

Deep-fiber broadband access networks

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Millions of subscribers around the world are today connected via deep-fiber broadband (FTTx) access. Countries with notable installations are Japan, Korea, the Netherlands, Sweden, and the USA. In some countries FTTx constitutes the fastest-growing type of broadband access.^{1-4, 9}

One of the driving forces for FTTx access is surging demand for IPTV fueled by the transition to HDTV. Important aspects that affect the deployment of FTTx access networks are regulatory conditions and competition, which vary from country to country.

The authors describe Ericsson's FTTx access solution, which emphasizes recent additions of GPON and VDSL2 to the product portfolio. They also highlight lessons learned from several years of deploying FTTx networks.

Introduction to GPON and FTTx broadband networks

Early deep-fiber broadband (FTTx) access networks seldom had to deliver more than fast internet access. Today's broadband access networks, by contrast, are expected to deliver a bundle of services, such as the popular triple-play offering of internet access, telephony, and TV and video services. Of these, TV and video have the greatest appeal but they are also the most bandwidth-hungry of services. This combination – subscriber appeal and the requirement for bandwidth – is driving the demand for higher speeds (50-75Mbps). Analysts anticipate that the growing trend to deploy FTTx broadband access will continue for many years (Figure 1) because:

- a growing number of homes have more than one TV set (HDTV);
- video services are increasingly becoming personalized and on-demand; and
- new forms of user behavior, such as video blogs, continue to grow in popularity.

Two new key access technologies and standards, GPON and VDSL2, have been developed and ratified, enabling vendors to deliver new products. Ericsson expects to see major rollouts of both of these technologies in 2007 as carriers seek to gain the formidable advantage of being first movers.

Traditional incumbents are not the only parties building FTTx networks. In many countries, utilities and municipal operators were the first to build (often with government support). And not surprisingly, where FTTx networks exist or are being deployed,

cable TV operators are quick to respond, sometimes with FTTx initiatives of their own.

High-speed access technology

In recent years, IEEE and ITU-T have ratified standards for several important new technologies. Vendors, in turn, have incorporated these standards into products that are now ready for large-scale deployment in FTTx networks.

This article examines the two most recent standards, GPON and VDSL2⁶⁻⁷, which build on and effectively replace earlier standards (BPON and VDSL). At first thought, one might think of the GPON and VDSL2 standards as competing technologies, but Ericsson considers them complementary and has incorporated them into the EDA broadband access family (Figure 2). In all likelihood, operators will have to use both of these technologies to provide a comprehensive and flexible access solution.

GPON

Gigabit passive optical networks (GPON) build on a series of technology enhancements that extend and improve on earlier forms of passive optical networks (PON). Like its predecessors, GPON is a point-to-multipoint technology in which a single optical port (optical line terminal, OLT) communicates, by means of an optical splitter, with multiple subscriber devices (optical network terminal, ONT) over common optical fiber. In point-to-point technologies, by contrast, each OLT is connected by a dedicated fiber to a single ONT.

Sharing the OLT port and a substantial part of the fiber cable plant reduces the costs of opto-electronics, cabling, and civil works. A typical PON installation is designed for up to 32 ONTs per OLT port.

A passive optical splitter, positioned between the OLT and tributary ONTs, fans out light (at 1490nm) from the OLT to all associated ONTs and allows light (at 1310nm) from ONTs to be sent to the OLT. Downstream, the OLT broadcasts to ONTs. These, in turn, select incoming data based on the port ID field in each GEM frame (Figure 3). Upstream, a time-division multiple access (TDMA) protocol keeps ONT transmits from colliding with one another.

GPON is a major advance on the earlier BPON. It is approximately four times faster

BOX A, OTHER ACCESS TECHNOLOGIES

The subject of next-generation broadband networks generates lively debates. Many technologies have been advanced as offering the next great leap forward. A full comparison is beyond the scope of this article but it is useful to acknowledge the candidates.

Point-to-Point FTTH (EFM P2P)

P2P is a simple, mature and effective technology that is especially popular with utilities operators. P2P is supported by the EDA hybrid solution (Figure 2). A P2P fiber access switch (for example, EFN324) can be deployed in a basement or cabinet, or in the operator exchange and connected over dedicated fibers (up to 10km) to the subscriber. P2P is particularly popular with corporate customers who are reluctant to share cables. All deep-fiber networks have some P2P services.

Wireless broadband

Even as new wireless technologies get faster, the capacity of deep-fiber access will maintain the performance advantage of fixed broadband. Nevertheless, mobility is a very desir-

able feature, and mobile internet and telephony access are deservedly popular. Ericsson expects that both fixed and mobile broadband will prosper, and in any case, mobile broadband will call for extensive fiber coverage as backhaul.

Cable (hybrid-fiber-coax, HFC)

New standards for cable modem service (DOCSIS 3.0) offer fast speeds for internet access over HFC networks. Notwithstanding, these networks are notorious for their deficiencies (variable performance due to shared coax, inflexible as buildings change, inadequate support for business customers). As cable operators upgrade their networks, many are turning to FTTx solutions for a superior long-term architecture for their business.

and supports twice as many ONTs. Furthermore, GPON employs a multipurpose frame format (GEM) that supports Ethernet frames (legacy BPON uses ATM cells at the frame level), making it an attractive solution for modern IP-Ethernet-based access networks. A majority of carriers have indicated that they consider GPON the most desirable fiber access technology. And many carriers who use BPON equipment intend to migrate to GPON to provide the capacity that is necessary for IPTV services.

Compared with GPON, Ethernet PON (EPON, also called Gigabit EPON or G-EPON)⁵ supports fewer ONTs, has slower OLT ports, and it is less efficient at transporting data. Because Gigabit EPON lacks comprehensive standardized operations and management features, it will be more complicated and costly for network operators to provision EPON-based services and to fulfill service layer agreements.

VDSL2

DSL technology was originally intended to provide a data connection over the conventional copper loop from a carrier's exchange (central office, CO) to subscriber premises. A series of innovations have driven several generations of DSL (from HDSL, to ADSL, to VDSL) offering progressively faster speeds and higher frequencies over shorter and shorter copper loops.

VDSL2, the most recent DSL technology, can support up to 100Mbps over short loops.⁸ Speeds of 50-75Mbps can be achieved at distances of 1-2km (depending on factors such as grade of copper, cable length, and interference). Beyond these distances, ADSL2+ is still the superior technology. Ericsson's EDN612 VDSL2 DSLAM has been designed to support VDSL2 and ADSL2+.

In most cases, the number of end users who can be reached directly by VDSL2 from the central office is quite limited because the loop lengths from the exchange to the subscriber are typically more than 1-2km. VDSL2 is an excellent option, however, where the copper runs are short – for instance, for services over existing copper from a building basement or street-side cabinet near a building. A VDSL2 DSLAM aggregates many copper subscriber lines onto a 1Gbps backhaul link to a metro Ethernet switch.

Hybrid gigabit access

For incumbent operators, a typical installa-

tion uses GPON for new (greenfield) suburban residences; VDSL2, for existing (brown-field) residential apartments and suburban residences; and dedicated point-to-point gigabit services for corporate and business customers.

Hybrid networks are feasible and necessary for supporting a mix of users and buildings whose character and needs change over time. Ericsson's passive cable-plant solutions readily support practical hybrid gigabit access (Figure 4).

FTTx architectures

The main FTTx architectures can be categorized as

- fiber to the curb (FTTC), where the optical fiber stops at a street-side cabinet and services continue to the subscriber via VDSL2

Connected households
(million)

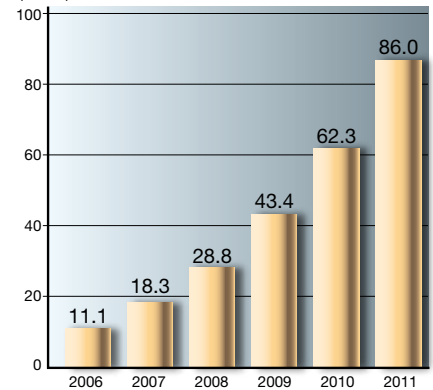


Figure 1
FTTH growth forecast, worldwide
(Source: Heavy Reading).

Figure 2
EDA 1500GPON and gigabit access network.

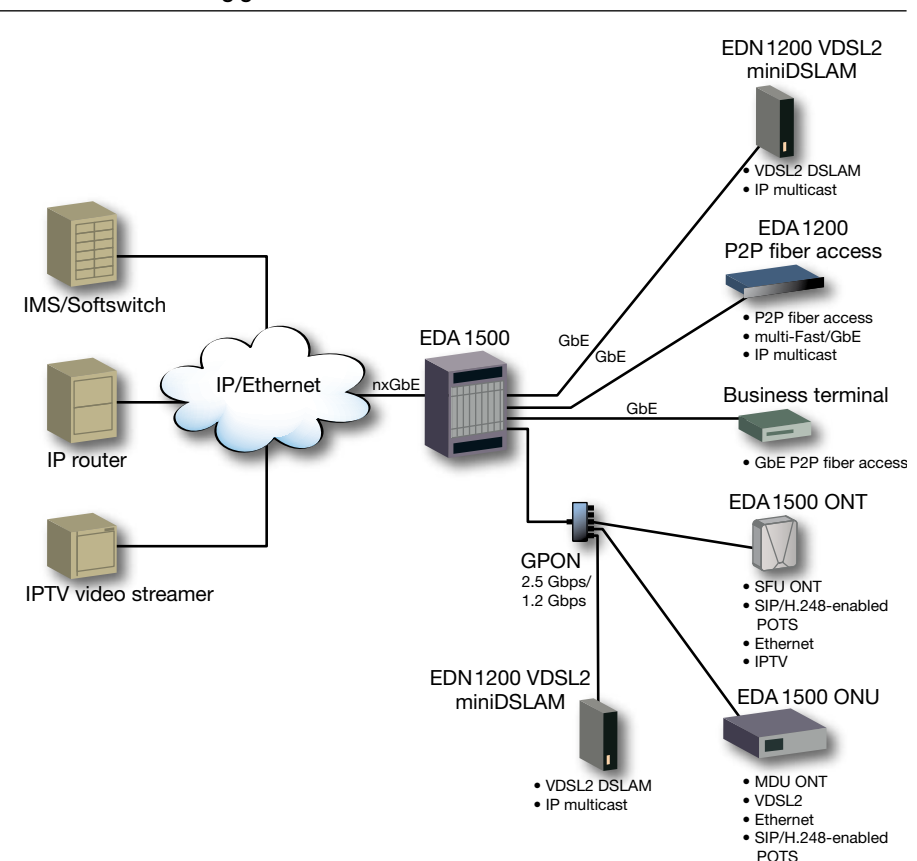
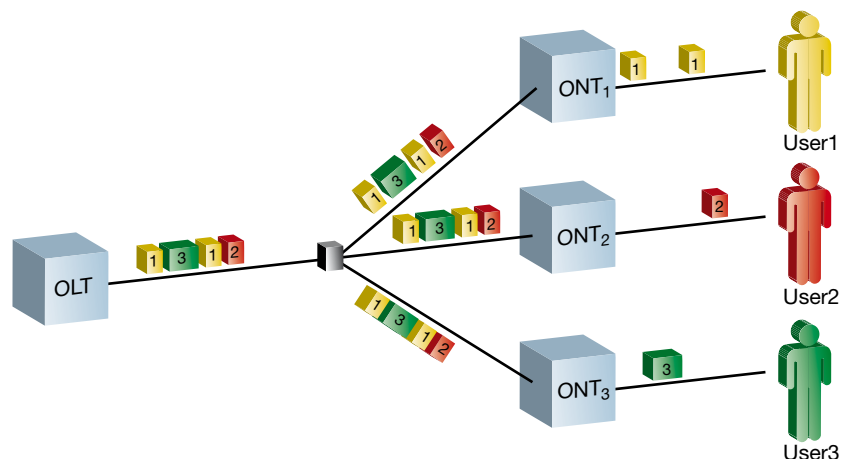


Figure 3
Overview of the PON downlink broadcast architecture.



- over copper;
- fiber to the building (FTTB), where the optical fiber stops in the basement of an apartment or office building and services continue to the subscriber via VDSL2 or 100BASE-T Ethernet over copper; and
- fiber to the home (FTTH), where the optical fiber continues all the way to the subscriber's home or office (PON or point-to-point service). Note: The expression fiber to the premises (FTTP) is sometimes used instead of FTTH.

Collectively, these architectures are labeled FTTx. Each of these complementary architec-

tures has its place in an access network. The actual choice of architecture is usually determined by the business models available to the operator and national regulatory constraints.

FTTC, for example, might be an attractive choice in brownfield areas where an incumbent operator has copper installed into premises. However, given that the cost of installing new copper plant exceeds the cost of installing new fiber access plant, operators are not likely to use FTTC in greenfield areas.

FTTB is very popular in high-rise buildings and in countries with many large apart-

ment buildings, such as India, Korea, Northern Europe, and Taiwan. Competitive and incumbent carriers alike use FTTB. Given that the capital cost of FTTB is modest, one can build a satisfactory business case where penetration is adequate.

FTTH is currently the most popular access alternative in greenfield areas. This is true for competitive as well as incumbent carriers. In developed countries, the majority of real estate developers understand that having FTTH to a property will increase its sale price. Developers are thus willing to contribute to the costs of the build. Furthermore, it is generally understood that one can achieve very high take rates by bundling the FTTH services with attractive concessions, such as free one-year internet access.

A seemingly related expression – fiber to the node (FTTN) – entails taking fiber from the subscriber to a remote DSLAM several kilometers away. The services are then delivered over the fiber via ADSL2+. Market researchers typically consider FTTN a variant of DSL, and while transmission rates are good (12-20Mbps), they cannot compete with FTTC, FTTB and FTTH (50-100Mbps). In the long run, therefore, FTTN limits the potential for advanced TV and video services.

BOX B, ERICSSON'S EDA1500 GPON SYSTEM

The Ericsson EDA1500, the latest addition to the award-winning family of EDA broadband access products, is a chassis-based gigabit access system that supports thousands of subscribers connected through GPON or subtended EDA access nodes (such as the EDN612 VDSL2 DSLAM or the EFN324 EFM P2P switch). The EDA 1500 thus supports implementations that provide pure GPON, VDSL2, EFM P2P, or hybrid solutions that incorporate these technologies.

Many competing products carry the heritage and shortcomings of previous technologies (ATM and TDM) and typically suffer from low capacity and inefficiencies. The EDA1500, on the other hand, was designed from the outset as a GPON/gigabit access device. For instance, it has an extremely powerful 320Gbps backplane capacity and 80Gbps switch fabric.

The four-port GPON blades support full

standard GPON (ITU-T G.984.1-4), making the EDA1500 one of the densest and most powerful GPON OLTs in the world.

The eight-port Gigabit Ethernet blades can be used to connect subscriber equipment, subtended EDA access nodes, or connected to backhaul switches.

The EDA1500 also works with a range of indoor and outdoor ONTs and (for MDU/MTU sites) ONUs.

A particular strength of the EDA 1500 is its support for IPTV. Indeed, EDA 1500 is an ideal IPTV access switch thanks to the inherent multicast capability of GPON, embedded IGMP IP multicast support in each GPON blade, and sophisticated packet-level admission control and security measures.

The EDA1500 is uniquely capable of delivering the flexibility and scalability that today's FTTH gigabit access networks require.

Business case

The main costs of building an FTTH network are well understood, though the actual proportions vary from country to country and from network to network. The main costs, listed in descending order, are:

- civil works (aerial construction is cheaper

- than underground construction);
- passive cable plant (cables, cabinets, closures, and so on);
- active equipment (ONTs, OLTs, aggregation switches, and so on); and
- planning and project management.

With this in mind, Ericsson has worked together with operators primarily to reduce the costs of civil works and cable plant, for example, by pioneering innovations in laying cable and using blown-fiber technologies for aerial as well as underground deployments.

The service life of a modern fiber-optic cable plant should exceed 20 years if it has been planned properly and designed. Figure 4 shows the architecture and components of Ericsson's FTTH cable plant, which can simultaneously handle GPON and point-to-point service delivery. The solution

- supports a wide range of access speeds from tens of megabits per second to gigabits per second; and
- introduces low-cost repair or replacement of distribution and drop cables (through the use of blown-fiber construction).

Access network costs can be grouped into two categories: the costs of building the network before services can be offered (*homes passed*), and the costs of building connections to new subscribers (*homes connected*).

More specifically, the *homes passed* portion of costs consists of exchange/CO fitout, feeder cables and civil works, cabinet and splitters, and distribution cables and civil works.

The *homes connected* portion of costs relates to drop cable and civil works, ONT, and a portion of OLT.

The take rate – that is, the ratio of *homes connected* to *homes passed* – is a measure of how attractive subscribers find the network and its services. Triple-play packages in brown-field areas commonly have 30% to 40% take rates after a few years. In greenfield areas, one can often reach 90% to 100% take rates in the first year of operation.

Commercial success is dependent on the mixture of user services (for instance, fast internet, VoIP, TV and video) and the go-to-market strategy. If regulatory constraints impede opportunities for achieving a high take rate, the business might not be commercially viable.

Capital expenditures (CAPEX) are extremely important but they are not more important than operating expenses (OPEX). In some cases, opportunities to reduce OPEX might justify the transition from older access technologies to FTTx or

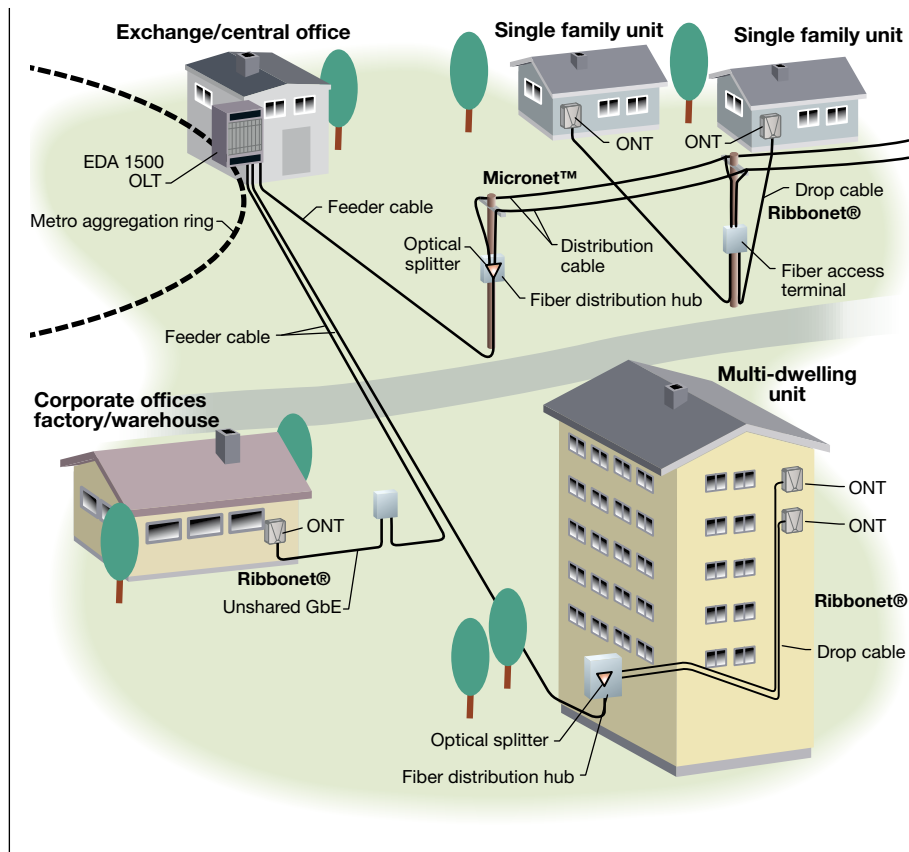


Figure 4
Architecture of FTTH cable plant using blown-fiber technology.

TERMS AND ABBREVIATIONS

ADSL	Asymmetric DSL	Greenfield	Newly constructed residential, industrial or commercial premises
ATM	Asynchronous transfer mode		
BPON	Broadband PON		
Brownfield	Existing residential, industrial or commercial premises	HDSL	High bit rate DSL
CAPEX	Capital expenditures	HDTV	High-definition television
CO	Central office	IEEE	Institute of Electrical and Electronics Engineers
Docsis	Data-over-cable service interface specification	IP	Internet protocol
DSL	Digital subscriber line	IPTV	IP television
DSLAM	DSL access multiplexer	ITU-T	International Telecommunication Union -Telecommunication Standardization Sector
EFM	Ethernet in the first mile		
EPON	Ethernet PON	MDU	Multiple dwelling unit
FTTB	Fiber to the basement	MTU	Multi-tenant unit
FTTC	Fiber to the curb	OLT	Optical line terminal
FTTH	Fiber to the home	ONT	Optical network terminal
FTTN	Fiber to the node	OPEX	Operating expenses
FTTP	Fiber to the premises	P2P	Point to point
FTTx	Fiber to the x	PON	Passive optical network
GEM	GPON encapsulation method	TDMA	Time-division multiple access
GPON	Gigabit PON	VDSL	Very high bit rate DSL

a decision to use FTTH instead of FTTC. NTT and Verizon, for example, have each indicated that they based their decisions to build full FTTH networks in large measure on lower OPEX – a 40% to 60% reduction compared with the costs of operating copper access networks. Reductions like these can be realized in a number of ways, including lower maintenance costs, fewer field repairs, and lower new-service-activation costs once subscribers have been connected.¹⁰

Regulatory models

In many countries, local and national governments understand that the business efficiencies made possible through advanced telecommunications infrastructure, such as FTTx, can yield economic benefits for the entire community. Consequently, there are numerous instances of government assistance to facilitate the build of FTTx networks, especially in brownfield areas. The mechanism employed may vary from country to country but the principle is well established. Authorities in the USA, for example, have encouraged operating companies to build by granting them protection from unbundling. In Japan, the government has offered tax advantages and low-cost funds. And in Sweden, the national government encourages local governments to build municipal FTTH networks and offers rebates to subscribers who connect to them.

When government funds are used directly, authorities usually stipulate that the network must be an open-access or wholesale network available to any retail service provider. This is true of the networks in Sweden and Japan, which were funded in part by government contributions. In the USA,

on the other hand, the regulatory authority provided a concession instead of funds. As a consequence, operators have mostly built vertically integrated services that incorporate a range of retail services.

Several governments have also acted to modify regulations that impede operators from deploying FTTx to businesses. For instance, several state governments in the USA have simplified the process of establishing local TV franchises to help carriers roll out statewide pay-TV services.

Key lessons

FTTx networks are a fascinating blend of technology, business, and regulation. Successful commercial and technical operation is dependent on several key aspects, such as maximizing the take rate, a long-term business plan, a lasting passive plant, the proper selection of active equipment, and flexible staffing.

Maximizing the take rate

Obviously, to enjoy commercial success, an FTTx business must achieve satisfactory penetration in the areas it serves. The relatively high cost of building FTTx is a deterrent, but also means that the first FTTx network to market will enjoy an enormous advantage. Once the network has been built and reached adequate takeup, it is unlikely that a competing FTTx network will ever be built.

Long-term business plan

The days of double-digit internet-style returns are over. FTTx is a technology for building powerful access networks and broadband businesses that should last at least 20 years,

delivering moderate long-term returns. The depreciation models for passive and active equipment must thus be consistent with the business.

Lasting passive plant

Some modern buildings will not last for 20 years, at least not without frequent remodeling and changes to their role and the activities of their tenants. The FTTx cable plant, however, is expected to last at least 20 years. Ericsson's model for passive cable plant is designed to be flexible and handle change. It is also scalable and can presently handle services at tens of megabits and gigabits per second.

Choosing active equipment with a future

Subscribers may not all currently require gigabit speeds, but in the years to come they will. The EDA1500 has an internal structure that allows it to grow and handle

- vastly increased access speeds (up to 1Gbps per subscriber); and
- a mixture of GPON, point-to-point, and FTTC services.

Flexible staffing

The processes of building and operating FTTx networks require different sets of staff and skills as well as very different numbers of staff. Ericsson helps operators to deal with these challenges, for example, through the use of temporary staff and managed services contracts.

Conclusion

The main deep-fiber broadband access architectures are FTTC, FTTB and FTTH. Collectively, these are termed FTTx. Each has its place in an access network – operator business models and national regulatory constraints usually determine the actual choice of architecture.

Two new key access technologies and standards, GPON and VDSL2, have been developed and ratified, and vendors have incorporated them into products that are now ready for large-scale deployment.

Ericsson considers GPON and VDSL2 as complementary technologies and has incorporated them into its family of EDA broadband access products. In all likelihood, operators will have to use both of these technologies to provide a comprehensive and flexible access solution.

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