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Doctoral Dissertation

Priority Medical Image Delivery Services over DTN on Disaster Situation

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Priority Medical Image Delivery Services over DTN on Disaster Situation*

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Abstract

This dissertation presents the medical mobile network to transfer medical image data, targeting eye injuries caused by volcano disaster. We propose a priority medical image delivery service, which optimizes the delivery of victim image data from a disaster area to specialist doctors in city hospitals using the Delay Tolerant Network (DTN). DTN is a promising technology used for transmitting data on unstable wireless network. However, transmitting a high-resolution medical image over DTN is a challenging task because the file size is large. Our medical image delivery service assumes to be used for an emergency response to provide quick feedback to healthcare workers after images are received by a hospital. By analyzing the received images, specialist doctors in the city hospital can identify the seriousness of an injury to a victim's eye. To reduce image delivery delay of DTN, we introduce a priority data forwarding method based on an image processing technique. In our system, eye images captured during an emergency situation are automatically divided into some pieces. Each piece is manually assigned a priority based on its content (e.g., based on the severity of the injury) by healthcare workers. These data are transmitted over DTN where some Android smartphones with Wi-Fi Direct relay the data.

Finally, based on the priorities assigned to the pieces, we designed a priority-forwarding method, where higher priority pieces are assigned more bandwidth and transmitted with higher resolution. As a result, an important part of a picture, which is mandatory for diagnosis, will arrive at the main hospital faster than other parts. Through a computer simulation with the Merapi volcano disaster scenario, we confirmed that the proposed medical image delivery service could deliver more diagnosable images faster than a conventional method within a time period. With prioritized medical image delivery service, we found that the message delivery rate at the hospital can be improved by up to 20% comparing with the case without the priority forwarding mechanism when we use epidemic routing.

Keywords: Medical Image Delivery, Emergency Response, DTN, Priority Forwarding, Volcano Disaster

Contents

List of Figures

List of Table

.

Chapter 1
Introduction

1.1. Research Background

Volcano eruptions can result in many health impacts, which depend on the size of the volcano. As the global population is predicted to reach 7 billion by 2012, land pressures and rapid population growth are resulting in more people living within danger zones of natural hazards, for example, around volcanoes. In the case of volcanic eruption, healthcare workers will need to treat many injuries. Ash particles can affect the eyes by causing irritation and conjunctivitis as happened in some areas after the Mount St. Helen's eruption and the Mount USU eruption in Japan [1].

There are many active volcanic mountains in the world. They suddenly erupt and cause a lot of economical and human damages. For example, Mount Merapi in Indonesia erupts periodically. It is one of the most active volcanoes in the world and the most active among 129 volcanoes in Indonesia. Since the year 1930 to 2006, it has made a number of injuries more than 900 people. It erupts at 4-year interval within 20 years major eruption period. Table 1 shows a human impact of Merapi Volcano.

We target the area of interest which is located around the summit of Mount Merapi which is situated in Central Java, shown in Figure 1 (red circle). Mount Merapi is located at 7º32'26''S and 110º26'48''E, the summit is 2,950m above sea level. The volcano's most recent eruption(s) were on the 26th October 2010 and the 3rd November 2010, while the last major eruption (that caused a large death toll) was in November 1994. Merapi has a varied chronologic and geologic record, which is mainly due to its relatively persistent activity (the most active volcano in Java). Merapi exhumes ash and steam throughout the year.

Table 1. Human impact of selected eruptions of Merapi volcano

Date of eruption	**VEI of eruption**	**Number Killed**	**Number Injured**	**Number evacuated**
1930	3	1.369	-	13.000
1961	3	6	6	8.000
1994	2	64	500	6.026
1998	Effusive	-	314	6.000
Total (20th century)		1.590	932	32.275
2006	Effusive		-	12.000

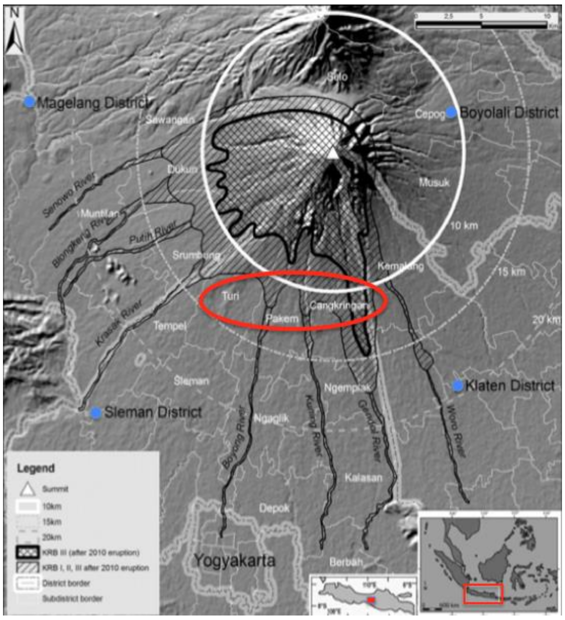


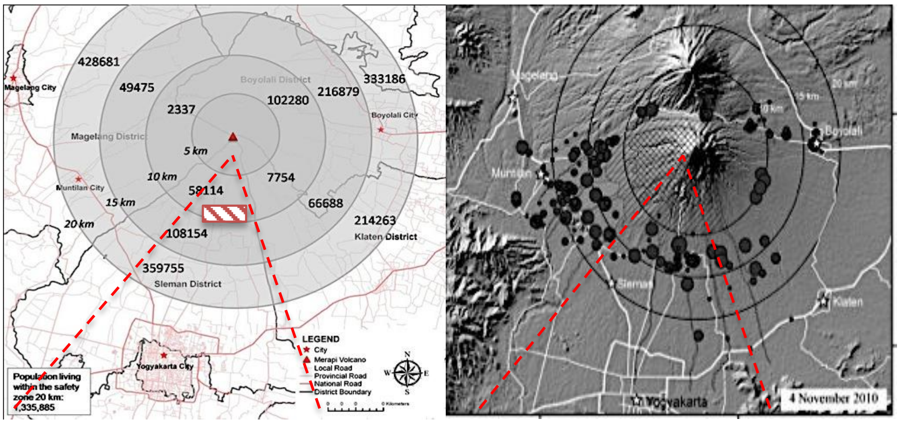
Fig.1 Map of volcano disaster

(https://www.researchgate.net/figure/256980412_fig1_Fig-1-Map-of-Merapi-volcano-and-surrounding-areas-showing-major-government-districts)

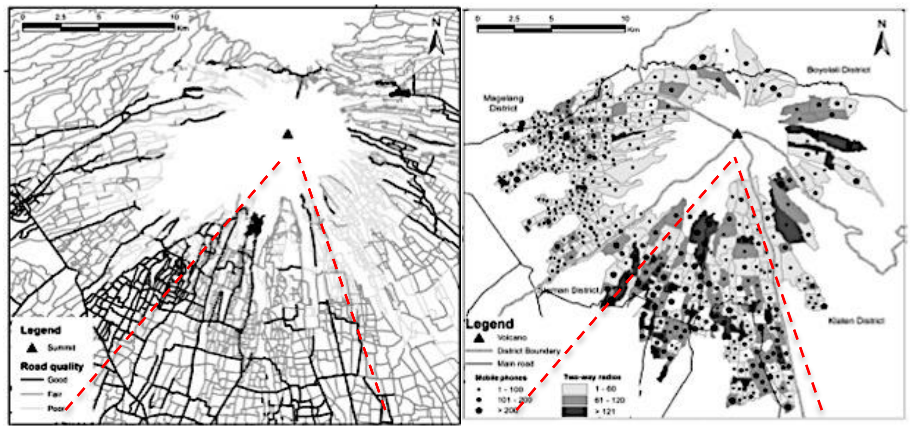
It gives big damages to rural roads and telecommunication network as well as human's health (eye injury). Because ash (pyroclastic) flows resulting from periodic partial collapse of the growing lava dome on the summit of Merapi [2]. A range of ash and tephra thicknesses were deposited around Merapi, with greater depths found around the valleys on the western, southwestern and southeastern flanks of the mountain, where the large block and ash flows travelled as shown in Figure 2.

In Merapi eruption, there was the loss of telecommunications in a rural area during the volcano eruption. Immediately after the larger block and ash flow, cellular telephone service in the village suffered from bad quality. Whether this is resulted from over-usage, physical destruction of communications infrastructure, or the presence of ash in the air obscuring signals is not clear [3].

Fig.2 Impact of ash fall Merapi volcano eruption



a).Populations b). Refugees Camp



c). Roads condition d). Mobile-phone

Fig.3 Merapi eruption 2010 situation to emergency evacuation [4]

The population around Mt. Merapi was 526,023 in the Sleman district area (area between red lines in Figure 3). For case study, we focus on the 3 small rural areas (Turi, Pakem and Cangkringan in the stripped box in Figure 3a) in 5 Km from the summit whose population was 58,114. One day after the second eruption (the 4-th November 2010) there were approximately twenty refugee camps located at less than 10 km points from the summit (Figure 3b). During the 2010 evacuation, each household in Merapi has at least one motorcycle. However, a people did not use their vehicle because the many roads were broken and dangerous (Figure 3c).

Further, as mobile phones are becoming common in 1-100 mobile phones at a rural area (Figure 3d), people also used this tool to inform others during the crisis. The role of local organizations also became important in crisis communication, as exemplified by the actions of JalinMerapi, a local organization supported by several NGOs working around the volcano.

The services focus on eye injuries among various volcano-caused injuries such as skin burns and respiratory diseases because there is a need for supporting health care workers to appropriately treat eye injuries without bringing the victims to the hospital with ophthalmologist. The services utilize mobile devices and applications for transferring eye pictures and ontain medical instructions to/from an ophthalmologist at the hospital.

The services also focus on the use of DTN for emergency data delivery services, to cope with the problem of low quality, speed, and high cost of using a conventional communication infrastructure (e.g., cellular network and the internet) in large disaster area.

1.2 Problem Statement

The 40,000 people within a 10 km zone in prone areas should be evacuated and become refugees in Merapi area. Health problem threatens the refugees in the evacuation camps. The healthcare workers are expected to build coordination between the parties involved in the emergency response for Merapi eruption to avoid serious health problem to refuges while the eruption is still going on. A lot of people are potentially exposed to an acute eye injury from volcanic products such as ash fall, which contains varying proportion of free crystalline silica in short duration (days to week). We consider only eye injury victims in each region of Sleman-district area to whom we apply the emergency response using Information Delivery in Disaster Scenario [5]

In this regard, researchers are also thinking how to deliver a content using Mobile Network and application. There are currently several ways of providing Mobile Network solutions for content delivery in disaster situations. In our study, we focus on the application of the smartphone as our Mobile Network for delivering medical images which are actual information of victims. More specifically, we require these solutions to be in the form of a new message forwarding system that is also easily implemented and useful for healthcare workers to identify and treat an eye injury emergency after Merapi volcano eruption occurs.

The research problems targeted in this thesis for disaster situations are summarized as follows.

The research problem 1: **"It is difficult for healthcare worker to handle special eye injury of victims. How should the victims be quickly treated when communication is not available from disaster area to the ophthalmologist in a city hospital?".** In this situation, for treatment of victims on the emergency disaster, healthcare workers will often need instructions from an ophthalmologist for specific eye injuries in a volcano disaster zone by text, audio, or video. Thus it is necessary to send an ophthalmologist medical images quickly to obtain feedback in the form of instructions that can be used by healthcare workers in the affected areas. At the time of eruption, there was great difficulty in transmitting medical images over the large rural area to a destination in the city without mobile or wireless network. The possibilities of travel are also very limited by the poor condition of the roads. After a healthcare worker has found a victim with symptoms of eye injury, they immediately take a picture with his/her smartphone's camera. To reduce the total amount of data size to be transmitted, we employ an approach that a healthcare worker uses medical image processing and application for color-marking the victim's picture so that the injury part in the picture is picked for prior transmission over DTN.
The goal of the research problem 1 is *to realize efficient medical image transmission between disaster areas and the hospital over DTN*

The research problem 2: "**It is required to fast deliver medical images and handle a large size of image data. Thus, critical part of an image should be identified and sent prior to others in DTN.**" In this study, we realize priority medical image delivery services toward emergency healthcare applications in a disaster situation, which try to tackle the limitation of communication in a volcano disaster. In developing such services, the following technical problems need to be solved: a) a mechanism to prioritize an image before sending it to network, b) a priority message delivery mechanism in DTN. In our study, instead of developing a new priority routing mechanism, we modify an existing DTN routing protocol (epidemic routing) to handle priority and deliver messages based on priorities put to them (e.g., severity of injury in medical images). Healthcare workers manually put a priority to each piece of an image. The goal of research problem 2 is to devise a way of *priority assignment to each piece and develop a priority message delivery mechanism in DTN.*

1.3 Organization of Dissertation

This dissertation is organized as follows. In Chapter 2, we give a brief survey of existing studies related to this work. In Chapter 3, we design a prioritized medical image delivery services with a new approach to an image prioritization scheme and a priority message forwarding scheme. We first introduce the image priority scheme where an image is divided into pieces for putting different priority, and then describe the details of the experiments as well as the results. We also give basic performance evaluation through preliminary experiments using a network simulator. In Chapter 4, we give a complete design and implementation of the proposed priority medical image delivery services and conduct thorough experiments for evaluation on a large scale. We reproduce realistic volcano situations on a network simulator and evaluate performance of the proposed method in terms of message delivery rate between cases using priority and non-priority by changing a number of mobility node and message size. Chapter 5 concludes this thesis with detailed discussions and recommendations for future research.

Chapter 2
Related Work

In this chapter, we will briefly overview existing work on applications of mobile devices for emergency situations with delivery of images through DTN. Applications are being developed based on mobile devices and wireless networks as a solution to the occasional breakdown of communication networks. Here we will look at existing work on applications of mobile devices for emergency situations with delivery of images through a DTN priority routing protocol. Many studies have proposed applications to enhance effective communication in emergency situations. However, these applications do not consider the receiving images at its destination in real time, i.e., the time required at the destination. So they are difficult to be used in building an efficient medical image delivery service in a disaster scenario.

2.1 Application in Emergency Scenarios

Mobile devices are frequently used in disaster areas, especially for medical emergencies, where data are delivered by DTN. The Mobile Agent Electronic Triage Tag System [6] creates mobile agents that store and carry triage information about victims. Mobile agents are able to move through a MANET (Mobile Ad-hoc Network) created by mobile devices without the need for an end-to-end connection from the origin to the destination. Mobile Maps [7] presents a low-cost mobile collaborative system, which may be used in emergency situations to overcome most communication problems of firefighters. This application allows ad-hoc communication, decision support and collaboration among firefighters in the field using mobile devices. The information accumulated can be analyzed after a crisis and studied for future emergencies. The DTN on Android smartphones used in emergency scenario [8] allows users to interconnect without network facilities. This study shows that a DTN node can transfer automatically to other DTN regions whatever it receives in one DTN region. It can accommodate the challenged environment and can be utilized in emergencies. It can deliver a rescuers' messages including text and video formatting through an epidemic routing protocol and IP Neighbor Discovery.

2.2 Image-delivery Services using DTN

Photo-Net [9] is an image-delivery service for mobile camera networks and can be used in disaster response applications. Photo-Net can send an image from the first responder who finds the victims at the disaster area by using an opportunistic-forwarding scheme. The Photo-Net application can store images while assigning to them priorities for forwarding and for replacement processes based on the degree of similarity or dissimilarity among images. Similarity here is, the similarity in the content of different images of the same scene taken from slightly different angles. CARE [10] is a system that eliminates images from a collection. It can detect the similarities among photos in DTN delivery services and optimize the capacity of the buffer on a mobile phone.

2.3 Prioritized Message Delivery in DTN

In [11], a priority routing of messages for DTN in a disaster area is presented. It assumes that an earthquake has occurred in a city, and roads have been damaged. It is shown that a message priority routing protocol can deliver more messages with a lower overhead ratio and lower latency. Priority scheduling for participatory DTN [12] implemented a priority scheduling on top of an existing DTN protocol and evaluated both end-user satisfaction and message delivery rate. Infobox [13] creates a system for DTN-based delivery of word-of-mouth information with priority and deadline that allows users in a sightseeing area to exchange each other word-of-mouth information and photos of the spot. For efficient bandwidth utilization, Infobox discards data that do not meet the delivery deadline.

There are several future research areas including message priority and delivery over DTN. We could further demonstrate the utility of our priority medical image forwarding protocol design. In [14], they provide some mechanisms to rule the participation of the relays to the delivery of messages in DTNs, In [15], they perform delivery ratio and message delivery delay without incurring high message or protocol maintenance overhead in epidemic routing case, In [16], They introduce a novel social-based forwarding algorithm to enhance delivery performance, and improve forwarding performance compared to a number of previously proposed algorithms. Furthermore, in [17], they accomplish data delivery in such challenging environments. The researchers have proposed to use of store-carry-forward protocols, in which a node stores a message and carries it until a forwarding opportunity arises through an encounter with other nodes

Chapter 3
Prioritized Medical Image Delivery Services over DTN: Basic Design

3.1 Introduction

This chapter gives our basic design for the proposed prioritized medical image delivery service over DTN for volcano disasters and preliminary experiment results through simulations.

One of the main problems in image delivery is how to recognize critical images as high priority data especially for eye injury image. To solve this problem, we introduce two methods: Color Marking based image segmentation and priority forwarding. By dividing a large medical image into small pieces, we try to improve the throughput and reliability of DTN. After the system divides the image, the important pieces of the image are identified and a high priorities are assigned to them. In addition, each intermediate node in DTN forwards the pieces that have higher priority prior to other pieces. As a result, important pieces can be delivered to the hospital as fast as possible. We show the effectiveness of the proposed method through a computer simulation by evaluating the time until all of the high priority pieces in each image are received at the hospital and by comparing our method with a conventional method without prioritization of pieces for two representative DTN routing protocols (Epidemic and Spray-and-Wait).

3.2 Target Medical Image Delivery Service.

Here, we model a DTN as a set of mobile nodes. A contact occurs when two nodes meet within their wireless transmission range, creating an opportunity to transmit data between nodes. In a realistic scenario of Merapi Mount disaster, the rescue services are provided by an emergency medical response team that consists of rescuers and ambulance drivers. They are treated as mobile nodes in our DTN model.

As shown in Figure 4, we assume that multiple health posts (where medical doctor treats patients) and one or more ambulance parking lots are placed in the disaster area. Rescuers move between the ambulance car parking lot and one of the health posts selected at random. Thus, we model the mobility of rescuers as a variant of Random Way Point (RWP) mobility model. Similar to the ordinary RWP, nodes corresponding to rescuers wait for a pause time and then moves to a randomly chosen location at a speed chosen from the range (Vmin,Vmax) [18]. They walk from a health post to a parking lot in the disaster zone. Meanwhile, ambulance drivers move between a parking lot and a hospital in the city. Based on the geographical features on a specific Merapi disaster area, we assume that the distance between the disaster area (ambulance parking lots) and a hospital is around 20-30 km. We also assume that the parking lots are located about 5 km from the farthest health post. In this situation, we consider how to deliver images quickly from a source location (i.e., health post) to a destination location (i.e., hospital) by forwarding messages over DTN among the nodes.

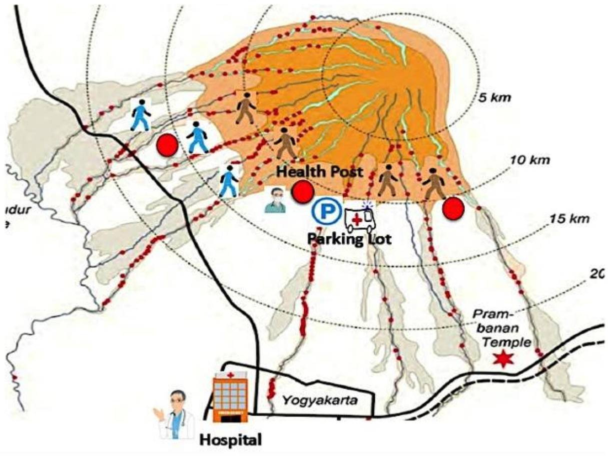


Fig.4 Example of medical response to deliver victims
to hospital in Merapi Disaster

We consider an evacuation process within 24 hours after eruption to find 50-70 victims. In this setting, we assume that there are 5-10% victims that will potentially cause acute eye injury. After a doctor has found a victim with symptom eye injury, the doctor immediately takes a picture with his/her smartphone's camera. To reduce the total amount of data size to be transmitted, we employ an approach that a doctor manually makes a marking on injury part based using a color (corresponding to priority level or resolution) in the patient's picture so that the injury part in the picture is picked for prior transmission over DTN.

We assume that Android smartphones, which are capable of peer-to-peer communication through WiFi Direct, are used in the disaster area for multi-hop communication between nodes. In this context, we assume that each smartphone acts as a node of DTN, which ensures network connectivity without relying on communication infrastructure (e.g., 3G cell towers) by following a store-carry-and-forward manner for message delivery. We focus on a medical image delivery service over DTN, where medical images are generated by doctors in disaster area, packed to bundle messages, then they are carried and forwarded by the rescuers and ambulance drivers to deliver the images to the city hospital for diagnosing the condition of eye injury.

We propose a new priority forwarding routing scheme with the image prioritization method over the existing DTN routing protocols such as Epidemic and Spray-and-Wait. These protocols are flooding based routing algorithms. In an epidemic routing, all messages in source node will be copied on the other meeting node. While in Spray-and-Wait the number of copies of a message is limited with a specified number of hops.

The goal of the proposed scheme is to minimize the delivery delay and to find the good ratio of delivering medical images at the hospital per unit of time.

3.3 Priority Medical Image Delivery Scheme

We propose a priority medical image delivery services with an image prioritization method used in standard DTN routing protocols such as Epidemic Routing. The goal of the proposed is to minimize the delivery delay and to achieve a good ratio of medical images that will be delivered to a hospital per unit of time. Taken into account the mobile device's buffer size and capacity, we design strategies to create the system, which efficiently deliver the messages during a disaster scenario. In our services, we will assign higher priorities to images and messages of more urgent cases. Furthermore, we select the parts of images that show the most serious injuries to give higher priority than others.

One of the main problems in image delivery is how to recognize urgent images as high priority data especially for seriously eye injury. To solve this problem, we introduce two methods: Color Marking based image segmentation and priority forwarding routing strategy. By dividing a large medical image into small pieces, we try to improve the throughput and reliability of DTN. After the system divides the image, the important pieces of the image are identified and a high priority is assigned to them. In addition, each intermediate node in DTN forwards the pieces that have higher priority prior to other pieces.

3.3.1 Priority Assignment to Images

Here, we describe the proposed priority assignment scheme in our system. In the proposed scheme, an image which is captured by a healthcare worker's smartphone is analyzed by an existing algorithm (android OpenCV to do image processing) [19] to detect the regions of eyes (i.e., the regions of left eye and right eye), and these regions are extracted from the image. This process is necessary for reducing the data size of the whole image. Then, the image is partitioned into sub-blocks [20], by splitting the whole image into pieces (or chunks) (see Figure

5 (left)). In our method, a region is partitioned into $n \times n$ (pieces) equal-sized sub-blocks as shown in Figure 5 (middle). Then, priorities are assigned to the subset of the whole pieces in the image, which a doctor thinks important (i.e., injured) by manually specifying the pieces with an interface provided by a developed smartphone application. For example, high priority is assigned to pieces containing serious eye injury such as eye blood, blur, or acute irritation (red eye). We suppose n=5 (the number can be changed), about 25 are assigned priorities by marking specific color. Here, red, green, and blue colors are marked for very-high, high, and medium-priority, respectively, and a gray color for low-priority.

Then, the remaining pieces without marking are removed from the storage. To diagnose medical images precisely, high-resolution image is needed. Thus, the system gives higher resolution to pieces with higher priority. For example in Figure 5 (right), red color pieces are stored with the highest resolution (i.e., largest data size) than the pieces with other colors.

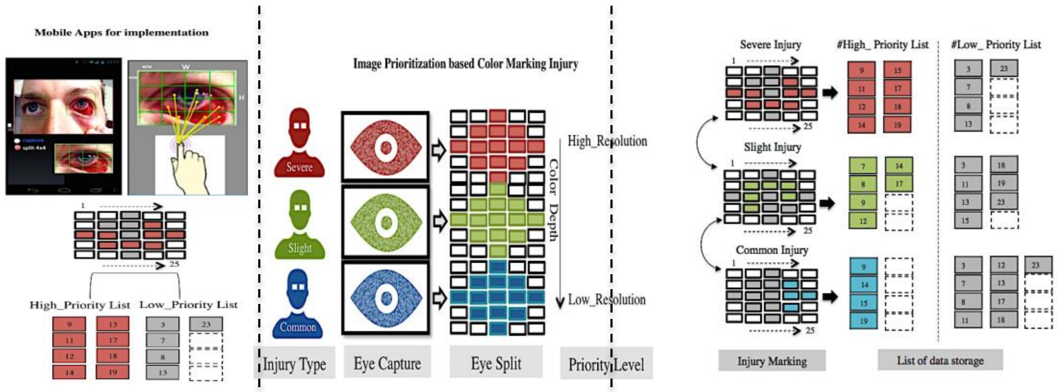


Fig.5 Image partitioning and image prioritization method

3.3.2 Message Priority Forwarding Scheme

In this section, we describe message selection scheme for priority forwarding on a small scale of disaster scenario. When a rescue node visits a healthcare post (source node location), it transmits pieces in the decreasing order of their priority level.

For example as shown in Figure 6, we suppose that there is a source node S which has 2 victims high-injury level (8 red pieces), 3 victims medium-injury level (12 green pieces) , and 4 victims low-injury levels (10 blue pieces). The high-priority list consist of 2x8=16(red pieces), 3x12=36(green pieces), and 4x10=40(blue pieces). And the low-priority list consist of [(2x13)+(3x13)+(4x13)-(16+36+40)]= (117 gray pieces). Further, All messages list will be divided into 4 priority message order such as 16, 36, 40, and 117 pieces with very-high, high, medium, and low priority, respectively that node S wants to deliver the pieces to node D. Suppose that node S meets nodes A and B in this order and that 16 pieces can be transmitted during a contact. When node S meets node A, it transmits 16 pieces with very-high priority to node A. After that, when nodes S meets node B, it transmits 16 high priority pieces to node B. Similarly, node S transmits the remaining pieces whenever it meets other node.

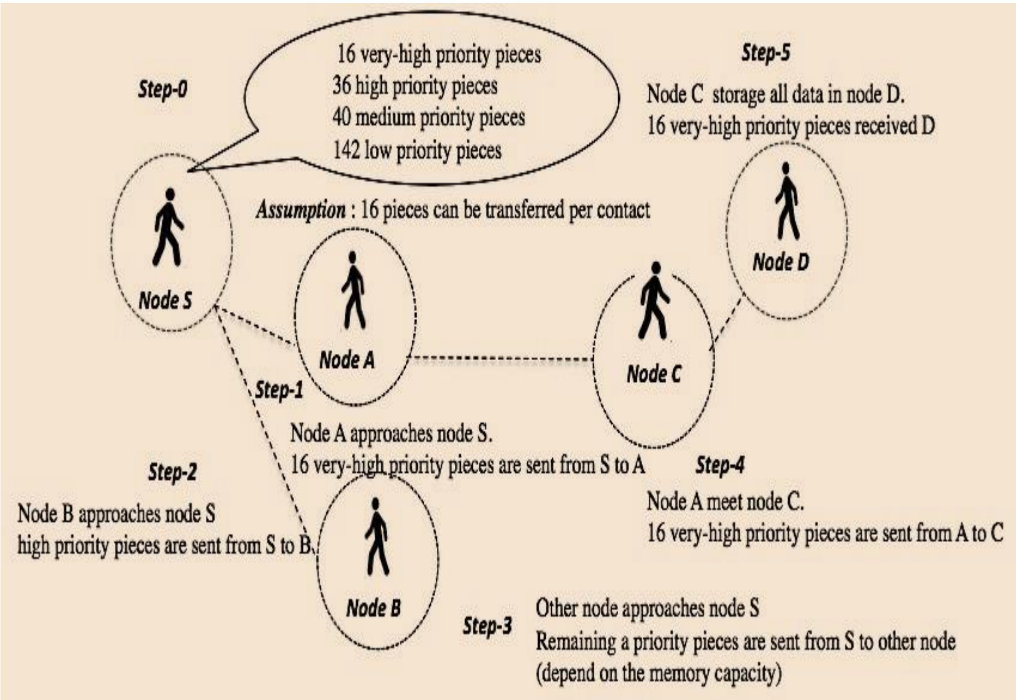


Fig.6 Messages selection and priority forwarding routing mechanism

Here, note that when higher priority pieces are received at node S (e.g., by taking new pictures, receiving the pieces from other node, etc), the highest priority pieces are always transmitted first. Then, when node A with 16 very-high priority pieces meets other nodes, say node C, the pieces are transmitted to C, similarly. Like this way, pieces are transmitted through multiple paths depending on their priority level to the destination node D.

3.4 Experiment

In order to confirm the effectiveness of our methods, we carried out some experiment for priority message delivery service.
We set up a simulation environment with a realistic eruption disaster map and some mobility node in an emergency medical response and compared performance of our proposed medical image delivery method with a conventional non-priority image delivery method through simulations. In order to create realistic node mobility to simulate emergency medical response, we used the Multi-Agent Module of Scenargie Simulator [21].

3.4.1 Volcano Disaster Scenario

We configured a simulation field of 2km × 2km using OpenStreetMap corresponding to an actual geographical area near Mount Merapi, Indonesia as shown in Figure 4. In our scenario, mobile nodes in a disaster area are equipped with smartphones or similar devices with Wi-Fi Direct at effective transmission rate of 5Mbps with 100m effective radio transmission ranges. The simulation parameters used for a small disaster scenario are shown in Table 2.

We assume a small-scale model scenario where 21 mobile nodes (20 rescuers and 1 ambulance) move in the simulation field (Figure 7). As shown in Figure 7, there are 10 red circles representing PoIs (Points of Interest), which correspond to health posts. In each health post, a healthcare worker treats patients. A hospital

(D) with ophthalmologists is located 30 km away from the disaster area parking lot (A) through only a direct path A-D.

Table 2. Simulation Parameters Small Scale

Parameter	Value
Simulation time	3600 second
Network interface	Wireless link
Interface type	Simple broadcast
Transmission range	100 m
Mobility of rescuer	Map Based Random Way Point
Buffer size	10 MB
Routing protocol	Epidemic, Spray-and-Wait
Number of nodes :	32
Number of rescuers, drivers, doctors	21,1,10
Speed of pedestrian nodes	0.5-1.5 m/s
Speed of Vehicle nodes	2.5-15 m/s
High-priority pieces size	35KB, 25KB,10KB,
Low-priority pieces size	5KB

Mobility patterns of rescuers and ambulance are specified as follows. Each rescuer moves to one of PoIs (reds dots in Figure 7) to find victims, following the shortest path from the current location. After visiting the PoIs, the rescuer moves to the parking lot (A) to carry the critical patient who needs the treatment at a city hospital. After that, the rescuer selects the other PoIs, and repeats the above behavior. Meanwhile, the ambulance shuttles between the hospital (D) and the parking lot (A) in the disaster area. Once the ambulance reaches a parking lot, it stops for 5 minutes (to carry a patient in ambulance), and back to the hospital again. At each health post, one doctor treats patients (there are 10 doctors in total in the disaster area). Each generated image is divided into 25 pieces and 13 of the pieces are marked with a color (red, green, blue, or gray) and delivered to the parking lot (A) through DTN by rescuers and then delivered to the hospital (D) by the ambulance. Here, in one-hour simulation time, 10 images (130 pieces with priority) are generated where 80 pieces are high-priority (40_{red}, 24_{green}, 16_{blue}) and 50 pieces are low-priority (50_{gray}). The total of image size is 3,005 KB. In simulations, we compare the performance of the proposed method with a conventional method in which there are non-prioritization by using Epidemic and Spray-and-Wait routing protocols.

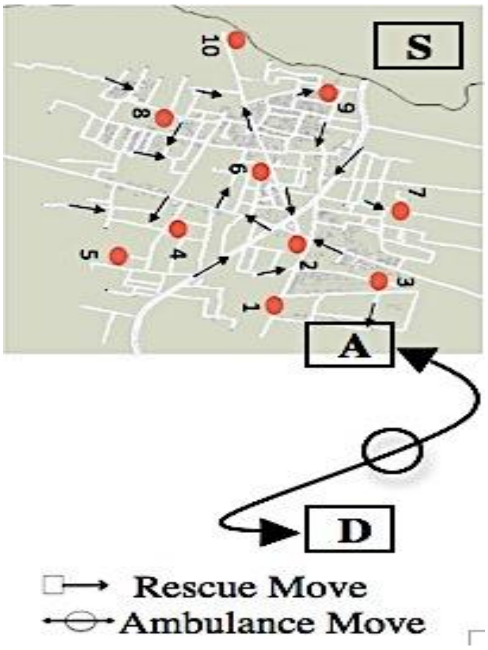


Fig.7 Simulation field on a small disaster scenario

3.5 Results

The DTN measurement results based simulator goals to maximize message delivery rate and minimize delay. The delivery rate is a ratio of the messages that arrived at the destination over all the messages generated in simulation time. The message delivery rate is defined by the following formula.

$$Message\ delivery\ rate\ =\ \frac{Number\ of\ message\ arrived}{Number\ of\ message\ send}\ \text{x}\ 100\ \%$$

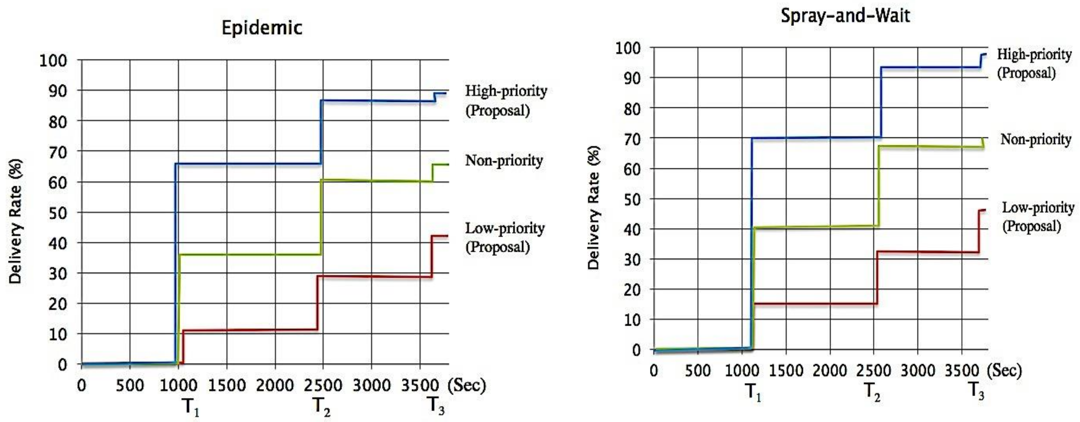


Fig.8 Message Delivery Rate

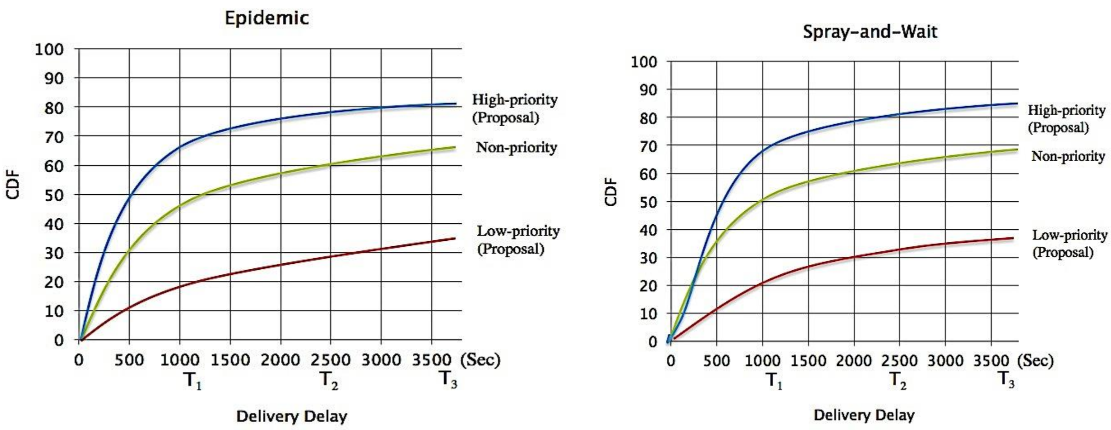


Fig.9 CDF of Message Delivery Delay

We measured the message delivery rate and the CDF (cumulative distribution function) of delivery delay at three points of simulation time (T_1=1200s, T_2=2400s, and T_3=3600s), which are shown in Figure 8 and Figure 9, respectively. Note that, in the experiment, we repeated the simulation 4 times with different random seeds, and the results are averaged. In the figures, high priority and low priority correspond to the performance of the proposed method and non-priority corresponds to the conventional method.

In Figure 8, there are three points where the delivery rate increases. These points correspond to the time when the ambulance arrives at the hospital. When comparing Epidemic and Spray-and-Wait, the latter shows a slightly better performance. The non-priority achieves about 70% delivery rate at the end of simulation time. On the other hand, the high-priority (our method) achieves 90% delivery rate, although the low-priority's delivery rate becomes lower than the non-priority. It is shown that the proposed method with message prioritization can deliver high-priority pieces faster than the conventional method without prioritization.

Figure 9 shows the CDF of message delivery delay. At simulation time of 1200 seconds, more than 70% of high priority pieces arrive at the hospital, while about 50% (Epidemic) and 55% (Spray-and-Wait) of non-priority pieces. For high-priority pieces, Spray-and-Wait slightly outperforms Epidemic, while for non-priority pieces, Epidemic performs better. In case of Spray-and-Wait bounds the total number of copies and transmissions per message without compromising performance. Under low load, Spray-and-Wait results in much fewer transmissions and comparable or smaller delays than Epidemic.

Table 3. Ratio of diagnosable images arriving at hospital by non prioritized method (10 images with 130 non-prioritized pieces where piece size is 25KB)

Received Message (KB)	ID of received image	ID of received pieces	# received pieces	# diagnosable image
T1=1250	Sa-Sh	SaP1-13,SbP1-13,ScP1-9,SdP1-5,SeP1-4,SfP1-3,SgP1-2,ShP1	Pt=30, Pn-42	2
T2=1600	Sa-Si	SaP1-13,SbP1-13,ScP1-13,SdP1-5,SeP1-5,SfP1-4,SgP1-3,ShP1-2,SiP1	Pt=42, Pn-54	3
T3=2110	Sa-Sj	SaP1-13,SbP1-13,ScP1-13,SdP1-13,SeP1-13,SfP1-5,SgP1-5,ShP1-4,SiP1-3,SjP1-2	Pt=48, Pn-62	5

We also evaluated our proposed method by introducing performance metric called “number of diagnosable images” referring to the number of images which can be diagnosed by ophthalmologist in a hospital. Our method manually detects eye injury part in each generated image and put a color (i.e., resolution) for each injury marked as described in Section 3.3.1. We define that for each image, we say the image is diagnosable if all high-priority pieces (i.e., red, green, and blue color pieces) in the image are received at the hospital. As shown in figure 10, an example testing which amount of red pieces should be complete delivered from source to destination at the simulation time for displaying the final image.

Table 4. Ratio of diagnosable images arriving at hospital by prioritized forwarding method (10 images with 80 high-priority and 50 low-priority pieces where piece size are 35KB and 5KB)

Received Message (KB)	ID of received image	ID of received pieces	# received pieces	# diagnosable image
T1=1400	Sa-Sh	SaH1-8,SbH1-8,ScH1-8,SdH1-8,SeH1-4,SfH1-3,SgH1-2,ShH1,SaL1-3,SbL1-4,ScL1-5,SdL1,SeL1-2,SfL1-3,SgL1-4,ShL1-5	H=32, L=20	4
T2=1850	Sa-Si	SaH1-8,SbH1-8,ScH1-8,SdH1-8,SeH1-8,SfH1-5,SgH1-3,ShH1-2,SiH1, SaL1,SbL1-2,ScL1-3,SdL1-3,SeL1-4,SfL1-4,SgL1-4,ShL1-5,SiL1-5	H=40, L=25	5
T3=2400	Sa-Sj	SaH1-8,SbH1-8,ScH1-8,SdH1-8,SeH1-8,SfH1-8,SgH1-8,ShH1-5,SiH1,SjH1,SaL1,SbL1-2,ScL1-3,SdL1-3,SeL1-3,SfL1-4,SgL1-4,ShL1-4,SiL1-5,SjL1-5	H=56 L= 35	7

We show that how many diagnosable images can be received at the hospital by using the conventional method in Table 3 and the proposed method in Table 4, respectively. As we see in Tables 3 and 4, the number of received diagnosable images at the end of simulation time is 5 for the conventional method and 7 for the proposed method. This result shows that our priority-based scheme can improve reception rate of diagnosable images, and give effective medical treatment to more patients with eye injury in volcano eruption than the conventional method without the prioritization scheme. The number of image diagnosable slightly improve two images, its mean that the probability of pieces to be received at the hospital that contains injury part higher than piece without injury by sending with the message priority mechanism. In case of non-priority transmission send the pieces based on the index of pieces order from top to down.

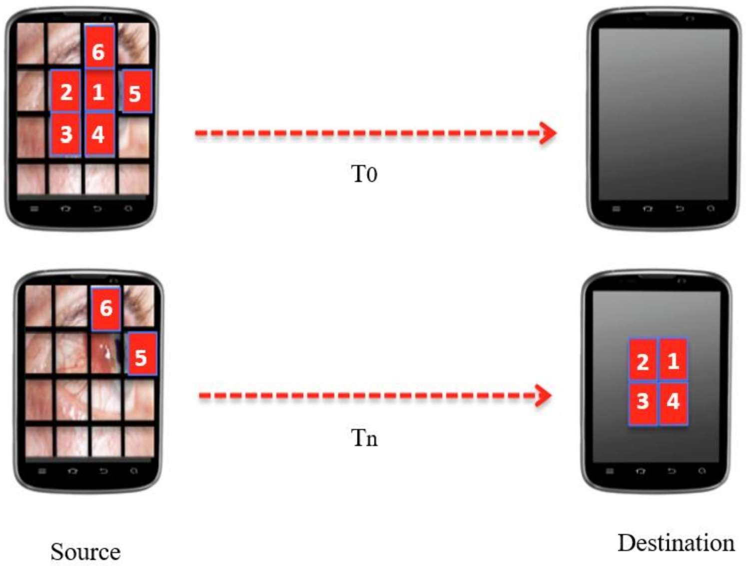


Fig.10 Diagnosable image measurement

3.6 Summary

In this chapter, we showed our basic design of a medical image delivery service over DTN in emergency situations, based on color marking prioritization of pieces in each injury image with color resolution value. The proposed priority forwarding mechanism shows better performance than non-priority approach when we use the Epidemic and Spray-and-Wait routing in terms of message delivery rate and message delivery delay.

Chapter 4
Prioritized Medical Image Delivery Services over DTN: Complete Design and Implementation

4.1 Introduction

This chapter gives a complete design and implementation of the proposed prioritized medical image delivery services over DTN.

The big challenge is how to deliver the most important images of injuries for a long distance from a disaster zone to the city hospital faster and with good delivery performance. In Chapter 2, we showed a basic design of a medical image delivery service over DTN with priority forwarding in a volcano disaster. This service shows better performance than existing systems in terms of message delivery rate and message delivery delay. It also delivers images of high priority faster, although the experimental scenarios in the simulation were limited

To support medical image delivery services for healthcare workers through DTN in a volcano disaster situation, in this chapter, we focus on how to make our services more practical by designing a more efficient prioritization method of images and a data forwarding/routing mechanism, and implementing the service on prevalent mobile devices. To achieve an efficient delivery service in a volcanic emergency, first we extend our prioritization method so that an image is divided into multi-level priority pieces and different bandwidth is allocated to each priority level. We have also developed a new Android application that divides each captured image into fixed-size pieces and facilitates healthcare workers in manually assign a priority level to each piece depending on existence of the injury and its seriousness. Pieces are then sent to the destination (e.g., city hospital with a specialist) as messages via DTN. To deliver higher-priority pieces (messages) faster and with better quality, we propose a priority messages forwarding scheme for DTN. In this method, first the size of each message is reduced depending on its priority (i.e., more bytes are used for a higher priority piece) and each DTN node sorts messages in its buffer in the order of their priority and sends the highest priority message to its neighboring nodes one by one through a general DTN routing protocol (e.g., epidemic routing).

Through computer simulations supposing a realistic volcano disaster, we found that the proposed method improved the message delivery rate at the hospital by up to 20% compared with the non-priority case when we use epidemic routing.

4.2 Medical Image Delivery Services Model: Target Scenario and Assumptions

The medical image delivery service sends images of victims via a DTN in a volcanic disaster scenario. We model the DTN as a set of mobile nodes. A contact occurs when two nodes meet within their wireless transmission range, creating an opportunity to exchange data (see Figure 11).

We suppose a realistic volcanic scenario where emergency medical response teams consisting of rescuers and ambulance drivers provide services to victims. In this scenario, emergency medical response teams are treated as mobile nodes. We assume that multiple healthcare posts and one or more ambulance parking lots are located in the disaster area. At each healthcare post, a healthcare worker treats victims and takes pictures of their eye injuries using a mobile phone. Ambulance drivers move between a parking lot and a hospital to convey the victims with heavy injuries to the hospital.

In this situation, the proposed medical image delivery service aims to deliver the eye injury images of victims taken at healthcare posts to a city hospital with a specialist (i.e., ophthalmologist) and get feedback (i.e., medical instruction) for appropriate treatment of the victims.

For connections between healthcare posts and the city hospitals, the service assumes the following.

- Healthcare workers, rescuers, and ambulance drivers have mobile phones (e.g.,Android smartphone) with cameras and Wi-Fi Direct communication.
- On the mobile phones, the medical image delivery application for taking and segmenting pictures of injuries and placing priority on each piece of the pictures is already installed.

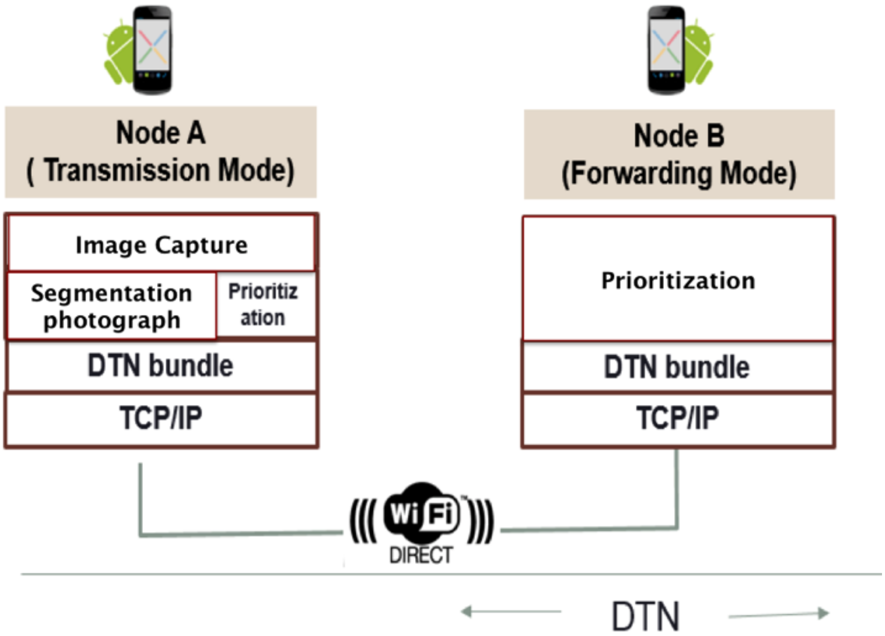


Fig.11 Mobile Nodes Exchange Data with DTN model

The application includes mobile DTN networking software including a bundle routing protocol (e.g., IBR-DTN) [22] and our priority message forwarding mechanism (proposed in Sect. 4). We also assume that hospitals have network infrastructure such as an Emergency Medical Network or Wi-Fi network through which ambulance drivers can send messages stored in their phones to specialists in the hospital.

The schematic architecture of the proposed medical image delivery service is shown in Figure 12. All images can be transferred from a disaster area to a hospital using DTN by using the proposed medical image delivery application. First, the image will be processed in the application by a healthcare worker and passed to the bundle protocol. Second, the images will be forwarded (e.g., from a rescuer's mobile phone) using Wi-Fi Direct communication to the mobile phone of another rescuer who arrives at the healthcare post and then returns to the ambulance parking area. Finally, the ambulance driver will deliver the images received from the rescuer to the city hospital, which has a communication network for sending images to the ophthalmologist at the hospital.

In the application, we also implemented a function to automatically stitch together received image patches to restore the original image so that the ophthalmologist can easily examine the image with his/her smartphone/tablet.

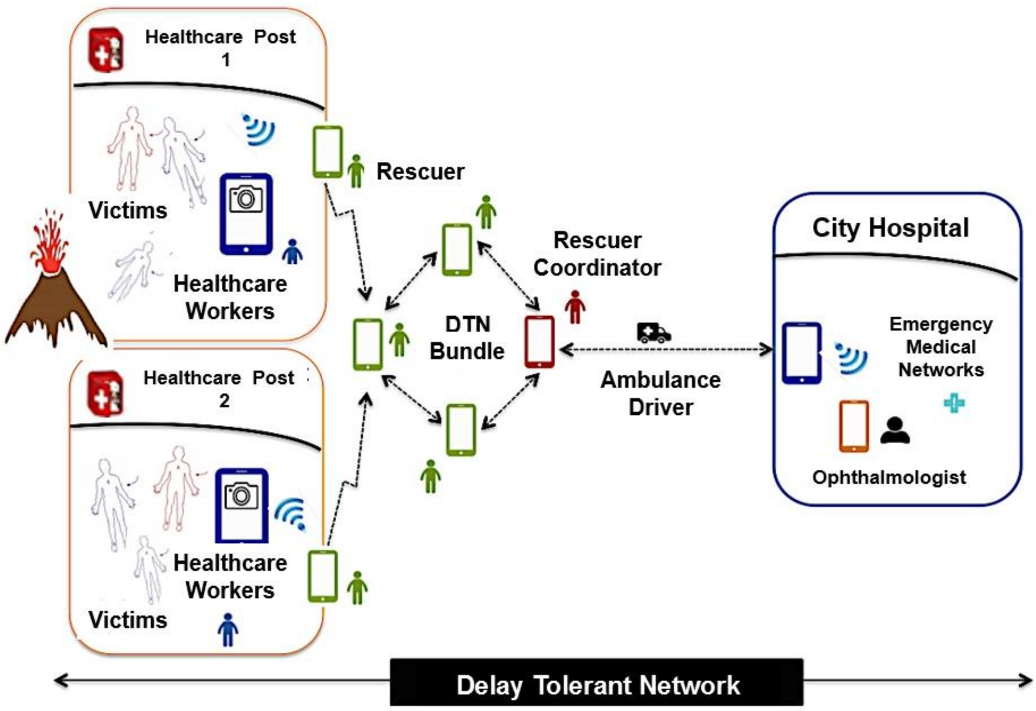


Fig.12 Schematic architecture of medical image delivery services

4.3 Priority Medical Image Delivery Scheme

We propose a priority medical image delivery scheme with an image prioritization method used with standard DTN routing protocols such as epidemic routing. The goal of the proposed scheme is to reduce the delivery delay and to achieve a good delivery ratio of good quality medical images delivered to a hospital per unit of time. Taking into account the mobile device's buffer size and communication capacity, we have designed strategies to build the system for efficiently delivering images in a disaster scenario.

In our proposed scheme, we assign higher priorities to more urgent images so that those images are delivered faster. Furthermore, we select the parts of images that show the most serious injuries to give them a higher priority.

4.3.1 Assigning Priorities to Images

We use a method like medical triage (i.e., color codes), for recognizing volcano victims who are in critical condition and must be brought to a hospital for immediate treatment. In disaster situations, victims are grouped into four categories, coded red, yellow, green or no color. Then, the image of each victim is partitioned into sub-blocks by dividing up the whole image into pieces. For efficient delivery of both high-and low-priority pieces, we make each piece have a different data size and number of pixels depending on the color code assigned to the piece.

The color code indicates the degree of priority. Based on the seriousness of the injury, we classify the images into two groups, high-priority and low-priority. Here, we suppose that high-priority is assigned only to the pieces including eye injury. High-priority pieces are coded with red (meaning that immediate treatment is needed), yellow (treatment can be delayed), and green (injury is minor). Low priority images have no color code.

In our method, an image is partitioned into $n \times n$ pieces. Hereafter, we suppose n=5, but the number can be changed. We suppose that a healthcare worker takes an eye injury image and marks some of the pieces in each image using the medical image delivery application we developed.

Figure 13 illustrates the marking process with the application where three eye injury images are taken and, red, yellow, and green codes are given to them, respectively. The total number of high-priority pieces is 15: seven red, five yellow, and three green. The remaining 60 are of low priority. In a disaster zone without an ophthalmologist, this application can support healthcare workers by providing a way to transmit information about the symptoms of common eye diseases [23].

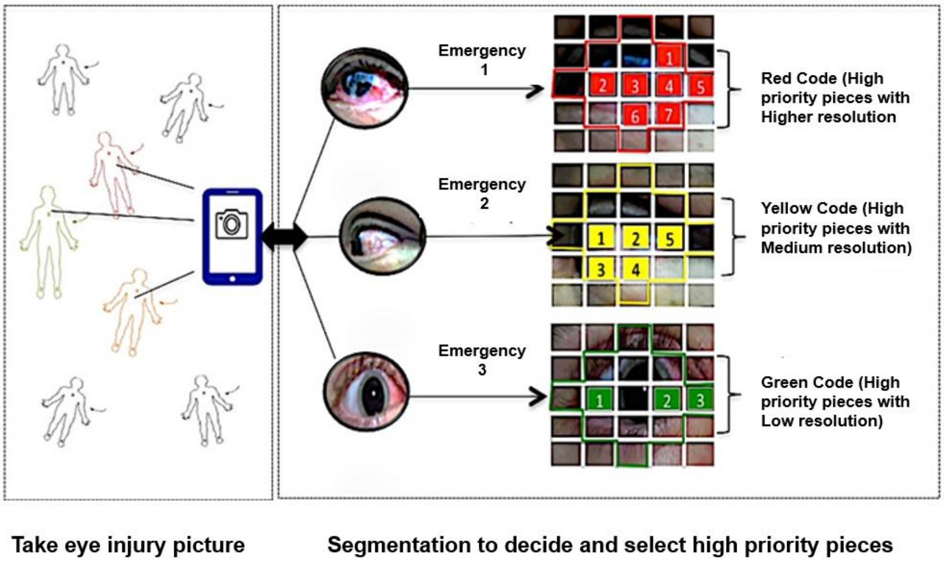


Fig.13 Assigning priorities to image

In the context of DTN application development, the message size affects the message priority forwarding strategy that will be used in our application. For a good delivery ratio in a disaster scenario, we use epidemic forwarding which can effectively handle data up to 500KB [24]. Thus, if the message size exceeds this value, we need to reduce the size to fit this value. Therefore, in our scheme we use image quality measures and reduce the image size-reduction approaches [25], [26] to solve this problem. Figure 14 shows an example of using the image-resizing method based on JPEG compression to reduce the size of the pieces. The application provides a blue seek-bar to adjust quality level from 1 to 100%.

For example, if the quality level is set to 80% for red pieces, each red piece is compressed to have the file size of 80% of the original piece. That is, specifying a higher quality level maintains the good quality in pieces. In Figure 13, 80%, 60%, and 40% quality levels are specified for red, yellow, and green pieces, respectively. The resulting sizes of red, yellow and green pieces are 64KB, 48KB and 32KB, respectively.

In general, JPEG file size does not depend on its quality and we need to carefully adjust the JPEG file size. We assume that various eye injury images have similar complexity in the images, and use 1.5MB (fixed size) for the base JPEG file size because Ref. [27] reported that ophthalmologists confirmed that this file size provides sufficient quality for diagnosis. Moreover, we use compression ratios of 80%, 60%, and 40% for red, yellow, and green pieces of injury images, because the JPEG images compressed with these ratios still have marginal quality that can be used for diagnosis by ophthalmologists [27].

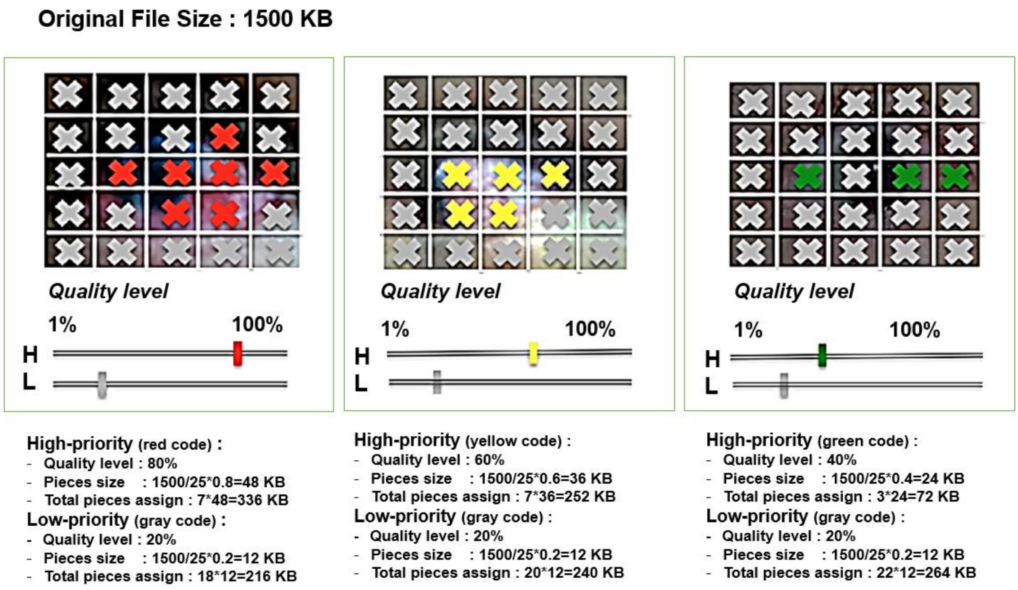


Fig.14 Sample of image resizing by image quality measures

To determine the actual size of pieces with good quality, the size of each piece should determined throug evaluation by an ophthalmologist (for example, finding grade quality such as good, acceptable, or poor). This investigation will be done as part of future work when implementation of android application is done and the proposed service is ready for actual operation in the future

4.3.2 Priority Forwarding Strategies

The most popular routing method used in a DTN is epidemic routing. To raise the probability of messages reaching their destination, each mobile terminal copies the messages received from other terminals and holds them. This routing scheme is appropriate when the message size and generation rate are small [28]. However, during disaster situations, images with large file size are difficult to deliver using epidemic routing. The drawbacks of epidemic routing are a rapid increase in network traffic, higher power consumption, and more terminal resource requirements. Thus, it is necessary to devise a way of reducing delivery time by prioritizing messages taking into account buffer size and the power consumption of mobile terminals. Therefore, we employ the following strategies.

1. To add a priority forwarding mechanism to epidemic routing where higher priority pieces are copied to other nodes prior to lower priority pieces.
2. Allocate a different size to each piece depending on its priority as we already explained in the previous subsection.

For strategy 1, we employ different message-handling algorithms between the healthcare worker nodes and other nodes. The details are described below.

Algorithm for healthcare worker nodes

To increase message delivery rate, after each healthcare worker node generates messages (corresponding to an image), it sets TTL (e.g., 3,600 seconds) for those messages and sends them to the rescuer node it contacts. Each message has a chance to be sent to multiple nodes within its TTL. The messages are removed after their TTLs have expired.

Let U and S denote the set of unsent messages in the buffer, and the set of already sent messages in the buffer, respectively. Initially both U and S are empty. Whenever a new image is generated, the corresponding pieces (messages) are added to U. During the contact between the healthcare worker node and the rescuer node, messages in the buffer are handled in the following steps 1 to 3.

1. If $U \neq \emptyset$, then send the highest priority message $u \in U$ and update U and S as follows: $U \leftarrow U \setminus \{u\}$, $S \leftarrow S \cup \{u\}$.
2. If $U = \emptyset$, then send the highest priority message $s \in S$.
3. For each $s \in S$, if TTL of s has expired, then $S \leftarrow S \setminus \{s\}$.

Algorithm for other nodes

Each node other than healthcare worker nodes removes messages in its buffer after sending them to another node.

- When a node meets another node, it sends the highest priority messages in the buffer during the contact.
- When a node receives messages from another node, those messages are added to the buffer and all messages in the buffer are sorted in the order of their priority (i.e., high: red, yellow, green, then low).
- When the buffer has no room for new messages, the lower priority (or the same priority but older) messages in the buffer are dropped or new messages are dropped if they have lower priority than those in the buffer.

By using these strategies, high-priority pieces are delivered to the destination faster, and at the same time, lower priority pieces can also have higher probability of being delivered than using the original epidemic routing. Below, we show how these strategies are incorporated to the proposed prioritized medical image delivery.

4.3.3 Priority message forwarding

As shown in Figure 15, victims are treated at healthcare post sites (S) by healthcare workers, who need to find the shortest path for sending messages (pieces of images) to a destination (a city hospital, D_1, D_2, or D_3). A message (m) containing a high-priority piece should be sent before other messages with lower priority. Each message is propagated by rescuers (R) in the DTN and eventually delivered to a rescue coordinator (C) stationed in the parking lot. In this case, rescue coordinators store the messages and forward them to the ambulances, and the ambulances take the volcano victims (with serious injuries) together with the messages to the hospital.

In Figure 15, let us suppose that only one message (which includes multiple pieces) can be copied during a contact between nodes and messages m_{11}, m_{12}, and m_{13} include only high priority pieces, both high and low priority pieces, and only low priority pieces, respectively. To deliver multi-priority message transmission over DTN, we employ a strategy for first selecting messages that contain pieces with a higher priority. Suppose that the source node (S) meets multiple rescue nodes one by one. In this case, the first rescue node, which has a high memory capacity, will receive message m_{11} (high-priority pieces) prior to others. The second rescue node will receive a message m_{12} (high and low priority pieces). The third rescue node meeting the source node later will receive a message m_{13} (low priority pieces). This strategy is shown in detail as follows.

Step.1 Each healthcare worker (S) node has an ordered list with a number of pieces coded with red, yellow, green, and no-color. When a contact happens, it creates a message containing multiple pieces picked from the top of the list and sends the message to the rescue (R) nodes (i.e., intermediate nodes).

Step.2 The intermediate nodes deliver the received messages to the parking lot. They keep an ordered list of the received pieces. When each intermediate node meets another node, it creates a message consisting of multiple pieces picked from the list and forwards the message during the contact.

Step.3 All messages that arrive at the parking lot are sent to the rescue coordinator

(C). The rescue coordinator (C) collects all messages, creates/updates the ordered list of the received pieces and forwards messages containing pieces picked from the list to the ambulance driver when the ambulance comes to the parking lot.

Step.4 The ambulance driver keeps the received messages until they reach a hospital (D) and sends the messages to an ophthalmologist at the hospital.

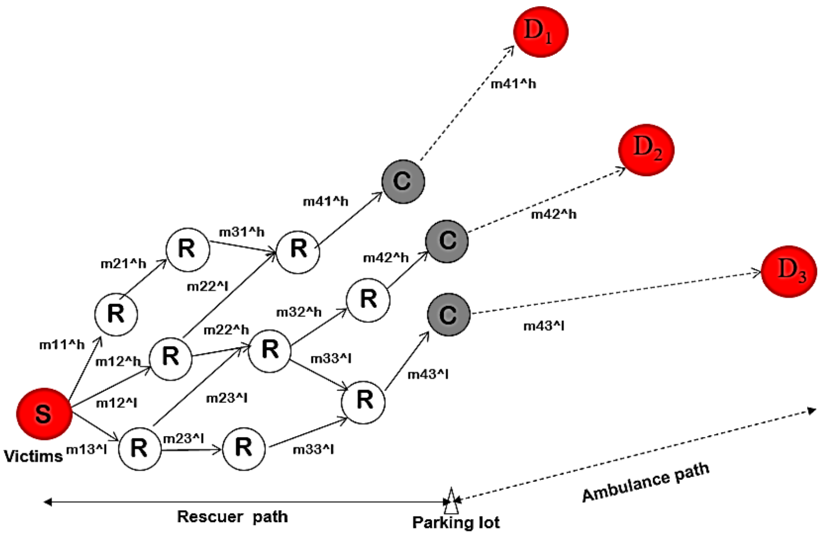


Fig. 15 Overview of DTN-based priority medical image delivery

4.4 Experiment

We set up a simulation experiment supposing a realistic volcanic eruption disaster map and a mobility model. Through simulations, we compare the performance of our proposed medical image delivery method with that of ordinary epidemic routing. To run the experiment in a realistic environment and thus simulate image delivery in an emergency situation, we use Scenargie Simulator (http://www.spacetime-eng.com/) with the Multi-Agent Module and DTN-Dot11. We present the simulation results using the volcano disaster scenario shown below.

4.4.1 Volcano Disaster Scenario

Using OpenStreetMap, we configured a simulation field on the main simulation area of 5 km by 5 km corresponding to an actual geographical area near Mount Merapi (in the region of the disaster area) and the city area (Yogjakarta, Sleman, Klaten) in Indonesia, as shown in Figure 16. There are healthcare workers, rescuers, and rescue coordinators in the disaster area. In each city hospital in the city area, there are ambulance drivers and an ophthalmologist at each city hospital. We determined randomly the location of 20 healthcare posts where victims are treated by a healthcare worker. Each of these locations accommodates 100 people, and we assume that 5-10% of them have serious eye injuries based on the Merapi eruption situation. Rescuers walk at a normal speed between a healthcare post and a parking lot. Also, each rescuer selects a healthcare post inside the disaster area, and finds the shortest path to a parking lot. A rescuer repeatedly walks between the parking lot and the healthcare site decided at random.

We set three locations for parking lots and placed one rescue coordinator at each of these, as shown in Figure 17. The rescue coordinators receive the image data, do a priority sorting of the data, and store the data in an ambulance. After arriving at the parking lot and picking up the emergency victims, the ambulance driver remains there for 10 minutes. During this time, the rescue coordinators transfer the image data to the ambulance driver, who then carries the messages to one of the city hospitals. The ambulance returns to the hospital from which it was originally dispatched. A contact opportunity with the ambulance comes only when the ambulance reaches the city hospital or the parking lot.

Table 5. Simulation Parameters large scale

Parameter	Value
Simulation Area	5 Km×5 Km
Simulation Time	2 hours
Wireless Com.	IEEE802.11g
Transmission range	10m
Buffer size	20MB
Message size :	500Byte, 1KB, 10KB, 100KB
	1MB, 2MB
Contact times	1s – 600s
TTL	3,600s
Numbers of nodes:	
- Victims (stationary)	100
- Healthcare workers (Stationary)	10
- Rescuer Coordinators (Stationary)	3
- Ophthalmologists (Stationary)	3
- Rescuers	20,40,60,80,100
- Ambulances Drivers	3,6,9,12,15
Mobility speeds:	
- Pedestrian (rescuers)	1-2 m/s
- Vehicle (ambulances)	5-12 m/s
- Distance to hospital	20 Km, 30Km, 40km

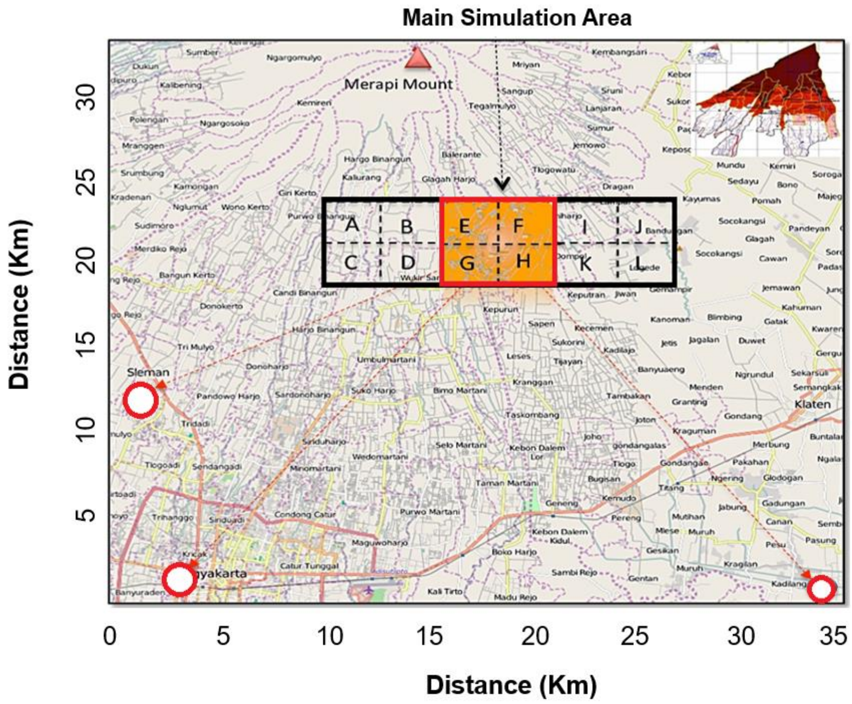


Fig.16 Mount Merapi Volcano Situation and Simulation Area

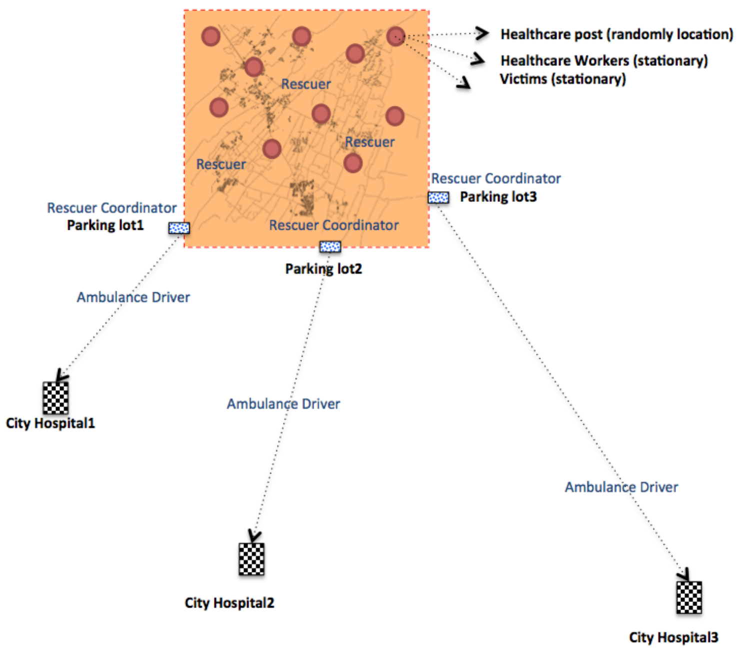


Fig.17 Simulation field for image delivery scenario

All nodes (healthcare workers, rescuers, rescuer coordinators, ambulances drivers, ophthalmologists) have mobile phones that have wireless communication capability and have installed our application. At the same time, each healthcare post has a healthcare worker who is generating images at rates of two messages per minute. The healthcare worker determines the priority of images depending on the seriousness of each injury. Each healthcare worker takes picture images with a smartphone camera and stores them in the buffer. After the images are split into pieces, they are transferred to the hospital via the parking lot.
To consider the delivery probability of data from each healthcare post to a hospital, we simulate different scenarios by changing the number of ambulances. The detailed parameters of simulation are shown in Table 5.

4.4.2 Testing Implementation on Mobile Devices and Applications

To analyze pieces delivered between nodes through the DTN protocol, an Android mobile terminal is used to transfer the image pieces between nodes when they come in contact.
As shown in Figure 18, we developed the DTN medical image delivery application, which can be used by healthcare workers to capture photographs and divide images into pieces. Pieces are stored in high-and low-priority files to be easily selected and forwarded as a prioritized images using an IBR-DTN Android implementation [29].
With the user interface of the mobile application, users (healthcare workers) manually capture images of an eye of a victims. A user can easily recognize the seriousness of an injury and determine the priority of the image pieces by using the interface. Then, all pieces are stored and forwarded using a DTN bundle protocol. Finally, the pieces are sent based on their priorities to facilitate the diagnosis using the image by an ophthalmologist. The pieces received at the hospital can then be merged.

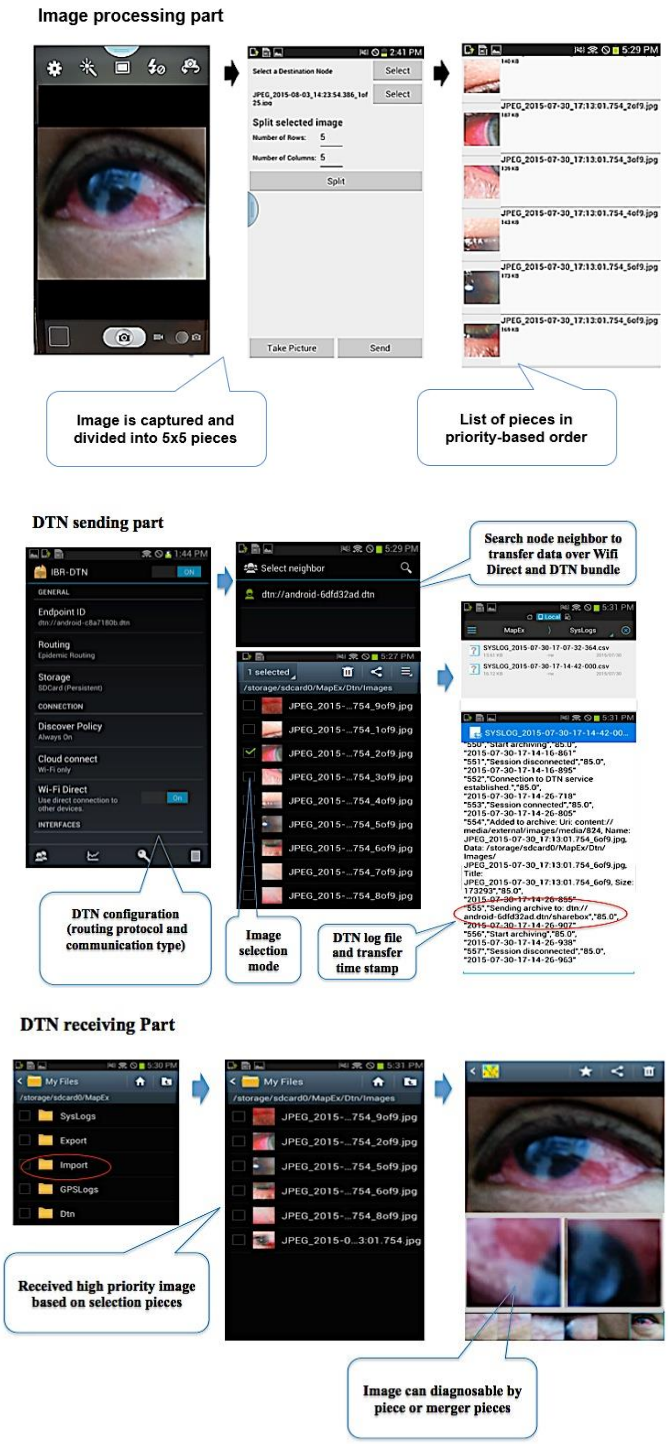


Fig. 18. User interface of medical image transfer by mobile application

We assume that the ophthalmologist in the hospital has a smartphone in which our app is already installed. Therefore, when all (or part of) image patches arrive at the destination (final user, that is, the ophthalmologist), they will be automatically stitched together to restore the original image. Here, note that the missing (not-received) pieces in the restored image remain blank.

To complete a testing and implementation part on android devices, the services needs to be built as an app with the priority forwarding scheme in the future. For this purpose, a priority scheme needs to be embedded into IBR-DTN routing protocols by modifying their code.

4.5 Results

In this section, we measure the message delivery rate with respect to time, message size and number of mobility nodes (ambulance drivers, rescuers).
Figure 19 shows how the delivery rate of a message is varied over an interval of two hours when the number of rescuers is 60 and the message size is 500Byte. Each simulation is conducted four times and averaged.
Moreover, to know the impact of each parameter, we changed the message size from 1 KB to 2MB, the number of mobility nodes from 20 to 100 rescuers and the number of ambulances from 3 to 15, which deliver messages from the disaster area to the city hospital on three-lane roads. We show the results in Figure 20a, 20b and 21a, respectively. In all cases the message delivery rate when priority is considered is higher. In Figure 21b, it is clearly seen that the message delivery rate is quite high when giving priority to the image of eye injury as well as increasing the number of rescuers and ambulances.
A showcase timeline of the total time transfer measurement process is presented in Figure 22. The generic steps were: (1) record the image processing time (T1); (2) send pieces copy file to send DTN bundle delivery time (T2); (3) start image transfer to other device time (T3); (4) store pieces copy file to receive DTN bundle

delivery time (T4) and view images kept in storage (T5). The areas marked in a gray block represent the time slots relevant for our measurement. The average times of total image transfer is shown in Table 6

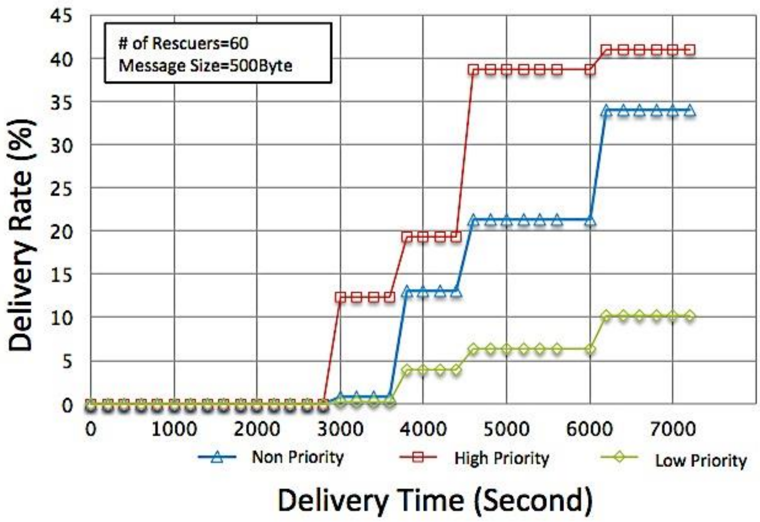


Fig. 19 Message Delivery Rate vs. Delivery Time

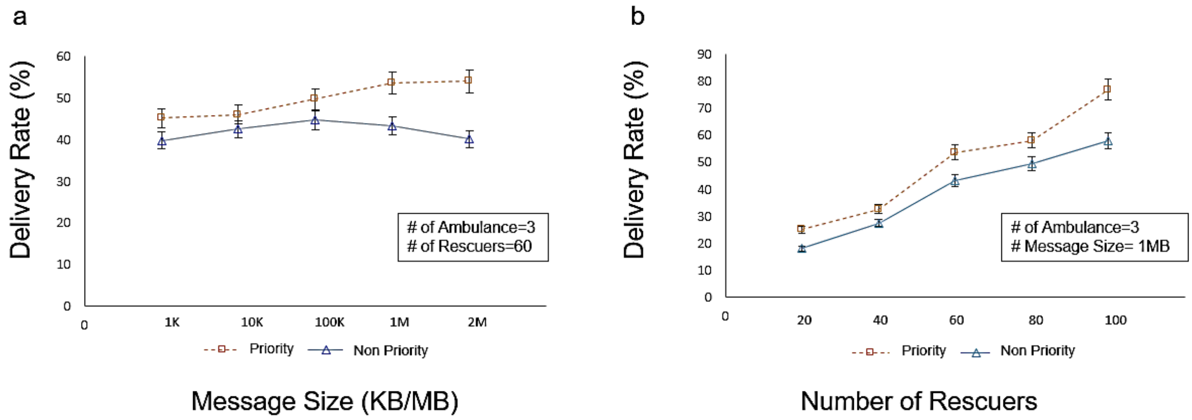


Fig. 20. Message Delivery Rate vs. Message Size, Number of rescuers

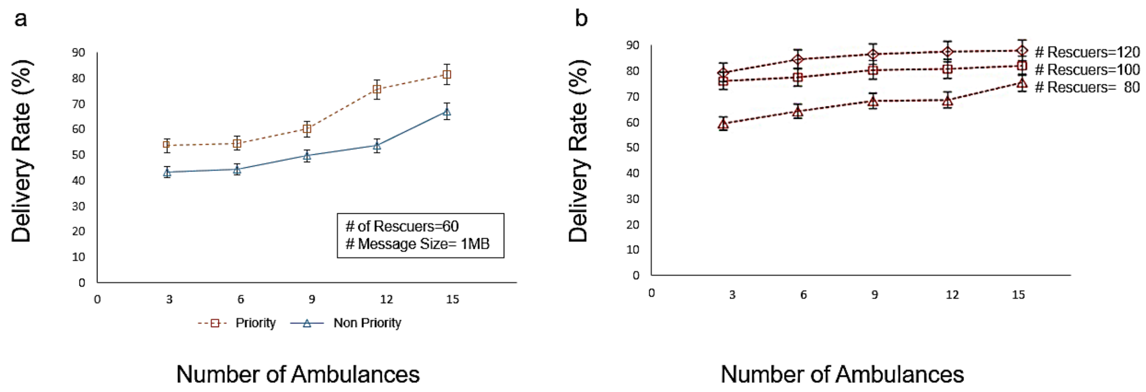


Fig.21 Message Delivery Rate vs. number of Mobility Nodes (ambulances)

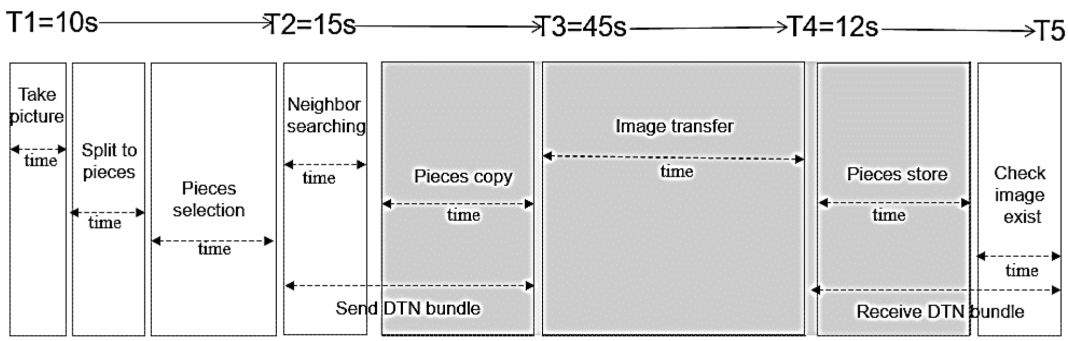


Fig.22 Timeline for image transfer measurement

Table 6. Time transfer measurement for priority images

Users	Image Size in KB	# of pieces		Time in Seconds
		High	Low	
A				
Image1	1890	7	6	74
Image2	1640	5	8	61
Image3	1310	3	10	50
B				
Image4	1920	8	5	85
Image5	1685	5	8	68
Image6	1380	4	9	57
C				
Image7	1845	7	6	72
Image8	1610	5	8	67
Image9	1275	4	9	51
D				
Image10	1935	8	5	82
Image11	1630	6	7	70
Image12	1395	4	9	60
E				
Image13	1870	7	6	75
Image14	1625	5	8	66
Image15	1370	3	10	51

4.6 Evaluation

We performed a medical image transmission analysis on a simple mobility scenario in a volcano disaster area to determine the successful delivery ratio using a mobile wireless link. The available time that a node can use for data transfer is based on priority and the message forwarding strategies in an environment where only DTN or opportunistic links are available. The performance metrics we considered are of two types: (a) the first one is measuring a good probability of delivering a message taking into account additional variation of parameter settings such as message size, number of intermediate nodes, and ambulances nodes; (b) the second type is to measure the actual time of transferring a medical image with the implementation on the mobile devices using a prioritized image and DTN protocol.

Figure 19 shows the message delivery rate. There are four points at which the delivery rate increases. The high-priority pieces' delivery rate is approximately 41% at the end of the simulation. In other cases, non-priority pieces' delivery rate is 34% whereas the low priority pieces' rate is about 10%. As a result, the proposed method can deliver a message faster than the conventional method (i.e., epidemic routing without a priority mechanism). In this case, each ambulance has a different route and distance to travel from the hospital to the parking lot in the disaster area. In the figures, the performance of the proposed method is shown for high-priority and low-priority delivery, while non-priority delivery corresponds to the conventional method (epidemic routing without prioritization)

By evaluating the results in Figure 20a, it can be observed that there is a significant improvement (10%) in the message delivery rate using prioritization if there is an increase in message size. These results are due to a better choice of high-priority messages. That is, based on the proposed forwarding scheme, the message with the highest priority should be on top of the queue and be forwarded before the others. The messages with high-priority images, tend to reach their destination faster, thus keeping the average delay lower.

According to the results (Figures 20b and 21a), it can be observed that both priority and non-priority images can have better delivery rates as the number of mobile nodes such as rescuers or ambulance drivers increases. This is because the contact opportunity between mobile nodes increases as the number of the mobile nodes increases.

Many messages with a low priority could not be delivered due to the limited capacity of the ambulance when the number of ambulances is small. Therefore, we increased the number of ambulances and the number of rescuers. As a result, the message delivery rate increased from 76% to 90% by the end of the simulation (Figure 21b). This shows that 90% of all 60 generated images could be delivered as a result of the increased frequency of ambulance coming to the parking lot.

To evaluate the actual transferring time on the medical delivery service implementation, we have measured an average time transfer for each piece in a priority image between two Android devices. We asked five participants to join the experiment. Each participant was asked to transfer three images with injuries of varying seriousness and of different sizes. The total number of pieces to be transmitted (of high and low priority) was 13 pieces. As shown in Table 2, the average transfer time for the 1st, 2nd, 3rd images were 77.6s, 66.4s and 53.8s, respectively. The transfer time decreases as the users get used to do the transfer process. The transfer time was greater when the number of high priority pieces exceeded the number of low priority pieces.

4.7 Summary

Based on priorities in medical image delivery through DTN in a volcano disaster scenario, we noted that the message delivery time could be shortened by using message priority routing strategies and prioritizing images according to the seriousness of injuries. We have improved the delivery rate in the simulated experiments by increasing the number of mobility nodes (rescuers and ambulances drivers)

In this chapter, we described the performance of medical image delivery using existing DTN protocols in a disaster situation. We proposed a message priority forwarding scheme, which is added to the epidemic routing protocol. The proposed method is designed to increase the delivery rate of high-priority messages so as to increase the number of messages delivered by healthcare workers at a volcano disaster. The results were evaluated using simulations and by implementation on mobile devices. The outcome showed faster delivery of medical images in the emergency scenario, and the number of successfully delivered images with prioritization that could be used for diagnosis at a hospital was higher than with a conventional method (epidemic routing without prioritization).

Chapter 5

Conclusion and Future Work

5.1. Conclusion

In this dissertation, we have presented priority medical image delivery services over DTN, whereby messages are being forwarded based on an image prioritization scheme and a priority message forwarding scheme.

The main motivation of this dissertation was to fill a need for the development and evaluation of new, priority based, message-forwarding strategies in the context of medical image delivery for treatment of injuries in disaster areas, utilizing the existing DTN technologies. Additionally, we sought to evaluate the performance of this modified DTN forwarding schemes through simulations. Then, we decided to focus our development on the priority message forwarding mechanism on top of Epidemic routing. This was due to its ability to faster sending a message by adding a priority forwarding scheme to maximize message delivery rate.

In the meantime, the developed prototype of mobile phone applications has been tested through a simple experiment, where images are captured, divided to pieces, the pieces are manually marked by colors, and high-priority pieces are transferred between two android devices over Wi-Fi direct link and IBR-DTN protocol. From the experiment, we found that the average time to transfer one image was about 1-2 minutes. For practical use of the service on the real world Merapi disaster in Indonesia, we should consider to reduce the image delivery time by adding the function for automatically prioritizing image pieces with an image processing using android OpenCV.

Other problems to be solved in the future are to reduce overall image delivery delay to the hospital, when the ambulance driver in the scenario just stores and forwards image data until reaching the hospital. One of the possible solutions is to use embedded ubiquitous multimedia services integrating with the DTN application on the smartphone. We will describe the special services in the next section.

5.2 Future Work

In the future, we will implement the proposed priority medical image delivery service on top of an existing DTN protocol, aiming to help emergency victims. We have two problems to solve. First, the services need to be implemented not only for the volcano disaster but also for other types of disasters. Second, the services need to be extended to handle images of victims with a variety of diseases other than eye injuries such as skin burn, head injuries and others.

For the implementation of services on the Merapi Mount volcano disaster, we should consider mobile network communication problems in terms of the communication link between the parking lot and the hospital. The link capacity can be enhanced by using vehicle nodes with smartphones other than ambulances, but battery and memory capacity overhead may need to be solved. In this case, image data are distributed and stored directly on the smartphone. We will plan to create the services by designing and modeling mobile content sharing via Wi-Fi direct technology with some new algorithms to increase the probability of message delivery rate. For example, using a content sharing scheme can effective to analyze the practical feasibility of the priority image transfer by multi-hop phone to phone. Also, it can reduce the battery lifetime.

As mentioned above, to improve the performance of medical image processing and analysis, it is necessary to achieve automatic eye injury part detection in images. This is necessary because the application helps a healthcare worker to assign priority to image pieces based on the severity of image victim and reduces the time of delivery process compared to manual color-making to the injury part.

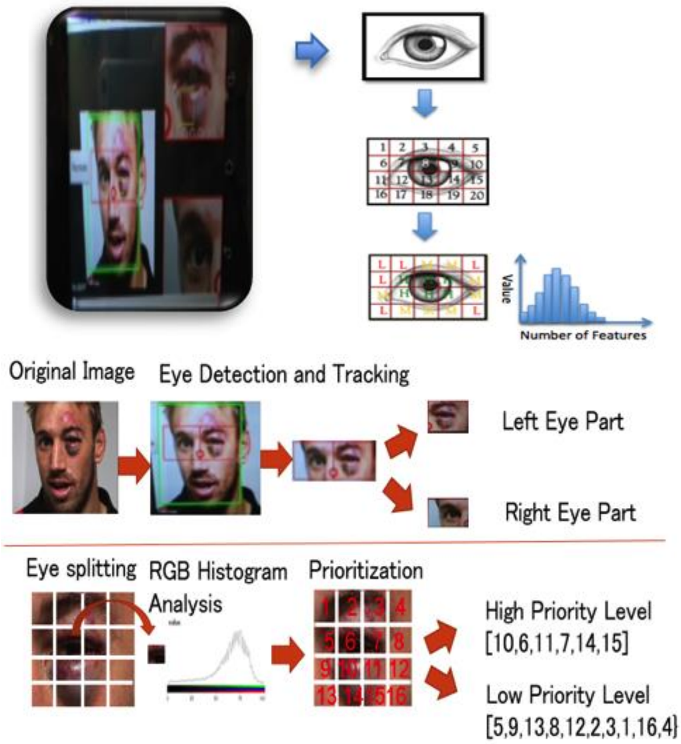


Figure 23. Prototype user interface automatically image priority

In addition, the application should also be able to detect diseases other than eye injuries even in the case of the volcano disaster situations, although automatic image detecting and segmentation algorithms for that purpose need to be studied more thoroughly. For the user interface, we will also need to improve it so that it processes more tasks such as capturing, splitting, storing, forwarding, sending and receiving of images (see Figure 23).

As part of future work, we will improve the proposed service in terms of efficiency of selecting high-priority pieces. For example, automating high-priority pieces selection through image analysis may be worth exploring; It could reduce the burden on healthcare workers at the disaster sites to a great extent.

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