What Makes Wireless Work? Explaining Spectrum Allocation

Center Forward Basics

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Overview

In modern America, cell phones, internet connections, and wireless connectivity technologies are so well established they are nearly universal. These technologies operate on the electromagnetic spectrum, and with the continuing rise of wireless technologies in daily life, consumers and industry leaders are demanding more spectrum bandwidth than ever. Regulating telecommunications and managing scarce spectrum resources are recurring issues facing policymakers, and ensuring reliable access has only become more pressing with the rise of the digital economy. The answers to these policy questions will pave the road for critical industries and technologies. This Basic will explore how these technologies work, how telecommunications are coordinated for various uses and providers, and the regulatory bodies who make the rules of the road for this essential infrastructure.

What is Spectrum? How Wireless Connections Work

When technologists and regulators talk about "spectrum," they refer to the electromagnetic spectrum, a physics term describing the full range of electromagnetic (EM) waves organized by frequency. These waves radiate through space at the speed of light, and technology can harness this energy at different wavelengths for various commercial uses.

The EM spectrum includes radio waves, microwaves, infrared, visible light, ultraviolet, X-rays, and gamma rays from long to short wavelengths. The frequency of these waves is measured in hertz (Hz), including kilohertz (KHz), megahertz (MHz), and gigahertz (GHz). Some of the names for EM waves are familiar due to their applications in medicine, communications, and references in popular media.

Wireless communication technologies use wavelengths called the radiofrequency spectrum or "the airwaves." These airwaves are the infrastructure of modern wireless communications, serving as the pathways to carry information and signals for applications like radio and television broadcasts, Wi-Fi, radar, GPS, satellite communications, and wireless data.

Spectrum Bands and Organizing Transmission

Communications devices such as cell phones, radios, satellites, and wireless access points emit and capture EM waves at certain frequencies to send and

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In order to meet our challenges we need to put aside the partisan bickering that has gridlocked Washington and come together to find common sense solutions.

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Key Terms:

- **Spectrum Band:** a range of electromagnetic frequencies used for telecommunications licensed or assigned to specific users or applications.
- **Bandwidth:** the maximum amount of data that can be transmitted over an electromagnetic wave in a given period of time, often measured in megabits per second (Mbps). Bandwidth can also refer to the width of a spectrum band measured in MHz.
- **Spectrum Allocation:** the regulatory process of dividing the

receive data. The device "sending" the EM waves will encode the information being transferred into a digital binary, a chain of zeroes and ones - a bit like Morse code. The digital binary is transferred by varying the amplitude or frequency of the EM wave, or simply by turning the wave on or off. Then, the device "receiving" the EM waves will decode the digital binary into usable data again.

Wireless communications transmitted between devices are radiated in certain **spectrum bands**. A spectrum band is a range of EM frequencies defined by an upper and lower limit. Different frequency bands have different characteristics as determined by their wavelength and frequency, so wireless devices will communicate using different bands depending on the nature of the communication.

Low-frequency EM waves, or "low-band spectrum," have greater propagation – meaning the waves can travel further distances without degrading signals. Low-frequency waves are also less sensitive to interference from physical obstacles or obstructions in more densely populated or heavily built places. This means low band spectrum provides better coverage to larger geographic areas and a longer range between devices. "High-band spectrum" has a shorter range and is more easily disrupted but has a greater capacity, meaning it can carry more data. Between the low and high-band spectrum is also the "mid-band spectrum," used for its balance of coverage and capacity, ideal for next-generation technologies like 5G.

Spectrum Allocation

The spectrum used for wireless communications is a limited resource. Any connection on a designated spectrum band has a set **bandwidth**, the maximum amount of data able to be transmitted over a connection in a given amount of time. Overusing a single spectrum band can interrupt or block critical signals. To avoid this, users must work in a coordinated system, typically run by a national or international regulator. **Spectrum allocation**, sometimes called frequency allocation, divides the electromagnetic spectrum into frequency bands and designates individual frequency ranges for use by one or more services under certain conditions.

electromagnetic spectrum into frequency bands and coordinating the use of those bands to avoid interference, provide opportunities for effective use, and optimize efficiency.

- **International Telecommunication Union (ITU):** the specialized branch of the United Nations responsible for coordinating the global use of radio spectrum and providing guidance for telecommunications policy.
- **Federal Communications Commission (FCC):** an independent regulatory body, the chief regulator for interstate and international commercial use of telecommunications through radio, television, cable, satellite, and spectrum.
- **Unlicensed Spectrum:** frequency bands on the electromagnetic spectrum available for anyone to use for non-exclusive purposes, subject to some regulatory restrictions.
- **Licensed Spectrum:** frequency bands that a country's regulatory body, such as the FCC, reserve for exclusive use by authorized users.
- **Shared Spectrum:** frequency bands made available on both a licensed and unlicensed basis for use by multiple companies, organizations, or users.

Globally, the **International Telecommunication Union** (ITU) is a specialized branch of the United Nations (UN) responsible for managing the radio-frequency spectrum. Based in Geneva, with a membership of 193 countries and roughly 900 businesses, academic institutions, and regional organizations, the ITU promotes the shared global use of radio spectrum, facilitates international cooperation by assigning satellite orbits, and supports developing telecommunication infrastructure in the developing world.

Every four years, the ITU member states convene for the ITU Plenipotentiary Conference, a treaty-making gathering to determine the policies and direction of the agency. Following the conference, the ITU Radiocommunication Sector (ITU-R) releases global recommendations on spectrum use. The ITU's charter recognizes its members' sovereign right to regulate their own telecommunication infrastructure but also establishes their recommendations are binding on all member states.

In the U.S., the Federal Communications Commission (FCC) is the agency responsible for regulating non-federal and commercial spectrum use. The FCC is led by five Commissioners, appointed by the President and confirmed by the Senate to serve five-year terms, except when filling a vacancy. Only three Commissioners from the same political party can serve at any time, and the President will appoint one Commissioner to serve as the Chairman. Additionally, the National Telecommunications and Information Administration (NTIA), led by an Administrator, is part of the Department of Commerce managing spectrum use for the federal government.

Spectrum Access and Licensing

Access to spectrum is regulated through allocation. The FCC determines who can use a spectrum band for non-federal spectrum and under what terms. Generally, bands are either unlicensed, exclusively licensed, or operated on a shared-licensed basis.

The rights to use those airwaves are made publicly available for an **unlicensed spectrum** band, granting users non-exclusive access subject to adherence to certain operating parameters. Equipment used to operate on the band must be certified by the FCC to conform to specific technical rules and, once approved, can be sold to the general public for use. Unlicensed spectrum fosters innovation and lowers barriers to entry for users, allowing a diverse network of devices to connect consumers. Wi-Fi and Bluetooth, essential modern technologies, are two of the most common uses of unlicensed spectrum. These technologies serve as the capillaries of our increasingly wireless world, with most internet traffic moving over unlicensed spectrum. Despite the flexibility and accessibility unlicensed spectrum use can provide, it is generally less reliable, more congested, and prone to interruption.

The FCC also grants individual users rights to exclusively licensed spectrum bands. Under **exclusively licensed spectrum**, licensees have the sole rights to transmit on an assigned frequency within a specific geographic area. Wireless carriers, television and radio broadcasters, utility companies, and government agencies rely primarily on licensed spectrum because of its reliability and the certainty of access. Licensed spectrum has been essential to the success of these industries and necessary to justify the considerable investments needed to deploy communications infrastructure. With exclusive rights to their frequency band, licensees can deploy equipment to utilize the spectrum's bandwidth with the assurance of access to the band for continued, high-quality service to their customers.

In some cases, licensees do not utilize the full bandwidth of their spectrum, so they can lease excess bandwidth on their network or frequency band to other users. Exclusive licenses are also subject to buildout obligations from the FCC in most cases to ensure networks are sufficiently deployed. Although fewer end users access licensed spectrum directly, the substantial investment in this spectrum provides the quality, reliability, and security to allow consumers to enjoy many of the technologies and services of modern life.

Aside from unlicensed and exclusively licensed spectrum bands, some frequency ranges operate under shared licensing agreements. The agreements and structure of **shared-licensed spectrum** are a recent innovation and can take many forms to facilitate licensed spectrum use by two or more distinct services or applications, or multiple users on the same frequency band. The most prominent example of shared spectrum use is the Citizens Broadband Radio Service (CBRS), where the FCC has coordinated a multi-tiered access system to the 3.5 GHz frequency band. The incumbents who have historically held exclusive rights to this band, namely the U.S. Navy and satellite ground stations, are given priority access – meaning they always have the option to operate without interference. However, since these incumbent users do not need constant access to the spectrum, the FCC made the spectrum available to two other classes: licensed priority access users and unlicensed users. The unlicensed users are then allowed to access the spectrum band when neither the incumbents nor priority users occupy the spectrum. Shared licenses support several applications, including private mobile networks, intelligent manufacturing, and school and library-operated deployment.

Links to Other Resources

- Federal Communications Commission - What is Spectrum Allocation
- International Telecommunications Union – About the International Telecommunications Union
- Information Technology and Innovation Foundation (ITIF) - Good and Bad Reasons for Allocating Spectrum to Licensed, Unlicensed, Shared, and Satellite Uses
- National Telecommunications and Information Association - How the Spectrum is Shared