Development of Wireless Systems for Disaster Recovery Operations

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SUMMARY  This paper presents wireless systems for use in disaster recovery operations. The Great East Japan Earthquake of March 11, 2011 reinforced the importance of communications in, to, and between disaster areas as lifelines. It also revealed that conventional wireless systems used for disaster recovery need to be renovated to cope with technological changes and to provide their services with easier operations. To address this need we have developed new systems, which include a relay wireless system, subscriber wireless systems, business radio systems, and satellite communication systems. They will be chosen and used depending on the situations in disaster areas as well as on the required services.

key words: disaster recovery operation, business radio, subscriber wireless system, satellite communications, the Great East Japan Earthquake

1. Introduction

The serious damage to communication infrastructures caused by the Great East Japan Earthquake and tsunami of March 11, 2011 knocked out public communication services. As a result, the services could not be provided until they were restored. The number of fixed-line services affected reached 1.5 million, and 4,620 base stations within the NTT Group went off the air [1].

Wireless systems are useful for disaster recovery operations because of their quick readiness in providing the services, which is attributable to the nature of “wireless.” Figure 1 illustrates wireless systems for disaster recovery operations. They are used to resume telecommunication services by temporarily substituting for damaged systems and/or by bridging the point to point(s) communications bypassing the cutoff relay transmission lines.

Business radio systems are also used to provide communications for people doing restoration work through communication methods independent from damaged mobile and telecommunication lines.

Satellite communication systems are especially useful in disaster areas because of their wide coverage and the ease with which links can be established. The NTT Group’s protocols for restoring communications infrastructure in the event of a disaster such as the Great East Japan Earthquake and tsunami call for the use of satellite communication systems to provide evacuation and disaster response centers with temporary lines of communication while optical fiber and other transmission lines are being restored [2], [3].

For these reasons, NTT Group companies have introduced various wireless systems for disaster recovery operations. However, even the newest system’s specifications were formulated back in 1995 [4]. When using such obsolete systems after the 2011 earthquake, we faced a number of problems regarding their capabilities and/or operations. In order to address these problems, we started renovating the systems by incorporating present technologies into them so that they could provide better services [5]. The new wireless systems for disaster recovery operations are presented in this paper.

2. Terrestrial Wireless Systems

Terrestrial wireless communications systems used for disaster recovery operations include relay wireless systems, subscriber wireless systems [6], and business radio systems [7]. After the 2011 earthquake it was found that certain features and functionalities needed to be added to their then-current capabilities. These included IP-based communications, increased capacity, aerial and communicable distance expansions, and priority and QoS controls. It was also found that information regarding the location of portable stations and equipment needed to be amassed, especially for business radio so that locations and damage could be visualized. We have developed new systems to meet these requirements.

The new business radio and subscriber wireless systems are introduced in detail in the following sections. They are expected to provide added capabilities for use in disaster recovery operations.

2.1 Subscriber Wireless System

Our new subscriber wireless system for disaster recovery operations is a major improvement over its predecessor, which only enabled networks to be switched to provide special public telephone service in disaster areas. The 2011 earthquake reminded us of the need to provide Internet capability in addition to telephone service. The modulation technology also needed to be changed from analog to digital [6]. The new system’s use of nonlinear distortion compensation technology narrowed the necessary bandwidth for a single channel from 640 kHz to 300kHz and increased the number of channels that could be used from 3 to 7. The increased number of available channels eases frequency reuse and enables the system to expand its service area through cyclical...
use of the channels. The system adopts IP-based transmission and QoS control technologies, which enable efficient sharing of the links between voice and web traffic. Table 1 summarizes typical system parameters. Figure 2 shows an example system configuration.

<table>
<thead>
<tr>
<th>Table 1</th>
<th>Typical system parameters.</th>
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<tbody>
<tr>
<td>Frequency band</td>
<td>400 MHz</td>
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<tr>
<td>Modulation scheme</td>
<td>Adaptive 64QAM/16QAM/QPSK</td>
</tr>
<tr>
<td>Throughput</td>
<td>750kbps/300kHz channel</td>
</tr>
<tr>
<td>Total channel number</td>
<td>7</td>
</tr>
<tr>
<td>QoS class</td>
<td>4</td>
</tr>
<tr>
<td>Weight</td>
<td>52.5 kg</td>
</tr>
</tbody>
</table>

2.2 Business Radio System

Our previous business radio system was formulated in 1991 and used an analog modulation scheme. It could provide only voice communications between the control station and portable stations and among portable stations.

One of the most serious problems encountered during the Great East Japan Earthquake was the difficulty in contacting field workers who went to the stricken areas. It was also difficult to find information about the location of the tank lorries that were delivering fuel for emergency electric power generators. At that time the commercial electric power source had been knocked out, so it was necessary to carry the fuel to the appropriate location. The unavailability
of the commercial power source had knocked out communication facilities with resultant expanded damage [1].

The newly developed system has been digitalized to efficiently utilize frequency resources and has adopted IP technology [7]. Various new functions have also been added to it, such as gathering the location information of portable stations and displaying the locations on a map, broadcasting text messages to portable stations, and establishing communication either for a specific portable station or grouped portable stations. Table 2 summarizes typical system parameters.

Figure 3 shows an example business radio system configuration. The system comprises IP networks, base stations, portable stations, on-vehicle portable stations and portable relay stations, a remote controller and a location information management server. The locations of portable stations are detected through the use of GPS satellites. Figure 4 shows the devices that were developed for the system.

The system can provide three types of voice communications. The first is voice communication between a remote controller and a specific portable station or grouped portable stations via IP networks and radio communications. The second is direct voice communication between portable stations via radio communications. The third is voice communication by relay stations via radio communications.

A location information management server gathers location information of portable stations via IP networks and VHF band radio links. Then the location information of portable stations in the location information management server is shown in a remote controller in a disaster headquarters. So it is possible to send field workers to the appropriate location.

3. Satellite Communication System

Satellite communication systems are especially useful in disaster areas because of their wide coverage and the ease with which links can be established. Figure 5 shows an example configuration of a satellite communication system.

3.1 Motivation

The issues with our older satellite communication systems can be stated as follows.

- More than 15 years have passed since the systems were developed; this makes it difficult to effectively maintain them.
The Portable Earth Station System antenna reflectors are large and thus difficult to carry to the disaster area. Further, they cannot easily be broken down into components and reassembling the components would take upwards of half an hour.

The systems require hand operation for tracking the desired satellite; this makes tracking difficult and time consuming (upwards of 15 minutes).

Japanese radio regulations stipulate that radio operators must be present during uplink access tests (which take upwards of 15 minutes).

Azimuth, elevation, and polarization angle depend on the installation location; this has created a strong demand for automatic tracking of the desired satellite.

To address these issues, we have developed a new type of small earth station system and describe it in the following sections. We have developed three devices and one program as follows.

To offer terminal configurations suited to different kinds of disaster situations, we developed two different types of earth stations, a flyaway type and a vehicle-mounted type. The flyaway type is easy to carry to a disaster area because it can be dismantled and packed into four separate carrying cases, while the vehicle-mounted type can be installed in a normal-sized car capable of reaching the stricken area quickly to help restore communications. Both stations can be up and running in about 15 minutes owing to the satellite auto-capture function (older systems needed about 60 minutes). These stations support transmission speeds of up to 384 k bits/s for the return link, which can carry ten VoIP channels simultaneously.

The technologies that we developed are summarized in the following sections.

3.2 Flyaway Antenna

Our flyaway antenna is shown in Fig. 6. This antenna can easily be carried by hand into disaster areas that are inaccessible by car or other means of transportation. We chose to use a 0.75 m reflector dish that can be dismantled and packed inside a carrying case. Older reflector dishes were made of steel and very heavy. The new reflector dish is built of aluminum honeycomb and very light. The other parts can also be carried in cases, which greatly increases their portability compared with existing devices. Moreover, no tools are needed for disassembly, packing, and reassembly and the automatic satellite capture function eliminates the need for operators to have special skills to set it up: setup can be finished within approximately 15 minutes.

A GPS receiver, an azimuth meter, and an attitude sensor are necessary for the automatic satellite capture function. First, the antenna uses the GPS receiver to detect accurate location information, such as latitude, longitude and height. It also uses a direction meter to detect direction. Then it calculates the azimuth direction, elevation, and polarization angle of the desired satellite. Detecting and calculating these values enables it to capture the desired satellite automatically.

3.3 Vehicle-Mounted Antenna

The vehicle-mounted earth station antenna that we developed is shown in Fig. 7. This antenna is mounted on the roof of a vehicle and is suitable for use in disaster areas that are still accessible by vehicles. The dish diameter was reduced to approximately 0.6 m to enable mounting even on ordinary cars. In addition to an automatic satellite capture function, it also has a function for automatically tracking satellites while the vehicle is moving. Antennas of this type are widely used in ships, but ours is considerably simplified, making it lighter in weight, lower in height, and less costly.
3.4 Simple Modem

If a disaster affects a wide area, a large number of earth stations will need to be installed. However, there is a limit to the frequency range that can be used for satellite communications. Thus, to enable simultaneous use in as many places as possible, we have developed a modem with limited communication speed and frequency band for each earth station. This device uses the same transmission system as older satellite communication systems, and can thus be put to use with only minimal changes to the configuration and settings of existing base stations. By removing unnecessary functions and reducing the capacity to the minimum necessary, we were able to reduce the weight to one quarter and the size to one half of the older modem.

3.5 Remote Uplink Access Test Program

In older systems, an uplink access test is carried out after the earth stations have been installed but before they begin operations. This test is conducted through phone conversations between technicians of the satellite operator and field workers to check that the antenna direction and power transmission levels are correct. Thus, in order to conduct these tests, the field workers need to be proficient in radio communication systems. However, in a large-scale disaster like the Great East Japan Earthquake of 2011, it can be difficult to assemble enough field workers with sufficient knowledge. To make it easy for field workers without specialist knowledge to set up earth stations in the field, NTT Labs has developed an uplink access test program that can be operated remotely from a control station. The procedure for conducting this test remotely using this program is shown in Fig. 8.

3.6 Effectiveness of Developed Systems

Featuring improved portability, the flyaway antenna is easy to carry to a disaster area and can be set up without the need for any tools. The setup time is thus reduced from 30 minutes to five minutes. After it is set up it can capture the desired satellite automatically. The time for capturing the desired satellite is reduced from 15 minutes to three minutes. The antenna can be installed and ready for operation in less than 15 minutes including warm-up time, thus reducing installation time by nearly 25% compared with the existing antenna. In addition, the use of a remote uplink test makes it unnecessary to send a radio operator to the installation location.

The vehicle-mounted antenna is also easy to set up. Because the antenna can track the desired satellite while the vehicle is in motion, communication can commence immediately when the vehicle arrives at a shelter in a disaster area.

4. Future Work

The experience of the Great East Japan Earthquake and tsunami reminded us of how critical electric power is in times of disaster. Although the current stations consume much less power than the older ones, power is still supplied by a generator with batteries used as a backup source. Accordingly, it is necessary to develop more powerful batteries (such as fuel cells) and find further ways to reduce electric power consumption in systems for use in disaster recovery operations.

5. Conclusion

This paper described the NTT Group’s new wireless systems for disaster recovery operations, which have been designed to possess new and required capabilities. These capabilities will enable them to contribute in providing aid for disaster victims and system operators working to restore systems after disasters. Cogently combining these systems in times of disaster will further enhance their effectiveness in recovery operations.

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References


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