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

5G Transport Networks: Heavy Reading Operator Survey & Analysis

A Heavy Reading white paper produced for Huawei

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EXECUTIVE SUMMARY

The coming 5G era is not just about handsets, sensors and other mobile devices; the wireline network has a critical role to play in 5G, by providing the access and aggregation networks that will enable all the interesting high-bandwidth and ultra-low-latency applications for those millions of end devices. In fact, the industry has recognized that this wireline infrastructure must be put in place before 5G applications can be rolled out in volume. Work to standardize new 5G radio continues, and leading-edge operators plan to begin launching 5G services in 2020 – some as early as 2019. This aggressive timeline makes the next two years an urgent time for 5G wireline access networks.

Scale and performance requirements dictated by the 5G radio network are forcing a radical rethink of access and aggregation transport networks. There is strong industry consensus that the preferred physical medium for 5G is fiber and we are seeing operators extend their access fiber assets to prepare for 5G, whether through new builds or through acquisitions (or combinations of both). As operators extend their access fiber networks, many decisions must be made on architectures and protocols. Further, even as fiber advances deeper into access, a continued role for microwave backhaul is likely as microwave moves to 10 Gbit/s data rates.

The emergence of the centralized RAN architecture solves some problems but introduces new challenges for the "fronthaul" transport network. Operators have declared traditional Common Public Radio Interface (CPRI) inefficient for 5G, but a newly released enhanced CPRI (eCPRI) specification promises to remove at least some of old CPRI's inefficiencies in carrying data. Whether eCPRI's improvements are enough, however, remains an open question. Coupled with eCPRI, Packet-OTN could be a potential candidate for a better latency and larger bandwidth. There is also interest in adopting Ethernet transportation, but work must be done to make it time-sensitive for 5G applications.

Given the importance of wireline networks in the future of 5G, and coupled with the increasing number of technology, protocol, standard and architectural options for 5G transport, Heavy Reading conducted a custom global network operator survey, to help answer some of the main transport network questions. This research paper is based on that Web-based survey, conducted in May 2018. Respondents were drawn from the network operator list of the Light Reading readership database. From the total group of survey takers, Heavy Reading deemed 75 respondents as qualified participants and counted them in the final results. To qualify, respondents had to work for a verifiable network operator based outside of North America.

Operator Timelines

A starting point for planning around 5G is when 5G services will be commercialized. Operators around the world are scrambling for bragging rights to claim first deployment status in their regions. While first applications provide high marketing value, these targeted and limited deployments have little real impact on the transport network.

For operators' access network planning teams (and their equipment suppliers), the critical question to understand is: When will 5G be rolled out at scale? According to our survey, 2018-2020 will largely be a period of pre-commercial trials. Most operators expect to move into commercial 5G deployments in the 2021-2023 timeframe, with 59 percent of commercial launches expected during this period. Mass-market adoption will also be great from 2021-2023, according to the survey, with 48 percent of mass-market launches expected to occur.
Significantly, transport networks must be built and upgraded before 5G services are widely deployed, since the 5G radio network has little value if the access network can’t accommodate the capacity or the application performance requirements (ultra-low latency or high availability, for example). The greatest percentage of operators surveyed (39 percent of the survey group) expect to upgrade their networks one to two years before commercial deployments. For 26 percent, those upgrades will be more closely timed to commercial deployments – less than one year before commercial launch.

Mapping expected commercial launches to upgrade timelines, it appears that 2019-2022 will be the critical years for access network investment. Not surprisingly, just 7 percent of surveyed operators believe there will be little to build or upgrade in advance of 5G. There is much work to be done, and the clock is ticking.

Transport Network Trends

Fiber will be the first choice for 5G base station backhaul. Heavy Reading survey data mostly confirms this trend. For 38 percent of respondents, 5G base stations will be 100 percent fiber-connected. For an additional 44 percent of the group, 80 percent fiber access connectivity is expected.

In a related 5G trend, mobile operator functions will move increasingly closer to end users (i.e., mobile edge compute architectures). The largest group of respondents (50 percent) expect the mobile core network to reside at the distribution layer, defined in our survey as roughly 80 km from the end users. A significant minority (38 percent) expect the mobile core to move closer – at the central office, or roughly 30 km from end users by our definition. With functions moving closer to users, more and more base stations must be deployed.

Still, some vendors and industry observers were initially expecting "all fiber everywhere" with 5G, and this will not be the case. Microwave will be used when fiber is unavailable or uneconomical. This is particularly true for backhaul networks. In our survey, 60 percent of operators said they expect to use some level of microwave backhaul in their 5G deployments. However, microwave backhaul will require 10 Gbit/s microwave radio connections; 10 Gbit/s microwave products are now coming on the market to meet this need.

Architecture Preferences: C-RAN vs. D-RAN

There is a significant architectural decision that will have a big impact on which optical technologies will be used: That is whether the radio access network (RAN) architecture will continue to be a distributed RAN (D-RAN) – as almost all are today – or if they will migrate to a new centralized or cloud RAN architecture, or C-RAN.

In the classical D-RAN, there is some separation of the remote radio head (RRH) and baseband unit (BBU) functions, but this separation extends only along the length of the cell tower (top to bottom, measured in meters). The BBU sits at the cell tower, and a mobile backhaul network connects the BBUs to the mobile switching center. In 4G, the mobile backhaul network is predominantly Ethernet-based, due to lower costs and statistical multiplexing efficiencies.

A distributed RAN architecture with Ethernet backhaul is the state of the art in 4G mobile networks today, but there are challenges as operators move to 5G, including high operational costs caused by technician provisioning and maintenance truck rolls. Distributed RAN architectures place all BBU and RRH equipment at each cell site. Operations costs mount as operators densify cell coverage for 5G.
There is a lot of interest in the C-RAN architecture as a solution to the D-RAN problems. In C-RAN, the BBU functionality is all pooled in a central location, and the connection to the RRH at the cell tower is called the fronthaul network. Centralizing the BBUs promises several benefits to mobile network operators, including economies of scale efficiencies and reduced opex through fewer truck rolls to cell towers (since most functions will be centralized). Still, while solving some challenges, C-RAN also introduces new challenges, particularly around how to connect the RRH at the cell site to the BBU pool in the network. We believe the C-RAN connectivity challenges are non-trivial and will inhibit adoption, despite the hype surrounding the C-RAN architecture.

Our survey results indicate that 5G will include a mix of D-RANs and C-RANs, with RANs more likely to be distributed than centralized. In our survey, 37 percent of respondents expect an equal mix of C-RAN and D-RAN, while 35 percent expect D-RANs to dominate, with only limited C-RAN deployments. By contrast, just 7 percent expect their networks to be mostly C-RANs. Furthermore, our question was specific to 5G only, and respondents were not asked to consider their 4G and previous-generation networks, which are already distributed.

We also expect a mix of RAN transport technology choices for 5G. Significantly, 5G access network requirements for C-RANs will differ from D-RAN access requirements, and the different requirements will affect the types of transport networks used for each.

**Transport Network Challenges**

Meeting ultra-low latency requirements emerged as the top challenge operators face in architecting their transport networks for 5G, and by a wide margin. The survey results are consistent with our one-on-one discussions with operators, in which the low-latency challenge is consistently mentioned. Operators know they can meet low-latency demands with dedicated high-speed optics, but the costs quickly erode the business case. Packet technologies are more bandwidth-efficient and less costly but guaranteeing latency is an issue. This is the transport network dilemma.

We note that 80 percent of delay on the transport network depends on the fiber distance, so shortening the distance between the core network and the user is the best way to reduce delay. The delay of devices on the transport network matters when congestion occurs. Therefore, network slicing can be used to prevent congestion and ensure low delay.

After low latency, extending wireline connectivity to new cell sites and achieving RAN capacity requirements came in second and third, cited as a major challenge by 40 percent and 39 percent of respondents, respectively. These concerns are also consistent with anecdotal data and relate directly to cost challenges of meeting performance/capacity requirements without eroding the business case.

Automation ranked in the bottom half of the list of challenges. It's not clear, however, whether this is because automation challenges are minimal or if it's because automation is not particularly urgent in the near term, as operators will focus primarily on building out the infrastructure.

**Technologies & Standards**

To meet service requirements and address the top network challenges, 5G adoption will bring with it a host of transport-related access network technologies and protocols. Some of these technologies are being created specifically for 5G.
In our operator survey, three technologies/standards were identified as "very important" by at least 30 percent of respondents in our survey. Specifically, these are the International Telecommunication Union's (ITU) Optical Transport Network (OTN); the Institute of Electrical and Electronics Engineers' (IEEE) Time Sensitive Networking; and the Internet Engineering Task Force's (IETF) segment routing standard, Source Packet Routing in Networking (SPRING). Additionally, five technologies/standards were identified as "very important" by at least 20 percent of respondents, specifically: 10 Gbit/s microwaves, the CPRI Consortium's eCPRI, Optical Internetworking Forum's (OIF) Flex Ethernet (FlexE), IEEE's 25 Gbit/s Ethernet and ITU-T's NGON2.

The top tier of technology priorities has some surprises, including the position of OTN as the highest priority. There is a great deal of talk about packet technologies for 5G transport, but OTN is not a packet technology – it is an advanced time-division multiplexing (TDM) technology. From early survey results, we know that WDM with high capacity and low latency will play a key role in 5G base station connectivity, particularly for C-RAN fronthaul architectures.

Another important technology trend is that 25GE, 50GE, and FlexE technologies are gradually gaining attention. As a new Ethernet port that uses the PAM4 coding scheme, 50GE can reduce the network construction costs. FlexE, as a next-generation Ethernet technology, can provide network slicing hard isolation to ensure low latency.

Along with achieving low latency, timing synchronization is another critical requirement for 5G services, particularly as operators look to increase the role of packet networks, for the greater efficiency and lower costs they deliver. According to our survey, however, there is little debate about how operators plan to handle time synchronization in 5G: End-to-end 1588v2 through the transport network is the preferred choice for nearly three quarters of respondents, an overwhelming majority.

Conclusions & Recommendations

Based on our survey data, Heavy Reading provides the following conclusions and recommendations for operators and their suppliers.

- **The years 2019-2022 will be the critical years for access network investment in advance of 5G commercial launches and mass adoption.** There is much work to be done, and the clock is ticking. Operators that wait to upgrade their access networks will be left behind.

- **Even while technology choices are being made, operators should begin rolling out fiber to cell sites, as fiber will be the dominant means of 5G cell-site connectivity.** Within the fiber medium, there are many options for topologies and technologies, and our data suggests that all of the major fiber options will play a role. Operators will be best served by suppliers with broad technology sets that won't force architectures that don't fit.

- **Meeting ultra-low latency requirements is the top challenge operators face in architecting their transport networks for 5G.** Operators must balance reducing network costs (capex and opex) with meeting latency requirements for 5G. Suppliers must propose solutions that achieve a balance between cost and performance. As we noted, 80 percent of delay on the transport network depends on the fiber distance, so shortening the distance between the core network and the user is the best way to reduce delay. To prevent congestion, network slicing can be used to ensure low delay.
• Despite the hype surrounding the C-RAN architectures, operators are looking to a mix of distributed and centralized 5G RANs. In fact, based on our survey data, 5G RANs are more likely to be distributed than centralized.

• Timing synchronization is a critical requirement for 5G services, particularly as operators look to increase the role of packet networks, for the greater efficiency and lower costs they deliver. The preferred choice will be end-to-end 1588v2 through the transport network.

• The ITU's OTN, IEEE's Time Sensitive Networking and IETF's SPRING formed a top tier of key technologies for 5G transport. Additionally, 10 Gbit/s micro-waves, CPRI Consortium's eCPRI, OIF's Flex Ethernet (FlexE), IEEE's 25 Gbit/s Ethernet and ITU-T's NGON2 will be important for many. Operators are looking to these mostly new technologies to economically address capacity, performance and cost requirements for 5G. Just as there will be a mix of architectures, there is no "one size fits all" technology for 5G.
SURVEY RESULTS & ANALYSIS

The following analysis is based on the 2018 Heavy Reading 5G Transport Networks Survey, conducted in May 2018. Survey respondents were drawn from the network operator list of the Light Reading readership database. From the total group of survey takers, Heavy Reading deemed 75 respondents as qualified participants and counted them in the final results. To qualify, respondents had to work for a verifiable network operator based outside of North America. For a full breakdown of respondent demographics, refer to the Appendix at the end of this report.

We analyze the survey results across five distinct topics:

- Operator timelines
- Fiber and microwave trends
- Architecture preferences (C-RAN vs. D-RAN)
- Transport network challenges
- Technologies and standards

Operator Timelines

Figure 1 looks at timeframes for the expected stages of 5G deployment, including pre-commercial trials, commercial launch and mass-market launch.

Figure 1: Expected Stages of 5G Deployment

<table>
<thead>
<tr>
<th></th>
<th>2018-2020</th>
<th>2021-2023</th>
<th>2024 or later</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-commercial trials</td>
<td>82.2%</td>
<td></td>
<td>13.7%</td>
</tr>
<tr>
<td>Commercial launch</td>
<td>30.9%</td>
<td>58.8%</td>
<td>10.3%</td>
</tr>
<tr>
<td>Mass-market launch</td>
<td>9.0%</td>
<td>47.8%</td>
<td>43.3%</td>
</tr>
</tbody>
</table>

Not surprisingly, operators expect 2018-2020 to largely be a period of pre-commercial trials, with 82 percent of the pre-commercial phase expected to occur during this time. Most operators expect to move into commercial 5G deployments during 2021-2023, with 59 percent of commercial launches expected during this period. Mass-market adoption will also be great from 2021-2023, according to the survey, with 48 percent of mass-market launches...
expected to occur. Additionally, 43 percent of mass-market adoption is expected to take place from 2024.

It is clear that the wireline infrastructure to support 5G radio must be put in place before 5G services can be rolled out at scale.

**Figure 2** looks at operator timeframes for upgrading their transport networks to support coming 5G services. Specifically, we asked the question: *When does your company plan to build or upgrade its transport network to support 5G rollout?*

### Figure 2: Timeframe for Upgrading Transport Networks to Support 5G

<table>
<thead>
<tr>
<th>Timeframe</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>More than two years before</td>
<td>23%</td>
</tr>
<tr>
<td>commercial deployments</td>
<td></td>
</tr>
<tr>
<td>1-2 years before commercial</td>
<td>39%</td>
</tr>
<tr>
<td>deployments</td>
<td></td>
</tr>
<tr>
<td>Less than one year before</td>
<td>26%</td>
</tr>
<tr>
<td>commercial deployments</td>
<td></td>
</tr>
<tr>
<td>After commercial deployments</td>
<td>5%</td>
</tr>
<tr>
<td>have begun</td>
<td></td>
</tr>
<tr>
<td>Little or no building/upgrade of</td>
<td>7%</td>
</tr>
<tr>
<td>the transport network is required</td>
<td></td>
</tr>
<tr>
<td>for commercial 5G</td>
<td></td>
</tr>
</tbody>
</table>

*N=74*

At 39 percent, the greatest percentage expect to upgrade their networks to support 5G from one to two years before commercial deployments. For 26 percent, those upgrades will be more closely timed to commercial deployments – less than one year before commercial launch. And for 23 percent, transport upgrades are expected to have a long runway, occurring more than two years before commercial deployments. Significantly, operators largely agree that there is transport work to be done in advance of 5G. Just 7 percent believe there will be little to build or upgrade.

**Transport Network Trends**

In 5G architectures, mobile operator functions are moving increasingly closer to end users (i.e., mobile edge compute architectures). In our survey, we wanted to get a better sense of operator plans for their mobile core network plans. Specifically, we asked respondents to identify how far from end users they expect the mobile core network to reside in their 5G architectures. The responses are shown in **Figure 3**.

At 50 percent, the greatest percentage of operators expect the mobile core network to reside at the distribution layer, defined in our survey as roughly 80 km from the end users. A significant minority (38 percent of respondents) expect the mobile core to move closer – at the central office, or roughly 30 km from end users by our definition.
In addition, we asked questions about microwave connectivity in 5G. Contrary to early 5G marketing information spread by all-fiber proponents, operators are, in fact, interested in microwave connectivity for 5G – particularly for 5G backhaul in D-RANs. We asked our survey respondents whether they plan to use microwave technology for 5G backhaul. Figure 4 shows the results.

**Figure 3: Mobile Core Network Proximity to End Users**

- The central office layer (~30 km from the end user) 38%
- The distribution layer (~80 km from the end user) 50%
- The core distribution layer (~200 km from the end user) 12%

$N=74$

$N=73$

In addition, we asked questions about microwave connectivity in 5G. Contrary to early 5G marketing information spread by all-fiber proponents, operators are, in fact, interested in microwave connectivity for 5G – particularly for 5G backhaul in D-RANs. We asked our survey respondents whether they plan to use microwave technology for 5G backhaul. Figure 4 shows the results.

**Figure 4: Operator Plans to Use Microwave for 5G Backhaul**

- Yes 60%
- No 40%

$N=73$
Earlier survey results pointed to a role for microwave technology in 5G backhaul, and this direct survey question on the topic further reinforces this finding. In our survey, 60 percent of operators reported that they expect to use some level of microwave backhaul in their 5G deployments.

The remaining questions in the survey were only asked to the 60 percent of operators that plan to use microwave backhaul for 5G. In the first question, we asked operators to identify the greatest challenges in making current microwave networks ready for 5G backhaul. Operators could select all that apply. Results are shown in Figure 5.

**Figure 5: Top Microwave Network Challenges for 5G**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Solving bandwidth bottleneck by upgrading to 10 Gbit/s</td>
<td>67%</td>
</tr>
<tr>
<td>Simplifying network topology and decreasing link latency</td>
<td>54%</td>
</tr>
<tr>
<td>Saving spectrum cost by maximizing spectrum efficiency</td>
<td>51%</td>
</tr>
<tr>
<td>Improving reliability of microwave links</td>
<td>37%</td>
</tr>
<tr>
<td>Improving OAM function by enabling SDN and routing technology</td>
<td>23%</td>
</tr>
<tr>
<td>Other</td>
<td>2%</td>
</tr>
</tbody>
</table>

The need to upgrade to 10 Gbit/s microwave data rates was selected as the top challenge, by two thirds of respondents. The good news is that several vendors are now bringing 10 Gbit/s microwave radios to market, which – if performance lives up to expectations – should resolve this challenge. Other significant challenges included saving spectrum cost by maximizing spectrum efficiency, and simplifying network topology and decreasing link latency, at 54 percent and 51 percent of respondents, respectively.

**Architecture Preferences: C-RAN vs. D-RAN**

One of the biggest access network questions surrounding 5G is how the RAN will evolve from today's (primarily) D-RAN architectures to new C-RAN architectures. We asked operators to predict their companies' architecture distribution for 5G RAN deployments five years from now, including D-RAN, C-RAN, and the mix between them. **Figure 6** shows the results.

Despite the hype surrounding the C-RAN architecture, survey results indicate that 5G will include a mix of D-RANs and C-RANs, with RANs more likely to be distributed than centralized. In our survey, 37 percent of respondents expect an equal mix of C-RAN and D-RAN, while 35 percent expect D-RANs to dominate with only limited C-RAN deployments. By contrast, just 7 percent expect their networks to be mostly C-RANs. Furthermore, our question was specific to 5G only, and respondents were not asked to consider their 4G and previous-generation networks that are already distributed.
Transport Network Challenges

We asked operators to identify the most significant transport network challenges for 5G. We gave respondents a list of potential challenges and asked them to identify each as either a major, moderate or minor challenge, or as not a challenge at all. Figure 7 shows the survey results ranked in descending order according to the percentage that selected a "major challenge" for each.

**Figure 7: Top Transport Network Challenges for 5G**

<table>
<thead>
<tr>
<th>Challenge</th>
<th>Major challenge</th>
<th>Moderate challenge</th>
<th>Minor challenge</th>
<th>Not a challenge</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meeting ultra-low latency requirements</td>
<td>57%</td>
<td>33%</td>
<td>9%</td>
<td>0%</td>
</tr>
<tr>
<td>Costs of extending wireline connectivity to new cell sites (densification)</td>
<td>40%</td>
<td>37%</td>
<td>17%</td>
<td>5%</td>
</tr>
<tr>
<td>Achieving RAN capacity requirements</td>
<td>39%</td>
<td>48%</td>
<td>11%</td>
<td>3%</td>
</tr>
<tr>
<td>Meeting timing and synchronization requirements</td>
<td>36%</td>
<td>51%</td>
<td>14%</td>
<td>0%</td>
</tr>
<tr>
<td>Costs of upgrading existing RANs</td>
<td>35%</td>
<td>37%</td>
<td>23%</td>
<td>5%</td>
</tr>
<tr>
<td>Network automation</td>
<td>31%</td>
<td>51%</td>
<td>13%</td>
<td>5%</td>
</tr>
<tr>
<td>Implementing network slicing in the transport network</td>
<td>28%</td>
<td>51%</td>
<td>16%</td>
<td>5%</td>
</tr>
<tr>
<td>Implementing cloud/virtualization of BBU functions</td>
<td>21%</td>
<td>43%</td>
<td>29%</td>
<td>7%</td>
</tr>
<tr>
<td>Compatibility of new and legacy protocols (i.e., MPLS/segment routing/EVPN)</td>
<td>19%</td>
<td>44%</td>
<td>32%</td>
<td>6%</td>
</tr>
</tbody>
</table>

Meeting ultra-low latency requirements emerged as the top challenge operators face in architecting their transport networks for 5G, and by a wide margin. The survey results are
consistent with our one-on-one discussions with operators, in which the low-latency challenge is consistently mentioned. Operators know they can meet low-latency demands with dedicated high-speed optics, but the costs quickly erode the business case. Packet technologies are more bandwidth-efficient and less costly but guaranteeing latency is an issue. This is the transport network dilemma.

We note that 80 percent of delay on the transport network depends on the fiber distance, so shortening the distance between the core network and the user is the best way to reduce delay. The delay of devices on the transport network matters when congestion occurs. Therefore, network slicing can be used to prevent congestion and ensure low delay.

After low latency, extending wireline connectivity to new cell sites and achieving RAN capacity requirements came in second and third, cited as a major challenge by 40 percent and 39 percent of respondents, respectively. These concerns are also consistent with anecdotal data and relate directly to the cost challenges of meeting performance/capacity requirements without eroding the business case. Automation ranked in the bottom half of the list. It’s not clear, however, whether this is because automation challenges are minimal or if it’s because automation is not particularly urgent in the near term, as operators will focus primarily on building out the infrastructure.

Technologies & Standards

We asked operators to rate the importance of 14 different technologies and protocols relative to their planned 5G transport networks. For each, respondents could select “very important,” “moderately important,” “slightly important” or “not important at all.” Figure 8 shows the results in descending order, according to the percentage that chose “very important” for each.

**Figure 8: Importance of Various Protocols & Technologies for 5G Transport**

<table>
<thead>
<tr>
<th>Technology</th>
<th>Very important</th>
<th>Moderately important</th>
<th>Slightly important</th>
<th>Not important</th>
</tr>
</thead>
<tbody>
<tr>
<td>OTN</td>
<td>35%</td>
<td>35%</td>
<td>21%</td>
<td>9%</td>
</tr>
<tr>
<td>Time Sensitive Networking (IEEE)</td>
<td>31%</td>
<td>45%</td>
<td>20%</td>
<td>4%</td>
</tr>
<tr>
<td>Segment routing (IETF SPRING)</td>
<td>30%</td>
<td>32%</td>
<td>34%</td>
<td>4%</td>
</tr>
<tr>
<td>10 Gbit/s Microwave</td>
<td>29%</td>
<td>35%</td>
<td>26%</td>
<td>10%</td>
</tr>
<tr>
<td>eCPRI</td>
<td>26%</td>
<td>46%</td>
<td>18%</td>
<td>10%</td>
</tr>
<tr>
<td>OIF Flex Ethernet (FlexE)</td>
<td>26%</td>
<td>26%</td>
<td>35%</td>
<td>13%</td>
</tr>
<tr>
<td>25 Gbit/s Ethernet</td>
<td>24%</td>
<td>33%</td>
<td>36%</td>
<td>7%</td>
</tr>
<tr>
<td>NGPON2</td>
<td>23%</td>
<td>43%</td>
<td>23%</td>
<td>11%</td>
</tr>
<tr>
<td>50 Gbit/s Ethernet</td>
<td>19%</td>
<td>44%</td>
<td>27%</td>
<td>10%</td>
</tr>
<tr>
<td>ITU-T Flexible OTN (FlexO)</td>
<td>17%</td>
<td>36%</td>
<td>39%</td>
<td>9%</td>
</tr>
<tr>
<td>edge ROADMs/WSS</td>
<td>16%</td>
<td>51%</td>
<td>28%</td>
<td>5%</td>
</tr>
<tr>
<td>Symmetrical XGS PON</td>
<td>16%</td>
<td>49%</td>
<td>28%</td>
<td>7%</td>
</tr>
<tr>
<td>CPRI</td>
<td>13%</td>
<td>57%</td>
<td>21%</td>
<td>10%</td>
</tr>
<tr>
<td>Asymmetrical 10G PON</td>
<td>13%</td>
<td>50%</td>
<td>31%</td>
<td>7%</td>
</tr>
</tbody>
</table>

N=72
Three technologies/standards were identified as "very important" by at least 30 percent of respondents: ITU-T's OTN; IEEE's Time Sensitive Networking; and IETF's segment routing standard, SPRING. Five additional technologies/standards were identified as "very important" by at least 20 percent of respondents: 10 Gbit/s microwaves; CPRI Consortium’s eCPRI; OIF’s Flex Ethernet (FlexE); IEEE's 25 Gbit/s Ethernet; and ITU-T's NGON2.

The top tier of technology priorities has some surprises, including the position of OTN as the highest priority. There is a great deal of talk about packet technologies for 5G transport, but OTN is not a packet technology; it is an advanced TDM technology.

From early survey results, we know that WDM will play a key role in 5G base station connectivity, particularly for C-RAN fronthaul architectures, but also in D-RAN backhaul. OTN and WDM are tightly coupled, due to the use of OTN framing in transport, so this could be an explanation. Another explanation could be the combination of high capacity and low latency provided by 5G – both critical requirements for 5G services. The details need to be further studied.

Another important technology trend is that 25GE, 50GE and FlexE technologies are gradually gaining attention. As a new Ethernet port that uses the PAM4 coding scheme, 50GE can reduce the network construction costs. FlexE, as a next-generation Ethernet technology, can provide network slicing hard isolation to ensure low latency.

Along with achieving low latency, timing synchronization is another critical requirement for 5G services, particularly as operators look to increase the role of packet networks, for the greater efficiency and lower costs they deliver. According to our survey, however, there is little debate about how operators plan to handle time synchronization in 5G (see Figure 9): End-to-end 1588v2 through the transport network is the preferred choice for nearly three quarters of respondents, an overwhelming majority.

**Figure 9: Preferred Choice for 5G Time Synchronization**

<table>
<thead>
<tr>
<th>End-to-end 1588v2 through the transport network</th>
<th>GPS per each site</th>
<th>Other</th>
</tr>
</thead>
<tbody>
<tr>
<td>73%</td>
<td>26%</td>
<td>1%</td>
</tr>
</tbody>
</table>

N=73
**APPENDIX: SURVEY METHODOLOGY & DEMOGRAPHICS**

This research paper is based on a Web-based survey of network operators worldwide, conducted in May 2018. Respondents were drawn from the network operator list of the Light Reading readership database.

From the total group of survey takers, Heavy Reading deemed 75 respondents as qualified participants and counted them in the final results. To qualify, respondents had to work for a verifiable network operator based outside of North America. In cases where a respondent’s employer could not be verified or was dubious, that response was omitted from the final results. The survey demographics are detailed below.

**Figure 10** shows the type of communications service providers respondents worked for. Respondents that said they do not work for a service provider were rejected and could not complete the survey.

**Figure 10: Respondents by Service Provider Type**

![Pie chart showing the distribution of respondents by service provider type]

- Mobile operator: 31%
- Converged operator (fixed and mobile assets): 52%
- Fixed-line telecom operator: 11%
- MVNO, MVNE with infrastructure: 2%
- Cable operator: 1%
- IPX/wholesale/roaming or signaling hub provider: 1%
- Other CSP: 1%
- OTT service provider: 1%

*N=75*

**Figure 11** shows survey respondents broken down by geographic region. Note that North America was excluded from this survey, and there are no North America responses in the final results.
Figure 11: Respondents by Geographic Region

- Europe: 45%
- Central/South America (including Mexico & the Caribbean): 15%
- Asia/Pacific (including Australia): 19%
- Middle East: 13%
- Africa: 8%

N=75

Figure 12 shows survey respondents broken out by company annual revenue.

Figure 12: Respondent Breakout by Company Annual Revenue

- Less than $50 million: 12%
- $50 million to $200 million: 19%
- $200 million to $500 million: 5%
- $500 million to $1 billion: 5%
- $1 billion to $5 billion: 27%
- $5 billion to $10 billion: 9%
- More than $10 billion: 23%

N=75
Figure 13 shows survey respondents broken out by job function.

**Figure 13: Respondents by Job Function**

<table>
<thead>
<tr>
<th>Job Function</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Engineering</td>
<td>30.7%</td>
</tr>
<tr>
<td>Network planning</td>
<td>17.3%</td>
</tr>
<tr>
<td>Corporate management</td>
<td>16.0%</td>
</tr>
<tr>
<td>Operations/transmission</td>
<td>8.0%</td>
</tr>
<tr>
<td>Operations/services</td>
<td>6.7%</td>
</tr>
<tr>
<td>Sales &amp; marketing</td>
<td>6.7%</td>
</tr>
<tr>
<td>Consulting</td>
<td>4.0%</td>
</tr>
<tr>
<td>Provisioning/installation/repair</td>
<td>2.7%</td>
</tr>
<tr>
<td>Sourcing/procurement</td>
<td>4.0%</td>
</tr>
<tr>
<td>Other</td>
<td>4.0%</td>
</tr>
</tbody>
</table>

N=75

We asked respondents whether they are involved in planning and/or purchasing of network equipment. Results are shown in Figure 14.

**Figure 14: Respondent Involvement in Network Equipment Planning/Purchasing**

- Yes: 80%
- No: 20%

N=75

The 75 qualified respondents to our survey include 53 unique operators from all major geographic regions (excluding North America). The following are all of the operators included in the survey results:
• ANTEL
• Batelco
• BT
• China Mobile
• Claro
• CYTA
• Deutsche Telekom
• Digi
• Er-Telecom Holding
• H3G
• HKT
• iQ Networks
• Jawwal
• JSC RASCOM
• KIFÜ
• Kyivstar
• LGU+
• Libyana Mobile Phone
• Lifecell
• Megafon
• Millicom
• Mobily
• Movistar
• MTN
• MTS
• Multimedia Polska
• Nuevatel
• ONI Telecom
• Optus
• Orange
• PLDT Inc.
• Portugal Telecom
• Reliance
• Safaricom
• SINET
• STC
• T.S.T.T.
• Tanzania Telecommunication
• Telecom Italia
• Telefónica
• Telefónica Móviles Argentina
• Telenor
• Telstra
• T-Mobile Czech
• Triolan
• TTCL
• Ukrtelecom
• Viettel
• Viva Bahrain
• VIVO
• Vodafone
• Vodafone India
• Wind Tre