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東日本大地震津波災害における衛星通信
－広域災害に強い社会を目指して－

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あらまし　2011 年 3 月 11 日の東日本大地震によって東北地方の広大な地域において通信網が壊滅的な被害を受けた。壊滅した通信網の早期復旧のためにあらゆる努力が払われ、セルラー通信の基地局機能と電源設備を備える自動車が広く展開された。セルラー通信網のエントランス回線の復旧に予想外の時間がかかることが明らかになると衛星通信回線に対する需要が急増した。そのため利用可能なあらゆる衛星通信網が総動員された。IPSTAR は被災地の高速インターネットの早期復旧に広く利用された。またエントランス回線の提供によりセルラー通信網の早期復旧に大きな貢献をする事ができた。千年に一度の大災害により衛星通信の果たせる役割が明確になった。本稿においては衛星通信が災害復旧に果たした役割とぶつかった問題を報告し、将来に向けての改善策を提案する。

キーワード　衛星通信、インターネット，　高速伝送, VSAT, MSAT, セルラー通信網、 Femto, IMT-2000, Mesh, マルチキャスト, 電源, 地震, 津波, 原発事故, IPSTAR

Satellite Communications for Large Scale Disasters
- In search of a robust society -

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Abstract The Great earthquake and tsunami on 11, March, 2011 destroyed the communications infrastructure over wide areas in Tohoku regions. Great efforts were made for prompt recovery of the communication infrastructure; many emergency vehicles with power supply and transportable BTS functions were dispatched in the disaster areas. It was soon recognized that recovery of the damaged optical fiber entrance links would take so long that the demand for satellite communication suddenly surged. The satellite communication systems available in Japan were fully mobilized. IPSTAR system was also widely used for the entrances links for mobile communication operators and also for the Internet connections in the emergency facilities. The great natural disaster clarified the essential roles of satellite communications in emergency situations. In this paper we will report how satellite communications including IPSTAR were used for the relief efforts, review the problems and propose a few improvements and new applications of satellite communications for the future.

Keyword　Satellite communication, Internet, Broadband, VSAT, MSAT, Cellular, Femto, IMT-2000, Mesh, Multicast, Power supply, Earthquake, Tsunami, Disaster, Nuclear power plant, IPSTAR

1. Damages on the communication infrastructure by the Great East Japan Earthquake and Tsunami

The great East Japan Earthquake and Tsunami on 11, March, 2011 was a once in a thousand years disaster with the magnitude 9.0 earthquake and accompanied Tsunami as high as 30 meters. Vast coastal areas in Tohoku region were flushed away by the Tsunami which reached as far as a few kilometers inland carrying huge ships aground and washed away houses, farms, factories and the people. About 20,000 people were killed or are missing. In addition to the natural disaster the breakdown of the nuclear power plants in Fukusima caused wide spread

contamination of highly noxious radioactivity which still keeps a great many people from going back to their home lands. The nuclear power plant failure enhanced the power shortages in wide Kanto and Tohoku areas.

According to the government report (ref[3]), damages on the communication infrastructure in Tohoku regions were;

♦ Fixed line telephony links;

Lost; 1.9 million circuits out of total 24 million were lost.

Congestion; Traffic surged 4～9 times higher than normal.

♦ Mobile communication networks;

Lost; 29,000 Base Stations out of total 132,000 sites

Traffic controls; Connections limited to curb the traffic;

- NTT docomo(voice) ; 90 (%)
- NTT docomo(packet) ; 30 (%)
- au (voice) ; 95 (%)
- au (packet) ; 0 (%)
- SBM (voice) ; 70 (%)
- SBM (packet) ; 0 (%)

<> Emergency radio systems were also gravely damaged Directly by broken equipment, fallen towers, systems washed away, broken lines and indirectly by power loss, loss of operator or regulatory access limitations.

2. Recovery efforts of the communication infrastructure

2.1 Government and private organizations

<Government>

- Lending radio communication user terminals (MCA, NSTAR and Inmarsat BGAN)
- Simplified licensing procedure
- Coordination among relevant organizations

<NTT>

- Nine hundred (900) S-bands mobile communication terminals were lent to emergency centers
- Ku-bands（14/12GHz）VSAT systems were lent
- Transportable satellite communication systems lent;
- At requests of local governments 30 units deployed
- 276 circuits were provided for emergency public telephony services

< SBM>

- IPSTAR had been used for expansion of coverage areas of SBM services since before the disaster.
- Temporary Urgent Coverage for Emergency Shelters at about 170 sites.
- Recovery of Macro Base Stations at about 150 sites.
- 10 vehicles with satellite backhauled Node-B stations functions were dispatched.

<> KDDI

- 1,933 KDDI base stations destroyed by the tsunami in 6 prefectures of Tohoku region.
- Dispatching vehicle-mounted base stations with satellite backhaul.
- Recovery with satellite backhaul and enlarging coverage areas of existing base stations.
- Installation of femto-cell with satellite backhaul.
- Installation of small, transportable base stations with microwave backhaul.

<> JAXA

- Provided to the government pictures and images taken by observation satellite “Daichi.”
- Supply of broadband satellite communication links by satellite “Winds”to Iwate prefecture
- Supply of mobile communication terminals by “ Kiku No.8” to Ohfunato City and Otsuchi town.

<> JSAT

- Additional satellite BW of 500MHz to government and enterprises
- About 400 VSATs lent

<> Volunteer groups

Many volunteer groups worked to help set up emergency communication systems. They set up 3G mobile routers backhauled by satellite links at schools and emergency relief sites.

2.2 Efforts by IPSTAR (ref.[5])

IPSTAR provides broadband services in 14 countries in Asia and Oceania through Thaicom-4 satellite. IPSTAR had assisted emergency relief efforts for the Tsunami disasters in Phuket Island and the great Earthquake on 22, February, 2011 in New Zealand and other disasters.

After the earthquake on 11, March, an IPSTAR team entered the area on 13 and set a VSAT site and a PC with Skype In/Out capable to work with telephony network at Rokugo junior high school; the relief center in the area.

IPSTAR provided backhaul links for mobile services providers; SBM, NTT docmo, KDDI and Eaccess.

IPSTAR provided for the above services about 500 VSATs and a few hundred Mbps satellite links by the end of May, 2011. IPSTAR contributed VSATs and satellite links to such volunteer groups as Earthquake Disaster Recovery Internet [ref.[3]; M.Oe and K. Uehara], Iwate prefectural university (ref.[6]), Cisco systems, Microsoft and others.

3. Summary of communication problems in the large scale disaster

Valuable lessons are obtained from the great disasters as summarized in the following (ref.[6]) ;

[1] Immediate problems after the disaster

- Scarcity of fuels for automobiles
- Failure of power supply for the communication
- Failure of communication or servers equipment
- Breaking of wired links
- Failure of mobile communication networks and congestion
- Failure of emergency radio system
- TV unavailable because of lack of power supply
- Thus, the communication at the relief centers was made paper-based.

[2] Problems in the recovery phase

- Slow recovery; took one to two weeks even for the temporary recovery.
- Many temporary relief centers needed construction of the Internet access links.
- Local government offices needed reconstruction of the Internet access links as the internal LAN systems were damaged by the disaster.
- The local community networks were damaged causing failure in information dissemination. The local people began access to the external world via the recovered Internet.
- Medical systems suffered loss of communication between the clinics at relief centers and the regional core and university hospitals. The communication was resumed via the recovered Internet.
- Relief volunteers worked through the Internet.
- The Internet at the relief centers were promptly recovered by satellite broadband IP networks.

4. Communication networks robust against large scale natural disasters

The above problems suggest the required features of the communication systems as follows.

4.1 Integration of existing networks for large scale disasters

A lesson is that the emergency systems need to be used in normal operations in order to function well in emergency situations. Thus it needs to be integrated in daily operational systems.

The systems essential in emergency situations are

- Temporary shelter villages system
- Information system for the temporary shelter villages
- Medical information system (to relieve the pain of the people and the burden of medical doctors)
- Health support system for the residents
- Watch and support systems for the aged
- Employment information systems for the workers
- Education systems for children

4.2 Requirements for communication networks in the recovery steps (ref.[1, 2, 3, 6])

Different steps in the disaster recovery efforts require different features for the communication systems.

Step 1 Immediate stage after the disaster

(1) Voice communication for families, relatives and friends urgent for safety confirmation

(2) Mobile satellite communication systems (MSAT) such as Inmarsat, Iridium, Widestar (NTT), etc. are quite useful at this stage.

(3) A problem is the rather limited channel capacity of mobile satellite communication (MSAT) systems.

Step 2 Recovery stage

(1) Demand for the Internet emerges for relief efforts by the governments.

(2) The residents in the disaster areas need access to the Internet for daily living and recovery efforts.

(3) Mobile backhaul by satellite links is quite effective for quick recovery of the remote areas networks.

4.3 Features of IPSTAR system in normal and emergency situations

IPSTAR meets the above requirements and is quite suitable for emergency as well as normal operations.

[1] Broadband Internet

IPSTAR provides broadband Internet access not only for business corporations but also for consumers. As it serves the mass market, the system is so designed for easy installation of the user terminals, remote monitoring and controls of the system status and affordable utility charge and easy operation for the customers. Actually the activity of IPSTAR in the disaster recovery was a mere extension of its standard operations. The maximum forward/return data rates of 4/2 (Mbps) are quite sufficient for most applications.

For more details, please visit; http://www.ipstar.com/

[2] Backhaul for Mobile Communication Networks

This is one of the standard menus of IPSTAR which is applied to expansion of service areas of mobile communications to remote areas and islands. This service was very effective in the disaster recovery efforts. The mobile systems served were Femto and IMT-2000 networks. The Femto is a totally IP based system which was readily backhauled by IPSTAR satellite links. The IMT-2000 systems used T1 or VLAN interfaces for their entrance links, hence IP MUX apparatuses were used to match the interface to IP basis.

The feature of IMT-2000 systems is the low bit rates for voice coding, which are about 12kbps. A 1Mbps satellite link can carry about 70 voices simultaneously. The combination of IPSTAR with enlarged zones cells was quite effective in early recovery of communication infrastructure in the disaster areas.

5. Integration of Satellite and Terrestrial Communications Systems

The essential role of satellite communications in large scale disaster was verified by the great East Japan earthquake and tsunami disasters. Further improvements are proposed in the following.

5.1 Inter Hospitals Satellite Communication Systems

One of the most urgent needs for communication was the information exchanges among hospitals. The emergency radio systems for hospitals, fire prevention branches and other government offices were heavily damaged, which severely hampered the rescue operations. It sometimes occurred the rescue teams from outside could not operate at all because communication with local hospitals was totally lost. Such problems can be solved by IPSTAR system as follows.

Network Configuration and Function;

[1] Set up IPSTAR UT at each hospital.

[2] Normal communications through the Internet is provided via IPSTAR GW.

[3] IPSTAR can provide multicast which is quite effective for information dissemination to a group of UT sites. IPSTAR is a STAR network with the GW at the hub, but it can also form mesh networks among IPSTAR UTs though IPSTAR GW (double hops).

The mesh network with multicast function is suitable for conferences modes of communications quite useful in wide area disaster situations. The internal communications among related parties can be maintained even when the terrestrial communication infrastructure is widely destroyed.

5.2 Integration of VSAT, MSAT and Cellular Communications Networks

The VSAT and MSAT systems can be easily combined by connecting the Gate Way stations of each network. The connection is simple as both systems are IP based networks. Then the rescue teams with MSAT terminals on the disaster areas can communicate with the hospitals on the VSAT networks. In addition cellular mobile communication networks can be also combined. By adopting the common IP interfaces, the above integration can be made relatively easily. Such integrated systems will be quite useful in normal as well as abnormal situations.

A system block diagram is given at the end of this paper.

5.3 Power supplies

The East Japan Earthquake and Tsunami disaster revealed one of the most serious problems in such large scale disasters is an energy problem; the shortage of fuels and loss of electric power supply. The horrible nuclear power plants disaster in Fukushima clarified the vulnerability of the conventional centralized structure of energy systems in Japan. Based on the hard lessons from the disaster, we need to realize a more distributed society with local communities more independent in energy, food and other supplies.

[1] Cogeneration of electricity and heat

The feature of local power generation is cogeneration of electricity and heat. In conventional centralized systems the heat has been wasted. Thus the distributed energy systems can not only realize more robust society but also realize far more efficient usage of resources. In Japan the forestry can provide regenerative sources of energy in most parts of the country.

[2] Biomass fuels

Japan is abundant of biomass; rice straws, chaffs and other unused parts of plants and even garbage can be used to generate such biofuels as ethanol and BDF.

[3] Storage of electricity

The wind and solar rays give the most abundant source of energy on the earth. A problem is the possibly unstable availability of those resources. Owing to the advanced development of electric vehicles (EV), this shortcoming is now easily solved by storage of electricity.

Conclusion

The great East Japan Earthquake and Tsunami disasters revealed the vulnerability of our communications infrastructure in Japan and verified the essential roles of the satellite communications systems. The portability of MSAT and transportability of VSAT user terminals were quite effective in the recovery efforts from the disaster. IPSTAR services were widely used for broadband Internet accesses at the relief centers. The mobile backhaul services by IPSTAR were quite effective for the early recovery of the communications infrastructure in the disaster areas. The common IP interface enabled easy connection of IPSTAR satellite links with different cellular communications networks.

One of the greatest problems after the disaster was the loss of the power supply. The terrible accidents of the Fukushima nuclear plants revealed the weakness of the conventional industrial structure of Japan. In order to establish a more robust society, Japan needs to develop more distributed power systems and more independent local communities.

The communication systems need to be used in normal daily operations in order to function fully in abnormal situations. The IP based VSAT systems can be used for wireless LAN services at public places in normal as well as emergency situations. The transportable VSAT user terminals (UT) can be used for setting temporary coverage areas with wireless LAN or cellular communications for festive events in remote areas as well as in emergency situations.

The common IP interface enables easy integration of the Internet with VSAT, MSAT, PSTN and Cellular mobile communications networks. The integrated network with fully utilizing features of the sub-networks will realize new applications useful in normal and abnormal situations.

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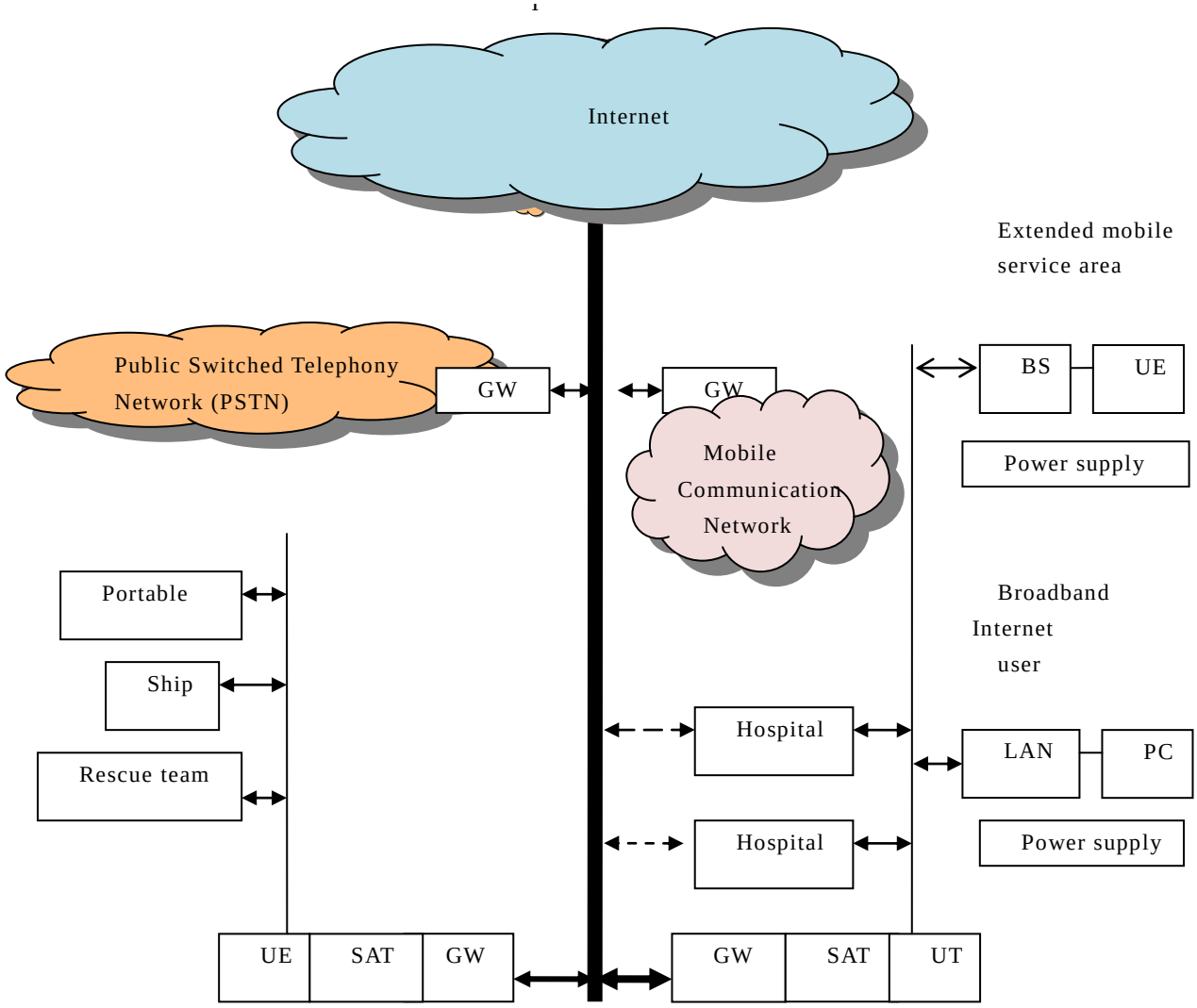
Notes;

GW ; Gate Way

UE ; User equipment (mobile phone, PC, etc.)

UT ; User Terminal or Very Small Aperture Terminal (VSAT)

BS ; Base Station such as BTS (Base Telephony Station), RAN(Radio Access Node) or AP (Access Point)



Mobile Satellite Network (MSAT)

VSAT network, i.e .IPSTAR