Fiber–to–the–Home Technologies and Standards

Andjelka Kelic
Massachusetts Institute of Technology, USA

INTRODUCTION

Fiber-to-the-home (FTTH) refers to the provisioning of narrowband and broadband services to the residential customer over an optical cable rather than traditional copper wiring. Early trials in the United States, England, and France to provide telephone and broadcast video service to residential customers occurred in the mid- to late 1980s, however, widespread deployment did not follow from these trials (Esty, 1987; Rowbotham, 1989; Shumate, 1989; Veyres & Mauro, 1988). Studies conducted at the time suggested that consumer demand for video and telephone service was not sufficient to warrant the funds necessary for wide-scale deployment of the systems (Bergen, 1986; Sirbu & Reed, 1988).

The studies did not foresee the interest in residential broadband service spurred by the growth of the commercial Internet and the World Wide Web. Since the days of the early trials, residential and small-business lines providing at least symmetric 200-kbps services have grown to 18.1 million as of December 2003 in the United States alone (Federal Communications Commission, 2004), and FTTH has been standardized with an eye toward providing multimedia services.

BACKGROUND

Deployment of residential broadband has been growing around the world. The most commonly deployed technologies are DSL (digital subscriber line) and cable modems (Ismail & Wu, 2003). Wireless for residential broadband also has a small showing.

Both DSL and cable modem services run over existing copper or hybrid fiber-copper plants. The newest DSL technology is VDSL (very-high-fata-rate digital subscriber line), which promises to de-liver asymmetric speeds of up to 52 Mbps from the provider to the customer (downstream) and 6 Mbps from the customer to the provider (upstream), or symmetric speeds of 26 Mbps (The International Engineering Consortium, n.d.). Unfortunately the technology is distance limited and the maximum speeds can only be achieved up to a distance of 300 m. Longer distances result in a reduction in speed.

Cable modem services' newest standard, DOCSIS 2.0 (Cable Television Laboratories, Inc., 2004), is capable of a raw data rate of 40 Mbps in the downstream and 30 Mbps in the upstream. However, due to the broadcast nature of the system, this bandwidth is typically shared among a neighborhood of subscribers.

Fixed wireless services are also targeting the residential broadband market with a technology capable of up to symmetrical 134.4 Mbps depending on the width of the channel and the modulation scheme used. The technology is known as WiMax and is defined in IEEE 802.16 (Institute of Electrical and Electronics Engineers (IEEE); IEEE, 2002). The original WiMax standard, and the 134.4 Mbps transmission capability, is for use in a frequency range that requires line of sight for transmission. The standard has since been updated via IEEE 802.16a (IEEE, 2003) for use in frequency bands that do not require line of sight for transmission. The drawback to using non-line-of-sight frequency bands is a lower data rate of up to 75 Mbps depending on channel width and modulation scheme. Similar to cable modem service, WiMax also shares its bandwidth among groups of customers.

The technologies under development for fiber to the home promise far greater dedicated bandwidth than any of the proposed future modifications to DSL, DOCSIS, or fixed wireless, and in the case of DSL, over much longer distances. This makes FTTH better suited as a platform to support multimedia services to residential customers.

FIBER-TO-THE-HOME TECHNOLOGIES AND STANDARDS

FTTH technologies fall into two categories: active or passive. Both types of technologies are capable of delivering voice, video, and data service. Active technologies have an active component such as a switch or router between the central office and the customer. Passive technologies have a passive (unpowered) component, such as an optical splitter, between the central office and the customer.

Standards work for FTTH technologies has been taking place in two different organizations: the Institute of Electrical and Electronics Engineers and the Telecommunication Standardization Sector of the International Telecommunication Union (ITU-T). The IEEE standards work is focused on the use of Ethernet-based technologies in the access network (Ethernet in the First Mile or EFM) and the ITU standards work (called recommendations) focuses primarily on passive optical networks (PONs). The ITU-T and IEEE standards groups communicate regularly in order to ensure that the standards that are developed do not conflict.

FTTH technologies can be deployed in three different topologies: home run, active star, or passive star (Committee on Broadband Last Mile Technology, National Research Council, 2002).

Home Run

A home-run network topology is a point-to-point topology with a run of fiber from the provider's central-office optical line terminal (OLT) out to each

Figure 1. Home-run topology

customer optical network terminal (ONT). The fiber run can be either one fiber, with different wavelengths for upstream and downstream transmission, or two separate fibers, one for upstream and one for downstream transmission. A home-run network topology is shown in Figure 1. This architecture is costly because it requires a dedicated fiber for each customer from the central office to the customer premise. The central-office equipment is the only resource that is shared amongst the customer base.

ITU-T G.985, approved in March 2003, is defined as operating over a point-to-point network topology. G.985 came out of efforts by the Telecommunications Technology Committee (TTC) in Japan to achieve interoperability between vendors for deployed Ethernet-based FTTH systems (ITU-T, 2003c) and has contributed to the EFM Fiber standards work.

The recommendation describes a single-fiber, 100-Mbps point-to-point Ethernet optical access system. Included are specifications for the optical distribution network and the physical layer, and also the requirements for operation, administration, and maintenance. Transmission is on a single fiber using wave-division multiplexing (WDM), with downstream transmission in the 1480- to 1580-nm range and upstream transmission in the 1260- to 1360-nm range. WDM divides the fiber by wavelength into two or more channels. The standard currently defines a 7.3-km transmission distance with 20- and 30-km distances for further study.

Active Star

In this topology, a remote node with active electronics is deployed between the central office and the customer premises, as shown in Figure 2. The link between the central office and remote node is called the feeder link, and the links between the remote nodes and the customer premises are called distribution links. A star topology is considered more cost effective than a home-run topology because more of the network resources are shared amongst the customers.

EFM Fiber (IEEE 802.3ah) is most commonly deployed in an active star configuration. It is similar in architecture to traditional hubs and switches that run 10BaseF and 100BaseFX today. The standards for EFM Fiber were developed by the IEEE 802.3ah Task Force.
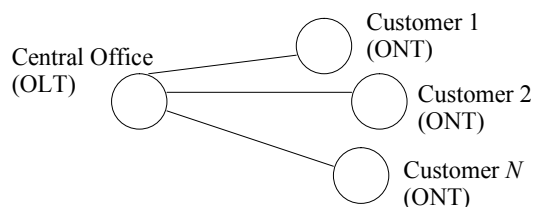
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