, "Energy-efficient wireless sensor network design and implementation for condition-based maintenance," ACM Transactions on Sensor Networks (TOSN) archive, Volume 3 , Issue 1, 2007.

[xviii]M. Alwan, S. Dalal, D. Mack, B. Turner, and J. Leachte, "Impact of Monitoring Technology in Assisted Living: Outcome Pilot," in IEEE Transactions on Information Technology in Biomedicine., 2011, pp. 132-40.

[xix] D. S. J. De Couto, D. Aguayo, J. Bicket, and R. Morris, "A High-Throughput Path Metric for Multi-Hop Wireless routing," in ACM Mobicom, 2003.

[xx] J. Elson, L. Girod, and D. Estrin, "Fine-grained network time synchronization using reference broadcasts," in In proceedings of the fifth symposium OSDI '02, pp. , 2002, pp. 147–163.

[xxi] C. Tymstra, R. W. Bryce, and B. M. Wotton, "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., 2009.

[xxii] M. Ghovanloo and K. Najafi, "A wideband frequency-shift keying wireless link for inductively powered biomedical implants”," in IEEE Transactions on Circuits and Systems,

2004, pp. 2374 – 2383.

[xxiii] M. H. Hayes, Statistical Digital Signal Processing and Modeling.: Wiley, 1996.

[xxiv] Y. B. Her and J. G. S. Kim, "A design and implementation of forest-fires surveillance system based on wireless sensor networks for South Korea mountains.," IJCSNS, 6, 9B , pp. 124-158, 2006.

[xxv] M. D. Y. Bergeron, O. Engelmark, and W. B. M. Flannigan, "Future wildfire in circumboreal forests in relation to global warming.," Journal of Vegetation Science, pp. 469-476, 1998.

[xxvi] G. X. Fleming and R. G. Robertson, "Fire Management Tech Tips: The Osborne Fire Finder.," USA, October 2003.

[xxvii] W. Tan, Q. Wang, H. Huang, Y. Guo, G. Zhang "Mine Fire Detection System Based on Wireless Sensor Network," in Information Acquisition International Conference ICIA '07, 2007.

[xxviii] K., H. Belani, et al. Pripužic, "Early Forest Fire Detection with Sensor Networks: Sliding Windows Skylines Approach," , 2008.

[xxix] A. Harry, P. Shaltis, and R. Andrew , "Mobile monitoring with wearable photoplethysmographic biosensor. ," in IEEE Engineering in Medicine and Biology Magazine, 2003, pp. 28-40.

[xxx] A. S. Rafi, "Filtering Electrocardiographic Signals using filtered- X LMS algorithm," ACEEE Int. J. on Signal & Image Processing, vol. 1, no. 3, pp. 23-27, 2010.

[xxxi] K. Romer and M. Friedemann, "The Design Space of Wireless Networks," IEEE Wireless Communications, no. 12, pp. 54-61, Mar. 2004.

[xxxii] F. Mihai, "Survey of secure wireless ad hoc routing published," IEEE computer society, pp. 4-12, Mar. 2004.

[xxxiii] A. Rehman, M. Mustafa, N. Javaid, U. Qasim, and Z. A. Khan, "Analytical Survey of Wearable Sensors," arXiv preprint arXiv:1208, p. 2376 2012, 2011.

[xxxiv] H. Salem and N. Mohamed , "Middleware Challenges and Approaches for Wireless Sensor Networks," IEEE Distributed Systems Online 7 (3): 1, 2006.

[xxxv] R. Szewczyk, E. Osterweil, J. Polastre, and M. Hamilto, "Habitat monitoring with sensor networks, ," in Commun. ACM 47 (6) , 2004, pp. 34–40.

[xxxvi] R. Kravets, P Naldurg , and S Yi, "Security-aware ad-hoc routing for wireless networks. ," Report No.UIUCDCS-R-2002- 2290, UIUC, , 2002.

[xxxvii] H. H. Asada, P. Shaltis , A. Reisner, and Rhee Sokwoo, "Mobile monitoring with wearable photoplethysmographic biosensors," in Engineering in Medicine and Biology Magazine, IEEE, Volume 22, 0H Issue 3, 2003, pp. 28 – 40.