PREPARED STATEMENT FOR THE RECORD OF

INTEL CORPORATION

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SUBCOMMITTEE ON ANTITRUST, COMPETITION POLICY AND CONSUMER RIGHTS

Hearing On

GAME OF PHONES: EXAMINING THE COMPETITIVE IMPACT OF THE PROPOSED T-MOBILE/SPRINT MERGER

June 27, 2018

Chairman Lee, Ranking Member Klobuchar, and Members of the Subcommittee, thank you for inviting me to speak about the opportunities that 5G will offer citizens, communities and our economy. I serve as Vice President, Technology, Systems Architecture & Client Group and General Manager of Next Generation and Standards at Intel Corporation. In this role, I am responsible for investigating and delivering the technologies, business use cases, collaborations and trials that will usher in the era of 5G wireless connectivity as well as broadly fostering innovation in mobile communications and ecosystem intelligence for future products. It is my job to drive the benefits of 5G to various other businesses by fueling innovation for homes, cities and enterprise.

Today, I will focus on the opportunity 5G will offer citizens, communities and our economy. 5G, the next evolution of wireless networks that build on existing 2.5G, 3G, 4G, LTE and Wi-Fi networks, will transform the way people and digital things – from smart homes and rich entertainment to the Internet of Things – communicate and interact with the world. Simply put, we are reaching the intersection of computing and connectivity. Through 4G, we worked to connect everyone. Now, through 5G, we are working to connect everyone and everything. For this, the 5G infrastructure must be powerful, agile and flexible. It will take innovation from the devices all the way to the cloud: we will need the technical expertise from a variety of companies with different assets to make the benefits of 5G a reality.

Intel Leading on 5G

Building on our current leadership in 4G, Intel has a comprehensive strategy to help lead the industry transition to 5G from standards to devices to 5G networks. Intel is unique in its ability to deliver end-to-end solutions that will make 5G a reality across the network, the cloud and consumer and industrial devices. We are working with leading operators worldwide to ensure the 5G networks are ready. Given the substantial differences with 5G networks, we've collaborated in more than 25 trials focused on network, cloud and device deployments around the world on many "world's first" successes, including applications such as sporting events, home consumer use, 4K video, connected cars and remote controlled construction equipment. We showcased many of these applications at the Winter Olympics in Pyeongchang.

Intel has been bringing 5G out of the lab and into the field, with real world deployments of 5G technologies. Last November, Intel announced our first multi-mode 5G modem which will be the core of user equipment such as cell phones, tablets, and laptops. Intel is also finalizing interoperability testing with various base station (i.e. the electronics and antennas on cell towers) vendors. Intel is no longer just "inside" your computer: Intel's technological innovation is expanding to 5G network, consumer and industrial applications and the cloud.

All of this work throughout the mobile ecosystem provides a broad view and an appreciation for the contributions made throughout the industry to bring the benefits of 5G to society. At today's hearing, I will focus on four questions: What is meant by 5G, What new capabilities will it enable, What does 5G require to succeed, and What near-term advancements are possible when 5G becomes widespread.

Understanding 5G

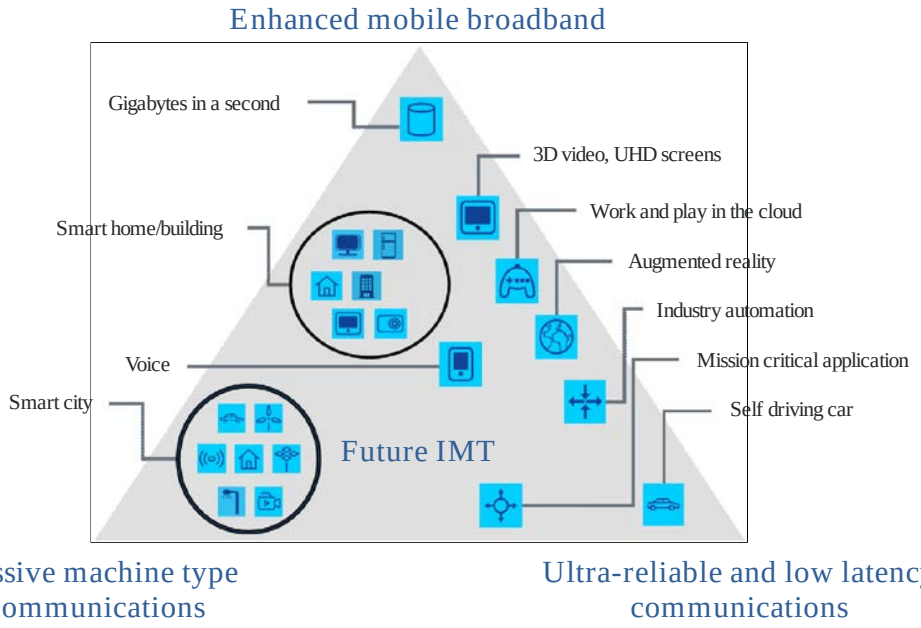
A good way to understand 5G is to place it in context. Second generation cellular or 2G enabled digital voice, 3G enabled digital data, 4G enabled much higher data rates within the same resources used by 3G, and 5G can enable a fully connected intelligent mobile society. 5G will be the first time cellular networks will utilize low, mid, and high band spectrum, which has broad implications on the range of applications and services- and the industries- that benefit. Thus, 5G is not simply a newer, better version of 4G. By promoting faster data rates, more rapid response times, and facilitating support for significantly more connected devices than possible in its predecessor technologies, 5G technologies -- using both licensed spectrum (the next generation beyond LTE) and license-exempt spectrum (such as Wi-Fi)— will change the way we work, play and live.

Earlier in my career at Intel, we made a decision to enable Wi-Fi in every laptop powered by Intel processors. At the time, many others raised questions about whether this would be commercially successful and whether there was a sufficient user base for such capabilities. But we persevered, along with some industry partners, despite those questions because we had a vision of broadly enabling a whole new way of computing. Two key words in that sentence are "vision" and "enabling". Today, we envision applications that 5G will facilitate including smart cities, the Internet of Things, autonomous driving, etc. But part of our role is also to enable applications and use cases that might not be as apparent. Believe it or not, a leading chain of truck stops was one of the earliest adopters of widespread Wi-Fi in order to enable truck drivers to stay connected with their companies and customers. This was an important lesson in understanding that the technologies we are shaping enable use cases we have yet to consider.

Similarly, 4G deployments have enabled a wide range of applications we use every day. Whether it's video conferencing with our co-workers or family, checking in for a flight with mobile check-in, finding recommendations for a nearby restaurant, arranging transportation, watching audio-visual content such as streaming a movie, or countless other things, these human-centric applications have fundamentally changed- indeed improved- our daily lives.

5G has the potential to expand these improvements well beyond human-centric applications and into a wide range of industries, enabling an even broader transformation. These applications span the global economy from industrial automation to e-health and tele-medicine, from smart cities to autonomous operation of machines and from smart agriculture to mining, to name only a few. 5G will support a wide variety of use cases, as described in the figure below:

Usage scenarios of IMT for 2020 and beyond[1]



In trials, Intel is collaborating with leading service providers to architect, trial and deploy the use cases of tomorrow. We have already learned from our early 5G applications. For instance, at the Winter Olympics in Pyeongchang, we had the largest 5G deployment to-date (with 22 active 5G links across 10 sites), showcasing many different use cases, and providing "real" services to spectators and visitors in the venues, including virtual reality demos 4K video streaming[2] and a connected car experience.

Intel and its partners recently completed the first 5G golf broadcast at the U.S. Open, where consumers were able to experience the tournament with our 5G equipment transmitting live video captured by two 4K High Dynamic Range cameras positioned at the 7th hole of the event. As this was done entirely over a wireless network, this also reduced programming costs. Another example used the Intel GO Automotive Platform to enable a 5G connection to a smart passenger bus in Japan. This connection broadcasted four 4K video streams simultaneously to large screens in the bus theater room: this is just one example of how enabling the wireless communication of rich media could change something as mundane as bus travel into immersive experiences. Intel 5G technology has also been used in the testing of 5G fixed wireless access in multiple U.S. markets, as plans are being developed to use this technology to deliver residential broadband services.

Differentiated 5G Capabilities

Along with other industry leaders, Intel has been developing new specifications that will enable 5G to provide substantial improvements over 4G. The improvements in 5G are not merely focused on higher data rates; rather, these improvements are paving the way for the most diverse set of applications and

[1] Source: Recommendation ITU-R M.2083-0 IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond

[2] The standard for High Definition is 1080p (number of vertical pixels). 4K has a resolution of at least 3840 x 2160 (horizontal pixels).

use cases ever supported by any wireless communication system. The concept of 5G, as being shaped by industry and formulated by governments and regulators around the world, revolves around significantly improving performance of mobile cellular systems challenging the constraints and assumptions of 4G and its predecessor technologies and by pushing the limit on several fronts.

In 5G, peak data rates will increase from 1 Gigabit per second to 20 Gigabit per second, or 20 times greater than we have today. Downloading a high definition movie today would take over one hour on a 4G network versus only a few seconds over 5G: this is the equivalent of transmitting data over a fire hose instead of a garden hose.

Latency (related to the "response time") will decrease from tens of milliseconds to one millisecond, enabling mission critical applications. Improved latency will reduce the amount of "buffering" for video content and improve how quickly an industrial device such as construction or mining equipment can react to instructions received remotely. 5G also substantially improves connection density (that is, the number of simultaneously connected wireless devices within an area) that can be supported, which will increase from 10,000 to 100,000 devices per square kilometer to facilitate the Internet of Things. Industry is driving these remarkable technological improvements while increasing the spectral efficiency (the amount of information that can be transmitted over the same bandwidth) by a factor of up to five.

Role of Spectrum in 5G

Spectrum is the crux of wireless communications. The level of performance possible in any given frequency range for a given bandwidth is a function of the signal propagation characteristics (i.e. how radiowaves travel). To deliver on its goals, 5G will require both access to the right amount of spectrum and access to the right type of spectrum. Without access to this spectrum, the U.S. will not be able to reap the full benefits of 5G.

In particular, 5G will require access to a combination of low, mid and high band spectrum in order to fulfill the various use cases of 5G as different bands have different propagation characteristics and available bandwidth. On one hand, in order to deliver extreme high data rates needed for applications such as 4K/8K video streaming or Virtual Reality/Augmented Reality (VR/AR), 5G needs access to very large bandwidths (or "fat pipes"). These applications can be optimally accommodated in high bands (e.g. millimeter wave bands) where such large bandwidths could be made available. On the other hand, to provide reliable connectivity to Internet of Things applications, which often operate in industrial or remote environments, 5G needs access to low frequencies with their characteristic radio waves capable of penetrating through obstacles, such as industrial complexes. Therefore, low band spectrum, e.g. around 1.5 GHz or lower, is needed to support applications requiring wide coverage and outdoor to indoor communication.

Some other envisioned 5G applications require a balance between coverage area/range and data rate, for which mid band-spectrum, such as those below ~6 GHz, are optimal. In the mid band, frequencies are low enough to have adequate coverage areas and at the same time are high enough to enable use of advanced antenna techniques for significant performance improvements over what is currently possible in lower frequency ranges. In particular, enhanced mobile broadband (eMBB) in mid-range frequencies is one of the early targets for 5G deployments by mobile operators around the world as a means to provide significantly better user experiences relative to 4G. Access to low, mid-range, and high frequency spectrum is essential for optimal operation of 5G mobile systems.

The U.S. has made good progress on making low-band and high-band spectrum available for commercial use. But access to sufficient mid-band spectrum particularly the 3.7-4.2 GHz and 6 GHz bands will be essential to enabling applications across 5G usage scenarios including those requiring a combination of larger coverage areas and higher data rates. Indeed, expeditiously making more mid-band spectrum available in a market-friendly manner is a critical action that U.S. policymakers can take now to foster 5G. As you may know, Intel has been a leader in developing novel, market-driven solutions to enable access to mid-band spectrum for both licensed and unlicensed technologies. We are encouraged that the FCC has announced that it intends to issue a Notice of Proposed Rulemaking for additional licensed mid-band spectrum at its July 12th meeting and begin a separate rulemaking for additional mid-band spectrum for unlicensed technologies later this year. In both cases, we believe there are market-based approaches that if adopted would protect the interests of existing users at the same time that they expeditiously free up valuable mid-band spectrum for 5G. We are encouraged that the FCC under Chairman Pai with bipartisan support appears committed to moving forward quickly on both of these rulemakings.

A few last thoughts on the government's role with respect to spectrum. First, it is important for the National Telecommunications & Information Administration within the Department of Commerce to continue to work towards making additional spectrum available for commercial use and not to place unnecessary regulatory burdens on spectrum that is made available.

In addition to making spectrum available, other regulatory aspects are also crucial. For example, there are efforts in Congress and at the FCC to facilitate 5G deployments via updated infrastructure siting rules. Implementation of the network supporting the future connected society, with its billions of connected devices, objects, and systems, requires a new way of organization and operation. The infrastructure supporting 5G networks will be complex as well as more resilient, more efficient, and more reliable. However, access to adequate support/backhaul facilities, especially in dense urban areas, could be a challenge for 5G deployments. Streamlined regulations are needed to help tackle this challenge.

Finally, one other regulatory area must be addressed to foster 5G: the U.S. must ensure that equipment certification regulations and processes for 5G devices are published in a timely manner. Clear guidance will provide the certainty needed to avoid delays and optimize 5G performance.

Advancements Possible through 5G Deployment

Industry has moved from research and development to initial prototypes to lab trials and to field trials. We are now on the cusp of initial 5G commercial deployments. It is important to note that 5G standardization efforts will continue in the future as more features and enhancements are added in order to support all envisioned use cases. To put this in perspective, the first LTE specifications were completed in 2008 and still continue to evolve today.

The recent approval of the first phase of "5G" specifications by 3GPP marks a critical step to facilitate the first wave of 5G deployments around the world. This first phase focuses on enabling the most differentiating features of 5G over previous generations, both in combination with existing 4G networks (primarily relying on 4G as a fallback technology in limited coverage scenarios) as well as in standalone 5G deployments. With these specifications, 5G users will be able to enjoy many enhanced mobile broadband features for key applications such as high-definition video streaming and other immersive experiences. More importantly, these specifications include essential features that enable applications requiring ultra-high reliability and very low latency to support many vertical industries such as

automotive, public safety, and smart cities. As we approach 2020, the next phase in 5G standardization will focus on also enabling another major 5G use case - massive machine type communications, paving the way towards creating the connected societies of the future.

Thank you for providing me the opportunity to share our perspective on the benefits of 5G and why it's so important to Intel to work with government and industry on its advancement. It is critical for Congress, the FCC and NTIA to work together with industry to propel these advances. With your leadership on the regulatory and legislative front, society will be able to enjoy the immense benefits and growth from being connected through this revolutionary infrastructure.