MSc Program
Engineering Management

A study on comprehensive fiber-optic expansion in rural areas

A Master's Thesis submitted for the degree of
“Master of Science”

supervised by
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Affidavit

I, **MATTHIAS KRENMAIR, BSC (WU)**, hereby declare

1. that I am the sole author of the present Master's Thesis, "A STUDY ON COMPREHENSIVE FIBER-OPTIC EXPANSION IN RURAL AREAS", 65 pages, bound, and that I have not used any source or tool other than those referenced or any other illicit aid or tool, and
2. that I have not prior to this date submitted the topic of this Master's Thesis or parts of it in any form for assessment as an examination paper, either in Austria or abroad.

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Abstract

Information and communication technologies are an important driver of economic growth. It is in the interest of the European Union and national decision-makers to form a knowledge and information society. With the aim of creating a holistic European information society, actions must be taken against the "digital gap", the gap between urban and rural areas in particular.
In order to master the fundamental technological changes, forward-looking political actions are required. It calls for political convergence and a willingness to adapt to the regulatory environment so that it is feasible to meet the changing needs of the digital economy.
The main purpose of this thesis is to support municipalities, planning offices and companies that build empty pipework in their actions to form a suitable information society. Since there are a variety of empty pipe systems and components on the market, the choices are not easy. This paper identifies the most commonly used solutions with an additional goal to achieve a certain degree of standardization, in order to facilitate cooperation between infrastructure owners and network operators.
The structure of this paper follows, in addition to the legal and political aspects, its attempts to cover the actual status of the broadband supply on a worldwide and European level, contains clarification of important technology standards in this industry, leads to the most commonly used solutions of the various installation methods in the trench and trenchless sector in order to ensure an efficient and cost-effective installation in rural areas.
At the end of this paper, a profound planning guideline was drawn up, with the aim to support already existing and potential infrastructure architects. This planning guideline has the potential to prevent the people responsible from numerous planning errors, which will result in a decrease of the overall project costs and thereby increase the chances of future project realizations even in less populated areas.

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1 Introduction

Broadband data networks are the infrastructure of the information society. They enable, facilitate and speed up countless economic, social and cultural processes. Access to modern, internet-based forms of communication is becoming increasingly important for participation in social, cultural and political life. At the same time, powerful data networks are an indispensable location factor for our companies.

Broadband coverage is playing a progressively important role, especially in rural areas. If telecommunications companies do not promote broadband expansion in rural areas due to a lack of economic attractiveness, and in the medium term no operator subsidies are foreseeable, alternative solutions are needed.

It should be examined whether other investors should invest in a passive network infrastructure in order to maintain and improve the attractiveness of the location. This infrastructure can then be leased to an operator who provides the necessary quality of service. In order to exploit synergies, such decisions are often linked to other civil engineering projects.

1.1 Problem formulation and goals

This master's thesis is a planning guide that should be of particular help to municipalities, planning offices and companies that build empty pipework. Since there are a variety of empty pipe systems and components on the market, the choice is not easy. This paper’s aim is to identify the most commonly used solutions. The goal is also to achieve a certain degree of standardization, in order to facilitate cooperation between infrastructure owners and network operators.

This document attempts to cover all aspects from planning to the construction of passive fiber access networks. It starts with the actual status of the broadband supply and will continue right up to the holistic and sustainable planning of a glass fiber infrastructure.

1.2 Research question

In the course of this thesis the following questions will be answered:

Research question:	How can a comprehensive fiber-optic expansion with a focus on rural areas be realized cost effectively and swiftly in Austria?

Subquestion 1: What are the essential cost components of this infrastructure?

Subquestion 2: Is a sophisticated network planning capable of reducing investment costs and operational costs until rural areas become an acceptable investment?

1.3 Scientific method

In addition to traditional literary research, analysis of various studies on European Union communications, on European as well as national legislations and my professional experience, this document has been used to assist in fiber-optic expansion.

2 Actual status of the broadband sector

This chapter addresses the actual state of the broadband sector on a national, European and global basis. Furthermore, it illustrates especially the Austrian position in this sector, as well as its importance with regard to future requirements.

2.1 Broadband supply as a challenge

The telecommunications market is a regulated competitive market. Established providers are building networks, especially in areas with higher customer density, where it pays off. Due to the high demand there is therefore more than one provider in metropolitan areas. This is where the market works and with it the competition.
In rural areas, on the other hand, investments are often made only if they are supported by public funds. Thus, the broadband supply in the countryside becomes a challenge. To tackle this task, new concepts are needed. The need for it is particularly urgent when:

- an undersupply is emerging or already prevails
- complaints from private users or companies are present
- when new businesses want to settle and need ultra-speed internet
- new commercial or residential areas are to be developed
- telecommunications companies are willing to invest only with public assistance
- civil engineering projects are pending (for example, residential water engineering, district heating, gas supply, road rehabilitation)
- there are insufficient regional links, i.e. backhaul lines or too long links, between districts

2.2 Competition of access technologies

In the access network, i.e. in the last mile to the subscriber, several technologies currently compete in the transmission medium (copper double wire, coaxial cable, optical-fiber, radio). Each technology has specific characteristics and a separate distribution.
Of course, providers try to use the infrastructure that they have for economic reasons as long as possible and then gradually to go in the direction of glass fiber by moving closer and closer to the customer with the glass fiber.
In peripheral and scattered settlement areas, the copper technologies will continue to be used for a transitional period and supplemented with fiber-optic cables to the local centers, in order to be able to offer a temporary solution for fast broadband (FTTC).

Mobile communications have also evolved. The 4th generation "LTE" and "LTE-Advanced" radio technology is increasingly being used in rural areas as well. This can definitely bring about a noticeable improvement in underserved areas. While mobile internet is not a substitute for landline internet for users with increased bandwidth needs, it can be an important addition and bridging in rural areas.

Currently, there are high expectations in the future mobile generation 5G. This technology is expected to provide a significant increase in performance over the 4th generation. 5G mobile stations need a fiber-optic network for connection. Thus, the construction of a fiber-optic infrastructure is not a contradiction to 5G, but 5G is the complement of fiber-optic networks.

In rural areas, the 700 or 800 MHz frequency range is expected to be used to reach economically wider ranges. Data rates of 1 to 3 times are expected for LTE-Advanced.

	Old Technology	Bridging Technology	Future Technoloy
Fixed Network	ADSL2+ VDSL2 DOCSIS 1.0 DOCSIS 2.0	VDSL-Vectoring VPlus DOCSIS 3.0 DOCSIS 3.1	Fiber-optics
Mobile Internet	GSM UMTS HSDPA HSPA+	LTE LTE-A WLAN WiMax	5G

Table 1: Technology overview

2.3 The future in the fixed network is called fiber-optics

In the long term, fiber-optic technology in the fixed network has the best future prospects. It has unrestricted bandwidth reserves and will eventually lead to the customer. The usual telephone cable as a transmission medium of data will become less important in the medium term. However, the coax cable of cable operators will have its part over the next few years until they will be fully replaced by fiber-optic cables.

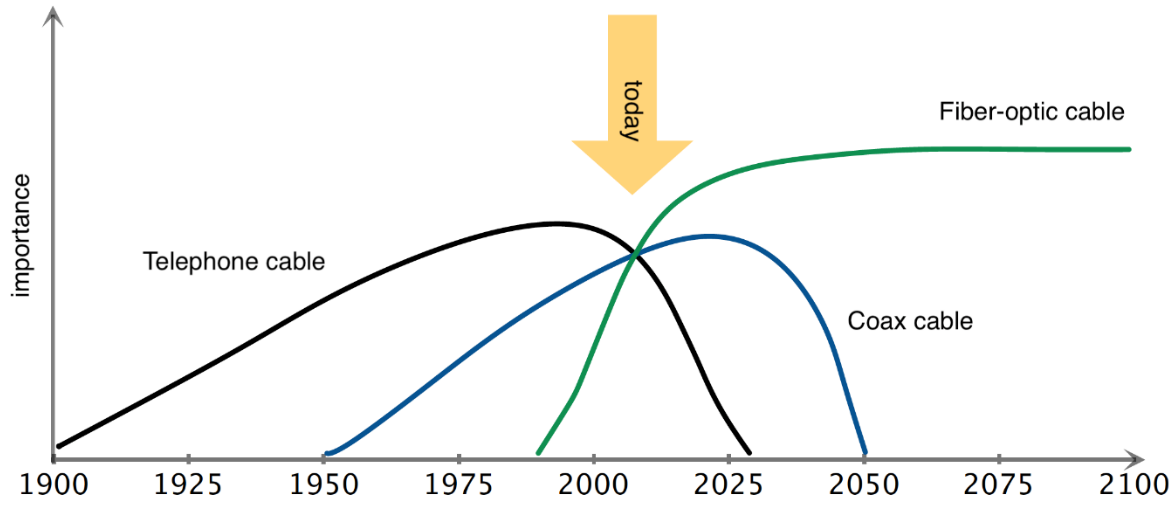

Figure 1: Temporal development of access technologies in the fixed network (Bmvit, 2018)

The main obstacle of nationwide fiber-optic expansion are enormous civil engineering costs. The ultimate goal of all considerations must therefore be to plan the expansion so skillfully and cost-effectively, that in the long-term economic operation is possible.
This master's thesis focuses on the planning and construction of fiber-optic networks right up to the home (FTTH - "Fiber to the Home") or to the house (FTTB - "Fiber to the Building").

2.4 Internet access on a FTTH/B basis - International and European comparison

This chapter aims to give a brief insight into the current situation of the European and international FTTH/B internet access availability and thus have the possibility to update it´s down- and up- load capacity, in order to meet current and future demands. Furthermore, it will be shown which countries are currently leaders in this area and which are on the lowest end e.g. Austria.

2.4.1 FTTH/B internet access of the EU countries

The Digital Agenda for Europe set a target that by 2020 at least 50 % of European homes should subscribe to ultrafast broadband of at least 100 Mbit/s. A precondition to achieving this target is the wide availability of ultra-speed broadband networks. Currently, only FTTH/B cable networks are capable of delivering this standard.

Looking at the Member States, the top three countries are Latvia, Lithuania, and Spain. At the bottom of the list are Austria and the United Kingdom, which are in total more than 45 % behind of the leaders.

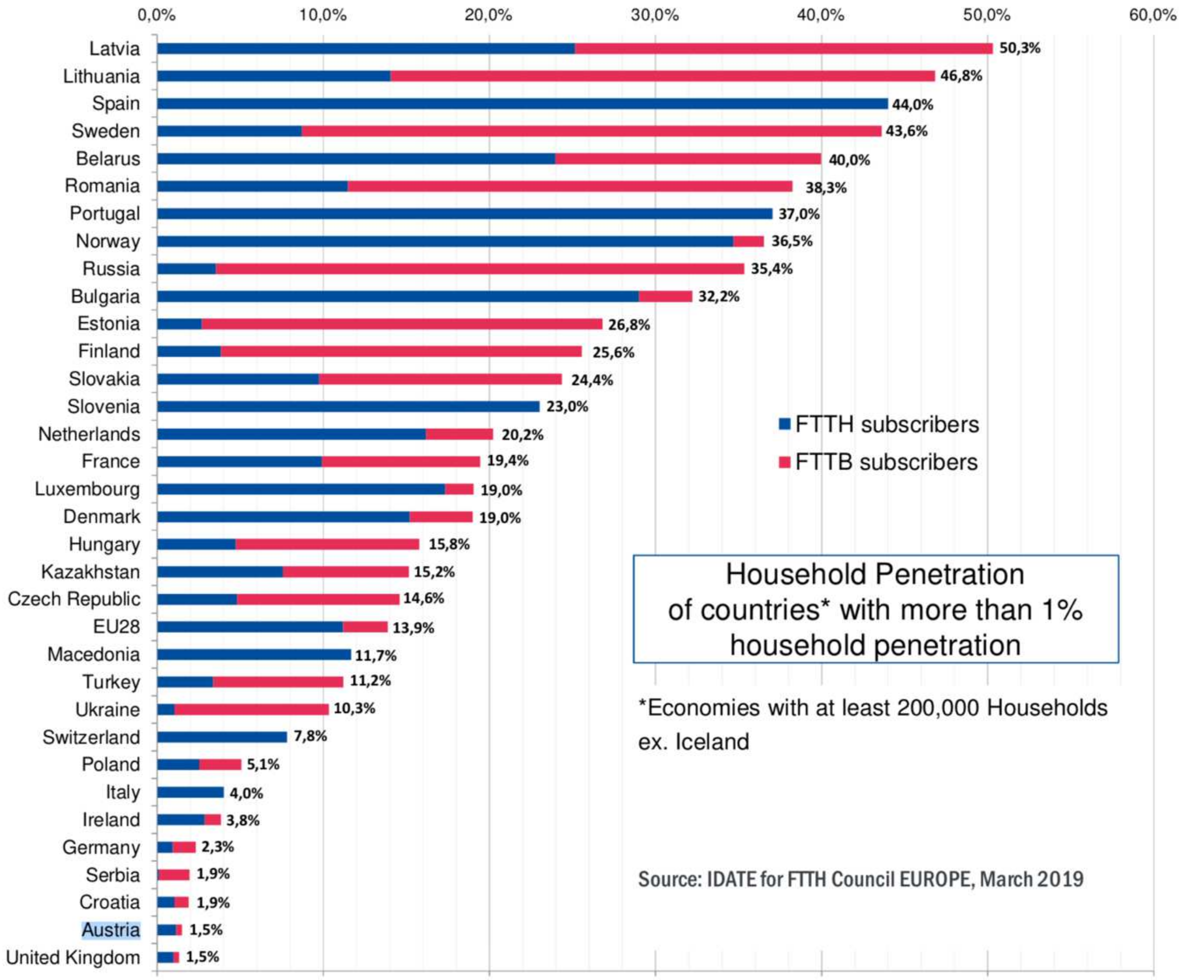

Figure 2: FTTH/B internet access of the EU countries (FTTH Council Europe, 2019)

2.4.2 FTTH/B internet access globally

Fiber-to-the-home or fiber-to-the-building connections account for only 13.9 % of all broadband connections in the EU, while in UAE, Qatar and Singapore, fiber access accounts for more than 92 %. In the United States, 12 % of all broadband connections are FTTH/B connections.

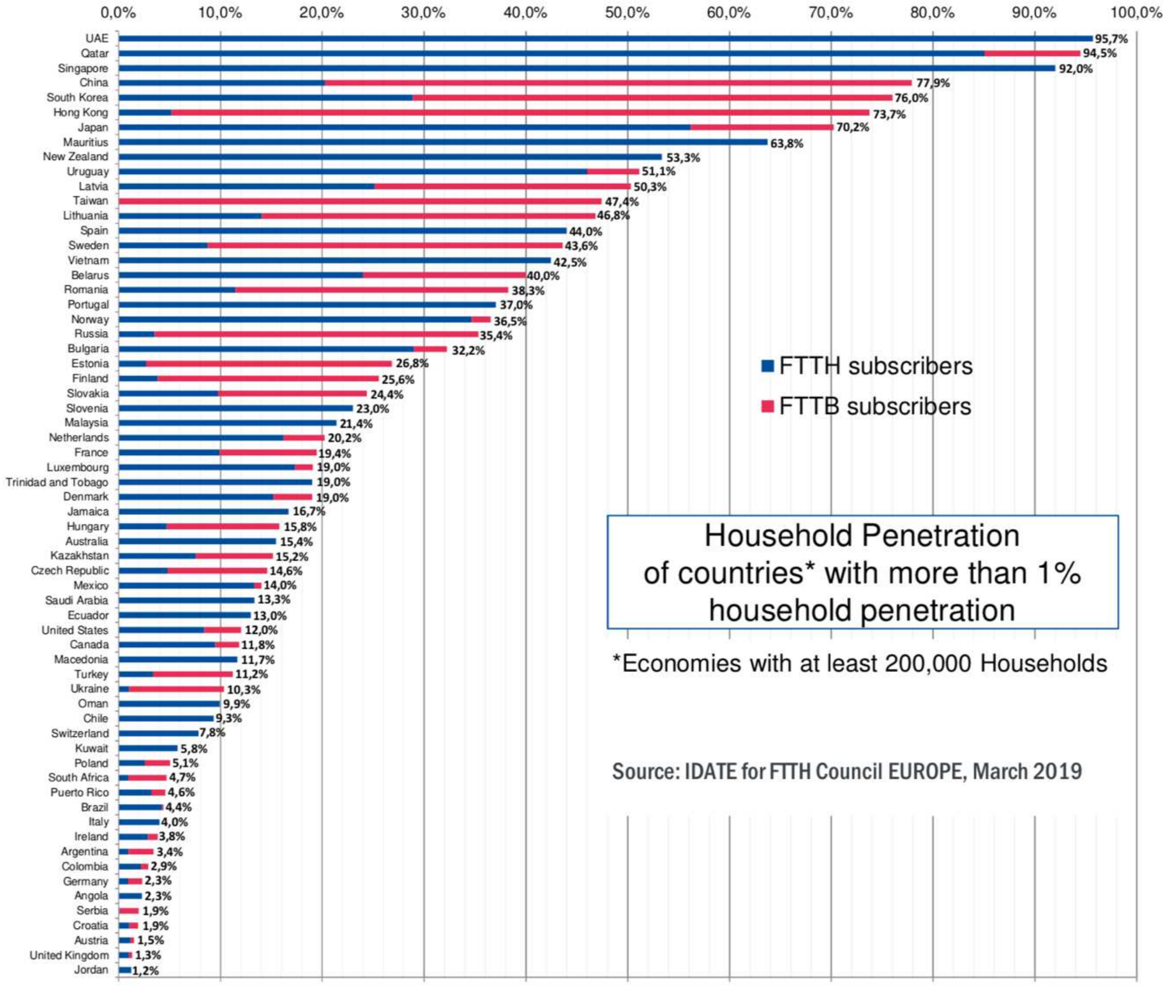

Figure 3: FTTH/B internet access globally (FTTH Council Europe, 2019)

2.5 FTTH/B internet access in Austria

Austria is at the bottom of the European comparison when it comes to the availability of fiber-optic connections. In no other European country, there are so few fiber-optic connections to buildings (FTTB) and to individual households (FTTH) relatively as in this country.

By comparison, the country with the strongest fiberglass expansion is Latvia, which boasts a connection rate of 50.3 %. So, there are over half of all internet lines already fiber-optic connections. In Austria, on the other hand, it is only 1.5 %. This means that not even two out of 100 citizens in such a developed country are able to surf and download at the speed of light. Industry experts cite several possible reasons for this. Above all, costs are an important factor. So far, the fiberglass expansion in Austria is hardly promoted at the municipal basis, which represents a major shortcoming. Municipalities should become more involved in this area and offer cooperation and funding. In the near future it will not be possible for an industrialized nation like Austria to stay at its global ranking, if such key infrastructural elements are missing. In the mobile sector, the next upgrade is just around the corner - the 5G technology. This means that the mobile network will be even faster and more powerful. The internet use over

the mobile phone is thereby again improved by a massive jump. 5G can only work smoothly if the base stations are attached to the fiber-optic network.
If Austria wants to keep up with world economic and information technology in the long run, it will not be possible to get around a reasonable fiber-optic network.

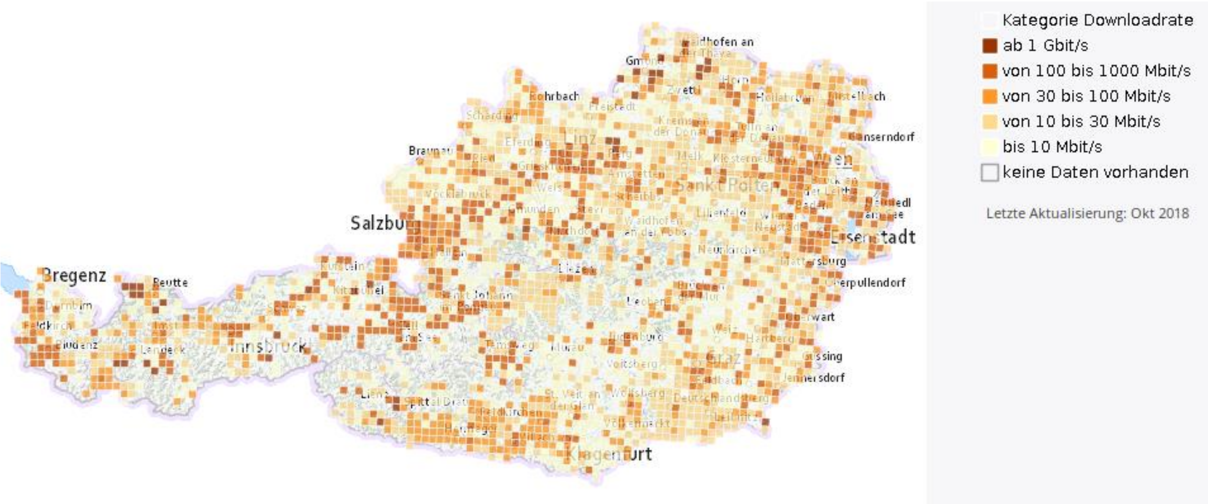

Figure 4: Maximum download rate of Austrian households (Bmvit Breitandatlas, 2019)

2.6 Broadband in the future

Internet traffic has been steadily increasing in the last 20 years. The amount of data to be transmitted is generally getting bigger and the macroeconomic digital traffic is constantly growing, which means that the data transmission quality has to grow proportionately. This is also being pursued by well-known companies that calculate fixed-line data volume growth of 30 % to 40 % per year.

3 Network structures and their cooperation models

3.1 Network structures

In principle, telecommunications networks can be divided into three sub-areas: the Access Network (AN), the Backhaul Network (BN) and the Core Network (CN).

In the AN the connection of the individual participants takes place by means of wired technologies or over radio. In both cases, concentrators are used within the access network in order to be able to realize an inexpensive connection to a CN with already concentrated traffic (adapted from Bmvit, 2018).

If the term access network is used here, this refers to the network section between a local center and the house introduction of the subscriber.

The following figure shows an access network in a rural village with a connection to a core network. It can be seen from this practical example that a backhaul can often be very long and therefore causes high costs.

Furthermore, it can be seen that in this case an interruption of the backhaul leads to a failure of the access network, since there is no second connection.

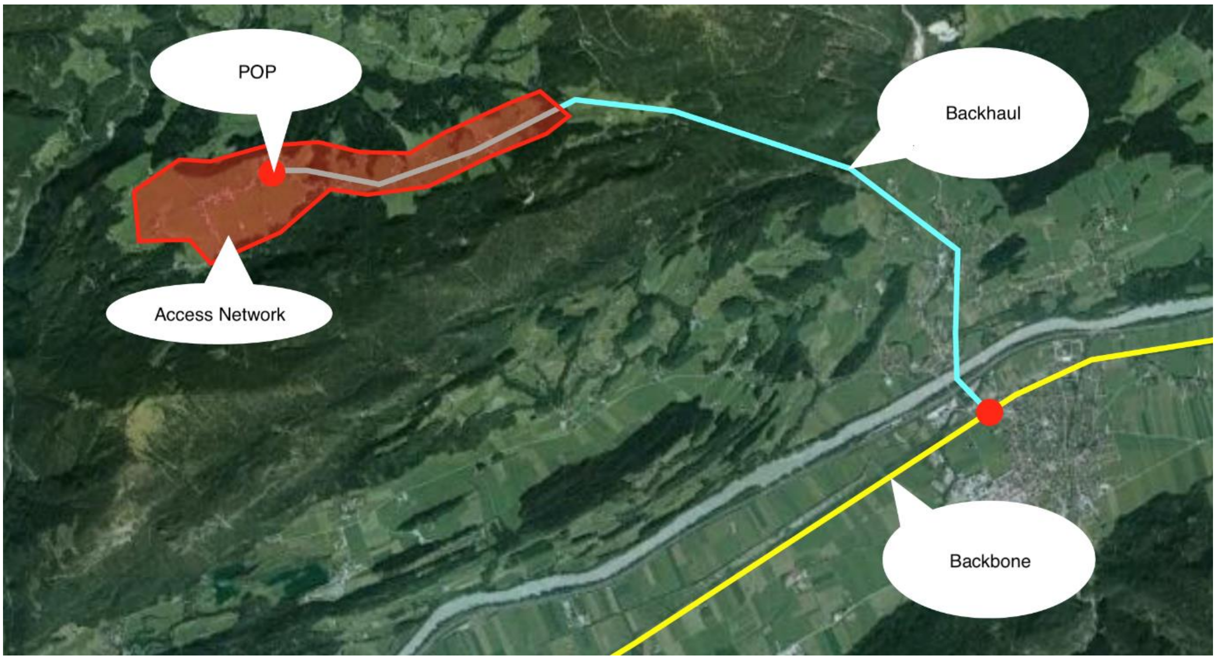

Figure 5: Access network with connection to the core network (adapted from Bmvit, 2018)

In the local area itself, in a rural setting, the planning of an access network looks like the following figure.

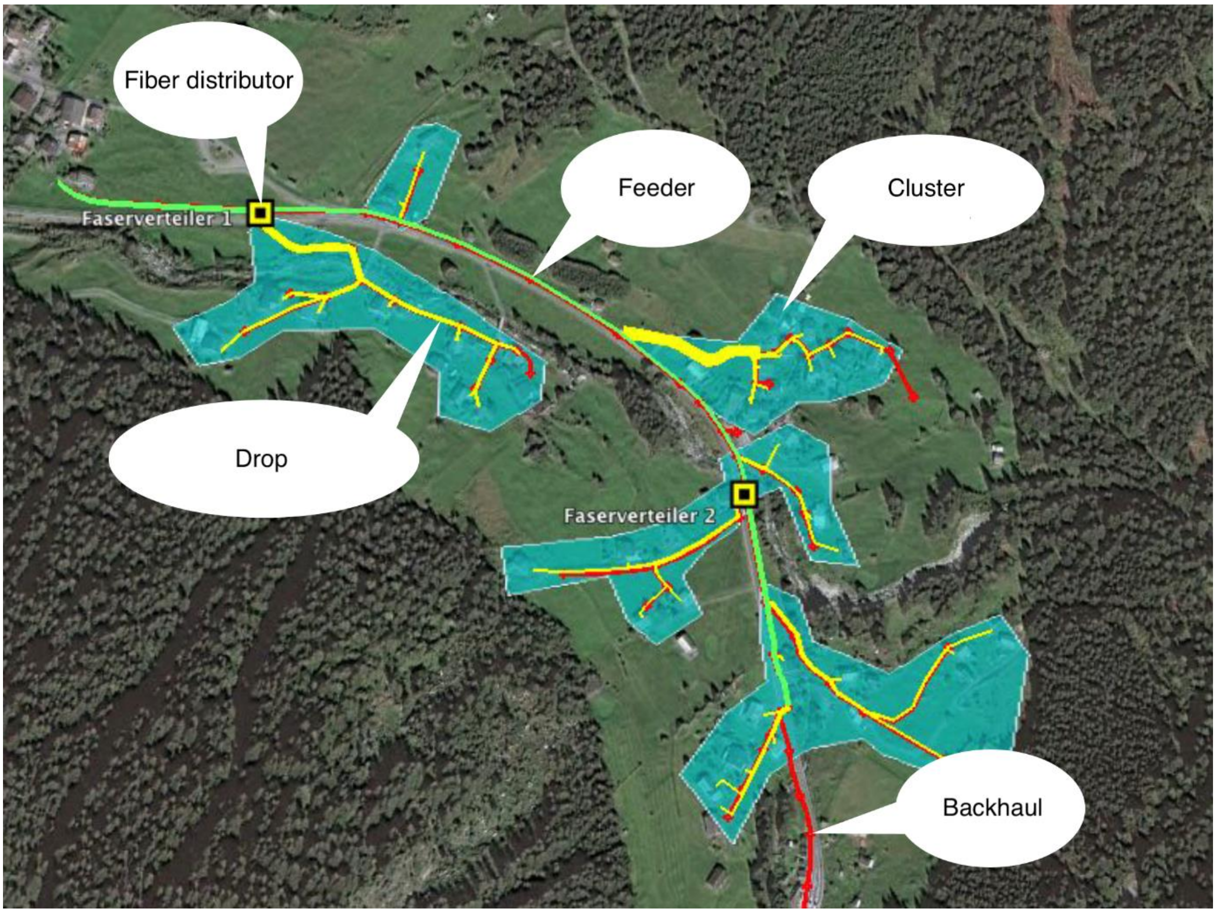

Figure 6: Example of a network planning in the local area (adapted from Bmvit, 2018)

First, it must be considered which extent the network should have. Then supply cells (clusters) of buildings are formed, which are connected via microtubes with a fiber distributor. The maximum cluster size must be specified in advance (typically 32, 48, 72 or 94 buildings per fiber distributor). It is also important that the permissible blowing-in lengths for the optical fiber entry cable are not exceeded (typically 300 to 500 m) (adapted from Bmvit, 2018).

3.1.1 Construction of optical access networks

In order to provide a better understanding of the individual components of an optical access network (OAN), the structure is shown schematically below. The cluster areas drawn in the previous example can be seen here as a hexagonal honeycomb structure.
In detail, an OAN consists of the following elements:

- Point of Presence (POP) or Central Office (CO)
- fiber-optic feeder
- fiber distribution
- fiber-optic drop
- house infeed

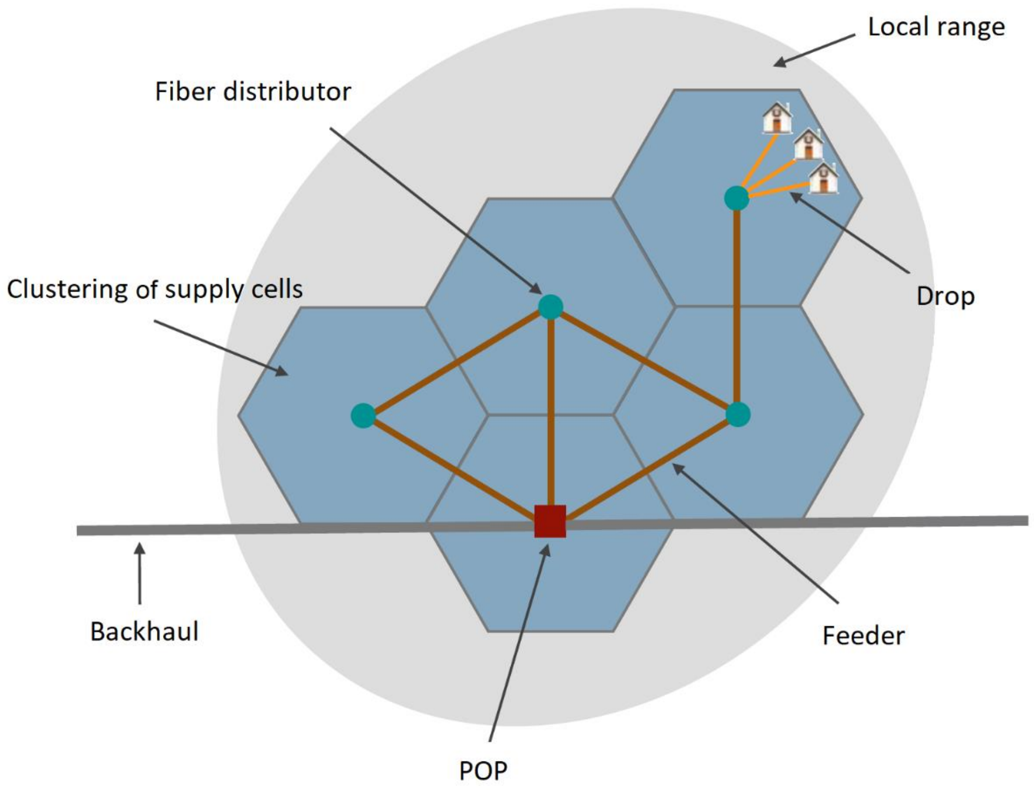

Figure 7: Construction of an optical access network (adapted from Bmvit, 2018)

A POP is the concentrator for a local access network. Here you will find active network components and fiber management. The point of presence must be equipped with appropriate protection measures similar to a server room. From the POP, the feeder leads to the fiber distributors. Fiber distributors are passive points of concentration from which the fiber-optic drops lead to the customer's building. In projects in Austria and Switzerland fiber-optic cables with four fibers per customer are used in this section. These cables are blown into microducts. From the fiber distributor to the sidewalk, they are being summarized as pipe bundles. A single microtube is used from the property boundary to the house connection. The fiber-optic network itself is purely passive and contains no active components. Active network components are only available at the POP and at the customer. As a result, optical access networks have very high technical availability and low maintenance costs. As shown in the figure above, with this honeycomb structure a meshing is possible, which leads to an even higher reliability (adapted from Bmvit, 2018).

3.1.2 Reference model of an optical access network

The following figure shows the technical reference model of an optical access network in a more abstract form.

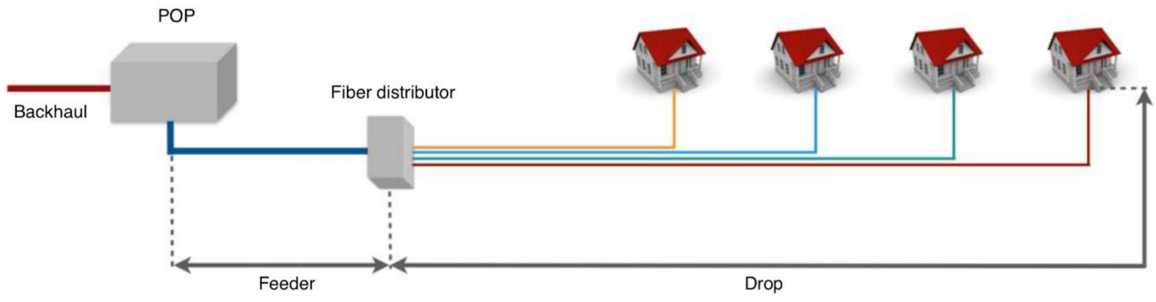

Figure 8: Reference model of an optical access network

3.2 Cooperation models

With a cooperation model, one or more network operators and service providers can use the network infrastructure in cooperation with the infrastructure owner. There are different solutions for cooperation opportunities and vertical integration.
There are mainly three different layers in the model:

- the passive network: tracks, conduits, fiber-optic cables, fiber distributors, rooms, cabinets
- the active equipment: active network components such as routers and switches, including electro-optical converters
- the services: internet, telephony, television, video on demand, games, videoconferencing, databases etc.

These three layers also have different investment cycles (25 to 30 years for the passive network and 5 to 7 years for the active network, 3 years for services).
The following table shows the different cooperation models in an optical access network.

<table>
<tr><th></th><th colspan="2">Vertically Integrated</th><th colspan="2">Passive Sharing</th><th colspan="2">Active Sharing</th><th colspan="2">Full Separation</th></tr>
<tr><td>Service</td><td rowspan="3">Full-service provider</td><td rowspan="3">Full-service provider</td><td rowspan="2">Provider and Operator combined</td><td rowspan="2">Provider and Operator combined</td><td>Provider</td><td>Provider</td><td>Provider</td><td>Provider</td></tr>
<tr><td>Active Equipment</td><td colspan="2" rowspan="2">Operator and Infrastructure owner combined</td><td colspan="2">Operator</td></tr>
<tr><td>Passive Network</td><td colspan="2">Infrastructure owner</td><td colspan="2">Infrastructure owner</td></tr>
</table>

Table 2: Possible cooperation models

Vertically Integrated

With the vertically integrated model, a telecommunications provider as a full-service provider delivers its products via its own network infrastructure to the end customer. Marketing, sales and after-sales tasks are also part of the company's range of services (adapted from Bmvit, 2018).

Passive Sharing

An infrastructure owner (e.g., municipal, municipal utility) leases its passive infrastructure to multiple network operators and service providers (adapted from Bmvit, 2018).

Active Sharing

In this operator model, a company maintains the passive and active network and offers open access to various service providers. This model can often be found in municipal utilities (adapted from Bmvit, 2018).

Full Separation

This model can be found more and more often in larger networks. An infrastructure owner (e.g., a utility) attributes the operation of the network as a service concession for a longer period of time. Several service providers deliver the requested services to the network and the end customer (adapted from Bmvit, 2018).

Cooperation models in Austria

There are several examples in Austria where the passive sharing model is practiced. The municipal has built a network. The operation and the supply of services is provided by a network operator, who is also a service provider. The collaboration is based on revenue sharing (for example 1/3 passive infrastructure, 1/3 network operation, 1/3 internet and TV).

In other networks utilities are infrastructure owners and network operators combined and offer the cooperation model active sharing.

In Lower Austria, the Niederösterreichische Glasfaserinfrastrukturgesellschaft (nöGIG) implements the full separation model, in which a "neutral" operator is advertised on a regional basis and starts operations (adapted from Bmvit, 2018).

Open Access

Open access includes business models that enable non-discriminatory network access for third parties based on broadband infrastructure. Infrastructures that are supported by public funds are subject to open access.

The challenge is to make open access business models equally attractive to suppliers and buyers. An integral part of attractive open access business models is therefore non-discriminatory access, which allows providers and customers a fair scope of action. The prerequisite is equal access for requesting companies without privileges for individual market participants. Criteria for non-discriminatory access for third parties are an appropriate, market-driven price, as well as the timely provision of wholesale products, which must comply with the regulatory requirements in technical and economic terms (adapted from Bmvit, 2018).

This network access can be granted at different points:

- in the passive network (Layer 0 and Layer 1)
    - empty pipe, dark fiber at the fiber distributor or POP
    - several operators can rent fibers or conduits
    - the investment risk lies with the infrastructure owner

- in the active network (Layer 2)
    - layer 2 - access to the POP
    - several buyers can use a fiber-optic
    - higher technical complexity in the interconnection

- in the active network (Layer 3)
  - central activation of the services
  - low entry barrier for service providers
  - lower added value for the customer

The interconnection in the active network is also called "bitstream access" (layer 3) or "virtual unbundling" (layer 2), in contrast to "physical unbundling" in the passive network.

4 Technologies and standards

This chapter briefly explains the various elements of an optical access network, the fiber architecture, traditional wireline transmission techniques and various mobile transmission methods for broadband implementation. In particular, the technologies and standards which are discussed are most common in the Austrian area, and according to the author, are essential for the further understanding of this master´s thesis.

4.1 Elements of an optical access network

In the following, the most important elements of an optical access network are explained and visualized in pictures.

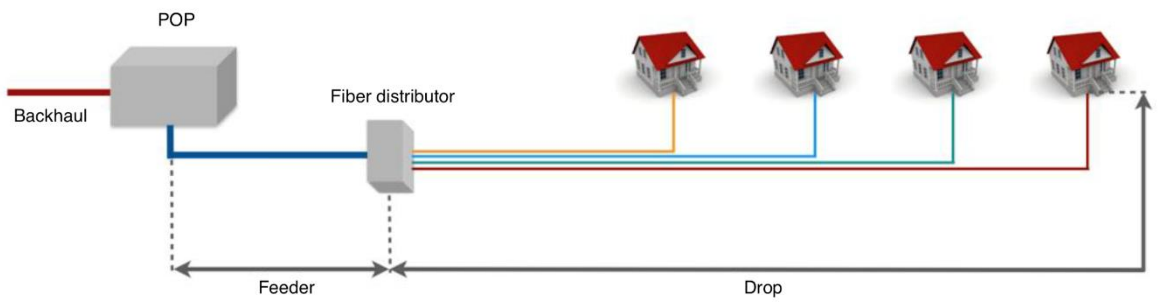

Figure 9: Elements of an optical access network

Point of Presence (POP) or Central Office (CO)

POPs are active network components, such as switches and routers, with fiber-optic interfaces. In the case of a P2P network, each optical output is connected to a single subscriber. The CO is located either in a secure room, in a building, or in a container or precast concrete building (adapted from Bmvit, 2018).

Street Cabinets or Manholes

In street cabinets or manholes, the fibers are distributed from the feeder to the drops. In a fiber distributor there are thus only splice connections and no active components (adapted from Bmvit, 2018).

Backhauls

Backhauls are necessary for connecting POPs to higher value networks or other nodes.
They often use DA50 cable protection tubes with directly injected fiber-optic cables. Existing cable ducts can also be subdivided for subducts.

However, a new trend is towards buriable microducts (e.g., 14 mm with 2 mm wall thickness). They are used individually or in pipe assemblies of 2, 4 or 7 microtubes. This makes it easy to make branches (adapted from Bmvit, 2018).

Feeder

The feeder connects the POP to the fiber distributors and are usually routed in buriable microtubes dressings to the fiber distributors. Here, too, the trend is towards n x 14 mm microducts with 2 mm wall thickness (see Figure 9). The number of microtubes will be determined according to the number of customers and reserves during planning (1, 2, 4 or 7 microducts 14 mm) (adapted from Bmvit, 2018).

Drop

The drop is guided by the fiber distributor along the road (usually in the sidewalk) in a buriable microtube bundling, from which then a single microduct is branched off for each house connection. This drop microtube has an outside diameter of 7 or 10 mm (adapted from Bmvit, 2018).

4.1.1 Elements of an optical building installation

The following are the essential elements of an optical building installation. This is mentioned for general understanding only, but is not crucial to this master's thesis.

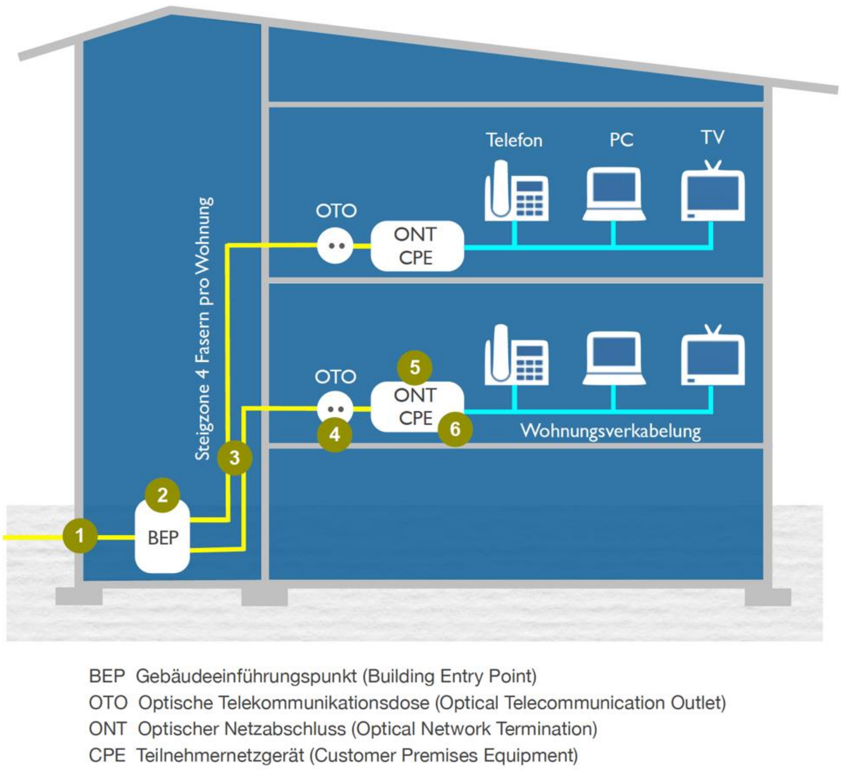

Figure 10: Reference model of a FTTH house installation (Bmvit, 2018)

House Infeed

The house entrance leads the drop microtube through the cellar wall into the cellar to the building entry point. For a house infeed, there are various solutions for sealing against moisture from the outside. The house infeed should be provided below the outdoor level to complicate willful damage (adapted from Bmvit, 2018).

Building Entry Point (BEP)

The building entry point allows the transition from the outer cable to the inner cable. It is designed as a splice box and is usually mounted in the basement near the riser. The connection between the outer and inner cables is made by splices or optical connectors (adapted from Bmvit, 2018).

Building Wiring

The building wiring connects the building entry point with the optical telecommunication socket in the apartment. Optical inner cables are used, which are equipped with bend-insensitive fibers (adapted from Bmvit, 2018).

Optical Telecommunication Outlet (OTO)

The optical telecommunication outlet is a fiber-optic socket in which the fiber-optic cable ends. It forms the optical interface to the device cord of the optical network terminator / subscriber network device. However, it may also be that the optical socket is omitted and used for cost reasons in the subscriber network device plug (adapted from Bmvit, 2018).

Optical Network Termination (ONT)

The optical network termination completes the FTTH network on the customer side. It contains an electrical-optical converter. The optical network termination and the subscriber network device are sometimes combined in one device (adapted from Bmvit, 2018).

Customer Premises Equipment (CPE)

The customer premises equipment is an active device that provides the FTTH services (data transmission, TV, telephony, etc.) to the end user. Subscriber power supply units have conventional interfaces for the usual terminals. The optical network termination and the subscriber network device can be integrated. Fortunately, prices for CPEs have fallen sharply in recent years as they are mass-produced. The subscriber network device is provided to the customer by the network operator (adapted from Bmvit, 2018).

4.2 Network architecture

Fiber-optic cables are the basis of every broadband infrastructure. In order to achieve high and stable end-customer bandwidth, network operators are forced to convert the "last mile" from copper cabling to fiber-optic cabling. The "last mile" refers to the line from the main distribution frame (MDF) to the customer.

On the way to complete "glazing", there are several intermediate steps involving a combination of copper cables and fiber-optic cables. The following describes network architectures that use "last mile" fiber-optic cabling to the customer.

4.2.1 Fiber to the Curb (FTTC)

The FTTC architecture provides that the fiber-optic cable ends in the MDF. From there, the systems use the existing copper cables till the telephone sockets. In the MDF an active component is installed for this, which converts the signal from glass fiber to copper cables or vice versa, the so-called DSLAM (adapted from Schnabel, 2018).

This implementation is comparatively easy and inexpensive in urban areas, as the main cables are laid in pipes. For this purpose, manhole covers are opened and a fiber-optic cable is pulled in a free tube until the next manhole cover. The problem is the cabling between the MDF and the cable distributor in rural areas. There, the copper cable is usually being buried directly in the ground and therefore cannot be replaced by a fiber-optic that easy without any trenching (adapted from Schnabel, 2018).

4.2.2 Fiber to the Building (FTTB)

Fiber to the building requires that the fiber-optic cable terminates inside the building. The fiber-optic cable usually ends at the DEMARC which is usually in the basement. Within the building, the existing copper cabling is used to reach the apartments (adapted from Schnabel, 2018).

The architecture is mainly used in urban areas. Usually, the MDF is directly in front of the house. In these cases, it is likely to lay a fiber-optic cable into the building (adapted from Schnabel, 2018).

4.2.3 Fiber to the Home (FTTH)

A FTTH standard is reached, if the customer is provided with a fiber-optic cable till the inside of one's apartment. In this network structure, everything is based on fiber-optic cables, so there are no more copper cables in the system (adapted from Schnabel, 2018).

4.2.4 Network architecture in fiber-optic networks

There are two basic network architectures for optical access networks: point-to-point (P2P) and point-to-multipoint (P2MP). The former is the most widespread in Europe.

The P2P network architecture, which uses the ethernet protocol, consistently routes dedicated fibers from a POP to the customer. This variant has several advantages (adapted from Loibner, 2019):

- every customer only uses their own dedicated fibers
- demand-oriented expansion (only the connected customers blow in fibers)
- easy maintenance and troubleshooting
- higher reliability (only one customer would be affected)
- technical upgrades can be made according to the customer
- support of open standards
- several operators can use fibers (open access)

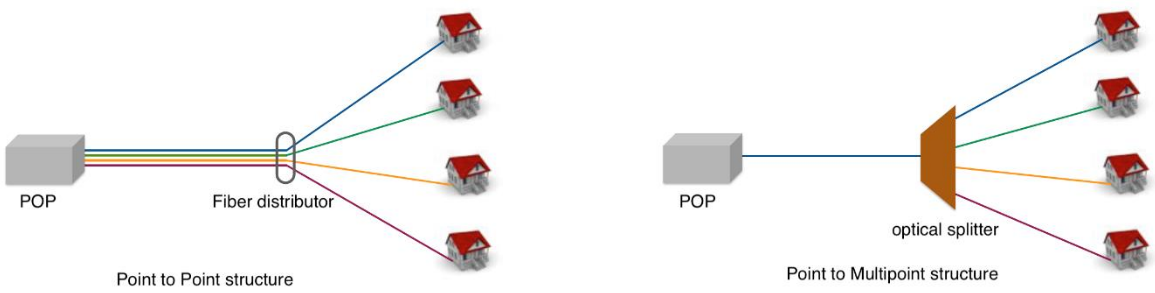

Figure 11: Network architecture P2P and P2MP

P2MP networks use a passive optical splitter in the field that allows simultaneous use of a single laser source from multiple subscribers in the POP. The splitter distributes this optical signal to fiber-optic links or subscriber lines. The optical network termination at the subscriber then filters out the portion determined for the respective subscriber from the overall signal. In the opposite direction, the subscriber device transmits in time windows, which are uniquely assigned to the respective subscriber in the POP.

Currently the most common P2MP transmission system technology is GPON. The data rate at GPON per cell is 2.5 / 1.25 Gbps. In the worst case, it drops to 75 / 37.5 Mbit/s at the subscriber with a splitting factor of 32. The advantages of GPON are fewer fibers and optical interfaces in the POP and less fiber in the main cable. However, GPON cannot provide subscribers with guaranteed gigabit-capable connections and is therefore not very sustainable.

The EU calls for networks built with the support of public funds to have a "neutral" infrastructure that supports both network topologies. However, the current aid guidelines point out that a P2P topology, compared to a P2MP topology, is more competitive in the current state of market development (adapted from Loibner, 2019).

4.3 Empty pipe technology

Fiber-optic cables are only routed in cable protection tubes today. Since there are a variety of tube types for different applications, the table below gives an overview of the most common ones.

situation	type	segmentation	application
existing installation	cable duct DA50 x 4,6 out of PE-HD with longitudinal	none	backhaul, feeder
		tube in tube microduct	
	cable duct DA110 out of PVC with bar shape	none	
		PE-HD-subduct	
		buriable microduct	
new installation	buriable microduct	none	backhaul, feeder, drop
	buriable microduct	none	drop

Table 3: Overview of cable conduits

4.3.1 Empty pipe technology for backhauls

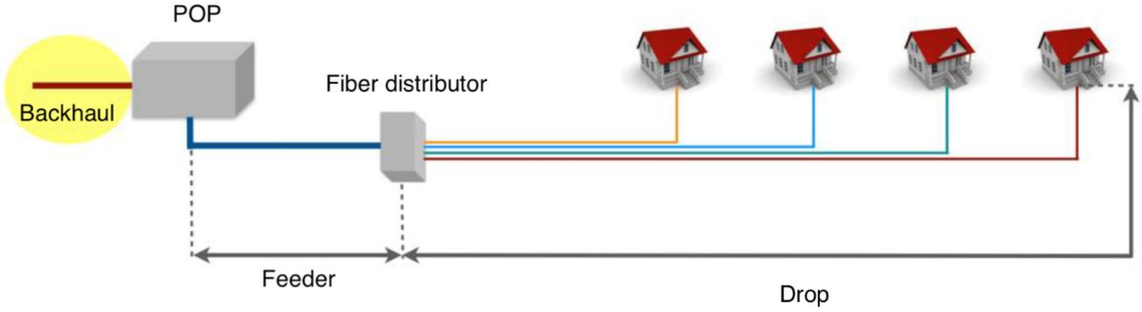

Figure 12: Section backhaul

Backhauls are necessary for connecting POPs to higher-value networks, or for connecting POPs or other nodes with each other.

Often, these backhauls are co-located without network concepts in the course of other civil engineering projects (sidewalk, road rehabilitation, etc.). Most of the time frame is determined by these civil engineering projects, so that the decision-makers have to decide at short notice whether they want to use the synergies or not.

In rural areas, backhaul links are a huge cost component, so using synergies through co-relocation or co-use is a must. For backhaul cables, cable protection tubes are used in these designs:

- cable protection tube e.g. DA50 (city and out-of-town)
- cable duct pipe e.g. DA110 (only in town)
- earth-portable micro-eared bandages

Cable conduit DA50 wound on drum or coil bundled

This cable conduit is laid by the drum or the bundled coil in the trench. In this tube you can implement fiber-optic cables or tube-in-tube microducts, in which then fiber-optic cables are blown in.

If no fiber-optic cable is blown in immediately after installation, DA50 cable protection tubes must be pressure-tested and calibrated during inspection (inspection of the clear width by blowing in a caliber with locating capability).

It is also important that no recycling pipes or other pipes are used, as these have a high susceptibility to failure.

If a fiber-optic cable is inserted directly into a DA50 tube, this is usually a fiber-optic cable with 144 fibers. Locally, even higher fiber-optic cables with up to 576 fibers can be accommodated in a DA50 tube.

Subdividing the DA50 tube with sub-tubes (e.g., 7 x 10 mm with a wall thickness of 1 mm) allows the use of 6 fiber-optic cables with 72 or 96 fibers each. Of these, a sub-tube should remain free for service or emergency.

Beside DA50 also the dimensions DA32, DA40 and DA63 are installed. Cable protection pipes made of PE-HD are specified according to ÖNORM 6513, DIN 16874 and DIN 16876. The pipes should be grooved inside to reduce friction when blowing in (adapted from Bmvit, 2018).

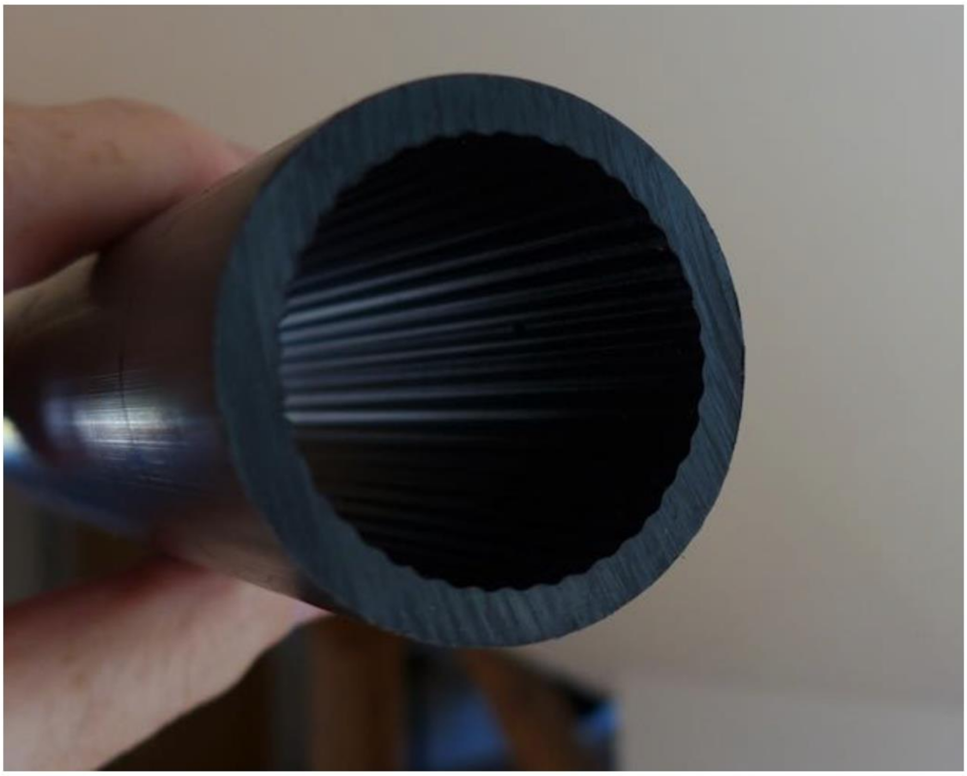

Figure 13: Cable conduit DA50 (Bmvit, 2018)

Cable conduit DA110 in bar shape

This is the classic thermowell design that has long been used in urban areas. Shafts are to be provided at a distance of 150 to 200 m, which are used for drawing in. Everything can be installed in DA110 like direct fiber-optic cables, sub-pipes with DA32 and / or DA40 and micro drill dressings. However, the installation is cumbersome, so today more and more DA50 protective pipes are being processed by the drum or direct buriable microducts. Due to the limited branching possibility, this pipe technology can be used for point-to-point connections.

Other dimensions are of course also available like DA50, DA63, DA125 and DA160. These PVC conduit ducts are standardized according to DIN 16872. In addition, there are also cable ducts in half-shell technology for repairs (adapted from Bmvit, 2018).

Figure 14: PVC conduit with subdivisions (Bmvit, 2018)

Microducts for tube-in-tube use

For existing cable conduits, thin-walled microducts for tube-in-tube use can be injected for subdivision. For new installations, however, more and more buriable microducts are being used today for cost reasons.

Microducts that are inserted into a cable conduit have a thinner outer wall than buriable microducts. This provides a larger inner diameter for the blowing in of fiber-optic cables. They are not suitable for being buried in directly.

Tube-in-tube microducts are either blown into the surrounding conduit or retracted for short distances.

There are also cable protection tubes with already populated thin-walled microducts in the market, e.g. DA50 with 24 x 7 mm microtubes. Their use is problematic, since the so-called "spaghetti effect" can lead to the retraction of microtubes due to the different lengths during installation (adapted from Bmvit, 2018).

Figure 15: Cable conduit DA50 with 7 tube-in-tube microtubes 10 x 1 mm (Bmvit, 2018)

Buriable microducts

Buriable microducts are now increasingly used due to cost reasons for backhaul lines. Since they are also used for feeders, they are described in detail in the feeder section.

4.3.2 Empty pipe technology for feeders

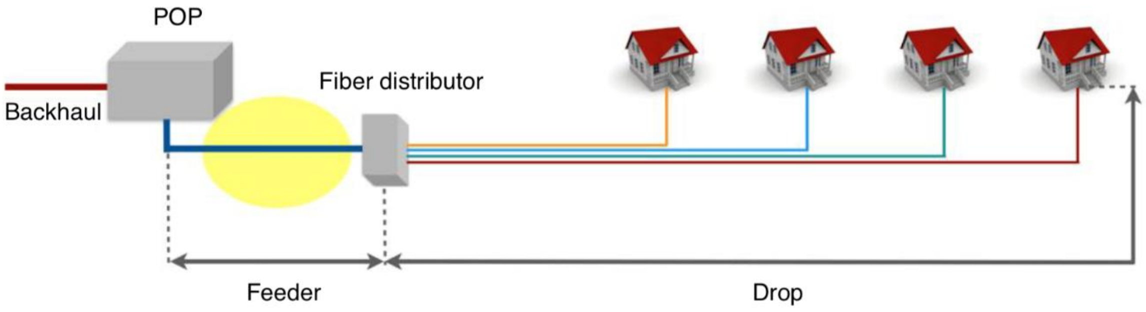

Figure 16: Section feeder

The feeder connects the POP to the fiber distributor and the fiber distributors to each other. In this application, buriable microducts are used today. These pipes are buriable, because they can be placed by their higher wall thickness directly into a ditch with sand bed.

They are designed as microtube dressings, which are held together by an outer shell. This shell can also be cut open to remove a pipe for a branch.

Figure 17: Buriable microducts (Bmvit, 2018)

The inside of the microtube is grooved to minimize friction when blowing in the fiber-optic cable for better blow-in results.

An advantage of the microtube dressings is that they can be equipped with fiber-optic cables as needed.

During laying, care must be taken to ensure that no dirt or water penetrates during each processing step, and that the microducts are sealed gas-tight and watertight throughout with the appropriate terminating elements.

The following table gives an overview of available sizes of microtubes and microtube assemblies. Likewise, the maximum inflatable fiber cable diameter is given with a common number of fibers. The values in brackets refer to fiber-optic cables with 200 µm fibers (adapted from Bmvit, 2018).

external diameter (mm)	inner diameter (mm)	outer sheath (mm)	multitube with n microducts	cable diameter (mm)	number of fibers
12	8	2	3, 4, 5, 7	4,0 - 6,5	96 (144)
14	10	2	3, 4, 5, 7	5,0 - 8,5	144 (216)

Table 4: Overview of buriable microducts for feeder

4.3.3 Empty pipe technology for drops

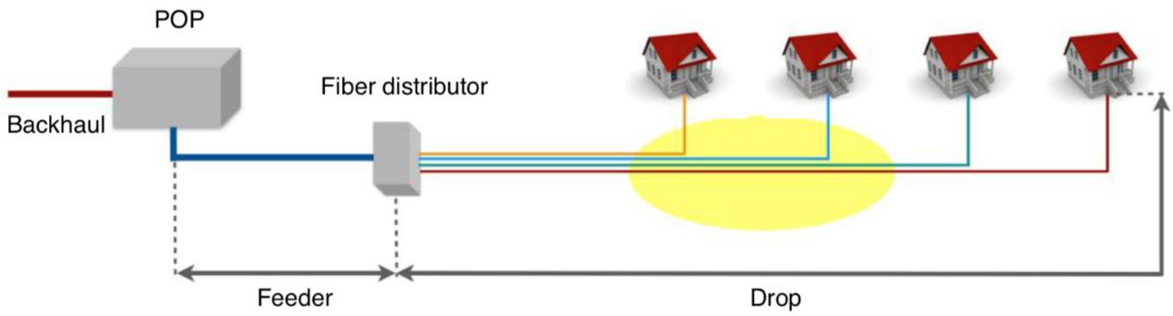

Figure 18: Section drop

Drop cables make the connection between fiber distribution and the house connections. In recent years, buriable microducts have become established in this section.

In the first section, they are often routed along the sidewalk as microtube dressings along roads. That means they are on public grounds.

A microtube is then removed from this microtube dressing and laid over a plug-in sleeve as a single tube to the respective building. The single tube is thus on private land. The plug-in sleeve should not be in the turn of the branch to avoid the formation of a gap. Otherwise, it could cause difficulties when blowing in the fiber-optic cable.

If a homeowner does not order a connection, a pipe reserve is usually placed on the private property, which can then be used later for a connection. Thus, no construction measures are necessary on public land.

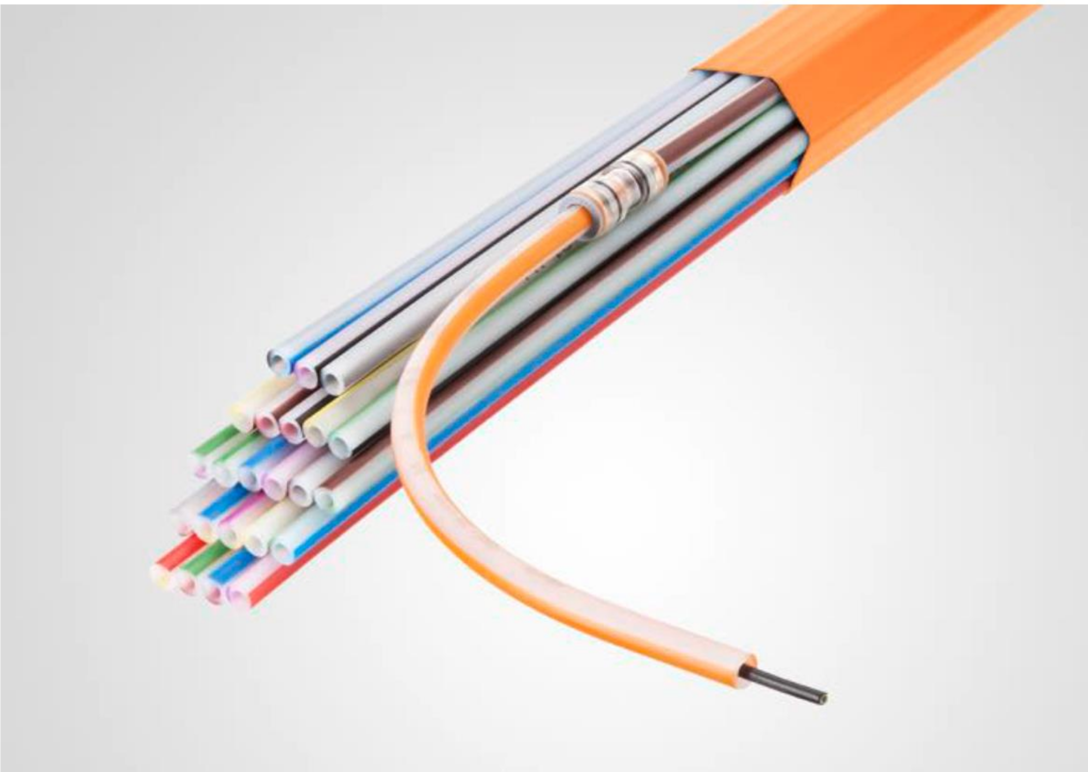

Figure 19: Buriable microducts for drop cables (Bmvit, 2018)

In practice, 7 mm and 10 mm microducts for drop cables have prevailed. In densely built-up areas, construction with 7 mm tubes is an advantage as more connections can be accommodated in the fiber distributor. This is also the preferred design of the major telecommunications companies. In rural areas, 10 mm tubes are often used. The following table shows typical data from 7 and 10 mm microducts. The values in brackets refer to fiber-optic cables with 200 μm fibers (adapted from Bmvit, 2018).

Also, microtube dressings having a larger microtube in the middle are used, e.g. 22 x 7 mm + 1 x 14 mm. This microduct in the middle is either used to power additional fiber distributors, or it remains empty for potential emergencies or service.

external diameter (mm)	inner diameter (mm)	outer sheath (mm)	multitube with n microducts	cable diameter (mm)	number of fibers
7	4	1,5	6, 8, 10, 12, 14, 18, 24	1,0 - 2,5	12 (24)
10	6	2	4, 5, 7, 12	2,0 - 4,5	48 (72)

Table 5: Overview of buriable microducts for drop cables

Supplying a road from two sides

Another planning method should be mentioned. Of course, it is also possible to supply a region or a road from two sides with a microduct union. This is shown in the following graphic. Thus, the material-saving supply of longer streets is possible (adapted from Bmvit, 2018).

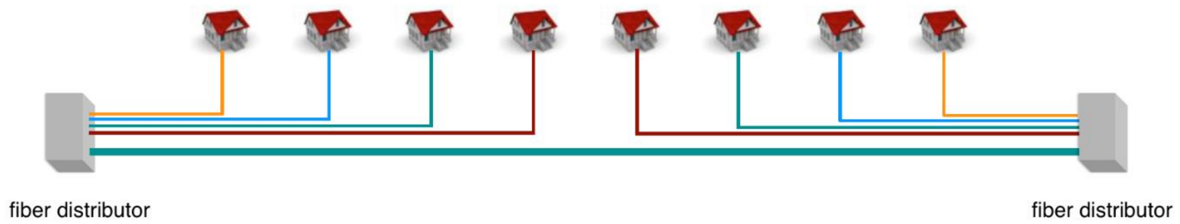

Figure 20: Supplying a road from two sides

Supplying a building with two drop cables

There is also an easy way to furnish a building with two house-insertion cables from two sides, so that two fiber distributors can supply one building. This is used for larger company buildings and optimally exploits a microtube bond (adapted from Bmvit, 2018).

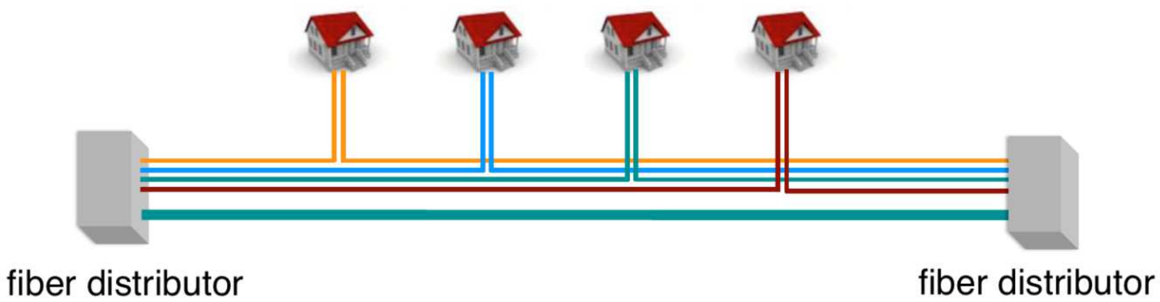

Figure 21: Supplying a building with two drop cables

Plug-in sleeves

Plug-in sleeves have an important function, which are used for branches or connections of microtubes. They must seal the microducts against moisture and gas throughout the useful life of the conduit system. Plug-in sleeves should not be used in bends, because it could form a gap where fiber-optic cables can get caught while blowing in.

Plug-in sleeves must not open when blowing in fiber-optic cables, otherwise high costs arise if trenching is needed again (bursting pressure min. 30 bar). Here is to pay attention to quality. Plug-in sleeves must comply with the standard DIN EN 50411-2-8. For end caps, the standard applies mutatis mutandis. Transparent plug-in sleeves indicate whether a fiber-optic cable is equipped or not (adapted from Bmvit, 2018).

Figure 22: Plug-in sleeve (Bmvit, 2018)

4.4 Mobile transmission techniques

In order to enable the most comprehensive and economical supply of mobile high-speed internet in Austria, the frequency band below 1 GHz is primarily suitable, since this range has a comparatively good physical propagation characteristic. These UHF frequencies reach a greater range than higher band frequencies and additionally allow comparatively good reception within buildings (adapted from Holznagel, 2008).

GPRS connections also work behind thick walls compared to UMTS services operating in the 900 – 2.100 MHz range. The so-called indoor coverage is very high at UHF frequencies and therefore these frequencies are not only interesting for broadcasters, but also for providers of mobile services (adapted from Börsen et at., 2010).

Not only the technically possible data transmission rates are important for the broadband communication, but rather the available frequencies. Therefore, frequencies corresponding to the upper digital dividend (790 - 862 MHz) are ideal for the nationwide expansion of a NGMN (Next Generation Mobile Network) using LTE technology, in order to enable the economic supply of rural regions via high-speed internet (adapted from Börsen, Breuer, 2008).

Figure 23: Overview of frequency ranges (RTR, 2019)

Frequencies in the GHz range have the major disadvantage that the physical propagation conditions and the associated short ranges do not allow economic operation in rural areas (adapted from Börsen, Breuer, 2008).

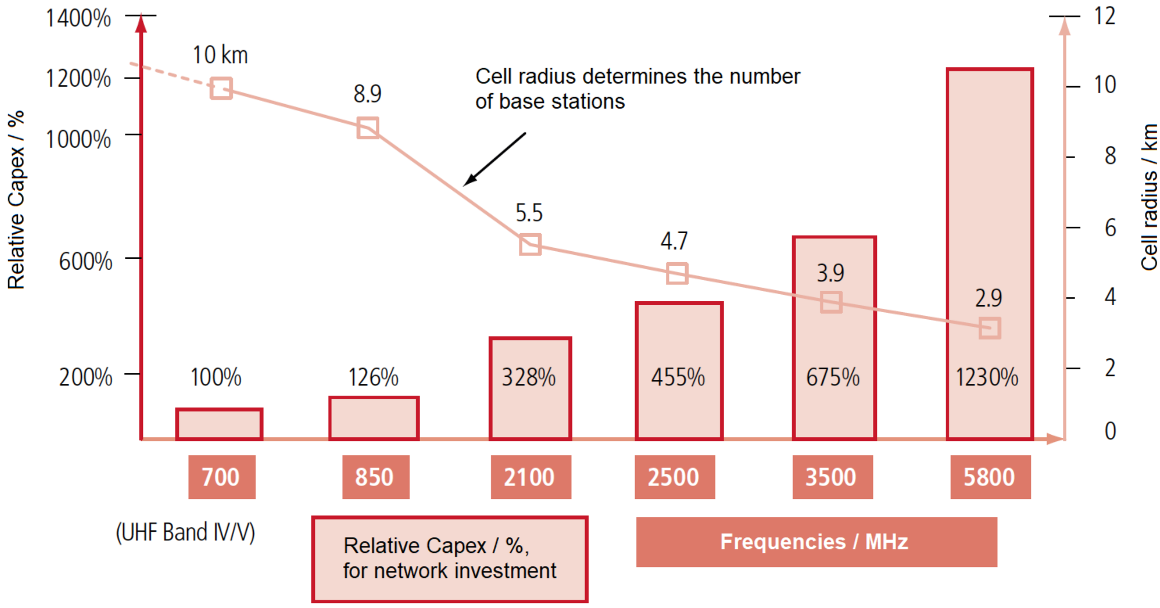

Figure 24: The interplay of frequency, distance and costs (Börsen, Breuer, 2008)

Because of the relatively high CAPEX shown in the graph for network investment, upgrading in rural areas with frequencies in the GHz range will be uneconomical for network operators. The business term CAPEX stands for Capital Expenditure, which is the capital expenditure of a company for long-term usable assets quantified (adapted from Börsen, Breuer, 2008).

4.4.1 UMTS – Universal Mobile Telecommunications Systems

The Universal Mobile Telecommunication System refers to a mobile transmission standard of the 3rd generation, short 3G. In the UMTS network, data transfer rates of up to 28 Mbit/s in the downlink (and uplink of up to 11.5 Mbit/s) can be achieved (adapted from Gutt, 2019).
The UMTS technology operates in the 900 – 2.100 MHz range and supplies a radius of up to 5 km. A longer range is not feasible due to the used frequency spectrum of 2.1 GHz. Therefore, a widespread expansion in rural areas is not profitable for operators, because of the poor propagation characteristics for reasons of cost (adapted from Gutt, 2019).
For the sake of completeness, it should be mentioned that in a 3G network various standards such as HSDPA, HSUPA, HSPA+ can be realized, which in turn have different download and upload speeds (adapted from Gutt, 2019).

4.4.2 Long Term Evolution (LTE)

Long term evolution is a transmission standard of the 3rd respectively 4th generation, which can reach up to 300 Mbit/s in the download. Since LTE uses the basic scheme of UMTS, an upgrade from UMTS to LTE is relatively inexpensive. From a technical point of view, LTE is a 3rd generation standard and therefore at one level with UMTS, but for marketing reasons it is often touted as 4G. Only the extension LTE-Advanced, which allows up to 1.000 Mbit/s, fulfills the requirements of a 4G standard due to its channel width of 40 MHz (adapted from Tarife.at, 2019).
In October 2013, the LTE frequencies for the 800, 900 and 1.800 MHz bands were auctioned in a much-criticized auction - these areas are particularly relevant, as they reach higher transmission ranges of up to 10 km due to their lower spectrum. The auction, whose minimum bid was set at 526 million Euros, yielded more than 2 billion Euros. Pending were couples consisting of up and down link (adapted from Tarife.at, 2019).
The speed of LTE depends on a variety of factors. Since LTE is a so-called shared medium, in particular the number of devices, which use the same LTE radio cell, plays a major role. As each radio cell has only a limited capacity, it is split between the connected devices, which is why a fair distribution must be ensured. Also important is the connection of the radio cell to the provider (backbone). As a rule, fiber-optic cables are used here, which enables a fast connection to the provider. In rural areas without fiber-optic cables, the maximum speed is thus severely limited, inter alia, by the connection of the radio cell (adapted from Tarife.at, 2019).

4.4.3 5th Generation of cellular mobile communication (5G)

5G represents the newest generation in mobile transmission and promises data rates of up to 10 Gbit/s. The first contending 5G frequencies, which have been auctioned at the beginning of this year (2019), are in the band at 3.4 and 3.8 GHz. Here you can assume a maximum range of up to 1 km. Therefore, this frequency would be wholly unsuitable for 5G expansion in rural areas (adapted from Schöne, 2019). This was recognized by Bitcom president Achim Berg in mid-2018 and he warned:

"There is no economic coverage possible. On average, every mile a transmission tower would have to be set up, connected with fiber-optics and supplied with power. We would have to dig up the whole country to produce the required area coverage. This is simply not feasible and goes past the realities of mobile."

In conclusion, from today's perspective, a holistic supply of 5G transmission cannot be realized. Only further auctions of the 700, 1.500 and 2.100 MHz bands, which are planned in 2020, could possibly achieve an economical supply of this technology.

5 Installation of cable protection pipes

This chapter briefly explains the most common installation methods of standard trenches, alternative installation methods, co-location and shared use. Choosing the right cabling method is therefore crucial for the cost-effectiveness and improves the profitability of a holistic fiber optic expansion network, especially in rural areas.

5.1 Laying in trenches

The largest share (60 % - 80 %) of the total investment costs of a FTTH network lies in civil engineering. Therefore, civil engineering measures should be carried out in cooperation with several stakeholders (co-location). The standard installation is done in the open construction in ditches. Depending on requirements, the trenches are made with an excavator, trench cutter or cable laying plow. Cable protection pipes are designed with a standard installation depth of 0.6 m on the trench sole in one layer. Current-carrying cables and copper cables are usually laid deeper (see ÖNORM E8120). Protective distances must be observed for current-carrying cables and gas lines. Over the cable protection tubes warning straps should be inserted at a distance of 30 cm (adapted from Bmvit, 2018).

5.1.1 Laying in standard trenches

In conventional or classical civil engineering, ditches for laying the empty pipe systems are excavated by dredging. The depth is usually at least 60 cm. Only relatively short distances are achieved per day, but this can vary depending on the top layer and soil class. After the trench has been dug, the empty pipe system or the buriable cable is laid in the trench and then the area filled again. Afterwards the original level and the grassland areas of the area are restored. Compared to other laying techniques, the space and time required is relatively large. Furthermore, conventional civil engineering is overall comparatively expensive (150 EUR/m or even higher are frequent) and road traffic can be affected by the required working strip width of more than 2.5 m (adapted from Breitband NRW, 2017).

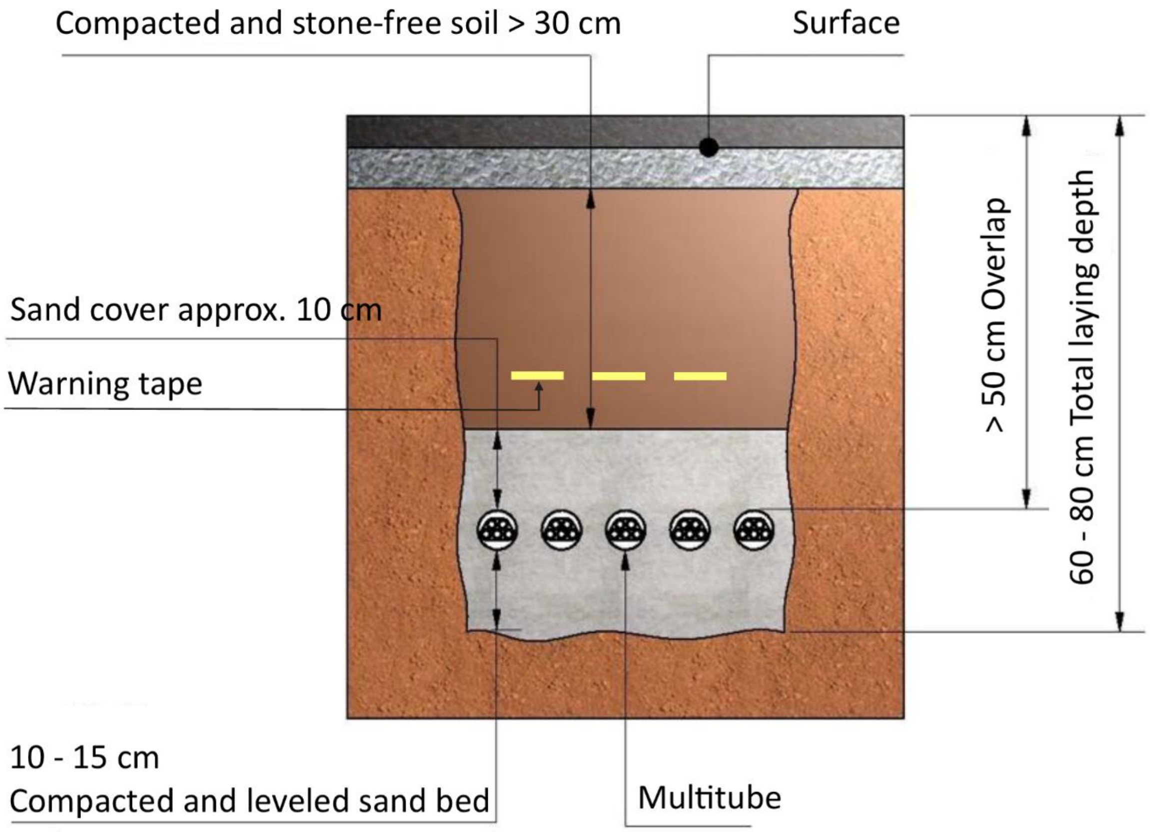

Figure 25: Laying in standard trenches (Bmvit, 2018)

5.1.2 Laying by plowing

It is a cost-effective laying method (approximately 10 EUR/m), which is applicable on meadows, unpaved surfaces and also in the forest. The laying performance can amount to several kilometers per day. With a laying plow, a slot is produced in one process by surface displacement, in which one or more conduits and a warning tape are inserted in one operation. Depths of up to 110 cm are possible with this technique. The laying of conduits or buriable microtubes with the cable laying plow is applicable when there is no paved road surface, no significant obstacles in the ground and the location of third-party equipment is known (adapted from Bmvi, 2019).

Figure 26: Laying by plowing (Breitband NRW, 2017)

5.1.3 Laying with trencher

The term trenching describes a variety in detail of different methods for laying conduits or buriable microtubes. This can be done with the help of a milling machine, which mills slots in the ground or asphalt where the empty pipes can be introduced. This method of laying requires little space and allows rapid completion of empty pipe or cable routes (200 – 600 m per day). The different trenching methods (micro-, mini- and macro-trenching) differ in the depth and width of the realized installation joint, as well as in the cutting or milling technique used. In addition to paved surfaces, other floors can be processed with a width of up to 60 cm and a depth of up to 200 cm. The dissolved material is deposited laterally next to the trench by means of distribution route and, after the conduits have been laid, immediately backfilled with the stored excavation. In comparison to conventional civil engineering, a cost reduction of 30 – 40 % can be assumed here (adapted from Breitband NRW, 2017).

Since only paths and shoulders are affected by the milling process and the construction site area is limited to the parking space for the tractor, the construction site and the need for a road closure is comparatively low. With regard to the noise emission and structural change in the surface, however, the effects in the milling process are by comparison higher. If the trenching method is applied to paved surfaces, changes in the surface structure of the road may result, which could have a negative impact on the road and adversely affect the strength of the surface and possibly the safety standard of the road (adapted from Breitband NRW, 2017).

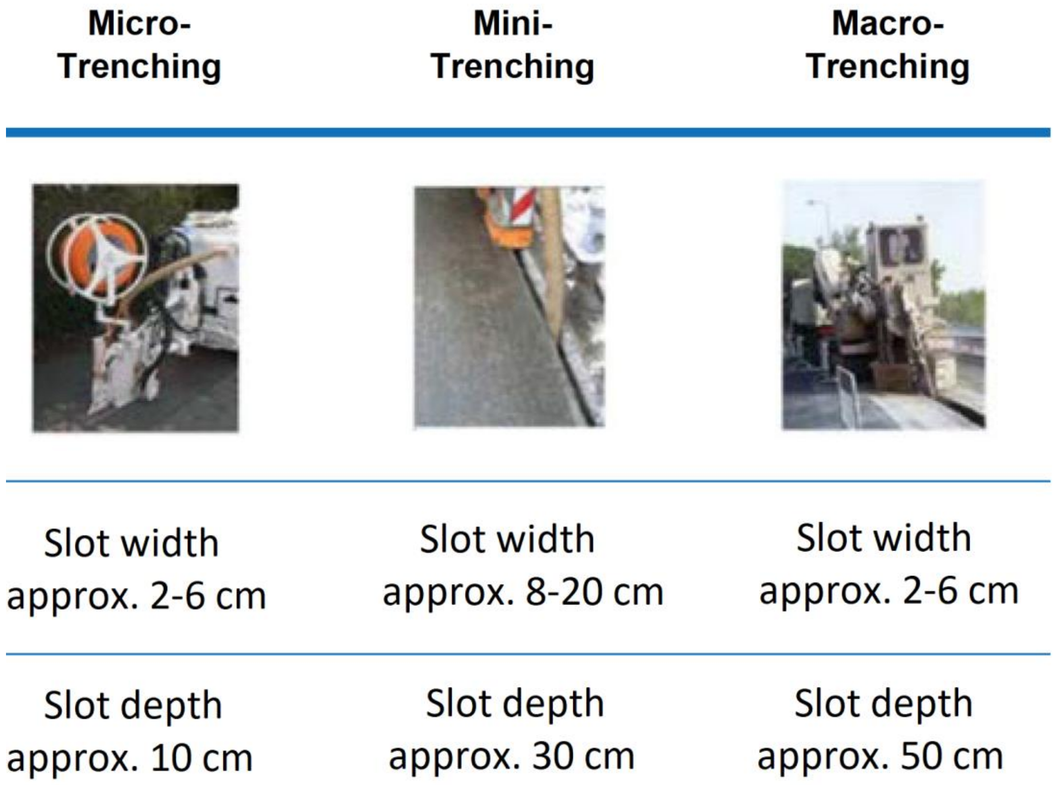

Figure 27: Laying with trencher (Breitband NRW, 2017)

5.2 Subsequent installation of microtubes

5.2.1 Insertion of buriable microtubes into existing cable protection pipes

In existing cable ducts DA32 to DA63 buriable microtubes can be pulled with the aid of a pulling head. For this purpose, the liner shell is slit before reaching the tube by means of a slicing and removed. The achievable catchment length of approximately 300 m is limited by the permissible tensile force of the microtubes. The use of lubricant has a positive effect. The number of maximum possible microtubes for a particular outer tube can be found in the manufacturer's instructions (adapted from Bmvit, 2018).

5.2.2 Blowing tube-in-tube microtubes into existing cable protection tubes

Tube-in-tube microtubes (with a thin outer wall) are blown into existing conduit walls to create subdivisions. This requires a coil holder for the individual microtube coils, a powerful compressor and a suitable blowing device. To increase the mechanical stability of the microtubes, they are already pressurized on the drum (7 to 8 bar). For this, the microtubes must be closed at the end. The use of a suitable lubricant is recommended.

For example, in a PE-HD DA50 tube with longitudinal grooves 7 pieces of 10 x 1.0 mm microtubes up to 2.000 m or 10 pieces of 7 x 0.75 mm microtubes up to 1.500 m in the tube-in-tube version can be blown in. In exceptional cases, microtubes are drawn in over shorter distances (up to approx. 100 m). The permissible tensile forces of the manufacturer must be observed (adapted from Bmvit, 2018).

5.3 Alternative installation methods

Due to the high civil engineering costs of a conventional installation in ditches, methods were sought that promise lower costs and a higher installation speed. In the following, seven methods of them will be described.

5.3.1 Laying in slot ditches

This special construction method is described in leaflet RVS 03.08.61 of the Austrian Research Association Road-Rail-Traffic. When laying in the trench, a slot is milled into the upper bituminous layers of paved traffic areas into which buriable microtubes are inserted. These are usually point-to-point fiber-optic links. The slot is then immediately closed with a potting compound. The minimum values for coverage and residual thickness in the asphalt layer depend on the load. This laying method has shorter construction times and lower costs than the usual laying in of standard trenches. The process has a construction capacity of approximately 600 m per day. Every 600 m to 800 m, shafts are required for blowing in the fiber-optic cables that are installed next to the roadway. However, there is still a lack of experience on the long-term behavior of the method. Compared to an undisturbed road body, a slotted trench causes weakening of the superstructure and thus shortens the life. Likewise, due to the low installation depth, there is a greater risk of damage. This procedure is therefore only permissible, if the road operator expressly agrees (adapted from Bmvit, 2018).

Figure 28: Laying in the slot ditches (Bmvit, 2018)

5.3.2 Laying with ground rockets

Sometimes it is not desirable to make the customer connection by excavating the garden. There are high-quality surfaces, plants or stairs that one does not want to change. Here is the use of a soil displacement method, using a suitable ground rocket. This procedure is normally used between two pits (start and finish pit). However, it can also be used directly from the basement. For this purpose, a core hole with a diameter of 60 mm is created in the basement wall. The earth rocket is driven through the core well to the target pit using soil displacement techniques. It is powered by compressed air from the normal construction site compressor. A percussion piston drives the tubular housing automatically through soil, rocks or masonry. The soil is displaced and it creates a ground tube into which a cable conduit or microtube is often drawn directly in the same operation by the ground rocket. The method is an uncontrolled process and can be used up to 30 m. The accuracy is sufficient in practice. A construction crew can produce up to four connections per day depending on their length. Of course, the soil displacement method is also used for penetrations under roads. The cost of the procedure amounts to about 100 EUR/m (adapted from Breitband NRW, 2017).

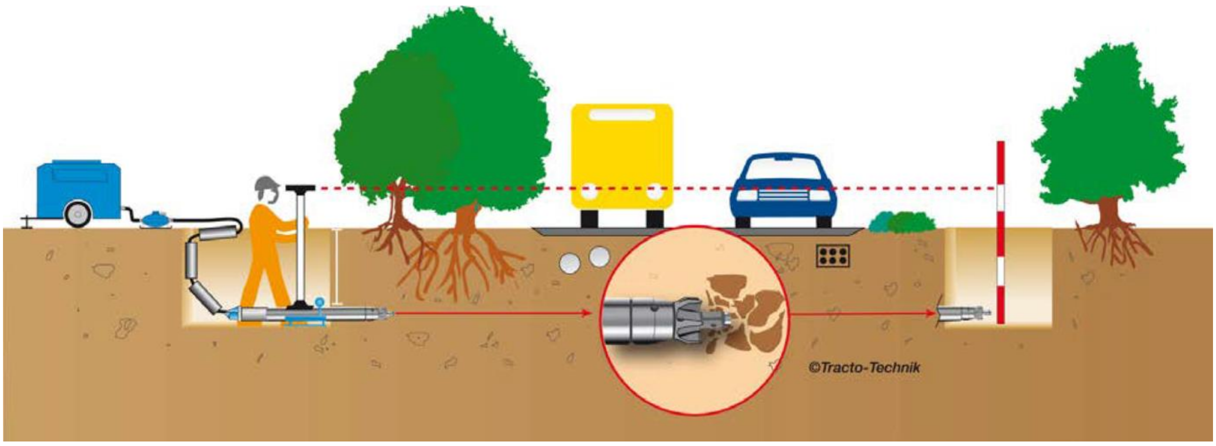

Figure 29: Laying with ground rockets (Breitband NRW, 2017)

5.3.3 Flush drilling procedure

In the horizontal flush drilling method, the tubes are laid trenchless by means of a hydromechanical drilling process. With the horizontal flush drilling method, obstacles such as rivers, tree avenues (tree protection) and railway lines can be bypassed and distances up to 300 m bridged. This minimizes interference with nature and the disruption of neighbors caused by the construction site operation. The cost of the procedure amounts to about 50 EUR/m. The proceeding is carried out mainly in three steps. First, a pilot hole is made by controlled propulsion with permanent location of the drill bit. Thereafter, this hole is widened in reverse depending on the required dimension and retracted a cable protection tube in the bore thus prepared (adapted from Bmvi, 2019).

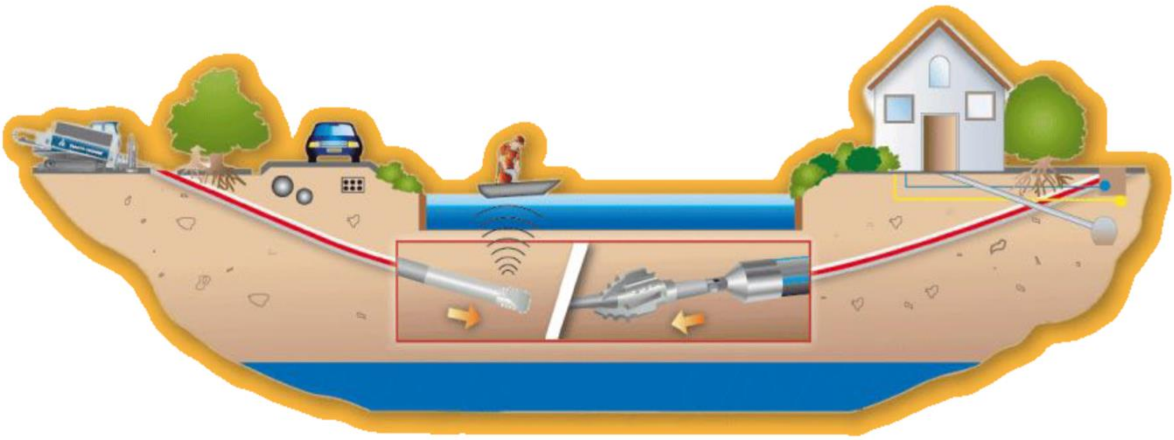

Figure 30: Flush drilling procedure (Breitband NRW, 2017)

5.3.4 Mounting on electricity pylons

For above-ground laying of fiber-optic cables, corresponding mast lines must be present or newly erected. The installation of new pylons is often rejected because of possible damage to the landscape. As far as possible, above-ground routes are generally not considered for the internal relocation. A functional impairment is not given when using the appropriate cable class (ADSS). The maximum permissible mast spacing is 60 to 700 m, depending on the cable type. Generally, pylons have a distance of 50 to 70 m. Major disadvantages of this method are the possible effects of weather (wind, ice, UV radiation), damage by third parties and increased maintenance. The cost is about 100 EUR/m. Often an above-ground laying is used as a bridge for a later underground laying (adapted from Breitband NRW, 2017).

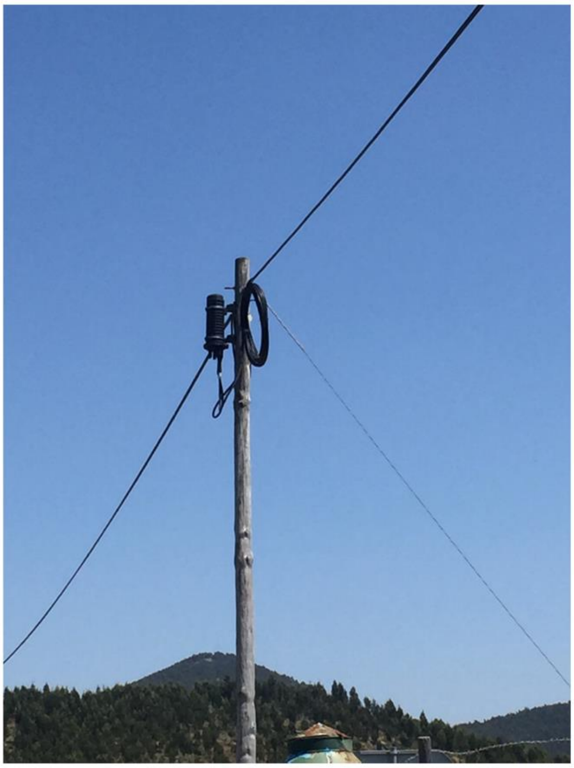

Figure 31: Mounting on electricity pylons (Bmvit, 2018)

5.3.5 Laying in sewer tunnels

These technologies use existing and new sewage pipes for the laying of fiber-optic cables. In accessible pipes, the work is performed by fitters. In non-accessible pipes diameters from DN 250 to DN 800, assembly robots are used.

5.3.5.1 Laying system with cable duct

With this method, a cable duct is mounted by hand in the impost block in accessible pipes, where a modular cable system (bundles of 5 mm injection pipes), empty piping or single cables can be laid as required by the client. The cable duct is made of hard, sleek PVC, the fastening straps are made of stainless steel. In non-negotiable cross-sections, a cable duct with a laying robot can be mounted on the channel ridge. This conduit provides space for two empty pipes or modular cable systems. The method is resistant to aggressive wastewater and high-pressure cleaning. However, a subsequent holistic pipe rehabilitation without removing the modules is not possible. The costs of the procedure amount to approximately 90 EUR/m (adapted from Bmvit, 2018).

Figure 32: Laying system with cable duct (Bmvit, 2018)

5.3.5.2 Laying system with clamping rings

In Germany, metallic laying systems are often used in cities. An empty pipe system consisting of corrugated stainless steel microtubes will be created, each of them can hold a cable with up to 216 fibers. Stainless steel clamping rings are used as fastening elements for the system to avoid mechanical stress on the sewer pipe walls, which would occur if using drilling or dowelling methods. The space requirement of the empty pipe system - usually mounted in the pipe apex - is minimal and does not represent a significant impediment to the hydraulic flow conditions. The cleaning of the sewage pipes as well as the rehabilitation of sewers is possible, but connected with additional effort and expense. The costs of the procedure amount to approximately 90 EUR/m (adapted from Breitband NRW, 2017).

Figure 33: Laying system with clamping rings (Bmvit, 2018)

5.3.5.3 Patented BOP system – Bytes in old pipes

This innovative installation system is suitable for new tunnels, already existing tunnels, as well as for sewer tunnel rehabilitation. Likewise, house connections can be realized easily with the BOP system. Within the method, a shallow pipe bundle in a felt belt is introduced by a robot into the pipe, which is then pressed and glued by an air hose.
In the case of pipe rehabilitation, the entire pipe is lined with a new inner layer, in which the felt belt is equipped with the microducts (adapted from FTTP, 2019).

Figure 34: Patented BOP system – bytes in old pipes (FTTP, 2019)

5.4 Co-location and shared use

Due to the high costs of civil engineering 60 % - 80 % of the total costs of a fiber-optic network, the use of synergies has one of the highest priorities. These are realized most effectively by co-relocation of pending civil engineering work and on the other hand by shared use of existing infrastructures.

5.4.1 Co-location

There are a number of developers who are constantly building underground structures such as:

- utilities (electricity, gas, district heating, water, sewage)
- telecommunications companies (telecommunications companies, cable network operators, mobile operators, municipal utilities)
- preservation of roads, cycle paths and sidewalks
- transport companies (train, cable cars)
- industry (industrial networking)

Here, it makes sense to check within these construction measures a co-laying of conduits, if it is technically and economically useful.

Incidental costs incurred by the additional installations:

- empty tubes
- sand bed
- laying
- calibration and pressure test (if necessary)
- surveying and documentation

Furthermore, the lead developer still tries to accommodate proportionate costs in most cases:

- trench
- bedrock
- restoration of the surface (asphalt, natural stone)
- other complications

5.4.2 Shared use

Frequently, infrastructures already exist that are not fully occupied and therefore can and should be shared. This is economically sensible and desirable. In practice, however, there are some hurdles, as many infrastructure owners do not provide information about their infrastructure to the outside world. These are conduits into which fibers can be introduced directly or via sub-tubes, as well as fiber-optic fibers that are still freely available. The joint use can be enforced under Austrian Telecommunications Act in case of dispute, if this is technically and economically reasonable for the infrastructure owner. The fees are determined by the RTR by notice.

6 Project schedule

Before investing in broadband deployment at local or regional level, as appropriate with public support, a comprehensive broadband concept should be developed. This should describe all aspects of mid- and long-term broadband development in the affected area based on the actual condition. A vote with neighboring regions is highly recommended.
The following phase model should provide an example in this process.

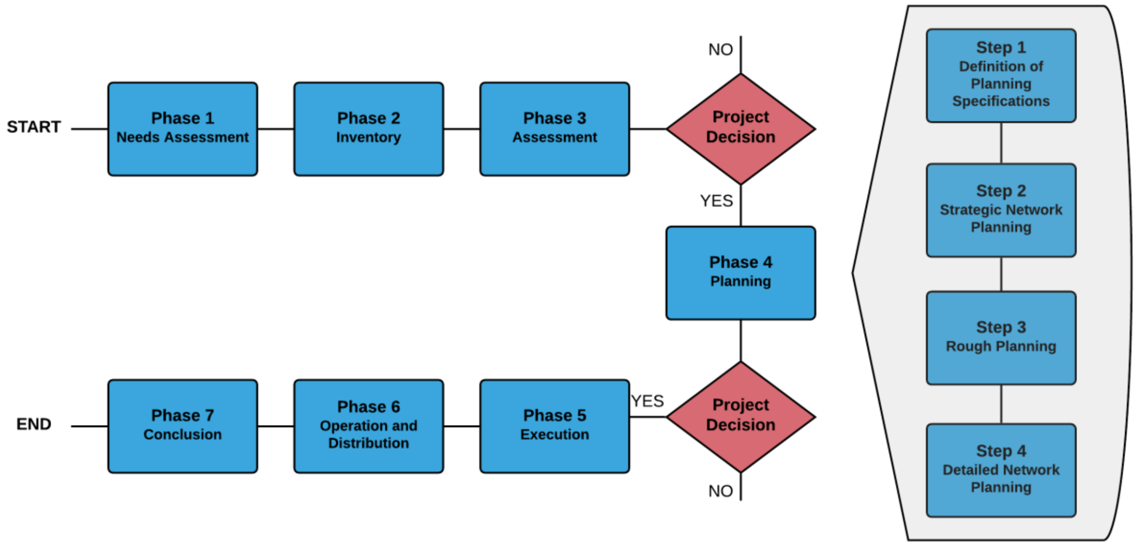

Figure 35: Phase model for the project process and planning

Phase 1 – Needs Assessment

- define area to be supplied
- supply check with “Breitbandatlas” of the “Breitbandbüro”
- raise demand from
  - private households
  - commercial enterprises (in particular tourism businesses)
  - public facilities (municipal offices, schools, child and elderly care facilities, function rooms, fire brigades, medical practices, pharmacies, etc.)
- to assess the assessment of future individual and collective needs
- evaluate and present demand (take-up rate)

Phase 2 – Inventory

- contact TC companies operating in the investigated area
- check supply situation with telecommunication providers

- request expansion plans of the TC providers
- existing infrastructure of telecommunication providers as far as possible
- raise owned infrastructure (pipes, tunnels, shafts and premises)
- pending upcoming civil engineering projects
- raise existing backhaul lines
- georeferenced presentation of the results
- contact “Breitbandbüro”

Phase 3 – Assessment

- assessment of current supply, access technologies offered and existing infrastructures.
- assessment of expected demand from private, commercial and public users
- joint use of other infrastructures and cooperation with network operators
- assessment of regional cooperation opportunities
- presentation of synergies through planned construction measures
- assess whether an own investment makes sense
- added value and synergies of such an investment
- dimensioning and network architecture
- potential locations for the active infrastructure
- search and evaluation of suitable network operators and service providers
- desired cooperation and sales model with operators
- framework conditions and possible subsidies
- schedule
- cost estimate
- summary in a result document

Phase 4 – Planning

- tender and award of planning services
- definition of planning specifications
- strategic planning
- rough planning
- detailed planning with the results:
    - general plans for civil engineering
    - material planning with material lists
    - cost planning
    - scheduling
    - funding with possible subsidies

Phase 5 – Execution

- tendering and awarding of construction and service contracts
- material procurement
- conclude agreements with property owners
- carry out construction work
- laying of empty pipes
- install fiber distributors and house connections
- acceptance inspections
- surveying and GIS-capable documentation
- data transmission to “Breitbandbüro” and RTR

optional:

- insert fiber-optic cable
- install splice boxes and make splice connections
- set up passive equipment of the POP
- establish backhaul
- fiber-optic acceptance inspections
- fiber management with labeling and documentation

finally:

- holistic acceptance inspection and cost control

Phase 6 – Operation and Distribution

- definition of an operator and revenue model
- tender and award of network operation and service feed-in
- sales support in order to establish the created infrastructure in the market and open up new possibilities of use

Phase 7 – Conclusion

- evaluation of the project
- project completion
- tracking of the strategy for further network expansion

7 Planning process

In principle, network planning should be carried out before the laying of empty pipes on the basis of an overall concept.
A transfer without a detailed network concept is only meaningful in cases where other infrastructure providers selectively carry out civil engineering work in a location that does not create a flat network structure. This also applies to backhaul roads out of town or in the connection of districts.

Selection of a planning company
Planning an optical access network is a complex task that requires great expertise. Good planning can minimize investment and running costs.
The planning should be carried out by a qualified body. Planning assignments must be awarded in the competition.
Should a cost-effective possibility (e.g. co-location) arise in the short term for the expansion of a subarea of a local network, this can also be carried out in advance. In this case, the entire network does not have to be planned in advance. Although this is not the optimal procedure, it should always be worked in such a way that an early operation is possible.
If an open-pit project is co-implemented with another civil engineering project (e.g. district heating project), it may be useful for the planning company, which also manages the other construction project, to undertake the detailed planning.

Use of planning tools
In network planning, the use of planning tools is indispensable. Larger design companies use FTTH-specific planning software. This can process georeferenced data, optimize it and finally deliver a series of results automatically. Smaller planning companies use standard software tools for planning such as AutoCAD or Google Earth and thus have to create many result lists by hand.

Number of fibers
According to today's technologies, it is possible to route the traffic as well as the TV distribution for a customer over one single fiber. This is possible through the use of wavelength multiplexers.
As fiber costs account for only a small percentage of total project costs, more fiber is used. In practice, usually four fibers are provided per customer connection:

- 1 fiber for data transmission bidirectional
- 1 fiber for TV distribution

- 2 fibers as a reserve for the future

The reserve can also be used by other network operators. This supports the "open access" approach.

When planning private customer connections, 100 % of households or residential units are taken into account per building or address. The number of households is usually the same as the number of electricity meters. Optionally, one fiber per building can be provided for future building management.

For micro enterprises four fibers are to be provided, whereas for small and medium-sized companies fiber-optic cables with at least 12 fibers are used.

Number of pipe types

An empty pipe network should function with few different types of pipes, as minimum lengths must be procured on entire drums for each type of pipe. Usually you can get by with two to three different buriable microducts, a buriable single tube and possibly a DA50 cable protection tube.

Common planning errors

The most common planning errors are:

- laying of empty pipes in the local area without planning
- laying empty pipes without house branches
- too small sized main pipes / empty pipe capacities
- no definition of the fiber distributors and the central office
- island planning without backhaul
- planning without expertise

The planning process

The planning process should include four phases, which will be successively completed. Feedback loops can exist.

- definition of planning specifications
- strategic network planning
- rough network planning
- detailed network planning

Definition of Planning Specifications

- which areas have to be supplied and which extend of expansion stages?
- are there any expected development plans for private and commercial buildings?

- which areas are new developments (Green Field Installation), which are already built-up areas (Brown Field Installation)?
- are there existing roads (conduits, fiber optic cables, etc.) and other TC connection points?
- how many subscribers should be provided (households, companies, buildings, public institutions etc.)?
- are there already expressions of interest from potential customers?
- are there any interested network operators and service providers?
- should television be distributed as well? Where can the programs be sourced?

Strategic Network Planning

- where is the network being built?
- in which expansion steps will be built?
- is competition to be expected?
- which locations and executions are suitable for a local office?
- which cooperation partners are suitable?
- where can joint use or co-location be offered?
- are fiber distributors made above ground or underground?
- should only an empty pipe network be set up or the same fiber-optic cables installed?
- which dimensions are used for microtubes?
- how is the feeding of television realized?
- which possibilities of "open access" are planned?
- who will operate the network?
- scheduling
- clarification of possible subsidies
- rough cost estimate
- model of refinancing

Rough Network Planning

- defining the position and execution of the POP
- planning the backhaul line, if not already available
- determining the supply cells per fiber distributor
- determining the positions of the fiber distributors
- planning the routes for the feeder and drops
- dimensioning of cable conduits and fiber-optic cables

- lengths and minimum purchase quantities for conduits and fiber-optic cables depending on the version
- material lists of empty pipe connections, sleeves, fiber distributors and house connections
- georeferenced representation of the network
- scheduling
- statement of costs

Detailed Network Planning

- precise positioning of the POP, fiber distributors, routes, crossings and building entries
- exact specification of the material such as cable conduits, fiber-optic cables, fiber distributors, splice boxes and house entries
- revision of the material lists
- preparation of tender documents for civil engineering, materials and services
- concept for color coding for microtubes in microtube dressings
- concept for color coding for glass fibers
- splice plan for fiber-optic tapes
- labeling requirements
- project planning for execution
- execution plans for the civil engineering company
- scheduling and cost plan

A rough planning result is shown in the figure below.

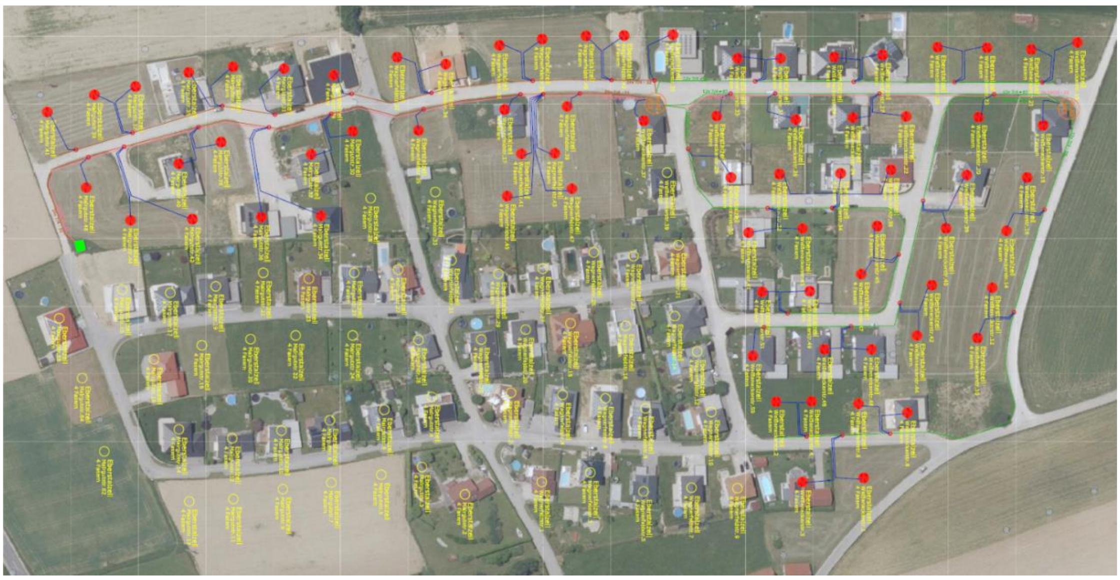

Figure 36: Example of rough planning

It can be seen in this exemplary planning that future construction areas are already taken into account with branches.

Today there is specialized planning software that supports the rough planning process. You can select objects from a library and place them. Some solutions also offer auto-routing. In addition to the geographical representation of the network, one also receives bills of materials, cost plans, route assignments, pipe plans, splice plans, etc.

7.1 Cost planning

An important part of an FTTH project is cost planning. From the point of view of an infrastructure contractor, cost planning can initially be limited to the investment costs. As a result, one can think about what the revenue model can be to refinance it.

For pure investment costs, there are a number of parameters that influence the outcome:

- number and type of potential customers
- number of buildings
- building density
- network expansion
- soil quality and surfaces
- reusability of the excavated material
- special civil engineering difficulties
- network architecture
- take rate
- co-relocation and other synergies
- length of backhaul lines

In the following, some calculation results are shown by way of example in order to show these dependencies. Modern planning software should make it possible to calculate and display several variants. The results presented here are based on assumptions that may vary depending on the project.

Investment costs depending on joint use

In this example, the civil engineering costs vary by co-laying (100 % without co-relocation, 50 % and 20 % cost share after co-relocation). As civil engineering accounts for a dominant share of costs, it is imperative to strive for the multiple use of a trench.

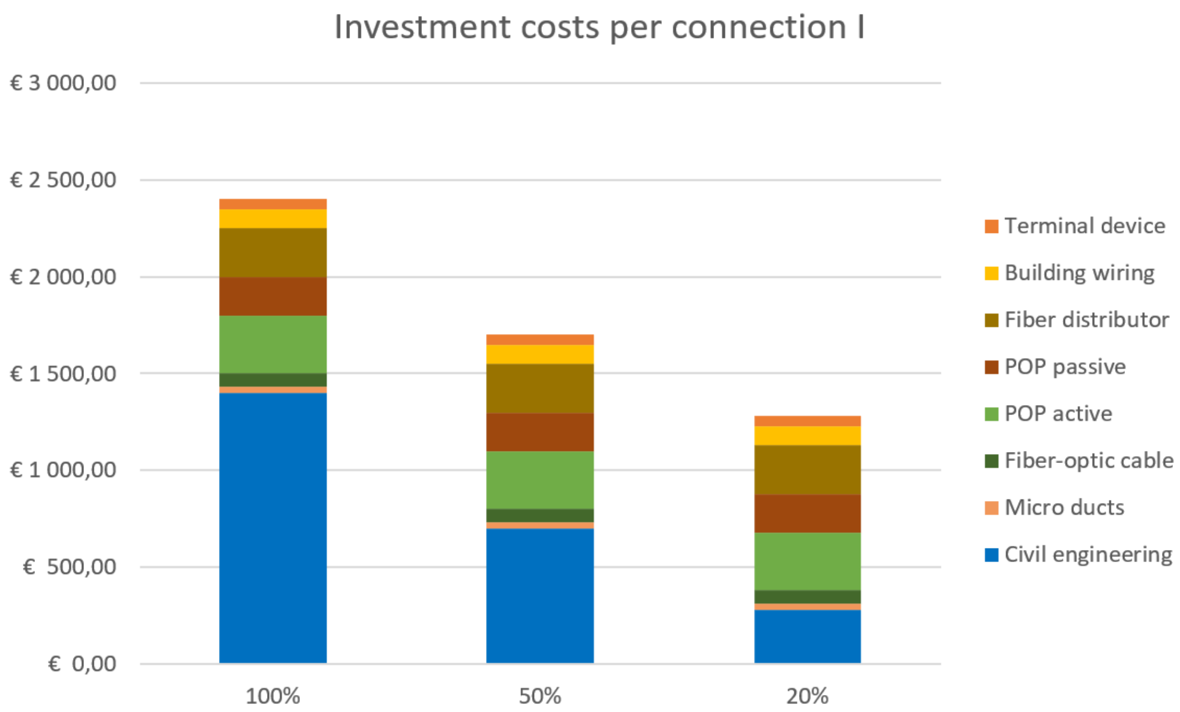

Figure 37: Investment costs depending on joint use

Investment costs after take-up rate

It is equally important that as many customers as possible can be acquired, otherwise there will be too high development costs. The common network sections must be split at a low take-up rate to fewer customers. This example shows the investment costs per connection for take-up rates of 100 %, 50 % and 30 %.

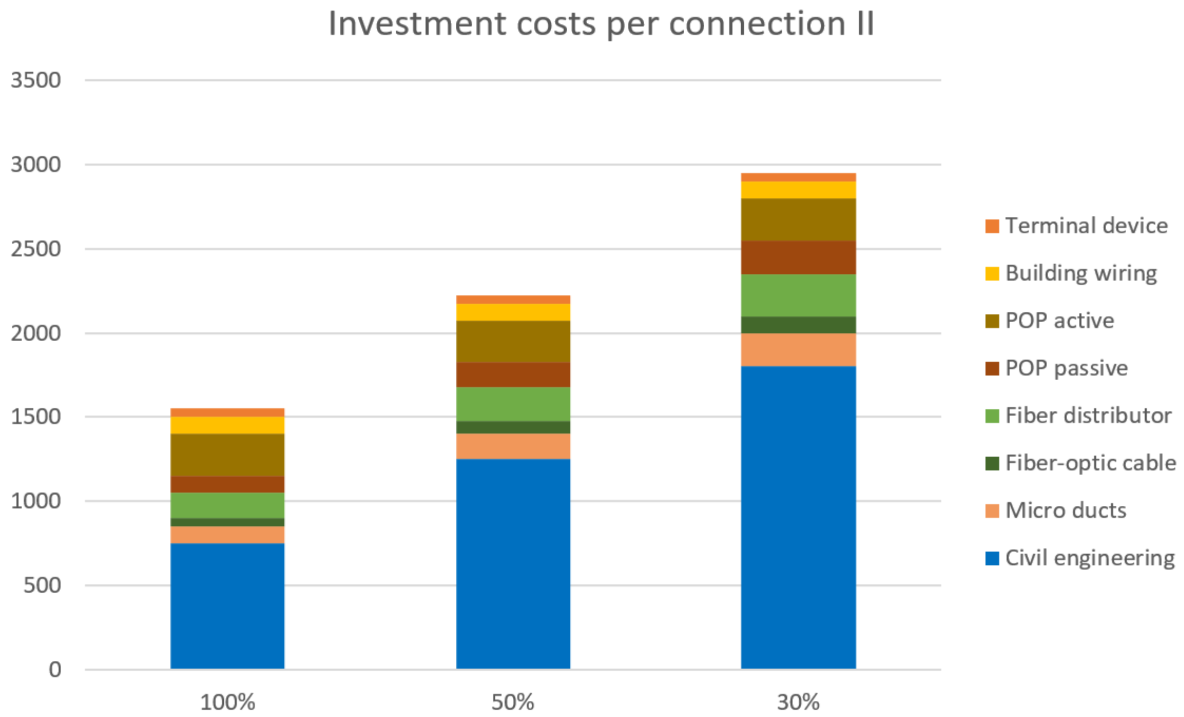

Figure 38: Investment costs after take-up rate

Cost shares

This diagram shows the proportionate installation costs of an FTTH network for a connection rate of 40 % without co-routing. It can be seen that the empty pipe system and the fiber-optic cables make up only a small part of the costs.

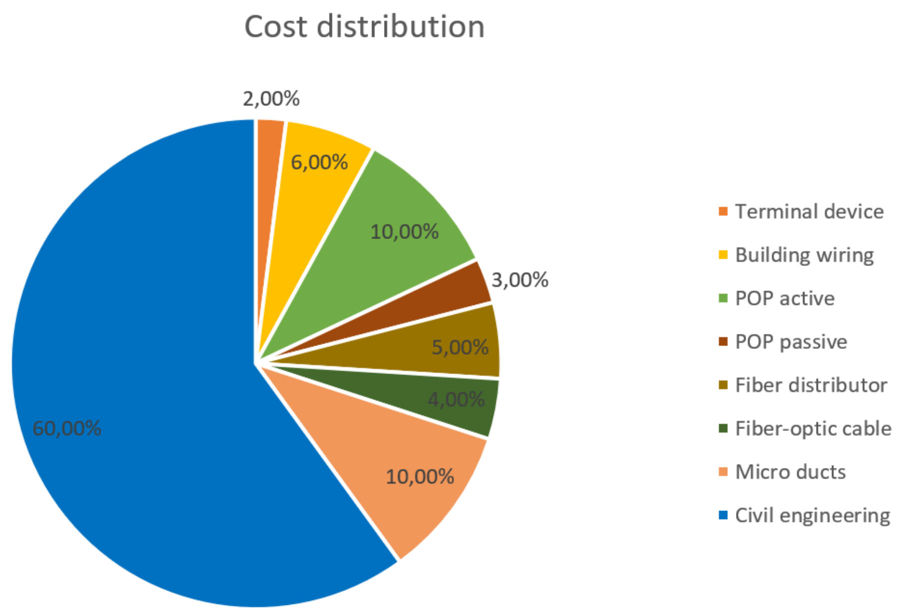

Figure 39: Cost distribution

8 Summary and outlook

8.1 Summary

The main objective of this paper is to show, that a comprehensive ultra-speed internet infrastructure on a FTTH basis is even possible in rural areas. This can be mainly achieved through two important factors, which are on the one hand conclusively substantiated planning of the infrastructure and on the other hand selecting the appropriate cabling method for a chosen section of the infrastructure development area. In order to strengthen this statement, the underlying thesis addresses four main aspects.

Firstly, it displays the current status of Austria, its comparison at European and global level, as well as future expectations in the broadband sector.

Secondly, it aims to give an overview of the fiber architecture, traditional wireline transmission techniques and various mobile transmission methods, with the aim to provide households with ultra-speed internet.

Thirdly, it contains several laying methods in the trench and trenchless sector so as to compare their different advantages and disadvantages in order to support the following planning guide.

Fourthly, it describes a profound planning guide for the realization of internet infrastructure especially in rural areas. Furthermore, this chapter includes some calculation results which emphasize that civil engineering costs are the main cost-drivers of those projects.

8.2 Outlook

Austria is lagging behind in broadband expansion. It is a fact, that one of the richest countries in the world has below-average values for factors that are very important for its future. However, it seems that politics has registered this problem and is already setting ambitious goals at regular intervals. The latest publication by the Federal Ministry for Transport, Innovation, and Technology (BMVIT) named “Broadband Strategy 2030” has the aim to achieve a nationwide coverage of Austria with ultra-speed internet by 2030. Such publications over the last decade express significant interest in becoming more active in this area, and with the corresponding commitment of political decision-makers, a higher interest in improvements is given for private investors, which will further lead to the demand for efficient processes and enhances the outlook of expansion of this critical infrastructure overall.

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10 List of Figures

11 List of Tables

12 List of Abbreviations

ADSL	Asymmetric Digital Subscriber Line
ADSS	All Dielectric Self Supporting
AN	Access Network
BEP	Building Entry Point
BN	Backhaul Network
CAPEX	Capital Expenditure
CN	Core Network
CO	Central Office
CPE	Customer Premises Equipment
DEMARC	Demarcation Point
DOCSIS	Data Over Cable Service Interface Specification
DSL	Digital Subscriber Line
DSLAM	Digital Subscriber Line Access Multiplexer
FOC	Fiber-Optic Cable
FTTB	Fiber to the Building
FTTC	Fiber to the Curb
FTTH	Fiber to the Home
GPON	Gigabit Passive Optical Network
HSDPA	High Speed Downlink Packet Access
HSPA+	High Speed Packet Access
HSUPA	High Speed Uplink Packet Access
ICT	Information and Communication Technology
IP	Internet Protocol
LTE	Long Term Evolution
MDF	Main Distribution Frame
NGMN	Next Generation Mobile Network
NGN	Next Generation Network
OAN	Optical Access Network
ONT	Optical Network Terminal
OTO	Optical Telecommunication Outlet
P2MP	Point-to-Multipoint
P2P	Point-to-Point
POP	Point of Presence
PSD-Shaping	Power Spectrum Density Shaping
SC	Switching Center
TC	Telecommunication
TKG	Telecommunications Act (Telekommunikationsgesetz)
UHF	Ultra-High Frequency
UMTS	Universal Mobile Telecommunication System
VDSL	Very High Speed Digital Subscriber Line
WiMax	Worldwide Interoperability for Microwave Access