5G Emerging Technology

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Bill Gate’s is famously quoted as having said that “640kb is more than enough memory for a computer.” Back in the early 1980s it may have seemed that was enough because the use cases for personal computing had not matured to point we routinely see in 2019. A parallel exists in networking as we transition into the 5th Generation of Wireless Technology.

The big picture of 5G Wireless is that bandwidth will increase to terabit per second rates, which will enable immediate access to enormous amounts of data for billions of devices. This will enable many scenarios such as IoT sensor networks, smarter Device-to-Device (D2D) communications, and rich interactive video content (Prasad, 2014).

# Provide Necessary Background on Topic

According to IEEE Spectrum these innovations will be driven by advancements in: Millimeter Waves, Small Cell Architecture, Massive Multi-in Multi-out (MIMO), Beamforming, and Full Duplex channeling (IEEE Spectrum, 2017).

## Millimeter Waves

For an increase in magnitude of both the speed and number of connected devices to be possible; more network channels need to exist. Efforts are being made to increase the frequency range as high as 300ghz (Prasad, 2014). The challenge with using these high frequencies is that they become fragile over long distances. For instance, they can be absorbed by trees and cannot penetrate through walls or other structures (IEEE Spectrum, 2017).

## Small Cell Architecture

Previous generations of wireless technology scaled by using large base stations that would cover large distances (Gupta, Jha, & and Jain, 2017). Due to the challenges of reliably sending millimeter waves over long distances; lots of small base stations are used in a honeycomb configuration (Prasad, 2014). The overlap of multiple small stations enables the device to maintain high quality of service (QoS) as the device physically moves around obstacles (IEEE Spectrum, 2017).

## Massive Multi-in/Multi-out (MIMO)

The number of connected devices is expected to increase by a factor of 1000 (Prasad, 2014) (Zappone, A; et al, 2016). According to IEEE, “a modern 4G base station has 12 antennas ports versus 5G will use closer to 100 ports. This will increase the capacity of each base station by factor of 22 or more (IEEE Spectrum, 2017).” MIMO also represents an evolutionary model over Single-in/Single-out antennas which are typically used today (Inzillo, Quintana, De Rango, & Zampogna, 2018). As the technology progresses the connection density per antenna is also expected to increase.

## Beam Forming

A challenge with simply adding more ports is that the signal is broadcasted in all directions and will fill up the available radio frequencies, resulting in interference (IEEE Spectrum, 2017). To mitigate this issue, advancements are being made to send the signal in only the direction of the connected device (Gupta, Jha, & and Jain, 2017). By having fewer transmissions spanning less physical space there is a reduced chance of collisions.

## Full Duplex

As the number of devices increases the necessity to optimize each of the frequencies increases as well. IEEE describes how modern wireless systems will either (1) use different frequencies for the sender and receiver or (2) requires they take turns on a single channel. Instead 5G will leverage fast network switches to enable both parties to send across a shared channel in full duplex mode. By improving the utilization of each channel more devices can join the wireless network before it becomes oversaturated. This ultimately means more bandwidth for more devices.

# Detail the Findings from the Reading

There were two assigned reading for the week; “5G: 2020 and beyond” and “Extended Task Queuing: Active Messages in Heterogenous Systems.”

## 5G: 2020 and Beyond

The text begins with describing the evolution from the first to the fifth generation of wireless communication. As each generation has been released new features and capabilities have become available. This has largely been driven by the increase in bandwidth required to enable these scenarios. For example; 2G was limited to 9.6kb/s which was fast enough for text messaging, but it was not until 3G and it’s 384kb/s speeds that video chat became mainstream (Prasad, 2014).

Next it goes on to describe the Wireless Innovative System for Dynamically Operating Mega Communications (WISDOM). WISDOM is the holistic architectural changes that are required to evolve the 4G network into 5G—with burst speeds up to 1TiB/s (Prasad, 2014).

This connects into the Global Information Multimedia Communication Village (GIMCV) which is a mesh of macro, micro and pico-communication cells that are interconnected together (Prasad, 2014). The tiering allows for wireless technologies to span connectivity from an American office building to a rural part of Africa – providing full global coverage.

## Extended Task Queuing: Active Messages in Heterogenous Systems

The article describes a general framework for using remote memory and accelerator cards such as GPU, APU, or GPGPU. What makes this implementation novel over vanilla MPI is that it does not rely on the remote CPU resources to dispatch the task. This improves the efficiency of the invocation by 10-15% (LeBeane, M; et al, 2016).

Remote Direct Memory Access (RDMA) technologies are typically found on wired systems, as the networking latency can significantly impact the performance. LeBeane, et al describes a goal starting a remote invocation within 7 to 30 microseconds. However, with the availability of 5G and its terabit/s speeds – the wired requirement could be removed.

That would enable thin clients to leverage cloud resources and have virtually unlimited capacity. For instance, a game console could economically and efficiently use dozens of remote GPUs to render ultra-photorealistic graphics (Prasad, 2014) (LeBeane, M; et al, 2016).

# Identify the Process used By Each Resource

Autonomous driving vehicles could become safer as blazing fast networking and remote accelerator cards become commoditized. Most self-driving vehicles operate by collecting local sensor data and then using on-board AI to determine the best action (Lapan, 2018). This local data could be enhanced through Device-to-Device (D2D) peering-- between itself and other vehicles on the road (Prasad, 2014). Consider the scenario where it is raining, and every vehicle knows the next action of its fellow drivers in advance; along with the health status of everyone’s braking systems. These sensor values could then be pushed into the cloud to give extremely precise guidance to infinitely detailed scenarios.

Other IoT scenarios, such as smart cities, will benefit from the transition to 5G as it increases the density count of devices on the local network. This is due to antenna improvements and the wider spectrum range (Inzillo, Quintana, De Rango, & Zampogna, 2018). These heterogenous networks will require new open protocols to efficiently collect and broadcast observations to its mesh peers (Prasad, 2014).

For these observations to be trusted, each of the devices will need to be authenticated, authorized, and audited (Howard, 2003). Due to the Small Cell Architecture, it is expected that a network session will likely hop across multiple base stations before completion. This introduces a challenge that authentication must complete within single milliseconds or the overall efficiency of 5G could suffer (Prasad, 2014). The authentication system will need to be highly scalable and work across multiple service providers.

Another resource that will need to exist is the Intrusion Detection and Previous Systems (IDS/IPS) (Gupta, Jha, & and Jain, 2017). There will be a percentage of devices on the network which are hostile due to malicious intent, malware, or misconfiguration. Even if the percentage is small it becomes a large problem when multiplied by the billions of expected devices. These IDS/IPS systems will need to comb through the audit log to identify and quarantine such devices.

# Predict the Future Work in this Area

## Going Green

“5% of all global CO2 is caused by information and communication technology (Zappone, A; et al, 2016).” After the broad adoption of 5G wireless services, the number of always on/always connected devices (AO/AC) is expected to increase by a factor of 1000. Each of those devices will be sped up by another factor of 1000.

Under these growth parameters it will not be sustainable to the environment to linearly scale CO2 emissions by devices count. Instead new technics and optimizations will be required to make 5G eco-friendly.

## Wireless Safety to Humans

With billions of devices continuously emitting millimeter wave signals across the frequency range; “the radiation from 5G will be 30x greater than 4G LTE (Mottus, 2018).” This raises questions around the long-term health impact to humans and wild life. The topic is complicated by conspiracy theories that research has been stifled by service providers, similar too Big Tobacco during the 1960s (Hertsgaard & Dowie, 2018).

An argument has been made that mobile radiation is different from x-ray and nuclear radiation; which were incorrectly assumed to be safe (Wilson, 2018).Wilson states that the physics are better understood and will not cause increases in tumors due to the non-ionizing properties of the signal.

However, the questions cannot be simply dismissed as control groups have found a correlation between wireless signals and increased risk of certain cancers (Miller, Morgan, Udasin, & Devra, 2018). Ultimately if wireless technologies are hazardous-- then research needs to quantify that risk and discover methods to deliver it more safely to the customers (Di Ciaula, 2018).

## Device to Device (D2D)

One of the challenges with 5G wireless is that it requires lots of base stations, as the radio frequencies are unable to traverse through physical barriers (IEEE Spectrum, 2017). It might be possible to instead create mesh networks between other devices in the local area, such that more efficient network routes can be leveraged (Ansari, et al., 2017).

This idea could be further expanded to securely offer unused local device resources over RDMA to peers in the same region. The service could be offered without impacting the performance of the main CPU resources via XTQ (LeBeane, M; et al, 2016). Members of the mesh would collectively gain greater performance, as they are able to tap into the collective unused hardware. To further incentivize participation micro-transactions could be paid between devices.

## Interference Reduction

The 5G frequency range is finite while billions of devices will be having numerous conversations concurrently across it. This is further compounded by base stations needing to relay the signal multiple times across the Small Cell Architecture. This leads the need for finding mechanisms, such as beamforming, to reduce the radio interference between devices.

WISDOM comes with technologies for beamforming however the need to further improve this scenario still exists (IEEE Spectrum, 2017). Ansari, et al describe the need for a centralized Device Interference Coordinator (DIC). The DIC would essentially act as a traffic cop, making sure that each heterogenous device efficiently operated within the multi-tenant environment. Optimization strategies for the DIC will need to be created to further increase connection density.

# Do you agree with the works Primary Findings?

Yes, the key argument of Prasad is that networking speeds are going to continue increasing and it will bring about new and innovative scenarios for the end user. This makes logical sense as the ability to consume and produce vast amounts of data will power complex algorithms. When coupled with the RDMA and cloud patterns as described by LeBeane; it creates an environment where resources available to a local device are virtually unlimited.

Devices with unlimited resources can produce more interactive content that will be delivered at significantly higher resolutions. That will aid in the adoption of technologies such as augmented and virtual reality. These properties will also lead to smarter devices which will be more personalized and responsive to opportunity or risk.

IoT based scenarios will also become more widely deployed as it will become easier to access high speed wireless from anywhere on the globe. For example; large scale sensor networks will be deployed across entire supply chains. They will stretch from the manufacturing plant, to the autonomous trucks, to the receiving bay at the distribution center. It will provide a treasure trove of information which can be unlocked through machine learning algorithms.

There will be physical challenges to delivering on this vision such as the short distances that millimeter wave can reliably be sent. This is addressed with the design of Small Cell Architecture; however new protocols will be needed for better collaborative interactions across heterogenous D2D meshes. Innovations around radio interference will also be needed as the number of simultaneous network conversations increases exponentially. However, in exchange for overcoming these challenges the world gains ubiquitous connectivity and networking.

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