

THE LOCAL EXCHANGE NETWORK IN 2015

LAWRENCE K. VANSTON

**TECHNOLOGY
FUTURES INC.**

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Lawrence K. Vanston, Ph.D.

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(800) 835-3887

(512) 258-8898

Fax: (512) 258-0087

www.tfi.com

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The Local Exchange Network in 2015

Lawrence K. Vanston, Ph.D.

This is a forecast of the North American local exchange network at the end of 2015, viewed from the perspective of 2001. We look beyond the current ups and downs of the telecommunications industry and describe a future that reflects the fundamental drivers of technology change over the long run.

This view is based on published and unpublished forecasts by Technology Futures, Inc. (TFI) that reflect logical extensions of current trends and are consistent with technology evolution principles. The technologies described are all known and either commercially available or under development. Choosing among competing technology alternatives is one of the more dangerous technology forecasting activities. Where it could not be avoided, the choice reflects current majority thinking circa mid-2001.

Before we transport ourselves to the end of 2015, let's take a moment to go in the opposite direction to year-end 1986 and review a few statistics, as shown in Exhibit 1.

Exhibit 1

The World of 1986

Household PC Penetration	<1%	Digital Switching (% of lines)	<17%
Household Online Penetration	0%	Fiber Interoffice (% of circuits)	<12%
Office LAN Connections (% of PCs)	6%	Fiber Feeder (% of lines)	<1%
Typical Modem Speed	1.2K	SONET Penetration	0%
Typical PC	286 (XT)	ATM & IP Switching Penetration	0%
Typical Hard Drive	20 MB	Cellular Penetration (% of pop.)	<1%
CDs (% of recordings)	7%		

<i>Common Wisecrack</i>	"Next year is always the year of LAN!"
<i>Common Wisdom</i>	"There's no driver to replace the analog (ESS) switches; they'll all still be here in 2000."
<i>Common Wishful Thinking</i>	"ISDN will meet your data needs!"
<i>Heard on TV</i>	"That was a pin?"

Source: Technology Futures, Inc.

So, things change, especially over 15 years. The forecast that follows will almost certainly be wrong in some respects, but the basic conclusion is likely to be about right:

By the end of 2015, we will have transformed the local exchange from a narrowband network of circuit switches and copper cable to a broadband network of packet switches and fiber optics.

Of course, in 2001, this transformation was well underway; now, as we ring out 2015, the work is all but done.

Residential Customers

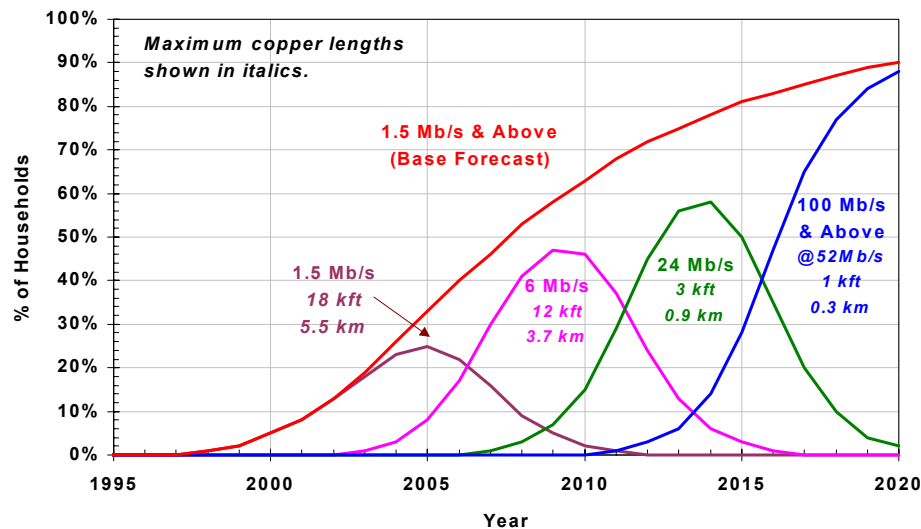
Broadband Internet Access

At the end of 2015, 88% of North American households are online. About 82% of households are served on broadband systems, and about 6% still use only analog modems or narrowband wireless connections. Most residential customers have a residential gateway that provides an interface between their broadband access service and their home local area network (LAN) to which devices such as

computers, televisions, telephones, utility management devices, and smart appliances are connected.

Broadband systems in 2015 offer data rates considerably higher than the 1.5 megabits per second (Mb/s) service that dominated the early 2000s. As shown in Exhibit 2, half of North American households now have 24 Mb/s service and 28% have 50 Mb/s to 100 Mb/s service. Only 3% of households still have 1.5 Mb/s to 6 Mb/s service, down from 50% just five years ago.¹

Exhibit 2
North American Online Households by
Data Rate—Percentage of All
Households



Source: Technology Futures, Inc.

Whether for entertainment, shopping, school, or work, people make frequent and routine use of the Internet. At any given moment, several people from the same household may be online simultaneously, not to mention devices and self-activating agents on computers making use of the network. Browsing web pages and downloading files are still common activities. Web pages have gotten very complex, taking advantage of the bandwidths now available in the network.

¹ For more information regarding these forecasts, see L. K. Vanston, *The Impacts of Competition and Technology on Local Exchange Outside Plant Assets* (Austin, TX: Technology Futures, Inc., 2001), Chapter 5, "Forecasts for Internet Access."

The Local Exchange Network in 2015

Downloads of software upgrades, virus updates, and other files often require several gigabytes in 2015. For households with the slower 6 Mb/s service, downloads can take half an hour or more. For households with 24 Mb/s broadband service, downloads can take five or 10 minutes, sufficient motivation for many to switch to 100 Mb/s service.

Television

In 2015, people still watch a lot of TV. Most households get their programming in the traditional ways—cable, over-the-air, satellite, DVD, etc. Many households access some of their television programming over the Internet via high-speed streaming video delivered to televisions and occasionally computers. Since 80% of households have high-speed Internet access of at least 24 Mb/s, using streaming video to deliver targeted or specialized broadcast content has become common. In addition to television, streaming video is used for various computer applications. Video chat rooms, video calls, music videos, instructional programs, infomercials, distance education, news clips, etc. are routine uses of streaming video to computers.

About two-thirds of households have at least one high-definition television (HDTV) set, and regular over-the-air and cable HDTV programming is a reality. Because HDTV channels require 20 Mb/s, broadband service at 24 Mb/s is insufficient to provide HDTV video streaming plus the additional requirements of the typical household. Thus, most analysts forecast that, five years from now in 2020, most homes will have converted to 100 Mb/s service.

Full-Service Providers

Most households in 2015 get their Internet access, cable television service, and wireline voice from the same company. As wireline voice revenues declined throughout the 2000s, incumbent local exchange carriers (ILECs) added video services to effectively compete against cable television and new entrants, both offering a full bundle of services at a discount. (In many areas, new facilities-based carriers entered the market for bundled services, using the most modern technology to compete with both the ILEC and the cable company.) This gave rise to a redefinition of the industry from separate telephone and cable companies to two or more full-service providers in any given territory.

Wireless for Wireline

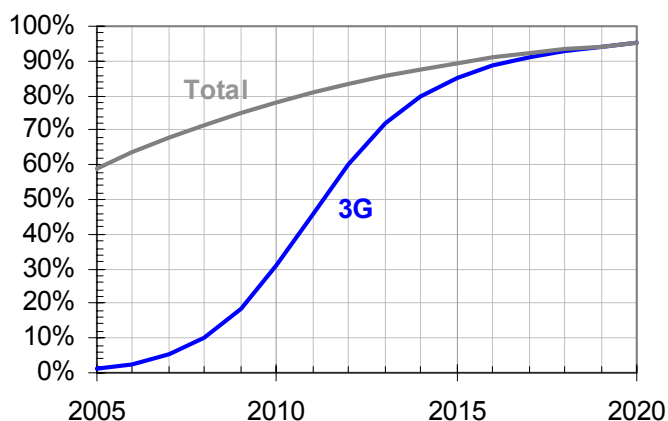
Wireless has largely displaced wireline for voice and low-speed data applications. In 2015, about 90% of North Americans are wireless users. Almost 70% of North American households no longer have a standard wireline telephone connection and use wireless or, occasionally, computer telephony instead. All wireless systems in 2015 are digital, and over 90% of wireless subscribers are on third-generation (3G) systems (see Exhibit 3) that provide packetized data as well as voice.² The 3G data rates are typically 144 kilobits per second (Kb/s) to 384 Kb/s, sufficient for many simple data transactions. Broadband wireline and 3G wireless have all but replaced the use of analog modems. Less than 2% of North American households still access the Internet over ILEC-provisioned analog narrowband lines. As shown in Exhibit 4, North American ILECs serve a total of 24.3 million wireline narrowband lines providing voice, narrowband data, or both. This compares to a peak of 135 million lines in 2001.³ Of course, many of the wireless, cable, and voice over Internet protocol (VoIP) lines are served by ILECs; thus, the ILEC share of the voice market is greater than wireline narrowband lines.

² L. K. Vanston, *Forecasts of Cellular Subscribers by Technology Generation* (Austin, TX: Technology Futures, Inc., 2001).

³ For details of these forecasts, see *The Impacts of Competition and Technology on Local Exchange Outside Plant Assets*, Chapter 6, “Forecasts for Local Competition.” U.S. figures have been converted to North American figures for this report.

Exhibit 3

**Adoption of 3G Wireless Technology—
Percentage of North American
Population**



Source: Technology Futures, Inc.

Exhibit 4

**Narrowband (NB) Access Lines—North
American Households (Millions), 2015**

	Primary Voice Line	Secondary Voice Line	Dedicated NB Data Line	Total
Wireless (NB)	91.1	29.0	3.6	123.7
Wireline Telephone (NB)	20.0	2.8	1.5	24.3
Cable & Other (NB)	9.7	3.1	1.8	14.6
VoIP (NB or BB)	12.6	85.9	0.0	98.5
Total	133.4	120.8	6.9	261.1

Source: Technology Futures, Inc.

Broadband fixed wireless services, including offerings via LMDS, MMDS, and LEO⁴ and geosynchronous satellites, captured a small part of the broadband access market in the 2005 through 2010 period. However, as customer demand

⁴ LMDS = local multipoint distribution service. MMDS = multichannel multipoint distribution system. LEO = low earth orbit.

shifted to higher speeds over the last five years, full-service wireline providers have captured most of these customers.

Business Customers

In 2015, most office computers are connected via local area networks operating at between 1 gigabit per second (Gb/s) and 10 Gb/s. Medium and large businesses use high-performance IP switches or gateways to provide intranet service, access to the Internet, and other data services. Most of these enterprises interface with the wide area network via fiber optics at data rates ranging from 2.4 Gb/s (OC-48) to 40 Gb/s (OC-768) or on dedicated wavelengths. Some operate their own wide area network using leased wavelengths or virtual circuits; others use virtual private networks. Medium businesses connect to the wide area network at OC-3 to OC-12. Most small businesses connect at data rates of 20 Mb/s to 100 Mb/s.

Enterprise networks are used for both general intranet/Internet applications such as database access, e-commerce, knowledge management, web surfing, etc. and specialized applications such as telemedicine, distance learning, and visualization.

Businesses are also heavy users of wireless LANs and 3G wireless services. Wireless LANs are often used in building and campus settings, while 3G is most often used for roaming. Both 3G and wireless LANs provide voice and low-speed data applications, and wireless LANs provide higher-speed data services—11 Mb/s or more—as well.

Whether wireless or wireline, almost all premises switching equipment use packet switching as opposed to circuit switching. IP-PBXs (including IP-key systems) are standard in most enterprises. Telephones, unless wireless, are usually connected to the switch via an Ethernet. For access to the public voice network, IP-based PBX/central office (CO) “trunks” are carried on the customer’s broadband access channels.

The Local Exchange Network

General Architecture

The general architecture of the local exchange network in 2015 is illustrated in Exhibit 5. There are three major types of nodes in the network:

- ❖ *Central offices.* Buildings where the major switches and network junction points are located, as well as points of presence (POPs) for interconnection to long-haul facilities, competitors, and content providers. Servers and headend equipment may also be located here.
- ❖ *Remote nodes.* Remote nodes are located in special environmental enclosures, vaults, or buildings and are generally within 12,000 feet of subscribers.⁵
- ❖ *End nodes.* These are located at the telephone pedestal, telephone pole, cabinet, or similar location within 1,000 feet of the customer. The end node is fed by fiber optics. The final connection, or “drop,” is made to the customer via traditional copper pairs, fiber optics, or coaxial cable. Depending on the system, the end node may contain active electronics or only simple passive optical elements.

The nodes are connected by transmission facilities, generally categorized as follows:

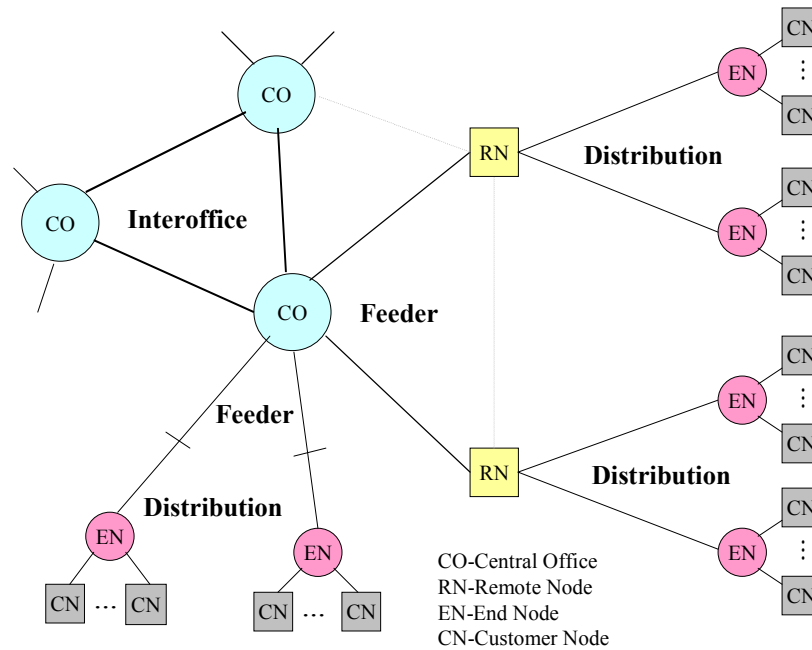
- ❖ *Interoffice network.* The fiber optic connections among central offices.
- ❖ *Feeder network.* The fiber optic connections among remote nodes and central offices. Originally, the feeder network consisted only of connections between central offices and remote nodes, but now many remote nodes are connected directly to provide route diversity and other benefits.

⁵ Remote nodes were originally built to hold digital loop carrier (DLC) equipment and digital subscriber line access modules (DSLAMs), but with the decline of first generation digital subscriber line (DSL) and ILEC voice services, these functions have diminished in importance. Passive and active optical multiplex equipment, feeding end nodes or large enterprises, remain an important use for remote nodes.

- ❖ *Distribution network.* The connections from the remote nodes to the end nodes, and the “drop” from the end node to the customer.

Exhibit 5

The Local Exchange Architecture—2015



Source: Technology Futures, Inc.

Traditionally, interoffice, feeder, and distribution were very much distinct networks, but recently the distinctions have begun to blur. Remote nodes are often connected to each other, and end nodes are often directly connected via fiber to central offices. Thus, the network has lost much of its tree-like structure, and traditional distinctions matter less.

Network equipment accounts for most of an ILEC’s investment in 2015. The three major categories of network equipment are:

- ❖ *Outside plant.* The physical facilities on which communications are carried, namely fiber optic cable, copper twisted pair cable, and coaxial cable.

The Local Exchange Network in 2015

- ❖ *Circuit equipment.* Electronics and/or optics that derive the communications channels that are carried by the outside plant. Also provides the connections among the channels at network nodes.
- ❖ *Switching equipment.* Equipment that routes packets over the proper channels to reach their destination.

Below, we review the status of each category at the end of 2015.

The Outside Plant

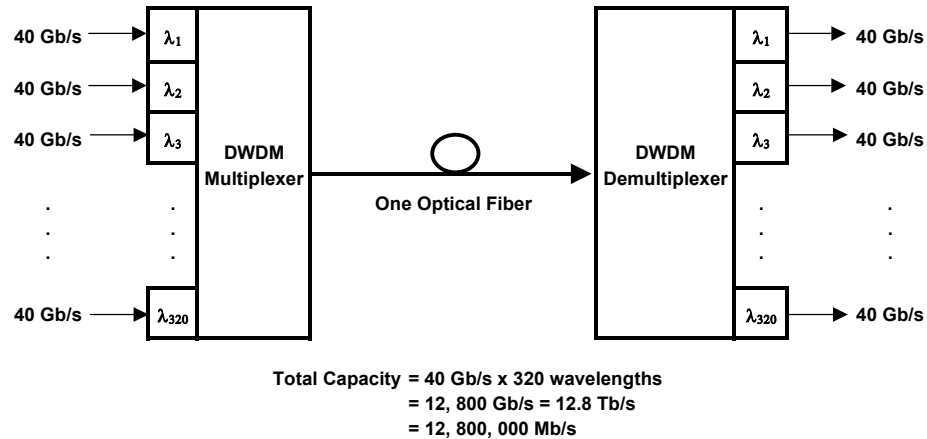
The Interoffice Network

In 2015, the interoffice network is entirely fiber, with dense wavelength division multiplexing (DWDM) used on most routes. Single wavelength systems, the technology of the 1980s and 1990s, created a digital signal by turning off and on a laser emitting a single wavelength, or color, of light. DWDM systems, on the other hand, use many wavelengths simultaneously on the same fiber. Thus, the capacity of a single fiber is multiplied by the number of wavelengths. Early DWDM systems used only a handful of wavelengths, but modern systems in 2015 use up to 320, although some long-haul systems use 1,024 wavelengths. The number used in a given metropolitan application depends on tradeoffs between fiber costs and multiplexing costs, as well as network architecture specifics.

In the early 2000s, 10 Gb/s single-wavelength systems were common, and 40 Gb/s systems were commercially available. In 2015, each of the 320 wavelengths can carry up to 40 Gb/s, bringing total capacity to 12,800 Gb/s as shown in Exhibit 6. Thus, a single metro cable of 20 fibers can carry 256,000 Gb/s, equivalent to 12.8 million 20-Mb/s HDTV channels, several for every household even in the largest cities. This translates to over four billion voice channels!

Exhibit 6

**State of the Art Metro DWDM System—
2015**



Source: Technology Futures, Inc.

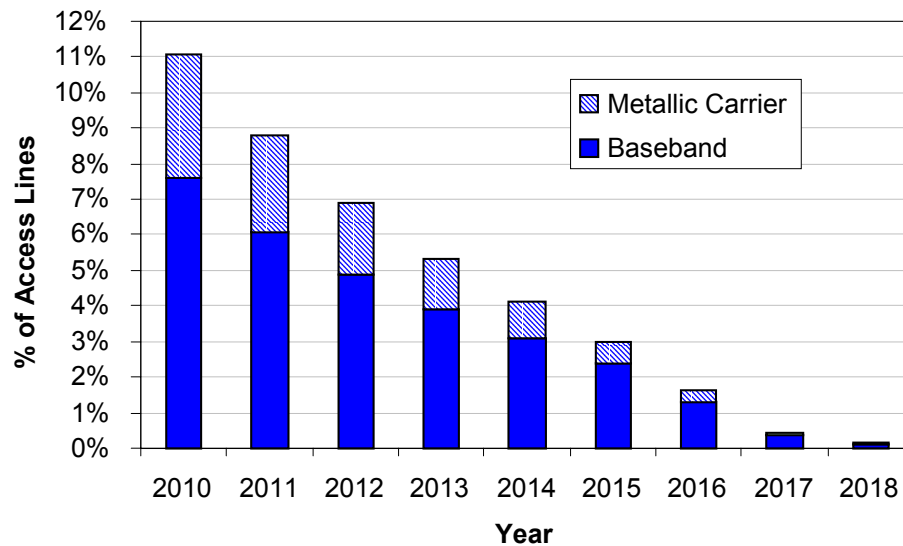
The Feeder Network

In 2015, only 3% of access lines remain on copper feeder. The other 97% of access lines are either served on fiber feeder or are too close to the central office to involve feeder facilities. By 2020, the last of copper feeder plant is expected to be displaced by fiber, as illustrated in Exhibit 7.⁶

⁶ See *The Impacts of Competition and Technology on Local Exchange Outside Plant Assets*, Chapter 2, “Forecasts for Fiber in the Feeder Network.”

Exhibit 7

Percentage of Access Lines on Copper Feeder Cable



Source: Technology Futures, Inc.

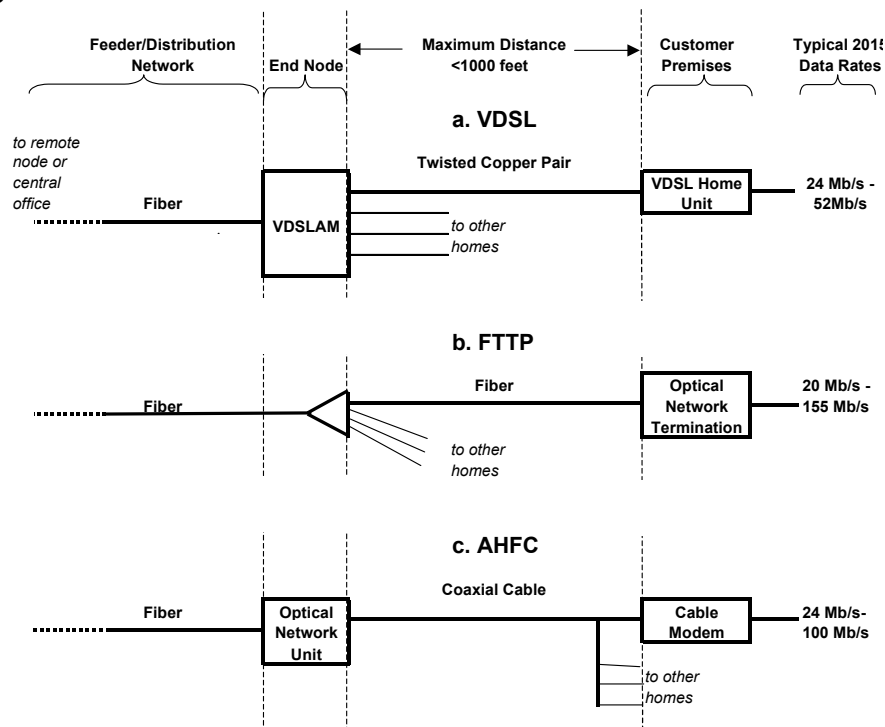
The Distribution Network

In 2015, essentially all ILEC medium and large business customers are served directly by fiber optics. Most ILEC residential and small business customers are served by deep fiber systems. This is a generic term for several systems in use by ILECs and their competitors in 2015. All deep fiber systems have fiber extending to a end node within 1,000 feet or less of the customer premises. Most deep fiber systems use DWDM and/or passive optical network (PON) technology in the fiber systems supplying the end node. PONs use optical couplers to share optical signals on a fiber among several connected fibers. This means that several customers or end nodes can share the same fiber without the use of active electronics. As illustrated in Exhibit 8, the most common deep fiber systems in use are:

- ❖ *Very high-speed digital subscriber line (VDSL).* The connection from the end node to the customer is on traditional copper pairs, providing 52 Mb/s service to small businesses and residential customers. In some cases, special drop cable has been recently installed to provide higher data rates than possible over traditional telephony cable. (Some older

VDSL systems are limited to 24 Mb/s because the end node is farther than 1,000 feet from the customer; these systems were designed with a 3,000-foot maximum distance guideline.) VDSL end nodes include VDSLAMs (VDSL access modules), which are the active electronics that interface with the customer and provide optical/electronic conversion.

Exhibit 8 Deep Fiber Systems in Common Use in 2015



Source: Technology Futures, Inc.

- ❖ *Fiber-to-the-premises (FTTP).* The connection from the end node to the customer is on a dedicated fiber. A PON optical coupler at the end node combines the individual fibers onto a single fiber back to the remote node or central office. Older systems don't use DWDM and provide lower speeds, typically 20 Mb/s for homes and 52 Mb/s for businesses, as shown in Exhibit 9A. Most modern FTTP systems in 2015 provide 155 Mb/s to 622 Mb/s service. As illustrated in Exhibit

9B, these systems combine DWDM and PON technology, which allows wavelengths to be dedicated to customers.

Exhibit 9A

Older PON Systems without DWDM

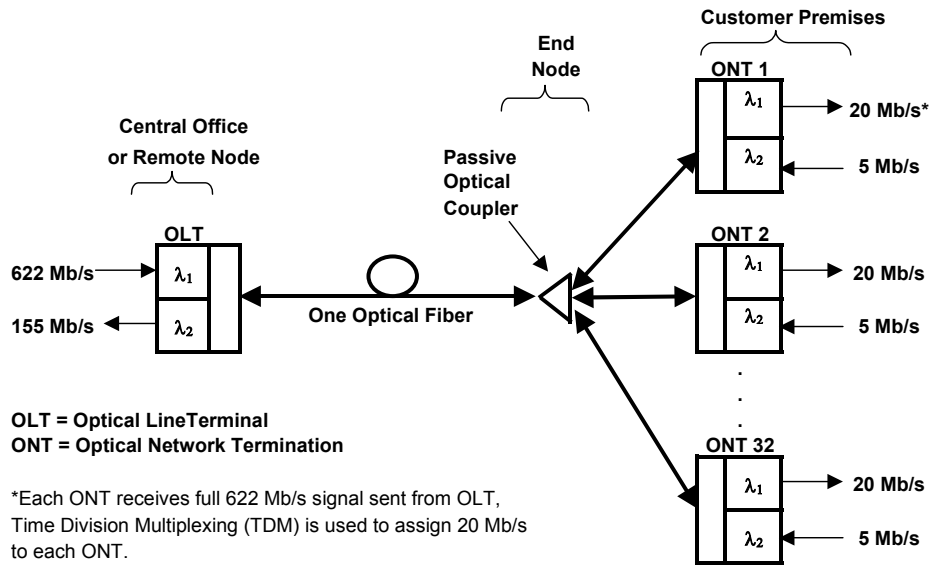
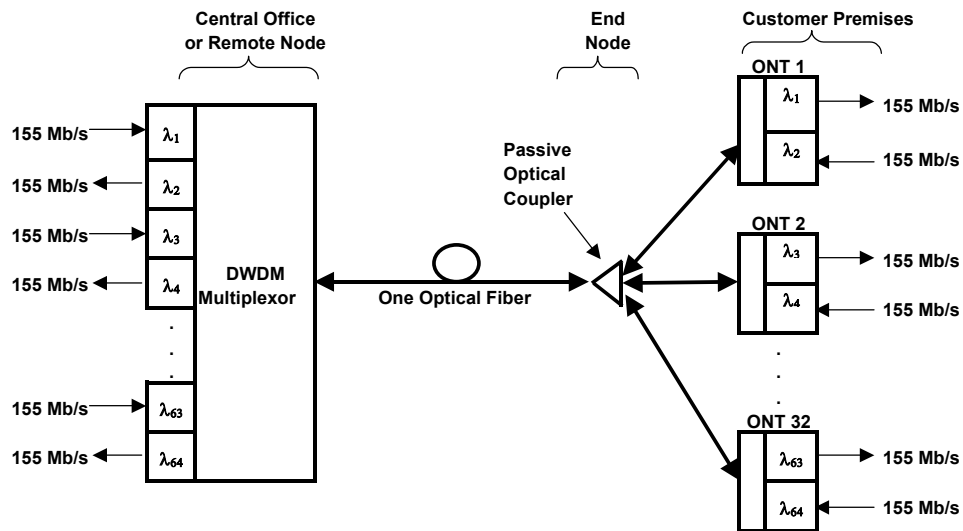


Exhibit 9B

Modern PON Systems with DWDM



Source: Technology Futures, Inc.

- ❖ *Advanced hybrid/fiber coax (AHFC)*. The connection from the end node to the customer is via traditional coaxial cable. Most AHFC systems provide a standard selection of broadcast television channels, plus 24 Mb/s to 100 Mb/s Internet access. Most AHFC systems use combinations of DWDM and PON technology to maximize bandwidth per customer, while minimizing fiber and electronics requirements.

The particular system in any given location reflects pre-2015 history to some extent. ILECs favored VDSL systems for existing neighborhoods and business areas served by the ILEC. VDSL allowed them to use existing copper pairs between the end node and the customer premises, avoiding the need to dig up yards, sidewalks, etc. Similarly, cable TV companies favored AHFC systems for the existing neighborhoods they served. For new neighborhoods or new out-of-territory installations, FTTP systems became attractive to both types of carriers starting in about 2005. In addition to high bandwidth, a key advantage of FTTP systems is that active electronics are not required at the end node, and the nodes are extremely small, about the size of a paperback book.

Again, almost all medium and large enterprise customer locations are connected to the network via dedicated fiber. As noted above, medium and large customers are connected at rates ranging from 2.4 Gb/s (OC-48) to 40 Gb/s (OC-768). Some customers bypass the public IP network entirely, running their own network of dedicated wavelengths, with the carrier providing only wavelength switching.

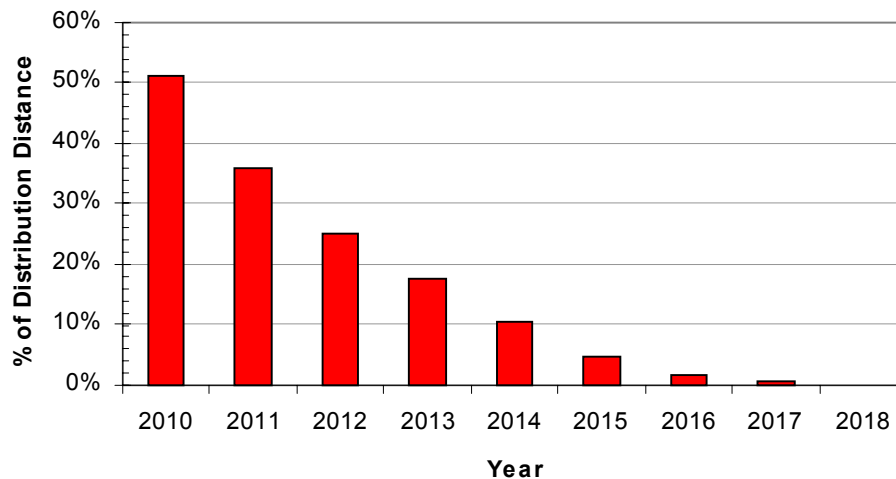
Baseband Copper

Baseband copper, which dominated the distribution network at the turn of the century and was still being installed in the early 2000s, is rapidly disappearing. By 2015, less than 5% of the distribution copper cable that was in place in 2000 is still useful. As shown in Exhibit 10, network planners currently expect the last copper cable to be removed from the distribution network by 2020, with VDSL drop wires being the only copper left in the outside plant.⁷

⁷ This forecast is based on TFI's 2001 middle scenario for fiber optic adoption. See *The Impacts of Competition and Technology on Local Exchange Outside Plant Assets*, Chapter 3, "Forecasts for Distribution Fiber."

Exhibit 10

Percentage of Distribution Distance on Copper



Source: Technology Futures, Inc.

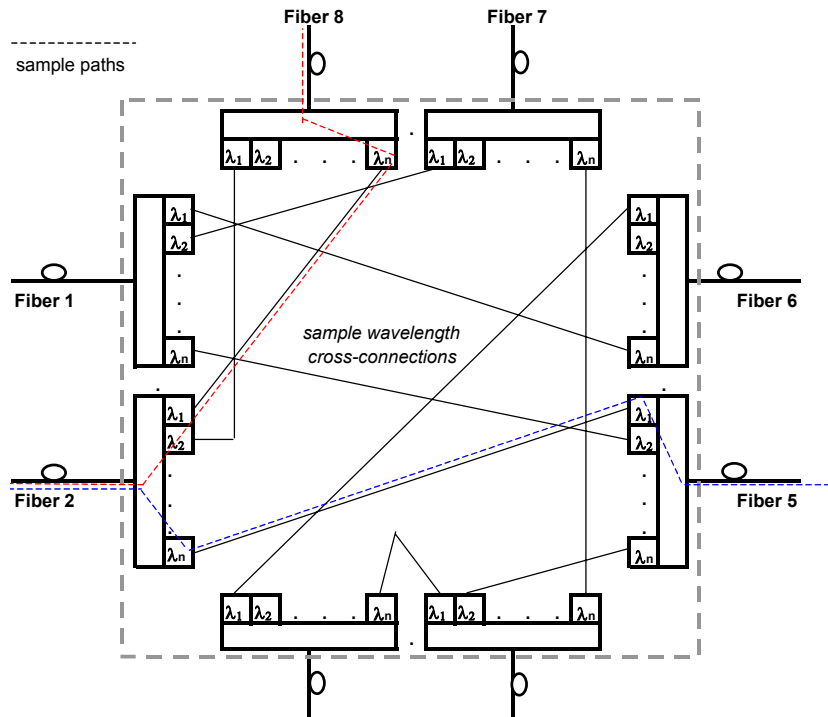
Circuit Equipment

Circuit equipment plays a support role in the network, providing the communications channels that are carried on fiber and switched by IP switches at network nodes. In 2015, there are several general types of circuit equipment in use: WDM switches, optical multiplex equipment, SONET (Synchronous Optical Network) equipment, DSL and VDSL equipment, and DLC equipment.

WDM Switches

WDM switches crossconnect wavelengths at junction points in the fiber network, as illustrated in Exhibit 11. With one or more WDM switches, an optical path can be set up between any two nodes in the network of fibers, WDM multiplexers, and WDM switches, collectively called the optical transport network (OTN). IP switches at those two nodes are assured of a high-speed communications path between them. The optical paths can be set up and torn down almost instantaneously in response to the demands of the higher-level IP networks served by the OTN. Optical network controllers maintain all the topology and resource availability information about the OTN and receive and act on the orders of higher levels.

Exhibit 11

Diagram of an Eight-Fiber by n-Wavelengths WDM Switch

Source: Technology Futures, Inc.

Optical Multiplex Equipment

This equipment combines the individual wavelengths from separate sources onto a single DWDM fiber. In the reverse direction, it splits the signal from the DWDM fiber into the individual wavelengths for separate destinations. Some versions of this equipment provide electrical instead of optical interfaces to the individual sources or destinations. Optical multiplex equipment is generally used at the (1) interfaces between the optical transport network and switch nodes, (2) the interfaces between networks, and (3) the interface between customers and the network. (By 2015, WDM switches have replaced optical multiplex equipment at the OTN junction points.) This category also includes the PON couplers in the distribution plant.

The Local Exchange Network in 2015

SONET Equipment

SONET is the traditional format for organizing information on a fiber optic wavelength and managing bandwidth. It was developed in the 1980s for single-wavelength fiber systems and widely adopted over the 1990s and 2000s. It had many advantages over its predecessors including standardization, add/drop multiplexing ability, protection-switching over rings, and bandwidth management features. By 2010, SONET technology had replaced all previous asynchronous circuit equipment and had gone through several generations of upgrades itself.

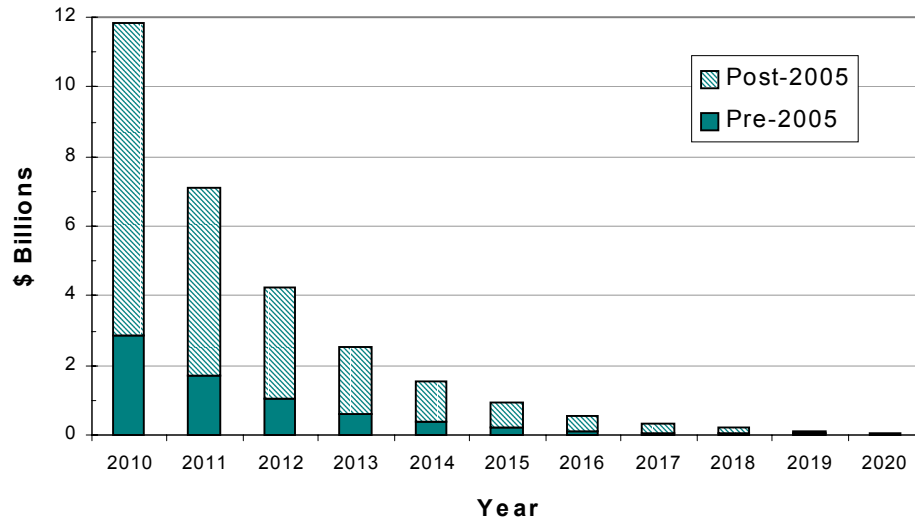
In the early 2000s, network planners recognized that SONET equipment would be unnecessary once the following occurred:

- ❖ DWDM replaced single wavelength fibers in the local exchange network.
- ❖ WDM switching was ubiquitous.
- ❖ Wavelengths had become the standard for IP/asynchronous transfer mode (ATM) switch interconnection.
- ❖ A robust, standardized optical network controller was proven.

This all came together in the 2010 timeframe. By 2015, about 80% of the SONET equipment in place in 2010 has been removed. From the perspective of 2015, most planners expect the last piece of SONET equipment to be removed in 2020.⁸

⁸ See R. L. Hodges, *Technology Forecasts for Local Exchange Circuit Equipment* (Austin, TX: Technology Futures, Inc., 2001), Chapter 4 for forecasts of SONET adoption and Chapter 6 for SONET displacement.

Exhibit 12
**Survivors from SONET Investment in
Place in 2010**



Source: Technology Futures, Inc.

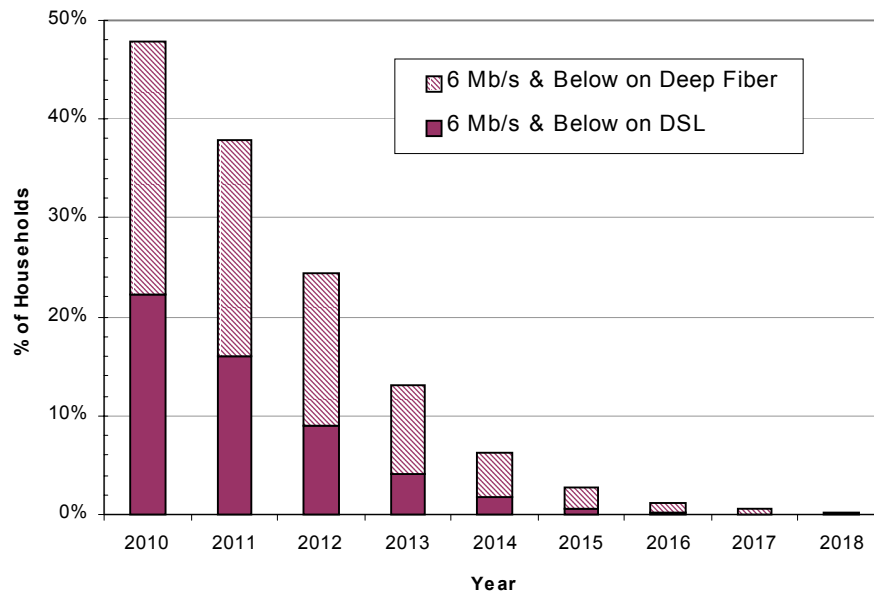
DSL and VDSL Equipment

Most first-generation DSL access modules (DSLAMs) installed in central offices and remote nodes in the 2000s have been made obsolete by higher-speed services at 24 Mb/s and above. Today, in 2015, only 3% of households and small businesses subscribe to low-speed (up to 6 Mb/s) service, and most of these are now served on deep fiber systems, as illustrated in Exhibit 13.

The VDSLAMS in use in 2015 are small units at end nodes fed by fiber from the central office or a remote node.

Exhibit 13

Percentage of Households with 6 Mb/s & Below Broadband Access on DSL and Deep Fiber



Source: Technology Futures, Inc.

DLC Equipment

By 2015, traditional digital loop carrier (DLC) equipment has all but disappeared from the network, and what is left is severely under-utilized. During the previous 15 years, competition from wireless services, cable telephony, and broadband Internet access displaced tens of millions of traditional analog access lines used for voice and analog modems. (Broadband access also displaced ISDN [Integrated Services Digital Network] lines primarily used by businesses.) For example, in 2015, ILECs provide only about 27 million North American homes with traditional analog service, down from a peak of about 135 million in 2001. With the transition to IP switching, most households and small businesses retaining wireline service switched to voice over IP services carried on the customer's broadband channel, bypassing the analog local loop and any associated DLC equipment. (Of course, medium and large businesses, almost all being served on fiber, have long been disassociated with DLC equipment.)

Despite the changes, about 20% of North American households and small businesses still subscribe to traditional ILEC narrowband voice service in 2015. They are served in one of several ways:

- ❖ With VoIP on broadband facilities, with an analog converter installed on the customer premises.
- ❖ With narrowband channel units built into VDSLAMS and late-model DSLAMS that convert the voice to packets for transport via VoIP.
- ❖ On wireless local loop technology (including, in some cases, mobile cellular).
- ❖ On copper pairs to the central office for customers close to the central office.
- ❖ On copper pairs to traditional DLC equipment or remote switching modules.

Only the latter method involves DLC equipment. The under-utilization of DLC equipment tended to make the maintenance and space requirements of DLC equipment inefficient and increased the attractiveness of the alternatives. Thus, while 30% of access lines were served on traditional DLC systems in 2000, only about 1% are in 2015.

Switching Equipment

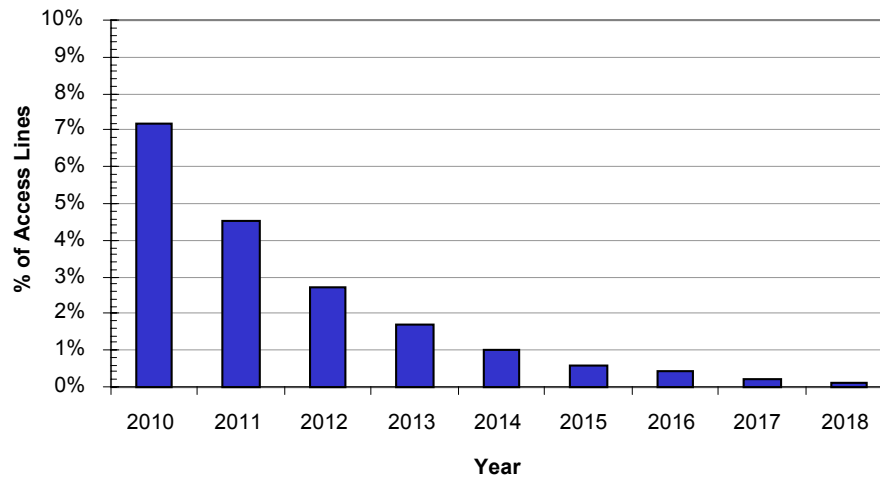
Narrowband Switching

By 2015, the last narrowband circuit switches such as the 5ESS and DMS 100, as well as their remote switching modules, are being removed from the network, as shown in Exhibit 14.⁹ Thus, digital circuit switching has joined other switching technologies in history's junkyard (see Exhibit 15). Voice signals are packetized at the edge of the network at remote terminals or by customer equipment and then transported on VoIP. In 2005, 95% of traffic was data traffic, more suitable for packet switching than circuit switching. As data traffic dominated, it became more efficient to carry voice on the same packet network as data rather than maintain separate switched networks.

⁹ See *Technology Forecasts for Local Exchange Circuit Equipment*, Chapter 5, "The Adoption of Packet Switching."

Exhibit 14

**Percentage of Access Lines Served on
Circuit Switches**



Source: Technology Futures, Inc.

Exhibit 15

**End of Switching Eras—Year Use of
Switching Technology Fell below 1% of
Access Lines (Major U.S. Companies)**

Manual	1965
Electromechanical	1994
Analog Electronic	2002
Digital Electronic	2014
Electronic IP	?

Source: Technology Futures, Inc.

Call control and management signaling and processing using SS7 and network databases still goes on, but the intelligence for switching has migrated out of the switch and into outboard servers.

Packet Switching

By 2015, the battle between ATM and IP that started in the late 1990s is winding down. IP switching has become the dominant switching technology. Most of these communicate directly with each other via DWDM channels and are capable of ordering additional channels instantly in case of network congestion or failures. The tremendous bandwidth of DWDM, combined with multiple protocol label switching, allowed IP to provide the acceptable quality of service (QoS) needed for delay-sensitive voice and video traffic. Some ATM switches are still used in some networks, but IP, once achieving reasonable QoS, has displaced many ATM switches, their function, like SONET, having become redundant.

Summary

The typical household of 2015 subscribes to broadband service at 24 Mb/s to 100 Mb/s, using it for traditional Internet activities, such as web surfing and downloading files, and new uses such as voice communications, device monitoring, and video streaming. ILECs provide these services using deep fiber systems, including VDSL, FTTP, and AHFC. These technologies are also used to provide small businesses with access to the network at data rates up to 622 Mb/s. Medium and large businesses access the network directly with fiber at data rates from 2.4 Gb/s to 40 Gb/s. By 2015, most customers obtain voice and narrowband data service via wireless or VoIP on broadband channels.

In 2015, fiber dominates the outside plant, comprising 100% of the interoffice network, 97% of the feeder network, and 95% of the distribution network. Circuit equipment revolves around DWDM, with WDM switches, optical multiplexing equipment (including PON couplers), and VDSLAMs comprising the bulk of circuit investment. There remains some SONET equipment in 2015, but it is rapidly being removed from the network. Switching is 100% packet-based, with IP switching dominant and ATM switching on the decline.

Little remains in 2015 of the local exchange network that was in place at the turn of the century. Most of the copper cable is no longer used, nor is most DLC equipment. The first generation of DSLAMs has been replaced by VDSLAMs or PON equipment. Most SONET and ATM equipment in place in 2000 was replaced by 2010 with newer models then made obsolete by DWDM and IP. Digital circuit switches, still state-of-the-art in 2001, are also gone. Of the \$355 billion of network investment in place in 2001, well under 10% is still in use in 2015.