T-Mobile Site DN01675A RF Justification
CO-0077

T-Mobile Wireless submits this RF analysis in association with its proposed wireless communications facility to be located at 16650 Alameda Pkwy.

1. QUALIFICATIONS

This report was prepared by T-Mobile Wireless' in-house RF Engineering Department, which consists of experienced and properly credentialed radio frequency engineers. The RF Engineering Department designs T-Mobile Wireless' nationwide network to provide adequate and effective wireless communications services in compliance with all FCC requirements, including T-Mobile Wireless' licensure requirements. The RF Design Engineers use proprietary software and tools in addition to industry-standard RF propagation modeling and network performance simulation programs to identify network coverage, performance and capacity deficiencies, and develop and implement solutions based on these analyses with the goal of maximize network performance and efficiency.

2. WIRELESS TELECOMMUNICATIONS SYSTEMS

The FCC licenses a specific amount of RF spectrum to each wireless carrier and stipulates that each carrier efficiently use that spectrum to provide adequate wireless communication services to emergency services, businesses and individuals in the licensed areas. Wireless carriers achieve this mandate by continuously reusing the allocated radio frequencies throughout their licensed service area. This is accomplished by building small radio base stations, or cell sites, in a particular pattern (also known as a grid). The application of the grid concept affords a wireless carrier the ability to effectively and efficiently plan the reuse of radio frequencies. Indeed, it is the only way a cellular system can adequately function. Following proper planning techniques (as originally defined by Bell Labs and further refined by the wireless industry), the same radio frequency is reused at reasonably close intervals throughout the licensed area, without causing harmful interference (noisy or dropped calls or the inability to originate a call are typical manifestations of harmful interference), but only if placed properly. There is extremely limited flexibility as to where a cell site can be located, and limited flexibility as to the proper height.

When designing a wireless network, an RF Design Engineer starts with a theoretical grid pattern and applies it to the licensed area. Each licensed area has many variables that can affect the design and must be considered. These variables include terrain features, use of existing structures, traffic distribution, and many others. In order to provide effective coverage while maintaining an appropriate frequency reuse plan, the RF Design Engineer must perform a balancing test of all applicable technological variables. The primary variables that the engineer must balance/take into consideration are location, and the overall height of the cell sites. Too close and there is interference. Too far and calls are dropped. If a cell site is too high, it will have increased coverage but will cause interference throughout the rest of the wireless network, thereby significantly affecting network efficiency. If a cell site is too low, it will not provide effective coverage.

Therefore, a properly designed wireless network design begins with strategically located cell sites. At each cell site there is a building, tower, water tank or other structure on which antennas are mounted.

Typically, radio-transmitting equipment (base station) is located at the base of the structure. Radio signals leave the base station and travel through transmission lines to the antennas or to fiber optic cable to the remote radio head (RRH) at the top of structure and then to the antennas. Radio signals are broadcast through the antennas and travel to the customer's wireless device, thereby completing a call. When a wireless customer transmits back to the cell site, the signal is received by the antennas, travels down the transmission line and into the base station. The base station converts the signal into digital data and combines it with all the other wireless calls and digital traffic at that cell site. This data is then sent over fiber optic digital leased lines to the main switching computer. The main switching computer or Mobile Switching Center (MSC) is interconnected to the national Public Switched Telephone Network (PSTN) and Internet service providers where calls are routed to other wireless or land-line phones, or Internet locations.

As this technology enables mobile calling, once a wireless call is originated and the customer travels away from the cell site of origination, the system tracks the changes and begins a process of determining if there is a better serving cell site (a "dominant server"). Upon determination of a stronger serving site, the system automatically switches the wireless customer over to the new cell site. This process is known as a handover and allows for seamless coverage within a wireless carrier's service area. By design, this process is supposed to happen so quickly, the wireless customer does not perceive it. If the network is designed properly, there is no interruption of service and connection quality remains adequate. Proper, effective RF design requires the location (and height) of cell sites in fairly rigid parameters.

3. PERFORMANCE METRICS

(a) Coverage

The critical issue for T-Mobile Wireless is the provision of "adequate and substantial" Radio Frequency (RF) service to serve its wireless customers. The wireless industry is governed by the Rules of the FCC. The FCC mandates in CFR 47, Parts §22.940 and §24.16 that each carrier must provide "substantial service" in its licensed service area, or risk having their license revoked. The FCC defines "substantial service" as service which is sound, favorable, and substantially above a level of mediocre service.

A metric called Reference Signal Received Power ("RSRP") is used to specify the coverage capabilities of wireless networks. This standard best represents the Long-Term Evolution ("LTE") data technology (also known as 4G) being utilized as well as the Voice-Over LTE ("VoLTE") technology, which is being deployed on 4G to augment and ultimately replace T-Mobile Wireless' wireless voice capacity. RSRP is the average received power measured across an LTE broadband channel.

RSRP is measured in units of "decibels" referenced against 1 milliwatt, or dBm. The decibel is a logarithmic unit that allows ratios to be added or subtracted. The definition formula for decibels referenced against 1 milliwatt is $dBm = 10\log(P / 1mW)$ with P measured in milliwatts. So 10 mW would be 10dBm, 100 mW would be 20dBm, etc.

The service boundary of a 4G site is defined using a RSRP equating to an acceptable receiver signal threshold. This value is derived from industry standards, 4G receive signal levels and quality and acceptable signal to noise ratios, along with statistically quantifiable variations in terrain. This threshold must also take into account additional losses associated with location of the mobile user.

T-Mobile Wireless must provide adequate service to all of its users. In order to account for users within buildings, additional margin must be added to RSRP so that adequate coverage exists inside. Industry and T-Mobile Wireless engineering standards include an additional 10dB of margin to RSRP to be used for light suburban areas, with increasing values for higher density land usage. This additional margin is also required for in-vehicle service specifically to account for increased attenuation associated with the use of hands-free headsets, where the phone is typically placed on the seat or in the center console.

An industry standard RF computer-aided engineering tool is used in the design of wireless networks. This tool is used to generate a plot of RSRP that shows underlying geographic data (highways, arterial roads, etc.). The propagation map is drawn showing the region where the RSRP equates to the minimally acceptable received signal level for adequate service, as measured at the device's receiver. The propagation map depicts the RSRP of the surrounding environment including the attenuation of in-building and in-vehicle use of service and visually demonstrates existing coverage patterns. Plots can also be generated to demonstrate proposed coverage patterns.

With the preceding in mind, T-Mobile Wireless' network standard for reliable 4G LTE wireless service for highway and rural settings is -105 dBm RSRP. Network reliability and accessibility decreases dramatically for mobile devices operating in or traveling into RF environments outside (or weaker than) the -105 dBm RSRP coverage boundary (represented as white space in the provided coverage plots). Similarly, and as described above, -95 dBm RSRP is used in areas where additional signal strength is needed to penetrate into buildings (e.g., city centers, dense residential, commercial and industrial type environs).

(b) Capacity

Significant deficiencies in service can occur in T-Mobile Wireless' telecommunication network in and around the existing sites. These deficiencies can be a result of capacity demands that are taxing the surrounding sites in the T-Mobile Wireless network. The FCC mandates in CFR 47 Part §22.940 that when a Commercial Mobile Radio Service ("CMRS") licensee (i.e. "wireless carrier") is up for renewal, the carrier must demonstrate its proposal for expanding system capacity in a coordinated manner in order to meet anticipated increasing demand for both local and roamer service, or be at risk of license revocation.

T-Mobile Wireless regularly monitors customer traffic on each site in its network and identifies which sites are reaching 4G capacity limits or are projected to reach these limits over a rolling two-year window. Capacity is defined as the amount of customer data traffic (voice and data) a given site can process before significant performance degradation occurs. Performance issues include an inability to access the network (make a call), calls being abruptly dropped from the network (dropped calls), or poor call or data throughput performance while connected to the network (delayed upload or download speeds). Data volume, or throughput, is the main factor used to determine the existing 4G capacity for a given site and to project when that site is expected to run out of capacity (i.e., reach a point where it can no longer process the volume of data requested by local wireless devices). Capacity relief solutions, typically development of additional sites capable of "offloading" the "loaded" sites, are then required to solve the problem.

Forward Data Volume ("FDV"), a measure of usage (data throughput) on a particular site over a given period of time, is the performance metric used to evaluate the capacity of an existing facility. The "forward link" is used since there is generally more data being downloaded[1] (or transmitted) from a given site to the mobile devices within its coverage area, than uploaded. Therefore, it is the "forward link", not the "reverse link" that is used to determine the capacity limitations. Spikes resulting from anomalies such as seasonal events (tourist spikes, major outdoor concert venues or sporting events, etc.), college

[1] By comparison the reverse link, or information transmitted from mobile devices to an associated wireless facility, generally carries in the order of 1/10th of the data volume as the forward or downlink path.

breaks, holiday sales events or celebrations, and major accidents or emergencies are accounted for as they can inflate the capacity demand and result in a premature capacity offload prediction. Trending actual and recorded throughput data over time for a site and comparing it to the theoretical maximum throughput capabilities for that site determines when that site will require capacity relief.

The above are some of the concepts and parameters used when determining adequacy of the existing network.

4. PERFORMANCE SOLUTIONS

When the T-Mobile Wireless Radio Frequency Engineer identifies coverage gaps in the system or sites that have or will reach data capacity exhaustion, they issue a “search area.” A search area is a geographical area located within the inadequately serviced area, and it is designed such that if a wireless telecommunications facility is located within the search area, and at an appropriate height, it will likely provide the required coverage. For the most part, locations outside of the search area will fail to provide adequate service to the cell. Due to technological constraints, there is limited flexibility as to where a new facility can be located, and still function properly. The goal of the search area is to define the permissible location for placement of a cell site that will provide adequate service in the subject cell, and also work properly as part of the overall network.

5. Coverage and Capacity Maps and Justification- Attached