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A Consideration on R&D Direction for Future Internet Architecture

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Abstract

The professional Internet system has been operated more than 20 years, while preserving the continuous introduction of technical innovations. The Internet architecture, of course including the future Internet, must preserve the following five essential features of Internet architecture. These are (1) autonomous, (2) distributed, (3) disconnected, (4) inter-domain, and (5) global operation. The current Internet system is challenged by the following three aspects; global, ubiquitous and mobility.

ISOC, Internet Society (www.isoc.org), has initiated the strategic initiative that is focusing on the "Trust and Identifier". We must re-design identifier, directory service, trust model, routing and communication model for the computer system and computer networks. For example, DTN (Delay Tolerant Networking) or P2P (Peer-to-Peer) system architecture would challenge the introduction of new technological frameworks to the existing Internet. Finally, this paper discusses how to build and how to deploy the future Internet infrastructure.

1. Introduction

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" [1]-[3]. This paper tries to identify the issues and R&D direction of future Internet, from the other point of view.

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 [4]. 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) inter-domain, and (5) global operation. The current Internet system has been challenged by the following three aspects; global, ubiquitous and mobility.

ISOC, Internet Society (www.isoc.org), has initiated the strategic initiative that is focusing on the “Trust and Identifier” [5]. This paper tries to roll out the particular research direction around the “Trust and Identifier”, with the author’s understanding. The following three points are the abstracted brief understanding among Trustees of ISOC board.

1. An Internet transaction between two or more verified or verifiable personae should be predictable within the context, appropriate traceable, auditable, and non-repudiatable.
2. Two or more personae that consider themselves to be in the same context should be able to perform relevant transactions. The choices available to connected personae in the Internet include anything they agree on.
3. Maintain “Layer”(Horizontal) service/business model

We must re-design identifier, directory service, trust model, routing and communication model for the computer system and computer networks. For example, DTN (Delay Tolerant Networking) or P2P (Peer-to-Peer) system architecture would challenge the introduction of new technological frameworks or component technologies to the future Internet.

Finally, this paper discusses how to build and how to deploy the future Internet infrastructure. 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”[6] and of “Invention is the mother of necessity”[7], 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.

Yet, another paradigm shift from the current R&D tendency 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.

The structure of this paper is as followed. Section 2 discusses the analysis and the observation of current Internet. Section 3 discusses the requirements for the Future Internet. Section 4 discusses the key components toward the Future Internet. Section 5 discusses how we deploy the Future Internet Infrastructure with a practical project example. Finally section 6 gives a brief conclusion of this paper.

2. Analysis and Observation on the current Internet

2.1 Change of technical assumption in computer networks

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 low performance and functional capability
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.

2.2 Emerging technologies

In the last decade, the digital wireless technologies have been developed and deployed, as the access link technology to accommodate digital equipments. Most of these digital wireless technologies adopt the packet based data transmission, rather than circuit based data transmission. Before the introduction of these packet based digital wireless access technologies, the computer networks have implicitly assumed that the nodes are basically continuously connected to the network without system failure, and the network topology is not changed frequently. This means that the emerging wireless technologies are going to change the character of computer systems, so that the nodes are not always connected with the stable network topology.

The other new characteristics, which emerging wireless technologies are going to introduce, is the introduction of Uni-Directional digital link. Even in the era using the satellite links to establish the Internet system around 1960s, the computer system has implicitly assumed that the links are of bi-directional. Since the power of signal, which mobile node can send, is far smaller than the power of access point, due to the restriction/limitation on signal transmission power for mobile node, a lot of asymmetric (or uni-directional) links are emerging in the computer networks. One of the intereting and exciting frequency resources, which we could use, would be the range of frequency, which is now used for analogue TV or radio services. These frequency ranges have potentially the large available bandwidth for digital communication platform.

Though we may potentially have large (uni-directional) bandwidth to be able to be integrated with the legacy bi-directional-link computer networks, the existing and legacy communication model, which is applied to the existing computer networks, would be ought to be changed.

2.3 Traffic analysis of Japanese commercial ISP traffic [8]

In this subsection, the author wants to discuss and realize the current status and issues, that the current (and future) Internet must solved. The author's research group has proceeded the traffic measurement and analysis of Japanese commercial ISP traffic. The six ISPes, OCN, KDDI, Yahoo BB!, K-Opticom, Softbank Telecom, IIJ(Internet Initiative Japan),have provided the real traffic data twice in a year since 2004. The followings are some interesting features of Japanese commercial Internet traffic.

1. Traffic volume
   The Japanese total Internet traffic in May of 2009 was 1.234 Tbps in average, while the traffic volume has increased around twice in two or three years, as shown in figures 1 through 7. Most of the Internet traffic in Japan is by the broadband residential customer traffic, i.e., proportion of non-residential customer traffic is relatively small (less than 10-20%). An interesting tendency observed by the data is regarding the incoming traffic from oversea to Japan, as shown B3(in) in figure 2. The increase ratio of incoming traffic from oversea to Japan is exceptionally larger than other traffic. Figure 5 shows the weekly traffic pattern of international traffic. Outgoing traffic from Japan to oversea is almost flat during whole of the days. On the other hand, the incoming traffic from oversea to Japan has large variation of amplitude, that is align with the human activity in Japan. Also, when we look at figure 6, the variation of amplitude has increased year-by-year, while the outgoing traffic from Japan to oversea has not but only total traffic volume has increased (as

shown in figure 7). We have not realized the reason of this tendency, but it might be because of small volume of chache or mirror (rich) content servers in Japan due to the strict copyright management in Japan.

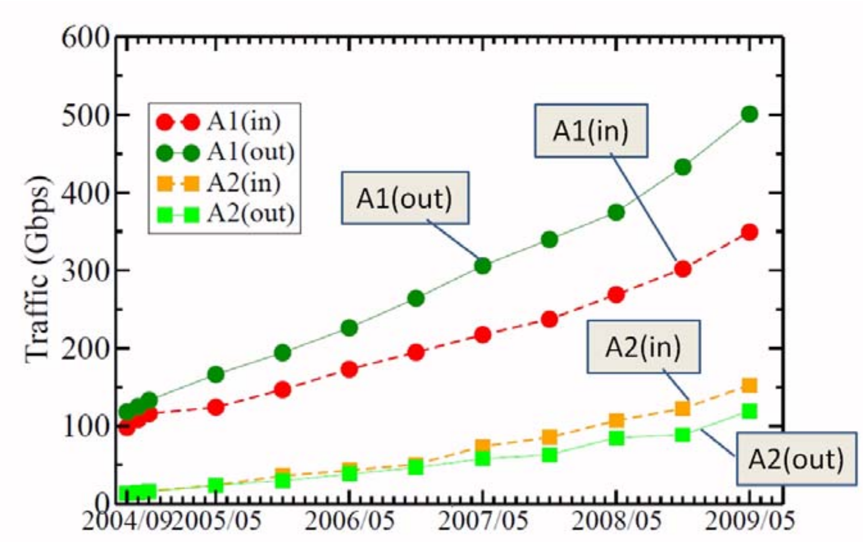

Figure 1. Total residential customer traffic in Japan
(A1: Broadband users, A2: Non-Broadband users)

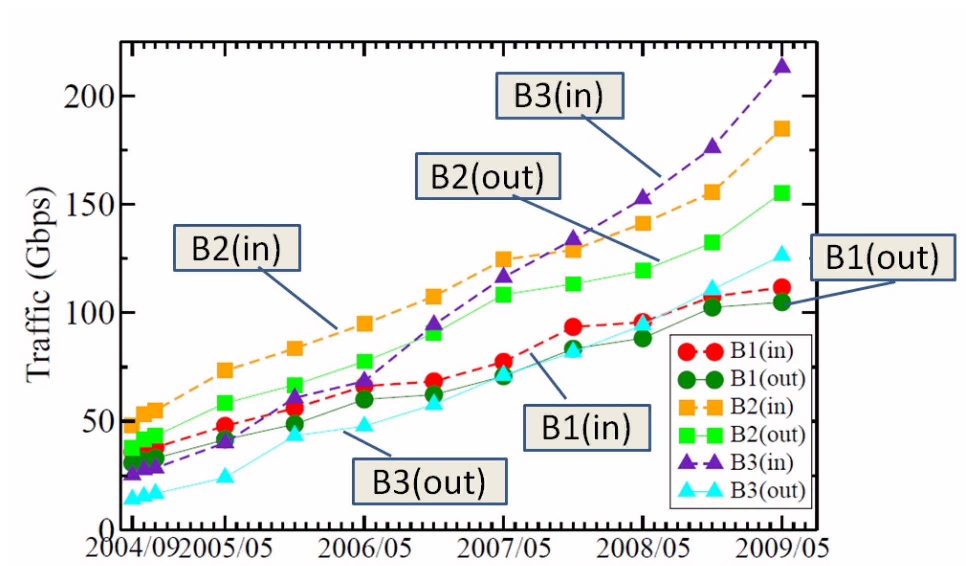

Figure 2.Total Non-residential traffic in Japan
(B1: Traffic at IXes, B2: Traffic by private peerings, B3: Oversea traffic)

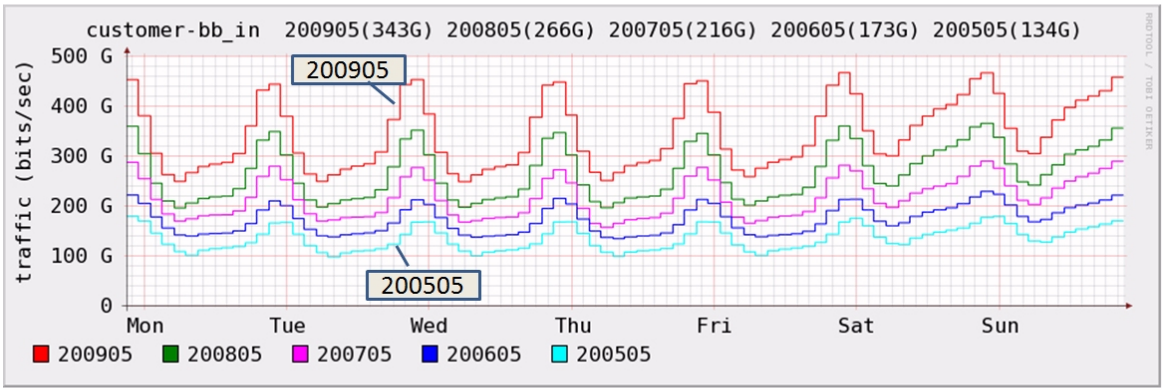

Figure 3. Weekly uploading traffic (customer ➔ network)

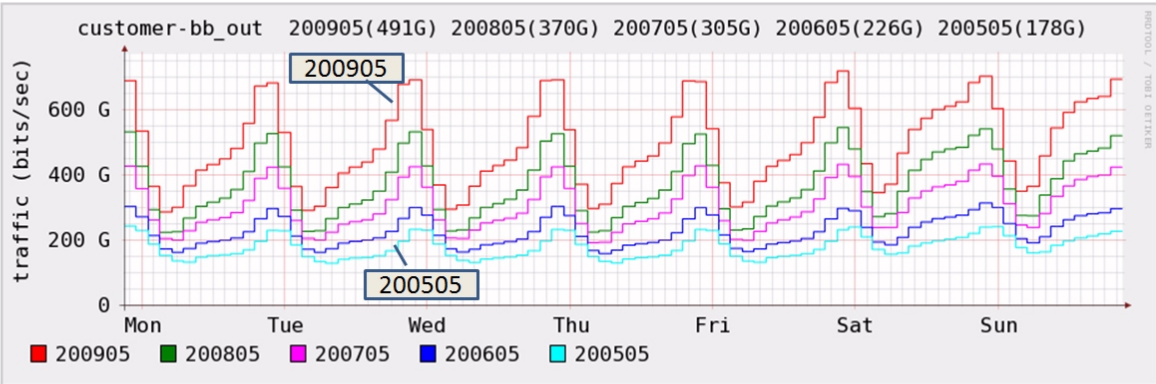

Figure 4. Weekly downloading traffic (network ➔ customer)

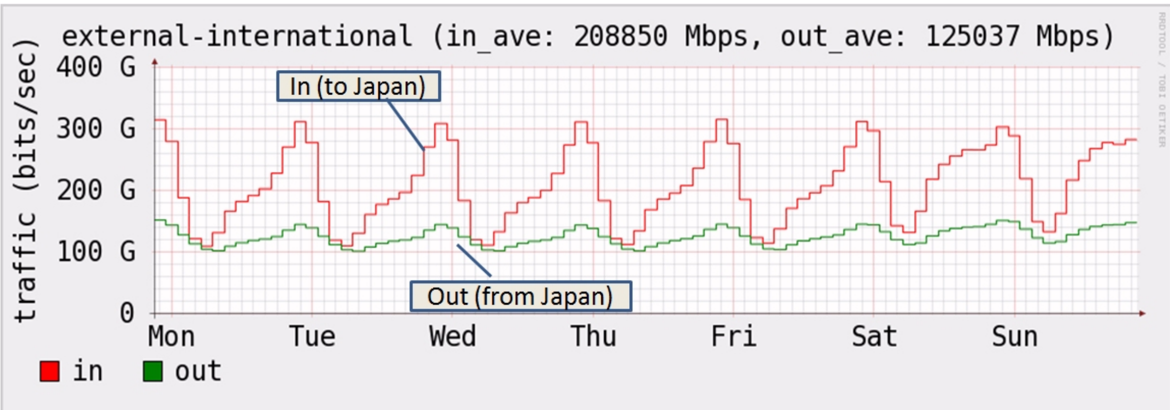

Figure 5. Weekly oversea traffic in November 2007

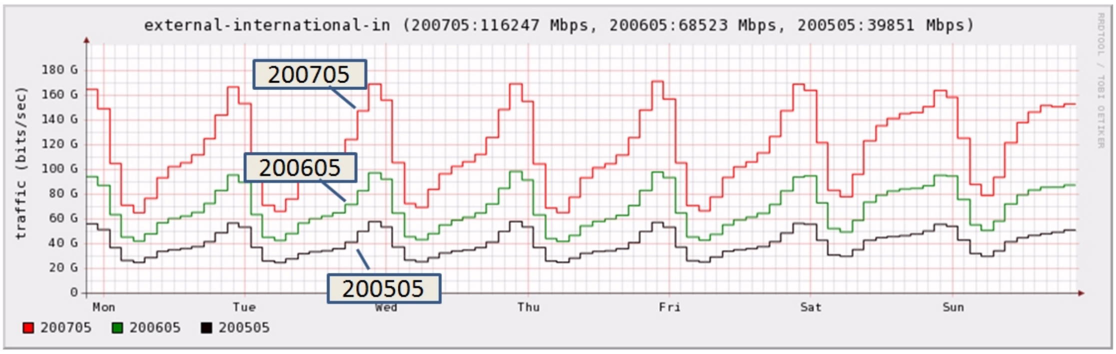

Figure 6. Weekly oversea traffic (oversea ➔ Japan)

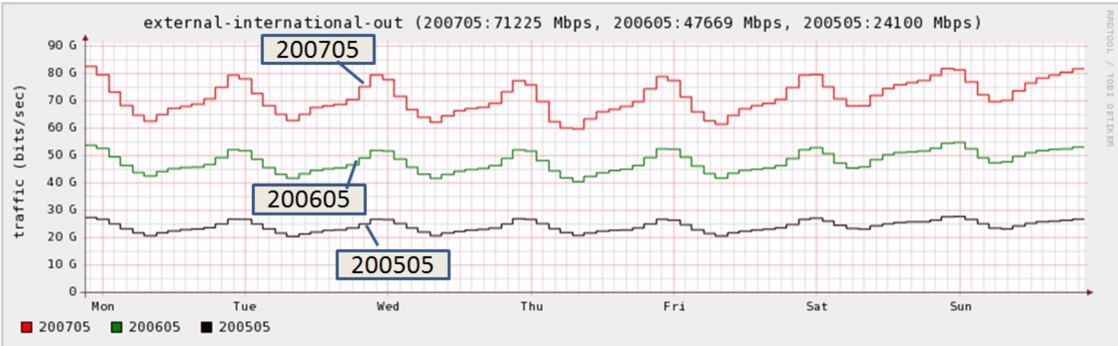

Figure 7. Weekly oversea traffic (Japan ➔ oversea)

2. Changing the traffic, which may be hard to control

   In 2004, the daily and weekly traffic pattern was almost symmetric and of small variation of traffic amplitude, as shown in figures 3 and 4. However, the variation of traffic amplitude has been increased year-by-year. In order to grasp the detail of individual user traffic, we have analyzed the total traffic per individual customer traffic [8]. How we evaluate the user traffic is described in [8]. Figure 8 shows the overview of the distribution of user density against the total traffic volume of individual customer. As shown, the data looks the convolution of (log-scaled) two normalized distributions. The distribution of higher volume in horizontal axis would be of the P2P traffic, and that of lower volume would be of the interactive traffic (e.g., VoD or streaming). Here, we have to perform the deep packet inspection, so as to correctly identify the type user traffic, i.e., P2P traffic or interactive traffic. Due to the network operation policy by ISPes and due to the technical difficulty, we can not perform deep packet inspection to identify the type of user traffic, at this time. This work should be for further study. As discussed in [8] and shown in figure 9, the higher peak has slightly shifted to right, but the lower peak has significantly shifted to right. This means that the increase ratio of lower peak traffic (i.e., interactive traffic) has been significant. This is aligned with the tendency shown in figures 3 and 4, i.e., the increase of variation of traffic amplitude year-by-year. It would be in general that the P2P traffic is relatively constant volume against the time, but the interactive traffic has large variation of traffic amplitude against the time. The traffic control for the traffic, that has larger variation of traffic amplitude, is generally harder. This means that the traffic control in ISPes has been getting harder year-by-year, since 2004.

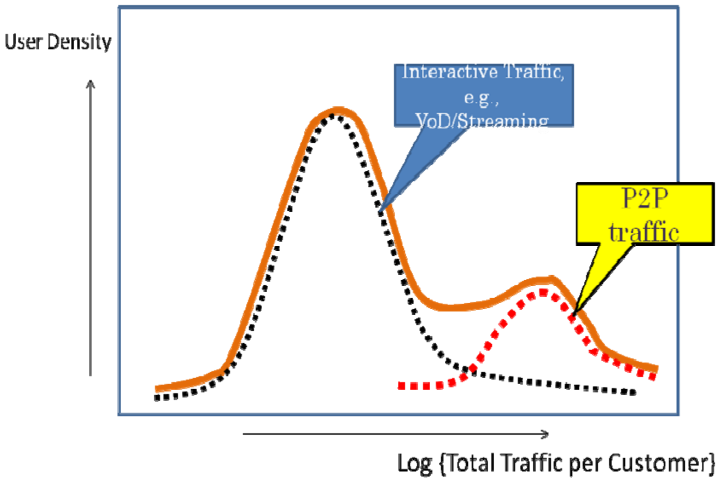

Figure 8. User density versus total traffic volume per customer (1)

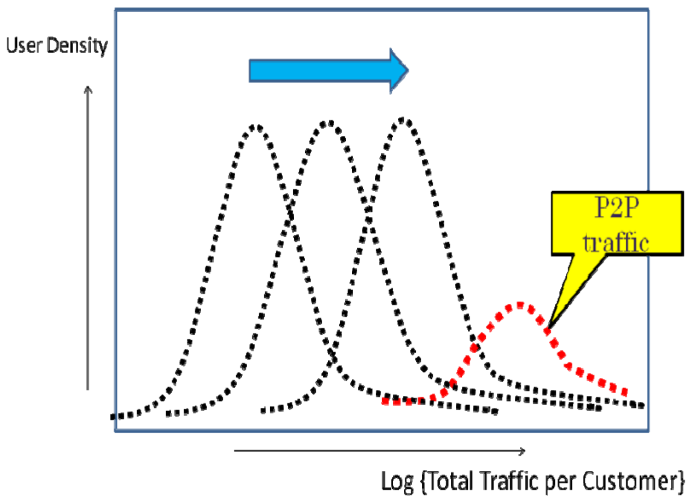

Figure 9. User density versus total traffic volume per customer (2)

3. TCP and UDP port usage

Table 1 shows the protocols and ports ranking used in TCP and UDP connections, observed in some commercial ISP in Japan. Here, this data is not by traffic volume, but by the number of observed sessions using the traffic data. As shown, more than 80% of TCP sessions do not use the well-known port. This means that the packet filtering based on the TCP/UDP port number would not work well. The detailed discussion regarding the Table 1 is performed in [8].

Table 1. Protocols and ports ranking in TCP/UDP connections [8]

protocols/ports ranking

classify client-type/peer-type with threshold: 100MB/day upload

protocol	port	2005 total (%)	2005 client type	2005 peer type	2008 total (%)	2008 client type	2008 peer type
TCP	*****	**97.43**	**94.93**	**97.66**	**96.00**	**95.51**	**96.06**
	(< 1024)	*13.99*	*58.93*	*8.66*	*17.98*	*76.16*	*11.35*
	80 (http)	9.32	50.78	5.54	14.06	64.96	8.26
	554 (rtsp)	0.38	2.44	0.19	1.36	8.21	0.58
	443 (https)	0.30	1.45	0.19	0.58	1.63	0.46
	20 (ftp-data)	0.93	1.25	0.90	0.24	0.17	0.25
	(>= 1024)	*83.44*	*36.00*	*89.00*	*78.02*	*19.35*	*84.71*
	6346 (gnutella)	0.92	0.84	0.93	0.94	0.67	0.97
	6699 (winmx)	1.40	1.14	1.43	0.68	0.24	0.73
	7743 (winny)	0.48	0.15	0.51	0.30	0.04	0.33
	1935 (rtmp)	0.20	0.81	0.14	0.22	0.73	0.16
	6881 (bittorrent)	0.25	0.06	0.27	0.22	0.02	0.24
UDP	*****	**1.38**	**3.41**	**1.19**	**1.94**	**2.50**	**1.88**
	53 (dns)	0.03	0.14	0.02	0.04	0.12	0.03
	others	1.35	3.27	1.17	1.90	2.38	1.85
ESP		**1.09**	**1.35**	**1.06**	**1.93**	**1.85**	**1.94**
GRE		**0.07**	**0.12**	**0.06**	**0.09**	**0.08**	**0.09**
ICMP		**0.01**	**0.05**	**0.01**	**0.02**	**0.05**	**0.02**

3 Requirements and Key Components for Future Internet

3.1 Requirements for the Future Internet

This subsection discusses the requirements for the future Internet system.

(1) Features of future Internet

The followings are how the future Internet looks like.

1. Covering our "Earth" with high speed network

   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.
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.
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) Technical dimensions, that the future Internet must take care of

The following three technical dimensions should be taken into account for the development of future Internet.

A) Global space deployment
   - Global network environment; the future Internet must be deployed and have a scalability for global operation.
   - Diversity of connectivity; the future Internet must take care of variety of characteristics regarding the connectivity, such as latency, bandwidth and data loss ratio.

B) Re-definition of communication model
   - Transparency; the legacy Internet architecture has strictly preserved the "naïve" end-to-end transparency for data communication, i.e., may not allow any proxy nor cache in the middle-boxes.
   - Object abstraction/definition; the legacy Internet system only define the "interface" by IP address and the "stream data-flow" by the socket communication, assuming the interactive bi-directional data transaction between communication peers with reasonable data transmission latency.

C) Autonomous system
   - Inter-networking of heterogeneous networks; the sub-systems have adopted various technologies and operational/control policies, even when the IP may not be adopted in some sub-systems.
   - Trust model, without some absolute authority; the legacy Internet architecture may assume the existence of absolute authority to establish the trust among the communication peers. However, especially in the ad hoc or disconnected mobile/wireless network environment, we would not be able to assume we have any reachable absolute authority.

3.2 Key components for the Future Internet

This subsection discusses some key components for the future Internet system.

(1) DTN

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. In order to come up with the large latency and with disruption of connectivity, we may have to change the existing communication model, which is assumed in the communication system with the current TCP/IP protocol suits.

(2) Message routing

The existing Internet system has adopted the (IP) packet routing. In the IP packet routing, (1) the source node resolves and informs the destination IP address with TCP/UDP port, when the source node starts the communication, i.e., source node initiates the communication, and (2) the stream oriented data communication, i.e., virtual connection, is established between peer nodes. 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), rather by means of the on-the-fly fashion, and (b) the peer nodes may not be required any state synchronization for data communication, i.e., one-way communication rather than bi-directional communication. The message routing, e.g., publisher-subscriber model, would be a possible communication model in the future Internet system. Also, from the view point of network topology management, the message routing may be better than the un-structured networks, e.g., ad-hoc networks or overlay networks.

(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

   The old main-frame computer or personal computer has implemented very small (or no) cache memory or proxy function. As similar to the introduction of cache or proxy into the stand-alone computer system, the P2P system would introduce the "networked" cache or proxy function into the legacy naïve Internet system.

2. {networked} DMA (Direct Memory Access)

   The old computer system has experienced poor processing performance, because of a lot of CPU interruptions, due to lack of the DMA function in the system. The DMA reduces the CPU interruptions, by means of autonomous peer-to-peer data transmission among memory devices without any intervention by CPU. We could realize that the P2P technology introduces the "networked" DMA function into the legacy "naïve" Internet system. Here, when we apply the idea of networked DMA to the real network, we have to solve the security issues, e.g., authorization or authentication, which would be the same discussions as Trust

Computing framework has carried out [9].

3. {networked} Virtual memory system (by DHT)
   By the introduction of virtual memory into the computer system, the computer system can accommodate and access the wide variety of devices (e.g., memory or processing devices) with the single and common interface. This is the abstraction of memory, by the separation of data handler (i.e., identifier) and the real storing address, in order to achieve the access to heterogeneous memory devices via the unique and single (virtual) interface. The similar function, but the different level/layer, has been achieved in the P2P system. This is achieved by the following three functional components; (1) separate the contents handler(identifier) and the real storing address, (2) access heterogeneous devices with single {virtual} interface, and (3) abstraction of contents by number (by DHT) concealing file name, file descriptor or other identifiers.

4 Deployment of Future Internet Infrastructure

4.1 Methodology of the future Internet infrastructure deployment

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

(1) "Experienced Design"
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"
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". As a result, we should avoid the fragmentation of individual (global) IP networks, as a governance of digital network development and deployment.

4.2 Example of R&D Project toward the Future Internet Development

The Green University of Tokyo Project [10] is the Green IT campus project established in June 2008 at Building No.2 of the Faculty of Engineering at the University of Tokyo, Japan. 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. 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. We could realize that this is a yet another "end-to-end" model that the Internet has achieved. 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.

Figure 10 shows the system overview of Building No.2. There were separated sub-systems, which uses their own proprietary or standardized technologies for the corresponding sub-system categories. Since these sub-systems could not mutually exchanged the data, the components, such as sensor and actuator nodes, in the sub-systems could not collaborate nor co-operated to each other. In order to interconnect these sub-systems, we have adopted the message routing framework based on XML format with the pub/sub architecture. In the backbone area, the XML message routing over IP technology has been adopted, so that all the sub-system and management application software can share and use the data stored in the common database [11][12][13]. Also, since some sensor will be mobile nodes, we have designed that the system has the DTN function, by means of message routing paradigm. This would be a feasible example how to build the future Internet infrastructure. Autonomous sub-systems have been designed, investigated and operated for their own original objectives. Since the sub-systems are mutually interconnected (i.e., federated heterogeneous system, rather than single owner homogeneous system), all the data among the sub-systems can be used by any node and application across the sub-systems.

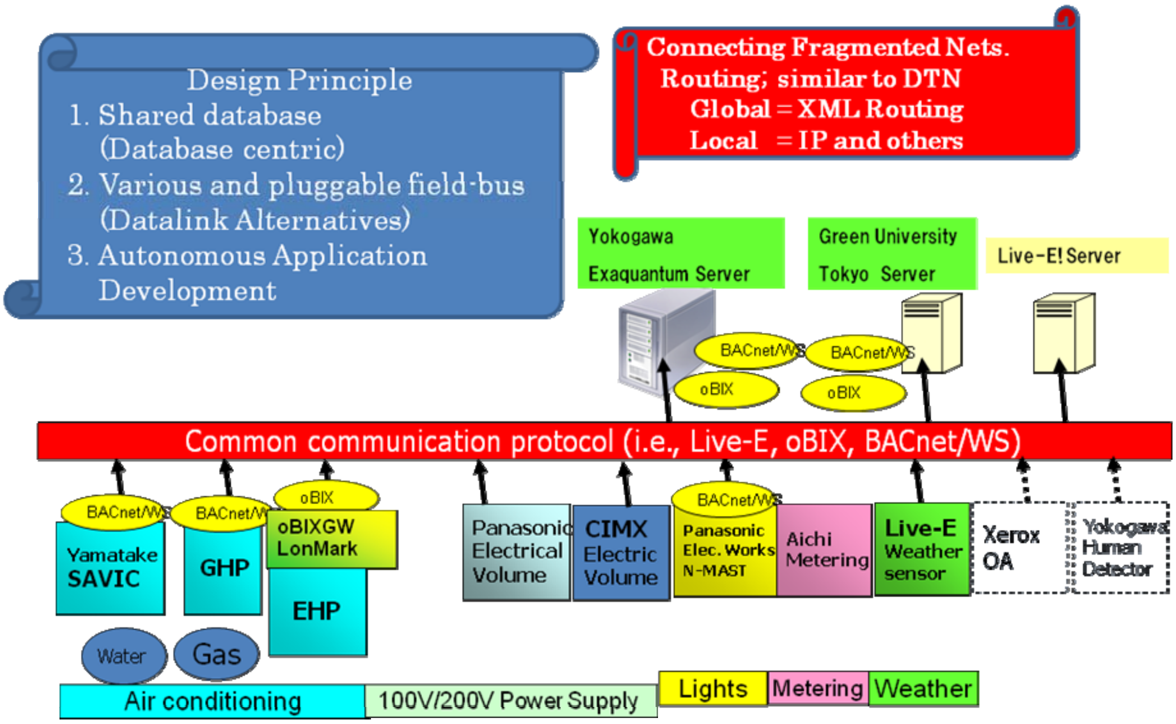

Figure 10. System overview of Green University Tokyo Testbed

5 Conclusion

In this paper, 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 feature of the Internet architecture; (1) autonomous, (2) distributed, (3) disconnected, (4) inter-domain, and (5) global operation.

As the ISOC has initiated the strategic initiative "Trust and Identifier", we must re-design identifier, directory service, trust model, routing and communication model for the computer system and computer networks. For example, DTN (Delay Tolerant Networking) or Peer-to-Peer system architecture would challenge the introduction of new technological frameworks into the existing 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, we have to avoid that these networks will be disconnected, i.e., fragmented. 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. As a result, we should avoid the fragmentation of individual (global) IP networks, as a governance of digital network development and deployment toward the future Internet.

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