

YAN TAW (Y.T.) BOON Director of Equity Research Asia

HARI RAMANAN Chief Investment Officer—Research Funds

Investing in Connectivity: Beyond Telecoms, Beyond 5G

Almost every aspect of our lives is likely to be changed by the coming of 5G, so we believe understanding the true breadth and depth of this investment theme means understanding more than just the semiconductor and telecoms industries.

In this paper, we discuss a handful of the leading providers of key technologies, products or services in each main category of the theme to give a sense of that breadth and complexity. These are not household names and their relevance to the 5G and 6G theme is arguably under-appreciated. We believe this is what makes dedicated research and active management necessary components of a successful 5G investment strategy: Next-generation investment themes call for next-generation investors.

Executive Summary

- The 5G investment theme captures much more than just network infrastructure manufacturers and semiconductor producers.
- We see a broad range of potential opportunity within our three major 5G investment categories of Network Infrastructure, Internet-of-Things Devices and Applications and Services.
- Network Infrastructure: Beyond Base Stations
- Gallium nitride (GaN) and optical lasers for reconfigurable optical add/drop multiplexers (ROADMs) will be critical to increasing the speed and capacity of our communications networks for 5G.
- Increasing demand for testing as networks become more sophisticated.
- Potential opportunities for Sumitomo Electric, RFHIC, Qorvo, Infineon, Lumentum, II-IV Inc, Keysight Technology, Anritsu and others.

• IoT Devices: Beyond Smartphones

- 5G has the ability to make seamless augmented, virtual and even "extended" reality possible for the first time, increasing demand for 3D sensors and the vertical cavity surface emitting lasers (VCSELs) that are a key component in them.
- More expensive smartphones will likely increase demand for secondary products and services, such as device warranties and insurance.
- Potential opportunities for Lumentum, II-IV Inc, AMS, Assurant and Asurion.

• Applications and Services: Beyond Telcos

- 5G is likely to increase the use of cloud computing, moving more and more of our business and working processes online and making network security even more critical.
- Potential opportunities for ServiceNow, Zendesk, Zscaler, OKTA and Crowdstrike.

• 6G: Beyond 5G

- 6G is likely to be with us sooner than you think—perhaps as soon as 2028.
- As well as amplifying the trends of 5G, we believe 6G connectivity will create a huge number of new applications for artificial intelligence.
- We believe these examples of potential 5G investment opportunity show why a research capability covering all industrial sectors is a prerequisite for capturing the theme properly.

At Neuberger Berman, we like to say that if 3G was the motor car and 4G was the airplane, 5G is the space travel of connectivity. As it rolls out over the next decade, we think we will all be amazed at how profoundly it changes our lives.

At its most basic, 5G will radically reduce "latency," which is the amount of time it takes for a device to connect to a server and initiate a data transfer, and it will increase the speed at which data can be shared. That will create a telecommunications network that could work 100 times faster and connect 100 times more devices than the current 4G standard.

As it helps to make things like remote robotics and the "Internet of Things" a pervasive reality, over the next 15 years IHS Markit estimates that 5G will create more than \$13 trillion of economic growth and 22 million new jobs. Moreover, we believe that can be sustainable growth: the World Economic Forum has argued that 5G-enabled applications help to meet 11 of the 17 United Nations Sustainable Development Goals (SDGs), most obviously SDG number nine covering "Industry, Innovation and Infrastructure;" it could lower our carbon emissions by enhancing operational efficiency, and help to create more socially and environmentally sustainable smart homes, smart warehouses, smart logistics and even smart cities.





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But what exactly might this investment opportunity look like?

That is what we try to describe in this paper. We see three major categories in the 5G investment universe: Network Infrastructure, Internet-of-Things Devices and Applications and Services. We will discuss one or two leading providers of a key technology, product or service in each of those categories—all companies reported or estimated to derive at least 50% of their earnings growth from 5G connectivity.

Our aim is to give a sense of the under-appreciated breadth and complexity of the 5G investment theme. Alongside the need to be forward-looking as the 5G rollout develops and 6G technology emerges, we believe this is what makes dedicated research and active management necessary to identify the winners and losers from this transformative development.

Network Infrastructure: Beyond Base Stations

The first thought when it comes to 5G network infrastructure is understandably the big, visible stuff and the companies that make it: base stations and small cells and companies like Huawei, Ericsson and Nokia, and perhaps the household names in semiconductors, such as Samsung, TSMC and Xilinx. But the network also creates a host of lesser-known opportunities for component manufacturers.

FIGURE 2. THE NEXT-GENERATION 5G NETWORK ARCHITECTURE



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The migration from 4G to 5G will require a significant increase in data traffic. That in turn demands major changes to network architecture and upgrades to infrastructure equipment to enable higher-speed connectivity. Here, we highlight three next-generation technologies that we believe are critical for 5G infrastructure: GaN radio frequency components, reconfigurable optical add/drop multiplexers (ROADM) and network testing equipment.

Gallium nitride (GaN) crystals are used in the production of semiconductors and radio frequency components. As a technology, it competes against silicon in laterally diffused metal-oxide semiconductors (LDMOS) and against gallium arsenide amplifiers (GaAs). Silicon LDMOS and GaAs both work perfectly well for the lower-frequency, lower-traffic connectivity of 4G, but in our view GaN is much more efficient for 5G base stations because its higher electron mobility enables it to handle higher voltage in a much smaller area and power a wider range of microwave frequencies.

FIGURE 3. THE ADVANTAGES OF GALLIUM NITRIDE IN 5G SEMICONDUCTORS AND RADIO FREQUENCY COMPONENTS



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This is likely to be a big advantage as the 5G network shifts to massive multiple-input, multiple-output (MIMO) technology, which utilizes active antennae and hybrid beamforming and demands higher data throughput and speed, in order to connect a vast number of mobile devices and the wider Internet of Things.

As a result, the GaN market, which was worth just \$410m as recently as 2018, is forecast by specialist consultancy Yole Développement to grow 80% to \$750m by 2022, with 60% of that demand coming from 5G network infrastructure.

We would identify five key suppliers of GaN technology: Sumitomo Electric, RFHIC, Qorvo and Infineon supply more than 85% of the world's GaN radio frequency chips, and Win Semiconductor supplies two thirds of the GaAs that go into those chips.



FIGURE 4. LEADING PLAYERS IN THE GALLIUM NITRIDE AND GALLIUM ARSENIDE AMPLIFIER MARKETS

Source: RFHIC Corporation and Neuberger Berman estimates, Yole Développement. As of June 2020.

In addition, as shown in figure 2, the optical networks that connect base stations, edge servers, network switches and data centers will need to be upgraded from 100-gigabits (G) to 400G (and eventually 800G), in order to handle the exponential increase in transported data. This is where ROADMs become important.

This piece of kit enables optical transmission and switching of information spanning multiple network nodes, which, among other things, drastically reduces the number of optical fiber connections required in the network. ROADMs also facilitate remote reconfiguration and automatic power balancing of optical networks. This all helps to substantially increase network capacity and enables the voluminous data flow associated with the migration to 5G.

FIGURE 5. ROADMS INCREASE DATA TRAFFIC CAPACITY IN THE 5G NETWORK

ROADMs massively simplify optical fiber connections...



... at hundreds of critical nodes of the 5G network



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As major metropolitan 5G networks build out, Grand View Research forecasts that the demand for ROADMs will grow by around 12% a year. ROADMs in turn require optical laser components. So who makes those optical lasers? Between them, Lumentum and II-VI Inc supply 90% of this market, and it accounts for around half of Lumentum's earnings.

	Key Technology	Market Share
Lumentum	Optical laser for ROADM	50 - 60%
II-VI Inc	Optical laser for ROADM	30 - 40%

Source: Neuberger Berman estimates as of June 2020.

As 5G networks become more sophisticated with GaN radio frequency components and optical networking, the demand for network testing is also likely to increase, potentially benefitting leading testing equipment providers such as Keysight Technology, Rhode & Schwartz and Anritsu.

These companies are able to simulate real-world environments to expose defects early, increase the speed in developing and updating test systems, and validate the quality of wireless services at massive scale. This will likely help to smooth the transition to 5G.

	Key Technology	Market Share
Keysight Technology	Network testing	30 – 35%
Rhode & Schwartz	Network testing	15 – 20%
Anritsu	Network testing	10 – 15%
Viavi	Network testing	10 – 15%
Spirent	Network testing	5 – 10%

Source: Neuberger Berman estimates as of June 2020.

Internet of Things Devices: Beyond Smartphones

The Internet of Things is often reduced to being a story about smart household appliances, remotely operated smart factory robots and smarter smartphones. But in addition to these smart devices, we see Internet-of-Things investment opportunities in the sometimes science fiction-worthy possibilities of augmented reality, as well as the rather more humdrum but underappreciated opportunities associated with 5G smartphones.

The low latency, high reliability and high bandwidth of the 5G network will likely make seamless augmented reality possible for the first time. Augmented reality applications superimpose computer-generated images onto the real world. Perhaps the simplest and best-known example is Pokémon GO, the game in which Pokémon characters showed up as you peered at specific places in the real world through your smartphone camera.

As Pokémon GO indicated, there is huge opportunity for augmented and virtual reality to create a more immersive experience when gaming or watching arts, entertainment and sporting events. So-called "six degrees of freedom" (6DoF) immersive content could put you in the crowd at the World Cup Final, or even on the pitch with the players.

But the same technology could also enable a machine manufacturer to stand next to an on-the-spot technician in a virtual version of her own factory as they work together on maintenance, or allow a surgeon to be virtually present at a medical procedure while operating with a robot, or an architect to stand inside his design before it has been built. It's not much of an exaggeration to say that anything we do in the real world today could be done virtually or remotely.

To make it work, we not only need high-speed communication networks, but also 3D-sensor technology, which can sense gestures and capture a 3D model of an object. The leading 3D-sensor technology in the world is Time-of-Flight (TOF), which bounces light off of objects to measure distances. Specifically, that light is a vertical cavity surface emitting laser (VCSEL).



FIGURE 6. A VERTICAL CAVITY EMITTING LASER (VCSEL) IN A "TIME-OF-FLIGHT" 3D SENSOR

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With the TOF market set to grow by 20% per year between now and 2025, according to research firm MarketsandMarkets, from \$2.8 billion to \$6.9 billion, it is worth knowing that our optical laser specialists, Lumentum, AMS and II-VI Inc, are the world's leading suppliers of VCSELs—the former currently owns two thirds of the market share.

	Key Technology	Market Share
Lumentum	VCSEL	60 - 70%
AMS	VCSEL	15 - 20%
II-VI Inc	VCSEL	10 - 15%

Source: Neuberger Berman estimates as of June 2020.

What could be the opportunities when we move from the leading-edge technology of virtual reality to the everyday world of smartphones?

Remember that, back in 2000, a Nokia 3310 would set you back around \$40. You could use it to make calls, send texts and play Snake. By 2017, the iPhone X was priced at close to \$1,000. It gave you the power of the internet in the palm of your hand.

The smartphone reversed 15 years of deflation for handsets and the 5G smartphone is likely to give that inflation a further boost. High replacement costs are likely to increase demand for mobile device warranty, while longer ownership times and upgrade cycles have also tended in the past to result in higher attach rates—that is, bigger sales of secondary products and services such as insurance.

The mobile phone insurance market is relatively fragmented as many of the telecom companies and smartphone original equipment manufacturers, such as Apple, offer their own insurance plans for customers. Nonetheless, there are potential opportunities.

Insurance companies such as Assurant and Asurion are among the world's leading mobile device insurance providers, partnering with a number of major telecom operators, such as T-Mobile and Sprint in the U.S. and KDDI in Japan, as well as consumer electronics retailers. These companies offer home, auto and home appliance insurance, but mobile insurance is one of their fastest growing businesses.

Applications and Services: Beyond Telcos

Just as it's natural that many would think of 5G infrastructure as an opportunity for the builders of base stations and small cells, it's also natural that many think of 5G in general as an opportunity for telecom companies.

We do see some very selective potential among telcoms: T-Mobile, for example, appears to have consistently executed efficiently on its business plans and could gain substantial market share by building a competitive 5G network in the U.S. In our view, however, this is generally not the sector to look at for significant earnings growth. Instead, we are interested in the next-generation applications that are enabled by the potentially massive performance gains that 5G network could create, especially in cloud computing.

Cloud computing is an application-based software infrastructure that stores data on remote servers, which can be accessed through the internet. It is not a new idea—you probably already read emails and listen to a lot of your music via cloud-based apps, among other things. But the improved capacity, speed and reliability of 5G connectivity is likely to accelerate the shift of enterprise applications and business workflow processes online. The fact that the COVID-19 lockdown has necessitated what looks like a decisive shift toward working, shopping and interacting with service providers from home only adds impetus.

Even before the full extent of the impact of the pandemic was clear, in April 2020, MarketsandMarkets estimated that the cloud applications market could grow by almost 16% per year between now and 2025, reaching \$356 billion. We would identify companies such as ServiceNow and Zendesk as potential beneficiaries from these trends.

ServiceNow is the world's leading cloud-software provider for automated back-office functions such as human resources, legal, finance, security and facility management, with around 50% market share.

Zendesk has established a leading position in cloud-based customer service software for clients as high-profile and varied as Apple, Uber, Shopify, Twitter and Four Seasons. It provides customer communications and engagement applications, including "chatbots," that enable customer support teams to respond in a timely way to client inquiries, as well as streamlining help desk, email, voice, chat and text channels into a single platform. Instead of hours on hold waiting for a helpdesk agent, the cloud-based, AI-powered software enabled by 5G will likely be better able to deliver instant customer service for the text-messaging generation.



FIGURE 7. CHATBOTS CAN RESPOND TO CUSTOMER INQUIRIES IMMEDIATELY

For illustrative purposes only.

In much the same way that 5G smartphones are likely to raise demand for mobile device warranties and insurance, shifting more and more business functions onto the cloud at a time when cyberattacks are becoming increasingly common and sophisticated is likely to raise demand for online security.

Here, we would point to Zscaler, OKTA and Crowdstrike.

Zscaler acts as an intermediary between users and the cloud, enabling the user to set cybersecurity policies that follow them, giving a consistent level of protection no matter where they are located or how they are connected to the internet.

OKTA is a leading cloud-centric identity access management platform: its single-sign-on application enables users to access all the applications in their work space, saving time on log-ins and forgotten-password inquiries.

Crowdstrike provides endpoint security, threat intelligence and cyberattack response software. Most importantly, every day Crowdstrike reports that it collects and analyzes more than 30 billion events from internet-connected devices around the world ("endpoints"), using millions of sensors: that constantly growing dataset is used to strengthen Crowdstrike's protection capabilities in real time, even enabling it to predict cyber-attackers' moves and act to stop breaches before they occur. This technology represents a significant step up from the usual antivirus and spyware-removal software.

6G: Beyond 5G

We think it's necessary not only to think outside of the box when it comes to seeking out 5G's more attractive growth and value prospects. We also think investors should be looking forward to the changes that 6G will bring.

As mobile communication systems have evolved from 2G to 5G, each generation has involved a big step up in new technologies, but the time required to develop technical standards has shortened from 15 years for 3G to only eight years for 5G. We therefore think it is sensible to assume that the earliest commercialization for 6G could be as early as 2028, with mass commercialization achieved around 2030, which is why we are already looking out for next generation connectivity opportunities even while 5G commercialization is still in its early stages.



FIGURE 8. 6G COULD BE HERE SOONER THAN YOU THINK

Source: Samsung. For illustrative purposes only.

Right now, the best assumption we can make about 6G is that it will likely take the capabilities introduced by 5G and make them faster, bigger and better. Its peak data rate is likely to be 50 times faster than that of 5G, with perhaps one-tenth of the signal breaks, allowing for uninterrupted connections that could be used to collect and process data from all devices in real time.

First of all, that is likely to mean a proliferation of the Internet of Things: Samsung estimates that there could be 500 billion connected devices by 2030, from drones and home appliances to robots and traffic lights—that's almost 60 for every single human being on the planet. Second, it could release the true potential of augmented and virtual (and even "extended") reality: meetings could be replaced not by video conferences but with virtual reality devices or even high-fidelity mobile holograms that mimic a person's movements in real time; "digital twins" of real-world people, devices, objects, systems and places could enable us to work in an environment on the other side of the world using extended reality and robotics—perhaps where that environment is hazardous, or where the specific skills of an individual surgeon or other expert are required.

This new world is likely to create further demand for the products, applications and services we have already mentioned. Where we can already anticipate 6G creating genuinely new demand is in artificial intelligence ("AI"). All is likely to have a range of applications, from working in combination with advanced sensors to help create realistic digital twins, to informing "split computing" (where the heavy computational tasks demanded by the capabilities made possible by 6G are offloaded from limited mobile and desktop devices onto network resources), and making the "spectrum sharing" decisions that improve network efficiency by allocating data traffic based on usage patterns.

Public Health Concerns?

Given there are already concerns that 5G may be a public health hazard, focused on its more intense use of the "ultra-high frequency" microwave spectrum relative to the existing 4G network, should investors be concerned about resistance to the rollout of these technologies, particularly when people start to hear about the potential for 6G?

We think that growing awareness will reassure consumers and the public. While the 5G network is "ultra-high frequency" compared with the radio frequencies used for 4G, at around 25 – 40 gigahertz (GHz) we still consider it to be relatively low. Even as we move to 6G connectivity, cell towers will still emit at frequencies between 300 Ghz and, at most, around 3 tetrahertz (THz). By comparison, the sun emits visible light at a much higher frequency, between 430 and 750 THz. Radiation starts to become hazardously ionizing only at the higher end of the ultraviolet spectrum.

In short, in terms of radiation exposure, visible and ultraviolet light from the sun is more hazardous than the microwave frequencies used in 5G or posited for 6G communications networks.



FIGURE 9. 5G AND 6G OPERATE AT RELATIVELY LOW FREQUENCIES ON THE ELECTROMAGNETIC SPECTRUM

Source: Neuberger Berman. For illustrative purposes only. Electromagnetic wave frequency is measured in hertz (Hz), kilohertz (kHz), gigahertz (GHz), tetrahertz (THz), petahertz (PHz) and exahertz (EHz).

Conclusion

Almost every aspect of our lives is likely to be changed by the coming of 5G and 6G connectivity. For that reason, we contend that understanding the true breadth and depth of the next-generation connectivity investment theme means understanding more than just the semiconductor and telecoms industries.

We believe investors need to have a good understanding of arcane corners of industrial technology, from advanced lasers to sophisticated cameras and sensors to artificial intelligence. But they should also understand the developing context for everyday products such as household appliances and automobiles; financial services such as insurance; medical devices; and the hundreds of industrial processes and leisure pursuits that are set to be enhanced or transformed by the Internet of Things and augmented reality. The list is almost endless.

That is why we believe connectivity is an investment theme that is much better suited to active than passive management. But it is also why we believe that a research capability covering all industrial sectors is a prerequisite for uncovering the connectivity investments that best combine its growth potential with reasonable valuations. Without this capability, a 5G and 6G investment strategy potentially risks being either a straightforward telecoms and semiconductors portfolio, or an over-diversified portfolio of everything-and-nothing.

In short, we believe next-generation investment themes call for next-generation investors.

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Neuberger Berman 1290 Avenue of the Americas New York, NY 10104-0001

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