The Impact of 700 MHz Spectrum on LTE Deployment and Broadband in Canada

Report prepared for

Rogers Communications Inc.

Gazette Notice No. SMSE-018-10

FINAL REPORT

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1. Executive Summary

1.1 Overall context related to the 700 MHz spectrum band and LTE deployment

In July 2010, Lemay-Yates Associates Inc. (LYA) developed a Report for Rogers Communications Inc. entitled "The Performance of Canada's Consumer Broadband Networks in 2010". The Report discussed the performance of Canada's fixed as well as mobile broadband networks.[1]

As part of its research, LYA reviewed the status of mobile broadband networks in fourteen countries, including Canada, key European as well as Asian countries in addition to the US.[2] This research demonstrated that Canada was in the lead among developed economies with three HSPA[3] national service providers offering mobile broadband services with downstream bandwidth up to 21 Mbps. The Report also concluded that, based on 2009 information, mobile data usage per subscriber in Canada was relatively high.[4]

We have reproduced below relevant excerpts of the key conclusions of that Report with respect to mobile networks:

[1] "The Performance of Canada's Consumer Broadband Networks in 2010", Report prepared by Lemay-Yates Associates Inc. for Rogers Communications Inc.; submitted on July 13, 2010 in response to Industry Canada's consultation paper on the Digital Economy Strategy, "Improving Canada's Digital Advantage – Strategies for Sustainable Prosperity", May 10, 2010.
[2] The list of countries reviewed for mobile broadband network performance: Australia, Japan, Korea, USA, France, Belgium, Italy, Austria, The Netherlands, Denmark, Finland, UK and Sweden.
[3] HSPA: High Speed Packet Access
[4] "The Performance of Canada's Consumer Broadband Networks in 2010", *op.cit.*, Figure 4, page 47

* *Canada is the only country among the 14 surveyed to benefit from three national mobile network providers operating at 21 Mbps, with more to come and being launched from new entrants and regional carriers. While other countries have one or two carriers that have started deployment of LTE providing higher mobile bandwidth, Canada is currently in the lead if one considers overall availability and consumer choice.*

* *Canada's subscriber consumption, slightly higher than the US and higher than mobile data consumption in France and Germany is only second to the UK's, which ranks as first among these countries.*

Wind Mobile Canada launched its services in late 2009 in the Toronto area and has since expanded to key cities of the country where it holds spectrum licenses. In the spring of 2010, Mobilicity and Public Mobile started offering service in Canada, using AWS licenses auctioned in 2008 and focused mostly on serving core urban areas where they hold spectrum licenses.

On the other hand, Vidéotron launched its new mobile network in many of the major and smaller markets of the province of Quebec in September 2010.

All of the new entrants except Public Mobile have deployed HSPA technologies, similar to the incumbents Bell, Rogers and TELUS, at downstream speeds ranging from 7.2 Mbps to 21 Mbps, in the case of Vidéotron.

However, in other countries, ranging from Japan to Norway and including Austria and Estonia, in addition to Germany and the United States, mobile operators have launched services using "long term evolution" (LTE) technology for broadband applications in the

700 MHz and 800 MHz spectrum bands as well as in the 2500 MHz spectrum band.[5] We note that the auction of digital dividend spectrum in the 800 MHz spectrum band will start in Sweden on February 28, 2011. In Sweden, though, as well as in other countries such as Norway, LTE deployment had already begun in the 2500 MHz band in late 2009 and has been expanding since with a clear focus up to now on urban areas.

Nevertheless, Canada continues to be one of the top performers worldwide in terms of the number of network providers offering services with downstream bandwidth greater than or equal to 14 Mbps, as reported by the Global Mobile Suppliers Association (GSA) on January 24, 2011.[6]

Notwithstanding the growing success and deployment of HSPA worldwide, in an earlier release on January 12, 2011, the GSA also "*confirms LTE as the fastest developing mobile system technology ever*".[7]

Canadian carriers have yet to deploy LTE for broadband applications. But we highlight that a number of technical trials of LTE have been announced by Canadian mobile carriers. Furthermore, in its conference call with financial analysts on February 16, 2011, Rogers indicated that the increase in capital investment in its 2011 financial guidance "*primarily reflects incremental spending directed towards our multi-year deployment of LTE wireless technology which as you know we began trialing during the second half of 2011.*[8] Rogers also indicated during the same conference call that it will use a multiband approach to deploy a robust LTE network.

[5] MetroPCS launched LTE in the AWS band in the USA but does not provide a full broadband service comparable to other LTE services around the world.
[6] Global mobile Suppliers Association (GSA), GSM/3G Market/Technology Update, January 24, 2011
[7] Global mobile Suppliers Association (GSA), press release, January 12, 2011
[8] Rogers IVQ2010 Earnings Conference Call, February 16, 2011.

Industry Canada recently released its decision regarding the band plan for the 2500 MHz spectrum in Canada.[9] There will be an auction of 2500 MHz spectrum in the future as part of the conversion of the current spectrum licenses to Broadband Radio Service (BRS) licenses. Thus, this spectrum band is also expected to become available to a number of Canadian carriers over the coming years for mobile deployment, in addition to existing BRS licensees.

The objective of the present Report is to discuss the intertwined technology and spectrum related issues that will impact the deployment of post 3G broadband technologies and services across Canada in the context of Canada's digital economy strategy and to assess the role to be played by the 700 MHz spectrum band.

This Report has been developed independently by LEMAY-YATES ASSOCIATES INC. (LYA) on behalf of Rogers Communications Inc. to be submitted in response to the *Gazette Notice No. SMSE-018-10* entitled *"Consultation on a Policy and Technical Framework for the 700 MHz Band and Aspects Related to Commercial Mobile Spectrum"*, released by Industry Canada on November 30, 2010. This consultation focuses on the upcoming auction for 700 MHz (digital dividend) spectrum licenses, which may possibly also include the 2500 MHz BRS spectrum.[10]

[9] Notice No. SMSE-005-11 — Decisions on a Band Plan for Broadband Radio Service (BRS) and Consultation on a Policy and Technical Framework to License Spectrum in the Band 2500-2690 MHz, Released on February 10, 2011.

[10] The term "digital dividend" refers to the economic benefit of re-licensing spectrum that becomes unused as a result of the transition of off-air television to digital. Digital television requires much less bandwidth than analog and thus occupies less spectrum "space". In North America, the digital dividend spectrum is in the 700 MHz frequency range. In Europe and elsewhere it is typically in the 800 MHz range. The spectrum in question becomes available for other uses once analog off-air television is "shut off". In Canada the date for this is August 31, 2012.

1.2 Key findings

The 700 MHz spectrum band will be a key building block of Canada's digital economy to provide ubiquitous, high-quality post 3G broadband access to every consumer and business across the country. Carriers focusing on offering broadband services across all types of markets will be best able to leverage the capabilities of LTE in the 700 MHz band to maximize its benefits and ensure that all Canadians, wherever they are, can indeed leverage post 3G mobile broadband innovations.

The following key findings from our analysis support the conclusion expressed above and highlight among other things:

- the key benefits of LTE technology in terms of speed, quality of service and coverage, spectral efficiency and its expected evolution,
- the target applications and thus the relevant market for LTE deployment based on the characteristics of LTE technology,
- the spectrum requirements of different mobile carriers, according to different business strategies being pursued, as well as,
- how the 700 MHz spectrum band is intertwined with LTE deployment for Canadian carriers when it comes to being able to access the overall technology ecosystem being developed now (comprised of handsets, applications and network equipment) in the North American context and how this affects the relative attractiveness of other spectrum bands for LTE deployment.

We have also reviewed how a few other countries have chosen to award digital dividend spectrum in the 700 MHz or 800 MHz spectrum band, as applicable, focusing on countries where the award of this spectrum has either been completed or will be underway shortly. This review has been focused on the key market determinations made by licensing authorities prior to the award of digital dividend spectrum and the ensuing impact on auction eligibility rules, key auction parameters and relevant conditions of license that impact industry structure and the roll out of new technology.[11]

I. ***Consumer mobile bandwidth and capacity demands are accelerating and expected to reach similar levels to those experienced today for wireline Internet access and even more, being spurred by an increasing proliferation of devices in service on these networks. This implies monthly usage increasing to reach tens of GBytes, far higher than the range of hundreds of Mbytes to 1 GByte levels typically reported today.***

Customer bandwidth requirements are accelerating as they make increasing use of high-data consumption mobile devices such as Smartphones – including iPhones, Android devices, Blackberries, iPADs and tablet computers – and mobile data modems.

With the greater capabilities on these devices, customer applications are increasingly data-rich and require large amounts of data transfer capability across the mobile network infrastructure, whether for using mobile television services, transferring data files, video-chatting, sending and receiving increasingly higher quality pictures or other applications.

Based on current trends, LYA estimates that mobile broadband usage is expected to increase by factors in the order of 100 to even 500 compared to the average now, to reach levels of 10-30 Gigabytes (GB) per month over the foreseeable future, fuelled by the rapid growth of mobile video usage. As an example commercial offers in 2011 reflecting this level of demand, in the deployment of LTE by Vodafone in Germany beginning in rural areas, broadband services are being provided – less than one year after the digital

[11] This intent of this review was not to discuss detailed auction-specific rules.

dividend auction – with up to 50 Mbps downstream speed and a 30 GB monthly usage cap.

Recent data released by Cisco in its Visual Networking Index support these trends and indicate that traffic generated by mobile video will exceed 50% of all mobile traffic in 2011 for the first time and that on a worldwide basis, mobile traffic will increase 26-fold over the next 4 years, from now until 2015.[12]

II. *LTE deployment in the 700 MHz spectrum band across Canada will bring substantial benefits to enhance broadband access*

Customers have increasing expectations of much higher data speeds on their wireline Internet services and increasingly migrating their usage and quality of service expectations unto their mobile broadband service.

The FCC's 2010 National Broadband Plan has stated an objective of 100 Mbps Internet access speed per home. Wireless is a key technology to fulfill this objective in many areas of the country.

The 700 MHz band is a key enabler for the deployment of LTE technology and of broadband data speeds of 100 Mbps or more – "true" fourth generation (4G) mobile service or post 3G service, to the entire population across the country. It is an important new spectrum band that will help support dramatic growth in customer data needs and will be complementary to existing bands.

[12] Cisco Visual Networking Index; Global Mobile Data Traffic Forecast Update, 2010-2015, February 1, 2011

LTE has a number of attractive characteristics, particularly when deployed in the 700 MHz band. These include ability to support data speeds of 100 Mbps and higher, large cell sizes, improved indoor and suburban/rural coverage, ability to be deployed in different channel sizes and bands, and lower latency to enable broadband conversations as well as to support the rapidly increasing use of mobile video services. LTE has a future evolution path which includes aggregating bandwidth across bands to support even greater data throughput, potentially up to 300 Mbps.

To date, LTE deployment focuses on providing broadband data capabilities, with voice services falling back on legacy 2G/3G networks.[13] For this reason as well as due to its attractive propagation characteristics, LTE deployment in the 700 MHz spectrum band will be complementary to its deployment in other spectrum bands, including the BRS spectrum band in the 2500 MHz range.

And of course, LTE in the 700 MHz spectrum band is particularly important because of the need to harmonize LTE deployed in Canada with the LTE ecosystems being deployed and expanding in the US.

III. The exponential growth in usage and speed will translate into overall spectrum requirements in the range of 200 MHz or more for large carriers focusing on broadband applications in the Canadian context.

A key component of this infrastructure is the mobile spectrum, the demand for which is growing consistent with the growth in the customer's data usage and applications.

There is often a perception that large carriers in Canada have a sufficient amount of mobile spectrum to fulfill customer demand.

We note that large carriers in other countries with well-developed mobile markets currently hold in the range of 66 to 130 MHz of core mobile spectrum, excluding digital dividend spectrum (in the 700 or 800 MHz spectrum range) and BRS spectrum (in the 2500 MHz spectrum range).[14] This includes:

- US carriers AT&T (95 MHz), Verizon (85 MHz) and T Mobile (70 MHz),
- UK carriers Vodafone (76 MHz), O2 (66 MHz) and the new merged entity Everything Everywhere (130 MHz),
- French operators Orange (100 MHz), SFR (100 MHz) and Bouyges (90 MHz),
- German operators E-Plus (110 MHz), T Mobile (90 MHz), Vodafone (70 MHz) and O2 (75 MHz).

In comparison, the maximum total mobile spectrum holdings of Canadian incumbent mobile carriers in any given city range from 75 MHz (Bell and TELUS) to 105 MHz (Rogers) and are thus within the range observed in other countries before considering 700 MHz and BRS spectrum. We highlight that Rogers' spectrum holdings in the Toronto area, where it experiences its highest demand for capacity, totals 95 MHz, 10 MHz less than in other cities.

While it is normal for larger carriers to require larger spectrum holdings to fulfill customer needs, it is not just the amount of spectrum in total that is important, but which spectrum band, particularly when looking at a specific technology such as LTE and

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[13] Voice over LTE (or VoLTE) is under development as detailed further in this Report.

[14] This comparison is presented excluding 700 MHz and BRS holdings to provide an equal basis of comparison since not all countries have yet awarded spectrum in these bands. However, the analysis presented in Section 2.3 makes reference to other holdings, including Rogers and Bell via Inukshuk.

broadband service deployment, since not all spectrum is created equal and different spectrum bands have different technical characteristics and technology ecosystems.

The frequency range covered by a band is a major distinguishing factor due to differences in propagation characteristics between high and low frequencies. And of importance is also the amount of mobile spectrum that is “contiguous” in the band, i.e. to provide for use of large frequency channels.

Even with the improvements brought about by enhanced spectral efficiency in LTE and HSPA+ technologies, and the deployment of additional sites by mobile carriers to increase capacity, the anticipated magnitude of usage per mobile subscriber will drive significant demand for additional spectrum capacity.

The FCC, as well as other regulators in Germany and Sweden, has already concluded that there is insufficient spectrum available to meet increasing broadband capacity needs, even when considering the completed awards of 700 MHz spectrum and the adoption of more efficient technologies.

LYA modeled scenarios of spectrum demand considering increasing data speed and consumption and reflecting typical numbers of subscribers served by wireless sites in the Canadian context, considering population density and the differences in market shares for different carriers. The spectrum needed by a single carrier to serve its customers is a function of the traffic carrying capacity or spectral efficiency of the network expressed in bits per second (bps) per Hertz (Hz) of spectrum and of customer density and usage parameters. Carriers with higher market shares, especially among broadband customers, will require more spectrum than others.

LYA's analyses demonstrate that a large carrier providing peak downstream speed of 100 Mbps with strong average usage per subscriber based on current trends will require in the order of 200 MHz of mobile spectrum in total (downstream and upstream) to fulfill the demand of its customers, if LTE technology fully delivers its expected enhancement in spectral efficiency within the necessary timeframe. Much more than 200 MHz would be required to meet customer demand if average spectral efficiency achieves levels of 3bps/Hz instead of the maximum of 5 bps/Hz currently anticipated in the long term, or alternatively, if future data usage exceeds our forecasts. Total mobile spectrum requirements will be higher in urban areas where customer concentration is at its highest and lower in rural areas and will also increase with the number of customers served at each site, especially in urban areas.

On the other hand, a voice-centric carrier with a smaller market share serving fewer customers per site and with lower usage of data services could support its customers with less than 25 MHz or in some cases less than 10 MHz of spectrum, even considering that it would also offer services at increasing speeds up to 42 or 100 Mbps and would also experience much higher data usage than present levels.

IV. A key objective of the upcoming 700 MHz spectrum auction should be to promote broadband deployment at speeds of 100 Mbps or more to all Canadian consumers and businesses.

Many countries have determined based on the key performance characteristics of LTE, that the relevant market for the 700 MHz spectrum is broadband services and hence that 700 MHz spectrum is a critical element to achieve the objectives of their National Broadband or Digital Economy strategies, often with a focus on providing broadband access services outside of urban areas.

In the US, the FCC determined that "broadband" was the relevant market for services to be offered via 700 MHz spectrum, prior to the auction of this spectrum in 2008. Wireless broadband access is a key element of the FCC's National Broadband Plan subsequently announced in 2010 coupled with a process to identify and award more spectrum capacity to eventually double what has already been awarded. The FCC has concluded that there is not enough spectrum capacity available now to meet consumer demand.

Similar conclusions were reached in Germany and Sweden. Both countries highlight the prominent role of digital dividend spectrum in fulfilling their National Digital Strategies, as do other countries where the spectrum has not yet been awarded such as the UK, France and Australia.

Considering the 700 MHz band an integral component supporting development of the digital economy in Canada, implies that Industry Canada should then put in place an auction framework and license conditions that are consistent with this objective.

This could mean providing for strong network deployment requirements as a condition of license to ensure investment takes place, and implementing a license structure to provide for maximum access to new technology development being led by major carriers and vendors in the US market.

V. Specific network population coverage obligations were put in place in Germany and Sweden for digital dividend spectrum; this approach could be considered in Canada to further the deployment of competitive post 3G, high-quality broadband infrastructure as part of Canada's Digital Economy Strategy

The digital dividend spectrum is a key element underlying national digital strategies and broadband plans and a critical enabler in bridging the rural and urban digital divide. The

Canadian government could thus consider coupling the award of the 700 MHz spectrum band with roll out obligations specific to the Canadian environment, to further the objectives of broadband coverage outside of urban areas, as a condition of license.

Applying this condition of license to all licensees of the 700 MHz spectrum band would be a major contribution to ensure the deployment of competitive post 3G broadband networks across the country, fulfilling a key objective of the Canadian government to continue to foster competition in telecommunications networks and enhancing the competitive landscape in line with the Government's agenda not only in key urban areas, but also in smaller towns and cities as well as in rural areas.

This would be different than the approach implemented for Advanced Wireless Services (AWS) spectrum awarded in 2008, where one objective of the auction was to increase the level of competition in the mobile industry by facilitating entry by new carriers able to bid on a license set-aside, and where deployment criteria were only targets or guidelines.

VI. *Given that the relevant market is broadband service, all mobile carriers, incumbents and smaller carriers, national and regional carriers, have been eligible to participate in auctions concluded for 700/800 MHz spectrum. There were no set aside spectrum or eligibility constraints imposed on existing carriers, even those with large market share in their served markets*

The FCC did not implement a set aside or a spectrum cap for the auction of the 700 MHz spectrum band in 2008. Since there is no monopoly on provision of broadband services in general, the FCC concluded that there would be no incentive for one bidder to unilaterally block new entrants from acquiring 700 MHz spectrum. This would be because "*an incumbent attempting to block new entrants would bear all the costs of doing so, while other incumbents would capture much of the gain.*"[15]

Even though large carriers Verizon and AT&T acquired the bulk of the spectrum available, it is worth noting that smaller players and a few new entrants were also successful in acquiring 700 MHz licenses, and that a number of larger and smaller US carriers chose not to participate in the auction of 700 MHz spectrum. This includes two of the four national carriers, T-Mobile and Sprint Nextel.

It is however increasingly clear that the 700 MHz spectrum band is playing an important role in stimulating the development of the wireless broadband market in the US amongst all carriers, not just those with 700 MHz licenses. The auction was run in a way that did not restrict or encourage any particular type of bidder, since the FCC recognized that there are many different ways to address the broadband services market.

Auction specific spectrum caps were put in place in Germany and Sweden for digital dividend spectrum. The spectrum cap set out implied that not all existing mobile carriers would necessarily obtain digital dividend spectrum, due to the scarcity of digital dividend spectrum. In Germany, three of four mobile carriers chose to acquire spectrum at 800 MHz during the 2010 mega auction, while the fourth carrier focused on spectrum being offered in various spectrum bands above 1 GHz obtained at a fraction of the cost of the digital dividend spectrum.[16] Thus as a result of the auction, all carriers are well equipped to carry out their business strategy.

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[15] FCC 07-32, paragraph 256

[16] The German mega spectrum auction included spectrum in the 2.6 GHz spectrum band, various leftover spectrum in other bands (1.8 GHz, 2.1 GHz) as well as the digital dividend spectrum (800 MHz spectrum band).

VII. *Different business plans imply different spectrum requirements; it is very conceivable that not every carrier needs 700 MHz spectrum*

Although 700 MHz is often being positioned as a high value spectrum property, it is very conceivable that not every mobile carrier needs 700 MHz spectrum to be successful in realizing its business strategies and objectives. Smaller carriers in particular experience lower overall demands on spectrum and would be able to succeed without 700 MHz spectrum, especially when focused on deployment in urban areas.

Neither Sprint Nextel nor T Mobile – two of the four national carriers in the US – currently holds 700 MHz spectrum licenses because they chose not to be part of the auction process in 2008.

Sprint Nextel decided instead to concentrate on deploying 4G WiMAX technology in 2500 MHz spectrum available to it via Clearwire. And T-Mobile has been focusing on the evolution of HSPA+ as a 4G technology in the AWS band.

VIII. *Technology and spectrum bands are intertwined and the option of acquiring 700 MHz spectrum is critical, even for carriers who already own substantial spectrum holdings*

Even large Canadian carriers who might be considered spectrum rich need access to new spectrum not only to fulfill increasing customer demand, but also to deploy new technologies and to be able to access the same spectrum bands as their US counterparts to deploy LTE technologies and leverage its growing ecosystem.

Mobile technologies are closely linked or intertwined with spectrum bands. Even though there are many bands identified on the 3GPP list of candidate bands for LTE, many are not available in North America and many are already in use by 2G and 3G technologies and will continue to be in use for the foreseeable future.

Deployment of an entirely new technology such as LTE requires new spectrum since existing bands cannot readily be re-farmed to accommodate an entirely new technology, particularly one such as LTE whose deployment is optimal with wide bandwidths or contiguous spectrum. Existing customers and handsets, as well as roaming partners, require access to legacy technology and services making re-farming expensive and impractical. Given that the impact would be on each subscriber, the larger the carrier, the larger this cost would be.

For example, HSPA technology is currently deployed in cellular spectrum bands by the larger Canadian mobile carriers and this technology will continue to be deployed in this spectrum band for many years to come. The cellular spectrum bands are thus not available for deployment of LTE technologies in Canada. Of note, no US carrier has announced a trial or the deployment of LTE using cellular spectrum to date.

Deployment of LTE technology for broadband applications is currently driven in the 700 MHz spectrum band by a few large US carriers, notably Verizon and AT&T, and by vendors, with handset vendors garnering increasing clout in the mobile ecosystem. Because of the US developments, Canadian carriers looking to deploy LTE for broadband applications across the country will require 700 MHz spectrum in order to obtain equipment and handsets to meet the needs of their customers and to provide roaming.

For example, Canadian iPhone, Blackberry and Android customers, of which there are already a large number, will clamor to upgrade to the next generation post-3G 700 MHz handsets as soon as they become available to benefit from their enhanced capabilities not only when in Canada but also when traveling in the US.

In addition, not all frequency bands can be supported on every handset because of “real estate” or space restrictions. This is particularly true for lower frequencies such as 700 MHz. Thus, in many cases, Canadian carriers will have to adopt the same handsets using the same frequencies as US carriers and likely as their own US roaming partners, to provide ubiquity of high quality broadband service in North America to their clients.

IX. Other spectrum bands and future spectrum auctions

The amount of spectrum that will be made available in Canada from the 700 MHz and the BRS will be of the order of 134 MHz in total, including both bands and both paired and unpaired spectrum,[17] subject to final Industry Canada decisions on the 700 MHz band plan. Issuing all of this would bring Canada on par with the US in terms of total awarded to date.

The 700 MHz spectrum band is not the only vehicle for LTE, and LTE is not the only “4G” technology, depending on the strategies of individual carriers. There are alternative spectrum bands such as 2500 MHz, already being used for LTE deployment in urban areas in a few countries in Europe. AWS is also a spectrum band for LTE that is well suited to urban focused deployment, and is being used by MetroPCS, a regional mid-size mobile carrier in the US, albeit focusing on voice services and thus with a very different business strategy than the Verizon or AT&T national broadband deployments.

[17] This estimate excludes the Upper D-Block in the 700 MHz spectrum band.

However, the development of LTE-based ecosystems for both the AWS and BRS spectrum bands, in particular to provide mass market mobile broadband services in the North American context, is somewhat lagging that of the 700 MHz spectrum band at the moment. Furthermore, AWS and BRS spectrum bands by themselves, i.e. without the support of broad geographic deployment in the 700 MHz spectrum band, are not well suited to fulfill the objectives of ensuring the availability of post-3G mobile broadband services everywhere in Canada.

Industry Canada can be further supportive of broadband service development by continuing to auction spectrum in other bands in the future as well to fulfill the needs of the different carriers and of their customer expectations and business strategies. This includes the upcoming auction of BRS spectrum for which a consultation was recently initiated.

However, we highlight that the FCC as well as other spectrum regulatory entities have already concluded that much more spectrum is required in the near future to fulfill the needs of wireless broadband, even after having already awarded 700 MHz spectrum bands and BRS in the 2500 MHz band. The LYA analyses provided in this Report demonstrate that similar conclusions hold in the Canadian environment

1.3 Organization of the Report

This Report is organized as follows:

- Section 2 provides a discussion of increasing mobile customer usage of data services and estimates of the amount of spectrum required to provide different levels of service comparing a carrier's needs focused on mobile broadband (data/video) services to one focused on voice services.

- Section 3 discusses the linkages of technology and spectrum, including characteristics and performance targets for fourth generation (4G) mobile service considering the 4G announcements by various carriers as well as discusses the attributes of LTE technology impacting customer experience, roaming and development of ecosystem as well as versus HSPA+ and WiMAX.
- Section 4 discusses how 700 MHz spectrum was awarded in countries where this process is completed as well as other jurisdictions that have announced plans for the award of digital dividend spectrum.
- In light of the above, Section 5 discusses what could be the objectives of the 700 MHz spectrum auction in Canada to fulfill the agenda and promises of the Digital Economy in order to benefit all Canadians.

2. Accelerating Bandwidth Requirements to Fulfill Customer Needs; especially for carriers focusing on mobile data and Internet

Customer bandwidth requirements are accelerating as they make increasing use of high-data consumption mobile devices such as Smartphones – including iPhones, Android devices, Blackberries and tablet computers – and mobile data modems.

With the greater capabilities on these devices, customer applications are increasingly data-rich and require large amounts of data transfer capability across the mobile network infrastructure, whether for using mobile television services, transferring data files, video-chatting, sending and receiving increasingly higher quality pictures or other applications.

A key component of this infrastructure is the mobile spectrum, the demand for which is growing consistent with the growth in the customer's data usage and applications.

This section first looks at the drivers of demand for increased spectrum, then considers the amount of spectrum required for typical carriers in a number of scenarios. How much mobile spectrum has been issued to date and expectations for future spectrum in Canada are presented. The analysis confirms the US FCC view that available spectrum needs to approximately double to accommodate anticipated growth in data and broadband usage by mobile subscribers.

2.1 Evolving applications and growth in data usage

The growth in consumer mobile data usage has been supported by increasing data speeds and usage buckets provided by mobile carriers. Increasing speed and usage means that carriers need to deploy networks with ever greater capacity, implying greater needs for cell sites and spectrum resources.

2.1.1 Growth in Data Included in Mobile Service Packages

The table below summarizes the mobile megabytes (MB) included in typical consumer mobile service packages from 1995 to 2010.

Table 1 – Mobile MB Included in Consumer Packages 1995 to 2010

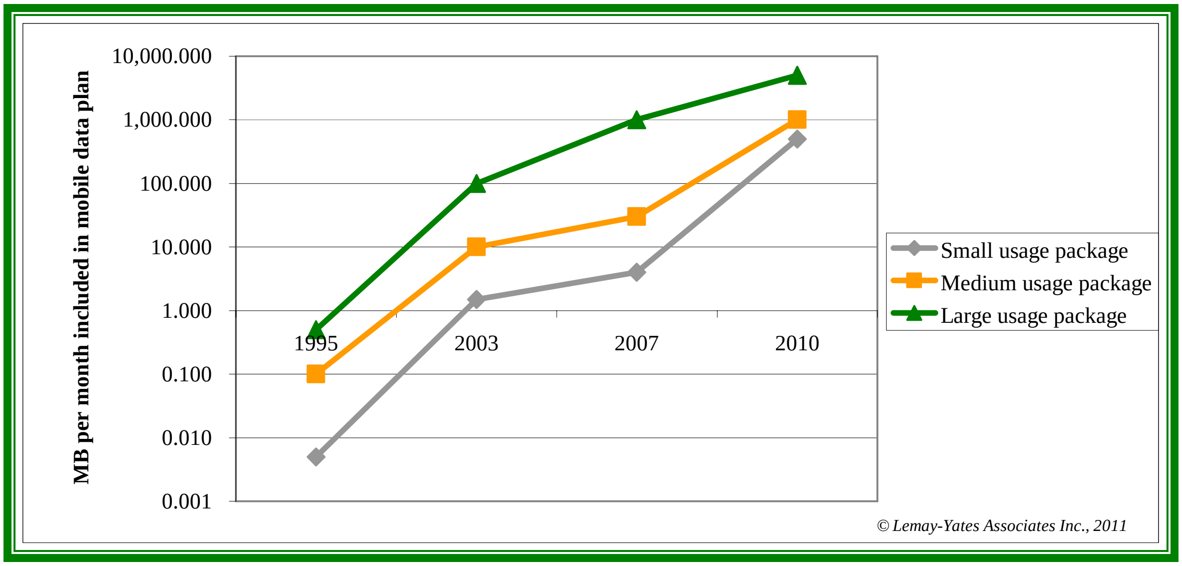
	1995	2003	2007	2010
Small usage package	0.005	1.5	4	500
Medium usage package	0.10	10	30	1,000
Large usage package	0.50	100	1,000	5,000

MB per month of mobile data usage included in typical packages for small, medium and large users

Historical information from Mobitex (1995), Rogers GPRS (2003), Bell Blackberry (2007) and Bell, Rogers, TELUS (2010/2011)

Thus a subscriber with a "small" usage package has 100,000 times more data transfer capacity available by the end of 2010 compared to 15 years ago. And for medium and large service packages, the ratio is 10,000 times, as illustrated below.

Figure 1 – Growth in MB per month in mobile service packages 1995 – 2010



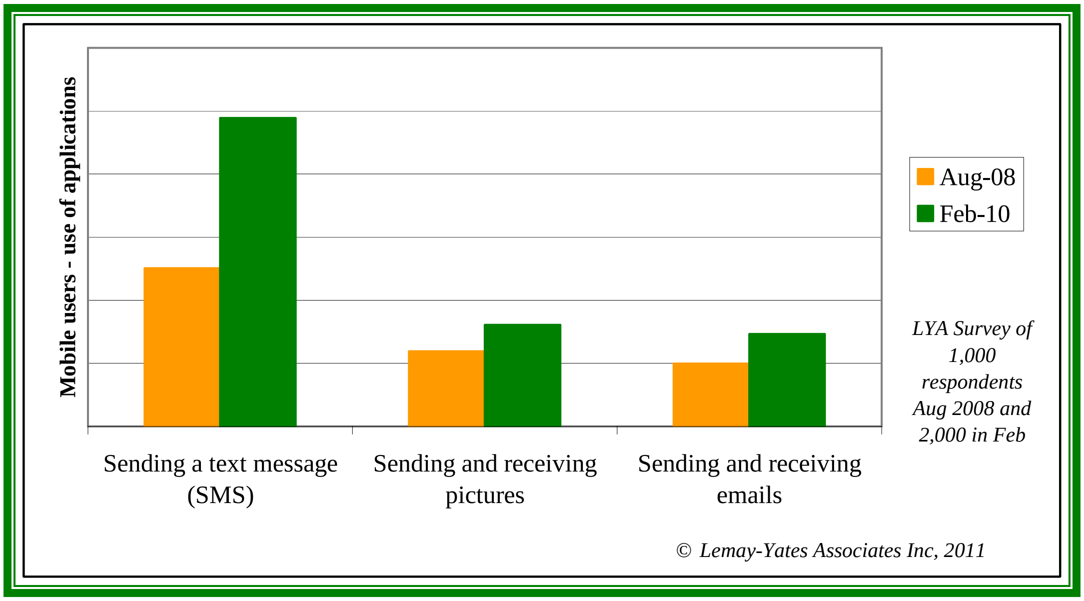
Technology enhancements have been the key driver behind this increase in data offerings, supported by continued growth in cell sites and use of spectrum resources.

The figures above illustrate what subscribers could do, if they were to make full use of the data included their package. It is expected that subscriber data usage will continue to increase, thus the current package offers provide a starting point for the anticipated evolution of mobile data consumption.

2.1.2 Evidence from the Market – Growth in Subscriber Application Usage and Media Apps

Subscriber data usage has been growing rapidly, as is evidenced by the increasing customer use of mobile applications, shown below for the top three mobile applications based on LYA consumer surveys conducted in August 2008 and February 2010.[18] Even though the two surveys were only 18 months apart, usage of the top 3 applications increased significantly, even by as much as close to 50%, during that short period.

Figure 2 – Growth in Customer Usage of Mobile Applications

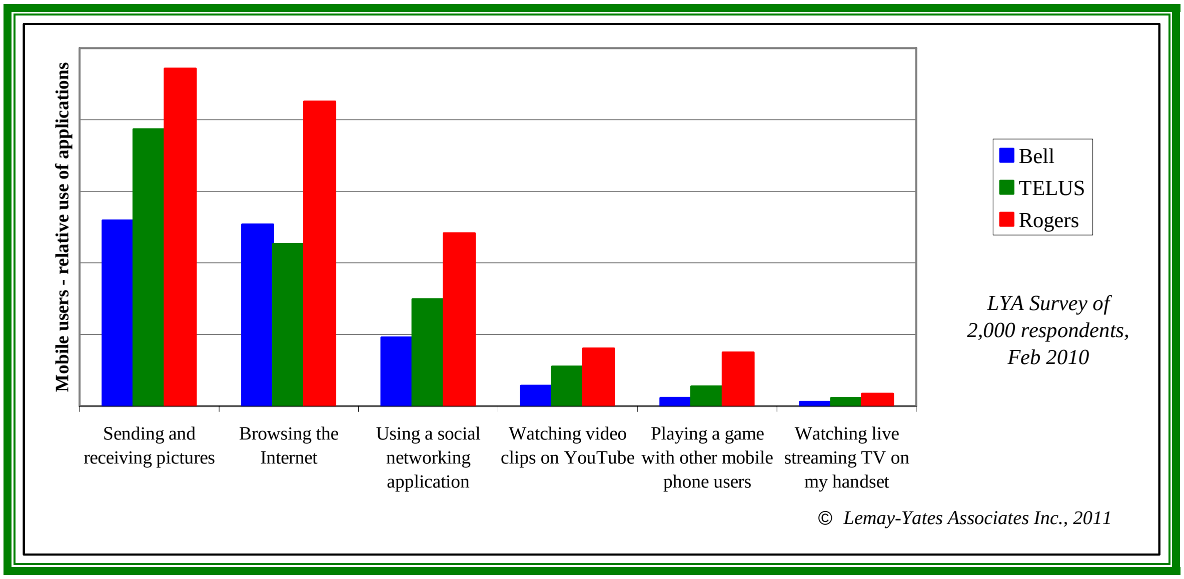


While not all applications require a lot of data, the following figures highlight the usage of bandwidth-consuming mobile applications among Canadian subscribers to the three largest carriers.[19]

[18] From Survey data included in MOBILE APPLICATIONS, APPS AND SMARTPHONES IN CANADA, Lemay-Yates Associates Inc., June 2010
[19] *Ibid*

All three carriers experience usage of the main applications, but Rogers has much higher usage relative to the other carriers, which translates into more data being carried on its network and hence more bandwidth and spectrum required to meet customer demand.

Table 2 – Comparison of Application Usage by Subscribers of Large Canadian Carriers

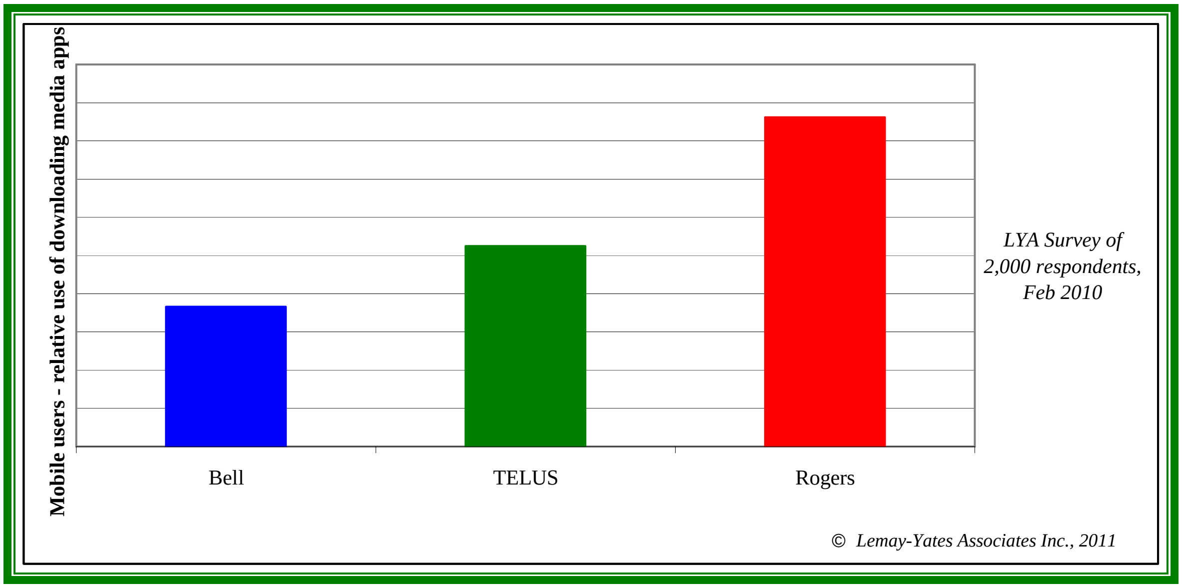


A similar trend is observed when comparing subscriber downloading of media apps amongst the three largest carriers, with Rogers again having the lead.

The February 2010 installment of the LYA surveys was conducted when the three national mobile carriers operated HSPA+ networks and all offered the iPhone, which generally results in higher data usage and download of applications.[20]

[20] However, these capabilities were fairly recent for TELUS and Bell.

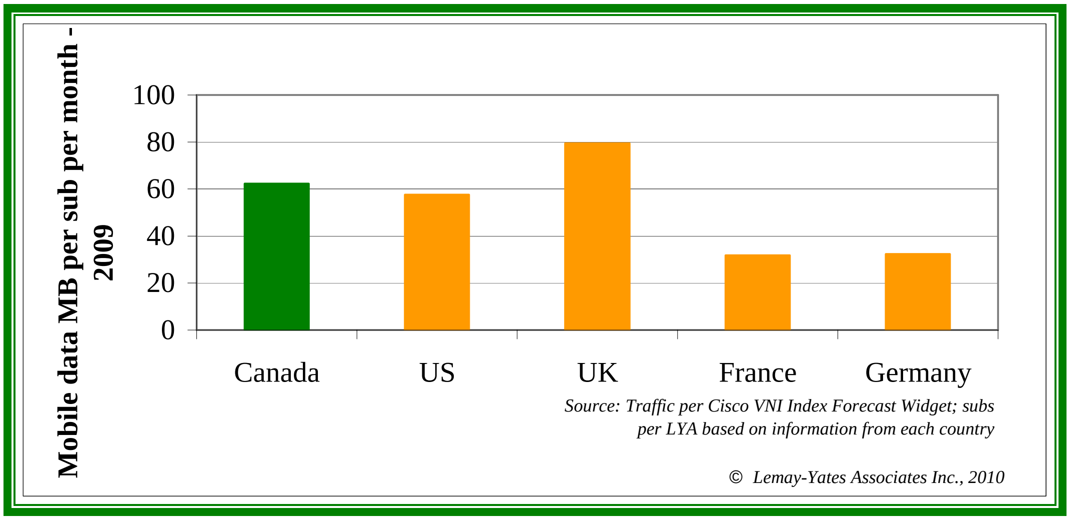
Figure 3 – Comparison of Subscriber Downloading of Media Apps of Large Canadian Carriers



As consumers make greater use of mobile television and video services and/or increasingly use their mobile service as a replacement for a fixed high speed Internet services, the potential increase in mobile data traffic will be very dramatic. This will in turn mean that the mobile carriers will have to offer increasingly large packages of mobile data in their service offerings.

Canadian mobile usage per customer is already strong and on par with the US usage levels as well as higher than countries such as France and Germany, as shown below. This represents usage estimates from 2009, thus reflecting data usage on the top 3 national carriers. This in turn supports the view that these large carriers need substantial amount of spectrum to fulfill the needs of their mobile broadband customers.

Figure 4 – Comparison of Mobile MB Consumption per Month per Subscriber in 2009

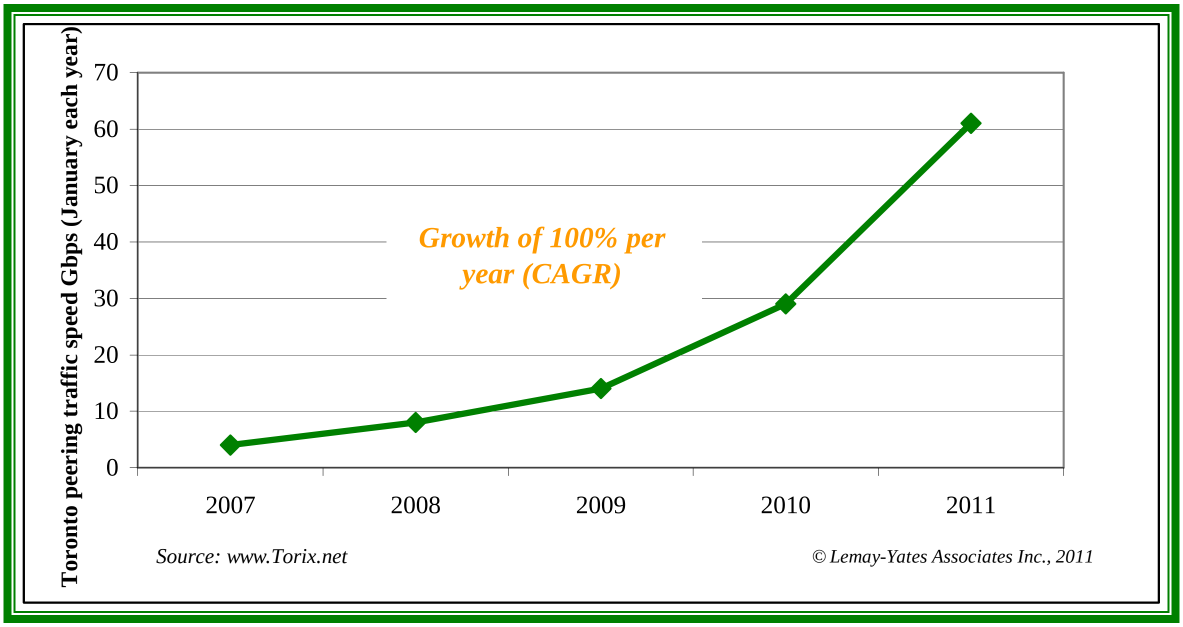


2.1.3 Total Internet traffic growth

One indicator of the growth in Internet traffic –which we have used in our analysis as on the inputs to forecast the growth in mobile Internet traffic – is the ever increasing speed of traffic passing through Canada's largest Internet peering point (traffic exchange) in Toronto.

This is shown below for each year at January since 2007. The Internet peering speed – in Gbps – has been growing at 100% per year since 2007.

Figure 5 – Internet peering speed Gbps in Toronto – 2007 to 2010



Taking one year, 2008 to 2009, to compare with CRTC statistics, for example, the speed of peering traffic increased by 75% based on the figures shown above.

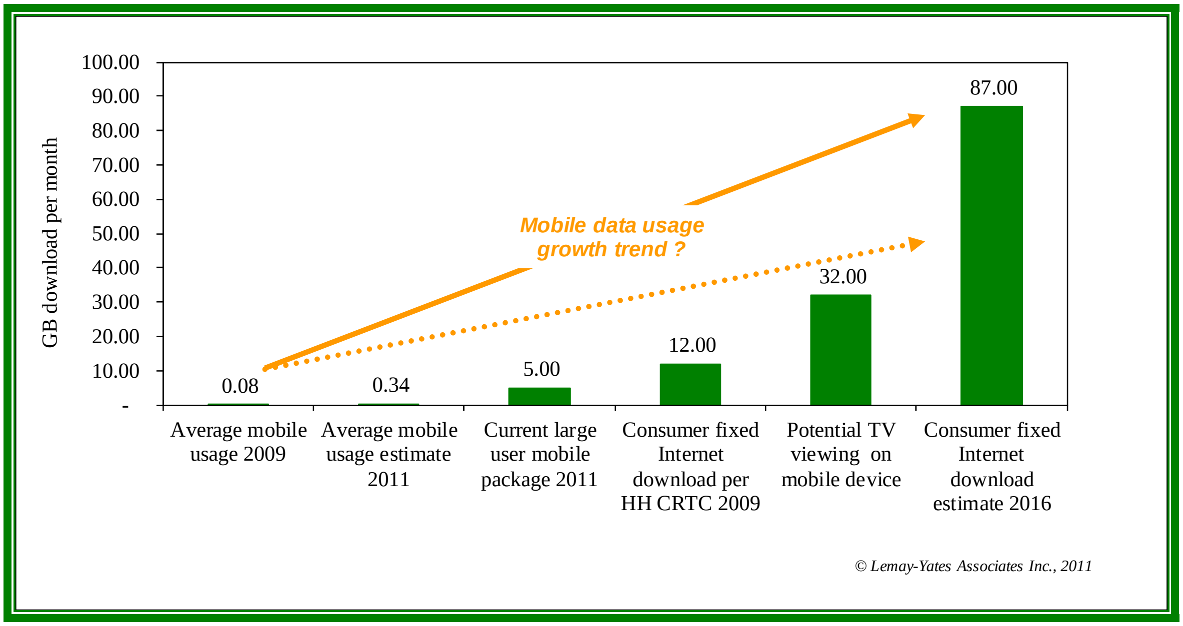
In terms of consumer Internet usage, in GB per month actually used (including download and upload), the CRTC reported growth from 2008 to 2009 of 25%.[21]

Assuming this relative growth rate relationship continues into the future, household usage in GB per month would be in the range of 87 GB by 2016, over seven times the 12 GB reported by the CRTC for 2009, based on the acceleration of Internet peering speeds as reported in 2010 and 2011.

2.1.4 Scenarios for growth in mobile data usage

Given the growth in take-up of Smartphones and tablets, customers will increasingly use mobile as a substitute for a portion of their HS Internet consumption. This will lead to large increases in mobile data traffic. This is summarized below to compare with average mobile usage in 2009 and estimated for 2011, along with the current 5 GB potential usage included in large service packages, along with a range of future scenarios.

Figure 6 – Potential mobile data usage range of growth trends – 2009 to 2016



Shown in the figure is a scenario of 32 GB per month representative of the potential for high quality television viewing making use of a mobile service (but not on current mobile

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[21] For 2008 the CRTC reported 9.1 GB/month download and 3.2 GB/month upload per HS Internet user and in 2009 the figures were 12.0 GB and 3.4 GB respectively. CRTC 2010 Communications Monitoring Report, Section 5.3

handsets). This is based on assuming that 10% of the CRTC-reported viewing hours of television per household would evolve to being viewed over an alternate platform, and translated into the equivalent amount of data bytes.[22]

This is just one example that highlights that migration of only a relatively small portion of consumer high speed Internet usage and/or television viewing to a mobile device would require a dramatic increase in data throughput. This excludes additional usage that may be offloaded to WiFi access.

2.2 *Amount of Spectrum Capacity Needed per Carrier*

Given the growth in data usage, as discussed above, the amount of spectrum mobile carriers need to serve the marketplace will continue to grow.

Customers have increasing expectations of higher data speeds now that Internet service providers, notably cable companies, offer fixed wireline speeds of 50 Mbps and in some cases 100 Mbps. In the FCC's National Broadband Plan an objective of 100 Mbps Internet access speed per home was established.[23] End customers will increasingly expect similar performance from their mobile service, particularly as a portion of fixed Internet traffic migrates to mobile services. They also increasingly expect consistency of data speed from their mobile devices wherever they are, which implies increasing the number of sites in any given area or a "densification" of the mobile networks.

[22] Using 3 Mbps to 6 Mbps for SD programming and 15 Mbps for HD programming. On-line and mobile video currently uses much lower bit rates, but these higher rates are used to provide a better comparison to consumer cable television experience if viewed on another type of networked device such as a tablet, iPAD, personal computer or other device using an embedded wireless connection.
[23] "Connecting America: The National Broadband Plan", Goal no. 1, FCC, March 2010

Thus, providing data rates of 100 Mbps or more will require considerable amounts of additional mobile spectrum bandwidth, even while carriers continue to increase the number of sites deployed to enhance the quality of the coverage and the consistency of data speeds provided, subject to engineering and coordination, and there is a trade-off between the cost of adding sites and the cost of deploying new spectrum.

Deployment of additional sites implies additional physical tower and rooftop installations that may be costly to obtain and long to build out. New sites are not always a practical solution and are increasingly difficult to obtain, particularly in cluttered urban areas. Additional new spectrum resources on the other hand can usually be added "on top" of existing transmitters.

2.2.1 Assessing the Amount of Spectrum Needed

The amount of spectrum needed by a carrier is a function of service mix and usage, in particular the data speed offered to the customers. Increased data speed typically implies increased data usage and vice versa. The more capabilities the customers are provided with, the greater use they are likely to make of them. This is coupled with the take-up in terms of the number of customers using the service as well as the distribution of the traffic over time.

The combination of these factors defines the data throughput required per customer, which needs to be translated from "bits per second" (bps) to required spectrum capacity in "Hz".[24]

[24] One Hertz (Hz) is one cycle per second. 1 kHz means a radio wave of 1,000 cycles per second; 1 MHz means 1 million cycles per second, etc.

While there are many factors that come into play in converting bps to Hz, the aggregate throughput for different technologies can be factored down to this parameter to allow for calculation of the radio spectrum required to support a given customer demand. This approach provides a ballpark estimate to support planning.

Data rates of 100 Mbps or higher require integration of several techniques on the radio systems, including high modulation rates, multiple input/output antennae and large contiguous channels of spectrum. If a 100 Mbps service can be implemented on a contiguous 20 MHz of spectrum, this implies a theoretical maximum data throughput of 5 bps/Hz.[25] This design objective would be a dramatic increase from legacy technology – e.g. the original 3G HSDPA downlink supported less than 0.5 bps/Hz.[26]

A target efficiency of 5 bps/Hz would be for long term deployment – likely beyond the next five years. If the average efficiencies are lower, then for the same service offer, the amount of spectrum needed would be higher. On the other hand, if the effective experienced data rate to the customer is lower, the amount of spectrum needed would be lower.

Over time, carriers can expect improvements in the bps/Hz carrying capacity of the radio equipment as new network equipment is deployed and as customers change their handsets to newer versions. For analytical purposes to illustrate the potential impact on spectrum requirements, the average bps/Hz parameter for mobile networks in our calculations is assumed to grow from 1 bps/Hz – similar to legacy technology – to 3 bps/Hz then to 5 bps/Hz.

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[25] 3GPP identifies a number of user equipment categories, one of which provides for 100 Mbps downlink on 20 MHz of RF bandwidth. http://www.3gpp.org/LTE. The figure of 5 bps/Hz was chosen for analytical purposes only and not to provide a conclusion regarding any particular technology or implementation.
[26] MOBILE BROADBAND: THE BENEFITS OF ADDITIONAL SPECTRUM, *op.cit.,* Exhibit 9

It should of course be kept in mind that many customers will retain their legacy handsets for a period of time operating at lower efficiency. A real network has to support a combination of new and old technology, and the average efficiency in bps/Hz will be lower than the best possible spectral efficiency based on the latest technology development.

The effective data rate to the customer will also vary depending on exactly where the customer is relative to the cell site. At cell “edges”, throughputs will be lower than the maximum available closer to the center of a cell.

And customers will not necessarily experience “peak” data rates, depending on how many other customers are making use of the data service at the same time.

With these elements in mind, the following tables provide estimates of the spectrum capacity needs of an individual carrier for two scenarios as a function of the customer data rate and the bps/Hz deployed on the radio link.

The tables show an evolution from a voice-centric business model with relatively low data rates, to a data/video business model akin to the current 3G+ deployment at 21 or 28 Mbps peak downlink and then increasing to 42 Mbps and then 100 Mbps.

In the first scenario, 33% of customers are assumed to make use of the data service. It is also assumed that the customer experiences a service bit rate that is lower than the “advertised” or peak bit rate of the technology as is typically the case today. In the second scenario, take-up is assumed to be higher at 50% of customers and that they make greater usage of the data service.

Table 3 – Total MHz Required by a Carrier for Given Service Data Speeds – Scenario 1: 33% Subscriber Take-Up

	Service characteristics			Total MHz required at 33% take rate		
	Data service speed - kbps		Network usage per average sub			
Small voice-centric carrier	Peak	Experienced	MB/month	1 bps/Hz	3 bps/Hz	5 bps/Hz
Voice centric business model - low data	7,000	5,600	390	8.7	2.9	1.7
Data/video centric business model	28,000	22,400	1,561	34.5	11.5	6.9
Data/video centric business model - future	42,000	33,600	2,342	51.8	17.3	10.4
Longer term data/video centric business	100,000	80,000	5,576	123.5	41.2	24.7

With 500 subscribers per site and 6 sectors deployed per site on average

Service speed is for downlink; MHz calculated for downlink and multiplied by two assuming FDD spectrum

Network usage is per average user; assumes uplink is 10% of downlink usage; traffic spread over six busy hours

Table 4 – Total MHz Required by a Carrier for Given Service Data Speeds – Scenario 2: 50% Subscriber Take-Up and Increased Data Usage

	Service characteristics			Total MHz required at 50% take rate		
	Data service speed - kbps		Network usage per average sub			
Large data-intensive carrier	Peak	Experienced	MB/month	1 bps/Hz	3 bps/Hz	5 bps/Hz
Voice centric business model - low data	7,000	5,600	1,561	67.6	22.5	13.5
Data/video centric business model	28,000	22,400	6,246	269.5	89.8	53.9
Data/video centric business model - future	42,000	33,600	9,368	404.3	134.8	80.9
Longer term data/video centric business	100,000	80,000	22,306	962.9	321.0	192.6

With 1300 subscribers per site and 6 sectors deployed per site on average

Service speed is for downlink; MHz calculated for downlink and multiplied by two assuming FDD spectrum

Network usage is per average user; assumes uplink is 10% of downlink usage; traffic spread over six busy hours

In the above tables, the service drivers other than those shown are the same for each case to illustrate the changing bandwidth requirements in terms of MHz of spectrum.[27]

[27] The service characteristics are assumed to be downlink – i.e. bit rate towards the customer – which then drive the amount of downlink spectrum required based on the bps/Hz assumption in each case as shown. For simplicity, as with existing mobile systems, the spectrum is assumed to be used in with frequency division duplex (FDD) techniques, implying that the amount of spectrum in the uplink is the same as the amount in the downlink. Thus the total MHz shown in the tables for each case is 2x the amount calculated

Data customers are assumed on average to use the data service for 20 minutes per day, spread over six busy hours. There are assumed to be 500 customers per site for the "small" carrier and 1,300 customers per site for the "large" carrier reflecting the current Canadian environment.[28] A carrier with fewer customers per site would require less spectrum capacity.

Depending on how the usage is concentrated the data throughput requirements can be very high. Network usage in terms of MB per month are shown as examples of possible average subscriber usage, assuming use of peak rates for only 3% to 5% of total usage. Of course some subscribers will have very high usage and others very low. Cisco, for example, recently reported that 1% of mobile data subscribers account for 20% of mobile data traffic.[29] As a point of comparison with Scenario 2, above, the average user in the "longer term data/video centric business" model is shown as having usage of 22 GB per month. With this as average and if the Cisco figure holds, then the 1% that account for 20% of mobile data traffic would be using in the range of 450 GB per month, much higher than the average use of the network.[30] Put another way, the large user could be thought of as streaming data at 100 Mbps for a continuous 20 minutes each day… 12.5 Mbytes per second for 20 minutes for each of 30 days results in 450 GB per month. Most users of course would be at much lower throughput per month.[31]

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for the downlink. The service data speed in the uplink is typically lower than that in the downlink; i.e. the spectrum is symmetrical, but the data speed to the customer is not.

[28] Based on an assessment of approximate customers in urban markets using Rogers subscriber information pro rated based on population, and site information for PCS and cellular service from Industry Canada.

[29] Cisco Visual Networking Index, *op.cit.*

[30] I.e. assuming 50% of 1300 customers using 22 GB per month on average = 14.3 TB per month. 20% of this is 2.86 TB, over 1% of customers = 440 GB per customer per month.

[31] It should be kept in mind as well that the customer's device may limit its ability to consume data, depending on processor speed, memory availability, etc. Also, for video usage, even if a customer has the ability to stream data at 100 Mbps, the video sources themselves are more typically encoded at up to 15

The results of the analysis show a best case scenario regarding total spectrum requirements under each spectral efficiency (bps/Hz) scenario as all customers are assumed to be operating at the same spectral efficiency, which as discussed will not occur in reality owing to the various legacy mobile technologies and devices deployed.

For example, as part of its near-term spectrum planning, the FCC uses 1.5 bps/Hz as the downlink efficiency for LTE and assumes growth to an average of 1.25 bps/Hz by 2014 for all technologies and devices deployed.[32]

Thus for a large carrier with intensive data needs, the amount of spectrum needed could be greater than shown to support the speed and usage identified.

Based on trends in usage, data traffic could increase by a factor of 35x over the next five years according to an FCC analysis. Translating into spectrum and offsetting by improvements in spectral efficiency, increases in cell sites and cell splitting, the FCC estimates that this increase in data usage will translate into added spectrum requirements, only for data, of the order of 12.5x times the amount of spectrum currently used for data.[33] The results of this underlie the FCC's objective to issue licenses for 300 MHz of new spectrum by 2014.

Mbps for high definition and less than 10 Mbps for standard definition, when delivered over cable. Via Internet or mobile delivery, video is coded at much lower bit rates.

[32] MOBILE BROADBAND: THE BENEFITS OF ADDITIONAL SPECTRUM, *op.cit.*, Exhibits 9 and 10

[33] Presentation by FCC staff at Spectrum Summit, October 21, 2010

2.2.2 Voice Centric Operator with Low Data Usage Requires 5 to 10 MHz

For a voice centric operator as highlighted in Scenario 1, with lower subscriber data take up and usage, the business model can be implemented with modest spectrum resources, varying with the spectral efficiency deployed. For such a carrier not offering high data speeds, the data downlink requirement is relatively low – less than 10 MHz even with legacy technology.

This type of deployment would be more typical of carriers whose priority is voice carriage and which do not offer many handsets and devices to support high data usage

2.2.3 Data/Video Centric Business with High Take-Up Requires Up To 200 MHz

For a data/video centric operator, spectrum capacity needs increase dramatically with subscriber take-up and usage as well as with the increased speed assumed to support customer expectations in the future.

Providing a 42 Mbps experience to 50% of customers, for example, would require in the range of 135 MHz of spectrum (at a spectral efficiency of 3 bps/Hz). And to fully implement LTE – i.e. to provide 100 Mbps to the customers – almost 200 MHz is required at 5 bps/Hz efficiency.

Given the greater take-up assumed in Scenario 2, coupled with more mobile broadband devices and services being promoted, results in higher data consumption – from 1.5 to 22 GB per month. As noted above, these usage levels are examples to illustrate possible scenarios, but they are somewhat indicative of the type of usage seen for fixed home Internet service (9 GB per month in 2008 and 12 GB in 2009 according to the CRTC), and are in the range of Clearwire's initial WiMAX service consumption of 7 GB per month and consistent with forecasts for increased data usage.[34] As shown in Figure 6, the range of forecasts could lead to 32 GB per month up to 87 GB. We also highlight that LTE services being launched in 2011 in Germany include up to 30 GB monthly usage at download speeds of 50 Mbps, and thus bear many similarities to our assumptions.

2.3 Amount of Mobile Spectrum Licensed to Date

The spectrum band plans – and hence the available spectrum capacity – in Canada and the US for mobile services are essentially the same – cellular, PCS, AWS as well as the specialized SMR/ESMR bands. For 700 MHz and BRS, the overall ranges are the same as those in the US. Industry Canada has not yet finalized the detailed band plan for 700 MHz.[35]

2.3.1 Over 20% Less Spectrum has been Awarded in Canada Compared to the US

In terms of total spectrum capacity licensed to date, in the US the FCC has issued approximately 542 MHz of spectrum that can be used for mobile services. In Canada, Industry Canada has issued approximately 418 MHz, about 23% less.

This is summarized by service type in the table below. There are three differences between Canada and the US:

[34] MOBILE BROADBAND: THE BENEFITS OF ADDITIONAL SPECTRUM, *op.cit.,* Page 5

[35] The band plan for the BRS 2500-2690 MHz range is set out in "Decisions on a Band Plan for Broadband Radio Service (BRS) and Consultation on a Policy and Technical Framework to License Spectrum in the Band 2500-2690 MHz", *op. cit.*, page 17. Also note: the focus of this Report is on mobile spectrum and excludes discussion of bands that are not allocated for and/or not suitable for mobile service such as the 3.5 GHz band. The 2.3 GHz WCS band has a "flexible" use allocation in both Canada and the US and in principle could in theory be used for mobile service. However, there has been very limited focus on this band in deployment and in technology and it is also not included in the discussion in this report.

- The FCC auctioned 700 MHz licenses in several auction processes from 2001 to 2008; in Canada the 700 MHz auction is not expected before late 2012,

- The 2500-2690 MHz BRS range was licensed in both Canada and the US for fixed service, and is now being converted to mobile in both countries. In exchange for being permitted to provide mobile service, Industry Canada required fixed service licensees to return about one third of their spectrum capacity for re-licensing; the US did not,

- For ESMR, in the US the PCS G Block (10 MHz) was licensed to Sprint Nextel nationally to replace a portion of its 800/900 MHz ESMR spectrum. In Canada the G Block was auctioned in 2008 and did not replace 800/900 MHz ESMR spectrum already licensed for commercial use (e.g. TELUS MiKE service). Thus the total of cellular/PCS/ESMR (including G Block) in Canada for commercial operators is 10 MHz greater than the total in the US.

Also shown in the table is the remaining spectrum available amongst bands that are already licensed, before "new" spectrum opportunities.

Table 5 – Licensed Mobile Capacity – US and Canada – Existing and Upcoming

Service	Licensed mobile capacity US	Licensed mobile capacity Canada		Band
Cellular	50	50	MHz	850 MHz
PCS	120	120	MHz	1900 MHz
SMR/ESMR (1)	13	13	MHz	800/900 MHz
Other 2 GHz (2)	5	15	MHz	1900 and 1670 MHz
AWS	90	90	MHz	1700/2100 MHz
700 MHz	74	-	MHz	700 MHz
BRS - FDD spectrum (3)	140	80	MHz	2500-2690 MHz
BRS - center portion (TDD)	50	50	MHz	
Total licensed	542	418	MHz	*124 MHz more issued in the US*
Upcoming to be awarded	US	Canada		Band/licenses
700 MHz	10	84	MHz	US: Unsold 700 Upper D (4)
Less 700 MHz if D Block is excluded	*(10)*	*(10)*	*MHz*	*If unavailable for commercial use*
BRS - FDD spectrum (5)	-	60	MHz	Cda: Returned FDD spectrum (5)
Total before additional future spectrum	542	552	MHz	*difference due to ESMR/G Block licensing (6)*

(1) SMR/ESMR spectrum in 800/900 MHz varies by market due to site-by-site licensing
(2) In Canada icludes PCS G Block (10 MHz) and I Block 1670-1675 MHz (5 MHz); In the US, Sprint Nextel has the PCS G Block nationwide, but replaces SMR spectrum already held - MHz included in SMR; WCS (2.3 GHz) is "flexible use" - not included above (30 MHz)
(3) approximate portion useable for mobile (FDD spectrum); 42 MHz additional is allocated for TDD (center portion) plus guard bands. BRS shown for Canada per Industry Canada SMSE-005-11; For US - BRS is shown as completely licensed but licensing was done by channel by market, so there may be areas where licenses were not issued. BRS total MHz is 186 MHz plus 4 MHz for guard bands
(4) Canada: 108 MHz total less 24 MHz assumed to for public safety users; US 10 MHz is unsold D Block
(5) Canada: spectrum from approximate 1/3 returned from incumbents - per Industry Canada SMSE-005-11
(6) US PCS G Block was licensed to Sprint Nextel to replace a portion of 800/900 MHz. In Canada G Block was auctioned in 2008 and did not replace 800/900 MHz spectrum held by TELUS (Mike). Thus the total in Canada is 10 MHz greater than the total in the US

The only remaining "piece" in the US is the 700 MHz Upper D Block, which did not sell in the 2008 auction. The Upper D Block was established by the FCC with a requirement to implement a sharing arrangement with public safety users and did not meet its reserve price in the bidding. The FCC had targeted a re-auction for 2011.[36]

However it now appears that the Upper D Block will end up as an allocation for public safety only, in which case it will not be available at all for commercial operators.[37]

[36] FCC National Broadband Plan, March 2010, Exhibit 5-E, page 84

Cellular, PCS and ESMR licenses have been issued in both Canada and the US. The same amount of spectrum has been licensed in both countries:

- Cellular = 50 MHz (two licenses of 25 MHz),[38]
- PCS = 120 MHz (originally six licenses – three of 30 MHz, three of 10 MHz, with two of the 30 MHz licenses subsequently divided into 3x10 MHz licenses),
- ESMR = approximately 13 MHz, variable by market (awarded site by site).

AWS-1 licenses were auctioned in the US in September 2006 and in Canada in 2008. AWS-1 consists of 90 MHz in total made up of six licenses: three of 20 MHz and three of 10 MHz each.

Industry Canada also included the PCS G Block (10 MHz) in the same auction as AWS-1 as well as 5 MHz in the 1670-1675 MHz range. These bands were previously licensed in the US.[39]

2.3.2 Upcoming Spectrum in Canada Could Increase Total to US Level

The upcoming spectrum to be awarded in Canada as shown above is the amount that could be available subject to final Industry Canada rulings on band plans. In particular:

- 700 MHz – The total in the band is 108 MHz consisting of the 18 former UHF TV channels 52-69 of 6 MHz each. With 24 MHz allocated to public safety, this

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[37] President Obama Details Plan to Win the Future through Expanded Wireless Access, The White House, February 10, 2011. The plan includes reallocation of the Upper D Block for public safety to support development of nationwide, interoperable wireless network for public safety.

[38] The two licenses consist of four sub-bands. The Rogers A License is 11+11 MHz noncontiguous with 1.5+1.5 MHz; The Bell/TELUS B License is 10+10 MHz noncontiguous with 2.5+2.5 MHz.

[39] G Block to Sprint Nextel, 1670-1675 MHz to Crown Castle

leaves 84 MHz that could be licensed for commercial operators. Excluding the 10 MHz of Upper D Block spectrum as additional public safety exclusive leaves 74 MHz. In the US band plan, two 6 MHz blocks are unpaired and 4 MHz is taken up by guard band licenses. Excluding unpaired blocks and guard bands, the "net" amount of paired spectrum "prime land" is potentially 58 MHz for commercial mobile services.

- BRS 2500 MHz – The total band is 2500-2690 MHz; i.e. 190 MHz of spectrum capacity. The BRS band plan restructures the legacy MCS/MDS licensing structure into high frequency and low frequency paired blocks and a middle section of unpaired blocks.[40] The paired blocks are for FDD technology, important for mobile services, and the unpaired could be for TDD.[41] Based on the policy of requiring incumbents to return one third of their spectrum capacity, Industry Canada decided to make 60 MHz available for re-licensing.[42]

Pending the final band plan for 700 MHz, the amount of spectrum that can be made available in Canada from the 700 MHz and the BRS ranges would be approximately 134

[40] MCS is multipoint communications systems, covering the lower part of the band for fixed access services. MDS is multipoint distribution systems, originally awarded for "wireless cable" applications in the upper portion. In the US, the legacy licenses were Instructional Fixed Television (services), licensed block by block, and MDS.

[41] To date mobile services make use of a Frequency Division Duplex (FDD) technique meaning that pairs of frequencies are used – one set for transmission from basestations to customers and another set for transmission from customers to basestations. Time Division Duplex (TDD) technology makes use of the same frequency set in both directions and thus can be used in unpaired spectrum. Unpaired spectrum blocks can also be used for unidirectional transmission (e.g. to provide additional capacity towards the customers).

[42] In areas of the country where both MCS and MDS spectrum has been licensed already. There is more available in other parts of the country where MDS licenses were not issued and in Manitoba where neither MDS nor MCS was issued. See "Decisions on a Band Plan for Broadband Radio Service (BRS) and Consultation on a Policy and Technical Framework to License Spectrum in the Band 2500-2690 MHz", *op. cit.*, pages 31-32

MHz in total including both bands and both paired and unpaired spectrum. This is summarized below.

Table 6 – Potential MHz in Canada – 700 MHz and BRS Ranges

	MHz potentially available		
	FDD MHz	Unpaired MHz	Total
700 MHz	58	16	74
BRS	60	-	60
Total (MHz)	118	16	134

700 MHz excludes D Block; Unpaired includes guard band capacity;
Amount of 700 MHz may change subject to final band plan;
In parts of Canada where MDS spectrum was not awarded and in Manitoba more BRS spectrum will be available than shown per SMSE-005-11.

Assuming spectrum is awarded as show above the Canadian total would then be 552 MHz across all of the mobile bands. Issuing all of the above would bring Canada on par with the US in terms of total awarded to date. Canada would effectively have issued 10 MHz more mobile spectrum than the US due to the different treatment of the PCS G Block, as discussed above. But this additional spectrum is insufficient to meet future spectrum demand forecasts.

2.3.3 Future Spectrum Identified in the US Expected to Double Licensed Capacity

Over and above the 700 MHz and BRS ranges, in the US, the FCC has a target of auctioning an additional 500 MHz of spectrum in the next 10 years (from mid-2010), with a five-year target of 300 MHz. After 10 years, assuming the FCC is successful in realizing its objectives, there would be just over 1 GHz of mobile spectrum in the US market, almost double that at present, as summarized below.

Table 7 – Future Total Mobile Broadband Spectrum MHz

	US	Canada
Total licensed MHz to date for mobile service	542	418
Upcoming to be awarded *	-	134
Total before additional future spectrum	542	552
Objective for new spectrum		
-- next five years	300	TBD
-- next ten years	500	TBD
Total after ten years (MHz)	1,042	TBD

** Excluding the 10 MHz Upper 700 MHz D Block*

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The FCC intends to license an additional 300 MHz, more than 50% more than at present, over the next five years and to add another 200 MHz to almost double licensed spectrum for mobile broadband on a ten-year horizon. This objective was recently re-affirmed in a White House Statement concerning the National Wireless Initiative which is intended to make available high-speed wireless services, "4G" or post 3G, to at least 98 percent of Americans within five years, in part by conducting voluntary incentive auctions and by making more efficient use of government spectrum.[43]

2.3.4 Spectrum Holdings per Carrier in Other Countries – UK, US, France, Spain, Germany

The following Table summarizes current spectrum holdings for major carriers in a number of countries. The Table compares current spectrum holdings excluding digital dividend and 2500 MHz spectrum to provide an even basis of comparison as not all countries have awarded these spectrum bands to date. However, spectrum holdings in the

[43] President Obama Details Plan to Win the Future through Expanded Wireless Access, *op.cit.*

700 MHz and 2500 MHz spectrum bands where already awarded, are noted in the comments column. The Table also indicates if spectrum is held on a national or regional basis.[44]

Table 8 – Maximum Mobile MHz per Carrier, excluding Digital Dividend and BRS

Country	Carrier	Maximum total mobile MHz in a given area	National (N) or Regional (R) spectrum licenses	Comments
Canada	Bell	75	R	Bell and Rogers via Inukshuk share up to 80 MHz paired and 50 MHz unpaired BRS spectrum (1)
	Rogers	105	R	NOTE: Rogers has 95 MHz in Canada's largest market Toronto
	TELUS	75	R	
	Videotron	50	R	
	Shaw	20	R	
	Eastlink	40	R	
	Globalive	20	R	
	Mobilicity	20	R	
United States	Verizon	85	R	Also 22 to 46 MHz of 700 MHz spectrum depending on the area
	AT&T	95	R	Also 12 to 24 MHz of 700 MHz spectrum plus unpaired blocks
	Sprint Nextel	43	R	Did not participate in 700 MHz auction; has access to >100 MHz of BRS
	T-Mobile	70	R	Did not participate in 700 MHz auction
	MetroPCS	40	R	Also has one 700 MHz license (6+6 MHz) covering 4 States MA-NH-RI-VT
United Kingdom	Everything Everywhere (2)	130	N	Net of 15+15 MHz of 1800 MHz to be returned
	Vodafone	76	N	
	O2	66	N	
	H3G	29	N	
France	Orange	100	N	
	SFR	100	N	
	Bouygues	90	N	
	Free (3)	20	N	4th 3G licensee since 2010. Not yet in service.
Spain	Telefonica	112	N	
	Vodafone	104	N	
	Orange	92	N	
	Xfera	30	N	
Germany	T Mobile	90	N	Also 20 MHz of 800 MHz, 40 MHz of paired 2.6 GHz, 5 MHz unpaired
	O2	75	N	Also 20 MHz of 800 MHz, 40 MHz of paired 2.6 GHz, 10 MHz unpaired
	E-Plus	110	N	Also 20 MHz of paired 2.6 GHz spectrum, 10 MHz unpaired
	Vodafone	70	N	Also 20 MHz of 800 MHz, 40 MHz of paired 2.6 GHz, 25 MHz unpaired

(1) Inukshuk has less in Manitoba and in markets where legacy MDS spectrum had not been issued (Alberta, Atlantic Canada, N.Ont., N.Que)
(2) Merged entity - UK operations of T Mobile and Orange
(3) Free's spectrum includes 5+5 MHz of 900 MHz spectrum returned by incumbents
Excluding digital dividend (700 MHz/800 MHz), excluding 2500-2690 MHz BRS and excluding unpaired spectrum

[44] Note: Spectrum holdings per carrier may change in the coming years as some regulatory entities are engaged in re-farming processes for spectrum as part of their activities to liberalize the use of spectrum for any technology, rebalance spectrum holdings and award new spectrum bands, namely the digital dividend spectrum and the 2600 MHz spectrum where not already awarded.

It should be kept in mind that the total MHz held by any carrier is not just a function of government-run spectrum awards, but also the result of secondary market transactions. Everything Everywhere (the name of the T Mobile/Orange joint venture in the UK) has a large amount of spectrum (net of 30 MHz being returned for re-licensing) due to the approved merger of the two carriers that make it up.

About 30% of the Rogers' core mobile spectrum (i.e. including cellular, PCS and AWS) comes from its acquisition of Microcell, which had a 30 MHz PCS license. Rogers was not the sole bidder for the acquisition of Microcell, which could have just as well been acquired by Bell Canada, TELUS (which participated in the bidding) or another party altogether. This was similarly the case for earlier acquisition of Clearnet by TELUS, the 30 MHz PCS license of which accounts for about 40% of TELUS's total spectrum capacity.

There are a number of key elements indicated in the above Table:

- Spectrum holdings per carrier vary from a low of 20 MHz for a new entrant in France for which a license was awarded in 2010, to the 70-130 MHz range for larger carriers that have been in operation for many years and have acquired spectrum in different bands, in some cases by acquisition in secondary markets.[45]
- Before the award of digital dividend and BRS licenses, large mobile carriers typically hold of the order of 70 to 130 MHz of total spectrum, a range similar to what is found among Canadian carriers. An exception is Sprint Nextel which holds only 40 MHz of 1900 MHz PCS spectrum. However, Sprint via Clearwire has access to the order of 107 to 180 MHz of 2500 MHz BRS spectrum which

brings its effective total in the range of 150 MHz to 220 MHz depending on the city.

- If one includes an estimate of the 2500 MHz BRS spectrum in the total holdings of Bell and Rogers (via their Inukshuk joint venture), this would add 80 MHz of paired and 50 MHz of unpaired spectrum, shared between them, with some variation depending on the area of the country.
- Each carrier in Germany holds from 70 MHz to 110 MHz of core mobile spectrum – GSM900, DCS1800 and 2100 MHz (3G) – on a national basis post the 2010 mega auction, and more when digital dividend and BRS spectrum is included.
- Many carriers hold a mix of spectrum below and above 1 GHz, especially the first carriers that launched cellular in 850 MHz in North America or GSM900 in other countries. However, others such as MetroPCS, T-Mobile and Sprint Nextel do not hold spectrum below 1 GHz. T-Mobile and Sprint Nextel chose not to participate in the auction of 700 MHz spectrum in 2008. E-Plus in Germany also has no spectrum below 1 GHz and neither in the UK does 3UK nor Everything Everywhere (T-Mobile/Orange). In the German auction, E-Plus participated and entered bids for digital dividend spectrum in the early part of the auction, in the end it decided to focus on acquiring spectrum in the higher bands (1.8 GHz, 2.5 GHz, etc.) at a much lower cost per MHz.
- In Canada, Bell Canada does not hold spectrum below 1 GHz in Western Canada and TELUS does not hold spectrum below 1 GHz in Ontario, most of Quebec or other parts of Eastern Canada.[46] Bell and TELUS however have been sharing the

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[45] Some AWS new entrants in Canada only hold 10 MHz of spectrum in certain cities. For example, Globalive holds 10 MHz of spectrum in many cities but holds 20 MHz in Toronto. Videotron holds 40 MHz in the key cities of Quebec, but 10 MHz in Toronto.

[46] Except for TELUS' ESMR "MiKE" service.

cost of building new network infrastructure for some time, notably their shared HSPA+ network, and both have stated that they intend to evolve to LTE.

2.4 Conclusions Regarding the Need for More Spectrum

Given the anticipated growth in data usage by mobile subscribers, carriers will have a continuing need for more spectrum resources. This will be more apparent for a large carrier with a very large base of customers using Smartphones, tablets or other data-intensive devices.

It is expected that such carriers will require 200 MHz or more of spectrum to fulfill customer demand for both increased speed and unabated growth in usage.

The need for additional spectrum resources has been recognized by the FCC in the US, which is planning to approximately double the spectrum available to carriers over the next 10 years – over and above present licensing in the US which already includes most of the 700 MHz range as well as all of the BRS 2500 MHz range.

This magnitude of increase is validated by LYA's analysis that estimates carriers' need for capacity under various scenarios of subscriber data usage and the evolution of network technology to LTE. For a large carrier with a data-intensive customer base, the theoretical amount of spectrum needed could be greater, particularly if LTE technology yields less efficient usage of spectrum than anticipated and when considering the spectral efficiency of legacy technologies already deployed and which will be in operation for many years to come.

Technology and spectrum bands are intertwined. Even carriers who might be considered spectrum rich need access to new spectrum and to the same spectrum as their US counterparts to deploy LTE technologies as mobile technologies are closely linked with spectrum bands. And because of the US developments with LTE in the 700 MHz bands, Canadian carriers looking to deploy LTE across the country in both urban and rural areas will require 700 MHz spectrum in order to obtain suitable equipment and handsets to service their customers and provide roaming services.

The next section discusses the evolution of technology and its relationship to specific spectrum bands, and in particular the spectrum implications of migration to fourth generation (4G) service using LTE.

3. Technology and Spectrum

Mobile technology ecosystems have evolved from first generation analog cellular service to the current third generation (3G) and are now moving to fourth generation (4G).

New generations of technology typically come with new spectrum bands – first generation (cellular) was introduced in the 850 MHz band, second generation (PCS) was in the 1.9 GHz band. Spectrum bands are one component of the mobile ecosystem, also driven by technology standards, handset vendors and customer applications and usage.

Third generation mobile in North America, unlike in Europe, loosened the association of bands and technologies… third generation HSPA technology was deployed by Canadian carriers in the legacy 850 MHz band although the third generation band for North America was identified as AWS in the 1.7/2.1 GHz ranges.

The "official" technologies for 4G are LTE and WiMAX, along with the evolution of HSPA, and many bands have been identified as candidates to support 4G. These are presented and discussed in this section in the context of potential for deployment in the North American context. Focusing on long term evolution (LTE) technology – often seen as the leading contender for 4G – different band options are discussed for LTE deployment.

The section concludes with the observation that while there are many bands potentially available for LTE deployment, on a practical level the list narrows very quickly to only a few – mainly the 700 MHz band with its growing North American technology ecosystem, the AWS spectrum band - possibly with a more limited technology ecosystem in the early days and more urban focused deployment, and the BRS spectrum band – also similar to the AWS spectrum band with deployment likely limited to urban areas as well as potential roaming issues in the North American context due to Clearwire in the US.

3.1 Evolving Mobile Ecosystem Increasingly Driven by Handsets

For mobile service there are two broad ecosystems of technology, GSM and CDMA, which have been evolving since the 1990's, coupled with a third ecosystem that has been striving for adoption around WiMAX and now facing increased headwinds.[47]

3.1.1 The Status of Mobile Broadband Ecosystems

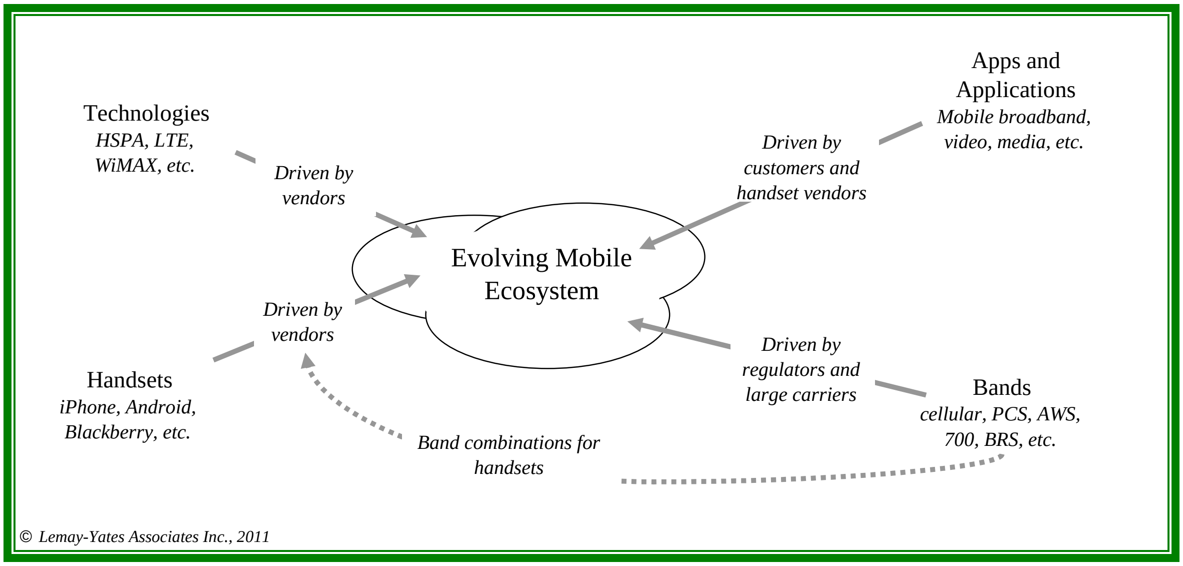
Mobile legacy networks have been built on one or more technology "tracks" – usually either GSM or CDMA – and have been evolving through various "generations":

- First Generation (1G) – analog cellular,
- Second Generation (2G) – digital cellular and PCS – GSM and CDMA-based,
- 2.5G – data capabilities such as GPRS/EDGE (GSM-based)[48], CDMA2000,
- Third Generation (3G) technologies… HSPA, EVDO Rev A,[49]
- 3.75G – data capabilities to 21 Mbps such as HSPA+,[50]
- Fourth Generation (4G) – LTE, evolved HSPA+[51] and WiMAX.

[47] GSM is the "Global System for Mobile" developed initially in Europe, but now global. CDMA is "code division multiple access", a US-developed technology deployed primarily in North America. WiMAX is "Worldwide Interoperability for Microwave Access" and originally developed as a fixed service standard, but has become a third alternative technology track for mobile.
[48] GPRS is a "general packet radio service", data transmission that runs on frequencies "beside" the GSM voice service. EDGE was a set of techniques that increased GPRS transmission speed.
[49] HSPA is "high speed packet access". EVDO Rev A is a CDMA-based technique "evolution data-optimized" which is typically deployed in its "Revision A" version.
[50] HSPA+ uses some of the same techniques as LTE and provides up to 42 Mbps (million bits per second).

Specifications and standards are important to the development of the industry because they ensure that technologies operating in the various bands are interoperable, technically compatible, non-interfering with other bands and services, meet certain equipment standards, etc. This also helps ensure that a global ecosystem of technology develops, creating economies of scale for equipment makers and eventually providing for lower costs for consumers of mobile services.

Figure 7 – Drivers of the Mobile Ecosystem – Canadian carriers have less clout



The mobile ecosystem is increasingly driven by handset vendors as well as by US carriers and very large multinational carriers. Canadian carriers have much less clout in terms of determining what bands and technologies are supported on the mobile networks.

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51 Also referred to as HSPA Evolution.

With the increasing proliferation of bands worldwide, handset vendors must choose the combinations of bands they will support, driven by the most attractive market segments. The spectrum bands that are held by large carriers such as Verizon, AT&T, Vodafone, and other large players represent the largest markets for handset vendors to target.

Not all possible bands can technically be supported on a given device; 4G handsets in particular will focus on specific carriers and markets. The evolution of spectrum requirements will then in turn be driven by the take-up of these devices by customers and the usage they make of applications on the devices. In North America, development of the 700 MHz band – and the combinations of bands and technologies employed on handsets – is being driven by Verizon in the upper sub-band and AT&T in the lower sub-band.

3.2 Fourth Generation (4G)

3.2.1 4G Evolving "Official" Definition

In October 2010, ITU-R approved LTE and WiMAX as 4G technologies meeting the requirements of IMT-Advanced.[52] Key features of "IMT-Advanced" include: enhanced peak data rates to support advanced services and applications (100 Mbps for high and 1 Gbps for low mobility were established as targets for research).[53]

These data rates were set out as targets – thus the exact specification and requirements associated with 4G remains somewhat nebulous. Or as stated by the ITU more recently,

[52] LTE meaning 3GPP LTE Release 10 and Beyond (LTE Advanced) and WiMAX meaning IEEE standard 802.16m (Wireless MAN-Advanced), ITU press release, October 21, 2010

[53] http://www.itu.int/ITU-R/index.asp?category=information&rlink=imt-advanced&lang=en and ITU-R Rec. M.1645, Figure 2

the term 4G is "undefined", and "may also be applied to the forerunners of these technologies" (i.e. enhancements to 3G technology).[54] Thus HSPA+ is now considered to be a 4G technology along with LTE and WiMAX.

The target data rates were also intended to be "shared between active users" and "the achievable (peak or sustained) throughput for any individual user depends on many parameters, including the number of active users, traffic characteristics, service parameters, deployment scenarios, spectrum availability, and propagation and interference conditions.[55]

That said it should be kept in mind that the IMT-Advanced definition was developed many years ago – 2003 or earlier – and that "user" expectations of broadband speed based on landline and more recent mobile experience have evolved considerably since then. Thus an objective of providing 100 Mbps speed has tended to become viewed as an objective *per user* as opposed to one that is only reflective of the maximum available to all users at once.

Apart from the official definition of 4G, however, the use of the term "4G" has come to signify simply the next generation of mobile services, regardless of the underlying technology or capability base, including LTE, WiMAX as well as HSPA+ technology.

There is a different market positioning of what is 4G, depending on the carrier and the starting point for the definition of what is next.

[54] ITU, Press Release, December 6, 2010

[55] Framework and overall objectives of the future development of IMT-2000 and systems beyond IMT-2000, Rec. ITU-R M.1645, page 12

3.2.2 Market Positioning around 4G in the US

There are several battles around the concept of 4G in the US market, as distinct from the official ITU definition of 4G:

- Sprint: "4G provides peak download speeds of more than 10 Mbps and average download speeds of 3-6 Mbps. Sprint 3G (EV-DO Rev. A) generates expected average upload speeds of 350-500 kbps and download speeds of between 600 kbps and 1.4 Mbps. Peak 3G download data rates are 3.1 Mbps and peak upload data rates are 1.8 Mbps."[56]

- T-Mobile: "T-Mobile's 4G network, HSPA+, is capable of faster speeds than our 3G network without HSPA+; improved speeds vary due in part to device capabilities. HSPA+, operates at today's 4G speeds; not available everywhere. It delivers theoretical peak download speeds of up to 21Mbps and peak upload speeds of up to 5.7Mbps."[57]

- Verizon launched its LTE network in late 2010 covering of the order of 100 million population and expanding: "4G LTE – customers can expect download speeds of 5 to 12 Mbps and upload speeds of 2 to 5 Mbps in 4G Mobile Broadband coverage area".[58] And "field trials have demonstrated download rates of 50 to 60 Mbps peak speeds".[59]

[56] Sprint press release, October 19, 2010
[57] http://t-mobile-coverage.t-mobile.com/hspa-mobile-broadband
[58] Verizon press release, December 3, 2010
[59] Verizon press release, February 18, 2010

- On January 5, 2011, AT&T announced the launch of its LTE network in 2011 and that it is accelerating its LTE roll out to be "largely complete by YE 2013". Initial LTE offerings will include LTE smartphones, tablets, modems and mobile hotspots, to be offered starting in mid-2011. Also in January 2011, however, AT&T also re-branded its present "enhanced" 3G network as 4G, capitalizing on the undefined nature of the term and to effectively as a competitive response to T Mobile and Verizon. AT&T reported that its HSPA+ network today provides speeds up to approximately 6 Mbps and "expects these speeds will increase as it accelerates its LTE build and further deploys expanded backhaul".[60]

- MetroPCS: "LTE Handset Allows Consumers to Do More with Entertainment and Provides a Faster Web Experience."[61] But… the average download speed reported was around 700 kbps.[62] This reflects MetroPCS's business model which is focused on low cost voice services.

While there are considerable differences amongst these examples of 4G, none of the commercial offerings to date in the US approach the "official" definition of 100 Mbps service speed.

Lightsquared (formerly SkyTerra) – not yet in commercial operation – is building a national combined satellite/terrestrial 4G network using LTE, anticipated to include 40,000 cell sites covering 92% of the US population by 2015 with speeds up to 100

[60] AT&T Announces Plans to Deliver Nation's Most Advanced Mobile Broadband Experience, January 5, 2011.
[61] MetroPCS news release, September 21, 2010
[62] For $55, What Kind of LTE Experience Does MetroPCS Deliver?, GigaOM, Nov 26, 2010

Mbps.[63] Lightsquared is planned as a wholesale-only network, with T Mobile being rumored as possibly being a customer for it.[64]

Sprint's 4G uses WiMAX technology but at speeds only in the 10 Mbps range. Clearwire – which provides the BRS spectrum based network used by Sprint – has been testing LTE on BRS spectrum and has reported speeds of 90 Mbps in the downlink and 30 Mbps in the uplink.[65]

T Mobile and AT&T now label their HSPA+ deployments "4G" even though HSPA+ is a third generation technology providing up to 21 Mbps speed and potentially 42 Mbps, also deployed in Canada but not yet referred to as 4G.

MetroPCS offers an LTE handset but appears to be using as a variant on its voice-centric strategy. It uses LTE in AWS frequencies but supports voice via its legacy CDMA technology in the PCS bands. MetroPCS does not advertise data speeds.

Even Verizon's 4G, while using LTE technology in a 10 MHz channel, is only being promoted at the moment to support download average speeds in the 12 Mbps range. On the other hand, carriers which have launched LTE in a few European countries are advertising average speeds from 20 to 80 Mbps, closer to true 4G.

[63] http://www.lightsquared.com/what-we-do/network/
[64] Clearwire spectrum auction interest dwindles, Reuters, January 19, 2011. Note: the Lightsquared service would require a dual mode terrestrial/satellite handset but the FCC may provide additional flexibility to lease the terrestrial portion as implied in the ruling allowing the Harbinger/SkyTerra merger (FCC DA 10-535). The terrestrial bands in question are not currently on the 3GPP's list of potential bands for LTE.
[65] Clearwire Quarterly Report, 3Q10

3.2.3 Canadian Carriers and the G's

Canada boasts three national HSPA+ network providers operating at speeds up of to 21 Mbps. HSPA+ was initially deployed by Rogers Wireless and since the fourth quarter of 2009 also by Bell and TELUS via their joint network build. Bell and TELUS also both plan to evolve to use LTE; but it is unclear if this is included in their network sharing arrangement.[66]

The original Bell-TELUS 2001 agreement covers "next generation" technology, terminology now applied to 4G. TELUS recently announced it will be launching HSPA+ service at 42 Mbps in March 2011 and refers to this as 4G.[67] Bell announced on November 23, 2010 that it was doubling the downstream speed on its HSPA network in Toronto to 42 Mbps.[68]

Since late 2009, new entrants Wind Mobile Canada and Mobilicity have been rolling out mobile broadband networks also based on HSPA offering mobile data services with up to 7.2 Mbps downstream maximum bandwidth, focused primarily on core urban areas. They were followed by Videotron in September 2010. Videotron's network operates at HSPA+ 21 Mbps downstream bandwidth. Shaw is expected to launch its mobile network at a later date.[69]

No country other than Canada can currently boast to benefit from three national mobile broadband network providers with services at up to 21 Mbps to the majority of its

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[66] Bell and TELUS Press Releases, October 10, 2008
[67] TELUS Press Release, February 8, 2011
[68] Bell Canada Press Release, November 18, 2010.
[69] Another new entrant, Public Mobile, does not provide mobile data services other than texting.

population by mid-2010, with an additional network operating at 21 Mbps in Quebec and more to come over the short to medium term.[70]

Rogers announced its trial of LTE technology in October 2010.[71] Bell Canada was also reported at the time as stating it had also been testing LTE technology. Wind Mobile announced a successful 4G live LTE trial on February 3, 2011, in conjunction with the introduction of High Definition Voice Calling.[72] Wind indicated that download speeds of 50-60 Mbps were experienced during the trial.

The issue is not one of whether services are labelled as a particular "G", but the underlying spectrum and high quality performance, both speed and latency, that is achieved. In order for Canadian carriers – and other carriers worldwide – to move to the next generation of services, new technology and new spectrum bands are required. The next section discusses the candidate spectrum bands for LTE and their expected usefulness in the short to medium term.

[70] For a discussion of Canada relative to other countries, see Section 3.4 of "The Performance of Canada's Consumer Broadband Networks in 2010", Lemay-Yates Associates Inc., prepared for Rogers Communications Inc. and filed in Industry Canada's Digital Economy Consultation, July 2010
[71] Rogers Announces First LTE Technical Trial in Canada, Press Release, October 6, 2010
[72] Wind Mobile Press Release, February 3, 2011.

3.3 Spectrum Bands for LTE

The following table shows the various frequency bands that have been set out as candidates for deployment of LTE technology.

Table 9 – Global Candidate Frequency Bands for LTE

	Band	Uplink	Downlink	Acronym	Area where licensed
FDD bands	1	1920-1980 MHz	2110-2170 MHz	IMT2000 (UMTS)	Europe and elsewhere
	2	1850-1910 MHz	1930-1990 MHz	PCS	North America
	3	1710-1785 MHz	1805-1880 MHz	GSM 1800	Europe and elsewhere
	4	1710-1755 MHz	2110-2155 MHz	AWS	North America
	5	824-849 MHz	864-894 MHz	Cellular (1)	North America
	6	830-840 MHz	875-885 MHz	CDMA	Japan
	7	2500-2570 MHz	2620-2690 MHz	IMT Extension/BRS	Europe and elsewhere/North America
	8	880-915 MHz	925-960 MHz	GSM 900	Europe and elsewhere
	9	1749.9-1784.9 MHz	1844.9-1879.9 MHz	UMTS	Japan
	10	1710-1770 MHz	2110-2170 MHz	Expanded AWS	n/a
	11	1427.9-1452.9 MHz	1475.9-1500.9 MHz	UMTS	Japan
	12	698-716 MHz	728-746 MHz	Digital Dividend (2)	US
	13	777-787 MHz	746-756 MHz	Digital Dividend (2)	US
	14	788-798 MHz	758-768 MHz	Digital Dividend (2)	US
	17	704-716 MHz	734-746 MHz	Digital Dividend (2)	US
	18	815-830 MHz	860-875 MHz	Digital Dividend (2)	Europe
	19	830-845 MHz	875-890 MHz	Digital Dividend (2)	Europe
	20	832-862 MHz	791-821 MHz	Digital Dividend (2)	Europe
	21	1447.9-1462.9 MHz	1495.9-1510.9 MHz	UMTS	n/a

	Band	Uplink/Downlink	Acronyms and notes
TDD bands	33	1900-1920 MHz	DECT Extension (Europe); overlap with AWS-2 (3)
	34	2010-2025 MHz	IMT2000 Extension; overlap with AWS-2 (3)
	35	1850-1910 MHz	Same as N.Am PCS Uplink
	36	1930-1990 MHz	Same as N.Am PCS Downlink
	37	1910-1930 MHz	PCS - center (including lower portion of G Block) (3)
	38	2570-2620 MHz	IMT Extension/BRS - center
	39	1880-1920 MHz	DECT/DECT Extension (Europe), China, PHS (Japan)
	40	2300-2400 MHz	Portion WCS (N.Am.); China and Korea (WiBRO)
	41	2496-2690 MHz	

Bands for E-UTRA (LTE), per 3GPP TS 36.101 (2010-10), Release 10
Allocations in certain countries may differ somewhat from those shown (e.g. China, Korea)
Other bands exist, e.g. North American SMR 800/900 MHz, 1670-1675 (I Band), Japan cellular 900 MHz,
450 MHz, 1400 MHz range (L Band), 3400-3600 MHz reallocated fixed-mobile in many countries
NOTES:
(1) Cellular downlink portion is actually 869-894 MHz (25 MHz) due to public safety use of 821-824/866-869 MHz
ESMR (TELUS) is 806-821/851-866 MHz - see SRSP-502
(2) "Digital Dividend" bands - US 700 MHz, which is 698-806 MHz and Europe 800 MHz, which is 790-862 MHz
(3) FCC identified AWS-2 as 1915-1920/1995-2000 MHz (PCS H Block) and 2020-2025/2175-2180 MHz

LTE can work with various channel sizes and is designed to be deployed in many different bands. But the advantage goes to the largest contiguous spectrum allotments, which maximize data throughput and enable provision of greater bandwidth capabilities to the end users. Thus LTE deployment favors bands with wide swaths of spectrum, in particular bands with 10 or 20 MHz contiguous spectrum each direction.[73]

Existing bands that have 3G or earlier generations of technology may make use of varying radio channel sizes, historically ranging from 25 kHz to 5 MHz. And given the variety of channel and block plans put in place over the years, spectrum is not always available contiguously (i.e. where a series of small channels or blocks can be "lined up" together). Past upgrades, notably to add data capacity, involved allocating a specific set of radio channels for data traffic as a network overlay.

3.3.1 Re-farming Existing Bands – Expensive and Impractical

To deploy LTE optimally – i.e. to make use of 10 or 20 MHz downlink – in an existing band that is already using 3G (or an earlier technology), the band essentially has to be re-farmed.

This would mean taking out the legacy radio access systems – base stations and related gear – and replacing them with the new technology. Also existing subscribers would have to be provided with new handsets and other devices that work with the new technology in the re-farmed band and/or would have to be provided with handsets that work on another band.

Thus even for carriers that have large amounts of spectrum potentially available, clearing out a band in order to optimize it for LTE deployment is time consuming and comes with

[73] Evolution to LTE – an overview, Global Mobile Suppliers Association, April 7, 2010, page 23

a non-negligible cost as well as disruption to subscribers – and given that the impact would be on each subscriber, the larger the carrier, the larger this cost would be.

Also, existing carriers have to account for legacy technology and roaming arrangements, keeping some spectrum in existing bands dedicated for this purpose. And legacy bands in any case cannot be cleared of 2G/3G technology in the near term due to the need to support voice services over existing networks in parallel with data on LTE.

Existing bands that in principal could support LTE, but would be impractical to re-farm would notably be the case in North America with the highly-used Band 2 (PCS) and Band 5 (cellular), and to some extent Band 4 (AWS).

Thus, deployment of LTE essentially requires new spectrum and the fact that many already allocated spectrum bands have been identified by 3GPP for LTE deployment does not mean that there will be availability of LTE network equipment and handsets in these bands any time soon.

3.3.2 Candidate bands for LTE

On the list in Table 9, the only candidate bands for LTE to provide for mobile broadband services that are not already occupied by services of existing mobile carriers are the 700 MHz bands – Bands 12 to 17.

The two BRS bands – Band 7 and Band 38 – will also become available to all Canadian mobile carriers in Canada once the transition from legacy MCS/MDS systems is complete. BRS technology will benefit from being a close-to global allocation, although

North American deployment to date (i.e. Clearwire) has focused on WiMAX technology and not LTE.

LTE deployment in the US typically focuses on deployment in new bands, notably 700 MHz and in AWS, and not on legacy cellular and PCS bands. Both Verizon and AT&T are deploying LTE for broadband applications in the two bands identified as part of 700 MHz spectrum, in the Upper and Lower 700 MHz spectrum band respectively. In light of the global market clout of these carriers, and particularly for North American deployment, these are the bands that are the focus of LTE handset vendors and equipment manufacturers. LTE and the 700 MHz spectrum bands also bring particular challenges when it comes to roaming as discussed in the next section.

3.3.3 Implications for Roaming

Roaming is an important component of a mobile service offering and the ability to roam is dependent on carriers having common band plans, sets of frequencies and the same network technology. Roaming arrangements between carriers are by necessity spectrum band and technology specific.

A number of factors will impact 4G technology and deployment relating to roaming, particularly for LTE.

700 MHz actually consists of four different 3GPP bands as well as some US-specific bands. This is different from legacy bands such as cellular, PCS and AWS as well as BRS where each refers to one band. Thus "band specific" for 700 MHz will likely mean specific to a particular sub-band of 700 MHz and not to the range overall.

Another factor specific to LTE is the different approach to deployment being implemented in Europe. To date LTE deployment has focused on the 2500 MHz (BRS) range. In the US, the BRS range is primarily held by Clearwire which has deployed WiMAX technology. Hence to date, there is no commonality of European and North American technology deployed in the BRS spectrum band.

Given the large number of candidate bands for LTE, there could be many different implementations worldwide. LTE is not just one technology implementation… and there are also potential implementations using TDD techniques in unpaired frequency ranges, which would then have specific requirements for roaming.

The North American 700 MHz ecosystem limits available roaming partners and will be driven by Verizon (focused on the Upper C block) and AT&T (focused on the Lower blocks). Their specific technologies, implementation and band combinations will be expected to be seen on their respective handsets. This will also be influenced by their particular roaming arrangements offshore and the extent to which these offshore agreements develop specific to digital dividend and/or BRS spectrum using LTE technology.

For Canadian carriers, roaming specific to LTE and 700 MHz will be important both for Canadian customers that are travelling in the US – meaning roaming onto Verizon or AT&T but probably not both – and for US customer travelling to Canada.

Existing national networks in Canada provide support for legacy 2G/3G roaming which would support LTE implementation where voice is likely to “fallback” onto a GSM or CDMA network. National coverage of 700/LTE, combined with 2G/3G networks, will be required to facilitate roaming arrangements specific to the developing LTE ecosystem.

3.3.4 TDD or Unpaired Bands for LTE

There are a number of non-paired blocks that have been identified for LTE. These are intended to use time division duplex (TDD) techniques rather than traditional frequency division duplex (FDD). TDD technology however is new and has yet to be proven for LTE or any high mobility service.

And in any case, many of the TDD bands that could be available to carriers in Europe or Asia are not available in North America. This may be due to incumbent use of the bands in North America – for example Bands 35 and 36 which cover the same frequency range as North American PCS (Band 2) – or due to differing allocations where the specific range cannot be used in North America due to government, satellite or broadcasting users.

As shown by recent acquisition of Qualcomm MediaFLO and other 700 MHz licenses by AT&T, there is possible longer term development of LTE in unpaired spectrum in the US as well. AT&T has the symmetrical FDD blocks in 700 MHz (US Blocks B and C), which it likely intends to use on an asymmetrical basis with the unpaired D and E block spectrum acquired for Qualcomm. But for the foreseeable future, TDD bands are not candidates for LTE deployment by Canadian mobile carriers.

3.3.5 Future Potential for Re-farming European Bands for LTE in North America

Some of the non-North American bands – FDD or TDD – could in theory be re-farmed in North America for use by commercial operators for LTE. However the process of "converting" bands and clearing them is a long and complex one.

Bands 1 to 4 for the most part cover overlapping frequency ranges. For example the lower part of Band 3 (GSM1800) covers 1710-1785 MHz, and the lower part of Band 4 (AWS-1) covers 1710-1755 MHz.

Thus Band 1 (UMTS) and Band 3 (GSM1800) as deployed widely in Europe and elsewhere cannot be "re-created" in North America without completely disrupting North American use of Band 2 (PCS) and Band 4 (AWS).

Band 8 – known in many countries as GSM900 – covers a highly segmented and "cluttered" 900 MHz range in North America, including many specialized applications, public safety and other users. Re-farming this range for use in North America could be a longer term banding option, but would involve relocating many incumbent users to other spectrum that would have to be identified.

3.4 Status of LTE Technology

3.4.1 LTE vs. HSPA+ Technology

LTE and HSPA are built on much the same technology and are IP-based. Both employ advanced modulation schemes on the radio link, notably 64 QAM, multiple carriers, and advanced antenna technology such as MIMO.[74] This gives them theoretical user data rates of 100 Mbps or more, consistent with the ITU's definition of 4G.
LTE is expected to have lower latency and higher quality of service relative to HSPA+.[75] LTE's use of OFDM techniques makes the transmission more robust in an environment with many paths and reflections, such as in dense urban areas.

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[74] MIMO is multiple input multiple output – meaning use of more than one antenna at both the basestation and subscriber handset ends of transmission to improve reception.
[75] LTE – An Optimized OFDMA Solution for Wider Bandwidth Spectrum, Qualcomm, May 2009, Page 4

OFDM makes use of multiple paths across the spectrum bandwidth – it is a “spread spectrum” technique that transmits simultaneously over many radio carriers. This helps make the transmission more immune to noise by taking advantage of the path(s) with the best characteristics at any given time.

This also means however that LTE is better suited to use of wider bandwidths and contiguous spectrum, in order to be able to spread the signals over more and diversified carrier frequencies.

LTE builds on the “best of both worlds”, using proven 3G techniques of HSPA+ and its predecessors, combined with OFDM spread spectrum techniques borrowed from WiMAX. An OFDM system makes use of all the available bandwidth, but the more of it there is the more impact use of OFDM will have.

The combination of OFDM and MIMO makes a radio system non-line of sight (NLOS) in the sense that a straight “visual” line is not required between the transmitter and the receiver. The receiver can choose the best transmission from the different carriers it is receiving – directly or indirectly.

Unlike LTE, HSPA+ is based on fixed 5 MHz carriers, although these can be aggregated to increase throughput. Ericsson, for example, recently demonstrated transmission of 168 Mbps using HSPA technology using a combination of techniques including use of multiple radio channels and MIMO antennas.[76]

[76] Ericsson Demonstrates HSPA at 168 Mbps, cited on PCWorld.com, January 31, 2011

3.4.2 LTE Implications for Voice and SMS services

LTE is now a technology focused on providing broadband services. Services that have been launched provide mobile or fixed broadband service using USB keys or other types of terminals. Since the backbone of LTE makes use of Internet protocol (IP) systems, voice service can eventually also be integrated onto an LTE network using VoIP techniques.

There are currently four implementations of Voice over LTE (VoLTE) being considered:

1. Circuit switched fallback (CSFB) to 2G or 3G circuit voice on standard GSM or CDMA technologies,
2. Over the Top (OTT) such as Skype and GoogleTalk services,
3. Circuit Switched over Packet Switched (CS over PS), and,
4. IMS based, such as the 3GPP solution providing IP Multimedia Subsystem (IMS) Multimedia Telephony (MMTel) provided over LTE.

The CSFB fallback option is the standard solution put forward by 3GPP until IMS voice services are possible. Initial LTE handsets are expected to make use of LTE for data service, but retain GSM or CDMA for voice. Of the carriers committed to LTE, eleven also operate CDMA networks – including Bell and TELUS in Canada, which also have a common HSPA+ network.[77] Thus LTE implementation with voice will come in variants supporting GSM and/or CDMA and with the relevant spectrum band combinations specific to the carriers.

[77] "Enabling Societal and Personal Communications for a Changing World", Adrian Scrase, 3GPP, ATIS Webinar May 12, 2009, page 8

To date the only carrier that has launched LTE with voice services using a telephone handset is MetroPCS in the US. In this case, although MetroPCS promotes its LTE offering for voice services, the mobile voice services on the Samsung Craft handset are actually provided using CDMA technology over MetroPCS's existing 2G network and PCS spectrum.

Over the top (OTT) solutions are available now but do not provide the same level of voice quality as conventional telephony. Up to now, OTT services provide increased competition for long distance for mobile voice services but are not a suitable full replacement for mobile voice services. OTT essentially treats voice as data, which for customers without unlimited mobile data plans can mean very high charges. This is why most OTT solutions tend to focus on use over WiFi. CS over PS is also considered an interim solution to carry voice services and is not currently being deployed.

IMS-based voice over LTE (VoLTE) is a future capability for LTE that would integrate voice and SMS service onto the same delivery platform as data.[78] MMTel has been selected by GSMA as a unified solution to provide voice as well as SMS services over LTE. However, its full implementation cannot be achieved until carriers have deployed LTE to a large proportion of their serving territory to be able to support proper handover.

Therefore, this implies that CSFB – circuit switched fallback – will likely be the first choice for voice and SMS services on LTE handsets over the short to medium term as this enables services across countrywide networks, enables carriers to retain their existing voice roaming and SMS interconnection arrangements, while still serving consumers with LTE for mobile broadband data applications, from the same handsets.

This fact may have implications for carriers that do not enjoy widespread voice coverage with 2G or 3G technologies at the moment. Put another way, near term deployment of LTE technology is not a "standalone" business plan, but complementary to existing 2G/3G services that support voice and SMS roaming and interconnection.

3.4.3 Unique Characteristics of LTE for Broadband Deployment Everywhere

LTE has a number of unique characteristics that may provide it with advantage over other technologies for broadband deployment everywhere:

- Indoor coverage and non-line of sight: Use of OFDM facilitates more reliable data transmission in high density areas where there many paths and non-line of sight is advantageous. This will create an advantage for LTE in urban areas where there are many sources of reflection and multiple paths. Combined with lower frequency deployment of LTE in the 700 MHz band will create a benefit in terms of facilitating broad geographic as well as indoor coverage.
- Various spectrum bandwidth: LTE can be deployed to use various spectrum bandwidth "sizes", including 1.4 MHz, 3 MHz, 5 MHz, 10 MHz, 15 MHz and 20 MHz, thus lending itself to deployment in many bands, both FDD and TDD spectrum. Thus a carrier can have common technology across many legacy bands, as well as take advantage of new spectrum to get the benefits of wideband transmission. The more spectrum that is available, the more benefit carriers will see from deploying LTE.
- Large cell size: In rural areas, use of OFDM means greater immunity to noise via the use of spread spectrum techniques. This effectively increases cell size, or put

[78] GSM World announcement February 15, 2010

another way, a given bit rate will reach further by using OFDM than not, particularly when also deployed in lower frequency ranges.

- Use of multiple carriers up to 100 MHz: Future evolution beyond the initial objective of 100 Mbps in 20 MHz is being considered for LTE. Through the use of multiple 20 MHz carriers, downlink rates of 300 Mbps or more combined with uplink rates of 150 Mbps or more are being considered.[79]
- Spectrum aggregation across different bands: LTE (as is HSPA+ but using smaller carriers) is expected to permit use of multiple carriers together to further increase potential throughput – e.g. by combining carriers of up to 20 MHz to aggregate 100 MHz total, from different bands, which could be contiguous or not.[80] This helps counter the issue of having small "pieces" of spectrum, allowing carriers to gain efficiencies by using the total throughput available on different bands, including combining the aggregate capability of HSPA+ and LTE together.[81] This capability is part of 3GPP Release 10 development, not likely to be commercially available before 2013.[82]

While LTE and HSPA+ performance will be similar when deployed under the same circumstances, LTE's use of OFDM should ultimately provide it with an advantage over other technologies, particularly in areas with high noise and many obstacles. This will be particularly the case when deployed in lower frequency bands, improving rural and indoor coverage.

[79] "Technology Roadmaps November 2009", Qualcomm, ex parte submission to the FCC in GN Docket 09-51, page 7
[80] LTE Advanced – RF Aspects, 3GPP TSG-RAN-WG4 Chairman presentation, December 2009
[81] Long Term HSPA Evolution Mobile broadband evolution beyond 3GPP Release 10, White Paper, Nokia Siemens Networks, December 2010
[82] Press release of T Mobile and Nokia Siemens Networks concerning long term HSPA evolution, December 15, 2010

Of course as with many other developments, the “winning” technology will ultimately be determined in the marketplace and will be based on consumer take-up, not solely on the elegance and performance of the underlying technology.

3.5 BRS and AWS Compared to the 700 MHz Spectrum Bands

Both BRS (2500 MHz range) and AWS (1700/2100 MHz ranges) are spectrum bands that can be used for 4G deployment and are identified as candidate bands for LTE. As noted above, in the US, Sprint makes use of Clearwire’s BRS spectrum for its WiMAX-based 4G service and MetroPCS has begun deploying a version of LTE in its AWS spectrum.

Different bands all have differing technical characteristics and thus are optimally deployed in different situations. The combination of high and low frequency bands permits ubiquitous coverage – urban, suburban, and rural as well as indoor.

While LTE will be deployed in the BRS and AWS bands, a number of factors should be kept in mind considering these other bands.

3.5.1 BRS and AWS are both higher frequency ranges than 700 MHz

The higher frequency range of BRS means that cell sizes will be smaller than those with 700 MHz – this favours deployment in urban areas, making them complementary from a coverage perspective to 700 MHz. Application of LTE’s OFDM technique – particularly in the BRS range where wider bandwidths are available – would likely improve the coverage performance. Given the different characteristics neither BRS nor AWS are substitutes for 700 MHz, but are complementary from a deployment perspective.

Rogers' LTE trial is being conducted in both AWS and 700 MHz spectrum bands (using a development license for the 700 MHz spectrum) to test its functionality in various types of deployment, from urban areas to less densely populated areas.

3.5.2 BRS development in the US has focused on uncertain WiMAX technology

BRS technology to date is based on mobile WiMAX (802.16m) standards, for which the ecosystem is more limited at the moment. Sprint in particular has reportedly acknowledged that there will be a bigger ecosystem for LTE and that WiMAX was a quicker solution for them, initially intended to provide them with early to market advantage, using the spectrum that Sprint had access to.[83]

With the focus of Verizon and AT&T on LTE in 700 MHz, the likely longer term evolution of BRS spectrum is to make use of LTE. LTE in 2500 MHz has a head start in a few European countries but the deployment of LTE in North America in the BRS spectrum band may come with certain restrictions or limitations – i.e. Canadian carriers deploying LTE in the 2500 MHz range would not have a US roaming partner offering a similar broadband service in the 2500 MHz spectrum band at the moment. For example in the US, the Sprint EVO handset uses WiMAX in BRS frequencies for "4G" but it is also equipped with CDMA/EVDO Rev.A operating in cellular/PCS frequencies. It thus roams as a CDMA/EVDO legacy technology device and customers lose their home network WiMAX capabilities. And roaming onto European BRS networks built on LTE is not possible on this handset.

[83] See for example: http://thedroidguy.com/2010/12/sprints-dan-hesse-holding-onto-unlimited-wimax-was-a-quick-fix/

3.6 Conclusions on the Evolving LTE Ecosystem and its Implications

The key findings concerning LTE technology, its expected performance, standardization processes across different international organizations, as well as the related spectrum bands, are summarized below.

- The implication of international cooperation surrounding LTE means that deployment of new technology in specific bands will be driven by a few large carriers and vendors – increasingly by handset vendors particularly in terms of what bands are supported on customer equipment. This needs to be taken into account in planning for future auctions to maximize benefits to Canadian mobile users.

- LTE is initially a technology focused on providing next generation mobile broadband services. The majority of LTE services launched to date have focused on broadband services. Until widespread LTE deployment is achieved, voice and SMS services provided by LTE handsets will likely be provided by relying on existing 2G and 3G technologies. LTE handsets will have to support voice services using these older technologies and by inference use the spectrum bands in which these technologies have been already deployed.

- Deployment of an entirely new technology such as LTE requires new spectrum bands since other spectrum bands currently used cannot readily be re-farmed to accommodate an entirely new technology. Existing customers and handsets, as well as roaming partners, require access to legacy technology and services making re-farming expensive and impractical.

- There are competing technologies and approaches to LTE. LTE will have an advantage when using wider contiguous spectrum bandwidth due to its use of OFDM and will thus have better rural coverage particularly when deployed in lower frequency bands such as 700 MHz. The increasing capability of HSPA+ though has led to its branding in the US market as "4G". One person's 4G may be HSPA+ while another's may be LTE and yet another's may be WiMAX. And different carriers are focusing deployment in different sets of bands – cellular, PCS, AWS, 700 MHz and BRS. Other ecosystems may also develop internationally – e.g. TD-LTE in bands focused on Asian markets.

The 700 MHz band is an important enabler of LTE technology and true 4G capabilities and its availability in all areas of the country. It is important new spectrum that will help support dramatic growth in customer broadband data needs and will be complementary to existing spectrum bands that support 2G/3G services.

700 MHz will also be complementary to other bands such as BRS and AWS helping to ensure ubiquitous broadband coverage across Canada and increased capacity where needed in urban areas. Canadian carriers will need to be able to offer service using the same band/technology combinations that will develop in the US driven by new customer handsets as well as roaming arrangements.

4. Considerations Regarding the Award of Digital Dividend and 4G Spectrum around the World

This section highlight a few examples of how 700 MHz spectrum or digital dividend spectrum was awarded in a few countries focusing on those that have completed this award as of the start of 2011 – i.e. the US and Germany, to be able to discuss the outcome of these auctions in light of the rules put in place, as well as for which a firm date has been announced for the start of the auction, in the case of Sweden.

4.1 US 700 MHz Auction held in 2008

The US 700 MHz auction took place in early 2008 resulting in the sale of 1,090 licenses for US$19.1 billion (gross bid value). There were five licenses on offer per market covering the entire US – two of 12 MHz (the Lower A and B licenses), one of 22 MHz (the Upper C license), one of 6 MHz (the Lower E license) and one of 10 MHz (the Upper D license).[84]

The FCC combined its objective to license commercial operators in 700 MHz with that of the development of a broadband network for public safety. It did this by designating one block – Upper D – to be licensed nationwide as part of a public/private partnership between a commercial licensee and a public safety licensee.[85] The Upper D Block did not reach the minimum reserve price and the license was not awarded.

[84] The 700 MHz band has 84 MHz total capacity including the Upper D Block; the 2008 auction included 62 MHz of spectrum capacity since some licenses had been issued in earlier license processes.
[85] FCC 07-132, paragraph 5

4.1.1 License Term and Deployment Criteria

The 700 MHz licenses that were awarded were issued for ten years, and also came with a "keep what you use rule" designed to prevent warehousing of spectrum if coverage requirements are not met.

For licenses with smaller geography (cellular market area, CMA, and economic area, EA licenses), licensees are required to cover 35% of the geographic area of their licenses within four years and 70% within ten years. For the large regional economic area group (REAG) licenses, the requirement is based on population coverage – 40% population coverage within four years and 75% population coverage within ten years.

Failure to meet the interim benchmark would result in a reduction in license term of two years, with the final benchmark then applying at year eight, after which time unused spectrum would be made available to other users.[86]

The FCC ran the 700 MHz auction with no restrictions, i.e. with no spectrum set aside or reserved spectrum for particular entities, nor did it have a hard spectrum cap. The FCC eliminated its spectrum cap rules in 2003, replaced by a case-by-case market analysis of merger transactions and a general "spectrum screen" on overall holdings of "critical spectrum input".[87]

[86] *Ibid*, paragraph 6

[87] FCC 10-81, paragraph 263; the spectrum screen identifies markets within which aggregation exceeds one-third of critical spectrum. And in those markets the FCC conducts further analysis to determine whether sufficient capacity is available to other providers to compete effectively.

4.1.2 Relevant Market for the 700 MHz Spectrum Auction – Broadband Services

The main rationale for use of an auction process with no restrictions was that the FCC considered that the specific market of interest relevant to the 700 MHz spectrum was that of "broadband services".

Considering the "broadband services" market, the FCC found that consumers can already access services from wireline providers, cable companies, satellite and other wireless providers as well as wireless ISP's using unlicensed spectrum. They also identified additional competition possible from carriers with spectrum such as WCS (2300 MHz), AWS, BRS and 3650-3700 MHz licenses.

And since there is no monopoly on provision of broadband services in general, the FCC concluded that there would be no incentive for one bidder to unilaterally block new entrants from acquiring 700 MHz spectrum. This would be because "an incumbent attempting to block new entrants would bear all the costs of doing so, while other incumbents would capture much of the gain".[88]

4.1.3 Elements of the 700 MHz Spectrum Auction Process

There were several elements of the auction that were put in place in order to ensure there would be a competitive process, notably:

- Open access: In the largest block – the Upper C Block – the FCC required the licensee to provide for open access, meaning third party customers, device

[88] FCC 07-32, paragraph 256

manufacturers and application developers will be able to offer services and devices using the spectrum in an unrestricted manner and cannot be blocked or locked out (subject to meeting technical specifications of the network).[89] This was a response particularly to Google that was seeking unrestricted access to any spectrum license. The FCC decided only to implement the requirement on only one block.

- Anonymous bidding: This was implemented to help reduce potential for anti-competitive bidding behavior, including activity that aims to prevent entry of new competitors including use of signaling and retaliatory bidding.[90]

- While not specific to the 700 MHz auction, the FCC also ensures in its auction process that there are a variety of licenses with a mixture of geographies and license MHz available – i.e. to provide smaller bidders with the ability to bid on smaller areas and/or small amounts of spectrum. And the FCC also provides for bidding credits for qualified small businesses.[91]

- Package bidding: The auction design included "package bidding for the C Block licenses to facilitate the entry of a new nationwide competitor in that block, while not introducing undue difficulties for bidders on licenses in that block that do not desire a nationwide license".[92]

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[89] *Ibid*, paragraph 7
[90] *Ibid*, paragraph 280
[91] In the 700 MHz auction very small businesses (last three years with less than $15 million annual average gross revenues) received a 25% discount on its winning bids. Small businesses (last three years from $15 million to $40 million annual average gross revenues) received at 15% discount.
[92] FCC 07-32, paragraph 292

Entry in and of itself was not an objective for the auction and in the end, package bidding on the Upper C Block did not result in entry of a new national competitor. Verizon bid on individual licenses instead of the package of licenses and won the seven largest licenses covering the continental US and Hawaii.[93]

One mechanism that was rejected by the FCC was a new entrant bidding credit. The FCC found that it could not define "new entrant" (which had been suggested by Google) so instead relied on varied geographic sizes of licenses and a large number of licenses offering a "variety of opportunities to provide service".[94]

4.1.4 Upper D Block and the Public Safety Conundrum

The Upper D Block was included the 2008 auction with a requirement that the resultant licensee build a network to be shared for broadband services for public safety users. Narrowband public safety services are provided via exclusive spectrum – allocated for narrowband – adjacent to the D Block, with insufficient capacity to accommodate broadband services.[95]

Thus the concept was that in times of need, public safety broadband users would override the commercial operator in the D Block. While conceptually this would be intended to occur only in times of a major disaster or crisis, in large markets such as New York City or Los Angeles some valid reason to use the D Block for public safety could conceivably occur practically on a daily basis.

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[93] Verizon did not win licenses covering Alaska, Puerto Rico, Gulf of Mexico, American Samoa, Guam or Northern Mariana Islands.
[94] FCC 07-32, paragraph 296
[95] In Canada, a portion of the public safety exclusive spectrum is designated as being for "narrowband and wideband" services (SP 768, June 2009). A flexible allocation approach is also being discussed as one option in the US, which would reduce the need for use of the D Block.

Perhaps given the uncertainty in how sharing would impact a commercial operator's business plan there was very little interest in the Upper D Block in the 2008 auction process. In fact, the D Block received only one bid, $472 million from Qualcomm, which was below the FCC's predetermined reserve price of $1.33 billion. Since the bid did not meet the reserve price, the license was not awarded.[96]

The Upper D Block continues to be on the FCC agenda for a future auction and was identified in the FCC's National Broadband Plan issued in March 2010 as one component of helping to fill the projected spectrum "deficit".

The FCC's intent was to reconsider the sharing concept and to issue an Order in 2010 leading to an auction process in 2011. The industry though has been embroiled in a debate over how to deal with the D Block, with two diametrically opposed views:

- AT&T: The D Block should be allocated solely to public safety. Flexible use of the existing public safety spectrum is not feasible since narrowband and broadband cannot "coexist using existing technologies" and would be inefficient.[97] This view is also shared by Motorola, a major provider of equipment to public safety organizations and that there is not enough spectrum within the public safety band for broadband.[98]

[96] There were reserve prices for all blocks in the 700 MHz auction. The FCC based these on market values seen in the 2006 AWS auction which would have meant a reserve price of $1.7 billion (US). This was factored down by over 20% recognizing the shared nature of the band; i.e. to only account for about 80% of the value for the commercial licensee. See FCC 07-132, paragraph 305
[97] AT&T Reply Comments, FCC PS Docket No. 06-229, January 7, 2011
[98] Motorola Reply Comments, FCC PS Docket No. 06-229, January 7, 2011. Also noted that since there is no guard band between the D Block and the public safety spectrum, that there is a potential for interference from public safety into the D Block as well.

- T Mobile: Flexible use of the narrowband public safety spectrum should be allowed, providing users with the opportunity to use broadband if they wish. This would reduce the need for public safety use of the D Block. T Mobile's view, contrary to AT&T's, is that a flexible allocation is different from mandatory re-purposing. With a flexible allocation, public safety users could manage their technology transition plan and spectrum for existing services would not be "prematurely" reduced. Designating D Block for public safety – part of 3GPP Band 14 – would create an "orphan" band leaving public safety entities with more expensive and less feature-rich equipment.[99] This view is echoed by Sprint Nextel.[100]

While Verizon does not appear to be weighing in on this debate, underlying the commentary is also the position of the 700 MHz haves versus have-nots. With its major holdings in 700 MHz, AT&T's position supports using the D Block for public safety exclusively. On the other hand, T Mobile and Sprint Nextel – having chosen not to participate in the 2008 auction – have no 700 MHz spectrum and not surprisingly would prefer arrangements that support issuing the D Block for commercial use.

On January 25, 2011, the FCC approved a Report and Order address certain issues surrounding use of public safety spectrum. In particular, it ruled that a national interoperable public safety spectrum would make use of a standard LTE air interface and also set up an advisory committee to oversee implementation. This would also presumably ensure compatibility with the commercial network in the D Block, if a sharing arrangement is ultimately put into place.

[99] T Mobile, Reply Comments, FCC PS Docket No. 06-229, January 7, 2011
[100] Sprint Nextel, Reply Comments, FCC PS Docket No. 06-229, January 7, 2011

The question of auctioning D Block itself though remains with the US Senate Committee on Commerce, Science and Transportation – Public Safety Spectrum and Wireless Innovation Act, tied up with questions surrounding public safety networks and of extending the FCC's authority to auction spectrum set to expire in September 2012.

4.1.5 Outcomes and Lessons Learned from the US auction

In monetary terms, the outcome of the 700 MHz auction was highly influenced by the bidding of Verizon and AT&T, accounting for 48% and 34% respectively of the total gross bids. On the other hand, there were many smaller players that also acquired licenses, including US Cellular, MetroPCS, Cox Cable, Cellular South, CenturyTel, and others. One third of the MHz-pops covered by the 700 MHz band are held by licensees other than Verizon and AT&T.[101]

According to Verizon:

- "… 99 bidders, other than the nationwide service providers, won 754 (or 69%) of the 1,090 licenses sold, including at least one license in every market. In addition, 55% of the winning bidders claimed designated entity bidding credits as small businesses, and there were also substantial license acquisitions in rural areas by new players – 75 new entities won 428 licenses in 305 rural service areas."[102]

While Verizon and AT&T will clearly be leading the way in terms of technology ecosystem and service development – Verizon particularly in the Upper C Block and

[101] FCC 10-81, Table 25. Note: % of MHz-pops in mid 2009. In December 2010 AT&T acquired licenses that Qualcomm held in the 700 MHz band.
[102] Verizon letter to the FCC, WT Docket No.'s 09-66 and 06-150, May 12, 2010, page 4

AT&T in most of the Lower Sub-band – the number of different licensees will add to the dynamic in the market.

And other major carriers – in particular Sprint Nextel and T Mobile – do not have 700 MHz spectrum and will thus make use of other solutions to address the mobile broadband services market. Sprint Nextel has been building on its relationship with Clearwire to deliver its "4G" using 2.5 GHz range BRS spectrum. T Mobile's "4G" is HSPA+ operating in the 1.9 GHz PCS range.

The post auction landscape is already leading to a more dynamic market and is being reflected in the current positioning surrounding what is "4G".

And smaller bidders that won 700 MHz licenses will also ultimately benefit from the technologies developed for AT&T and Verizon, bringing new services and capabilities to niche markets and rural areas that may be the focus of less attention from the national carriers.

Verizon turned up its LTE network using the 700 MHz band in late 2010. It now covers 38 markets representing one third of the US population, is adding 140 markets in 2011, and intends to have the same LTE coverage it has with 3G by the end of 2013. Verizon is introducing ten new consumer devices that use 700 MHz LTE during 2011 – four Smartphones, two tablets, two notebook computers, two mobile/WiFi devices.[103]

Other licensees have yet to start offering service using the 700 MHz band. MetroPCS launched LTE using its AWS frequencies and now boasts a few devices. MetroPCS has one license for 700 MHz covering New England.

Many small rural licensees – such as James Valley Cooperative, Bluegrass Wireless, Cable Montana, Iowa Telecommunications, Panhandle Telecom, Red River Rural, etc. – in some cases may be building out areas on a cooperative basis with Verizon or will ultimately capitalize on development of the band to provide service in their operating areas.

It is increasingly clear that the 700 MHz spectrum is playing an important role in stimulating the development of the wireless broadband market in the US amongst all carriers, not just those with 700 MHz licenses. The auction was run in a way that did not restrict or encourage any particular type of bidder, since the FCC recognized that there are many different ways to address the broadband services market.

Whether by luck or by design, the FCC's approach is playing out in the market. Two of the national players – Verizon and AT&T – are positioned strongly in the 700 MHz band, while the other two – T Mobile and Sprint Nextel – are positioning 4G service offerings using other bands. T Mobile has 50 to 70 MHz of spectrum in most markets in the PCS and AWS bands. Sprint Nextel has over 40 MHz of PCS spectrum in most markets but almost 180-200 MHz in total, when its access to the Clearwire BRS spectrum is included.[104]

[103] Verizon press release January 6, 2011

[104] Clearwire has indicated it is reviewing a number of bids from other carriers interested in acquiring some of its spectrum, but would prefer a strategic investor to solve its current financial difficulties, Total Telecom, February 18, 2011.

4.2 Germany's 4G Auction Including 2.6 GHz held in 2010

There are four national incumbent mobile operators in Germany: E-Plus Mobilfunk (KPN), T Mobile (Deutsche Telekom), Telefonica O2, and Vodafone D2. Germany conducted the first European 800 MHz spectrum award in 2010 and this section discusses the rationale and approach chosen by the German government as well as the outcomes of the spectrum award process.

4.2.1 Broadband Strategy, the 2010 Auction and License Conditions

As a follow on to Germany's economic stimulus plan and Broadband Strategy, and following a consultation initiated in 2005 (including consideration of re-auctioning the returned Mobilcom license), during 2009 the German Federal Network Agency set in motion plans for a so-called 4G auction that would include over 350 MHz of capacity in multiple bands.

This included the digital dividend (800 MHz – 6 blocks of 5+5 MHz) spectrum – the digital television transition was completed in 2008 – along with 1.8 GHz (5 blocks of 5+5 MHz), 2 GHz (4 blocks of 4.95+4.95 MHz, plus 5 MHz unpaired and 14.2 MHz unpaired) and 2500-2690 MHz range (14 blocks of 5+5 MHz and 10 blocks of unpaired 5 MHz) licenses.

The 800 MHz frequencies were included in the already planned auction of the other frequency bands (1.8 GHz, 2 GHz, 2.6 GHz) to avoid "*regulation induced spectrum scarcity*".

The Federal Network Agency indicated that it had reached a conclusion that there is an insufficient quantity of frequencies available for assignment in these bands and thus that spectrum scarcity exists now and will persist, especially in light of the need to provide broadband access in rural areas at increasing speeds.[105] Spectrum claims at 800 MHz were made by all mobile operators regarding the provision of broadband access services in the range of 2-3 Mbps in rural areas. The Agency states that "*The requirements voiced for 800 MHz band for rural area coverage alone exceeds the available spectrum several times over.* [106]

The relevant product market was the wireless access market for the provision of telecommunications services on the entire territory of the Federal Republic of Germany, as the view was retained that "*nationwide frequency assignment is better suited for the implementation of the requirements of the federal government's broadband strategy to enable nationwide broadband access*".[107] Licenses were awarded for 15-years.

Six organizations applied to participate in the auction but only four, the existing mobile carriers, were qualified. One potential new bidder withdrew its application while another did not qualify. The German authorities did not release the names of the two entities, which submitted their initial qualification for the auction but did not participate.

As part of the objectives pursued by the German government in its Digital Strategy, the 2010 auction and particularly the 800 MHz digital dividend spectrum were positioned as key elements to enhance broadband access and bridge the digital divide uniformly in

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[105] Decision of the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway as of 12 October 2009 regarding a combined award of spectrum, pages 28 and 38 (English translation)
[106] *Ibid*, page 40
[107] *Ibid*, page 25

rural areas where broadband access is still deficient. Requirements for coverage were included in the conditions of licenses for the spectrum as follows:

- For spectrum at 1.8 GHz, 2 GHz and 2.6 GHz: 25% of population coverage as of January 1, 2014 (or less than 4 years after spectrum award) and 50% of population coverage as of January 1, 2016 .
- Staged roll out obligations for the 800 MHz Digital Dividend spectrum:
    - Priority Stage I: towns and districts specified by the Federal States with less than 5,000 population,
    - Priority Stage 2: towns and districts specified by the Federal States with population ranging from 5,000 to 20,000. Build out of Stage 2 areas can only begin when 90% of the population in Stage 1 has been completed,
    - Priority Stage 3: towns and districts specified by the Federal States with population ranging from 20,000 to 50,000. Build out of Stage 3 areas can only begin when 90% of the population in Stage 2 has been completed,
    - Priority Stage 4: towns and districts specified by the Federal States with population above 50,000. Build out of Stage 4 areas can only begin when 90% of the population in Stage 1 has been completed.

These conditions are being applied within each Federal State or region of the country. Each 800 MHz licensee is also required to cover at least 50% of the entire population as of January 1, 2016, similar to the licensee for the other spectrum bands that were part of the same auction process.

The conditions being used in Germany are specific to German demographics and geography and are shown for illustration only as an example of a way that governments can tailor license conditions to meet specific policy goals. If similar conditions were to be considered for Canadian licenses, the target objectives in terms of % population and staged rollouts would have to be tailored to the specifics of the Canadian environment, particularly considering Canada's vast geography.

Another element of interest to the German spectrum award is network sharing among mobile carriers. German mobile carriers have been sharing the costs of network deployment for many years.

The German President's Chamber (Bundesnetzagentur) had indicated in its October 2009 Decision regarding the planned 4G spectrum auction that *"economic cooperation with other network operators is possible, within the bounds of what is permitted in regulatory and competition terms"*. The existing German framework for network was updated to reflect technological advancement and the increased flexibility in terms of spectrum usage provided to mobile carriers as part of these auctions.[108]

Site sharing, the sharing of site support cabinets (with separate base stations transmitting and receiving the digital payload on the frequencies assigned) as well as Radio Access Network Sharing (RAN sharing) are permitted as long as each licensee guarantees that it will remain as an independent competitor. Any proposal regarding the shared used of scarce spectrum resources or pooling of spectrum resources will require examination by the Bundesnetzagentur and possibly by the antitrust authorities.

Participants in the auction had called for the possibility to share spectrum resources as well as infrastructure to fulfill the rural roll-out obligations part of the Conditions of License for the Digital Dividend 800 MHz spectrum. The response to this request was

[108] President's Chamber, "Shared use of wireless infrastructures and spectrum resources", English Translation, August 17, 2010

basically an indication that these requests would be addressed individually with the objective of meeting the time and geographic constraints, as highlighted below (in the English Translation):

> *Especially where the aim of the federal government's broadband strategy is concerned, to provide rural areas with broadband at the earliest possible opportunity, economic reasons could make it attractive for the network operators to share the use of frequencies, at least for a certain time, thus minimising the cost of network build and operation. This would also increase the network capacity in such regions and provide the population with the fastest possible transmission rates. Such forms of cooperation that involve the shared use of limited spectrum resources and are thus of relevance to competitive independence might be permissible, however, given the time and geographic constraints.*
>
> *The Bundesnetzagentur will continue to explore the possibility of further cooperation. However, attention must be drawn to the fact that the agreements between network operators wishing to cooperate are also subject to checks by the anti-trust authorities in individual cases.*[109]

4.2.2 German 2010 Spectrum Auction Structure and Outcomes

In the German 2010 spectrum auction process, there was considerable spectrum available – over 350 MHz in four different bands, there were many licenses on which to bid – 29 paired and 12 unpaired blocks, all with national coverage, and there were only four bidders.

Auction spectrum caps were implemented for the 800 MHz band only and varied according to the quantity of 900 MHz spectrum already assigned to a particular operator.

[109] *Ibid*, page 4

The D network operators were thus entitled to a maximum entitlement of four blocks of 5 MHz while the E network operators could obtain a maximum of six blocks of 5 MHz and new entrant bidders were eligible to obtain 8 blocks of 5 MHz or 40 MHz in total.[110]

While the German auction rules did not preclude the possibility of entry and even had in place rules providing more sought-after 800 MHz spectrum to a potential new entrant, the four incumbents were the only bidders remaining after the qualification process.

In the end, three out of the four the existing mobile carriers acquired spectrum in the 800 MHz band while E Plus acquired spectrum in the three other frequency bands.

The auction lasted from April 12 to May 20, 2010 and ended at Round 224 with a total value of about €4.38 billion… much lower than what some analysts apparently had pegged for the proceeds.

Telecom Deutschland (DT), Vodafone D2 and Telefonica O2 Germany each spent in the range of €1.3 to €1.4 B to acquire 95 to 99 MHz of total spectrum for an average price of €14 to €15 per Hz. Each acquired 20 MHz of 800 MHz spectrum (2*10 MHz). Each also acquired 40 MHz in the 2.6 GHz band as additional unpaired spectrum to complement their deployment.

[110] Decision of the Federal Network Agency for Electricity, Gas, Telecommunications, Post and Railway as of 12 October 2009 regarding a combined award of spectrum; Section V. 1.5 Restrictions on bidding entitlements (English translation).

Table 10 – Cost per Hz in German 2010 Spectrum Auction

	Total MHz obtained	€ per Hz
Telefonica O2	99.1	€ 13.91
DT	95.0	€ 13.68
Vodafone D2	94.9	€ 14.99
E Plus	69.8	€ 4.06

E Plus spent €284 M to acquire a total of 69.8 MHz for an average price of €4.06 per Hz. Thus, although E Plus did not secure spectrum in the 800 MHz band, its cost per MHz was much lower, approximately 27% of the cost paid by the other three mobile carriers.

The German auction structure ensured that no carriers were denied the opportunity to acquire new spectrum. E Plus now has a different set of licenses from the other operators, providing it with an opportunity to differentiate its business case with more spectrum capacity in the higher frequency range.

The deployment plans for LTE in Germany started in earnest once the spectrum award process was completed. Less than a year after the end of the auction, at the start of 2011, Vodafone has launched wireless broadband services using LTE in some of the priority rural areas identified in their license conditions. Vodafone prices its service in a range from €30 to €70 per month and has usage caps in line with typical Internet household usage (10-30 GB per month). Downstream bandwidth starts at 3.6 Mbps and goes up to 50 Mbps. Thus these services are indeed addressing the urban/rural digital divide and provide not only competitive alternatives, but also high performance options for broadband access in rural areas.

4.3 Sweden

Swedish mobile carriers provide service to a relatively small population over a fairly limited territory, at least in comparison to Canada. There are four key mobile operators and other smaller stakeholders.

On December 13, 2010, the Swedish regulator PTS published its Decision Ref 10-10534 “Limiting the number of licenses with a frequency space under Chapter 3, Section 7 of the Electronic Communications Act (2003:389) and issuing an “Open invitation to apply for a license to use radio transmitters in the 800 MHz band”, which is essentially an invitation to carriers interested in participating in the auction of 800 MHz digital dividend spectrum. The auction is due to begin on February 28, 2011.

As in Germany, the award of 800 MHz spectrum is also closely linked to the objectives of Sweden’s national Broadband Strategy.

PTS prior survey on the level of interest in this spectrum yielded that 2*125 MHz was being requested and thus that potential demand was much higher than the amount of spectrum available at 60 MHz in total.

A spectrum cap of 2*10 MHz has been set for this auction corresponding to 2 blocks of 5+5 MHz spectrum, i.e. 5 MHz upstream and 5 MHz downstream. Not all market participants in Sweden will be able to obtain 800 MHz spectrum even with a relatively low spectrum cap set at 2*10 MHz. Thus, spectrum is expected to be awarded to the carrier with the highest valuation for this opportunity, similar to what happened in Germany.

There are six FDD licenses of 5+5 MHz each being offered, similar to the German auction. The licenses will be valid until the end of 2035. Only FDD technologies are permitted for deployment in these frequency bands.

PTS has chosen to require specific coverage and roll out requirements for one license, the FDD6 license (the sixth license on offer) coupled with a separate process for license award, to support the objectives of Sweden's national Broadband Strategy. While PTS highlights that "there is currently good broadband coverage in Sweden", it believes specific coverage and roll out requirements for FDD6 are needed to ensure that "all households and businesses should have good opportunities to use electronic public services and other services via broadband".

In this context, coverage means that the license holder "shall cover the permanent homes and fixed places of business that lack broadband and which have been identified by PTS" and that a broadband service at 1 Mbps or higher speed needs to be provided.[111] PTS will also ensure that the roll out costs are appropriate as part of its spectrum award process.

The FDD6 license award process is a combination of comparative selection and auction. Firstly, bidders will compete on an offer for coverage for bids ranging from a minimum (SEK 150 m) to a maximum mount (SEK 300m), in the range of $20M to $40M (Cdn).

If several bidders have offered coverage up to and including the maximum amount, they can continue to compete for the license via the auction.

[111] PTS Decision, December 13, 2010, p. 10

The license holder will not pay the bid amount but will use it to provide coverage. We highlight that based on the information provided by PTS, only a few thousand homes and businesses will need to be covered by this mechanism.

4.4 The Perspective on Digital Dividend Spectrum in a Few Other Countries

4.4.1 Australia

The discussion on digital dividend spectrum in Australia was initiated by the publication of the "Digital Dividend Green Paper" by the federal government in January 2010. This Paper discussed the concept of digital dividend and underlying rationale, its potential benefits, amount of spectrum to be allocated and associated costs.

This was followed by a decision to dedicate 126 MHz of spectrum to the digital dividend and by the subsequent publication of a discussion paper by the Australian Communications and Media Authority (ACMA) entitled "Spectrum reallocation in the 700 MHz digital dividend band" in October 2010. Submissions were due on December 6, 2010.

Australia plans to award 700 MHz spectrum in the second half of 2012, a similar timeframe as in Canada.

Australia considers that the digital dividend arrangements in the US and in Europe are not optimal. One of the key objectives of the Australian plan is to reorganize the spectrum in larger contiguous blocks to enhance its benefits.

The Australian government views fixed line and mobile broadband access as complementary and that mobile broadband has been identified as the key technology to provide broadband access in areas of the country that will not be covered by fiber based access as part of the Government's National Broadband Network plans.

The ACMA Discussion paper highlights a number of questions that include options related to band plans, geographic scope of licenses and potential roll out obligations. The possibility of excising remote areas from the planned award of 700 MHz spectrum is also discussed in the context that spectrum usage in these areas is fairly limited and often used by community groups as opposed to major carriers.

On the other hand, ACMA notes that the 700 MHz spectrum is particularly well suited to deployment and usage in the remote areas of the country. No recommendations or initial views are provided by ACMA.

4.4.2 Status in the United Kingdom and in France

OFCOM, the regulator in the UK, ran consultations in 2007-2008 concerning both spectrum ranges. The question of these awards is now part of broader considerations as part of the Digital Britain strategy, which includes possibly combining spectrum from many bands into one auction, similar to what was done in Germany. In the UK, though this has effectively put the auction process on hold since June 2009. The 2500 MHz range in particular is also tied up for use during the 2012 Olympics.

One related area only recently resolved was the question of the license terms for the 3G licenses (2100 MHz) awarded in 2001 which were set to expire in 2021. The term for these licenses was recently made indefinite, improving certainty for the industry.[112]

[112] Notice of proposed variation of 2100 MHz Third Generation Mobile Wireless Telegraphy Act Licenses, OFCOM, February 2, 2011, Section 3

OFCOM also recently changed GSM900 (2G) license conditions to allow operators to implement 3G technologies.[113] These developments in the UK could help pave the way for OFCOM to move forward more quickly. The merger of the UK operations of T Mobile and Orange (Everything Everywhere) may add further impetus to the plan for new awards.

In France, the transition of off-air television to digital will be complete by November 2011, freeing up the frequencies for mobile service. ARCEP, the French regulator, ran a consultation in 2009 on future licensing of 2.6 GHz and the digital dividend spectrum for mobile broadband services. The 2.6 GHz band is presently occupied by the Ministry of Defense but is being freed up by geographic region over the period from late 2010 to 2014. Among other things, ARCEP was considering if it should license the 800 MHz and 2.6 GHz spectrum together to facilitate broad geographic deployment, whether the assignment rules should be set up to enable new entrants beyond the new entrant from the 3G process and whether an auction process should be used rather than comparative selection.[114] Final decisions have not been made on these issues.

France now intends to auction licenses in mid-2011 to allow operators to be in service in 2012. Licenses will come with coverage objectives focused on serving 99% of the French population with at least two operators using the digital dividend spectrum.[115]

[113] OFCOM opens up more frequencies for 3G services, press release, January 6, 2011
[114] France only awarded its last 3G license in 2009 to Free Mobile.
[115] Ministry of Economy, Industry and Employment, speech of Eric Besson, National Frequency Agency (ANF), January 10, 2011

4.5 *Conclusions from the review of digital dividend spectrum award in other jurisdictions to date*

The US as well as Germany and Sweden have all determined that the relevant market for the purpose of setting the rules for the award of digital dividend spectrum is the broadband services market. The digital dividend spectrum is considered a key element underlying national digital strategies and broadband plans and an enabler in bridging the rural and urban digital divide.

While not yet awarded in the UK and France, there is a similar theme in inclusion of the digital dividend as a key component of national digital economy strategies.

This is corroborated by the review of the performance and key characteristics of LTE technology and by the initial service offerings both in the US as well as in Germany.

There were no eligibility restrictions or spectrum set asides put in place in any of these digital dividend auctions, ensuring that all carriers can bid for this spectrum according to its importance in their respective business strategies.

In Germany, spectrum caps were imposed on digital dividend spectrum coupled with restrictive network roll out obligations for all licenses offered in this band focusing on rural areas first, to leverage the good propagation characteristics of 700 MHz spectrum and bridge the rural/urban divide for very high quality broadband services. Vodafone has already launched service offerings in some rural areas in Germany less than one year after the end of the auction providing up to 50 Mbps downstream and 30 GB of usage per month. This is equivalent to very high-speed wireline services offered today around the world and thus a real alternative and competitor to wireline service. Deutsche Telekom has also already announced similar service plans. The German approach of network roll out obligations on all digital dividend licenses means that consumers and businesses in these areas will benefit from three competitive networks offering high quality broadband offerings.

No new entrant participated in the German auction. One of the existing mobile carriers in Germany, E-Plus, which also has the lowest overall market share, did not acquire digital dividend licenses but instead focused on acquiring spectrum in higher bands also put up for auction at a much lower cost and with much less stringent network roll out obligations.

The results of the German auction highlight that rules for 700 MHz auction can be implemented to further the broadband agenda while ensuring access to spectrum for all as well as a continued high level of competition for these services in the future in all areas of the country.

A similar result was achieved in the US auction without the use of spectrum caps or set asides, but also including population coverage requirements. Large carriers expanded their holdings and ability to provide broadband services. Some national carriers chose not to participate in the auction and are moving forward with their individual business strategies for 4G using other spectrum bands. There were also regional licensees in the US as a result of the 2008 auction.

Germany and Sweden like most European countries only awarded national licenses for mobile spectrum. In the AWS auction, Canada chose to award spectrum similar to the US approach with regional licenses and different geographic tier of licenses being provided which bolsters regional level competition and opportunities for smaller players in an auction.

There will be a spectrum cap of 10+10 MHz in the Swedish auction, which will start on February 28, 2011. Since there is a total of 60 MHz of spectrum available and more than 3 carriers, not all carriers will be able to obtain 10+10 MHz of spectrum as in Germany. Only one 5+5 license is coupled with rural network roll out obligations in Sweden, implying that the customers in these areas may only have one alternative in terms of service provider in the future.

5. Objectives for the Auction of 700 MHz Spectrum in Canada

As demonstrated in this Report, the total spectrum needs of carriers are expected to continue to grow. Large carriers focused on delivering broadband services will require considerably more spectrum capacity than smaller carriers with less aggressive focus on broadband and mobile data as part of their business strategies.

Increased spectrum needs can be somewhat offset by building more cell sites, a time consuming and not always a practical or economic alternative particularly in urban areas. And in any case introduction of a completely new technology such as LTE – which among other things is optimally deployed using wide channel bandwidths – requires new spectrum to avoid high re-farming costs and subscriber disruption.

The 700 MHz band has excellent propagation characteristics – particularly attractive in serving rural and remote areas and for in-building coverage – and it is the expected focus of new technology development surrounding LTE, led by Verizon and AT&T.

LTE deployment in the 700 MHz band will be a key development supporting broadband service coverage across the country and therefore not just in urban areas. This is consistent with the approach used to auction the spectrum elsewhere, notably in the US in 2008 and for the similar 800 MHz digital dividend spectrum auctioned in Germany in 2010.

There are many spectrum bands identified for LTE deployment, including many spectrum bands already licensed in Canada – cellular, PCS, AWS and BRS. In the short to medium term, however, only AWS and BRS are likely to benefit from the availability of equipment and handsets for deployment in the North American context, particularly for urban focused deployment, and likely with some restrictions related to roaming for broadband services since not all spectrum bands can be carried on a single handset or device.

The cellular and PCS spectrum bands, which are currently occupied by HSPA and GSM/CDMA technologies respectively, are used for 2G/3G services. There are no current plans for LTE deployment in these bands, even though these spectrum bands appear on the 3GPP list of possible bands for LTE.

LTE is also not the only technology that is considered to be “4G” mobile. Both HSPA+ (already deployed extensively in Canada) as well as WiMAX and combined terrestrial/satellite networks are positioned as 4G particularly in the US market.

In licensing the 700 MHz spectrum bands in the US, the FCC determined that carriers operating with this spectrum would be competing in the broadband services market, given the potential for 700 MHz to support high data speeds and broad coverage – consistent with the objectives of the FCC’s National Broadband Plan.

The 700 MHz spectrum is playing an important role in stimulating the development of the wireless broadband market in the US amongst all carriers, not just those with 700 MHz licenses.

While Canada does not have a set objective for broadband speeds – pending the outcome of the Digital Economy Consultation held in 2010[116] – the focus of broadband

[116] Consultation Paper: Improving Canada’s Digital Advantage – Strategies for Sustainable Prosperity, Government of Canada, May 10, 2010

deployment could conceivably be on access speeds for consumers of 100 Mbps or more available to all Canadians. Wireless is a critical technology to achieve this objective in a timely and cost effective manner, while ensuring that facilities based competition is enhanced everywhere across the country in line with the Government's objective.

This would be consistent with the US National Broadband Plan, but also with typical Canadian cable high-speed Internet deployment, with telco fiber-to-the-home initiatives, as well as with the potential of LTE and WiMAX technologies.

An objective in auctioning 700 MHz spectrum could therefore be to support increased development of competing broadband networks with speeds of 100 Mbps or more, promoting 100 Mbps "everywhere" provided by LTE.

By considering the 700 MHz band as an integral component supporting development of the Digital Economy in Canada, Industry Canada could then put in place an auction design for the licenses that is consistent with that objective.

This could mean, for example:

- Providing for strong network deployment obligations for the 700 MHz spectrum as a condition of license to ensure investment takes place and that consumer benefits ensue. Applying this obligation to all licensees for the 700 MHz spectrum band would be a major contribution to ensure the deployment of competitive post-3G broadband networks across the country, fulfilling a key objective of the Canadian government to continue to foster competition in telecommunications networks.

- Implementing a license structure to provide for maximum access to new technology development being led by major carriers and vendors in the US market. This would imply following the US 700 MHz spectrum band plan as closely as possible – potentially with minor improvements – so Canadians can benefit from economies of scale in equipment purchases as well as from innovative new technology expected for the band.
- Ensuring that all Canadian mobile carriers can bid for 700 MHz spectrum according to their business plans. This point is critical as our analysis and research demonstrate that:
    - With the growth in data consumption, large carriers will need in the order of 200 MHz of spectrum or more in order to support future deployment meeting broadband service requirements of 100 Mbps speed and the accompanying unabated growth in usage, and,
    - Deployment of entirely new technology such as LTE requires new spectrum since existing bands cannot practically be re-farmed to accommodate entirely new technology. The 700 MHz band is an important enabler of LTE technology and true 4G capabilities. It is important new spectrum that will help support dramatic growth in customer data needs and will be complementary to existing 2G/3G bands.
- 700 MHz will also be a critical and necessary spectrum band to complement developments in other bands such as BRS and AWS, with a range of high and low frequency bands enabling ubiquitous coverage in all areas of the country.

There is considerable focus on the 2500 MHz range in Europe for LTE deployment complementing 2G and 3G services already deployed in other bands. Moving ahead with auctioning of the BRS spectrum in Canada will provide all carriers with an opportunity to capitalize on these developments.

The German 4G auction included the digital dividend spectrum along with licenses for the 2500 MHz range (equivalent to BRS in Canada) and for 1.8 GHz spectrum. Whether the BRS spectrum should or could be auctioned in the same process as the 700 MHz band in Canada is beyond the scope of this Report. However BRS and other bands represent good opportunities for broadband service deployment complementary to the 700 MHz spectrum band.

In closing, we highlight that spectrum authorities in the US and Germany have also identified the need for more spectrum, over and above the 700 MHz and BRS spectrum bands and that the LYA analyses provided in this Report demonstrate that similar conclusions hold in the Canadian environment.

6. Background – Lemay-Yates Associates Inc.

Development and implementation of business strategy has been at the heart of Lemay-Yates Associates Inc. (LYA) services since 1993, providing us with a unique ability to integrate market, technical, network, economic, regulatory and investment analyses – helping address all the Strategic **C**’s – across the blurring lines of mobile-telecom-cable, as well as carriage-content, in a competitive environment that is increasingly dynamic, complex and risky.

LYA is a key advisor to the telecom industry, helping to drive major investment decisions and strategy. LYA also does independent strategic research and has published a number of reports on telecom markets with topics covering Local Competition, Foreign Investment, Mobile 911, Consumer Telecom, Mobile Broadband Services and others.

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