A Radio Wave Condition Collection System for Mesh Network Recovery During Disasters

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Abstract: In recent years, information and communications technology has played an important role in disaster response. One of its most important aspect is maintaining the communication between the various organizations. When a large-scale disaster strikes, power failures and destruction of communication components can result in the breakdown of the existing communication infrastructure. However, timely and accurate information is critical at this point in order to assess the situation in the affected area as well as to provide an effective and immediate assistance. Hence, it is necessary to establish the communication system first prior to everything else. In this study, we introduce a system to restore the communication network effectively. In our system, we collect, aggregate, and analyze radio wave conditions of the affected area to determine the areas that are isolated. Based on our analysis, additional equipment would then be installed in those network-isolated areas to repair the communication network.

1. Introduction

Based on data from EM-DAT: the OFDA/CRED International Disaster Database, disasters caused 314 billion dollars (USD) in economic damages with 96 million people affected and around 9,000 people killed for the year 2017. However, the human impact of natural disasters in 2017 was much lower than the last 10 year average [1]. Perhaps, this is due to the success of various disaster prevention measures supported by the government and non-governmental organizations. However, these efforts need to be continued and further improved to better manage and respond to future crises.

With the advances of information and communications technologies (ICT), disaster management systems could further be improved to deliver an effective and immediate response. Better disaster management is achieved when ICT is used before, during, and after a disaster. The application of ICT has been proven to be helpful in disseminating information such as earthquake alerts preventing the loss of lives [2]. Communication is always important especially between the different organizations involved in disaster response, to whom constant coordination during and after the disaster is critical. However, the communication infrastructure is usually unavailable in disaster situations due to power outage, damaged components, or overloaded networks. Communication networks have difficulty operating resulting in the isolation of some areas. Thus, there is a need to immediately restore or augment the network in order to facilitate an effective and immediate assistance. Additional equipment needs to be deployed for communication restoration. However, during this time, the availability of equipment and personnel is limited thus, there is a need to predetermine the most suitable location for equipment deployment.

In this study, we propose a radio wave condition collection system to aid in network recovery during disasters. To do this, we developed a mobile application for multiple users to collect radio wave conditions within the affected area. The application leverages on the people who are already in-field or on the ground for a fast collection of data. We also developed a Web application to visualize and analyze the collected radio wave conditions using our mobile application. With the aggregated information, we are able to identify the network-isolated areas that are suitable targets for equipment deployment. This will help to fully restore the wireless mesh network, ensuring reliable network connectivity throughout the affected area.

2. Related Work

2.1 Participatory Sensing during Disasters

In disaster scenarios, it is of the utmost importance that there is access to a wide range of information such as information about the environment like the location of fires, flooded areas, and available resources. However, in the aftermath of the disaster, predeployed sensors may be damaged posing a problem for information collection in the disaster area. During these situations, the mobile phones of people on the ground can be used to gather and access critical information. Currently, most mobile phones have a rich set of sensors, including a camera, microphone, global positioning system (GPS), gyroscope, accelerometer, and proximity sensor, resulting in the rise of participatory sensing applications in a variety of domains [3]. Numerous studies describe the use of participatory sensing in achieving an effective and

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prompt information sharing in a disaster context [4] [5].

With participatory sensing, information gathering and transmission is not limited to rescuers alone, but the general public can also gather and transmit data using ad-hoc network infrastructures. Data integrity can be assured when certain information sources are prioritized, thus leading to more efficient communication during disasters.

2.2 Wireless Mesh Networks during Disasters

Networks in extreme environments, such as disaster areas, are unreliable because of the damage in its communication infrastructure. Network connectivity between users may not be available or there is none at all. In such cases, a multi-hop wireless network can be deployed to provide wireless network coverage. Moreover, due to its rapid deployability and self-configuration capabilities, wireless mesh networks, in particular, have been greatly considered as an emergency network [6] [7].

2.3 Network Restoration during Disasters

When both the fixed and wireless communication network are impaired, a movable and deployable communication unit can be used to establish a network in the affected area for connectivity between the users [8]. This approach takes time to be implemented because the additional equipment has to be transported, deployed, and initialized. Thus, there is a need to optimize the placement of such units and prioritize areas where the networks are heavily incapacitated.

2.4 Contribution of the Study

This paper describes a system that leverages the power of participatory sensing and a data manager with enough processing power to aggregate and analyze the available data, which processes the collected information before transmission so that less bandwidth is needed. From the processed information, the proposed system is able to determine network-isolated areas before deploying the equipment for immediate network restoration.

3. System Overview

The proposed overall system, as shown in Figure 1, is composed of three main parts: (1) mobile application, (2) Web application, and (3) data manager (Scenargie®Scene Manager [9]). The mobile application is mainly used for data acquisition while the Web application is used for data visualization and analysis of the aggregated data. Moreover, the data manager, known as Scenargie®Scene Manager shown in Figure 2, is used for the aggregation and synchronization of the measured data from the mobile application.

3.1 Mobile Application

The developed mobile application runs on the open-source Android mobile operating system, and is intended to be used by multiple users. It can be used by first responders in charge of field investigation or ordinary people who are already in the disaster zone. Users need to preinstall the application and once launched, the application automatically gathers the measurement data. These measurement data includes the SSIDs and their corresponding RSSIs, frequencies, and channel numbers of active and functional wireless networks in range. These data are geo-tagged and time-tagged. While the users go around the area of interest, radio wave status are displayed on the screen automatically and are also uploaded to the data manager for further analysis. A simple view of our mobile application is shown in Figure 3.

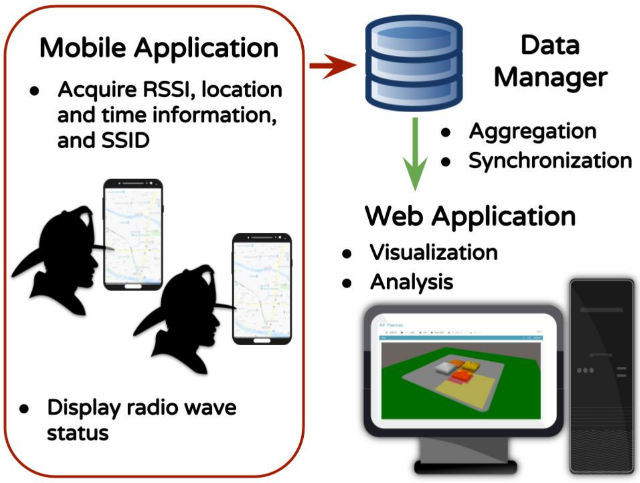


Fig. 1 Overall system

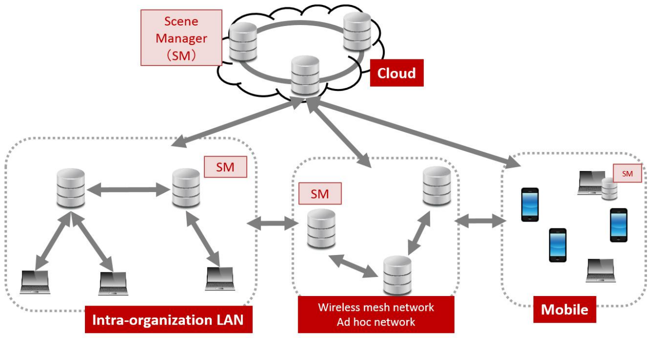


Fig. 2 Scenargie®Scene Manager

(a) Login (b) Main screen

Fig. 3 Radio wave visualizer mobile application

3.2 Web Application

From the data manager, the Web application displays on the screen a summary or aggregate of measurement values processed by Scenargie® ' s Scene Manager. These raw values were gathered from multiple users using the developed mobile application shown in Figure 3. The measurement values are then displayed on a map based on its corresponding position information. Moreover, the measurement data's corresponding RSSI is also displayed with its corresponding color label based on its value as shown in Figure 4. Upon clicking a particular measurement value on the map, details of the measurement data are displayed. Details include the SSID, frequency, channel number, and RSSI value as shown in Figure 5(b). The preset value range and color labels can be easily modified by the user for better visualization.

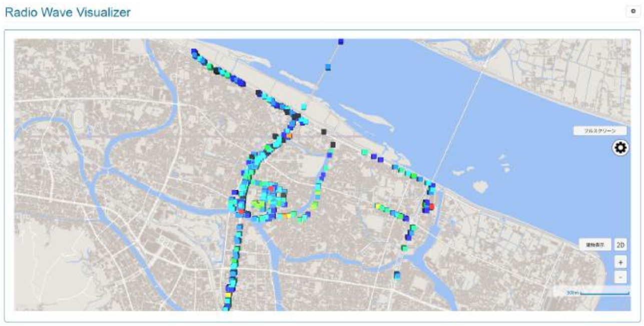
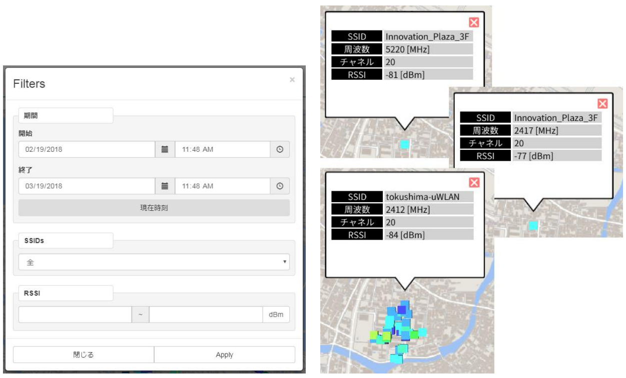


Fig. 4 Web application

The heat map visualization of the aggregated radio wave intensity data at each point serves as an aid for the decision-making in determining the target areas for equipment deployment so that the wireless mesh network is restored throughout the affected area. To assist in data analysis, different filters such as period, SSIDs, and RSSI value range are also available as shown in Figure 5(a).



(a) Filters (b) SSID selection

Fig. 5 Web application features

4. Evaluation

In order to demonstrate the readiness of our system, we ran an initial field test in Tokushima City. First, we pre-installed our developed mobile application on an Android phone as shown in Figure 6(a). Using our *Radio Wave Visualizer* mobile application, we acquired measurement data from different areas in Tokushima City over a 2-day period. This measurement data include the SSIDs, RSSIs, frequencies, and channel numbers with corresponding position and time information. For this field test, we also installed Scenargie®Scene Manager in a Raspberry Pi as shown in Figure 6(b) wherein the acquired measurement data is sent to the data manager automatically. The saved measurement data can then be visualized through our Web application. Results of the the initial field test is shown in Figure 7. Through this visualization, it is possible to determine network-isolated areas especially in times of disasters.

(a) (b)

Fig. 6 Field test setup

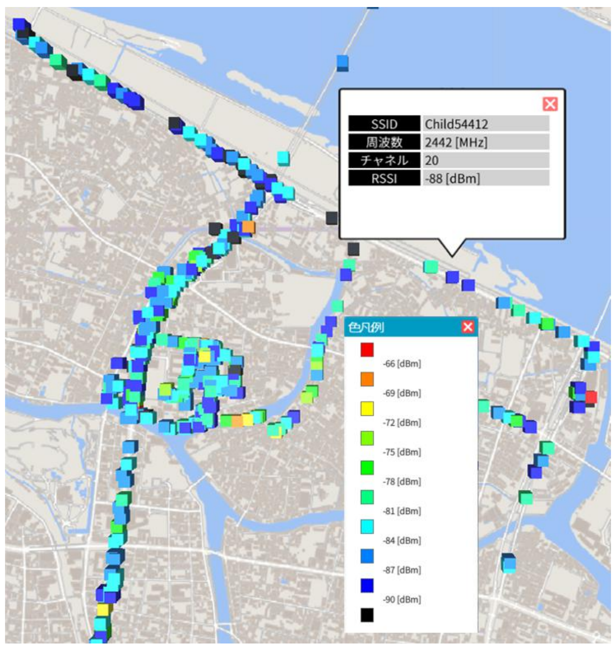


Fig. 7 Visualization result

5. Conclusion

In times of disasters, communication networks have difficulty operating because of possible damage. However, communication within the affected area is critical for an effective response. Thus, this study describes a system to predetermine network-isolated areas for equipment deployment in order to facilitate an efficient and immediate network restoration. In order to determine the isolated areas, we developed a mobile application for the collection of radio wave conditions and a Web application for the visualization of the aggregated radio wave conditions and determination of network-isolated areas. For evaluation, we acquired the radio wave conditions in different areas of Tokushima City using our system. Our initial field test demonstrates the readiness of our proposed system to determine suitable targets for equipment deployment in disaster mesh network recovery.

Acknowledgment

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