GSMA Intelligence

5G fixed wireless: a renewed playbook

March 2021

GSMA Intelligence

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info@gsmaintelligence.com

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Authors
Tim Hatt, Head of Research
Peter Jarich, Head of GSMA Intelligence
Emanuel Kolta, Senior Analyst
James Joiner, Analyst

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Executive summary

One of the most interesting potential applications of 5G is in providing access to home broadband, through fixed wireless access (FWA). This hybrid approach combines aspects of traditional mobile and fixed-line delivery methods but is primarily marketed as a ‘home’ internet product.

FWA offers the principal advantages of (generally) lower upfront deployment costs relative to fixed options, and capital efficiency gains through the reuse of existing spectrum holdings. The technology has been around for more than a decade through the 3G and 4G eras, particularly in serving rural areas that lack fixed broadband access or have low speeds. At the end of 2020, 492 mobile operators (approximately 50% of the sector) had launched 4G FWA services, with varying levels of ambition.

5G will enable FWA to target a broader opportunity. We envisage the following deployment scenarios where FWA can be competitive:

- broadband provision in countries with low existing home internet take-up (mostly emerging markets)
- a broadband alternative in higher income countries (either as the primary fixed line asset or as a complement to existing cable and/or fibre products for converged operators)
- an offering for the enterprise segment (especially companies with fewer than 250 employees).

Service availability depends on the breadth of 5G network coverage. As of January 2021, about 40% of the 135 5G commercial launches worldwide contain an FWA offering – a relatively high proportion at this early point in the generational cycle and one which could rise further as operators take stock of pilots, demand and return on investment. One real change factor compared to the LTE era is an expected rise in lower cost routers (CPE) with enhanced performance capabilities. A range of industry estimates indicates a projected cumulative sale of 250–350 million CPE units over the next five years – the majority of which will be 5G.

However, if the economics of deploying FWA services are not there, the business case will be difficult to justify. This is particularly important for those operators considering whether to allocate resources to FWA versus mobile broadband services. It is also why the technical enhancements to CPE matter, including the use of massive MIMO and multiple antenna selection, among others.

Spectral efficiency refers to the amount of cellular data that can be transferred per unit of spectrum (Hz); it is generally measured in bps per Hz. As new CPE units percolate into the customer base, indications suggest that 5G FWA is likely to gain a spectral efficiency advantage of 2.0–3.5× relative to 5G mobile broadband (for smartphones) over the next three to five years, based on the immobility of CPE (situated nearer to windows), multi-user pairing and other enhanced technologies. This is important for the economics of the FWA business case as it provides the underpinning for increased asset efficiency and revenues as operators monetise home data usage. The efficiency can be expressed in terms of revenue per unit of spectrum (Hz). If we compare FWA versus 5G mobile broadband, the revenue per Hz is primarily driven by three variables:

- spectral efficiency (cellular data transferred per Hz)
- customer ARPU
- cellular data usage (per day or month).

The revenue yield rises in parallel with ARPU and spectral efficiency, while being inversely related to data usage.

Increased spectral efficiency is, however, the key determinant. It helps to offset what could otherwise be very high bandwidth consumption relative to revenues for FWA versus mobile broadband. As spectral efficiency increases, it should drive the FWA revenue per Hz on an upward path towards parity with mobile broadband by 2025, significantly strengthening the underlying business case.

The extent to which profitability gains are realised at a retail level will depend on the spectrum holdings of the mobile operator, FWA data usage and commercial pricing strategy.

In a subsequent phase of research, we will explore the FWA economics in more detail based on the above inputs.

Prioritising urban/metropolitan areas before expanding into rural locales – which may be financed through part subsidy and/or co-investment models with government – means FWA will be marketed primarily in higher density areas in the near term (the next 12–24 months). Regulatory acknowledgement of FWA as a high-capacity option in helping achieve national broadband goals is also important, with BEREC's guidelines in Europe providing a good example.

Some challenges related to network architecture remain: urban and suburban areas require a higher density of small cells to provide sufficient capacity and mitigate the risk of signal obstruction (such as from trees). Expedited planning approvals and permissions from local governments will be important to facilitate rollout of small cells in these areas. Partnerships between telcos and organisations that control city infrastructure (e.g. utilities, transportation authorities and municipal governments) are also important to increase the number of points where small cell sites can be located. Finally, a multi-band spectrum strategy will help balance trade-offs in capacity and coverage bands depending on the deployment scenario.

Context: why now?

A longstanding but underutilised option

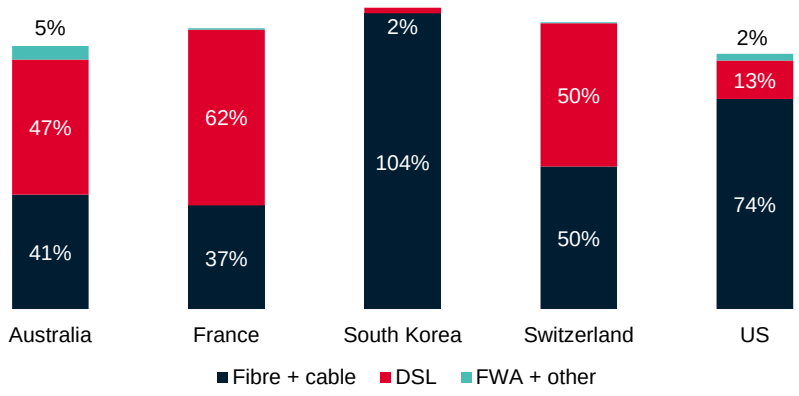
One of the most interesting potential applications of 5G is in providing access to home broadband, through fixed wireless access (FWA). This hybrid approach combines aspects of traditional mobile and fixed-line delivery methods. Cellular spectrum is used as the last-mile means of transmission to the home – as opposed to fibre, cable or copper. It is then converted into an internet access point through a home router. While FWA does not require fixed-line infrastructure, it is marketed and promoted as a 'home' internet product.

FWA offers the principal advantages of (generally) lower upfront deployment costs relative to other fixed options, and capital efficiency gains through the use of existing spectrum holdings. The technology has been around for more than a decade through the 3G and 4G eras, particularly in serving rural areas that lack fixed broadband access or have low speeds. At the end of 2020, 492 mobile operators (approximately 50% of the sector) had launched 4G FWA services, with varying levels of ambition. SoftBank, Globe Telecom, Dialog, Zain, Deutsche Telekom and other groups in countries including the Philippines, Japan, South Africa, Kuwait and Mexico have deployed large-scale FWA networks to cover millions of households.

Adoption has remained relatively limited compared to other fixed options. In a host of higher income countries in Europe, the US and parts of Asia where overall home broadband penetration rates are above 80%, 4G-based FWA is in the 1–2% range on average (see Figure 1). This can be ascribed to a combination of reasons including inferior performance relative to fibre and cable, limiting data caps, and the need for extensive CPE installation on and within home premises – an underappreciated deterrent.

5G offers FWA a larger addressable opportunity. In addition to the deployment cost advantage versus fibre and cable, several things have changed to drive a more promising outlook for FWA adoption over the next five years.

Figure 1: FWA has always been an option via 4G, but adoption has remained limited
Home broadband penetration, 2020 (percentage of households)



Note: fixed broadband connections as a share of households. As households can have more than one connection, data can sum to more than 100%.
Source: GSMA Intelligence

A competitive and viable alternative to fibre

The most important recent developments in FWA are the performance gains inherent in the 5G standard and advances in CPE that simplify onboarding.

Table 1 compares download speeds available through different broadband access technologies, with a speed gain from 4G to 5G FWA of up to 10× or more (depending on deployment scenario). While actual speeds are likely to be lower in practice, any deficit compared to fibre and cable will be far less than with 4G and indistinguishable to an average household, as most bandwidth-hungry use cases such as video streaming and even multiplayer gaming do not require more than 200–300 Mbps. Capacity will also rise for mid-band and mmWave spectrum, which alongside CPE improvements will help drive higher spectral efficiency and revenue per Hz.

Table 1: Broadband speed comparisons

	Technology	Download speed range (average)
DSL	ADSL/ADSL2+	24 Mbps
	FTTC/VDSL2	200 Mbps
	G.Fast	100 Mbps – 1 Gbps
Fibre	FTTP/H	2.4–40 Gbps
Cable	DOCSIS 3.1	10 Gbps
Satellite	LEO satellite broadband	50–500 Mbps
FWA	LTE (4G)	Up to 100 Mbps
	5G	**1–10 Gbps***

*Depends on spectrum band used and cell-site density.
Source: GSMA Intelligence

Service availability is expanding in line with 5G network rollouts, which have continued unabated in 2020 despite the financial pressures and restrictions associated with the Covid-19 pandemic. A total of 135 operators in 52 countries had live 5G commercial services as of January 2021; of these, 51 (nearly 40%) have launched 5G FWA. The fact that FWA launches trail 5G mobile service availability is not surprising. It reflects the mixed fortunes of 4G FWA deployments and a desire to take the time necessary for local pilots to gauge consumer interest and work through teething problems before launch.

Meanwhile, CPE shipments are likely to expand significantly to an estimated 250–350 million over the next five years, based on a range of industry estimates. The vast majority will be 5G, driven by falling costs. CPE costs are often built into customer tariffs, so any reductions will help to mitigate purchasing friction. The other important change with CPE is a streamlined installation process. This removes the requirement for aerial installation on roofs or other outdoor fascia, with a single router installed indoors on a plug-and-play basis – in line with most other broadband products. Ease of installation should not be underrated in the pandemic environment, where social distancing guidelines have resulted in delays to customer upgrades where a provider switch is involved and an engineer visit is required to activate a connection.

The net effect of such changes is to make FWA more competitive compared to fixed-line alternatives, either in direct competition or to complement the other access technologies of an operator. The speed to market and capital efficiency advantages further strengthen the business case, which we expect eventually to be implemented in some form by a majority of operators. However, there is no one-size-fits-all approach, with some groups opting for micro-scale/tactical

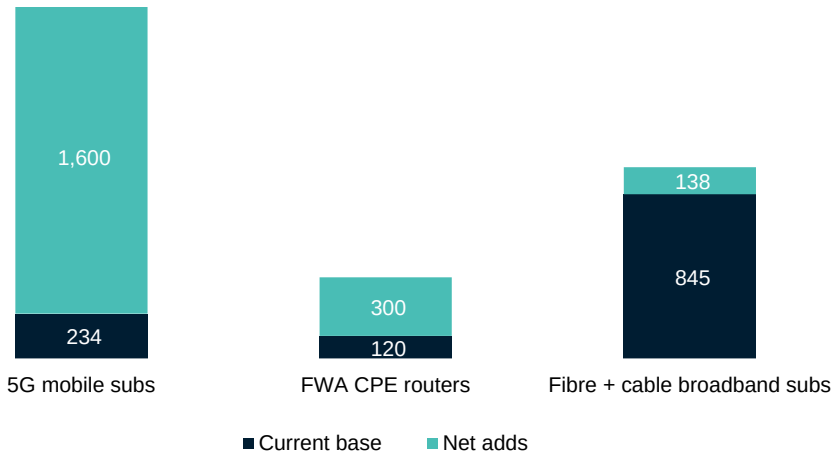
deployments (for example, to compete with an incumbent cable provider) and others using FWA as their main fixed-line strategy (e.g. in emerging markets or mobile-only operators).

An opportunity to close the price and coverage gaps

The addressable audience for 5G FWA arises from a mix of sources. In countries with high levels of home broadband adoption, it includes existing cable/fibre/DSL households with price-conscious tendencies and the mobile-only segment – whether by choice or through lack of access (still 10–20% of the population). If we assume 30% of the existing broadband base would be susceptible to an FWA swap and add the 10–20% of mobile-only households, the addressable base for FWA is 35–45% of households for an average higher income country. This is not to suggest FWA will reach that level of penetration – it will not; rather, it shows there is a yawning gulf between current ownership levels (1–2%) and the underlying potential.

The opportunity should further benefit from the trends of cross-selling into the 5G mobile base and cord cutting, provided speeds are seen to be in line with cable (content is less important here). The 5G subscriber base currently numbers approximately 200 million worldwide, concentrated in China, South Korea and the US. We forecast 5G subscribers will rise an incremental 1.6 billion over the next five years (see Figure 2) to reach around 20% of the global total. There is, of course, a degree of overlap in that the vast majority of 5G smartphone customers will already take home broadband. However, as 5G coverage expands into lower income countries such as India, Thailand and parts of Africa, the FWA option becomes more relevant considering the paucity of fixed-line infrastructure.

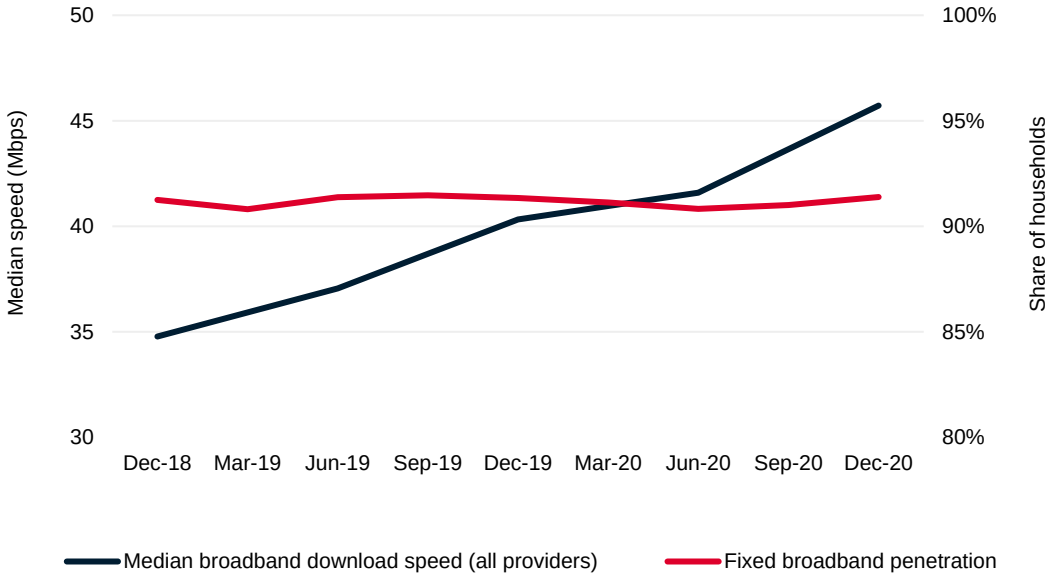
Figure 2: FWA should benefit from a 5G mobile cross-sell and flood of lower cost routers
Projected net additions worldwide (million), 2021–2025



Source: GSMA Intelligence, company reports

It is worth remembering that the coverage gap and associated digital divide is not purely an emerging market phenomenon. Rural access rates in many developed, high-income countries remain stubbornly low as a result of challenging deployment economics. This can clearly be seen, for example, in the UK (see Figure 3). Despite average speeds rising by about 10 Mbps (actual rather than advertised) over the last two years, overall household take-up rates have stayed flat at 90%. The remaining 10% is the 'final frontier', where long distances and harsh topography make fibre rollout costs per premises passed 5–10× higher than suburban locales. FWA over lower band spectrum (sub-1 GHz or C band) could help alleviate the divide, with technical improvements making it easier for signals to reach premises unimpeded by natural phenomena such as hills.

Figure 3: In the UK, broadband speeds have risen but penetration has stayed flat



Source: GSMA Intelligence analysis, based on Speedtest Intelligence® data provided by Ookla®

Strategic rationale

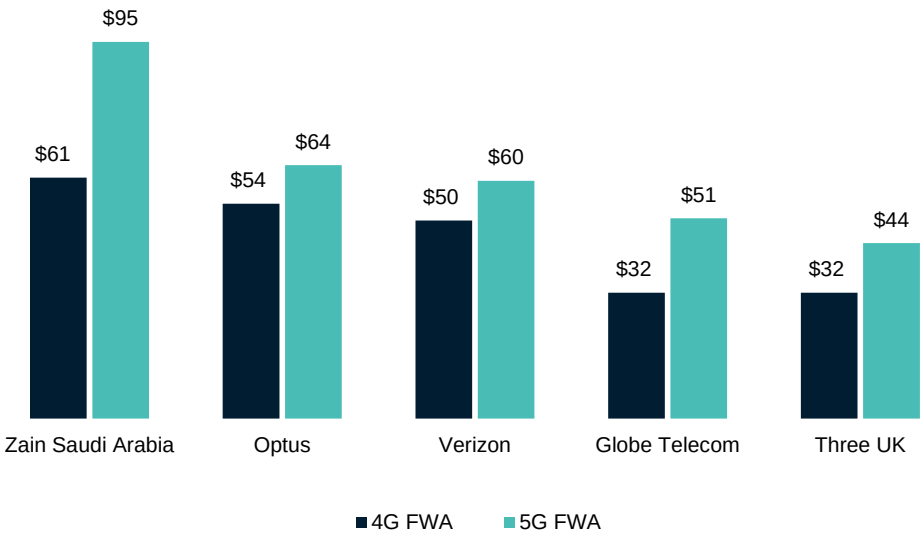
The 5G FWA revenue opportunity

Mobile operators have long sought new revenue streams to offset stagnating core revenues. While many of these new streams involve operators growing their presence in the digital ecosystem, there are also opportunities to capture new revenues from connectivity. Home broadband services through FWA represent one such avenue. This could prove particularly appealing for mobile operators that do not currently have a significant presence in the fixed broadband market.

Some operators have reached material revenue contributions from FWA (over 10% of service revenues is an indicative threshold). For example, we estimate that FWA accounted for 14% of total service revenues for Globe Telecom in 2020 and helped the operator grow home broadband service revenue by 23% year-on-year. In Poland, almost a third of fixed broadband revenue is attributed to FWA networks.[1]

In most cases, however, operators have used 4G FWA as a cost-effective way to provide broadband services to specific market segments, such as households in sparsely populated rural areas. As a result, 4G FWA services represent a minor proportion of revenues for the majority of mobile operators. 5G creates a larger addressable revenue opportunity. This is, in part, because its enhanced capabilities allow operators to offer customers larger data bundles and faster speeds on FWA plans that can drive a price uplift.

Figure 4: The 5G FWA premium
Monthly price of FWA plans (US dollars)



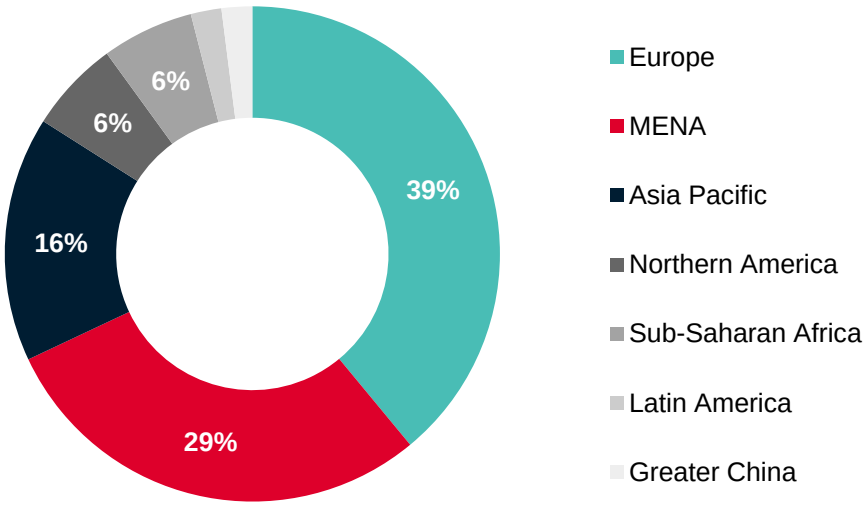
Pricing correct as of 10 February 2021. Prices include the cost of equipment.
Source: GSMA Intelligence

[1] Report on the State of the Telecommunications Market in Poland in 2019, UKE, 2020

There is also scope to deploy FWA across a wider footprint than previous generations and therefore increase the addressable customer base. For example, Zain Saudi Arabia's 5G FWA service already reaches more than 50 cities, with plans for further deployments in 2021. Three (CK Hutchison) has launched 5G FWA in Austria and the UK, targeting xDSL households, which account for more than half of broadband connections in both markets. Optus is deploying 5G FWA in areas where it previously relied on Australia's national wholesale fixed network. In a market where many households still only receive single-digit speeds on xDSL connections, the operator is advertising average download speeds of 239 Mbps, guaranteeing a minimum of 50 Mbps.

The rationale for mobile operators deploying 5G FWA extends beyond simply wanting to grow fixed broadband revenues. There is potential to grow revenues indirectly in pay TV and from bundling additional services (content add-ons or smart home, for example) with 5G FWA packages. 5G FWA can also be deployed as a defensive strategy to protect mobile revenues from the advances of fixed broadband providers. In the US, for example, cable MVNOs have shown increasing ambition in mobile, accumulating more than 4 million subscribers. To scale their own fixed-mobile convergence offerings, all three major US mobile operators have 5G FWA plans, allowing them to extend their fixed broadband networks into markets where the cable providers are present.

Figure 5: Europe and MENA account for around two thirds of 5G FWA commercial launches
5G FWA commercial launches, by region



Data as of 10 February 2021.
Source: GSMA Intelligence

No one-size-fits-all approach

Tracking by GSMA Intelligence indicates there have been 51 5G FWA commercial launches to date, with mobile operators adopting a range of strategies depending on local market conditions. In markets with low levels of fixed broadband penetration, home broadband represents an untapped opportunity for most operators. As more social and economic activity moves online in a post-Covid world, mobile operators can use 5G FWA to meet growing demand for high-quality broadband.

There are also opportunities to deploy 5G FWA in markets with high fixed broadband take-up, due to the significant disparity between countries in terms of broadband user experience. Speeds and prices vary considerably, as a result of the fixed broadband technology choice by incumbent operators and local regulatory conditions, creating opportunities for 5G FWA deployments. In some markets, 5G FWA is best positioned to compete on price; in others, there is scope to compete on broadband performance.

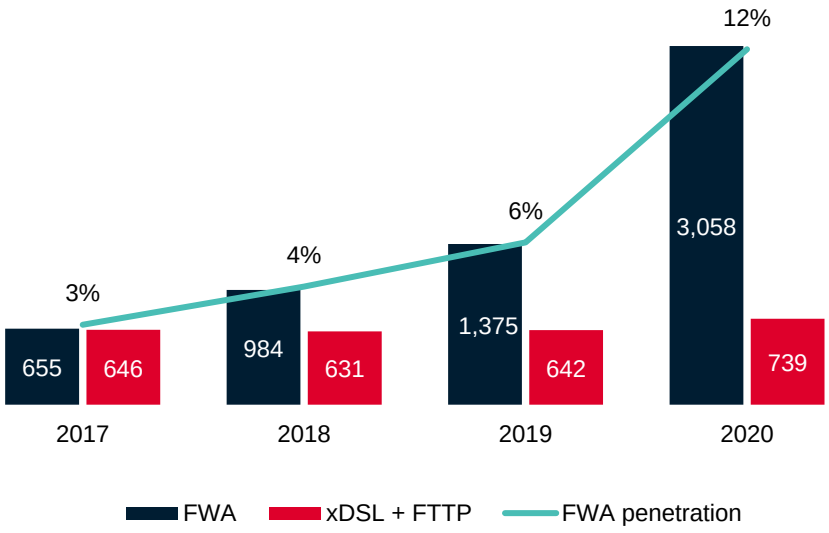
We outline below four deployment scenarios/strategies for 5G FWA. The first three evaluate 5G FWA deployments aimed at the consumer market. The final strategy, which can be used alongside any of the first three, examines deployments for locations with a high concentration of enterprises.

Scenario 1: countries with low fixed broadband penetration (emerging markets)

In countries with low fixed broadband penetration, mobile operators can use 5G FWA to drive first-time broadband adoption. In many such markets, mobile operators will require a targeted approach to 5G FWA deployment, due to existing affordability and usability barriers (set-up and actual internet usage). In Sub-Saharan Africa, for instance, fixed broadband penetration is typically below 2%. 5G FWA is likely to be concentrated initially in affluent neighbourhoods and dense urban areas, before expanding to more rural parts. This underpins the approach of Vodacom and MTN, which launched the first major 5G networks in Sub-Saharan Africa in Q2 2020, offering 5G mobile and FWA services in parts of South Africa. Both mobile operators have an opportunity to build market share by delivering a compelling 5G FWA proposition before competition increases as alternative broadband solutions arrive.

Mobile operators in other regions with low fixed broadband take-up are also pursuing the 5G FWA opportunity. In June 2019, Globe Telecom became the first mobile operator in Southeast Asia to launch a commercial 5G FWA service with its rollout in the Philippines. The proposition, targeted at the country's growing urban middle class, aims to build on Globe's 4G FWA success by offering download speeds of up to 100 Mbps and a data allocation of 2 TB. With the operator's 5G FWA plans priced at an average premium of 60% compared to its 4G FWA plans, there is a significant incremental revenue opportunity from 5G FWA for the operator, which is helped by a significant share of the labour market working from home. Other mobile operators that have witnessed significant demand for 4G FWA, such as Dialog in Sri Lanka, are also gearing up 5G deployments.

Figure 6: Working from home propels FWA adoption in the Philippines
Globe Telecom: fixed broadband subscribers (thousands) and FWA household penetration



Source: GSMA Intelligence

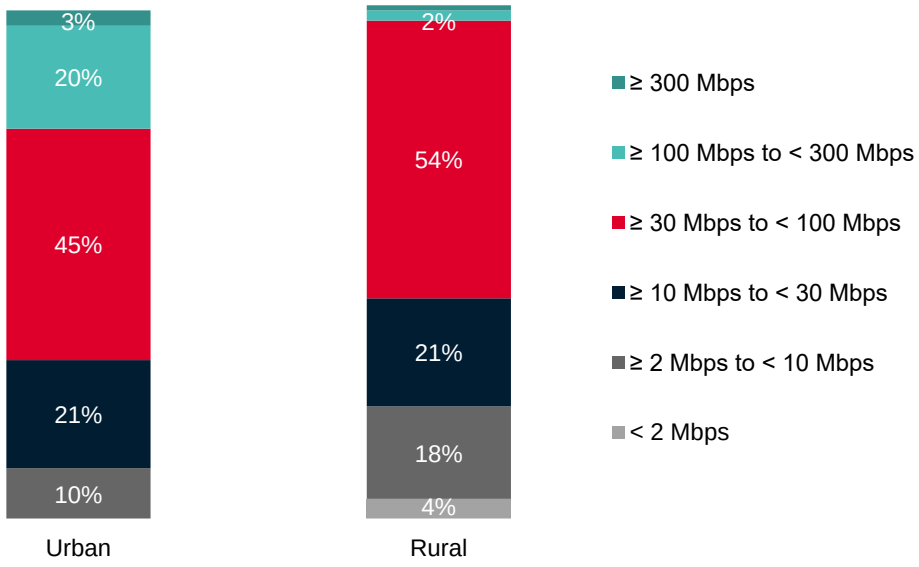
There are likely to be opportunities for broader 5G FWA deployments in high-income countries with low fixed broadband penetration. The Middle East provides an informative view: only around one in three households subscribes to fixed broadband in Kuwait, while the figure is around one in two in Oman and Saudi Arabia. Considering the high income and PC penetration levels in these countries, there is a sizeable and relatively uncontested space for 5G FWA services. This is reflected in the number of 5G FWA launches in these markets, with at least two mobile operators launching 5G FWA services in each country. Moreover, there are operators in all three markets reporting nationwide 5G coverage, laying the foundations for 5G FWA take-up. Commercial offerings vary between countries, but a common approach is to price 5G FWA in line with FTTP plans and target 5G FWA at the family segment, where data usage is highest.

Scenario 2: primary fixed strategy in high-income countries

In markets with established broadband uptake (Europe, US, Canada, Australia, Japan, South Korea), mobile operators without existing fixed infrastructure can use 5G FWA to challenge DSL/fibre/cable competitors. The clearest opportunity is likely to be in markets where a significant number of households rely on xDSL broadband products with low speeds (usually less than 10 Mbps), such as Austria, Germany, Italy and the UK. In this situation, 5G FWA can be positioned as an upgrade in terms of performance – particularly download speeds. In the UK, where two thirds of fixed households rely on xDSL broadband, the average download speed is 64 Mbps.[2] For comparison, Three UK's 5G FWA product offers an average speed of 100 Mbps – a clear uplift.

[2] UK Home Broadband Performance, Ofcom, May 2020

Figure 7: Switching to 5G FWA will boost download speeds for the majority of households in xDSL-dominated markets – an issue for rural areas in particular
UK fixed broadband download speeds during peak time (20:00–22:00), 2019



Source: GSMA Intelligence, Ofcom, SamKnows

There is also scope for mobile-centric operators to deploy 5G FWA to compete against FTTP and cable broadband providers. In this scenario, it will be difficult for 5G FWA to compete on speed alone. However, there are a variety of factors that influence the broadband purchasing decisions of consumers, meaning 5G can compete in other ways. For example, 5G FWA providers can offer subscribers the convenience of self-installing their broadband – an obvious advantage during the pandemic. 5G FWA can also be positioned to target cost-conscious consumers in high fixed broadband ARPU markets such as the US. T-Mobile could replicate the disruptive pricing and novel marketing strategy that won it share in the US mobile market when it launches its 5G FWA proposition. The operator expects to roll out its 5G FWA product later in 2021, with a view to cover 10 million premises (8% of US households) by 2024.

Scenario 3: complementary fixed strategy in high-income countries

5G FWA can be used by operators looking to complement existing FTTP networks. Due to deployment costs, it is not always possible to extend FTTP networks into new areas. Verizon's Fios FTTP service, for example, is available to around 15 million US households, 12% of the total. To expand its fixed broadband footprint outside Fios coverage areas, the operator plans to use 5G mmWave FWA, citing an addressable market of 30 million households – double its current FTTP footprint. The service, marketed as 5G Home, will move Verizon into direct competition with cable providers, which account for 60% of fixed broadband connections in the US. With unlimited data and typical download speeds of 300 Mbps for $50 per month, 5G Home can compete on performance and price against cable alternatives, representing a potential new revenue stream for Verizon.

Using 5G FWA as a complementary fixed broadband strategy is also a viable approach for mobile operators that rely on wholesale agreements to offer fixed broadband in certain areas. In Switzerland, Sunrise has the opportunity to sell 5G FWA to subscribers that still rely on the incumbent's DSL networks to access the internet. The rationale is two-fold. Firstly, 5G FWA allows Sunrise to offer households higher speeds than currently received over DSL. Secondly, there is an opportunity for Sunrise to improve its margins by avoiding the wholesale fees it would normally have to pay to the fixed-line incumbent. Sunrise prices 5G FWA at a similar level to VDSL to drive take-up; longer term customer value can be gained with churn reduction and future price rises.

5G FWA can also be used as a complementary strategy for incumbent operators looking to migrate existing fixed broadband subscribers from copper-based (PSTN) networks. This allows operators to decommission their copper networks, presenting substantial opex savings. Copper switch-off will play an important part in reducing operator energy emissions. In Estonia, Telia is trialling 5G FWA with the intention of using the technology as part of its plan to replace copper access lines. Similarly, FWA is part of Telkom South Africa's planned technology mix to replace its copper network.

Scenario 4: enterprise

Much of the attention around 5G in the enterprise has so far focussed on Industry 4.0 initiatives. However, 5G's enhanced capacity and speed also make it suitable for delivering connectivity to PCs, laptops and other work devices. There could be particular demand for 5G FWA where offices and work spaces tend to be temporary, such as construction sites and SME premises. The latter would benefit from positive proof points in the home for small business owners. 5G FWA allows businesses to simply unplug the router and perform the setup process again at a new location, as long as it is in a 5G coverage area.

Two additional business benefits should also not be discounted:

- **Backup.** The critical nature of connectivity to enterprise productivity means businesses must ensure there is very little – if any – downtime in their operations. Compared to running a leased line into a premises, 5G FWA is likely to provide a more cost-effective backup to fixed broadband. Converged operators are particularly well placed to deliver this type of solution. In the UK, BT's 4G Assure broadband provides small businesses with a mobile broadband dongle to plug into their BT router. The router automatically switches to 4G if the fixed broadband connection fails, minimising any interruption to internet use. This type of solution is likely to grow in popularity, driven by the shift towards homeworking and the advanced capabilities of 5G.

- **Services cross-sell.** FWA offers the opportunity to cross-sell enterprise communications suites (such as unified communications), cloud and hosting, as well as potentially more advanced products such as private networks. 5G FWA is also likely to be a key early 5G use case for mobile operators in emerging markets, considering the greater purchasing power of enterprises compared to consumers.

Technology enablers

Innovations driving the success of FWA

The strategic rationale and demand drivers for FWA in 2021 help to explain the steady growth in deployments around the world. But they are only part of the story. Ultimately, if the economics of deploying FWA services are not positive, the business case will be difficult to justify. This holds for FWA services leveraging 4G, 5G or other technologies. As operators carefully consider their fixed wireless technology options, the link between those options and the economic viability of FWA services becomes patently obvious; the right technology decisions can make or break the business case, and new innovations are making launches more attractive than they might have been in the past.

New network technologies offer to keep FWA deployment costs in check, while driving an improved user experience. The same is true for the user equipment (CPE) supporting fixed wireless services. Across these, several innovations and technology developments represent enablers to successful FWA outcomes:

- 3GPP standards
- spectral efficiency gains
- RF innovation
- cell planning and RF intelligence
- CPE features and functions
- new spectrum.

3GPP standards

Fixed wireless networks and services are not new concepts. For decades, wireless technologies have been used to provide last-mile connectivity. For much of this time, the technologies used were often proprietary solutions, Wi-Fi-based implementations, or (at best) adaptations of existing cellular standards.

The rationale, in the past, for eschewing existing mobile standards included a range of justifications. In some cases, companies were simply exploiting technology they already had easy access to, and the cost savings would naturally follow. In other cases, performance improvements were the goal; it was argued that by optimising the wireless connection (the network infrastructure, user device and way they talked to one another), coverage and capacity could be enhanced, often through the use of advanced RF capabilities. Coverage and capacity improvements would lead to their own cost efficiencies.

While successful FWA services can be built on proprietary technologies, the use of 3GPP technologies promises to deliver the ecosystem scale needed as operators look to grow their fixed wireless businesses, while still ensuring optimal user experiences. At a basic level, the value of nearly any technology standard lies in the interoperability across different suppliers, simplified solution development and a consistent user experience. In the case of FWA, 4G- and 5G-based solutions bring key benefits critical to the success of the market:

- **Ecosystem scale**. The maturity of 4G and 5G brings a broad ecosystem of component and solution vendors, giving FWA operators a strong set of supplier options, while keeping solution costs in check. The GSA, for example, estimates more than 1,500 LTE devices are commercially available on the market.
- **R&D scale**. Thanks to global adoption and an open specification process, 4G and 5G standards are the result of collaboration (and competition) between thousands of experts across the world. This ensures continual delivery of cutting-edge capabilities to the advantage of operators and consumers alike; today's investments are not stranded by a limited technology roadmap.
- **Common service sets**. While FWA is dominated by a focus on broadband access, operators are concerned with delivering services to customers. Beyond connectivity, 4G and 5G standards include service standards (voice, video, messaging, security) that can be leveraged in support of additional revenue sources.
- **Spectrum availability**. Where fixed wireless services can operate in spectrum allocated for mobile services (where allowed by regulators), FWA operators using 3GPP standards-based solutions need not necessarily obtain new, dedicated spectrum before launching services.
- **Fixed enhancements**. Within a fixed context, 3GPP specifications still allow for the optimisation of key solutions to improve cost efficiencies and the user experience. Compared with mobile devices, for example, CPE can employ higher order MIMO configurations. Similarly, FWA-focused RAN equipment can take advantage of simple (e.g. narrow cell site) and more complex (e.g. beamforming) optimisation to support improved coverage and capacity.

Spectral efficiency gains

The NR standard of 5G underpins a significant rise in spectral efficiency compared to LTE by increasing the data capacity that can be transferred per unit (Hz). This is a feat of engineering but also has a significant read-across to the 5G FWA business case when combined with improvements to signaling and CPE technology, including:

- antenna gains
- massive MIMO
- SRS[3] antenna selection (allows CPE to switch between antennas to optimise signal reception)
- CPE placements nearer to windows.

Precise efficiency gains depend on the specific circumstances of network deployment. However, we can make a high-level representation by combining the uplift associated with 5G NR and, separately, the gains of 5G FWA compared to 5G mobile broadband as a result of CPE enhancements:

- 5G NR versus LTE = 1.5× (50% uplift)[4]
- 5G FWA versus 5G mobile broadband = 2.5× (150% uplift).[5]

The FWA 2.5× uplift versus 5G mobile broadband is an estimate within a range. This means it could rise higher but that would depend on the rate CPE manufacturers implement and distribute

[3] Sound Reference Signal
[4] GSMA Spectrum programme estimates
[5] Based on a range of industry sources

routers with the latest specifications that underpin the spectral efficiency gains, which will likely happen over a period of years.

This implies that 5G FWA will accrue a spectral efficiency advantage of 2.0–3.5× compared to 5G mobile broadband (for smartphones). This is particularly important for the economics of the FWA business case as it provides the underpinning for increased asset efficiency and revenues as operators monetise home data usage.

The efficiency can be expressed in terms of revenue per unit of spectrum (Hz). If we compare FWA and 5G mobile broadband, the revenue per Hz is primarily driven by three variables:

- spectral efficiency (cellular data transferred per Hz)
- customer ARPU
- cellular data usage (per day or month).

Specifically, revenue per Hz = ARPU / (data usage / spectral efficiency).

The revenue yield rises in parallel with ARPU and spectral efficiency while being inversely related to data usage.

Increased spectral efficiency is, however, the key determinant because it helps to offset what could otherwise be very high bandwidth consumption relative to revenues for FWA versus mobile broadband. As spectral efficiency increases, it should drive the FWA revenue per Hz on an upward path towards parity with mobile broadband by 2025, strengthening the underlying business case.

In a subsequent phase of research, we will explore the FWA economics in more detail based on the above inputs.

The generally lower cost of passing homes with FWA compared to fibre or cable further improves the economics once a certain level of scale is passed. The extent to which profitability gains are realised at a retail level will depend on the spectrum holdings of a mobile operator, FWA data usage and pricing strategy. For example, if unlimited usage plans are offered, the profitability gains can only go so far before being diluted. This is, however, not a zero-sum game; we would expect operators offering FWA to drive bundling with 5G mobile and potentially content offerings (in much the way other broadband providers do) as opposed to a pure-play value broadband strategy.

RF innovation

Before 2020, most radio layer innovation in mobility was focused on coverage and beam management robustness. Vendors proudly announced new, long-range transmission records each quarter on higher and higher speeds. Enhanced beam management and beam failure recovery was a key area of innovation that helped increase the coverage and reliability of FWA services. Vendors were focusing on proving that this time the technology worked well and could provide connectivity for masses of households and enterprises.

The next major step is to help make 5G FWA more economical than its predecessors. Compact, smaller network elements lower in weight and power consumption, fronthaul sharing and carrier aggregation are the focus of innovation helping operators to lower the cost-per-bit attribution. Improvements in network performance are currently driven by two main areas:

- more advanced chipsets from chipset vendors
- new software releases from equipment vendors.

The software releases improve the capabilities of existing massive MIMO technology and beamforming, driving improvements in signal strength. Thus, overall network capacity and coverage footprints should increase in parallel. We expect this to be supported by next-generation radios, inter-band aggregation and use of advanced algorithms, such as for dynamic spectrum sharing.

A final area identified for improvement is the cost efficiency of increasing coverage. 3GPP Releases (16, 17 and 18) include elements to improve coverage without physically backhauling new sites with time- and resource-intensive fibre deployments. Once integrated access backhauling (IAB) is mature enough, network operators can utilise existing macro sites as donors and create access links to connect new nodes easily and cost-effectively. This transformative network architecture will help operators deploy multilayer networks, easily roll out coverage extensions to connect the unconnected, or mitigate the market power of an incumbent broadband provider. For FWA, the use case is relatively straightforward compared to mobile and will benefit from other innovation related to the 5G network.

Network planning and customer intelligence

Fixed wireless network and equipment innovations are critical to helping operators deliver compelling services (access and beyond) at competitive and profitable prices. However, to market, plan and sell those services, robust network coverage and granular demographic data is also needed.

User demographics play an important role in planning sales and marketing efforts, as well as network build-out strategies. Household income and fixed broadband penetration data, for example, can help drive effective sales and marketing, ensuring only the most relevant prospects within a certain coverage area are targeted. When this is combined with data on existing service uptake (mobile broadband, voice, pay TV), FWA bundle opportunities can be included in the messaging. As operators look to expand their fixed wireless coverage and capacity, a detailed understanding of demand demographics is crucial to direct investments to only the most profitable areas of opportunity. Even where an operator leverages an existing mobile network to provide FWA services, demand demographics can support decisions around capacity and coverage expansion.

FWA network coverage data is also a critical input into sales, marketing and build-out plans. Most mobile broadband network equipment suppliers, and many third-party vendors, offer radio planning solutions that allow an operator to estimate coverage, capacity and user experience while building the network. These solutions leverage topographic data, radio access network configurations and user equipment assumptions to indicate the expected end-user experience at specific points in a coverage area. Post-deployment, this data can be validated by user-experience feedback and/or testing.

Network performance data can feed into successful service sales and marketing efforts. As a starting point, accurate performance data (coverage, capacity and latency) can form the foundation of targeted FWA service marketing, guaranteeing that would-be customers are capable of receiving services. More granular performance data can then inform the services offered, such as specific speed tiers or high-quality video services. While network planning and experience modelling tools are an important component of effective sales and marketing, the tools need to be seamlessly integrated into an operator's sales and marketing systems to enable front-line sales teams to make use of the data.

It is impossible – or, at least, unwise – to sell FWA services where they cannot be well delivered. To do so risks an operator's reputation and relationship with its customers. Given the incumbent legacy of fixed-line broadband services, this is not a risk any operator driving new FWA services can entertain.

CPE features and functions

For fixed wireless services to be successful, they must scale to reach a critical mass of users. With each new user, additional CPE must be deployed, spreading network infrastructure costs over a broad subscriber base. This fundamental reality – that user nodes will (ideally) outpace network nodes by a magnitude of order or more – has profound implications for the economics of FWA. In particular, CPE innovation and sourcing decisions can have an outsized impact on fixed wireless business outcomes.

At first glance, the imbalance between CPE and network node deployments might suggest CPE costs are the most important selection criteria for operators sourcing their fixed wireless user equipment. Indeed, CPE (device and installation) costs are front of mind for any fixed wireless operator. However, they are only one component of the business case. Where higher-priced CPE can deliver a premium service experience or keep network deployments in check (perhaps allowing full reuse of the mobile network), trade-offs may be justified.

Also of importance is CPE model diversity. Any operator planning a comprehensive FWA launch will need multiple CPE models to target diverse user segments. Thanks to the use of 4G and 5G standards, the FWA industry has benefitted from multiple suppliers developing CPE models. As suppliers evolve their offers going forward, they can help drive the success of the market by considering a number of key criteria for operators:

- **Deployment model**. CPE designed for deployment outdoors can deliver improved coverage and capacity, as there is no need to penetrate walls of buildings. Indoor CPE, however, may be self-installed, keeping deployment costs in check; because of this, the vast majority of deployments are planned to be indoors, though this does imply a greater requirement for more advanced RF features. Both can benefit from installation tools that guide CPE placement to yield the optimal signal strength.
- **Home networking**. Inside the home, FWA CPE will need to connect with a range of consumer electronics and networked devices. An array of home networking options can support different operator service strategies and residential use cases: Ethernet, Wi-Fi 4/5/6, powerline networking, Bluetooth and Zigbee (for IoT in the home).
- **Service enablement**. In addition to video and VoLTE support, quality-of-service and class-of-service capabilities can help deliver differentiated services and drive premium revenues.
- **Service management**. Fixed wireless operators need to be able to manage their customers' CPE, just as operators offering fixed-line connectivity do. At a minimum, that

means the CPE must support common management protocols such as TR-069. The ability to manage and troubleshoot in-home Wi-Fi services is also increasingly important.

- **RF features**. Improved signal quality for a user's CPE is critical to delivering consistent service availability and high data rates, while maximising service reach (putting more users within reach of the network). Ultimately, antenna gain and EIRP are the measures of how well signals can be sent and received. While space and power constraints limit room for RF innovation in mobile devices, FWA user equipment can implement higher-order antenna gain, higher-order MIMO and high power output where needed and where the costs are justified.

New spectrum

Forecast data traffic increases in an existing environment of spectral capacity constraints were precursors to the use of mmWave spectrum (24–70 GHz). These same constraints help to explain the value in an FWA context.

The majority of live commercial 5G FWA networks are reliant on spectrum within the 3.3–3.8 GHz range. Bands also in play for 5G FWA include 700 MHz, 1800 MHz, 2100 MHz and 2600 MHz. Ultimately, a mixed strategy is likely: mmWave bands will be beneficial to meet high traffic demand at high network speeds, while mid-band spectrum supports coverage (see *Economics of mmWave 5G*).

The use of mmWave spectrum promises fibre-like speed and significantly lower cost-per-bit attribution. The new high-band spectrum offers enhanced performance to customers that previous generations of wireless broadband could not provide. However, weak propagation characteristics bring new challenges: the secure transmission radius is significantly lower than for mid-band spectrum and is prone to obstructions such as walls or foliage. These bottlenecks reduce the average inter-site distance in the network, while the associated cost of the new sites can erode the theoretical competitiveness of high-band FWA.

A fair amount of scepticism surrounded the potential use of mmWave for FWA until recently. Several network operators successfully carried out field trials on mmWave services in 2017, with vendors and OEMs developing 5G CPE and network equipment. In October 2018, Verizon became the first operator to launch a commercial pre-5G FWA internet service using 28 GHz. These efforts will be further underpinned by the release of new spectrum. WRC-19 resulted in agreement to free approximately 17 GHz of spectrum identified for 5G in the 26 GHz (24.25–27.5 GHz), 40 GHz (37–43.5 GHz), 50 GHz (45.5–47 GHz and 47.2–48.2 GHz) and 66 GHz (66–71 GHz) ranges.

The growth in available mmWave CPE over the last two years has been marked. Despite the uncertainty caused by the Covid-19 pandemic and associated economic downturn, the FWA 5G mmWave device ecosystem continues to grow. Consumers can expect more than 50 FWA CPE models to be available on the market in 2021.

Outlook and implications

The outlook for 5G FWA rests on a combination of 5G network rollout pace, spectrum availability and refarming, and the marketing and pricing strategies of operators pushing the service.

The networks front is generally positive, though with some technical challenges. 5G macro cell rollouts are generally proceeding at or ahead of pace despite the challenging economic environment. The sequencing strategy of prioritising urban/metropolitan areas before expanding into rural locales – which may be financed through part subsidy and/or co-investment models with government (see Table 2) – means FWA will be marketed primarily in higher density areas in the near term (the next 12–24 months).

Regulatory acknowledgement of FWA as a high-capacity option to help achieve national broadband goals is also important. For example, the Body of European Regulators for Electronic Communications (BEREC) guidelines issued in October 2020 explicitly note FWA as one of several technologies that will be used to construct very high-capacity networks (VHCNs) in the European Union – a directive now reflected in the European Electronic Communications Code (EECC). It is ultimately at the discretion of infrastructure providers as to which network access technologies are deployed, but the regulatory blessing of FWA should be seen as reflecting industry pragmatism to use solutions that are both high performance and cost efficient.

Some challenges related to network architecture remain: urban and suburban areas require a higher density of small cells to provide sufficient capacity and mitigate the risk of signal obstruction (such as from trees). Expedited planning approvals and permissions from local governments will be important to facilitate the rollout of small cells in these areas. Partnerships between telcos and organisations that control city infrastructure – utilities, transportation authorities and municipal governments – are also important to increase the number of points where small cell sites can be located. Spectrum also matters. The capacity advantages with FWA are greatest using high-band spectrum. Of the 38 countries where new spectrum has been assigned for 5G, only 12 (33%) have assigned mmWave spectrum. We expect operators to increasingly gravitate to a multi-band strategy for pragmatic and economic reasons, but this will require a tick-up in mmWave assignments.

Table 2: National broadband plans to reach rural areas (selected countries)

Country	Regulatory authority	Government investment	Target properties passed
Canada	CRTC Broadband Fund	$600 million	380,000 and 1,000 public institutions
Italy	Government-owned infrastructure company, Infratel	Varies (regional tenders)	1 million in initial phase (to 2021)
Spain	Government Programme for the Extension of Next Generation Broadband; EU	€500 million (+ €400 million from EU)	2.2 million additional people by 2021
UK	Ofcom: Rural Gigabit Connectivity, other schemes	£5 billion	All: gigabit-capable broadband to every household by the end of 2025
US	FCC: Rural Opportunity Fund, phase 2 of the Connect America Fund	$22 billion	700,000 in 10 years

Source: GSMA Intelligence

At a retail level, the CPE element is moving in the right direction, and the option for self-installation by customers will help by obviating the cost and time associated with engineer visits. The main questions come down to product and pricing strategy. Whether operators choose to offer 5G FWA standalone or as part of a converged bundle will depend on their network asset profile, existing customer behaviour and propensity to switch from competitors (especially in the consumer market). Timing matters: the next 12–24 months (2021 and 2022) provide a window of opportunity while fibre rollouts are still in progress. After this period, the competitive levers against higher capacity fibre and cable products will be mitigated by the anticipated price competition to win share, especially in saturated markets such as the US and UK. The same is true in the B2B space for SOHOs and SMEs. 5G FWA has a genuine opportunity here in the near term considering the value shift in the market associated with business spend reductions and general macroeconomic uncertainty. This will, however, require a creative sales approach not reliant on in-person account management, which augurs for integrated offerings with other enterprise communication products and potentially flexible pricing.

GSMA Head Office
Floor 2
The Walbrook Building
25 Walbrook
London EC4N 8AF
United Kingdom
Tel: +44 (0)20 7356 0600
Fax: +44 (0)20 7356 0601