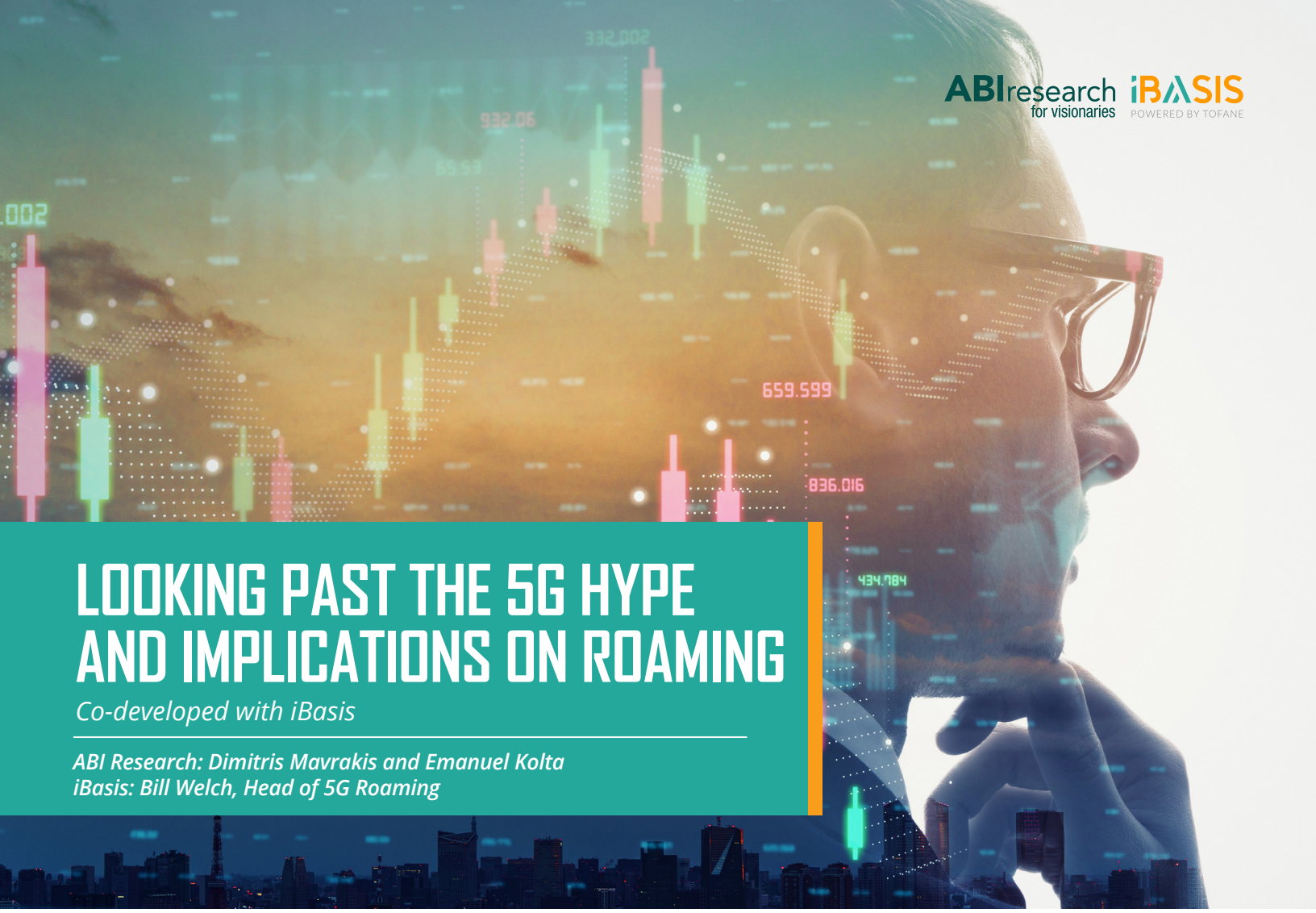

LOOKING PAST THE 5G HYPE AND IMPLICATIONS ON ROAMING

Co-developed with iBasis

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MARKET UPDATE

INTRODUCTION

The global economy is experiencing rapid changes during the first years of the 21st century, with new technologies, concepts, and behaviors now changing the way we live and work. Blockchain, self-driving cars, artificial intelligence and machine learning, 3D printing, 5G, and augmented reality are just a few examples of technologies that hold the potential to create new markets and disrupt legacy businesses.

The availability of enhanced data connectivity for human users has already disrupted almost every market and collaborative economy including, Airbnb, Deliveroo, and Uber and created a new market for nowadays almost-essential services globally. Apart from the popular Western applications that include Airbnb, Snapchat, and Uber, there are markets where the smartphone has become a wallet, a parking meter, a shopping assistant, and much more. For example, in China, Alipay and WeChat are ubiquitous for every facet of city life, including communication, payment, parking, and shopping. None of these applications would have succeeded if it wasn't for consistent mobile broadband connectivity. Firstly, most of these applications do not have global coverage; they are focusing on unique countries or regions.

When these applications overcome institutional borders and become more scalable, roaming will gain even higher importance.

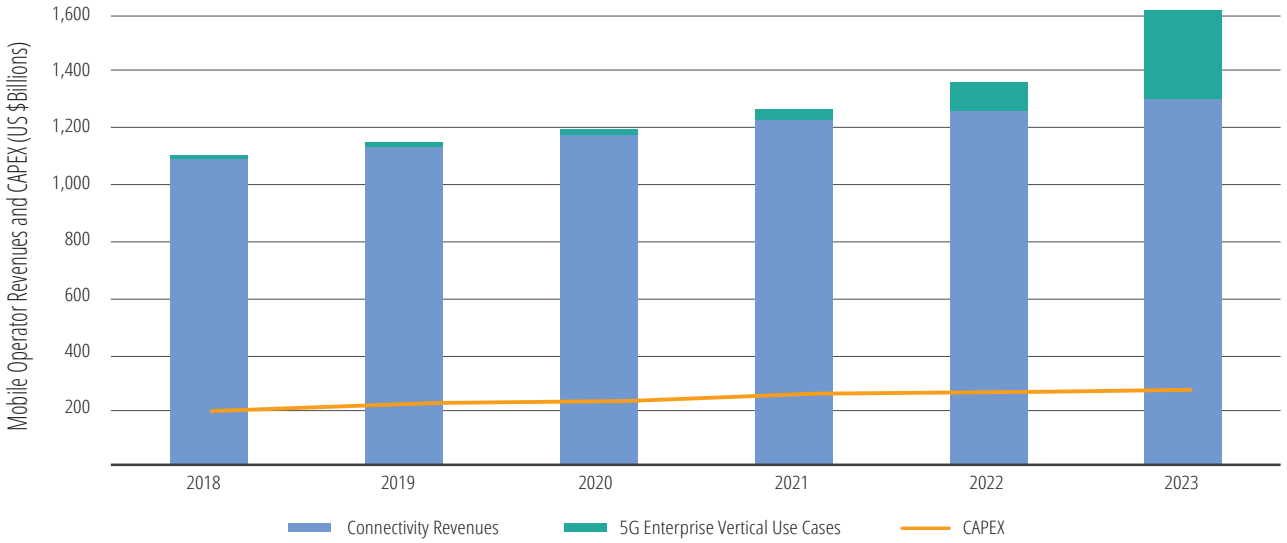
Secondly, these disruptions mainly impacted human subscribers, until now. The last 25 years primarily concerned subscriber to subscriber connections, but 5G will help to create a hyperconnected era and satisfy the diverse connectivity needs of different enterprise verticals and connected devices. In this new era, machine to machine communication, global connectivity solutions, and 5G roaming will be more essential than ever before.

MARKET OVERVIEW

The telecoms value chain is currently facing a challenging era, when market saturation, increased regulation, and competition within and from outside the value chain are confronting profit margins. The following chart illustrates ABI Research's forecast for mobile operator service revenues and network CAPEX for the next few years.

Figure 1: Mobile service provider service revenues and CAPEX forecasts

(Source: ABI Research)



Although service revenues are expected to grow, the imminent deployment of 5G will create pressure on operator financials, but new use cases in enterprise verticals will allow them to grow past their connectivity legacy and become enterprise vertical enablers. Nevertheless, 5G will continue to create innovation in the consumer domain for the next 2-3 years, and early deployments indicate that early adopters are willing to embrace the new generation and even the new services it will enable.

5G deployments started in Q4 2018, with mobile service providers deploying 5G connectivity in big cities across the world. The urban areas are where new services will appear, and 5G will act as the catalyst for the emergence of new service paradigms, including richer content services such as AR, VR and immersive media, and machine vision use cases for security in a smart city, predictive maintenance in the

manufacturing space, and near-real-time healthcare applications. These are a few examples of applications that will radically change the way we live and work. 5G in the city environment will be the vital ingredient to start this evolution.

CURRENT STATUS OF THE 5G JOURNEY AND LONG-TERM VISION

The extent of the potential value pool behind 5G is unprecedented: consumers and industrial players both claim that high-capacity, reliable, and low latency connectivity will become the fourth essential utility. Based on the vast CAPEX intensity of 5G deployments and the fragmented demand for connectivity, ABI Research expects that 5G will be deployed in phases, starting in dense urban areas, or megacities.

As of 2019, 5G began entering the commercial deployment stage. Early adopters, including the United States, China, Japan, South Korea, and the United Kingdom, all announced their commercial mobile 5G launches for 2019, and telecommunication infrastructure vendors have already started to ship 5G-capable network equipment to operators. While the first 5G related use cases will be fueled by enhanced mobile broadband (eMBB), advanced 5G features such as Ultra-Reliable Low Latency Communications (URLLC) and massive Machine Type Communications (mMTC) will start to be relevant from 2021. Early 5G Non-Standalone deployments will enable greater data-bandwidth complemented by moderate latency improvements for customers and help to realize use cases such as AR/VR media and applications, massive surveillance, UltraHD, and 360-degree streaming video. In the early phase of 5G deployments, ABI Research expects that Mobile Service Providers (MSPs) will develop new RAN topologies as they are introducing eMBB in different ways. Several of these have already taken place in 2018 and 2019:

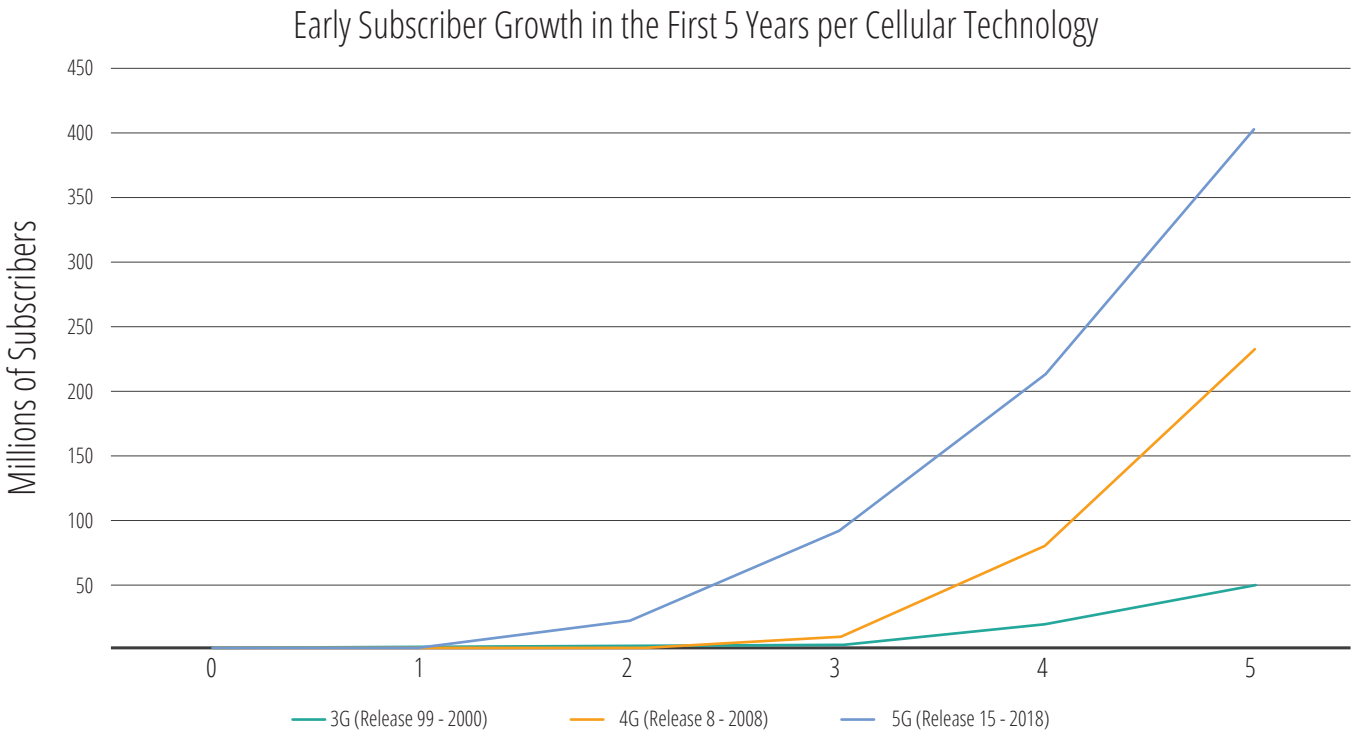
- U.S. mobile service providers have pioneered the Fixed Wireless Access (FWA) use case, with Verizon, followed by AT&T, in deployments.
- Approximately 35 5G networks have been launched, some of which initially included MiFi units – due to unavailability of smartphones – but as of Q4 2019, there are nearly 30 5G capable smartphones in the market and subscribers are adopting them gradually. ABI Research expects 50 5G commercial networks by the end of 2019, with more than 4 million subscribers globally.
- The first networks to have been launched in a large scale and have already reached critical mass are those in South Korea, where Korea Telecom, South Korea Telecom and LG U+ simultaneously launched their consumer offerings in April 2019. Since then, there has been a massive uptake of 5G services and the South Korean mobile service providers now report nearly 2 million 5G subscribers, more than they expected.
- Several other deployments are progressing and mobile service providers in developed markets are proceeding to deploy networks in busy areas. For example, Vodafone UK is deploying 5G in Gatwick airport in the United Kingdom. More of these deployments will take place late 2019 and early 2020.

COMPARING 5G WITH PREVIOUS GENERATIONS

5G is being deployed and adopted at an astonishing rate, much more quickly than previous generations. Indeed, ABI Research forecasts indicate that 5G will reach the mass market – 50 million subscribers globally – only 2.5 years after the standard was frozen. In contrast, 4G reached the same figure in 3.5 years, while 3G achieved this in 5 years. The following chart illustrates ABI Research's subscriber forecasts for the 3 generations.

Figure 2: Subscriber forecasts for 3G, 4G and 5G from year of standardization

(Source: ABI Research)



There are several reasons for the rapid growth of 5G, both inside and outside the value chain. First of all, the supply chain for 5G infrastructure, chipsets, and base stations has accelerated much more quickly compared to previous generations. As such, there are now 200,000 5G base stations deployed, 4 device chipsets, and about 100 5G smartphones announced. In contrast, in the first year of 4G, there were no chipsets or smartphones, and only about 400 4G base stations deployed.

There are also external factors driving the growth of 5G, including the increasing rate and willingness of several enterprise verticals to transform their operations and become digital companies. This will surely drive the need for additional bandwidth and more data traffic, but will also present an opportunity for mobile service providers to become enterprise service enablers through the advanced features of 5G, including network slicing and service chaining.

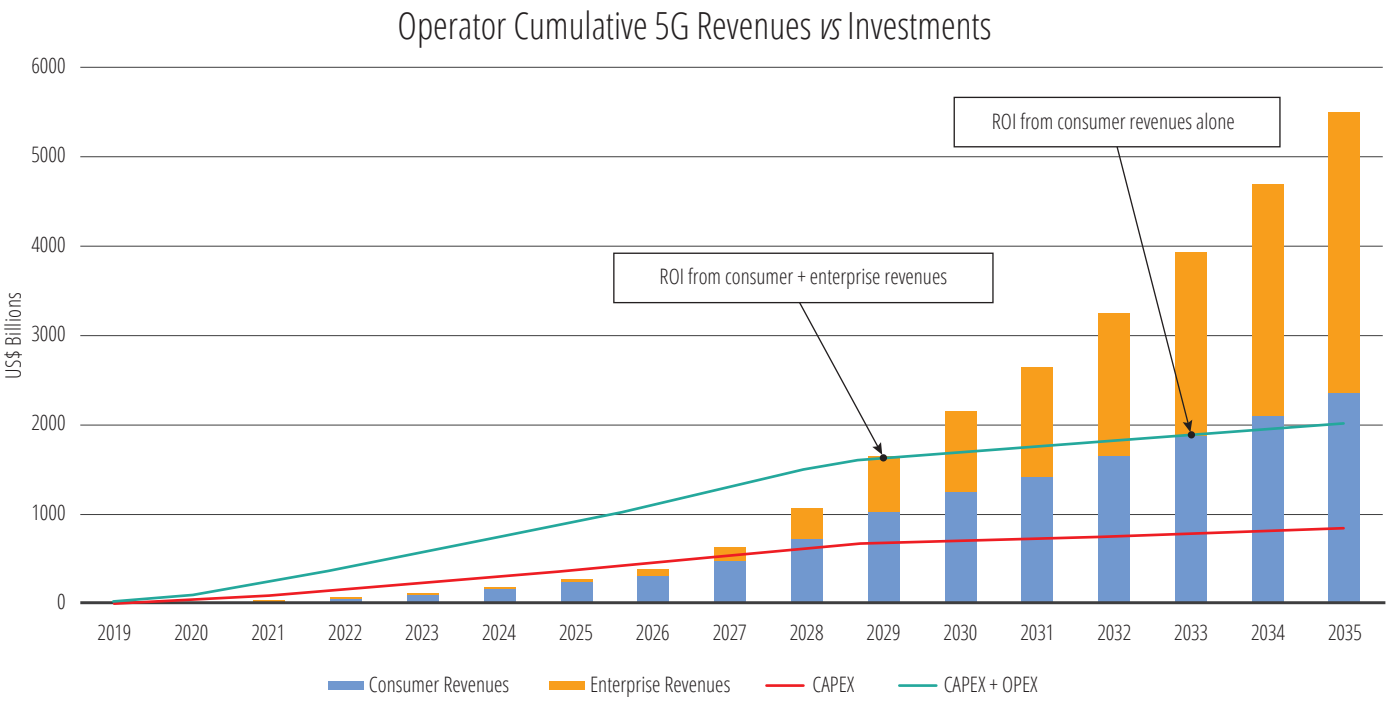
5G RETURN OF INVESTMENT AND FINANCIAL CONSIDERATIONS

Every cellular generation needs to justify its rollout financially. With previous generations, there had been an immediate driver for deployment: 3G for mobile data and 4G for mobile broadband. 5G will enhance the mobile broadband value proposition and offer consistent, high speed, and high-quality data connectivity for all consumers. 5G will then distribute processing capabilities throughout a country with edge computing and other advanced features. Services like 4K video and AR/VR become available over 5G where 4G would fall short. However, given that 5G is typically deployed in higher frequency bands, its nationwide deployment will likely be more costly compared to previous generations. ABI Research has attempted to calculate the ROI of 5G, assuming that only 5G revenues will be used to justify 5G rollouts, but in reality, it will likely be 4G

revenues that drive the new generation's deployment. Nevertheless, this calculation is a high level exercise to compare 5G with previous generations, which took approximately 10 years to reach ROI.

Figure 3: 5G Return of Investment with and without enterprise vertical revenues

(Source: ABI Research)



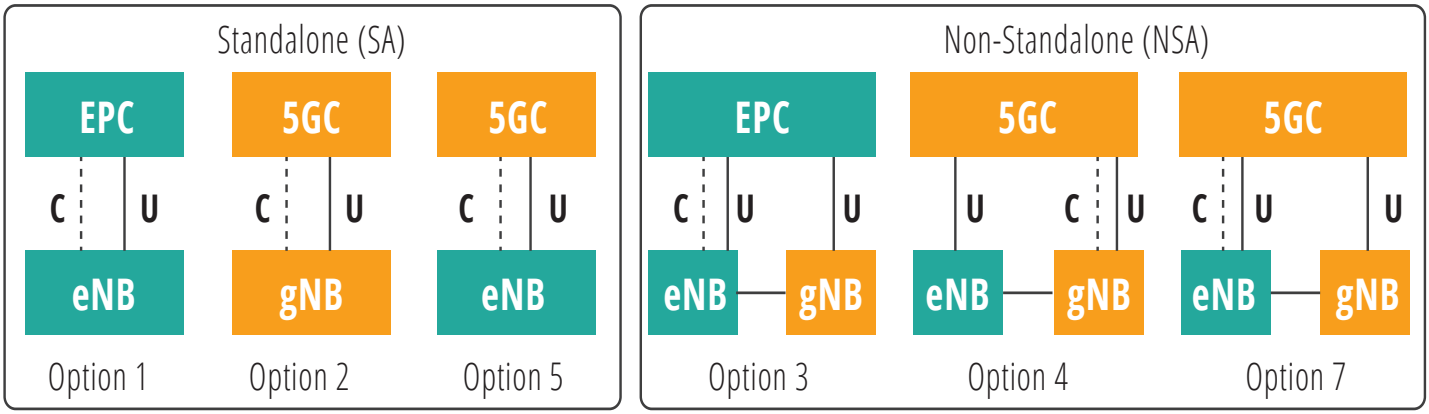
As seen from the figure above, consumer revenues alone will likely mean a 14-15 year ROI for 5G. If we assume that enterprise vertical revenues are included, then ROI is achieved in 10 years, roughly in line with previous generations. Consumer applications, traffic, and revenues will drive 5G in the first 3-4 years, but enterprise revenues will be necessary to achieve nationwide rollouts and acceptable ROI timeframes.

5G DEPLOYMENT MODELS: NSA VS SA

There are several deployment options for future 5G networks falling under either a Standalone (SA) operation or Non-Standalone (NSA) operation. Current LTE networks use EPC and LTE eNB access, also known as Option 1. Option 2, or a full 5G network, is, in theory, the target architecture for the complete 5G deployment of both 5G access and core networks. Given the investment in the EPC, it follows that a viable strategy is Option 3 and one that is currently being adopted by MSPs. In Option 3, the existing "legacy" EPC core connects to LTE access technologies (eNB) and 5G radio (gNB). Both the control plane and user plane is handled by LTE, and NR is only introduced as an add-on data rate capacity booster. NSA 5G subscribers are considered dual connected to both LTE and 5G where traffic can flow over one radio or the other, or both, for maximum bandwidth and coverage.

Figure 6: SA and NSA Options

(Source: ABI Research)



For the industry to have an informed discussion over how best to transition from Option 3 in the short term to Option 2 in the long term, they ought to consider all the options and determine if their IPX carrier has specific capabilities that can ease this transition. MSPs should have a discussion that is framed around a high-level framework that touches on the following:

- **Mobile Devices**: Need to support NSA and NA deployment architectures of 5G. In the case of NA, devices will need to implement a new protocol so that they can gain access to unique capabilities that 5G core brings above an 4G core.
- **Spectrum**: The bulk of spectrum below 6 GHz available today is used by LTE networks for LTE-only devices; hence, some spectrum-sharing capabilities should be factored in. Some vendors have already launched solutions on this front.
- **Multiple Core Networks**: Legacy networks such as circuit-switched and packet-switched will continue to cater to 2G/3G-only devices and subscribers/roamers. It is now feasible to virtualize these networks, but the underlying technology remains inherently different, so they will need to co-exist with EPC/5G core networks. Over time, these 2G and 3G networks will be decommissioned. There are lots of potential migration steps and strategies along the way, and this will need to be carefully considered. Some use cases require maturity of the entire ecosystem for large-scale monetization. A network slice that traverses multiple domains (core, wireless, radio) across different industry verticals is a case in point.

It is clear that NSA will drive 5G deployments in the next 3-5 years, especially when NG Core and advanced enterprise use cases are not yet finalized in 3GPP standards. ABI Research expects SA to present a considerable opportunity for new services and enterprise business models, but consumer use cases and NSA will be vital for most mobile service providers to begin the 10-year journey to payback this considerable investment in 5G.

5G USE CASES

The most important differentiation of 5G compared to previous generations is that it is designed for enterprise use cases, not only consumer applications. Indeed, 3GPP Release 16 is focusing largely on enterprise use cases, including URLLC, support for Time Sensitive Networking (TSN) and other features that go well beyond consumer requirements. As such, 5G is split in 3 main use cases (4 if FWA is considered):

EMBB

Enhanced Mobile Broadband (eMBB) will extend previous mobile broadband networks with new underlying capabilities, including Massive MIMO and various other physical layer improvements. eMBB is what is being deployed at the moment throughout the world, with consumer applications initially driving traffic and revenues.

Early networks from South Korea indicate that the availability of higher speeds and more capacity is yet again affecting user behavior: average daily consumption of data in these 5G networks has increased to approximately 4GB, while this was 400MB in similar 4G networks. Consumers are watching more video content, playing cloud games and even experimenting with AR/VR applications developed South Korean operators have. We expect the same trend to take place in all regions, once networks and device adoption reaches a critical mass. Obviously, these new traffic patterns create a strain on the support infrastructure, including backhaul, transport, and wholesale networks, but also present an opportunity for organic growth.

URLLC

Ultra-Reliable and Low Latency Communications (URLLC) was introduced in 3GPP Release 15 and fully standardized in Release 16. It is the first case where the network is designed for reliability and deterministic performance, rather than just pure higher capacity. This feature will be pivotal for manufacturing, automotive, and critical communication use cases, and it is the first case where a cellular generation can support these features without sacrificing overall system capacity or other KPIs.

URLLC is the biggest and most important feature of 5G. Although eMBB will drive the early stages of 5G and will justify rollouts in cities, it will be URLLC that will unlock the enterprise vertical opportunity and coupled with edge computing, will likely allow enterprise vertical companies use 5G as a platform for innovation and other technologies, *e.g.,* AI. URLLC will allow 5G to evolve beyond connectivity and become a platform for new services.

MMTC

Massive Machine Type Communications (mMTC) is the last 5G use cases, that aims to extend cellular networks for IoT use cases. These features have been extended to Release 17, mostly because NB-IoT and eMTC (LTE Cat. M) are currently being deployed, and there is no immediate need for IoT specifications to be built into the standard. However, eMBB and URLLC will likely create new use cases for 5G and sensor-type communications may need to extend to thousands of devices in several enterprise verticals. When this happens, mMTC will be necessary to handle both traffic and signaling from these devices. Currently, 3GPP is also discussing a new device category, called NR-Lite, which is positioned between eMTC and LTE in terms of capacity and throughput.

5G ROAMING

Given that eMBB for consumers is the top use cases for 5G, it is necessary to enable roaming, since users will expect high-quality services when traveling abroad. This is especially the case with early adopters who are likely premium users and equipped with smartphones often costing more than US$1000. Although 5G roaming is not yet a key priority for most mobile service providers, it is necessary to address it before 5G reaches a critical mass – after which its growth will follow an exponential curve.

5G introduces several new functions that are different to previous generations. These will affect the deployment of the network and in extent, roaming.

- Advanced services that include network slicing, service chaining, and enterprise use cases will completely change the way networks will be designed and dimensioned. Roaming will also need to change since several 5G enterprise use cases will need to traverse beyond the borders of a country.
- 5G signaling is based on HTTP/2, rather than SS7 (2G/3G) or Diameter (4G). This means that a new deployment of HTTP/2 based roaming service will be necessary when mobile service providers start deploying a 5G core network. In particular, roaming enablers that offer IPX services will need to factor in HTTP/2 based roaming service into their product mix.

However, the biggest question is when mobile service providers will migrate from NSA to SA. According to ABI Research's understanding, there are several options, illustrated in the following table.

Table 1: Roaming options between 4G and 5G networks Home and visited networks

(Source: GSMA, ABI Research)

	Home SA with NSA interworking	Home network NSA only	Home: both SA and NSA
Visited: SA	5G roaming	No roaming specified	5GS roaming
Visited: NSA	4G and 5g interworking	4G roaming	4G roaming
Visited: both SA and NSA	5G or 4G roaming	4G roaming	5G or 4G roaming

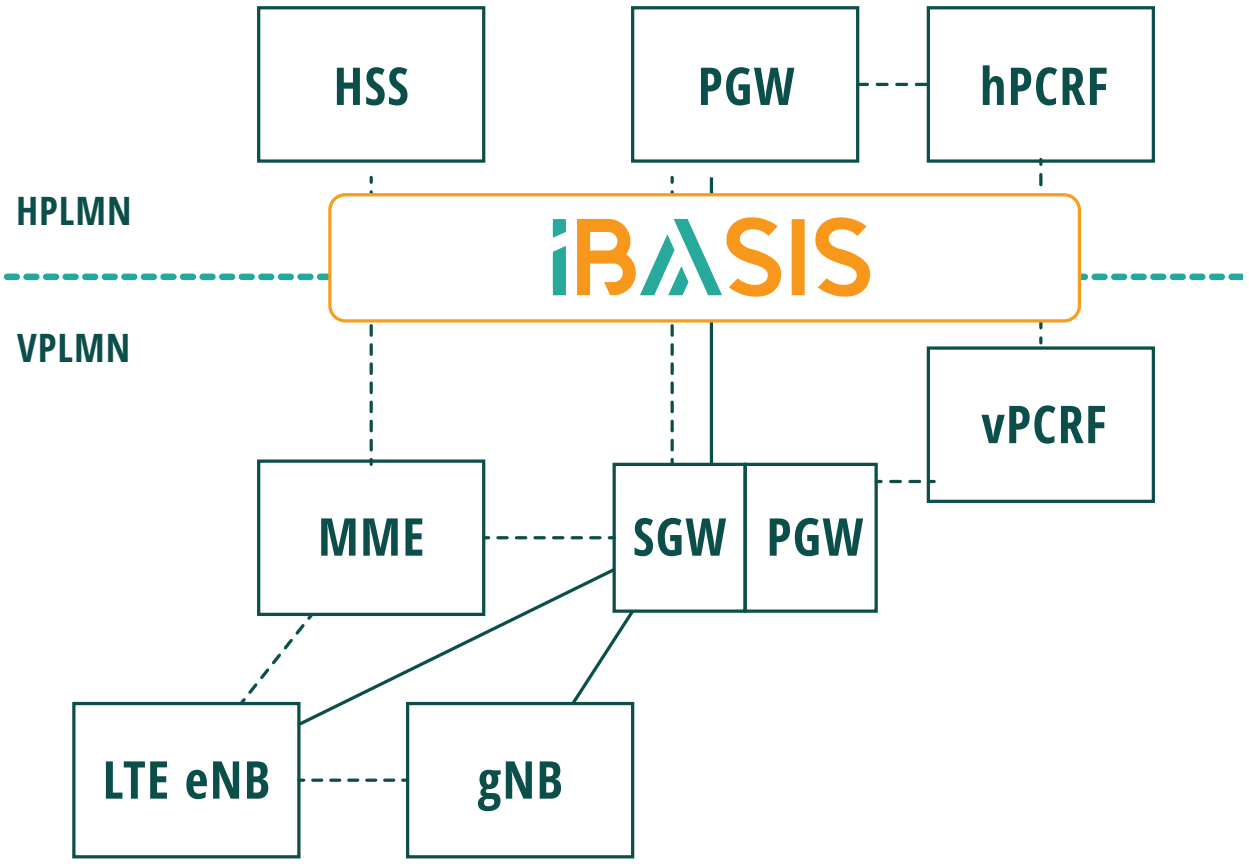
The role of third party IPX providers is expected to increase, since it is more difficult for individual mobile service providers to sign multi-faceted bilateral agreements with other mobile service providers, that may, or may not have SA. The role of IPX providers will likely become much more important in the 5G domain by providing interworking solutions for roaming.

5G ROAMING FOR NSA AND SA

5G NSA networks will utilize existing LTE core networks and as such, roaming services will depend on existing protocols, namely Diameter and GTP/GRX. The following diagram illustrates a typical configuration for NSA roaming. The green dotted line is the interface between the home and visited mobile networks and is the domain of the IPX provider connecting the two mobile service providers.

Figure 4: Roaming architecture for NSA

(Source: GSMA)



This mode of roaming operation will likely persist for many years to come, since 5G roaming will require both the visited and home network to be running on standalone mode. It is imperative for mobile service providers to start preparing for 5G roaming with a standalone model, since experience with previous generation networks shows us that subscribers adopt new usage behaviors when more bandwidth is available to them. This will certainlty be the case with early 5G eMBB (NSA) roaming, but also with mature 5G Cores and URLLC (SA), so mobile service providers need to proactively plan their network deployments, at the roaming domain as well.

5G NG Core will introduce a Service-Based Architecture, which will break free from the peer to peer core network connectivity approach on which previous generations were focused. This will allow APIs to be exposed in different layers, thus fostering business and technology innovation throughout the operator business. 5G NG Core also introduces HTTP/2 as the signaling protocol, in contrast with previous signaling protocols SS7 and Diameter. HTTP/2 and RESTful interfaces are well-documented protocols in the Web industry, allowing mobile service providers and vendors great flexibility in terms of tools and infrastructure.

5G NG core roaming will require interfaces between different flavors of these signaling protocols. IPX providers will likely need to operate an HTTP/2 proxy – similar to their existing Diameter proxies – in order to inspect and in some cases, modify, signaling messages.

NETWORK SLICING AND ROAMING

As MSPs address more enterprise customers, eventually the enterprise use cases will most likely require an international footprint, thus moving network slicing to the roaming domain. Indeed, DT and SKT have demonstrated a network slicing scenario between Germany and South Korea, but there are still several development steps before network slicing reaches the international domain. Nevertheless, there is certainly the opportunity for mobile service providers, for example: an enterprise use case may require a separate network slice and at the same time, roaming coverage. The home MSP will need to cooperate and integrate with the visited MSP to ensure that this use case can be enabled, while maintaining the high levels of SLA guaranteed with this particular network slice. Assuming that both MSPs can support this stringent requirement, then the IPX provider will need to support the same feature, thus enabling network slicing at an international domain.

5G USE CASES

As discussed above, 5G is designed to include 43 main use cases that will likely be combined to enable connectivity or advanced features for a specific enterprise market or consumer applications. Indeed, most consumers and enterprises will likely utilize a combination of FWA, eMBB, URLLC and mMTC once 5G matures and it will likely be difficult to separate the three flavous of the standard completely. Nevertheless, ABI Research expects 5G to be deployed in three distinct phases, as outlined in the diagram below.

Figure 5: Phases of 5G

(Source: ABI Research)

	Static **Phase I. – Consumer Driven**	**Dynamic** **Phase II. – Early Enterprise**	**Hyper-Connected** **Phase III. – Enterprise transformation**
Time frame	2019-2022	2022-2025	2025-2030
Coverage	Dense-Urban areas, hotspots: train stations, malls, universities, research labs	Cities, private promises, stadium, venues, motorways	Extensive indoor-outdoor coverage
Use cases	▪ Basic mobile consumer eMBB ▪ Static network slicing ▪ Basic enterprise offers ▪ Fixed Wireless Access ▪ Early small cell deployments ▪ Early vertical applications	▪ Advanced mobile consumer 5G ▪ On demand dynamic network slicing ▪ Private 5G Networks ▪ UHD 8K Video services ▪ AR-VR gaming services ▪ Early Industry 4.0 ▪ IoT offers	▪ Unlimited connectivity as a utility ▪ Widespread 5G related vertical applications ▪ AI based solutions in verticals ▪ Autonomous V2X ▪ Industry 4.0

PHASE 1: STATIC, CONSUMER DRIVEN

The first phase of 5G rollouts, which is currently taking place in the market, will be driven by consumer applications, while mobile service providers grapple with initial teething problems of the new technology and iron out nuances and early challenges. Phase 1 will solely be driven by eMBB in the consumer domain, primarily by smartphones and Fixed Wireless Access use cases. Nevertheless, 5G will create a massive uptake in terms of traffic throughout networks as subscribers get accustomed to new types of content AR/VR and new applications. A few mobile service providers will also experiment with enterprise vertical applications – especially Tier-1 multinationals like DT, Telefonica, and Vodafone – in order to prepare their business operations for the next phases beyond this initial phase. ABI Research expects this phase to be the only activity through 2022, dominated by NSA and it's usage of 4G roaming infrastructure. After 2022, the additional Phases begin, but eMBB will still dominate the revenue curve until at least 2030.

PHASE 2: DYNAMIC, EARLY ENTERPRISE APPLICATIONS

The second phase of 5G will likely start in 2022, 2 years after 3GPP Release 16 is frozen mid-2020. This phase will see mobile service providers being more confident with 5G technology throughout their network, certainly in the radio domain and will start to experiment with NG Core deployments. More advanced enterprise applications will appear, including Private 5G deployments and dynamic network slices in the latter years of Phase 2. Consumer use cases will be mature by this time, and mid-tier smartphones will drive new applications and higher traffic. At this stage, network slicing and HTTP/2 roaming will start to be introduced in the market while MSPs consider what they need to deploy to add these two new features.

PHASE 3: HYPERCONNECTED AND ENTERPRISE TRANSFORMATION

The third, and final, phase of 5G deployment will see advanced enterprise vertical applications that will help many industries transform to the digital domain. Consumers will likely enjoy seamless nationwide mobile broadband connectivity in this phase, while B2B and B2B2C business models will revolutionize the way we live and work. At this stage, applications will be a mix of FWA, eMBB, URLLC, and mMTC while mobile service providers will have deployed network slicing and most networks will operate in SA mode.

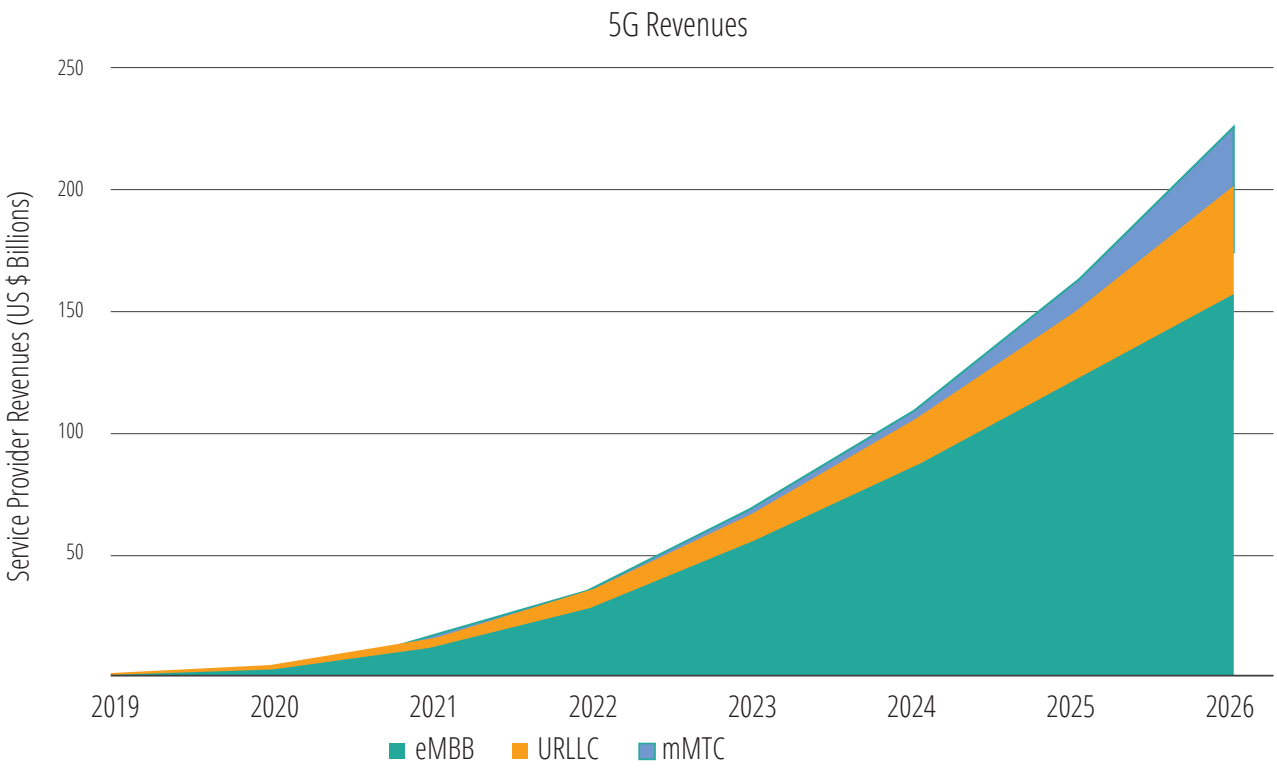
DOMINANT 5G USE CASES FOR THE NEXT 5 YEARS

Despite the enterprise vertical discussion in 5G, it is now clear that consumer applications will drive the new generation for at least another 5 years, mainly due to the fact that mobile service providers are most familiar with the consumer space and as connectivity enablers, rather than platform or ecosystem enablers that enterprise vertical use cases require. As such, 5G will likely be gradually deployed in dense urban areas in large cities, followed by other urban areas and then suburban areas, to reach a critical mass of subscribers. New technologies will allow this, including Dynamic Spectrum Sharing (DSS) between 4G and 5G, UL Sharing between 5G and 4G while Massive MIMO will mitigate propagation constraints due to the higher deployment frequencies. Consumers will, in turn, adopt the new generation gradually while application developers will take advantage of the new generation to create immersive applications. 4K video, AR/VR, interactive video content, and cloud gaming applications are expected to drive traffic through 5G networks.

According to ABI Research forecasts, the dominant use case for 5G service revenues will clearly be eMBB, as illustrated in the following chart.

Figure 6: 5G eMBB, URLLC, and mMTC revenue forecasts

(Source: ABI Research)



FIXED WIRELESS ACCESS

5G's higher throughput and efficiency open the door for FWA (Fixed Wireless Access) and the option to replace Fiber-to-the-Home (FTTH). FWA utilizes wireless connectivity, instead of fiber or copper cables, to provide last-mile fixed broadband connectivity to homes and enterprises. Based on the uniqueness of each household, home broadband providers are currently dealing with high costs and uncertainty during cable laying. While the deployment of fixed broadband has a significant variable cost nature, deploying a wireless cell is a one-time, foreseeable fixed cost. For example, trenching in an urban area may cost as high as $50,000 per km, which is a prohibitive cost to deploy copper, cable, or fiber networks.

Consequently, MSPs will likely carefully choose where to deploy FWA, so that the new service does not cannibalize their fixed broadband business. For example, it would not make sense to deploy FWA in areas where the fixed network offers high-speed broadband services, but it would certainly make sense in areas where the operator cannot yet reach with a fixed connection. Several dense, urban areas and megacities will fulfil these conditions and experience faster-growing coverage. Both AT&T US, Verizon US, and Three UK are focusing on synergies and trying to provide 5G FWA services on a different scale. MSPs are looking at FWA as a complementary deployment solution to provide home broadband services and enter the home broadband market.

CONCLUSIONS

This paper has argued that the most important use case for 5G will be eMBB in the next 5 years, and roaming for both NSA and SA architectures will be required. Most operators will start with NSA architecture and will utilize the existing 4G roaming services to achieve 5G device roaming in the short term. This solution is active today for many 5G enable operators around the world. Operators will begin to transition their subscribers and networks to SA architecture and HTTP/2 based roaming services. Both architectural options will play an increasingly important role as mobile subscribers embrace the new generation of wireless technology. IPX providers will continue to play a vital role to interconnect 5G and 4G networks and help mobile operator manage network transformations All of this investment and partnership are foundational elements to address today's available use cases and grow the business with the additional use cased that 5G will bring.

The mobile industry will need to work together to overcome early challenges and position 5G as a transformational technology rather than just another generation. Openness, collaboration and partnerships need to define 5G and position it as a key technology for the future of both consumer and enterprise domains.

About iBASIS

iBASIS is the leading communications solutions provider enabling operators and digital players worldwide to perform and transform. Powered by Tofane Global, the new iBASIS is the first independent communications specialist, ranking third largest global wholesale voice operator and Top 3 LTE IPX vendor with 700+ LTE destinations. With the integration of the Tofane's acquisition of the Altice Europe N.V. international voice carrier business in France, Portugal, and the Dominican Republic, iBASIS today serves 1,000+ customers across 18 offices worldwide. iBASIS optimizes access, connectivity, and value-added solutions, so customers achieve high return on voice, mobile data, and IoT requirements to be first in their respective markets and in the digital era.

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Published September 17, 2019

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