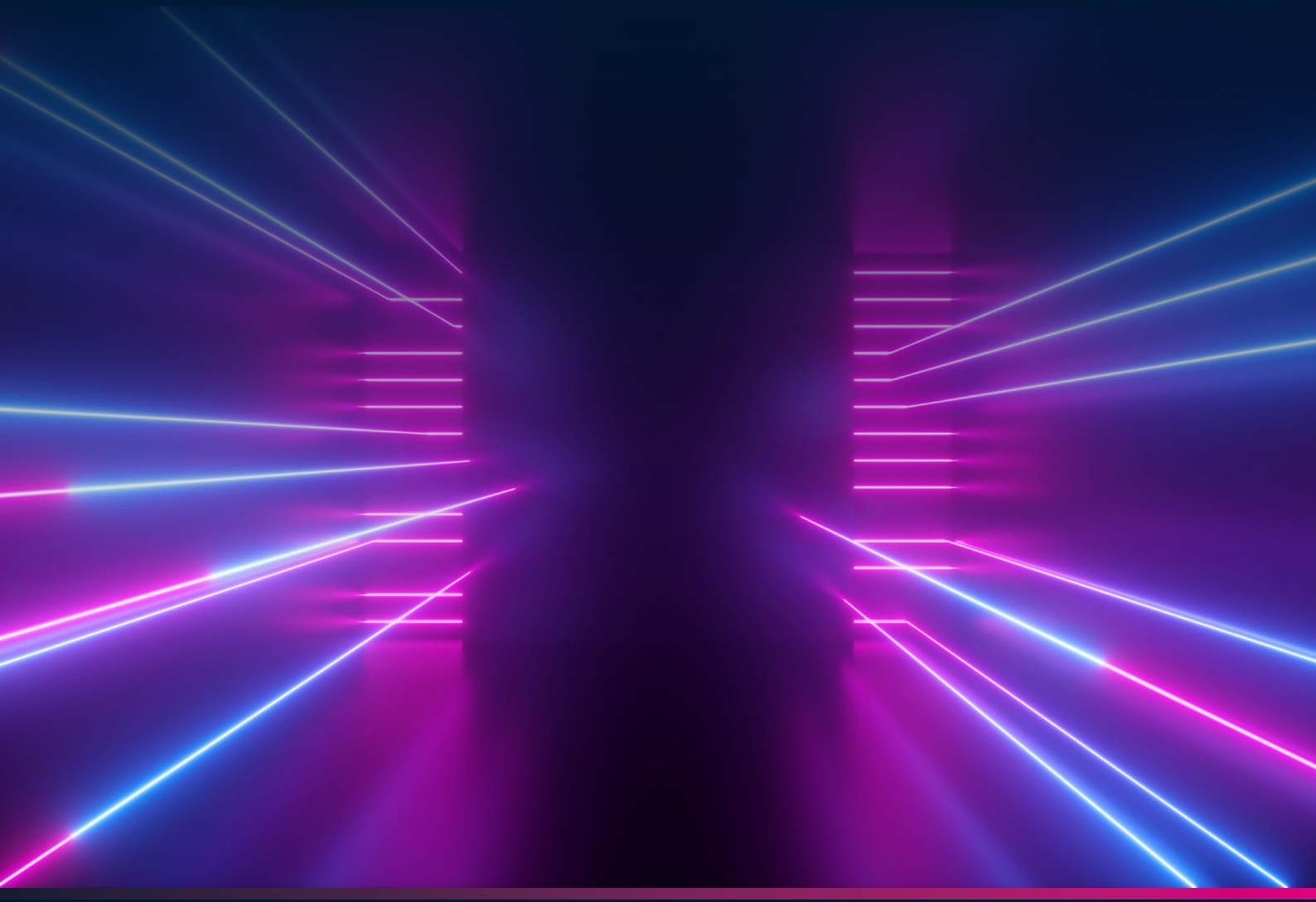
WHITEPAPER

Rethinking the Network Edge

Next-Gen Applications Will Drive New Transport Innovations at the Converged Access Edge

Deploy-Anywhere Form Factor of DZS Saber 4400 Platform Changes Economics of DWDM Deployment



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Executive Summary

Communications service providers (CSPs) of every description finally have an opportunity to fully exploit the power of edge-based and software-defined optical networking technology in their networks to drive their businesses to new heights at sustainable costs.

All entities engaged in delivering broadband services, including utility and municipally owned CSPs and independents as well as incumbent telephone and cable companies, share the same priority. They need to be able to respond to market demand for ever more bandwidth and services while keeping capex and opex in check.

It's widely recognized that edge-based network evolution is vital to CSPs' achieving higher returns on their investments in their pursuit of new service opportunities. The win/win that comes with lowering capex and opex as ARPU goes up is operators' route to overcoming the low-margin financial performances that have dampened investor confidence for several years.

Successful edge-based network strategies give operators greater flexibility to expand access bandwidth and localize service configurations by moving front-haul distribution nodes closer to end users in conjunction with maintaining high bandwidth mid-haul connectivity to all the telecom-related data centers, central offices, and mobile core infrastructure now dotting the metro, ex-urban and rural service area landscapes. Such strategies also open the path to leveraging distributed computing intelligence for instantaneous execution of cloud-based software functionalities that are essential to a vast range of emerging fixed and 5G mobile consumer and business services.

But there's been a big two-pronged impediment to CSPs' ability to capitalize on the edge-centric optical networking potential. On the one hand, there aren't enough temperature-controlled indoor facilities that can be used to house the advanced optical components that are essential to cost-effective implementation of next-gen network topologies.

At the same time, until now it's been impossible to neutralize this problem by deploying environmentally protected platforms with form factors small enough for even small or fully-populated cabinets in CSP-controlled spaces. There's no mystery as to why this has been the case.

Suppliers have found it's extremely difficult to condense platforms with protection against temperature extremes to the required dimensions. This is a hardware stack that must encapsulate the fiber and electronics cost-saving capabilities of high-capacity multi-wavelength coherent transport in ring and point-to-point deployments capable of handling the ever-increasing volumes of traffic flowing across all regional core and end-user connections.

Fortunately, **this barrier to unprecedented efficiency and flexibility in network operations has been broken by DZS, the global leader in next-generation network technology**. DZS has met the challenge with the introduction of the environmentally hardened, small form-factor and modular Saber 4400 optical transport and networking edge platform. This is a condensed software managed package that can be deployed virtually anywhere to support operations at the industry's highest levels of performance under outdoor conditions ranging from -40° to +65°C and consuming less power while supporting ESG initiatives.

The cost savings resulting from these outside plant cabinet options can add up to millions of dollars in initial capex as well as millions more in electrical power savings. Industry engineers calculate the typical cost of buying land and building just one temperature-controlled enclosure large enough to house traditional edge network components is close to $200,000.

The DZS Saber 4400 platform can support any next-generation edge and metro network configuration, from point-to-point connections to multi-point ring and complex mesh topologies.

Modular flexibility in the use of edge components allows CSPs to satisfy whatever networking requirements might be at each edge location.

By delivering payloads at terabit-plus speeds and low latency over DWDM transport links between edge locations, the Saber 4400 platform enables CSPs to connect at multi-gigabit access speeds to every type of end user location, from individual homes and small businesses to multi-tenant residential and office buildings, factories, and industrial parks. With similar levels of connectivity to regional central offices, data centers, and mobile radio access network (RAN) processing centers, CSPs can fulfill the potential envisioned for next-generation edge network support of distributed cloud computing and service personalization at costs and levels of future-proof scalability that are essential for business success

Chief among the many components that can be incorporated into the DZS Saber 4400 optical edge platform are long-distance coherent transport modules including transponders, muxponders, add/drops and amplifiers operating at hundreds of gigabits-per-second per wavelength optionally connected to Saber Reconfigurable Optical Add-Drop Multiplexers (ROADMs) or OADMs in the case of point-to-point scenarios.

Operating on a single shelf in the DZS Saber 4400 cabinet, each of four 1 RU hot-swappable Saber 4400 transponder/muxponder modules with optional 2° ROADM connectivity on a second 1 RU shelf generate coherent throughput at 100 to 400 Gbps per wavelength to support up to 1.6 terabits per second (Tbps) per shelf of unamplified propagation at up to 120 Km. Overall, using add/drops, 25.6 Tbps optical transport is possible between two ROADM sites. Co-located and/or mid-span-installed optical amplifiers extend the reach between Saber 4400 installations to much longer distances.

A second 1 RU shelf in the Saber 4400 cabinet can be used to stack other components such as additional coherent transponders with another ROADM shelf, which can operate as a single element with the primary transponders to create 4° add/drop coverage in more complex ring and mesh applications. Similarly, 8° add/drop coverage is also possible with the Saber ROADM. In accord with the DZS commitment to open standards, the Saber 4400 ROADMs are mapped to the Open ROADM standard, which enables DZS Saber 4400 nodes to interoperate with other vendors' Open ROADM-compliant transport nodes on the same ring as needed, although book-end configurations are more common.

The platform also supports multiple point-to-point use-cases for transporting 100G or 400G circuits from one edge site to another using a single DWDM wavelength over dark fiber, or over a single DWDM channel between sites on an existing DWDM or ROADM network.

Other dual-shelf configurations can also be used to support seamless transport redundancy, use of DZS Velocity OLTs in support of passive optical network (PON) distribution, or optically amplified dense wavelength division multiplexing (DWDM) transmissions on the ring network.

An unhardened version of this hierarchy of Saber 4400 and other edge options is available for deployments in temperature-controlled buildings and hubs.

The following discussion begins in Part 1 with an overview of market developments shaping CSP opportunities for growth and challenging them to find ways to capitalize on those opportunities at new levels of profitability. Part 2 explores the surging role of fiber optics in edge network operations worldwide in the context of developments calling for the deployment of next-generation optical networks that can meet operators' commitments to cost containment.

In Part 3 the discussion explores the optical technologies CSPs can apply in edge-network architectures that are best suited to achieving their goals and explains how DZS through its introduction of the Saber 4400 platform has opened a viable path to success. In the concluding Part 4, we look at additional factors associated with reliance on Saber 4400-based edge networks that underscore the unique role DZS Saber 4400 plays in network transformation.

Part 1 Demand Trends Driving Network Transformation

To weigh the networking challenges ahead and why a highly versatile, low-cost approach to creating an edge-based approach to network operations is essential to meeting those challenges, it helps to take stock of the true dimensions of demand for CSP services taking shape worldwide.

Outstanding Growth Prospects Amid Unrelenting Demand for More Bandwidth

In a nutshell, the prospects for growth in the telecommunications services market have never been better. Forecasters as reflected in Figure 1 are in general agreement that global fixed and mobile telecom revenue will increase by over 50% to more than $2.5 trillion by 2030.

Figure 1

Researchers Expect Telecom Revenues to Grow 50+% by 2030

Grand View Research		
2022	**2030**	**CAGR**
$1,805.6B	$2,874.7B	6.0%

Straits Research		
2021	**2030**	**CAGR**
$1,797.9B	$2,765.3B	4.9%

Precedence Research		
2022	**2030**	**CAGR**
$,1,810.0B	$2,650.0B	4.85%

Sources: Grand View Research[i]
Straits Research[ii]
Precedence Research[iii]

A potent mix of trends is burnishing the outlook for network service providers (CSPs) of every stripe, including telephone and cable incumbents, mobile operators, new entrants pursuing underserved markets, and overbuilders backed by utilities, municipalities, and other entities.

This starts with the fact that nearly every facet of life in today's world depends on internet connectivity. Traffic flowing across internet transit points worldwide increased by an average rate of 30% between 2019 and 2023, according to data compiled by researcher TeleGeography. While

this average includes the peak rates in the stay-at-home Covid era, the researcher reported the latest year-to-year comparison from 2022 to 2023 showed the surge continued at a 23% pace.

The upswing in traffic flow is mirrored in bandwidth consumption, with an increase in the global average fixed broadband access speed from 45.9 Mbps in 2018 to 110.4 Mbps in 2023, according to Statista. The diversity of regions with the highest levels of broadband access was reflected in the wide mix of countries from different parts of the world appearing in the Statista top-ten listing as of 2023.[vi]

Figure 2

Global Access Bandwidth Acceleration

Average Fixed Access Rates 2018-2023					
2018	**2019**	**2020**	**2021**	**2022**	**2023**
45.9 Mbps	52.9 Mbps	61.2 Mbps	77.4 Mbps	97.8 Mbps	110.4 Mbps

Top 10 Countries 2023			
Singapore	242.01 Mbps	**Thailand**	204.26 Mbps
Chile	222.49 Mbps	**U.S.**	202.40 Mbps
UA Emirates	216.78 Mbps	**Denmark**	199.94 Mbps
China	215.80 Mbps	**Spain**	175.96 Mbps
Hong Kong	205.69 Mbps	**Romania**	174.26 Mbps

Sources: Ookla 2021

Such metrics have silenced assertions that CSPs are offering more bandwidth than people need, which is why the pace of 1 Gbps availability is skyrocketing. As of mid-2022, 60% of the world's CSPs surveyed by Omdia were offering service tiers at 1 Gbps or higher rates, marking what Omdia estimated to be a doubling of the number of gigabit subscribers from 24 million at the end of 2020 to 50 million in 2022.[vi] In the U.S, the share of users on 1-Gig tiers jumped from 12.2% in 2021 to 26% in 2022, according to OpenVault.[vii]

And there's no end in sight. According to projections from Analysis Mason, two thirds of premises worldwide will have access to 1 Gig service by 2028.[viii] This squares with projections from researcher RVA, which says the global average residential bandwidth will hit 1.2 Gbps in 2028.[ix]

Service Demand Trends Underlying Pressure on Network Capacity

Video Dominates Usage Patterns Across All Market Segments

Demand-side drivers to ever-increasing bandwidth consumption proliferate across every service category in the consumer and enterprise markets. Video, with usage jumping 24% in 2022, is the primary force multiplier now accounting for 65% of global internet traffic, according to Sandvine.[x]

In the consumer market, with HD 1080p resolution now the norm for TV-caliber streaming on connected TVs (CTVs) and the shift to 4K UHD well underway, higher bandwidth consumption with any volume of streamed M&E content is inevitable. And, of course, the volume of over-the-top (OTT) streaming is going up rapidly, with global penetration rising from 40.9% in 2022 to 49.9% in 2026, according to Statista.[xi]

Across all market segments from social media to business meetings and virtual conferences, video communications have become the norm. Here, too, higher bandwidth-consuming video resolutions have taken hold with 720p now the average default resolution in most commercial teleconferencing systems with offerings of 1080p and even UHD 4K options.

On the enterprise side, the teleconferencing services market is projected by Global Market Insights to grow at a 10% CAGR from $25 billion in 2022 to $95 billion in 2032, by which time super-high resolution telepresence services will account for nearly a third of the market. And video conferencing is just one of the many applications driving video consumption in the enterprise sector. With video usage soaring in marketing, training, seminars, and much else the enterprise video market will grow at a 9.7% CAGR from $19.8 billion in 2022 to $31.4 billion in 2027, according to MarketsandMarkets.[xiii]

IoT Has Taken Off in Consumer as well as Enterprise Markets

Adding to the momentum is an explosion in the per-household video-capable device count, including not only connected gaming consoles and devices used in personal streaming sessions but also a growing array of security, telehealth, and other video-consuming Internet-of-Things (IoT) devices. Transforma Insights projects the number of connected devices in use worldwide, including everything from connected IoT gadgets and smartphones to smart TVs, will increase at an annual rate of 12% to 29.4 billion by 2030 compared to 11.3 billion in 2021.[xiv]

IoT is now a significant factor in the household device count. In the U.S., where Parks Associates says the connected-device average now tops 16,[xv] even video doorbells have reached 20% market penetration.[xvi]

Meanwhile, applications continue to multiply across the commercial markets, led by the manufacturing, retail, transportation, and utility sectors with new categories like smart cities and buildings taking hold everywhere. Overall, MarketsandMarkets projects the global IoT market for hardware, software solutions, and services will increase to $650.5 billion in 2026, marking a 16.7% CAGR jump from $300.5 billion in 2021.[xvii]

XR Reaches Mass Market Crossover

Going forward, researchers expect network support for connectivity to extended reality (XR) applications, including services supporting artificial (AR), virtual (VR), and mixed reality (MR) will surge in tandem with XR market growth. Researcher ASD predicts the global XR market, valued at $40.1 billion in 2023, will reach $111.5 billion by 2028.[xviii] Statista sees even greater growth with a prediction that global spending for XR content, equipment and services across all market segments will grow at a 36.72% CAGR from $28 billion in 2021 to $250 billion in 2028.[xix]

As noted by ASD, this is an arena impacting the consumer, enterprise, healthcare, and education markets alike, with business adoption of AR and VR in training, architecture, product engineering, and other applications outpacing the consumer side in the early going. Live interactive use cases from consumer gaming and immersive sports viewing to many applications in these other markets require network throughput exceeding the highest levels in 2D video streaming.

In the context of XR and other applications, low latency at the network edge becomes imperative given the sensitivity of these applications to latency for proper function.

Business Demand for CSP Services

Beyond video and IoT connectivity, business use of networks is soaring with reliance on cloud services. Access to cloud-stored data, cloud-based software applications, and other uses of virtualized computing along with adoption of cloud-anchored unified communications across all fixed and mobile worker locations is driving demand for bandwidth and a vast tier of value-added services. For example, what was a new market for software-defined wide-area-networks (SD-WANs) calculated at $1.4 billion in 2019 is on course to hit $43 billion by 2030, according to P&S Intelligence.[xx]

And with this reliance on cloud connectivity comes a much greater need for end-to-end security, adding another important value-added-service to CSPs' portfolios. Losses from cybercrime added up to about $6 trillion in 2021 on a trajectory to hit $10.5 trillion in 2025, as calculated by the research company Cybersecurity Ventures.[xxi] With the provision of next-generation firewall services (NGFWs), which combine intrusion-detection and intrusion-protection system (IDS/IPS) technologies with application-specific policies based on traffic analysis, CSPs can take a leading role in helping businesses combat the cybercrime scourge.

The immensity of the service opportunity in the enterprise sector is also driven by the burgeoning utility communications market where CSP networks are essential to rapid restoration of problems in gas, electric, and water resources, management of power grids involving a new class of virtual power plants (VPPs), and interactions with residences and businesses in energy conservation. The market for utility communications services is on track to increase at a 5.3% CAGR from $20.2 billion in 2022 to $26.1 billion by 2027, according to MarketsandMarkets.

Overall, the global enterprise telecom services market, pegged at $848.2 billion in 2022 by Global Market Insights, will reach $1.2 trillion by 2032, the researcher says.[xxiii] Grand View Research with a more aggressive take on market growth, projected it will reach $1.2 trillion by 2030 on a 6.7% CAGR pace from $724.52 billion in 2022.[xxiv]

These numbers include business services delivered

over mobile networks with 5G projected to take an ever-greater role as penetration surges in response to business demand for IoT and emerging XR and autonomous vehicle support services. MarketandMarkets projects the 5G services market, including the consumer sector, will treble in size from $107.0 billion in 2022 to $331.1 billion in 2027.[xxv]

5G connectivity across all market segments will more than double by 2025, according to a recent report from Statista.[xxvi] (Figure 3).

Figure 3

5G Connections Worldwide		
Region	**2023**	**2025**
North America	230M	410M
China	720M	1040M
Other APAC	170M	310M
Western Europe	160M	320M
Rest of the World	110M	640M
Total	**1.39 Billion**	**2.72 Billion**

Source: Statista

Part 2 The Edge-Network Imperative in a Capex-Shy Climate

The Surging Availability of Fiber

Fiber optics, of course, is the networking technology on which the transformation in broadband access is based. Fiber now dominates the global network landscape, extending beyond longstanding usage in long-haul and regional core networks to consumer and business premises on the fixed-access side and to ever deeper points of connectivity to mobile terminals as 5G takes off.

Passive optical network (PON) technology has been instrumental to the rapid expansion of FTTP connectivity. Utilizing time division multiplexing (TDM) and other modes of designating signals targeted to specific users, PONs passively split payloads distributed from optical line terminals (OLTs) for bidirectional transmissions in targeted service areas over multiple end-run fibers to and from optical network units (ONUs) installed at consumer and commercial customer premises or local points of wireless distribution.

Globally, as of 2021 FTTP coverage stood at 43% of premises and will increase to 57% by 2026, according to Analysis Mason.[xxvii] A report issued by the FTTH Council Europe in mid-2023 showed that the 32 countries topping 40% penetration, led by the United Arab Emirates, Qatar, Singapore, and Hong Kong at over 90%, represented all sizes across Asia, the Middle East, and Europe.[xxviii] (Figure 4)

Figure 4

Nations with FTTP Penetration Above 40%		
UAE 98.1%	Vietnam 73.8%	Slovakia 48.1%
Qatar 97.8%	Spain 73.5%	Taiwan 45.7%
Singapore 96.5%	Portugal 71.1%	Lithuania 45.1%
Hong Kong 91.6%	Japan 68.4%	Latvia 44.1%
China 89.4%	Sweden 67.5%	Denmark 43.0%
Barbados 85.8%	Norway 67.5%	Finland 42.7%
Mauritius 85.3%	Romania 67.3%	Chile 42.7%
Andorra 84.9%	Bahrain 62.0%	Luxembourg 40.5%
South Korea 82.1%	New Zealand 59.6%	Slovenia 40.0%
Iceland 76.8%	France 55.2%	Trinidad 40.0%
Uruguay 76.1%	Bulgaria 48.3%	

Sources: FTTH Council Europe

Not shown here, the bottom tier of nations below 24% penetration is largely occupied by countries in Africa and the Western Hemisphere, including Canada and the U.S. at 27.8% and 23.8%, respectively. In the latter two cases, however, the broadband markets are dominated by cable providers who, in the case of the U.S., now offer 1 Gbps service to about 90% of all households, according to J.P. Morgan.[xxix]

But while there's ample fiber just about everywhere, CSPs need to be able to put it to use in ways that will allow them to fully capitalize on market demand with higher rates of return on their investments. The solution lies with cost-effective deployments of advanced optical systems at network edges that will allow them to leverage the distributed intelligence essential to accommodating a new generation of services.

Consensus on Why Edge Network Transformation Is Essential

There's broad concurrence on the edge-based network architecture imperative to address the bandwidth gap in access and edge transport networks (often termed Middle Mile networks in the US). As access networks move from 1G or less to 10G, today's 10G-capable edge transport networks need to expand to100G/400G and address gaps in coverage to reach unserved and underserved areas to address the digital divide.

In an advisory noting the time has come for CSPs to move in this direction, Boston Consulting Group said a survey of industry executives revealed all planned to "transform their traditional networks to a low-cost, software-defined infrastructure" with half of the respondents already in the early stages of implementing their strategies.[xxx]

Most said they are responding to a surging need for connectivity that can support the value-added service requirements associated with IoT applications and IT-oriented services. With the ability to execute timely computation of data, these edge-centric networks could be supporting "fully autonomous technology, including self-driving vehicles, remote surgery, and industrial robots" as early as 2025, the report said.

BSG noted CSP goals can best be met with implementations of edge-centric network architectures that make use of advanced optical ring transport to facilitate connectivity as localized data processing proliferates. This allows CSPs to satisfy the most demanding applications now and into the future through balanced, low-latency data flows that minimize distance and congestion between processing centers, users and IoT end points, BSG said.

The report also emphasized the cost-saving improvements in network reliability that come with ring routing around points of failure. And it noted that networking support for distributed processing also cuts the traffic load over long-distance connections to core public cloud locations, freeing up those resources to handle the massive amounts of processing that will be required in those domains for less latency-sensitive applications as artificial intelligence takes hold.

> A recent report from the Forbes Technology Council echoed these points. "Network edges — both fixed and converged — are crucial for telecom companies to move up the value chain." [xxxi]

Given the volume of data processing workloads now flowing to the cloud from every direction, FTC said CSPs need to quickly get to a point where they can assure customers their networks can meet the challenges ahead. Otherwise, there's a growing probability of data processing bottlenecks cropping up routinely across network nodes.

Looking at what it takes just to handle cloud processing related to cell phone usage, the FTC report cited recent calculations performed by Gartner. With the number of cellular IoT connections at 3.5 billion and the average person triggering 5,000 data interactions per day, Gartner said the global daily public cloud data processing workload has reached 90 zettabytes or about 90 billion terabytes. The report also cited research showing that 25% of 5G use cases depended on edge computing as of 2023.

Additional evidence that the edge-based networking future has arrived abounds worldwide. In a comprehensive survey comparing next-generation metropolitan optical network infrastructures under consideration in the telecommunications industry, researchers at universities in Germany and Brazil noted the "ongoing change on the location of storage/ computing systems towards the edge has already impacted the traffic profile in metropolitan transport networks."[xxxii] They said they're seeing "unprecedented changes marked by data traffic granularities "varying from below 1 Gbs up to 800 Gbs with different modes of communications and traffic profiles, different patterns of traffic distribution, both in time and space, coexisting in the same network segment."

The Cost-Containment Imperative

But even as CSPs invest in their networks to keep pace with these market dynamics, they face pressure to reduce recent spending patterns that have led to a falloff in telecom return on capital investment (ROIC) by more than 25% over the past ten years, as measured by Capital IQ.[xxxiii] The focus on capex optimization is evident in researchers' projections. For example, Analysis Mason forecasts that by 2027 total industry capex will be 27% lower than it was in 2019.[xxxiv]

The importance of both capital and operations cost-saving versatility that can be derived with reliance on edge-based optical network architecture was evident in a global survey of 200 network operators conducted in 2023 by the change-management firm Accenture.[xxxv] The company reported that, with 90% of telecom finance executives putting a high priority on optimizing total cost of ownership (TCO), 83% of the executives overseeing network technology were stressing the need for greater infrastructure flexibility as a top priority.

Accenture found a wide gap between expectations among CSPs who are committed to investing in next-generation architectures and those who expect to capitalize on market developments with reliance on what they've already done to accommodate change. The revenue and gross-margin expectations of the next-gen group for the next three years when adjusted for apples-to-apples comparison exceeded the latter group's expectations by multiples of 1.5x and 1.8x, respectively.

Changing the Economics of Network Edge Transport

Those higher margin expectations are on track with what can be achieved with smart spending on edge-centric network architectures that take full advantage of advanced optical technologies. Next-generation edge networks heavily rely on automation and remote software-based operations management and quality control to eliminate most of the opex costs incurred in the past. And more efficient use of fiber, reductions in the need for signal amplification, modular component upgradability, hot-swap replacement mechanisms, and vendor interoperability enabling choices of components best suited to operators' requirements allow CSPs to keep capex at a minimum without impeding their ability to serve market needs.,

But there's one important caveat: smart spending means taking into account the need to keep the costs of deploying key network edge components at a minimum without compromising on the requirement to install them wherever they're needed.

The costs of building temperature-controlled enclosures large enough to contain all the components that are required at each network edge location can be prohibitive even with network topologies that make the most efficient use of advanced optical technologies. As calculated by the South Carolina-based network engineering consultancy Palmetto Engineering and Consulting, the costs of laying a pad and building a hut just large enough to contain the essential gear has typically run close to $200,000[xxxvi] (Figure 5).

Figure 5

Analysis of Typical Next-Gen Edge Node Enclosure Costs	
Item	**Cost**
Heat Exchanger	$3,000
HVAC	$12,000
Building (8×12)	$55,000
Land	$20,000
Site Work	$15,000
Inside Infrastructure	$50,000
Equipment Labor	$10,000
Fiber Cabling Labor	$15,000
Total	**$180,000**

Sources: Palmetto Engineering and Consulting

Add to that the ongoing costs of powering and maintaining such enclosures, and it's easy to see why many CSPs have been struggling to find a way forward that will allow them to capitalize on their business opportunities at the levels of expectations expressed in the previously noted Accenture survey by the minority of respondents who have started building these next-generation networks. With such costs on the balance sheets, it's hard to square engineering department's preferred networking strategies with corporate commitments to lowering spending.

Fortunately, as shall be seen in Part 3, DZS has overcome this dilemma with introduction of the Saber 4400 next-generation edge network platform, which, for the first time, compacts all the essential equipment in an environmentally hardened cabinet small enough for deployment virtually anywhere, including at pedestal locations and on pole-mounted strands. As noted by Palmetto CEO Chris Roland, "**The hardening, compactness, modularity, and scalability of the DZS Saber 4400 is a game changer.**"

Of course, there's much more to achieving success than making the right hardware choices in a next-generation network upgrade or buildout. There are new capabilities in network operations associated with choosing hardware wisely that can make it possible to holistically orchestrate service development, quality control, upgrades, and component replacements across traCSPort, access, and cloud domains.

This, too, is a major benefit CSPs can expect when implementing the DZS Saber 4400 platform to anchor their edge networks. Because every platform component has been designed in compliance with industry standards, operators can take advantage of the ground-breaking DZS Xtreme multi-network orchestration platform.

As discussed at greater length in Part 4, Xtreme is a cloud-based automation, orchestration, software-defined networking (SDN) control and management solution that applies logical integration of fixed and mobile facilities across access, transport, and mobile domains to support highly automated vendor-agnostic approaches to providing a new generation of carrier-grade services at far lower total costs of ownership (TCO) than once seemed possible.

Part 3 The Saber 4400-Based Next-Gen Edge Network

Basic Edge Network Requirements

CSPs seeking to serve market needs now and into the future at targeted levels of ROI require networks that can support all the service categories described in Part 1. They must be able to offer these services at the highest access rates supported by currently available optical technologies such as 10-Gbps XGS-PON and point-to-point 400 Gigabit Ethernet (400GE). And they must have in place network components and management systems that allow them to move to higher levels of throughput as new options like 50 Gbps and 100 Gbps PON take hold.

Great versatility in optical networking is required to link all locations housing essential network and computing facilities with all edge points supporting service distribution to CSP customers. The size of the targeted edge transport and networking area might be confined to a single small city, extend across a large metro area, encompass one or multiple counties or precincts in a rural region, or cover an entire state, province, or small country. Point-to-point use-cases extend connectivity and service provider reach by transporting 100G or 400G circuits from one edge site to another using a single DWDM wavelength over dark fiber, or over a single DWDM channel between sites on an existing DWDM or ROADM network.

The Importance of Ring Topologies

The best approach to bringing all local cloud and network processing centers into connectivity with the distribution nodes relies on advanced optical technology in ring configurations with use of ancillary point-to-point connections when needed. The essential technology components have been standardized and well-proven with worldwide vendor compliance that allows CSPs to choose best-of-breed solutions without fear of vendor lock-in.

Distribution nodes connected to the regional ring infrastructure partition the market into smaller service areas that allow service providers to maximize the benefits of distributed cloud computing while raising access throughput by minimizing simultaneous usage. The edge nodes connect over fiber or any combination of fiber, copper wiring or cell sites to any mix of user environments, including houses, MDUs, single- and multi-tenant office buildings, industrial parks, and college campuses.

Local cloud computing facilities connected to the network include any location that provides processing support for applications delivered over the CSP network to end users. Connected facilities related to network operations can include telecom central offices and video headends as well as mobile centers of operation.

In the case of traditional cell sites, links to the local transport system can be used to aggregate backhaul traffic for long-haul connections to distant processing centers. Equally if not more important to cellular operations are connections to the radio access network (RAN) data processing centers used with distributed 5G architecture.

One or more 5G facilities connected over the fiber network can accommodate data processing for the multitude of 5G cell sites that are positioned deep in the segmented service areas to enable high throughput to end users. This is the key to realizing the high expectations set for next-gen 5G with its ability to support application-specific slicing and Ultra Reliable and Low Latency Communications (URLLC).

Coherent Transport and ROADMs

The transport system used in the ring and point-to-point configurations connecting all these facilities and distribution nodes relies on coherent optical transmitters paired with either remotely reconfigurable optical add-drop multiplexers (ROADMs) in the case of most ring configurations or passive OADMs when all signals are exchanged between two end points with no branching required. As the name implies, the ROADMs serving as the gateways for payloads targeted to or received from specific service areas can be adjusted from operations centers to accommodate changes in the allocations of wavelengths and their payloads at each edge location.

Signals moving into or out of the ring or point-to-point transport go through two phases of multiplexing and demultiplexing. Along with the ROADM/OADM process, muxing/demuxing occurs with the aggregation and disaggregation of signals assigned to the wavelengths used in coherent transport. These wavelengths are transmitted in the O-Band (1310 nm.) owing to the superior propagation characteristics of that spectral range and therefore rely on the lower wavelength counts used with coarse WDM (CWDM) as opposed to the dense WDM (DWDM) wavelength counts used with non-coherent C- and L-band (1525-1610 nm.) transmissions.

Coherent transmissions significantly extend signal reach by combining amplitude and phase modulation across two polarizations in a single light-wave transmission. One or more coherent transport modules, each with capacity to support up to 400 Gbps throughput per wavelength over distances up to 120 Km., can be deployed in stacked assemblies to support virtually any local traffic load.

The Unique Capabilities of a Saber 4400-Enabled Edge Network

All of this describes the ideal approach CSPs can take to satisfying market demand wherever it leads, provided they can execute their strategies within prescribed budget limits. As noted earlier, DZS has made this possible with development of the DZS Saber 4400 platform, which CSPs have been putting into operation worldwide since its launch in 2022.

An Environmentally Hardened Form Factor Suited to Deployment Anywhere

This is the only next-generation edge platform that condenses all the essential edge network components into environmentally hardened cabinets small enough for outdoor plant installation. Operating at the industry's highest levels of performance, the Saber 4400 can be deployed in even the smallest of cabinets or installed in existing unhardened structures.

With the ability to operate at temperatures ranging between -40°C and 65°C, the Saber 4400 eliminates the need to build temperature-controlled enclosures or to add heat exchangers or air conditioners when the platform is installed in existing unprotected structures. As a result, in addition to saving the costs of building new facilities, which, as outlined in Figure 5, add up to close to $200,000, the Saber 4400 saves approximately the $20,000 or more that it would cost to harden each existing unprotected facility that's used to house edge components.

Moreover, in all instances where the hardened Saber 4400 platform is in use, operators avoid the costs that would be incurred if those locations required support from external energy sources. And, of course, there's a climate-friendly sustainability benefit that comes with these reductions in energy consumption, especially in regions requiring large-scale deployments.

Space for Multiple Component Arrays Suited to Specific Edge Needs

There are many options available for using shelf space in the Saber 4400 cabinet to support the many miniaturized DZS components operators need to meet all the requirements of a future-proof edge network. Multiple units of these components can be stacked for treatment as a single network element.

The fundamental components in all locations are the transponders and multiplexers supporting coherent transmissions and the ROADMs or OADMs responsible for managing wavelengths. In accord with the DZS commitment to interoperability through adherence to open standards, the DZS ROADMs are mapped to the Open ROADM standard, which enables DZS Saber 4400 nodes to interoperate with other vendors' Open ROADM-compliant transport nodes on the same ring.

The 1 RU DZS Saber 4400 with 2° ROADM (two-way connectivity on the transport system) generates coherent throughput at 100 to 400 Gbps per wavelength with four hot swappable modules per shelf supporting up to 1.6 terabits per second (Tbps) of unamplified propagation at up to 120 Km. Much longer distances can be achieved with Raman optical amplification co-located with the Saber 4400 transponders (up to 190 Km) or installed mid-span (500+ Km).

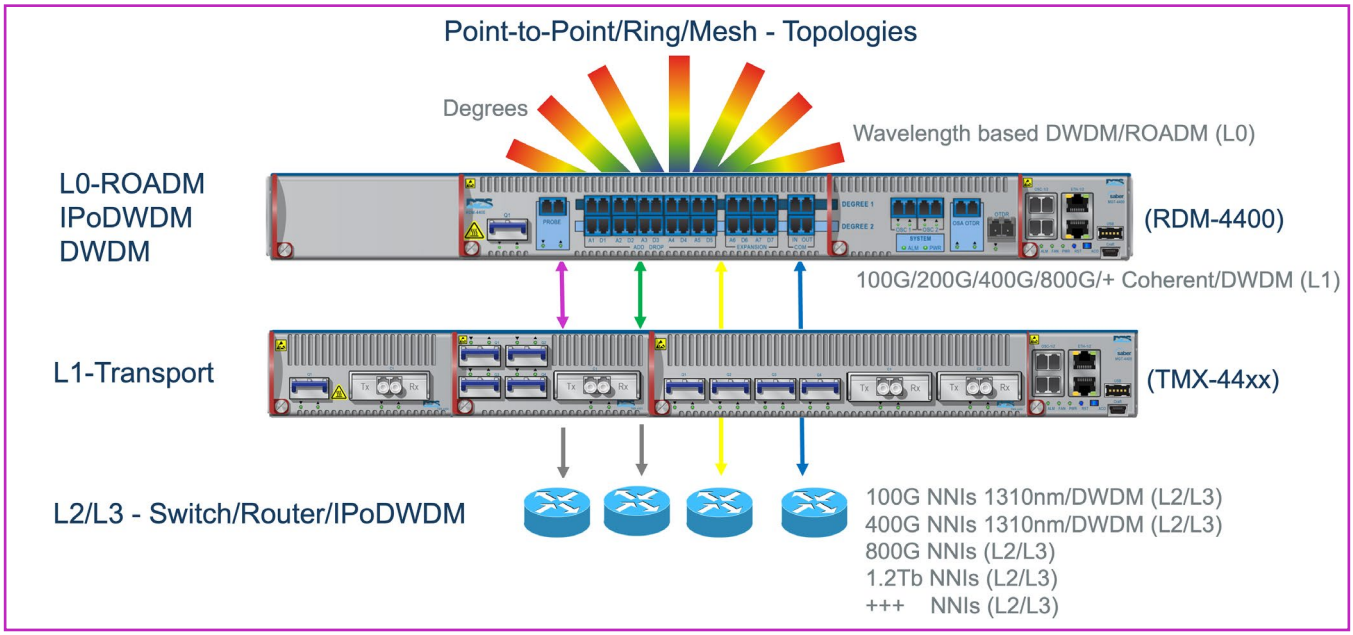
Operating on a single shelf in the DZS Saber 4400 cabinet, each of four 1 RU hot-swappable Saber 4400 transponder/muxponder modules with optional 2° ROADM connectivity on a second 1 RU shelf generate coherent throughput at 100 to 400 Gbps per wavelength to support up to 1.6 terabits per second (Tbps) per shelf of unamplified propagation at up to 120 Km. Overall, using add/drops, 25.6 Tbps optical transport is possible between two ROADM sites. Co-located and/or mid-span-installed optical amplifiers extend the reach between Saber 4400 installations to much longer distances.

DZS has ensured maximum versatility in the use of optical add/drop technology by bringing the full capabilities of colorless, directionless, contentionless (CDC) Flex Grid ROADMs to the new network edge. These qualities mean operators are free to set wavelengths on the same fiber to different spectral parameters at different spacings (colorless), dynamically switch the directional signal flow of each wavelength (directionless) and switch the direction of any wavelength assigned to a specific colorless channel mux/demux (CCMD) (contentionless).

Additional shelves in the Saber 4400 cabinet can be used to stack other components such as additional coherent transponders with another ROADM shelf, which can operate as a single element with the primary traondnspers to create 4° add/drop coverage in more complex ring and mesh applications. Similarly, 8° add/drop coverage is also possible with the Saber ROADM. Figure 6 provides schematics of the multiple options supported by the Saber 4400 platform.

Figure 6

Saber - Layer 0 and Layer 1



Alternatively, along with the O-band four-wavelength multiplexing used with coherent transport, operators can use the additional shelf space to support DWDM transmissions operating with erbium-doped fiber amplifiers (EDFAs) in the C- and L-bands. These components can be used to deliver lower capacity wavelength payloads through passive add/drop connections to endpoints on the same ring infrastructures.

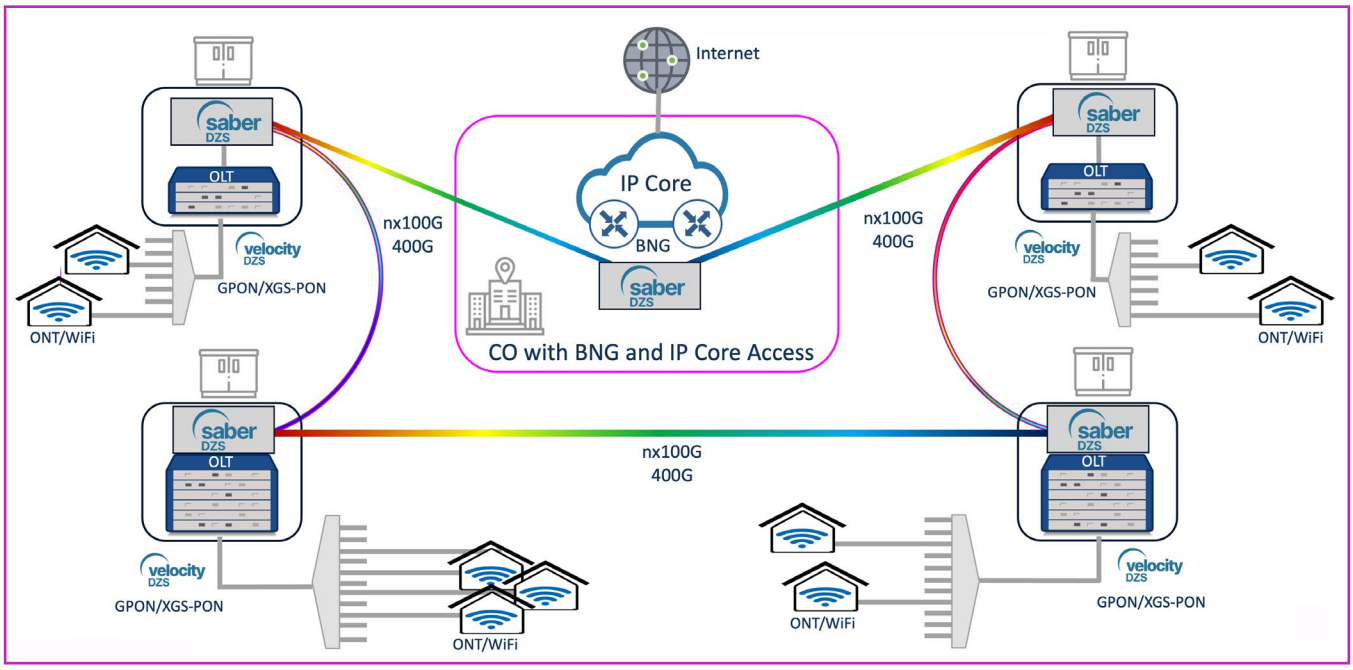
In cases where operators want to use PON distribution to reach end users from a Saber 4400 location, they can allocate available shelf space to the DZS Velocity V1 optical line terminal (OLT). This 1-IU component is equipped with 16 ports supporting any combination of XGS-PON (10×10Gbps) and GPON (10×2.25 Gbps) feeds.

Operators who want to reach more PON access customers at any point on their Saber-supported ring networks can take advantage of the DZS FiberWay platform, an environmentally hardened cabinet combining Saber 4400 and ROADM components with multiple Velocity 1RU modules that can serve up to 25,000 end users with throughput aggregating to 3 Tbps. In all cases, Velocity OLTs will support simple in-place upgrades to 50Gbps and 100Gbps PON as those options become commercially viable.

The hierarchy of Saber 4400 configuration options also includes combinations suited for use in temperature-controlled buildings and hubs (see Figure 7 for a listing of primary variations in the Saber 4400 lineup). But, given the rarity of such structures in optimal locations, for most CSPs the Saber 4400 platform will serve as the anchor to next-generation edge networks, including cases as described in Part 4 where operators are connecting edge points across vast reaches of territory in rugged terrain.

Figure 7

N x 100G/400G Access Ring / IP Over DWDM



Part 4 Other Factors Underscoring the Case for DZS Saber 4400

The Best Approach to Closing the U.S. Broadband Divide Is Made in America

CSPs of every type, from independent startups to utility- and local government-backed operations and telecom incumbents, are competing for hundreds of billions of dollars in government funding aimed at closing the broadband divide in the U.S. (Figure 8). The emphasis of these programs includes not only the last-mile, but the construction of middle-mile networks directly connecting local distribution areas to in-region central offices, cellular processing sites, and cloud computing centers while interfacing with first-mile links to more distant locations. The Middle Mile is where the Saber 4400 platform capabilities provide for optimal operational cost containment and faster time to market for building out these networks and address the connectivity and reach challenges associated with bridging the digital divide for unserved and underserved communities.

Figure 8

U.S. Programs Funding Broadband Everywhere	
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
Total	**$101.13 Billion**

CSPs have every reason to pursue these funding opportunities. In an era when the availability of broadband in rural areas is drawing businesses to locate out of high-cost metro regions, the upsides include the likelihood that operators will have many more high-paying enterprises to serve over time than were there when they started building their networks. In fact, that outcome is a big reason the national and local governments are investing in CSPs who are willing to commit to delivering services that are on par with the norms in more urbanized areas.

Uncertain Outlooks

But there has been a lot of skepticism over whether broadband network technology is capable of fully narrowing the gap between user experiences in rural and urban environments. The wide disbursement of processing centers and service areas often across multiple rural counties requires network topologies that at one time would have kept user access rates in the 25 Mbps or slightly higher range. This is why the FCC in 2020 set minimum bandwidth requirements at just 25 Mbps downstream and 3 Mbps upstream in first-phase bidding for financing under its $20.4-billion Rural Development Opportunity Fund.

But as it turned out, with completion of 10 Phase 1 RDOF auctions awarding $9.23 billion for broadband network construction reaching 5,220,833 locations without broadband connectivity in 49 states, winning bids have committed CSPs to providing download speeds at 100 Mbps or more to 99.7% of those locations.[xxxvii] In fact, over 85% are covered by winning bids committing to gigabit speeds.

Now, with allocations in progress under the $42.5-billion Broadband Equity, Access, & Development Program (BEAD) program, which targets under-served as well as unserved regions, 1 Gig is a regulator-recommended benchmark. Under guidelines issued by the U.S. National Telecommunications and Information Administration (NTIA), local administrators have been advised not to award support to any entity offering bi-directional access bandwidth below 1 Gbps as long as there's at least one bidder who can demonstrate long-term business stability with a commitment to delivering 1 Gig services.

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 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.

Critically, under BEAD requirements and increasingly in the awarding of bids through other U.S. programs, the priority is on American-built solutions. In the case of BEAD funding, compliance with the Build America, Buy America (BABA) Act enacted in November 2021 as part of the Infrastructure Investment and Jobs Act is mandatory.

But even as regulators raise the bar on funding requirements, the question of whether winning bidders in these and other competitions for financing will actually be able to achieve financial success over the long haul remains unanswered. Nor does anyone know whether operators will be able to keep the digital divide from re-emerging in those areas as broadband rates continue going up in more urbanized areas. And BABA requirements make it even harder for bidders to cobble together solutions that pass muster.

Eliminating Uncertainty with DZS FiberWay

However, there's one sure way CSPs can proceed with confidence that they'll be able to answer these questions in the affirmative. By committing to building middle-mile edge networks anchored by DZS's implementation of the Saber 4400 platform in the environmentally hardened FiberWay cabinet, they can achieve market-leading performance with future-proof scalability at business-sustaining costs using a platform manufactured in the USA and developed by a company headquartered in Plano, Texas.

As noted in Part 3, FiberWay provides a larger enclosure for components that can be employed to deliver high levels of access bandwidth across large low-density population areas. Along with the elements previously described as options available for use in the Saber 4400 platform, FiberWay is equipped to support higher densities of Velocity OLT modules as well as the DZS M4000 converged routing platform, which enables Layer 1-3 service delivery and traffic management related to cell-tower connectivity and enterprise-scale customer operations.

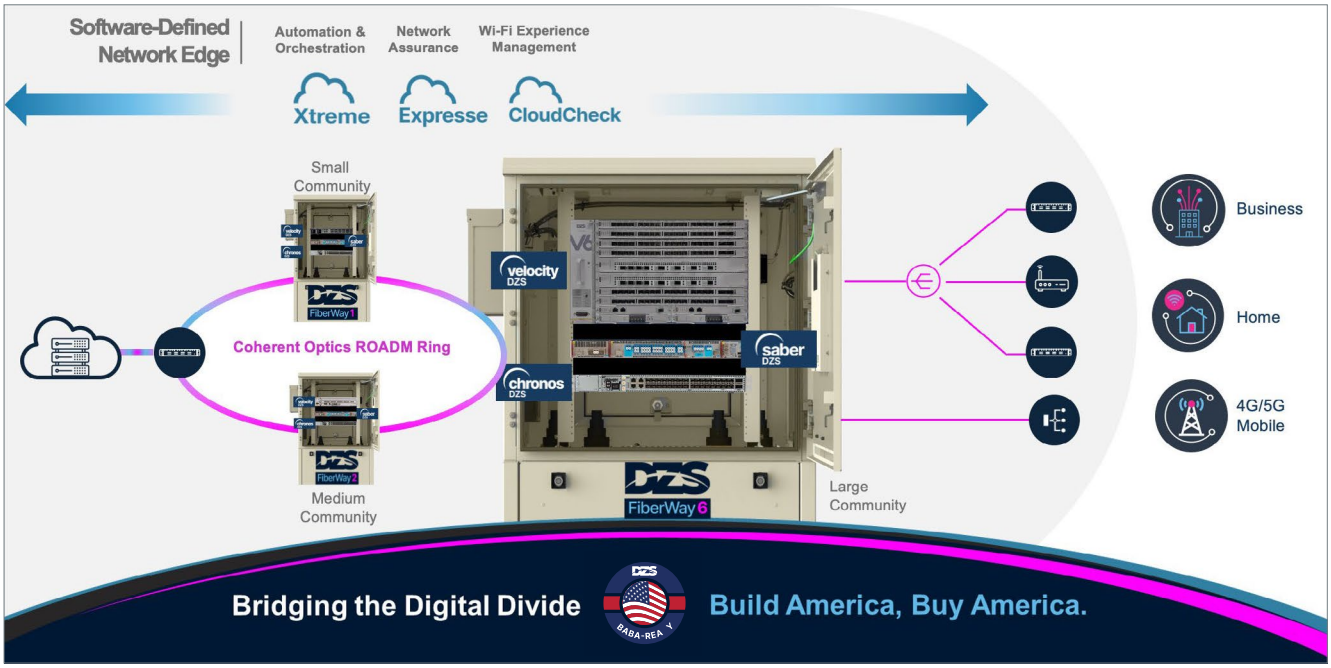
Both are vital to enabling the far-flung reach of networks deployed in unserved/under-served regions to deliver services on par with networks in urban environment. Notably, when the Saber 4400 transport and ROADM components intersect at edge points with distribution networks there needs to be enough OLT support to deliver multiple

high-capacity outputs to splitters serving the local service areas scattered across the edge-targeted territory.

The FiberWay DZS Velocity OLT stack makes this possible by supporting industry-leading high density and non-blocking performance with GPON and XGS-PON connectivity over multiple paths to PON passive splitter junctions in the field. (Figure 9). 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.

Bringing Multi-Gig, Low Latency Services to Communities

Figure 9



That translates to support for connecting to 9,600 subscribers to GPON or XGS-PON transmissions. In any configuration available with DZS FiberWay, Velocity OLTs will support future in-place upgrades to 50Gbps and 100Gbps PON.

The 1RU M4000 module mounted on a FiberWay shelf applies the Layer 1 and 3 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.

Saber 4400 Aligned with Cross-Domain Approach to Service Versatility

No More Silos

The standards-compliant portfolio of DZS solutions supported by the environmentally hardened DZS Saber 4400 platform perfectly aligns with the DZS Xtreme network orchestration and service acceleration platform to provide CSPs an automated life-cycle management path to profitability. Once and for all, CSPs who leverage Xtreme in conjunction with building next-generation edge networks on the Saber 4400 foundation can do away with the costly siloed approach to launching fixed and mobile services.

As the industry's only vendor-agnostic solution supporting zero-touch network orchestration across all network elements, the cloud-based Xtreme software stack allows CSPs to remotely manage 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. At the same time, Xtreme plays a major role in enabling operators to quickly develop and launch services with whatever characteristics are required for use in their targeted mobile and/or fixed domains.

The platform capitalizes on network element (NE) interoperability enabled by standards-based components and APIs while applying an innovative plug-in approach to integrations with proprietary systems. This ensures its ground-breaking benefits can be realized even in network migration environments populated by aging pre-standardization NEs.

Xtreme enables orchestration of service-specific aggregations of components housed in transport, access, and mobile edge facilities by leveraging models of the workflows on which industry standards are based together with algorithmic abstractions of the NEs in every domain. The platform systemizes application of the workflow models by employing modules architected to address the specific components and functionalities of each networking domain as well as the software domains associated with SDN and cloud virtualization technologies.

Vendor-Neutral Control over ROADMs and OLTs

The Xtreme architecture opens possibilities for dynamic orchestration of NEs that go far beyond the norms of traditional CSP operations. For example, in the transport domain, Xtreme maximizes dynamic versatility by managing ROADM components and the elements used in DWDM networks.

In the access domain, Xtreme workflows interact with DZS Velocity and other vendors' OLTs and their constituent control and switching modules (CSMs) and EPON link modules (ELMs) in the CO and ONUs. The platform orchestrates the NE functionalities to execute service applications calling for adjustments in wavelength payload assignments, topological reconfigurations, or activation of new wavelengths.

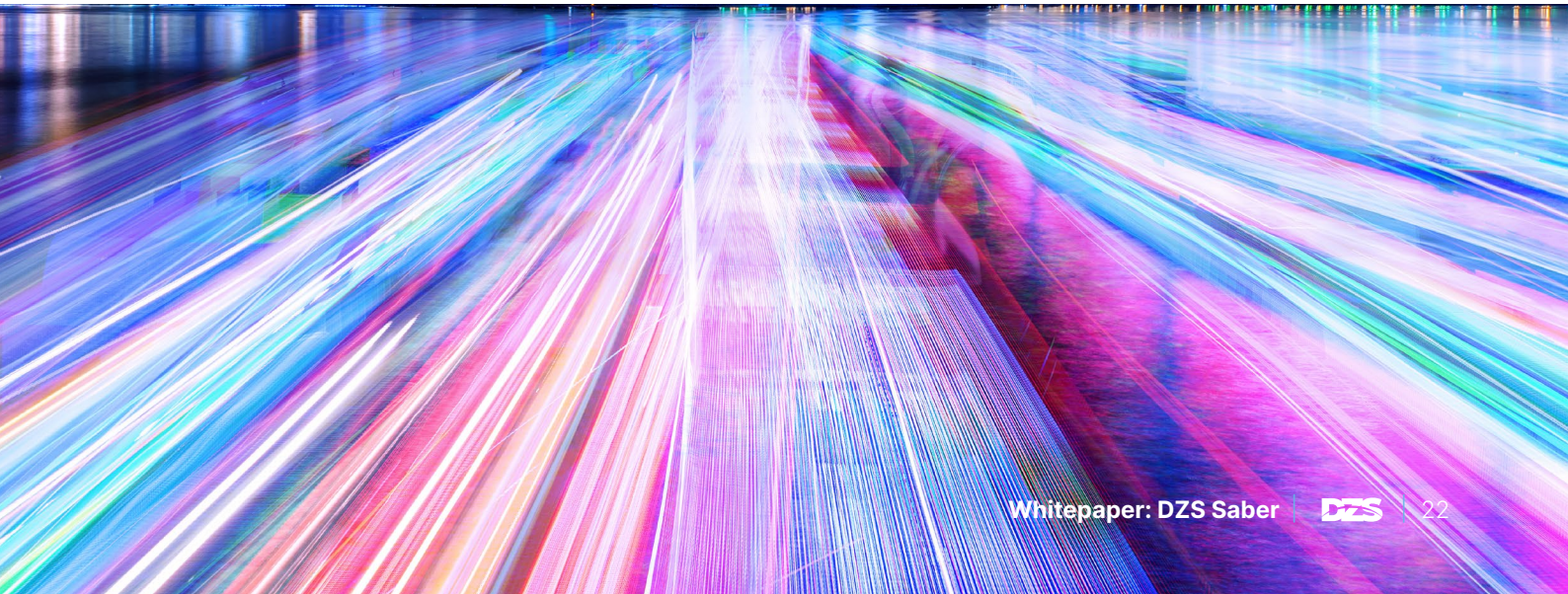
Critically, the platform is able to align fixed network service distribution with 5G slicing capabilities by employing elastic optical network (EON) technology to manage optical spectrum within wavelengths for assignment of bandwidth segments to specific services. In FTTX scenarios involving last-segment distribution over XDSL, Xtreme interacts at the interfaces between ONUs and DSL modules to extend dynamic bandwidth and slicing capabilities over copper infrastructure.

The Saber 4400 Cost-Benefit Equation Is Unmatched by Other Solutions

There's no next-generation edge networking solution comparable to the DZS Saber 4400 platform, as is readily apparent in the following overview of comparisons between the Saber 4400 components and components typically used with other vendor solutions.

The assessment starts with the fact that no other vendor supports the full range of essential edge functionalities in environmentally hardened form factors suitable for outdoor plant deployments.

But there are many other aspects to the comparisons that highlight the superiority of the Saber 4400 platform. The vendors included in this overview are unnamed, but all are leaders in the telecom equipment market.



Comparisons between Saber 4400 & Typical Industry Components

	Saber 4400	Industry-Wide Norms
Overall Platform	Up to 4 modules per RU	2 modules per RU
	11” depth	15”-24” depth
	Stackable acting as single network element	Implementations vary
	Hot-swappable management card	N/A in most cases but some support this
	Management card redundancy	N/A in most cases
	Beyond Layers 0 & 1, platform supports L2-L3 modules	Transport only in most cases
ROADM Support	Uniquely compact 2-degree solution in ¾ width form factor	1-degree per full RU
	Unique testing/troubleshooting capabilities: • Integrated optical spectrum analyzer with external text input Optional OTDR pluggable on ROADM faceplate for line fault testing • Optional tunable coherent test pluggable module on ROADM faceplate for end-to-end circuit testing	Subset of troubleshooting features, typically requiring additional card(s)
TMX (transponders/ muxponders)	Pluggable coherent optics from 3rd parties, enabling best-of-breed choices	Home-grown optics, often lacking plugability
	DZS avoids Razor and Razor-blade optics	Razor-blade model with expensive transponders & coherent optics
	1-slot & 2-slot solutions	2-slot or full-width solutions
Flexible Optical X (FOX) connects	3-slot 32 port add/drop solution	2-slot ½ density options or full slot full density options only
	1-slot low port add/drop solution	Only high-density options
Amplifiers (OFA & RMN)	Integrated Quad-Amp in ROADM Module	Often requires separate card
	Very small 1-slot amplifier solutions for both RAMAN and EDFA directly into Saber 4400 chassis	Larger dedicated amplifier footprint
	Hardened for mid-span amplification Applications	Varies by vendor

Conclusion

Surging levels of bandwidth consumption across all market sectors as the variety of services and applications multiplies has shaped a perspective on the future of broadband services that calls for new approaches to using network resources. Maturation of standardized advanced optical components has set the stage for a transformation impacting network service providers of every stripe who want to avail themselves of the network flexibility and scalability essential to meeting market demand now and well into the future can be achieved.

The key to this transformation is the installation of mid-haul transport, networking and access components that can interact automatically under remote management at edge locations to shape the use of multiple wavelengths in dynamic response to the needs of end users in local service areas. The combination of high-power coherent transport, reconfigurable and passive add/drop multiplexing, cost-saving approaches to extending fiber distribution to end users and remotely distributed 5G cell sites, and a wide range of options in the use of optical wavelengths provides network service providers the tools they need to address connectivity and bandwidth gaps and to secure their futures in any type of environment, from the densest population centers to the far reaches of unserved and under-served rural markets.

But while CSPs understand the strategic importance of implementing this edge-based network transformation a large share of the industry, including newcomers as well as incumbents are hesitant to move beyond the early planning stages to aggressive deployments owing to concerns over capital and operations costs that have kept operating margins at persistently low margins for many years. Having spent record amounts to achieve the current levels of fiber and mobile technology utilization, many are inclined to leverage the architectures they have in place to serve their customers.

DZS has taken ground-breaking steps in the development of edge transport and networking technology and the means to orchestrate operations that represent major inducements to reconsidering CSP perspectives that are based on previous norms in vendor solutions. With the availability for the first time of an environmentally hardened edge networking platform that radically reduces the costs of network connectivity across any realm of regional operations, CSPs can forge ahead with confidence that gains in ARPU stemming from high-bandwidth service versatility and the support of distributed cloud computing will lead to significant gains in ROI.

The DZS Saber 4400 is a game changer of historic proportions. Ever more CSPs worldwide are discovering what they can accomplish with edge networks anchored by the Saber 4400 platform, especially when it's used in combination with the industry-first vendor agnostic orchestration of network elements enabled by the DZS Xtreme cloud network management, automation and orchestration platform.

In the U.S., operators who stand to benefit from use of the DZS Saber 4400 platform and DZS FiberWay solution include any entity seeking to participate in multi-billion-dollar government funding initiatives aimed at bringing first-class broadband services to every corner of the nation's unserved and under-served markets. There's no better way to succeed in those endeavors than to take advantage of a market-transforming platform that's been developed and manufactured in America.

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