FTTH ARCHITECTURE WHITE PAPER SERIES

BROADBAND ACCESS TECHNOLOGIES OVERVIEW

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Video, Cloud, and the Internet of Things – these trends are having a profound effect on the demand for higher bandwidth and greater connectivity. Optical fiber is the medium of choice in backbone, transmission, and increasingly in data center networks, due to its unparalleled bandwidth capacity. Once installed, the fiber remains in place while the switching equipment is upgraded from SONET/SDH to 10GbE to DWDM, as each new generation surpasses the last. Fiber's longevity is remarkable: even at 100Gbps, a fraction of 1% of a fiber's total capacity is used. There's room for growth.

In the access network there are more choices. This white paper, one in the TE Connectivity FTTH Architecture Series, reviews popular broadband access technologies: FTTH – Fiber To The Home; xDSL – Digital Subscriber Line; HFC – Hybrid Fiber Coax; and Wireless. Each possesses its unique set of strengths, weaknesses and trade-offs. Depending on a service provider's business model, the proper mix of technologies and migration strategies will help optimize the return on investment.

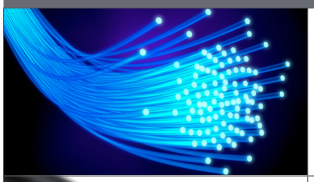
Physical Medium		Bands	Total spectrum
	**Fiber** High purity glass	O-band: 1260 - 1360nm E-band: 1360 - 1460nm S-band: 1460 - 1530nm C-band: 1530 - 1565nm L-band: 1565 - 1625nm	**45,000GHz** not all bands are used on the same fiber - today
	**HFC** Coaxial cable	Upstream: 5 – 42MHz TV (analog): 54 – 552MHz TV (digital): 552 – 678MHz Data: 678 – 690MHz TV (digital): 690 – 750MHz Future upgrade: up to 1700MHz	**1.7GHz**
	**Wireless** Radio Frequency	Licensed (mobile operator): 700, 800, 1700, 1900, 2100, 2300, 2500MHz Unlicensed (WiFi): 2400MHz, 5000MHz	**0.5GHz** licensed spectrum
	**xDSL** Copper wire	Voice: 0 - 4kHz DSL: 26 - 138kHz ADSL: 26kHz – 1.1MHz ADSL2: 26kHz – 2.2MHz VDSL: 26kHz – 8.8MHz VDSL2: 26kHz – 30MHz	**0.03GHz**

Table 1: Comparison of total spectrum for broadband access technologies

FTTH
Fiber To The Home

Gigabit speeds are available today, and there's virtually no limit to how fast it can go

Fiber optics was invented in the 1970s. Its potential to revolutionize telecommunications was recognized very early: a fiber has up to approximately 45,000GHz of optical spectrum, while a mobile operator owns perhaps 50MHz of 4G spectrum – a factor of 900,000 times less. HFC (i.e. cable modems) uses up to 1GHz today and VDSL uses up to 30MHz of spectrum.

The initial applications for fiber were in long distance networks such as international submarine cable, national and regional backbones. Gradually as costs came down, fiber moved into metro and access networks, data centers, IT server rooms, and office cabling. Fiber is also used to backhaul other access networks. The last mile or last 50 meters from the node to the customer may be copper, coaxial cable, or wireless, but regardless it is usually fiber that brings it back from the node.

From the data center to the central office to the customer, single-mode fiber is the medium of choice for reasons

beyond providing a bandwidth-unlimited upgrade path. The fact that it uses light instead of electricity has important implications. First, transmitting data over fiber consumes far less power than over copper or coax. Operating costs are therefore lower, with the added benefit that fiber is a more environmentally-friendly technology. Second, FTTH utilizes a Passive Optical Network (PON). Passive means no active electronics, batteries, or power supplies are used in the outside plant. This translates into lower failure rates, lower maintenance costs, and a more reliable network, particularly in areas prone to rain, flooding, and harsh conditions.

FTTH represents a generational technological shift in much the same way that copper networks did a century ago. Its benefits are not disputed, rather the question is how to drive costs down even more to increase coverage. Civil works and construction costs for laying fiber underground up on poles account for two-thirds or more of the total cost of deploying FTTH. Similar to other infrastructure projects, up-front costs are high and require careful planning. Maintenance and operating costs are lower than for other fixed access networks, so this compensates for the initial outlay of capital and helps the network achieve a reasonable payback period.

For greenfield (i.e. a new real estate development) sites, fiber and FTTH is the preferred choice. Investing in the latest and best technology, which has a proven track record, is clearly preferable to sinking money into technologies with limited upgrade potential. It is also the preferred choice for business and enterprise customers, where the upfront costs can be more easily justified.

As the industry evolves, competition is intensifying with more service providers building FTTH networks and positioning their higher-speed services as a key differentiator over other access network providers. Cities and municipalities have also started to join in, bringing alternate sources of funding and new business models. Ubiquitous broadband access represents a competitive advantage for the local community and economy, attracting businesses and homeowners.

xDSL

Evolution to higher and higher speeds … but over shorter and shorter distances

For a hundred years, the copper-based PSTN (Public Switched Telephony Network) has supported voice calls. DSL (Digital Subscriber Line) enabled data over standard telephone lines and helped usher in the Internet. First was DSL operating at 256kbps (faster than dial-up, at least!), quickly followed by ADSL, with download speeds up to 8Mbps and capable of reaching most homes directly from the central office. Speeds of 100Mbps are now possible with VDSL2/2+, today's generation of xDSL technology.

As bandwidth increases, distance decreases. This is the key trade-off with xDSL. VDSL slows down considerably after several hundred meters. This means that either the subscriber must live close to the central office, or remote DSLAMs must be placed closer to the subscriber – at the bottom of an apartment building, or in a street cabinet. Such architectures are called FTTB (Fiber To The Building), FTTC (Fiber To The Curb/Cabinet), or FTTN (Fiber To The Node). Optical fiber is used to backhaul the aggregated traffic from the remote DSLAM to the central office.

Beyond xDSL is G.fast, which is being standardized in 2014 and able to support 500Mbps at up to 100 meters over copper wires. It's a hybrid architecture utilizing an FTTH network – but instead of being deployed all the way to the home or premises, the fiber terminates at a distribution point (Fiber To The distribution point, or FTTdp) that is located less than 250 meters from the subscriber. The potentially large number and remoteness of the distribution points means that the G.fast modem or terminal situated there relies on electrical power from the subscribers' CPE (i.e. reverse powering). Such developments will help extend the life of copper.

The main attraction for incumbent carriers is the economics of copper wiring. There are little or no CAPEX outlays as copper is already present in 80% of the brownfields in the world today. Activating new subscribers can be quick and cost effective. A

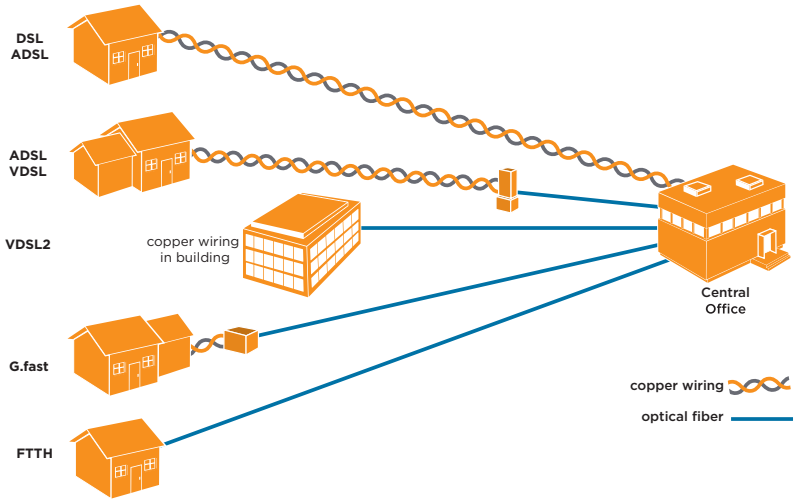


Figure 2: Each evolution of xDSL gets faster, but shorter

phased approach that leverages existing copper while fiber is deployed ever closer to the subscriber makes for a strong business case.

Where copper technologies ultimately fall short is speed. How much longer will subscribers be satisfied with 20Mbps, or even 200Mbps? If 4G networks can offer similar speeds with the added convenience of mobility, how does copper compete? New carriers, often with different business models, are beginning to leapfrog incumbents by building all-fiber access networks with disruptive 1Gbps+ service offerings. Thus, incumbents must be careful to balance the short term cost advantages of copper against its inherent long term competitive liabilities. Meanwhile, as copper gets shorter so fiber gets longer, being deployed ever closer to the customer.

HFC

Upgrade path to gigabit services exists, but will require significant investments in the network

Cable television operators initially built their coaxial cable networks to broadcast analogue TV signals. With the advent of cable modems and the DOCSIS standard in the late 1990s, cable networks carried bi-directional data traffic and helped fuel the growth of the Internet. Optical fiber was first introduced to improve TV signal quality and reliability. With cable modems, service area footprints became smaller and fiber made its way closer to the subscriber (similar to the FTTN/FTTC architectures for xDSL). The Hybrid Fiber Coax network thus emerged.

Download speeds of 100Mbps are typical, and range up to 300Mbps for selected markets. The availability of top speeds depends on factors such as the subscriber's distance from the fiber, the physical condition of the cable plant, and the number of homes served – very similar to xDSL. Where you live determines what you can get. Cable models adhere to the DOCSIS standard and the latest version (DOCSIS 3.1) offers a theoretical download speed up to 10Gbps. Equipment trials are expected no earlier than 2016, and achieving such speeds would first require a network migration to fully digital TV service in order to reclaim the necessary cable spectrum used to carry analogue TV channels today. Higher speeds also require node-splitting (adding nodes to lower the number of subscriber served by each node), with the nodes and fiber being deployed closer to the subscriber.

With a relatively competitive bandwidth offering and an upgrade path forward, why are some cable operators investing in FTTH networks? This is the case for business services, where FTTH is being deployed to deliver Carrier Ethernet and cellular/WiFi hotspot backhaul services. For residential greenfield sites, building out future-proof fiber makes far more sense than laying coaxial cable. Operating costs for coax are high due to maintenance of the active infrastructure (power supplies, batteries, RF amplifiers, etc.). It has been estimated that per kilometer of outside plant, an HFC network is over 10 times more expensive to operate than a PON network, and 5x more expensive on a per subscriber basis.

The HFC network is a cable operator's core asset, and therefore remains the foundational technology. Optical fiber and FTTH are growing and important supporting strategies that help deliver more bandwidth to the subscriber, used to target specific market segments, and keep cable operators competitive.

Wireless

The convenience of mobility, supported by fixed access networks

Consumers love the freedom of mobility made possible by wireless technologies. At home, consumer electronics and appliances can be easily connected over WiFi, since most devices are now WiFi-equipped. The technology continues to improve with gigabit speeds now available. Of course, access from the home to the Internet still depends on a fixed access network such as FTTH, xDSL, or HFC.

Outside the home, Internet access for smartphones, tablets, and connected cars is provided by the 4G network. Peak download speeds of 100Mbps are possible, depending on the mobile operator's network, number of other users in the same cell, distance from the cell tower, etc. From the cell tower back to the network, copper and microwave backhaul have been traditionally used for 2G/3G networks. The growth of 4G networks and its high speeds have driven fiber deployments.

New fiber-based mobile systems are also being adopted at an increasing rate. When fiber is used between the basestation on the ground and the antennas mounted at the top of the cell tower, electrical losses are lower, resulting in higher wireless output power. This is known as Fiber to the Antenna (FTTA). Feature and performance enhancements are possible with digital Distributed Antenna Systems (DAS) and Remote Radio Head (RRH) fiber-based systems. All the mobile traffic can be carried over dedicated fiber rings, or over FTTH and

PON networks. Operators with both FTTH and 4G/WiFi hotspot networks are in a perfect position to efficiently leverage their networks to create operational synergies.Consumers use WiFi hotspots to save money on their mobile data bill. Mobile operators also try to offload traffic from 4G to WiFi hotspots in order to relieve network congestion. During peak hours in busy venues such as conferences and sporting events, network congestion can seriously degrade the user experience and negatively impact customer satisfaction. Picocells and femtocells are being deployed to offload traffic from the 4G network. These small cells cover a smaller area, so more bandwidth can be shared among fewer users. Small cells require a fixed access network for backhaul. Hence for wireless as for xDSL and HFC, fiber is making its way closer and closer to the consumer.

Offloading traffic remains a key challenge for mobile operators as they cope with the explosion in smartphone and tablet usage. Because FTTH, xDSL, and HFC networks offer widespread coverage and provide connectivity for WiFi hotspots and small cells, they play an important part in a mobile operator's strategy.

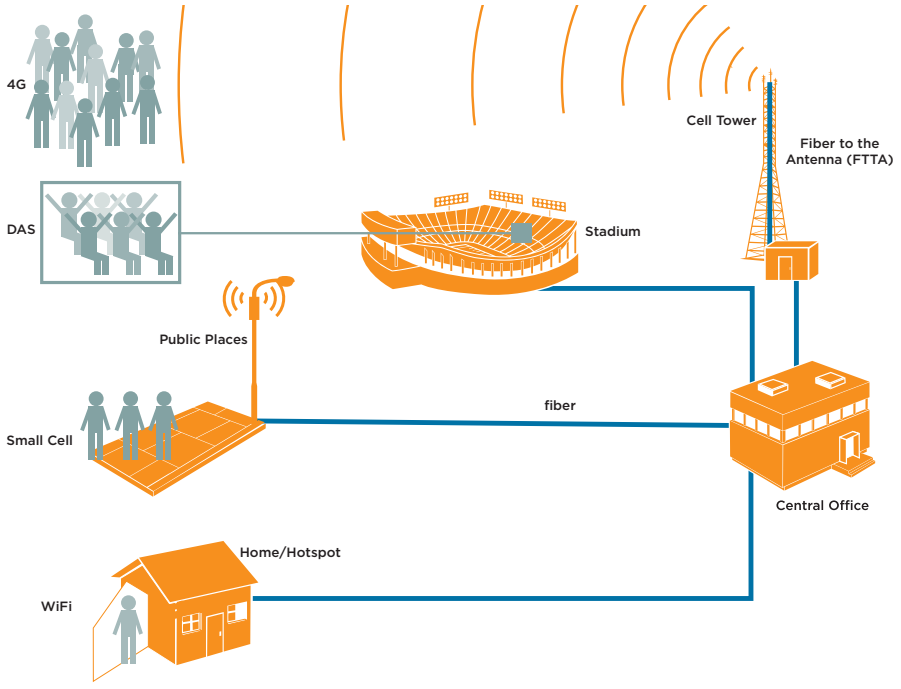


Figure 3: Wireless is a heterogeneous network comprised of 4G macrocells, DAS (Distributed Antenna System), small cells, and WiFi hotspots for maximum coverage and capacity.

Conclusion

This paper has provided a brief overview of key fixed and mobile broadband access technologies. While each service provider may face a different set of challenges, it is evident that fiber and FTTH are important components of all their strategies. In all cases, fiber is being deployed closer and closer to the customer because nothing else can compare for bandwidth. In the case of FTTH, fiber goes all the way to the customer – which puts FTTH service provides in an excellent competitive position for delivering gigabit services and beyond.

TE Connectivity has comprehensive and in-depth experience in designing, implementing, and maintaining fiber and FTTH networks around the world. The FTTH Architecture Series is a complete set of white papers that explore the key issues and decision criteria for building best-in-class FTTH networks. For more information, please visit www.te.com/bns.

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