Design and Development of Decision Support Nodes Using Near Cloud for Disaster Management and Risk Reduction

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Abstract—**In disaster scenarios, the lack of wireless internet or weak cellular network signal poses a very real threat to crucial information gathering and sharing. Using Near Cloud to store, load and upload information, this project has designed and developed decision support nodes that is able to gather and distribute intelligent information before, during, and after disasters. These nodes are cached in with key information and data needed for disasters i.e. maps, message reports, and images. The nodes serve as the command and control in early warning and disaster management systems. Key capabilities featured in for the decision support node include: beacon mode that is broadcasting message via RF, mapping and visualization, data mining, near cloud, and the medical decision support system. A decision support node architecture is then developed and proposed as the main command and control as mobile kiosks. This mobile kiosk architecture is developed with a number of Raspberry Pi 3's, each of which are connected to perform and handle one application in a grid pattern.**

Keywords—decision support node, mobile information kiosk, Near Cloud

I. Introduction

The Ateneo Innovation Center (AIC) is engaging in collaborative effort with different institutions and companies to develop platforms and systems for disaster risk and management. This stems from the recognition of the importance of disaster preparedness because on average, the Philippines is affected by around 20 tropical storms each year. Geographical location of the country also puts it in a disadvantaged position as it is surrounded by vast warm oceans and therefore, often is on the path of low pressure areas and tropical thunderstorms. For a country with 100 million people, densely populated cities, and poor city planning, a natural disaster places people especially the marginalized in a very vulnerable position. In the event of a disaster scenario, communication lines may be cut off due to damages to infrastructure, making information sharing difficult. Information that may be crucial for damage assessment and rescue operation is lost or not being transmitted effectively. Given this backdrop of past experiences and the ever-present threat of disaster, the Ateneo Innovations Center puts a prime on disaster management in order to eventually reduce casualties and damage. This risk reduction preparation happens long before disaster even strikes. Our project is a gear in the overall mechanism of disaster management and risk reduction that is being developed by the different teams in the Ateneo Innovations Center. This is a continuation of existing efforts on disaster management, risk reduction and decision support system on multiple platforms.

Sources of crucial information in preparation i,e. early warning and in the event of a disaster is received from responders with smartphones using the IBR- Delay Tolerant Network (DTN), and the unmanned aerial vehicles (UAV). Information is sent to a near cloud or directly to the command center to which our design processes this data.

This paper have answered the following questions:

1. How will cached data in the near cloud be used with UAVs and DTN responders?
2. How will the information from the responders and UAV be presented at the command center?
3. What is the mechanism to make transmission of data from the UAV to the Raspberry Pi possible?
4. What will be the design of the rapid development kiosk as a mobile information kiosk?
5. How to direct the flow of information?

The accomplishment of this project is the design and development of an intelligent information gathering and distribution support node capable of presenting coherent information collected from those sending in data while utilizing the Raspberry Pi to provide the functionality of a Near Cloud. The Near Cloud, being low power and low maintenance is suitable for the purpose of acting as a node for information storage and retrieval without using the Internet, especially as this may not readily be available in disaster-struck areas.

II. Review of Related Literature

A. Near Cloud Architecture

Plug computers with terabyte hard drives and connected wirelessly form a network that could provide all the requirements of a wireless mesh network with additional capabilities such as proxy and caching servers.

The following shows a non-exhaustive list of the services that the Near Cloud architecture used in a research paper has been configured to perform. Using an Ionics Cumulus Plug Computer, the following were performed:

- Proxy server
- Caching server
- Web server
- Database
- Peer-to-peer node
- Client Torrent and Dropbox capabilities
- Video-on-demand server Communication services (VoIP, text chat)

In addition to these services, the Near Cloud architecture allows optimization of any limited bandwidth that is available. The Raspberry Pi computer, while falters with the Cumulus in terms of processing speed is a possible alternative. Since it also supports Linux operating systems such as Raspbian, it can perform all the capabilities of the plug as well. [1]

B. IPTV for Disaster Risk Reduction

In a previous research, "IPTV as an Interactive Application for Disaster Management and Education", channels with emphasis on user and content interaction were developed by being able to successfully parse tweets, and input and output TV-information via IPTV. A powerful environment where the architecture can be deployed and modified according to needs was demonstrated. [2]

C. Live Streaming and Interactive Content

Live streaming capabilities and interactive content applications can be integrated to the near cloud. Live streaming is possible as the Near Cloud can transmit data as fast as fiber optic speeds. [3]

D. Requirements of Information and Communication System Using Vehicle during Disaster

Designated station servers automatically send/retrieve messages to/from vehicles. Figure 1 shows the data flow of the message relay to the stations which in turn become Decision Support Nodes. On the other hand, Figure 2 shows information sharing between two stations. [4]

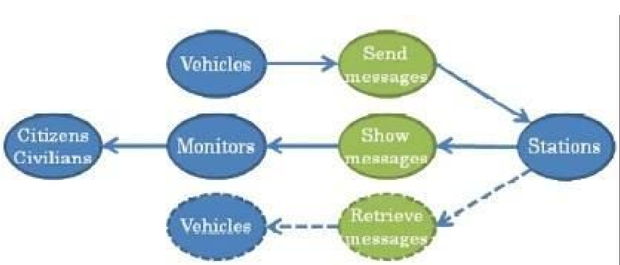

Figure 1. Information Data Flow Between Stations and Citizens

Figure 2. Information Data Flow Between Stations

E. Requirements for Disaster Relief System

This deliverable describes requirements for a Disaster Relief System including an Early Warning System, which are used for real and potential victims, before, at or during and after disasters. [5]

III. Methodology

A. Hardware

1. Raspberry Pi 3

Some of the Raspberry Pi 3's are supported by Windows 10 IoT Core, a version of Windows 10 that is optimized for smaller devices and which utilizes the extensible Universal Windows Platform. Others are supported with Raspbian a linux-based operating system that is also Raspberry Pi's official supported operating system.

Contents of the hard drive is accessible across multiple devices simultaneously. Raspberry Pi specializes in video outputs because this is its main intended purpose. The Raspberry Pi is equipped with HDMI to which the IPTV unit is connected to.

Some of its advantages are as follows: it is low cost, portable and multi-faceted. With its size being roughly the same of a credit card, it boasts mobility and versatility especially in disaster scenarios wherein it may be hard to transport large devices. Aside from this, the Raspberry Pi needs minimal power to function.

2. RF Module

The RFD900+ Modem is a portable device that enables the transmission and reception of radio signals between devices. The RF modules operate across medium even without line-of-sight conditions.

915 MHz Frequency is used for sending and receiving messages from the phones to the RPi. This frequency is favorable because of its propagation characteristics and low congestions as compared to other unlicensed frequencies. The frequency also performs better even if devices are not in the line-of-sight as it has lesser likelihood of absorption and reflection as it interacts with different media. [7] According to tests conducted by the UAV team, the RF can cover a radius of 5km point-to-point without obstacles.

One RF module is connected to the smartphone with IBR-DTN and Whisper and the other is connected to the laptop that runs the Universal Windows app in Visual Studio. The message received is parsed and displayed accordingly on the map.

3. Multiple Screens for Command Center

The War Room utilizes an IPTV unit to display the IoT browser as command and control system ran through the Raspberry Pi. Another screen is used for the Rapid Deployment Kiosk to display various information resources and services stored in a hard drive that is connected to a

Raspberry Pi. The files are accessed through the web server and can be accessed by multiple devices such as laptops and cellular phones via hotspot.

B. Software

1. Raspbian

Raspbian is Raspberry Pi's official supported operating system. It can be installed with NOOBS (New Out Of the Box Software) or by downloading the OS based on Debian directly. Raspbian comes pre-installed with plenty of software for education, programming and general use. It has python, scratch, sonic pi, java, mathematica and more. [8]

2. Windows 10 IoT Core

Windows 10 IoT (Internet of Things) Core is a version of Windows 10 that is optimized for smaller devices with or without a display and that runs on the Raspberry 3. It utilizes the rich, extensible Universal Windows Platform (UWP) API for building great solutions. [9]

3. PHP and MySQL

PHP (recursive acronym for *PHP: Hypertext Preprocessor*) is a widely-used open source general-purpose scripting language that is especially suited for web development and can be embedded into HTML. [10]

MySQL is the world's most popular open source database. With its proven performance, reliability and ease-of-use, MySQL has become the leading database choice for web-based applications, used by high profile web properties including Facebook, Twitter, YouTube, Yahoo! and many more. [11]

4. Visual Studio

Universal Windows apps can only be developed and run using Visual Studio 2015, Microsoft's Integrated Development Environment for its platforms, which can be written using a range of languages. This research uses JavaScript with HTML and Extensible Application Markup Language (XAML).

5. IBR-DTN and Whisper

The IBR-DTN is a bundle protocol daemon based on RFC5050 which provides an API for DTN applications to exchange routes and bundles between them. Whisper is a chat application for use with IBR-DTN. Both of these were downloaded onto a smartphone which is connected to an RF module, used to relay messages and act as an aggregator. [12]

C. Web Server

1. Apache

Apache is a free and open-source software, most widely used to serve files that form Web pages. In this project, files are accessed from a hard drive through a web browser through the Apache web server.

Figure 3. Apache Web Interface

IV. Results

A. Overall Structure

The whole system for disaster risk and management is a collaborative effort amongst different research teams. The IBR-DTN team employs the delay tolerant network to send data across devices. These information could be in the form of text, sound recordings and images embedded with metadata. The UAV team takes information while on flight and sends data through the RF to the ground. The teams work together to come up with a resilient system of information collection and transmission. The current team handles the data. The responders using IBR-DTN need an aggregator to send information to the mobile center using the designated RF band, this is the same for the UAV employing the same RF system of sending data. The mobile center receives and displays said information as discussed in the next sections.

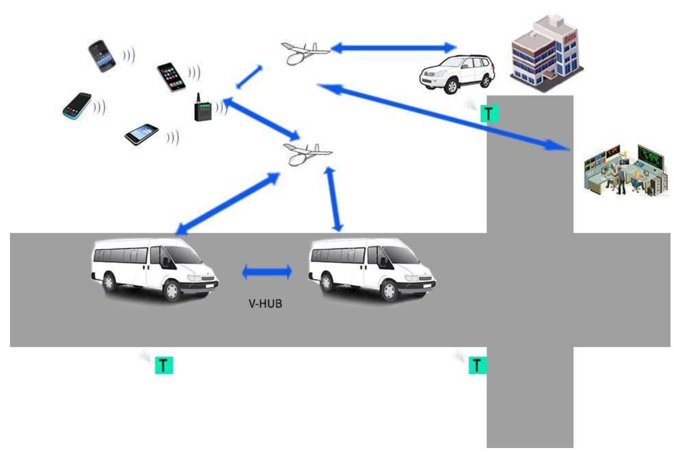

Figure 4. Exchange of information from different sources connected to the near cloud architecture

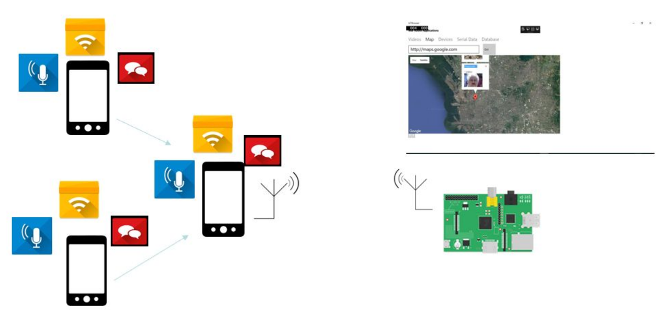

Figure 5. Information Flow Across Devices

Recalling the objectives mentioned, the main goal is to create a near cloud architecture which is achieved using the mobile kiosk. With the mobile kiosk, this research has developed a system to handle, store and synthesize all data being sent by designated devices and responders. This kiosk is functional as its own network of information sharing and storing devices even without having to rely on outside sources of internet WiFi as these may not be an available resource in the aftermath of a disaster.

B. Beacon

The beacon mode on the UWP application is capable of sending messages periodically to all accumulators, responders, and even UAVs. Its components include the RF which can reach a distance of 5 km point-to-point, as well as the kiosk, equipped with the Raspberry Pi and gateway. The beacon can either send a ping or broadcast a message, where the data is then interpreted by the IBR-DTN team. This mode is significant when the mobile kiosk needs to send a message to all those out in the field.

C. Mapping

The Universal Windows Platform application is also capable of detecting devices and receiving serial data with the use of the RF module. The serial data includes the content, timestamp, latitude and longitude of the message. Messages are received, parsed, and marked on the map with the corresponding coordinates. The coordinates sent in through the phone are marked on a Google map API. Accompanying this marker is an info window which displays the message or image sent. IBR-DTN is employed in the reception and transmission of messages. IBR-DTN applications such as Whisper and Talkie were modified to fit the specifications required by the command center.

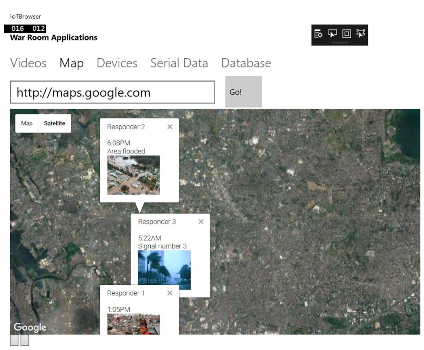

Figure 6. UWP Application Mapping Interface

The flow in which information is passed on are as follows: a responder phone with the IBR-DTN and Whisper application sends a message and its coordinates to the aggregator phone. An aggregator has a modified Whisper application and is connected to the RF module. The message is then received by the aggregator phone, which is sent out through the RF module. The RPi or device connected to the RF module will then receive the message. The message will then be displayed in the Serial Data tab of the UWP app interface. The message can also be seen displayed on the Map tab based on the coordinates given.

D. Data Mining

1. Facial Recognition

All the information gathered, such as images, from the different accumulators are received by the Raspberry Pi, which also acts as a data mining node. Once data have been gathered and plotted on the map, various data mining applications may be used to generate new information. One such application that has been integrated with the kiosk is facial recognition. This is used to gain information about the images, which are then processed for further supported decision making in disaster management.

E. Near Cloud

1. Hotspot and Network-Attached Storage

One of the Raspberry Pi 3 has been configured as a hotspot, which has a functionality of a plug computer. It acts as a network-attached storage (NAS). A NAS is an intelligent storage box that connects directly to the network or home router. [13] The terabyte hard-disk dives act as the storage box while the RPi 3 serves as the web server that provides the network connection. The NAS is dedicated to file sharing and allows to add more storage to the network without affecting the server operations.

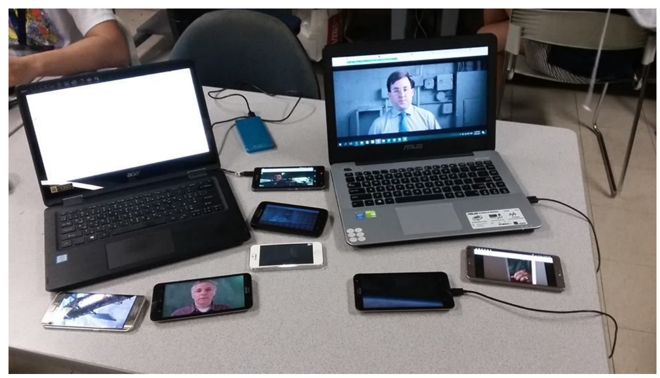

Figure 7. Multiple Devices Accessing Data from the Web Server

2. Messaging

The near cloud chat feature that is available in the Pi is a modified version of an open source PHP messaging program. The user who is connected to the RPi hotspot may use this feature by logging in first and then sending messages. The messages will show up on all the devices on the near cloud chat which are connected to the network.

Figure 8. Instant Messaging Feature in Rapid Deployment Kiosk

3. File Sharing

Connected devices have access to a file-sharing solution for collaboration and storage. It is an open-source, self-hosted file sync and share app platform, an in-house “Dropbox”. Files are stored in the hard drives of the Raspberry Pi. The admin can add, remove and modify users’ access to the file-sharing platform.

F. Medical Decision Support System

The Medical Decision Support System allows the messages sent to be tagged based on the need of medical assistance. A yellow and red infowindow marked on the map signifies second and first priority assistance, respectively. This system allows messages to be received, pertaining to the status or situation at hand, mapping the location given, and giving it appropriate priority. This is significant to assess what kind of assistance is needed, how much of it is needed, and how immediate do they need it.

G. Architecture

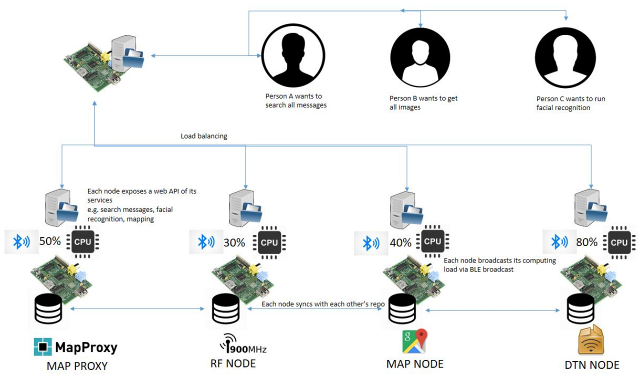

Figure 9. Proposed System Architecture

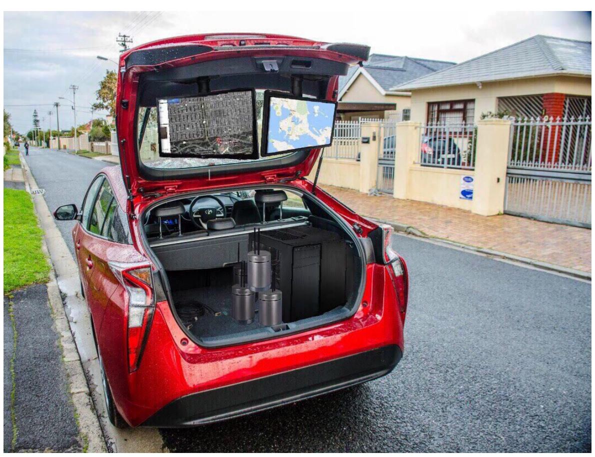

Figure 10. Proposed mobile command center

In this project, a system architecture of the mobile kiosk has been proposed. Figure 9 illustrates how each Raspberry Pi is connected to perform and handle one application in a grid pattern. This allows for easy implementation whenever a new capability is integrated, as well as a light-weight and low-cost architecture with the use of Raspberry Pis.

As seen in Figure 10, the mobile command center is housed in a vehicle so it may disseminate and receive information as soon as possible, efficiently and quickly to areas that are affected by disaster. This mobility is crucial in disaster scenarios where responders may not have the logistics, access and time to set up a command center. The design for the mobile kiosk is conceptualized by mechanical engineering student Mr. Eduardo Bellido. It includes two large screens in which to display information, batteries for power and sturdy cases containing the RF and RPi. The case design is shock and shake-proof; where the delicate devices such as the RPi (which does not have a protective casing) will be held in place inside along with the RF.

V. Conclusion

With a mobile Kiosk for access of information, this research shows that the near cloud architecture can provide a versatile platform for various services such as those that efficiently use pre-loaded data, as well as those that process crucial information in early warning and in the event of a disaster to create a decision support system. The mechanisms in place in the acquisition, reception and transmission of all types of data has the limitations of a disaster scenario in mind. Thus, there is an importance of employing delay tolerant networks to make sure no information is lost which may be crucial for disaster risk and management. The study has been built upon from previous design concepts and technology to present an improved near cloud architecture. This is achieved by being able to utilize an RPi instead of a plug computer and improving and adding new features and functionality to the mobile kiosk.

VI. Recommendation

The whole system may be tested in a more rigorous simulated evacuation and disaster response scenario. The mobile command center functionalities are still in its development phase. There can be more sophisticated ways in the reception and transmission of data. Further applications may also be integrated with the kiosk to add on to its capabilities.

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