



BSI Standards Publication

Cable networks for television signals, sound signals and interactive services

Part 10-1: Guidelines for the implementation of return paths in cable networks

National foreword

This Published Document is the UK implementation of CLC/TR 50083-10-1:2014. It supersedes PD CLC/TR 50083-10-1:2009 which is withdrawn.

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**Cable networks for television signals, sound signals and
interactive services - Part 10-1: Guidelines for the
implementation of return paths in cable networks**

Réseaux de distribution par câbles pour signaux de
télévision, signaux de radiodiffusion sonore et services
interactifs - Partie 10-1: Lignes directrices relatives à la
mise en oeuvre de la voie de retour dans les réseaux
câblés

Kabelnetze für Fernsehsignale, Tonsignale und interaktive
Dienste - Teil 10-1: Leitfaden für die Einrichtung von
Rückkanälen in Kabelnetzen

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Foreword

This document (CLC/TR 50083-10-1:2014) has been prepared by CLC/TC 209 "Cable networks for television signals, sound signals and interactive services".

This document supersedes CLC/TR 50083-10-1:2009.

CLC/TR 50083-10-1:2014 includes the following significant technical changes with respect to CLC/TR 50083 10-1:2009:

- a) the introduction of a new "General Scope";
- b) the introduction of new upper frequency limit 85 MHz for return path as an option;
- c) the introduction of some new "Terms and definitions" due to the new general scope and due to the introduction of the extended return path frequency range to 85 MHz;
- d) the deletion of Clause B.1 on "Noise power ratio";
- e) the deletion of Clause B.2 on "10-tone measurement";
- f) the deletion of Clause B.3 on "MER measurement".

EN 50083 is currently composed of the following parts:

- EN 50083-2, *Cable networks for television signals, sound signals and interactive services — Part 2: Electromagnetic compatibility for equipment*;
- CLC/TR 50083-5-1, *Cable networks for television signals, sound signals and interactive services — Part 5-1: IP gateways and interfaces for headends*;
- EN 50083-8, *Cable networks for television signals, sound signals and interactive services — Part 8: Electromagnetic compatibility for networks*;
- EN 50083-9, *Cable networks for television signals, sound signals and interactive services — Part 9: Interfaces for CATV/SMATV headends and similar professional equipment for DVB/MPEG-2 transport streams*;
- EN 50083-10, *Cable networks for television signals, sound signals and interactive services — Part 10: System performance for return paths*;
- CLC/TR 50083-10-1, *Cable networks for television signals, sound signals and interactive services — Part 10-1: Guidelines for the implementation of return paths in cable networks* [the present document].

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. CENELEC [and/or CEN] shall not be held responsible for identifying any or all such patent rights.

1 Scope

1.1 General

Standards and other deliverables of the EN 50083 and EN 60728 series deal with cable networks including equipment and associated methods of measurement for headend reception, processing and distribution of television and sound signals and for processing, interfacing and transmitting all kinds of data signals for interactive services using all applicable transmission media. These signals are typically transmitted in networks by frequency-multiplexing techniques.

This includes for instance:

- regional and local broadband cable networks,
- extended satellite and terrestrial television distribution networks and systems,
- individual satellite and terrestrial television receiving systems
- and all kinds of equipment, systems and installations used in such cable networks, distribution and receiving systems.

The extent of this standardization work is from the antennas and/or special signal source inputs to the headend or other interface points to the network up to the terminal input of the customer premises equipment.

The standardization work will consider coexistence with users of the RF spectrum in wired and wireless transmission systems.

The standardization of any user terminals (i.e. tuners, receivers, decoders, multimedia terminals etc.) as well as of any coaxial, balanced and optical cables and accessories thereof is excluded.

1.2 Specific scope of this Technical Report

This document is intended to provide guidance to network designers on the issues which should be addressed when considering the design of return paths for regional or local broadband networks.

Items such as return path architecture & design, channel performance, channel planning and sources of interference, measurements, segmentation and re-segmentation, in home networks, distortion and commissioning are included. This document is not intended as a design reference but provides details which need to be addressed on individual issues relating to the design of the return path for a regional or local broadband network.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 60728-1:2008, *Cable networks for television signals, sound signals and interactive services — Part 1: System performance of forward paths (IEC 60728-1:2007)*

EN 60728-3, *Cable networks for television signals, sound signals and interactive services — Part 3: Active wideband equipment for cable networks (IEC 60728-3)*

EN 60728-4, *Cable networks for television signals, sound signals and interactive services — Part 4: Passive wideband equipment for coaxial cable networks (IEC 60728-4)*

EN 60728-5, *Cable networks for television signals, sound signals and interactive services — Part 5: Headend equipment (IEC 60728-5)*

EN 60728-6, *Cable networks for television signals, sound signals and interactive services — Part 6: Optical equipment (IEC 60728-6)*

EN 60728-10:2014, *Cable networks for television signals, sound signals and interactive services — Part 10: System performance for return paths* (IEC 60728-10:2014)

ETSI EN 302 878 series, *Access, Terminals, Transmission and Multiplexing (ATTM); Third Generation Transmission Systems for Interactive Cable Television Services — IP Cable Modems*

ETSI ES 201 488 series, *Access and Terminals (AT); Data Over Cable Systems*

ETSI ES 202 488 series, *Access and Terminals (AT); Second Generation Transmission Systems for Interactive Cable Television Services — IP Cable Modems*

3 Terms, definitions, symbols and abbreviations

3.1 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

NOTE As far as possible the available terms and definitions are taken from IEC 60050 series and are repeated below. The relevant IEC-numbers or other references are given in rectangular brackets after the definition text.

3.1.1

CATV networks

regional and local broadband cable networks designed to provide sound and television signals as well as signals for interactive services to a regional or local area

Note 1 to entry: This was originally defined as Community Antenna Television networks.

3.1.2

common path distortion

intermodulation distortion of downstream signals, mainly due to nonlinearities found at metallic junctions

Note 1 to entry: The distortions are manifest as a series of beats (caused by analogue downstream channels) or a band(s) of noise (caused by digital downstream channels) most noticeably in the upstream path. CPD may also be present in the downstream path, but since it adds with other downstream distortions (i.e. CTB and CSO), caused by active components, it is difficult to differentiate between the two. The nonlinear behaviour found at passive junctions may be due to a number of reasons including corrosion, typically from exposure to the elements, dissimilar metals, contact pressure, and junctions involving connectors contaminated with carbonaceous materials.

3.1.3

downstream direction

direction of signal flow in a cable network from the headend or any other central point (node) of a cable network towards the subscriber

[SOURCE: EN 60728-10:2014, modified]

3.1.4

extended satellite television distribution network or system

distribution network or system designed to provide sound and television signals received by satellite receiving antenna to households in one or more buildings

Note 1 to entry: This kind of network or system could be eventually combined with terrestrial antennas for the additional reception of TV and/or radio signals via terrestrial networks.

Note 2 to entry: This kind of network or system could also carry control signals for satellite switched systems or other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.5

extended terrestrial television distribution network or system

distribution network or system designed to provide sound and television signals received by terrestrial receiving antenna to households in one or more buildings

Note 1 to entry: This kind of network or system could be eventually combined with a satellite antenna for the additional reception of TV and/or radio signals via satellite networks.

Note 2 to entry: This kind of network or system could also carry other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.6

forward path (downstream)

physical part of a cable network by which signals are distributed in the downstream direction from the headend or any other central point (node) of a cable network towards the subscriber

[SOURCE: EN 60728-10:2014, modified]

3.1.7

gateway

functional unit that connects two computer networks with different network architectures

EXAMPLES LAN gateway, mail gateway.

Note 1 to entry: The computer networks may be either local area networks, wide area networks or other types of networks.

[SOURCE: IEC 60050, IEV 732-01-16 – definition altered and original Note 2 turned into the present "EXAMPLES" paragraph]

3.1.8

headend

assembly of equipment feeding signals into a cable network from local or external sources, including equipment for reception and signal processing

[SOURCE: IEC 60050, IEV 723-09-11, modified – definition altered]

Note 1 to entry: The headend may, for example, comprise antenna amplifiers, frequency converters, combiners, separators and generators.

3.1.9

hub

local area distribution point for the insertion and recovery of two-way narrowcast signals such as DOCSIS/EuroDOCSIS with broadcast transmissions from the headend in the RF domain (frequency multiplexing)

3.1.10

hybrid fibre coaxial network

HFC network

cable network which comprises optical equipment and cables and coaxial equipment and cables in different parts

[SOURCE: EN 60728-10:2014]

3.1.11

individual satellite television receiving system

system designed to provide sound and television signals received from satellite(s) to an individual household

Note 1 to entry: This kind of system could also carry control signals for satellite switched systems or other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.12

individual terrestrial television receiving system

system designed to provide sound and television signals received via terrestrial broadcast networks to an individual household

Note 1 to entry: This kind of system could also carry other signals for special transmission systems (e.g. MoCA or WiFi) in the return path direction.

3.1.13

ingress noise

noise which is caused by electromagnetic interference into cable networks. Its power decreases with increasing frequency. It is permanently present but slowly varies in its intensity as a function of time

[SOURCE: EN 60728-10:2014]

3.1.14

local broadband cable network

network designed to provide sound and television signals as well as signals for interactive services to a local area (e.g. one town or one village)

3.1.15

(network) segment

part of a cable network comprising a set of functions and/or a specific extent of the complete cable network

[SOURCE: EN 60728-10:2014]

3.1.16

network termination unit

NTU

equipment for access to the cable network connected between home network interface (HNI) and system outlet

3.1.17

node

point in a cable network where two or more links are interconnected

[SOURCE: IEC 60050, IEV 715-08-06, modified – definition altered]

3.1.18

Optical Modulation Index

OMI

index which is defined as:

$$m = \frac{\phi_h - \phi_l}{\phi_h + \phi_l}$$

where

ϕ_h is the highest and ϕ_l is the lowest instantaneous optical power of the intensity modulated optical signal. This term is mainly used for analogue systems

[SOURCE: EN 60728-10:2014, modified]

Note 1 to entry: This definition doesn't apply to systems where the input signals are converted and transported as digital baseband signals. In this case the terms modulation depth or extinction ratio defined in 2.6.79 and 2.7.46 of IEC/TR 61931:1998 will be used. A test procedure for extinction ratio is described in EN 61280-2-2.

3.1.19

regional broadband cable network

network designed to provide sound and television signals as well as signals for interactive services to a regional area covering several towns and/or villages

3.1.20

return path (upstream)

physical part of a cable network by which signals are transmitted from any subscriber, connected to the network, to the headend or any other central point (node) of a cable network

[SOURCE: EN 60728-10:2014, modified]

3.1.21

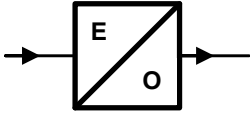
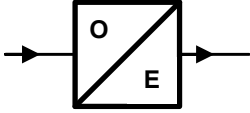
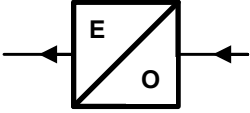
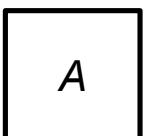
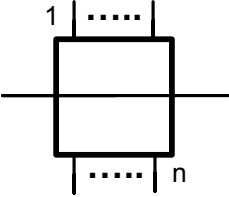
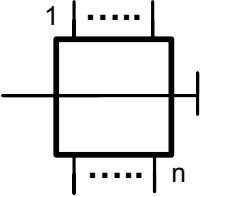
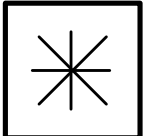
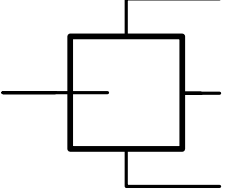
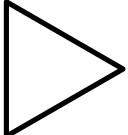
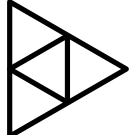
upstream direction

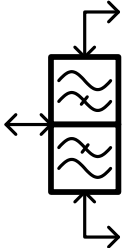
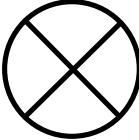
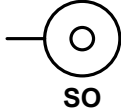
direction of signal flow in a cable network from a subscriber towards the headend or any other central point (node) of a cable network

[SOURCE: EN 60728-10:2014, modified]

3.2 Symbols

The following graphical symbols are used in the figures of this Technical Report. These symbols are either listed in IEC 60617 or based on symbols defined in IEC 60617:

Symbol	Function	Symbol	Function
	Optical transmitter forward path		Optical transmitter return path
	Optical receiver forward path		Optical receiver return path
	Analogue-Digital Converter		Digital-Analogue Converter
	Multiplexer [IEC 60617-S01626]		De-multiplexer [IEC 60617-S01626, modified]
	Attenuator (fixed) [IEC 60617-S01244]		
	Tap-off (n ports)		Multi-tap (n ports) with terminated feeder line
	Distribution network		Splitter Combiner (in the reverse direction)
	Amplifier, one-way [IEC 60617-S01239]		Amplifier, two-way [IEC 60617-S00433]

Symbol	Function	Symbol	Function
	Low-pass filter [IEC 60617-S01248]		High-pass filter [IEC 60617-S01247]
	Diplexer		Band-pass filter [IEC 60617-S01249]
	Fibre cable		Multiplier
	Equalizer		System outlet
	Sinewave Generator		Headend
	Network termination unit		Cable modem termination system
	AC power supply		Returnpath transmitter
	Test Receiver		Test transmitter

3.3 Abbreviations

For the purposes of this document, the following abbreviations apply.

AC	Alternating current
ADC	Analogue-to-digital converter
ALSC	Automatic level & slope control

AM	Amplitude modulation
BNI	Building network interface
BNTU	Building network termination unit
C/NLD	Carrier to non-linear distortion ratio
CATV	Community antenna television
CB	Citizens band
CF	Centre frequency
CMTS(s)	Cable modem termination system(s)
CPD	Common path distortion
CPE	Customer premises equipment
CSO	Composite second order
CTB	Composite triple beat
CW	Continuous wave
CWDM	Coarse wavelength division multiplex
DAC	Digital-to-analogue converter
DAVIC	Digital Audio Visual Council
DC	Direct Current
DeMUX	De-multiplexer
DFB	Distributed feedback (laser)
DOCSIS	Data-over-cable service interface specification
DS	Downstream
DVB	Digital video broadcasting
DWDM	Dense wavelength division multiplex
EDFA	Erbium doped fibre amplifier
EMS	Element management system
EuroDOCSIS	European data-over-cable service interface specification
EUT	Equipment under test
FM	Frequency modulation
FP	Fabry-Perot (laser)
FSK	Frequency shift keying
HE	Headend
HF	High frequency
HFC	Hybrid-fibre-coax
HNI	Home network interface
IP	Internet protocol
ISF	Ingress suppression filter
MDU	Multiple dwelling unit
MER	Modulation error ratio
MUX	Multiplexer
NGN	Next generation network

NLD	Non-linear distortion
NPR	Noise power ratio
NTU	Network termination unit
OMI	Optical modulation index
PID	Packet identifier
PIM	Passive intermodulation
PMD	Polarization mode dispersion
PRBS	Pseudo random bit sequence
PSTN	Public switched telephone network
QAM	Quadrature amplitude modulation
QPSK	Quadrature phase shift keying
RF	Radio frequency
RP	Return path
Rx	Receiver
SBC	Session border controller
SDH	Synchronous digital hierarchy
SDU	Single dwelling unit
SIP	Session initiation protocol
SIR	Signal to ingress ratio
STB	Set-top box
SUT	System under test
Tx	Transmitter
US	Upstream
VOD	Video on demand
VoIP	Voice-over-IP
VSB	Vestigial side-band

4 Network architecture

4.1 HFC architecture

Access networks today are required to carry a multitude of different services. As a result, network engineers and architects are challenged to build infrastructures that are able to deliver these new services.

CATV networks, using HFC technologies have become the standard for providing both broadcast and interactive services. In an HFC network the forward path and return path portions are closely linked together. Where needed, for a better understanding, both portions will be considered in this document. This document will however focus primarily on return transmission. The return path portion of such networks is related to the corresponding standard document (EN 60728-10). The return path frequency range of such networks (Figure 1, network portion between reference points) is typically specified up to a maximum frequency range of 5 MHz to 65 MHz; (other frequency ranges, e.g. 5 MHz to 85 MHz, may apply).

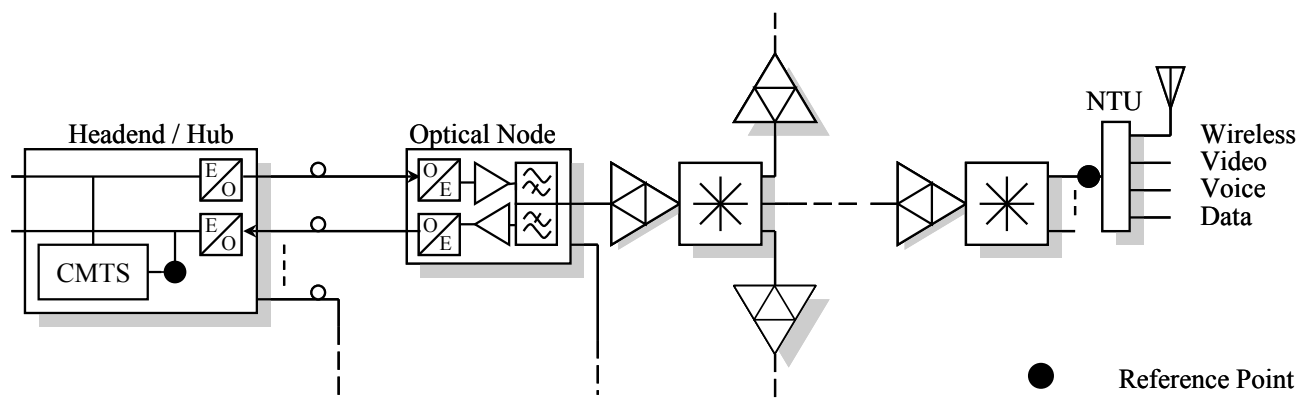


Figure 1 — Typical HFC topology

Most of the guidelines in this document are also valid for legacy networks, consisting only of an RF distribution networks. To enable interactive services the CATV network shall be made “bidirectional” by adding diplex filters and active or passive return path hardware. The return path portion in the RF distribution network is to be considered active, when at least one amplifier station is equipped with a return path amplifier module; otherwise it should be considered as passive.

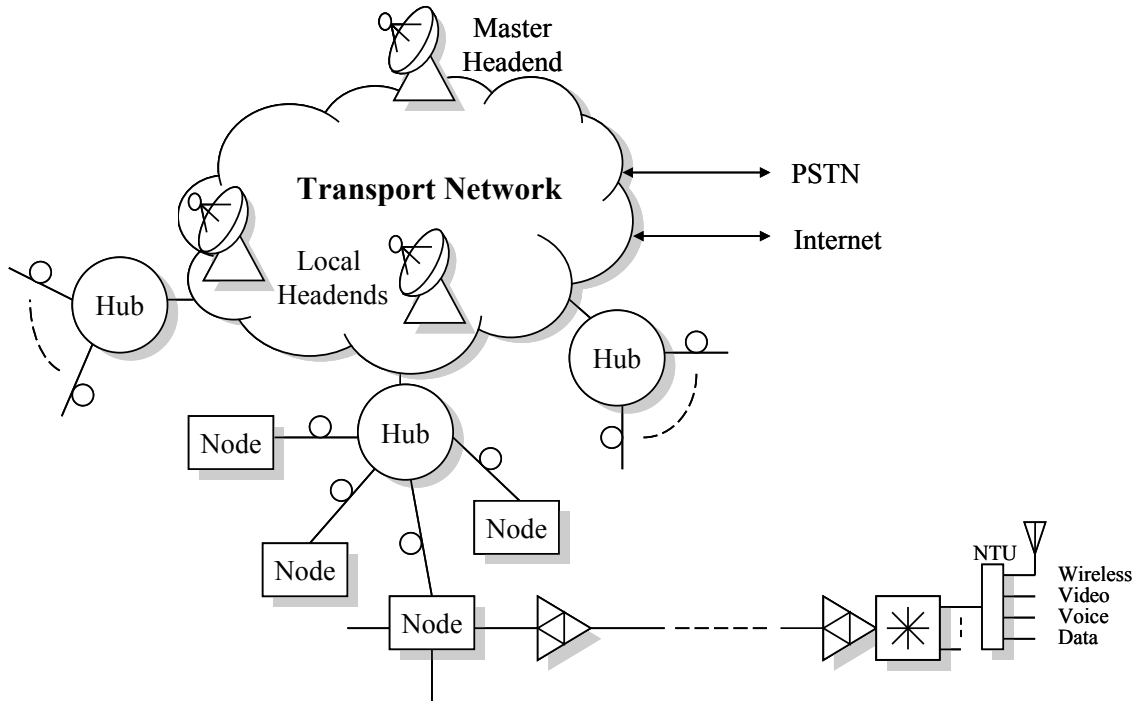
It is assumed that in the HFC network optical links are feeding optical nodes, which are followed by the RF coaxial distribution network. It is also assumed that the trunk and distribution networks are subdivided in nodal areas, which provides a more reliable and manageable topology. Greater reliability is achieved due to the fact that an interruption in the signal path will at most affect only the nodal area. It is also more manageable because upgrades and interventions need not be extended over the whole network, but can be performed on a “per nodal area” and therefore phased as needed.

The subdivision into nodal areas has an additional benefit of providing serving zones that can be managed individually and provides greater flexibility with regards to traffic capacity and capacity planning. At the subscriber site typically a network termination unit (NTU) is connected to the reference point of the given home network interface (HNI). An NTU (network termination unit) provides the necessary interfaces to the system outlets.

In practice real networks are more extensive and sophisticated. Therefore the issues to be considered have to be broadened to include possible multiple headends, hubs, cascaded optical links and interfaces for service interconnection. Several serving zones could be combined to connect with a regional broadband network by means of (a) transport network(s) (Figure 2). Different technologies are available for the transport networks. If the distance is short an RF analogue transport network may be used. For longer distances optical transport may be employed using, either at 1 310 nm or 1 550 nm optical links.

NOTE At 1 550 nm the fibre attenuation is lower than at 1 310 nm and also optical amplification of the signals using optical amplifiers (EDFAs) is possible.

For long distances and high data rates high speed digital transport standards e.g. SDH, Gigabit Ethernet, 10 Gigabit Ethernet are possible transport technologies.



NOTE In Next Generation Networks (NGN) PSTN gateways will be replaced by IP gateways and SIP session border controllers (SBC).

Figure 2 — Regional network

4.2 Upgrade alternatives

4.2.1 Introduction

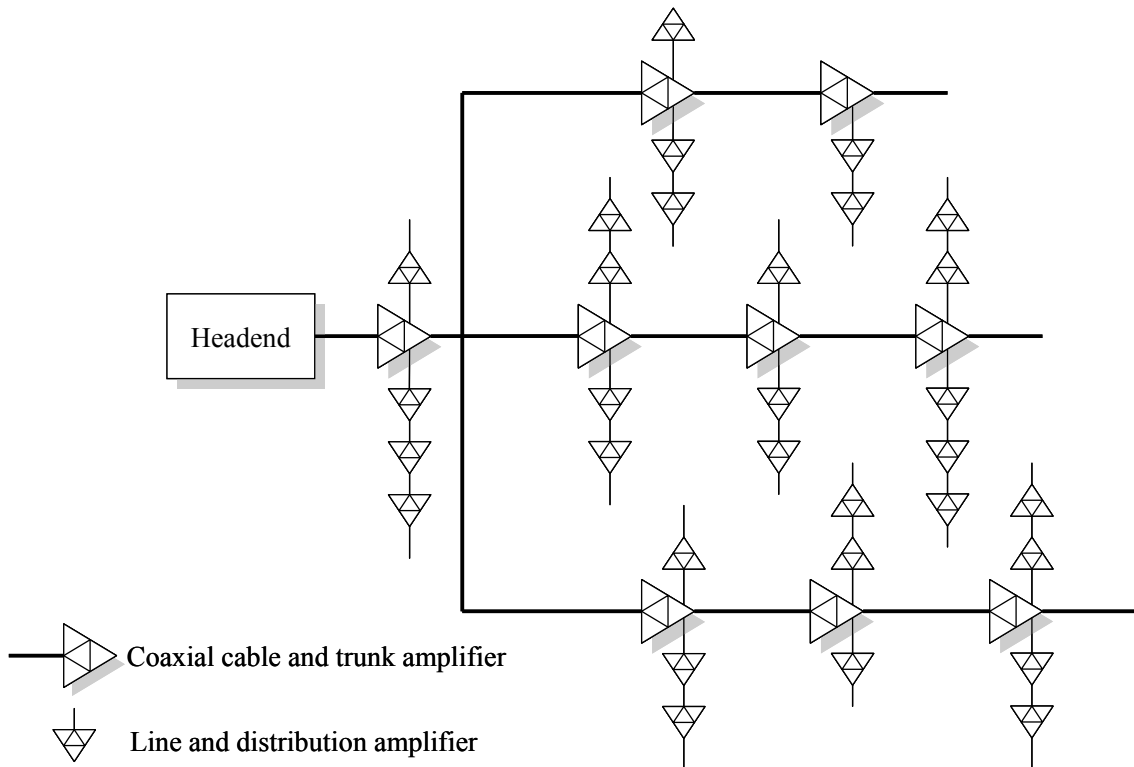


Figure 3 — Trunk-and-distribution architecture using only coaxial equipment

The HFC architecture is typically derived by means of traditional trunk-and-distribution architectures as shown in Figure 3. During any upgrade often some of the amplifiers are replaced by optical nodes and connected by two-way optical fibre links directly to the local headend (see Figure 4).

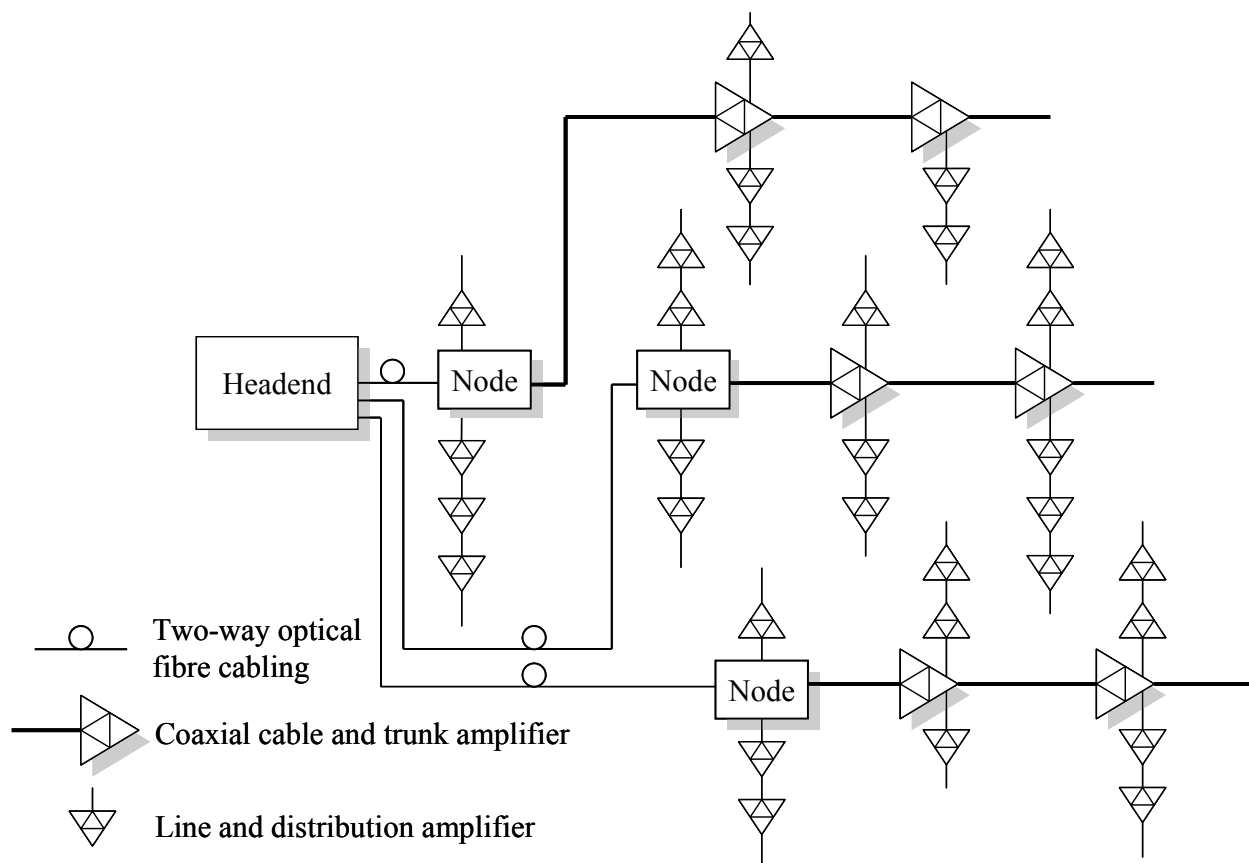


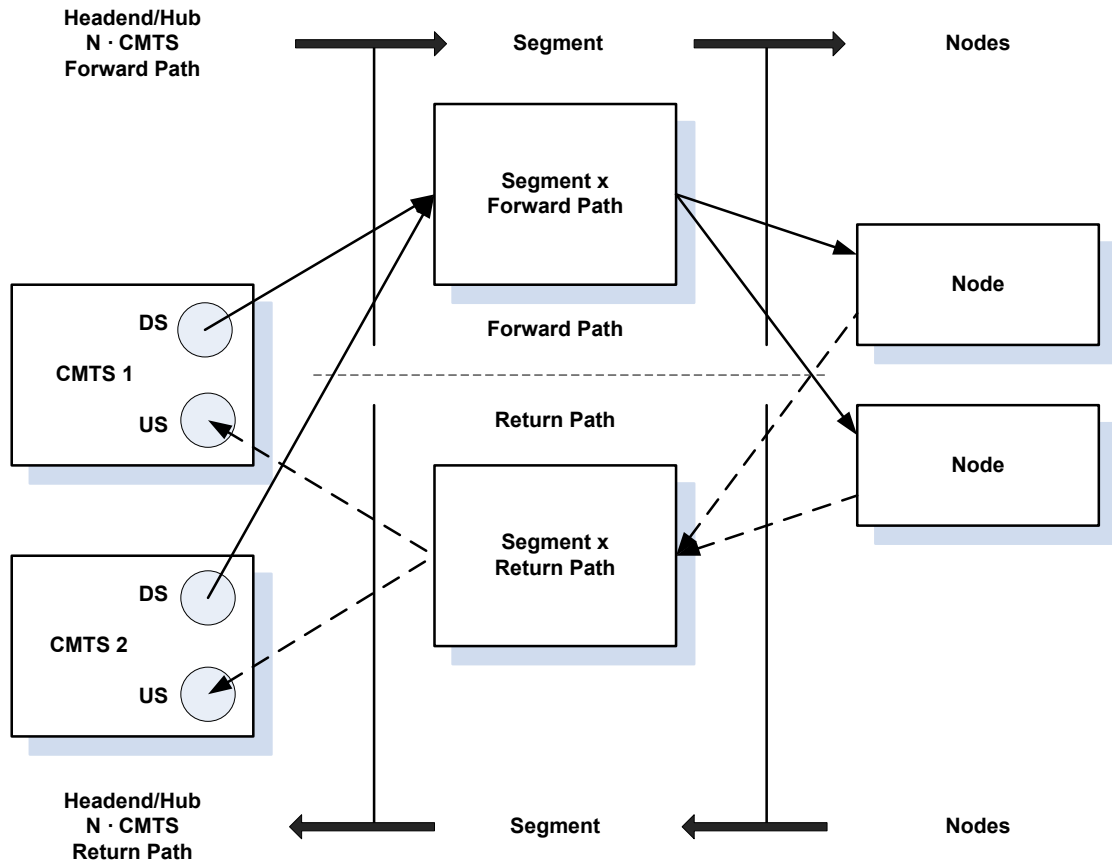
Figure 4 — HFC system

In an early phase of any upgrade 500 to 5 000 homes passed per optical node is a typical starting value for network engineers. A “segment” serving between 500 and 20 000 homes passed consists of several optical nodes and is configured to handle the initial data requirements. However, with the potential requirements of future services, and increased number of connections, there is usually a need to increase the upstream data capacity either by the use of smaller segment sizes (fewer optical nodes per segment) or by adding more data channels. As a result a single segment could be served by one or more downstream DOCSIS/EuroDOCSIS channels together with the associated upstream channels.

One of the tasks for network engineers is to connect optical nodes to any termination system, in a way which guarantees the required bandwidth to all subscribers. Most networks have been configured with a single segment (500 to 20 000 homes passed) being served by a single downstream feed together with a single upstream feed (Figure 6). The downstream feed typically carries a single DOCSIS/EuroDOCSIS QAM channel with the associated upstream link carrying between 1 and 6 upstream RF channels.

Figure 5 shows a theoretical segment for interactive traffic. This segment can consist of a number of nodes and be served by a number of CMTS units. On “day 1” a single CMTS may serve 6 or 8 optical nodes. As traffic requirements increase this may change to a single CMTS serving a single optical node and eventually say 4 CMTS units feeding a single node. This process is known as “re-segmentation”.

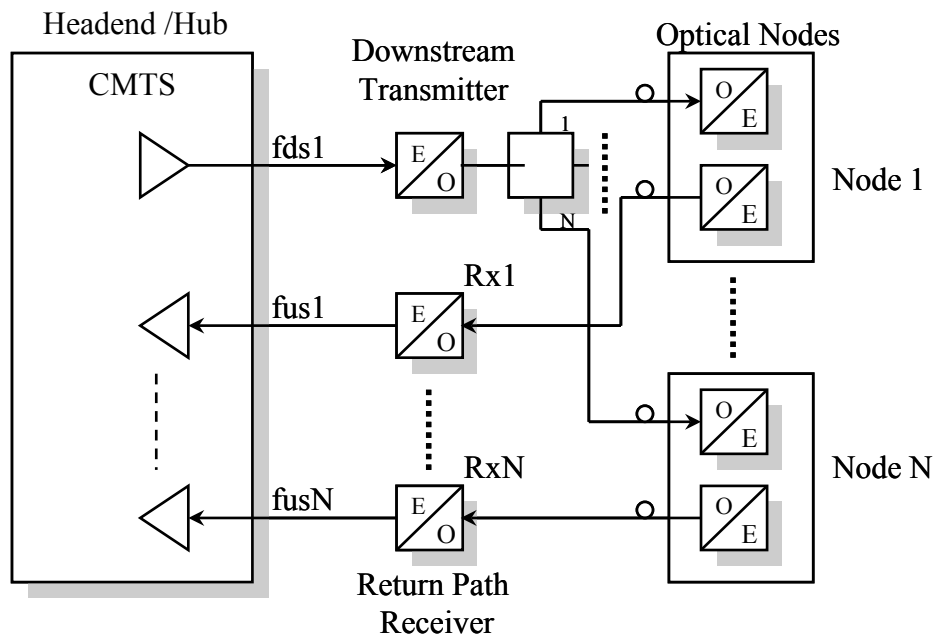
Further options and considerations for re-segmentation are given in the following sections.



NOTE 1 Only one segment is shown in the diagram for clarity.

NOTE 2 As protection against equipment failures is of paramount importance, more segments, hubs and CMTS cards are added as required for the number of homes passed, penetration and traffic requirements.

Figure 5 — Generic diagram showing the mapping of nodes and CMTS(s) to segments



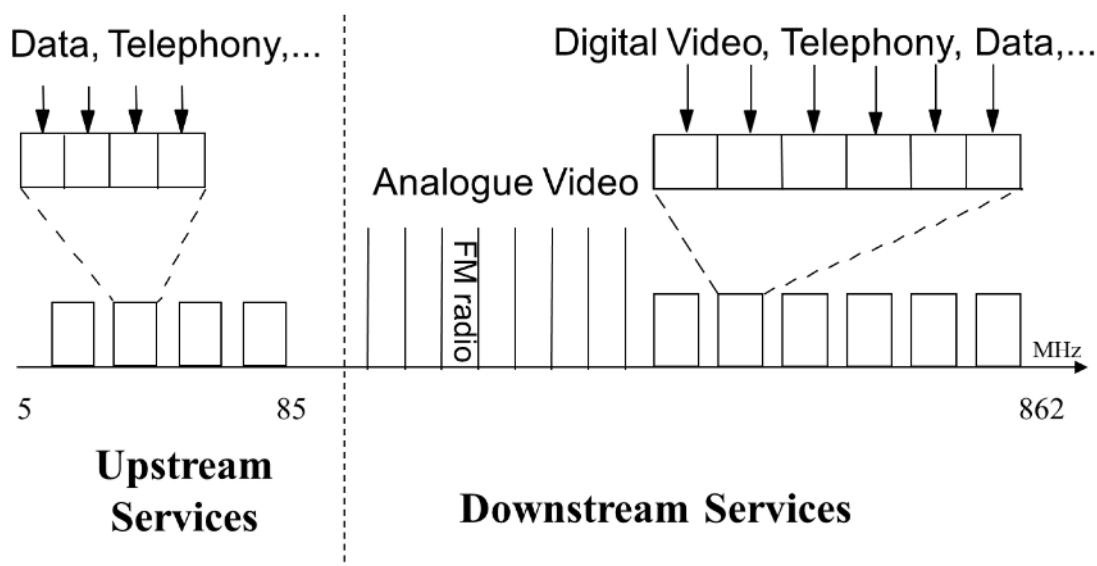
fds = downstream frequency, fus = upstream frequency

NOTE No standby protection; see Figure 19 for a protection scheme.

Figure 6 — Segment comprising a single CMTS to N optical nodes

Different ways, depending on the cost and the structure of the existing network, could be used to re-arrange this connectivity.

Historically the return path of HFC networks has been used for low speed data transmission using FSK or QPSK modulation. In recent years, the return path has been upgraded to enable the carriage of multiple return path DOCSIS and Euro-DOCSIS channels, which allow modulations with higher bandwidth efficiency (QPSK, 16QAM, 64QAM and 128QAM). Nevertheless, in the coaxial portion of the network the available bandwidth is limited. The frequency allocation (Figure 7), defined by EN 60728-10, allows 80 MHz (at the very maximum, limited by group delay) to be shared by all users.



NOTE The upper frequency limit of the return path is reduced to 65 MHz where FM radio signals are transmitted in a cable network.

Figure 7 — Spectrum allocation bandwidth

A much higher bandwidth (> 200 MHz) could be used in the return path optical link even with low cost optical lasers and receivers. Several return path frequency ranges are up converted at different suitable frequencies and multiplexed together in the optical node (frequency stacking). A further possibility is the analogue-to-digital conversion of each return path frequency range in the optical node and time domain multiplexing of several digitised return path frequency ranges (digital return). Further detail on these options is given below.

When an interactive service is implemented, traffic is usually low, both in the forward and return path. As more subscribers are connected and/or the levels of service are increased, there is insufficient network capacity to handle the increase in traffic. When coaxial upstream capacity is exhausted changes need to be made to the network, either as a whole or individual part, in order to address this issue. (This exercise is usually referred to as “re-segmentation”).

Physically splitting the network and adding more equipment and fibres reduces the number of subscribers served per “segment” thus increasing the available bandwidth to each subscriber. One advantage of carrying out this option for re-segmentation is that the ingress per segment is reduced.

Other options for re-segmentation are as follows:

- ✓ Re-arrange the feeds
- ✓ Multiple fibres
- ✓ Digital return technology
- ✓ Frequency stacking
- ✓ Wavelength division multiplexing

The node configuration of Figure 8 will be taken as the basis of the architecture evolution.

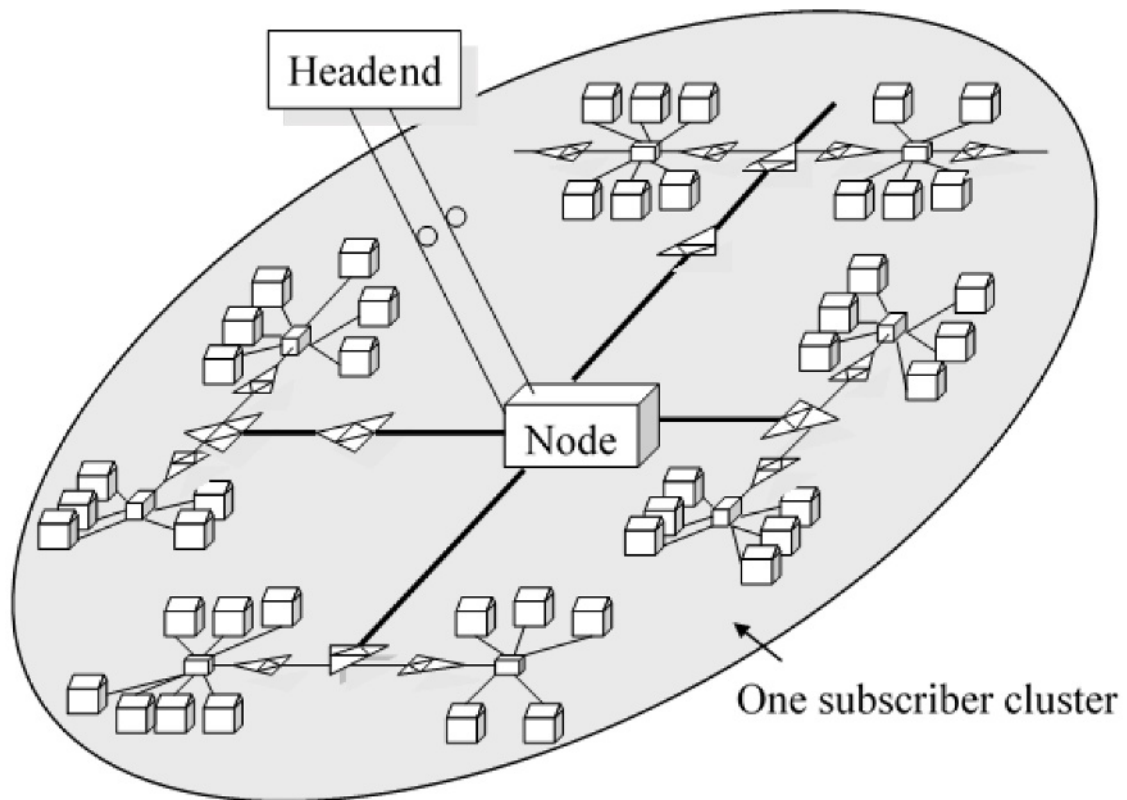
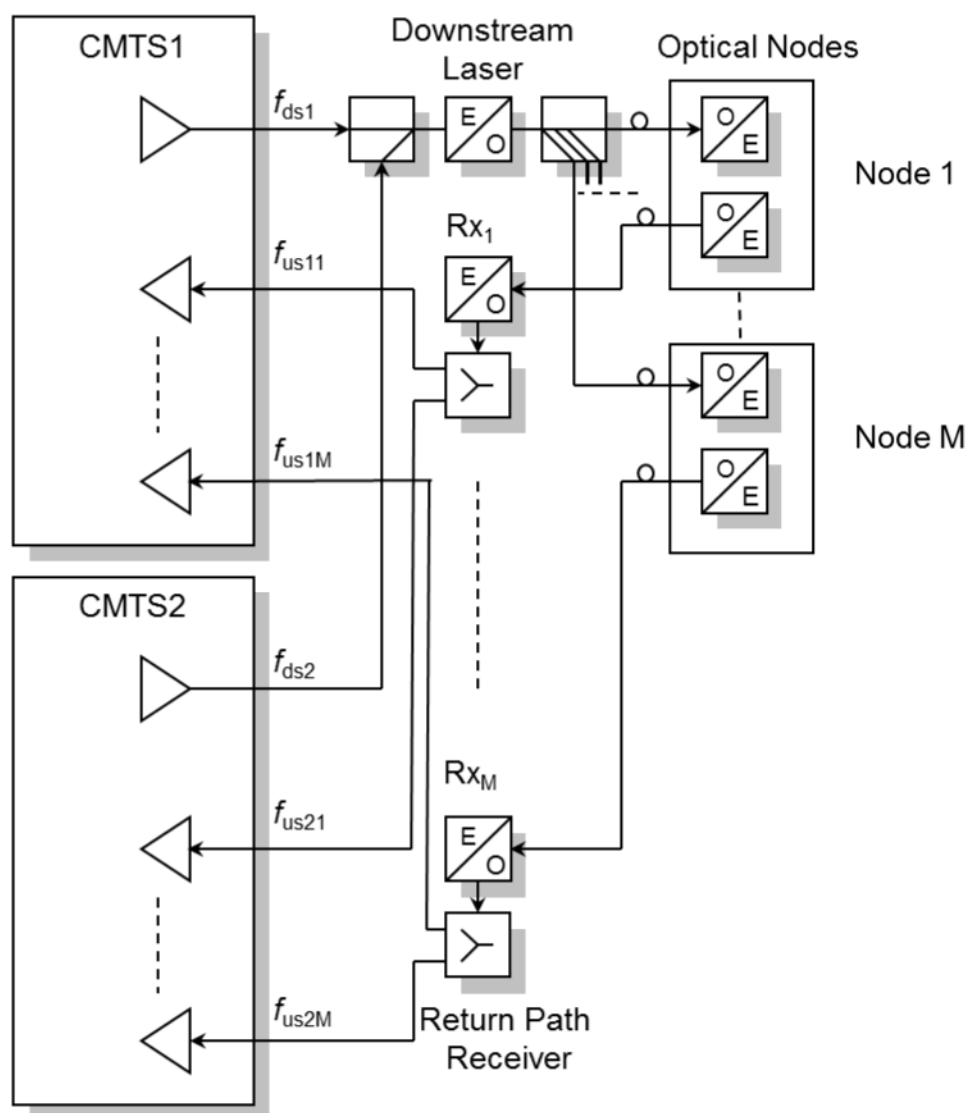


Figure 8 — Basic node architecture

4.2.2 Re-arrange the feeds

The flexibility of the CMTS systems gives the operator different options to re-segment the network by adding upstream and downstream channels.

As an example, initially one downstream data channel together with TV channels is connected to different optical nodes and one upstream channel is connected to each node (Figure 6). Progressively additional downstream channels can be added as well as additional upstream channels (Figure 9).



Key

f_{ds} = downstream frequency

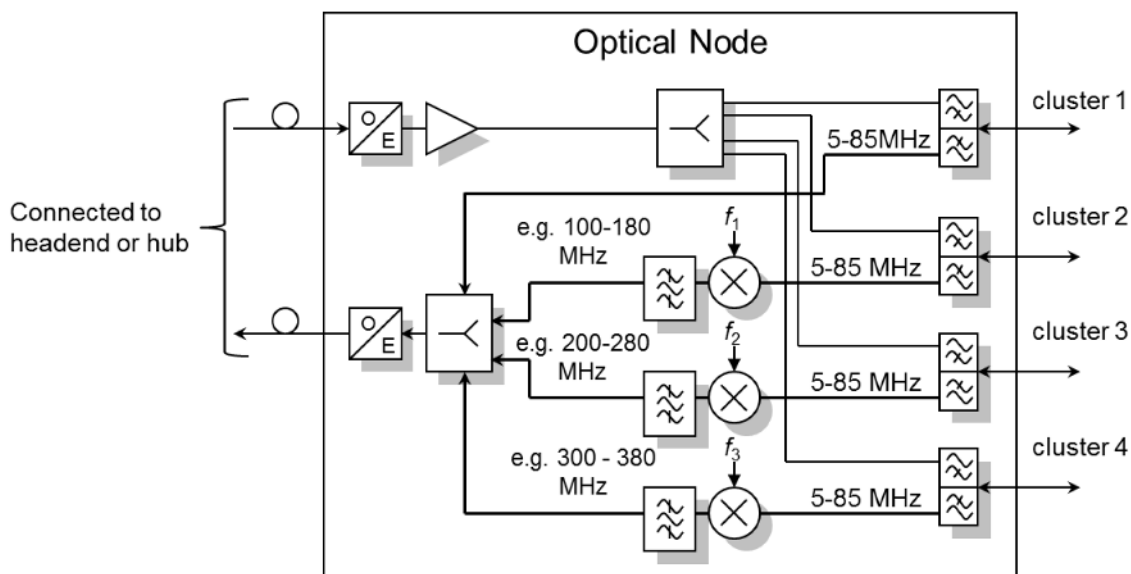
f_{us} = upstream frequency

Figure 9 — Re-arranged feeds (two CMTS serving four nodes)

4.2.3 Frequency stacking

This is relevant to return path optical links only. By changing the return path optical link to a link with similar design to the forward path link multiple 5 MHz to 85 MHz return paths can be stacked onto a single 5 MHz to 860 MHz optical link. A typical design may stack 4 full return paths (Figure 10). All unconverted bands would be phase locked both “up” and “down” using double conversion. Local oscillator and oscillator harmonics would be arranged to fall in the unused slots between individual, unconverted, return paths. Link monitoring could easily be implemented by transmitting the master reference oscillator over the fibre link. In event of a faulty converter that return path would switch to the unused 5 MHz to 85 MHz frequency band.

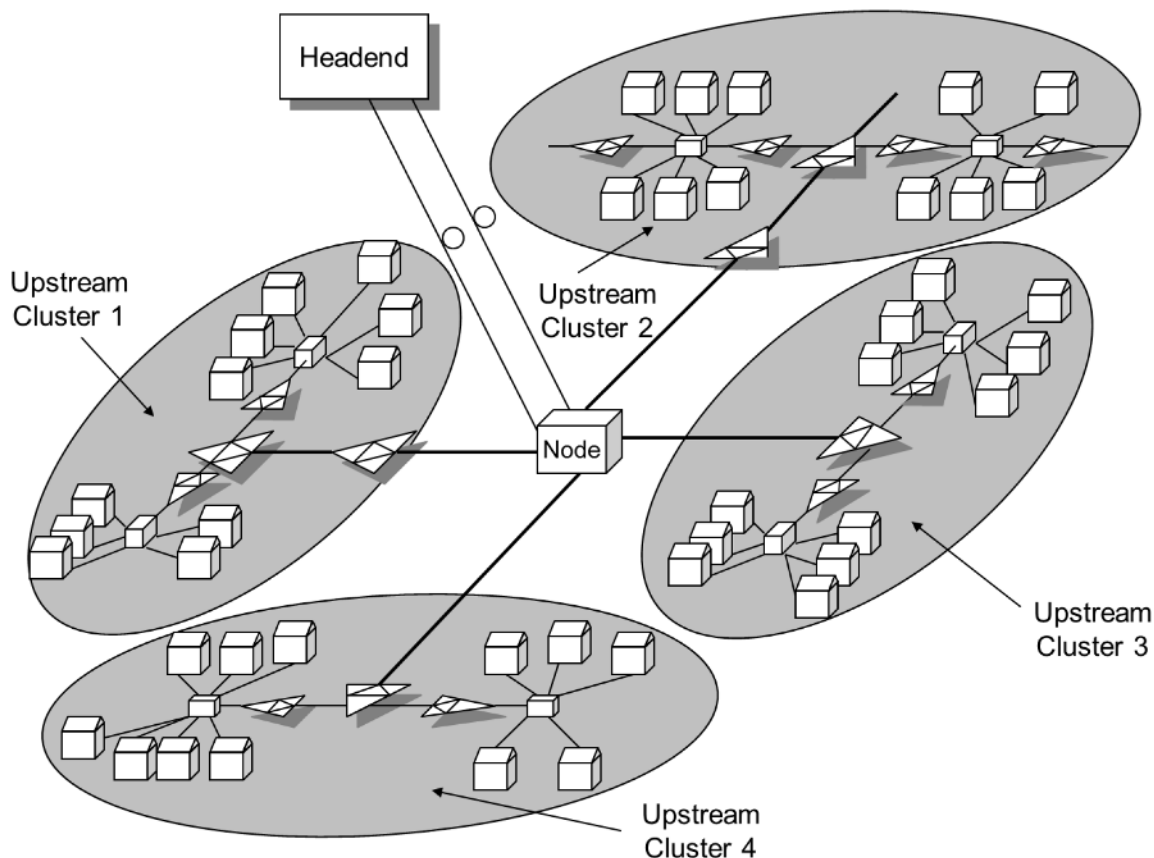
In the headend each converted return path frequency range is down-converted to the initial range 5 MHz to 85 MHz.



NOTE Frequency plans are vendor dependent.

Figure 10 — Optical node with frequency stacking

Multiple downstream channels would map individually to each upstream band (Figure 11).



NOTE Each return spectrum is stacked in frequency before modulating the laser.

Figure 11 — Divided node

However, it is difficult to design block up- and down-converters with acceptable dynamic range and frequency stability and therefore other methods to increase the upstream capacity are normally used.

4.2.4 Multiple fibres

Increasing the number of optical fibres, as well as the number of attached return path transmitters and receivers, allows the provision of higher bandwidth per node as service penetration is rising. To minimise investment costs in early phases of the upgrade multiple e.g. 4 return paths inputs are combined before modulating the laser in the optical node. Later on when the needs for bandwidth will increase, only two return path inputs will be combined and used to modulate a single laser (Figure 12).

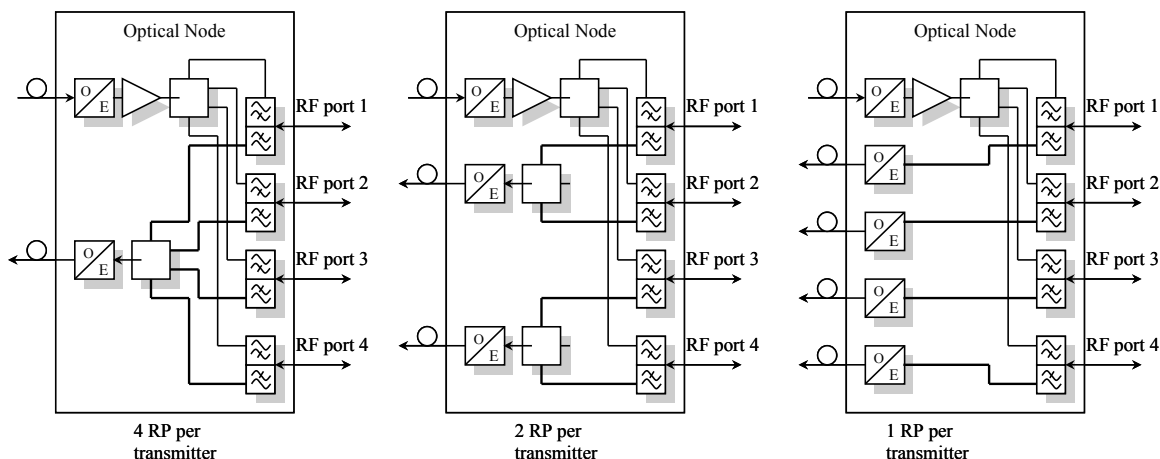


Figure 12 — Return path segmentation

A second possibility given by the extensibility of the HFC architecture is installing additional optical fibres to the amplifier locations after an optical node (Figure 11) and converting these amplifiers to new optical nodes. This leads to the structure shown in Figure 13. The type of a cluster is named "Node + n", where n represents the maximum number of amplifiers cascaded after the node. "Node + 0" represents the maximum order of segmentation and provides the highest bandwidth per customer. Due to the passive network behind the node in "Node + 0" clusters this type of cluster has very likely the best RF performance. It is suitable for future higher order modulation schemes.

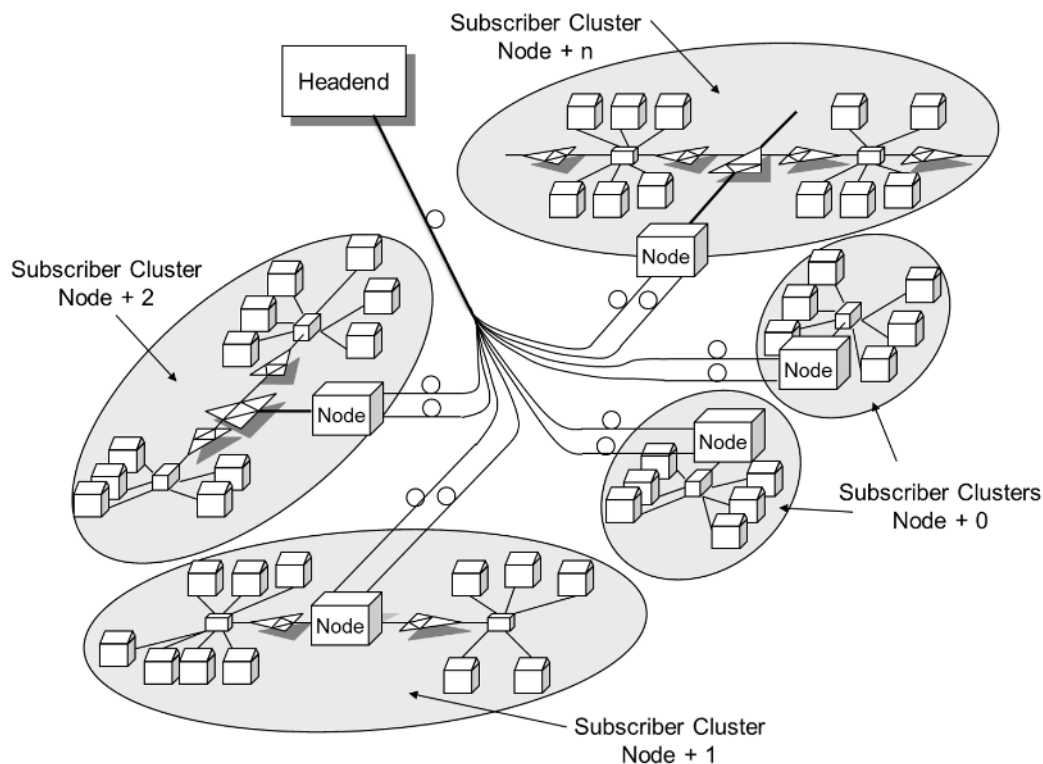


Figure 13 — Division of the node areas using additional fibres

4.2.5 Wavelength division multiplexing (WDM)

Dense wavelength division multiplexing (DWDM) is a fibre-optic transmission technique that employs light wavelengths to transmit data. The wavelength spacing is defined in the ITU-T Recommendation G.692 [14]. The actual tendency is to use DWDM, transmitting only 4 to 16 well separated wavelengths from the ITU-grid. By using transmitters with defined wavelengths and the appropriate filters, a single fibre can transmit several wavelengths, each wavelength carrying different information. The typical channel spacing for DWDM wavelengths is 1,6 nm (100 GHz). But for analogue transmission this spacing is too close, therefore 200 GHz is recommended with the current state of technology. The ITU DWDM Grid is shown in Table C.1.

Each return port, or combination of ports, is fed into an optical transmitter at a defined wavelength. A DWDM multiplexer then combines the optical outputs from multiple transmitters onto a single fibre. At the receiving site, an optical de-multiplexer separates the wavelengths and detects each block independently (Figure 14).

Due to the narrow channel spacing DWDM equipment is rather expensive. An alternative with lower cost is coarse wavelength division multiplexing (CWDM). To implement CWDM the system architecture shall not be changed (Figure 14). Only the channel spacing for CWDM wavelengths is different. A typical value for the channel spacing is 20 nm.

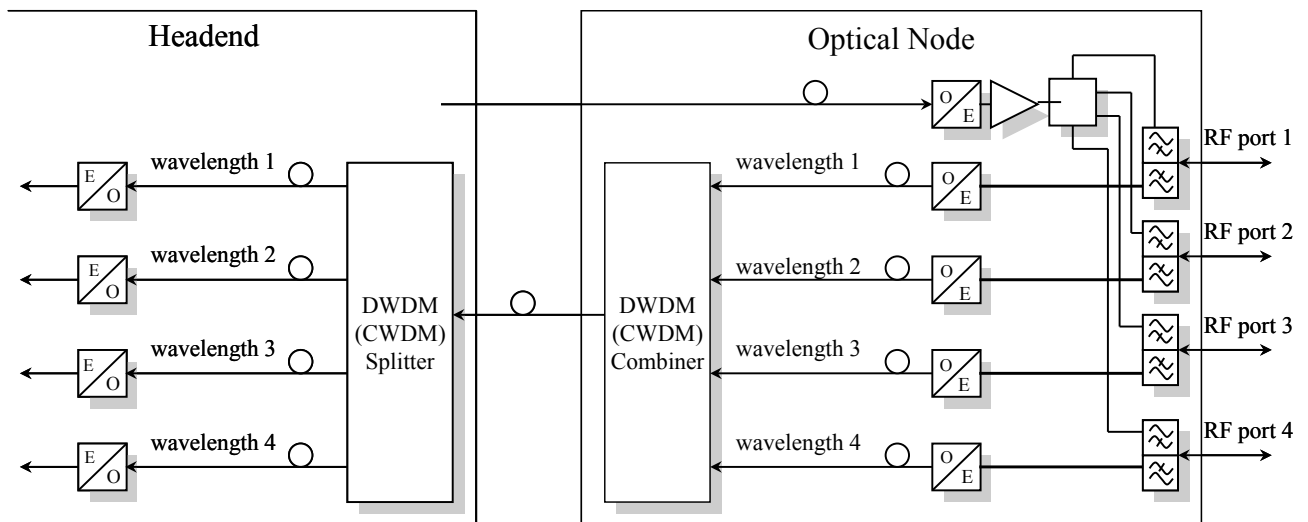


Figure 14 — DWDM (CWDM) return path transmission

4.2.6 Digital return technology

The basic concept of digital return technology is to digitize the broadband (5 MHz to 65 MHz) return path signal converting it to a high speed serial data stream.

Sampling is carried out at least twice the highest frequency with a sampling rate > 130 MSample/s. The parallel output of the analogue-to-digital converter (ADC) is converted into a serial data stream and then transmitted by means of baseband digital optics. The receiver detects the optical data stream, synchronises and converts the serial data stream in parallel inputs to the digital-to-analogue converter (DAC). After the DAC the original broadband signal (5 MHz to 85 MHz) is reconstructed. Figure 15 shows the principle of digital return technology.

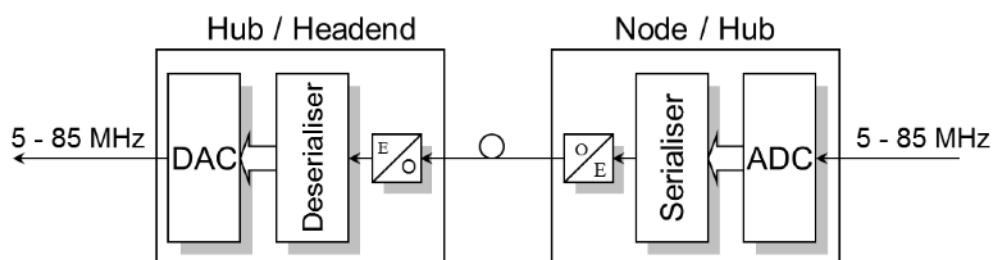


Figure 15 — Digital return technology basic concept

The digital return link, viewed as a black box between the broadband return input and return output, is transmitting return path signals transparently. The performance of a digital return link is analogous to that of