

5G and IoT in the Age of the CoronaVirus

Presented to the Lexington, MA Technology
Users Group

By Bob Primak, July 8, 2020

5G, IOT and The Virus

- Please use Chat to post questions or comment topics.
- I'll monitor Chat at intervals and address points made.
- There will be general Q and A at least once.
- In the case of images, I have included in my other document all the references and sources. (It's OK to do video or record.)
- So let's begin with a Summary of Sections to be Covered:

Topics To Be Covered

I. Technical Descriptions

1. WHAT IS 5G?
2. 5G Characteristics
3. Optimizing Bandwidth Utilization
4. Further Refinements in Bandwidth Utilization

Topics To Be Covered

- II. Carriers and Bands
- Remember, there are three main bands involved.
- These bands have different uses and requirements.
 - 5. Spectrum Reallocation
 - 6. Sprint and T-Mobile – Wide Range and Rural Coverage

Topics To Be Covered

- III. Transmitter and Receiver Changes
 - 7. New Home internet Router Technologies --
 - 802.11ax (aka. WiFi 6)
 - 8. Beamforming – Even More Throughput

Topics To Be Covered

- IV. 2020 Update of 5G Rollout in the US and the World
 - 9. Speed And Coverage (And Materials Penetration)
 - 10. Recent Developments in the 5G Rollout
 - 11. When, What, Where and How Much?
 - (?) 12. Devices for 5G Cellular (I haven't really researched.)
 - 13. Massachusetts Case Studies

Topics To Be Covered

V. Futuristic Technologies –

Satellites and Fixed 5G Home Internet Services

14. Satellite Phone Services – A Historic Failure
15. Iridium Saved By A Plane Disaster
16. Iridium NEXT For Air Traffic Tracking
(This is IoT in Transportation.)
17. SpaceX and IoT for Internet Services – Iridium NEXT
18. Fixed 5G – Starry– Not Here Yet – But Closing In

Topics To Be Covered

- Large Scale Applications (Skip for now)
 - 19. Industrial Internet of Things – IIoT
 - 20. Smart Cities

VI. The Coronavirus Pandemic – Lessons to Be Learned

- 21. 5G, IoT, and The Pandemic
- 22. Supply Chain Logistics
- 23. Impacts on Work
- 24. Impacts on Learning and Teaching

Topics To Be Covered

- VII. Public Resistance to the New Technologies
- 25. Public Resistance to Upgrading Communications Infrastructure
- 26. Huawei and Government Policy (Probably skip for now)

- I don't think I'll get through all possible materials today.
- I expect some help with the more technical parts of how these technologies work.
- I'll try to allow time for more general discussion as we end.

What Is 5G?

4G vs. 5G Characteristics

Technology	4G	5G
Core network	Internet	Internet
Bandwidth	200 Mbps	Greater than 1Gbps
Maximum speed	100 Mbps	10 Gbps
Latency	20-30 milliseconds	Less than 10 milliseconds
Power Consumption	High battery consumption	10% more durable battery
Mobile coverage	Limited coverage	Coverage reaches every corner

What Is 5G?

- **1G and 2G** – There never was something called as 1G at first. It basically was a network with only voice call capabilities and only got the name 1G after 2G was put to use. During the 2G era, that lasted for quite a while from 1980's to 2003, there were quite a few advancements made within the spectrum itself such as GSM, GPRS and EDGE.
- **3G** – 3G has speed capabilities of up to 2 mbps. It enabled smartphones to provide faster communication, send/receive large emails and texts, provide fast web browsing, video streaming and more security among others. It was widely based on CDMA2000 (Code-division multiple access) and EDGE technologies. Now you might wonder why EDGE? Well, because EDGE was so advanced it was able to provide enough capabilities to be considered as 3G. CDMA2000, on the other hand, operated on similar key concepts but did it better. It enabled multiple channels to communicate at one same thus improvising on the over speed and connectivity.

What Is 5G?

- **4G** – The 4G standard sets several requirements for mobile networks
 - including mandating the use of Internet Protocol (IP) for data traffic and minimum data rates of 100 Mbps. [LifeWire] which was a huge jump from the 2 mbps for 3G. It is often referred to as MAGIC
 - M – Mobile multimedia
 - A – Anytime anywhere
 - G – Global mobility support
 - I – Integrated wireless solution
 - C – Customized personal service

What Is 5G?

- **4G** – It is not much to do with the technology it uses but rather than the requirements set forth by International Telecommunication Union's Radio communication Sector (ITU-R). These standards are known as International Mobile Telecommunications-Advanced (IMT-Advanced). The list of standards is quite complicated and thus were a barrier in fast adoption of the 4G spectrum.
- Soon after 4G, 4G LTE was introduced. LTE stands for Long Term Evolution and it isn't as much a technology as it is the path followed to achieve 4G speeds. It was a complete redesign and simplification of 3G network architecture, resulting in a significant reduction in transfer latency and thus, increasing efficiency and speeds on the network.

What Is 5G?

- **Eight Defining Characteristics:**
- Peak data rate of 10 gigabits per second.
- Mobile “data volume”, aka network capacity, of 10 terabits per second per square kilometer.
- Mobility. Users can connect while traveling at 300 miles per hour. (Not airliner speeds.)

What Is 5g?

- **Defining Characteristics (continued):**
- One million connected devices per square kilometer. That's versus a similarly theoretical maximum of 100,000 connected devices per square kilometer for 4G networks.
- End to end latency of 5 milliseconds. That's at least ten times faster than what 4G networks deliver.
- Reliability of 99.999%.
- Service deployment of 90 minutes. (Also, Network Slicing. *)
- Energy efficiency of 10% of current consumption. (Small sites.)

What Is 5G?

- * “network slicing” [means] the ability to easily create subnetworks for specialized uses such as, say, for first responders or internal organizational networks.
- So how do we achieve these goals?
- “Verizon will only be able to hit these benchmarks, assuming it can, where 5G infrastructure is fully deployed. That means deploying a lot of small cell sites and stringing a lot of fiber to connect them.”
- – Steve Blum, CEO, Verizon – January 09, 2019 –

5G Technologies

- WiFi 6, aka 80211.ax
- Most [of us] have heard about 5G, the soon-to-be-adopted standard for mobile data. But that's just half of the picture for the next generation of high-speed internet.
- The future for homes, business and many public places will be using a different technological innovation: Wi-Fi 6.
- WI-FI'S WEIRD NAMING SCHEME: Wi-Fi 6 was adopted in place of 80211.ax by a Standards organization. You won't hear about Wi-Fi 1-5, though, due to current use and familiarity among users with older naming.

5G Technologies

- Wi-Fi 6 Explained:
- Wi-Fi 6 is all about improving the network when a bunch of devices are connected.
- When Wi-Fi 5 came out, the average US household had about five Wi-Fi devices in it. Now, homes have nine Wi-Fi devices on average, and various firms have predicted we'll hit 50 on average within several years.
- Connected Homes = Consumer IoT

5G Technologies

- Wi-Fi 6 – Not about absolute speed – about managing multiple simultaneous connections.
- More on Wi-Fi later. Let's talk about the 5G Bands and their characteristics and uses.

5G Technologies

- 5G bands cheat sheet: Verizon vs AT&T vs Sprint vs T-Mobile vs World. (No this isn't about a musical Battle of the Bands!)
- (Scrolling Image – use IrfanView if possible.)

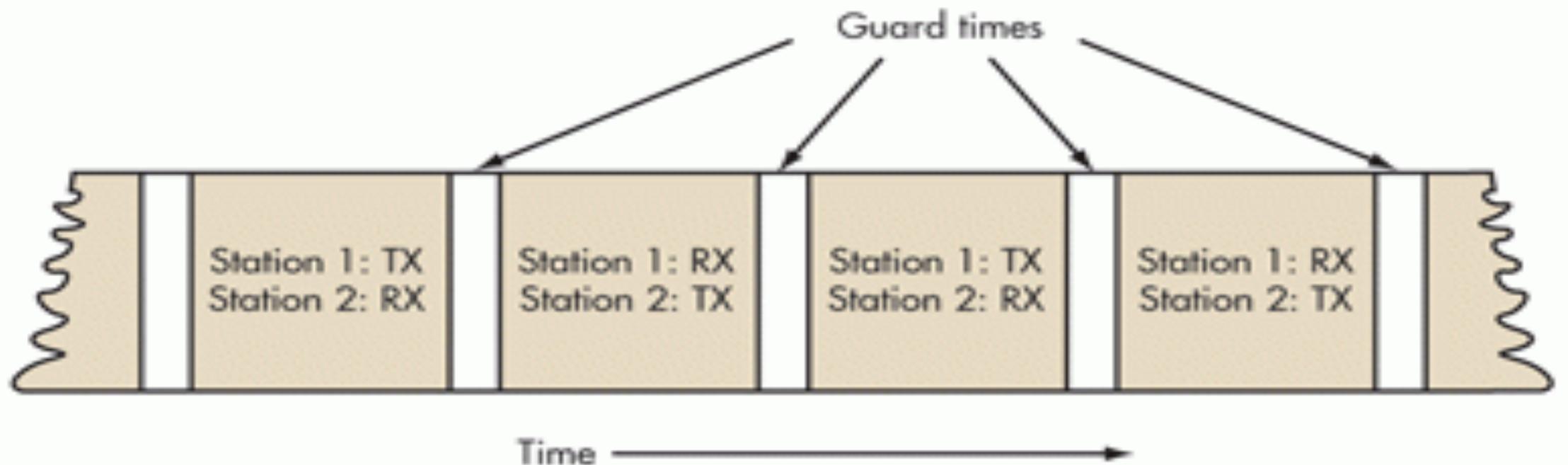
Low Band – longer distances and better coverage in open areas. Lower data capacity.

Mid-Band – Best compromise between building penetration and speed and latency.

High (mm) Band – Best download speeds. Poor building penetration. Environmental materials can slow or block.

TDD and FDD

- Frequency Division vs. Time Division Duplexing in Wireless Communications
- TDD (Illustration) – TDD uses a single frequency band for both transmit and receive.

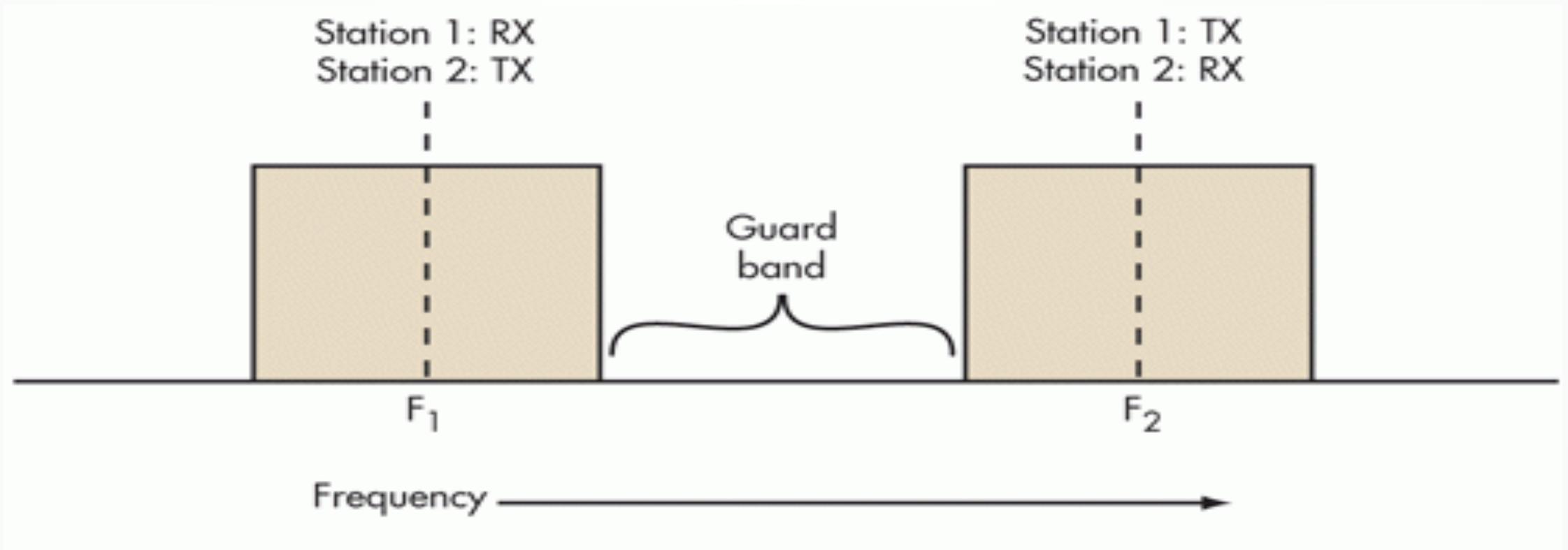


TDD and FDD

- TDD alternates the transmission and reception of station data over time. Time slots may be variable in length.
- TDD is used in the following wireless systems:
 - WiFi Networks
 - Some 4G/LTE networks (some use FDD)
- The communicating parties cannot tell that the transmissions are intermittent.

TDD and FDD

- FDD requires two separate wireless communications channels on separate frequencies, one for transmit and the other for received data.



TDD and FDD

- FDD is used in the following wireless systems:
 - Microwave (MW) Links
 - Millimeter Wave (MMW) links
 - Some 4G/LTE networks (some use TDD)
- Filtering or duplexers and possibly shielding are a must to avoid interference.
- This tech goes hand in glove with MIMO and MU-MIMO
- (We'll see these later.)

TDD and FDD

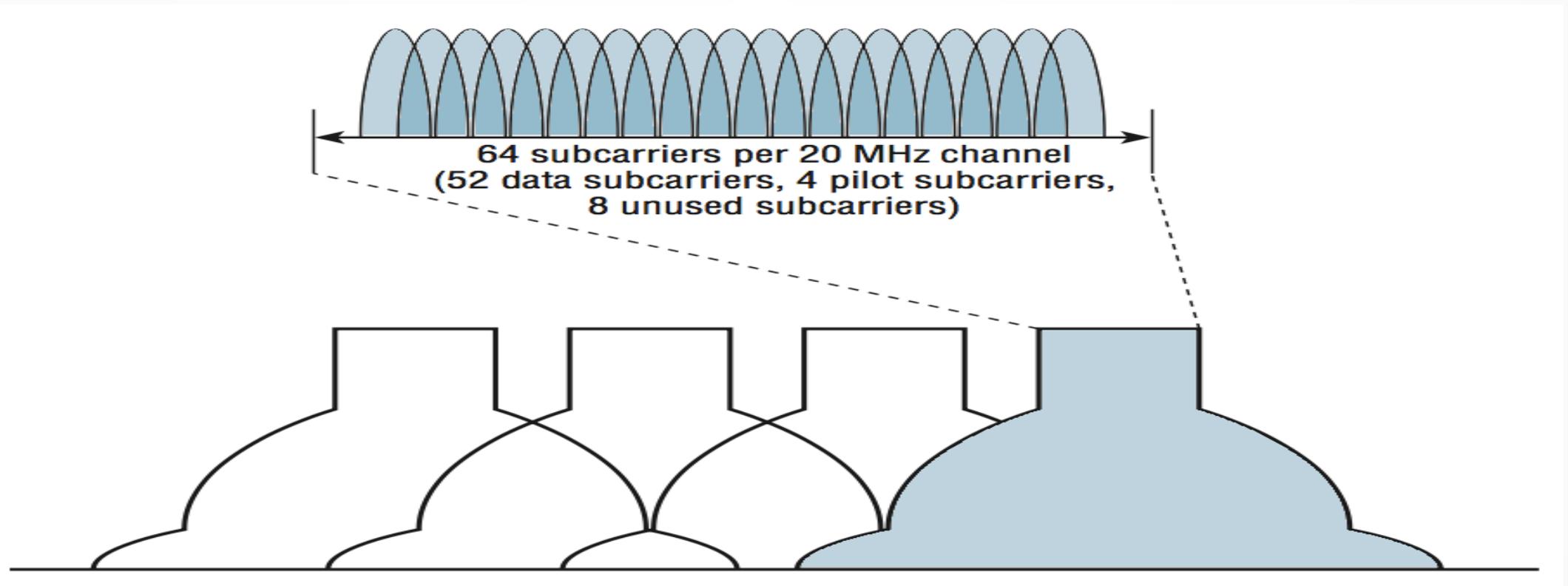
- In most parts of the world, all previous and current mobile network generations are based on Frequency Division Duplex (FDD), i.e. there is one channel for the downlink and a separate channel for the uplink. However, there are huge spectrum allocations for Time Division Duplex (TDD), especially in the US and China. This is why a few years after LTE networks started mostly as FDD networks, we also saw LTE being deployed in a TDD variant in those geographies.

TDD and FDD

- Not so in 5G NR! Here, the first EN-DC deployments that will use 4G LTE as an anchor will use 5G in the TDD variant first. For those network operators deploying 5G in 3.x GHz, 3GPP band n78 will be used, which is TDD. And for those network operators going for mmWave, TDD is also the only option.
- (The band referred to is in the mid-band range of the 5G spectrum.)

OFDM and OFDMA

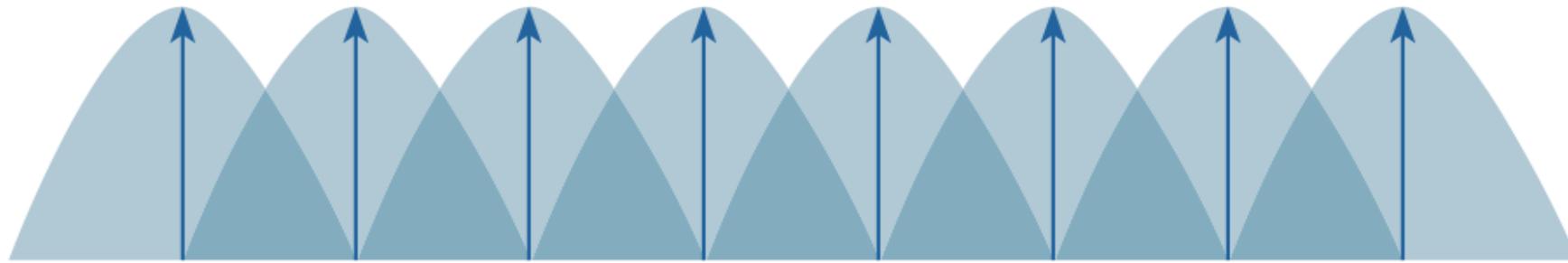
- OFDM and OFDMA Subcarriers
- OFDM:



OFDM and OFDMA

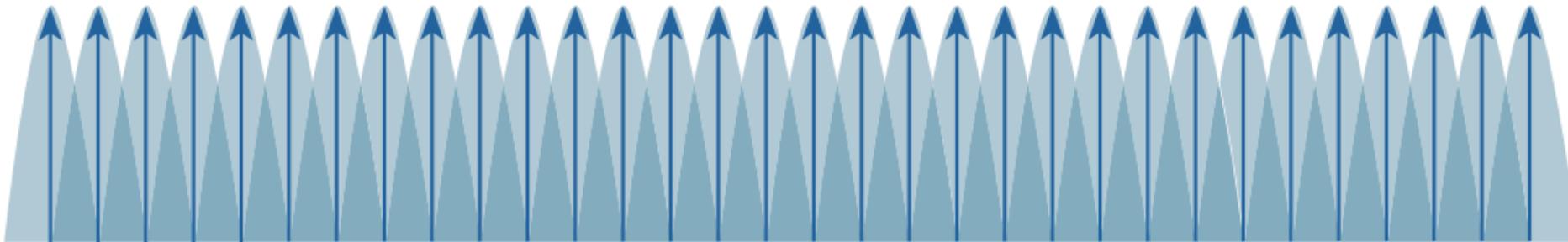
- OFDMA:

802.11a/g/n/ac subcarriers



312.5 kHz

802.11ax subcarriers



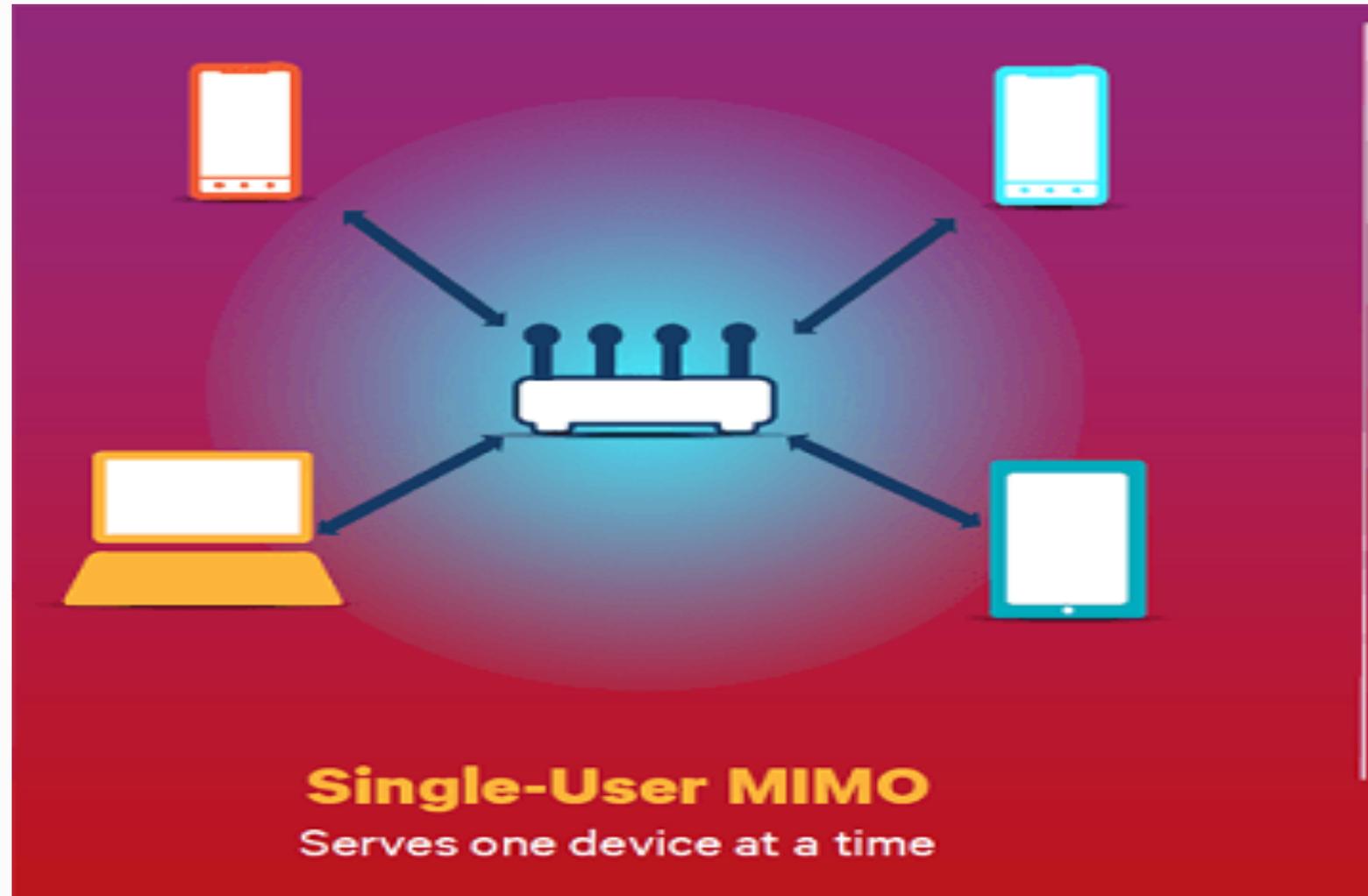
78.125 kHz

MIMO and MU-MIMO

- “MIMO” stands for “Multiple-Input, Multiple-Output”, and it refers to the way bandwidth is broken up by a router and pushed to individual devices. Most modern routers use “SU-MIMO”, or “Single User, Multiple-Input, Multiple-Output”.
- “MU-MIMO” routers, on the other hand (“Multiple User, Multiple-Input, Multiple-Output”) are able to break up this bandwidth into separate, individual streams that each share the connection evenly, no matter the application.

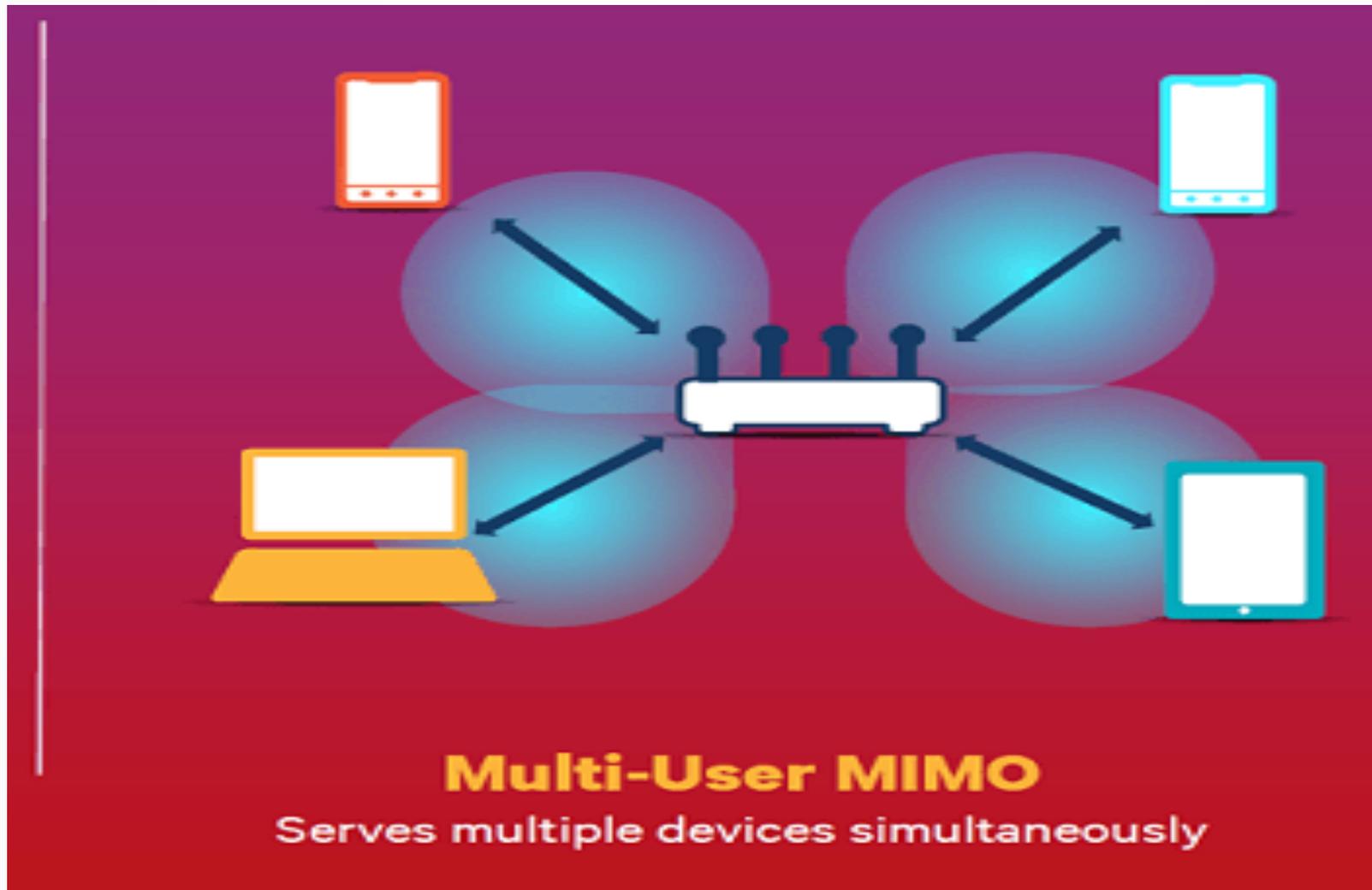
MIMO and MU-MIMO

- SU-MIMO Router or Antenna:



MIMO and MU-MIMO

- MU-MIMO router or antenna:



MIMO and MU-MIMO

- MIMO is designed to avoid latency and dropouts caused when multiple users want to access the same router, antenna or Access Point.
- MU-MIMO reduces lag and latency, so allows even more devices to share a common access point.
- Edge Processing at the antenna site allows even lower latency, and Massively MU-MIMO is an even denser array used in outdoor mobile and fixed 5G towers.

5G Networks

- So let's put all of this together:
- (Big Illustration of 5G Networks and characteristics.)
- We have bands with enormous data capacity.
- We have antennas and transmission methods with capacity for massive numbers of simultaneous transmissions.
- Let's also consider Beamforming, then go on to case studies.

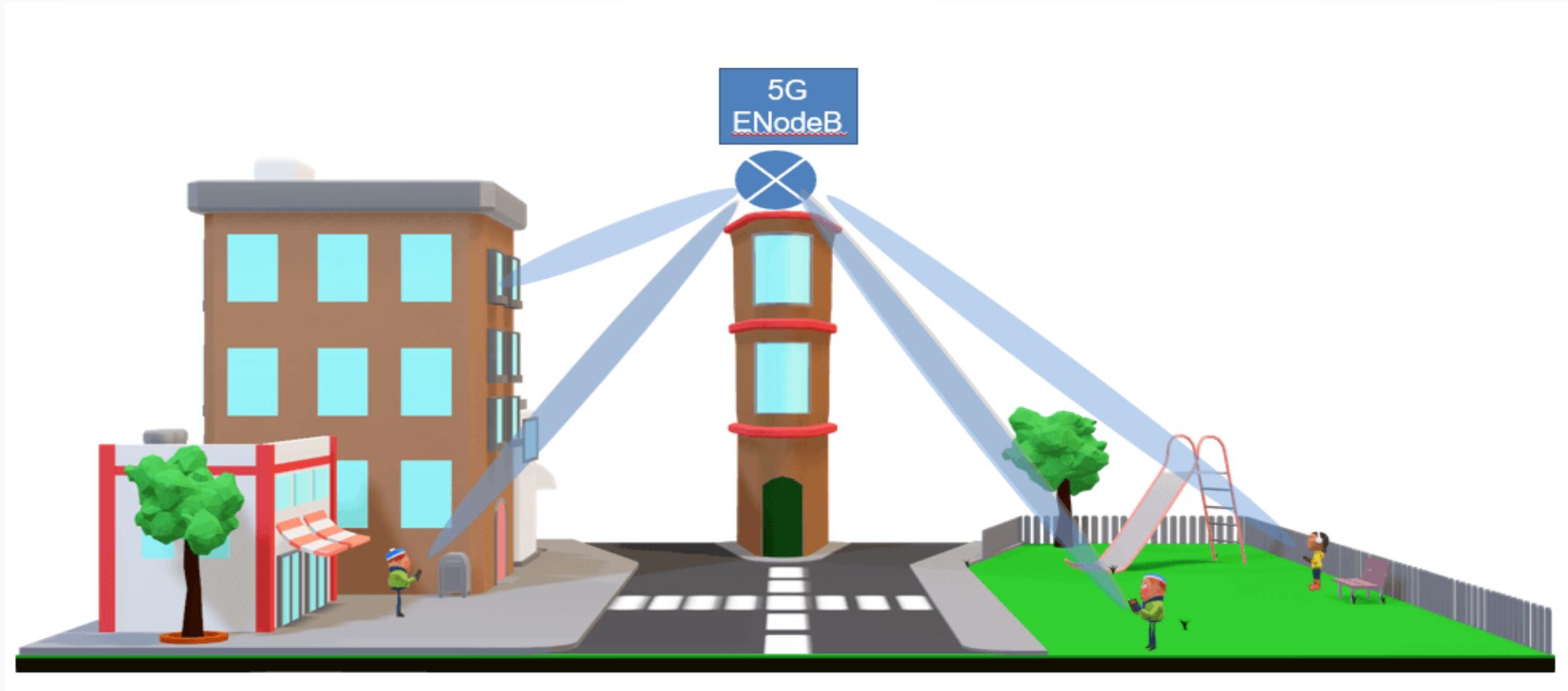
Beamforming and Overcoming Obstacles

- Normal Wi-Fi coverage vs. Beamforming – Home Router



Beamforming and Overcoming Obstacles

- Beamforming in Outdoor Antennas



Beamforming and Overcoming Obstacles

- How effective is beamforming?
- The promise of 5G gains with improved throughput, latency etc and the user-centric network needs to ensure that the narrow beams focused towards the user are physically feasible from both the UE side as well as the eNodeB. These beams will require having the ability to steer the beams in Horizontal and Vertical axis. A poorly shaped beam will completely kill the link budget and hence performance, Beam-Centric optimization will be required to quickly identify and fix root cause issues.

Beamforming

- Translation – When it works, it's wonderful. When it doesn't work, it fails miserably!
- We shall see momentarily how different city environments are handling things like reflections off buildings (you can actually take advantage of this) and materials which don't transmit high-frequency radio signals.
- As we go along, let's look at what's new, and where 5G services are being rolled out.

How Fast Will 5g Be?

- It depends:
- Low Band is slower. High Band is very fast.
- High Band doesn't travel as far, signal strength falls off very fast outside of beamformed coverage "sweet spots".
- Mid-Band is often called the "sweet spot" for balance.
- T-Mobile and Sprint merged to take advantage of both mid-band and high-band holdings.

How Fast Will 5G Be?

- Tech companies are promising a lot from 5G. While 4G tops out at a theoretical 100 megabits per second (Mbps), 5G tops out at 10 gigabits per second (Gbps). That means 5G is a hundred times faster than the current 4G technology—at its theoretical maximum speed, anyway.
- At these speeds, 5G beats current home cable internet connections and is more comparable to fiber. Landline internet companies like Comcast, Cox, and others may face serious competition... *(more on this later)*

How Fast Will 5G Be?

- 5G promises to significantly reduce latency, which means faster load times and improved responsiveness when doing just about anything on the internet. Specifically, the specification promises a maximum latency of 4ms on 5G versus 20ms on 4G LTE today. (Even for Home Internet, 4ms latency is very good.)
- 5G base stations will also run at full duplex, which means they can transmit and receive at the same time, on the same frequency. Today, they have to switch between transmitting and listening modes, slowing things down.

How Fast Will 5G Be?

- RootMetrics: Verizon's 5G blazes past wider, slower T-Mobile and AT&T:

Carrier	Highest 5G availability rate (%)	Fastest 5G median download speed (Mbps)	Fastest 5G maximum download speed (Mbps)			
AT&T	9.5%	Indianapolis	47.1	Indianapolis	175.2	Indianapolis
Sprint	45.7%	Dallas	136.7	Chicago	249.9	Chicago
T-Mobile	57.1%	Washington, D.C.	34.0	Chicago	147.8	Chicago
Verizon	3.1%	Chicago	247.0	Los Angeles	845.7	Washington, D.C.

How Fast Will 5G Be?

- Real-World Testing
- Produced a “mixed bag” of results: Verizon 5G users continue to see the fastest average and peak download speeds, but with very low availability, while T-Mobile and AT&T are delivering 5G at 4G-like speeds that are less likely to impress consumers.
- These results are a bit different from those last year when I reported on field tests by tech publications in a few cities.

How Fast Will 5G Be?

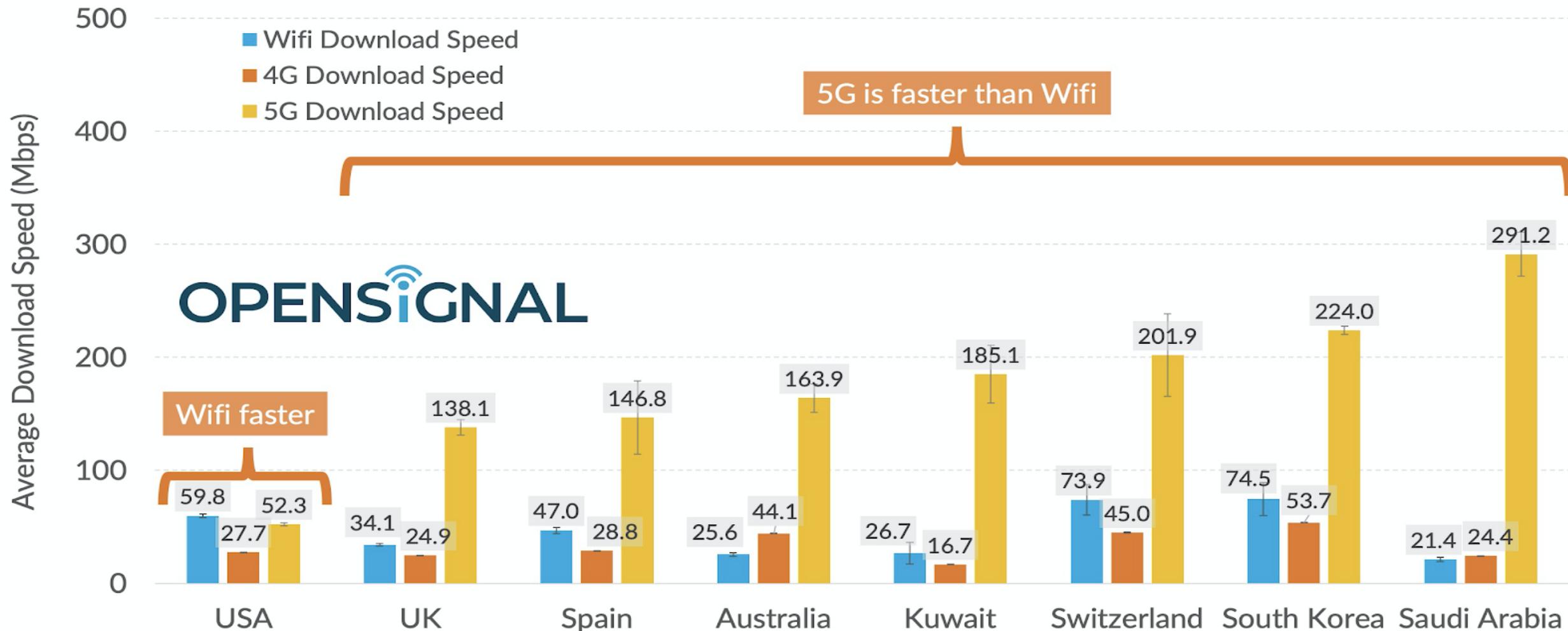
- Improvements since a couple of years ago generally can be seen but are not impressive at all.
- Areas of coverage have been increased from a few street corners downtown to larger areas of some cities. We'll cover Boston and other MA towns and cities later.
- T-Mobile/Sprint has expanded coverage faster, but AT&T's High-Band 5G still overwhelmingly wins on speed of downloads. (There are still no services with 5G uploads.)

How Fast Will 5G Be?

- This is all about outdoor cell phone service. Indoor cell or fixed wireless home Internet services are a whole different ballgame, and have not yet been introduced.
- Starry, which claims to be gearing up to 5G wireless home Internet is NOT 5G today.
- Then again, neither is AT&T's 5GE or 5G-evolution.
- T-Mobile has also been calling advanced 4G-LTE services "5G" or "5G speeds". Also not true.

How Fast Will 5G Be?

5G download speed is now faster than Wifi for smartphone users in seven leading 5G countries



Data collected January 22– April 21, 2020

Summary of 5G Evolution

<p>1981 1G Analog radio signals connecting voice transmissions to main phone networks.</p>	<p>1992 2G Introduction of digital voice transmissions with increased capacity and text messaging.</p>	<p>2002 3G Addition of wireless data, providing access to the internet.</p>	<p>2010 4G (LTE) High-speed wireless broadband, allowing video transmission.</p>	<p>2018 5G Very high-speed broadband access with almost instant responsiveness, even for large, tightly packed crowds. Immediate connection to infrastructure sensors and wearable devices. Greatly reduced lag time will play a critical role in vehicle safety systems.</p>
-------------------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------	----------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------	--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

Download speed | MEGABYTES PER SECOND

Time to download a feature-length movie:	10-26 hours	6 minutes	3-4 seconds for ultra-HD
0.002 MBps	0.064 MBps	2 to 10 MBps	10 to 100 MBps
		6 MBps	55 MBps
			850 MBps

Data volume increase over previous generation → **32x**

Real-world data speeds vary extensively. Numbers are rough averages. In graphic, average data volume is proportional to sphere volume. **100x**

~10x

850 MBps

~15x

Source: Politico: The What, When and How of 5G
<https://www.politico.com/news/agenda/2020/02/25/the-what-when-and-how-of-5g-114485>

US 5G Rollout

- Verizon: Fixed and mobile 5G is live in several areas.
- AT&T: Mobile 5G for customers in hundreds of cities.
- T-Mobile/Sprint: Commercial 5G service available in more than 5,000 cities and towns.
- U.S. Cellular: 5G is available in parts of Iowa and Wisconsin.
- C Spire: Fixed 5G services in Mississippi.
- Charter's Spectrum Mobile: Began providing 5G in March 2020.
- Comcast/Xfinity: 5G rolled out in select locations in May 2020.
- Simple Mobile: Nationwide 5G coverage powered by T-Mobile.
- Nex-Tech Wireless: 5G service will launch by the third quarter of 2020.
- US Mobile: Officially launching via Verizon's network in July 2020.

US 5G Rollout

- (We'll get back to Starry fixed 5G wireless later.)
- Verizon currently offers 5G broadband internet, called 5G Home, in areas of Houston TX, Sacramento CA, Indianapolis IN, Los Angeles CA, Chicago IL, and Detroit MI. Pre-orders for Verizon 5G Home started on September 13, 2018, and service began October 1.
- Mobile 5G from Verizon began rolling out on April 3, 2019, and is currently available in parts of 35 cities. Verizon will continue expanding the mobile network throughout 2020.

US 5G Rollout

- 5G from AT&T is available in two forms. One operates on the mmWave spectrum and is called 5G+. It's available in 35 cities, including Los Angeles, San Diego, San Francisco, San Jose, West Hollywood, Jacksonville, Orlando, Atlanta, Las Vegas, New York City, King of Prussia, Dallas, Houston, San Antonio, Waco, and others.
- AT&T's low-band 5G network works in 355 areas, including Birmingham AL, Indianapolis IN, Los Angeles CA, Milwaukee WI, Pittsburgh PA, Providence RI, Rochester NY, San Diego CA, San Francisco CA, San Jose CA, Wichita KS, Dayton OH, Boston MA, Allentown PA, Brown County IN, Hancock County GA, Hancock County OH, Harrisburg PA, Topeka KS, Trenton NJ, and others.
- The initial rollout was available to particular businesses and consumers only, but AT&T for consumers launched on December 13, 2019. Service is available via several 5G phones.

US 5G Rollout

- T-Mobile launched 5G across 5,000 US cities and towns on December 2, 2019. Here are some later rollouts:
- February 11, 2020: 95 additional areas
- March 9, 2020: Corvallis OR, Jackson TN, Twin Falls ID
- March 12, 2020: Evansville IN and surrounding areas
- March 19, 2020: Hatch NM, Hood River OR, Cordes Lake AZ, Ault CO
- April 21, 2020: Philadelphia PA, Detroit MI, St. Louis MO, Columbus OH

US 5G Rollout

- T-Mobile/Sprint (cont.)
- Their network currently covers nearly 6,000 cities. See T-Mobile's 5G coverage map for details on where in those cities you can get service.
- T-Mobile's 5G network currently covers over 200 million people. This includes customers in thousands of cities, including millions of people in rural areas.
- But remember, this is low-band 5G. About as fast as 4G-LTE.

US 5G Rollout

- U.S. Cellular is another carrier launching 5G in 2020. Service began on March 6 2020 in Iowa and Wisconsin, specifically in larger communities like parts of Cedar Rapids, Davenport, Des Moines, Dubuque, Waterloo, Green Bay, Madison, Milwaukee, Oshkosh, and Racine.
- The company began testing 5G for fixed wireless access in 2016 with Nokia, followed by rural and urban 5G testing with Ericsson in 2017. In early 2019, U.S. Cellular again tested various 5G use cases with Ericsson, like virtual reality, augmented reality, and massive MIMO, in both urban and rural areas.

US 5G Rollout

- The 5G service from C Spire costs \$50 /month, has no data cap or long-term contract, and offers peak speeds of up to 200 Mbps.
- 5G is currently available for select customers in 31 Mississippi counties.
- You can even get free 5G internet from C Spire by becoming a 5G Internet Hub Home, which is where you agree to let C Spire attach 5G equipment to your house which is then relayed to your neighbors, thus extending their network.
- The 5G FWA service from C Spire uses 28 GHz equipment provided by Phazr. Despite the standard service speed set at 120 Mbps, users have reportedly been able to achieve download speeds of up to 750 Mbps and upload speeds as fast as 600 Mbps, with latency as low as 8 ms.

US 5G Rollout

- Charter's Spectrum Mobile is rolling out 5G services across dozens of cities, including Omaha, Dallas, Boston, Detroit, Washington D.C., St. Paul, Denver, Miami, Spokane, and Kansas City.
- Comcast (Xfinity) offers 5G through an MVNO agreement with Verizon. 5G service is included in their data plans at no extra charge.

US 5G Rollout

- As of March 2020:
- Nex-Tech Wireless is currently working to deploy 600MHz sites that are 5G ready with spectrum in each of the bands.
- US Mobile is a mobile virtual network operator (MVNO) that operates on Verizon's and T-Mobile's networks.
- They will offer 5G service to customers via Verizon's towers in July 2020

US 5G Rollout

- Boom! Mobile runs their service using other networks' towers, and one option they have is 5G service. Boom! BLUE is the plan type that supports 5G.
- =====
- Fixed 5G Home Internet Services are mentioned for several of these companies. But none specializes in services comparable to what Comcast, RCN and Verizon have offered for years.
- **Except for a company known as Starry.**
- (Starry currently operates in selected areas of Boston and other MA cities and towns. Waltham is considering Starry for a future rollout.)

Fixed 5G Wireless and Satellite Internet

- A “fixed” antenna is installed on the house, similar to how a satellite dish might be installed. This antenna then creates a wireless connection with a nearby wireless tower, which can connect to many antennas at the same time.
- The antenna connects wirelessly to a neighborhood array of antennas, usually favoring the nearest one. But you are not paired to just one antenna, so there is fail-over redundancy.

Fixed 5G Wireless and Satellite Internet

- Like other wireless connections, 5G does operate on the radio spectrum, but in a very different way from past wireless internet options. We covered the possible bands, but this uses high-band (mm wave) frequencies.
- Rural areas will be better served by satellite Internet improvements. (We'll see this later.)
- So what's Starry, and what's it like to be their customer?

Starry Fixed 5G Internet

- Starry buys 24GHz spectrum to serve apartment buildings, some single-family homes. (Ars Technica)
- Starry's network already passes more than 1.5 million households in Boston, Washington, DC, Los Angeles, New York City, and Denver. Its first launch was in Boston in 2016. The company sells 200Mbps Internet service for \$50 a month, but it doesn't reveal how many subscribers it has.

Starry Fixed 5G Internet

- Today, Starry uses shared spectrum in the 37GHz band. Starry's new, exclusive licenses in the 24GHz band provide about 200MHz worth of spectrum in each market.
- "Combined with Starry's current deployment roadmap, Starry's fixed wireless footprint will reach more than 40 million households, covering more than 25 percent of all US households," the company said.

Starry Fixed 5G Internet

- Starry's early rollouts have focused on multi-unit buildings in big cities, so 40 million households won't necessarily be anywhere close to 40 million buildings. Starry also needs access to buildings from building owners, so there's no guarantee that all 40 million households will be able to get service.
- Starry's public statement that its network currently "passes" 1.5 million households includes all the apartments in any building that it could theoretically put an antenna on, even if Starry hasn't yet been able to gain access to the building.

Starry Fixed 5G Internet

- The company told us that its technology doesn't work in very rural areas where houses are miles apart but that it does plan to offer service in some smaller towns.
- Starry's unique point-to-multipoint design enables the company to provide gigabit-capable coverage to a community with dozens, not thousands of base station sites, at a cost of less than \$20 per home passed.
- Starry publishes its customers' average speeds each quarter—the latest numbers are average download speeds of 226Mbps, average uploads of 229Mbps, and average latency of 11.8ms.

Starry Fixed 5G Internet

- So how does Starry work?



Starry Fixed 5G Internet

- Starry told us that it plans to pilot different prices and speeds, including gigabit, but it isn't seeing a demand for gigabit speeds in its current markets yet.
- Starry says it imposes no data caps and that the \$50 monthly charge includes all taxes, fees, and equipment costs. It's "commitment-free" with "no long-term contracts," the ISP says.
- The company also promises to follow net neutrality and privacy principles (no throttling based on content provider or type).

SpaceX, Elon Musk and Iridium NEXT

- Iridium – Build It and They May Not Come
- Iridium was initially envisaged as a constellation of 77 satellites oriented in 7 planes about the Earth with 7 satellites orbiting in each plane. The satellites would cover a set portion of the Earth with coverage overlapping with other satellites providing near continuous and nearly global coverage. It is from the number 77 that the name "Iridium" was chosen - element 77 on the periodic table. It was later decided to scale this constellation back to 66 satellites orbiting in 6 equally spaced orbital planes 421 miles high with 6 spacecraft in each group.

SpaceX, Elon Musk and Iridium NEXT

- Motorola started the project for cell phone (radio phone) coverage worldwide, especially in remote areas.
- The phones were big and heavy, and the service was very expensive (over \$350/mo).
- The service never really caught on, and as cell phone coverage expanded the market shrank even smaller.
- The US Military considered reviving the project, but lost interest. The satellites have since been brought down from orbit.

SpaceX, Elon Musk and Iridium NEXT

- Years later, and Elon Musk is hard at work launching satellites and manned rockets. He gets the idea to do a modern upgrade of Iridium.
- This idea was driven in part by a terrible tragedy:
- What Really Happened to Malaysia's Missing Airplane
- <https://www.theatlantic.com/magazine/archive/2019/07/mh370-malaysia-airlines/590653/>

SpaceX, Elon Musk and Iridium NEXT

- Malaysia Airlines Says It Will Use Satellites To Track Its Fleet
- <https://www.npr.org/sections/thetwo-way/2017/04/19/524681431/malaysia-airlines-says-it-will-use-satellites-to-track-its-fleet>
- This was one of several incidents which prompted the airlines to try to track their aircraft everywhere and at all times using satellites. This gave birth to the new Iridium NEXT project.

SpaceX, Elon Musk and Iridium NEXT

- Under the same category, Elon Musk's SpaceX is launching an array of satellites which he calls Starlink.
- Like Iridium, this is a communications network using a large number of satellites to provide coverage everywhere.
- Starlink ultimately aims to provide low-cost, high speed broadband connectivity to customers globally, with the specific goal of offering service to customers who don't currently have reliable or quality access due to their remote location. Pricing has not been announced. Public Beta will begin three to six months from now.

5G Rollout in Boston and MA

- Verizon announced that its customers now have access to its 5G network in the Fenway neighborhood. And a few days later, AT&T said it would be rolling out a “low-band” 5G network across eastern Massachusetts.
- Verizon has rolled out its 5G service to a total of 18 cities in the United States. Boston was included in the latest batch. Verizon 5G Ultra Wideband will allow those with 5G-compatible devices (more on that below) to stream 4K movies with “virtually no buffering” and video chat with near-zero lag, plus experience quicker downloads, more responsive gaming, and augmented reality that responds in near real-time.

5G Rollout in Boston and MA

- Because you have to live or work close to a small cell, coverage starts off limited to a patchwork of streets in the Fenway neighborhood. Infrastructure will be built out over the next few years.
- AT&T will offer much broader coverage, though a company spokesperson acknowledged that their 5G service won't be as fast as what Verizon is offering in Fenway. It will solely rely on low-band spectrum.

5G Rollout in Boston and MA

- The 5G network will be significantly better than 4G services, specifically offering lower latency (meaning faster buffering), “massive connectivity,” and faster speeds.
- It’s expected to be complete by the end of the year.
- The coverage map for the low-band network includes virtually all of Greater Boston, swathes of eastern Massachusetts, Providence, and much of southeastern New Hampshire.

5G Rollout in Boston and MA

- AT&T will offer mm-wave 5G service to consumers within the next few years, they say. Businesses already can get this service from AT&T.
- Verizon is also offering 5G services in Medford, MA.
- The short-range mobile cell sites, known as "small cells," would be installed on existing utility poles in Medford.
- See next slide for what a utility pole neighborhood 5G antenna (cell or fixed or both) would look like.

5G Rollout in Boston and MA

- <https://emfacademy.com/5g-cell-towers-near-me/>



5G Rollout in Boston and MA

- Anyone heard about 5G building or service rollouts in Lexington? I have heard a presentation in Waltham in March, 2020 about both cell service and fixed 5g Internet infrastructure. Neighborhood antennas are getting much attention, or were, before
- The Coronavirus Pandemic. This has changed a lot of things about 5g, IoT and Industrial IoT and Logistics.

Coronavirus and 5G Technologies

- Why the coronavirus pandemic may fast-forward 5G adoption in the US
- <https://www.cnbc.com/2020/03/20/why-the-coronavirus-pandemic-may-fast-forward-5g-adoption-in-the-us.html>
- The coronavirus outbreak and the rise in remote work has advanced the need for more robust 5G technologies in the U.S.
- Verizon issued a press release on Wednesday stating the demands on bandwidth increased 75% over the previous week.
- The FCC and federal government are trying to accelerate deployment in urban and rural areas.
- The global pandemic has forced a supply chain slowdown that may delay further expansion of 5G.

Coronavirus and 5G Technologies

- 9 Ways 5G Could Impact the World's Supply Chains
- <https://supplychain.toolbox.com/guest-article/9-ways-5g-could-impact-the-worlds-supply-chains>
- 1. Quicker Decision Making
- 5G will reduce the need for all operations and tasks that don't require a high skill level.
- 5G technology will enable optimal performance across all stages of the delivery process.
- Predictive analysis tools will detect errors, identify the shortest possible delivery routes and send notifications to staff when maintenance is necessary.

Coronavirus and 5G Technologies

- 2. IoT Ready
- Many logistics companies are already utilizing IoT in their warehouses for the following benefits:
 - tracking inventory
 - predictive analytics
 - tools for location management
 - drone delivery systems

Coronavirus and 5G Technologies

- 3. Precise Item Tracking
- 4. Better Vehicle-to-Vehicle Communication
- 5. Increased Productivity with Automation
- Those companies in the supply chains that already use robots in their distribution centers will see very noticeable improvements in their performance. (And robots don't get sick.)

Coronavirus and 5G Technologies

- 6. Increased Customer Satisfaction
 - Tracking will finally become totally accurate and updated in real-time, which will significantly improve the customer experience.
- 7. Drone Based Delivery Systems
- 8. More Control Over Inventory
 - Noticing when demand is surging and inventory is not keeping up.
- 9. Route Optimization and Better Location Tracking
 - This is a logistics application. It differs from package tracking or inventory controls.

Coronavirus and 5G Technologies

- How 5G Technology Will Support A Faster, More Reliable Supply Chain
- <https://www.advertisepurple.com/how-5g-technology-will-support-a-faster-more-reliable-supply-chain/>
- The Wall Street Journal just reported on the rollout of 5G technologies that will soon be available and able to provide much needed clarity and efficiency in the global supply chain infrastructure.

Coronavirus and 5G Technologies

- Supply and demand
- Essentially, the technical capabilities of 5G (which were lacking in previous 4G tech) are going to be able to analyze, quantify, and report on key information throughout the delivery process.
- “With 5G, you suddenly have the capability to transfer a lot of information faster, and in more efficient ways.”

Coronavirus and 5G Technologies

- This is all taking place at a time when e-commerce is having a moment, not only in quarantine, but the trends were pointing to a market less reliant on brick and mortar stores and more on warehouse and supply-chain-backed ordering processes.
- Limiting food waste will be a major economic win from this new technological advancement
- 30% is simply way too high, and there are various reasons food is wasted at such a high percentage, but one of those major reasons is oversupply in grocery stores and other locations, leading to spoiled products and the need to toss out items that have gone bad.

Coronavirus and 5G Technologies

- On the other hand, just-in-time or lean inventory schemes were shown to have a fatal weakness. In fact, two weaknesses.
- A sudden surge in buying which did not die down quickly (hoarding and panic buying). Systems have to be able to respond to such events and maybe even predict them. Analyzing Big Data in real time could help – if the algorithms aren't fooled by momentary fluctuations in demand.

Coronavirus and 5G Technologies

- And we still have human workers. Systems and staffing have to be able to handle times when workers get sick in large numbers. Shifting production and warehouse operations from one location to another, and proving ways to get animals and food to these new locations requires rethinking industrial and transportation logistics.
- There will likely be an opening for software companies to develop technology that can assist along the supply chain, and we'll probably see many new innovative technologies developed over the next few years.
- 5G, IoT, Industrial IoT (IIoT) and Big Data analysis will all play a role.

Coronavirus and 5G Technologies

- A Change in How (and Where) We Work?
- The COVID-19 pandemic is forcing companies to take a closer look at how they communicate with employees digitally as remote work becomes more prevalent
- Cloud platforms allow for more secure data processing for remote workers, but contingencies are needed to mitigate potential bandwidth or internet issues
- Employers can leverage in-app communication to manage availability and create employee-centric experiences for non-remote workers. (These Apps are business apps which are accessed remotely from a company server or under contract for the company. Not games or consumer apps.)

Coronavirus and 5G Technologies

- “While digital workers can work from home in many cases, [certain] mission critical, highly regulated industries could face challenges that will come to head now in wake of the coronavirus, and that people will have to put into place moving forward.”
- Though cloud-based infrastructure can provide the base layer needed for more secure and accessible systems, contingencies must also be in place in the event of limited Wi-Fi or internet availability for remote workers – something that may not always be predictable. Further, an influx of remote workers can also place stress on ISP and network bandwidth, risking slowdowns and impact on productivity.

Coronavirus and 5G Technologies

- “Teams need to take a look at the core of their practices — how to write efficient emails, how to drive efficient outcomes in meetings, how to communicate to clients clearly, and even how to be effective leaders and mentors when you're not in proximity to teams.”
- Digital conference rooms, one-on-one stand-ups, and personalized communication can be used help keep employees aligned, get used to new processes, and create connected virtual workspaces across the organization.

Coronavirus and 5G Technologies

- The coronavirus outbreak will put remote-work strategies and contingency plans to the test.
- “It’s a test of whether companies can truly build a true digital workforce where employees can work from anywhere.”

Coronavirus and 5G Technologies

- We Might Have Gotten Remote Learning Wrong.
- Experts weigh in on how the sudden, forced adoption of technology-delivered instruction will affect the well-being of professors and students alike.
- If the coronavirus and our response persist for a year or more, academia will be redefined.
- If COVID-19 gnaws on nations for semesters on end, that will gut higher education's finances.

Coronavirus and 5G Technologies

- Humanities and the Arts might be sacrificed to give “core” subjects and STEM subjects more funding and attention.
- Given equity issues worsened by recession, open education resources and open-access publishing could triumph. We may also see inequality drive different technology uses.
- Research is experiencing a stall now as faculty remove themselves from on-campus resources. An attenuated pandemic could depress scholarly output for a year or more.

Coronavirus and 5G Technologies

- We recommend that faculty not rely too heavily on synchronous videoconferencing so as not to disadvantage students whose internet infrastructure is poorer, or who use a shared device at home, or who have other family members who need the internet bandwidth for other things.
- e.g., doing a seminar-style class online without synchronous video.

Coronavirus and 5G Technologies

- I think equitable access to students will require more flexibility than we anticipate, with everything from attendance to deadlines to modalities of communication. It's not just about communication here, but affect, which is more needed than ever when we are being advised to apply social distancing.
- I worry that this will turn out to be a horrible experience of online learning for many and they will never want to do it again.

Coronavirus and 5G Technologies

- If this negative experience becomes a public outcry, pressures could mount for medically unsafe reopenings or even a premature return to “normal education”. (In-person, crowded classrooms, and the new surge in virus infections which would certainly follow.)
- I think we will need to be a lot more creative than just opening Zoom rooms or posting stuff in the LMS, especially when so many of the students (and even adjuncts) at my own university don't have reliable internet access.

Coronavirus and 5G Technologies

- While technology now offers ways to do a lot of things online, there is no tech which will help Special Needs kids get the support and social skills training they need. Also, advanced students can't do practical labs at home. Vocational Education has similar limitations on distance learning.
- We have just heard how MOOCs operate. Similar ways of delivering course content are being developed for High School and the lower grades.

Coronavirus and 5G Technologies

- Sports and social experiences are also an important part of education throughout life. Distance and wearing of masks is already having negative impacts on people's emotional well-being. This could continue to get worse during a prolonged period of enforced distancing.
- Unfortunately, technology, great as it is, does not have all the answers for educating kids in a time of pandemic disease.

Community Resistance to 5G Buildout

- <https://connectedremag.com/latest-issues/us-cities-are-saying-no-to-5g-small-cell-antennas/>
- Cities and towns in Northern California are issuing ordinances that would exclude the 5G cell sites from residential areas, citing supposed health concerns.
- Residents of Portland, Oregon, and Whitefish, Montana are also lobbying for restrictions. Four states, including New Hampshire have proposed bills that mandate studies on the health effects of 5G radiation.

Community Resistance to 5G Buildout

- More than half a million new cell towers and small cell sites need to build out a nationwide 5G network fully. Residents can be unhappy and concerned about the appearance of small cell antennas in front of their homes and backyards.
- The activist group EMF Safety Network lobbies to reduce exposure to electromagnetic fields. The issue they fight is about the unknown health impact from 5G radio frequencies. They also fight non health related issues, like municipalities centers around fees, property values, and who has the power to zone and regulate infrastructure.

Community Resistance to 5G Buildout

- In the meantime, Verizon is finding new ways to appease residents and municipalities by installing 5G smart poles . Verizon has recently collaborated with a Colorado-based Comptek Technologies. They have designed a stand-alone pole that house wireless small cell equipment that is completely hidden inside the poles. The City of Denver has approved the design of the new poles, and Verizon is now deploying them in Denver for 4G and 5G small cell equipment.

Community Resistance to 5G Buildout

- The wildest 5G conspiracy theories explained — and debunked https://www.digitaltrends.com/news/5g-conspiracy-theories-debunked/?itm_medium=editors
- A relatively new theory suggests that 5G could be the cause of the coronavirus, officially known as COVID-19. Both the rollout of 5G and the first cases of coronavirus supposedly happened at the same time in late 2019, the theory claims.

Community Resistance to 5G Buildout

- Radio waves have no impact on a virus' development.
- 5G as we've seen, has been under development for years, long before the Coronavirus jumped species to humans.
- Last but not least is the fact that China isn't using mmWaves for its 5G networks just yet — it's only using sub-6 GHz waves, which fall in the mid-band spectrum. These radio waves, however, have been used for other things for years — all 4G towers use frequencies in this range, they've just been repurposed for 5G.

Community Resistance to 5G Buildout

- Conspiracy theorists burn 5G towers claiming link to virus
- <https://www.bostonherald.com/2020/04/21/conspiracy-theorists-burn-5g-towers-claiming-link-to-virus/>
- Popular beliefs and conspiracy theories that wireless communications pose a threat have long been around, but the global spread of the virus at the same time that countries were rolling out fifth generation wireless technology has seen some of those false narratives amplified.

Community Resistance to 5G Buildout

- Some 50 fires targeting cell towers and other equipment have been reported in Britain this month, leading to three arrests. Some 16 have been torched in the Netherlands, with attacks also reported in Ireland, Cyprus, and Belgium.
- The current wave of 5G theories dates back to January, when a Belgian doctor suggested a link to COVID-19.
- Older variations were circulating before that, mostly revolving around cellphone radiation causing cancer, spreading on Reddit forums, Facebook pages and YouTube channels.

Community Resistance to 5G Buildout

- The theories gained momentum in 2019 from Russian state media outlets, which helped push them into U.S. domestic conversation, disinformation experts say.
- The conspiracy theories have also been elevated by celebrities including actor Woody Harrelson (you may know him from “Cheers”) who shared a video claiming people in China were taking down a 5G tower.

Community Resistance to 5G Buildout

- None of these theories has any basis in peer-reviewed scientific or medical studies. Some research linking daily cell phone use when held to an ear turned out to be more noise than signal in the data. “Cancer clusters” are largely a myth. Power lines do not cause autism or any other disease or infirmity.
- To gain an understanding about how and why people see patterns in data which actually have no statistical patterns, check out Neil DeGrasse Tyson’s book “The Null Signal”.

5G, IoT and the Coronavirus

- **Conclusions:**
- 2020 is seeing new developments in 5G technologies.
- Boston and surrounding communities are deciding on the best practices for rolling out 5G infrastructure and choosing service providers.
- 5G Technology has been controversial from a public policy and a public health point of view.
- Governments have faced off over technology transfers, and communities have resisted infrastructure buildouts.

5G, IoT and the Coronavirus

- **Conclusions**
- 5G buildout reaches from in the ground cables to the tops of lamp posts to the tops and sides of buildings, clear out into space.
- Most of the future of communications will be wireless, no longer wired.
- It remains to be seen whether broadcast media (radio, television) survive the 5G/Wi-Fi 6 transition. Streaming is now a real alternative. Cable TV as we've known it (wireline services) may also be going away.

5G, IoT and the Coronavirus

- The 5G revolution is already changing how we work, how we learn and teach, how we get our news, and how we conduct our government and voting. The coronavirus pandemic has accelerated these changes.
- The coronavirus pandemic has made clear some of the weaknesses and inefficiencies in our logistics and supply chains, in the USA and worldwide.
- We will be living with virus related changes and tech related changes from now on, for the foreseeable future.

5G, IoT and the Coronavirus

- And it isn't all grim and cold. We can look forward to the day some of our best friends will be AI machines and robots!
- And with that I ask:
- Are there any questions?
- Any Comments?
- – Presented to the Lexington, MA Technology Users Group
- – By Bob Primak, July 8, 2020 via Zoom Meetings.