CB INSIGHTS

# What Is 5G?

## Understanding The Next-Gen Wireless System Set To Enable Our Connected Future

2019

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## The next generation of wireless technology will offer new consumer and business applications, with near real-time connectivity.

In the last decade, 4G wireless technology has become the standard for many mobile consumers around the world.

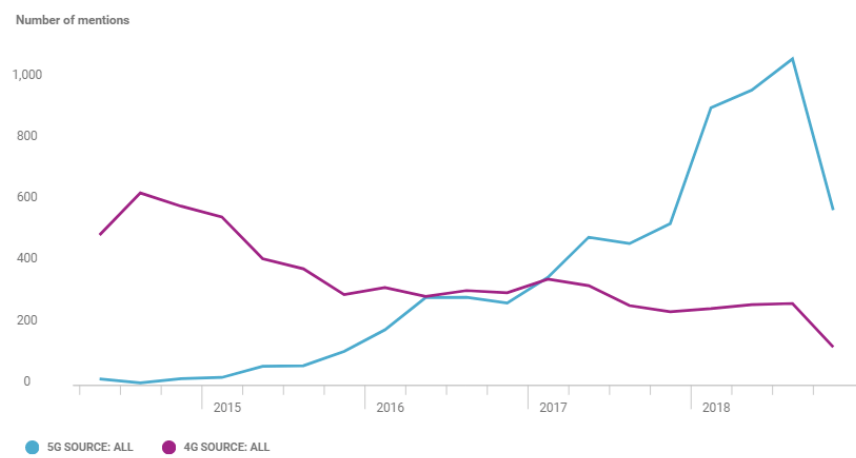
From social media platforms like Snap and Instagram to transportation apps like Uber and Lyft, many companies have benefited tremendously from the reliable connectivity and speed provided by today's 4G systems.

While this fourth generation of wireless technology has paved the way for new mediums of mobile consumption, it does have limitations. Over the next decade, the rise of connected (IoT) devices will require networks to transmit massive sums of data in near real-time.

The next generation of wireless technology, known as 5G, will allow just that.

Early 5G deployment began at the end of 2018 when AT&T launched 5G wireless networks in 12 cities, but widespread implementation of the technology may take the better part of a decade.

## Mentions in Earnings Calls




Even so, corporates are increasingly focused on this technology: according to CB Insights' Earnings Transcript tool, at its peak in Q3'18, "5G" was collectively mentioned over 1,000 times, up more than 100% from Q4'17.

Corporates like Nokia, Qualcomm, Ericsson, Broadcom, and Verizon have all discussed the implications of 5G, as well as plans for technology and/or service deployment.

We dive into the background of wireless technology, the introduction of 5G, and how the next generation of connectivity will come to be.

## History of wireless technology systems

Wireless communications have existed for over a century, but it wasn't until the late 1970s and early 1980s that they became a commercially viable consumer service.

The first generation (1G) of wireless technology systems came with the introduction of cell phones. These devices and networks allowed for mobile voice calls, but nothing more.

The second generation (2G) provided improvements to voice calling and introduced text messaging via SMS (and later media messaging via MMS), which ultimately helped the cellular industry to gain widespread adoption in the early 2000s.

Later iterations of 2G introduced data transmission, but it wasn't until 1998 that 3G allowed for media-rich applications like mobile internet browsing and video calling. The most recent iterations of 3G are able to reach speeds up to 4 Mbps.

The most recent generation of wireless technology, known to consumers as 4G (now 4G LTE), is able to reach real-world speeds between 10 – 50 Mbps, depending on the carrier. These speeds allow for mobile online gaming, live streamed HD-TV, group video conferencing, connected home solutions, and even emerging experiences like AR/VR.

That said, downloading or buffering is typically required at 4G speeds. For most consumers, this is a small price to pay for media-rich wireless freedom. But for industries like transportation or healthcare, latency (the delay before data transfer) can have a direct impact on system outcomes.

For example, 5G will enable near-instant communication between autonomous vehicles — communication that may prevent fatal accidents.

5G will have the biggest impact on these mission-critical systems while also providing the necessary infrastructure for tomorrow's connected technologies.

## What is 5G?

5G is the next (and fifth) generation of wireless technology systems. It will provide speeds faster than any previous generation, comparable to those delivered via fiber-optic cables.

Early testing of this technology shows real-world speeds of 700 – 3025 Mbps (3.025 Gbps), which consumers may experience once 5G becomes commercially available. Movies that took minutes to download with 4G will take seconds with 5G.


While smartphones and other mobile devices are the obvious use cases for 5G, there are many other applications for the technology.

The Internet of Things (IoT), for example, will benefit tremendously from the speed and bandwidth provided by 5G, especially as the industry grows: Gartner estimates over 20.4B IoT units will be installed by 2020, while IoT-related spending will reach nearly $3T.

Autonomous vehicles, robotic surgery, and critical infrastructure monitoring are just a few of the potential applications of 5G-enabled IoT.

# Industries being disrupted by 5G

5G's quantum leap in connectivity creates tremendous opportunity for numerous industries, but also sets the stage for large-scale disruption. Industries such as healthcare, manufacturing, and auto are already adopting technologies and becoming more connected.

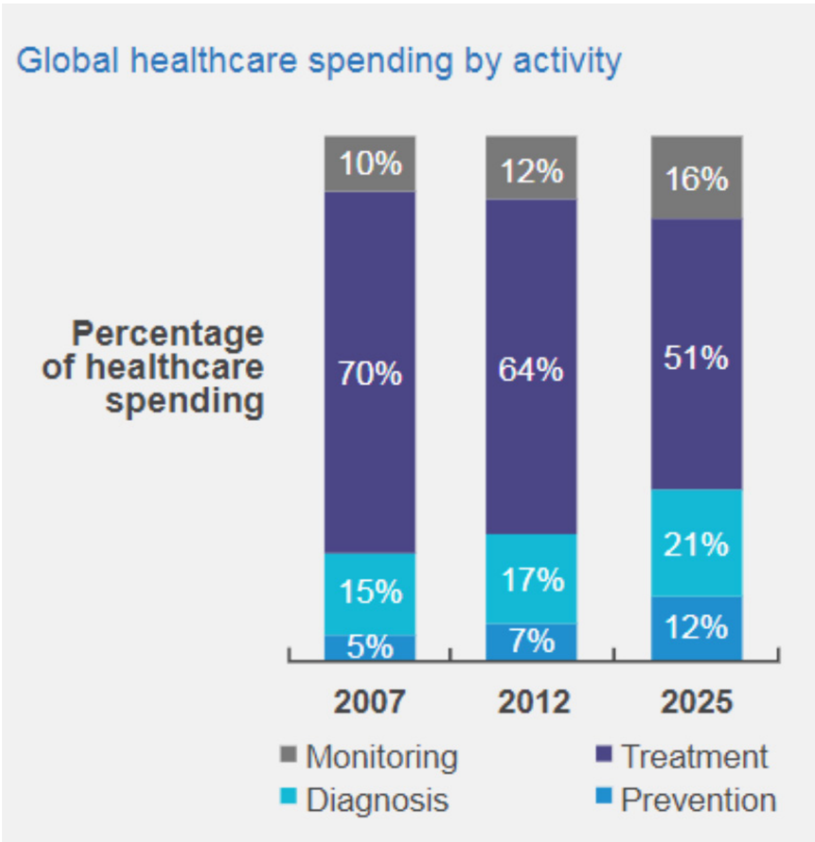
Once 5G becomes widespread, the effect on these industries could be transformative for 3 main reasons:

1. 5G devices are **lower latency,** enabling faster transmission of larger data streams
2. 5G devices are **more reliable,** enabling better transmission of data in extreme conditions
3. 5G is **more flexible** than Wi-Fi and can support a wider range of devices, sensors, and wearables

We dive into several industries that could see a drastic impact from 5G technology below.

## HEALTHCARE

In an attempt to reduce costs and improve overall health, western medicine is shifting towards preventative care.




*Source: Principal Global*

5G offers enormous opportunity for expansion of both preventative and monitoring practices via wearable devices. Such devices are already being used to track everything from sleep to blood glucose levels to physical activity, among other things.

5G's faster speeds and greater network reliability will allow for the development of more complex devices, including those implanted directly into a human body rather than worn externally.

Microscopic cameras equipped with 5G will be able to provide real-time streaming in and out of patients' bodies, setting the groundwork for more remote diagnoses and other more complex telehealth practices.

Today, for example, recovering stroke patients for whom repeated hospital visits are a burden often suffer from a lack of home monitoring and care. New kinds of wearables that track patients around their daily lives — not possible today with 4G — could allow for such patients to get more personalized monitoring and care without having to visit a hospital.

In the field of robotic surgery, 5G has the potential to dramatically expand the ability of doctors to bring critical and specialized care services to patients worldwide.

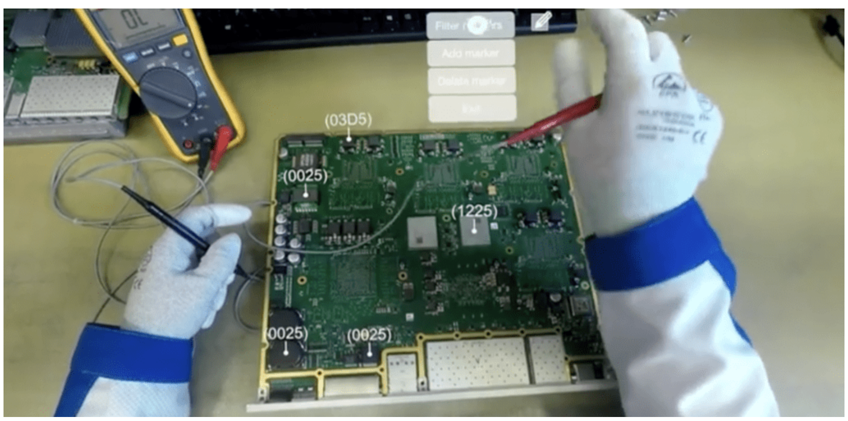
Robotic surgery is feasible today, especially in dense urban areas with access to fast broadband internet, but doctors generally have to be located in the same operating theater as the patient for it to work. By allowing for low latency and jitter-free communication over long distances, 5G could enable operations to take place from anywhere in the world. In January 2019, a team in China tested 5G remote surgery for the first time, removing an animal's liver in the province of Fujian.

## MANUFACTURING

The manufacturing industry has already started adopting artificial intelligence and IoT technologies to increase efficiency, improve data collection, and build better predictive analytics.

With 5G, manufacturers gain a faster, more reliable means of collecting and transmitting that data, as well as a broader range of sensors and devices they can integrate into their factories and workflows.

One major potential improvement with 5G will be augmented reality for manufacturing. Ericsson began testing augmented reality troubleshooting in its Tallinn, Estonia factory in January 2018. With an AR app, technicians can observe a part that needs maintenance and pull up the relevant schematics and instructions within their field of vision, drastically shortening the time it takes to complete the repair.




*A technician repairs a circuit board using an augmented reality overlay at Ericsson's Tallinn factory. (Source: Ericsson)*

While the higher latency of 4G and lower reliability of Wi-Fi make such technology limited today, 5G's ability to transmit low latency video at a high resolution could potentially make it much more broadly usable.

Other industrial use cases for 5G (according to AT&T) include:

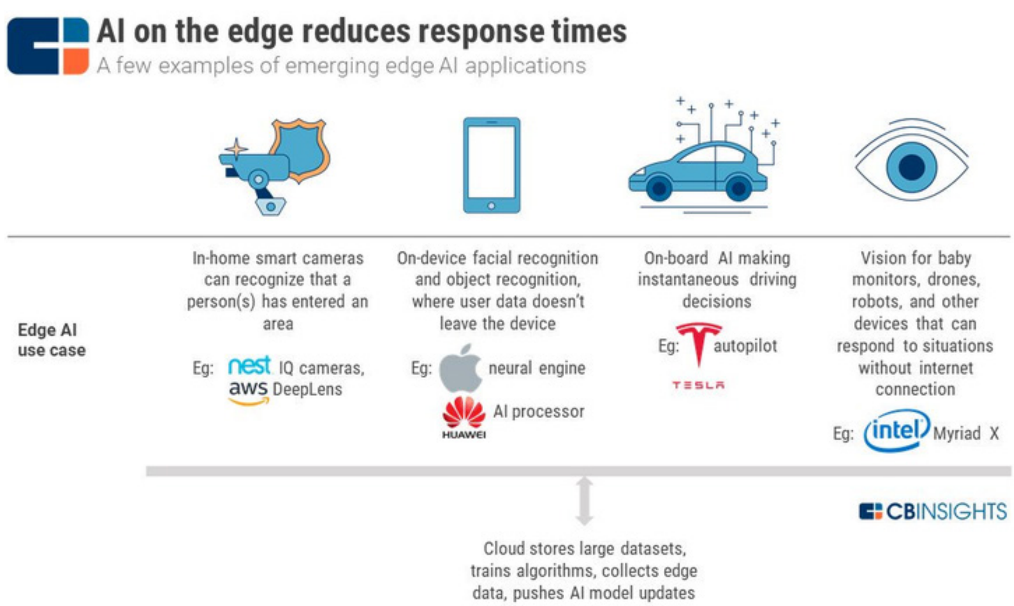
- Continuously monitoring equipment performance
- Robotic visual recognition that autonomously performs quality assurance on products
- Predictive analytics to tell when a part is going to fail

## AUTOMOTIVE

Tesla, Google, and others have been racing for years to build the first viable autonomous vehicle capable of navigating all environments without the input of a human driver.

Their primary approach to the problem thus far uses onboard computers and radar to scan the environment around the vehicle, and decide a car's next movement based on the information.

Other companies, including Qualcomm, Ericsson, Huawei, and Nokia, are looking to 5G and edge computing as a potential solution to the problems faced by autonomous vehicles.




Their consortium, the 5G Automotive Association (5GAA), began work on "cellular-vehicle-to-everything" or C-V2X technology in 2016. Rather than cars determining individually how to act, in the C-V2X system, vehicles communicate with one another and with parts of the physical environment like traffic lights and construction signs in order to coordinate movements safely and efficiently.

The system is in a testing phase today, but researchers believe 5G could permit truly autonomous driving in the future.

5G availability would mean a greater density of sensors in the environment and faster data transmission from centralized servers to those sensors and vehicles — and as a result, faster improvement via machine learning algorithms.

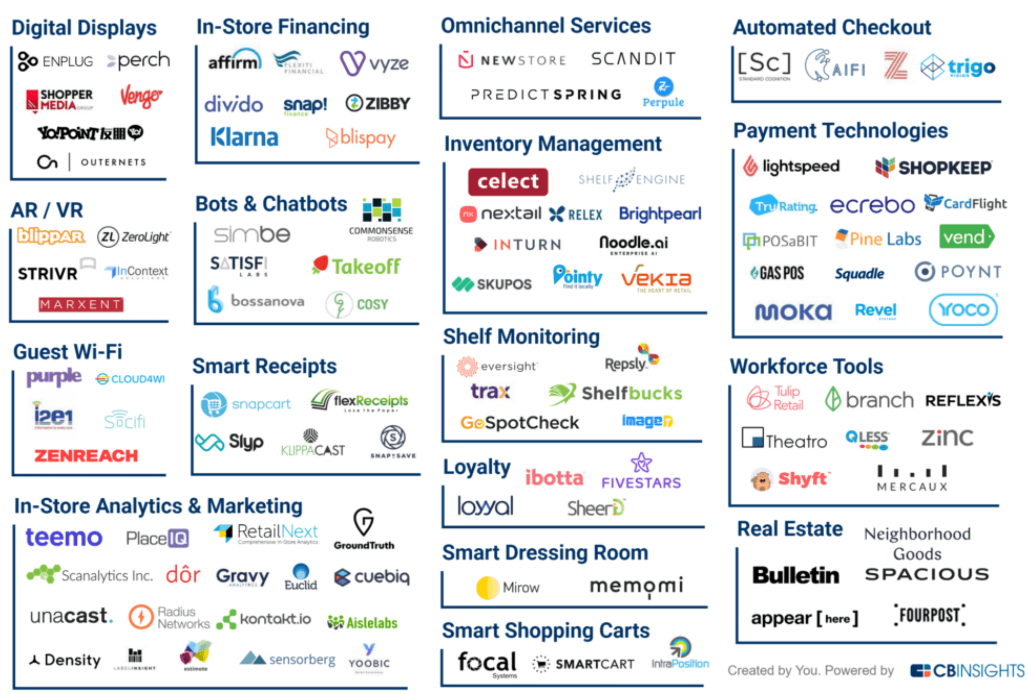
The average autonomous car of the future could produce as much as 2M gigabytes of data per week, and moving all of that data to the cloud or a regional server isn't feasible today with Wi-Fi or 4G.

## RETAIL

Over the last several years, retailers have invested millions in smart technologies to help customers shop more efficiently and check out faster, while collecting more data on the customer experience.

Emerging retail technologies, from in-store analytics to visual recognition-driven shelf monitoring, depend on or benefit from the ability to quickly transmit large amounts of data, which is why 5G technology stands to have such a large impact on the way retailers operate.

### The Retail Store Tech Market Map




Current "smart shelves" incorporating RFID technology, for example, can tell a business owner the ratio of item pick-ups to sales and display dynamic prices. With 5G technology, shelves equipped with sensors could determine low stock on a product, ping a distribution center to restock its inventory, and dynamically monitor the progress of that shipment.

Today, companies like Sephora use virtual try-on technology to help in-store customers see what a particular makeup would look like on them before they buy, but the product is constricted by data streaming limits. 5G technology eliminates such limits — we could one day try on our clothes in augmented reality with such accuracy that it would be hard to tell apart from reality.

5G also has the potential to create entirely new types of shopping experiences that would be unthinkable with today's technology: an augmented reality application on your smartphone, for example, that triggers when you enter a store and guides you directly to the shelf where you can find your items of choice. The physical groundwork for these kinds of experiences is already occurring with cashier-less retail (e.g. Amazon Go).

## ENTERTAINMENT

Media giants such as Fox and Warner Brothers have already begun to explore the use of 5G technology.

5G channels will be able to offer live streaming of unparalleled quality. Amazon and Dish Network are already in negotiations to jointly build and support a 5G network.

Download speeds will also increase dramatically over 5G, making movie, game, and TV downloads possible in seconds rather than minutes. This could propel a shift away from streaming and towards mobile downloads, as downloaded media can be accessed and enjoyed with or without connectivity.

5G could have an even more transformative effect on augmented reality (AR) and virtual reality (VR). VR and AR applications have a higher field of view, resolution, and frame rate than conventional media, and as such require a significantly higher level of bandwidth and lower level of latency in order to transmit a consistent experience to the viewer.

Your typical 4G connection has about 60ms of latency, far too slow for the VR experience, which can become disorienting and jarring even at 15ms. 5G, on the other hand, promises potential latency of between 1-4 milliseconds.

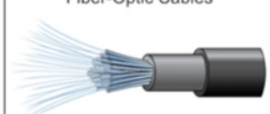
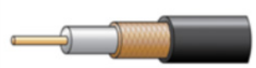
# Four drivers paving the way for 5G

Below, we identify 4 primary drivers that will bring widespread 5G adoption to reality, and highlight how they will contribute to the deployment and use of 5G systems.

### FIBER-OPTIC INFRASTRUCTURE

While sometimes perceived as competing technologies, fiber-optic networks and wireless networks often work in tandem. In the case of 5G, fiber is required to reach the multi-Gbps speeds promoted by wireless carriers because fiber-optic cables can quickly transport large amounts of data across long distances.

**Fiber-optic cables are faster than coaxial copper cables**

| | Fiber-Optic Cables | Coaxial Copper Cables |
|---|---|---|
| Cable Types: |  |  |
| Typical Bandwidth: | More than 1 GB/s | Up to 1 GB/s |
| Benefits: | Immune to electromagnetic and radio frequency interference. | Inexpensive |
| Limitations: | Expensive | Affected by electromagnetic and radio frequency interference. |

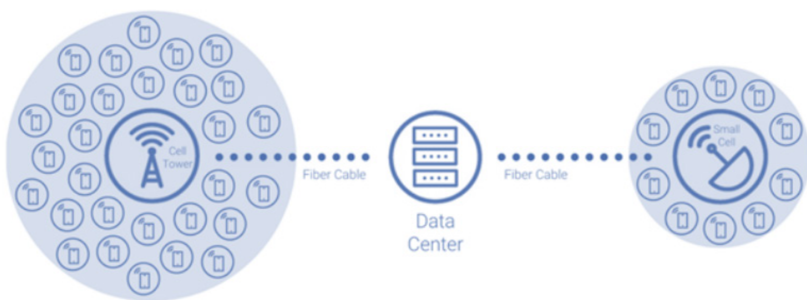
Source: cbinsights.com CBINSIGHTS

Data travels through wires the majority of the time, with wireless antennas typically completing the last few miles of delivery.

In this way, fiber functions as the nervous system to the mobile network. Connecting data centers to cellular antennas (cell towers or small cells) with fiber will allow for the near real-time speeds expected from 5G.

Fiber-optic infrastructure is prevalent today and used by current 4G systems, but more will be required to support widespread 5G.

**Fiber-optic cables are necessary for 5G speeds**




Source: cbinsights.com

Wireless providers are leveraging different strategies to scale their 5G networks. For example, Verizon is looking to own its fiber backhaul (underlying connective infrastructure).

The company has worked with specialty glass manufacturer Corning and fiber provider Prysmian to design and install fiber-optic cables for 5G.

In April 2017, Verizon announced a three-year purchase agreement with Corning to buy 12.4M miles of optical fiber each year for the next three years.

T-Mobile, on the other hand, leases “dark fiber” (unused or underutilized fiber) to support its small cells deployment. While the company may not own the fiber, it can provide 5G services sooner as much of the leased backhaul is already installed.

Both providers aim to further roll out out 5G services in 2019.

Most of these 5G deployments will probably look to support urban centers before expanding to rural areas. However, areas already infused with pervasive fiber — urban or rural — are likely candidates for early 5G deployments.

### SMALL CELL DEPLOYMENT

Much of today's wireless data is delivered through macrocells, known more commonly as cell towers. They provide the foundation for wireless connectivity and can serve thousands of mobile users within a radius of up to 40 miles.

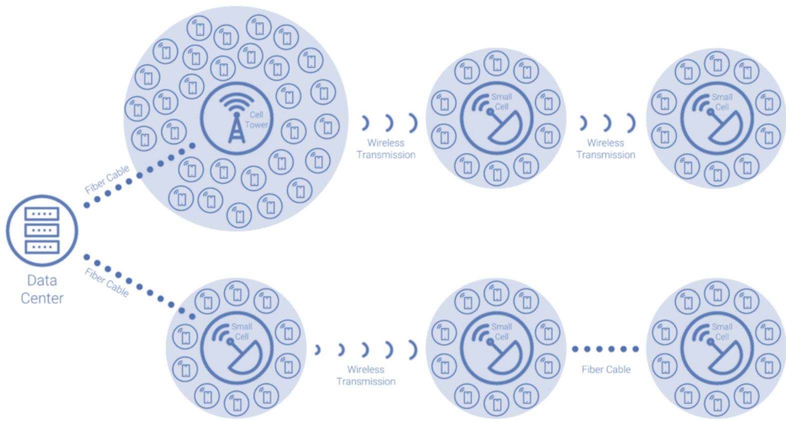
While macrocells continue to serve the telecom industry well, they're difficult to deploy and maintain. The costs of regulatory approval, construction, power, and maintenance make traditional macrocell towers a necessary burden for wireless connectivity.

Small cells (or microcells) are growing contributors to wireless connectivity, supporting the wireless systems of the present and future. They serve fewer mobile users but are much easier to install and maintain. They're also cheaper, more energy efficient, and require less red tape than macrocells.

Small cells communicate wirelessly with macrocell towers, other small cells, and individual mobile devices. Certain small cells connect directly to fiber cables while others provide support to wireless mesh networks that improve wireless coverage.

In rural areas, small cells can help extend coverage; in densely populated areas, they can strengthen capacity.

**5G requires data centers, fiber, cell towers, and small cells**




Source: cbinsights.com
CBINSIGHTS

Some of the newest small-cell technology is hidden in plain sight. In Los Angeles, small cells have been deployed as part of smart streetlights to strengthen 4G networks.

In deploying these small cells, LA has also installed some of the necessary infrastructure required for tomorrow's 5G networks.

5G will only be able to travel short, unobstructed distances. A number of small cells will be required to serve the same area that a single macrocell can cover — though the small cells will provide much faster speeds.

T-Mobile has already installed 15K small cells, with plans to deploy another 25K in the near future. These cells support the rollout of the company's 5G services in 30 cities, including Los Angeles, New York, and Dallas.

In October 2018, the FCC announced a new set of guidelines that restrict the ability of states and local communities to charge carriers for deploying small cells colocated with public infrastructure, a step expected to speed up the rollout of small cell technology across the country.

In addition to the successes with small cell deployment, there have been a string of complications.

Wireless carriers are beginning to realize that small cells will have to comply with a host of new regulations and meet certain demands from local residents who are concerned about the pervasive new technology.

Sprint paid an $11.6M fine for failing to secure the appropriate permits. AT&T received pushback due to the "needlessly messy" design of certain small cells, and the city of Santa Rosa, CA, suspended Verizon's deployment for similar reasons.

The city of Hillsborough, California charged AT&T $60,000 in application fees for sixteen nodes. It rejected the applications. Some of these roadblocks led to the FCC's decision to reduce states and localities' ability to charge carriers for small cell deployment.

Small cell deployments are still in their earliest stages. That said, many carriers will offer their first 5G services in 2019. Mobile users should expect major carriers to offer 5G services in the largest US cities by the early 2020s.

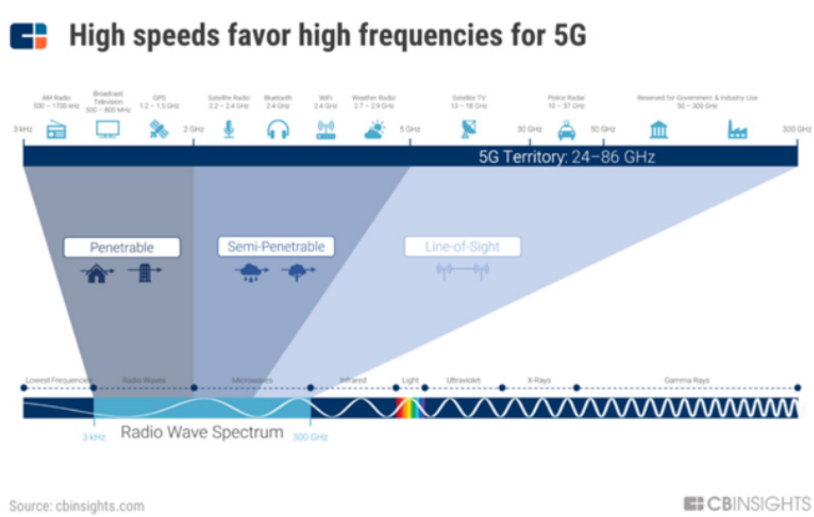
### HIGH-FREQUENCY SPECTRUM AVAILABILITY

In addition to fiber infrastructure and small cell deployment, 5G speeds also require radio waves with extremely high frequencies. These frequencies need line-of-sight within a small radius to successfully communicate.

In other words, increasing demand for wireless coverage, speed, and consumption requires the use of new bands within the radio wave spectrum. A band is a specific frequency range on the radio wave spectrum. They range from very low (3 – 30 kHz) frequencies to extremely high (30 – 300 GHz) frequencies.

For context, AM radio uses the medium frequency band (300 kHz — 3 MHz), leveraging the specific frequencies between 500 and 1700 kHz (or 1.7 MHz).

Wi-Fi and Bluetooth, on the other hand, use the ultra-high frequency band (330 MHz — 3 GHz), leveraging the specific frequency of 2.4 GHz. Mobile devices are designed to communicate on both the 2.4 and 5 GHz frequencies for Wi-Fi.



While higher frequencies allow for faster data transmission, they're unable to pass through certain structures. For example, satellite TV, which typically uses frequencies between 13 -18 GHz, requires a direct line-of-sight to prevent disruptions. Heavy rainfall or an overgrown tree could impact viewing quality.

For most 5G networks, the super high (3 – 30 GHz) and extremely high (30 – 300 GHz) bands will be used to deliver the Gbps speeds promised by wireless carriers. Frequencies between 24 and 86 GHz will be particularly popular.

The FCC began auctioning off the rights for the 28 GHz 5G band in November 2018 to a total of 40 telecoms, wireless carriers, and other entities.

Verizon did not take place in the auction because it already owns a license for part of the 28 GHz band, which it obtained through the acquisition of XO Communications.

By mid-December, total bids in the auction had reached more than $688M.

The agency has never distributed this volume of spectrum at auction previously, and is doing so now since "wireless carriers have been talking up the need for speed and bandwidth for an internet of everything, 5G world," according to the FCC.

Auctions for additional bands will begin later in 2019.

Certain spectrum will be allocated for shared access. With the use of a Spectrum Access System (SAS), carriers can dynamically access shared frequencies based on availability. This will allow carriers to scale bandwidth up and down based on network demand.

It will also provide spectrum access to smaller commercial users that don't license dedicated spectrum of their own. SAS providers like Federated Wireless ensure secure, interference-free bandwidth using proprietary software.

Shared or licensed outright, these higher frequencies will require small cells to be arranged in a way where they maintain line-of-sight between mobile users or other small cells. While an abundance of small cells will help to maintain 5G coverage, another wireless configuration called "fixed wireless" will help deliver wireless coverage indoors.

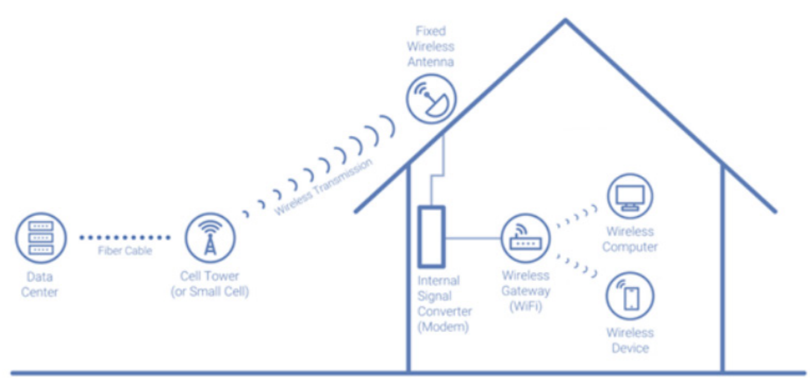
## BRINGING 5G INDOORS WITH FIXED WIRELESS

Though the high frequencies of 5G require direct line-of-sight, "fixed wireless" will allow for cellular coverage within buildings and homes, without the use of cables/lines.

Fixed wireless antennas are placed on top of homes and buildings to communicate with nearby small cells or macrocell towers. While these fixed wireless antennas must maintain line-of-sight with the nearby cells, they are able to extend cellular coverage into homes and buildings.

These antennas may be connected by fiber to internal picocells or femtocells, which are used to relay wireless coverage to a small number of mobile users indoors. The wireless signal can also be converted to conventional Wi-Fi with the use of specially designed modems and routers.

**5G may also provide stationary internet with fixed wireless**




Source: cbinsights.com

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The ability to convert a cellular signal to Wi-Fi may enable wireless carriers to compete with traditional ISPs like Comcast and Time Warner.

Verizon, which already provides internet access to homes and businesses, rolled out fixed 5G wireless services in a handful of cities in 2018. These services will provide an alternative to internet access delivered via fiber while maintaining comparable speeds.

The company is partnering with Samsung for its fixed wireless 5G routers, which will convert wireless 5G signals and enable Wi-Fi compatibility.

While Verizon plans to offer fixed 5G wireless access before any of its mobile 5G services, the infrastructure will help to support both mediums.

In September 2018, Verizon unveiled its first service offering in this space, named “Verizon 5G Home.” The service became available for residents of Houston, Indianapolis, LA, and Sacramento, with advertised speeds between 300 Mbps and 1 Gbps: slower than initially promised by the company.

AT&T, while initially skeptical of the fixed wireless opportunity, announced in September 2018 that it would begin to rollout a fixed wireless service by late 2019.

Both companies are working with Samsung for the delivery of critical infrastructure for their 5G launches.

On the other end of the spectrum, companies like Google may start to build a mobile 5G network using the fixed wireless assets installed as part of its growing Webpass business (acquired in 2016).

Ultimately, fixed wireless is early in its progression to extend mobile 5G service into buildings beyond line-of-sight or to provide internet access to homes and businesses.

## What’s next for 5G

As numerous wireless carriers plan to offer 5G service in the coming year, the entire telecom industry is hard at work to capitalize on this shift to higher radio wave frequencies:

- Qualcomm recently unveiled the Snapdragon 855 chipset, which grants smartphones 5G capabilities. The Snapdragon 855 will roll out in early 2019.
- Verizon launched its first 5G broadband internet networks in 4 cities during late 2018 and plans to release 5G wireless service in 2019 after its first 5G-ready phones hit the market.
- AT&T rolled out 5G mobile hotspots in a dozen cities in 2018 and will be adding at least 9 more in 2019.
- Sprint and LG plan to release the first 5G smartphone in the first half of 2019. Sprint will have its 5G network in place in at least 9 cities by the time the smartphone launches.
- Motorola unveiled its new 5G Moto Mod in 2018; the mod snaps onto the back of the Moto Z3 and turns it into a 5G-capable device. The 5G mod will be available for purchase in 2019.

Companies like Zayo are helping to lay the necessary fiber to support these 5G networks, while others like Siklu are providing fixed wireless antennas and small cells.

Manufacturers of 5G devices also play one of the more important roles in 5G adoption: device manufacturers need growing coverage, while wireless networks need a growing number of compatible devices.


It is likely that the new technology will affect device design. Some prototypes currently exist, but it may take some time before manufacturers can properly — and aesthetically — integrate new 5G antennas into mobile devices.

But with so many companies working to make the technology a reality, consumers should expect to see a range of 5G-enabled devices in the near future. Once carriers activate 5G in a minimum viable number of cities, compatible phones will soon follow.

While 5G service may start to become more broadly available in the coming year, 4G will still remain the default service in areas outside of a select few densely populated cities. Widespread 5G coverage could take over a decade — and as for the broader industrial applications of 5G, estimates suggest that adoption will take off in the early 2020s.

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