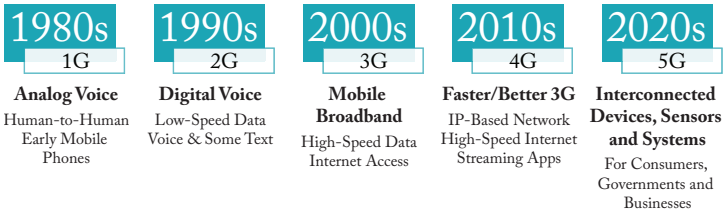
Secular Theme: The 5G Revolution

Executive Summary

Roughly 10 years after the launch of 4G LTE, the current wireless technology in the U.S., 5G offers potentially significant leaps forward in wireless network speed, responsiveness and scale. It holds the promise of fixing many of LTE's most frustrating shortcomings, including slower speeds when too many users connect simultaneously, dropped calls and slow network response times. Improvements offered by 5G should improve the network experience for mobile phone users and provide the network reliability and speed required by emerging technologies that include autonomous cars and virtual reality. 5G networks will be able to handle connectivity requirements of billions of new devices and sensors that will be added to networks in the coming decade and beyond. We view 5G's potential to transform the wireless network landscape as a revolution rather than simply the next technology evolution.



Why is 5G Better?

It's been called "the next industrial revolution," "a seismic technological shift" and "the dawn of a new wireless era," among other monikers hyping the promise of the next generation in mobile wireless technology. But can 5G eventually live up to expectations? We believe the potential exists to exceed even the most bullish expectations if one looks beyond the historical evolution of wireless networks, where benefits have largely been limited to mobile phone devices and applications. Our view is rooted in what we believe will be significant improvements over existing LTE standards and associated applications, to include new applications that 5G will create across virtually every industry, as well as possible new industries that will be created to leverage the technology in new ways.

Potential benefits of 5G technology shouldn't be limited to improvements in connectivity for existing mobile phone users, which was the primary driver for today's LTE network design. To be sure, as more and more devices are added to existing wireless networks and data demand continues to grow exponentially, wireless carriers are running out of LTE capacity in many parts of their networks, especially in densely populated urban areas. Cisco Systems forecasts the number of Internet-connected devices to exceed 50 billion by 2020, with 500 billion networked sensors deployed by 2030[1]. In addition, by 2022, mobile data traffic is expected to quadruple from 2018 levels[2], and emerging technologies are increasingly demanding faster and more responsive network connections. LTE networks don't have the capacity to meet this demand or exceedingly complex network requirements, but 5G networks, by design, should. Two key metrics most differentiate 5G from existing LTE networks: higher bandwidth and greater scale. Bandwidth (more is better), which determines how much data can travel across a network during a specific period of time, works hand-in-hand with latency (lower is better), a measure of how fast the data travels between two points,to deliver a user's perception of network speed. By providing higher bandwidth with lower latency, 5G networks can offer significant advantages over current LTE networks that are essential for efficiently delivering increasing volumes of network data traffic while meeting the near-zero latency requirements of innovations such as autonomous cars.

Comparing 4G and 5G		
	4G	5G
Latency	10 MS	<1 MS
Data Traffic	7.2 Exabytes/ Month	50 Exabytes/ Month
Peak Data Rates	1 Gb/s	20 Gb/s
Available Spectrum	3 GHz	30 GHz
Connection Density	100 Thousand Connections/Km^2	1 Million Connections/Km^2

Source: Qorvo

Greater scale in 5G is measured in terms of connectivity, or the number of devices that can be simultaneously connected in a given geographic area without degradation in speed and bandwidth, a key limitation and common occurrence in today's LTE networks, especially in densely populated urban areas. The explosive growth in the number of mobile connected devices in the future will not be limited to smartphones, but rather will include a multitude of new, smaller devices and sensors, each with unique characteristics and applications across numerous industries. It is estimated that 5G networks will be able to handle up to one million simultaneously connected devices in a square kilometer area versus just one thousand for LTE, a 1000x connectivity advantage[3]. Only 5G will be able to handle connections on such a massive scale, as well as the multitudes of varying connectivity requirements for individual devices, depending on specific applications.

How Will 5G Deliver as Promised?

If existing LTE networks were capable of delivering massive improvements in speed, latency and scale, they would, but they can't. New wireless network technologies have been invented that will form the foundation of how 5G will meet performance expectations, including, but not limited to, Massive MIMO, beamforming, carrier aggregation, network splicing and more efficient use of existing wireless spectrum. These technologies are often utilized in conjunction with each other to deliver higher network bandwidth and capacity.

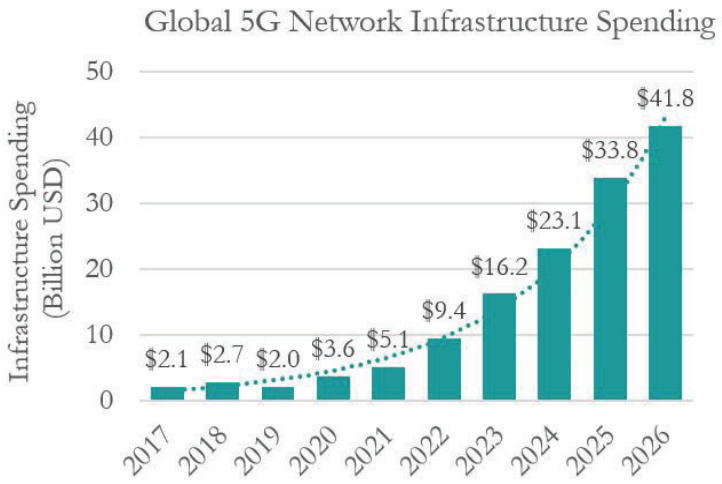
While it is important that 5G networks utilize existing wireless spectrum more efficiently, it will require much more new spectrum across much broader frequency ranges. Current LTE devices operate in low-range (< 1 GHz) and mid-range (1 GHz-6 GHz) frequency spectrum bands, but as the number of connected devices has grown, these ranges have become increasingly saturated. As a result, speed and reliability of connections in these ranges can experience degradation, a problem that would only be made worse by the expected exponential growth in 5G devices. New 5G networks will utilize existing low- and mid-range frequencies, but also extend into high-band (> 6 GHz) and so-called "millimeter wave" frequencies above 28 GHz[4].

All frequency ranges are not created equal, each having its own coverage and capacity characteristics that must be considered when building 5G networks. Low-band spectrum offers significant geographic coverage and excellent penetration through objects such as buildings. However, peak speeds are limited compared to higher frequency bands. Mid-range bands offer the best balance between speed and geographic coverage, which is a key reason why so much of today's LTE infrastructure has been deployed in this spectrum range. The upper spectrum bands (high band and millimeter wave) offer the highest network speeds, but signals don't travel very far and don't penetrate buildings very well. The challenge for wireless carriers will be to balance wide geographic range/lower speed requirements (i.e., those suitable for rural areas) with lower geographic range/higher speed requirements (i.e., urban areas). In addition, 5G networks must meet speed and latency requirements of connected devices. Whereas low-powered agricultural sensors might function well on relatively slower lower-band frequencies, ultra-fast higher-band frequencies will be required for applications such as virtual reality and automated vehicles. Wireless carriers will be faced with designing and building 5G networks that most efficiently meet the needs of end users and connected devices, each with unique technology challenges based on geographic location, as well as speed and latency requirements.

Timeline

Countries around the world are racing to build 5G networks, with the U.S., China, South Korea and Japan building early leads. In the U.S., major wireless carriers AT&T and Verizon took a major step in the effort by rolling out "fixed-wireless" 5G in several cities. This service, an alternative to cable broadband, is serving as an initial test case for mobile high-speed 5G service in largely urban markets. All four major U.S. wireless carriers, including T-Mobile and Sprint, have ramped up their 5G network efforts by beginning to upgrade existing cellular with new 5G-capable antennas and other equipment, deploying added spectrum in low- and high-band frequencies, and beginning to build out small cell antenna networks in more densely populated areas.

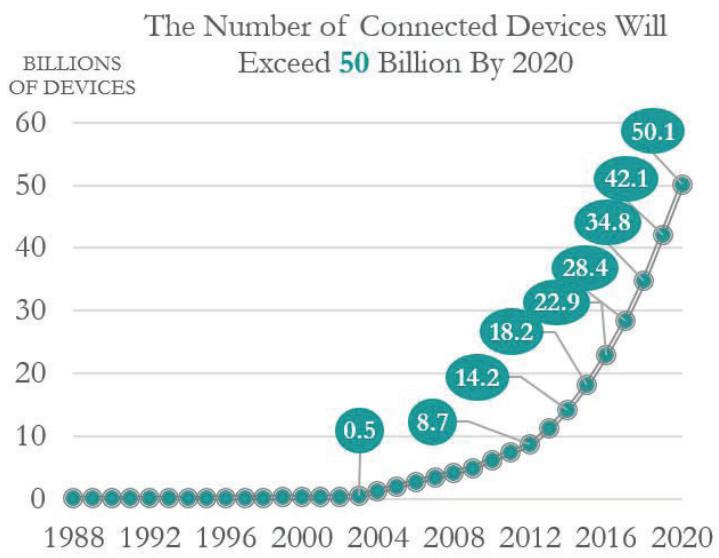
Initial investment in 5G infrastructure has been relatively small to date but we believe is poised to accelerate over the next few years as carriers race to complete their nationwide network upgrades. New cell towers and small cell antennas are being installed, and fiber backhaul networks are being expanded and upgraded to meet the needs of 5G. The U.S. government is also expected to help accelerate the process by freeing up additional spectrum suitable for 5G and updating aging government regulations that might otherwise inhibit network expansion. Although we believe consumer markets, particularly mobile wireless, will see the first successful launches and implementation of 5G technology, we think the longer-term growth potential of 5G will be realized through new applications enabled by the technology.



Source: Edge of Cloud – Forecasted Global 5G Network Infrastructure Spending

What Does the Future of 5G Look Like?

It's easy to envision the near-term impact 5G can have on consumer markets in fixed and mobile wireless, similar to the advances enabled by the launch and growth of LTE, which was a key catalyst in the explosive growth in smartphone adoption by consumers. Residential fixed-wireless service has the potential to replace cable broadband, offering equal or higher speeds and lower cost. In mobile, carriers may be able to charge additional fees for 5G speeds, over and above base fees charged for LTE service. However, we think limiting 5G expectations to these existing consumer applications misses much larger and broader applications that have the potential to transform technology and industries much the same way the Internet has done over the past 25 years.



Source: Cisco Systems – Forecasted IOT Connected Device Data

By delivering higher speeds, massive scale, ultra-low latency and high reliability, 5G networks can potentially drive innovation not possible with existing LTE networks. Its applications might enhance existing technology and industries and lead to the introduction of new technologies not yet conceived. The Internet of Things (IoT), perhaps the largest growth opportunity, is a network of connected devices, each with unique identifiers, sensor types and applications. These devices typically have low power requirements and are cheap to manufacture. When deployed in a myriad of monitoring applications, IoT devices can enable vast amounts of data collection and associated analytics. Examples include sensors embedded in agriculture to monitor crop data and deployment by logistics companies to monitor and improve efficiency in the movement of freight. Power companies might use IoT sensors to monitor electricity usage on a house-by-house basis, perhaps even on a device-by-device basis, helping consumers and businesses improve energy efficiency. Cisco projects the number of IoT connected devices will reach 50 billion by 2020 with early projections of 500 billion by 2030[5]. These projections could prove conservative given the likely IoT applications yet to be conceived. Other widely mentioned 5G applications include virtual and autonomous vehicles, virtual/augmented reality, remote health care and video game streaming.

Investment Opportunities

The coming 5G revolution will likely create significant investment opportunities over the next decade and beyond. We believe opportunities will exist in three sequential phases. **Phase 1**, currently underway, is the 5G network buildout that involves the upgrade of existing cell towers and building of new towers, massive deployment of small cells, and the upgrade and expansion of fiber-optic backhaul networks. In addition, new antennas, switches, servers, testing equipment and other technology will be required. We recommend a "picks and shovels" investment approach as U.S. wireless carriers race to complete their 5G networks and offer nationwide coverage. We can't predict which carrier will win, if any, but they all will need similar equipment, software and services in their efforts.

Phase 2, in our view, will be a massive consumer device upgrade cycle that probably will begin in earnest once 5G coverage in the U.S. is ubiquitous and reliable. In order to utilize 5G network service, every smartphone, tablet, watch and other device utilizing a cellular connection will have to be upgraded to a model capable of connecting to a 5G network. During this phase, we believe U.S. wireless carriers will continue to fiercely compete for new customers and maintain existing market share while struggling to monetize their new 5G offerings through higher pricing. During this phase, which we think could begin to gain traction in late 2020, we would favor device providers over wireless carriers.

Phase 3, possibly the longest phase, will, in our view, involve the adoption of 5G technology across almost every sector and industry, including the proliferation of IoT devices. We expect to see advances in automated vehicles, virtual reality, remote medicine and agricultural management, just to name a few. In our view, 5G can create endless opportunities for companies to enhance revenue growth, realize cost efficiencies and improve customer experiences. We also think there will be opportunities that haven't been imagined yet, leading us to ponder what might be the next "killer app" that 5G enables, similar to the way 4G LTE accelerated the growth of the smartphone.

We believe it's too early to invest in Phase 2 and 3 opportunities and instead focus our attention on near-term Phase 1 opportunities. U.S. wireless carriers are spending billions of dollars to build out 5G networks and have accelerated deployment plans due to intense competition, thereby creating attractive "picks and shovels" opportunities for investors.

Based on our positive secular outlook for 5G, we seek to find companies that we believe are well positioned to benefit from increased spending on the building of 5G networks in the U.S. Among these companies is our current holding in Keysight Technologies.

Keysight Technologies* manufactures electronics test and measurement equipment and software, mainly for the telecommunications, aerospace, industrial and semiconductor industries. Its products include oscilloscopes, meters and network analyzers, as well as software and related design tools utilized in the design and manufacture of electronic equipment. Our primary investment thesis on Keysight is tethered to optimism around 5G investments. Management has been positioning the company to benefit from ongoing investments in 5G infrastructure. We believe recent acquisitions Anite and Ixia add to Keysight's core capabilities of RF (radio frequency) and optical testing and allow the company to participate in different phases of 5G rollout, from testing to deployment.

**Aristotle Atlantic's proprietary research involves identifying secular themes and attributing portfolio holdings to these themes. 5G represents one of the secular themes and Keysight Technologies is the only portfolio holding directly identified under this theme as of November 30, 2019.*

[1]https://www.cisco.com/c/en/us/solutions/collateral/service-provider/visual-networking-index-vni/white-paper-c11-741490.html
[2]https://www.statista.com/statistics/271405/global-mobile-data-traffic-forecast/
[3]https://www.qorvo.com/design-hub/blog/getting-to-5g-comparing-4g-and-5g-system-requirements
[4]https://www.telit.com/blog/understanding-5g-spectrum-bands-allocations/
[5]https://www.cisco.com/c/dam/en/us/products/collateral/se/internet-of-things/at-a-glance-c45-731471.pdf
[6]http://edge-of-cloud.blogspot.com/