CWA Submission to Federal Communications Commission, T-Mobile/Sprint Merger Review, WT Docket No. 18-197, Aug. 27, 2018

APPENDIX D:
DECLARATION OF ANDREW AFFLERBACH, PH.D., P.E.
Chief Executive Officer and Chief Technology Officer,
CTC Technology & Energy

BEFORE THE
FEDERAL COMMUNICATIONS COMMISSION
WASHINGTON, D.C.

WT Docket 18-197	)
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DECLARATION OF ANDREW AFFLERBACH, PH.D., P.E.

1. I have been the Chief Executive Officer and Chief Technology Officer of Columbia Telecommunications Corporation (d/b/a CTC Technology & Energy), a communications engineering consultancy, since 2000, and was Senior Scientist at CTC from 1996 until 2000. I specialize in the planning, design, and implementation of communications infrastructure and networks. My expertise includes fiber and wireless technologies and state-of-the-art networking applications. I have closely observed the development of wireless technology since the advent of the commercial internet in the 1990s.
2. As CTO, I am responsible for all engineering work and technical analysis performed by CTC. I have planned and overseen the implementation of a wide variety of wired and wireless government and public safety networks. I have advised cities, counties, and states about emerging technologies, including successive generations of wireless networks across a range of licensed and unlicensed spectrum bands. I have developed broadband technology strategy for cities including San Francisco, Seattle, Atlanta, Washington, D.C., and New York; for states including Connecticut, Delaware, Kansas,

Kentucky, and New Mexico; and for the government of New Zealand's national broadband project.

3. I have designed wireless networks for large cities, counties, and regions. I lead the CTC team advising the State of Texas Department of Transportation and many local governments on wireless facilities standards and processes. I also lead the CTC technical teams conducting FirstNet planning for the District of Columbia and the State of Delaware.
4. I have prepared extensive technical analyses for submission to the U.S. Federal Communications Commission and U.S. policymakers on broadband expansion to underserved schools, libraries, and other anchor facilities; on due diligence for the IP transition of the U.S. telecommunications infrastructure; and on the relative strengths and weaknesses of various wired and wireless technologies.
5. Under my direction, the technical team at CTC has advised hundreds of public and non-profit clients, primarily in the United States. My technical staff has been engaged on projects encompassing the evaluation or planning of hundreds of miles of fiber optics and hundreds of wireless nodes in rural, suburban, and urban areas across the country. My experience with rural broadband engineering encompasses the full range of geographic typologies in the United States, from the desert and mountains of the West to the plains in the Midwest to the mountain and coastal areas of the East.
6. I am a licensed Professional Engineer in the Commonwealth of Virginia and the states of Delaware, Maryland, and Illinois. I received a Ph.D. in Astronomy in 1996 from the

University of Wisconsin–Madison and an undergraduate degree in Physics from Swarthmore College in 1991. My full CV is included in Attachment A.

New T-Mobile would only marginally improve rural broadband relative to stand-alone T-Mobile and Sprint

7. Based on my review of the redacted public version of T-Mobile and Sprint's Public Interest Statement (hereinafter, "Statement"), one of the justifications T-Mobile and Sprint ("Applicants") emphasize for their merger is the enhanced broadband service that "New T-Mobile" would be able to provide to underserved rural areas. However, based on my review of the information presented in the Applicants' Statement, the merged New T-Mobile would only provide marginally better broadband options than stand-alone T-Mobile in much of rural America.

8. The deployment plan does not appear to harm or reduce the capacity or coverage for rural Americans and may provide benefits for some. However, for the great majority of rural Americans, the level of coverage and capacity would be similar for the merged New T-Mobile network and the stand-alone T-Mobile network.

9. By the Applicants' own admission in Table 9 of the Statement, as discussed in more detail in Paragraph 12 below, most of New T-Mobile's rural customers would be forced to settle for a service that has significantly lower performance than the urban and suburban parts of the network. This is because (a) Sprint's network is mostly concentrated in urban and suburban areas and therefore the New T-Mobile network would gain relatively few new sites in rural areas from Sprint to add to stand-alone T-Mobile's network; (b) Sprint's "mid-band spectrum" (i.e., 2.5 GHz and PCS) that would

become available for use at T-Mobile sites will not be activated in many rural areas in the next six years; and (c) for technical reasons described in more detail below, that mid-band spectrum is only marginally useful in rural areas. Therefore, the merger does not by itself provide a meaningful solution to the lack of adequate broadband options in most rural parts of the country.

New T-Mobile's mid-band spectrum coverage would be insufficient to support rural broadband

10. In his public statement, T-Mobile CTO Neville Ray touts many potential benefits of 5G (described in more detail below), but the full degree of these benefits will largely be limited to customers in urban and suburban areas with adequate mid-band and millimeter-wave (mmWave) spectrum coverage. The wide mid-band and mmWave spectrum bands have more capacity than low-band and therefore are the key underlying factor in potentially providing speeds of hundreds of Mbps (mid-band) or Gbps (mid-band plus mmWave). However, they also have more limited propagation characteristics than the lower bands and, as indicated by Table 9 in the Statement and discussed in more detail in Paragraph 12 below, will not be activated in most of New T-Mobile's rural markets in the coming years. Without the added capacity of the mid-band spectrum, New T-Mobile would be unable to support bandwidth-intensive applications on its networks in most rural parts of the country. In areas with both low- and mid-band coverage, New T-Mobile's network (assuming adequate engineering, construction, and operations) would potentially support bandwidth-intensive applications such as telehealth services, autonomous vehicles, high-definition video streams, virtual reality, and online gaming—

but rural subscribers would have limited or no access to these services without mid-band coverage.

11. Mr. Ray explains that low-band spectrum (below 1 GHz) can support cell site operating radii of up to 18 miles, while mid-band spectrum (from 1 GHz to 6 GHz) can support cell site operating radii of up to approximately 4 miles around cell sites.[1] T-Mobile has aggressively extended its coverage in rural areas using its 600 MHz and 700 MHz spectrum in the past few years. Sprint also has licenses for 14 MHz of 800 MHz spectrum in most of the United States, but Sprint's narrow holdings in the 800 MHz spectrum band will only contribute a small amount of additional spectrum, relative to the hundreds of MHz in the mid-band spectrum (see table below). Moreover, Sprint service is limited in rural areas away from major roadways, where it relies mostly on service from its roaming partners;[2] adding its relatively few rural towers will not add much to the coverage already provided by T-Mobile in the rural areas. Therefore, even if New T-Mobile were to add Sprint's mid-band spectrum assets to all its rural towers, only a fraction of the total covered area would be within range of the mid-band signal and able to provide hundreds of Mbps to customers of the merged network. The T-Mobile and Sprint spectrum holdings are summarized in the following table.[3]

[1] Declaration of Neville R. Ray, Executive Vice President and Chief Technology Officer, T-Mobile, US, Inc., Appendix B, at ¶36.

[2] Sprint roaming coverage, https://coverage.sprint.com/roamingmap.jsp (accessed August 23, 2018).

[3] *See T-Mobile US, Inc. and Sprint Corporation Seek FCC Consent to the Transfer of Control of Licenses, Authorizations, and Spectrum Leases held by Sprint Corporation and Its Subsidiaries to T-Mobile US, Inc.*, WT Docket No. 18-197, Description of Transaction, Public Interest Statement, and Related Demonstrations, at Appendix L, Spectrum Holdings and Aggregation Data (filed June 18, 2018).

T-Mobile and Sprint Spectrum Holdings

Carrier	Band	Amount	Rural Propagation
T-Mobile	600 MHz	20–50 MHz	Good
T-Mobile	700 MHz	0–36 MHz	Good
T-Mobile	AWS-1	10-50 MHz	Limited
T-Mobile	AWS-3	0–30 MHz	Limited
T-Mobile	PCS	0–50 MHz	Limited
T-Mobile	28 GHz	0–850 MHz	Very limited
T-Mobile	39 GHz	0–200 MHz	Very limited
Sprint	800 MHz	4.9–14 MHz	Good
Sprint	PCS	20–60 MHz	Limited
Sprint	2.5 GHz	0–156.5 MHz	Limited

12. In fact, the Statement acknowledges that much of rural America would be left without mid-band coverage after the proposed merger. Even under the best-case scenario presented in the Statement, T-Mobile projects that if the merger were approved, 84.6 million Americans (26 percent of the 325.5 million total population assumed by the Statement)[4] would still lack New T-Mobile mid-band coverage in 2021, and by 2024, 45.9 million Americans (14 percent of the 328.1 million total population assumed by the Statement) would continue to lack access to these high-capacity mid-bands.[5] These numbers are calculated based on the data provided by T-Mobile in Table 9 of its Statement (reproduced below), subtracting the projected New T-Mobile mid-band covered population for those years from the total population (as calculated based on the table's estimate of the corresponding percentage of uncovered Americans).

[4] The U.S. population was derived from the Statement's numbers by taking the Covered Pops in Table 9 and dividing by the percent served for 2021 and 2024. For example, dividing the Covered Pops in 2021 mid-band (240.9 million) by one minus the 26 percent unserved number provides a total population for 2021 of 325.5 million. Dividing the Covered Pops in 2024 mid-band (282.2 million) by one minus the 14 percent unserved number provides a total population for 2024 of 328.1 million.

[5] Description of Transaction, Public Interest Statement, and Related Demonstrations at p. 47.

Table 9 from T-Mobile's Statement

		T-Mobile	Sprint	New T-Mobile
	Network Coverage Footprint	Covered Pops (Millions)	Covered Pops (Millions)	Covered Pops (Millions)
Year 2021	Mid-band (PCS & 2.5GHz)	74.6 (77% uncovered)	174.7 (47% uncovered)	240.9 (20% uncovered)
	Low-band (600)	317.9 (2.9% uncovered)	0 (100% uncovered)	319.6 (2.4% uncovered)
Year 2024	Mid-band (PCS & 2.5GHz)	173.2 (47% uncovered)	194.0 (41% uncovered)	282.2 (14% uncovered)
	Low-band (600)	323.0 (1.4% uncovered)	0 (100% uncovered)	324.1 (1.0% uncovered)

13. Additionally, Figure 10 of the Statement shows New T-Mobile's predicted low-band and mid-band coverage. The dark red areas depicting the mid-band coverage indicates that the Americans unserved by the mid-band are outside metropolitan areas. Because Figure 10 is a low-resolution map of the entire U.S., it does not precisely resolve the mid-band service areas, which are a few miles across; a higher-resolution map would likely indicate many additional uncovered areas within the dark area. Therefore, assuming that the country's rural population is the least served by mid-band, and using the numbers above, New T-Mobile will likely provide mid-band coverage to few or no rural Americans by 2021, and, under best-case projections, only 26 percent of rural Americans by 2024.

T-Mobile and Sprint's claims of enhanced rural broadband for New T-Mobile are not supported by their stated reliance on the same low-band coverage as the unmerged company

14. The Statement refers to enhanced coverage in rural areas driven by increased cell site density but does not quantify the increased number of cell sites for New T-Mobile in

rural areas compared to stand-alone T-Mobile and stand-alone Sprint. Further quantitative information about the number and locations of additional towers, ideally in high-resolution maps or shapefiles, is necessary to evaluate the magnitude of New T-Mobile's proposed rural buildout.

15. Judging by the relatively small change in the low-band-covered population with and without the merger (Table 9 in the Statement), New T-Mobile may not be contemplating a large buildout in rural areas of the country. Table 9 provides T-Mobile's estimate of the covered population for the merged companies and for T-Mobile and Sprint separately, in 2021 and 2024, for mid-band and low-band.

16. According to Table 9, the low-band coverage (reflecting the total urban, suburban, and rural coverage) will be relatively constant regardless of whether the merger happens. Without the merger, Table 9 indicates that T-Mobile's low-band network will cover 317.9 million users by 2021 and 323 million by 2024, compared with New T-Mobile's 319.6 million users covered by 2021 and 324.1 million by 2024.[6] Thus, the New T-Mobile's low-band network would only serve an additional 1.7 million users by 2021 and an additional 1.1 million users by 2024 compared to stand-alone T-Mobile. Since most of the new spectrum that Sprint would bring to New T-Mobile is in the mid-band, the 45.9 million (2024) to 84.6 million (2021) customers discussed above that can only access New T-Mobile's low-band network would not receive large amounts of new spectrum and would receive speeds similar to what they would receive from stand-alone T-Mobile.

[6] Description of Transaction, Public Interest Statement, and Related Demonstrations at p. 47.

17. Since the actual speeds that users of mobile 4G and 5G networks experience are largely dependent on the signal strength they receive, it is also important to note that the user experience will deteriorate for users who are farther from the antenna site, who are indoors, or who are obstructed by terrain or foliage. It is not clear from the Statement whether and how this variation has been taken into account in the capacity and coverage estimates. As mentioned in Paragraph 13 above, the Statement's Figure 10 is a high-level approximation and implies a consistent level of mid-band coverage over large areas. For these reasons, higher-resolution maps and model assumptions are required to enable a full understanding of the potential capacity and coverage in rural areas.

18. Even according to the projections offered in the Statement, of the 59.4 million rural Americans that New T-Mobile expects to serve with outdoor mobile coverage by 2024, 13.5 million will still receive speeds below 10 Mbps.[7] To put these speeds in perspective, the Statement claims that New T-Mobile will provide average data rates above 500 Mbps to 208.7 million Americans, mostly in urban and suburban areas, by 2024.[8]

T-Mobile states that the merger will improve the path to 5G, but 5G is still in conceptual phases

19. Given the strong emphasis that the Statement places on accelerating the transition to 5G technology as a justification for the merger, it is important to note the considerable uncertainty around emerging 5G standards, equipment, pricing, capabilities, and deployment patterns. As a starting point, the Statement is centered around projections for

[7] Declaration of Neville R. Ray, Executive Vice President and Chief Technology Officer, T-Mobile, US, Inc., Appendix B, at ¶ 36.

[8] Declaration of Neville R. Ray, Executive Vice President and Chief Technology Officer, T-Mobile, US, Inc., Appendix B, at ¶ 20.

2021 and 2024. Three to six years is a significant amount of time in technological evolution. For example, six years ago, mobile broadband was in the early days of 4G LTE and much of the current mobile application environment and industry development could not have been easily foreseen.

20. The standards for both mobile and fixed 5G are still in development, which means that equipment is not yet being built to standards and is thus neither interoperable nor at scale. This is true not only for networking equipment but also for 5G-capable devices such as smartphones, laptops, tablets, and other consumer electronics. None of these equipment categories is yet being mass-manufactured, let alone adopted by consumers; the timeline, deployment, and uptake patterns are still uncertain.

21. 5G mobile standards are being developed by participants in the 3GPP standards development process.[9] 3GPP approaches standardization in stages, and in December 2017 announced completion of phases 1 and 2 of the mobile 5G standard.[10] These stages include a system architecture, the services to be provided in 5G, and coexistence with and evolution from 4G. Work in progress includes specifications for the radio access network (RAN), including the switching and service node descriptions to implement the 5G

[9] The cellular communications standards process is overseen by the International Telecommunication Union (ITU) and by 3GPP, the organization of global standards bodies that were responsible for developing earlier GSM and LTE standards.

[10] Frank Mademann, "System architecture milestone of 5G Phase 1 is achieved," 3GPP, News Release, Dec. 21, 2017, http://www.3gpp.org/news-events/3gpp-news/1930-sys_architecture (accessed August 22, 2018).

services.[11] In other words, the standards are in a conceptual stage, with significant detailed work yet to be completed.

22. Given that 5G equipment has not yet been built or tested in its final form, and is still years away from mass production, the exact performance characteristics of operational 5G equipment are not known. Therefore, the increases in capacity and the deployment schedules presented by T-Mobile based on 5G equipment are necessarily estimates. The cost and complexity of upgrading a network to 5G, both of which are critical inputs into a buildout schedule, also are not yet well known. In my experience, there still exist many questions within the network engineering community about the form in which mobile 5G deployment will emerge, and whether it will emerge within five years, 10 years, or at all.

23. Indeed, the Statement notes that Verizon and AT&T are pursuing a different approach than New T-Mobile with respect to 5G, with an initial focus on urban mmWave and fixed deployments rather than mobile. The different approach by the two industry leaders, described as "tepid" by Dr. David Evans in the Statement, may also indicate a broader industry-wide reluctance toward 5G and a more cautious walk to the technology (including by investors). Indeed, there is precedent for widely heralded wireless technologies never reaching maturity; WiMAX, for example, was anticipated as a wireless response to fixed broadband nationwide but only played a niche role.

[11] "Method for the Characterization of Telecommunications Services Supported by an ISDN and Network Capabilities of an ISDN," ITU-T I.130, International Telecommunications Union, https://www.itu.int/rec/T-REC-I.130/en (accessed August 22, 2018).

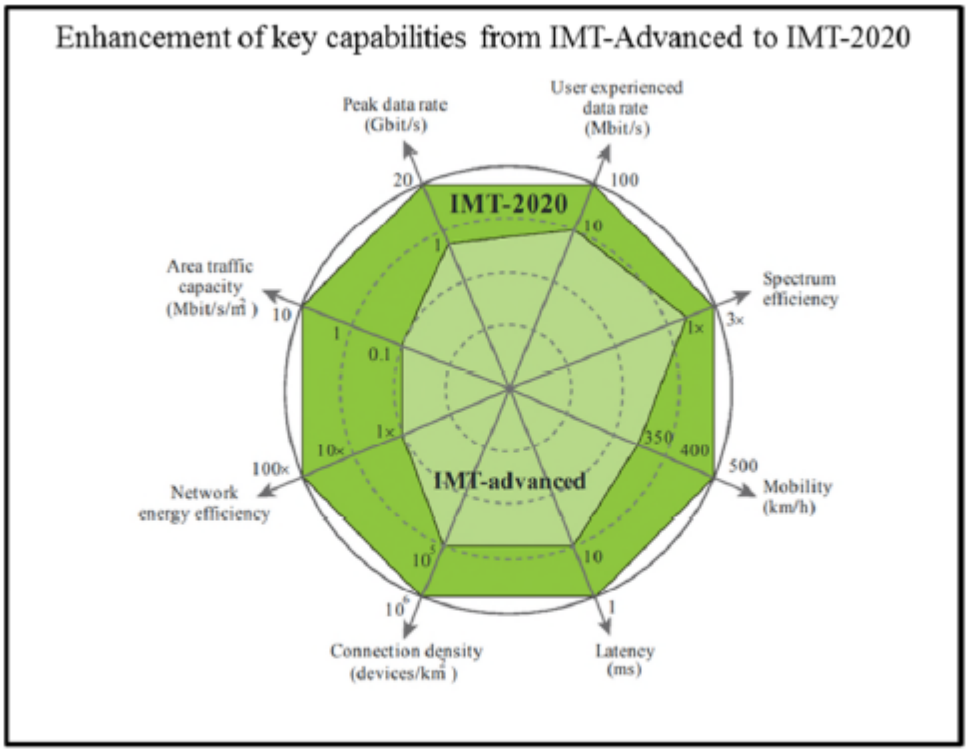
T-Mobile's claims for 5G depend on spectrum that will not be useful in rural areas

24. Despite T-Mobile's advocacy for a 5G that goes beyond mmWave spectrum, the Statement's sweeping technical claims about the capabilities of 5G only apply when the technology is used with mmWave spectrum—spectrum that has not been widely used, is limited to short distances (and therefore not useful in rural areas), and would only be available to New T-Mobile in relatively small quantities in most of the United States.

25. For example, Mr. Ray, in his statement, implies by inclusion of Figure 2 (reproduced below), a diagram created by the International Telecommunications Union, depicting eight key performance parameters for 5G as part of the standards development process, that New T-Mobile "expect[s] from 5G": 20 Gbps per site, 1 ms latency, and triple the spectrum efficiency of LTE. However, as noted in the source document,[12] attaining this level of performance requires (a) use of mmWave bands at short range distance with good line of sight and (b) a large amount of spectrum within the mmWave band.

[12] Mr. Ray's Figure 2 is excerpted from p. 14 of ITU's "Recommendation ITU-R M.2083-0 (09/2015), IMT Vision – Framework and overall objectives of the future development of IMT for 2020 and beyond, M Series, Mobile, radiodetermination, amateur and related satellite services," http://www.itu.int/rec/R-REC-M.2083-0-201509-I (accessed August 22, 2018). This "Recommendation" indicates that the sought-after performance in this Figure requires spectrum above the low-band and mid-band: "In particular, bandwidths to support the different usage scenarios in § 4 (e.g. enhanced mobile broadband, ultra-reliable and low-latency communications, and massive machine type communications) would vary. For those scenarios requiring several hundred MHz up to at least 1 GHz, there would be a need to consider wideband contiguous spectrum above 6 GHz" (p. 9). Additionally, the "Recommendation" indicates a need for "network densification" [i.e., placement of antennas close to the user] to attain the specified level of performance (p. 8). Neither mmWave spectrum nor densification is feasible in most rural areas, therefore Mr. Ray's Figure 2 is not relevant in most rural areas, nor is it relevant in any other area where a dense mmWave network is not available.

Figure 2 from T-Mobile's Statement



Source: ITU Recommendation ITU-R M.2083-0

Figure 2: 5G Network Improvements

26. In fact, New T-Mobile will have a relatively small amount of mmWave spectrum. As of early this year, T-Mobile had 200 MHz in most markets in which it has publicly shared plans for 5G buildout (except in most of Ohio, where it owns 1150 MHz). Though the majority of these bands have not yet been auctioned, Verizon already owns 23 percent, AT&T owns 7 percent, and T-Mobile owns just 2 percent. Because of the limitations of mmWave technology (discussed in more detail below), its usefulness is limited to dense urban and suburban areas.

27. The mmWave bands—for example, the 28 GHz band where a portion is held by T-Mobile—provide broad spectrum channels. Furthermore, because mmWave

communications are physically more like light beams than a shared wave, mmWave networks can theoretically set up individual paths to each device, reusing the same spectrum for many users simultaneously. This is what makes it possible for an antenna site to have enormous aggregate capacity, and for individual users to have very-high-speed connections.

28. However, mmWave requires proximity and/or line of sight to function well. If there are obstructions in the line of sight, the mmWave signal scatters and bounces. If the user and the device are close together, they may still be able to connect using scattered signals. Using the 28 GHz band, for example, if the device is more than one-third to one-half of a mile away, without a line of sight, the performance of mmWave will begin to deteriorate,[13] and high-speed connections must be made with the mid-band and low-band spectrum (i.e., 3.5 GHz and below).

29. With New T-Mobile's 2.5 GHz spectrum, as provided in Table 2 of the Statement, the increase in spectrum efficiency that will potentially be created through use of future 5G radios, taking into account advances in MIMO and new radio technology, will be only 52 percent relative to LTE. For 600 MHz—the band that will carry most of the New T-Mobile's rural broadband—there will be an increase of only 19 percent.

[13] "The Power of Millimeter Wave," Video, Verizon, May 23, 2018, https://www.youtube.com/watch?v=jnyG2bliKCs (accessed August 22, 2018), illustrating an upper limit of one-third to one-half mile for gigabit performance based on field trials.

30. As a result, my engineering judgment is that Mr. Ray's sweeping, optimistic claims of increased benefit from 5G (p. 6-7) are based on limited, best-case scenarios for very limited parts of the T-Mobile footprint (if any) and are not relevant to rural communities.

31. Because the filing makes broad-brush overstatements of network performance when many rural areas clearly will not receive this performance, it is also necessary to closely examine and question the availability of new applications and services in rural areas. It is not clear from the Statement whether the rural users who (a) will obtain service only on low-band and (b) live in a wide range of signal quality conditions will have access to the 4K video and online gaming applications Mr. Ray describes on p. 7, not to mention access to "unlimited" data packages without throttling of bandwidth.

32. Similarly, it is doubtful that the "virtual and augmented reality, connected vehicles and highways, real-time translation, and drone control/monitoring services" Mr. Ray describes on p. 8 will be available in rural areas if T-Mobile is not able to deliver very-low-latency services in those areas.

33. In terms of latency, the design specification for 5G calls for less than 10 ms in general, and less than 1 ms for ultra-reliable, critical machine-to-machine communications.[14] However, latency of this level may not be attainable in the version of 5G that is deployable in rural areas without mmWave. The reduction in latency in 5G is enabled in part by rapid assignment of resource blocks (i.e., the combinations of spectrum and time blocks that constitute the LTE signal) to intersperse highly time-critical blocks within

[14] Andreas Maeder et. al, "A Scalable and Flexible Radio Access Network Architecture for Fifth Generation Mobile Networks," IEEE Communications Magazine, Volume: 54, Issue: 11, November 15, 2016, p. 17, http://ieeexplore.ieee.org/document/7744804/?reload=true (accessed August 22, 2018).

other communications streams. Other key technical requirements for reducing latency are optimization of backhaul and caching of content close to the access point.[15] Therefore, a rural deployment, with long backhaul distances, limited or no use of mmWave spectrum, and less likelihood of data being cached close to the user, will likely have significantly higher latency than an urban or suburban 5G network, with the actual latency potentially similar to that of current 4G networks.

34. So far, the design latency has not been attained consistently in 5G tests. For example, AT&T has only reported latencies around 10 ms in its testing.[16]

Conclusion

35. Although I do not see a situation where New T-Mobile will result in worse technical performance than T-Mobile without the merger, most rural broadband users will experience similar availability of capacity and coverage from New T-Mobile as they would from old T-Mobile, regardless of whether the merger happens. Even under the best-case scenarios presented by the Statement, New T-Mobile's rural offerings will still

[15] I. Parvez, A. Rahmati, I. Guvenc, A.I. Sarwat, H. Dai, "A Survey on Low Latency Towards 5G: RAN, Core Network and Caching Solutions," accepted in *IEEE Communications Surveys and Tutorials*, arXiv:1708.02562v2 [cs.NI], May 29, 2018, https://arxiv.org/pdf/1708.02562.pdf (accessed August 22, 2018).

[16] Dave Burstein, "AT&T Shocker: 5G mmWave Latency 9-12 Milliseconds, Not 1-5 Ms.," *Wireless One*, April 10, 2018, http://wirelessone.news/10-r/1020-at-t-shocker-5g-mmwave-latency-9-12-milliseconds-not-1-5-ms (accessed August 22, 2018).

fall dramatically short of those in urban and suburban markets and will not be dramatically improved relative to stand-alone T-Mobile and Sprint.

DATED: Kensington, Maryland
August 23, 2018

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