A Technical Report on the Advanced Real-time Earth Monitoring Network in the Area

(ARENA)

Chapter 2: Network Overview

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Contents

2. Network Overview

2.1 Introduction

In this chapter, the overall concept of the ARENA project will be discussed first (**Section 2.2**) However, it will only be an overview given that the cable route, landing locations and other details are subject to future studies.

To carry out technical study of a large-scale system such as ARENA, it is essential that the technical requirements be clarified first. For this reason, **Section 2.3** will lay out the technical requirements for ARENA. Since cable length, topology and the like are bound to change with the progress of future studies, the best way to carry out technical study at this stage is to simplify and model the proposed network. To this end, the network will be modeled in **Section 2.4**. The types of sensors to be deployed at various observation points will then be identified in **Section 2.5**, with their power consumption levels, data bit rates and synchronization accuracy requirements estimated.

Figure 2-1 Future Network Configuration envisaged under ARENA Project

2.2 Configuration of cable network

As has been discussed in **Chapter 1**, the scientific submarine cable network envisaged here is a multipurpose network that can be used in many scientific areas. In light of the fact that the Japanese archipelago is situated very close to a plate boundary, along which gigantic earthquakes have been periodically occurring, and that seismological study is a main research theme for scientific submarine cable networks, it would be a rational decision to develop the proposed submarine cable network along the plate boundary.

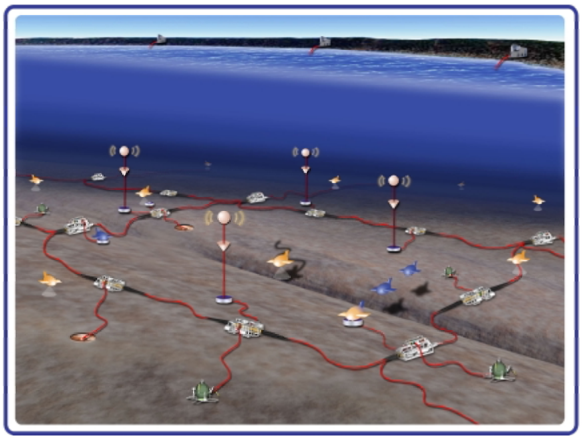

Figure 2-2 Conceptual Image of Network

Figure 2-1 shows the future cable network envisaged under the ARENA project. The submarine cables that make up the network basically run along the plate boundary. Multiple landing stations increase network robustness and reliability against cable faults. The segmentation of the submarine cable system allows construction to proceed on a segment by segment basis and observation to commence from completed segments.

It is envisaged to lay two cables off Sanriku to sandwich the plate boundary. This configuration makes it possible to observe plate movements from both sides of the boundary, as well as enabling the acquisition of greater amounts of data through a two-dimensional deployment of observation instruments. In seismic monitoring, a wide two-dimensional coverage of seismometers and other instruments is particularly useful.

Figure 2-2 shows a conceptual image of the network. Apart from ocean-floor seismometers, the network is expected to accommodate diverse measuring instruments, including tsunami gauges, inclinometers, current profilers, thermometers, geodetic acoustic transponders, television cameras, radiometers and other miscellaneous scientific sensors. These measuring instruments are to be connected to the system via underwater mateable connectors. This arrangement enables the replacement/repair of failed sensors without stopping the system as a whole. Moreover, it readily accommodates the future addition of new sensors as they are developed. In this manner, underwater mateable connectors give flexibility to the system.

In addition to sensors that are directly connected to it, ARENA will support AUVs, ROVs and buoy mooring systems, as well as borehole observatories set up inside boreholes drilled into the ocean floor.

An AUV transmits/receives signals and recharges its built-in battery as it receives power from an ocean-floor docking station. Its possible uses include the regular patrolling and observation of the area around the docking station and ad-hoc inspection of the area in the event of an earthquake, an underwater volcanic eruption, or the like, as well as the post-installation inspection of a submarine cable or observation equipment and fault investigation in the wake of a fault.

Equipped with a manipulator and remotely controlled from land, an ROV carries out complex tasks while receiving power from a submarine cable. It transforms the ocean floor into a laboratory where various experiments can be undertaken. All necessary laboratory equipment is transported using a mother ship, although transportation via an AUV is a future possibility.

Various observation instruments will be connected to a land-based data management center via an optical fiber network, while the data management center will be accessible from laboratories via the Internet. Some observation instruments will be directly controlled from laboratories. Indeed, the establishment of a direct link between laboratories and the ocean floor will be a main feature of ARENA.

2.3 Technical requirements

Important general technical requirements will be listed below. The requirements for individual systems will be discussed in their respective chapters.

(1) Costs

Cost and reliability are mutually exclusive. While components designed for space applications or underwater telecommunication cable systems are highly reliable, they are also very expensive. Moreover, they are limited in choice. Custom-made components with high reliability are not much better as they would result in enormous development costs. For these reasons, the use of standard general-purpose components should be pursued, accompanied by efforts to enhance the reliability of the system as a whole.

(2) Reliability

Since faults occurring in the power feeding system or signal transmission system greatly affect the overall operation of the observation cable system, it must have high reliability. This is particularly true of underwater power supplies, as underwater equipment is difficult to repair or replace. For this reason, underwater telecommunication cable systems are designed to conform to a failure rate of not less than two failures throughout their design life typically, which is 20 years. Nevertheless, it is unrealistic to expect a similar level of reliability from underwater equipment to be used for ARENA due to greater system complexity. This gives rise to the need to find other ways of increasing the reliability of the system as a whole, including the provision of redundancy for important underwater equipment. It is also important to minimize the reach of the effects of faults occurring in underwater equipment.

(3) Expandability

It is more realistic to build the envisaged large-scale scientific cable network in stages over several years than trying to complete it all at once. For this reason, the cable network is required to be easily expandable.

(4) Fault location function

To be able to easily and swiftly repair faults occurring in a submarine cable, underwater sensors or communications equipment, it is necessary to provide a fast fault location function.

(5) Deployment and installation operations

It is envisaged to use a cable laying vessel capable of handling two cables simultaneously when laying submarine cables. The size and weight of underwater equipment need to be within the capability of such a cable laying vessel. If a fault occurs in underwater equipment during installation, it will have to be retrieved onto the vessel. Therefore, retrieval via a cable laying vessel needs to be a design consideration for underwater equipment.

(6) Repair operations

There are only a limited number of specialized cable ships, and they are expensive to operate. For this reason, it is necessary to make it possible to install and maintain observation equipment using ordinary workboats, although the repair of submarine cables will still require the use of cable ships.

(7) Compatibility with land seismic observation network

On land, a fine seismic observation network has already been put in place by the Japan Meteorological Agency, with observation data being managed in an integrated manner. It is therefore necessary to ensure the compatibility of ocean-floor seismometers to be deployed under the ARENA project with the land seismic observation network.

(8) Flexible data management and system operation

Given that a variety of observation instruments are to be connected to ARENA, a highly flexible system capable of adjusting to the nature of observation in terms of the operation method, data management method, data distribution method, and the like is needed. Observations are classified as shown below according to their nature.

(a) Routine observations

The following are possible routine observations:

(A) Seismic measurement

Data needs to be managed continuously in an integrated manner, while being forwarded to the seismic observation network run by the Japan Meteorological Agency without delay or interruption.

(B) Camera

Broadband signals are continuously transmitted. There is a need to record large amounts of signals on a continuous basis.

(C) Other routine observations

Typical examples are borehole measurement and physical-chemical oceanography. The regularity of observation and integration of data management are important.

Data from these observations needs to be managed without any losses. It is desirable that such data and observation equipment be managed in an integrated manner, with data distributed to research organizations and researchers as necessary.

(b) Ad-hoc observations

Geodetic observations and AUV or ROV-based observations fit this category. Of these, AUV or ROV-based observations involve sophisticated and complex maneuvering/manipulation. As these observations are nonroutine and require specialist knowledge and experience, the support of experts with advanced knowledge and experience is essential.

(c) Cutting-edge observation equipment development

Newly developed observation equipment and observation techniques being used on an experimental basis fit this category. Since the operation of cutting-edge observation equipment requires specialist knowledge and experience, the support of experts with advanced knowledge and experience is essential. The development and management of such equipment also needs the active involvement of experts.

(9) Common interface and management

The operating condition of sensors, their power consumption, on-off state of power supplies and the like need to be managed in a standardized manner throughout the system. The issue of standardization must be handled carefully as some aspects of it contradict the "flexibility" discussed above. Despite this, the standardization of the interface of sednsors is an important step towards a flexible system. In this regard, testing facilities to verify the conformity of observation equipment with the common interface will be needed.

2.4 Modeling of cable network

As discussed above, the detailed cable route and landing locations of ARENA will change in the course of future studies. For this reason, the best way to carry out technical investigations at this stage is to simplify and model the proposed network. Along these lines, a simplified model of the off-Sanriku portion of the network, which has the most complex configuration throughout the system (see **Figure 2-1**), was produced as shown in **Figure 2-3**. This model represents the mesh-like network. Along the submarine cable, observation nodes will be set up at 50 km intervals. A total of 66 observation nodes are envisaged. In this regard, the power feeding scheme for this network will be applicable to all networks covering other sea areas, which take simple comb shapes.

At each observation node, multiple observation points will be set up. The configuration of an observation node will be discussed in Chapter 5 "Underwater System".

2.5 Power consumption, data bit rate and synchronization accuracy

Table 2-1 shows estimated power consumption for observatories to be set up at each observation node. Geophysical observatories are to be set up at a rate of two per node. To work out the overall power consumption of the system as a whole, other factors, such as the power conversion efficiency of the power supply built into

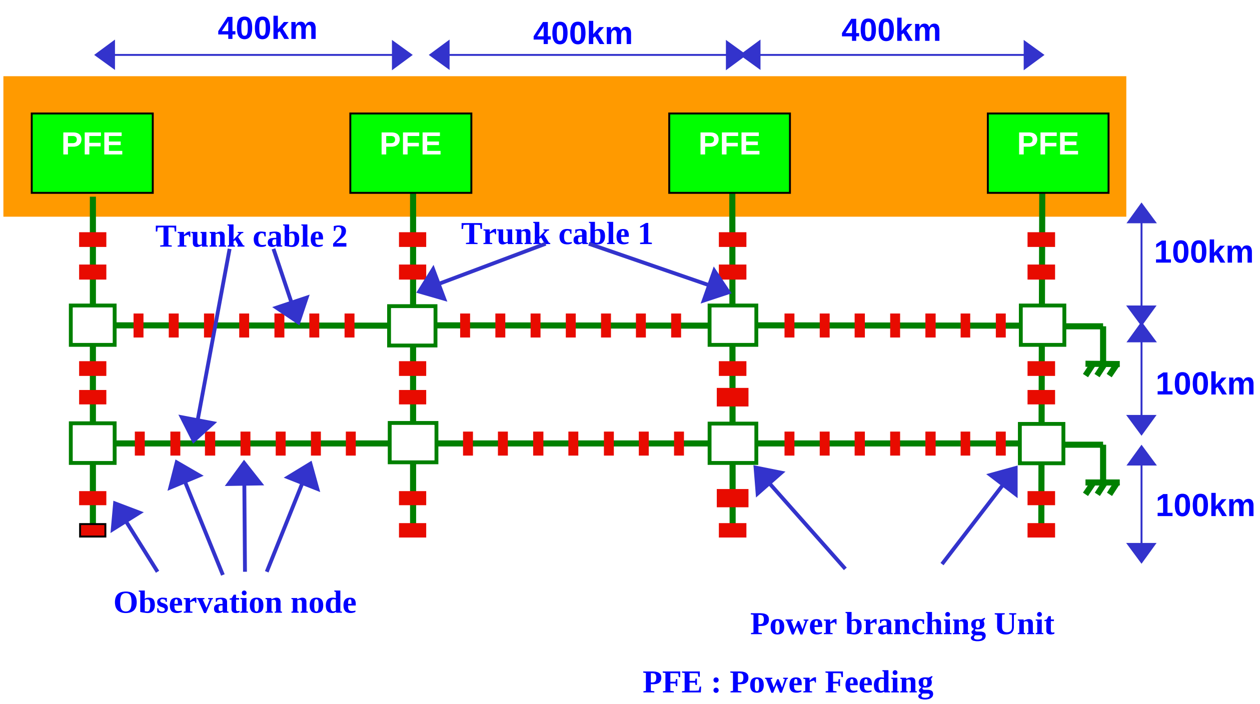

Figure 2-3 Modeling of Scientific Cable Network

underwater equipment and power transmission efficiency of the submarine cable, also need to be taken into account. The combined power consumption of all observatories is about 18.2 kW, and this translates to about 303 W per node, assuming 66 nodes.

Table 2-1 Estimated power consumptions for various observatories

Sensors	Average power	Maximum power	Data bit rate	Syncronization Accuracy
	W	W	kbps	msec
Total	5,443	3,162	105,197	
Geophysical observatory	1,996	2,323	1,426	
Broadband seismometer	3	4	7	1
Tsunami sensor	1		1	1
Gravimeter	9	14	1	
Heat flow sensor	2		1	
Total	15	18	11	
Borehole observatory	138	149	352	
Broadband seismometer	3	4	14	1
Strain gauge	6	7	14	
Inclinometer	2	3	1	
Geomagnetometer & electrometer	3		1	
Gravimeter	9	61	1	
Heat flow sensor	2		1	
Radiometer	12		1	
Optical tiltmeter array	16		12	
Optical seismometer array	16		130	0.010
total	69	75	176	
Oceanographic observatory	1,229	218	824	
ADCP	84	308	0	
Hydrophone array	4	6	50	0.010
CTD	4		5	
Current profiler	3		5	
Geomagnetometer & electrometer	3		10	
Gravimeter	9	14	1	
Metal ion sensor			1	
Chlorophyll sensor	2		1	
pH sensor	0		1	
Dissolved oxygen sensor	0		1	
Transmissivity sensor	0		1	
Soil thermometer	1	2	1	
Radiomerter	12		5	
Total	123	22	82	
Geodetic observatory	696	400	2,511	0.001
Accoustic transponder	5	5	1	0.001
Inclinometer	2	3	1	
Acoustic range profiler	1	1	1	0.001
Hydrophone array	4		50	
CTD	4		5	
Total	16	9	58	
Optical sensor array	0	0	0	
Optical hydrophone array	0	0		
Optical seismometer array	0	0		
Total	0	0	0	
Camera observation	545	72	46	
TV camera	12		23	
Stage		36		
Codec	60			
Light	200			
Transmissivity sensor	0			
Total	272	36	23	
AUV station	600	0	100,000	
Charger	60			
Total	60	0		
Accoustic tomography	240	0	38	
Global warming monitoring system	60		10	
Total	60	0	10	

Optical data transmission syste,				
Optical amplifier	10			
Controller	10			
Ethernet switch (100Mbps)	47	49		

2.6 Technical terms