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EDITORIAL GUIDE

Approaches to Gigabit Broadband

Service providers have already launched gigabit broadband services via GPON and EPON. But a new generation of PON technology promises even better gigabit delivery. Meanwhile, other approaches to gigabit services have emerged with threaten fiber's primary role. This Editorial Guide offers insight into next-generation PON as well as some of these non-fiber alternatives.

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The Bright Future of TWDM-PON and Wavelength Unbundling

By **ANA PESOVIC,** Nokia

TODAY, NETWORK PROVIDERS have several options when it comes to investing in next-generation PON technology. However, in the race to more effectively monetize network investments, address growing needs for symmetrical bandwidth, and better serve future evolving end-user demands, network providers are increasingly turning to time and wavelength division multiplexed PON (TWDM-PON). Why? For many, it starts with the flexibility the technology provides.

Unlike GPON or XG-PON1, TWDM-PON offers up to four wavelength pairs (eight in the future) that can each be configured at different bitrates (10G/10G, 10G/2.5G, 2.5G/2.5G) to best address the specific requirements of residential, business, or backhaul services. Providing up to 10-Gbps symmetrical speeds on each wavelength, TWDM-PON enables operators to easily differentiate existing residential service offerings and efficiently capture new revenue opportunities at the enterprise level. The technology also facilitates a multi-service access approach that enables the convergence of services onto a single architecture, which helps to further accelerate the monetization of fiber networks. With the flexibility to add wavelengths one by one, service providers can effectively scale their fiber networks and seamlessly evolve network capacity from 10 Gbps to 40 Gbps, and beyond, as demand grows in the future.

Julie Kunstler, principal analyst at Ovum, has commented on this trend, saying:

> "TWDM-PON's ability to support different types of subscribers or applications through the use of different wavelengths, and different bit rates on those wavelengths, provides a significant advantage over other next-gen PON technology. The technology's ability to simultaneously support more subscribers, more applications, and even network sharing leads to faster network monetization, which is important given the costs associated with building an FTTx network."

In addition to some of these well-known benefits, TWDM-PON also provides a unique capability — wavelength unbundling — that is changing the economics of fiber networks. This feature can help network providers secure additional revenue from wholesale opportunities, reduce business risk through network infrastructure co-investment, accelerate fiber deployments, and reduce overall costs.

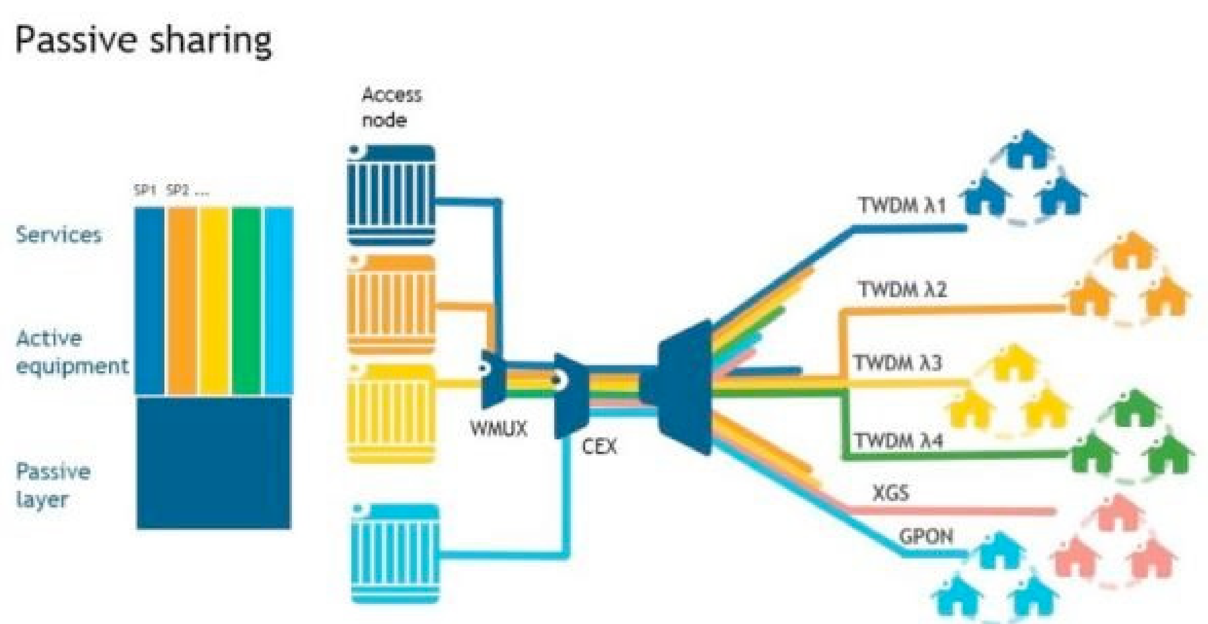
How? In considering TWDM unbundling scenarios, it helps to look at the network as consisting of three separate layers:

1. The bottom (passive) layer, composed of network elements that are not subject to frequent changes, such as ducts, poles, dark fiber, and splitters.
2. The middle (active) layer, composed of active elements such as access nodes and end-user modems, which are subject to moderate change due to innovations in technology.
3. The top (service) layer, composed of residential, public, and business services; these elements often are subject to significant change due to constant shifts in the market and customer preferences.

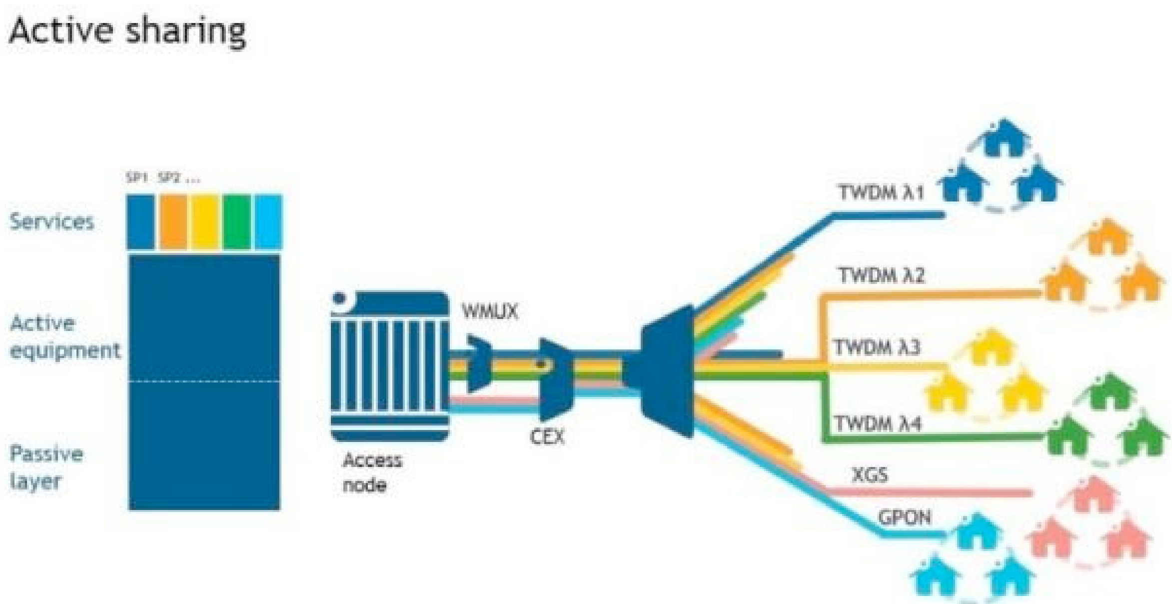
Implementing TWDM-PON Technology

The actual unbundling in TWDM-PON networks can be done in three ways:

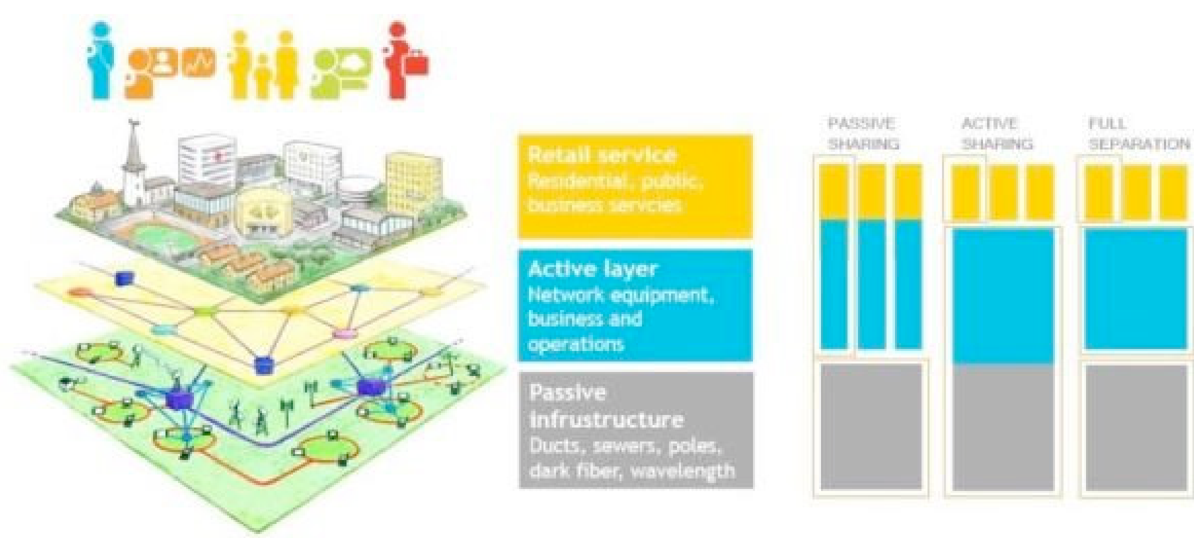
1. Unbundling at the bottom layer ("passive sharing"; Figure 1). In this scenario, a municipality or wholesale operator could build the passive infrastructure



and provide multiple service providers with their own dedicated wavelength for their own active equipment. The service providers would then operate the access nodes and provide their respective services to the end-user. The passive sharing model is growing in interest with alternative providers due to the co-investment opportunities it provides. Providers leveraging this model can share the risk and cost associated with building the passive layer and outside plant, which are often the most expensive parts of any fiber network.



2. Unbundling at the middle layer ("active sharing"; Figure 2). Here, an organization that builds the passive layer also provides and maintains the active layer (i.e., the active equipment). From there, dedicated wavelength(s)



can be given to one or several service providers who can then deploy their own services. In this scenario service providers do not own or operate the access node and only provide the service.

3. Unbundling at each layer ("full separation"; Figure 3). In this scenario, each layer is fully separated and one organization would deploy and maintain the passive network. A separate organization would then provide and operate the active equipment for use by multiple service providers, who would each have a dedicated wavelength(s) over which to provide their respective services.

The scenario a network provider ultimately implements can be influenced by the infrastructure, technology available in the network, the organizations involved, and each organizations' motivations. However, the flexibility available through TWDM-PON provides more options from which operators can choose to best meet their specific business-model needs.

TWDM makes it possible to have up to four service providers (each with their own wavelength) on a single network, which is sufficient for most markets. Because TWDM can co-exist with other PON technologies, it also leaves plenty of room for operators to grow and add wavelengths as needed. As a result, today operators are able to run a GPON network, add TWDM on the same network, and then source out the wavelengths to service providers or keep them for their own future needs and operational use.

Different Sharing Models and Their Benefits

TWDM-PON shows great promise for deployment across both new "greenfield" networks and existing "brownfield" fiber networks with an objective for further growth. Operators increasingly consider TWDM-PON the technology of choice for both applications.

In both scenarios, operators can generate new revenue streams, create more capacity, and have more flexibility in offering wholesale services. Here's how:

- In a brownfield scenario, where the wholesale operator owns the bottom (passive) and middle (active) network layers, the wavelength unbundling can occur on either layer; full separation is very unlikely to happen. In the case of passive sharing, the new entrants would deploy and operate their own access nodes on a dedicated wavelength. In the case of active sharing, the new entrants would be served from the access node owned by the wholesale provider. The latter is a simpler approach, as all network elements are managed by one entity (the wholesale provider). Adding TWDM on an existing GPON network is easy, as both technologies can co-exist on the same fiber plant, using the same passive plant and access node. The wholesale operator will need to add a new network element, called a co-existing element, which multiplexes GPON and TWDM signals on the same fiber. Growth can be managed gradually. For instance, if only one service provider is using one wavelength, the network operator can choose to use the other wavelengths for operations or future enhancements. TWDM-PON in brownfield creates potential new revenue-generating opportunities through wavelength wholesale.

- In a greenfield scenario, any of the unbundling models are possible and likely to happen. The network should be designed from the start to support wavelength unbundling; growth can be managed gradually by adding a wavelength for each new entrant. This scenario is particularly interesting for municipalities, utilities, or joint ventures for co-investment in a common network. As a result, unbundling encourages investments in fiber networks, as the cost and risks are shared. The advanced properties of TWDM-PON, such as high capacity, independence in evolving the capacity, etc., will also attract more service providers, resulting in better network monetization and better service offerings for end-users.

Achieving Additional Flexibility with TWDM-PON and Wavelength Mobility

Wavelength mobility is another unique characteristic of TWDM-PON technology that can benefit both multi- and mono-operator environments.

In a mono-operator network, for instance, wavelength mobility can be used for bandwidth rebalancing or creating operational efficiencies (e.g., during maintenance work or low-usage hours). In multi-operator unbundling scenarios, wavelength mobility can help streamline processes.

For instance, if an end-user wanted to switch service providers today, the task would often require a truck-roll and replacing the user equipment (ONT). With tunable TWDM-PON, an operator can simply change an end-user's wavelength directly from the central office – assuming there is interoperability between the access node and the ONUs. In the active sharing scenario, this is not an issue because one organization (the wholesale provider) controls all the active elements. Therefore, the assignment of wavelengths does not require complex, multi-vendor inter-node synchronization mechanisms.

However, in a passive sharing model, where each service provider has its own access node, there is a need for communication on a higher level to ensure synchronization between all access nodes. Currently, a standard protocol for this communication is under discussion within the Broadband Forum; it would prevent unauthorized switching of wavelengths and would ensure transparency for both end-users and service providers. These standards-based applications are expected to be ready within the 2018-19 timeframe.

TWDM-PON Drives Demand in 2016 and Beyond

With its promise of enhanced flexibility, more capacity, and new potential revenue streams, TWDM-PON is capturing the attention of operators everywhere. In early 2015, for example, several large operators and utility companies – including Vodafone in Spain and Energia in Japan – announced trials around the technology. Additionally, EPB in Chattanooga, TN, announced the first community-wide deployment of TWDM-PON as part of a growing effort to bring 10-Gbps services to all residential and business customers in the area.

As demands and requirements continue to evolve, TWDM-PON affords operators a new way to future proof their network, increase revenues, and accelerate the monetization of their network investments.

ANA PESOVIC leads Fixed Network Fiber Marketing at Nokia. She has more than 20 years of experience in telecom and is a board member of the Fiber to the Home Council Europe.

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ADTRAN describes NG-PON2 tunable ONT transceivers (sort of)

By **STEPHEN HARDY**

ADTRAN LAST AUGUST announced the development of Subscriber Edge Tunable (SET) optical transceivers for use in its upcoming NG-PON2 optical network terminals (ONTs). As Verizon named ADTRAN and a team of Calix and Ericsson finalists for its NG-PON2 contract competition, the development is not a surprise (see "Verizon narrows NG-PON2 choices to Ericsson/Calix and ADTRAN"). Given the fact that the competition is ongoing, it's also not surprising that ADTRAN isn't saying too much about the tunable transceivers' design.

NG-PON2, based on ITU-T specifications, will support up to eight wavelengths of symmetrical 10-Gbps transmissions over the same PON infrastructure; initial systems likely will limit themselves to support of four such wavelengths. Regardless of the number of wavelengths deployed, each ONT will need a way to receive and transmit via the wavelengths assigned to it. The specifications call for the use of tunable transceivers to promote flexibility and a variety of operational benefits, obviating the need to swap out fixed-wavelength transceivers every time the assigned wavelengths change (see "The Bright Future of TWDM-PON and Wavelength Unbundling").

Speaking at the ADTRAN Connect analyst and press event the company held at its Huntsville, AL, headquarters, several ADTRAN sources noted the SET tunable optical transceivers must meet a variety of requirements, including rapid tuning speed at an access-friendly price point, high output power, and minimal spectral drift during burst-mode operation. Jared Cress, principal strategist and senior staff scientist at ADTRAN, said during his presentation that the company expects the SET devices to support switching times of less than 25 ms. Cress added the module also should prove to be an order of magnitude less expensive than current DWDM tunable transceivers, which would mean they will cost in the hundreds of dollars.

However, Cress and other speakers at the event were much more willing to describe the techniques they're not using to achieve such performance than to say what they are using. The rejected approaches include:

- Adopting the design of most current tunable DWDM transceivers, as they're costly, complex, and wouldn't readily support burst-mode operation (in which the laser would need to be turned on and off – or, at least, blocked from transmitting – rapidly and repeatedly). They also would have trouble supporting the 29-dB power budgets NG-PON2 systems will require.
- Thermal-based tuning, which Cress said is unappealing again because of the difficulty of accurate tuning in the face of burst-mode requirements as well as operation in environments that aren't temperature controlled, such as on the side of a residence. Adding components to compensate for these problems would compromise optical power, he noted.

Cress and other speakers noted that, in the face of such issues, researchers have investigated alternative approaches, including designs leveraging distributed Bragg reflector lasers, external cavity lasers paired with MEMS-assisted tuning, and photonic integrated circuits. ADTRAN isn't following any of these paths either, at least not wholly so, said the speakers. What they did say is that the design leverages conventional components that are mature and easily sourced, with the implication that the company may be using elements of the alternative approaches just described (and perhaps other approaches they didn't mention) in a novel configuration.

Cress did reveal that the resulting device will be close to the size of an XFP; it will fit into an XFP cage, but likely will be slightly longer than a fully MSA-compliant module. He said he expects them to be ready for field trials in 2017 .

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Alternatives emerge to FTTH for gigabit broadband

By **STEPHEN HARDY**

WHILE FIBER TO the home (FTTH) remains the premier approach for gigabit broadband provision, plenty of service providers continue to look for ways to avoid the cost of an all-fiber deployment. Options such as VDSL2 and 3G wireless still don't have the necessary horsepower, we've seen. However, new classes of wireline and wireless technology have emerged that may postpone FTTH investments among some carriers.

Is G.fast fast enough?

Vendors have touted G.fast, based on the ITU-T Recommendation G.9700 family, as the pathway to gigabit over twisted-pair copper and, recently, coax. However, while several vendors say they have managed to support gigabit links via G.fast in the lab, we haven't seen such speeds in the field so far.

One aspect of G.fast is that the technology creates a pool of capacity that must be shared by upstream and downstream traffic. On the face of it, this would imply that, to support gigabit in the downstream, the total pool must be greater than a gigabit – and perhaps at least 2 Gbps if you want to deliver symmetrical gigabit service.

However, the ITU-T recently completed specifications work on a technology called Dynamic Time Assignment (DTA) that offers flexibility in the use of available upstream and downstream capacity based on expected use. So the total capacity needed to support symmetrical gigabit services should be significantly less than 2 Gbps.

Typical G.fast deployments use an architecture called fiber to the distribution point (FTTdp). As the name implies, a fiber connection (often based on PON, for future evolution to fiber to the premises) runs to a distribution point node in the field, where the optical signal is converted to electrical and served via a copper-based connection. The distribution point can be anywhere between the central office and the customer – including in the basement of apartment and other multi-tenant buildings. In fact, G.fast is finding its most widespread use as a means of serving high-speed broadband to apartment dwellers via existing in-building twisted-pair or coax wiring. In the U.S., CenturyLink and Windstream have announced they are using G.fast for this purpose. AT&T is expected to follow suit as well.

But there's no reason G.fast couldn't be used in the outside plant – and it is, notably in a pair of deployments in Europe. Both BT and Swisscom have embarked on trial and production deployments of G.fast in fiber to the cabinet (or, as Swisscom terms it, "fiber to the street") architectures. BT, for one, doesn't appear to view G.fast as an immediate pathway to gigabit broadband, however. Company sources have called for the technology to deliver 500 Mbps within the next 10 years. That timetable could accelerate, of course, with the addition of DTA and other technologies, such as channel bonding.

DOCSIS does it

Cable operators have increased their use of FTTH as a complement (or in some cases, an alternative) to their traditional hybrid fiber/coax (HFC) networks over the past few years. However, advances in DOCSIS technology may limit FTTH to greenfield and specialized applications for the foreseeable future for some operators.

For example, several U.S. cable operators have launched 1-Gbps downstream services by bonding DOCSIS 3.0 channels. Suddenlink (now part of Altice USA), Mediacom, and Cable One are among the service providers who have taken this approach.

But the primary gigabit broadband engine for cable operators will soon be DOCSIS 3.1 technology. With initial specifications in place from CableLabs, DOCSIS 3.1 promises downstream capacity of approximately 10 Gbps and upstream in the neighborhood of 1 Gbps – or, more or less the same rates as XG-PON1.

The primary technical advances within DOCSIS 3.1 is the use of Low Density Parity Check forward error correction instead of Reed-Solomon, the use of orthogonal frequency division multiplexing (OFDM) modulation, the support of multiple modulation profiles, and use of additional spectrum (as well as improved use of existing spectrum).

The technology supports channel bonding as well; in fact, as the technology is designed to be able to run alongside DOCSIS 3.0, operators are expected to bond DOCSIS 3.1 and 3.0 channels together.

Several operators have begun DOCSIS 3.1 deployments, with Comcast leading the way in the U.S. and Liberty Global doing the same in Europe. Comcast, in fact, believes it can use DOCSIS 3.1 to support its 2-Gbps Gigabit Pro service. Other operators, such as Mediacom and WOW!, have launched deployments as well, with Cox and Charter expected to follow very soon.

Of course, this initial implementation of DOCSIS 3.1 leaves in place the approach's main weakness versus FTTH – more trouble supporting high-speed symmetrical services. Particularly with business services support in mind, CableLabs has launched an effort to develop specifications for Full Duplex DOCSIS 3.1, which would support 10 Gbps in both directions.

CableLabs and the operators its serves appear to see DOCSIS 3.1 as a long-term answer for gigabit and beyond. The group recently revealed that it has begun investigating the use of coherent transmission technology for the "F" portion of the HFC network, to enable the feeder network to keep up with the demands that DOCSIS 3.1 will create without requiring additional fiber.

Here comes fixed wireless

Wireless technology, particularly fixed wireless, has made rapid strides as a broadband delivery mechanism over the past year in the eyes of service providers.

Perhaps the most salient example of this trend is Google Fiber's adoption of the technology. Frustrated by the red tape that has surrounded its FTTH efforts, not to mention take rates that reportedly haven't lived up to expectations, Google has purchased broadband service provider Webpass, which uses fixed wireless to serve multi-tenant buildings. The company subsequently called a timeout in several of its previously identified FTTH markets as it ponders whether a wireless strategy might create a better business model.

Meanwhile, mainstream service providers also are looking at adding fixed wireless to their broadband delivery portfolios. AT&T, for example, has launched a trial of point-to-point millimeter-wave wireless to deliver 100-Mbps broadband to multiple apartment complexes in Minneapolis – a territory in which it currently doesn't provide service.

In the trial, AT&T delivers fiber-based broadband to a central location. That location is then connected to subscriber buildings using "multi-gigabit" millimeter-wave links. At the subscriber building, the signal is converted from wireless to a format that AT&T can transmit to individual units using existing in-building wires (or new wiring if necessary). Subscribers then can access the service by plugging their Wi-Fi routers into existing wall jacks.

The company didn't immediately target gigabit broadband as a goal for such an approach – in fact, it mentioned 500 Mbps as a next step. However, earlier this year, AT&T said it expects to deliver 1 Gbps over its 4G network and has demonstrated 14-Gbps transmission and latency of less than 3 ms via 5G technology in its labs. It expects to begin field trials of video delivery via 5G this year.

So it seems only a matter of time before wireless becomes a true competitor to FTTH in the battle to dominate gigabit broadband services delivery.

STEPHEN HARDY is the Editorial Director and Associate Publisher of Lightwave.

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Gigabit Broadband Approaches to Realize a Better Connected World

By **JACK ZHUI**

AN INTELLIGENT WORLD is emerging, and the need for ultra-broadband networks to accelerate this new world is growing at an unprecedented pace. There are currently 350 deployed gigabit network projects across the globe, and it is becoming increasingly accepted that gigabit broadband will be the cornerstone of the intelligent world.

Gigabit broadband networks as well as relevant services and applications will provide many opportunities in areas such as healthcare, education, employment, transportation, agriculture, trade, and government services, and will greatly enhance the growth of the global economy. In the 21st century, gigabit broadband networks have already influenced our lives in many ways and are fast becoming an indispensable infrastructure like roads, railways, water supply, and electricity supply networks.

Gigabit broadband networks have accelerated the development of new experiences and created business opportunities such as Alibaba Group's "Buy+" virtual reality (VR) online shopping platform, Mobike's app-driven bike-sharing services, Airbnb's hotel sharing network, and Amazon and JD.com's revolutionary online shopping services. Analysts now predict that the number of gigabit subscribers could hit upwards of 100 million by 2020.

This trend is also ushering in a new era of "Gigaband Cities" that use next-generation PON technologies to deliver gigabit coverage for the cities' communities. For example, Shenzhen has become the first city in China to deliver gigabit broadband connectivity to 900,000 homes. Services will be available for residential users, government agencies, and enterprises, and will be capable of

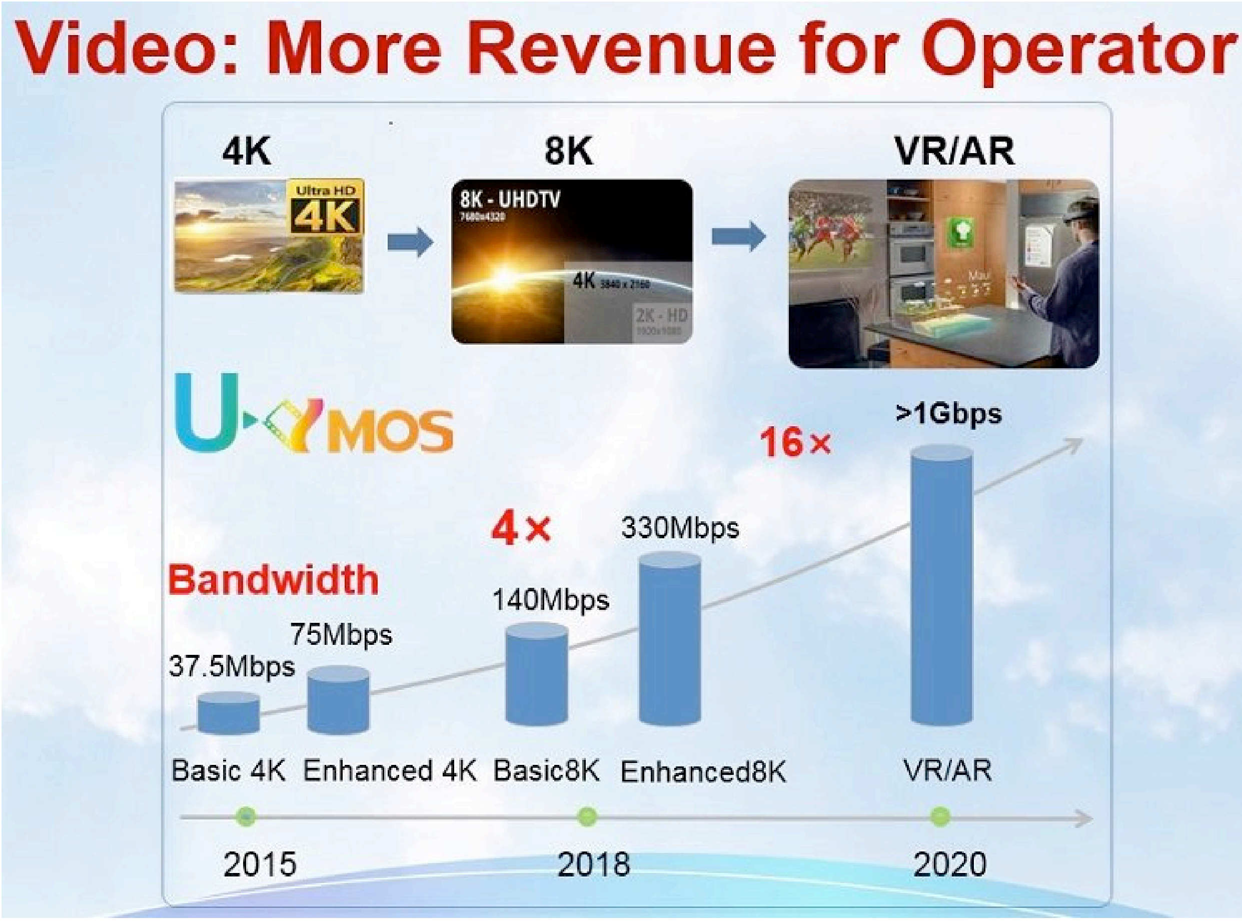

FIGURE 1. *The delivery of enhanced video services will be one of the main benefits of gigabit broadband.*

enabling advanced services including 4K video and VR film streaming, Gigaband hotels, and passive optical LANs (see Figure 1). Based on the experience with the rollout, this first project in China is expected to define the standards for a Gigaband City, paving the way for future deployments.

Gigaband Cities will strive to keep pace with consumer demand for new internet applications such as 4K/8K video, VR and augmented reality (AR), Gigaband campuses, and smart homes. Gigabit broadband networks will also foster digital innovation within vertical industries such as healthcare, financial services, transportation, manufacturing, and more.

Government Approaches to National Broadband Projects

ICT and broadband infrastructure have become core economic competencies, critical for national competitiveness. At the same time, broadband has become a basic need for citizens, who cannot imagine their lives without a broadband network and applications.

As a result, governments across the globe have made national broadband programs an imperative to ensure high-speed internet is accessible and affordable to everyone. However, the development of broadband initiatives varies greatly around the world. In Asia-Pacific, for example, Japan, Republic of Korea, and Singapore are world leaders with a broadband penetration of 95%. However, in countries such as Myanmar, Bangladesh, and Cambodia, less than 5% of the population has access to broadband. In these countries, government and policy support is essential to accelerate infrastructure growth and increase external connectivity.

Governments in these countries and around the world play an instrumental role in advancing national broadband initiatives to improve services for citizens. They can lead infrastructure development by building alliances among different government departments and industry, as well as creating broadband-friendly industrial policies.

Governments can also improve infrastructure synergy and find ways to simplify the process of obtaining rights of way. They can ensure new buildings and renovation projects include fiber connections, produce explicit standards for compensation for eminent domains, and start universal service funds. Governments can also legislate comprehensive frameworks for ICT; expand international fiber links; loosen restrictions on carriers, investors, and infrastructure builders; release more spectrum; and make more efficient use of spectrum resources.

Gigabit broadband can provide many benefits to both businesses and residents. For businesses, it helps them to innovate and expand into different markets. It also has the potential to increase efficiency and drive down costs. These business gains will help accelerate economic growth and prosperity for the country.

For residents, they will have improved access to online shopping, banking, healthcare, and public services. They also will connect seamlessly with family and friends and enjoy new levels of home entertainment. Providing fast and

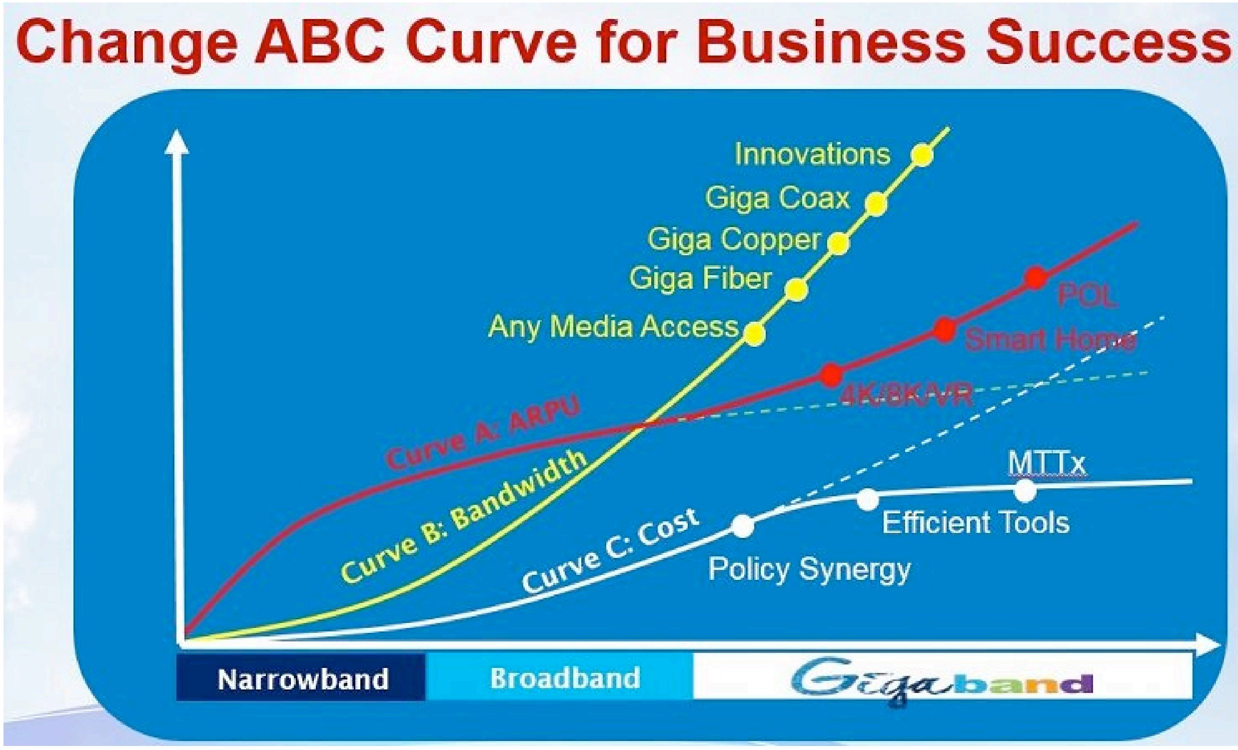

FIGURE 2. *There are several approaches to Gigaband. And multiple factors influence the choice of technology.*

effective gigabit broadband will drive social empowerment, helping citizens thrive in their work and home lives.

Telecom Operator Approaches to Accelerate Gigabit Broadband

To remain competitive telecom operators need to take advantage of new and advanced technologies such as next-generation PON over fiber, G.fast over copper, and DOCSIS 3.1 over coax that enable greater bandwidth, agility, and scalability to meet the demands of the gigabit era. However, according to Ovum, operators face many network transformation challenges, such as choosing the best technology strategy and understanding its impact on future upgrades, identifying new revenue opportunities, and meeting rollout targets and network optimization goals.

With the development of cloud computing, the internet of things (IoT), and 4K video industry chains, the fixed broadband industry has entered a new round of rapid development.

Globally, fixed broadband has become a focal point for investment in the ICT industry. We now see demand for access devices for fiber to the building (FTTB), fiber to the cabinet (FTTC), fiber to the door (FTTD), fiber to the home (FTTH), and Distributed CCAP (D-CCAP) scenarios as well as matched outdoor cabinets, and ODN products for offering "one-stop" Gigaband access to customers (see Figure 2).

Video services are the most important business opportunity for telecom operators today. Many global telecom operators have a well-developed video strategy, which is designed to drive the growth of broadband services and increase the number of broadband customers and the average revenue per user (ARPU), instead of merely positioning video services as a value-added service.

Looking forward, the industry's digital transformation is another strategic opportunity for operators. Operators should rethink their positioning and business scope in the B2C, B2B, and IoT markets. As enterprise customers require integrated ICT services that can provide a Real-time, On-demand, All-online, DIY, and Social (ROADS) experience instead of just basic communications service, operators need to "cloudify," and transform themselves into cloud service providers. Only then will they be able to meet enterprise customers' ever-growing demand for digitalization.

FIGURE 3. *Several advances can speed the deployment and reduce the costs of all-fiber gigabit broadband networks.*

Evaluating Gigabit Broadband Success

In terms of coverage, we can expect gigabit broadband networks will cover over 90% of households by 2020, making the ubiquitous ROADS experience possible. Operators will need to invest in broadband infrastructure to provide low latency, high bandwidth, and advanced customer experiences to all their customers.

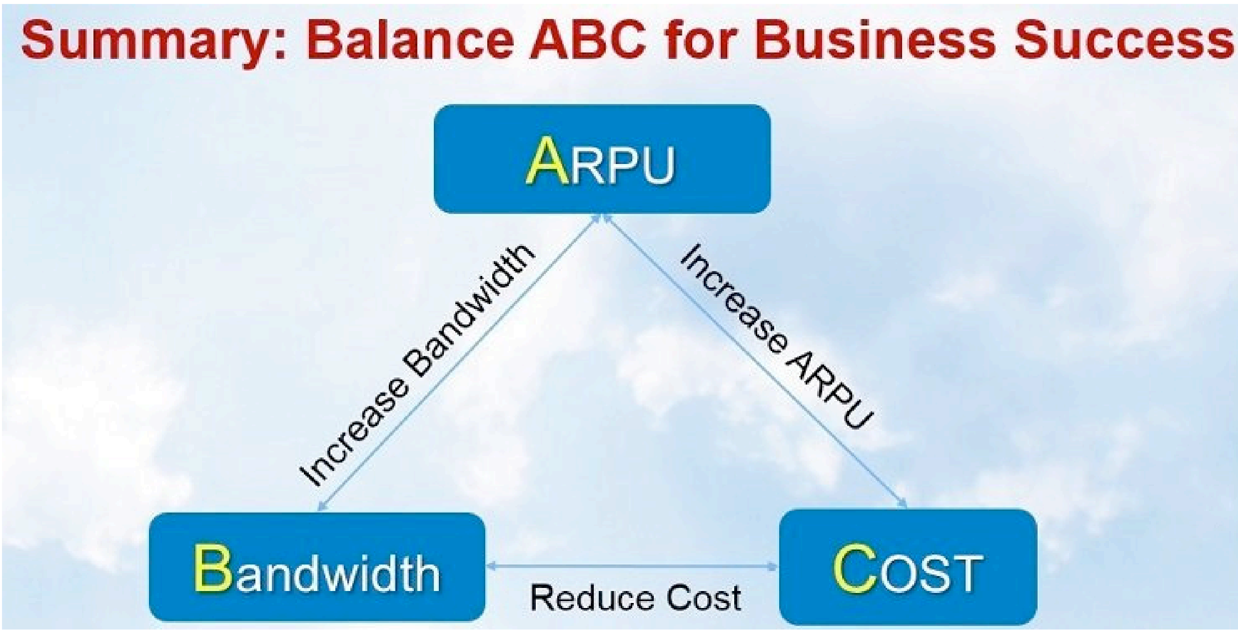

FIGURE 4. *Success with gigabit broadband is as easy as ABC.*

Implementing a gigabit broadband strategy requires the joint efforts of ultra-broadband industry players and governments. Industry policies must change from encouraging competition to promoting investment, and municipal infrastructure can be opened to operators, helping operators reduce FTTH and deployment difficulties (see Figure 3). For example, China implements fiber-from-the-home for new buildings to facilitate FTTH. Operators also need to formulate network development strategies to support a gradual evolution and build data center-based simple and agile ultra-broadband networks. Operators should increase investment in innovative gigabit applications to realize the value of gigabit networks and form a healthy ultra-broadband industry circle.

JACK ZHU is vice president, Access Network Product Line, at Huawei.

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