RYSAVY RESEARCH

The Power of Wireless Broadband

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Notice

Introduction

Communications technologies, both wireline and wireless, have steadily improved over time, increasing throughputs and capacity while reducing latency. Users of today's 4G LTE cellular networks are accustomed to download speeds of tens of megabits per second (Mbps), a thousand times faster than wireless data of twenty years ago.[1] Meanwhile, the wireless industry is readying 4G LTE networks and devices that will have peak speeds of 1 gigabit per second (Gbps).[2]

5G technology, with the first phase of standards being completed in 2018 and first deployments in 2019, will have even greater capabilities. Given peak speeds of more than 10 Gbps, 5G will be the only broadband connection that many people will need.

Due to global economies of scale, cellular technology is the leading approach for wireless broadband, but other wireless technologies are also available to wireless internet service providers (WISPs) to provide broadband service, particularly in areas of lower population density. Meanwhile, satellite systems also deliver consumers speeds of tens of Mbps, reaching geographical areas that may not be served by terrestrial networks.

Today's wireless networks address the demands of nearly all consumer applications, including web browsing, social networking, and streaming. For example, streaming Netflix in high definition requires 5 Mbps[3], well below the 10 to 20 Mbps capability of many wireless internet services.

Capacity and Performance Principles

The capacity of both wireline and wireless networks is a function of three variables, as shown in Figure 1: the amount of spectrum available in the communications channel, the efficiency of that channel, and frequency reuse.

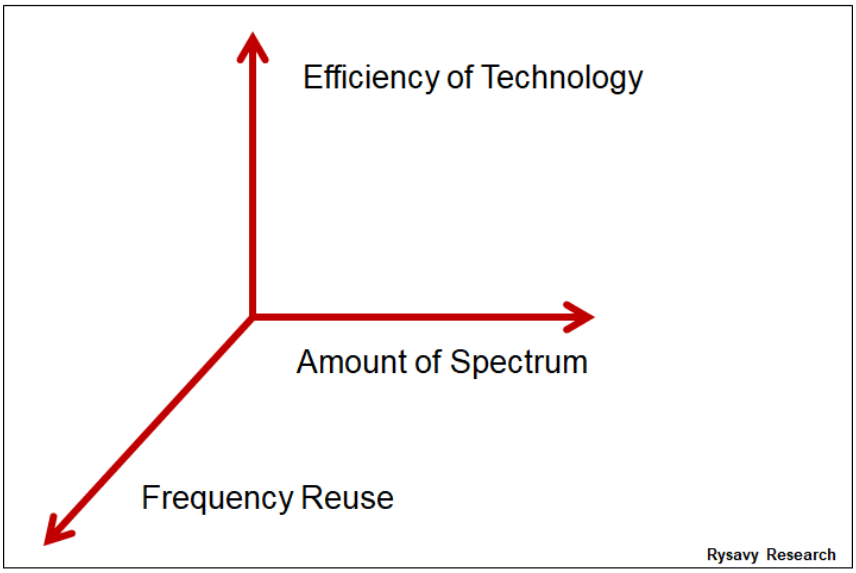
Frequency reuse refers to how soon the spectrum of the communications channel can be reused at another location. For instance, a cellular network with smaller cells has higher frequency reuse than a network with larger cells, and so has higher capacity.

[1] Cellular Digital Packet Data in the 1990s had a peak speed of 10 Kbps.

[2] For example, see "AT&T to Showcase Gigabit LTE on Galaxy Note 8, T-Mobile Hits 1.1Gbps in Lab," Sep. 2017, available at http://www.droid-life.com/2017/09/08/att-tmobile-5g-1gbps-download-speedtest/.

[3] Netflix, "Internet Connection Speed Recommendations," https://help.netflix.com/en/node/306, viewed Nov. 7, 2017.

Figure 1: The Three Variables That Determine Capacity



The progression of wireless technology has addressed each of these variables, harnessing ever more spectrum, improving efficiency in each new generation, and increasing the number of cells. A number of technology and market developments are enabling these advances:

- The ability to use ever-higher frequencies, often ones previously not practical.
- Improvements in antenna technology, such as Multiple Input Multiple Output (MIMO), with which radio waves can travel through multiple paths in an environment or be focused into beams to both reach longer distances and serve more users.
- Increased computation of radio wave signals, enabling higher efficiency through interference cancellation and other radio methods.
- Miniaturization of technology, making radio equipment less expensive and easier to deploy.

As a result of these advances, today's 4G LTE technology has spectral efficiency that is double that of 3G technology, and 5G is being designed to be three times as efficient as 4G.[4]

Analyzing these parameters over the past twenty years, Rysavy Research has calculated that wireless network capacity has doubled every three years. With 5G's access to huge amounts of new spectrum in

[4] Rysavy Research, *LTE to 5G: Cellular and Broadband Innovation*, Aug. 2017, available at https://rysavyresearch.files.wordpress.com/2017/10/2017-08-5g-americas-rysavy-lte-5g-innovation-v2.pdf.

the mmWave bands[5], this capacity growth trend will accelerate. In the past, wireline networks have had greater capacity than wireless networks, but this gap is closing. 5G mmWave networks deployed in small cells will have capacity that matches or exceeds that of today's coaxial cable networks.[6]

As wireless capability has improved, many applications that previously used wired connections have shifted to wireless connections. Examples include wireline telephony moving to mobile telephony, Ethernet to Wi-Fi, and now, Digital Subscriber Line (DSL) and coax cable to fixed wireless and satellite systems. Particularly in rural areas, wireless technologies can be built at a fraction of the cost of wireless networks, extending the reach of broadband to more people. A board member of the Wireless Internet Service Provider Association recently stated that these costs are one fifth to one tenth that of cable or fiber.[7]

Fixed Wireless Technologies

Wireless ISPs are using multiple technologies and spectrum bands for providing broadband service. In many cases, the providers also offer optional telephone service, using voice over IP over the broadband connection. Unlike the need to provide extended coverage for mobile networks, fixed-wireless service can be offered in select areas, enabling both smaller companies and larger companies to offer services.

The technologies used include proprietary ones, cellular (3G and 4G), Wi-Fi, and white-space technologies (for example, using IEEE 802.22). Technologies coming online soon, such as Citizen Bands Radio System (CBRS) and 5G, will provide even greater options. Similarly, wireless ISPs have ever more spectrum options, which today and in the near future include multiple cellular bands, unlicensed bands (2.4 GHz, 5 GHz), 2.5 GHz, 3.5 GHz, white spaces at 600 MHz and 700 MHz, and mmWave bands.

Mobile networks must address a wide range of operating conditions and demands, but fixed-wireless networks can be optimized by using outdoor antennas and supporting only fixed subscribers with relatively predictable traffic demands.

In addition to fixed wireless systems, some cellular operators also offer home internet and phone service using their mobile networks.

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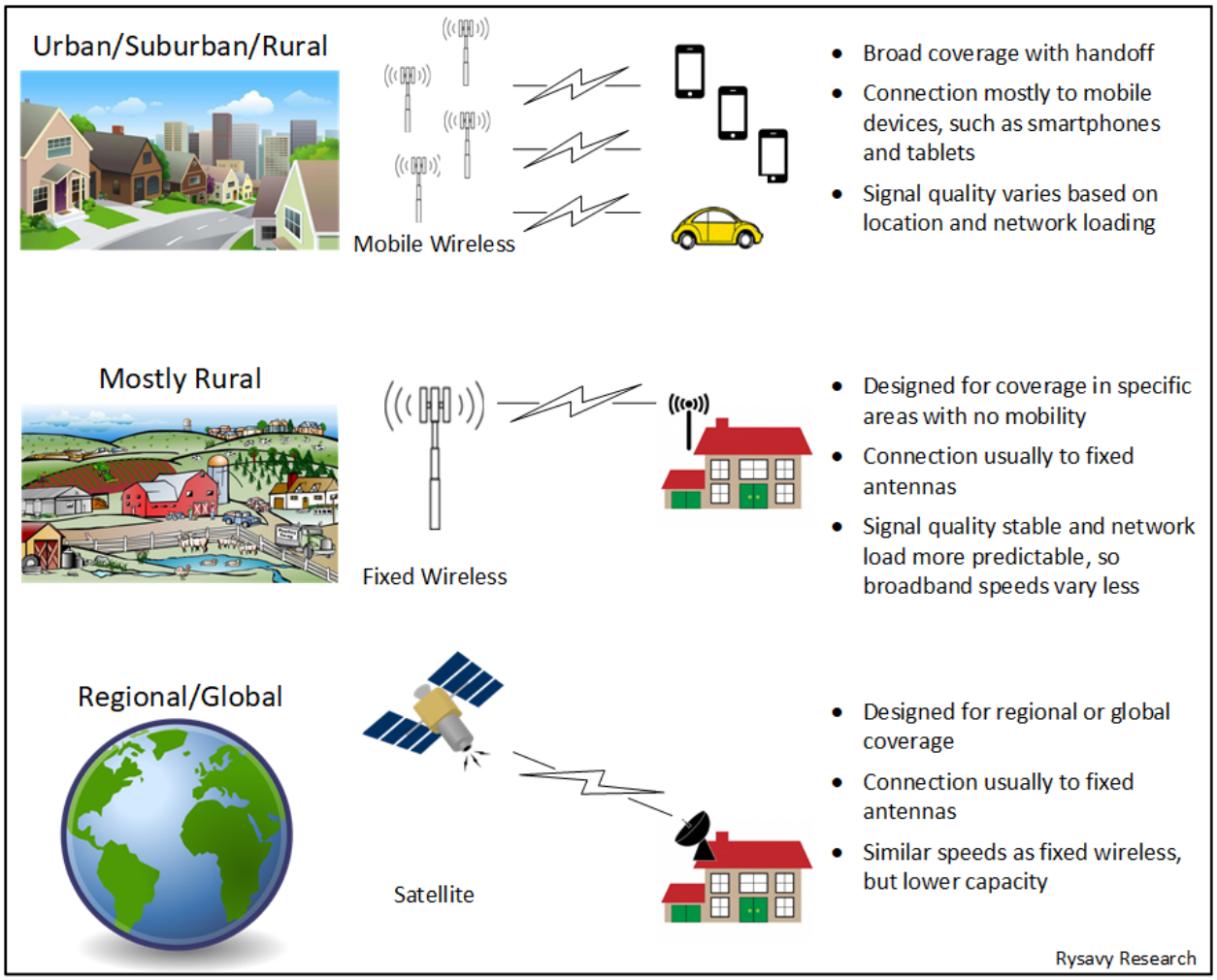
[5] mmWave bands are those at which wavelengths are 1 millimeter or less, corresponding to frequencies of 30 GHz and higher. Planned 5G frequencies, such as at 28 GHz, are also considered "mmWave."

[6] Rysavy Research, *Broadband Disruption: How 5G Will Reshape the Competitive Landscape*, Aug. 2017, available at https://datacommresearch.com/reports-broadband/.

[7] BroadbandBreakfast.com, "Wireless Internet Service Providers Pitch Fixed Wireless Technology in Forthcoming Infrastructure Bill," Oct. 2017, available at: http://broadbandbreakfast.com/2017/10/wireless-internet-service-providers-pitch-fixed-wireless-technology-in-forthcoming-infrastructure-bill/.

Figure 2 shows the characteristics of these different wireless systems, including those of satellite systems that are discussed in the next section.

Figure 2: Types of Wireless Connections



Many different services exist in this robust, growing market, using multiple technologies and spectrum. Table 1 provides examples of different services that provide broadband internet, detailing their technologies and capabilities.

Table 1: Examples of Wireless Systems for Broadband Internet

Service	Technology	Capabilities
AT&T Fixed Wireless[8]	4G LTE, fixed network, available in select areas.	10 Mbps or higher download. 1 Mbps or higher upload.
AT&T Wireless Home Phone & Internet[9]	4G LTE, mobile network, available in most areas.	5 to 12 Mbps download typical.
C Spire Internet[10]	4G LTE, fixed network, available in select areas.	Up to 25 Mbps download. Up to 3 Mbps upload.
Paladin ExteNet[11]	3.5 GHz Citizens Broadband Radio Service (CBRS), available in select areas.	Up to 20 Mbps download. Up to 10 Mbps upload.
Frontier	Fixed network using 3.7-4.2 Gbps spectrum.[12]	Service being tested, expected soon.
Rise Broadband[13]	LTE in 2.5 GHz and 3.65 GHz bands, available in select areas.	UP to 50 Mbps download.
Verizon LTE Internet and Home Phone[14]	4G LTE, mobile network, available in most areas.	5 to 12 Mbps download. 2 to 5 Mbps upload.

[8] Additional information at: https://www.att.com/internet/fixed-wireless.html

[9] Additional information: https://www.att.com/cellphones/att/wireless-home-phone-and-internet.html

[10] Additional information: https://www.cspire.com/home-services/

[11] Additional information: http://www.paladinwireless.com/index.php/plans/

[12] DSL Reports, "Frontier Testing New Fixed Wireless Services," Oct. 09, 2017, available at http://www.dslreports.com/shownews/Frontier-Testing-New-Fixed-Wireless-Services-140478.

[13] Additional information: https://www.risebroadband.com/residential/

[14] Additional information: https://www.verizonwireless.com/home-office-solutions/verizon-lte-internet-and-home-phone/

Satellite Systems

While fixed-wireless technologies enable service in specific coverage areas, satellite systems can reach much wider geographical areas. Multiple satellite service providers exist, and as with other wireless systems, ongoing technology enhancements are improving capacity and throughput rates. Today's broadband satellite services operate at 500 percent of the speed of systems at the beginning of this decade, and even faster services are on the way.[15]

The aggregate throughput capacity of satellite systems is usually lower than terrestrial systems, so monthly data allocations for customers tend to be lower, measured in tens of gigabytes per month compared with a hundred or hundreds of gigabytes per month for terrestrial fixed wireless systems. Although these data allocations discourage heavy amounts of streaming, they readily support most other internet applications.

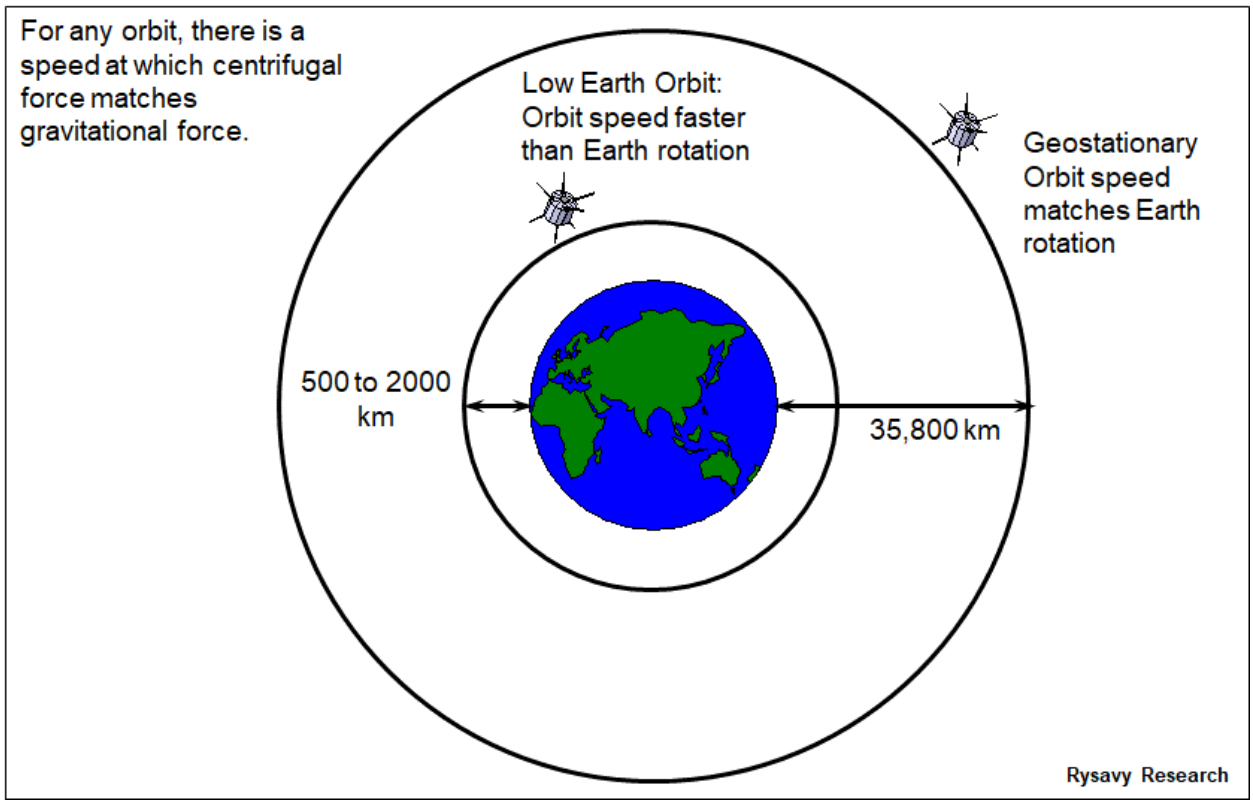
Satellite systems, as shown in Figure 3, are either in an orbit that is fixed above Earth, referred to as a "geostationary orbit," or low-Earth orbiting (LEO). LEO satellites move relative to Earth, and a larger number of satellites are required to provide continuous coverage. The lower position translates to lower latency, and the larger number of satellites can result in greater capacity. Existing LEO services include Globalstar[16] and Iridium[17], which provide voice and narrowband data services. A broadband LEO service anticipated in 2019 is OneWeb.

[15] Satellite Industry Association, "Satellite Broadband: Connecting America," Nov. 2010, available at http://www.sia.org/wp-content/uploads/2010/11/SIA_Broadband_Presentation_2010.pdf. See page 8 indicating speeds of 5 Mbps compared to today's services of 25 Mbps.

[16] Additional information: https://www.globalstar.com/en/

[17] Additional information: https://www.iridium.com/

Figure 3: LEO Versus Geostationary Satellite Orbit



Throughput performance from satellite systems can match terrestrial fixed wireless systems. As shown in Table 2, both HughesNet and Exede Internet deliver 25 Mbps download speeds and 3 Mbps upload speeds.

Table 2: Examples of Satellite Systems

Service	Technology	Capabilities
EchoStar HughesNet[18]	Fixed orbit.	25 Mbps download. 3 Mbps upload.
ViaSat Exede Internet[19]	Fixed orbit.	Up to 25 Mbps download. 3 Mbps upload.

[18] Additional information: https://internet.hughesnet.com/residential-plans.html

[19] Additional information: http://promo.viasat.com/exede-liberty/liberty-2582X-3646EM.html

Service	Technology	Capabilities
OneWeb[20]	Low-Earth orbiting, scheduled for launch in 2018 with service in 2019.	Information on service plans not yet available. Lower latency than geostationary systems.

Market and Conclusion

Obtaining broadband internet service using wireless connections is effective today, and options will continue to improve. The market is real, with 2,000 network operators in the United States.[21] Demonstrating the strength of the market, revenues in the United States are projected to increase from $2.7 billion in 2017 to $5.2 billion by 2021.[22]

Multiple forces are driving this opportunity, including superior technology, lower costs from commoditization, more spectrum options, growing demand for broadband in rural areas, and an exploding number of communications-based applications and services.

The economics, capabilities, and convenience of wireless broadband, especially in areas of low population density, make it the best broadband solution. As the technology matures, even many people who use wireline broadband today will switch to wireless broadband.

[20] Additional information: http://www.oneweb.world/

[21] Telecompetitor, "Fixed Wireless Market Report: Subscribers to Double to 8 Million by 2021, Generating $5.2B," Sep. 15, 2017, http://www.telecompetitor.com/fixed-wireless-market-report-8-million-subscribers-by-2021/.

[22] Ibid.

About Rysavy Research

Peter Rysavy is the president of Rysavy Research LLC, a consulting firm that has specialized in wireless technology since 1993. Projects include analysis of spectrum requirements for mobile broadband, reports on the evolution of wireless technology, evaluation of wireless technology capabilities, strategic consultations, system design, articles, courses and webcasts, network performance measurement, test reports, and acting as expert in patent-litigation cases. Clients include more than 75 organizations.