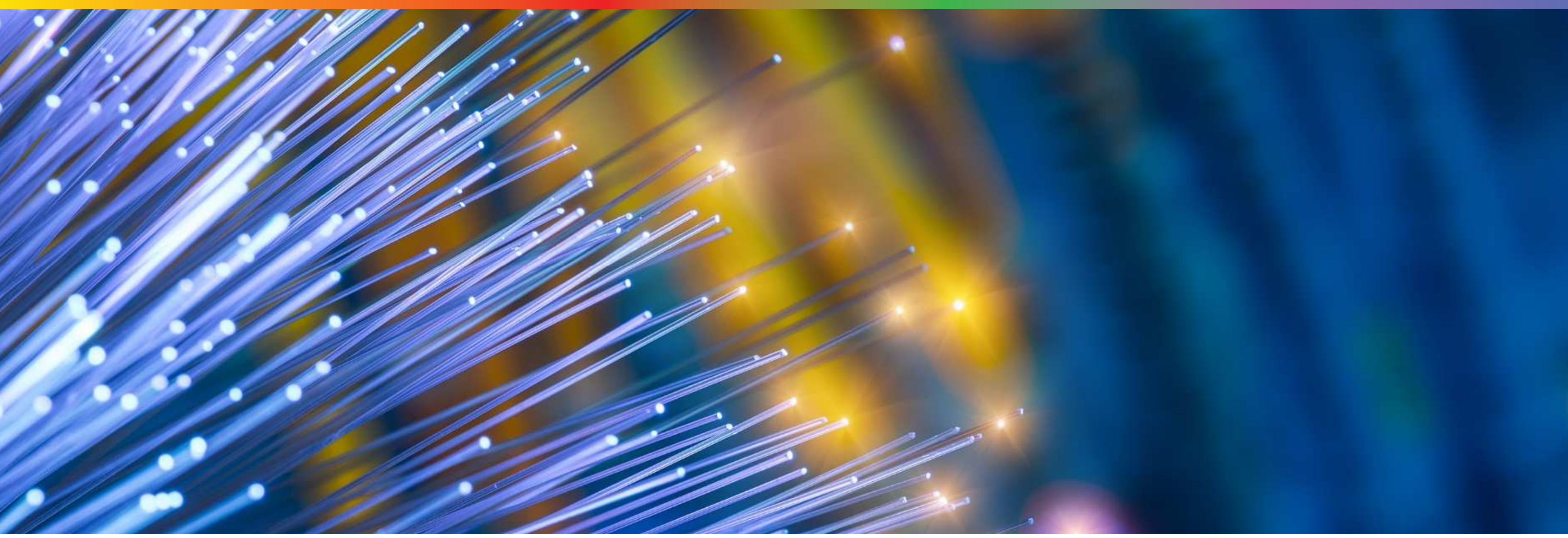
5G Wireless Broadband Service Delivery

An Overview



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Summary

5G fixed wireless can be complementary to a fiber access network as a last mile or perhaps "last 100 feet" technology. However, rural broadband presents many geographic and low user density issues that make a 5G fixed wireless broadband solution less than satisfactory as a viable long-term solution for bridging the Digital Divide. The capital and recurring costs of associated with towers, Line of Sight (LOS) issues, detrimental weather effects, rate/range limitations, and a typical 5-to-7-year technology life span suggests that 5G for fixed wireless is better as a complement to a Fiber to the Home (FTTH) broadband solution than as a primary network gigabit broadband solution.

5G Wireless technology is a complex and costly operation. Managing backward compatibility with generations of hardware/software radios and core network over time requires constant maintenance. Both FTTP fiber infrastructure and the 5G wireless infrastructure can achieve Gigabit speeds, but fiber has the potential to reach terabit speeds and beyond. An infrastructure investment in a fiber access broadband network provides for 20 to 30 years of useful outside plant life with basically no electronics in the distribution system, so maintenance is easy, and its reliability is extremely high.

5G wireless for advanced mobility, smart home/city, industrial automation, and Internet of Things (IoT) makes good sense. FTTH provides a better long-term solution for fixed broadband deployment and community economic development. The combination of 5G wireless and fiber can enable the operator to accelerate time to market, create new business and revenue opportunities, and provide gigabit speeds to customers both at home and on the move.

Introduction

5G is the latest evolution of mobile telecommunications technology that brings about significant improvement in data speed, traffic capacity, and low latency. 5G improves upon 4G technology greatly by unifying and expanding the spectral range used to achieve these improvements, including low, mid and mmWave spectrum throughout licensed, shared, and unlicensed frequency bands. With its low latency and high traffic capacity, 5G offers support for billions of Internet of Things (IoT) devices and applications such as autonomously driven automobiles.

5G increases bandwidth and enables a myriad of applications, but a slightly deeper understanding of the technology will be useful in assessing the value of 5G in applications such as fixed wireless in rural deployments.

Understanding Frequency Spectrum and Performance in 5G

Lower frequencies mean longer range at lower data rates; higher frequencies mean higher data rates at shorter ranges. Let's quantify this basic principle with some numbers:

- Low band - Spectrum in the <1GHz range offers the best propagation properties and coverage and served as the basis for backward compatibility with previous generations of mobile technology that 5G replaces. These bands have traditionally been used for broadcast radio and television and penetrate walls well. While the 5G NR (New Radio) standard offers new features such as security, encryption and low latency mode, its capacity will be limited due to scarcity of the available bands in these low frequency bands. Therefore, the typical service rate in this low band of frequencies is only similar or slightly better than LTE in 20-200Mbps range.

- Mid band – The range of the wireless spectrum from 1 GHz to 6 GHz, used by Bluetooth, Wi-Fi, and mobile networks. 5G reuses and expands the existing 2.5GHz Broadband Radio Service (BRS) and 3.5GHz Citizen Broadband Radio Service (CBRS) where BRS were licensed and CBRS bands were shared in three tiers user structure. Multiple 10 MHz channel can be aggregated which allows 5G NR to provide 100 – 500Mbps of usable throughput in this mid-band spectrum as shown in Figure 1.

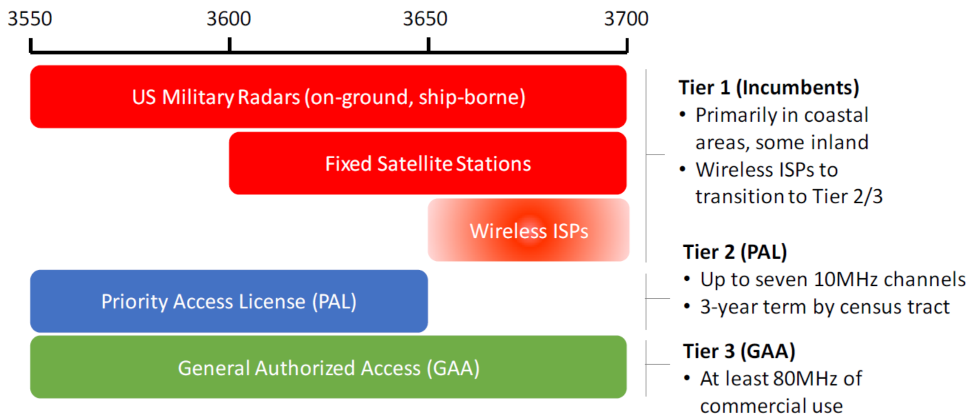

Figure 1. CBRS 3-Tier Shared Spectrum Licensing Structure.

CBRS GAA has the lowest tier priority which means it may have trouble operating near coastal areas, airports, and satellite ground stations. However, it is free to use for non-PAL operators on a first come first serve basis where the contention is handled by a Spectrum Access System (SAS).

In April 2020, the FCC opened 1200MHz of unlicensed spectrum in the 6GHz range to improve wi-fi performance by increasing data rate and relieving interference encountered in 2.4GHz and 5GHz bands. Expected to be used in home routers, it will likely be used by mobile operators as well. This band must coexist with utility companies already using licensed 6GHz spectrum, and Automatic Frequency Controllers (AFCs) must be implemented to ensure compatibility.

- High band - mmWave or the high band spans from 24GHz - 70GHz. The upside for mmWave spectrum is that the available bandwidth is very wide, in hundreds of MHz to multiple GHz per band. The downside to mmWave is its poor propagation through air and foliage due to absorption of RF energy in short wavelengths. It has less than 1 km radius in typical effective range, and its coverage is typically discussed in terms of feet or city blocks. The mmWave high band will be used mostly in dense urban areas where the cell is small, and stations have a near line of sight (LOS) condition. The maximum throughput for high band is around 1- 3 Gbps. It is not relevant in the rural area as the macro cell radius coverage is usually far larger than 1 km.

- Spectral efficiency, achievable rate per base station, downstream/upstream allocation - While the theoretical peak spectral efficiency is 30 bps/Hz in downlink and 15 bps/Hz in uplink in 3GPP release 16, the real-world spectral efficiency is highly dependent on the number of MIMO (Multiple Input and Multiple Output) paths and the signal strength. Therefore, most observable spectral efficiency is in 3-7 bps/Hz in urban area and 2-5 bps/Hz in rural areas where multipath is not available to achieve the high theoretical gains. Each base station could have up to 256 antenna elements for both uplink and downlink. The allocation of the downlink/uplink can be Time Division Duplex (TDD) or Frequency Division Duplex (FDD); most mobile UE (User Equipment) is uplink power limited, so FDD is the dominant duplexing method. For rural fixed wireless access deployment, the Wireless Internet Service Provider (WISP) uses a dedicated outdoor antenna for subscriber UE. Hence, TDD is more flexible in downlink/uplink bandwidth allocation for both consumer and business customers.

- Rate/range performance - 5G rate and reach is highly dependent on the available bandwidth and achievable multipath gain. Gigabit speeds are only achievable with the combination of mmWave band and short distances (<1 km). For rural areas, the expected performance will be tens of Mbps to a few hundred Mbps in typical fixed wireless deployment.

- Latency performance - The stated goal for 5G NR is 1ms of radio interface latency. This does not include the backhaul and buffering delay due to upper layer switch/routers. From an access interface delay perspective, fixed wireless is said to have a lower latency than fiber due to the Line of Sight (LOS) nature of the RF transmission compared to the increased delay in photonic transmission due to fiber's reflection index, and fiber route distance is longer than a straight line.

5G Wireless Vulnerabilities

All radio access technologies have different degree of vulnerabilities in building material penetration, seasonal foliage, weather conditions, and fading due to other moving objects in the path of transmission. For the rural area fixed wireless application, the mmWave band is not particularly useful due to long distance and near Line of Sight (LOS) requirements. Additional investment in new towers/radios and subscriber outdoor antenna installation and maintenance add to the cost of the operation of a new Radio Access Network (RAN).

5G Wireless Applications

The mobility feature in 5G wireless is the main driver for its expansion in commercial and industrial investment. The momentum from IoT and V2x are also driving many economic developments tied to industrial automation and smart city/infrastructure investments.

There are three major 5G applications described in Figure 2:

Enhanced Mobile Broadband (eMBB) – Next Generation Mobile with Gigabit Capability

Initial hardware development will be focusing on extending LTE capabilities in eMBB applications while utilizing the existing 4G Radio Access Network (RAN) packet core. This architecture leverages the existing fiber transport network to connect each cell to the core network. A successful 5G wireless deployment depends on a solid fiber backbone foundation.

Massive Machine Type Communications (mMTC) - IoT for Billions of Interconnected Devices

Oriented toward industrial applications such as robotics, sensors, smart home, and business. These additional IoT devices currently were fragmented into many proprietary systems such as LoRa, SigFox, NB-IoT and Wi-Fi. These fragmented networks will require many proprietary gateways to manage which may not be optimal for long term infrastructure investment.

It is still unclear if the new 5G chipsets will achieve low power and long range to consolidate this fragmented market, but it is one of the perspective markets that the mobile operators want to take on to justify the 5G investment.

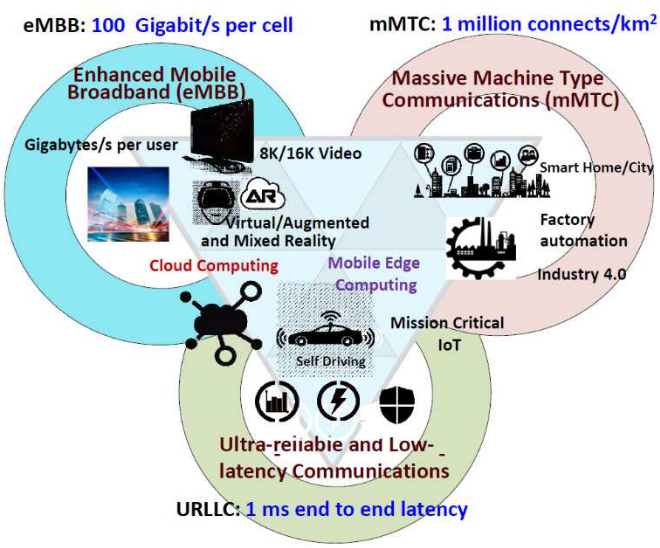

Figure 2. 5G Applications as Specified in 3GPP Releases 15/16/17.

Ultra-Reliable and Low Latency Communications (URLLC) – Automation

Used for applications such as autonomous driving cars and intelligent highway infrastructures. These applications are built on top of existing mobile tower and core network and overlay new radios and Mobile Edge Compute (MEC) devices to enhance their performance as shown in Figure 3. The low latency of 5G and security protocols enhance the performance and reliability for V2x and secured public safety communications as shown in Figure 3. This is yet another unproven use case where 5G wireless has yet to conquer. Some experts suggest 6G will be required to fulfill all the goals and Key Performance Indicators (KPI) for the URLLC use cases.

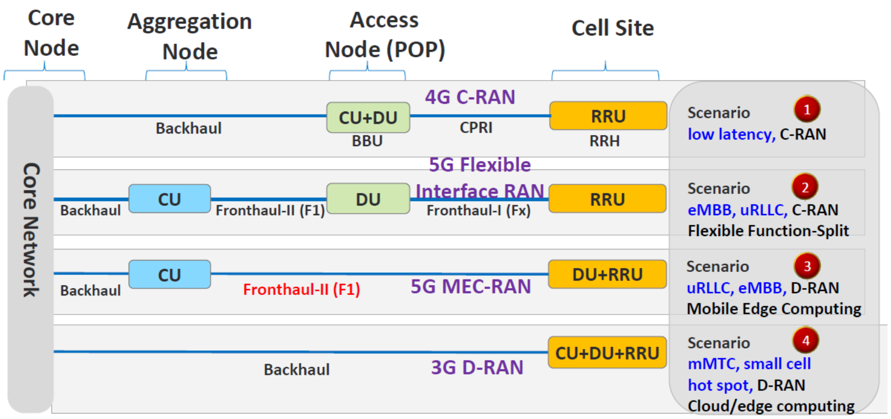

Figure 3. Network Architecture for Multi-Generation RAN.

Figure 3 also points out the need for fiber x-haul (front haul, mid-haul and backhaul) to interconnect multiple generations of RANs. It is possible to deploy 4G LTE C-RAN (Cloud-RAN) and then migrate it into 5G MEC-RAN (Mobile Edge Compute -RAN) with a flexible front haul interface to support both eMBB and uRLLC use cases. A direct migration for 3G D-RAN (Distributed -RAN) to 5G will require more investments in CU, DU and eCPRI (evolved Common Public Radio Interface) compatible fiber interconnects.

Observations and Conclusions

- Average speeds for rural 5G fixed wireless broadband users will be asymmetric and in the 10’s or 100’s of Mbps, not gigabit.
- New hardware is required for 5G for each generations of upgrades.
- 5G at mmWave frequencies is very short range and is affected by weather, foliage, and building structures. mmWave is required for gigabit speeds.
- Mobility, smart home/city, industrial automation and intrabuilding connectivity, enhanced telehealth, and IoT are good use cases for 5G wireless.
- Fiber for fixed broadband access has more capacity than any other transmission technology.

As a complement to fiber access and economic development, 5G is a useful component in a complete, gigabit broadband enabled community. As a primary broadband solution for a rural community and surrounding region, 5G is simply an incremental improvement that cannot overcome the Digital Divide.