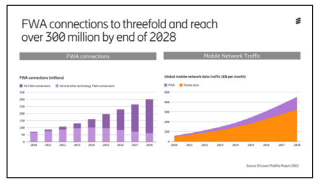
Fixed Wireless Access handbook

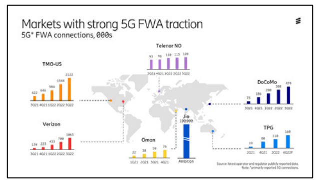
Extracted version

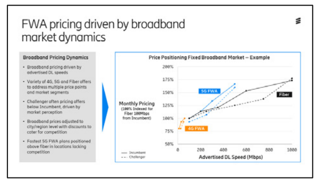
2023 edition

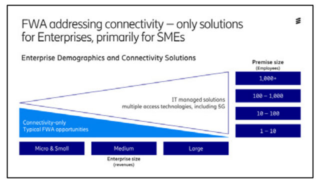
ericsson.com/fwa

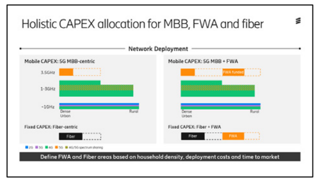
Discover what's new in FWA Handbook 2023

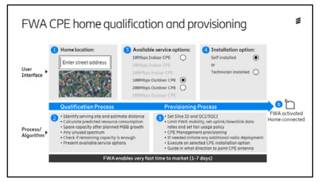


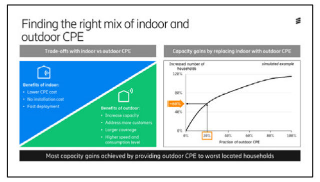


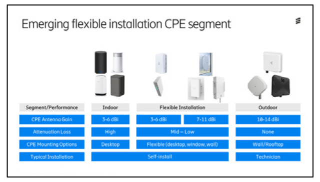












...and more...

In this 2023 edition of the Fixed Wireless Access Handbook, you will find new and updated information, offering deeper insights and knowledge on how to build a large scale FWA business

Chapters 1–2 have been updated with insights that reflect new Ericsson-internal research and dialogue with customers and analysts since the last edition. Our research shows over 75 percent of all service providers globally are now offering FWA services. 5G FWA now accounts for about one-third of the FWA offerings, a 50 percent increase over the past year, driven primarily by emerging markets. Furthermore, Speed-based FWA (QoS) continues to grow and, as of October 2022 it accounts for 25 percent of all FWA offerings. We also continue to see more focus and policymaker initiatives to foster broadband investments to close the digital divide. This edition offers expanded insights into the operator opportunity to deliver FWA services to business customers. It is encouraging that more service providers (and regulators) are now reporting FWA connections on a quarterly basis. We have also updated our FWA forecasts, which indicate growth to over 300 million FWA connections by the end of 2028.

Chapter 3 has been expanded with new insights into monetization, home broadband usage and traffic profiles. The chapter includes updated 5G FWA information and more detail on FWA monetization and pricing dynamics in relation to the broadband market. In addition, we share some data on the change in usage patterns caused by the Covid-19 pandemic, and how local variations can influence home broadband usage volumes.

Chapter 4 includes new perspectives on the end-to-end process operators need to manage their FWA businesses, especially the need for a holistic approach to capital allocation for funding FWA deployments, and to qualification and provisioning processes for FWA.

Chapters 5, 6 and 7 have been updated with new insights from the 5G FWA CPE and network ecosystems; in particular, an analysis of how to support the right mix of indoor and outdoor CPEs, as well as examples of new CPEs that offer flexible indoor–outdoor installation.

Appendix A, 'Tailored network solutions' includes six relevant case study from previous FWA Handbook editions and has not been updated.

Appendix B, 'FWA operator reference cases' offers inspiration from some real-world FWA deployment and service examples from leading operators around the world.

Our ambition with this latest edition is to give new and previous readers deeper insights into FWA business and technology trends, and to support decision-making as the FWA market momentum continues.

Happy reading!

Table of contents

1. FWA market opportunity 4

2. FWA solution 34

Appendix A.
Tailored network solutions for different segments 52

Appendix B.
FWA operator reference cases 62

Abbreviations and references 66

This document is an extract from the Fixed Wireless Access handbook.

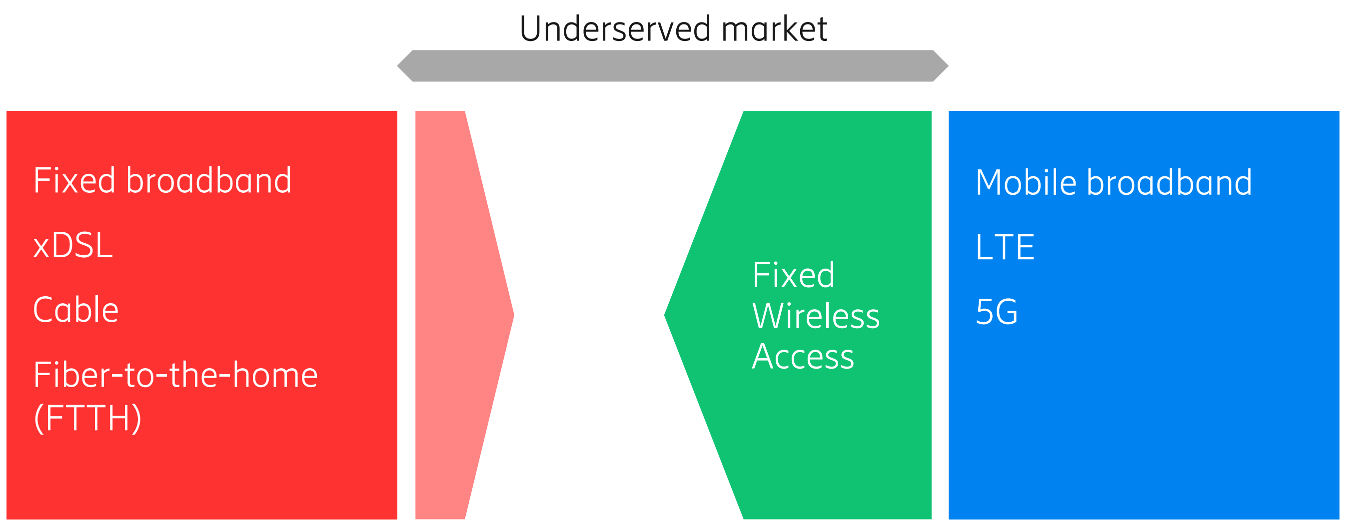
The full version has more than 200 pages, divided into seven chapters and three appendices.

Please contact your local Ericsson representative for information about the complete version.

EN/LZT 1/28701-FGD 101 449 Uen Rev H

1. FWA market opportunity

Broadband market



Global demand for broadband connections from both households and Small and Medium-sized Enterprise (SMEs) has been strong for several years.

Essentially, the broadband market can be divided into fixed and mobile. From a global subscription perspective, the mobile broadband market is substantially larger than the fixed broadband market: over 7.1 billion mobile broadband versus approximately 1.4 billion fixed broadband subscriptions (Ericsson, 2022). It is worth noting that the number of fixed broadband users is at least three times the number of fixed broadband connections due to shared subscriptions in households, enterprises and public access spots.

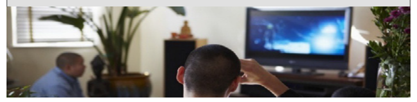
Globally, the fixed broadband subscriptions have increased by eight percent annually over the past five years. Furthermore, this growth is expected to slow down as existing technologies struggle to reach a growing number of households economically. The mobile broadband market has enjoyed a similar growth; increasing on average by approximately seven per cent annually over the past five years (Ericson, 2022).

Despite the growth in both fixed and mobile broadband, there is a large underserved household market. This market can, to a very large extent, be served cost-efficiently with FWA, when it is built on the huge installed base and global reach of 3GPP mobile technologies such as LTE and 5G New Radio (NR).

Fixed broadband pros and cons

xDSL (copper infrastructure)	
Pros	— Relatively low investment if copper is available
Cons	— Limited speeds (dependent on copper lengths) — Heavily asymmetrical — Heavy investment in active equipment — Increasing OPEX — Limited copper availability
Futureproof	Low
Typical speeds	20 to 100 Mbps DL 1 to 40 Mbps UL

Cable (coax cables)	
Pros	— Relatively low investment for passive equipment via existing CATV
Cons	— Slightly higher speeds than xDSL (but dependent on distance) — Bandwidth is shared — Impossible to unbundle services limits competition — Limited availability globally (digital-divide-areas)
Futureproof	Medium
Typical speeds	200+ Mbps DL 100+ Mbps UL



Fiber (FTTH)	
Pros	— Very high speeds
Cons	— Very high and upfront investment costs (civil engineering, ducting, etc.) — Deployment challenges with permitting, often resulting in slow time to market
Futureproof	High
Typical speeds	100 to 1000 Mbps DL 100 to 500 Mbps UL

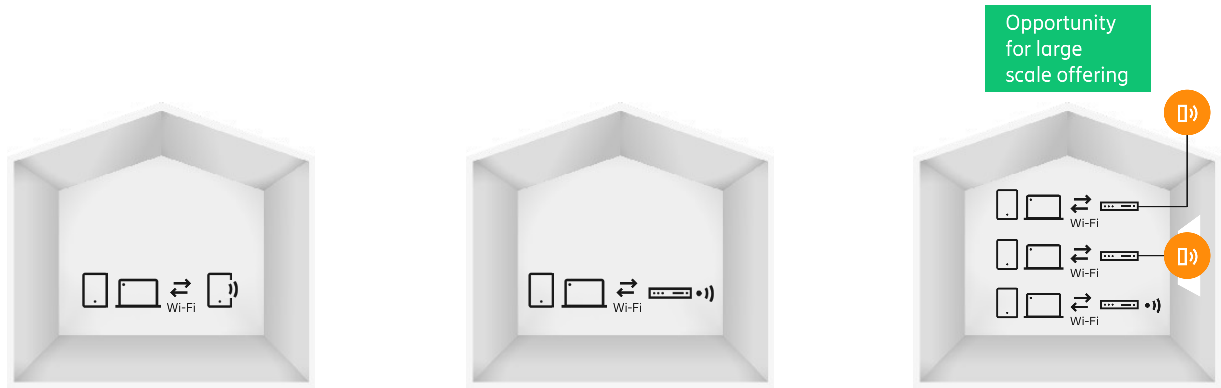
The three main fixed broadband technologies are xDSL, cable and fiber. The main advantage of both xDSL and cable is their relatively low investment requirements if there is existing copper or cable TV equipment. The advantage of fiber is the very high speeds it can offer.

The key disadvantage of all these technologies is their limited availability globally. There are also large regional differences in availability, ranging from household broadband penetration of around 11 percent in India to over 90 percent in North America (Omdia, 2022).

Furthermore, both xDSL and cable are restricted in speed and dependent on distance. The future-proofness of these technologies is limited. A further disadvantage of cable is that it is not possible to unbundle connectivity from services, which limits competition.

The main disadvantage of fiber is the very high upfront investment needed for things like civil engineering and ducting projects. Deployment challenges such as obtaining permits often result in slow time to market. According to Fierce Wireless, FWA providers can enter rural and urban markets at about one-tenth of the cost of laying physical fiber (Fierce Wireless, 2018).

Our definition of Fixed Wireless Access



Tethering
Mobile Broadband
Standard MBB pricing, device logistics and management

Includes tethering to Wi-Fi only devices.

Best effort
Fixed Wireless Access
Nomadic indoor device (CPE) with MBB-like device handling.

Typically volume based price plans (e.g., GB bucket per month)

Speed-based (QoS)
Fixed Wireless Access
Managed device (CPE), indoor or outdoor.

Price plan based on sold data rate. Subscription tied to known location.

To put FWA properly in context, it is important to distinguish between a few different cases of wireless service delivery to households.

Tethering – Mobile broadband
In this case, one or more mobile phones are used to communicate to and from the household. This also includes tethering to Wi-Fi only devices. Mobile broadband implies standard mobile operator pricing schemes, and standard ways of handling retail, provisioning, fault handling, and so on.

Best effort– Fixed Wireless Access
Here, the household has obtained an indoor wireless router, with wide-area wireless (such as 3GPP) capabilities to and from the household, and Wi-Fi (or LAN cabling) used within the house, between the router and other local devices.

The device and subscription are normally nomadic in nature, meaning the family can take the router elsewhere, and as long as the subscription is valid, the device will continue to work. The subscription normally reuses MBB paradigms, possibly with higher data allowances to cater for the whole household's needs.

Device handling is inherited from MBB, in terms of retail setup, provisioning and fault management. It is like a mobile phone without a screen.

Despite the nomadic character of this case, we include it in the definition of FWA, since, from the household perspective, it resembles fixed broadband. We add the label 'best-effort' since it is a challenge to provide very high grade guaranteed offerings when customer premises equipment (CPE) is nomadic and the subscription terms need to be valid everywhere.

Speed-based (QoS) – Opportunity for large scale offering
This case is where we believe the industry needs to focus more, and is one of the reasons for writing this handbook.

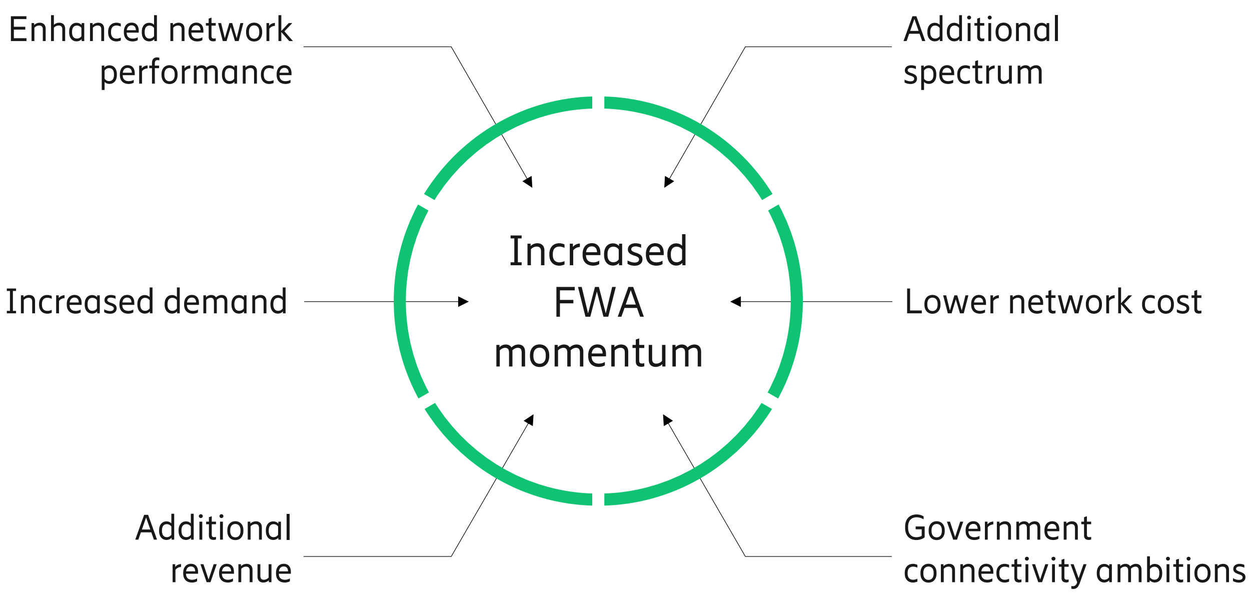
Here, the household is provisioned with a wide-area wireless-capable (such as 3GPP) device. This could be outdoor-mounted on a roof or wall, or an indoor unit, either fully integrated like a standard router, or with a more advanced antenna arrangement to improve performance. It is normally managed according to the fixed broadband paradigm, enabling remote configuration and fault management from a customer service center over standard protocols.

The price plan is specially designed for the service, typically inheriting the focus on sold data rate, from fixed broadband offerings. In terms of pricing positioning, Speed-based (QoS) offerings typically can have higher ARPU than Best-effort offerings given the superior performance, with pricing levels similar to fixed broadband offerings available in the market.

Finally, the subscription agreements are typically only valid in the subscribed location, either inherently though the fixed-mounted CPEs, or logically so that if the CPE is moved, the unit does not work or the subscription is modified.

We will focus on this case in this handbook, since this is what requires extra insights and actions to capture its opportunities, while being aware that FWA best-effort offerings do exist in many mobile operator networks today.

Drivers and momentum



There are six main reasons FWA is gaining momentum in the industry.

Network performance keeps improving, making FWA increasingly competitive and good enough for various use cases, including extensive video streaming. In addition, new spectrum in several bands is being made available globally.

At the same time, the network cost (cost per delivered bit) keeps dropping, enabling a viable operator business case for FWA, and making it affordable to households for services such as TV/video streaming. As an example, a site fully evolved with 4G and 5G capacity will deliver mobile data 10 times more cost-efficiently than a basic 4G site (Ericsson, 2018). However, many of the cost-efficiency steps can already be achieved through the LTE-A evolution.

The growing global popularity of the Internet and video streaming has led to increasing demand for high-performance broadband services. This demand cannot be meet with legacy xDSL or cable.

In addition, many operators are struggling to find revenue growth. FWA is seen as a good opportunity for additional revenue streams.

Governments are also fueling connectivity and broadband roll-outs through various programs and subsidies, as there is a clear link between increased broadband penetration and economic growth (Ericsson and Imperial College London, 2017).

These six factors combined are generating increased industry momentum behind FWA, and are further elaborated throughout the handbook.

FWA has three main advantages over fiber

1
Time to market
- Fiber roll-out is time consuming
- Fast time to market with FWA

2
Financial attractiveness
- Fiber build-out is capital intense with lower ROI outside dense urban areas
- FWA has light investment profile with lower risk

3
Re-use
- Fiber build is resource-intensive
- FWA reuses existing site infrastructure
- 5G enables operators to have one network for multiple services, including MBB, FWA and IoT

Many operators view FWA and fiber as their future fixed technologies, replacing legacy fixed technologies as well as bringing access to unconnected homes and businesses. FWA deployments have three main advantages over fiber deployments, related to time to market, financial investment profile and re-use of mobile infrastructure.

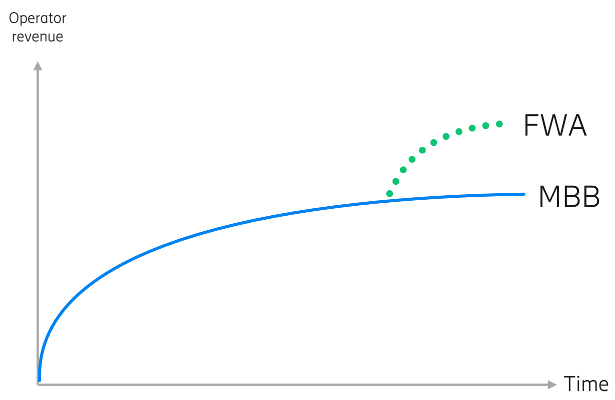
First, FWA has a shorter time to market than fiber. FWA leverages existing mobile network infrastructure, utilizing spare capacity and already-acquired but undeployed spectrum. Once that capacity is utilized, new capacity can be added to existing sites, either through software upgrades or additional new hardware – meaning there is no immediate need to build new sites. Conversely, building out fiber is a much longer process, often requiring permits and civil works to dig fiber. FWA deployment on customer premises is also typically faster than fiber deployment. Fiber always requires home activation on site, while FWA can be deployed through self-installation in the majority of cases.

FWA also has a more attractive investment and risk profile than fiber. Fiber build-out is a capital-intensive process, with most of the investment made up-front (that is, before signing up customers and earning revenues). At the same time, the investment returns diminish as fiber deployments move away from dense urban areas and fewer homes are served per kilometer of fiber. According to Broadband Communities Magazine (2021), the cost per home connected for rural homes is 2.5 times higher for Fiber compared to FWA when 30 percent of the households are subscribing. As a comparison, Norway is offering subsidies for FWA connected rural homes in the range of USD 1,000, whereas Sweden has offered subsidies for Fiber connected rural homes that is five times higher, i.e. USD 5,300.

FWA has a lighter investment profile, with lower initial investment (if any, when spare capacity is utilized) and investment scaling in line with subscriber growth. Moreover, capacity investments for FWA can be shared with other mobile network services resulting in lower risk. Even if there is no uptake of FWA services, the operator can still use that capacity for other services, including MBB and IoT.

Finally, FWA deployments reuses existing infrastructure. FWA reuses main sites and towers that are already built, with most upgrades performed without the need for site visits (unless new hardware is required). On the other hand, fiber build-out is resource-intensive, requiring construction, often with excavation and transportation of resources, including site visits to customer premises.

Operator opportunities for additional revenues targeting residential household spending



Upsell opportunities

Telephony — Voice services	**Bundles** — MBB Quad-play — Music, e.g. Spotify etc.
Video on-demand and Entertainment — Netflix/HBO/Amazon Prime etc. — Gaming — AR/VR	**Smart home services** — Work and study — e-health — e-climate — e-security

Over the past five years, global service revenues, in constant currency, have increased slightly with approximately five percent (Strategy Analytics, 2022). As a result, many operators are struggling to find top-line growth. FWA is seen as a good opportunity to increase revenues.

For mobile-only operators, household broadband is in many cases an unaddressed market. By targeting this market with FWA, these operators can tap into a considerable pool of residential spending.

For converged operators, FWA also offers a new revenue opportunity in areas and segments that are not cost-efficiently addressed or reached by their existing fixed broadband offerings. FWA is also of interest to converged operators trying to close down existing POTS/xDSL services, which are getting increasingly outdated and costly to maintain. By replacing their POTS/xDSL service with FWA, built on existing mobile infrastructure, converged operators can find significant cost savings and efficiencies, strengthening the business case for FWA.

The additional revenue streams that can be targeted are highly dependent on the operator strategy being pursued. For instance, many operators act as a triple-play Internet Service Provider (ISP), selling Internet connectivity, fixed telephony and TV over internet. Those who do not already offer TV over internet can use FWA to open up new revenue streams. All of these offerings can also be bundled with mobile services, including MBB, as a quad-play offering.

Interest in connected homes is growing fast and they include home security, energy and utility management, online shopping and health and wellness, to mention a few. There are also upselling opportunities through offering add-on video-on-demand services, such as Netflix, Hulu and others. It is worth noting that such services are only revenue generating if they are bundled into service packages, as they can be bought separately (over-the-top, OTT) by households. Furthermore, there are large opportunities within gaming, augmented reality, and Virtual reality.

In addition, there are opportunities to offer new services in areas such as e-health, e-security, and e-education.

Which new services are offered will vary according to the operator's current position. For example, a converged operator may already have a number of offerings on the fixed side that can be easily extended into an FWA offering; while a mobile-only operator may be very selective about which services they want to offer.

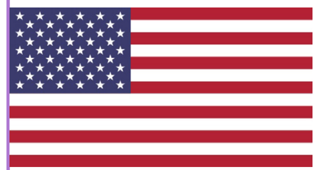
In summary, connecting a home with FWA opens up a number of possible revenue streams beyond pure connectivity.

Examples of government connectivity initiatives

USA

Broadband Equity, Access, and Deployment (BEAD) Program

Affordable Connectivity Program (ACP)



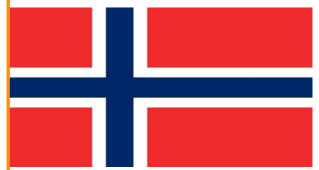
Europe

Path to the Digital Decade

Recovery and Resilience Facility

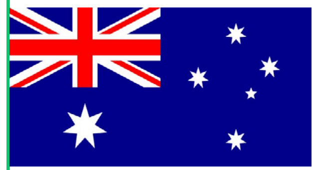
Norway

District development model



Australia

National broadband network



As mentioned earlier, governments are fueling connectivity and broadband rollouts through various programs and subsidies, as there is a clear link between increased broadband penetration and economic growth (Ericsson and Imperial College London, 2017). There are a number of initiatives to close the digital divide, addressing issues such infrastructure availability, affordability, digital literacy and digital institutions (Harvard Business Review, 2021). Forward-thinking governments employ a technology-agnostic approach, permitting a mix of technologies to be deployed to address each of these issues as needed.

The USA has been a pioneer in connectivity programs, starting with the Connect America Fund (CAF I and CAF II) to expand the benefits of high-speed Internet to millions of consumers in every part of the country (FCC 2017). Recently the USA has launched a series of initiatives to further close the digital divide, among them:

1. Rural Digital Opportunity Fund (RDOF) with USD 20 b. allocated to broadband roll-out to unserved and underserved census blocks, with winners utilizing fiber, FWA and satellite solutions (FCC, 2020)
2. Broadband Equity, Access, and Deployment (BEAD) Program, provides USD 42 b. to expand high-speed internet access to fund planning, infrastructure deployment and adoption programs
3. Affordable Connectivity Program plays an integral role in addressing affordability barriers to broadband access and adoption by providing qualifying low-income households with a monthly discount of up to USD 30/month (or up to USD 75 for households residing on qualifying Tribal lands). Affordable Connectivity Program received USD 14 b. as part of the Infrastructure Investment and Jobs Act (Infrastructure Act)

Europe has a mix of initiatives at local and central level. In 2021, European Commission (EC) presented the Path to the Digital Decade, setting out mechanism for cooperation between EU institutions and the Member States to ensure they jointly achieve the Digital Decade targets, objectives and principles. Moreover, the EC approved the Recovery and Resiliency Facility for post-Covid 19 economic support. Broadly, National Recovery and Resilience Plans (NRRP)s funded through this facility include initiatives to close the digital divide across four main areas:

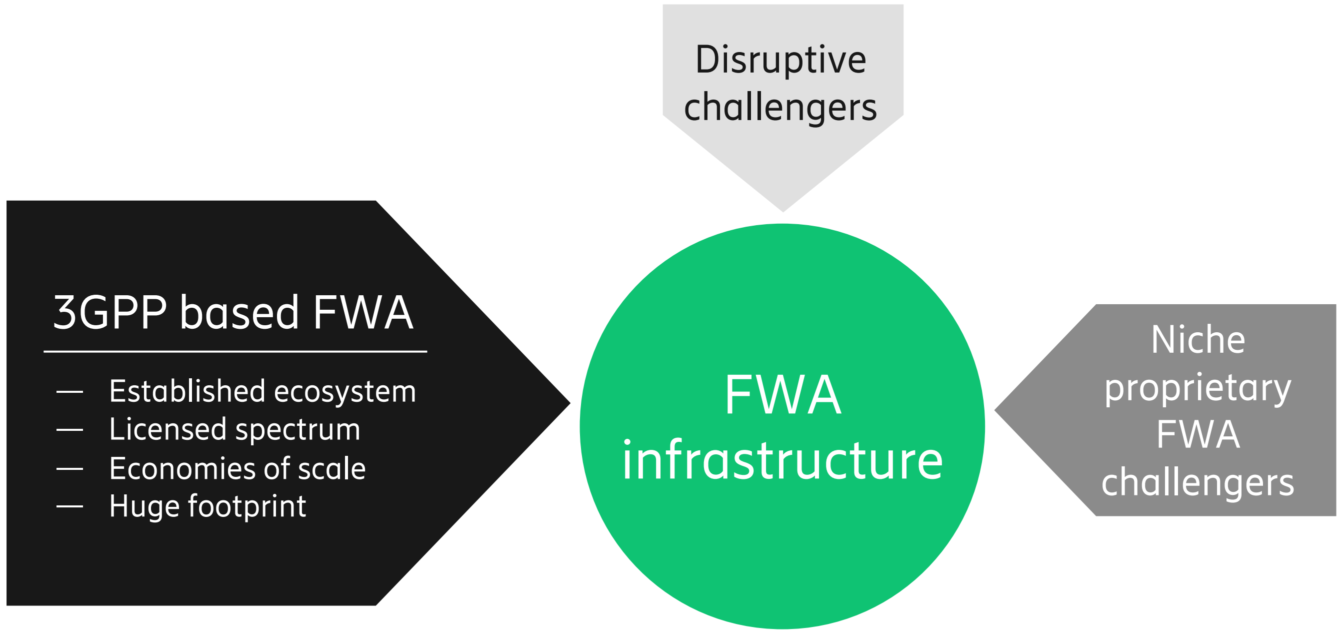
1. Infrastructure: 5G coverage in populated areas and household gigabit connectivity
2. Digital skills: aimed at adults with basic digital skills, and ICT specialists
3. Digitalization in public services: online services availability, e-medical records, and e-IDs
4. Business digitalization: aimed at improving SME basic digital intensity and cloud usage.

European Union (EU) member states set out in their NRRPs the reforms and investments that they aim to be implemented by 2026. A report covering 20 EU member states estimates funding for infrastructure programs totaling Eur 32 b. (Deloitte, Jun 2021), of which Eur 17 b. is for household Gigabit connectivity, and Eur 15 b. is for 5G coverage.

Norway has implemented a unique model to foster FWA deployment as part of its latest 5G spectrum auction. The District Development model was launched in conjunction with the 2.6GHz and 3.6GHz spectrum auction, where operators could apply for spectrum auction discounts for providing 100/10Mbps DL/UL connectivity to 62,000 premises (including homes, business, and schools) up to NOK 560 m. (NKOM 2021). The spectrum auction was completed in September 2021, with three winners (Telenor, Telia and Altibox) committing to district development against spectrum auction discounts totaling NOK 480 m.

Another approach has been adopted in Australia, where state-owned National Broadband Network (NBN) is building a fast, wholesale local access broadband network to connect the nation and bridge the digital divide. NBN's key objective is to ensure all Australians have access to fast broadband as soon as possible, at affordable prices and at the lowest cost (NBN, 2019). It is worth noting that NBN is technology-agnostic and uses the technology that is most appropriate for the household or area – including fiber, FWA and satellite, among others. Similar nationwide wholesale model has been launched in Malaysia, where the Digital Nasional Berhad (DNB) has been mandated by the Government of Malaysia to be the single neutral party to undertake nationwide deployment of 5G infrastructure and network to provide wholesale 5G coverage and capacity to other licensees.

Competitive FWA infrastructure landscape



The vast new opportunities opened up by FWA are attracting three main types of vendor, each aiming to address and supply equipment to operators.

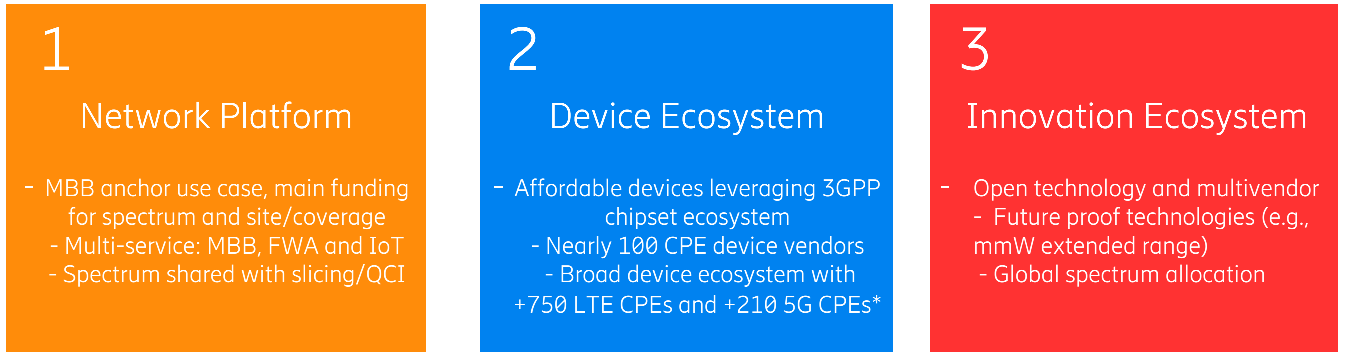
There are a handful of disruptive challengers' initiatives. For example, Google's Project Loon promises to create a network of balloons, floating on the edge of space, to extend Internet connectivity to people in rural and remote areas worldwide (Google, 2020). More recently, we have seen several Low Earth Orbit (LEO) satellite constellations targeting broadband services. The two most prominent of these are Starlink/SpaceX and One-Web. As of August 2022, Starlink/SpaceX had over 3,000 satellites in space out of a planned 12,000 satellite constellation. Starlink has been rapidly gaining customers to its commercial beta service available in 36 countries, produced more than 1,000,000 satellite dishes (CPE) up to August 2022. OneWeb has been launching satellites, reaching 428 satellites in space by March 2022 from a total 648 satellite constellation. These LEO satellite companies target the most remote 3-5% of the population without broadband services nor 3GPP coverage.

There is also a group of 'small niche proprietary challengers', which are providing FWA solutions. These include start-ups as well as more established vendors (many with a history of offering WiMAX or proprietary solutions based on IEEE 802.11). Such vendors offer single-frequency-band products in both licensed and unlicensed spectrum, ranging from 3.5 GHz to up to 60 GHz. The 3.5 GHz band was the main spectrum band for WiMAX deployments, but this band will now be used for 3GPP deployments instead. The established proprietary IEEE 802.11-based vendors are targeting many smaller operators, which cannot afford licensed spectrum and need to use the unlicensed 5 GHz band. These niche FWA proprietary solutions are common in the US, driven by market demand, local spectrum allocations, unlicensed CBRS band and fragmented ISP market. There are also a few commercial proprietary IEEE 802.11-based solutions emerging for the unlicensed 60 GHz band.

Unlicensed spectrum, such as that in the 5 GHz and 60 GHz bands, is particularly useful when combined with licensed spectrum. The 5 GHz band is already supported by 3GPP and the support for the 60 GHz band is expected in 3GPP Release 18.

By far the largest group is the 3GPP industry, offering multi-purpose 5G networks with FWA as one of the main use cases. Given the enormous established ecosystem of 3GPP, vast number of frequency bands, the focus on high-quality spectrum and the corresponding performance and capacity, economies of scale, and huge footprint, this is the group which will provide FWA on a massive scale globally.

Scale of 3GPP ecosystem delivers FWA with lowest TCO, future-proof evolution, and no vendor lock-ins



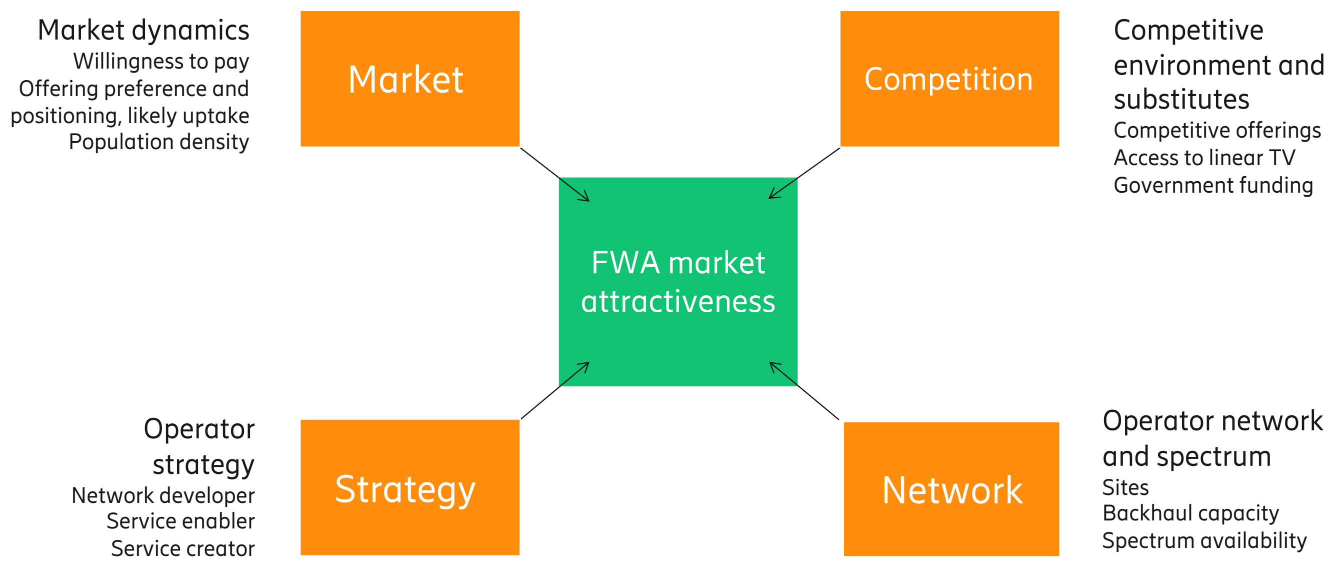
* GSA FWA report June 2022

To be competitive, FWA operators need to be able to offer data at the lowest possible Total Cost of Ownership (TCO) with a future-proof evolution of the network and the entire broad ecosystem. 3GPP offers all this through three main aspects:

1. **Network platform**
   3GPP offers a network platform where mobile broadband (MBB) is the anchor use case, and has funded large parts of the site infrastructure and spectrum costs. Most incumbent 3GPP operators are in an advantageous starting position, since they can reuse the entire mobile network, and much of its business processes, to offer multiple services, including MBB, FWA and IoT. The spectrum can be shared, and network slicing offers a way to manage both network and spectrum across multiple services, while meeting or exceeding the emerging requirements of a wide range of use-cases (including 5G FWA).
2. **Device ecosystem**
   The 3GPP CPE ecosystem benefits from the large innovative smartphone and device chipset market. Costs are driven down by economies of scale, and the availability of LTE and 5G FWA CPE with attractive form-factors and functionality evolution. There are nearly 100 different FWA CPE vendors, with more than 750 LTE CPEs and approximately 210 5G CPEs (GSA, June 2022).
3. **Innovation ecosystem**
   A further advantage of 3GPP is a future-proof ecosystem that ensures innovation combined with scale and cost-efficiency. One of the latest innovations benefiting FWA is mmWave extended range. 3GPP also offers an open technology platform with multiple vendors, without lock-in. Furthermore, it ensures global licensed spectrum allocations, further driving economies of scale for both network equipment and the entire FWA CPE ecosystem.

In summary, 3GPP mobile and converged operators are in an excellent position to address the FWA market. They will be able to offer services with the lowest possible TCO, and provide a future-proof evolution of the network and corresponding FWA services, coupled with a broad ecosystem that offers economies of scale and no-vendor lock-in.

Drivers influencing FWA market



There are a number of drivers influencing the attractiveness of the FWA market. These may be divided into four main categories, as illustrated in the picture. It is worth assessing these drivers at a national, regional or local level (such as a small city or a suburban area) to gain a better understanding of how successful and profitable an FWA rollout would be in that specific area. It makes sense to 'cherry-pick' and find the most profitable geographical 'sweet spot' areas in which to make first deployments.

Let's take a closer look at each of the four main FWA success factors.

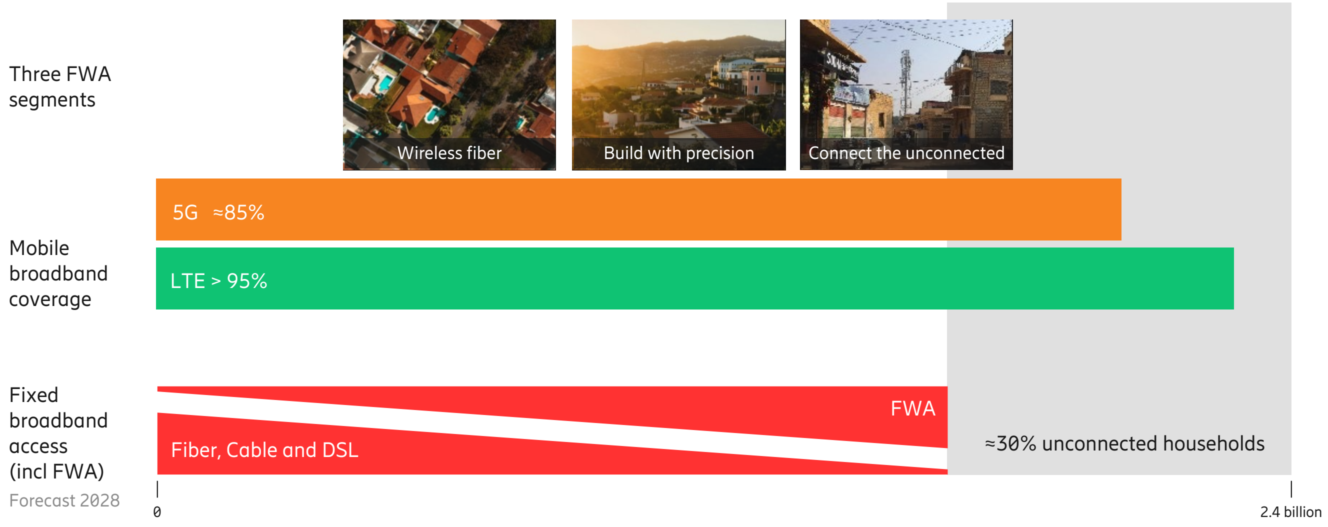
Operator strategy
Independent of operator strategy, FWA offers an opportunity to increase topline revenue. The exact market positioning and nature of the offering depend on the operator's overall strategic ambitions. For instance, an operator pursuing a 'network developer' strategy may decide to focus on earning money profitably on the pure connectivity part of FWA. While an operator pursuing a 'service creator' strategy may want to launch innovative smart home services in addition to the connectivity part.

Market dynamics
It pays to get a better understanding of the market being evaluated for an FWA rollout. This process involves assessing consumers' willingness to pay and the types of service offerings they are likely to want. Further key factors in determining the market potential are population density and likely uptake.

Competitive environment and substitutes
It is also important to assess the competitive environment. The first step is to determine the availability of other fixed broadband alternatives, such as fiber, xDSL and cable. In addition, other mobile operators' capabilities and likelihood of offering competitive FWA services need to be evaluated. The availability of government funding for the specific area should also be assessed.

Operator network and spectrum situation
The condition of the network in the targeted FWA area needs to be assessed, as it is an important factor in the ease and cost of FWA rollout. Key considerations are: site and current installed hardware and software, backhaul capacity, spectrum availability and current system load.

Broadband households by 2028 -Three FWA segments



FWA segments
We We have divided the FWA market opportunities into three distinct segments, each with different characteristics, mainly based on the offering, availability of fixed access and the corresponding average revenue per user (ARPU) that can be expected from customers.

The first segment is 'Wireless Fiber'. Here, there is competition with fixed broadband, driving a need for higher-rate offerings and capacity. The ambition is to provide fiber-like speeds and handle households' TV needs with a corresponding high ability to pay. Typical sold data rates are 100–1,000+ Mbps, and typical ARPU levels are USD 50–100.

The second segment is 'Build with Precision'. Here, there may be some availability of xDSL. However, there is a limited business case for providing fixed broadband alternatives. The need is for high data rate and capacity, and a willingness to pay. Typical sold data rates are 50–200 Mbps and ARPU levels are around USD 20–60.

The third segment is 'Connect the Unconnected'. This segment is characterized by virtually non-existent fixed broadband alternatives, and mobile broadband using smartphones is the dominant way of accessing the Internet. ARPU levels are limited and user expectations of access speed are relatively low. Typical sold data rates are 10–100 Mbps and ARPU levels are around USD 10–20.

It is worth noting that for 'Connect the Unconnected' and 'Build with Precision' segments, we assume that linear TV needs are satisfied by other means, such as terrestrial or satellite TV. For the 'Wireless Fiber' segment, some offerings may include a full IP-TV offering, implying dramatically higher data consumption.

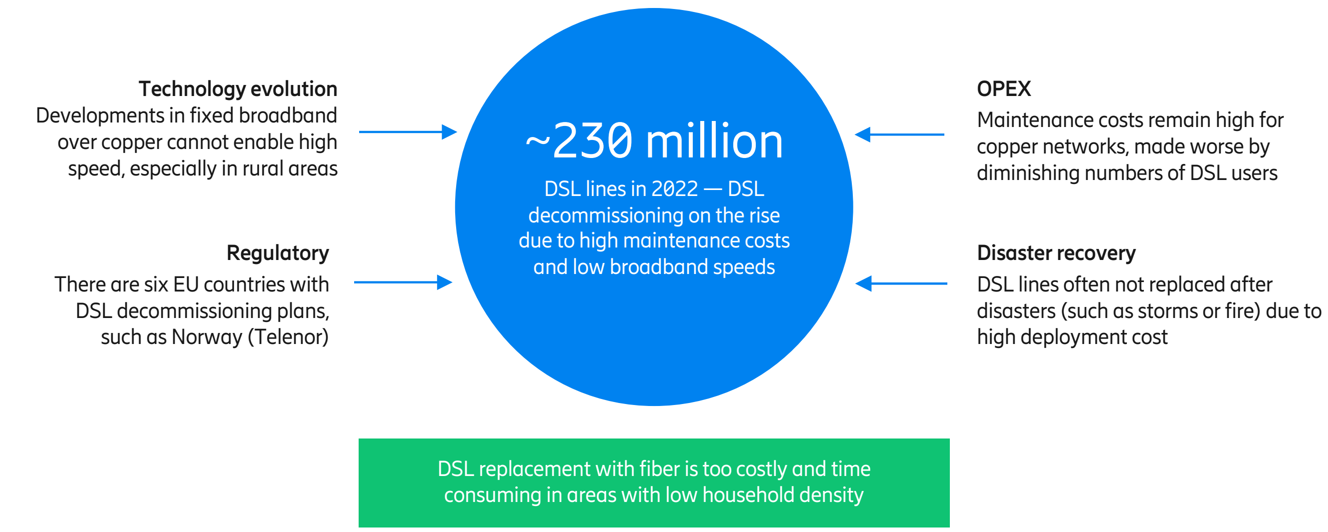
These three segments will be used throughout this handbook to distinguish the offerings and technical solutions tailored to them.

FWA segments and broadband market
The chart above shows a forecast of how household broadband needs will be met by a variety of technologies in 2028.

3GPP technologies are forecast to have huge population and household coverage by 2028. For instance, LTE is forecast to reach over 95 percent population and household coverage, while 5G is expected to cover around 85 percent of the world's population by 2028 (Ericsson, 2022). The huge potential household coverage creates a great opportunity for mobile operators to deliver FWA services on top of their existing MBB offerings.

When it comes to fixed broadband, including FWA, approximately 70 percent of all households are forecast to have a copper, cable, fiber or FWA connection in 2028. In many markets, it's not economically viable to build such broadband infrastructure much further. The forecast of over 300 million FWA connections by the end of 2028 represents over one billion individuals having access to a wireless broadband connection, which we expect to be spread across all FWA segments. Based on ITU data, we estimate that around 30 percent of households will still be unconnected in 2028.

Growing opportunity for DSL replacement – drivers for copper network decommissioning



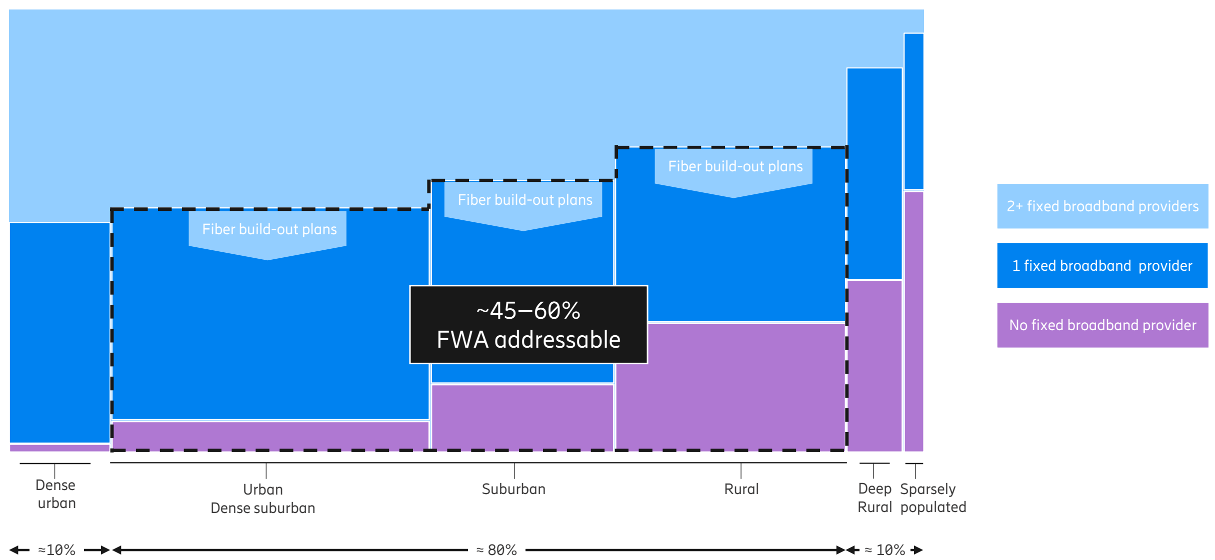
There are several reasons FWA is of growing interest as a DSL replacement.

First, even with developments to increase the broadband speeds offered by copper-based networks, speeds are reduced as the distance between the home and the first aggregation point increases. As a result, these networks need to be upgraded. FWA offers a very effective DSL replacement, especially in areas with low household density (such as rural areas) where fiber build-out is costly.

Second, most incumbent operators around the world has plans of decommissioning the existing legacy copper networks. For instance, in Europe, more than a dozen countries have announced plans to consider decommissioning in the next decade, with a handful of operators successfully implementing copper sunsetting projects. Smaller markets like Singapore and the island of Jersey have already achieved 100% decommissioning, of their legacy copper networks. Other markets like Norway, Sweden, Spain, Portugal, Estonia, and the Netherlands, among others, have active programs in place to accelerate copper decommissioning (Arthur D Little, 2021). Some of these markets are driven by regulatory conditions, while others are driven by economic conditions, as maintenance and operational costs remain stable while the number of copper-based subscribers falls steadily.

Third, some service providers are not replacing copper networks after damage caused by disasters such as storms, fires, floods and earthquakes. It is increasingly common for service providers to rebuild these networks with newer technologies such as fiber and FWA.

FWA country potential across geographical areas



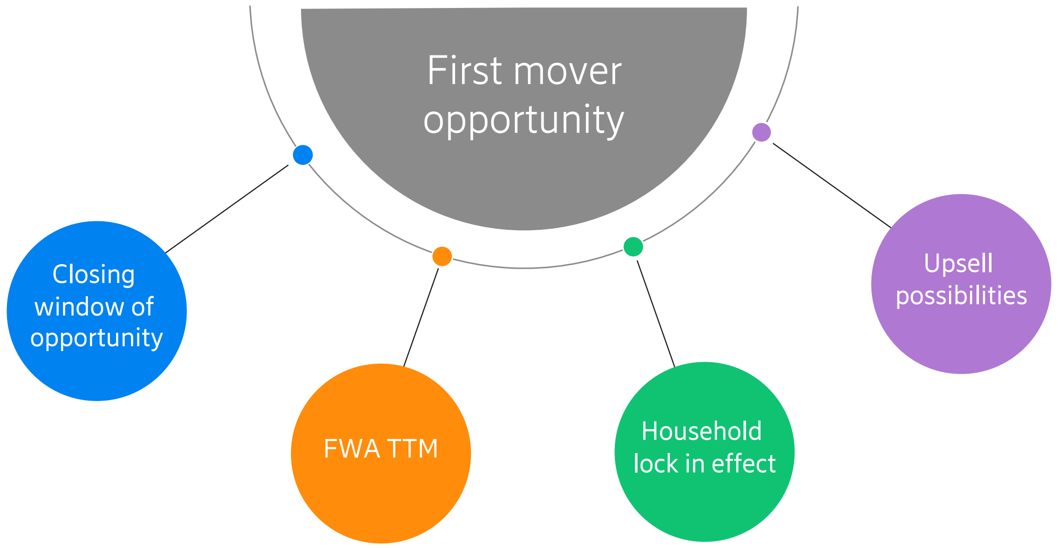
Source: Ericsson analysis

Successful FWA operators adopt a surgical approach to selecting attractive areas for FWA deployment, just as fixed broadband providers do. Unlike for MBB, where mobile operators usually focus on achieving broad population coverage and maximizing broad marketing reach, fixed broadband providers have a localized approach, selecting neighborhoods based on existing assets and competition. The chart above illustrates a fictive country example.

A surgical FWA approach starts from the exclusion of less attractive areas based on household density. Dense urban areas – the approximately 10 percent of households are excluded because these are more likely to have fiber, and because most spectrum assets in these areas are needed for MBB. Deeply rural areas and sparsely populated areas – the around 10 percent of households often lack high-speed MBB coverage, and FWA deployment would imply major, costly densification, putting pressure on the FWA business case. This means that around 80 percent of households remain addressable, in urban and dense suburban, suburban and rural areas.

Next, the attractive areas for FWA deployment are filtered further by analyzing fixed broadband competition and estimated fiber build-out. For fixed broadband competition, the FWA focus is to add consumer choice in locations with one or no fixed broadband provider. Many households have only one fixed broadband provider; for an example a cable operator providing large bundles of TV channels and limited broadband speeds. Removing households in target areas with two or more fixed broadband provider leaves around 60 percent of the market addressable for FWA. At the same time, fiber build-out is expected to continue, covering an additional 15 percent of households in target areas in the years ahead, at a pace that is partly dependent on FWA deployment effort and speed. As a result, the potential addressable market for FWA is estimated to be around 45-60 percent of all households in this example. Here operators who act fast could grab areas for FWA and render competitors' fiber build-out plans uneconomical.

First mover advantage



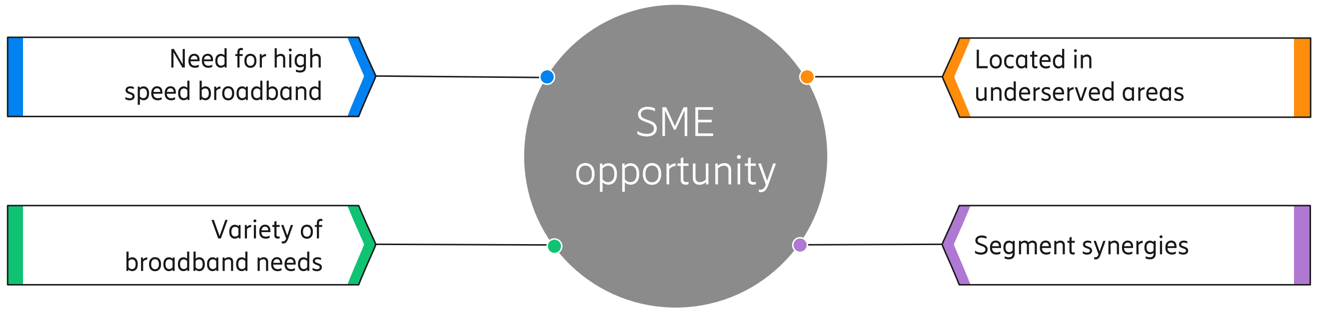
Substantial academic research has found that 'first movers' – firms that enter a market early – tend to exhibit higher business performance than firms that enter the market at a later stage. The degree of improved performance varies according to several factors and across industries. Studies within the telecommunication industry tend to support the theory of first-mover advantage, showing that they enjoy higher market share and operational financial results than later entrants (Jakopin and Klein, 2012).

For FWA, there are four main areas contributing to first-mover advantage:

- **Closing window of opportunity** – as has been mentioned previously, the FWA and broadband opportunity needs to be assessed at a local level. However, the opportunity window is closing as fiber build-out are targeting the most profitable household areas. In addition, there are also operators with proprietary wireless technologies addressing these areas. The reverse situation is also true: when FWA is deployed in an area, it is very hard to develop a sustainable business case for fiber, as it tends to need a high sign-up level among households in a given area to be profitable.
- **FWA time-to-market (TTM)** – in view of the closing window of opportunity, FWA service providers have a competitive advantage as it is typically around four times faster to deploy FWA than fixed broadband alternatives. For example, fiber deployment has the challenge of obtaining permits for trenching, meaning much slower time to market than FWA, which is built on top of existing MBB infrastructure. In addition, FWA is much more capital-efficient and, according to Broadband Communities Magazine (2021), the cost per home connected for rural homes is 2.5 times higher for Fiber compared to FWA when 30 percent of the households are subscribing.
- **Household lock-in effect** – once operator sign up households to broadband subscriptions there tends to be a 'lock-in' effect. In some cases, there are long-term contracts which contribute to this. Experience shows that for FWA household broadband subscriptions – with CPE installations as well as bundling with MBB, fixed telephony and entertainment, for example – tend to increase this lock-in effect.
- **Upselling possibilities** – building on the household lock-in effect, connecting a home with FWA opens up several potential revenue streams beyond pure connectivity, including bundles with MBB and Smart home services.

To summarize, FWA offers a business opportunity that needs to be addressed by operators, as there are many indications of a strong first-mover advantage.

Small & Medium Enterprises – Opportunity to address a large underserved market



Beyond consumers, there is an opportunity for FWA to address enterprises, in particular, the sizable small and medium enterprise (SME) segment, especially in emerging markets where SMEs represent a significant part of the economy.

Growing digitalization across many aspects of doing business is accelerating the need for high-speed broadband connectivity among enterprises of all sizes. Better connectivity is needed for enterprises, including main and branch offices to satisfy the increasing reliance on electronic payment and ecommerce, cloud services and enterprise resource planning (ERP) applications.

Furthermore, there are a growing number of connected, including IoT, devices being deployed by businesses across a variety of applications, including security, process control, logistics and inventory management.

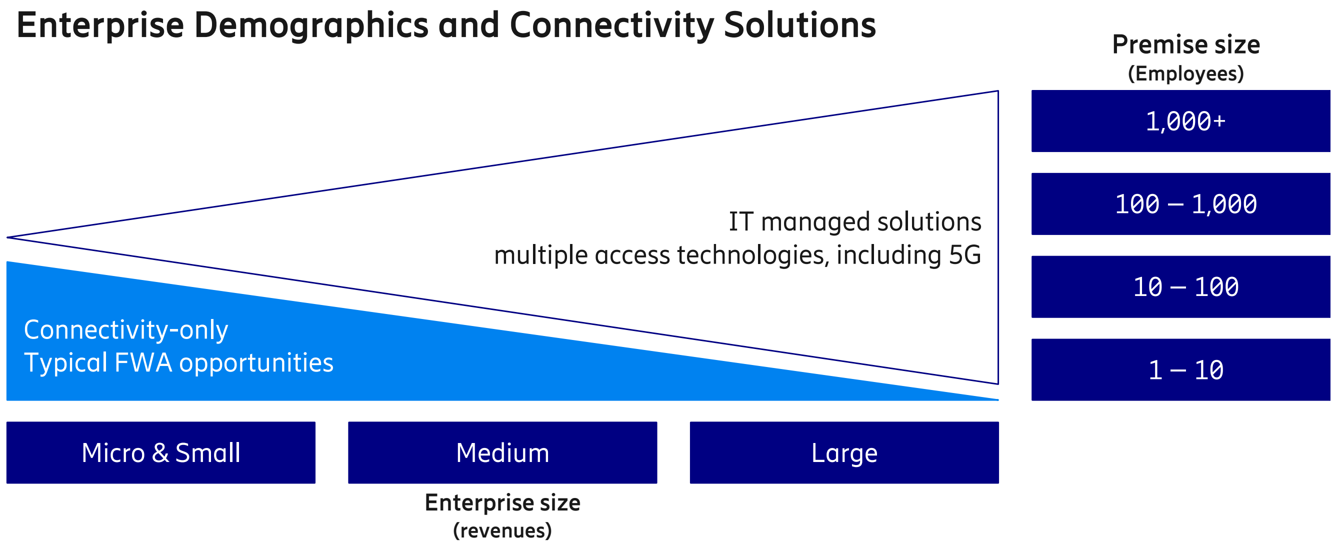
Many SMEs are located in underserved areas with low speeds, lack of broadband alternatives or no connectivity whatsoever. Many of these underserved companies could include SME and SoHo (Small Office and Home Office) businesses are located in suburban areas, in city outskirts (for example, light industrial or distribution/storage facilities, or in buildings and business parks that lack in-building cabling to reach their facilities. In some markets, there are also many small enterprises being served by dedicated microwave point-to-point access which can be expensive and slow, and in need of upgrade or replacement.

In general, SMEs have higher purchasing power than consumers. Offering FWA to both consumers and SMEs in the same area may provide synergies: SMEs' usage patterns differ from consumers', as most of their usage is during the day rather than during evenings and weekends. In addition, SME traffic is more balanced in terms of downlink and uplink traffic levels. The busy-hour network capacity can therefore be kept lower than the simple sum of the two segments' traffic needs.

US commercial buildings example

As an illustration of the size of this opportunity, let's consider broadband provision to commercial buildings in the USA. According to Vertical Systems Group, around 1.3 million of USA's 5 million commercial buildings (~25%) were lit with optical fiber in 2021. Of these, buildings with more than 20 employees had a fiber availability rate of 75%, while those with fewer than 20 employees had a fiber availability rate of just 16%, even though this segment accounted for most of the new fiber-lit buildings. Moreover, nearly three-quarters of all US fiber-lit commercial buildings are served by a single fiber provider.

FWA addressing connectivity – only solutions for Enterprises, primarily for SMEs



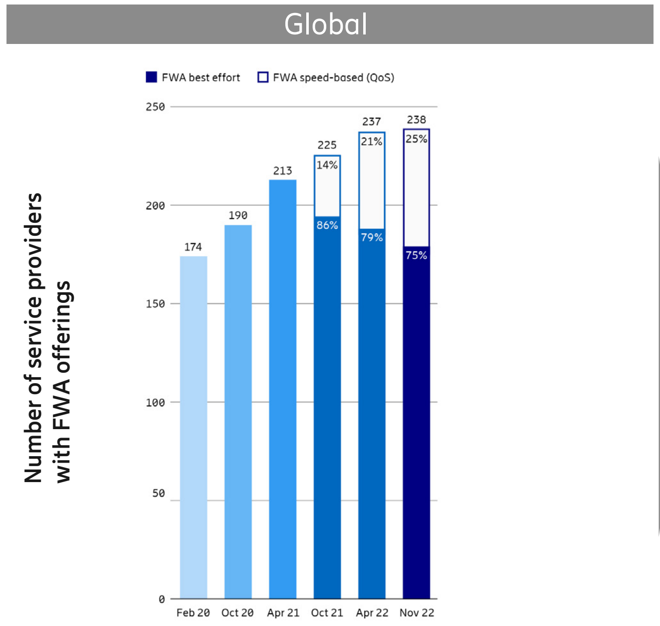
Targeting the enterprise market with FWA solutions means understand the market opportunity being addressed taking into account businesses' wide diversity of broadband needs. Business size (revenue), premises size, and number of employees per location are just some of the basic parameters to consider.

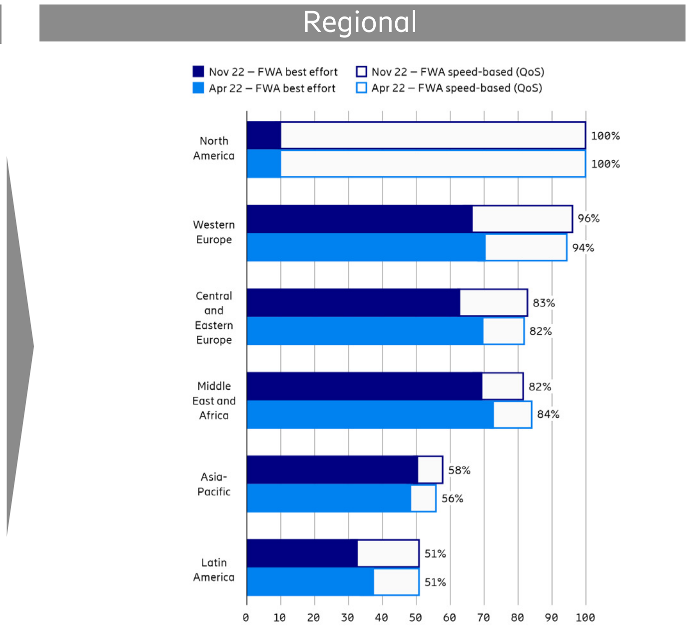
Regarding size of business, it is referred to the company revenues which then relates to presence and size of workforce. The other dimension is related to the size of the premise that needs connectivity. Small and micro enterprises are typically only present in one location. On the other extreme, large enterprises have multiple premises, including often a large headquarter with many employees, regional offices and even local offices. The larger the enterprise, the more sophisticated IT systems, centralized and standardized solutions.

In addition to size of enterprise and premise, it is also important to understand how company segments drives usage of IT solutions and connectivity needs. For instance, some retail branch offices (such as small stores or fast food outlets) may require connectivity only for payment, inventory management, and facilities management (such as security), which have relatively low connectivity needs. On the other hand, IT-intensive service companies (such as gaming developers or design agencies) with high level of cloud-based IT solutions, will have much higher demands on connectivity. As a result, some market segments may want to procure integrated managed IT solutions which include connectivity as part of the offer (using multi-access solutions, encompassing wireline and wireless, to enable redundancy).

When it comes to FWA for enterprise, the opportunity is typically for connectivity-only solutions, primarily addressing premises with fewer than 100 employees – that is, micro and small and medium businesses. Some operators may include value-added services on top of connectivity-only solutions, including security, SD-WAN and IT services (like Microsoft 365).

FWA adoption on the rise





Almost one-third of service providers now offering 5G FWA
An updated Ericsson study of retail packages offered by service providers shows that, out of 310 service providers studied worldwide, 238 (or 77 percent) had an FWA offering. During the last 12 months, the number of service providers offering 5G FWA services has increased from 57 (19 percent) to 88 (29 percent).

5G FWA arrives in emerging markets in 2022
Almost 40 percent of the new 5G FWA launches in the past 12 months have been in emerging markets. 5G FWA has arrived in populous countries such as Mexico, South Africa, Nigeria and the Philippines.

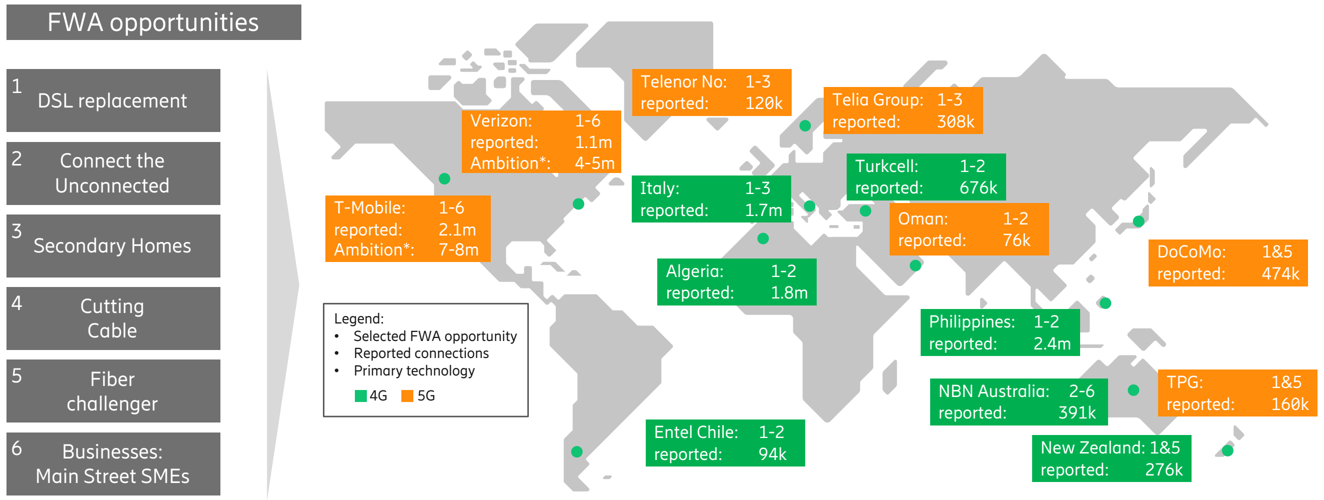
In addition, following the 5G spectrum auction in India in July, a major service provider has expressed a goal to serve 100 million homes and millions of businesses with 5G FWA services.

Speed-based tariff plans doubled in the past 12 month
Most FWA offerings (75 percent) are still best effort, with volume-based tariff plans (that is, buckets of GB per month). About 25 percent of service providers offer speed-based tariff plans (also referred to as quality of service, or QoS), which is twice as many compared to a year ago.

Speed-based tariff plans are commonly offered for fixed broadband services such as those delivered over fiber or cable. These types of plans are well understood by consumers, enabling the service providers to fully monetize FWA as a broadband alternative. Around 35 percent of these speed-based offerings are basic, with average/typical speeds being advertised. Almost 65 percent are more advanced offerings, involving speed tiers, such as 100 Mbps, 300 Mbps and 500 Mbps.

Service providers with 5G FWA are more likely to have QoS FWA with speed-based offerings, with 42 out of 88 utilizing this approach (48 percent). Speed-based offerings are growing across all regions, but there are large variations. In North America, 90 percent of offerings are speed based, while the Asia-Pacific and Middle East and Africa regions have below 15 percent.

FWA opportunities, connections and ambitions



* refers to coverage ambition 2025
Source: latest operator and regulator publicly reported data

We have identified six common FWA opportunities pursued by operators. Often operators use more than one of these approaches in their FWA deployments according to the specific needs of the targeted area.

One of the largest FWA opportunities is DSL replacement, targeting users with copper-based networks often to provide higher speeds and to reduce network operation costs.

Another strategy is to connect unconnected homes and businesses, which is applicable mainly to emerging markets but also in rural areas of developed markets.

Secondary homes could also be an opportunity for FWA, as many people want broadband connectivity for leisure and/or work. As an example, Norway has some 400,000 cottages and Sweden just over 600,000 secondary homes (around 12% of permanent homes).

'Cutting the cable' is an opportunity driven by three trends. First, we see some operators targeting cable customers with high speed FWA offerings.

Another approach it is to target cable users with cheaper offers and/or broadband-only offerings, as many consumers prefer to access content such as streaming services over the top.

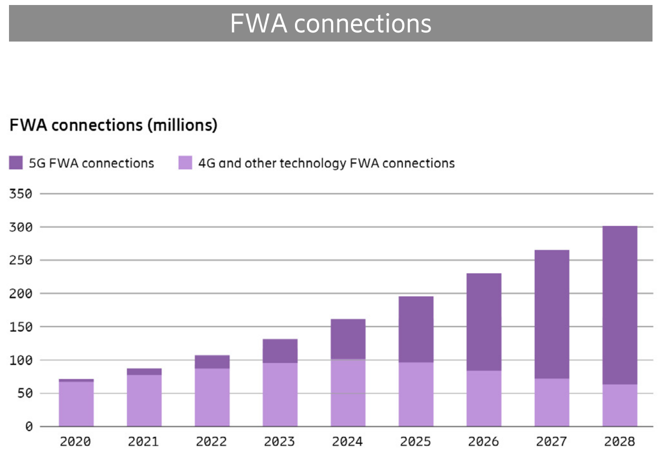
In some markets, FWA operators provide an alternative for cable consumers when there is no other choice of fixed broadband provider.

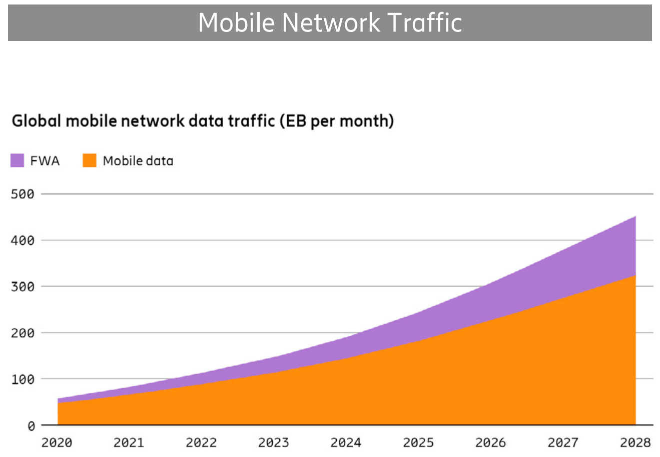
Last, there is an opportunity to serve small and medium-sized businesses, where connectivity plays an important role.

Several operators and regulators around the world report FWA subscriptions, uptake and ambitions. The chart above shows some examples from operators who have communicated their FWA ambitions externally (such as Verizon targeting 50 million homes in the USA, and T-Mobile USA targeting 7–8 million FWA connections by the end of 2025).

In FWA Handbook, annex B there are examples of operator FWA offerings like T-Mobile (USA), Verizon (USA), Omantel (Oman) or Telenor (Norway), NBN (Australia), SoftBank (Japan), Telcel (Mexico) and more.

FWA connections to threefold and reach over 300 million by end of 2028



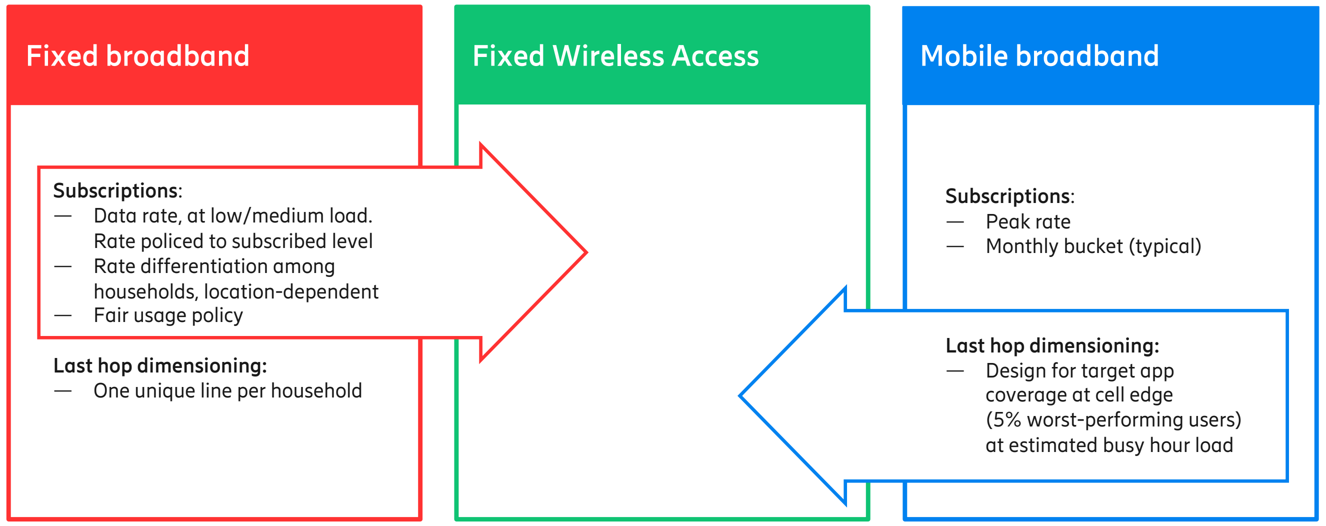


Source: Ericsson Mobility Report 2022

FWA set to reach 300 million connections by 2028
There will be more than 100 million FWA connections estimated by the end of 2022. This number is projected to triple by 2028, reaching over 300 million. This figure represents 17 percent of fixed broadband connections. Of these over 300 million connections, the number of 5G FWA connections are expected to grow to around 235 million by 2028, representing almost 80 percent of the total FWA connections. The forecast has been adjusted to include the high ambitions of 5G FWA in emerging markets, increasing the number of connections as well as the share of 5G FWA connections. Higher volumes of 5G FWA in large high growth countries such as India have the potential to drive economies of scale for the overall 5G FWA ecosystem, resulting in affordable CPE that will have a positive impact across low-income markets.

FWA data traffic projected to grow by almost five times
FWA data traffic represented 21 percent of global mobile network data traffic by the end of 2022, and is projected to grow more than 5 times to reach almost 130 EB in 2028.

FWA paradigms are influenced by both fixed and mobile broadband



Fixed and mobile broadband paradigms are different, both in terms of subscription offerings and dimensioning.

Subscriptions
Fixed broadband subscriptions tend to focus on maximum data rates, achieved under normal circumstances, that is, at low to medium load. The user traffic is often shaped to not exceed the sold data rate. Additional monetization usually takes the form of upgrade packages with increased data rates. Monthly usage buckets are seldom advertised as a part of the subscription, although there are often fair usage policies and rules against over-consumption in the contract details.

Hence, for fixed broadband, the sold data rate is the normal value that household subscribers relate to.

By contrast, for mobile broadband, peak rates are sometimes used for marketing, and normally the network transmits the maximum rate that the mobile device can handle. Monthly data buckets dominate the subscription paradigm, and additional monetization is achieved through upgrades to larger data buckets, all the way to 'unlimited' data.

Hence, for mobile broadband, monthly data buckets are the normal subscription value that mobile subscribers relate to.

This difference needs to be understood by both consumers and operators (fixed and mobile). Our view is that fixed broadband subscription paradigms will be inherited for FWA, rather than mobile broadband ones. Households should buy on the basis of data rate and not be concerned about consumption in terms of data buckets.

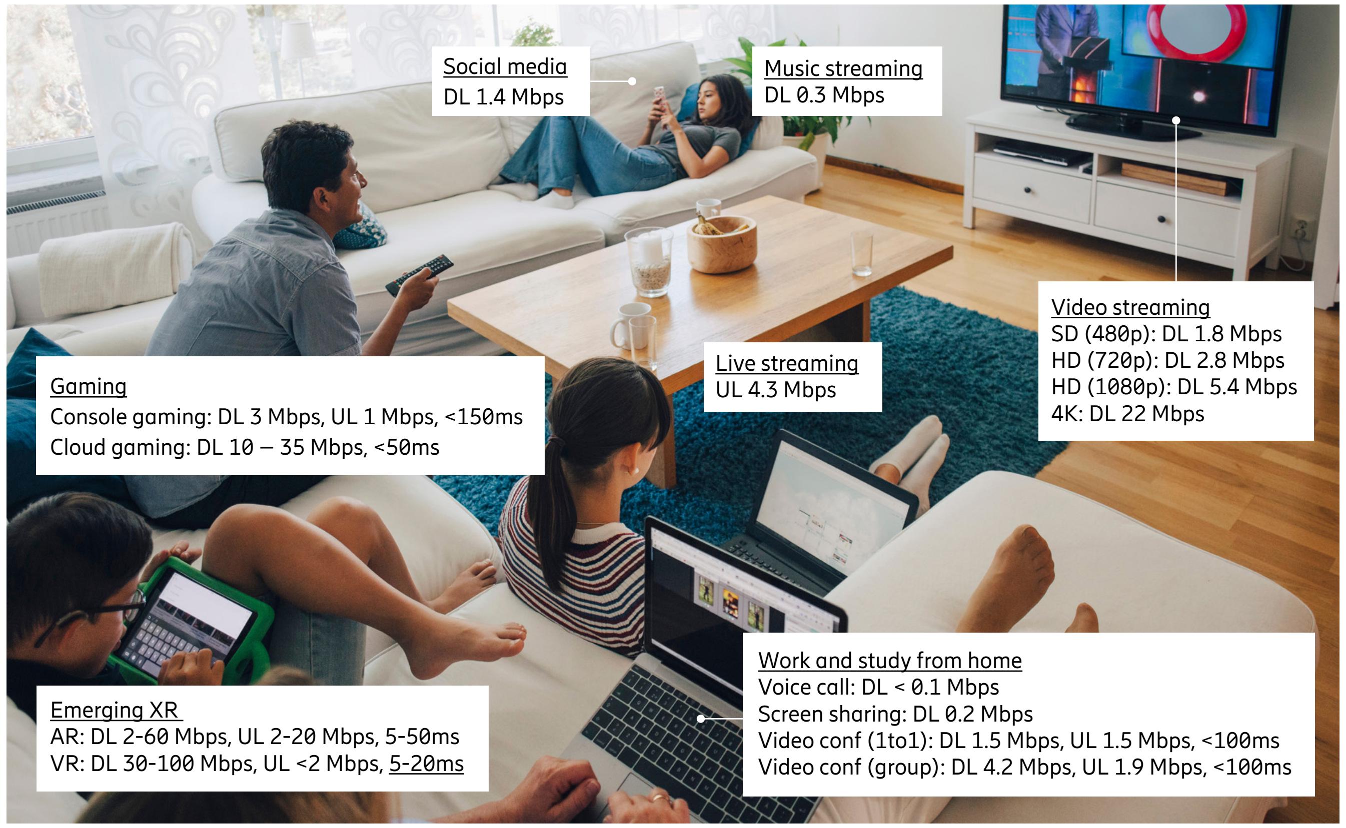
Last hop dimensioning
For dimensioning, the last hop is wireless, so all the characteristics of a wireless network will apply. Unlike fiber, but similar to DSL loop length, there will be varying connection quality to different households. And, unlike fixed broadband overall, the last hop is radio and so shared, which means that quality will degrade with load.

All these characteristics will have to be taken into account when dimensioning an FWA network, and since we promote the use of sharing assets with mobile broadband (when available), it needs to be brought into the operator's general RAN dimensioning exercise.

Note that for fixed, FWA and mobile broadband alike, there is transport aggregation above the last hop, which is dimensioned according to standard principles and can also contribute to a varying user experience.

In essence, FWA will reuse subscription paradigms from fixed broadband, while for dimensioning, due to the radio properties of the last hop to households, FWA will use modified dimensioning methods and terms from the mobile broadband paradigm.

Home broadband usage to remain downlink centric, driven by video applications



Household broadband is dominated by video and entertainment usage. The main applications are video streaming, music streaming, gaming, social media and internet browsing and downloads. Since the start of the Covid-19 pandemic there has been an increase in work and study from home, which includes voice, screen sharing, cloud storage and video conferencing. Overall household data consumption depends on the number of people per home. The illustration shows some examples of required data rate for different applications (source Cartesian 2021 and Ericsson Technology Review, 2021).

Data rate
The data rate requirement depends on the quality of the video, which in turn depends on the resolution, frame rate and encoding quality. Modern video servers have content coded in multiple qualities, and end-to-end protocols switch between these, depending on the data rate experienced by the receiving client.

Video providers work with rather big device buffers to avoid quality degradation when network conditions vary. For example, Netflix typically strives to build up a 90-second buffer. Video providers, with YouTube leading the way, can rather accurately predict how each consumer will continue watching the shows once started, which means that significant buffers (up to one hour) of 'good' data could be built up using free capacity.

This relieves the dimensioning requirements, since a longer time interval than the actual peak can be considered.

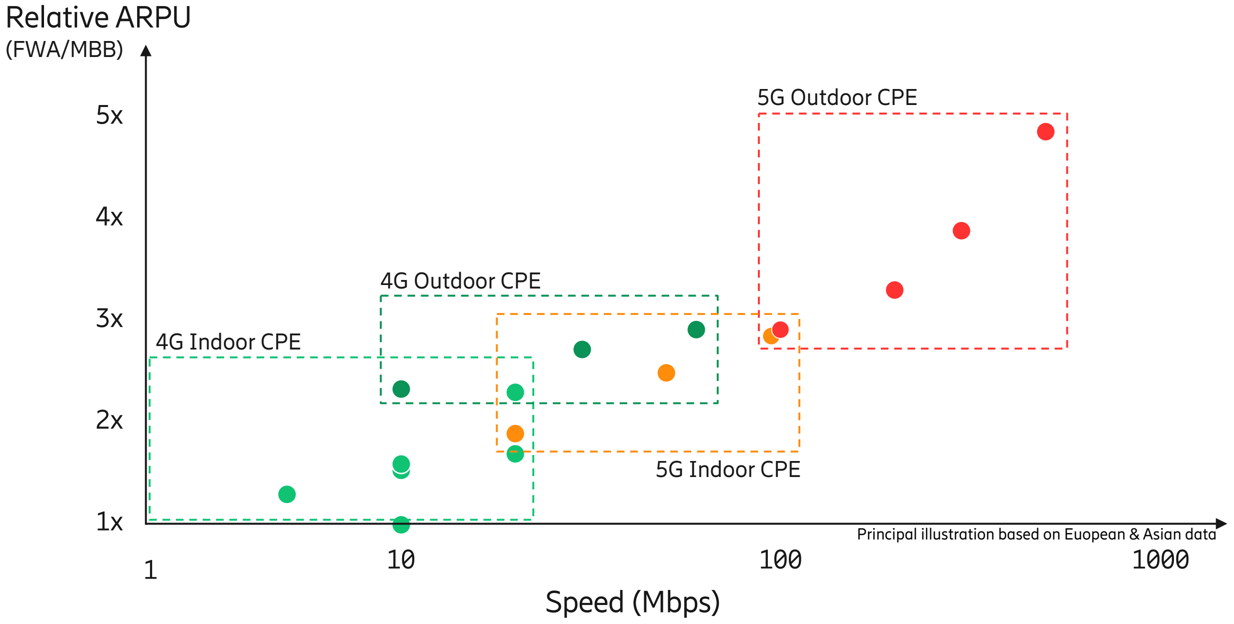
Delay
The absolute delay of starting the play out is not very strict: one or a few seconds is acceptable. However, to be able to quickly get up to speed (say 10 Mbps) with TCP after possible link interruptions, a quite low delay is still desirable.

Direction
The FWA household traffic is highly downlink-centric, as video streaming is the dominant service. Even future emerging XR applications for augmented-, virtual- and mixed-reality for gaming and volumetric video are likely to remain downlink-centric, with requirements not exceeding 100Mbps and with many efforts to optimize and lower data rates. The uplink must still support the application signaling to get the video started, and a relatively high rate of TCP acknowledgments, as well as reasonable experience for uploads and uplink webcam-type streaming. Later in the chapter we discuss usage patterns for a typical full broadband home.

FWA monetization with multiple offerings

FWA solutions addressing variety of speed and price tiers

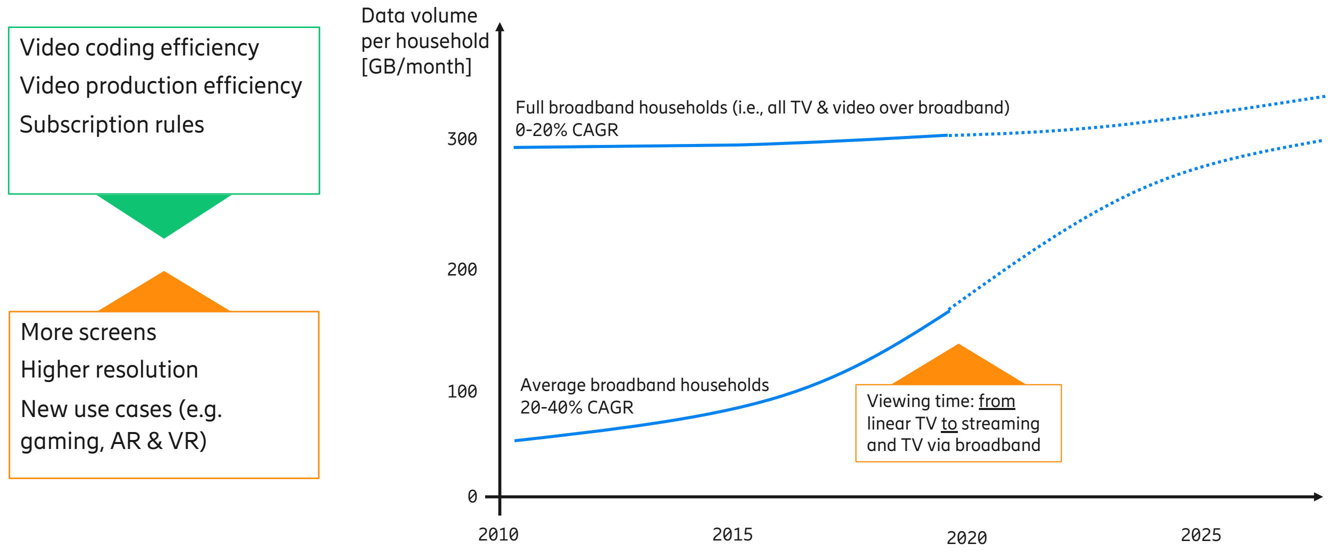
(Each dot represents an FWA operator's offerings grouped by relative ARPU and speed)



As with fixed broadband, segmentation of the FWA market is critical to targeting a broad variety of market segments. As a result, operators use a mix of FWA offerings to serve different price and speed tiers. Such speed–price tiers are achieved primarily by using a combination of technology (including 4G/LTE and 5G) and CPE alternatives (including indoor and outdoor).

The chart depicts offerings from four operators categorized by relative ARPU and speed. Relative ARPU is based on the ratio of FWA tariffs to the equivalent mobile broadband ARPU to adjust for local market conditions. Entry-level offers are based on 4G using indoor CPEs, where speeds in these examples are between 5 and 20 Mbps and prices range from 1 to 2.3 times MBB ARPU levels. High-end FWA offerings are based on 5G using outdoor CPEs, with speed tiers from 100 to 500 Mbps and tariffs ranging from 3 to 5 times the MBB ARPU levels.

Average and full broadband households' traffic profile converging towards large volume and lower growth



Principal illustration based on Euopean & Asian data

Household broadband generates much more traffic per subscriber than mobile broadband, leading to lower revenue per bit, even though ARPU for a household broadband connection is often higher.

Given this circumstance, it is not surprising that some operators fear that data-hungry FWA would quickly flood the network with low-ARPU bits, invading mobile spectrum and forcing the operator into large investments for limited return. Some are especially wary of offering FWA with 'unlimited' data to mimic and compete with fixed broadband. How can this fear of FWA 'unlimited' traffic flooding the network be handled?

Important insights for FWA
First, it is worth remembering that any communication system is dimensioned for the busy hour: how many busy hours there are, or how much data is consumed in off-peak hours, is of little interest. This means the common focus on monthly consumption value is overstressed – it has no direct impact on investment needs. We need to focus on what happens in households during the busy hour, for example Sunday evenings (MMS, 2017).

Second, FWA is dominated by video, and so has a limited needed data rate by nature. At peak times, the maximum household data rate needed is governed by the number of simultaneously active household screens and their resolution. And these needs, as explained previously, are typically only small fractions of the sold data rates in the offering. In other words, although an 'unlimited' data offering with a high sold data rate could in theory induce constant busy-hour consumption at that rate, this will never happen in practice.

The amount of video consumption is also largely governed by the viewing habits of households, where the split between scheduled TV (linear and time-shifted) versus video-on-demand is key… Naturally, there are large regional variations. This implies that as long as households' linear TV needs are catered for by satellite or terrestrial broadcasting, data consumption over the broadband connection is rather limited (such as in our 'Connect the unconnected' and 'Build with precision' FWA segments).

Only if the FWA solution is also aimed at full broadband households, consumption is substantially higher, requiring special consideration (as in the 'Wireless Fiber' FWA segment). In these households, however, the viewing time is already fully spent on services over FWA, and so viewing time is rather constant and growth is limited to 0–20 percent. An increased number of parallel screens with higher resolution drives data consumption upwards, while advancements in coding and production techniques drives a reduction, as shown in the illustration (Strategy Analytics, May 2021).

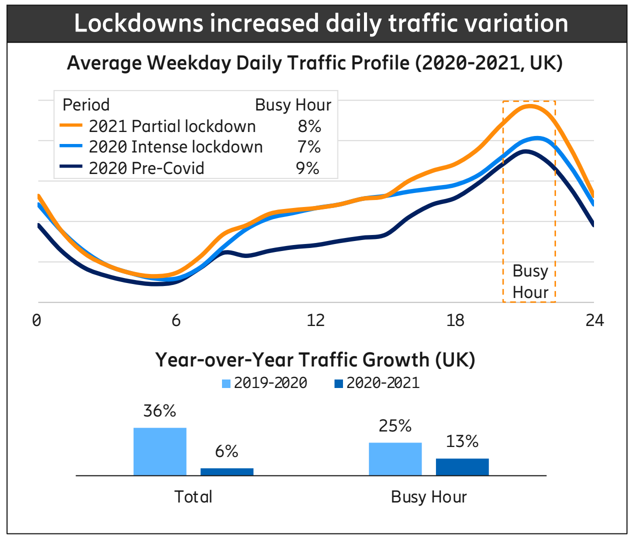
As for the average broadband household, an ongoing transfer of viewing time from linear TV to streaming and TV over broadband explains much of the 20–40 percent growth seen across markets today (for example, Cisco VNI, 2019). As viewing time is spent increasingly on streaming and TV over broadband, the consumption is likely to approach the level and limited growth rate of full broadband households. (Strategy Analytics May 2021)

A final important insight for FWA is that, unlike mobile broadband, the traffic location is very well known. The CPE is stationary, which greatly reduces statistical uncertainties in network performance observability and predictability. Mobile broadband planning, at best, employs statistical busy-hour traffic averages per sector, while for FWA the exact location of traffic consumption is known. This also enables a simpler planning process for network expansion – there is no need to provide data capacity in a general area in a statistical 'just in case' sense. The geographically stationary nature of data consumption facilitates build-outs with almost surgical precision – which is of course less investment-heavy than a general expansion over large statistically overloaded areas.

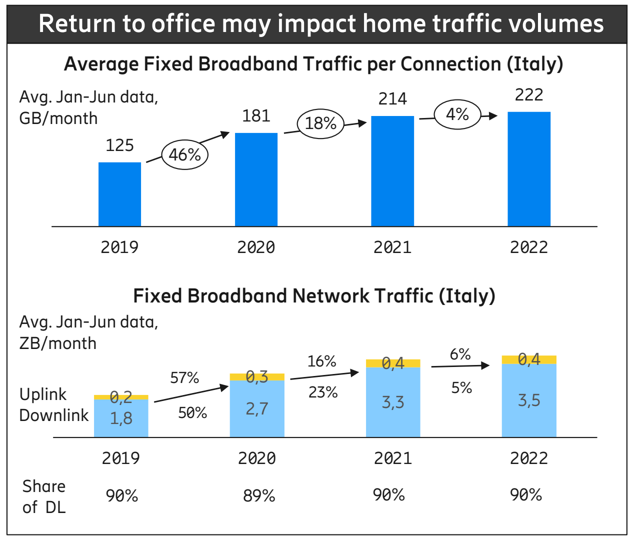
Actions to handle FWA data consumption
There are a number of ways to control FWA data consumption in the network, even with an 'unlimited' data offering, with varying degrees of sophistication, including:

- Limiting the number of signed-up households in a sector. The operator can observe spare resources in a location and predict whether a new household at a certain street address would fit into the existing capacity headroom, or which expansions would be needed.
- Outdoor CPE can be used to squeeze 2–3 times higher performance out of the network, as explained further in the CPE chapter. There is also the option of trading CPE performance with CPE cost, for example to offer a more capable (outdoor) CPE to households in a particular location that place extra load on the network.
- Existing network functionality such as QoS differentiation or RAN slicing should be used to separate mobile broadband from FWA traffic using the same spectrum, in order not to jeopardize mobile broadband quality as FWA traffic grows. This is further explained in the RAN chapter.
- As with fixed broadband, even 'unlimited' offerings often include a contract clause about over-consumption and fair usage, enabling a de facto limit on consumption.
- More sophisticated methods include stimulating video end-points to transmit at a lower resolution, such as SDTV, and to pre-load likely desired video-on-demand content to household devices during off-peak hours.

Home broadband usage impacts due to Covid-19



Source: Ofcom 2022, Ericsson analysis.



Source: AGCOM, 2022, Ericsson analysis.

The past 3 years of Covid-19 pandemic has affected home broadband usage behavior and traffic profile. The level of impact in each country has varied according to when Covid-19 hit, and the duration and severity of restrictions and lockdowns. As at September 2022, there are still several countries being affected by Covid-19. However, even with all restrictions removed, there are still noticeable changes in home broadband usage behavior that have remained. This is in large part because of the continuing prevalence of home-working, which influences broadband usage patterns significantly.

Analysis of recent traffic data from UK and Italy provide insights into the continuing influences and trends arising from the pandemic.

1. 2020 pre-Covid (Jan 27—Mar 23): normal traffic behavior before the rapid increase in working from home
2. 2020 intense lockdown (Mar 22—Jul 31): large increase in daily home broadband traffic as people worked and studied from home
3. 2021 partial lockdown (Feb 1—Jul 31): daily work-from-home traffic remains stable, while traffic increases after 4pm as children return home from school.

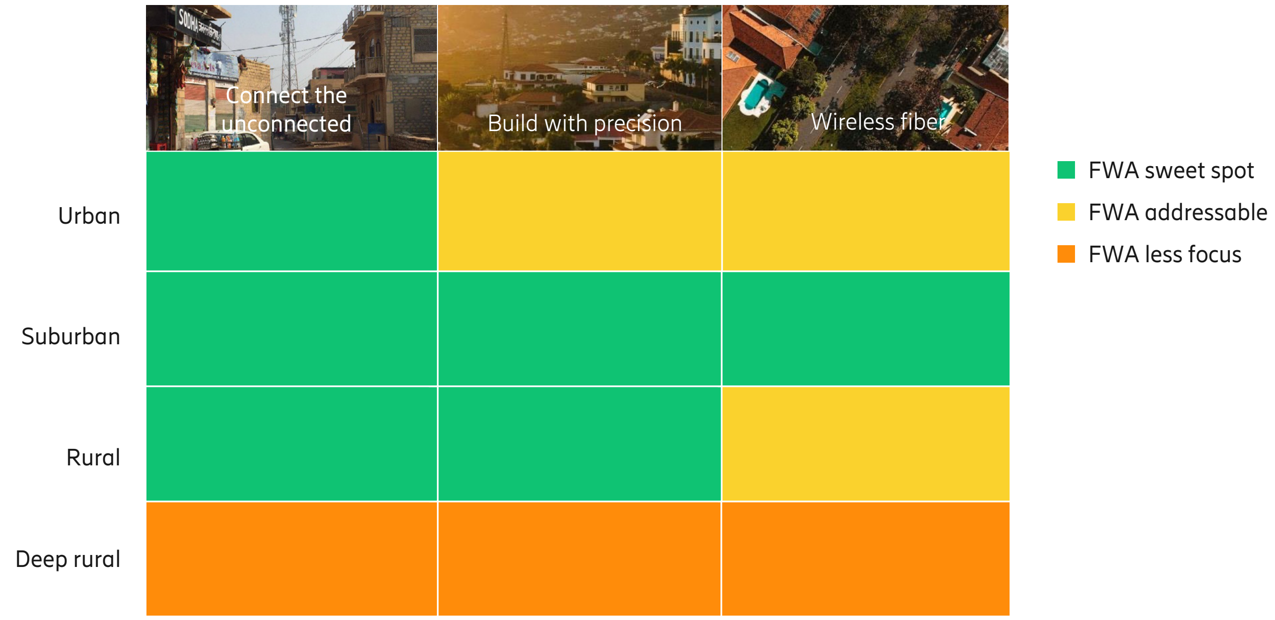
Daily traffic variation, but evening busy-hour remains
An analysis of average weekday traffic profiles from Ofcom, the UK's national telecoms regulatory agency, clearly shows three main phases of home broadband usage:

Total home broadband traffic volumes in 2020 increased significantly (36%) compared with 2019, driven primarily by daytime usage as shown in the data relating to 2020 intense lockdown. During this initial period, busy-hour annual traffic was lower than total growth (25% vs 36%). For 2021, the total home broadband traffic growth was much lower (6%), as daytime usage remained stable (as shown in data relating to 2021 partial lockdown), while busy-hour traffic was higher (13% vs 6%). Busy-hour traffic remained high during evenings across all datasets, driven by longer-term trends such as migration from linear to on-demand TV viewing.

Return to office may reduce home traffic volumes
A report from AGCOM, Italy's national telecoms regulatory agency, also illustrates the distinct home broadband usage profiles before, during and after the Covid-19 pandemic. Looking at the home broadband traffic data for March for the years 2019 to 2022, we can infer the steep (85%) traffic growth from 2019 to 2020 as people start to work and study from home. These traffic levels remained high during 2021, as the effects of the pandemic continued. During 2022 we can see a decrease of 5% in total home traffic volumes, as people start to return to the office, at least partially. Aggregate traffic data also show that the majority of home broadband traffic remains downlink-oriented, and uplink/downlink ratio has remained stable throughout the four-year period.

2. FWA solution

Typical geographical areas within segments



As previously discussed, it makes sense to address the most profitable geographical areas with FWA first. The above chart illustrates the applicability of each segment in different geographical areas, with green representing the most attractive opportunity and orange the least (the size of each opportunity is not represented).

The chart takes a number of factors into account, including the availability of fixed broadband alternatives, the population density and the cost of deployment to address these homes.

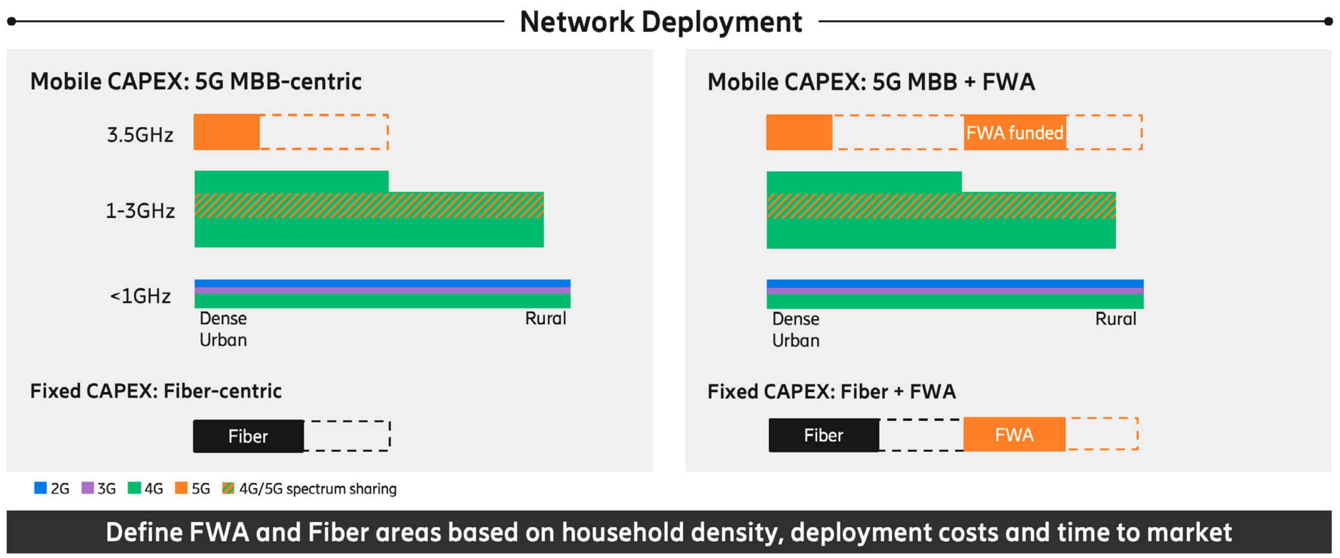
The 'Wireless fiber' segment is characterized by fiber-like speeds and the ability to handle households' TV needs. The sweet spot here is typical suburban environments, where there is a good operator business case. Urban and rural areas are addressable but needs to be carefully evaluated based on existing assets and the competitive environment in order to ensure a profitable deployment. In deep rural areas, a positive business case is much harder to achieve (without government subsidies) as the network costs are often rather high in relation to the total revenue potential.

The 'Build with precision' segment is characterized by possible competition with xDSL. ARPU levels are good and there is high demand for high data rates and capacity. The sweet spot here lies in suburban or rural villages/towns that are underserved.

The 'Connect the unconnected' segment is characterized by virtually non-existent fixed broadband alternatives. Even though ARPU levels are limited, it has a sweet spot that stretches from urban environments to rural villages.

The FWA operator business case for each of the three segments will be further elaborated in Appendix A.

Holistic CAPEX allocation for MBB, FWA and fiber



As operators embark on 5G and fiber deployments, it is critical to have a holistic approach to avoid technology biases and maximize investment benefits.

5G network deployments: MBB-centric vs MBB+FWA
It is common to see MBB-centric 5G roll-outs where 5G mid-band spectrum is utilized in dense urban areas (often using MIMO radios), and slowly expanded to urban and suburban areas as additional capacity is needed. Nationwide 5G coverage is achieved by utilizing lower bands (such as the 4G NSA anchor band) using spectrum sharing. In this scenario, the high-speed 5G experience delivered by midband spectrum gradually extends out from dense urban as utilization increases.

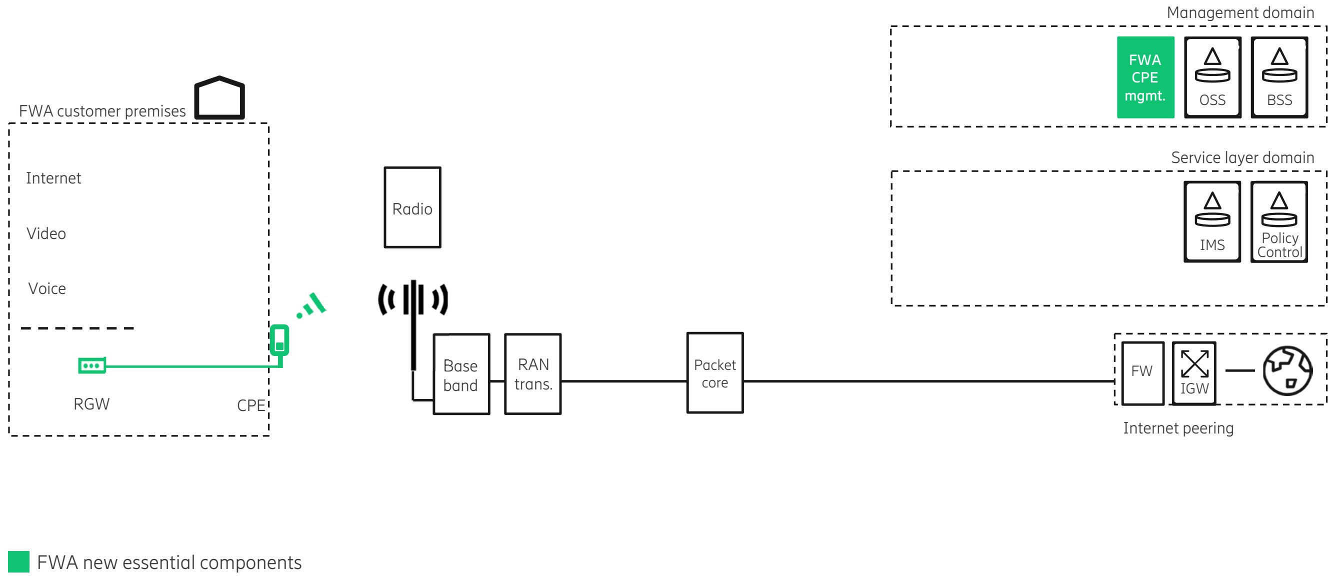
Operators with holistic MBB and FWA 5G deployment strategies take a different approach. In addition to deploying 5G midband in dense urban areas, these operators also add high-capacity mid-band in suburban and rural areas, which are sweet-spot locations for the FWA business case (typically lacking fiber, or having just one fiber provider).

The main benefits of this approach include:

- Improved MBB experience in suburban and rural areas as consumers also get midband coverage
- Site capacity configuration based on two complementary use cases
- Network roll-out synergies, avoiding a second site visit later for FWA services.

Mobile and fixed capex synergies
There are benefits from having a technology-agnostic capital allocation process, where fiber and FWA can complement each other. Operators with a holistic capital allocation approach can determine – at a detailed local level – where it is more suitable to deploy fiber or FWA. This enables them to optimize the delivery cost per home, and so cover more homes with the same investment. Moreover, by leveraging FWA, operators can achieve faster coverage, detering competitors from making fiber investments in the same area. Such a broad approach may also include use of government subsidies, perhaps including a mix of fiber and FWA to meet service obligations.

FWA for a mobile-only operator



Mobile network operators already have most of the network components needed to offer an FWA service, giving them an advantage over greenfield stand-alone FWA providers.

Radio Access Network (RAN) including RAN transport
The 3GPP RAN, with its high-capability 4G LTE and 5G access, already exists, implying that equipment and processes to operate the network are already in place – from radio, via baseband and RAN transport and their management systems, to the site infra-structure and other related equipment. Adding FWA capability to these merely involves adding capacity and coverage in a well-de-fined and geographically selective way, while observing the FWA traffic model and its differences from mobile broadband when dimensioning the network. Smart slicing of the RAN capabilities helps in allocating suitable resources between mobile broadband and FWA.

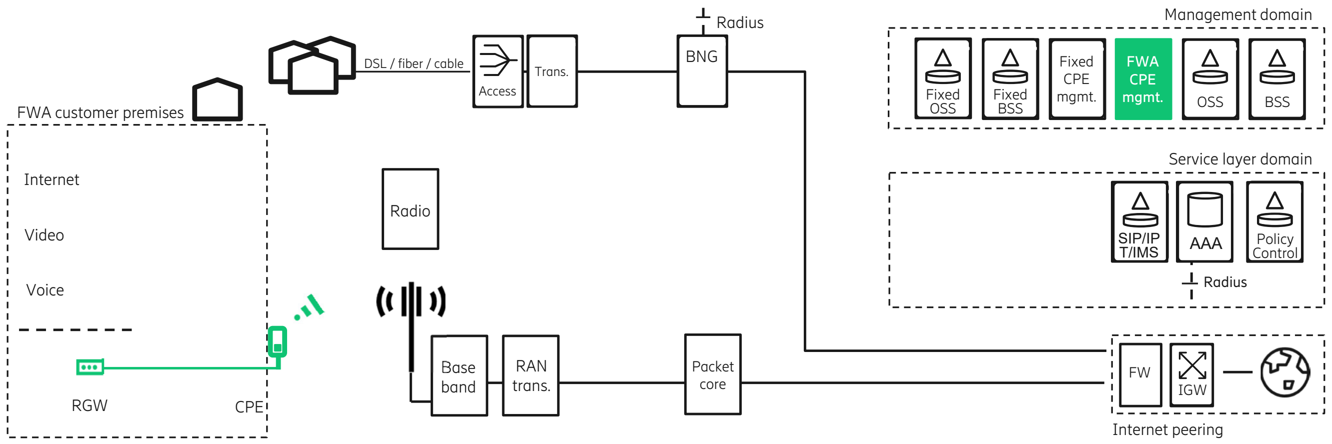
Core network (CN)
The 3GPP core network is already deployed, with its ability to handle high numbers of flows and high volumes of traffic. When adding FWA, operators should ensure that core network handling of the data is suitably 'low touch', in order not to drive unnecessary cost. It is also worth considering a number of func-tional additions that will be valuable for FWA, including new ways of regulating bandwidth or data rates, flexible charging support, and limiting the use of FWA to a local geographical area.

Service layer
In the service layer domain, policy control is often already deployed, and helps to set policies for the core network functions listed above. In addition, when the FWA service includes a fixed telephony offering, the existing IMS/VoLTE system can act as the backend voice telephony server for that service too.

Management domain
Network management is already deployed to handle existing cellular services and can be reused for FWA. Operators may con-sider additional management tools to optimize their understand-ing of network performance in the FWA-launched areas, and for detailed analysis of customer behavior and generated traffic. In the BSS field, operators will need to add the desired charging schemes for FWA.

CPE and CPE management
New FWA CPE is needed, from simple indoor nomadic devices to fixed outdoor-installed units, and provisioned through standard device retail or new methods. A new CPE management system is likely to be needed to manage CPE in the fixed broadband sense – enabling the operator to log in to the devices, configure them and check status remotely. Both CPE and CPE management sys-tems are separate network entities with generally quite limited integration with cellular networks, meaning that the operator can acquire best-of-breed products and expect them to work using standard protocols.

FWA for a converged operator



FWA new essential components

In a converged network operator – where both mobile and fixed access are offered by the same company – the degree of actual convergence of organizations and network components (such as BSS systems, network management and core networks) can vary widely, from very limited to moderate. Most converged operators have a clear strategy to converge more of their organizations and networks to realize synergy and cost benefits.

This means that, when combining their existing assets, converged operators will already have most of the knowledge, processes and network components needed to offer an FWA service. This puts these operators in an excellent position and represents a clear advantage over greenfield stand-alone FWA providers.

Radio Access Network (RAN) including RAN transport
The 3GPP RAN (including RAN transport), with its high-capability 4G LTE and 5G access, already exists, implying that equipment and processes to operate the network are already in place – from radio, via baseband and RAN transport and their management systems, to the site infrastructure and other related equipment. Adding FWA capability to these merely involves adding capacity and coverage in a well-defined and geographically selective way, while observing the FWA traffic model and its differences from mobile broadband when dimensioning the network. Smart slicing of the RAN capabilities helps in allocating suitable resources between mobile broadband and FWA.

Core network (CN)
The 3GPP core network is already deployed, with its ability to handle high numbers of flows and high volumes of traffic. When adding FWA, operators should ensure that core network handling of the data is suitably 'low touch', in order not to drive unnecessary cost. It is also worth considering a number of functional additions that will be valuable for FWA, including new ways of regulating bandwidth or data rates, flexible charging support, and limiting the use of FWA to a local geographical area.

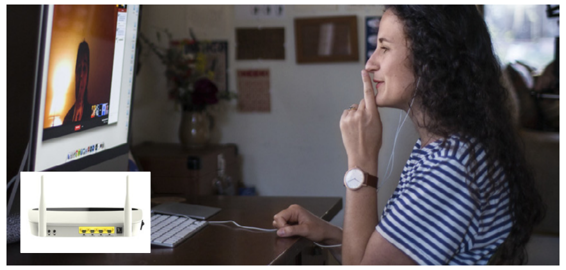
It is also worth operators considering reusing some components of the fixed access core network. This typically involves functions on the Internet side of the Broadband Network Gateway (BNG), such as firewall and caching.

Service layer domain
In the service layer domain, policy control is often already deployed, and helps to set policies for the core network functions listed above. In addition, when the FWA service includes a fixed telephony offering, the existing IMS/VoLTE system can act as the backend voice telephony server for that service too. Operators can also reuse an existing fixed VoIP service solution, different from IMS, for the new FWA offering if desired.

Management domain
Network management is already deployed to handle existing cellular and fixed services, and can be reused for FWA. Operators may consider additional management tools to optimize their understanding of network performance in the FWA-launched areas, and for detailed analysis of customer behavior and generated traffic. In the BSS field, operators will need to add the desired charging schemes for FWA. Depending on the degree of convergence between the operator's mobile and fixed BSS systems, the operator can choose whether to reuse mobile or fixed BSS systems and principles for FWA.

CPE and CPE management
New FWA CPE is needed, from simple indoor nomadic devices to fixed outdoor-installed units, and provisioned through standard device retail or new methods. A new CPE management system is likely to be needed to manage CPE in the fixed broadband sense – enabling the operator to log in to the devices, configure them and check status remotely. Converged operators have the choice of reusing the fixed access CPE management system or deploying a separate one for FWA. Both CPE and CPE management systems are separate network entities with generally quite limited integration with cellular networks, meaning that the operator can acquire best-of-breed products and expect them to work using standard protocols.

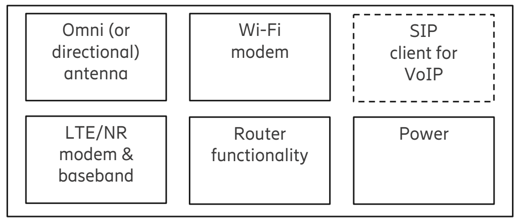
Different types of CPEs



Indoor CPE

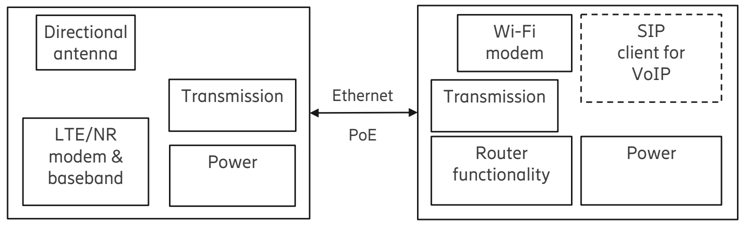
Outdoor CPE

Combined LTE/NR modem including residential gateway



Outdoor LTE/NR modem

Separate indoor residential gateway



Customer Premises Equipment (CPE) is a vital part of an FWA solution, as it terminates the 4G LTE and 5G NR air interfaces. This means it has a direct impact on end-user service and quality, as well as the operator cost for providing FWA services. There are two types of CPEs: outdoor and indoor. From a performance perspective, an outdoor unit is always preferable unless the home is close to the serving radio base station.

Outdoor CPE typically contains a directional antenna and all the necessary functions to terminate the air interface protocols. It is connected via Ethernet to an indoor Residential Gateway (RGW), which connects end-user devices over Wi-Fi or via Ethernet. The outdoor unit itself is powered via Power-over-Ethernet, so only one cable is needed. There are different varieties of outdoor CPEs: some designed for rooftop installation and others for wall mounting. One advantage of outdoor CPE is that it can be used with any Wi-Fi router, whether an operator-provisioned and managed RGW, or an off-the-shelf Wi-Fi router.

As well as terminating 4G LTE and 5G NR, indoor CPE also contains the necessary RGW functionality – making it a one-box solution which is easy to install and connect to the network. However, indoor CPE has significantly lower antenna gain which makes it less suitable in FWA deployments where many households are served. Additional receiver branches (4Rx) can be added to compensate for the lower antenna gain, normally with an omni antenna. Another side-effect of integrated LTE-NR/Wi-Fi units is that LTE and NR evolve in line with 3GPP standardization, while Wi-Fi evolves in line with IEEE standards, meaning that the unit may never meet the latest of both standards.

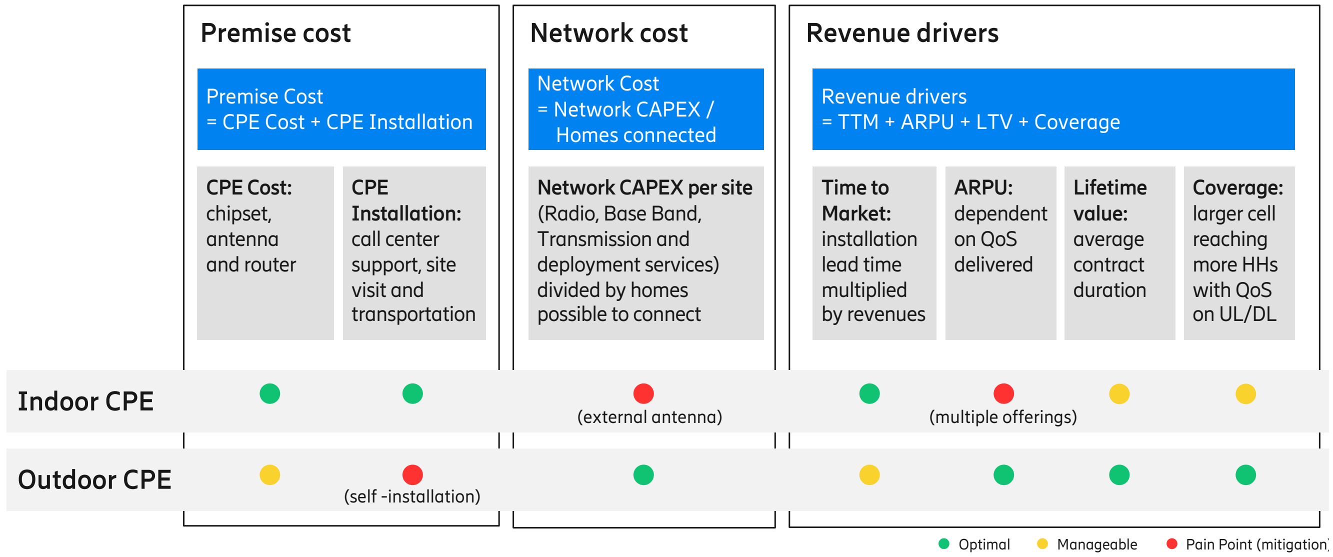
There are also hybrid solutions coming to market which can be installed on a favorable window either inside or outside. Window placement may be of particular interest for urban 5G NR services, where Inter Site Distance (ISD) is small but it is still essential to minimize wall, window and deep indoor attenuation losses. For outdoor window placements, a Wi-Fi unit may also be included, so that RF and power go through the window from an indoor support module, even though securing the required Wi-Fi coverage may be a challenge.

While indoor CPE units are widely available today and sold to end-users in operators' retail stores, outdoor CPE units are normally owned, controlled and managed by the operator, with continuous management and supervision of performance done via TR-069/TR-143 (see the description of CPE management). The outdoor CPE functions as a network termination point, where quality of service is measured and secured. With an indoor device there is always a higher uncertainty of the positioning and the corresponding radio link quality, as well as the risk that it gets moved or obstructed somehow.

If the operator wants to offer voice services, the indoor CPE or the stand-alone RGW should contain a SIP client that is compatible with IMS VoIP telephony, so that an RJ-11 device can be connected (see the description of voice support).

The type of CPE that makes best sense for an FWA deployment depends on many factors, including ISD, topology, offered service levels and number of households connected.

CPE choices impacting TCO in three areas



Selection of CPE form factor is a key parameter for designing FWA offerings. There is a lot of focus on the CPE premise cost while two other drivers, Network cost and Revenue drivers, are often not assessed in defining the complete TCO analysis for the CPE choice.

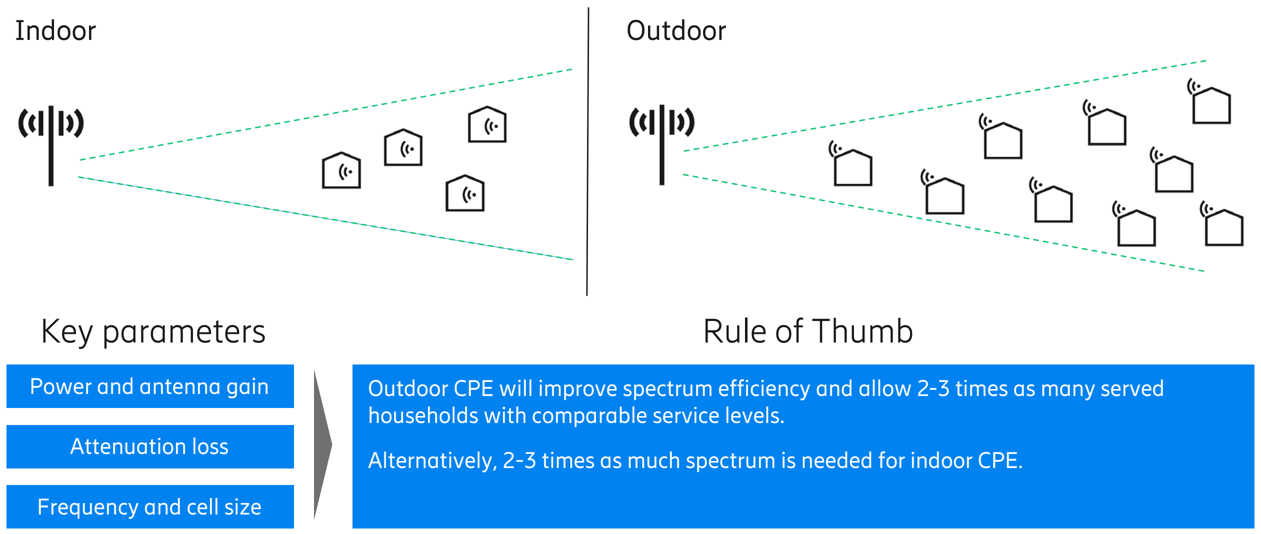
Premise Cost related to the direct costs to connect a premise, home or Small Medium Business premise. It includes the cost for the CPE, where indoor CPEs tend to be cheaper than outdoor CPEs as these include less expensive antenna components. Installation cost is another parameter, with indoor CPE having an advantage as there are no/minor cost associated such as eventual call center support for self installation. While outdoor CPE´s many times comes with a self-installation APP, many homes might prefer professional installation. Based only on this criteria, indoor CPEs scores better than outdoor CPEs.

Network Cost is a key parameter that is often not quantified properly. This includes all related FWA network costs for a RAN site (and proportion for Core and other elements such as packet core), which needs to be allocated for connected FWA users. Outdoor CPEs have a much higher spectral efficiency compared to Indoor CPEs, enabling 2-3x more FWA connections per site. As a result of that, Outdoor CPEs score much better than Indoor CPEs on this parameter as unitary network cost per CPE would be 2-3x lower for Outdoor CPEs compared to Indoor CPEs. Some operators address the drawbacks of Indoor CPEs adding external antennas as an option, including upgrade to external antenna for high end users at a later stage.

A complete CPE TCO analysis takes into consideration four revenue drivers related to the CPE choice. Time to Market (TtM) is a key differentiation for FWA, with CPE choices also affecting that parameter. Indoor CPEs would generally enable a faster time to market as there is no need for on site installation. The lead-time difference of Order-to-Activation days between Indoor and Outdoor deployments multiplied by monthly ARPU would quantify the TtM difference. Another parameter is related to customer lifetime value, where outdoor CPEs could provide higher stickiness resulting in longer customer contracts and lower churn compared to Indoor CPEs. Last, Outdoor CPEs will provide larger cells reaching more households and will be able to provide faster and more predictable broadband speeds compared to Indoor CPEs and could be monetized with higher ARPU levels.

Some of these trade offs are also managed with intermediate form factors leveraging the optimal characteristics such as window mounted CPEs as well as outdoor wall mounted CPEs. Best of operator strategy is to have multiple CPE´s depending on market offering and area type (suburban and/or rural)

CPE performance difference



The biggest difference between outdoor and indoor CPE versions is the ability to achieve promised service levels, especially during busy hours. An indoor CPE device is comparable with a smartphone device in terms of the radio resources required, or slightly worse as it's always located indoors. By contrast, an outdoor CPE device has the advantage of a 15–25 dB better signal quality, which equates to lower Mbps production cost, higher speeds and better coverage – which is especially valuable further out in the cell in mid band and mmWave deployments.

There are many parameters impacting the network gain when it comes to selecting CPE type like antenna gain, CPE power class, attenuation, inter-site distance, frequency, etc.

An outdoor CPE provides the best performance as it has an in-built directional antenna (for example, 10–14 dBi at 3.5 GHz) and is installed with a predictable radio link quality to the selected Radio Base Station. The typical antenna configuration has two Rx antennas, but devices with four Rx antennas are also available. More Rx antennas can be useful in urban environments, as multiple signal paths are available to the device. However, the transmission mode for a single CPE is still only rank-2 as the modem is expected to be installed with good line-of-sight or near line-of-sight.

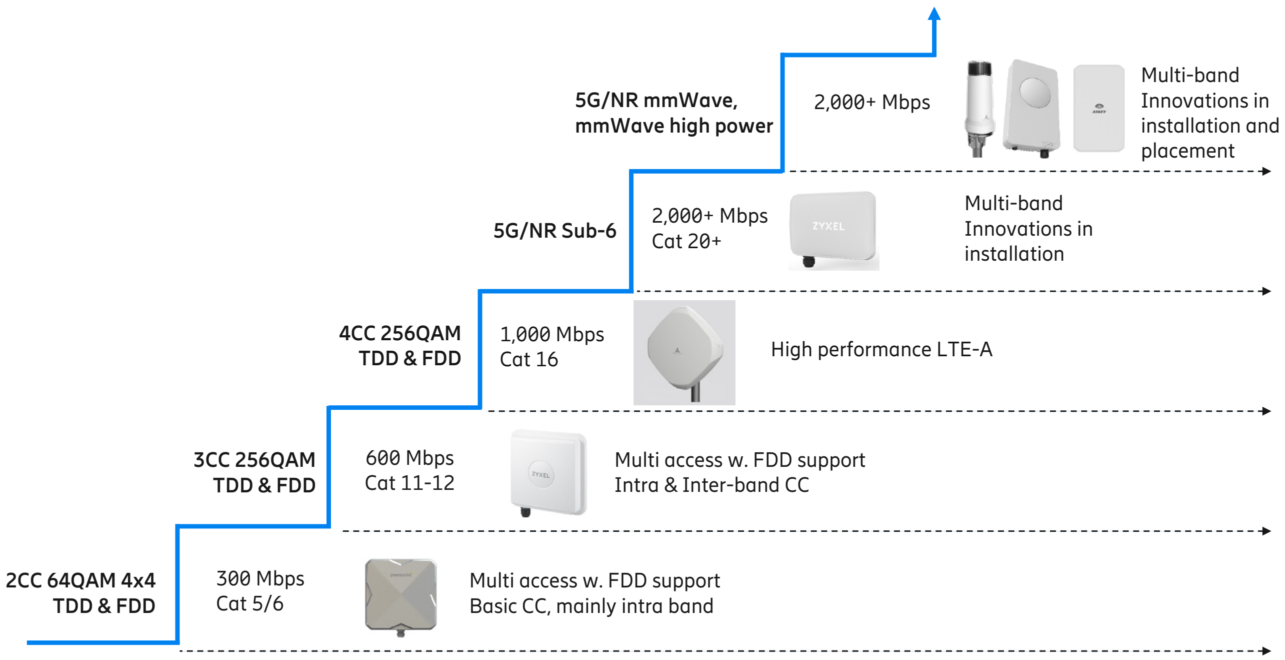
A correctly installed outdoor CPE is directed to the best serving cell, leading to a lower link budget path loss and improving the utilization of mid band and mmWave TDD spectrum. The large gain in signal quality is a result of the 10–15 dB difference in antenna gain and the avoidance of another 10–15 dB in wall/window attenuation losses suffered by indoor devices. Another contributor to signal attenuation in indoor devices is the deep indoor loss, as the device is likely to be placed in a hidden location, perhaps to provide optimal Wi-Fi coverage, contributing another 5 dB in path loss.

Whereas indoor CPE is comparable to a smartphone in terms of spectrum efficiency, outdoor CPE is typically two to three times more efficient. Put another way, for the same data consumption, around two to three times as many households can be served or, alternatively, two to three times as much spectrum would be needed to serve indoor-only FWA households. A final advantage of outdoor CPE is that the relative performance difference between the best, median and worst users is significantly lower, which makes FWA commercial service agreements easier. The most important aspect is to make sure that the users on the cell edge or in poor radio conditions get an outdoor CPE in order to use radio network resources as efficiently as possible.

End-users may detect that they receive fairly good coverage and acceptable speed with an indoor device, but this can change very fast once a specific cell gets loaded with more users. In an unloaded cell, any user can get many radio resources (PRBs) allocated, and achieve acceptable speeds whatever the radio link quality and the fact that only QPSK modulation may be possible, for example. In a loaded busy hour scenario, significantly fewer resources get scheduled and only the devices able to handle higher modulations (such as 64- and 256-QAM) can achieve acceptable speeds.

The modulation and channel coding scheme are determined by the devices' continuous Channel Quality Indicator (CQI) feedback in the uplink. A lower CQI indicator will make it very 'expensive' for the radio network to stream higher data rates, for example for video and TV with a lower modulation level.

3GPP CPE evolution



One of the main advantages of using 4G LTE and 5G NR FWA over 'proprietary' FWA technologies is the large availability and continuous development of new 3GPP devices. As the same chipsets are used in FWA CPEs as in MBB smartphones, there is an ecosystem of multiple chipset suppliers producing hundreds of millions of chipsets a year. Apart from the previously described indoor, flexible and outdoor CP types, there are other varying characteristics across different products.

The device capabilities are described in the 'UE Category' information, and enable the Base Station to communicate as efficiently as possible with the device. For example, Cat6 supports up to 300 Mbps, Cat12 600 Mbps and Cat 16 1,000 Mbps in the downlink. In addition, 256QAM modulation is supported by Cat12, Carrier Aggregation (CA) capabilities are also defined: for example, 2 CC with Cat6 and 2, 3 or 4 CC with Cat12 devices. Apart from basic carrier aggregation, it may also be valuable to support inter-band CA and the ability to combine different spectrum assets, including 1,800 and 2,600 MHz. Clearly, more advanced devices will be more expensive as a result of their more complex chipsets and more limited competition for later chipset releases.

To reach higher peak speeds and support 'wireless fiber' FWA deployments, support for later and higher 'categories' will be essential for operators and end-users. Even with more moderate data usage, support for higher peak speeds is important as network capacity will increase as end-users can download and stream the same content faster. Ultimately, device capabilities such as bandwidth (CA) and MIMO layers should correspond with those the FWA network is built for. For example, with an FWA network configured for 100 MHz of total bandwidth, end-user devices should at least support 60–80 MHz.

Multi-band and multi-access (FDD and TDD) solutions are very useful, as FWA operators can use total spectrum assets and share FWA and MBB usage across several bands. For example, an operator might start offering FWA services on widely deployed 1,800 MHz (B3) spectrum for a small number of FWA users. Later expand capacity and number of households on the 2,600 MHz (B7) band or with higher, mid band spectrum such as 3.5 GHz, and having CPE already prepared for these spectrums will be of great value.

There are a lot of industry innovation in CPE design for both indoor, flexible and outdoor devices. The main objective is to achieve the right balance of the benefits of indoor devices in terms of zero or low installation cost, and all the way to better performance of outdoor devices. One example is LTE/ 5G and antenna units mounted on the inside or outside of a window. This could be further enhanced by feeding RF and power through the window from a special indoor module. The outdoor unit could also include Wi-Fi functionality, making it a convenient, one-box solution.

CPE ecosystem cooperation

There are a large number of vendors who offer both indoor and outdoor CPEs for FWA. However, quite a few of them are small players compared with MBB device vendors, with typically a handful of customers. Currently, the largest market is for indoor LTE CPEs including Wi-Fi and router functionality, which are sold in mobile operators' retail stores. The Global mobile Supplier Association (GSA) now regularly publishes a '4G/5G FWA Device Ecosystem Company Directory' (4G-5G FWA Company Directory), and regularly reports on operator FWA activities and devices (5G - FWA Global Status Update). In June 2022, the GSA identified more 504 operators in 172 countries or territories selling FWA services based on LTE, as well as more than 645 LTE and 214 5G CPEs.

In principle, any CPE device on the market will work – after relevant and normal IODT has been conducted at the chipset level – just as with smartphones. Ericsson is currently working with seven OEM suppliers of LTE and NR CPE, all capable of design and adaptation, and with the ability to supply the necessary volumes to meet market demand. Some vendors focus on 'off-the-shelf' product portfolios, while others are ODM design houses.

Several of these OEM suppliers are based in Taiwan, and include:

- Zyxel Communications who offers CPEs with high-capacity connectivity, enhanced network security and deployment flexibility. Zyxel 5G NR FWA solutions incorporate the most advanced technologies providing customers with a superior self-adaptive, zero-dead-zone WiFi experience.
- WNC is one of the world leading company for RF design especially in Cellular and Wi-Fi products. WNC's sub-6 5G CPE had won CES innovation award in 2022 and currently shipping to the biggest Tier 1 operator in Europe. WNC has also designed and tested advanced high-power mmWave CPEs, which make use of mmWave extended range feature reaching more than 4 km.
- Askey, which is another innovative OEM, focused on being early to market with 5G NR mid band and mmWave products for both outdoor and indoor use.

Both Askey and WNC have also designed and tested advanced high-power mmWave CPEs, which make use of mmWave extended range.

GreenPacket, a Malaysia-based company which offers innovative 5G/ 4G FWA CPE solutions, with different characteristics for multiple usage scenarios. GreenPacket is capable in redesigning product to fit every customer unique deployment scenario with a wide range of high performance indoor, outdoor and flexible installation FWA CPEs to meet customers' diverse needs.

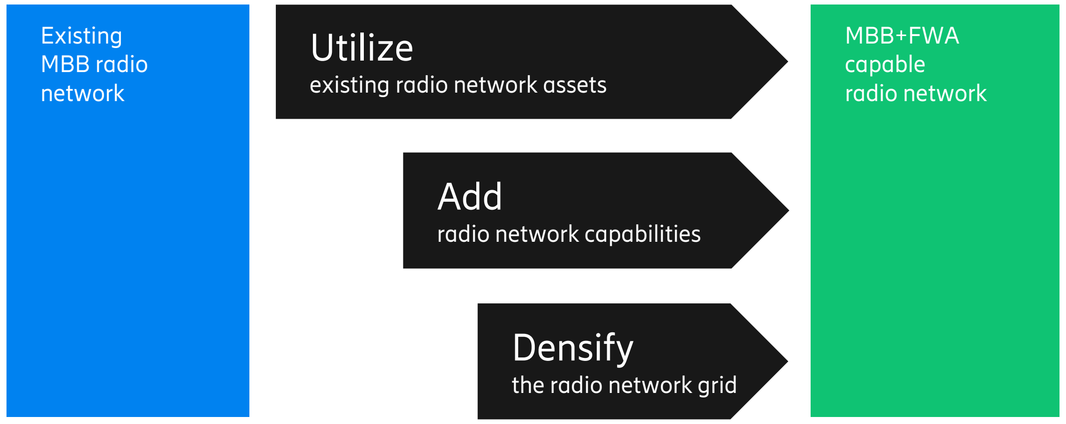
Inseego Corp., based in San Diego, California, focus on advanced 5G NR FWA CPEs, including unique designs with an installation app for ease of installation. Inseego has a broad portfolio of mmWave and sub-6GHz FWA indoor and outdoor solutions as well as a high-power mmWave CPE to support many different installation scenarios.

Casa Systems, with over 15 years experience in 3GPP Fixed Wireless devices and many industry firsts, has products spanning from Indoor to outdoor, WiFi 6 gateways to modems, and self or technician install, and Sub6 and high-power mmWave. Its device portfolio is supplemented by several generations of toolset development including both physical support tools for installers and smartphone-based applications for installers and consumers.

Oppo is one of the leading smartphone manufacturers, who has been actively promoting the development of 5G around the world. Oppo has started to engage in the growing FWA market, with indoor units, bringing its ability to industrialize products for high-volume manufacture to bring 5G to more people and homes around the world.

Overall, there is a fast pace of innovation and evolution in the FWA CPE market, and we will see new products continuously being introduced. The 3GPP device ecosystem is huge, and operators with an Ericsson FWA network will be able to benefit from this, by using and interworking with the most suitable CPE at the best price, functionality and performance.

FWA toolbox



An existing mobile radio network, normally designed for voice and mobile broadband, is an excellent base for offering an FWA service. Depending on the radio network starting point and the operator's ambitions for FWA, there is a toolbox available to make the network capable of handling a combination of voice, mobile broadband and FWA in combination.

This document describes these tools under three main categories:

- **Utilize** the existing radio network assets
- **Add** radio network capabilities, and
- **Densify** the radio network grid

A well planned mix of these tools should be deployed to meet the particular needs of each local situation.

Utilize existing radio network assets
The ability to utilize existing radio network assets is a fundamental advantage that sets mobile operators apart from start-ups or greenfield competition in the FWA market. However, the advantage is only fully realized if all relevant RAN assets are efficiently combined for voice, MBB and FWA. If the operator chooses to not utilize existing assets built for voice and MBB, the financial case for FWA becomes more difficult, which reduces the number of economically viable local areas for FWA. It also levels the playing field with stand-alone FWA providers and so opens up unnecessary competition.

Radio network assets to utilize include:

- Existing radio sites – a very important asset, both when sites are operator-owned and when rental agreements and processes exist with tower company-owned sites. The 'tool' of utilizing existing sites is not used by itself, but in combination with other actions to make those more cost-efficient
- Spare load in deployed spectrum and associated deployed radio, baseband and transport network equipment, which is quite common in FWA target areas. A very efficient tool, since it can be realized without new CAPEX
- Acquired but undeployed spectrum – a situation common in FWA target areas, making radio deployment in new bands possible without the cost of acquiring new spectrum.

Add radio network capabilities
In a mobile broadband RAN, radio capabilities are continually added to handle more traffic, more customers and higher app coverage.

To handle FWA as an additional service, some of these additions may have to be made sooner, to achieve a combined network with sufficient capabilities. Again, the opportunity to add capabilities and co-finance these from MBB and FWA together is an important advantage for an existing mobile operator.

Radio network capabilities to add include:

- Add spectrum – new wide spectrum bands in 3–6 GHz and mmWave open up potential for high data rates and capacity, benefiting both MBB and FWA
- Add higher-order modulation, MIMO and beamforming – offering the potential to squeeze out the most from each spectrum band
- Add FWA-tailored software features – important capabilities to handle FWA in its own right, and to provide adequate quality to MBB and FWA in shared deployments
- Add additional sectors on existing sites
- Add 5G NR access – designed for low latency and for wide spectrum bands, creating an excellent overall network together with LTE.

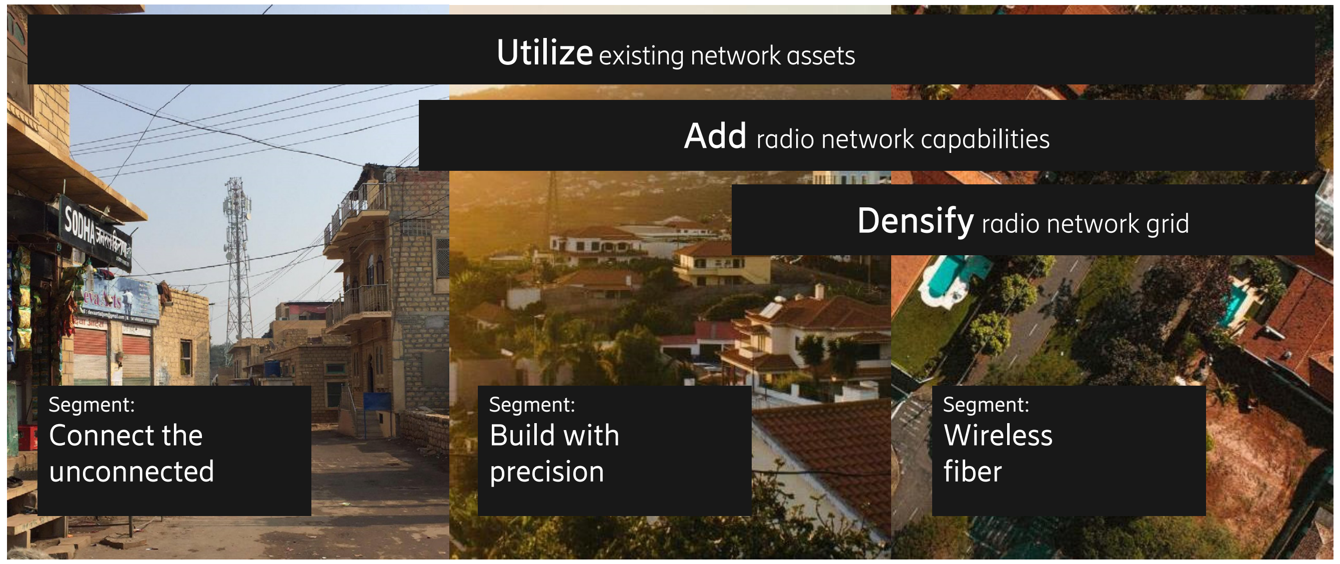
Densify the radio network grid
Densification of the radio network grid is an established way of increasing area capacity. In FWA target areas, and when the ' utilize' and 'add' tools have been used to their full potential, densification can offer further gains. Normally in such areas, there needs to be action taken to enhance MBB so, again, the MBB and FWA upgrade needs should be considered together and should co-finance densification of the network.

Options for densifying the radio network grid include:

- Macro site densification – this is an opportunistic approach: where new macro sites can be found, such opportunities can be taken.
- Small cell site densification on poles – can be needed if the macro grid is sparse and the operator's ambition level is high.

As described, these tools are also used to improve MBB, and since we advocate sharing resources and assets between MBB and FWA, all the actions taken will benefit both services simultaneously. This means that both decisions and financing of the actions can be taken jointly, considering both MBB evolution and FWA.

Choose FWA tools depending on segment



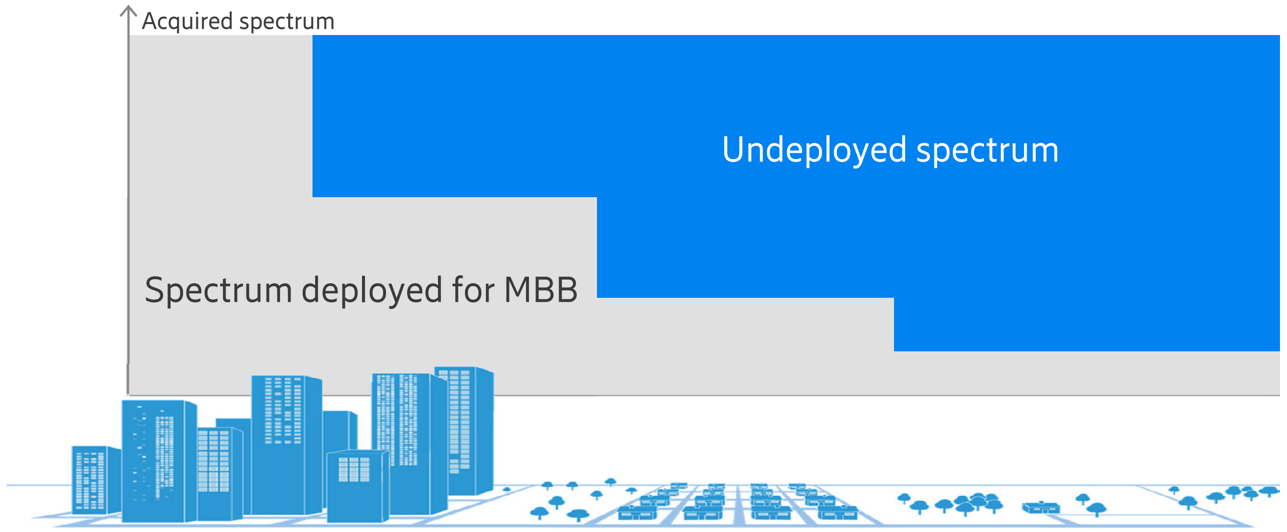
The choice of tools used depends on the network starting point and the operator's ambition level for the FWA offering; it is highly correlated with the segments we use to describe the FWA markets.

'Utilize existing network assets' is always applicable, across all segments.

'Add radio network capabilities' is mostly applicable in 'Build with precision' and 'Wireless fiber' segments, where ambitions are higher and there is competition with fixed broadband, driving the need for higher-rate offerings and capacity.

'Densify the radio network grid' is mainly applicable when absolutely needed, typically only for the 'Wireless fiber' segment, as it drives cost which need to be matched by a corresponding ARPU level.

Utilize acquired but undeployed spectrum



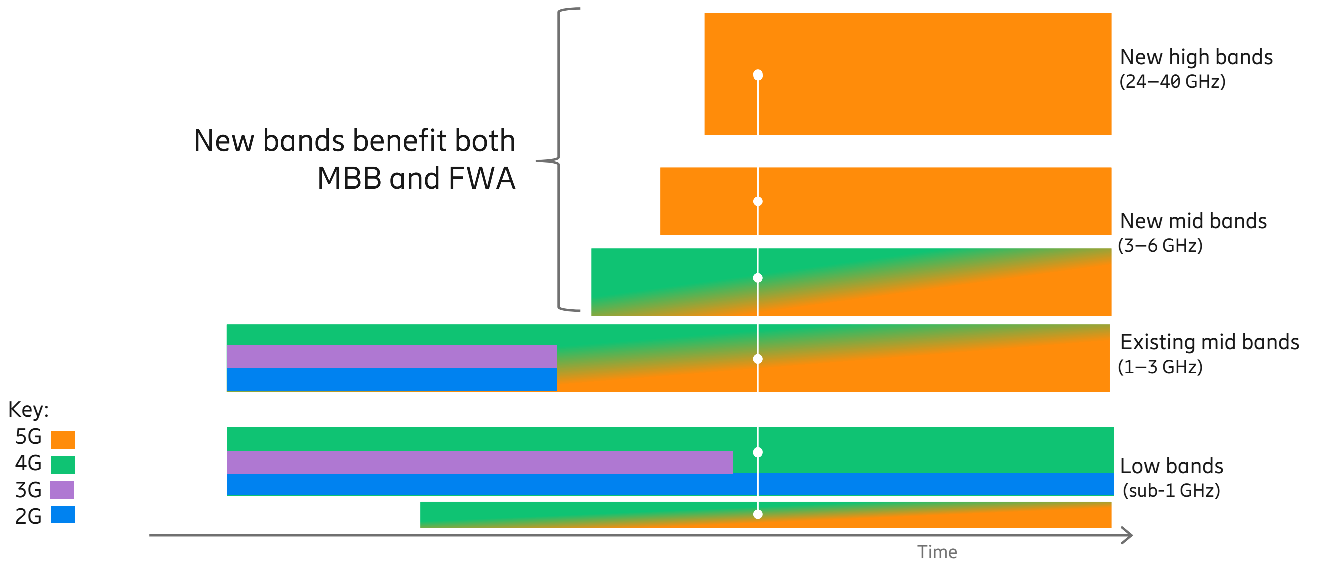
Spectrum is normally auctioned and acquired nationwide or over large areas or markets, including urban, suburban and rural areas. The full capacity is often only needed in dense urban and crowded areas for MBB.

The spectrum already acquired in auctions, but still undeployed in suburban and rural areas, is a great asset for which large investment are already made.

The geographical fit for FWA is excellent, since FWA targeted areas are often suburban and rural, where unused spectrum is most prevalent.

Utilizing undeployed bands and adding radios for them is a natural next step to cater for FWA, if utilizing previously deployed bands is not sufficient to meet FWA ambitions. Baseband and RAN transport equipment can be reused from the existing deployment, but a new dimensioning exercise is needed (see specific case studies).

Add new spectrum bands and radios

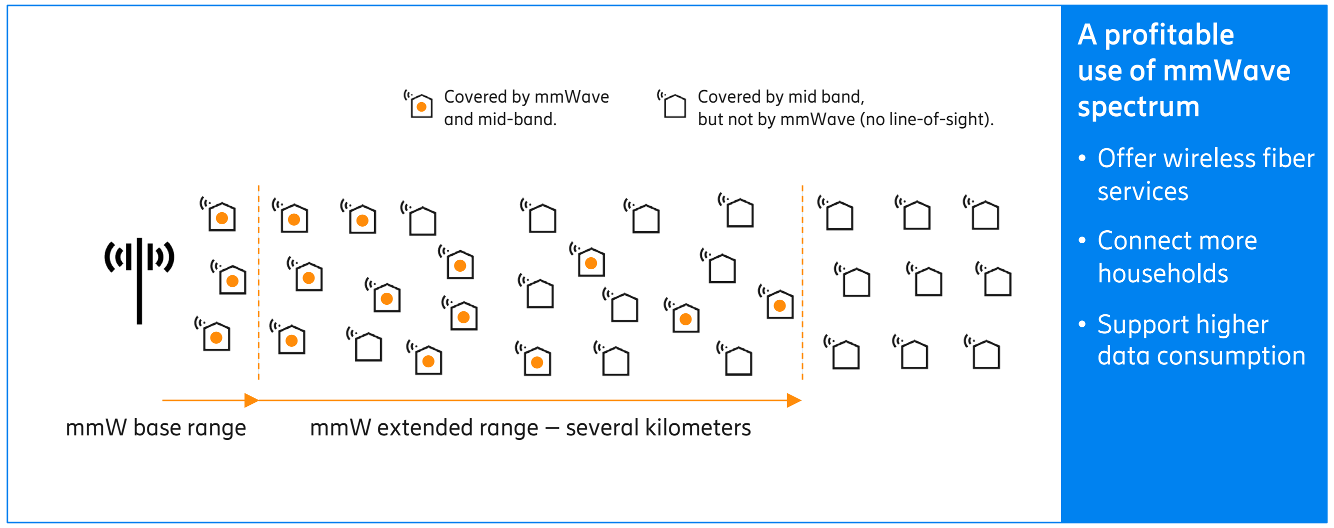


New spectrum with large bandwidths is becoming available in increasing quantities. This includes mid band TDD spectrum in the 3-6 GHz range, with typically 50–150 MHz per operator, and high bands in the mmWave range, notably 26, 28 and 39 GHz, with typically 400–800 MHz per operator.

Such broad bands can carry large amounts of traffic. This is one of the reasons the FWA opportunity has come to the fore recently.

All these bands are important for MBB and can also benefit FWA – as long as operators view their spectrum assets as one common pool and deploy a fully coordinated multi-layer network for best performance.

Add mmWave with extended range to offer wireless fiber in more rural areas



The large amount of mmWave spectrum can provide unprecedented peak rates, low latency and high capacity. However, the adverse propagation characteristics of mmWave spectrum produce much shorter cell range than for lower frequencies. Currently, mmWave cells are typically configured to support cell ranges of up to about 600 m, corresponding to an inter-site distance (ISD) of around 1 km.

FWA deployments with good line-of-sight propagation conditions, between high tower radio sites and outdoor roof-top mounted CPEs, would deliver much longer mmWave cell ranges – up to several kilometers. This requires the use of high-power radios, high-power CPEs, and a new software innovation – mmWave extended range – that can accommodate the increased propagation time at longer distance. Field trials across three continents have demonstrated good performance over several kilometers and enhanced the value of 5G mmWave spectrum (TIM, 2020) (NBN, 2021) (USCC, 2021).

The 3GPP NR specification allows for large cell ranges on mmWave. The guard period – the gap between the downlink and uplink in the TDD format – allows for the transmission roundtrip time and the time needed for the equipment to switch from reception to transmission. An extended cell range is enabled using a larger gap, but with the trade-off that it slightly reduces the downlink peak rates for all users in the cell. By combining these measures, mmWave FWA can be used to serve selected households in good signal conditions at several kilometers distance.

The larger the distance is from a household to the radio site, the more challenging it is to achieve good line-of-sight conditions. The combined use of mmWave and mid band is the winning recipe, where mmWave serves household in good conditions and mid band households in less favorable conditions. With the capacity offload enabled by mmWave, mid band can serve more households at more distant, challenging locations. This provides an opportunity to offer high-end wireless fiber services even in more rural areas, serve more households per radio site, as well as support higher data consumption. This unlocks the full business and technology potential of mmWave FWA, and is an attractive opportunity for a profitable use of mmWave spectrum.

Densify with street sites

Densification using street sites is an option when utilization of existing assets and adding radio capabilities are not sufficient to meet FWA ambitions, and no macro densification is possible. This is a high-investment action, due to the relatively limited coverage area per site and the consequential high transport and site cost per household covered. It is a powerful tool, but should be used very selectively.

First, it is worth noting that street sites are already deployed in various ways across different markets. A large variety of equipment is already installed on lighting and utility poles, and not just cellular equipment. The images on the left show such installations in North America. Often, there are permits to load the poles with considerable equipment weight and size, so it is not always the case that weight and size limitations limit the installation of normal microcells on poles. Of course, local regulations vary, and it is possible to find areas where the use of existing poles is virtually impossible, and others where the use of poles is perfectly viable for today's microcells and associated equipment.

Since the cost of acquiring the site and deploying its transport is high per area covered, the strategy must be to aim for maximum possible use of the site. Therefore, as many frequency bands as possible should be deployed, including both LTE and NR, and especially those used in smartphones, to also get an instant MBB benefit from the new site.

The availability of utility poles is heavily dependent on the use of overhead power lines. These tend to be common in parts of the Americas, and are a good asset when searching for FWA deployment target areas.

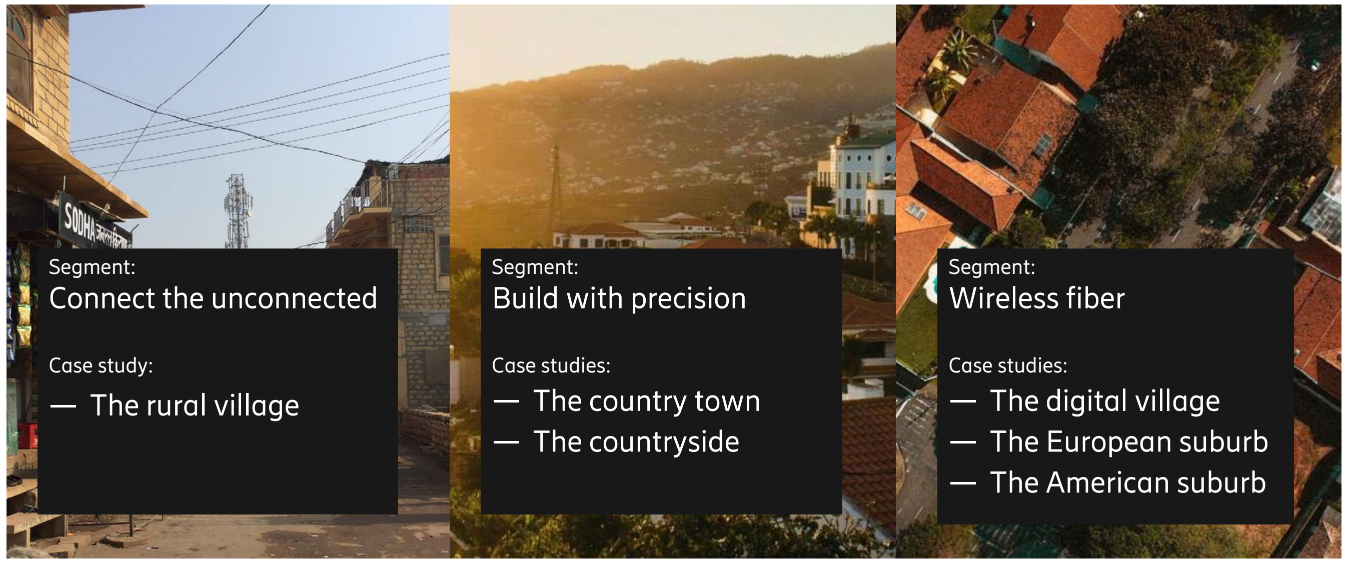
There is a need for good and easily deployable RAN equipment on such poles – both when using legacy poles, and when exchanging the light pole infrastructure with new poles ready-equipped with RAN equipment. The images above show some examples of efficiently deployable RAN solutions.

Site acquisition is another key factor: unlike macro sites, small cell sites must be acquired in bulk, for the process and administration cost to be viable. For example, site access can be obtained to all poles in a certain neighborhood or all bus stops in a certain area. However, this should not be confused with the density at which base stations are actually deployed at FWA launch. As we will examine in the transport section, providing transport connectivity to a pole site is a substantial cost item, so while the site acquisition needs to be done in bulk, the actual deployment has to be done selectively, with almost surgical precision to minimize transport deployment cost. Undeployed pole permits can be saved for further densification at a later date, if possible.

Finally, in some situations, strand mounting may be a cost-efficient deployment variant, although for that case, weight and size of equipment really matter more, and tend to drive a higher site density. This, in turn, increases overall transport cost and other cost items that scale with the number of sites.

Appendix A. Tailored network solutions for different segments

Case studies: Tailoring solutions to various needs



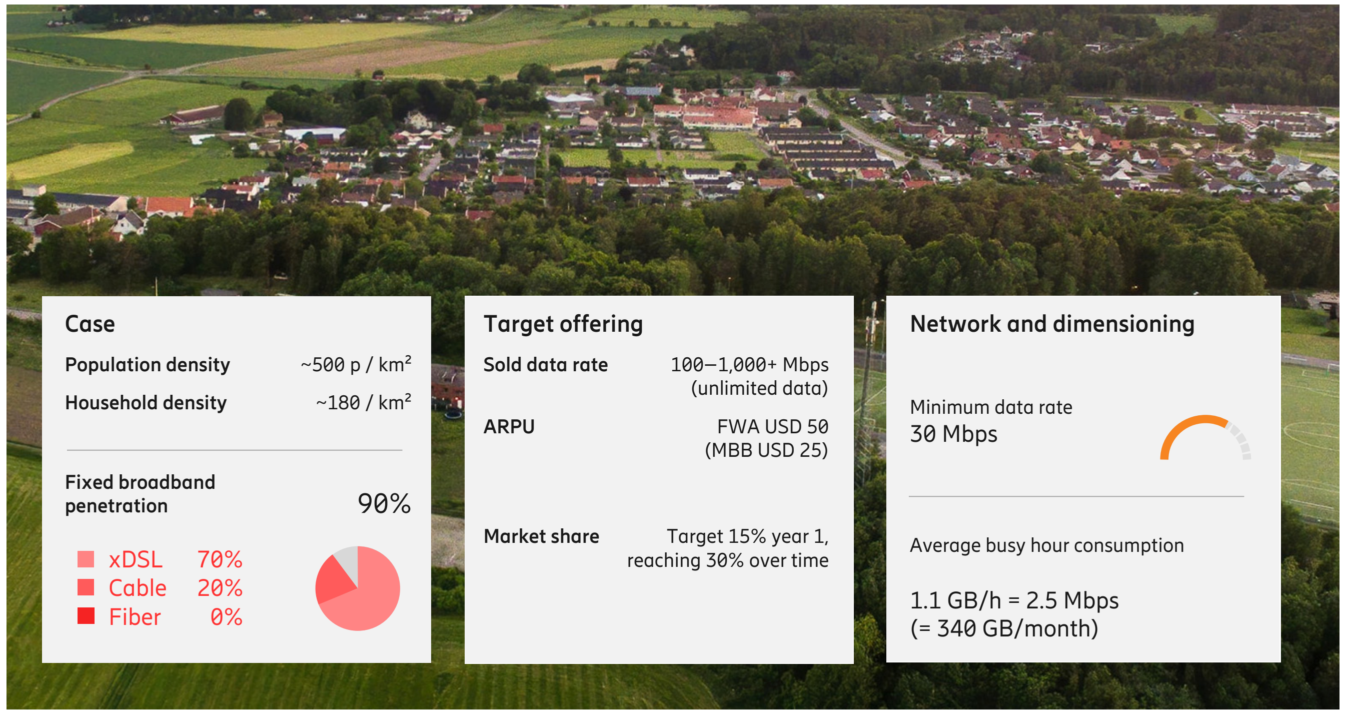
Our three FWA segments divide the FWA target markets into three broad groups, mainly according to the offering, and the corresponding expected ARPU. These range from the low-end 'Connect the unconnected' offering, with a corresponding limited ability to pay, to the high-end segments where the offering is fiber-like and should also handle the household's TV needs, with a correspondingly higher ability to pay.

Case studies offer a concrete way of showing how the FWA network solution for these segments can be designed. In this chapter, we examine a number of cases in the different segments, and present a recommended solution based on the input data from each case.

The solution is presented in the form of a basic overview of each case; an overview of the main principles, including which spectrum bands to use; the evolution of the solution over time; the impact on network architecture and radio sites; and the Ericsson products for designing the solutions. We also examine the economics of the solution by including a business case which compares the expected ARPU with the cost additions needed to serve the new FWA customers. Finally, we also include a few real-world examples of operator deployments which roughly correspond to the cases.

The cases have been chosen to span the diversity of the segments. They are intended to be concrete, yet general enough to map on to common situations in multiple markets around the globe. 'The rural village' is a small village in a developing country; 'The country town' is a village in a developed country, for example in Western or Eastern Europe, while 'The countryside' addresses a more rural area for example farming land in a developed country. Three capacity demanding cases are presented in 'The digital village', 'The European suburb', and 'The American suburb'. In 'The digital village', we leverage mmWave extended range support. This enables mmWave-based FWA services up to several kilometers — distances which until recently not have been associated with mmWave signals. 'The European suburb' and 'The American suburb' are high-end cases for denser deployments, with expected offerings and ARPU levels appropriate to each market.

Case: The digital village



'The digital village' exemplifies how more demanding requirements in the 'Wireless fiber' FWA segment can be met in a less densely populated area, such as in and around a small town or village in the countryside. The case is also applicable to sparsely populated suburbs. The service area has a mature LTE network dimensioned for MBB coverage in general; however capacity is strengthened in areas that have a higher-than-average smartphone density. The existing fixed broadband offerings (mostly ADSL) has been considered satisfactory to date, but with no general fiber infrastructure planned in the near future, the demand for better fixed connections is increasing. In particular, higher demands on, both downlink and uplink have been driven by the working-from-home trend triggered by the Covid-19 pandemic.

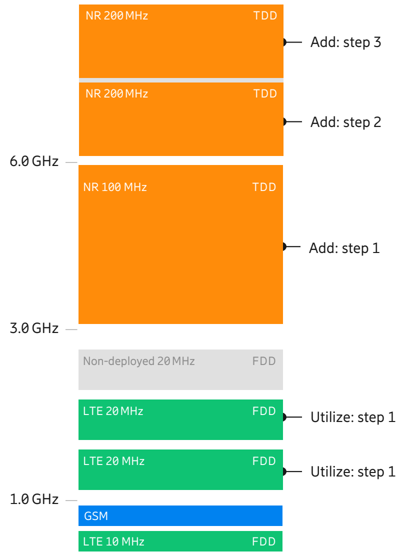
In this use case, we assume a population density of 500 people per km² and, with an average of 2.8 people per household, that equates to 180 households per km².

Typical ARPU for MBB is around USD 25, and we expect to be able to charge USD 50 for a dedicated household FWA Internet service, with a sold rate of 100–1,000+ Mbps and 'unlimited' data (with fair usage policy limitations).

The operator uses the following as the basis for dimensioning the system:

- The network should be designed to be able to connect at least 30 percent of households with a target of 15 percent for the first year
- The households' TV needs are assumed to be served by the FWA service
- For video streaming support, households should, when needed, experience at least a minimum data rate (R_{min}) of 30 Mbps even during busy hours. As a reference, a 1080p HDTV video stream requires around 5.4 Mbps (see the chapter 'Household data rates and data consumption')
- Based on the operator's experience from similar FWA areas, 90 percent of the total traffic is in the downlink and the average household's downlink data consumption during busy hours is 1.1 GB/h, corresponding to an average data flow of 2.5 Mbps during busy hours. (With the assumption that 10 percent of the daily data being consumed during a busy hour, this would correspond to 340 GB per month.)

Overall solution



Utilize existing macro sites, baseband and transport
Utilize available spare capacity on deployed sub-3 GHz bands for LTE

Add NR in TDD mid band

Add NR in TDD mmWave band with mmW extended range support

Add baseband and transport capacity

Use all LTE carriers above 1 GHz for MBB and FWA
– **Add** QoS/slice separation

Outdoor CPE focus to maximize performance
– Indoor CPE as complement

Here is an overview of the solution for introducing FWA services for this case.

Utilize
We recommend utilizing the existing sites, radios and baseband deployed to provide MBB, and sharing these resources between FWA and MBB users. Current deployments have spare capacity both in LTE carriers and in baseband units. To reduce CPE requirements and complexity, we have not anticipated support for bands under 1 GHz, even though we recommend also using such bands if supported by the CPE.

Carrier aggregation improves peak speeds as well as coverage for both MBB and FWA services.

The ambition to provide 'fiber-like services' means it will not be sufficient for the first step only to utilize the un-deployed 2,600 MHz FDD band, so it is left un-deployed. This band can be seen as a buffer which could be deployed if, for example, MBB grows faster than anticipated.

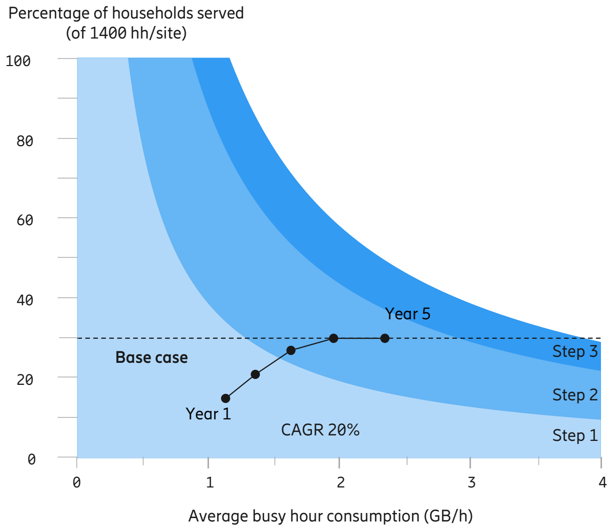
Add
As a part of the first step, a new 100 MHz TDD allocation in the 3.4–3.8 GHz band is added using 5G NR. New MU-MIMO 32 T/R radios and baseband are added for the new frequency band.

In step 2, the mmWave band is introduced. We add radios and baseband with Massive MIMO capability to handle up to 800 MHz. In step 2, 200 MHz will be sufficient to offload the mid band. With mmWave extended range support, it is possible to serve households with good conditions far out in the cell using the mmWave band. Even though this is not the case for all households, it will still enable substantial offload of the mid band with just 200 MHz of mmWave spectrum. By adding another 200 MHz of spectrum (step 3), even higher capacity can be obtained. For step 3 no additional hardware is required.

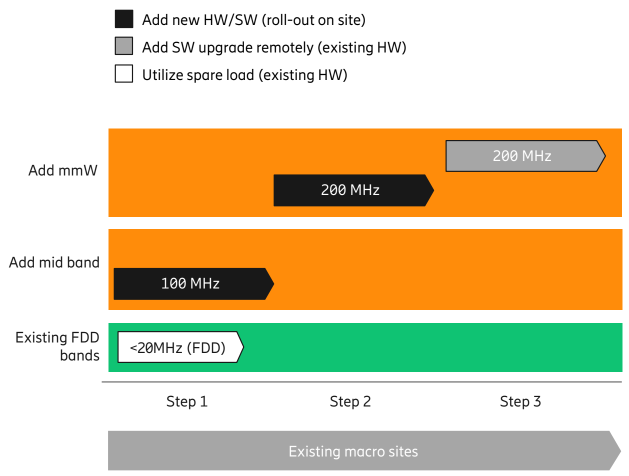
In all steps, baseband and transport capacity needs to be revisited and potentially upgraded to handle higher peak rates and capacity.

Business case introduction

Network Evolution – usage and market share



FWA RAN Solution – scalable CAPEX investment



Base case assumptions
The digital village FWA business case is based on a five-year period. Market share is expected to reach 30 percent of households, resulting in a total of 420 households per site. Uptake is assumed to be 15 percent market share in year 1, 21 percent in year 2, 27 percent in year 3, and 30 percent in years 4 and 5.

The FWA usage per household in year 1 is 340 GB per month, which includes all the Internet and TV traffic from the household, including linear TV, video on demand, Internet traffic and other data. The monthly usage is equivalent to 1.1 GB per hour during busy hour, assuming 10 percent consumption of overall traffic at the busy hour. Monthly traffic consumption is assumed to grow at a compound rate of 20 percent per year over the five-year period.

The left side of the illustration shows how the usage and market share evolve over time in the available capacity curves. As a result, the base case is handled with step 1 for years 1 and 2, while step 2 is needed to meet demand in years 3, 4 and 5. We also see that steps 3 would be able to manage even higher future traffic or market share increases

FWA RAN solution
The right side of the illustration shows the principles for RAN CAPEX investment at each network evolution step. All four steps in this scenario are based on reusing the existing macro site, with no need for densification. In addition, sharing of bands with MBB enables utilization of spare capacity on FDD.

Step 1 adds 100 MHz of mid band spectrum, which requires new site hardware and software.

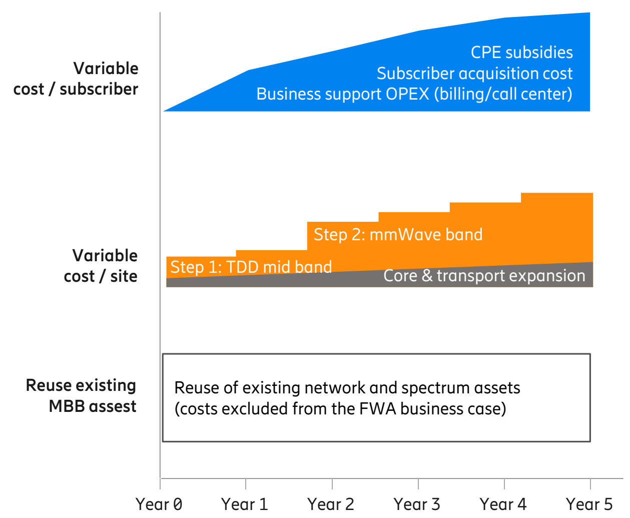
Step 2 represents a new radio in mmWave spectrum, requiring new hardware and software as well as installation on site.

Step 3 adds an additional 200 MHz in the same band, using the same hardware and requiring only a remote software upgrade.

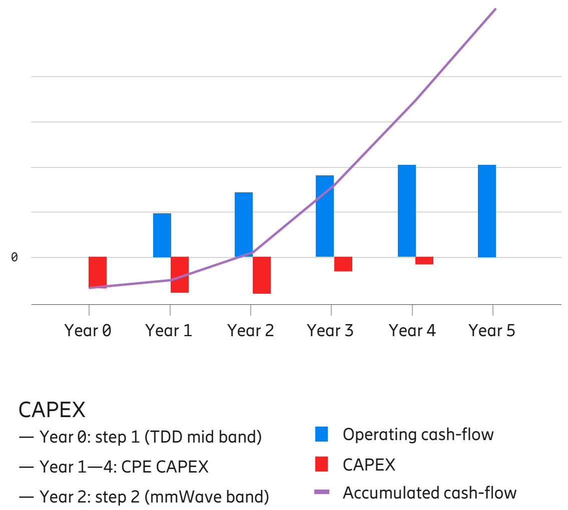
As described previously, MBB traffic growth of 28 percent is included in the overall solution. This implies spectrum is available for both MBB and FWA traffic. Still 100 percent of incremental CAPEX and OPEX for this FWA solution is included in the business case, indicating a conservative approach. This is important to consider when comparing different business cases for FWA.

Business case financial results

Cumulative OPEX and CAPEX – low upfront investment



Cash-flow base case – payback in 22 months



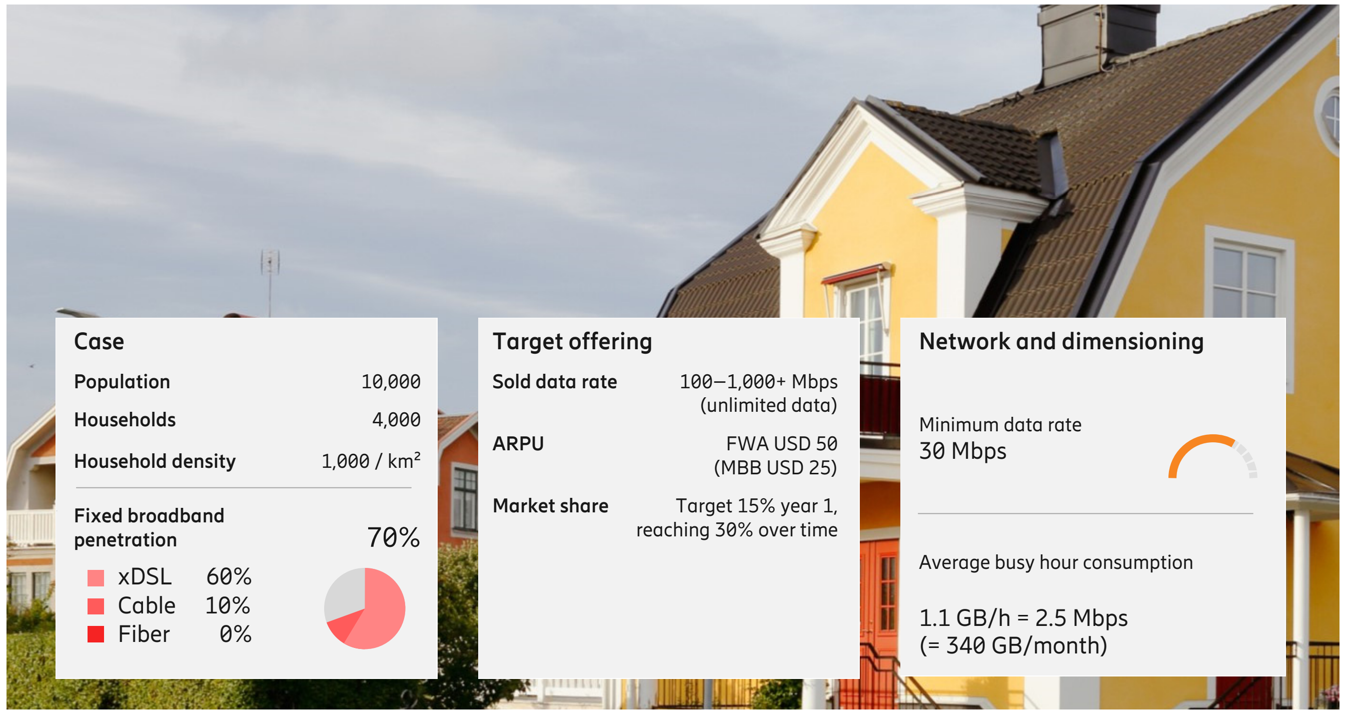
OPEX and CAPEX investments over time
FWA investments (OPEX and CAPEX) are very scalable, varying with subscriber uptake and number of site deployments. This is an important advantage over fixed broadband, where the investment profile is characterized by large upfront investments, before subscriber uptake is known. Moreover, FWA reuses existing MBB assets, including site infrastructure and spectrum assets.

Incremental FWA OPEX includes power consumption, backhaul transmission, core and network support, as well as subscriber acquisition costs and incremental business operation costs. The incremental CAPEX includes network systems and outdoor CPE (fully subsidized in this case). Network CAPEX includes radio and baseband hardware, software and installation services, as well as a cost allocation of 10 percent of the radio CAPEX to allow for incremental transmission and core costs.

The left side of the illustration shows cumulative OPEX and CAPEX divided into variable cost per subscriber and variable cost per site for each of the first five years. The variable cost per subscriber grows with the new subscriber uptake, reaching 30 percent market share at year 4. The site-related variable CAPEX and OPEX – where step 1 radio, baseband and other site equipment is taken for year 0 and year 1 onwards – also include RAN OPEX. Step 2 is taken at year 2, ahead of the capacity needs expected for year 3.

Cash-flow – payback in 22 months
The estimated revenues are based on a monthly ARPU of USD 50, growing with subscriber uptake over time. The operating cash-flow (dark blue) in the cash-flow graph is represented by the difference between annual revenues and FWA operational costs. Annual CAPEX is related to CPE costs (distributed over years 1 to 4) and network CAPEX, where network investments take place at year 0 (step 1) and year 2 (step 2). The accumulated cash-flow curve indicates break-even in about 22 months from launch, resulting in an attractive business case.

Case: The European suburb



'The European suburb' represents a market within our 'Wireless fiber' FWA segment, characterized by relatively mature LTE MBB, decent fixed broadband offerings (mostly ADSL), but with no general fiber infrastructure deployed in the targeted areas.

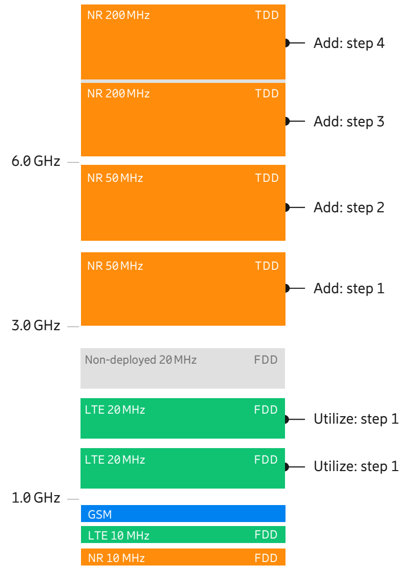
In this use case, we assume a population density of 2,500 people per km² and, with an average of 2.5 people per household, that equates to 1,000 households per km².

Typical ARPU for MBB is around USD 25, and we expect to be able to charge USD 50 for a dedicated household FWA Internet service, with a sold rate of 100–1,000+ Mbps and 'unlimited' data (with limitations against excessive consumption in the contract, as with fixed broadband services).

The operator uses the following as the basis for dimensioning the system:

- The network should be designed to be able to connect at least 30 percent of households with a target of 15 percent for the first year
- The households' TV needs are assumed to be served by the FWA service
- For video streaming support, households should experience at least a minimum data rate (R_{min}) of 30 Mbps even during busy hours. As a reference, a 4K HDTV video stream requires around 22 Mbps, see the chapter 'Household data rates and data consumption'
- Based on the operator's experience from similar FWA areas, the average household's consumption during busy hours is 1.1 GB/h in the downlink, corresponding to an average data flow of 2.5 Mbps during busy hours. (With the assumption that 10 percent of the daily data being consumed during a busy hour, this would correspond to 340 GB per month). For the uplink, the corresponding average busy hour consumption is 0.13 GB (average data flow 0.28 Mbps), and the monthly consumption is 38 GB/month

Overall solution



Utilize existing macro sites, baseband and transport
Utilize available spare capacity on deployed sub-3 GHz bands for LTE

Add NR in TDD mid band (e.g. 3.5 GHz)

Add NR in TDD mmWave band (e.g. 28 GHz)

Add baseband and transport capacity

Use all LTE carriers above 1 GHz for MBB and FWA
– **Add** QoS/slice separation

Outdoor CPE focus to maximize performance
– Indoor CPE as complement

Here is an overview of the solution for introducing FWA services for this case.

Utilize
We recommend utilizing the existing sites, radios and baseband deployed to provide MBB, and sharing these resources with MBB users. Current deployments have spare capacity both in LTE carriers and in baseband units. To reduce CPE requirements and complexity, we have not anticipated support for bands under 1 GHz, even though we recommend also using such bands if supported by the CPE.

Carrier aggregation improves peak speeds as well as coverage for both MBB and FWA services.

The ambition to provide 'fiber-like services' means it will not be sufficient for the first step only to utilize the un-deployed 2,600 MHz FDD band. Instead, a 50 MHz TDD allocation in 3.4–3.8 GHz band is used (see below). (If the new capacity deployment is instead primarily driven by MBB, it may be desirable to use the 2,600 MHz band as well for MBB and FWA traffic, particularly if a large proportion of smartphones do not support the 3.4 – 3.8 MHz band. This could delay when steps 2, 3 or 4 need to be taken, but this variant has been left out of our analysis for simplicity.)

Add
As a part of the first step, a new 50 MHz 5G NR TDD allocation in the 3.4–3.8 GHz band is added. New 32 T/R radios and baseband are added for the new band.

Step 2 adds an additional 50 MHz in the same band, using the same hardware and requiring only a remote software upgrade.

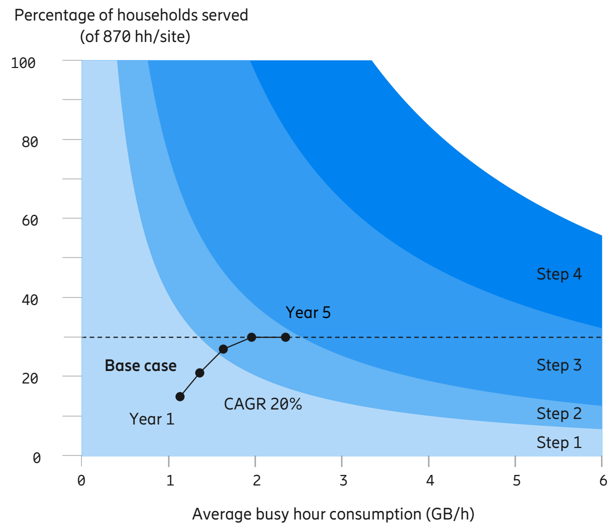
If even higher capacity is needed in the future, mmWave band can be added. In this use case, we have added 200 MHz TDD bands in steps 3 and 4. Massive MIMO radios and baseband are added in step 3, and these are capable of handling both step 3 and step 4.

Again, due to the differences in spectrum regulations, some operators might take step 3 before step 2.

In all steps, baseband and transport capacity needs to be revisited and potentially upgraded to handle higher peak rates.

Business case introduction

Network Evolution — usage and market share



FWA RAN Solution — scalable CAPEX investment

Base case assumptions
The European suburb FWA business case is based on a five-year period. Market share is expected to reach 30 percent of households, resulting in a total of 260 households per site. Uptake is assumed to be 15 percent market share in year 1, 21 percent in year 2, 27 percent in year 3, and 30 percent in years 4 and 5.

The FWA usage per household in year 1 is 340 GB per month, which includes all the Internet and TV traffic from the household, including linear TV, video on demand, Internet traffic and other data. The monthly usage is equivalent to 1.1 GB per hour during busy hour, assuming 10 percent consumption of overall traffic at the busy hour. Monthly traffic consumption is assumed to grow at a compound rate of 20 percent per year over the five-year period.

The left side of the illustration shows how the usage and market share evolve over time in the available capacity curves. As a result, the base case is handled with step 1 for years 1 and 2, while step 2 is needed to meet demand in years 3, 4 and 5. We also see that steps 3 and 4 would be able to manage even higher traffic or market share increases.

FWA RAN solution
The right side of the illustration shows the principles for RAN CAPEX investment at each network evolution step. All four steps in this scenario are based on reusing the existing macro site, with no need for densification. In addition, sharing of bands with MBB enables utilization of spare capacity on FDD bands (for example, on 1,800 MHz).

Step 1 adds 50 MHz of mid band spectrum, which requires new site hardware and software. Step 2 also involves the addition of 50 MHz of mid band spectrum, using the same hardware and requiring only a remote software upgrade.

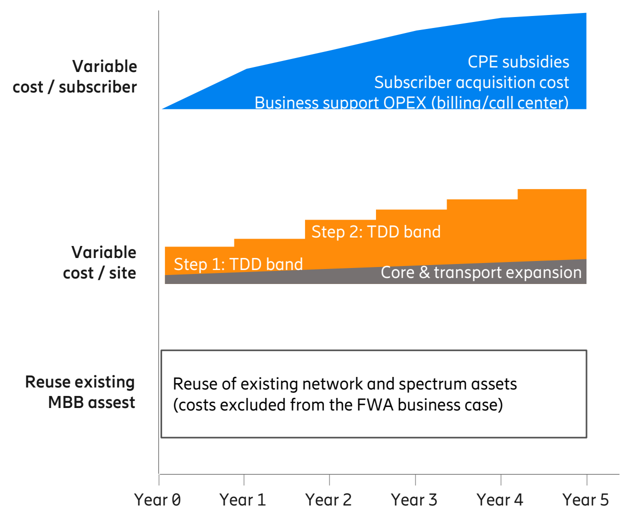
Step 3 represents a new radio in mmWave spectrum, requiring new hardware and software as well as installation on site.

Step 4 adds an additional 200 MHz in the same band, using the same hardware and requiring only a remote software upgrade.

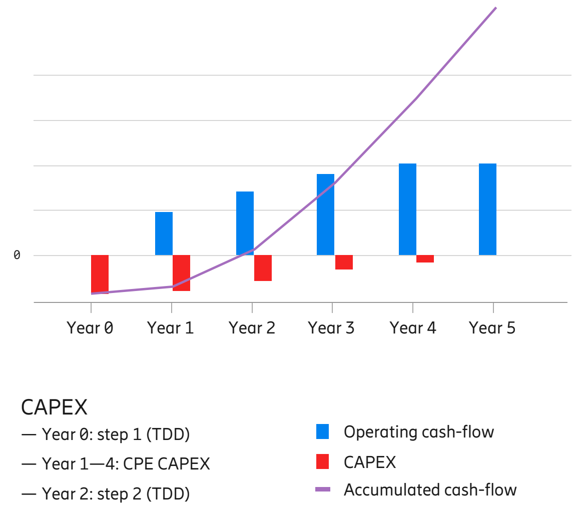
As described previously, MBB traffic growth of 28 percent is included in the overall solution. This implies spectrum is available for both MBB and FWA traffic. Still 100 percent of incremental CAPEX and OPEX for this FWA solution is included in the business case indicating a conservative approach. This is important to consider while comparing different business cases for Fixed Wireless Access.

Business case financial results

Cumulative OPEX and CAPEX — low upfront investment



Cash-flow base case — payback in 22 months



OPEX and CAPEX investments over time
FWA investments (OPEX and CAPEX) are very scalable, varying with subscriber uptake and number of site deployments. This is an important advantage over fixed broadband, where the investment profile is characterized by large upfront investments, before subscriber uptake is known. Moreover, FWA reuses existing MBB assets, including site infrastructure and spectrum assets.

Incremental FWA OPEX includes power consumption, backhaul transmission, core and network support, as well as subscriber acquisition costs and incremental business operation costs. The incremental CAPEX includes network systems and outdoor CPE (fully subsidized in this case). Network CAPEX includes radio and baseband hardware, software and installation services, as well as a cost allocation of 10 percent of the radio CAPEX to allow for incremental transmission and core costs.

The left side of the illustration shows cumulative OPEX and CAPEX divided into variable cost per subscriber and variable cost per site for each of the first five years. The variable cost per subscriber grows with the new subscriber uptake, reaching 30 percent market share at year 4. The site-related variable CAPEX and OPEX — where step 1 radio, baseband and other site equipment is taken for year 0 and year 1 onwards — also include RAN OPEX. Step 2 is taken at year 2, ahead of the capacity needs expected for year 3.

Cash-flow — payback in 22 months
The estimated revenues are based on a monthly ARPU of USD 50, growing with subscriber uptake over time. The operating cash-flow (dark blue) in the cash-flow graph is represented by the difference between annual revenues and FWA operational costs. Annual CAPEX is related to CPE costs (distributed over years 1 to 4) and network CAPEX, where network investments take place at year 0 (step 1) and year 2 (step 2). The accumulated cash-flow curve indicates break-even in about 22 months from launch, resulting in an attractive business case.

Appendix B. FWA operator reference cases

T-Mobile 5G Un-carrier to home & business broadband

5G Home offerings

- USD 55/month with taxes included or USD 50/month with autopay
- Unlimited data, no annual contract, no upfront costs or fees
- Typical speeds between 33-182 Mbps for DL and between 6-23 Mbps for UL
- Promotes maximum speeds available – not offering tiered pricing
- Indoor CPE provided at activation and self-installation
- Return CPE at canceling service or pay up to USD 370
- Partnership with Google to expand home internet coverage with Nest Wifi routers
- Ended 3Q22 with 2.1+ million 5G Home Internet customers
- Targeting to serve 7-8 million customers by 2025

FWA Business offering supports LTE and 5G

- USD 50, with autopay, with best effort speed and unlimited GB/month, not available in all areas
- USD 25 with best effort speed and 10 GB/month
- USD 45 with best effort speed and 25 GB/month
- USD 50 with best effort speed and 100 GB/month
- USD 70 with best effort speed and 300 GB/month

https://www.t-mobile.com/isp/plan

https://www.t-mobile.com/business/solutions/business-internet-services/business-internet

Network

Ericsson Radio System
5G NR
- FDD Band <2.6 GHz
- TDD Mid Band 2-6 GHz

Telenor modernizing home broadband with 5G FWA

5G FWA focusing on DSL/copper network decommissioning, with almost half of net adds have been FWA (other half fiber). Received government incentive (5G spectrum auction discount) to deploy FWA 100/10Mbps in underserved areas.

FWA offers for homes and for secondary homes. TV services can be added.

Several 5G unlimited* offerings available:

- 500 Mbps: USD 127/month
- 300 Mbps: USD 102/month
- 200 Mbps: USD 87/month
- 100 Mbps: USD 76/month

Several 4G unlimited* offerings available:

- 60 Mbps: USD 76/month
- 30 Mbps: USD 71/month
- 10 Mbps: USD 61/month

5G-ready outdoor CPE including installation for USD 203 with 12-month contract USD 509 without an agreement period

FWA connections reaching total 120,000 connections by 3Q2022.

*Unlimited amount of data. The speed is maintained up to a consumption of 2 TB per month, then the speed is reduced to 5 Mbps rest of month

Network

Ericsson Radio System
5G NR and LTE

Total 110 MHz available in:
- FDD Band <2.6 GHz
- TDD Mid Band 2-6 GHz

Utilize existing macro sites and spare load on existing carriers

Started with 4G FWA with network prepared to smooth 5G migration

Ericsson Cloud Core

NBN FWA wholesale offering

NBN Australia launched in 2012

Wholesale provider with over 391,000 customers and 650,000 premises covered in regional and remote Australia where the economics of fixed line technologies are less favorable

- Four wholesale offerings, currently DL/UL speeds of 12/1 Mbps, 25/5 Mbps, 25-50/5-20 Mbps, and the newly launched Wireless Plus (Best effort)
- Outdoor CPE or CPE with external antenna to meet minimum service quality requirements. Professional installation is used in 100% of cases. NBN Co owns the CPE as it is the wholesale Network Termination Device
- It presents a layer 2 bitstream ethernet service towards the retail service provider's residential modem/gateway
- NBN targeting about 600,000 homes and businesses with FWA, deploying extended range 5G millimeter wave FWA to provide high-speed broadband connectivity services
- Over 2,200 fixed wireless infrastructure sites and over 22,000 cells

Regional upgrade plan from 2023

- Deployment of 5G, including midband and mmW extended range. Increase FWA coverage from 650k to 770k, including 120k premises covered by satellite
- Provide busy hours at minimum speeds of 50Mbps and potential maximum wholesale download speeds of up to 250 Mbps

Network

Ericsson Radio System
LTE TDD

3.4 GHz with up to 60 MHz bandwidth

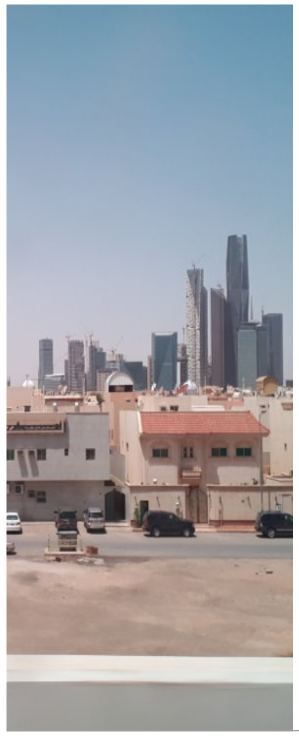
2.3 GHz with up to 95 MHz bandwidth

mmWave trials ongoing

Ericsson Cloud Core
Cloud Packet Core

Unified Data Consolidation

5G or fiber for homes from STC in Saudi Arabia



Baity 5G,4G Home Services

- 5G FWA positioned as complementary offering to fiber-based broadband services
- LTE offering with 12-month contract including indoor CPE
  - 50 Mbps with unlimited date for USD 76/month
  - Unlimited speed and data for USD 107/month
- 5G offers with different speed tiers and 18-month contract
  - Unlimited speed and data for USD 79/month for eSIM users
  - 200 Mbps with unlimited data for USD 92/month
  - Unlimited speed and data for USD 107/month
- Some service packages are geographically locked
- FWA subscriber growth at 18.1% in 3Q22 compared to 1.5% for fiber. FWA has had higher growth rate than fiber in the past 5 quarters (3Q21 to 3Q22).

Baity packages (stc.com.sa)

Network

Ericsson Radio System

TDD Mid Band 2-6 GHz, 160 MHz for both FWA and MBB 5G NR

Abbreviations and references

3GPP	3rd Generation Partnership Program
5QI	5G QoS Identifier
AAA	Authentication, Authorization and Accounting
AAS	Advanced Antenna System
ABR	Adaptive Bit Rate
ACS	Auto-Configuration Server
ADSL	Asynchronous Digital Subscriber Line
AGF	Access Gateway Function
AIR	Antenna Integrated Radio
ANIP	Application Network Interaction Protocol
API	Application Programming Interface
APN	Access Point Name
ARPU	Average Revenue per User (per month if not stated otherwise)
AS	Application Server
AWS	Advanced Wireless Services
BB	Baseband
BBF	Broadband Forum
BGF	Border Gateway Function
BNG	Broadband Network Gateway
BSS	Base Station (Sub)system
BSS	Business Support Systems'
CA	Carrier Aggregation
CAGR	Compound Annual Growth Rate
CAPEX	Capital Expenses
CAT	Category
CAT-n	Category n
CATV	Cable TV
CBRS	Citizen Broadband Radio Service
CC	Component Carrier
CDMA	Code Division Multiplexing Access
CDR	Charging Data Records
CG-NAT	Carrier-Grade Network Address Translation
CP	Content Provider
CPE	Customer Premise Equipment
CPRI	Common Public Radio Interface
CQI	Channel Quality Indicator
CRAN	Centralized RAN
CRM	Customer Relationship Management
CSCF	Ericsson Call session Controlling Function
CUPS	Control and User Planes
CWMP	CPE WAN Management Protocol
DC	Dual Connectivity
DDOS	Distributed Denial of Service
DHCP	Dynamic Host Configuration Protocol
DL	Downlink
DRAN	Distributed RAN
DSCP	Differentiated Services Code Point
DSL	Digital Subscriber Line
DTH	Direct-to-Home
eCPRI	Enhanced CPRI
EIRP	Effective Isotropic Radiated Power
ENIQ	Ericsson Network IQ
ENM	Ericsson Network Manager
EPC	Evolved Packet Core
EPG	Evolved Packet Gateway
ERS	Ericsson Radio Systems
EUR	Euros
EVS	Enhanced Voice Service
FDD	Frequency Division Duplex
FTTH	Fiber to the Home
FTTN	Fiber to the Node
FTTP	Fiber to the Premises
FWA	Fixed Wireless Access

GB	Gigabyte
GBR	Guaranteed Bit Rate
GE	Gigabit Ethernet
GHz	Giga Hertz
GRE	Generic Routing Encapsulation
GSM	Global System for Mobile Communications
GW	Gateway
GW-C	Control plane GW
GW-U	User plane GW
HAG	Hybrid Access Gateway
HARQ	Hybrid Automatic Repeat Request
HDTV	High Definition TV
HEVC	High Efficiency Video Coding
HFC	Hybrid Fiber Coaxial
H-RGW	Hybrid RGW
HSPA	High Speed Packet Access
HSS	Home Subscriber Server
HTTP	Hypertext Transport Protocol
HW	Hardware
IAB	Integrated Access and Backhaul
IBCF	Interconnection Border Control Function
IEEE	Institute of Electrical and Electronics Engineers
IGW	Internet Gateway
IMS	Internet Protocol Multimedia Subsystem
IMSI	International Mobile Subscriber Identity
IMT	International Mobile Telecommunications Specification
IMT-A	IMT-Advanced Standard
IODT	Interoperability Development Testing
IP	Internet Protocol
IPTV	IP Television
IPvn	Internet Protocol version n
ISD	Inter Site Distance
ISDN	Integrated Services Digital Network
ISP	In-service performance
ITU	International Telecommunication Network
KPI	Key Performance Index
LAN	Local Area Network
LTE	Long Term Evolution
LTE-A	LTE advanced
MBB	Mobile Broadband
MHz	Mega Hertz
MIMO	Multiple Input Multiple Output
MMTel	Multimedia Telephony
mmW	millimeter wave
MRF	Media Resource Function
MRFC	Media Resource Function Control
MRFP	Media Resource Function Processor
MS-ISDN	Mobile Station Integrated Services Digital Network number
MSRP	Message Session Relay Protocol
MTAS	Multimedia Telephony Application Server
MTC	Machine Type Communication
MU-MIMO	Multi User MIMO
NAT	Network Address Translation
NBI	Northbound Interface
NI	Network Instance
NPV	Net Present Value
NR	New Radio
NSA	Non Stand Alone
ODM	Original Design Manufacturer
OPEX	Operational Expenses
OSS	Operations Support System
OTT	Over The Top

PAL	Priority Access License
PCFICH	Physical Control Format Indicator Channel
PCRF	Policy and Charging Role Function
PCS	Personal Communications Service
PDCCH	Physical Downlink Control Channel
PDN	Packet Data Network
PDP	Packet Data Gateway
PHICH	Physical Hybrid ARQ Indicator Channel
POTS	Plain Old Telephony Service
PRA	Presence Reporting Area
QCI	QoS Class Identifier
QoS	Quality of Service
RADIUS	Remote Authentication Dial-In User Service
RAN	Radio Access Network
RAT	Radio Access Technology
RBSs	Radio Base Stations
RF	Radio Frequency
RGW	Radio Gateway
RJ11	Registered Jack 11
RTP	Real Time Protocol
RTT	Round Trip Time
SA	Stand Alone
SAPC	Service Aware Policy Controller
SBC	Session Border Controller
SBG	Session Border Gateway
SDTV	Standard Definition TV
SD-WAN	SSoftware-defined Wide Area Network
SGSN-MME	Serving GPRS Support Node - Mobility Management Entity
SIP	Session Initiation Protocol
SLA	Service-Level Agreement
SME	Small and Medium-sized Enterprise
SNR	Signal to Noise Ratio
S-NSSAI	Single Network Slice Selection Assistance Information
SPID	Service Profile Identifier
STB	Set Top Box
SW	Software
TAS	Telephony Application Server
TCP	Transport Control Protocol
TDD	Time Division Duplex
TR-n	Technical Report n (Broadband Forum)
TRP	Transmission Point
TTI	Transmission Time Interval
TV	Television
UL	Uplink
USD	US dollars
WAN	Wide Area Network
WCDMA	Wideband Code Division Multiple Access
VoLTE	Voice over LTE
VoNR	Voice over NR
VRAN	Virtual RAN
WWC	Wireline-Wireless Convergence
xDSL	arbitrary Digital Subscriber Line, e.g. ADSL
XML	Extensible Mark-up Language

1. Broadband market & FWA overview
Ericsson Mobility Report, Ericsson, 2022

GSA, 2021

ITU, 2021

Omdia, 2022

Mobile broadband boosts the economy, Ericsson and Imperial College London, 2017.

Broadband Communities Magazine, 2021

WCIS, 2021

Harvard Business Review, 2021

FCC launches $20B Rural Digital Opportunity Fund, February 2020

The contribution of National Recovery and Resilience Plans, Deloitte, Jun 2021

NBN, 2019

2. FWA drivers and the Opportunity
Ericsson Mobility Report, Ericsson, 2022

Copper switch off: Opportunity to drive infrastructure convergence? Arthur D Little, 2021

Cullen, 2019

Jakopin and Klein, 2012

Fierce Wireless, 2018

Jio, 2019

Vertical Systems Group's 2022

3. Data rates, data consumption and subscriptions
US Broadband: Household Bandwidth Demand Study, Cartesian 2021.

Uppföljning av regeringens bredbandsstrategi 2017, PTS, 2017.

From AT&T to Cable One: Who has the highest data caps in wireline, wireless and cable?, Fierce Telecom 2018.

MMS Årsrapport 2017, MMS 2017.

The Zettabyte Era: Trends and Analysis, Cisco, 2017.

Mobile data plan, Google, 2018.

Mobile Visual Networking Index (VNI), Cisco, 2019.

Is Fixed Broadband Traffic Growth Slowing Down?, Strategy Analytics May 2021

Connected Nations 2020, Ofcom

Connected Nations 2021, Ofcom

AGCOM, Italy

4. Fixed wireless access end-to-end network layout

5. Core and BSS/OSS systems aspects
Hybrid Access reference architecture TR-348, BBF TR-348.

Broadband Forum TR-069 CPE WAN Management Protocol, BBF TR-069.

6. Device aspects: the Customer Premise Equipment
4G-5G FWA Company Directory

FWA-Market Update July 2022

CPE Cost Declines Will Fuel 5G Fixed Wireless Deployments, Dell'Oro, August 2021

7. Radio Network aspects
Auction 97: Advanced Wireless Services (AWS-3), FCC, 2015.

nbn sets 5G long-range transmission world record, nbn, 2021

TIM, Ericsson and Qualcomm set record for long-distance speed with 5G mmWave, TIM 2020

UScellular, Qualcomm, Ericsson, and Inseego Address Digital Divide.., USCC 2021

Advanced Antenna Systems for 5G Network Deployments, Elsevier, 2020.

8. Tailored network solutions for different segments
Ericsson Mobility Report, Ericsson, 2021

Turkcell Superbox offering, Turkcell, 2021

Telia Estonia offerings, Telia Estonia, August 2021

NBN Fixed Wireless, NBN 2021

Telenor offerings, Telenor 2021

Omantel 5G Home offer, Omantel 2021

Verizon 5G Home, Verizon 2021

T-Mobile Home Internet, T-Mobile 2021

EN/LZT 1/28701-FGD 101 449 Uen Rev H