5G Fixed Wireless Access for Broadband Services: an Operator's Perspective

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Abstract *Fixed Wireless Access has emerged as a major 5G use case and one of the fastest growing broadband services. We discuss its capabilities and performance, compare it with other fixed access technologies, review the role of optical technologies in FWA, and explore future directions.* ©2023 *The Author(s)*

Introduction

Traditionally, broadband access is provided by digital subscriber line, cable, optical fiber or cellular technologies. With the mass 5G deployments in recent years, fixed wireless access (FWA) technology has become the fastest growing broadband service to both residential and business customers. As of March 2023, the total number of Verizon's FWA subscribers approached 2 million. This number is expected to grow to up to 5 million in 2025, with 50 million households and 14 million business locations passed. The global 5G FWA market size will potentially expand from $700 million USD in 2020 to $23.3 billion USD by 2025, at a CAGR of 97.4% between 2021 and 2025 [1].

As a relatively new offering in Verizon's broadband product portfolio, FWA complements the company's existing cellular, FiOS (fiber-to-the-x), wireless xHaul transport, and enterprise services. All these services are supported by one unified architecture, called the intelligent Edge Network (iEN), designed to optimize network flexibility, resiliency, and cost effectiveness [2].

In this paper, an overview of FWA – its capabilities, deployment status, and challenges is first provided. It is followed by discussions of optical access technology and standards supporting wireless xHaul transport. Verizon's requirements and network architecture of broadband access are described. Finally, a vision of converged wireline wireless network using a common 5G core is explored before the concluding remarks.

Overview of Fixed Wireless Access

FWA is a generic terminology implying non-mobile broadband internet access for services provisioned over the mobile spectrum. A *fixed* access gateway unit with line of sight to a cell site is installed at a customer premise. The unit provides *wireless* connectivity to and throughout the premise. While FWA is not a new technology, it is experiencing rapid growth in North America as more wireless spectrum has become available. As spectrum is a very valuable and expensive resource, it is very important to share the resource across multiple business models (e.g., fixed, mobile, IOT, slicing) in order to maximize the return of investment.

FWA has enabled mobile network operators to make efficient use of the available 5G spectrum, in particular in the high-band (>7 GHz) and mid-band (1-7 GHz) frequencies, to offer both mobile and fixed broadband access services. Note that as defined by 3GPP, the 5G frequency bands consist of two ranges (FR): FR1 (400 MHz to 7.1 GHz) and FR2 (>7.1 GHz). Mid-band is the upper portion of FR1 [3].

In addition to leveraging the 5G spectrum capital assets, another consideration is to share the 5G core (5GC), gNodeB, transport hardware and operational expenses across both fixed and mobile services. All these resource sharing can ultimately lead to lower prices to consumers.

FWA has inherent disadvantages and advantages compared to fiber access. Its capacity is limited by spectrum availability and can fluctuate when mobile subscribers move in and out of particular cell coverage areas. Similarly, hybrid fiber coaxial (HFC) networks have limited bandwidth for broadband services because a large portion of the RF spectrum on the coax infrastructure is used for broadcast video and video-on-demand services, and are especially constrained in upstream bandwidth. Optical fiber access, in particular, passive optical network (PON), can provide the highest capacity.

From the operational perspective, FWA can be more survivable compared to Fiber or HFC access. This is because FWA is not subject to physical cuts due to constructions, car accidents, or other factors.

Another operational aspect is related to power sources. FWA and fiber access can both withstand power outages because there is generally backup power (generators and battery) at macro cell sites and central offices. In contrast, providing backup power can be challenging in HFC because of the many active components (e.g., optical nodes, amplifiers) in the field. Compared to mobile access, FWA also has better access to uplink power source because user equipment can be readily connected to traditional AC outlets.

FWA has emerged as one of the key early use cases for 5G technology. As discussed earlier, it is primarily enabled by significantly higher bandwidth in 5G deployments. For example, Verizon deploys 5G services using the C-band spectrum at 3.7-3.98 GHz and mmWave at 28 and 39 GHz.

As of 1Q2023, Verizon covers a total of 200 million populations in the U.S. with its C-Band deployment. By the end of 2023, the available C-Band bandwidth will expand to an average of 160 MHz. Currently, Verizon's FWA service offers up to 1 Gb/s peak (300 Mb/s sustained) downlink and 50 Mb/s peak (30 Mb/s sustained) uplink bandwidth. With standalone 5G Core deployment, increased capacity and additional services such as slicing and voice over 5G network can be available.

The available capacity of FWA depends upon many factors, not just the usable frequency bands. Factors, such as time of day, user demand, duration of user connection, and mobile usage, all impact the capacity available for FWA. Figure 1 shows a typical usage distribution for mobile and FWA over a 24-hour period. As can be seen in the figure, peak FWA usage is in the evening, similar to fixed access usage pattern, and does not overlap with the peak mobile usage.

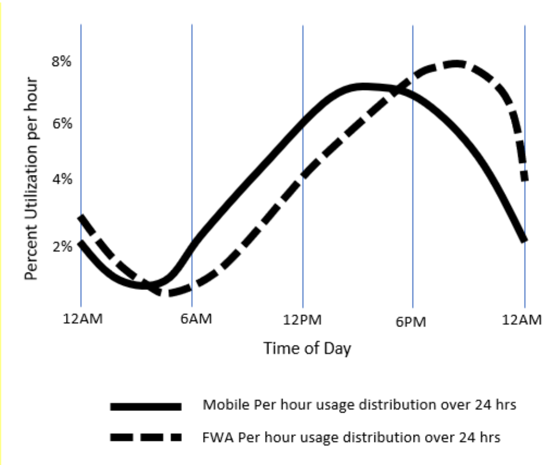

Fig. 1 FWA and mobile usage distribution

Optical access technologies for FWA

The use of wider spectrum at mid-band and mmWave drives the corresponding evolution in 5G xHaul transport technologies. Currently, optical technologies for 5G xHaul include 10 and 25 Gb/s PtP Ethernet over fiber, 25 Gb/s WDM links, as well as multi-gigabit PON infrastructure. Requirements for future evolution are discussed in the next section. Notably, the use of PON infrastructure enables scaling to much denser 5G deployment using mmWave technology.

Even though the upstream bandwidth is generally limited in 5G deployments, this has not been a major issue with FWA broadband service over 5G infrastructure. This is because most Internet applications, especially video streaming, use significantly more bandwidth downstream than upstream. Typically, the average downstream bandwidth utilisation during peak periods is 5-10 times of upstream bandwidth for broadband services.

One might ask why optical links capable of tens and hundreds of Gb/s line rates should be necessary to support merely 300 Mb/s downstream and 30 Mb/s upstream user traffic. This is because the CPRI fronthaul transport protocol requires the capacities being continuously provided without interruption and with very low jitter. The industry has since adopted a functional split architecture and the eCPRI protocol, which allows the fronthaul transport bandwidth to vary with the actual aggregated user traffic on the air interface [4]. Table 1 summarizes the bandwidth and latency requirements for 4G LTE and 5G fronthaul and midhaul transport.

Table 1 Wireless xHaul bandwidth and latency requirements

	Bandwidth (Gb/s)	Roundtrip latency
4G LTE CPRI fronthaul	~ 120	150 – 200 μs
5G CPRI fronthaul	80-300	150 -200 μs
5G eCPRI low layer split fronthaul	40 - 80	200 μs
5G mmWave midhaul	10 - 20	5 ms

In the ITU-T, several ongoing projects address the wireless transport networks: higher speed PON (G.9804.x) and bidirectional (BiDi) point-to-point (PtP) (G.9806) standards. The G.9804.x family Recommendations specify single wavelength 50 Gb/s (line rate) TDM-PON, and 50 Gb/s per wavelength TWDM-PON [5]. The G.9806 Recommendation and its follow-up amendments specify end-to-end BiDi PtP systems at 15, 25, 50, and 100 Gb/s line rates [6].

Aligned with the ITU-T G.9806 standards, the IEEE 802.3 working group has published 25 and 50 Gb/s BiDi PtP specifications [7] and is presently working on the 100 Gb/s system [8] for the PHY and MAC layers.

Network architecture for FWA transport

Designed as one unified network architecture for multiple broadband services, Verizon's intelligent edge network (iEN) provides the underlying transport infrastructure for multiple services. The iEN architecture comprises of both point-to-multiple and point-to-point optical fiber connectivities, supporting symmetric and asymmetric service rates in both the downstream and upstream transmission directions.

Point-to-multiple (PtMP) connectivity

The PtMP connectivity is typically provided by PON technology. In Verizon's case, the multi-wavelength NG-PON2 system [9] is being deployed to gradually upgrade legacy G-PON systems for Verizon FiOS (fiber-to-the-x) service. Future generation systems will continue to support deployed optical distribution network with 1x128 splits, asymmetric service rates of minimum guaranteed 40 Gb/s per wavelength channel in the downstream and TDMA in the upstream, optical path loss up to 31dB, fiber distance of 20 km for urban and suburban and 40km for rural deployment.

FiOS infrastructure can provide wireless xhaul transport in addition to residential broadband and enterprise Ethernet services.

Point-to-point (PtP) connectivity

Currently, Verizon wireless xHaul transport is supported by dual-fiber PtP connectivity. For the radio units (RU) using wireless mid-band spectrum, the current service rate is 25 Gb/s per fronthaul link with 12 strands of fiber connecting to each macro cell site. The link distance is typically 15 km. Future service rate of 50 Gb/s and 100 Gb/s are anticipated. Symmetric and constant service rate for downstream and upstream is required for frequency division duplex (FDD) and asymmetric for time division duplex (TDD). A maximum roundtrip latency of 200 μs is required.

For the midhaul link, where user traffic is asymmetric and selectable service rate is 10 and 25 Gb/s in downstream. The upstream service rate is typically budgeted to be one third of the downstream rate. Link distances can extend to tens of kilometres. The maximum roundtrip latency, 5 ms –much more relaxed than fronthaul.

For the backhaul link in Verizon's networks, the centralised unit (CU) and 5G core are collocated via direct fibre connection with service rate around or slightly higher than 10 Gb/s.

In the future, fronthaul and midhaul networks could benefit from bidirectional PtP connectivity for immediate fiber saving. Recently, coherent subcarrier multiplexing technology is being discussed to provide logical PtP service over a PtMP fiber infrastructure to further reduce fiber resources [10]. In the downstream, service rates of 50 and 100 Gb/s are desired in the future.

In addition, PtP connectivity can be used to support enterprise customers and 5GC network functions using symmetric and constant service rate. The service is expected to grow from the current 100 Gb/s dual-fiber deployments at 10-40 km to single fiber bidirectional at 400 Gb/s.

Future wireline wireless convergence

Following the iEN design concept, the potential of a common converged core for wireline and wireless networks is being studied. Such architecture may provide significant synergies in the network as well as enabling potential new service models.

Conceptually, as illustrated in Fig. 2, the convergence can be achieved by emulating the wireline access network (e.g., PON-based FTTx network) as a 5G RAN, both of which are connected to a single 5GC. This involves presenting the N1, N2 and N3 interfaces towards the access and management mobility function (AMF) and user plane function (UPF) in 5GC. A new access gateway function (AGF) in the wireline network would then be added to accomplish the convergence [2].

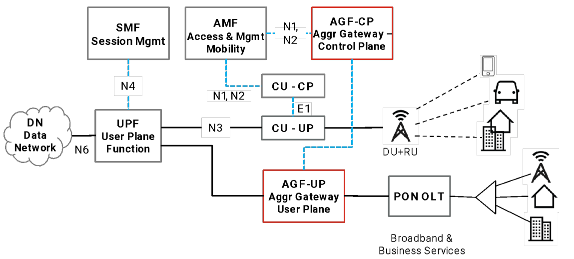

Fig. 2: Reference architecture of wireline network evolution towards 5GC [2]

The integration of the two networks opens up opportunities for consumers as well as business customers, whose wireline and wireless services are currently provided via separate networks. With a converged network, customers could access new services utilising multi-access edge computing and 5G network slicing, which offers reduced latency and different classes of services according to specific application requirements. Furthermore, for business customers, 5G access traffic steering, switching and splitting (ATSSS) capabilities can also be realized to provide redundant access models (e.g., using wireless and wireless access network for redundancy) for Ethernet and IP business services.

Conclusions

Fixed wireless access has emerged as a key 5G use case, adding to existing fixed access and cellular broadband service offerings. It enables network operators to share their 5G spectrum assets, hardware and operational expenses across fixed and mobile services. Although its capacity can be limited by spectrum availability and bandwidth usage of mobile subscribers, FWA has better survivability compared to other fixed access technologies. Point-to-multipoint and point-to-point optical technologies are essential to provide symmetric and asymmetric service rates for the underlying xHaul transport network. Finally, studies are ongoing to explore a common core for a converged wireline and wireless network to enable new service models.

References

[1] Zion Market Research report, Nov. 2022 https://www.globenewswire.com/en/news-release/2022/11/21/2560094/0/en/Global-5G-Fixed-Wireless-Access-FWA-Market-Size-to-Exceed-23-291-5-Million-by-2025-at-97-4-CAGR.html

[2] J. S. Wey, D. A. Khotimsky, M. T. Watts and R. Yadav, "Charting the future of optical access networks: an operator's perspective [Invited]," in *Journal of Optical Communications and Networking*, vol. 15, no. 7, pp. C1-C8, July 2023, doi: 10.1364/JOCN.481699

[3] "User Equipment (UE) radio transmission and reception," 3GPP specification TS 38.101 V17.9.0, Mar. 2023

[4] J. S. Wey, Y. Luo and T. Pfeiffer, "5G Wireless Transport in a PON Context: An Overview," in *IEEE Communications Standards Magazine*, vol. 4, no. 1, pp. 50-56, March 2020, doi: 10.1109/MCOMSTD.001.1900043.

[5] "Higher speed passive optical networks," ITU-T G.9804 series of Recommendations. G.9804.1 (Requirements), Aug. 2021. G.9804.2 (ComTC), Sept. 2021. G.9804.3 (50G-PON PMD), Sept. 2021.

[6] "Higher-speed bidirectional, single fibre, point-to-point optical access system (HS-PtP)," ITU-T Recommendations G.9806 (06/2020), G.9806Amd.1 (10/2020), G.9806Amd.2 (05/2021)

[7] "IEEE Standard for Ethernet -- Amendment 14: Bidirectional 10 Gb/s, 25 Gb/s, and 50 Gb/s Optical Access PHYs," in IEEE Std 802.3cp-2021, 16 July 2021, doi: 10.1109/IEEESTD.2021.9491981

[8] IEEE P802.3dk Greater than 50 Gb/s Bidirectional Optical Access PHYs Task Force, https://www.ieee802.org/3/dk/index.html

[9] "40-Gigabit-capable passive optical networks (NG-PON2)," ITU-T G.989 series of Recommendation, 2013

[10] D. Welch et al., "Digital Subcarrier Multiplexing: Enabling Software-Configurable Optical Networks," in *Journal of Lightwave Technology*, vol. 41, no. 4, pp. 1175-1191, 15 Feb.15, 2023, doi: 10.1109/JLT.2022.3211466.