WHITEPAPER

A Fast and Affordable Path to Bridging the Digital Divide

DZS FiberWay offers quick multi-gig service deployments, high-capacity connectivity, low latency and in-place migrations to higher bandwidth.

www.dzsi.com

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Executive Summary

Communications service providers (CSPs) have a generational opportunity to mount sustainable approaches to bridging the digital divide in unserved and underserved markets by utilizing broadband initiative funding to open the door to multi-gigabit, low latency services.

This historic change in the prospects for unserved/underserved markets rests on technology breakthroughs encased in the new environmentally hardened DZS FiberWay platform. For the first time, NSPs can install a combination of small form factor, climate resilient, and ultra-high capacity last-mile PON optical line terminal (OLT) systems, middle-mile 400Gbps coherent optical transport platforms featuring reconfigurable optical add-drop multiplexer (ROADM) capability and a converged routing solution for 4G/5G wireless xHaul transport in existing cabinets or in a small, unprotected enclosure at virtually any available edge location. This equipment can be complemented by advanced AI-driven DZS experience management, service and network assurance, and automation and orchestration software that allows for efficient and agile remote management of the broadband service and applications.

Essentially, this means that capabilities akin to local Central Offices linked to core Central Offices and 4G/5G processing centers by coherent ring networks can be positioned close enough to even the most dispersed populations to deliver all the benefits of advanced high bandwidth, low latency technologies. Utilizing the middle-mile coherent optical ring and point-to-point connectivity supported by the DZS Saber 4400 transport system, CSPs deploying DZS FiberWay will be able to immediately serve multiple end-user clusters and single points of high-volume usage such as anchor institutions with DZS Velocity DWDM PON OLTs operating at 10Gbps per wavelength. And they'll be able to seamlessly expand to 50Gbps and 100Gbps PON on the installed OLTs.

The DZS FiberWay platform ties all these elements together without the processing transitions that typically add delay in terms of time-to-market to dispersed Central Office operations. This support for ultra-low latency end-to-end is vital to meeting the requirements of current and future interactive video applications.

The breakthrough of integrating a compact coherent optical a coherent optical transport system with these other network elements in an environmentally hardened chassis that can be unobtrusively deployed virtually anywhere is a major achievement. In fact, it's a gamechanger that

DZS FiberWay: Our Vision for BEAD Success

can ensure deficiencies in telecommunications will no longer prevent rural communities from enjoying the broadband experiences available in the most advanced urban centers.

Until now, it's been a foregone conclusion that a new generation of broadband networks reaching rural populations would have a hard time keeping pace with escalating demand that is rapidly pushing services toward multi-gigabit rates in more heavily populated markets. Even as governments raise the bar on expectations by soliciting commitments to 1 Gig services through programs like the $42-billion U.S. Broadband Equity and Access Deployment (BEAD) initiative, no one is requiring operators to prove they can sustain operations at much higher access rates.

But funding authorities in the U.S. and abroad will soon realize they no longer have to accept any limitations on network capacity and services that would expand the digital divide in the years ahead. While 1 Gbps was once seen as more than sufficient to meeting future needs, the surges in household and business usage as a new generation of high-bandwidth applications enters the market leaves no doubt that deployment of networks capable of supporting multi-gigabit services, let alone new AR/VR applications, is essential to closing the digital gap once and for all.

Nothing stands in the way of bringing this vision to life. While DZS FiberWay represents a new approach to architecting broadband networks, all network elements associated with the platform are field-proven products supporting CSP services reaching tens of millions of customers worldwide.

In the U.S., CSPs basing their strategies on DZS FiberWay-enabled network architectures can be assured they will meet BEAD and other plans' Build America, Buy America (BABA) requirements. DZS is a Dallas-based company that has for over two decades leveraged U.S. manufacturing for its systems and solutions and continues to maintain strong ongoing contractual relations with stateside suppliers.

Critically, even as DZS FiberWay lifts the barriers to multi-gigabit services in underserved/unserved regions, it lowers the cost impediments to sustainable operations at 1 Gig and higher capacities. Whereas in the past CSPs had to contemplate spending anywhere from $50,000 to $200,000 on environmentally protected huts to extend high capacity connectivity into individual rural environments (which can add up to millions of dollars across multiple environments), those costs are eliminated with use of environmentally hardened DZS FiberWay solutions.

And by eliminating the time consumed lining up real estate and building facilities at deep edge locations, FiberWay significantly accelerates network deployments. This is a big advantage in cases like the BEAD program where speed-to-deployment is an important consideration in funding allocations as well as quickly gaining penetration and scale for faster ROI.

Moreover, DZS FiberWay allows CSPs to make use of DZS software-defined Cloud Edge solutions that are instrumental to ensuring they will never have to compromise on the scope, scalability, and quality-of-service offerings in low-density population areas. This is essential to mounting a sustainable operation with significant upside ROI potential and aiding the CSPs to become true Experience Providers and drive a long-term sustainable business model for each community served.

Service providers making use of DZS FiberWay can unleash the service acceleration and vendor-agnostic cross-platform network management versatility of the DZS Xtreme platform. And they can implement end-to-end quality assurance (QA) using DZS Expresse software-as-a-service (SaaS) to orchestrate performance across external network assets while employing the DZS CloudCheck SaaS to execute on-premises WiFi management and experience assurance.

Adding to the versatility, DZS FiberWay is well suited to be the foundation for extensions of existing networks into new territory. With activation of the DZS Xtreme network orchestration platform, CSPs can take advantage of seamless vendor-

neutral integrations to bring best-of-breed performance to new areas without disrupting existing infrastructure.

DZS FiberWay is available in three configurations based on the OLT capacity needed to accommodate the subscriber base served from any given edge location. These include a fixed form factor 1 RU Velocity system designed for delivering services to 2,000+ subscribers, a 2 RU, 2-slot Velocity system serving 4,000+, and the 6-slot, 6-RU V6 system serving up to 25,000 subscribers.

Each DZS FiberWay solution is complemented by the 1 RU Saber 4400 edge transport platform and, optionally, the M4000 system for advanced business and xHaul applications, and benefits from full support of the DZS Cloud software with roadmaps for rural service optimization.

In this document:

- **Part 1** will provide an overview of the trends shaping broadband initiatives worldwide, including the dimensions of the digital divide in different parts of the world, what bridging that gap means to local economies, the expectations and policies dictating funding allocations, and how emerging services and market demand are likely to impact those expectations over time.
- **Part 2** explores the technical challenges that must be met to implement sustainable broadband operations in underserved and unserved regions, especially in the case of sparsely populated areas.
- **Part 3** along with explaining how the DZS FiberWay solution makes it possible to meet those challenges, offers a perspective on what these capabilities mean to the range of services NSPs will be able to deliver now and into the future.

As the ensuing discussion underscores, the fundamental principal guiding broadband expansion is that CSPs and funding administrators alike must do all they can to ensure that today's underserved and unserved communities can share with equal opportunity in the benefits everyone else derives from services powered by advances in broadband connectivity. This can be done if CSPs have maximum cloud-driven software flexibility and network infrastructure solutions to deliver whatever services consumers and businesses demand at reasonable costs free of constraints on the network capacity that's essential to meeting those demands.

Given these new developments, it's reasonable for CSPs to expect that the benchmarks defining what constitutes a winning approach to qualifying for rural broadband funding will change. U.S. and other nations are pouring tens of billions of dollars into closing the digital divide on expectations that the economic upsides will be worth the investment. To ensure the right choices are made, they have implemented rules stipulating prudent allocation of funds that must be followed by decision makers as technology evolves.

Moreover, the competition for those funds is heating up, leaving no room for business cases built on outmoded technology. Increasingly, regulators in the U.S. and elsewhere are stipulating it doesn't matter whether funds go to incumbent telcos, cable companies, or overbuilders operated by utilities, municipalities, and other entities, as long as they can demonstrate that their commitments to operating in challenging environments will pay off.

The DZS FiberWay platform opens a path to success for any type of CSP in any low-density population environment no matter how far signals will have to travel to reach end users and communities. With the flexibility to consolidate placement of the optical components essential to connecting all middle- and last-mile endpoints in the most optimal locations – whether in existing cabinets or optimized new cabinets – CSPs can design their infrastructures to deliver the best possible user experiences at the lowest possible costs.

Part 1 Trends & Policies Shaping Broadand Everywhere Agendas

Broadband connectivity, long recognized in the U.S. as vital to the well-being of individuals and local economies, has gained similar priority status worldwide. There's now global consensus that, as the World Bank puts it, broadband access "is not a luxury, but a basic necessity for economic and human development in both developed and developing countries." [i]

According to research conducted by the Munich-based Center for Economic Studies and Ifo Institute, a 10 percentage-point increase in broadband penetration raises a country's annual per-capita growth by 0.9-1.5 percentage points. [ii] As for the value of higher throughput, a study backed by the European Investment Bank found that doubling broadband speeds produces a 0.3% increase in a country's GDP. [iii]

Global Funding Surge Makes Broadband the Solution to the Digital Divide

Such findings have spawned government-backed broadband initiatives across the globe, which we calculate aggregate to $450 billion in committed funding, not including any associated private investments. Figure 1 lists our compilation of programs that funders have defined as broadband initiatives.

Figure 1

Government Outlays for Broadband Top $450 Billion Worldwide

North America – $104.36B

U.S.
- Broadband Equity, Access, & Development Program – $42.5B
- Rural Development Opportunity Fund – $20.4B
- Affordable Connectivity Program – $14.2B
- Capital Projects Fund – $10B
- Emergency Broadband Benefit Program – $3.2B
- Tribal Broadband Connectivity Program – $3B
- Digital Equity Act Programs – $2.75B
- Connect America Fund – $1.93B
- USDA ReConnect Loan & Grant Program – $1.15B
- Middle-Mile Grant Program – $1B
- Wireless Supply Chain Innovation Fund – $1B

Canada
- Universal Broadband Fund – $3.23B

Europe – $46.35B

EU
- Connecting Europe Broadband Fund – $1.88B

Germany
- Gigabit Funding 1.0 and 2.0 – $16.5B

U.K.
- Project Gigabit – $8B

Italy
- Italia 1 Giga Fund – $7.93B

Spain
- Digital Infrastructure & Connectivity – $4.74B

France
- Tres Haut Debit & later programs – $4.68B

Greece
- FTTH Expansion – $0.41B

Austria
- Gigabit Broadband Fund – $2B

Sweden
- National Broadband Fund – $0.21B

Asia – $276.88B

China
- Broadband China – $181B

India
- National Broadband Mission – $94.4B

Singapore
- FTTH Plan – $0.75B

Maylasia
- National Fiber & Connectivity Plan – $0.73B

Australia – $18.5B

State-Run NBN Co.
- National Broadband Network – $18.5B

Africa – $3.35B

Nigeria
- National Broadband Plan – $1.06B

Egypt
- Decent Life initiative – $1.54B

Kenya
- Rural Broadband project – $0.39B

South Africa
- State IT Agency Broadband Initiative – $0.36B

Latin America – $0.59B

Peru
- MTC National Broadband Plan – $0.48B

Chile
- Subtel National Fiber Optic Project – $0.11B

Sources: Official Statements, Research Reports, & Press Coverage of Government Actions

With many of these projects underway since the mid-2010s, some of this funding has already produced results, but there's a long way to go While, according to the ITU, the number of internet users worldwide grew by 7% to about 5.3 billion from 2021 to 2022, leaving 2.7 billion people or about a third of the world's population unconnected, only about 2.8 billion of the connected users had what the ITU defines as broadband access, which is access at any speed over the 1.5-2 Mbps achieved with primary rate ISDN.[iv]

But bleak as this picture is, the true dimensions of the digital divide are much worse. While minimal broadband rates as defined by the ITU represent a big improvement in areas where, at best, 2G mobile is the primary mode of linking to the internet, there's growing recognition everywhere that bandwidth targets must be set much higher if there's to be a meaningful closing of digital gaps. Virtually all the projects listed in Figure 1, including the latest revisions of older ones, are targeting much higher broadband speeds.

A better gauge of where things stand can be seen in metrics compiled in 2022 by research house Point Topic, which reports there are only 1.36 billion fixed broadband access lines operating at ADSL or higher throughput worldwide.[v] Fiber-to-the-Premises (FTTP) with 66% of the connections accounts for the largest share compared to cable DOCSIS at 16.3%, ADSL and VDSL at 15.6%, and fixed wireless access (FWA) and satellite comprising the remaining 2%.

The top five regions as measured by Point Topic account for about 84% of global fixed broadband connectivity, underscoring just how far behind the rest of the world is (Figure 2).

Figure 2

Global Distribution of 1.36B Fixed Broadband Access Connections

	East Asia	Western Europe	Southern Asia	North America	Other
Lines	667m	185m	147m	145m	216m
Shares of Total	49.1%	13.58%	10.82%	10.67%	15.88%

Source: Point Topic

Looking ahead, researcher Omdia projects that basic internet connectivity will expand somewhat to 70% of the global population by 2026 with 40% of the population connected via fixed broadband compared to the current 17% penetration rate as measured by Point Topic. But Omdia predicts that, barring stepped-up support for higher broadband rates, the speed gap between currently well-served and underserved regions will increase significantly.

As is the case in many European and Asian countries, 1Gbps service in the U.S. has become a ubiquitous option available to 90% of the nation's households, according to a recent report from JP Morgan.[vii] And take rates are surging, as reflected in research conducted by OpenVault, which found that as of July 2023, 31.6% of U.S. broadband households were subscribing to services at 1Gbps or higher compared to 14.2% a year earlier and 10.5% in 2021.

While cable operators have the biggest 1 Gig footprint in the U.S. with gigabit speed competition from mostly telco-provided FTTP connectivity increasing rapidly, FTTP is the dominant high-bandwidth option in Europe and the APAC countries, where region-wide penetrations exceed 50% (Figure 3). According to the Organization for Economic Cooperation and Development (OECD), among its 38 member nations, FTTP is now the dominant mode of broadband connectivity supporting 34.9% of all subscriptions compared to cable HFC at 32.4% and DSL at 27%.

Figure 3

European & APAC Countries with 50+% FTTP Penetration

Europe – Average: 55.3%			
Latvia	91.5%	**Estonia**	74.0%
Iceland	91.3%	**Malta**	67.7%
Portugal	90.9%	**Netherlands**	67.7%
Romania	88.5%	**Ireland**	67.6%
Spain	87.4%	**Hungary**	66.2%
Bulgaria	87.0%	**Slovakia**	59.6%
Sweden	84.5%	**Lithuania**	59.5%
Denmark	78.2%	**Italy**	55.5%
France	76.7%	**Poland**	54.8%
Luxembourg	76.2%	**Finland**	52.0%
Estonia	74.0%	**Cyprus**	51.7%

APAC – Average: 50.7%	
South Korea	108.9%
Singapore	100.7%
Hong Kong	97.5%
Australia	94.2%
New Zealand	90.0%
China	81.6%
Japan	74.7%
Vietnam	73.3%
Taiwan	70.8%
Thailand	61.3%

Sources: Europe – European FTTH Council[x]
APAC – S&P Global Market Intelligence[xi]

Sustainable Operations at Multi-Gigabit Access Rates Is the New Benchmark

In light of these developments, it's no wonder that the benchmark for closing the digital divide is now 1Gbps, even in less developed countries that have adopted funding programs. Virtually all the initiatives listed in Figure 1 are emphasizing a preference for, if not absolute requirements that funded projects offer services at 1Gbps.

Under guidelines issued to local authorities by the U.S. National Information and Telecommunications Administration (NTIA), no entity offering bi-directional throughput below 1Gbps will be considered eligible for funding if there's at least one bidder committed to rates at or above that level.

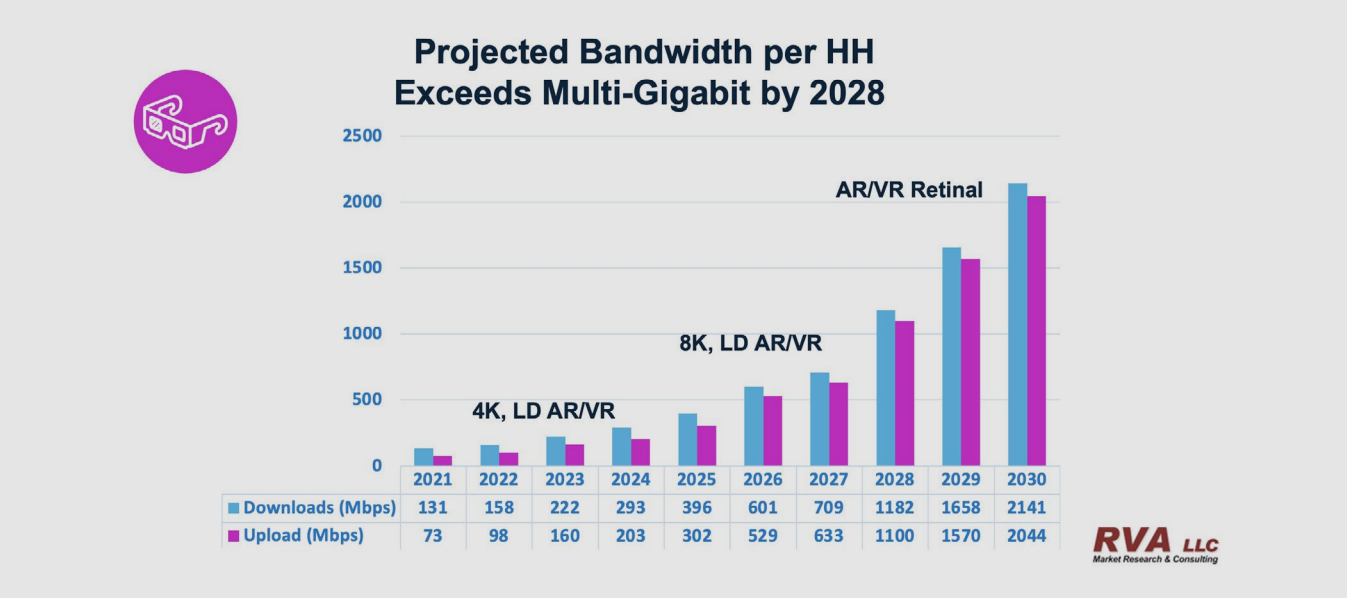
Bidders must demonstrate they can sustain operations long-term over network infrastructure reaching everyone in the service area. But sustaining operations at 1Gbps without the flexibility to go to higher throughput in response to market demand will lead to a reopening of the digital divide not long after buildouts are completed.

Not so long ago there was pervasive skepticism among CSP strategists and analysts that people would ever really make use of Multi Gig throughput. Now there's concern that regions without access at much higher multi-gigabit speeds will be left behind as a new generation of immersive extended reality (XR), high-resolution gaming, 8K UHD, and new video-rich e-commerce services captivates mass audiences in better served markets.

According to projections from researchers RVA, average residential bandwidth will hit multi-gigabit levels starting in 2028.[xii] (Figure 4). And judging from the bandwidth requirements associated with growing individual device usage and emerging services, the pace of bandwidth expansion could be even faster (Figure 5).

Secular: Broadband Connectivity

Figure 4



Consumer entertainment, of course, is just one of the factors driving demand for higher speed networks. Equally, if not more important to local economies in underserved and unserved areas is the need for broadband networks that can draw businesses to those areas.

That means networks will need to have the capacity to support surging business reliance on cloud software-as-a-service (SaaS), private high-capacity WANs and SD-WANs, video conferencing, and bandwidth-consuming smart-building and smart-city applications. And CSPs will need more mid- and backhaul capacity to support wireless infrastructure.

Of course, many service-related developments are impacting the need for higher network capacity among businesses and consumers alike. As illustrated in Figure 6, these include demand for XR applications, the growing role of full- and part-time remote working in business operations worldwide, and surging reliance on telehealth services.

Secular: New Applications Driving Bandwidth

Figure 5

Figure 6

3 Trends with Big Implications for Both Businesses & Consumers

Extended Reality (XR) Market Growth		
2020	**2025**	**CAGR**
$21B	$98B	36%

Remote Work Workforce Share - 1+ Days/Week				
Leading Regions				
Global	**U.S.**	**Europe**	**China**	**India**
32%	53%	52%	28%	30%

Demand Split	
Business	55%
Consumers	45%

Global Telehealth Market		
2023	**2030**	**CAGR**
$148B	$867B	28.73%

Sources: XR Market – ResearchandMarkets[xiii], Demand Split – Grand View Research[xiv]
Remote Work – Gartner[xv] , Telehealth – Market Research Future[xvi]

The Mobile and FWA Components in Broadband Strategies

Beyond requirements bearing on wireline network connectivity, there's a wireless component to use of fiber assets in cases where CSPs seeking to satisfy fixed broadband demand in unserved or underserved areas also operate as MNOs. While government funding under broadband initiatives like those listed in Figure 1 is focused on driving 1 Gig fiber connectivity, there are opportunities for CSPs with MNO spectrum allocations to apply expansion funds to fixed wireless access (FWA) in rural environments where FTTP deployment is seen as cost prohibitive.

In addition, in cases where FTTP is the preferred fixed broadband solution, CSPs with MNO operations will want to make use of their fiber infrastructures to bring mobile services to areas where they don't have cell towers. And, where they do have cell towers supporting 4G or earlier generations of cell service, operators who are making the transition to 5G using airwaves at the millimeter (6 GHz and above) end of the spectrum will benefit from using fiber in deployments of cell sites deeper into their service areas while backhauling the mobile traffic to the core network and to internet connectivity points..

The case for such strategies is especially strong in underserved and unserved areas. MNOs have gone a long way toward closing mobile coverage gaps worldwide, but according to data compiled by the Global System for Mobile Communications Association (GSMA), there's still a long way to go in some regions (Figure 7). And something must be done about the fact that 22% of mobile connections globally are still operating at 2G or 3G. In all these cases, MNOs want to be able to leapfrog 4G with upgrades to 5G.

Figure 7

Mobile Coverage & Usage Gaps Worldwide

	Global	Europe	North America	China	Eurasia	Latin America	APAC	MENA	Sub-Saharan Africa
Gaps in Coverage	4%	1%	1%	1%	5%	3%	4%	6%	17%
Usage	41%	14%	16%	20%	28%	35%	47%	55%	60%

Source: GSMA[xvii]

Part 2 Broadband Networking Challenges in Underserved/Unserved Regions

CSPs everywhere, whether they're building out broadband infrastructure in underserved and unserved areas or upgrading existing facilities, face major challenges in their efforts to keep pace with market needs in this new era of unprecedented technology development and intensifying competitive pressure from cloud-based super-scalers. Meeting these challenges in densely populated areas is hard enough, but operating in low-population areas takes the challenges to another level.

Network Flexibility, Service Innovation, Quality Assurance Pose Challenges Everywhere

The scope of the challenges is reflected in the stipulations set out by the U.S. NTIA for funding through the BEAD program, with one important addition. These requirements are essential to ensuring successful operations in any rural market worldwide.

NTIA says funding is to be prioritized in support of CSPs that can make symmetrical 1 Gig service available to every household and business with scalability to new performance levels at costs conducive to business sustainability long-term assurance of financial success. Other NTIA requirements pertain to speed to deployment, affordable pricing of services, and issuance of periodic reports by operators verifying plans are on track.

In the U.S., funding often has a made-in-America component, as is the case with the BEAD program. This requires compliance with the Build America, Buy America (BABA) Act.

The scalability requirement brings into immediate focus the need to design networks that can keep pace with the bandwidth demand drivers discussed in Part 1. That means authorities who don't want to support networks that will begin depriving rural areas of the throughput customers need as soon as they're built will want to allocate funding to CSPs that have a sustainable path to multi-gigabit access data rates and beyond.

Funding policies are also considering the need for lowering latency in broadband networks. NTIA stipulates that 95% of latency measurements must fall below 100ms in roundtrip time.

In addition, business sustainability requires an ability to exploit existing and future network performance levels through rapid development and implementation of new services across all wireline and wireless end points. And this must be done with consistent end-to-end support for quality assurance (QA) that delivers all services in accord with customer expectations and SLA commitments.

In essence, the requirements for long-term CSP success enumerated here represent the Holy Grail of strategic aspirations in telecommunications across all regions. In rural and urban environments alike, long-term viability requires an ability to streamline network and service expansion through every phase from the start of a newbuild or upgrade through ongoing responses to evolving market demand in both the consumer and enterprise service sectors.

This means operators must be able to unify operations across core, edge, and user access domains while minimizing manual processes through software-based automation. There can't be any tolerance for incurring the costs and hassles of repetitive processes resulting from working in disparate network silos. And to ensure they have the freedom to take advantage of performance and cost benefits offered by best-of-breed technology, CSPs must be able to avoid vendor lock-in every step along the way.

In rural environments, the priority is to put advanced optics technology to use in ways that neutralize distance as an obstacle to optimal performance at sustainable costs. If that can be done, the costs of bringing FTTP PON connectivity to homes and businesses over great distances will be radically reduced, ensuring the sustainability mandate will be fulfilled as the multi-gigabit era unfolds.

Moreover, advanced PON technology is instrumental to making FWA a more affordable option as well as one that, with use of 5G, creates opportunities to drive throughput to much higher levels than has been the case with 4G-based FWA. As shown in Figure 8, 5G FWA connections and revenues are growing by leaps and bounds.

Figure 8

The Shifting FWA Landscape

Annual Pace of 5G vs. 4G Connections

	2020	2021	2022	2023	2024	2025	2026
FWA Connections (million)	61	73	89	108	128	150	168
5G Share	2%	3%	7%	13%	20%	28%	39%

Projected NSP Revenue Generated by 5G FWA Worldwide

2023	2024	2027	4-Year CAGR	Consumer Market Share
$515M	$2.5B	$24B	161%	96%

Sources: FWA Connections – Deloitte[xviii]
5G Revenue – Juniper Research[xix]

FWA, even when 5G is used, currently falls short of the 1 Gig speeds sought in broadband funding initiatives, but it achieves the 100/20Mbps fallback target set by the NTIA. In fact, as the Juniper Research study cited in Figure 6 notes, some 5G FWA offerings are topping 200 Mbps with expectations the throughput will go much higher over time.

The potential depends in part on future radio spectral efficiency gains and, more immediately, on spectrum allocations in the sub-millimeter 3 GHz range, which in the U.S. are drawn from Citizen Band Radio Service (CBRS) segments. Of course, FWA as well as mobile 5G throughput can go much higher when much more spectrum available at millimeter tiers above 6 GHz is involved. But this reduces radio propagation distances from a mile or more, depending on signal power, at the 3 GHz level to 100 meters or less, which is largely impractical in rural settings.

The Need to Make PON More Useful in Rural Areas

Whether FTTP or FWA access is employed, the use of advanced PON technology is essential to keeping the rural digital divide from expanding as market demand pushes network capacity ever higher in more densely populated regions. Forward-compatible PON standardization means CSPs can minimize the costs of transitioning from the current z10 Gbps bidirectional rate per wavelength to higher tiers as needed incrementally across their service areas.

While XGS-PON is widely deemed to be sufficient to consumer and SMB market needs for the time being, usage trends cited in Part 1 point to higher capacity needs further out. And on the larger SMB and enterprise sides of the business market the push in that direction is already underway. Following next-gen standards, operators will be able to swap XGS-PON components for components supporting 25Gbps (now in early commercial deployments but unlikely to become a long-term scaled technology), 50Gbps (quickly moving beyond the prototype stage and the likely next widely deployed technology), and, eventually even, 100Gbps PON (likely DWDM based).

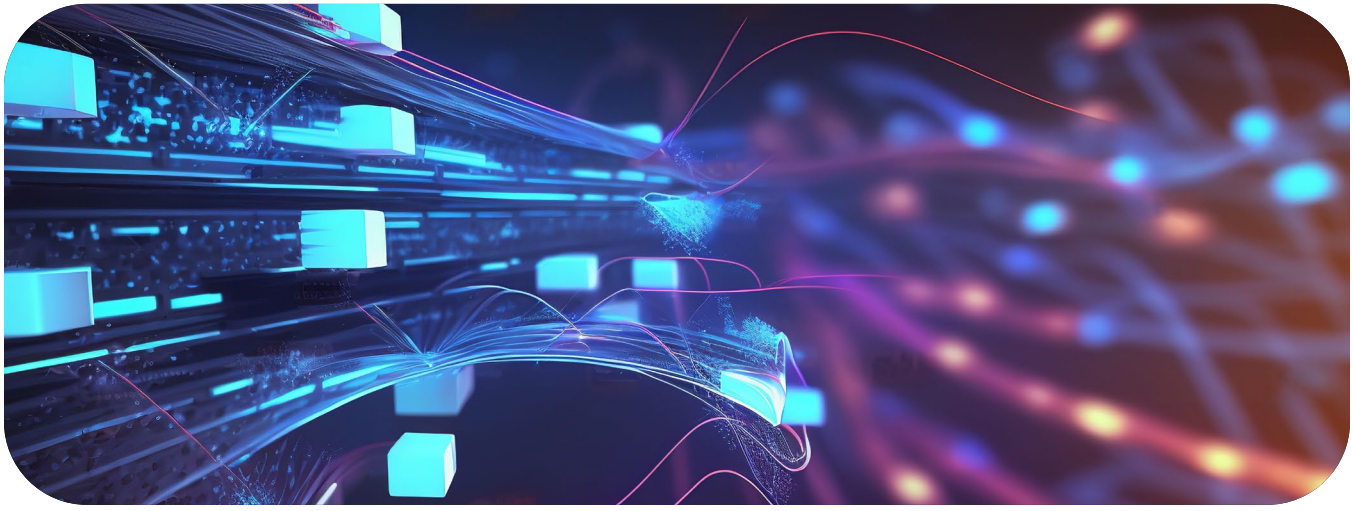
To make this possible in low-population regions the top priority is to neutralize the distance impact on CSPs' ability to maximize the reach and versatility of PON technology. That's been hard to do at sustainable business costs.

Typically, a rural service region is characterized by an array of far-flung small towns and villages interspersed by outlying smatterings of widely separated homes and businesses. The starting point for putting PON to work in this environment involves the use of coherent optics technology, which enhances unamplified signal reach by combining amplitude and phase modulation across two polarizations in a single light-wave transmission.

Coherent transport systems with the remote software-based configuration of wavelengths across end points enabled by reconfigurable optical add-drop multiplexers (ROADMs) can be used to support middle-mile connectivity of dispersed local distribution points to core Central Office and mobile RAN processing centers. Local distribution centers served by coherent optical rings can be equipped with high-capacity optical line terminals (OLTs) using DWDM technology to deliver multi-gigabit PON services over individual wavelengths to communities of end users.

But in environments where there's a lack of environmentally protected buildings or other facilities suited to housing all this equipment, the costs of getting close enough to homes and businesses to deliver gigabit+ services can be prohibitive. Such deep-edge deployments require placement of the essential components in small environmentally hardened enclosures far from core processing centers.

Until now there was no way to co-locate the complex middle-mile coherent transport components with the essential network distribution elements in environmentally hardened chassis sized for placement in small unprotected enclosures in remote locations. Fortunately, as discussed at length in Part 3, DZS has succeeded in environmentally hardening the coherent optics transport and ancillary OLT and data-routing modules for use in outdoor chassis at the deep edge.



Part 3 The New Path to Success in Broadband-Deprived Regions

The DZS FiberWay Platform

With its introduction of the environmentally hardened DZS FiberWay edge platform, DZS has broken through the barriers to bringing market-leading network performance, upgrade efficiency, and service versatility to remotely populated regions. For the first time, CSPs can meet all the requirements for success in underserved areas as outlined in Part 2.

By deploying compact DZS FiberWay chassis in environmentally exposed cabinets deep in targeted service areas, operators can support the coherent optical transport, ROADM, OLT, and converged optical transport and routing techniques that are essential to PON-optimized multi-wavelength network operations in remote locations. This, of course, has implications for more densely populated service areas as well, given that the capabilities as described below can be invaluable in any scenario where CSPs need to streamline end-to-end network performance, deploy fiber-deep architectures, or initiate multi-service, multi-haul transport upgrades.

The cost benefits of deploying DZS FiberWay-based network architectures are immense, considering what operators would have to spend if they had to bring all this equipment together for deep edge deployments in temperature-controlled buildings or standalone huts. Figure 9 lists typical costs incurred with construction of such enclosures. In a region requiring installation of multiple such deep-edge enclosures the costs add up to millions of dollars.

Optical EDGE: Deploying a 100G Coherent System Today

Figure 9

Saber- 4400 Cost Benefit Analysis	
Item	**Cost**
Heat Exchanger	$3,000
HVAC	$12,000
Building (8X12)	$55,000
Land	$20,000
Sitework	$15,000
Inside Infrastructure	$50,000
Labor to move existing equipment	$10,000
Labor to move fiber cable	$15,000
Total	$180,000

As illustrated in Figure 10

Environmentally hardened DZS FiberWay chassis capable of withstanding -40˚C to +65˚C temperature extremes are available in three basic models that can be further customized to match local conditions. In all cases, the DZS FiberWay solution can optionally include a cabinet sized and configured for maximum efficiency.

DZS FiberWay: Our Vision for BEAD Success

Figure 10

Each version of a DZS FiberWay cabinet houses a Saber 4400 transport and M4000 IP-based packet-routing module with a Velocity OLT suited to accommodating the subscriber count in a targeted service area or community. FiberWay 1 contains a 1RU Velocity V1 OLT serving 2,000 or more subscribers in a small community while the FiberWay 2 with a 2-slot 2RU Velocity OLT serves 4,000+ subscribers and the FiberWay 6 with the 6-slot, 6RU Velocity V6 serves up to 25,000 subscribers for larger rural communities. All components are managed seamlessly by DZS software for easy operations.

Critically, the consolidation of components deep in service areas enables an all-optical end-to-end infrastructure that's essential to meeting the ultra-low latency requirements of online gaming, virtual and augmented reality, video conferencing at UHD levels of resolution, telemedicine applications, and surveillance in unfolding emergency situations. Adding to the benefits, all DZS optical components are latency optimized in their respective operations for high performance applications.

Coherent Optical Transport with ROADM Flexibility

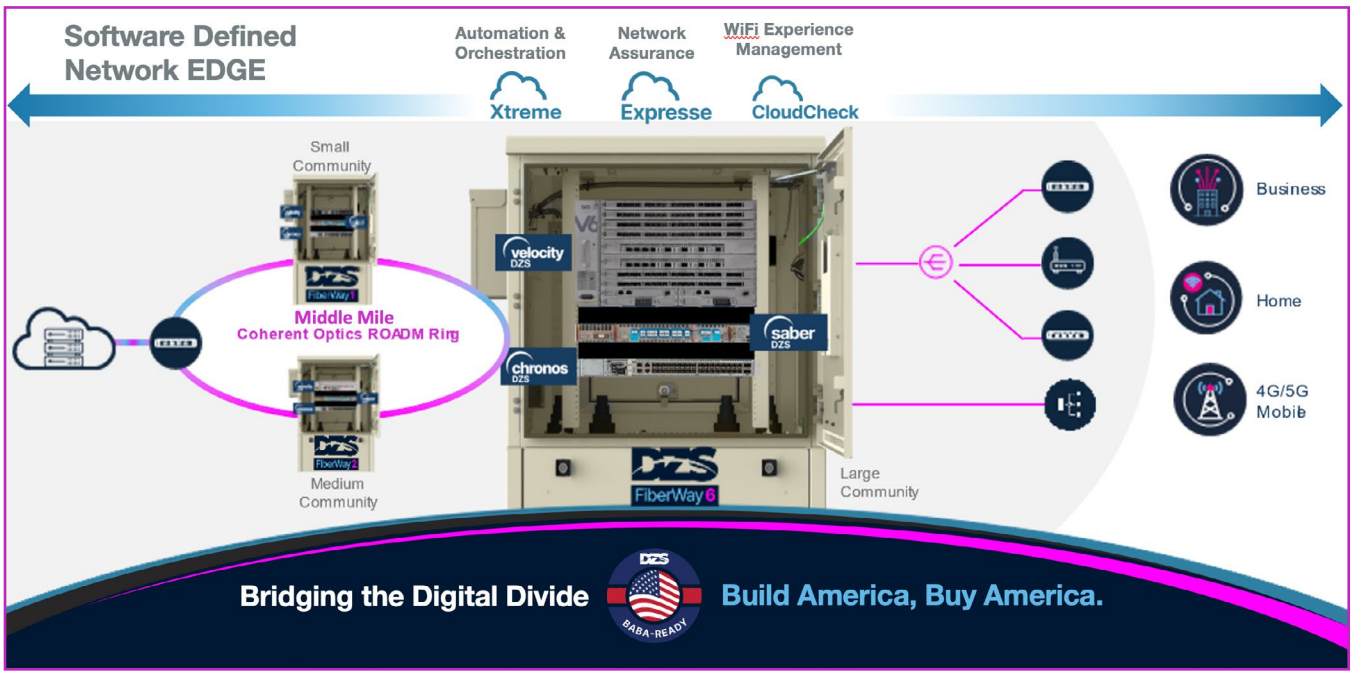
Unamplified coherent optical transport support for middle-mile connections extending to 120 km are provided by the DZS Saber 4400, the first coherent optical edge transport platform optimized for deployment in environmentally exposed edge locations. Operators can double the reach of the coherently modulated payloads using optical amplifiers containable within the DZS FiberWay form factor.

The highly compact 1RU, 11-inch-deep Saber 4400 platform houses four transport modules each of which can scale from 100Gbps to 400Gbps per wavelength for a total throughput of 1.6Tbps per unit. Multiple units can be stacked with a common management interface in a FiberWay chassis in rare instances where there's a need for more capacity.

The Saber 4400 provides Open ROADM support for coherent lightwave connectivity into Middle-Mile ring topologies at the deep edge (Figure 11). The Saber ROADM employs the wavelength routing flexibility of Colorless Directionless and Contentionless (CDC) technology with FlexGrid mechanisms that allow operators to define the spectral widths of individual wavelengths.

Bringing Multi-Gig, Low Latency to the EDGE

Figure 11

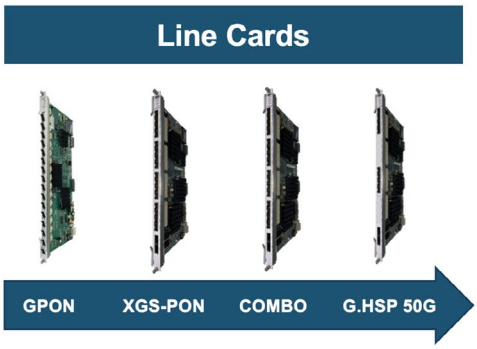


Advanced OLTs

The DZS Velocity OLT systems supports industry-leading high density and non-blocking performance with GPON and XGS-PON connectivity (Figure 12). At the high end of DZS Velocity options, the 6RU Velocity 6 offers a record-setting four- to eight-fold capacity gain over other OLT systems with delivery of 800Gbps per slot of bidirectional throughput.

Access Edge: Fixed, Modular, Scalable Chassis

Figure 12



velocity DZS

	V1-16XC	V2 Chassis	V6 Chassis
Max # OLT ports (or combo ports)	16	32	96
Rack Units	1	2	6
Max Uplink (NNI) Capacity	200Gps	400Gps	3Tbps
	FiberWay 1	FiberWay 2	FiberWay 6

- **Velocity Platform designed for current and future service delivery needs**
- **System-on-a-Card enables non-blocking designs to 50 and 100 Gbps PON**

That translates to support for connecting up to 25,000 subscribers to GPON or XGS-PON transmissions over networks designed to reach anywhere from 20,000 to 20 million subscribers. Moreover, Velocity in any configuration available with DZS FiberWay will support simple in-place upgrades to 50Gbps and 100Gbps PON as those options become commercially viable. Security features supported by the OLT platform include secure bridging, broadcast storm detection and suppression, dynamic IP filtering, SSH and SFTP, and RADIUS authentication.

As a standards-based PON OLT, DZS Velocity works with any ONTs designed to GPON and XGS-PON specifications, and that will apply as well to next-gen ONTs mapped to future PON specifications. But it's important to note there's also a broad array of Velocity-compatible DZS Helix GPON and XGS-PON single-home and MDU ONTs along with fiber-terminating Wi-Fi 6 and 5 gateways linking to the unique DZS Cloud software management features which, as discussed below, allow subscribers to enjoy hyper-connected multimedia services faster and with greater reliability.

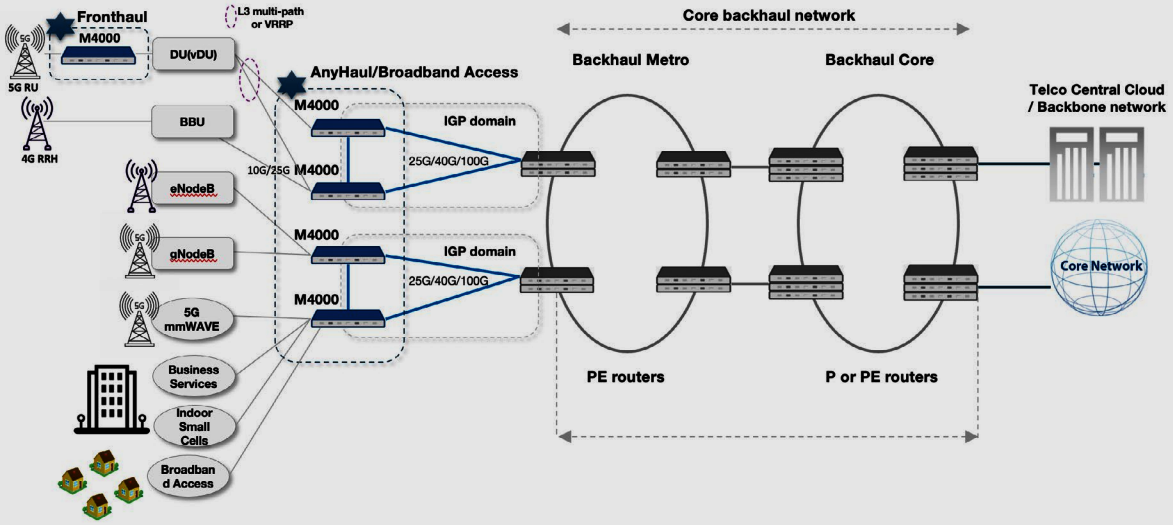
Converged Routing

Rounding out the components comprising the FiberWay platform is the DZS M4000 high-performance edge router. This is the DZS solution in the software-defined Chronos portfolio that supports Layer 1-3 service delivery and management of traffic related to cell tower connectivity, xHaul transport of that traffic, and enterprise-scale customer operations and anchor institution requirements (Figure 13).

Reference Network Architecture

Figure 13

L3 based Mobile Midhaul / Backhaul Solution



The 1RU M4000 as used in the FiberWay chassis applies these capabilities across the mid- and fronthaul domains with support for 360Gbps switching capacity and synchronized network operations across 32 1/10/25Gbps ports and 2 100Gbps ports. This level of interface density and switching and routing capacity in a small form factor is essential to aggregating traffic in multi-gigabit fiber access networks and to making things like ultra-low latency xHaul connectivity and Grand Master synchronization functionality available to cell sites.

The M4000 supports both SR-MPLS-based convergence of routing with optical transport and more advanced traffic management under direction of the SRV6 protocol, which is especially critical to a wide range of timing and QoS functionalities tuned to mobile requirements. In addition, SRV6 has become the primary means of executing packet-based slicing over xHaul optical links in tandem with over-the-air 5G slicing supported by 5G Standalone Architecture.

Bringing the Power of DZS Cloud Edge Solutions to Underserved & Unserved Markets

Along with satisfying the requirements for successful operations in unserved/underserved markets that we've touched on so far, DZS FiberWay brings to the rural networking environment all the features in the DZS Cloud Edge portfolio of solutions that are essential to addressing the remaining requirements as outlined in Part 2.

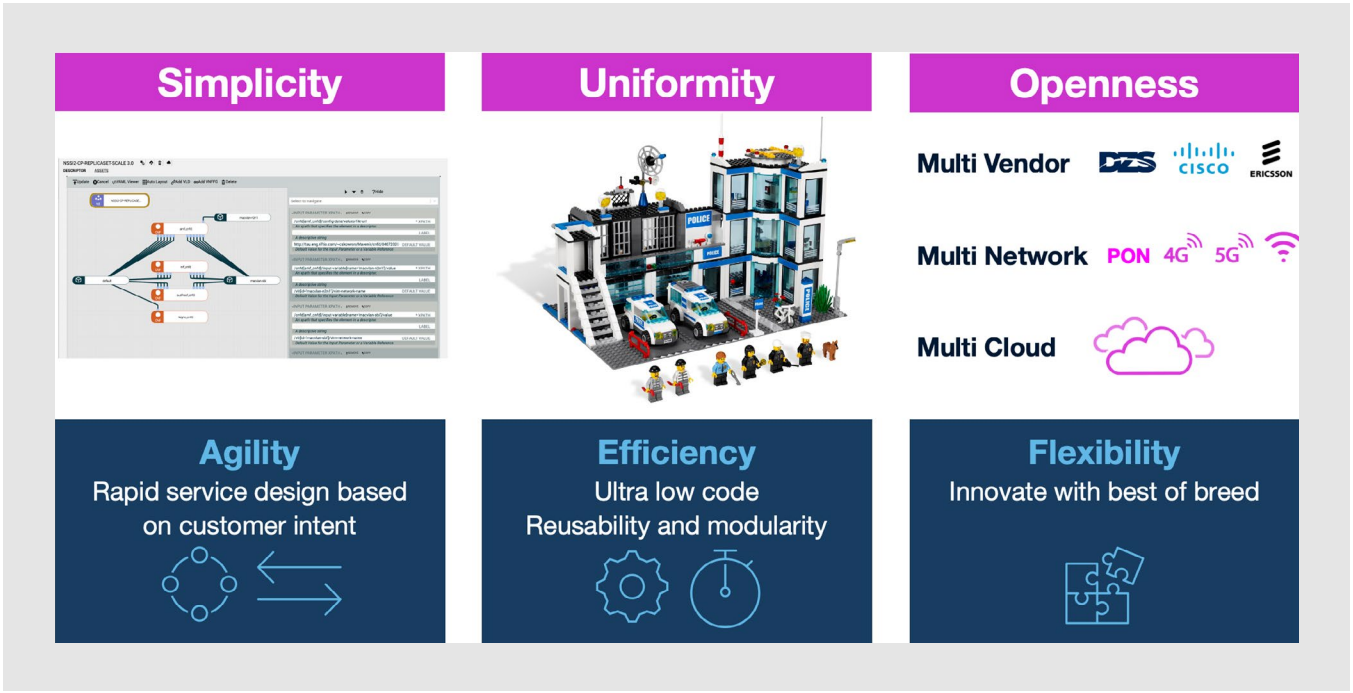
The solution set includes Xtreme, Expresse, and CloudCheck, which, together, provide CSPs an automated cloud-based approach to managing network resources free of vendor lock-in while supporting accelerated service innovation, rapid service deployment over fixed and mobile networks, and end-to-end QA.

Vendor Agnostic Network Management

As explained in this white paper, the Xtreme solution is the first platform to provide CSPs a means of remotely managing the allocation and performance of fixed and mobile network resources from any mix of vendor solutions at high levels of reliability, quality, and security without the need for manual intervention in the field (Figure 14).

The Path to Faster Services

Figure 14



The platform heavily relies on wide vendor adoption of standardized open interfaces which facilitates algorithmic abstractions of network elements (NEs) and models of the workflows on which industry standards are based. In instances involving proprietary systems that aren't standards compliant, operators have recourse to plug-ins developed by DZS that can be used to import integrations with third-party IP. These measures allow Xtreme to support zero-touch orchestration of any aggregation of dispersed transport and access network components that might be needed for any given service activation or implementation of security or other performance enhancements.

Xtreme supports standards-compliant approaches to using SDN technology when needed. And the platform is designed to tap NE functionalities that are assigned for activation through any combination of network function virtualization (NFV) technologies at any assigned cloud location or hybrid mix of locations. In all cases, the net result is a radical reduction in the time and money spent on launching new services, making adjustments in allocations of resources to existing services, or implementing software-based upgrades in network performance.

Accelerated Service Development

Xtreme also plays a major role in enabling operators to quickly develop and launch services. This results in part from the reduced coding burden on developers stemming from the automated model-based approach to operations. This allows ready use of any previously abstracted service design element that might be pertinent to a new service.

More fundamentally, Xtreme's abstraction of NE functionalities allows developers to quickly activate whatever functions are needed to test and eventually launch a new service. It's also important to note that once the Xtreme platform has been integrated with a CSP's OSS, BSS, and specialized systems like CRMs and service assurance tools, interactions with those components remain stable as services, use cases and suppliers change. This eliminates the need for new northbound integrations when new services are in play.

Another aspect to service acceleration involves the extension of logically independent virtual circuits for various categories of service as enabled by 5G slicing into the wireline environment. This ensures that the improvements in service innovation and performance resulting from dedication of network resources to specific flows are experienced by all users.

In part, support for slicing in the optical domain has to do with the previously mentioned M4000 support for SRv6 over the optical backbone connections to cell sites. But, critically, Xtreme also brings slicing into the FTTP and FTTX/DSL spaces through mechanisms supporting the partitioning of bandwidth spectrum into virtual circuits.

AI/ML Based End-to-End Quality Assurance

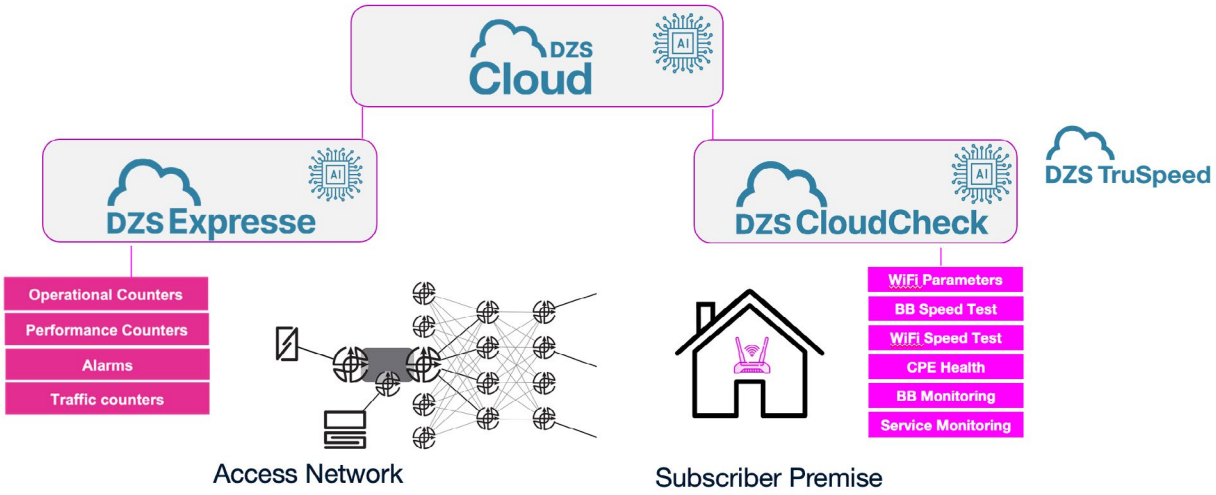
There are significant impediments to persistent quality of performance in external and premises segments of broadband networks in the best operating environments. Things get even more difficult in underserved and unserved areas where CSPs are harder pressed to handle the customer complaints and maintenance truck rolls triggered by poor performance.

Making matters worse, in this era of DIY home Wi-Fi management and OTT service providers, CSPs are taking the brunt of the fallout from things they don't control with the drain on resources stemming from customer calls for help. But there's an even bigger issue that must be addressed when it comes to elevating operators' ability to ensure services are delivered at the highest levels of performance.

Essentially, as explained in another DZS white paper, the challenge pertains to CSPs' need to create a compelling case for their services by delivering a quality of experience as "Experience Providers" that far surpasses what users are experiencing with reliance on OTT super-scalers. For all these reasons, operators stand to benefit immensely from the AI/ML based QA mechanisms implemented over external networks by the DZS Expresse cloud service and over premises WiFi links by the CloudCheck service (Figure 15).

AI/ML–Powered E2E Service Assurance Portfolio

Figure 15



Open & End-to-End Performance Assurance

Employing the pay-as-you-go SaaS model, Expresse allows CSPs to execute QA over all broadband access infrastructures through real-time monitoring, diagnosis, and resolution of any impairment to performance regardless of which vendor solutions might be involved. DZS's commitment to advancing Expresse in tandem with new generations of access technology ensures operators will be able to sustain comprehensive unified control over quality management across all facilities no matter what migration paths they choose to pursue.

The CloudCheck SaaS gives CSPs the same degree of quality control when it comes to sustaining a high level of performance in multifarious premises environments where WiFi dominates as the network medium of choice. Using CloudCheck, operators can execute automated control over any vendor's WiFi gateways and APs as long as they comport with the prplMesh Foundation's open-source, carrier-grade and certifiable implementation of the WiFi Alliance's Multi-AP EasyMesh specifications.

Of course, the best way to ensure households are equipped with such components is by following the common practice of making WiFi part of the CSP's service offering. With the insight into whole-home performance provided by CloudCheck, operators are able to identify instances where coverage is subpar, and, if the rerouting mechanisms that can be applied from CloudCheck to EasyMesh configurations prove inadequate, they can implement DIY assistance to ensure any additional APs shipped to or purchased by customers are properly installed.

Rounding out the fulfillment of broadband funding requirements, the monitoring, analytics, and reporting capabilities of Expresse and CloudCheck, including TruSpeed, provide CSPs all they need to keep authorities abreast of their progress. And, when it comes to reporting, over the long haul it's essential that CSPs be able to generate detailed reporting for their own internal needs as well data vital to substantiating performance under SLA agreements and commitments to advertisers.

Conclusion

Introduction of the deep-edge DZS FiberWay solutions has opened a new perspective on what can be expected as CSPs supported by broadband funding initiatives take on the task of closing the digital divide. Fundamentally, there's no longer any reason to expect this divide to persist by virtue of the cost and operational impediments to delivering first-class multi-gigabit services across underserved and unserved landscapes.

Components encased in the DZS FiberWay solution cabinet or alternatively deployed in existing potentially unprotected cabinets deep in service territories take much of the costs and hassles out of serving rural environments with the same levels of throughput and service capabilities users experience now and into the future in more urbanized regions of the most advanced countries. With easy scalability beyond today's 10Gbps XGS-PON feeds to future 50Gbps and 100Gbps generations of PON technology, DZS FiberWay-supported infrastructures will prevent digital divides from ever taking hold again.

CSPs deploying FiberWay solutions will always be able to evolve their networks free of vendor lock-in. They will be able to orchestrate use of network elements across all domains in support of shifting service requirements. They will be able to create and launch new services with minimal time wasted on coding or duplication of service architectures. And, through it all, they will be able to deliver the highest-caliber user experiences based on their ability to manage QA end to end as well as be given valuable AI-driven insights.

CSPs utilizing the aforementioned DZS Cloud Edge solutions are averaging 2-4x increases in ARPU with 20% gains in customer retention retention, as well as dramatic reductions in service requests and truck rolls. These operational improvements will prove to be essential in the long-term viability of rural remote networks, and place the CSP on the path to long-term sustainable success.

With over 60,000 OLT chassis, over 20 million ONTs and WiFi gateways, and over 70 million cloud software subscribers served worldwide, DZS has a long track record of delivering the innovations that CSPs have counted on to thrive. With DZS FiberWay, we are providing the tools that allow CSPs to leverage unprecedented resources to finally fully bridge the digital divide. We believe this is a noble cause, and we would be honored to be your partner in providing a fast path to success to deliver world-class broadband to the unserved and underserved markets that you have the opportunity to connect.

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