

# A Proposal of IP-based Computer Network Architecture for Facility Maintenance Information

Hiroyuki Yusa<sup>†</sup>, Tetsuo Otani\* and Masahiro Kurono\*

**Abstract** – In this paper, we propose IP-based computer network architecture for communications of facility maintenance information. This architecture enables realization of overlay network on the IP network to control the communications. We also examined a feasibility of the architecture with an experiment system. The result shows that the feasibility of the architecture is confirmed.

**Keywords:** Facility maintenance, IP network, Network control, Network management

## 1. Introduction

It is necessary for Japanese electric companies to operate electric apparatus until limit of their performance and life and maintain them with a broad view all over power system. Technologies for condition-based maintenance (CBM) are being researched and developed. It is expected various sensors are allocated in substations and power plants and sensor information is collected across wide area to check electric apparatus, repair them and formulate a maintenance plan in the future. It is effective to realize facility maintenance networks to collect and deliver the information with proof and stability for long time and utilize the information by compiling data in accordance with their usage. The networks are also required to be adaptive to plugging sensors in and out in accordance with secular variation of electric apparatus and collect and deliver their information.

Japanese electric companies already have built wide area IP networks to transfer information for their business supporting systems. It is effective for utilizing their existing IP networks as foundation of the facility maintenance networks, which realizes facility maintenance systems. The IP networks enclose information for other application systems including business support systems. Controlling the communications for each application systems has activity on assuring the quality of the communications. It is required for satisfying requirement of the facility maintenance network to build communication control functions for the network.

Therefore, Section 2 illustrates the outlines and problems of existing technologies to satisfy the requirements for the facility maintenance network. Section 3 follows by proposing architecture to control communications for facility maintenance information. Section 4, we also examined feasibility of the architecture with an experiment system and the result shows that the feasibility of the architecture is confirmed, before concluding in Section 5.

## 2. Communications For Facility Maintenance Information

### 2.1 Requirements for Facility Maintenance Network

It is assumed that sensors and sensor networks are located around electric apparatus and utilized to get maintenance information in a substation for CBM. The information can be collected for wide area across many substations to be made the most use of the maintenance information. A facility maintenance system is assumed to extract the requirement to the facility maintenance network. The facility maintenance system is to collect and manage the information in a centralized manner illustrated in Fig.1

The information acquired in substations is collected in a data center. From the view point of this collection, requirements for the facility maintenance network are extracted and Table 1 and the following show the requirement.

- a) **Measures against increase of traffic**, which is caused by increase of the number of sensor and application of standardized data format to be shared
- b) **Measures against excessive traffic in short time**, which is caused by mixed transfer for cyclic monitored information and status change information

<sup>†</sup> Corresponding Author: System Engineering Research Laboratory, Central Research Institute of Electric Power Industry, Japan (yusa, @criepi.denken.or.jp)

\* System Engineering Research Laboratory, Central Research Institute of Electric Power Industry, Japan ({ohtani, kurono}@criepi.denken.or.jp)

(for example, switching of circuit breaker)

- c) **Measures against mal-distribution of traffic**, which is caused by management of information in centralized manner to inspect conditions for a set of same type of electric apparatus and plan schedules to maintain electric apparatus.

## 2.2 Technologies and Problems for Facility Maintenance Network

We surveyed and analyzed technologies for the facility maintenance networks. The result is described below.

### 2.2.1 QoS Control Technology

The existing IP networks are composed of Network Equipment (NE) including routers and switches. A measure for controlling communications in a NE is Quality of Service (QoS) control function. The QoS control function works in accordance with IP header (Fig. 2) including IP

address and DSCP, which can be used as priority. The control function has the problems for facility maintenance networks, which is not flexible for controlling communications of various types of information. Details are described below.

- Regulation for utilization of DSCP with other application systems' communication
- Difficulty for adding functions specific to communications of facility maintenance

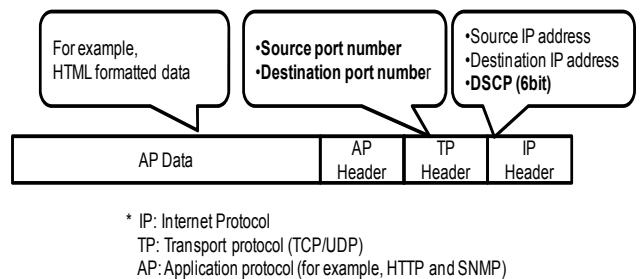


Fig. 2. IP packet.

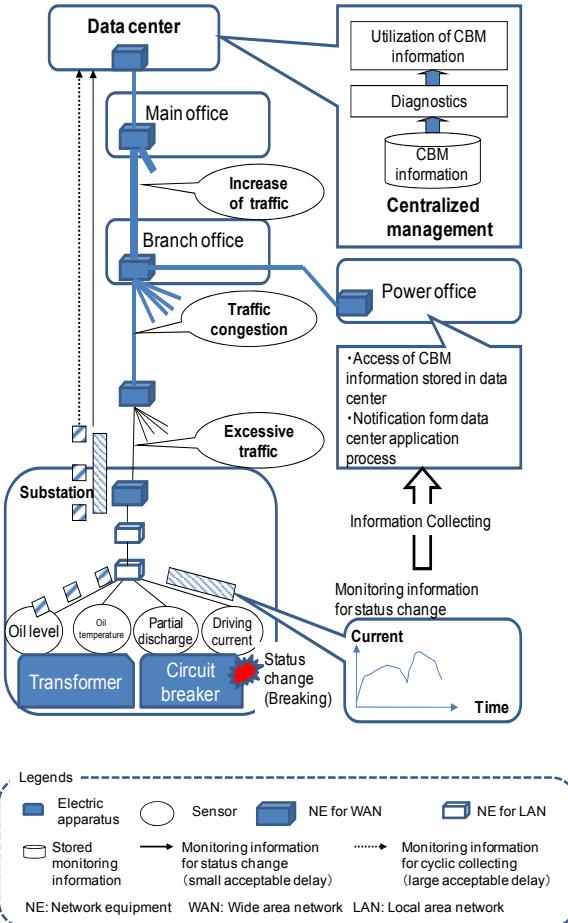


Fig. 1. Image of communications for facility maintenance information.

### 2.2.2 Relating Technologies

Standards and specifications, which can be applicable to facility maintenance networks, are described below (Table 1).

IEEE 802.3ba (100G Ethernet) [1] and ITU-T OTN (Optical transport network) [2] can be applicable as measures against the increase of traffic. But the application is extension of the existing IP networks and not utilization of them. Therefore other measures are required.

A measure against excessive traffic in short time is traffic shaping. The traffic shaping in a NE can be realized with autonomous control with sender request including acceptable delay. ITU-T NGN [3-5] can be applicable to interface for sender request. But it is necessary for mechanisms to assure the requested delay as a complement to be developed.

OpenFlow [6] can be applicable to interface of controlling information flow as a part of the measure against mal-distribution of traffic. ITU-T Y.1731[7], IEEE 802.1ag[8] and IETF IPFIX[9] can be applicable to monitoring traffic as a part of the measure. It is also necessary for realizing the measure to develop a function for managing information flow mapping on transmission route.

Therefore, there are these problems for facility maintenance networks. It is required to realize communication control function specific to the networks as a solution.

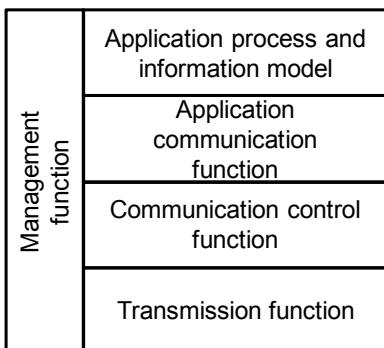
### 3. IP-Based Computer Network Architecture

IP-based computer network architecture for communications of facility maintenance information is proposed to solve the problems and satisfy the requirements.

#### 3.1 Overview

The facility maintenance network is defined with referencing with Distributed Real-time computer Network Architecture (DRNA) [10]. The facility maintenance network is composed of layers of functions. The layers are described below (Fig. 3).

- a) Layer of application process and information model
- b) Layer of application communication functions
- c) Layer of communication control functions
- d) Layer of transmission functions
- e) Layer of management functions



**Fig. 3.** Proposed architecture.

An application process exchange communication data via the facility maintenance network to interact with another application process. The communication data are generated

based on the information model. The information models define information for sensors, diagnostics, inputs/outputs for other application systems and so on.

The application communication functions include application protocols.

The communication control functions include ones to assure the quality of the communications for facility maintenance. The functions are supported by terminals (sensors including sensor networks, application servers and clients) and advanced NEs, which are described below. Transport protocols like TCP and UDP, which are used in terminals, is one of the functions. The functions provided by advanced NEs enable realizing an overlay network on an existing IP network to resolve the problems in Section 2.

The transmission functions are to transfer data among NEs, advanced NEs and terminals. Routers and switches provide the function in existing IP networks.

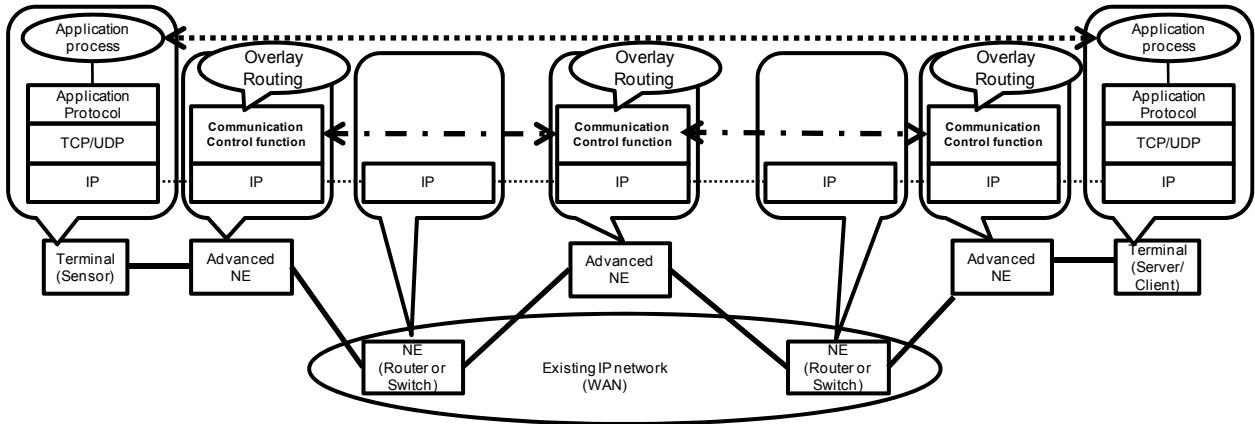
Fig.4 illustrates an example of behavior of the facility maintenance network. An IP network is composed of NEs (routes and switches). The IP networks can be composed of area networks and a core network. The area networks are located in each branch office's management area. The edge networks are connected to the core network. Advanced NEs are connected to the edge networks and core networks to build an overlay network. The overlay network enables to control the application communications among terminals. The details of the advanced NE are described as follows.

#### 3.2 Advanced NE

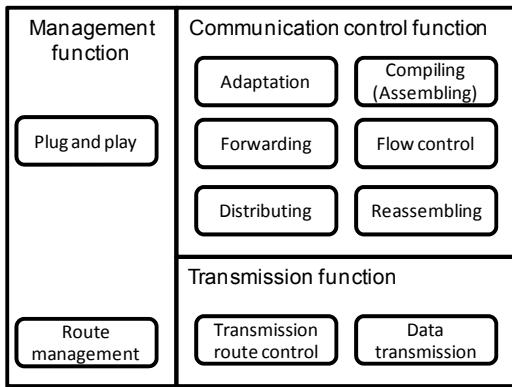
The advanced NEs is to realize overlay network and include the functions for communication control, transmission and management illustrated in Fig. 5. They can be allocated in substations, power offices, branch offices and so on.

**Table 1.** Requirements, communications technologies' trends and problems for facility maintenance networks

Characteristics for CBM with communications	Requirements for facility maintenance network	Trends of communications technologies	Technological Problems
		(Standards and specification)	
Increase of the number of sensor and application of standardized data format to be shared	Measures against increase of traffic	IEEE 802.3ba (100G Ethernet)	Method to replace existing transmission routes with new routes.
Mixed transfer for cyclic monitored information and status change information (for example, switching of circuit breaker)		ITU-T OTN (Optical transport network)	
Management of information in centralized manner to inspect a set of same type of electric apparatus and plan schedules to maintain electric apparatus	Measures against excessive traffic in short time	ITU-T NGN (applicable to interface of sender request including allowable delay)	Method to shape traffic
	Measures against mal-distribution of traffic	OpenFlow (applicable to interface of controlling information flow)	Method to manage information flow mapping on transmission route
		ITU-T Y.1731, IEEE 802.1ag,	
		IETF IPFIX (applicable to monitoring traffic)	



**Fig. 4.** Behavior of facility maintenance network.



**Fig. 5** Functions of advanced NE

### 3.2.1 Communication Control Functions

Communication control functions are to resolve problems described in Section 2 and are as follows.

- a) Adaptation function
- b) Compiling (assembling) function
- c) Forwarding function
- d) Flow control function
- e) Delivering function
- f) Resembling function

The adaptation function is to convert application communications for terminals to and from communications for advanced NEs. The compiling function is to package application data in accordance with their context to enhance the efficiency of transmission. The forwarding function is for routing for compiled data among the advanced NEs. The flow control function is to shape traffic of the compiled data. The delivering function is to deliver the compiled data with selecting an effective transmission route. The resembling

function reconstructs the compiled data into the application data.

### 3.2.2 Transmission Functions

The transmission functions are composed of transmission function and transmission route control function. The data transmission function utilizes transmission interface and transfers data between other equipment. The transmission control functions is routing between them.

### 3.2.3 Management Functions

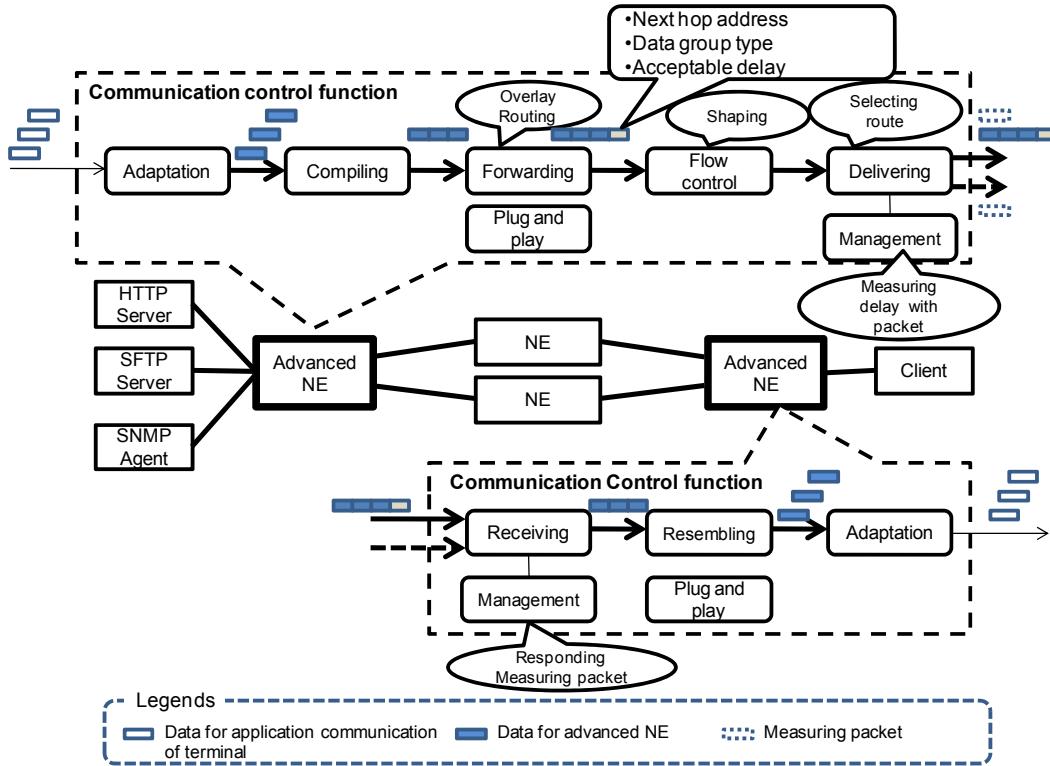
The management functions involve plug-and-play function and route management function. The plug-and-play function is to adapt the changed of information flows caused by sensors' plug-in and out. The route management function is to monitor performance and fault of transmission routes.

### 3.2.4 Behavior

Fig. 6 illustrates an example of behavior of communication control by advanced NEs. An advanced NE converts data of application communication. The advanced NE compiles, forward, shape the data and transmit data via a selected transmission route by the delivering function. This behavior enables to control communications in a way specific to the facility maintenance network.

## 4. Evaluation

We developed advanced NE software as a prototype, composed an experiment system with this to evaluate the



**Fig. 6.** Communication control of advanced NE.

feasibility of proposed architecture.

#### 4.1 Experiment System

##### 4.1.1 System Configuration

Fig. 7 illustrates the configuration of the experiment system. The system is composed with terminals, advanced NEs and NEs.

Terminal:

- One computer as server
- One network camera
- One computer as client

Advanced NE:

- Two computers

NE:

- Two L2 Switch

Transmission interface of them are Fast Ethernet with 100Mbps.

##### 4.1.2 Advanced NE

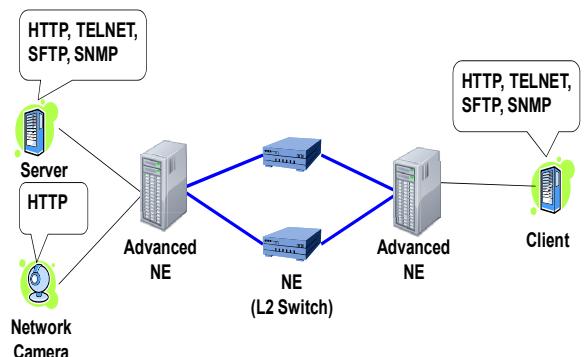
We developed an advanced NE software supporting functions described below.

- Adaptation function
- Compiling (assembling) function
- Forwarding function
- Flow control function
- Delivering function
- Resembling function
- Route management function

The software is built with Sun Java. Linux is used as OS. The details about the software are shown below.

Java: SUN Java Standard Edition 5.0

OS: SUSE Linux (Kernel 2.6)



**Fig. 7.** Configuration of experiment system.

## 4.2 Behavior Test

It was confirmed that the communication control functions of the advanced NEs works fine for application protocol described with the test system,

- HTTP
- SNMP
- TELNET
- SFTP

## 5. Conclusion

In this paper, we proposed the architecture for the facility maintenance networks to control communications for facility maintenance information. A network based on the architecture utilizes the advanced NEs to make full use of an existing IP network and control communications specific to facility maintenance network.

We also composed the experiment system to evaluate feasibility of proposed architecture and conducted an evaluation of communication control functions for application protocols including HTTP. The result shows that an overlay network with the advanced NEs can be realized and the proposed architecture has feasibility.

## References

- [1] IEEE 802.3ba, “40Gb/s and 100Gb/s Ethernet,” 2010.
- [2] ITU-T G 709, “Optical Transport Network”, 2009.
- [3] ITU-T Y.2011, “Next Generation Networks – Frameworks and functional architecture models, General principles and general reference model for Next Generation Net-works,” Oct. 2004.
- [4] IETF RFC 3261, “SIP: Session Initiation Protocol,” 2002.
- [5] ITU-T H.248.1, “Gateway Control Protocol: Version 3,” 2005.
- [6] The OpenFlow Switch Consortium, <http://www.openflowswitch.org/>, Accessed date: Jan. 2011.
- [7] ITU-T Y.1731, “OAM functions and mechanisms for Ethernet based networks,” 2008.
- [8] IEEE 802.1ag, “Connectivity Fault Management,” 2007.
- [9] IETF RFC 3917, “Requirements for IP Flow Information Export (IPFIX),” 2004.
- [10] Y. Serizawa, T. Tanaka, H. Yusa, Y. Koda, G. Yamashita, M. Miyabe, S. Katayama, T. Tsuchiya, K. Omata, “Verification of distributed real-time computer

network architecture associated With off-the-shelf and dedicated technologies,” IEEE Transactions on Power Delivery, Vol. 24, No. 3, pp. 1206-1217, Jul. 2009.



**Hiroyuki Yusa** received the B.S. and M.S. degrees in electrical engineering from Tokyo University of Science, Japan, in 1993 and 1995, respectively. In 1995, he joined the Central Research Institute of the Electric Power Industry (CRIEPI). His work has been in the research of distributed object, mobile agent, and active network technology and management systems for telecommunication networks. He is a member of IEEJ and IEICE.



**Tetsuo Otani** received the B.S. degrees in instrumentation engineering, M.S. and Ph.D degrees in computer science from Keio University, Japan, in 1992, 1994 and 2003, respectively. He has worked for Central Research Institute of Electric Power Industry since 1994. His work has been in SCADA systems for power systems and related data exchange. He is a professional engineer in Japan (Information Engineering). He is a member of IEEE, IEEJ, IEICE and IPSJ.



**Masahiro Kurono** received the B.E., M.E. and Dr.Eng. degrees from Nagoya University in 1982, 1984 and 1999, respectively. He joined the Central Research Institute of the Electric Power Industry, Tokyo, in 1984. Since then, he has been engaged in research on the optical communications and the applied optical sensors.