IPTV Standardization and Global Testbed Trials by Japan

Hideki Yamamoto
Broadband Media Department
Carrier Systems Division,
Telecom Systems Business Division
Oki Electric Industry Co., Ltd.

1. IPTV deployment in Japan

The delivery of video to personal computers via the Internet started in around 1998. This service (called Internet streaming) entailed transmitting streams of video images with bandwidths ranging from a few kbit/s to several hundred kbit/s, and at resolutions smaller than the desktop size of PC monitors. Internet streaming was an innovative service in that it provided real-time video images, but it was quite unlike other types of video service such as TV broadcasts that are enjoyed for recreational purposes.

Around 2003, the growing popularity of broadband services and developments in video compression and IP network technologies led to the arrival of IPTV services offering TV-quality video. In a broad sense, IPTV is another type of Internet streaming, but in a more narrow sense it refers to a service for distributing video via a closed IP network to ordinary television sets connected to set-top boxes (STBs) via broadband access networks. We will use this narrow definition of IPTV in the remainder of this paper.

When the Act Concerning Broadcast on Telecommunications Service came into force in Japan in January 2002, it became possible for broadcasters to make use of telecommunication lines. Telecommunication service operators offering services based on this act were registered as Priority Broadcasters, and the services they provided were considered official broadcasting services, which meant they were obliged to meet certain quality criteria in much the same way as conventional broadcasters. The packets carrying video data were therefore distributed via dedicated networks that were managed by telecommunication service operators (called Managed IP networks).

Since then, forums have been set up for the preparation of industrial standards for IPTV. The IPTV Forum Japan — comprised of domestic telecommunication service operators, broadcasters and consumer electronics manufacturers — was established to promote the utilization of IPTV services and increase their popularity by providing broadcasting and providing communication services based on standardized technical specifications that allow IPTV functions to be incorporated into consumer receiver equipment.

By September 2013, commercial services were already being provided to over 2.6 million subscribers in Japan, and this number was increasing by hundreds of thousands per year. At first, these were basic IPTV services such as linear TV and VOD (Video On Demand). Linear TV is a system that uses the IP network to deliver TV programs that are traditionally broadcast using radio waves, while VOD allows the viewer to control the playback of video through the IP network in a way similar to watching a recorded program at home. Recently, a greater range of new services have become available, including services that allow viewers to restart a program during the middle of the broadcast, and services for viewing programs on tablets/smartphones, interacting with Twitter, buying e-books and music, and playing games.

2. ITU IPTV standardization overview [1, 2]

2.1 IPTV standardization overview

Because IPTV services are delivered over IP networks managed by communication carriers, many of these services have different technical specifications due to the differing requirements of individual communication carriers. Efforts are now being made worldwide to standardize the details relating to IPTV in order to popularize IPTV services. With standardized services, users will ideally be able to receive a variety of services without having to switch between different terminals for individual carriers. In the United States, IPTV related specifications are being considered by the Alliance for Telecommunications Industry Solutions (ATIS), while in Europe, similar work is being done by the Digital Video Broadcasting (DVB) Project, and by TISPAN (Telecoms and Internet-converged Services and Protocols for Advanced Networks) — a part of the European Telecommunications Standards Institute (ETSI).

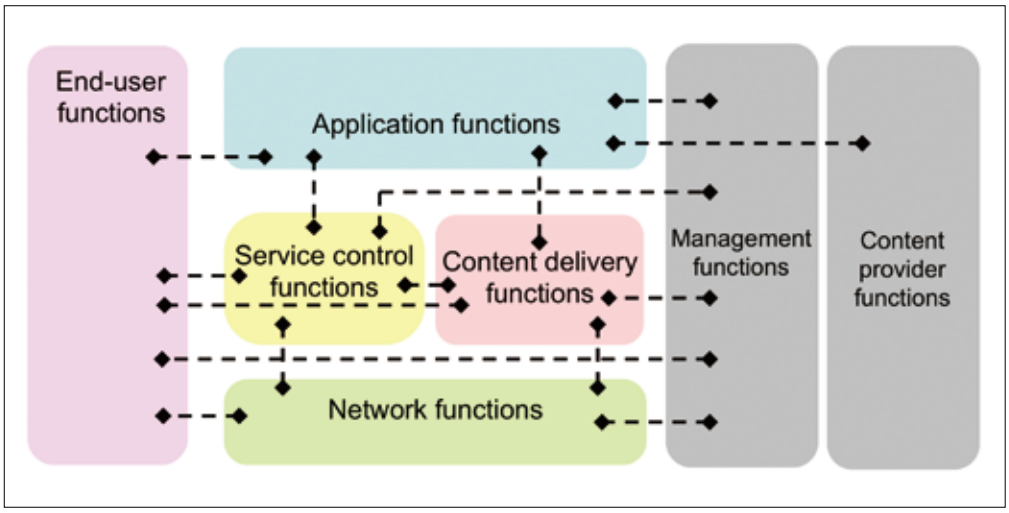
There is also a forum working on the preparation of industrial standards for IPTV. The Open IPTV Forum consists of companies in the United States, Europe and Asia, and aims to prepare an industrial standard encompassing all aspects of IPTV by summarizing the standards prepared by various other standardization organizations and forums.

2.2 Standardization trends of IPTV at ITU-T

Against this background of disparate standardization efforts being conducted in various regions by a diverse range of organizations, ITU-T established the Focus Group IPTV (FG IPTV) in April 2006 to promote and start coordinating the establishment of an international IPTV standard. The seven meetings conducted by FG IPTV were attended by a total of 1,300 participants and resulted in 20 documents — the sheer number of which was due to the fact that participation was not limited to ITU members but was open to any individual or organization from any member country of the ITU. In December 2007, this led to the formation of the IPTV Global Standard Initiative (IPTV-GSI), and the preparation of recommendations was started in January 2008 based on the resulting documents and discussions by the Study Group (SG) at ITU on the relevant topics.

General descriptions of the major recommendations, which are classified into categories of "Architecture and Services", "Middleware, Applications, Content Platforms" and "End Systems", are provided below.

Figure 1: IPTV architecture overview



2.3 Architecture and services

The requirements for realizing IPTV services, including their design, installation and operation, are described in Y.1901 (Y.IPTV-Req). This document forms the basis for IPTV recommendations from the ITU-T, and other recommendations can be considered to have stipulations on technical specifications that satisfy the conditions provided in this document. Individual requirements are classified into levels of "required", "recommended" and "can optionally".

The recommendation on the architecture for IPTV services, Y.1910 (Y.IPTV-Arch) calls for an IPTV architecture with a high degree of abstractness as shown in Figure 1. The end user function group is intended to provide functions to serve users, like a home network function and the IPTV terminal functions of set-top boxes. The application function group provides application functions for use with IPTV services. These include program guides for selecting or purchasing content, and guides for video on demand (VOD) content. Protection functions for services and content are also provided. The service control function group releases networks and service resources according to requests from terminals, in order to provide the services of IPTV in an appropriate manner. The content distribution function group is a group of functions that actually distribute content to the terminals of users and includes the distribution of VOD by unicasting and distributing IP broadcasts through multicasting. Included among these are functions for selecting the most suitable server for a user, depending on the user's physical location and the server load conditions, whenever distribution functions are provided by multiple servers. The network function group provides managed IP networks. These functions also dispense IP addresses and secure the bandwidth necessary for video distributions. The management function group monitors the status and sets the aforementioned end user functions, application functions, service control functions, content distribution functions and network functions. The content provider function consists of functions that provide content and metadata.

In anticipation of evolution of NGN (New Generation Network), Y.1910 (Y.IPTV-Arch) stipulates three architecture types:

(a) IPTV over non-NGN networks
(b) IPTV over NGN networks (non-IMS based)
(c) IPTV over NGN networks (IMS-based)

Unlike existing Internet technologies, quality and security can be assured with NGN networks. IMS (IP Multimedia Subsystem) and is a framework that implements service controls based on the Session Initiation Protocol (SIP), which are necessary for providing IP telephone and IP video phone services. It is expected that IMS will be used as a function for providing multimedia services over NGN networks.

When IPTV is classified into the above three architectures, the service management function group is expected to use existing specifications like RTSP and HTTP for (a), and protocols that are based on (a) (to be stipulated in the future) for (b). On the other hand, it is expected that the SIP control protocol of IMS will be used for (c).

Various services provided by IPTV are described in Y.Sup5, which is not a Recommendation but a supplementary document. The services described in this document are therefore not limited to the services currently provided by various carriers, but include service scenarios for new services that can be expected in the future. Aside from the technical requirements, this document is considered to be important from the perspective of considering and realizing services in the future.

2.4 Middleware, application and content platforms

Metadata necessary to realize services, such as electronic program guides for IPTV services, is stipulated by H.750. Although this document does not specify the extent of XML tags used to describe specific metadata, it does mention the elements of metadata necessary to realize various services. This document includes the metadata of specific elements stipulated thus far by the TV-Anytime Forum.

IPTV not only streams video, but is also capable of offering services that converge with data broadcasting or utilize the bi-directionality of IP services. An outline of the framework for multimedia features necessary to realize such services is defined in H.760 (H.IPTV-MAFR.0). H.761 is based on the Ginga middleware component, which is used for digital broadcasting in Brazil. H.762 is a recommendation for an environment called LIME (Lightweight Interactive Multimedia Environment) based on the Broadcast Markup Language (BML) used for digital broadcasting in Japan.

2.5 End systems

Terminals used to receive IPTV services are described by

documents of the H.720 series. A general description is provided in H.720, and subsequent documents in the series (H.721, etc.) deal with the preparation of recommendations for various terminals. Of these, H.721 (Basic terminal) is based on the specifications of IPTV Forum Japan, a standardization organization for IPTV in Japan. This recommendation includes the specification of IPTV terminals that accommodate conformity to existing digital broadcast receivers in Japan. This makes it possible to receive services not only with a set top box, but also with the IPTV terminal function built into television receivers. Television sets with features based on these specifications are now actually available on the market in Japan.

2.6 Standardizing the measurement of audiences

2.6.1 The importance of IPTV viewer information

It is important for broadcasters to be able to collect information about who is viewing their programs. Audience surveys of traditional broadcasted programs required the use of special information-collecting equipment in the homes of carefully selected sample audiences. IPTV makes this equipment unnecessary because the terminals are already connected to the network. Information can be gathered by implementing collection and transmission functions in the IPTV terminals. The IPTV audience information discussed here consists of program-independent information about the actual audience (user information) and what the audience has been watching (viewing history). IPTV audience measurement has the following characteristics.

(1) Collect large volumes of user information

With sufficient equipment, an information collector can collect information from all IPTV users. The terminals can also be classified according to user attributes, allowing information to be collected from users belonging to a particular audience segment.

Determining how many users view which content is critical to service providers for selecting future contents. If advertisements are streamed along with the content, the advertising rates can be changed according to the number of users. Information about each audience segment is also important for targeted advertisements.

(2) Collect detailed information on IPTV terminal operations

In addition to information regarding which programs were viewed, it is also possible to collect information on VOD programs that were fast-forwarded or stopped mid-way. If the user terminal is closely linked with a TV, then volume changes or zoom-ups during certain parts of the program can also be detected. This sort of information is useful for helping content (program) producers to create content that can be viewed without extra operations from the user.

(3) Collect IPTV information for other services

When an error occurs in a communication channel, the time and information of users at that time can be used to ascertain how many users switched channel/content and measure other ways in which the error affected the service. Furthermore, the user's selections can be used to make recommendations to other users who have made similar choices.

The first type of information is vital for network operators while the second would be useful for IPTV service providers.

2.6.2 Scope of audience measurement standardization

To tap the potentials of user information for application in an IPTV system, the following functions are required.

- Measure user information
- Collect and process this information for use by stakeholders

The first function is referred to as the Audience Measurement Function and latter as the Aggregation Function. The relationships between IPTV users, the two information collection functions and stakeholders are shown in Figure 2. Due to the variety of possible applications, it is currently considered to be too difficult to develop a standardized Aggregation Function for all applications. Therefore, the scope of IPTV audience measurement standardization is currently limited to the interface between the Audience Measurement Function and Aggregation Function

2.6.3 IPTV architecture including audience measurement

IPTV architecture has already been standardized by the ITU-T in Recommendation ITU-T Y.1910. The collection of user information requires an Audience Measurement Function (AMF) and an Aggregation Function. An IPTV user's selection of programs and channels can be measured at various locations in addition to the IPTV terminal (STB or STB-equipped TV). Possible locations of the AMF are shown as XX-AMF (where XX corresponds to TD, etc.), and are connected to the Aggregation Function with a dotted line in the IPTV architecture (Figure

Figure 2: The flow of IPTV viewer information

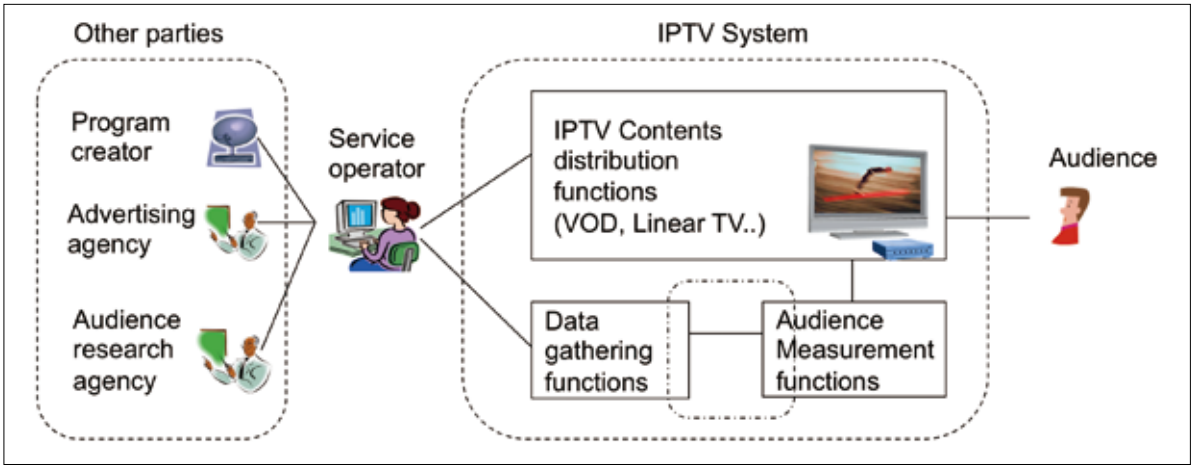
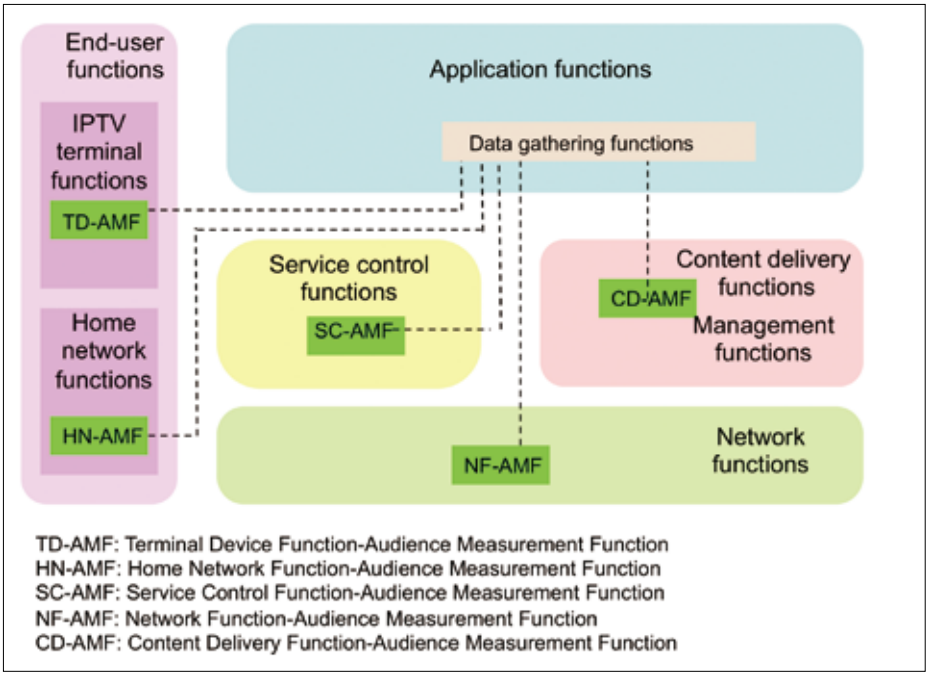


Figure 3: IPTV architecture including audience measurement functions



3). AMFs placed in locations other than the IPTV terminal are described below.

Channel selections of linear TV that are streamed using multicast technology can be measured at the home gateway or router as part of the multicast protocol. That is, the AMF can be integrated into the Home Gateway or Network Functions.

When viewing VOD, the viewer's content selection is sent from the IPTV terminal to the VOD server, which is part of the Content Delivery Functions, and then VOD server delivers the selected content. Therefore, VOD audience measurement can be implemented as part of the Content Delivery Functions. Similarly, measurements of various application services selected from the IPTV terminal can be placed with the Service Control Functions.

2.6.4 Obtaining permission for audience measurements

To perform IPTV audience measurements, giving the user the choice of simply permitting or not permitting the wholesale collection of their channel/VOD viewing history would not be an adequate way of obtaining user consent. For example, users might wish to impose time restriction so that measurements are only taken during periods when children are primarily making channel selections, and are forbidden at other hours. Based on such considerations, work is now under way to standardize the specifications for indication of audience measurement permission.

2.6.5 User information privacy levels and provided services

IPTV user information is personal information that can be used for variety of services as described above, and naturally it must be handled in accordance with the privacy laws of each country. The IPTV audience measurement standard divides user information into privacy levels and indicates the services provided at each level. This ensures that service providers who need to access user information to actually implement a service will not handle sensitive information more than is necessary.

The privacy levels are shown in Table 1. Level 1 grants access to a user's viewing history but does not allow use of identifiable

Table 1: AM permission levels, their impact on the AM system, privacy infringement potential and services supportable

	Level 1	Level 2	Level 3
Permitted measured data	End-user behavior and device info, distinguishable end user, no end-user information	End-user behavior and device info, distinguishable end user, and anonymous end-user information	End-user behavior and device info, distinguishable end user, anonymous end-user information, and identifiable subscriber or end-user information
Example data	Channel 5 was watched by anonymous end user #12683304 on mobile device model	Channel 5 was watched by anonymous end user #12683304, interested in gardening, on mobile device model "X"	Channel 5 was watched on mobile device model "X" being used by subscriber or end user "John Smith" who is interested in gardening.
End-user permission	Required	Required	Required
Privacy infringement potential	Measured data alone may not influence privacy profile. Measured data plus additional data may influence privacy profile	Measured data alone may not influence privacy profile. Measured data plus additional data may influence privacy profile	Measured data alone may influence privacy profile
Services supportable	Targeted advertisement and content recommendation. Content rating and Engagement reporting.	Better targeted advertisement and content recommendation. Content rating and engagement reporting.	IPTV end-user engagement driven personalized communications. Even better targeted advertisement and content recommendation. Content rating and engagement reporting.

user information. Only anonymous information is available at this level, although audience ratings can be collected to measure content popularity. At level 2, access is granted to user attributes such as age, gender, family structure and geographical region. Along with user's viewing history, this information can be used to determine the primary audience of a particular program. If most of a program's viewers are women, the advertisements delivered with the program can be geared toward women, thus enabling segmented advertising. User identifiable information like names and email addresses are accessible at level 3. Information available at this level can be used with the user's viewing history to provide direct adverting.

There are two important points here. First, level 3 access is not always necessary. Even at level 1, the use of IPTV user information enables collection of accurate large-scale information compared with what can be achieved from audience ratings of traditional TV. Second, information available at level 1 is still personal information, and user consent is required according to each country's privacy laws before information is collected.

2.6.6 User information collection messages and transmission timing

Audience measurement messages consist of configuration messages that indicate what information will be measured, and reporting messages that are used to send the measured results to the Aggregation Functions. The configuration messages include the following information: (a) which service to measure, (b) when to measure, (c) what to measure, (d) when to report, (e) how to report, and (f) how to handle exceptions.

Reporting messages are created according to the configuration messages and sent to the Aggregation Functions. When collecting information from the Audience Measurement Functions, simultaneous transmissions of messages will congest the network or place heavy loads on the Aggregation Functions. Therefore, the transmission timing needs to be different for each terminal.

3. Japan's involvement in the ITU's activities to promote the IPTV standard [3]

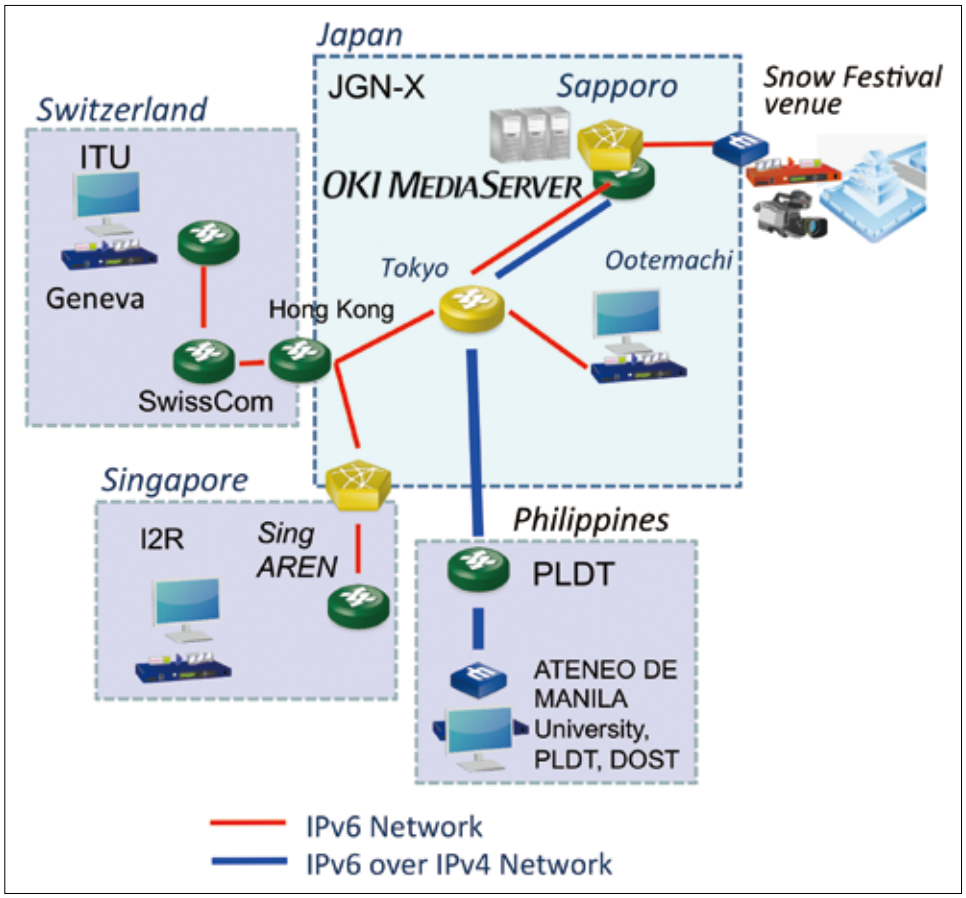
3.1 ITU's promotion activities

ITU-T has been promoting ITU's IPTV standards in workshops and exhibitions held in several countries that have expressed an interest in introducing IPTV. However, these events only last a few days, and there is not enough time for them to try their own applications.

Therefore, in October 2012, OKI and HTB have launched the ITU IPTV IPv6 Global testbed (I3GT) project in a cloud environment that connects with JGN-X provided by National Information Institute of Information and Communication Technology (NICT). LIME standard contents developed by HTB were used in I3GT.

The purpose of I3GT is to provide a test environment for service providers, research institutes, and universities in several countries planning to adopt the IPTV Standard, and to promote the spread of ITU-T IPTV standards. They can utilize the testbed to understand the standards, and establish an environment for service verification by service providers. The following sections present an outline of the tested, the experiments performed on it, and the future direction of this technology.

Figure 4: I3GT at the Sapporo Snow Festival



3.2 Overview of the ITU IPTV standard testbed system I3GT

To advance the adoption of the above ITU IPTV standards, OKI and HTB launched I3GT in October 2012. Using an IPv6 network, I3GT is intended to provide a worldwide testing environment for the ITU IPTV standards. The testbed can be used to (1) verify that a network has sufficient bandwidth and quality (delay, loss) for IPTV video distribution; (2) test the interactive functionality of applications with video/still image/text of LIME compliant contents; and (3) try out the interface during terminal development, thereby enabling a better understanding of the standard's value.

The testbed is built on a server located in NICT's JGN-X. OKI MediaServer, considered an ITU standards compliant reference, is

utilized as the IPTV platform.

The conceptual architecture of I3GT is shown in Figure 4. The tester at the left side of the figure interconnects the network (to which his terminal is connected) to JGN-X where the I3GT is located. Here, the interconnected tester's network and JGN-X act as the managed network (pseudo managed IP network) for IPTV.

The IPTV service description provider and IPTV service provider in Figure 1 are functions provided on the distribution server side of the network by the OKI MediaServer. Based on H.770, the IPTV service description provider maintains a database (DB) for the IPTV services available over the network and provides service-related information to the terminal. An IPTV service provider is one of the service providers registered in the IPTV service description provider DB, and provides actual VOD, linear TV and other video service based on H.721, or delivers LIME content based on H.762.

To the right of the IPTV service provider is the operations network used to add/delete content, authenticate service manage testers and manage software for the distribution server.

Besides testing the terminal, the tester can make use of area *A* (surrounded by dotted lines in the figure) to perform actual tests on distribution server performance and functions. To implement IPTV service provider functions such as VOD and linear TV in area *A*, the tester registers *A* with the IPTV service description provider DB. Then the tester can receive the services in *A* on his terminal following the steps below.

a) Connect to the IPTV service description provider when starting up the IPTV terminal.
b) The terminal will display *A* among the entries in the IPTV service description provider DB and IPTV service provider connected with JGN-X.
c) When the tester selects *A*, the terminal will connect with service provider *A* and begin receiving the service.

The mechanism by which an IPTV terminal connects to a newly added service as described above is called service discovery.

Rather than implement new IPTV service provider functions described previously, *A* can simply be connected as a server placed at different geographic location. From the IPTV terminal's point of view, it is simply connecting to a different server without notice while selecting content.

Table 2 shows the ITU IPTV standards that can be currently evaluated with the testbed. Since the IPTV service is still under development, active discussions are continuing in ITU IPTV-GSI toward the establishment of new standards. Therefore, the standards listed in the table below are liable to change.

Table 2: ITU Standards Evaluated with Testbed

ITU-T Rec. No.	Contents
H.762	Lightweight Interactive Multimedia Environment for IPTV
H.721	Basic terminal specification for VOD, Linear TV and information services.
H.770	Service discovery for IPTV terminals
H.701	Error compensation such as packet losses in network
H.264	Video compression standards for standard and high definition television.
H.750	Metadata for IPTV services.

Figure 5: Linking with a subtitling service on the Internet

3.3 Overview of I3GT experimental trials

(1) Trial at WTSA-12, November 2012

The first I3GT experimental trial and exhibition was conducted on November 20 and 21, 2012 at the ITU World Telecommunication Standardization General Assembly (WTSA-12) in Dubai, UAE. The system architecture for the trial is shown in Figure 5. Dubai's communication carrier, du, constructed a temporary 15Mbps IPv6 network to the trial site using IPv6 over IPv4. To demonstrate the system, a high-definition video created by HTB was delivered as VOD from Sapporo Japan. Additionally, video from a camera installed at the entrance to the United Nations in Geneva was also transmitted to demonstrate live video delivery. Over 1,000 people from 101 of the 190 United Nations member countries associated with communication service providers or communication related regulatory agencies were in attendance. In ITU Secretary-General's opening speech, I3GT was cited as an example of ITU's interconnection experiment, prompting many attendees to visit the exhibit during the meeting.

Although temporary, the experimental trial proved that a system compliant with ITU IPTV standards — which were originally created for video delivery in a closed network — can be built over intercontinental networks for viewing high-definition videos. This shows that I3GT can fulfill its goal as a worldwide testbed for ITU IPTV standards

(2) Video delivery trials at the Sapporo Snow Festival in February 2013

The second I3GT trial was carried out between February 5 and 7, 2013 at the Sapporo Snow Festival. Figure 4 shows the system architecture used for the trial. While the first trial tested delivery to a temporary trial site, this second trial tested delivery from the trial site to terminals set up at the Singapore National Information and Communication Institute, at Ateneo de Manila University in the Philippines, and at the ITU headquarters.

Currently, the transition to IPv6 is taking place globally. However, there are still many countries where actual construction is not progressing. For those countries, IPv6 packets are

encapsulated with IPv4 at the server-side and delivered to their destination via IPv4. At the receiving end, the encapsulated IPv6 packets are extracted and sent to the STB. This feature was demonstrated at the trial with content delivered to Ateneo de Manila University in the Philippines. The trial used live content and high-definition VOD created by HTB especially for the snow festival as well as VOD content provided by ITU.

A large-scale OpenFlow testbed known as RISE built over JGN-X by NICT was used to connect between the trial site and Singapore. In addition to the video content mentioned above, 4K video created with an encoder from MEDIAEDGE Co., Ltd. was also used. New IPTV applications that interact with SNSs (Social Network Systems) and subtitle services on the Internet were also tested during the trial.

The former service simultaneously displays high quality IPTV video and associated SNS information on the viewer's terminal, allowing video content to be enjoyed via an SNS. This demonstration used technology developed by NTT Communications Corporation that allows IPTV to interact with an SNS.

In the latter, LIME's Internet communication function was used to synchronize IPTV video content with an Internet subtitling service provided by ASTEM Inc. in order to deliver subtitles in the language and font size selected on the viewer's terminal.

Compared with methods where video is multiplexed with other information such as subtitles and broadcast as a single stream, as in digital broadcasting, it is possible to adapt flexibly to viewers requiring different subtitle languages, screen layouts and the like, thereby making services more accessible. An image of the screen display is shown in Figure 5.

In this trial, we were able to confirm that the two abovementioned functions worked as originally intended. This means that it is possible to perform trials of new IPTV applications linked with Internet services in I3GT, and in the future, this should be very important for confirming services that the countries participating in the trial actually want to introduce.

3.4 Activities in Asia-Pacific region

The APT/ITU Conformance and Interoperability (C&I) event was held in Bangkok, Thailand over a four-day period from September 9 to 12, 2013. Hosted by the Asia-Pacific Telecommunity (APT) and the International Telecommunication Union (ITU), the C&I event serves as a venue for showcasing products and technologies in order to evaluate their interoperability and compliance with international standards. At this event, OKI exhibited the OKI MediaServer — an IPTV video distribution system designed to achieve compatibility with international ITU IPTV standards, which is currently attracting attention in emerging countries. OKI also exhibited its GE-PON optical access system, which is ideally suited to building FTTH for high-quality video distribution. In the conformance testing event, Asian vendors participated in the event and tested their products based on ITU-T IPTV conformance document.

3.5 Activities in Africa region

For the purpose of industrialization, the Government of Rwanda (GoR) considers that it is important to diversify into different media platforms in order to provide better services and increase the penetration of TV. GoR recognizes the changing trends of video consumption and the immense potential of interactive multimedia, applications and services, particularly IPTV and is willing to connect to I3CT. As a first step towards the deployment of IPTV, a workshop ("Engagement of Rwandan Academia in ITU Activities") was held in Rwanda on 25 October 2013. This workshop introduced I3GT's activities and off-line showcasing. GoR is now preparing to connect with I3GT, which seems to be recognized as one of the key drivers of ICT deployment.

4. Conclusions

The ITU's IPTV standards are open and global, and are used in Japan's commercial IPTV services. The service menus and subscribers are increasing year by year.

Emerging countries are working feverishly to build broadband networks and to deploy applications that run over such networks to close the ICT gap with respect to advanced nations. Installing network equipment that complies with international standards and ensures the interoperability of products from multiple vendors will make it possible to continue procuring equipment with the required functionality from a wide range of vendors. This, in turn, is expected to enhance expandability and help reduce the cost of operating and expanding systems for many years into the future. Emerging countries are currently eyeing broadband-supporting products that meet international standards as they plan and build their telecommunications facilities.

In order to satisfy the expectations from emerging countries, the ITU IPTV IPv6 Global testbed (I3GT) has been launched by the ITU and several vendors including OKI. Several experimental trials have been done on the testbed.

Based on our experimental findings, OKI plans to expand the scope of the IPTV testbed to countries/regions that (1) have not deployed IPv6, (2) have deployed IPV6 and are planning 4K and higher image quality, or (3) are planning to improve accessibility or provide value-added video services such as e-health and e-learning.

OKI will enhance the features of the OKI MediaServer to meet market needs, push for standardization of features such as H.265 and 4K, work to promote the standards and advance the deployment of an appealing video distribution platform.

References
1 Hideki Yamamoto, Standardization Trends of Internet Protocol Television (IPTV) and Activities Undertaken by OKI, OKI Technical Review, No.215 (2009)
2 Hideki Yamamoto, Standardization Trend for IPTV audience measurement, OKI Technical Review, No.218 (2011)
3 Hideki Yamamoto, Kazuhiro Watanabe and Toshihiro Moriya, ITU IPTV Standards Testbed System based on OKI MediaServer, OKI Technical Review, No.221 (2013)

Notes:
JGN-X
A testbed environment operated by NICT since April 2011 for the implementation and deployment of new generation network technologies.
OpenFlow
One of the technologies behind SDN (Software Defined Network), a network that uses software to perform configurations instead of hardware such as routers and L2 switches. Standardization is carried out by Open Networking Foundation (ONF).
RISE (Research Infrastructure for large-Scale network Experiments)
A large-scale OpenFlow testbed developed on top of JGN-X. It is one of JGN-X's new generation network planes, virtually deployed over a wide area on an existing L2 virtual network.