Sustaining the **Mobile Miracle**

A 4G Americas Blueprint for Securing Mobile Broadband Spectrum in this Decade

March 2011

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1. EXECUTIVE SUMMARY

Mobile broadband in the Americas is in a 'delicate' state. On the one hand, the growth in subscribership has been phenomenal - a '*mobile miracle*', as the ITU characterized it in 2008, when mobile broadband subscriptions first exceeded fixed broadband subscriptions globally. The features and capabilities of today's mobile broadband networks, devices and services are astounding, with the promise of future enhancements even more exciting.

On the other hand, the mobile broadband stands at a potentially perilous time. Today the industry lacks sufficient incremental supply of one of its essential raw materials – spectrum. Based on a review of recent forecasts, one can reasonably draw the conclusion that mobile broadband networks will hit capacity shortages **by the middle of the decade** unless steps are taken to secure the additional spectrum needed.

Such steps need to be taken **today** to avoid these risks. Helpfully, the industry has a long history of driving innovation in radio access technologies, from EDGE through HSPA to LTE, allowing it to exploit spectrum assets as intensively as possible. In parallel, the industry also has invested billions in building cell sites to enhance network coverage and capacity. Such steps will continue to be needed, and there is no indication of deployment slowing.

At the same time, additional spectrum for mobile broadband is vital. Countries must begin now to plan for the future, in order to preserve the promise of the *mobile miracle.* Historically, spectrum allocations can take at least 5 years, and often longer, to effectuate.

4G Americas offers the following guideposts to aid stakeholders in the region in working together to secure a bright mobile broadband tomorrow.

1. *Well Considered Spectrum Allocation Policies are Imperative*
    A. *Configure Licenses with Wider Bandwidths*
    B. *Group Like Services Together*
    C. *Be Mindful of Global Technology Standards*
    D. *Pursue Harmonized/Contiguous Spectrum Allocations*
    E. *Exhaust Exclusive Use Options Before Pursuing Shared Use*
    F. *Not All Spectrum is Fungible – Align Allocation with Demand*
2. *Market oriented spectrum assignment approaches work – spectrum caps should be disfavored.*
3. *There is no time to lose – spectrum allocations can take years to effectuate.*

4G Americas members, as well as its member companies, stand prepared to aid stakeholders in securing the promise of mobile broadband.

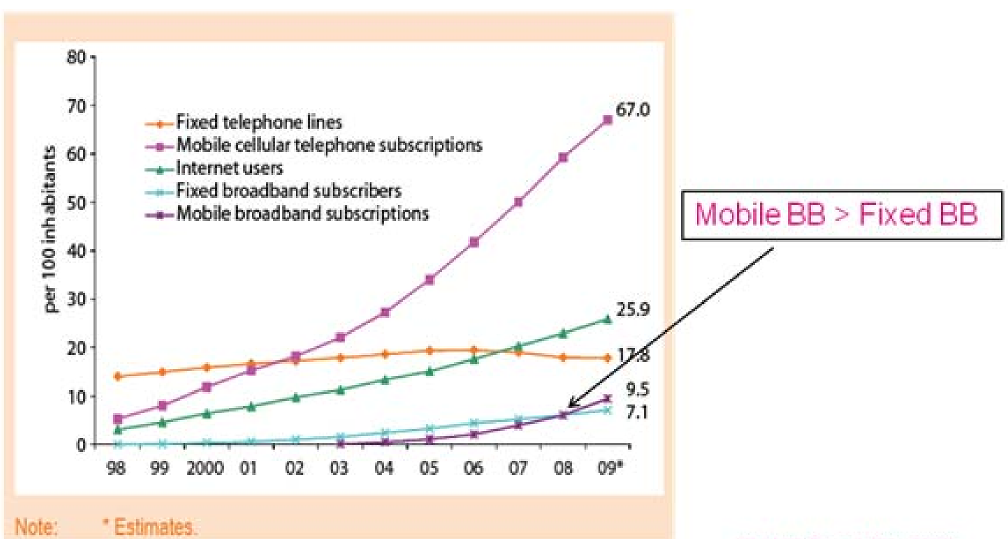
2. INTRODUCTION

2.1 THE 'MOBILE MIRACLE'

It is nothing short of a "mobile miracle." So remarked the International Telecommunications Union ('ITU'), an agency of the United Nations, in a May 2010 report on measuring the global Information Society. Taking note of the astounding developments in the growth of mobile broadband, the ITU stated that:

> "Promising developments are currently taking place in the mobile broadband sector. The introduction of high-speed mobile Internet access in an increasing number of countries will further boost the number of Internet users, particularly in the developing world. Indeed, the number of mobile broadband subscriptions has grown steadily and in 2008 surpassed those for fixed broadband. At the end of 2009, there were an estimated 640 million mobile and 490 million fixed broadband subscriptions."

The ITU highlighted that mobile broadband subscriptions now materially surpass fixed broadband subscriptions, and provided the following graphic punctuating this inflection point:



(ITU MIS Report, May 2010)

Prior to delving into these trends in more depth, it is instructive to pause to reflect on the significance of these trends for our society and its development. Specifically, why is it important to nurture mobile broadband[1] deployment?

2.2 WHY IT MUST BE NURTURED

As the United Nations Conference on Trade and Development ('UNCTAD') succinctly phrased matters, the benefits of broadband for social and economic development are "well acknowledged."[2] It references the frequently cited World Bank finding that, in low- and middle-income countries, every ten percentage point increase in broadband penetration corresponds to an increase in economic growth of 1.38 percentage points; double that of high income countries.

More precisely for present purposes, UNCTAD notes that --

> Wireless offers a *more practical* broadband entry point for developing nations. Installation costs are lower than fixed broadband and for mobile broadband, countries can leverage existing networks.

Most nations in Latin America and the Caribbean are faced with the urgent need to reduce the digital divide by increasing broadband penetration. At best, broadband penetration hovers around ten percent. In contrast, wireless penetration for basic voice and data services already reaches 95% in the region, and has surpassed 100% in several countries.

As a result, mobile broadband is likely the optimal – sometimes the only – enabler of Internet connectivity for residents of the region. Encouragingly, in burgeoning Latin American economies such as Argentina, Brazil, Chile, Colombia, Mexico and Uruguay, growth in mobile broadband has exceeded the rate of broadband access provided by fixed networks during the last twelve months.

Mobile broadband is already contributing significantly to the GDPs of emerging countries. Globally, the economic boost to the GDPs of these nations is estimated at US $300-$400 billion,

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[1] By 'mobile broadband' we refer to networks, devices, and services powered by contemporary high speed mobile data networks (principally HSPA+ and LTE).

[2] UNCTAD, Information Economy Report 2010 at pages 24-25, http://www.unctad.org/Templates/webflyer.asp?docid=13912&intItemID=1397&lang=1.

and represents 10-14 million jobs. In Latin America, comparable figures are US $50-70 billion and an additional 1.1-17 million jobs.[3]

Thus, the trends evident in other developing countries are manifested in Latin America as well. In due course, as characterized by Professor Gerald Faulhaber of the Wharton School, "[M]obile will become the portal of choice to the Internet for most of the world's population."[4]

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[3] Navigant Economics Presentation to Wireless Communications Association International, 26 February 2010.
[4] Gerald Faulhaber, "Mobile Telephony: Economic & Social Impact" (4 February 2010), http://regulation2point0.org/wp-content/plugins/download-monitor/download.php?id=25.

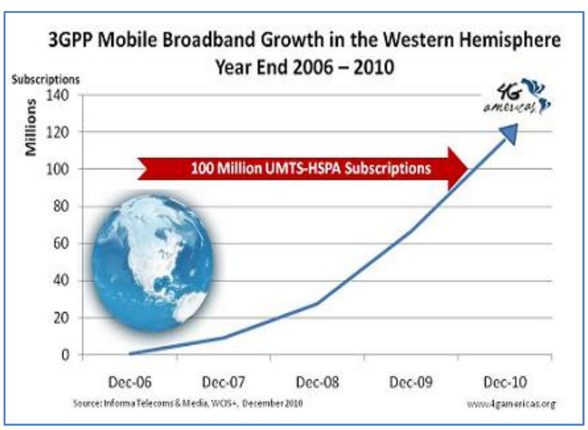
3. SPECTRUM FOR MOBILE BROADBAND

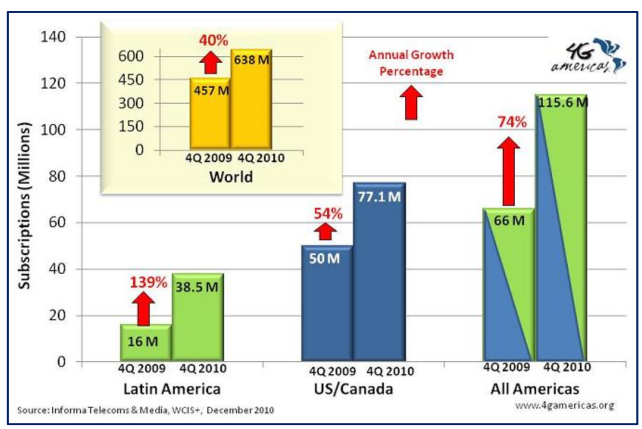
3.1. SPECTRUM DEMAND

3.1.1 MARKET OVERVIEW

The market in the Americas for mobile broadband is in rapid ascent. Based on the most recent subscription data from Informa, UMTS-HSPA is the fastest-growing mobile technology in the Americas (North America, Latin America and the Caribbean), with subscriptions of 116 million at the end of 2010. Operators continue to deploy HSPA, the world's most popular mobile broadband technology, with a total of 77 commercial networks in 29 countries throughout the region.[5]

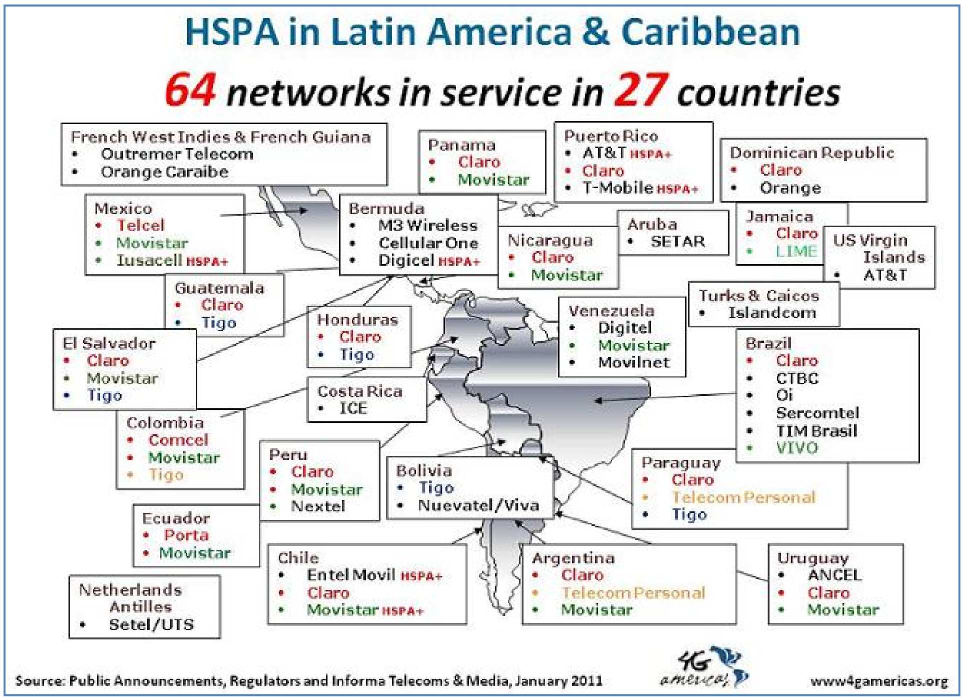
The rate of growth, quarter over quarter, for UMTS-HSPA at the end of December 2010 was 54% for the US & Canada (77 million total subscriptions) and 139% for Latin America (38 million total subscriptions). Both rates of growth surpassed the global quarter-over-quarter rate for UMTS-HSPA subscriptions of 40%. The combined quarter over quarter growth rate for the hemisphere at the end of December 2010 was 74%. These trends are depicted in the charts below.





5 4G Americas, 3GPP Mobile Broadband Technologies Lead the Way in the Americas, Press Release (14 March 2011), available at http://www.4gamericas.org/index.cfm?fuseaction=pressreleasedisplay&pressreleaseid=3076.

Supporting this growth is the growing number of commercial HSPA networks in the region. Presently there are 13 commercially deployed UMTS-HSPA networks in the U.S. and Canada, including 5 HSPA+ networks. In Latin America and the Caribbean, there are 64 HSPA networks commercially deployed in 27 countries, including seven HSPA+ networks, as depicted below.

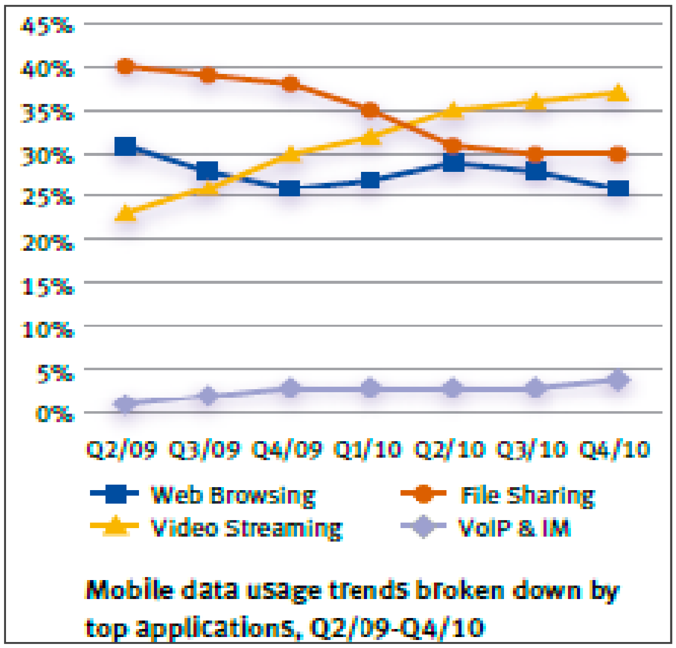


LTE networks are emerging as well. In the second half of 2010, Verizon Wireless and MetroPCS launched LTE service in the United States. AT&T is expected to launch LTE mid-2011. In Latin America, according to Maravedis Research, momentum is beginning to build as well. By the end of 2011, Maravedis expects there will be more than 20 LTE commitments, an additional 7 LTE trials will be conducted (in addition to the 7 that have been conducted already), and there may be up to 4 operators with commercial launches of the technology. Maravedis also expects that by 2014-2015 more than 25 operators will have commercial LTE services.[6]

[6] Maravedis Research, 26 January 2011.

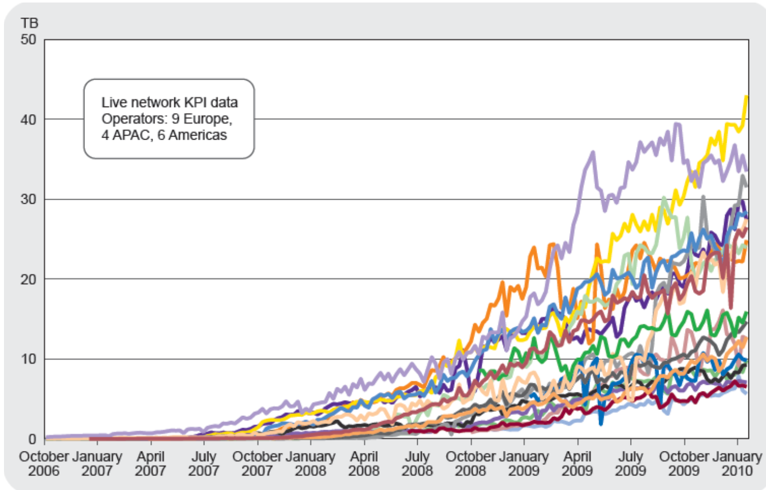
3.1.2 GROWTH IN USAGE

In its most recent Global Mobile Broadband Traffic Report, published in February 2011, Allot Communications calculates that mobile data bandwidth usage grew by 73% in the second half of 2010, culminating in an overall annual growth rate of 190% for 2010. Over one third of global mobile data bandwidth consists of video streaming, while file sharing and web browsing represent another 30% and 26% of global mobile bandwidth, respectively. The following chart further illustrates these trends, including the clear upswing in video streaming over the past two years.



[Source: Allot Communications, February 2011]

The Americas is not immune from the impacts of subscriber, device and usage growth rates on mobile broadband networks being exhibited in other regions of the world. The snapshot below of network key performance indicators ('KPIs') from Asia-Pacific ('APAC'), Europe and the Americas provides a glimpse of the accelerating levels of traffic being carried by mobile broadband networks from just before January 2007 (roughly a year following the first global launch of a wide-scale HSDPA network by AT&T, then Cingular, during 2005) to January 2010.



[Source: Nokia Siemens Networks, 2010]

In its most recent *The State of the Internet* Report, for Q32010, Akamai provides additional insight on traffic growth in the hemisphere. Its analysis of consumption on mobile networks worldwide spans 111 providers, including 29 operators from 14 countries in the region (Argentina, Bolivia, Brazil, Canada, Chile, Colombia, El Salvador, Guatemala, Netherland Antilles, Nicaragua, Paraguay, United States, Uruguay, and Venezuela). Overall, data consumption on mobile networks grew quarter over quarter for 101 of the 111 operators, including five operators for which usage more than doubled quarter over quarter.[7]

Looking towards the future, IDATE estimates that total mobile traffic will reach more than 127 exabytes[8] ('EB') globally in 2020, increase over 2010 levels by a factor of 33.

Total mobile traffic (EB per year - World)

	2010	2015	2020
Europe	1.03	10.88	28.15
Americas	0.78	9.84	27.33
Asia	1.65	16.31	43.85
Rest of the world	0.41	8.22	28.48
World	3.86	45.25	127.82

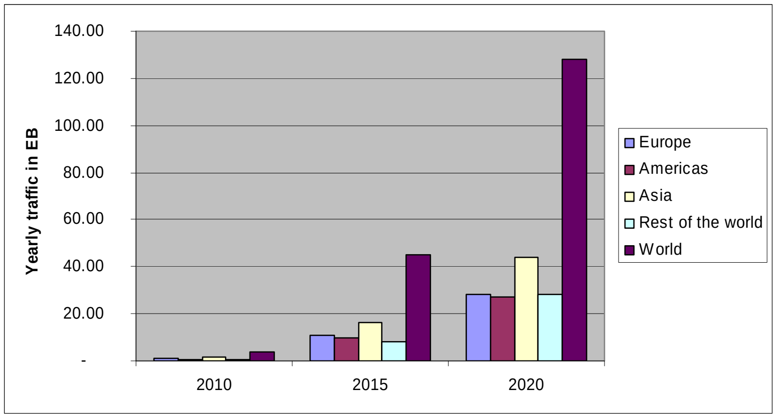
[Source: IDATE, January 2011]

[7] Akamai, The State of the Internet - 3rd Quarter, 2010 Report (January 2011) at page 27.

[8] An Exabyte is 10^{18} bytes, or as RTT memorably explains, equivalent to "all the words ever spoken by mankind."

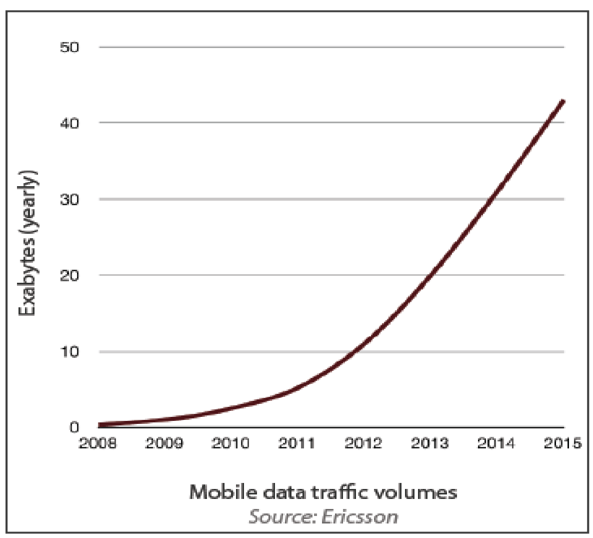
By 2020 Asia will represent 34.3% of total world mobile traffic, Europe 22% and the Americas 21.4%, according to IDATE and as portrayed below.

Total mobile traffic (EB per year - World)



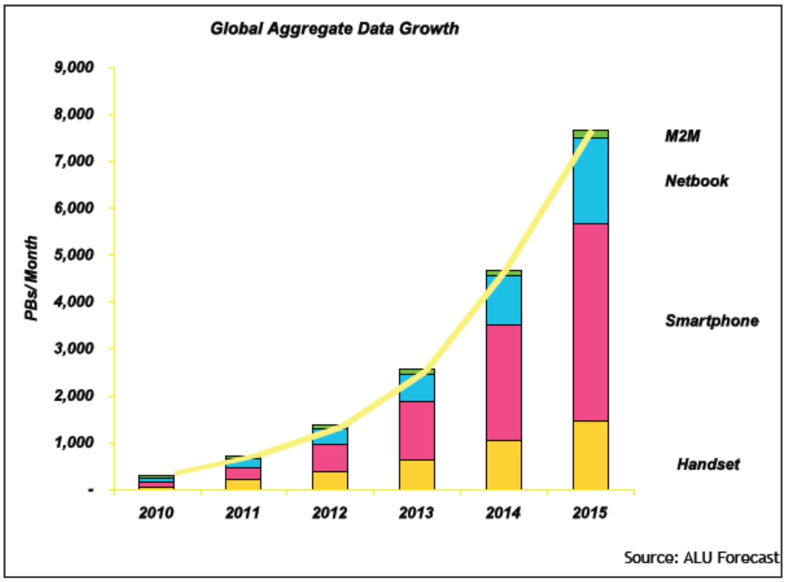
[Source: IDATE, January 2011]

Ericsson has recently estimated similar growth rates as IDATE for mobile data on a global basis for the upcoming 5 year period. Both firms forecast annual global mobile data traffic volumes in excess of 40 exabytes per year by 2015. Ericsson's projection is depicted in the graph below.



[Source: Wireless Intelligence, February 2011]

On the other hand, Alcatel Lucent forecasts even higher global mobile data volumes by 2015. It predicts a twenty fold growth in global mobile traffic by 2015 to 8,000 petabytes (or 8 exabytes) per month, or 96 exabytes on an annualized basis.[9] Alcatel Lucent's forecast, as depicted below, is fueled in significant part by expanding smart phone data growth over the period.



[Source: Alcatel-Lucent, February 2011]

The divergence in these figures is less important than their directionality and even more critically their drivers. Regarding the latter point, underneath these trends lie a variety of factors motivating a growing number of users to intensify and diversify their use of mobile broadband. The increase in both the number and capability of mobile broadband networks over the past couple of years as one driver is a given. Powerful new handheld devices and richer content and applications are additional factors. Finally, as 'connected devices' increasingly penetrate the subscriber base, the number of devices 'per head' will also add to the total traffic on the network.[10]

Considerations such as devices, mobility, and rich applications are not simply additive, but work synergistically in a way that compounds the impact on mobile broadband networks more than

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[9] RTT's forecast of data volume is on the high side as well, predicting 87 exabytes of offered mobile data traffic globally by 2015. *See* RTT, *LTE User Equipment Efficiency & Network Value*, at page 4.

[10] Credit Suisse (6 February 2011) estimates that the number of devices per unique user in the United States will climb from 1.2 in 2009 to 3.9 in 2015, as consumers add mobile broadband enabled laptops, tablets and connected devices to their device collections.

just considering these factors in a mutually exclusive manner. For example, Facebook currently reports that there are more than 200 million active users accessing the site through their mobile devices, and that people using Facebook on their mobile devices are twice as active on Facebook as non-mobile users.[11]

Moreover, high end devices continue to have distinct, multiplicative impacts. For example, Cisco's most recent Global Mobile Data Traffic Forecast Update (2010-2015), released 1 February 2011, documents that relative to non-smart phones, the multiplier for high end device usage in 2010 as follows: smart phones (24x); handheld gaming console (60x); tablet (122x); mobile phone projector (300x); and laptop (515x).[12] These multiplicative effects will persist through 2015 for all categories of devices, according to Cisco, as illustrated in the following chart listing average traffic per device (MB/month).

Device Type	2009	2010	2015
Non Smartphone	1.5	3.3	54
E-reader	5	11	245
Smartphone	35	79	1,272
Portable Gaming Console	Not Available	250	879
Tablet	28	405	2,311
Laptop and netbook	1,145	1,708	6,522
M2M module	3	35	166

[Source: Cisco VNI Mobile, February 2011]

With respect to what consumers are using mobile broadband capacity for, North American and Latin American consumers exhibit important similarities and a few interesting differences. According to Sandvine's most recent Global Internet Phenomena Report (Fall 2010), the top two mobile application categories in North America and Latin America during 'peak periods' when bandwidth utilization is the heaviest are 'Real-Time Entertainment' (consisting of applications and protocols permitting 'on demand' entertainment consumed as it arrives), and web browsing. This continues the trend in the data seen in 2H2009. Interestingly, while P2P filesharing profiles are falling in both regions, the relative proportion in Latin America is about three times the proportion in North America. The following charts illustrate these trends.

[11] http://www.facebook.com/press/info.php?statistics

[12] Cisco VNI: Global Mobile Data Traffic Forecast Update (1 February 2011) at page 7.

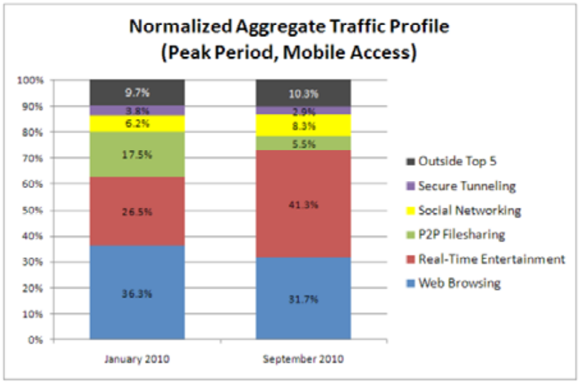


Figure 8 - North America - Normalized Aggregate Traffic Profile Comparison (Peak Hours, Mobile Access)

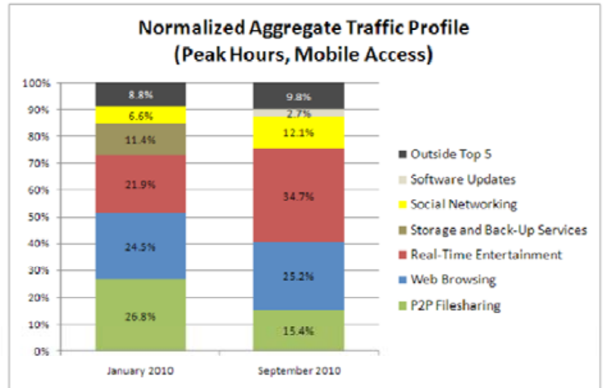
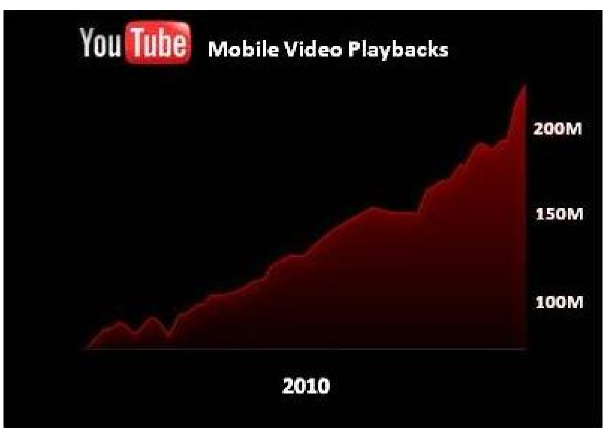


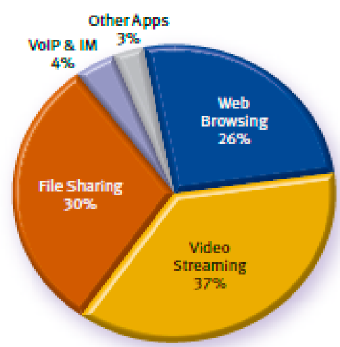
Figure 18 - Latin America - Normalized Aggregate Traffic Profile Comparison (Peak Hours, Mobile Access)

[Source: Sandvine, October 2010]

Further expounding on these trends, T-Mobile USA CTO Neville Ray recently noted that the amount of data consumed by subscribers on T-Mobile's network is doubling every seven months, and that video use tripled on its network in 2010.[13] Interestingly, the latter figure coincides with Google's recent disclosure that YouTube now exceeds 200 million views a day on mobile, a 3x increase in 2010.[14] Allot Communications also illuminates this trend by observing that YouTube is responsible for an astounding 17% of overall global mobile data bandwidth. The latter two trends are further visualized below.



[Source: YouTube, January 2011]



Mobile data usage broken down by top applications, H2/10

[Source: Allot, February 2011]

Where are all these drivers ultimately headed? In short, an end-state exhibiting the ascendency of the mobile internet. By 2012, according to Morgan Stanley, more smart phones

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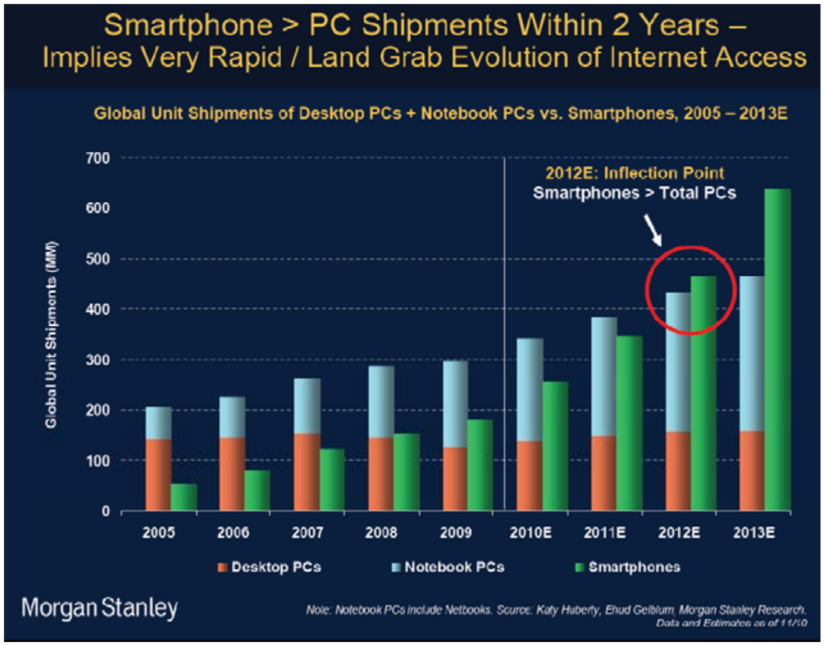
[13] http://gigaom.com/broadband/t-mobiles-hspa-doubling-down-on-speeds-in-2011/
[14] http://youtube-global.blogspot.com/2011/01/music-videos-now-on-youtube-app-for.html

will be shipped than PCs (including netbooks and notebooks). This reflects an 'inflection point' according to Morgan Stanley, suggesting the onset of a fundamental shift in how the typical consumer will be accessing the Internet in the coming years.



[Source: Morgan Stanley, November 2010]

Providing an appropriate coda for this inflection point, Ericsson observed at the recent Mobile World Congress that it expects mobile broadband subscribership to reach 1 billion in 2011, and potentially 4-5 billion by 2015-16 (out of a total of 7-8 billion total global mobile subscribers). Ericsson also anticipates that mobile data growth usage by 2015 will attain such levels as to come full circle with typical usage levels on PCs.[15]

[15] Morgan Stanley, Ericsson, Quick Comment: Feedback from MWC, 4 February 2011.

3.2 SPECTRUM REQUIREMENTS

"If you don't know where you are going you might wind up someplace else."

- Yogi Berra

Predicting the future carries obvious risks, and predicting future spectrum requirements is not immune from this reality. Yet, the effort needs to be made - while the future may be unknowable, nevertheless it can be shaped and influenced. The effort to quantify the incremental spectrum needed to support mobile broadband's continued vibrancy is a critical exercise, even if it is an imprecise one.

At a conceptual level, spectrum forecasts require data and assumptions in the following areas:

- **Available spectrum**: current and foreseen levels of allocations for the relevant study period, tempered by the industry structure (e.g. operator market shares; incumbent versus entrant status, etc.)
- **Traffic demand**: typically parameterized in terms of 'peak' or 'busy' hour throughput required, and highly sensitive to user profiles, devices in use, and services demanded
- **Network design**: assumptions related to the network architecture, encompassing such factors as spectrum portfolio (e.g. high versus low bands), subscriber demographics (rural versus urban versus suburban), network topology (e.g. cell densities, degree of utilization of offloading via femtocells and/or Wi-Fi, etc.); radio access technology (e.g., EDGE, HSPA, HSPA+, LTE, etc.)
- **Network Costs**: estimations of RAN CAPEX and OPEX levels required for a given network design, including potential spectrum costs, which factors into investment considerations, that is, tradeoffs among various options to address future capacity needs (e.g. cell splits versus. additional spectrum purchases)

Spectrum forecasts are complicated and highly detailed undertakings, involving the development of complex demand/capacity models based on the above factors. For purposes of this paper, we have not undertaken our own forecast, but have chosen to survey and summarize the findings of recent forecasts conducted at a global or national level, and to draw reasonable inferences from this effort. The summary and distillation of key points follows.

3.2.1. ITU-R M.2078 (2006)

ITU-R M.2078, published in 2006, is probably the most frequently cited long term spectrum forecast for the mobile industry. The ITU undertook to determine how much spectrum would be needed per country in the years 2010, 2015 and 2020. The table below summarizes the results of the ITU's analysis, which are broken down by 'higher' or 'lower' market development status compared to a single 'global common market,' as well as by Radio Access Technology Group (RATG). RATG 1 covers preIMT and IMT, as well as enhancements to IMT, and RATG 2 is comprised of IMT-Advanced.

Market setting	**Spectrum requirement for RATG 1 (MHz)**			**Spectrum requirement for RATG 2 (MHz)**			**Total spectrum requirement (MHz)**		
Year	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**	**2010**	**2015**	**2020**
Higher market setting	**840**	**880**	**880**	**0**	**420**	**840**	**840**	**1 300**	**1 720**
Lower market setting	**760**	**800**	**800**	**0**	**500**	**480**	**760**	**1 300**	**1 280**

[Source: ITU-R M.2078, 2006]

The ITU concluded that total spectrum requirements for the higher market setting would be 840 MHz by 2010, 1300 MHz by 2015 and 1720 MHz by the year 2020. Even for the situation in which a lower level of market development is assumed, the ITU projected total spectrum requirements of 760 MHz by 2010, 1300 MHz by 2015 and 1280 MHz by 2020.[16]

Extrapolating from the ITU's forecast, in 2007 the NGMN Alliance (a global coalition of operators, industry partners, and academic advisors) determined what the net spectrum requirement would be, based on existing allocations, in each of the three ITU regions. The following chart presents the NGMN Alliance's findings, which in summary are that between 500 MHz and 1 GHz would be needed depending on region by 2020.[17]

		Region 1		Region 2		Region 3	
Market Setting	Predicted total (MHz)	Identified (MHz)	Net additional (MHz)	Identified (MHz)	Net additional (MHz)	Identified (MHz)	Net additional (MHz)
Low	1 280	693	587	723	557	749	531
High	1 720	693	1 027	723	997	749	971

[Source: NGMN Alliance, June, 2007]

16 *Estimated Spectrum Bandwidth Requirements for the Future Development of IMT-2000 and IMT-Advanced*, Report ITU-R M.2078 (2006).

17 *Spectrum Requirements for the Next Generation of Mobile Networks,* NGMN Alliance (20 Jun. 2007) at p. 22, available at http://www.ngmn.org/uploads/media/Spectrum_Requirements_for_the_Next_Generation_of_Mobile_Networks.pdf.

3.2.2 NATIONAL BROADBAND PLAN (2010)

In March 2010, the US Federal Communications Commission (FCC) released its National Broadband Plan (NPB), a report mandated the previous year by the US Congress. Among other matters, the NPB described the critical role that mobile operators will play in meeting US broadband objectives through the remainder of the decade, as well as the incremental spectrum requirement that mobile operators will require in order to do so. [18]

In short, the NPB concluded that the US Government should make 500 MHz of new spectrum available for broadband within the next ten years, of which 300 MHz should be made available for use within five years. Further, pursuant to an Executive Memorandum to federal agencies issued in June 2010, U.S. President Obama directed agencies to work to secure this incremental 500 MHz of spectrum in a timely fashion.[19]

The FCC published a technical paper*, Mobile Broadband: the Benefits of Additional Spectr*um,[20] in October 2010, the goal of which was to make a "reasonable demonstration that mobile data demand is likely to exceed capacity under current spectrum availability in the near-term." The FCC's conclusions were three-fold:

- It is likely that mobile data demand will exhaust spectrum resources in the next five years;
- A spectrum deficit approaching 300 MHz is likely by 2014[21]
- A narrowly circumscribed estimation of the economic benefit from releasing additional spectrum (that is the avoidance of unnecessary costs in satisfying mobile data demand) is likely to exceed $100 billion (USD).

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[18] National Broadband Plan, Chapter 5: Spectrum (March 2010), http://www.broadband.gov/plan/5-spectrum/#_edn67.

[19] http://www.whitehouse.gov/the-press-office/presidential-memorandum-unleashing-wireless-broadband-revolution

[20] http://download.broadband.gov/plan/the-broadband-availability-gap-obi-technical-paper-no-1.pdf

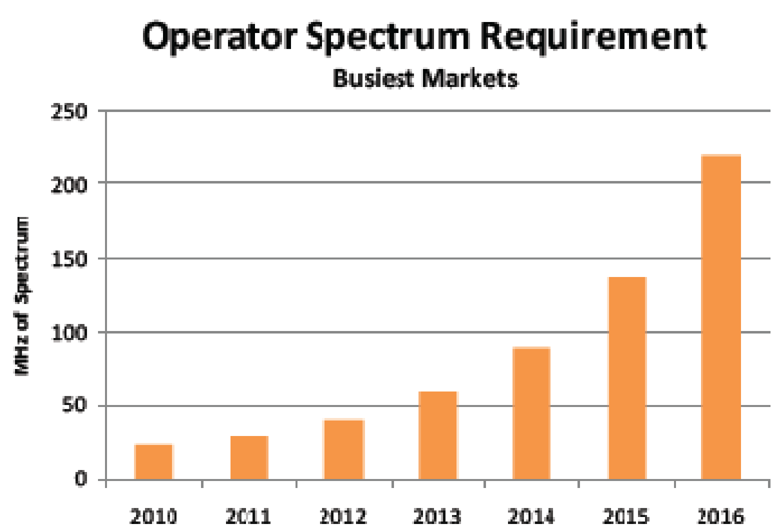
[21] Credit Suisse's May 2010 analysis of the NPB further demonstrates the looming spectrum gap. Using the FCC's assumed rate of increase in data consumption and interpolating to 2015 (yielding a 72x increase in data consumption by 2015), 300 MHz incremental spectrum (1.6x increase over current levels), and accounting for improvements in utilization and spectral efficiency, 65% of future demand would still be unmet. "It is hard," Credit Suisse argues, "to imagine that these capacity gains can be achieved by further cell splitting." Credit Suisse, *Telecom Industry Themes: Profiting from the Spectrum Crisis*, 24 May 2010, at pages 4-5.

3.2.3. MOBILE BROADBAND CAPACITY CONSTRAINTS (RYSAVY RESEARCH)

In February 2010, Rysavy Research published *Mobile Broadband Capacity Constraints & the Need for Optimization*,[22] a report which included results of a spectrum demand modeling exercise suggesting that "many operators' spectrum could be consumed within three to five years."

The model is based on an examination of how much data users consume in a month, which depends in part on the type of device. It calculates the bit-per-second load per broadband subscriber per device type during the busiest times of the day. The model then multiplies the per-user traffic amount by the number of mobile broadband users in a typical cell sector to obtain a total data load in that sector. Then, knowing the spectral efficiency of the technology being used, the model determines the amount of spectrum needed to support that load. The model makes certain projections to account for growth in mobile broadband usage and increases in spectral efficiency over time, and calculates the amount of spectrum that a large operator would need to support the given demand or total data load in a sector.

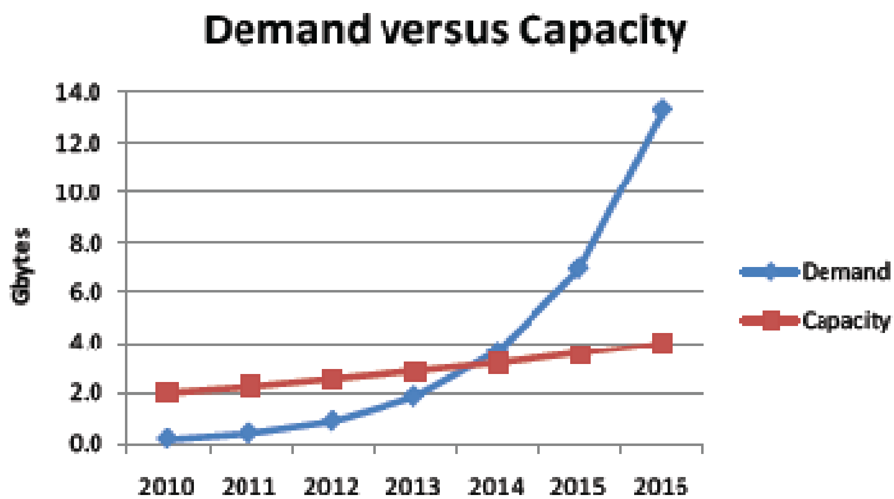
The following chart depicts the amount of spectrum an operator would require in its busiest markets to meet forecasted demand.



[Source: Rysavy Research, February 2010]

[22] http://www.rysavy.com/Articles/2010_02_Rysavy_Mobile_Broadband_Capacity_Constraints.pdf

Another way to consider this trend, according to the report, is to compute average data usage across all subscribers and then compare that with the average capacity for each data user, using a generous assumption that an operator has 50 MHz of spectrum (25 MHz + 25 MHz) deployed for just broadband data services (10-20 MHz of spectrum for broadband is more common for the typical operator today).



[Source: Rysavy Research, February 2010]

These results are broadly consistent with the FCC's conclusion in its October 2010 technical paper, noted above, that demand is likely to outstrip supply by 2015, if not earlier, in the absence of incremental spectrum.

3.2.4. SPECTRUM MARKETS: MOTIVATIONS, CHALLENGES, AND IMPLICATIONS (2010)

Professors Berry, Honig and Vohra of Northwestern University, writing in the November 2010 issue of *IEEE Communications* Magazine, outlined a vision of an expansive two-tier spectrum market (consisting of a secondary market for owners trading spectrum assets and a spot market for limited duration rentals at particular locations). A fundamental premise to the workability of such a market is, according to the authors, the assumption that spectrum is indeed a scarce resource. To test this hypothesis, they estimated the achievable rate per user assuming all spectrum assigned to non-government services between 150 MHz and 3 GHz in the United States is available for mobile broadband access. The total bandwidth is 1,018 MHz, and the specific spectrum bands are provided in the following table from the article.

Broadcasting TV (total: 348 MHz)	174–216 MHz, 470–608 MHz, 614–764 MHz, 776–794 MHz
Fixed, Mobile, Satellite, Amateur (total: 669.7625 MHz)	150.8–157.0375 MHz, 157.1875–162.0125 MHz, 173.2–173.4 MHz, 450–460 MHz 764–776 MHz, 794–902 MHz, 928–932 MHz, 935–941 MHz, 944–960 MHz 1390–1395 MHz, 1427–1429 MHz, 1850–2025 MHz, 2110–2200 MHz 2300–2310 MHz, 2385–2417 MHz, 2450–2483.5 MHz, 2500–2655 MHz
The table is based on U.S. Frequency Allocation Table as of October 2003, and includes all non-Federal Government exclusive spectrum between 150 MHz and 3 GHz. The total bandwidth shown in the table is 1.018 GHz.	

[Source: IEEE Communications Magazine, November 2010]

The authors do not go so far as to establish specific levels of scarcity over time. However, their conclusions are instructive. Based on their modeling, they find that with generous assumptions as to the availability of a managed infrastructure, coordinated frequency reuse, extensive spectrum sharing, relatively small cell radii, and others, data rates in excess of 1 Mbps could in principle be made continuously available to every member of a dense urban populations.

Even so, the authors acknowledge that this rate is “optimistic” as a result of the assumptions made. As a practical matter, they find, a spectrum shortfall is a real risk in the United States, and “demand for spectrum may exceed supply as users, applications and systems proliferate.”

3.3 TAKE-AWAYS

In the preceding section we have reviewed data reflecting the demand for mobile broadband in the Americas. The region is poised for accelerated growth in data being transited over mobile broadband networks. Existing studies of whether these networks will have sufficient capacity to meet burgeoning demand are limited and not susceptible to one-on-one comparison. Some important broad implications can, however, be drawn.

1. DEMAND IS LIKELY TO OUTSTRIP SUPPLY IN SHORT ORDER UNDER A BUSINESS AS USUAL APPROACH.

In the absence of significant actions to address capacity trends, mobile networks are likely to begin experiencing capacity crunches in the next several years. “It is unlikely,” observes Goldman Sachs, “that the current spectrum availability will be able to support the amount of data traffic that is expected to occur.”[23] Credit Suisse recently concluded that, with regard to

[23] Goldman Sachs Equity Research, *LTE: fueling the mobile super cycle; implications across TMT* (9 February 2011) at page 27.

the United States, "demand for wireless capacity will outstrip what can be offered by all spectrum currently available to wireless carriers *by 2013.*"[24]

While the situation may be less well quantified in the rest of the hemisphere, this is not a reason to delay addressing the issue in the rest of the region. As explained further below, other countries in the hemisphere generally begin with a relatively smaller spectrum portfolio for mobile broadband compared to the United States. While demand may empirically be smaller in these countries compared to the United States, it is also true that new spectrum allocations will take considerable time to put to use, including potentially for spectrum whose utilization depends on the broadcast TV analog switch over.

2. THERE IS NO SINGLE PANACEA TO ADDRESSING THIS GAP.

Historically, capacity on mobile broadband networks has been augmented in three basic ways – (1) driving increased spectral efficiency from spectrum allocations (as measured in 'bits per Hz'); (2) increasing the number of sites in the network so as to intensify frequency re-use; and (3) securing additional spectrum.[25]

Network operators have a long history, continuing up to the present, of driving spectral efficiency improvements and investing significant resources to 'densify' their networks. Regarding the former, the evolution of 3GPP technologies from EDGE to HSPA to LTE is reflected in the increasing levels of spectral efficiency over time.[26] This is illustrated in the chart below.

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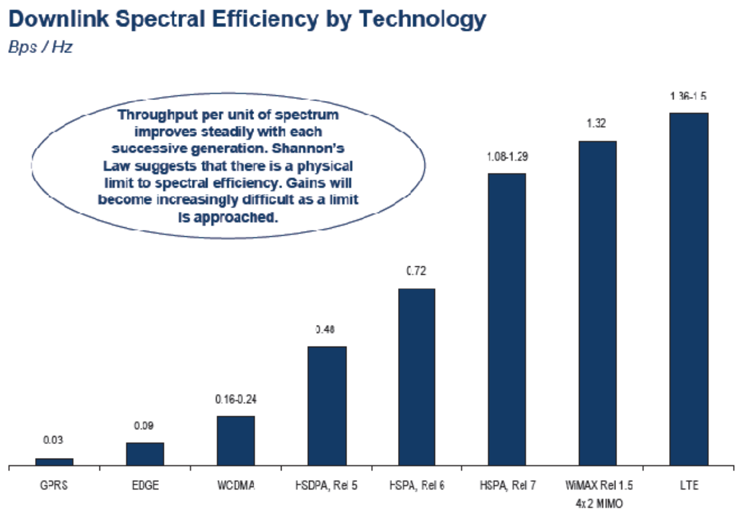
[24] Credit Suisse Equity Research, Clearwire (6 February 2011) at pages 27-28. Credit Suisse forecasts that without additional spectrum data capacity shortfall in the United States would reach 400K terabytes ('TB') per month by 2015. (A TB is 10^{12} bytes.)

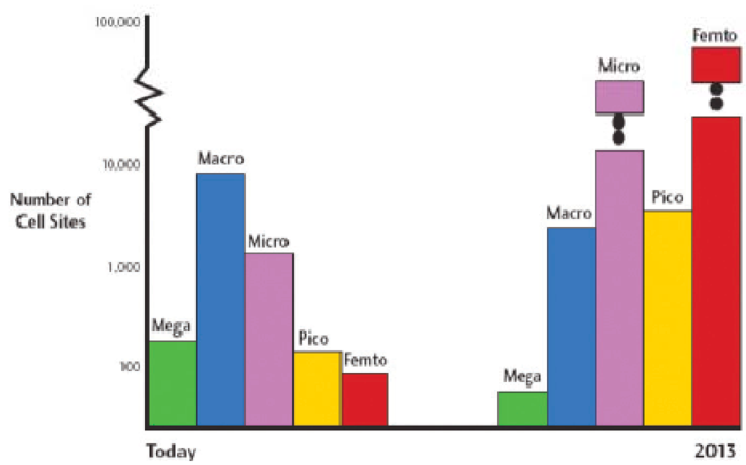
[25] Capacity issues can also be addressed from the demand side, that is, by providing tools and incentives for users to better forecast needs, including usage based service offerings as well as graphical user tools to help consumers monitor and apportion data consumption. This is a potentially important component of addressing capacity shortfalls, but lies beyond the scope of the present report.

[26] Enhancements to the spectral efficiency of HSPA+ and LTE continue unabated, exemplified by the consensus reached at the most recent 3GPP RAN Plenary related to additional feature sets for HSPA+ beyond Release 10. See Draft Report of December 2010 3GPP RAN Plenary, http://www.3gpp.org/ftp/tsg_ran/TSG_RAN/TSGR_50/Report/Draft_Report_RAN_50_friday.zip; 4G Americas, *4G Mobile Broadband Evolution – 3GPP Release 10 and Beyond*, Section 7 (February 2011).



[Source: Credit Suisse, February 2011]

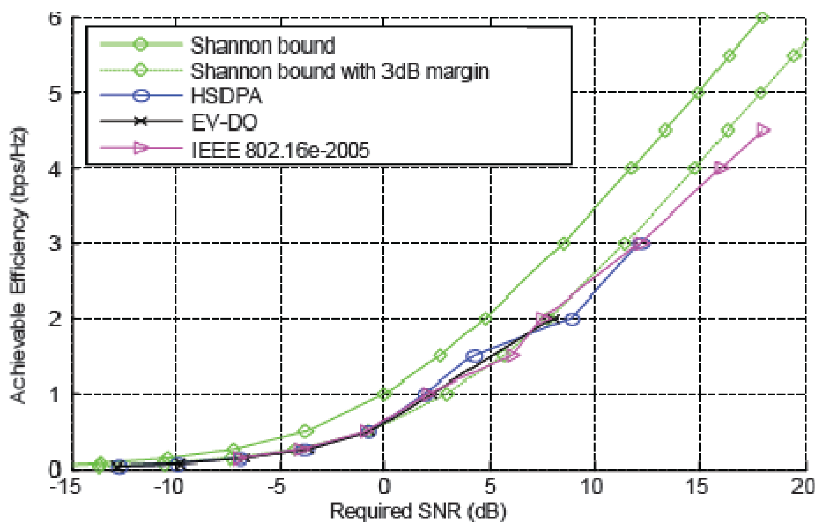
Similarly, topologies for mobile networks have been characterized by an increasing number of smaller sized cells. The trend toward more and more cells with diminishing cell radii is forecast to continue in the near term; Alcatel-Lucent provides one estimate below.



[Source: Alcatel Lucent, June 2010, (based on Yankee Group 2008 analysis)]

Cell densification and spectral efficiency gains are bounded, however, by basic technical and financial realities. Incremental site builds are frequently time intensive, involving additional zoning and/or leasing approvals. By increasing the number of cell edges, operators also risk an increase in the potential for inter-site interference, adding to the complexity and resources needed for RF network design and management. Finally, densification is subject to diminishing returns on invested capital as the number of end users that can be served in a financially prudent way shrinks per cell site as the result of more intensive reuse.

Similarly, the spectral efficiency gains that can be accrued from technology innovation also come with a price. These gains may be accompanied by increased complexity (and attendant costs) in end user devices and network equipment. In addition, technology innovation is subject to diminishing returns in the form of the Shannon Bound. The Shannon Bound is a theoretical limit to the information transfer rate [per unit bandwidth] that can be supported by a given communications link. The bound is a function of the Signal to Noise Ratio ('SNR') of the communications link. As shown in the figure below, current mobile broadband technologies are all within 2 to 3 decibels (dB) of the Shannon Bound, indicating that there is little room for improvement in spectral efficiency, speaking strictly from the perspective of innovations in the radio access technology.



[Source: 4G Americas, September 2010]

The technical and economic limits on cell densification and spectral efficiency as a means to bolster capacity mean that each technique cannot be relied upon individually to address capacity concerns. In fact, there is no single panacea to address future mobile broadband capacity requirements. Both methods will continue to be vital, as will be the importance of additional spectrum allocations, the subject of the next section.[27]

[27] Additional measures to address mobile broadband capacity exist, and these also need to be thoroughly investigated and adopted where appropriate for a given operator. These techniques include but are not limited to: (a) WiFi offloading; (b) femtocells; and (c) application layer compression.

3. SUPPLEMENTAL SPECTRUM ALLOCATIONS ARE A CRITICAL PART OF ADDRESSING THIS GAP.

Each country faces unique circumstances in terms of mobile broadband demand and available spectrum. The common thread uniting all, however, is the looming gap between the two.[28] The Broadband Commission for Digital Development, established last year by the United Nations and UNESCO, perhaps summed it up best in its September 2010 report, *A 2010 Leadership Imperative - The Future Built on Broadband,* when it stated that countries must **"radically** rethink the availability of adequate radio frequency spectrum in the broadband era."[29]

The United States may be an outlier in the hemisphere in terms of the quantity of spectrum allocated to mobile broadband in comparison with other countries, as suggested in the following chart from CTIA – the Wireless Association.

	USA	Japan	Germany	U.K.	France	Italy	Canada	Spain	S. Korea	Mexico
Spectrum Assigned for Commercial Wireless Use	409.5 MHz*	347 MHz	305 MHz	352.8 MHz	374.6 MHz	311.4 MHz	205 MHz	358 MHz	233 MHz	120 MHz
Potentially Usable Spectrum/In the Pipeline***	50 MHz	165 MHz	340 MHz	355 MHz	72 MHz	254 MHz				120 MHz

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

** *Glen Campbell, et al.,* "Global Wireless Matrix 1Q09," Merrill Lynch, June 25, 2009, at Table 1.

****Complete information on "pipeline" spectrum was not available for all countries at the time of filing/publication.*

[Source: CTIA, May 2010]

Note that the chart above does not reflect AWS auctions concluded in Mexico (as well as Germany) last year, or preparations being made in Canada and Mexico to auction spectrum at 700 MHz and elsewhere as spectrum 'in the pipeline.'

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[28] Although the topic of this paper on mobile broadband spectrum, growing data usage particularly from smartphones takes its toll on other parts of the network as well. Smartphones are notoriously "chatty" or in other words demand inordinate signaling resources from the network. This intensifies demand for spectrum, but in addition has capacity implications for network nodes (especially Radio Network Controllers ('RNCs') and Serving GPRS Support Nodes ('SGSNs')) that must process these signals. It may often be the case that these nodes were not dimensioned for the smartphone onslaught when they were installed, meaning that they must be upgraded in order to handle escalating signaling loads. RTT estimates based on present trends that signaling volume in mobile networks will have increased 40% between 2008 and 2012. RTT Economics, *LTE User Equipment, Network Efficiency & Value* (September 2010), at page 45.

[29] The Broadband Commission for Digital Development Declaration and Report (19 September 2010) at page 6 (emphasis added), http://www.broadbandcommission.org/report1/report1.pdf.

Notwithstanding, all countries in the hemisphere will confront a critical decisional juncture in the short term. The NGMN Alliance, as described above, extrapolated from ITU's 2006 spectrum forecast to determine that 500 MHz - 1 GHz of incremental spectrum would be needed by countries in the Americas by 2020, depending on the level of market development.

Observing that congestion on broadband network is set to worsen, ITU Secretary-General Dr. Hamadoun Touré recently called on governments to "take urgent action now to support mobile broadband growth," remarking that steps including "greater spectrum availability" are imperative in order to avoid network bottlenecks.[30] Will countries heed this mobile broadband call to action?

[30] ITU, *Network congestion set to worsen -- ITU calls for international broadband commitment,* 11 February 2011, http://www.itu.int/net/pressoffice/press_releases/2011/01.aspx.

4. SPECTRUM ANIMATING PRINCIPLES

4.1 WELL CONCEIVED SPECTRUM STRATEGIES ARE VITAL

In this section, we describe a set of principles that 4G Americas believes should animate the development of strategies for ensuring the continued vitality of mobile broadband services in the Americas. We present principles in the area of spectrum allocation, spectrum assignment, and timing. Together with these principles, we present specific illustrations of how individual countries have pursued or are pursuing efforts which are generally aligned with these principles. By instantiating these principles, meaningful guidance can be provided on how to bring them to life, to convert words into action.

4.1.1 CORE SPECTRUM ALLOCATION TENETS

Notwithstanding continuing innovation and investment that has led to more intensive use of spectrum assets, suitable and sufficient additional spectrum is critical to meet the growing demand for mobile broadband. 4G Americas believes that the following tenets should animate efforts to allocate spectrum resources. The principles outlined below will further stimulate investments, keep costs down, and ultimately help meet demand for broadband services in a timely manner.

- ***CONFIGURE LICENSES WITH WIDER BANDWIDTHS***

Technologies that support ever more supple mobile broadband capability, such as LTE, will increasingly require wider bandwidth channels to meet consumer demand for bandwidth intensive and content-rich services.[31] Wider spectrum blocks maximize spectrum use by accommodating more bits and allowing more resources to be pooled for sharing among users. Spectrum allocations should therefore be in sufficiently large, contiguous blocks to accommodate the future development of mobile broadband networks. Particularly in urban and suburban areas, allocations should focus, at a minimum, on 2x10 MHz blocks.

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[31] HSPA+ performance can be enhanced by combining two or more 5 MHz carriers in a technique known as *carrier aggregation*. LTE can be deployed in a range of bandwidths from 1.4, 3, 5, 10, 15 to 20 MHz, and can also benefit from carrier aggregation techniques. From a spectral efficiency standpoint, however, carrier aggregation cannot be considered a substitute for wider channels in the first instance.

❖ *GROUP LIKE SERVICES TOGETHER*

Current spectrum allocation frameworks tend largely to compartmentalize spectrum by types of services. The grouping of like services can reduce complexity and cost, and allow more flexibility in the form factor of the subscriber equipment. For example, allocating additional spectrum adjacent to similar services and with similar duplex distances reduces the number of bands that a device must support. Standards development would as a result be accelerated, and existing user equipment would be more easily modified rather than requiring new technology developments, which accelerates the market availability of those devices.

This would be accomplished because the selection of the additional spectrum would not increase the number of bands to be supported in a multiband device. We offer as potentially positive developments in this area two inquiries recently begun by Mexico and the United States to consider allocating additional spectrum for mobile broadband above 1755 MHz and 2155 MHz. These efforts are in alignment with 3GPP Band 10 (the 'extended' AWS Band directly adjacent to 3GPP Band 4), which is harmonized throughout the Americas.[32] Supplementing current allocations in this way would reduce device complexity and cost -- the additional spectrum band can be implemented largely as an extension to an existing band. Designating spectrum for certain services adjacent to like-service spectrum bands, with similar duplex distances, would consequently maximize performance and efficiencies.

❖ *BE MINDFUL OF GLOBAL STANDARDS.*

Technical standards are the foundation for service providers and manufacturers to develop competitive products and services. Further, standards help facilitate regulatory compliance, establish patent policies for use of essential technologies, provide a platform for third party supplier solutions, and serve to energize investment. Finally, standards allow companies to take advantage of economies of scale that lower costs and promote growth, maximizing opportunities for innovation.

In many instances, globally accepted standards are developed with specific spectrum bands in mind, and take into consideration coexistence with adjacent services. Therefore, whether certain spectrum bands have been harmonized and whether a standard exists should be factored into spectrum allocation decision making.

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[32] See http://www.ntia.doc.gov/press/2011/500mhzstatement_02012011.html (NTIA announces 31 January 2011 that it will begin detailed analysis of whether government spectrum at 1755-1850 MHz can be repurposed for commercial broadband use); http://www.cft.gob.mx/es/CofetelCofetel_2008/Reporte_Consulta_Publica_Espectro (Cofetel summary issued 8 February 2010 of public consultation initiated in November 2010 on several spectrum bands, including 1755-70 MHz & 2155-70 MHz—notably, all respondents expressed interest in these bands).

❖ *PURSUE HARMONIZED/CONTIGUOUS SPECTRUM ALLOCATIONS.*

Ensuring that spectrum allocations are, to the greatest extent possible, in accord with international allocations promotes innovation and investment by creating critical economies of scale. Similarly, harmonization facilitates global roaming and helps countries that share borders manage cross-border interference. Without harmonization, new technologies and services can be difficult to export to other markets, and internal markets will fail to benefit from developments in international markets. Fragmented spectrum allocations hamper innovation and require companies to dedicate resources to develop new or adapt existing products or technologies for a single market, rather than sharing those development costs globally. This, in turn, increases the costs and limits the potential availability of products and services for the consumer. Moreover, new/modified technology takes time to commercialize, delaying the availability of services and devices in the market to meet burgeoning mobile data demand.

One of the main reasons OFDM was selected as the multiplexing technique for LTE relates to its ability to substantially increase spectral efficiency when the transmitted RF signal is composed of a relatively large number of orthogonal sub-carriers. The latter requires a relatively large amount of contiguous spectrum. The resulting increase in spectral efficiency is in the nature of a statistical gain, also known as 'trunking efficiency.' Trunking efficiency increases as data for various users are scheduled ('multiplexed') for transmission over larger numbers of sub-carriers, and its magnitude is thus determined by two factors: (a) the robustness of the network scheduling algorithms, and (b) the amount of spectrum the RF signal occupies. From an operational standpoint, OFDM based technologies like LTE can exhibit a significant increase in spectral efficiency if the occupied spectrum is at least 10 MHz (or 10 x 10 MHz if considered on a paired basis).

❖ *EXHAUST EXCLUSIVE USE OPTIONS BEFORE PURSUING SHARED USE.*

The "exclusive use" model refers to a framework in which a licensee has rights that are exclusive, flexible, and transferable, while at the same time inheriting specific responsibilities that come with these rights. In an exclusive rights model, the licensee in some cases can lease some or all of the spectrum usage rights associated with their licenses to third parties. Licensees are also afforded protection from interference and may use the spectrum in a flexible manner consistent with the terms of the license. Moreover, the certainty provided by the exclusive use licensing approach encourages investment by promoting an environment in which interference and system capacity can be predicted.

Successful sharing arrangements must be tailored to the specific conditions in the band, on a band-by-band basis. These conditions must be known at the point of design inception to avoid inappropriate and costly technology development. Because each sharing environment is unique, technology research and development suitable for the services sharing frequency bands and knowledge of the specific sharing constraints are required; otherwise, investment and innovation will be impeded by such operational uncertainties.

Some sharing environments are less constrained than others. These environments are created by grouping like services where technologies and technical rules are similar among operators. For example, a fixed service can be easier to predict and engineer than a mobile service, and with appropriate licensing or notification requirements, can provide regulatory certainty – a prerequisite for investment.

In a spectrum sharing environment, spectral resources are made available based on established technical “etiquettes” or standards that set power limits and other criteria for operation of devices to mitigate potential interference. In addition, the sharing environment must be well understood -- sharing criteria may include geographic ‘protection’ zones, power limits and temporal restrictions. For example, spectrum may not be available at certain times of the day, or may not be used near certain sites, for instance near radar sites.

The uncertainty of spectrum access and potential sharing constraints can translate into higher network costs, and can limit the types of services that can be supported. Thus, proposals for spectrum sharing need to be closely examined, weighing the benefits and opportunities provided with a variety of other factors including service viability, technology support, and adequate knowledge of the operating environment.

- ***NOT ALL SPECTRUM IS FUNGIBLE --- ALIGN ALLOCATION WITH DEMAND.***

Future networks will in all likelihood be ‘networks of networks’ consisting of multiple-access technologies, multiple bands, widely varying coverage areas, all self-organized and self-optimized. [33] Part of the consideration to support the development of such networks and the evolution of data services will be the availability of suitable spectrum, cell site spacing, and increases in spectral efficiency to support an increase in the number of users and an increase in the data throughput available to each user.

Essentially, these networks will need to address **coverage** requirements, that is, adequate service across a broadly defined geographic area. This would include rural and isolated areas where the population density is low. In this case, the ability to provide services more efficiently is enhanced using spectrum with appropriate propagation characteristics, which are characteristic of the lower radio frequencies. There are also specific needs for **capacity**,

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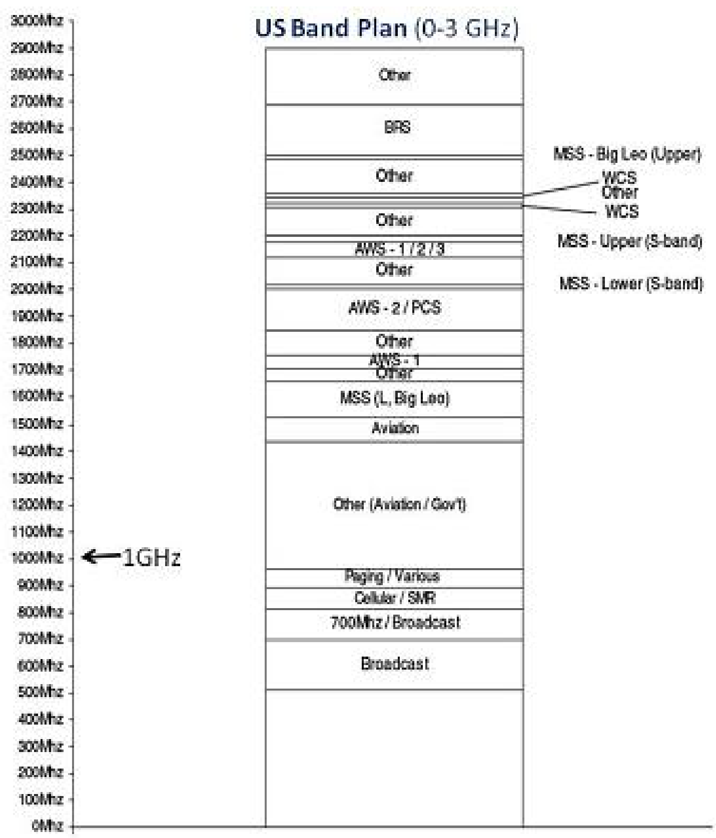
[33] *Transition to 4G: 3GPP Broadband Evolution to IMT-Advanced*, Rysavy Research/4G Americas, Sept 2010, http://www.4gamericas.org/documents/3G_Americas_RysavyResearch_HSPA-LTE_Advanced_FINALv1.pdf.

in which greater bandwidth is needed across a smaller area, but by a number of interests contending for limited spectral resources. This tends to be the case particularly in dense, urban environments. Even with the latest digital air interfaces and other new network features, carriers still need to add new cell sites or purchase additional spectrum to supplement network capacity. [34]

Stated differently, when considering frequency bands and combinations thereof, device manufacturers often categorize bands in terms of "high band" or "low band" designations. High bands are frequency bands above 1 GHz (for example, 1900, 2100, and 2100 MHz); low bands are the frequency bands below 1 GHz (examples 700, 850, and 900 MHz). The higher bands are generally easier to implement in a device in terms of size, as the higher frequency bands require shorter antenna length. The lower bands require longer antennas for optimal performance. In 3G and 4G devices with multiband support, the number of high bands supported always exceeds the number of low bands. See the accompanying chart for US high and low band allocations.



[Source: Credit Suisse, May 2010]

[34] In Focus: The Capacity Challenge , Ross Ernst, TenXc Wireless, *http://connectedplanetonline.com/wireless/technology/infocus_capacity_challenge_112706*

Propagation characteristics are sometimes overlooked, but their impact can be tangible and very significant for overall design and performance. Suitable lower band frequencies can penetrate walls of buildings and have a significant coverage range without requiring the mobile handset to support an unwieldy antenna.

Future IMT-A networks will support 100 Mbps for high mobility and 1 Gbps for low mobility.[35] The spectrum to serve those areas where the demand for services reaches these levels will largely come from higher frequency bands that have adequate contiguous spectrum to support the traffic generated.

The implementation of future networks must support access to communications anywhere, anytime. Therefore these networks will rely on multiple-access technologies supported by a variety of spectrum bands to address both coverage and capacity needs. This will require suitable lower frequencies to support in-building coverage as well as sparsely populated areas, in addition to higher bands supporting capacity objectives through a mix of macro, micro and pico cell deployments.

[35] ITU-R M.1645, Framework and Overall Objectives of the Future Development of IMT-2000 and Systems Beyond IMT-2000 (2003).

4.1.2 SIDEBAR "WHY DOES ALL THIS MATTER?"

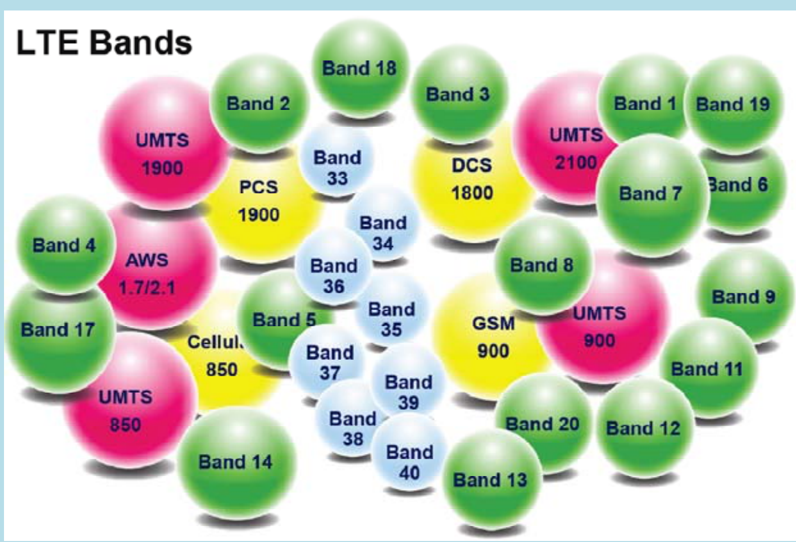
Why Does All This Matter?

The Impact on Devices, Equipment, Cost and Performance

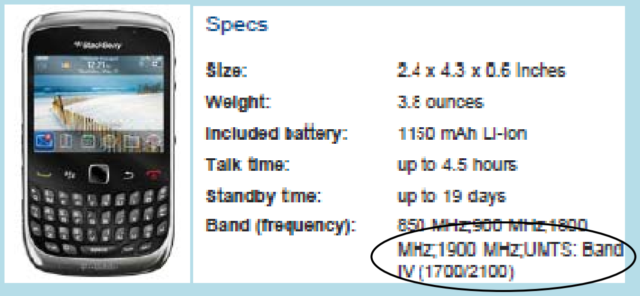
A. Spectrum Band Proliferation/Fragmentation

If one goes back 10-15 years in time, in the context of GSM, device manufacturers only had to consider one or two frequency bands when designing a mobile phone. Multiband GSM devices which allowed for global roaming soon followed in the early 2000s, bringing support for 2-3 frequency bands, typically including a band solely for global roaming. With the mid-2000s came the advent of UMTS/WCDMA technology, creating the need to support "local" 3G frequency bands in a device in addition to the required GSM bands for both local and global roaming use. Not surprisingly, the demand for global roaming with 3G put further pressure for inclusion of additional roaming bands in handsets.

The advent of Long-Term Evolution (LTE) technology will place additional frequency band requirements on mobile device manufacturers, as LTE supports interworking with the legacy technologies. As LTE technology matures and home network coverage increases, device manufacturers will be expected to support the "local" and roaming bands which support this technology as well. This, in practice, could mean supporting two to three additional frequency bands, on top of what is required for the legacy technologies. Currently, over 30 frequency bands are supported in the standards for LTE, as depicted below.



As network capabilities evolve further into the HSPA+ domain and enter the LTE domain, smart phones and their associated features have become a growing area of industry attention and benchmarking. One common benchmark of a mobile device identifies the radio technology supported in a particular frequency band support (see one example below).



[Source: www.t-mobile.com]

On a basic level, this provides an idea of where (or on what network) the device can operate and what level of operation can be supported (e.g. GSM/EDGE versus UMTS/HSPA).

Today, most smart phones support the four GSM/EDGE frequency bands, allowing for support of both local operations and global roaming. The local GSM/EDGE operations in the Americas include mainly the 850 and 1900 MHz bands, and the GSM/EDGE global roaming bands include the 900 and 1800 MHz bands. When considering the 3G band, the focus in the Americas is typically on 2-3 frequency bands. These include the 850 MHz (cellular), 1900 MHz (PCS) and the AWS (1700/2100 MHz) band, depending on the operator's requirements. In cases where global 3G roaming support is desired, the 1900/2100 MHz band prevails, with the 900 MHz band being concurrently supported in some cases.

Consequently, WCDMA/HSPA implementations across the globe have resulted in spectral fragmentation into the aforementioned 5 major bands (850, 900, 1700/2100, 1900 and 2100 MHz bands). In the extreme case, a mobile device capable of supporting the 4 GSM/EDGE bands and 5 WCDMA/HSPA bands would be capable of supporting full 2G and 3G operation on a global level. There are some high-end smart phone devices available which can support this configuration today, but this level of support is certainly not widespread at this time.

Compounding matters, device manufacturers also face the reality that not all frequency bands are "equal" from an implementation standpoint. Considerations here include whether or not the band is a "high band" or a "low band" as well as the spectral proximity of a given band to other bands.

B. Limits on Frequency Band Support

In theory, there is no "hard" upper limit on the number of frequency bands that can be supported in a mobile device. However, there are very pragmatic limits on the number of bands, driven generally by cost, size, and performance issues. An additional frequency band increases the number of RF components required in the device, resulting in bill of material increases as well as additional pressures on limited real estate inside the device.

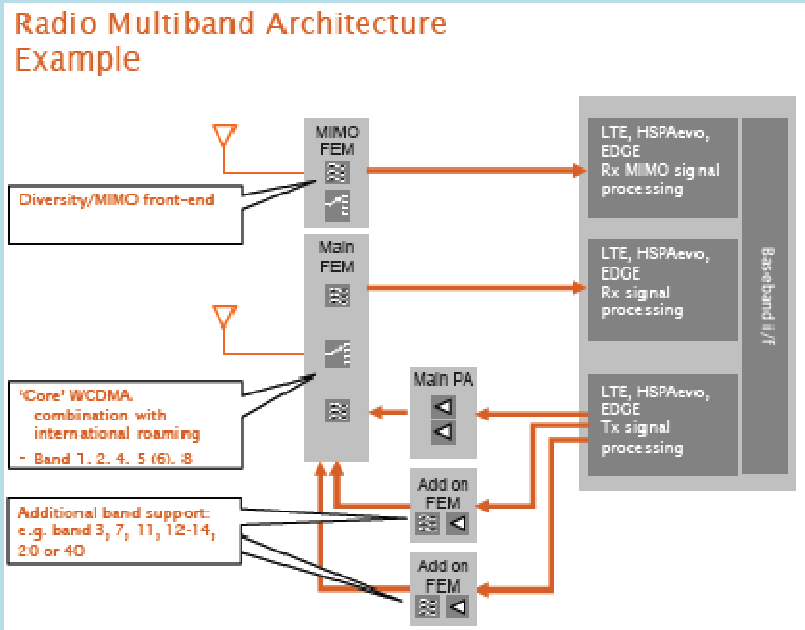
The impact of adding an additional band also depends on what band is being added relative to what other bands are present in the device. If the additional band lies close to an existing band, it may be possible to cover this additional band with some of the same RF components and the existing antenna(s). If the "additional" band is far away from other bands there is a much greater impact on cost and size. New, possibly dedicated RF components must be added and in some cases even an additional antenna (or antennas).

Sometimes, antennas are designed to cover multiple bands in the mobile device where feasible. There can be a performance tradeoff in attempting to increase antenna bandwidth to accommodate new bands. These tradeoffs can be particularly acute if the new band is a "priority" band for the operator, which might otherwise drive device vendors to build narrower antenna bandwidths so as to obtain better over-the-air performance. In this case, the cost versus performance calculation can be particularly vexing for operators and their vendors.

C. Impact on Device Components

(1) Basic Handset Design.

At its most elemental, mobile RF devices consist of one or more "front end modules" ("FEMs") connected to digital baseband units as well as one or more antennas. One representation of a multiband radio design identifying these various components is provided below.



[Source: RTT Economics, September 2010]

The FEMs manage the RF signal paths into and out of the device, and include numerous components such as filters and amplifiers. Many front end functions are analog in nature, as befits the radio waves exiting and entering the device. In contrast, the baseband units perform the complex digital signal processing required to encode or decode RF transmissions according to the technology embedded in baseband chips. Although baseband, FEM and antenna performance are closely interrelated, spectrum fragmentation has comparatively more significance on the design and performance of antennas and FEMs than baseband units, due in no small measure to their dependence on the physical layout of the various device elements.

(2) Antennas.

A critical consequence of spectrum fragmentation relates to the feasibility of manufacturing devices with increasingly more sophisticated antennae technology. For example, the ability for mobile devices using HSPA+ and LTE technologies to provide ever higher data rates over time depends on the incorporation of innovative new techniques. Once such innovation is known as MIMO - "Multiple Input/Multiple Output" - which allows the device to send data to and from the network on parallel data streams, thus boosting the theoretical data rates of these devices. As a design matter, MIMO requires that multiple radio paths be supported within the spectrum bands designated for HSPA+ or LTE. In practice, this means multiple antennas must be implemented in the mobile device for these bands, meaning not only additional antenna elements but also front end components.

Multiple antenna techniques such as MIMO depend on antenna separation, polarization and radiation pattern in order to achieve the best possible performance. If there is "coupling" between the antennas, the positive performance effect of MIMO might be reduced, particularly due to increased losses (i.e., antenna efficiency). The result is sub-optimal performance, with data rates lower than desired, including the possibility of being lower than in the single antenna case.

As a very rough estimate, a minimum 0.15 wavelength separation between antennas is needed to allow a mobile device to achieve its target performance levels. In the case of 700 MHz this would mean a physical separation of approximately 2.5 inches between the antennas. When considering the 1900 MHz band this would translate to roughly 1 inch. Clearly, there is a sizeable difference between these separation requirements when considering support for different spectrum bands and the consequent impact on the size of the device.

Experience from commercial launch LTE networks suggests that MIMO can perform in small mobile device form factors comparably in lower frequencies as in higher frequencies, notwithstanding the need for increased wavelength separations. The problem arises when more and more spectrum bands need to be introduced into the device to provide sufficient bandwidth (as well as for other considerations including roaming and coverage requirements), which presents additional, significant design challenges for mobile devices.

Device manufacturers must also consider the following factors in their device designs when incorporating multiple antenna technologies:

- Frequency band of operation
- Signal to noise ('SNR') targets
- Interference mitigation targets (from users both inside the cell and in adjacent cells)
- Form factor of the device
- Other radios in the device which may include Wi-Fi, GPS, Bluetooth, and FM Radio

When these factors are considered and then extended to include multiple frequency bands of operation, the design equation becomes dramatically more complex. The above considerations all depend to various degrees on the frequency bands employed in the device. The other radios present in a device may operate near one of the required mobile frequency bands, for example, or may require some additional isolation inside of the device from other bands.

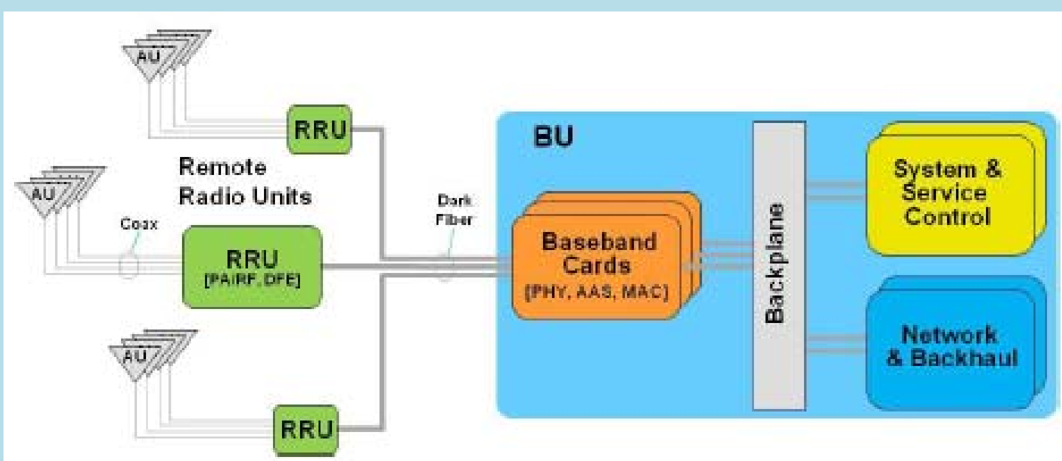
(3) Other Components.

As the band requirements for mobile devices continue to grow, and bands become increasingly fragmented, device manufacturers face growing challenges associated with finding the additional real estate within the device for additional front end components and antennas. The additional front elements do not 'scale' to quite the same degree as baseband units, due partly to their dependence on physical layout and space constraints.

As a result, including new bands in a device adds non-recurring engineering ('NRE') and production costs. This would not prove problematic to the extent the market for the newly designed device was sufficiently large so that the costs could be amortized over a large customer base. However, by definition, devices incorporating non-harmonized spectrum bands will find appeal in only isolated markets, which save for China or India, will almost invariably lack the necessary scale.

D. Additional Band Proliferation/Fragmentation Impacts

It should also not be overlooked that spectrum band proliferation and fragmentation can have impacts on the cost and performance of radio network infrastructure. Existing radios at base stations may need to be upgraded, or entirely new radios may need to be deployed. Increased CAPEX will be required for the new infrastructure, which frequently also entails increased OPEX for servicing and maintaining the equipment. See below for a schematic of modern base station architecture, wherein radios ('remote radio units' or 'RRUs') are increasingly situated closer to the 'antenna units' ('AUs').



[Source: Design Art Networks (2010)]

4.1.3 ILLUSTRATIONS

Mexico

In November 2010, Mexico initiated a consultation to solicit information on the potential to make spectrum available in three bands: 700 MHz, 1.7/2.1 GHz and 3.4-3.7 GHz.[36] With respect to the second category, Cofetel sought specific responses to questions about 1755-70 MHz and 2155-2170 MHz. This 30 MHz is an extension to the 90 MHz of AWS-1 frequencies which were auctioned in 2010. Together, they constitute 3GPP Band X, a band harmonized throughout this hemisphere for HSPA and LTE. The questions were designed to provide input on interest in and optimal uses for the band, device ecosystem and infrastructure readiness, preferred channelization, and possible auction concepts.[37]

Canada

In June 2010, Industry Canada commenced a consultation on the transition to Broadband Radio Service ('BRS') in the 2500-2690 MHz band and associated modifications to the existing band plan. With respect to the band plan, Industry Canada outlines the benefits and disadvantages of two possible options, one consistent with the US allocation and the other consistent with ITU Option 1 and which is being adopted by numerous countries across the globe. Industry Canada concludes by proposing to adopt ITU Option 1 and seeking input on the implications of such a band plan.[38]

Brazil

Anatel is moving to accelerate the process of licensing the 2.5 GHz band, which was recently reserved for mobile telephony service and aligned with ITU Option 1. According to the draft schedule, the auction may occur in early 2011, at least one year ahead of previous forecasts. If the tender takes place in February 2011, LTE networks may be deployed in Brazil by 2013.

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[36] http://www.cft.gob.mx/es/CofetelCofetel_2008/Cuestionario_para_la_banda_1721_GHz (11November 2010). 4G Americas filed comments in support of taking action consistent with the Band X regional harmonization scheme.

[37] As noted earlier in this paper, the United States has recently begun an examination into whether government spectrum at 1755-1850 MHz can be repurposed for commercial wireless broadband use. Such actions could also be synergistic with the Band X allocation in the hemisphere.

[38] IC consultation: http://www.ic.gc.ca/eic/site/smt-gst.nsf/eng/sf09881.html. 4G Americas filed comments in the proceeding, available at http://www.ic.gc.ca/eic/site/smt-gst.nsf/vwapj/dgso-001-10-3GAmericas-comments.pdf/$file/dgso-001-10-3GAmericas-comments.pdf

4.2 MARKET ORIENTED ASSIGNMENT APPROACHES WORK – SPECTRUM CAPS SHOULD BE DISFAVORED.

Since 1998, spectrum caps – the total amount of spectrum that an operator can own – have been applied by Latin American regulators in an attempt to stimulate competition by limiting the ability of the established operators to acquire new spectrum, fueling new entrants to enter the market, and discouraging mergers. The majority of countries in the region have three or four mobile operators competing in the market. With mobile penetration in Latin America above 96%, the region is ripe for the advancement of mobile broadband services. However, such deployment is being constrained by spectrum caps, which creates lengthy delays every time new auctions are planned. Existing operators with cost-efficient access to capital and operational knowledge are often prohibited from participating. Given the degree of competition in countries applying them, caps may not be necessary to ensure a competitive market, and may actually undermine those countries' goals of deploying spectrum-intensive mobile broadband technologies. Caps may discourage operator investment in both urban and rural areas, and raise costs for consumers.

Recent academic work supports these conclusions. Berkeley University Professor Michael Katz summarizes the risks as follows:

> Spectrum caps act as a tax on success and can distort and limit competition. A binding spectrum cap can increase the costs of expansion for a service provider that has developed a successful business model that requires additional spectrum to meet consumer demand for its services. A spectrum cap therefore punishes success and, thus, discourages firms from competing to attract consumers through improved services and lower prices.[39]

Econometric modeling of the impact of spectrum caps in Chile, Argentina and Colombia suggests this very outcome – caps can increase prices and lower service quality, the very objectives presumably disfavored by policy makers. Francisco Marroquín University Professor Wayne Leighton's quantification of the impact of spectrum caps in these markets led to the following conclusions: (a) halving the spectrum available to an operator for LTE from 40 MHz to 20 MHz resulted in a doubling of costs to provide service; and (b) a further halving to 10 MHz

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[39] Declaration of Michael L. Katz, *Public Policy Principles for Promoting Efficient Wireless Innovation and Investment*, in FCC Docket 09-66, 30 September 2009.

led to a further quadrupling of the cost of LTE service. Higher costs invariably lead to lower demand, and hence lower adoption, of mobile broadband.[40]

As the mobile wireless industry moves to the next generation of technologies and services, the spectrum caps of the 1990s seem antiquated and built upon a past era of low penetration voice services. In many countries the old spectrum cap rules are becoming limiting factors to bringing to market new broadband services and applications that would benefit society.

As spectrum regulators review their countries' specific caps, they should consider a few key questions:

1. Does significant and measurable operator competition exist in the marketplace?
2. Is enough spectrum available today for operators to commercially deploy mobile broadband data technologies such as HSPA+ and LTE in the next few years?
3. Is the country proactively aligning with International Telecommunication Union (ITU) or other established guidelines for the amount of spectrum required to foment the next generation of wireless technologies?

The following table shows the current spectrum caps applied in large markets such as Argentina, Brazil, Chile, Colombia, Mexico and Peru.

Selected Spectrum Caps in Latin America

Country	*Current Spectrum Cap, MHz*	*Spectrum update*
Argentina	**50**	Secom announced in June 2010 that would auction 1.7/2.1 GHz soon; most likely will happen in 2011
Brazil	**85**	11 of 13 H-band (20 MHz) lots in 1.9/2.1 GHz won by Nextel. Auction process of 2.6 GHz band defined by Anatel for IMT-FDD and IMT-TDD systems will start 2011-2012
Chile	**60**	Subtel plans to auction 2.3 GHz and 2.6 GHz (LTE) following ITU Option 1 recommendation. Time: 2011
Colombia	**55**	50 MHz in 2.6 GHz awarded July 2010; MINTIC plans new auctions in 1.9 GHz, 2.6 GHz, 1.7/2.1 GHz and 700 MHz
Mexico	**80**	Auction 20 of 30 MHz in 1900 MHz awarded. Auction 21 of 60 MHz in 1.7/2.1 GHz awarded. Cofetel issued a public consultation for 700 MHz, 1.7/2.1 GHz and 3.4 GHz
Peru	**60**	25 MHz in 1.9 GHz auctioned in January 2011 to a new player. Government plans to auction 700 MHz in 2011

Source: Telefonica, National Regulators' Websites, Comision Federal de Competencia (Mexico); Arthur D Little Spectrum Report; January 2011

[40] Wayne A. Leighton, *Measuring the Effects of Spectrum Aggregation Limits: Three Case Studies from Latin America* (25 October 2009).

The results of Mexican spectrum Auctions 20 & 21 held in July 2010 serve to demonstrate the consequences of imposing spectrum caps in an era of skyrocketing demand for mobile broadband. The spectrum cap established by the CFC (Comisión Federal de Competencia) for Auctions 20 & 21 meant that the maximum amount of spectrum that any operator could accumulate, including any spectrum held in 850 MHz, 1900 MHz and 1700/2100 MHz, could not exceed 80 MHz. Due to the fact that three of the four operators had more than 50 MHz accumulated in several or at least one of the nine regions where the auction was going to take place, this effectively meant that none of them could bid for a ***nationwide*** AWS license because they would then exceed the 80 MHz cap in one or more of the regions monitored by the CFC. The end result is that of the 90 MHz available in this band for 3 nationwide licenses, only one license was awarded to a new consortium, while one license went *without a single bid*.

Similarly, Colombia's auction of spectrum in the 2500-2690 MHz band in July 2010 demonstrates the flaws of bluntly applied spectrum caps. The Colombian government imposed a new spectrum cap of 55 MHz for the established and new operators in the 850 MHz, 1900 MHz and 2500-2690 MHz bands AND also mandated that minimum bids would need to be at least 30 MHz. In practice, this meant that the three established operators could not participate, and that this spectrum was off-limits to those operators.[41]

In summary, spectrum caps in place in some countries in Latin America will inhibit and delay the deployment of mobile broadband services. Caps can actually limit competition by restricting output and preventing mobile operators from growing and innovating. Several more flexible regulatory alternatives have been implemented by other countries to address potential lack of competition and to achieve universal service goals without having to depend upon distortive overall spectrum aggregation limits. In general, case-by-case review of a market's competitiveness, as reflected by the absence of any single provider being able to control price or restrict output, is a preferable tool. Such an approach will better allow for mobile broadband to be deployed to consumers throughout the Americas.

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[41] Colombia's Ministry of ICT, it has been reported, recently decided to raise its spectrum cap to 60 MHz. http://www.telecomsinsight.com/file/95347/colombia-creates-capacity-for-mobile-broadband-growth.html. Tellingly, this report also indicates that data from the Ministry shows that "mobile data usage has grown exceptionally" in Colombia.

4.2.1 ILLUSTRATIONS

United States

In 2001, the Federal Communications Commission (FCC) decided to eliminate spectrum caps of 55 MHz (in all geographic service areas) and replace them with a case-by-case competitive review to ensure competition. A screening guideline was adopted, at which level an operator's spectrum holdings and situation could be reviewed for potential anti-competitive effects. Since the elimination of spectrum caps, the U.S. has led the world in mobile broadband deployment. Presently, the screening guideline is defined as between 95 - 145 MHz, depending on the availability of AWS-1 and/or 2.6 GHz BRS spectrum in a given market.

Canada

In 2004, Industry Canada ('IC') eliminated its spectrum caps after finding that the policy to oversee spectrum concentration had become less relevant.

United Kingdom

Competition in the U.K. mobile market has been enabled by the issuance of separate licenses rather than by the imposition of spectrum caps. The sector regulator Ofcom has pronounced in favor of applying general competition policy and relaxing restrictions on spectrum use to resolve or preempt potential competition problems, accompanied by band-specific spectrum caps that are loose and flexible. Ofcom is planning an auction of the 2.6 GHz band in 2012 according to the following guidelines:

- Technology and service neutrality
- A "loose" or "safeguard" band-specific spectrum cap of 80 MHz (out of 190 MHz)
- No rollout or coverage obligations
- Acquired spectrum will be tradable

4.3 THERE IS NO TIME TO LOSE – SPECTRUM ALLOCATIONS CAN TAKE YEARS TO EFFECTUATE

For a variety of reasons, the process of allocating spectrum has traditionally taken five or more years to complete. In the United States, for example, the major bands for mobile broadband service have taken anywhere from six to thirteen years to complete the reallocation process, as illustrated in the chart below.

Band	First Step	Available for Use	Approximate Time Lag
Cellular (Advanced Mobile Phone System)	1970	1981	11 years
PCS	1989	1995	6 years
Educational Broadband Service (EBS) Broadband Radio Service (BRS)	1996	2006	10 years
700 MHz	1996	2009	13 years
AWS-1	2000	2006	6 years

[Source: FCC Broadband Plan, March 2010]

While circumstances will certainly vary by country and by spectrum band, one can reasonably conclude from prior history and current circumstances that the process will unfold generally along similarly timescales – and certainly so if the process to identify spectrum for mobile broadband is not undertaken with a keen sense of urgency.

4.3.1 ILLUSTRATIONS

Mexico

On 2 September 2010, Mexican President Felipe Calderón issued a decree to accelerate the country's transition from analog to digital TV, freeing up 700 MHz frequencies currently used by broadcasters with the intention to auction this spectrum by 2012. Under the decree, all analog TV transmissions are to migrate fully to digital standards by 2015, six years ahead of the original plan. Cofetel has been instructed to auction the 700 MHz band for next generation mobile broadband services, with preliminary expectations of US$10 billion in auction receipts. Mexico is the first country in Latin America to announce a Digital Dividend spectrum auction and under its proposed schedule will also be the first country in the region to conclude the analog transition.

Moreover, in early January 2011, Cofetel announced that it was working to release 300 MHz of spectrum from the 700 MHz, 1.7/2.1 GHz, and 3.4-3.7 GHz bands within twenty-four months. This would be the most ambitious program to release spectrum ever conducted, and would if accomplished result in a doubling of the spectrum currently dedicated to wireless services.[42]

Brazil

On December 2010 Anatel concluded the auction of a left-over block of 20 MHz of the 1.9/2.1 GHz band which was initially auctioned in December 2007. The amount received by the government for this auction was US $ 1.7 billion dollars for 13 lots of the so called H-Band. Eleven (Lots 1-4, 6-7 and 9-13) of the thirteen lots were won by Nextel Brasil, one lot (# 5) by CTBC, and another lot (# 7) by TIM.

[42] http://eleconomista.com.mx/industrias/2011/01/05/avanza-plan-cadenas-tv

5. CLOSING CONSIDERATIONS

Mobile broadband in the Americas is in a 'delicate' state. On the one hand, the growth in subscribership has been phenomenal, a 'mobile miracle' in the words of the ITU. On the other hand, the industry lacks sufficient incremental supply of one of its essential raw materials–spectrum. Our review of the literature leads us to the conclusion that mobile broadband networks will hit capacity shortages **by the middle of the decade** unless steps are taken to secure the additional spectrum needed.

Such steps need to be taken **today** to avoid these risks. The industry has a long history of driving innovation in radio access technologies, from EDGE through HSPA to LTE, allowing it to exploit spectrum assets as intensively as possible. In parallel, the industry has invested billions in building cell sites to enhance network coverage and capacity. Such steps will continue to be needed, and there is no indication of deployment slowing.

At the same time, incremental spectrum allocations for mobile broadband are vital. Countries must begin now, if they have not done so already, to plan for the future in order to preserve the promise of the *mobile miracle.* Historically, spectrum allocations can take at least 5 years, and often longer, to implement.

4G Americas offers the following guideposts to help stakeholders in the region in working together to secure a bright mobile broadband tomorrow.

1. *Well Considered Spectrum Allocation Policies are Imperative*

    A. *Configure Licenses with Wider Bandwidths*
    B. *Group Like Services Together*
    C. *Be Mindful of Global Standards*
    D. *Pursue Harmonized/Contiguous Spectrum Allocations*
    E. *Exhaust Exclusive Use Options Before Pursuing Shared Use*
    F. *Not All Spectrum is Fungible – Align Allocation with Demand*

2. *Market oriented spectrum assignment approaches work – spectrum caps should be disfavored.*

3. *There is no time to lose – spectrum allocations can take years to effectuate.*

4G Americas, as well as its member companies, stand prepared to aid stakeholders in the region in securing the promise of mobile broadband.

6. APPENDICES

6.1 ABBREVIATIONS

3GPP – Third Generation Partnership Project
ANATEL – Agência Nacional de Telecomunicações (Brazilian telecom regulator)
AU – Antenna Unit
Bits/s/Hz – Bits per Second per Hertz, a measure of spectral efficiency
bps – Bits per Second
CAGR – Compound Annual Growth Rate
CAPEX – Capital Expenditure
CDMA – Code Division Multiple Access
CFC - Comisión Federal de Competencia (competition agency in Mexico)
COFETEL - Comisión Federal de Telecommunicaciones (telecom regulator in Mexico)
CRTC - Canadian Radio and Telecommunications Commission
dB – Decibel
dBm – Decibel ratio of watts to 1 milliwatt
EC – European Commission
EDGE – Enhanced Data Rates for GSM Evolution
EU – European Union
FCC – Federal Communications Commission
FDD – Frequency Division Duplex
FEM – Front End Module
FTP – File Transfer Protocol
GB – Gigabyte
Gbps – Gigabits per Second
GGSN – Gateway GPRS Support Node
GHz — Gigahertz
GPRS – General Packet Radio Service
GSM – Global System for Mobile communications
GSMA – GSM Association
HSPA – High Speed Packet Access (HSDPA with HSUPA)
HSPA+ – High Speed Packet Access Plus (also known as HSPA Evolution or Evolved HSPA)
Hz – Hertz
IC – Industry Canada
IMT – International Mobile Telecommunications
IMT-A – IMT-Advanced
IP – Internet Protocol
ITU – International Telecommunications Union
Kbps – Kilobits per Second
LTE – Long Term Evolution (evolved air interface based on OFDMA)
LTE-A – LTE Advanced
M2M – Machine to Machine

Mbps – Megabits per Second
MHz – Megahertz
MIMO – Multiple Input/Multiple Output
ms – Millisecond
OBI – FCC's Omnibus Broadband Initiative
OFCOM – U.K. communications regulatory authority
OFDM – Orthogonal Frequency Division Multiplexing
OFDMA – Orthogonal Frequency Division Multiple Access (air interface)
OPEX – Operating Expenses
P2P – Peer to Peer
RAN – Radio Access Network
Rel. 'X' – Release '99, Release 4, Release 5, etc. of 3GPP Standards
RF – Radio Frequency
RX – Receive
RNC – Radio Network Controller
RRU – Remote Radio Unit
SAE – System Architecture Evolution, also known as EPC
SGSN – Serving GPRS Support Node
SNR – Signal to Noise Ratio
TE – Terminal Equipment
TX – Transmit
UE – User Equipment
UL – Uplink
UMTS – Universal Mobile Telecommunications System
UNCTAD – United Nations Conference on Trade and Development
WAN – Wide Area Network
WWW – World Wide Web
WiMAX – Worldwide Interoperability for Microwave Access

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