HEAVY READING
WHITE PAPER

Independent market research and competitive analysis of next-generation business and technology solutions for service providers and vendors

The New Optical Edge

A Heavy Reading white paper produced for DZS

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INTRODUCTION

Led by 5G and next-generation fiber optic broadband rollouts, access networks are set to deliver tremendous benefits to consumers and businesses over the next five years. But increased traffic, new application needs, and changing traffic patterns place new demands on the aggregation segment (or middle mile), which must undergo a major transformation to keep pace. Key to this transformation is the migration of DWDM systems and coherent optics to the service provider edge.

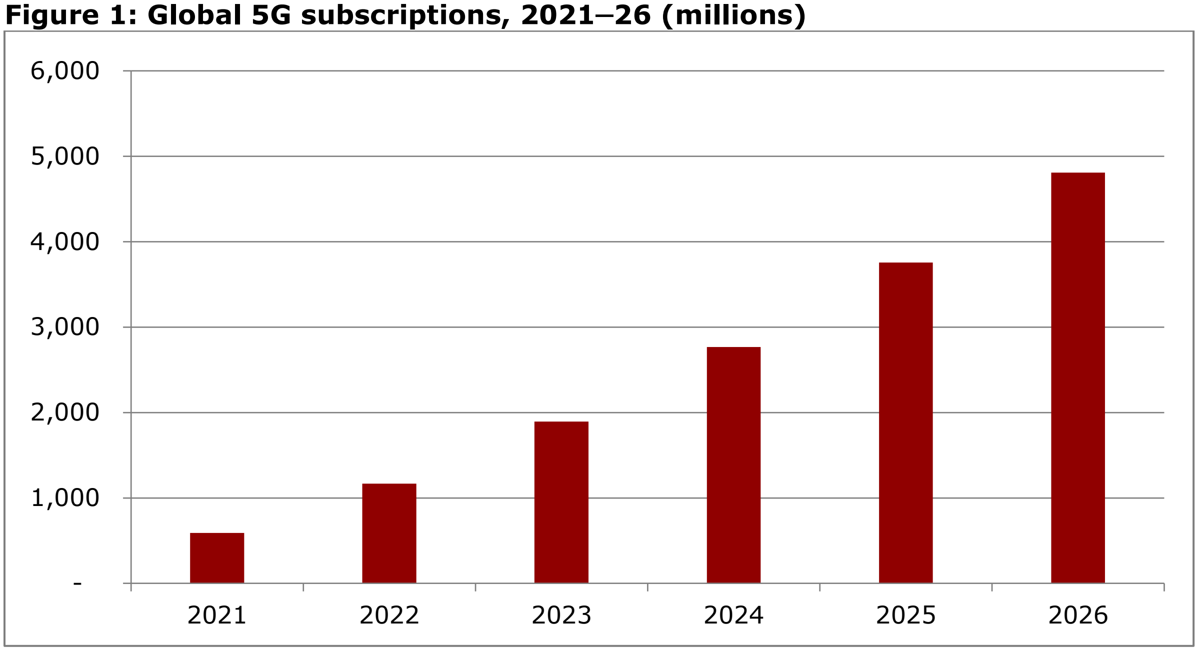
This white paper traces the evolution path of the new optical edge, starting with an overview of the primary drivers for edge connectivity. The paper then maps those drivers to the resulting operator requirements for edge connectivity and identifies the enabling technologies required for the new optical edge. Lastly, it profiles the optical edge architecture of North American operator Windstream.

EDGE CONNECTIVITY DRIVERS

5G

5G rollouts are in full swing globally. Omdia counted 540 million global 5G subscriptions as of year-end 2021, set to exceed 1 billion subscriptions in 2022 and increase to 4.8 billion by the end of 2026. In terms of uptake, 5G is already the most successful mobile generation in history, with much more growth to come.

Figure 1: Global 5G subscriptions, 2021–26 (millions)



Source: Omdia, June 2022

For network operators, the 5G migration requires a rethinking of the access and edge networks that include backhaul, fronthaul, and midhaul. The most fundamental requirement is greater capacity for cell sites, which must move from 1Gbps to 10Gbps connectivity—at a minimum. Multiband/multi-carrier sites and sites with fronthaul connectivity require more capacity—from 25Gbps to up to 100Gbps for a busy hub site.

5G also drives greater cell density. Millimeter wave, and to a lesser extent mid-band, deliver higher capacities but cover less distance compared to 4G and low-band 5G spectrum. Thus, rollouts require more cell sites to serve end customers, and these new sites require high capacity connectivity. Some operators will also deploy small cells for low-band spectrum.

Significantly, 5G is not just about mobility. Operators are deploying fixed wireless access (FWA) as a competitor to fixed broadband.

Fixed broadband

A broadband surge globally is also driving network investment in the access and aggregation portions of the fixed network, often referred to as last mile and middle mile, respectively. Broadband subscribers continue to grow globally, but more importantly, average broadband speeds are skyrocketing. Omdia estimates that the average broadband download speed was 159Mbps in 2021 and forecasts it will increase to 744Mbps by 2026 (a 36% CAGR over the time period). Due to capacity and reliability, fiber is the technology of choice for next-gen broadband. The operator investment case for fiber is strong. Omdia estimates that fiber ARPUs in 2020 were 29% higher than DSL and nearly double that of cable.

Governments are prioritizing fiber broadband investments as they realize that ultra-broadband is a critical engine for economic growth. The US government's $42.5bn Broadband Equity Access and Deployment (BEAD) program, which prioritizes fiber, is one example. Other government examples include the $8bn Project Gigabit in the UK, the $14bn BVMI in Germany, and France's $24bn Tres Haut Debit.

Edge cloud

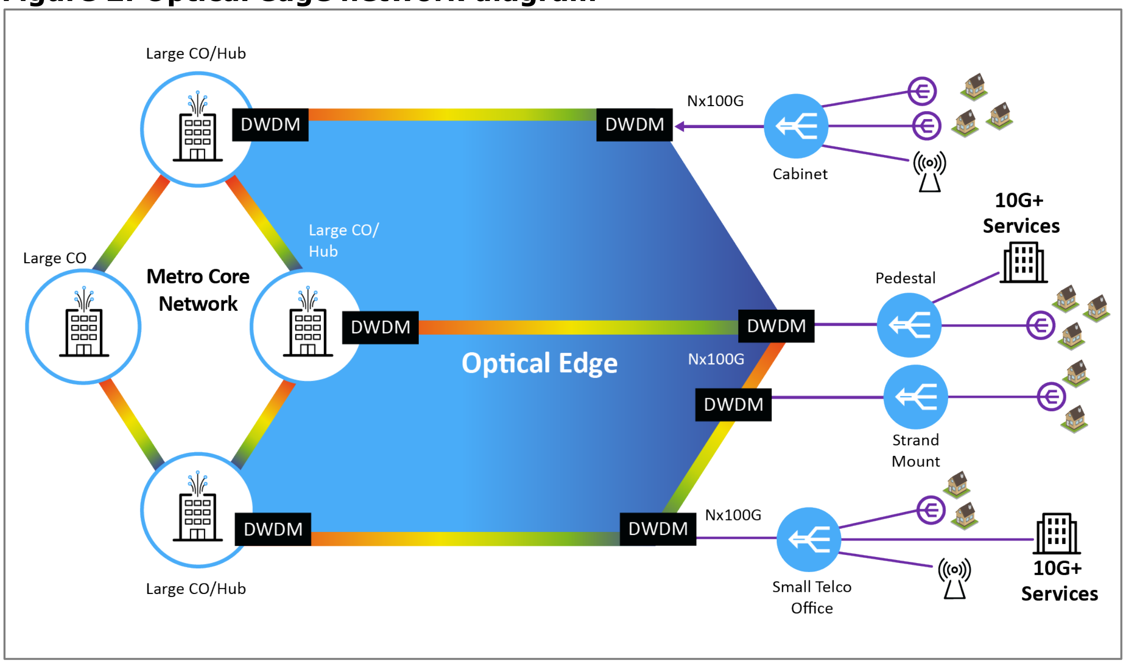
Data center infrastructure is evolving from the centralized mega hub model that characterized the early internet to a distributed model that places computing and storage resources closer to users—at the edge. These data centers are much smaller, but there will be orders of magnitude more of them. Low latency applications (<20ms) are one major driver, including augmented and virtual reality (AR/VR) for consumers and businesses, cloud gaming, industrial automation, and many others. Significantly, the major hyperscalers—including leaders Amazon Web Services (AWS), Google, and Microsoft—are building out edge cloud strategies. They are partnering with network operators but also competing directly in private wireless services.

REQUIREMENTS FOR THE NEW OPTICAL EDGE

Greater bandwidth in the access network—whether from consumer broadband, enterprise access services, or mobile 5G—has implications for the aggregation network that connects access to the large central offices (CO) or hub sites in the metro network. Because it sits between the access network (last mile) and the metro CO, this aggregation segment is also often referred to as the "middle mile." Optical infrastructure is an essential component of this segment.

Figure 2 depicts a generic operator network offering fixed and wireless services and serving consumer and business customers. The shaded portion represents the aggregation segment with connectivity provided by DWDM equipment, and Heavy Reading labels this portion the optical edge.

Figure 2: Optical edge network diagram



Source: DZS and Heavy Reading, 2022

The market trends and drivers described in the previous section place a set of requirements on the new optical edge network, as described below.

High capacity

The most obvious consequence of higher access network traffic demand is greater traffic demand in the aggregation/edge portion of the network. With 5G, individual cell sites move 1Gbps backhaul to 10Gbps backhaul, or to 25Gbps in fronthaul architectures. With fiber broadband, connectivity is moving into the Gigabit broadband realm. As a result, aggregation must step up to 100Gbps data rates with Nx100Gbps needed at higher traffic hubs and to address future growth needs. Networks that relied on single wavelength transport in the past will move to DWDM to address fiber exhaust and for greater operations efficiency.

Optical layer flexibility

The edge is not just about increasing traffic volumes but also about how capacity flows are changing. The centralized internet was based on north-south traffic patterns, with data flowing from the users to centralized mega data centers. The edge is based on a distributed data center model, and traffic will increasingly remain within the metro from which it originated. Here, north-south traffic is reduced as the volume of east-west traffic increases. This trend is very relevant for local breakout use cases such as private network deployments, multi-access edge computing (MEC), and content delivery network (CDN)-type architectures. Changing network traffic patterns place demands on the transport network to be more flexible.

Low touch operations

Low human involvement or low touch is an important concept for installation and provisioning services. Any point along the end-to-end service provisioning chain that requires manual input will slow down the entire provisioning process. Furthermore, as optical equipment is placed at the edge in locations outside the CO (such as in street cabinets), the need for low touch and zero touch operations becomes even more important. These remote sites are not staffed, and truck rolls cost both time and money.

High reliability

Network reliability has always been important, and it is moving up the priority ladder for network operators and their customers. COVID-19 pandemic lockdowns and the related work-from-home trend have made consumers more reliant on broadband than ever. In Omdia's *Digital Consumer Insights 2021 – Digital Consumer Operator Strategies* survey, quality of service (QoS) was prioritized over cost and network speed, with 55% of respondents saying 100% reliability ranked top among the most important features of their home broadband. Similarly, in a competitive 5G market, mobile operators are focusing on reliability and resilience to differentiate services—for both business and consumer customers.

ENABLING TECHNOLOGIES FOR THE OPTICAL EDGE

Hardened systems

As optical systems move from the metro to the edge, they move out of controlled CO environments to new locations closer to users that were constructed only for outside plants, such as outdoor cabinets. To date, most DWDM systems have been built for operation in COs only. Leasing temperature-controlled facilities (if available in the location) or building or upgrading new controlled facilities to house this optical equipment can quickly erode the edge business case. A better option is environmentally hardened optical equipment that has been designed specifically for outside plants.

An environmentally hardened optical edge can save network operators $50,000–$100,000 per site by eliminating the need for heat exchangers and backups, power upgrades, and, in some cases, completely new physical facilities, according to some operator estimates.

Such systems are coming to market. North America-based equipment supplier DZS demonstrated its environmentally hardened Saber-4400 platform delivering 400Gbps wavelength capacity with coherent optics across over 80km at Fiber Connect 2022.

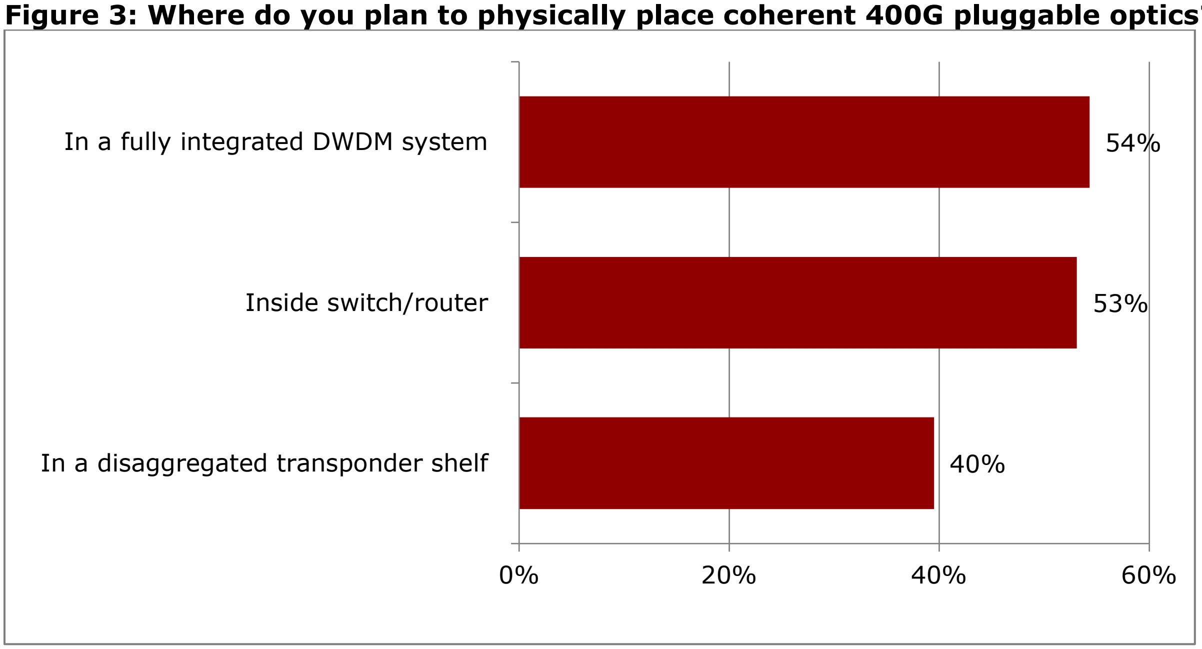
Coherent optics at the edge

Coherent optical transmission and pluggable optics form factors were combined in the 2020 OIF 400ZR implementation agreement. This agreement specifies that pluggable coherent 400 Gigabit Ethernet modules can be housed in QSFP-DD and OSFP form factors, with amplified transmission distances of up to 120km.

Initial 400ZR deployments are being driven by hyperscalers' data center interconnect (DCI) applications. However, strong network operator interest has led to higher performance 400Gbps pluggable modules that can work with reconfigurable optical add-drop multiplexer (ROADM)-based optical networks (something that is not possible with 400ZR). The OpenZR+ Multi-Source Agreement (MSA) and Open ROADM MSA are both targeting network operator use cases at 400G.

While the 400ZR/ZR+ renaissance is often associated with pluggable optics on routers—called IP over DWDM (or IPoDWDM)—the pluggables value proposition extends well beyond this use case. In fact, network operators are looking to house coherent pluggables in all types of optical equipment, including packet-optical DWDM systems, compact modular DWDM platforms, disaggregated systems, and perhaps others as well. At 400Gbps and below, the optical industry is rapidly moving away from embedded systems and toward pluggable optics, regardless of the host platform (see **Figure 3**).

Figure 3: Where do you plan to physically place coherent 400G pluggable optics?



Note: Respondents could select multiple options (n=81)
Source: Heavy Reading, Coherent Optics at 400G, 800G, and Beyond, November 2021

At the optical edge, 400Gbps coherent optics may be too much capacity and cost for many operators' applications. Most recently, 100G ZR pluggable optics have been introduced to address edge/access applications. These new coherent pluggables operate at 100Gbps data rates and are housed in QSFP-28 form factors. Separately, the Open XR Forum was formed in 2021 to address access and edge applications with coherent pluggables that operate at 100/400G.

Due to the addition of the digital signal processor (DSP) chip in the pluggable, coherent optics come at a cost premium compared to direct-detect alternatives. However, the embedded DSP at every termination point provides additional benefits in visibility and channel monitoring that do not exist in current middle mile architectures.

Edge ROADMs

For years, ROADMs have been moving "upmarket," adding higher port counts to meet traffic and add/drop requirements in large CO hubs, with 16-degree nodes being the state-of-the-art. In addition to higher port counts, ROADM vendors have added colorless, directionless, contentionless (CDC) to fully automate the ROADM network. Finally, FlexGrid functionality has become a necessity at 400Gbps data rates (and above), as optical channel widths have expanded beyond the historical 50GHz spacing. All of these technical advances—though necessary for large networks—come at higher costs.

Edge locations, by contrast, are not hub sites and are suited to low port count ROADMs (such as 2 or 4 degrees) that are compact in size and low in cost. Edge ROADMs must evolve to meet optical edge application requirements while preserving compact form factors and relatively low costs. In particular, optical layer flexibility requires CDC functionality coupled with software automation for low touch operation. And the migration to 400Gbps at the edge will mandate FlexGrid to expand channel spacing beyond 50GHz.

CDC ROADMs at the edge are key to an innovative new wholesale service called spectrum as a service. In addition to selling wavelengths to enterprises and cloud providers, a wholesaler can dedicate to individual customers blocks of optical spectrum (e.g., 200GHz in a specific frequency range). Those customers, in turn, can use that spectrum; however, they choose using their own optical equipment, giving customers more flexibility.

Network automation

Network automation is needed to deliver low touch operations. Given the prioritization of low touch operations, it is not surprising that 39% of operator respondents in a 2022 Heavy Reading global survey reported that automation is a "critical" pillar of their next-gen transport network strategy. Top initial use cases for transport automation include traffic engineering, service provisioning and activation, network inventory and resource management, and network configuration.

Automation and open optical networking are tightly linked. Open interfaces are necessary as operators seek to automate processes across domains, across vendors, and across OSI network layers (such as with IPoDWDM). Open optical networks include a combination of hardware interoperability, open APIs for multi-vendor management and control, and certification/testing to ensure multi-vendor interoperability.

Automated control and management is also a key enabler for spectrum as a service.

WINDSTREAM OPTICAL EDGE PROFILE

North American network operator Windstream Communications is evolving its optical network in response to a surge of high bandwidth traffic flows from the edge to the core and demanding edge-to-edge traffic growth across multiple business units and customer classes. Windstream calls its architecture the Intelligent Converged Optical Network (ICON).

According to Windstream CTO Art Nichols, "The goal of ICON is to provide a modern intelligent optical network that is service, data rate, and location agnostic. The key concept is that the optical spectral capability of every networking domain—Core, Regional/Metro, and Edge is the same, ensuring that irrespective of a node's geographical location or its location within the network hierarchy, it can fully support the overlaying service architecture."

An important part of the strategy is that each element type can interface with any other without a requirement for optical electrical optical (O-E-O) conversion between domains. The variations of network element properties are solely the maximum degree/adjacent node connections, maximum number of add/drop/client ports, and maximum node-to-node reach. This leads to an underlying optical fabric of CDC FlexGrid ROADMs in a multi-tier hierarchy spanning edge, regional/metro, and core.

At the network edge, the program focuses on extending all transport and packet network services and capabilities deeper to the edge. ICON Edge consists of multiple layers that can be leveraged as service demands require. Despite the specification of multiple, independently scaled layers, the Windstream ICON network accomplishes the goal of being easy to design, install, and configure due to a reduced variety of element types with simplified form factors:

- **Optical edge:** Layer 0 FlexGrid CDC ROADM optical "node on a blade"
- **Coherent pluggable optics:** Layer 1 "OpenZR/+" 100G to 400G pluggable coherent optics
- **Intelligent hosts:** Transponder systems and packet edge switch/routers
- **Multi-layer controller:** An open optical/packet software-defined network (SDN) controller platform

Most importantly, this network relies upon a multi-domain SDN controller for design, provisioning, and management. According to Nichols, "Windstream has specified a controller that operates and integrates the optical, transmission, and packet domains. Correspondingly, the network layers must support API integration for all layers, settings, and analytics into the cross-domain solution. This will ensure adoption and flexible growth accommodating current and unforeseen network demand stressors."

CONCLUSIONS

The adoption of 5G, fiber-based broadband, and edge cloud globally is causing a rethink of the edge aggregation networks that connect access to data centers and to the core. Optical networks are a prime component of the service provider edge.

Key operator requirements at the optical edge include the following:

- 100G to 400G+ wavelength capacity to meet traffic aggregation needs with an eye to future growth.
- A flexible optical layer that shunts high capacity traffic as the edge cloud requires.
- Low touch operations for fast capacity delivery and low opex.
- High reliability to match what is being demanded by consumers, businesses, and wholesale customers.

Fortunately, a blueprint is evolving to meet these network needs, as evidenced by Windstream's pioneering ICON Edge architecture. The new optical edge will be defined by temperature-hardened optical systems deployed in outside plant environments. These systems will increasingly be designed for coherent pluggable optics at 400G and 100G data rates. Finally, these systems will combine edge-built ROADM hardware with transport network automation to provide new levels of flexibility in activation and provisioning with low touch operations suitable to the outside plant.