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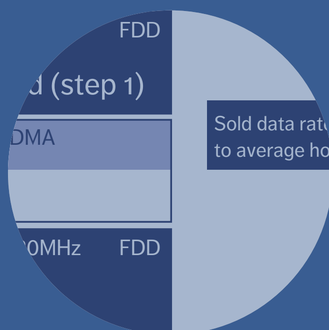
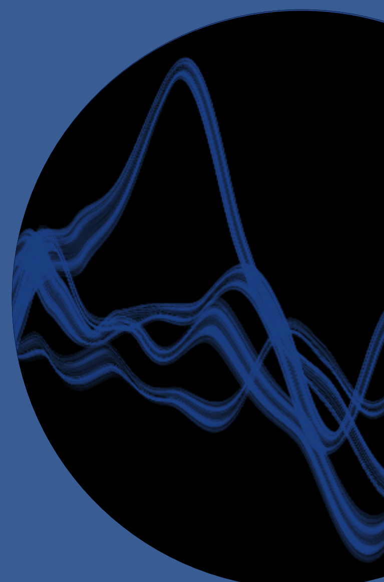
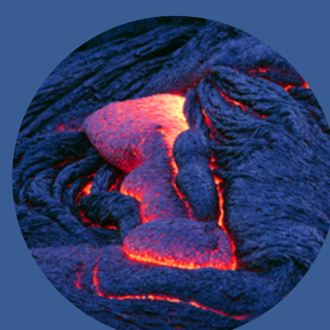




FIXED WIRELESS ACCESS IN LTE AND 5G



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LEVERAGING LTE AND 5G NR NETWORKS FOR

Fixed wireless access

Globally, there is a huge underserved market for broadband connections, with more than one billion households still unconnected. The growth in high-speed mobile broadband coverage enabled by LTE and 5G New Radio is opening up much more commercially attractive opportunities for operators to use fixed wireless access to deliver broadband services to homes and small and medium-sized enterprises.

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Unlike the country-wide decisions typically made for mobile broadband (MBB), decisions about fixed broadband and targeted fixed wireless access (FWA) deployments tend to be made at the local market level, and operators have a critical role to play. A number of different drivers govern local market attractiveness, as outlined in Ericsson's recently published FWA handbook [1].

■ We have organized the FWA market opportunities into three distinct segments that we call 'Wireless Fiber', 'Build with Precision', and 'Connect the Unconnected'. Each of these has different characteristics mainly based on the offering, the availability of fixed access and the corresponding average revenue per user (ARPU) that can be expected from customers [1]. The Wireless Fiber segment consists of those cases in which there is a need for very high-rate offerings and capacity as a direct alternative to high-end fixed broadband. The ambition is to provide fiber-like speeds and handle households' TV needs, matched with a correspondingly high ability to pay. Typical sold date rates are 100 to 1,000+ Mbps and monthly ARPU levels of USD 50-100. The FWA sweet spot for this segment is typically suburban environments.

The Build with Precision segment is comprised of those cases where there is competition from performance-limited fixed broadband alternatives, such as xDSL. Here, the need is for high data rate and capacity, with a corresponding level of ARPU. Typical sold data rates are 50 to 200Mbps and monthly ARPU levels are around USD 20-60. The FWA sweet spot for this segment is in suburban or rural villages or towns that are currently underserved. Some more sparsely populated areas are also addressable.

The Connect the Unconnected segment is made up of cases in which fixed broadband competition is virtually non-existent, and smartphones that use MBB are the dominant way of accessing the internet. User expectations of access speed are relatively low. Typical sold data rates are 10 to 100Mbps and monthly ARPU levels are around USD 10-20. Even though ARPU levels are limited in this segment, it has a FWA sweet spot that stretches from urban environments to rural villages, due to limited investment needs.

Subscriptions, data rates and consumption

The paradigms for fixed broadband and MBB are different, both in terms of subscription offerings and dimensioning. Fixed broadband subscriptions tend to focus on maximum data rates that are achieved under normal circumstances – that is, at low to medium load. The user traffic is often shaped so that it does not exceed the sold data rate. Hence, for fixed broadband, the sold data rate is the normal value that household subscribers relate to.

By contrast, for MBB, 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 MBB, monthly data buckets are the normal subscription value that mobile subscribers relate to.

Terms and abbreviations

ADSL – Asymmetric Digital Subscriber Line | **ARPU** – Average Revenue per User | **CAT** – Category (in LTE) | **CPE** – Customer Premises Equipment | $\mathbf{d_{av}}$ – Average Busy-hour Data Consumption | **DL** – Downlink | **DSL** – Digital Subscriber Line | **FDD** – Frequency Division Duplex | **FWA** – Fixed Wireless Access | **MBB** – Mobile Broadband | **MIMO** – Multiple-input, Multiple-output | **mmWave** – Millimeter Wave | **NR** – New Radio | $\mathbf{R_{min}}$ – Minimum Data Rate | **TDD** – Time Division Duplex | **Tx/Rx** – Radio Transmitter/Radio Receiver | **WCDMA** – Wideband Code Division Multiple Access | **xDSL** – DSL family (e.g. ADSL)

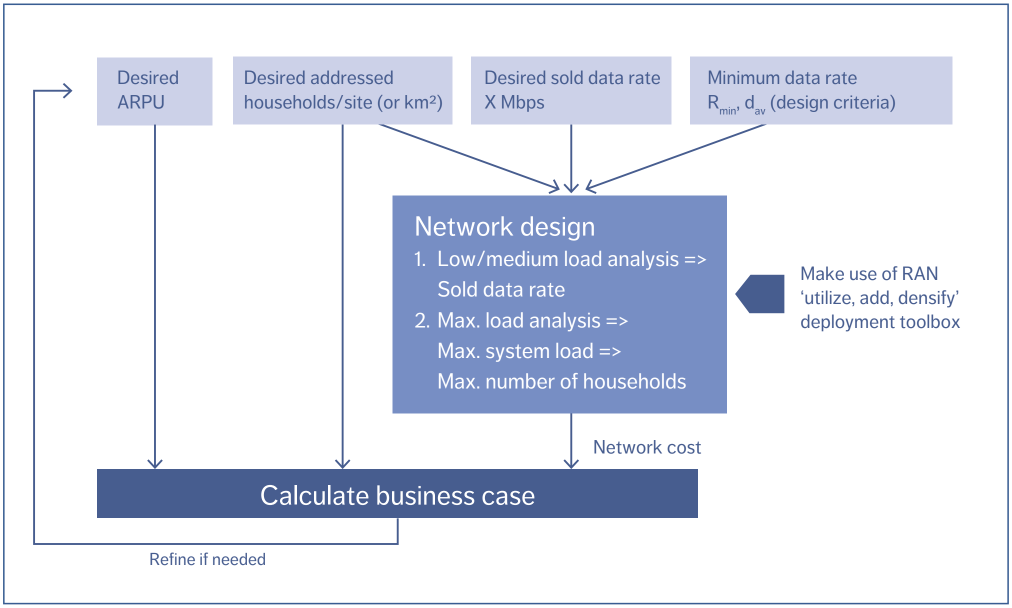

Figure 1: FWA deployment analysis flow

It is important that both consumers and operators (fixed and mobile) understand this crucial difference. Our view is that FWA will inherit the subscription paradigms of fixed broadband rather than those of MBB. That is, households should pay for FWA on the basis of data rate and not be concerned about data consumption.

Last-hop dimensioning

In FWA the last hop is wireless, so all the characteristics of a wireless network apply to the dimensioning. Unlike fiber, but similar to digital subscriber line loop length, there will be varying connection quality to different households. And, unlike fixed broadband overall, the last hop is radio and therefore shared, which means that speeds will degrade with increasing network load. All these characteristics must be taken into account when dimensioning an FWA network. Further, since Ericsson promotes the sharing of assets with MBB (when available), we recommend that FWA is brought into general RAN dimensioning.

Note that for fixed broadband, FWA and MBB 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 short, while FWA will inherit the subscription paradigm of fixed broadband, due to the radio properties of the last hop to households, it must use modified dimensioning methods and terms from the MBB paradigm.

Figure 1 illustrates a typical FWA analysis flow. It starts with input on the subscription and offering, including dimensioning criteria, which triggers a selected, maximally efficient network design that depends on the offering ambitions and network starting point. A business case can be calculated by balancing the resulting cost items of the deployment with the extra revenues foreseen.

FWA toolbox

An existing mobile radio network, normally designed for voice and MBB, 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, MBB and FWA.

These tools fall into three main categories: utilize, add and densify. The particular needs of each local situation can be met by deploying a well-planned mix of these tools.

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 competitors 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 not to utilize existing assets built for voice and MBB, the number of economically viable local areas for FWA will be smaller, and the operator risks facing unnecessary competition with standalone FWA providers.

The radio network assets that should be utilized include existing radio sites, spare capacity in deployed spectrum (including associated equipment), and acquired but undeployed spectrum. Existing radio sites are critical assets, whether they are operator-owned or rented. The 'tool' of utilizing existing sites is not used by itself, but in combination with other actions to make those more cost-efficient. Spare capacity in deployed spectrum and associated deployed radio, baseband and transport network equipment is quite common in FWA target areas, and making use of it requires no new capital expenditure. Acquired but undeployed spectrum is also common in FWA target areas, which makes radio deployment in new bands possible without the cost of acquiring new spectrum. The geographical fit for FWA is excellent, since FWA targeted areas are often suburban and rural, where unused spectrum is most prevalent.

Add radio network capabilities

In an MBB RAN, radio capabilities are continuously added to handle more traffic, more customers and better app coverage. To handle FWA as an extra service, some of these additions may have to be made sooner to achieve a combined network with sufficient capabilities.

An existing mobile operator has the significant advantage of being able to add the following radio network capabilities and co-finance them for MBB and FWA:

- Spectrum – upcoming wide spectrum bands in 3-6GHz and millimeter wave (mmWave) open up potential for providing high data rates and capacity, benefiting both MBB and FWA
- Higher-order modulation, multiple-input, multiple-output (MIMO) and beamforming – offering the potential to squeeze out the most from each spectrum band
- FWA-tailored software features – to enhance performance for FWA users and to provide adequate quality to MBB and FWA in shared deployments
- Additional sectors on existing sites
- 5G New Radio (NR) access – designed for low latency and for wide spectrum bands, creating an excellent overall network together with LTE.

> THE ABILITY TO UTILIZE EXISTING RADIO NETWORK ASSETS IS A FUNDAMENTAL ADVANTAGE

Densify the radio network grid

When the 'utilize' and 'add' tools have been used to their full potential, densification can offer further gains. In these cases, MBB enhancements tend to be necessary as well, so the upgrade needs of MBB and FWA should be considered together and the densification of the network should be co-financed.

The two options for densifying the radio network grid are macro site densification and small cell site

> QUALITY ACROSS BOTH SERVICES IS ENSURED THROUGH EXISTING SOFTWARE FEATURES

densification on poles. Macro site densification is an opportunistic approach: where new macro sites can be found, such opportunities can be taken. Small cell site densification on poles may be necessary if the macro grid is sparse and performance requirements are high.

Spectrum sharing across MBB and FWA

Sharing spectrum across FWA and MBB enables significant gains in overall spectral efficiency because higher utilization is possible with one 'bigger pipe'. This is explained by the trunking gain effect, which has been known and used in mobile systems since their infancy, all the way from voice channel capacity to LTE carrier aggregation for MBB. It is also applicable to FWA.

The logical consequence of this is that spectrum assets should be shared as one pool, employing carrier aggregation for LTE and dual connectivity for LTE/NR to ensure that all resources are utilized to the maximum, while securing good user experience for both MBB and FWA. Quality across both services is ensured through existing software features such as RAN slicing.

By contrast, any artificial split of spectrum resources for different services would result in under-utilization of the spectrum assets.

Performance differences of FWA CPE types

Using FWA to deliver broadband services requires new FWA customer premises equipment (CPE), from simple indoor nomadic devices to fixed outdoor-installed units, provisioned through standard device retail or new methods. A 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 that generally have limited integration with cellular networks, meaning that the operator can acquire best-of-breed products and expect them to work using standard protocols. The biggest difference between the CPE alternatives is the ability to achieve promised service levels, especially during busy hours.

An outdoor CPE provides the best performance, as it has a built-in directional antenna (3.5GHz, 10-14dBi) and is installed with a predictable radio link quality to the selected base station. The typical antenna configuration has two Rx antennas, but devices with four Rx antennas are also available. The normal transmission mode is rank-2 MIMO, as the modem is expected to be installed with good line-of-sight. Most outdoor LTE devices support CAT 6 and 20+20MHz carrier aggregation but more advanced devices up to CAT 16 support are also available. Inter-band carrier aggregation between FDD and TDD is especially useful, as services can be started on existing FDD bands and later expanded as FWA subscribers and traffic increase.

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

Whereas an indoor CPE is comparable to a smartphone in terms of spectrum efficiency, an outdoor CPE is two to three times more efficient. To put it another way, for the same data consumption, around two to three times as many households can be served using outdoor rather than indoor units – or 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 five-percentile users is significantly lower.

In terms of performance, indoor CPE units normally start with CAT 6 capabilities of up to 300Mbps. More advanced devices could support CAT 16 up to 1Gbps and offer rank-4 MIMO. More advanced CPE architectures are also being discussed, such as a split design, where an outdoor window antenna is connected to an indoor unit via induction through the window glass.

Case study: the country town

The country town example represents a market within our Build with Precision segment, characterized by relatively mature LTE MBB and decent fixed broadband offerings, complemented by terrestrial or satellite broadcast services to meet households' linear TV needs. The typical monthly ARPU for MBB is around USD 20, and the predicted willingness to pay is USD 40 for a dedicated household FWA internet service with a sold rate of 50-200Mbps and unlimited data.

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. In contrast to the extensive upfront investments required in a fiber deployment, the ability to design and invest for a limited market share from the beginning and expand later as the subscriber base grows is a useful property of FWA.
- There is no ambition to offer IPTV over FWA, as household TV needs are assumed to be served by satellite or terrestrial access.
- The dominant use case is meeting all the households' internet needs.
- For video streaming support, households should, when needed, experience at least a minimum data rate (Rmin) of 10Mbps even during busy hours. This corresponds to one high definition TV video stream, with some margin, or a combination of multiple standard definition TV streams.
- Based on the operator's experience from similar FWA areas, the average household's consumption during busy hours is 0.9GB/h, corresponding to an average data flow of 2Mbps during busy hours. With the assumption that 10 percent of data is being consumed during busy hours, this would correspond to 270GB per month.

Network starting point

Coverage is provided by a macro network with three-sector sites and an inter-site distance of about 1km. The operator has access to six FDD bands: three bands below 1GHz (typically 700, 800 and 900MHz), and three bands in the 1-3GHz range (typically 1,800, 2,100 and 2,600MHz). The MBB traffic in this area is handled using a subset of the available bands. The majority of smartphones are LTE-capable, and there is also GSM and WCDMA coverage to handle simpler phones. A typical macro site has two LTE carriers (800 and 1,800MHz) as well as a WCDMA carrier in the 2,100MHz band, and a few GSM carriers in the 900MHz band.

High-level analysis [2] has shown that the deployed LTE capacity in western and central Europe is less than 40 percent utilized, given the LTE smartphone subscriber density in the area. This means that there is spare radio capacity that can be utilized by FWA.

> “THE ABILITY TO DESIGN AND INVEST FOR A LIMITED MARKET SHARE... IS A USEFUL PROPERTY OF FWA”

Overall solution

We recommend utilizing the existing sites, radios and baseband deployed to provide MBB, and sharing these resources across FWA and MBB users. Current deployments have spare capacity both in LTE carriers and in baseband units. In addition, we recommend utilizing the acquired

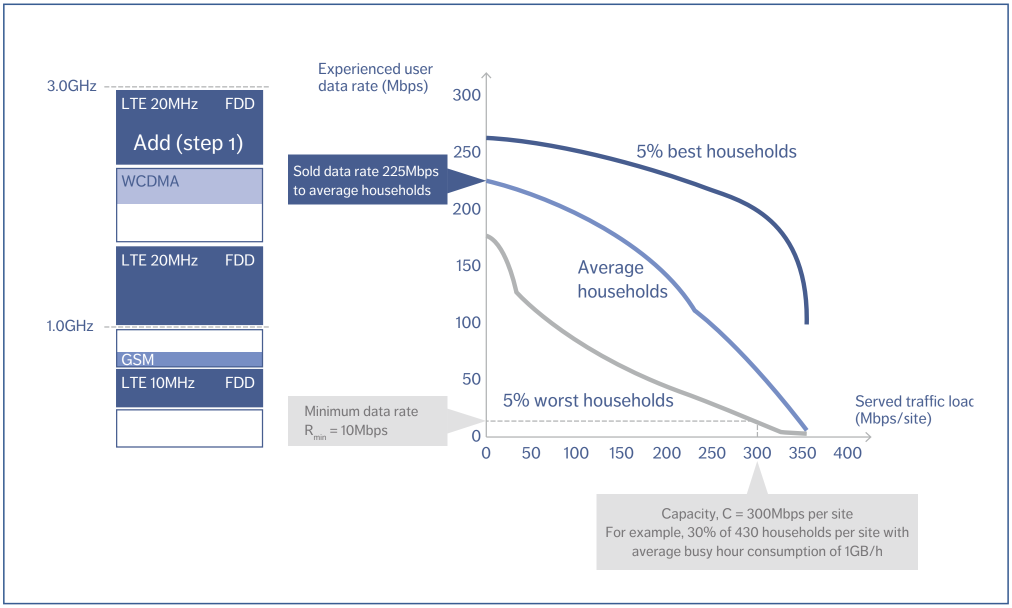

Figure 2: Performance and spectrum use of FWA deployment step 1

but undeployed band below 3GHz (such as 2,600MHz), with a new 2 Tx/Rx radio, together with the existing LTE bands by means of carrier aggregation for both FWA and MBB. Carrier aggregation improves peak speeds as well as coverage for both services. The left side of *Figure 2* shows the spectrum use of the FWA deployment at this first step deployment. A RAN slicing feature can be applied to ensure that there is no negative impact on MBB services (and vice versa) during peak loading as a result of FWA and LTE users sharing the same carriers.

There is no need to densify the network in this case. With regard to CPE choices, we suggest using high-end 4 Rx outdoor (roof-top mounted) CPE, as FWA speeds need to be high in this case to compete with xDSL services in the area. Indoor CPE may be deployed as a complement for households where their performance is acceptable.

Performance analysis

Although MBB and FWA services share spectrum in the country town case, to simplify the presentation of the performance analysis, our evaluation only shows FWA. Further, we have chosen to focus on the downlink (DL) because the FWA traffic (and broadband traffic in general) is DL-heavy and so capacity is DL-limited.

The performance is illustrated in Figure 2. The experienced DL data rate for a specific household depends on its location, as with xDSL services, and may be up to 270Mbps in this scenario. An average household would experience around 225Mbps at low system load. This could be used as the sold data rate to a typical customer.

Note however that, unlike MBB, where users move around and experience both good and bad radio environments, in this scenario the CPE is fixed and variation in the radio environment is smaller,

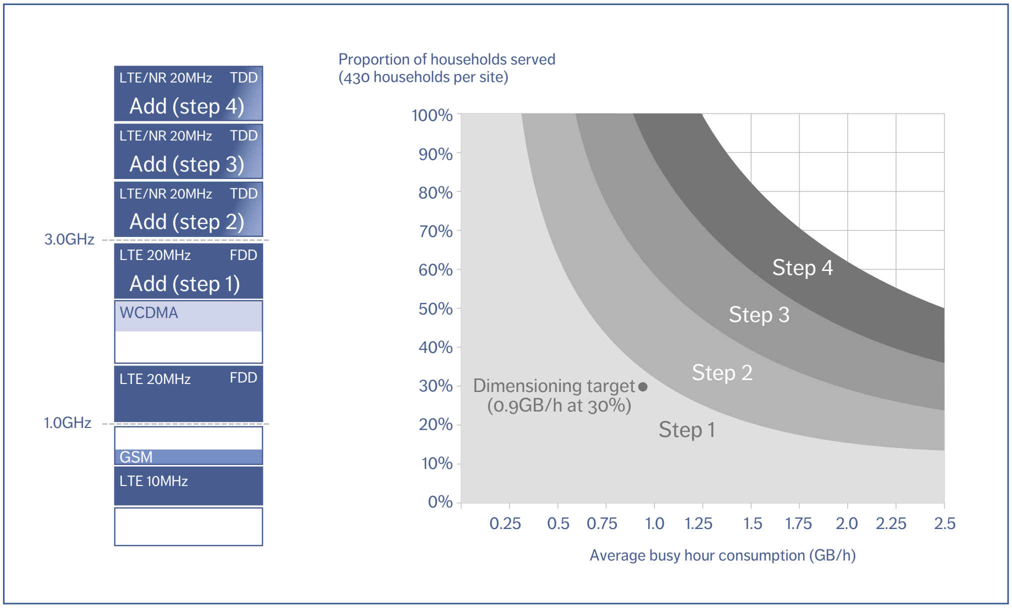

Figure 3: FWA deployment solution evolution to steps 2-4: spectrum use and performance

meaning that households with worse radio environments will likely always have worse than average data rates. In this scenario, the five percent worst-performing households experience close to 175Mbps at best. Therefore, it may be worth considering having different subscription categories; it may not be possible for all households to subscribe to the higher service level.

To dimension the system, the Rmin is set to 10Mbps. This means that the five percent worst-performing households should experience at least 10Mbps DL data rate during busy hours. This results in a capacity of 300Mbps, or 135GB/h, per site. As long as the total traffic in all three sectors does not exceed 300Mbps, the Rmin requirement will be fulfilled.

Assuming there are 500 households per square kilometer, and an inter-site distance of 1,000m, an FWA market share of 30 percent corresponds to some 130 households per site. At 135GB/h capacity, this market can be served with an average busy hour consumption of slightly above 1GB/h – that is, above the dimensioning target of 0.9GB/h (2Mbps). In addition, MBB will benefit from the additional 20MHz spectrum, for example in terms of increased peak rates.

Solution evolution

It is important that the solution is future-proof and can evolve to handle more connected households and higher demand per household over time. To provide higher capacity and cope with greater demands, operators can acquire and add a new TDD band above 3GHz (such as 3.5GHz) using 8 Tx/Rx advanced antenna system radios. The multi-user MIMO feature can be activated to provide additional capacity. *Figure 3* illustrates how additional capacity can be provided in several evolution steps.

Initially, the system is dimensioned to serve 30 percent of households with an average busy hour consumption of 1GB/h. The area of the graph in Figure 3 marked as Step 1 indicates the possible combinations of percentages of households and average busy hour consumption for this solution.

The area of the graph that is marked as Step 2 indicates the capacity provided by an additional 20MHz. This shows that the system can serve a customer base of 30 percent with an average busy-hour consumption of 1.9GB/h. Alternatively, the higher capacity can be used to serve an increased market share (up to 58 percent) with an unchanged average busy hour consumption.

Increasing the bandwidth with another 20MHz of TDD spectrum provides a system capacity represented by the area marked Step 3 in the graph. This will serve 30 percent of households in the area with an average busy-hour consumption of 3GB/h. Again, the higher capacity could instead be used to serve an increased market share with an unchanged average busy-hour consumption, or a combination of increased market share and increased average consumption.

Finally, Step 4, the darkest grey area of the graph in Figure 3, indicates what can be achieved when a total of 60MHz of TDD spectrum is added beyond Step 1. Assuming a 30 percent market share, an average busy-hour consumption of up to 4.1GB/h can be met (outside graph range).

In summary, by using the FWA toolbox and limited initial investments, and then adding TDD spectrum as needed, the chosen deployment is able to support high data rates and consumption immediately at launch. Then, through a series of smooth solution evolution steps, capacity can grow to more than four times the initial offering.

Conclusion

The large number of underserved households around the world represents a profitable FWA growth opportunity for current 3GPP operators. Mobile-only operators can explore a new business opportunity with FWA, and converged operators can add FWA as a complement to their fixed broadband strategy for certain locations as a more cost-efficient solution with faster time to market. Segmented solutions are needed, with subscriptions and dimensioning based on fixed and mobile paradigms. We believe that the best way to deliver future-proof broadband solutions is based on the evolution of LTE and 5G NR, and that the most promising approach is shared investment using the same ecosystem, assets and spectrum bands for both MBB and FWA.

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Further reading

» **Ericsson Technology Review, Fixed wireless access on a massive scale with 5G, 2017, Furuskär A; Laraqui, K; Nazari, A; Skubic, B; Tombaz, S; Trojer, E, available at:** *https://www.ericsson.com/assets/local/publications/ericsson-technology-review/docs/2017/2017-01-volume-94-etr-magazine.pdf*

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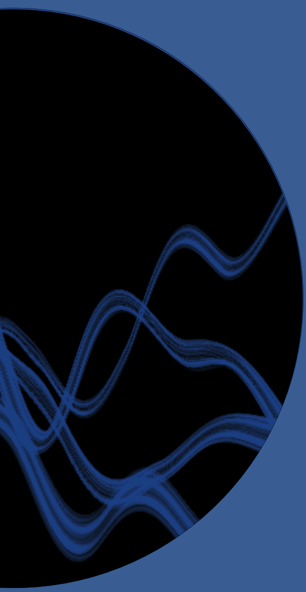

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