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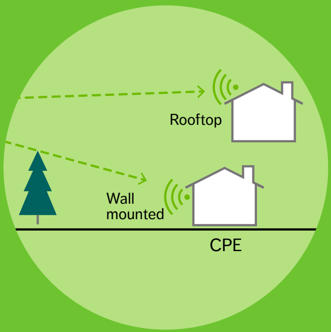

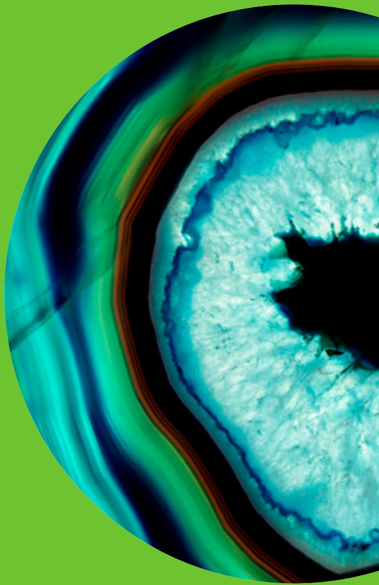

5G AND FIXED WIRELESS ACCESS

ERICSSON

fixed wireless access

ON A MASSIVE SCALE WITH 5G

The promise of ubiquitous fixed wireless access (FWA) looms large with every new generation of wireless or mobile technology, and 5G is no exception. Indeed, one of the 5G use cases currently gaining momentum in the industry is FWA for both small and medium-sized enterprise (SME) and residential applications.

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FWA is a concept for providing broadband service to homes and SMEs that is particularly attractive in cases where there is no infrastructure in place to deliver wired broadband via copper, fiber or hybrid solutions. It can also be used when the existing infrastructure is not able to provide sufficient service. With 5G due to provide 10 to 100 times more capacity than 4G, it has the potential to enable cost-efficient FWA solutions on a massive scale.

■ Already today, in LTE with 40MHz of bandwidth, there is often a working business case for FWA as an add-on improvement to mobile broadband (MBB) and it only becomes stronger as LTE evolves. The further evolution toward 5G has the potential to take FWA to a whole new level. This is because 5G offers unprecedented technology options that make it possible to use larger chunks of radio spectrum and provide consumers with benefits like low latency (1ms) and major capacity improvements. Many of these options are relevant to the evolution of 4G as well.

Compared with fiber-to-the-home (FTTH) and other wireline solutions, FWA offers a variety of benefits including significantly lower rollout costs, rapid service rollout and lower opex. This is because the bulk of the costs and most of the complexity involved in fixed access deployments are associated with the last mile: the portion of the network that reaches the user premises.

FWA also offers an opportunity to double the impact of a 5G deployment by addressing the two prominent 5G use cases – MBB and fixed wireless – simultaneously. The 5G beams that serve mobile users outdoors during the daytime can be redirected to an FWA terminal when people return home in the evening, thereby strengthening the case for 5G deployment and its outlook as an affordable and sustainable technology.

5G-based FWA is expected to enable robust services with sustainable rates that are high enough to meet the foreseeable needs for home use well into the future. It is also poised to offer peak cell rates that few fixed technologies will be able to match without very costly investments into deep-fiber fixed access infrastructure deployments.

In many situations, FWA – based on 3G, 4G or 5G – may be the only feasible broadband access (BBA) option, particularly in rural areas and emerging markets with limited fixed BBA infrastructures, which comprise the majority of homes around the globe. For example, although more than one-third of all households in developing countries have internet access, only about 20 percent of that access is provided through fixed broadband [1]. 5G in lower frequency bands – such as 3.5GHz – opens up for much higher capacities in the realm of 3GPP radio access as a residential broadband technology.

“ 5G-BASED FWA IS EXPECTED TO ENABLE ROBUST SERVICES WITH SUSTAINABLE RATES THAT ARE HIGH ENOUGH TO MEET THE FORESEEABLE NEEDS FOR HOME USE WELL INTO THE FUTURE ”

5G FWA could also be used to boost existing fixed BBA in dense urban deployments to achieve higher peak rates and thereby meet increasing bandwidth and latency requirements without having to make comprehensive upgrades to the

Abbreviations

BBA – broadband access | **BF** – beamforming | **CO** – Central Office | **CPE** – customer premises equipment | **CPRI** – Common Public Radio Interface | **CWDM** – coarse wavelength division multiplexing | **FDP** – Fiber Distribution Point | **FSO** – free-space optics | **FTTH** – fiber-to-the-home | **FWA** – fixed wireless access | **GE-PON** – Gigabit Ethernet Passive Optical Network | **IoT** – Internet of Things | **ISD** – inter-site distance | **ISP** – internet service provider | **MAC** – Media/Medium Access Control | **MBB** – mobile broadband | **MNO** – mobile network operator | **MU-MIMO** – multi-user multiple-input, multiple-output | **MVNO** – Mobile Virtual Network Operator | **MW** – microwave | **NGCO** – next generation central office | **NG-PON2** – Next Generation Passive Optical Network 2 | **NR** – New Radio | **ODN** – optical distribution network | **OTN** – optical transport network | **P2P** – peer-to-peer/point-to-point | **PHY** – physical layer | **RBU** – Radio Baseband Unit | **RRU** – remote radio unit | **SME** – small and medium-sized enterprise | **SNR** – signal-to-noise ratio | **STA** – Station | **TWDM-PON** – time and wavelength division multiplexed passive optical network | **UE** – user equipment | **WDM-PON** – wavelength division multiplexed passive optical network | **WR-WDM-PON** – wavelength routed WDM-PON | **WS-WDM-PON** – wavelength selective WDM-PON | **XG-PON** – 10-gigabit-capable passive optical network physical infrastructure. In particular, 5G FWA appears capable of addressing the bandwidth saturation issue caused by the high demand for typical residential services such as IPTV. The very low latency of 5G access is also a potential key enabler for future applications.

Thanks to high-efficiency data compression techniques, variable bitrate video and adaptive bitrate streaming, 5G FWA is well positioned to become a leading media distribution technology. High-efficiency data compression techniques allow for the delivery of high-resolution video with less bandwidth, while variable bitrate video enables the transport of more video streams using less bandwidth than constant bitrate. Finally, adaptive bitrate streaming is a technique that enables the best possible multimedia viewing experience, as it adapts automatically to any changes in network conditions (such as fluctuations in available bandwidth).

5G and the FWA opportunity

To enable higher user data rates and greater system capacity, 5G radio will make use of new and often higher frequency bands. The most prominent band options currently under consideration are 3.5GHz, 28GHz, 37GHz and 39GHz, in addition to the bands used for legacy cellular technologies.

A technique called beamforming makes it easier to provide coverage at high frequencies. Massive beamforming at high frequencies creates narrow beams that can be redirected easily as required. The signals from multiple user terminals can be multiplexed simultaneously on the same frequency resource in different beams. This is often referred to as multi-user multiple-input, multiple-output (MU-MIMO).

The possibility of using high-gain antennas on the terminal side (both indoors and outdoors) makes the higher frequencies more useful. The more static channels simplify beamforming and MU-MIMO user pairing.

FWA works by using wireless technologies (such as 5G) to connect a base station or wireless access point to a special kind of user terminal referred to as a fixed wireless terminal (FWT), which then provides backhauling services for customer premises equipment (CPE). Sometimes the FWT is integrated with the CPE in the same enclosure. But most often the FWT is installed in one place (fixed on a particular premises) in proximity to an outdoor antenna, and it is rarely moved.

Figure 1 outlines a few alternatives for possible 5G FWA deployments. The placement of the RBS in relation to other nodes depends on the frequency it operates on – the higher the frequency, the shorter the reach of radio links from the RBS. The mainly indoor entities that provide consumer connectivity are orange, and the corresponding outdoor entities are green.

Since 5G will support multi-access networks, it will be possible to deploy FWA as a complement to existing fixed BBA to boost peak rates for the home CPEs [2]. It is also increasingly evident that 5G FWA will be able to offer very attractive services that can compete with high-capacity fixed solutions.

FWA is steadily becoming a more sustainable alternative to fixed BBA due to the ongoing incorporation of more spectrum, beamforming, advancements in terminals, optimization of media distribution, virtualization of RAN and core, and other forms of technological progress in the 4G/5G arena. *Figure 2* is a schematic illustration of production cost per subscriber as a function of traffic per subscriber, depicting how 5G technologies can add value for consumers in an FWA scenario. (Note that the numbers on the x and y axes are representative – the actual numbers depend on many factors that may vary in different parts of the world.)

One obvious advantage of 5G FWA is its ability to support very high peak rates without requiring dedicated fixed facilities for each consumer. In fixed networks, the fiber or copper plant needs to be physically dimensioned for each consumer's fixed rate. Upgrading existing fixed plants is typically a slow and costly process, not least due to deployment costs and rights of way. By 2020, BBA speeds in excess of 100Mbps are expected to be available in less than 10 percent of all residential connections worldwide [3]. In

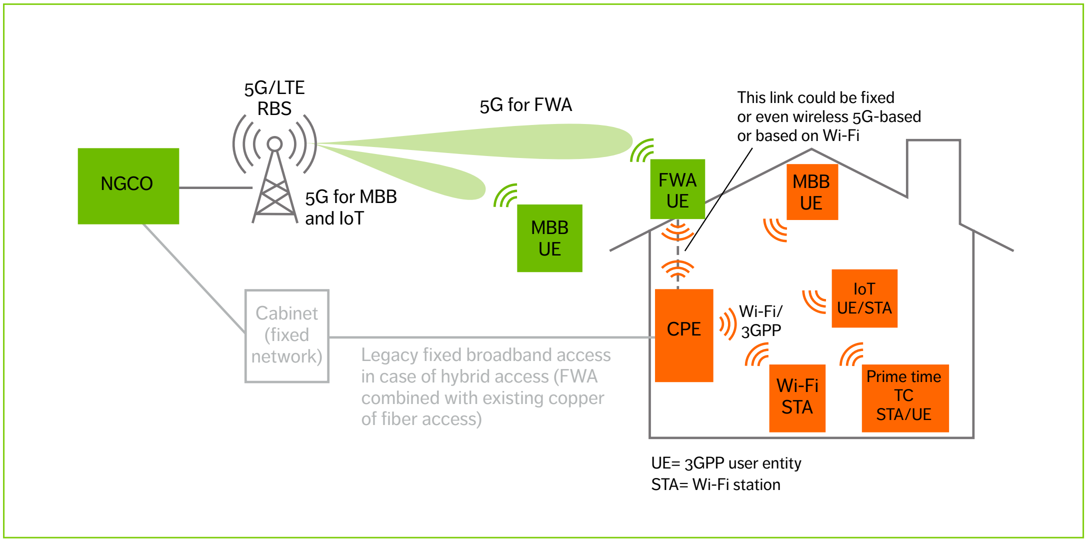

Figure 1 Examples of FWA deployment alternatives

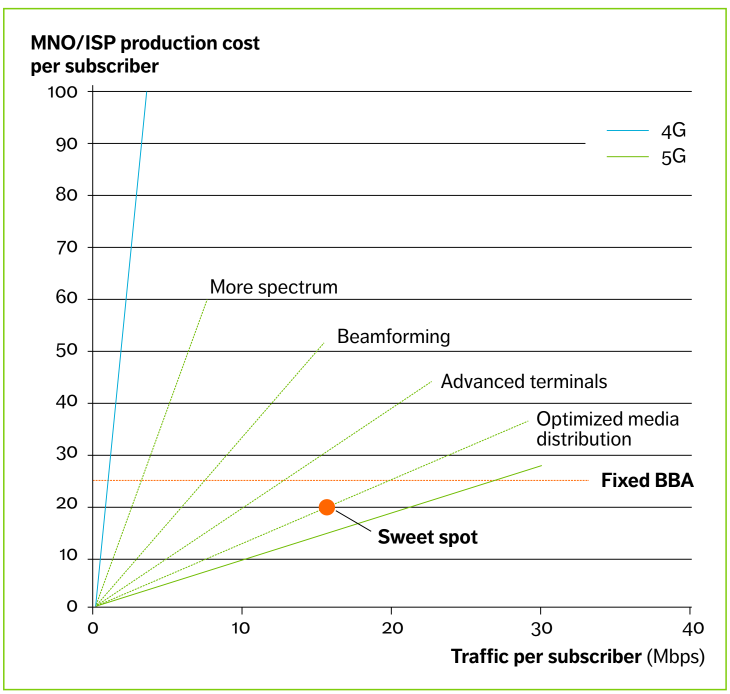

Figure 2 Production cost per subscriber as a function of traffic per subscriber

Parameter	Value
Base station transmit power	35dBm
CPE transmit power	30dBm
Channel bandwidth	200MHz
Operating frequency	28GHz
Duplex mode	TDD with 57 percent downlink allocation

Figure 3 Simulation assumptions

fact, in 2020, almost two-thirds of all broadband connections will still provide peak rates below 25Mbps. Such numbers suggest that there are many opportunities around the world for 5G to complement existing solutions or create new ones, as our use case below also suggests.

The 5G-based FWA use case

We have studied a range of different scenarios to assess the system performance that is achievable in fixed wireless use cases. Our findings show that coverage and overall performance largely depend on which frequency band is used, the environment or terrain the system operates in and the placement of the terminal antenna.

One of the key scenarios we have studied is a suburban environment with 1,000 households per square kilometer. Twenty-five percent of the households use a 4K UHD video service (video on demand or linear) that requires a download speed of at least 15Mbps for uninterrupted playout of basic 4K video streams. To support this demand, a network is deployed with base stations on utility poles that are 6m tall. Terminal antennas are placed outdoors – often on rooftops or walls – as well as indoors. The buildings are 4-10m tall, and there are trees in the area that reach heights of 5-15m and attenuate the signal. In our study, the buildings and trees were represented on a three-dimensional digital map, and a ray-tracing technique was used to create a model showing their impact on radio propagation; this included diffractions, reflections, path loss owing to the effect of foliage, and building penetration loss.

The system design was based on a preliminary 5G New Radio (NR) concept operating at 28GHz with a bandwidth of 200MHz, utilizing beamforming and MU-MIMO and enabled by a base station antenna array of 8x12 cross-pole elements. We made the conservative assumption that terminal antennas were omni-directional with a 10dBi gain. Two-layer MIMO was used for each user. A summary of the simulation assumptions is presented in *Figure 3*.

Figure 4 shows a map of the environment where each user was assigned a color based on the data rates they received at a low traffic load. A majority of the users enjoyed data rates in excess

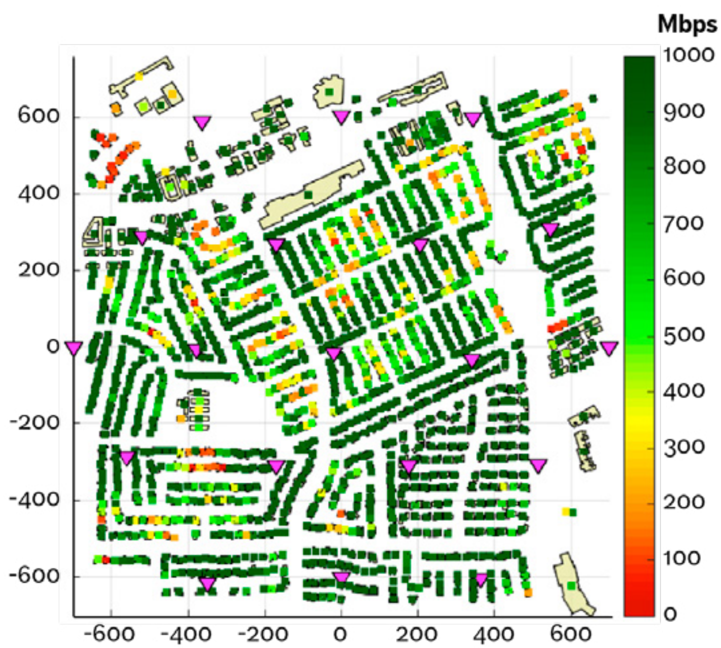

Figure 4 Throughput map of suburban area at low load

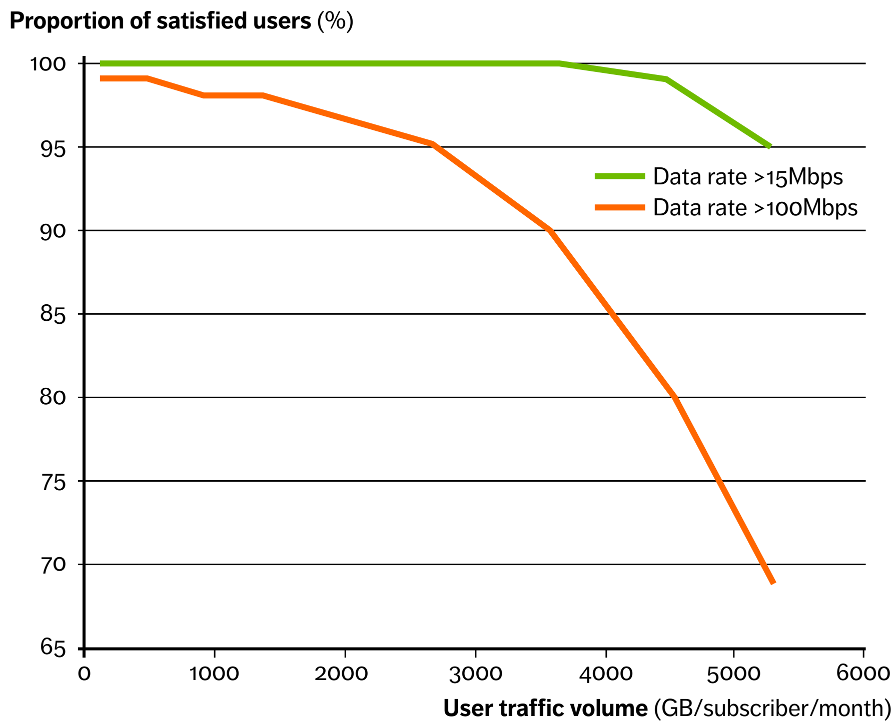

Figure 5 Proportion of satisfied users as a function of traffic

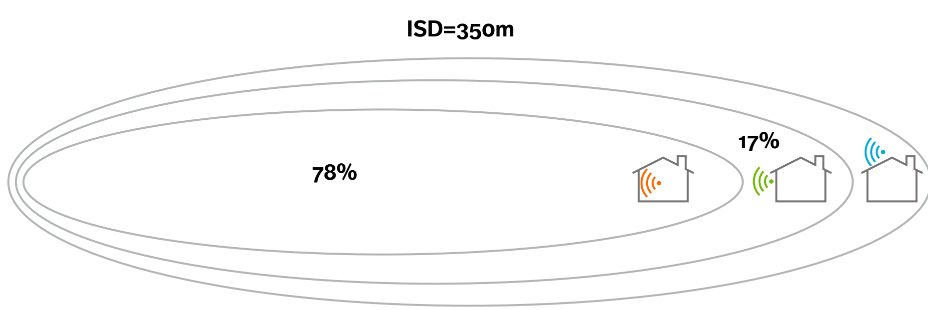

Figure 6 Breakdown of indoor, wall-mounted and rooftop antennas for an ISD of 350m

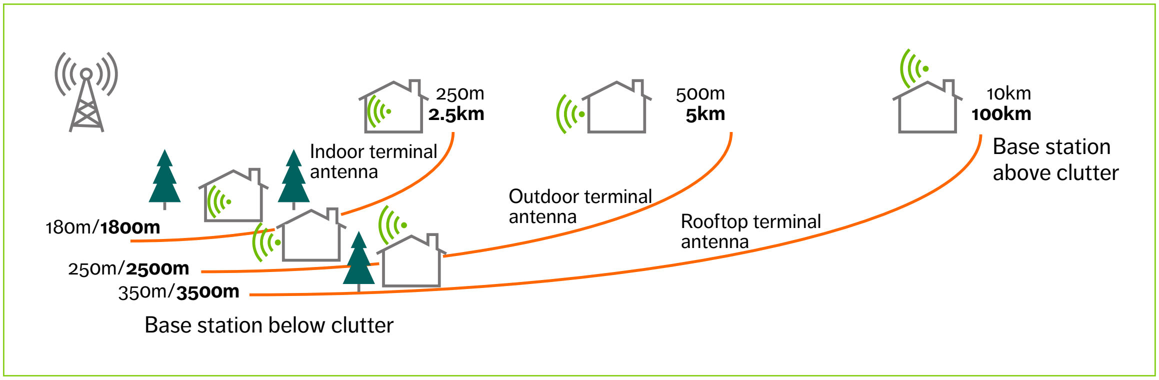

Figure 7 Key findings on FWA feasibility for different scenarios and frequencies (3.5GHz cell ranges appear in bold text and 28GHz cell ranges in plain text)

of 800Mbps. Only 11 percent of them had a data rate of below 400Mbps and all of them had the targeted 15Mbps.

When the traffic load increases in this scenario, user data rates decrease owing to greater interference and queuing. *Figure 5* shows the proportion of users with data rates exceeding the required 15Mbps and 100Mbps, depending on the traffic load. The maximum traffic load in this scenario is 5200GB per month per subscription, with 95 percent of the users benefiting from a data rate that exceeds the targeted 15Mbps. This is equal to 1Gbps per site. Sixty nine percent of the users enjoy a data rate of more than 100Mbps at this high load level.

The results shown in Figure 5 are based on the use of rooftop antennas. However, it is possible to achieve similar results with wall-mounted and indoor antennas, but only for smaller cells, due to diffraction and indoor penetration losses.

Our research indicates that the optimal 5G FWA solution is likely to include hybrid terminal antenna placement, where only the users who are furthest from the base station use rooftop antennas, while those closer to it use outdoor wall-mounted or indoor alternatives. The percentage of households using each of the three antenna placement variations is illustrated in *Figure 6*. The results show that for an inter-site distance (ISD) of 350m, 78 percent of the households can use indoor antennas (usually integrated into CPEs), whereas the rest should rely on either outdoor wall-mounted antennas (17 percent) or rooftop-mounted antennas (5 percent) to achieve better propagation conditions.

We made similar analyses for other combinations of frequency bands, environments and terminal antenna placements. *Figure 7* provides a summary of a selection of these, focusing on the 3.5GHz and 28GHz frequency bands. While these two bands are by no means the only frequency options for FWA, they are good examples of low and high frequency FWA solutions that can provide insight in terms of the feasibility and usability of FWA for different applications and services.

The key performance findings for both 3.5GHz and 28GHz are encouraging. As expected, 3.5GHz provides very good mobile coverage, allowing longer reach compared with the 28GHz band. Although the available bandwidth is smaller

> THE ABILITY TO USE SOFTWARE TO DYNAMICALLY CONFIGURE CORE AND SERVICE NETWORKS ALSO PLAYS AN IMPORTANT ROLE IN GENERATING THE FLEXIBILITY REQUIRED TO ENABLE THE DEPLOYMENT OF FWA SOLUTIONS ON A TRULY CONVERGED MOBILE AND WIRELINE HARDWARE INFRASTRUCTURE

at 3.5GHz, the use of massive beamforming and MU-MIMO provides very high cell spectral efficiency, making this band a great candidate for delivering video services. Moreover, this band can be used to deliver basic home broadband connectivity – as an outside-in MBB available to indoor users, for example – which would make it easier to realize the vision of connecting the billions of unconnected people in rural and remote areas.

With 28GHz, the achievable cell ranges are much lower owing to worse propagation conditions, and they strongly depend on the environment or terrain in which the system operates. The most important factors affecting the feasible ranges are:

- the placement of the terminal antenna
- the height and density of the trees and buildings
- the height of the base station antenna placement.

Since the 28GHz band is more sensitive to building penetration and diffraction losses, rooftop placement of the terminals provides the largest range due to higher line-of-sight probability between the terminals and the base station. Use of outdoor wall-mounted and indoor terminals reduces the ranges significantly.

It is critical to consider the propagation effect of foliage on the cell ranges at 28GHz. Deploying the base station antennas at a height greater than that of the tallest trees in the area significantly boosts the cell ranges. In terms of capacity, the availability of larger bandwidth and the possibility of utilizing a large number of antennas for massive beamforming enables very large cell capacity at 28GHz. These factors make the 28GHz band suitable for fixed wireless service in dense suburban and urban areas.

Several options for FWA transport

FWA poses new challenges in providing cell site connectivity. Compared with conventional macro deployments, FWA may require 10 times more cells and cell site connections, putting significant strain on the backhaul network. As shown in

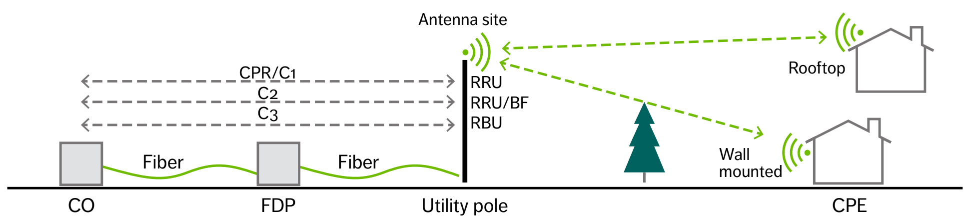

Figure 8 Schematic figure of FWA showing CPE, antenna site, FDP and CO

RAN split	Parameters that determine capacity (antenna configuration, user traffic and so on)	Required transport capacity per site
CPRI (4G)	Bandwidth, SNR (quantization, reach), number of antennas, traffic load, overhead	40-100Gbps
C1 – Evolved CPRI Any form of digital time-domain radio carrier and beamforming weight representation in 5G, including compression	Bandwidth, SNR (quantization, reach), number of antennas, traffic load, overhead	40Gbps
C2 – Split-PHY (lower stack split) Digital frequency domain radio signal and weight representation	Bandwidth, SNR, number of layers, traffic load, overhead	10-25Gbps
C3 – MAC-PHY split (higher stack split) Digital MAC bearer and state representation	Bandwidth, SNR, number of layers, traffic load	5-10Gbps

Figure 9 Table showing interface capacities of different RAN splits

Figure 7, the required ISD varies from several hundred meters to a few kilometers depending on the actual 5G radio deployment.

With 5G, several functional splits have been proposed to enable new scenarios for the deployment of RAN functions across sites [4]. Three of these – C1, C2 and C3 – are shown in *Figure 8*. The specific requirements on the transport network depend on how the RAN is deployed and which interfaces are carried over the transport network.

Generally, FWA deployment requires the use of advanced array antennas to support MU-MIMO and beamforming for the required capacities and peak rates of residential access. This in turn determines the interface capacities of different RAN splits, as shown in *Figure 9*.

In the FWA use case we have presented here, each cell site (utility pole) serves approximately

25 customers, resulting in user data bandwidth requirements per utility pole of 5Gbps at peak rate and 1Gbps sustainable rate. For lower splits such as CPRI, the antenna configuration in FWA would require very high transport bitrates, which is not feasible in the access segment. Instead, splits higher up in the layers are more likely (MAC-PHY, for example) where transport bitrates can be kept below 10G per site.

Compared with fixed access systems, the fan-out requirements for FWA transport solutions are lower, while requirements on capacity are higher. The requirements on latency and jitter are also more stringent. The densification of cell sites required by FWA means that the transport solutions may need to provide connectivity to 10 times as many sites as in today's mobile deployments. This is still just a fraction of the number of connections needed in fixed wireline access deployments, though.

The choice of optimal transport solution depends on factors such as available copper/fiber infrastructure and site structure. A range of possible transport solutions (both optical and wireless) that could support FWA are listed in *Figure 10*.

Enabling technologies

The 5G FWA concept will only become stronger and more flexible as a result of the family of enabling technologies that is currently being incorporated into implementations of various portions of 5G systems, including:

- 5G and 4G RAN [4], which will increase deployment flexibility and network scalability – necessary for meeting a wide variety of coming performance requirements
- core networks [5], with a focus on software-defined networking and virtualization to provide elastic connectivity
- next generation central offices (NGCOs) [6], which will be able to provide the necessary facilities (such as mini data centers) required to meet fixed and mobile service and infrastructure convergence challenges.

Taken together, these new attributes of next generation mobile networks will provide a very potent toolbox to meet future FWA needs.

A split 5G and 4G RAN architecture is of particular significance when building FWA solutions because it makes it possible to place functions (including those in the RAN) dynamically across the access network to fulfill various needs. Functional node types execute on pools of hardware with both special and general purpose processors. This provides the necessary flexibility to adapt networks to future capacity, latency and other needs, such as supporting future virtual and augmented reality applications in homes.

The ability to use software to dynamically configure core and service networks also plays an important role in generating the flexibility required to enable the deployment of FWA solutions on a truly converged mobile and wireline hardware infrastructure. This means that features, functions and operational capabilities conceived for mobile networks can also be used for FWA where appropriate. Solutions like blind cache [7] for optimized content delivery, models for network sharing, and unbundling via Mobile Virtual Network Operators (MNVOA) and other approaches are just a few examples.

Conclusion

Key technology enablers such as beamforming and new frequency bands, in combination with advances in mobile back and front hauling, network virtualization and network programmability, are strengthening the FWA concept significantly. While the exact characteristics of any FWA deployment are case specific, our research suggests that 5G-based FWA is definitely an option to fulfill the advanced future service requirements of the homes and SMEs of tomorrow in many types of environments around the globe.

With 5G, we have the opportunity to achieve true network convergence, since the same technology and indeed the same infrastructure can be used to provide next generation MBB, IoT and FWA.

	Solution	Advantages and disadvantages
Optical systems	P2P fiber (grey optics)	⊕ Low-cost optics and support for high capacity and low latency ⊖ Requires fiber-rich deployment
	TWDM-PON (such as XG-PON, NG-PON2, GE-PON)	⊕ Low-cost potential and potential system reuse between FWA and FTTH clients ⊖ Limited capacity (≤10G) and limited low latency support, limiting possible RAN deployment options (functional splits, RAN coordination) and RAN services (low latency services)
	WDM-PON (such as WS-WDM-PON, WR-WDM-PON)	⊕ Dedicated solution for RAN transport where optical distribution network (ODN) deployment can be tailored for desired RAN deployment ⊖ Limited reuse of potentially existing FTTH infrastructure and potential issues for future migration of customers (individuals or groups) to FTTH, which then requires a separate ODN. Low fan-out of typical scenarios limits need for dense WDM (CWDM is sufficient)
	P2P WDM overlay (such as NG-PON2)	⊕ Reuse of potentially existing fiber plant for providing P2P connections for mobile transport. Support for high capacity and low latency ⊖ High costs and footprint associated with ODN filters
Active systems	Ethernet (such as for CPRI over Ethernet), OTN	⊕ Reuse of existing infrastructure suitable for active network deployment ⊖ Deployment options (RAN splits) practically limited by deployed active equipment (capacity and protocol support)
Wireless systems	In-band wireless (5G, LTE)	⊕ Low-cost deployment ⊖ Spectrum is shared between access and transport (less overall capacity or more spectrum needed)
	Out-of-band wireless (MW, FSO and so on)	⊕ Low-cost deployment compared with fiber but more effort needed compared with in-band ⊖ Dependent on solution or spectrum, whether or not licensed spectrum is needed, sensitivity to weather conditions and so on

Figure 10 Possible transport solutions for FWA

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Further reading

- **Ericsson 5G PlugIns, Enabling the evolution:**
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- **The Connected Building – Microwave to and between buildings :**
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