Device-to-Device Communication based DTN for Disaster Information System by using Emergent User Policy and Locational Information

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Abstract

The Delay Tolerant Networks (DTN) is well known as the resilient routing protocol for robust network conditions such as the situation just after the large scale disasters. This paper introduces the implementations of the DTN routing with the Data Triage Method and the group priority transmission by using the Device-to-Device (D2D) communication API on the android smartphones in order to realize the assumed Disaster Information System. In the proposed methods, the user policy is introduced for the Data Triage Method from the evacuators messages and the static body detections, and the historical locational information is introduced for the priority node selection method by the implementations using the D2D API. Then, the evaluations of the prototype system are reported in this paper, and the results shows the affectivity of the prototype systems because the delivery rates of the high priority messages reached to 100 percent within one second in the experiments.

Keywords: Delay Tolerant Networking, Disaster Information System, D2D

1 Introduction

It is considered that the communication just after disaster has been one of the significant subjects. For example, the previous papers [10][17] reported the robust network conditions just after the East Japan Great Earthquake in 2011, and it was pointed out the importance of the network connectivity for the QoS (Quality of Service) Controls of the (DIS) Disaster Information System in the future studies. Then, the DTN (Delay Tolerant Networking) [6] is the one of the major approaches against such a robust network.

However, some previous papers [11][5] pointed out the low delivery rates and the high latency of the epidemic models [8] of the DTN routing, and they introduced the modified DTN methods such as the Maxprop [5] and the Prophet [8]. Besides, when it is considered the DTN methods for the DIS, it is necessary to consider the user policy and the node movements in the damaged areas. The recent papers [15][13] mentioned that these modified DTN methods such as the Spray and Wait [15] and the prophet showed the lower delivery rate and the higher latency than these of epidemic mode according to the experiments with the data from the East Japan Great Earthquake. The papers also indicated that

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the rapid developments of the broadband wireless networks and the hardware resources affected to these previous research results, and it is necessary to consider the new effective approaches for the DIS under the current technologies.

Therefore, this paper introduces the queue-order typed DTN method called the Data Triage Methods [8][14] and the priority node selections by the POI (Point Of Interest) [15]. Additionally, the paper especially reports the implementations of the DTN proposed routing to improve the message delivery rates and the latency in the assumed DIS. In the proposed methods, the D2D (Device-to-Device) API [13] on smartphones is used for the implementations, and the user policy in the Data Triage Method is considered by the user menus in the application and the autonomous static body detections by the sensors on smartphones. Then, the Android ID and the MAC address are used for the establishments of the wireless connection between the smartphones without the DHCP configurations. Finally, the history of the locational information on smartphones is used for the proposed the priority node selections. In the method, when the D2D wireless connections are established, the nodes that are mostly located in the outside areas are selected by the proposed Markov Chain based POI calculations. The proposed node priority selections also support the multicast data transmissions as well as the unicast data transmission by the grouping function in order to improve the DTN routing for the DIS.

In the followings, section 2 in this paper explained the assumed DIS network structures and the general functions. Then, section 3 presents the details and the implementations of the proposed Data Triage Method by using the D2D API on smartphones, and section 4 also explains these of the priority node selection by the POI. Finally, section 5 reports the experimental results by the prototype system, and section 6 discussed the conclusion and the future studies of the proposed methods.

2 Proposed Disaster Information System

When the ultra-large scale disaster is happened, the disaster information such as the life safety, the rescues, or the damaged areas becomes significantly important for the evacuators. The previous paper [10] reported the caused problems from the network disconnections by the East Japan Great Earthquake, and it also discussed the subjects for the future DIS. In the paper, the user policies of the evacuators are changed by the period after the disaster, and it is pointed out that the evacuators in the damaged areas need the information of the life safety, the evacuation shelter, and the damage during first 48 hours after the disaster. The paper also indicated that the network connectivity is the most important even if the communication network shows the lower throughput and the high delay, and that the priority contents should be these text contents for the QoS controls for the DIS. Therefore, this paper considers that the text based life safety information from one's smartphones to the disaster headquarter, and the assumed DIS is presented in Figure 1.

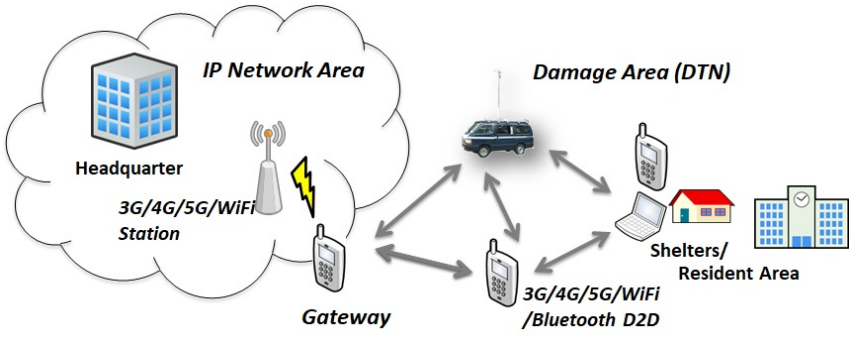

Figure 1: Assumed Network Structures of Disaster Information System

In the DIS, first of all, it is supposed that there are three parts in the networks. One is the IP network area where the IP network is available to use by the wired and wireless networks. Especially, it is assumed that the wireless networks such as the 3G/4G/5G fixed stations and Wi-Fi fixed stations can provide the Internet access to mobile devices in the area. Secondly, there is the damaged area where the Internet services are available because of the damages of the wireless stations. In this area, it is assumed that the proposed DTN services are available to mobile devices such as smartphones, wireless cars, or note PCs. Finally, these mobile devices provide the gateway service between the IP network area and the damaged area. Therefore, if the mobile devices move to the transmittable ranges for the survived wireless stations, it is assumed that these devices can share the stored disaster information data to the disaster server in the disaster headquarter in the IP network area.

In addition, Figure 2. presents the general functions of the assumed DIS based on the D2D Communication.

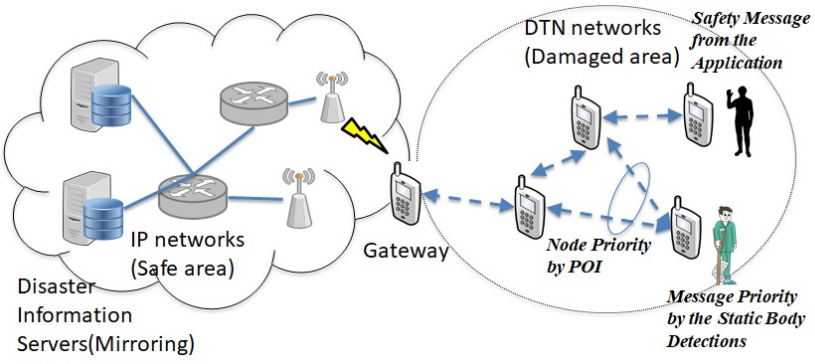

Figure 2: General Functions of the Assumed DIS

First, when the evacuators input the life safety information into the application on smartphones, the safety messages transmit to other transmittable mobile devices by the proposed DTN routing. In addition, if the evacuators did not operate the life safety application, the application with the static body detections automatically search the abnormal static conditions by the locational sensors and gyro sensors. Then, if the application detects abnormal static body conditions by injured, the application automatically creates the life safety message with their locations and the priority value for the proposed DTN routing. The autonomous messages are continuously created during the evacuator are staying the abnormal static conditions, and the priority values in the safety messages are increasing in order to improve the efficiency of the proposed DTN routing.

Secondly, the proposed DTN method uses the node priority selections by POI when the smartphone establishes the wireless connections to other transmittable nodes. According to the study [7], there were mainly two movements of the evaluators in the disaster. One is the short movement from the damaged area (seacoast) and the evacuator's shelters. It is supposed that the evacuators tend to move this way because they are like to check the damaged area, and that the distance of the movement is short because the main transportation is on foot or by bicycle. The secondary is the longer movement along the major road such as the Figure 3. It is supposed that this movement is mainly by the rescues or the public supports from the other areas. Therefore, the proposed node priority selections focus on the secondary node in order to widely share the disaster information for the disaster headquarters, and the D2D establishments confirm by unicast or multicast data transmission based on the POI.

Finally, in the gateway functions, when the smartphone reaches in the IP available area by 3G/4G/5G or WiFi, the smartphone shares the stored messages to the disaster information servers by using the previously configured IP address.

Figure 3: The Assumed Movements after Disaster

In the followings, the prototype system is implemented by the WiFi P2P[1] and WiFi Aware of the Android D2D API[3] because it supports direct LTE/WiFi/Bluetooth connections among the devices. Also, the establishment of the wireless connections is faster than the common DHCP connections because the D2D establishments need only Android ID and MAC address. Then, 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.

3 User Policy for Data Triage Method

As mentioned the previous sections, the user policy is used for the proposed DTN routing in this paper. Firstly, the three levels of the emergent radio button are implemented in the window menu of the application as shown in Figure 4. When the evacuators are able to input their safety information, they can select one of the emergent levels when they send the messages in the system. Then, these levels are used for the priority values for the Data Triage Method.

However, if the evacuators are unable to use the application because of injured or Information illiterates, it is difficult to use this kind of disaster related applications. Therefore, secondly, the static body detections is considered to introduce for the assumed DIS in the future studies. In this method, the application automatically starts by detecting the earthquake from the gyro sensors on the smartphone. Then, the priority values are increased one level if the smartphone detects abnormal static body conditions. The process of the static body detections is shown in Figure 5.

In the process, after activating the application by detecting the certain shaking patterns from the gyro

Figure 4: Window Menu of the Application in Assumed DIS

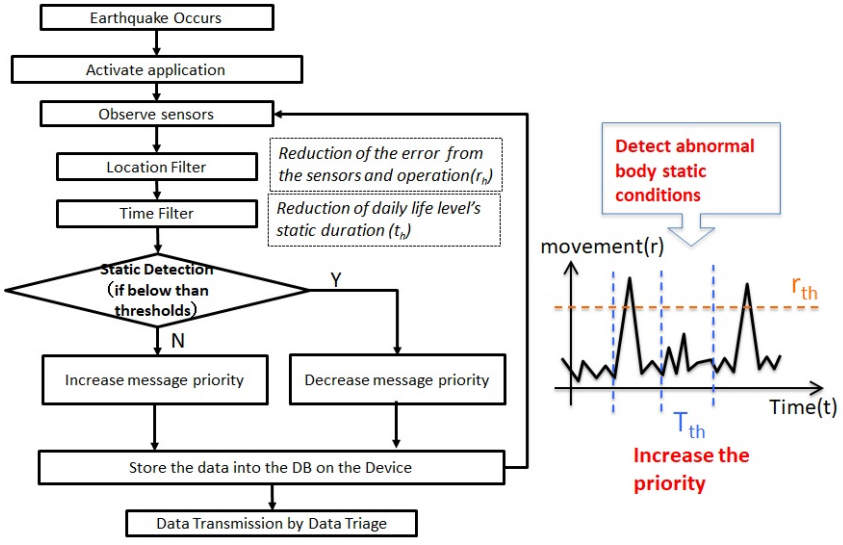

Figure 5: Process of Static Body Detections by Sensors on Smartphones

sensors, the application starts to observe the local time and the locational data on smartphones by the GPS and gyro sensors. Then, the algorithm such as the MCMC (Markov chain Monte Carlo) method [4][9] calculates the threshold values of the movement (r_{th}) and the time (T_{th}). Although we are now evaluating the MCMC methods by using the implementations of the MCMS API [2][18], it is supposed that The MCMS methods is one of the effective methods because it is often used to solve integration and optimization problems for machine learning and decision analysis [4].

Then, the priority ID are introduced for the database on smartphone for the priority values of the Data Triage Method [13]. SQLite on smartphone is used for the implementations, and the priority ID is configured as 81 digits consisted of priority (3digits), date (14digits), and the Android ID (64digits). In the prototype system, the message data in the database is sorted by the order of the priority ID just after each node receive the messages from others.

4 Node Priority for the D2D Connections

Then, the D2D connections are established as shown in Figure 6.

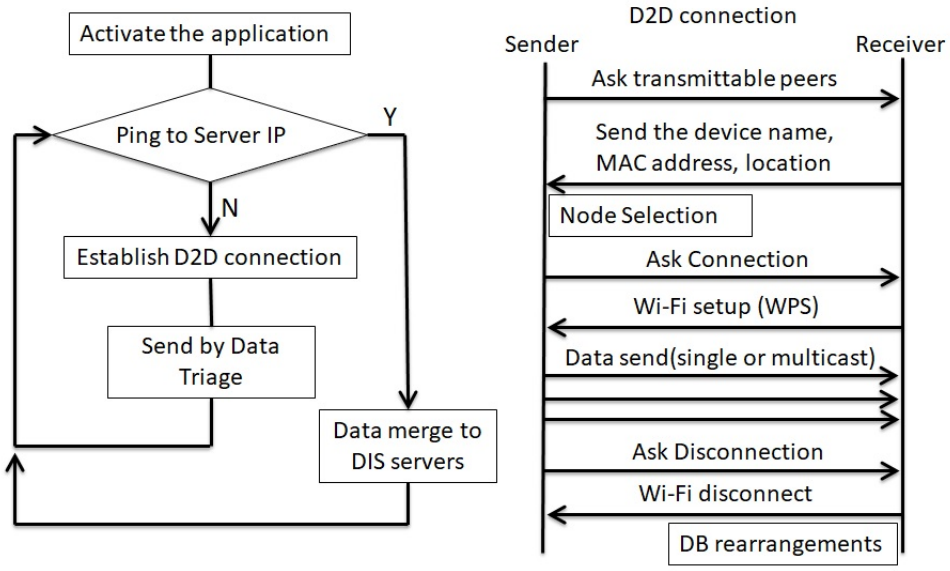

Figure 6: Flowchart of D2D Connections in the Proposed DTN Method

The left of Figure 6 shows the flowchart of the gateway and the D2D connection in the proposed method. The application on the smartphones check the connection to the previously configured DIS server IP by the ping command with short TTL, and the stored data is merged to the DIS server if the DIS server is available to connect. If not, the application tries to establish D2D connection to other mobile devices.

The right figure is the details of the D2D connection implemented by D2D API. One of the benefits of the proposed D2D connection is that the wireless connection establishes by Android ID (Device Name) and MAC address, and it is supposed that the connection can establish faster than that of the DHCP configuration. In the process, the radio scan by the WifiManager API [1] of the Android OS is continuously confirmed to seek the transmittable node. Then, if there is transmittable node when the other nodes come into the radio range, the sender ask to the receiver about the device name and the MAC Address. Also, for the proposed node priority selections, the sender also asks the locational information. Then, after the proposed node selections, the sender asks to the selected receivers to establish the

D2D connections. Then, after finishing the data transmissions, the stored messages in the database on smartphones are sorted by the priority ID as the previously discussed.

Figure 7 shows the area map image for the proposed node priority selection.

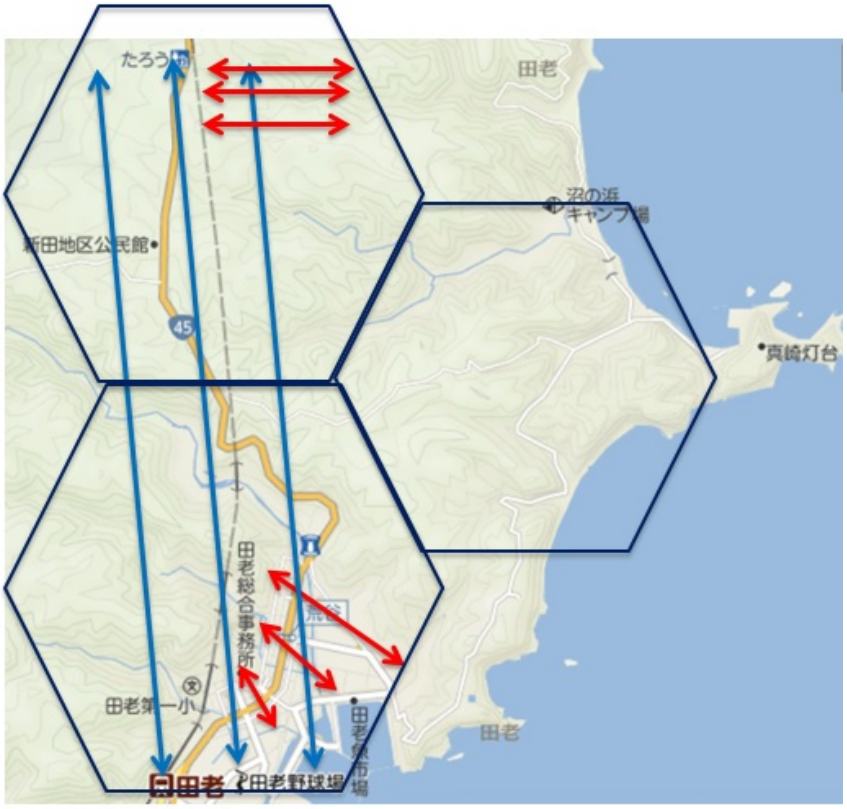

Figure 7: Area Map for the Proposed Node Selections

The proposed method focuses on the node that often belongs to other areas in the figure. Therefore, Formula 1 is introduced for the calculation of the node priority selections in the prototype system.

$$S(t_n) = \alpha \Delta D_n(t_n) + \beta \Delta D_{n-1}(t_{n-1}) + \gamma \Delta D_{n-2}(t_{n-2}) \quad (1)$$

Here, α, β, and γ are the weight values satisfied with $\alpha + \beta + \gamma = 1$, and $\alpha = 0.6$, $\beta = 0.3$, and $\gamma = 0.1$ are previously set in the prototype system. $\Delta D_n(t_n)$ is the differences of the longitude and the latitude from the starting point to the current point. The application continuously observes the current location each 10 minutes in the prototype system, and the difference of the locations is calculated for the threshold of the node priority.

Therefore, if the sender finds multiple transmittable nodes by radio scans, the nodes more than 1000 meters from the calculated values are selected in the prototype system. Although the evaluations of the weight values and the threshold of the node's movements are the future studies in this research, we are now planning the field experiments for the effectiveness of these values.

5 Experiments

The experiments were confirmed for the effectiveness of the prototype system. In the experiments, the speeds of the wireless connections were compared with the proposed method and the DHCP connection,

and also the delivery rate by the field experiments was confirmed by the field experiments. First, Figure 8 shows the duration time from the wireless establishment to the data transmissions completed.

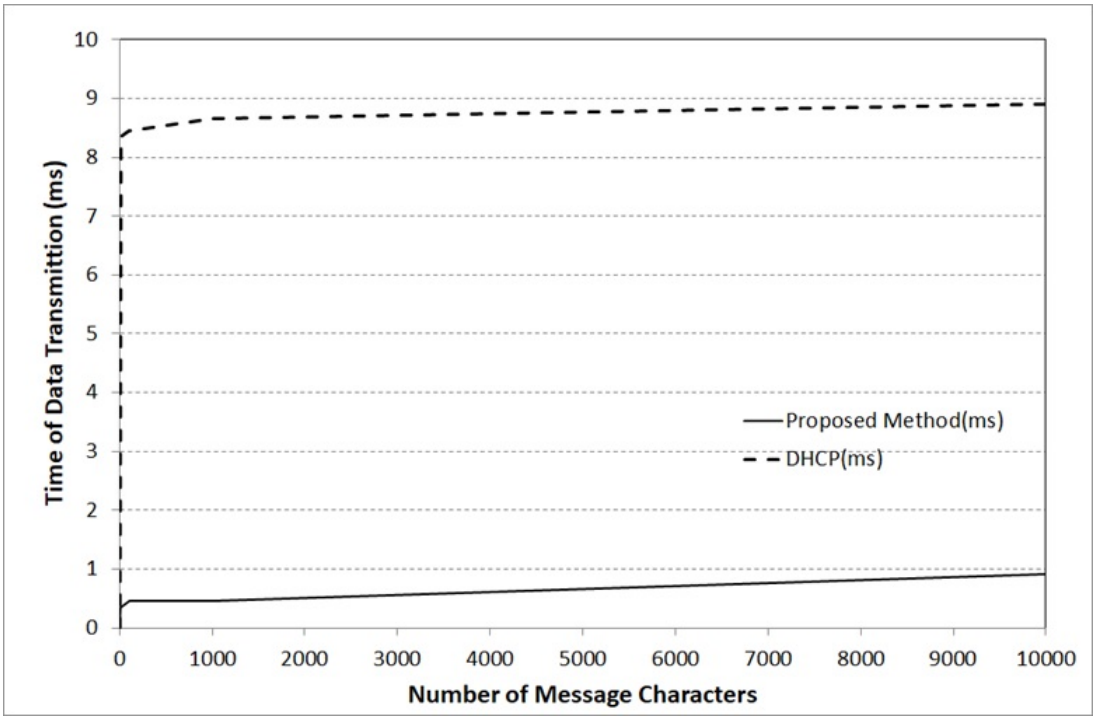

Figure 8: Duration Results between the proposed D2D and the DHCP connection

In the experiments, the messages were previously prepared in the database on the sender, and the messages were varied from 1000 Japanese characters to 10000 characters in the experiments. Then, the duration time was observed by the local time on both the sender and the receiver, and the D2D connections with the proposed method and the DHCP configuration were compared. The results show that the proposed method took less than one second to transmit the message, while the DHCP configuration took more than eight seconds. The results indicate that the proposed D2D connection expect to improve the quality of the DTN routing even if the usage of V2V (Vehicle-to-Vehicle) communication [12] because it is necessary to consider the short period of the data transmission.

Secondly, the delivery rates between the proposed Data Triage Method and the epidemic DTN routing with the DHCP configuration were compared for the effectiveness of the DTN routing, and Figure 9 shows the results of the experiments.

In the experiments, the three levels of the messages consisted of 100 Japanese characters are previously stored in the database of the sender node, and the number of the messages are almost equal such as 33 high priority messages, 33 moderate priority messages, and 34 less priority messages out of 100 messages. Then, the experiments were held in the Fukuoka Institute of Technology, Japan, and the delivery rates were measured. In the experiments, the sender pretended to fall down under the boxes and chairs, the receiver pretended to walk through the corridor with the short look to the inside of the laboratory as the previous study [16].

The results show that there are differences between the proposed method and the epidemic DTN routing. While the epidemic DTN routing fall down gradually from the 100 messages in the experiments, the high priority messages by the proposed method keeps 100 percent of the delivery rate. It is pointed out that the emergent messages are possible to transmit with the short period of the D2D communication

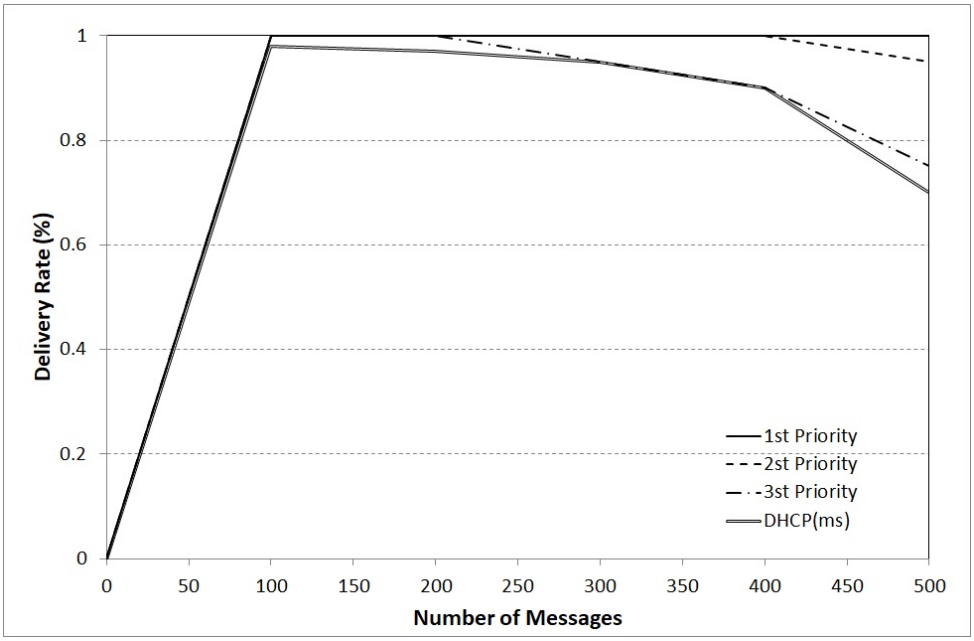

Figure 9: Results of Delivery Rates

even if the moderate and less priority messages might be low delivery rate. Thus, these experimental results indicated the better results of the DTN routing, and it is supposed that the high priority messages such as the rescues or the injured are transmitted to the disaster information servers in the assumed DIS.

6 Conclusion and Future Studies

It is supposed that the connectivity of the DIS become significantly important just after disasters. Therefore, this paper proposed the DIS focused on the DTN method with the user policy and the node priority. Then, the paper presents the Data Triage Method by the priority ID from the window menu of the life safety information and the static body detection method. Besides, the paper presents the node priority selection method by the calculation of the historical locational information on each smartphone. In the calculation, the node of the large movements is assumed for the improvements of the DTN routing, and the D2D connection with unicast and multicast data transmissions are implemented in the prototype system.

Then, the experiments by the prototype system indicates the effectiveness of the proposed method because the quickness of the wireless establishments and the delivery rates are greatly improved in comparison with the DHCP configuration or the epidemic DTN routing.

However, it is considered that the future studies need more field experiments such as for the efficiency of the node priority selections or for the priority from the static body detections. Therefore, we are now planning the additional implementations of the prototype system and the additional field experiments for the future studies.

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