A Flawed Metric of Spectrum Efficiency

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History and Use of a Metric of Spectrum Efficiency

This Comment is a follow up to our filing on May 13 2013 in both Dockets 12-268 and 12-269[1]. In the initial filing we reported our conclusion that the findings of economic harm and adverse employment effects that would result from the imposition of selective bidding eligibility conditions presented in the Georgetown University McDonough School of Business report "The Economic Implications of Restricting Spectrum Purchases in the Incentive Auctions"[2] are invalid because they rely on a spurious metric for spectrum efficiency. In this follow-up filing, we analyze the flawed calculation of spectrum efficiency known as the Verizon/CTIA metric.

This metric of spectrum efficiency initially came to our attention through its use by the CTIA and Verizon to support claims of the spectral efficiency and superiority of the U.S. mobile sector compared to other countries, and also of the largest U.S. mobile operators compared to their smaller competitors along this dimension of technical, engineering, and functional performance.

These claims are being used to support their proponents' recommendations related to important public policies that the Commission will soon make regarding spectrum allocations and assignments, and the rules and criteria that should be applied in forthcoming spectrum auctions (especially bidding eligibility conditions if any), as well as in reviews of secondary market transactions for spectrum licenses.

Consequently, questions of whether the claims are valid, or should be disregarded by the Commission because they are based upon the results of applying a flawed methodology for calculating spectrum efficiency, are pertinent to the FCC's decisions in these two Dockets, as well as to others in which issues of spectrum management, allocation, and assignment are involved.

Furthermore, we have noted that the results obtained by applying the metric have been reproduced and approved by 4G Americas[3]. 4G Americas is a leading industry association of mobile operators and manufacturers, including the largest and most influential among them, whose stated mission is: *"With a focus on the Americas region, 4G Americas informs and educates key industry stakeholders, such as media, industry analysts, government officials and companies that form the wireless industry ecosystem, about the merits, technical standards and*

[1] http://apps.fcc.gov/ecfs/document/view?id=7022312455 and http://apps.fcc.gov/ecfs/document/view?id=7022312454

[2] This report was filed in Docket 12-269 on May 3, 2013 - http://apps.fcc.gov/ecfs/document/view?id=7022309583

[3] http://www.4gamericas.org/index.cfm?fuseaction=page&pageid=2007 and http://www.4gamericas.org/index.cfm?fuseaction=pressreleasedisplay&pressreleaseid=3795

global leadership role of the 3GPP family of technologies – GSM, GPRS, EDGE, UMTS, HSPA and LTE and LTE-Advanced."

The metric also continues to be used by well-known telecommunications analysts in their assessments of the implications and potential consequences of operators' competitive moves. For example Roger Entner, who among other activities conducts independent research for the CTIA, has analyzed the Sprint/Clearwire transaction in the following language linking an operator's competitiveness and network capacity to the spectrum available to an operator to serve each of its subscribers, i.e., the inverse of Verizon/CTIA metric:

"If the FCC approves this transaction, Sprint will be the largest spectrum holder in the United States with an average of just over 200 MHz of spectrum across the country. According to the National Broadband Plan, there is 547 MHz of spectrum useable for wireless broadband. If this transaction is approved, Sprint will own more than a third of the available spectrum allocated by the U.S. government, but with less than one sixth of U.S. customers. That gives Sprint (on average 200 MHz and 56 million subscribers) the chance to use roughly 3.57 MHz of spectrum to support each of their subs. Compare that to a Verizon (on average 105 MHz and roughly 100 million subscribers) which has only 1.05 MHz of spectrum to support each customer's uses. More spectrum means faster speeds, more capacity, and a stronger competitive position."[4]

Of course more spectrum does mean faster speeds and more capacity. However, the statement that Sprint has 3.57 Hz and Verizon only 1.05 Hz to support each subscriber *(we assume that the MHz in the quote instead of Hz is a misprint)* is meaningless. In calculating the bandwidth an operator has available to support each customer, it only makes sense to consider the worst or highest traffic density case, i.e., the cell where an operator has the greatest number of customers that then have to share the capacity the operator can deliver in its licensed spectrum. Neither the entire base of an operator's customers nor all the mobile customers in a country, share the same pool of frequencies, i.e., millions or tens of millions or even larger numbers of mobile subscribers do not have to compete for access to transmission capacity on just one nationwide or one operator-wide access network. These customers are spread over thousands, or in the U.S., hundreds of thousands of cells. Competition for access to shared network capacity is confined to the customers served by he same cell site. The average number of mobile subscribers per cell site in the U.S. was just under 1,100 as of end-2012, according to the CTIA[5].

Over the past 12 months we have tried, without success, to engage in an open, fact-based dialog with its proponents about the use of this spurious metric, with the goal of formulating a credible alternative for measuring and comparing operators', or national mobile industries' performance with respect to the efficiency with which they are exploiting scarce spectrum to deliver mobile communications services. The repeated use of the metric by prominent and influential organizations and institutions such as 4G Americas, the CTIA and the McDonough School of Business at Georgetown University makes it important to answer definitively the question of its validity. We are convinced that this metric is invalid, and therefore that findings based upon the

[4] http://www.fiercewireless.com/story/entner-sprint-be-largest-us-spectrum-holder-if-clearwire-deal-approved/2012-12-18 ; presumably this analysis means to compare numbers of Hz per subscriber of an operator or numbers of MHz per million subscribers, i.e. the inverse of the Verizon/CTIA metric of number of subscribers per MHz.

[5] "Wireless Quick Facts," http://www.ctia.org/advocacy/research/index.cfm/AID/10323

results of its use should not be invoked to support or justify regulatory and policy decisions regarding the optimum exploitation of spectrum, which is a scarce and valuable public resource.

We first referred to the use of this metric by Verizon and the CTIA and explained why it was meaningless and fatally flawed in a filing to the Commission on May 29th, 2012 in Docket 12-4[6]. On August 3 2012 Verizon filed a rebuttal to our filing[7] in which we had raised several points in addition to the issue of comparative spectrum efficiency where we argued Verizon was in error on the issues involved in this Docket. However, as we pointed out shortly thereafter on August 12 2012 in a surrebuttal[8] Verizon did not acknowledge and was silent in its rebuttal of our filing on the specific question of the flaw we had clearly identified and demonstrated in the Verizon/CTIA metric of spectrum efficiency.

We also contacted the CTIA directly in early June 2012 about this metric (the email is reproduced in the Appendix in this filing). We have received no acknowledgment of this communication. As reproduced in our filing with the Commission of May 13 2013, referred to earlier, we recently contacted Professor Mayo, author of the Introduction to the McDonough School report by email on May 7 2013, informing him of the spurious nature of the metric used in this report. In addition we have recently contacted Dr. Robert Shapiro about the metric (by email on May 23,' also reproduced in the Appendix). He was the author of Part 2 of this report and was responsible for introducing the metric into its analyses. The metric was also invoked by his two co-authors in their accompanying analyses in Part 1 of the report.

During the entire period of one year since we first became aware of and began to alert key stakeholders of the bogus characteristics of the Verizon/CTIA metric, we have received no substantive responses and no attempts to rebut our findings from any of the individuals or organizations that we have contacted, either directly and/or in public forums such as Commission Proceedings. This lack of response is surprising and disturbing, given the seriousness of the flaw we have identified.

In further support of our position, we recently came across independent confirmation of the invalidity of this metric of spectrum efficiency from Canada that preceded our own awareness of the issue. In April 2011, one of the three leading mobile operators in Canada, Bell Mobility, filed a Reply Comment with Industry Canada in its "Consultation on a Policy and Technical Framework for the 700 MHz Band and Aspects Related to Commercial Mobile Spectrum," that objected to a report by a Vancouver-based consultant using the metric that found Canadian operators to be much less efficient in their use of spectrum than their U.S. counterparts. Bell Mobility's analysis of the metric can be found on pp. 34-36 of its Reply Comments[9]. Its finding is consistent with ours namely that, *"Therefore the only conclusion one can draw, using SeaBoard's calculation of the subscribers/MHz metric, is that it is a meaningless method of comparing spectral efficiency, between operators, when the underlying market sizes are so vastly different."*

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[6] *Ex parte* Addendum, http://apps.fcc.gov/ecfs/document/view?id=7021920798
[7] http://apps.fcc.gov/ecfs/document/view?id=7021996661
[8] http://apps.fcc.gov/ecfs/document/view?id=7022003838
[9] http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/SMSE-018-10-bell-mobility-submission.pdf/$file/SMSE-018-10-bell-mobility-submission.pdf

The following Tables and explanatory remarks present examples of the ludicrous and incredible results produced by calculations based on the Verizon/CTIA metric of spectrum efficiency. These results show quantitatively and definitively that this metric inevitably produces nonsensical results since it bears no relation to the operational realities and functioning of cellular networks.

Examples of the Results of Applying the Verizon/CTIA Metric

Table 1a: Spectrum Efficiency According to the Verizon/CTIA Metric[1]

End-2011	U.S.	Japan	Germany	U.K.	France	Italy	Canada	Spain	Korea	Mexico	China	India
Mobile Subs., Million	331.6	126.1	114.1	76.9	64.3	92.4	26.6	58.1	52.5	93.2	1,000	900
MHz, Million	409.5	347	615	375	375	375	270	625	270	260	400	220
SSMA	1.0	0.449	0.229	0.253	0.212	0.304	0.122	0.115	0.240	0.443	**3.087**	**5.052**

Sources: Adapted from CTIA and Information Age (IAE) estimates – figures for all countries except China and India are taken from CTIA documents
1. Notes: MHz = Spectrum assigned for Commercial use – this amount changes as more spectrum is assigned and in some countries the current (mid-2013) amounts have increased significantly since end-2011; SSMA= Spectrum efficiency defined as "Subscribers Served per MHz of Spectrum Assigned", normalized to the U.S. at 809,755 subscribers/MHz – a higher number indicates greater spectrum efficiency

Table1b: Spectrum Efficiency According to the Verizon/CTIA Metric[1]

End-2011	Verizon Wireless	China Mobile	Ratio China Mobile/VZW
Subscribers, million	109	649.6	5.96
Spectrum Depth, MHz	89	165	1.85
SSMA, million	1.225	3.937	3.21

Source: Operator reports and IAE

Among the most incredible of the findings in these Tables are:

- In North America, Canada is less than one eighth as efficient as the U.S. and Mexico is over 3.5 times more efficient than Canada.
- Mexico is almost twice as efficient as Germany.
- India is over 60% more efficient than China, which is itself over three times more efficient than the U.S., and China Mobile is similarly over 3 times more efficient than Verizon.
- India is over 11 times more efficient than Japan.

The flawed character of the Verizon/CTIA metric can be further demonstrated by another example, based on the CTIA's own figures from Table 1a above. If the spectrum efficiency is

calculated for a combination of three of the larger countries in the European Union - the U.K., France and Italy - then since the total assigned spectrum is the same for all three countries it will also be 375 MHz for their combination. The total number of mobile subscribers in the three countries is 233.6 million. Therefore, according to the Verizon/CTIA metric, the spectrum efficiency of this combination of countries would be 0.623 normalized to that of the U.S., i.e., miraculously it would be between two to three times higher than the efficiencies of its individual national components although the networks involved are exactly the same. An honest measure of spectrum efficiency would produce a result that is a weighted average *and not an addition* of the efficiencies of the individual networks being evaluated.

Conclusion

The Verizon/CTIA metric is not a useful or honest representation of spectrum efficiency. Silence in this case speaks volumes about the unanswerable content of the exposure of this metric's fatal flaw and fundamentally deceptive character. This silence violates the letter as well as the spirit of the pursuit of an open, fact-based reasoned debate about spectrum efficiency and other important issues in spectrum management, as expressed eloquently by Professor Mayo in his introduction to the McDonough report.

The Commission is addressing critical issues about the use of spectrum in Dockets 12-268 and 12-269 that involve the public interest as well as the commercial and business goals of competitive mobile operators and the quality and performance of the wireless services available to customers. Interveners and stakeholders in these Dockets who use this metric in submissions to the FCC, as well in other channels of communication, in order to support claims of the superior spectrum efficiency of specific mobile operators may be ignorant of the structure and operation of cellular networks. Alternatively, they may be knowledgeable about cellular technology while attempting to impress the Commission and others with data generated by a flawed spectrum efficiency metric that they are more efficient than they really are, and therefore should be rewarded for their efforts as the Commission makes important decisions about spectrum allocations and assignments. In either case, the Commission should disregard any findings and assertions that rely on the use of this spurious metric.

Key stakeholders should collaborate and cooperate in order to formulate an honest, generally acceptable metric for spectrum efficiency that can be applied with reasonably reliable and verifiable data to compare the spectrum efficiencies that have been achieved by various operators. The goal of the metric should be to help identify best practices, and lay a credible foundation for regulatory policy and decisions in order to achieve the most efficient and economically valuable use of this scarce public resource in current and future mobile broadband networks.

Appendix

A1: Email to Dr. Robert Roche, June 4, 2012

Dear Dr. Roche,

I wanted to let you know that I recently came across a CTIA Table reproduced here comparing the commercial spectrum efficiency of the US with other countries to substantiate a claim that

the US is the world's most efficient commercial spectrum user. I regret to say that I have concluded that the methodology the CTIA has employed in this case is spurious and indefensible and I would recommend that you withdraw this particular Table. The basis for my conclusion and recommendation is as follows.

CTIA
The Wireless Association®

	USA	Japan	Germany	U.K.	France	Italy	Canada	Spain	S. Korea	Mexico
Subscribers#	302.9M	117.1M	107.4M	79.9M	63.2M	90.0M	24.6M	56.0M	50.8M	91.0M
Average Consumers' Minutes of Use per Month**	793	141	133	204	231	153	373	150	303	191
Average Revenue per Minute – A Measure of the Effective Price per Voice Minute**	$0.04	$0.23	$0.11	$0.10	$0.13	$0.11	$0.10	$0.16	$0.08	$0.05
Efficient Use of Spectrum -- Subscribers Served per MHz of Spectrum Allocated	739,579	337,351	174,634	213,067	168,461	240,000	90,992	134,940	188,030	350,000
Spectrum Assigned for Commercial Wireless Use	409.5 MHz*	347 MHz	615 MHz	375 MHz	375 MHz	375 MHz	270 MHz	415 MHz	270 MHz	260 MHz
Potentially Usable Spectrum/In the Pipeline***	50 MHz	400 MHz	Recently auctioned 350 MHz	310 MHz	250 MHz	250 MHz	up to 200 MHz	270 MHz	120 MHz	150 MHz

*Figure includes AWS-1, 700 MHz spectrum not yet in use and 55.5 MHz of spectrum at 2.5 GHz. #Regulatory and company websites.

** Glen Campbell, et al., "Global Wireless Matrix 1Q11," Bank of America Merrill Lynch, May 1, 2011, at Tables 1-2. ***Regulatory and company websites and press reports.

It defies commonsense to accept that for example the US mobile sector is EIGHT times more spectrally efficient than Canada and over FOUR times more efficient than Germany, while the closest country to the US according to this metric is Mexico.

Furthermore as of March 2012 the three mobile operators in China - a country not included in this Table (I wonder why?) - served a combined 1,020 million customers with estimated total allocated spectrum of no more than 400 MHz, i.e., an "efficient use of spectrum" of 2.55 million subscribers per MHz allocated. In other words, according to calculations that faithfully follow the CTIA methodology, China's mobile sector is operating with a spectral efficiency that is an astonishing 3.23 times higher than the US.

The fundamental flaw in the CTIA metric is that it is not based on the actual cellular structure within which operators strive to maximize the capacity they can deliver by deploying mobile systems in the spectrum they hold. The larger the population covered by the spectrum licenses of a operator or by all the operators in a country then once mobile penetration is high the greater the relative "spectral efficiency" determined according to the CTIA's metric is likely to

be. So all that this metric tends to demonstrate is the well known fact that the US has more inhabitants than the other countries in the Table - but of course far fewer than China.

I do not know where the US truly stands in terms of the relative spectral efficiency of its commercial mobile networks compared to those in other countries. I would be happy to work with you to produce a more defensible and useful definition and evaluation of the values of this parameter which would be accepted as credible by both Americans and foreigners.

The CTIA provides a treasure trove of statistics and thoughtful analyses. I would not like to see its credibility undermined by the continued propagation of the meaningless metric presented in this Table that in no way justifies the conclusion of remarkable US global superiority in spectral efficiency.

best regards,

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A2: Email to Dr. Robert Shapiro, May 23, 2013 (minus attachment)

Dear Dr. Shapiro,

I have read the report you wrote with Coleman Bazelon and Douglas Holtz-Eakin. I have reviewed your findings that imposing bidding eligibility restrictions on Verizon and AT&T in forthcoming Incentive Auctions would substantially reduce auction revenues and would have significant negative macroeconomic consequences and adverse employment effects.

I believe that the question of the potential value or damage from such restrictions is an important one. However, unfortunately your findings and those of your colleagues are invalid because they are derived from the premise among others that these two leading mobile operators in the U.S. are the most efficient users of spectrum. But this characterization of the relative performances of U.S. mobile operators is based upon the use of a metric for spectrum efficiency that is fatally flawed. The numbers produced by this metric are meaningless in the context of the realities of cellular technology. They lead to ludicrous results as can be seen from the examples I have given in an email to Professor Mayo who wrote the Introduction to your report. Both the report and this email - http://apps.fcc.gov/ecfs/document/view?id=7022312455, also attached to this message- have been filed with the FCC.

I assume that you used this metric because it has been presented by (among others) Verizon and the CTIA who might very reasonably be considered to be knowledgeable about how to determine and compare operators' spectrum efficiencies.

Nevertheless use of this metric is a fundamentally deceitful methodology as I have been pointing out to Verizon and the CTIA (and to the FCC) over the past 12 months. Neither of these organizations has acknowledged my analysis in any way whatsoever nor have they attempted to justify their use of this metric. The inherent flaw in this metric is not a matter of opinion or judgment. The assessment of the validity of the metric is not an exercise that has alternative plausible outcomes. Its invalidity is a fact that is based on the very nature and purpose of cellular technology.

Professor Mayo wrote in his introduction, " I believe this study provides important inputs for informed public discussion and can make a major contribution to the FCC and its stated desired for decisions driven by facts and data. No doubt, the study will and should be subject to deep scrutiny and peer review by other analysts and the Commission itself. As Executive Director of the Center on Business and Public Policy I am pleased to release these findings for public review and consideration. Let the debate begin."

I agree with the spirit and philosophy expressed in Professor Mayo's words. I would welcome the opportunity to debate the questions you and your colleagues raise in this article. But as he says this debate should proceed on the basis of facts and premises or assumptions that are based on plausible and reasonable judgments and methodologies, and not on misleading, fatally and obviously flawed calculations that ignore the principles of engineering and the laws governing electromagnetic propagation that underpin the architecture and operation of cellular networks.

I would be happy to discuss at your convenience.

Sincerely,

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