Point-to-Point based Fiber-to-the-Home Networks in Europe

Elroy Pluk, Gerlas van den Hoven, and Bojan Božič

***Abstract* — An overview is given of fiber-to-the-home networks based on the point-to-point architecture. Ethernet is used as the dominant communications protocol. It is shown how point-to-point network compare to passive optical networks. Based on these arguments, European networks are shown to choose point-to-point as the architecture of choice for fiber-to-the-home.**

***Keywords* — Ethernet, Fiber-to-the-Home, FTTH, Point-to-Point, PON.**

I. Introduction

As more and more people require broadband connectivity the limitations of existing network technologies such as DSL and coax cable become apparent. Therefore, many network operators in Europe are choosing fiber-to-the-home (FTTH) as the way to provide future-proof broadband communication. Today, already several leading European operators are deploying FTTH: In Amsterdam a network is being built and operated by BBned to provide fiber to 40,000 homes, and this is only the first phase! Similarly, incumbent operator KPN is deploying FTTH in the Netherlands as part of its All-IP program, which includes also high speed ADSL and VDSL. This is in fact a nice example of how FTTH and copper based networks go hand-in-hand. Many other deployments are underway in Europe, predominantly in Denmark and Sweden, but also in Eastern Europe. A good example is the FTTH network being built by leading cable operators in Maribor, Slovenia, with already 2500 active users.

When deploying a FTTH network, the network operator has to make a choice in network architecture. Two possibilities exist: Point-to-point (PtP) Ethernet or so-called passive optical networks (PON). Figure 1 shows the basic architecture of each network. PON is a point-to-multipoint network, where one feeder fiber is shared by typically 32 or 64 users. In PtP, each user has its own fiber connection direct to the access switch.

Elroy Pluk is with Genexis, Lodewijkstraat 1A, 5652 AC Eindhoven, the Netherlands (phone: 31-40-2513220; fax: 31-40-2519542; e-mail: e.pluk@genexis.nl).

Gerlas van den Hoven is with Genexis, Lodewijkstraat 1A, 5652 AC Eindhoven, the Netherlands (phone: 31-40-2513220; fax: 31-40-2519542; e-mail: g.vdhoven@genexis.nl).

Bojan Božič is with Optisis, Avtomobilska 17, 2000, Maribor, Slovenia (phone: +386-2-3338750; e-mail: bojan.bozic@optisis.si).

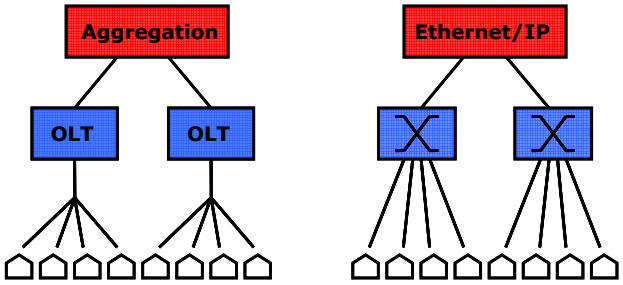

Fig. 1. PON network architecture on the left and PtP network architecture on the right.

In Europe, network operators are choosing PtP as the network of choice for FTTH. such deployments, since it not only provides the bandwidth, but also scalability and manageability advantages over PON networks. A first major advantage of PtP is the use of Ethernet as standard for layer 2 communication. This makes the networks open; multiple services from multiple service providers can be provided over a multi-vendor network. This is especially important, since it enables equipment from different vendors to be inter-operable. Secondly, PtP is simple: every end-user gets a fiber connection. Ultimately, this is the most flexible and future-proof architecture. Taking into account that in densely populated areas such a Europe the distance between end-user and central office is small, the cost such a network is low. In addition, the cost of fiber itself is continuously decreasing, making such "fiber-rich" deployments attractive.

Point-to-point networks also win in terms of scalability and upgradeability. Imagine two fiber-to-the-home deployments, one PtP and one a PON network with 32 users on one fiber. After a few years, the demand for bandwidth rises to the Gigabit per second level for the top 10% end-users (the early adopters of bandwidth). Just like with DSL, these users pay the highest subscriptions. To upgrade these users, the whole PON network needs to be upgraded, since all users share the same network. Increasing the bandwidth requires changing everyone's home gateway and replacing all central office PON equipment. In point-to-point, with every user on its own fiber, upgrading can be done on a per user basis. One can gradually and gracefully introduce new equipment to the highest demanding, highest paying customers, while maintaining the current equipment for the "normal" users. The investment in equipment and technology is therefore much more effective than in PON, and the lifetime of the network is much greater.

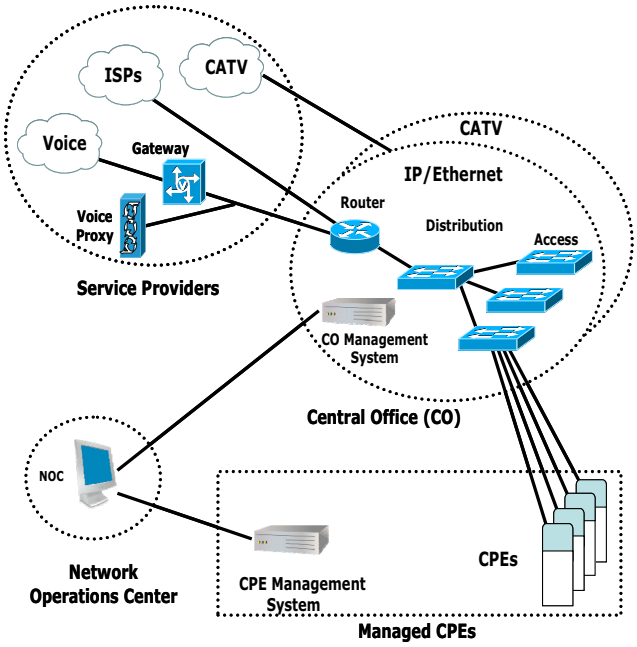

Fig. 2. Typical triple play point-to-point network for fiber-to-the-home.

II. Build-up of Point-to-Point Networks

In the following part of this paper, the build-up of a typical PtP network in Europe will be discussed.

Point-to-point fiber-to-the-home networks are designed to deliver broadband services to end-users over fiber. The network consists of a passive fiber infrastructure and active equipment to enable distribution of the communication services. Figure 2 shows how the service providers and users are connected through the FTTH network. The active network can be divided in a user part (customer premises equipment, CPE) and a central office (CO) part. The CPE terminates the network at the user, providing a conversion of the communication signals to services that the user can access. The CO functions as a transport network to connect the users to service providers. The network is managed through the network operations center.

Both the CPE and the CO parts have their own management tools and can be operated independently from each other. In this way, each of these parts becomes a modular building block within the FTTH network. In order to provide network guarantees, it is essential that the interfaces between the building blocks or network elements are well-defined. With the right set of Ethernet-based standards and specifications, inter-working can be achieved.

The physical link between the CPE and central office parts of the network is based on a point-to-point architecture. Within this architecture, the FTTH network enables the transport of two basic service types: communication through an Ethernet/IP network, and broadcast of (video) content through a CATV network overlay. The following sections will discuss the details of the Ethernet/IP network and the CATV network overlay.

III. Ethenet/IP Network

Figure 3 provides an overview of the Ethernet/IP network. Within this network the router functions as the central element, directing the transport of IP packets through the network. The access switches transport the IP packets to the end-user. The CPE, located at the end-user, receives the IP traffic and translates it into application-related signals, like Internet and (POTS) telephony.

The router performs several functions. Primarily it connects the various service providers to the network: for example, internet-services via a firewall and telephony via a SIP-Proxy and PSTN gateway. Furthermore the router functions as an access-point to the network for the Network Management server, permitting it to distribute network management signals across the network.

As the network is scaled to more users, the routing function is distributed over an array of interconnected routers. Eventually, the routing function can be partitioned into two levels: a lower level with distribution switches and a higher level with routers for interconnection. The distribution switches distribute the IP traffic to the various access switches, while the interconnection routers are optimized to establish the interconnection to the service providers.

The distribution of IP traffic via the Ethernet/IP network is based on standards:

Inter-working at layer 1: Physical layer

Optical interfaces at both sides of the passive infrastructure are compliant to the international IEEE 802.3ah standard:. The attenuation of the passive infrastructure should remain within a specified window (minimum – maximum attenuation); in practice this means that the span loss of the link between access switch and CPE needs to remain below the limit specified by the standard. The optical transceivers in the CO and the CPE, performing the basic electric-to-optical conversions, need to fulfill the requirements given by the IEEE 802.3ah specification; in practice, this is guaranteed by the transceiver suppliers.

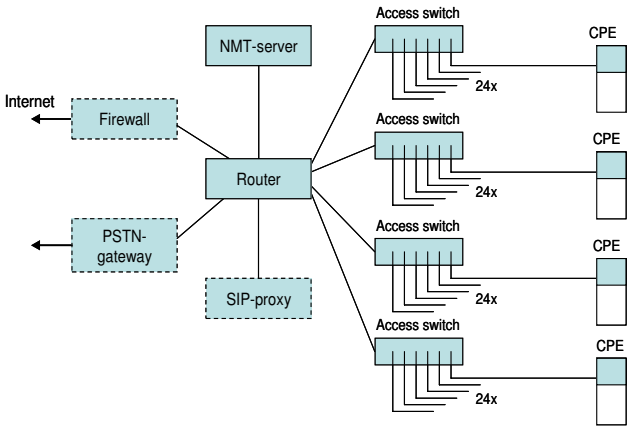

Fig. 3. Overview of the Ethernet/IP network.

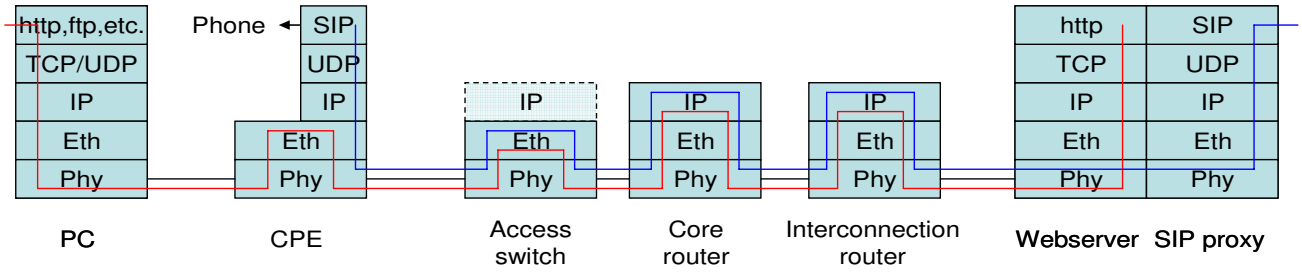

Fig. 4. Overview of the various protocols in the FTTH network.

Inter-working at layer 2: Ethernet layer

At this layer, the transport of information between two points is defined. Both the CPE and CO-equipment need to comply with the Ethernet standard, IEEE 802.3. Full network transparency is guaranteed by this standard. In a FTTH environment a number of functions are of critical importance. First is the setting of VLANs to provide transparent connection between services providers and CPEs. Second is the Quality-of-Service (QoS) setting that enables prioritization between different types of services: e.g. high quality traffic such as voice gets priority over lower quality traffic such as internet.

Inter-working at layer 3: IP layer

Within the IP-layer, the routing of IP packets through a network is defined. Items of relevance to this layer are, for example, IP addressing, subnetting, and routing. Above Layer 3 the application protocols, such as TCP/UDP, HTTP, SIP, are defined. The equipment within the Central Office area is transparent to these service-related protocols. The central office equipment is managed by using the Simple Network Management Protocol (SNMP).

Within the CPE, the traffic streams are handled on layer 2 as explained above, guaranteeing transparent connectivity between the end-user and the service provider. The voice service, as well network management, terminates at the CPE. Voice is supported through the SIP protocol (according to RFC 3261).

Figure 4 gives an overview of the various protocols, supported by a Ethernet-based PtP FTTH network.

IV. CATV NETWORK

Figure 5 provides an overview of the Genexis CATV network overlay. Four basic elements are of relevance:

1. The optical transmitter translates the electrical (analog) signal of the head-end into an optical signal suitable for distribution. This signal is transmitted within the 1550 nm wavelength band in order to allow optical amplification of this signal;

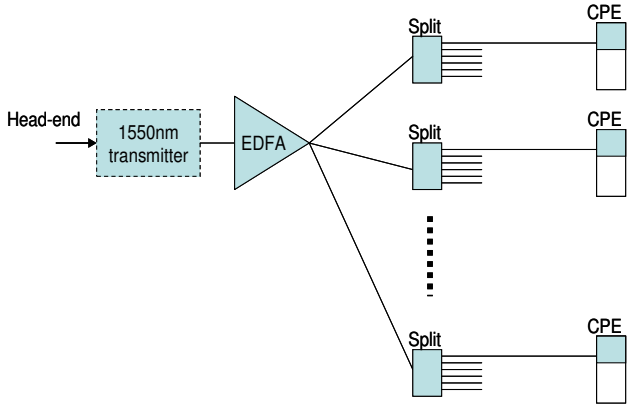

Fig. 5. Overview of the CATV distribution network.

2. The Erbium Doped Fiber Amplifier (EDFA) amplifies the optical signal to a level appropriate for connecting the head-end to a large number of end-users. Depending on the number of users and their physical location, one or more EDFAs can be used each with its own gain and power.

3. The splitters arrange the actual distribution of the signal to the various end-users. These are fully passive devices, not requiring any electrical power feeding or maintenance.

4. The CATV-receiver, located at the end-user, translates the optical input signal into an electrical signal, suitable for direct connection to conventional TV and Radio equipment.

V. SUMMARY

In summary, an overview is given of point-to-point networks for fiber-to-the-home. The Ethernet standard plays an important part, enabling interoperability between equipment vendors and a multi-service network environment. Also PtP offers scalable networks in a future-proof architecture. Therefore, most European operators are choosing point-to-point networks for their FTTH roll-out.