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Commissioner:	C. Rechtschaffen
Admin. Law Judge:	K. J. Bemesderfer
CalAdvocates Project Mgr.:	Shelly Lyser
CalAdvocates Expert Witness:	Cameron Reed

Public Advocates Office

California Public Utilities Commission

Public Advocates Office Testimony on Fifth Generation Wireless Service for the Proposed Transfer of Control of Sprint to T-Mobile

- PUBLIC -

San Francisco, California
January 7, 2019

MEMORANDUM

This report was prepared by Cameron Reed of the Public Advocates Office at the California Public Utilities Commission (Public Advocates Office or Cal Advocates) under the general supervision of Program & Project Supervisor, Shelly Lyser. Attachment A to this testimony is a statement of qualifications from Cameron Reed. The Public Advocates Office is represented in this proceeding by legal counsel, Travis Foss.

This testimony is comprised of the following chapters:

Chapter	Description
I	**Introduction**: Background information about the importance of a thorough review of the merger.
II	**Fifth Generation Wireless Standards**: A discussion about Fifth Generation Wireless technologies, standards, and deployment.
III	**Conclusion:** A summary of the main points of discussion.

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ATTACHMENTS

SUMMARY

An essential part of the required public interest review is an examination of whether the merger will maintain or improve the quality of service for California customers. The Amended Assigned Commissioner's Scoping Memo and Ruling filed October 4, 2018, (Scoping Memo) makes this requirement clear by asking what new services would arise from the merger,[1] how the merger will impact service quality,[2] and whether the benefits of the merger exceed any detriments.[3] In answering these questions, this testimony examined Sprint Spectrum L.P (Sprint), Virgin Mobile USA, L.P. (Virgin), and T-Mobile USA, Inc., A Delaware Corporation (T-Mobile) (Collectively "Applicants") claims of purported service benefits of the merger.

Key Findings:

The key findings of my review of the Applicant's proposed 5G wireless service include the following:

- The International Technical Union's Radio Telecommunications sector (ITU-R) outlined performance standards that prospective 5G services must meet by year 2020 which will improve mobile wireless service independent of the merger.
- Sprint and T-Mobile are independently deploying 5G network equipment in select markets and both are capable of fully deploying 5G services as stand-alone companies.
- New T-Mobile and T-Mobile will have the same amount of low-band spectrum dedicated to 5G by 2024, **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>**. T-Mobile will also have **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** of midband spectrum devoted to 5G by 2024.

[1] Scoping Memo at p. 2. Question #2.

[2] *Id* at p. 3. Question #10.

[3] *Id* a p. 3. Question #14.

- New T-Mobile plans to aggressively refarm 4G spectrum to 5G spectrum which will outpace customer demand for 5G service leading to unused 5G capacity and constrained 4G capacity.[4]
- 5G handsets are expected to be widely commercially available by year 2020. Low turnover rates for handsets and an approximately 5-year average life for smart phones predict that consumer demand for 5G capabilities will not overtake demand for 4G capabilities until 2025.
- Both Sprint and T-Mobile's stand-alone 5G networks will rival existing wireline networks in broadband download speeds by 2024, meeting or surpassing the 100 Megabit per second 5G standard for throughput.
- New T-Mobile's in-home broadband offering is in its conceptual stages and is lacking important details regarding customer cost and data usage plans.
- Sprint is planning to offer in-home broadband service using its 5G network independent of the merger.[5]
- Sprint and T-Mobile's concerns about having free spectrum available for a 5G transition are transient and will abate by 2024.

Key Recommendations:

The harms caused by the loss of a facilities-based provider that is a viable carrier and competitor does not outweigh the benefits of the merger. The California Public Utilities Commission (Commission) should deny the merger. If the Commission fails to deny the merger, it must implement wireless market improvements to mitigate the harms to California customers:

- Require that New T-Mobile adhere to its commitments to offer in-home broadband services and to expand and improve service in rural California.[6]
- Require that New T-Mobile adhere to its commitments to provide wireless speeds in excess of 100 Megabits per second by 2021 and 400 Megabits per second by 2024.[7]

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[4] When I refer to New T-Mobile's refarming plan, I am referring to the plan holistically to include encumbered 4G LTE spectrum (spectrum used to active support cellular subscribers) which will be gradually refarmed to 5G spectrum and unencumbered 4G LTE spectrum (spectrum not currently supporting cellular subscribers) that is already allocated to 5G spectrum. New T-Mobile's 5G plan for both free and used spectrum outpaces demand.

[5] *See* https://www.fiercewireless.com/5g/sprint-may-tackle-market-for-home-broadband-internet

[6] Application at p. 4.

[7] *Id* at p. 15.

I. INTRODUCTION

The Scoping Memo requires a review of whether a proposed merger is within the public interest.[8] This review includes in part an examination of whether the merger would maintain or improve the quality of service and services available to California ratepayers. The Scoping Memo makes the review requirement clear by asking "[w]hat new services, if any, that are not currently provided by T-Mobile or Sprint, are contemplated to be provided by the merged entity? How would the merger impact competition for such services in any metropolitan area or other geographically distinct market?"[9] and "[h]ow would the merger impact the quality of, and access to, service to California consumers in metropolitan areas, rural areas, or other geographically distinct markets?"[10] Further, the Scoping Memo makes it clear that merger impacts on quality of service or access to new service must have benefits that outweigh the detrimental effects of the merger by asking "[w]ould the benefits of the merger likely exceed any detrimental effects?"[11]

If approved, the proposed transaction will significantly reduce wireless competition in California and consolidate an already highly concentrated industry.[12] A large majority of Californians rely on their cell phones as their primary means of voice communication, with approximately 80 percent of 9-1-1 calls originating from wireless devices.[13] Furthermore, many low-income families rely on their mobile phones to connect to the Internet at home.[14] If the merger is approved, New T-Mobile will serve approximately **<<BEGIN CONFIDENTIAL>>**

[8] Scoping Memo at p. 2.

[9] *Id* at p. 2. Question #2.

[10] *Id* at p. 3, Question #10.

[11] *Id* at p. 3. Question #14.

[12] Decision (D.)16-12-025 at p. 11. "Mobile broadband markets are highly concentrated" and at p. 74.

[13] *See* National Emergency Number Association Statistics on Call Volume at: https://www.nena.org/page/911Statistics.

[14] Approximately 31% of US households that make less than $30,000 use smart phones as their only connection to the Internet. https://finance.yahoo.com/news/study-1-5-american-homes-get-broadband-smartphones-192623829.html.

[redacted] **<<END CONFIDENTIAL>>**[15] California customers, which means the proposed transaction will have a significant impact on a large number of Californians.

Fifth Generation (5G) wireless service is the next major advancement in the wireless industry. 5G service is generally expected to focus on breakthroughs that support the enhancement of mobile Broadband (emBB) and Mission Critical Communication (MCC) along with expanding to new applications such as Machine-to-Machine (M2M) and Internet of Things (IoT) communication.[16] 5G standards and expectations are defined by the International Technical Union – Radiocommunication Sector (ITU-R) in its International Mobile Telecommunications for 2020 framework (IMT-2020). The specifications and capabilities of IMT-2020 are discussed in Attachment B to this testimony.

In July 2018, the 3rd Generation Partnership Project (3GPP) issued release 15 which included the first 5G stand-alone radio specifications. In addition to the 5G NR air interface standard for radios, several new infrastructure and antenna technologies will enable 5G's improved coverage, throughput, and capacity. 5G deployments will also use new millimeter Wave spectrum (mmWave) to support high density areas; the Federal Communications Commission (FCC) is making mmWave available to carriers through auctions. 3GPP and industry groups are still finalizing 5G standards and both 5G equipment manufacture and customer adoption will take time.

The Commission should consider the ability of both companies to implement 5G wireless deployments absent the merger to determine whether the merger provides benefits to the public. Furthermore, due to recent advances in 5G New Radio (NR) technology, the Commission should also distinguish between potential benefits derived from new 5G technologies and benefits derived solely from the merger. The Commission should adopt the recommendations discussed in the sections below to ensure that customers' service quality is maintained or improved if the

[15] Confidential Appendix A to Application (A.) 18-07-011.

[16] Exhibit CR-1: International Technical Union – Radiocommunication Sector (ITU-R) Recommendation M.2083 at p. 11-12.

Commission fails to reject the merger on the grounds of competitive harms discussed in the testimony of Dr. Lee Selwyn.[17]

[17] Public Advocates Office testimony of Dr. Lee Selwyn at p. viii-xvii.

II. THE BENEFITS OF 5G SERVICE ARE NOT UNIQUE TO THE MERGER

A. The Capabilities of IMT-2020 Dictate That 5G Services Will Have Faster Broadband Speeds and More Capacity Than 4G Services.

The ITU-R's IMT-2020 framework set forth discrete specifications and use cases that a 5G wireless service needs to meet.[18] IMT-2020 defined eight parameters to consider as key capabilities of a 5G wireless solution, such as 5G service providing 100 Megabits per second (Mbps) average broadband speeds and 20 Gigabit per second (Gbps) peak broadband speeds. In setting forth the key capabilities of the IMT-2020 framework, the ITU-R envisioned that 5G wireless service should match fixed networks as closely as possible. Many of the merger's purported benefits can be tied to improvements gained from 5G networks. As discussed further in the following sections, the stand-alone companies will realize these 5G benefits independent of the merger. Attachment B to this testimony illustrates the key capabilities of 5G service compared to the IMT-advanced capabilities that defined Long Term Evolution (LTE) Advanced wireless services.

Several of the Applicant's purported merger benefits of faster speed, more capacity, and new services are benefits that are enabled by 5G services, and thus not unique to the merger. As discussed more in the following sections, the Sprint and T-Mobile will deploy 5G technology as stand-alone companies and many 5G benefits could be realized without the merger. Further, it is important that the Commission recognize that while the Applicants are beginning 5G infrastructure deployment, 5G standards are still in the final phases of development and the full scope of 5G's use cases and impacts are unknown.

B. 5G Wireless Infrastructure Improvements Will Depend Mostly on Network and Cell Site Improvements, Not on Acquiring New Spectrum.

5G NR services are supported by a variety of new technologies or methods to improve existing technologies. These new infrastructure techniques are key elements of the increased capabilities that 5G services have compared to 4G and 4G LTE wireless services. There are

[18] Exhibit CR-1: International Technical Union – Radiocommunication Sector (ITU-R) Recommendation M.2083 at p. 10-14.

many individual advancements in physical and frequency transmission methods that combine to create the basis for 5G NR services, the most prominent technologies including massive Multi-Input Multi-Output (mMIMO), beamforming, small cell deployments, virtualization, and millimeter wave spectrum (mmWave). Most of these new technologies depend on cell site improvements and high frequency spectrum, not existing spectrum portfolios. Attachment B to this testimony discusses these technologies are discussed in detail.

Radio equipment manufacturers have designed the first 5G NR radios using these technologies. In 2018, Ericcson introduced the Ericsson AIR 6468, which is capable of supporting LTE services and 5G service.[19] Further, Ericcson radios created after 2015 will be capable of providing 5G wireless service after an over-the-air software update.[20] The first full 5G deployments are coming in 2019 along with the first 5G capable consumer handsets; the earliest 5G phones will be released in the first quarter of 2019 with more following towards late-2019 and 2020.[21] Nokia is also developing 5G radios and has recently partnered with T-Mobile to facilitate $3.5 billion in 5G NR system deployments.[22] T-Mobile is already building 5G infrastructure and plans to deploy it nationwide.[23] Sprint will also be launching 5G services in the first half of 2019 using its 2.5 GHz Spectrum.[24]

While spectrum will be an important aspect of 5G deployment, most of 5G's improvements will be realized through capital intensive cell site and network management improvements. Sprint and T-Mobile are committed to deploying 5G services independently and have adequate spectrum resources to do so, as discussed below. Further, Sprint and T-Mobile have both committed billions in funds to facilitate 5G deployment, as discussed in the Public

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[19] *See* https://www.ericsson.com/en/networks/offerings/5g/5g-nr-radio.

[20] *See* https://www.ericsson.com/en/networks/offerings/5g/5g-radio.

[21] *See* https://5g.co.uk/phones/.

[22] https://www.nokia.com/about-us/news/releases/2018/07/30/t-mobile-and-nokia-ink-35-billion-multi-year-5g-network-agreement/.

[23] Declaration of Neville R. Ray at ¶'s 16-18.

[24] Declaration of John C. Saw at ¶'s 17-18.

Advocates Office testimony of Mr. Adam Clark. Absent the merger, Sprint and T-Mobile are fully capable of deploying 5G as stand-alone companies.

C. New T-Mobile's 5G Deployment Plans Outpace Projected Customer Adoption Rates and Sprint and T-Mobile Are Capable of Independently Deploying 5G Wireless Service.

The Applicants have expressed numerous times that the merger is necessary so that Sprint and T-Mobile can have the spectrum and scale to quickly build a 5G network.[25] However, even if it was true that Sprint and T-Mobile needed more spectrum to build their 5G network (an assumption which I contest below) there are other options besides merging that allow them to opportunity to acquire more spectrum. Further, New T-Mobile's plan for refarming 5G spectrum is unduly aggressive and outpaces projected customer demand, exaggerating the need for 5G spectrum in the next six years.

Spectrum refers to the set of frequencies on the electromagnetic spectrum used to transmit cellular traffic. These frequencies typically range from 600 MHz to 6 GHz. With the coming 5G wireless service, frequencies viable for cellular traffic will expand into spectrum bands greater than 6 GHz. Two upcoming Federal Communications Commission (FCC) spectrum auctions will provide wireless carriers, like the Applicants, an opportunity to bid for licenses for some spectrum bands in the 28 and 24 GHz frequency range.[26] Auction 101 will offer county-based licenses for 425 MHz blocks of spectrum. Auction 102 will offer licenses in Partial Economic Areas, or markets, in seven 100 MHz blocks. Further auctions may be upcoming, as groups are advocating that the FCC auction portions of the 3.5 GHz midband spectrum for use in 5G services.[27] These auctions provide an ample opportunity for the Applicants to acquire new high capacity and high throughput spectrum to support 5G deployments without merging.

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[25] Application at p. 2-3.

[26] FCC 18-109 released August 3, 2018 *Auctions of Upper Microwave Flexible Use Licenses For Next-Generation Wireless Service*, at p. 5-6 Table 1 and Table 2.

[27] The FCC is considering the option for opening up the 3.5 GHz band for mobile 5G services: Forbes https://www.forbes.com/sites/fredcampbell/2018/06/28/fcc-action-in-3-5-ghz-band-will-speed-5g/#6ee7cbc91c83.

Further, customers will have to acquire new handsets in order to use 5G wireless services.[28] As discussed above, 5G capable handsets are going to be released intermittently over the course of 2019. Early 5G capable phones will require multiple mmWave antennas that will cause these phones to be bulky, expensive, and have a shorter battery life.[29] As such, consumer adoption of 5G capable devices will take time. A study conducted in 2015 found that 54 percent of Americans upgrade their cell phones only when their current phone becomes totally obsolete and 44 percent upgrade as soon as their cellular carrier allows it.[30] Considering that smartphones have an average life expectancy of 4.7 years,[31] widespread consumer adoption of 5G handsets is reasonably expected to take at least 5 years, with approximately 50 percent consumer adoption expected by 2025.[32] As demonstrated, there is no pressing need to immediately make available a large amount of 5G spectrum, especially considering that 5G wireless service is more spectrally efficient than 4G LTE services. Consumers will take years to adopt 5G service, which means New T-Mobile's plan to refarm encumbered and unencumbered spectrum into 5G spectrum is unduly aggressive.[33] The Applicants have stated that they will continue to maintain LTE services going forward, with[34] or without[35] the merger, which is prudent as customers will continue to use LTE services past 2025. Given that adoption of 5G services are expected to be around 50 percent by 2025, it's reasonable to expect that spectrum assets would be distributed roughly the same way to accommodate customer use.

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[28] Exhibit CR-2: Sprint Response to Cal Advocates Data Request 001 Question 1-24.

[29] Arstechnica: "Don't buy a 5G smartphone, at least not for a while" at https://arstechnica.com/gadgets/2018/12/dont-buy-a-5g-smartphone-at-least-not-for-a-while/.

[30] Gallup Survey: Americans Split on How Often They Upgrade Their Smartphones https://news.gallup.com/poll/184043/americans-split-often-upgrade-smartphones.aspx?version=print.

[31] https://www.cta.tech/News/Blog/Articles/2014/September/The-Life-Expectancy-of-Electronics.aspx.

[32] The Mobile Economy North America 2018 Report by GSMA which can be found here: https://www.gsmaintelligence.com/research/?file=1edb46b8f8d86187a7508bad348c3e87&download.

[33] When I refer to New T-Mobile's refarming plan, I am referring to the plan holistically to include encumbered 4G LTE spectrum (spectrum used to active support cellular subscribers) which will be gradually refarmed to 5G spectrum and unencumbered 4G LTE spectrum (spectrum not currently supporting cellular subscribers) that is already allocated to 5G spectrum. New T-Mobile's 5G plan for both free and used spectrum outpaces customer demand.

[34] Application at p. 3.

[35] Application at p. 27 and p. 29.

The Applicants have outlined their spectrum refarming plan[36] in their Public Interest Statement (PIS). Like many aspects of its proposed business model, the PIS proposed that New T-Mobile would pursue an "aggressive refarming strategy."[37] Figure 1 below illustrates the spectrum refarming and allotment plan that T-Mobile, Sprint, and New T-Mobile expect to follow:

[36] Refarming refers to the process for repurposing frequency bands for use with a new generation of mobile technology. In this case, 4G bands would be refarmed into 5G bands.

[37] PIS at p. 32.

Figure 1: Spectrum Holdings and Refarming Plan[38]

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By 2024, T-Mobile projects that it would have about **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>**, Sprint would have **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** and the combined companies would have **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted]

[38] Exhibit CR-3: T-Mobile Response to Cal Advocates Data Request 001 Question 1-24.

[redacted] **<<END T-MOBILE CONFIDENTIAL>>** New T-Mobile plans to use over **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** of its non-mmWave spectrum for 5G service, as compared to about **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** for T-Mobile and **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** for Sprint.

Clearly, New T-Mobile plans heavy investment in 5G spectrum refarming. However, given customer adoption predictions and the increased spectral efficiency of 5G services, New T-Mobile's spectrum re-farming plans are unduly aggressive. With its own spectrum refarming efforts, stand-alone T-Mobile will be able to cover 323 million US Population (POPs) by 2024 with its lowband spectrum and 173.2 million US POPs with its midband spectrum. The Applicants have suggested that New T-Mobile needs the increased spectrum portfolio to have spectrum free to transition to 5G. The transition to 5G is a transient problem, one that every carrier will have to deal with. The Commission should not approve a merger to obviate temporary issues associated with a technology transition.

Projected customer adoption rates and the ability for older radios to be converted through a software update imply that there is no pressing need for the companies to merge in order to fully deploy 5G services by 2021 or 2024. The Applicants overestimate the need for refarming 5G spectrum and have underestimated their ability to deploy 5G NR services as stand-alone companies. Sprint recently affirmed that the company is in a good position to deploy competitive 5G services.[39] The companies do not need to merge to deploy 5G services, especially considering that upcoming mmWave auctions will allow T-Mobile and Sprint to expand their spectrum portfolios to supplement 5G deployment in dense urban areas were demand for 5G services and capacity will be the highest.

[39] Exhibit CR-4: Sprint 3rd Quarter 2017 Earnings Call, "I am very confident in Sprint's future based on the competitive advantage that we will have with the deployment of 5G on our 2.5 GHz spectrum" at p 4.

1. Rural Deployment Will Depend on Capital Investment, Not New Spectrum. T-Mobile Already Has Adequate Spectrum to Serve Rural Areas.

The Applicants focus on possible benefits that the merger will potentially bring to rural America and by extension rural California. These possible benefits include increased speed and in-home broadband options.[40] While rural communities do need faster speeds, the merger is not the only way to achieve that goal, nor is it the best way. Sprint notes that 2.5 GHz coverage is limited in its ability to provide coverage, especially in rural areas.[41] Yet, the Applicants claim that New T-Mobile will rely on this exact spectrum to provide coverage in rural areas.

Midband spectrum, such as 2.5 GHz spectrum, has a coverage range of approximately four miles.[42] Covering rural areas with midband spectrum will require significant capital build-outs of more cell sites. As discussed in Attachment B, most new technologies enabling 5G service such as mMIMO and beamforming are infrastructure-related antenna technology, which will require further investment to upgrade existing antennas and radios. These benefits are not directly enabled by larger spectrum portfolios, even if more spectrum can benefit 5G deployments.

Further, rural areas have low population densities that do not need as much capacity as dense, urban areas. As such, carriers need less available spectrum to provide service to rural areas, especially considering that 5G NR will improve spectral efficiency over 4G. The merger will lead to portions of spectrum being unused in rural areas. T-Mobile will have **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** available for use in rural areas by 2024 and T-Mobile and New T-Mobile will have the same amount of available lowband 5G spectrum, **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>**, to serve rural areas. Stand-alone T-Mobile already has the spectrum resources to provide high speed 5G services to

[40] Application at p. 24.

[41] *Id* at p. 28.

[42] Declaration of Neville R. Ray at ¶36.

rural areas. T-Mobile can also replace and upgrade its existing 600 MHz radios to provide 5G service as demand grows in rural areas.

2. New T-Mobile's In-home Broadband Concept is Neither Fully Planned nor a Unique Benefit of the Merger.

The Applicants claim in-home broadband offerings as a benefit of the merger.[43] While competition in the in-home broadband market would benefit consumers, the proposed merger is not the sole, or even the most impactful, enabler of a potential in-home broadband offering. Further, the in-home broadband offering is not well defined, and the application includes no material plans to implement this service, how it would be marketed, or what quality of service could be provided to customers.[44] Several technical issues about network capacity and building penetration also remain unanswered. Sprint also plans to offer in-home broadband service using 5G independent of the merger.

First, the in-home broadband offering is a service enabled by the significant advances in capacity, coverage, and throughput derived from 5G NR. As discussed in Attachment B, small cell deployments and mMIMO will enable speeds of 100 Mbps or more, which is comparable to existing wireline services. The stand-alone deployments of T-Mobile and Sprint in 5G services are projected to meet or exceed the expected 5G average speeds by 2024, which would enable the stand-alone companies to provide an alternative to fixed wireline service without needing to merge.

In addition to attributing 5G NR benefits to the merger, the Applicants also lack specific details about the nature of an in-home broadband option. While New T-Mobile has preliminary plans to use customer premises equipment such as a wireless router to convert the cellular signal into a Wi-Fi signal,[45] there is no information on what this device may cost consumers, when the device will be commercially available, how customers will sign up for service, or even what areas will have a strong enough signal to be eligible for in-home broadband.

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[43] Application at p. 4.

[44] Exhibit CR-5: T-Mobile Response to Cal Advocates Data Request 002 Question 2-2(g).

[45] *Id.* Question 2-2(b).

Critically, wireless data plans typically come with data limits. Even unlimited plans will have a soft data cap where users will start to be 'deprioritized' and face slower download speeds. These caps tend to be in the 6 to 10 Gigabyte (GB) range; for unlimited plans the soft cap at which data customers are deprioritized and may receive slower speeds is 50 GB. As such, mobile users typically tailor their data use around these limitations, as well as the limitations of their mobile devices which have smaller screens that limit the quality from higher video resolutions. This user behavior is reflected by T-Mobile's BingeOn customers, where the largest data customers consumed on average **<<BEGIN T-MOBILE CONFIDENTIAL>>** [redacted] **<<END T-MOBILE CONFIDENTIAL>>** of data per month to stream video.[46] In 2017, mobile users consumed on average 7.1 GB of data per month.[47] In home broadband has considerably higher data limits and data consumption rates than mobile broadband services. In 2016 an iGR research study found that, on average, US homes use 190 GB of data per month.[48] This number has undoubtedly risen over the past two years and is nearly four times the soft data cap of most unlimited plans before deprioritization. Streaming TV and high-resolution video[49] are also very bandwidth demanding, often using up to 400 to 500 GB of bandwidth a month.[50] Figure 2 summarizes data caps and consumption rates of these various services.

[46] Exhibit CR-6: T-Mobile BingeOn Statistics.

[47] Taken From: https://www.ericsson.com/en/mobility-report/reports/november-2017/mobile-data-traffic-growth-outlook

[48] Average data consumption per household taken from: https://www.telecompetitor.com/igr-average-monthly-broadband-usage-is-190-gigabytes-monthly-per-household/.

[49] 4K video can use up to 7GB of data per hour.

[50] Information taken from "How much data do different activities use" https://www.whistleout.com.au/Broadband/Guides/Broadband-Usage-Guide.

Figure 2: Comparison of Data Consumption Rates and Caps for Internet Plans (in GB)[51]

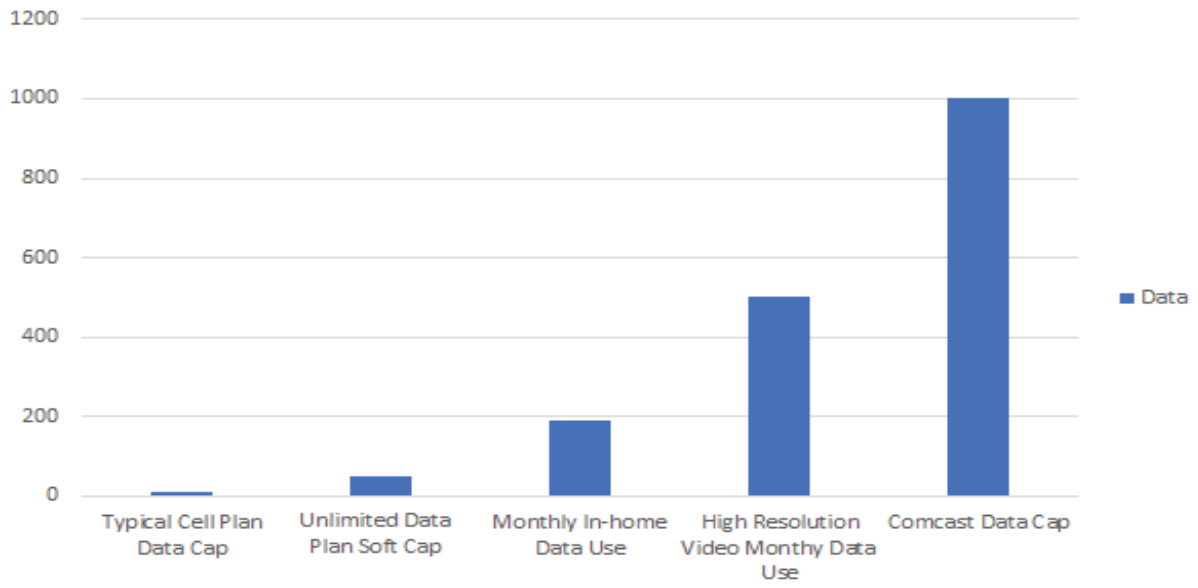


Figure 2 demonstrates the large differences between in-home data consumption and caps and cellular data caps. Existing information about wireless service suggests that without a significant change in network management and available customer plans, New T-Mobile's in-home broadband offering will not be a substitute for wireline services for the average home.

Furthermore, stand-alone T-Mobile will have the same amount of 5G low-band spectrum that provides adequate coverage and building penetration for in-home service. Stand-alone T-Mobile will also have a significant amount of midband and mmWave spectrum to provide capacity in dense environments using small cells and mMIMO deployments. While stand-alone T-Mobile may not be able to match the projected speeds of New T-Mobile, it can still provide speeds equal to, or surpassing, existing wireline networks by 2024, as discussed in Public Advocates Office testimony of Mr. Cameron Reed on Service Quality and Public Safety.[52] Sprint also announced plans to launch a new 5G mobile smart hub[53] that can support in-home

[51] Comcast's Data Cap is taken from https://www.xfinity.com/support/articles/exp-unlimited-limit.

[52] Public Advocates Office testimony of Mr. Cameron Reed on Service Quality and Public Safety at p. 20.

[53] Sprint and HTC announce innovative new 5G mobile smart hub coming in First Half of 2019: http://investors.sprint.com/news-and-events/press-releases/press-release-details/2018/Sprint-and-HTC-Announce-Innovative-5G-Mobile-Smart-Hub-Coming-in-First-Half-of-2019/default.aspx.

broadband independently of the merger.[54] The Commission does not need to approve the merger to improve in-home broadband options for Californians and the Commission should not consider a loosely defined idea of a potential future service as a benefit of the merger. The Commission should ensure that Sprint remains as a 5G competitor so that competition can help prices remain affordable to low-income Californians, and so they can also benefit from 5G services. The impacts of the merger on low-income customers are discussed more in the Public Advocates Office testimony of Mrs. Eileen Odell.

[54] https://www.fiercewireless.com/5g/sprint-may-tackle-market-for-home-broadband-internet.

III. CONCLUSION

5G services will bring a host of benefits to the wireless market, including increased speeds. However, the Commission should not attribute the benefits of 5G deployment as benefits of the merger, as both companies are fully capable of deploying 5G services independently and are already doing so in certain markets. The Applicants' plans for 5G deployment are also unduly aggressive, moving ahead of projected customer demand and adoption rates for 5G services. Sprint and T-Mobile independently will have adequate spectrum capacity to deploy 5G service and will be able to deploy it in a time frame that will meet with projected adoption figures.

5G benefits will also carry through to rural areas and in-home users without the merger, and the Commission should not consider New T-Mobile's conceptual in-home broadband offering as a merger benefit as there are still considerable issues about its viability, pricing, and availability. Further, Sprint plans to deploy in-home broadband independent of the merger. While it is true the merger will enable New T-Mobile to refarm more spectrum to 5G faster, these proposed benefits of the merger do not outweigh the harms of losing a 5G facilities based wireless provider. If the Commission fails to deny the merger, it should at the very least ensure that New T-Mobile carries through on its promise to provide in-home broadband services and deploy infrastructure in rural California through concrete commitments to serve underserved, unserved, and low-income communities.

ATTACHMENTS

ATTACHMENT A

Statement of Qualifications and Experience

My name is Cameron Reed. I am currently employed by the California Public Utilities Commission (Commission) as a Utilities Engineer assigned to the Public Advocates Office Communications and Water Policy Branch. I have a Bachelor of Science in Mechanical Engineering from the University of California-Davis. My studies included courses in engineering control systems, electrical circuits, experimental methodology, and mechanical systems design. I am a member of the Phi Theta Kappa honor society.

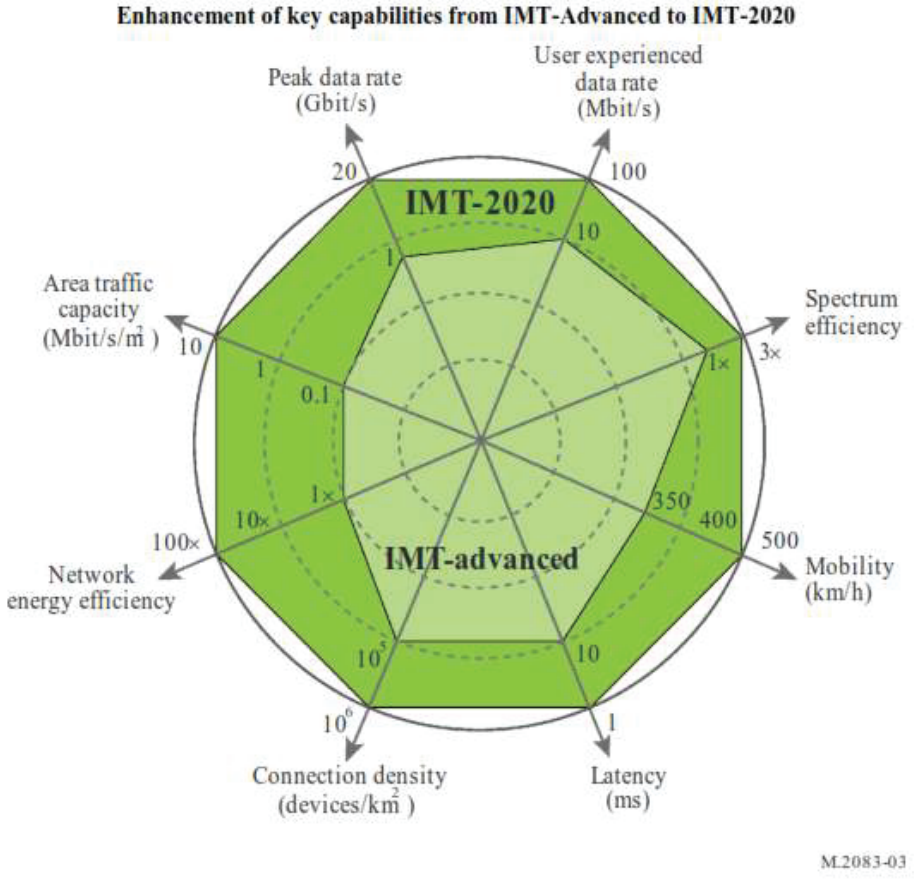
I began work with the Commission on July 5, 2016. I have worked on evaluating California Advanced Services Fund (CASF) Infrastructure and Public Broadband Housing applications. The CASF program funds broadband deployment projects in unserved or underserved areas of California and involves, among other items, evaluating utility financial information, deployment plans, and any existing broadband infrastructure in the area. I have previously submitted testimony concerning Telecommunications Public Safety in the general rate case (GRC) of Sierra Telephone Company (Application 16-10-003), Service Quality and Public Safety in the GRC of Ducor Telephone Company, (Application 17-10-003), Service Quality in the GRC of Foresthill Telephone Company (Application 17-10-004), and Public Safety and Cybersecurity in the Application of Pacific Gas and Electric for a Certificate of Public Convenience and Necessity to become a Competitive Local Exchange Carrier (Application 17-04-010). I reviewed the merger between CenturyLink and Level 3 Communications (Application 17-03-016). I have reviewed thousands of the Federal Communications Commission's Network Outage Reporting System outage reports. During my time at the Commission, I have completed the National Exchange Carrier Association's (NECA) Foundations of Telecommunications Curriculum and completed the 38th Western National Association of Regulatory Utility Commissioners (NARUC) Utility Rate School.

ATTACHMENT B

Fifth Generation Wireless Service Technical Appendix

The ITU-R's IMT-2020 framework set forth discrete specifications and use cases that a 5G wireless service needs to meet.[55] IMT-2020 defined eight parameters to consider as key capabilities of a 5G wireless solution. In setting forth the key capabilities of the IMT-2020 framework, the ITU-R envisioned that 5G wireless service should match fixed networks as closely as possible. Figure B1 below compares the target capabilities of 5G service to the capabilities of 4G LTE service.

Figure B1: ITU-R M.2083 Figure 3[56]



[55] International Technical Union – Radiocommunication Sector (ITU-R) Recommendation M.2083 at p. 10-14.

[56] *Id.* at p. 14.

Figure B1 indicates that the ITU-R expects that 5G wireless service will be faster and more efficient than 4G LTE services. The ITU-R's capability targets are explained more in the following sections.

i. Peak Data Rate

Peak data rate is the maximum achievable data rate under ideal conditions per user or connected device, measured in Gigabits per second (Gbps). IMT-2020 expects that a peak user data rate of 20 Gbps under certain conditions and scenarios, which is faster than the peak data rates that the Applicants are expecting of their networks. Customers will most likely experience 20 Gbps data rates in low traffic or cell site dense portions of the network.

ii. User Experienced Data Rate

The User Experienced Data Rate is the throughput speed that mobile users and connected devices can expect to experience throughout the areas covered by 5G services. IMT-2020 expects that average user will reliably have access to speeds of at least 100 Megabits per second (Mbps) for wide area coverage scenarios, such as urban and sub-urban areas.[57] IMT-2020 standards expect average data rates to reach as high as 1 Gbps in hotspot[58] environments such as inside buildings or in urban deployments with high small cell density.[59]

iii. Latency

Latency refers to the time it takes from when the source, such as a user or connected device, sends a packet to when the destination receives it, typically measured in milliseconds (ms). Regarding 5G wireless networks, Latency refers to the delay contributed by the radio access network. IMT-2020 expects that certain 5G use cases, such as MCC and some M2M communication, will have network Latencies as low as 1ms.

iv. Mobility

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[57] *Id.* at p. 14.

[58] Hotspots are wireless access points created by a hardware device that takes advantage of cellular network data connections. In the context of IMT-2020, a hotspot also refers to use cases in an area with high user density, high traffic capacity expectations, and low user mobility such as user connections within a building.

[59] ITU-R Recommendation M.2083 at p. 14.

Mobility refers to the maximum expected speeds, in kilometers per hour (kmph), where networks can seamlessly transfer connected devices between network radios at cell sites and maintain quality of service. For 5G applications, IMT-2020 expects signal transition to be seamless at speeds up to 500 kmph, or approximately 300 miles per hour (mph). IMT-2020 conceptualized 5G services to handle traffic seamlessly on high speed trains.

v. Connection Density

Connection Density refers to the number of connected devices per unit of area, defined devices per square kilometers (km). 5G wireless service is expected to support ten times more devices than 4G LTE wireless service, with the possibility of supporting 1 million devices per km^2. 5G's large connection density will enable large scale IoT and M2M communication services.

vi. Energy Efficiency

5G wireless services are expected to be more energy efficient for radio access networks and for user devices. Energy Efficiency is represented as the amount of information transmitted in bits per unit of energy consumed to transmit that information in Joules. IMT-2020 expects that 5G wireless service, radios, and devices will be approximately 100 times more energy efficient than services based off the 4G LTE standard. This means 5G services will result in more energy efficiency customer handsets and remote sensors.

vii. Spectrum Efficiency

Spectrum efficiency refers to the average data throughput per unit of spectrum and cell resource used to provide that data, represented in bit per second per Hertz (Bit/s/Hz). Spectral Efficiency can be represented by the formula below:

Spectral Efficiency = Average Throughput / (Number of Cell Sites x Spectrum Deployed)

5G services are expected to be three times more spectrally efficient than 4G LTE services. This means 5G provide more capacity per Hz of spectrum than 4G.

viii. Area Traffic Capacity

Area traffic capacity refers to the total traffic throughput available per geographic area, measured in Mbit per second (Mbps) per square meter. Area traffic capacity is expected to

increase by 100 times, to 10 Mbps per square meter, or 1 Gbps of capacity for a 100 square meter space in hotspot areas.

IMT-2020 does not expect 5G services to meet all key capabilities simultaneously but that 5G service should be configurable in order to meet the capabilities needed for emBB, IoT, M2M, and MCC applications.[60] The ITU-R outlines the capabilities it expects these use cases will specialize in, which figure B2 represents below:

Figure B2: ITU-R M.2083 Figure 4[61]

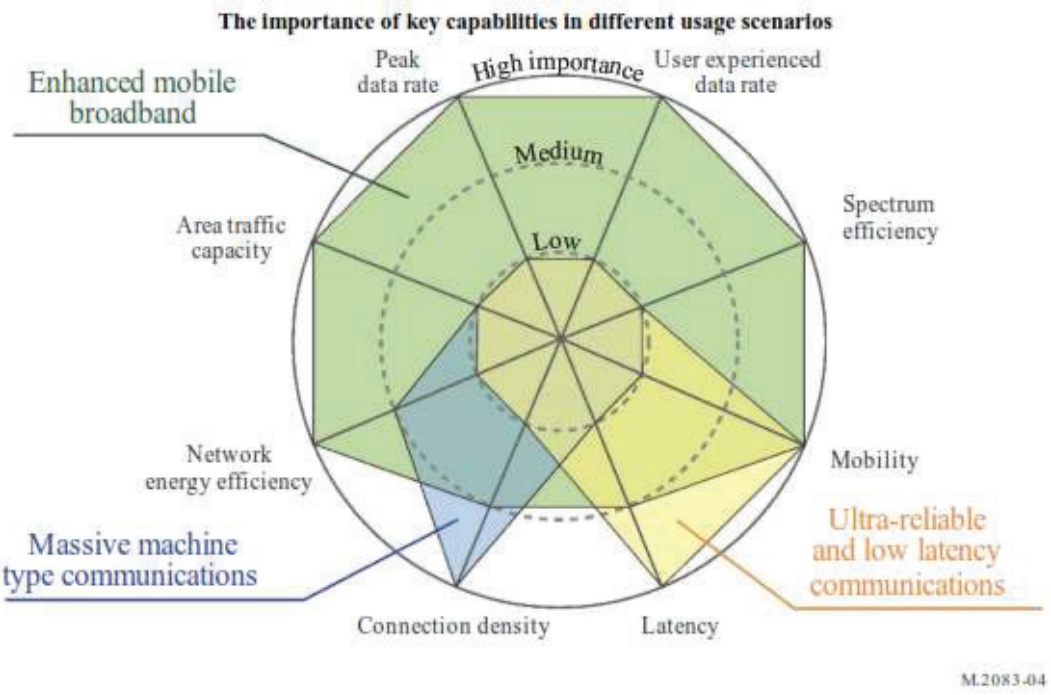


Figure B2 demonstrates that IMT-2020 expects emBB, or consumer 5G wireless service, to meet six of the key capabilities defined for 5G service. Specifically, IMT-2020 expects consumer 5G wireless service to have needs for high throughput, high mobility, and high capacity. Similarly, Massive machine type communications, such as those in M2M or IoT communications will specialize in large communication density and efficiency environments and MCC communications will focus on low latency and high mobility configurations.

[60] ITU-R Recommendation M.2083 at p. 15.

[61] *Id.* at p. 15.

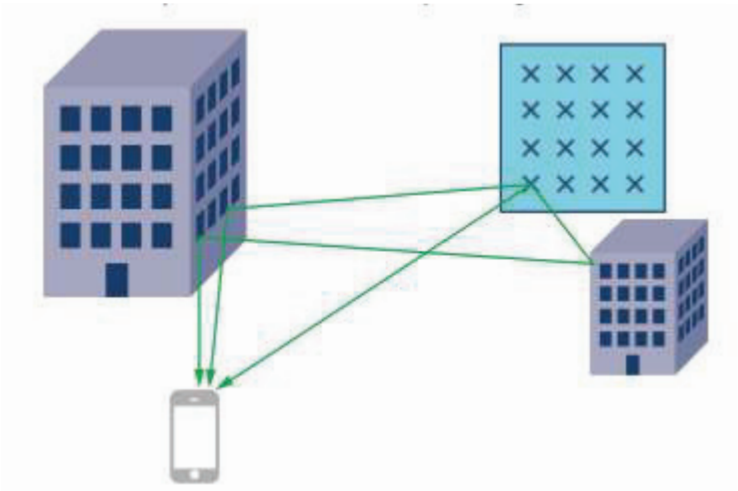
The performance advancements expected from 5G NR services are supported by a variety of new technologies or methods to improve existing technologies. These new infrastructure techniques are key elements of the increased capabilities that 5G services have compared to 4G and 4G LTE wireless services. There are many individual advancements in physical and frequency transmission methods that combine to create the basis for 5G NR services, the most prominent technologies including massive Multi-Input Multi-Output (mMIMO), beamforming, small cell deployments, virtualization, and millimeter wave spectrum (mmWave). Most of these new technologies depend on cell site improvements and high frequency spectrum, not existing spectrum portfolios.

One network technology that 5G will be built on is mMIMO. Massive MIMO is an evolution of 4G's MIMO, in which cell sites have multiple antenna elements that are used to send and receive signals. 4G LTE MIMO used 4 transmission and receiving (4x4) antenna elements. 5G mMIMO will use at least 16 transmission and receiving (16x16) antennas, with the possibility of using hundreds of antennas,[62] to increase capacity, throughput speeds, and spectral efficiency. Nokia, a manufacturer of massive MIMO systems, predicts that mMIMO antennas have the capability to provide services with 5 times more capacity and five times more throughput than 4G services.[63] Accompanying mMIMO infrastructure is a transmission technique called beamforming. Beamforming is a radio signal broadcasting technique that will enable mMIMO and millimeter wave spectrum systems to function. Beamforming refers to the ability of a cell site to use multiple antennas to direct a single band of signal at a cellular end user. This will reduce the interference users experience from other signals and even allow 5G cell sites to reflect signals off structures to reach a nearby user which increases the coverage and signal strength a cell site is able to provide.

[62] Some manufacturers are making Antennas with 64 transmitting and receiving elements. *See* https://5g.co.uk/guides/what-is-massive-mimo-technology/.

[63] *See* https://networks.nokia.com/solutions/massive-mimo.

Figure B3: Beamforming and mMIMO[64]



Small cells are small cellular antennas site that can be deployed on utility poles or street lights and are used in deployment strategies that compliment mMIMO by increasing the density of cell sites in a geographical area. Small cells typically have a broadcast range of 100 meters or less, depending on the size of the cell. Because small cells are smaller, lighter, and require less power, it is easier for cellular providers to deploy small cells to bolster coverage, capacity, and throughput. Small cells are typically deployed in dense urban environments close to the cellphone users.[65] Small cells and mMIMO will be used in conjunction with mmWave spectrum to greatly increase the capacity and data throughput speeds of 5G wireless networks. MmWaves operate in the electromagnetic spectrum band between 30 to 300 GHz and wavelengths between 1 to 10 millimeters.[66] Because mmWave have shorter wavelengths than traditional cell phone signal bands, mmWave spectrum can transport more data to enable greater capacity and speeds at the expense of reduced coverage and building penetration. This reduction in coverage necessitates network denser deployments that are closer to the customer.

Similar to how small cells will allow carriers to deploy cell sites closer to end users, network virtualization will allow cellular providers to move cellular network nodes closer to end users. Network virtualization allows providers to move from a predominately hardware driven

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[64] Exhibit CR-7: Massive MIMO and Beamforming.

[65] *See* https://www.verizon.com/about/our-company/5g/what-small-cell-technology.

[66] https://transition.fcc.gov/Bureaus/Engineering_Technology/Documents/bulletins/oet70/oet70a.pdf at p. 1.

network management architecture to a software managed network configuration.[67] Virtualization reduces the amount of time it takes for the network to process user requests for information by bringing more core switching and authentication functions closer to end users. Virtualization will also be used to create cloud-based radio access networks (C-RANs) which use software to centralize call processing for cell sites which increases coordination and performance between cells.

[67] *See* https://business.sprint.com/5g/core-network-virtualization/.