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5G Wireless Expectations, Implications, and Safeguards

General Introduction

Mobile technology has made our personal lives comfortable and convenient, brought people and businesses closer, and ushered in an era of customized entertainment. Now, the fifth-generation mobile platform, the 5G, is all set to deploy starting in 2020. Let us have a look at the expectations, implications, and safeguards addressed in this whitepaper to better understand this technology as the disruptor of the next decade.

Expectations with 5G

NGMN (Next Generation Mobile Networks), the consortium tasked with developing 5G, anticipates a highly connected society of the future with an increased volume of heterogeneous traffic. It is expected 5G will offer latency, throughput, reliability, connection density, and mobility, much advanced than the previous generations, while also safeguarding security, trust, identity, and privacy of the people and businesses it serves.

The need to stay in touch matters for machines as much as it does for human beings and requires connectivity with the maximum bandwidth and the minimum latency. Internet of Things (IoT) and Industry 4.0 will bring unsupervised machine connectivity to the fabric of home, industry, and transportation environments. 5G proffers to realize these expectations wirelessly.

Sustainability

Sustainability and mass adoption of 5G cannot be feasible unless it is reliable and large scale. Interested telecom players take part in government-run spectrum-auctions to bid, win, and set up 5G infrastructure in cities and suburbs. The local governments plan, decide, and approve the neighborhood sites where the installation will be carried out. Because 5G uses millimeter wavelengths to transmit and receive data against centimeter wavelengths as in the case of LTE/4G, a lot more cells are needed to achieve the expected coverage. Consideration will need to be given to the increased costs and operational expenses that result with the deployment.

Even More Applications

The low-latency high-throughput advantage of 5G drives the below applications proposed for smart life:

- High quality video streaming and high-speed broadband access
- Internet of Things: Smartphones, home appliances, cars, other sensors and machines

- Public Transportation: High Speed Trains, Logistics and Fleet management
- Automotive: Ride-Sharing and Autonomous Driving
- Industry 4.0: Remote Manufacturing
- Energy 4.0: Smart Grid automation
- Lifeline communication: Natural Disasters
- Medical: Remote Surgery and Healthcare
- Entertainment: Cloud gaming, mobile TV, Virtual / Augmented Reality
- Intelligent Buildings and Smart Metering
- Broadcast services
- Government and e-tailing: Payment and identity verification
- Life: Health, security and safety, social life
- Smart Agriculture

Mobile technology that was once designed to enhance personal communications has successfully spread its reach to so many more markets.

Living in the 5G era

Living in the 5G era can be as challenging as it can be fascinating. To better grasp how 5G influences the society, it is important to understand some terms and concepts that come into play:

1. Edge Data Centers

Unlike previous generations, 5G aims to deliver prompt and seamless data to any connected machine or person. While the latency value – the delay humans perceive in receiving or sending data – for Long Term Evolution Technology (LTE) is around 56 milliseconds, for 5G it is 1ms or less. A cloud node or datacenter can be centralized to a city or an open space, and it could stay distributed, in other words, on the edge, in proximity to every site containing a cell radio. The so-called "Edge Data Centers" will be numerous, each the size of a shipping container, each packed with servers, storage, and networking components and cables. Although expensive, this helps to realize the expected sub-millisecond latencies. Businesswise, this increases the demand for data communication components and equipment.

2. Highly Mobile

Until now, high speed train passengers had to be content with low internet speeds onboard. High speed infotainment inside a train had been a distant dream because of the sheer number of travelers involved compared to other land transportation. With LTE, the connectivity to a nearby tower worsens when the train takes on speed. 5G tests however reveal promising results on high mobility. For a train moving at 300 kph and carrying 1000+ passengers, 5G can channel very high-speed data from cellular towers with minimal disruption. Each passenger can then stream media to their devices, rather than limiting themselves to text or email.

3. 5G and Urban Planning

The Internet of Things is a heterogeneous environment with billions of wireless devices. Take an urban street bustling with traffic, with each pedestrian or motorist equipped with a smart watch, cell phone, or a fitness tracker. Self-driving cars ferry riders to a preset destination. Autonomous vehicles wirelessly communicate not only with peer vehicles but also computers built into any traffic signal or street sign. As mobile internet involves people, two-wheelers, automobiles, buildings, signboards, public transport, and street objects of any type, the government and telecom providers must work together to gauge the accumulated demand experienced on any given day during the busiest rush hour. To what bandwidth should the cloud nodes scale up so that each mobile device can avail a decent service? In the case of ride-sharing equipped with self-driving cars, regulating the number of cars on the road keeps 5G infrastructure from scaling up to unreasonable levels that could choke up other services like remote surgery, public transport, industry 4.0, as well as prohibit home/personal usage. The ride-sharing service should be scaled up enough to satisfy a cab-hailing majority expecting last-mile connectivity and lesser wait times, while simultaneously allowing for transmission bandwidth for other key services. With the spread of IoT, each 5G urban roll-out brings with it the need to balance taxpayer’s convenience with public resource usage.

4. Cloud Computing and Big Data

It is no secret that personal preferences of millions of commuters are tracked while waiting for public transportation or in transit. This data exists in volumetric proportions and is termed Big Data which is analyzed to sell targeted ads to the user.

The images and videos collected by witnesses at scenes of crimes and natural disasters can also form Big Data, which is analyzed against a historical repository of previous occurrences to predict risks and prevent future events. When it comes to criminals fleeing a location, but getting caught on camera, latency plays a major role. The ultra-low latency of 5G improves the tacking-effectiveness of such situations, but the data is still at risk of being eavesdropped or hacked, requiring advanced malware prevention, detection, and elimination.

Artificial Intelligence is another area where Big Data can have a striking impact on society. Left unchecked, it, can be misused to create false media and to deceive viewers, especially in the political arena. 5G makes it easy for someone to release fake videos of politicians or celebrities. The fake voices, tones, expressions, and gestures may confuse voters and lead to skewed election outcomes. It is therefore paramount to develop counter-AI that can effectively spot the fakes and eliminate them.

The Technology

To improve wireless transmission and reception, 5G uses established techniques like

- Multibeam antenna propagation, where one data signal is altered and beamed as several

- MIMO (Multiple Input Multiple Output), where more than one data signal is beamed along several paths
- Carrier aggregation, where the same data signal is beamed across multiple carrier bands in the spectrum
- Cloud RAN (cRAN), where a single hardware unit performs the function of more than one carrier decoder

Some are relatively novel, like

- "Slicing", a networking method developed to handle heterogeneity
- Network Functions Virtualization (NFV), where servers running software mimic network hardware
- Software Defined Networking (SDN), where the software mimics function of any network hardware
- Hyper Converged Infrastructure (HCI), where server, storage, and networking converge as one.

NFV and SDN go hand-in-hand, and the same goes for Slicing and Carrier Aggregation. Let us have a look at these ideas in detail:

5G Slicing

NGMN categorizes everyday applications into so-called "use cases". For LTE, the predominant use case is mobile broadband. With 5G, additional use cases step in, like delay-sensitive video, ultra-reliable health and safety, complex data handling (in factories), and machine-to-machine communication.

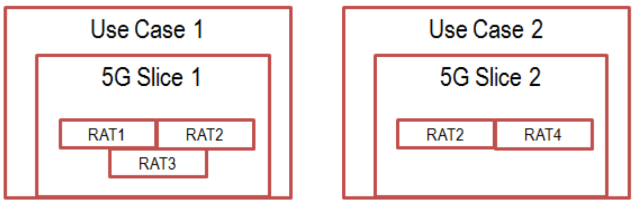

Fig. A

A 5G network for an area can be sliced into components which are then reserved for various use cases by tagging them with any of the Radio Access Technologies (RAT) LTE, LTE-A, or WiFi. The choice of the optimal RAT decides the best Quality of Service. Let us take the case of one such slice. Consider two online gamers, gamer1 and gamer2, located on different sides of an urban neighborhood. Let us choose RAT1 as LTE-A (LTE-Advanced) and RAT2 as 5G. Device1 is a smartphone, and Device2 is a game console. Antenna1 is a micro-cell located on gamer1's building that transmits Device 1's inputs. Antenna 2 is a macro cell that receives the inputs and relays to Device 2. This scenario is illustrated as a block diagram in Fig A.

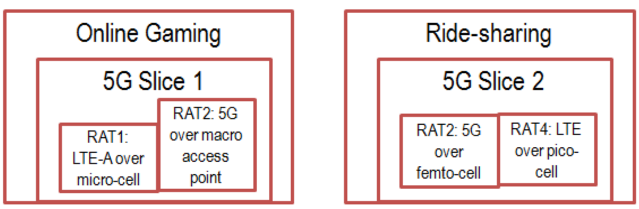

Fig. B

Practically, several of these use cases are serviced simultaneously. Use case 1 (online gamers) can share the bandwidth with use case 2 (ride-sharing services) because 5G slices are designed to co-ordinate with each other. Use case 1 could be game developers letting their systems train on actual traffic (use case 2) to make game simulation as realistic as ever. Fig. B illustrates block diagrams depicting this scenario.

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Network Virtualization

To implement "5G slicing", we would need an enormous quantity of networking gateway hardware like switches and routers. Replacing this hardware with software brings down costs and complexity, making 5G practicable, affordable, and sustainable. Network Function Virtualization (NFV) and Software Defined Networking (SDN) helps to "virtualize" hardware by taking advantage of software run on commonplace x86 or ARM servers. NFV allows servers in an edge node to mimic what network gateways do, which is transfer data from present location to another. When the use case needs more resources, NFV requests other nodes nearby to scale up and perform as one unit. Functioning alongside NFV, SDN gives operators the freedom to decide the latency and bandwidth for the use case.

The Market

According to market research publication *Markets and Markets*, 5G will start off with an impressive USD2.86 billion in 2020, climbing 50.9% annually to reach USD33.72 billion in 2026. It is forecast that countries in Asia will have the highest adoption rate for 5G technology, while the region with the largest market share will be North America.

Role of Connectors and Cables in 5G

1. Introduction

Connectors and cables help us to build safe, reliable, and serviceable 5G equipment. Either as components on a printed circuit board, or as attachments to cables that plug into the box, each connector plays a role as diverse as ever. They work in sync to bring out the very best of 5G. Connectors evade our notice unless the equipment is pried open for service, upgrade, or repair. Yet, they play the critical role of transferring signal or power into or out of the PCB trace. They may distribute the energy inside the box or outside. To make space on board for other components, modern connectors are engineered to be as small as possible. They have excellent quality, reliability, robustness, and heat dissipation.

2. Amphenol ICC

Amphenol ICC, a major connector and cable assembly manufacturer with a strong understanding of 5G applications and its related equipment, offers an extensive line of products like Minitek® 2mm, Minitek® Pwr, CoolEdge®, ExaMEZZ®, ExaMax®, and PwrMax®, selected from its range of commercial, power, and server portfolios. Let us lay these out for a few applications:

- **Coaxial RF connector for antennas and test boards**
  - 5G has called for a rampant redesign of the test boards for wireless equipment to accommodate the required millimeter wave frequencies. RF connectors undergo re-certification as part of this effort.
- **High performance PCB connectors for automotive and communication equipment**

  - Exorbitant levels of information from Big Data to Vehicle-to-everything pass through connectors attached to cables and backplane boards of network communication switches and servers. A large part Vehicle-to-Everything and Level 4 automation in self-driving automobiles will be controlled here.
- **Power and signal connectors for Outdoor Antenna and Base Band Unit**
  - Field-installable, surge-protected, and sealed connectors are attached to active antenna units mounted on poles and their connection extended via cable to base stations on the ground.
- **High performance server and storage connectors for edge data centers**
  - Special connectors and cables are deployed to address the vast range of memory and peripherals inside the edge-deployed processing and storage power houses.
- **Commercial board-to-board, wire-to-board, and IO connectors and cables**
  - Generalized and multi-purpose IoT connectors meet their purpose across segments as diverse as industrial, communication, energy, medical, automotive, transportation, retail, and consumer.

3. Connecting to the Internet of Everything

Let us now place these connectors in a heterogeneous environment.

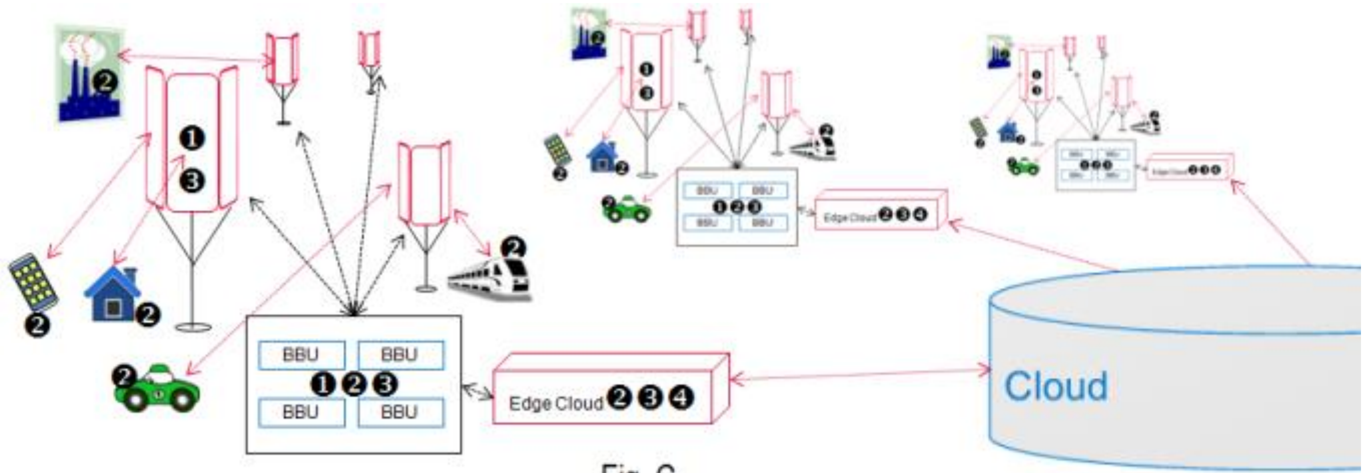

Fig. C

As depicted in Fig. C, the Internet of Everything - take phones, homes, cars, and trains - is serviced through a set of active antennas. They are driven by virtual base stations connected to an edge data center. Sets of these are allotted through the city, each having its own IoT to cover, each merging into the center main cloud. Compare this development with previous generations of connectivity, mostly limited to phones or tablets at the receiving end, and passive antenna units, base stations, and the center cloud at the providing end.

Enter the *active antenna,* conjoined radio base band unit + passive antenna, a single entity. We can see batches of these atop telecom poles or buildings. For 5G, they are a key enabler of urban cellular connectivity. Zoom in a bit and we see OCTIS™, a circular-molded connector with optional RJ45, USB, and power interfaces, connecting to the antenna's radio unit. Open unit to observe Lynx™ QD and ExaMEZZ®, two efficient mezzanine connectors bridging parallel daughter cards, and carrying signal through the boards at very high speeds. We also see wire-to—board products like the Minitek® Pwr connectors that carry power.

The ground-based *Next Generation Front Haul Interface* is tasked with driving the antenna units. In other words, it is a virtual base station hardware built on C-RAN, emulating the action of the erstwhile BS units that did one-on-one correspondence with antennas. The power needed to drive one such unit is rather high, calling for connectors like PwrMax® with 100A per contact ratings. On the signal side, AirMax® is one exemplary product that connects backplane motherboards and add-in daughter cards to drive the internet signal traffic to various high speeds. These have virtual shields, a technology hallmark to Amphenol ICC, where air acts as virtualized dielectric in place of the physical material, making them ultra-compact and light weight. While the MEG-Array® series of Ball Grid Array (BGA) technology connectors is fast enough to attain 28 Gb/s speeds on mezzanine the M-Series™ 56 takes this to even further north as 112 Gb/s for backplane and mezzanine.

An *edge data center* connects to the front haul and trains on Big Data before sending it to central cloud. This development meets the latency expectations of 5G when compared to earlier generations where the training would only be processed at the center. Inside the edge container, the architecture is primarily compute, storage, and network, existing either as rack servers and Network-Attached Storage with a RAID configuration, or as blade servers and all flash arrays part of a wider Storage Area Network (SAN). Or even as Hyper Converged Infrastructure (HCI), saving on the time, cost, and complexity it takes to set up numerous of these edge units. Inside the units, we can see NVMe-ready Slim Cool Edge and Gen4/Gen 5 PCI Express® card edge products ready to take control of the high speed peripheral bus. The advanced RAID5 fabric of a SAN will see adoption of 24 Gb/s SAS/PCIe 4.0 U.3 connectors as well as some board connectors and mating high speed cable assemblies such as Mini SAS HD. Rack servers, switches and external IO ports are interlinked by cabling based out of industry-standards like SFP, QSFP, QSFP DD (400G) and OSFP interfaces, and composed of connectors and their mating copper / optical cable assemblies.

At the receiving end of these services are billions of *IoT devices*. We find advanced-performance Bergstak® and USB 3.1 superspeed Type C connectors servicing self-driving cars and smart home security cameras, and building-block connectors like Bergstik® headers and receptacles inside antennas, buildings, vehicles, and the grid. Then there are wire-to-board signal connectors like the unshielded but vibration-tolerant Minitek® Microspace™ built into cars and trains. On the consumer end, Minitek® board-to-board connectors solve the PCB stack height requirements for 5G-compliant mobile phones. The FLH series wire-to-wire connectors and the FLA series dimming receptacles will play a large part in intelligent building lighting based on DALI (Digital Addressable Lighting Interface) and on IoT-controlled auto-dimming smart streetlighting.

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In an *Industrial 4.0 Computer*, traditional backplane connectors such as DIN 41612 and Millipacs® HS go inside the box, while panel connectors like VerIO™ and Boltrack™ go outside. The various harsh environment interfaces enhance Ethernet-based machine-to-machine connectivity on the smart factory floor.

4. Connector-Application Mapping

Let us now assemble the connectors and match them to their applications.

5G Market	Commercial board-to-board, wire-to-board, and IO connectors and cables	High performance server and storage connectors and cables for edge data centers	Power and signal connectors for Outdoor Antenna and Base Band Unit	High performance PCB connectors for automotive and communication equipment
Industrial	*	*	*	*
Data communication	*	*	*	*
Energy	*		*	*
Medical	*	*	*	*
Automotive	*	*	*	*
Transportation	*	*	*	
Business and Retail	*	*	*	
Consumer	*	*	*	*

We see the intense adoption of commercial connectors in Industry 4.0, Intelligent Buildings, and Internet of Things. Again, this is besides every other possible area they serve. Outdoor power and signal connectors for antenna are field-installable with built-in lightning surge protection making them useful to cars and public transit, disaster prone areas, outdoor TV broadcasting equipment, and automated smart highway toll stations. These are also rugged enough to tolerate harsh indoor applications in food and beverage and pharmaceutical industries. Besides edge data centers, server and storage connectors have a fair role assisting pretty advanced industrial and medical applications like remote manufacturing and remote surgery. High performance PCB connectors aid advanced data communication technology to make autonomous driving and vehicle-to-everything, a reality.

Conclusion

Starting in 2020, 5G as a mobile technology will define smart life and redefine how governments and businesses operate. The Internet of Things will usher in a heterogeneous environment that 5G has been found to successfully facilitate. Electronics equipment sales will shoot up as more cellular infrastructure gets added. 5G binds governing bodies and businesses like never before by allowing urban planning in key areas like logistics and mobility. Because 5G brings enhanced accessibility to Big Data and the cloud, data security can face concerns which hopefully are mitigated with advances in artificial intelligence and malware detection. Modern electronic connectors are battle-ready to meet the challenges of sustained reliability and improved latency any time, through their advanced design, sealing, shielding, and durability. Trials on 5G have so far proven successful, and the world is ready to embrace the birth of a technology disruptor.