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Latest Trends in Home Networking Technologies

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SUMMARY Broadband access service, including FTTH, is now in widespread use in Japan. More than half of the households that have broadband Internet access construct local area networks (home networks) in their homes. In addition, information appliances such as personal computers, networked audio, and visual devices and game machines are connected to home networks, and many novel service applications are provided via the Internet. However, it is still difficult to install and incorporate these devices and services because networked devices have been developed in different communities. I briefly explain the current status of information appliances and home networking technologies and services and discuss some of the problems in this and their solutions.

key words: *home network, appliance, DLNA, ECHONET, OSGi*

1. Introduction

Services featuring always on Internet access using broadband access such as ADSL and FTTH are now popular in Japan. As these infrastructures have spread, many kinds of information appliances including personal computers (PCs), digital AV (Audio and Visual) devices, and highly functional mobile phones have also become popular. Now, novel home network services using these devices are attracting attention in the market. For example, there are now home security and home automation systems that consist of combinations of information appliances and sensor devices. Network architecture and protocols indispensable for the interactions between these devices are gradually being standardized. However, there are still several problems that prevent smooth, easy collaboration between information appliances and generating flexible home network services. In general, information appliances in a home are roughly categorized into three groups. The first is IT (Information Technology) devices, which include telecom devices, mobile phones and PCs and their components. The second group is digital AV devices, which are digital audio and video devices and networked broadcast terminals such as STBs (Set Top Boxes) and TV sets. The last group is so-called "white goods" such as air conditioners, microwaves, refrigerators, and so on. These devices developed by various industry groups independently have been and are therefore subject to many different standards and protocols. What's worse, appliance vendors prefer proprietary products.

The latest trends in information appliances and home network services and their current problems are briefly presented. After that, some technical approaches to resolving the problems and the ongoing standardization and the bodies responsible are discussed. These technologies and standards are constantly evolving, and by the time this paper is published, the information presented here may be out of date. Therefore, to aid interested readers get the most up-to-date information, a list of the alliances and standardization bodies in the field is attached at the end of this paper.

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2. Latest Trends in Information Appliances and Home Network Services

In this section, latest trends in appliances and home networks are introduced. Mainly, user demand for home services and existing problems are described.

2.1 Definition of Information Appliance

The New Energy and Industrial Technology Development Organization (NEDO) [1] has defined network appliance as an appliance that has the capability to connect to networks such as the Internet. In general meaning, they include so-called "digital IT devices" such as computer systems and mobile phones, and home appliances connected to some network. Therefore, we can call them "networked appliances." In considering home network services, we should take account of other devices that can be connected to networks, such as networked sensors for home security and telemetry. Of course, the latest game machines, which have network interfaces, must also be included. Figure 1 shows the current status of these devices and home networks. IT and AV and amusement devices can be connected to LANs using Ethernet or WiFi, but there are few protocols for collaboration. Other devices are connected to their own independent networks.

2.2 User Demand and Services

According to surveys done by official bodies, there are four major areas of public demand for home networking services using networked devices [2].
1st. Home Security Services
2nd. Health Care Services
3rd. Remote Control and Maintenance of Appliances
4th. AV Control and Amusement Services
The type of service people want most is home security,

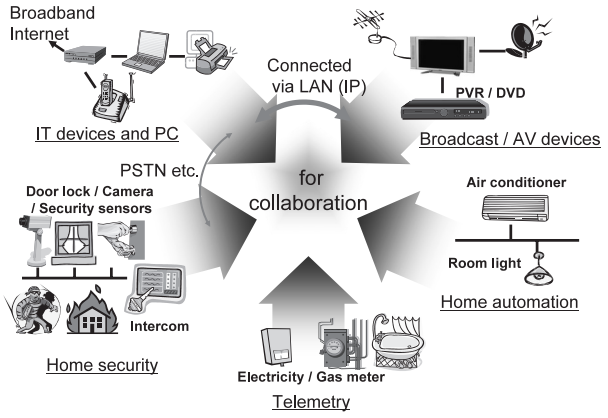

Fig. 1 Current home network.

such as crime (burglar etc.) and fire prevention, which has been provided by security companies for several years using PSTN. The latest trend in this field is the movement toward connection to the Internet. In addition, device vendors are now selling lightweight security systems using web-cameras and wireless sensors. This kind of system is called a self-security system and uses the Internet as its network and mobile phone for the user interface. This area of services, including disaster-prevention systems like earthquake alert services, is attracting attention in many business fields.

The second most popular service, health care services, is still being developed as a home network service because there are few biological sensors with network interfaces. In addition, the service itself will be subject to legal regulations. The third most popular service is called home automation or remote maintenance. The most popular example of this service is controlling air conditioners remotely using a mobile phone. Though this service is anticipated by both customers and of appliance vendors, it is not yet widely available. Only remote desktop control applications for PCs, firmware downloads, and upgrade services for some appliances are now available. Networking is especially limited in the field of white goods because of the conservative and cost-conscious business style of these manufacturers.

The fourth most popular service, controlling AV devices and amusement applications like video games is the most aggressively marketed area in home networking. The main reason to network AV devices is content sharing: putting content such as video, music, and pictures into a home server so off-site users can enjoy them using networked terminals. In this area, however, there is no consensus among stakeholders. Personal computer-related companies such as Intel, Microsoft, and Apple have their own vision of home networking, which differs from that of AV appliance vendors. What's worse, digital rights management is still a big problem.

2.3 Current Problems in Home Networking

Major problems preventing construction of useful and flexible home network services coordinating networked appliances include as follows.

(1) Installation
- wiring
- device configuration

(2) Communication
- communication among heterogeneous networks
- communication among multi-vendor environments

(3) Coordination
- service coordination
- service management

The first problem is how to install a network into a house (especially existing houses). Wiring is the important problem in the physical network layer. Then, various devices must be connected to the networks and some of these devices must be configured. If this operation is complex, consumers will not be able to do configure the networks. Some easy or user-friendly protocol must be developed. This is the problem in the link and network layer.

Communication between heterogeneous networks and appliances is indispensable to providing convenient and flexible home network services. This will enable users to choose various vendors' networked appliances based on their preferences and needs. Currently, there are few standards and protocols to enable communication and collaboration between home appliances and devices from multiple vendors. This is the problem of session and presentation layers.

Finally, to build a highly functional service application using appliances and devices from multiple vendors, there must be a unified platform for developing service application software. For instance, imagine an interaction between a home security service and an AV service. When a motion sensor or camera detects someone in front of the house, the picture captured by the camera appears on the TV screen. The door sensor and the camera are for home security, and the TV is for entertainment. Even in this simple application, coordination between the security application and the entertainment application is required. A unified platform such as an OS or middleware must be developed.

3. Solutions and Approaches

In this section, some technologies and ongoing standardizations are presented. These will be the solutions to existing problems in the home network and services.

3.1 Current Possible Solutions

There are several problems preventing implementation of convenient and flexible home network services using various types of networked appliances and devices. In this section, I discuss the more promising solutions to these problems. These include particular technologies, protocol standards, and alliances between companies and industry groups. These represent the latest trends in home networking.

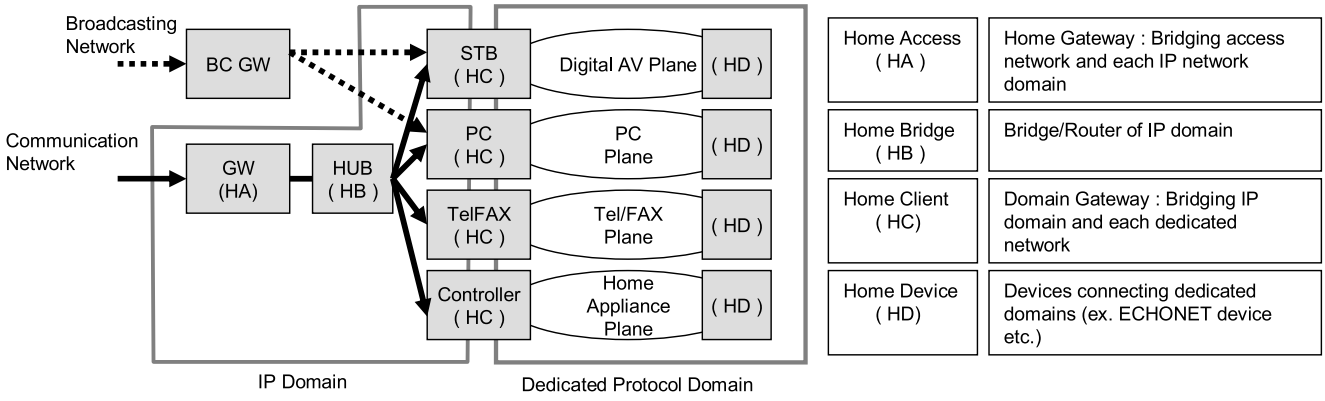

Fig. 2 Home network reference model.

First, the reference model of home network should be defined. Figure 2 shows the ITU-T J.190 model of a home network, which was issued in 2002 but remains a reasonable model even now. It separates home network and appliances into proprietary domains according to existing de-facto standards. It then groups them into IP capable domains. Finally, a gateway device coordinates them in a connected access network for the WAN such as the Internet.

In the latest trend, the TEL/FAX plane is connecting IP domain directories with VoIP technologies. In addition, current high-end AV appliances have network interfaces, so the AV plane will soon be able to directly join the IP domain. For some VoD (Video On Demand) services, dedicated STBs are still required. IPTV, which stands for digital TV broadcasting service and technologies using IP, is one of the latest keywords. IPTV technologies, which is discussed in some standardization bodies, might provide unified protocols in this field. For example, ITU-T Focus Group of IPTV is discussing several aspects of IPTV standards such as its architecture, QoS, security, end-system and management of network and contents. There is also the problem of collaboration between broadcasting and communication businesses. The home appliance plane includes white goods and various sensors for home security of telemetry (gas and water service, for example). This field still uses its own network and protocols, which is an industry consensus standard. In other words, this field is farthest from the IP domain, and some bridge device, for example "HC" in Fig. 2, will be required.

There are so many industry consensus standards and de-facto standards in each business field that describing them is beyond the scope of this paper. Therefore, in this chapter, only a few major trends in this area are discussed briefly.

3.2 Physical Layer of Home Network

The first problem of establishing a network in a home is installation. Various network architectures and networking protocols have been proposed as the physical and link layer of a home network. For instance, there are IEEE802.3 (Ehternet), HDMI (High-Definition Multimedia Interface), IEEE1394, PLC (Power Line Communication), HomePNA (Phoneline Networking Alliance) using Phone Line and MoCA (Multimedia over Coax Alliance) using coaxial cable for networking. Ethernet is very popular for IP networking. Almost all computers and current game machines, and high-end AV devices such as TV sets and HDD video recorders have this interface by default. Ethernet interface and network gears are mass produced and affordable. In addition, category 7 cable enables 10 GBASE-T communication; it has sufficient bandwidth. The latest "IT condominiums" have built-in Ethernet networks and have rooms with Ethernet ports as "information plugs."

Table 1 802.11 standards.

Standard	Band	Max Speed	Remarks
IEEE802.11	2.4-2.5GHz	2Mbps	Infra-red included
IEEE802.11a	5.15-5.25GHz	54Mbps	Only in-door in Japan
IEEE802.11b	2.4-2.5GHz	11M/22Mbps	
IEEE802.11g	2.4-2.5GHz	54Mbps	Upper compatible to IEEE802.11b
IEEE802.11j	4.9-5.0GHz 5.25-5.53GHz	54Mbps	Customize IEEE802.11a for Japan

However, in existing homes and old condominiums without network equipment except for phone lines, inter-room wiring is a very difficult problem. Therefore, in Japan, wireless and PLC networking are attracting as lot of attention for the IP domain network. Table 1 shows existing standards of IEEE 802.11 wireless technologies. Now the devices of all of them are available from volume retailers at affordable prices. More high-speed wireless networking devices providing 100 Mbps communication based on the 802.11n standard using MIMO (Multiple Input Multiple Output) technology are being marketed, but the 802.11n is in draft status now. Table 2 shows the current standards for PLC technologies and their commercial products. These standards are not compatible. Another problem is electromagnetic leakage, which can disturb several existing wireless communications. There are also the problems of degradation of transmitting speed by various kinds of noise from other appliances (AC adaptors, hair dryers, etc.) and the

Table 2 PLC standards.

Standard	Max speed	Member	Commercial Products	Remarks
HomePlug (HPA)	14Mbps (1.0) 200Mbps (AV)	Intel, Motorola, CONEXANT SHARP etc.	KDDI SHARP etc.	Including Access Network
CEPCA	190Mbps (HD-PLC)	Sony, Panasonic, Mitsubishi, Hitach, Sanyo, Pioneer, YAMAHA etc.	NTT-EAST Panasonic, IO-DATA, BUFFALO, NEC etc.	Only for in-door network, nearly de-fact in Japan
UPA	200Mbps	DS2(Spain) Logitech, Toshiba etc.	Sumitomo Electric, Logitech etc.	Suitable to large scale NW ex. Bill NW

complex topology of power lines in old houses. These are applications of PLC for in-house communication. Standardization of access networks is being discussed by the working group P1901 of the IEEE. This standard is called "BPL (Broadband over Power Line)." It includes physical and MAC (Media Access Control) layers of PLC. In addition, the proposals of the HomePlug Group and Matsushita Elec. were adopted by the working group. Therefore, the activities of IEEE P1901 should be watched.

IEEE1394 has been designed as the network for the AV plane. However, HDMI, which is mainly used for the connection between TV and video recorders, has begun to supersede it. For advanced applications such as content sharing in the AV and PC planes, networks and protocols in the IP domain are now being used, as explained in the next section.

Home security systems, which are the most popular application, use many kinds of wireless sensors, such as door and window sensors and fire alarm boxes. Low power radio networks have recently been used in home security systems; however, there is no unified standard. Zigbee technology is gaining attention as a possible standard for wireless communication within residential houses.

3.3 Digital Living Network Alliance (DLNA)

The number of vendors of digital information appliances joining DLNA [3] is increasing. There are currently around 250 companies in the alliance. In the AV and PC planes, the number of appliances that conform to DLNA standards is gradually increasing. DLNA is the body that formulates guidelines enabling interoperability and sharing of digital content between PCs, information alliances, and mobile devices. Figure 3 shows the building blocks of the guidelines. As shown in the figure, DLNA guidelines adopt UPnP (Universal Plug and Play) as a key part of the protocols. Therefore, the devices that conform to DLNA guidelines must have IP addresses (a interface with IP communication capability). The primary functions of this guideline are automatic discovery and configuration of the devices and exchanging of digital content. DLNA ver.1.0 defines these basic protocols and platform architecture. Figure 4 shows an example of the operations based on the guidelines. DLNA ver.1.5, formulated in 2006, includes QoS architecture for streaming and a content protection mechanism using DTCP-IP. It is expected that digital AV appliances equipped with these new features will be on the market in a few years. In the future, the next version of DNLA will include the devices for automobiles and remote appliance control via wide area networks.

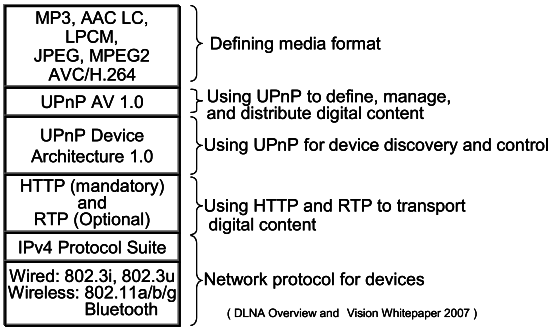

Fig. 3 Overview of DLNA guidelines.

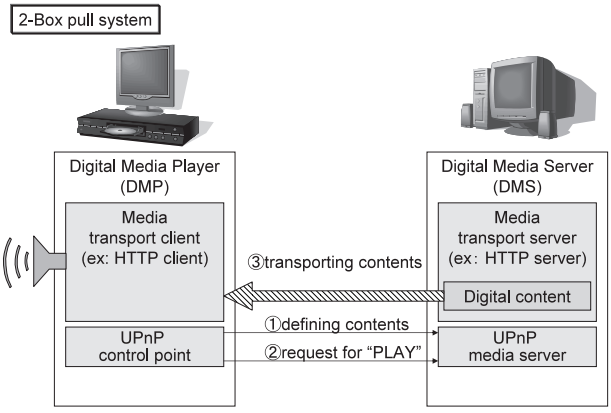

Fig. 4 Operation based on DLNA (2-BOX Pull System).

3.4 ECHONET

ECHONET [4] is a versatile and standard network system that enables users to easily control many home appliances. It is designed to build home networks that systematically enable energy, security management, and medical care at home. The ECHONET consortium was founded in 1997 to develop such a network. Now over 100 companies have joined this consortium. However, there are only ten appliance vendors with the capability to contribute technically to the consortium. Figure 5 shows ECHONET's proposed vision. As shown in the figure, the gateway has an important role in extending the home network to a WAN. Figure 6 shows the scope of ECHONET development. It has been implemented as a kind of middleware that covers from the

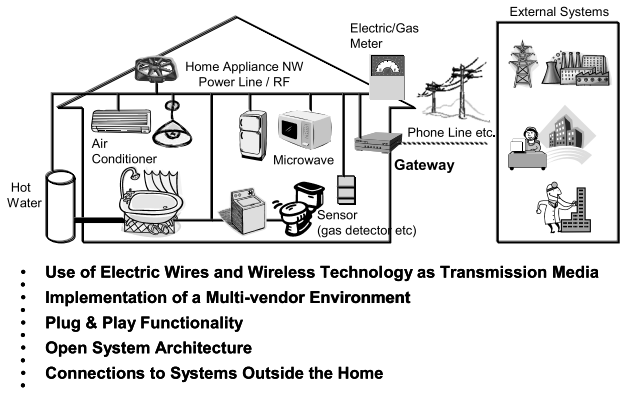

Fig. 5 Vision of ECHONET.

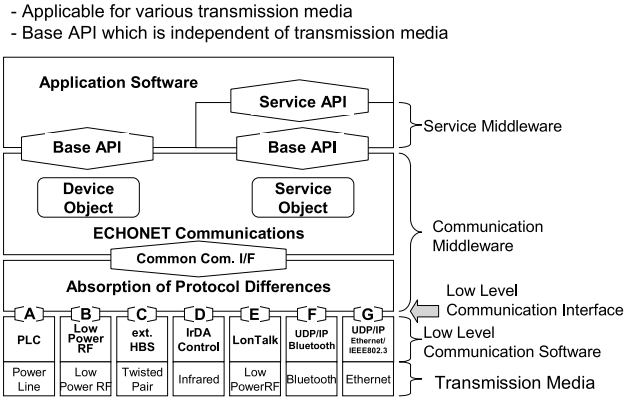

Fig. 6 Scope and stack of ECHONET.

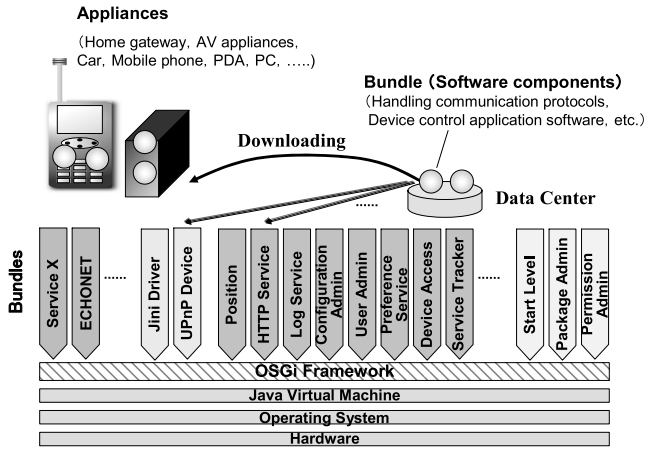

Fig. 7 Basic architecture of OSGi service platform.

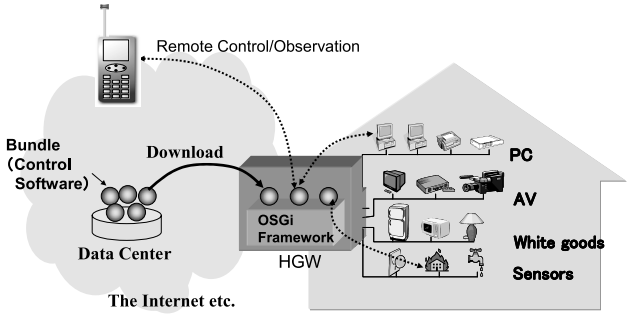

Fig. 8 OSGi control model (home gateway).

physical layer to the application software of the network. Currently, ECHONET is the most promising network architecture candidate in the home appliance plane. However only air conditions are ECHONET-ready products in the market practically.

3.5 OSGi Service Platform

As shown in Fig. 2, a home gateway device is the key to building a home network and the various services it links. Therefore home gateway must both act as a broadband router between LANs and WANs and act as a functional and flexible service gateway that can handle multiple protocols for communicating with various appliances, and coordinate service applications in each plane.

Open Services Gateway Initiative (OSGi) Alliance [5] is the body now developing specification and promotion of Java-based open and general-purpose software component technologies named "OSGi Service Platform." It was founded in 1999. There are now around 40 companies that are members of this alliance. Figure 7 shows the basic architecture of the OSGi Service Platform. In the platform, the software controlling appliances constructs modules called bundles. By downloading and updating these bundles via a network, control software for appliances is customized. The lifecycles of these bundles can be controlled independently of each other by the platform. Bundles can be installed, started, stopped and uninstalled according to the circumstances. Behavior of the bundles, such as accessing file systems (read/write) and operating sockets, can be restricted using pre-defined configurations. This restriction enforces the security of the platform. OSGi is specified as JSR291 by the Java community. Figure 8 shows an example of the use of OSGi as middleware for a home gateway [6]. Various service applications can be constructed in the home gateway downloading and combining bundles from service providers. The bundles execute the home security application program, home automation, and so on. Therefore, the OSGi service platform enables construction of flexible and programmable home gateway that can handle heterogeneous home networks and appliances as sown in Fig. 8. OSGi middleware is penetrating several field of industry, such as bill control, factory automation, office automation, car navigation system, and, of course, home networking.

4. Conclusion

This paper discussed the latest trends in home networking technologies and the problems associated with these trends. Various commercial products and services for next generation home networking have recently been marketed. However, from the viewpoint of their underlying technologies and standards, they are still not standardized. Various al-

liances and standardizing bodies are now active in this area. We should keep watching their activities. For reader's reference, URLs and relationship between some of alliances and bodies are attached in an appendix.

Acknowledgments

Special thanks are directed to Hisashi Matsukawa and Masayuki Ito (NTT Cyber Solutions Laboratories) for their cooperation.

References

[1] NEDO, http://www.nedo.go.jp/
[2] http://www.johotsusintokei.soumu.go.jp/whitepaper/ja/cover/index.htm
[3] DLNA, http://www.dlna.org/
[4] ECHONET, http://www.echonet.gr.jp/
[5] OSGi Alliance, http:/www.osgi.org/
[6] H. Maeomichi, R. Kawamura, I. Yamasaki, A. Tsutsui, and K. Yata, "Home service management based on open service aggregationplatform concept," 9th IFIP/IEEE International Symposium on Integrated Network Management (IM2005), 2005.

Appendix

There are many (standardization) bodies and alliances related to home networks and services as shown in Table A· 1. I referred to some of them in this paper. For the others, please access their Websites via their URLs. In addition, the relationships between some of the major bodies are shown in Fig. A· 1.

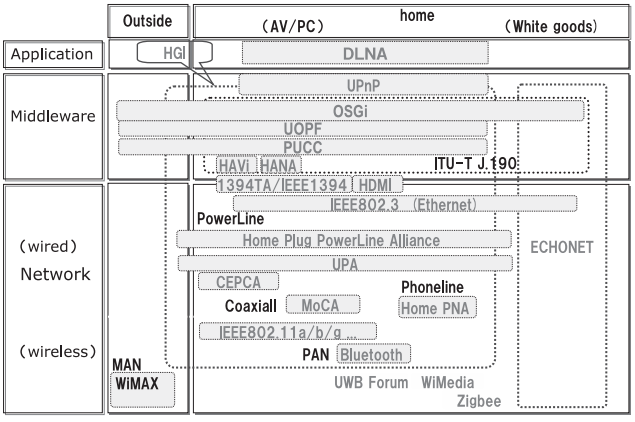

Fig. A· 1 Alliances and standard bodies related to home networking.

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Bodies	Official Name	URL etc.
IEEE1394TA	The 1394 High Performance Serial Bus Trade Association	http://www.1394ta.org
ALICE Forum	Forum for Agreeable Living and Intelligence, Communication, and Electronics	http://www.alice-for.or.jp
Bluetooth	Bluetooth SIG	http://www.bluetooth com/
BSF	Broadband Service Forum	http://www.broadbandserviceforrum.org/
Cable Modem	Cable Modem Project	http://www.cablemodem.com/
CELF	CE Linux Forum	http://www.celinusforum.com/
CEPCA	Consumer Electronics Powerline Communication Alliance	http://www.cepca.org/
DLNA	Digital Living Network Aliance	http://www.dlna.org/home
DSLF	DSL Forum	http://www.dslforum.org/index.shtml
DTG	Digital Television Group	http://www.dtg.org.uk
DVB	Digital Video Broadcasting	http://www.dvb.org
ECHONET	ECHONET Consortium	http://www.echonet.gr.jp
EPCglobal	Electronic Product Code global Inc	http://www.epcglobalinc.org/
HANA	High-Definition Audio-Video Network Alliance	http://www.hanaalliance.org/
HAVi	Home Audio Video Interoperability	http://www.havi.org/
HDMI	High Difinition Multimedia Interface	http://www.hdmi.org/
HGI	Home Gateway Initiative	http://www.homegatewayinitiative.org/
HomePlug	HomePlug Alliance	http://www.homeplug.org/en/index.asp
HomePNA	Home Phoneline Networking Alliance	http://www.homepna.org/

Bodies	Official Name	URL etc.
IMTC	The International Multimedia Telecommunication Consortium	http://www.imtc.org/
IPv6	IPv6 Forum	http://ipv6forum.com
LPA	Liverty Alliance	http://www.projectliberty.org
LONMARK	LONMARK Interoperability Association	http://www.lonmark.org
MCPC	Mobile Computing Promotion Consortium	http://www.mcpc-jp.org/
NFC	Near Field Communication	http://nfc-forum.org/home
OASIS	Organization for the Advancement of Structured Information Standards	http://www.oasis-open.org/
OIF	Optical Internetworking Forum	http://www.oiforum.com/
OMA	Open Mobile Alliance	http://www.openmobilealliance.org/
OSGi	Open Services Gateway Initiative	http://www.osgi.org/
Parlay	Parley Group	http://www-perlay.org/en/index.asp
PHS MoU	Personal Handyphone System Memorandum of Understanding Group	http://www.phsmou.or.jp/
PLC-J	High Speed Power Line Communication Promoters' Alliance of Japan	http://www.olc-j.org/
SPIA	Forum of Service Platform for Information Appliances	http://net2.intap.or.jp/SPIA/index.htm
TCG	Trusted Computing Group	https://www.trustedcomputinggroup.org/ohme
TEAHA	The European Application Home Alliance	http://www.teaha.org
TVAnytime	TVAnytime Forum	http://www.tv-anytime.org/
UbiqNet	Ubiquitous Networking Forum	http://www.ubiquitous-forum.jp/
uID Center	Ubiquitous ID Center	http://www.uidcenter.org/japanese.html
UOPF	Ubiquitous Open Platform	http://www.uopf.org
UPA	Universal Powerline Association	http://www.upaplc.org
UPnP	Universal Plug and Play Forum	http://www.upnp.org/
UWB Forum	Ultra-Wide Band Forum	http://www.uwbforum.org/index.php
W3C	World Wide Web Consortium	http://www.w3.org
WFA	WiFi Alliance	http://www.wi-fi.org
WiMAX	Worldwide Interoperability for Microwave Access Forum	http://www.wimaxforum.org
WiMedia	WiMedia Alliance	http://www.wimedia.org
Zigbee	Zigbee Alliance	http://www.zigbee.org
MoCA	Multimedia over COAX Alliance	http://www.mocalliance.org
PUCC	P2P Universal Computing Consortium	http://www.pucc.jp/index.html
ITU	International Telecommunication Union	http://www.itu.int/net/home/index.aspx
ISO	International Organization for Standardization	http://www.iso.org/iso/home.htm
IEC	International Electro technical Commission	http://www.iec.org
ETSI	European Telecommunications tchnology Committee	http://www.etsi.org/WebSite/
TTC	The Telecommunication Technology Committee	http://www.ttc.or.jp/
ARIB	Association of Radio Industries and Business	http://www.aribe.or.jp
ANSI	American National Standard Institute	http://www.ansi.org
IETF	Internet Engineering Task Force	http://www.ietf.org
IEEE	Institute of Electronic Engineers	http://www.ieee.org

Akihiro Tsutsui received the B.S. and M.S. degrees in Kobe University in 1988 and 1990, respectively. In 1990, he joined NTT. From 2005 to 2007, he was with NTT Cyber Solution Laboratories. Then he is engaged in development of home network technologies. Currently, he is with NTT Network Innovation Laboratories, where he is engaged in research and development on the network architecture and its management middleware. He is a member of IPSJ.