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DR. ION: Disaster Rescue over Information-Oriented Network

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***Abstract*—Disasters often cause inevitable and tremendous loss in lives and properties. Appropriate use of the rapidly growing IT technologies will ease disaster rescue missions. Lightweight mobile device has become a ubiquitously essential element in people daily activities. Therefore, mobile devices are used to support information synthesis and delivery services in designing emergency response systems for disaster rescue and relief operations. In this paper, we present the inception of Disaster Rescue over Information-Oriented Network, abbreviated as DR. ION. DR. ION is an information-oriented framework consisting of a set of ION nodes. The ION nodes are self-organized into an information exchange network with or without network infrastructure support. To reduce the complexity of using the underlying network by the rescue teams, a message in DR. ION is *self-evolving*, which means that the message is active: it delivers rescue instructions along with its information content, and interacts through the ION nodes with the surrounding environment.**

***Keywords*-Disaster Management, Content-Centric Network, Virtual Repository**

I. Introduction

The rapid growth of IT technologies has resulted in lighter and more efficient mobile devices. Lightweight mobile devices have become irreplaceable components, which accompany people ubiquitously in their day-to-day lives. Mobile devices are also used to support information synthesis and delivery services in designing emergency response systems for disaster rescue and relief operations [1], [2]. A large number of digital sensors has been deployed to collect a large quantity of data for assessing damage during and after disaster or for supporting rescue operations. An information synthesis and delivery system may provide an efficient way for rescue teams to find and make use of information in a disaster region.

We envision a typical scenario as follows. After the occurrence of a drastic natural disaster (*e.g.*, the 2010 Haiti earthquake), the infrastructure necessary to respond to the disaster may be severely damaged or destroyed. In such disasters, the affected region could span a widespread geographical area. For example, the 2010 Haiti earthquake covered approximately 250 square kilometers[1] and the 2010 Pakistan floods affected 796,095 square kilometers of land[2]. These disaster regions may be larger than New York City (1214.4 square kilometers). Based on these experiences, the infrastructure (*e.g.*, transportation facilities, medical facilities, and communication and information connections) may all become unstable or heavily damaged during and after the disaster. Moreover, reaching the disaster area may be extremely difficult for rescue teams. Only a few rescue teams are able to arrive at the disaster area during the "golden hours". For example, in the 2010 Haiti earthquake, the Haiti government organized relief efforts in two days after the quake, and the first rescue team arrived in Haiti 24 hours later.

In this paper, we investigate how to organize a geo-distributed ad hoc information network for disaster management into a proactive integrated information exchange and storage platform. We also present a preliminary design of an information-oriented framework, i.e., Disaster Rescue over Information-Oriented Network (DR. ION), to deliver and synthesize information flows for large-scale disaster rescue systems. DR. ION framework is organized from a set of self-organizing ION nodes with or without network infrastructure support. An ION node could be a container [3] that contains survival kits, communication systems (including wire, wireless, and satellite), power packages, computation power, storage capacity, or even (mobile) devices carried by the staffs in rescue operations.

Our scenario is that the geographical area of disaster is widespread, such that the rescue teams have difficulty to acquire an overview of disaster areas and may not be able to establish a command center immediately. For instance, these rescue teams and their stations may be dropped into the disaster area by a parachute[3]. Also, the rescue teams may be separated from each other by a long distance or may not be able to communicate directly. We need to provide a network with high availability and adaptability in these environments.

The paper is organized as follows. Section II describes the context of related work. Section III describes an overview and the preliminary design of DR.ION framework. We conclude this paper and describe future works in Section IV.

[1] http://en.wikipedia.org/wiki/2010_Haiti_earthquake
[2] http://en.wikipedia.org/wiki/2010_Pakistan_floods
[3] http://en.wikipedia.org/wiki/Airdrop

II. RELATED WORK

There are several projects related to the development of a disaster management system, for example, OSIRIS [4], SensorNet [5] and IPAWS-OPEN [6]. Their works include risk management, sensor data collection and alert and warning system, which all act as useful references for designing DR. ION.

The concept of Named Data Networking (NDN) [7] motivates our work in the manner of duplicating and routing information. But different from NDN, our design allows information providers to instruct intermediate and/or receiving nodes. Shvartzshnaider and Ott discussed requirements and challenges for an efficient disaster management system, and proposed add/map operations of data publication and subscription [8]. In their vision, the network itself does not interpret transmitted data, but leaves it to be dealt with by end hosts. The Medical Emergency Disaster Response Network [9] focuses on utilizing semantic technology for disseminating and querying information without knowing the information providers. Our design further focuses on the availability of information under extreme situations, such as unstable communication channel and possibly nodes failure.

III. DESIGN OF DR. ION

DR. ION is a framework for addressing information exchange and delivery issues during and after a calamity. In this section, we illustrate the main idea and functionality of DR. ION. Specifically, we present DR. ION's design, its operations, and the concept of the information-oriented schema. We also provide a brief description of DR. ION's components during rescue operations.

A. Overview of DR. ION

The primary goal of DR. ION aims to improve information exchange between rescue teams and other domains (*i.e.*, a person or machines) that request for information or advertisement during rescue operations. More importantly, upon receiving a message, a DR. ION node will operate based on the instructions within the message. Additionally, the information carried by the message or the contextual information collected by sensors of the ION node can also support the operation. The information may also evolve before being further transmitted.

Figure 1 depicts the information delivery scenario of DR. ION: the search team *S1* sends a request message to allocate medical resources from medical teams. Thus the instructions within the message are: *Deliver me (the information) to a medical team, or to any team with tourniquets*. If an ION node received this message, it would forward this message to other ION nodes that may approach a medical team or may provide tourniquets for team *S1*. The message is drawn as the small nodes with "i". ION nodes with specific task assignment in the disaster sites are labeled with letters as follows: "S" for search teams, "R" for rescue teams, "L" for logistics teams, and "M" for medical teams. The messages pass through different types of ION nodes and reach two destinations, a medical team *M1* and a rescue team *R1* that possesses tourniquets. In order to increase the reliability of DR. ION, the information should transmit through any available resources.

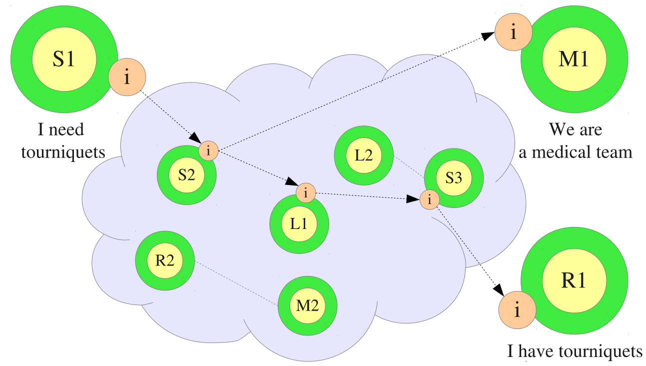

Figure 1. An overview of DR. ION

B. Information-Oriented Schema

Anyone who is involved in the disaster rescue operations is an information consumer and/or a provider. They hunger for information exchange to help each other. However, communications are not always stable in disaster sites. Information exchange becomes an uneven distribution that increases the difficulty of the search and rescue mission under the scene. To ease the limitation of information exchange, we propose an information-oriented model. Each ION node processes the information according to the instructions within a message. It not only reduces the complexity of the underlying network, but also mitigates the boundary of information exchange and elevates the reliability and capacities of communication networks.

In DR. ION, information is encapsulated into an active message, which contains its operating instructions and additional information. A plain-text based format like JSON, a structured-base format like XML, or well-known protocols like Common Alter Protocol (CAP) [10], are all taken into consideration [11], [12].

C. Design Details

DR. ION is a scalable and flexible system. It can be used in a single rescue organization for small-scale disasters, such as mountain accidents or car accidents. It can also be expanded to support multiple international rescue teams when a catastrophe occurred, such as tornado, earthquake, tsunami, airplane crash, and debris flow.

1) The ION Node: ION nodes are the basic unit of our network infrastructure that includes several operation functionalities. To reduce the complexity of the underlying network, the messages in DR. ION are *self-evolving*. It

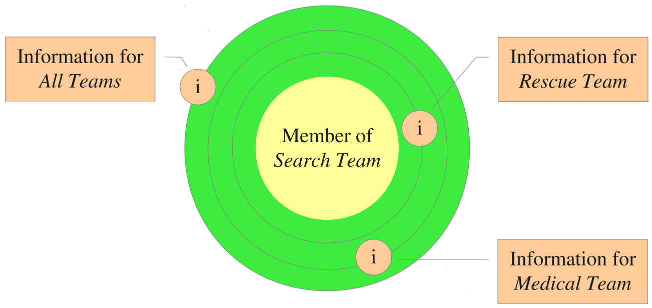

Figure 2. The schematic diagram of ION node

means that the message in DR. ION is *active*. It also enables ideas such as delivering rescue instructions along with its information content and interacting through the ION nodes with the surrounding environment. In particular, DR. ION exploits the synergy between publish/subscribe and information-oriented framework, as neither requires an end-to-end connection at any particular point in time. This capacity is based on the sole idea that we should exploit any means of communication possible, such as radio, WiMAX, WiFi or physical devices (USB disks) when there is no available connection.

An ION node that contains a universal storage model is called a Mobile Virtual Repository (MVR), a mobile version of the Virtual Repository (VR) design [13]. VR is a disaster management system, which handles data caches, data hosting, networking and feed services, and scientific and historical databases. We extend the main idea of VR to suit the needs of search and rescue missions in disaster sites: any device can participate in the network, and any available information resources can be utilized (*e.g.*, sensor data reports, emergency broadcasting messages, or evacuation alerts) by the network.

MVR enables participants to deliver or store messages, to follow information resources, and to authenticate messages. The basic idea for MVR in disaster rescue is to categorize messages into different types of *tracks*. As shown in Figure 2, a track is a specially designed channel storing a specific type of messages. Messages can be stored temporarily for further processes or exchanges with other ION nodes, or be stored permanently when it has accomplished its purpose (*e.g.*, reach the destinations or a permanent VR in the Internet). For example, an ION node of search team contains three tracks of information: *All Teams*, *Rescue Teams* and *Medical Teams*. The tracks are set as a mission is initiated, and can be altered during mission. The *All Teams* track contains messages that should be known to all members in the mission (similar to a broadcast). However, the *Search Team* and *Medical Team* tracks store messages for specific teams or members.

2) Functionalities: To deal with a large amount and a variety of information, we describe the Application Program Interface (API) for ION nodes as follows. Note that APIs are elastic and can be implemented by hardware or firmware in devices, or by software.

Routing: Routing plays a major role in DR. ION. Connection establishment method and media selection are also included. The common networking media such as Bluetooth and WiFi in mobile devices are typical communication media used in DR. ION. Besides, DR. ION is also designed to utilize communication devices, such as satellite, wired connections, or devices with uninterrupted power, as a static routing.

Due to the unreliable connection environment in a disaster region, instead of using traditional exchange methods, *e.g.*, using routing table, an ION node selects the routing path of a message based on the message itself and the contextual information of the ION node. Note that the policies (even constraints) in the contextual information may vary during a mission. These variations come from environmental factors such as power level, connection reliability, or storage spaces of devices. Urgency, priority, and/or privacy of information are also examples of environmental factors.

In an ION node, the routing policies are stored as a weighted value in an *activation matrix*. An activation matrix is a brief summary of the self-adaptive ION nodes or network. In search and rescue mission, the activation matrix can be set as urgency-awareness, giving priority to important information. When suffering a low battery level, the policy can be switched to power-awareness to ensure smooth information exchange.

Storage: In order to better utilize the device, we define different strategies for each type of incoming message, for example: *temporary* and *permanent*.

If the MVR temporarily cannot reach other ION nodes and thus is not able to send out a message, then the message will be stored in its memory. When communications becomes available, then the message will be transmitted. However, when a message has accomplished its purpose, it can be stored permanently to reduce memory usage and power consumption. Similar to the routing function, policies can be added into storage strategies to improve the reliability of information and delivery. To avoid loss of data when an ION node is low in battery level, main storage should be altered to disk (or permanent storage). Moreover, MVR should include additional functions (*e.g.*, data fusion and data compression) to reduce the amount of information in DR. ION.

Authentication: In DR. ION networks, authentication strategies perform security operations to avoid mischief or information flooding. It is similar to that in wireless sensor networks [14]. Information can be protected by any mechanisms for correctness, such as device registrations or user verifications. In DR. ION, the trust-relationship is built into ION nodes to reduce further verifications during missions. Nevertheless, additional verification may still be performed for better authentication.

Filter: Data filter selects for appropriate action when a message has been retrieved. The filter can also be a checker (or verifier) to discard spoofing, out-of-date, or useless information.

Optional functions: The design of DR. ION is elastic, meaning that users can add custom functions if needed. Users can add encryption and decryption support to avoid information tempering from malicious users [15]. Moreover, compressing message can decrease bandwidth consumption and/or transmission time when exchanging a large amount data [16]. Finally, performing data fusion [17] is another way to combine useful information for exchanging between ION nodes, as well as performing a decision fusion [18] for multiple actions. On top of the above functions, to adapt to a variety of disasters, inclusion of additional functionalities in DR. ION is required in the future.

IV. Conclusion and Future Work

DR. ION is an information-oriented framework to deliver and synthesize information flows of large-scale disaster rescue systems. To achieve the goals, we devise ION and MVR to handle the operations of data exchange and storage.

Each ION node performs actions according to the instructions within a message when it is received. ION nodes also have adaptive abilities such that they can alter their characteristics to adjust to the changing environment. MVR is a conceptual design adapted from the orbits of ion: information is stored in different tracks depending on the properties of information. We also define the functionalities for further development and demonstrate the flexibility and scalability of DR. ION.

We are now focusing in the implementation details of DR. ION: modularization of each function, the (extended) publish/subscribe model of ION nodes, and the storage strategies of MVR. We also focus on low-end devices rather than only smart phones, such that DR. ION will be universally applicable in any disaster-rescue system or even daily lives.

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