特集 ■ 東日本大震災を振り返って

東日本大震災時における情報通信ネットワークの状況と分析

Telecommunication Status and Analysis of Information Network Systems on East Japan Great Earthquake

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Abstract— **East Japan Great Earthquake on March 11 in 2011 caused severe damages over the wide area of Northern Japan. A massive 9.0 earthquake destroyed many buildings and information systems, and a devastating tsunami swept over cities and farmland in the northern part of the country and set off warnings as far away the west coast of the United States and South America. Also, the large-scale earthquake brought the secondary disasters such as blackout, fire, and nuclear crisis.**

Many information network systems are also severely damaged with the East Japan Great Earthquake. Compared with the recent historical severe earthquakes in Japan such as Hanshin-Awaji Great Earthquake in 1995 and Chuetsu Earthquake in 2004, there were many different types of problems because of the recent highly developed information society. They were the congestion of cellar phone, the lack of fuels and electricity, and so on.

In this paper, the problems of information network systems on East Japan Great Earthquake are analyzed, and the solutions of these problems are discussed. Through our network reconstructing activity just after the earthquake, the connection of information network is the most important other than throughput or latency for disaster information system. In fact, satellite system, wireless LAN, and cognitive wireless system were useful for the reactivating network connection in the disaster area.

Keywords-component; Disaster Information Network; East Japan Great Earthquake; QoS;

1. INTRODUCTION

East Japan Great Earthquake on March 11th in 2011 caused severe damages over the wide area of Northern Japan, and there are still many problems for reconstructing activities in the disaster area. A massive 9.0 earthquake destroyed many buildings and equipment, and a devastating tsunami swept over cities and coast resident's area in the northern part of the country. This tragedy was shocked to the world, and about 15,841 dead and 3,490 missing persons are still increasing even today [1].

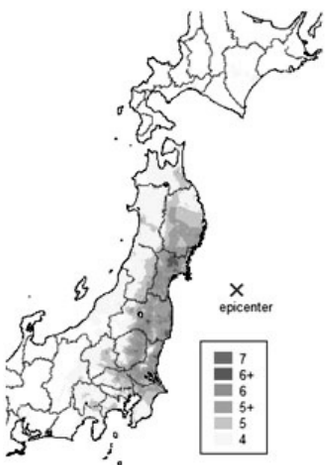

Figure 1　JMA Scale (Shindo) by Japan Meteorological Agency

In the aspects of major earthquake in world history, it was the fourth largest earthquake next to Great Chile Earthquake in 1960 (M9.5), Great Alaskan Earthquake in 1964 (M9.2), and Indian Ocean Earthquake and Tsunami in 2004 (M9.1) [2]. Moreover, this large-scale earthquake also brought the serious secondary disasters such as blackout, fire, and nuclear crisis.

TABLE 1　LARGE SCALE EARTHQUAKE IN THE WORLD

Year	Disaster	Magnitude	Fatalities
1960	Great Chile Earthquake in 1960	9.5	2231
1964	Great Alaskan Earthquake	9.2	131
2004	2004 Indian Ocean earthquake and tsunami (off the west coast of northern Sumatra)	9.1	220000～
2011	Japan Earthquake and tsunami	9.0	Death15,841. Missing 3,490 (at 12/21/2011)

1952	Kamchatka earthquake	9.0	0
2010	Great Chile Earthquake in 2010	8.8	525
1906	Ecuador-Colombia earthquake	8.8	1000
1965	Rat Islands earthquake, Alaska	8.7	0
2005	2005 Sumatra earthquake, Indonesia	8.6	1346

However, the earthquake also caused many problems other than such a major secondary disasters. The problems about information network systems are also serious by the East Japan Great Earthquake. Compared with the recent historical severe earthquakes in Japan such as Hanshin-Awaji Great Earthquake in 1995 and Chuetsu Earthquake in 2004, there were many different types of problems because life style have been dramatically changed by the recent highly developed information society. Cellar phone system have been greatly increased during several years, and the damage and congestion of cellar phone caused serious problems for rescue, life safety information, food distribution and so on. The lack of disaster information is considered with the reason of these activities' delay. Moreover, the lack of fuels and electricity may cause the delay of rescue and support activities for the evacuators.

Under this disaster, Iwate Prefectural University located in the middle of Iwate Prefecture could barely have the electricity and network functions because of the backup systems, and Ph. D. Shibata and their staffs have worked for the support activities based upon their previous studies of Disaster Information Systems for earthquake, tsunami, typhoon, and so on. Iwate Prefecture is located in the northern part of Japan, and one of the severe damaged area including Miyagi and Fukushima Prefecture. Especially, the coast side cities of Iwate such as Rikuzentakada, Ofunato, Kamaishi, Otuchi, Miyako, and so on were seriously damaged by the great tsunami disaster. The area scale of Iwate is 15,200km, and this is the second largest prefecture in Japan. The population is about 1,370,000 and the most of area is consisted of the mountain area and the Coast of Pacific Sea. According to the Ministry of Internal Affairs and Communications in Japan, broadband and internet adoption rate's ranking is 46th and 45th out of 47 in Japan [3], and there are still some unavailable areas of cellar phone around the mountain and coast side. Historically speaking, there have been many disasters such as earthquakes, tsunami, volcano, and storm in winter in this prefecture, and therefore the disaster activities are considered to be well prepared and trained in comparison with other areas. However, the large-scale disaster caused 4,696 death and 1,663 missing person in the prefecture.

In this paper, the problems of information network systems on East Japan Great Earthquake are analyzed, and the solutions of these problems are discussed. Through our network reconstructing activity just after the earthquake, the connection of information network is the most important other than throughput or latency for disaster information system. In fact, satellite system, wireless LAN, and cognitive wireless system were useful for the reactivating network connection in the disaster areas.

In the followings, in section 2, network conditions of various information systems on East Japan Great Earthquake are reported. Section3 deals with the problems with and by information network systems on the earthquake. Then, it discussed about internet usages on the earthquake at section 4. Finally section 5 derived discussions and future works of information network system on a large-scale disaster like East Japan Great Earthquake.

2. NETWORK CONDITIONS OF INFORMATION NETWORK SYSTEM ON EAST JAPAN GREAT EARTHQUAKE

East Japan Great Earthquake caused many problems such as rescue, food distribution, and evacuation. Malfunction of information network system was a part of major problems after the earthquake. Especially, the lack of disaster information such as life safety, damages, and so on brought much confusion of various activities. The following table 1 is the summary of various information systems' condition in Iwate Prefecture through our network relief activities.

TABLE 2　NETWORK CONDITIONS OF VARIOUS INFORMATION NETWORK SYSTEM ON EAST JAPAN GREAT EARTHQUAKE

System	Conditions	Details
Radio	○	Small area service such as local FM radio was useful for evacuators.
TV	×	It did not worked because of wide area's blackout.
Fixed phone	×	Devices were damaged and blackout
Cellar phone (audio)	△	Highly congested
Internet (Cellar phone)	△	Highly congested
Iwate Information Highway (Government's Information Network System)	×	Broke down network and devices.
LAN in City Hall	×	Broke down network and devices.
Disaster Government Radio System	△	Unable to hear inside of house or car.
Amateur Radio	○	Worked but only a few devices and licensed users

Wireless LAN	○	Worked but electricity was needed
Satellite system (internet)	○	Worked

One of the major problems of information network systems was the rapid growth of cellar phone system in today. According to Ministry of Internal Affairs and Communication, numbers of telecommunication on cellar phone became about 10 times as the usual just after the earthquake, and the maximum limitation of audio communication became up to 95% which is the meaning that only one user could used the service out of 20 persons. [4]

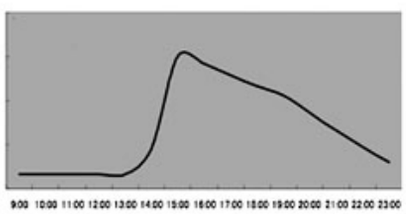

Figure 2　Numbers of calls by cellar phone (au) on 3/11/2011 (the Northern Japan)

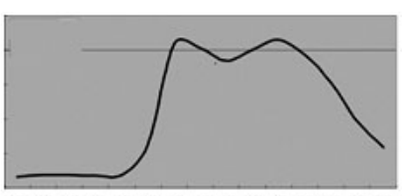

Figure 3　Numbers of Calls by cellar phone (au) on 3/11/2011 (Tokyo)

Figure 1 shows the congestion of cellar phone system in the northern part of Japan where is heavily damaged by the earthquake on 3/11/2011. The figure showed the numbers came up to about 8 times as the usual in the disaster area, and the maximum congestion was about 30 minutes after the earthquake. Moreover, figure 2 is about Tokyo, Japan. Compared with figure 1, there were two peaks about 15:30 and 18:00 on 3/11/2011, and the numbers were about 10 times as the usual communication. In case of Tokyo area, whole public transportation was stopped and there were many peoples who could not come back to home around 18:00. That is considered as the reason why Tokyo has two congestion peaks from the data.

Thus, a cellar phone became hard to use after the earthquake, and it caused serious communication problems wide area of Japan. As the results, not only by the damages of network devices but also the congestion of cellar phone is considered with the reasons with the serious lack of disaster information such as about rescues, evacuation shelter, life safety, and so on.

Moreover, in the disaster area such as the coast city in Iwate, many wired networks and servers on information network systems were break down by the huge tsunami. Therefore, fixed phone, broadband internet service, and even the local government network system were unable to use. The public web services and email systems in Iwate Prefecture was also down, and it may affected to the isolation of the coast cities in Iwate.

However, there were some information network systems considered as useful in disaster area. In the case of network relief activities in the coast side of Iwate, satellite system for internet such as IPSTAR and wireless LAN were useful for reactivating network communication systems. Although there were problems about electricity, both systems were used for the reactivating in some evacuation shelters and disaster headquarters quickly. The following picture is about the network relief activities in Taro, Miyako City.

Figure 4　Satellite Configuration in Taro, Miyako City

Although satellite system does not have high quality network condition like FTTH, the major contents under the emergent situation were text-based contents such as email, web based life safety information, and SNS. Therefore, satellite system was practically useful even such an emergent situation. Wireless LAN was also practically worked for temporal LAN reconstruction. Since the inside of public buildings such as city hall was damaged by the disaster,

It is also said that radio, especially local FM station, was very practical in evacuation shelters. Since most of evacuation shelters and headquarters didn't have electricity, radio was the only way to method to know about disaster information. However, the needs of the evacuators was mainly the small local information such as evacuation shelters, food distribution, hospital, life safety information around them, so information from major radio and TV station is said that they were not so practical for the disaster area.

With information network relief activities in the coast cities in Iwate, the important thing was considered as the connectivity of network system and electricity for disaster information on a large-scale disaster. Therefore, future disaster information system needs such robust network connectivity by satellite system and wireless network system.

3. PROBLEMS ON EAST JAPAN GREAT EARTHQUAKE

From 18th of the March, the authors' network relief activities were held in the severe damaged coast side cities of Iwate. At that

time, there was still less information in the coast side of Iwate even after a week passed from the earthquake. Although tragic tsunami news were on aired, phones or email communication did not connect with the cities.

The followings are the equipment for reactivating the communication network through the activities.

(1) Disaster Center in Miyako (3G network, 5PCs3)
(2) Disaster Center in Iwaizumi (3G network, 5PCs)
(3) Taro City Hall (Satellite, 7PCs)
(4) Green Peer Taro (3G network, 2PCs, Printer)
(5) Green Peer Taro Aiina (3G network, 2PCs, Printer)
(6) Miyako City Hall (3G network, 2PCs) , and so on

However, there were many problems in the activities. First of all, gas for track was difficult. Lack of gas had been spread to whole northern and middle Japan, and the car line of waiting gas became over 3km long around IPU. Secondary, sudden lower temperature made mountain roads frozen. It is clear that lack of information and frozen road made the delay of rescue activities for the coast side area.

The followings are major problems of our network relief activities.

(1) Fuel for cars was difficult to get.
(2) Electricity and battery for information network system was damaged
(3) Network devices and servers were damaged
(4) Wired networks were disconnected
(5) Cellar phone system was damaged and congested
(6) Government Disaster Radio System was break down
(7) TV could not be watched
(8) Many evacuation shelters used papers for life safety information and disaster information.

Figure 5　Trafic Jam by waiting for A Gas Station

Therefore, those problems should be concerned for the future study of disaster information system.

4. INTERNET USAGE ON THE EARTHQUAKE

Many information network systems didn't work after the earthquake, but Internet is used for the various ways for many activities on East Japan Great Earthquake. Internet adoption rate was 74.7% before the earthquake in Tohoku area (the northern Japan), but the rate was greatly decreased until about 20% just after the earthquake. This is because many internet service in Tohoku area was unable to use by the damages and congestion. Then, it takes about from one to two weeks to reactivating temporal network services around Morioka, Iwate.

In case of temporary houses for evacuators, the most location was originally no internet service area like mountain side, so temporal communication cables were needed to construct for the area. Therefore, there are still many temporal house area where internet service cannot be used in now. However, satellite system and FWA are used for those area by Ministry of General Affairs, and internet services are spreading now.

Local governments also had to construct temporal internet cables because their LAN and internet cables were damaged by the tsunami. They reconstructed temporal cables for the communication with prefectural office, and began their works for a while after the earthquake. Moreover, the most servers at local governments in Iwate were damaged, and so disaster information was not informed to the residents in Iwate. Therefore, they came to share disaster information by using internet such as twitter and blog in a couple of days after the earthquake.

Medical services also used internet for temporal communication between local hospitals and central hospitals. Not only evacuation shelters but also all local hospitals and central hospitals were disconnected for communication in Iwate. The use of internet temporally reconnected between shelters, local hospitals, and central hospitals.

Volunteers are used internet for many their activities. They were the sharing of disaster information by SNS, name's lists in evacuation shelters by picture images on web broads, possible road conditions on GIS, and so on. Compared with the other previous Japanese earthquake, there were many new trials by using internet by the volunteers on the earthquake. Because of IT developments of these days such as smart phone, wireless broadband services, Web services, and SNS, the use of internet for disaster is considered to be getting important.

5. USEFUL SYSTEMS FOR TEMPORAL REACTIVATING INFROMATION NETWORK SYSTEMS

Although there have been many problems on East Japan Great Earthquake, there were many information network systems in practice for temporal network reactivating. This could be important for the future studies of disaster information system. Major useful network systems in network relief activities in Iwate are the followings.

- Satellite IP system (IPSTAR) quickly recovered internet communication in many disaster areas.
- Available area of cellar phone had been gradually spread.
- The router consisted of 3G and wireless network (IEEE802.11 b/g/n) was used for many city halls and evacuation shelters in temporal.
- Wireless network (IEEE802.11 b/g/n) could be used for covering

disaster area quickly.

- Satellite phone system was fully used (each local city government possessed about two phones.)
- Cognitive wireless router (NiCT) was useful. [5]
- Twitter, blog, and SNS was practical for realtime information sharing such as gas station, transportation, foods, and ATM.

The authors' team was also use twitter for sharing disaster information in Takisawa and Morioka area in Iwate. Table 3 is summary of the disaster information by twitter on the activities.

TABLE 3　SUMMARY OF NEEDED INFORMATION

	Needed information around IPU	Needed information from other area
3/12 AM	Shelters, food distribution, public transportation, medical, stores, life lines, entrance exam.	Damages around IPU, Takizawa, and Morioka
3/12 PM	Bank and ATM, possible places for charging cellar phone battery, electric stores, gas stations, Shelters, food distribution, public transportation, medical, stores, life lines	Damages around IPU, Takizawa, and Morioka. Life safety information (seeking persons)
3/13 AM	Gas stations, stores, bank and ATM, possible places for charging cellar phone battery, life line (electricity), electric stores, public transportation, medical.	Damages around Takizawa and Morioka. Life safety information.
3/13 PM	Gas stations, stores, life safety information, alert of secondary disaster, bank and ATM, life line(electricity), electric stores, public transportation, medical.	Damages around Takizawa and Morioka. Life safety information.
3/14 AM	Gas stations, public transportation (bus), secondary disaster, life line(electricity), life safety information.	Damages around Takizawa and Morioka. Life safety information.
3/14 PM	Gas stations, public transportation (bus and railway), secondary disaster, life line(electricity), life safety information.	Damages around Takizawa and Morioka. Life safety information.
3/15	Gas stations, public transportation (bus, railway, highway, roads conditions for Tokyo), life safety information, food (rice, bread).	Life safety information.
3/16	Disaster information around the coast side of Iwate, Gas stations, public transportation (bus, railway, highway, roads conditions for Tokyo), life safety information, food (rice, bread, noodles).	Life safety information.
3/17	Restaurant, public bath house, gas station, public transportation, life safety information, road and gas information for the coast side, food (rice, bread, noodles).	Life safety information. Delivery of relief goods.
3/18	Restaurant, public bath house, gas station, public transportation, life safety information, road and gas information for the coast side, food (rice, bread, noodles).	Life safety information. Delivery of relief goods. Volunteers
Later	Road and gas information for the coast side, food (rice, bread, noodles), employment information for students, aftershock.	Life safety information. Delivery of relief goods. Volunteers. Secondary disaster.

According to this table, it is understood that electricity, cash, and fuels were important for evacuators after shelter and food information was needed. Since most of internet services and servers were unable to use for a couple of weeks, the role of internet usage was important for communication and sharing disaster information in Iwate.

6. DISCUSSION AND FUTURE STUDY

Network infrastructures have been recovering in Iwate even now, but there are still more problems that must be considered with the reconstruction of disaster area. The followings are parts of major subjects that should be considered for the reconstruction in information network systems.

- To raise the quality of livings in temporal houses
- Information systems for life and reconstruction information
- Medical Information System for residents (Especially for the reducing work time of medical doctors in the disaster area)
- Health condition check for residents (Physical and mental conditions)

- Remote observation system for elder persons
- Employment information system for residents
- Education system for students, and so on

In this paper, the problems of information network systems on East Japan Great Earthquake are analyzed, and the solutions of these problems are discussed. Through our network reconstructing activity just after the earthquake, the connection of information network is the most important other than throughput or latency for disaster information system. In fact, satellite system, wireless LAN, and cognitive wireless system were useful for the reactivating network connection in the disaster area.

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BIOGRAPHY

Yoshitaka Shibata received his Ph.D. in Computer Science from the University of California, Los Angeles (UCLA), U.S.A. in 1985. From 1985 to 1989, he was a research member in Bell Communication Research, U.S.A., where he was working in the area of high-speed information network and protocol design for multimedia information services. Since 1998, he is working for Iwate Prefectural University, Japan as an executive director of Media Center and a professor of Faculty of Software and Information Science in the same university.

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