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Technical Report

Access, Terminals, Transmission and Multiplexing (ATTM); Cable Network Handbook

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Contents

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Foreword

This Technical Report (TR) has been produced by ETSI Technical Committee Access, Terminals, Transmission and Multiplexing (ATTM).

Introduction

The core expertise within ETSI responsible for European Standards covering Integrated Broadband Cable and Television Networks (ATTM-AT3) has received requests from industry to produce a cable network handbook in order to assist decision makers, both technical and regulatory people.

The current document is a cable handbook produced in cooperation with Excentis and Cable Europe in order to provide the reader with a high level technical understanding of the CATV and Broadband Cable Networks.

1 Scope

The present document is a technical report providing general overview of the Integrated Broadband Cable and Television Networks and is intended as a handbook for engineers and non-engineers to familiarize themselves with the Cable Network infrastructure, architecture, components and protocols including high level description of its transmission principles

2 References

References are either specific (identified by date of publication and/or edition number or version number) or non-specific. For specific references, only the cited version applies. For non-specific references, the latest version of the reference document (including any amendments) applies.

Referenced documents which are not found to be publicly available in the expected location might be found at http://docbox.etsi.org/Reference.

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2.1 Normative references

The following referenced documents are necessary for the application of the present document.

Not applicable.

2.2 Informative references

The following referenced documents are not necessary for the application of the present document but they assist the user with regard to a particular subject area.

Not applicable.

[i.1] ETSI ES 201 488 (all parts): "Access and Terminals (AT); Data Over Cable Systems".

NOTE: EuroDOCSIS 1.1 is ES 201 488 (parts 1, 2, 3).

[i.2] ISO/IEC 13818:"Information technology - Generic coding of moving pictures and associated audio information".

[i.3] ETSI ES 202 488 (all parts): "Access and Terminals (AT); Second Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems".

NOTE: EuroDOCSIS 2.0 is ES 202 488 (parts 1, 2, 3).

[i.4] ETSI TS 102 639 (all parts): "Access and Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services - IP Cable Modems".

NOTE: EuroDOCSIS 3.0 is TS 102 639 (parts 1, 2, 3, 4, 5).

[i.5] ETSI TS 101 909-4: "Digital Broadband Cable Access to the Public Telecommunications Network; IP Multimedia Time Critical Services; Part 4: Network Call Signalling Protocol [Partial Endorsement of ITU-T Recommendation J.162 (11/2005), modified]".

[i.6] ISO/IEC 14496-10: "Information technology -- Coding of audio-visual objects -- Part 10: Advanced Video Coding".

3 Symbols and abbreviations

3.1 Symbols

For the purposes of the present document, the following symbols the following apply:

Gbps	Gigabit per second
GHz	GigaHertz
kbps	kilobit per second
kHz	kiloHertz
MHz	MegaHertz

3.2 Abbreviations

For the purposes of the present document, the following abbreviations apply:

AM	Amplitude Modulation
ANC	Announcement Controller
ANP	Announcement Player
ANS	Announcement Server
AS	Authorization Server
ATV	Analogue TeleVision
CA	Call Agent or Conditional Access
CATV	Cable TeleVision / Community Antenna TeleVision
CM	Cable Modem
CMS	Call Management Server
CMTS	Cable Modem Termination System
CPE	Customer Premise Equipment
CSA	Common Scrambling Algorithm
DC	District Center
DHCP	Dynamic Host Configuration Protocol
DNS	Domain Name Server
DOCSIS	Data Over Cable Service Interface Specification
DS	DownStream
DTV	Digital TeleVision
DVB	Digital Video Broadcasting
ETSI	European Telecommunications Standardisation Institute
EuroDOCSIS	European Data over Cable System Interface Specification
FA	Final Amplifier
FDM	Frequency Domain Multiplexing
FDMA	Frequency Division Multiple Access
FM	Frequency Modulation
GA	Group Amplifier
GC	Gate Controller
HDTV	High-Definition Television
HE	HeadEnd
HFC	Hybrid Fibre Coax
HTTP	HyperText Transfer Protocol
IP	Internet Protocol
IPTV	IP Television
ISO	International Standardisation Organisation
KDC	Key Distribution Center
LC	Local Center
MAC	Media Access Control
Mbps	Megabit per second
MG	Media Gateway
MGC	Media Gateway Controller
MPEG	Moving Pictures Expert Group
MPLS	Multi Protocol Label Switching

MTA	Multimedia Terminal Adapter
MTP	Multi-TaP
MUX	Multiplexing
NIU	Network Interface Unit
NOC	Network Operating Center
NTU	Network Termination Unit
ON	Optical Node
OSS	Operating Support System
PAL	Phase Alternating Line
PSI	Program Specific Information
PSTN	Public Switched Telephone Network
QAM	Quadrature Amplitude Modulation
QoS	Quality of Service
RC	Regional Center
RF	RadioFrequency
SDH	Synchronous Digital Hierarchy
SDTV	Standard-definition Television
SECAM	SEquentiel Couleur A Mémoire
SG	Signalling Gateway
SI	Service Information
SONET	Synchronous Optical NETwork
SS7	Signalling System 7
STB	Set-Top Box
TDMA	Time Division Multiple Access
TFTP	Trivial File Transfer Protocol
TGS	Ticket Granting Server
ToIP	Telephony over IP
US	UpStream
UTP	Unshielded Twisted Pair
VoD	Video on Demand

4 Network of the Cable operator

4.1 History of the CATV network

The CATV (Community Antenna TeleVision) network was originally set up to deliver one-way, analogue broadcast TV transmission (unidirectional from headend to subscriber) services (Figure 1). A headend (HE) has in the cable network operator's terminology two meanings: the first one refers to the equipment for receiving television signals for processing and distribution over a cable television system, the second one describes facilities in which the equipment is installed that converts the received signals into ones that are distributed in the CATV or HFC (see clause 4.2) network.

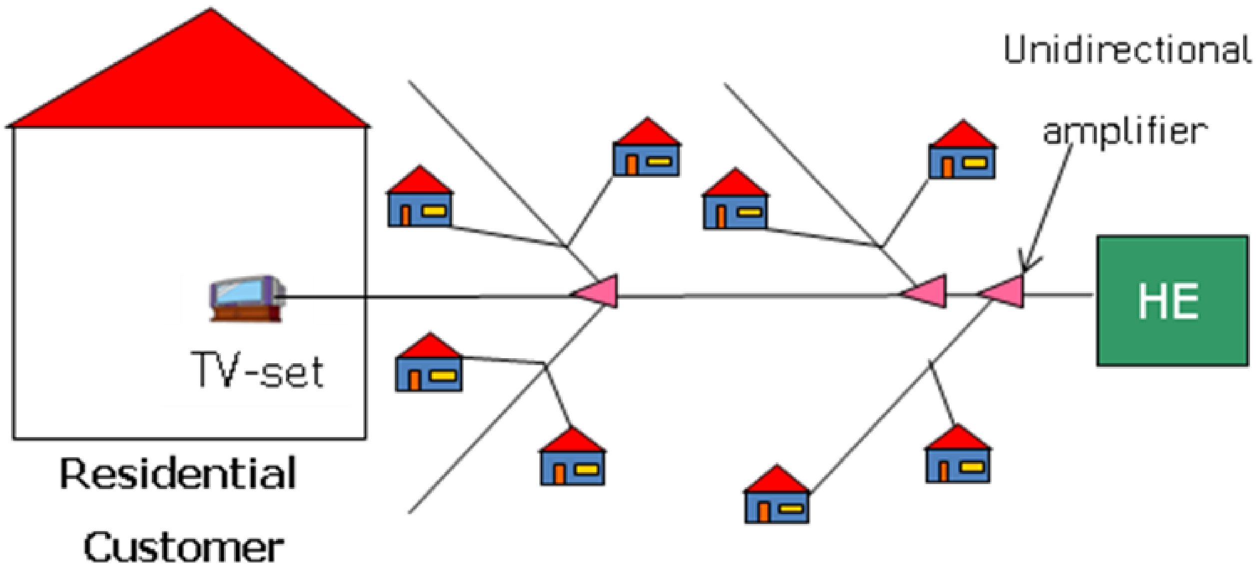


Figure 1: The CATV network (HE=headend)

Signals were captured using terrestrial and satellite antennas and distributed using a coaxial network within the local community. The earliest deployments started in the thirties. Until the nineties, there were thousands of small networks all over Europe most of these are now consolidated into larger cable operators.

Amplifiers are used to compensate for the attenuation of the coaxial cables. Although the attenuation for two types of cable for in-home use is depicted in Figure 2, it shows the general frequency-dependent trend of the attenuation of coaxial cables. This frequency dependency is normally compensated for by equalisation filters in the amplifiers. However the length of the cables between the amplifiers may not be too long in order that the input signal at the amplifier is above the noise level. This shows that extending the frequency spectrum above 1 GHz would necessitate the reduction of the distance between the amplifiers which would require a complete re-implementation of the CATV/HFC network. This brings us to the conclusion that the frequency spectrum of the CATV and HFC network is limited at present to below 1 GHz.

The amplifiers and tap values were chosen such that each house gets an equal TV signal. A huge number of houses (e.g. between 50 000 and 1,6 million) can be served by one headend.

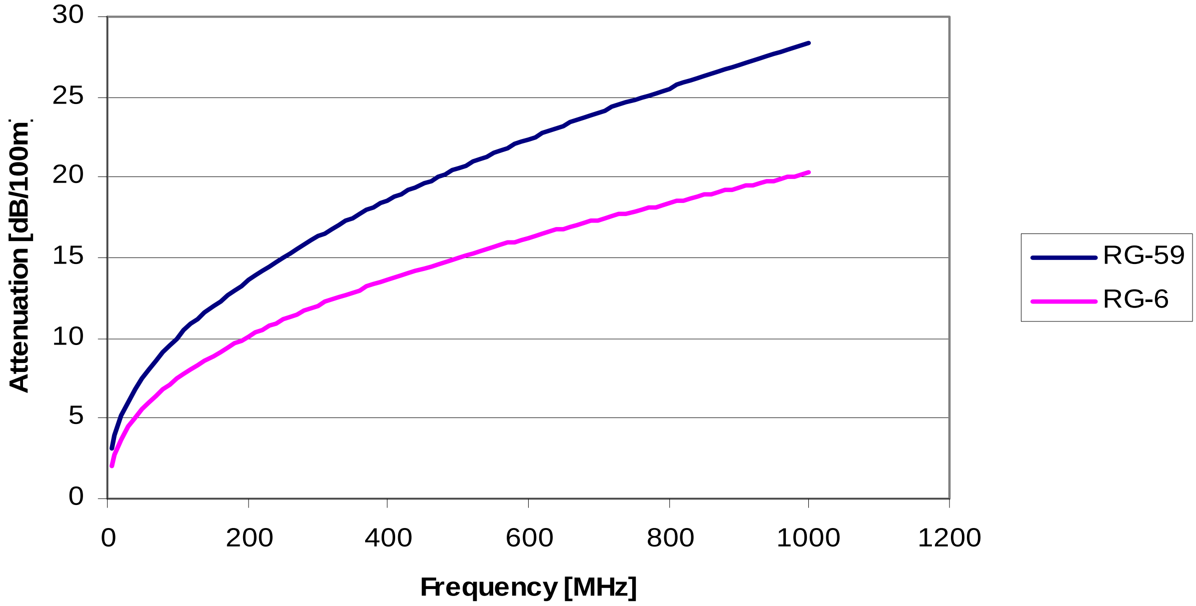


Figure 2: Frequency dependence of the attenuation of two types of coaxial cables

Since the end of the nineties, most of the CATV networks have been converted for bi-directional operation into a Hybrid Fibre Coax (HFC) architecture.

4.2 HFC Network

4.2.1 Architecture

Hybrid Fibre Coax (HFC) access networks are composed of optical fibre and coaxial cables (Figure 3).

Typically, optical fibre rings radiate from the regional headend to optical nodes where the signals are transferred to coaxial cables and then carried to the customer location. A headend may serve many tens of thousands of customer premises, with substantial resilience in the access network resulting in the need for network power at many roadside locations. Optical nodes typically serve between several hundred to some thousands of homes.

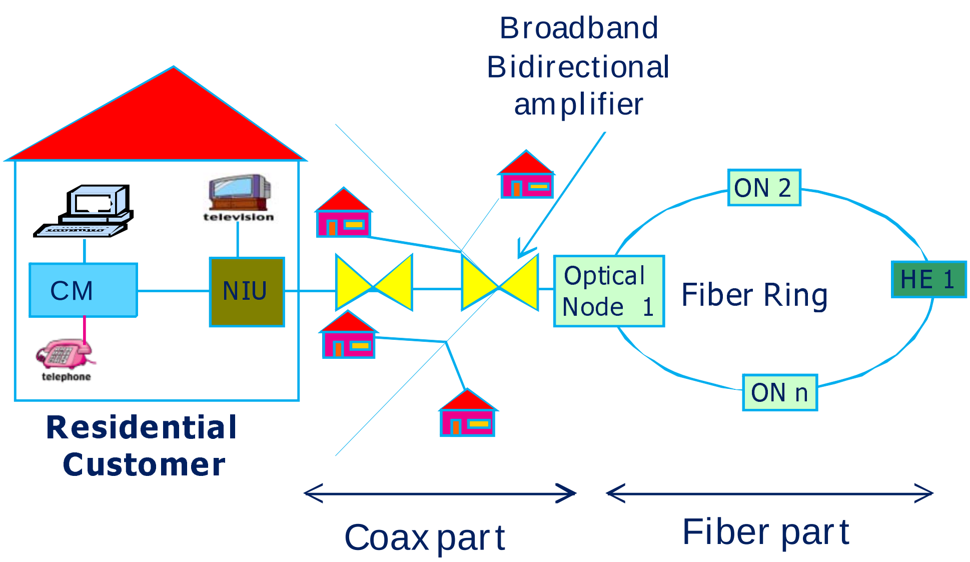


Figure 3: HFC network

4.2.2 Components

If we have a closer look at the HFC network from the optical node to the home, we can distinguish different components (see Figure 5).

Two optical fibres arrive in the optical node (in practice 4 for redundancy reasons), one with the upstream signal and one with the downstream signal.

In the fibres, digital and analogue information is transmitted over the optical fibre through modulation of a sine carrier. Simply said, light is sent all the time and it is the fluctuation of the light that tells the receiver what information the sender is transmitting.

In the optical node two conversions are executed: the optical signal is converted to an electrical signal by a photodetector (o/e conversion) and the diplex filter only puts the downstream signal on the coaxial cable; the upstream signal on the coaxial input of the optical node is also filtered by the other part of the diplex filter and is sent as input to the laser (electrical to optical - e/o conversion) to modulate the light signal in the upstream fibre.

Behind the optical node towards the homes, the coaxial distribution plant delivers all downstream signals to the homes and transports the upstream signals coming from the homes back to the optical node.

Individual components are shown in Figure 4.

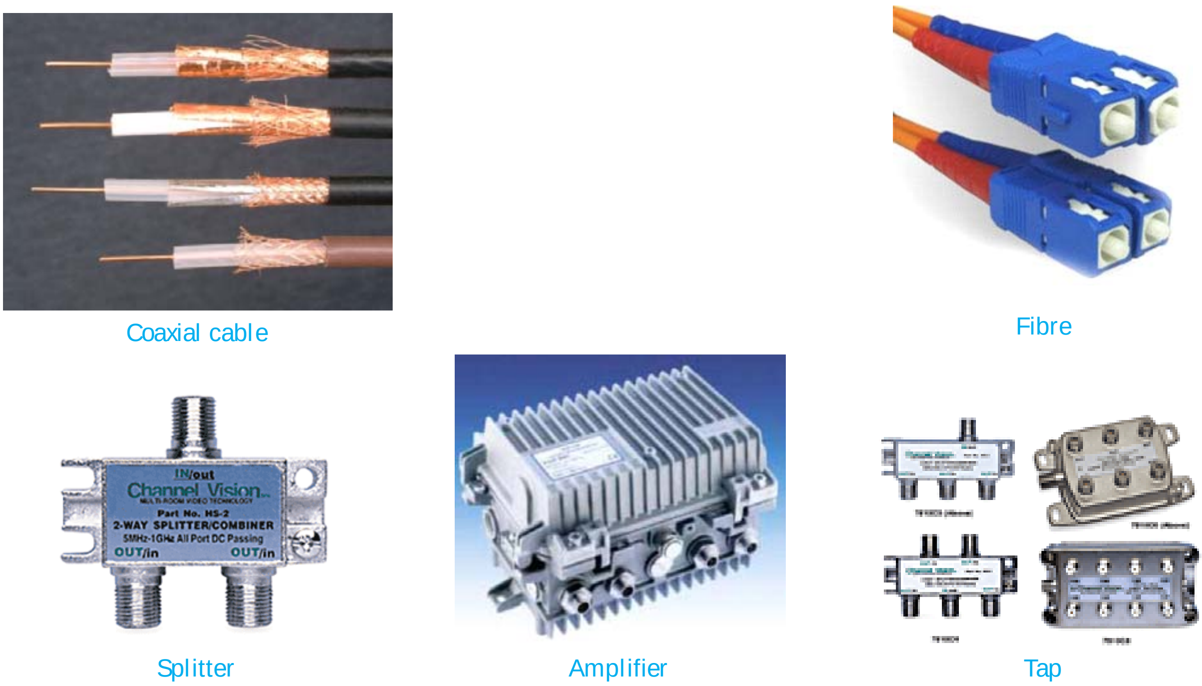


Figure 4: HFC network components

Two topologies for the coaxial part of the HFC network are in use in Europe: the tree-and-branch and the star architecture.

4.2.3 Tree-and-branch topology

Tree-and-branch is the most typical architecture for the coaxial distribution plant (Figure 5). The main trunk cable is split in branches though splitters. Splitters are bi-directional passive components used to split and combine signals over different paths.

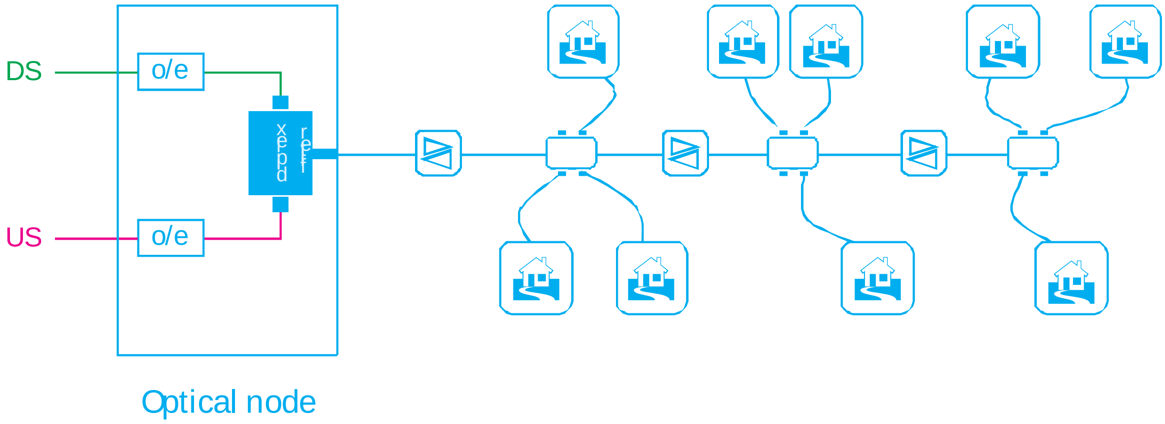


Figure 5: Tree-and-branch HFC network topology

At regular intervals, bi-directional amplifiers amplify both the up- and downstream signals.

To connect the houses taps and "drop" coaxial cables connected to the taps are used. A tap provides basically the same function as a splitter, i.e. dividing and combining signals, but while a splitter is a symmetrical component (equal distribution of the signals), a tap is asymmetrical. Taps are also bi-directional, but it has one input port and a number of output ports, of which one is the main output. The tap takes a small "portion" of the downstream signals on the branch cable and sends it to the house. Upstream signals from the house are inserted in the branch cable through the tap. The main output of the tap receives the biggest portion of the signals. Figure 6 shows a picture of an outdoor tap with the input and main output taps and 4 taps connected to 4 drop cables attached to the front of 4 houses.

Figure 6: Outdoor tap

4.2.4 Star topology

An alternative topology is the star configuration as shown in Figure 7. Splitters with multiple outputs or multi-taps (mtp) are used to connect several houses. This star topology is typical for the networks in the Netherlands. A specific terminology is also shown on Figure 7.

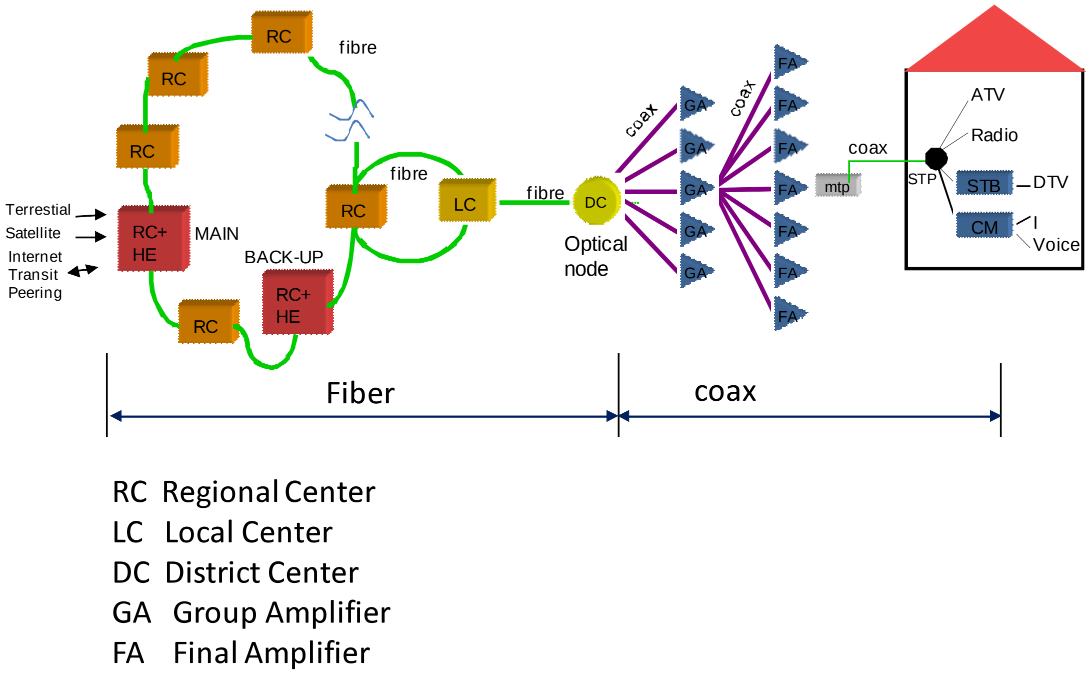


Figure 7: HFC-network based on a star topology

Figure 8 shows pictures of the centers and amplifiers in a real-life star-topology network.

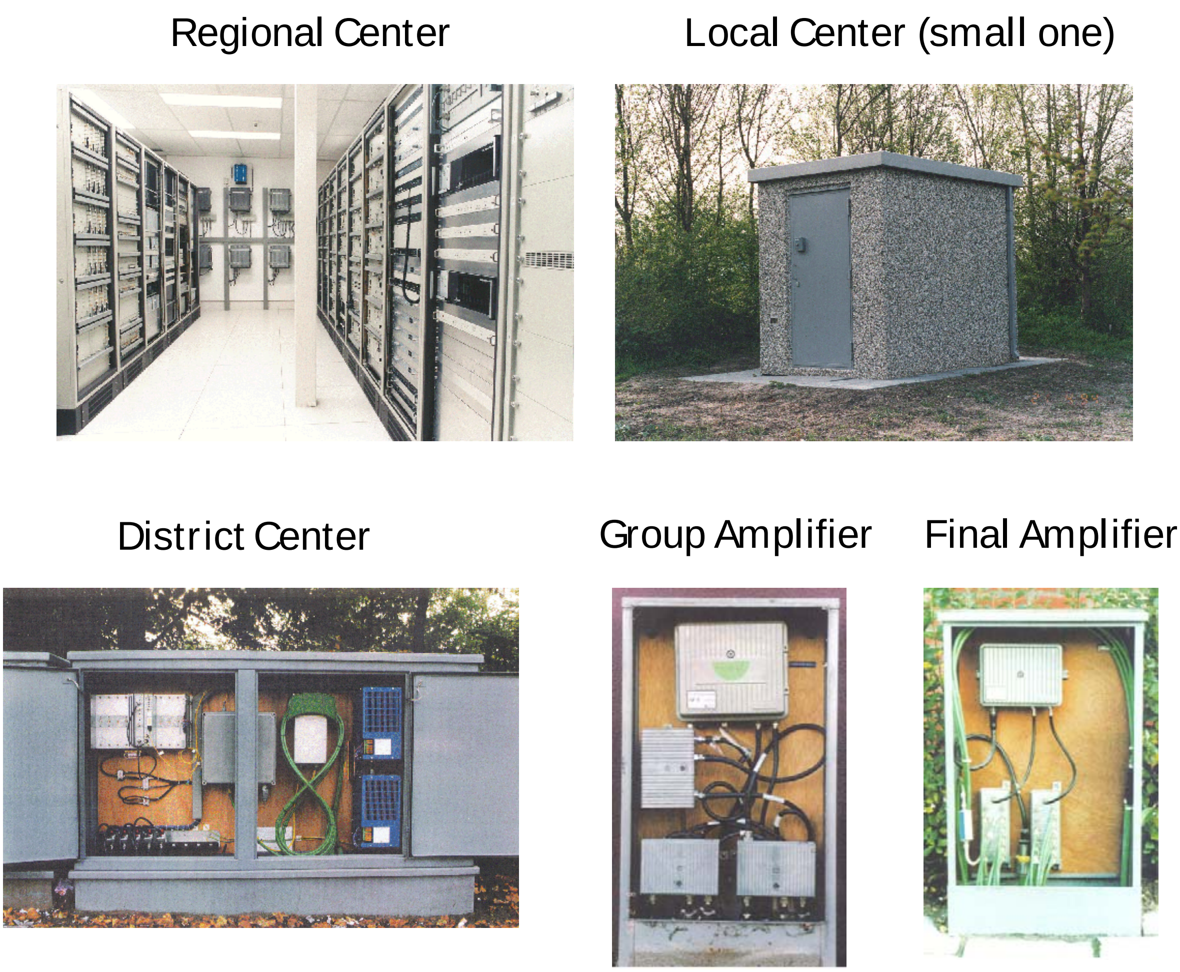


Figure 8: Different facilities and equipment in case of star-type HFC network

The HFC network is a shared medium. This means that the signals transmitted by the different customers connected to the same segment of the optical node, will be transported on the same cables. Therefore, solutions to avoid interference between the signals were needed (see clause 5.1). Moreover the bandwidth provided by the spectrum of the HFC network will be shared among all customers of the coaxial segment connected to the optical node.

4.3 Backbone network

Cable network operators covering larger areas operate a number of headends interconnected via optical links, i.e. the backbone network. The backbone uses fibre optics to transport information. Backbone technologies that are used are Synchronous Optical Network (SONET), Synchronous Digital Hierarchy (SDH), and Ethernet. These technologies can only transport digital information in contrast to the HFC network where analogue and digital signals are present. The to be transmitted bit-stream modulates a pulse train. A "1"-bit is transmitted by sending a light pulse, a "0"-bit by not sending a light pulse. SONET, SDH and Ethernet use what is called a baseband signal.

The backbone enables the cable operator to achieve national coverage, with content being inserted and distributed on a national, regional or local basis as appropriate. The backbone network (network across country or between countries) typically consists of a primary ring, which runs through all the regions where the operator offers services. In each region, one or more secondary rings depart from the primary ring (Figure 9).

A master headend and its associated servers are located in the Network Operating Centre (NOC). In the NOC gateways to the internet and to traditional telephony providers are installed.

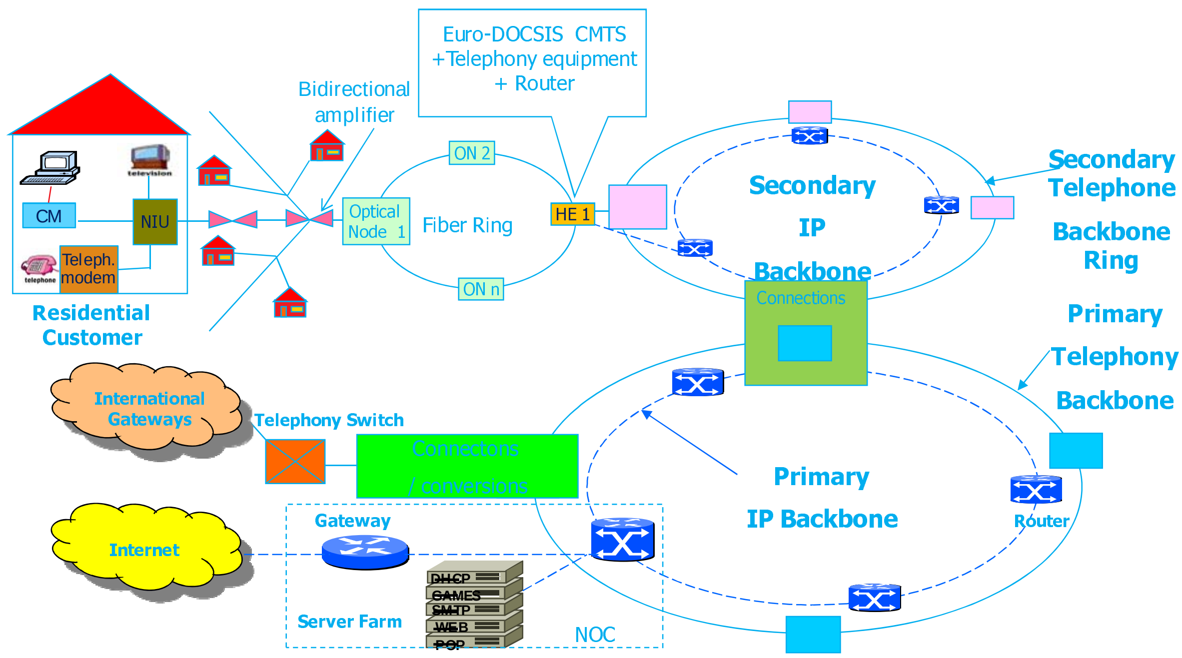


Figure 9: HFC and backbone network topology of the cable operator's network

The secondary rings interconnect a number of regional headends. From each headend, an HFC network consisting of multiple nodes departs. A fibre ring runs through a number of optical nodes and each optical node is the starting point of a coaxial distribution plant. A regional headend therefore contains multiple optical transmitters and receivers that are connected over fibre to the different optical nodes in the field.

In the case where telephony is replaced by VoIP, the telephone backbone is merged to the IP backbone.

It should be stressed that this "ring" topology is the ideal case, based on local circumstances, variations exist.

Backbones of cable systems are the same as those used by the "telecom" operators.

4.4 Home network

4.4.1 Network Interface Unit

The Network Interface Unit (NIU, also called the Network Termination Unit (NTU), terminates the signals on the drop cable at the entrance of the home. It isolates the network of the cable operator from the in-home network. The NIU contain filters to separate video, data and in case of telephony over cable (see clause 6.2.1) also the telephony signals.

Figure 10 shows an in-home setup with an NIU and a cable modem connected to the NIU.

Figure 10: In-home set-up with NIU and cable modem

Sometimes an amplifier is embedded in the NIU (active NIU) to bring the signal in the home to the correct level. NIUs are not used in all countries.

4.4.2 Distribution of video signals

In the home the signals are mostly distributed through coaxial cables. Sometimes splitters and amplifiers are used to distribute the signals to different rooms. By using amplifiers cable losses are compensated such that in each room an acceptable signal level is obtained.

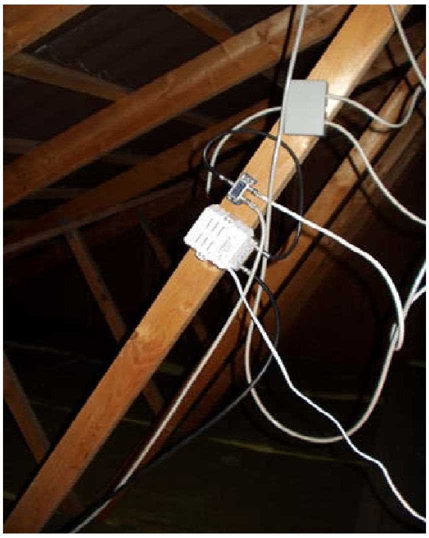
As the installation of the home networks are the responsibility of the home owner and not of the cable operator, the quality of the in-home installation is in the hands of the home owner or electrician who installs the cables. The home cables used are mostly of low quality. This means that they may have a large and frequency-dependent attenuation and poor shielding. This has a large impact on the pick-up of ingress noise (see clause 5.4.2). The choice of low-quality cables is due to the limited expertise of the installer and due to much lower prices than those of the high-quality cables used in the professional networks.

4.4.3 Distribution of data signals

In most residential homes the cable modem is installed where the coaxial cable enters the home. The Ethernet signal is then transmitted by an UTP cable directly to the computer or to a wall outlet where a connection to the computer can be made. If a Wifi interface is available on the cable modem, a cable can be avoided.

4.4.4 Examples of poor in-home installations

Figure 11 shows some examples of poor in-home installations.



Installation with many cables crossing each other

Bad wall-plate connection

Figure 11: Examples of poor in-home cable installation

Whilst only analogue television was deployed, these installations did not pose a problem as long as the television signal strength was high enough. However with the distribution of digital TV and data signals, problems did show up. Also the installation in multi-dweller apartment blocks is often problematic. Therefore delivery of broadband to these types of typical homes in towns is sometimes cumbersome. Rewiring in the building may be needed.

5 Physical layer

5.1 Radio-frequency carrier and spectrum

How can multiple signals (different TV channels, FM radio, internet traffic, etc.) co-exist on the shared medium of the coaxial cables? A solution is to make sure that all signals use different frequencies. Each signal occupies a certain frequency band in the spectrum. As long as two signals do not have overlapping frequency bands, they will not interfere with each other. This technique is called Frequency Division Multiplexing (FDM).

The frequency spectrum used in a HFC network is split into a downstream spectrum for delivering the services from the headend to the end-user and an upstream spectrum for the traffic from end-user to the operator (Figure 12).

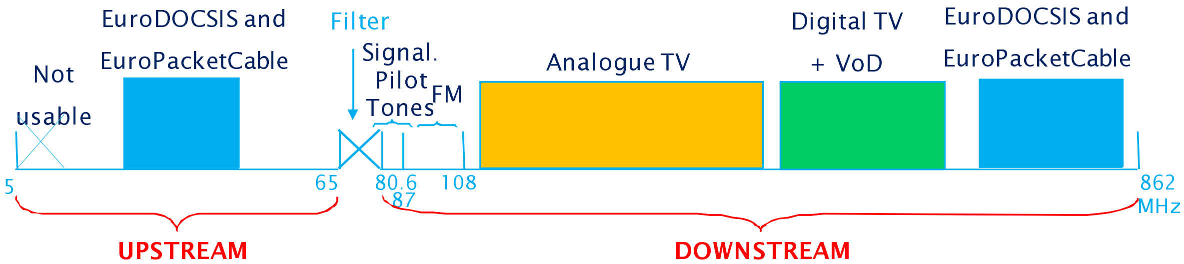


Figure 12: Down- and upstream spectrum in an HFC network

5.1.1 Downstream frequencies

Each HFC network carries in the *downstream* (DS) signals modulated on to a number of frequencies that are selected in the downstream spectrum. The DS part of the spectrum in Europe typically starts from 80.6 MHz and can go up to 862 MHz. In the downstream, analogue and digital TV, video applications such as Video on Demand (VoD) and broadband internet (EuroDOCSIS standard) and telephony (IPCablecom standard [i.5]) signals are present. In the future, the number of analogue TV channels may be reduced but the freed frequency channels will be quickly taken by the expansion of digital TV channels, through the increasing number of channels and the introduction of bandwidth consuming HDTV channels and by the proliferation of broadband internet services requiring larger bandwidths (> 100 Mbps).

5.1.2 Upstream frequencies

In most European countries, the *upstream* (US) part of the spectrum starts at 5 MHz and ends at 65 MHz. In the United States, the US band stops at 42 MHz. Some networks are not yet equipped to enable upstream transmissions up to 65 MHz, they have a "low split" which stops at a lower frequency, e.g. 23 MHz.

Upstream spectrum is much smaller than the downstream spectrum which is because most of the information and content is sent from the operator to the customer. Recently, this is has been changing a little due to the popularity of upstream streaming of user generated content and peer-to-peer applications. However there is no tendency to change the split of the upstream and downstream spectrum.

5.2 Analogue transmission

5.2.1 AM modulation

AM (Amplitude Modulation) means that the amplitude (strength) of a sine wave (called the carrier) is modulated by the signal that carries the information. The carrier signal typically has a much higher frequency than the information signal. By modulating the amplitude of the carrier signal it occupies a certain frequency spectrum (bandwidth) around the carrier frequency. AM is used in the HFC network for transporting the analogue TV signals (see clause 6.3.3.2).

5.2.2 FM modulation

FM (Frequency Modulation) means the frequency of a sine wave (called the carrier) is modulated by the signal that carries the information. As in AM modulation, the carrier signal typically has a much higher frequency than the information signal. By modulating the frequency of the carrier signal it also occupies a certain frequency spectrum (bandwidth) around the carrier frequency. FM is used in the HFC network for transporting radio signals (FM-radio) and also for transporting sound (audio). In the Analogue TV SECAM system it is also used to modulate the colour information.

5.3 Digital transmission based on QAM modulation

QAM stands for Quadrature Amplitude Modulation. QAM is used to transport digital information over an analogue transmission network. In QAM the amplitude of a sine and cosine carrier at the same frequency (carrier) is determined by the bits to be transported. Since sine and cosine are orthogonal signals the bits that are transported are independent from each other. Different forms of QAM are used, 4 QAM (QPSK) uses only 1 bit (sign bit) per carrier (sine or cosine) to define the amplitude, in 64 QAM 5 bits (4 different amplitude and one sign bit) are used to define the amplitude. It is clear that if more amplitude levels (higher-order QAM forms) are used, less noise can be tolerated on the network, since the different amplitudes are closer to each other for the same maximum power of the signal.

5.4 Noise and interference

5.4.1 Upstream noise and interference

In the upstream direction, noise consists of thermal noise produced by the active components and externally interfering noise. Generally, the externally interfering upstream noise is defined as deterministic signals that are caused by all kinds of physical phenomena.

Externally interfering upstream noise consists of ingress and impulse noise.

Ingress is narrowband and relatively stationary noise, typically generated by narrowband transmission equipment such as:

- shortwave broadcast transmitter;
- amateur radio;
- CB (citizen's band) at 27 MHz;
- pagers.

Figure 13 shows an example of the ingress as a function of frequency. As can be seen from the figure the ingress is strongest at the low frequencies. The percentage on the figure refers to the percentage of time that the ingress noise is higher than the curve.

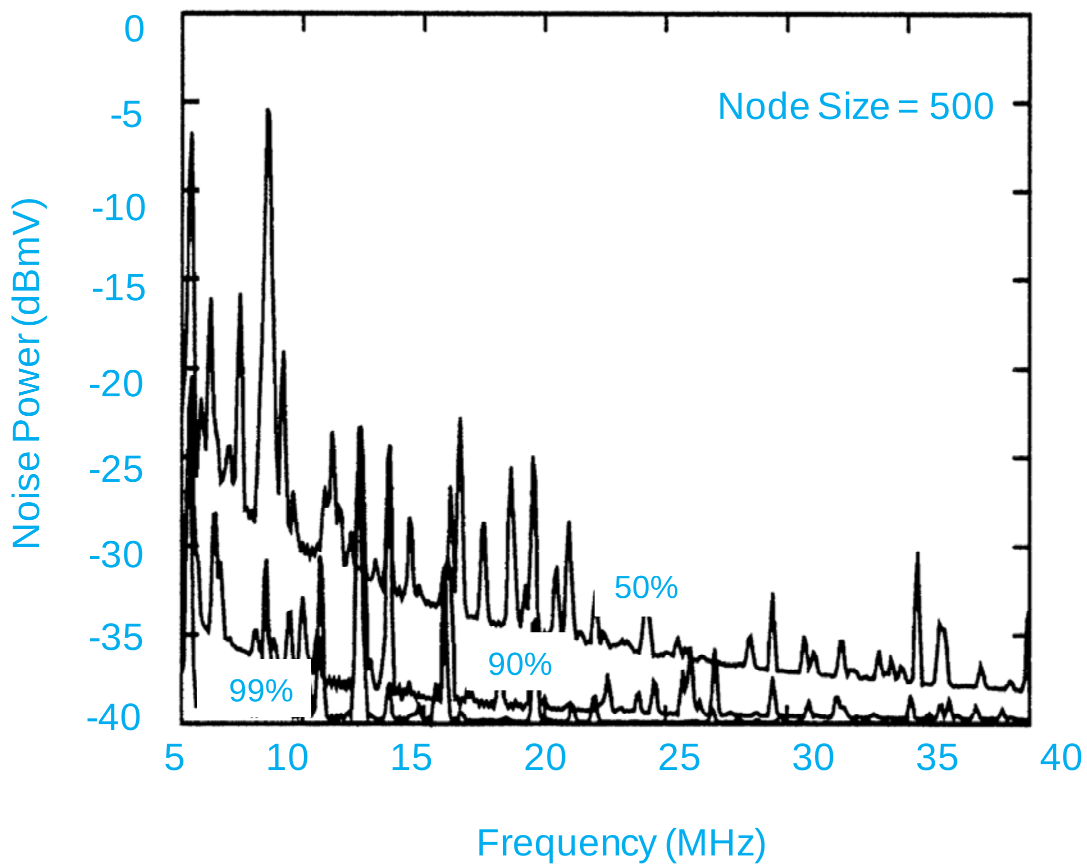


Figure 13: Example of the upstream ingress noise spectrum

Impulse noise is the general name given to short-duration noise (sometimes repetitive) with a large bandwidth. It is typically generated by switching currents of several devices connected to the power net. Impulse or impulsive noise is generated by all sorts of electrical signals that generate short pulses: arcing, switching transients, and intermitted grounds.

The noise enters the cable network because the shielding of the different network elements is insufficient.

By monitoring the upstream noise, one can place the carriers for data signals in the clean bands, and as such, it is possible to use higher-order modulation (see clause 5.3) and increase the throughput for one channel.

It should be noted that the shared character of the upstream frequencies means that the noise which is inevitably picked up or generated by the network elements is additive and is presented at the headend together with the wanted signal, potentially affecting service to all customers on that network segment. Therefore most of the spectrum below 15 MHz to 20 MHz is not usable due to ingress.

5.4.2 Downstream noise and interference

Noise and interference in the downstream is caused by:

- Intermodulation due to non-linearity of active components in the HFC network.
- Interference from terrestrial TV network (DVB-T systems) operating at the same frequencies as the channel frequencies used on the cable network.
- When wireless systems are used in the allocated "digital dividend" frequencies they may cause interference on the services used on the cable network in the same frequency band. Especially mobile phones or dongles operated in the vicinity of television sets, set-top boxes, and cable modems will disturb TV pictures as well as data and voice services over the cable modem.

6 Services

6.1 Data services

6.1.1 EuroDOCSIS protocol

On the HFC cable network each internet access channel has a Cable Modem Termination System (CMTS) associated with it installed in the headend. The CMTS is the gateway between the HFC network and the backbone network. In most cases CMTSs are routing devices. The (Euro)DOCSIS (standard for data services over cable networks) signals from the CMTS are modulated onto its carrier and passed to the shared network as a radiofrequency signal. The EuroDOCSIS standard is essentially a MAC protocol that organises the traffic in the shared down- and upstream channels of an HFC network. Additionally management and security protocols are specified.

In the currently deployed EuroDOCSIS 1.1/2.0 products, each digitally-modulated *downstream* carrier is capable of carrying about 38 Mbps (64 QAM) or 51 Mbps (256 QAM) in an 8 MHz channel shared by up to 2 000 or more homes in a network segment (node), giving a continuous equivalent bandwidth of up to about 50 kbps per home, although this may be restricted by management controls. The full 38 Mbps (or 51 Mbps) bitrate of a downstream channel could theoretically be made available to any one of the homes served. In practice, each customer is allocated a maximum data speed, the aggregate of which may well exceed 38 Mbps. Therefore, a degree of contention is used in the HFC network and managed by the CMTS. This enables customers to achieve much higher burst speeds, providing them with a differentiated product, on the basis that they are contending with the other end-users for the total segment capacity. With the advent of EuroDOCSIS 3.0, 4 or more channels can be bonded, making bitrates of more than 200 Mbps possible.

The upstream spectrum is divided in frequency channels of 200 kHz, 400 kHz, 800 kHz, 1,6 MHz, 3,2 MHz or 6,4 MHz wide; typically the three smallest bandwidths are not used. The customer may send data in these channels based on a Media Access Control (MAC) mechanism that divides the upstream radiofrequency channels in time slots. This means that a customer has access to the upstream spectrum through the combined use of Frequency Division Multiple Access (FDMA) and Time Division Multiple Access (TDMA).

The maximum upstream bitrates that can be delivered in one upstream carrier (6,4 MHz wide channel, 64 QAM) is about 30 Mbps for EuroDOCSIS 2.0 systems. EuroDOCSIS 3.0 again provides bonding of 4 or more channels making bitrates of 120 Mbps or more possible.

It should be noted that all these rates are raw bitrates (overhead included). In most cases the achievable net bitrates will be much lower.

6.2 Telephony services

6.2.1 Telephony over cable

Initially cable operators used voice modems that modulated the voice signal on an RF carrier. Specific frequencies had to be reserved for the telephony service on the HFC networks.

In a few cases cable operators supply a dedicated copper pair for telephony and use conventional telecom techniques.

6.2.2 IP telephony based on EuroPacketCable

Telephony services are nowadays offered on the cable networks through the Telephony over IP protocol implemented in the IPCablecom 1.0/1.5 standards [i.5].

This protocol uses the Quality of Service (QoS) mechanisms defined in the EuroDOCSIS 1.1/2.0/3.0 standards to provide toll-grade telephony to the customers. EuroPacketCable Multimedia extends this IP based technology to enable a wide range of multimedia services, such as multimedia conferencing, interactive gaming, and general multimedia applications.

The EuroPacketCable architecture is shown in Figure 14. We distinguish the following components:

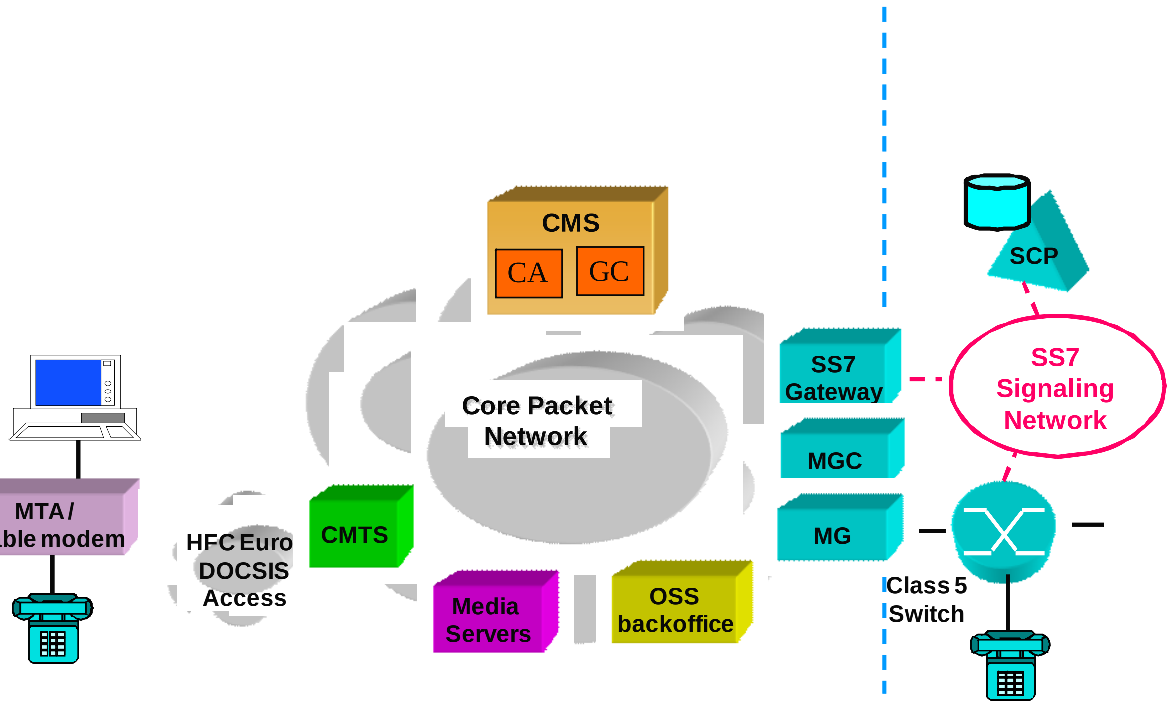


Figure 14: EuroPacketCable architecture

The Call Management Server (CMS) provides call control and signalling for MTA, CMTS and PSTN gateways.

The CMS has two functional components. The first one is the Call Agent (CA) responsible for signalling with the MTA and the announcement server, maintaining the call progress state, collecting and processing dialled digits and implementing call features (like call forwarding, etc.). The second one is the Gate Controller (GC) which controls the CMTS related to Quality of Service admission.

In case the call is going to a telephone on the PSTN network, the CMS will signal using the SS7 or Signalling Gateway and communicate with the Media Gateway Controller.

The Multimedia Terminal Adapter (MTA) is a slave to the Call Agent. The CA tells the MTA what to observe (tones, hook state, digits, etc.), what to generate (ringing tones, etc.) and to create, modify or delete connections

The PSTN gateway enables calls from an MTA to telephones on the PSTN network. Three components generate this connection: Media Gateway Controller (MGC), the SS7 or Signalling Gateway (SG), and the Media Gateway (MG).

The Media Gateway functions as a proxy MTA to the EuroPacketCable network. It implements many features of an MTA. It provides telephony traffic connectivity and media transcoding between the PSTN and EuroPacketCable network. It is controlled by the MGC: it detects and generates events on demand of MGC and reports usage of resources to MGC.

The Media Gateway Controller maintains and controls the overall call state for calls to and from the PSTN. It instructs the MG to create, modify or delete connections to and from "other" MTAs. It receives and mediates call signalling information between the EuroPacketCable and PSTN network.

The Signalling Gateway sends and receives circuit-switched network signalling (Signalling System 7) at the edge of the EuroPacketCable network. It also terminates physical SS7 links from the PSTN. It finally executes other functions that are less relevant.

Like cable modems, the MTAs should be provisioned through DHCP, DNS, and TFTP / HTTP servers. In EuroPacketCable, media servers responsible for event messaging and recording for fault and account management are defined. The SYSLOG server collects events from an MTA. The Audio or Announcement Server (ANS) manages and plays international tones; it consists of an Announcement Controller (ANC) and the Announcement player (ANP).

For security implementation a Key Distribution Center (KDC) is provided consisting of an Authorization server (AS) and a Ticket Granting Server (TGS) granting tickets for an MTA that contain information to set up authentication, privacy, integrity and access control for the signalling between MTA and CMS.

6.3 Audio and Video Services

6.3.1 Compression

An uncompressed standard 625-line studio original picture needs 270 Mbps when transmitted in a digital form. An HDTV data stream needs 1,485 Gbps. However, the good thing about digital data is that all kinds of processing techniques can be performed on the data such as compression.

Video and audio compression are usually based on MPEG standards. MPEG standards are developed by the ISO/IEC Moving Pictures Expert Group.

MPEG-1 was the initial video and audio compression standard. It was later used as the standard for Video CD. It includes the popular Layer 3 (MP3) audio compression format.

MPEG-2 is until now the most used transport, video and audio standard for broadcast-quality television. It is used for over-the-air digital television, digital satellite TV services, digital cable television signals, and (with slight modifications) for DVDs.

The MPEG-2 standards allows compression of standard-definition TV pictures bit rates from 1 Mbps to 12 Mbps (Table 1). The compression level will be dependent on how fast movements are taking place in the pictures. A sporting event, where movements are fast, will require 6 Mbps to 9 Mbps while some cartoons or films could be transmitted with bit rates down to 1,5 Mbps with negligible distortions. The audio channel can be compressed to bit rates from 64 kbps to 384 kbps.

Table 1: MPEG-2 compression rates

Programme	Required Bit rate (Mbits/s)
Sporting events - fast movement	6 to 9
Entertainement programmes and documentaries	2 to 4
Films, cartoons	1,5 to 3
Audio channel	0,064 to 0,384

High-definition television (HDTV) pictures can be compressed to 15 Mbps to 18 Mbps again depending on the sort of TV pictures.

Increasingly MPEG-4 is replacing the MPEG-2 standard. It expands MPEG-2 to support video/audio "objects", 3D content, low bit rate encoding and support for Digital Rights Management. Several new (newer than MPEG-2 Video) higher efficiency video standards are included (an alternative to MPEG-2 Video): MPEG-4 Part 2 [i.2] (or Advanced Simple Profile). MPEG-4, Part 10 [i.6] (or Advanced Video Coding or H.264) which is used on high density next generation optical discs, along with VC-1 and MPEG-2. When one talks about MPEG-4 compression in a cable television environment, one typically means MPEG-4 part 10 [i.6]. Figure 15 shows the comparison of the performance of MPEG-2 and MPEG-4 compression.

The gain compression of MPEG-4 is at least double in comparison to MPEG-2. MPEG-4 will bring the rate for HDTV down to 6 Mbps to 8 Mbps. Therefore MPEG-4 and the popularity of large LCD-screens have accelerated the broadcasting of TV content in HDTV format.

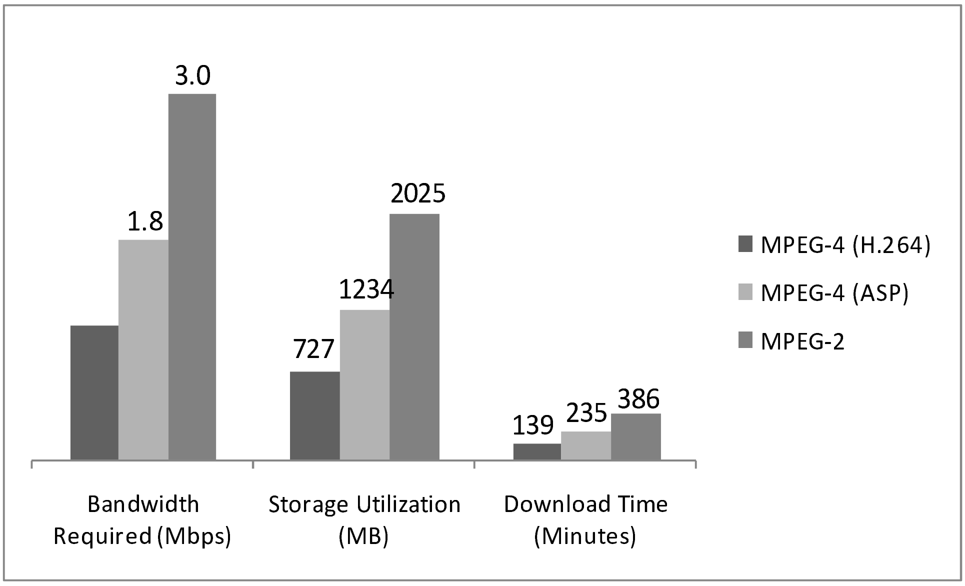


Figure 15: Performance comparison of MPEG-2 and MPEG-4 compression for a 90-minute DVD-quality movie (download time at 700 kbps)

6.3.2 FM radio

FM radio is broadcasted on some of the cable operator's networks using the same frequencies as on air: from 87 MHz to 108 MHz. This allows connection from the wall plate via a coaxial cable to the receiver aerial socket. No frequency conversion is needed.

6.3.3 Broadcast TV

6.3.3.1 Cable television headend

A cable television master headend is a facility for receiving television signals for processing and distribution over the cable network. The headend facility is normally installed in the network operating centre and is typically a building housing electronic equipment used to receive and re-transmit video over the cable network (video backbone and HFC network).

Figure 16 shows the block diagram of television and internet part of the master cable headend.

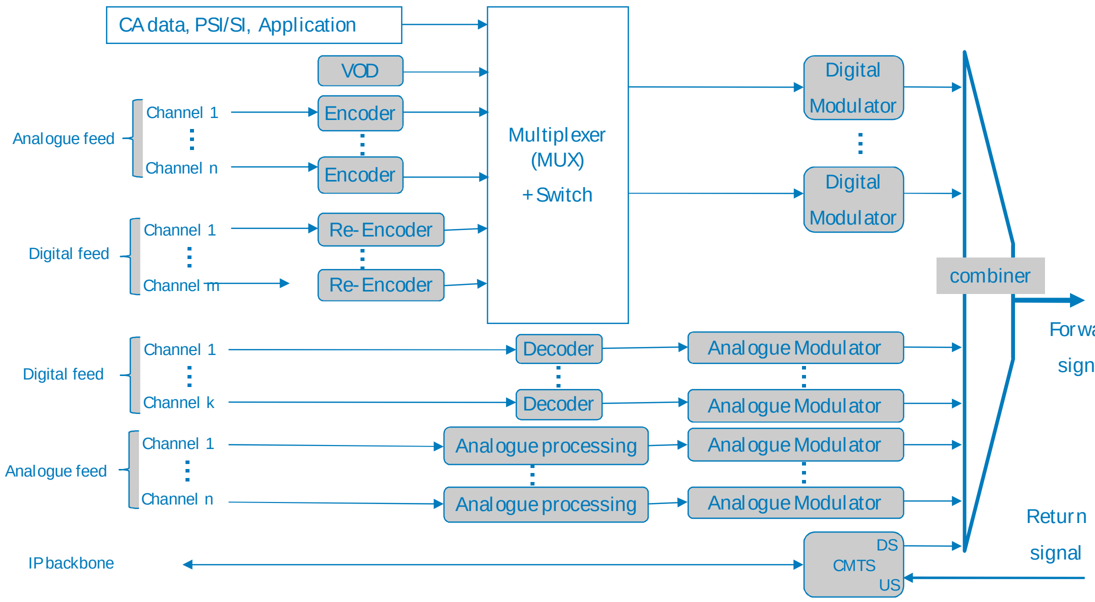


Figure 16: Block diagram of the television and internet part of the cable headend

The cable TV headend will normally have several large satellite television dishes for reception of satellite TV channels; a dedicated, non-movable dish is required for each satellite that the cable TV utility wishes to receive cable channels from for distribution over its system. For reception of signals from several adjacent satellites, a larger non-parabolic multi-satellite dish is often used.

Cable TV networks sometimes also carry local over-the-air television networks for distribution. Since each terrestrial channel represents a defined frequency, a dedicated receiving antenna is needed for each channel that the cable operator wishes to receive and distribute. These antennas are often built into a single tower structure called a master antenna television structure. Often, commercial TV pre-amplifiers are used to strengthen weak terrestrial TV signals as much as possible before distribution.

Some cable TV operators receive the local television stations' channels though a dedicated coaxial or fibre-optic cable installed between the local station and the headend. A modulator, installed at the local station's facilities, is used to feed their programming over this cable to the cable TV headend, which demodulates the signals. It is then distributed through the cable TV headend to the subscriber. This is usually a more reliable method than receiving the local stations' broadcasts over the air with an antenna, however, off-air reception is used as a backup by the headend if the dedicated line, modulator or demodulator were to fail.

Other sources of programming include those delivered via fibre optics, telephone wires, the Internet, microwave towers and local community access channels that are sent to the cable headend via a dedicated connection set up by the cable operator.

Once a television signal is received, it should be processed. For satellite TV signals, a dedicated commercial satellite receiver is needed for each channel that will be distributed by the cable operator;. Other signal types such as Analogue terrestrial TV signals do not need a special receiver for reception; instead, these channels can be received with a commercial RF antenna.

Digital channels are usually received in a stream called a Multiplex or MUX. Using special receivers, the signal can be de-multiplexed or "Demuxed" to extract specific channels from the ones in the original MUX. After the signal is de-multiplexed, the cable TV operator recombine these signals with for example local programming in to a new MUX and then redistribute the new MUX out on to their cable plant.

Once the channels are received, the channels are processed according to the requirements of the cable operators. Channels that are received in a digital compressed format will be re-encoded (to enforce the operator bitrate) before feeding them into the multiplex system. If the digital received channel needs to be transmitted in an analogue form a decoder will be used. Analogue received channels will be encoded (compressed) before feeding them into to the multiplexers. Analogue received channels that are distributed in analogue form on the cable network might require some analogue processing before feeding them into the modulators. The digital modulators are responsible for the digital encoding of the received bitstream that leave the multiplexers. The analogue modulators (PAL or SECAM) perform an analogue modulation on the received analogue signals. The modulators (both analogue and digital) typically have integrated upconvertors (if not a separate box is required) that puts the signals at the right frequency. The output of the modulators and the CMTS downstream signals are electrically combined and these combined signals are distributed on the HFC network.

6.3.3.2 Analogue TV

In Europe, two competing techniques were developed for colour TV: PAL and SECAM. Both standards are compatible for B/W with each other. This means that both types of TV sets are able to watch the Black & White version of the signal.

PAL/SECAM signals mostly use 7 MHz or 8 MHz of the downstream spectrum. The carrier frequencies are in the range 80,6 MHz to 862 MHz.

The baseband TV signal is AM modulated. The amplitude of the base band signal is used to change the amplitude of the RF carrier. This technique is still in use today.

An AM modulated visual part of a TV signal is symmetric. In order to save bandwidth, the left part is almost completely filtered away. Only a small part is still available (the Vestigial sideband). It is theoretical not necessary, but it was needed for the first analogue circuits, and it is still there to allow backwards compatibility.

The bandwidth of the visual part is also limited. The visual bandwidth is typical between 4,2 MHz and 6 MHz (Figure 17).

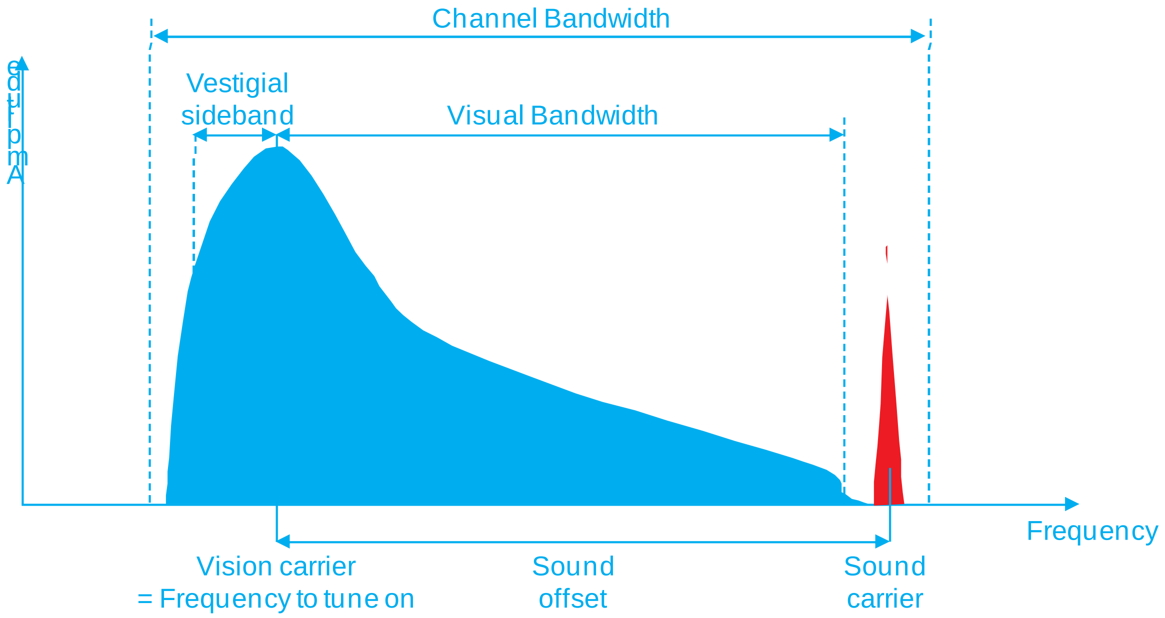


Figure 17: RF spectrum of an analogue TV signal

In the available spectrum next to the visual part, a sound carrier is added. Most systems use FM to modulate the sound. The distance between the visual carrier and the sound carrier is called the sound offset.

6.3.3.3 Digital TV based on DVB-C

The European DVB or Digital Video Broadcasting project was set up in 1993 in Europe. It is a forum of suppliers to agree on specifications and gives input to standardisation organisations such as ETSI and ISO.

The DVB specifications are based on ISO 13818 [i.2] MPEG-2 coding and multiplexing specifications. It further specifies a common encryption system and publishes a code of conduct for conditional access suppliers.

The DVB standards are defined for satellite (DVB-S), cable (DVB-C) and terrestrial (DVB-T) transmissions.

In DVB-C, two modulation formats are defined: 64 QAM and 256 QAM. As the digital signals are sent in the 8 MHz channels this delivers a channel capacity of 38 Mbps for 64 QAM and 51 Mbps for 256 QAM. This allows transmission of some 8 to 10 standard digital TV (SDTV) programmes in one 8 MHz channel.

The compressed TV-pictures are embedded in an MPEG-2 transport stream. Also multiplexed in the transport stream are the Program Specific Information (PSI) and Service Information (SI) that give indication of the type of information and provide the way to reconstruct the streams. This information is embedded in of a set of elementary streams that contain a set of database tables that describe the:

- Structure of a transport stream.
- Services.
- Useful information that digital TV receivers can show the user.

Digital TV needs a set-top box at the customer's premises. A set-top box is a device which integrates the video and audio decoding capabilities of television with a multimedia application execution environment. It provides a user friendly interface offering personalised multimedia services and regular cable TV service. A simplified box that only executes the decoding of video and audio of regular TV is called a zapper box.

6.3.4 IPTV

IPTV (IP Television) technology supports the transmission of standard television video programs over the Internet and Internet Protocol (IP). IPTV allows a television service to be integrated with a broadband Internet services and share the same home Internet connections.

IPTV needs high-speed internet connectivity due to the high bandwidth requirements of digital video.

The big advantage of IPTV is that the TV and video services can be delivered to all kind of devices with an IP stack such as laptops, game consoles, etc. However, this also needs a reformatting of the TV pictures to the variety of sizes and resolutions of screens.

More than just technology, the term "IPTV" represents a broad-based effort in the telecommunications and media industry to build a worldwide video creation and distribution environment. However, IPTV is not limited to the telecommunication industry. As IPTV is ideal for on-demand television, cable operators have an interest in using it. However as it has high-bandwidth requirements and will only be used when (Euro)DOCSIS 3.0 [i.1] is rolled-out.

It is expected that for a long time a mixed solution of DVB-C TV for broadcasting popular channels and IPTV for more specialised on-demand television will be used.

For IPTV an additional problem arises with the translation from the content protection on the HFC network (DVB) to content protection in the in-house network.

6.3.5 Interactive TV

Interactive TV adds to television interaction of the user. Interactivity can be either local or over the network, e.g. a programme guide will be downloaded on the set-top box and the user will locally interact with it. When interactivity is done over the network, a return path is needed. Some cable operators choose a set-top box with integrated cable modem to provide the interactive path, others use an external standalone cable modem with an Ethernet (UTP), wireless or powerline connection to the modem. Interactivity over the network is for example used in applications such as voting, when ordering is needed e.g. in case of Video on Demand and shopping on TV, web browsing on TV, etc.

Interactivity needs a set-top box with middleware (software) that can support interactivity.

6.3.6 Video on Demand

Two systems are in use:

- Near VoD: a program or movie is sent in different channels in a time-slotted way i.e. the program is shifted over a time delay from channel to channel. 15 minutes seems to be the maximum for an acceptable delay. Again transmission can be analogue or digital and is done in a linear way. This system has the advantage that even if a large number of users watches the movie, it is still only transmitted a limited number of times. Near VoD can be implemented without the need for a return path.

- True VoD: this enables an individual customer to demand a program or movie when and where she/he wants it. Control channels are needed for management of the distribution of the videos. A return path (can be sometimes by phone) is required for this service.

Video-on-demand needs powerful video servers in the master headend. Mostly, a distributed architecture with video servers at the regional headends are implemented.

6.3.7 Encryption and conditional access

Conditional access (CA) is the protection of content by requiring certain criteria to be met before granting access to it. Part of the protection of the content is provided by encrypting the content. The DVB consortium has defined the Common Scrambling Algorithm (DVB-CSA) which is the encryption method to use to encrypt content. The algorithm to get the decryption keys for this content to the set-top box are vendor-dependent and are called the CA-system. Cable operator select a CA system to use and the set-top box manufacturers implement this system on their STB. These CA systems use proprietary methods and technologies that are not publicly available.

A CA system consists of both the hardware and software on the set-top box and servers and systems in the headend of the operator that transmit the necessary messages to the set-top boxes. Note that most of the CA systems in use do not require a return path.

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