Eco-System Design Based on Internet Architecture Framework

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Abstract

Future Internet will contribute to the improvement of efficiency regarding all the activities developed and deployed on the Earth. The internet system discussed in the paper is not only meant the global computer network using the IP (Internet Protocol), but is rather logical architecture of the system applied in the Internet architecture. As discussed in Green ICT business, we need the ubiquitous and global scaled sensor and actuator networks in order to develop and to deploy the energy aware system. In this paper, the author discusses why the "Internet" is very efficient platform, leading to Eco-System. Many networks to contribute to energy saving and to environment preservation as a control-plane, will adapt the IP technology, so as to deliver the Eco-City or Eco-Town. The design principle is (1) Avoiding the fragmentation of IP systems and networks, (2) Encourage the collaboration among sub-systems, that use IP or may not use IP, (3) Explore the Eco-system, that delivers the cheaper system development and deployment, while preserving the technical and business innovations.

Key words: *Internet, Eco-System, Green IT, sensor network.*

1. Introduction

Future Internet will have to contribute the improvement of efficiency regarding all the activity developed and deployed on the Earth, i.e., saying smarter city or town. The internet system discussed in the paper is not the global computer network using the IP (Internet Protocol), but is rather logical architecture of the system applied in the Internet. As discussed in Green ICT business, we need the ubiquitous and global scaled sensor and actuator networks in order to develop and to deploy the energy aware system. In this paper, the author discusses why the "Internet" is very efficient platform, leading to Eco-System. Many networks to contribute to energy saving and to environment preservation, will adapt the IP technology. However, these networks would be of so-called closed IP network, which is not connected to the global Internet.

For many under-discussing/under-developing "future" networks, even when it would be a closed network, it will be a global network. However, these may be disconnected, i.e., fragmented. So as to conduct and to deliver the innovation, the network should be interconnected with smaller technical and operational difficulties. Also, it has been proven by the existing Internet that building the network by single entity is so/too expensive, but shared by multiple entities may be far cheaper for all entities.

ISOC (Internet Society; www.isoc.org/) Board of Trustee (BoT) has a concrete direction regarding the future Internet, which is toward the Internet Eco-System. Eco-system has the sustainability, while preserving the continuous innovations. It may not optimal solution, but, as a result, it is flexible and adaptable, against the change of condition or environment with low cost.

As a background, when we look at large computer systems, including facility networks, there are many systems and networks that adapt the IP (Internet Protocol). However, still, there are many non-IP or closed IP systems, in the real world. And, many networks and systems tend to be fragmented, from the view point of each company's business strategy. This is serious concerning toward the "Eco-System" development.

This paper tries to define the objective and goal of the future Internet for smarter city or town. It is that; (1) Avoiding the fragmentation of IP systems and networks., (2) Encourage the collaboration among sub-systems, that use IP or may not use IP, (3) Explore the Eco-system, that delivers the cheaper system development and deployment, while preserving the technical and business innovations.

2. Future Internet

2.1. What is an Eco-System?

An Eco-System is a natural unit consisting of all plants, animals and micro-organisms in an area functioning together with all of the physical factors of the environment. Ecosystems can be permanent or temporary, in both spatial domain and in time domain. An Eco-System is a unit of interdependent organisms which share the same habitat. Eco-Systems usually form a number of food webs/chains, as the interaction among the independent organisms.

In the area of economics, the Eco-System is defined as a business structure among related organizations (e.g., private companies), which form the cooperative and collaborative business activities to yield benefits and innovations for themselves.

With the author's understanding, the followings are some of required features for Eco-Systems;

(1) **Independency** of individuals and sub-systems
Each individual and sub-system must live or be operate-able by themselves, at least temporally.

(2) **Autonomous** operation of individuals and sub-systems
Each individual and sub-system can make their operational and governance rules by themselves.

(3) **Interaction** among individuals and sub-systems
Individual and sub-system have some level of interaction, e.g., cooperation and collaboration, with other individuals and sub-systems.

(4) **Adaptability** against the change of environment
Individual and sub-system can adapt themselves, according to the change of environment.

The existing Internet and the future Internet, discussed in the following subsection, have the features of Eco-System described above. Also, the framework of Internet architecture could be applied to the other systems, such as energy system, educational system or e-healthcare system.

2.2. How the Future Internet Looks Like

The professional Internet system has been operated more than 20 years, while preserving the continuous introduction of technical innovations. There are many discussions on "future Internet" or "post Internet architecture".

The Internet architecture does not mean the particular protocol suites, such as existing TCP/IP. TCP/IP itself has experienced a lot of protocol modifications and functional enhancements, during the deployment of global Internet system. We must recognize that the Internet architecture is the "logical" architecture framework, not the particular protocol sets nor routers and switches [1]. The Internet architecture, of course including the future Internet, must preserve the following five essential features of the Internet architecture. These are (1) autonomous, (2) distributed, (3) disconnected, (4) inter-domain, and (5) global, operation. The current Internet system has been challenged by the following three aspects; global, ubiquitous and mobility.

According to the experience of development and deployment of the Internet system and Internet architecture, the use of live testbeds has been very effective to realize the requirements of the system and the future direction of research and development. We may realized the importance of "Experienced Design"[2] and of "Invention is the mother of necessity"[3], by the Internet development history. The TCP/IP suite has been modified and has been added new functions, according to the real operational experiences. Without the real operational experiences at the testbeds, we could not recognize and find the technical innovation or evolution. This would be a implementation of "Eco-System" in the computer networks or information and communication networks.

2.3. Change of Technical Assumptions

As known as Moor's law, the IT technologies have been achieved the exponential performance improvement for more than three or four decades. According to the continuous improvement of ICT technologies, the technical and system assumption for system design has been significantly changed. The followings are the old and legacy system and technological assumptions, which would be long time considered as the given condition.

1. User and end-station is poor and stupid
2. Users' terminal only turns on, when it is needed
3. Fixed node is far major and superior than mobile node

4. “service” must be provided either by provider or by enterprise
5. Cost of transmission, storage and copy, is not little, but is expensive

Especially, the assumption 5 would be recently realized a wrong assumption, by the introduction of Peer-to-Peer (P2P) technologies over the transparent IP network. It has been believed that Internet architecture must be transparent, sometimes said as “stupid network”, as the default system architecture, when we design the large scale computer networks.

The other important paradigm shift from the current R&D tendency regarding the Internet architecture is regarding the assumption on the communication model if the nodes are always connected or not. We have developed and deployed the broadband internet environment, especially in the developed countries. However, even in the metropolitan area in the developed countries, we have experienced the case of disconnection from the network. In the under-developing counties or in the country side of developed counties, we have many geographical areas, which does not have any connectivity to the Internet.

2.4. Requirements for Future Internet

The followings are the requirements for the future Internet system, from the view point where how the future Internet looks like.

(1) Covering our “Earth” with high speed network, i.e., global scale Eco-System
According to the significant installation of land-cables and submarine-cables in the last decade, the fiber-cable system has been surrounding the surface of our Earth, including the under-developing countries, as a backbone network of the Earth.

(2) Design and obtain the “earth” scale computer system
We could obtain the enough network resource and computing resource, which are distributed on the Earth and are somehow connected by digital networks. Here, this computer system is a collection of sub-systems, which can operate independently, while the sub-systems are somehow interacting to each other, i.e., as a aspect of interaction and independency for Eco-System.

(3) Impossible to accommodate earth with single technology
We have wide variety of technologies so as to connect the digital devices. In order to maintain the continuous innovation of networking technology, we have to intentionally maintain the capability of alternativeness in the networking components. This feature, i.e., diversity and replace-ability, leads to the aspect of sustainability and adaptability in Eco-System.

(4) Investment and operation is always autonomous
Installation and operation of system by the single organization is neither scalable nor realistic. We have to design the system, which collaborates and cooperates to each other in a distributed and autonomous manner.

(5) We have large area, where we could not be wired
The legacy Internet system (or computer system) would assume that the nodes are interconnected via the stable wired cables. However, in the current and future computer networks, the larger number of nodes is connected to the network via the various wireless links.

(6) We have large area where, even, wireless would be hard to use
Though we have a lot of nodes, which are connected to the network via wireless links, we will still have a lot of nodes and area, which could not be connected to the Internet. This will be true both in country sides and even in metropolitan sides.

(7) Uni-Directional Digital Link
The legacy Internet system would assume that the nodes are interconnected via the bi-directional links. However, the current and future Internet will use a lot of uni-directional (digital) links.

(8) Real integration between “logistics”
Small size of mobile nodes, such as sensor or actuator nodes, will be connected to the Internet, and those nodes would be attached with the wide variety of objects. A typical object would be of the logistics, which are likely to the new object and a contribution of the future Internet system. This could be said as the integration of current cyber space with the logistics or as the “real-space” internet.

2.5. Key Components for Future Internet

The followings are some key components for the future Internet system.

(1) DTN [4]
DTN represents Delay Tolerant Networking or Delay Disruption Networking. The legacy Internet architecture has implicitly assumed that the communicating peers can mutually transact the IP packets with a certain and reasonable latency. However, in order to accommodate all the digital equipments and human-being on our planet, we could not assume that all the equipments and human-being were always connected to the Internet.

(2) Message routing [5][6]
The existing Internet system has adopted the (IP) packet routing. In the IP packet routing, the source node resolves and informs the destination IP address with TCP/UDP port, before the source node starts the communication, i.e., source node initiates the communication. However, in the future Internet system, (a) the source nodes may want to send the data, without resolving and informing the particular destination node(s), and (b) the peer nodes may not be required any state synchronization for data communication. The message routing, e.g., publisher-subscriber model, would be a possible communication model in the future Internet system.

(3) P2P technology
P2P technological framework would be a key component of future Internet system. We could implicate the P2P technology as followed, i.e., introduction of three key functions into the existing "naïve" Internet architecture;
   1. {networked} Cache and Proxy
   2. {networked} DMA (Direct Memory Access)
   3. {networked} Virtual memory system (by DHT)

2.6. Deployment of Future Internet Infrastructure

In this subsection, the author discusses how the future Internet infrastructure should be developed and deployed.

(1) "Experienced Design" [2]
None of us living with the current Internet system may know how the future Internet will be. The future Internet system will be the result of interaction with real society, i.e., technologies will be modified and mutated via the practical feed-back from the real operation. In order to adjust with the practical, un-expected and un-forecast-able feed-backs, the initial future Internet system should have technical vagueness and room to be able to be added or to be modified, in the future, as the architecture design principle.

(2) "Invention is the mother of necessity" [3]
None of us may know how to use new technologies. Also, the new technologies would introduce the new functions or services with their native interfaces. The emulating the legacy or existing services with new technologies may not good for the development of new technologies. New technologies may eager their "native" applications or services.

(3) Challenging to the theme of physics, economics and mathematics
The networking and digital technologies have been always challenging the legacy themes. It will be time-domain, geographical-domain or economical-domain.

(4) Federated networking for the next stage of the "Internet".
Though many networks will adapt the IP technology, these networks would be of so-called closed IP network, which is not connected to the global Internet. For many under-discussing/under-developing "future" networks, even when it would be a closed network, it will be a global network. However, these networks may be disconnected, i.e., fragmented. So as to conduct and to deliver the innovations, the networks should be able to be interconnected with smaller technical and operational difficulties. Also, it has been proven by the existing Internet that building the network by single entity is so/too expensive, but shared by multiple entities may be far cheaper for all entities; "Eco-System", that is the aspect of cheaper system cost. As a result, we should avoid the fragmentation of individual (global) IP networks, as a governance of digital network development and deployment.

3. Energy Saving Business “BY” ICT

3.1. Potential of Business Opportunity “by” ICT

Energy saving and the protection of environment for sustainable society is now global agenda, which we must achieve for the next generation and for our Earth. This activity around IT and ICT industry is called as “Green IT/ICT”. Though the most of the Green IT/ICT would focus on the energy saving “of” IT/ICT equipments, we are focusing on the energy saving “by” IT/ICT technologies.

It is said that the revenue contribution by ICT industry in the GDP is less than 10%. More than 90% revenue is come from non-ICT industries. Nowadays, almost all the companies depend on ICT technology for their corporate operation. And, how to use the ICT defines the marketing power and operating power of companies.

One of new business area for ICT industry would be energy saving using the ICT, such as Internet technology.

Figure 1 gives the energy consumption in Japan, as of 2005. One third is by manufacturing, one third is by energy generation and transportation, and last one third is by daily life by us. Also it shows that offices and residents consume more than 20% of energy. We are spending a lot of money on utility or energy.

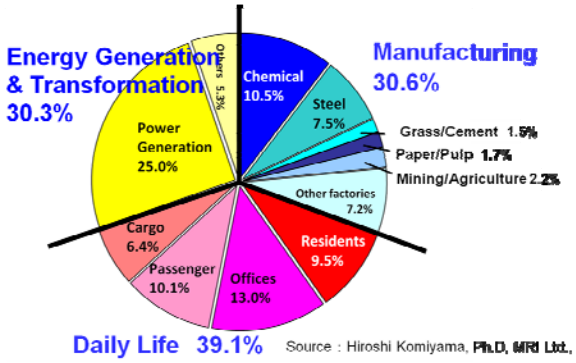

Figure1 Japanese Energy Consumption in 2005

And, the facility system, such as building system, uses a lot of proprietary technologies by each segment and by each company. For example, it has been reported that the major complex in down-town Tokyo has more than 200 K monitors and actuators in a single building, while each sub-systems would use different technologies.

So, we can realize that the energy saving is now “Global” agenda, as well as good new business area for ICT industry. This is because all the facility components must be monitored and controlled by computer system, so as to achieve the effective energy saving performance. However, the facility system uses a lot of proprietary technologies and components have never cooperated to each other, in the past.

People in facility networking area start to realize the benefit of open system, such as Internet technology and Internet architecture. We have two important messages delivered at last INTEROP Tokyo, held in June 2009.

(1) The concept of “smarter planet” offered by IBM, saying to let smarter all the facility and activities by computer networks or by ICT. We will have computer networks, which will be able to achieve global scale real-time PDCA cycle.
(2) The fact that a lot of energy consumption is by facility system, rather than ICT equipments. For facility system, more than 75% of energy is consumed by non-ICT equipments, such as HVAC (i.e., air conditioning system) or by lights.

Some data shows that, surprisingly, the initial construction cost and the lifetime utility cost is almost the same amount. This is a big business potential and incentive for each organization.

3.2. Third Wave of City/Metropolitan Design Principle

We would be the process of innovation or revolution, regarding how to design to build the city or metropolis.

(1) The first wave; agricultural age
At this age, the agriculture is the main industry, and the symbol of valuable assets would be fruitful and fertile land, mainly a farmland. Rich people in the age have larger rich farmland. Therefore, the village or city was built near the river and the location, where have good weather. In other words, the most important parameter or component would be a water supplying infrastructure.

(2) The second wave; industrial age
At this age, the manufacturing is the main industry, and the symbol of valuable assets would be artificial products, objects or money. Rich people may love to have much products or money. Therefore, the city or metropolis was built at the location, where the logistics condition is better. In other words, the most important parameter or component to build the city would be a logistic infrastructure.

(3) The third wave; information age
At this age, the digital intellectual activity would be the main industry, and the symbol of valuable assets would be knowledge or intellectual property, with less energy consumption. The best performance on intellectual activity is recognized as the responsibility of civilized people or country, and is recognized as the global agenda. Rich people may love to have rich intellectual communication and life. Therefore, the city or metropolis was built so as to effective network environment, with effective energy supply and demand system. In other words, the most important parameters or components to build the city or town would be an information infrastructure and energy SCM(Supply Chain Management) infrastructure.

3.3. Contribution of Internet and Internet Architecture Framework

The future Internet system, that is a real object of the Internet, will be a nerves system, and the server systems, such as cloud computing platform, will be a brain, in the future smart city or smart town, when we compare the smart city/town with the human-being. Even when human has strong components, e.g., leg, arm, muscle or bone, the human can not work well without coordinated control among the components. When we have better coordination and cooperation among the components (organs), we can achieve the same work with less energy, or we can achieve better work with the same energy consumption. This means that, so as to achieve an Eco-body in human body, the nerves system and brain must achieve high performance to integrate all the information at components, and to control the components. On the contrary, the components have to run somehow independently and autonomously. Of course, each component has diversity and replace-ability, for the sustainability of human body and it's component. As a result, the future Internet system will contribute to the Eco-Social-Infrastructure development through the physical entity and though the concept of Internet architecture framework, discussed in section 2.

When we observe the future computer facility in a city or in a town, a lot of computers, currently in every organization, will move into IDC (Internet Data Center), at least by the following two reasons. Computers widely spread in cities or in towns can communicate with far smaller latency and larger bandwidth, since the physical distance among the computers can be reduced. Also, the computers can be installed stable and better environment, regarding the temperature control and power supply management. The other benefit will be the achievement of energy saving as a total system. When we run the computers in the individual offices, we must run the air-conditioning system 24 hours a day, so as to take care the heat generated by the computers. However, when we move these computers to IDC, we will be able to reduce the amount of energy consumption at the {usual} offices. Energy consumption will move to IDC, since IDC can have far better operational efficiency than the {usual} office. Based on the above discussion, we are designing the system and protocol architecture of future Internet system, especially focusing on the facility networking. The referenced architecture is shown in figure 2. It is the database-centric architecture. We allow various types of field-bus technologies, while those filed-bus systems report to the data to {global scale} shared database. Any application on the Earth can access any data in shared database using the same API. Also, the control and management API between the field-bus system and applications are commonly defined.

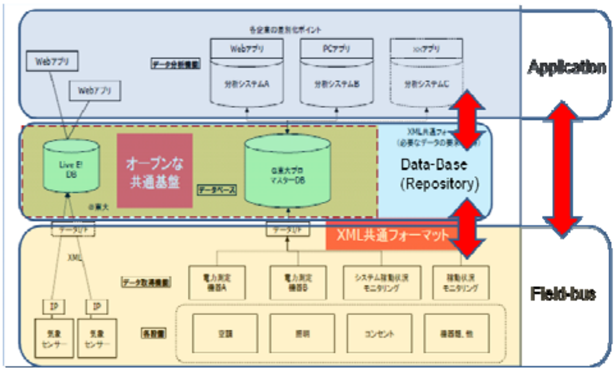

Figure2 Referenced Architecture for Facility Networks

3.4. Eco-System Development Scenario

The real target of energy saving by ICT is not the energy saving itself, but is to establish ubiquitous digital sensor and actuator network environment and to encourage the technical innovation/revolution or new applications using this network platform.

We try to establish the Win-Win relationship between environment /energy-saving and ubiquitous networking.

As the Step 1, we have to establish the following three mandatory components;

1. Sensors and actuators network
2. Collaborative operation among individual components
3. Control the energy flow using the information.

Then, as the Step 2, we will obtain the ubiquitous digital space sharing all the digital information. Here, the important point is each equipments and components are already paid-off for their own objectives. Finally, we would go into Step3; using this ubiquitous digital space, we could deliver a lot of inventions, innovations and new applications using the same infrastructure.

We could realize that this is a yet another “end-to-end” model that the Internet has achieved. So, the real goal of energy saving activities using ICT (and by future Internet system) is sharing any digital information over the globe, so to achieve higher efficiency on human and social activities and to establish the digital network infrastructure to achieve sustainable innovations.

4. Conclusion

In this paper, first, the requirements, key components technologies and the methodology of system development / deployment for the future Internet, which must preserve the continuous introduction of technical innovations, are discussed. The Internet architecture must preserve the following five essential features; (1) autonomous, (2) distributed, (3) disconnected, (4) inter-domain, and (5) global, operation. Though many networks will adapt the IP technology, these networks would be of so-called closed IP network, which is not connected to the global Internet. We have to avoid that these networks will be disconnected, i.e., fragmentation. So as to conduct and to deliver the innovation, the network should be interacted with smaller technical and operational difficulties. Also, it has been proven by the existing Internet that building the network by single entity is so/too expensive, but shared by multiple entities may be far cheaper for all entities.

Then, this paper discusses the contribution of ICT system and of the future Internet for energy saving, that is now global agenda for all the countries and for human-being. We should design the energy saving system, similar as the “Eco-System”, as the existing Internet system has achieved. By the achievement of sharing any digital information over the globe, we will be able to deliver higher efficiency on human and social activities and to establish the digital network infrastructure to achieve sustainable human and social innovations.

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Energy Saving with ICT
-- Green University of Tokyo Project --

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Abstract

Energy saving and the protection of environment for sustainable society is now global agenda, that we must achieve for the next generation and for our Earth. This activity around IT and ICT industry is called as "Green IT/ICT". Though the most of the Green IT/ICT would focus on the energy saving "of" IT/ICT equipments, we are focusing on the energy saving "by" IT/ICT technologies. The real target is not the energy saving, but is to establish ubiquitous digital sensor and actuator network environment and to encourage the technical innovation/revolution or new applications using this network platform. This is the "end-to-end" model that the Internet has achieved.

In this presentation, the speaker gives the overview of R&D projects related with energy saving, e.g., Green University of Tokyo Project. The real goal of these projects is sharing any digital information over the globe to achieve higher efficiency on human and social activities and to establish the digital network infrastructure to achieve sustainable innovations.

Key words: *The Internet, Facility Management, Mieruka, Electric Consumption*

Background

Due to the current trend of tackling global warming, reducing electric consumption becomes one of the biggest topics in the industrial sector. Kyoto Protocol [1] has entered into force in 2005, and then Japan takes a responsibility to reduce green house gas by 6% compared to it in 1990.

In 2006, Hongo Campus of the University of Tokyo emitted huge volume of CO2, and therefore the energy saving is one of pressing issues to address for the university. Todai Sustainable Campus Project (TSCP) [2] has started its activity since 2008 to reduce CO2 emission at the campus and to realize a sustainable society in the world. The Green University of Tokyo Project (GUTP) has started its activity since June 2008 complying with the TSCP.

The main role of the GUTP is to establish IT/ICT based facility management systems and to reduce electric consumption through optimized facility controls. Since the university consists of multidiscipline laboratories, there exist various technical challenges to overcome.

There exist various facility management systems that aim not only to manage facilities but also to reduce or optimize energy consumption, but most of previous approaches usually require proprietary systems to develop. Due to its proprietary, it is hard to adapt new features by ourselves or to inter-connect different systems. As a result, it is impossible to manage facilities in a building with a single facility management system.

Different from those previous works, the GUTP aims to deploy open facility management system based on open architecture specification. Providing an open and a standard protocol for facility managements, the project tries to be a referential model of facility managements for complexes.

Green University of Tokyo Project

Project Overview

The GUTP [3] has started its activities since June 2008 complying with the TSCP. The basic goal of the project is to show technical approaches of reducing CO2 emissions, more properly electric consumption. To achieve the energy saving, the scope of the project contains both "of" and "by" IT/ICT for the energy saving. In detail, we, our project members, try to not only save electric consumption of IT/ICT equipments but also adapt IT/ICT technologies for more efficient and intelligent facility managements.

To demonstrate and validate our approaches, we set up an experimental field in the Faculty of Engineering Bld.2 (Eng. Bldg.2) and conduct various types of demonstration experiments there.

At the same time, since we do realize that compulsory energy-saving activities do not work well as our experiences, we recognize that there should be a way that all the people are willing to tackle the energy saving. So, through demonstrating energy-saving experiments we also try to model a scenario that make people tackle the energy saving.

Project members mainly consist of private companies, universities and organizations/associations and various types of companies participate in the project; some of them are giant electronic corporate, some of others focus on facility managements and some of the rest are trading companies. The project started with twenty-seven companies/organizations and now the number of participants becomes forty-one as of 1st September, 2009. Since the project has not been funded by public institutions such as government agencies or national institutes, the project activities are supported by participants' budgets.

Structure of GUTP

To achieve two main objectives; (1) Saving energy "of" IT/ICT equipments and "by" IT/ICT technologies; (2) modeling a scenario that people can actively tackle for the energy saving, the project forms five technical working groups (WGs); Concept WG, Facility Control WG, Experiment WG, Mieruka (Making Visible) WG and Protocol Standard WG. Each WG plays an important role for managing our PDCA (plan-do-check-act) cycle as shown in Figure 1.

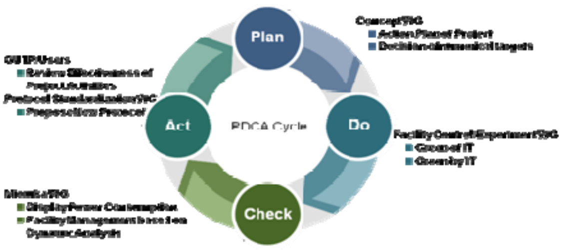


Figure 1 GUTP's PDCA Cycle

Here, the roles of Concept WG are to produce a model that makes people actively tackle for the energy saving and to enlighten people on the energy saving. Facility Control WG and Experiment WG actively conduct demonstration experiments in the Eng. Bldg. 2. Achievements of the WGs so far are to develop and deploy IT/ICT based facility measurement systems in the building. Mieruka WG mainly focuses on visualization (Mieruka) of data which Facility Control WG collects.

Protocol Standard WG was established relatively recent. The goal of Protocol Standard WG is to design / formulate a standard protocol for facility managements. Although there exist "standard" protocols for facility managements, those protocols have problems for the interoperability between them.

Energy Saving "by"/"of" ICT

In this section, we introduce our achievements so far. Especially, we focus on measurement systems of electric consumptions and Mieruka tools.

Protocol Design and Implementation

We design the protocol architecture so that the system has the feature of "Eco-System" [1]. With the author's understanding, the followings are some of required features for Eco-Systems;

(5) **Independency** of individuals and sub-systems
Each individual and sub-system must live or be operate-able by themselves, at least temporally.

(6) **Autonomous** operation of individuals and sub-systems
Each individual and sub-system can make their operational and governance rules by themselves.

(7) **Interaction** among individuals and sub-systems
Individual and sub-system have some level of interaction, e.g., cooperation and collaboration, with other individuals and sub-systems.

(8) **Adaptability** against the change of environment
Individual and sub-system can adapt themselves, according to the change of environment.

Also, we consider that the Internet architecture does not mean the particular protocol suites, such as existing TCP/IP. TCP/IP itself has experienced a lot of protocol modifications and functional enhancements, during the

[1] An Eco-System is a natural unit consisting of all plants, animals and micro-organisms in an area functioning together with all of the physical factors of the environment. Ecosystems can be permanent or temporary, in both spatial domain and in time domain. An Eco-System is a unit of interdependent organisms which share the same habitat. Eco-Systems usually form a number of food webs/chains, as the interaction among the independent organisms. In the area of economics, the Eco-System is defined as a business structure among related organizations (e.g., private companies), which form the cooperative and collaborative business activities to yield benefits and innovations for themselves.

deployment of global Internet system. We must recognize that the Internet architecture is the "logical" architecture framework, not the particular protocol sets nor routers and switches.

Therefore, we design the protocol architecture of the Green University of Tokyo system, so as to include the following five essential features of the Internet architecture. These are (1) autonomous, (2) distributed, (3) disconnected, (4) inter-domain, and (5) global, operation. The current Internet system has been challenged by the following three aspects; global, ubiquitous and mobility.

The followings are yet other design parameters for us.

(a) Impossible to accommodate earth with single technology
We have wide variety of technologies so as to connect the digital devices, especially in the field of facility networks. In order to maintain the continuous innovation of networking technology, we have to intentionally maintain the capability of alternativeness in the networking components. This feature, i.e., diversity and replace-ability, leads to the aspect of sustainability and adaptability in Eco-System.

(b) Investment and operation is always autonomous
Installation and operation of system by the single organization is neither scalable nor realistic. We have to design the system, which collaborates and cooperates to each other in a distributed and autonomous manner.

(c) We have large area where, even, wireless would be hard to use
Though we have a lot of nodes, which are connected to the network via wireless links, we will still have a lot of nodes and area, which could not be connected to the Internet. This will be true in facility networks, when we have mobile objects in the system.

Figure 2 shows the overview of protocol architecture in the GUTP system, developed in our real office in downtown Tokyo, Japan. The design principle is; (1) common database, i.e., database centric, (2) accommodating various types of field-buses and sub-systems and (3) common APIs for database system and field-buses from applications. So as to accommodate various types of field-buses and sub-systems, we adopt (a) the XML routing among these heterogeneous sub-systems as a common communication protocol, (b) pub-sub system (as a DTN capability) and (c) IP technology in the backbone area. By the introduction of XML routing, we can accommodate various types of field-buses and sub-systems, while preserving the capability of smooth migration to IP-based sub-systems in the future. Also, the introduction of DTN capability is very important and critical for the system, so as to improve the operational robustness in the system.

Figure 3 shows the concrete system diagram of our GUTP system. The left-bottom square is the system originally installed in the building. We have added the gateways to connect with the common bus among the sub-systems, such as HVAC or lightening system. Through the common bus, multiple common database systems are installed and operated, autonomously and independently. Also, the multiple application software is installed and operated, autonomously and independently, as well. With this system configuration, we can provide the environment where the sub-systems can cooperate and collaborate to each other. In other words, the legacy system was enough stupid and expensive to deny the cooperation and collaboration among the sub-systems, since the sub-systems are isolated by their own proprietary technologies. By the introduction of common protocol, we can provide the opportunity of cooperation and collaboration for these sub-systems, even though they use their own proprietary technologies. Actually, by the introduction of this platform, participating players and components start to consider the new applications and richer applications, with small or less cost, compared with the legacy facility system.

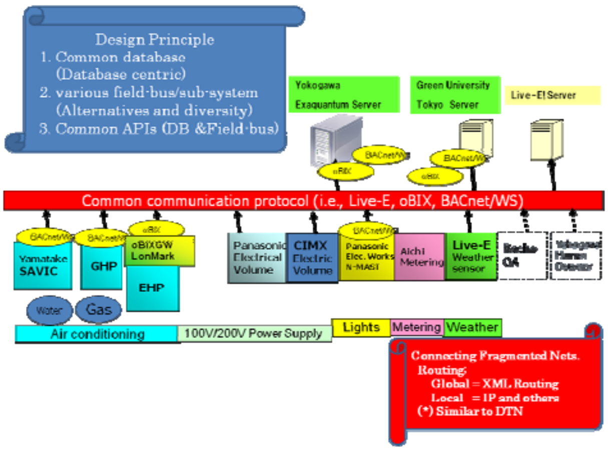


Figure 2 Protocol Overview of GUTP System

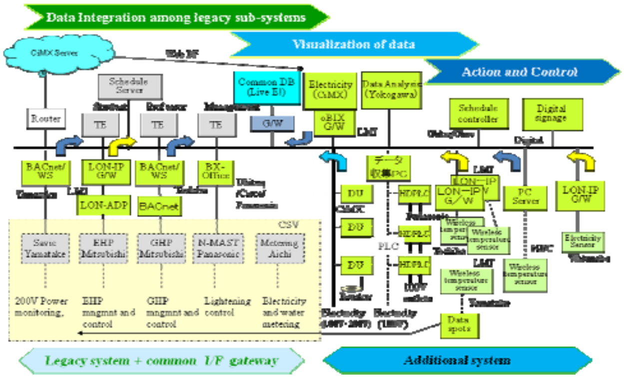


Figure 3 System Overview of GUTP

Developing Measurement Systems

First of all, to save the energy, it is necessary to find out where there is room for the improvement. Since utilizing the IT/ICT technologies for the energy saving is one of the important objectives of the project, the project also applies the IT/ICT technologies to the electric consumption monitoring.

But there were three issues to develop the IT/ICT based electric consumption monitoring system inside the Eng. Bldg.2 as follows; (1) the building had already been in the operational phase when the project started in June 2008: (2) the power monitoring system in the building was not designed to utilize the IT/ICT system: (3) due to the conventional facility management scheme, power lines were managed by equipments/sub-systems not by facilities/users.

As a result, it was hard for users such as faculties, officers and students to realize how they really use electronic equipments and emit greenhouse gases.

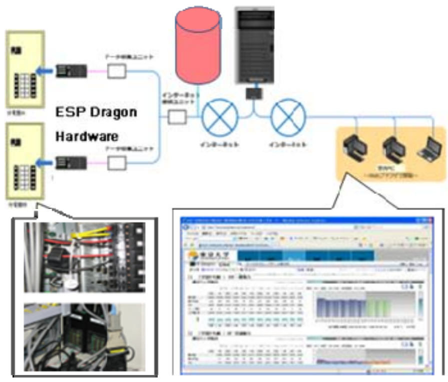
To monitor the electric consumption through the IT/ICT technologies, the project introduces various techniques and technologies. Some of monitoring technologies the project applies are described below;

(1) Standardized facility management protocol:

There exist standardized facility management protocol s such as BACnet[2]®/WS [4] and oBIX[3] [5]. In these days, many companies deploy their equipments so as to interpret those protocols, and those protocols are now available through the IT/ICT technologies. So, electric consumption of equipments can be collected through those protocols.

(2) Contactless sensor:

Cimx Corporation deploys and develops ESP Dragon® that can collect electric consumption through setting up proprietary hardware, contactless sensors, inside distribution boards. Data collected through contactless sensors are sent to a management server through the Internet and is visualized (Mieruka) there as shown in Figure 4.



(Source: GUTP Experiment WG)

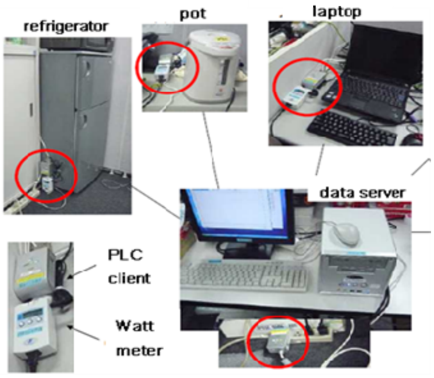
Figure 4 Contactless Sensor Monitoring

(3) HD-PLC (Power Line Communication):

Panasonic Corporation deploys an electric consumption monitoring module that works with the HD-PLC. The module is set between a socket and a plug, and then collected data is sent to the Internet through the HD-PLC (Figure 5).

2 A Data Communication Protocol for Building Automation and Control Networks; BACnet is a registered trademark of American Society of Heating, Refrigerating and Air-Conditioning Engineers (ASHRAE).

3 OASIS Open Building Information eXchange Technical Committee;



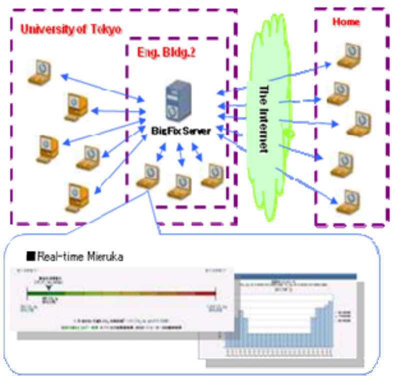
(Source: GUTP Experiment WG)

Figure 5 HD-PLC Power Monitoring

(4) Power Monitoring for PCs:

Mitsubishi Corporation introduces BigFix® to monitor electric consumption of PCs (desktop/laptop) and servers as shown in Figure 6. Different from the above system, we can measure electric consumption with the BigFix even when PCs are out of offices. This is useful, because especially laptop PCs are carried by people who move around in the building and therefore it is hard to trace a unique PC for the purpose of the power monitoring.

Leveraging these techniques/technologies, the project is now collecting more than 1,500 point data constantly, which include electronic, gas and water consumptions and facilities' status information (as of May 2009). All the collected data can be accessed through the standard protocol that the project is now design/formulat-ing.



(Source: GUTP Experiment WG)

Figure 6 Power Monitoring for PCs

Implementing Mieruka for Collected Data

Even though collecting data, users do not make effective use of the data for the energy saving unless users can easily access to the data. Furthermore, the data should be not only accessible but also understandable for users. To provide the easily understandable data to users, the project recognizes that implementing Mieruka (making visible) should be one of the ways.

In the project, some of member companies, such as Cimx Corporation, Panasonic Corporation, Ubiteq Inc. and Digital Electronics Corporation, address on Mieruka, and what they focus on are listed as follows;

(1) Display time-line trend of electric consumption:

As shown in Figure 7, by displaying time-line trend of electric consumption such as daily, weekly or monthly, users can notice that how their usages differ in a one day from the one in another day. Also, by comparing the difference in daily variation, users can examine what kind of activities causes it. Therefore, users could know how they act next.

(2) Display effectiveness of the energy saving:

By displaying effectiveness of the energy saving makes, the project tries to show how each people's activity really contributes the energy saving. Some of the companies try to show how the activities can cut the cost or protect the environment through Mieruka (Figure 8). We believe this kind of approach is important to encourage people, since simple data display does not provide how people's activities contribute the energy saving.

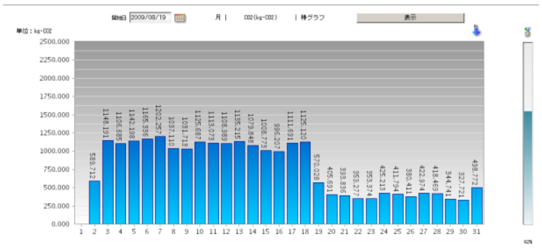
(3) Dynamic Facility Management:

Ubiteq, Inc. and Cisco Systems develop BX-Office that controls facilities such as lights and air conditioners based on timetables of schoolrooms as shown in Figure 9. The basic idea of this system is to manage facilities based on their usage. Since especially classrooms are usually used along a timetable, it would become effective if facilities are managed based on it. And, since the BX-Office also works with motion sensors, facilities can be managed when people use them without a reservation.

We believe that showing the effectiveness encourages people and makes them tackle the energy saving more seriously. So, implementing Mieruka should be one of the optimal ways to show how people's daily approaches contribute the energy saving.

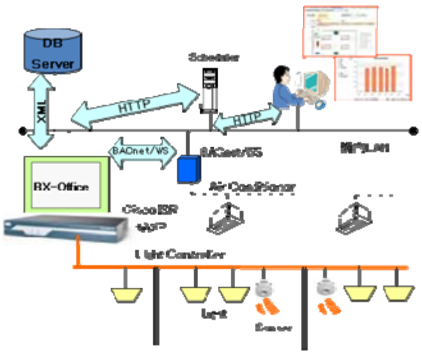
(Source: GUTP Experiment WG)

Figure 7 Time-line based Power Consumption



(Source: GUTP Experiment WG)

Figure 8 CO2 Emission Display



(Source: GUTP Mieruka WG)

Figure 9 Dynamic Facility Management

Conclusion

In this paper, as a practical project operation, we give the overview of the GUT (Green University of Tokyo) project. We design the protocol architecture of the Green University of Tokyo system, so as to include the following five essential features of the Internet architecture. These are (1) autonomous, (2) distributed, (3) disconnected, (4) inter-domain, and (5) global, operation. Also the design principle of GUTP system is; (1) common database, i.e., database centric, (2) accommodating various types of field-buses and sub-systems and (3) common APIs for database system and field-buses from applications. So as to accommodate various types of field-buses and sub-systems, we adopt (a) the XML routing among these heterogeneous sub-systems as a common communication protocol, (b) pub-sub system (as a DTN capability) and (c) IP technology in the backbone area. Based on the collaboration among academia and industry, a lot of and vide variety of components technologies are introduced in to the common platform and start the cooperation and collaboration.

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

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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

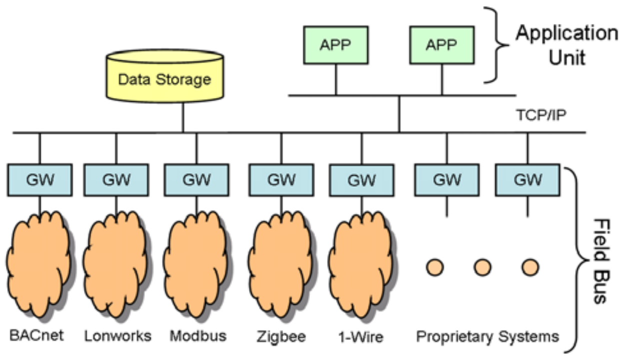

Figure 1. Three-tiered facility networking architecture.

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

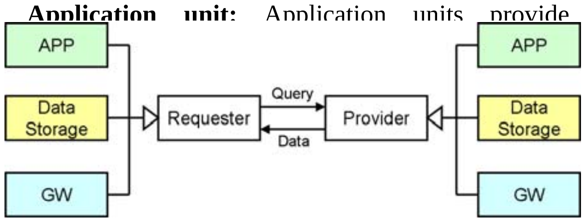

Figure 2. Data transfer

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

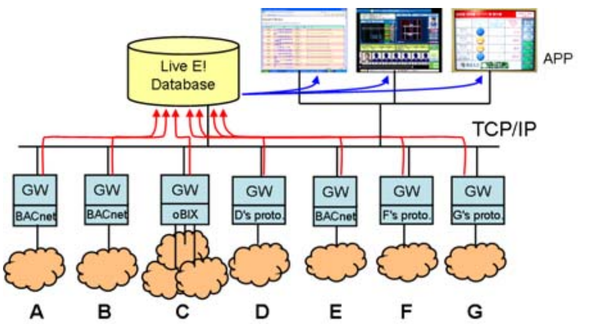

Figure 3. Prototype System

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.

- Data structure needs to be modified so that

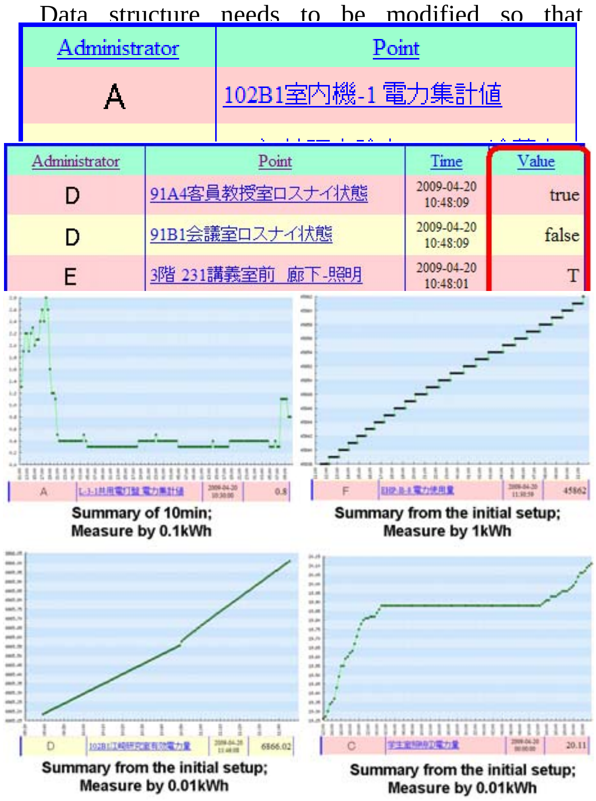

Figure 6. Sequence pattern for consumed energy.

- 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.

Acknowledgement

Along with authors, Cisco, Daikin Industries, Digital Electronics Corp., IEIEJ, Keio University, Kajima Corp., NTT facilities, Shimizu Corp., Toshiba, Ubiteq, Yamatake Corp. involve in this standardization activity.

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