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ON TOPIC:

Options for Next-Generation PON

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Breaking the barriers of 10G PON

BY ANA PESOVIC

With the world's first live deployment of 25G PON by Proximus and the first demo of 100G PON technology with Vodafone both taking place earlier this year, broadband technology innovators continue to demonstrate the unlimited potential of fiber.

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But at this point in 2021, most fiber broadband networks around the world (fiber-to-the-home or to-the-premises) still use 2.5G-capacity GPON, although next-generation PON technologies (predominantly 10G XGS-PON) are being deployed at an accelerating rate and will be the dominant PON technology within the next few years.

With GPON and XGS-PON largely capable of handling current demand, is there really any need for a *next* next-generation PON?

The short answer is yes, because the increased capacity creates new opportunities for broadband providers. Not many are thinking about delivering 10-Gbps or 20-Gbps home internet connectivity—at least not yet. But a 25G pipe solves some problems and opens some new doors for operators.

What's the use?

The most obvious, and the most compelling from the point of view of costs, is convergence. Many operators today run separate networks for residential services, business services, and backhaul. The savings from having residential FTTH and mobile transport on the same network, for example, are significant, halving total costs of ownership for mobile transport over five years. 25G PON can easily support mobile transport and business services and still have capacity left for residential broadband.

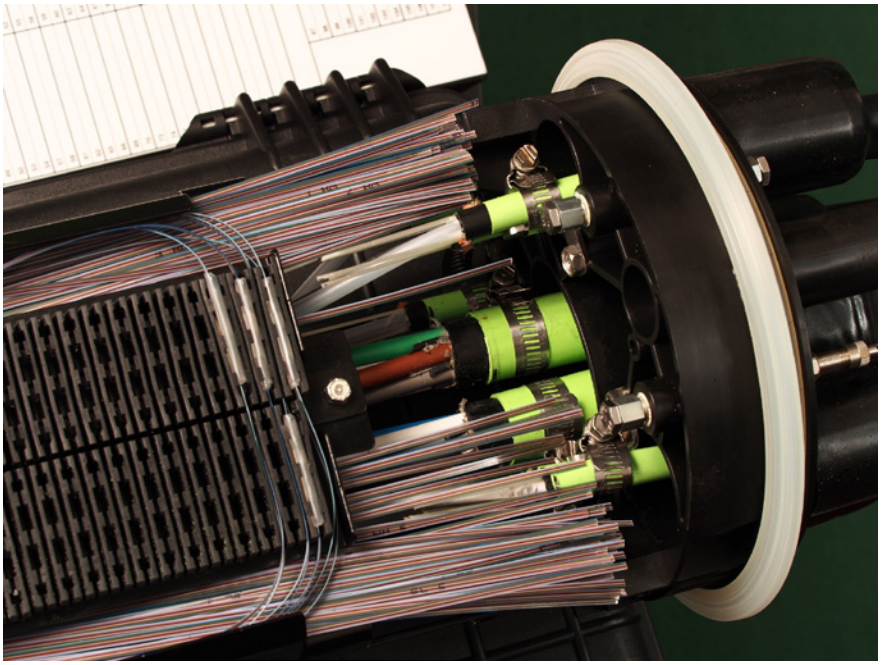
With regards to residential services, 25G PON is primarily an opportunity to design a greenfield network with a high split ratio and connect more users on a single PON. But operators could also decide to differentiate with premium multi-gigabit offers in the near-future. With the pace of

change in the entertainment sector with cloud gaming, virtual reality, and interactive video, multi-gigabit residential broadband may become a standard sooner than we think.

Another factor driving convergence is the arrival of 5G mobile. Mobile operators have realized that FTTH networks can provide 5G transport, letting them deploy more quickly and cheaply. The evolution of PON technologies will ensure that the transport requirements are met. 10G PON, 25G PON, and beyond ensure that PON has enough capacity for dense 5G deployments. In addition to speed, other innovations have enabled lower latency on a PON and can efficiently separate fixed and mobile traffic, so that mobile transport traffic has the quality of service it needs.

Then there are business services. Fiber is increasingly being used to connect business premises to the internet and as a local area network to connect all types of devices within the premise. Fiber is attractive because it supports very high symmetrical bit rates, it is the most energy efficient access technology, and it is the most cost-effective. Business services are lucrative, generating high revenues with good margins, and operators are considering how to differentiate their enterprise offerings to create more revenues. With increasing use of video and cloud computing applications, the gold standard for business broadband is becoming 10 Gbps. To connect multiple businesses with true 10-Gbps speeds, XGS-PON may not be enough, opening the door for 25G PON.

Greater capacity also creates new revenue opportunities through network sharing. It's perhaps no surprise that many operators signing up to the 25GS-PON MSA group are wholesale providers. Wholesale needs big pipes to meet the demands of tenants and applications. 25G PON is ideally suited to software-defined network slicing, which can be used to maximize network utilization and differentiate quality of service for each tenant or service.



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Network convergence is driving more traffic onto fiber networks.

25G PON: the best next step

The evolution of PON has always depended on the existence of mature, high-volume technologies that would drive down the cost—a key condition for any new access technology to be massively adopted. In the past, PON relied on long-haul optical technologies. Today, there is a slightly different but highly efficient path that comes from the data center world. The increased demand for data center capacity has begun to drive large volumes and reduced

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Next-gen PON technologies ensure that the future-proof promise of fiber becomes a reality.

costs on 25G components. This is the mature ecosystem that 25G PON leverages and that provides the baseline for further evolution to 50G and 100G PON.

25G PON makes the most sense as the next generation of PON for several reasons. Besides the high capacity, cost-efficiency, and compelling use cases described above, 25G PON is simple to introduce.

Co-existence is a major requirement for graceful migrations that avoid complicated (and costly) operations and disrupted services. One of the great attributes of 25G PON is that it can seamlessly co-exist with both GPON and XGS-PON, so there can be three generations of PON on the same fiber infrastructure. There are no forced migrations, no restrictions, and no overlay deployments.

Beyond 25G PON

Going beyond 25G PON is more of a quantum leap than an evolution because it will require a new generation of components. Running at such high speeds has technical challenges, and the options to address these challenges increase cost and complexity.

50G PON, which is also under standardization, will be able to use some 25-Gbps components, but not everything. For example, if a 25-Gbps transmitter is used to transmit at 50 Gbps, the signal will be distorted. There are two possible solutions: either use a 50-Gbps transmitter or a 25-Gbps transmitter in combination with amplifiers. In both cases the cost is higher. In receivers, 50G PON will be able to leverage 25-Gbps components but will need advanced digital signal processing (DSP) to achieve 50-Gbps bit rates with 25-Gbps optics. These DSPs will need to be integrated on a chip and reach high volumes to drive down the cost, and this could take 7-8 years. Co-existence is also proving a challenge. The current ITU standard for 50G PON enables co-existence with GPON or XGS-PON but not both at the same time. None of this is an issue for 25G PON.

As for 100G PON, trials may have taken place with Vodafone, but the actual commercial availability is still far away. 100G PON will need advanced DSPs, just like 50G PON, and these are not available yet. Once they become available for 50G PON, the step to 100G PON will be straightforward.

The beauty of PON evolution is not only in higher speeds. With every new generation of PON technology, new techniques become available to improve the overall performance: lower latency, software-defined automation, and so on. The 100G PON prototype tested with Vodafone also included flexible-rate transmission, which is an industry-first in a PON network. Flexible-rate transmission groups ONUs with similar physical characteristics (e.g., loss or dispersion), so these groups benefit from dedicated, optimized performance, e.g., more efficient data transmission, lower latency, lower power. But 100G PON comes with even higher power loss budgets than 50G, and this is an ongoing area of research.

New power of fiber

It is important to keep pushing the boundaries of PON technology and make sure today's fiber networks will be usable for many years to come. After all, there will be no relenting in demand for faster, more responsive, and immersive internet services. 25G PON is ready to go, clearing a path for 50G and 100G in the next couple of decades. While they require much more research, development of a new generation of lasers, optical amplifiers and DSPs, and further optimization to reach maturity and an acceptable cost point, they will ensure fiber networks become a unified infrastructure to connect everything, everywhere.

Ana Pesovic *is marketing director, Fixed Networks, at Nokia. She has more than 20 years of experience in fiber access technologies.*

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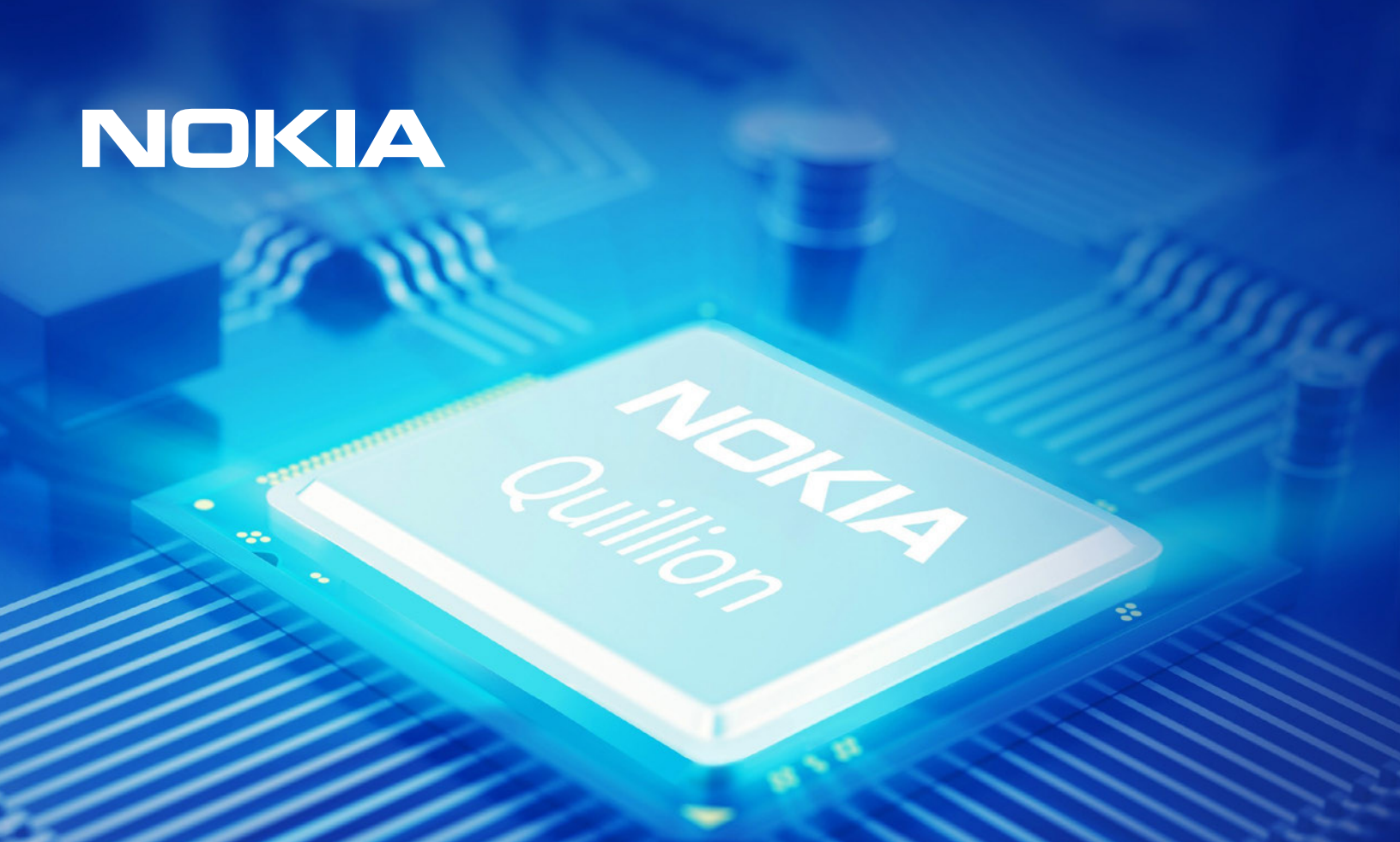

What if you could increase the speed of your GPON network by a factor of 10x so you can connect everyone and everything?

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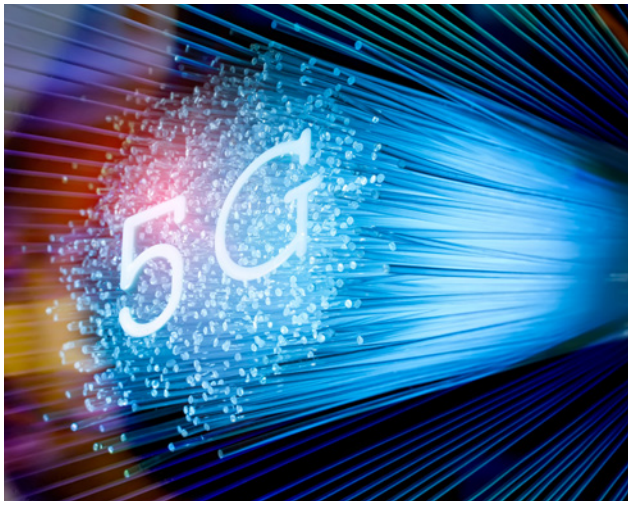
The Case for Using PON for 5G Fronthaul

BY DAVID LEVI

There has been a lot of publicity recently for China's leading role in 5G deployment, primarily focused on the installation of over 600,000 5G towers and base stations throughout the country. While this is significantly more than any other country has built, it is a mere fraction of the total number of towers that will be required for China to offer true nationwide 5G coverage.

To drive and sustain the required high bandwidth in 5G, the wireless radio channels had to be adjusted toward using a millimeter-wave band. Although this has the ability to support higher capacities, it comes with one major drawback: distance. Millimeter waves can drive large throughputs, but the signal radius is reduced from 1 km in 4G radio to only 100 m (or even less, depending on the terrain). This necessarily means that 5G requires more access points for the same coverage as 4G. In fact, estimates range from between 20-50 times more antennas are required, which means it could take as many as 10 million towers before China can achieve complete 5G penetration.

Similarly, as North American and European operators are rolling out their 5G offerings, they are touting nationwide coverage. The truth is that there is no such thing as a nationwide network for 5G yet. Operators have begun their



rollouts by testing the network with towers that can reach pockets within certain cities and in rural areas that struggled to receive 4G signals. Until there are enough towers in place to provide coverage wherever and whenever, there will be limited 5G service in every country in the world.

This mass deployment of a dense network of base stations will lead to a major infrastructural challenge that is rarely discussed when 5G networks are planned: *How are all these towers going to be connected?*

Whereas in legacy 4G network architecture, a base station was co-located with each tower, requiring a large physical space complete with backup battery and temperature control, 5G networks have separated the data processing within the distributed unit (DU) from the signal-

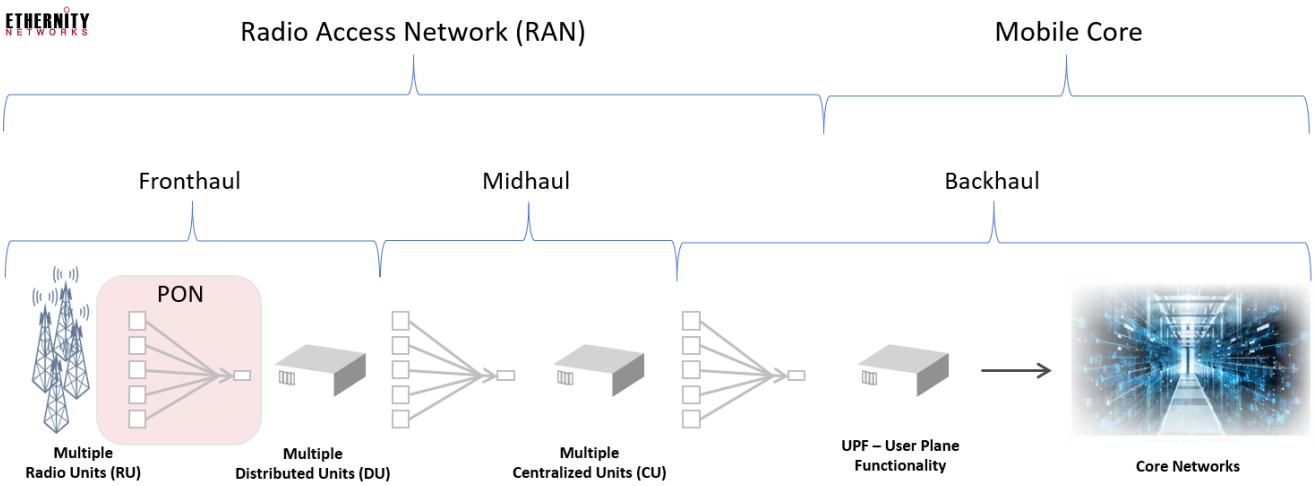


Figure 1. 5G mobile networks have several parts that will need to be connected.

bearing radio unit (RU). Moving DUs to telco central offices at the edge of the access network reduces both the size and cost of base stations, which is critical given the significantly greater number of towers (Figure 1).

Most 3G/4G cell towers use microwave technology for connectivity as a main backhaul element; however, 5G networks will be deployed based on cloud RAN topology where antenna-sector data will run directly over fiber towards DUs. Such data will require 10-Gbps to 25-Gbps connections, which is at the high end for microwave technology.

Plus, the physical separation of the DU from the RU requires a much greater reliance on fiber to bridge between them. Moreover, that fiber must now accommodate much larger capacity to meet 5G bandwidth requirements, which can extend to as much 20 times the required capacity of 4G LTE. And these fiber connections must enable extremely low latency of up to 10 times less delay than LTE.

The first option would be to lay all new fiber to connect these millions of radio towers. But this would result in a huge delay, fraught with logistical constraints and a major added cost for operators.

The benefits of 5G cannot be fully realized until operators can find a way to address these tremendous infrastructure expenses. It is therefore important for operators to optimize the cost of deploying their towers and the last-mile transport to reach the base stations. To do so, it makes sense to maximize capacity within the RAN by exploiting existing fiber infrastructure.

Therefore, the logical solution is to use passive optical networks (PONs) where they are already available for fiber-to-the-home connectivity. PONs can enable the 5G data to be transported via fiber s from the radio towers to the RAN.

The opportunity for PON

PON is flexible, reliable, and efficient enough to provide fronthaul transport for both cellular and fixed broadband in a single network, which is a huge advantage over other distribution networks that require different types of distribution for different technologies.

In many countries, there is an existing PON network that is deployed to enable broadband fiber-to-the-home/business (FTTx). For 5G to reach home and enterprise locations, there also must be a connection from the millions of radio antennas to the RAN. By using an architecture based on the point-to-multipoint tree topology of PON, operators can reduce the amount of trunk fibers that are used.

Existing FTTx networks are large and extensive, with sufficient line and port resources as well as the necessary optical devices and power supply. PON offers resilience, such that connectivity is maintained even if a line is disconnected. Most of all, PON reduces networking costs by reusing existing fiber and optical filters, and it can handle various traffic streams with much greater capacity than other transport options.

As such, existing PON fiber is an ideal conduit and cost-effective solution for transporting 5G traffic from the RUs to the DUs and perhaps even onward to the rest of the access network.

upstream and downstream, on the road toward 25G PON.

Many operators are now seeking support for WDM-PON (sometimes called Combined PON – CPON), which overlays new wavelengths onto legacy PON networks without compromising the bandwidth of the existing fixed broadband service. For example, a single fiber could make use of four colors (wavelengths) within the fiber for GPON (two upstream and two downstream) to serve both GPON for FTTH and XGS-PON for

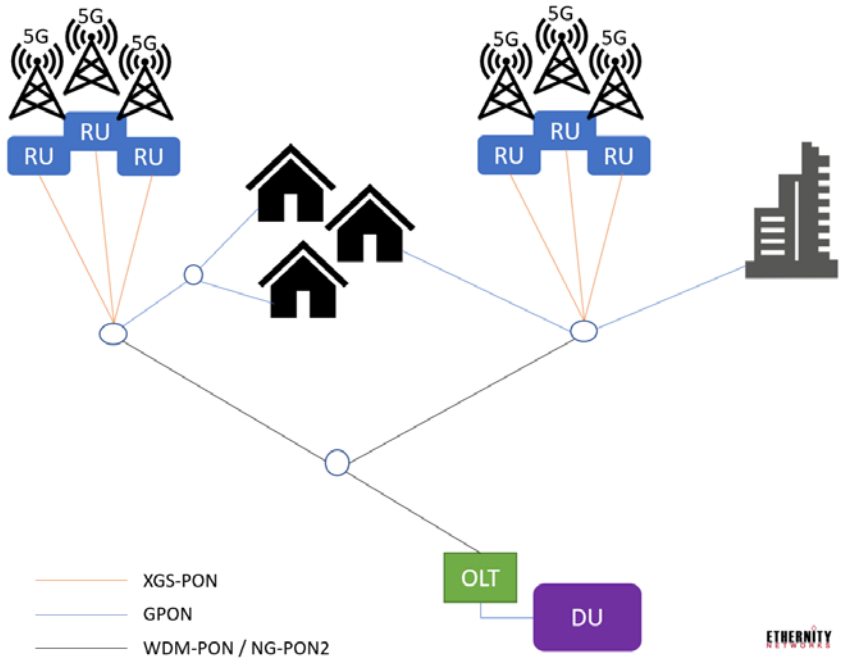


Figure 2. PON enables the use of the same network to support both broadband services delivery as well as 5G fronthaul

PON options

There are different flavors of PON that are being discussed as possible options for 5G infrastructure. FTTH has a maximum requirement at present of GPON, which can provide a top capacity of about 2.5-Gbps downstream and 1.2-Gbps upstream. But fronthaul requires significantly more capacity, such as XGS-PON, which can offer 10-Gbps 5G fronthaul on the same fiber. Thus, the same existing infrastructure and same optics can be used both to reach the home and to connect from the RU to the DU (Figure 2).

The most recent flavor being proposed is NG-PON2, which can handle up to 40 Gbps in each direction over PON by using eight wavelengths of XGS-PON. This then requires a

tunable receiver in each endpoint to be able to differentiate and supervise the various colors. Because of its tremendous transport capacity, it has the potential to extend the PON network to also connect midhaul between DUs and central units (CU) even deeper into the radio access network.

There is one primary limitation implicit in the use of PON for 5G. Because PON is a TDMA protocol, there is naturally added delay between the arrival of the traffic and the response to permit delivery. This can pose as much as a millisecond delay, which is very significant in 5G terms. That said, WDM-PON has shown promise as a low-latency fronthaul transport option.

Otherwise, there has not been a lot of progress related to overcoming latency issues in fronthaul to date, although there have been various solutions proposed to address this limitation. One such proposal makes use of the DU and CU to notify an OLT whenever a user in its region is accessing the 5G network, so that bandwidth can be allocated in advance without the need to wait for permission.

PON and 5G match well

Certainly as more 5G networks are advanced toward mass deployment, and as PONs are recognized as cost-efficient, high-capacity means of deploying 5G transport from antenna to RAN, more effort will be dedicated toward working around and reducing the latency to meet the 5G benchmarks.

Ultimately, PON differentiates itself to service providers as the optimal 5G fronthaul transport option because it is readily available and it offers a single distribution network for both fixed broadband and cellular data transport. But PON also provides value because it is simple to install, it scales and can be configured easily based on demand, it is interoperable with other deployed networking architectures, and it is extremely reliable. Most of all, PON optimizes operator costs, which is critical at a time when so much infrastructure expense is being allocated toward implementing the necessarily dense network of towers that are the backbone of 5G.

David Levi *is the CEO and founder of Ethernity Networks. Prior to Ethernity, David was granted two U.S. patents regarding GPON protocol-related inventions. He founded Broadlight, which created BPON and GPON components and was acquired by Broadcom.*

Nokia, Vodafone lab test 100G PON

BY STEPHEN HARDY

Nokia and Vodafone say they successfully trialed last week a prototype 100G PON system in Vodafone's Eschborn lab in Germany. The prototype used a single 25G laser and DSP technology developed at Nokia Bell Labs to create the single-wavelength 100G PON transmission.

The technology trialed supports flexible transmission rates up to 100 Gbps and is the first technology to offer such flexibility, the collaborators assert. The flexible rate approach involves the grouping of optical network units (ONUs) with similar physical network characteristics (e.g., loss or dispersion) to improve the efficiency of data transmission. The result is lower latency and a 50% reduction in power consumption, Nokia and Vodafone say. These characteristics would make PONs more appealing for a variety of applications including the support of mobile broadband services, the companies add.

Nokia and Vodafone note that 25G optics are mature and available today (and, among other things, underpin Nokia's recently announced 25G PON approach; see "Nokia offers symmetrical 25G PON via ISAM FX"). "Once this DSP is adopted," in the words of a joint press release, 50G and 100G PON development would become relatively straightforward, leading to commercial availability in the second half of this decade, the companies assert.

Vodafone is interested in high-speed PON approaches as it evolves towards a unified, fiber-based approach to access, aggregation, backhaul of cable nodes, and mobile transport. The company says such high-speed capabilities could enable a series of futuristic applications and services, from "virtual teleportation" and 3D holographic capabilities that could aid healthcare, education, retail, and leisure applications.

"100G PON has 40 times the capacity of today's GPON networks, and 10 times the capacity of XGS-GPON, so it will help us keep ahead of the demand curve," commented Gavin Young, head

of Vodafone's Fixed Access Centre of Excellence. "In addition to ultra-high speeds, the technology supports our vision of highly efficient and adaptable next-generation networks. 100G PON enables flexible rates and works by grouping modems using a technique similar to the one we already use in our cable networks, so this experience can help us to better evaluate and exploit this new PON technology."

"For the first time, we show a unique flexible-rate capability that allows optimizing capacity depending on the link losses and low-cost optical component capabilities in an optical network termination. We believe fiber will play a key role in 5G and 6G, and that is why we are truly excited about the 100G PON demo, and its potential in creating the future of fiber broadband," added Peter Vetter, head of Access and Devices Research at Nokia Bell Labs.

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