Requirements for Generic Cabling Systems

Best Practice Document

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Executive Summary

This document provides specification of the Norwegian Higher Education (HE) sector's recommended standards for generic cabling systems.

When setting up generic cabling systems, it is recommended that the latest version of any currently applicable norms or standards be used at all times. If one wishes to install cable of higher quality than is called for by the applicable norms or standards, one must be aware of any possible disadvantages.

Currently, the recommendation is to use:

- At least 1 Gb/s capacity in the horizontal cabling system, in other words, Class E / Category 6
- Building backbone cabling and campus backbone cabling subsystems consisting of single-mode (SM) fibre-optic cable.

In connection with new building and renovation, it is important to ensure the allocation of necessary space and pathways to enable the establishment of a fully functional IT environment.

The standard of workmanship is considered extremely important, as regards both interior and exterior installation work. The characteristics of the selected products shall be appropriate to the area of use, installation location and environment. Installation firms shall have the necessary authorisations for the work to be carried out as well as certification for the products used.

Installation personnel shall always be required to provide documentation for the installation, and Documents of Conformity as required by the authorities. In the case of complex installations or installations of a quality exceeding the applicable norms or standards, a system and application guarantee from the manufacturer shall also be required.

Introduction

This document provides specification of the Norwegian HE sector's recommended standards for generic cabling systems, and is a revision of version 2, dated 22 December 2009. A revision log will be found in Chapter 7.

The target group comprises IT managers and IT operations personnel in the HE sector. The purpose of the document is to improve the quality of cable infrastructure in the sector and it is intended that the recommendations in this document will form the basis of expansion, renovation and new building projects, and that they will be applied in everyday work contexts.

1 Definitions from Norwegian Cabling Standards

This document uses a number of technical terms and references to Norwegian standards for generic cabling systems used in information technology. To facilitate understanding of the document, some important definitions derived from NEK EN 50173 and NEK EN 50174 are reproduced below. Reference is also made to Figure 1: “Structure of a generic cabling system” and to Figure 2: “An example of the location of functional elements”.

<u>Building backbone cable:</u>
Cable which connects a building distributor to a floor distributor.

<u>Campus backbone cable:</u>
Cable which connects a campus distributor to a building distributor. A campus backbone cable may also form a direct connection between building distributors.

<u>Floor distributor:</u>
A distributor which is used to make connections between horizontal cables, other elements of the cabling system or operating equipment. The number of floor distributors is determined on the basis of the nature of the buildings, as well as the requirement for the maximum physical length of horizontal cable (90 m). A floor distributor will often be capable of serving several floors. A room in which floor distributors are located is often referred to as a Telecommunications Room (TR) or Equipment Room (ER).

<u>Building distributor:</u>
A distributor in which a building backbone cable or cables terminate, and where through-connection to the campus backbone cable can be made. A room in which a building distributor is located is often referred to as an Equipment Room (ER), but a building distributor may also be located in a Telecommunications Room (TR).

<u>Campus distributor:</u>
A campus distributor is a distributor in which a campus backbone cable is terminated.

<u>Horizontal cable:</u>
A cable which connects floor distributors with telecommunications output jacks. The maximum physical cable length is 90 m.

<u>Consolidation point (CP):</u>
A consolidation point is used to make the horizontal network more flexible with regard to furnishing and adaptations of the work space, and is often used in connection with the use of power poles. Examples:

1. Consolidation points are located above ceilings.
2. Telecommunications output jacks are located on a power pole. The cable connecting telecommunications output jacks in a power pole to the consolidation point is referred to as a CP cable.
3. Terminal equipment is connected to a telecommunications output jack in a power pole using a work space cord (appliance cord).

A consolidation point should be located at least 15 metres (cable length) from the floor distributor.

<u>Telecommunications output jack:</u>
A fixed connecting device in which the horizontal cable is terminated. The telecommunications output jack forms an interface with the cabling in the work space.

<u>Channel:</u>
The total transmission path (end-to-end) which connects one application-specific device to another. The horizontal cable, appliance lead and work space leads are elements of the channel (from switch to terminal equipment). The maximum channel length is 100 metres, of which 90 metres comprise the installed horizontal cable and no more than 10 metres comprise the combined appliance and work space cords.

The maximum channel length may be somewhat reduced because the maximum length of the horizontal cable is affected by the length and quality of the CP cable, appliance cords, work space cords and patch cables included in the channel.

The figures below illustrate these definitions and the composition of a generic cabling system.

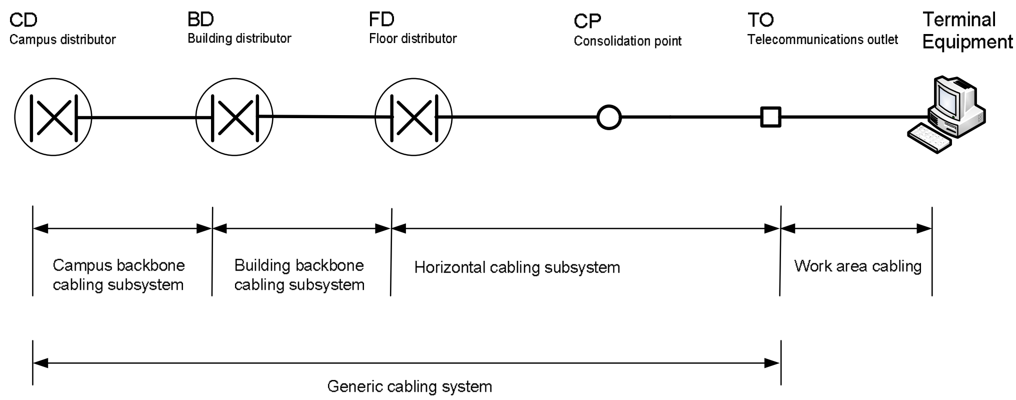


Figure 1. Structure of a generic cabling system

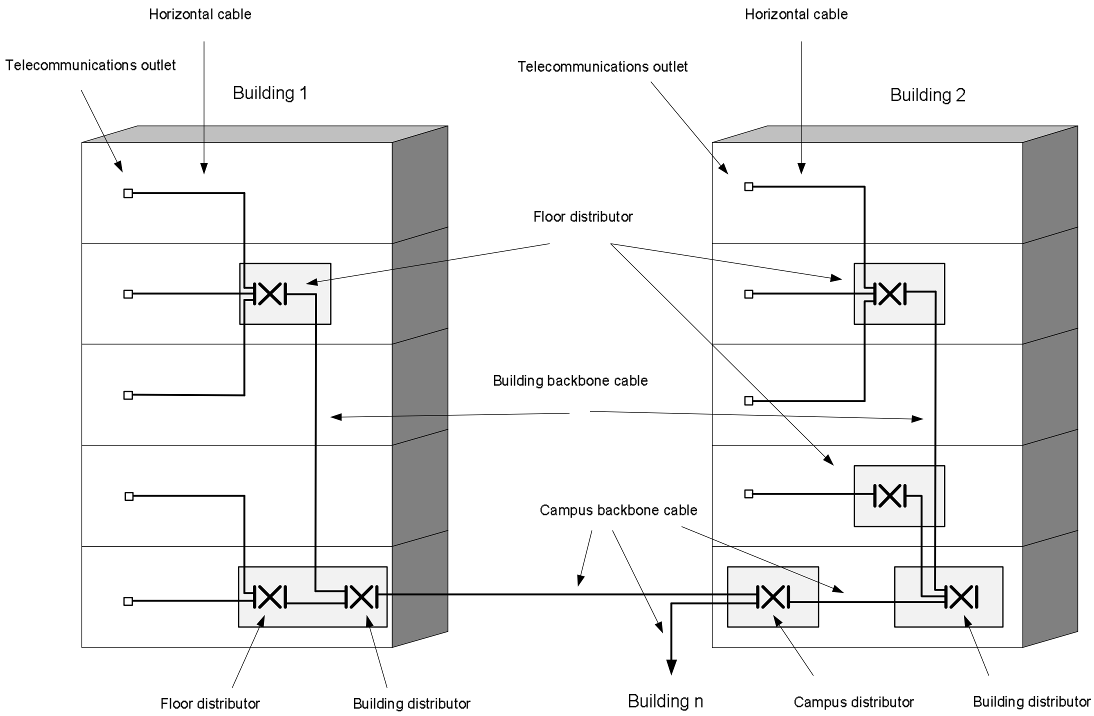


Figure 2. Example of the location of functional elements

2 Generic Cabling System for Information Technology and Standardisation

Traditionally, cabling in buildings has consisted of application-specific networks and multi-function networks.

More recently the trend has been towards setting up a standardised, structured cabling network which is independent of applications and which can be used by various systems such as data, telephony, access control, building automation, and so on. This sort of generic cabling network, based on one type of cable, termination, and so on, provides great flexibility and economical operation.

In Norway, the standardisation of generic cabling networks for information technology is administered through the Norwegian Electro technical Committee. The Norwegian standards are adaptations of the European norms prepared by CENELEC, the European Electro technical standardisation organisation. Norway influences the content of the European norms through its involvement in committee work.

The content of the European norms is largely identical with that of the international standard, ISO/IEC 11801 and the American standards, ANSI/TIA/EIA 568-C and ANSI/TIA/EIA 569-B (installation). The standardisation authorities CENELEC, ISO and ANSI revise their standards at somewhat different intervals, with the result that there may be slight differences in their content at any given time.

2.1 General Requirements

The Norwegian Electronic Communications Act, No. 83 of 4 July 2003, makes it compulsory to use a structured generic cabling system which is in compliance with the common European norms. The following standards shall form the basis of the establishment or renovation of structured cable networks:

- NEK EN 50173 Information technology – Generic cabling systems
  a. NEK EN 50173-1:2011 – Part 1: General requirements and office environments
  b. NEK EN 50173-2:2007 – Part 2: Office premises
  c. NEK EN 50173-3:2007 – Part 3: Industrial premises
  d. NEK EN 50173-4:2007 – Part 4: Homes
  e. NEK EN 50173-5:2007 – Part 5: Data centres

- NEK EN 50174 Information technology – Cabling installation
    a. NEK EN 50174-1:2009 – Part 1: Installation specification and quality assurance
    b. NEK EN 50174-2:2009 – Part 2: Installation planning and practices inside buildings
    c. NEK EN 50174-3:2003 – Part 3: Installation planning and practices outside buildings
- NEK EN 50310:2006 Application of equipotential bonding and earthing in buildings with information technology equipment
- NEK EN 50346:2002 Information technology – Cabling installation – Testing of installed cabling

The latest version of the above-mentioned norms, including any amendments, shall form the basis of design, installation and testing.

The above-mentioned requirements apply to all components of the cable network, that is, cable, termination and connection equipment in communications rooms, as well as patch cables, rising mains, appliance cords (work space cords and drop cables) and so on.

If there is a need to establish a network of higher capacity than the applicable standard, this may result in reduced lifetime and problems with replacements, spare parts, and so on. Before any decision is made regarding the use of non-standard equipment, all advantages and drawbacks should be thoroughly assessed. While one must endeavour to ensure that selected equipment will satisfy future standards, it is of course impossible to guarantee this if products are chosen according to a standard which has not been approved. If one selects non-standard equipment, one should formulate requirements based on the voting draft for a new standard, rather than on the comment draft.

In general, cables should be selected which use halogen-free, fire-retardant materials.

For further information, refer to the standards.

2.2 Horizontal cabling

The minimum requirement for horizontal distribution networks in connection with the GigaCampus project (2006-2009) is Gigabit Ethernet all the way to each end user or terminal. This requirement is satisfied by cables and connection equipment to Class D / Category 5e standards or better.

Table 1, Summary of cable grades, showing the different cable standards in distribution networks of up to 100 metres extent in accordance with the latest version of cabling standards in CENELEC, ISO/IEC and ANSI/EIA/TIA:

NEK EN 50173 (CENELEC) ISO/IEC 11801	**ANSI/EIA/TIA 568-C (USA)**	**Bandwidth**	**Max. bitrate**	**Cable type**	**Termination**
Class D / Cat. 5	Category 5e	100 MHz	1 Gb/s	UTP, STP *)	RJ45
Class E / Cat. 6	Category 6	250 MHz	1 Gb/s ***)	UTP, STP	RJ45
Class E_A / Cat. 6_A	Category 6A	500 MHz	10 Gb/s	UTP, STP	RJ45
Class F / Cat. 7	n/s **)	600 MHz	10 Gb/s	STP	GG45/TERA/A RJ45
Class F_A **) /Cat. 7_A	n/s **)	1000 MHz	40 Gb/s	STP	GG45/TERA/A RJ45

Table 1. Summary of cable grades

*) UTP = Unshielded Twisted Pair,
STP = Shielded Twisted Pair

**) ANSI/EIT/TIA 568-C (2009 version) does not include a definition of quality corresponding to Class F and Class F_A

***) Class E will support 10 Gb/s at a distance of at least 55 metres.

ANSI/EIA/TIA use the term "Category" both for the cabling system and for components. ISO 11801 and NEK EN 50173 use the term "Class" when referring to the cabling system as a whole and "Category" when referring to components.

In general it is recommended that all new installations be set up with a horizontal cable satisfying at least Class E / Category 6, and if one wishes to use cable with higher performance than Class E / Category 6, Class E_A / Category 6_A (10 Gb/s) is recommended. This applies to all equipment making up the channel, i.e. from terminals in the work space to routers and switches in floor distributors.

It is recommended that all equipment which only complies with Category 3 (under 100 Mb/s) and used for computing purposes be replaced with equipment satisfying the above-mentioned standards.

2.2.1 Comparison between STP and UTP

Horizontal twisted pair cable is supplied both as shielded (STP) and unshielded (UTP) types.
Shielded cables provide better EMC properties but demand correct earthing.

It should be pointed out that correct earthing must be provided irrespective of whether UTP or STP is selected. For information regarding earthing, see UFS 107 "Power Supply Requirements for ICT Rooms" and NEK EN 50310:2006 "Application of equipotential bonding and earthing in buildings with information technology equipment".

If shielded cable is to be effective, continuous shielding is required in all components in the channel, i.e. from terminals in work spaces to routers and switches in floor distributors. Note that incorrect use of STP or inadequate earthing may result in reduced performance (even compared with the use of UTP).

When installing shielded cable, it is important that the horizontal cables follow the earthing structure of the building, so as to avoid any connection between differing earth potentials and to avoid earth loops. When using STP in connection with renovation, the earth structure of the building should be thoroughly assessed.

The choice of UTP or STP has traditionally been determined on the basis of local EMC conditions. Office and teaching premises normally do not contain equipment which calls for the use of STP. The standardisation of 10 Gbit Ethernet and the desire to run 10 Gbit Ethernet using twisted pair cable has revived the question of whether STP should be used instead of UTP in such environments.

The most important factor limiting the ability to transmit 10 Gbit Ethernet in a Category 6_A distribution network cable is interference from adjacent cables, or so-called "alien crosstalk" (ANEXT). This problem is eliminated by using shielded cable. Hence, when using shielded cable it is not necessary to measure ANEXT. In the case of an unshielded cable system, measurements must be carried out to verify that ANEXT satisfies the requirements of Category 6_A. Carrying out a complete verification of a cabling system can be an extensive, complex and time-consuming process.

In the case of building extension or renovation a shielded system is not necessarily preferable. Poor quality, complicated earthing structures may often make equipotential balancing difficult. In the worst case, a shielded system may prove to have lower performance than an unshielded system.

Based on the above, it is recommended to use shielded horizontal cable in new buildings, but in connection with reconstruction or extension the practicality of shielding or not shielding must be considered in each case.

To avoid problems with different earth potential in different buildings it is recommended as far as possible to avoid copper connections between buildings, i.e. to use fibre-optic instead of copper lines for such connections.

2.2.1.1 *S/FTP or U/FTP*

There are a number of different screened options, and one way of classifying these is based on whether there is a common shield surrounding all the pairs or whether each individual pair is shielded separately. The commonest types are:

- S/UTP (each pair unshielded, with a common braided shield surrounding all four pairs)
- F/UTP (each pair unshielded, with a common metal foil shield surrounding all four pairs)
- S/FTP (each pair shielded with metal foil and a common braided shield surrounding all four pairs)
- U/FTP (each pair shielded with metal foil, no external shield).

All these configurations provide protection against ANEXT. The first two options do not use a shield on each individual pair and provide poorer protection than S/FTP and U/FTP relative to the requirements of Category 6_A. To fulfil the requirements, the cable diameter must be increased, and these cables are therefore thicker than S/FTP and U/FTP cables. It is recommended to choose S/FTP or U/FTP, rather than F/UTP or S/UTP.

S/FTP performs even better than U/FTP and provides better mechanical protection than U/FTP. S/FTP is of a slightly larger diameter than U/FTP, is typically more expensive and is slightly more difficult to install.

The choice should be made based on a consideration of the project economics and of whether there are special requirements as regards mechanical protection which call for the selection of S/FTP. One should request a price for the other option in order to be able to carry out an economic assessment.

Currently there are very few institutions which have experience of the use of Cu-based horizontal cables with 10 Gb/s bandwidth. Until now, one of the basic requirements for horizontal cabling has been that it should be achievable using RJ45 connectors (8P8C connectors) and unshielded cable. With the advent of 10 Gb/s and higher bitrates, it appears that this condition must be abandoned. In the national and international technical press it has been pointed out that Class E_A/Category 6_A, which handles 10 Gb/s using UTP, has poor tolerance and that the specified bandwidth is very often not achieved. This is the result of extrinsic crosstalk, i.e. interference from neighbouring channels, which can be avoided best by using shielded cable. This means that when wiring for 10 Gb/s bitrates and the use of Class E_A/Category 6_A, the use of shielded cable (S/FTP or U/FTP) should be carefully assessed. It is also recommended to refer to experience with other installations.

Class F has somewhat higher bandwidth than Class E_A/Category 6_A and is supplied only as a shielded type (S/STP). To date, no unique standardised Category 7 connector type exists, see Table 1. There are three different Category 7 connector versions on the market – GG45 (Nexans), ARJ45 (Bel Stewart) and Tera (Siemon). At present, network electronics with Category 7 connectors are not

available. In the meantime it is recommended to terminate using Category 6_A connectors and to re-fit when standardised connectors become available.
Another factor which should be considered is the use of PoE and its possible effects on horizontal cable, i.e. heating of horizontal cable which may result in reduced performance. The IEEE 802.3af PoE standard specifies power supply up to approximately 15 W and IEEE 802.3at (PoE Plus) specifies approximately 25 W. There are also suppliers who can provide up to approximately 50 W per port. In addition, some equipment suppliers claim to be able to supply up to 60 W per port by using all the cable's conductors. It is reasonable to assume that transmission of this level of power might result in temperature rise and deterioration in cable quality. The problem is assumed to be applicable to large cable bundles when many units are to be supplied with power.

It is important to be aware that increasing transfer rate requirements (one or more monitors) and power supply to equipment will necessitate cables of greater cross-section and stiffness. This will in turn place stricter demands on the quality of workmanship and the amount of space in pathways and racks.

It should be pointed out that higher velocities than 10 Gbit/s in copper cables are being discussed in various development environments and standardisation committees. The most likely application which is currently being envisaged is 40 Gb Ethernet. Various scenarios are under discussion, from communication over distances of just a few metres (e.g. inside computer centres) to communication at normal distribution network distances of around 100 metres. Work is in progress on systems for implementing this for existing cable standards (e.g. Class 7_A) as well as systems which will demand the development of cable standards to handle greater bandwidths than 1 MHz.

No clear timetables exist for the development of transfer speeds higher than 10 Gb/s using copper wires, and such systems and requirements are considered to be so far in the future that it should not be necessary to take them into account when selecting cable quality for the time being.

2.2.1.2 *Distribution of sound and images using twisted pair and fibre-optic cables via generic cable networks (common wiring systems for ICT)*

Generic cable networks can also be used for the distribution of sound and images, using both twisted pair and fibre-optic cables.

There are three different principal types of system:

- Point-to-point analogue transmission: baseband or modulated transmission
- Point-to-point digital transmission: use of converters/extenders
- IP-based systems: switched systems.

The subject is described in detail in UFS 120 "Operational support systems and audiovisual transmission", and reference should be made to that document for further information.

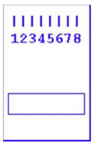
2.2.2 Pin/pair assignment for horizontal twisted pair cable

Termination of the horizontal cabling in a given installation must be completed according to the same configuration. At present, two termination configurations are generally used: T568A and T568B. Both are defined under the American standard ANSI/EIA/TIA 568. Traditionally, T568B is used in Europe. Table 2 shows pin/pair assignments according to T568B.

Pin RJ45	1	2	3	4	5	6	7	8
Cable colour	Orange/ white	Orange	Green/ white	Blue	Blue/ white	Green	Brown/ white	Brown
Pair	2a	2b	3a	1b	1a	3b	4a	4b

Table 2. Pin/pair assignments according to T5568B

Figure 3 shows the pin numbering for the RJ45 connector



RJ45 pin numbering, jack viewed from above (spring clip at the top).

Figure 3. RJ45 pin numbering

The table below shows RJ45 pin assignment for different types of equipment.

Equipment type	**RJ45 jack pin assignment**							
	1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
Analogue telephone				B	A			
Digital telephone				B	A			
Telex				B	A			
Modem, 2-wire dial-up				B	A			
S0 internal interface (e.g. rising mains)			U	I	I	U		
Modem, fixed 4-wire			U	I	I	U		
ISDN	P3	P3	U	I	I	U	P2	P2
Digital telephone, 4-wire, Alt. 1			A2	B1	B1	A2		
Digital telephone, 4-wire, Alt. 2, 2Mb/s, ISDN (UT)	SA	SB		TA	TB			
Datex / Datapak			U	I	I	U		
V.11 (RS-422-C) ASYNC	R (B)	R (B)	T (B)			T (A)		(J)
V.24 (RS-232-C) ASYNC	D	D	D	D	D	D	D	D
Current loop	SD A	SD B	RDA			RDB		
Synchronous data unit	U	U	I			I		
Asynchronous data unit	I	I	U			U		
IEEE 802.3, 100 Base-TX (2-pair)	Tx+	Tx-	Rx+			Rx-		
IEEE 802.3, 1000 Base-T (4-pair)	x	x	x	x	x	x	x	x
IEEE 802.3, 10 GBase-T (4-pair)	x	x	x	x	x	x	x	x
IEEE 802.5 / Token ring 4 and 16 Mb/s			U	I	I	U		
IEEE 802.3af (PoE) Mode A	x	x	x			x		
IEEE 802.3af (PoE) Mode B				x	x		x	x

Table 3. Pin assignments for equipment

The three different Category 7 connectors are shown in Figure 4 (a to c).

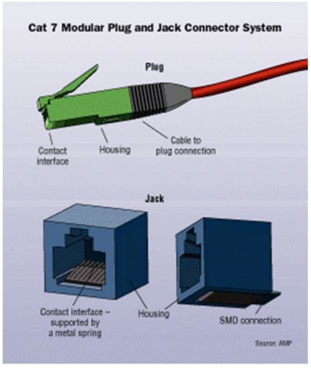


Figure 4a: ARJ45

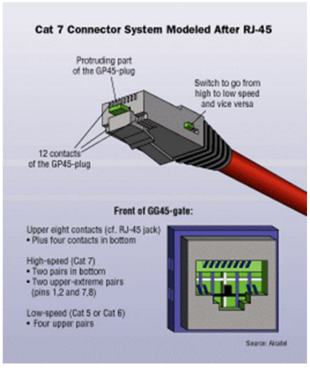


Figure 4b:GG45

Figure 4:.Tera

2.2.3 Optical fibre

Fibre cable is divided into the following grades:

1. Multi-mode (MM) 62.5/125 µm (IEC/EN 60793-2)
2. Multi-mode (MM) 50/125 µm (IEC/EN 60793-2, ITU-T G.651)
3. Single-mode (SM) 9/125 µm (IEC/EN 60793-2, ITU-T G.652)

NEK EN 50173 assigns MM fibre to categories OM1, OM2 and OM3, based on the fibre's ability to transmit bandwidth over distance (bandwidth × distance). Traditionally, MM fibre (62.5/125 µm, OM1) and (50/125 µm, OM2) has frequently been used in campus and building backbone cables for transfer rates of from 10 Mb/s to 1 Gb/s. Their large core diameters have enabled the use of relatively inexpensive LED-based optics. Requirements for higher transfer rates have led to the development of laser-optimised MM fibre systems (50/125 µm, OM3 and OM4).

OM4 has a better bandwidth×length performance than OM3 at a wavelength of 850 nm. OM4, for example, may be especially favourable for future internal 40 and 100 Gbit/s systems in computer centres, and in rising main networks and backbone networks it will have somewhat greater range than OM3.

NEK EN 50173 also defines two categories of single-mode fibre: OS1 and OS2. OS2 has lower attenuation than OS1 and is especially suitable for wavelength division multiplexing (CWDM) and for outdoor use (corresponds to ITU-T G.652c or d).

Table 4 shows the minimum limiting ranges of fibre types OS1, OS2, OM1, OM2, OM3 and OM4 in connection with a number of defined Ethernet interfaces at 1 Gb/s, 10 Gb/s, 40 Gb/s and 100 Gb/s:

NEK EN 50173 classification	**OS1**	**OS2**	**OM1**	**OM2**	**OM3/OM4**
	SM - 9/125 µm	SM - 9/125 µm	MM - 62.5/125 µm	MM - 50/125 µm	MM - 50/125 µm
1000BASE-SX					
- 850 nm			275 m	550 m	550 m
1000BASE-LX					

- 1300 nm			550 m	550 m	550 m
- 1310 nm	2,000 m	5,000 m			
10GBASE-SR/SW					
- 850 nm			32 m	82 m	300/400 m
10GBASE-LX4					
- 1300 nm			300 m	300 m	300 m
- 1310 nm	2,000 m	10,000 m			
10GBASE-LR/LW					
- 1310 nm	2,000 m	10,000 m			
10GBASE-ER/EW					
- 1550 nm	2,000 m	22,250 m			
40GBASE-LR4					
- 1310 nm	4,700 m	10,000 m			
40GBASE-SR4					
- 850 nm					100/150 m
100GBASE-SR10					
- 850 nm					100/150 m
100GBASE-LR4					
- 1310 nm	8,300 m	10,000 m			
100GBASE-ER4					
- 1550 nm	16,000 m	40,000 m			

Table 4. Minimum limiting ranges for different fibre types for 1 Gb/s and 10 Gb/s Ethernet

Note that for SM fibre-optic cable, transmission distances depend on the choice of fibre-optics and greater distances can be attained. Moreover, some of the distances in the table above depend on losses in connecting equipment not exceeding certain limits. For more a detailed description, refer to NEK EN 50173-1:2011.

If MM fibre is to be used for campus and building backbone cables, OM3/OM4 must be selected. This calls for the use of laser optics corresponding to those for SM. Studies show that MM OM3 and OM4 is a more expensive solution than SM.

Most communications providers used by the HE sector supply their interfaces by way of SM fibre-optic cable. If SM is used in campus and building backbone cables, it is possible to patch through the communications providers' interfaces to the desired room or termination. The use of SM makes it easier for users or equipment in different institutions to participate in a grid network, in other words, a network in which equipment with large bandwidth requirements can be connected together without network electronics being involved in the connection.

Based on the above-mentioned, only SM fibre-optic cable is recommended for use as campus or building backbone cable. Similarly, the use of SM is recommended in cases where the distance from a building distributor to a telecommunications outlet exceeds 90 m and UTP/STP cannot be used. In connection with renovation of existing buildings and in places where MM fibre-optic cable is in use, it may be appropriate to install MM cable, but in that case only as a supplement to SM fibre-optic cable.

Fibre-optic cables for indoor and outdoor use typically have different cable construction. Outdoor cable is often supplied with loose sheathing whilst indoor cable has fixed sheathing.

Cable must be selected with characteristics appropriate to the area of use, the installation location and the environment.

Outdoor cable shall generally be terminated less than 2 metres from the point of entry (the point at which the cable penetrates the fire zone – floor, ceiling or wall). Alternatively the cable may be brought further into the building, provided that it is laid in a fireproof pathway such as a metal conduit.

Note that fibre-optic cables are available which are intended for both indoor and outdoor use. These cables satisfy the requirements of EN 60332-1-2, and have no restrictions with regard to termination less than 2 metres from the point of entry.

Fibre cables with fewer than 24 fibres shall not be used. Even though the requirement at the time of installation is lower, it may increase in the future. The additional cost of using 24-fibre cable rather than a lighter cable is insignificant and the saving in terms of avoiding having to install additional cables later is considerable.

2.2.4 Termination

Floor and building distributors in telecommunications rooms (TR) may be installed on walls or in racks. The latter is generally recommended. All termination equipment shall be designed so as to facilitate patching to active or passive equipment. This applies to data, telephony and other systems. Termination of horizontal cable for telephony in terminal blocks which only enable patch connection is not recommended, as this results in a less flexible and practical distribution network.

Routines should be established for effective, tidy patching in the respective distributors. This applies to the use of cable guides, cables of suitable length, different coloured patch cables for different systems, the removal of cables which are not in use, and so on. Cables which hang over switches result in reduced ventilation which in turn may cause reduced lifetime. Effective routines are important to maintain good operational stability and uptime.

To achieve a good working environment in telecommunications rooms and racks, the following recommendations should be followed:

1. The maximum number of termination points (UTP/STP) in a rack should not exceed 240.
2. Termination points shall be labelled in increasing numerical order.
3. If a telecommunications room facilitates the termination of cables from several floors a solution should be found whereby each floor is terminated in a separate rack.
4. The racks shall have enough cable guides for both horizontal and vertical routing. Wire straps may be used for horizontal routing. Be aware that at transfer rates of 10 Gb/s, too small bending radius will cause deterioration of the properties of the patch cables and the link.
5. All fibre-optic cables should be terminated in separate fibre shelves, i.e. one shelf per cable.
6. Power should be distributed in a rack using horizontally and vertically installed power rails or Power Distribution Units (PDUs).
7. If racks are located in small bays or restricted spaces without adequate ventilation, one should consider making slots in the door into the room and perhaps installing a fan to ensure air circulation.

Figures 5 and 6 show examples of different rack arrangements. Note that practice may differ between small and large installations.

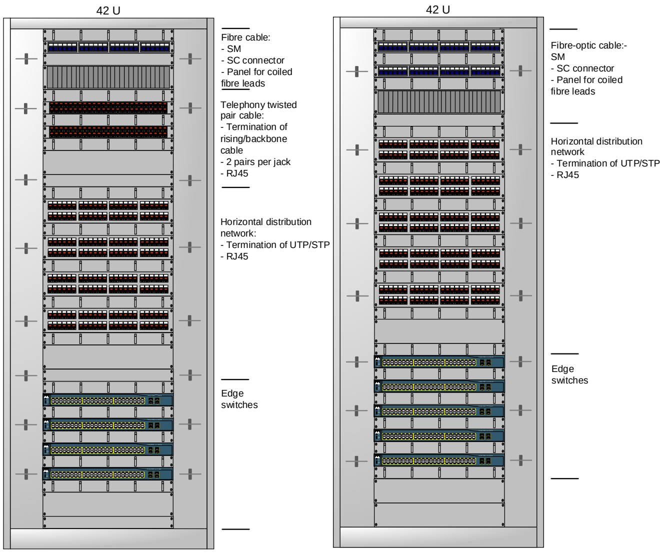


Figure 5. Examples of termination of small installations, i.e. with cable and switches in the same rack.

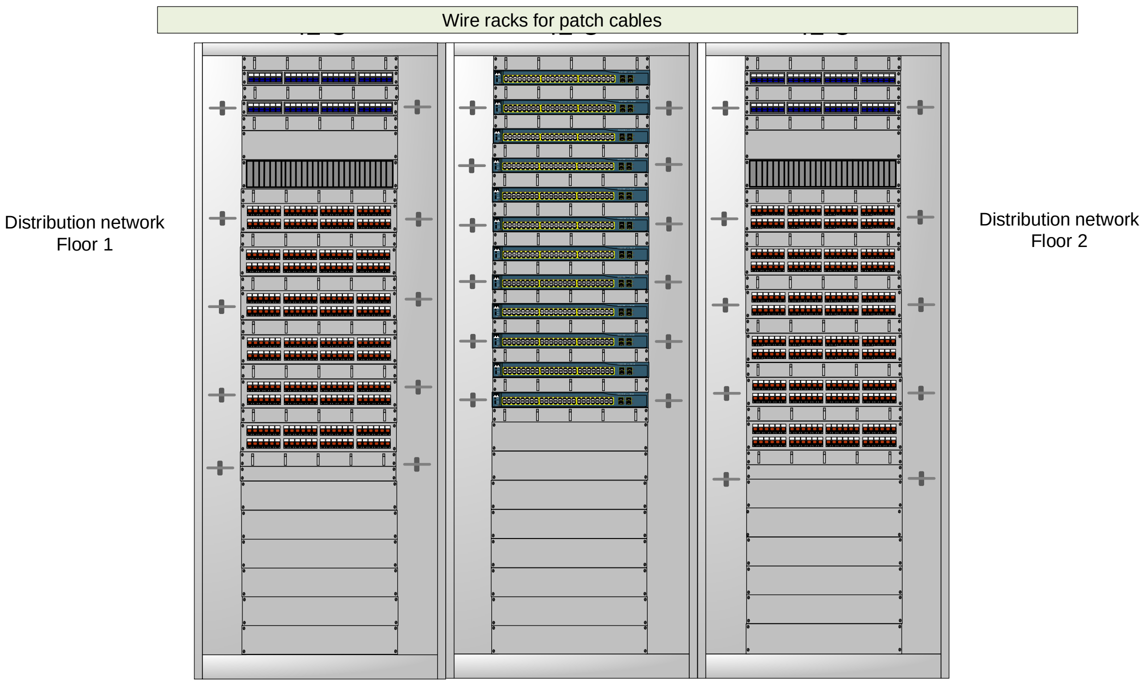


Figure 6. Example of termination of large installations, i.e. with one distribution network rack per floor

2.3 Building and campus backbone cable

2.3.1 Fibre cable

All building and campus backbone cables shall be of SM type (9/125 μm), see Section 2.2.3 Optical fibre. The reason for this is based on the coming requirement of 10 Mb/s bitrates between core, aggregation and edge switches and feeding of wavelengths and grid networks. SC-PC (Subscriber Connector – Physical Contact) connectors have traditionally been used for the termination of building and campus backbone cables. LC connectors have become popular in recent years, especially because of their low space requirements (so-called Small Form Factor or SFF design). LC connectors are typically used in network electronics. However, the recommendation is still to use SC-PC connectors in patch panels owing to their user-friendliness. Pigtails, fibre patch cords and connectors shall at least satisfy the requirements made by or referred to in NEK EN 50173.

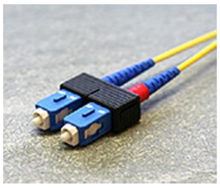


Figure 7a. SC-PC connector

Figure 7b. LC connector

With a transfer rate of 10 Gb/s combined with high power output it is very important that connectors and adapters are kept clean. The use of dust covers, as well as cleaning devices such as cleaning pens, Q-tips, spirit, and so on, is considered very important. It is recommended that connectors and adapters be inspected using an optical inspection instrument and be cleaned before connection. At high power levels, dirt (dust, grease, etc.) in connectors or adapters will be likely to lead to damage to connectors and laser optics. Typically, a patch cable may overheat and stick to the laser optics.

To solve this problem, UNINETT has taken the initiative for creating a first-aid kit containing fibre cleaning equipment, connectors, adapters, and so on. This kit is distributed to all universities and university colleges.

When installing and terminating fibre-optic cable, it is important to follow the cable manufacturer’s instructions, especially with regard to bending radius and tensional loading. Moreover, the installation firm should carry out a survey and final testing (post termination test) of fibre-optic cable before hand-over. Such measurements are important both with regard to providing documentation concerning the installation and as a basis for the design and verification of fibre-optic transmission links.

Following installation and connection, all fibre connections in building and campus backbone cabling shall be tested. Testing should include both end-to-end attenuation measurement using a power meter (OLTS) and OTDR measurements. Use of an OTDR (Optical Time Domain Reflectometer) is widely considered a better technique than the use of a power meter, since the instrument can indicate attenuation as a function of distance. An OLTS (Optical Loss Test Set) is however quicker to use and more accurate, and typically has a greater range than an OTDR. An OTDR enables exact identification of points in a cable system where attenuation occurs (poorly welded joints, patches, cable breaks, and so on).

Measurements should be carried out at the following wavelengths:

1. For single-mode connections, at 1310 nm and 1550 nm.
2. For any multi-mode building backbone cables, at 850 nm and 1300 nm.

Measurement from only one end may result in failure to detect defective connectors at opposite ends. For this reason, measurement from the opposite end is recommended for at least one wavelength.

In addition to the measurements specified above, testing should be performed at 1625 nm. This test will indicate if a cable has been subjected to mechanical loading during installation.

To measure any optical fibre connections in a distribution network, it is recommended that end to end attenuation be measured in one direction and at one wavelength. OTDR measurements in the distribution network are not necessary.

1. MM connections should be tested at 850 nm or 1300 nm
2. SM connections should be tested at 1310 nm or 1550 nm.

GigaCampus possesses complete measuring equipment for fibre-optic and twisted pair cable, as well as an optical fibre splicing machine which all the GigaCampus institutions may borrow as required.

Colour codes are used to identify the individual fibres and fibre tubes in fibre-optic cables. Standardised and manufacturer-specific colour code tables exist. NEK EN 50174-1 refers to IEC 60794-2 as an appropriate standard, while ANSI/TIA/EIA 598-B is another applicable colour code standard.

Colour codes for fibre-optic cables of AXAI, AXXI and AWAI types from Draka Norsk Kabel AS are summarised below:

Fibre No.	AXAI/AXXI	AWAI	Fibre No.	AXAI/AXXI	AWAI
1	White	White	13	White with black dots	White
2	Red	Red	14	Red with black dots	Red
3	Yellow	Yellow	15	Yellow with black dots	Yellow
4	Green	Green	16	Green with black dots	Green
5	Blue	Blue	17	Blue with black dots	Blue
6	Grey	Grey	18	Grey with black dots	Grey
7	Brown	Brown	19	Brown with black dots	Brown
8	Black	Black	20	Black with black dots	Black
9	Purple	Purple	21	Purple with black dots	Purple
10	Turquoise	Turquoise	22	Turquoise with black dots	Turquoise
11	Orange	Orange	23	Orange with black dots	Orange
12	Pink	Pink	24	Pink with black dots	Pink

In the AWAAI cable type, fibres 1 to 12 are arranged in an inner ring while 13 to 24 are in an outer ring.

Table 5. Colour codes for AXAI, AXXI and AWAI cable types

Note that other cable types may use different colour codes and it is therefore important to obtain the correct colour code from the cable manufacturer and to follow the code carefully.

2.3.2 Twisted pair cable

On some campuses it may be appropriate to establish a building or campus backbone cable (in and between buildings) for the distribution of telephony, alarm lines, and so on. Cable shall be constructed as for telephony and its minimum specifications shall be:

1. 50/100-pair
2. Bandwidth complying with NEK EN 50173 Class C (16 MHz).
3. Conductor diameter 0.6 mm
4. Shielded (foil shield and/or steel reinforcement, depending on installation method and shielding requirements)
5. Vaseline-filled (Vaseline-filled cables should be spliced to other cable upon entering a building to prevent soiling with Vaseline).

To avoid overvoltages (resulting from lightning, power grid surges etc.), cable should be fitted with surge protection and earthed according to the Norwegian Post and Telecommunications Authority's "Guidelines for Private Telephony Networks – Earthing, surge protection and EMC". Surge protection shall be provided for cables laid out-of-doors.

In the case of laying in shared conduits with power cables (for example in trenches), reference should be made to the distance requirements and laying methods supplied by Rational Electrical Network Operations (REN), cf. Section 2.3.3 Outdoor cable installation.

2.4 Internal building pathways

The term pathway applies to both horizontal pathways (e.g. cable trays) and vertical pathways (shafts).

Pathways shall be established so as to achieve rational and organised cable installation. ICT rooms, and in particular specialised rooms such as entrance facility rooms, equipment rooms and telecommunications rooms should be constructed close to both vertical and horizontal pathways. In new buildings and renovation projects, pathways shall be constructed with at least 30% reserve capacity.

Separate pathways should generally be constructed for electrical power supply and telephony cables. Pathways for high-priority, non-interruptible power supply must be carefully assessed so as to achieve optimal supply reliability. Routing of electrical power and telephony/data cables in common conduits should only be carried out in exceptional circumstances. It is important that the overall separation requirements form the basis of common routing arrangements, cf. NOK EN 50174-2.

If common routing of power, telephony and data cabling cannot be avoided, the pathways should be divided up using plates (dividers) made of the same material as the cable racks. Dividers must be mechanically stable and shall be at least as high as the maximum stacking height of the cable racks.

Materials used in cable racks (steel/aluminium) shall be selected on the basis of the loads they are to carry. Cable racks and attachments shall be dimensioned and fitted in such a way that any lateral forces and personnel loads to which they are subjected during installation and cable-laying will not result in permanent deformation. Sagging of cable racks at their design load shall not exceed 1%.

Attachment methods shall be designed so that it is possible to install cables from the side, without having to thread them. Pathway sidewalls over which cables are to be laid shall be fitted with protective guards. In bends and junctions where the bending radius results in the cables protruding outside the cable rack's width, support plates shall be used.

In cable channels, the channel and equipment (contact equipment such as junction boxes, cover plates, etc.) shall be adapted to be mutually compatible. Penetrations in walls shall be fitted with cover plates. Colour codes for equipment installed in channels supplied by different manufacturers shall be co-ordinated by means of NCS/RAL codes.

Feeding to different areas of use should preferably be achieved by means of wall-mounted electrical channels, if necessary in combination with cable racks in ceilings. Concealed conduit routes shall be used only where dictated by special circumstances.

In laboratories, treatment rooms, and so on, special channels shall be used with integrated outlets for electrical supply, telephony/data and gas. The channels should be adapted to the function of the room with respect to placement and construction.

Cable racks should not pass through walls or decks where sealing against fire or sound is required. Cable troughs or racks shall be terminated 100 mm from walls or decks and shall be connected by two yellow/green coded copper straps (minimum 6 mm^2) to maintain electrical continuity. When cable racks penetrate ICT rooms, they should not be connected electrically, cf. UFS 107 "Power Supply Requirements for ICT Rooms".

Fireproofing and soundproofing shall be ensured. Approved wall penetrations shall be used which have fire classification and soundproofing specifications at least equivalent to those that apply to the building unit in which they are installed. All fireproofing elements shall be prepared for eventual expansion involving new telephony or data cables by fitting PVC conduits of different diameters. The conduits should be sealed with mineral wool or some other approved sealing material which can easily be removed when new cables are installed.

Electromagnetic compatibility (EMC) shall be assessed, to prevent telephony and data cables being affected by harmful electromagnetic fields from power supply equipment and cable installations. Proximity to cables and equipment with particularly strong or transient-rich ambient fields shall be avoided.

2.5 Separation requirements

Requirements for the separation of telephony/data cable from power and high-voltage cables are provided in NEK EN 50174-2:2009. Note that the standard has recently been revised and that new installations shall comply with this latest version in accordance with the Norwegian Act relating to electronic communication.

The minimum separation distance "A" is calculated by multiplying the minimum separation distance "S" with the power factor "P" obtained from Tables 4 and 5 of NEK EN 50174-2, respectively.

The separation distance "S" depends on which segregation class the cable type complies with. In principle, distinction is made between 4 segregation classes as shown in the following table:

Segregation class	Description
D	Shielded cable of Category 7 or better
C	Shielded cable of Category 5 or 6
B	Unshielded cable of Category 5 or 6
A	Cable of type KKT-B (BCT-C), cables for broadcasting and communications technology buildings or cables used for applications not limited to those listed in NEK EN 50173 (Annex F)

Table 6. Segregation class according to Table 3 of NEK EN 50174-2:2009

The minimum separation distance "S" for different segregation classes is presented in Table 7. The table is a simplified version of the standard and NEK EN 50174-2:2009 should be referred to for detailed treatment.

	Pathway used for IT cables or power supply cables			
Segregation class	Separation without electromagnetic barrier	Open metal conduit [a]	Perforated metal conduit [b,c]	Fixed metal conduit [d]
D	10 mm	8 mm	5 mm	0 mm
C	50 mm	38 mm	25 mm	0 mm
B	100 mm	75 mm	50 mm	0 mm
A	300 mm	225 mm	150 mm	0 mm
a) Level of shielding in the frequency band 0-100 MHz, equivalent to a welded metal basket pathway with mesh size 50 × 100 mm (e.g. a rising main). Equivalent shielding is obtained using a steel-sheet cable rack of less than 1 mm thickness (without cover) and more than 20% evenly distributed perforated area.				
b) Level of shielding in the frequency band 0-100 MHz equivalent to a steel-sheet cable rack (without cover) of 1 mm thickness and no more than 20% evenly distributed perforated area. This level of shielding can also be obtained with shielded power cables which do not meet the requirement of footnote d.				
c) The upper surface of installed cables in the pathway shall be at least 10 mm below the top of the barrier.				
d) Level of shielding in the frequency band 0-100 MHz equivalent to a steel conduit of 1.5 mm wall thickness. The separation is in addition to that which exists because of the barrier or division.				

Table 7. Minimum separation distance as a function of segregation class and pathway type, cf. Table 4 in NEK EN 50174-2

The multiplier (the power cabling factor) depends on the current load and is defined in Table 5 in NEK EN 50174-2.

Power cable type [a,b,c]	Number of cables (circuits)	Power factor P
20A 230V single-phase	1 - 3	0.2
	4 - 6	0.4
	7 - 9	0.6
	10 - 12	0.8
	13 - 15	1.0
	16 - 30	2
	31 - 45	3
	46 - 60	4
	61 - 75	5
	> 75	6
a) Three-phase cables should be treated as three single-phase cables.		
b) Circuits carrying more than 20 A shall be treated as multiple 20 A circuits.		
c) Lower-powered AC or DC power supplies shall be treated on the basis of their output. For example, one 100 A, 50 V DC cable is equivalent to 5 × 20 A cables (P=0.4)		

Table 8. Separation multiplier P

The old “35 metre rule” no longer applies since the latest revision of NEK EN 50174-2.

The requirements above apply on condition that local requirements or specifications do not impose stricter requirements. In addition, it is assumed that for power supply or high-voltage cables the electrical environment complies with the NEK EN 50081 series and NEK EN 50082 series with regard to cable-related and radiated interference. Special separation requirements also apply when telephony and data cables are installed in proximity to EMI cables, cf. Table 6 in NEK EN 50174-2.

No separation
If IT cabling is not close to an EMI source as mentioned above, it may be permissible to have no separation between power cables and IT cables in two different scenarios:

1. The IT cabling is application-specific and the application supports a situation with no requirements for separation
2. Alternatively:
    - The IT cables are laid together with single-phase power cables which in combination do not exceed a current load greater than 32 A (the power cables shall be within a common shield or bundled together)
    - The IT cabling satisfies segregation Class b, c or d
    - The IT cabling satisfies at least environmental Class E1 according to NEK EN 50173-1:2007.

It is recommended to adhere to the minimum distances stated in the design specifications. If the distance increases beyond this, problems with inductive current loops may arise.

NEK EN 50174-2 should also be referred to for exact information.

2.6 Outdoor cable installation

2.6.1 Lines and conduits

Construction of outdoor cabling shall in general make use of cable conduits into which cables are pulled or blown. The advantage of laying conduits as opposed to laying cable in a trench (direct burial) is that the conduits may be re-used.

The following methods are normally used:
1. 110 mm channel conduit laid in a trench. Frequently used. Normally one cable is laid per conduit, which in connection with pulling or blowing of fibre-optic cable (small diameter) makes poor use of the conduit capacity.
2. 110 mm sub-ducting. To improve the use of capacity in 110 mm conduits, multi-channel bundles can be installed in them. The duct bundles may be supplied in various dimensions, for example: 1 × 50 mm + 2 × 40 mm, 1 × 40 mm + 2 × 32 mm, 3 × 40 mm, and so on.
3. Laying of duct bundles directly in a trench. This method is often used and a large range of duct bundles is available, corresponding to the range of sub-ducts. Note that ducts which are to be laid directly must have greater ring stiffness than sub-ducts.

Normally, only one cable should be installed in each conduit. If more than one cable is installed in the same conduit, it is recommended that these be pulled simultaneously. It is possible to install additional cables in conduits which are already in use but great care must be taken to ensure that the existing cables are not damaged. Note particularly that:
1. It is important that the distance between manholes is short and it may be necessary to dig additional manholes.

2. The use of blowing tools is preferable since experience has shown that pulling cords often results in the cable twisting itself around existing cable with resulting risk of damage.
3. Pulling out existing cable and then pulling in new and old cable simultaneously will result in the interruption of existing communication services.

In the HE sector, unused conduit capacity may be a useful tool or bargaining point with respect to operators, i.e. by changing conduits to achieve cable connections where one's own institution does not have available conduit capacity. Experience shows that when constructing outdoor cable lines, excavation constitutes about 80%, while conduits, manholes and cables make up about 20% of the total costs. This means that once the decision has been made to dig, one should take care to create spare conduit capacity. Another reason for providing reserve conduits is that it normally is not practical to pull new cables in conduits which are already in use.

Standards exist for the construction of cable lines in different environments. Norms and standards can be purchased from Rational Electrical Network Operations (REN – www.ren.no) cf. Section 6 References, below. Moreover, installation shall always be based on the conduit manufacturer's installation instructions, since different types of conduit may have different ring stiffness and may have different levels of tolerance with respect to compression or overburden.

Before excavation commences, permits must be obtained from property owners, whose requirements with regard to the performance of the work must be ascertained. Normally, the cable route must be returned to its original state, but be aware that property owners may have requirements which deviate from REN's standards. For example, some municipalities permit replacement of tarmac only by officially approved companies. In addition, detection of cables, conduits and so on must be carried out in order to prevent excavation damage to existing installations. The party or parties responsible for detection may vary in different municipalities, and this should be clarified by making enquiries to the local government administration. This would normally be:

1. The local electricity supplier: Power cables, telecommunication cables installed by electricity suppliers (e.g. Broadnet, formerly BaneTele) and district heating suppliers
2. Geomatikk AS: Telecommunications cables owned by Telenor and Canal Digital
3. Municipality: Signal cables, pipelines (water, surface water, waste water, refuse suction).

Figure 8 shows a typical section of a cable trench for common routing (power and telephony/data) in "built-up areas and road constructions". Note that all measurements in the figure represent minimum distances. The figure illustrates alternative conduit types, i.e. 110 mm channel conduit, 110 mm channel conduit with 3 × 40 mm sub-ducts (which may be installed later) and 4 × 40 mm duct bundles laid directly in a trench. More conduits may be laid, both alongside and above each other, than are indicated in the figure. Moreover, in exposed locations (areas with insufficient overburden, areas subject to heavy traffic, etc.) it may be necessary to enclose conduits in concrete (e.g. OPI channels).

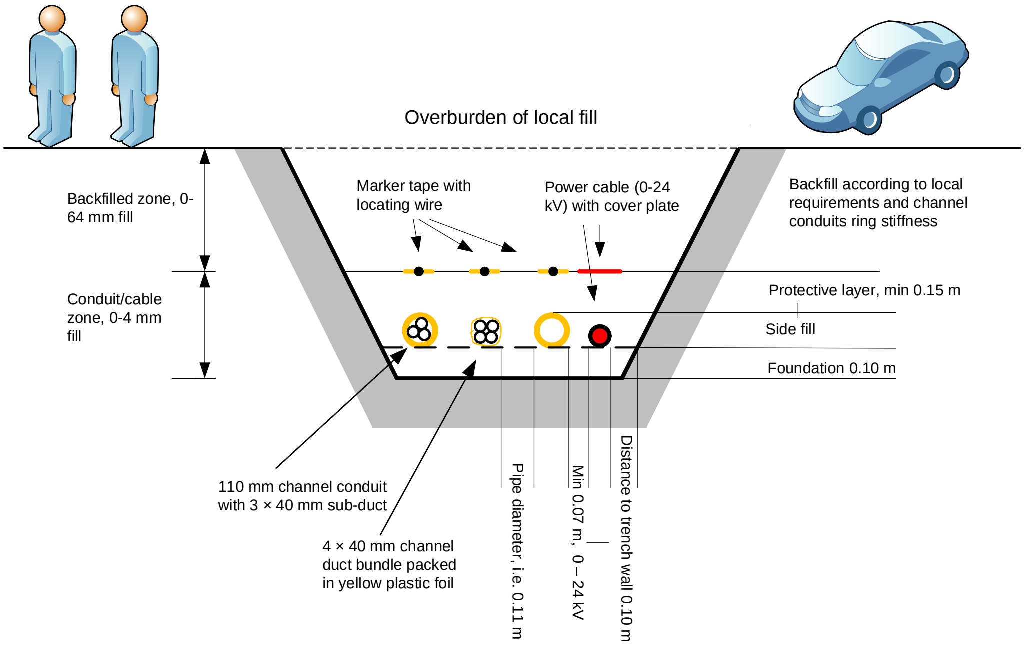


Figure 8. Example of trench section for common routing

The following applies to the example in Figure 8:

1. The trench bottom shall be free from stones, sharp edges, snow and ice. If there is a danger of subsidence into the substrate (marsh, clay, etc.) material must be replaced or fibre cloth must be used.
2. The foundation should have a depth of at least 0.1 m and be composed of fill material of 0-4 mm commercial grade, cf. NS 3420, Table H2:1. The fill shall be compressed according to NS 3458, Table 4, fill group B, compaction class light.
3. The conduit/cable zone shall be backfilled with 0-4 mm commercial grade fill, cf. NS 3420, Table H2, and compressed according to NS 3458, Table 4, fill group B, compaction class light. Fibre cloth shall be used if there is a danger that fill may be transported into or out of the conduit/cable zone.
4. Local fill materials should preferably be used for backfilling. Stones or objects which may damage conduits or cables should be removed and the fill material used should have a nominal grain size of 64 mm. Compressible fill material shall be compressed according to NS 3458, Table 2, fill group B, compaction class normal.
5. Depending on the ring stiffness of the selected conduit, the depth of the backfilled zone may vary from 0.4 to 0.6 m.
6. It may be appropriate to provide an additional marker tape approximately 0.2 m below the top of the overburden (not shown in the figure).
7. All channel conduits and conduit components, including protective sheets and marker tapes, used for telephony and data communication shall be coloured yellow.
8. All cables or lines shall be provided with a marker tape and copper locating wire. Locating wires are particularly important in routes used only for fibre-optic cable. Instead of using a marker tape with a locating wire, it may be economical to install marker tape without a locating wire, and an inexpensive copper twisted pair cable of good quality. Such a twisted pair cable will have higher breaking strain and provide more effective location.
9. Copper twisted pair cable should not be used in common conduits with power cables bearing higher voltages than 24 kV (connection to the public telephone network not permitted).
10. Earth cables may not be laid without insulation in common trenches containing telephony/data cables if these have a conductive or semi-conductive sheath.
11. All pipes shall be provided with pulling cords except in installations in which cables are to be blown in.

In the event that a line for telephony/data cables is to cross a high-voltage cable route, this shall be done at right angles, as shown in the figures below. Perpendicular crossing reduces the danger of inductive effects between copper cables as well as the danger of excavation damage to the line being crossed.

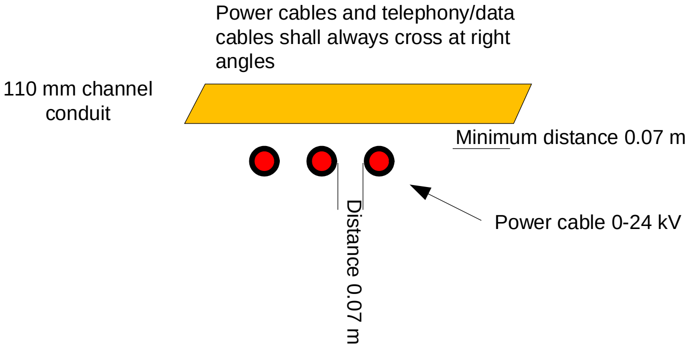


Figure 9. Line crossing, minimum distance between pathways

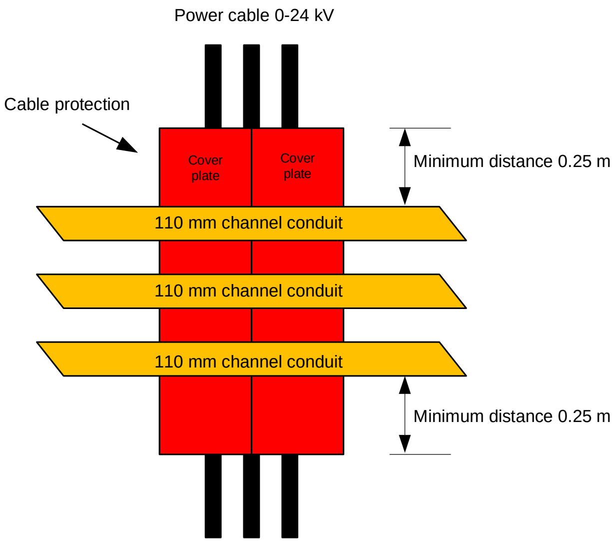


Figure 10. Line crossing, cable protection (cover plates)

2.6.2 Manholes

Manholes shall normally be provided to facilitate pulling or blowing of cables and for joining fibre-optic cables. The distance between manholes depends on the type of cable to be installed (by pulling or blowing) and on how the line is to be constructed in the horizontal or vertical plane. The minimum bending radius of channel conduit is 3 m. If a conduit is to be bent with a radius less than 3 m (for example, at 90°), manholes must be provided for this purpose. In a cable length containing a number of curves (3 m bending radius), the combined pulling resistance may be so large that it will be necessary to use several manholes.

Manholes must be dimensioned to suit the number of fibre-optic cables entering them during their lifetime.

In general, prefabricated manholes designed for telephony/data communication should be used. Telenor has produced its own specification for telephony/data manholes (various types of cylindrical and square manholes), which are manufactured by several concrete suppliers. Examples are cylindrical 100/120 cm diameter, 50 cm high and square 60 cm wide, 120 cm long (with two or three covers) and 60 cm high. The manholes are manufactured with pre-formed conduit cut-outs (plastic lined) which can easily be adapted to suit the installation. Most of the manholes have no base and should be provided with drainage. Plastic manholes are also available, but these are less stable.

With subsequent repair work in mind, coils (typically 6 m) of each cable are laid in each manhole. There should also be room for a splice closure in each manhole.

2.6.3 Splice closures

The dominant splice closure on the market is the Tyco FOSC 400. This is cylindrical, typically 71 cm long, (the cable bend shall also fit in the closure) and 26 cm in diameter. The Tyco splice closure is often combined with a coil frame, cf. Figure 11.

When selecting splice closures, it is important to choose the correct number of cable ports. In connection with backbone cables, there should be at least one oval port with room for two cables. The remaining ports are round and intended for distribution cables.

A flat splice closure in stainless steel is also available, which was originally developed for OPGW (Tycoflex). These have a diameter of 27 cm and heights of 14-24 cm. Table 9 gives typical dimensions of Tyco FOSC splice closures.

Type	Ports	Length	Diameter	Number of trays	Number of splices
400 A4 A8	1+4 1+8	42	18	2	48
400 B4	1+4	54	18	4	96
400 D5	1+5	71	24	8	288
GC02-BE6	1+6	70	28,5	SOSA2	224

Table 9. Tyco FOSC splice closures

2.6.4 Fibre-optic cabinets

Fibre-optic cabinets are not recommended because they are vulnerable to damage as a result of snow clearance, collisions, subsidence, vandalism, and so on. If cabinets must be used, they should have splice closures located inside them.

2.6.5 Cable entry into buildings

When entering buildings, cables should never be introduced directly to ICT rooms, so as to avoid incursion of water, dust, rodents, and so on. Cable entries should be made into rooms with floor drains, at a safe distance from power cables or transformers and with easy access to the pathway to an ICT room.

Manholes should be constructed so that they drain into the building’s drainage system. Channel conduits from manholes to the building should be installed with a fall towards the manhole, to prevent water flowing into the building via the channel conduits.

If pipes are manufactured from combustible sheathing material, generate hazardous or corrosive gases at high temperatures or in the event of fire, or are Vaseline-filled, they should be spliced to suitable indoor cables when crossing the building foundation. The splice shall be made no more than two metres from the point of crossing of the foundation wall.

Copper twisted pair cables should be straight-spliced using blade contact equipment such as Scotchlok or Picabond, self-vulcanising tape and heat-shrink tubing (following the recommendation of the cable manufacturer). Fibre cables should be spliced using a splice closure and coil frame. Figure 11 shows examples of splicing equipment for fibre-optic cable.

Figure 11. Splice closures for fibre and coil frame (Tycho – formerly Raychem)

Only channel cables produced for both indoor and outdoor installation may be terminated directly in ICT rooms.

3 Project Implementation

In connection with new buildings and renovations it is very important that IT departments express their own requirements for space and pathways as early as possible. Traditionally, building projects involve competition for space and various interests will often be in conflict. Hence it is important that the IT department presents a well-founded argument for being allocated the necessary space and pathways to enable the establishment of a well-functioning IT environment. In general, it can be said that:

1. Telecommunications rooms and pathways shall last for the lifetime of a building and the institution will have to live for many years with decisions made regarding a building project.
2. Because structured cabling will have a lifetime of 10-15 years, one should choose cabling systems which are as forward-looking as possible.
3. Network electronics, servers, and so on, have a depreciation period of 3-5 years.

In view of the above, it may be wise in connection with a building project to prioritise areas and cables with long lifetime, rather than network electronics and servers which have a short depreciation period and will have to be replaced by new equipment in a relatively short time anyway.

The workmanship of the construction is of considerable importance to the quality and lifetime of the distribution network. Hence it is very important to employ electricians who have good references and are authorised in accordance with the Norwegian Post and Telecommunications Authority's requirements. Thorough monitoring in the building period can be both important and profitable. Demand a system guarantee and declaration of compliance (documents of conformity), cf. Chapter 4 Documentation and labelling.

In connection with renovations it is very important that all old and unused cable is removed. The reasons for this are as follows:

1. It occupies space in pathways which in most buildings will be in short supply.
2. In emergency escape routes, fire loads higher than 50 MJoule per running metre are not permitted. To comply with this sort of requirement, there will probably not be room for more cables than those necessary to maintain essential communications. Cable racks are often installed in emergency escape routes (corridors).
3. Old, unused cable in shafts should be removed because it represents considerable danger of fire propagation between floors.

Note that all cabling which penetrates fire barriers or fire cells shall be fireproofed. The installation firm shall be approved in accordance with the Norwegian Planning and Building Act.

4 Documentation and labelling

Structured distribution networks used in the HE sector shall be constructed in accordance with the Norwegian Electronic Communications Act and its associated regulations. In practice, this means that networks shall be constructed in compliance with the current regulations which in turn refer to the respective standards (NEK EN 50173, NEK EN 50174 and NEK EN 50310).

An important factor in this connection is that the installation contractor shall issue a *declaration of compliance* (document of conformity) as required by the authorities, confirming that the installation is in accordance with applicable laws and regulations. If the installation deviates from prevailing legislation, this must be stated in the declaration of compliance. It is prerequisite that any deviations are in accordance with an agreement with the client or orderer. An example of a deviation may be the installation of equipment with higher capacity than that described in the legislation. The documentation and labelling of generic cable installations shall also be in accordance with NEK EN 50173 and NEK EN 50174. The Norwegian Post and Telecommunications Authority has announced the introduction of control of contractors, and declarations of compliance will be an important item for inspection.

If a generic cabling system is to be installed which has a capacity or output in excess of that described in the standards, the supplier shall furnish a *system guarantee* in addition to a *declaration of compliance*. It is important to be aware that a system guarantee is normally provided by the cable supplier and therefore does not represent an additional expense. If the system guarantee is to be valid, the supplier/manufacturer will normally require that the cable installation be carried out by electricians with approved training in the installation of their cable. It is therefore important to require the contractor to use personnel with the necessary training and certification to enable the required guarantee to be issued.

It is very important that all outdoor cables and lines be positioned (using GPS) and their positions posted on local maps, and also that cables are registered with the local excavation notice service (Geomatikk AS, the electricity supplier, municipal offices, etc.), which can carry out cable location as necessary. If unregistered cables are damaged in connection with excavation work, the cable owner must cover all the costs of repairs. An excavating contractor will be able to claim compensation from the cable owner if unregistered cables lead to delays to the contractor’s work schedule. Registration of cables by the local excavation notice service is subject to an annual fee which covers registration in the map archives and location information for other parties in the case of subsequent excavations.

The following minimum requirements are placed on documentation:

1. Declaration of compliance (document of conformity)
2. System guarantee for non-standard capacities
3. Product information, i.e. data sheets for all components included in the delivery

4. Inspection sheet for all cables and terminations (TE) including consolidation points (CP) (surveying of twisted pair and fibre-optic cable). Types and serial numbers of measuring instruments shall be stated.
5. Date of completed survey and name of surveyor shall be stated.
6. Plan drawings and rack diagrams showing cable laying, junctions and telecommunications jacks.
7. All junctions and telecommunications jacks shall be labelled and the jacks' numbers indicated on plan drawings.
8. Documentation shall be electronic and in a format which facilitates import to database applications (e.g. comma-separated text files). Documentation shall also be provided in PDF format.

Labelling:

1. All labelling shall take place according to the institution's labelling system and by agreement with the builder. Labelling shall at least satisfy the requirements of NEK EN 50174-1:2009.
2. Telecommunication jacks and junctions shall have corresponding labelling.
3. Cables must be labelled at junctions and should also be labelled at fire barriers (on both sides).
4. All labelling shall be permanent and have the same lifetime as the remainder of the installation.

Institutions which have not adopted a labelling system should refer to:

1. The Norwegian Post and Telecommunications Authority's "Guidelines for Private Telephony Networks – Documentation"
2. Statsbygg's R&D project, "Multidisciplinary labelling system for buildings".

It is specially recommended to visit Statsbygg's web pages at http://www.statsbygg.no/dokumenter/tfm (in Norwegian), which contain further information about the subject, including descriptions and examples of its use.

A number of examples of labelling systems are available on the Internet which are based on Statsbygg's project directions PA 0802 "Multidisciplinary labelling system", with any necessary adaptations to a business's requirements, wishes and needs. For example:

- UiO
- Oslo Municipality

Label cable systems simple enough to enable all authorised installation companies to carry out installation and modification assignments, as well as maintenance of such networks in a simple and rational manner.

5 Recommended Design

1. A minimum of two telecommunications jacks per workplace and a minimum of four per room. It is not possible to use split adapters when using cabling according to Class E, Class E_A, Class F and Class F_A, i.e. at larger capacities than 1 Gb/s, cf. Table 3.

2. Meeting rooms and auditoriums: Reference should be made to the imminent UFS 115 “AV Functional Description for Auditoriums and Meeting Rooms”.

3. Reference is made to separate UFS documents dealing output jacks for connection of Access Points for wireless computer networks (WLAN), i.e. UFS 112 “Recommended Security System for Wireless Networks” and UFS 113 “Radio Planning of Wireless Networks on Campuses”. Note that the imminent IEEE 802.11n wireless standard requires cabling satisfying at least Class E.

References

The Electronic Communications Act (the Norwegian Ministry of Transport and Communications)

1. Lov 2003-07-04 nr 83: Lov om elektronisk kommunikasjon (ekomloven) [Act No. 83 of 4 July 2003 relating to electronic communications (the Electronic Communications Act)], http://www.lovdata.no/all/hl-20030704-083.html (in Norwegian)
2. FOR 2004-02-16 nr 401: Forskrift om elektronisk kommunikasjonsnett og elektronisk kommunikasjonstjeneste (ekomforskriften) [Regulations relating to electronic communications networks and electronic communications services (the Electronic Communications Regulations)] http://www.lovdata.no/cgi-wift/ldles?doc=/sf/sf/sf-20040216-0401.html (in Norwegian)
3. Veiledning Private ekomnett [Guidelines for private electronic communications networks] http://www.npt.no/iKnowBase/Content/49078/veiledning_private_ekomnett290107.pdf (in Norwegian)

Norwegian standards (in Norwegian) can be purchased from: Standard.no (formerly Pronorm AS) http://www.standard.no:

1. NEK EN 50173-1:2011 – Part 1: General requirements and office environments
2. NEK EN 50173-2:2007 – Part 2: Office premises
3. NEK EN 50173-3:2007 – Part 3: Industrial premises
4. NEK EN 50173-4:2007 – Part 4: Homes
5. NEK EN 50173-5:2007 – Part 5: Data centres
6. NEK EN 50174-1:2009 – Part 1: Installation specification and quality assurance
7. NEK EN 50174-2:2009 – Part 2: Installation planning and practices inside buildings
8. NEK EN 50174-3:2003 – Part 3: Installation planning and practices outside buildings
9. NEK EN 50310:2006 Application of equipotential bonding and earthing in buildings with information technology equipment
10. NEK EN 50346:2002 – Cabling installation – Testing of installed cabling

REN (Rational Electrical Network Operations), http://www.ren.no (web site in Norwegian). REN standards are used in connection with the construction of common trenches for power and telephony/data cabling:

Trench lines:

1. REN blad nr. 9000 Distribusjonsnett kabel - Retningslinjer for kabelhåndtering og forlegging [Pamphlet No. 9000 “Distribution network cable – Guidelines for cable handling and installation”] (in Norwegian).
2. REN blad nr. 9001 Distribusjonsnett kabel - Kabelforlegging i jordbruksareal [Pamphlet No. 9001 “Distribution network cable – Cable installation in agricultural areas”] (in Norwegian).

3. REN blad nr. 9002 Distribusjonsnett kabel - Kabelforlegging i utmark [Pamphlet No. 9002 “Distribution network cable – Cable installation in outlying land”] (in Norwegian).
4. REN blad nr. 9003 Distribusjonsnett kabel - Kabelforlegging i tettbygd strøk og i veiområde [Pamphlet No. 9003 “Distribution network cable – Cable installation in built-up areas and road constructions”] (in Norwegian).
5. REN blad nr. 9004 Distribusjonsnett kabel - Kabelforlegging 2 plan i tettbygd strøk og i veiområde [Pamphlet No. 9004 “Distribution network cable – Cable installation plan 2 for built-up areas and road constructions”] (in Norwegian).

Overhead cables:

1. REN blad nr. 2013 HS distribusjonsnett luft – Fellesføringer med HS luft, LS luft og Teleledninger [Pamphlet No. 2013 “Overhead HV distribution networks – Common routes for overhead HV, overhead LV and telephony lines] (in Norwegian).

The Norwegian Post and Telecommunications Authority, (http://www.npt.no) (web site partially translated into English):

1. Veiledning – Private telenett, Jording, overspenningsbeskyttelse og EMC [Guidelines – Private telephony networks, earthing, surge protection and EMC] (in Norwegian) http://www.npt.no/iKnowBase/FileServer/jording04.doc?documentID=1161
2. Veiledning – Private telenett, Dokumentasjon [Guidelines – Private telephony networks, Documentation] (in Norwegian) http://www.npt.no/iKnowBase/FileServer/dokumentasjon05.doc?documentID=44325

Statsbygg (http://www.statsbygg.no) (website partially translated into English)

1. Tverrfaglig merkesystem for bygninger [Multidisciplinary labelling systems for buildings] (in Norwegian) http://www.statsbygg.no/FilSystem/files/Dokumenter/prosjekteringsanvisninger/0GenerellePA/PA0802_TFM/TFM_Start.pdf

Revisions

This version includes the following amendments to the version dated 22 December 2009.

A general linguistic and text layout revision has been performed.

Introduction

1. Revision of date.

2. Generic cabling system for information technology and standardisation

1. Revision to reflect new standard revisions.

2.2 Horizontal cabling

Editing of text in table.

2.2.1 Comparison between STP and UTP

1. Revision of text. More detailed information as a basis for choice of cable type.
2. New section about 40 Gb/s Ethernet.
3. New section referring to the use of generic cable systems for the transmission of sound and images.

2.2.4 Termination

New item (No. 7) in the bullet list referring to actions when installing racks in small spaces and bays.

2.6.1 Lines and conduits

Correction of figure number, cf. Figure 8.

2.6.3 Splice closures

Reference to Figure 11 in description of Tyco splice closure, as well as use of coil frame.

2.6.5 Cable entry into buildings

Specification of distance requirements within foundation walls for splicing of cable not intended for indoor use.

4. Documentation and labelling

Reference to relevant documents/websites providing more information about examples of relevant labelling systems.

Additional details about system guarantees. This service is often included by supplier and in such case no additional fee shall be paid for it.

Glossary

ANSI	American National Standards Institute
CENELEC	The European Committee for Electrotechnical Standardisation (Comité Européen de Normalisation Électrotechnique)
CP	Consolidation Point
Cu	Chemical symbol for copper
CWDM	Coarse wavelength-division multiplexing
EIA	Electronic Industries Alliance
EMC	Electromagnetic compatibility
EMI	Electromagnetic interference
ER	Equipment Room
IEC	International Electrotechnical Commission
IEEE	The Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
TR	Telecommunications Room
MM	Multimode fibre-optic cable
NCS	Natural Colour System
NEK EN	Norwegian Electrotechnical Committee European Norm
OLTS	Optical Loss Test Set
OTDR	Optical Time Domain Reflectometer
PDU	Power Distribution Unit
PoE	Power over Ethernet, IEEE 802.3af / at
REN	Rational Electrical Network Operations (a Norwegian consulting company)
SC-PC	Subscriber Connector – Physical Contact
SFF	Small Form Factor
SM	Single-mode fibre-optic cable
STP	Shielded Twisted Pair
TIA	Telecommunications Industry Association
The HE sector	The Norwegian higher education sector
UTP	Unshielded Twisted Pair
VoIP	Voice over Internet Protocol