BEFORE THE MINNESOTA PUBLIC UTILITIES COMMISSION
SUITE 350
121 SEVENTH PLACE EAST
ST. PAUL, MINNESOTA 55101-2147

Nancy Lange	Chair
Dan Lipschultz	Commissioner
Matthew Schuerger	Commissioner
Katie Sieben	Commissioner
John Tuma	Commissioner

In the Matter of the Petition of CenturyLink QC to be Regulated Pursuant to Minn. Stat. § 237.025; Competitive Market Regulation

DOCKET NO. P-421/AM-16-496

AFFIDAVIT OF WES LEGURSKY

STATE OF MINNESOTA)
) ss.
COUNTY OF RAMSEY)

I, Wes Legursky, having been duly sworn, state under oath as follows:

I. INTRODUCTION

My name is Wes Legursky. I am President of Zylatek Systems and work as a senior telecommunications consultant. My business address is 11606 Schuett Circle, Woodstock, IL 60098.

I hold a B.S. degree from the Ohio State University in Industrial and Systems Engineering, specializing in Operations Research. I have over 35 years of experience in the telecommunications industry. Thirteen years of that time were spent in various organizations at Ameritech, an Incumbent Local Exchange Carrier (ILEC) similar to Qwest Corporation dba CenturyLink (CenturyLink). For over 20 years, I have been a consultant in the industry working with equipment vendors and carriers to determine the costs of provisioning new services and architectures. My Curriculum Vitae is included as Attachment 1 to this affidavit.

I have provided testimony in Minnesota in the following cases:

- U S WEST Communications Generic UNE Cost Case (Docket No.P421/CI-96-1540)
- Universal Service Fund (Docket No. P999/M-97-909)
- Line Sharing Cost Case (Docket No. 1 P421/CI-99-1665)
- AT&T vs. Qwest on UNE-P Testing (Docket No. P421/C-01-391)
- Review of Qwest’s UNE Element Prices (Docket No. P421/CI-01-1375)

- Review of Qwest's TELRIC Rates (Docket No. P421/AM-06-713)
- Commission Investigation into Qwest Corporation's Provision of Network Elements to CLECs and Into Related Marketing Practices Targeting CLEC Customers (Docket No. P421/CI-09-1066)

The purpose of this affidavit is to analyze the results provided by the Radio Frequency (RF) model in the Affidavit of Mr. Adam S. Nelson.

II. RF PROPAGATION BASICS

In his authoritative book on cellular networks, Paul Bedell says:

> "In the cellular world, radio frequency (RF) propagation refers to how well a radio signal radiates or travels, into a cell base station's intended coverage area."[1]

The model used by CenturyLink and described in Mr. Nelson's Affidavit estimates the signal strength in several wire centers in Minnesota, based on the current location of towers and the topography of the land. In essence, the model calculates the relative strength of the RF signal as it propagates throughout a wire center. Many factors must be considered in order to determine this RF signal strength.

The most powerful and thus important RF signal in the model's calculation is the direct, line-of-site path. As one would expect, the strongest signals between a transmitter and receiver occur when the receiver has an unobstructed, straight path from the transmitter. This is commonly known as line-of-sight. When a line-of-sight path exists, the most important factor in determining signal strength is distance. Bedell says:

> "Free-space loss, also known as path loss, describes the attenuation of a radio signal over distance, or the path length of the signal. In other words, free-space loss defines how a cell base station signal can fade over distance. As a base station signal propagates through the air, it is continually fading and losing its strength."[2]

There are many factors to consider in addition to distance, however, which affect the signal strength of a cellular signal at a particular location. Two important factors are absorption and multipath. Bedell says:

> "At UHF[3] frequencies, absorption by 'molecular resonance' in the atmosphere (mostly water and oxygen) is a major factor in radio propagation. Absorption describes to what degree a radio signal in cellular networks is absorbed by objects. When a radio wave

[1] Paul Bedell, Cellular Networks: Design and Operation, A Real World Perspective, (Outskirts Press: 2014), pages 40-41.
[2] Bedell, Cellular Networks, page 44.
[3] UHF: Ultra High Frequency radio waves are defined as beginning at 300 MHz and ending at 3000 MHz or 3GHz. This includes all cellular frequencies.

strikes materials, it can be absorbed by buildings, trees, foliage or even hills. The greater the amount of absorption of an RF signal, the less geographic area covered." [4]

Absorption. An RF signal is affected by the composition of the air and any objects through which it travels. Dense, moist (*i.e.*, humid) air creates more signal loss than dry, arid air. In other words, the air found in desert areas is better than that in Minnesota because it would result in less signal loss over distance. The weather also affects signal loss – rain, snow and fog result in more signal loss due to the amount of water through which the signal must pass. Summer foliage also absorbs more RF signal. Evergreens, such as pines, are particularly bad for signal propagation absorbing RF energy all year round. Bedell states:

> "Organic materials tend to absorb wireless signals more than inorganic materials. Pine needles are noted for absorbing a great deal of RF transmissions because their needle length is close to ¼ the wave length of base station RF signals."[5]

Multipath. Between a transmitter and receiver, there exists more than the line-of-sight path for an RF signal to travel. These multiple paths often result in a weaker, more degraded signal at the cell phone. This phenomenon is known as multi-path fading and is discussed by Bedell:

> "In any terrestrial environment, a radio signal will travel from a number of different paths from the transmitter to the receiver. The most obvious path is the direct, line-of-sight path. However, there will be very many objects around the direct path. These objects can serve to reflect the radio signal. As a result of this, there are many other paths by which the signal may reach the receiver, which are known as reflected paths. When the signals reach the receiver, the composite signal is the combination of all the signals that have reached the receiver."[6]

In almost all cases, this multipath fading results in a degraded, weaker signal, because the signals arrive at the receiver out of phase with one another. According to Bedell:

> "If all the signals were in phase with each other, they would all add together to form a greater, or better signal. However this is not normally the case, as some of the reflected signals will be in phase (with the direct signal) and others will be out of phase (with the direct signal), depending on the various path lengths. So some of the reflected signals will tend to add to the overall signal whereas others (which are out of phase with the direct signal) will subtract from the composite signal that's generated. Multipath signals can reflect off bodies of water, vehicles, buildings, or really anything on their way to a receiving antenna."[7]

In other words, having reflected paths that add to the overall composite signal isn't a good thing. For example, prior to High Definition broadcasting, TV signals were transmitted in analog format. It was not uncommon for a channel to have "ghosts" which were faded images of the

[4] Bedell, Cellular Networks, page 44.
[5] Bedell, Cellular Networks, page 44.
[6] Bedell, Cellular Networks, page 45.
[7] Bedell, Cellular Networks, page 45.

picture offset on the screen. These ghosts were reflected, multipath signals that were relatively close in phase to the main signal and strong enough to be seen. While these ghost signals added to the overall signal strength, they actually degraded the viewing of the main signal.

Multipath signals that subtract from the overall signal strength are also easily observed. Most people have experienced the phenomenon of “search for a signal” by walking around looking for stronger signals. When one walks a few feet and has a signal go from zero or one bar to several bars on their phone, they are observing the negative aspect of multipath fading. The signal does not suddenly get significantly stronger because they are now closer to the transmitter, it is because they have moved out of an area where one or more multipath signals is degrading the total, composite signal.

Calls from inside buildings require additional analysis. Many larger buildings today may make use of a system known as a Distributed Antenna System (DAS). In these situations, the carrier has deployed technology inside the building to improve cellular reception. Malls, airports and large office buildings are examples of locations where A DAS may be deployed. In most buildings like residences and apartments, however, the signal within the building is much weaker than outside. The additional signal loss a user experiences inside these buildings is dependent upon the number of walls between the user and the cellular tower and the construction of the walls. For example, a user who stands near an outside window experiences less signal loss than a user who stands away from the window, behind additional walls in an interior room, or within an interior stairwell or elevator. Importantly, basements and subterranean floors may experience total signal loss because the RF signal cannot penetrate the earth and concrete walls. The construction of the walls also affects the penetration of an RF signal. Concrete, brick, stucco, and stone walls are denser than wooden framed walls and result in more RF signal loss. Walls framed with metal studs provide many, many reflection points for multipath signals that degrade the service quality.

The cellular propagation model described by Mr. Nelson attempts to account for these difficulties by adding an additional 10 dB of signal loss to the calculated signal strength values.

III. MODEL RESULTS

In order to estimate the cellular coverage in certain wire centers, CenturyLink has submitted results in this case that were obtained from the Advanced Topographic Development and Images (ATDI) model. Mr. Nelson describes this model and its results in his affidavit. A carrier could use a model of this type to support its business decisions based upon understanding RF coverage in a geographical area. For example, the carrier could generate two different scenarios to compare. The first scenario might conclude that the use of a single tower in the area results in 80% coverage of the area. A second scenario might show that using two towers would increase the coverage rate to 98%.   The carrier could then decide if the revenues generated by the additional 18% coverage (from 80 to 98%) would justify the cost of adding an additional site in the area.

In this case, CenturyLink has used the model to estimate the cellular coverage in 32 of its wire centers based upon the locations of existing towers. Briefly, the modeling process submitted by CenturyLink can be broken into six steps:

1. Random points are generated for the wire centers.
2. The ATDI model generates an outdoor RF signal level at this point.
3. That outdoor point is determined as either receiving an acceptable RF signal or not.
4. An additional -10 dB is added to the outdoor computation to represent the expected RF signal level inside a building.
5. That indoor point is determined as either receiving an acceptable RF signal or not.
6. Indoor and outdoor results for wire center are tallied and presented as percentages.

The following two tables illustrate example results. For this example, I assume that the minimum acceptable RF signal is -80 dB and indoor losses are -10 dB more than outside losses. Each wire center contains ten random points. Column B contains the calculated outdoor RF signal level at each random point. If that outdoor level exceeds the -80 dB limit, then a 'Yes' is recorded in column C to indicate that point has failed to meet the minimum acceptable signal level. Column D represents the modeled view of indoor RF signal level by adding the -10 dB to the calculated result in column B. If that indoor level exceeds the -80 dB limit, then a 'Yes' is recorded in column E to indicate that point has failed to meet the minimum acceptable signal level.

Table 1. Wire Center Example 1

A	B	C	D	E
Point	**Outdoor Signal Level**	**Outdoor Service Failure?**	**Indoor Signal Level**	**Indoor Service Failure?**
1	-20		-30	
2	-40		-50	
3	-66		-76	
4	-74		-84	Yes
5	-33		-43	
6	-55		-65	
7	-82	Yes	-92	Yes
8	-66		-76	
9	-21		-31	
10	-69		-79	

In this example, only one of the ten points fail to meet the acceptable signal level for outdoor service while two would fail inside a building. The outdoor coverage would then be 90% and the indoor coverage would be 80%. The Bemidji wire center is an example of a wire center with similar results. For Bemidji, the model calculated outdoor coverage at 98.3% and indoor coverage at 92%. This narrow difference between indoor and outdoor coverage occurs when the random points fall into marginal coverage areas only occasionally.

Table 2. Wire Center Example 2

Point	Outdoor Signal Level	Outdoor Service Failure?	Indoor Signal Level	Indoor Service Failure?
1	-20		-30	
2	-40		-50	
3	-66		-76	
4	-81	Yes	-91	Yes
5	-73		-83	Yes
6	-77		-87	Yes
7	-74		-84	Yes
8	-76		-86	Yes
9	-21		-31	
10	-71		-81	Yes

In this example, again only a single point fails to meet the acceptable outdoor signal level but six fail the indoor test. The outdoor coverage is 90% but the indoor coverage is only 40%. Many more points fall into an area of marginal coverage in this example so there is a large difference between the outdoor and indoor results. The Cook wire center is an example of this kind of result with outdoor coverage at 43.9% and indoor coverage at 8.7%.

The results illustrated in the above two tables are significantly different. The wire center represented by table 1 would pass the 60% coverage rule and the table 2 wire center would fail. This result occurs because of the location of the randomly generated points selected. While this example illustrates the difference between two wire centers, it also could represent the results for the same wire center and two different runs of the model. Because the points are generated randomly, it is possible for the wire center to pass in the first case entirely due to the points selected. If another run of the model selected the second set of points as inputs, then the very same wire center would fail to meet the minimum acceptable service levels. Clearly, the selection of the random points is a key factor in determining the results.

IV. A REAL WORLD EXAMPLE

I have had a vacation home in central Wisconsin for the last 18 years. It has proven to be a very challenging location for cellular services. From a user perspective, I would have to say that service quality is generally very poor and unreliable. During the time I have lived there, I have had service from three different carriers: AT&T, US Cellular and, currently, Verizon. My experience with all three has been the same. All three carrier coverage maps on their websites indicate that this area is well covered.

The land around this location is very flat, with no significant hills, and contains many small ponds and marshy areas. Trees are an even mix of evergreen and deciduous. The house is oriented such that the front door faces northeast and the back southwest. There is a large lake about a quarter mile to the east and a smaller pond (several dozen acres) about 150 feet to the south and southwest. Absorption of the RF signal caused by the trees and multipath fading caused by the water features contribute significantly to the poor service quality.

On the deck at the back of the house (*i.e.*, the southwest side), signal strength[8] varies from one to three bars with two bars being typical. This is based on many different phones and all three networks. This location results in about 60-80% call origination but with a very high call drop rate. Driving less than a half-mile away – to the southwest – results in a boost in signal strength to at least three or four bars and much better service. Call origination approaches 90-95% with a lower call drop rate.

Inside the house service quality is even worse. The best location is on a second floor, southwest facing bedroom at a window. Here service is similar to what is found just outside on the back deck. Anywhere else inside the house, the signal strength is evenly divided between zero and one bar. The call origination rate drops to perhaps one in three or four calls. When trying to place a call, users either wander through the house or go outside looking for a signal. It is impossible to complete a call from the basement.

Because service is so poor at this location, we have landline telephone service from the local provider in case of an emergency. Also, people trying to call us there have discovered that they often must use the landline because cellular calls frequently do not complete.

V. CONCLUSIONS

RF propagation modeling is very complex. Cellular carriers use models, such as the one CenturyLink provides in the current case, to support business decisions. Their criteria are unlikely to provide the same landline based service quality or reliability to all the users in an area. More likely, the model criteria selected for business decisions is to provide cost-effective and acceptable service to as many cellular users over as wide an area as possible. Cellular customers over the years have come to tolerate much lower call completion rates, higher dropped call rates and lower quality of the voice signal than they experienced on their landline service. Service contracts do not specify that 911 calls are guaranteed or even assure a minimum call completion rate. Even in areas with relatively good service (my cabin with two outside bars), call failures can be very high, which means that a second method for placing 911 calls is necessary.

[8] This measurement is based upon the display of the cellphones indicating received signal from zero to five bars. Most cell phones provide this visual indication to the user.

The results of the modeling done by Mr. Nelson in this case should be viewed as an upper bound. Actual service rates to real customers over an entire year are likely to be lower, not as high or higher, than described by the model. If the indoor coverage shown by the model is less than 60%, the actual service rates to customers are likely to be less than 60%. If the indoor coverage shown by the model is only marginally larger than 60%, such as between 60% and 70%, the actual service rates to customers may or may not be larger than 60%.

FURTHER YOUR AFFIANT SAYETH NOT.

Wes Legursky

Subscribed and sworn to before me on
this 9th day of February, 2017.

Valeria Castaneda
NOTARY PUBLIC
My Commission Expires 09/15/2018

OFFICIAL SEAL
VALERIA CASTANEDA
Notary Public - State of Illinois
My Commission Expires Sep 15, 2018

Attachment 1

Curriculum Vitae
Wes Legursky

Professional Summary:

Over 35 years experience in telecommunications planning and engineering experience. Skills include:

- Technology assessment and modeling.
- Business planning and development.
- Primary market research in telecommunications.
- Product development and planning.
- Expert witness in legal cases.

Project Experience:

Chief Consultant **8/00 – 5/01**

TRAIAN Internet Products

- Provided management and services for a new line of business in telecommunications consulting.

Director, Telecommunications Consulting **8/98 – 7-00**

ObjectWave Corporation

- Provided management and services for a new line of business in telecommunications consulting.

Independent Consultant **3/94 – 7-98 and 06/01 - Present**

- Provided management consulting services in business process improvement, strategic & tactical business, product, network, operations, architecture and procurement planning.
- Supported internal business planning processes and major technology RFPs.
- Developed analytical models for new and existing telecommunications architectures.
- Provided expert witness in regulatory cases.

Director, Engineering, IOS and SCI **11/95 – 6/97**

Intelligent Object Solutions and Subscriber Computing Inc.

- Provided engineering and business support to start-up company Intelligent Object Solutions (IOS) which developed Wireless Intelligent Network software.

Director, Architecture Planning – Director, Network and Operations Planning10/87 – 2/94

Ameritech Services, Inc.

- Provided Network technical support to Corporate Strategic Planning efforts -- specifically, developed an Outside Plant Strategy, a Data Evolution Strategy and a Fundamental Network Plan.
- Technology areas supported include AIN, PCS, FITL, SONET and ATM as well as Operations Architectures such as CMISE.

- Provided Fundamental Network Planning support for the five Ameritech Operating companies in areas of switching, transmission systems, outside plant, numbering, signaling and forecasting.
- Deployed planning tools such as INPLANS, INFORMS, CBAS and PBAS.

Manager, Strategic Planning – Engineer, Transmission Engineering **7/81 – 9/87**
Ohio Bell Telephone

- Provided market technical support for strategic customers.
- Project manager for deployment of X.25 Packet Network.
- Provided new technology assessment for ISDN, CO LAN, Switched 56kbs, DLC and SONET.
- Represented Ameritech on national committees related to above topics.
- Responsible for third tier maintenance and technical support of T-Carrier systems and the Digital Data System (DDS) network.
- Performed technology assessments of first fiber optic systems deployed by OBT.
- Developed district office automation software.
- System Administrator for district UNIX platform.

Education: B.S., Industrial & Systems Engineering, Ohio State University, 1981

Professional Affiliation: Member IEEE