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May 8th 2006

The Honorable Kevin J. Martin,
Chairman
Federal Communications Commission,
445 Twelth Street, S.W.
Washington, DC 20554

Re: WT Docket No. 05-211
AU Docket No. 06-30
Written Ex Parte Presenation

Dear Chairman Martin:

By this letter,

FCC 06-52

Introduction

This letter has been prepared by myself **Dr. Phil Whiting** at the request of **Council Tree Communications** who requested my professional opinion on an extract taken from FCC 06-52, which is entitled SECOND REPORT AND ORDER AND SECOND FURTHER NOTICE OF PROPOSED RULE MAKING.

The extract is as follows "Specifically, except as grandfathered below, an applicant or licensee has "impermissible material relationships" when it has agreements with one or more other entities for the lease (under either spectrum manager or de facto transfer leasing arrangements) or resale (including under a wholesale arrangement) of, on a cumulative basis, more than 50 percent of its spectrum capacity of any individual license. Such "impermissible material relationships" render the applicant or licensee (i) ineligible for the award of designated entity benefits, and (ii) subject to unjust enrichment on a license-

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by-license basis. Furthermore, except as grandfathered below, an applicant or licensee has an "attributable material relationship" when it has one or more agreements with any individual entity, including entities and individuals attributable to that entity, for the lease (under either spectrum manager or de facto transfer leasing arrangements) or resale (including under a wholesale arrangement) of, on a cumulative basis, more than 25 percent of the spectrum capacity of any individual license that is held by the applicant or licensee. The "attributable material relationship" with that entity will be attributed to the applicant or licensee for the purposes of determining the applicant's or licensee's (i) eligibility for designated entity benefits, and (ii) liability for unjust enrichment on a license-by-license basis."

In my professional opinion as an expert in wireless communications the term **spectrum capacity** used by the FCC in the above document **is far too vague and inspecific to be reasonably applicable in any legal proceeding pertaining to wireless network commerce**. (It should be noted that this opinion pertains only to myself and not to any employer of myself past or present, or any other organization involved in wireless communications with which I am or have been associated.)

Before discussing this question further I now provide a brief resume of my professional experience. I am a scientist currently attached to Bell Laboratories Murray Hill and have had 19 years experience with wireless systems as a researcher/engineer in industry and as a consultant, as well as in academia. I have published over 40 academic papers on various aspects of wireless networks, including Information Theory, Coding, Resource Allocation, Scheduling and Object Tracking and Location in leading journals and conferences. I have also been awarded several patents for algorithms in connection with the operation and planning of such networks. My experience in resource allocation for diverse wireless networks particularly qualifies me for discussion of the term "spectrum capacity". A detailed account of my professional experience, publications etc. is provided in the attached CV.

Before going into any specific calculations I would like to point out that although I have come across the term **Spectrum Capacity** in a number of connections, I know of no commonly agreed definition for this term. In fact in my experience, not even distinct groups of professionals in this field have an agreed upon definition. These groups include designers of wireless systems both military and commercial, as well as operators of wireless networks and academic theorists. Nevertheless the term is significant as it is often used either to reflect the capabilities of a particular system or as a means of comparing one system with another. Such definitions only attain significance once the relevant system parameters and other details have been provided. The FCC extract on the other hand provides no such details and does not even state the units in which spectrum capacity is to be measured. This is contrary to usual engineering practice.

Finally before going into further details, I would like to point out that as an important special case of the above **there is no definition of spectrum capacity based on fundamental theory**. This is because the results of such theory depend on the communication channel which in turn depend on the type of system used (number of antennas, choice of decoding scheme, wireless propagation etc.) and because the results of such theory do not in any case produce a single number but rather an achievable rate region, except in the special case of point to point communications.

I will now show that one may arrive at widely disparate values for spectrum capacity and its commercial value depending on which definition of spectrum capacity is adopted. As the FCC document is concerned with broadband wireless access let us take as an **example the EV-DO system** which was originally designed to carry Internet traffic and other high speed delay tolerant services such as streaming audio/video on the base to mobile (forward) link. (Please refer to my CV for my **publications, awarded patent and other work in connection with this system.**) Similar examples could be made for other wireless systems as well.

Evolution-Data Only (EV-DO) System Example

The EV-DO system allocates short duration timeslots (about 2 ms.) for data transmission - one user per slot - according to transmission rate estimates provided by the user handsets over a feedback link. A time multiplexed pilot signal is provided in order for the handsets to make these estimates. For exemplary purposes we will suppose these rates to be 2 Mbits/sec, 1 Mbits/sec, 0.5 Mbits/sec and 0.25 Mbits/sec. and that an example operator, operator A uses 2x1.25Mhz duplex bands to support his network thus using 5 MHz of spectrum in total. The rates quoted are for information rates exclusive of overheads, for packetisation, channel coding etc.

Spectrum Capacity Based on Ideal User

Since A's system is capable of supporting the maximum bit rate continuously, the maximum throughput on the forward link could be deemed the spectrum capacity. This rate being that corresponding to an "ideal" user. Hence

$$Spectrum\ capacity\ =\ 2 \times 2\ Mbits/s\ ---per\ sector = 4Mbits/s\ per\ sector$$

Spectrum Capacity based on Typical User

As an alternative operator A could define spectrum capacity in terms of "typical users". This could be done by using wireless propagation models, and by taking into account the distribution of users within the network relative to the deployed infra-structure etc.. It might then be concluded that the rates allocated in each slot occur according to the following fractions,

$$2Mbits/s - 0.1,\ 1\ Mbit/s - 0.2\ 0.5\ Mbit/s - 0.3\ 0.25Mbit/s - 0.4$$

In this case the spectrum capacity is

$$2x(2x0.1 + 1x0.2 + 0.3x0.5 + 0.25x0.4) = 1.3Mbits/s/sector$$

The two figures for spectrum capacity differ by a factor of 3.

Definitions of a typical user such as A employed above depend on a reference model. In practice no one reference model will stand out and in fact *different reference models can be used in the same system* as user distribution and wireless propagation (affected by user speed and position) can change substantially even over periods as short as an hour. Definitions of typical users based on actual usage run into similar difficulties for the same reason, network usage is time varying so that the definition of a typical user based on actual usage can always be disputed.

Spectrum Capacity Based On Slot Division

As an alternative definition of spectrum capacity operator A may measure his capacity by simply counting the timeslots themselves.

$$Spectrum\ capacity = No.\ of\ slots\ available\ per\ unit\ time$$

He may then agree to reserve half of the slots over the day on his entire network to carry the traffic of another service provider, provider B. Such an allocation of half capacity covers the commercially advantageous busy periods when there is high traffic volume. Let us suppose the total busy period duration is 5 hours.

Provider B supports Internet service. If the system throughput is on average 0.5 Mbit/s/sector for B's traffic and a typical web page is 100 kbits. Then in the busy period alone provider B supported

$$(0.5/0.1)x5x3600 = 90,000\ \ Webpage\ downloads/day/sector$$

In an alternate agreement the operator may agree to provider C using his entire network for 12 out of the 24 hours of the day. Since half the slots are allocated this is again half the spectrum capacity according to the previous definition. Provider C may also offer Internet service. Let us suppose that the average throughput of C's traffic is 50 kbits/s/sector with the same average Web page size as provider B. Then provider C supports

$$12x3600x(0.05/0.1) = 21,600\ \ Webpage\ downloads/day/sector$$

This is less than 1/4 the traffic supported by provider B. Both providers were given half the spectrum capacity and yet the commercial value in terms of service provided differs by a factor of at least 4. Hence if operator A restricts himself to 49 % of the slots in the transaction with provider B he will not be seen as using over 50 % of his spectrum capacity as will be the case if provider C is actually allocated the slots for 13 hours instead of 12, according to the stated definition.

Instead of dividing his slots according to time, operator A could just as well divide his slots spatially, allowing service provider D to use one half of the total number of base stations in his network and hence once again half of the slots. As before the commercial value of this arrangement depends on the spatial usage pattern associated with As network.

Summary

To summarise in using the term spectrum capacity, **there is no commonly held or fundamental definition upon which the FCC can rely.** Instead there are **multiple definitions which can be reasonably adopted** and which will lead to **widely differing values for spectrum capacity.** None of these definitions **stand out from the others as being more authorative than any other** and the allocation of the same fraction of spectrum capacity can have radically different commercial implications depending on the circumstances, as I have discussed.

The conclusion is that the term **spectrum capacity** cannot be reasonably applied to legal proceedings for wireless commerce.

Respectfully submitted,

P.A. Whiting

Philip A. Whiting
Ph. D.

cc: The Honorable Jonathan S. Adelstein
The Honorable MIchael J. Copps
The Honorable Deborah Taylor Tate,
Fred Campbell,
Barry Ohlson,
John Giusti,
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Education

PhD in Engineering 1984-1987
"On a Class of G/M/1 Priority Queues
University of Strathclyde, Glasgow, Scotland.

MSc. Probability and Statistics 1983
Birkbeck College, University of London.

BA Mathematics 1975
University of Oxford.

Professional Societies

ROYAL STATISTICAL SOCIETY

MEMBER INSTITUTE OF ELECTRICAL AND ELECTRONIC ENGINEERS: INFORMATION THEORY SOCIETY

Experience

RESEARCH IN MATHEMATICS OF WIRELESS NETWORKS AT BELL LABS, MURRAY HILL, NJ Jan. 97-curr.

- **Resource Management**

- Dynamic Channel Assignment
-Scheduling Algorithms for Wireless Networks
-Performance and Network Planning for Proportional Fair
-Blocking in Circuit Switched Networks
-Power Control for CDMA Networks
-Blocking in Optical Packet Switches
-Spectrum Management for DSL Lines

- **Information and Coding Theory**

-Coding Theorems for CDMA
-Feedback Schemes for Fading Channels.
-Hybrid ARQ

Current Activities

- In building tracking and localization using RSS
- Scheduling in MIMO Data Networks
- Received Power Control for Real Time Data

Skills

Languages : MATLAB, C, FORTRAN, BASIC.
Operating Systems : Unix, DOS.
Systems : Sun workstations, IBM-PC compatibles.

Awards

- Best Paper Award from the Bell Labs Technical Journal in the area of Wireless/Mobility in 1998.

Appointments, Visits and Talks

Appointments

- Adjunct (Full) Professor, Columbia Univ. New York Sept 2004-Jan 2005

Visits

- Centrum Wiskunde Informatica (CWI) Amsterdam 1999
- Centrum Wiskunde Informatica (CWI) Amsterdam 2003
- Visiting Scholar University of Melbourne, June 2003
- Visiting Scholar Vreij University (Amsterdam) March 2004

Talks

- Large Deviations Asymptotics for Occupancy Problems, EURANDOM, Eindhoven, March 2nd 2003
- Scheduling Algorithms and Planning for Cellular Data Networks, CWI, Amsterdam, March 4th 2003
- From Occupancy Models to Star Networks, ATT Shannon Labs, May 23rd 2003
- Scheduling Algorithms for Wireless Data Networks, University of Melbourne, June 2003.
- Blocking Networks and Occupancy Models,University of Melbourne, June 2003
- Occupancy Models, Princeton University, April 2004.
- Higher Order large Deviation Asymptotics for the Classical Occupancy Problem, CWI, January 2005.
- Spectrum for Trapping Sets, WINLAB, Rutgers University, 2006.

Publications and Patents

- Sem Borst and P. Whiting. Achievable Performance of Dynamic Channel Assignment Schemes under Varying Reuse Constraints. *IEEE Trans. on Veh. Tech. July 2000*
- Matthew Andrews, Krishnan Kumaran, Kavita Ramanan, Alexandar Stolyar, P Whiting Providing Quality of Service over a Shared Wireless Link *IEEE Personal Communications, January 2001*
- A. Grant, B. Rimoldi, R. Urbanke and P. Whiting Rate Splitting Multiple Access for Discrete Memoryless Channels *IEEE Transactions Information Theory Vol. 47 No. 3, March 2001*
- D. M. Andrews, S. C. Borst, F. Dominique, P. Jelenkovic, K. Kumaran, K. G. Ramakrishnan and P. Whiting. Dynamic Bandwidth Allocation Algorithms for High-Speed Data Wireless Networks. *Bell Labs Technical Journal*, Fall 1998 Issue.
- J.R.McDonald, K.L.Lo and P. Whiting Optimized reaction of large electrical consumers in response to spot-price tariffs. *Int. Jou. Elec. Power and Energy Systems (1994)*
- J.R.McDonald, K.L.Lo and P. Whiting Spot Pricing: Evaluation and Modeling of Dynamic Tariff Structures. *Int. Jou. Elec. Power and Energy Systems (1994)*
- P. Whiting. Queueing Systems *in Telecommunication Engineer's Handbook (Ed. F. Mazda) Butterworth-Heinmann 1993*
- S.Hanly and P. Whiting. Information-Theoretic Capacity of Multi-Receiver Networks. *Telecommunication Systems Vol. 1 No. 1 (1994)*

Awarded Patents

- S. Borst and P. Whiting "Dynamic Rate Control Methods and Apparatus for Scheduling Data Transmissions in a Communication Network" US Patent No: 7,006,466 B2
- K. Kumaran and P. Whiting "Method For Partitioning Mobile Stations of a Wireless Network Between an Underlay and an Overlay", Issued
- D M. Andrews, P. Whiting et al. "Method For Dynamically Allocating Carriers In A Wireless Packet Network, With Reuse Of Carriers", Issued
- S. Borst, P. Whiting et al. "Down Link Inter-Cell Scheduling in CDMA Data Networks", Issued

- Phil Whiting Stochastic Control and Scheduling in Wireless Networks *Invited Presentation, IMA Workshop on Wireles Networsk, IMA, Minneapolis, 2001*
- Sem Borst and P. Whiting. Dynamic Rate Control Algorithms for CDMA Throughput Optimisation. *in INFOCOM 2001, Anchorage, Alaska.*
- C. Chekuri, K. Ramanan, P. Whiting and L. Zhang Blocking Probability Estimates in a Partitioned Sector TDMA System *Proc. 4th ACM Inernational Workshop on Discrete Algorithms and Methods for Mobile Computing and Communications, Boston, August 2000*
- P. Whiting On a Non-Degraded Fading Channel Model *CCIS Princeton University,* **(Invited Paper)** *March 2000*
- P. Whiting and E. Yeh Optimal Encoding Over Uncertain Channels with Decoding Delay Constraints *ISIT 2000, Sorrento, Italy.*
- A. Bedakar, S. Borst, K. Ramanan, P. Whiting and E. Yeh Downlink Scheduling in CDMA Data Networks *Globecom '99, Rio de Janeiro, Brazil.*
- K.Kumaran and P. Whiting. The Design of Underlay-Overlay Networks. *WCNC '99*
- S. Borst, E. Coffman, E. Gilbert, P. Whiting and P. Winkler Optimal Carrier Sharing in Wireless TDMA *System Performance Evaluation, Methodologies and Applications*, ed. E. Gelenbe (CRC Press, Boca Raton),203–213 (2000)
- K. Kumaran and P. Whiting. Rate Processor Scheduling *Venice MMT '99*
- K. Kumaran and P. Whiting. Design and Performance of Underlay-Overlay Cellular Networks. Proc. of *Multi-access, Mobility and Teletraffic Conference (MMT'98)*, Washington DC, Oct. 1998.
- D M Andrews, P Whiting et al. Scheduling Algorithms for Delay Tolerant Traffic in Mobile Networks. Proc. of 5th Intl Wkshp on Mobile MultiMedia Communications, (MOMUC 98), Berlin, Germany.
- Sem Borst and P. Whiting. Achievable Performance of Dynamic Channel Assignment Schemes under Varying Reuse Constraints. *in Proceedings INFOCOM 98, San Francisco.*
- P. Alexander, A. Grant and P. Whiting. Spreading Codes for Multiple Access Spread Spectrum Systems *PIMRC 1995 (Canada)*
- A. Grant, B. Rimoldi, R. Urbanke and P. Whiting. Single User Decoding for Discrete Memoryless Multiple Channels *ISIT 95 (Canada)*
- S.Hanly and P. Whiting. Interference Cancellation Schemes for Groups of Users *ISIT 95 (Canada)*
- P. Whiting. Performance of Random Spreading Codes with Multi-User Decoding *Mobile and Personal Communication Systems (Adelaide)*
- S.Hanly and P. Whiting. Constraints on Capacity in a Multi-User Channel. *ISIT 94 (Norway)*
- S.Hanly and P. Whiting. Asymptotic Capacity of Multi-receiver Networks. *ISIT 94 (Norway)*
- P. Whiting. A Review of Mathematical Models for Spread Spectrum Networks *8th Australian Teletraffic Seminar (Melbourne)*

Referees

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