Optimization Study on Emergency Communication in the Great East Japan Earthquake

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Abstract. Emergency communication is a special communication mechanism used for disaster rescue. The article took the Great East Japan Earthquake as the research object. It was found that mobile communication was the main way in general communication and social media played an important role in emergency communication. The causes of traffic congestion were studied to provide strategies for PSTN and mobile communication. Unitary management system in Japan for the restoration of services was studied, too. At last, the development of satellite communication in Japan and its needs for emergency communication were researched to provide references for emergency communication in China.

1. Introduction
On March 11, 2011, an earthquake measuring 9.0 on the Richter scale occurred in the northeastern waters of Japan. As far as intensity is concerned this earthquake ranks the third among those occurred since the 20th century. It caused 15,894 deaths and 2,561 were missing. Although the strong earthquake triggered a 39-meter tsunami, continued aftershocks and the leakage of nuclear power plants, thanks to the experience accumulated in the event of frequent earthquakes, Japan’s good performance in post-disaster rescue is still admired by the world[1]. At the same time, experts in the field of disaster prevention and rescue pointed out that there is a big gap between China and Japan in emergency rescue[2]. Emergency communication is an important aspect of post-disaster rescue, which directly affects the efficiency of search and rescue. Scholars like Maurice[3] proposed that the scientific knowledge provided by geoscientists through the emergency communication system can help the people affected make safe behaviour choices, thereby improving rescue rate. Therefore, it is rather necessary to learn Japan's emergency communication technology in disasters.

2. New Features of Communication and Social Networking
With the in-depth development of the information age, the field of communication media is undergoing profound changes, and mobile phones, e-mail and social network services have also been popularized. In terms of telephone communication, the public switched telephone network has been mainly replaced by mobile communication, and pure audio communication has become the combination of audio and non-audio communication. Changes in communication media and the popularity of social media have affected the mode of emergency communication.

2.1. Changes in Phone Users
During the past ten years, the number of public switched telephone network users has continued to decrease, while that of mobile phone users has remained to increase. Around 1999, the number of mobile phone users in Japan was equal to that of the public switched telephone network. Although the
development of telecommunications industry in China is slower than developed countries, the trend is the same. According to statistics from the Ministry of Information Industry, at the beginning of 2005, the number of mobile users also surpassed that of the public switched telephone network. The rapid development of communication technology has played a positive role in the popularization of mobile phones. The changes in the number of users of various tools in Japan are shown in Figure 1[4].

![The number of users](image)

**Figure 1.** The changes in the number of users of various tools in Japan.

It can be seen from Figure 1 that when the Hanshin-Awaji earthquake occurred in Japan in 1994, the communication media was mainly the public switched telephone network, and mobile users were a minority. However, when the Chuetsu Earthquake occurred in Niigata Prefecture in 2004, the number of mobile users surpassed that of the public switched telephone network, and people began to use fiber-based OABJ-IP telephone services, and Japanese telephone communications began to develop in a diversified direction with mobile communications as the mainstay.

The number of mobile users continues to surge, making it the focus of emergency communications. The great significance of mobile communication for emergency rescue can be seen in two aspects. One is that mobile communication tools are easy to carry and have a long standby time, which makes it convenient for the trapped ones to send distress signals. The second is the benefit of the GPS positioning and navigation function on the smart phones. Thus, the locations of trapped ones have become more and more accurate, which greatly promotes the development of rescue operations. Therefore, emergency technology for supporting mobile communications should be developed first.

2.2. The Rise of Social Media

Within a short time after earthquake, the public switched telephone network and mobile phones may be unavailable in a large area. Under such condition, the advantages of social media can be used because people can connect to social networking sites through mobile devices[5]. Social media is fast and efficient and has users in various ages and occupations. It occupies quite an important position. It can help implement emergency rescue, provide emotional support, and share information.

The rise of social media has changed the emergency communication strategy to a certain extent. With the prevalence of various social media in Japan, the previous top-down communication mode tends to be replaced by point-to-point communication. For the information issued on social media, it is not the government, but the individuals who dominate. In the Fukushima nuclear leakage, Twitter issued relevant information about 20 minutes earlier than Japan’s mainstream media. Although Twitter has been popular all over the world, Japan has not made good use of it. Government agencies only started to apply for accounts after the 3.11 Earthquake. Subsequently, the prime minister alone applied for 926 Weibos[6]. In China, social software like WeChat, QQ and Weibo has gradually become an important way for people to communicate in daily life. China Earthquake Administration and many provincial earthquake bureaus have got official WeChat public accounts and Weibo public accounts to establish a convenient two-way relationship between earthquake departments and the public. This interactive communication platform has received wide attention and gained some influence.

With the quick spread of WeChat App, more and more scholars in China have seen its advantages and are considering how to apply it to post-disaster rescue. Some have conducted evaluations and study on relevant official accounts on this App[7-9]. To study the popularity of WeChat public accounts and knowledge related to earthquake, 30 people were investigated, of which 15 were engaged in seismic
rescue (the first group) and 15 had other occupations (the second group). According to statistical analysis, these WeChat public accounts have been subscribed by 80% of the first group and by less than 14% of the second group. In addition, in terms of earthquake common sense, the first group obviously knows more accurate knowledge than the second group. The second group still has many misunderstandings about self-rescue and common sense of saving people in earthquakes. Therefore, it is particularly important to promote the influence of the earthquake WeChat official accounts and the spread of earthquake common sense.

It can be learned from the lessons of the Great East Japan Earthquake that emergency rescue departments should establish accounts in advance and release authoritative information as soon as the earthquake occurs, so as to avoid personal release of inaccurate and false information, and rapid dissemination on social media that causes social problems. Panic and anxiety make people give wrong responses, and these accounts can also provide support for disaster relief operations. In addition, in order to keep social media available during the earthquake period, the servers of major domestic social networking sites should be set up in areas with a low probability of earthquakes. Those sites can also be set up on cloud servers.

3. Communication Network Maintenance

Earthquakes of different intensities will cause varying degrees of damage to communication system. Compared with the Niigata Prefecture earthquake and the Hanshin Awaji earthquake in Japan, the damage in the Great East Japan Earthquake was much more severe. See Table 1 for relevant details.

Table 1. Damages to communication facilities.

| Earthquake          | 3.11Earthquake | Niigata Earthquake | Hanshi Awaji Earthquake |
|---------------------|----------------|--------------------|-------------------------|
| Date                | 2011.3.11      | 2004.10.23         | 1995.1.17               |
| Recovery time (days)| 50             | 4                  | 14                      |
| Transportation lines| 90             | 6                  | 0                       |
| Switch buildings    | 18             | 0                  | 0                       |
| Poles               | 65000          | 3400               | 3600                    |
| Tubes (km)          | 3000           | 11                 | 220                     |
| Aerial cables (km)  | 6300           | 100                | 330                     |

As can be seen from the table above, the Great East Japan Earthquake caused more damages to Japanese communication facilities than the Niigata Prefecture earthquake and the Hanshin Awaji earthquake. It took 50 days to restore the damages, which seriously affected the emergency rescue. Therefore, how to carry out the maintenance of the communication network in case of a strong earthquake is an important aspect of emergency communication.

3.1. Traffic Control

The network control centre is an organization that maintains the network by continuously monitoring the network. After the earthquake, it achieves the purpose of maintaining the communication network mainly through traffic control and service restoration. Traffic control is to restrict ordinary calls to ensure that as many nodes as possible can operate. When the traffic on a specific node is highly congested, it may cause the network nodes to decrease, which requires traffic control.

In the Great East Japan Earthquake, the characteristics of communication congestion varied with the distance from the epicentre. According to relevant statistics that after the 3.11 Earthquake, communication congestion has two obvious characteristics: one is that communication congestion occurs in a large area. The trafficl volume in Miyagi and Tokyo is more than 4 times of that during the peak hours under normal conditions, and the call volume to Miyagi in Japan has even reached 9 times
the normal volume. Therefore, after a major earthquake, we should implement communication control across the country instead of only controlling user switches and long-distance switches in several regions. Second, the traffic congestion in the epicentre area is mainly caused by external calls. It can be seen that the number of calls to Miyagi nationwide is more than twice that of calls inside Miyagi. After the earthquake, the epicentre quickly became the focus of a nation, so the number of calls to the epicentre increased sharply, causing traffic congestion in the epicentre area.

In the 5·12 Earthquake in China, Sichuan also suffered a network interruption for several hours due to communication congestion, which severely delayed the rescue process. In order to maintain emergency communications for important departments in the epicentre area, such as firefighting, medical, police and other institutions, it is necessary to impose restrictions on external calls. For the traffic control of the public switched telephone network, the load balancing technology of the call initiation protocol server in Japan can be used for reference. Load balancing is achieved by assigning users and their user extension numbers to SIP servers\[10\]. The users who have the same user extension number across the country are assigned to the same SIP server. Load sharing can be achieved without adding load balancing equipment. As for mobile networks, because of the shortage of bandwidth, traffic control is mainly achieved by limiting the call time.

3.2. Service Restoration

The earthquake resistance of exchange buildings in Japan is designed to be as high as 7 on the Richter scale. Small disasters will only interrupt partial services without destroying the equipment, and the service can be restored by restarting or replacing the system. However, it can be seen from Table 1 that the intensity of the Great East Japan Earthquake is as high as 9, undoubtedly the damage to the Japanese communication system is severe, and it is quite difficult to restore services.

In the 3.11 earthquake, in addition to the strong earthquake, insufficient power supply and limited resources were also the main reasons for the slow recovery of communications in Japan. China should prepare for resource reserves and power supply during the disaster-free period, especially the power supply after the disaster, which is the basis for all communications restoration work. In addition, Japan's unscientific communication restoration methods during the 3·11 Earthquake also affected the communication restoration process. The engineers of the network control centre need local engineers to manually upload the status data, and after frequent downloads and analysis, decide the parts to be repaired first. This mode of operation wastes a lot of precious time. Therefore, Japan has proposed a management system that integrates networks, facilities, and electricity.

The management system designed in Japan integrates relevant information provided by local maintenance engineers, network operation centres, and operating systems, including facilities and equipment, power supply and so on. Through this way, it is possible to quickly and accurately determine the priority of parts to be repaired and the current state of the network, which can not only reduce the workloads of various departments, but also greatly improve the efficiency of network repair and resource utilization. However, to develop this system, it requires the cutting-edge virtualization technology. Besides, related software and user interfaces are also necessary, making it more difficult.

4. Satellite Communication System

After the Great East Japan Earthquake, Japan conducted a communication satisfaction questionnaire survey on 196 rescue teams. As a result, in the first 4 days after the earthquake, the application frequency of mobile phones, notebooks and wired phones was lower than the medium level, and the satisfaction level was very poor, while the that of satellite phones was relatively good\[11\]. When ordinary communication methods fail, satellite communication is undoubtedly the best alternative. Toshima\[12\] pointed out that satellite communications could help reduce the scope of damage, especially the damage to the communication system caused by strong earthquakes based on the future construction, adoption, and use of satellite communications as an independent or backup system.

NTT (Nippon Telegraph and Telephone Corporation) Eastern and Western companies deployed ku-band ultra-small earth station systems and portable earth station systems before the earthquake, and used the equipment for post-disaster rescue. The s-band mobile satellite communication system established by NTT was also used in the disaster relief process. Although the above systems played an
important role in the emergency rescue process, there are still some problems: (1) The system is relatively old and maintenance is difficult; (2) Manual tracking satellites is time-consuming and difficult; (3) It is inconvenient to carry, install, and use; (4) The wireless telephone operator is required to be at present during the uplink access test. These all lowered the efficiency of the satellite communication system. In order to overcome the above shortcomings, Japan began to develop and improve satellite communication systems after the earthquake[13].

4.1. Wing Antenna
In order to improve the portability of the earth station, the aperture of the fin antenna reflector has been reduced to 75cm, which can be disassembled into 4 parts, reducing the installation time by 25%. In addition, the antenna has the function of automatically tracking the target satellite.

4.2. Vehicle Satellite
The vehicle-mounted antenna developed by Japan has a diameter of 60 cm and is highly compressible (see Figure 2). This antenna can track the desired satellite while the vehicle is moving.

4.3. Simple Modem
Japan has developed a small and lightweight modem that can be connected to existing group modems with a maximum transmission frequency of 384kbps.

4.4. Remote Uplink Access Test Procedure
Remote uplink access test procedures have been designed. Using these antennas and modems allows user stations to manage uplink access tests from the control room. This can avoid the trouble of sending a wireless telephone operator to the location of the satellite system, and at the same time can effectively shorten the test time and improve the efficiency of the satellite.

Based on the above-mentioned advantages of satellite communication, China is also studying how to use satellite communication systems for emergency rescue. However, most of the studies focus on the internal communication of the earthquake department system. It is suitable for short-distance communication and can be used as a communication tool in a small area, but it is difficult to satisfy the communication demands of a large number of disaster-stricken people. So it should be appropriately added in earthquake-prone areas in case of the failure of other communication methods under strong earthquakes and "islanding" condition. In addition, in the research and development process of China's new satellite system, in addition to the problems mentioned above, we must also pay attention to provide sufficient power to meet a large amount of information transmission, and stable communication is also vital.

5. Results and Discussion
In the article, the new characteristics of emergency communications, network maintenance and satellite communications during the Great East Japan Earthquake were studied, and the main conclusions are as follows:
(1) In recent years, the main method of communication is mobile communication, which should be regarded as the focus of communication support in emergency communication. Social media is less affected by earthquakes, and at the same time it is widely used and spread quickly. Relevant organizations must establish accounts in advance, expand their influence, and spread relevant knowledge to deal with disasters.

(2) Traffic congestion occurs on a large scale. Controlling the public telephone switching network traffic depends on load balancing technology, and controlling mobile communication depends on controlling the calls and time. Integrating network, facilities, and power management systems can improve the efficiency of restoring services.

(3) Make good use of the small satellite communication system inside the earthquake system to deal with the "islanding phenomenon" under strong earthquakes, and gradually develop a satellite communication system that facilitates the communication of disaster-stricken people. The system should have remote uplink access testing and automatic satellite tracking functions. It must be easy to carry, install, and have a high connection rate.

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