Solving the Economic Challenge of Delivering High-Speed Broadband to Rural Areas

Extending broadband to rural and underserved areas cost efficiently by leveraging efficient optical transmission technologies can maximize the capabilities and life cycles of newly deployed or existing infrastructure and lower the cost of vital layer-1 equipment.

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In an era in which access to modern digital technologies is crucial, a significant number of people in the U.S. still lack reliable, high-speed internet connectivity. Unfortunately, deploying new fiber optic networks in rural areas has consistently proven costly and challenging, even with government subsidies. A new approach is necessary.

Every fiber network deployment has three sides: the fiber cables themselves, the layer-1 equipment (optical transceivers and related components) required for leveraging it, and the optical transmission technology used for sending and receiving data. Not much can be done to lower the cost of fiber cables. However, reducing expenses associated with layer-1 equipment and maximizing the available bandwidth of deployed infrastructure through efficient transmission technologies can play a pivotal role in accelerating the delivery of reliable, high-speed broadband to rural parts of the U.S.

The good news is that network operators such as MSOs and MNOs have a lot of choice when it comes to reducing the capital and operating expenses of connecting rural areas. To highlight this, we delve into the technical intricacies of dense wavelength division multiplexing (DWDM), passive optical network (PON) technology and tunable transceivers and digital return technology, highlighting their transformative potential in making network operations more efficient and cost-effective, particularly in rural areas.

THE COST CHALLENGE

As noted earlier, the deployment of fiber optic networks in rural areas has historically been expensive, making it financially unviable for many network operators. However, the landscape is changing, thanks to government initiatives such as the Rural Digital Opportunity Fund (RDOF), which provides subsidies to facilitate the expansion of broadband access.

The RDOF program will bring a new surge in demand for the optical equipment manufacturing industry. For now, auction bids show that the winning network operators are examining multiple options for delivering better broadband to rural customers, including fiber-to-the-premises (FTTP), fiber-to-the-home (FTTH), fixed wireless and hybrid fiber coaxial (HFC) architectures. Yet even with funding, some individuals are already raising concerns that the winners may run into trouble attempting to deliver on their commitments.

Here is the critical point: Deploying fiber in rural areas creates a host of challenges. Finding ways to reduce the need for new fibers and minimize the cost of the layer-1 equipment required for delivering connectivity will be the optimal strategy for forward-thinking network operators.

MAXIMIZING AVAILABLE BANDWIDTH THROUGH DWDM

DWDM stands out as a key technology that can effectively multiply the bandwidth available for data transmission on any new or already-installed fiber cables in rural areas. By enabling the transmission of multiple active wavelengths of light over a single fiber, DWDM significantly enhances network capacity and efficiency, making it a crucial component in bridging the connectivity gap in rural areas.

With DWDM, network operators can create multiple network links on one fiber or fiber pair, essentially multiplying the available bandwidth of the existing infrastructure. In fact, this multiplexing technique enables network operators to transport up to 80 channels with 100 GHz spacing and up to 160 channels with 50 GHz spacing in the C-band spectrum for all channels in the 1510 to 1580nm spectrum range. DWDM allows seamless aggregation of traffic from various sources – including voice, video and data – onto a single fiber (while keeping data streams separate), thus optimizing the utilization of network resources.

From a rural perspective, one key advantage of DWDM is its ability to support long-haul transmissions, enabling

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data to travel extended distances by using erbium-doped optical amplifiers (EDFAs) and dispersion compensation modules (DCMs). Using DWDM, a signal can be transmitted over hundreds of kilometers before regeneration. This makes it particularly well-suited for areas in which the populations are dispersed and fiber deployment over vast geographical regions is challenging. Leveraging this technology, network operators can efficiently extend the reach of their networks, serving remote communities without compromising on speed or quality of service.

In addition to its capacity-enhancing capabilities, DWDM also improves network reliability and scalability. With multiple wavelengths operating in parallel, without interfering with one another, an issue with one wavelength does not affect the others. This ensures uninterrupted connectivity.

By leveraging the power of multiple wavelengths on a single fiber or fiber pair, DWDM enables network operators to maximize their existing infrastructure. The cost-effectiveness and efficiency DWDM offers will make it a crucial technology for bridging the digital divide as network operators deploy new fiber or seek to maximize the capabilities of existing cables.

PON REDUCES NEED FOR NEW FIBERS

Maximizing existing fiber assets is one element needed to make delivering high-speed broadband to rural areas more cost-effective. Reducing the need for dedicated fibers between the headend and end users is also a part of the equation. PON technology eliminates the need for individual fiber lines from the central office to each subscriber, drastically reducing network deployment costs in rural areas.

A typical PON architecture consists of an optical line terminal (OLT) at the headend and a single fiber optic cable that runs from the OLT to a passive optical beam splitter. The splitter multiplies the signal and then transmits it to up to 32 optical network terminals (ONTs). Network subscriber devices such as computers connect to the ONTs. Because the same strand of fiber sends and receives data, the passive optical splitter also serves as an optical combiner through wavelength and time division multiplexing (TDM). Wavelength-division multiplexing (WDM) enables bidirectional traffic across a single fiber using a different wavelength for each traffic direction. TDM reserves time slots in a data stream to enable multiple end-user devices to transmit and receive independent signals on a single fiber.

PON's unique point-to-multipoint (P2MP) architecture allows it to reach nearly any user, even in previously isolated and remote areas where fiber optics now enable internet access. Though PON technology has been around for a while, recent advancements have made it even more powerful. For example, symmetrical 10G PON (XGS-PON) dramatically improves on GPON technology, which offers asymmetrical downstream and upstream rates of only 2.5 Gbps and 1 Gbps respectively. XGS-PON also overpowers GPON on transmission distance and split ratio. GPON enables a maximum transmission distance of just 60 km and a split ratio of 1:128; XGS-PON delivers a transmission distance of 100 km with a maximum split ratio of 1:256.

Using XGS/GPON Combo SFP+ and SFP-DD transceivers, offering both types of PON services over the same network is possible. PON technology itself can be leveraged to reduce the need for individual fibers to run to every rural household or business, and advancements in transceiver capabilities offer the scalability necessary for network operators to adjust to rural subscribers' future bandwidth needs.

STREAMLINING HFC OPERATIONS WITH DRT

Digital return technology (DRT) and its compatible optics can further contribute to cost savings, operational efficiency, improved performance and a reduced need for new fiber for network operators leveraging DWDM in rural HFC networks.

DRT improves HFC upstream performance by converting customers' RF analog signals into optical signals for transmission back to the headend. An analog to digital converter (ADC) accomplishes the initial digitization and the conversion to an optical signal is completed in an outdoor fiber node. Once at the headend, the optical transmission is turned back into an RF analog signal using a digital to analog converter (DAC). DRT creates a digital path from the node to the headend using existing infrastructure. That means network operators do not necessarily have to spend more money laying new fibers within their HFC networks to get improved performance.

From a transceiver perspective, the use of DRT requires MSOs to upgrade analog modules inside the remote nodes and deploy digital ones. Even though this comes with an upfront cost, the long-term benefits of DRT are still significant.

- Digital optics, such as the 10G SFP+ family, are less expensive overall to operate than traditional analog equipment, especially when it comes to power consumption.
- Elimination of analog lasers directly leads to a reduction in optical noise and improved signal-to-noise ratios (SNRs). This helps facilitate the full implementation of enhanced protocols such as DOCSIS 3.1.
- DRT enables digital transmission deeper into access networks, making R-PHY architectures competitive with FTTH buildouts.

In rural areas, where population densities vary across regions and HFC networks provide the best option for network operators, the ability to optimize existing resources becomes crucial. The functionality and scalability of DRT and digital optics reduces the need for deployment of costly, additional fibers and empowers network operators to improve the performance of existing HFC networks as needed for rural customers.

TUNABLE TRANSCEIVERS ENHANCE FLEXIBILITY, COST SAVINGS

Traditionally, network operators relied on fixed-wavelength transceivers that operate within specific frequency ranges. Tunable transceivers, however, offer newfound flexibility to deploying and managing optical networks as well as significant cost savings on inventory. These benefits provide a critical third aspect of the formula for reducing the cost of the equipment needed to bring better connectivity to rural areas.

Network operators using DWDM can choose between either a fixed channel or tunable transceiver. Both options have similar specs in terms of TX and RX power capabilities and come in C-Temp or I-Temp versions. The main differences between the two:

- **Fixed-Channel DWDM optics** – Each optic is a fixed wavelength/ ITU channel and can be deployed only as such.
- **Tunable DWDM optics** – Each optic is tunable within a specific range of the ITU spectrum of wavelengths, typically between ITU channels 13.5 and 61. The optic can be tuned as needed to meet the required wavelength based on the network design.

By far, the clearest benefit of employing tunable optics is the elimination of hundreds of spare fixed channel DWDM transceivers at each headend or regional office. Just one 10G or 25G tunable transceiver can make tuning to any of the standard ITU C-band 50 GHz or 100 GHz spaced channels possible. Instead of keeping a spare fixed-channel transceiver for every wavelength, network operators just need one tunable. Significantly reducing the high costs of procuring, deploying and inventorying transceivers is crucial to bridging the digital divide more cost-effectively.

As the world becomes increasingly interconnected, addressing the digital divide by extending reliable broadband connectivity to rural and underserved areas is imperative. Although this has traditionally been an exorbitantly costly endeavor, it is possible to make it more cost-effective through a twofold strategy: 1) leveraging efficient optical transmission technologies that maximize the capabilities and life cycles of newly deployed or existing infrastructure and 2) lowering the cost of vital layer-1 equipment, such as optical transceivers.

This article provides network operators with a menu of choices for accomplishing this strategy. That said, there is more to the story. Each technology and transceiver type discussed is worth its own article. Each has its own benefits and deployment challenges. Everything shared in this article points to the final, concluding piece of the economic puzzle: the need for network operators to work with equipment manufacturers that can also serve as network systems integration specialists knowledgeable about host platform compatibility issues and interoperability requirements. In bringing reliable, high-speed broadband to rural areas, network operators will face various challenges that true partners can help solve. Together, they can close the digital divide and provide a future rich in opportunities for millions of citizens.

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