International Journal of Scientific Research in Computer Science, Engineering and Information Technology
© 2016 IJSRCSEIT | Volume 1 | Issue 1 | ISSN : 2456-3307

A Survey on WSN-based Forest Fire Detection Techniques

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ABSTRACT

In this paper, we will present a survey on existing studies of forest fire detection system. Every year, thousands of forest fires across the world cause disasters including thousands of hectares of forests and hundreds of houses. Various methods are implemented in this area. We will explain in detail the advantages and disadvantages of each method. In addition, at the end we will show the comparison between the methods that are used for forest fire detection system.

Keywords: Forest Fire Detection System, GPS, WSN, CCD, MEMS

I. INTRODUCTION

Forest fires generally occur due to human uncontrolled behavior in social activities and change in weather conditions. Forest fires may result in human and animal deaths. They are fatal threat in the world: it is reported [1] that a total of 77,534 wildfires burned 6,790,692 acres in USA for 2004. Unfortunately, forest fires are usually only observed when it has already spread over a large area, making its control difficult and even impossible at some times. Forest fires have also a huge impact on atmosphere (30% of carbon dioxide in the atmosphere comes from forest fires).

Every year thousands of hectares of forests are destroyed by fire .carbon monoxide produced from the areas that are destroyed by fires are more than the overall automobile traffic. There are many methods for the detection of forest fires like satellite based monitoring, wireless sensor networks based detection etc. The objective is to detect the conditions that results in forest fires. In this paper we will show the different techniques that are implemented for the detection of forest fires and we will briefly discuss its advantages and disadvantages.

II. METHODS AND MATERIAL

A. Optical Sensors and Camera Surveillance

These systems are also used to detect fire in the forest. But every technology has it pros and cons. In a camera-based system, CCD cameras and IR detectors are installed on top of towers. In case of fire or smoke activity, the cameras and detectors sense this abnormal event and report it to a control center. However, the accuracy of such a system is highly affected by terrain, time of day, and weather conditions such as clouds, light reflections, and smoke from innocent industrial or social activities. Optical sensors or camera systems in general need to be improved in order to reduce the number of false alarms due to various dynamic phenomena, such as wind-tossed trees, cloud shadows, reflections, and human activity. This kind of technology only provides a line of sight vision; where high trees or the hills and mountains can block the vision; and it might be impossible to provide images for ignition place. The performance of the camera can be affected by weather conditions and in darkness. To cover large area these system was developed with minimum number of towers; each tower has to detect smoke in range of 15–80Km, where it requires a long delay after the ignition to produce a watchable smoke cloud that can be detected by the camera. These systems were tried for short distances but for large areas they are inefficient because the installation of camera have to be manual and have to be in appropriate position. However, these systems are very expensive and the cost of one camera tower is in thousand dollars.

B. Satellite Based Systems

Another alternative technology for detecting forest fires is the use of satellites and satellite images. Usually, satellites provide a complete image of the earth every 1–2 days. This long scan period, however, is not acceptable for detecting forest fires quickly. Additionally, the smallest fire size that can be detected by such a system is around 0.1 hectare, which also prevents fire detection just at the time when the fire starts, and fire localization error is about 1 km, which is not very accurate. Two main satellites launched for forest fire detection purposes, the advanced very high resolution radiometer (AVHRR) [2], launched in 1998, and the moderate resolution imaging Spector radiometer (MODIS), launched in 1999 these satellites are used to detect the forest fire. Unfortunately, these satellites can provide images of the regions of the earth every two days and that is a long time for fire scanning; besides the quality of satellite images can be affected by weather conditions [3]. Any existing satellite-based observations for forest fires suffer from severe limitations resulting in a failure in speedy and effective control for forest areas. Some of the limitations in an approach based on direct observation of forest fires from geostationary (GEO) or Low Earth Orbit (LEO) satellite are as follows: it might be impossible to provide a full satellite coverage or even intermittent coverage.

Geo and Leo satellites are located on orbits over 22,800 miles above the earth's surface. The satellite might not be equipped with transponders, antennas, amplification reception, regeneration, frequency translation, and downlink transmission suited for detection of forest fires. In fact, there may not yet be formal allocation of the appropriate frequency and bandwidth for forest fire detection.

C. Wireless Sensor Networks

In recent years, wireless sensor networks (WSNs) have gained worldwide attention, particularly with the proliferation of Micro-Electro-Mechanical system (MEMS) technology that has facilitated the development of smart sensors. These sensor nodes are inexpensive and small with limited processing and computing resources. These sensor nodes can sense and gather information from the environment and transmits the sensed data to the user. These sensor nodes have limited battery power and limited memory and are normally deployed in difficult to access locations where humans cannot go easily. In wireless sensor network, a radio is implemented on every sensor node, which is used for wireless communication between nodes and base station. In WSNs the deployment of sensor nodes are of two types: Random deployment and replanned deployment. In random deployment, nodes are deployed normally from the helicopter or plane and are used in large wireless sensor network in which the number of nodes is in thousands. In pre-planned deployment, nodes are deployed in pre-planned manner and are used in small wireless sensor network in which the number of sensor nodes is less than the number of sensor nodes in random deployment. Maintenance of random deployment is difficult as compared to the maintenance of pre-planned deployment. Wireless sensor network have many application like Environmental monitoring, Acoustic detection, Seismic detection, Military surveillance, Process monitoring etc.

Forest fire detection is the main problem faced by number of countries all over the world. In early detection of forest fire, camera surveillance and satellite based monitoring were used but that was inefficient in a number of manners. In recent years, Wireless sensor network was used to detect the forest fire. A number of research have considered using wireless sensor network for wood fire system Son et al.[4] presents in their paper a forest fire detection system in the south Korean mountains using wireless sensor networks. WSNs can be connected to the internet so that the information can be used for future risks. The developed system consists of WSNs, middleware and web application. The protocol they used for routing was MCF (minimum cost path forwarding) which required a routing table for each sensor node to find a minimum path to the base station. Sensor nodes sense the temperature, humidity and smoke to forward it to the base station node and then to the gateway. The gateway is connected to the middle ware and web application, which analyse the collected data and information on daily basis, and looks for the likelihood of an event. Son's network is more concerned with detection of the fire and decision making than the network communication reliability. They did not discuss the network coverage and distribution of the sensors.

Hurting et al. [5] in their paper presents FireWxNet, a multi-tiered portable wireless system for monitoring weather conditions in rugged wild land fire environments .In early stages the main aim of their studies was to investigate the behavior of the forest fire rather than the detection of the fire. In their network, they used wireless sensor networks and web cameras. Wireless sensor network for weather status and web cameras for images of the fire. Their system uses a tiered structure beginning with directional radios to stretch deployment capabilities into the wilderness far beyond current infrastructures. They stated that for vision, they used web cameras and for location information, they used sensor nodes with small GPS.

Doolin and Sitar [6] proposed wireless sensor network for wildfire monitoring in which they used environmental sensors for sensing the temperature, humidity, and barometric pressure. In addition, with every sensor node a GPS device is used which is one of the problems in this network because using a GPS device with every sensor node will make the network more expensive. GPS device will consume power so they will reduce the network lifetime. The nodes will send the sensed data to the base station. The base station was connected to the MySQL database and clients for alarm monitoring. The main problem in this network is the deployment of sensor nodes are pre-planned so deploying every sensor manually will be impossible for large forests. Another problem is the distance between the sensor nodes are too far so in case of node failure the connection between sensors and base station might be lost.

Yu et al. [7] in their paper proposed real-time forest fire detection with wireless sensor network. To prolong the network life time they have used neural wireless sensor network and for routing the data they relied on clustering algorithm in which the nodes sends the sensed data to the cluster head and then to the base station. They have used in-network processing approach to reduce the communication between the sensor and saves energy consumption.

Aslan [3] presented a framework for the use WSNs in forest fire detection and monitoring. Their framework incorporates the design of four main components of a wireless sensor network: the deployment scheme, the logical topology and architecture of the network, the intra-cluster communication scheme, and the inter-cluster communication scheme. They used cluster scheme as network topology. Sensor deployment scheme was represented as the distance between sensors, minimum collision, and minimum number of sensors deployed with full coverage. The communication between nodes and clusters divided into initialization phase, risk free phase, fire threat phase, and progressed fire phase. Nodes enter or change their phase according to danger rate calculation, which depends on NFDRS (National Fire Danger Rating System), temperature, and humidity ranges. The aim of the intra-cluster communication scheme is the power balancing for cluster heads.

Lloret et al. [8] in their paper presents a mesh network of wireless sensors with internet protocol (IP) cameras in order to detect and verify fire in rural and forest areas in Spain. In the proposed network they suggested that the sensor will first detect the fire and then it will sends information to the base station. The base station will then sends the response and will switch 'on' the camera closest to the event to catch real images and avoiding false alarms. Their paper is based on testing the performance of four IP cameras and energy consumption. The problem in their network is that IP cameras are not efficient in dark, foggy, and severe weather conditions and also the transfer of captured images that will be very huge and that will consume a lot of energy and will occupy a lot of space. In addition, we know in sensor network we have limited memory and limited energy. The installation of IP cameras should be manual and will be in appropriate position.

Conrad et al. [9] produced a business case for the Enhanced Forest Fire Detection System with a GPS project in Pennsylvania. They say that every year in Pennsylvania 2554 acres are damaged because of forest fires, which causes economic loss and potential loss of human life and environment. They proposed using fire sensors and GPS devices for the detection of fire. They want to use the existing technology and replacing the existing technology with more good ones. When smoke was detected, the sensors will send a signal to GPS satellite, and then the GPS satellite would duplicate the signal to the handheld GPS device and the central monitoring database to display the fire location on the installed map for that area. The problem here is that this project will require a lot of money and also using GPS devices will reduce the network lifetime because they will consume much more energy. Garcia et al. [10] present a simulation environment that can create a model for a fire by analysing the data reported by sensor nodes and by using some geographical information about the area. The use of topography of the environment distinguishes the study from some other solutions. The estimation of the spread of a fire is sent to hand-held devices of fire fighters to help them in fighting against the fire in field.

III. COMPARISON AND CONCLUSION

Hefeeda et al. [11] developed a wireless sensor network for forest fire detection based on Fire Weather Index (FWI) system, which is one of the most comprehensive forest fire danger rating systems in USA. The system determines the spread risk of a fire according to several index parameters. It collects weather data via the sensor nodes, and the data collected is analysed at a centre according to FWI. A distributed algorithm is used to minimize the error estimation for spread direction of a forest fire [12-45].

Table 1: Comparison among Various Schemes

Comparison	Human based observation	Satellite based observation	Camera based surveillance	WSN
Cost	Low	Very high	High	Medium
Efficiency and practicality	Low	Low	Medium	High
Faulty alarms repetition	Low	Low	Medium	Medium
Fire localizing accuracy	Low	Medium	Medium	High
Detection delay	Long	Very long	Long	Small
Fire behavior information	---	Yes	---	Yes
Can be used for other purposes	No	Yes	No	Yes

IV. REFERENCES

[1] http://www.nifc.gov/fireinfo/2004/index.html, “Wildland Fire Season 2004 Statistics and Summaries,” National Interagency Coordination Center.

[2] NOAA satellite and information service, “Advanced Very High Resolution Radiometer AVHRR,” 2012, http://noaasis.noaa.gov/NOAASIS/ml/avhrr.html.

[3] Y. Aslan, A framework for the use of wireless sensor networks in the forest fire detection and monitoring [M.S. thesis], Department of Computer Engineering, The Institute of Engineering and Science Bilkent University, 2010.

[4] Son, Y. Her, and K. Kim, “A Design and Implementation of Forest-Fires Surveillance System based on Wireless Sensor Networks for South Korea Mountains,” International Journal of Computer Science and Network Security, vol. 6, no. 9, pp. 124– 130, 2006.

[5] C.Hartung, R. Han, C. Seielstad, and S. Holbrook, “FireWxNet: Amulti-tiered portable wireless systemfor monitoring weather conditions in wildland fire environments,” in Proceedings of the 4th International Conference on Mobile Systems, Applications and Services (MobiSys ’06), pp. 28–41, ACM, Uppsala, Sweden, June 2006

[6] D.Doolin and N. Sitar, Wireless Sensors for Wild Fire Monitoring, Smart Structure and Material, San Diego, Calif, USA, 2005.

[7] L. Yu, N. Wang, and X. Meng, “Real-time forest fire detection with wireless sensor networks,” in Proceedings of the International Conference on Wireless Communications, Networking and Mobile Computing (WCNM’05), pp. 1214–1217, September 2005.

[8] J. Lloret, M. Garcia, D. Bri, and S. Sendra, “A wireless sensor network deployment for rural and forest fire detection and verification,” Sensors, vol. 9, no. 11, pp. 8722–8747, 2009

[9] A. Conrad, Q. Liu, J. Russell, and J. Lalla, “Enhanced Forest Fire Detection System with GPS Pennsylvania,” 2009.

[10] E. M. Garc´ıa, M. ´ A. Serna, A. Berm´udez, and

R. Casado, "Simulating a WSN-based wildfire fighting support system," in Proceedings of the International Symposium on Parallel and Distributed Processing with Applications (ISPA'08), pp.896–902, December 2008.

[11] M.Hefeeda and M. Bagheri, "Wireless sensor networks for early detection of forest fires," in Proceedings of the IEEE International Conference on Mobile Adhoc and Sensor Systems (MASS '07), October 2007.

[12] Khan, F., & Nakagawa, K. (2013). Comparative study of spectrum sensing techniques in cognitive radio networks. In *Computer and Information Technology (WCCIT), 2013 World Congress on* (pp. 1-8). IEEE.

[13] Khan, F., Bashir, F., & Nakagawa, K. (2012). Dual head clustering scheme in wireless sensor networks. In *Emerging Technologies (ICET), 2012 International Conference on* (pp. 1-5). IEEE.

[14] Khan, F., Kamal, S. A., & Arif, F. (2013). Fairness improvement in long chain multihop wireless ad hoc networks. In *2013 International Conference on Connected Vehicles and Expo (ICCVE)* (pp. 556-561). IEEE.

[15] Khan, F. (2014). Secure communication and routing architecture in wireless sensor networks. In *2014 IEEE 3rd Global Conference on Consumer Electronics (GCCE)* (pp. 647-650). IEEE.

[16] M. A. Jan, P. Nanda, X. He and R. P. Liu, "PASCCC: Priority-based application-specific congestion control clustering protocol" Computer Networks, Vol. 74, PP-92-102, 2014.

[17] Khan, S., & Khan, F. (2015). Delay and Throughput Improvement in Wireless Sensor and Actor Networks. In *5th National Symposium on Information Technology: Towards New Smart World (NSITNSW)* (pp. 1-8).

[18] Khan, F., Jan, S. R., Tahir, M., Khan, S., & Ullah, F. (2016). Survey: Dealing Non-Functional Requirements at Architecture Level. *VFAST Transactions on Software Engineering*, *9*(2), 7-13.

[19] Khan, F., & Nakagawa, K. (2012). Performance Improvement in Cognitive Radio Sensor Networks. *the IEICE Japan*.

[20] Khan, F., Khan, S., & Khan, S. A. (2015, October). Performance improvement in wireless sensor and actor networks based on actor repositioning. In *2015 International Conference on Connected Vehicles and Expo (ICCVE)* (pp. 134-139). IEEE.

[21] M. A. Jan, P. Nanda, X. He and R. P. Liu, "A Sybil Attack Detection Scheme for a Centralized Clustering-based Hierarchical Network" in Trustcom/BigDataSE/ISPA, Vol.1, PP-318-325, 2015, IEEE.

[22] Jabeen, Q., Khan, F., Khan, S., & Jan, M. A. (2016). Performance Improvement in Multihop Wireless Mobile Adhoc Networks. *the Journal Applied, Environmental, and Biological Sciences (JAEBS)*, *6(4S)*, 82-92.

[23] Khan, F. (2014, May). Fairness and throughput improvement in multihop wireless ad hoc networks. In *Electrical and Computer Engineering (CCECE), 2014 IEEE 27th Canadian Conference on* (pp. 1-6). IEEE.

[24] Khan, S., Khan, F., Arif, F., Q., Jan, M. A., & Khan, S. A. (2016). Performance Improvement in Wireless Sensor and Actor Networks. *Journal of Applied Environmental and Biological Sciences*, *6(4S)*, 191-200.

[25] Khan, F., & Nakagawa, K. (2012). B-8-10 Cooperative Spectrum Sensing Techniques in Cognitive Radio Networks. *電子情報通信学会ソサイエティ大会講演論文集*, *2012*(2), 152.

[26] Khan, F., Jan, S. R., Tahir, M., & Khan, S. (2015, October). Applications, limitations, and improvements in visible light communication systems. In*2015 International Conference on Connected Vehicles and Expo (ICCVE)*(pp. 259-262). IEEE.

[27] Jabeen, Q., Khan, F., Hayat, M. N., Khan, H., Jan, S. R., & Ullah, F. (2016). A Survey: Embedded Systems Supporting By Different Operating Systems. *International Journal of Scientific Research in Science*, *Engineering and Technology (IJSRSET), Print ISSN*, 2395-1990.

[28] Jan, S. R., Ullah, F., Ali, H., & Khan, F. (2016). Enhanced and Effective Learning through Mobile Learning an Insight into Students Perception of Mobile Learning at University Level. *International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Print ISSN*, 2395-1990.

[29] Jan, S. R., Khan, F., & Zaman, A. The perception of students about mobile learning at University level.

[30] M. A. Jan, P. Nanda, X. He, and R. P. Liu, "A Sybil Attack Detection Scheme for a Forest Wildfire Monitoring Application," *Elsevier Future Generation Computer Systems (FGCS)*, "Accepted", 2016.

[31] Jan, S. R., Shah, S. T. U., Johar, Z. U., Shah, Y., & Khan, F. (2016). An Innovative Approach to Investigate Various Software Testing Techniques and Strategies. *International Journal of Scientific Research in Science, Engineering and Technology (IJSRSET), Print ISSN*, 2395-1990.

[32] Khan, I. A., Safdar, M., Ullah, F., Jan, S. R., Khan, F., & Shah, S. (2016). Request-Response Interaction Model in Constrained Networks. *In International Journal of Advance Research and Innovative Ideas in Education, Online ISSN-2395-4396*

[33] Azeem, N., Ahmad, I., Jan, S. R., Tahir, M., Ullah, F., & Khan, F. (2016). A New Robust Video Watermarking Technique Using H. 264/AAC Codec Luma Components Based On DCT. *In International Journal of Advance Research and Innovative Ideas in Education, Online ISSN-2395-4396*

[34] Jan, S. R., Khan, F., Ullah, F., Azim, N., & Tahir, M. (2016). Using CoAP Protocol for Resource Observation in IoT. *International Journal of Emerging Technology in Computer Science & Electronics, ISSN: 0976-1353*

[35] Azim, N., Majid, A., Khan, F., Jan, S. R., Tahir, M., & Jabeen, Q. (2016). People Factors in Agile Software Development and Project Management. *In International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)* ISSN: 0976-1353

[36] Azim, N., Majid, A., Khan, F., Tahir, M., Safdar, M., & Jabeen, Q. (2016). Routing of Mobile Hosts in Adhoc Networks. *In International Journal of Emerging Technology in Computer Science & Electronics (IJETCSE)* ISSN: 0976-1353.

[37] *Azim, N., Khan, A., Khan, F., Majid, A., Jan, S. R., & Tahir, M. (2016) Offsite 2-Way Data Replication toward Improving Data Refresh Performance. In International Journal of Engineering Trends and Applications,* ISSN: 2393 – 9516

[38] Tahir, M., Khan, F., Jan, S. R., Azim, N., Khan, I. A., & Ullah, F. (2016) EEC: Evaluation of Energy Consumption in Wireless Sensor Networks. . *In International Journal of Engineering Trends and Applications,* ISSN: 2393 – 9516

[39] M. A. Jan, P. Nanda, M. Usman, and X. He, "PAWN: A Payload-based mutual Authentication scheme for Wireless Sensor Networks," *Concurrency and Computation: Practice and Experience*, "accepted", 2016.

[40] Azim, N., Qureshi, Y., Khan, F., Tahir, M., Jan, S. R., & Majid, A. (2016) Offsite One Way Data Replication towards Improving Data Refresh Performance. *In International Journal of Computer Science Trends and Technology,* ISSN: 2347-8578

[41] Safdar, M., Khan, I. A., Ullah, F., Khan, F., & Jan, S. R. (2016) Comparative Study of Routing Protocols in Mobile Adhoc Networks. *In International Journal of Computer Science Trends and Technology,* ISSN: 2347-8578

[42] Tahir, M., Khan, F., Babar, M., Arif, F., Khan, F., (2016) Framework for Better Reusability in Component Based Software Engineering. *In the Journal of Applied Environmental and Biological Sciences (JAEBS)*, *6(4S)*, 77-81.

[43] Khan, S., Babar, M., Khan, F., Arif, F., Tahir, M. (2016). Collaboration Methodology for Integrating Non-Functional Requirements in Architecture. *In the Journal of Applied Environmental and Biological Sciences (JAEBS)*, *6(4S)*, 63-67

[44] Jan, S.R., Ullah, F., Khan, F., Azim, N., Tahir, M., Khan, S., Safdar, M. (2016). Applications and Challenges Faced by Internet of Things- A Survey. *In the International Journal of Engineering Trends and Applications,* ISSN: 2393 – 9516

[45] M. A. Jan, P. Nanda, X. He, and R. P. Liu, "A Lightweight Mutual Authentication Scheme for IoT Objects,", "Submitted", 2016.