Green UT Energy-Aware Facility Networking: a Challenge to the Standardization of Architecture and its Protocol

Hideya Ochiai — *The University of Tokyo* — *jo2lxq@hongo.wide.ad.jp*

Noriaki Fujiwara — *Panasonic Electric Works* — *fujiwara@panasonic-denko.co.jp*

Hiroshi Esaki — *The University of Tokyo* — *hiroshi@wide.ad.jp*

Abstract

This paper describes an activity of architecture and protocol standardization for energy-aware facility networking. Standardization allows world-wide product development by industries with reasonable cost, enhancing the installation of energy-control systems into buildings, factories and houses. We present the working status and the overview of the developing standard. Our work is based on a prototyping and operational experiences in Green UT project and Live E! sensor networking project. We are also going to develop reference codes for the specification in order to encourage industries to develop their own product for the standard.

Key words: *green IT, facility networking, standardization*

1. INTRODUCTION

Facility networking in buildings, factories and houses is widely acknowledged as a promising technology for energy saving or the reduction of energy wastes. The major changes from the traditional facility networking (i.e., building automation) to the energy-aware facility networking are (1) analytical works on wider range of dataset, (2) density of deployed sensors and actuators, (3) flexibility of working mode setting and (4) collaborative system operation.

There are many standards for facility networking, which had certainly increased the deployment into buildings by industries with reasonable cost. However, the existing standards targeted at building automation cannot cover our intended energy-aware facility networking. We urgently need standard architecture and protocols for this purpose.

We have started a protocol standardization activity. In this paper, we describe the working status and the overview of the specification. We develop the specification, based on a three-tiered architecture as

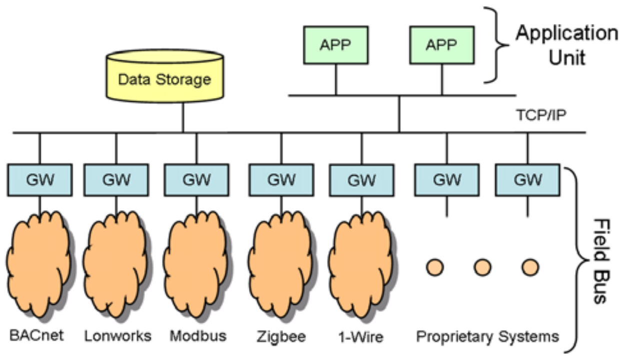

Figure 1. Three-tiered facility networking architecture.

figure 1. This architecture has three types of components: i.e., (1) gateways and field-buses, (2) data storage, and (3) application units. Gateways, data storages, and applications are networked by TCP/IP, and each component is developed, deployed and operated by different vendors and companies. We describe the detail in section 3.

Standardization of energy-aware facility networking systems will enhance the installation of energy-reduction systems more easily. Once we made a standard, any companies will be able to join in developing a part of the system. The industry by several companies continues developing the system components, which makes the initial and running costs reasonable for building, factory and house owners.

The protocol standardization activity in Green UT[1] has started from February 2009. At the first stage of discussion, we have listed up the system requirements. Now, at the second stage, we have been developing a protocol specification in detail. We are also going to develop an open reference code in Java in order to encourage product development by industries.

In energy-aware facility networking, data analysis from wide range of dataset is necessary. Most of the analysis will be statistical-based. For example, understanding energy-wasting situations will require the track of people, the log of light control and HVAC system over at least one month. In order to manage those data, the system needs data storage that archives such amount of dataset.

Our work is based on the development and operational experiences on Live E!-based facility networking system. We have studied lots of issues from the prototype operation. This practical study certainly helps for designing the specification, avoiding system design pitfalls.

This paper is organized as follows. Section 2 describes related technologies to our work. In section 3, we present the progress and the overview of our standardization activity. In section 4, we describe our operational experiences on our prototype system Section 5 gives the conclusion of this paper.

2. RELATED TECHNOLOGY

2.1. Field-bus technologies

There are existing standard field-bus technologies. Lonworks[2] defines device-to-device communication protocols over twisted-pair lines. Modbus[3] defines a communication protocol over power lines. Zigbee[4] is for wireless sensor networking. 1-Wire[5] enables device networking without power supply using the line signal as the power source of devices.

These field-bus specifications have enabled the device development open; any companies can develop their own products and sell world wide where the protocol is used. However, these field-bus technologies themselves basically do not consider IP-networking and data storage.

2.2. Facility networking over IP

The need of facility networking over IP (e.g., remote monitoring and control, generalized access for different types of field-buses, and field-bus clustering at a large building) has motivated the development of standard access protocols.

BACnet/WS[6] defines device access protocol by SOAP-based web service. oBIX[7] defines another device access protocol by HTTP-based web service. Hosts in IP networks can access devices behind gateways in the same manner. These protocol standards have allowed any field-bus implementation; however, the protocol itself is not designed for large dataset management, which must be necessary in energy-aware facility networking.

3. GREEN UT SPECIFICATION

3.1. System Requirement

We have discussed six months for summarizing system requirement carefully, and the working document has grown to 46 pages. Since we cannot describe them all in this paper, we present the major requirements below.

1. To archive the historical data of INPUT and OUTPUT devices.
2. To design communication protocol for large dataset management (we explicitly state this because most of the existing protocols do not aware it)
3. Co-existence of system operators and developers from different organizations and policies.
4. To share semantic information for basic knowledge exchange among multiple operational domains.

The following requirements are related to 1. and 2.:

5. On-demand transfer (large dataset) for INPUT dataset
6. Event-based transfer for INPUT dataset
7. Configuration method for OUTPUT devices

The following requirements are related to 3.:

8. User Authentication / Authorization
9. Access Control
10. Access Confliction Management
    - Access Priority
    - Mutual Exclusion

The following requirements are related to 4.:

11. Search (or lookup) method
12. Location naming
13. Measurement unit naming
14. Data type identification (boolean, integer, etc.)
15. Other application specific semantics

3.2. Architecture

The architecture has three components as we have presented in figure 1: i.e., gateway (GW), data storage and application unit.

- **Gateway and field-bus:** A gateway provides input and output (I/O) methods for data points, encapsulating any concrete field-buses that have real sensors and actuators. The logs of the input and output values should be submitted to storage. Application units can directly access to a gateway to read the current value and to write a new value.
- **Data storage:** Storage archives the history of observed and setting values of data points.
- **Application unit:** Application units provide

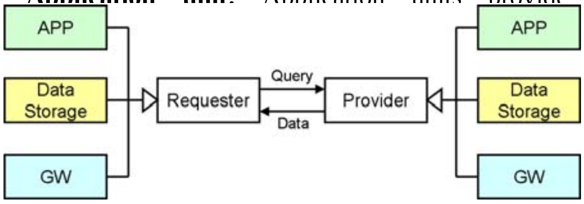

Figure 2. Data transfer

control. To perform these tasks, application units retrieve data from the storage and sometimes from sensors directly, and submit new setting to the gateways.

3.3. Data Transfer

We present data transfer protocol for INPUT dataflow as an example of the specification. In transferring data, we assume requester and provider (Figure 2); requester submits query that describes the range of interested dataset, and provider returns the body of data. GWs, storage and application units can work both as a requester and a provider.

We define two types of data transfer modes: on-demand transfer and event-based transfer. On-demand transfer is for retrieval of the *existing* data: i.e., current data or archived data that stored in memory space or storages. Event-based transfer is for notification of the data *updates*: i.e., data transfer when the timestamp has changed or the value has changed. On-demand transfer request will be made mainly on GWs and storage, and event-based transfer request will be made mainly on GWs. On-demand transfer mode should be able to work even at the large data scale.

3.3.1. On-Demand Transfer

1. A requester calls read procedure at a provider. The requester submits the range of dataset by a query and acceptable data size.
2. The provider returns the corresponding data to the query. Here, if the data size exceeds the acceptable data size, it returns a part of the dataset and a handle associated to the succeeding dataset.
3. If the requester received a handle, it calls read procedure again with the handle. Go to 1.
4. If not, all the data are retrieved, and it finishes.

3.3.2. Event-Based Transfer

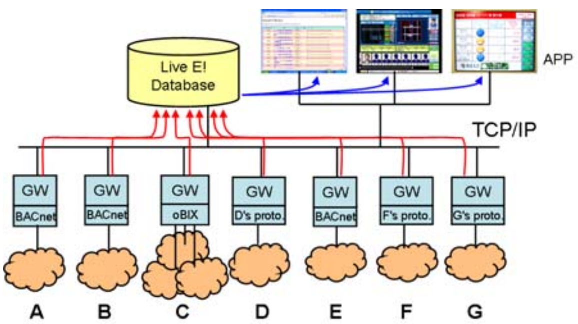

Figure 3. Prototype System

1. A requester calls subscribe procedure at a provider. It also submits query, the validity time of the query, and callback location. This call should be made periodically to update the lifetime of the query hold in the provider.
2. The provider notifies to the callback location when it has observed the updates that match the query.

4. PROTOTYPE EXPERIENCES

Along with our standardization activity, we have been practically working on our Live E!-based prototype facility networking system and studying the issues on the experiences, which helps for avoiding the pitfalls in system designs. Figure 3 shows the configuration of our prototype system.

The total number of data point is 1609 as of September 2009. Most of the data points are associated to the devices deployed in Eng Bldg. 2 in the University of Tokyo. 868 points are for electric power management, 40 points are for lighting control, 669 points are for HVAC systems.

7 companies' field-buses have joined to this facility networks. They use BACnet, Lonworks, and other protocols at their field-bus level. Gateways encapsulate those differences and submit the historical data to a Live E! database[8].

The dataflow going into the database is about 788,000 records per day. Some data points submit data every minute, others every thirty minute and so on. The size of dataflow certainly changes depending on the frequency of data submission.

Live E! database[8] was originally designed for weather data collection from internet weather stations. In fact, facility networking is different from weather sensor networking, and we learned lots of issues from the operational experiences on this prototype.

Administrator	Point
A	102B1室内機-1 電力集計値
B	10F江崎研実験室102B1－冷蔵庫
D	102B1江崎研究室電流
F	10F江崎教授室 温度(1)
C	学生室照明①電力量

Figure 4. Description of the same room by different operators.

- Data structure needs to be modified so that operators can handle them more easily in facility networking. Live E! database is designed generic for any data types and it can import any types of sensor data. However, dataset is structured so that

Administrator	Point	Time	Value
D	91A4客員教授室ロスナイ状態	2009-04-20 10:48:09	true
D	91B1会議室ロスナイ状態	2009-04-20 10:48:09	false
E	3階 231講義室前　廊下-照明	2009-04-20 10:48:01	T
E	3階 機会系会議室前　廊下-照明	2009-04-20 10:48:01	F
F	EHP-B-8 運転状態	2009-04-20 10:47:59	運転

Figure 5. Description of system status by different operators.

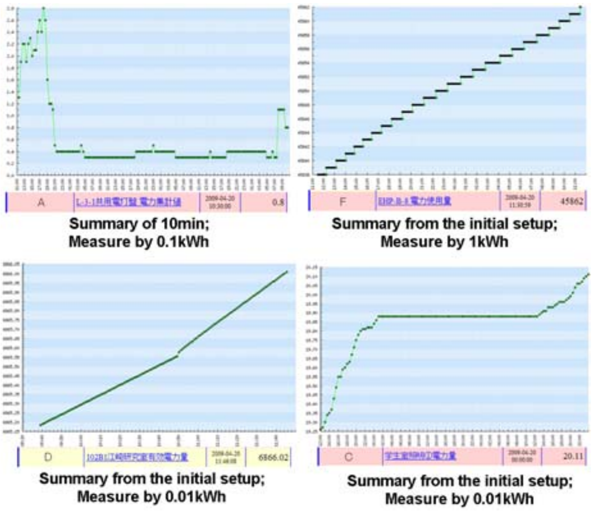

Figure 6. Sequence pattern for consumed energy.

operators can handle them easily in weather sensor applications.

- The retrieval interface must support large dataset retrieval. Live E! database provides RPC-based data retrieval interface. When a user inquires a large dataset, it takes a long time and sometimes fails before returning the requested data.
- We have to manage semantic information space to tell background information of points to other domain systems. This leads to the semantics modeling part in the specification.

Without managing semantics, the following three types of issues have certainly happened.

- Operators have described each data point differently in their own manner, which made applications difficult to search the data points (Figure 4).
- Different field-buses used different expressions for data values (Figure 5).
- Even for the same category's data point, the detailed meanings were different among different companies (Figure 6).

5. CONCLUSION

We have been developing standard protocols for energy-aware facility networking. Our standard considers the use of IP and data storage, which is essential to energy-aware facility networking.

The standardization activity has stared on February 2009, and we have already summarized basic requirements for the specification. As of September 2009, we are now designing the specification, and developing reference codes for the specification.

This specification is based on our prototype experiences in Green UT project.

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