Introducing xHaul:

REWRITING THE PLAYBOOK FOR TRANSPORT NETWORKING IN THE RAN IN 5G

Executive Summary

The continuing introduction of 5G will have a profound impact on the infrastructures service providers use to deliver their offerings. The expansion of radio capacity and performance and the increased densification of cell sites for 5G generate new requirements for transport networks used in mobile operators' radio access networks (RANs) to meet. These include significant increases in the capacity of the RAN transport network, broadened support for the RAN's stringent latency controls, expanding the footprint of the network to support increased cell site densification, enhancing the modularity of network elements to support flexibility in deployments, and containing costs in as many areas of the networks as possible.

Although prior generations of RAN transport have used a relatively simple backhaul design, the scope of enhancements in 5G has stimulated developing a new, more modular network architecture dividing the path from radio sites to the mobile core into three complementary tiers named fronthaul, midhaul and (as in predecessor generations) backhaul. We refer to this set of tiers as xHaul, which in the 5G RAN can be configured in a variety of ways based on operator needs.

Supporting this architecture has motivated the development of new versions of xHaul-ready IP router, Ethernet switch, active and passive optical network, cable operator DOCSIS designs. It is stimulating development of new software in orchestration and automation to increase operational efficiencies and add speed and agility to deployments. These developments

Report Highlights

- 5G radio and cell site deployments are creating a broad, new set of requirements to be met by the transport networks SPs use in the RAN
- A new three-tier, fronthaul, midhaul, and backhaul architecture adds versatility, capacity, and efficiency in meeting these requirements
- We refer to this as xHaul in the 5G RAN
- New versions of IP router, Ethernet switch, active and passive optical network, and DOCSIS cable offerings are being developed to meet the requirements of xHaul

collectively provide operators with a new playbook to use in meeting the transport networking requirements of 5G RAN.

Initial versions of these offerings are coming to market currently (2020 and 2021). ACG foresees broader uptake for them beginning in earnest during 2022, and by 2025–2026 we believe the overall market for transport networking products in 5G RAN will be approximately twice the size of the current market for RAN transport networking products. Resulting deployments will have higher capacity, greater versatility, and an order of magnitude larger scale than mobile networks have had to date. Throughout this adoption cycle and with the introduction of new products and services, ACG will apply a multidisciplinary approach to researching its developments, innovations, economic and operational dynamics, and results. As with many of the most significant innovation cycles, we expect the outcomes to create capabilities and benefits not achievable in prior modes of operation. We look forward to researching and evaluating those accomplishments as the journey unfolds.

Report Highlights

- Being introduced now (2020–21) we expect these xHaul-ready products and designs to support approximately 50% of the world's mobile cell sites and users by 2026
- We expect the value of the resulting xHaul products market to be approximately twice the size of the current market for mobile backhaul products

TABLE OF CONTENTS

A New Transport Networking Model Is Emerging In The RAN.

For several years now, 5G has inspired a wellspring of innovation and development, producing a bold vision for the future of mobile networking, a comprehensive set of forward-looking architectures, an array of new technologies, and an imaginative mix of business and service delivery models for service providers and their ecosystems to pursue. As its technologies and offerings are adopted in coming years, 5G's impact on the infrastructures service providers use to support them will be profound.

Among the domains whose deployments will be most heavily impacted is the transport networking infrastructure providers use to carry their traffic. Although many parts of transport infrastructure will evolve, none will change more than the access networks connecting radio sites into core operator networks. We have historically called this part of the transport infrastructure backhaul.

The purpose of backhaul has been to aggregate the traffic of many cell sites into larger transport networks using a mix of Layer 1 optical, Layer 2 Ethernet/MPLS, and Layer 3 IP/MPLS technologies. Priorities overall have been on capacity and cost effectiveness.

5G introduces new considerations to the picture. The expanded radio capacities and capabilities of 5G, its higher throughput, broader scale, diversity of use cases, and more flexible deployment architectures are changing the outlook on how transport networking in the RAN needs to be designed. Operators' goals of supporting the considerable new capabilities of 5G while still controlling their overall costs has stimulated the industry to develop a new transport networking framework for the RAN, including three distinct tiers and categories of link to be supported in the networks. These tiers are:

- Fronthaul
- Midhaul
- Backhaul

Figure 1 shows how they fit into the RAN transport networking infrastructure.

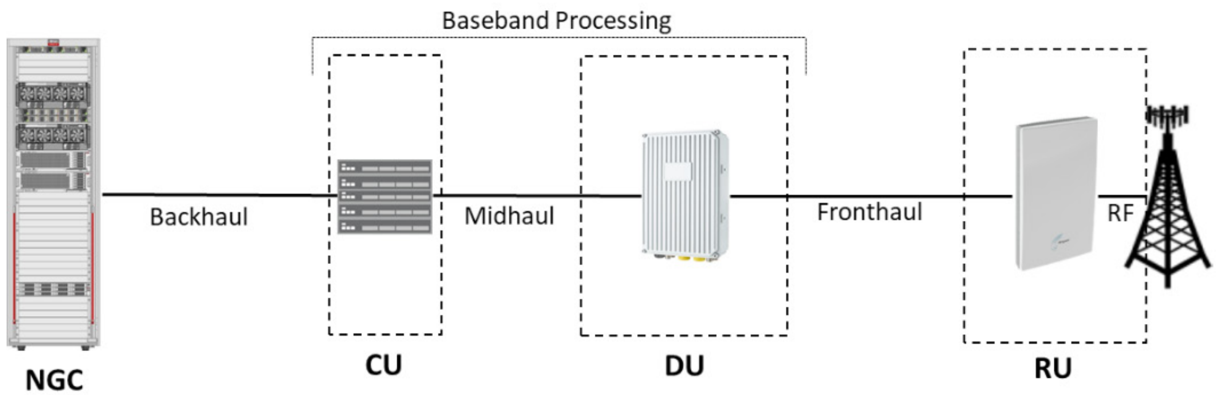

Figure 1. Adding Fronthaul and Midhaul Links to Backhaul in Transport Networks for the 5G RAN

This combination of links has been referred to as anyhaul and xHaul in various contexts in industry initiatives. For simplicity and consistency in our discussion, we will use xHaul to refer to this collection of network links.

As one would expect from its name, fronthaul is the portion of the network connecting the radio equipment at the cell site (the Remote Unit, RU) to the baseband processing equipment in the Radio Access Network (RAN), whether that baseband equipment is collocated with the radio at the cell site or located remotely from it. Midhaul is the portion used to interconnect the equipment performing baseband processing when these functions are split out and performed in separate units at different sites (such as in the Distributed Unit, DU, and the Central Unit, CU shown in the diagram).

Backhaul is the portion of the network connecting the baseband processing infrastructure (whether integrated or disaggregated) to the next generation core of 5G. Backhaul in 5G plays generally the same role as backhaul has historically performed, except supporting higher capacities, greater service versatility and more robust software controls than has been the case before.
Now that we have an outline of the framework of the emerging RAN transport network in 5G, in the remainder of this paper we:

- Clarify why the new xHaul framework has been developed
- Highlight requirements the xHaul infrastructure needs to meet
- Outline developments that key participants in the industry are pursuing to meet these requirements
- Share our perspective on the likely timing and scale of adoption of new xHaul platforms
- Summarize the work we are doing at ACG to analyze this new market segment, which is intricately connected to our ongoing research in adjacent areas

Why The xHaul Framework Is Emerging

xHaul is designed to support new service offerings being brought to market in 5G. Specific aspects of new radios and their operation in 5G and the nature of many services 5G will introduce, generate the need for this new last-mile design.

The first consideration in the new design is to meet 5G's significantly higher transport capacity requirements (especially in fronthaul) than its predecessor backhaul designs. The amount of fronthaul capacity needed varies with the type of radios installed at a given radio site. Table 1 gives an indication of the capacities required in some of the fronthaul links between the radios and the baseband controls using existing transport protocols.

Antenna	10 MHz	20 MHz	100 MHz
1	0.49 Gbps	0.98 Gbps	4.9 Gbps
4	1.96 Gbps	3.92 Gbps	19.6 Gbps
8	3.92 Gbps	7.84 Gbps	39.2 Gbps
32	15.68 Gbps	31.36 Gbps	156.8 Gbps
64	31.36 Gbps	62.72 Gbps	313.6 Gbps

Table 1. Fronthaul Bandwidth Required as a Function of Radio Size [1]

Although this table does not illustrate all of the possible fronthaul configurations of 5G, it gives a clear indication that supporting 5G using existing 'native Common Public Radio Interface (CPRI) protocols can introduce several 100 Gbps of transport on the fronthaul links between the radios and their controls.

A second factor influencing the development of xHaul configurations is the increased densification of radio deployments expected to occur in 5G. Densities will increase partially as a function of increased numbers of macro cell sites. They will also increase as more small cells are deployed to broaden coverage. Although small cell increases will not impact fronthaul capacities in the same manner as macro cell installations do, they will increase the capacity required in the aggregation of traffic from serving areas into the operators' midhaul and backhaul transport networks.

[1] From Preparing Transport Networks for 5G, Viavi Solutions, 2019, and related 3GPP and ITU specifications.

What Requirements Does The New Framework Address?

5G introduces a number of new requirements for the new RAN transport network to meet. We highlight several of the most important of them here. In the 5G RAN, the xHaul transport network must:

- Support fronthaul using the CPRI protocol and its newly created sibling, the Enhanced CPRI (eCPRI) protocol;
- support increased transport bandwidth and throughput;
- support the tightly bounded latencies of 5G;
- allow for varying degrees of disaggregation and protocol split;
- support advanced radio control functionalities;
- support significantly enhanced automation in the life cycle of deploying and operating the transport network;
- enable network slicing;
- coexist with previous generations of mobile network technology.

Introducing eCPRI

CPRI is well-established as the protocol used between cell site radios and their baseband controllers. The link carrying CPRI traffic is the fronthaul link. CPRI based links are not optimized for bandwidth efficiency. When considering disaggregation of baseband controls and placing some of them remotely from the radio site (to control costs and enable the networks to scale) using native CPRI in that link would generate an enormous amount of traffic for them to carry (see Table 1). This consideration stimulated the work to develop eCPRI, which reduces the amount of RF signal information carried over the fronthaul link and thus reduces the bandwidth required in it compared to a native CPRI link, enabling deployment of baseband processing in virtualized computing pools as far as 20 kilometers away from the radio sites.

Disaggregating Baseband Processing and Allowing for Flexible Configurations

Mobile traffic is transported using a layered radio network protocol hierarchy in the RAN. It comprises (similarly to other hierarchies) PHY, MAC, link control (RLC), packet adaptation (PDCP) and control plane (RRC) layers. To create flexibility in disaggregation, architects created a set of splits to allow xHaul nodes to be configured and placed in a variety of locations based on requirements.

Figure 2 shows a subset of these splits. Each provides distinct functionality, ranging from much control located at the radio site (for example, Split 2) to much control installed remotely from the site (for example, Splits 7 and 8). Because the higher numbered splits require more of the signals to be processed remotely, fronthaul capacity in those cases is greater than in the lower numbered splits. This increase in capacity is represented by the thicker transport links in the diagram for the higher numbered splits. The trade-off in deciding which split to use is that units at the radio site in the higher numbered splits can be designed more economically than in the lower numbered splits (because the higher numbered splits reduce the amount of functionality required at the radio site) and control processing performed on behalf of the radios in the higher numbered splits can be more robust. For example, when co-locating higher levels of processing for multiple radios in a remote virtual computing pool, important control functions such as carrier aggregation, spectrum sharing, interference management, and coordinated multipoint processing can be done more flexibly and efficiently for the cells that are under their control.

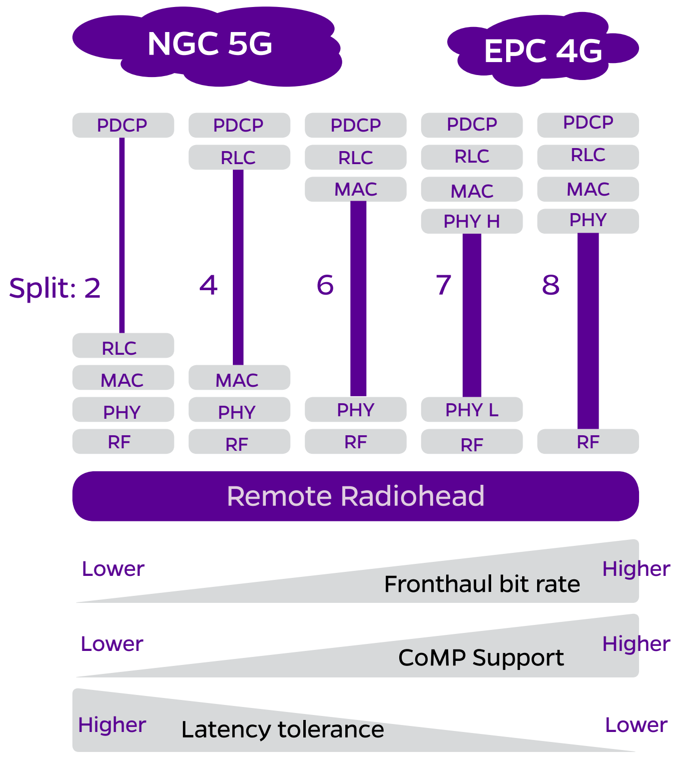

Figure 2. Radio Protocol Processing Splits and the Transport Networking Configurations They Create

Based on the diagram from the Viavi 5G FH Handbook

Enter RUs, DUs, and CUs

To realize the splits, baseband controller functionality has been divided into RU, DU and CU combinations (as depicted previously in Figure 1). The composition of these in a deployment, especially of DU and CU, varies by split. One primary value of these unit names is that they provide clear terminology for identifying how the layers of the hierarchy can be deployed in a given split. In the more disaggregated splits, they describe functionality in the devices deployed at each point in the topology.

A view of how the protocol layers are aligned into different splits is shown in Figure 3.

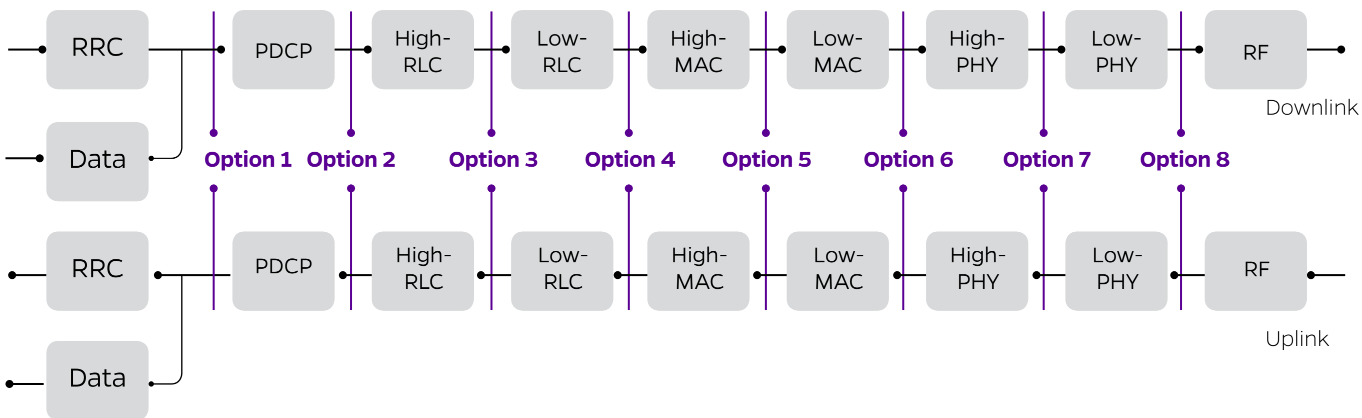

Figure 3. Options for Implementing the Radio Protocol Splits in xHaul Designs

Split numbers in Figure 3 are aligned with the numbers in Figure 2. How the splits are supported in products and deployments is an essential element of xHaul design. How the economics and operation of the splits compare, and how they meet operators' goals will be the ultimate litmus test of their value.

Add Midhaul to Fronthaul and Backhaul

Reflecting on the two preceding diagrams we see, in a Split 2 configuration, the cost of cell site equipment will be relatively high and the amount of bandwidth connecting the site to the backhaul infrastructure relatively low. By comparison, in a split such as 7.2, the cost of radio site equipment will be relatively low, while the bandwidth of the transport to the DU site will be high.

Also, because the latency between the RU and the DU must be kept to less than 100 μs (microseconds) a deployment that disaggregates DUs requires them to be kept within 20 km of the radios they support. Although DUs must function within these tolerances, the same is not true for CUs. Functions that CUs are processing can tolerate higher latencies. Thus, CUs can be aggregated farther away from radio sites than DUs. This introduces a two-stage xHaul aggregation, in which the first stage is deployed between RUs and DUs (for fronthaul) and a second stage is deployed between DUs and CUs (for midhaul).

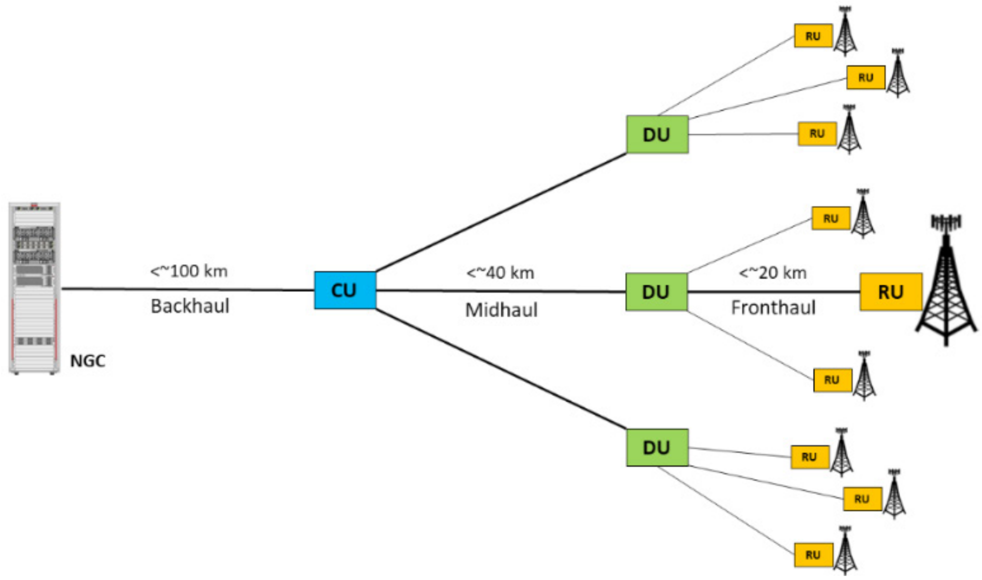

Figure 4. Aggregation of Midhaul and Fronthaul Connections

The composition of DU and CU remains based on which split is supported. In all cases the amount of bandwidth required in fronthaul far exceeds the amount required for midhaul. From this it is easy to see that the composition and topology of the xHaul network will include links and capacities and functions not present in its predecessor backhaul designs. A new design model is required.

xHaul Deployments Will Need Substantial Automation to be Deployed Efficiently, and at Scale

In addition to expanding the capacity and performance of mobile networks, 5G will dramatically expand their scale and versatility as well. Understanding this, operators will do everything they can to simplify operations with added intelligence in their infrastructures and expanded software controls. Beyond this, to support a wider variety of services, operators hope to leverage network slicing to provide services with distinct functional attributes for a range of different customers over a common and highly versatile network. Slicing will occur at every level of configuration (from radio to transport link to forwarding node; in control planes, analytics, in network cores and in the cloud). Accomplishing this requires a degree of automation that has not been available in the past. Although progress has been made toward these goals in the earlier stages of SDN, NFV, and MANO, continued enhancements will be required to reach the objectives of 5G.

How Are RAN Transport Designs Evolving To Meet These Requirements?

Network equipment and virtual network function (VNF) suppliers, service providers, standards development organizations and industry consortia[2] have being creating reference architectures and designs to meet these requirements at multiple layers of the operational stack.

For example, the companies that are party to the CPRI specification have collaborated on developing eCPRI for xHaul.[3] eCPRI is being designed into new radio and transport nodes, including interworking functions (IWFs) to allow CPRI and eCPRI to be carried over the same transport path. In parallel the IEEE has developed specifications for an enhanced version of Ethernet to support time synchronization and latency controls in xHaul, called Time Sensitive Networking (TSN).[4] Products supporting TSN are beginning to arrive to the market now.

Simultaneously, transport product vendors and industry consortia have invested in developing a new generation of 5G xHaul routers and switches to address requirements for:

- Increased capacities (from about 1 Gbps per radio site to capacities ranging from 10 to 20 to 100 Gbps per site);
- increased forwarding and traffic control (supporting eCPRI, IWFs, TSN, clock synchronization, new Internet protocols, telemetry, and slicing at every layer);
- enhanced power and space efficiency; and
- smooth integration with backhaul and core transport (via IP/MPLS, Segment Routing, Carrier Ethernet, and Synchronous Ethernet).

[2] Such as the O-RAN Alliance (https://www.o-ran.org/) and the Telecom Infrastructure Project or TIP (https://telecominfraproject.com/).

[3] https://www.gigalight.com/downloads/standards/ecpri-specification.pdf

[4] https://1.ieee802.org/tsn/

Some of these platforms are designed as units for the radio site, called either cell site routers or cell site gateways. (For simplicity in the remainder of the paper we will refer to these as CSxs). These often have complementary products in suppliers' portfolios for use in aggregation roles, at a CU, VRAN or backhaul aggregation site. This new generation is designed to support both 5G and traffic of prior generations (2G/3G/4G) in converged transport. They are also capable of supporting other types of services (such as enterprise VPNs) and in this way are capable of providing a versatile component for operators in the 5G transport mix.

In an adjacent service provider segment, cable multisystem operators (MSOs) are enhancing the DOCSIS protocol to increase its capacities and improve its support for latency guarantees.[5] Although these improvements may ultimately be better for small cell aggregation, they will enable MSOs to play a role in 5G, giving mobile operators options in meeting their transport requirements. There are also enhancements being explored in passive optical networking (PON) (a parallel broadband access domain) with similar attributes to those being investigated for DOCSIS, which may be useful for similar reasons.[6]

Further to these transport node and transport medium-related developments, suppliers of VRAN and other 5G network software are providing new modules for CU and other 5G functions to run in the virtualized computing pools included in many xHaul designs.

Finally, there are significant advances being made in software for automation, analytics, orchestration, and life cycle management to simplify deployments. These are occurring at multiple layers of stack and in many types of applications. Silicon and operating software in new xHaul network nodes are more capable of capturing metrics, reporting them, and making updates and optimizations in real time than prior generations of equipment. Orchestration and analytics software are more capable of integrating multiple layers and domains of operation (such as mobile core and network transport or metro area and xHaul networks) into a more scalable and versatile management environment than has been possible in the past.

All of these are leading toward a more powerful networking environment for 5G services on which to rely. Each makes its own contribution, and together they supply the xHaul capabilities 5G requires.

[5] Low Latency Mobile Xhaul over DOCSIS Technology, CableLabs Specification CM-SP-LLX-I01-190628, 2019.
[6] ITU-T Series G Supplement 66–5G Wireless Fronthaul Requirements in a Passive Optical Network, 7-2019.

How Soon Will These New Offerings Be Deployed Into Operators' 5G Networks?

5G is in its early stages of deployment now (CY 2020 and 2021), and operators have generally not started upgrading their RAN transport networks in the manner we are describing in this document, such as by introducing disaggregated DU-CU designs. Early deployments have been done with BBUs retained at radio sites to concentrate on validating 5G functionality, deferring until a later time the work of reconfiguring the xHaul network.
This said, as the installation of 5G sites expands, requirements to economize on transport, and integrate sites into a more robust, higher capacity infrastructure will increase. Tipping points will emerge on an operator by operator (and a region by region) basis that will trigger the deployment of disaggregated BBUs and incrementally lead to the installation of xHaul configurations.

Within individual product categories, new xHaul switches and routers (CSxs, TSN switches, and access/aggregation nodes) are being brought to market now (CY 2020) and will be used in test and trial modes by operators during 2020 and 2021. We expect incrementally broader adoption of disaggregated xHaul taking advantage of these new platforms during 2022. We expect this will be true in North American, European, and Asia-Pacific operators. We expect early stages of cable and residential broadband (PON) use in xHaul—at least for small cell aggregation—to expand beyond trial modes in the 2022 time frame.

These timelines correspond with when 5G core and VRAN software will begin to materialize in operators' distributed configurations. They are also the time frames in which orchestration and automation software that supports xHaul will be progressing to support cross-domain operations in xHaul and neighboring backhaul and core. In parallel this software will be in the early stages of integrating northbound with end-to-end service orchestration software at this timing to begin early stages of testing in network slicing and streamlined activation of new service offerings.
We expect integration of xHaul with backhaul and core transport to be relatively straightforward (compared with creating the new xHaul infrastructures themselves). One reason is the packet and optical transport employed in these domains will be using relatively evolutionary implementations of IP, Ethernet, and optical transport that we expect to support 5G gracefully. Yes, capacities will increase (400 Gbps and higher will be used). Support for enhanced forwarding will expand, as segment routing in IP and robust carrier Ethernet are deployed. The functionality of software controls in multi-layer, multi-domain, and multi-vendor environments will increase. All of this will accrue to the benefit of 5G and should provide an important but somewhat less challenging evolution for backhaul and core than the xHaul transformation will involve for the RAN.

How Big Will The Market For New xHaul RAN Transport Networking Elements Be?

This is ultimately a question to be answered in ongoing analysis as the uptake for 5G proceeds. We have a preliminary perspective that helps shape our analysis of developments, which is worth highlighting at this stage. To preview that, we expect the xHaul transport networking market to be approximately double the size of the current mobile backhaul networking products market in the 2025–2026 time frame.

Why do we think this is likely? Fundamentally, we know 5G will require both higher capacity and richer functionality in RAN transport than has been used up until now. This will be true at the cell site, at new front-haul/mid-haul aggregation sites, and at backhaul integration sites. While this is the case at a high level, let us consider the impact these uptakes will have on each of the equipment categories involved. This includes CSxs, packet/optical transport, and aggregation switch/router nodes.[7]

As a baseline, let us note the existing market for RAN transport (backhaul) equipment has a run rate slightly greater than $4 billion per year[8]. This includes each of the aforementioned categories.

Now consider the potential size of the xHaul RAN transport networking market at a point of approximately equivalent maturity in the adoption of 5G, five to six years hence.

Starting with next-generation CSxs, we know from our discussion of 5G radio sites (Figures 2 and 3, for example) that there will be a mix of fronthaul configurations deployed (Splits 2 and 7, for example). If we make an assumption that 50% of the cell sites in the world will have 5G radios installed by 2025, then at least 3 million cell sites will have 5G radios in them at that time.[9] If we make a further assumption that 50% of the 5G sites will use disaggregated

[7] We are also interested in the impact of xHaul on DOCSIS/cable and PON/broadband fiber access supplier markets but are limiting the discussion to the three categories mentioned here in this paper, for the sake of brevity and to keep the sizing conversation at the broader impact level (versus deeper details, which we take up in category research on an ongoing basis).

[8] Based on analyses and data from ACG's existing worldwide SP routing, switching, optical transport, and mobile network infrastructure vendor revenue analyses, as well as secondary market data sources.

[9] Using estimates of total cell site counts today as approximating 7 million, and projections that over 50% of the global population will be reached by 5G network services by 2025 (Ericsson Mobility Report, November 2019).

baseband then and the other 50% will use integrated baseband, we will have over 1.5 million xHaul CSxs deployed. We know there will be different CSx configurations based on whether they are at the cell site, supporting only equipment at that site or they are installed at a DU aggregation site, supporting eCPRI aggregation and other functions for 10s of remote 5G radios. If we make a further assumption that the average selling price of an xHaul CSX on the whole is in the neighborhood of $7K [10], then by 2026 mobile operators will have bought and deployed on the order of $12 billion worth of CSxs. Taken on a linear basis using equal amounts each year, this portion of the xHaul market alone would have a run rate of $2.4 billion per year. However, it is more likely the adoption rate will be lower in 2021 and 2022 than it will be in 2025 and 2026. So it is safer to say the segment size in 2026 will be more on the order of $3 billion per year, using those assumptions.

On its own this approximates the size of the total current RAN backhaul and transport networking equipment market, as previously summarized. If we add the likely value by 2025 of two additional major categories of transport equipment in xHaul—packet/optical transport and aggregation switch/router nodes—we emerge with a prognosis for a substantially larger market size for xHaul transport equipment than the size of the current market.
To give this a bit more color, consider just a couple of aspects of each of these final categories in the process. In the case of packet/optical equipment, because of the increased capacity and amount of aggregation required in the RAN for 5G, we know the number of 100, 200, and 400 Gb/s links required in xHaul topologies will be significantly greater than the number that has been required in prior generations. This is partially because of the higher throughputs of 5G radios and also because of the increased cell densification 5G will have. Based on capacity predictions it could easily be that the number of packet/optical nodes required for xHaul compared with prior backhaul deployments will double in number.

Adding this to support the 50% of the global RAN transport we expect to be required by 2025 adds an additional $2 billion per year to this category's revenue (beyond the $2 billion per year already spent). This takes us to the range of $8 billion per year after CSxs and packet optical transport have been accounted for.

Finally we can make a similar observation about the number of 400 GE switch/router ports that required at the boundary of the xHaul and the backhaul domains. Because of the increased traffic being carried in the transport networks (projected to quadruple by 2025) and of the increasing amounts of traffic being carried closer to the edge of operator networks, we expect capacity expansion at the xHaul/backhaul boundary to be a high priority. If capacity in this portion of the infrastructure is doubled by 2025 it will add an additional $1.5 to $2 billion to the xHaul infrastructure spend.

[10] This is the average selling price after discounts, not the vendor's list price, and includes optics. ASP tends to be at least 60% below list for offerings of this type.

Depending on where one draws the line on categories of equipment to include in the RAN transport networking investment, it is clear the aggregate spend operators will make to supply transport in their 5G RANs will be at least two times higher than the investments per year they have made in supporting backhaul transport to date.

Will there be enough revenue in 5G services for operators to make the investments they have made in bringing the new services to market (including xHaul transport) to create the returns they seek? That, of course, is the multi-billion dollar question in the early build-out stages of 5G plans. It is a question we will consider on many levels going forward as 5G offerings materialize.

How is ACG Working on the Developments Shaping the xHaul Transformation

ACG is pursuing a multi-disciplinary program of research in xHaul. We can see from the discussion in this analysis there are close synergies in the adoption and use of multiple different product classes in building xHaul out. It will be a new topology supporting a heterogeneous mix of sites and services. A new design and deployment playbook will be used.

In researching this evolution we will consider the technical and operational requirements of xHaul, the nature of its product developments, operators' perspectives on the deployments they are making, the timing of deployments, and results being achieved. We will do this in coordination with analyses we do in closely related network infrastructure categories:

- 4G and 5G mobile/wireless networks overall
- IP/MPLS, Segment Routing, and Ethernet transport
- Active and passive optical networking transport
- Cable operators' DOCSIS networks
- Private, hybrid and public cloud environments
- Edge computing installations
- Network and service orchestration
- Use cases, applications and services shaping the direction of the deployments

As we do in each of our categories of research, in xHaul we will:

- Perform primary research on goals and criteria operators are using in making their decisions and on how their choices align with the new 5G services they are offering;
- retain close interactions with suppliers in each of the product categories used (IP, Ethernet, DOCSIS, packet-optical, cloud-native, analytics, control, and orchestration);
- engage with industry consortia working on architectures and standards focused on xHaul;
- Do in-depth analyses of the TCO, return on investment, and the economic impact of alternative xHaul implementations.
- communicate our findings on industry media platforms as well as on our own web site;
- engage with clients in private studies and ongoing syndicated research, as well as publicly offered communications and reports.

In all of this we will focus on the motivations for and the nature of the initiatives being pursued in xHaul for 5G and the results they are achieving.