International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

J.282

(11/2006)

SERIES J: CABLE NETWORKS AND TRANSMISSION OF TELEVISION, SOUND PROGRAMME AND OTHER MULTIMEDIA SIGNALS

Digital transmission of television signals

Architecture of multi-channel video signal distribution over IP-based networks

ITU-T Recommendation J.282

ITU-T
International Telecommunication Union

ITU-T Recommendation J.282

Architecture of multi-channel video signal distribution over IP-based networks

Summary

This Recommendation defines the architecture of IP-based video signal distribution systems. Because IP transmission technologies allow the use of various physical media due to their media-independent nature, this Recommendation describes some additional broadband access network technologies such as optical access network, xDSL and cable modem.

Source

ITU-T Recommendation J.282 was approved on 29 November 2006 by ITU-T Study Group 9 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

The International Telecommunication Union (ITU) is the United Nations specialized agency in the field of telecommunications. The ITU Telecommunication Standardization Sector (ITU-T) is a permanent organ of ITU. ITU-T is responsible for studying technical, operating and tariff questions and issuing Recommendations on them with a view to standardizing telecommunications on a worldwide basis.

The World Telecommunication Standardization Assembly (WTSA), which meets every four years, establishes the topics for study by the ITU-T study groups which, in turn, produce Recommendations on these topics.

The approval of ITU-T Recommendations is covered by the procedure laid down in WTSA Resolution 1.

In some areas of information technology which fall within ITU-T's purview, the necessary standards are prepared on a collaborative basis with ISO and IEC.

NOTE

In this Recommendation, the expression "Administration" is used for conciseness to indicate both a telecommunication administration and a recognized operating agency.

Compliance with this Recommendation is voluntary. However, the Recommendation may contain certain mandatory provisions (to ensure e.g. interoperability or applicability) and compliance with the Recommendation is achieved when all of these mandatory provisions are met. The words "shall" or some other obligatory language such as "must" and the negative equivalents are used to express requirements. The use of such words does not suggest that compliance with the Recommendation is required of any party.

INTELLECTUAL PROPERTY RIGHTS

ITU draws attention to the possibility that the practice or implementation of this Recommendation may involve the use of a claimed Intellectual Property Right. ITU takes no position concerning the evidence, validity or applicability of claimed Intellectual Property Rights, whether asserted by ITU members or others outside of the Recommendation development process.

As of the date of approval of this Recommendation, ITU had not received notice of intellectual property, protected by patents, which may be required to implement this Recommendation. However, implementers are cautioned that this may not represent the latest information and are therefore strongly urged to consult the TSB patent database at http://www.itu.int/ITU-T/ipr/.

CONTENTS

Introduction

This Recommendation defines the architecture of IP-based video signal distribution systems that satisfy the requirements defined in [b-ITU-T J.281]. Primary and secondary distribution of broadcasting programmes, the key services of CATV, are the goals of this architecture. Hence, some important issues, which are not derived from the requirements of generic video transmission service but are important in terms of broadcasting, such as area restriction and anonymous reception, are taken into account.

Because IP transmission technologies can be used with various physical media due to their flexibility, this Recommendation also introduces some additional broadband access network technologies, which are not covered in [b-ITU-T J.281], such as xDSL and cable modem.

ITU-T Recommendation J.282

Architecture of multi-channel video signal distribution over IP-based networks

1 Scope

This Recommendation describes the architecture of IP-based video signal distribution systems that can provide functionalities and services equivalent to those of a conventional CATV system, including secondary distribution of broadcasts.

High quality video distribution over the IP network requires broadband access network technologies such as optical access network, xDSL and cable modem. This Recommendation describes the functionalities of the CDN and access network required for multi-channel video services. The CDN is under the obvious control of network operator(s). Programme distribution on a global basis is outside the scope of this Recommendation.

The service configuration is roughly equivalent to conventional CATV. HDTV is available as one part of the video service.

The two Internet protocols, IPv4 and IPv6, are basically the same with some differences such as the address architecture and multicast management protocol. This Recommendation does not define which protocol should or should not be used. The choice of Internet protocol is left to the operator.

IP technologies can be applied for contribution, primary and secondary distribution, and in-home transmission/distribution. This Recommendation focuses on primary and secondary distribution. The other usages, for example video on demand, may be added to the architecture of this Recommendation.

2 References

The following ITU-T Recommendations and other references contain provisions which, through reference in this text, constitute provisions of this Recommendation. At the time of publication, the editions indicated were valid. All Recommendations and other references are subject to revision; users of this Recommendation are therefore encouraged to investigate the possibility of applying the most recent edition of the Recommendations and other references listed below. A list of the currently valid ITU-T Recommendations is regularly published. The reference to a document within this Recommendation does not give it, as a stand-alone document, the status of a Recommendation.

[ITU-T H.222.0] ITU-T Recommendation H.222.0 (2006) | ISO/IEC 13818-1 (2006), *Information technology – Generic coding of moving pictures and associated audio information: Systems*.

[ITU-T J.94] ITU-T Recommendation J.94 (1998), *Service information for digital broadcasting in cable television systems*.

[ITU-T J.183] ITU-T Recommendation J.183 (2001), *Time-division multiplexing of multiple MPEG-2 transport streams over cable television systems*.

[ITU-T J.290] ITU-T Recommendation J.290 (2006), *Next generation set-top box core architecture*.

[ITU-T J.292] ITU-T Recommendation J.292 (2006), *Next generation set-top box media-independent architecture*.

3 Definitions

This Recommendation defines the following terms:

3.1 IP stream (IPS): A flow of IP packets that is identified by destination/source IP address and port number.

3.2 network termination (NT): Generic term for equipment that terminates an access network at the user side. NT includes ONU, cable modem and xDSL modem.

3.3 transport stream (TS): A TS is a data structure defined in [ITU-T H.222.0].

4 Abbreviations and acronyms

This Recommendation uses the following abbreviations and acronyms:

CAS	Conditional Access System
CATV	CAble TeleVision
CDN	Content Distribution Network
CPE	Customer Premises Equipment
DHCP	Dynamic Host Configuration Protocol
ECM	Entitlement Control Message
EMM	Entitlement Management Message
EPG	Electronic Programme Guide
FEC	Forward Error Correction
FTTB	Fibre To The Building
FTTH	Fibre To The Home
HDTV	High Definition TeleVision
IGMP	Internet Group Management Protocol
IP	Internet Protocol
IPS	Internet Protocol Stream
L2	Layer 2
MAC	Media Access Control
MLD	Multicast Listener Discovery
MPEG	Moving Picture Experts Group
NIT	Network Information Table
NT	Network Termination
ONU	Optical Network Unit
PC	Personal Computer
PES	Packetized Elementary Stream
PSI	Programme Specific Information
QoS	Quality of Service
RA	Router Advertisement
RTP	Real-time Transport Protocol

SI	Service Information
SLA	Service Level Agreement
STB	Set-Top Box
ToS	Type of Service
TS	Transport Stream
TSMF	Transport Streams Multiplexing Frame
TTL	Time To Live
UDP	User Datagram Protocol
WWW	World Wide Web
xDSL	x Digital Subscriber Line

5 Conventions

Throughout this Recommendation words that are used to define the significance of particular requirements are capitalized. These words are:

"MUST"	This word or the adjective "REQUIRED" means that the item is an absolute requirement of this Recommendation.
"MUST NOT"	This phrase means that the item is an absolute prohibition of this Recommendation.
"SHOULD"	This word or the adjective "RECOMMENDED" means that there may exist valid reasons in particular circumstances to ignore this item, but the full implications should be understood and the case carefully weighed before choosing a different course.
"SHOULD NOT"	This phrase means that there may exist valid reasons in particular circumstances when the listed behaviour is acceptable or even useful, but the full implications should be understood and the case carefully weighed before implementing any behaviour described with this label.
"MAY"	This word or the adjective "OPTIONAL" means that this item is truly optional. One vendor may choose to include the item because a particular marketplace requires it or because it enhances the product, for example; another vendor may omit the same item.

6 Architecture

6.1 Architectural framework

A CATV service is a collective of service elements including video programmes, sound programmes, data broadcasts, EPGs and CASs that are produced on an MPEG-2 system. In order to provide services equivalent to conventional CATV, the protocol stack of a CATV system above the MPEG-2 TS layer is applied with minimum modification as shown in Figure 6-1. CAS is also provided as part of the service functionalities that resides above the MPEG-2 TS layer.

The transmission functionality that is defined in [b-ITU-T J.83] for conventional CATV is replaced with IP and related functionalities. FEC functionalities, which enhance the transmission quality, reside on the MPEG-2 TS layer and/or the IP layer.

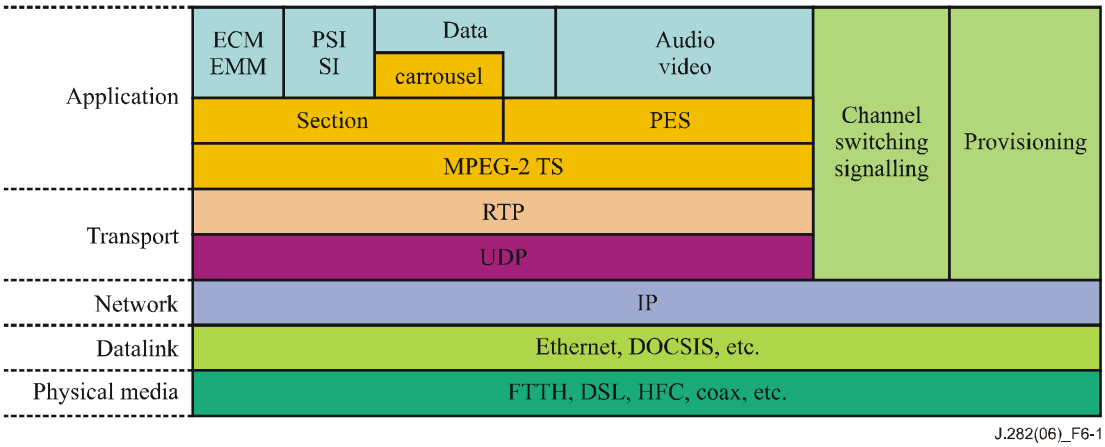

Figure 6-1 – Protocol stack

The system physically consists of a headend, CDN and CPE (customer premises equipment) as shown in Figure 6-2.

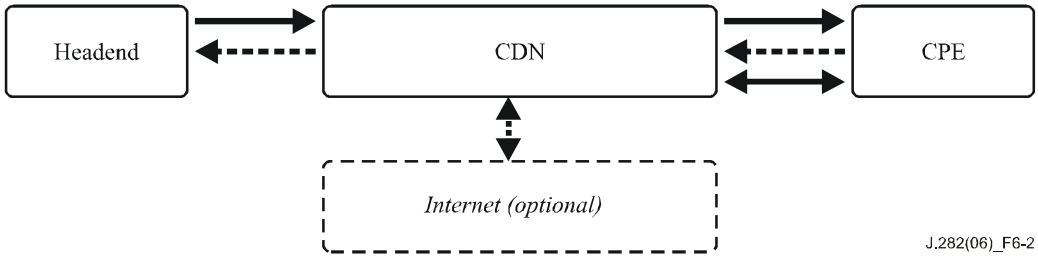

Figure 6-2 – System configuration

A headend coordinates video programmes and ancillary information, produces transport streams and transmits into CDN, as does a conventional CATV headend. At least one headend MUST be connected to the CDN. Two or more headends MAY be connected to the same CDN if necessary. In the case of multiple headends, CPE MAY be allowed to receive programmes generated from each headend.

CDN delivers IP packets encapsulating MPEG-2 TS packets to CPE. Unlike conventional transmission technology such as [b-ITU-T J.83], designed for transmission over coaxial cable, IP technology allows the programmes to transit various physical media, and so is expected to ease the network design constraints. With regard to the access network, many access network technologies such as optical access network, xDSL and cable modem, if sufficient bandwidth is available, can be employed. Since the CDN is a closed network, the global reachability required for conventional Internet applications such as the WWW and e-mail is provided through connection through the Internet.

CPE functionalities are equivalent to those of CATV STBs except for the functionality of physical layer termination.

6.2 CDN

CDN provides video distribution functionality from a headend to CPE. CDN may also provide connection with the Internet through interconnection with it. Also, bidirectional capability between a headend and CPE may be provided. The configuration of CDN is shown in Figure 6-3.

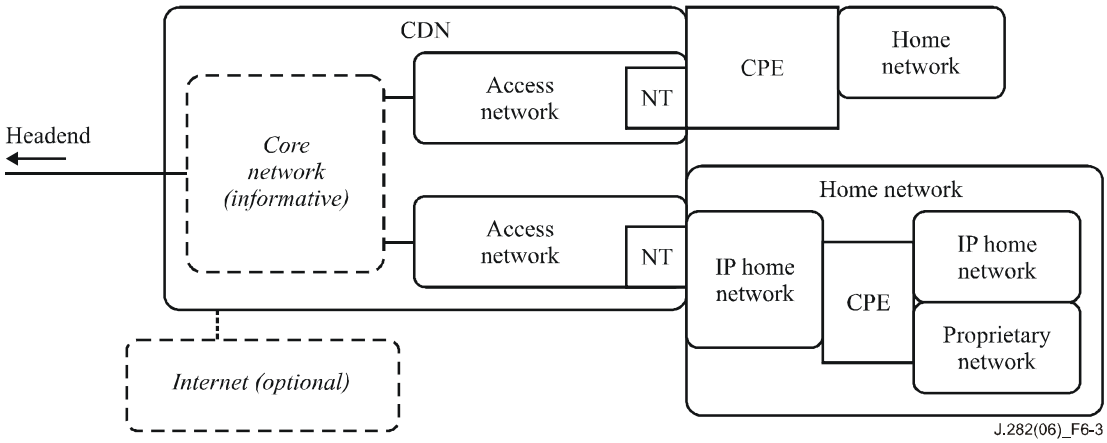

Figure 6-3 – Block diagram of video signal distribution

CDN consists of a core network and an access network. Although CDN does not include the Internet, CDN can provide connectivity with the Internet when CPE uses services that demand it.

CDN needs to guarantee high transmission quality so as to meet the demands imposed by the video streams. Thus, the network operator responsible for CDN is required to maintain transmission quality. If several network operators are involved in the construction and operation of CDN, an SLA SHOULD be made that defines the transmission quality of the network and the technology employed.

6.2.1 Core network

The core network is responsible for distributing the injected IP packets to each access network with sufficient transmission quality. It has appropriate bandwidth, QoS functionality and/or network architecture so as to guarantee the quality needed for video transmission services, against the traffic generated by Internet applications such as the WWW and e-mail.

The detailed functionality of the core network is outside the scope of this Recommendation.

6.2.2 Access network

The access network connects the core network and the CPE or home network.

The access network is required to provide sufficient bandwidth for video distribution. The access network MUST be able to deliver at least one IPS with sufficient quality. Also, it SHOULD be possible to deliver multiple IPSs in order to take care of multiple CPEs connected to the same access network.

This Recommendation applies to, including but not limited to, FTTH/FTTB, xDSL and cable modem as broadband access network technologies. The following are examples of appropriate access network technologies:

- [b-ITU-T G.983.1];
- [b-ITU-T G.983.3];
- [b-ITU-T G.984.2];
- [b-ITU-T G.993.2];
- [b-ITU-T G.992.5];
- [b-IEEE 802.3ah];
- [b-ITU-T J.112];
- [b-ITU-T J.122].

6.2.3 IP home network

There may be network equipment between a NT and CPE in a customer's home. This Recommendation refers to a set of network equipment of this kind as an "IP home network".

An IP home network delivers programmes from a NT to CPE as a part of a home network. A NT is allowed to transmit a programme to CPE. CPE MUST NOT be allowed to transmit a programme to a NT or other CPE. Also, CAS MUST be used for programme protection within the IP home network.

An IP home network SHOULD be able to provide at least one IPS for each CPE with sufficient quality and MAY be able to provide multiple IPSs for each one.

6.3 Internet protocol

6.3.1 IPv4/IPv6

It is well recognized that two Internet protocols, IPv4 and IPv6, exist and are being used. Some differences can be found between them such as address length. Procedures for multicast distribution, signalling and address management have been defined for each protocol. This Recommendation does not define which protocol should or should not be used.

6.3.2 Restriction of distribution area

It may be desired or required to restrict the distribution area for a broadcasting service. That is, unlimited distribution of broadcast contents across the globally reachable network may cause business concerns among stakeholders. There are several schemes to restrict the physical area of distribution as described below.

Routing restriction

The routing path of multicast packets, as well as unicast packets, is controlled by routing information. The distribution area can be controlled by the appropriate management of routing information.

TTL/hop-limit

Time-to-live (IPv4) and hop-limit (IPv6) are defined in each IP header in order to prevent undeliverable packets from staying permanently on the network. The 8-bit value of this field is decreased when a router processes the packet. Generally, this field is filled with a relatively large value, for example 254, to be able to reach a distant destination. If this field is filled with a small value, the reachable area of multicast packet can be limited to a relatively small area. However, the logical distance recognized by this field may sometimes be significantly different from the corresponding physical distance. For example, a huge L2 network can convey IP packets without consuming the TTL/hop-limit value. This characteristic of TTL/hop-limit needs to be considered further.

Gateway filtering

Gateway filtering is a straight forward approach to area restriction. The filtering gateway, located within the CDN or on the border with another network, restricts the distribution area according to the applied filtering policy.

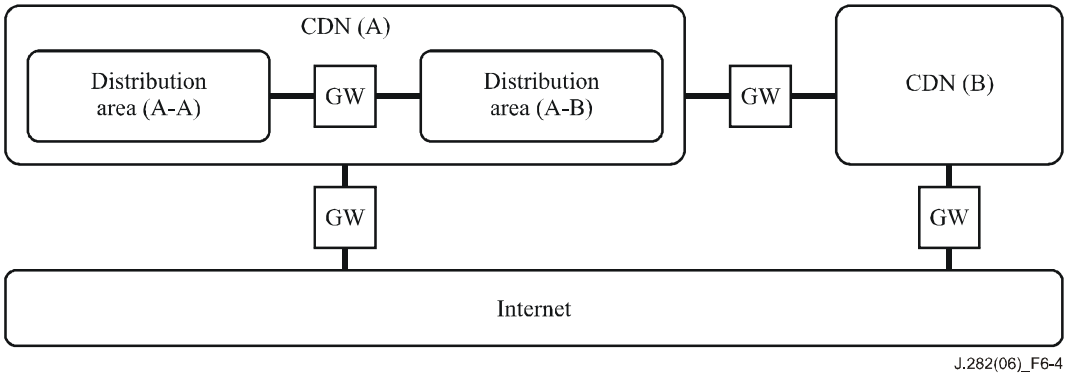

Figure 6-4 – Example of gateway filtering

Figure 6-4 shows an example of distribution area restriction. The potential gateway locations are listed below:

- Interconnection point between the CDN and the Internet.
- Interconnection point between CDNs.
- Inside the CDN.

All programmes travelling across the filtering gateway located between a CDN and the Internet MUST be cut out so as to prevent unmanaged distribution through the Internet. Filtering gateways located between or inside of CDNs will cut programmes according to the policy mounted on the gateways.

Location awareness of CPE

By the use of CPE location information, a CPE can verify its access validity to the content for the designated distributed area. In other words, this method can restrict an unauthorized CPE's access to the content which is improperly transferred from other region. The mechanism may be installed in a CPE to be aware of location information automatically from its behaviour with an access or core network. The location information can be manually preset by the user or the network operator.

Refer to [ITU-T J.292] for details.

6.3.3 Assignment of multicast IP address

Since global reachability of programmes is not required, it is not necessary to allocate multicast addresses on a global basis. The multicast addresses reserved for local scope are sufficient for this purpose.

A class D address is designated as a multicast address in IPv4 networks. [b-IETF RFC 2365] describes the local scope of this block of addresses.

The address architecture for IPv6 including multicast is described in [b-IETF RFC 3513]. Also, [b-IETF RFC 3306] describes IPv6 multicast addresses with unicast prefix that is appropriate for this distribution.

6.4 Service delivery model

With regard to the multiplexing structure of MPEG-2 TS, refer to [ITU-T J.94].

Each IPS SHOULD contain one TS. If [ITU-T J.183] is applied as a multiplexing scheme, one IPS MAY convey multiple TSs. Figure 6-5 shows the service delivery model for IP distribution.

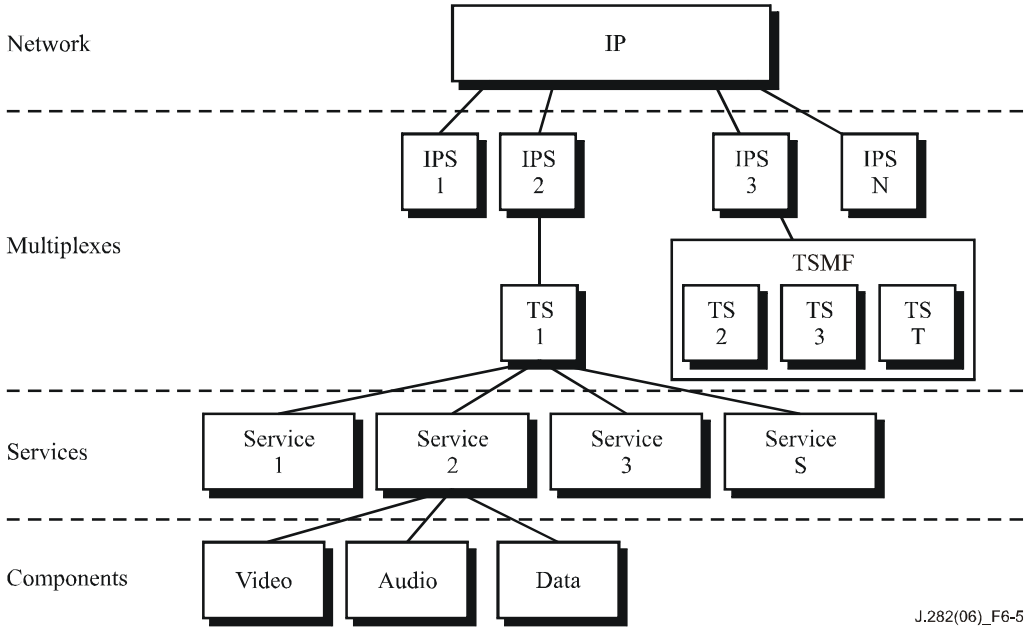

Figure 6-5 – Service delivery model

The relationship between the IPS and TS SHOULD be stable. Instability may cause coordination failure with SI and result in a technical problem.

A programme SHOULD be identified with a set of identifications used in the MPEG-2 system including original network ID, network ID, transport streams ID and service ID. In order to avoid MPEG-2 level problems, identifying a programme with an IP address without using network ID, transport stream ID and service ID SHOULD be avoided.

6.5 Channel switching

6.5.1 Channel switching model

Figure 6-6 shows the channel switching model.

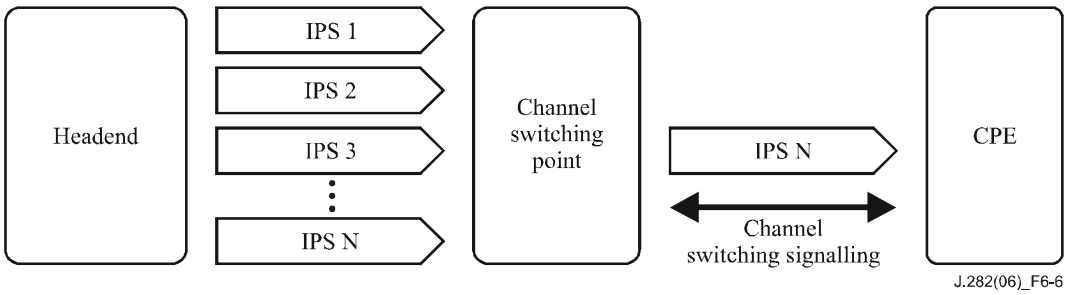

Figure 6-6 – Channel switching model

This Recommendation defines the channel switching point as a function equivalent to the tuner of a CATV STB. The channel switching point receives a number of IPSs and outputs a selected IPS. All the IPSs departing from the headend SHOULD be distributed to the channel switching point simultaneously. The channel switching point selects an IPS and transfers it to the CPE. The channel switching signalling designates the IPS to be selected at the channel switching point.

6.5.2 Location of the channel switching point

The following are the possible physical locations for placing the channel switching functionality:

- interconnecting point between the access network and core network;
- network terminal;
- inside the IP home network;
- inside the CPE (embedded channel switching point).

If the channel switching point is located on the core network, it needs to process channel switching signalling more frequently than when it is located on an edge portion of the network. This may cause a perceivable degradation in channel switching performance. Thus, the channel switching point SHOULD NOT be located on the core network.

It is possible to construct dynamic multicast trees for multicast data distribution. It seems to be appropriate to use the dynamic multicast tree for its ability to consume less bandwidth than the static multicast scheme. However, instable positioning of the multicast handling point would increase the channel switching duration. Thus, the channel switching point SHOULD be located statically.

6.5.3 Channel switching signalling

Channel switching signalling is a functionality to control the channel switching point and designates which IPS should be chosen. It can be implemented as a multicast management protocol except in the case of an embedded channel switching point. Examples of protocols that are appropriate for channel switching signalling are as follows:

- IGMPv2 [b-IETF RFC 2236];
- IGMPv3 [b-IETF RFC 3376];
- MLDv2 [b-IETF RFC 3810].

No method other than channel switching signalling should be used for designating IPSs. Any such method may cause channel switching that is not desired by the user. Hence, it causes concerns over the identities of programmes that are generally required for the secondary distribution of broadcasting programmes.

6.5.4 Duration of channel switching

When the user switches the channel, several processes, including IP-level processes, MPEG-2 TS level processes (e.g., waiting PSI/SI and I-picture) and decoding processes, will be invoked. IP-level processes contain the following steps.

- Process of channel switching signalling.
- Buffering in CPE.
- Decoding of FEC.

Short channel switching durations are desirable, because long durations annoy the user.

6.5.5 Anonymous reception

Since programme distribution over the IP network involves some interactive processes between the CDN and CPE, there is a concern about the violation of anonymous reception, an important worry in broadcasting. CDN and network operators SHOULD NOT observe channel switching behaviour or collect view-logs if there is no technically-justifiable reason (e.g., maintenance). If there is a reason to the collection of view-logs, such as billing, it SHOULD be carried out by the CAS, not by functionality of the CDN.

Some technical methods can enhance the anonymity of reception. Possible technical methods are listed below.

- *Stateless address*

  Stateless address autoconfiguration allows the CPE to generate its address locally from RA (router advertisement) and locally available information (generally MAC address) as defined in [b-IETF RFC 2462]. Centric address management entity, which is required for stateful address configuration such as DHCP, is not required. Identification of each user from its address becomes harder than stateful address configuration, because no entity accumulates configuration information.

- *Embedded channel switching point*

  Embedding a channel switching point in the CPE eliminates the possibility of detecting channel switching signalling. In this case, all IPSs reach the CPE, and selection of IPS is carried out inside the CPE. Although anonymity is enhanced in this scheme, greater bandwidth is consumed in the access network including, in-home plant.

- *Secured channel switching point*

  The device that contains the channel switching point provides an opportunity to collect view-logs if it is managed inappropriately. To reduce the possibility of this abuse, it is desirable to separate the management interface from interfaces handling user traffic physically and/or logically. If it is impossible to separate the management interface, a protection measure that prevents unauthorized access to the device needs to be applied.

6.6 Services

The following services SHOULD be provided:

- digital video service;
- digital audio service;
- EPG service;
- data broadcasting service;
- CAS;
- bidirectional service.

6.7 Service information

[ITU-T J.94] and [ITU-T H.222.0] define service information used for digital CATV systems. Basically, PSI and SI defined in these Recommendations | International Standards are also applicable to IP-based transmission and should be used in order to harmonize with conventional CATV systems.

The designation of programme location is based on an IPS as the equivalent of a RF carrier, which is identified with frequency, in conventional CATV. The information required for acquiring an IPS is listed below. There are several schemes to distribute this information to CPE. The inclusion of this information in NIT is an example of push-type distribution.

- IPv4/IPv6;
- destination IP address;
- destination port number;
- channel switching signalling;
- usage of RTP header;
- FEC;
- frame format.

The following items are not mandatory, but are generally desirable in terms of ease of operation of CPE:

- identification of unicast and multicast;
- IP packet size;
- TS packet size;
- TS rate.

EPG can be generated from the information contained in the SI defined in [ITU-T J.94].

6.8 CPE

The following Recommendations define basic CPE architecture:

- [ITU-T J.290];
- [ITU-T J.292].

6.9 Provisioning

It is desirable to make the provisioning step of CPE as simple as possible. The complication of some PC set-up procedures for Internet access should be avoided. It is desirable to automate the CPE start-up process in combination with the headend and CDN.

The following steps are required for CPE to reach the operational state:

- establishment of IP connectivity;
- reception of IPS containing programmes;
- activation of service.

These processes correspond to the layer structure of the protocol stack, and CPE is provisioned from lower layer functionality.

6.9.1 Establishing IP connectivity

The equipment connected to the IP network, including CPE defined in this Recommendation, needs to establish IP connectivity. The basic elements of IP connectivity include configuration of the IP address and related information. The following technologies are recognized as address configuration technologies:

- DHCP [b-IETF RFC 2131];
- stateless address autoconfiguration [b-IETF RFC 2462].

6.9.2 Acquiring IP stream

Upon establishment of IP connectivity, CPE is ready to accept IPSs. It is appropriate to receive the last IPS if the CPE successfully received a programme previously.

If CPE is in a factory-default condition or failed to receive an IPS due to a condition change (e.g., the CPE moved to another operator area, or a configuration change of IPS), the CPE needs to receive effective IPSs. The following methods can be used for informing CPEs.

- *Remote configuration*

  Mechanisms such as DHCP and downloading a configuration file can inform CPE of the information regarding IPS.

- *Well-known address*

  MPEG-2 TS contains information regarding organization of programmes in the form of PSI and SI. Thus, if CPE can receive one MPEG-2 TS successfully, the CPE can also know the information regarding the other MPEG-2 TSs. Defining a well-known address, for example 239.192.0.1, is one way that a CPE in an initial state can receive MPEG-2 TS. An IPS-assigned well-known address may or may not contain programmes.

Navigating to a specific programme, when CPE is in an initial state, could unfairly bias the opportunity of programme reception. Any possibility of biased selection of programmes in the provisional process SHOULD be avoided.

6.9.3 Activating service

When CPE is ready to receive an IPS, it is also ready to receive MPEG-2 TS. To finalize the provisional process, several procedures are needed, such as initialization of CAS, including reception of ECM.

6.9.4 Restarting of CPE

Since a once-successfully provisioned CPE can remember the configuration needed to receive programmes, it can restart without needing to repeat all steps. In this case, establishment of IP connectivity is a mandatory step. The other steps can be omitted in order to shorten start-up time.

6.10 Security

Any information systems, including video distribution systems, face various threats that may potentially violate normal operation of the system. The threats associated with IP-based video distribution systems are as follows:

- unauthorized access of headend equipment;
- unauthorized use of committed bandwidth, and unreasonable use of bandwidth;
- unauthorized access to content;
- unauthorized modification to MPEG-2 TS.

6.10.1 Protection from unauthorized access to headend equipment

Unauthorized access to the headend equipment prevents normal operation of the equipment and seriously affects the presentation of content. In general, servers used for Internet services are protected by user authentication and are sometimes located in a physically protected area, for example a cage, and/or logically protected area, for example behind a firewall. These methods are effective and should be applied for headend protection.

6.10.2 Protection from unauthorized use of committed bandwidth

Assured bandwidth is required for stable distribution of video streams. QoS technologies that separate video streams from the other traffic generated by Internet applications SHOULD be applied. Using a ToS field is an example of traffic prioritization.

6.10.3 Protection from unauthorized access to the content

CAS SHOULD protect programmes delivered across a CDN including an IP home network. Requirements and technical specification of CAS may depend on operators. This Recommendation does not define technical details. Refer to [ITU-T J.290].

6.10.4 Protection from unauthorized modification to MPEG-2 TS

It is common sense to prohibit improper content delivery and to protect users from encountering fake programme injected by malicious users as IP packets can be captured by a general-purpose PC with an Ethernet interface, and manipulation of a stream over IP is easier than other media. For secure content delivery, the enhancement of content protection is recommended in addition to the existing CAS system. For example, encrypting chunk MPEG-2 TS packets in RTP/UDP payload is a method that could be considered.

Bibliography

[b-ITU-T G.983.1] ITU-T Recommendation G.983.1 (2005), *Broadband optical access systems based on Passive Optical Networks (PON).*

[b-ITU-T G.983.3] ITU-T Recommendation G.983.3 (2001), *A broadband optical access system with increased service capability by wavelength allocation.*

[b-ITU-T G.984.2] ITU-T Recommendation G.984.2 (2003), *Gigabit-capable Passive Optical Networks (G-PON): Physical Media Dependent (PMD) layer specification.*

[b-ITU-T G.992.5] ITU-T Recommendation G.992.5 (2005), *Asymmetric Digital Subscriber Line (ADSL) transceivers – Extended bandwidth ADSL2 (ADSL2plus).*

[b-ITU-T G.993.1] ITU-T Recommendation G.993.1 (2004), *Very high speed digital subscriber line transceivers (VDSL).*

[b-ITU-T G.993.2] ITU-T Recommendation G.993.2 (2006), *Very high speed digital subscriber line transceivers 2 (VDSL2).*

[b-ITU-T J.83] ITU-T Recommendation J.83 (1997), *Digital multi-programme systems for television, sound and data services for cable distribution*.

[b-ITU-T J.112] ITU-T Recommendation J.112 (1998), *Transmission systems for interactive cable television services*.

[b-ITU-T J.122] ITU-T Recommendation J.122 (2002), *Second-generation transmission systems for interactive cable television services – IP cable modems*.

[b-ITU-T J.190] ITU-T Recommendation J.190 (2002), *Architecture of MediaHomeNet that supports cable-based services*.

[b-ITU-T J.281] ITU-T Recommendation J.281 (2005), *Requirements for multichannel video signal transmission over IP-based fibre network.*

[b-IEEE 802.3ah] IEEE Std. 802.3ah-2004, *Information technology – Telecommunications and information exchange between systems – Local and metropolitan area networks – Specific requirements Part 3: Carrier Sense Multiple Access with Collision Detection (CSMA/CD) Access Method and Physical Layer Specifications Amendment: Media Access Control Parameters, Physical Layers and Management Parameters for Subscriber Access Networks.*

[b-IETF RFC 768] IETF RFC 768 (1980), User Datagram Protocol.

[b-IETF RFC 791] IETF RFC 791 (1981), Internet Protocol.

[b-IETF RFC 2131] IETF RFC 2131 (1997), Dynamic Host Configuration Protocol.

[b-IETF RFC 2236] IETF RFC 2236 (1997), Internet Group Management Protocol, Version 2.

[b-IETF RFC 2365] IETF RFC 2365 (1998), Administratively Scoped IP Multicast.

[b-IETF RFC 2460] IETF RFC 2460 (1998), Internet Protocol, Version 6 (IPv6) Specification.

[b-IETF RFC 2462] IETF RFC 2462 (1998), IPv6 Stateless Address Autoconfiguration.

[b-IETF RFC 3306] IETF RFC 3306 (2002), Unicast-Prefix-based IPv6 Multicast Addresses.

[b-IETF RFC 3376] IETF RFC 3376 (2002), Internet Group Management Protocol, Version 3.

[b-IETF RFC 3513] IETF RFC 3513 (2003), Internet Protocol Version 6 (IPv6) Addressing Architecture.

[b-IETF RFC 3810] IETF RFC 3810 (2004), Multicast Listener Discovery Version 2 (MLDv2) for IPv6.

SERIES OF ITU-T RECOMMENDATIONS

Series A	Organization of the work of ITU-T
Series D	General tariff principles
Series E	Overall network operation, telephone service, service operation and human factors
Series F	Non-telephone telecommunication services
Series G	Transmission systems and media, digital systems and networks
Series H	Audiovisual and multimedia systems
Series I	Integrated services digital network
Series J	**Cable networks and transmission of television, sound programme and other multimedia signals**
Series K	Protection against interference
Series L	Construction, installation and protection of cables and other elements of outside plant
Series M	Telecommunication management, including TMN and network maintenance
Series N	Maintenance: international sound programme and television transmission circuits
Series O	Specifications of measuring equipment
Series P	Telephone transmission quality, telephone installations, local line networks
Series Q	Switching and signalling
Series R	Telegraph transmission
Series S	Telegraph services terminal equipment
Series T	Terminals for telematic services
Series U	Telegraph switching
Series V	Data communication over the telephone network
Series X	Data networks, open system communications and security
Series Y	Global information infrastructure, Internet protocol aspects and next-generation networks
Series Z	Languages and general software aspects for telecommunication systems

Printed in Switzerland
Geneva, 2007