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Disaster Management System using Smart Phones

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Abstract: Recently, the world is facing more risk of natural disasters as a result of ongoing climate changes. One of the most critical obstacles in disaster mitigation (especially rescue operation) is lack of communication and localization of survivors in disaster sites. This paper develops a disaster rescue platform for quick and accurate rescue operation with utilizing direct communication on smart hand-held devices such as Bluetooth and Wi-Fi. Specifically, we attempt to design an application-layer ad hoc network over smart devices without relying on centralized cellular networks or wireless access points. This study also incorporates a mobile localization algorithm to effectively perform disaster rescue objectives. Specifically, it aims (1) to accurately locate survivors, (2) to help rescuers to find victims quickly, and (3) to minimize calculation overheads for power saving on smart devices. This article verifies the proposed approach with presenting simulation and implementation results compared to other studies.

Keywords: Mobile communication, device-to-device, disaster, rescue, ad-hoc network, localization

I. INTRODUCTION

The world is facing more risk of natural disasters as a result of ongoing climate change. The economic costs and the number of victims of weather-related disasters have increased dramatically in recent decades. In response, many research works have concentrated on developing frameworks to overcome difficulties of disaster rescue operations. One of the most critical obstacles in disaster mitigation (especially rescue operation) is lack of communication and localization of survivors in disaster sites. For instance, when an earthquake or tornado strikes, many people are likely to be buried and trapped under the wreckage of buildings, bridges, and so on. In this case, survivors would try to use their smart hand-held devices to get help from outside and let rescuers know their locations to find them. But, it is very likely that survivors cannot get any signal available because conventional network infrastructure such as cellular network and Wi-Fi access points (APs) would be damaged as well as shown in Figure 1. Recently, many researchers have devoted their efforts to address this issue. Some of them are exploiting wireless ad hoc networks as replacement of damaged infrastructures[1-6] by exploiting Wi-Fi Direct[7] and/or device-to-device (D2D) service in 5G cellular networks. A wireless ad hoc network refers to a network in which specialized pieces of equipment forming the backbone are not present. Instead, the client devices such as smart hand-held devices act as both client and backbone nodes. Such an ad hoc network is decentralized in the sense that there is no need of existing infrastructure to centrally manage communication.

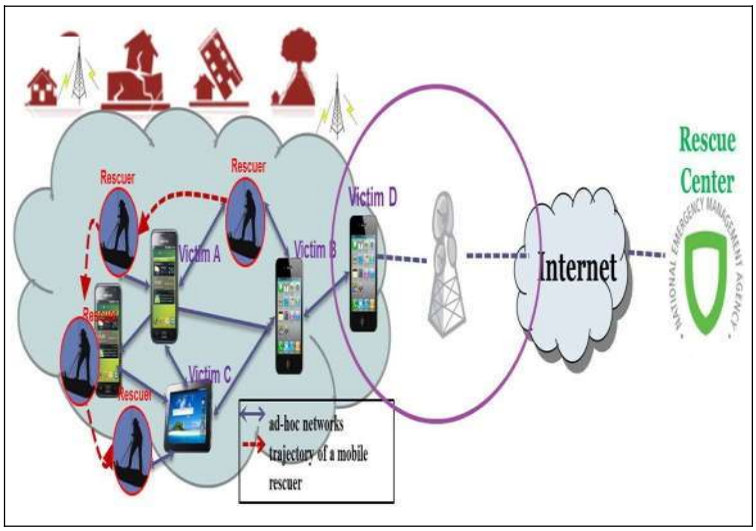

Figure 1. Target scenario: victims and a rescuer are all on ad hoc networks without GPS and infrastructure networks, and a rescuer moves around searching victims.

Especially, D2D communication is an emerging technology in 5G cellular networks. D2D provides direct peer-to-peer communication between mobile devices without going through a centralized eNodeB. Thanks to its Peer-to-Peer (P2P) nature, mobile devices easily associate and quickly create an efficient network between each other anytime anywhere. This feature makes it suitable for disaster and rescue scenarios. Also, Wi-Fi Direct [7] is one of the most popular P2P technologies. Wi-Fi Direct is based on the Wi-Fi technology that most smart devices use to communicate with wireless APs. Conceptually, each Wi-Fi Direct smart device has a ‘‘software AP’’ installed on itself and so that it can essentially function as an AP. Other Wi- Fi-enabled devices can connect directly to this Wi-Fi Direct smart device. Motivated by this observation, this article exploits a wireless ad hoc network over smart devices to effectively perform search and rescue operations in disaster sites. Main idea is that we make it possible for both rescuers and victims to join an ad hoc network for quickly localizing and rescuing survivors. Specifically, this article proposes *RescueTalk* with which survivors can communicate with each other and even might be able to talk to outside of the disaster site to ask for help. Over this ad hoc network, this article also proposes a localization method which is customized to search-and- rescue operation in disaster sites with no GPS service and no infrastructure.

Many indoor localization methods including our previous work [8] have been proposed so far. However, most of them require hand-held devices in everyday lives to be additionally equipped with other modules such as ultra-sonic, and hence these works are not suit- able to support a disaster rescue scenario.

II RELATED WORK

A. Disaster rescue

CodeBlue is one of the frameworks which use both infrastructure and wireless ad hoc networks. It pro- vides health care service for victims in disaster. Vital signs of patients are reported to nearby paramedics and emergency technicians. In additional, locations of rescuers and victims are calculated with the received signal strength from infrastructure such as Wi-Fi APs. However, in many cases of disaster, conventional infra- structures are likely to get damaged easily and/or do not

work properly. So, these infrastructure-dependent platforms have limitations to be practically deployed. There are other studies without conventional infra- structure. *DistressNet* [4] establishes multiple heterogeneous networks (802.11, 802.15.4, and IPv6), some of which are dedicated to disaster management. However, such platform requires additional network modules to be installed and hence impractical to be implemented in everyday-use smart devices.

However, *RescueMe* project [5] designs a rescue frame- work that needs few additional infrastructures. The framework securely collects locations of normal net- work users from their daily networking activity via conventional infrastructure. If disaster breaks out, it creates ad hoc networks and provides locations of survivors saved prior to disaster. However, it is dealing with the ‘‘prior’’ locations before disaster. So, it would not be accurate if victims are moving and natural disaster happens inside building where no GPS available for a while.

B. Location service

Many researchers have proposed various versions of localization algorithms. Localization algorithms can be classified into two categories: (1) anchor-based and (2) anchor-free methods. Anchor-based algorithms assume multiple anchor nodes with known positions obtained by GPS or other infrastructure-aided methods. With such information of anchors, algorithms calculate locations of unknown nodes [9-13]. For example, Niculescu and Nath [9] proposed ad hoc positioning system (APS), which is a distributed algorithm similar to distance vector routing. However, this method works well only with the high connectivity between nodes. Some studies including Horiba et al.[10] and Kim et al.[11] proposed the indoor localization algorithms for non-line-of-sight (NLOS) scenarios. Also many multilateration algorithms [12], [13] called MLAT, have been proposed including but not limited to. MLAT methods basially use the position information of the anchor node that is several hops away. This algorithm refines the position using the least square estimation and prevents accumulation of errors using Kalman filters. However, this method has limitations that when the network has not sufficient anchor nodes or when anchor nodes’ locations have error factors, then their calculation results are not accurate either. We show these features in the evaluation section compared to our proposed method.

Recently, many researchers have adopted machine learning methods to overcome these NLOS limitations.

The acoustic location processing system (ALPS) system [14] for example, combines Bluetooth and ultrasound signals and applies machine learning algorithms on the received signals. Xiao et al. [5]also used similar learning systems. However, performance of the above learning-based systems might be heavily dependent on learning parameters, which are inherent limitations of machine learning systems. Also, the map-based system requires pre-processing of the target area, which might not be suitable in some real-world disaster scenarios.

As anchor-free localization methods, mobile beacon methods have been proposed. [6]Generally, localization error is reduced as the number of anchor nodes increases. Based on this observation, Sichitiu and Ramadurai[16] proposed a localization algorithm that only uses a single mobile anchor and considers each of its dynamic locations as an anchor. Sun and Guo suggested a

localization scheme based on probabilistic estimation, but the trajectory of the mobile anchor is fixed to helix trajectory. Ssu et al. [8]and Yu et al. [9]also pro- posed an algorithm which selects the anchor points on the received signal strength indication (RSSI)-range circle and calculates the node position using the characteristic of the circle and perpendicular bisector of a chord. However, these previous works assume the trajectory of the mobile anchor is fixed and so the locations of the mobile anchors are assumed to be pre-known. These constraints make hard it to be applied in our target disaster and rescue scenario. In our target scenario, we consider that rescuers would go into the disaster sites where rescuers' trajectory cannot be static and so rescuers' locations are not pre-known just like unknown victims.

III METHODOLOGY

In most natural disaster scenarios such as an earth- quake, a tornado, a landslide, and so on, victims are very likely to be buried and trapped in the wreckage of buildings, bridges, houses, and so on. To find and rescue them, rescuers would be deployed into the disaster sites. However, under the wreckage of buildings, network infrastructures such as cellular networks and Wi-Fi APs are very likely to be damaged and so conventional communications among victims and rescuers are not possible. Also, GPS are unlikely to work under disaster sites as well. To reflect these observations, we propose an ad hoc network method targeting to such a disaster scenario and attempting to help rescuers by accurately and promptly locating survivors without GPS and infrastructure networks. Figure 1 illustrates the target scenario of this article. In particular, we assume that each rescuer under disaster sites moves around to find victims. Most rescuers and victims do not have any network infrastructure available except a node at the edge of the disaster site such as a victim node *D* in Figure 1. The edge node might have network connection to an outside the disaster site. By exploiting this edge node, we attempt to build an ad hoc network with which victims can send their help messages to an outside rescue center.

With such ad hoc network, this article also incorporates a localization method specialized in this disaster scenario. For example, suppose dotted lines in Figure 1 represent a trajectory of a rescuer. As the rescuer moves, a victim *A* can receive beacon frames from three different locations, which makes it possible to calculate a location of victim *A* by itself. In that way, victims close to rescuers can be located first. After that, the location information of victim *A* is propagated to victim *B* and *C*, then victim *C* can calculate its location using location information received from victim *A* over an ad hoc network among them. Finally, victim *B*'*s* location could be found after all.

Challenges

Given a target disaster and rescue scenario in the previous section, there exist several challenges as follows:

- ***No infrastructure available***. In the target disaster site, we assume that both rescuers and victims do not have any centralized and infrastructure communication available (such as cellular net-works and AP-based Wi-Fi network). Only communication method they can use is an ad hoc network among them. This implies that their net- works are very likely to be isolated network and does not have a connection to outside. So, we assume that there would be no central command center and so each rescuer and victim should make a decision by themselves.

- ***No GPS service available***. In the given target disaster situation, GPS might not work properly at rescuers' sides as well as victims' sides.
- ***Nodes are mobile***. A rescuer is very likely to be mobile, not stationary. So, the localization method should consider not only between static nodes but also mobile nodes.
- ***Power limitation.*** Especially, victims are very likely to have limited power resource (e.g. battery) and so the proposed method should be power-efficient and have low complexity. Especially, the proposed localization method should converge fast to find victims as fast as possible to rescue them.

Proposed rescue platform: RescueTalk

This article designs and develops an application-layer ad hoc network, called RescueTalk. The proposed platform consists of three parts: (1) ad hoc platform development, (2) survivor localization, and (3) ad hoc routing, In the following, we present the details of these three parts.

IV ARCHITECTURE

Ad hoc network architecture

This article designs and develops an application-layer ad hoc network called *RescueTalk* on smart devices based on open-source project. In the developed ad hoc network application, we first design an application- layer protocol customized for localizing victims and messaging among the victims and rescuers, as illustrated in Figure 2. When the infrastructure such as Wi-Fi and cellular base stations is be available in the disaster site, the rescuer and victims are able to communicate and localize each other using the *RescueTalk*.

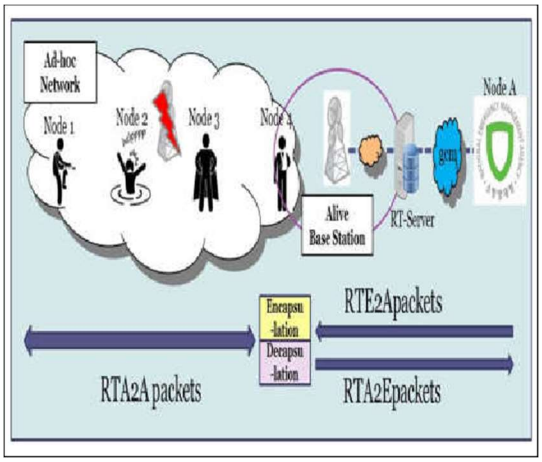

Fig 2: System Overview

Also, when an edge node is still connected to the out- side disaster site (e.g. a rescuer node 2 in Figure 2) and receives *RescueTalk* messages from a victim, it can for- ward the messages to the outside rescue centre for further rescue process. Specifically, the edge node performs encapsulation or decapsulation to forward *RescueTalk* packets to the outside or to forward the outside packets into an ad hoc network, respectively. To make this scenario possible, this article designs *RescueTalk* message formats and protocols as shown in Figure 3. Using this application-layer protocol, each node under the disaster site can communicate with each other and also can further forward this message through an edge node to outside rescue centre. Note that there is no need to modify network infrastructures such as base stations and Wi-Fi APs because the pro- posed platform is an

application-layer ad hoc network. We only need to install applications to each mobile device for setting up the platform.

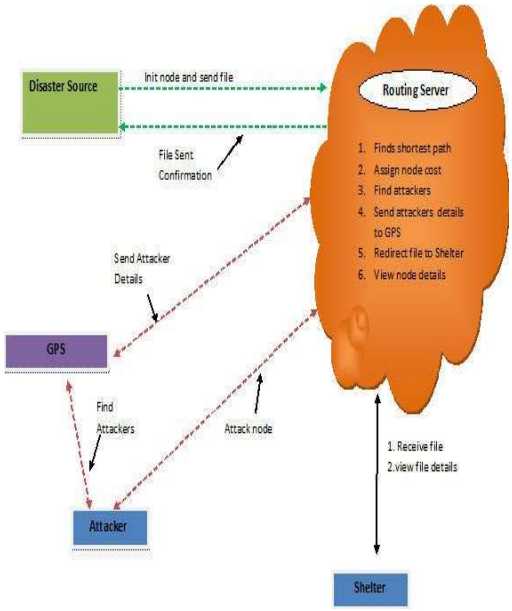

Fig 3: System Architecture

IMPLEMENTATION

Disaster Source:

In this module, the data **Disaster** Source will browse the data file related to Disasters and initialize the nodes, then select a node & send to the particular shelter like Hospital, Apartment, and Cottage. Data Source will send their data file to routing server and in a routing server less distance node will select and send to the particular end user. After receiving successful the data provider will get response from the router.

Router Server

In this module, the Routing server consist of n-number of nodes (A, B, C, D, E and F) to provide a data service. The Routing Server will receive the data file from the Source and select a less distance node and send to the particular end user. If any attacker will found in a router, then the Routing Server will select another less distance node and send to particular end user. In a routing server we can assign node distance, view node details and view attackers. If we want to assign distance, then select node name and enter new distance and submit, then it will be stored in a routing server.

GPS

In this module, we can do some operation such as view path trajectory and view attack destination. If we click on view path trajectory, then we will get all information about path with their tags such as city name, metadata, time & date. In GPS we can view an attacker details with their tags such as attacker name, city name, Mac address, time and date.

Shelter (Hospital, Cottage, Apartment)

In this module, there are n-number of end users are present (A, B, C and D). The end user can receive the data file from the Source via Routing Server. The end user will receive the file by without changing the File Contents. Users may receive particular data files within the router only.

Attacker

Attacker is one who is rerouting the trajectory node. The attacker will select the node and inject fake key to the particular node. After attacking successful the attacker details will store in GPS and Routing Server with their tags such as attacker name, city name, IP address, time & date.

V CONCLUSION

The proposed *RescueTalk* is a mobile ad hoc network platform specifically developed too quickly and accurately searches and rescue survivors in disasters. *RescueTalk* is built at an application-layer by exploiting underlying direct communications such as D2D for 5G and Wi-Fi Direct. The proposed method has several strengths over other related studies. First, it presents and implements a real-world platform for rescue operations by effectively utilizing direct communications between smart devices. It does not rely on infra- structure such as GPS, cellular, and Wi-Fi APs. Furthermore, the proposed platform is built at an application-layer over smart hand-held devices. This implies that the proposed protocol requires little modification of existing underlying protocols. With this plat- form, survivors are able to communicate with each other and even send help messages to an outside rescue center so that rescuers can easily locate and rescue survivors.

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