Executive Briefing Memo

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Subject: Capabilities and Impacts of 5G Wireless Service

Introduction

This briefing memo examines 5G cellular technology and its capabilities as well as the claims made about the impacts of 5G for consumers, low-income residents, businesses, and municipalities.

5G is marketed as the next generation of wireless technology for voice and data services, following 4G/LTE. 5G is rolling out in very limited trials in some US cities; consumer 5G devices are not yet commercially available. It is, therefore, very difficult to speculate about the real impacts that 5G will bring. In this memo, I have summarized what is known about the technology itself and have overlaid those facts with some of the more prominent claims about how it can be used. I have tried to rely on literature and research that has not been produced or funded by the wireless industry.

This paper does not touch on the current issues around regulatory changes mandated by the FCC related to small cell deployment in the right-of-way, which have been covered in an earlier briefing memo.

Executive Summary

5G is an emerging encoding protocol for wireless voice and data traffic. 5G can utilize a much broader wireless spectrum than previous cellular generations. 5G is designed to use very high frequency bandwidth to achieve faster transmission speeds over much shorter distances. To support this, short-range transmission antennas (“small cells”) must be deployed much more densely than current or earlier network technologies.

Wireless carriers are likely going to deploy 5G at multiple frequencies depending on an area’s specific needs, and will have to sacrifice transmission speed for distance in many cases. Because of the large variability in frequencies used, it is difficult to trust claims about 5G being able to operate at a particular “speed” as this will be highly dependent on deployment patterns, economics, and geographic requirements.

Because 5G is not one “thing,” it is difficult to predict its impacts for consumers, businesses, or cities. Consumer use cases include faster mobile data speeds and the potential for “fixed-point residential wireless” as an alternative to cable for high-speed home internet. The limits of the technology and the high costs of deploying the additional fiber-optic cabling and antennas to support this technology at scale, however, may be limiting factors for some time in seeing widespread availability or adoption.

Business use cases are typically cited around manufacturing and retail automation and virtualization, which may make 5G an attractive entrepreneurial platform and serve to maximize productivity-based profitability, perhaps at the expense of job creation.

Projected municipal use cases tend to cluster around "smart city" solutions, such as power grid management and traffic control. These solutions, however, have been available for years and have realized hundreds of millions of dollars of benefits for cities already without the need for 5G networks. It is unclear from the reviewed literature that 5G is necessary to support some of the use cases that have been cited as "benefits."

Finally, the memo includes a brief review of current state and speculation about autonomous vehicles (AVs), which are often cited as leading a transformative change that will require the high-speed and low-latency networking promised by 5G. As we will see, however, that future is not entirely clear and the AV sector may, in fact, be moving away from network dependencies.

Definitions

5G

5G is an emerging encoding protocol for wireless voice and data traffic. It is intended to be the "next generation" of cellular protocols, following 4G/LTE. The 5G standard has not yet been fully ratified by the 3GPP consortium, which is responsible for defining international wireless communications standards. 5G is also intended to operate at different frequency levels – shorter wavelengths support faster transmission speed over very short distances; longer wavelengths transmit further at lower speeds.

Small Cell

A "small cell" is a cellular radio antenna that is both smaller in size than larger "macro cells" (i.e. "cell towers") and has a much smaller transmission range. Small cells are not new – they have been used as part of Distributed Antenna Systems (DAS) for years to amplify 3G and 4G cellular signals in indoor settings and provide denser coverage in facilities such as convention centers and stadiums. **It is important to note that "small cell" does not equate to "5G."**

5G Technical Details

It is challenging to settle on a single definition because 5G is capable of operating across a large swath of frequencies within the wireless radio spectrum, and different frequencies are capable of different speeds and transmission distances. It is, therefore, not a single service with common characteristics. Some general claims of 5G capabilities are:

- Enhanced mobile broadband - faster transmission speeds.
- Increased capacity - the ability to connect more devices to the network with less performance loss.
- Lower latency - reduced response times from antennas and other network components.
- Network virtualization and quality of service – the ability to dedicate certain frequency bands to specific applications and guarantee a particular level of service.
- Reduced power consumption – devices can receive and transmit at higher speeds using less energy.

For example, 5G will be able to operate at 700 MHz, a low-frequency band that is currently used for 4G. Many small cells that are being sited in communities today are operating at this frequency and are serving to supplement existing 4G networks. It is widely expected that 5G will also need to operate in this band in

order to cover large areas or transmit longer distances, however the promised speed and latency improvements of 5G will be more modest at this frequency.

At higher frequencies, such as mid-band 3.5 GHz and high-band 28-32 GHz (also known as "millimeter wave" or "mmWave"), speeds and capacity benefits will be experienced, but transmission distance will be greatly reduced. Small cells operating at these frequencies will need to be more densely sited – possibly every 500-1000 feet – and connected to each other and to a network backbone with fiber-optic cabling. Also, at the higher frequencies, obstructions such as buildings, reflective glass, and even trees can interfere with and disrupt signal transmission.

Consumer Benefits

Mobile Use

5G is being marketed as capable of delivering gigabit speeds wirelessly for users of mobile devices. The implication is that 5G-capable smartphones will be able to upload and download data at 1,000 Mbps as if they are connected directly to a fiber-optic network. However, given the limitations described above with regard to the frequency-to-speed-to-coverage relationship, it is much more likely that "mobile 5G" will operate in lower frequency bands and at closer to 4G speeds in areas other than those with extremely dense cellular coverage in the millimeter wave band. It is likelier that mobile consumers will benefit from the increased *capacity* of cellular networks brought about by the greater efficiency of the 5G encoding protocol.

Limited pilots and some initial deployments of 5G service are happening now. There is no consensus on when 5G networks and/or 5G devices will be widely available. An industry analyst for the website "Tom's Guide" writes, "2018 saw a lot of progress with 5G. And despite 2019 looking like a big year for network launches, 2020 is when the fifth generation of wireless connectivity will really start to take off."[1]

Fixed Residential

Fixed-point residential wireless internet service is being marketed as an alternative to traditional "wireline" internet service, like that provided by Comcast and CenturyLink. Residential wireless service would eliminate the need for a cable to extend from the operator's nearest point-of-presence (e.g. a nearby utility pole) to a demarcation point on a home – typically no more than 150 feet.[2] Once connected to a 5G router inside the home, the 5G signal would be converted to standard WiFi to support home devices. This is similar to how mobile "hotspots" operate today on 4G networks.

In order to achieve speeds comparable to wireline service, fixed-point wireless service would need to operate in 5G's highest frequency (millimeter wave) bands, which limits transmission range and increases

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[1] "The Truth About 5G: What's Coming (and What's Not) in 2019." https://www.tomsguide.com/us/5g-release-date,review-5063.html. Published 3/13/2019. Retrieved 3/14/2019.

[2] The FCC has established 150 feet as the maximum distance between a provider's existing facilities (i.e. its cable infrastructure) and a customer's home that qualifies as a "standard installation" – i.e. an installation that the customer does not need to pay extra for. The assumption here is that the vast majority of residences are within 150 feet ("standard" range) of a provider's infrastructure, and so a "5G residential wireless service" would effectively only be truly wireless for no more than 150 feet in most cases.

the signal's sensitivity to interference and obstructions. There are limited trials of fixed-point service in several US cities, but I was not able to find any independent reports of the results.

In April 2018, *Ars Technica* published an article covering AT&T's limited fixed residential tests in some markets. The article cited the company's reports of positive initial results for both connectivity and penetration. However, given the density of equipment required to achieve results at high-frequency bands, it remains to be seen how widespread this service will be outside of areas where the service is likely to be profitable. The article states: "Carriers will use millimeter waves to *improve their networks where they're able to*, but they won't abandon the sub-1GHz spectrum…. [emphasis added]"[3]

Nevertheless, the availability of fixed-point residential service from wireless carriers could represent a potential increase in marketplace competition for home internet service. Traditional and incumbent providers, such as Comcast, CenturyLink, and Wave, may consider this a threat to their established market shares and may respond by offering higher speeds and/or lower prices. Comcast, for example, has claimed that speeds up to 10 Gb/s are theoretically possible over existing copper-wire infrastructure. CenturyLink's fiber-to-the-home infrastructure is likewise theoretically capable of greater-than-gigabit speeds. With nearly 100% market penetration today, the wireline/cable industry is well-positioned to compete on both network speed and price with any new residential service marketplace entrants.

Rural/Low-density Urban Areas

Industry and the FCC claim that 5G will be a solution to limited broadband availability in rural areas. FCC Commissioner Brendan Carr sponsored an order in September 2018 to limit municipal regulatory authority and fees claiming that it would pave the way for 97% of wireless infrastructure to be built in total and suburban areas. FCC Commission Jessica Rosenworcel, however, disagreed with the rule changes observing that they did not include actual commitments for rural investment and no carriers have changed their investment plans to include rural deployment.[4]

The Digital Engagement Office is aware that there are small parts of Seattle that are underserved, or even completely un-served, by wireline internet providers. We have received a handful of reports from residents who have been informed by Comcast or CenturyLink that they must pay "non-standard installation" costs of up to $20,000 to get connectivity to their homes because of their distance (> 150 feet) from existing infrastructure. While it is possible that fixed residential wireless service could provide an alternative high-speed internet option for these residents, the transmission distances for truly high-speed wireless service are still relatively short and would likely require a comparable infrastructure build to deliver service to these residences.

To illustrate this: In 2017, Digital Engagement staff entered into discussions with Verizon to identify a location for a limited trial of a prototype 5G residential service. We recommended an area in south Seattle

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"AT&T's 5G Trials Produce Gigabit Speeds and 9ms Latency." *Ars Technica*. [3] https://arstechnica.com/information-technology/2018/04/atts-5g-trials-produce-gigabit-speeds-and-9ms-latency. Published 4/11/2018. Retrieved 3/10/2019.

[4] "Could 5G close the digital divide between urban and rural communities?" *SmartCitiesDive*. https://www.smartcitiesdive.com/news/5g-digital-divide-urban-rural-communities/545211/ Published 1/7/2019. Retrieved 3/14/2019.

that was not served by any wireline providers. Verizon determined, however, that it would be too costly to build the necessary fiber infrastructure to that area in order to provide the wireless connectivity for the remaining 150 or so feet from the pole to the home. Verizon instead conducted its trial in the Bitter Lake area of north Seattle, which was already served by their infrastructure. To date, Verizon has not provided the City with any data on the results of that trial.

Digital Equity Impacts

5G service by itself will not likely deliver a direct digital equity benefit to the community unless wireless carriers explicitly agree to deploy in underserved communities, offer discounted service programs to low-income subscribers, or directly invest in the City's digital equity programs. However, even in a more *laissez-faire* situation low-income subscribers may indirectly benefit from the marketplace disruption and increased competition that 5G may inspire.

Research conducted in 2018 by the Digital Engagement office of Seattle IT has confirmed that mobile connectivity is increasingly supplanting traditional home internet adoption among low-income residents in Seattle.[5] While 5G service and devices are expected to be expensive during the early phases of deployment (2021-2023), there is a possibility that the cost of 4G service will be discounted, just as 3G service was discounted with the advent of 4G.[6]

Although this "trickle-down" model runs the risk of sustaining or creating further technology access inequities between higher- and lower-income residents, the performance gulf between 4G and 5G is not as great as that between 3G and 4G. In other words, it is likely that the most common online applications and activities will continue to perform adequately over 4G for the foreseeable future, and so 4G users will not suffer as large of a service degradation as 3G users did when 4G services became standard.

Also, as networks expand and become more dense to support the requirements of 5G service, *and* if carriers continue to overlay legacy 4G service on those networks, users of 4G service may benefit from increased availability and capacity of the network.

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[5] "2018 Technology Access and Adoption Study." City of Seattle. http://www.seattle.gov/Documents/Departments/SeattleIT/DigitalEngagement/TechAccess/City%20of%20Seattle%20IT%20Summary_Final.pdf

[6] It should be noted that the mobile experience is not an effective substitution for traditional access modes when it comes to education, employment, job training, health care, and other critical life tasks that are increasingly only available to be performed online. It continues to be the case that reliable access to *both* mobile and residential methods of internet access are necessary to achieve an adequate online experience for most users, especially those who are underserved.

Commercial and Economic Benefits

A 2017 Accenture released a report[7] on the commercial benefits of 5G. The report was commissioned by the CTIA, a wireless industry trade association, and makes bold claims about the economic impact of 5G investments:

- Increase of $500 billion to the US GDP
- Savings and local benefits of $160 billion to local communities
- Creation of over 3 million jobs in the US

The report claims that a community of 100,000 people could see 100 new jobs and a GDP growth of $180 million. It uses a simple multiplier formula to project benefits at larger scales. Extrapolated to Seattle's population of about 700,000 and using the report's own methodology and assumptions, investment in 5G could result in the creation of 700 jobs and a local GDP rise of $1.2 billion in Seattle.

To realize these benefits, the report urges municipal governments to "streamline permitting, change their fee structures, and reduce regulatory hurdles to support the new small-cell deployment model."

However, the specific methodologies used by Accenture to determine these benefits are not documented in the report, and it is not clear how the job creation and economic benefits were derived.

In the book *The 5G Myth*, wireless engineer and IEEE Fellow William Webb further explores the claims of commercial and economic benefits from 5G. Webb examines industry claims about growth in manufacturing (robotics), telemedicine, and logistics (drone delivery). He writes, "While there are some valuable applications here, they can be well served with existing solutions. There is nothing of sufficient novelty, scale, and value to make the deployment of an expensive 5G solution worthwhile."

It is likewise unclear from the reviewed literature how 5G-related job creation projections are derived. This is especially puzzling when job creation numbers are often listed side-by-side with discussions of 5G's enablement of autonomous vehicles, retail virtualization, and manufacturing automation – all of which are thought to be threats to existing jobs. Looking backward, a 2015 report from Ball State University found that productivity-based job creation claims made in 2000 failed to materialize as predicted by 2010. "Almost 88 percent of job losses in manufacturing in recent years can be attributable to productivity growth. Had we kept 2000-levels of productivity and applied them to 2010-levels of production, we would have required 20.9 million manufacturing workers. Instead, we employed only 12.1 million."[8] Though the Ball State research applies to a different era, it is included as an example and cautionary tale about assuming job creation as a result of technology or productivity gains. Indeed, it is possible that the opposite may be true.

Municipal Benefits

The Accenture/CTIA report also discusses a few "smart city" applications that are expected to deliver higher performance and cost savings for the public sector. For example, the report claims that "smart electric grid"

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[7] "How 5G Can Help Municipalities Become Vibrant Smart Cities." Accenture. https://api.ctia.org/docs/default-source/default-document-library/how-5g-can-help-municipalities-become-vibrant-smart-cities-accenture.pdf

[8] Hicks, Michael J., Srikant Devaraj. "The Myth and Reality of Manufacturing in America." *Ball State University.* https://conexus.cberdata.org/files/MfgReality.pdf Published June 2015 (updated April 2017).

technology can generate savings for utilities (and ratepayers) via improved demand-side management and load balancing. It also suggests that deploying "smart streetlights" can reduce power consumption and costs.

While cost savings from these technologies may in fact be demonstrable, the report does not explain why 5G – as opposed to existing networks – is required to produce these benefits. In fact, the report cites an example of savings from smart grid technology in Chattanooga, TN, from a 2013 report, and it cites savings from smart streetlights in San Diego from a 2012 report. 5G networks were not available in 2012 or 2013; 5G is clearly not necessary for those communities to benefit from "smart city" technology.

One of the most often-cited use cases for 5G is autonomous vehicles (AVs). Discussions of 5G for AVs include both vehicle-to-vehicle (V2V) and vehicle-to-everything (V2X) scenarios, and reference both the increased speeds and lower latency of 5G networks as primary benefits.

For V2V communications, a wireless spectrum band (5.9 GHz) is currently reserved for AVs. That extremely high (but low-range) frequency is intended for dedicated short-range communications (DSRC), a wireless network that operates separately from 4G/5G and Wi-Fi to enable vehicle-to-vehicle and vehicle-to-infrastructure signaling. Given the high-risk scenarios AVs operate in, it is very likely that AV manufacturers and government regulators will insist that dedicated (non-consumer) bandwidth be used for this application.

For V2X communication scenarios, such as vehicle communication with traffic signals and other pieces of communications-enabled infrastructure, analysts do not agree that 5G will be necessary or even beneficial. Webb writes, "Self-driving cars have to be completely safe and reliable without mobile coverage, and if this is possible, then why do they need mobile coverage at all?"[9] Instead, as with V2V scenarios, dedicated wireless networks operating in reserved frequency bands to support AVs are likelier to be effective rather than reliance on what the industry is promoting as "5G."

Gartner is a little more optimistic about 5G's role vis-à-vis AVs, but foresees a long timeframe. "5G will indeed be essential to the development and use of autonomous vehicles, with two important caveats - the network must truly be 5G, and the vehicle must truly be autonomous…. Neither of these appear to be likely in the near term."[10]

IEEE offers a more balanced view. "Engineers began working on autonomous vehicles long before 5G. There are plenty of self-driving technologies that don't require a vehicle to communicate with its environment." However, they write, "5G can offer high data throughput and low latency to move at least some real-time data processing out of the vehicle itself."[11]

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[9] Webb, William. "The 5G Myth."

[10] "Will 5G be necessary for self-driving cars?" *BBC News*. https://www.bbc.com/news/business-45048264. Published September 27, 2018. Retrieved March 14, 2019.

[11] "On the Road to Self-Driving Cars, 5G Will Make Us Better Drivers." *IEEE Spectrum.* https://spectrum.ieee.org/telecom/wireless/mwc-barcelona-2019-on-the-road-to-selfdriving-cars-5g-will-make-us-better-drivers. Published March 1, 2019. Retrieved March 12, 2019.