Device to Device based Delay Tolerant Networks with Group Priority for Disaster Information Systems

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Abstract

The East Japan Great Earthquake in 2011 brought various damages such as the delay of rescue, the heavy traffic jam, and the shortage of rations because of the heavy damages of the information networks. Therefore, this paper proposed the D2D (Device-to-Device) based DTN (Delay Tolerant Networks) for Disaster Information Systems. The methods consist of the D2D wireless connection controls with the group priority that is based on the historical locational data and the Data Triage method that is the data priority functions based on the user policy when the device transmits the data. Then, the results are discussed by the experimental data using the prototype system, and also the future works for the usages of the vehicle to vehicle communication are discussed.

Keywords: Delay Tolerant Networks, Disaster Information System, D2D

1 Introduction

It is considered that the current life circumstances are heavily based on the information networks, and it might bring the catastrophic damages if there is an ultra-large scale disaster such as the East Japan Great Earthquake in 2011. In fact, according to the paper [5], the high packet errors and latency caused just after the disaster, and the malfunctions of the information networks brought the secondary disasters various damages such as the delay of rescue, the heavy traffic jam, and the shortage of rations because of the lack of the disaster information. Moreover, the papers [5] [7] suggested three requirements for the future Disaster Information Systems (DIS). Firstly, the possible communication methods were the wireless networks such as the WiFi and the satellite system if the electricity is available. Secondly, it is necessary to use the devices that the user usually use in the life. Although there are some possible devices such as satellite cellular phones under disasters, it is considered that most people need the instructions how to use it. At last, the information that the evacuators tend to need belongs on the closer locations. Since the evacuators usually walk around the evacuation shelters or their houses, it is necessary to share the closer information such as the possible grocery stores or the places they get rations.

Therefore, it is assumed that this research uses cellular phones for the devices under disaster because most of the people now carry cellular phones. Also, it is assumed that the Delay Tolerant Networks (DTN) [3] is introduced for the wireless network connections. However, the DTN routings have the subjects such as the high latency and the lower delivery rate under the number and the movements of the mobile nodes, and the previous papers such as [6][2][4] introduced these problems, and they proposed the enhanced DTN routing methods such as the Spray and Wait, the MaxProp, and the PRoPHET. Moreover,

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the IP configurations among the mobile devices and the gateway functions between the DTN networks and the IP networks are also problems if it is considered to use the DTN routing in the field circumstances.

This paper proposed the Device-to-Device (D2D) based DTN routing with gateway functions to the IP networks, and the Data Triage methods [4][8] and the node's group controls are proposed for the efficiency of the data transmission. In details, the mobile device firstly searches the connectable devices by the wireless signals such as IEEE802.11 a/b/g/n/ac or Bluetooth, and the device establishes the possible wireless connection for the possible encounters by the layer 2 level including MAC address and the device name. Also, when the device establishes the connection, the historical locational data are exchanged for the grouping of the possible devices. Then, the group of the devices that have located in the same area is set to the high priority group. At last, the high priority data such as injured or rescue are transmitted to the others by the Data Triage Method.

In the followings, the assumed network circumstances and the related studies are explained in section II, and section III explains the proposed D2D based DTN routing, the gateway functions, and the implementations of the prototype system. Section IV reports the experiments by the prototype system, and section V discussed the conclusion and the future study for vehicle-to-Vehicle networks.

2 Network Architectures

This study assumes the following networks consisted of the DTN network, the IP network, and the gateway between these networks for the sake of the disaster uses.

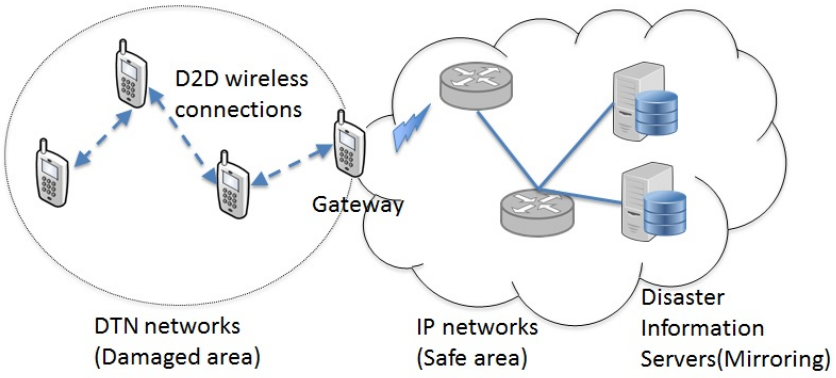

Figure 1: Proposed Networks

In Fig. 1, the DTN network mainly includes the mobile devices such as the smartphones, and the disaster information data is transmitted by the proposed D2D based DTN routing. The DTN routing is the stored-and-carried typed routing protocol, and the data is stored in the queue of the sender device if there is no transmittable device around the sender. Then, if a device comes into the possible wireless range, the data is duplicated to another device. Also, the proposed DTN network supports the D2D wireless connection that is the direct Layer 2 level connection with one of the possible wireless interfaces such as IEEE802.11a/b/g/n/ac, Bluetooth, and LTE as the previous study [5] suggested. Therefore, it is supposed that there is no IP configuration such as the DHCP setting among the DTN network.

The IP network is assumed as the usual internet access that is consisted of the wired and wireless connection, and it is also assumed that there are some disaster information servers that have the mirroring functions for the synchronization of the data. Also, these servers are spread over the whole nations, and so some servers are survived even if there is an ultra-large scale disaster.

Moreover, the assumed network includes the gateway function between the DTN network and IP

network. In the function, the sender periodically observed the IP connection to the disaster information servers that is previously configured by the DNS name or the global IP address, and so the mobile device quickly switches to the ordinal IP mode if the device reaches inside of the IP transmittable area that survived from disasters.

Besides, the proposed method introduced the Data Triage Methods [6] to improve the delivery rate and the latency of the data transmission. The Data Triage Method is one of the enhanced DTN routings that is the queue-order data transmission methods by the user policy. In the method, the priority tag is automatically added to the disaster messages when the user input the message, and the queue-stored data are rearranged by the priority tag and the time stamp. Therefore, the most newly significant messages are transmitted to others.

This research also discussed the D2D functions for the node priority decisions and the gateway functions when the devices are connected by the possible wireless interfaces in the following sections.

3 D2D and Gateway Functions

The previous paper [10] indicated that the evacuators tend to require the information in the closer area because they usually walk to the closer places such as the evacuation shelters, grocery stores, or gas station. That is, just after disasters, the evacuators likely stay in the certain area and it is necessary to consider the historical location data for the node selections in DIS.

Therefore, the proposed D2D connection uses the average GPS values for the node selection. Fig. 2 shows the way of the establishment of the D2D connection in this system.

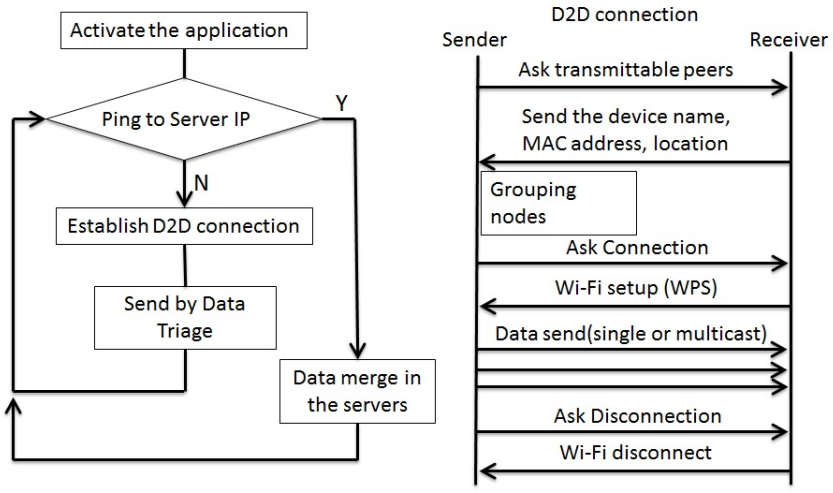

Figure 2: The Flowcharts of the D2D Connections

The left figure of Fig. 2 shows the flowchart of the proposed D2D connection. After the activation of the application in the mobile device, the sender device continuously checks the previously installed server IP address by ping command. If the IP network is disconnected, the sender confirms the D2D connection as the right figure. However, if the sender success the ping command to the server, the sender merge the disaster information data in the server through the usual IP connections. This method realizes the gateway function between the DTN and IP networks.

Next, the D2D connection is explained in the right figure. In the proposed method, the sender continuously seeks the transmittable nodes by the wireless signal levels with IEEE802.11a/b/g/n/ac, Bluetooth, and LTE interfaces. Then, when there is a transmittable node, the sender asks to send the MAC address,

the device name, and the calculated locational data though the strongest wireless signal interface. If there are some transmittable nodes, the sender makes the group setting by the historical location data, and the sender asks the connection only to the high priority receiver's group to reduce the overhead data in the queue. Then, the receivers establish the connection by such as WPS. Next, the data are transmitted by the Data Triage method for the receivers either unicast or multicast, and the wireless links are disconnected after the data transmissions.

For the evaluations of the proposed methods, the prototype system is implemented by the WiFi P2P and WiFi Aware of the Android API, and Fig. 3 shows the implemented prototype system. In the window, the user can input their information such as name and address, and one can send the short message and three levels of one's status such as emergent, injured, and safe. The data priority is set by these levels or the Static Body Object Detection [9] that is the duration of the static body if one gets injured.

Figure 3: The prototype system by the Android smartphone.

The WiFi P2P and WiFi Aware frameworks [1] are provided from the Android 4.0 and Android 8.0, and they realize the direct D2D connection with the possible wireless connections among IEEE802.11a/b/g/n/ac, Bluetooth, and LTE. Also, Nexus 5X (Android OS 6.0.1, IEEE802.11a/b/g/n/ac, 2GB MEM, 16GB Storage), Nexus 7 (Android OS 6.0.1, IEEE802.11a/b/g/n/ac, 2GB MEM, 16GB Storage), Android Studio 2.1.3, and Java 8.0 are used for the implementation of the prototype system.

4 Experiments

The implemented prototype was used for the evaluations of the proposed D2D based DTN routing, and the experiments were confirmed during the earthquake evacuation training program at the Fukuoka Institute of Technology, Japan. In the scenario, the message sender pretends to stack under the furniture, and the receiver walks from the starting point to the evacuation shelter as shown in Fig. 4. The receiver did not seem aware the sender who were under the furniture, and the delivery rate and the connection speed were compared.

First of all, the connection speed is evaluated by the proposed D2D based DTN and the DTN with the DHCP. In the experiment, four smartphones are statically located in the way of the receiver who walks to the evacuation shelter, and 100 text messages are transmitted from these senders. 100 messages are consisted of the 33 high priority messages, 33 moderate priority messages, and 34 low priority messages. Also, the size of each message is 50 Japanese characteristics, and these messages are merged to the information server at the evacuation shelter of the last walking point. Then, the average duration were calculated from the connection establishments to the disconnection.

Figure 4: The Scenario of the Field Experiments.

As the results, the average duration of the data transmission by the proposed method was 1.998 seconds, and the duration by the DHCP was 8.31 seconds. The results shows the significant improvements for the data transmission of the DTN routing, and it is necessary to consider about the IP setting of DTN usages even in the realistic internet circumstances.

Secondly, the message delivery rates are compared by the DTN with the D2D based the Data Triage method and the epidemic model of the DTN routing. In this time, 400 messages are prepared, and messages consists of 132 high priority, 132 moderate priority, and 136 low priority in the same scenario. The results are shown in Table 1.

Table 1: The Experimental Results of the Data Delivery Rate..

	D2D with Data Triage		D2D	
	Send Message	Received Message	Send Message	Received Message
High	132	123	132	103
Moderate	132	99	132	101
Low	136	84	136	102
SUM	400	306	400	306
Low	136	84	136	102
Total delivery rate	0.77		0.77	
Delivery rate in high priority	0.90		0.76	

The results indicate the improvements of the high priority messages such as the rescues or injured even if the total delivery rates were same. Also, it is supposed that the proposed method is more effective if there are more mobile devices for the DTN network.

5 Conclusions and Future Studies

There might be various damages such as the delay of rescue, the heavy traffic jam, and the shortage of rations because of the heavy damages of the information networks after large-scale disasters. Therefore, this paper intoduced the D2D based DTN with group priority for the DIS. The proposed methods consist of the D2D wireless connection controls with the group priority that is based on the historical locational data, and the network connection is confirmed by the layer 2 level message sending. Moreover, the previously proposed Data Triage method is also introduced for the improvements of the DTN routing for the prototype system.

As the results of the experiments, the proposed methods made the significant improvements for the link connection speed and the delivery rate of the higher priority messages.

Now, the additional field experiments including the effectiveness of the group functions are planning for the future studies, and also the enhance usage for the vehicle-to-vehicle communication is researched because of the shorter link connection speed for the future studies.

Acknowledgments

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Author Biography

Noriki Uchida received the B.S. degrees from University of Tennessee in 1994, M.S. degrees in Software and Information science from Iwate Prefectural University in 2003, and Ph.D. degrees in the same University in 2011. Currently he is an associate professor in the Saitama Institute of Technology. His research interests include Cognitive Wireless Networks, QoS, and Heterogeneous Network. He is a member of IEEE, Information Processing Society of Japan (IPSJ), and Institute of Electronic and Communication Engineering in Japan (IEICE).

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[1] No photo is available.