Cloud-Based Early Warning System for Forest Fire using IoT Techniques

R Kanesaraj Ramasamy, Fang-Fang Chua and Gaik-Yee Chan

Multimedia University, Malaysia, {r.kanesaraj@mmu.edu.my, ffchua@mmu.edu.my, gychan@mmu.edu.my}

ABSTRACT

A forest fire is a national hazard which happens almost every year in Malaysia. Millions of Ringgit is used to save the life stocks and also the villagers around the affected areas. Although many traditional methods have been used to prevent the fire merely based on experience, no accurate plan is being implemented. Some systems are able to provide warning using historical data, but they are yet to provide an evacuation map. Hence, in this paper, we propose a cloud-based early warning system for a forest fire. The proposed system shall be able to provide warning to the firefighters before the fire starts. Additionally, it shall provide an evacuation plan for both the firefighters and also the villagers. Through the use of such a forest fire warning system coupled with an evacuation plan, life, property and environment damage could be reduced to a minimum.

Keywords: Forest Fire, Early Warning, cloud-based System.

I INTRODUCTION

Forest fires cause millions of ringgits in damage to property and environment in Malaysia. To be able to fight fire effectively, a system that is able to detect fire early and could track it continuously is very important. Many methods have been proposed and used for monitoring forest and the most popular method used is image processing. Images are taken from satellite and processed to identify if there is any occurrence of fire.

In this paper, the Internet of Things (IoT) method of detecting fire is proposed. The usual practice is to detect fire at an earlier stage and put off before the fire spreads. In our proposed solution, factors which cause fire are first identified and then being monitored. Once these factors are under control, the system will be able to prevent the fire. On the factors which cause forest fire is Soil Moisture (Causes and effects of global forest fires - WWF Deutschland, 2017). The El Nino impact in 2015 caused outrageous dry season, prompting extreme backwoods fires in Indonesia from June to November. As recommended by World Wildlife Fund, prevention of fire should be given the highest priority in order to reduce the fore fire risk and resulting damage.

This paper is organized as follows: Section II discusses the similar research works done for Forest fire in various countries, for example, the forest warning system which is being used in Australia and Denmark. Section III presents the proposed solution and also the advantages of using this solution as compared to others. Section IV presents discussion of the previous system against the proposed system. Finally, Section V concludes and presents future work

II RELATED WORK ON PREVENTION OF FOREST FIRE

According to Ioannis & Thanailakis (1997), the prediction of a forest fire can be made in two ways which are homogeneous and also inhomogeneous based on the incorporation of weather condition and also land topography. Ioannis & Thanailakis, (1997) have proposed a prediction model of fire spreading in the forest over the time based on physical landscape under various weather conditions. The proposed algorithm can only be used to simulate the real situation to find out the defect in the forest.

Keetch (1968), has agreed that among the factors of forest fire is the soil moisture. Besides that, the dried out organic materials are frequently embedded in the shallow upper layer of mineral soils. This can become the fuel packets to start the fire from the soil. Among the reasons the soil can be less moisture or dry is the vegetation covered in that particular area, annual rainfall and also the evapotranspiration.

The conventional forest fire checking and early cautioning frameworks are mainly based on ground watching, watching tower, aerial patrolling, long-distance video monitoring and satellite observing (Wang., 2008). Due to the inefficient method by monitoring manually, Gao & Huang (2015), propose to have wireless sensor network which is much more low power loss, low cost, dynamic multi-routing, protocol flexibility, self-organization and real-time monitoring.

Yu, Neng & Xiaoqiao (2005) have proposed a constant forest fire recognition strategy by utilizing remote sensor systems.Their goal is to detect or predict forest fire to minimize the loss of forests, wild animals, and people in the forest fire. They will have to deploy a large number of sensor nodes across the forest. These sensor nodes are used to measure and collect data such as temperature and humidity on the air. The prediction is made by calculating the weather index which leads to the cause of the fire. Smoke and wind speed is considered to be the factor that could determine the danger rate of the forest fire. Besides that, Yu et al., (2005) also claim that compare to satellite imagery, small sensor nodes are cheaper and can detect the forest fire more promptly and accurately. MÜLLER & BIENGE (2013) have developed a system based on hydrogen sensor, “which makes it possible to detect a smouldering forest fire before the development of open flames”. This sensor has the capability of measuring in distance of 100 meters. Field trials have shown that it is possible to identify a forest fire in its early stages when hydrogen concentrations are still low.

Veeraswamy et al., (2018) have emphasized the importance of evacuation. The frequent occurrence of forests fire leads to the necessity to create suitable evacuation plan based on regions that are defenseless to rapidly spreading fires. They have proposed an urban-scale evacuation modelling system. According to Veeraswamy, et al. (2018), “when planning an evacuation for a community threatened by wildfire, it is essential for villagers to know the areas which will be affected due to a fire”. Among the factors for evacuation which have been highlighted are the time required to evacuate the threatened villagers to a safe place, the distances travelled by the villagers and the level of congestion incurred during the evacuation. These factors need to be considered during the development of evacuation map for an early warning system. Veeraswamy, et al., (2018) suggest that the integration of an early warning system for forest fire with an evacuation plan is important.

One of the applications which is being used in Australia (Australia, n.d.) is Fire Watch Optical Sensor System. This system screens the scene utilizing refined sensor unit to gather information. This sensor (as shown in Figure 1) is fixed on any existing telecommunication tower or any fire towers which used for manual monitoring. It rotates 360 degrees every 4 to 8 minutes with the sensors capturing the images in every 10 degrees.

Figure 1. Fire Watch Camera Sensor

Each sensor is able to detect to a range of 40 km depending on the topography of the land. Compared to another camera which watches and triggers when there is fire, Fire Watch is able to detect the smoke in grey colour and identify the smoke which is from smoke, fog or cloud. Once the smoke is identified, the system alerts the control centre, and it’s on the hand of firefighters to use their expertise to put off the fire and evacuate the villagers or livestock. Figure 2 shows how Fire Watch works.

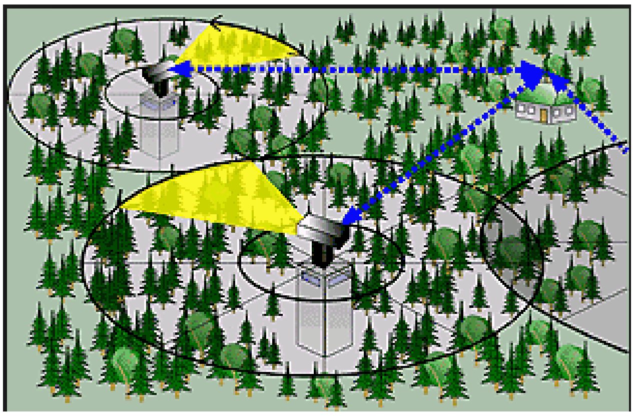

Figure 2. How fire watch works.

One other system being used in Denmark is the Global Fire Monitoring Center (GFMC) (Fire Ecology Research Group, 2015). This was founded by Freiburg University (Germany) the Fire Ecology Research Group at the 1970s. Figure 3 shows the forest fire map produced by GFMC. GFMC produces this map based on satellite images. They compile a range of forest fire satellite images and produce a forest fire map. This takes time compared to Fire Watch, as fire watch is a real-time system which triggers the warning in the range of 40km.

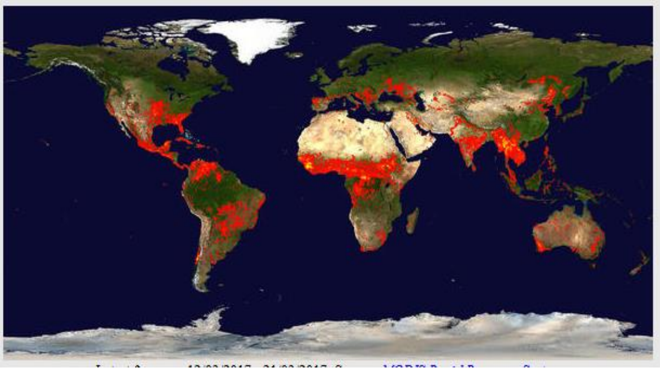

Figure 3. Forest Fire Map By GFMC

III PROPOSED SOLUTION

Based on the recommendations from various researchers as explained in related work, we would like to propose an early warning system for forest fire together with an evacuation map. The proposed study area will be a forest along the ELITE highway as shown in Figure 4 and Figure 5. Study area in Figure 4 is located nearby a village, where they have life stocks. We have chosen this specific area as the fire breaks out every year. This area is also very close to Kuala Lumpur International Airport (KLIA). If the forest is on fire and the wind blow towards the direction of KLIA, flights schedule will be affected.

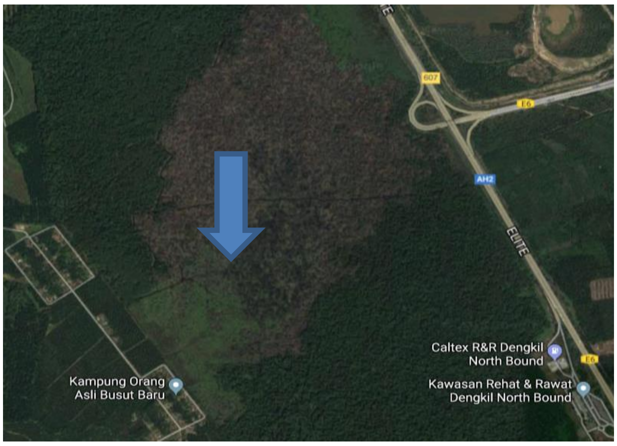

Figure 4. Study area 1 (ELITE Highway) – Near a village

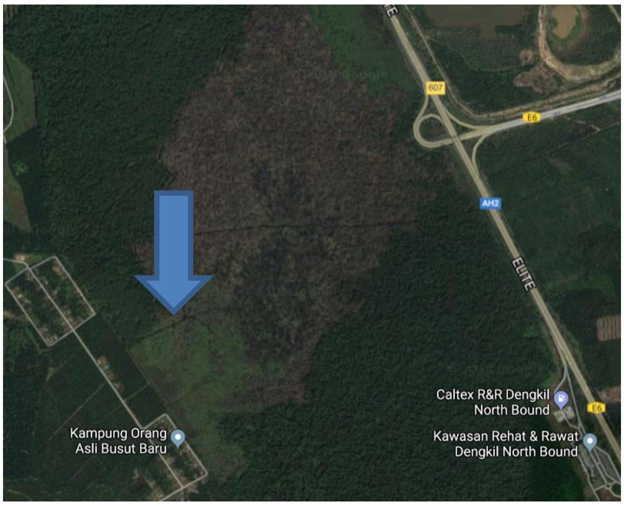

Figure 5. Study Area 2 (ELITE Highway)

Among the parameters which will be monitored to provide more accurate early warning system are as follows:

1. Soil Moisture
   Soil Moisture is required to identify the water level in the soil as fire can also be triggered if the soil is too dry.

2. Soil Temperature
   Soil temperature is required to ensure the current weather situation. The soil might be dry, but if the temperature is low, the chances of fire to be triggered is very low.

3. Type of Root
   Type of root plays a big role in a forest fire. Fibrates root starts a fire even faster compared to the taproot. Identifying the root types in each forest is also important to predict where the fire might start if both moisture and temperature meets its threshold point.

4. Wind Direction
   Wind direction is taken into consideration as it is required to identify which direction the fire is going to spread too. This information is important to identify the evacuation route for the villagers during the forest fire is up.

Different sensors will be used to capture various data and threshold values shall be determined. All these data will be collected in a cloud database before its being processed to be viewed by the end user. The proposed architecture is as shown in Figure 6.

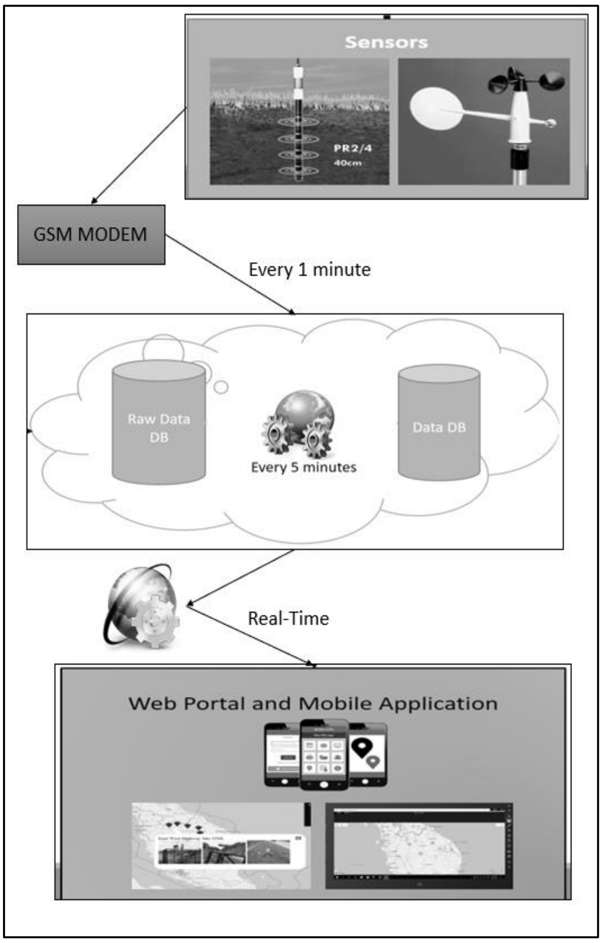

Figure 6. The proposed architecture for Forest Fire Early Warning System.

Referring to Figure 6, the proposed system uses cloud-based approach to develop the early warning system. According to Ramasamy et al. (2015), deployment using cloud-based architecture especially for a mobile application saves the resource of the device and also speed up the processing part. As an early warning system, it consumes a lots of sensor data and will need to be able to provide real time update. The data collected from the sensor will be saved in the Raw database in the cloud environment. The raw data will be processed and updated to the public database every 5 minutes. This database will be used to send information to the web services to provide the notification to the end user. The final output to the user will be available in all platforms, so the processing of threshold data will be done in a web service which will be shared by all the platforms.

There are 6 different modules in the proposed architecture as shown in Table 1.

Table 1. Modules in Proposed Architecture

Modules	Description
Sensors / Data Collection	The sensors used are soil moisture, soil temperature and wind direction. These sensors are connected to each other through a microcontroller.
GSM Modem & Microcontroller	As for this project, the system will be using Raspberry Pi 3 Model B as the microcontroller. All the sensors data will be read and interpreted to number / integer-based data before sending to cloud server through GSM Modem. It is cheaper to use a GSM modem rather than sending the data using Short Message System (SMS).
Raw Database	This database is placed in the cloud environment. This database is split compared to the staging database as we do not want the staging database to have too many connections going in. This database will have a record from the sensors for every 1 minute.
Processing Web Service / Data Preprocessing	The data from the raw database will be transferred to the staging database by comparing the threshold point before storing it in the Staging database.
Staging Database	This will only carry one line of value for every point created. The new record will be overwritten every 5 minutes by the processing web service. This is to make sure the public faced database do not have too much information which might be misused.
Intermediate Web Service	This web service picks the data from the staging database and supplies the notification to both the mobile application and also the web application. The author uses an intermediate web service rather than a direct call to the database from the application to avoid rebuilding the same functionality multiple time. Where reusability of code is supported in this project. In future, if the data also need to be supplied to other rescue parties will just have to provide the web service link rather than the access to the cloud or database.
Mobile Applications and Web Application	This is the final User Interface which will be used by both enforcers and also the villagers. This is split into two different faces which are: 1. Fire Fighters

	Will have two sets of the system. One system will be placed in their control system, where the live stats can be viewed here. That specific system will also present the historical data for future prediction. Other than that, every firefighter will have a mobile application which will help them during evacuation plan in the hazard scene area. 2. Villagers Villagers will also have the evacuation map which was pre-planned earlier. They will also be provided with wind direction data so they could plan their own evacuation in case of any delay from the rescuers.

IV DISCUSSION

This architecture (Figure 6) will be able to provide early warning in real time to the firefighters, the end users of the proposed system. They will also be able to use this system to plan the evacuation map before reaching the hazardous location. As for the other end users, the villagers, will be able to view all the pre-planned evacuation map to find an exit before the emergency rescuers arrive. As for the usage of sensors, Fire Watch is only able to warn the firefighters if there is a smoke released into the air, which also means the fire has already started.

As for this proposed system, early warning are provided to the firefighters even before the fire starts by measuring the moisture of soil and also the temperature. If the data collected is showing above the threshold point, then the firefighters can prevent the fire from starting by increasing the soil moisture through spraying water or flood the affected area. The current trend used in Malaysia is to build a small drain and cover the drain with water. This also helps them to flood the fire area. If this can be done even earlier, then haze issue is prevented. The sample area chosen is in a very critical area, as it is located nearby the Kuala Lumpur International Airport (KLIA). By preventing the fire from starting, haze, which is very dangerous for flights to take off could be stopped.

The determination for the threshold values represents a research problem yet to be ironed out with the related authorities of Malaysia. The proposed warning system consists of 3 different levels of warning as shown in Table 2. The icons will be shown in different colours based on the status.

Table 2: Sample Notification in the system

Status	Indicator
Danger	Red
Warning	Yellow
Safe	Green

First, the priority will be given to soil moisture where most of the literature suggest that dry soil is the main cause of fire. It is then followed by the temperature of the soil and surrounding. The estimation of calculation will be done as shown in the Algorithm 1.

Algorithm 1: The indication process

```
Begin
  a = Obtain Soil Moisture
  b =  Obtain Surrounding Temperature
  Tsoil = Obtain Threshold for Soil Moisture
  TTemp = Obtain Threshold for Soil Temperature

IF (a < Tsoil)
 Then
  Create Warning Zone indication
  IF (b> TTtemp)
  Then
   Create Danger Zone indication
   End IF
End IF

END
```

This proposed algorithm might change based on the expert's advice. This algorithm will be placed in the intermediate web service where it calculates the status of every station within its range. Wind direction is not included in this algorithm as it will be used to determine which direction the fire will flow in. This will be used in the map to show the direction of the wind.

V CONCLUSION

As can be seen from previous works with drawbacks such as only the warning part is done, and evacuation part is not done. There are also warning systems that provide warning when a fire is already up rather than warning before the fire has started. In this proposed solution, a system which will be able to give warning before the fire starts, shows the evacuation plan to the firefighters if the fire starts before they arrive and also the pre-set evacuation plan for the villagers to exit from the fire zone or the red zone is presented. The future work will be to plant the sensors in both Study Area 1 and 2. The development of web application and mobile application will follow the proposed architecture.

REFERENCES

Australia, F. (n.d.). The FireWatch System. Retrieved from The FireWatch System: http://www.firewatchaustralia.com/the-firewatch-system

Causes and effects of global forest fires - WWF Deutschland. (2017). WWF Study.

Fire Ecology Research Group. (2015). Global Fire Monitoring Center (GFMC). Retrieved from http://www.fire.uni-freiburg.de/

Gao, Z., & Huang, L. (2015). A Forest Fire Monitoring and Early Warning System Based on the Technology of Multi-sensor and Multilevel Data Fusion. 2nd International Conference on Electrical, Computer Engineering and Electronics.

Ioannis, K., & Thanailakis, A. (1997). A model for predicting forest fire spreading using cellular automata. Ecological Modelling, 87-97.

Keetch, J. J. (1968). A drought index for forest fire control. US Department of Agriculture, Forest Service, Southeastern Forest Experiment Station.

MÜLLER, J., & BIENGE, J.-E. (2013). Early forest fire detection using low energy hydrogen sensors. Journal of Sensors and Sensor Systems, 171-177.

Sahani, M., Zainon, N., Wan Mahiyuddin, W., Latif, M., Hod, R., Md Firoz Khan, Chan, C.-C. (2014). A case-crossover analysis of forest fire haze events and mortality in Malaysia. Atmospheric Environment, 257-265.

Veeraswamy, A., Galea, E., Filippidis, L., Lawrence, P., Haasanen, S., Gazzard, R., & Smith, T. (2018). The simulation of urban-scale evacuation scenarios with application to the Swinley forest fire. Safety Science, 178-193.

Wang., F. (2008). Application of IPSTAR satellite communications system for rapid Disposal of forest and grassland fire. Satellite and Network,.

Yu, , L., Neng , W., & Xiaoqiao , M. (2005). Real-time Forest Fire Detection with Wireless Sensor Networks. Wireless Communications, Networking and Mobile Computing (pp. 1214-1217). International Conference on. Vol. 2. IEEE.

Ramasamy, R. K., Chua, F. F., & Haw, S. C. (2015). Adaptive and Dynamic Service Composition for Cloud-Based Mobile Application. In Advanced Computer and Communication Engineering Technology (pp. 963-973). Springer, Cham.