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WHITE PAPER

THE EVOLUTION OF 5G

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About the Author



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Introduction

Mobile devices have fundamentally changed the way the world works in ways no one could have predicted.

From 1890, when the very first messages were transmitted wirelessly via telegraph until the present day, the demand for improved capability and capacity of wireless networks has consistently increased.

Years later, in 1958, two separate inventors totally unaware of each other's work invented nearly identical integrated circuits or microchips. This invention enabled manufacturers to reduce the size of radio transmitter circuits to fit into a smaller and smaller device, which resulted in the creation of more than 31 billion Internet of Things that are connected to the World Wide Web today. Now, experts are predicting that this number will climb to over 75 billion by 2025.

This explosion in the need for wireless devices and their growing range of capabilities has also impacted the demand on the radio frequency spectrum, requiring increased efficiency of its use.

Today, much of the world is embracing the latest advances in telecommunications technology as 5G comes into play. Here's what you need to know about this next generation of wireless technology.

Communication Evolution

The progression of wireless technology is best understood in the context of the evolution of communication. In the early days, information was sent by a series of “dots” and “dashes” and was abbreviated to just the essential message.

Today we can not only send messages, but we can stream complete movies in high-definition video and audio over wireless links. Our modes of communication have become increasingly sophisticated, which drives the demand for more data, more bandwidth (speed), and more users on our wireless networks.

So, how did this all get started?

The Generations of Mobile Networks

It's no surprise that mobile telecommunications have undergone significant advances over the last forty years. The first generation of mobile networks, now referred to as 1G, was launched in [Tokyo in 1979](#). By 1983, the US approved the first 1G operations, with other countries following suit in the years shortly after.

This early version of technology encountered a significant number of issues, including poor coverage, low sound quality, and no compatibility between various operators. And perhaps the most frightening fact was that calls remained unencrypted and easy to tap into with basic radio scanners.

Yet despite all of this, its popularity grew among more than [20 million global subscribers](#) by 1990 and made way for future generations of mobile technology.

By the second generation of mobile networks, calls were encrypted and much clearer from static and background interference. However, 2G signified much more than another generation of telecommunications: it provided a framework for the impending cultural revolution. For the first time in history, telephones could be used to transmit text messages, pictures, and other forms of multimedia.

By the time the third generation of mobile technology came around, data transfer capabilities had increased, making way for new services such as video streaming and conferencing services and smartphones.

In recent years 4G has acted as the current mobile network standard around the globe, yet there are still issues to be considered. For example, unlike the simple SIM card transitions from 2G to 3G, mobile devices required specific design features in order to support 4G, leading to increased profits by cell phone manufacturers. And 4G networks still encounter a fair share of connectivity problems, leading to patchy service across the world.

Today, the fifth-generation mobile network, or 5G, has enabled a new kind of network that is designed to virtually connect both people and machines, objects, and devices. This latest generation of technology has revolutionized what mobile devices can do – and there will be more advances uncovered in years to come.



Radio Frequency Spectrum: A Finite Public Resource

Electromagnetic waves in the 30 Hz to 300 GHz frequency range are known as the radio spectrum, and are widely used in modern technology, especially within telecommunication.

Radio spectrum is a limited resource fast approaching its limits thanks to existing user demand. The frequencies which are useful for radio communication are unchanging. As the radio spectrum becomes more congested, it is not possible to increase the amount of spectrum to accommodate the demand.

Because it is a fixed resource, it's in the public's best interest to allow the use of the spectrum by those services who will use it most effectively and efficiently. This requires a regulatory authority to implement and enforce how it is to be used and shared in order to avoid interference and other compatibility issues. In response, the International Telecommunication Union (ITU) allocates different portions of the radio spectrum for varying radio transmission technologies and applications. Their regulatory focus is not so much on the actual content itself but rather on if the user is "wasting" spectrum space.

But what caused this growing demand for radio spectrum over the last forty years?

Internet of Everything

The number of devices connecting to the internet wirelessly is increasing at an unprecedented rate. In 1999, the term “Internet of Things” (IoT) was coined to describe physical objects with embedded sensors, software, and other technologies in order to connect and exchange data with other devices and systems via the internet.

It was estimated that within 2020 there were more than **31 billion IoT devices connected to the internet and is projected to reach 75 billion by 2025**. Most of these devices connect with the internet wirelessly. Applications like wireless IoT, wearable devices, and 5G are all designed to comply with existing exposure and other related guidelines.

The Federal Communications Commission (FCC), in the United States, and the Innovation, Science and Economic Development in Canada are responsible for creating and enforcing solutions to minimize both noise and interference among these devices.

The FCC has indicated it is growing more and more difficult to manage interference as the number of IoT and other wireless devices increase each year and plans to track rising demand in order to make additional areas of the spectrum available as needed. After all, this tremendous loading of the wireless networks requires that more spectrum be cleared or reallocated, so the existing spectrum can be used with maximum efficiency.

What methods can be used to increase the efficient use of the radio spectrum before there’s not enough bandwidth left to meet user demands?

Method One: Modulation Technology

One way to increase the efficient use of the radio spectrum is through improved modulation methods. Modulation is the process of converting data into radio waves by adding an electronic or optical carrier signal and is typically applied to electromagnetic signals.

There are better ways of modulating the radio wave, which creates a waveform that can contain more data per radio spectrum bandwidth. Spectral efficiency is a measure of the number of data bits per second that can be transmitted per Hz of radio bandwidth (b/sec/Hz). When comparing the efficiency of 4G modulation techniques with 5G, it’s easy to see that 5G allows for much more data to flow across the airwaves per Hz of RF bandwidth used:

Spectral efficiency comparison	
4G	5G
30 bits/sec per Hz	120 bits/sec per Hz

This means that for every Hz of radio spectrum used, four times more data can be transmitted with 5G as opposed to 4G. This is a significant increase in data speed, meaning that an IoT sensor using 5G can send its information four times faster and can clear the radio spectrum for other sensors

or devices. And since data network providers bill per data bit, this efficiency translates to a more profitable network.

Method Two: Antenna Technology

Another aspect of efficient use of the spectrum is examining and optimizing how efficiently the radio energy is sent from one transmitter to its companion receiver. In a crowded radio frequency (RF) environment, it is much more efficient to target the radio energy to the user in a relatively narrow beam of energy rather than wasting energy by sending the radio wave in all directions.

This method reduces interference between radio devices and allows the transmitter to operate at a longer distance without increasing the RF output power of the transmitter. Operating at a lower radio frequency power also requires less source power from the power mains network or battery. These antenna systems rely on multiple RF output ports that can be fed a portion of the radio signal at different phases which allows the radio beam to be “steered” or directed to the target receiver.

This is commonly known as Multiple-In-Multiple-Out (MIMO) technology, meaning that multiple RF signals can be both transmitted and received simultaneously from the device. A newer version, Massive MIMO is a multi-user MIMO system with tens or even hundreds of antenna outputs and can provide uniform, stable service to wireless terminals in high-mobility environments. These antenna configurations are sometimes called Multi-User MIMO (MU-MIMO) systems because they service multiple users at the same time and within the same spectrum.

Method Three: Spectrum Access

As mentioned earlier, the radio frequency spectrum is a limited public resource. That means it's necessary to have more than one service or wireless network provider use the same frequency spectrum on a shared basis to make full and fair use of the spectrum.

Some radio spectrum is used exclusively by government or military users who only have authorization to use the spectrum infrequently. Although the incumbent user only has a requirement to use the frequency spectrum for short intervals, it may be for a critical purpose such as an emergency or national security situation.

In this scenario, it's possible to allow other users to access the spectrum until a serious need arises, but there must be a means by which access to the spectrum can be managed in order to allow certain users to have priority when absolutely necessary. In the past, the spectrum has traditionally lay dormant for significant periods of time, but with the right spectrum user management system in place, it can be utilized by other services.

The spectrum-sharing concept can also be used by network service providers who have purchased access in a spectrum auction but would like to lease the spectrum to other networks for a short period of time. This is referred to as dynamic spectrum sharing and is often seen when a network service provider is not fully always utilizing their band of frequencies.

Dynamic spectrum sharing allows the service provider to notify a spectrum access system of the

vacancy, who can then provide another service provider access to those frequencies on a temporary basis and keep track of their time of use for billing purposes. This is yet another way to use the radio spectrum more efficiently.

Frequency Bands and 5G

A question that often comes up when discussing 5G is this: what frequency bands are used for these networks?

All existing spectrums that are currently in use for both 3G and 4G networks will be used with 5G in addition to new frequency bands. Some of these new bands that have become available are shared bands that could not previously be used due to inadequate spectrum sharing until now.

In general terms there are two spectrum ranges that have been identified:

Band	Range	Description
FR1	450 MHz – 6 GHz	Sub-6 GHz
FR2	24.25 – 52.6 GHz	mm-Wave

It's important to note that the exact frequency bands that are available will vary from country to country since the allocation of frequency bands has not been a consistent process until recent years.

Perhaps the most significant development with 5G frequency allocations is the use of millimeter wave (mm-Wave) frequencies. Mm-Wave frequencies can be effectively used at closer distances and take pressure off the lower frequencies to expand wireless communications into the outer limits of radio technology. It is often used in environments like sports stadiums and shopping malls where there is a high volume of users, so it is practical to cover the space with multiple mm-Wave transmitters.

Other Important 5G Improvements

Besides higher data rates, higher user volumes, and more efficient usage of the radio spectrum, 5G offers the world a few other incredible advantages.

Data latency is simply the time between when the data is generated in the transmitter and is received and processed by the receiving device. Low latency is when this process occurs when a computer network is optimized to process a high volume of data with minimal delay. For the first time, lower data latency of 5 milliseconds or less may be realized with 5G technology.

Latency is an issue in sensor networks, and this delay can have serious and negative consequences. This is particularly undesirable in systems such as self-driving automobiles or vehicle-to-vehicle communications, where high latency can become of a safety issue.

Another significant improvement with the introduction of 5G is a lower link budget as opposed to previous generations of wireless networks. The link budget is a compilation of the gains and losses in the system between the transmitter output and the receiver input. It is made up of cable losses, transmitter and receiver antenna gains, and even environmental factors such as propagation loss

caused by foliage or rain droplets. Now, 5G technologies are much more tolerant of noisy radio frequency environments.

Is 5G Dangerous?

Beyond its list of advantages, there is much confusion regarding any negative drawbacks concerning 5G technology.

Initially, there was concern regarding mm-Wave transmitters since they must be operated at a closer distance to the user. This caused concern about the user being exposed to RF energy, potentially posing a greater health risk. However, because energy can be beamed directly to the user, a lower level of RF energy is emitted.

However, biological research has found no link between these posed risks and an individual's health. There is no scientifically based evidence that 5G or mm-Wave energy poses a greater risk to human health than any other radio network technology.



Summary

Over the last forty years, there has been an incredible amount of growth and innovation in the field of wireless telecommunication. From manufacturing the latest and greatest cellular devices to optimizing the network to allow more and more people to connect faster and more efficiently, many are curious as to what the future will hold for this rapidly expanding industry.

In our world of connected devices, not all products are ready to make the move to 5G. Many components in devices actively used today are built for the 4G network, but that will change in future years as technology continues to advance.

In the end, it is challenging to define and summarize 5G because it is not just a singular thing. It is a collection of improvements to global wireless networks that allow more users to reliably connect and experience greater data speeds. The end result is a more efficient network that better enables a connected world, transforming the lives of people across the globe.

Interested in learning more about what is involved in the 5G certification program and how it could potentially affect you in the future? [Visit our website to get started, today!](#)

About Nemko

The NEMKO foundation works for safety, sustainability, and the environment through the Nemko Group. Companies around the world trust Nemko to assess their products, systems, installations, and personnel for conformity with relevant standards and regulations. Since 1933, we have ensured that our customers comply with requirements anywhere in the world. Our services include international approvals, product and system certifications, cyber assurance services as well as product testing and pre-compliance. Through our offices, laboratories and extensive partner network in Asia, North America, Europe, Middle East, and Africa we are able to serve our customers in a reliable, efficient and open manner. We provide local presence coupled with global knowledge.

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