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Real-time Monitoring IoT-based System for Early Flash Flood Notification in Melaka

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Abstract: Flash flood is a type of flooding that possibly happen within three hours of heavy rainfall. A couple of years back, flash flood often occurs in the urban areas of Wilayah Persekutuan, Selangor, Negeri Sembilan, and Melaka. This tragedy caused more than 1,000 residents have been displaced from their homes. Due to this unavoidable threat, this study proposes an early warning system for flash floods in Melaka based on the type of lightning flashes that occur during heavy rainfalls. The project incorporates a smart Internet of Things (IoT) system with a web-based application for monitoring and a mobile application for early notification. This system provides flash flood monitoring and forecasting as well as a warning system with a lead time of three hours. The raw data is processed by the IoT hardware and transmitted to the centralized network access storage. A web-based dashboard system visualizes the data for monitoring and forecasting. The fast alert notification of the predicted flash floods and locations generates early warning through the mobile application.

Keywords: IoT, Flood, Real-time monitoring

1. Introduction

According to World Health Organization (WHO), a natural disaster is a natural act of such magnitude. It creates a catastrophic situation that leads the day-to-day life patterns to be suddenly disrupted. People are plunged into helplessness and suffering. As a result, they need food, clothing, shelter, medical and nursing care and other necessities of life, and protection against unfavourable environmental factors and conditions [1]. Natural disasters are growing due to constant changes in the earth's climate. The most common and destructive disaster is flooding. It can cause infrastructure loss,

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life threats, and destruction in multiple public utilities. Although the threat to lives by the flood is considerably less compared to other types of disasters, the number of lives affected is much higher. According to a forecast in the United Nations survey report, floods will affect approximately two billion people by 2050, and Asia will be the most affected part. In Malaysia, aside from regular floods that commonly occur in the East Coast Region during the monsoon season, flash floods are another type of flooding. It often occurs in urban areas of Wilayah Persekutuan, Selangor, Negeri Sembilan, and Melaka [2].

Flash flood starts within six hours, sometimes as fast as three hours after heavy rainfall [3]. Flash floods are caused by various factors but the most commonly attributed to heavy rain from thunderstorms. Between June and July of 2019, Melaka was hit by flash floods due to heavy rainfall. It caused more than 1,000 residents to be displaced from their homes [4-7].

Currently, there are many research works on the Internet of Things (IoT) in disaster management. This technology gives benefits in terms of monitoring, tracking, controlling, and sensing the environment using real-time data. For monitoring the water level purposes, M.A. Winster et al. [8] developed the system and then posted data using social networking, namely Facebook. Meanwhile, A.N. Yumang et al. [9] designed a monitoring system by integrating sensors with Arduino and GSM shields. To notify people about the potential flood risk, they manage to use SMS media and LED lights. However, the usage of SMS is not flexible and too limited only to pre-registered users. On the other hand, S. Bande et al. [10] proposed the flood prediction system using an Artificial Neural Network (ANN) with several environmental parameters such as humidity, temperature, pressure, rainfall, and river water level. Allison S. S. [11] also proposed a monitoring system for a runway or river, triggering emergency alerts to the authorities through telephone calls and SMS messages. The data is collected in the cloud server through the Ubidots server, and it is possible to visualize them in real time.

Table 1: Examples of the existing Flood Warning System

Reference	Environmental Parameters	Connectivity	Application Programming Interface (API)	Notification
[8]	Water level	Aptana Web Object	C Language	Facebook
[9]	Water level	GSM	C Language	SMS LED lights
[10]	Humidity Temperature Pressure Rainfall River water level	Wi-Fi	Python	ThingTweet
[11]	Pressure Accelerometer Fluvial pollution detector	Zigbee	C Language	Telephone SMS
[12]	Rain condition Water Level Flow Rate	GSM	C Language	Mobile applications

Studies in [8-12], as summarized in **Table 1**, utilized water level readings to detect the monsoon flood event. However, this study monitors flash floods using the occurrences of +CG and –NBEs produced by a storm in real-time, together with cloud top height and constant altitude plan position indicator (CAPPI) rainfall rate. The proposed system will be able to forecast the rainfall intensity and rate for the next 1-3 hours period as well as the location where the downpour would impact most significantly. Additional details for real-time forecasting of flash floods using the above technique are given in [13-14].

For that reason, an early warning system for flash floods in Melaka is needed based on the form of lightning flashes that occur during heavy rainfalls. The system is a real-time application that provides flood forecasting and a warning system with a better lead time.

2. Materials and Methods

2.1 Materials

The development of the Real-time Flash Flood Monitoring and Notification System (RFMN) project is an IoT-based system consisting of two main parts. Testbed implementation refers to hardware, while the development of flash flood monitoring and early alert notification refers to software.

i. Hardware

The testbed was developed and implemented based on the proposed system architecture in **Figure 1**. It consists of three data collection sites, centralized network-attached storage, and a web server.

- Data collection sites - Raspberry Pi 3+ with LTE module, Synology Network Assess Storage (NAS) and Processed data from EMS sensor.
- Centralized network-attached storage - Synology Network Access Storage (NAS) and LTE Modem.
- Web Server - Server, End-user (Workstation & Smartphone).

ii. Software

- Mobile Operating System - Android
- Internet web browser - Any (Chrome, Edge, Firefox etc.)

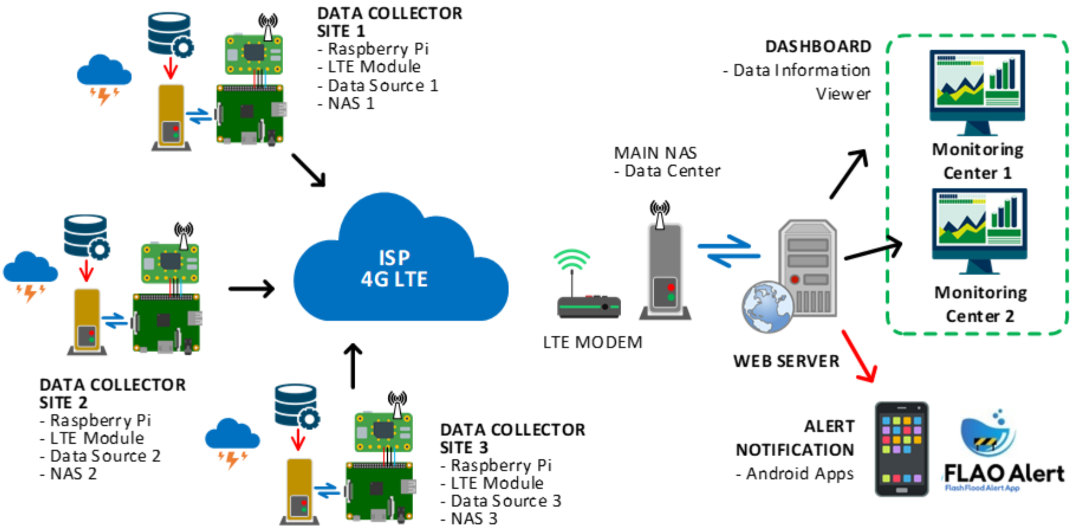


Figure 1: The system architecture for RFMN

2.2 Methods

Real-time application is different from regular applications in one significant aspect. Real-time applications depend on instantaneous input and rapid analysis to develop a decision or action within a short and precise timeline. Early warning systems for natural disasters are developed from a fast alert notification with the primary objective of saving lives. These systems have included the time-critical processing of a massive volume of distributed data to predict natural disasters. The data are collected from sensors or other sources such as weather information and geographic map.

For an early warning system, it becomes useless if a decision cannot be made within a specific timeline that would benefit the public. Thus, it is crucial to make all data necessary for such a timely fashion decision and that the analysis is done in a fast and reliable way. Therefore, the following phases have been implemented to achieve those requirements, as shown in **Figure 2**.

Figure 2: Phases implementation workflow of RFMN

i. *Detection* - Data gained from the IoT sensors will be processed and saved in the site NAS before being sent to a centralized NAS using a wireless 4G/LTE connection
ii. *Forecast* - Develop a web-based application dashboard to monitor the lightning coordinates, types of lightning, and rainfall rates. A map of the location is shown on the dashboard to view the lightning's locations and the predicted locations of the flash flood.
iii. *Notification* - Develop a mobile application that generates a fast alert to the residents with an early warning notification of the location and time of the flash floods.

3. Results and Discussion

3.1 Results

The thorough process conducted using responsive methodology has contributed to the successful development of the RFMN. To achieve the RFMN objectives, three (3) major components have been implemented in an integrated manner using the latest technology. The components are as follows:

i. IoT Infrastructure
ii. Web-based Application
iii. Mobile Application

3.1.1 IoT Infrastructure

Figure 3 shows the components integrated around the Raspberry Pi 3+ as the main computer. The integration is done by connecting the EMS to the Raspberry Pi with the additional module listed in Section 2.2. The digitized lightning signal was fed into the Raspberry Pi to be processed by the custom-written Python program and produced the lightning strike locations. The resulting lightning strike locations are saved into the site NAS before being sent to the centralized NAS via an IoT gateway.

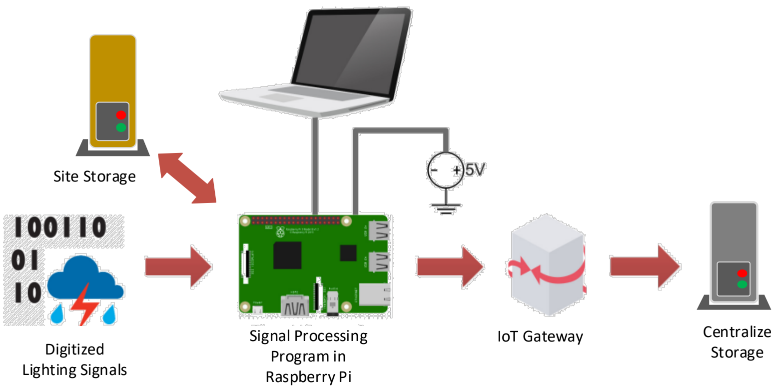
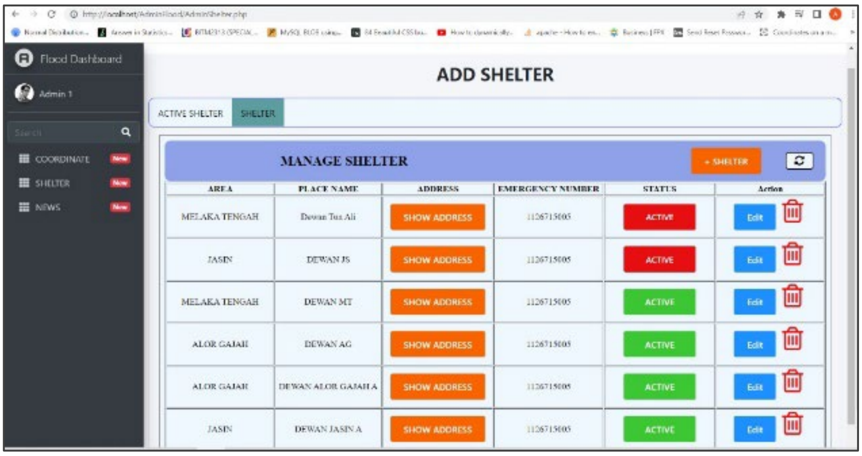


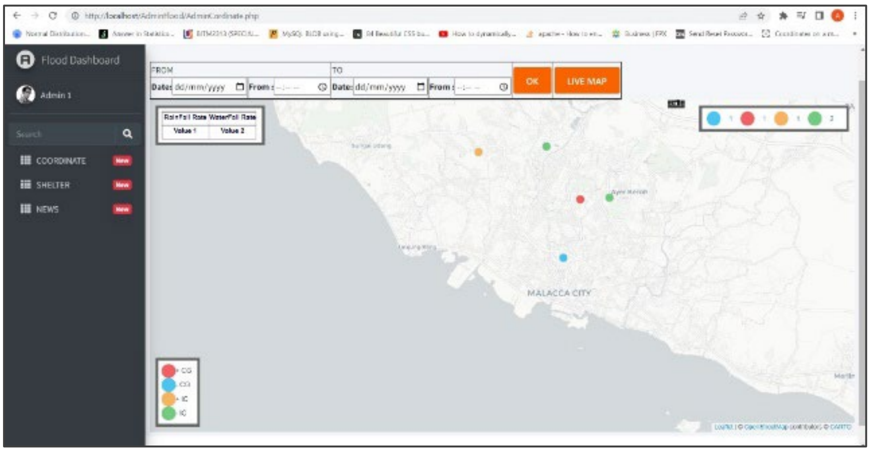
Figure 3: The IoT infrastructure

3.1.2 Web-based Application

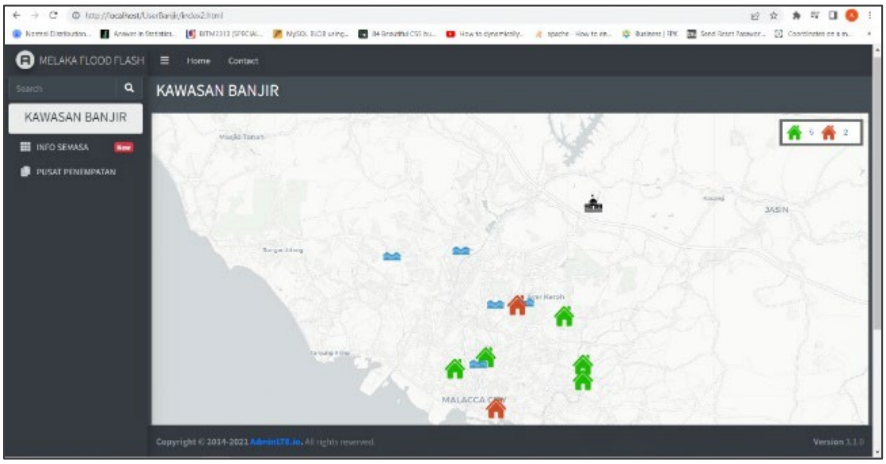
The examples of the interface contained in the web-based application as shown in **Figure 4**.



(a) Interface for adding shelter location information



(b) Interface for flash flood locations



(c) Interface for flash flood locations with the nearest shelter locations

Figure 4: Web-based interfaces of monitoring and forecasting

Figure 4(a) presents the interface for adding the shelter location information. **Figure 4(b)** shows the flash flood locations, whereas **Figure 4(c)** depicts the flash flood locations with the nearest shelter locations.

3.1.3 Mobile Application

The interfaces in **Figures 4(a) – 4(c)** can also be accessed in the mobile application. The developed mobile application is capable of sending early warnings of flash floods with predicted locations to residents around Melaka. **Figure 5** shows the various screenshots of the Android-based mobile application called Flash Flood Alert App (FLAOA).

Figure 5: Screenshots of mobile application interfaces for alert notification

3.2 Discussions

The results of the testing found that RFMN meets the objective requirements. The three components that comprise the RFMN are capable of helping local service agencies prepare to anticipate possible flash floods. RFMN is able to provide sufficient time for agencies and residents to act before the flash floods. This action can reduce the loss of public and government property. Indirectly, RFMN can increase the level of public confidence in the delivery system. In addition, RFMN also makes it easier for agencies to coordinate logistics and displacement strategies more efficiently and effectively. At the same time, the disaster agencies with RFMN can improve the ability to plan and implement flood evacuation in a more organized and timely manner.

4. Conclusion

This case study has shown how IoT technology was applied to the real-time system to make up the RFMN. This system is proven to be able in monitoring to forecast flash floods and generate alert notifications for early warning systems. In the near future, RFMN aims to improve the system to be more advanced and have a more significant impact on the public with broader coverage of flash flood warning dissemination.

Acknowledgement

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