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AUTO-ID CENTER

WHITE PAPER

Internet and Auto-ID Architecture

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ABSTRACT

With the power of the Auto-ID related technologies, every physical object can be identified with a unique identifier when an Auto-ID tag is attached to the object. The identifier can be related to a set of information which is very likely representing semantics or attributes of the object. Combined together, they can be viewed as a single logical object accessible and identifiable on a space by a computer network like the Internet. This model is realized by the Auto-ID Center's basic architecture of the software: Savant and ONS.

On the other hand, the Internet employed a new version of protocol called IPv6 and becomes ready to connect on-computer elements. This environment is strongly demanded for implementing ubiquitous computing where relationships between the context of the real world and an object is discussed. Thus, the Internet is binding the logical virtual space (sometimes called cyber space) and the real space context. We call it as the real space networking environment.

This paper is intentionally views the software architecture around Auto-ID from a standpoint of the Internet architecture and its future real space networking. The focal point of the discussion in this white paper is the name space design and operational issues for real space related object.

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Internet and Auto-ID Architecture

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Yojiro UO received the bachelor degree in Electrical and Electronic Engineering from Tokyo Institute of Science and Technology, and his master and Ph.D degrees from school of information science, Japan Advanced Institute of Science and Technology. He is an associate director of research and development of the Auto-ID Center Japan and a researcher of iijlab, Research Laboratory of Internet Initiative Japan Inc. His research background is Internet architecture, especially Sub-IP layer to extend Internet operational flexibility. His currently research target is a global naming service of the Auto-ID architecture and next generation Internet which is applied Auto-ID concepts.

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1. INTRODUCTION – ID MANAGEMENT ON THE INTERNET AND REAL WORLD

From the networking and ubiquitous computing point of view, every single information object can be properly accessed and shared in the future information space. Here the information object can be either a logical object which is a collection of digital information (such as two digits, '12'), the logical object with a name attached to it (such as 'temp=' and '12'), or even a physical object with a lot of attributes attached to the logical object (such as a thermometer in a particular location has a value of 'temp=' and '12'). This new information space is achieved by the consequence of carefully merged result of logical information technology and physical object.

The Internet has been constructing a logical space where digitized information can freely be exchanged and shared; sometimes called 'cyber space'. The production of this space is achieved by computer elements and networks connecting them. The protocols and their software handle the data recognized by the computers.

This Internet space has been evolving very rapidly, especially because of the evolution of its elements. A computer has been built-in to a non-computer looking object and has started to behave as an element object of the Internet. A camera, for example, consists of CCD and protocol software so that it is behaving as an autonomous object on the Internet now. A digital appliance without such a sophisticated protocol software even behaves as an autonomous object with the help of a near-by computer's software which behaves as a proxy of the original object. A (dumb) printer connected to a computer has been living such a life on the network for a long time already; a software on the computer creates an illusion that the printer is an autonomous Internet object with proper identifier and protocol software to the Internet space (but actually it does not have such a function on its own system).

These examples of a camera, being an input device to a computer, and a printer, which of course is an output device from a computer, both are bridges from the Internet space to the real space. As the value of information handled with such devices, we care very much about their attributes on the real world. Location is one of the primary real attribute to be attached to such an object. We do care about the location where a picture is taken and the location where the printer physically locates. Such a 'non-computer' object is now accessible and handled over the global network, even though its identifiers and its autonomous interactions are largely supported by a neighbor computer.

Any physical object with a tiny IC chip can be tagged with an identifier, communicating over radio waves with RFID technologies. A reader and possibly RFID writer and the software around it can create a new 'illusion' of every single object being recognized and accessed by others. This discussion leads us to the design of RFID being a new element of the ubiquitous computing space using the real space Internetworking technology where the scalability and mobility are not a big issue for communication on the global space.

The real space Internet employs Internet Protocol version 6 (IPv6) [IPv6] where scalability, mobility and autonomy of an element are supported. Security, stability and privacy are the common area of such technologies, so that should be challenged as a whole system. A RFID-equipped object can be abstracted into an autonomous element on the real space network with some neighboring software. In this architecture of the network the RFID can be a dumb ID because the rest of the functions are an independent autonomous element supported by external software, and also the RFID can be a super intelligent and powerful computing element which by itself can be an autonomous object in the space.

This view is totally consistent with the classified plan of an Auto-ID Center's definition of the future evolution of an Auto-ID tag, although the application concept is somewhat the network-to-Auto-ID view

rather than the Auto-ID-to-network approach of the original Auto-ID Center's approach. This paper intentionally discusses the way approaching the Auto-ID architectural design from the advanced Internet design point of view.

In our view, it is most probable that various technologies proposed by the Auto-ID Center will make it possible to connect RFID-tagged objects in the real space with the associated data in cyber space. The concept of the Auto-ID Center is that RFID-tagged objects have their own ID, and the ID is able to point various data associated with the tagged objects in the cyber space. Both the relationship between the object ID and data, and the relationship between object itself and the ID will be useful to address the "real-space oriented networking"

On the assumption that this premise is accepted, the attributes and metrics of the object and any data which related to the object are processed and manipulated in the cyber-space indirectly.

The currently available RFID tag has only a static ID. However, there are a lot of attempts being made for a RFID chip to become more intelligent, having sensing facilities, and owning dynamic ID. For example, there are researches of an ID chip, which changes its own response according to its environment and access situation [MANTIS]. The design of the networking system accommodating the Auto-ID has to be consistent with such a future with a sophisticated architecture.

2. THE NEW INTERNET ARCHITECTURE FOR AUTO-ID

A virtual space that spreads on the computer network is sometimes called "cyber-space", which is a logical space for information and digital data. For the past decades, this concept has represented the space created by the Internet pretty well. Though the very much deployed Internet has become a real communication media with real activities on it. This change introduces the merging of cyber space with real space where we physically live.

Understanding the Internet itself is important in dicussing the relationship between cyber-space and real-space. This section attempts to describe the current and future of the Internet to represent perception of Internet area.

2.1. Internet Architecture

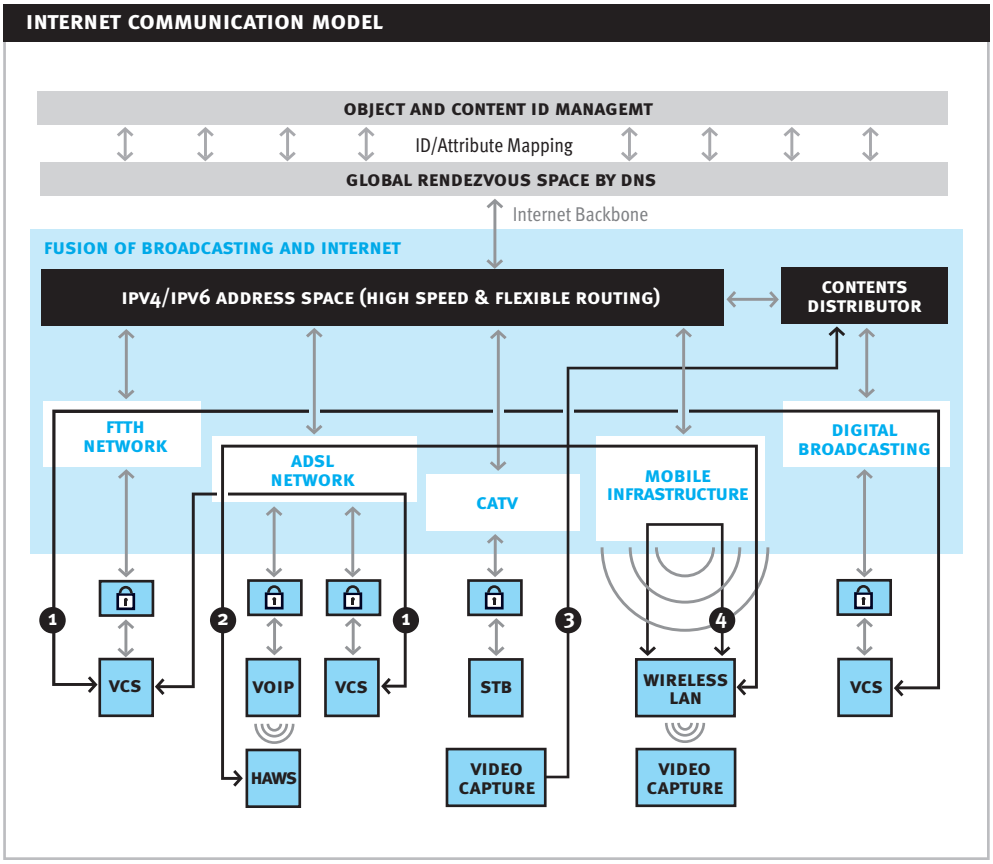
The Internet can be defined as a platform to exchange information. This information is generated and stored in various places. The cyber space consists of the information, and it is sustained by interactions of own information.

In the near future, as far as they are encoded to bit strings, such as all contents video, audio and broadcasting can be exchanged via the Internet. In addition, since the broadband infrastructure can make network available anywhere, various devices which process digital data can be connected to the Internet, for example existing electronic devices, such a television, mobile and PSTN phone and others, as shown in figure 1.

Figure 1: Shows the communication model of Internet

1 End-to-End Communication
2 Remote Access
3 Contents Delivery
4 Mobile IP

VCS Video Conference System
HAWS Home Appliance with Sensor
AAA Security



Since all devices in the real world, such as refrigerators, lightings, switches, air conditioners, thermometers and some other home appliances, potentially interact with these environments, the connection between these devices and Internet would reinforce the relationship with the real and cyberspace. In such environment, these devices communicate with each other and and generate more value-added information.

2.2. Direction of the Internet Evolution

In the 1990s, the Internet established the status of a practical infrastructure. Now, the Internet is widely used in the office and at home. Many people use broadband connectivity over 10Mbps (by the ADSL and FTTH connection). In addition, various technologies has been improved in the Internet. The Internet Protocol version 6 (IPv6) is the good example of these improvements.

2.2.1. Internet Protocol Version 6 (IPv6)

IPv6[RFC2460] is the successor of IPv4 (the current protocol of Internet) and it applied the latest research experience to its protocol design. IPv6 has almost infinite address space (128bit length) and some efficient function extensions, such as extensional header structure, effective routing control, auto configuration and security support.

Of course, the IPv6 would contribute to ubiquitous computing and some real space applications. The large address space enables the connection of various devices to the Internet and the end-to-end communication. The IPv6 architecture will help to handle a large amount of devices in the real space.

The deployment and transition of IPv6 network has already been started in Asia, Europe and US area. For example, the Japanese government has supported IPv6 deployment since 1999. Currently many ISPs are able to provide IPv6 connectivity. If a RF reader can handle the IPv6 protocol, such a RF reader can be accessible by a global IP address. Many consumer electric appliance companies have developed the consumer electric products which can connected to the Internet, such as an Internet refrigerator.

2.2.2. Home Environment for the RF Readers and Sensors

Recently, new possibilities of Real Space Networking have been arising. Broadband connectivity has been introduced to home and offices, and home products are proposed and developed on the assumption that every home has the Internet connectivity. There are two ways to deploy these devices as candidates for the RF readers and sensors.

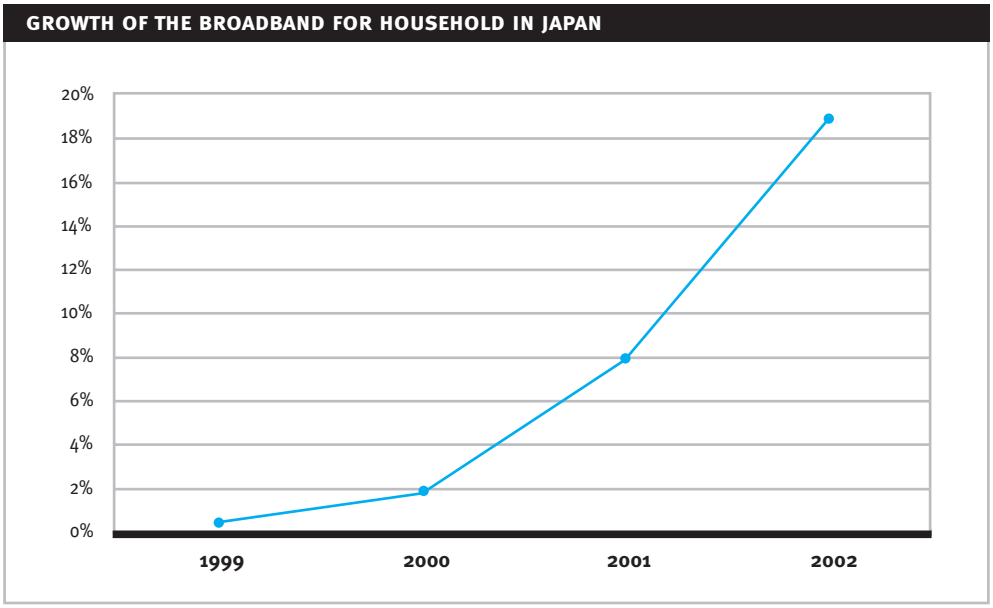
The first approach is to connect the existing home electronics to the Internet and enhance their computation power. This is generally called the “Home network environment”. Many electronic makers have proposed concept model of such products, for example the Internet refrigerator. In some proposals, a video camera or a bar code reader is installed on the refrigerator and receives information within the equipment. With the introduction of Auto-ID in the near future, RFID will be attached on many products in SCM field. Furthermore, a refrigerator could have a RFID reader and would be integrated in the Auto-ID architecture. Not only a refrigerator, but also other home electronics, which are related to tagged products, such as microwave oven or audio equipments, will be integrated into Auto-ID architecture.

The other approach is to install Internet connectivity to various inexpensive devices with small capability at home, and make it work as a RFID reader. Most Auto-ID applications assume many RFID readers within a house or an office. BAS (Building Automation System) platform research proposes a specification such as EMIT (Embedded Micro Internetworking Technology), where lightings and plug outlets to have IP connectivity. These devices exist densely in a space, and when they work as RFID reader, they play an important role for Auto-ID architecture.

2.2.3. Current Status of Broadband Networks in Japan

In Japan, the situation of the broadband Internet was dramatically changed in those a few years. Figure 2 shows the increasing number of home with the broadband Internet connectivity.

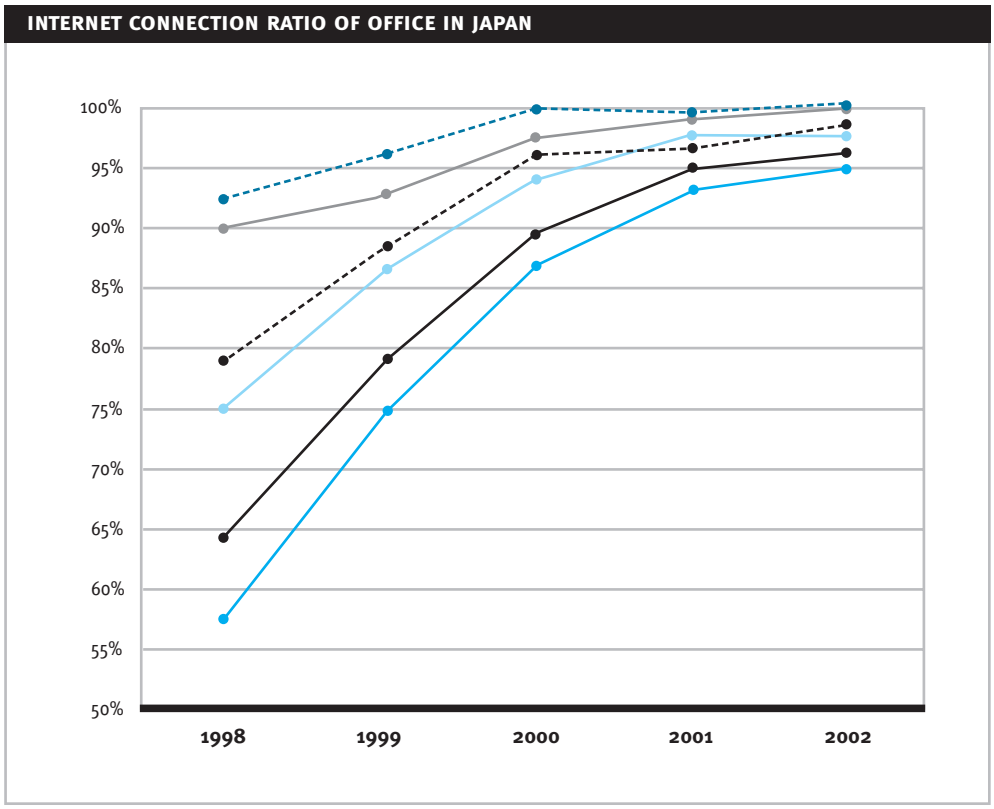
Figure 2: The percentage of the broadband connectivity contracts in the total number of households in Japan.



In 2003, about 20% of household (about 9 million home) in Japan has the broadband Internet connectivity. The capacity for the broadband Internet connectivity is about 74 million for home. The capacity means the number of perpetrated facilities to connect broadband Internet to a home at the Internet service providers. The broadband Internet connectivity is provided by Optical Fiber, ADSL, cable TV and FWA (Fixed Wireless Access). Those technologies do not provide only broadband connectivity, but most bandwidth is consumed in Internet purpose. Many public spaces, coffee shops, train stations, airports, hotel lobbies and so forth, supports Wi-Fi hot spot services.

Figure 3 shows the ratio of the office connectivity. Now, over 90 % of the offices have Internet connectivity.

Figure 3: Transition of Company Connected to the Internet (according to employee scale)



3. ID SPACE MANAGEMENT

Thorough our operation on the Internet, a lot of experiences has been accumulated on the ID space related issues – design, implementation and management, thorough actual operation in Internet. Generally, among them, name space and identification are hard to discuss. Furthermore, management of ID space and ID system has other difficulties because there are so many issues to be resolved.

This section looks at the point of discussion about the ID space management, referring to our experience in Internet.

3.1. Naming Architecture of Internet

Internet consists of many nodes which are identified by its own IP addresses. Each node using Internet Protocol use IP address to identify communicate-peer, and every IP packet include IP addresses to specify source node and destination node(s). In other words, IP address space is “native” name space in the Internet, because IP address is the identifier for communications.

As you know, there are many kinds of name spaces that are observed on the current Internet. For example, URL (Uniform Resource Identifier), E-mail address, domain name and VoIP phone number is used for various applications on Internet. These name space are independent from the IP address name space, but the name space mapping mechanism enables to use these different addresses in Internet. All of these name spaces are finally mapped to IP address when communication peer is established. Therefore, Internet can manage miscellaneous devices and objects that would have different name space consistently by introducing the mapping mechanisms between name spaces, for example the IP address space and domain name spaces.

3.1.1. General Name Space Mapping

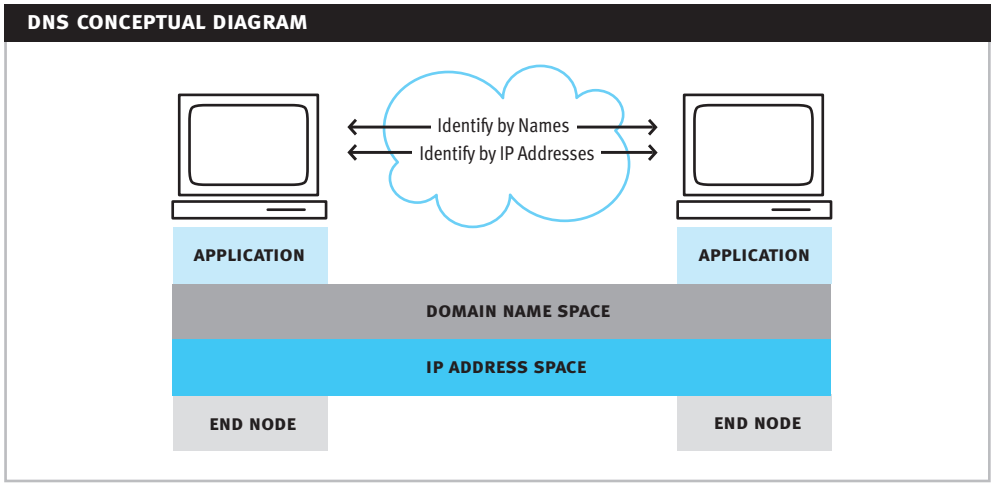
The idea of inter-name space mapping is used everywhere on the Internet. Generally, most network models are designed as layering models. In this model, name space mapping mechanisms between layers is introduced to acquire its transparency and independency between conjunction layers. It is also useful for clear implementation.

Particularly, Domain Name Service (DNS) is the global directory service, which is designed and managed in order to map a domain name (FQDN) to IP addresses. The DNS serves scalable mapping service using distributed, tree-structured, delegation base information architecture. Because the DNS is a great success, we cannot imagine the Internet without it. In addition, between data-link layer (L2) and network layer (L3), there are mapping mechanism that exchange IP address and L2 address, for example MAC address of Ethernet, VCI/VPI of ATM or label stack of MPLS. Communication transparency can be realised not by using node ID directly, but by using abstruct name (e.g. domain name) and naming system (e.g DNS) for the exchange from domain name to node ID. In other words, as far as there is a dynamic mapping system, users can communicate by acquiring new node ID from domain name, even if node ID changes.

3.1.2. Domain Name Service/System

Figure 4 shows DNS conceptual diagram. DNS is the naming system mapping from key entity that can be represented as FQDN form like a host name or mail address to IP address or pointers to other name space such as URI.

Figure 4: DNS conceptual diagram



The DNS is designed as a system to manage mapping between IP addresses and domain names dynamically using distributed lazy-sync database architecture. The DNS specifications are originally defined as RFC1034, RFC1035 and RFC1123, and continuous effort are made to extend various functions such as security extension and new resource record definition.

DNS performs name space mapping which uses FQDN as the key. Mapped objects are called Resource Recode (RR). Currently many kinds of RR are specified and used, for example, A RR for declare IPv4 address, MX RR for Mail eXchanger, CNAME RR for aliasing name. If someone recognize the needs of to add the new resource record to DNS specification, the IETF[IETF] start to discuss the feasibility and reasonability of it. In these days, AAAA RR for IPv6 address, NAPTR(Name authority PTR)[RFC3401-3404] and some others are defined.

3.2. Issues of Name Space and Naming System Design

We have to give careful consideration as to the requirements and use cases of its name space before designing a naming system, because name space structure and its naming system are firmly linked.

This section shows our experience of several naming system designs and large scale name space management in the Internet, to give some points to start the discussion about these issues.

3.2.1. Scalability and Expendability

Since the Internet domain space is very large and the naming system must be scalable, the DNS takes tree hierarchical structure and the sub-tree delegation mechanism. This is an example showing a name space structure and naming systems are inseparably related to each other.

Name space expendability and scalability are almost the same but metric of expansion is different. DNS obtains name space extensibility and scalability through using techniques in order to restrict the query key format to FQDN (Fully Qualified Domain Name) format, to use sub-tree delegation mechanism and to allow the multiple-stage resolve mechanism, for example a FQDN to CNAME to CNAME to A; this is a resolveing sequence of a FQDN to a IPv4 address with 2 aliases mappings. In addition, the DNS is able to treat other name space mapped the FQDN format, such as IP address. For example, the PTR RR, the pointer to another name space, is used as reverse mapping from the IP address space (IN-ADDR.ARPA.) to the domain name space.

If the key entry to search in name space is structured, the name lookup model could remain simple. The well structured name space. Furthermore, it has some inflexibility for new reference requirement digressing from basic design. When someone designs a name space, he or she need to understand these advantage and disadvantage, without a blind belief in the success of DNS.

Followings are the issues that should be taken into account for name space design: relationship between name spaces of mapping targets, granularity of query and response operation and name space structure.

3.2.2. Security, Privacy and Access Control

Security, Privacy and Access control are all important issues on the naming system mapping among name spaces.

Since DNS was designed to reflect the Internet usage pattern in those days, it has a structure with the following features.

- to equalize every access(non access control)
- to use the plain text for query/response(non security and/or privacy)
- to have no certification for the communication between server/clients.

Since the preference and purpose of Internet usage have been changed with widely spread of the Internet, several attacks to the DNS infrastructure have occurred in recent years. Especially, some types of zone hijacking and a DNS ID spoofing attack are serious problem because of the possibly that they spoil Internet integrity. Of course, the cyber squatting and DoS attack to DNS servers are also harmful. The IFTF, ICANN [ICANN] and RIRs [RIR] are discussing to make the DNS protocols more resident, such as to apply some AAA (Authentication, Authorization and Accounting) functions to DNS [ICANN DNSSEC].

3.2.3. Other Issues

Moreover. The following additional issues exist on the naming system designing:

- System stability
- Integrity, such as intermediate entities that support transmits mapping data, authentication, authorization of origin of mapping information and other system behavior.
- Efficiently of system performance such as “data retrieve time”.
- Data flooding time, if the system is using distributed data model.

3.3. Discussions About Naming System Architcture

Followings are important point to discuss and make decisions of name space and naming space design.

3.3.1. Centralize Model vs. Distributed Model

DNS is a naming system based distributed database model. The management model of data, such as centralize or distribute, provide important point of its architecture. This models will affects the scalability, management model, access model and some other characteristics of the naming system.

3.3.2. Well-organized Structure vs. Amorphous-like Structure

The precision of naming system behavior, such as database synchronization and reflection periods of data updates, is a one of the metrics of naming system measurements. The requirement for the precision of name space mapping also affects the naming system design.

These metrics are affected by the database structure of naming system. As a matter of fact, well-organized structure, which is optimized for database update has good performance but it would be low performance of scalability. In contrast, DNS is one of lazy synchronous type database which using cache and it allows quite long-term synchronization delay, rather than the good characteristics of scalability.

3.3.3. Anonymous of Information that is Served

The characteristics of handled information, especially the anonymity of this information, also affects the naming system design. Since the issue regarding anonymousness may affect the scope of naming system. It should be discussed further along with the issue of the naming system architecture.

4. AUTO-ID AS THE REAL SPACE TAGGING SYSTEM ON THE WORLD

As mentioned in the previous section, information in cyber-space is manipulated as independent objects such as Web pages or host applications. The information becomes "knowledge" by communicating and getting relationship among these objects. In the cyber-space, no piece of information has a direct relationship with real objects. The relationship between the information and real object is defined by pointers such as a logical name of the objects. RFID technology is able to realize new relationship with real object in the cyber-space. The real object tagged by the RFID has a direct link into the cyber-space. In the near future, several memories and sensors will be integrated in order to store information, and the RFID tag will get more intelligence. In this circumstance, we assume that the tagged object with RFID technology will be a cyber-space object and it will be a real-space object at the same time. In this model, the tagged object with ID is treated by a proxy entity which is bound to the ID.

Following is an example of a situation using above concept at a hospital.

Please note that this story does not discuss about the privacy issues at all. This just to discuss how the technology can work.

In the morning, a nurse prepares medicine for patients in a pharmacy as her daily work. The nurse puts medicine on a tray for each of her patients. At that time, when two doses of medicine were put on the same tray, they warned the nurse that they should no be prescribed at the same time, because it may cause a harmful effect. The nurse can avoid combination errors thanks to the warning by "intelligent" medicine. The nurse moves from the pharmacy towards one of a patient room with medicine trays. Entering the room, the nurse put the medicine tray on a bedside. The bed and the medicine tray communicate with each other as usual. However something is different usual on that day, an empty bottle of whiskey is under the bed. The patient was drunk last night. His old friend visited him with a bottle of whiskey. The bed has detected that whiskey bottle underneath it. And then the bed talks with the medicine tray about the relationship with alcohol and the medicine. The nurse can protect the patient from the undetectable error with the help of the real-space networking.

Each object acts as an autonomous system depending on its own environment parameter, such as location and time. As show as this case study, the concept of inter-object communication directly will extend our environment.

4.1. Global Object

The Auto-ID system constitutes parts of the real-space network. In the Auto-ID system, real objects are identified by EPCs™, and the information of the real object is managed by proxy entity, called as PML object. In the first place, the Auto-ID system will be applied to the supply chain management area

Before the Internet's advent, many application systems were developed with own networking capabilities. The information of online reservation systems for airline tickets, the banking system, the stock trading systems was limited within the system, and we needed to maintain several terminals in our office in order to access to each information. However, the Internet enabled us to access to almost all information as global sense.

The current situation of RFID technology-based system is similar to the situation where there was no Internet. For example, several railway companies in Japan have applied RFID technologies to their commuter passes. However, commuters have to possess several commuter passes in their wallets, because each railroad company adopted different standards of RFID technologies, and there are no negotiations with exchanging the commuter pass information. This case shows two issues we should consider for real-space networking. One is the standard of the RFID technologies and the other is global information exchange mechanisms.

Everyone agrees that a certain standard for RFID technology is a must, such as shared band of the radio frequency and common protocols between tags and readers. Even though we agree that there should be certain standards on these matters, we believe that such standards are not sufficient. RF technologies are growing continuously, and we do not need to stop such growth. The real-space network will be able to handle the real-space objects that are linked with real objects by the different RFID technologies.
In the previous example of rail pass, if users are identified by some kind of technology in real-space networking, the user can pass the station gate without the commuter pass. This means that, in the real-space networking, the information should be accessed as global manner. This is important rather than the standardization of media layer technologies, For example, there are several media layer technologies exists in the Internet such as the Ethernet and optical fiber, however the basement of communication identifier is the IP address. It is the same as this example, in the real-space networking; every real-space object should be handled as global manner, and should communicate each other.

4.2. Design Issue of Name Service for Real space Networking

There are many methods for designing the name space, name service and naming system for the Auto-ID architecture. For example, the naming system will be constructed as a part of DNS (Domain Name System). Using DNS as a base system, there are two implementation methods. The first one constructs the naming system as adding the new RR (Resource Recode) for handling Auto-ID related resources. The other operates the whole naming hierarchy and systems for them rather than current naming hierarchy maintained as alternate naming tree.

We should design and implement the real-space naming system consistent with the architectural concept of the Internet. Previous works identify the following issues:

- Name space structure
- Name space management
- Name Space Resolution
- Scalability/bottleneck
- Diversity/stability
- Flexibility of resolution methods
- ID structure

Current specification of Auto-ID naming system is based on DNS NAPTR mechanism. This is the first step for constructing naming system for the Auto-ID architecture. There are several limitations for using DNS system, such as single management authority for the single resource. But this approach is suitable for current demands and use case of Auto-ID applications, such as supply chain management support. To realize the real-space network environment, we should work for above research items further.

5. SUMMARY

Research and development experiences of Internet name space will contribute to discuss and design new name space of real world objects. This white paper indicates some issues of name space design, from the point of view of Internet technologies as the start point of discussion.

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