THE FULL IMPACT OF 5G ON IT INDUSTRY HARDWARE SPENDING

INDUSTRY POSITIONED TO TAKE ADVANTAGE OF 5G WITH E2E APPROACH

EXECUTIVE SUMMARY

There are many reasons the IT industry is heavily investing in 5G. The most obvious is that 5G is a major shift in the way wireless cellular technologies work that represents a quantum leap from 4G Long Term Evolution (LTE). The deeper, non-technical reasons include the industry's desire to deliver more services with improved capabilities and to do so at a broader scale, at a lower cost and to do it faster. The industry's desire to fulfill these wishes come from an understanding that the world is becoming more connected and that there will need to be a common way to connect it from the end point to the datacenter and everything in-between. This new connected world will bring about a new paradigm in wireless with the implementation of 5G and the new technologies and capabilities that come along with it. The GSMA expects 5G connections to reach 1.1 billion, 12% of total mobile connections, by 2025. New 5G connections are expected to boost overall operator revenues to $1.3 trillion in 2025.[1]

While 4G LTE does provide broad coverage, it is not low-cost enough, fast enough, or have low enough latency to meet the future needs of autonomous vehicles, smart cities, robotics, augmented reality and virtual reality, manufacturing and many other verticals at scale. In addition to the cellular networks themselves, the current state of data centers does not allow for them to handle the incoming tsunami of data and analytics that will be needed to handle the flood of incoming IoT (Internet of Things) data, as much as 173 Zettabytes by 2025 by some estimates.[2] The networks that connect today's data centers and 4G LTE networks also present problems for the implementation of 5G with proprietary and inflexible architectures.

Companies looking to benefit from the adoption of IoT and 5G will be spending as much as $275 billion according to the Cellular Telecommunications Industry Association (CTIA)[3] to meet the demands of this new reality. There will be many IT industry growth opportunities because of this need to deliver 5G and the massive expected investments.

[1] The 5G era: Age of boundless connectivity and intelligent automation
[2] Data Age 2025
[3] How 5G Can Help Municipalities Become Vibrant Smart Cities

These new opportunities will span beyond endpoints and the modems inside of them and into new infrastructure that will be necessary and drive new spending to meet the demands of 5G. Moor Insights & Strategy believes the 5G infrastructure opportunity is huge and in many ways undercounted − by 2025, MI&S believes the combination of data center, edge compute, network transformation activities, modems and IP, driven by 5G, will total $326B, growing cumulatively $1,197B from 2017, not including handsets. Some companies will be better positioned than others to take advantage of the major investments that will come with the transition to 5G than others.

CURRENT TECHNOLOGY AND LIMITATIONS

Data Center

Even today's data centers, with their data oceans and lakes, cannot handle the influx of all this new data that will feed into them through all these new 5G-enabled use cases. Current data centers also cannot turn that data into immediate, actionable insights quickly enough. To fully support IoT enabled by 5G, more of the processing and storage needs to reside at the edge.

Edge computing is the idea of bringing servers and data processing as close to the edge of the operator's network and as close physically to the devices that are using the network. Edge computing usually sits at or near the cellular tower and is generally lower power than regular servers in the datacenter. Datacenter 5G compute will also likely need to have specialized AI (Artificial Intelligence) processing capabilities to increase the efficiency of the machine learning required to churn through the data. That storage will need to be fast enough to align with the need for responsiveness as well as be large enough to handle the influx of massive data. Networks must be intelligent, flexible and software-defined to enable quick and secure data inflow and outflows and to support quick enablement of new applications.

Core Network (EPC) and RAN

The current core network, the wired networks today's cellular operators' wireless networks are built on top of, is even more inflexible and hard-coded than the enterprise network of today. Current core network architectures need to change to be able to adjust to the multi-layer slices and quality of service (QoS) nature of 5G networks. 5G requires different speeds and qualities of service, and the only way to do that is to virtualize the network and add intelligence to it. The radio access network (RAN) must evolve, too, as it must be as flexible and software-defined as the core.

End points

Most IoT endpoints with wireless wide area network (WAN) are 3G with some being 4G LTE and no unified network or experience between any of it. This has caused many IoT deployments to mostly be proof of concept deployments until 5G rolls around. Most "brownfield" IoT capable "networks" are analog and if digital, are proprietary. Brownfield endpoints will need to convert analog or proprietary digital interfaces to industry standard and secure interfaces to fully integrate into future IoT deployments. Other issues with older IoT deployments are security. If that end point cannot update its firmware to deal with the ever-increasing security risks, those should be deemed unsafe and need replaced or blocked off from any network.

WHAT IS 5G?

5G completely changes the way a wireless cellular network works and promises to deliver the network that satisfies the needs of our globally connected world. 5G is a sea change from today's 4G LTE networks, unlike the upgrade 4G LTE was to the 3G networks of the early 2000's. 5G today is represented by a couple of pre-3rd Generation Partnership Project (3GPP) 5G New Radio (5G NR) technologies that deliver mmWave (ultra-short-wave radio signal, 24GHz+) signal that is used for fixed wireless deployments which will start to deploy in 2018 with trials this year. The rest of currently planned 5G networks will begin to launch in 2019 and 2020 with the rest launching later. In total, there are 22 operators in 16 countries currently committed to deploying 5G according to the Global Mobile Suppliers Association (GSA).[4] Soon, 5G will operate in the mmWave spectrum as well as a current mid-band spectrum where most cellular networks operate today as well as low-band spectrum for IoT. This is partly what gives 5G the ability to address so many different challenges simultaneously.

The 5G NR specification is the global specification for 5G set up by the 3GPP industry partnership. 5G NR is the specification by which devices, cellular networks, and data centers will be designed to deliver the different use cases of 5G and interoperate. There are a few features within the 5G NR specification that enable these new capabilities to cellular networks to empower new use cases. These include a new air interface that replaces the current air interface used in 4G LTE as well as new Core Network and RAN that power the new air interface and the devices that connect to it.

[4] Evolution from LTE to 5G July 2017 Update

New Air Interface Enables New Cellular Capabilities

5G NR's new unified air interface allows for the low-latency efficient multiplexing of 5G services thanks to the flexible framework established by 5G NR that allows different types of radio and services to coexist in the same space. This means having enhanced mobile broadband, mission-critical services and massive IoT all on the same network.

Enhanced Mobile Broadband (EMBB) is the utilization of mmWave or existing cellular networks in combination with the 5G New Radio technology to deliver a faster and lower latency connection to mobile devices. This application of 5G NR is the one with which most people are familiar and appears as a speed upgrade to today's existing cellular networks and devices.

Mission critical services are the types of services that are essential to the operation of the device and cannot be interrupted by a loss of connection. This kind of critical connectivity will be enabled by the low-latency capabilities of 5G as well as the ability to control the QoS between different classes of devices and create service layers. Because of these new service layers, drones, robotics, and other remote operations can be prioritized over less critical network traffic like standard internet traffic and text messaging.

Massive IoT is the ability to support massive city-wide and nation-wide IoT deployments across a single network that communicates with EMBB and mission-critical devices as well as the core network and data center to provide analytics. Having IoT running on 5G networks rather than proprietary radio networks will provide broader scalability and accessibility while still staying within reasonable costs.

The scalability and flexibility of 5G NR are what help to deliver the capabilities of a next-generation cellular network, and a lot of that is enabled by the new core network and RAN.

New Core Network and RAN Enable New Air Interface Capabilities

There are many new capabilities of the new unified air interface in 5G, and a lot of those capabilities are tied to the ability to do network slicing between different service layers. To do network slicing and create different service layers, you need to have a more flexible and adaptive network. Such needs translate to a complete network transformation, or virtualizing the entire network itself including the network functions and software-defined networking that can adapt to the constantly shifting demands of the network. Ericsson and SK Telecom performed a successful demonstration of 5G network slicing back in 2015 to prepare for this need. The companies created virtual

network slices optimized for “super multi-view, augmented reality/virtual reality, massive IoT and enterprise solutions.”[5]

One of the big reasons that so many industries are excited for 5G is the ability to deliver low latency connectivity thanks to the 5G NR specification and the new subframe. However, for low latency communications to stay low latency, both ends need to communicate in low latency. This means that the topography of cellular networks will have to change, and they will become denser. Part of this increased density will be driven by the fact that mmWave radio does not penetrate or propagate as far as mid-band or low-band frequency radio waves. Because the network will be denser and needs to be lower latency to keep up with the low latency devices and services, the core network will need to move closer to the edge with edge computing to quickly process data and send it.

With 5G’s ability to slice the network, provide lower latency and create different layers of service, new types of services will arise that utilize these network capabilities. This would allow operators to lease out *parts* of their network for special events or customers to provide a *certain* type of service with a specific type of service layer, coverage area, and speeds. Additionally, 5G will enable numerous IoT services that will run the IoT devices on the 5G network and will continue to drive continued core network usage. Ultimately, the use cases for 5G will be what will drive current infrastructure network investment as well as future investments as the networks roll out and begin to reach scale and new services arise. Trials are underway with operators like SK Telecom and equipment maker Samsung already testing a complete 5G End-to-End connection with speeds of over 1 Gbps and latency of only 1.2 ms.[6]

The End to End Captures the Most of 5G’s benefits

Companies like Huawei, Intel and Samsung are approaching 5G from an end-to-end position, spanning nearly all the company’s businesses from cloud data center, core network, access network and wireless technology to smart devices. Coincidentally, these areas are all impacted by 5G. This strategy allows the companies to potentially benefit the most among the semiconductor vendors when it comes to a transition to 5G. Huawei, Intel and Samsung have all the components one would need to serve 5G end-to-end with high-performance datacenter offerings, low-power datacenter and edge server offerings, network accelerators, machine learning processors, high-speed and mid-speed storage, modems and radio frequency (RF). These companies with an end-

[5] Ericsson and SK Telecom demonstrate 5G network slicing technology
[6] SK Telecom and Samsung Complete 5G End-to-End Network Trial Based on 3.5 GHz 5G NR Tech…

to-end approach can address the major areas of 5G in a meaningful manner with many products for their infrastructure customers.

5G USE CASES

EMBB – Enhanced Mobile Broadband

One of the most immediate 5G applications is EMBB. This translates to taking the mobile broadband of today's 3G and 4G and supercharging it with mmWave spectrum and other available spectrum. This means using it for indoor and outdoor wireless broadband, replacing existing cellular networks with higher bandwidth, denser cellular networks. Longer term, EMBB will also be available in the existing bands of cellular spectrum utilized for 4G LTE, but re-farming takes time, and licensed spectrum is still relatively scarce in those bands. This will translate to faster connections for smartphones, tablets and other mobile broadband-enabled devices available today.

In addition to having faster mobile devices, fixed wireless broadband is another application for EMBB as a cable replacement opportunity that still delivers gigabit bandwidth to homes. One of the biggest barriers to the deployment of fiber in larger countries like the United States has been the last hop from the node to the household, and fixed wireless broadband offers an opportunity for operators to offer gigabit speeds without a physical connection.

Utilizing EMBB enables improved, immersive experiences like augmented reality (AR) and virtual reality (VR) through faster download speeds, improved latency, and more consistent high-speed connections. Companies like NextVR who deliver live VR content have stated that they need consistent 100 Mbps download speeds to deliver a high enough resolution to make 360 VR viewing look as good as users expect. Additionally, AR will need to download, and stream holograms in real-time which right now are in the hundreds of megabytes each. Simultaneously to using AR and VR, some operators are already testing the possibility of delivering real-time 4K broadcast over EMBB because it would lend well to 5G's low latency and high bandwidth.[7] This could be beamed not only to mobile consumers on their smartphones but also into their homes. Fiber to the home or business could be a thing of the past.

Remote cloud rendering is another possible application of 5G through EMBB by utilizing the low latency internet connection afforded by 5G to allow for high frame rate

[7] 5G use cases demonstrated by SoftBank and Huawei

streaming of applications. These applications include remote desktop, gaming, and professional visualization, all of which benefit from a faster, lower latency connection.

Mission Critical Services

5G enables mission-critical services through its different service layers and low latency capabilities. The ability to have mission-critical services that are prioritized with QoS and network slicing for things like smart grid and drones allows the devices to operate on the same 5G network as smartphones and fixed wireless broadband connections. These drones could easily be used for security, validation or mapping since they are now connected to the network directly and analytics can be done in real time.

Robotics and automation is another promising area for 5G mission-critical services because of their dependence on a reliable, low-latency connection. Applications like remote mining, logging, and other energy or resource gathering can be done out of harm's way thanks to 5G mission-critical services. This could reduce the cost of performing these functions because people are not at direct risk and the cost of insurance and injuries and health problems can be lowered. Robots can also work 24x7 in inclement weather. Autonomous factories could also benefit from 5G mission-critical services because machines and factories could be connected directly to one another and the potential logistical issues can be identified and resolved more quickly. As robots become smarter and more intelligent, updating their AI (artificial intelligence) frameworks will be important, and 5G will be one of the best ways to accomplish that.

Healthcare and telemedicine could also benefit from 5G mission-critical services. While this may seem like a basic IoT service, when it comes to medical devices, there is an absolute mission-critical nature to healthcare. Because of that, things like remote patient monitoring with 5G offer an opportunity for hospitals and doctors to lower healthcare costs and improve care. There are also opportunities for telemedicine including remote surgery using robotics and a 5G connection where a surgeon can perform a surgery from anywhere if the patient is too far away.

Autonomous vehicles will also benefit greatly from the 5G mission critical layers, especially those that are used for public transportation. Having mass transit utilize autonomous vehicles is another way to reduce pollution and improve traffic in densely populated metropolitan areas. These will operate in conjunction with personal transportation where autonomous vehicles sync with one another through technologies like Vehicle to Vehicle, or Vehicle to Infrastructure (V2X) that allow vehicles to be aware of each other and other connected devices. Through being connected, 5G autonomous

vehicles can gather and download up to date road telemetry that can be used to improve autonomous vehicle performance and safety while reducing traffic as well.

Massive IoT

Massive IoT takes the idea of today's IoT deployments and looks at deploying them broadly all at once and across the same network in an even larger area. This means deploying on a single nation-wide carrier that gives you connectivity for your IoT devices and sensors as well as your other devices simultaneously. One of the most talked about applications of 5G for massive IoT is smart cities, connecting a city's different infrastructure together to make it more intelligent and manageable. The CTIA estimates that 5G Smart City solutions could produce upwards of $160 billion in benefits and savings.[8] One immediately obvious application is to use it for city-wide surveillance to help with crime prevention and investigations.

Smart homes are a microcosm of smart city applications for 5G, but when you replicate a smart home deployment many hundreds of thousands of times, you need a 5G network support them all. A 5G network would allow for these homes to be connected simultaneously and to be served by their service provider without needing to connect to unreliable Wi-Fi or Bluetooth.

Asset tracking and agriculture are also great applications of 5G for massive IoT because 5G could provide up to the second and foot location of different assets. For agriculture, that would obviously be knowing where cattle are and how different crops are doing, and for logistics, it could be locating individual palettes or entire containers. It is possible that if the cost of sensors and connectivity gets low enough, we could have individual asset tracking for logistics purposes as well.

5G Investment & Spending Increases

Operators are investing in 5G networks because many of them in developed markets have already mostly reached market saturation with a number of possible phone customers. 5G enables an entirely new business model outside of being just another dumb pipe and allows operators to offer more services and to more customers and to more endpoints than ever before. 5G is expected to start to launch globally in 2019 with the addition of non-standalone (NSA) 5G NR to the 3GPP specification which was agreed-to earlier this year, accelerating from 2020. However, fully 5G NR compliant deployments (standalone 5G NR) will still likely not happen until 2020 and non-

[8] Smart Cities – How 5G Can Help Municipalities Become Vibrant Smart Cities

standalone give companies an opportunity to build in a half-step towards 5G.[9] Right now, North America, Australia, China, Korea and Japan are the most prepared to deliver on 5G within the 2019/2020 timeframe. Others are expected to lag these geographies and may impact total global growth numbers.

The 5G NR specification and the deployment of standalone 5G NR in roughly 2020 will mean that operators and those that provide services that run on the operators' networks will have to invest in new infrastructure. Things like network slicing, which provide some of the fundamental differentiators for 5G, will not be possible with the new 5G packet core.

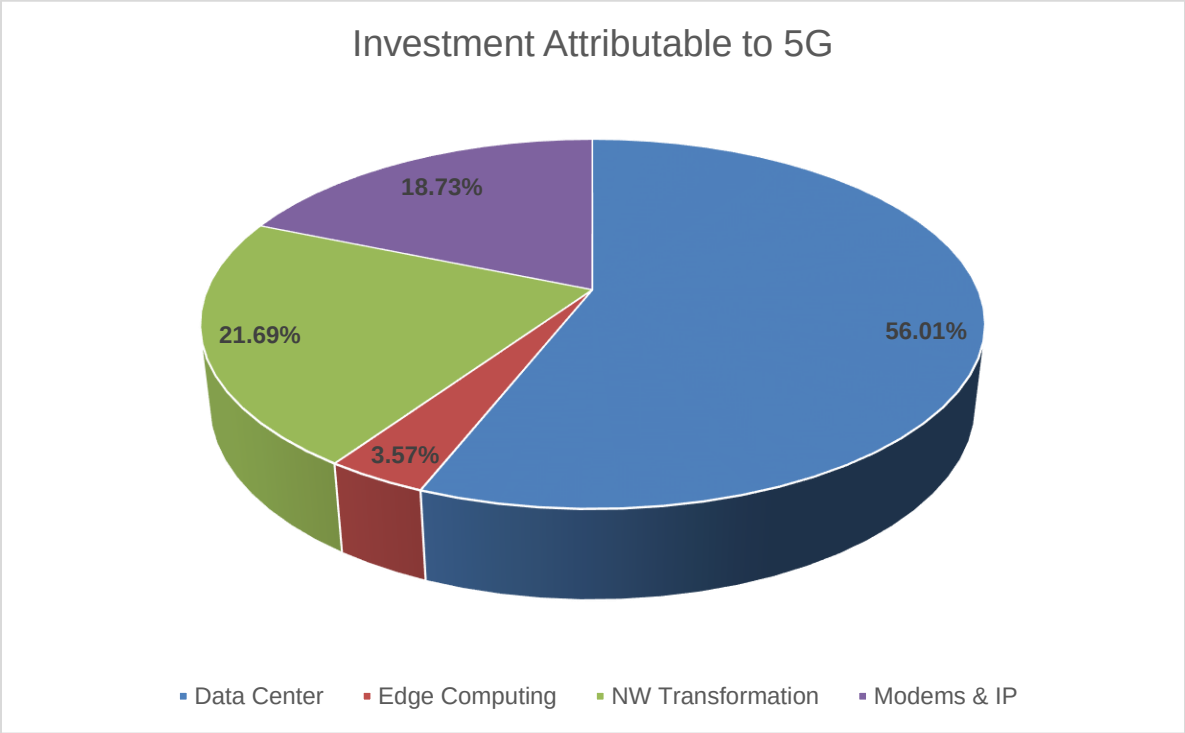
Companies like Nokia expect that "5G will last longer and be deeper than their first thought" meaning that the technology will drive more than just small cell spending but also macro cell and cover low, mid and high bands as well as drive changes and investment requirements in other parts of the network.[10] Ericsson also projects that by 2022 there will be roughly 9 billion connections with 500 million of them on 5G and the average user will consume 12 GB of data and in total globally will generate 71 Exabytes of data.[11] This amount of data and growth will put orders of magnitude greater demand on existing infrastructure.

In mainland China alone, the Chinese Ministry of Industry and Information Technology (MIIT) believes that 5G expenditures of the three domestic operators will hit a peak of $47 billion in 2023. They also believe that there will be 588.3 million 5G subscribers in China alone by 2022, up from 31.9 million in 2019.[12] The GSMA also estimates that by 2025, total 5G connections will already be 1.1 billion.[13]

Based on our projections, we believe that new IT hardware infrastructure spending attributable to 5G will grow to be approximately $326 billion by 2025, including datacenter, edge compute, network transformation activities, not including handsets. Cumulatively, this represents $1,197B of investment from 2017.

[9] 5G-NR workplan for eMBB
[10] Nokia Q2 2017 Earnings Call
[11] Ericsson Mobility Report 2017
[12] China Plans 28 Trillion Yuan Expenditure
[13] The 5G era: Age of boundless connectivity and intelligent automation

FIGURE 1: $326B INVESTMENT ATTRIBUTABLE TO 5G



Source: Moor Insights & Strategy

5G Data Center

Cloud and enterprise data centers will have to evolve to meet the higher demands of 5G devices and networks. The increase in 5G-enabled end points and gateway data will drive this. There will be a need for faster servers with AI capabilities to address expanded cloud utilization in 5G and new content services as well as network slicing. Memory and the highest-speed storage will enable massive pools or "memory" enabling giant analytics and AI processing. New, faster storage to keep up with low latency and higher bandwidth expectations to serve content and services will be necessary as well. New networking will be needed in the data center to meet the demands for new network functions, flexibility and speed. The 5G-impacted datacenter must be intelligent, software-defined and secure. Because of the introduction of new mission-critical services and 20 billion new end points, security will be even more important and necessary with 5G.

5G Edge Computing

The datacenter will see growth, but the edge will see an even higher per cent gain due to 5G. Compute will have to move closer to the edge to keep up with 5G requirements

and the 20 billion new end points that are expected by 2025. New high-performance low-power servers will be needed at the edge to meet the latency demands of 5G. Edge AI will also be required to help deliver real-time processing with minimal latency. Limited low-power storage will be needed closer to the edge to meet latency compute needs, but it will still be necessary for minor caching. There will be a need for lower latency edge networking so that the storage or servers already at the edge connect unimpeded to the data center. New edge and "campus" networks will be the first place the new 20 billion end points will hit. Edge security will be crucial because it will be one of the first points of attack for the new, even more important, 5G networks that will have mission-critical services running on them.

5G Carrier Network Transformation

There is a major change underway in the make-up of what carrier core networks look like, and that will be driven by 5G and its capabilities. To meet the requirements of the 5G NR specification, the new 5G Core Network will have to be low latency to enable new devices and services. The new 5G Core Network will also have to be able to do network slicing which when paired with low latency, allows for different service layers with QoS. These new 5G Core Networks will have to have support for NFV (Network Functions Virtualization), VNF, and SDN (Software Defined Networking) to support the flexible needs of new 5G networks. The new 5G Core Networks will also need to be able to be both intelligent and software-defined to meet all the dynamic needs of all the new services and service layers. Many of these dynamic needs are tied to network slicing and all the new services that they will enable, without a network transformation network slicing is unlikely to happen on today's networks.

The 5G carrier network transformation will also require improvements across the board including storage, networking, the RAN, backhaul, and security. These upgrades will be necessary to keep up with the increased specifications of 5G NR and the demands put on the carrier network by the edge and data centers. There cannot be any weak links in the chain from the data center to the end point. Otherwise the latency and performance improvements are negated. A recent demonstration by Ericsson in partnership with SK Telecom and Deutsche Telekom utilized the company's 5G Ready Core technologies including NFV, SDI (Software Defined Infrastructure) distributed cloud and network slicing. This demonstration was the world's first transcontinental 5G trial and showed the importance of having equally capable core networks across the world.[14]

[14] Ericsson, SK Telecom and Deutsche Telekom in world's first transcontinental 5G trial

New End Points

Some of the 5G end points we will see will be like what we see today, while others are devices that weren't connected before. Smartphones are naturally one of the first things you can think of when it comes to a mobile 5G device. The first 5G phones will likely be larger phablets (phone + tablets) to accommodate for the multiple antenna arrays needed to beam form around your hand and body. PCs, specifically notebooks and convertible tablets will also be new end points for 5G because they are not very common on 4G LTE right now and 5G will offer a fiber-like connection to them. Autonomous vehicles have a significant need for compute and connectivity with the 5G network and V2X communications which should be integrated into 5G.[15] These vehicles will need to constantly update their telemetry by both downloading new maps and uploading updated maps to improve the overall autonomous experience.

Medical equipment and telemedicine promise to be among the many end points that will drive 5G demand. These devices will harness the power of 5G modems and connect to the 5G networks to deliver the experience that people are expecting. Telemedicine will allow for improved patient support through both new devices and services that have yet even to be invented. 5G will enable entrepreneurs to think of new content and applications that weren't possible with 4G LTE modems and networks. These new services and applications are what will prolong the network investment beyond the expected 2025 horizon. These new services may arise as a secondary economic impact that may drive additional spending in the data center, edge computing and carrier network transformation beyond our expectations. These primarily will include new IoT services that arise from the introduction of ubiquitous 5G networks and new content medium delivery through immersive content (AR & VR) and higher quality video.

Call to Action

5G is going to fundamentally change the way that we and our devices interact with cellular networks. Many of those changes are going to be driven by the new interface and new radio. The new radio and new air interfaces are being driven by the new core network with enhanced capabilities. These new technologies will require new hardware and investment from everyone in the value chain. The bulk of incremental 5G investment up to 2025 will come from new infrastructure spending to make networks capable of delivering 5G use cases.

[15] 5G V2X

IMPORTANT INFORMATION ABOUT THIS PAPER

CONTRIBUTOR(S)

Anshel Sag, Associate Analyst at Moor Insights & Strategy
Patrick Moorhead, Founder, President, & Principal Analyst at Moor Insights & Strategy

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