IMPLEMENTATION OF A CONTEXT-AWARE ROUTING MECHANISM IN AN INEXPENSIVE STANDALONE COMMUNICATION SYSTEM FOR DISASTER SCENARIOS

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ABSTRACT

Natural disasters often destroy and disrupt communication infrastructures that hinder the utilization of disaster applications and services needed by emergency responders. During these circumstances an implementation of a standalone communication system (SCS) that serves as an alternative communication platform for vital disaster management activities is essential. In this study, we present a design and implementation of an SCS realized using an inexpensive microcontroller platform. Specifically, the study employed Raspberry Pi (RPi) devices as rapidly deployable relay nodes designed with a context-aware routing mechanism. The routing mechanism decides the most efficient route to send messages or disseminate information in the network by utilizing a context-aware factor (CF) calculated using several context information such as delivery probability and link quality. Moreover, with the use of this context information, the proposed scheme aims to reduce communication delay and overhead in the network commonly caused by resource contention of users. The performance of the proposed SCS, was evaluated in a small-area case-scenario deployment using a messaging application and web-based monitoring service. Additionally, a simulation-based performance analysis of the proposed context-aware routing mechanism applied to an urban area map was also conducted. Furthermore, in the simulation, the proposed scheme was compared to the most commonly used Flooding and AODV schemes for SCS. Results show a high delivery probability, faster delivery time (low latency) and reduced message overhead when using the proposed approach compared with the other routing schemes.

KEYWORDS

Standalone communication systems, disaster communication systems, context-aware routing

1. INTRODUCTION

According to the 2016 World Disaster Report [1], 574 major disasters occurred around the world have been recorded by the Centre for Research on Epidemiology of Disasters' Emergency Events Database [2]. The number was considered the fourth lowest number in the past decade but still has claimed 32,550 lives. Ray-Bennett in [3] pointed out three common causes of mortality during disasters namely; traditional perspective, vulnerability perspective, and complex perspective. The traditional perspective details the harmful nature of the disaster while the vulnerability perspective refers to the social, economic, cultural factors. Finally, the complex perspective involves factors like citizen disaster unpreparedness [4], inefficient or lack of information dissemination [5], and communication infrastructure support failures in disaster management [6]. Undeniably, communication infrastructures play an important role in management, coordination, intervention, rescue and recovery missions, and post-disaster

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evaluations during disasters. Unfortunately, damage to communication infrastructures also occurs during these times. For example, during the 2011 Great East Japan earthquake, and the tsunami thereafter, approximately 1.9 million fixed communication lines and 29,000 base stations were reportedly damaged [7].

When disasters occur, affected citizens may need emergency responders help and guidance, access information and communicate their current situations with friends and relatives. For some cases, there may be few communication infrastructures remaining, and the problem in network congestion occurs as a greater number of users try to utilize the scarce communication resources [8]. In these circumstances, when both emergency responders (ERs) and normal users utilize and rely on the remaining infrastructure, bottlenecks often go undiscovered, pushing the infrastructure to its limit and making the services completely limited or cut off completely at some point in time.

When most of the communication infrastructures are destroyed and immediate repair and restoration are nearly improbable. Fast establishments of temporary communication systems that can support emergency services and applications should be one of the most urgent tasks in disaster management. The research field in standalone communication systems (SCSs) emerges as a potential solution during these events. Among SCSs characteristics that make it a suitable solution for disaster scenarios is its rapid deployment that can be done within less than an hour to few hours after the disaster and the wide communication coverage of significant disaster area for some implementations [9].

With the advancement in wireless technologies and the inexpensiveness of devices capable of building special-purpose networks, the design and development of SCSs and services have become more interesting research area in recent years. With this growing trend in SCSs and the development of valuable network solutions during disasters, this study presents a model SCS using inexpensive microcontroller platform that aims to serve as an alternative network for the infrastructure-stricken area, especially during a disaster. It is important to emphasize, that this work does not intend to replace larger implementations such that of big telecommunications companies listed in [10] but rather as an additional communication option that can alleviate network congestion and support specialized disaster activities. Moreover, this paper’s contributions include 1) development of a rapidly deployable relay nodes implemented using Raspberry Pi, 2) a mobile messaging application for emergency responders and disaster victims, 3) a context-aware routing scheme that secures faster delivery of mission-critical messages, and 4) a deployment experiment and simulation-based comparison of the proposed routing mechanism.

In the remainder of this work, section 2 discusses existing implementations of standalone communication systems. Section 3 focuses on the details of the proposed standalone communication system and context-aware routing mechanism. Section 4 details the implementation, performance evaluation and discussion of the results. Lastly, concluding remarks and future works are discussed in section 5.

2. STANDALONE COMMUNICATION SYSTEMS

This section provides a comprehensive background of SCSs and a review of several SCS implementations. For the purpose of comparison, the SCS presented in this paper are not limited to providing data communication services. Furthermore, to have a broader perspective on network implementation, this paper reviews existing SCS designs that employ various network models.

2.1. Overview

Standalone communication systems (SCS) as their name implies serves as an alternative form of communication infrastructure and provide services without relying on the established infrastructures such as telecommunication towers or telephone lines that are commonly deployed for a specific application scenario. SCSs for disaster and emergency scenarios are often called or associated with different names in literature, such as rapidly deployable systems, emergency communication systems, and temporary communication systems. In this paper, we will refer to these systems collectively as standalone communication systems, hence SCSs. Some common distinctions among these systems in literature lies with various characteristics such as computing resources, deployment time, portability, mobility, and network scope. Authors in [10] have surveyed existing SCSs approaches from a large telecommunications company and cognitive radio network (CRN) implementations for disaster.

2.2. Related Works on SCS for Disaster Scenario

Due to the rising interest in low-cost SCS development in the past decade, several design solutions have been presented in the literature. Some works utilize existing ad hoc networks and available devices (mobile devices, access points, etc.) in the disaster area. Work in [11] has focused on identifying relevant characteristics of Wireless Sensor Network (WSN) and Unmanned Aerial Vehicles (UAV) systems that can be applied to a general disaster management application. The study also provides an overview of several proposed solutions in the literature that utilizes different nodes, networks, and technologies to implement an SCS to support disaster activities.

LTE- based Solutions. Authors in [9] presented a disaster communication system using standards-based subsystems that support basic citizen services. It consists of Wi-Fi, a satellite link, a single-carrier GSM system, and an LTE base station. This design, however, highlights the use of a Long Term Evolution User Equipment (LTE_UE), to provide GSM access to users which serves caters its core service like victim registration. Undeniably, one drawback to this solution is the setup of the LTE_UE mounted on a weather balloon which needs technical expertise and a great amount of time compared to readily deployable ground relay nodes.

Ad - hoc Network - based Implementations. Work in [12] has made use of WSN and mobile ad hoc network (MANET) configured devices that are already present in the disaster site. The study enables local communication and information collection. Moreover, to communicate with the remote disaster-safe areas, a satellite gateway is used and is interconnected with the locally deployed MANET. Furthermore, the design also made use of cellular gateways as alternative remote communication means when the expansion of local networks reaches a working cellular base station.

Unmanned Aerial Vehicle (UAV) Designs. In [13], a network solution, using WiMAX technology without fixed access points, based on UAVs has been proposed to realize a resilient network backbone in emergency scenarios. Moreover, the network is consists of balloons, electric vehicles (EV) and UAVs to supplement an emergency wireless network during large-scale disasters [14]. Their implementation scenario uses a Delay Tolerant Network (DTN) architecture that aims to reduce the number of nodes required for communication.

Smartphone - based Solutions. There are also works in literature that proposed the use and availability of handheld devices without the integration of other mobile devices, the SPAN (Smartphone Ad-Hoc Networks) project [15] attempts to answer issues by providing an alternative means of information distribution. The project utilizes MANET technology to provide a resilient backup framework for communication between individuals. The project harnesses the ubiquity of smart phones to provide durable communication. Table 1 summarizes the various standalone communication systems that use different nodes, devices, and network architectures.

Table 1. Comparison of various standalone communication systems implementations

Components and Devices Used	**Network Model**	**Application/ Services**	**Coverage**	**References**
Mobile Devices, LTE_UE, Balloons	Text Messaging (GSM)	Victim Registration and Management	Large Area	[9]
Sensor and Mobile Devices	WSN and MANET integration	Disaster Area Monitoring	Small Area	[12]
Mobile Devices, UAV	WiMAX	Disaster Area Assessment	Small to Medium Area	[13]
Vehicles, Balloons, UAV	Message Replication (DTN)	Not specified	Large Area	[14]
Mobile Devices (Smartphone)	Device to Device Communication	Disaster Area Monitoring	Small to Medium Area	[15]

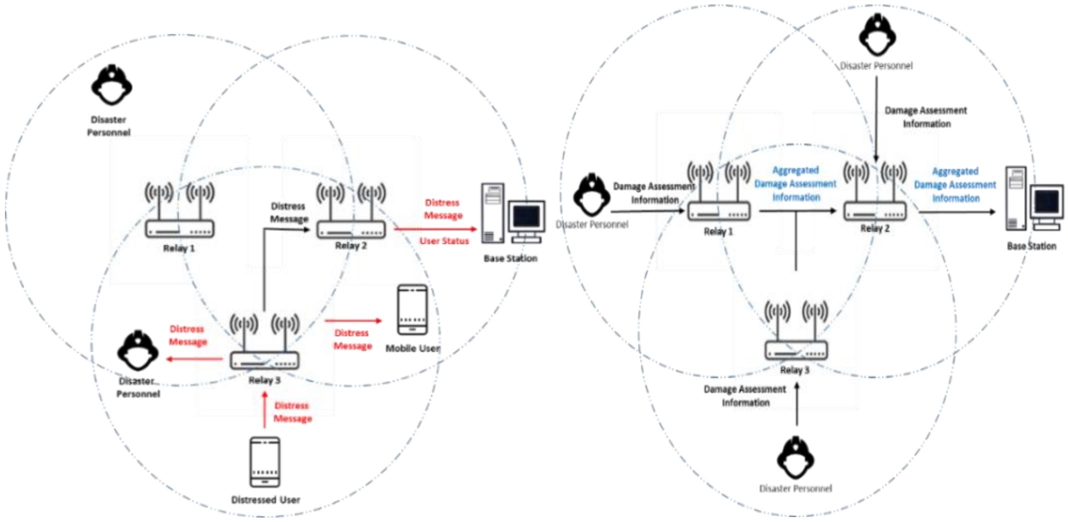
3. PROPOSED WORK

3.1 Description of the Proposed SCS, Architecture and Components

In Section 2.2, most of the presented solutions of SCSs are implemented using various ad hoc network architecture like wireless sensor networks (WSN), mobile ad-hoc networks (MANET), and special purpose networks like Disruption Tolerant Networks (DTN). Other solutions utilized deployable unmanned aerial vehicles (UAV) and different devices. It can be observed that these factors or considerations depend on the availability of resources as well as the application and services that need to be supported by the SCS.

For a disaster area and considering the availability of a plethora of mobile devices (e.g. smart phones, wearable’s, and IoT devices), this study prototyped a functional SCS using Raspberry Pi (RPi) platform. It is with the assumption, that prototyping with RPi will ensure compatibility and interoperability with a multitude of devices. For the hardware components, the RPi is equipped with a 32GB memory, installed with Raspbian Stretch image and has been integrated with two (2) Wi-Fi interfaces with a 100-meter communication range. The two Wi-Fi interfaces are used to separate the connection (SSID) for the relay node connections and user connections. The general architecture of the proposed study is a non-hardware specific in contrast with the works in [15] where they utilized an ASUS EePad as another node relay, and are assumed to require a fixed source of power. Moreover, the RPi has been chosen as relay nodes due to its small form factor and portability, lower energy consumption and has the option to be powered by portable power supplies like batteries or power banks. These considerations make the proposed SCS suitable to be used in mobile environments which are evidently beneficial in disaster scenarios. Moreover, the study also takes into account that RPi as a relay node can be embedded with processing scripts (in this case the proposed context-aware routing mechanism) which is described in detail in the next subsection.

Figure 1 illustrates the proposed communication architecture, and message transmission routing flow for two (2) disaster phases namely response and recovery. According to Alexander [16], a disaster event is divided into four (4) phases, prevention, preparedness, response, and recovery. In particular, the proposed study is envisioned to be the most beneficial during the last two phases: the response and recovery phases. The response phase includes the search and rescue (SAR) missions and emergency relief while the recovery phase is mostly concerned with disaster damage management and victim assessments. Consequently, the transmission scheme enables faster delivery of the messages in both scenarios such that the relay nodes are capable of evaluating which path (which exact relay node has a connection with the corresponding device/user) is the most reliable and efficient for the message to traverse.

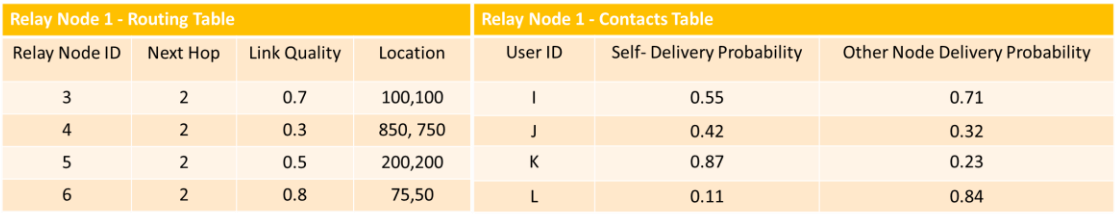


(a) (b)

Figure 1. The proposed communication architecture in (a) during a disaster response scenario and (b) post-event recovery, damage assessment scenario.

3.2 Message Transmission using Context-aware Routing

Context-aware routing implies the use of multiple context criteria, which can be static or dynamic in nature that directly influences the routing process [17]. In this proposed approach, the context-based mechanism primarily captures several dynamic context information such as encounter/connection frequencies and link quality of nodes. The encounter frequency information is used to compute the delivery probability of a next hop node to a particular user. While the link quality adopted in [18] exhibits the communication state of relay nodes to one another. The encounter frequencies of users with a particular relay node (RPi) are periodically updated to every relay node with the implementation of Contacts Table (CT). The proposed system utilizes this feature on the assumption that knowledge or even previous knowledge of where a particular individual/entity is very significant for disaster logistics, and rescue and recovery operations. As shown in Figure 2-b, a relay node (the RPi) calculates for its Self-Delivery Probability and the Delivery Probability of next hop node (or in a mobile state an encountered node). These features are utilized for the efficient selection of forwarding messages from source to destination. Furthermore, A routing table (RT) shown in Figure 2-a, is utilized by the relay nodes to record the connections to other relay nodes.



Relay Node 1 - Routing Table			
Relay Node ID	Next Hop	Link Quality	Location
3	2	0.7	100,100
4	2	0.3	850, 750
5	2	0.5	200,200
6	2	0.8	75,50

(a)

Relay Node 1 - Contacts Table		
User ID	Self- Delivery Probability	Other Node Delivery Probability
I	0.55	0.71
J	0.42	0.32
K	0.87	0.23
L	0.11	0.84

(b)

Figure 2. The proposed (a) routing table and (b) contacts table used in the routing decision.

3.2.1 Node Delivery Probability

To obtain the Delivery Probability, each encounter of a particular user on a particular relay node is recorded and updated. Equations 1 and 2 show the formula for each relay node to compute their probabilities with each user in contact. In Equation 1,$P\left(N_i, U_j\right)_{curr}$, is the self-delivery probability of relay node $N_i$for user U_j that is updated every time U_j connects withN_i, and $P_{init} \in (0,1)$ is an initialization constant. An aging mechanism in Equation 2 is utilized as time elapses when the relay node and user do not meet, where $\gamma \in (0, 1)$ is the aging factor, and k is the amount of elapsed time since the last update.

$$P\left(N_i, U_j\right)_{curr} = P\left(N_i, U_j\right)_{prev} + \left(1 - P\left(N_i, U_j\right)_{prev}\right) * P_{init} \qquad (1)$$

$$P(N_i, U_x)_{curr} = P(N_i, U_x)_{prev} * \gamma^k \qquad (2)$$

3.2.2 Link Quality

The other context information incorporated in this work is the link quality, for a simpler approach, we adopted the Link Quality metric used in [18] which is based on the connection quality measured by the relay nodes using received signal strength indicator (RSSI). The link quality can have a value from 0 to 1 and the metric divided the bounds of good links and bad links by two threshold values $\mathrm{LQI_{Good}}$ and $\mathrm{LQI_{Bad}}$, this then defined an $\mathrm{LQI_t}$ and $\mathrm{LQI_{Max}}$ as the measured link quality value and pre-defined maximum value, respectively.

$$Link\ Quality = \begin{cases} 1 & ,\text{if } \mathrm{LQI_t} > \mathrm{LQI_{Good}} \\ \dfrac{\mathrm{LQI_{Max}} - \mathrm{LQI_t}}{\mathrm{LQI_{Max}}} & ,\text{if } \mathrm{LQI_{Bad}} < \mathrm{LQI_t} < \mathrm{LQI_{Good}} \\ 0 & ,\text{if } \mathrm{LQI_t} < \mathrm{LQI_{Bad}} \end{cases} \qquad (3)$$

3.2.3 Context-awareness Factor

With the above-mentioned context information, each relay nodes calculate for the Context-awareness Factor (*CF*) given in Equation 4, where *CF* is the Context-awareness factor, $CU_i$is the context-information utilized, and *m* is the total number of context-information being utilized.

$$CF = \sum_{i=1}^{m} CU_i \qquad (4)$$

With this metric, a message to a particular user is routed to the next hop if the *CF* of the next relay node is higher than the *CF* of the current relay node (message source). With these, routing to inefficient relay nodes is avoided. Furthermore, this metric can easily be adjusted even with the expansion and use of multiple context-information factors.

4. PERFORMANCE EVALUATION AND RESULTS

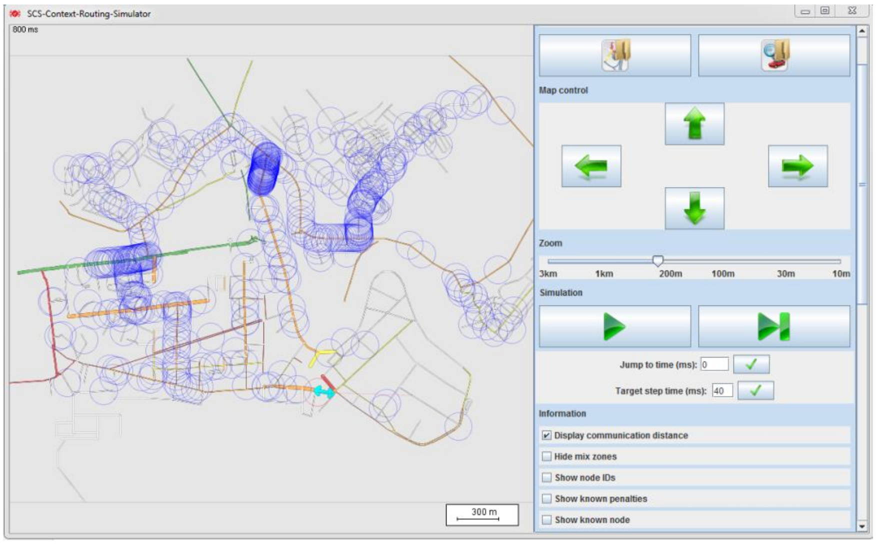
4.1. Performance Evaluation Comparison using Simulation

To evaluate the performance of the proposed routing mechanism and SCS parameters in an urban disaster scenario, a simulation experiment was conducted. A customized Java simulator was developed (shown in Figure 3) to compare the performance of the proposed approach with Flooding mechanism [19] and Ad-hoc On-Demand Distance Vector (AODV) [20] approach which has been studied and employed for emergency communications.

The simulation scenario was performed with a 1:10:1 relay node to a user and disaster responder ratio which involves 20 relay nodes, 200 mobile devices, and 20 emergency responders in 2000x1000m area for an 8-hour period and the relay nodes are deployed in the area randomly with a given restriction that they are within range with one relay node. Two scenarios have been put into consideration, (1) one scenario involves of all relay nodes assumed to be stationary and (1) another scenario considers half (50%) of the relay nodes are mobile and assumed to be carried by an emergency responder. Furthermore, the simulation is set to have 2 types of messages, 1) one originating from random users and intended going to other users and emergency responders and 2) emergency responders to emergency responders. To differentiate these messages, a message type field in the simulation is used. However, for the purpose of analyzing the message overhead and delivery rate efficiently, it is collectively summed up to capture the total messages generated. Furthermore, these messages are created randomly in time and location. The RSSI values that are used for the Link Quality have been given approximate measures based on relay node distances in the simulation. The simulation was repeated 5 times and a summary of the simulation parameters is depicted in Table 2 below.

Table 2. Simulation Parameters used in the simulation.

Parameter	**Value**
Simulation area	2000 x 1000m
Number of relay nodes	20
Number of responders	20
Number of users	200
Simulation time	8 hours
Communication Interface	Wi-fi
Relay node communication range	90m
Responder speed	1-2m/s
Message size	512bytes – 1MB



Jump to time (ms): 0

Target step time (ms): 40

☑ Display communication distance

☐ Hide mix zones

☐ Show node IDs

☐ Show known penalties

☐ Show known node

Figure 3. Screenshot of the simulation with deployed relay nodes, responders and users.

Previous works like in [19] have relied on the Flooding mechanism or investigate the appropriateness of AODV [20] on the network which commonly results in high message overhead and network bottleneck. The implementation of the context-aware routing mechanism on the relay nodes aims to primarily address this problem. Due to the unavailability of open-source codes with other proposed context-aware mechanisms, this study opted to compare the proposed approach with the aforementioned routing mechanisms. Tables 3 and 4 below summarizes the simulation experiment results for the two (2) scenarios.

For the performance metrics Message Delivery Ratio, Delivery Latency, and Delivery Overhead were used to assess and compare the various schemes. Delivery Ratio depicts the rate of successfully delivered messages versus the number of generated messages. On the other hand, Delivery Latency is the elapsed time (milliseconds) from the time the message is created and the time it was received by the destination. Lastly, Delivery Overhead is the measure of a number of the total number of transmissions versus the number of delivered messages. The results of the simulation using the aforementioned metrics are discussed below.

In scenario one, when there are only static relay nodes, Table 3 depicts that using the Flooding technique, as users are moving, results in 619% overhead and AODV achieved 211% overhead which is very high considering the number of users and relay nodes for the experiment. This verifies that in Flooding, every message traverses into all relay nodes every time. On the other hand, the proposed context-aware mechanism achieves fairly a 42.3% overhead ratio and has reduced the number of unwanted messages in the network, alleviating each relay nodes of too much traffic.

There are relatively several cases that the message was propagated to all relay nodes during the simulation, from the analysis, these scenarios happen because of a) the recipient is mostly connected to edge relay nodes, or furthest nodes which need to be traversed using all the other relay nodes, this scenario is mostly caused by the relay node topology and random placement of nodes b) intended recipient or user has few encounter frequencies with most of the relay nodes and lastly c) the delivery probability computed is lower giving the relay node a choice to send it to a much more higher delivery probability relay node.

The delivery ratio of using the proposed approach resulted in an acceptable 84% compared to 81% and 53% for Flooding and AODV schemes, respectively. With this high delivery rate, a minimal trade-off in delivery latency in the proposed approach can also be seen in Table 3. The proposed approach achieves a slightly higher delivery latency, about 200ms compared to Flooding but is significantly lower of 2000ms (2sec) compared with AODV.

Furthermore, the scenario where 50 percent of relay nodes are assumed to be mobile (shown in Table 4) has shown reduced results compared to when relay nodes are stationary. When relay nodes move, the contacts and routing table rapidly changes in time and the calculation of delivery probability for some relay nodes decreases. Thus, there is a smaller change in the delivery ratio for the proposed approach while it maintains a low overhead compared with the other two schemes which have resulted in 2 times the value from the previous scenario. Significantly, the delivery latency in the proposed approach for the second scenario barely changes compare to the 50% mobile relay node scenario.

Table 3. Impact of a stationary relay node in SCS in terms of Message Delivery Ratio, Delivery Latency and Overhead Ratio of simulated approaches

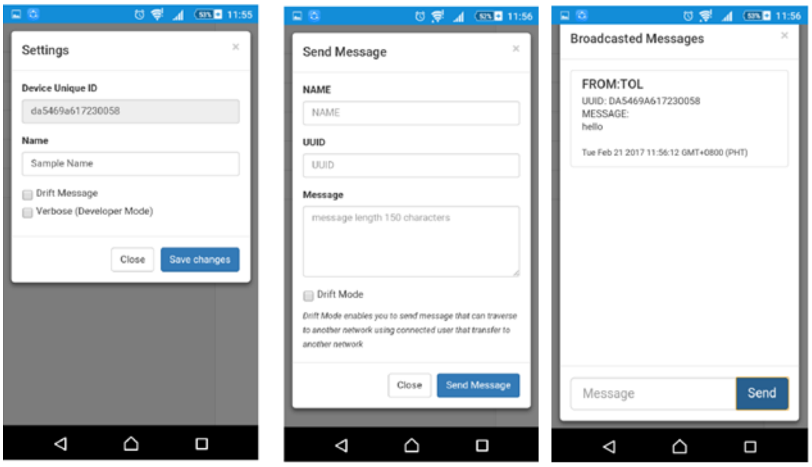
Metric / Routing Schemes	**Flooding**	**AODV**	**Proposed**
Delivery Ratio (%)	0.81	0.53	0.84
Delivery Latency (ms)	3512	5543	3731
Delivery Overhead (%)	619.13	211.16	42.3

Table 4. Impact of 50 percent mobile relay node in SCS in terms of Message Delivery Ratio, Delivery Latency and Overhead Ratio of simulated approaches

Metric / Routing Schemes	**Flooding**	**AODV**	**Proposed**
Delivery Ratio (%)	0.77	0.44	0.75
Delivery Latency (ms)	4762	7641	3814
Message Overhead (%)	1311.17	424.11	56.18

4.2 SCS Experimental Deployment with Messaging Application

To be able to evaluate the performance of the proposed SCS relay nodes in a real-world application, an initial simulated experiment was conducted. The implementation envisions of unavailability of communication infrastructures where services are neither available for emergency responders nor disaster victims. In the experimental deployment, six (6) relay nodes were deployed stationary in an approximately 600m x 400m area building. The topology was made sure that every relay node is within at least one relay node's communication range. In this deployment, for users to utilize the deployed SCS, an Android mobile messaging application was created as a proof of concept that the SCS can support disaster applications and services for disaster victims and emergency responders. The application also was utilized to capture the encounter of each user (device) with the relay node, and pre-simulated encounters have been fed to the relay nodes before conducting the actual message/information forwarding. Shown in Figure 4 is the mobile interface of the mobile messaging application to register and a message compose form to enable the user to send messages to other users.


Settings

Device Unique ID: da5469a617230058

Name: Sample Name

☐ Drift Message

☐ Verbose (Developer Mode)

Send Message

NAME: NAME

UUID: UUID

Message: message length 150 characters

☐ Drift Mode

Drift Mode enables you to send message that can traverse to another network using connected user that transfer to another network

Broadcasted Messages

FROM:TOL
UUID: DA5469A617230058
MESSAGE:
hello

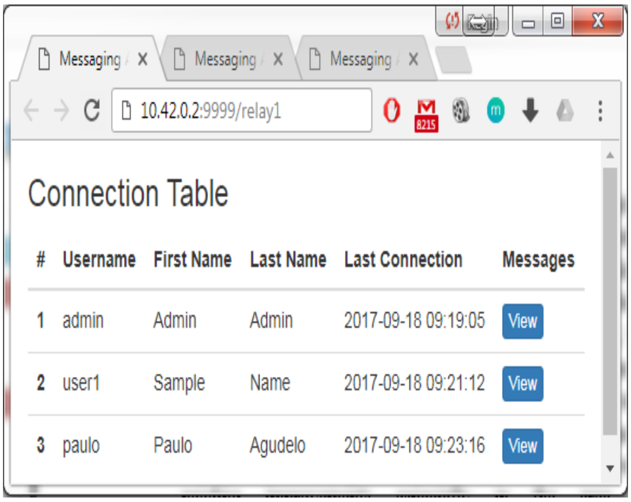
Tue Feb 21 2017 11:56:12 GMT+0800 (PHT)

(a) (b) (c)

Figure 4. User interfaces for (a) user registration, (b) message creation in the application (c) sample broadcast message

When a user device connects to a relay node (in the process of registration), it will be assigned with a Unique User Identification (UUID) that is associated with a name, this becomes the basis of its identification in the messaging application. It is assumed that the emergency responders are given UUID which are already pre-stored in the messaging application and is known by default to other emergency responders. Finally, the message inbox in Figure 4-b and a sample broadcast message in Figure 4-c is utilized to send the messages to individual users or all users respectively. Broadcast messages are mostly applicable for event notifications and warnings from emergency responders or from the disaster operations center (DOC).

A web interface for performance monitoring shown in Figures 5 – 7 have also been implemented. Figure 5 shows the active devices and the relay node (indicated in the URL in the address bar) they are connected to. These records show the last active connection of the devices, which can be beneficial to locate their whereabouts, whenever a particular event happens. In addition, these records are consolidated from the entire relay node connection table shown in Figure 6 which are processed and summarized by the DOC server.

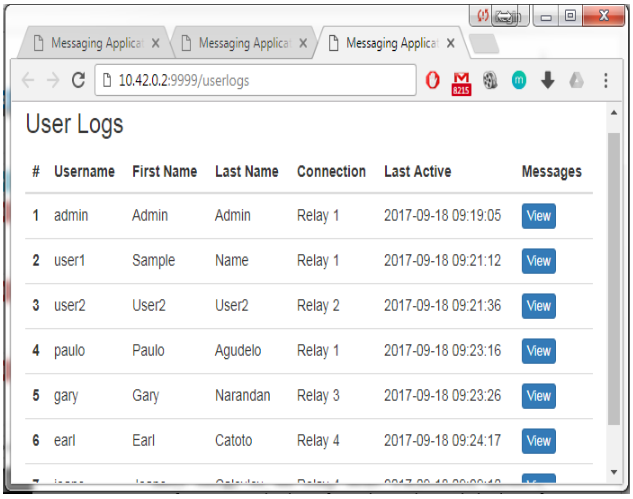


Connection Table

#	Username	First Name	Last Name	Last Connection	Messages
1	admin	Admin	Admin	2017-09-18 09:19:05	View
2	user1	Sample	Name	2017-09-18 09:21:12	View
3	paulo	Paulo	Agudelo	2017-09-18 09:23:16	View

Figure 5. Web interface for monitoring connected users for a particular relay node.

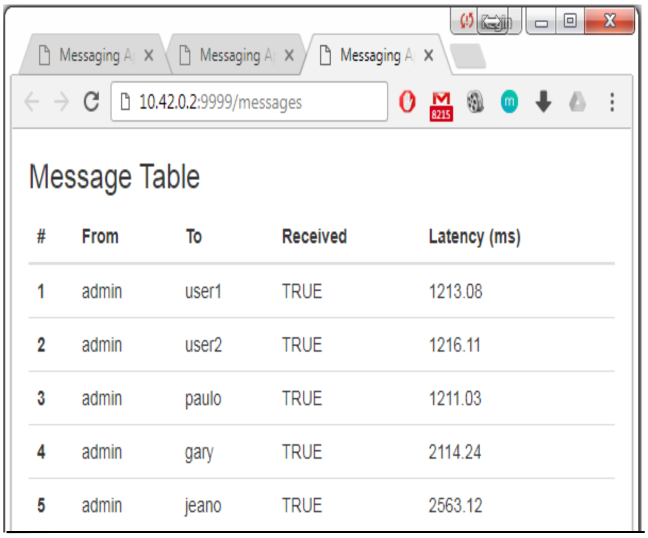
In Figure 7, the delivery status of the messages and the records of message delivery latency are depicted. From the initial experiment, the delivery latency for messages on the same relay node is 1215ms in average and about 2234ms to other relay nodes. Moreover, a particular analysis of the cause of this result is essential in order to achieve optimal delivery latency that takes into account the Quality of Service (QoS) requirement of disaster applications.



User Logs

#	Username	First Name	Last Name	Connection	Last Active	Messages
1	admin	Admin	Admin	Relay 1	2017-09-18 09:19:05	View
2	user1	Sample	Name	Relay 1	2017-09-18 09:21:12	View
3	user2	User2	User2	Relay 2	2017-09-18 09:21:36	View
4	paulo	Paulo	Agudelo	Relay 1	2017-09-18 09:23:16	View
5	gary	Gary	Narandan	Relay 3	2017-09-18 09:23:26	View
6	earl	Earl	Catoto	Relay 4	2017-09-18 09:24:17	View

Figure 6. Web interface for monitoring connected users and tracking last connection time with particular relay node.



Message Table

#	From	To	Received	Latency (ms)
1	admin	user1	TRUE	1213.08
2	admin	user2	TRUE	1216.11
3	admin	paulo	TRUE	1211.03
4	admin	gary	TRUE	2114.24
5	admin	jeano	TRUE	2563.12

Figure 7. Web interface for monitoring messages and delivery latency to particular recipient

4.3 SCS Requirement Analysis

This section further provides an analysis of the essential characteristic of the presented SCS and qualitatively evaluated if it meets the ease of deployment, low deployment and development cost, portability and mobility requirements of SCS.

a. Ease of Deployment

The use of Raspberry Pi as relay nodes proves to be an excellent potential solution that addresses ease of deployment. As all the software components can be run on the device boot up by creating a service, this makes it easier for disaster personnel to just turn on the device and use as is. The deployment and initial setup take very less time. The only consideration that needs to be done in the next phase is the creation of a compact RPi packaging for resiliency and robustness of the device. Furthermore, there is a need for improvement in the strategic placement of these nodes for optimal performance, as mentioned that in the initial experiment it was just assumed and checked to have good connectivity with the other relay nodes.

b. Development and Deployment Cost

The development cost would barely sum up by the Raspberry Pi 2 Model B price, retailed at $35 per device [21]. The two wireless interfaces (Edimax EW-7811UN) and the RPi device can be set up for less than $100 in total. The scripts used for the development of the proposed context-aware routing mechanism is Python, while Node.js and Express were utilized as frameworks for the web monitoring component and server-side scripting, respectively. The deployment cost does not also entail large transportation logistics as previous implementations in [9] and [15].

c. Portability

As previously stated, the small form factor and light weight of the RPi makes it a portable device for many applications. The bare unit only weighs 42 grams and the wireless dongles barely add weight to it. These characteristics of the device can be integrated into resilient backpacks and can be carried over also as a mobile relay node for several disaster activities.

d. Mobility

In connection with its portability, the capability of being carried by a user and perform as a mobile relay node enables also the proposed SCS to be more beneficial in disaster scenarios. The next thing to consider in the mobile relay node scenario is the device connection configuration with the nearby mobile nodes. As shown in the simulation when using the proposed SCS relay node with the context-aware routing mechanism, it is able to achieve excellent results in terms of message delivery, delivery latency and reduced the overhead.

5. CONCLUSION AND FUTURE WORKS

This paper presented a rapidly deployable standalone communication system (SCS) using Raspberry Pi as relay nodes and is envisioned to be beneficial as an alternative network when communication infrastructures are destroyed in disaster scenarios. Additionally, this work also presented a proposed context-aware routing mechanism that enhances the communication function of the proposed SCS. Moreover, the routing mechanism employed utilizes a connection and routing table implemented to effectively deliver the messages to the right recipient in the least possible time with minimal routing hops and replication. The proposed works were evaluated using a small-scale deployment implementation, a simulation experiment, and requirement analysis. With the deployment experiment, the messaging application has shown promising results in terms of delivering messages to the correct recipient at the least possible time with the efficient selection of the route. However, a significant improvement in the recording and updating of the connections table should also be considered as this will reduce operational time and save more energy of the relay node. The simulation results showed a relatively higher performance of the proposed approach in comparison with Flooding and AODV routing schemes. The designed

SCS works well based on the initial deployment, can be deployed rapidly and easily, portability and mobility are also considered in the design. However, the form factor or the packaging of the relay nodes for resiliency needs to be further improved. Furthermore, an intensive performance evaluation focused on the optimization of a number of deployed relay nodes should be done, as well as a large-scale test of the messaging application and addition of other applications or services for a disaster like audio and voice communications.

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