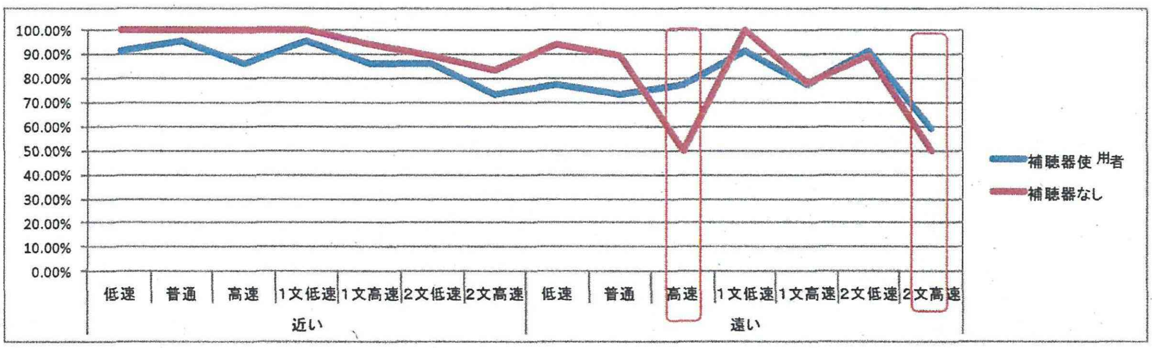
表３．赤の高速表示の部分で聴覚障害者の視覚認知度が有意に上昇する。



研究全体の具体的なロードマップ

平成24年度　システム設置、作動確認、初期評価

宮城県立聴覚支援学校

支援情報システム設置
アンドロイド端末メール機能、+クラウド連携、
電子表示器

アンケート・ヒアリング実施
対象：情報発信者　教職員
情報受信者　生徒・父兄

システム作動安定性確認

資料整理・解析

途中経過を学会発表

研究代表者　矢部
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アンドロイド端末10台
電子表示器　5台

評価用質問紙表作成、評価実施

研究分担者　上田
研究代表者　矢部、研究分担者　角田
研究協力者　伊藤、田内

平成25年度　問題点・現場の要望を抽出、中間評価

支援情報システム稼働状況確認

問題点・現場の要望を抽出

アンケート、ヒアリング
中間評価実施

資料整理・解析

途中経過を学会発表

フィードバック
ハード面での改良：通信状況の改善
ソフト面の見直：超高速表示対応

アンドロイド端末10台
電子表示器8台

平成26年度　最終評価、システム・機器の機能向上と完成、報告

支援情報システムの総合チェック

問題点・現場の要望を再抽出

→

フィードバック

ハード面:　**ネットワーク;AODV→OLSR**
CPU; Raspberry pie
中継ノード設置
家庭用表示器

ソフト面：超高速表示用ソフト
音声入力機能
返信機能
詳細避難ルート表示機能

アンケート、ヒアリング、評価用質問紙表
最終評価実施

↓

資料整理・解析

→

システム・機器全体の総合評価

↓

成果を学会発表・論文報告

- **成果報告**
- **障害者施策の充実への貢献**
- **聴覚障害災害時要援護者情報支援システム構築**
- **低予算、省スペース、手軽で使いやすい効果的な情報支援機器開発**

Ⅱ．研究成果の刊行に関する一覧表

研究成果の刊行に関する一覧表（雑誌）

発表者氏名	論文タイトル名	発表誌名	巻号	ページ	出版年
矢部多加夫	聴覚障害災害時要援護者支援情報機器評価（５）	日本集団災害医学会誌	18	219	2013
A Ito	Information delivery system for deaf people at a large disaster as web based embedded system	The Fifth International Workshop on Ad Hoc, Sensor and P2P Networks (AHSP2013)		422-428	2013
A Ito	Evaluation of an information delivery system for hearing impairments at a school for deaf	15^{th} International Conference on human-computer interaction	Ⅲ	21-26	2013
T Yabe	Development research of communication systems for the deaf people in a major disaster	AAO-HNSF Annual meeting & Oto Expo 2013			2013
矢部多加夫	聴覚障害災害時要援護者支援情報システム	第 58 回日本聴覚医学会	56	375-376	2013

Ⅲ．研究成果の刊行物・別刷

1. Atsushi Ito, Takao Yabe, Koichi Tsunoda, et al.: A study of optimization of IDDD (Information Delivery System for Deaf people in a major Disaster); ASON 2014 2014. 3. 6-8

2. Atsushi Ito, Takao Yabe, Koichi Tsunoda, et al.: Evaluation of an information delivery system for hearing impairements at a school for deaf. HCII 2014 2014.7

3. 矢部多加夫、角田晃一：聴覚障害災害時要援護者支援情報システム．第58回日本聴覚医学会誌56: 375-376, 2013

A study of optimization of IDDD (Information Delivery System for Deaf People in a Major Disaster)

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***Abstract*—In this paper, we describe the optimization of our prototype information delivery system (IDDD) designed for deaf people encountering major disasters for a scheduled trial in 2013, based on problems detected in a preliminary trial experiment. The two major problems that need to be addressed for the optimal design of IDDD are the delay of sending messages from the server, and the flexible maintenance of connections between LED displays, especially in emergency situations. Firstly, we compare performance between two information delivery methods (SMS and GCM) in detail. We conclude that GCM is better than SMS from the viewpoints of delay and stability. Next, we evaluated performance of OLSR from the viewpoint of quick route change, which is necessary to establish connection between devices. We conclude that ad hoc network performance using OLSR is better than implantation of last year using AODV for the purpose of our system. As a result of our analysis, we explain how to enhance IDDD for our planned trial in 2013.**

Keywords*—disaster information system; mobile phone; ad hoc network; OLSR; GCM; SMS;

I. Introduction

Based on research of the status of people with disabilities during the earthquakes in Kobe and Tottori [1,2], we designed the Information Delivery System for Deaf People in a Major Disaster (IDDD), using mobile phone and ad hoc networking technology with an evaluation test conducted in many different locations since 2007. We found many of the deaf were left without support during the disaster. Some of them were left alone at home and were unable to go to a shelter. In the case of a disaster, as the electric power supply is usually stopped, they are unable to receive information from TV. Half of those that died in the Kobe earthquake [1] were people who required support for evacuation, such as the elderly or disabled people. Therefore, an information delivery method for hearing impaired people is strongly required. We developed an information delivery system based on the mobile phone network and without AC power and performed several trials [3, 4], and obtained good results for commercial release. This system was designed based on the following requirements [3,4].

R1: Accurate information rapidly for deaf people

R2: Appropriate information according to individual situation

R3: Robust equipment to display information definitely

R4: Applicable for use in daily life

R5: No complicated operation

R6: Works during blackout

To achieve these requirements, we designed IDDD as follows.

1. IDDD was designed to send disaster information during a blackout. The main components are a mobile phone and LED display. Both can work with a battery. Disaster information is sent through the network or directly from a mobile phone.
2. IDDD displays disaster information on both mobile phones and displays.

3. A disaster message received by a mobile phone is directly transferred to a display via near field communication such as Bluetooth.

4. Display has the function of ad hoc networking to transfer disaster information to rooms automatically. A large wall-mounted or rack-mounted LED display is used in an office or public space, and a small box-type display is used in a residential living room.

We started a long-term (three years) field trial of IDDD at a school for the deaf in Miyagi prefecture, Japan. For the trial, we designed a new system and completed the trial of the first year [5]. Such a system has to guarantee the delivery of information. We designed IDDD from two viewpoints. One is quick delivery of information and second is stable connection of the LED display using ad hoc networking technology. Also, easy operation and maintenance are required. For that purpose, we introduced a web server based LED display using node.js. We installed LED displays in the school and used them as described in Fig. 1.

Fig. 1. Field trial at a school for the deaf in Miyagi prefecture

At the end of the first year, we discussed the problems of IDDD that were detected during the trial. There were three major problems as follows.

P1: The delay in sending the message from the server. One teacher felt that the delay was longer than expected.

P2: Flexible maintenance of the connection of LED displays in an emergency situation, such as the firewall in a corridor was closed. WiFi communication should be disconnected when a firewall that is located between two LED displays is closed.

P3: WiFi connection of LED displays between the first floor and the second floor was sometimes unstable.

In this paper, these three issues are discussed to optimize IDDD. To solve these problems, we performed several researches and found new design criteria.

We report the results of the system performance test and the user's evaluation of the new IDDD system [6] based on an experiment at a school for the deaf in Miyagi.

In Section 2, we explain the outline of IDDD and discuss related works in Section 3. Then in Section 4, we describe how to solve the problems described above. Future works are described in Section 5 and finally, we conclude this paper in Section 6.

II. Outline of IDDD

In Section 2, we explain the outline of IDDD. Fig. 2 is the outline of the design for the IDDD. IDDD consists of the person sending the information (S1, S2, S3 and S4 in Fig. 2), a receiver (mobile phone: Android Smart Phone, R1 and R2 in Fig. 2) and an LED display (D1 and D2 in Fig. 1). Utilizing this system has four patterns:

(1) Disaster information is sent from a person who is aware of the disaster (S1 or S2). The information is received by a mobile phone (R1 and R2) and transferred to the LED display (D1 and D2) directly.
(2) Disaster information is sent from a disaster information center of the government or an NPO (S2). The information is received by a mobile phone (R1 and R2) and transferred to the LED display (D1 and D2) directly.
(3) Disaster information in an office or home is sent locally by using a personal PC or mobile phone (S3 or S4) to the LED display (D1 and D2).
(4) Support information is sent by using a mobile phone or PC (S4), such as the time to provide lunch or information on missing people in an evacuation area to people. The information is sent to the LED display (D1 and D2) directly.

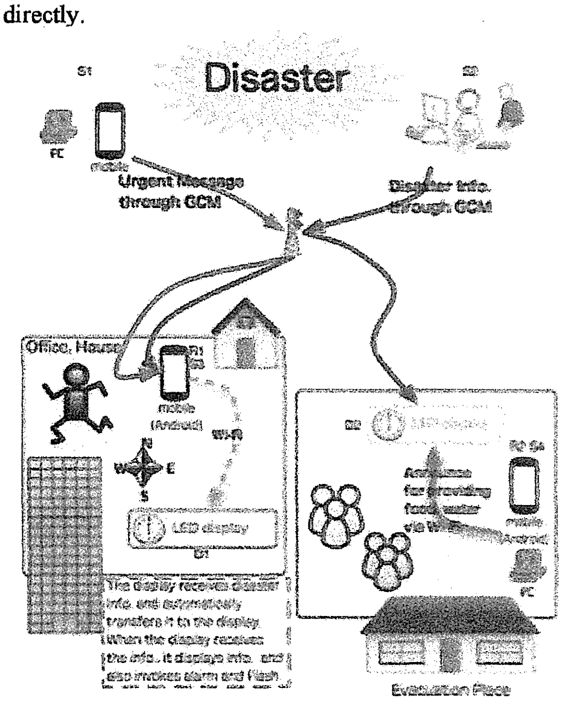

Fig. 2. Outline of behavior of IDDD

III. RELATED WORKS

Much research relating to disaster mitigation technology has been conducted. In this section, we introduce three researches and explain the difference of our approach.

A. SEMA4[7]

Reference 7 discusses the ontology for emergency notification systems accessibility. SEMA4A ontology presents an interesting idea. They proposed ontology to reduce the numbers of victims of accidents and diseases. The ontology presents a system of accessibility to information in the case of accidents for various people such as the disabled, elderly persons or tourists under different circumstances such as fire or traffic accidents. They also discussed various devices that can be used in the case of accidents and diseases.

Based on the SEMA4A ontology, they developed a prototype for automatically creating and sending personalized emergency notifications using different media and devices. Emergency notification is transferred by a combination of email, SMS, MMS, fax, phone etc. Also, they proposed an effective combination of media for various people profiles such as the deaf, blind, elderly, dementia sufferers, people with color blindness etc. Information is displayed using characters, pictures, sound, vibration, movies etc.

This research provides excellent ontology not only for the deaf, but also for various types of disability. However, they do not focus on large disasters specifically. We focus on large disasters that cause failure of electric power, broken lifelines, and the lack of information.

B. Mobile app development system [8]

This paper describes the mobile application development tool to support the transfer of food and blankets to victims of a disaster and harmonize the activities of volunteers. This is an excellent idea to support late Phase 1 and Phase 2 of the cycle of disaster (Fig. 3). However, our system also focuses on Phase 0.

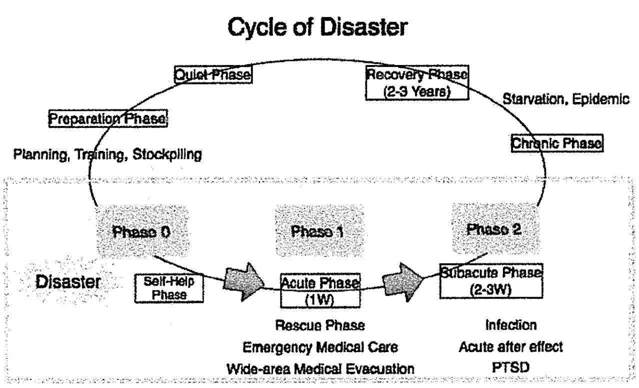

Fig. 3. Outline of Cycle of Disaster

C. New email notification of mobile phone in a disaster [9]

This research describes a new email notification mechanism that will work during traffic congestion in a disaster situation. This research describes the idea of WiFi offloading of SMS messages since SMS is now used to inform the arrival of email. This research focuses on sending email notification; however, our system focuses on sending a disaster message to deaf people.

IV. DESIGNING IDDD FOR TRIAL IN 2013

As described in Section 1, we mentioned three problems were detected during the trial in 2012.

Firstly, we would like to clarify which media is suitable for the WAN access network. We used SMS in the first generation of IDDD [3,4] and GCM (Google Cloud Messaging [10]) in the second generation IDDD [6]. We need to clarify which is better for IDDD since one teacher asked us as described in P1 in Section 1. We compared the performance of SMS and GCM in detail. SMS is a telephone network and GCM is an IP network. Both communication methods have different features. SMS covers both smart phone and feature phone and has a long history in sending short messages. GCM only covers Android, not iPhone and feature phones. However, there are several technologies based on IP based messaging such as MQTT (Message Queue Telemetry Transport) [11]. We evaluated GCM as one typical implementation of IP based messaging. We discuss the performance of SMS and GCM in the following two subsections.

A. Performance analysis of SMS

We set up the test environment as described in Fig. 4 to measure the performance of SMS. This test measured delay from mobile phone in S1 to R1 of Fig.2. Two mobile phones, Galaxy S2 with Android 4.04, were set in two locations, one was in Aizu-Wakamatsu (Fukushima prefecture) and the other in Ueno (Tokyo). We selected Aizu as typical local city and Ueno as typical larger city. Another reason we selected Tokyo as a research point was we are planning to perform next trial in one of school for deaf in Tokyo. In the both location, the smart phones were located in a room, fixed position where the condition of receiving and sending SMS were good. When a sender sent an SMS, a time stamp was included in the message and the receiver recoded the received message. We measured the delay at three time point per day at 10AM, 1PM and 5PM from August 8 (Thursday) to August 11 (Sunday). At the each time point, the phones sent SMS 16 times. The sending interval was two minute.

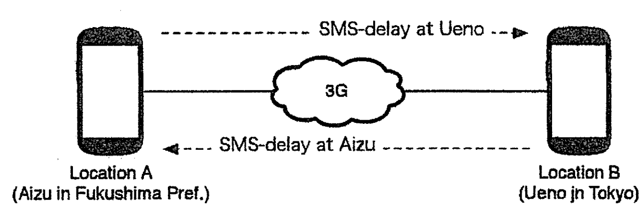

Fig. 4. The test system to measure performance of SMS

The result is displayed in Fig. 5. The average delay in the Ueno area was 16.6 seconds and 13.25 seconds in the Aizu area. In addition, delay in the evening of weekends was higher than other timeslots. The result of ANOVA (Analysis of variance) means that these two samples are different and the delay of SMS is affected by location. In the city area, the delay may increase. Also, the failure rate of SMS is sometimes very high. In addition, Fig 7 shows the message loss rate of SMS. The meaning of lost was calculated as follows.

Loss rate = (the number of received message / 16) * 100

For example, at August 10, 5PM, almost 60% of the message was lost. We think that it may be affected by congestion of telephone network. Also delay of the same time spot is high.

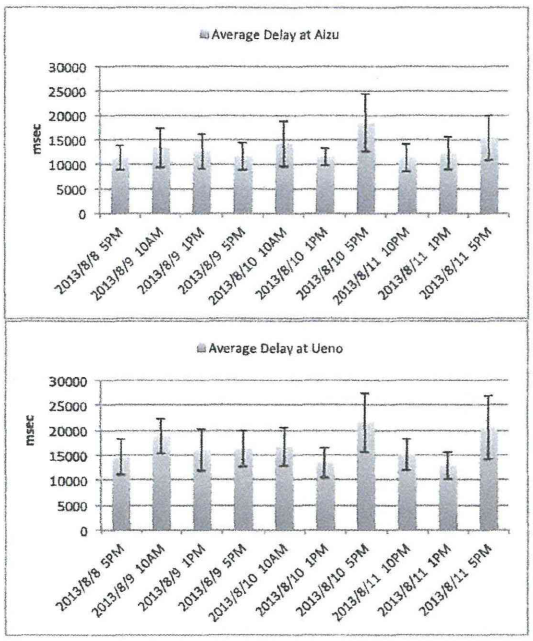

Fig. 5. Performance of SMS

Analysis of Variance (One-Way)

Summary

Groups	Sample size	Sum	Mean	Variance
Average Delay a	10	166,099.74762	16,609.97476	8,358,861.76838
Average Delay a	10	132,471.21805	13,247.1219	5,323,878.83887

ANOVA

Source of Variatio	SS	df	MS	F	p-level	F crit
Between Grou	56,543,896.69387	1	56,543,896.69387	8.265	0.01008	4.41387
Within Groups	123,144,665.46525	18	6,841,370.30362			
Total	179,688,562.15922	19				

Fig. 6. Result of ANOVA to compare the delay of SMS measured at Aizu and at Tokyo

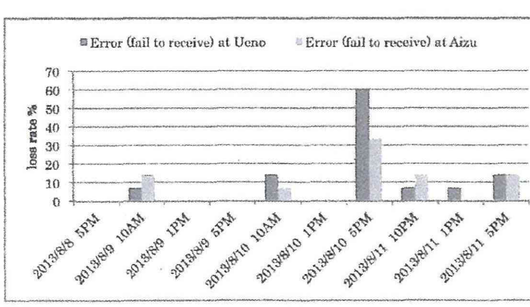

Fig. 7. Missing message of SMS

B. Performance analysis of GCM

We set up the test environment as described in Fig. 8. This test measured delay from PC in S1 to R1 and PC in S2 to D2 in Fig.2. Firstly, we set up a server in Amazon EC2 and sent a message to the GCM server and the GCM server sent a message to an Android phone. Two mobile phones, Galaxy S2 with an Android 4.04, were set up in two locations: one in Aizu-Wakamatsu and the other in Ueno. Setting position at the each location was as same as the test of SMS. A server in the Amazon EC2 sent a message to the GCM server with a time stamp. When the GCM server received that message, GCM server re-sent a message to a smart phone via mobile phone network. After the smart phone received the message, the smart phone sent back a message to the Amazon EC2 server with a time stamp of the message receiving time. We measured the delay three times at 10AM, 1PM and 5PM from July 29 (Monday) to August 4 (Sunday). The date of experiment of GCM was different from the experiment of SMS because of the restriction of equipment. We thought that measuring GCM at the same time spot is more important than measuring before or after the measurement of SMS to see the effect of congestion of the network.

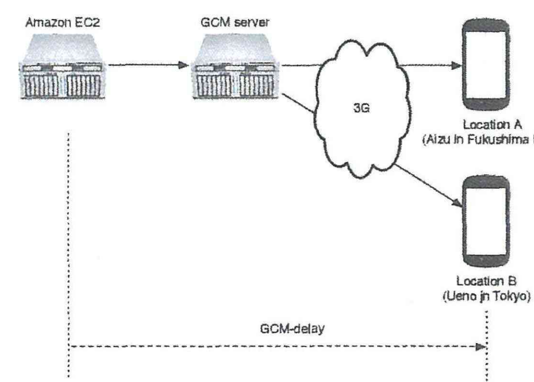

Fig. 8. Test system to measure performance of GCM

The average delay of GCM received at Aizu is described in Fig. 9. The average delay was 3.8 seconds. This is about 1/3 ~ 1/4 of the delay of SMS and the difference is about 10 second. Figure 10 shows the delay of GCM in the Ueno area. The average delay was 4.3 seconds. The result of ANOVA is shown in Fig. 11. The result shows that there is a difference between Aizu and Ueno. In Ueno, sometimes such as on August 1st at 10AM and on August 2nd at 5PM, volatile behavior from 10 seconds to 2 seconds is displayed. The delay of GCM in a city area is also not as stable as SMS. Comparing SMS and GCM as described above, the delay of GCM is shorter than that of SMS. As we described in [17], walking speed of children is about 50 or 60 m per minute. If we assume the length of corridor of a school is 30 m, difference of 10 second is 10m. It might be important such as large earthquake. Also there was no missing message in the case of GCM. This is a very important point to consider when designing IDDD. Therefore, we decided to use GCM as the message delivery network.

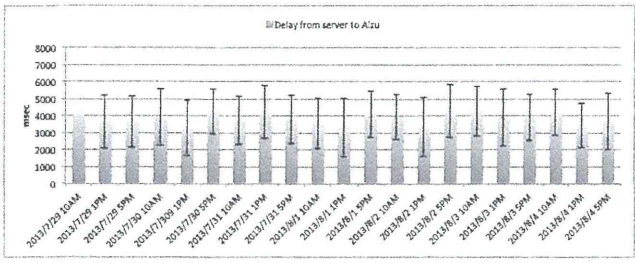

Fig. 9. Performance of GCM in Aizu (Fukushima prefecture)

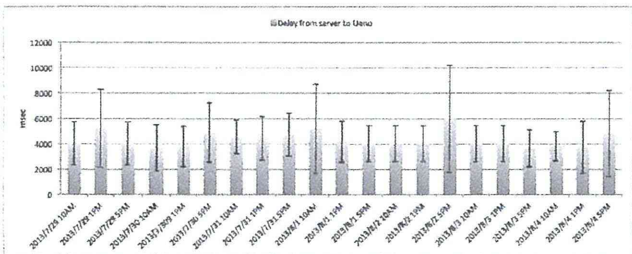

Fig. 10. Performance of GCM in Ueno (Tokyo)

Analysis of Variance (One-Way)

Summary

Groups	Sample size	Sum	Mean	Variance
Delay from server to Aizu	21	80,538.66667	3,835.1746	112,687.44999
Delay from server to Ueno	21	90,529.4381	4,310.92562	378,484.37511

ANOVA

Source of Variation	SS	df	MS	F	p-level	F crit
Between Groups	2,376,559.85106	1	2,376,559.85106	9.6771	0.00343	4.08475
Within Groups	9,823,436.50207	40	245,585.91255			
Total	12,199,996.35313	41				

Fig. 11. Result of ANOVA to compare the delay of GCM measured at Aizu and at Tokyo

C. *Performance analysis of OLSR*

Secondly, we would like to discuss the flexible and automatic maintenance of the connection of LED displays in an emergency situation, such as when the firewall in a corridor is closed. Usually, larger buildings such as schools and hospitals install firewalls to isolate damaged areas and protect healthy areas. We received a question from a teacher of the School of the Deaf in Miyagi prefecture on how to maintain the connection of LED displays in a real fire since firewalls are quickly closed in the event of a fire.

We have already introduced AODV (Ad hoc On-Demand Distance Vector) [15] as ad hoc networking technology to maintain the connection among LED displays [6]. However, we assumed a situation whereby LED displays had a flexible layout but did not consider firewalls. In addition, we changed CPU of the LED display from Beagle Bone [6] to Raspberry Pi [14] for the trial of this year since latter one is cheap, easy to get and performance is almost same (700MHz). Unfortunately, there is no AODV working on Raspberry Pi, so that we chose OLSR [13] as the ad hoc networking protocol. OLSR is proactive protocol and we expected that OLSR might have good performance for route change in the case of fire comparing to reactive protocol like AODV. But this is first time for us to use OLSR, so we have to check the performance of OLSR by using real device before construction system.

To discuss the performance of ad hoc networking, especially re-routing delay, we considered the relation between walking speed and scroll speed of characters on a LED display. Let's assume situation that students of a school are escaping from a classroom.

- They are not running but walking.
- They are walking 60m/min (3.6km/h) (based on our previous research in [17]).
- They can read information on an LED display 3m before arriving at the nearest edge of the display. This means that it is at about 4 seconds they can read the characters displayed on the LED display based on the above assumption.
- The fastest scroll mode can display 8 characters in one second.
- A message is scrolled until the next message arrives.

Based on these assumptions, if the re-routing is finished within one or two seconds, students never miss the emergency message. Usually, research of ad hoc networking is discussed based on throughput [12]; however, for an emergency information system like IDDD, no interruption of message delivery is the most important aspect.

Fig. 12 shows the experiment network to measure the re-routing speed of OLSR [13]. We designed this layout to measure the sensitivity of OLSR to change topology based on strength of WiFi signal. The layout described in Fig.12 was designed to emulate change of strength of WiFi signal by moving M to change distance between M-A and M-B. So that we decided the distance between A-Y and distance between B-Y were 1:2. Also the distance of B-Z and that of A-Z were also 1:2. For that purpose, we developed four nodes using Raspberry-Pie. Each node has an OLSR daemon and WiFi connection. Three nodes, S (start), A, and B in Fig. 12, are fixed. One node (M) moved from S to X, X to Y, Y to Z, Z to Y and finally returned to S via X. We call this node M (moving). The detailed movement is as follows.

(Step 1 in Fig. 12) M moved from S to X (15m, 0.5 minute)

(Step 2) M moved from X to Y (10m, 0.5 minute) and stay there (2 minute)

(Step 3) M moved from Y to Z via X (20m, 1 minute). M moved between Y and Z 10 times

(Step 4) M moved from Y to X (10m, 0.5 minute)

(Step 5) Finally, M moved from X to S (15m, 0.5 minute)

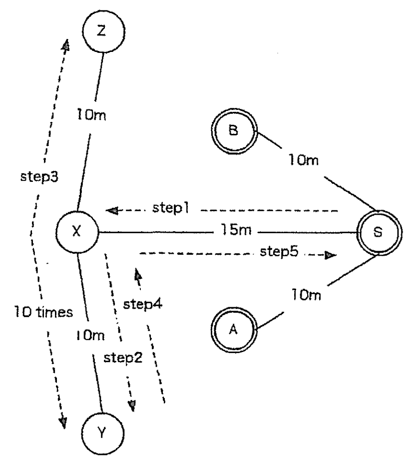

Fig. 12. Experiment network to measure re-routing speed of OLSR

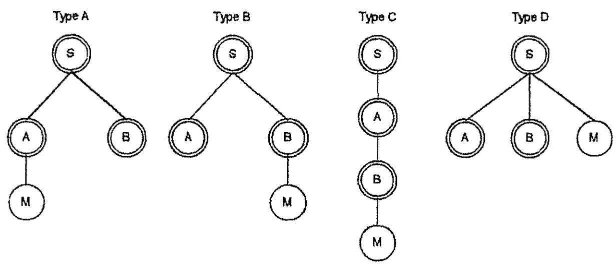

Fig. 13. Topology of nodes

Fig. 13 shows four network topologies we observed during this experiment. Of course, there are more possible topologies, however, we observed four types.

Fig. 14 shows the relation of history of movement of M and topology change. Fig. 14 also shows that the topology change between A and B is directly correspondent the movement of M between Y and Z via X. The topology change wad occurred in the middle of movement. Especially from 5:00 to 14:00, only one topology change was occurred during moving between Y and Z via X as described in Fig.12. Between 14:00 and 15:00, there are topology changes including C. I think that this change occurred by some disturbance caused by walking person etc.

Sometimes, OLSR was very sensitive. For example between 4:31 and 4:34 in Fig.14, topology changed in 3 seconds. In other measurements, we observed topology change in one second or two second. We assume that if connection of WiFi is blocked by firewall, OLSR can change topology immediately.

Fig. 15 shows the delay of message relay. This delay was measured by using "traceroute" command from S to other nodes. As described in Fig. 15, average delay was 98msec. There are 4 measuring points that shows large delay. The largest delay was about 1.1 second, so that the transmission among LED displays could be faster than delay measure in the trial at 2012 [5]. The average delay of trial in 2012 by using AODV was about 200 msec [15].

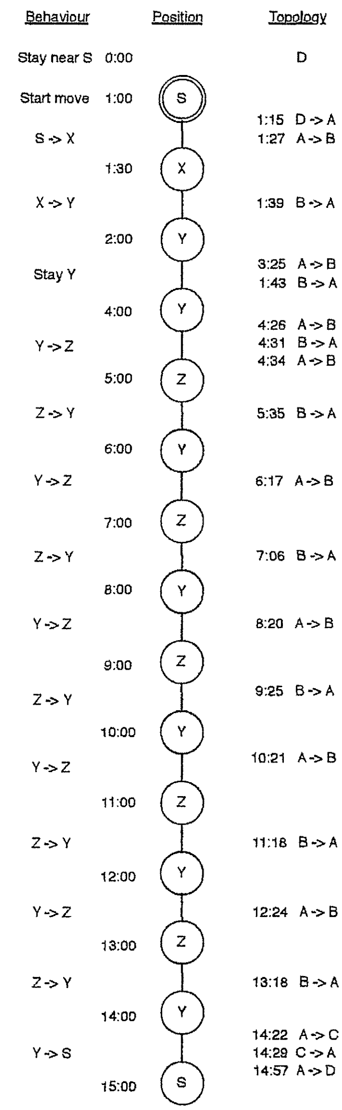

Fig. 14. Change of topology according to the movement of node M

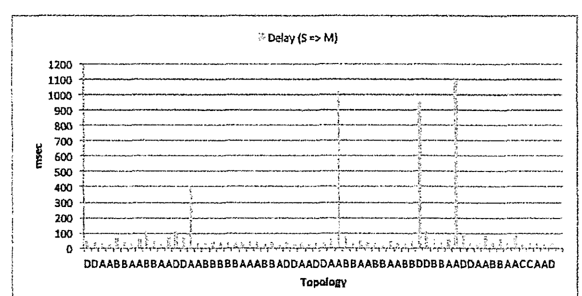

Fig. 15. Delay between root node (S) to mode M

We consider that the ad hoc network using OLSR may provide faster re-routing.

Of course, AODV may also be useful to decide the possible route automatically at the evacuation space, since the communication in the evacuation place is not as urgent and AODV may consume less power since AODV displays reactive behavior.

Finally, based on the above discussion, we decided to continue using GCM as WAN access and OSLR for ad hoc networking among LED displays stored in the school.

V. FUTURE WORKS

We recognize there are two remaining problems.

One is the unstable WiFi connection between the 1st floor and 2nd floor. One easy way to address this is to install a relay point of WiFi on the landing of the stairs; however, it is not easy to install a relay point in a school. Usually there are very few AC wall sockets in a school building. Even in an office building, it is very rare that stairways have a wall socket. We discussed with a teacher about the possibility of installing a solar battery to operate the relay point. In public buildings including schools, it is important to prevent accidents caused by falling objects. They refused this idea of installing solar batteries on stairs.

We are now planning to set a reflector on the landing of the stairs. There have been several trials conducted using reflector panels made of aluminum for WiFi [16]. We are now testing the safest way to install a reflecting panel.

The second problem is the detailed comparison of GCM and SMS in cities that are far from Tokyo such as Hokkaido, Kyushu, Okinawa and the islands. As the distance may cause delay of the IP network, we will endeavor to understand the effect of distance in the network. Also we need to measure the performance of out system at more severe network condition such as Christmas day and New Year since network condition at such timing is similar to that of disaster.

VI. CONCLUSIONS

In this paper, we discussed the optimization of IDDD for the trial in 2013. Firstly, we explained the problems found in the trial in 2012. Then we showed the result of discussion to enhance IDDD for the trial in 2013 from the viewpoint of guaranteeing the disaster message delivery. Firstly, we compared the performance between SMS and GCM in detail. We concluded that GCM is better than SMS from the viewpoints of delay and stability. Next, measured performance of OLSR from the viewpoint of quick route change by using real devices. We conclude that ad hoc network performance using OLSR is better than implantation of last year using AODV for the purpose of our system. How to fix the problem of instability of connection between floors is a topic for future study.

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Evaluation of An Information Delivery System for Hearing Impairments at a school for deaf

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Abstract. We have been developing IDDD (Information Delivery System for Deaf People in a Major Disaster) system [7, 8] from 2007. In 2012, we have a chance to develop new IDDD system and test it at the school for the deaf in Miyagi. In this paper, we report the results the system performance test and the user ' s evaluation of the new IDDD based on an experiment at the school for the deaf in Miyagi. As the result, the network performance was increased and application development cost might be half of that of the old IDDD. Also, Fast-Scroll is most legible for hearing impairments people.

1 Introduction

Based on research of the status of people with handicaps during the earthquake in Kobe and Tottori [1,2], we designed the Information Delivery System for Deaf People in a Major Disaster (IDDD), using mobile phone and ad hoc networking technology with an evaluation test conducted in many different locations since 2007. We found many of the deaf left without support during the disaster. Some of them were left in a house and could not go to shelter. In case of disaster, usually electric power supply is stopped, so that they could not receive information from TV. Half of the dead people of the earthquake in Kobe [1] were people who required support for evacuation, such as elderly people or disables people. So that, an information delivery method for hearing impairment people is strongly required. We developed information delivery system based on mobile phone network and without AC power and performed several trials [3, 4, 5, 6], and obtained good results for commercial release. This system was designed based on the following requirements [3,4].

R1 Accurate information rapidly for deaf people
R2 Appropriate information according to individual situation

R3 Robust equipment to display information definitely
R4 Applicable for the use in daily life
R5 No complicated operation
R6 Work when blackout

To achieve these requirements, we designed IDDD as follows.

1. IDDD was designed to send disaster information at black out. The main components are mobile phone and LED display. Both can work with battery. Disaster information is sent through network or directly from a mobile phone.
2. IDDD displays disaster information on both mobile phones and displays.
3. A disaster message received by a mobile phone is directly transferred to a display via near field communication.
4. Display has function of ad hoc networking to transfer disaster information to rooms automatically. A large wall-mounted or rack-mounted LED display is used in an office or public space, and small box-type display is used in a residential living room.

We performed 19 trials of IDDD from 2007 to 2011, asked attendants to answer questioners, and received answers from 312 people. Fig. 1 is an example of a LED display of IDDD used for a trial in a hospital. In this case, the LED display shows the number of the person next in line, and we tested the display to show disaster information as part of the trial. The overall impression of 46 people was very good as described in Fig. 2. Details are described in [6]. Also, IDDD is used in three offices in Tokyo that employ people with hearing impairments. We confirmed that the size and color (Red for emergency messages and Green for normal messages) of characters are legible and recognizable.

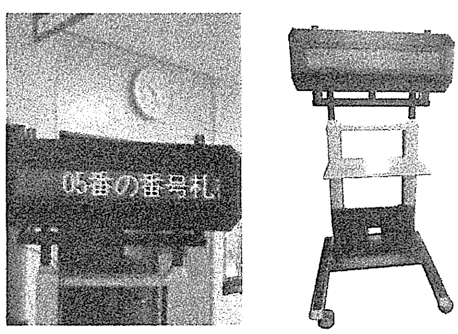


Fig. 1. An example of a LED display for testing IDDD in a hospital

During these trials, we received many different requirements at the different demo locations and from the different attendants. However, IDDD was expensive

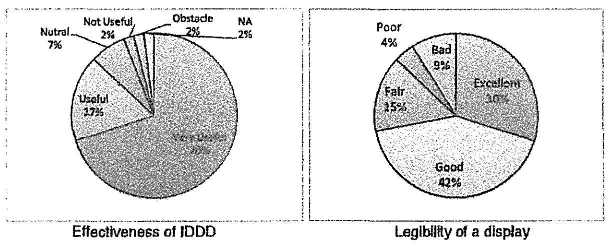


Fig. 2. Effectiveness of the system and legibility of the display of IDDD

and not sufficiently flexible to meet every request. Also we received the cost down of the LED display. So that, we re-designed new IDDD [7] and started a new project for the long-term evaluation of IDDD to check the usability at the school of deaf in Miyagi.

In this paper, we report the results the system performance test and the user ' s evaluation of the new IDDD system [7] based on an experiment at the school for the deaf in Miyagi. In the section 2, we explain the outline of the new IDDD system, then the result of evaluation at the school of deaf in Miyagi is mentioned in section 3. At lat we conclude this paper in section 4.

2 Outline of The New IDDD System

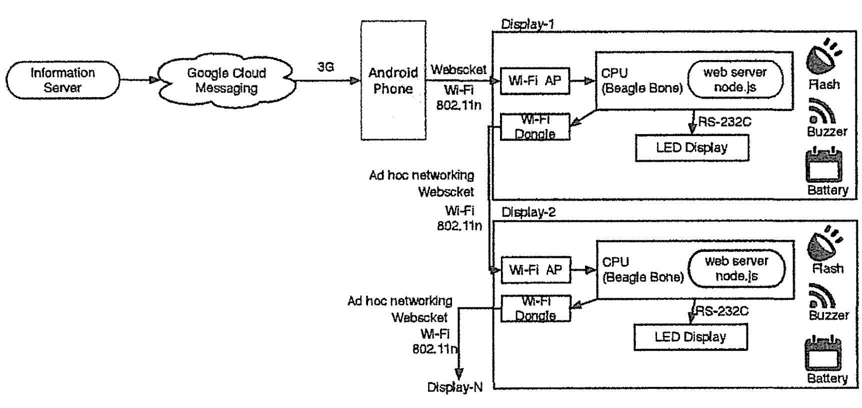


Fig. 3. Architecture of the new IDDD system

Fig. 3 is an outline of the new IDDD system. A disaster message will be sent from Webserver to Android phone. Then the message is transferred to Display-

1 and also transferred to Display-1 to Display-2 etc. using ad hoc networking function.

The difference between IDDD described in [3,4,5,6,7] and [8] is described in Table 1. To achieve flexibility, we changed the application platform for the LED display to allow easy customization of APIs as described in [7,8], altered the communication method to increase flexibility, and reduced the development costs. We used Web technology to achieve these requirements. For communication between Android phone and LED display, also between LED displays, we used Websocket [9]. To execute application on LED display and communications among devices, node.js [10] is used as application engine.

This architecture is very effective. For example, we implemented ad hoc network, AODV [11] in one week on node.js using Java Script. As our experience, it may take two weeks to implement AODV by using C on Linux. So that this approach is useful to reduce development cost of application to meet various requirement from users to make IDDD better.

Table 1. Difference Between Previous System and New System

Items	Previous System	New System
OS	Linux	Linux
App	Native	Java Script
Display	LED 2 color	LED 3 color
WAN	SMS	IP (Google Cloud Messaging)
Local Communication	Bluetooth	WiFi

3 Evaluation and Result

We performed evaluation of the new IDDD from two aspects, one is network performance and another is legibility of the LED display of IDDD. In this section, we will explain the result of evaluation from these points.

3.1 Evaluation of Network Performance

First, we evaluated the performance of the system from the delay in sending messages from the information provider to the LED display. We measured the transmission delay in each section of the network described. The measured delay is described in Fig. 4.

We measured several aspects of this system by using the test configuration described in Fig. 4. We measured three delays to check the performance. One is delay between two LED displays, Display-1 and 2, (Delay 1 in Fig. 4) , the second is delay between Android phone and LED display (Delay 2 in Fig. 4) and the

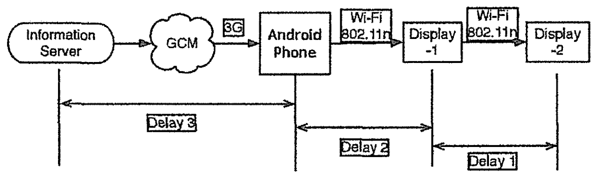


Fig. 4. Test setting to measure performance

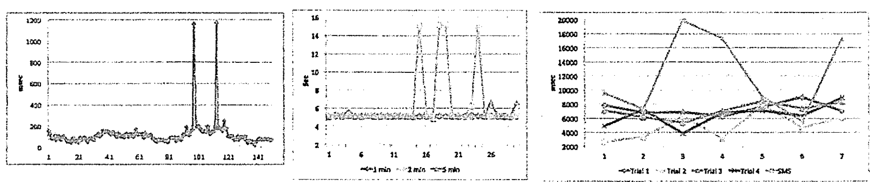
third is delay between information server and Android phone (Display 3 in Figure 5). Delay 1 is important to deliver information using ad hoc network function and Delay 2+3 is important to deliver urgent information as quickly as possible. We think that the following criterias are important to evaluate delay of information delivery. (C1) As fast as possible: Disaster information sometimes include urgent information such as tsunami alert and earthquake alert. So that, information should be delivered as soon as possible. (C2) Delay should be constant: Sometime the delay is short and sometime the delay is large, the system looks unstable and may give anxiety to people who use IDDD. So that the delay should be constant.

Delay between two LED displays (Delay1) As described in Fig. 3, we are using ad-hoc networking between two displays using Wi-Fi (802.11n). Fig. 5 (1) shows the delay between the two LED displays. There are two major delays, however almost under 200 msec. We are planning to set five LED displays in the school for the deaf in Miyagi, so that the maximum delay to display information on all LED display is one second. We think that this result satisfies criteria C2 and there is no problem for the delay in message transmission between two LED displays. In our previous system, we used Bluetooth for the message transfer between LED displays, and it usually took less than one second. We can conclude that Wi-Fi has the same performance as Bluetooth. Also, the range of Bluetooth is 10 m, but Wi-Fi is usually farther. Wi-Fi is useful for larger spaces or buildings like a school.

Delay between Android Phone and LED display (Delay2) Our greatest concern was the delay in the GCM and mode change of 3G to Wi-Fi in Android phones. Firstly, we measured delay between Android phone and LED display. This delay means the delay of mode change of 3G to Wi-Fi in Android phones. For this test, we used IS17SH (Android 4.0) with DHCP to get IP address. As described in Fig. 5 (2), the delay was 5.69 sec and there was no significant difference among variation of sending message interval. We think that if we use fixed IP address, the delay might be reduced.

Delay between Information server and Android Phone (Delay 3) Finally, we measured delay between information server and Android phone through

GCM. We used the Galaxy Nexus with Android 4.0 for testing of the delay of GCM. If we would like to maintain a short, stable response time using GCM, we need to send messages frequently (within 1 minute) from the information server. In addition, we compared delay of GCM and SMS as displayed in Fig. 5 (3). Average delay of GCM (5sec) was 6.4 sec and that of SMS was 12.4 sec. So that performance of GCM is better than SMS.



(1) Delay between two LED displays (Delay1) (2) Delay of message between Android Phone and LED display (Delay 2) (3) Comparison between GCM (5min) and SMS (Delay 3)

Fig. 5. Evaluation of Network Performance

3.2 Evaluation of Legibility

The second is the evaluation by the user. We plan to evaluate the system at the Miyagi School for the Deaf from October to December 2012. We plan to execute two types of subjective evaluations: one is a test of awareness of the display and the other is a test of the legibility of the display. There evaluation items are decided based on the discussion with medical doctors and teachers of a school of deaf.

- The number of examinees was 66.
- The size of the tested LED display was as follows: 128 dots x 16 dots (eight characters), 768 mm x 96 mm.
- Scroll speed: "Fast" is 3.45 sec to display eight characters, "Medium" is 6.9 sec to display eight characters and "Slow" is 10.35 sec to display eight characters.
- Display mode: "Scroll" or "Not-Scroll"

Awareness of the display: Firstly, we set up a LED display at the entrance of the school and displayed messages relating to the festival such as "Welcome to the festival" or "The next performance is "MOMOTARO" by 4th grade". We asked them whether they aware the display or not, and usefulness of them by using the following three questions.

Q1 Did you find and see the LED display?
Q2 Did you understand what was displayed on the LED display?

Q3 Do you think that this LED display is useful in showing various kinds of information?

77% of the examinees answered that they aware the Display as described in Fig. 6. 73% (Well Understand + Understand) of the examinees answered that they could understand the messages. 85% (Very Useful + Useful) of the examinees answered that this kind of display is useful. Awareness and understandability were lower than usefulness, so that we analyzed the effect of distance, speed of scrolling and color in the next subsection.

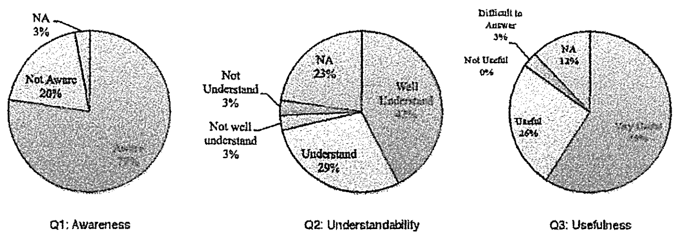


Fig. 6. Awareness and understandability of the Display

Legibility of the display: To investigate the legibility, we tested the following parameters.

- Effect of color: Red, Green
- Effect of speed of scrolling: Slow and Fast
- Effect of scroll: Still or Scroll

For that purpose, we set up two LED displays in a class room as described in Fig. 7. We asked visitors of the festival to join the evaluation and brought them to the class room where the displays were set.

First, we explain the result from examinees who were hearing impairments.

- There was no effect by difference of color (Green or Red) for legibility of display (Table 2).
- Also, faster scrolling was better (Table 3) and they preferred scrolling rather than still (Table 4).
- Some examinees answered in the comments; if the sentence is correctly segmented, still display mode might be better.

For this experiment, we prepared message that contains ten characters. So that, if we use Not-Scroll mode, after changing displayed message, only two characters were displayed. This might be one reason that they preferred Scroll mode.

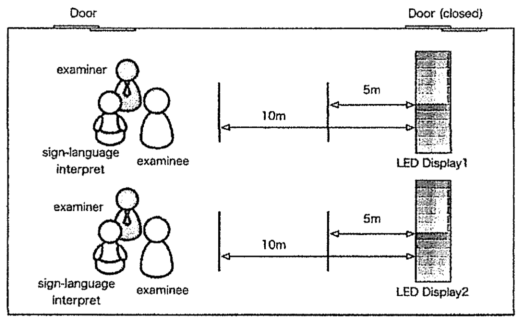


Fig. 7. Test setting to measure legibility

Next, we explain the result form examinees who were not have hearing impairments. They preferred Red rather than Green (Table 5). For scrolling speed and display mode (Scroll or Not-Scroll), the answer was as same as examinees who are hearing impairments (Table 6,7).

We also checked the effect of combination of color, speed and distance. For the group of hearing impairments, the most legible combination was as follows.

- 5m, Green, Fast: 100%
- 5m, Red, Fast: 95%
- 10m, Green, Fast: 95%
- 10m, Red, Fast: 91%

We could conclude that Fast-Scroll is better. However, there is no clear result on the difference of color.

Table 2. Color of characters (Hearing Impairments): P-value 0.290

Condition	Easy to read	Difficult to read	Total
Green	37	7	44
Red	33	11	44
Total	79	18	176

4 CONCLUSION

In this paper, we report the results the system performance test and the user's evaluation of the new IDDD based on an experiment at the school for the deaf in Miyagi. As the result, the network performance was increased and application development cost might be half of that of the old IDDD, and Fast-Scroll is most

Table 3. Speed of scroll (Hearing Impairments): P-value 3.761E-05

Condition	Easy to read	Difficult to read	Total
Slow	64	24	88
Fast	84	4	88
Total	148	28	176

Table 4. Usefulness of scroll (Hearing Impairments): P-value 4.082E-05

Condition	Easy to read	Difficult to read	Total
Scrolling	70	18	88
Not Scrolling	44	44	88
Total	114	62	176

Table 5. Color of characters (Normal): P-value 0.017

Condition	Easy to read	Difficult to read	Total
Green	38	24	82
Red	50	12	62
Total	88	36	124

Table 6. Speed of scroll (Normal): P-value 3.497E-07

Condition	Easy to read	Difficult to read	Total
Slow	73	51	124
Fast	111	13	124
Total	184	64	176

Table 7. Usefulness of scroll (Normal): P-value 2.696E-05

Condition	Easy to read	Difficult to read	Total
Scrolling	75	49	124
Not Scrolling	42	82	124
Total	117	131	248