A DTN based Multi-hop Network for Disaster Information Transmission by Smart Devices

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Abstract— **In Japan, large scale earthquakes frequently occur. At the occurrence of disaster, network infrastructure is often seriously damaged and traffic congestion occurs. Particularly since the network communication infrastructure of mountain areas are not well developed, so it is difficult to normally use the communication means once the disaster happened. So far we have investigated the network communication method which can be used in the case of disasters, and developed Never Die Network (NDN) [1] based on Software Defined Network (SDN) to realize as a resilient disaster network. Conversely, Delay / Disruptions Tolerant Network (DTN) can realize mobile devices communication without constructing infrastructure. DTN is effective at the time of disaster to construct a Multi-hop network, but more efficient routing and battery utilization have to be considered. In this paper, we propose a DTN based Multi-hop network for temporal network in the case of disaster and considered transmission disruption and transmission delay. Also the moving speeds of each node are different. So there is possibility of link down while transmitting data. We use sensor data to consider this issue. We constructed an experimental prototype by smart devices.**

Keywords— **Disaster Information; DTN; Multi-hop Network; Routing Management; Acceleration Sensor;**

1. INTRODUCTION

From the previous researches, it is clear that the wireless and mobile networks are very effective as disaster information communication means. However it is difficult to use cellular network in case of serious disasters because the cellular base stations are broken by the secondary disaster such as tsunami and landslide. For this reason, the network traffic of cellular network which is concentrated to the base station cannot be transferred to the destination. In fact, in the Great East Japan Earthquake on March 11th in 2011, most of the residents in the disaster areas could not leverage mobile phones. It is strongly required to develop the data transmission method even through serious disasters happened.

Multi-hop network can deploy without network infrastructure. However, since the people move with mobile terminal in disaster area, it is difficult to constantly keep connection and transmission of information data. Delay / Disruptions Tolerant Network, simply DTN uses store and forward transport method. The mobile node stores the data to storage device if the link to the neighbor mobile node is not existed. If the link to the neighbor mobile node can be found, then the mobile node sends the stored data to the neighbor mobile nodes. There are many researches concerned with designing the functions of DTN protocol and running them on network simulators, but there is few researches concerned DTN protocol using actual network devices.

In this paper, we propose a DTN based Multi-hop network as corresponding to challenge network environment. Our goal is to realize DTN communication in which the data issued from the source mobile node can be finally reached to the destination node or the gateway to Internet by multi-hopping the intermediate mobile nodes. At the same time, we suppose vehicle-to-vehicle (or walker) communication. Where vehicle speed is not constant, the vehicle can move out of communication range while transmitting data. So we use acceleration sensors mounted smart devices. In our system, by reducing redundant transmission or communication, battery energy can be saved.

The rest of this paper is organized as follows. The related works to our network is summarized in Section 2. The network system configuration in disaster areas is shown in Section 3. The data flow of our suggested DTN based Multi-hop network is explained in Section 4. A prototype system is shown in Section 5. Finally conclusions and future works are summarized in Section 6.

2. RELATED WORK

2.1. Delay / Disruption Tolerant Network (DTN)

DTN is a relay transmission technology to achieve end-to-end transmission under poor and unstable communication environment [1]. By using store-and-forward transmission method, it will be possible to realize reliable communications. There are several works using such as sensor data, metadata to achieve higher performance [2] [3] [4]. DTN Protocol is developed on the network simulator, can demonstrate in variety parameters.

2.2. DTN Application on Actual Devices

On designing DTN protocol, it is important to consider the following issues such as unstable data communication period between mobile nodes, amount of data transmission to send/receive and limited battery energy resource. In addition, the development of DTN protocol on the actual prototype system depends on network hardware and OS specification. Under those conditions, protocol overhead in limited environment has to be reduced in the system design. We summarized the related works with DTN protocol using the actual prototype system.

In the work [5], the proposed function of the system combining MANET and DTN can switch between MANET and DTN as necessary to avoid network resources consumption. DTN MapEx [6] integrates a DTN protocol and distributed computing function, generates maps for disaster information to share data for decision- making.

There are few DTN systems implemented on actual devices. So we propose a DTN based multi-hop network which can realize vehicle-to-walker communication using smart devices. On the occurrence of disasters, since many residents evacuate with smart devices, the limit of battery resource should be considered. We use a mange the node list and acceleration sensor data to reduce the redundant transmission and communication. The next section shows our proposed system configuration.

3. SYSTEM CONFIGURATION

3.1. System Configuration

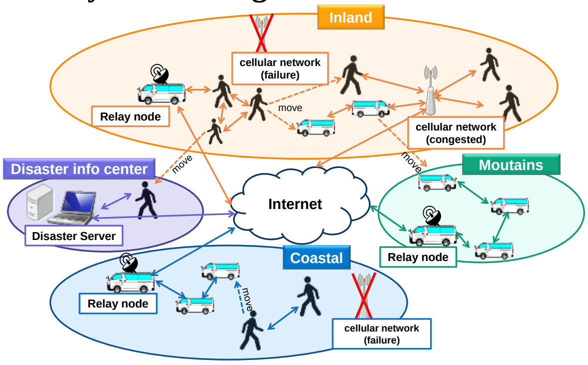

Fig. 1 System Abstract Diagram

Figure 1 shows our proposed network system configuration at the time of disaster, where inland, coastal and mountains areas are assumed in the following conditions.

- Cellular network is congested or cannot be functioned in the disaster areas.
- All the residents with smart devices move in disaster area.
- The relay nodes are deployed each area just after occurrence of disaster.

On the above conditions, DTN based Multi-hop network is configured using the smart devices by residents. The data from a smart device as mobile node are transmitted to the neighbor nodes by DTN protocol. This transmission is repeated until arriving at the destination node or the relay node as a network gateway to Internet. The relay node is assumed the following conditions.

- The relay node by wireless cognitive access network with long distance can connect to Internet.
- The relay node has a mobile server that collects the received data from other mobile nodes.

We regard the transmitted data as *Message* in our proposed network. *Message* consists of ID and disaster information, sender address, destination address, type of *Message*, *Message* Priority. We use the specific device name as *Sender Address* and *Destination Address*. Victims create *Message* and decide urgency using *Message Priority*. And Message is transmitted based this priority.

Sender Address	Destination Address	
Message ID	Type of Message	Date
Message Priority	Disaster Information	

Fig. 2 Message Structure

The relay node can send/receive those data to/from the disaster information center in the other areas through Internet. On the other hand, the disaster information center is assumed the following conditions.

- The disaster information center is allocated the place is no damage of tsunami and landslide. Therefore, electric power is enough to supply to those network systems.
- Access to Internet is always possible.

Thus, in our proposed system, the communication between the mobile node and the relay node can be performed in the same manner, and the relay nodes at the different areas can be realized.

3.2. Communication Flow

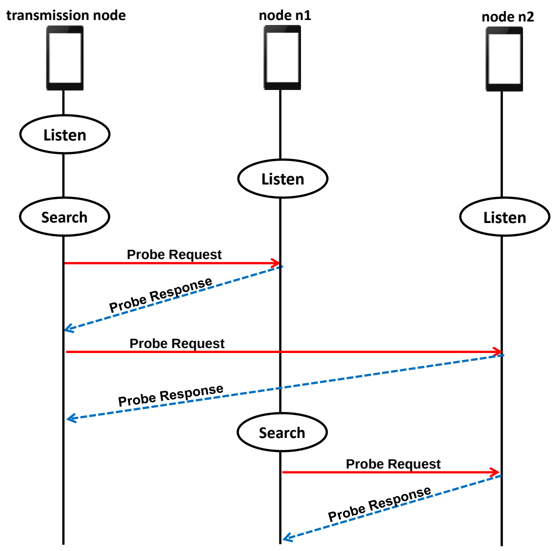

Fig. 3 Discovery Flow

Our proposed DTN routing is based on flooding method such as Epidemic routing [1]. In our routing protocol, since each node manages connection nodes using *past_connection* list (recording past connection) and *neighbor_list* (recording neighbor node).

Figure 3 shows discovery neighbor node process. First, the transmission node and neighbor node exchange probe request or probe response while changing *Listen* mode and *Search* mode. If the mode is *Search*, the node sends *Probe Request*. Also if the mode is *Listen*, the node waits for *Probe Request* and replies *Probe Response* When the source node received Probe Response, then adds *neighbor_list*. Then, the source node checks ***past_connection*** is empty or not empty.

Algorithm Managing list to routing

If past_connection is empty;

The source node sends connection request to the first node in *neighbor_list*.

Else;

The source node compares *neighbor_list* with the ***past_connection*** and focuses on the i-th node in *neighbor_list*.

If node *i* in *neighbor_list* $\notin$ *past_connection*;

The source node sends connection request to the node i

Else if the souce node had not transmitted all *Message* in the storage;

The source node sends connection request to the node

Else;

When the node *i* is existed and the source node had transmitted all *Message*, then tries the next node *i*+1.

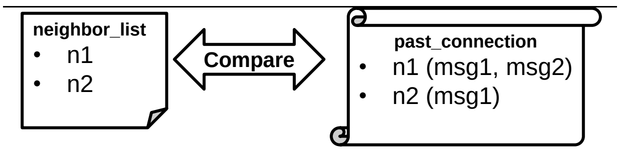

Fig. 4 Compare Lists Example

Figure 4 shows an example of *past_connection* and *neighbor_list*. In this example, the transmission node has *Message*1 (msg1) and msg2. First, the transmission node checks the neighbor node1 (n1) which is the top of *neighbor_list* whether there is n1 in *past_connection*. In this example, since n1 exists in *past_connection*, the transmission node passes n1 and goes to n2 which is the second of *neighbor_list*. In this case, since n2 exists in *past_connection*, but the transmission node had not transmitted all *Message* in the storage. So the transmission node decides to connect n2 and transmits msg2. If all of the nodes in *neighbor_list* exist in *past_connection* and the transmission node had transmitted all *Message* to all nodes in *past_connection*, the transmission node continues to discover new neighbor node to update *neighbor_list*. This step is completed until the connection has been established

After establishing the IP connection, then establishing TCP connection. Next, both nodes get acceleration data using acceleration sensor, and exchange this data. Both nodes select *Message* based relative speed in the storage. Finally, the transmission node transmits *Message*. And n2 transmits to other nodes as transmission node.

Thus, our algorithm uses ***past_connection*** and manages connections, moreover exchanging acceleration sensor data before transmission data. They lead to save duplication of data and reduce power supply by the unnecessary communication.

3.3. Network Model

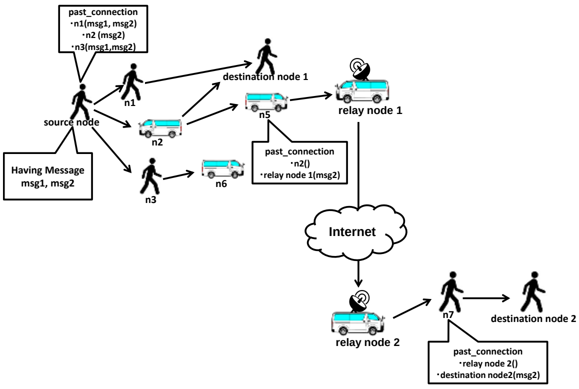

Fig. 5 Simple Network Model

We show network models that we suppose in Figure 5. The destination node 1 exists in same area as the source node. By the node received from the source node spreads to neighbor nodes, Message can reach the destination node.

The source node and n1 and n3 are walker, so moving speed is slowly. Thus the source can transmit all *Message* in device storage. If the source node has many *Meesage*, transmits high priority *Message* to the first. n2 is a vehicle and moving speed is quickly, so the source node may not transmit all *Message*. To prevent link down while transmission data, the source node selects transmitted possible Message based relative velocity and priority. Then *Message* can reach by n2 or n1 transmit *Message*.

On the other hand, we need Internet access to transmit to destination node 2. relay node 1 has the role of temporary destination. After relay node 1 received *Message* from n4, transmits to relay node 2 through the Internet. Then relay node 2 transmits to n6. Thus we aim the arrival of *Message*.

3.4. System Architecture

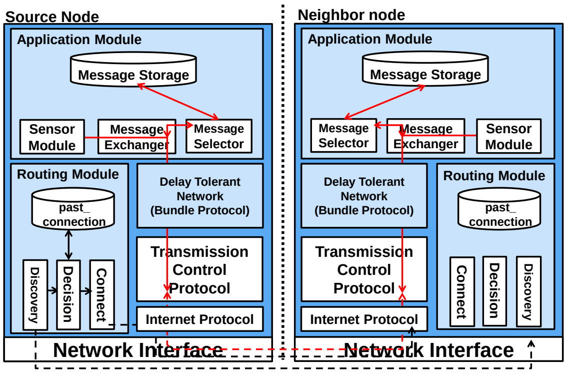

Fig. 6 System Architecture

Figure 6 shows the network system architecture. Our network system is realized by an application in smart device system. Our application layer is consisted of User Interface, Data Exchanger, Message Storage, Messsage Selector, Message Exchanger and Sensor Module. In Routing Module, this module is consisted of Discovery, Decision, Connect and ***past_connection*** modules which can manage connection state.

The user discovers the neighbor node or relay node by Discovery module in Routing module. Next, Decision module establishes to connect another node by referring to ***past_connection***. After completion of the node connection, *Message* is transmitted using Message Exchanger in Message Storage. Since TCP protocol is used in Message Exchanger, *Message* can be received/send from/to the other nodes bi-directionally. Then received *Message* is stored in Message Storage.

The relay node includes a smart device, a mobile server and an Internet access gateway such as long distance wireless devices. The smart device in the relay node securely transmits *Message* to the mobile server. It is desirable to avoid message duplication in our network system. So we implemented a module to temporarily check message duplication. The Disaster Server and mobile server check message duplication by referring Message Storage and delates if the duplication is found. After that, the Mobile Server transmits *Message* to the Disaster Server and Mobile Servers of other areas through

Internet access. The Disaster Server also detects duplication of the received data.

4. PROTOTYPE SYSTEM

4.1. Prototype System Configuration

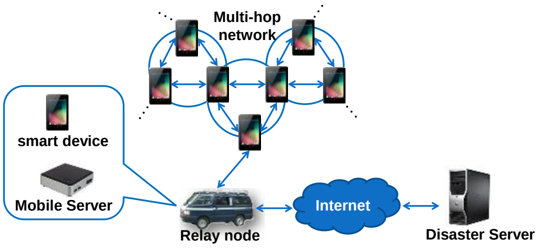

Fig. 7 Prototype System

So far, we discussed a full system configuration in Section III. In this Section IV shows a prototype system which we constructed based on the concept of Section III. Figure 7 shows a present prototype system which is consisted of multiple devices for the relay node by the actual hardware components. The Mobile Server in relay node checks duplication of message data and delates it if a duplication is found. Finally, The Mobile Server transfers the remained data to the Disaster Server through Internet access.

4.2. Details of System Specification

TABLE 1
HARDWARE SPECIFICATION

Smart Devices	Nexus 7 (2013) OS: Android 5.0 CPU:APQ8064 QuadCore1.5GHz MEM: RAM 2GB Develop: Android SDK NIC: IEEE 802.11n
Mobile Server	OS: Ubuntu 14.04 CPU: Core i3 4010U MEM: RAM 4GB Develop: JDK7
Disaster Server	OS: Ubuntu 14.04 CPU: Core 2 Extreme MEM: RAM 4GB Develop: JDK7

We describe the details of hardware system in Table I. Since our current DTN system is running on Android OS, we use Android SDK to develop our proposed system. We construct Multi-hop network using WLAN IEEE 802.11n which is mounted as common wireless network devices. All of the *Message* are managed by SQLite. Figure 8 shows our application image. This application shows a view at the time of the first login on the smart device, views the most recently *Message* on this screen.

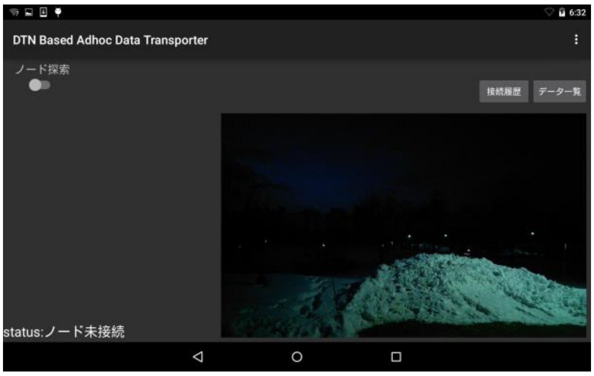

Fig. 8 Smart Device Applications

For Mobile Server and Disaster Server, mobile PCs operated by Ubuntu OS are introduced. JAVA and MySQL are used for software system development of our architecture.

5. PRELIMINARY EVALUATION

In order to verify the effect of our proposed system, we examine a measurement test and evaluated our application. The purpose of this test is to derive the results of transmission time by our application system in our Multi-hop network. In fact we use the actual devices and measure the transmission time.

Fig. 9 Experiment Configuration

TABLE 2
PARAMETERS IN MEASURE TEST

Parameter	Value
Number of hops	1 to 5
Distance btwn hop	3m
Data size	1MB, 512KB, 1KB
Test area	Indoor : 150×5 (m^2)
Number of test	5

Table II shows Measure Test of configuration. We measure to change in transmission time with the increase in the number of hops. We have placed node for each 1m. This test was repeated 5 times. In this test, all nodes were premise that does not move at all.

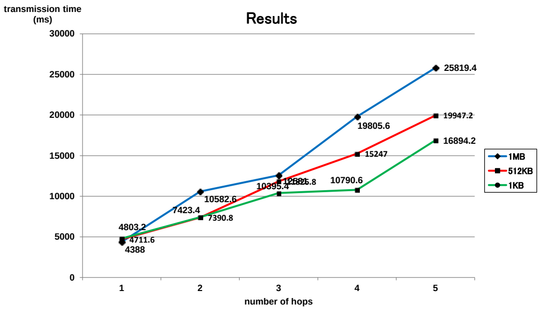

Fig. 10 Result of Measure Test

Figure 10 shows result of their tests. This result indicates the average values from each 5 times measurement. The value of transmission time is changed almost in proportion in accordance with the increase of the number of hops at each data sizes. Therefore it is possible to estimate in calculating the transmission time when n-hops.

On the other hand, there is a small difference in each data sizes. This reason is the overhead by unstable time which establishes IP connection. Establishing IP connection takes about 2 seconds to 5 seconds. So we have to measure the time transmitting more large size data to find changing in the transmission time. We do not consider improving this overhead at the present stage.

6. CONCLUSIONS

In this paper, we proposed an effective data communication method by DTN based Multi-hop network for the case of infrastructure failure at time of disaster. It is possible to consider the data transmission communication interruption or delay by using DTN protocol function. Also we used list to manage routing, and used acceleration sensor to reduce link down while transmitting data. Furthermore communication between disaster areas also becomes possible by using relay node capable of Internet access. In the measure test, we experimented measurement test with actual devices, and found that transfer time is changed almost in proportion in accordance with the increase of the number of hops.

In our future work, we will experiment the transmission time on vehicle-to-vehicle communication. Then we discuss more effective select transmission data using acceleration sensor data. Next, we plan to improve DTN protocol which can ensure to reach to the relay node, and attempt the experimental test with various metrics (duplicated data ratio, delivery ratio etc.) while we compare existing protocols. Also since performance changes due to the mobility of nodes, we will work for an experimental test for dynamic change of the nodes.

ACKNOWLEDGMENT

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