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SERIES L: ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

Framework of disaster management for network resilience and recovery

ITU-T L-series Recommendations – Supplement 35

ITU-T

ITU-T L-SERIES RECOMMENDATIONS

ENVIRONMENT AND ICTS, CLIMATE CHANGE, E-WASTE, ENERGY EFFICIENCY; CONSTRUCTION, INSTALLATION AND PROTECTION OF CABLES AND OTHER ELEMENTS OF OUTSIDE PLANT

OPTICAL FIBRE CABLES	
Cable structure and characteristics	L.100–L.124
Cable evaluation	L.125–L.149
Guidance and installation technique	L.150–L.199
OPTICAL INFRASTRUCTURES	
Infrastructure including node element (except cables)	L.200–L.249
General aspects and network design	L.250–L.299
MAINTENANCE AND OPERATION	
Optical fibre cable maintenance	L.300–L.329
Infrastructure maintenance	L.330–L.349
Operation support and infrastructure management	L.350–L.379
Disaster management	L.380–L.399
PASSIVE OPTICAL DEVICES	L.400–L.429
MARINIZED TERRESTRIAL CABLES	L.430–L.449

For further details, please refer to the list of ITU-T Recommendations.

Supplement 35 to ITU-T L-series Recommendations

Framework of disaster management for network resilience and recovery

Summary

Network resilience, the robustness of the network infrastructure, should ensure the continuity of telecommunication services against any damage caused by disasters. Network recovery is restoration of the network infrastructure and telecommunication services to their original status or a certain level of availability, even temporarily, to provide the users with an adequate grade of services after the disaster.

ITU-T L-series Supplement 35 provides a framework of disaster management for improving network resilience and recovery (NRR) by reviewing high-level objectives of NRR against disasters, identifying several approaches (i.e., redundancy, congestion control, repair, substitution and robustness) that meet the objectives, and clarifying the approaches with regard to the effective time frame (i.e., phase) for disaster recovery. Based on the identified approaches with effective disaster recovery phases, information about relevant technologies, including those already available and those emerging, is also provided.

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In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

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Table of Contents

Page

Supplement 35 to ITU-T L-series Recommendations

Framework of disaster management for network resilience and recovery

1 Scope

This Supplement provides a framework of disaster management for improving network resilience and recovery (NRR) by reviewing high-level objectives of NRR against disasters, identifying several approaches (i.e., redundancy, congestion control, repair, substitution and robustness) that meet the objectives and clarifying the approaches with regard to the effective time frame (i.e., phase) along with disaster.

Regarding outside plant facilities such as cables, poles and manholes, [ITU-T L.390/L.92] considers disaster management for them and describes countermeasures for natural disasters such as earthquakes, strong winds and floods.

2 References

[ITU-T G.694.1] Recommendation ITU-T G.694.1 (2012), *Spectral grids for WDM applications: DWDM frequency grid*.

[ITU-T G.872] Recommendation ITU-T G.872 (2017), *Architecture of optical transport networks*.

[ITU-T K.47] Recommendation ITU-T K.47 (2012), *Protection of telecommunication lines against direct lightning flashes*.

[ITU-T K.56] Recommendation ITU-T K. 56 (2010), *Protection of radio base stations against lightning discharges*.

[ITU-T L.302/L.40] Recommendation ITU-T L.302/L.40 (2000), *Optical fibre outside plant maintenance support, monitoring and testing system*.

[ITU-T L.390/L.92] Recommendation ITU-T L.390/L.92 (2012), *Disaster management for outside plant facilities*.

[ITU-T L.391/L.81] Recommendation ITU-T L.391/L.81 (2009), *Monitoring systems for outside plant facilities*.

[ITU-T L.392] Recommendation ITU-T L.392 (2016), *Disaster management for improving network resilience and recovery with movable and deployable information and communication technology (ICT) resource units*.

[ITU-T Y.1271] Recommendation ITU-T Y.1271 (2014), *Framework(s) on network requirements and capabilities to support emergency telecommunications over evolving circuit-switched and packet-switched networks.*

[ITU-R F.1105-3] Recommendation ITU-R F.1105-3 (2014), *Fixed wireless systems for disaster mitigation and relief operations*.

[ITU-R M.1854-1] Recommendation ITU-R M.1854-1 (2012), *Use of mobile-satellite service in disaster response and relief.*

[ITU-R S.1001-2] Recommendation ITU-R S.1001-2 (2010), *Use of systems in the fixed-satellite service in the event of natural disasters and similar emergencies for warning and relief operations*.

[IEC 61587-2] IEC 61587-2:2011, *Mechanical structures for electronic equipment – Tests for IEC 60917 and 60297 – Part 2: Seismic tests for cabinets and racks*.

[IEC 60794-3-70] IEC 60794-3-70:2016), *Optical fibre cables – Part 3-70: Outdoor cables – Family specification for outdoor optical fibre cables for rapid/multiple deployment*.

3 Definitions

3.1 Terms defined elsewhere

This Supplement uses the following term defined elsewhere:

3.1.1 movable and deployable ICT resource unit (MDRU) [ITU-T L.392]: A collection of information and communication resources that are packaged as an identifiable physical unit, movable by any of multiple transportation modalities, and which act as a stand-in (substitute) for damaged network facilities, and reproduce and extend their functionalities.

NOTE – Packed into a container or box, an MDRU accommodates equipment for reproducing ICT services such as switches/routers, wired/wireless transmitters/receivers, servers, storage devices, power distribution unit, and air conditioners.

3.2 Terms defined in this Supplement

This Supplement defines the following terms:

3.2.1 delay-tolerant networking (DTN): A technology that stores information when it is connected to a source (e.g., a mobile terminal), and delivers the information to a destination when it finds the end-user.

NOTE – A DTN is a technology that provides communications with and among extreme and performance-challenged environments where continuous end-to-end connectivity cannot be assumed. The addressed challenges include: large delay for transmissions resulting from either physical link properties or extended periods of network partitioning, routing capable of operating efficiently with frequently disconnected, pre-scheduled or opportunistic link availability, high per-link error rates making end-to-end reliability difficult, heterogeneous underlying network technologies [including networks not based on the Internet protocol (IP)], and application structure and security mechanisms capable of limiting network access prior to data transit in an environment where round-trip times may be very large. Refer to [b-DTNRG] and [b-Farrell].

3.2.2 local wireless mesh network: A local-area network that consists of multiple relay-capable nodes connected with each other via multiple wireless links (i.e., in mesh topology), governed by specialized control for discovering communication paths from among available nodes and wireless links and which provides information relay services to user terminals [typically wireless fidelity (Wi-Fi) terminals].

NOTE – The relay nodes are assumed to be placed on top of buildings or on the ground with good visibility in preparation for disasters, installed where needed or transported by car or plane. Local communication service in a relatively limited area provided by a private company or local government (rather than public network operators) is an initial design target.

3.2.3 network recovery: The process of recovering the service level of a given communication network after a disaster.

3.2.4 network resilience: The ability to provide and maintain an acceptable service level in the face of faults and challenges to normal operation of a given communication network, based on prepared facilities.

4 Abbreviations and acronyms

This Supplement uses the following abbreviations and acronyms:

BPSK Binary Phase Shift Keying

DTN Delay-Tolerant Networking

DR Disaster Relief

EDFA Erbium-Doped Optical Fibre Amplifier

HVAC	Heating, Ventilation, and Air Conditioning
IC	Integrated Circuit
ICT	Information and Communication Technology
IP	Internet Protocol
LAN	Local Area Network
MDRU	Movable and Deployable ICT Resource Unit
NE	Network Element
NEBS	Network Equipment – Building System
NMS	Network Management System
NRR	Network Resilience and Recovery
OSC	Optical Supervisory Channel
QAM	Quadrature Amplitude Modulation
SMS	Short Message Service
UAV	Unmanned Aerial Vehicle
Wi-Fi	Wireless Fidelity
WiMAX	Worldwide interoperability for Microwave Access

5 Conventions

None.

6 Introduction

Information and communication technologies (ICTs) provide crucial services and systems for our daily life as well as emergency and disaster situations. Based on the layering model, systems robust against disasters can be viewed from two aspects: service/application and infrastructure. Regarding the infrastructure aspect, it is necessary to improve network tolerance against damage and enable quick restoration to cope with large-scale communication congestion and the loss of network function by the destruction or failure of communication facilities. Network resilience is the robustness of the network infrastructure and should ensure the continuity of telecommunication services against any damage caused by the disaster. Network recovery is restoration of the network infrastructure and telecommunication services to their original status or a certain level of availability, even temporarily, to provide users with an adequate grade of services after a disaster.

According to past experiences and by considering latest available technologies in [b-FG-Overview], [b-FG-Frame] and [b-FG-Gap], some of the NRR technologies are considered to need further investigation with the development of common specifications as standards.

The requirements for disaster relief (DR) services and applications are described in [b-FG-DR] and [b-ITU-T E.108].

7 Overview of network resilience and recovery

7.1 General objectives of network resilience and recovery

The telecommunications infrastructure including, both wireline and mobile communication networks with fixed-line and mobile phones, makes instant exchange of information possible even in remote areas, and constitutes a vital part of the social underpinning of daily life and economic activities.

In particular, given the technological advances in recent years, the convenience and importance of the Internet and broadband connections have grown dramatically, and the communications infrastructure has become even more fundamental to society, not only as a means of providing traditional telephone service, but also as a medium for the delivery of all manner of information and services provided by government and business, etc.

During states of emergency, such as major natural disasters, the telecommunications infrastructure also provides a means of confirming people's safety status through emergency calls and emergency priority-line phones, and provides a necessary means of communication for the maintenance of basic administrative functions, such as police and fire brigades. The telecommunications infrastructure is essential to ensuring the safety and wellbeing of citizens and underpins the ability to function as a nation.

Just after or during a disaster, voice calls over the telephone and mobile phone networks are mostly used for safety confirmation and information exchange in the disaster area. Voice calls are easy for anyone to make when used for emergency communication and thus trigger an enormous surge in the number of calls. Network congestion is the best-known issue in the event of a disaster, which we can tackle using different approaches by leveraging the latest technologies.

It is also essential to restore the telecommunications infrastructure swiftly. Mobile base stations, local switches and transmission cables may undergo major damage in disasters. In order to respond effectively to post-disaster emergency situations, verify the safety of individuals, facilitate information-gathering and provide means of communication, the infrastructure should be recovered by employing every possible means.

From the viewpoint of NRR, these two issues are considered fundamental and crucial. Preventing, mitigating or circumventing congestion in an emergency situation and minimizing disruption to communications in the event of infrastructure damage are two major objectives of NRR.

7.2 Approaches to achieving the objectives

The telecommunications infrastructure is important for social life, and there are many measures, including those existing and proven as well as those under study and newly developed, to maintain communication stable, both in normal and emergency use, in response to a disaster. Approaches to achieve NRR objectives can be summarized as follows.

– Redundancy: for equipment and functions that are likely to be damaged, extra capacity or capabilities are prepared in advance and activated as needed or used in normal operation.
– Congestion control: the rapid increase in the number of voice calls in response to a disaster causes congestion by overloading the switching equipment. To detect this congestion and control the traffic, some functions are expected to be installed. Mitigating or circumventing the congestion is also a valid solution.
– Repair: systems for switching equipment and transmission facilities, multiple route of transmission facilities, spare equipment and resources necessary for temporary service restoration (emergency restoration construction, installation of temporary telecommunication lines, electric power supply) are prepared to repair damaged equipment and facilities.
– Substitution: damaged equipment and facilities are replaced by newly deployed multi-purpose facilities or surviving resources originally installed for a different purpose.

Robustness by maintaining buildings and facilities in a physically stable state is another common approach to prevent or mitigate infrastructure damage in practice. The following are the steps for consideration and the guidelines to each step that are widely employed in terms of robustness.

a) Location: the location of telecommunications buildings should be stable and at a low enough risk of disaster susceptibility to maintain the network buildings in normal operation without experiencing serious service breakdown. Probability of severe earthquakes, storms, floods and large-scale fires (including both wild fires as well as explosions in neighbouring factories) should be taken into account. Information about disaster probability available to the public (typically provided by the local government) should be referenced.

b) Telecommunications building: at the location, the buildings should be of stable construction that resists physical collapse. The building should also be fire-resistant (including automatic fire alarms and extinguisher systems). Guidelines in terms of structural strength as well as fire protection should be referenced. The fire brigade and its associated organizations in each country may provide guidelines to ICT-specific buildings, such as data centres. The National Fire Protection Association [b-NFPA] is one such organization.

c) Facilities: in a building, the heating, ventilation, and air conditioning (HVAC) in floors and rooms should be arranged so that the temperature and humidity are under control and normal operations by workers are possible. Floors, rooms and machine racks should be sufficiently tolerant to tremors.

d) Equipment and its setup: Within facilities, the equipment should be securely set up. Requirements for machine equipment are available from several sources. For example, the network equipment – building system [b-NEBS] by Telcordia is one widely recognized specification for network equipment. Several operators also define their own requirements beyond [b-NEBS] specifications.

e) Outdoor facilities: such facilities are expected to be resistant to external environmental stresses (allowing for meteorological change, vibration, shock, pressure) in the setting area. [ITU-T L.390/L.92] describes details for outdoor facilities. IEC standards (e.g., [IEC 60794-3-70]) also cover cable systems that take into account tough outdoor conditions including cases of disaster. Some national specifications are also available such as those from the American Society for Testing and Materials [b-ASTM].

f) Electric power: stable provisioning of supply is expected. Spare power supplies, backup generators or batteries are prepared to ensure stable supply sufficient to continue communication functions even after main power failure. Several IEC documents cover power outage including measures, assessment (see [b-IECetech]).

Guidelines and requirements vary depending on the conditions and environment in which the network of the subject is deployed and in operation. Measures to meet requirements need extra expenditure and all possible measures may not be applicable. Operators and regulators should choose appropriate measures depending on the acceptable level of risk.

7.3 Classification and landscape of network resilience and recovery measures

Two categories are introduced to examine existing and newly developed NRR measures: target or effective time phase related to a disaster and relevant network parts. Based on the classification, possible NRR technologies and measures are summarized as a landscape in Table 1.

a) Time phase of the disaster
   - i) Before disaster
   - ii) During disaster
   - iii) After disaster

b) Parts of the network
   - i) Satellite network
   - ii) Core network
   - iii) Fixed access
   - iv) Mobile access

Table 1 – Landscape of network resilience and recovery measures

Phase and approach / Parts of the network	Preparedness before disaster / Response and relief during disaster	Restoration and reconstruction after disaster
	Network resilience (Redundancy and congestion control)	**Network recovery (Substitute networks and repair)**
Satellite	Increase in switching capacity at the satellite	Portable Earth station to reach the satellite [ITU-R M.1854-1] Mobile base station with satellite entrances [ITU-R S.1001-2]
Core network	Spares for switching equipment and transmission facilities Multiple routes of transmission facilities Installation of congestion detection and traffic control function, emergency priority voice calls [ITU-T Y.1271] Installation of fault detection [ITU-T L.302/L.40] Installation of automatic alarms, monitoring systems [ITU-T L.391/L.81] Secure facilities to a stable structure robust against collapse [IEC 61587-2] Stable outdoor facilities and solid building to ameliorate effects of disasters [ITU-T L.390/L.92] Flexible assignment of network processing resources, see Note Protection against lightning [ITU-T K.47]	Spares for switching equipment and transmission facilities Materials for makeshift (emergency restoration construction, installation of temporary telecommunication lines, electric power supply) Emergency restoration equipment (e.g., temporary repeater, see Note) Movable and deployable ICT resource units [ITU-T L.392] Emergency restoration cables [IEC 60794-3-70]
Fixed access and terminal equipment	Offload voice calls to other media (text messages, e-mail, Internet, storage-type media for emergency situations, packet communications) [ITU-T Y.1271] IP phones Installation of fault detection [ITU-T L.302/L.40] Installation of automatic alarms, monitoring systems [ITU-T L.391/L.81] Secure facilities to a stable structure robust against collapse [IEC 61587-2] Stable outdoor facilities and solid building to ameliorate effects of disasters [ITU-T L.390/L.92] Protection against lightning [ITU-T K.47]	Satellite mobile phones Repurpose resources from other stations (laying in cable from other areas and out-rigging of network facilities) Underground multipurpose duct of cables Emergency restoration cables [IEC 60794-3-70]
Mobile access and terminal equipment	Offload of voice calls to other means (text messages, e-mail, Internet, storage-type	Large-zone (long reach) mobile base stations

Table 1 – Landscape of network resilience and recovery measures

Phase and approach / Parts of the network	Preparedness before disaster / Response and relief during disaster	Restoration and reconstruction after disaster
	Network resilience (Redundancy and congestion control)	**Network recovery (Substitute networks and repair)**
	media for emergency situations, packet communications) Mobile IP phones Using the short message service (SMS) over the data transmission network User experience improvement in the event of unstable or intermittent network connectivity, see Note Protection against lightning [ITU-T K.56]	Mobile and compact base stations (including femtocells). Satellite mobile phones Fixed wireless system for disaster mitigation [ITU-R F.1105-3] Delay-tolerant networking, see Note Local wireless mesh network with portable advanced wireless base station, see Note
Electric power supply	Spare power supply Backup generators or batteries	Power-supply car
NOTE – These are new NRR measures that need study for standardization. Further descriptions are given in clause 7.4.		

Regarding the time phase of the disaster and reaction approaches to be taken, there is a general relationship between them, which is shown at the top of Table 1. Figure 1 shows the relationship with available resources indicated by the vertical arrows. For telecommunications infrastructure, tolerance to damage is the fundamental approach applicable to all phases. Before a disaster, the network infrastructure should be prepared by implementing redundancy and relevant control mechanisms. Once a disaster occurs, the infrastructure should resist the resulting physical damage. Some disasters will take some time to pass. As for traffic handling, the network just after the disaster should handle any surge with available resources, which may be less than those in normal operation. After a disaster, the infrastructure should again provide communication services by fixing damaged facilities, reconfiguring available facilities or installing new resources that replace the original infrastructure or provide alternative communication means.

NOTE – In Figure 1, the amount of infrastructure and complementary resources and their transition pattern depend on disaster type, implemented technologies, and recovery policies.

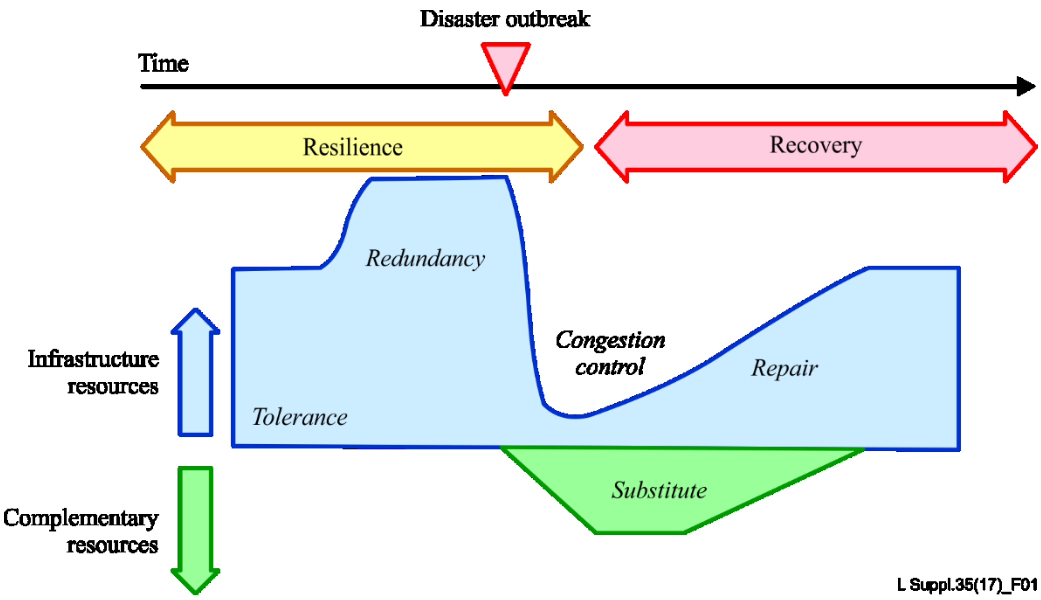

Figure 1 – Disaster phases and relevant approaches for network resilience and recovery

The following additional distinctions and observations are useful for some technologies and their use.

– The term "public network" is used for all networks that provide services and features not only to a specific user group, but also to the general public. The term "private network" is used to describe a network that provides services and all other features only to a single customer or to a group of customers (restricted user group) and which is not available to the general public.

– Some types of network for resilience and recovery have been designed, implemented and operated only for dedicated purposes. One example, special toll-free public phones, can be called a dedicated network. Other systems are commonly used for both conventional and irregular networks. One example is the satellite mobile phone. Those can be called shared systems.

7.4 New study areas for network resilience and recovery

As shown in Table 1, there are a variety of measures and technologies for NRR, some of which are new and need development and standardization. This clause introduces those new study areas (some of which are already under development) in accordance with the approaches described in clause 7.2. Some examples and experiences are described in appendices.

7.4.1 Redundancy and congestion control

Just after a disaster, communication traffic rapidly increases due to safety confirmation, medical status confirmation and evacuation control, so communication-processing servers will be overloaded and it will be difficult to complete telephone calls and exchange e-mails. With regard to access to the network, Wi-Fi will be congested, even if access points are available.

Issues of design and planning of switching equipment capacity, emergency priority calls, backup systems, multiple routing in transmission facilities and Internet protocol (IP) phones are already being discussed and standardized in several standards developing organizations. The following topics are under development, and well suit ITU-T for standardization as a new study area.

1) Flexible assignment of network resources

Flexible reconfiguration of communication resources (by changing the criteria for judging availability of the resources from normal-use level to emergency-use level) can maximize the use of limited resources to prioritize support for indispensable communication services during and after a disaster.

In some severe disasters, it has been reported that a significant number of services are disrupted beyond expectation, even in a fully protected optical network, and network operators struggle to recover affected services by managing limited surviving network resources. It is usually difficult to accommodate the affected services on unplanned network resources whose availability and possibly service quality of are not guaranteed. In terms of optical transport, the availability of optical frequency bandwidth and transmission quality of the surviving optical fibres must meet the given rigid transmission criteria. Latest technologies, systems and standards enable flexible and dynamic reconfiguration of optical network resources, which facilitate the adoption of new criteria (for emergency purposes) and thus improve network availability and efficiency even in the case of disaster.

One promising technology is referred to as the elastic optical network [b-Gerstel]. Based on the flexible grid defined in [ITU-T G.694.1], the elastic optical network enables network operators to accommodate services over optical fibres with aggregations denoted in [ITU-T G.872] and configure the optical transmission parameters, listed in [b-ITU-T G-Sup.39], according to frequency bandwidth and remaining optical cables.

Appendix III describes practices for re-establishing optical infrastructures with elastic optical network technologies.

2) User experience improvement in the event of unstable or intermittent network connectivity

One problem in a disaster situation is that terminal devices are often disconnected from the public wireless local area network (LAN) owing to radio wave interference and it is often difficult for people to share information among their devices. To overcome this unstable and intermittent network connectivity and maintain higher quality of user experience in use, it is important for terminal devices to control their processes of data storage and transmission, such as online or offline, to match network status.

7.4.2 Substitute networks and repair

After a disaster, it is essential to restore affected network facilities as soon as possible. However, it may take a long time to repair all facilities. Network recovery technologies are needed to restore the telecommunication infrastructure as much as possible.

1) Movable and deployable ICT resource units (MDRUs)

When a serious disaster occurs and a key network facility such as a local switch or edge node is destroyed, its lengthy repair time will cause serious communication failure in the disaster area. Even if the facility works, the decreased capacity may not be able to handle post-disaster traffic, which will propagate network congestion and thus cause more serious network-wide blackouts. To tackle this situation, an effective set of ICT resources that allows various settings and quick deployment, is prepared as a transportable package and sent to the area. The new ICT resource units substitute for the role of the lost network facilities as well as providing extra ICT resources to meet the explosive communication demands in the disaster area. Rescue-oriented ICT applications can be installed and activated on the unit. Movable and instantaneously deployable ICT resources are expected to work together with the remaining ICT facilities including user terminals. Physical appearances, reference resource components, their configuration procedures, and pre-installed application profiles are candidates for standardization.

[ITU-T L.392] describes disaster management for improving NRR with movable and deployable ICT resource units.

2) Temporary repeater: a portable repeater for post-emergency recovery of optical fibre links in remote areas

Underground optical cables have high survival rates even after disasters. To best use the surviving underground optical cable, a portable repeater would be effective in enabling swift reconnection of surviving fibre links to optical fibre networks or provide a means of bypassing damaged network infrastructure.

Appendix I describes practices for connecting surviving fibres and building temporary optical infrastructures [with a portable erbium-doped optical fibre amplifier (EDFA)].

3) Delay-tolerant networking (DTN)

Currently, most user terminals such as smartphones and tablet devices are equipped with Wi-Fi functionality. If they support DTN through Wi-Fi, each mobile terminal is able to send delay tolerant messages to other terminals in a multi-hop fashion and is likely to be able to establish communication even in the event of disasters.

Regarding DTN, refer to [b-DTNRG] and [b-Farrell].

Regarding the use of DTN for information communication in disaster areas, refer to [b-DTN-Tanaka].

4) Local private wireless mesh network with portable advanced wireless base station

Wireless technology, which does not depend on physically wired networks, plays an important role in planning resilient communications networks. Means of communication complementary to public networks are required to be prepared against disasters so that public networks do not become congested and are resistant to damage while local requirements can easily be met. A local-area privately operated wireless network with portable advanced wireless base station is effective in avoiding complete network blackout caused by some partial damage to the public network.

Appendix II describes the implementation of a local wireless network based on a decentralized mesh architecture.

Appendix I

Practices for connecting surviving fibres and building temporary optical infrastructures (with a portable erbium-doped optical fibre amplifier)

I.1 Introduction

This appendix describes a way to (re-)build optical infrastructures around a devastated area by connecting surviving optical fibres with portable optical amplifiers. Portable amplifiers enable surviving fibres to be connected to healthy core networks by skipping severely damaged transmission equipment and thus providing additional reach. As a result, temporary optical infrastructures can be built in a short period of time even in a blackout area.

In this appendix, an EDFA is discussed.

Such a portable EDFA can contain burst-mode gain block (or component) as an optional function considering an unstable network situation after disaster and the resulting intermittent traffic pattern (i.e., bursty). A specific EDFA, which is under development, eliminates optical surge and smooths gain transient. These characteristics are suitable for bursty traffic, which occurs in the temporary optical infrastructures described in the foregoing.

I.2 Background and concept

I.2.1 Background

According to reports of some major disasters (e.g., big earthquakes and tsunamis), even where operators' office buildings and indoor transmission equipment are severely or completely destroyed, outdoor optical cables, in particular underground ones, had very much higher survival rates in comparison to areal cables. This experience indicates that if the surviving optical cables are connected directly by bypassing damaged transmission equipment and buildings (that usually need a long time to recover) with 1-R repetition function (i.e., re-amplification only without reshaping nor retiming), temporary optical connections and infrastructures can be built in a short period of time.

Portable optical amplifiers are tools for this purpose.

I.2.2 Concept

A portable optical amplifier for emergency restoration is required to be small and light enough so that a maintenance worker can carry it on foot or by bicycle when a motor vehicle cannot be used. The severe environment of devastated areas requires that the amplifier be waterproof and shock-proof. In almost all cases, such areas will be subject to power cuts and the portable unit should have a long-term battery.

It is common that, after a disaster, transmission is intermittent due to network instability. When it comes to an EDFA, such an amplifier distorts the waveform of the amplified signal if the input light signal level changes steeply with bursty traffic. A burst-mode gain block, which is designed to prevent optical surge and gain transient regardless of signal level change, is suitable for emergency restoration.

I.3 Usage scenarios

Figure I.1 shows a usage scenario of a portable amplifier. Three exchange offices, Offices 1, 2 and 3, at the top of Figure 1 had been connected via fibres at the bottom. A disaster destroyed Office 2 in the middle and collapsed machine racks. The optical connection there was cut. If the surviving fibres in Office 2 are spliced, a new but longer optical path can be re-established between Offices 1 and 3. It should be noted that repeating power will no longer be provided in Office 2. In such a situation, a maintenance worker brings the portable optical amplifier to Office 2. By using this amplifier to connect a pair of surviving underground optical fibres with variable optical gain, the affected part of the physical network can be temporarily restored and connected with undamaged exchanges.

In other scenarios, such as a detour route creation not using perfectly broken fibre cables attached to a fallen bridge, a portable amplifier can provide redundancy for an alternative route providing variable optical gain.

In any case, the portable amplifier can support stable optical 1-R repetition driven by a long-term battery even in a blackout area. By this means, emergency restoration of a physical optical link can provide much flexibility.

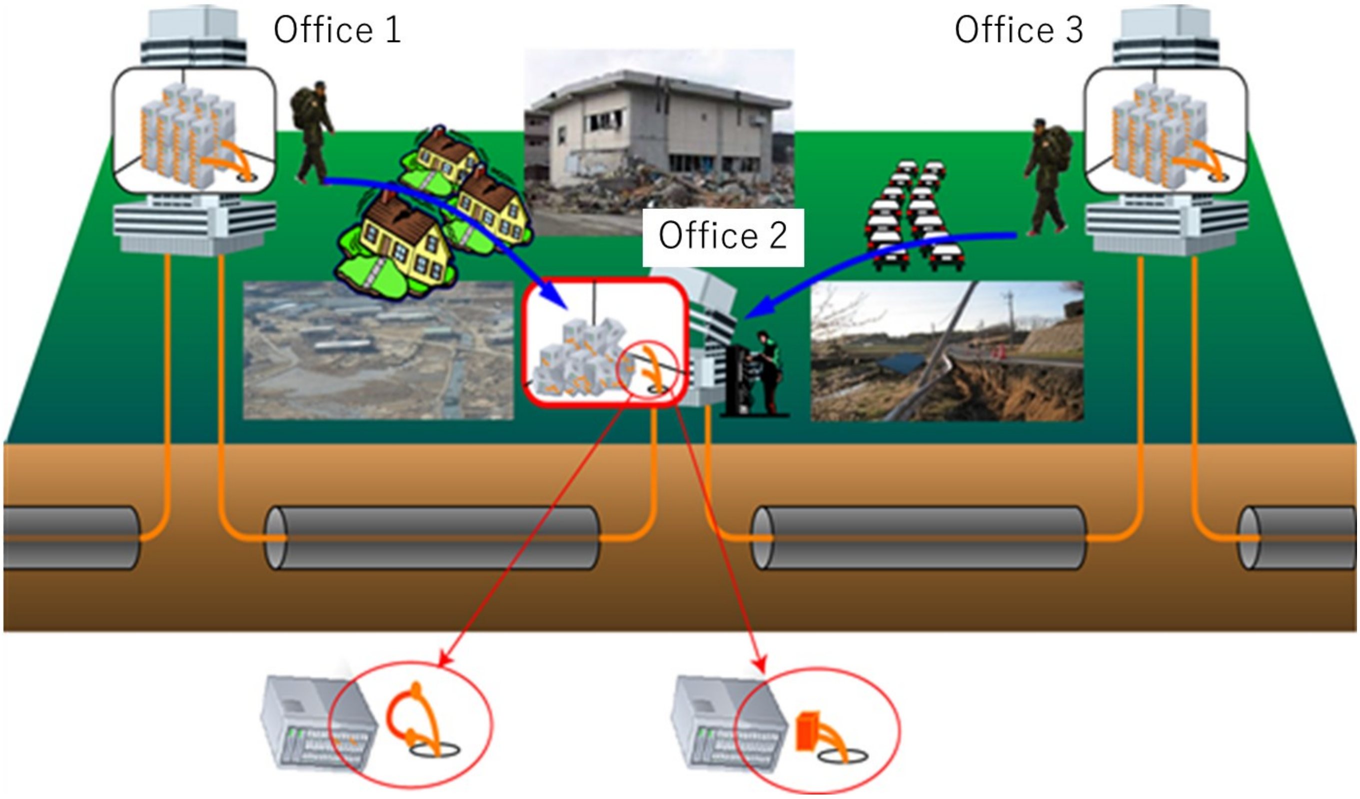

Figure I.1 – A portable erbium-doped optical fibre amplifier

I.4 Considerations concerning the equipment

I.4.1 Small and light

The equipment is expected to be small and light enough that a maintenance worker can carry it on foot or by bicycle when a motor vehicle cannot be used. Target mass is less than 10 kg per person. In order to complete fibre link restoration, the worker team also has to carry a portable splicer. Also, a removable battery in the portable amplifier unit makes payload-mass adjustment much easier. It means that, the payload of carried equipment required for optical fibre restoration is adjustable to the worker team size.

I.4.2 Waterproof and shock-proof

The severe environment of disaster areas requires that the equipment be waterproof and shock-proof.

I.4.3 Battery driven

The severe environment of a disaster area requires equipment to be battery driven, and offer continuous operation even during battery change. In some cases, it is also recommended that easily obtainable batteries such as those for smartphone be employed.

In other cases, it is recommended that a combination of small and large batteries in terms of power capacity be used. A small battery embedded in the equipment supports continuous operation even when the larger battery is replaced. A larger battery outside the equipment supports long-term operation and can be replaced when necessary. The small inside battery should be rechargeable by the larger outside one. A current flow controller is needed.

I.4.4 Optional amplifier specification

– Burst-mode optical gain block: The amplifier keeps the output wave pattern undistorted for any type of input light signal, even when communication traffic is unstable. The portable amplifier unit can contain a reconfigurable dispersion compensator for the purpose of compensating second order chromatic dispersion.

– The gain block inside should support multiples of duplex amplification supporting fibre pairs.

I.5 Other open issues

– Operation in a destroyed exchange office (e.g., identification method of fibres to be connected, confirmation method of amplifier gain, necessary tools).

Appendix II

Implementation of a local wireless network based on a decentralized mesh architecture

II.1 Introduction

This appendix describes a way to improve NRR by a wireless communication technology that connects radio relay nodes into a mesh topology where each relay node operates independently (even if it is not connected to the backbone network). To quickly restore the network stopped by a disaster, to (re)start the information exchange services for "safety confirmation" and "emergency responses" and to continue the service with unstable node and link availability, the wireless mesh network based on a decentralized mesh architecture is effective. Typical requirements for the local wireless mesh network are also described in this appendix.

II.2 Background and concept

II.2.1 Background

At least 10,000 cellular phone base stations ceased operation immediately after the great East Japan earthquake, owing to the damage and power failure caused. Because of the rapid increase in communication traffic, up to 90% of calls were suppressed by telephone companies to maintain stable operations. Many wired communication networks and the emergency municipal radio communication systems were destroyed, and the vulnerability of the systems to disaster was completely exposed. As a result of this, the safety of residents was compromised as well as their ability to grasp the magnitude of the disaster. It also proved to be fatal during DR operations, such as the mobilization of medical services and rescue supplies by government and public organizations. This resulted in extensive social and economic losses. Alternative means of communication should be prepared to counter a disaster in addition to mobile phone networks.

To support local communications in a devastated area, networking of major sites (e.g., local government offices and evacuation shelters) is one of the crucial issues. Wireless technology, which does not depend on physical wired networks and its installation efforts, plays an important role in setting up such local networks. For robustness, flexible alternative route provisioning and its distributed control is one approach to designing a network. A local wireless network based on a decentralized mesh architecture is effective in avoiding entire network shutdown that may be caused by partial damage to the network. See Figure II.1.

II.2.2 Concept

A local wireless mesh network is a local-area network that consists of multiple relay-capable nodes connected with each other via wireless links (i.e., in mesh topology), governed by specialized control for discovering communication paths from among available nodes and wireless links, and which provides information relay services to user terminals (typically Wi-Fi terminals).

The relay-capable nodes (or relay nodes) are assumed to be placed on the top of buildings or on the ground with good visibility in preparation for disasters, installed where needed or transported by car or plane. A local communication service in a relatively limited area provided by a private company or local government (rather than public network operators) is an initial design target.

In some implementations, worldwide interoperability for microwave access (WiMAX) links are also introduced in order to wirelessly link the separated relay nodes. The mesh network has a significantly enhanced disaster resilience due to its distributed database and distributed application technologies. The mesh network assumes that local governments allow them to run by themselves in a normal situation. In addition, it can also employ connections to on-vehicle satellite Earth stations and mobile repeaters and program-controlled small unmanned aircraft. These Earth stations and mobile repeaters are expected to rapidly establish communication and monitoring links to isolated areas until the infrastructure is recovered.

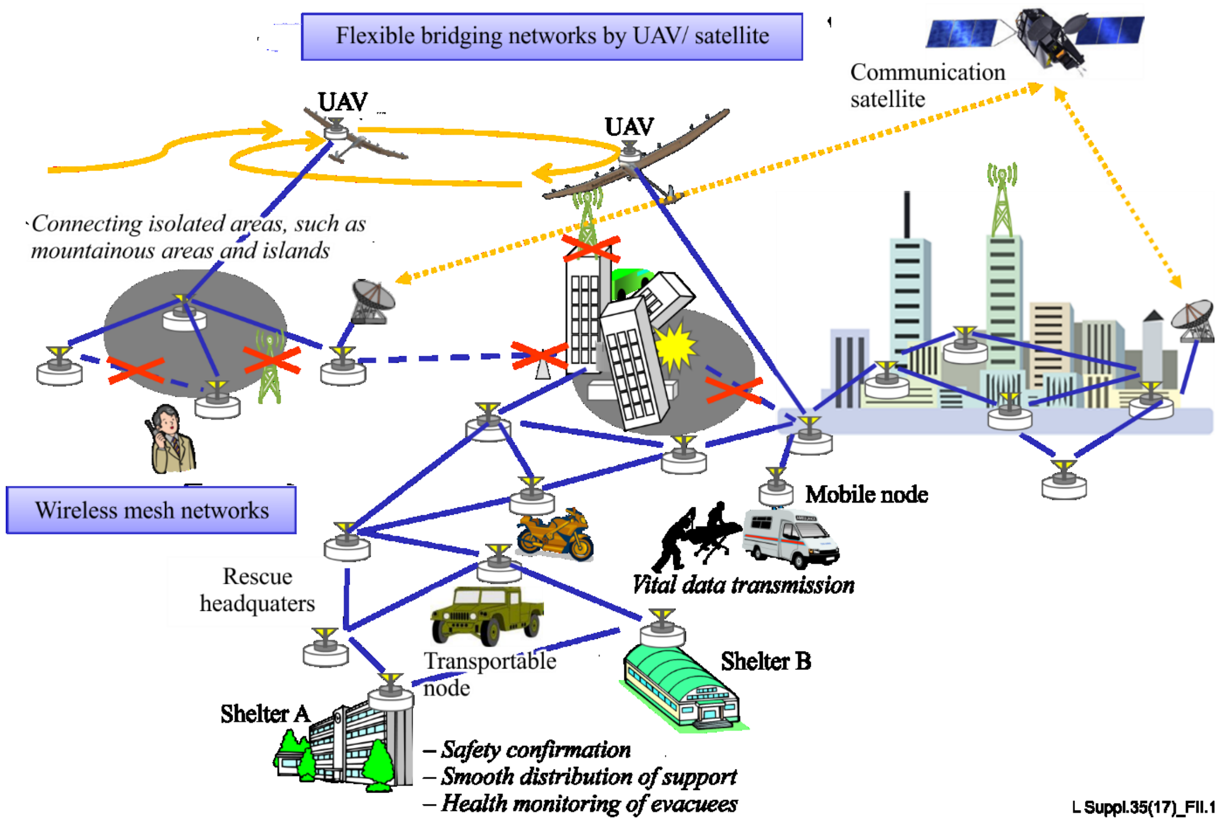

Figure II.1 – Local wireless mesh network based on decentralized mesh architecture

II.3 Usage scenarios

Several applications are needed to handle the various emergency situations possible. Typical applications are information sharing among groups, and safety confirmation among individuals. Some healthcare applications will also be implemented to help elderly or sick residents after a disaster. The nearest evacuation point and the user's current position are displayed on a map on the smartphone of the user after accessing a wireless LAN. In addition, a person's state and position input via a smartphone are delivered to other radio base stations as safety confirmation. As a result, a family can confirm the latest safety information even if its members are in different places. Children and the elderly who may not have a smartphone can register their safety information just by touching their chip card to an outdoor signage type radio relay node [with an integrated circuit (IC) card reader] and can view the safety information of others on the signage.

In the Kumamoto earthquakes having maximum magnitude M_w 7.0 in the Kyushu region in south-western Japan that occurred in April 2016, both a satellite Earth station and wireless mesh network systems were deployed in the disaster area. An Internet communication environment has been effectively offered to those affected by the earthquake.

II.4 General considerations for networking between nodes

– Continue communication automatically using surviving and operating facilities when parts of the network are damaged or congested.

– Use self-sustaining mesh architecture to support mobility, address resolution, and multicast even if Internet connection is lost.

– Quick rerouting with a distributed database of operation status of nearby radio relay nodes in each radio relay node.
– Quick restoration of a part of a damaged or congested network by substitution with a temporary communication network.

II.5 Considerations for individual nodes

II.5.1 Radio relay node (both fixed and portable)

– Provide an antenna to connect to adjacent radio relay node(s), an antenna (Wi-Fi etc.) for wireless LAN to connect nearby users, a solar panel or a battery. Provide wheels to permit hand carriage etc.
– Quick deployment of a temporary communication network in an isolated area.

II.5.2 Aerial radio relay node

– Quick deployment of a temporary communication network in an isolated area by an unmanned aerial vehicle (UAV), equipped with a small radio set, that can be hand carried, does not require a runway and whose autonomous flight can be computer controlled.

II.5.3 Fully automated portable satellite Earth station

– Connect to the wide area network via a satellite line with an antenna by a fully automated portable Earth station with antenna feed and antenna footstool with a chest that is easily assembled without tools.

II.5.4 Satellite Earth station on a vehicle

– Connection to the wide area network via a satellite line by an Earth station on a vehicle that also holds an antenna, an integrated power amplifier and automatic satellite tracker; high-speed transmission is to be possible by using a multi-beam satellite antenna.

II.5.5 Considerations about service platforms over a local private network

– Continue communication and applications for "safety confirmation" and "emergency responses", even if connection to the backbone network and the Internet is lost.
– Continue service even if the main server is stopped, using a synchronized and distributed database in each radio base station.
– Deliver alerts on daily use services via local access network.
– Pass refuge instructions, safety confirmation and relief requests after a disaster.

II.6 Other open issues

– Guarantee of power supply and battery life.
– Positioning the radio base stations with consideration of topology.

Appendix III

Practices for re-establishing optical infrastructures with elastic optical network technologies

III.1 Introduction

There are risks of telecommunication service disruptions even in a fully protected optical network after severe disasters, which affect a significant part of pre-planned network resources, so that recovery of services fails. This appendix describes recovery scenarios for such disrupted services. In order to efficiently accommodate recovery resources, flexible configuration of optical signal parameters is crucial to utilize surviving optical cables. To this end, one promising technology is the elastic optical network [b-Gerstel]. Here, use cases of re-establishment of optical infrastructures for disrupted services with an elastic optical network are addressed.

The elastic optical network is featured as flexibly configurable whose elements enable the selection of appropriate signal parameters corresponding to available optical fibre resources and transmission quality of the path routes. In terms of disaster recovery, two usage scenarios are expected to enhance survivability of network services, namely adaptive restoration and adaptive reallocation. Firstly, adaptive restoration offers various recovery routes by selecting optical signal parameters adaptive to their transmission quality. Secondly, adaptive reallocation reconfigures optical network resources according to the available optical wavelength slots in surviving optical cables. This reallocation method enables efficient identification of alternative wavelength slots for recovery in aggregated unoccupied wavelength slots. In clauses III.2 to III.6, recovery scenarios derived from lessons learned in severe disasters are described that significantly improve the success rate of service recovery with the previously mentioned two methods on an elastic optical network.

III.2 Background and concept

III.2.1 Background

The importance of optical networks is growing as they are able to offer stable long-haul communication with large traffic volume. However, so far, several cases have been reported of a significant proportion of communication services being affected beyond expectation, even in a fully protected optical network, due to extraordinary disasters. For instance, during the 2016 earthquake of M_w 7.0 in Kumamoto prefecture, Japan, nine relay points in optical backbone cables were damaged and 45 communication buildings lost electrical supply, as reported in [b-NTT-West]. The great East Japan earthquake of M_w 9.0 in the Tohoku area in 2011, devastatingly affected about 150 million telecommunication lines, about 90 relay points in optical backbone cables and 990 communication buildings, as reported in [b-NTT-East]. In the case of such severe disasters, pre-planned protection resources also break down, so it is necessary to recover disrupted services by reconfiguring surviving network resources. The recovery of affected services is challenging because surviving resources for recovery have a limited number of available wavelength slots. Also, transmission quality on recovery routes is not always guaranteed compared to the working route in ordinary use.

III.2.2 Concept

One promising technology to improve the success rate of service recovery after a disaster is the elastic optical network. The elastic optical network is based on the optical wavelength management technique of the so-called "flexible grid" defined in [ITU-T G.694.1] and enables efficient mapping of service requests on to optical signals by selecting appropriate optical signal parameters, such as modulation format, listed in [b-ITU-T G-Sup.39], according to the transmission quality of optical fibre cables. For disaster recovery, the success rate of re-establishing disrupted services will be improved by selecting optical signal parameters according to the available wavelength slots and quality of transmission in a recovery route constructed from surviving optical cables. The recovery scenarios with the adaptive restoration and adaptive reallocation are presented in clauses III.3 to III.6.

III.3 Usage scenarios

The elastic optical network in the usage scenarios is composed of a network management system (NMS), network elements (NEs) and optical supervisory channel (OSC) interfaces.

The following describes the functions of each component. First, an NMS searches stored network topology information and finds path routes corresponding to service requests, configures optical signal parameters according to the available wavelength slots and transmission quality required to accommodate the service. Then an NMS acknowledges the signal parameters to the NEs on the corresponding route. Second, an NE transmits and receives the optical signals conveying the requested services through optical fibre cables. Third, an OSC interface is utilized to transfer control messages between an NMS and NEs, such as configuration parameters of each NE and failure information.

When a severe disaster occurs, each of the NEs detecting failures in optical cables switches the affected optical communication path on to the backup route and sends a control message regarding the failure occurrence to the NMS via the OSC interface. After receiving the message, the NMS finds recovery routes out of the surviving network topology according to the failure messages, calculates the configuration parameters on NEs to re-establish the disrupted services and notifies the parameters to each NE. As the result, surviving network resources are efficiently reconfigured and disaster recovery is achieved.

Clause III.4 explains, with reference to Figure III.1, the two specific practices of disaster recovery that pre-configured redundant paths on to an optical cable connecting NE1 and NE4, as well as a communication building NE5 damaged by a disaster.

III.4 Adaptive restoration enhanced with an elastic optical network

Adaptive restoration increases the number of choices in recovery routes by selecting optical signal parameters according to the available wavelength slots and transmission quality of the routes.

As depicted in Figure III.1, service recovery by using pre-planned protection resources between NE1 and NE4 fails due to the breakdown of all the optical fibres connecting NE1 and NE 4. In this case, the NEs inform the NMS of the failure via the OSCs. Then, the NMS finds recovery routes for the disrupted services. Because surviving resources for recovery generally have a limited number of available wavelength slots and the transmission quality on recovery routes is not always guaranteed, recovery of affected services is challenging. With the help of adaptive restoration, by selecting the appropriate optical signal parameters according to the transmission quality of the corresponding recovery route, disrupted services are recovered from the dual failure of optical fibres. In the example shown in Figure III.1, one of the optical signal parameters, i.e., modulation format, of recovery resources is changed from the large-capacity but short-reach 16QAM (quadrature amplitude modulation) to the long-reach BPSK (binary phase shift keying) with wider optical bandwidth.

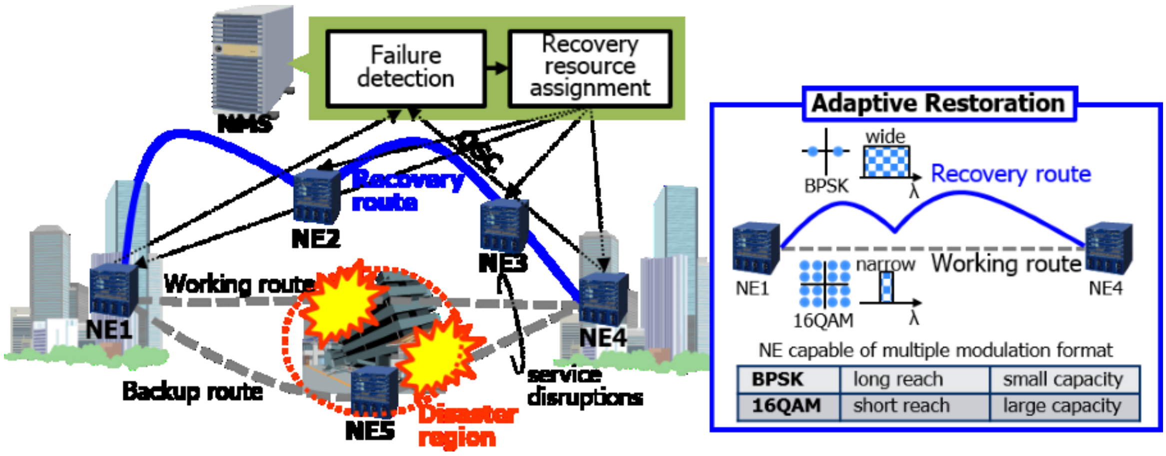

Figure III.1 – A scenario of service recovery with adaptive restoration

III.4.1 Adaptive reallocation enhanced with an elastic optical network

With adaptive reallocation, optical network resources are reconfigured according to the available optical wavelength slots in surviving optical fibres. That contributes to the efficient re-establishment of recovery paths for disrupted services. Furthermore, even if unoccupied wavelength slots are fragmented and there is no room to accommodate a single recovery path with continuous wavelength slots, a number of disrupted services are expected to be restored with a multiple of optical signals by aggregating the fragmented wavelength slots.

As depicted in Figure III.2, the link between NE2 and NE3 accommodates extra recovery optical paths and then is congested. Traffic congestion causes the optical fibre connecting NE2 and NE3 to be fragmented. The recovery of disrupted services using the congested fibre link is challenging, since allocating recovery resources with a single-carrier optical path fails on fragmented slots. Using adaptive reallocation, recovery resources with super-channel optical channels can be accommodated on the fragmented slots. In this example, the recovery path consisting of two super-channels re-establishes disrupted services.

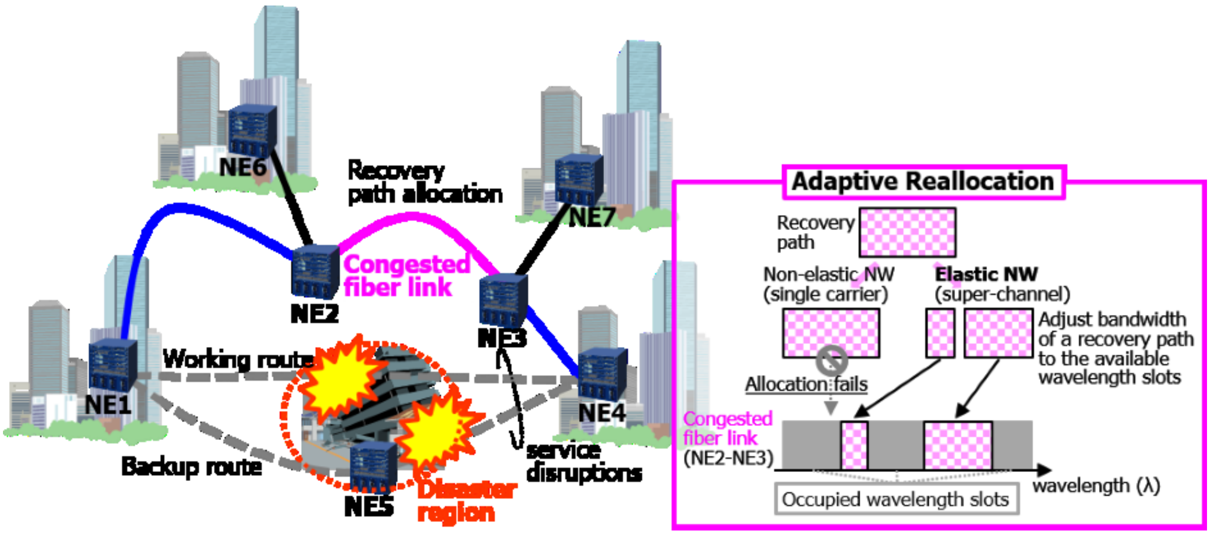

Figure III.2 – A scenario of service recovery with adaptive reallocation

III.5 General considerations

General considerations about the components of an elastic optical network in order to recover optical infrastructures are described.

III.5.1 Network management system

– Receive notifications of communication failures detected at each NE via the OSC interface.
– Quick optimal search for a recovery route out of the surviving optical fibre cables and NEs.
– Configure optical signal parameters such as a modulation format and optical bandwidth adjusted with the available optical wavelength slots and the quality of transmission in the recovery optical fibre cable.
– Notify the optical signal parameters to NEs via the OSC interface.

III.5.2 Network element

III.5.2.1 Optical nodes

– Control optical transceivers according to the control messages from the NMSs.
– Are equipped with several optical transceivers.
– Notify communication failures detected by equipped optical transceivers to the NMSs via the OSC.

III.5.2.2 Optical transceivers

– Establish communication by configuring optical signal parameters according to control messages from the optical node.
– Detect network failures and notify the failure status to the NMSs.

III.5.2.3 Optical supervisory channel interface

– Transfer control messages among the NMSs and the NEs.

III.6 Other open issues

– Repair schedule of failed NEs.

Appendix IV

Considerations by the Pacific Islands Telecommunications Association on disaster relief

This appendix introduces additional information for considering detailed requirements of DR supplied by the Pacific Islands Telecommunications Association (PITA).

PITA is a non-profit organization formed to represent the interests of small island nations in the Pacific region in the field of telecommunications. The objective of the Association is to improve, promote, enhance, facilitate and provide telecommunication services within member and associate member countries. PITA members are telecommunication entities in Melanesia, Micronesia, Polynesia, Australia and New Zealand. Associate members are suppliers of telecommunication equipment and services. Partner agencies are regional and international organizations with vested interest in telecommunications and its development. Governmental telecom regulatory bodies have a special membership category.

Further information about PITA is available in [b-PITA].

IV.1 Background

Many Pacific island telecoms have built-in redundancy and physical diversity that continuously provide contingency capability on international links. Many of those with two or more satellite antennas would still be severely impaired if one antenna or their international voice gateway failed. Many Pacific islands have only one antenna for all international services. Disasters can also occur in isolated regions where it is difficult to restore unprotected local network, e.g., the 2009 tsunami that devastated Samoa.

IV.2 Concepts and rationale

– To save lives and minimize losses.
– Small islands and most members are not able to afford disaster and emergency communication systems.
– Measures to support the public in three aspects: survey/triage teams with handhelds, response team with mini setups and public systems.

IV.3 Emergency/disaster recovery requirements

A fully integrated service restoration solution that:

– addresses both domestic and international services;
– covers loss of terrestrial or satellite backbone services;
– supports essential services (telephony and IP) during an emergency;
– offers service capacities of up to 2 Mbit/s or more per site;
– is scalable to support a large number of sites if needed;
– offers optional emergency access network for government and agencies;
– employs open standard technologies or transparent network architectures;
– uses standard building blocks for transmission, switching and customer access to interface with or replace existing network infrastructure;
– may be activated automatically or with a minimal level of expertise;
– can achieve critical service restoration;
– is cost effective to implement.

IV.4 Disaster scenarios

The disaster scenarios are classified into catastrophic failure of:

– main communications – satellite antenna;
– main communications and international gateway switch;
– communications to a region within island, e.g., tsunami in a remote area.

IV.5 Restoration levels

Restoration levels are classified into:

– LEVEL 1: Almost immediately using equipment or expertise within a country – basic phone/internet connectivity for lifeline services;
– LEVEL 2: Within 24 h – wireline or mobile and high-speed Internet for lifeline service, vital communications or limited media release;
– LEVEL 3: Within 48 h – full communications capability.

Bibliography

[b-ITU-T E.108] Recommendation ITU-T E.108 (2016), *Requirements for a disaster relief mobile message service*.

[b-ITU-T G-Sup.39] ITU-T G series Recommendations – Supplement 39 (2016), *Optical system design and engineering considerations*.

[b-ITU-TR] ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery, Technical report (2013), *Technical Report on Telecommunications and Disaster Mitigation.*

[b-IECe-tech] IEC e-tech (2017). When disaster strikes. Available (viewed 2017-08-25) at http://iecetech.org/issue/2015-03/When-disaster-strikes.

[b-ASTM] ASTM. Refer to www.astm.org.

[b-DTNRG] Delay-Tolerant Networking Research Group. Available (viewed 2017-08-04) at: https://sites.google.com/site/dtnresgroup/

[b-DTN-Tanaka] Tanaka, A. (2014). Technical challenges of information communication in disaster areas with delay tolerant networking technologies. In: *Proceedings of Asia-Pacific Microwave Conference (APMC)*, pp. 660–661.

[b-Farrell] Farrell S., Cahill V. (2006). *Delay- and disruption-tolerant networking*. Boston, MA: Artech House. 226 pp.

[b-FG-DR] ITU-T FG-DR&NRR, (2014), *Requirements for disaster relief system*.

[b-FG-Frame] ITU-T FG-DR&NRR, (2014), *Promising technologies and use cases – Part I, II and III*.

[b-FG-Gap] ITU-T FG-DR&NRR, (2014), *Gap analysis of disaster relief systems, network resilience and recovery*.

[b-FG-MDRU] ITU-T Focus Group on Disaster Relief Systems, Network Resilience and Recovery, (2014), *Requirements on the improvement of network resilience and recovery with movable and deployable ICT resource units.*

[b-FG-Overview] ITU-T FGroup-DR&NRR, (2014), *Overview of disaster relief systems, network resilience and recovery*.

[b-Gerstel] Gerstel, O., Jinno, M., Lord, A., Yoo, S.J.B. (2012). Elastic optical networking: A new dawn for the optical layer? *IEEE Communications Magazine* **50**(2), pp. S12–S20.

[b-NEBS] Telcordia. *NEBS™ documents and technical services*. Available (viewed 2017-08-04) at: http://telecom-info.telcordia.com/site-cgi/ido/docs2.pl?page=nebs

[b-NFPA] National Fire Protection Association. Available (viewed 2017-08-04) at: http://www.nfpa.org/

[b-NTT-East] NTT East (2012). *Recovering from the great East Japan earthquake NTT East's endeavors*. Tokyo: NTT East. 38 pp. Available (viewed 2017-08-05) at: http://www.ntt-east.co.jp/info/detail/pdf/shinsai_fukkyu_e.pdf

[b-NTT-West] Murao K. (2016). *Financial results for the fiscal year ended March 31, 2016 (17th term)*. Osaka: NTT West Corp. Available (viewed 2017-08-05) at: http://www.ntt-west.co.jp/news_e/1605dsyk/pdf/ntyw160513a.pdf

[b-PITA] *PITA – Pacific Islands Telecommunications Association* [home page]. Available (viewed 2017-08-05) at: http://www.pita.org.fj/

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