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FINAL PROJECT

BUILDING AN ACCESS NETWORK FOR TRIPLE-PLAY SERVICES

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PREFACE

This final project was done for the TeliaSonera Broadband department. I would like to thank my colleagues who helped me in tight situations and especially Heikki Helin who instructed me on this project. Huge thanks go to Miika Niissalo who helped me find material for this project. Also a lot of thanks go to Jouko Kurki who supervised this project and Jonita Martelius who helped me with the language.

I would also like to thank my wife to be who had to endure a lot during the spring of 2008.

I learned a lot during this project and I am quite certain that the knowledge will help me after I graduate.

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Jan Doktar

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Tämä lopputyö on tehty TeliaSoneran Broadband -yksikölle. Projekti antaa yleiskatsauksen siihen miten palvelun tarjoaja voi rakentaa liityntäverkon, jolla voi tarjota triple-play palveluja. Projektissa on myös tietoa siitä, mitä laitteita tarvitaan ja mitä vaaditaan liityntä-, agregointi- ja reunaverkoilta.

Työn alussa kuvaillaan triple-play palvelu. Sen jälkeen siirrytään valokuitukaapeleihin, tekniikkaan ja verkkoarkkitehtuuriin. Työn lopussa on esimerkki liityntäverkon rakentamisesta ja koko prosessista. Se antaa katsauksen koko prosessiin ja ongelmiin joita verkkosuunnittelija saattaa kohdata projektin suunnitteluvaiheessa. Työ antaa myös suuntaa miten yksi alue suunnitellaan alusta loppuun.

Liityntäverkon rakentaminen jaetaan ajanjaksolle kahdeksasta kymmeneen vuotta. Tässä yksi vuosi on yksi vaihe projektia. Projektissa vaihe jaetaan kolmeen osaan; kohteiden ja alueiden valitseminen, kohteiden ja alueiden suunnittelu, ja dokumentointi. Esimerkki alue antaa suuntaa miten alue suunnitellaan. Alue on miltei mahdoton rakentaa yhdellä kertaa kokonaan. Tämä tarkoittaa sitä, että palvelun tarjoajan pitää suorittaa rakentaminen alueella kahdessa tai kolmessa vaiheessa. Alue katsotaan valmis, kun 80 % kiinteistöistä on kytketty liityntäverkkoon kuitukaapelilla.

Avainsanat: Ethernet, Valokuitu, Liityntä verkko, Metro Ethernet, Agregointi verkko

ABSTRACT

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This final project was made for the Broadband department of TeliaSonera. This project gives an overview on how internet service provider might build an access network so that they can offer triple-play services. It also gives information on what equipment is needed and what is required from the access, aggregation and edge networks.

The project starts by describing the triple-play service. Then it moves on to optical fiber cables, the network technology and network architecture. At the end of the project there is an example of the process and construction of the access network. It will give an overview of the total process and problems that a network planner might face during the planning phase of the project. It will give some indication on how one area is built from the start to finish. The conclusion of the project presents some points that must be taken into consideration when building an access network.

The building of an access network has to be divided to a time span of eight to ten years, where one year is one phase in the project. One phase is divided into three parts; Selecting the areas and targets, Planning the areas and targets, and Documentation. The example area gives indication on the planning of an area. It is almost impossible to connect all targets at the same time. This means that the service provider has to complete the construction in two or three parts. The area is considered to be complete when more than 80 % of the real estates have fiber.

Keywords: Ethernet, Optical Fiber, Access Network, Metro Ethernet, Aggregation Network

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LIST OF ACRONYMS

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ADSL Asynchronous Digital Subscriber Line

ATM Asynchronous Transfer Mode

BRAS Broadband Remote Access Server

CE Customer Edge

CoS Class of Service

DHCP Dynamic Host Configuration Protocol

DSL Digital Subscriber Line

DSLAM Digital Subscriber Line Access Multiplexer

EDA Ethernet DSL Access

ECN Ethernet Controller Node

FEA Fast Ethernet Access

GigE Gigabit Ethernet

HMDF House Main Distribution Frame

IEEE Institute of Electrical and Electronics Engineering

IP Intrnet Protocol

IPTV Internet Protocol Television

ISP Internet Service Provider

LAN Local Area Network

Mbps Megabit per second

ME Metro Ethernet

MEF Metro Ethernet Forum

MPLS Multiprotocol Label Switching

NVoD Near Video on Demand

OSI Open System Interconnection

PE Providers Edge

POP Point of Presence

QoS Quality of Service

TCP Transmission Control Protocol

WAN Wide Area Network

VLAN Virtual Local Area Network

VoIP Voice over IP

VoD Video on Demand

VPLS Virtual Privalte LAN Service

1 INTRODUCTION

The subject for this study came from a project at TeliaSonra, where they concentrate on building an access network to offer triple-play services in the biggest cities in Finland. The old copper cabling does not offer enough capacity to support the new service. This means that optical fiber cable and new equipment have to be installed.

Building an access network is a huge investment for the service provider. The access network has to meet the current requirements, but at the same time it must fulfil possible future needs. Executing a project that would build an access network that could last for decades requires careful planning, time and money.

The purpose of this study is to give the reader an overview of the total process as well as problems network planners might face during the planning phase of the project. It will give some indication on how one area is built from the start to finish. It will give information on the equipment and network architecture one might use during the project. The study also includes an evaluation of the TeliaSonera project that will be given only to the company. That is the reason why there is only a brief summary at the end of the study. The research for this study was done at the TeliaSonera Broadband Product & Production department, where the actual planning of the access network was executed. This study will use the information and experience from the TeliaSonera project to get a better understanding of the project and to help to avoid possible errors in the process.

The contents of this study are divided into a theoretical and practical part. Sections two to five is the theory and overview and section six is the practical part. Section two describes the triple-play service. Section three gives information on optical fiber cables. Section four describes the network architecture. Changes are needed at the access, aggregation and edge networks before triple-play service can be offered. Section five gives information on the Ericsson equipment that are installed into the house main distribution frame. Section six describes the project. Area and target selection and planning are included in section six which also includes documentation and the project summary.

2 TRIPLE-PLAY SERVICES

In the last few years, internet service providers (ISP) have started to offer triple-play services to end users. In simple terms that means that video, voice and data services are being sent over an IP network to customers. The most common data service is internet access, but now service providers can also offer premium gaming services and walled-garden services. Voice over IP (VoIP) is probably the best known service and has been on the market for some time now. The term triple-play came when video over IP came to be a reality. The service consists of live TV broadcasting and Video on Demand (VoD), which enables users to watch movies and TV shows on-demand. The shows are streamed over the IP network connection. Households can watch digital television channels over IP network (IPTV). This chapter will give an overview on the triple-play services.

2.1 Video over IP

IP television (IPTV) means that digital television channels are being transported over a packet network using multicasting technique. It is achieved by sending a single copy of a media stream into the network. Then the network replicates the stream to subscribers closer to the edge. This method saves bandwidth at the core. Before the stream can go into the IP core, it has to go through a process. First it goes to the video feed receiver and decoder, then to the IP encoder and encryption process. Now the stream is ready to go through the IP core network to the end user.

Users have the possibility to select normal broadcasting or Video on Demand (VoD). In normal broadcasting service providers offer different channel packets that can contain channels that normal TV does not offer. There are two basic models of VoD. The first is called Near Video on Demand (NVoD). In this model, customers can watch their favourite movies as many times as they want for a period of time. The downside is that the stream can not be paused or fast forwarded. The full Video on demand approach gives customers more choices. In this model, the stream is sent to the user when requested. From these two models the NVoD is older and not very popular with ISP anymore. A full on-demand service is what internet service providers are aiming at. [1]

2.2 Data Services

The most common data service is the internet access. It is also the main reason customers get a broadband connection. Nowadays every ISP can offer high speed connections at affordable prices. So it is the additional services that ISPs use to get an edge over competitors.

Premium gaming services attract customers to use ISP gaming servers. Customers want a lower ping and a higher priority for their gaming traffic. With a higher priority, gamers will get less latency and jitter. For online gamers latency is not as bad as jitter. Online gaming needs fast and consistent feedback of players' movements and actions to the server. Jitter makes the connection slower and inconsistent. One solution is to mark the IP traffic with a DiffServ priority number. This will give the gamers traffic a higher priority over best-effort traffic.

Walled-Garden services usually need a unique device to access the content, for example the mobile phone or a satellite radio receiver. Accessing the internet from your mobile phone is probably the best known service. Customers can send e-mail, read the news and subscribe content such as games and other software.

2.3 Voice Services

Voice over IP (VoIP) has been very popular for many years and is the only narrowband service of triple-play. Users have had the chance to use Skype or Vonage to talk to each other over the internet for free and this makes it a familiar service. Now ISPs are offering data and video services, but at the same time they give users the possibility to use VoIP. It can offer services that were very difficult or too expensive for traditional phone lines. Users can now log onto a portal and enable a second VoIP line to the household. Now it is also possible to transmit more than one telephone call down the same broadband –connected telephone line. This makes adding extra phone lines to home or office very easy. VoIP also has 3-way calling, call forwarding, automatic redial and caller ID. These are all features that traditionally where chargeable. [1]

3 OPTICAL FIBER CABLES

To understand the network architecture, one has to be familiar with the basics of optical fiber cable. The development of fiber has come a long way since the 1970, when the world saw the first modern optical fiber. The basic idea is very simple. Light travels through glass. Optical fiber cable is a cable containing one or more optic fibers. This section will focus on the basic components of optical fiber cable. It will also answer questions on how and why the cable is constructed and protected.

3.1 Indoor and Outdoor Cable

The most common and recommended fiber type for access and backbone cabling is the ITU-T G.652 standard single-mode optical fiber. It is optimized for use at the 1310nm wavelength region, but it can also be used at the 1550nm wavelength. The attenuation is ≤ 0,45 dB/km in the G.652 standard at the 1310nm wavelength is. If the wavelength is 1550nm then the attenuation is ≤ 0,28 dB/km. The most notable dispersion in single mode fiber is the chromatic dispersion and in the G.652 standard at the wavelength of 1285-1310nm it is ≤ 3,5ps/(nmxkm). The cut-off wavelength is the smallest wavelength that the light will travel as single mode. In the G.652.A it is ≤ 1260nm. [3]

Cables can be divided into two categories, outdoor cables and indoor cables. Because there are different conditions outdoors and indoors, the cables have to be equally different. This division is important because it affects the reliability of the cables. There are also cable models that combine the qualities of outdoor and indoor cables. It is used by ISP for campus and building backbone cable. Because installing cable is more expensive than the fibre itself, the cable usually has more than one fibre. A small cable consists of 1, 2, 4, 6 or 12 fibers. A medium size cable has 18, 24, 30 or 36 fibers. The large cables start from 48 fibers and go up in steps of 12. Table 1 shows the main qualities of indoor and outdoor cables. [2] [3]

Outdoor cable	Indoor cable
Mechanically stronger, thick and rigid	Lighter by structure, thin and flexible
Needs to withstand outdoor temperatures, water and sunlight, temperature where there is no attenuation change -30 - +60°C	Needs to have adequate fire safety: Halogen free, creates little or no smoke and fire retardant
Needs to withstand outdoor conditions when installing	Installation to tight places cant be a problem

Table 1, Outdoor and indoor cable [2]

The most common cables are direct burial and duct cables for the campus backbone cabling and the outdoor/indoor cable for campus and building backbone cabling.

3.2 Cable Protection

Optical fiber has to be protected, before it can be used in the field. Without protection it can easily break. To make the fiber strong it is enclosed in a protected sleeve or sleeves, also known as jackets or buffers. The first set of protection is known as primary protection. The overall protection of the cable depends on the use. Some cables will be installed inside so the protection is light. While other cables are installed outside so they need a better protection against water, cold, sun light, rodents and road construction. They also need to withstand these conditions for several decades. Different coating methods are displayed in Figure 1 [2]

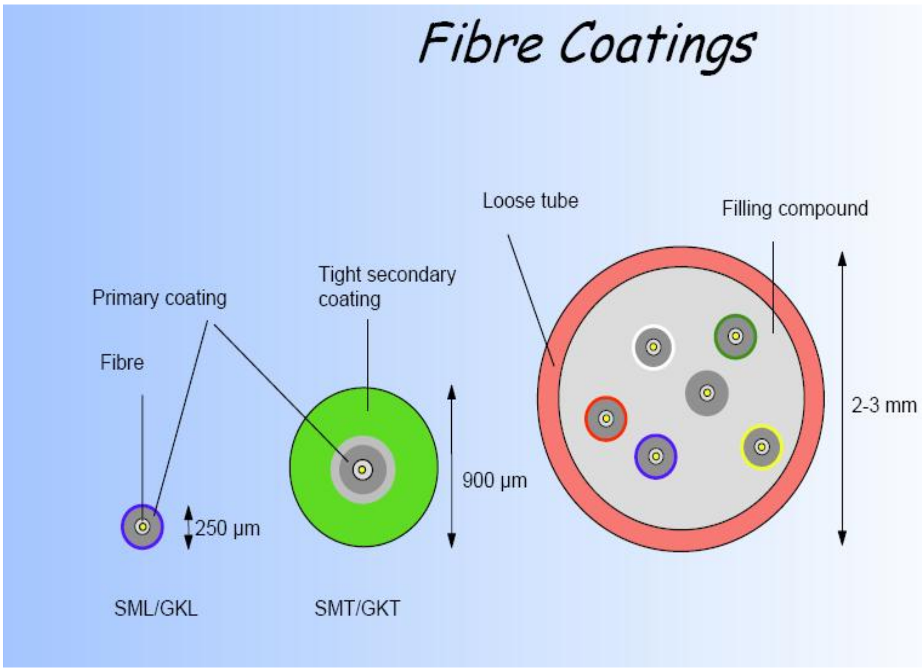

Figure 1 Fiber coatings, tight buffer and loose tube. [4]

Figure 1 shows different coating methods. There are two types of secondary protection for fibers, loose tube and tight buffer. Usually tight buffer cable is used inside buildings and loose tube outdoors. Tight buffer is typically just another coating on top of the primary protection. The diameter is typically $900\mu m$. In Loose tube protection, a hollow tube surrounds the fiber or fibers. The diameter is around $2-3mm$. In Figure 2, all the core structures are presented. [2] [3]

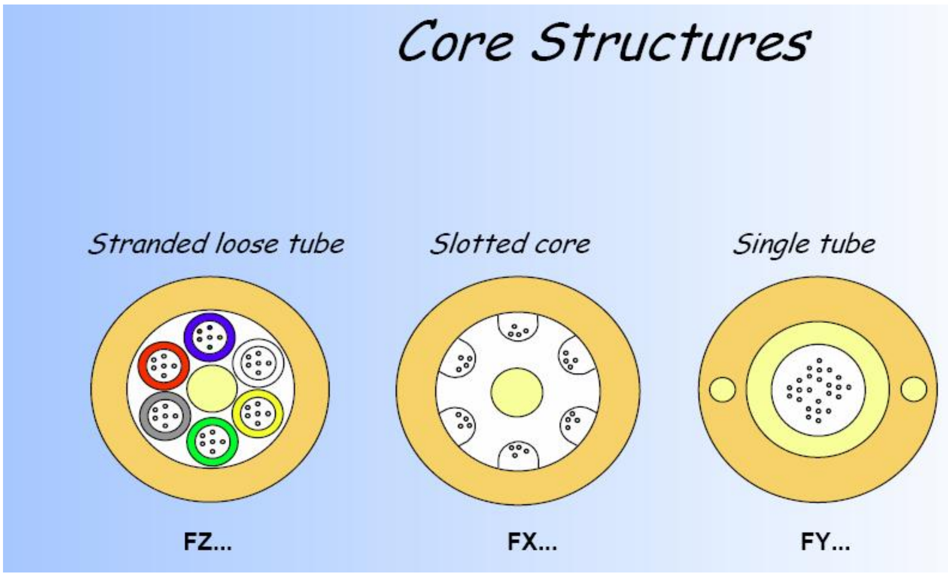

Figure 2, Core structures. [4]

Figure 2 shows the different core structures. After the secondary coating, there are three types of core structures. In standard lose tube the secondary coated cables are around a central element. The cable can be tight or loose. It depends on the secondary protection. The first optical cables were loose tube design and it still is a very popular cable. Next there is the single tube design. The heart of the cable is a strength member. Inside the strengthening member there are primary coated cables in a loose formation. The diameter of the pipe is around 5-10 mm. This design has a very good crushing protection. This is achieved by placing strengthening members inside the jacket and the core. The third design is called slotted core. The core is a plastic rod that has slots for the primary coated cables. This design has a good crushing strength and installing it is simple. This is because it has easy access to the fibres. One can take the fibres out one by one or in groups. In the center of the cable is a pulling element. [3]

3.3 Pulling Element and Strength Members

When installing fiber cable, it is pulled. The pulling will usually break the glass fibers, so some protection against it is needed. The protection has to be strong enough so that the cable can be moved without breaking the glass. This is why the cable is reinforced with strength members and pulling elements.

There are many different kinds of strength members and pulling elements and the location in the cable depends on the structure. In Standard loose tube and Slotted core the pulling element is in the centre of the cable (Figure 2). The material used for the element is either metal or non-metal. If metal, it is usually steel fiber that has been galvanized or copper plated. The non-metal choice for the element is plastic that has been reinforced with glass fiber. For further protection Kevlar is installed in the cable. In Single tube the fibers are at the centre. This means that the elements are at the sides of the cable (Figure 2). [2][3]

3.4 Cable Filling

Cables are installed outdoors and indoors. To protect the cable from water and moisture it is filled with gel or filling grease. The filling does not leave room for water. If for some reason water leaks to the cable, it does not have room to do any damage. This is because the filling stops the spreading of water. The filling can also be expanding fibers. When water comes in contact with them, they expand and block the water from reaching the core. [3]

3.5 Transceivers and Receivers

In order for the signal to go through the fiber it needs a transmitter to transmit the signal and a receiver to convert the signal back to electrical. In almost all cases the transmitter is either a Light Emitting Diode (LED) or Light Amplification by Stimulated Emission of Radiation (Laser). Transmitters need to be durable. They have to work at room temperatures continuously for many years. Also it must be possible to modulate the light output over a range of modulating frequencies. The output wavelength should coincide with the fiber type used. The receivers use a photodiode to convert the signal back to electrical. Two types can be used, a PIN photodiode and an Avalanche photodiode. [4]

3.6 Connectors

Optical cable by itself does not do very much. You have to connect the fibers in order to establish a connection. Connectors at the end of the fibre enable one to connect the fibers to equipment like routers for example. There are also Adapters that make it possible to connect two fibers to each other. The basic parameters for connectors are

1. *Insertion loss*

   If two connectors are connected with an adapter and the loss of the system is increased by for example 0.3 dB. Then the 0.3 dB is the insertion loss. Typically the value is around 0.2 - 0.5 dB per mated pair.

2. *Return loss*

   Fresnel reflection measure. The power reflected off a connector back to the light source. Typically around -40 dB.

3. *Mating durability*

   Also known as Insertion loss change. Indicates the increase in Insertion loss after the connector has been connected and disconnected a number of times. Typically around 0.2 dB per 1000 matings.

4. *Operating temperature*

   Compatible with optic fiber cables. Typically around -25C to +80C.

5. *Cable retention*

   Also known as tensile strength or pull-out loading. The number indicates what kind of load the connector can handle before the fibre is pulled out of the connection. Typically around 200N.

6. *Repeatability*

   Indicates how consistent the insertion loss is when a joint is disconnected and remade. Not always found in specifications because there is no uniform method of measuring it. Sometimes manufacturers describe repeatability as high or very high. [3]

   Some different connector types are shown in Figures 3 and 4.

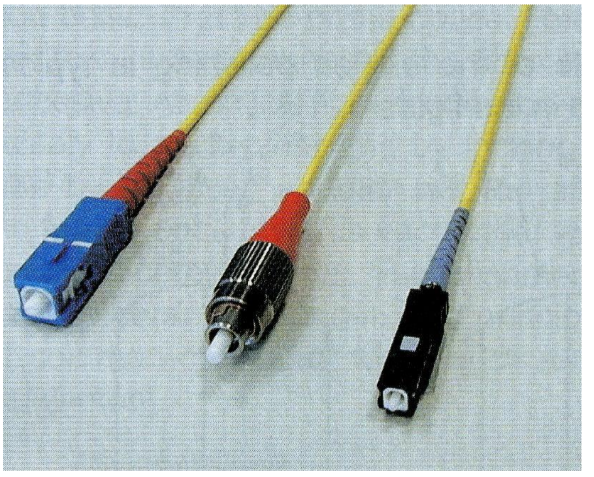

Figure 3, SC-connector, FC-connector and MU-connector [4]

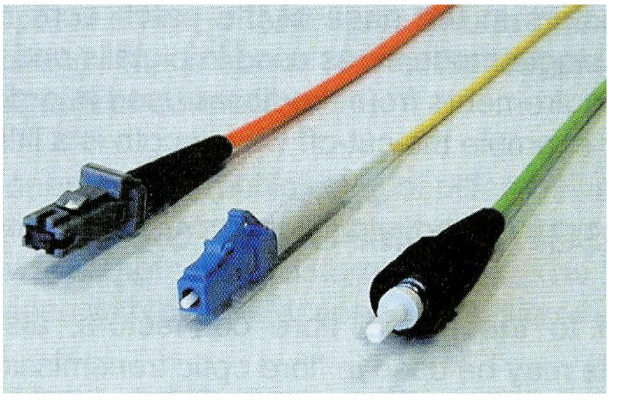

Figure 4, MT-RJ-connector, LC-connector and ST-connector [4]

The most common connector is the SC-connector (Figure 3, first on the left). It offers excellent packing density and the push-pull design of the connector reduces the chance of fiber end face contact damage during connection. The SC-connector has insertion loss of 0,2 - 0,45 dB and a return loss of ≥ 50dB. Its repeatability is around ≤ 0,3 dB for 500 matings.

The LC connector (Figure 3, in the middle) is slowly replacing the SC connector because of its small size. It has a insertion loss of ≤ 0,3 dB and a return loss of 55 dB. The repeatability is ≤ 0,3 dB for 500 matings. [2][3]

4 NETWORK ARCHITECTURE

This chapter will give an overview of the network architecture of a service provider. Before the customer can access the internet, three things have to be in place; Access Network, Aggregation Network and Edge Network. When all three network elements are put together, internet service provider can offer high bandwidth broadband access to business and individual customers.

4.1 Access Network

Eriksson's solution to the access network is Fast Ethernet Access Network (FEA Network). The main goal in FEA Network solution is to provide a high capacity broadband access based on Ethernet (IEEE 802.3) over fiber. FEA gives internet service providers the opportunity to offer services to residential users and small to medium businesses. [17]

In FEA, The traffic is carried by Ethernet frames within a structure of separate logical networks, over a common physical infrastructure. The logical networks are based on Virtual LAN (VLAN) technology (IEEE802.1Q). Figure 5 represents a FEA network. [5]

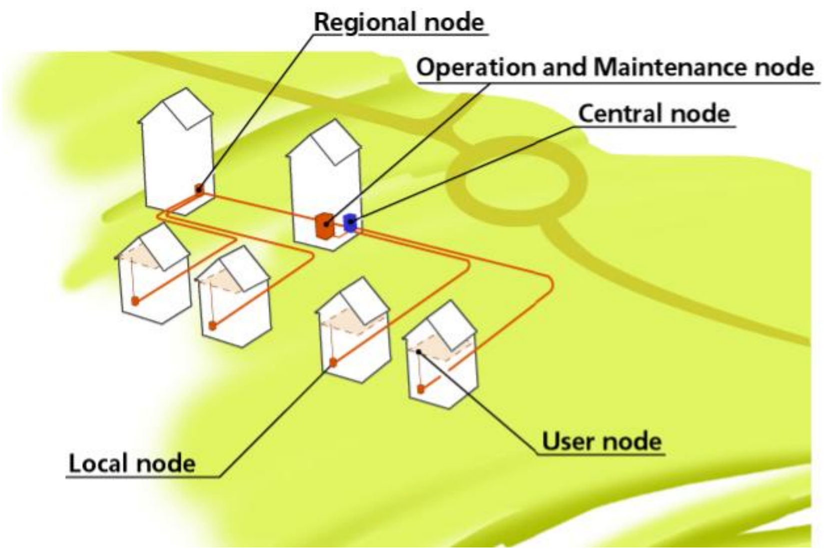

Figure 5, Fast Ethernet Access Network [6]

Figure 5 shows the different elements of the FEA network. The user node is connected to the Local Node in two different ways. In Ericsson's Ethernet Digital Subscriber Line Access solution this connection is made by ADSL and in FEA the connection is made by Category 5 or Category 6 cable. The FEA solution also supports fiber to the home feature. From there, the connection goes through the Regional Node to the Central Node.

4.1.1 User Node

From the end-user's perspective, the User Node is where the Fiber Ethernet Access begins. It is where the service providers' interface starts. The available services to the end user depend on the in-house cabling that connects the User Node to the Local Node. A User Node can do the following tasks: Physical media conversions (fiber-copper), Ethernet switching (one or several user ports), IP address translation (routing, filtering), Voice over IP encoding and decoding (VoIP Gateway) and Supervision of its own functionality for remote management. Different user nodes are presented in Figure 6.

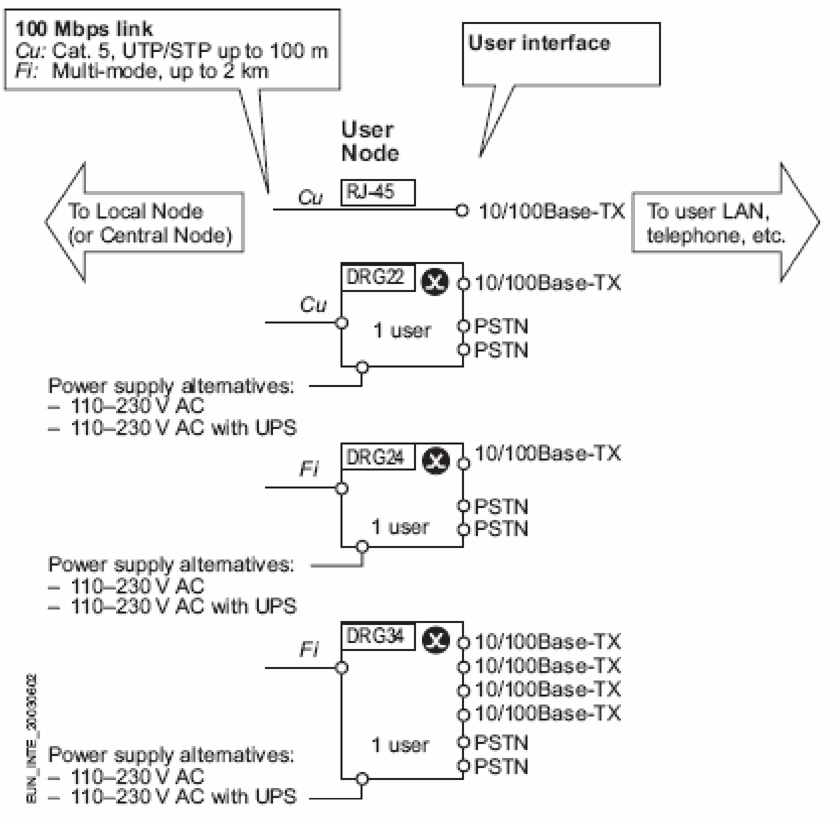

Figure 6, User Node alternatives [5]

The figure shows four different types of user nodes. Two are connected with copper and two with fiber. The basic model has just one Ethernet connection. Then there is the fourth model that has four Ethernet connections and two telephone lines. The connection speed between the User node and Local node is 100 Mbps. Using Cat6 in-house cabling the connection could be as high as 1 Gbps. [5] [6]

4.1.2 Local Node

The task of the Local node is to connect the User nodes to the Regional or Central node. It handles the upstream traffic for further transport. In the downstream direction, it handles traffic distribution and service delivery towards end user-devices. A Local node can perform the following tasks; Assignment and classification of traffic into separated logical networks, Priority handling of traffic for subscribed services, Selective filtering of end-user generated traffic, Supervision of its own vital functional entities, Control of used bandwidth per port and service. The Local node is usually located in the house main distribution frame (HMDF). Figure 7 shows two switches that are chained to create 48 downlink ports, which means that 48 households can be connected to the internet service provider's network.

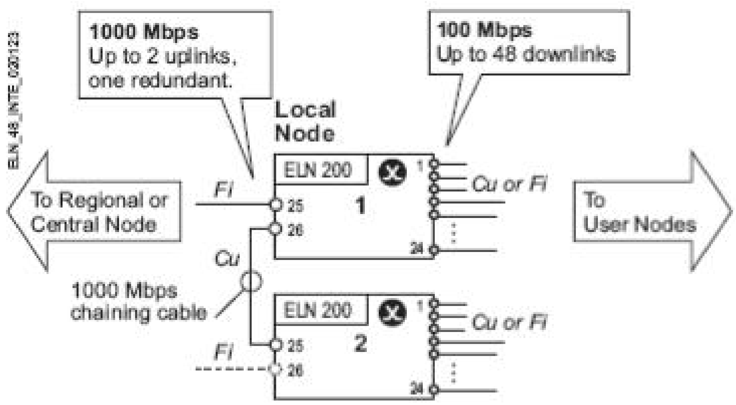

Figure 7, Local node [5]

In the figure above, the Local node aggregates the user connections to the Regional or Central node. The connection speed between the Local node and Regional node is 1 Gbps. The recommended maximum distance between the Local node and the Central node is 5km using the 1000Base-LX standard with single mode optical fiber at wavelength of 1310nm. [5] [6]

4.1.3 Regional Node

When building a Network, the Regional node is optional. It is used to support the hierarchical network structure (Figure 8). Its task is to aggregate Local node connections to the Central node. Regional nodes are used when the distance between Local node and Central node is too long. But the usage mostly depends on the excising fibers at the area.

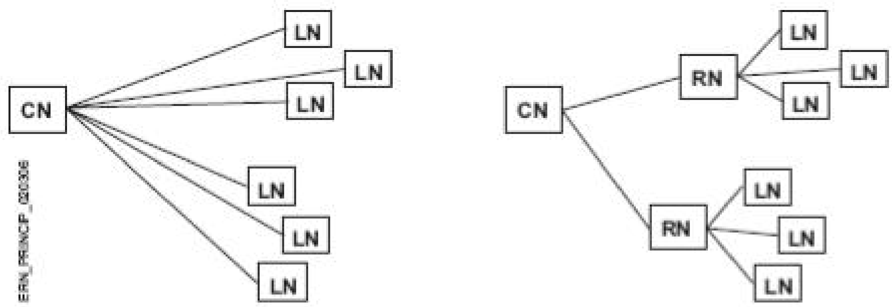

Figure 8, FEA Network without and with Regional node [5]

For example, if there is plenty of fiber at the area all Local nodes can be connected to the Central node individually using fiber pairs. This is the recommended solution to all areas. But, when there are just a few fiber pairs available Regional nodes can be used to connect a number of Local nodes to the Central node using one fiber pair.

Regional node can offer network efficiency in traffic aggregation and distribution. At the same time it decreases the number of access network interfaces needed in the Central node. Figure 9 represents a Regional node interface.

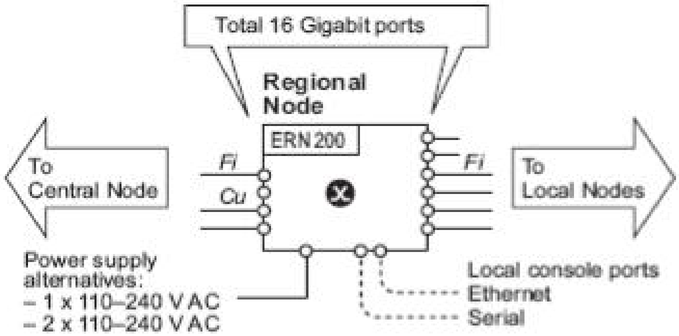

Figure 9, Regional node interface [5]

The figure above shows the Regional node aggregating the Local node connections into a one fiber connection. The speed between the Regional node and Central node is 1 to 4 Gbps. [5] [6]

4.1.4 Central Node

The most important node in the FEA is the Central node. It is basically the heart of the FEA network. It provides higher levels of connectivity between connected end users and service providers. It also supports monitoring and control of user traffic, for security and integrity purposes. The main tasks of the Central node are; to route all traffic to and from end users, to forward any allowed traffic pertaining to locally provisioned services, to connect all underlying Local nodes, to supervise its own functional entities. Figure 10 represents a Central node interface.

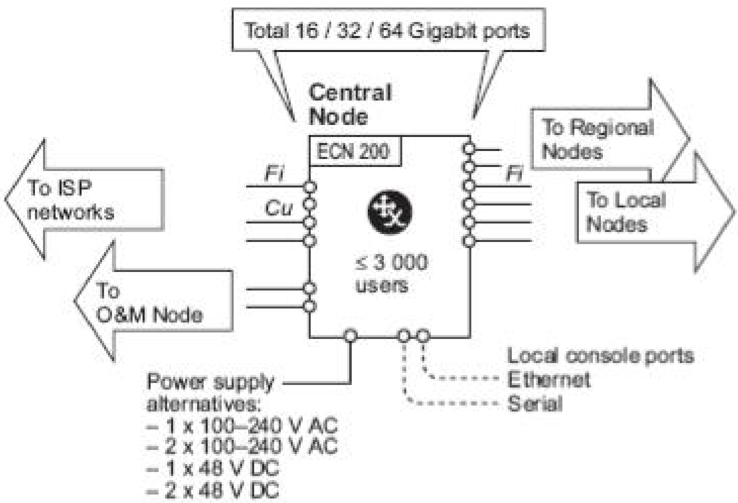

Figure 10, Central node interface [5]

In the figure above the Central node aggregates the Regional and Local node connections to the Metro Ethernet network. In the internet service providers network the Central node can also be a Metro Ethernet router. [5] [6]

4.2 Aggregation Network

Metro Ethernet (ME) network is an Ethernet based network platform. Service providers are starting to use Metro Ethernet to build a smarter and more efficient aggregation network. Using Metro Ethernet, service providers can offer Ethernet based network services cost-efficiently to end users and business customers. It is based on Ethernet standard IEEE802.3. It uses Multiprotocol Label Switching (MPLS) and L2 Virtual Private Network techniques. Metro Ethernet Forum (MEF) has been developing the ME services. Currently there are a total of 17 different MEF specifications that are divided into four categories. Table 2 is a list of the specifications. [7] [17]

Standards Body	Ethernet Services	Architecture/ Control	Ethernet OAM	Ethernet Interfaces
Metro Ethernet Forum - MEF	*MEF 10* – Service Attributes *MEF 3* – Circuit Emulation *MEF 6* – Service Definition *MEF 8* – PDH Emulation *MEF 9* – Test Suites *MEF 14* – Test Suites	*MEF 4* – Generic Architecture *MEF 2* – Protection Req & Framework *MEF 11* – UNI Req & Framework *MEF 12* - Layer Architecture	*MEF 7*– EMS-NMS Info Model *MEF 15*– NE Management Req	*MEF 13* - UNI Type 1 *MEF 16* – ELMI

Table 2, Metro Ethernet Forum Specifications [7]

The MEF specifications in Table 2 enable the following features in the internet service providers network; standardized services, network scalability, network reliability, Quality of Service (QoS) and service management. [7]

The ME network can offer point to point or point to multipoint services to customers. Service providers can offer customers connection speeds from 1GE optical to 10/100/1000 Mbit/s electrical. The speed of the connections can be configured to offer customers a variation of speeds. The ME network as a service platform is presented in Figure 11.

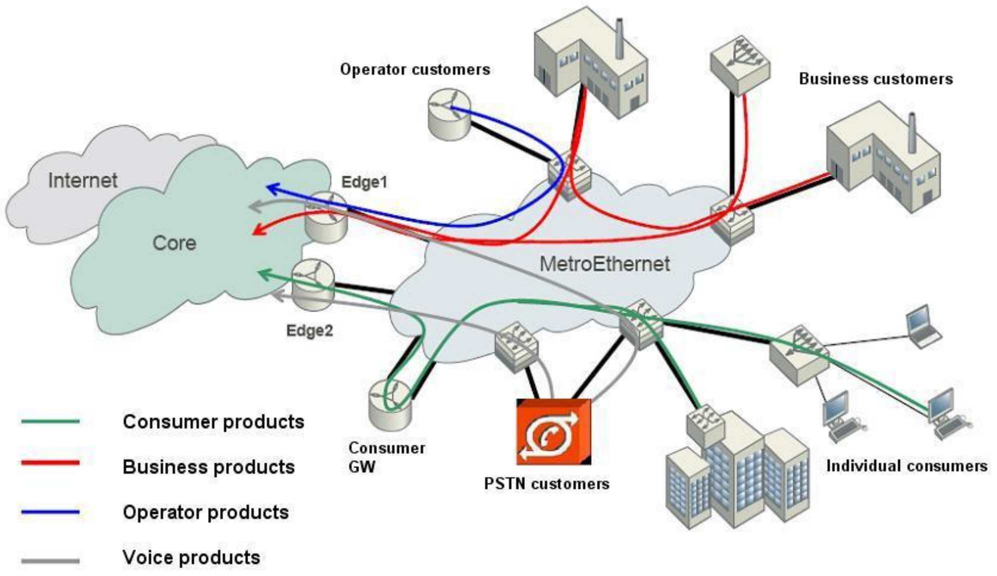

Figure 11, Metro Ethernet as a platform [8]

As figure 8 illustrates, ME network is a platform for many services. It is very useful for internal connections and to forward connections to other networks. ME can offer transit connections to operators as well as direct connections to business customers. It also provides backbone connections for Multi-Dwelling access. Service providers can also connect individual customers to the IP world through the ME. The network does not cover the whole Finland, but the ME areas are connected through the IP core network.

When planning the ME network, one must take into account the available fibers at he area. Also it is very important to pay attention to existing and future Place of Presence (POP) facilities.

The ME network consists of core nodes and access nodes. The access node is the same as the central node in the FEA network. It is connected to two Core nodes using two fiber pairs. These pairs have to have a different route and can not be in contact at any given time. This gives the access node an uninterruptible connection. If something happens to one of the fiber pairs, the access node will maintain the connection using the other pair. Access nodes will be installed next to core nodes for client connections. This is because if clients are connected straight to the core node the connection capacity will diminish. This will lead to big investments to get more connection capacity for other services and for routing purposes. Figure 12 shows an example of a metropolitan area Metro Ethernet network.

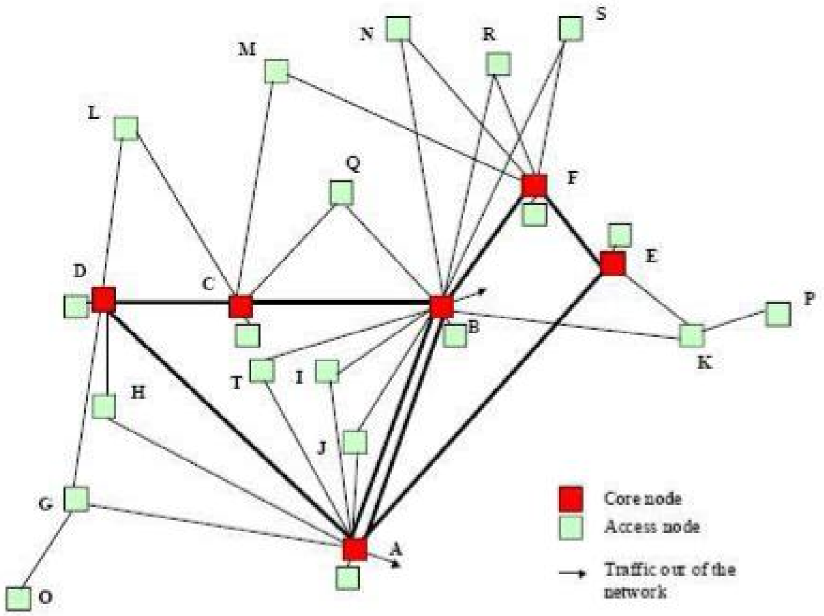

Figure 12, Metro Ethernet Network [8]

The example in the figure above consists of six core nodes and twenty access nodes. All nodes, except O and P, are connected with two fiber pairs. The connection between A and B is ensured using two fiber pairs. These pairs are from a different cable so that the connection is uninterruptible. Access nodes are connected to two core nodes for the same reason. [8]

4.2.1 Multiprotocol Label Switching

The ME network uses Multiprotocol Label Switching (MPLS) for data carrying. It operates between OSI Model Layer 2 and Layer 3 and is sometimes referred to as “Layer 2.5” protocol. MPLS can provide data-carrying services to circuit-based clients and packet-switching clients. It can carry various types of traffic from IP packets and Ethernet frames to ATM and SONET. The general label format of MPLS is illustrated in Figure 13.

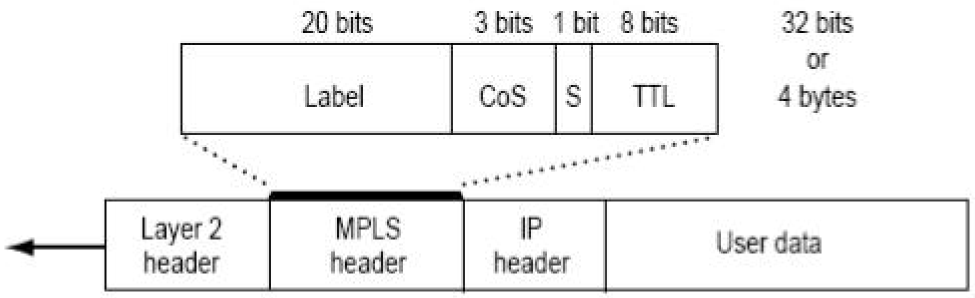

Figure 13, General MPLS label format. [9]

In the figure above, incoming data is given an MPLS header. It can contain one or more labels, also known as a label stack. One label takes 20 bits. In a MPLS network the entry and exit routers are known as Label Edge Routers. These routers insert MPLS labels onto incoming packets and take them off from outgoing packets. MPLS uses the following protocols for label distribution. [9]

- Label Distribution Protocol (LDP) – maps unicast IP destinations into labels
- Resource Reservation Protocol (RSVP) – used for traffic engineering and resource reservation
- protocol-independent multicast (PIM) – used for multicast states label mapping
- Border Gateway Protocol (BGP) – external labels (VPN)

4.2.2 Virtual Private LAN Service

MPLS was introduced in the late 1990s. Due to the new MPLS a number of Virtual Private Network (VPN) types were introduced. One simple way to classify the numerous MPLS-based VPNs is to use the service being offered to the customer. This results in three main categories.

- Layer 3 multipoint VPNs also known as IP VPNs or Virtual Private Routed Networks (VPRN)
- Layer 2 point-to-point VPNs. A collection of Virtual Leased Lines (VLL) or Pseudo Wires (PW)
- Layer 2 multipoint VPNs or Virtual Private LAN Service (VPLS)

IP VPN and VPLS are multipoint services. The difference between them is that VPLS can transport non IP traffic and it can also use the advantages of Ethernet. Service providers use VPLS within their network to aggregate services for delivery to residential and enterprise customers. [10] [11]

VPLS enables multiple locations to be connected in a single domain over providers managed IP/MPLS network, like Metro Ethernet network. This gives the impression that the multiple enterprise sites are on the same Local Area Network, regardless of the physical location. For a service provider to have a VPLS-capable network, it must have Customer Edges (CE), Provider Edges (PE) and a core MPLS network. The CE is a router or a switch. It is usually located at the customer’s premises, but it can also be at the service providers POP. This means that the CE can be managed and owned by the customer or the service provider. Ethernet interface is between the CE and the PE. The connection between the PE and CE is often optical fiber. The PE is located at the service providers POP. This is where the VPLS originates and terminates. This is also the place where all the VPLS tunnels are set up to connect to the other PEs. The Metro Ethernet network or IP/ MPLS core network connects the PEs together. It does not participate in the VPN functionality. The traffic is just switched based on the MPLS labels. Figure 14 represents the VPLS reference model.

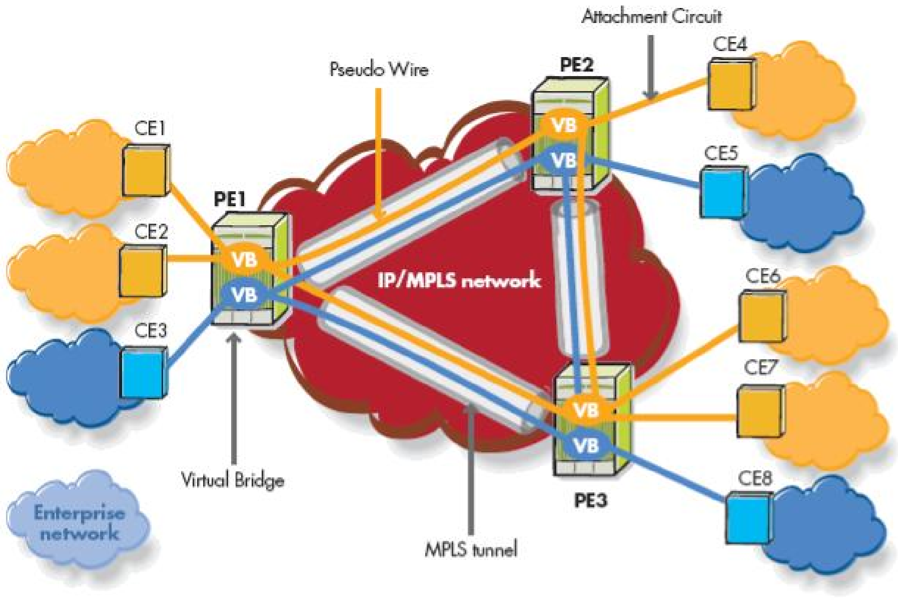

Figure 14, VPLS reference model [10]

In the figure 14, full mesh MPLS tunnels are between the provider edges (PE). This is the basis of any virtual private network service. Inside the tunnels there are inner tunnels (pseudo wires) that connect the participating PEs in the virtual private LAN service. The blue and orange customer edges (CE) appear to be in the same LAN as long as they are using the virtual private LAN service. [10] [11]

4.3 Edge Network

Service providers are beginning to offer next generation services such as triple play for customers and businesses. The new service consists of IPTV, voice over IP (VoIP) and data. Because the triple play significantly increases the bandwidth per subscriber, the network architecture is shifting from centralized model to a distributed model. In general, this means that a simple DSL aggregation layer is evolving towards a scalable multi-gigabit Ethernet. At the edge of the network it means that the old Broadband Remote Access Server (BRAS) products will have to move aside to give room for new Ethernet-centric edge routers. The starting point for building next generation network architecture is basically the same for all service providers. The main task in the old model was increasing access rates from dial-up speeds to the modest broadband data rates. The new services bring more variables to be taken into consideration when building next generation networks. The two new architectures that are now emerging are centralized architecture and distributed architecture. Figures 15 and 16 represent a centralized architecture and a distributed architecture. [12]

The centralized model is very similar to existing old broadband edge architectures. In this model, the network is centralized around the BRAS products. They aggregate the output from DSLAMs, provide end users with point-to-point protocol or IP-over ATM and enforce quality of service. Also, they route traffic to an internet service provider's backbone network. The architecture is called "centralized" because BRAS is the centralized control point for QoS policies for all services. This model is a simple-minded Layer 2 aggregation network. Figure 15 represents a centralized architecture.

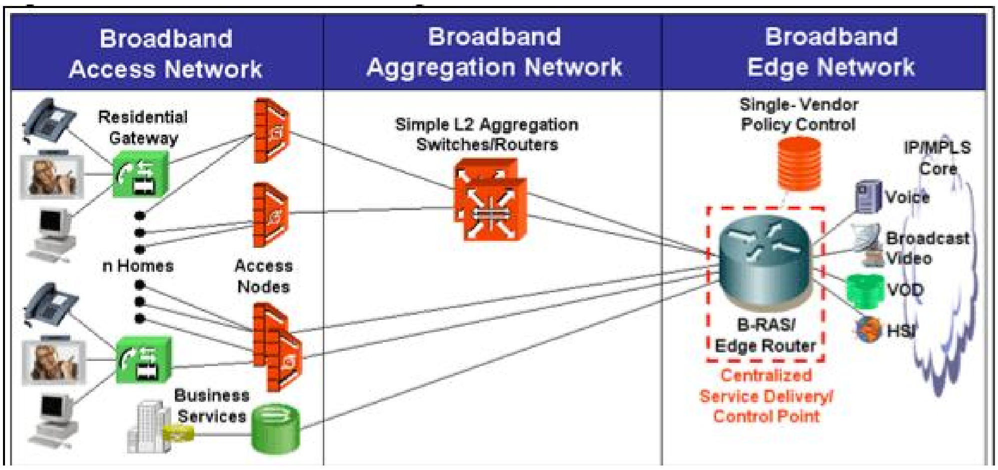

Figure 15, Centralized Architecture [12]

Figure 15 above represents the centralized architecture. The broadband access network has a limited visibility into the access link bandwidth and also into the available DSLAM capacity. Furthermore, it has a limited integration with end to end policy control. This extends from broadband access network to the broadband aggregation network. In the aggregation network, the port density of GigE/10-GigE is also limited. The edge network relies on high-cost BRAS routers. There are potential scaling issues in the network when it has large amounts of IPTV and VOD traffic. Because this model focuses on high speed internet, it compromises the high availability of the network. There is also limited support for converged business services. When taking all the limitation into account, one can easily see that the centralized model is a small improvement to the old model.

The distributed architecture is optimized specifically for the new network requirements and services. The new model distributes the functions among the IP service edge router, the GigE aggregation switch and the Ethernet/IP DSLAMs. So it basically redefines the traditional BRAS. QoS enforcing is distributed among the access, aggregation and edge network elements. The basic idea is that all services are centrally managed and the policy enforcement is distributed to access, aggregation and service edge router layers.

The architecture is built to support increased system capacity, port density and distributed subscriber density. These are the requirements from the network if the ISP wants to offer IP video services.

Ethernet is the key element in this architecture. It gives network planners the ability to create some intelligence to the network, especially in the aggregation layer. The scalability and distributed policy enforcement in the network is optimized using GigE aggregation devices. The aggregation layer also uses Virtual LANs (VLANs) to manage QoS per subscriber. VLANs are also used at the IP edge to manage QoS per service. Figure 16 illustrates the distributed edge architecture. [12]

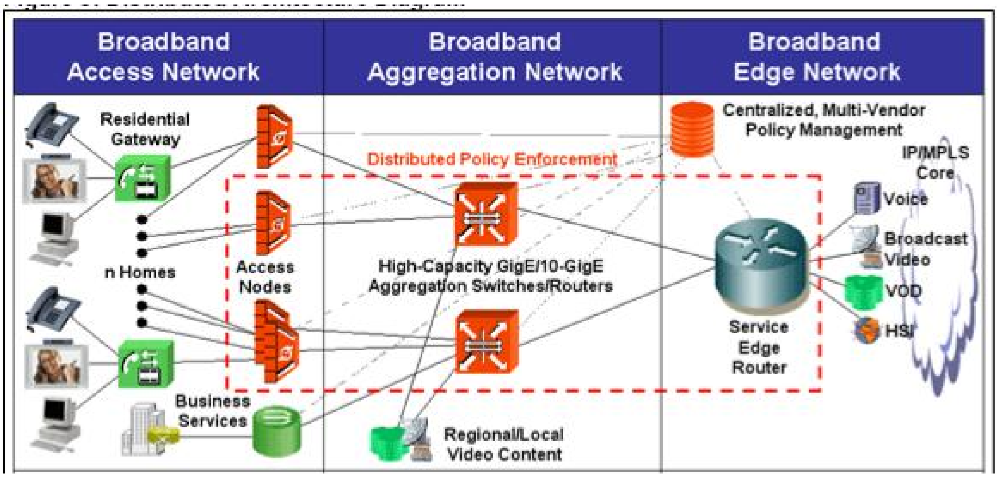

Figure 16, Distributed Architecture [12]

In the figure above, the access layer has some intelligence distributed to Ethernet and IP DSLAMs. This enables the access layer to get a better understanding of the available bandwidth and DSLAM capacity available to edge and aggregation layer. This layer also has centralized policy management and distributed subscriber-centric features. As mentioned above, the aggregation layer handles QoS, security, anti-spoofing, authentication accounting and multicasting per subscriber. To achieve high availability, the layer has carrier Ethernet equipment that gives the ISP the chance to provide non-stop services. To get some workload off the edge router, the regional and local TV channels are connected to the network using the Ethernet equipment in the aggregation layer. The support of MPLS and VPLS is a key feature in building a fully functional Metro Ethernet network. At the edge of the network a high-capacity router handles the per-service QoS, security and multicast routing. Because the router has higher capacity than the old BRAS it becomes more cost efficient. The edge of the network has centralized policy management, but the enforcement is distributed throughout the network. [12]

5 EQUIPMENT

Fiber will carry the data stream from point A to B, but it needs help from equipment to succeed. There are a lot of companies providing equipment for the access network. The reason why Ericsson is used as a provider is because TeliaSonera uses the Ericsson solution. The in-house cabling determines what kind of equipment the house main distributing frame (HMDF) needs. If the in-house cabling is Category 3 (Cat3) or older, the HMDF needs the Ericsson Ethernet DSL Access (EDA) solution. If the cabling is Category 5 (Cat5) or better, the HMDF needs the Ericsson Fast Ethernet Access solution (FEA). The equipment that Ericsson provides to these solutions are the Ericsson Ethernet Controller node model ECN320, ECN330 and Ethernet Access Node model EFN324. The EDA solution also needs an Ericsson IP DSLAM model EDN312 or a similar device. Broadband Remote Access Servers (BRAS) are at the end of the network. Through them, clients and the whole network are connected to the IP world. In this chapter the different equipment are introduced. Also the key features are summarized.

5.1 Ericsson Ethernet Controller Node ECN320 and IP DSLAM EDN312

When the in-house cabling is Cat3, an Ericson Ethernet Controller Node model ECN320 (Figure 17) is installed in the HMDF. It is connected to the Metro Ethernet network by single mode optical fiber. The speed of the connection between Metro Ethernet and the ECN320 is 1 Gigabit/s. IP-DSLAMs, in this case the EDN312 (Figure 18), are connected to the ECN320. The connection speed between the ECN320 and the EDN312 is 100Mbps.

Ericsson Ethernet Controller Node 320

- For downlink the node uses 24 IEEE 802.3 10/100Base-T/TX ports
- For uplink the node uses two IEEE 802.3ab10/100/1000 Mbps Ethernet on twisted pair or two 1000 Mbps optical interfaces
- Uses IEEE 802.1Q VLAN to separate traffic types or different services and to improve security
- Uses Internet Group Management Protocol (IGMP) to multicast video streams and multicast loading of IP DSLAMS

Figure 17, ECN320 [13]

IP DSLAM EDN312

- Has 12 lines for ADSL downlink
    - Asymmetric up to 13,4/1,6 Mbps (ITU G.992.1 Annex A, ADSL)
    - Symmetric up to 24/3,5 Mbps (ITU G.992.3 Annex M, ADSL2+)
- One 100 Mbps Ethernet uplink

Figure 18, EDN312 [14]

There are two kinds of ECN-switches, the 320 model and the 330 model. The main difference is that the 330 model has three trunk ports and the 320 model has only two. The trunk ports can be used for connecting to the network or chaining the switches.

The switches can also be chained to create more available ports for IP-DSLAMs. This can be achieved by disabling the EDA Management Proxy (EMP) attribute from all other switches except the root switch. The chained switches are the same as the root switch but work as data transmission switches. They are called Ethernet Switching Node (ESN) 310s.

Quality of service is achieved by priority queues. Some applications such as voice over IP, video conferencing and video broadcasting are very delay-sensitive. These applications will get a higher priority. This allows the packets to pass trough the switch first. [13] [14] [17]

5.2 Ericsson Ethernet Access Node EFN324 for Fiber and Cat5

When the in-house cabling is Cat5 or better, the Ericsson Ethernet Fiber Node 324 (EFN324, Figure 19) is installed to the HMDF. With this switch there no need for IP-DSLAMs or ADSL modems. The customers are connected to the switch by Cat5/Cat6 cabling or by optical fiber. The connection speed for the clients is configured at the switch. The maximum speed for the clients is 100Mb/s. The EFN324 is connected to the Metro Ethernet network the same way the ECN320 is. [15]

Figure 19, EFN324 [15]

Ericsson Ethernet Fiber Node EFN324

- For uplink the node has 2 Combo Gigabit Ethernet ports, RJ45 or SFP (SMF, MMF) according to IEEE 802.3z
- For downlink there are three versions of the node
  - The EFN324f model has 24 Fast Ethernet ports 100Base-10BX-D, single mode, single fiber, SC-SSF connectors, according to IEEE 802.3u
  - The EFN324df model has 24 Fast Ethernet ports 100Base-FX, multi mode, dual fiber, SC connectors, according to IEEE 802.3u
  - The EFN324c model has 24 Fast Ethernet ports 100Base-T, CAT5/RJ45 connectors, according to IEEE 802.3u
- Uses IEEE 802.1Q VLAN tagging to separate traffic types or different services and to improve security
- Multicast video streaming with IGMP proxy and IGMP snooping

The EFN324 is a second generation fiber access product. It uses the latest technology and standards to provide up to date services to end users. [15] [17]

5.3 Cisco 7600 Router Series

The Cisco 7600 router series can work as the Broadband Remote Access Server (BRAS) in the service providers EDGE Network. Its task is to route traffic to and from the aggregation network and to connect the network to the IP world. Cisco 7600 routers provide robust performance and IP/Multiprotocol Label Switching (MPLS) at the network edge. It gives service providers a chance to build an advanced network infrastructure that will support IP video and triple play (voice, video and data) applications. The routers provide WAN and metropolitan-area network (MAN) networking. It can also act as a devise for peering, a residential broadband service aggregator, a devise for Metro Ethernet aggregation and uplink. It meets the requirements for numerous tasks. The router has a forwarding rate of 240 Mbps distributed and 480 Gbps total throughput. [16]

6 BUILDING AN ACCESS NETWORK

Building an Access Network basically means that the service provider has decided to extend the reach of its network to new customers. The goal is to build new and extend the existing optical fiber network in the biggest cities in Finland. The building mainly concentrates in areas where traditional contenders are stronger or where the service provider does not have its own copper cabling.

Fiber to the Building (FTTB) enables service providers to offer customers Triple-Play services. Households can connect to the internet using 100 Megabyte high speed internet connections. They will also have the chance to watch IPTV, talk to friends and family using VoIP and hopefully in the future be able to use VOD.

The construction and planning of fiber routes and equipment takes the most time in the project. The network is expanded systematically to one city area at a time. In order for the project to work and stay on schedule it needs seamless co-operation between different departments, between the constructors and with equipment and material suppliers. The infrastructure department will handle the lead role in the project, because the building of pipelines and fiber routes takes the most time. The IP department is responsible for the HMDF and Metro Ethernet equipment.

From the real estate’s point of view, investing in optical fiber is investing in the future. If the real estate has optical fiber and in-house cabling updated up to modern standards (Cat5 or better) it increases the property value.

Although the whole project could take years to finish and would need big investments the result is an optical fiber network that will last for decades. It will serve end users and businesses for years to come. It is almost a guarantee that the investment the internet service provider makes will be a profitable one.

The project can be divided into three parts.

- The first part consists of selecting the areas and the targets. This typically takes two to three months. A more detailed description, see subchapter 6.1

- The second part is the route planning and sending the invitation for tenders to constructors. This typically takes three to four months. A more detailed description, see subchapter 6.2

- The last part is the pre- and final documentation of the areas and the targets into the database. This can take up to six months because the final documentation can be done after the whole area is finished. A more detailed description, see subchapter 6.3

6.1 Selecting areas and targets

The project starts by selecting the areas in which the internet service provider wants to extend its optical fiber network. It is almost impossible to build an access network for the whole city at the same time. This means that the city has to be divided into areas. Then the areas are constructed within a time period of eight to ten. In order for an area to be selected it has to fulfill certain criteria. For example population density has an important role in the selection of an area. Some areas can be selected just because the construction is cheaper and easier. This means a smaller investment in that area. That leads to the possibility to make bigger investments in some other areas that need more construction. There are also priority targets that influence the selection. Each service provider has its own priority targets. The list below is an example.

1. Leased copper lines from the contender, service providers own priority

2. GSM/3G base station, service providers own priority. The need to replace copper connections with fiber access

3. Company A, a business who wants a fiber connection to their residential buildings

4. Company B, a business who wants a fiber connection to their office buildings

All of the areas are given a priority number from one to five. The number simply indicates the importance of that particular area.

6.1.1 Selecting the real estates

After the area selection is finished the target selection can start. First the priority targets are marked on the map. This gives an indication on how much construction is needed. Then the targets on route to the priority target are marked on the map. Figure 21 represents a metropolitan city area.

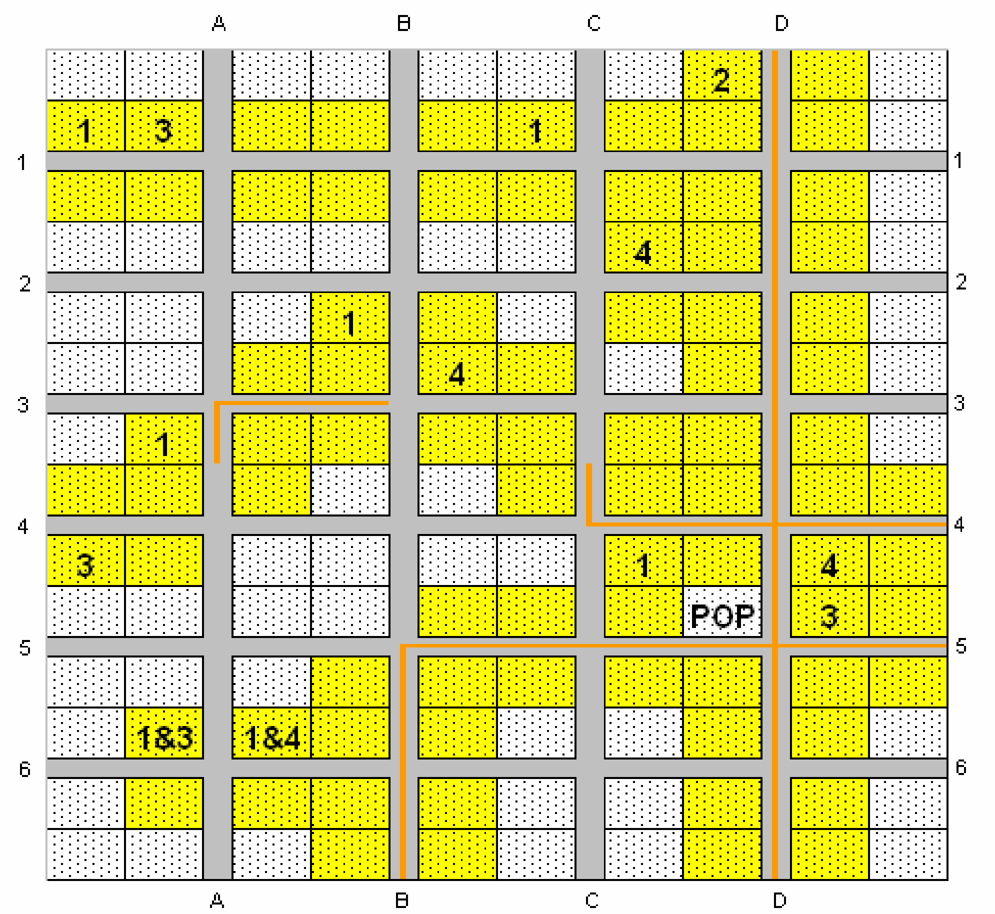

Figure 21, Selecting the targets

The figure above is an example area in downtown Helsinki that has 140 real estates. One street block consists of four real estates. The numbers one to four represent the priority target real estates. The blocks that are yellow are real estates that need minimal construction or they are on route to the priority targets. The orange line represents internet service providers pipeline in which the optical fiber cable is installed. Although there is only one orange line on one street, in reality the pipeline goes on both sides of the street. Also, every crossroad has two fiber wells. The service provider’s POP can be found at the crossroad of 5 street and D street.

In order for a real estate to be selected it has to have over a certain number of households. The exact amount is decided at the beginning of the project. The first list of addresses is gathered based upon the yellow real estates. In this case a total of 84 targets. Then the total amount of construction is calculated using the map application (see 9.2). This gives an indication on how much investment per household is needed in this area. If the investment is too high, some targets are dropped from the list to decrease the investment. By comparing Figures 20 and 21 one can see that the number of targets is dropped from 84 to 65. Taking targets off the list sometimes means that priority targets are also dropped. These targets can be reselected at a later stage of the project.

After the final address list is ready and the targets are marked on the map they are sent to the constructor. They start the process of getting permissions for the installation of fiber and equipment to the HMDF from the real estates. The constructors also make the in-house cabling report. This report indicates the location of the HMDF and what type of in-house cabling the real-estate has. They also figure out what is the best possible route to the HMDF. The information is then sent back to the service provider so that the second phase of the project can start.

6.2 Planning of areas and targets

The second phase of the project is the planning of pipeline construction, placement of the new cable wells, fiber junction locations and fiber routes. First the pipeline route is carefully planned. This is by no means a simple task due to the amount of pipeline already installed beneath the streets. Sometimes there is no room for new pipes and a different route has to be selected. Also the number of pipes installed has to be decided. In downtown Helsinki one might install a bundle of eight pipes. Then again in other parts of Helsinki a bundle of two pipes is more than enough. Another thing that has to be taken into consideration is the street coating. The streets can be covered with special stone. This means that the recoating will be more expensive than normal street pavement.

The placement of cable wells is important, because one well costs as much as 16 meters of new pipeline. The well is also permanent, once in place the location cannot be changed. A cable well is a hole in the ground with a lid and it is between the pipelines. The diameter of a well is 1.2 or 1.5 meters and the depth is 0.75-1.5 meters. Optical fiber cable can go through a cable well or a fiber junction can be placed in the well. A common place for a well is a street crossing.

After the placement of pipelines and wells is decided the construction plans have to be sent to the city. Then a city official either approves or rejects the plans. This process can take up to four weeks.

It is at this point that the area priority numbers are reselected. The area that needs the most construction is given a priority number one. The area that needs the second-most construction is given a priority number two and so on until every area has a new priority number. This is done simply because the area that has the most construction takes the longest time to finish. Then the order folder is put together and it is given to the constructor so that they can start the work. The order folder contains all the necessary information that the constructor needs in order to complete the construction. Figure 22 represents the downtown Helsinki area with new construction plans marked in red.

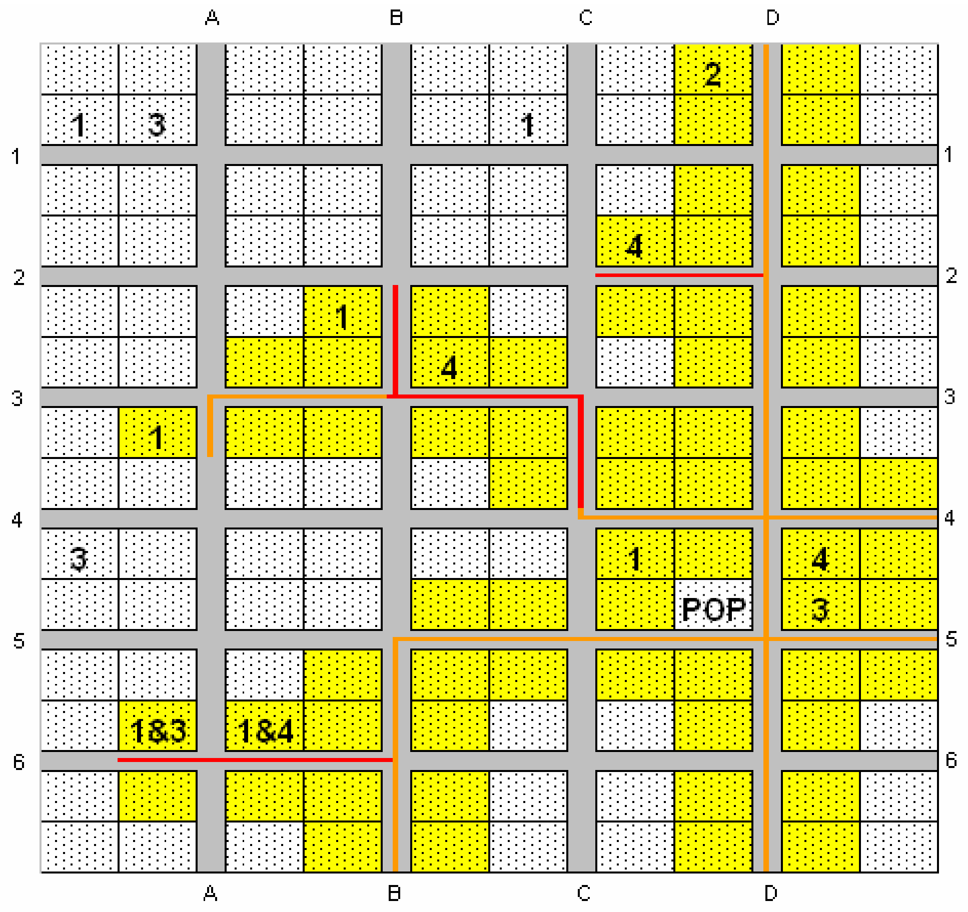

Figure 22, Planning the fiber routes

As the Figure 22 shows, new pipeline is installed to extend the reach of the access network. Because the area is in downtown Helsinki, a bundle of eight pipes is installed. This gives enough capacity for the cables now and for future needs. The construction is from crossroad A6 to B6, from C2 to D2 and from B2 to B3 to C3 and to C4. The pipeline in crossroad A3 and B3 has been constructed in a communal project with another service provider. Two new wells are placed at the crossroads of B2, B3, C3, C2 and A6.

The amount of cable needed is a mater of opinion. If the real estates are connected using one fiber pair, a total of 130 fibers are needed. Connecting the real estates with two fiber pairs, one for the broadband connection and one for spare, 260 fibers would be needed. Four 96 fiber cables are used to connect the real estates to the service providers network. Two fiber pairs will be brought into the real estates HMDF. The cable routes can be seen in Appendix 1 to 4.

This plan would connect 65 real estates into the service providers network. The area has a total of 140 real estates, so about 46.5% of the area would be connected with fiber. 53.5% of the real estates did not make the list. This means that the service provider can come back to the area in a later stage of the project and continue the construction. An area is finished when 80% of the real estates have fiber. This number of course varies from area to area.

The installation of the Ericsson equipment is an easy task after the fiber is in place. ISP orders the instalment of 65 switches from the constructor. After that, sales department can start to sell the new services to the real estates.

6.3 Documentation of area targets

Every pipeline, well, cable and junction has to be documented. This takes place in two stages, pre- and final documentation. Pre documentation is done simultaneously with the planning of fiber cable routs. The final documentation is done when the cables and equipment are installed. The two main programs that have to be updated are the graphical documentation tool and map application. Also a fiber junction scheme has to be drawn. The different documentation methods display similar information, but all three have a different use.

Graphical Documentation Tool

The main program used to document the network is the Graphical Documentation Tool. Every cable, HMDF, POP, fiber rack, fiber well, fiber junction, switch and router must be in the database. Everything is placed into their geographical location. The user can search for available or current connections from a precise HMDF.

The fiber routes, new wells and new HMDF are saved into the database. To separate the new from the old every new thing is marked with red until the project is finished. After the construction is done the connections are routed into the database and the new materials are marked as done.

Map Application

Map Application basically resembles the applications one might find in the Internet with a few modifications. The pipelines, cables, wells, junctions and HMDF are placed on top of the map. It is used to give a geographical view of an area. The construction plans are drawn on top of the map application. This gives the constructors an idea of where they have to dig and how much. The application also shows what real estates have fiber and which ones need construction. The first investment estimation is calculated based on the distances calculated from the application.

Fiber Junction Scheme

The fiber junction scheme shows the route of the fiber cable. The route starts from the POP and ends in the last HMDF. Every new cable is given a number and a fiber junction scheme. The most important information on the scheme is the fiber junctions. The cable is illustrated as a single line until it reaches the first cable well where it connects to a fiber junction. The scheme shows which cable comes in, for example a 48 fiber cable and which cables leave, for example two 24 fiber cables. It also displays which fiber pairs go into the first 24 fiber cable and which fiber pairs go into the next 24 fiber cable.

6.4 Summary

Building an Access Network for triple-play is a long process, because it needs considerable amounts of road construction. It is best to divide the city into areas and then divide the total construction into 8 to 10 years. During the first two years, when the total process is relatively new, service provider might have just a few areas where they are executing constructions. After the learning period of two years, it is best to slowly increase the number of areas each year. The infrastructure is the most important part, because it has to last for decades. A well built infrastructure now will serve the service provider for years to come. So it is best to invest time and money to minimize mistakes and to maximize future benefits.

The actual equipment installed into the HMDF is secondary. This is because technology advances quickly. The equipment installed now will be replaced in three to five years. However, the Ericsson EDA and FEA solutions give internet service providers the possibility to offer triple-play services now. The FEA solution is the latest edge technology for the Access Network and will probably have a life span of at least five years.

If the service provider wants to offer up to date services to customers it needs to make big investments. Although the technology advances quickly, the investment has to be made at some point in order for the company to stay competitive. Today the service is triple-play, but tomorrow it could be something entirely different, but at least something is certain, because the service will most definitely use the fibers installed now.

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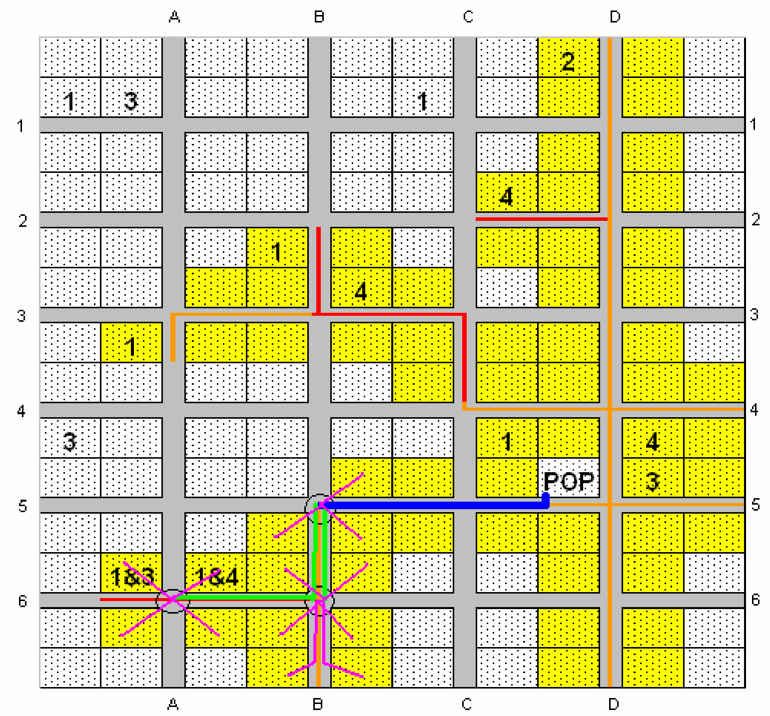
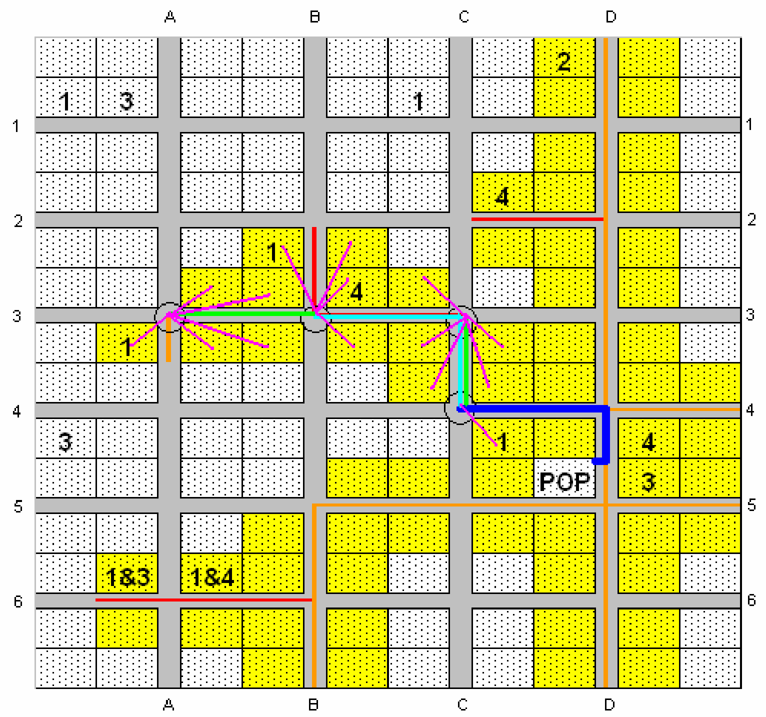


A 96 fiber cable leaves the service providers POP. The first fiber junction is placed at the corner of 5 street and B street. From there, two 24 fiber cables continue and three 12 fiber cables are used to connect three real estates. The first 24 fiber cable stops at the corner of 6 street and B street and a fiber junction is placed there. Six real estates are connected to the network using six 12 fiber cables. The other 24 fiber cable continues to the corner of 6 street and A street. Four real estates are connected using four 12 fiber cables.



A 96 fiber cable leaves the service providers POP. The first fiber junction is placed at the corner of 4 street and C street. From there, one 24 fiber cable and one 48 fiber cable continue and one 12 fiber cable is used to connect one real estate. The 24 fiber cable stops at the corner of 3 street and C street and a fiber junction is placed there. Five real estates are connected to the network using five 12 fiber cables. The 48 fiber cable continues to the corner of 3 street and B street. Four real estates are connected using four 12 fiber cables. A 24 fiber cable continues to the corner of 3 street and A street. Five 12 fiber cable are used to connect five real estates

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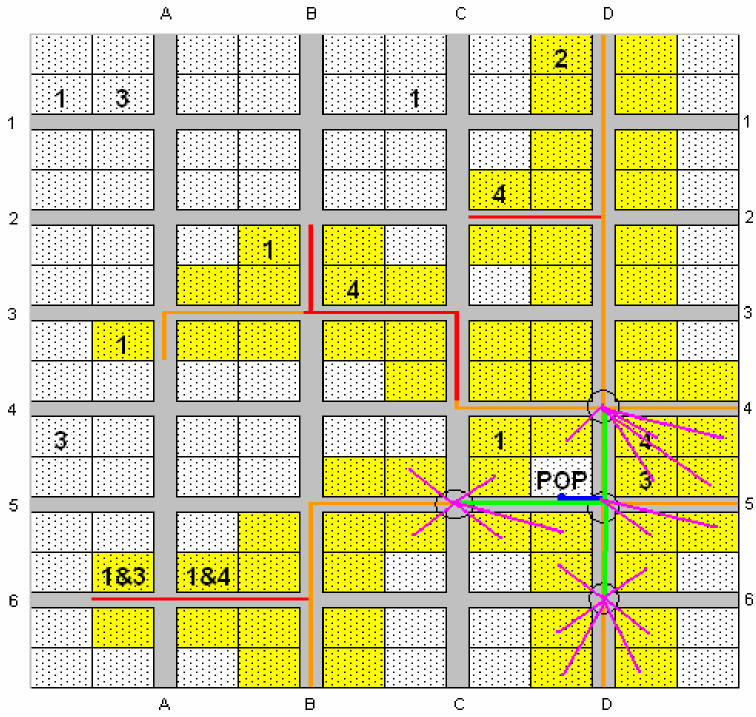
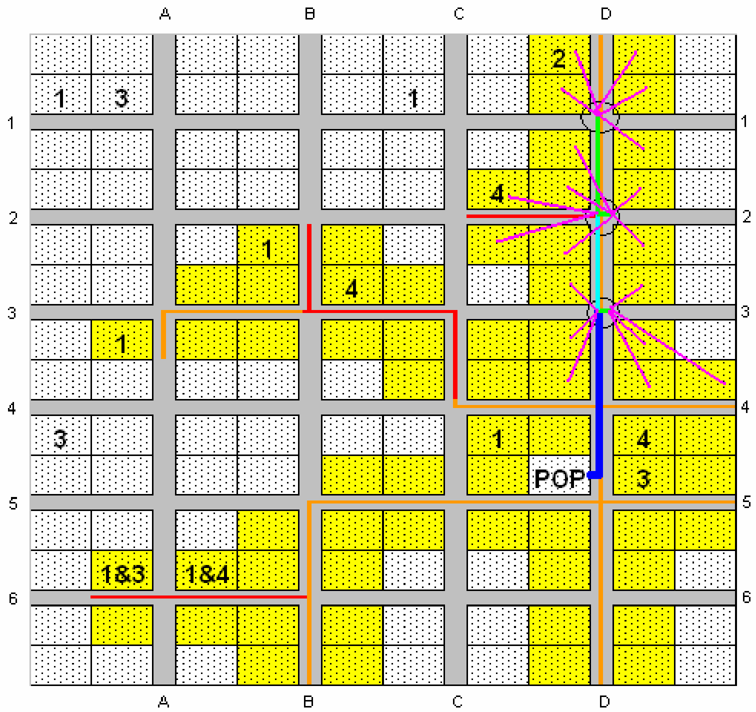


A 96 fiber cable leaves the service providers POP. The first fiber junction is placed at the corner of 5 street and D street. From there, three 24 fiber cable and continue and two 12 fiber cables are used to connect two real estates. The 24 fiber cable stops at the corner of 6 street and D street and a fiber junction is placed there. Six real estates are connected to the network using fsix 12 fiber cables. The second 24 fiber cable continues to the corner of 4 street and D street. Five real estates are connected using five 12 fiber cables. The third 24 fiber cable continues to the corner of 5 street and C street. Five 12 fiber cable are used to connect five real estates.



A 96 fiber cable leaves the service providers POP. The first fiber junction is placed at the corner of 3 street and D street. From there, one 24 fiber cable and one 48 fiber cable continue and three 12 fiber cables are used to connect three real estate. The 24 fiber cable stops at the corner of 3 street and D street and a fiber junction is placed there. Four real estates are connected to the network using four 12 fiber cables. The 48 fiber cable continues to the corner of 3 street and D street. Two real estates are connected using two 12 fiber cables. Two 24 fiber cables continue and the first stops at the corner of 2 street and D. Five 12 fiber cable are used to connect five real estate. The second 24 fiber cable stops at the corner of 1 street and D street. Five 12 fiber cable are used to connect five real estates.