1. Introduction

Over the past decade, mobile networks across the globe have grown and matured. The International Telecommunication Union (ITU) estimates over 87% of the world population is now covered by at least a 4G Long-Term Evolution (LTE) (or similar) network. Similarly, we have seen a dramatic shift toward smartphones. In 2019, mobile devices surpassed computers as the preferred online access method which were responsible for more than half of daily time spent online (global cohort). Mobile has grown from only 25% of daily time (in 2013), to now a dominant mechanism enabling 57% of users time spent online (4Q2022). Mobile connectivity is an increasingly entrenched “sticky” service, and now a well-established cornerstone of modern lifestyle.

1.1 A consumer perspective on historical telecommunications use cases

When consumers choose to spend more time with a product or use case, they are—to an extent—voicing their preferences. In other words, time (as a unit of measure) could be thought of as a proxy for the utility that an individual assigns to a good or service. There are a finite number of hours in each day, and theoretically, people are always optimizing those hours to maximize utility. With mobile phones becoming the preferred access medium for the internet, this behavior must be accomplishing things for the user in a unique way that is preferred (maximizing utility), compared to the previously existing or available alternatives.

The challenge for any industry is developing a clear understanding of associated use cases and finding a way to express the value creation in a relatable way. For example, in the early days of circuit-switched telephone networks, it was sensible to use “time” to represent costs, because the time a user spent occupying a circuit was directly proportional to the ability to monetize the circuit (since only one user could use the circuit at a time). It was also easy for the consumer to recognize time as both a unit that is billed (e.g., $0.10 per minute), and as a unit they are consuming. These units could be marketed in volume to represent value (e.g., 1000 minutes for $50). The telecommunications industry would continue this trend, and the broad adoption of text messaging would follow suit, with similar unit-based pricing (e.g., 500 texts for $5).

As 4G LTE networks were deployed, these packet-based internet protocol networks were now data-centric. Coupled with advances in consumer electronics (e.g., the first Apple iPhone), there was suddenly much more that could be done with the cellular network than simple talk and text. Consequently, consumer-facing unit economics for wireless shifted toward metering data (e.g., $10/GB, 5GB for $30). Meanwhile, the unlimited access granted by fixed-line home broadband led to throughputs (or data rate, e.g., in Mbps) as the primary way to differentiate different access product tiers.

Different product tiers and pricing allow the end user to address the business of optimizing and maximizing their utility. In other words, it creates the “quantity demanded” for a good or service.

1.2 A new lens for evaluating 5G use cases

Generally, the industry controls the end-to-end telecommunications ecosystem that creates the “supply” of new features and capabilities. This is an increasingly complex dynamic, with many interdependencies (e.g., device, network, application). Moreover, these “generation” shifts in technology often unlock a new set of use cases (i.e., sources of utility), only now achievable due to a fundamental change in production costs and capabilities. South Korean operator SK Telecom reflects on the supply and demand impact of deploying a 5G network, stating “...
costs-per-GB on 5G are more than 70% cheaper than on LTE, so 5G customers tend to use more than 50% more data than LTE customers. In this way, they highlight how the cheaper “production costs” of a 5G unit of data has enabled new 5G consumer behavior and usage that was previously unobtainable.

We propose a framework for categorizing 5G use cases across the two dimensions of the industry “supply” side and the end user “demand” side. There have been tangible examples of 5G use case success where there is a combination of established user demand, coupled with a sufficient maturity of the 5G supply-side technology enablers.

Figure 1: A 2x2 framework for evaluating 5G Use Cases. The x-axis is the level of 5G technology maturity (the available “supply” of a given 5G solution); the y-axis represents the perception of how useful the 5G solution is to the end user (the “demand”). (Source: 5G Americas 2023)

This framework has four quadrants:

**Quadrant 1: SUCCESSFUL Case Studies.** The main area of focus for this white paper. These are 5G Use Cases where commercialized 5G networks can be used in high-value ways (e.g., 5G Fixed Wireless providing additional customer choice for an internet service provider). These cases are recognizable as addressing a tangible customer need, or job to be done.

**Quadrant 2: UNMET Pain Points.** This is where innovation and ideas are sparked, and emerging technology (and standards) are steered toward future high-potential value use cases.

**Quadrant 3: UNCERTAIN Future.** Emerging technology that has failed to gain traction, or perhaps existing alternatives have better economics or performance, thus decreasing the utility of the 5G solution.

**Quadrant 4: LATENT Potential.** Use cases that fundamentally have a roadmap for supporting technology enablers, but are falling short of expectations. This could be for a variety of
reasons; perhaps there is a gating factor with regards to industry alignment/consensus, or stakeholder awareness, or perhaps there are regulatory challenges, etc. It is likely that several future 5G Use Cases reside in this quadrant, largely dependent on the commercialization and socialization of advanced 5G network features (e.g., features that require Standalone 5G and network slicing).

1.3 5G use cases that have gained commercial momentum

This paper seeks to explore successful use cases from quadrant 1, and potential use cases from quadrant 4 of the framework. The first section of the paper starts by recapping elements of architectural evolution, as well as key technology enablers. The next two sections of the paper gather recent observations across two 5G use cases that have seen commercial adoption and success over the past few years before concluding the paper with some final thoughts.

The two commercial 5G use cases for discussion are as follows:

- Fixed Wireless Access (FWA) (e.g., home internet)
- Private Networks (e.g., making 5G networks at smaller scale practical)

These are well recognized 5G use cases, and have been previously described by several 5G Americas Whitepapers (Huang et al., 2023; Daly et al., 2022; Pikle et al., 2021; Kalathil et al., 2021; Kia et al., 2021; Rysavy Research, 2020). Now, with the benefit of additional ecosystem maturity, this paper will reflect on insights derived from the success and momentum that are building in North America and globally.

In the future, monitoring use cases in quadrant 4 (Latent Potential) will be of particular interest. It is not always clear how a new technology will be used to its fullest potential. A large part of innovation is creating the building blocks that are enablers for a larger ecosystem (i.e., where 5G is abstracting underlying complexity and simplifying it for the end user). Given this, it is more than likely that some of the most impactful outcomes from 5G are still waiting to be fully realized.

As a final point, we acknowledge a recent article (Feb. 2023) by McKinsey & Company. They discuss “Navigating the three horizons of 5G business building” leveraging the classic three horizon model.12 They highlight that the early 5G Use Cases being observed are simple horizon 1 examples of continuing to offer core connectivity services, such as FWA. Moreover, they believe there is greater opportunity in horizon 2 use cases, such as edge computing and private networks. These horizon 2 examples go beyond simple connectivity (more than just wireless speed) and are expected to rely more on the customization of premium solutions.13

We share a common excitement, as we are entering a new era of 5G; one that finally allows us to break free of the previous monolithic “4th generation lens” of simple data speeds (and volumes). As 5G continues to mature, we expect to see both a tangible realization of additional use cases; and an increased focus on shared learnings that cultivate industry awareness. This whitepaper is an incremental step toward furthering that 5G vision.
2. The Role of Network Architecture and Technology

5G continues to prove a significant leap forward toward modern communications systems and improves legacy 4G services in several areas. The following subsections are highlights of critical architectural improvements and technology enablers that will play a key role in future 5G use cases and have contributed to the recent success of both 5G FWA and private 5G network adoption.

2.1 Architectural Evolution

Enhancements in telecommunication network architecture predominantly aim to enhance overall operational effectiveness. Recently, noteworthy architectural advancements have been witnessed within 5G networks, with a continuing trajectory of improvements. We anticipate the maturation of four key cutting-edge functionalities: the Radio Intelligence Controller (RIC), Network Application Programming Interfaces (APIs) for programmable networks, edge computing, and network slicing. It is important to acknowledge that current implementations of both Virtualized Radio Access Networks (vRAN) and Open Radio Access Networks (ORAN) have already begun yielding efficiencies and adaptable solutions for operators.14 15

The evolution of telecommunications in the last few years is witnessing an emerging transformative shift in the Radio Access Network (RAN) landscape. Traditional monolithic and single-vendor RAN solutions have the potential to give way to the dynamic principles of disaggregation, virtualization, and Open RAN. Disaggregation and Open RAN enhance flexibility by allowing operators to select best-of-breed RAN components, while 5G RAN virtualization fosters innovation, scalability, and efficiency. Together, they empower operators to deploy responsive networks that meet diverse 5G use cases. The February 2023 5G Americas whitepaper, “The Evolution of Open RAN” provides a more comprehensive overview of Open RAN.16 As the industry advances, disaggregation, Open RAN, and virtualization themes will contribute to a responsive, adaptable, and future-ready 5G ecosystem.

More broadly, we will provide a brief overview of the four advanced 5G capabilities that are expected to have a material impact on the overall 5G architectural evolution.

In Open RAN, the Radio Intelligence Controller (RIC) continuously monitors and analyzes factors such as radio conditions, traffic patterns, and user behavior to make informed decisions. It automates essential functions within the RAN, leading to reduced human intervention, improved operational efficiency, and rapid responses to network changes. The two RIC variants (real-time vs non-real-time) contribute to a network that can deliver real-time adaptabilities and future-focused network optimization insights. See the 5G Americas Whitepaper for more details.17

Network slicing is a revolutionary concept only possible in 5G Standalone (SA) that enables the creation of multiple virtual (or logical) networks within a shared physical infrastructure. Each network slice can be customized with the appropriate 5G features and capabilities required to fulfill the unique requirements of a use case (e.g., ensuring Quality of Service for a specialized service). See the 5G Americas Whitepaper “Commercializing 5G Network Slicing” (July 2022) for more details on the topic.18

Edge computing is a paradigm that shifts computational tasks and data processing closer in proximity to where the data is generated/used (e.g., the network edge). This can enable low latency and high-performance applications. In the context of 5G, edge computing leverages the proximity of edge servers to user devices, reducing data transfer times and enhancing real-time
application responsiveness. It is discussed in detail within the 5G Americas Whitepaper “Distributed Compute and Communications in 5G” (November 2022).19

The network and service APIs aim to simplify and “hide the complexity” associated with network functionalities and data. This abstraction allows software developers (with minimum telco domain knowledge) to create innovative applications and services that leverage the capabilities of 5G networks. Broadly speaking, network APIs come in two different forms: 1) externally exposed “northbound” APIs (e.g., service APIs), that are designed to be consumed by a 3rd party developer or customer, and 2) internal telco network facing “southbound” or “east/west” APIs, that are for technical capabilities. For example, the CAMARA project is an open-source project under the Linux Foundation, designed to promote global telco collaboration around Northbound Telco Service APIs.20 Together with an exposure platform like the 5G core network Exposure Function, these Northbound Service APIs can empower developers to create applications that offer enhanced user experiences, leveraging real-time data and network capabilities.

These four architectural elements (e.g., the RIC, edge computing, network slicing, and network/service APIs) create new possibilities for advancing 5G telecommunications capabilities. These technologies collectively will empower operators to deliver higher performance, responsiveness, customization, and innovative services, by shaping a connectivity landscape that holds the potential to reshape industries and transform the way we interact with technology. Many companies worldwide are investing time and resources to advance 5G network capabilities using these technological capabilities.

Some operators are moving forward with developer platforms to spur the development of new services. Developer platforms can serve as a centralized resource, offering developers documentation and network service APIs enabling developers to design applications by harnessing data from an operators’ network infrastructure. Also, operators are beginning to work with their vendor partners on various 5G network slicing initiatives to utilize the robust capabilities of 5G Standalone network technology specifications.

2.2 Technology Catalysts

In addition to broad architecture evolution, there are also crucial 5G technology enablers that have revolutionized wireless communication. These enablers tend to be no-regrets features that are often the first to become commercialized once the corresponding standards are published. Among these enablers are shared spectrum, Multiple-Input Multiple-Output (MIMO), and Carrier Aggregation (CA) and Dual Connectivity (DC) advancements. These enablers have collectively paved the way for the enhanced performance, capacity, and capabilities of 5G FWA and P5G networks.

Figure 2: 5G Technology readiness by Standalone and Non-Standalone 5G networks (Ericsson Mobility Report, June 2023)
**Shared spectrum** utilization has played a pivotal role in expanding the capacity and coverage of 5G networks. In addition to the traditional licensed spectrum, network operators (as well as private enterprises) now have the opportunity to harness previously untapped frequencies, such as the Citizens Broadband Radio Service (CBRS) band. This shared approach frees new spectrum by protecting federal incumbents, optimizes spectrum utilization, and enables efficient coexistence of various services, fostering improved network performance and offering a cost-effective strategy for network expansion. This critical enabler is further discussed in the recent 5G Americas Whitepaper “Mid-Band Spectrum Update” (March 2023).

**MIMO** is a transformative 5G enhanced Mobile Broadband (eMBB) technology that enhances capacity and user experience. As of the end of 2022, Massive MIMO technology is rapidly evolving. Innovations include larger array panels, higher radio chain numbers, utilization of new frequencies, and multiple transmission points (multi-TRP). Beyond these, interworking between emerging technologies, such as Artificial Intelligence (AI)/ML, are being integrated to further boost Massive MIMO’s performance. Additionally, considerations for energy efficiency, cost-effectiveness, and deployment ease are making Massive MIMO increasingly viable for widespread deployment. Beyond eMBB, Massive MIMO supports services like FWA, Internet of Things (IoT), and emerging industries, with XR services on the horizon. The rise of private networks suggests a rapid expansion in the range of supported services.

3GPP has plans to refine MIMO further, with enhancements like DL MU-MIMO operation in Frequency Division Duplexing) and Channel State Information feedback reduction. As a result, the performance of MIMO in 5G New Radio (NR) will continue to advance. Recent advancements have also improved upload performance. Notably, Samsung and MediaTek have showcased the potential of improved upload experiences in 5G by using three transmit antennas, a step up from the conventional two.

**CA and Dual Connectivity (DC),** often termed “multi-connectivity”, work alongside multi-antennas to bolster transmission reliability. Given the range of available frequencies, CA and Dual Connectivity are essential for 5G’s versatility, covering everything from standard sub-1GHz cells to broad mmWave ranges. 5G CA maximizes this spectrum, offering improved coverage and faster speeds. Dual Connectivity, by doubling up on transmission, plays a key role in ensuring reliable and quick communication. Many global customers view NR Dual Connectivity as a top choice in their 5G Standalone deployment plans, paving the way for multi-layer networks with speeds surpassing 5 Gbps using mmWave. This combination of better capacity, wider coverage, and faster response times is set to transform the 5G experience for users and industry alike.

These three enablers have collectively contributed to unlocking the potential of 5G technology, transforming how we communicate and connect. Shared spectrum optimizes spectrum usage, CA boosts data rates, and MIMO technology revolutionizes spectral efficiency. As 5G networks expand, these enablers will remain essential components of the technological landscape, shaping the future of wireless communication and powering various applications and services.
3. 5G Fixed Wireless Access

The first 5G use case we highlight is FWA. The demand for high-speed broadband connectivity continues to grow exponentially, driven by the increasing reliance on digital technologies and the proliferation of data-intensive applications. FWA has emerged as a promising solution to address the connectivity needs of both urban and rural areas, offering attractive opportunities for 5G-based residential and business services. This section provides an updated overview of the developments since our last whitepaper in 2021, emphasizing the strategic impact of 5G FWA and its potential in shaping the future of broadband connectivity.

3.1 Key drivers for FWA adoption

As the 5G era advances, FWA is swiftly emerging as a potent competitor to traditional fixed-line services in the broadband market. The broad implementation of FWA, particularly 5G-based, is redefining internet access for both residential and business services across urban and rural geographies.

The introduction of FWA, particularly 5G-powered FWA, has brought about significant changes in the broadband market. First, FWA expands the competitive landscape, as Mobile Network Operators can now offer high-speed internet services traditionally dominated by fixed-line providers. This increased competition is driving innovation and improvements in service delivery.

Second, FWA is altering the economics of broadband provision, particularly in areas where deploying traditional fixed-line infrastructure is challenging or cost-prohibitive. FWA offers a more cost-effective alternative, reducing the need for expensive infrastructure such as cabling and related civil works.

FWA has seen a significant uptick in recent years, driven by the introduction of 5G and advancements in related technologies. However, the rising interest in FWA is not only due to technical factors but also to the increasingly favorable economics of FWA deployments. An array of improvements is driving factors of favorable FWA economics.

- **Rapid Deployment & Scalability:** FWA can be deployed rapidly compared to traditional broadband networks. Faster deployment times mean quicker revenue generation, improving the return on investment for operators. Moreover, FWA networks are highly scalable, allowing operators to start small and grow their networks based on demand. This reduces initial investment and risk, contributing to a more favorable economic outlook.

- **Mid-band Spectrum availability:** Mid-band spectrum (2 GHz to 6 GHz) offers a balance between coverage and capacity, making it well-suited for delivering high-speed broadband services to many users. In the U.S., both T-Mobile’s Band 41 and Verizon’s C-band are considered critical for the FWA market because they can deliver the needed capacity.

- **Federal Grants:** The disparity between those with and without dependable internet access has become a significant issue. In response, the federal government has dedicated considerable resources to promote broadband growth, mainly via grants. FWA technology has emerged as a popular choice in these endeavors, providing an affordable and scalable means to narrow the digital gap.

- **Lowering Customer Premises Equipment (CPE) Costs:** The advent of 5G and the increase in demand for FWA have led to an upsurge in the development of CPEs. A wider range of CPE models is available in the market today, ranging from high-end devices supporting advanced 5G features to more cost-effective models designed for affordability. The Dell’Oro Group expects worldwide 5G CPEs to drop from $350 (2020) to around $100 by the end of 2023.

3.2 FWA’s role in bridging the digital divide

It is evident that the digital divide—representing the gap between those with reliable internet access and those without—is a mounting concern. To address this, the U.S. government has significantly invested in expanding broadband, with a focus on grant programs. In this endeavor, FWA emerges as a cost-effective and versatile solution.

5G FWA is on the rise with the government’s dedication to narrowing this digital gap. FWA’s potential in enhancing broadband access is evident. The government is providing funding with a flexible approach, supporting a variety of technologies to effectively tackle broadband gaps and overcome the digital divide. Although a specific amount of federal funding is not allocated to FWA, its emerging importance in the broadband sphere cannot be overlooked. As technology advances and with continued financial support, FWA’s contribution to nationwide broadband (and its role in diminishing the digital divide) is set to increase. For instance, as states strategize their five-year Broadband Equity, Access, and Deployment (BEAD) roadmaps, it necessitates a deep dive into the evolving technological ecosystem of broadband. In this context, fixed wireless cannot be relegated to the periphery. The practical challenges of extending fiber to remote and rural geographies underscore the importance of FWA.
Table 1: U.S. Broadband Infrastructure Programs (compiled by 5G Americas)

<table>
<thead>
<tr>
<th>U.S. Agency</th>
<th>Federal Broadband Infrastructure Grant Programs</th>
<th>Amount</th>
</tr>
</thead>
<tbody>
<tr>
<td>NTIA</td>
<td>Broadband, Equity, Access, and Deployment (BEAD)</td>
<td>$42.4B</td>
</tr>
<tr>
<td>FCC</td>
<td>RDOF Phases I &amp; II</td>
<td>$20.4B</td>
</tr>
<tr>
<td>FCC</td>
<td>RDOF Phases I (Auction 904)</td>
<td>$9.2B</td>
</tr>
<tr>
<td>FCC</td>
<td>5G Fun for Rural America - Phases I &amp; II</td>
<td>$9.0B</td>
</tr>
<tr>
<td>FCC</td>
<td>Emergency Connectivity Fund programs</td>
<td>$7.17B</td>
</tr>
<tr>
<td>Dept. of Agriculture</td>
<td>USDA Broadband ReConnect programs</td>
<td>$3.9B</td>
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<tr>
<td>NTIA</td>
<td>Tribal Broadband Connectivity Program</td>
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<tr>
<td></td>
<td><strong>TOTAL</strong></td>
<td><strong>$96.97B</strong></td>
</tr>
</tbody>
</table>

Especially when considering the BEAD mandate to prioritize unserved and underserved locales, FWA emerges as a pragmatic, forward-looking solution integral to our broadband future.

This commitment is further reinforced by regulatory initiatives like the U.S.’s CBRS. Earlier this year, U.S. Secretary of Commerce, Gina M. Raimondo, introduced the Public Wireless Supply Chain Innovation Fund. Supported by a $1.5 billion allocation, the fund’s goal is to promote the development of open, interoperable networks. This significant investment aligns with the Biden-Harris Administration’s objectives of driving wireless innovation, boosting competition, and ensuring a resilient supply chain. This initiative aims to place the U.S. and its global partners at the helm of 5G and upcoming wireless tech innovations.

WISPs (Wireless Internet Service Providers), pioneers in broadband outreach, are central to bringing broadband to various locations, from homes and offices to schools. They prioritize serving rural America’s challenging regions and offer affordable options to underserved urban areas. WISPs have a notable presence with a network of over 2,800 providers catering to 7 million-plus customers nationwide. WISPs are often small businesses, with an average team of less than ten and around 1,200 customers. For home users, their network provides download speeds typically range between 25 to 100 Mbps. The adaptability of the CBRS and its shared spectrum model plays a key role in FWA network expansion. An example is Mercury Broadband, leveraging CBRS’s shared spectrum to meet rural areas’ connectivity needs.

### 3.3 Bridging the connectivity gap for SME (Small Medium Enterprise)

FWA presents a significant opportunity not just for individual consumers but also for the enterprise sector, especially the SME segment. This is particularly true in emerging markets where SMEs play a pivotal role in the economic landscape. As businesses increasingly turn digital, the demand for high-speed broadband connectivity is on the rise. This is essential for a
variety of operations, from main and branch offices to the growing reliance on e-commerce, electronic payments, cloud services, and enterprise resource planning applications.

Moreover, the surge in connected devices, including those for the IoT, used in diverse applications such as security, process control, and inventory management, underscores this need. Many SMEs, including those operating as Small Office and Home Office (SoHo) entities, are situated in areas with limited or no connectivity. These areas can range from suburban locales to city outskirts, including light industrial zones and business parks that may lack adequate in-building cabling. Some markets even have enterprises relying on outdated microwave point-to-point access, which can be both costly and inefficient. It's noteworthy that SMEs generally possess greater purchasing power compared to individual consumers. Catering FWA services to both consumers and SMEs in the same vicinity can lead to operational synergies. SMEs typically have different usage patterns, with most of their activity occurring during daytime hours, resulting in a more balanced network traffic distribution. This can optimize busy-hour network capacity, ensuring efficient service for both consumer and enterprise segments.

3.4 FWA market update for 2023

FWA is experiencing significant growth globally due to its increasingly prominent role in providing home and business broadband. This trend is particularly pronounced in areas where fixed broadband infrastructure is lacking, making FWA an attractive solution for high-speed internet access. Ericsson predicts an impressive 19% annual growth in FWA subscriptions from 2022 to 2028, expecting the global total to exceed 300 million by the end of that period.28 Interestingly, 5G is set to dominate this space, making up 80 percent of these connections.

This rapid global expansion of FWA has been observed predominantly in emerging markets like India, Mexico, South Africa, and the Philippines. It is worth noting that these regions were responsible for 40% of the 5G FWA launches in the last year. Over 75% of service providers across more than 100 countries now offer FWA services, with about 33% delivering FWA over 5G. This marks a substantial increase from 20% the previous year.29

Furthermore, the number of 5G FWA connections is expected to approach 235 million by 2028, constituting almost 80% of all FWA connections. After India's 5G spectrum auction, a leading provider is preparing to provide 5G FWA services to 100 million homes and numerous businesses.

By the end of the year, 5G subscriptions in the India region, which encompasses Nepal and Bhutan, are expected to hit 31 million. The figures are predicted to surge to an astonishing 690 million by 2028, making up more than half of the region's estimated 1.3 billion mobile subscriptions by then.

Ericsson also underscores the fact that high 5G FWA uptake in rapidly developing nations like India can enhance the economies of scale for the 5G FWA ecosystem. As a result, the price of CPE may drop, benefiting lower-income markets. Despite facing global economic headwinds, Ericsson anticipates 5G subscriptions to reach 5 billion by the end of 2028. Between July and September, an additional 110 million 5G subscriptions were added worldwide, raising the global total to nearly 870 million. This growth is fueled by the increasing availability of devices, dropping prices, and extensive deployments in China. Northeast Asia and North America are witnessing substantial 5G growth. By the end of the year, 5G penetration in these markets is expected to touch around 35%.30

Several market research firms have also made notable findings and forecasts regarding 5G FWA. For instance, the Leichtman Research Group reported that last year, FWA services made up 90% of the net broadband additions in the U.S., a significant jump from 20% in 2021. T-Mobile and Verizon's 5G home internet services saw a remarkable increase in subscribers, from 730,000 in 2021 to about
3,170,000 in 2022. Fixed wireless subscriber growth has continued into 2023, with T-Mobile alone reporting 3.7 million high-speed internet subscribers at the end of 2Q2023.\textsuperscript{31} In the same period, Verizon gained an additional 386,000 FWA users, reaching a total of 2.26 million by June 2023.\textsuperscript{32}

The advantages of 5G FWA solutions are substantial. In some cases, they can deliver speeds that are more than ten times faster than 4G FWA, but more importantly, they provide significant capacity enhancements resulting from various technological advancements. These advancements enable FWA to cater to a broader market segment. Notably, T-Mobile in the United States surpassed 2.5 million 5G FWA customers by the end of 2022, with an anticipated growth to 7-8 million FWA subscribers by 2025. Similarly, Verizon aims to acquire 4-5 million FWA subscribers within the same timeframe. These projections suggest that FWA could capture approximately 10% of the fixed broadband market in the United States, highlighting its immense potential.

Additionally, EE UK, having launched its 5G FWA services in 2019, aims to achieve 90% coverage in the UK by 2028. Fastweb in Italy, which began offering 5G FWA in 2020, plans to extend its services to 12.5 million homes and businesses by 2025. In the Asia Pacific region, Reliance Jio is endeavoring to deliver 5G FWA to 100 million homes.

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3.5 FWA using mmWave

Various whitepapers and studies have explored the benefits and challenges of millimeter wave (mmWave) technology, laying a solid foundation of understanding its potential and drawbacks. Building upon these insights, the utilization of mmWave for FWA presents specific advantages that are worth underscoring.

The rise of 5G, coupled with the COVID-19 pandemic, has spurred the growth of data-heavy services like video calls, streaming, and mobile gaming. As these services gain traction and consumers seek more engaging extended reality (XR) experiences that challenge current network limits, operators must enhance both fixed and mobile network performances. Simultaneously, they should explore network convergence opportunities to boost service quality and cut operational expenses.

The millimeter wave (mmWave) spectrum, with its potential for FWA deployments with reduced latency and higher speeds, reaching gigabit levels, is increasingly acknowledged as 5G becomes more prevalent. Despite challenges like propagation losses, line-of-sight requirements, high power consumption, and device/CPE availability, mmWave technology offers the promise of ultra-fast speeds and expansive networks.

GSMA’s projections indicate that for dense urban households, 150 MHz to 700 MHz of mmWave spectrum bandwidth will be essential to meet the demands of 5G FWA, assuming a 30% FWA penetration rate. In regions with less Fiber-To-The-Home coverage, which includes suburban and rural locales, the mmWave spectrum requirement for 5G FWA could be higher. Specifically, suburban areas might need between 700 MHz and 1200 MHz, while rural towns could require a range of 50 MHz to 850 MHz, based on a 60% FWA penetration, as per insights from GSMA Intelligence.\textsuperscript{34}

The mmWave spectrum propagation characteristics result in shorter cell ranges compared to lower frequencies, typically up to 600 m - 1 Km. However, with optimal line-of-sight conditions, utilizing elevated radio sites and outdoor roof-mounted CPEs, mmWave cell ranges can extend to several kilometers. Achieving this necessitates high power radios and CPEs, coupled with software innovation such as mmWave range extension, to manage the increased propagation time over longer distances. Field tests across various continents have shown promising results over extended distances, underscoring the potential of 5G mmWave spectrum. The guard period in the TDD format, which is the interval between downlink and uplink, accounts for transmission roundtrip time and equipment switch time. An extended cell range can be achieved by increasing this gap, albeit at the cost of slightly reduced downlink peak rates. By integrating these strategies, mmWave FWA can cater to households several kilometers away under favorable signal conditions. Notably, Samsung achieved a 10 km long-range transmission over 5G mmWave in Australia with NBN Co, which marked the company’s longest 28 GHz 5G mmWave FWA connection.\textsuperscript{35}

However, maintaining optimal line-of-sight becomes challenging as the distance from a household to the radio site grows. The optimal solution combines mmWave for households with good conditions and mid-band for those in less ideal settings.
Figure 4: mmWave extended range can be used to provide FWA across several Km (Source: GSMA 5G mmWave coverage extension solution whitepaper)

With the capacity relief provided by mmWave, the mid-band can cater to more distant households in challenging locales. This approach not only extends wireless fiber services to rural areas but also increases the number of households served per radio site and supports greater data consumption. Leveraging this strategy fully realizes the business and technological potential of mmWave FWA, presenting a lucrative opportunity for mmWave spectrum utilization. Notably, Samsung and Qualcomm achieved a new 5G speed record, aggregating millimeter wave and C-band spectrum to attain 8 Gbps on a single device.

Smart repeaters cost-effectively extend mmWave coverage by amplifying and directing the mmWave signal. Their easy installation on various structures accelerates mmWave network deployment and eliminates the need for complicated infrastructure modifications. Additionally, addressing challenges in dense urban and indoor environments necessitates the integration of technologies like Integrated Access and Backhaul (IAB) architecture and Reconfigurable Intelligent Surface (RIS) technologies.

Reducing power consumption is crucial for successful smartphone mmWave applications. Techniques such as Discontinuous reception technology and network topology optimizations help achieve this. Furthermore, the mmWave device market has greatly expanded, offering a multitude of options. The industry forecasts considerable growth in FWA CPE device shipments, driven by high-speed connectivity demand, contributing to mmWave network expansion and a robust mmWave ecosystem.

### 3.6 CPE Advancements

In the realm of FWA solutions, a critical component is the CPE. Essentially, it ends the 4G LTE and 5G NR air interfaces, significantly influencing the end user service quality and the operator’s expenses associated with providing FWA services. Over time, the CPE market has evolved and developed momentum, significantly influencing the availability of FWA and millimeter wave (mmWave) CPEs.

The choice of CPE form factor plays a significant role in designing FWA offerings. While the focus is often minimizing the on-premises cost (e.g., cost-per-gross-add) with basic hardware features and self-install options, the broader economic implications to network costs, and revenue drivers are often overlooked. There are two primary types of CPEs: indoor and outdoor. While indoor CPEs offer ease of installation and lower initial costs, their performance can be compromised due to factors like wall/window attenuation and less effective antenna components. On the other hand, outdoor CPEs, though requiring a more involved installation...
process, ensure a robust and high-quality connection due to their superior antenna gain and minimized interference. The tipping point in CPE choice arises when considering long-term sustainability and network efficiency. While indoor CPEs may potentially seem cost-effective initially, their potential limitations can lead to network congestion and subpar user experience, especially during peak times. Outdoor CPEs, despite their possible higher upfront costs, could provide enhanced spectral efficiency, allowing for more FWA connections per site and ensuring consistent service levels even during high-demand periods. For operators, striking the right balance between the immediate benefits of indoor CPEs and the long-term advantages of outdoor CPEs is critical. It’s essential to consider not just the immediate cost but also the overall Total Cost of Ownership (TCO), which includes network maintenance, customer satisfaction, and potential revenue generation. As the FWA market evolves and innovates, operators must remain agile, ensuring they make CPE choices that serve both their immediate needs and long-term strategic goals.

The FWA CPE market is seeing a fast pace of innovation and evolution, with new products continually being introduced. The 3GPP device ecosystem is vast, and operators with an FWA network can benefit from this, selecting the most suitable CPE based on price, functionality, and performance.

Over the past two years, there has been significant growth in the number of millimeter wave (mmWave) devices in the market, with 854 SKUs from 52 companies. FWA is the primary growth engine for mmWave CPEs in the short term. Despite a dip in 2021 due to the pandemic-induced chipset shortage, the Global Mobile Supplier Association (GSA) forecasts that the aggregate shipments of FWA CPE devices will grow by 33% in 2022.

### 3.7 Future outlook on FWA

Last year, the U.S. witnessed a significant rise in FWA technology, especially on the 5G platform. A staggering 90% of broadband additions from major providers were attributed to FWA. While FWA has been a major source of 5G revenue, both in the U.S. and globally, its long-term performance, especially when compared to wired alternatives such as Fiber or DOCSIS (Data Over Cable Service Interface Specification), which can deliver up to 10G download speed and offer symmetrical throughput, remains a subject of discussion.

The primary concerns surrounding FWA’s future revolve around its performance and economic viability. Yet, most current FWA users find their broadband satisfactory. According to OpenSignal analysis from November 2022, FWA services were characterized as “typically middle of the pack” compared to cable and telco wireline alternatives. Furthermore, the demand for ultra-high-speed applications, including emerging market prospects like extended reality (XR) and 8K video streaming, is still in its infancy. This indicates that FWA speeds should suffice for the majority of the users until the new market matures.

At the Mobile World Congress (MWC) 2023 in Barcelona, the sustainability of 5G FWA was a hot topic. A key concern was the economics driven by spectrum availability. As telecom and cable companies expand their bandwidth offerings, new applications and use cases will emerge. As 5G attracts more users and new cases emerge, will there be enough bandwidth to support both mobile and FWA customers? Analysts at MWC urged operators to strategize their capacity allocation, hinting at potential challenges in the coming decade. However, technological advancements, like the shift to mmWave bands, could offer solutions to these challenges.

The success of FWA, particularly in the U.S., is closely tied to the availability of licensed mid-band spectrum. Limited access to this spectrum could deter FWA providers from offering competitive prices, raising concerns about service quality due to potential bandwidth constraints. Regulatory bodies, such as the Federal Communications Commission and the National Telecommunications and Information Administration, must develop a comprehensive spectrum roadmap. This would not only boost FWA’s potential but also ensure better pricing and value for consumers.

Planning for FWA encompasses more than just RAN and spectrum aspects. The integration of FWA also introduces advanced demands on the core network, given its role in handling increased data traffic and ensuring optimal service delivery. With the rise of FWA, especially in the context of 5G, there’s an amplified need for core networks to manage enhanced traffic loads, prioritize low latency requirements, and maintain stringent security standards. Furthermore, the introduction of new capabilities, such as network slicing, necessitates that core architectures be agile and scalable. Operators could prioritize optimizing their core networks to handle these challenges, ensuring resource management is efficient, backhaul choices are strategic, and redundancy measures are in place for reliability. This attention to the core is vital to guarantee that the promise of FWA as a reliable broadband solution is fulfilled without compromising on performance or user experience.
Furthermore, governments recognize the importance of enhanced connectivity. The U.S. government’s $42.5 billion BEAD grant program aims to ensure universal access to high-speed internet. Such initiatives, combined with public-private partnerships, can expedite the deployment of essential networks. The overarching objective of these investments should be to expedite 5G rollout and foster use cases in vital sectors that rely on integrated, green, secure, and reliable connectivity. T-Mobile, for instance, is exploring new technologies to enhance its FWA offerings (e.g., considering deploying mmWave spectrum to support faster speeds and cater to more customers).43

While the future of FWA and 5G remains dynamic, with the right strategies, technological advancements, and regulatory support, it holds immense potential for reshaping the broadband landscape.
4. Private 5G Networks

The second 5G use case we highlight is private 5G networks. In wireless networks, not all use cases share identical requirements; some require precise control and customization of network infrastructure and services, while others prioritize unwavering security and reliability. Private 5G networks provide purpose-built solutions that can be personalized and implemented to address these distinct needs.

Historically, businesses utilized private networks primarily for telephony services. However, as technology advanced, the focus shifted to data-centric applications. While Wi-Fi was a go-to for private networks, it doesn’t meet the needs of modern applications like smart factories. In contrast, 5G offers enhanced mobility, latency, and security.

A private 5G network (P5G) is a discreet mobile network that uses licensed, unlicensed, or shared spectrum to provide dedicated 5G connectivity with top-notch performance and heightened security. P5G centers on devices chosen explicitly by users, eliminating worries about impacts from public users that could affect connected device numbers, data speed, and crucial network performance measures.

5G is crucial for digital transformation, introducing features like Ultra-Reliable Low Latency Communication (URLLC) and massive Machine-Type Communication (mMTC) that redefine business operations. For instance, URLLC facilitates real-time autonomous vehicle control. Unlike Wi-Fi, 5G ensures security by authenticating devices using SIM or eSIM and provides connections via licensed spectrums.

The digital transformation wave, fueled by technologies like IoT and AI, demands more than traditional networks offer. 5G, with its advanced features like network slicing, emerges as the ideal choice for private networks. As industries evolve, the importance of 5G, especially in private networks, becomes even more pronounced. Over the last year, the commercial rollout of private 5G networks has become evident. Consequently, experts in the field anticipate substantial expansion of P5G deployments. Predictions indicate that the worldwide market for P5G networks, valued at around $1.3 billion in 2021, is on track to experience significant growth, with estimates ranging between $39 billion and over $100 billion by 2030 underscoring its growing significance in the digital landscape.

4.1 Drivers, benefits, and challenges of P5G adoption

P5G networks are set to transform industries by boosting productivity, integrating IoT devices, and enabling real-time data-driven decisions. Despite initial costs, the long-term advantages, such as better operational efficiency and cost savings, make P5G appealing. The changing regulatory landscape, including shared spectrum availability like the CBRS band, further speeds up P5G adoption.

The integration of 5G in the industrial sector drives digital transformation, notably impacting the Industry 4.0 revolution in manufacturing. P5G, boasting ultra-low latency and high data bandwidth, is revolutionizing manufacturing methods. Gone are the days of restricting devices with Ethernet cables, ushering in enhanced mobility across manufacturing spaces. Additionally, the localized data management of the 5G system prioritizes data security, a paramount issue for numerous sectors. To realize these benefits, Industrial and Manufacturing entities must implement a blend of hardware, software, and connectivity tools that synergize. This demands coordination between teams responsible for Information Technology (IT) solutions.
and those overseeing Operational Technologies (OT) that bolster specific use cases. However, the adoption journey isn’t straightforward. Grasping the intricacies and interdependencies of new technology can be daunting. For Industry 4.0, the technology framework is extensive, spanning from device to cloud, and the vendor environment is evolving, causing overlaps between traditional OT, IT, Original Equipment manufacturers (OEMs), cloud, and communication service providers. Add to this the hurdles of integrating age-old systems, methodologies, and organizational culture, and the undertaking can appear formidable.

Organizations like 3GPP have collaborated to develop enhanced specifications that improve the reliability of LTE and 5G networks, particularly for critical communications such as public safety. The latest 3GPP Rel. 16 builds on the foundational 3GPP Rel-15 and has been instrumental in enabling advanced 5G applications like network slicing and enterprise services. Unfortunately, the introduction of new specification, notably 3GPP Rel. 16, faced significant global challenges due to the COVID-19 pandemic and economic slowdown, led to delays in standardization and pushed back the availability, testing, and deployment timelines for P5G-related features.

Regarding devices, the 5G device landscape is still maturing. Industrial chipsets, based on the 3GPP Rel. 16 release, are expected by 2024. Once these 5G industrial features become available, they will require validation in tandem with industrial OEMs to underscore 5G’s superiority in industrial settings. Consequently, a surge in 5G private network adoption is anticipated after 2024.

As we overcome these challenges, 5G will likely be the top choice for private networks. However, its use will vary by industry. Manufacturing and transport are leading in 5G adoption, with healthcare and public sectors catching up. P5G networks have several drivers that are fueling their adoption in various industries. Here are some key drivers for P5G networks:

Digital transformation demand continues to accelerate. The paramount importance of safety and security drives the adoption of P5G networks. These networks bolster safety and security through advanced data protection, isolation and privacy measures, network segmentation, infrastructure control, support for mission-critical applications, robust surveillance and monitoring capabilities, resilience and redundancy features, improved emergency response capabilities, compliance with regulatory requirements, and establishment of trustworthiness and control. These factors position private networks as an appealing option for industries and organizations that prioritize safeguarding sensitive data, critical operations, and safety.

Spectrum and regulatory landscape are constantly evolving, becoming increasingly favorable for private network deployments. Internationally harmonized exclusive use spectrum is preferred, and it is important for this valuable resource not to lay dormant or unused. The rise of P5G, along with the utilization of the CBRS band, underscores the option of shared spectrum, eliminating the necessity for exclusive licenses. Many countries are now designating dedicated spectrum resources for private networks. For example, in the United States, the 37.0 - 37.6 mmWave band holds promise for high-performance private 5G networks, targeting lower latency and improved throughput applications, although its shared use availability remains uncertain. Some countries have specifically allocated spectrum for localized industry and enterprise use. While direct spectrum allocation to industries or the reservation of spectrum for private networks could maybe boost private network adoption, it may also lead to underutilization of spectrum if the spectrum goes unused. To address this challenge, global policy makers should strongly consider spectrum policies that ensure spectrum is being fully and appropriately utilized by recipients of the allocated spectrum.

P5G Performance Superiority and Flexibility (vs alternatives) enhanced performance and flexibility. It’s versatile, supporting the Sub-6GHz and millimeter Wave spectrum, which allows for a range of coverage and capacity scenarios. However, it’s worth noting that while P5G is a formidable solution, it’s not the only option for high-performance wireless connectivity. There are alternatives, each with its own set of challenges and limitations.

- **Wi-Fi 6** relies on unlicensed spectrum to provide wireless local area network (WLAN) services to devices within a limited range. It delivers improved speed and capacity for WLAN applications. However, it offers smaller coverage (compared with 5G), and lacks seamless mobility support.
- **Public 5G** mobile networks are set up and run by Mobile Network Operators using licensed spectrum to deliver cellular services to consumers and businesses. But, because the network is shared with the public, there’s a heightened security risk. During peak times, all users may face slowdowns. Conversely, private 5G networks are created for a specific entity or use case. They provide increased security and customization, ensuring users have better safety and control.
- **Private 4G** networks provide secure and reliable
wireless connectivity, like 5G. They are built on mature technology and support a broad range of devices. However, they lack some 5G features, such as the ability to utilize a broader spectrum and architectural flexibility like service-based architecture and network slicing. The 3GPP exclusively has outlined SNPN (Standalone Non-public Network) and PNI-NPN (Public Network Integrated Non-Public Network) for 5G. In contrast, enhancements for 4G private networks were established using external standards, such as MultiFire for unlicensed spectrum. As the industrial 5G device ecosystem matures, 4G is a transitional technology.

Diving deeper into what makes 5G so unique, one of the standout features of 5G is network slicing, which allows operators to create multiple virtual networks on a shared 5G platform, each tailored to specific applications. It's a way for operators to make the most of their existing macro network assets, delivering specialized networks that meet unique needs.

The rise of eSIM technology in 5G devices, now supported by major platforms like Android and iOS, has given 5G adoption a significant boost. eSIM simplifies provisioning as with eSIMs, devices can be remotely set up with subscriber credentials, eliminating the need for physical handling, speeding up the integration across various verticals. The GSMA’s eSIM working group is refining eSIM specs. While dual SIMs suit devices requiring two network access, eSIMs are more efficient and cost-effective with their ability to store multiple profiles.

Network exposure is another key feature, with RESTful APIs that securely open up network capabilities, fostering greater programmability. Coupled with this is the power of network data analytics. By analyzing data from the network, applications, and devices, operators can gain invaluable insights that drive optimization and performance enhancement.

Automation and orchestration play pivotal roles in the swift setup of 5G networks. By leveraging virtualization, adaptable hardware, and comprehensive IT frameworks, operators can automate the expansion and configuration of 5G networks. This leads to better resource use, reduced manual tasks, and overall improved network reliability.

Security remains paramount in the 5G landscape. With advanced security features embedded in 5G devices, 5G networks are well-equipped to counter threats and uphold data privacy. The specifics of this security are detailed in 3GPP TS 33.501. Even once physically isolated, traditional manufacturing environments can now enjoy logical isolation in the 5G setting, ensuring they’re shielded from external threats. Devices operating within 5G networks provide a secure connection, fortified by methods such as network separation or the deployment of dedicated 5G private networks tailored to specific use cases.

In essence, as industries transition through this transformative phase, 5G is poised to become the preferred infrastructure for private networks. Different sectors are at varied stages of this adoption cycle, with manufacturing and transport at the forefront and domains like healthcare and public services gradually integrating. The narrative of 5G and 5G continues to evolve, promising a confluence of innovation, challenges, and unparalleled growth in the technical domain.

### 4.2 Technology Updates

The recent technological advancements in 5G private networks focus on the innovations that have transformed the landscape of private network deployments. With the rapid evolution of 5G technology, Industries and enterprises are increasingly adopting private networks to meet their specific connectivity needs. Below are insights into the key technological advancements that have enhanced the capabilities, performance, and security of 5G private networks, enabling organizations to harness the full potential of this transformative technology.

3GPP advancements for 5G networks are continuously improving to meet industry and business needs. These updates introduce the Non-Public Networks concept in 5G, which enhances network control, low latency, indoor coverage, and security. 3GPP Rel-15 was a pivotal release, introducing a new radio interface with scalable numerology, mMIMO, mmWave support, and the ability to deliver Gbps speeds flexibly. With SA, it added a service-based architecture in the core network, enabling flexible service creation, open APIs, and cloud-native capabilities.

3GPP Rel-16, the complete 5G specification, built on Rel-15’s foundation, focusing on advanced use cases like enterprise services and network slicing. It brought significant improvements, especially for the enterprise sector. The Rel-17, completed in March 2022, and the forthcoming Rel-18, expected in Q1 2024, promise evolutionary and revolutionary features tailored for enterprise applications. A standout feature, Sidelink, facilitates direct communication between devices, offering cost savings and optimizing deployments in enterprise scenarios. This enhancement extends network coverage and promotes safety by allowing devices like smartphones and wearables to interact with vehicles. In particular,
5G-Advanced will expand Sidelink capabilities, emphasizing Vehicle-to-Everything (V2X) communications, ensuring better public safety.

Figure 5: 5G related 3GPP capabilities (Samsung)

5G NR Positioning is now evolving as a key feature that enables the operator of a 5G network to position devices for both indoor and outdoor applications with much better accuracy and reliability than those of previous generations. A wide variety of use cases require positioning services—from locating emergency callers’ locations to autonomous driving to tracking automated forklifts moving in a factory. 5G networks offer the exciting possibility of deploying a single technology that addresses both the positioning and data needs of these use cases in an integrated solution, all in an ultra-reliable manner.

Another notable feature, Reduced Capability (RedCap) devices, will extend 5G to power-constrained devices, from smartwatches to IoT devices. 3GPP in Rel-17 started standardization development work for RedCap NR devices. The goal is to deliver lower-cost IoT devices that satisfy the design requirements for mid-range IoT use cases. This will allow important categories of use cases such as wearables, industrial sensors, and video transmission to be served by lower-cost NR devices, thus enabling cost-effective IoT solutions to be deployed in various vertical industries. Specifications essential to support RedCap devices were finalized last year, and we anticipate commercial deployment to begin from next year. Notably, early trials have already commenced this year.\(^{49}\)

### 4.3 Key industries transformed by P5G

The introduction of 5G technology is expected to drive innovation across key industry sectors:

In manufacturing, the growth of 5G is rapidly gaining momentum. 5G enhances production with real-time monitoring, automation, and Augmented Reality (AR)/VR. These networks allow manufacturing industries to create highly customized, reliable, and efficient communication environments. Utilizing 5G’s strength, private networks are revolutionizing production processes. As manufacturers seek to optimize operations, reduce downtime, and embrace Industry 4.0 principles, expanding 5G private networks in the manufacturing sector promises to drive innovation and unlock new productivity levels. For instance, BMW’s Leipzig plant has implemented a dedicated 5G private network within the facility to enhance its production processes and to increase efficiency through seamless communication among machinery.\(^{50}\)

The broadcasting industry leverages 5G for high-quality video streaming during events. 5G offers optimized mobility and mitigates video glitches especially when the camera operator
transition between locations. Several TV broadcasters and media companies are already using, or considering the adoption of, private 5G to support live events coverage. The recent Kings Coronation in the UK is a good example of this use case.\textsuperscript{51}

The aviation industry deploys bespoke networks for in-flight broadband and communications. For example, Gogo in the USA has deployed 150 sites, constituting one of the world’s largest 5G Open vRAN private networks, providing connectivity to private jets.\textsuperscript{52}

Ports and transportation adopt 5G for security, reliability, and mobility. For example, Frankfurt Airport’s large private 5G network.\textsuperscript{53}

Neutral Host model reduces 5G deployment complexity, as seen with Sunderland City Council’s public infrastructure connection and local business support.\textsuperscript{54}

4.4 Flexible 5G Architectures

By seamlessly merging the benefits of virtualization with the power of open architectures, organizations can forge private networks that are robust, secure, and highly adaptable to the diverse demands of modern connectivity. Incorporating virtualized ORAN technology into 5G private networks enables a diverse ecosystem of vendors. This promotes the flexibility to create cost-effective, feature-rich solutions for each use case. While private networks using virtualized ORAN technology are highly adaptable, the following key architectures can cover various deployment scenarios.

Figure 6: 5G Deployment Models (Samsung, 5G Americas)

The **Dedicated All On-Premises** approach emerges as a viable deployment architecture in situations where customers demand complete separation of their private network from public access. Within this deployment framework, customers can deploy essential components such as the RAN, User Plane Function, and applications on their premises. The **Dedicated RAN Only On-Premises** strategy presents a practical deployment architecture for scenarios where customers prioritize cost-effective and streamlined solutions. This approach suits situations where customers seek to minimize expenses and intricacies associated with end-to-end deployment while remaining receptive to utilizing shared core services. The **Dedicated RAN and User Plane only On-Premises** strategy of deploying only RAN and User Plane on-premises offers
a pragmatic architecture for scenarios where customers prioritize affordability while ensuring robust data security and retaining complete user data control. This approach is suitable for situations where customers aim to reduce costs and complexities linked with comprehensive deployment, all while retaining authority over user data. **Shared Macro Network-Based Private Networks** utilize current macro network installations and capitalize on functionalities like network slicing to establish separate virtual wireless networks, providing efficient 5G services. This method is apt for scenarios where customers demand a swift 5G network solution that utilizes shared resources effectively.

### 4.5 Private 5G networks go-to-market models

Despite the substantial revenue opportunities within private networks, analysts foresee earnings dispersed among multiple projects. While the network’s importance remains pivotal in the context of 5G, the revenue structure might originate from various components constituting the comprehensive solution. For instance, setting up a private network to facilitate collaboration and communication among construction workers via a 5G network could necessitate specialized applications and resilient devices customized to the demands of the construction field. The comprehensive solution provider must collaborate closely with industry partners to ensure that the tailored solutions are delivered. Ultimately, the provider offering an end-to-end solution will exercise comprehensive control over the entirety of the project.

**Figure 7: 5G P5G E2E Service Components & Solution Providers (5G Americas)**

Many market entry strategies exist in the rapidly evolving landscape of 5G networks, each tailored to address specific customer needs, industry sectors, and service provider capabilities. The choice of strategy depends on variables such as organizational resources, target sectors, competition, and desired sales process control. This section outlines several distinct market entry strategies that hold promise for 5G networks.

The Direct Sales Approach involves solution providers directly promoting 5G network solutions to particular industries. These providers establish and manage sales teams tasked with engaging potential clients. A notable example is the collaboration between Samsung Electronics and NAVER, where they collaborated to deploy 5G for offering services utilizing robots.55

The Cloud Service Providers Partnership strategy sees traditional OEMs teaming up with cloud service providers to integrate various 5G solution components. Cloud providers offer easily accessible services or end-to-end 5G solutions, seamlessly merging network services and cloud resources. For instance, AWS introduced a 5G based on CBRS radio, while Azure delivers a private 5G core as a service.56 57

Channel Partnerships involve solution providers collaborating with technology integrators, system resellers, or value-added distributors who already possess established customer relationships. This enables bundling 5G network solutions with existing offerings, providing clients with comprehensive solutions.

The Managed Services Providers Model sees managed service providers collaborating with various solution providers to design, install, deploy, and manage 5G networks. This model suits industries seeking to concentrate on their core business while outsourcing network complexities.

The Hybrid Model capitalizes on the versatility of 5G solutions to blend multiple market entry models into a hybrid approach suitable for target markets and available resources. For instance, larger customers might be approached through a direct sales team, while smaller businesses are reached through channel partnerships.

As the 5G landscape unfolds, selecting the most fitting market entry strategy becomes pivotal for success.

### 4.6 Future Horizon

The digital transformation across industries is setting the stage for a promising future. The need for fresh solutions becomes evident as outdated communication systems give way to modernization. Notably, sectors like manufacturing and logistics are discarding obsolete narrowband networks, recognizing their unsuitability in today’s dynamic environment. Additionally, the emergence of Adaptive Industry 4.0 underscores the importance of adaptable Information and Communication Technology (ICT) infrastructure that can seamlessly adjust to ever-changing
manufacturing processes. The present surge in data generation, propelled by technologies like AR, high-resolution imaging, and sensor networks, demands agile data management solutions to harness and leverage this abundance of information effectively. With an increase in the frequency of network changes, the critical significance of robust cybersecurity measures becomes apparent, safeguarding valuable data against potential threats. Together, these pivotal factors shape the course of digital transformation across industries and promote innovation.

Figure 8: 5G connections by Service (Source: GSMA 2023, ABI Research)

Looking ahead, ABI Research predicts a sharp increase in URLLC connections from 2024 to 2025, followed by a substantial surge in 2027. Manufacturers are expected to use more robots in their facilities and will need ultra-fast, reliable connections (uRLLC) for real-time data from devices and interfaces such as Human-Machine Interfaces (HMI) or robotic control-based industrial automation. Industries will use mMTC for equipment monitoring and eMBB for sending contents to and from AR glasses. The ongoing digitization of industries offers significant opportunities.

The path toward 5G has been a collaborative effort involving infrastructure vendors, network operators, and more. However, this only represents the initial phase; upcoming stages promise even more significant innovations and broader network expansions.

5G establishes a strong foundation for consumers, enabling diverse applications, from AR/VR to the metaverse. Further transformative experiences will reshape how consumers engage with technology in the coming years. Concurrently, in industrial and enterprise segments, the synergy between 5G and edge computing is emerging as a pivotal aspect of digital transformation. Additionally, the introduction of 5G-Advanced is laying the groundwork for the evolution toward 6G, which has the potential to redefine communication for both consumers and businesses. As we embrace the capabilities of 5G, we are also catching a glimpse of the revolutionary potentials that 6G might introduce.
Conclusions

Keep value propositions simple and relatable

It is often the simplest value propositions, that are most successful. Over the past few years, a confluence of events centered around 5G deployment has made residential FWA a commercial reality. FWA is a use case that now serves millions of households across America. This is a clearly observable first example of successful 5G use case adoption that goes beyond simple eMBB for smartphones. Skeptics might say delivering home internet is a commodity, but it is this simplicity and familiarity that promotes early adoption. In the case of home internet, 5G has been a positive catalyst for consumers choice.

When end users have an existing frame of reference, they can relate to the utility gained from a new use case (and their associated willingness-to-pay for it). Simply put, a successful use case like 5G home broadband FWA contains an important value proposition for some consumer segments. It can offer a viable alternative to traditional wired broadband, especially in regions where infrastructure is hard to establish. However, getting to this point required 5G development to align with many other factors such as mid-band spectrum availability, as well as capacity enhancing 5G features like CA. With continued 5G adoption and internet usage, the scarcity of appropriate spectrum to serve the demand will be a growing concern.

Going forward, the many government initiatives to bridge digital divides will play a key role in the continued success of 5G FWA. Moreover, the macroeconomic importance of these programs are supported with increasing evidence from the analyst community. In hindsight, Deloitte Consulting’s modeling estimated that “...a 10-percentage point increase of broadband access in 2014 would have resulted in more than 875,000 additional US jobs and $186 billion more in economic output by 2019.” They also highlight that both “increased broadband penetration” and “greater broadband availability” were more important economic drivers than incrementally “higher speeds.” This underscores the importance of digital inclusivity and its direct correlation with economic growth.

Industry fragmentation may dilute value and be a headwind to use case adoption

 Concurrently, we observe P5G networks are gaining traction in the industrial sector due to their evident advantages. Many of these advantages are realizable in the near term, such as 5G’s flexible architecture seamless mobility and expanded coverage, leveraging both shared and licensed spectrum. These are tangible capabilities, often perceived to be surpassing rival technologies like Wi-Fi 6 and private LTE.

However, early adoption of P5G appears concentrated in the industrial/manufacturing vertical, and we believe there may be several headwinds facing adoption at scale. We believe an overarching theme to these headwinds is industry fragmentation, across both 5G technology development, and go-to-market business models.

In the case of technology development, the original ambitious vision for 5G included three diverse aspects of eMBB, URLLC, and mMTC. However, the urgency to commercialize technology resulted in tradeoffs and a consensus to narrow early development focus toward eMBB. To further speed commercialization, the legacy 4G core network could continue usage in what became known as non-standalone architecture. As a result, the 5G SA ecosystems benefiting from aspects of URLLC and mMTC (like private 5G) have lagged and have not yet reached full potential.
Furthermore, use cases like private 5G are ones where a familiar go-to-market model is experiencing fragmentation into multiple options for the end users. This adds to the complexity and uncertainty associated with emerging technology; risk-averse end users may defer their adoption until the ecosystem is seen as reaching maturity.

According to various studies, the adoption of P5G is projected to surge in the upcoming years and can be attributed to a rapidly maturing ecosystem with greater availability of industrial-grade devices with new 3GPP capabilities. The advent of 5G-Advanced is set to reshape the landscape further, introducing features that cater to consumer, industrial and enterprise applications. P5G’s adaptability and customization make it a cornerstone in our interconnected, data-driven world, reflecting shifts in business and societal dynamics. With IoT enhancements, notably RedCap, 5G’s reach will extend into novel use cases. As we progress, subsequent 3GPP releases are poised to refine P5G further.

As two 5G use cases with early signs of success, both FWA and P5G are nonetheless at pivotal stages in their evolutionary journey. While FWA aims to democratize high-speed internet access, P5G seeks to set new benchmarks for industry-specific wireless connectivity. Their combined potential promises a future where digital access is universal, and industries operate with unprecedented efficiency, heralding a new era of digital transformation and value creation.

Unlocking latent potential

Achieving long-term success and value-creating sustainability of any use case requires reaching an economic equilibrium between supply and demand. We summarize this as needing to meet two criteria:

- **Tangible value/utility is generated and can be easily recognized by the end user.** This is also where time domain effects (i.e., time discounting) can play a material role. The more immediate the value generation (or reward), the more value that will likely be assigned to it. As a corollary, more complex or nuanced value propositions may require a more deliberate effort to educate users on the value potential.

- **The costs to provide the use case are aligned with the user’s willingness-to-pay.** This is simple economics, but it is worth repeating. Consumer FWA did not have widespread material adoption in the U.S. prior to 5G, because the required cost structure exceeded the potential revenue generation. However, when viewed as an accompanying capability that lives in the “fallow capacity” associated with serving the eMBB subscriber base, T-Mobile USA has driven their FWA adoption to 3.7M subscribers in 2Q2023.

These criteria are obvious at face value, however, future use cases will require managing these criteria under greater uncertainty/complexity, where either one or both criteria require additional discovery to build a strong understanding of the underlying mechanics.

To evolve our industry past the simplest use cases, we must unlock the latent potential residing within emerging use cases. As complexity increases, it is imperative to avoid ecosystem fragmentation and abstract complexity for the end user we aspire to serve. We expect a greater degree of collaboration and partnership will be needed to achieve this value generation. Given the high costs associated with technology commercialization, we expect these development efforts to be aligned with partnership insights around what future customer pain points could benefit most from 5G solutions.
## Appendix

### Acronyms

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<th>Definition</th>
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<tr>
<td>AGV</td>
<td>Automated Guided Vehicle</td>
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<tr>
<td>eSIM</td>
<td>Embedded Subscriber Identity Module</td>
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<td>FCC</td>
<td>Federal Communications Commission</td>
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<td>GSMA</td>
<td>Global Mobile Supplier Association</td>
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<td>IoT</td>
<td>Internet of Things</td>
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<td>LTE</td>
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<td>MIMO</td>
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<td>Open Radio Access Network</td>
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<tr>
<td>OT</td>
<td>Operational Technology</td>
</tr>
<tr>
<td>RAN</td>
<td>Radio Access Network</td>
</tr>
<tr>
<td>RIC</td>
<td>Radio Intelligence Controller</td>
</tr>
<tr>
<td>SA</td>
<td>Standalone</td>
</tr>
<tr>
<td>SIM</td>
<td>Subscriber Identity Module</td>
</tr>
<tr>
<td>SME</td>
<td>Small and medium enterprise</td>
</tr>
<tr>
<td>TSN</td>
<td>Time Sensitive Networking</td>
</tr>
<tr>
<td>URLLC</td>
<td>Ultra-Reliable Low Latency Communications</td>
</tr>
<tr>
<td>WISP</td>
<td>Wireless Internet Service Provider</td>
</tr>
<tr>
<td>WLAN</td>
<td>Wireless local area network</td>
</tr>
<tr>
<td>XR</td>
<td>Extended Reality</td>
</tr>
</tbody>
</table>
Acknowledgments

5G Americas’ Mission Statement: 5G Americas facilitates and advocates for the advancement and transformation of 5G and beyond throughout the Americas.

5G Americas’ Board of Governors members include Airspan Networks, Antel, AT&T, Cable & Wireless, Ciena, Cisco, Crown Castle, Ericsson, Liberty Latin America, Mavenir, Nokia, Qualcomm Incorporated, Rogers Communications Inc., Samsung, T-Mobile USA, Inc., Telefónica, VMware and WOM.

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Endnotes

1. ITU World Telecommunication/ICT Indicators database (November 2022). Time series (excel) of ICT data for the world, by geographic regions, by urban/rural area and by level of development. (retrieved 8/31/2023)

2. DataReportal, and We Are Social, and Meltwater. “Distribution of Average Daily Time Spent Online from 3rd Quarter 2013 to 4th Quarter 2022, by Device.” Statista, Statista Inc., 27 Apr 2023

3. While this is not supposed to be a paper on economics, the term “utility” is used to abstract a measure of the total subjective value that a person assigns to a particular outcome. This term also recognizes that there are non-monetary influences that can impact decision making.

4. In their original 1944 book, von Neumann and Morgenstern argued that rational players will try to maximize the expected value of utility. We promise, this is really a paper about 5G, not a paper on economics!


6. In basic economic terms, the “quantity demanded” of a good/service, will be related to the perceived usefulness (i.e., customer utility), and the relative cost to obtain it. (this i.e., the rate at which those two things change, relative to each other, is the “price elasticity of demand” for that good/service.)

7. SK Telecom 6G Whitepaper (August 2023)

8. The “jobs to be done theory” was introduced by Harvard Business School Professor Clay Christensen. He advocates for understanding the underlying customer motivation that causes them to “hire” a product or service to accomplish a “job” they need to get done.


10. In his 2018 book “Atomic Habits” author James Clear is credited with articulating latent potential as the time lag between when you expect results, and when you finally break through and see results


13. Ibid


16. 5G Americas Whitepaper “The Evolution of Open RAN” (Feb. 2023)

17. Ibid

18. 5G Americas Whitepaper “Commercializing 5G Network Slicing” (July 2022)

19. 5G Americas Whitepaper “Distributed Compute & Communications in 5G” (November 2022)

20. Linux Foundation Projects CAMARA scope (retrieved 8/28/2023)

21. 5G Americas. “Mid-Band Spectrum Update” (March 2023)

This is made possible by the U.S. federal statute “CHIPS and Science Act of 2022,” (where CHIPS stands for Creating Helpful Incentives to Produce Semiconductors).
Note: this concept goes beyond the time-value-of-money concept used in discounted cash flow analysis for business cases. It encompasses a broader view of behavioral economics; a historical literature review is provided by Frederick et. al., 2002.


Telecompetitor (June 20, 2023), Bank of America C-Suite TMT Conference.

T-Mobile USA Press Release (7/27/2023)

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