General guide to a future-proof IT infrastructure

Report 37/2001

The Swedish ICT Commission

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Preface

This guide is about IT infrastructure in Sweden. We believe that the advices and recommendations in the guide are of general interest wherever investments in new IT infrastructure are made.

Stockholm, May 2001

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Preface (from the guide in Swedish; report 25/2000)

In 1999 the Swedish ICT Commission presented a vision of a future-proof IT infrastructure for Sweden. That vision is in two parts. The first part is a fine-meshed fibre optical network reaching all inhabitants of Sweden not later than 2005. The fibre optical network is to be available within 100 metres of all buildings. The other part of the vision is that Internet service providers (ISPs) shall compete to deliver a basic service for permanent Internet connection. The cost to a user of using the basic service shall not exceed the price of a bus pass. The basic service shall have a capacity of at least 5 Mbps throughput between any two points in Sweden. 5 Mbps is an initial value and the capacity shall be doubled every year solely by changing the end equipment. The ICT Commission's vision is set forth in SOU 1999:134 "Framtidssäker IT-infrastruktur för Sverige"[1].

This guide is primarily intended as a support for the municipal process of planning and implementing the expansion of a future-proof general physical IT infrastructure as a basis for various applications. It contains general advice and specific recommendations. These must of course always be adapted to local needs and conditions.

The guide is addressed to persons in local government responsible for questions and decisions concerning the implementation of IT infrastructure within a municipality. It is also addressed to those who co-ordinate questions relating to IT infrastructure for neighbouring municipalities. In addition, it is addressed to the constructors of municipal networks.

This guide has been compiled within the ICT Commission's Observatory for IT Infrastructure, in close collaboration with the consultants Peter Bryne, Netcom Consultants and Johan Hjertström, Retea. The members of the Observatory com-

[1] In English "A future-proof IT infrastructure for Sweden" (a summary is available in English).

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Our hope is that this guide will be of use in the process of achieving a future-proof IT infrastructure.

The use to be made of this guide is decided by every organisation or its equivalent, on its own responsibility. The ICT Commission will accept no liability for properties or functions of the IT infrastructure established in accordance with the guide.

Stockholm, November 2000

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1 Introduction

Often *one* communications network is built per application, as for example with the telephone network and the ground-based TV network. Based, however, on IP architecture[2], different applications can be distributed through different physical IT infrastructures. During the 1990s, traffic on the Internet doubled every nine months. There are no indications of this traffic growth diminishing in future.

The new fine-meshed IT infrastructure shall be capable of serving as a basis for both new and existing applications. Existing ones include, for example, e-mail, the web and file transfer. The new applications include transmission of text, sound (e.g. speech or music) and images (e.g. still pictures and real time video) of high technical quality. In many cases, however, these new applications are not known at present as regards capacity, traffic patterns and low delay requirements. Briefly, this applies to all applications demanding high capacity, but of course to other applications as well. In other words, the new IT infrastructure shall be capable of supporting the aggregate digital communication needs of various organisations and private persons in households.

The interim report of the Broadband Commission, "Infrastrukturprogram för bredbandskommunikation"[3] (3rd April 2000), states the purpose of IT infrastructure expansion as being above all to strengthen:

- Competence and lifelong learning.
- The competitive capacity of business enterprise as a whole in Sweden.
- The availability of effective public service nationwide.

One conclusion which can be drawn from the above is that it is important to establish a general physical IT infrastructure in which the capacity of the network can be successively increased by upgrading the communications equipment. And similarly, that capacity must be equally high both to and from the user (symmetric).

Another conclusion is that the requirements of quality and operational dependability where services and physical IT infrastructure are concerned will be very high. Planning and construction of a new physical IT infrastructure, then, must have a long-term focus.

It should be noted that mobile communication is an access technology which can be used for accessing the Internet and services on the Internet, but it is not a technology for the basic, nation-wide infrastructure. A fibre optical IT infrastructure is a component used so as to be able to link the radio stations (base stations) together in mobile networks. Thus there is no contradiction between a general physical nation-wide fibre optical IT infrastructure and mobile networks like GSM[4] and

[2] IP, Internet Protocol
[3] In English "Infrastructure Programme for Broadband Communication".
[4] GSM, Global System for Mobile communications.

UMTS[5]. Much the same also applies when other radio-based solutions are used for “the last mile access” in order to reach users, as for example with systems based on LMDS[6].

The Swedish Government’s aim with the physical IT infrastructure which is now being constructed, for example, by Svenska KraftKom[7] is a first step towards establishing a coherent national network. The present guide pays as much heed as possible to the ongoing expansion and to existing networks.

[5] UMTS, Universal Mobile Telecommunications System, the third generation system of mobile communication.

[6] LMDS, Local Multipoint Distribution Service, microwave-based radio system for fixed connection (access).

[7] Svenska KraftKom is a fully-owned subsidiary of Svenska Kraftnät. Svenska Kraftnät owns and operates the Swedish national electricity grid.

2 Purpose, target group and issues considered

This guide is intended to support the process of planning and implementing the development of a future-proof IT infrastructure in a municipality and its neighbouring communities (region), as a basis for various applications.

The guide is addressed to persons in local government responsible for questions and decisions concerning the implementation of IT infrastructure within a municipality. It is also addressed to those who co-ordinate questions relating to IT infrastructure for neighbouring municipalities. In addition, it is addressed to the constructors of municipal networks. It is at the same time intended as support and input documentation for procurement purposes.

The IT infrastructure which is now being constructed consists of municipal networks, regional networks and national networks between main localities and on the whole is based on the needs of individual actors. In particular, the local development in progress presents a wide variety of conditions and objectives. Starting with a national vision of a future-proof IT infrastructure for Sweden, the purpose of this guide is to suggest a network structure for fibre optical networks in municipalities and connections to neighbouring municipalities in a region. This guide deals mainly with passive network components.

Using a structural approach it is possible at an early stage to obtain a clear picture of a future network. By creating a target network concerning the appearance of the IT infrastructure in, say, five years' time, the long-term development costs of municipal and regional networks can be substantially reduced. If the physical network structure is not adapted to future needs, communications equipment may prove very expensive or, alternatively, expensive restructurings of the physical network may become necessary.

This guide contains general advice and specific recommendations applying to municipalities and regional level. For present purposes, "regional level" refers to the co-ordination of IT infrastructure which should take place between neighbouring municipalities.

Adjustments would always have to be made to local needs and conditions. Radio-based and other solutions can also be used in certain connections, e.g. as a stopgap solution for the short-term connection of a point before a fibre optical cable can be laid.

Issues concidered

This guide deals with the ducting level and with the fibre optical cable level. The guide does not address matters concerning infrastructure and traffic exchange at IP level between Internet service providers (concerning the IP level, see illustration 3, Section 6.2.3). The guide does not take into account any classification of main nodes which should be made with reference to questions of vulnerability and operational dependability. Classification of this kind should take place at the county or national level.

The operation and maintenance of the fibre network is a central question, but this guide deals only in general terms with the necessary content of an operating strategy; see Section 7.4.3, under the heading Operating strategy.

This guide does not deal with questions relating to generic cabling system for buildings.

3 Structure of the document

Section 5 states definitions of the network parts and nodes of the IT infrastructure. Section 6 describes the ICT Commission's vision of a future-proof communications structure for Sweden, and also the national and local IT infrastructure requirements which this entails. This is followed, in Section 7, by a checklist for the compilation of supportive documentation for decision-making (Programme document). Section 8 describes the technical level of the network (System document). Section 9 then deals with the way in which planning can be conducted. The guide ends with a glossary of terms.

4 Summary

In order to meet the requirements which IP-based communications networks will entail in terms of capacity, operational dependability and diversity:

- Municipal and regional networks must be planned as general networks with a defined target network, not as functional networks based on a certain technical communications solution for one or a limited number of operators. A target network should also be defined by the municipalities which do not themselves intend building IT infrastructure. The target network can then be used in the specification of requirements when the municipality relies on the market for the development of IT infrastructure.
- A general ducting network must be planned and constructed as a basis for a fibre network.
- A generally redundant fibre network must be planned and constructed as a basis for the operators' differing needs of communications networks.
- Dark fibre[8] must be uniformly offered to operators[9] in a uniform manner with standardised agreements, and a network proprietor shall be able to resell other network proprietors' infrastructure.

In order for infrastructure development to be cost-effective:

- The development must be planned and financed on a long-term basis.
- A function must be established which supervises all excavation contracts and co-ordinates conduit routing in accordance with the structure indicated by the target network.
- Connection to a municipality's main node(s) must be co-ordinated with the needs of neighbouring communities.
- Co-ordination must be effected with national actors building fibre networks between principal localities in the country, in order if possible to achieve part-financing, e.g. of connections to other municipalities and for smaller localities.

[8] Dark fibre is optical fibre without communications equipment, i.e. the network owner gives both ends of the connection in the form of fibre connection to the operator without intermediate equipment.

[9] An operator is defined here as an Internet service provider (ISP) or other actor building active networks with the aid of fibre networks. Other actors include, for example, a business enterprise or public authority wishing to construct the active network for communication between different units.

5 Definitions

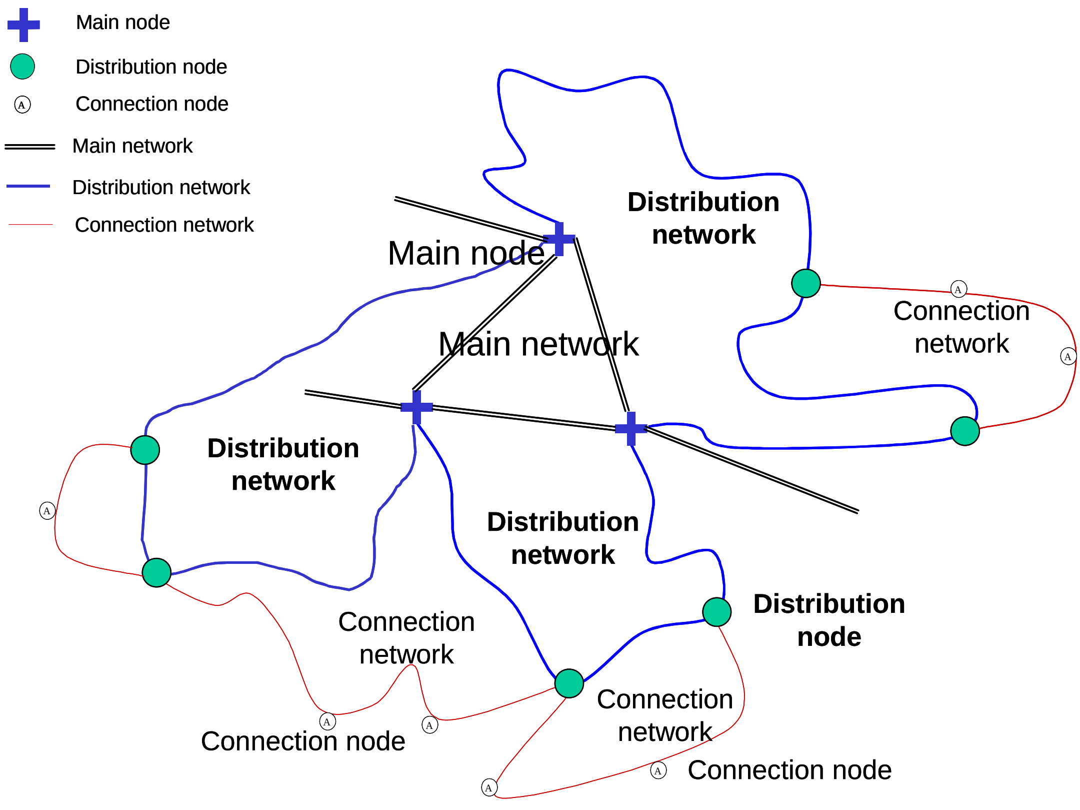
5.1 General

In connection with the development of fibre networks for IT infrastructure, a number of expressions and terms are used, above all as regards nomenclature for the different parts of networks. For the avoidance of misunderstandings, it is of the utmost importance that all parties concerned should be fully aware of the meanings of these expressions.

Illustration 1 shows the physical network parts required for a structured development:

- Main network – main node.
- Distribution network – distribution node.
- Connection network – connection node.

Illustration 1: *Definitions – the illustration shows the physical network*



Reference is also made to physical and logical networks. The physical network comprises the actual positioning of ducting and fibre optical cables between the different nodal points. Logical fibre optical networks are defined by the communication paths which the operators[10] create (configure) between the nodal points. This means that a node having a physical connection with another node need not necessarily be logically connected to that point.

The network paths of the IT infrastructure are defined below. Section 5.2 deals briefly with the existing IT infrastructure, Section 5.3 with the new, fine-meshed IT infrastructure.

5.2 Existing structure

5.2.1 National main networks

There are now in Sweden several fibre optical networks which can be called national main networks. They vary in terms of coverage and capacity.

The networks which now exist or are being constructed are mostly owned by State-owned enterprises and commercial actors. In limited parts of the country, several actors are simultaneously constructing fibre networks between major towns or cities and central municipal localities.

A combination of the national main networks and a structured development dealt with in this guide will make possible the fine-meshed IT infrastructure which should be aimed for.

5.2.2 National nodal points

At the national nodal points[11], traffic exchange takes place at IP level (concerning IP level, see illustration 3) between Internet service providers (ISP) for both national and international traffic. The majority of ISPs in the Swedish market are established at these national nodal points. There are at present three national nodal points in operation, but a fourth is planned. ISPs with large traffic exchange also have direct connections with each other.

[10] An operator is defined here as an Internet service provider (ISP) or other actor building active networks with the aid of fibre networks. Other actors include, for example, a business enterprise or public authority wishing to construct the active network for communication between different units.
[11] National Internet exchange points in Sweden.

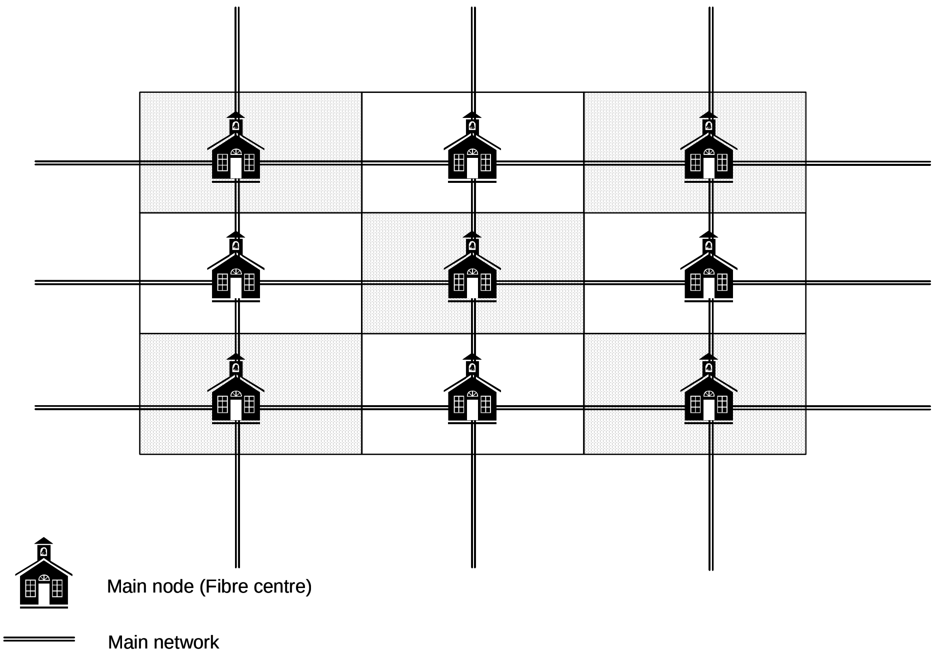
5.3 New structure

5.3.1 Main network

The fine-meshed main network described here is the foundation of the *coming* national network structure. See illustration 2, Network topology – main network.

The main network links the main nodes together. The requirement of redundant connections must be taken into account at an early stage of development. Co-ordination over wider areas must take place, e.g. between municipalities and between counties. An effort should be made to make the main network coincide physically with the existing national main networks insofar as it passes through the area. It can also physically coincide with distribution networks and connection networks as regards the division of ducting and perhaps also fibre cable.

Illustration 2: *Network topology – main network, national level*



5.3.2 Main node

The main node is the central place for fibre connection. Distribution nodes are connected to main nodes through the distribution network. The base for a main node is normally put at roughly 20,000[12] households, business enterprises, public authorities, hospitals, health centres, schools and other organisations within the area[13]. Thus large municipalities need several main nodes, while smaller ones can probably share a main node with a neighbouring community.

[12] The high concentration of connections possible in larger urbanised areas makes the norm for a main node to at least 30,000 households, business enterprises, public authorities etc.
[13] This presupposes *one* physical connection per household, business enterprise, authority etc.

An effort should be made to connect the national main networks to the main node. Svenska KraftKom's national network, now under construction as part of the Government's IT infrastructure commitment, is expected to be connected to these main nodes.

Between the main nodes there shall be complete redundancy, i.e. one main node will be connected to several other main nodes which together will make possible alternative transmission paths. The main network and the main nodes will be subject to very high security requirements.

The main node will also include the Internet operators' active equipment. Municipalities with demand for several main nodes can initially concentrate their "tele-hotel"[14] on one of the main nodes but prepare for the construction of additional main nodes later on.

5.3.3 Distribution network

The distribution network links together main nodes and distribution nodes in a locality or a geographically defined area.

In municipalities lacking sufficient demand for a main node of their own, at least one distribution node should be connected to the national main network.

5.3.4 Distribution node

The distribution node is primarily a passive cross-connection point at fibre level within the area.

The distribution node should, however, be constructed in consultation with the operators regarding the possible placement of active equipment. In order to achieve redundancy, connection of the distribution node should be planned in such a way that it is connected through two different links to two different main nodes.

The distance between distribution nodes varies in proportion to population density.

5.3.5 Connection network

The connection network comprises the connection between distribution network and connection node. The structure of the connection network will vary depending on the character of the area (industrial estate, multi-family housing development, residential area, rural area etc.).

The connection network consists of a number of loops which, if possible, link connection nodes with two distribution nodes.

[14] A "tele-hotel" is a communal space where operators can place their active equipment (communications equipment, servers etc.).

5.3.6 Connection node

The operator's active equipment, connected to the individual building, is placed in the connection node. The connection node is the handover point in a dark fibre network. Connection node and distribution node can be located in the same space, depending on the design of the connection network.

In order to achieve redundancy, the connection node should if possible be connected via two different links to two distribution nodes.

5.3.7 Generic cabling system for buildings

The network built within a building is called a generic cabling system for buildings and as a rule belongs to that building. The generic cabling system for buildings is connected to connection nodes. A generic cabling system for buildings can comprise anything from a network within a building to networks in several buildings and between them. Generic cabling system for buildings are not dealt with in this guide.

Reference (only available in Swedish): Fastighetsnät för informationsöverföring – Generella kabelnät, svensk standard SS-EN 50 173.

6 Visions and requirements concerning IT infrastructure

6.1 National vision

The communications architecture used for the Internet, IP architecture, is one of the factors driving the integration of telecommunications, data communication and video communication. All services, whatever their bandwidth requirement, will be carried by IP-based networks. The present IT infrastructure is optimised for telephony and will for the most part have to be replaced by a new infrastructure adapted to the IP communications architecture and to the estimated annual doubling of traffic which will follow the development of new services and the addition of new users.

The ICT Commission's vision of a future-proof infrastructure in Sweden is that:

- Everyone will have a permanent Internet connection of at least 5 Mbps real throughput capacity[15] within Sweden in 2005. 5 Mbps is an initial value and an annual doubling of capacity shall be feasible.
- By 2005, therefore, Sweden should have constructed a fine-meshed fibre optical network available to all.
- The network shall be technically and competitively neutral and open to all operators, the aim being for everyone, through free competition, to gain access to high transmission capacity at low cost.

6.2 National requirements

6.2.1 Network topology

The new national IT infrastructure shall consist of a fine-meshed fibre network offering redundancy and the possibility of traffic load distribution. The IT infrastructure shall be usable by several operators[16] simultaneously, i. e. operators shall have access to their own fibre pairs so as to be able to build their own network structures (e.g. star or ring networks). Among other things, this means parallel network structures using the same fibre cable. To achieve this, the national fibre structure will have to be built in the form of a grid between different main nodes constituting centres of local and regional fibre networks.

The communication is based on IP, which means that information can find the best path in a network, provided alternative paths are offered. Redundancy is therefore needed between main nodes in a municipality and between municipalities.

[15] Real throughput capacity means the capacity (speed) obtained between the communicating parties, e.g. between two users or between a user and a server from which information is collected.
[16] An operator is defined here as an Internet service provider (ISP) or other actor building active networks with the aid of fibre networks. Other actors include, for example, a business enterprise or public authority wishing to construct the active network for communication between different units.

A fine-meshed network at national level can resemble the main network in illustration 2 and will provide a possibility of decentralisation. In principle, every municipality is to set up one or more main nodes, depending on its geographical extent and on the number of points to be connected.

The main nodes shall also include room for several operators to place active equipment. In order for the main nodes to be practicably workable, they must be in neutral places, physically protected and capable of offering integrity between different operators.

The increasing volume of traffic on the networks will require traffic exchange at IP level between Internet operators to take place at more points than is currently the case. It is also to be expected that the networks will function on a more decentralised basis, since the large traffic volumes which will be generated will be more than a handful of nodes can manage.

6.2.2 Co-ordination

It is very important that connection between main nodes should be inter-municipally co-ordinated. The national comprehensive redundant fibre structure is dependent on co-operation for its development.

Location of fibre cables needs to be co-ordinated between neighbouring municipalities, together with the national actors constructing fibre networks between central localities in Sweden.

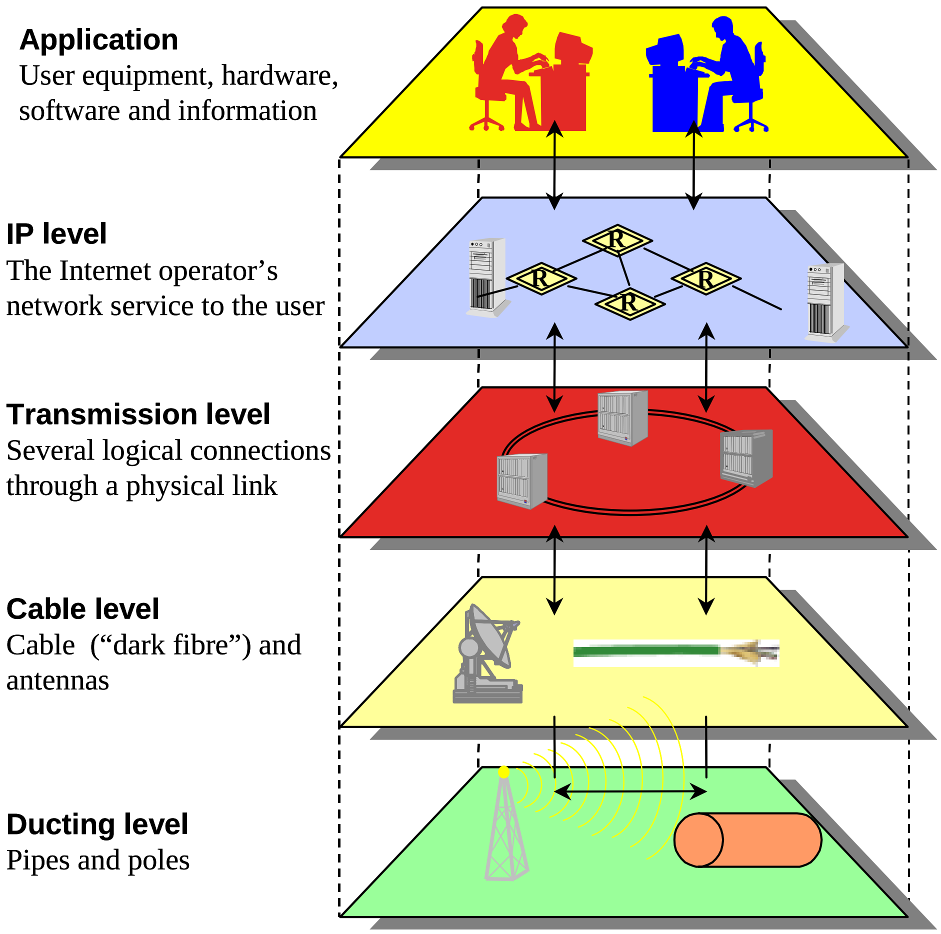
The local and regional structure is also dependent on co-operation for the cost-effective realisation of redundant networks. In many cases regional and local structure, e.g. ducting, can be made to coincide with the structure required for the main network.

6.2.3 Uniform products

With a fibre network, technical and competitive neutrality can be achieved. The products provided by the municipality should be based on ducting and dark fibre rentals and the provision of spaces for active equipment, i.e. tele-hotels. A municipality shall endeavour only to supply products on the two lowest levels (ducting and dark fibre) as per illustration 3. Adjustment to local conditions, however, will always be necessary, and it is conceivable that the municipality will operate the active network directly for the municipal administration’s own activities.

To make it practically possible for operators to construct national communication networks with the aid of rented dark fibre, uniform agreements will be needed and network proprietors must be able to resell other network proprietors’ infrastructure. This calls for co-operation between IT infrastructure proprietors at municipal, regional and national levels.

Illustration 3:
Different levels of IT infrastructure (source: SOU 1999:85: "Bredband för tillväxt i hela landet")



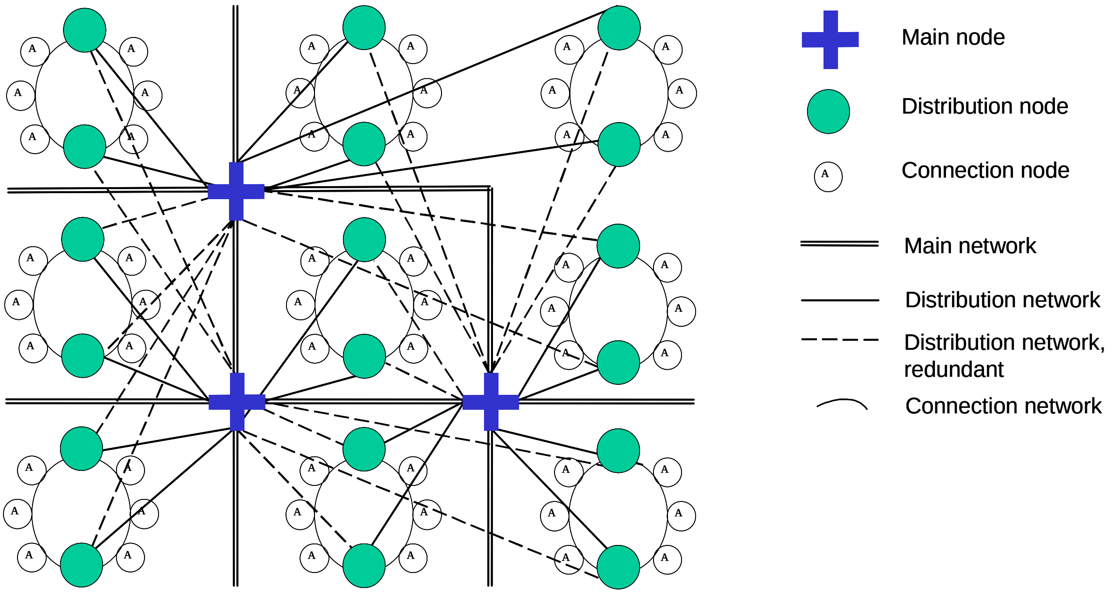
6.3 Local requirements

6.3.1 Network topology

The local network structure shall make it possible for operators to build active communications networks with ring or star topology, depending on the system solution chosen. Under each main node, distribution nodes will be required for the distribution of fibre to points where network users are to be connected, i.e. to connection nodes. In a fully developed network at local level, every distribution node is connected to two main nodes and every connection node is connected to two distribution nodes. Redundancy from connection nodes to distribution nodes must, however, be viewed in a longer perspective. In many cases, ducting, to begin with, will only provide a possibility of redundantly connected distribution nodes.

The active equipment of the Internet operators and other actors is placed in main nodes and in connection nodes while distribution nodes serve as cross-connecting points at fibre level. An ideal structure with redundancy cannot always be accomplished by an individual municipality, and inter-municipal co-ordination is therefore necessary to achieve the national structure of the main network and to create redundant connections of distribution nodes as per illustration 4. The structure shown in illustration 4, with direct and redundant connections between main nodes and distribution nodes, is necessary in order to offer the dark fibre product for different operators' system solutions. Illustration 4 shows the connection network with a ring structure. In practice, the connection network will logically also be able to comprise star networks.

Illustration 4: *Logical structure – fibre network*



Ducting

In order for the construction of general fibre networks to be possible, they have to be based on a flexible conduit system. Thus it is not sufficient to lay cable pipes (optical cabel pipes) in connection with other contracting operations. The conduit system is a network in itself which has to be planned in order for effective utilisation to be possible. The conduit network must be dimensioned to cope with 100% connection of buildings. The conduit system being the biggest item of expenditure in the development of fibre networks, planned and structured development is very important.

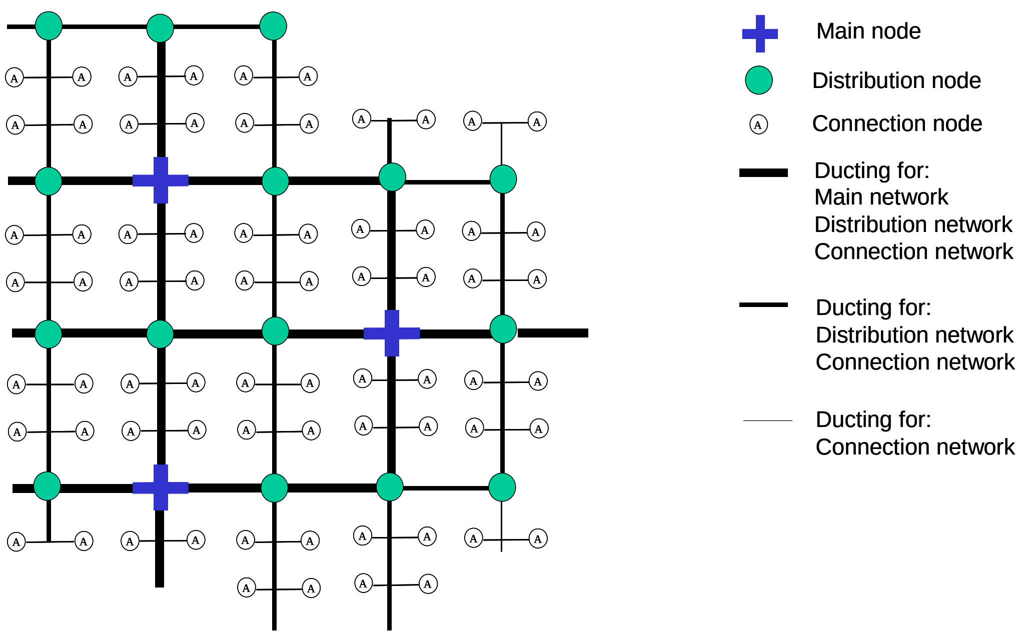
A general conduit network is planned by plotting a grid which conforms to the detailed development plan and the network of streets and roads. This grid corresponds to the geographic coverage of a fully developed conduit system.

One could also speak of main network, distribution network and connection network with reference to the conduit network, in the sense of different numbers of optical cable pipes being needed for optical cable-laying in the different parts of a local or regional network. In the central parts of the network structure, the main, distribution and connection networks of the fibre network coincide, and accordingly more optical cable pipes are needed there. Ducting is therefore reinforced in the central parts by a larger number of optical cable pipes between main nodes.

Slightly fewer optical cable pipes are laid further out in the network between distribution nodes and the smallest number are laid between distribution nodes and connection nodes. See illustration 5.

Given advance planning of ducting as described above, one can know at any time how many optical cable pipes are needed for collective laying with other contracting enterprises, without necessarily knowing the exact timetable for enlargement of the fibre network. It is also possible to see the gains which can be achieved by enlarging a contract and in this way obtaining redundancy or connecting an area at an earlier point in time.

Illustration 5: *Structure for conduit networks*



6.3.2 Summary of requirements for the technical solution

The requirements to be met by the technical solution can be summed up as follows:

- Networks shall be planned as general networks, not as functional networks based on a certain technical communications solution for one or a limited number of operators.
- A general conduit network shall be planned and constructed as the basis of a fibre network.
- A generally redundant fibre network shall be planned and constructed as the basis for the operators' different needs of active communications networks.

6.3.3 Co-ordination

Based on a target network for ducting, there are good prospects of achieving an efficient, structured development within a municipality or region. The single most important factor for quickly and cost-efficiently building a structured network is co-ordination between excavation contracts. A function needs to be set up within the municipality to supervise all excavation contracts and co-ordinate the positioning of ducting in accordance with the target network.

This function must also supervise contracts straddling municipal boundaries. This is an important prerequisite for the materialisation of a connection between main nodes and, ultimately, of a new main network. Co-ordination with Svenska Kraftkom and other fibre contractors is also necessary. Through co-ordination with State and private contracts which are planned or in progress, large parts of the stretches linking together localities within a municipality or region can be developed more rapidly and cost-effectively.

7 IT infrastructure programme document

7.1 General

A municipal or regional network is the concern of many parties and, to be feasible, requires properly worked-out input data for decision-making. In these data it is important to distinguish between vision and targets. The targets set should be based on concrete development plans, costs and estimated benefits.

Good planning is required in order to achieve a network which is future-proof and a good economic proposition for the municipality or region. Things which are not thought through beforehand often have to be decided in great haste while installation is in progress, in which case there may not be enough time to evaluate and choose the most beneficial course of action. A target network should therefore be established for the municipality (region), so that small development steps carried out in an early phase will fit in with the final network. The target network will probably develop and change with the passing of time, but planning will be stabilised by attempting to see the structure at an early stage of things.

7.2 Pilot study

To be able to prepare for the development of a new infrastructure, one has to analyse existing assets and the need for a new structure. First of all one should carry out a pilot study of the following:

- Existing networks and whether they can be used in a future structure.
- How is the vision of a network with high throughput capacity, i.e. with an initial value of 5 Mbps traffic throughput and the possibility of doubling every year, to be achieved?
- Special needs of communication with high transfer capacity on the part of new business undertakings, operators, content suppliers, municipal residents, the caring sector etc. Here one should bargain for at least 5 Mbps per employee.
- The number of Internet service providers (ISPs) and other actors[17] establishing themselves initially or eventually and requiring access to dark fibre and space for active equipment in tele-hotels.
- Development in neighbouring municipalities.
- How the municipality can become part of the national IT infrastructure.
- How co-ordination can be achieved with neighbouring municipalities and various regional organisations.
- How earlier investments can be integrated with the new infrastructure.

The pilot study documents the need for IT infrastructure enlargement.

A programme document is then involved from the pilot study. Work on a programme document should proceed in consultation with representatives of different interests in the municipality and region (housing enterprises, entrepreneurs etc.).

[17] Other actors include, for example, a business enterprise or public authority wishing to construct the active network for communication between different units.

7.3 Vision and purpose

The programme document describes the municipality's (region's) vision concerning IT infrastructure. The vision discussed in Section 6 is combined with the vision of growth and development possessed, for example, by each municipality.

The new IT infrastructure can create new possibilities and visions for the development of the municipality as a whole. One should have an eye to the possibilities rather than the difficulties. The municipality's IT infrastructure development targets for the coming five years should be described.

The purpose of the programme document is:

- To lay down guidelines and boundaries for the IT infrastructure, organisation, finance, times etc.
- To document visions and requirements.
- To serve as supportive data for decision-making.
- To establish the target network.

Suggestions concerning the possible content of a programme document are made below in the form of a checklist with headings and points which should be addressed under each heading. The checklist is addressed to a municipality but can also be used for a region.

7.4 Checklist for programme document

7.4.1 Information

Information as to how IT infrastructure is to be developed is an important stage: not everyone as yet has seen the extent of the new IT infrastructure which has been built. Intelligible information can make it easier for people to understand and accept the possibilities of the new technology. It is also important that the municipal agencies affected by the work to be done should be informed at an early stage.

The following are some examples of interest groups:

- Municipal residents.
- Business undertakings.
- Housing enterprises.
- Municipal Administration.
- County Council.
- County Administrative Board.
- Neighbouring municipalities.
- Operators.
- Landowners.

7.4.2 Market

Overview of the telecommunications and data communications market
An overarching analysis should be made of the market for telecommunications and data communications and its impact on the municipality/region, together with the possibilities it creates.

Regional market
Estimate the regional potential:

- What special communication needs do the household market, business undertakings, public authorities, hospitals and other organisations have in the short and long term over and above the initial value of 5 Mbps?
- What different customer groups are there?
- What traffic volume or IT infrastructure demand can the various segments generate?
- What services are available?
- Potential for Internet service providers and for providers of services and content.

7.4.3 Strategies

Market strategy
Which customer groups are to have priority in connection with an expansion? Where and when are products to be offered to different customer groups?

Price and product strategy
The pricing of products should be cost-based. Estimate how pricing is affected by write-off times, earnings from operators and the way in which funding is to be distributed to commercially less attractive areas.

The products which should be considered are:

- Ducting.
- Dark fibre.
- Tele-hotels.

Pricing should be such that when about 75% of the existing fibre is leased, further fibre resources will be constructed.

Distribution strategy
Describe how products are to be sold and what co-operation may be necessary in order to achieve a working organisation.

Operating strategy
The administration of operation and maintenance for the new IT infrastructure should be carefully evaluated. Operators will require an operation offering 24-hour service. An organisation of this kind requires heavy resources and will probably be too expensive for a small municipality. In the majority of cases, operation and

maintenance will have to be co-ordinated between municipalities. This applies regardless of whether operations are managed in-house or are put out to contract.

Generally speaking, a new organisation should not be built up under municipal auspices if there are municipal or private companies which can take charge of the operation and marketing of fibre products.

Higher availability makes heavier demands on the operating organisation but is to a great extent based on good network design. A network design with redundant paths in the main network and distribution network can, given good planning, be achieved without extra investment in the facility. Full redundancy in the connection networks requires bigger investments, but these can be heavily reduced by good planning. With redundancy in the fibre network, the operator's active equipment can itself switch over to emergency connection and cable repairs can be carried out during the daytime, which will mean a heavy cost-saving for the maintenance organisation.

Thus the operational guarantees which it is intended to give for the dark fibre product depends very much on the network design. High availability in those parts of the network which are not redundantly constructed depends very much on the ability to mend cable breaks at very short notice.

Monitoring

The benefit of and dependence on the large volumes of traffic which will be generated on the fibre network of the future mean that a very high level of dependability will be required. Monitoring of fibre network availability may come to be considered, in view of the need for high dependability. This means that whoever is responsible for the fibre network would in practice have dealings with the operators' operational and monitoring organisations.

In order to be a creditable supplier of dark fibre, one must be able to offer operators clear guarantees concerning, for example, response time, downtime and availability on a monthly, quarterly and annual basis. Certain operators will demand higher availability than can be guaranteed in an organisation active during the daytime only.

Monitoring of fibre networks can be easily arranged by setting aside one pair of fibres per optical cable for alarm purposes. Active equipment can then generate an alarm in real time if the fibre network is being interrupted. (More advanced and more expensive equipment can also give the alarm if the cable is subjected to physical interference without the connection being broken.) In this way the organisation responsible for operating fibre networks can begin work on rectifying the fault before the operators escalate the alarm from their monitoring systems.

Costs

The costs and requirements entailed by the operation of IT infrastructure are frequently overlooked in the evaluation and planning of new networks. Marketing, sales, administration and continuous training are also items of expenditure to be borne by existing fibre products.

Maintaining a stand-by organisation day and night all the year round requires a large number of people (between eight and ten) in order to maintain a rolling timetable with a reasonable periodicity and so as to cover for holidays, illness etc.

7.4.4 Objectives

Quality targets
The following are to be indicated in accordance with the focus and strategy chosen as described in the preceding section.

- The quality and availability of networks to exist initially and in four or five years' time.
- The service and availability of products (ducting, dark fibre, tele-hotels) to exist initially and in four or five years' time.

Delivery and expansion targets
Indicate how the network is to be expanded initially and in four or five years' time.

Economic targets
Describe when and for what parts cost coverage is to be achieved. What investments are to be made over and above this, e.g. in commercially less attractive areas?

7.4.5 Organisation

The running of a fibre network demands both administrative and operative personnel. Depending on the focus and strategy chosen, as described in Section 7.4.3, the calculations are made of the internal and external resources required for administration, marketing and operations. Particular importance must be attached to operative policy and to what is needed in order for an organisation to meet operators' availability requirements.

7.4.6 Finance and preconditions

Financial outcomes and the preconditions on which a planned development is based are presented in a cost-benefit analysis. This analysis then forms the basis of prioritisation for development within the municipality.

One basic precondition is that optical cable with its long technical lifetime of 30-40 years can have long write-off periods (20 years or more), which facilitates long-term planning. This contrasts with the short write-off time for active equipment (about three years), which demands more short-term repayment and makes active networks less suitable for local government activity. It is conceivable, however, that the municipality itself will operate the active network for the municipal administration's own activities.

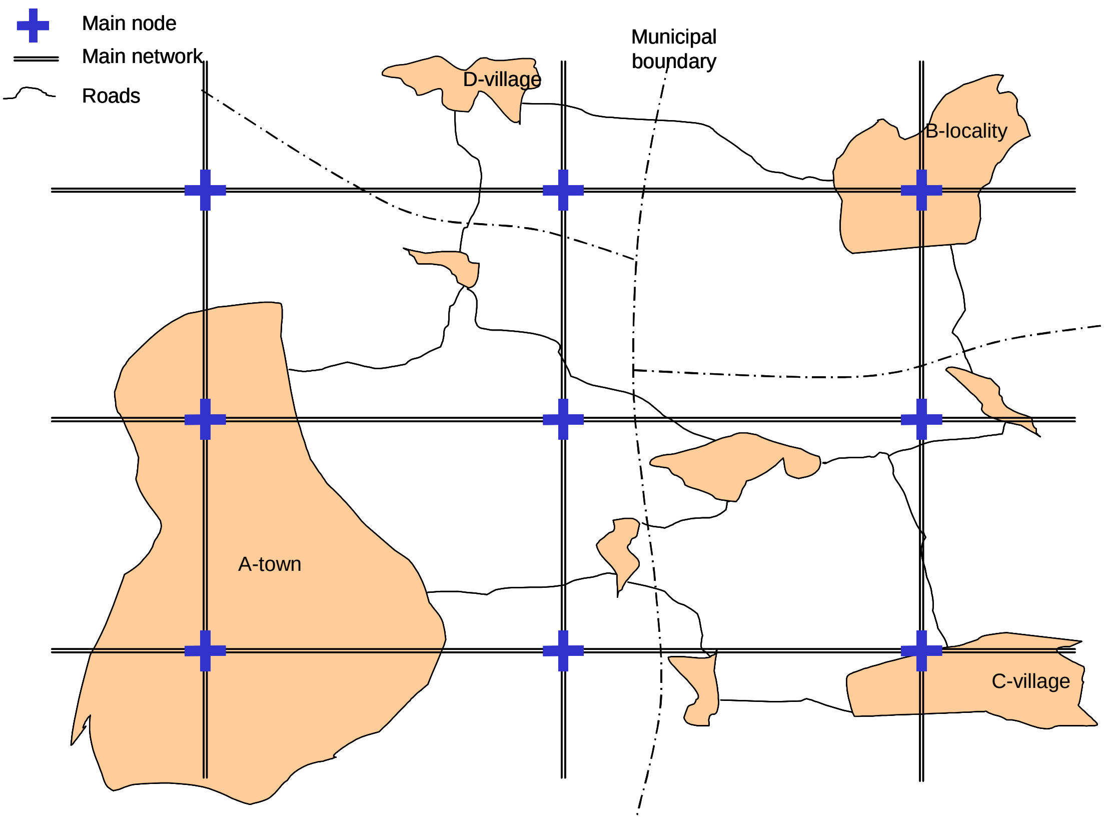
7.4.7 Expansion plan

Describe the existing network, target network and the IT infrastructure expansion plan on which the investments are based in a cost-benefit analysis. On the basis of target networks, areas and connections are prioritised and this prioritisation then forms the basis of a division of the development into stages. During this phase only a rough system solution is worked out, defining main nodes and indicating preliminary locations for distribution nodes.

Main network

In order to plan a network structure with full redundancy, primarily between main nodes, the picture of the target network has to be produced. Illustrations 6-12 exemplify the transfer of the theoretical network structure to a fictitious geographic map.

Illustration 6: *Main network – general logical structure*



The following should be taken into account when positioning main nodes:

- An approximate norm is one main node per 20,000[18] households, business enterprises, public authorities, hospitals, health centres, schools and other organisations within the area.[19]
- Joint planning with neighbouring municipalities if the population is too small for a main node.
- Geographic distances have to be taken into consideration.
- The structure of the community, population density, strategic location etc.
- Suitable facilities which can be made available for nodes.

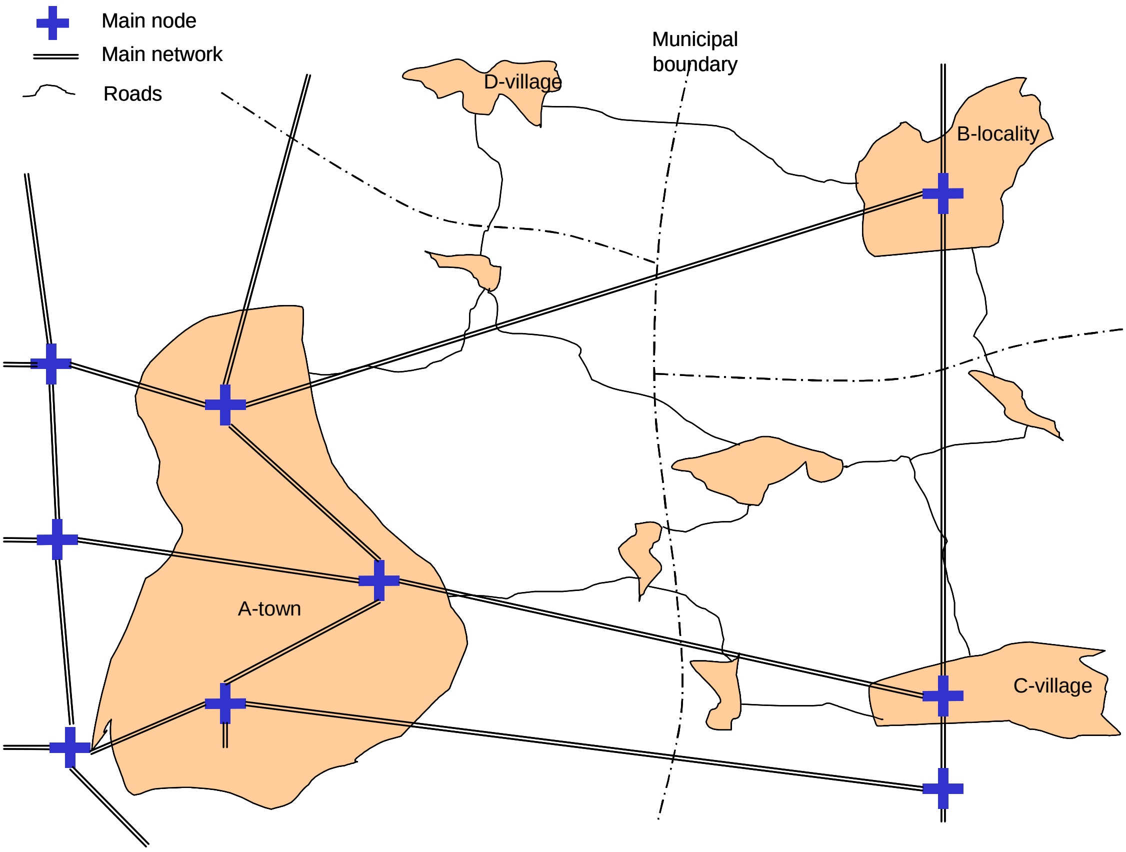
[18] The high concentration of connections possible in larger urbanised areas makes the norm for a main node to at least 30,000 households, business enterprises, public authorities etc.
[19] This presupposes *one* physical connection per household, business enterprise, authority etc.

A good starting point is to imagine an optimum grid with main nodes and main network covering the area concerned, as shown in illustration 6. This grid is adapted to the feasible positioning of main nodes in the area.

Every municipal central locality will be connected to Svenska KraftKom's national network. The node to be created for this purpose is a good point of departure for a municipal or regional fibre network. This node can become a main node or alternatively a distribution node, depending on the number of connections which it is to serve.

In cases where there is only sufficient demand for *one* main node or *one* distribution node in a municipality or in a locality, these should be divided into two physical nodes. This should at least be done in such a way as to obtain separation within the same building, with separate inputs for cables and ducting. It this is already taken into account when planning the networks, much expense can be saved by connecting distribution nodes and connection nodes redundantly within the locality, especially if there are long distances between localities.

Illustration 7: *Main network – adapted logical structure*



In this example the assumption is that four municipalities intend to co-ordinate the development of IT infrastructure within the region. Main nodes are positioned in suitable places as per the following argument (see illustration 7):

- A-town has about 80,000 households, business undertakings, authorities etc., and so there should be three main nodes in the central locality (i.e. roughly 30,000 connections per main node, bearing in mind that A-town is a large, urbanised area).

- B-locality has about 15,000 households, business undertakings etc. and the nearest town with sufficient demand for a main node is more than 10 km away. This makes it more economical to place a main node in the municipality's central locality, i.e. in B-locality, than to extend the fibre network through a number of distribution nodes to another main node.

- C-village has about 6,000 households, business undertakings etc. and the municipality as a whole numbers roughly 15,000 households. A main node for the municipality is placed in C-village. In principle, the municipal population justifies a main node. In addition, there are a number of smaller localities within the municipality which will be connected primarily to the central locality.

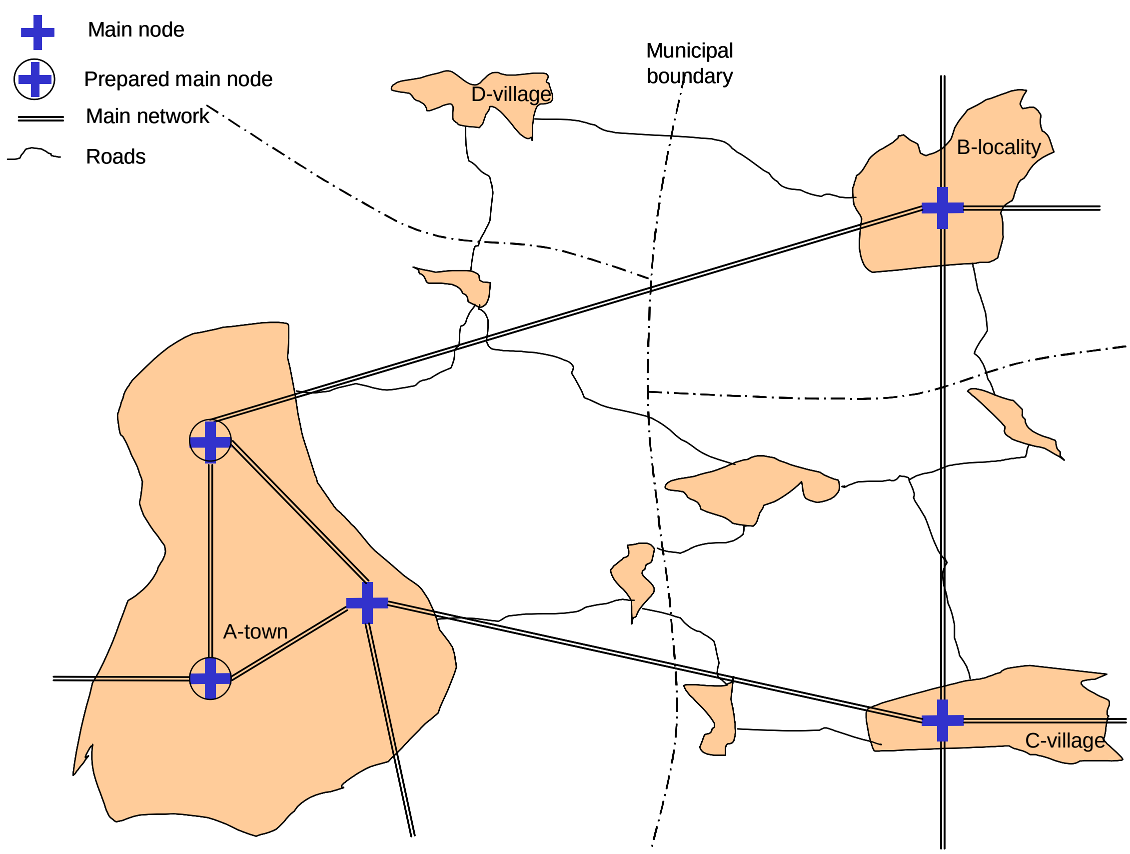
- D-village has about 3,000 households, business undertakings etc. D-village, which is the municipal central locality, will be connected to Svenska KraftKom's network, but the size of D-village and the municipality does not justify a main node. In this example, D-village will be connected to the regional network through a distribution node (see illustration 9).

A-town has sufficient population to support three main nodes. One of these points will connect up with Svenska KraftKom's network and will initially become the most strategic point in the municipal network. For reasons of expense, not all three points are constructed as complete main nodes with tele-hotels and connection to four other main nodes.

The three main nodes in A-town are viewed as a whole and connections to other main nodes are distributed between the three. In the municipality of A-town, the fibre network will be constructed as if all three were main nodes. The final structure of the main network will then be as shown in illustration 8, with three main nodes in the region and with two prepared main nodes in A-town.

The design of a "prepared" main node varies from one case to another. A prepared main node is used for optical cross-connection and, in an initial phase, not as a tele-hotel. Space ought if possible to be reserved from the outset for the subsequent addition of a tele-hotel.

Illustration 8: *Main network – final logical structure*



The positioning of the main node in each municipality is determined simultaneously with the planning of the intended physical route for ducting. In this example the three main nodes can be connected through physically separate paths by following the network of roads as per illustration 9. Illustration 9 also shows the distribution nodes which will be connected as a result of main network and distribution network coinciding (locally, connection networks will also coincide along certain lengths).

Illustration 9: *Main network – ducting*

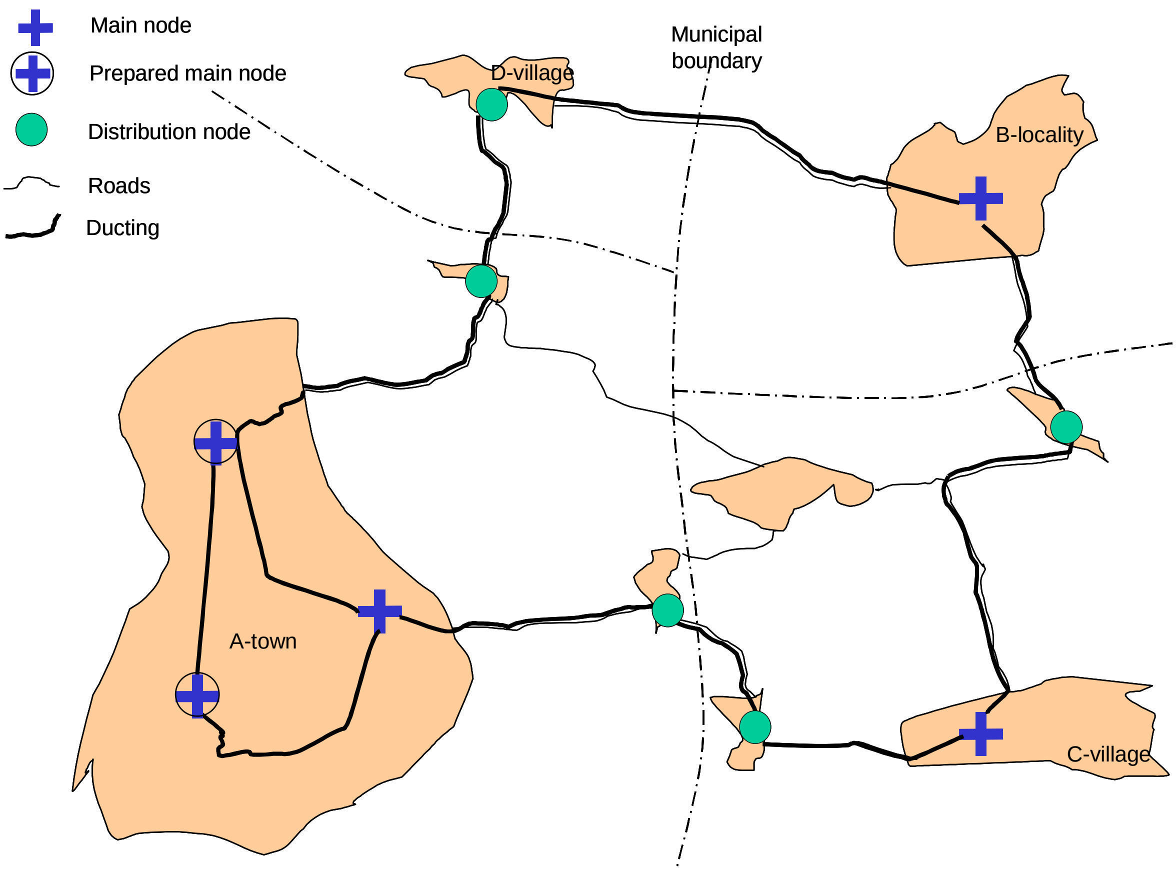
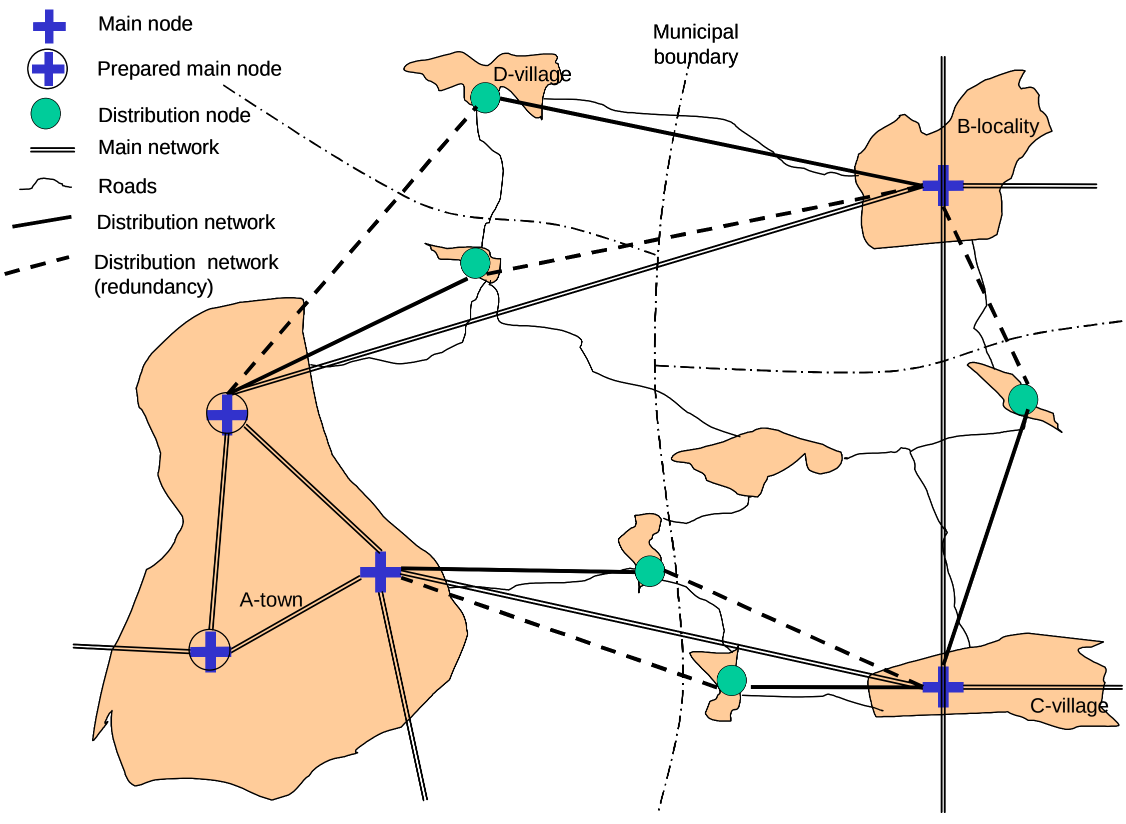


Illustration 10 shows the logical main network between main nodes and the part of the logical distribution network which can be created in the ducting shown in Illustration 9. All distribution nodes are connected redundantly to two main nodes. In rural areas distribution networks and main networks will in certain cases be able to physically utilise the same optical cable between main nodes. Through inter-municipal co-ordination, the region can also acquire a redundant network for smaller communities in between main nodes.

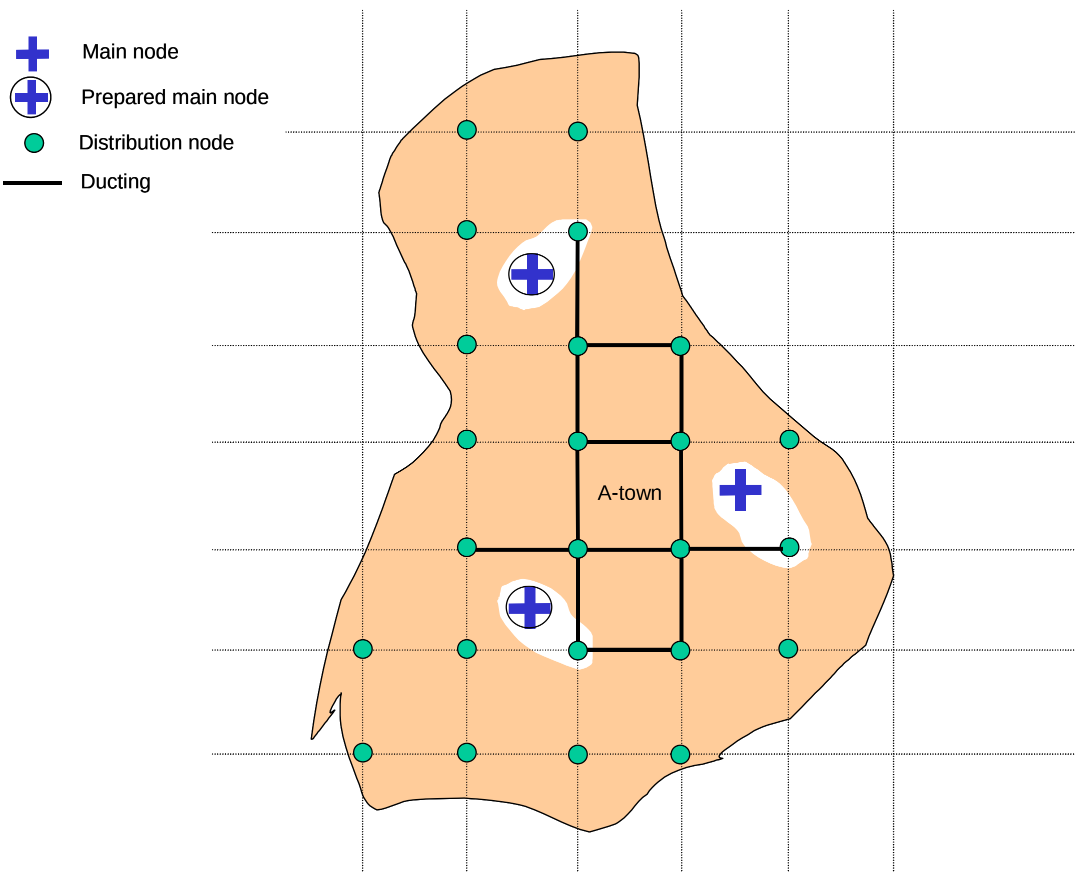
Illustration 10: *Main network and distribution network – logical structure*



Distribution network
Distribution nodes within an urban community are placed in an optimum grid as per illustration 11, where the lines between the distribution nodes symbolise conduit routes in a fully developed network. In illustration 11 a number of distribution nodes have priority for development in Stage 1. Ducting for Stage 1 is then constructed in accordance with the structure planned. The ducting follows the roads and other preconditions existing in the locality concerned. It is important that this structure should exist as a final objective and that it should be transferred to real conditions when the development comes to be materialised.

For convenience of technical drawing, the main node and prepared main node are placed separately from the ducting (see non-shaded area in illustration 11). In practice the positioning coincides with the position of the distribution node.

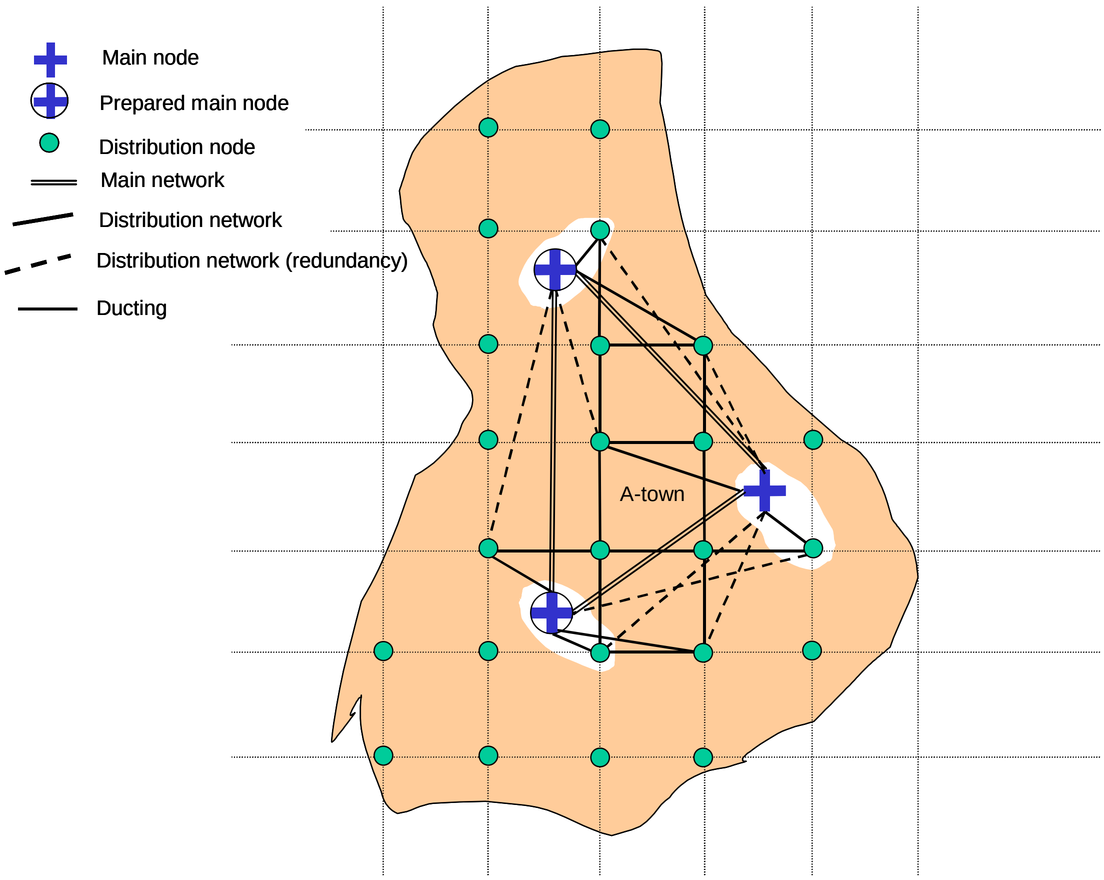
Illustration 11:
Distribution nodes, general structure and ducting for priority nodes



The priority distribution nodes are connected with fibre to two different main nodes. When development is complete, the distribution nodes will be logically connected to the main nodes as per illustration 12. The structure of the ducting is such that the fibre cables between distribution node and main node cannot always follow the shortest route, but it is important not to optimise ducting according to the first stage of expansion. Given a structured approach, subsequent development will greatly benefit from earlier stages and in this way be achieved at much lower total cost.

For convenience of technical drawing, the main node and prepared main node are placed separately from the ducting (see non-shaded area in illustration 12). In practice the positioning coincides with the position of the distribution node.

Illustration 12:
Logical fibre network for main nodes and priority distribution nodes, together with ducting for priority nodes



8 IT infrastructure system document

8.1 Purpose

Once it has been decided to construct an IT infrastructure, the technical level of the network has to be established. The input data for this are codified in a system document showing the technical requirements for the different parts of the network. Technical requirements can be cost-driving, and so it is essential that the system document should have a long-term, sustainable perspective. Changing or mixing materials or methods is, for the most part, not a paying proposition.

On the basis of the system document, both internal and external planners shall be able to carry out detailed planning of the expansion phases decided on. This ensures consistent quality in different phases of development, as well as a homogeneous solution and achievement of the intentions represented by the target network.

The purpose of the system document is to establish the following:

- Definitions.
- Scope and requirements for ducting and fibre.
- Standard for node space.
- Security levels.
- Documentation principles.

The guidelines described in this section are general recommendations. Adjustments always have to be made to local conditions.

For procurement of contractors and materials, procurement documentation should always be compiled in accordance with AMA (only for Sweden). The procurement documentation is based on the levels defined in the system document and is compiled in the course of planning.

Reference (only available in Swedish): AMA (Allmänna Material och Arbetsbeskrivningar), published by Svensk Byggtjänst.

8.2 Ducting

8.2.1 General

Ducting, for present purposes means the construction of optical cable pipes and manholes in which optical cables are to be laid subsequently.

The single most expensive item in the construction of fibre networks is the actual excavation and laying of optical cable pipes. This makes it important to have good forward planning for future needs.

When choosing a conduit route, consideration must be made to the future structure of each network. Ducting for main network, distribution network and connection network is separately dimensioned but must be included in the same conduit route as far as possible.

The amount of ducting will depend on the number of cables. As a general rule, one optical cable is laid per optical pipe.

Consideration must also be paid to future expansion plans as regards real estate, roads, cycle paths etc. In this way the size of ducting can be correctly assessed and the conduit routes can be positioned so that cables will not have to be relaid subsequently.

In addition to ducting for current optical cable needs, ducting is also required for future needs. In cases where it is decided to rent out ducting to external network constructors or operators, this too will affect the dimensioning. Experience hitherto has shown that new construction of ducting has often been under dimension as regards both the number of optical pipes and the number of manholes.

When planning for ducting in main networks, distribution networks and connection networks, at least one optical cable pipe must always be kept in reserve.

8.2.2 Ducting for main network

In between the main nodes of the main network, an effort should be made to lay fibre optical cables without a break. Usually only one optical cable, i.e. one optical pipe, is needed for linking together the main nodes themselves in one direction. In connection with a gradual expansion of main networks, with connections to other municipalities, and to make room for different operators, there will be a growing need for fibre and with it for cables and ducting in future.

Two optical pipes is the absolute minimum for main network ducting. Additional ducting is required, however, to cater to all the needs mentioned above.

An effort should be made to utilise the same conduit route for distribution networks and connection networks as well.

8.2.3 Ducting for distribution networks

A distribution network links a distribution node between two main nodes. Of these two optical pipes are laid between main node and distribution.

In many cases, ducting from several distribution nodes will coincide in one and the same conduit route, added to which, the same conduit route may need to be used for the connection networks.

8.2.4 Ducting for connection networks

The connection networks connect the connection nodes with the distribution nodes. From the connection node there is also a link to each individual building. At least two optical pipes should be laid between the splicing manholes in the connection networks.

When dimensioning the ducting for connection networks, it should also be borne in mind that the connections from the connection node to each individual building can use the same conduit route, which considerably affects the amount of ducting.

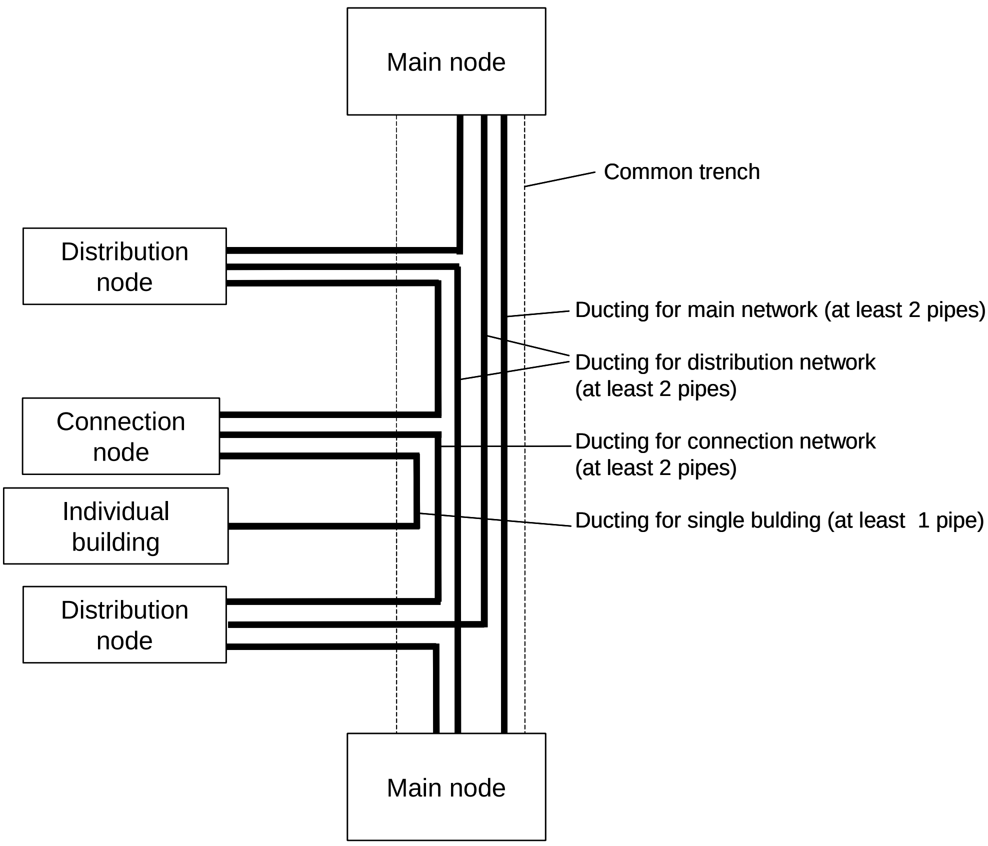
8.2.5 Ducting for individual buildings

Since, for economic reasons, joint laying of ducting is vitally important, ducting for individual buildings must also be taken into consideration in the course of planning. Primarily this concerns ducting for single-family housing development. Ducting for reaching all single-family dwellings in an area can be extensive and require careful planning.

Illustration 13 shows that for certain lengths, ducting can be jointly laid in a single trench. It is highly important for ducting to be planned so as to cover the needs of the foreseeable future. In this way an individual building owner can gain access to the IT infrastructure at reasonable expense. Responsibility for individual ducting for the connection of an individual building or dwelling (i.e. a “horizontal” generic cabling system for buildings) should be co-ordinated by the municipality.

Note that illustration 13 shows the ducting between two main nodes. Every main node shall be connected redundantly through separate ducting to two nearby main nodes (see Sections 8.3.2 and 8.5.4).

Illustration 13: *Ducting – joint laying*



8.3 Optical cable

8.3.1 General

The amount of optical cable and the number of fibres in each optical cable for the different typical stretches are chosen in accordance with the following criteria:

- The amount of existing ducting.
- Type of network (main network, distribution network, connection network).
- No. users.
- Possible or anticipated penetration in the area.
- Number of Internet operators active in the area.
- Leasing of dark fibre to Internet operators, businesses and other organisations constructing active networks.
- No. nodal points in each network.
- Positioning of active equipment.
- Degree of redundancy in the networks.
- Whether a cable is pooled for main network and distribution network and for distribution network and connection network.

As a general rule, if existing ducting is to be used, a careful assessment must be made of the best way to use it. If the number of existing optical pipes is small, an optical cable with many fibres will have to be laid so as to make maximum use of the ducting.

8.3.2 Optical cable in main network

In the main network there must be a direct redundancy between main nodes which are close together. This means that it must be possible from one main node to reach the main nodes next to it without passing through the active equipment of another node. The optical cables should be laid without a break between the main nodes, so as to achieve high operational dependability. The optical cables for the main network to different main nodes are to be separately ducted.

The number of fibres between the main nodes in the main network in a municipality ought, at an initial stage, to be not less than 96 per optical cable (optical pipe). If main nodes in different municipalities are long distances apart, the number of fibres may possibly be smaller if this is justified by great differences of fibre cost.

8.3.3 Optical cable in distribution networks

A distribution node shall connect to a main node and shall be planned to have a redundant connection to another main node. The optical cables should be laid without a break from each main node to the distribution node. Alternatively, an optical cable loop is laid with two or three distribution nodes where the need for each distribution node is hived off. Over long distances this will be a cheaper but more vulnerable option.

The number of fibres in the distribution network is affected by the following parameters:

- No. connection nodes connecting with each distribution node.
- No. operators[20] needing connections in the distribution network.
- Leasing of dark fibre to other actors.

The number of fibres to each distribution node ought not, however, to be less than 96 per optical cable (optical pipe) during an initial phase.

The number of fibres when the distribution network connects vastly populated areas can vary and in many cases may be less than 96 in the early stages.

8.3.4 Optical cable in connection networks

The connection network shall have at least 96 fibres in the loops emanating from the distribution nodes. The connection network shall be laid in loops between two distribution nodes, so as to obtain redundancy. The number of connection nodes in a loop should be adapted so that the total need will be, at most, 96 fibres per loop.

The number of fibres in the connection network can vary and is influenced by the following:

- The number of connection nodes connected to the loop.
- The number of operators needing connections in the connection network.
- Leasing of dark fibre to other actors.
- The needs of users along the loop (type of enterprise etc.).

8.4 Node space

8.4.1 General

The design of a node space will depend on its location in the network. The most qualified node spaces, as regards size and security, are those intended for the main nodes.

The possibility of placing active communications equipment in distribution nodes should also be planned for, the reason being that certain operators today are building networks in this way, which means that the distribution node should have access to electric power etc. By also planning at an early stage for this space requirement in the distribution nodes, future additions can be made without expensive reconstruction. In practice, main node, distribution node and connection node can also be located together.

The system document should establish the following for each type of node space:

- Space requirement.
- Burglary and fire safety classes.

[20] An operator is defined here as an Internet service provider (ISP) or other actor building active networks with the aid of fibre networks. Other actors include, for example, a business enterprise or public authority wishing to construct the active network for communication between different units.

- Alarm requirements (damp, intrusion, fire, smoke, power supply failure), see Section 8.5.3.
- Environmental requirement levels (heat, cooling, ventilation).
- No-break or reserve power supply.

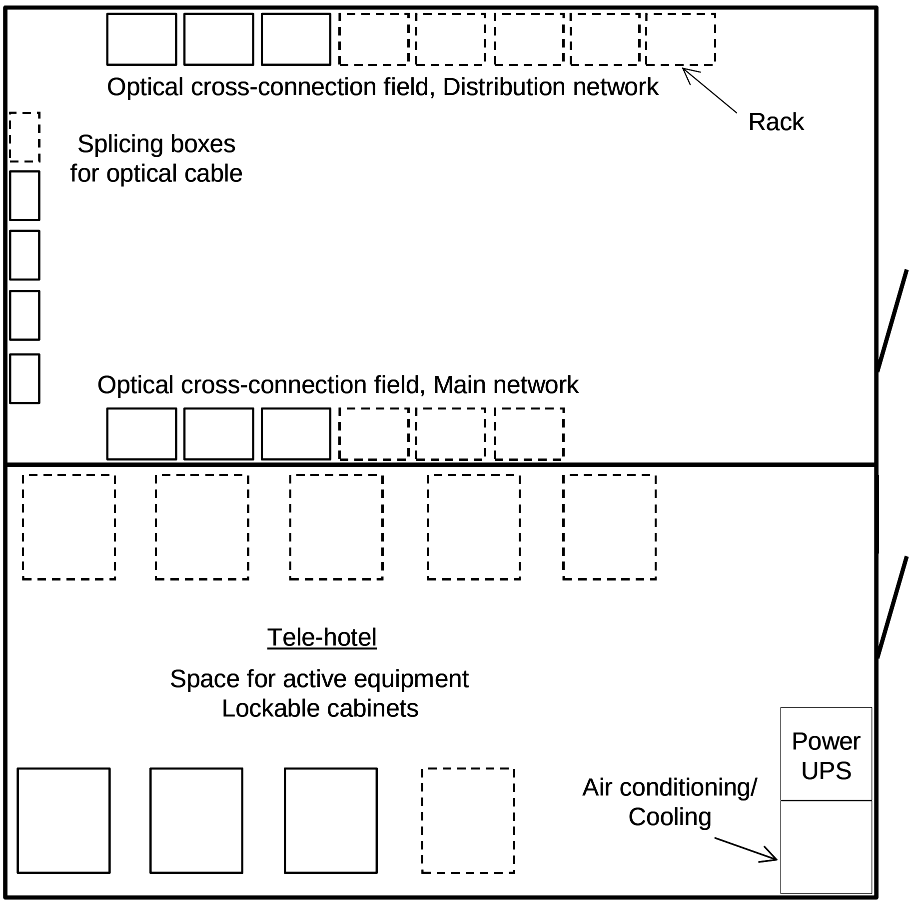
These nodal space recommendations are general and must be adapted to the conditions applying in the project concerned.

8.4.2 Main node

The node space for a main node shall be constructed in such a way that a very high level of operational dependability can be guaranteed.

The size of the nodal space shall include all material for optical cross-connection and also active equipment for different operators. In addition, there must be space for future expansion.

Illustration 14: *Explanatory sketch of main node with tele-hotel*



The nodal space shall be provided with a cooling unit and mechanical burglary protection. (See Section 8.5.3).

The nodal space shall have a common UPS (short-term battery backup) with no-break power supply for a certain length of time (at least 30 minutes). The actual length of time will depend on the operating organisation and on the measures to be taken in the event of a power supply failure. A reserve power supply unit shall be provided for one week's unsupervised operation.

The nodal space shall be provided with an authorised access system which ought preferably to have a logging facility.

The operator's equipment should be positioned in a separate space (tele-hotel) near the optical cross-connection.

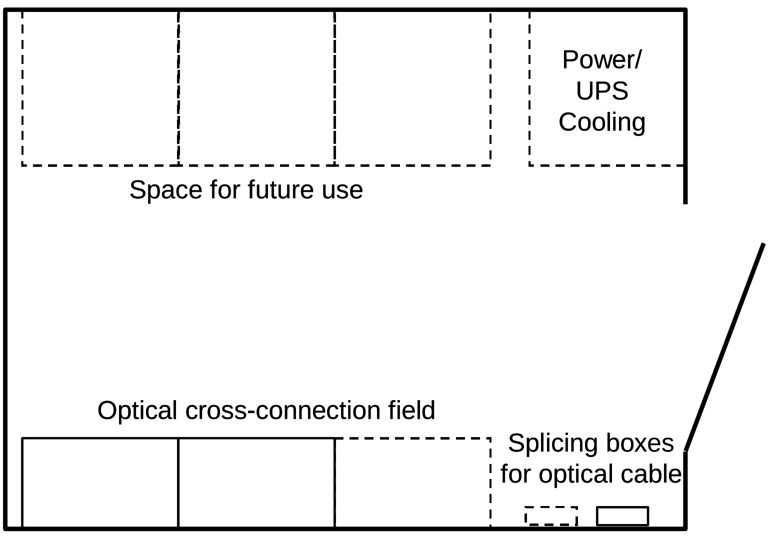
Different classes of main nodes in terms of vulnerability and operational dependability should be determined at county or national level.

8.4.3 Distribution node

The space should be provided with a system for access control. If active equipment is placed in the node, it must be possible to provide the space with uninterruptible power supply (UPS) and a cooling unit. The security level for burgary/damage and fire shall be determined.

The possibility of placing active communications equipment in distribution nodes should also be planned, because certain operators today are building networks in this way, which means that the distribution node should have access to its own power supply etc.

Illustration 15: *Explanatory sketch of distribution node*



8.4.4 Connection node

The connection node is the place where connections emanate to each individual user in the IT infrastructure, and it comprises both passive components and active equipment. The physical space requirements of the connection node depend on the number of users to be connected to the node. The connection node in a small residential area may consist of just one rack positioned in a lockable cabinet, while that in a larger housing development may correspond in size to a distribution node.

8.5 Security

8.5.1 General

A fibre network shall be built in such a way that the highest possible operational dependability will be achieved. Operational dependability means the network being constructed from the very outset in such a way that any disruptions due to harmful effects or accidents will be noticed as little as possible by the user. If a failure nevertheless occurs in a connection, it shall be rectifiable both quickly and easily.

In order to achieve a high level of operational dependability, the network must have:

- A uniform structure.
- Protection from damage, burglary and fire.
- Redundancy.
- High availability.

The system document should show the following:

- Minimum safety level requirements.
- Availability requirement.
- Special requirements concerning redundancy for certain places/users.

8.5.2 Uniform structure

A uniform structure makes the network easy to enlarge, maintain and repair. Repairs can be carried out quickly and easily because all parts having the same function are uniformly constructed.

8.5.3 Protection against damage, burglary and fire

The level of the protective measures which should be taken to counteract damage, burglary and fire shall in the first instance be defined in partnership with the insurance company which is to cover the IT infrastructure.

The different parts of the network shall be protected against damage and intrusion. Nodal spaces are established in keeping with a pre-defined level of burglary protection, but manholes, cable cabinets and conduit routes should also be protected. Cable cabinets should be fitted with lockable doors. Manholes are to be fitted with lockable covers. Conduit routes are to be chosen so as to afford maximum protection. Where conduit routes or cables pass through buildings, they should be enclosed in metal optical pipes, for the prevention of damage.

References (only available in Swedish):
Mekaniskt inbrottsskydd RUS 200:3, 1994.
Projektering och installation av Inbrottslarmanläggning RUS 130:6, October 1999.
Regler för automatisk brandlarmanläggning RUS 110:5, 1992.
The above documents are published by the Swedish Insurance Federation.

8.5.4 Redundancy

Redundancy is obtained by having several alternative collection paths between two points. Redundancy is especially important between the main nodes of the main network. When redundant connection paths are built between main nodes, it is important that the cables for the alternative paths should not be laid in the same trench, so that the node will not be knocked out, for example, in the event of the cable being severed by excavation work. Every main node shall therefore have two different cable paths into the nodal space. The same should be aimed for when the nodes of distribution and connection networks are concerned.

8.5.5 Availability

Availability means the availability of the network for transmitting communication. The system document should indicate the minimum availability which the network is to have, i.e. the maximum acceptable length of interruption.

8.6 Measurement and testing

Measurement and testing are carried out to obtain the right level of quality, so as to verify that the transmission requirements defined for a network are satisfied both by the optical cable itself and by splices and contacts.

Measurement and testing are based principally on two measuring procedures, namely OTDR measurement and stretch attenuation measurement (dB measurement). OTDR measurement provides an acknowledgement of each part of the fibre link being free from defects. Stretch attenuation measurement gives the most accurate value for the total attenuation of the fibre connection from end point to end point.

For each measurement procedure, different methods are possible. For the sake of comparability between measurements taken on different occasions, it is important that the method of measurement should be specified and documented.

A system document should indicate the values and levels which are to apply to the specific network. In this way the same requirements will be applied to different parts of the network, regardless of when it is planned or built up. This will also facilitate a theoretical calculation of the possibilities of connecting transmission equipment on a certain length of fibre.

The system document should establish:

- Limit values for attenuation and reflection in cables, splices and connectors.
- The types of instruments to be used for measurements.
- The methods of measurement to be used for the different measurements.
- The procedure for documenting and presenting the results of measurement.

8.7 Control and inspection

Control and inspection should be carried out regularly during the build-up phase by an inspector appointed by the buyer. Controls are carried out in the course of work, while inspections take place at predetermined points in time or stages of the build-up phase.

Through a combination of measurements and tests, together with controls and inspections, it is insured that the fibre network has the right level of quality. At the same time, any deficiencies will be discovered at an early stage and will thus be relatively simple to remedy.

The person who is to carry out control and inspection must have a very good knowledge and experience of cable laying and of fibre optical installation and measuring techniques.

The following shall be specified in a system document:

- What is to be checked.
- When controls and inspections are to be carried out during the development process.
- Competence requirements for a controller and inspector.

8.8 Marking

The purpose of marking is to make each individual component and part of the fibre network physically identifiable, so that future installations, operation and maintenance can be carried out rationally and safely. This calls for appropriate, co-ordinated and uniform marking with a unique identification of both nodal points and optical cable pipes, manholes and cables laid below ground.

The markings shall agree with and supplement the documentation previously compiled and should be suitable for processing in an electronic documentation program.

The system document should contain guidelines showing how the different network parts and components are to be marked on the network concerned. Marking should be carried out in direct conjunction with cable laying and installation.

The system document should establish the following:

- Nomenclature for the marking of nodal spaces, ducting, cables etc.
- Nomenclature for the marking of units in nodal spaces, such as racks, boxes, active equipment etc.
- Guidelines of marking procedure (type of marking plates etc.).

8.9 Documentation

Right from the initial phase of planning and designing an IT infrastructure, it is of the utmost importance to establish a uniform structure of documentation.

Documentation can comprise drawings and tables showing the positioning and connections with the different components. Much help can be derived from using a special computerised filing program for documenting the content of the network as regards cables, fibres, connections etc.

The following should be documented:

- Ducting and conduit routes.
- Optical cables (type of cable and number of fibres per cable).
- Cross-connection fields.
- Splices.
- Terminations.
- Nodal spaces (type, subscription).
- Fibre pairs used.

The system document should indicate the following:

- The parts of the network which are to be documented (nodal space, ducting, cables etc.).
- The way in which the different parts are to be documented.
- The software and other aids to be used.
- The procedure for presenting and storing/filing the documentation.
- Which persons are to have access to the documentation.

Reference (only available in Swedish): Registrering för interna tele- och datanät, svensk standard SS 455 12 00.

9 Planning

9.1 General

When establishing a fibre network, it is absolutely essential for it to be built up in a structured, uniform way in every part. For the achievement of uniformity, the preconditions need to be defined in the system document. These preconditions are basic input values for detailed planning.

The success of the planning and of the subsequent installation depends on careful, far-sighted timetabling. Time must be allowed for the making of decisions and for the collection of viewpoints through consultation procedures etc.

Reference (only available in Swedish): "Optokabelnät" EBR-publikation B 14.00.

9.2 Competence

The persons who are to design fibre networks should have very good experience of cable-laying below ground and in buildings and also a command of optical fibre technology.

Competence in optical fibre technology should have been obtained partly through:

- Basic studies of optical fibre technology.
- Training and experience in the handling and laying of optical fibre cable.
- Training and experience in the splicing and measurement of optical fibre cable.

9.3 Documents

The documents which should be compiled during the planning phase are:

- Conduit route drawings.
- Descriptions comprising:
  - Handling and laying of optical fibre cable.
  - Splicing and contacting of optical fibre cable.
  - Measurement and testing of optical fibre installations.
  - Registration procedure.

Parts of these documents may be included as parts of the system document referred to in Section 8.

9.4 Material and installation methods

9.4.1 General

The material with which fibre networks are built comprises everything from ducting and cables to racks and equipment in nodal spaces. Often there are several options and possible procedures for the installations to be made. The choice of specific material and method will most often depend on local conditions in the networks concerned, but it is important for networks in their entirety to be built up consistently and in a structured manner.

The following is a conspectus of certain options regarding different materials and methods for building up fibre networks.

9.4.2 Ducting

Ducting consists of optical cable pipes and manholes or alternatively of cable cabinets. When planning the amount of ducting, allowance should be made for the needs of other interests than those directly concerned with the fibre network, with a view to the benefits of common cable-laying.

In all excavation work in a municipality, optical pipes for the fibre network should be laid in accordance with the master plan presented in the program document/system document, even if the area where excavation takes place is not due for connection to the fibre network at the time of excavation.

Before deciding on excavation, other alternative procedures for the installation and laying of ducting should be investigated. These may comprise:

- Existing storm water and sewerage mains.
- Existing, disused gas mains.
- Existing heavy gauge ducting.

Manholes are used for three main purposes: for looping cable, for splicing cable, and as draw points for cable-laying. One and the same type of manhole can be used for all three purposes. In places where space in the ground is limited, cable cabinets are a possible option.

In urbanised areas with many buildings to be connected, splicing points have to be placed relatively close together, roughly 200 metres apart. In less densely built-up areas, the splicing points can be a good deal further apart.

A loop point is positioned where it is known that the stretch will be re-drawn in future. Looping some metres of cable in a suitably positioned manhole provides a certain flexibility for minor changes of the cable routing in future. One such instance is the future construction of roundabouts along a traffic artery where the exact locations of the roundabouts are not yet known.

9.4.3 Technical requirements for ducting

The optical pipes in which the optical fibre cables are laid must be of the low-friction type, i.e. have an inner surface which minimises the friction inside the pipes when optical fibre cable is laid. Pipes of a different kind can be used for very short cable distances.

The mechanical structure of the pipes can differ according to where and how they are laid. Optical pipes to be laid directly in the ground must have sufficient wall thickness and be sufficiently large for the pressure loads occurring not to harm either pipes or cable. Pipes laid inside pre-existing larger pipes (known as sub-pipes) can have thinner walls. For cable-laying in stormwater mains, it is important that the optical pipes should be able to withstand the mechanical wear which can occur, depending on water quantities, and the splices should be absolutely water tight. Pipes in sewerage mains have to withstand not only mechanical wear but also attacks from gases and any contaminants.

When ducting is laid directly in the ground, current directions and guidelines must be complied with.

Optical pipes should be marked at their end-points immediately when laid, so as to facilitate subsequent identification. When several optical pipes are laid in the same trench, it is a very great help if the pipes are also marked throughout their length with a colour code, number, letter of the alphabet or suchlike. This will simplify matters, not least if additional splicing points are added to the ducting later on.

Reference (only available in Swedish): "Kabelförläggning max 145 kV", EBR-standard KJ 41:99. This publication also covers the laying of ducting for optical fibre cable.

9.4.4 Optical fibre cable

In terms of mechanical structure, there is an immense variety of optical fibre cables to choose from:

- Slotted core cable is made up of a hard core with a slot in which optical pipes containing fibre are located. This type of cable has high mechanical strength.
- Ribbon cable consists of a hard core with a slot in which the fibre is laid in a ribbon. This cable contains many fibres and permits a rational splicing procedure.
- Loose-tube cable, in which the fibre is in pipes directly beneath the cable sheath. A cheaper alternative to the slotted core cable.
- Indoor cable, intended for indoor use with reference to fire safety requirements.
- Outdoor cable – longitudinally watertight cable for outdoor use.
- Submarine cable, intended for laying under water.

It is essential to choose the right cable for the right environment and for the intended laying method.

The fibre of optical fibre cable shall be single mode fibre (SM), intended for wave length division multiplex.

9.4.5 Laying technique

There are several different procedures for laying optical fibre cable in existing pipes. It the optical pipe is of a low-friction type, blowing of optical fibre cable is usually the most efficient method. Other methods such as winding and drawing can be used, but usually they are more expensive and have certain drawbacks (winding, for example, means that quantities of water have to be disposed of).

As a rule, every optical fibre cable has to be laid in its own optical pipe. If several cables are laid in the same optical pipe, they are very liable to suffer damage from crushing, which can cause elevated attenuation after a time. At every manhole or cable cabinet and at end points, the cable must be looped to facilitate subsequent splicing and connection work. In manholes the cable should be looped about 30 metres, at end points about 10 metres.

In connection with cable-laying it is very important that the optical fibre cables should be marked with a view to subsequent identification during splicing work.

When choosing and laying cables indoors, current standards and directions shall be complied with.

Reference (only available in Swedish): "Kabelförläggning i byggnader", svensk standard SS 424 14 38.

9.5 Planning of main networks

The main network, being the vital part of the IT infrastructure, has to meet very high security requirements. From each main node there must be redundant physical links to other main nodes in the network. "Direct link" means that the optical fibre cable must not be branched anywhere between any two main nodes. This may, however, be uneconomical when laying cable in sparsely populated areas, in which case it is essential to define which optical pipes and which slots in the cable are to be direct links between main nodes.

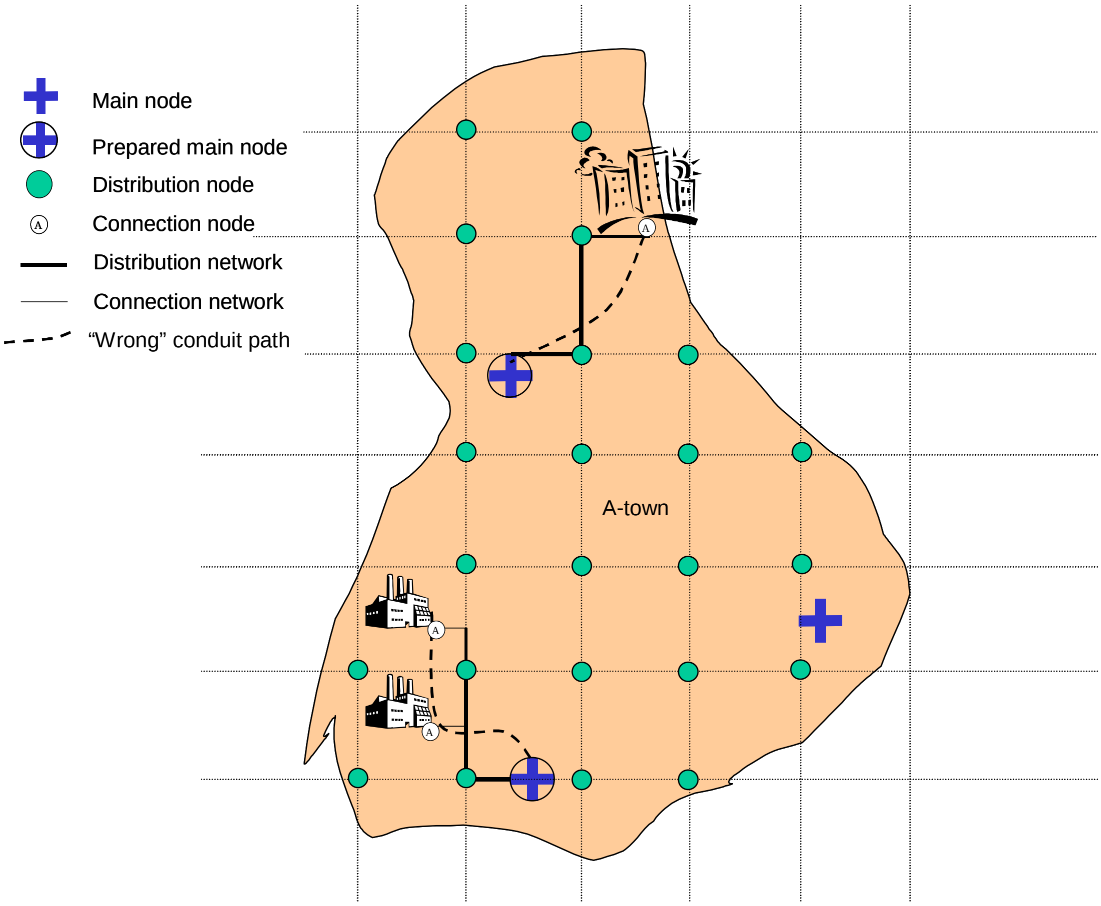
The appropriate procedure for overall planning of the main network is described in Section 7.4.7, Development plan, Main network.

9.6 Planning of distribution networks

When planning distribution networks it is important to choose conduit routes with future users and new connections in mind. New and planned housing and industrial developments should be taken into account when positioning splicing points, to avoid the necessity laying new cables to the additional areas.

It is important not to establish point-to-point connections for individual connecting points when planning for a structured network has started. The dashed line in illustration 16 indicates the simplest and shortest path for an intended connection. When a connection is to be established where ducting has to be laid, the conduit route shall be planned so as to link up with planned nodes. Even if a node is not to be established in near time, the ducting must come as close to the intended spot as possible. The grid shall be transferred to real (possible) conduit routes.

Illustration 16:
Planning of ducting and distribution nodes in a distribution network



Distribution nodes located far away from the central locality (and the main node) should be connected redundantly to the central locality in another municipality (see illustration 9, D-village).

When, for example, in a rural settlement there are long distances (more than 10 km) between main nodes and distribution nodes, it is not economical in a first stage of development to represent each connection node (through a fibre connection) in a main node. In these cases a distribution node can, as regards the structure of the fibre network, serve as a main node and as a tele-hotel for each operator's transmission equipment. This will have the effect of reducing the cost of fibre cables used in the distribution network, but the aim should be to increase the number of fibres in keeping with the operators' needs.

9.7 Planning of connection networks

The structure of the connection network will depend on the character of the area in which it is to be built (business campus, multi-family housing development, residential area etc.) and on the number of users to be connected. In the connection network it is even more necessary than in the distribution network for ducting to be planned for future connections.

The connection nodes ought if possible to be linked together in a loop to the distribution nodes. If this is not possible the amount of optical fibre cable ought possibly to be increased, to allow for future connections. In a looped connection network it is always possible to reach a node from two different directions.

For dimensioning of the connection network, 96 fibres should be laid in the loop for the connection network; under each type of area the amount of fibre is shown which should be spliced out to each connecting node. The number of fibres in a loop must be adapted to the connections which will have to be made along a loop. With 96 fibres in a cable, the number and types of areas along this connecting loop should be adapted to this number of fibres.

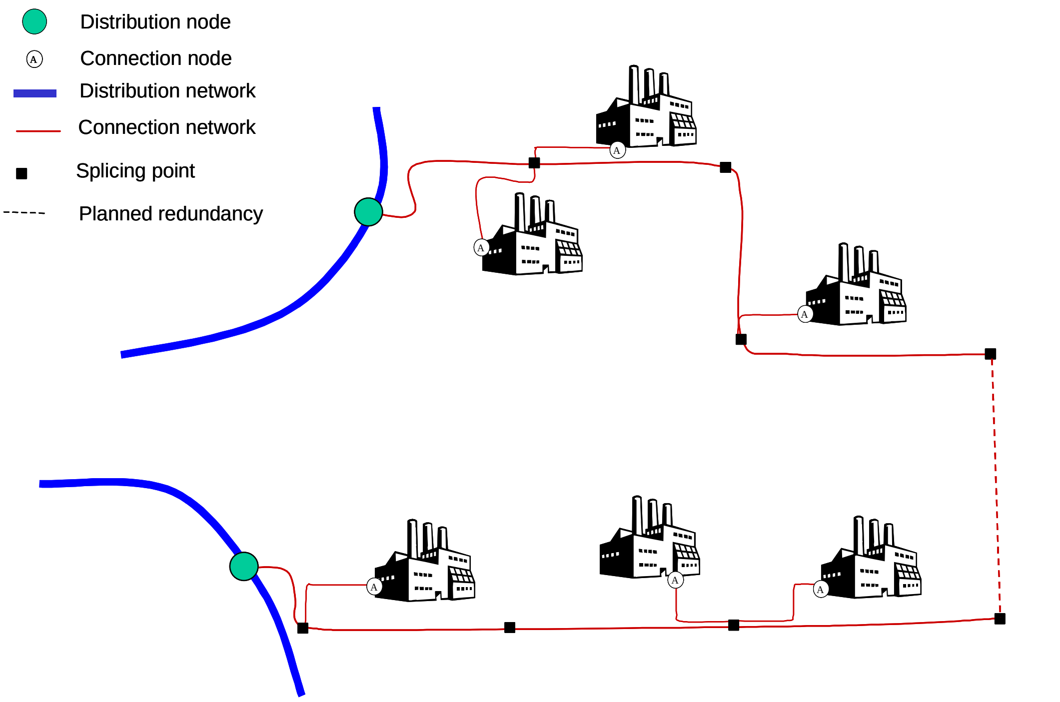
For the types of area described in the following sections, it is proposed that at least eight fibres be connected to each connection node. This number is based on an initial possibility for connecting four operators.

9.7.1 Business campuses

The connection network within a business campus[21] should be built with redundancy as far out towards the user as possible. The connection node is normally placed within a building.

From a connection node on the premises of a business enterprise or some other organisation with considerable communication needs, two different connection paths should always be established at two separate distribution nodes. The splicing point is the splice box or equivalent where the optical fibre branches out to each building.

Illustration 17:
Connection network for a business campus. Also applies to the connection of other organisations such as public authorities, hospitals, health centres and schools



[21] This also applies to the connection of other organisations, such as public authorities, hospitals, health centres and schools.

At least eight fibres should be laid per connection node. In each individual case, adjustments have to be made to local conditions.

The following factors may, for example, increase the need for fibre:

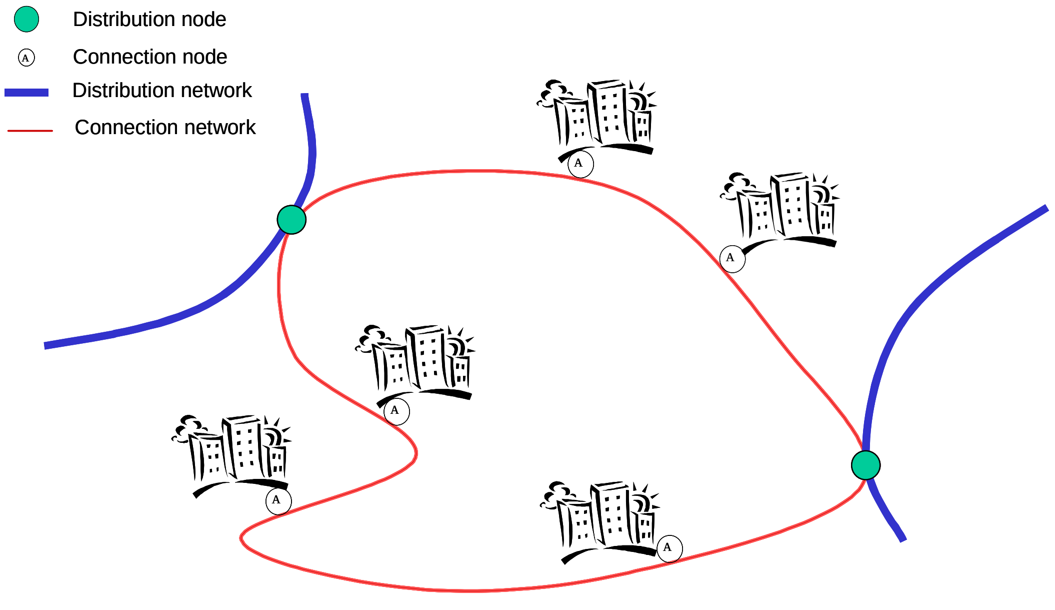
- Type of organisation, possible need of dark fibre for other organisational units within the locality.
- Number of business undertakings and other organisations within the building (e.g. an advance factory, where each company may need an exclusive connection).

9.7.2 Apartment blocks

In multi-family housing areas, the connection node is placed in each building or, in larger areas, in the building where the generic cabling system's area node is positioned. In these areas it is most often possible to take the connection network into the building, in which case splice points are not needed. Splice points may of course come to be considered in these areas as well. The connection network must if possible connect up with two distribution nodes.

For apartment buildings, there should be at least eight fibres per connection node.

Illustration 18: *Connection network for a multi-family housing development*



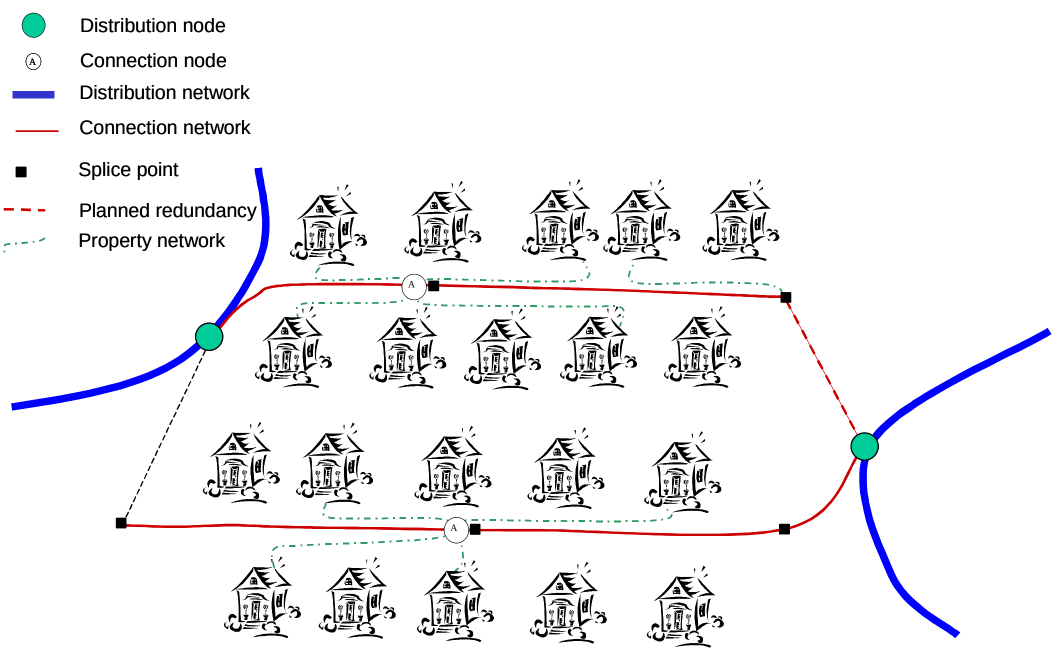
9.7.3 Residential areas

At suitable points in residential areas, connection nodes are positioned to which something like 75-100 houses are connected. The connection node is connected if possible to two different distribution nodes. Point-to-point links are established between the connection node and each individual building. Obtaining full redundancy all the way out to every user in a residential area is at present very expensive.

An approximate norm for residential areas are as follows:

- 75-100 houses per connection node.
- 8 fibres per connection node for single-family dwellings.

Illustration 19: *Connection network for a residential area*



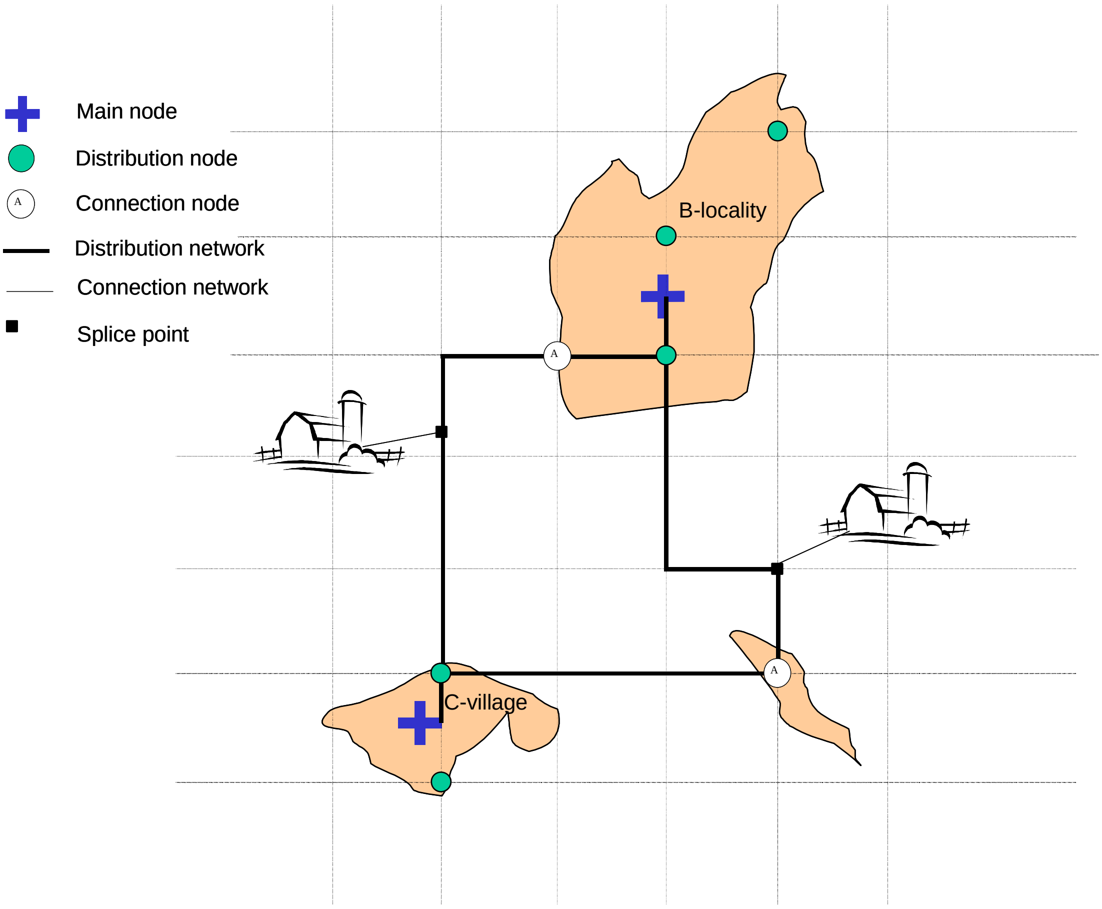
9.7.4 Rural areas

Illustration 20 shows the possibility of connecting individual properties in rural areas when a main network or distribution network is constructed between nodes. In order for this to be economically interesting, prospective connection points have to be taken into account when planning ducting and cable-laying in sparsely populated areas. In preparation for further connections, cable can be looped in the ground or at splice points.

Connection of properties in sparsely populated areas has to be adapted to:

- Geographic location.
- Distance from distribution node.

Illustration 20: *Connection of individual properties in sparsely populated areas*



Course of development for the IT infrastructure

The following is a general conspectus of the stages described in earlier sections.

Combination of program documents:
- Visions
- Interest groups
- Strategies
- Economics

↓

Decision:
- Boundaries of responsibility
- Leasing of ducting and/or fibre
- Investment

↓

Information to:
- Municipal agencies
- Businesses and residents
- County Council and County Administrative Board
- Operators
- Landowners, neighbouring municipalities

↓

Compilation of system document:
- Nodal space standard
- Extent of ducting and fibre network
- Security level
- Positioning of nodes
- Conduit routes

↓

Decision:
- Contracting of planners
- Procurement of material and contractors
- Timetable, priorities

↓

Implementation:
- Start of project
- Planning
- Cable-laying and installation
- Control

Glossary of terms

active equipment	For present purposes, active equipment comprises the operators' communication equipment, servers etc.
AMA	Allmänna Material och Arbetsbeskrivningar, published by Svensk Byggtjänst.
asymmetric communication	This means that transmission capacity is higher to than from the user.
bandwidth	For digital information transmission, bandwidth, i.e. transmission capacity, is given in bits per second, bps. Band width corresponds to the quantity of information transmitted per unit of time.
bit	Binary digit, either 0 or 1.
bps	Bit per second. Unit of measurement for data transmission.
broadband	This term can have a variety of meanings. In the present guide it means 5 Mbps and over.
communication architecture	A communication architecture includes, for example, protocols for different applications, transport of data and monitoring, globally unique network addresses, support systems for translation between logical and physical network addresses. The Internet uses the IP architecture.
dark fibre	Dark fibre is optical fibre without communication equipment, i.e. the network proprietor gives both ends of connection in the form of a fibre connection to the operator, without any intermediary equipment.
ducting	Laying of optical fibre pipes and manholes in which fibre optical cables are to be laid.
EBR	The Swedish Association of Electricity Suppliers.
e-mail	Electronic mail. Transmission of messages with the aid of computers, in such a way that a message can be read at any time.
GSM	Global System for Mobile Communications
Internet	Global network of computers using IP as its communication protocol.
Internet operator	An operator providing an Internet service to users.
IP	Internet Protocol, communication protocol used for addressing and routing data packets on the Internet and on other IP-based networks.
IP architecture	See communication architecture.
ISP	Internet service provider.
kbps	Kilobits per second: 1,000 bps.
km	Kilometers:1,000 m.
LMDS	Local Multipoint Distribution Service, microwave-based radio system for fast access.
logical network	A logical network is defined by the communication paths between nodes. The operator creates (configures) the logical network in the active equipment.

Mbps	Megabit per second: 1,000,000 bps.
network topology	The geometric appearance, form and location of a network's cables (conduit route) and nodes.
node	A point of interconnection in a communication network.
operator	An Internet service provider (ISP) or other actor building active networks with the aid of fibre networks. One example of another actor is a company or a public authority wishing to build the active network for communication between different units.
OTDR	Optical Time Domain Reflectometer.
physical network	The actual positioning of ducting and fibre optical cable.
protocol	A set of rules governing the interaction of one computer program with other programs, often located in another computer.
redundancy	Redundancy here means the existence of alternative connections.
router	A computer which selects a path for and forwards data packets in an IP network.
server	Computer program which provides common service functions in a computer network, e.g. data storage and e-mail communication. A server is a computer with one or more server programs.
SOU	Swedish Government official reports.
STUPI	Svensk Teleutveckling & Produktionnovation AB.
SUNET	The Swedish university data network
Svenska KraftKom	A fully-owned subsidiary of Svenska Kraftnät.
Svenska Kraftnät	Owns and operates the Swedish national electricity grid.
symmetric communication	This means that transmission capacity is the same both to and from the user.
tele-hotel	A tele-hotel is a common space where operators can place their active equipment (communication equipment, servers etc.).
topology	Geographic design.
UMTS	Universal Mobile Telecommunications System, the third-generation system of mobile communication.
UPS	Uninterruptible Power Supply.
wave length multiplex	A technique for simultaneously transmitting several signals through an optical fibre.
web	World Wide Web, a function on the Internet or on an intranet whereby interlink information can be easily collected in the form of text, image and sound.

References (only available in Swedish)

AMA (Allmänna Material och Arbetsbeskrivningar), published by Svensk Byggtjänst.

Bredband för tillväxt i hela landet, SOU 1999:85, betänkande från IT-infrastrukturutredningen (kommittédirektiv 1998:07, Kommunikationsdepartementet).

Fastighetsnät för informationsöverföring – Generella kabelnät, svensk standard SS-EN 50 173.

Framtidssäker IT-infrastruktur för Sverige, SOU 1999:134, delbetänkande från IT-kommissionen.

Infrastrukturprogram för bredbandskommunikation, delbetänkande från bredbandsutredningen, 2000-04-03 (kommittédirektiv 2000:04, Näringsdepartementet).

Kabelförläggning i byggnader, svensk standard SS 424 14 38.

Mekaniskt inbrottsskydd RUS 200:3, 1994, published by Försäkringsförbundet (the Swedish Insurance Federation).

Optokabelnät, EBR-publikationen B 14.00.

Projektering och installation av Inbrottslarmanläggning, RUS 130:6, oktober 1999, published by Försäkringsförbundet (the Swedish Insurance Federation).

Registrering för interna tele- och datanät, svensk standard SS 455 12 00.

Regler för automatisk brandlarmanläggning, RUS 110:5, 1992, published by Försäkringsförbundet (the Swedish Insurance Federation).