GUTP and IEEE1888 for Smart Facility Systems using Internet Architecture Framework

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Abstract

The GUTP(www.gutp.jp), Green University of Tokyo Project, is the multi-stakeholder R&D and promotional consortium composed by more than 30 private companies and 15 NPOs. Using the live testbed, i.e., 12 floor high R&D and R&E building in Hongo Campus of The University of Tokyo, we developed and deployed the IP-based open facility system with multi-vendor environment. The protocol and architecture framework has been standardized as IEEE1888 (UGCCnet; Ubiquitous Green Community Control networks) system. HVAC, lights, digital signage, various filed-bus or other sensors and actuators are integrated through common database, while running multiple applications, which referring the common database and controlling field devices. The primary objective of our smart building or smart facility was energy saving. However, as we recognized from the start of the GUTP, new applications and innovations, which is not directly related with energy saving, are emerging.

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. Energy Saving Business "BY" ICT

2.1. 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. 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.

2.2. 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.

2.3. 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.

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, as IEEE1888[1]. The referenced architecture is shown in figure 1. 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.

2.4. 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.

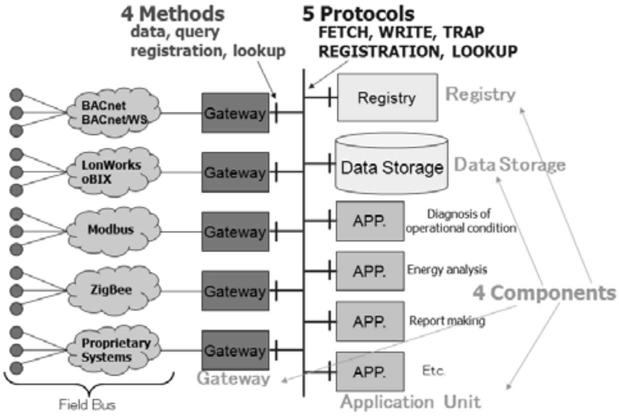

Figure1 Referenced Architecture for Facility Network

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.

3. Green University of Tokyo Project (http://www.gutp.jp/)

3.1 Project Overview

The GUTP, Green University of Tokyo [2], has started its activities since June 2008 complying with the TSCP. The basic goal of the project is to show technical approaches of reducing CO_2 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.

3.2 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;

(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.

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 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 [3].

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

[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.

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.

In order to realize the requirements discussed above, we have recognized that 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 in the facility, we could not assume that all the equipments were always connected to the system.

(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 our 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)

Figure 2 shows the system overview of 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.

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.

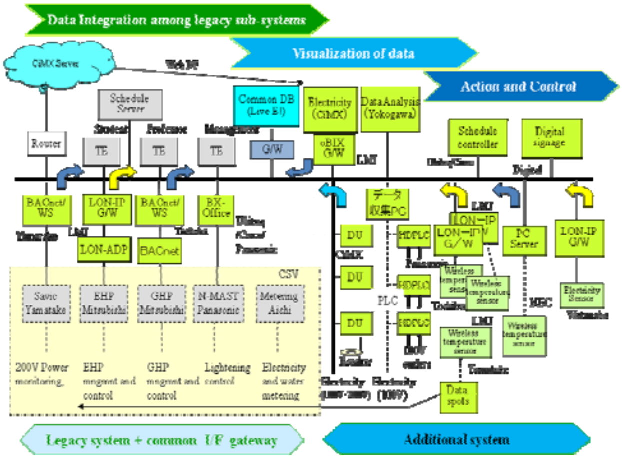

Figure 2 System Overview of Eng.No.2 Building

3.3 Development of 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 [7] and oBIX[3] [8]. 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).

(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 7).

(4) Power Monitoring for PCs:
Mitsubishi Corporation introduces BigFix® to monitor electric consumption of PCs (desktop/laptop) and servers as shown in Figure 8. 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/formulating.

3.4 Implementing "Mieru-ka" 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 "Mieru-ka" (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 Mieru-ka, and what they focus on are listed as follows;

(1) Display time-line trend of electric consumption:
As shown in Figure 3, 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) Dynamic Facility Management:
Ubiteq, Inc. and Cisco Systems develop the new router, called as BX-Office, that controls

[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;

facilities such as lights and air conditioners based on timetables of lecture and conference rooms. 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.

(Source: GUTP Experiment WG)

Figure 3 Time-line based Power Consumption

4. Conclusion

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.

In this paper, as a practical project operation, we give the overview of the GUTP (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, as defined in IEEE1888. 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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