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# Building Flexible and Open Architectures for 5G

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## INTRODUCTION

Even as operators launch their initial 5G services around the globe, big architectural decisions remain for the future of the radio access network (RAN). The RAN is the critical infrastructure that includes the 5G radio functions as well as the baseband and higher layer processing to coordinate communications and connect traffic to the core. Momentum is increasing around new open and disaggregated RAN architectures being championed by a growing list of Tier 1 operators and several influential standards groups and organizations.

Taking a holistic view of the 5G network, this white paper provides an overview of the major challenges operators face as they move to 5G and then describes how operators are looking to open and disaggregated architectures to address these challenges. With the core largely completed, the RAN and transport networks are the new focus areas for openness and disaggregation. This paper profiles some of the most influential organizations promoting open interfaces and concludes with a summary of the implications of open architectures and disaggregation for next-generation transport networks.

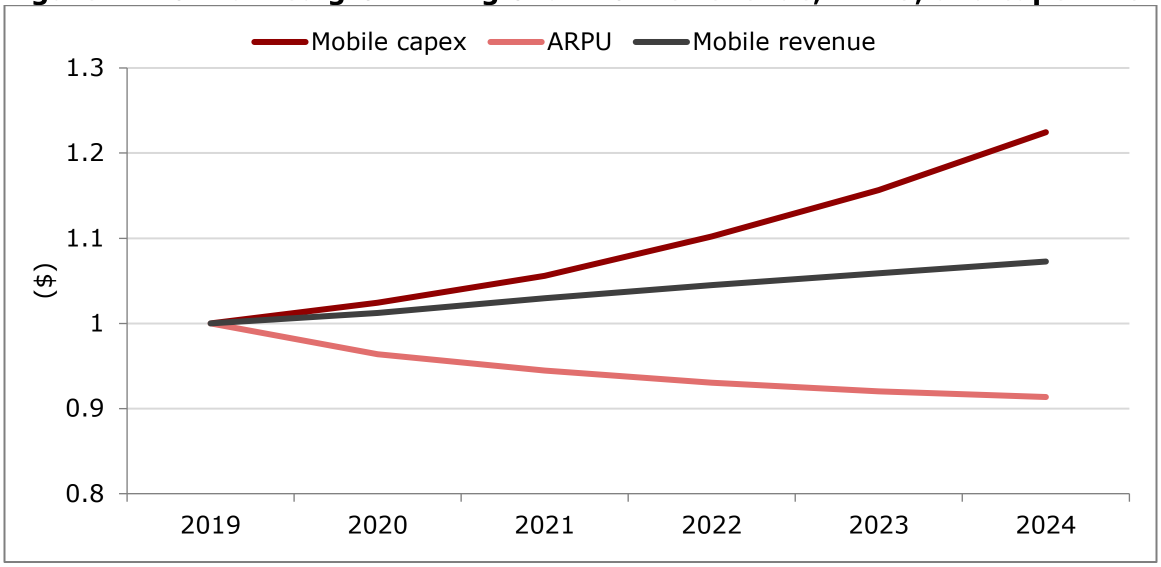
## OPERATOR CHALLENGES MOVING TO 5G

3GPP is currently working to finalize Release 16, known as 5G Phase 2. For the first time, Release 16 will make the full functionality promised by 5G available, including ultra-reliable low latency communication (URLLC) and massive machine-type communication (mMTC) use cases—in addition to the enhanced mobile broadband functionality that was the focus of Release 15. With some delays, Release 16 is now slated for completion in June 2020.

Network operators see opportunities in 5G and are moving aggressively and globally to enter the market, even as they await full 5G standardization. The Ookla site tracks 5G commercial activity and updates its data weekly. As of April 6, the site counted more than 7,400 commercial 5G deployments from 118 network operators globally. This includes the number of cities offering commercial 5G multiplied by the number of operators in each city (many cities already have multiple competing operators). As of the end of 2019, Omdia counted more than 19 million 5G subscriptions globally and forecasts that 5G subscriptions will increase at a 153% CAGR from 2019 to 2024.

But a deeper look at the data shows a complicated picture for operators looking to build out their networks to support the new 5G opportunities. In the vast majority of cases, 5G deployments are not greenfield. Operators offer a mixed of mobile services (or a mix of mobile and fixed services in the case of converged operators) and have existing networks in place for those services. Taken as a whole, the growth prospects for mobile operators are challenging. Overall, global mobile revenue is forecast to increase at just 1% annually, while ARPU is expected to continue to decline. Given the need for new 5G networks, however, mobile capex is set to increase faster than revenue growth (see **Figure 1**).

**Figure 1: Normalized growth in global mobile revenue, ARPU, and capex: 2019–24**




*Source: Omdia, March 2020*

Operators are under great pressure to drive the greatest efficiency in their networks when building out 5G infrastructure. They must do more with less. The flat and declining ARPUs also put great pressure on operators to expand beyond the consumer market to enterprise and industrial applications to drive future revenue and ARPU growth.

## OPENING THE RADIO ACCESS NETWORK

In mobile networks today, interoperability is common in the air interface, where standards-compliant mobile devices can operate over many operator networks. Interoperability is also common in the core of the network. The RAN, however, has remained closed and proprietary. As a result, many radio and baseband unit (RU and BBU) components that make up the RAN do not interoperate and cannot be mixed and matched across multiple vendors. Communications interfaces between subsystems are proprietary.

The momentum around open interfaces is changing, however, with the introduction of the open RAN concept. Heavy Reading defines open RAN as the ability to integrate, deploy, and operate RANs using components, subsystems, and software sourced from multiple suppliers. In 5G, the subsystems are the antenna unit (AU), the RU, the digital unit (DU), and the centralized unit (CU).

Major operators, including AT&T, China Mobile, Deutsche Telecom, NTT DoCoMo, Telefónica, and many others, are leading the charge in opening the RAN. They are working through organizations such as 3GPP, the O-RAN Alliance, Telecom Infra Project (TIP), Small Cell Forum, and others.

Against the backdrop of challenges operators face in moving to 5G, why is opening the RAN becoming such a priority? Based on global surveys of network operators combined with one-on-one interviews, Heavy Reading sees the following as the primary benefits driving the open RAN trend:

- **Break vendor-proprietary RAN lock-in:** Historically, RAN functions have been closed and proprietary, with all functions supplied by the same vendor. 3GPP decomposes the 5G RAN into separate RU, DU, and CU functional components. Centralized RAN architectures, a key component of 5G, physically separate the RU, DU, and CU components in the access network. In the absence of open interoperability, however, these components will continue to be vendor-specific and supplied by a single vendor. At the heart of the issue for many operators is the fact that the RAN market has consolidated so that just three vendors—Ericsson, Nokia, and Huawei—collectively account for about 80% of the global market, according to Omdia.
- **Reduce network costs:** The RAN accounts for about 70% of the total cost of a network build (per Accenture), so it is the segment of greatest concern. Opening the RAN presents opportunities for new entrants, leading to greater competition and thus lower pricing. But there are also other aspects that contribute to lower costs. The disaggregation of hardware and software creates new opportunities for radio software running on low cost white box hardware.
- **Offer new services and monetization opportunities:** Mobile ARPUs vary greatly by country, but the unmistakable trend is that ARPUs (whatever their starting point) are trending downward. With 5G, operators see an opportunity—and a necessity—to move beyond their consumer subscription base into new enterprise 5G opportunities that will drive new revenue streams to counter the downward-trending consumer APRU. 5G in general provides this opportunity, but some operators believe opening the RAN can accelerate the trend, providing benefits for private networks, venue networks, dense outdoor coverage, and other emerging applications.
- **Enable faster innovation with diverse ecosystem:** Speed of innovation is a defining characteristic of the hyperscalers, and telecom operators have been adopting hyperscaler best practices in hopes of emulating their successes. Disaggregation, open APIs, open ecosystems, and open source development are aspects of the open RAN. A key goal is to press the accelerator on telecom innovation when it comes to 5G and beyond.
- **Enable RAN virtualization:** Virtualization is another cloud/hyperscaler concept that has migrated broadly to telecom, as evidenced by the ETSI Industry Specification Group for Network Functions Virtualization (NFV). Virtualization is already happening in the mobile core with the virtualized Evolved Packet Core (EPC). Opening the RAN enables virtualization in the RAN, which presents a far greater virtualization opportunity for operators over the longer term, given the number of endpoints and contribution to network costs.

At this early stage, Heavy Reading survey data shows strong, but not unequivocal, support for open RANs. In a 2020 Heavy Reading global operator survey, 62% of respondents reported that open RAN or white box radio was at least important to their networks over the next two years, while a minority (18%) reported that open RAN is absolutely critical.

Early Tier 1 network operator adopters (including AT&T, Deutsche Telekom, China Mobile, etc.) are open RAN industry champions. Yet, significant obstacles remain, particularly in the near term, that give pause to many operators. Topping the list of concerns is assuring robustness and performance in systems that are built as white box and use multiple suppliers. A close second on the list of concerns is functional and protocol compliance across systems. Groups such as the O-RAN Alliance and TIP are working to solve these issues, but that work takes time.

# OPEN STANDARDS GROUPS AND PROGRESS

"Open RAN" is a broad concept and is not owned by any one industry group or standards body. Several industry groups have emerged to help meet the requirements of opening the RAN. Heavy Reading profiles the most significant ones in this section.

## O-RAN Alliance

The operator-led O-RAN Alliance was founded in 2018 to define requirements and help build a supply chain ecosystem around two specific objectives:

- Bringing cloud-scale economics to the RAN
- Bringing agility to the RAN

Cloud-scale economics includes adopting off-the-shelf hardware, modular software designs, and automated ways of managing infrastructure. Agility includes quickly tuning the RAN to adapt to new services and applications, breaking from big vendor development cycles, and quickly introducing new features and functions to the RAN, including internally developed ones. Cloud-scale economics and agility concepts come directly from the hyperscale world.

The founding members were AT&T, China Mobile, Deutsche Telekom, NTT DoCoMo, and Orange. Today, the alliance counts 23 operator members and more than 130 industry contributors (primarily vendors).

According to the group, openness is essential and fundamental to achieving the O-RAN Alliance's goals. Openness includes open interfaces for multi-vendor interoperability and open source software and hardware reference designs for faster innovation. "Intelligence" is also essential and fundamental. Here, the group means investment in software automation, including artificial intelligence and machine learning for hands-free and closed-loop operations.

The O-RAN Alliance is developing interfaces not yet addressed by 3GPP, including an open fronthaul between DU and RU and between CU and RAN intelligent controller (RIC) functions. The alliance has established nine working groups with ambitious technical objectives, including open fronthaul architecture, RAN cloudification, and software specifications for the New Radio (NR) protocol stack. To date, the fronthaul interface specification has been the organization's crowning achievement, as it has addressed a critical area of multi-vendor interoperability in the RAN that was not being addressed by 3GPP.

## Telecom Infra Project

In February 2016, Facebook, along with a group of 17 initial partners, announced the launch of TIP. Based on the model of the successful Open Compute Project (OCP), TIP's mission is to redesign networking hardware and software technology specifically for telecom networks, applying the benefits of open APIs and open source development. TIP has proven influential across providers and vendors and has grown its membership to more than 500 members today. With a growing membership comes a mushrooming scope of work, though the majority of TIP's existing projects focus on enabling mobility and, more specifically, fostering 5G.

**Figure 2** lists and describes TIP's current access projects in access, transport, and core networks, which are heavily (but not exclusively) focused on enabling 5G.

**Figure 2: TIP Project Groups**

| Focus | Project groups | Description |
|---|---|---|
| Access | CrowdCell | LTE relay architectures to extend indoor coverage |
| | OpenCellular | Connecting people in rural areas using open source and open ecosystem |
| | OpenRAN | Define and build 2G, 3G, and 4G disaggregated RANs on general-purpose vendor-neutral hardware and software-defined technology |
| | OpenRAN 5G NR | Define an open and disaggregated white box for a 5G NR base station that is easy to configure and deploy |
| | Wi-Fi | Foster collaboration, exploration, and standardization among organizations deploying Wi-Fi, vendors, and service providers |
| Transport | mmWave Networks | Define and advance products in the mmWave spectrum that can deliver gigabit-level data rates |
| | Non-Terrestrial Connectivity Solutions | Enable satellite, drone, balloon, and aircraft access, providing cellular connectivity focused on coverage extension and emergency relief |
| | Open Optical & Packet Transport | Define open technologies, architectures, and interfaces in IP, optical, and packet-optical networking |
| | Wireless Backhaul | Define and build next-gen modular backhaul systems for 3G, 4G, and 5G networks |

| Focus | Project groups | Description |
|---|---|---|
| Core and services | Edge Application Developer | Create open APIs and SDKs to build mobile apps running on operator edge infrastructure |
| | End-to-End Network Slicing | Develop commercially viable end-to-end network slicing ecosystem for fixed and mobile networks |
| | Open Core Network | Develop an open, cloud-native, converged core running on standardized hardware and software supporting 4G, 5G, and Wi-Fi networks |

*Source: Heavy Reading and TIP, 2020*

TIP works with other groups and standards bodies that relate to its project areas. In February, TIP and the O-RAN Alliance announced a liaison agreement to align on developing interoperable 5G RANs, including referencing O-RAN specifications. Also in February, TIP and the GSMA signed a memorandum of understanding to drive GSMA service provider requirements into TIP project groups. Additional partner agreements include those with the OpenStack Foundation, OpenAirInterface Software Alliance, Open Network Foundation (ONF), and others.

### 3GPP

The 3GPP consortium is well-known for defining standards for radio technologies dating back to 1998, including 2G, 3G, 4G, and now 5G NR technologies and standards. In the 5G RAN, 3GPP has defined the higher layer split interface (known as F1) between the DU and the CU, standardizing on Option 2. The related 3GPP standards documents are labeled TS 38.47x and are included as part of 3GPP Release 15 (known as 5G Phase 1). A standardized F1 interface for midhaul is necessary for multi-vendor interoperability among DU and CU functions supplied by different vendors.

Although 3GPP succeeded in standardizing the higher layer functional split, the organization has not moved forward with standardizing a lower layer split for RU-DU interaction, known as a fronthaul interface. Lack of direction in fronthaul standardization led directly to the formation of what is now the O-RAN Alliance in 2018.

## OPENING THE TRANSPORT NETWORK

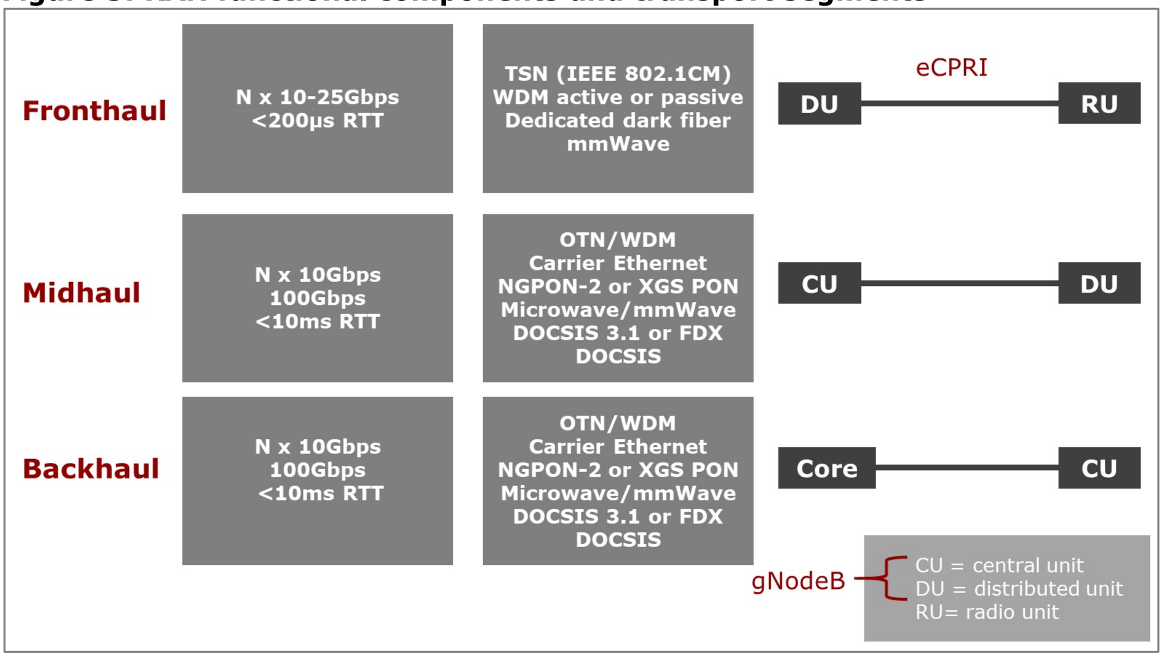
This paper has focused on the benefit of open RANs holistically. In this section, Heavy Reading focuses on the role of the transport network in contributing to open and disaggregated RAN architectures and on the trend of disaggregation in transport itself. Transport is just a piece of the network, but it is a piece that becomes far more significant in 5G due particularly to the functional decomposition of the BBU that physically separates the RAN functions in the network.

As shown in **Figure 3**, RAN functional decomposition creates distinct segments in the RAN to be addressed by transport networks in cases where those functions are physically separated in the access network. In decentralized RAN architectures dominant through most of 4G, the backhaul segment connects BBU processing with the mobile core. This is served by Ethernet.

New centralized and partially centralized RAN architectures maintain the backhaul segment but add two new segments:

- **Midhaul:** Connecting DU processing with a physically separated and centralized CU
- **Fronthaul:** Connecting the cell site-located RU to physically separated DU processing

**Figure 3: RAN functional components and transport segments**




*Source: Heavy Reading, 2020*

The fronthaul segment has been the area of greatest challenges and industry attention to date. The reasons are twofold:

- High bandwidth requirements relative to midhaul and backhaul
- Extreme latency restrictions relative to midhaul and backhaul

Keeping some Layer 1 functionality in the RU effectively reduces the fronthaul bandwidth burden by 10x compared to legacy Common Public Radio Interface (CPRI). Defined by the CPRI Cooperation as eCPRI, the development is a step forward in fronthaul performance, but achieving open interoperability across these functions has proven a challenge. 3GPP did not define a standardized lower layer functional split point, leaving vendors to define this for themselves (i.e., proprietary). In the absence of a standardized definition, the O-RAN Alliance took up this work and has defined an open interface for fronthaul (as discussed in the ***O-RAN Alliance*** section).

Even with open fronthaul, however, communications requirements between the DU and the remote RU place tight restrictions on latency—typically limiting fronthaul transmission delay between the RU and the baseband processing to 100µs. The latency restriction, in turn, has implications for transmission distance, typically restricted to 20km or less. This restriction is inherent to fronthaul and cannot be improved through standards or transport innovations.

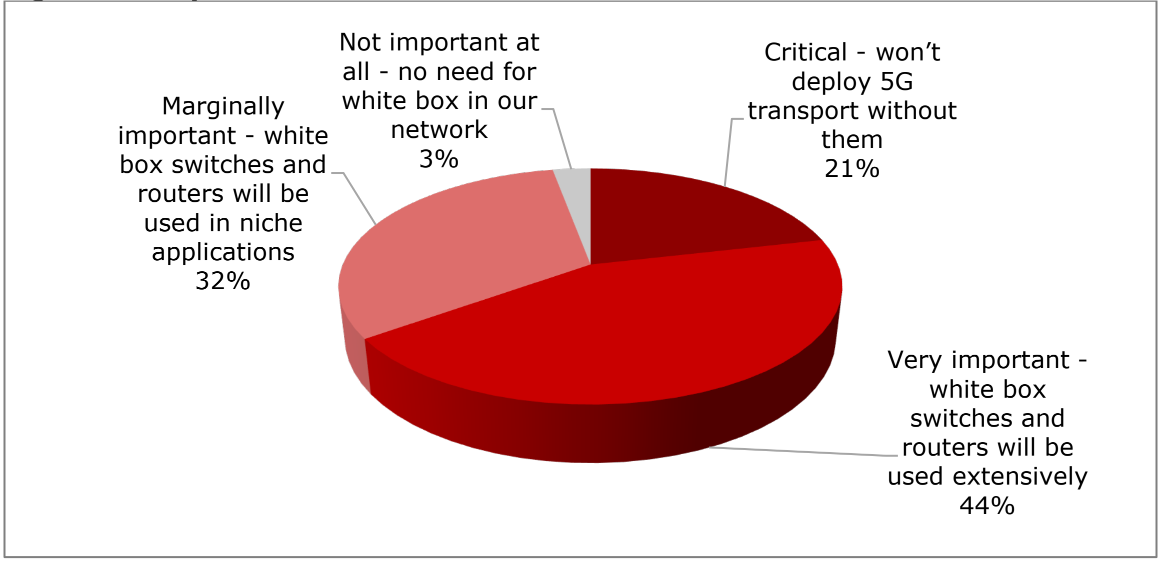
Many operators see benefits in centralizing Layer 3 processing (the CU) while distributing DU and RU functions (possibly colocating the DU/RU at the cell site). Significantly, midhaul differs greatly from fronthaul in both bandwidth requirements and latency restrictions. Layer 2 processing allows for Ethernet statistical multiplexing and transport, providing lower costs and reducing capacity burden. Operators expect 10Gbps Ethernet will be typical for midhaul connectivity. Equally significant, the 100µs network-imposed latency restriction does not exist in midhaul. Latency needs will be dictated by the applications and measured in the milliseconds range. As noted earlier, 3GPP has defined the Option 2 higher layer split option for DU and CU separation, known as the F1 interface. This midhaul standardization opens the door to open interoperability between different vendor-supplied components.

## Disaggregation in transport

Following the core and much like the RAN, the xHaul transport network is also undergoing a process of disaggregation that is being led by organizations, including TIP and OCP; Tier 1 operators, including AT&T, Deutsche Telekom, Telefónica, Vodafone, and others; and a growing hardware, software, and systems integration ecosystem. The end goals of transport equipment disaggregation are similar to the goals of opening the RAN: greater scale, flexibility, and cost efficiency with the ability to choose best-of-breed components from a wide ecosystem of suppliers, including innovative startups.

Heavy Reading research suggests that investments in disaggregated 5G xHaul transport are well-placed. In a 2019 survey, Heavy Reading asked operators about the importance of white box switching/routing for their 5G transport plans and strategy. Nearly two-thirds (65%) of respondents reported that white box switches/routers are at least "very important," with 21% of the group reporting that 5G transport will not be deployed without white box (see **Figure 4**).

**Figure 4: Importance of white box switches/routers in 5G**

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*Source: Heavy Reading, 2019*

It is still early days in commercialization, but one of the furthest along and highest profile examples of disaggregation in xHaul is TIP's disaggregated cell site gateway (DCSG) white box specification. In November 2019, Telefónica announced the first commercial deployment of the DCSG, initially in Germany. It has been working with router supplier Infinera and white box hardware supplier Edgecore Networks.

Significantly, while IP routing is important, it is not the only area of disaggregation targeted in xHaul transport. Notably, TIP has begun work on disaggregated white box wireless backhaul (as part of the Wireless Backhaul Project Group) and on millimeter wave (mmWave) for fixed wireless access, fronthaul, and backhaul applications (part of the mmWave Project Group).

## CONCLUSIONS

Operators around the globe are moving aggressively to launch 5G services, but it is a complex picture as they eye the new 5G opportunities amid a constrained environment for overall revenue growth and network spend. Operators must drive the greatest efficiency from their networks while also expanding beyond the historical consumer base to new opportunities in enterprise. To aid in this evolution, operators are taking a page from the hyperscalers' playbook: building open and disaggregated networks for maximum scale, efficiency, and agility.

The O-RAN Alliance and TIP are driving the architectures and specifications for an open RAN in which multi-vendor interoperability will ensure best-of-breed components. Here, the transport network is both an enabler for a disaggregated RAN and, ultimately, a beneficiary of disaggregation itself. As an enabler, the decomposition of RAN components makes the transport network more important than ever. As a beneficiary, the industry—led by organizations such as TIP—is in the early stages of disaggregating transport elements for fronthaul, midhaul, and backhaul. While there is work to be done, Heavy Reading research indicates that a majority of operators will be receptive.