International Telecommunication Union

ITU-T

TELECOMMUNICATION
STANDARDIZATION SECTOR
OF ITU

J.291
(11/2006)

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

Cable modems

Next generation set-top-box cable architecture

ITU-T Recommendation J.291

ITU-T

ITU-T Recommendation J.291

Next generation set-top-box cable architecture

Summary

This Recommendation describes the cable network architecture component of the next-generation Set-Top-Box (STB). When combined with companion ITU-T Recs J.290 (J.stb-core-a) and J.292 (J.stb-mi-a), the architecture defines a cost-efficient platform with capacity and flexibility to support growth of on-demand video, high definition digital TV, managed in-home networks connecting a wide range of consumer-provided devices, and future IP multimedia services including IP voice, video telephony, and multiplayer gaming. This Recommendation reflects key functional aspects of the next generation cable set-top-box, such as a common application platform and MPEG transport including advanced codecs.

Source

ITU-T Recommendation J.291 was approved on 29 November 2006 by ITU-T Study Group 9 (2005-2008) under the ITU-T Recommendation A.8 procedure.

FOREWORD

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Next generation set-top-box cable architecture

1 Scope

This Recommendation describes the cable network architecture component of the next-generation STB. When combined with companion ITU-T Recs J.290 and J.292, the architecture defines a cost-efficient platform with capacity and flexibility to support growth of on-demand video, high definition digital TV, managed in-home networks connecting a wide range of consumer-provided devices, and future IP multimedia services including IP voice, video telephony, and multiplayer gaming.

2 References

2.1 Normative references

None.

2.2 Informative references

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

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

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

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

– ITU-T Recommendation J.125 (2004), *Link privacy for cable modem implementations*.

– ITU-T Recommendation J.126 (2004), *Embedded Cable Modem device specification*.

– ITU-T Recommendation J.128 (2005), *Set-top gateway specification for transmission systems for interactive cable television services*.

– ITU-T Recommendation J.179 (2005), *IPCablecom support for multimedia*.

– ITU-T Recommendation J.197 (2005), *High level requirements for a Digital Rights Management (DRM) bridge from a cable access network to a home network.*

– ITU-T Recommendation J.200 (2001), *Worldwide common core – Application environment for digital interactive television services*.

– ITU-T Recommendation J.201 (2004), *Harmonization of declarative content format for interactive television applications*.

– ITU-T Recommendation J.202 (2005), *Harmonization of procedural content formats for interactive TV applications*.

3 Terms and definitions

This Recommendation defines the following terms:

3.1 asynchronous time division multiple access (A-TDMA): A variant on the protocol for wireless communication, used in DOCSIS 2.0.

3.2 cable modem termination system (CMTS): Located at the cable television system headend or distribution hub, which provides complementary functionality to the cable modems to enable data connectivity to a wide-area network.

3.3 downloadable conditional access system (DCAS): A technology for downloading conditional access into software on a set-top box; this is an effort under way at CableLabs and due for publication in 2006.

3.4 DOCSIS signalling: DOCSIS signalling as defined in ITU-T Recs J.125 and J.126. DOCSIS is the term for a system or device compliant with any one of the Cable Television Laboratories, Inc. ("CableLabs") series of specifications located at: http://www.cablemodem.com/specifications/.

3.5 DSG: The DOCSIS Set-top Gateway is an interface defining signalling to and from a DOCSIS modem embedded in a cable set-top device.

3.6 Digital storage media command and control (DSM-CC): DSM-CC is for developing control channels associated with MPEG-2 streams.

3.7 Edge QAM: A device that provides QAM modulation to increase capacity in existing legacy cable networks.

3.8 IPCable2Home: The domain in MediaHomeNet that is well bounded and specified based on Internet Protocol Layer 3 interoperability, as opposed to other domains that can be independently, arbitrarily, or privately designed to an individual manufacturer's specification.

3.9 IPCablecom: An ITU-T project that includes an architecture and a series of Recommendations that enable the delivery of real-time services over the cable television networks using cable modems.

3.10 J.200 series: ITU-T Recommendation for Worldwide common core – Application environment for digital interactive television services. J.200 is the common core underlying OpenCable Applications Platform (OCAP) in the United States.

3.11 media gateway control protocol (MGCP): A protocol used within a Voice over IP system.

3.12 multi program transport stream (MPTS): A transport stream with multiple programs.

3.13 OpenCable Applications Platform (OCAP): The middleware standard for United States cable set-tops; J.200 Worldwide common core is a part of OCAP.

3.14 packet identifier (PID): Unique integer value used to identify elementary streams of a program in a single- or multi-program MPEG-2 stream.

3.15 real time transport protocol (RTP): A transport protocol for real-time applications defined in ITU-T Rec. H.225.0. It is designed for real-time transmission of audio and video data.

3.16 Synchronous Code Division Multiple Access (S-CDMA): A variant of the protocol used for wireless communication, used in DOCSIS 2.0.

3.17 session initiation protocol (SIP): An application-layer control (signalling) protocol for creating, modifying, and terminating sessions with one or more participants. These sessions include Internet telephone calls, multimedia distribution, and multimedia conferences.

3.18 simple object access protocol (SOAP): A lightweight, XML-based protocol for exchange of information in a decentralized, distributed environment.

3.19 single program transport stream (SPTS): A transport stream in which there is a single program.

3.20 telemetry service: Remote monitoring of data for purposes such as energy management or security in the home.

3.21 universal plug and play (UPnP): Set of standards for device and content discovery on home networks, promulgated by the UPnP Forum.

4 Abbreviations and Acronyms

This Recommendation uses the following abbreviations:

CMTS	Cable Modem Termination System
CPE	Customer Premises Equipment
DRM	Digital Rights Management
DSG	DOCSIS Set-top Gateway
DSM-CC	Digital Storage Media Command and Control
GigE	Gigabit Ethernet
HD	High definition
HDTV	High definition TV
IP	Internet Protocol
IPCMM	IPCablecom Multimedia
MAC	Media Access Control
MGCP	Media Gateway Control Protocol
MPEG	Motion Picture Experts Group
MPTS	Multiple Program Transport Stream
NCS	Network Call Signalling
NGHE	Next Generation Headend
OCAP	OpenCable Applications Platform
PID	Packet Identifier
QAM	Quadrature Amplitude Modulation
QoS	Quality of service
RTP	Real Time Protocol
SCTE	Society of Cable Television Engineers
SD	Standard Definition
SOAP	Simple Object Access Protocol
SPTS	Single Program Transport Stream

SVD	Subscriber Video Device
UPnP	Universal Plug and Play
USB	Universal Serial Bus

5 Integrated multimedia architecture

Note that the numbering of the clauses in this Recommendation is intended to integrate with the clause numbering in ITU-T Rec. J.290. Also note that the requirements in this Recommendation are in addition to those in ITU-T Rec. J.290.

5.1 Reference architecture description

The reference architecture is described in ITU-T Rec. J.290.

5.2 Attributes of an integrated multimedia architecture

5.2.1 Video services architecture

At a minimum, cable-compliant CPE will have the following attributes.

- *DOCSIS Signalling*. All cable STB devices are two-way, using mature low cost DOCSIS 2.0 technology as foundation for two-way communications. See ITU-T Recs J.122, J.125 and J.126.
- *Cable Video Transport*. Will use MPEG encapsulated inside IP over DOCSIS.

5.2.2 IP multimedia architecture

- *Extension of established Recommendations*. Sets directions to extend and adapt IPCable2Home, IPCablecom, and IPCablecom Multimedia to support NG-stb requirements, building on previous investments in these programs.

5.2.3 Network segment: Customer premises

- *Subscriber Video Devices (SVDs)*. SVDs are cable-compliant video devices that include a tuner, such as set-top or set-back units or standalone digital TV sets (DTVs). A baseline (low end) SVD is defined with minimum required cable network functionality. Higher-end SVDs include various step-up options at the discretion of suppliers, network operators, and retailers. Baseline SVD functions and examples of step-up options are listed in Table 1.

Table 1/J.291 – Baseline and extended SVD functionality

Baseline SVD functionality	Optional step-up SVD functions (examples)
• Multiple tuners, capable of supporting any cable video transport mode or DOCSIS • Two-way (reverse path) via DOCSIS 2.0 • Support for multiple transport modes • Support for decoding MPEG-2 (SD and HD) plus H.264 • In-home networking connectivity as a client • Downloadable CA • Capability for J.200-Series Recommendations including OCAP middleware • Standard definition output • High definition output • Analog RF output interface with copy protection • Digital output interfaces with copy protection; requirements as described in ITU-T Rec. J.197. • OEM provided universal remote control capable of controlling the SVD and the legacy TV • Supports J.83 QAM downstream modulation • Includes general purpose USB-2 and/or Ethernet port for in-home networking connectivity and possible unspecified peripheral connection	• High definition output • Copy-protected digital interfaces (e.g., HDMI, DVI) • Built-in gateway (client, server, and IP address management) function between access and in-home networks • DVR baseline functionality • IPCablecom telephony features • Support for decoding SMPTE 421M (VC-1)

- *Rights management*. Cable CPE devices respect and protect rights of content owners over the use of their high-value content.

5.2.4 Network segment: Outside plant

- *Mid-split plan*. Upstream bandwidth in most current cable systems is very limited. As a result, many operators have difficulty in accommodating the very rapidly growing demand for upstream services and consider an upward shift in the point of division between upstream and downstream bandwidth. It is thus important that CPE of the future be able to accommodate a change in the use of the frequency spectrum.

5.2.5 Network segment: Head-end

- *Next generation head-end*. Logical partitioning of the CMTS to facilitate unbundling, providing more efficient use of network resources and flexibility to network operators to select the best subsystems from multiple suppliers. Definition of interfaces between CMTS components and integration of these components with other parts of the head-end. Includes unbundling of the data switching portions of the CMTS from the RF modulation portions, thereby allowing for sharing of the edge QAM resources among multiple services. Supports switching of both data and RF to enhance reliability through facility redundancy.
- *DOCSIS 3.0 Channel bonding*. Defines requirements for DOCSIS support based on the bonding of "N" DOCSIS channels to increase the data rate.

5.3 Video services architecture

The cable features of video services architecture include:

5.3.1 DOCSIS signalling (J.128)

It employs DOCSIS throughout to facilitate remote management services.

5.3.2 Security card

If a cable SVD employs a Security Card, the interface shall implement renewability and configurability in compliance with SCTE-41. Additional next generation copy protection methods will also be considered.

5.3.3 Edge to subscriber premises

The cable network architecture envisions three alternative means to carry audio/video data between the head-end edge (e.g., QAM or CMTS) and the subscriber premises. The video data will be compressed via MPEG-2 or an advanced encoding scheme described below. Audio data will be in MPEG-1 Layer 3, or an advanced audio encoding scheme. The three possible transport methods are:

- **Baseline: MPEG-2 transport over QAM**

  MPEG-2 Multiple Program Transport Stream (MPTS) over QAM is the conventional approach used in today's digital cable system. In order to maintain backward compatibility, the digital subscriber video device (SVD), or next generation video CPE, shall be able to process MPEG-2 transport over QAM for both broadcast and on-demand applications. The transport stream payload may be MPEG-2 audio/video or an advanced codec compressed stream.

- **Extended 1: MPEG-2 transport multiplexed with DOCSIS**

  In this approach, the MPEG-2 transport stream (DOCSIS downstream transmission convergence sub-layer) is used to multiplex audio and video program information with DOCSIS data. The well-known PID 0x1FFE is used for MPEG-2 transport packets carrying the DOCSIS payload (as defined in the DOCSIS specifications), and other PIDs are used for various audio, video and data streams. The cable network architecture envisions that this video transport approach can be used in addition to the baseline MPEG-2 transport over QAM approach to support advanced video-based multimedia services that are integrated with data over cable services.

- **Extended 2: Video and audio over IP/DOCSIS**

  In this approach, video is carried over IP and delivered over DOCSIS channels. This allows future services such as IP-based streaming media to the digital SVDs. The audio and video data may be carried in any of these formats:

  – MPEG-2 transport packets over IP over DOCSIS;

  – MPEG-2 transport packets in RTP payloads over IP over DOCSIS;

  – RTP (or other real-time IP timing protocol) payloads over IP over DOCSIS.

  The receiving CPE should be able to process streams delivered in any of the three formats.

It is required that the subscriber terminal shall support all three transport methods, Baseline, Extended 1, and Extended 2 (see Figure 1).

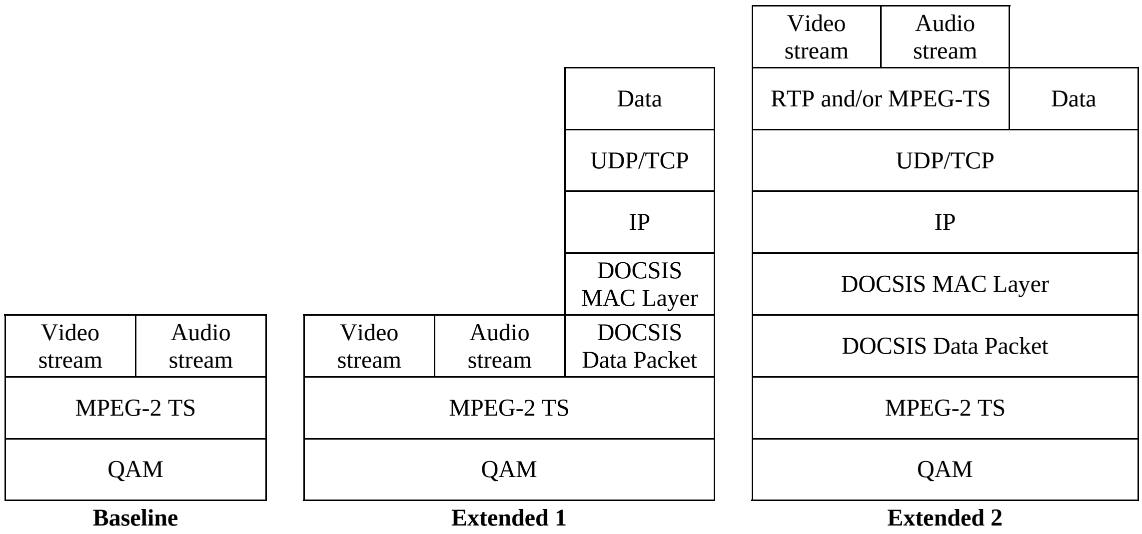


Figure 1/J.291 – Alternative video transport approaches

5.3.4 Video transport

Digital video and audio streams are typically carried over MPEG-2 transport streams. Both Single Program Transport Stream (SPTS) and Multiple Program Transport Streams (MPTS) may be delivered at various segments of the system. MPEG-2 Program Specific Information and ATSC/SCTE defined Service Information (ITU-T Rec. J.94 SI) are used at the MPEG transport layer.

5.4 DOCSIS signalling

The cable network architecture includes multiple roles for DOCSIS including secure signalling for all CPE and alternative transport of video. For multimedia services, DOCSIS supports streaming media for which QoS is an important factor. DOCSIS transport and DOCSIS set-top gateway (DSG) protocols support secure software download and remote configuration management of SVD subsystems enabling:

- Configuration of the DCAS processor;
- Download of renewable firmware for basic control of the devices;
- Remote configuration of the video decoder algorithm;
- Download of applications designed to run on J.200-Series Recommendations including OCAP middleware; and
- Session management traffic for interactive content such as VCR-like controls for VoD.

Important additional benefits of employing DOCSIS are its native features for remote management from customer support systems and operations support systems. Consistent with IPCable2Home (J.19x), this capability allows all CPE to be visible from the head-end.

5.4.1 Transport

In the HFC access network, the reference architecture calls for the use of DOCSIS as the underlying transport mechanism.

5.4.2 Access network QoS

The IPCablecom Multimedia Recommendation (ITU-T Rec. J.179) defines an application-agnostic technology framework for providing session-based dynamic QoS-enhanced network services over a DOCSIS 1.1 (or later) access segment.

A fundamental prerequisite to the deployment of the IPCablecom Multimedia framework is the availability of a DOCSIS 1.1 (or later) segment. DOCSIS 1.1 added MAC-layer support for Dynamic QoS. To facilitate the delivery of multimedia sessions requiring QoS guarantees, the IPCMM framework levers these DOCSIS mechanisms and expands upon the architecture to support general-purpose Dynamic QoS functionality based on mechanisms defined in the core DOCSIS 1.1 and IPCablecom voice specifications. While IPCablecom Multimedia is based on mechanisms defined in IPCablecom, it is important to note that a pure IPCablecom Multimedia deployment requires no IPCablecom network elements.

Several key network elements and interfaces have been identified and profiled within the IPCablecom Multimedia specification, ITU-T Rec. J.179.

While no session establishment protocol is defined in IPCablecom Multimedia (i.e., it is application agnostic), the cable network architecture recognizes the prevalence of SIP in many of today's multimedia applications. One of the goals of the architecture is to support a wide variety of applications and their associated session establishment mechanisms. The cable network architecture will implicitly support SIP in addition to other application-specific session establishment mechanisms.

SIP-based applications can take advantage of access QoS in one of two ways. For basic QoS-unaware devices, it may employ a 'push' QoS model where the SIP Proxy server makes a QoS request for access resources on the client's behalf. An alternative approach is to employ a 'pull' model where the SIP client contains more intelligence and requests its own access resources (pulling them from the network). Both of these approaches are currently defined in the IPCablecom Multimedia Architecture Framework (ITU-T Rec. J.179). While the 'push' method is currently supported by the IPCablecom Multimedia Recommendation, the 'pull' method is not.

Informative note – The 'pull' method will be introduced when in-home and access QoS are bridged via UPnP.

5.5 Use of coax for in-home networking

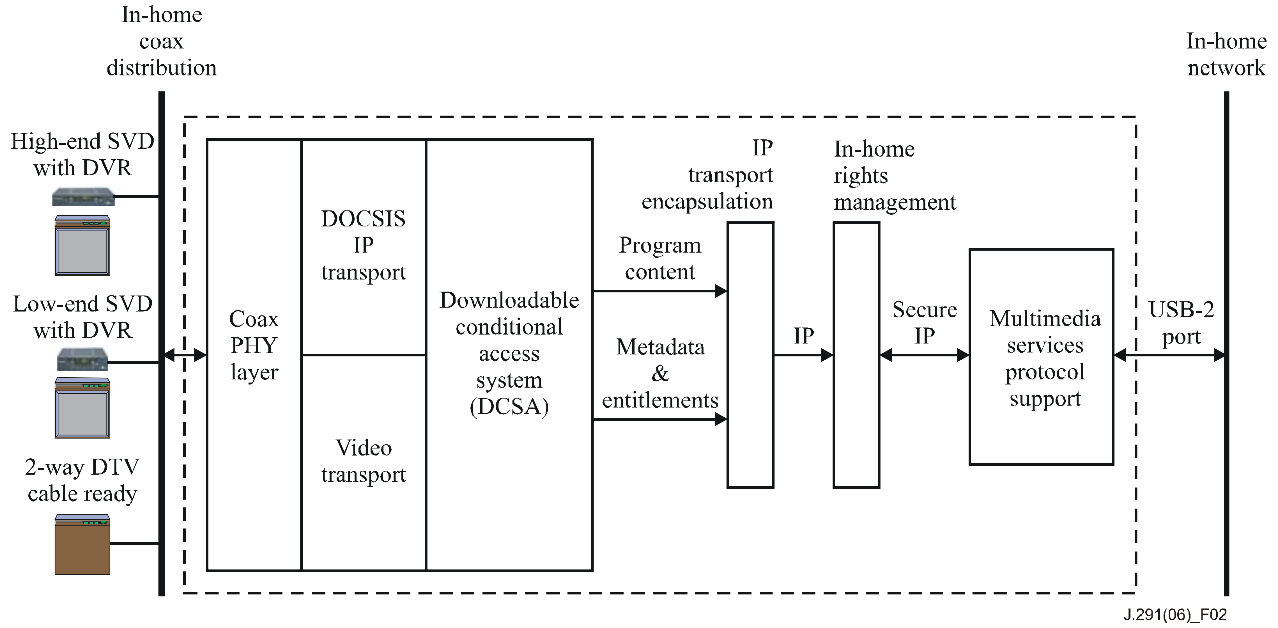
Coaxial cable is an attractive physical layer for in-home networks. It is generally present in many rooms in the house and has ample bandwidth to support a myriad of bandwidth-hungry services.

An important issue in using the coax for in-home communications is ensuring that in-home network signals do not interfere with current or future services being offered through the coaxial cable from the cable company. In addition to frustrating the customer by preventing access to cable services, such interference could affect other cable subscribers on the same cable network segment/node.

For this reason, any in-home coax physical layer must respect and be compatible with the outside plant physical layer in terms of upstream and downstream spectrum, and with signal levels within the dynamic range of the plant; this can be accomplished via interaction with the head-end to ensure compatible use of spectrum (preferred) or through isolation of the home coax segment from the outside cable plant. In the latter instance, such isolation may interfere with delivery of future cable services and also generally requires installation of an isolating element, such as a filter, near the point of entry to the home, which can be inconvenient.

The cable architecture assumes that the in-home coax physical layer operating parameters are visible to and may be managed by head-end systems to ensure compatible use of spectrum. The reference design assumes that the head-end provisions the in-home physical layer with these operating parameters, e.g., upper and lower spectrum boundaries, and that once provisioned, the in-home coax physical layers operate within the limits defined by the head-end.

With regard to the in-home physical layer, the MAC layer must mediate traffic between devices on the in-home coax network. The cable architecture assumes that all devices on the in-home coax network are peer devices and that once these devices are provisioned by the head-end, they can share the in-home coax physical layer without any centralized management. The cable architecture reference design assumes a MAC layer protocol that operates in a peer-to-peer distributed fashion to prioritize traffic so as to maximize the user experience. For example, a protocol should be capable of assigning higher priority access to the media to streaming video traffic between devices on the in-home coax network than to delay-insensitive data traffic.



NOTE – Figure 2 is identical to Figure 5 in ITU-T Rec. J.290, except for addition here of DOCSIS IP transport.

Figure 2/J.291 – Gateway communications architecture

5.6 Telemetry services

It is anticipated that next generation networks will support telemetry and control applications such as home security, remote health monitoring, and energy management. These services could be deployed to any home passed by the cable infrastructure, regardless of a home's current subscription status. The network should be able to support potentially large-scale deployments of endpoints that receive a constrained service set. To illustrate this further, consider the example of a remote meter reading service customized for use with a contracting utility. The meter would generate very low rate IP telemetry which could be carried over the broadband network from the source in the home (the electric meter) to the data aggregator (within the utilities' domain). The system will restrict data flows to those required for the application (in this case the electric meter and the data aggregation server) and prevent any unauthorized use of the network. The cable operator would ensure a monitored and robust connection to bring the meter data to the utility. The utility would deploy the equipment to every home in a geographical area.

6 Customer premises

Table 2 summarizes key features and attributes of cable-specific CPE devices, above and beyond those found in Table 3 of ITU-T Rec. J.290.

Table 2/J.291 – CPE feature overview

	Baseline SVD	Extended SVD (non-gateway)	Extended SVD (gateway)	Media client
DOCSIS 2.0	✓	✓	✓	
Tuner support	✓	✓	✓	

6.1 Subscriber Video Devices (SVDs)

- Basic support for in-home networking is provided by the presence of a USB 2.0 port. Various networking attachment can be connected to this port to provide PHY/MAC layer functionality for different in-home networking architectures (e.g., Ethernet, WiFi, coaxial cable).
- A companion universal remote control is provided that can be additionally configured by the subscriber to operate an existing TV and/or VCR. The remote control should support IR technology at a minimum, with RF support being optional. In addition, the remote control shall be compliant with the J.200-Series Recommendations including OCAP requirements for remote control devices.

7 Head-end network architecture

Consistent with the vision of cable network architecture as an integrated multimedia architecture, head-end integration will represent a significant departure from cable systems' traditional independent head-end "stovepipes" for video, data, and telephony. Benefits of integration will include:

- More efficient use of system resources (e.g., spectrum allocations, QAM streams);
- Facilitate interworking of network elements supplied by multiple vendors to enable more open competition, to extend the service life of the installed base, to provide flexibility for new service introductions, and to provide scalability to accommodate a range of system sizes;
- Provide a platform for innovation and rapid service creation that involves cross-over access among the former service stovepipes (e.g., viewing movies on a PC or caller ID on a TV).

Figure 3 describes the overall head-end network delivery architecture.

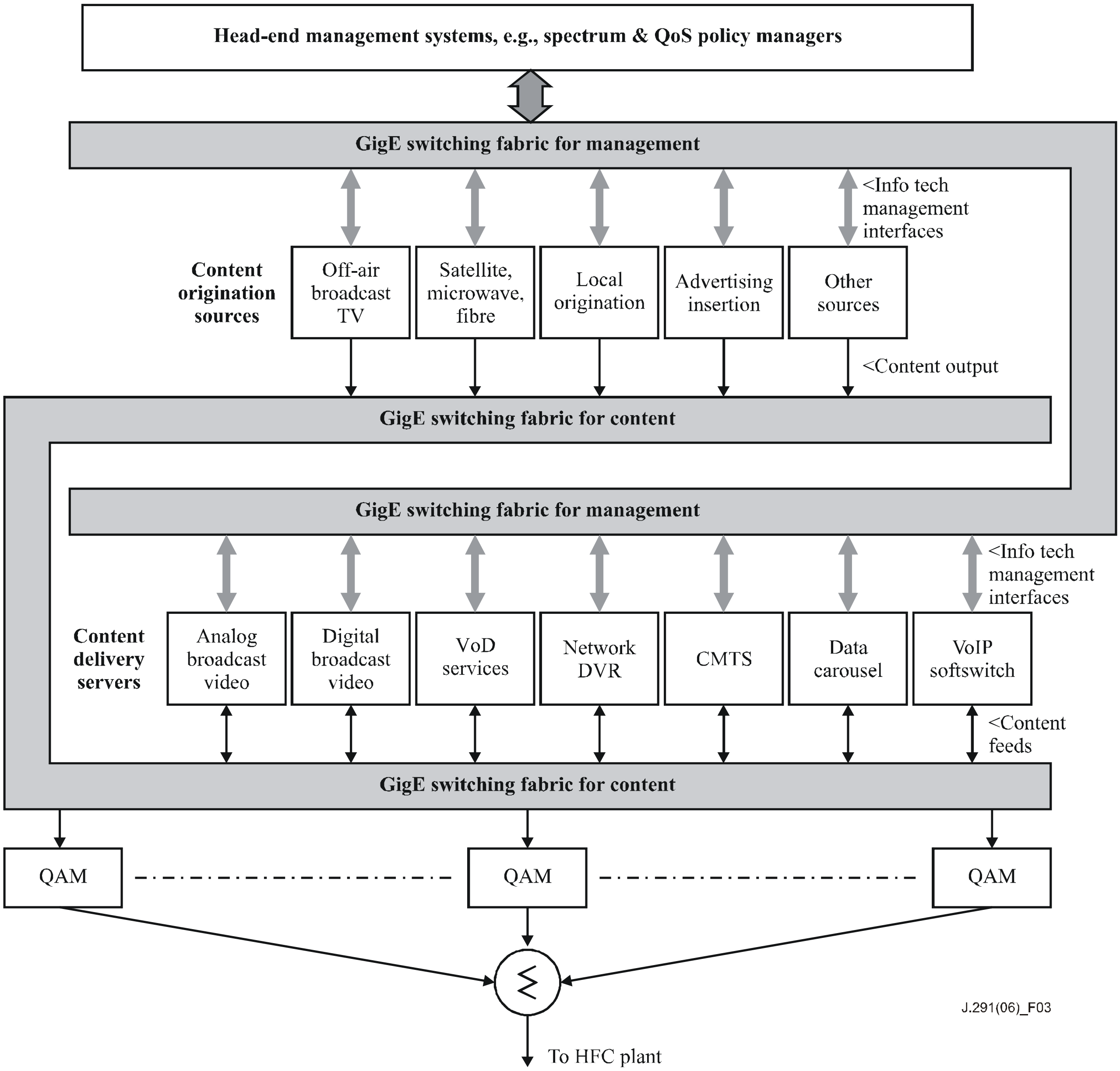


Figure 3/J.291 – Head-end network architecture

Key next generation features of head-end network architecture include:

- The head-end network enables the delivery of digital video traffic (encoded as MPEG transport streams) and generic IP datagram traffic (encapsulated in DOCSIS frames) over a common head-end network infrastructure.
- Applications are managed across all services by session and resource management systems, which shall have capability to operate autonomously in the event of communications failure with back-office systems.

- The control and RF aspects of the head-end servers are separate so that common third party resource management and network operations applications can manage the head-end as an integrated system rather than as standalone service-specific subsystems.
  - *QAM modulators*: QAM modulators are separate from head-end servers such as VoD servers and the CMTS DOCSIS MAC, and each CMTS and Edge QAM is equipped with a GigE compatible data interface. Next generation, multi-channel, shared-upconverter edge QAMs will operate in the cable environment without causing impairment or degradation to the physical plant beyond what would be seen by adding that same number of simple single unit QAM modulators. Modified DOCSIS specifications will codify the edge QAM RF output parameters necessary to maintain the integrity of the RF plant.
  - *GigE switching fabric for content*: The GigE switch fabric will be under the control of a network resource manager for content distribution and will ensure that any server can have data switched to any QAM stream and that any content source can switch easily between content servers.
  - *Session and Resource Management system*: Application managers, session managers and resource managers will have functionality that gives the operator the ability to control and monitor traffic loads, QoS needs, and subscriber entitlements, and will have policies and algorithms to dynamically assign spectrum and QAM stream resources in the most efficient matter.
  - *Ethernet or GigE switching fabric for management*: The switching fabric will provide a standard management plane interface by means of an Ethernet or GigE switching fabric so that each service can be managed and controlled by external IT management systems via open APIs.
  - IP, DOCSIS, and DSG (DOCSIS Set-top Gateway, for downstream-only communication) are used for the network transport of control and management messages to CPE. The set of signalling protocols for video-based services is likely to include DSM-CC (Digital Storage Media – Command and Control), RTSP, SIP, NCS/MGCP, and potentially XML-based "web services" protocols such as SOAP.

The following clauses provide additional details on the separation of QAM modulators from the DOCSIS CMTS, and on the architecture for session and resource management.

7.1 Evolution of the DOCSIS CMTS and QAM modulators

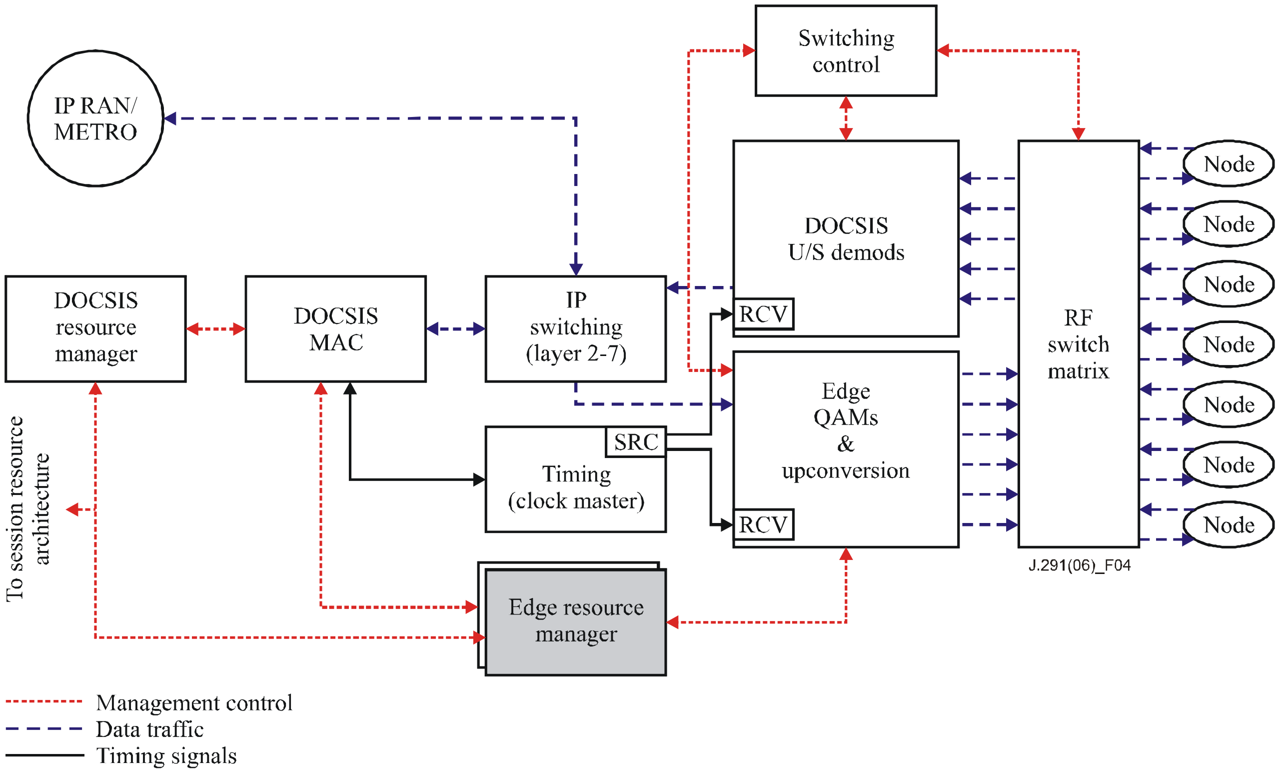


Figure 4/J.291 – Next generation head-end network architecture

Figure 4 shows the functional components and their linkages. Several components in this figure are considered as optional, including the RF switch and external timing interface. Components identified in Figure 4 are described below.

- **Edge resource manager**

The purpose of the ERM is to manage the allocation of Edge QAM resources for multiple applications such as VoD, DOCSIS, digital broadcast, etc. It is not intended to be inclusive of the inherent MAC processing that currently resides in today's CMTS.

- **DOCSIS Upstream (U/S) termination/demods (CMTS)**

In today's architecture, the purpose of the CMTS is to be the inclusive DOCSIS processing and Data distribution platform. To ensure the goal of facilitating the development of enhanced delivery systems, the CMTS will undergo several changes. One of the primary changes is separating the PHY (modulator and demodulator) and the DOCSIS MAC into separate devices. The MAC and PHYs in the cable network architecture are connected via a low latency non-blocking switching network. The remaining CMTS functionality, such as scheduling, is included in the "DOCSIS MAC" component in the next generation headend architecture.

- **DOCSIS MAC**

As shown in Figure 4, the DOCSIS MAC functions will remain the same. Features such as BPI+ processing, Packet Header Suppression, MAP Generation, and other DOCSIS centric features, will happen at the central MAC. However, physical location of this functionality can vary, based on scalability needs and other implementation scenarios.

- **Edge QAM**

Current Edge QAM devices handle both narrowcast and broadcast services received as MPEG-2 frames (carried over UDP). The Edge QAM depicted in the cable network architecture will additionally need to receive downstream DOCSIS frames (carried in MPEG-2 transport over UDP). Provided to the Edge QAM, is an external timing interface that supports the sync time stamps needed in order to meet low latency and jitter requirements currently listed in the DOCSIS specifications.

- **IP switching (Layer 2-7)**

While not representing a drastic HW/SW departure, existing platforms can be levered with minor extensions to support low latency timing requirements. This component should be able to handle hundreds of gigabits worth of traffic, have distributed processing, flexible physical interfaces, as well as robust L3 features.

- **Timing**

The timing block function is to distribute a common timing source to the Edge QAM, DOCSIS MAC, and DOCSIS US termination blocks. A common timing reference may be needed to meet the DOCSIS jitter requirements. As depicted in Figure 4, the upstream (U/S) and downstream (D/S) timing source should be coherent in order to support both A-TDMA and S-CDMA which are required within the existing DOCSIS 2.0 specification. Although jitter and latency requirements are less stringent in A-TDMA, the requirement for both A-TDMA and S-CDMA capable systems will remain a component of the cable network architecture.

- **RF switch matrix and control**

The purpose of the switch matrix is to provide an N to 1 fault tolerant capability, which provides one redundancy circuit in case that one of N circuits fail. The switch control functions in concert with the PHY blocks work to deliver a "hitless" failover in the event of an Edge QAM or DOCSIS US failure. The switch matrix also allows all RF cabling from the plant to terminate at a common point that does not require re-cabling if any component in the Edge QAM or DOCSIS US needs replacement. The RF switch matrix is optional in deployments.

Although the diagram depicts the RF switch as a means to increase availability, alternative means to achieve high availability are acceptable.

- **DOCSIS 3.0 channel bonding**

The near-term need to increase bandwidth, especially on the downstream, can be achieved via the implementation of DOCSIS 3.0 channel bonding. This feature, where multiple 6 or 8 MHz channels are bonded, can significantly increase throughput over existing DOCSIS specifications. A DOCSIS 3.0 implementation will be backward compatible to existing DOCSIS 1 (ITU-T Rec. J.112) and DOCSIS 2 (ITU-T Rec. J.122) specifications. The primary component impacted by a DOCSIS 3.0 implementation (with a downstream implementation) is the DOCSIS MAC.

DOCSIS specifications will need to be updated to reflect the fact that high-density edge QAMs are coming into use. High-density edge QAMs are QAM modulators with multiple, contiguous RF channels being sourced by a shared upconverter via a common connector. DOCSIS downstream RF characteristics are all contained in the table named, "CMTS Output" in ITU-T Recs J.112 and J.122. The number of channels in a block served by a single upconverter should be reflected in the RF specifications in the updated "CMTS Output" table. In no case should the specifications reduce the requirements for a single channel CMTS. Instead, the specifications should be updated to reflect the more complex situation of power addition from the multiple RF sources contributed by a single upconverted block of channels including both spectrally aggregating and spectrally non-aggregating spurious and noise components.

7.2 Session and resource management architecture

In order to satisfy the desire for common resource management across all services/applications, a framework for session and resource management is needed, as shown in Figure 5.

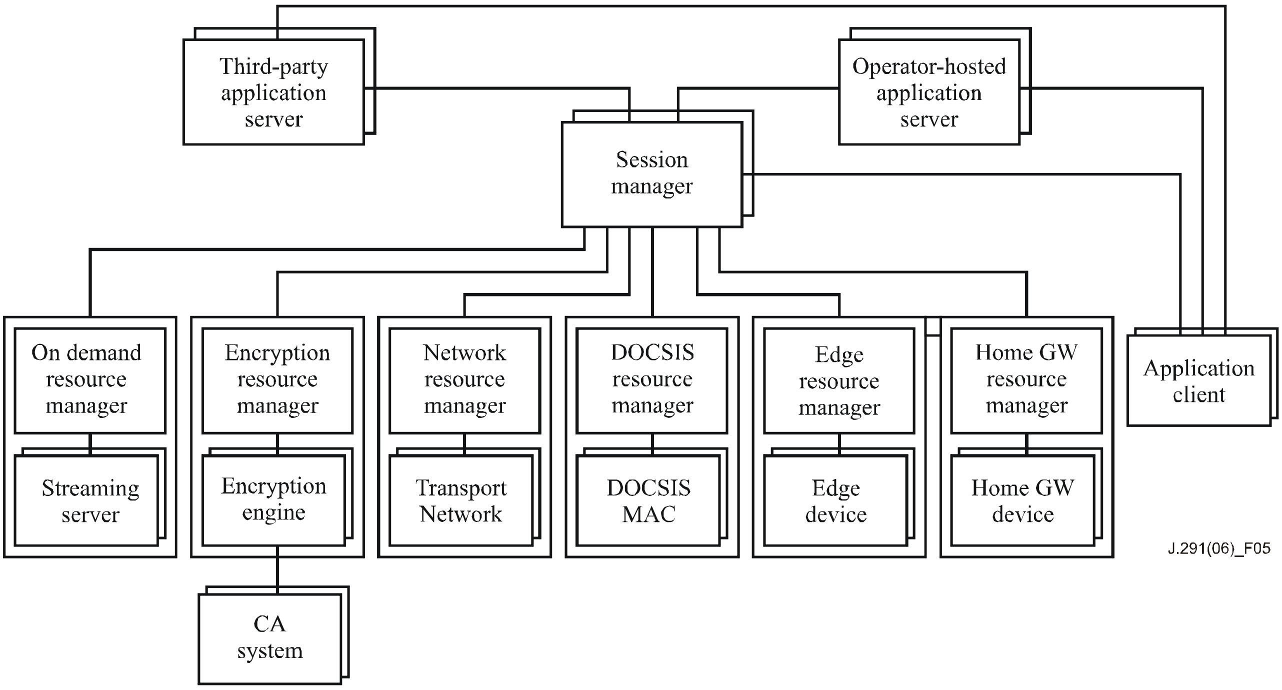


Figure 5/J.291 – Session and resource management framework

To increase efficiency in use of resources, the next generation head-end employs a session-based resource management architecture. Creation of such an architecture requires close control of the resources to ensure their efficient use. In an attempt to provide a generic framework, the session and resource management function is split into three domains: Application, Session and Resource Management. Each of these domains is discussed in detail in the following clauses.

7.2.1 Application manager

An Application Manager plays a coordinating role involving application signalling as well as interaction with the Head-End resource management framework via the Session Manager. In most cases the Application Manager is expected to be owned and operated by the cable operator. However, there may be cases where the Application Manager is in fact outside the cable operator's control. Examples of operator-hosted Application Managers would be VoD services and telephony services. Examples of third-party Application Managers could be streaming audio/video, and gaming services.

In a VoD system, it is the session manager's responsibility to maintain and manage the life cycle of session rather than the application manager. For such cases, the client can set up a session directly with session manager or proxy through the Application Manager. Since the Application Manager does not need to manage the session itself, this architecture allows for different applications to use the same session manager for multiple on-demand services.

For IP-based applications and services, the typical implementation actually integrates the session manager into the application server; while they may reside in the same physical box, they are considered logically separate.

7.2.2 Session manager

The role of a Session Manager is to broker head-end resource requests on behalf of the Application Manager. While an Application Manager only knows the QoS needs for the session, the Session Manager needs to understand how to translate those QoS needs into the various system resources as well as identify non-QoS based resources the session may also require (i.e., encryption resources, server resources). Since each operator network is expected to be a variation of the reference architecture, it is also the responsibility of the session manager to understand what resources are available in the system and choose the proper resources based on the specific applications needs.

To accomplish these tasks, Session Manager needs to understand the system topology and all the resources that are available to a session and then determine which resources are appropriate. While a system may have numerous resources available, a basic service such as switched video will only need to take advantage of subset of those resources. In order to facilitate the Session Manager in determining the resources needed, the Application Manager will provide application-identifying information in its request allowing the Session Manager to 'look up' the associated application resource needs. This frees the application manager to be unaware of the system topology and resources and to focus on managing applications and services.

It is important to note that multiple instances of a Session Manager may exist in a given head-end and each Session Manager communicates with a set of Resource Managers. The set of Resource Managers a Session Manager communicates with is determined by the applications for which the Session Manager is expected to handle resource requests. Such an architecture allows for more rapid introduction of new services by not requiring a central 'super' session manager to be upgraded every time a new service is trialled. It is envisioned that a given Application Manager will talk to a single session manager except where redundant Session Managers are implemented. Session managers need not be able to support all session types; in fact, it is likely that separate session managers will be deployed for different types of sessions, e.g., VoD versus DOCSIS versus switched broadcast.

The session manager will not make business-based policy decisions. Rather, it will coordinate application resource needs acting under the assumption that the request comes from a valid device and from a subscriber authorized to request such services. It may make resource-based policy decisions based on the current status of the system resources, i.e., it may decide to reject a request if the resources are unavailable, or it may decide to pre-empt an existing session in favour of a new session.

7.2.3 Resource manager

The Resource manager deals primarily with allocating the resources necessary to satisfy a session request. Each head-end resource will have an associated (logical) Resource Manager. It is the Resource Manager's task to track all consumption of resources and allocate new resources as needed. Examples of resource managers are:

- On Demand Resource Manager – Streaming Server resources.
- Encryption Resource Manager – Stream Encryption resources.
- Network Resource Manager – Switched IP Network resources.
- DOCSIS Resource Manager – DOCSIS MAC resources.
- Edge Resource Manager – QAM resources.
- Home Network Resource Manager – In-Home Network resources.

A Session Manager will translate and forward an Application Manager's QoS request to a given Resource Manager. The Resource Manager will then determine if the resources are available to grant the request and assign them if they are. For example, an Edge Resource Manager may get a request for a 3 Mbit/s stream; if it has resources available to grant this request, it will tell the Session Manager which resource to use.

To further explain the Session and Resource Management Framework, the following two examples are provided:

- When a CMTS (DOCSIS MAC) comes on line, its configuration will tell it how much bandwidth it should request. The CMTS will then make a request for edge QAM and Transport Network resources to satisfy its configured bandwidth. In this case the CMTS is acting as a combined Application/Session Manager and as such communicates directly with the resource managers.
- In contrast, a VoD service follows the following flow: The client starts the session by making a request for a VoD asset to the Application Manager. Upon receipt of such a request, the Application Manager will forward the request to the appropriate Session Manager who will then determine the overall resource requirements for the session. Once the session resources have been determined, the Session Manager will negotiate with multiple Resource Managers to obtain the corresponding resources. These may include (not necessarily in any order) server resource, network resource, encryption resource, and edge resource. For example, the edge resource allocated may be dependent on the required bandwidth and service group the client belongs to. The server resource allocated may be determined by where the VoD asset is located. And the network resource manager will determine a network path from the server to the edge.

Appendix I

Business requirements for the cable network architecture

This appendix may be considered informative only. Several business requirements have been taken into account in considering next generation network options, and it may be helpful for implementers to be aware of them. These items include the following:

Expanded capacity

As cable operators add new services, demands for network capacity continue to increase. The next generation network will need to support expanding requirements for video program services, including high-definition services; on-demand video services; high speed data services involving enhanced downstream data rates and symmetrical upstream capacity; and IP multimedia services.

R1. Provide sufficient capacity for foreseeable downstream and upstream applications, tools to manage available capacity efficiently, and low cost means to add capacity as required.

Solutions based on open standards or economically licensable terms

Solutions that are non-proprietary and/or openly licensable on economically favorable terms will be favoured as a means to ensure interoperability of equipment from multiple suppliers, to allow greater vendor participation in the market, to reduce cost, to increase innovation, and to support retail sale of customer premises equipment. It is desirable that interfaces be based on existing open standards wherever they apply and in areas lacking existing standards, it will be desirable to create open standards. It may be necessary to provide extensions to existing standards as long as the proposed extensions are open, i.e., they can be implemented by vendors with preferably no licensing costs, or on reasonable and non-discriminatory terms where there are significant intellectual property rights involved.

R2. Favour network elements and interfaces that adhere to non-proprietary standards and/or are openly licensable on economically favorable terms.

Exploit existing assets

A key objective is to expand available capacity to meet anticipated service requirements within the current typical cable system bandwidth up to 750 MHz for downstream transmissions. The next generation network also needs to continue to support multiple existing legacy assets, e.g., digital set-top boxes that use proprietary conditional access and out-of-band signalling.

R3. Achieve network objectives without additional rebuilds of cable outside plant or stranding of legacy subscriber CPE (customer premises equipment).

Secure rights management

Secure rights management of valuable content will encourage expanded participation by content providers in cable-provided services and support introduction of innovative new services and new business models. Content will need to be protected as it is networked among cable-managed devices in subscriber households.

R4. Protect valuable content within subscriber households and provide flexibility for new business models.

Network resource sharing

The next generation network needs to share network resources across services to enhance efficiency in the use of cable network assets. For example, QAM resources can be shared with dynamic provisioning by different services.

R5. Enable shared use of network resources.

Managed subscriber devices

Home networks for video, data, and interactive multimedia services represent an important component of the next generation network. For example, media servers will be sharable across multiple home devices including subscriber video devices and Internet appliances. Further, to enable cost-effective configuration, provisioning and management of the widest variety of possible CPE devices in subscriber households, these devices will need to support automatic discovery and remote monitoring and control. Remote monitoring includes both the health of the device as well as the health and performance of the individual services that the CPE supports or transits. To accommodate potential new arrangements with third-party transaction or content providers, it will also be desirable for CPE to enable usage accounting.

R6. Provide device auto-discovery, monitoring and control, and usage accounting, to support cable operator management of CPE in subscriber households. Provide performance monitoring and exception alarming on a service-by-service basis. Build on and extend elements defined in the IPCable2Home project.

Cable competitiveness

A key requirement for the next generation network is to enable cable operators to differentiate their services, or at minimum ensure competitive parity, in terms of features, functions and cost, versus offers from digital DBS providers, telephone companies and other competitors.

R7. Enable cable operators to maintain and build competitive advantages.

Scalability

The next generation network must be capable of cost-efficient growth to support additional services, new subscribers and/or increased simultaneous usage of on-demand and interactive services.

The architecture also needs to be able to scale "down" to work cost-effectively in smaller systems.

R8. Scalability. Enable cost-effective expansion of services and also work cost-effectively in smaller systems.

Flexible service delivery

Cable operators will need flexibility to rapidly provision and support new services with equipment, features, and pricing tailored to the disparate needs of the wide range of subscriber households. Such new services may involve different business models than those currently offered.

Operators also will need flexibility for cross-service promotions, for example to be able to offer free movies for upgrading data service.

The next generation network will be a platform for launching many new services and will need to be easily extensible to add such services without stranding earlier investments.

The next generation network also will need to accommodate new compression and transmission standards, for example allowing cost-efficient evolution from currently-deployed MPEG-2 video compression to standards offering equivalent video quality at much lower bit rates.

R9. Support rapid provisioning of new services and systems without stranding earlier investments.

Alignment with external technology

The next generation network should exploit the technologies that will most benefit from continued innovation and cost reductions, for example, the continuing gains in digital signal processing, memory, and optical communications systems. Innovation and cost reductions are expected in particular for non-proprietary technologies subject to competitive market forces and the focus of R&D efforts from direct and indirect suppliers.

Next generation network plans need to be based on technology assumptions that are realistic in terms of timing, capabilities, and cost.

R10. Deploy network solutions that will most benefit from technology trends (capabilities, cost) and R&D efforts, and that rely on realistic technology assumptions.

Support for retail sale of cable CPE

The next generation network needs to expand consumers' choices of CPE, including retail purchase of consumer electronics, PCs, and other devices that could connect to cable networks directly or indirectly. Such devices should work seamlessly in providing cable services along with network operator-provided CPE, in accordance with agreements between the cable industry and consumer electronics manufacturers, and with government regulations.

R11. Design for CPE product competitiveness and retail incentives to enhance competitiveness of cable-ready products in retail outlets.

Minimize operations burden

Next generation network solutions will be evaluated in terms of overall cost and operational implications including effects of new systems on operations in the field or back-office. Solutions with lower operational costs and lower complexity will be viewed favourably. It is anticipated that in many cases the next generation architecture should reduce cable operators' operational cost and complexity.

R12. Limit additional or complex tasks for field operations or back-office personnel.

Support for authorized third-party use

Cable TV systems currently serve as channels for third-party content providers under distribution agreements with the cable operators. The next generation network's increased capacity and capabilities will expand cable operators' opportunities to partner with third-party content and transactions providers. It is important that the next generation network provide the means for cable operators to encourage and support authorized uses, including authorized third-party use, while protecting the cable network from unauthorized third-party uses that may disrupt, impede or impair the authorized services offered to cable subscribers.

R13. Enable partnering incentives for third-parties to deploy authorized applications and services.

Satisfy performance criteria

The next generation network will need to satisfy quantitative performance criteria in terms of capacity, reliability and latency for the services or applications carried by the network. The ability of proposed solutions to enable measurable Service Level Objectives and Service Level Agreements is an important aspect of the next generation network.

R14. Achieve performance requirements, including the ability to measure performance, as defined for specific services and applications.

Alignment with network operator financial objectives

Each network investment will be evaluated on whether it represents the lowest possible overall cost to achieve the intended objectives taking into account total capital expenditures and operating expenses per subscriber, while avoiding potentially costly unknowns. The proposed architecture and interfaces need to be implemented in a cost-effective manner, based on commodity and/or specialized hardware and software as long as they are cost-effective.

Investments in next generation network equipment will need to result in near-term financial benefits such as improved operating efficiencies and/or growth in profitable subscriber revenue.

Current cable networks will need to migrate cost-effectively to the next generation architecture. Architectures and technologies requiring a complex or discontinuous migration path must provide significant benefits that clearly outweigh the cost and complexity of migration. "Cost effective" migration implies avoiding stranding existing assets. It also implies that the types of investments – fixed versus variable, integrated versus modular – are aligned with the nature of the market opportunities and subscriber environments in which the investments will be made.

R15. Minimize investment cost. Enable implementation of network enhancements in a cost-effective manner.

R16. Enable realization of near-term financial benefits.

R17. Support cost-effective migration to next generation network architecture.

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Printed in Switzerland
Geneva, 2007