GET TO FAST, FASTER

ACCELERATE THE EXISTING COPPER PLANT WITH VDSL2 VECTORING AND BONDING

STRATEGIC WHITE PAPER

As service providers face rapidly increasing bandwidth demand from consumers, businesses and governments, they are recognizing the need for immediate access to faster speeds. New technologies, such as Very High Speed Digital Subscriber Line 2 (VDSL2) vectoring and VDSL2 bonding accelerate the existing copper plant to help service providers get to fast, faster. This paper explores VDSL2 vectoring and VDSL2 bonding technology and the benefits they deliver. It compares the speed gains and investment requirements of these innovations with other technology options. This paper also provides a complete overview of the requirements for swift and successful deployments based on Alcatel-Lucent real-world experience.

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1. THE NEED FOR SPEED

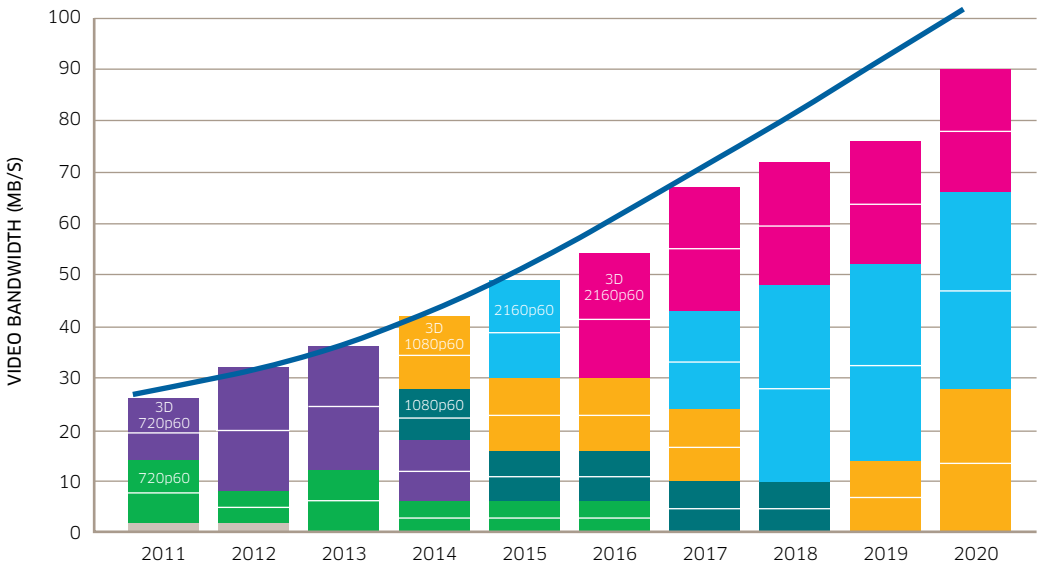
Video delivered on multiple screens in the home is driving access bandwidth requirements to new levels. The number of screens in the home is on the increase. At the same time, cloud services, video conferencing, and other bandwidth-intensive services are driving businesses' bandwidth requirements. In addition, governments see universal broadband as a priority for socio-economic development and as critical infrastructure for services such as e-health care and e-learning.

To attract and retain customers and compete with other providers, service providers need to:

- Offer attractive service packages that reliably deliver much higher bandwidths to the home
- Provide businesses with high upload and download speeds
- Help governments achieve national broadband targets

With these requirements, fast broadband has become table stakes for service providers. The question is, how much bandwidth is enough? Several government broadband plans are targeting 100 Mb/s. This is a reasonable target, as even the most aggressive assumptions about video traffic — which represents the bulk of the downstream traffic to households — will not reach 100 Mb/s before 2020 (Figure 1). This represents year-over-year residential video bandwidth growth of 15 percent.

Figure 1. Residential video bandwidth usage projection



Source: Alcatel-Lucent Bell Labs

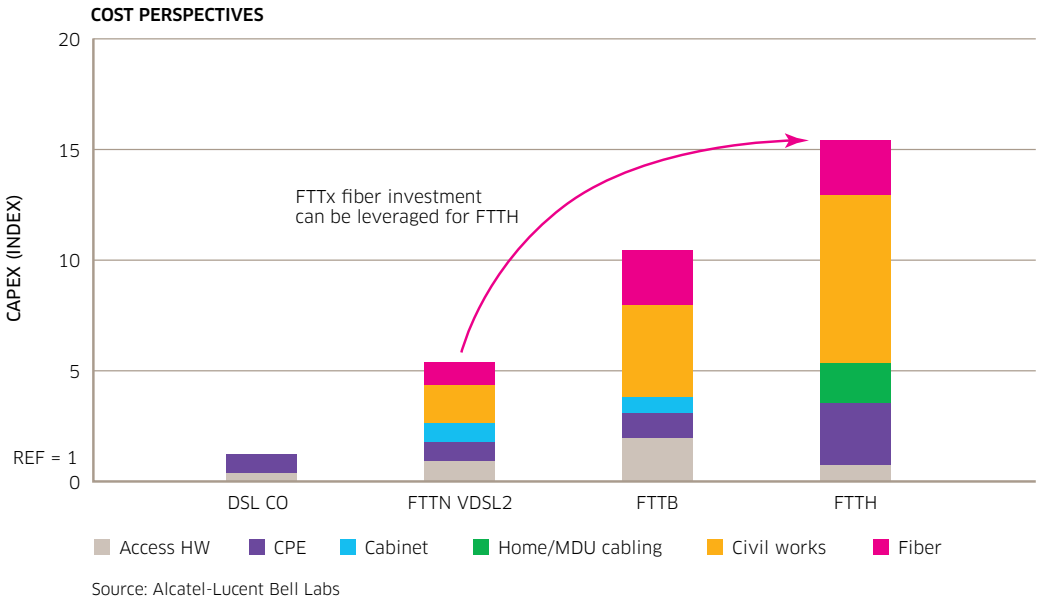
Figure 1 shows the Alcatel-Lucent Bell Labs view of the bandwidth requirements for a customer with reasonably high bandwidth consumption. Others will need less; a very few might need a little more. However, because the bandwidth consumed will be dominated by video, the graph sets a reasonable expectation for the amount of bandwidth needed to serve the majority of customers. Over time, video compression will decrease the amount of bandwidth needed by existing video types and new high-resolution video streams demanding more bandwidth will be introduced. However, this projection does not include compression gains so actual bandwidth requirements will be lower than projected.

1.1 Does copper make sense?

As we will discuss further in Section 2 with the latest innovations in Digital Subscriber Line (DSL) technology, copper can easily meet the bandwidth demand curve shown in Figure 1. In addition, getting more speed from the last mile of existing copper is cost effective and enables faster time to market compared to taking fiber all the way to the end customer.

Figure 2 confirms that copper is more cost effective than fiber by showing that a VDSL2 Fiber to the Node (FTTN) deployment can be almost three times less expensive than a Fiber to the Home (FTTH) deployment. These cost savings mainly result from reduced civil works costs because reusing existing copper reduces the extent to which new fiber must be installed. Any fiber investments to support VDSL2 cabinet deployments result in lower costs for future FTTH deployments as that fiber can be reused for FTTH.

Figure 2. VDSL2 FTTN deployments are much less expensive than FTTH deployments



Source: Alcatel-Lucent Bell Labs

The need to introduce higher bit-rate services to the majority of the population is also critical in determining which access technology a service provider deploys in the next step of their network evolution. Time to market for an FTTN network is considerably less than that needed for an FTTH network. The reduced civil works requirements for an FTTN network allow a service provider to deliver more bandwidth to more people faster.

2. INCREASING COPPER SPEEDS

Today, service providers have four main options to drive higher speeds on copper:

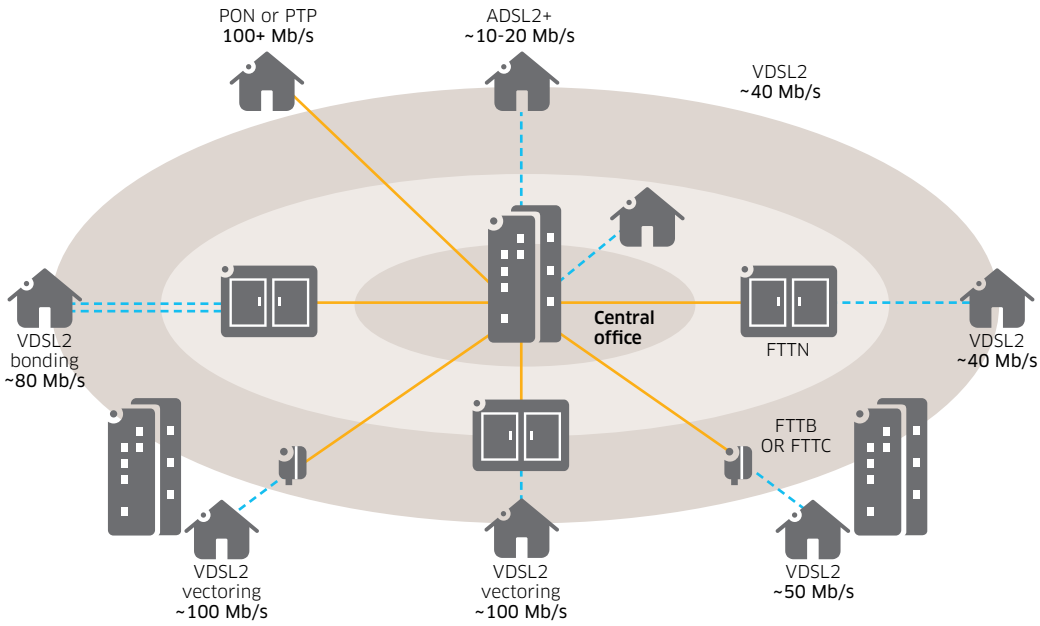
- Extend the frequency spectrum used by VDSL2; for example, from 8.5 MHz (profile 8b) to 17.6 MHz (profile 17a)
- Shorten the copper loops
- Use multiple copper pairs (known as bonding)
- Apply vectoring

Introducing one or more of these options can considerably increase access network speeds. Several service providers have already taken these steps, validating the viability of VDSL2.

As an example, starting from Asymmetric Digital Subscriber Line 2plus (ADSL2plus) as a first step and moving clockwise in Figure 3, a fast implementation is to introduce VDSL2 on short loops from the central office (CO). As a next step, introducing VDSL2 using fiber-fed cabinets (FTTN) or sealed DSL Access Multiplexer (DSLAM) deployments (Fiber to the Curb [FTTC] or Fiber to the Building [FTTB]) extends the network to reach nearly all subscribers.

While the above options shorten VDSL2 loop lengths and improve the bandwidth considerably, crosstalk between copper pairs prevents maximum performance and is typically the largest impairment reducing the bandwidth. VDSL2 vectoring is a technique to remove this crosstalk. Moving further around the circle in Figure 3, it can be seen that VDSL2 vectoring makes the full VDSL2 bandwidth available with FTTN, FTTC and FTTB deployment topologies. At 100 Mb/s, copper with VDSL2 vectoring provides plenty of bandwidth for projected residential needs. When bandwidth and budgets allow it, the fiber deployed to support the remote VDSL2 devices can be reused to provide fiber to the home.

Figure 3. Service providers' options to increase copper speeds



In addition, with VDSL2 bonding the possible distance from the DSLAM for a particular bit rate increases. This allows service providers to offer advanced services to subscribers who might otherwise remain out of reach for those services. Two-pair VDSL2 bonding can also double the attainable bit rate at the same distance from the DSLAM.

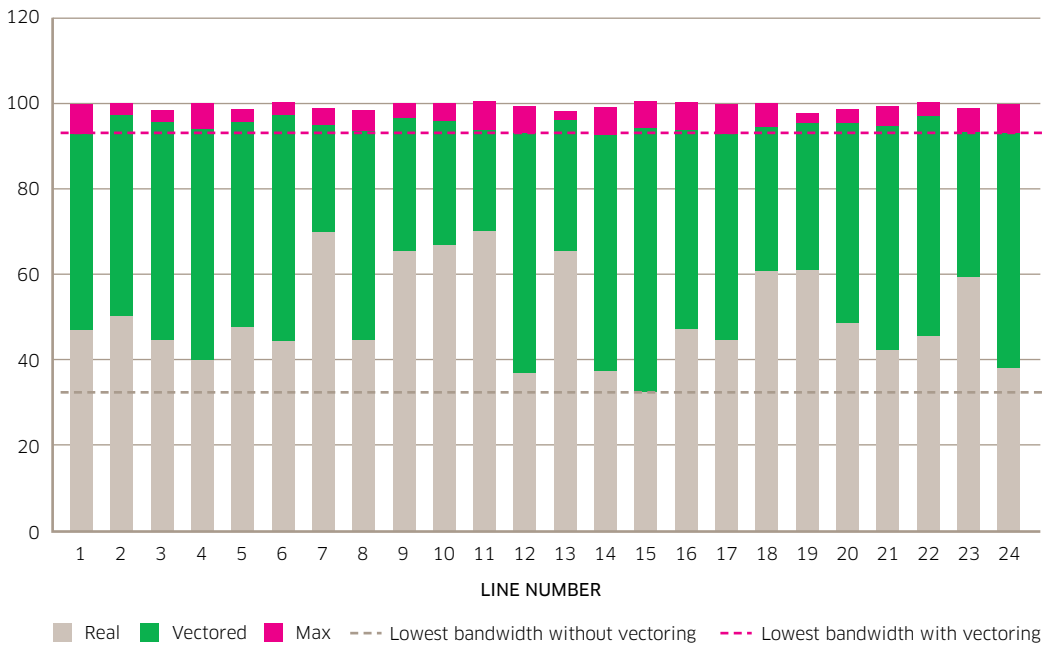
While two-pair VDSL2 bonding is typically used for residential deployments, bonding more than two pairs unleashes speeds that are attractive for demanding business users and mobile backhaul. Without vectoring up to eight pairs can be bonded to achieve speeds approaching 750 Mb/s. The Alcatel-Lucent Intelligent Services Access Manager (ISAM) family of products — part of a High Leverage Network™ architecture — supports this convergence of residential and business users.

2.1 VDSL2 Vectoring explained

VDSL2 vectoring is standardized in the International Telecommunication Union – Telecommunication Standardization Sector (ITU-T) G.vector standard.[1] It is a noise cancellation technology, comparable in concept to the technology found in noise canceling headphones. With VDSL2 vectoring, the crosstalk into each line in a DSL binder or cable is measured and anti-phase signals are applied to each line to remove the crosstalk.

With VDSL2 vectoring, every line in a binder can operate at peak performance, as if there were no other VDSL2 lines in that binder. This results in consistent, predictable, and most importantly, sellable performance gains. Figure 4 provides an example of gains achieved with VDSL2 vectoring. Actual gains will depend on loop length and line quality.

Figure 4. VDSL2 vectoring delivers significant performance gains



Source: Alcatel-Lucent

The grey bars show the bit rates in each of the 24 copper pairs in a 400-meter binder without VDSL2 vectoring. Downstream, the lowest bit rates in this example are in the low- to mid-30s in Mb/s. This low downstream bit rate sets the marketable bit rate to an equally low level.

[1] ITU-T G.993.5 Self-FEXT cancellation (vectoring) for use with VDSL2 transceivers

With VDSL2 vectoring, bit rates increase considerably, as represented by the green bars in Figure 4. The lowest bit rate available in this example is in the low- to mid-90s in Mb/s. The attainable bit rates in each network will vary.

3. VDSL2 VECTORING IN THE REAL WORLD

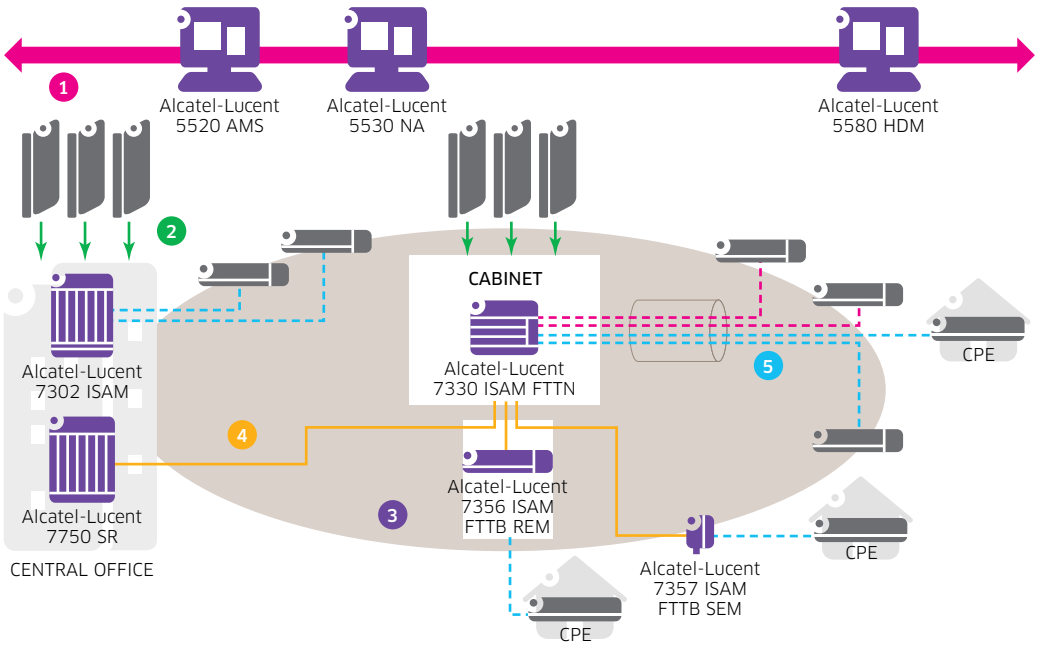
The Alcatel-Lucent extensive field and lab experience revealed that VDSL2 vectoring significantly increases sellable downstream and upstream bandwidth. Alcatel-Lucent also learned that, for VDSL2 vectoring technology to deliver its full benefits, service providers need a well thought-out introduction of the technology and a strong focus on customer quality of experience (QoE).

Swift and successful introduction of VDSL2 vectoring technology requires:

- Ability to smartly reuse the network elements that are already in the field
- DSLAM portfolio breadth and depth to enable the required topologies
- Availability of end-to-end management tools
- DSLAM capable to support higher sustained and peak bit rates
- Support for legacy VDSL2 customer premises equipment (CPE)
- Software tools to troubleshoot and manage outside copper plant cables

Figure 5 illustrates how Alcatel-Lucent helps service providers meet these requirements. The numbers in the illustration are referred to throughout the descriptions that follow.

Figure 5. Alcatel-Lucent provides a full solution set for VDSL2 vectoring.



AMS = Access Management System
CPE = customer premises equipment
FTTN = Fiber to the Node
FTTB = Fiber to the Building

HDM = Home Device Manager
ISAM = Intelligent Services Access Manager
NA = Network Analyzer
REM = Remote Expansion Module

SEM = Sealed Expansion Module
SR = Service Router

3.1 Smart reuse of existing network elements

VDSL2 vectoring is a brand new technology. However, service providers with an Alcatel-Lucent ISAM platform need only install new vectoring-capable line cards to upgrade to VDSL2 vectoring.

Alcatel-Lucent VDSL2 vectoring technology is supported on currently deployed ISAM DSLAM products. Installation of VDSL2 vectoring cards (reference 2 in Figure 5) in existing ISAM shelves is a simple swap out of cards. Cabling, shelves, racks, cooling, and other associated equipment can all be reused. This saves considerably on capital and operating expenditures (CAPEX/OPEX) because the new VDSL2 vectoring line cards simply replace the old line cards.

Alcatel-Lucent supports vectoring at the board level and system level, giving service providers flexible deployment options and minimizing the need for grooming. In the case of board-level vectoring (BLV), vectoring is performed across all lines connected to a line card. In the case of system-level vectoring (SLV), lines are vectored across an entire system with multiple line cards.

3.2 DSLAM portfolio breadth and depth

A prerequisite for bringing the bandwidth benefits of VDSL2 vectoring to all customers is a DSLAM portfolio that covers central office solutions as well as FTTN, FTTB or FTTC solutions. The Alcatel-Lucent DSLAM portfolio supports this requirement with central office shelves and remote solutions that can be cabinet- or building-mounted or housed in a Sealed Enclosure Module (SEM) (reference 3 in Figure 5). All of these deployment models are supported with the same ISAM family platforms, ensuring customers enjoy high QoE no matter how they are connected.

Along with the equipment variants for different network topologies, Alcatel-Lucent also offers an extensive cabinet and enclosure portfolio to allow mounting in almost any situation. For example, mounting options for multi-dwelling units (MDUs), cabinets that can house one or two shelves of equipment, pole mountings, pad mountings, strand mountings, and pedestal mountings are all available to match the customer's situation and to suit nearly any right-of-way geography.

3.3 End-to-end management tools

As part of any vectoring deployment, it is important to be able to manage the network from end to end. The ability to analyze loop issues, manage CPE and the nodes themselves is imperative to providing good QoE to customers.

Vectoring adds a new dimension to troubleshooting — the binder concept. In a binder, a problem on Line 17 might actually be caused by Line 23. As a result, performing only single-line troubleshooting on a line might not lead service providers to the root cause of the problem. The Alcatel-Lucent Network Analyzer (NA) (reference 1 in Figure 5) supports crosstalk mapping allowing service providers to detect the correct root cause of problems in a binder. For each line in the binder, the Alcatel-Lucent NA shows which other lines are the dominant crosstalkers. It also keeps track of the crosstalking lines over time. This information gives support engineers all of the information needed to efficiently identify the root cause of problems.

For service providers that are considering an upgrade to a DSL network, the NA provides a DSL predictor. Service providers can start with a forecast of the attainable bit rate when upgrading a line from ADSL to VDSL2 technology. This information increases the success rate for the upgrade, identifies where remote cabinets may be needed and makes it possible to accurately calculate the associated cost of offering an upgrade. Upgrade predictions with vectoring support then extends these forecasts, by offering a separate prediction of the attainable bit rate with VDSL2 vectoring implemented.

The Alcatel-Lucent 5520 Access Management System (AMS) can manage and upgrade (remote) nodes within an access network. Equally important is the ability to manage the access and home network as a whole. Alcatel-Lucent offers several additional applications, including the Alcatel-Lucent 5580 Home Device Manager (HDM) and the Alcatel-Lucent 5530 Network Analyzer – Copper, to support this requirement.

As an example, the Alcatel-Lucent 5580 HDM can upgrade legacy VDSL2 CPE to VDSL2 vectoring-capable or VDSL2 vectoring-friendly CPE as long as the hardware in the CPE supports the upgrade. Vectoring-capable CPE means the CPE supports the mandatory functionality as described in the G.vector standard and can benefit from vectoring gain if part of a vectoring group. Vectoring-friendly CPE means the CPE supports the functionality as described in the G.vdsl2 standard Annex X or Annex Y such that crosstalk from this line into neighboring vectored lines can be canceled in downstream (Annex X and Annex Y) and possibly upstream (Annex Y).

3.4 High-bandwidth support

Because the purpose of introducing VDSL2 vectoring is to deliver bit rates that can reach 100 Mb/s, the access platform should be able to absorb these higher speeds on the backplane with sufficient uplink capacity (reference 4 in Figure 5).

The Alcatel-Lucent installed base of ISAM platforms is based on a market-leading, high-capacity VDSL2 line card that provides 50 Mb/s sustained and 100 Mb/s peak per subscriber. It also provides network connectivity for multiple Gigabit Ethernet (GigE) and 10GigE uplinks.

These ISAM platforms have the capability to deliver even more bandwidth — meeting or exceeding VDSL2 vectoring requirements while maintaining quality of service (QoS) for many different types of data and video.

3.5 Legacy network support

In a realistic VDSL2 vectoring introduction scenario, not all CPE served in a single binder may support vectoring by software upgrade (the CPE connected to the dashed pink lines in reference 5, Figure 5). Moreover, even a single legacy VDSL2 line in a binder can severely reduce the vectoring gains on other lines. Therefore, upgrading legacy CPE can be a significant challenge for service providers. Alcatel-Lucent zero-touch vectoring technology solves the legacy VDSL2 CPE challenge automatically. Clever signal processing in the ISAM ensures that crosstalk from legacy VDSL2 lines into vectored lines can be measured and canceled without requiring any new functionality in the legacy VDSL2 CPE. As a result, firmware upgrades are not required. Legacy VDSL2 CPE behave as if they are vectoring-friendly without being touched.

With zero-touch vectoring technology, service providers have a quick and easy way to introduce vectoring in their network. They do not have to worry about the effects of legacy VDSL2 CPE or spend time on network-wide CPE upgrades. Zero-touch vectoring also provides a safety net by providing a solution when no firmware upgrades are available for a certain VDSL2 CPE model or if an end user connects a non-vectoring capable CPE.

Zero-touch vectoring helps make universal broadband a reality faster.

4. CONCLUSION

To meet customer demand, competitive pressures, and government targets service providers need to deploy access technologies that can meet the demand for bandwidth while enabling rapid deployments, reasonable time to market and the quickest return on investment.

Each service provider's business and network have different requirements. While FTTH deployments have started, they require significant investment and time to roll out. To meet customers' needs, it also makes sense for many service providers to consider the gains that can be realized from existing copper by using the latest VDSL2 vectoring and VDSL2 bonding technologies.

Fortunately, today most of the world's broadband subscribers already connect to the Internet through copper lines. According to networking and telecommunications market research group, Dell'Oro, two-thirds of the world's broadband subscribers are connected through DSL. Accelerating this existing copper plant is a fast and cost-effective way to deliver more bandwidth to more subscribers.

Alcatel-Lucent offers a unique and extensive solution set to deliver the fastest bandwidth over copper using its VDSL2 vectoring implementation. The breadth and depth of the Alcatel-Lucent DSLAM portfolio supports any topology, including FTTN, FTTC and FTTB. It enables smart reuse of existing network elements, including CPE. And it includes a full set of management tools and QoS functions, ensuring high customer QoE.

By enabling existing copper to deliver higher speeds, Alcatel-Lucent helps service providers get to fast, faster.

5. ABBREVIATIONS

ADSL2plus	Asymmetric Digital Subscriber Line 2plus
AMS	Access Management System
BLV	board-level vectoring
CAPEX	capital expenditure
CO	central office
CPE	customer premises equipment
DSL	Digital Subscriber Line
DSLAM	DSL Access Multiplexer

[2] Dell'Oro Access Report, Five-Year Forecast 2011 – 2015, Vol. 15, No. 2.

FTTB	Fiber to the Building
FTTC	Fiber to the Curb
FTTH	Fiber to the Home
FTTN	Fiber to the Node
GigE	Gigabit Ethernet
HDM	Home Device Manager
ISAM	Intelligent Services Access Manager
ITU-T	International Telecommunication Union – Telecommunication Standardization Sector
MDU	multi-dwelling unit
NA	Network Analyzer
OPEX	operating expense
OS	operating system
P2P	point-to-point
PON	Passive Optical Network
QoE	quality of experience
QoS	quality of service
REM	Remote Expansion Module
SEM	Sealed Expansion Module
SLV	system-level vectoring
SR	Service Router
VDSL2	Very High Speed Digital Subscriber Line 2

6. RESOURCES

For more information about VDSL2 vectoring, VDSL2 bonding and the benefits of converged wireline access, please contact your local Alcatel-Lucent sales team or visit http://www.alcatel-lucent.com/vdsl2-vectoring.

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