

NETWORK BUSINESS QUARTERLY<sup>SM</sup>

# 5G Telecom Market Landscape

First Calendar Quarter 2021

Publish Date: Jan. 25, 2021

Authors: Michael Soper ([michael.soper@tbri.com](mailto:michael.soper@tbri.com)), Telecom Senior Analyst;  
Steve Vachon ([steve.vachon@tbri.com](mailto:steve.vachon@tbri.com)), Telecom Analyst

Content Editor: Chris Antlitz ([chris.antlitz@tbri.com](mailto:chris.antlitz@tbri.com)),  
Telecom Principal Analyst

 **Have questions?**

Our analysts can provide additional insights and analysis unique to your business needs. Please contact the author directly or your account executive to arrange a discussion.



# Table of Contents

## Executive Summary

- 4 5G Taxonomy
- 6 COVID-19 Impact on the 5G Market
- 7 Key Findings

## Market Impact

- 9 Market Size
- 10 Regional Summary
- 11 Technology Trends
- 12 Phases of 5G Market Development
- 13 Use Cases
- 14 Scenario Discussions

## Operator Trends

- 20 Operator Key Trends
- 21 5G Adoption Curve
- 22 Featured Operator Developments
- 24 Key 5G Deployment Announcements
- 25 5G Spectrum Developments

## Vendor Performance and Strategies

- 27 Vendor Key Trends
- 29 Disruptive Vendors

## Acquisitions and Alliances

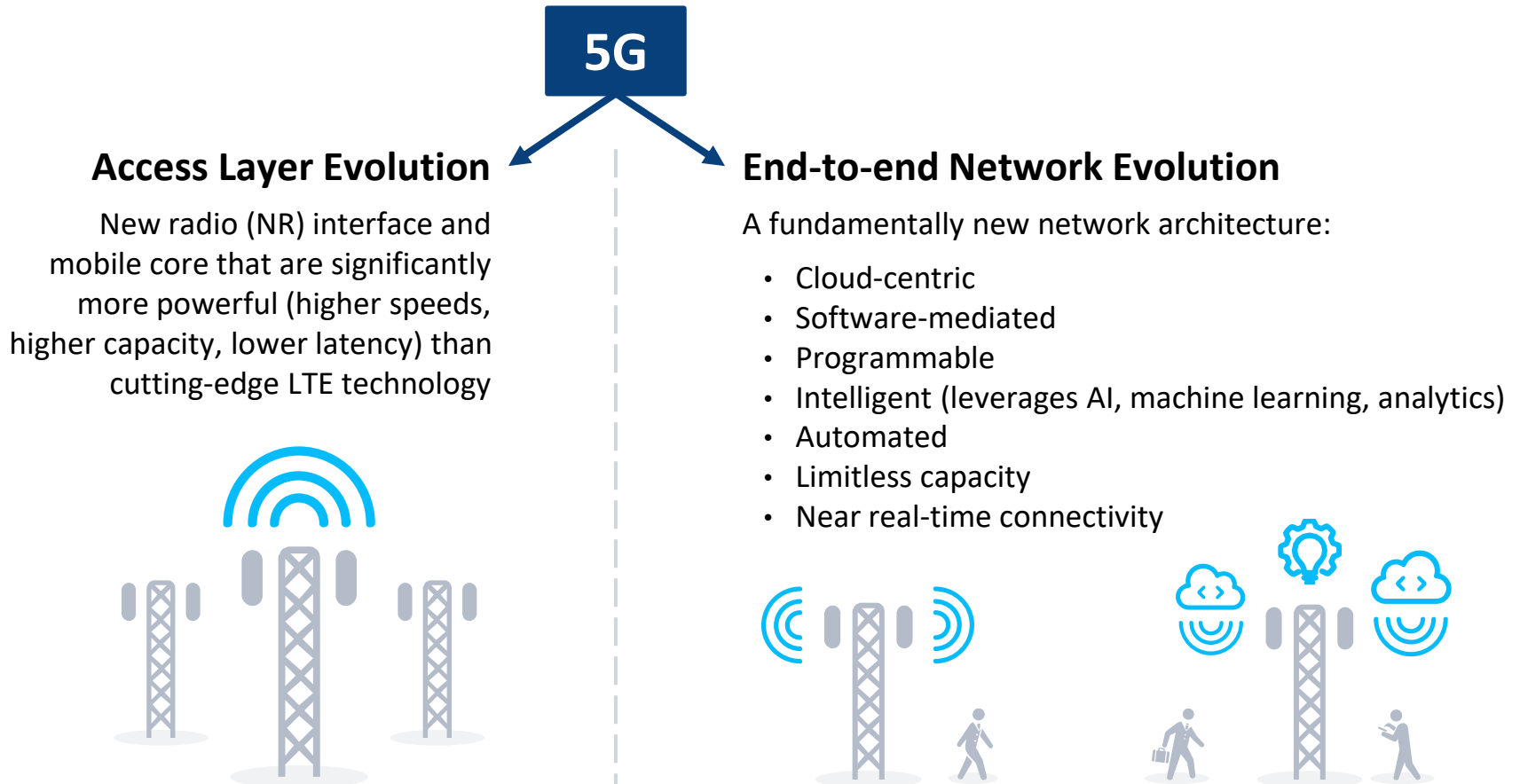
- 31 Acquisitions
- 33 Operator Alliances
- 34 Vendor Alliances

## Appendix

- 36 Definitions
- 37 About TBR

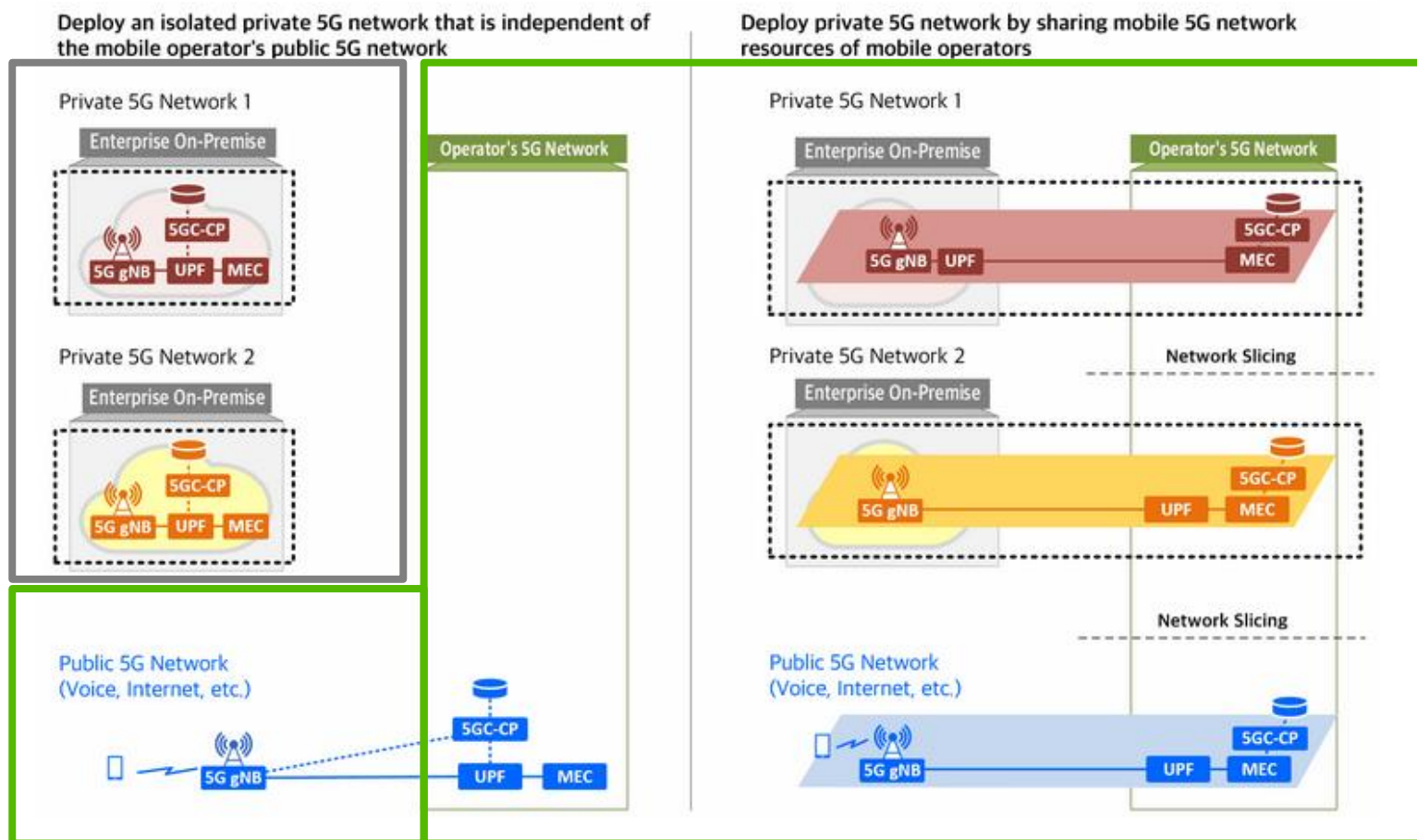
## Executive Summary

## There are 2 main ways the telecom industry characterizes 5G: An evolution of the access layer or, more broadly, an evolution of the entire network



Though TBR touches on the end-to-end network evolution aspect of 5G in this report, most of the content and all of the data in the market landscape pertain to the access layer evolution aspect of 5G, specifically as it relates to the use of 3rd Generation Partnership Project (3GPP) standards-based 5G RAN and mobile core technology. TBR's NFV/SDN reports cover the end-to-end evolution of the network in depth.

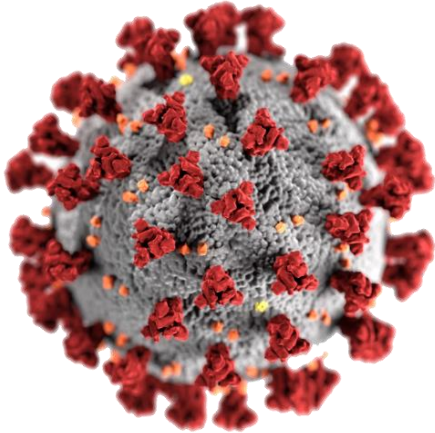
# 5G taxonomy



Note: Focus of research in this report is outlined in green. Topics covered in TBR's *Private Cellular Networks Market Landscape* and *Private Cellular Networks Market Forecast* are outlined in gray.

SOURCE: [HTTPS://WWW.NETMANIAS.COM/EN/POST/BLOG/14500/5G-EDGE-KT-SK-TELECOM/7-DEPLOYMENT-SCENARIOS-OF-PRIVATE-5G-NETWORKS](https://www.netmanias.com/en/post/blog/14500/5G-EDGE-KT-SK-TELECOM/7-DEPLOYMENT-SCENARIOS-OF-PRIVATE-5G-NETWORKS)

## COVID-19 is a catalyst for the digital era; governments in key countries are providing various types of support to ensure that 5G is widely deployed



- Governments in a growing number of countries are stepping in to support the ICT sector, which includes communication service providers (CSPs), via a range of stimulus mechanisms. This support is intended to offset the economic downturn precipitated by COVID-19 as well as to drive infrastructure development and other national agendas.
- Currently, governments in China, South Korea, Japan, Singapore, the U.K., the U.S., Taiwan and others have committed public funds to drive the adoption of new technologies to help mitigate public health issues, strengthen their national security and digitalize their economies. Governments are implementing 5G, along with edge computing, AI, blockchain and other technologies to help achieve these goals.
- This government support will help CSPs defray the capex associated with deploying 5G networks and help make a stronger business case for adopting the technology. It will also accelerate the telecom industry's migration to a stand-alone (SA) 5G architecture, which is the end-state goal.
- On a net basis, CSP spend on 5G infrastructure will accelerate through the middle of this decade as operators align with government initiatives and make use of the massive and growing pools of capital that key countries' governments are allocating for new technologies as part of stimulus and digitalization endeavors.

# Government stimulus and enterprise digital transformation will accelerate 5G deployments as societies and businesses adapt to the new normal

## Government stimulus will accelerate 5G rollouts

- An increasing number of governments worldwide are becoming directly and/or indirectly involved in ensuring new technologies, such as 5G, are widely deployed in their respective countries. This spend is, in many cases, tied to economic recovery packages to counter the impact of the COVID-19 crisis and is being justified based on economic, national security and public health grounds.
- TBR's research indicates governments worldwide will invest in excess of \$2 trillion in the ICT sector over the next five years, starting in earnest in 2021. Of that \$2 trillion, several hundred billion dollars will flow directly into the 5G market, primarily for the purposes of providing internet access to underserved and unserved people around the world as well as ensuring respective economies are able to transform to be relevant and competitive in the digital era.

## The pandemic is serving as a catalyst for enterprise digital transformation and 5G adoption

- The pandemic has accelerated enterprise interest in leveraging new technologies such as 5G as a foundational part of their digital transformations as well as for alignment with social distancing mandates and to support remote work environments.
- Leading enterprises view 5G as a future-proof platform on top of which the full scope of their digital endeavors can be supported. TBR believes sustained low latency is a primary benefit of 5G and that enterprises, particularly in verticals such as manufacturing, will increasingly realize 5G is superior to other technologies, such as LTE and Wi-Fi 6, in meeting advanced use-case requirements.

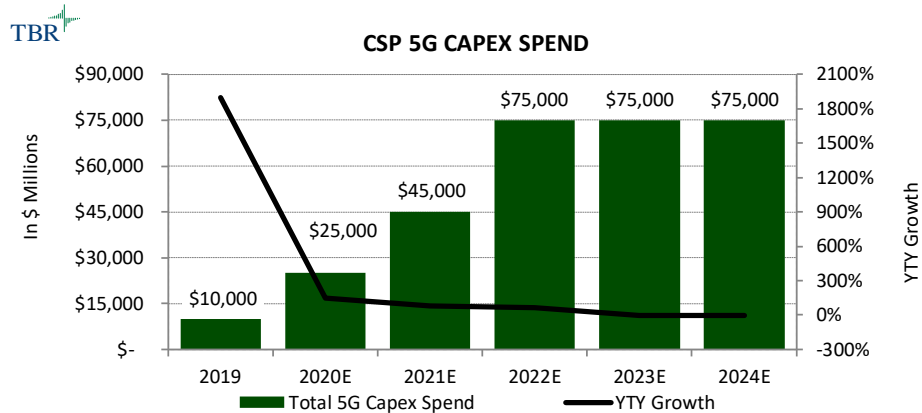
## China's CSPs will maintain an accelerated 5G RAN rollout in 2021; domestic vendors are primary beneficiaries

- Following the temporary shutdown associated with China's initial battle with COVID-19 in 1Q20, China's CSPs accelerated rollout of 5G RAN, deploying 700,000 5G base stations in 2020, in addition to the 100,000 base stations that were rolled out in 2019. China's investment in 5G will remain elevated in 2021, with between 600,000 and 1,000,000 base stations set for deployment as the government makes 5G a centerpiece technology of its newest infrastructure development initiative.
- These investments will primarily benefit China Communications Services (CCS), Huawei and ZTE, though Ericsson and smaller China-based vendor CICT are also taking part in 5G RAN builds. China's government heavily influences CSPs' contract allocation and prioritizes business for domestic firms. Huawei was allocated the bulk of business in the 5G cycle, increasing its share from the LTE cycle.
- TBR believes China's ICT ecosystem has sufficient chipsets to meet the country's 5G RAN deployment targets in 2021, which suggests the supply chain encumbrances instituted by the U.S. government are not having a significant impact on China's original deployment timelines.

## Market Impact



# Unprecedented levels of government support will help CSPs deploy 5G more quickly and broadly than originally anticipated



Note: CSP 5G capex spend includes 3GPP standards-based 5G RAN (i.e., 5G NR) and 5G core, as well as capitalized services attached to this infrastructure, such as deployment, maintenance and professional services. CSP 5G capex includes spending from telcos, cablecos and webscales.

SOURCE: TBR ESTIMATES

CSP spend on 5G infrastructure will scale faster and peak higher than originally anticipated due to the vast amount of support by governments in a range of countries, including but not limited to China, the U.S., the U.K., Japan, South Korea, Singapore and Taiwan. As a result, typical historical deployment curves for cellular technologies will not apply to the 5G market, which is now expected to be widely deployed globally by the middle of this decade instead of the later years of the decade. The pull forward and broadening of infrastructure investment are primarily due to attempts by leading countries to support their economies amid the COVID-19 crisis as well as to keep pace with China's aggressive and broad investment initiative for competitive reasons. 5G has become a highly political issue, and the unprecedented government involvement and funding is being justified on national security, economic competitiveness and public health grounds.

## Key Growth Drivers

- Government support and stimulus
- Social distancing-driven use cases — e.g., telehealth, robotics, video conferencing, gaming, education
- Dynamic spectrum sharing (DSS)
- Fresh spectrum (licensed and unlicensed)
- 5G iPhone
- Webscale network build-outs
- Need for additional capacity to support residential broadband (fixed wireless access [FWA]) due to work-from-home requirements


## Key Growth Detractors

- Complexity of new technology
- COVID-19 impact (economic and social)
- Geopolitical encumbrances (e.g., protectionism)
- Standards fracturing
- Policy roadblocks
- Supply chain issues
- Spectrum availability (auction delays)
- Tepid 5G smartphone adoption — end users view LTE as good enough for mobile broadband (MBB)

# End-user adoption of 5G is growing in nearly all developed markets, spurred by new spectrum, expanded 5G coverage and 5G device availability

## Geographic Analysis


### Americas

- 
- The balance of speed and coverage range offered by Sprint's 2.5GHz spectrum provides T-Mobile a significant advantage, spurring Verizon and AT&T to bid aggressively at the C-band auction, which received total bids exceeding \$80.9 billion following the closing of its clock phase in January, to remain competitive.
  - Tier 1 Canadian operators continue to expand 5G coverage, with Rogers currently holding an early advantage by providing coverage in 160 markets as of December. Tier 2 operators in Canada are also beginning to advance their 5G strategies, exemplified by Vidéotron launching commercial 5G services in December.

### EMEA

- 
- A memorandum of understanding (MoU) formed between Deutsche Telekom (DT), Orange, Telefonica and Vodafone in January will help the EU keep pace with market leaders such as the U.S. and Japan in open RAN. As part of the MoU, the operators will work with European authorities and industry groups such as the O-RAN Alliance and Telecom Infra Project to ensure OpenRAN becomes a viable alternative to traditional RAN.
  - MEA is trailing other regions in 5G development as the bulk of CSPs are still focused on migrating from 2G and 3G services to LTE. However, 5G development has commenced so far in all developed markets in MEA, including South Africa, the United Arab Emirates, Saudi Arabia, Kuwait, Qatar, Bahrain and Oman.

### APAC

- 
- China exceeded 250 million 5G subscribers in December, aided by the launch of lower-priced 5G subscription plans as well as broader 5G coverage and 5G device availability in the country.
  - TBR estimates South Korea reached around 12 million 5G users as of the end 2020. South Korea added 1 million 5G subscribers in November alone, driven by the launch of the iPhone 12 and other 5G handsets.
  - Although NTT Docomo, KDDI, SoftBank and Rakuten are advancing their 5G builds in Japan, the country is not expected to reach nationwide 5G coverage for several more years. The Ministry of Internal Affairs and Communications aims to have 280,000 5G base stations deployed by the end of fiscal 2023.
  - Reliance Jio intends to deploy 5G services on in-house infrastructure developed by parent company Jio Platforms beginning in 2H21, which will also enable Jio to offer its 5G solutions to other global operators.
  - Bharti Airtel is also teaming with vendors to develop its own 5G solutions, including OpenRAN technology.

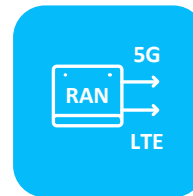
# Investments in technologies, such as DSS, IAB, open RAN and vRAN will enable operators to accelerate and improve the efficiency of 5G

## Key 5G Technologies



### Integrated Access and Backhaul (IAB)

Using millimeter wave spectrum for backhaul and/or fronthaul via IAB could help CSPs cost-effectively accelerate 5G deployments in areas where deploying fiber is not viable. IAB can also provide CSPs with a time-to-market advantage for 5G service.



### Dynamic Spectrum Sharing (DSS)

DSS will help CSPs accelerate 5G deployments by enabling the transmission of LTE and 5G signals out of the same base station while dynamically reallocating spectrum resources to align with end-user demands. Despite technical challenges with DSS, many CSPs will remain dependent on this technology to deploy 5G.



### Massive MIMO

Operators will leverage massive multiple-input, multiple-output (MIMO) to obtain significant capacity and coverage gains as well as to provide improved spectrum efficiencies.



### Open Virtual RAN (vRAN)

Open vRAN will enable operators to more cost-effectively add network capacity to support data traffic growth in the 5G era. Open vRAN also enables CSPs to integrate multiple network functions into commodity hardware while minimizing vendor lock-in.



### 5G Core


Transitioning to a cloud-native 5G core will yield benefits for CSPs, including opex savings and the ability to provide customers with dedicated network slices.



### Carrier Aggregation

Operators will tether disparate spectrum bands together using carrier aggregation to maximize wireless throughput and coverage.

## 5G investment will accelerate in the post-pandemic era as CSPs position to support advanced use cases aligned with the new normal

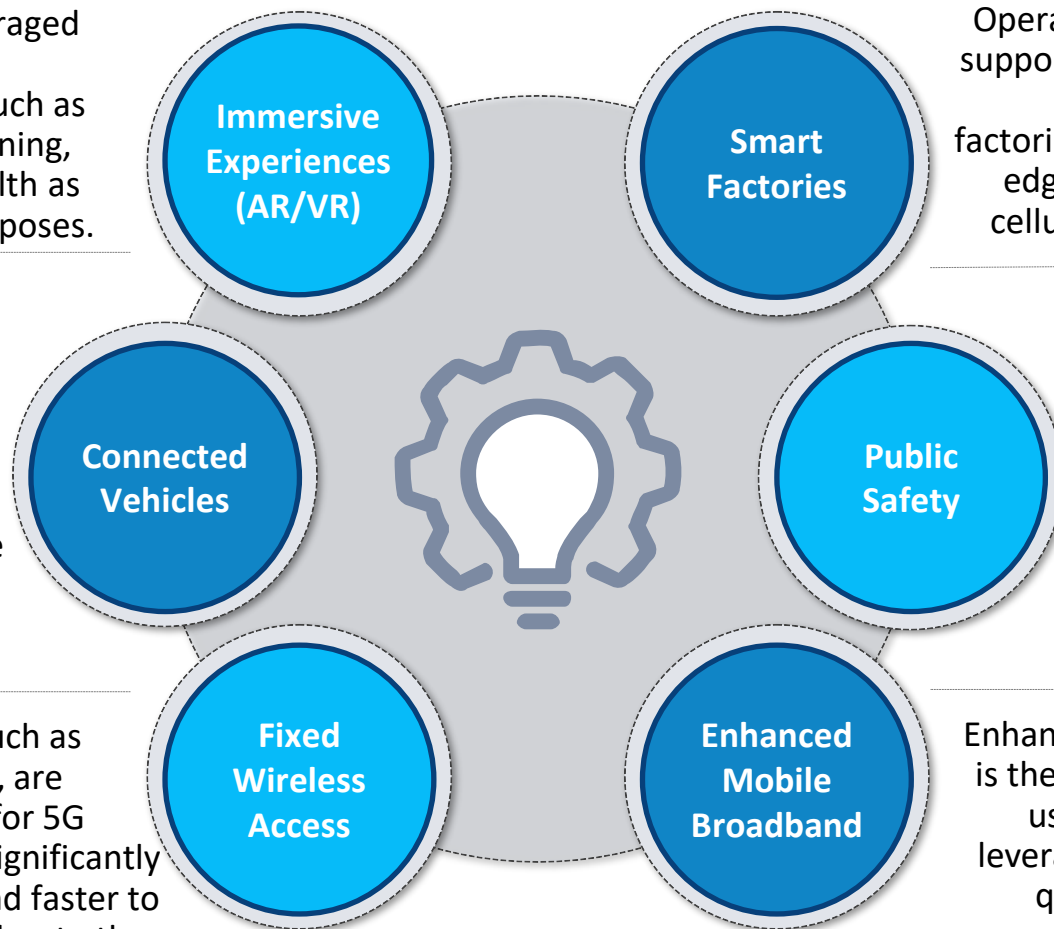
Phases of the 5G Era 		
Phase 1: Status Quo (2018-2019)	Phase 2: Post-pandemic New Normal (2020-2024)	Phase 3: Ecosystem Maturity (2025-2030)
<ul style="list-style-type: none"> <li>Operators justify 5G investment to more efficiently carry data traffic for traditional use cases of the network and for marketing and competitive purposes.</li> <li>5G Fixed Wireless Access (FWA) is a tool used by operators to compete directly with ISPs for high-speed internet subscribers via the launch of initial offerings such as Verizon 5G Home.</li> <li>Mobile 5G became available to end users in 2019 once 5G-compatible devices debuted. However, initial adoption was muted by limited use cases and service coverage as well as the high price of initial devices.</li> </ul>	<ul style="list-style-type: none"> <li>COVID-19 is a catalyst that has pushed governments in many countries to drive 5G ecosystem development via an unprecedented amount of stimulus. 5G is viewed as a must-do technology for economic competitiveness, public health and national security.</li> <li>Migration to SA is accelerated due to government pressure and because NSA is not sufficient to meet network requirements to support post-pandemic era use cases.</li> <li>3GPP Release 16 was completed in mid-2020, and Release 17 is expected to be completed in mid-2022. Both releases will make features such as URLLC, TSN, mMTC, NR-U and satellite access in 5G available.</li> </ul>	<ul style="list-style-type: none"> <li>Major economies will digitalize; Industry 4.0 will be realized in leading countries.</li> <li>Most operators in developed markets will have deployed nationwide 5G SA networks.</li> <li>CSPs will seek to capitalize on the next phase of advanced IoT solutions in areas such as autonomous driving, haptics and AR/VR.</li> <li>CSPs will leverage network slicing to provide cost-effective 5G solutions to SMBs, but in most cases, this will be supported via public infrastructure rather than private networks.</li> </ul>
<b>TBR Assessment</b> The 5G market has entered a new and different stage of development, catalyzed by the COVID-19 pandemic and the evolving geopolitical environment, with the technology increasingly under government purview and implicating CSPs in the process. Though CSPs will have to align with government mandates pertaining to 5G (such as open RAN and security compliance), there are benefits for complying with these mandates, such as more cost-efficient operations and a more economically supported path toward transforming into digital service providers.		

## 5G will enable CSPs to support ultra-low latency use cases in areas such as AR/VR, autonomous vehicles and manufacturing

AR and VR will be leveraged to create immersive experiences in areas such as gaming, employee training, education and telehealth as well as for military purposes.

Integrating 5G and edge computing with emerging technologies such as vehicle-to-everything will provide a foundation for autonomous driving.

Fiber-poor markets, such as Germany and the U.K., are attractive candidates for 5G FWA, as FWA can be significantly more cost-effective and faster to deploy compared to fiber to the premises (FTTP).



Operators are positioning to support the ultra-low latency requirements of smart factories by building out their edge compute and private cellular network portfolios.

The post-pandemic world will spur interest in leveraging 5G to support public safety use cases, such as video surveillance and HD body cameras.

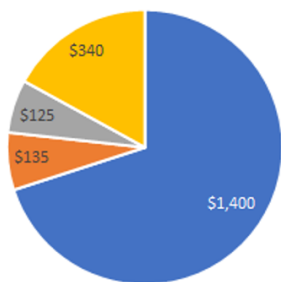
Enhanced mobile broadband is the most predominant 5G use case, which CSPs are leveraging to provide better quality of service and to more cost-effectively carry data traffic.

# Unprecedented government support boosts the ICT sector, with the telecom industry poised to be one of the key beneficiaries of the stimulus

## Scenario Discussion: Government stimulus powers ICT investment

**Summary:** The COVID-19 pandemic is expected to persist through at least 2021 as vaccines and other virus-mitigation efforts take time to make their way through societies globally. In the meantime, the global economy remains in a state of suspended animation following unprecedented injections of fiscal and monetary stimulus by governments across numerous countries, which total over \$20 trillion (or 23% of global gross domestic product [GDP] in 2019). The amount of stimulus is expected to continue growing steadily through 2021 and potentially beyond as governments aim to fully offset the impact of the pandemic on their economies as well as build a foundation for sustainable economic growth.

TBR **GOVERNMENT STIMULUS EARMARKED FOR ICT SECTOR AS OF OCTOBER 2020 (BUSD)**



■ China ■ South Korea ■ U.S. ■ Rest of World

SOURCE: TBR

Note: This support will be provided over the next five years beginning in earnest in 2021.

- A significant and growing portion of government stimulus is being earmarked to enable the ICT sector to accelerate infrastructure and ecosystem development. CSPs and their suppliers will be key beneficiaries of the trillions of dollars and other support mechanisms governments will directly and indirectly inject into the ICT sector and broader economy for these purposes. This stimulus will help CSPs ease their capex and opex burdens as they migrate to the new network architecture and will ensure they have the capital necessary to keep their businesses going and their debt obligations satisfied.
- Of the government support announced to date for the ICT sector, China will spend \$1.4 trillion of the \$2 trillion global total, with Western governments collectively spending the bulk of the remainder. TBR expects this \$2 trillion figure will increase to at least \$3 trillion over the next two years as Western governments realize they are falling behind in the technology race and provide more funding to encourage their domestic economies to catch up.
- This funding will take many forms and will provide a range of support mechanisms, such as grants, subsidies, low or no interest rate financing, and tax breaks, to encourage ICT infrastructure and ecosystem development in areas including 5G, AI, edge computing, quantum computing and semiconductor manufacturing.
- CSPs will leverage these public funds to accelerate and broaden the scope of their 5G deployments, ensuring high-capacity and nationwide coverage is available in their respective countries. A significant portion of these Western-aligned country funds will also support the swapping out of infrastructure from vendors considered to be security risks.



# Traditional RAN architectures will support the majority of 5G deployments through 2025, with open RAN and vRAN growing in the mix over time

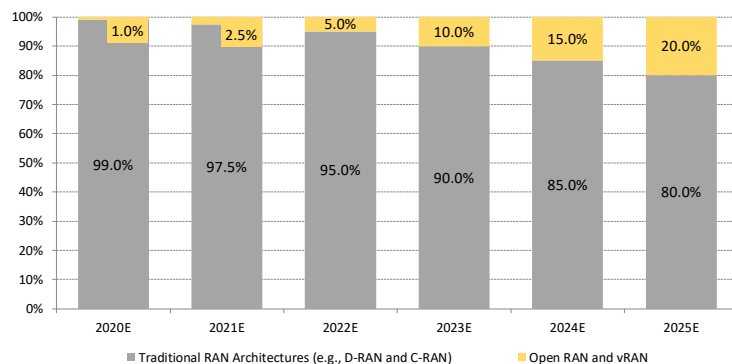
## Scenario Discussion: Open RAN and vRAN deployments will gradually gain traction through this decade

**Summary:** Open RAN and vRAN trials are accelerating as CSPs seek to realize benefits like capex and opex savings, greater flexibility, reduced vendor lock-in, and the ability to integrate AI and machine learning (ML) capabilities. Open RAN is also being leveraged for RAN swaps. Commercial deployments will begin to spread in 2021 as some incumbent CSPs, such as Verizon and Vodafone, ramp up and new entrants, such as Dish Network, begin their nationwide deployments in the new architecture.

- Despite growing CSP interest in open RAN and vRAN, most 5G implementations will be in traditional RAN architectures (e.g., D-RAN and C-RAN) through the middle of this decade. A key reason for this is the software upgradability of millions of existing LTE base stations to 5G, which will keep CSPs wedded to the traditional RAN architecture, slowing the pace of open RAN and vRAN adoption.
- TBR estimates nearly 10 million LTE base stations globally can be upgraded to 5G NR via a remotely delivered software upgrade, which will keep the traditional RAN architecture around for some time. Though upgrading LTE BTS via a remote software upgrade to 5G NR enables CSPs to more cost-effectively stretch their hardware investments, it keeps them tethered to the legacy model. Due to this, vRAN will be deployed primarily in net-new greenfield builds, where legacy RAN does not factor in as heavily and existing RAN will be evolved over time.
- vRAN and open RAN adoption will also be limited in certain countries, such as the U.S., U.K. and Germany, that lack sufficient fiber in the access layer of the network, which is critical to support the anyhaul requirements of the architecture.
- Despite a relatively slow start in the first half of this decade, vRAN and open RAN deployments will accelerate through the 2020s as the theoretical cost savings and other benefits, such as increased agility and flexibility, will be too attractive for CSPs to ignore. The success of early adopters, such as Rakuten, will also serve as a catalyst for industry adoption of the technologies.



SHARE OF GLOBAL RAN MARKET BY ARCHITECTURE



SOURCE: TBR ESTIMATES

# Operators are accelerating the transition to 5G SA to take advantage of benefits including throughput efficiencies and coverage extension

## Scenario Discussion: Operators are accelerating their 5G SA road maps

**Summary:** CSPs are increasingly pulling forward their 5G SA road maps as they recognize that the benefits of the new architecture outweigh the upfront investment cost and lack of new commercialized use cases that require SA.



### Year at least one CSP in country launched a commercial 5G SA network and is running live traffic on that network

2019	2020	2021 Expected
<i>N/A – all 5G deployments in 2019 were non-stand-alone (NSA)</i>	Australia China South Africa United Kingdom United States	Canada Japan Singapore South Korea  Select countries in Europe, such as Germany, the U.K. and the Nordics

- From a consumer business perspective, the primary drivers prompting CSPs to accelerate their transition to 5G SA are throughput efficiencies and coverage extension, with the ability to participate in new business models a secondary, more near-term consideration. The challenges and limitations of DSS are another key consideration prompting faster adoption of 5G SA because there is a negative user experience impact when base stations concurrently operate LTE and 5G traffic in the same band.
- Meanwhile, from a business-to-business (B2B) perspective, companies are rallying around 5G SA as part of private 5G network implementations as enterprises that opt for the next-generation technology look to leverage the key features (such as ultra-reliable low-latency communications [URLLC] and time-sensitive networking [TSN]) and future-proof aspects the SA platform provides. CSPs that aim to sell these advanced, 5G SA-enabled solutions to enterprises are therefore keen to ensure they are investing in the technology sooner rather than later.
- TBR expects a growing number of CSPs, mostly in developed markets, will also opt to deploy 5G SA faster than originally anticipated as they reason the benefits are more immediate than near-term in nature. CSPs in Japan, Singapore, South Korea and select countries in Europe will join CSPs in China, the United States and other early mover countries in adopting 5G SA for the aforementioned reasons, with 2021 shaping up to be a key launch year for the build-out of 5G SA networks in these countries.



# Acquiring C-band spectrum is essential for U.S. operators to remain competitive in the 5G race, but will result in significant financial strain

## Scenario Discussion: The C-band auction is the highest-grossing U.S. spectrum auction ever

**Summary:** With the notable exception of T-Mobile, U.S. operators are challenged by their current lack of midband spectrum as the spectrum provides the ideal balance of coverage and capacity to provide optimal 5G service nationwide. The C-band auction will have a pivotal impact on the U.S. competitive landscape and the country's position in the global 5G race.



**C-band Auction Participants**

Altice USA	Dish Network
AMA Communications	East Kentucky Network
AT&T	Granite Wireless
Bluegrass Cellular	Leap Communications
California Internet	Mark Twain Comm. Co.
Charter	Northern Valley Comm.
Columbia Capital	T-Mobile
Comcast	Union Telephone Co
Cox	U.S. Cellular
Cross Telephone Co.	Verizon
C Spire	Viasat

SOURCE: FEDERAL COMMUNICATIONS COMMISSION

Note: List is not comprehensive.

- The C-band auction closed its clock phase on January 15. The clock phase generated gross proceeds exceeding \$80.9 billion, surpassing the prior U.S. record of \$44.9 billion from the AWS-3 auction in 2015. The upcoming assignment phase will give participants the opportunity to bid on frequency-specific licenses.
- Participating in the C-band auction will be critical for U.S. operators to keep pace with T-Mobile due to the significant competitive advantage it currently holds due to its trove of 2.5GHz spectrum. TBR expects Verizon will be the highest bidder at the C-band auction due to its stronger financial position than AT&T and T-Mobile being less dependent on the auction due to its existing spectrum. Acquiring C-band spectrum will be pivotal for Verizon to provide optimal 5G service throughout the U.S., as the company currently relies on DSS to support its current 5G Nationwide services, which are yielding speeds only marginally faster than LTE.
- Though participating in the auction is critical to remain competitive, the auction will cause significant financial strain, evidenced by AT&T and T-Mobile seeking to borrow \$14 billion and \$3 billion, respectively, to fund spectrum. Verizon is also likely to issue bonds to support its spectrum purchases. AT&T is especially challenged by its heavy debt load, historically high leverage ratio and capital allocation plan objectives, which will in turn require AT&T to intensify cost-cutting and asset divestments to improve its balance sheet.
- TBR anticipates Charter and Comcast will also emerge as top bidders at the C-band auction as the operators seek to build out their own wireless networks in select locations. Offloading traffic onto their own networks would enable Charter and Comcast to significantly reduce mobile virtual network operator (MVNO) payments to Verizon over the long term.

## More governments are restricting China-based vendors, either implicitly or explicitly, from supplying 5G equipment to their local CSPs

**Scenario Discussion: List of bans prohibiting Huawei (and ZTE) from providing 5G gear to CSPs is growing**

-  **Strength:** Huawei maintains 5G market share leadership in contract count and the number of base stations shipped due to its dominance in China.
-  **Weakness:** Huawei is unable to participate in the 5G rollouts for CSPs in a growing number of countries due to security concerns and political pressure.
-  **Opportunity:** Gain share in emerging markets in Asia and MEA as governments in these countries are generally more open to China-based vendors.
-  **Threat:** More CSPs exclude Huawei from their networks, not only due to security concerns but also because of uncertainty over Huawei's ability to maintain its supply of vital components.



### Countries That Restrict Sales of Huawei's 5G Gear

Australia	India	Singapore
Canada	Japan	Sweden
Czech Republic	Latvia	Taiwan
Denmark (includes Greenland)	New Zealand	United Kingdom
Estonia	Poland	United States
France	Romania	Vietnam

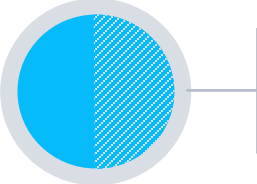
Note: List is not comprehensive; includes both government-announced and implicit bans on sourcing Huawei equipment for 5G

- Political issues arising out of security concerns, mostly in Western markets, will increasingly weigh on Huawei's results. Achieving growth in Europe is unlikely as Huawei has been banned from supplying networking equipment — both the RAN and the mobile core — in some markets, most notably the U.K. In North America, Huawei's presence in Canada will be dramatically reduced. The vendor provided LTE gear to Telus and BCE, but these CSPs have selected a mix of Samsung, Ericsson and Nokia for 5G. Additionally, Huawei's presence among Tier 3 operators in the U.S. will gradually shrink as its equipment is phased out in favor of vendors based outside of China, with the U.S. government footing the bill for the rip-and-replacement of Huawei gear. In APAC, countries including Taiwan, India, Australia, New Zealand and Japan have banned China-based vendor equipment, and Vietnam will avoid deploying Huawei equipment. In Japan, Huawei equipment will be removed from SoftBank's network. Thus far, no CALA operators or governments have indicated that China-based vendors will be excluded from consideration for network build-outs, though Brazil wavered before ultimately deciding in Huawei's favor.
- Some CSPs have also decided to exclude Huawei equipment without coercion from their domestic governments due to uncertainty around forthcoming government policy, or because they are concerned Huawei will be unable to meet demand due to trade restrictions placed on the company.

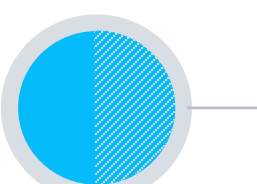
## Operator Trends

## Discounted service plans, fixed wireless expansion and the iPhone 12 launch serve as catalysts to bolster 5G adoption


### Operators are leveraging fixed wireless services to bridge the digital divide

- 
- A broad range of operators globally are seriously looking into FWA (especially 5G FWA) as a means of cost-effectively bringing new and/or better high-speed broadband services to end users.
  - The growing trend of people moving out of urban areas to suburban and rural areas also provides operators opportunity to offer fixed wireless services in strategic markets that have limited broadband options.
  - The limited speeds offered by LTE fixed wireless services mainly appeal to price-sensitive customers and those with no other residential broadband options, while the expansion of 5G fixed wireless services over the next several years will spur greater adoption as the faster speeds will enable providers to compete as a more significant disruptors to cable and fiber broadband providers.

### The iPhone 12 launch and the availability of lower-priced 5G handsets will accelerate 5G adoption

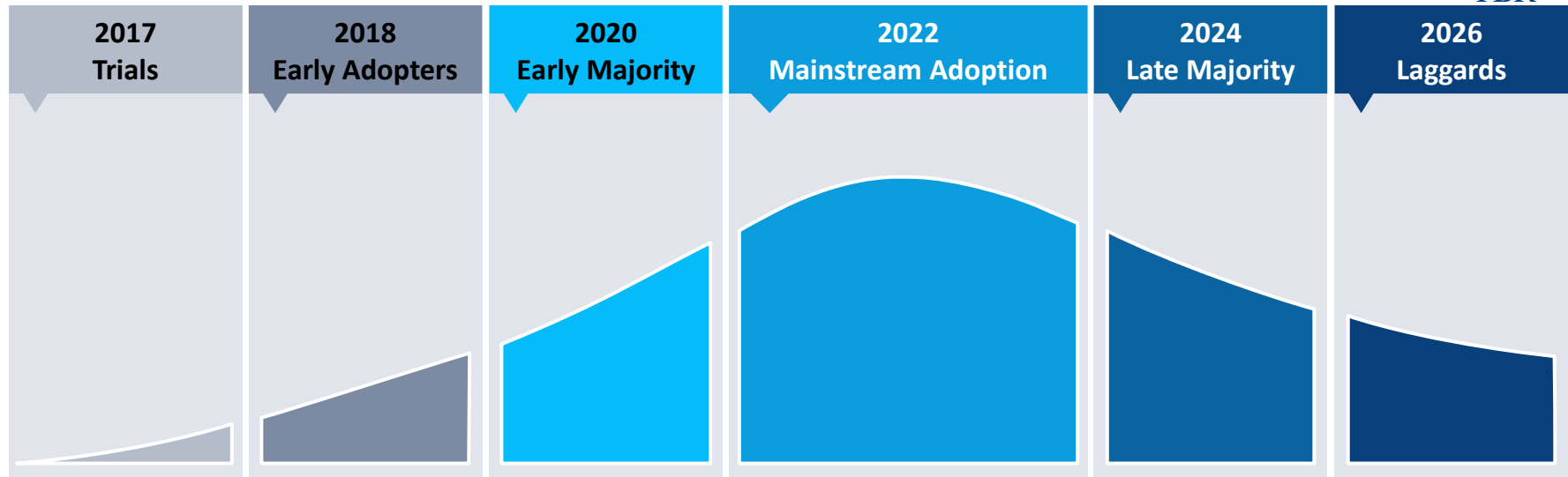
- 
- The iPhone 12 will bolster 5G adoption as many consumers were delaying 5G upgrades until the release as well as for the relatively low price point of certain models, such as the iPhone 12 Mini starting at \$699. To attract customers, telcos are launching aggressive offers such as BOGO (buy-one-get-one) deals, Verizon's 5G Fleet Swap program and AT&T offering the iPhone 12 for free to new and existing customers.
  - Economic challenges arising from the pandemic are hindering 5G smartphone adoption due to the high price of most initial 5G handsets. 5G device adoption will be aided by lower-price handset models gradually being released. For instance, Verizon's least expensive 5G handset offered as of January, the TCL 10 5G UW, has a \$400 retail price.

### Disruptive players will spur incumbent telcos to offer lower-priced 5G service plans

- 
- In September Rakuten launched 5G service plans that are approximately half the price of its Tier 1 rivals, which spurred NTT Docomo, SoftBank and KDDI to launch lower-priced service options.
  - Similar to Rakuten's model, TBR anticipates Dish Network will emerge as the 5G pricing leader over the next several years, which will help to reduce 5G access prices in the U.S.
  - Recently launched 5G services from Xfinity Mobile, Spectrum Mobile and Altice Mobile will also disrupt the U.S. market as the cable operators are offering 5G access at no extra cost on all plans, included tiered data options, as opposed to Tier 1 operators such as AT&T reserving 5G access to select unlimited data plans.

## Government stimulus and the need for network capacity will be key drivers of most Tier 1 operators commercially deploying 5G by the end of 2022

Operator 5G Adoption Curve



### Early Majority

Though a viable business case for operators to gain revenue from 5G has yet to materialize (except for fixed wireless access), operators' primary initial driver of 5G deployment is the efficiency provided by the technology versus LTE.

In response to COVID-19, TBR expects governments and businesses around the world to reassess their disaster response and risk profiles to mitigate risks to their societies and economies. This will encourage CSPs to accelerate 5G and edge-compute investment to support use cases such as video surveillance, drones, autonomous logistics and transportation, industrial automation, and AR/VR.

### Mainstream Adoption

TBR expects most Tier 1 and some Tier 2 and Tier 3 wireless operators globally will have begun deploying 5G by the end of 2022. This will be driven by the need to add capacity to support growing data traffic and to tap into new revenue opportunities brought on by emerging use cases for the network that materialize in the 5G era. Government support will be a key underlying driver of CSPs' push to adopt 5G regardless of an economically viable business case being firmly in place. TBR expects new, economically supported use cases for the network will ultimately arise around 2022, which will drive another phase of 5G investment.

## T-Mobile holds the competitive advantage in the U.S. 5G market, aided by its 2.5GHz spectrum and early deployment of 5G SA technology

### T-Mobile

#### Key Strategies

T-Mobile is deploying about 1,000 new 2.5GHz 5G sites every month as the operator aims to expand midband 5G coverage to provide nationwide coverage in the U.S. by the end of 2021. 5G deployments will be aided by the multiyear agreement T-Mobile signed with American Tower in September.

#### Activities and Analysis

- T-Mobile is outpacing rivals in FWA coverage as LTE Home Internet service is available to over 20 million households as of October. T-Mobile has begun providing certain customers 5G CPE ahead of the commercial launch of its 5G Home Internet services expected in 2021.
- In August T-Mobile became the first U.S. operator to deploy 5G SA, which is providing benefits such as coverage extension and throughput efficiencies.

### Vodafone

#### Key Strategies

Vodafone is encouraging the U.K. government to prioritize 5G rollouts as part of its COVID-19 recovery plans. For instance, Vodafone published a report in June detailing how 5G deployment could contribute up to \$194 billion to the U.K. economy over the next decade via job creation and business opportunities.

#### Activities and Analysis

- Vodafone will launch commercial 5G Multi-Access Edge Computing (MEC) services based on AWS Wavelength beginning in spring 2021 in London, which will be followed by additional markets in the U.K. and Germany.
- Companies have begun piloting the service, including counter-drone technology company Dedrone, video analytics company Digital Barriers and streaming application company Groopview.

### BCE

#### Key Strategies

BCE is focused on transitioning customers to 5G handsets to increase revenue and data usage. For instance, BCE is reporting 5G customers are consuming twice as much data usage and generating nearly 20% higher monthly recurring revenue compared to other wireless customers.

#### Activities and Analysis

- BCE expanded 5G coverage to markets in British Columbia and Alberta in October. Bell's 5G services are providing download speeds up to 1.7Gbps, and speeds will further increase once services are deployed on 3.5GHz spectrum following the June 2021 auction.
- BCE announced it will deploy 5G solutions at the Université de Sherbrooke to support research in areas including IoT, smart energy and manufacturing.

# Operators including Verizon and Telstra are leveraging 5G FWA services to support heightened demand for residential broadband amid the pandemic

## Telstra

### Key Strategies

Telstra is leveraging its 5G Innovation Centre, located on Australia's Gold Coast, to advance 5G network technologies and use cases. The facility is enabling Telstra to foster innovations in targeted areas including smart cities, drones and autonomous driving.

### Activities and Analysis

- Telstra is providing 5G coverage to over 50% of the Australian population as of January and expects to reach 75% by the end of June. Over 750,000 5G devices have been activated on Telstra's network as of January, though 5G access is reserved to select higher-tier service plans.
- In September Telstra launched 5G FWA services, which are initially available by invitation only but will become more broadly available in 2021 as Telstra acquires mmWave spectrum.

## China Telecom

### Key Strategies

China Telecom is leveraging the joint build-out of its 5G network with China Unicom to compete more aggressively against China Mobile. Additionally, the joint 5G build-out provides significant cost savings, enabling the telcos to reduce capex and opex by about 30% and 35%, respectively.

### Activities and Analysis

- China Telecom is steadily gaining 5G customers, as it added 7 million 5G subscribers in December to bring its 5G base to a total of 86.5 million. In comparison, China Mobile added 17.6 million 5G subscribers in December to bring its 5G base to 165 million.
- China Telecom launched its 5G SA network in November, following the completion of SA end-to-end capability testing with Tencent and Huawei in September. The network supported about 100 compatible devices by the end of 2020.

## Verizon

### Key Strategies

In October Verizon launched its 5G Nationwide services over DSS to over 200 million POPs. The services provide significantly slower speeds compared to 5G Ultra Wideband services but will enable Verizon to preserve market share amid the iPhone 12 release.

### Activities and Analysis

- Verizon is gaining additional spectrum from regional operators to enhance coverage in rural markets via recently announced acquisitions including Bluegrass Cellular and Iowa RSA 2 Limited Partnership.
  - Verizon is capitalizing on 5G Home to target remote workers requiring accelerated broadband speeds. In October 5G Home launched advanced CPE manufactured by Wistron NeWeb Corporation powered by Qualcomm's QTM527 antenna.
- ©2021 Technology Business Research, Inc.



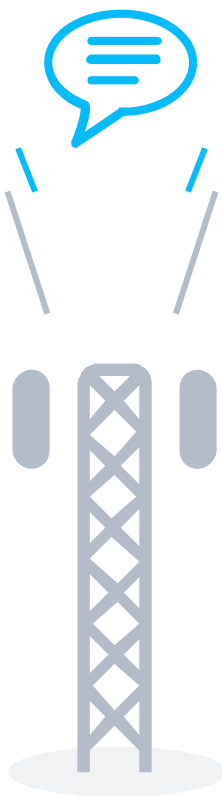
## Dish Network continues to advance its 5G network, though the company will not meet its initial commercial launch date target

### Dish adds vendors to support its 5G build

Dish Network continues to add vendors to support its 5G build, recently selecting Open RAN radio units from MTI, Mavenir's RCS Business Messaging solution, Qualcomm's 5G RAN Platforms, DigitalRoute's Usage Data Platform, Blue Planet's inventory and service order management software, and 5G infrastructure from Intel. Dish Network also formed a long-term agreement with Crown Castle to lease space on up to 20,000 towers and announced it will purchase fronthaul and backhaul fiber connections from Everstream, Segra, Uniti and Zayo.

Dish did not meet its initial target of deploying a 5G network core in at least one market by the end of 2020. Instead, Dish plans to launch commercial 5G services in several small preliminary markets in 1Q21 but will not be able to launch in a major market until 3Q21 as the company is facing delays due to factors including permit issuing and Fujitsu's radios not being widely available until 2H21.

### Key 5G Deployment Announcements



### Orange Spain selects 5G solutions from Ericsson

In September Ericsson was selected by Orange Spain to provide 5G solutions across various markets in Spain in a four-year agreement. 5G has been enabled in Barcelona and Madrid, while the operator plans to deploy Ericsson's 5G NSA EPC, including control plane, user plane and policy network functions, and ERS' Baseband 6648 and AIR 6488 antenna across additional regions.

### BT selects Nokia to upgrade to 5G and replace Huawei infrastructure

In September BT selected Nokia to replace portions of its existing RAN footprint, which is currently supplied by Huawei, as well as upgrade existing Nokia sites in the Midlands and Greater London areas to 5G. Nokia was already an incumbent RAN supplier to the operator. Nokia is providing its AirScale Single RAN base stations, ng-SDM and NetAct software, Cell Site Gateways for backhaul, as well as design, deployment, optimization and technical support services.



## The clearance of 12GHz would provide additional 5G capacity in the U.S., but is facing opposition from incumbents that possess the licenses

### The FCC issues an NPRM, which will potentially clear 12GHz spectrum for 5G usage

In January the Federal Communications Commission (FCC) voted to issue a Notice of Proposed Rulemaking (NPRM) that will explore methods of clearing 12GHz spectrum, which is currently designated for satellite services, for 5G usage while ensuring minimal interference to incumbents already using the licenses. The NRPM is receiving support from parties including Dish, which holds 12GHz licenses covering 75% of the U.S. population, and RS Access, which holds licenses covering 15% of the population. Conversely, AT&T and SpaceX oppose the NPRM due to concerns of 5G causing interference with their existing satellite services deployed over the spectrum.

### Australia will hold millimeter wave and low-band 5G spectrum auctions in 2021

In December the Australia-based Communications and Media Authority (ACMA) started taking applications for its 26GHz band auction, which will begin in April 2021. The millimeter wave licenses will complement existing 3.6GHz spectrum used for 5G by Australian operators; the country also intends to hold a low-band auction in late 2021 to ensure widespread 5G coverage across the country. Applicants for the 26GHz auction include Nokia, NBN, Telstra, Starlink, MarchNet, Dreamtilt, Field Solutions Group, Opticomm, Vocus and WorldVu.

### France allocates 5G spectrum to Orange, Altice, Bouygues Telecom and Iliad

In October France-based telecom regulator Arcep announced its auction of 3.4GHz-3.8GHz 5G spectrum was completed after three days of bidding totaling \$3.28 billion. Orange was the highest bidder at the auction, spending approximately \$1 billion and was followed by Altice, Bouygues Telecom and Iliad. France was the last major European market to allocate 5G spectrum, which was impacted by COVID-19 and disagreements over auction terms.

### 5G Spectrum Developments



### CBRS auction winners announced

In September Verizon was disclosed as the highest bidder at the CBRS spectrum, spending \$1.9 billion to acquire 557 licenses, including within the largest U.S. markets. Verizon was followed by Dish (\$913 million), Charter (\$464 million), Comcast (\$459 million) and Cox (\$213 million). CBRS spectrum will enable cable operators to offload their mobile customers' traffic onto their own networks to curb MVNO roaming costs. Other companies in the energy, utilities, education and hospitality segments also acquired spectrum at the auction, which is likely to be used for private cellular networks.

## **Vendor Performance and Strategies**

## Government action, and open and virtualized RAN present opportunities for nonincumbent vendors to capture share in the 5G era

### **Samsung's 5G RAN contract from Verizon demonstrates its status as a viable alternative to incumbents**

- Samsung has been doing significant 5G work for operators based primarily in the U.S. as well as in its domestic market of South Korea, though this activity has declined since South Korea-based CSPs completed initial coverage rollouts. Samsung has regained momentum, however, and in September Samsung signed a five-year, \$6.65 billion contract with Verizon to provide 5G RAN gear, making the contract worth about \$1.2 billion per year.
- Samsung outcompeted Nokia for the deal, and Nokia was an incumbent RAN supplier to Verizon, gaining entry via its acquisition of Alcatel-Lucent. Nokia continues to supply Verizon with other telecom solutions, but its inability to win this contract presents market share and perception challenges to the vendor.
- The contract award lends credence to the idea of Samsung as a viable and credible alternative to Tier 1 RAN vendors. Samsung has embraced open vRAN and is expected to capitalize on this market opportunity to a far greater extent than holdouts, namely Ericsson and Huawei. Open vRAN will be a growth driver for Samsung through this decade as the technology matures and CSPs gain a greater understanding of Samsung's value proposition. Samsung recognizes it has minimal market share to lose and a lot to gain from pursuing this strategy.

### **Rise in protectionism and government sponsorship of 5G initiatives presents opportunities for smaller RAN vendors to gain share; Japan's vendors are early beneficiaries of this trend as they reassert themselves domestically and on the global stage**

- A growing number of countries aim to build domestic 5G solutions and ecosystems and are leveraging protectionist government policies and pressure on CSPs to do so, which is leading to a fracturing in the 5G market. These policies are designed to address national security and to drive countries toward technological self-sufficiency and away from China-based or Europe-based incumbent vendors. This is occurring in developed markets such as the U.S., where the government has debated financially supporting domestic open RAN firms such as Parallel Wireless and Mavenir, as well as in emerging markets like India, where CSPs are encouraged by the government to leverage domestic vendors such as Tech Mahindra, or to develop their own technology, as Reliance Jio has done. Other countries pursuing similar strategies include the U.K., South Korea, Russia, Taiwan and Vietnam.
- Japan-based vendors have renewed momentum as a result of Japan's government's desire to foster a domestic 5G ecosystem. NEC and Fujitsu are key suppliers to Rakuten's network. This customer reference, combined with their embrace of open and virtualized networking have enabled these vendors to gain traction with allied countries. Until recently, NEC and Fujitsu were losing market share and mindshare to Western and China-based vendors due partially to a perceived lack of innovation. In 2020, however, NEC and Fujitsu made the shortlists of CSPs, including Vodafone, as potential vendors for their networks. In the most high-profile win to date, Fujitsu was selected by Dish Network to provide the radio units for the operator's greenfield 5G network leveraging open vRAN. TBR expects both companies will benefit as CSPs in countries banning the use of Huawei gear are looking for vendor alternatives to the Ericsson-Nokia "duopoly."

## Select CSPs increasingly behave like software-centric vendors

### **Rakuten and Jio Platforms increasingly position themselves as vendors**

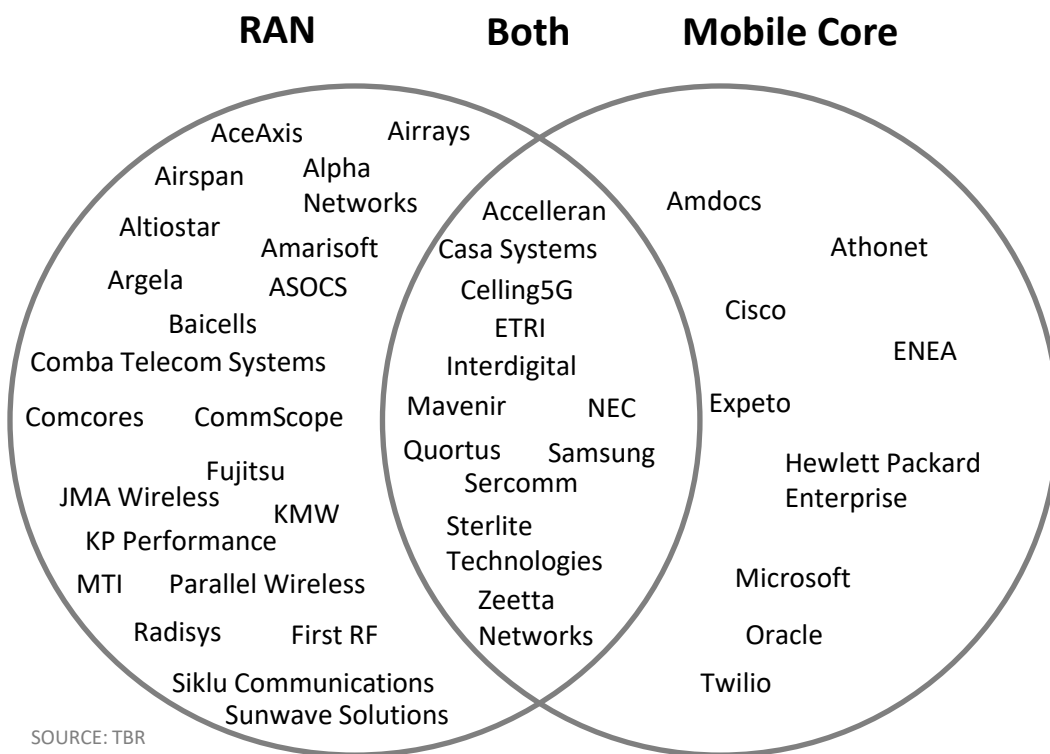
- Rakuten and Jio Platforms, the parent of Reliance Jio, increasingly resemble telecom vendors. Rakuten is taking its learnings and technology stack from the greenfield Rakuten Mobile deployment and packaging them together to form the Rakuten Communications Platform (RCP). Rakuten Mobile has demonstrated the commercial viability of its network, despite delays caused in part by complex integration work, and the company is betting that any operator interested in RCP will prefer to leverage vendors involved with the Rakuten build. This has led Rakuten to invest in several of its suppliers, including acquiring management and orchestration (MANO) provider Innoeye and taking a majority stake in AltioStar. In September Rakuten purchased Tech Mahindra's share of AltioStar, giving it a majority stake.
- Following the sale, Rakuten named Tech Mahindra as its preferred global go-to-market partner for RCP. The alliance will help reduce Rakuten's go-to-market costs — which will inevitably increase amid global expansion — as Tech Mahindra resells RCP and fulfills customers' systems integration needs. TBR expects the vendors' joint efforts will initially focus on Tech Mahindra's home market of India, then will expand into the U.S., where Rakuten is establishing a base of operations in California for sales and marketing efforts across the Americas.
- Similarly, Jio Platforms is actively looking to make acquisitions to help it produce 5G network equipment. The company's 5G vendor journey began in 2018 when it acquired Radisys, but its ambitions are growing as India adopts a posture of "self-reliance" to encourage domestic manufacturing and technology development. TBR expects Jio Platforms to acquire at least one India-based 5G-related vendor and leverage its recent influx of cash from U.S.-based companies to develop its technology and ramp up production.
- TBR is skeptical of Rakuten's and Jio Platforms' ability to sell their solutions to fellow CSPs at scale. Most obviously, their domestic competitors will not want to support a rival, but even international CSPs will be hesitant to adopt the barely proven technology from unestablished vendors.

### **Infrastructure swaps gain momentum; tens of billions of dollars are up for grabs for Western vendors**

- The pace and magnitude of infrastructure swaps are accelerating. Ericsson and Nokia have won the bulk of swap-out projects thus far, but TBR expects Samsung and Mavenir as well as other, smaller RAN vendors to win significant new business as well.
- Infrastructure swap projects could take at least several years to complete depending on the scope of the project, representing a massive market opportunity for Western vendors to claw back market share they have lost over the past two decades to China-based vendors.
- TBR expects governments to foot the bill for most of these swaps, with CSPs likely to contribute minimal amounts.
- TBR notes that these swap outs will, in most cases, replace legacy gear with 5G equipment, which is another accelerant for the 5G market.

## Microsoft is positioned to disrupt incumbents in 5G mobile core with the acquisition of Affirmed Networks

### Disruptive 5G RAN and/or 5G Core Vendors



SOURCE: TBR

Note: Vendor list is not comprehensive. Most of the key disruptive companies are represented in the diagram.

- Disaggregating proprietary RAN software from hardware poses a significant risk to incumbent RAN vendors Huawei, Ericsson, Nokia and ZTE. These incumbents are susceptible to disruption by niche firms such as AltioStar, Mavenir and Parallel Wireless.
- Transitioning to a cloud-native 5G core will yield benefits for CSPs, including opex savings and the ability to provide customers with dedicated network slices. To date, however, incumbents have been the primary beneficiaries of investment in 5GC despite their slow embrace of cloud-native and container technologies.
- Microsoft's acquisition of Affirmed Networks accelerated the company's foray into 5G, particularly in driving telco network migration into the cloud by combining its Azure Stack's edge computing offerings with Affirmed's 5GC. Affirmed's 100-plus virtual evolved packet core (vEPC) customers, which include marquee customers such as AT&T and Telus, provide a base to upsell 5GC. Affirmed provides a cloud-based, virtualized environment for running 5G workloads.

## Acquisitions and Alliances

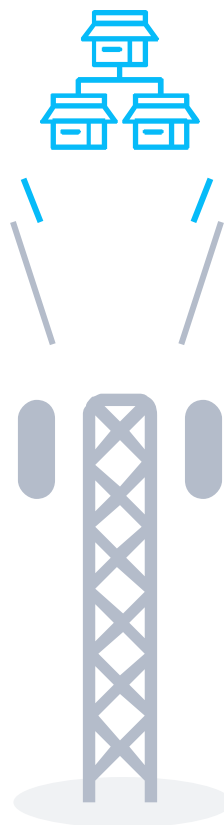
# Cradlepoint enables Ericsson to circumvent CSPs and sell to enterprises via VARs, but CSPs will remain the center of Ericsson's 5G enterprise strategy

## Ericsson acquired Cradlepoint

Ericsson acquired Cradlepoint, which is known for its 4G and 5G Wireless Wide Area Network (WWAN) solutions, for \$1.1 billion in November. Cradlepoint is now a subsidiary within Ericsson's Business Area Technologies & New Business portfolio.

Ericsson's go-to-market strategy in the enterprise space is typically led by CSP partners, and while TBR expects CSPs will remain the company's primary route to enterprises for private cellular networks (PCN), the acquisition of Cradlepoint opens a selling route — value-added resellers — that would have taken significant time and resources to build out organically. Although the acquisition could negatively impact Ericsson's relationships with CSPs that offer competing solutions to enterprises, TBR believes Ericsson's expanded addressable market will outweigh any downside. As interest in PCN intensifies, TBR believes Ericsson will utilize Cradlepoint's install base and portfolio as inroads to cross-sell Ericsson Radio System (ERS) and 5GC offerings to Cradlepoint customers, particularly enterprises in industries such as manufacturing that would substantially benefit from lower latency in a 5G-enabled network.

## 5G-related Acquisitions



## Juniper purchases Netrounds

In September Juniper Networks announced its intent to acquire Netrounds for an undisclosed sum. Netrounds would complement Juniper's automated WAN offerings with solutions for testing and monitoring SD-WAN environments. It would also improve Juniper's position in the 5G space, as Netrounds' technology can be used to analyze edge networks after cloud-based solutions are configured at the edge. In addition, Netrounds would add new capabilities for testing 5G network slices prior to commercial deployments.

## Viavi Solutions acquired Expandium

In August Viavi Solutions acquired Expandium, a vendor with microservices-based solutions for network monitoring and assurance, to build out its NITRO Mobile portfolio. Expandium's technologies will enable Viavi to support customers' cloud-based 5G mobile core networks, which are increasingly complex as operators create multivendor environments based on virtual machines and containers. In addition, Expandium will enhance Viavi's analytics capabilities by integrating technologies including ML, stream processing and pattern detection capabilities.



## Vendors leverage strategic acquisitions to enhance capabilities in areas including BSS, vRAN and 5G chipsets

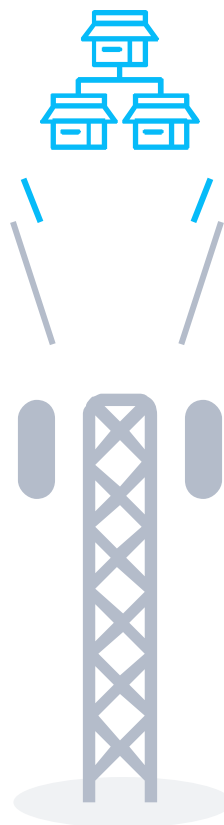
### Qualcomm announces NUVIA acquisition

In January Qualcomm announced it will acquire chip designer NUVIA for about \$1.4 billion, pending regulatory approval. Qualcomm would leverage NUVIA to support the demands of 5G computing and will integrate NUVIA's CPUs across Qualcomm's portfolio, including smartphone chips, laptop processors and Advanced Driver Assistance Systems. Acquiring NUVIA would enable Qualcomm to offer high-performance, power-efficient chips to support data centers and to compete more aggressively with rivals in CPU development, including against Apple's A-series mobile chips.

### Amdocs acquired Openet

In August Amdocs completed its \$180 million acquisition of Openet, an Ireland-based vendor with BSS, 5G charging, data management and policy solutions. While Openet previously competed with Amdocs and the former's offerings overlap the latter's in BSS, Openet's cloud-native 5G charging capabilities will complement Amdocs' commerce and billing portfolio. Amdocs will leverage the acquisition to cross-sell Openet's solutions into its customer base of roughly 350 global CSPs.

### 5G-related Acquisitions



### CommScope acquired Phluido's vRAN patents

CommScope acquired Phluido's full vRAN patent portfolio in October. CommScope will combine its ONECELL patent portfolio with Phluido's assets to enhance its indoor RAN portfolio, which will position CommScope to more fully capitalize on the private cellular network market. Phluido's 4G and 5G Layer 1 software will also provide cost savings by enabling RAN virtualization on commodity hardware without need for specialized accelerators.

### Mavenir acquired ip.access

Mavenir's September acquisition of ip.access enables the company to offer the full scope of RAN solutions, helping customers migrate from 2G and 3G to 5G over time. Mavenir's greenfield play to provide cloud-native solutions is unique and a key differentiator from incumbent OEMs that continue to push their relatively expensive, inflexible and closed systems. This differentiator applies to enterprises interested in PCN as well. Mavenir's vRAN offers relatively low price points and TCO and has also demonstrated high performance in trials and some select commercial production environments.



## Telcos are collaborating with other operators as well as network and technology vendors to foster 5G innovation

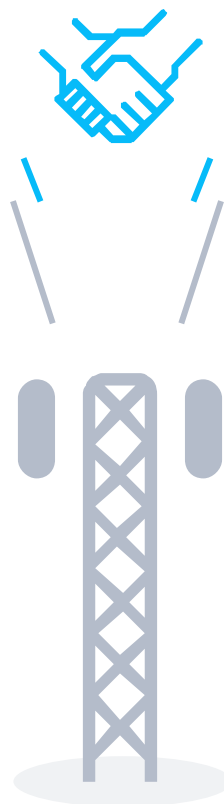
### Ubitus tests 5G cloud gaming with Singtel

Following the launch of Singtel's 5G SA trial network in October, Ubitus tested a cloud gaming experience on Singtel's network and MEC platform that delivered 85% lower latency compared to LTE. Leveraging 5G and edge computing will enable cloud-based gaming services to optimize the delivery of graphic-intensive titles while providing minimal latency to controller responses, which is especially beneficial for enhancing the QoS of multiplayer gaming.

### DT and SKT form 5G joint venture

In November DT and SKT announced the formation of a joint venture, in which each company will hold a 50% stake, that will focus on the development of innovative 5G solutions for the European market. The venture will initially focus on leveraging SKT's technology assets to develop distributed antenna system (DAS) solutions to enhance indoor 5G reception, which will serve as an alternative to solutions from vendors including CommScope, Corning and Axell Wireless. The partnership will also focus on developing 5G solutions in areas including AR/VR and MEC.

### 5G-related Operator Alliances



### Samsung joins KDDI's Co-creation Alliance

In October Samsung was announced as a participant of KDDI's Co-creation Alliance, which is focused on accelerating the development of new enterprise use cases. The partnership will focus on assisting customers in verifying 5G use cases and developing new businesses and will provide customers the choice of deploying solutions on KDDI's existing network infrastructure or their own private 5G networks. The development follows Samsung and KDDI successfully testing network slices over a 5G SA network via a RAN Intelligent controller.

### The 5G Open Innovation Lab adds new founding partners in September

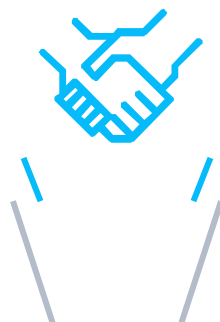
The 5G Open Innovation Lab, which was launched by T-Mobile and NASA in May, added Microsoft, Amdocs, Dell Technologies and VMware as founding partners in September and will provide the lab with engineering and technology resources. Collaborating with additional technology leaders as part of the 5G Open Innovation Lab will enable T-Mobile to enhance its 5G portfolio in areas including cloud, edge computing and IoT.

## Vendors are more deeply collaborating to support 5G use cases in areas including PCN, edge compute and Industry 4.0 solutions

### Samsung and IBM help enterprises with 5G PCN and edge compute analytics

In December Samsung and IBM expanded their alliance to integrate Samsung's 5G networking solutions and Galaxy devices with IBM's Watson AI, Edge Application Manager and Red Hat OpenShift. This will enable the two companies to provide customers with private 5G network solutions that integrate with IBM and Red Hat's hybrid cloud offerings, which will be particularly attractive for customers that need to upload data from the edge for AI-enabled analytics.

### 5G-related Vendor Alliances

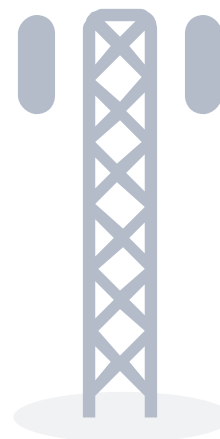


### HPE collaborates with multiple vendors at its 5G Lab

Hewlett Packard Enterprise (HPE) is collaborating with multiple vendors at its 5G Lab in Fort Collins, Colo., to test 5G core network functions including Nokia, Intel, Casa Systems, Amdocs' Openet and Red Hat, as well as the Microsoft-owned vendors Affirmed Networks and Metaswitch. The lab aims to ensure high performance and interoperability between vendor core functions.

### Keysight Technologies joins Ericsson' Industry 4.0 partner program

In July Keysight Technologies joined the Ericsson Industry 4.0 partner program. Ericsson will go to market alongside Keysight Technologies, which will provide testing and measurement solutions to help plan, deploy and operate industrial 5G networks leveraging solutions from Ericsson's portfolio. To join the program, Keysight employees were required to train on Ericsson's Industry Connect solution.



### IBM collaborates with Altran to advance its 5G edge compute capabilities

IBM is building out its partner ecosystem around its Edge Computing Platform for Clusters, evidenced by the vendor's recent alliance with Capgemini-owned Altran. IBM will provide the platform and orchestration technology, while Altran will offer 5G-related solutions and systems integration services to joint telecom customers.

# Appendix

## 5G-related Definitions

Carrier aggregation	Tethering disparate spectrum bands together to increase throughput, capacity and efficiency
C-RAN	Cloud RAN (C-RAN), also known as Centralized RAN, is a centralized, cloud computing-based architecture for radio access networks. C-RAN is similar to vRAN in that it centralizes the intelligence of the RAN in a cloud-based environment to optimize the performance of the access network.
Dynamic Spectrum Sharing	Software optimization technology that dynamically adjusts base station capacity to whichever spectrum band has more traffic
Fixed wireless	Delivering high-speed data via a microwave (wireless) connection between two fixed points
Fronthaul	Interconnecting wireless access points with fiber or microwave in a RAN environment. Fronthaul is required for C-RAN and vRAN.
Integrated Access Backhaul	Leveraging a wireless access point, such as a small cell, to provide last-mile access as well as leverage spectrum to hop network traffic back into the network (backhaul)
MIMO	Multiple-input, multiple-output (MIMO) is a method of multiplying the capacity of a radio link using multiple transmit and receive antennas to exploit multipath propagation.
NFV	Network functions virtualization (NFV) aims to transform the way network operators architect networks by evolving standard IT virtualization technology to consolidate many network equipment types onto industry-standard, high-volume servers, switches and storage, which could be located in data centers, in network nodes or on the end user's premises. NFV involves the implementation of network functions in software that can run on a range of industry-standard server hardware and that can be moved to, or instantiated in, various locations in the network as required without the need to install new equipment.
SDN	Software-defined networking (SDN) is an approach to networking in which control is decoupled from the physical infrastructure, allowing network administrators to support a network fabric across a multivendor environment.
vRAN	Virtual radio access network (RAN) — virtualizing and decoupling elements of the radio access network, including macros, small cells and distributed antenna systems (DAS)

## About Us

Technology Business Research, Inc. is a leading independent technology market research and consulting firm specializing in the business and financial analyses of hardware, software, professional services, and telecom vendors and operators.

Serving a global clientele, TBR provides timely and actionable market research and business intelligence in formats that are tailored to clients' needs. Our analysts are available to address client-specific issues further or information needs on an inquiry or proprietary consulting basis.

TBR has been empowering corporate decision makers since 1996.

To learn how our analysts can address your unique business needs, please visit our website or contact us today.

## Contact Us

+1 603.929.1166  
[info@tbri.com](mailto:info@tbri.com)  
[www.tbri.com](http://www.tbri.com)  
11 Merrill Drive  
Hampton, NH 03842  
USA

## Download

All reports are available in PowerPoint and PDF. If you are viewing a PDF and require access to data, tables, etc. for use in internal documents, please visit [www.tbri.com](http://www.tbri.com) and download the PowerPoint version.

## Connect With Us

 [Twitter](#)

 [LinkedIn](#)

 [TBR Webinars](#)



TECHNOLOGY BUSINESS RESEARCH, INC.

This report is based on information made available to the public by the vendor and other public sources. No representation is made that this information is accurate or complete. Technology Business Research will not be held liable or responsible for any decisions that are made based on this information. The information contained in this report and all other TBR products is not and should not be construed to be investment advice. TBR does not make any recommendations or provide any advice regarding the value, purchase, sale or retention of securities. This report is copyright-protected and supplied for the sole use of the recipient. Contact ©Technology Business Research, Inc. for permission to reproduce.