Mobile Broadband Capacity Constraints And the Need for Optimization

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Executive Summary

Powerful smartphones, fast networks, compelling applications, and user awareness are causing a dramatic surge in the use of mobile-broadband technology. Previously relegated to business executives or vertical-market applications, wireless data is now experiencing mass-market adoption. The advantages are obvious – flexible lifestyles, greater productivity, and the addictive sensation of always being connected. This market growth comes at a good time for operators, who are seeing increasing data revenue compensating for declining voice revenue.

But there is a problem. There simply is not enough network capacity to address the emerging demand, and we are already witnessing the effects of network congestion, with many users complaining of slow network operation on some networks. Capacity is based on a number of factors, but foremost is the amount of spectrum available for broadband services. The FCC chairman himself recently stated that he saw the biggest threat to the future of mobile activity in America as the looming spectrum crisis.

What is primarily driving network usage currently is rapidly increasing smartphone penetration, at more than 25% now and ready to hit 50% within a year or two. In early days, people used mobile phones to access mobile-specific content, of which there was little. But today's phones can do so much more: browsing the Web at large, e-mail with attachment viewing, navigating with maps, video, social networking, banking, business information access, cloud computing, and entertainment. People love their smartphones, because a small handheld device gives them access to the same tools and information that previously required a desktop computer. And this is just the beginning. New platforms, such as netbooks, are also seeing strong initial adoption and are about to be followed by entirely new categories of devices such as mobile Internet devices and smartbooks. Nobody can anticipate exactly how this world of new mobile computing devices will evolve, but the trends are clear: people desire powerful mobile computers with broadband connections.

If we were restricted to just mobile computing, application developers might design their apps with wireless capacity constraints in mind. But at the same time as mobile broadband is becoming ubiquitous, wireline broadband networks are becoming much faster, with technologies such as fiber to the home (FTTH) and next generation cable-modem technologies. These are providing throughput rates of tens of megabits per second, enabling applications not previously possible such as high definition video over the Internet. Users obviously would like to use the same applications on their mobile connections. Though that's not feasible, at least in large numbers of subscribers, users will certainly try.

Wireless networks inherently have far lower capacity than wireline networks. One fiber optic cable has greater data capacity than the entire RF spectrum. A shared, inherently unreliable medium like radio simply cannot match what wire can bring. And therein lies the problem. Just a smaller number of mobile users with bandwidth-intensive applications can consume the available wireless network capacity. We are not quite at the stage of capacity exhaustion, but we are seeing early instances of it, and analysis shows that the available capacity can be consumed by a relatively small percentage of high-bandwidth subscribers. Based on current trends in mobile broadband usage, a spectrum-demand model developed by Rysavy Research shows that many operators' spectrum could be consumed within three to five years.

To satisfy this quickly growing demand, especially since it will take five years or more to bring any new spectrum online, operators are using multiple strategies. One is building new cell sites. Spectrum reuse, which cellular technologies accomplish through the use of the same frequencies over and over in different cells is, in fact, the greatest determinant of overall network capacity. But building new sites is an expensive and time-consuming process. Offloading data onto other networks, such as Wi-Fi, is another option, and one that operators are pursuing aggressively. Femto cells could also eventually offload data in buildings, but the femto market has been slow to develop. New technologies, such as WiMAX and LTE, are spectrally more efficient than previous technologies, but not that much more, and wireless technology is approaching theoretical limits of spectral efficiency. Wireless network deployment in the 700 MHz band will provide a boost in network capacity, but it will be 2014 before these networks will be broadly deployed, and, even then, their capacity is quite finite.

All of these approaches, plus eventual new spectrum, will help address the demand. But even then, wireless capacity will remain constrained relative to demand. This is because augmenting capacity is only part of the answer. The other part is more efficient use of spectrum. It is imperative that mobile applications consume only the amount of bandwidth they really need. This is how solutions like BlackBerry provide a profound advantage, consuming significantly less data in applications such as e-mail and Web browsing. The benefit to operators is huge, as it means lower network costs and a greater number of users supported in the same amount of spectrum. And with pricing plans likely to move more to a usage-based model, users will benefit from lower monthly fees.

There is yet another consideration. Even a well dimensioned network will experience times of unexpected heavy usage, such as through dense user congregation or by a subset of users with high-bandwidth (e.g., video) applications. Operators may have sufficient spectrum, but in many markets have deployed only a limited number of radio channels for broadband. Or their backhaul may be constrained. Consequently, congestion is unavoidable. The effect on applications in these scenarios can be highly disruptive, resulting in timeouts and other failures, unless those applications are designed specifically for wireless connectivity. Again, BlackBerry has a significant advantage through its use of highly-optimized wireless-specific protocols. The result is greater reliability and availability, even under adverse conditions. Not only are the protocols more resilient, but with more efficient access, download times are faster, making it more likely to successfully complete data exchanges. Beyond this, BlackBerry offers multiple management options with which IT staff can control how much data BlackBerry devices consume. Tests have shown BlackBerry to be significantly more efficient for mail and web browsing. These efficiencies translate to significantly lower costs for users and operators.

The mobile broadband market is emerging as an extremely successful industry, but it is facing significant challenges that can only be met through a broad sweep of measures to augment demand. But, just as important, is efficient use of the network. This is the BlackBerry advantage.

Introduction

The mobile and wireless industries have succeeded beyond anybody's expectations. The smartphone has become the convergence point that brings together the capabilities of today's wireless networks, miniaturization of computers, innovative user interfaces, handheld operating systems, and vast numbers of applications. Other types of portable computers are also proving hugely successful, first with notebook computers, now with netbooks, and soon with new categories such as smartbooks and mobile Internet devices. Also coming online are electronic books, digital picture frames, cameras, and gaming consoles. The essential capability that makes all of these platforms so attractive to their owners is mobile broadband connectivity.

But there is a problem. Millions of new devices able to consume large amounts of data threaten to overwhelm the capacity of today's networks. How serious is this threat, and what are the consequences? Those are the topics of this report, sponsored by RIM, which begins with an overview of the growth in mobile broadband, the actual capacity of today's networks and how soon that capacity could be consumed, options available to operators to address demand, and the inevitability of network congestion and the effect on applications. The report demonstrates the advantages of BlackBerry in this context, including its e-mail efficiency, web browsing efficiency, resilient protocols, and management of data transmission. The report then quantifies the financial benefits of BlackBerry under different scenarios of adoption and usage.

Mobile Broadband Demand

To understand the impact of mobile broadband on wireless networks, one needs to quantitatively understand how much demand mobile broadband actually places on networks. There are several ways of doing this beginning with metrics on broadband growth in general, then mobile-specific metrics in particular, and by looking at the bandwidth requirements of different applications.

Broadband Growth

People are clearly drawn to broadband for the instant access to information, entertainment, web applications, and rich communications such as social networking. Cisco reports that the average broadband connection, on a global basis, already generates 11.4 Gbytes of Internet traffic per month, which is equivalent to 375 Mbytes per day.[1] This exceeds current average mobile usage, but there are a number of trends that indicate that mobile broadband usage will increasingly mirror usage in wireline networks:

- **Fixed Mobile Substitution.** An increasing number of subscribers will use mobile connectivity as their only form of connectivity. For voice, this already is about one fifth of US households.[2]

[1] Source: Cisco, "Cisco Visual Networking Index: Usage Study," October 21, 2009.

[2] Source: Nielsen, "Call My Cell: Wireless Substitution in the United States," September 2008.

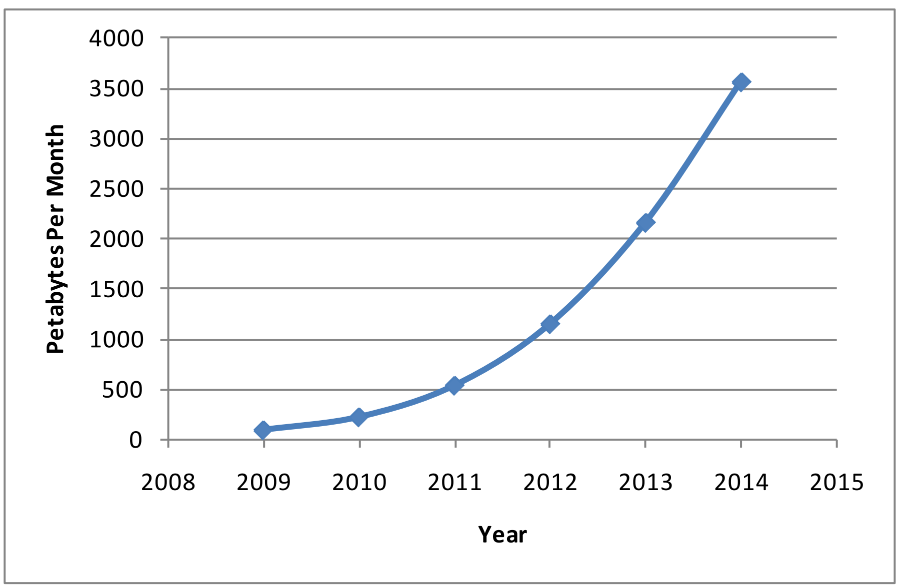
- **Netbooks.** Usage behavior on netbooks and other emerging devices, such as smartbooks and Mobile Internet Devices, will be increasingly Web-centric, demanding constant connectivity.[3] Also, with their larger screens, data consumption from these devices will more closely mirror desktop or notebook computers rather than phones.
- **Smartphone Destinations Match Wireline Destinations.** The most popular Web sites for wireless connections largely overlap those used with wireline connections. For example, the top ten US mobile sites for January to October 2009 were: Google, Yahoo! Mail, Gmail, Weather Channel, Facebook, MSN Hotmail, Google Maps, ESPN, AOL Email, and CNN News.[4]

As for growth, Cisco predicts annual global IP traffic to double every two years through 2012.[5]

Mobile Broadband Growth

Mobile broadband growth is even faster than wireline, because not only are individual users consuming ever more data, but the percentage of users using mobile broadband is increasing. The result is a huge projected increase in data consumption as shown in Figure 1, a Cisco projection of global mobile broadband traffic measured in petabytes (million gigabytes) per month. This growth is at a 108% compound annual rate over five years. [6]

Figure 1: Cisco Global Mobile Broadband Data Projection



[3] Source: PCCA meeting, "Emerging Mobile Platforms," November 5, 2009.

[4] Source: Nielsen, "Top Mobile Phones, Sites and Brands for 2009," December 21, 2009.

[5] Source: Cisco, "Approaching the Zettabyte Era", June 16, 2008.

[6] Source: Cisco, "Cisco Visual Networking Index: Global Mobile Data Traffic Forecast Update," February 10, 2010.

Consistent with this study, Coda Research Consultancy anticipates a 40-fold increase in traffic in 2017 over 2009.[7] Chetan Sharma shows even more accelerated growth with aggregate US mobile data reaching 20 exabytes[8] in 2013.[9] Would this much data overwhelm the carrying capacity of today's networks? The answer is yes.

Smartphones

Nowhere is mobile broadband visibly growing faster than with smartphones. From a historical perspective, smartphones weren't even possible before about 2002 when widespread availability of cellular-data became possible with General Packet Radio Service (GPRS). Before then, phones and networks were highly voice centric. Data capabilities since then have improved at a rapid rate with Enhanced Data Rates for GSM Evolution (EDGE), then 3G technologies like High Speed Packet Access (HSPA), Evolved Data Optimized (EV-DO), WiMAX, and 3GPP Long Term Evolution (LTE). Each wireless networking technology has enabled greater data consumption by phones. Coping with this rate of change, especially with data now outstripping voice in traffic volume, is extremely challenging for operators.

In looking at today's data usage by smartphones, Nielsen says that the average iPhone user consumes 400 Mbytes per month.[10] This is consistent with other industry data.[11] Smartphones already account for some 25% of phones today, on track to reach 50% within a year or two.[12]

Bytemobile issued a report on the impact of smartphones on mobile networks showing how smartphone usage is beginning to approach laptop usage.[13] This includes touch smartphone browsing sessions of 38 minutes being approximately 63% of laptop sessions. On networks that Bytemobile tracks, on wireless networks not offering touchscreen smartphones, laptops account for nearly all wireless data usage. But for those networks offering touch smartphones, those phones account for 52% of usage. The report also shows that one video user consumes fifteen times more network bandwidth than a Web user. At this time, there are still ten to fifteen times more Web users than video users, but video usage is growing quickly as Web sites offer more and more video.

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[7] Source: Coda Research Consultancy, "Mobile Broadband and Portable Computers: Revenue, User and Traffic Forecasts 2009-2017," July 19, 2009, http://www.fiercebroadbandwireless.com/story/report-laptops-netbooks-drive-exponential-mobile-broadband-growth/2009-07-19 .

[8] A terabyte is 1000 billion bytes, a petabyte is a million billion bytes, an exabyte is one billion billion bytes, and a yottabyte is one thousand billion billion bytes.

[9] Source: Chetan Sharma, "Managing Growth and Profits in the Yottabyte Era," 2009.

[10] Source: Edible Apple, "Average iPhone user consumes 400MB of data every month," June 17, 2009.

[11] For example, 500 Mbytes/smartphone/month was quoted by an operator at a 3G Americas analyst meeting attended by Peter Rysavy, October 2009.

[12] Nielsen, "The Droid: Is this the Smartphone Consumers are Looking For?" November 11, 2009, http://blog.nielsen.com/nielsenwire/consumer/the-droid-is-this-the-smartphone-consumers-are-looking-for/.

[13] Source: Bytemobile, "Mobile Minute Metrics: November 2009."

CTO Derek McManus of O2 in the UK stated "World-class smartphones have brought about an unprecedented demand on mobile data networks. Data on our network has increased 20-fold in the last year alone."[14] T-Mobile USA CTO Cole Brodman, at the Open Mobile Summit 2009, stated that Android users consume fifty times the data of other users.[15]

Applications and Bandwidth Requirements

It is difficult to specify exactly how much bandwidth each application requires. Does a Web page need to download in one second, five seconds, or is ten seconds sufficient? Generally, the faster a network responds, the better. Nevertheless, one can recommend bandwidths that provide an experience that would satisfy the majority of people. Some applications, such as streaming audio or video, must have a certain amount of bandwidth; otherwise the stream can be interrupted.[16] The following table lists recommended bandwidths for different applications.

Table 1: Recommended Bandwidths for Different Applications

Application	Recommended Bandwidth
Mobile voice call	6 kbps to 12 kbps
Text-based e-mail	10 to 20 kbps
Low-quality music stream	28 kbps
Medium-quality music stream	128 kbps
High-quality music stream	300 kbps
Video conferencing	384 kbps to 3 Mbps
Entry-level, high-speed Internet	1 Mbps
Minimum speed for responsive Web browsing	1 Mbps
Internet streaming video	1 to 2 Mbps
Telecommuting	1 to 5 Mbps
Gaming	1 to 10 Mbps
Enterprise applications	1 to 10 Mbps
Standard definition TV	2 Mbps
Distance learning	3 Mbps
Basic, high-speed Internet	5 Mbps
High-Definition TV	7.5 to 9 Mbps
Multimedia Web interaction	10 Mbps
Enhanced, high-speed Internet	10 to 50 Mbps, 100 Mbps emerging

[14] Source: GigaOm, "Like AT&T, O2 Pays the Price for Heavy iPhone Usage," November 19, 2009, http://gigaom.com/2009/11/19/like-att-o2-pays-the-price-for-heavy-iphone-usage/.

[15] Source: Fierce Wireless, "T-Mobile CTO: 40% of Q4 sales will be smartphones," November 4, 2009, http://www.fiercewireless.com/story/t-mobile-cto-40-4q-sales-will-be-smartphones/2009-11-04?utm_medium=nl&utm_source=internal.

[16] Some streaming applications, e.g., Netflix and Skype, can dynamically adjust to the amount of bandwidth available. Nevertheless, the effect can be quite disruptive as the system recalibrates itself. Most also maintain a buffer.

Mobile voice and text-based e-mail communications require relatively little bandwidth, whereas high-definition video consumes more bandwidth than any other application. A high-definition YouTube video at 2 Mbps consumes as much bandwidth as 200 voice calls, and a normal-definition YouTube video at 1 Mbps consumes as much bandwidth as 100 voice calls.

Equating Capacity with Demand

This report now turns to the actual capacity available in today's networks.

Capacity Introduction

The question is how much capacity do today's mobile broadband networks really have? Answering this is a complex exercise for the following reasons:

- **Networks have a blend of technologies.** At any moment in time, an operator has a mix of technologies, and even for the same technology there are ongoing improvements.
- **Users are mobile.** It is hard to know how many actual users there are in any coverage area at any moment in time.
- **Cell site density varies.** Operators attempt to deploy sites to achieve coverage objectives, but where they can actually place sites depends on many factors such as zoning restrictions, community acceptance, and availability of physical locations or structures to actually mount a tower or antennas. Operators also do not publicly disclose the location of their sites.
- **Efficiency/performance tradeoffs.** The network configuration for highest efficiency (users per amount of spectrum) is not necessarily the same as the configuration for the best user experience.

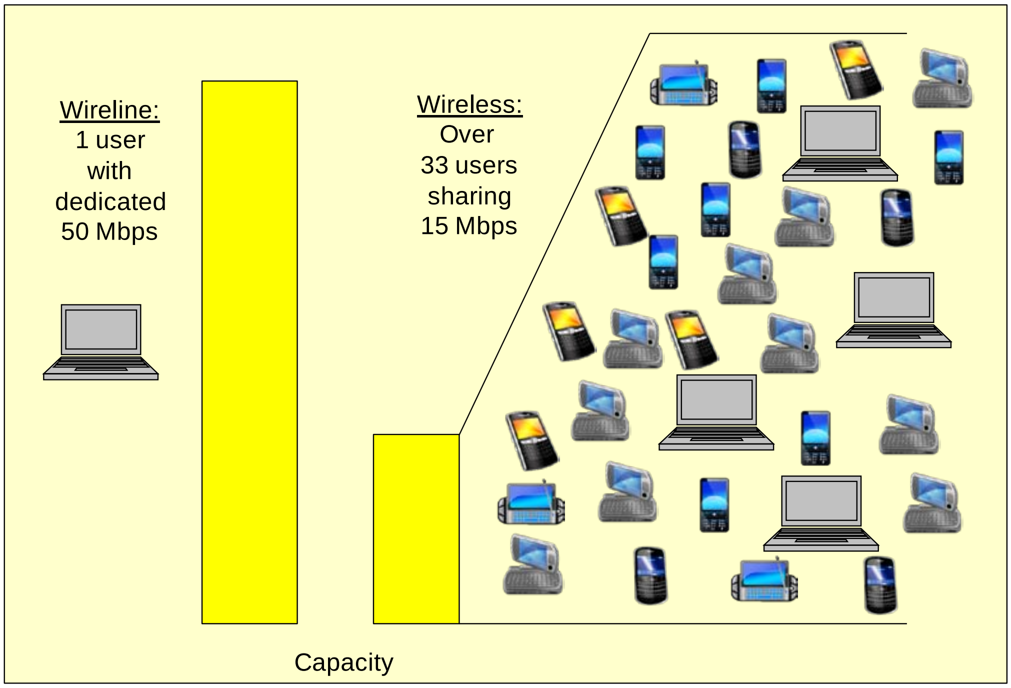
One initial way of thinking about capacity is to look at how 3G networks have been deployed. Operators initially deployed High Speed Packet Access (HSPA) in 5 MHz + 5 MHz radio channels. HSPA uses a 5 MHz radio channel, so this means one channel was for the base-station to mobile-user (forward) direction and one channel was for the reverse direction. Based on a spectral efficiency of .5 bps/Hz, HSPA in initial deployments had a data capacity of 2.5 Mbps in each sector[17] and EV-DO in a 1.25 MHz radio channel with the same spectral efficiency had a data capacity of 600 kbps. With improvements in radio technology, there will be a 50% increase in the capacity. But one can see how small a number of simultaneous YouTube viewers each at almost 1 Mbps can occupy the entire bandwidth of the data channel.

Looking forward to advanced technologies such as LTE, capacity will higher, but it will still be extremely limited compared to wireline capacity. Verizon Wireless' LTE network will operate in the 700 MHz band using 10 MHz radio channels. With a spectral efficiency of 1.5 bps/Hz, this delivers a sector throughput of 15 Mbps.

[17] Cell sites are typically divided into three sectors, with each sector operating as a separate radio-coverage area.

Meanwhile, there are about 1000 subscribers in the US for every cell site, which makes for an average of 333 subscribers per sector. If 10% of them were using the LTE data service, that would mean 33 users for the 15 Mbps data channel. Now, compare this with a subscriber of a wireline high-speed Internet service of 50 Mbps that is dedicated, and not shared, as shown in Figure 2.

Figure 2: Graphical Depiction of Wireline versus Wireless Capacity (Representative Scenario)



The point is not that the wireless network cannot deliver extremely useful and valuable services, since it can, but rather that wireless capacity is inherently limited compared to wireline capacity.

One network in the US that has considerably more capacity is Clearwire's WiMAX network. This has been deployed in 30 MHz of spectrum, which is considerably more than what any 3G operator has deployed for data so far. As demand increases, Clearwire has indicated it can make up to 120 MHz of spectrum available.[18] Whereas many 3G networks place caps of 5 Gbytes on monthly data usage, the Clearwire network currently has no caps. Even the Clearwire network, however, cannot match the capacity of wireline access networks that are fiber oriented (e.g., fiber to the home).

Demand Projection

To know to what extent demand is likely to exceed capacity, Rysavy Research has developed a spectrum demand model. Though this is a first-order analysis that focuses on the most important variables, the model offers considerable insight. This section discusses how the model works, the assumptions used, and the predictions.

[18] Source: PCCA Meeting, October 2008.

The model is based on an examination of how much data users consume in a month, which depends on the type of device. The model considers both smartphone platforms and other devices such as netbooks and notebooks. The model assumes that these “other” devices will consume considerably more data, since sessions are likely to be longer (e.g., watching longer videos) and because screen sizes are so much larger. A screen that is three times wider and three times higher has nine times the area and, assuming the same pixel density, can thus consume almost ten times the amount of data with graphical and video elements. On the other hand, there are many more users of smartphones than of these other devices.

The monthly usage amount with one value for smartphones and one value for other devices is a good starting point, because there are a considerable number of statistics available on monthly usage amounts, both for wireline networks and wireless networks. From that, the model calculates an average amount of data that a user consumes each day. The usage across a day, however, is not even. For example, Cisco reports for Internet traffic that 25% of the day’s traffic is consumed in the busiest four hours.[19] With this information, the model calculates the bit-per-second load per broadband subscriber per device type during the busiest times of the day.

The model then multiplies the per-user traffic amount by the number of mobile broadband users in a typical cell sector to obtain a total data load in that sector. Then, knowing the spectral efficiency of the technology being used, the model determines the amount of spectrum needed to support that load.

To reflect the growth in mobile broadband, the model then makes projections for the following items:

- The increase in time of the amount of monthly data usage.
- The increase in penetration of mobile broadband users for both smartphones and other device types such as notebooks, netbooks, and smartbooks.
- Increasing spectral efficiency as operators deploy new technologies such as HSPA+ and LTE.

The results of the model are shown in the following charts. First, the model anticipates rapidly growing data consumption by smartphones and other devices, as shown.

[19] Source: Cisco, “Cisco Visual Networking Index: Usage Study,” October 21, 2009.

Figure 3: Monthly Smartphone Data Consumption per Subscriber over Time

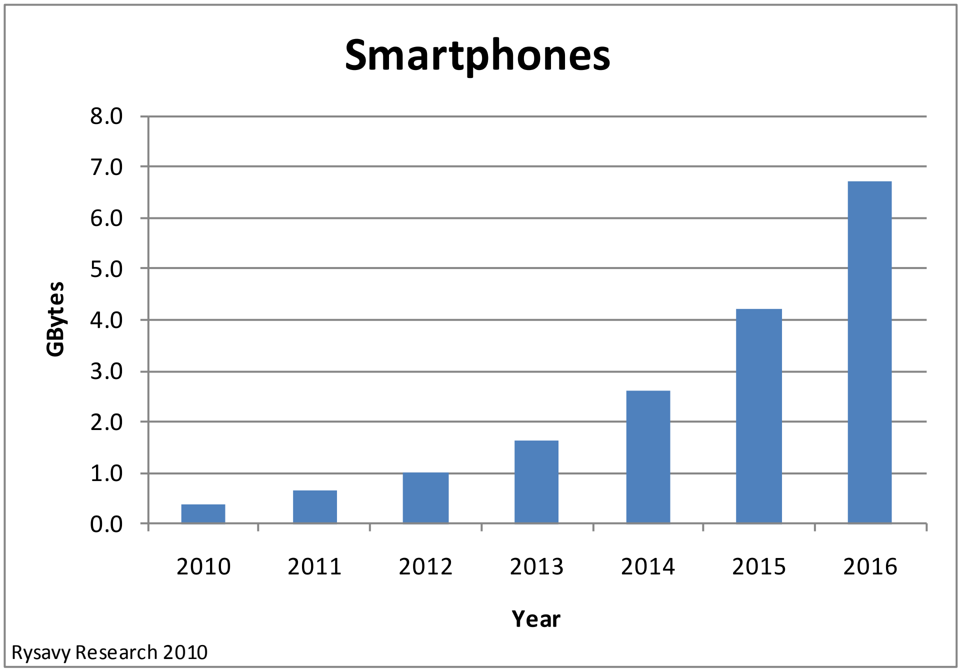
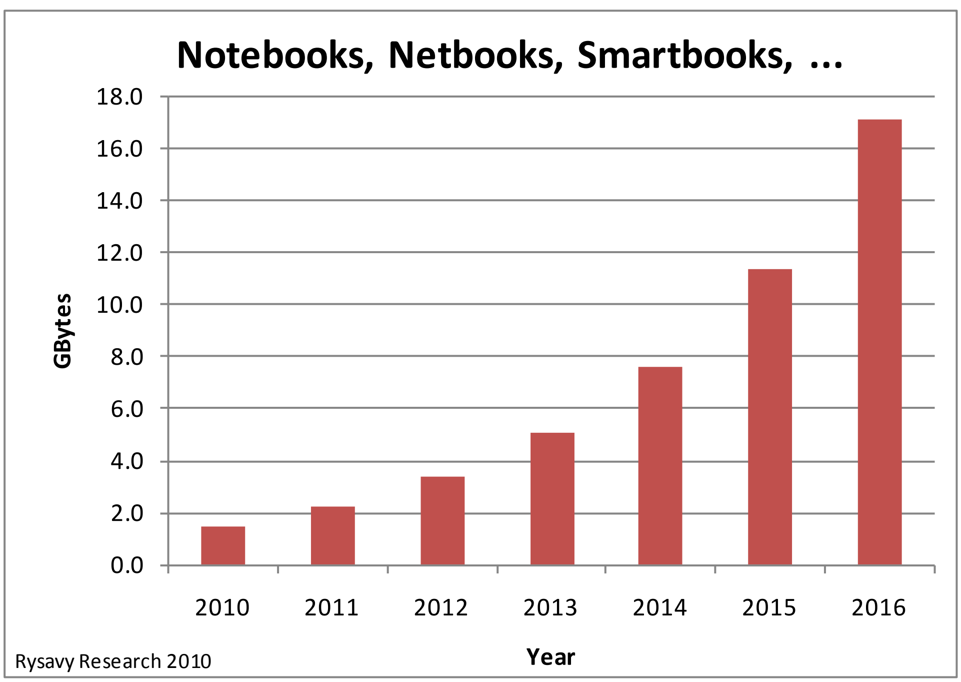
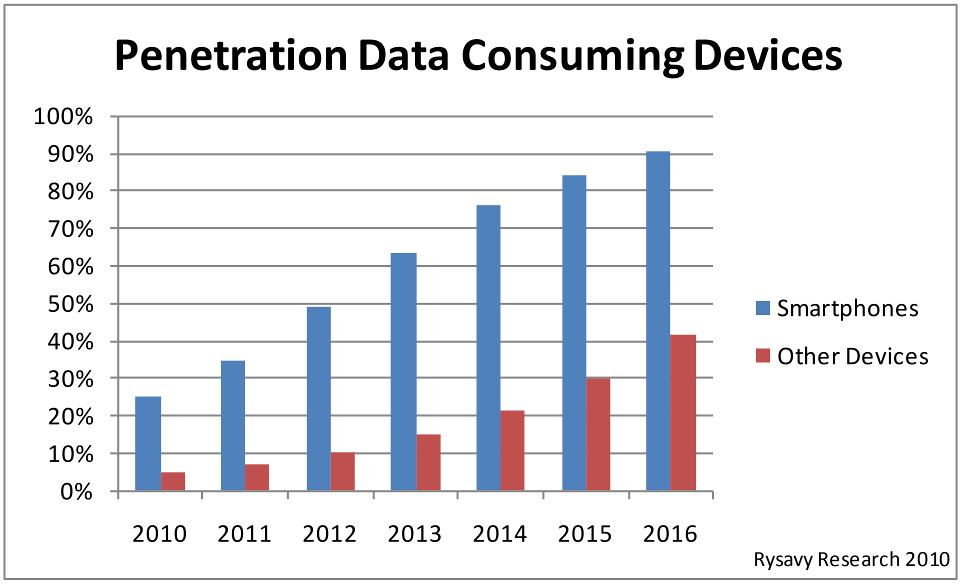


Figure 4: Potential Monthly Data Consumption per Subscriber for Other Devices over Time



One can reasonably extrapolate the following penetration rates of smartphone users and other device-type users as follows.

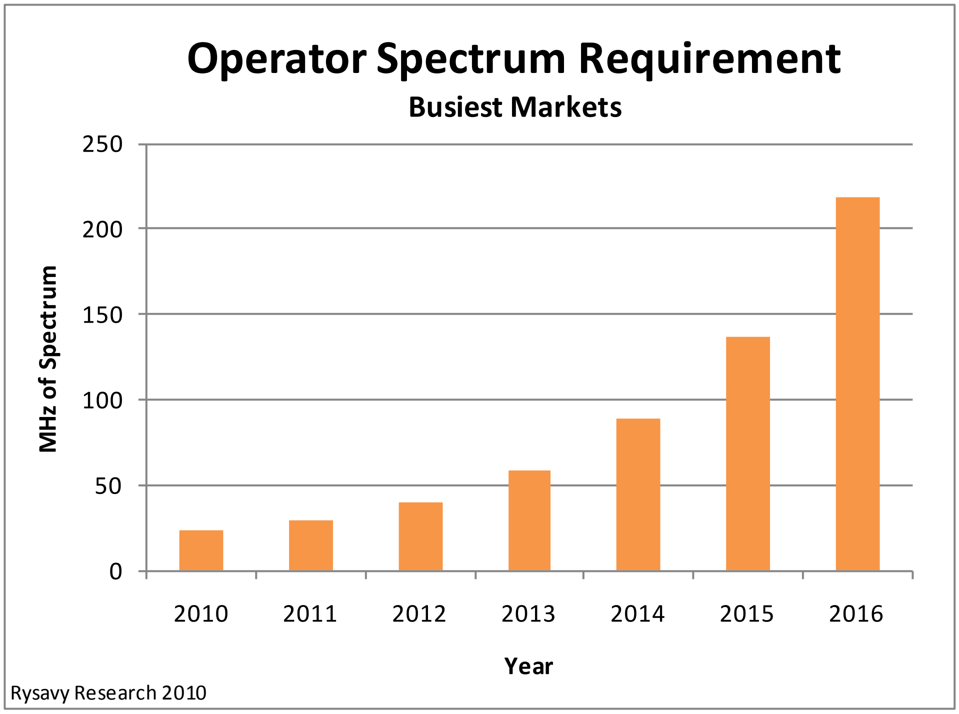
Figure 5: Penetration of Smartphones and Other Devices over Time



Based on these projections, the model calculates the amount of spectrum that a large operator would need to support this level of demand. The model assumes all services are supported in either 3G or enhanced 3G mode. In reality, any operators today have services deployed in less efficient 2G mode, meaning they would need more spectrum than shown. The model further assumes that the spectral efficiencies of the technology will improve as operators deploy technologies such as HSPA+, WiMAX and LTE. The model also accounts for spectrum required by voice services.

The following figure shows the amount of spectrum an operator would require in their busiest markets to meet the demand shown in the prior figures.

Figure 6: Projected Spectrum Requirements for a Large Operator



With many operators in the US holding 55 to 90 MHz of spectrum, one can see that total available capacity could soon be severely challenged. AT&T, in its most recent earnings presentation, stated that it is deploying third and fourth radio carriers to support some of its busiest markets, representing up to a 40 MHz spectrum commitment for mobile broadband.

It is important to note that the spectrum situation varies by operators. Some may experience shortages well before others depending on multiple factors such as the amount of spectrum they have, their cell site density relative to population, type of devices they offer, and their service plans.

Another important consideration is that the spectrum demand model looks at the amount of spectrum to carry the amount of projected traffic. But a user's actual experienced throughput at this level of loading may be less than desired. To provide true broadband experiences with typical user throughputs in the 500 kbps to 1 Mbps range could require even more spectrum than anticipated by the model.

There is a range in the projected spectrum requirements depending on the different assumptions used. But even experimenting with a range of values for the key assumptions, one can come to conclude the following with a high degree of confidence:

- Mobile broadband traffic has the potential to consume all available spectrum in the next three to five years, depending on the assumptions used.
- Substituting wireless connections for wireline for large percentages of subscribers would require significant amounts of additional spectrum.

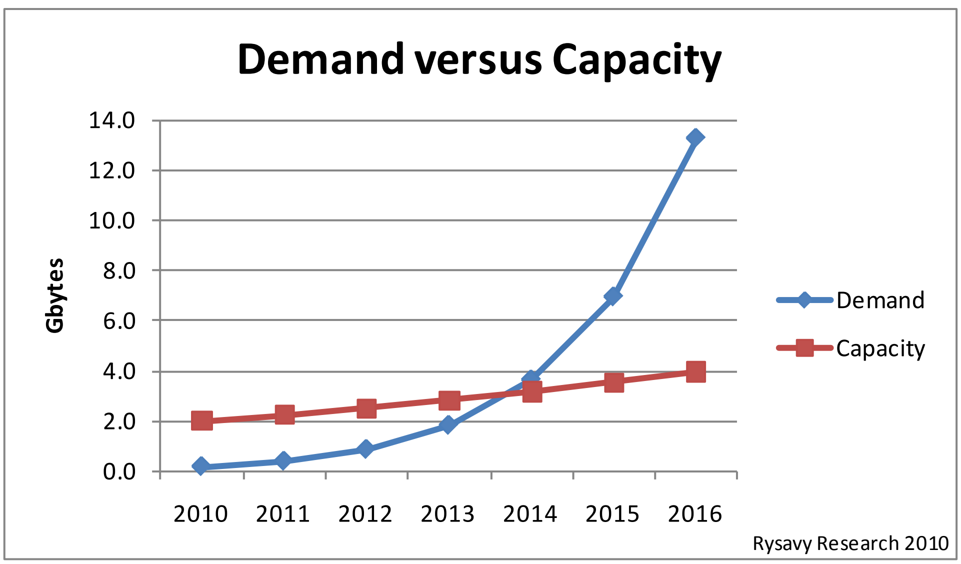
- As spectrum is consumed, it will result in congested situations.

Of particular significance is that usage from cell site to cell site is not uniform, and varies based on the location of users and their behavior. Even if a network has sufficient "average" capacity, these variations will result in some cells being overused and some cells being underused.

Operators acknowledge the problem. One leading operator recently stated to the FCC, "Wireless carriers continue to spend billions of dollars annually on infrastructure upgrades, but they will continue to face severe capacity constraints, particularly with demand growing far faster than anticipated."[20] Another large US operator stated "Wireless carriers face spectrum constraints, expanding yet highly unpredictable demand, interference hurdles, handset and device coordination requirements, and ongoing and fast-paced technological evolution."[21] This paper examines the overused congested scenario and its effects further below.

Another means of looking at spectrum versus demand is to consider the average data usage across all subscribers as per the previous charts, and to compare that with the average capacity for each data user, assuming that an operator has 50 MHz of spectrum (25 MHz + 25 MHz) deployed for just broadband data services. This is shown in the following figure, which again assumes an operator's busy market. (Note, however, that most data services today are deployed in significantly less than 50 MHz, with 10 MHz or 20 MHz being much more common.)

Figure 7: Average Demand Per User Versus Average Capacity Per User



[20] Comments of AT&T to the FCC, Exhibit 2, Jeffrey H. Reed & Nishith D. Tripathi, "The Application of Network Neutrality Regulations to Wireless Systems: A Mission Infeasible," January 14, 2010, http://fjallfoss.fcc.gov/ecfs/document/view?id=7020377220 .

[21] Comments of T-Mobile USA to the FCC, January 14, 2010. http://fjallfoss.fcc.gov/ecfs/document/view?id=7020377832 .

Other Reports on Spectrum Demand

There is not that much public data available that quantifies spectrum requirements. One report is from the New Zealand Ministry of Economic Development.[22] This reports projects the spectrum requirements for different degrees of market penetration looking at different levels of monthly data use per use. The technology is LTE. For 10 Gbytes per month per subscriber with 20% market share, the New Zealand data anticipates 61.7 MHz of spectrum. This is far greater than the amount of spectrum planned by various operators for their LTE deployments. Yet, 10 Gbytes per month is the amount of data being consumed today on wireline connections, and this amount of spectrum represents the amount needed for LTE to be able to compete with other broadband networks today. Over time, the spectrum requirement will only increase.

Table 2: Spectrum Requirement for LTE Deployment Relative to Monthly Usage and Market Share

Monthly Data Use Per User	20% Operator Share	30% Operator Share	40% Operator Share
5 Gbytes	30.8 MHz	46.2 MHz	62.0 MHz
10 Gbytes	61.7 MHz	92.5 MHz	123.0 MHz
15 Gbytes	92.0 MHz	139.0 MHz	185.0 MHz

Another report that has received a considerable amount of attention is in the International Telecommunications Union (ITU) report ITU-R M.2078, "Estimated spectrum bandwidth requirements for the future development of IMT-2000 and IMT-Advanced." This report uses a sophisticated model to predict spectrum requirements through the year 2020. It calls for total spectrum of 1300 MHz for the commercial mobile radio industry in 2015, as shown in the following table. This is about three times more spectrum than is currently available for commercial mobile radio service.

Table 3: ITU Projection on Total Spectrum Requirements

Type of Forecast	2010	2015	2020
Lower Adoption Forecast	760 MHz	1300 MHz	1280 MHz
Higher Adoption Forecast	840 MHz	1300 MHz	1720 MHz

[22] Source: New Zealand Ministry of Economic Development, "Future Demand for 900 MHz Spectrum." Based on Vodafone's projected 3G site count, Vodafone network traffic distribution, and long term evolution of 3G. http://www.rsm.govt.nz/cms/policy-and-planning/current-projects/radiocommunications/rights-at-expiry/cellular-rights/past-consultation-and-documents/submissions/cross-submissions/cross-submission-no-04/3-future-demand-for-900-mhz-spectrum/pdf/3-future-demand-for-900-mhz-spectrum.pdf

Spectrum Deployment Considerations

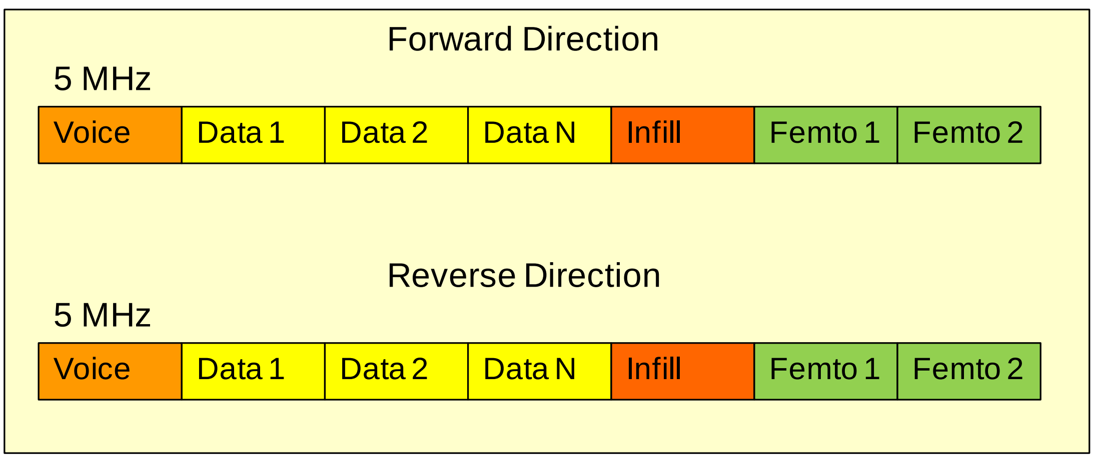
The previous analysis is for the amount of spectrum required relative to network loading. For actual network deployment, however, there are additional considerations. One is that data and voice requirements are different, especially while voice is carried by circuit-switched means. Ideally, an HSPA operator can use one 5+5 MHz radio channel for voice-oriented traffic, and then an additional carrier, or additional multiple carriers, for data. This results in at least 20 MHz of desired spectrum for HSPA (2 X [5+5] MHz).

Another consideration is that while a particular coverage pattern may be effective for voice, it can be less than ideal for data. This is because the minimum signal quality that still works well for voice can be too low for best data performance, resulting in relatively low data throughputs. Today's data technologies employ advanced features such as high-order modulation, but these are only possible at higher signal to interference ratios. A common approach to address this disparity is to use a separate radio channel layer for addressing performance holes in what are called infill sites. Lower frequency bands might be used for coverage, but higher frequency bands for these infill sites. This means yet more radio channels.

A further consideration is how to deploy femto cells. While femto cells promise significant benefits in offloading data (as well as improving indoor coverage in some situations), they work best if operating on separate channels. In dense three-dimensional urban environments, two femtocell radio channels may be needed.

Figure 8 summarizes the idealized spectrum deployment for HSPA. With one data-oriented channel and one femto channel, this adds up to 25 MHz in each direction for a total of 50 MHz of spectrum.

Figure 8: Ideal Radio Channel Deployment for HSPA



For LTE, this same approach with 20 MHz radio channels results in a 200 MHz spectrum requirement for an ideal type of deployment, and this is for just one operator. Compare this with the 20 MHz that operators will be using for their actual LTE deployments.

If the operator had overlapping HSPA and LTE coverage, then they could use as much as 250 MHz. This is clearly far greater than what any operator has today. Consequently, congestion will be experienced even faster than predicted by a model that simply equates demand linearly against spectrum.

Another consideration in spectrum deployment is that new technologies, such as LTE, achieve highest efficiency with wider radio channels like 20 MHz in each direction, which represents a 40 MHz spectrum commitment. Furthermore, with contiguous spectrum, fewer guard bands are required. While future spectrum allocations will hopefully accommodate these requirements, deployments of new technologies in current bands will likely involve narrower channels in which these technologies will not achieve their full potential.

Managing Network Capacity

There are a number of ways that operators can manage capacity. These include using new spectrum, deploying new technologies, offloading data onto other networks, and through pricing plans.

More Cell Sites

Though wireless technologies have become more efficient with respect to the amount of bits they carry relative to amount of spectrum used, by far the greatest gain in overall network capacity has been from aggressive reuse of frequencies through smaller cell sites. This represents a million-fold gain since 1957.[23]

Operators will continue to deploy more cell sites, but there are practical limits, including the difficulty of obtaining physical sites for towers and zoning restrictions. In addition, modern 3G and 3G+ sites can no longer be served with copper-based T1 or E1 circuits, but need fiber or broadband microwave backhaul connections. Obtaining more physical locations and connecting all these sites increases fixed network costs and complicates operation.

More cell sites will play a role in increased network capacity, but likely will not be a dominant factor.

Spectrum

New spectrum will be essential for the growth of the mobile broadband market. In the US, 354 MHz of spectrum has been allocated for commercial mobile radio service, including cellular, Personal Communications Service (PCS), Specialized Mobile Radio (SMR), Advanced Wireless Service (AWS) and 700 MHz bands.[24] But this is a small fraction of total spectrum required for the industry to address current market trends. Julius Genachowski, chairman of the Federal Communications Commission in the United States stated at the CTIA conference in San Diego in October 2009, "I believe the biggest threat to the future of mobile in America is the looming spectrum crisis."[25]

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[23] Source: Mark Pecen, Vice President of Advanced Technology, RIM, 2010.

[24] Source: Rysavy Research, "Mobile Broadband Spectrum Demand," December 2008.

[25] Source: MSNBC, "FCC warns of mobile's looming spectrum crisis," October 7, 2009, http://www.msnbc.msn.com/id/33216878/ns/technology_and_science-wireless/ .

The CTIA stated in its recent comments to the FCC on new spectrum allocation that another 800 MHz are needed in the next six years.[26] AT&T indicated in its comments to the FCC that an additional 800 MHz to 1 GHz are required.[27]

It is highly unlikely that this much new spectrum can be made available any time soon. The process of identifying, auctioning, licensing, moving incumbents and deploying new spectrum is a process that takes many years. Chetan Sharma, a wireless analyst, states that it takes seven to ten years to procure spectrum for wireless use.[28]

Given this spectrum shortfall, other strategies are needed including making more efficient use of available bandwidth.

Backhaul and Core Network

As quickly as operators augment the amount of capacity in the radio link, they also have to be able to support the resulting traffic in the backhaul and core network. For the backhaul connection between cell sites and core network, traditional T1 circuits are insufficient, and operators have begun a massive upgrade to fiber and microwave radio connections. These upgrades are by no means complete, and may take years to complete. Similarly, core infrastructure elements such as Serving GPRS Support Nodes (SGSNs) are designed to handle certain levels of traffic (e.g., 1 Gbps), and operators must add infrastructure to handle higher traffic loads. There are no theoretical limitations on capacity in the backhaul and core network, but there are no guarantees either that these will be able to scale fast enough to match demand.

Using New Technologies

Technologies such as WiMAX and LTE increase spectral efficiency. Compared to typical HSPA and EV-DO deployments today, LTE will approximately double spectral efficiency. Further spectral-efficiency gains are also available for HSPA through approaches like MIMO. These gains in efficiency will be important, but it is imperative to realize that wireless technologies are reaching the theoretical limits of spectral efficiency, due to what is known as a Shannon bound, which dictates the maximum possible spectral efficiency for a specific signal-to-noise ratio.[29]

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[26] Source: CTIA, "Comments of CTIA – The Wireless Association, NBP Public Notice #6, October 23, 2009, http://fjallfoss.fcc.gov/ecfs2/document/view?id=7020143313.

[27] Source: AT&T, "Comments of AT&T Inc. on NBP Public Notice #6, Spectrum for Broadband," October 23, 2009, http://fjallfoss.fcc.gov/ecfs2/document/view?id=7020143280.

[28] Source: RCR Wireless, "Analyst Angle: Solutions for the Broadband World, November 4, 2009," http://www.rcrwireless.com/apps/pbcs.dll/article?AID=/20091104/OPINION/910309995/analyst-angle-solutions-for-the-broadband-world .

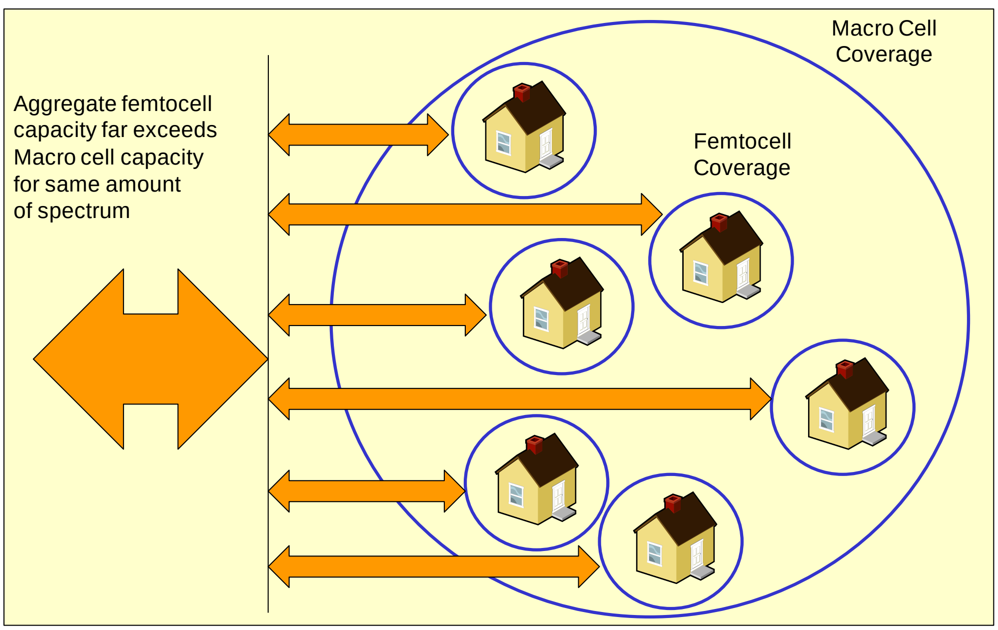
[29] Source: Rysavy Research, "HSPA to LTE-Advanced, 3GPP Broadband Evolution to IMT-Advanced (4G)," September 2009.

Offloading onto Other Networks

Operators can also reduce the demand on their networks by off-loading onto other networks such as femtocells and Wi-Fi. This will definitely help, although there are limitations. First, both femto and Wi-Fi represent only a small percentage of the overall coverage area available to the user. Second, both presuppose an existing wireline broadband connection in home environments. Neither Wi-Fi nor femto are possible if a user is trying to make mobile broadband their primary source of connectivity.

To minimize interference, femtocells are easiest to deploy in separate radio channels, which mandate a certain level of spectrum commitment even before any spectrum benefits are actually realized. Once deployed, femtocells do provide a higher aggregate capacity for a certain amount of bandwidth than using those same frequencies in a macro cell. This is due to the higher level of frequency reuse, as shown in Figure 9. The question is whether a sufficient number of femto cells can be deployed fast enough to head off congestion issues. So far, deployment has been slow, and issues remain such as making the devices sufficiently easy to install and manage. Consequently, it is unlikely that femtocells will make a material difference in capacity consumption over the next three years.

Figure 9: Femto Cells Provide High Capacity Due to High Reuse



Service Pricing Strategies

Service pricing and terms of agreement are another way that operators are controlling demand. Today's "flat-rate" plans usually have caps imposed, which for a laptop device is commonly 5 Gbytes per month. The projected monthly usage of broadband for non-phone devices shown above in Figure 4 is significantly higher than this. New lower-priced netbook plans have monthly limits of about 300 Mbytes, which represents a relatively low network load. Monthly laptop plans in the US are still priced at levels that discourage mass adoption. It is only with the current smartphone plans that are priced at relatively low levels and with which users are able to consume large amounts of data, that there is actually substantial growth in mobile-broadband usage.

If operators constrain usage through their service plans, there won't be necessarily be any so-called spectrum crisis. At the same time, however, if the limits are too restrictive, then people won't subscribe to the services in the first place. For platforms such as netbooks and smartbooks to become popular mobile broadband devices, they must be able to run the applications that users desire, including those that consume the most amounts of data such as video and social networking. This means that operators must deliver the amount of bandwidth these applications demand.

Pricing plans are the easiest way for operators to limit data consumption. Plans that are too restrictive, however, and that prevent users from doing much of what they do over wireline connections will significantly constrain market development and the data revenue opportunity.

Market Implications

Going forward, there are fundamentally two scenarios for the mobile-broadband market.

1. **Credible Broadband Alternative.** Through additional spectrum and other means like data offloading, the industry provides sufficient capacity that mobile broadband networks support users bandwidth-intensive applications at attractive price points.
2. **Constrained Broadband Alternative.** Due to delays in obtaining additional spectrum, operators are unable to deploy sufficient capacity to meet demand, and must rely on higher prices, limits on allowed applications, traffic shaping, and other means that result in mobile-broadband being a poor broadband alternative. Capabilities will be sufficient for phones and "light" Internet usage, but most subscribers will still need a fixed-broadband connection for data-intensive applications.

The Inevitability of Congestion and Impacts

The preceding discussion has demonstrated that with plausible increases in mobile broadband penetration and increases in data consumption per user that spectrum available for mobile broadband could be consumed within three to five years. But it will not take that long for the effects of congestion to manifest themselves, and, in fact, they already have on some networks. This section explains the reasons for congestion and the impacts on applications.

Reasons for Congestion

There are a number of reasons that congestion will occur on a localized, if not widespread, basis. Many of these are items have already been discussed and are summarized in Table 4.

Table 4: Reasons for Congestion Occurring

Source of Congestion	Explanation
Disproportionate network usage	Though there may be sufficient capacity on average, heavy usage (e.g., streaming video) by a subset of users in a specific coverage area can consume all available capacity.
Unpredictable user densities	Users are mobile and unpredicted large concentrations of users in a coverage area can quickly exceed local capacity.
Deployment on limited number of radio carriers	An operator may have sufficient spectrum relative to demand, but to minimize costs, deployment occurs on a radio carrier by radio carrier basis. The capacity of each radio carrier is relatively low and an insufficient number may be available for peak activity in some coverage areas.
Backhaul constraints	Even if the radio link has sufficient capacity, a large number of cell sites today have limited backhaul capability.
Cell site deployment restrictions	An operator may have spectrum and equipment available, but zoning or other restrictions may prevent installation of cell sites in needed areas.
Lag factor	Market growth can be faster in certain areas than the ability for an operator to upgrade their network to support demand.

As one operator states, “Accordingly, wireless providers face unique challenges in predicting how much capacity should be available or will be required at a particular location, because the number of users at that location can change minute by minute. As many customers have experienced when shopping at a crowded mall or attending a popular sporting event, use of the network by other customers in a given location can dramatically impact the speed and availability of the network."[30]

While congestion effects appear inevitable, it does not mean that networks will be unusable on a widespread basis. It is more likely that congestion effects will occur in certain locations at certain times, and not evenly across operators. The types of devices operators sell, the pricing plans they offer, and how many radio channels they have that support data, are all variables that will come into play.

An example is the most recent Consumer Electronics Show in Las Vegas this year where an operator experienced congested issues and a spokesman for the operator stated, “In preparation for CES, we optimized our network in Las Vegas by significantly augmenting our network capacity. However, at

[30] Comments of T-Mobile USA to the FCC, January 14, 2010. http://fjallfoss.fcc.gov/ecfs/document/view?id=7020377832.

an event such as CES, where large numbers of people in a dense area are using smartphones over finite spectrum, periods of network congestion can occur."[31]

Application Effects

The effects that congestion has on applications are multifold. The core problem is that there are more packets to send or receive than opportunities to send them over the radio link. Hence, they get queued up within devices or within the network. In milder cases, the queuing simply results in eventual transmission with some delay. Everything works as desired, just a bit slower. In more severe cases, the delays increase until application performance is so slow that it becomes unusable. For example, a Web page will take a minute or more to load instead of a few seconds. In worst-case situations, the following can occur:

- **Packets are dropped.** Most packet queues have a maximum size, and when that size is exceeded, the infrastructure simply discards packets. This can cause severe application malfunction.
- **Applications time out.** Most applications that employ communications have maximum times that they will wait for communications to complete. When that time is exceeded, how applications respond depends on the application. Some will make another attempt at communications; others will report a failure. Some applications, developed for more stable wireline environments, will lock up, requiring users to terminate the application or even restart their computers.

TCP/IP Limitations

One of the challenges with wireless networking is that the most widely used communications protocol, TCP/IP, is not ideal for the wireless environment, particularly Transmission Control Protocol (TCP), which employs sophisticated timers and acknowledgment protocols to provide reliable communications across disparate networks. TCP was designed for wireline networks that behave differently with respect to packet delays, and hence, does not always handle communications optimally. It is for this reason that many wireless applications or middleware employ their own wireless-specific transport-layer protocols.

Vinten Cerf, one of the key engineers in the development of Internet technologies, states "Mobile operations are highly stressed. Mobiles are used where people congregate. In a sense, mobile is already a dense and hostile environment. We all know that when you drive around, coverage isn't very good. It's so hostile, it's clear that mobile could take advantage of these more-resilient protocols. TCP/IP is very brittle."[32]

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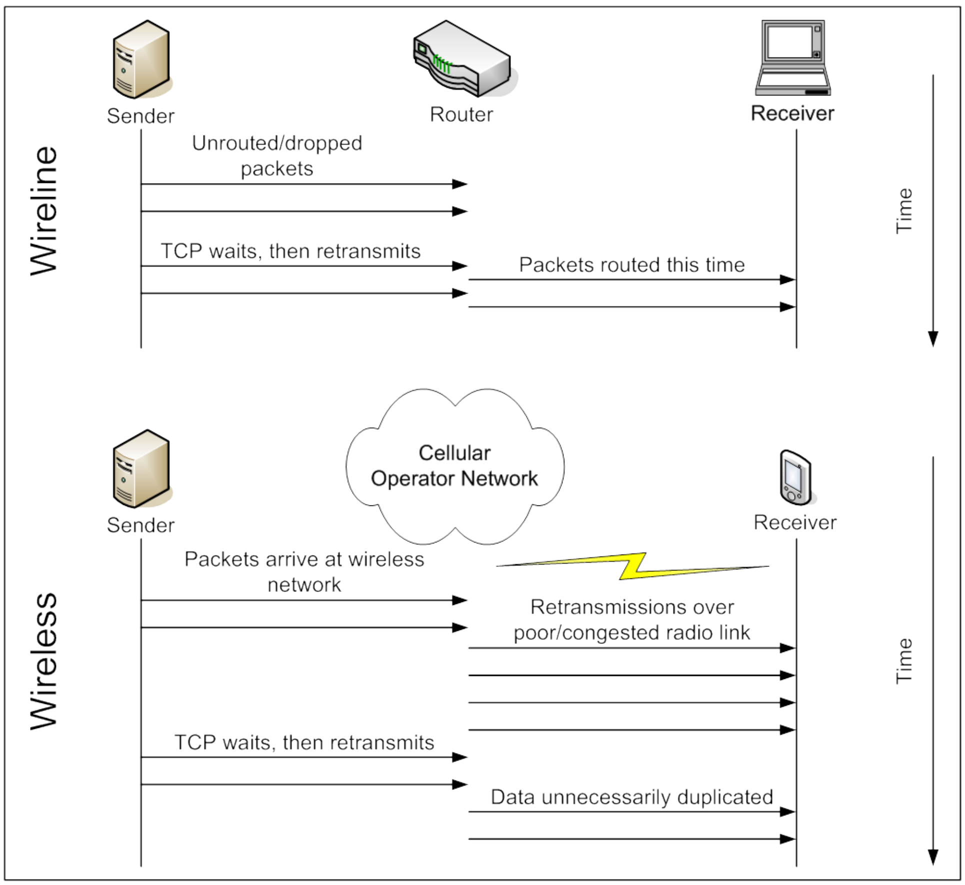
[31] Source: Washington Post, http://voices.washingtonpost.com/posttech/2010/01/at_the_worlds_largest_high-tec.html .

[32] Source: GigaOm, "Vint Cerf Plugs His Plucky Space Web Protocol Into Android ," November 6, 2009, http://gigaom.com/2009/11/06/vint-cerf-plugs-his-plucky-space-web-protocol-into-android/

Figure 10 illustrates the problem. The fundamental issue is that a missing acknowledgment over wireline or fiber typically means that a router queue was full, and the router had no choice but to discard some packets, and therefore a retransmission is needed for the missing packet. In wireless, a missing acknowledgment is normal at times, and usually means that the user moved out of coverage or the network was temporarily congested. The wireless network stores data for the mobile until it returns to coverage at which time the network sends the delayed data to the mobile. This procedure confounds TCP's behavior and results in a flooding of the radio network with unnecessary re-transmissions.

Figure 10: TCP/IP Behavior Under Different Conditions



Wireless-Optimized Applications

Most TCP/IP-based networking applications were never designed specifically for operation over wireless connections. While today's 3G and tomorrow's 4G networks can deliver IP packets reliably and efficiently, in a congested situation, or even with just a very weak radio signal, throughput rates can go down significantly, delays can increase, packets may be dropped, and connections can be lost entirely. Getting reconnected might be with a different IP address, which can confuse an application that is in mid-transaction. Moving rapidly such as in a train or car also stresses connections.

There are communications algorithms, however, that are designed to cope with such difficulties. Examples of systems that implement more robust communications include wireless e-mail systems; applications developed specifically for operation over wireless networks; and mobile middleware systems.

The methods used by wireless-optimized applications include:

- Handling communications in the background so the user never notices any communications difficulties.
- Longer timeouts so applications are more tolerant of delays.
- Sending only the portions of files that mobile users need.
- Compression to reduce the amount of data sent.
- Caching so previously sent data can be reused.
- Resuming from point of failure.
- Ability to handle IP address change.

Benefits of optimized applications are multifold: they impose a lower network load; transactions complete more quickly and, hence, are more likely to succeed in congested situations; a lower amount of communications translates to better battery life; and users incur lower monthly service charges, especially as the industry moves in the direction of usage-based pricing models. RIM BlackBerry is a prominent example of an extremely efficient wireless application environment that benefits both operators and its users.

The BlackBerry Advantage

There are multiple areas in which RIM BlackBerry provides advantages. One is in its efficient e-mail handling. Another is superior browsing efficiency. A third area is a policy management capability that allows managers to control bandwidth consumption of user devices. The last area is in the resilient communications protocols that BlackBerry uses.

E-Mail Efficiency

Rysavy Research has done a series of tests that compare BlackBerry e-mail efficiency with competing systems. Table 5 summarizes the test results.[33] The first column indicates the message size in bytes, the second column the type of attachment, if any, the third column the size of the attachment, and the fourth column the combined size of the message plus attachment. Subsequent columns show the results for Microsoft Direct Push and BlackBerry, listing the total number of bytes communicated over the radio interface as well as what percentage that number of bytes constitutes relative to the size of the message (plus attachment if any). Rysavy Research tested Direct Push using three

[33] Source: Rysavy Research, “Wireless E-Mail Efficiency Assessment – RIM BlackBerry and Microsoft Direct Push (Including iPhone),” January 27, 2009.

devices: the Motorola Q9h, the HTC TyTN II (the AT&T version is called the "Tilt"), and the Apple iPhone 3G. Tests included Windows Mobile devices both with and without the Microsoft System Center Mobile Device Manager (SCMDM).

A percentage value greater than 100 percent means that the wireless e-mail system communicated more bytes than the original message size, whereas a percentage value lower than 100 percent means the wireless e-mail system communicated fewer bytes than the original message size. Lower percentage values represent better wireless efficiency.

Table 5: BlackBerry E-Mail Efficiency Comparison

				DP, Motorola		DP SCMDM, Motorola		DP, TyTN II		DP SCMDM, TyTN II		DP, iPhone		BlackBerry 9000	
Msg Size	Attach Type	Attach Size	Msg + Attach	Sent OTA	% Sent	Sent OTA	% Sent	Sent OTA	% Sent	Sent OTA	% Sent	Sent OTA	% Sent	Sent OTA	% Sent
5120	None	0	5120	12147	237%	15051	294%	11077	216%	13547	265%	18634	364%	3445	67%
10240	None	0	10240	14668	143%	17923	175%	13767	134%	16641	163%	22888	224%	6121	60%
20480	None	0	20480	20244	99%	24447	119%	19552	95%	23030	112%	32041	156%	11527	56%
136737	None	0	136737	134060	98%	152889	112%	133656	98%	154224	113%	180044	132%	68757	50%
5120	JPG	152148	157268	267867	170%	299132	190%	266817	170%	297764	189%	271454	173%	14613	9%
5120	PDF full	363139	368259	564186	153%	629022	171%	563110	153%	626489	170%	570480	155%	577645	157%
5120	PDF text	363139	368259	564186	153%	629022	171%	563110	153%	626489	170%	570480	155%	85856	23%
5120	Word Doc	511488	516608	594921	115%	667484	129%	593882	115%	665745	129%	601919	117%	41922	8%
5120	PPT file	966144	971264	1438081	148%	1599568	165%	1436744	148%	1598236	165%	1453720	150%	329103	34%
5120	Excel	51200	56320	34395	61%	41039	73%	33310	59%	39714	71%	40675	72%	10126	18%

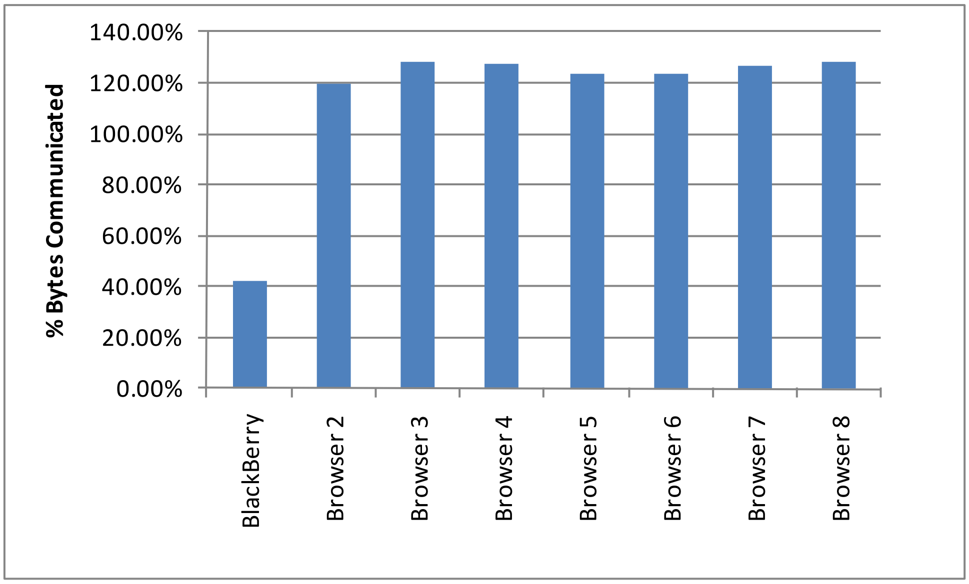
In nearly all cases, BlackBerry was significantly more efficient than competing solutions. And in nearly all cases, BlackBerry sent less data over the air than the original file size. In some cases, the amount sent was only a small percentage of the original file. One method by which BlackBerry achieves gains in network efficiency is by having efficient file viewers, so that a user can view portions of a file without having to download a whole file. Another is by employing superior text compression algorithms that are twice as efficient as common approaches like GZIP.

Web Efficiency

BlackBerry users have the ability to choose the image quality settings for Web browsing including low, medium, and high. The default setting is medium. The lower the image quality setting, the less data is transferred from the BlackBerry Enterprise Server or BlackBerry Internet Server to the device and the faster the downloading time. The rationale for providing this quality setting is first that the original image quality is unnecessarily high in many cases, and second that BlackBerry users may prefer an acceptable degraded image quality for a faster browsing experience and lower data usage. RIM also uses advanced image compression algorithms that are more efficient than common JPEG and GIF image-compression approaches.

Rysavy Research also tested BlackBerry browsing efficiency using RIM's latest browser technology that is used in the 9700 Bold, with the results shown in Figure 11. Browsers compared included Windows Mobile 6.5 Internet Explorer, Windows Mobile 6.5 with Opera, Android, IPhone 3G, iPhone 3GS, Nokia N97, and Samsung Jet. These are randomly represented as browsers 2 to 8 in the figure.

Figure 11: BlackBerry Efficiency Relative to Other Mobile Browsers



The test measured the number of bytes communicated to download popular mobile Web sites. Because BlackBerry employs multiple mechanisms to reduce the amount of traffic including compression of objects, it is able, on average, to use only a third of the data consumed by other browsers. This represents a substantial savings in network traffic for operators, as well as lower costs for users on usage-based data plans.

BlackBerry Policy Management

Beyond efficient operation, the BlackBerry Enterprise Server provides a number of ways that IT staff can control data consumption on BlackBerry devices.[34] These include the following:

- Restricting Web addresses that users can request when connecting to the Internet or an organization's intranet.
- Specifying which Web address patterns users can and cannot use to access Web servers from the BlackBerry browser and other applications on their BlackBerry devices.
- Controlling what media types can be accessed. For example, MP3 and video could be blocked.
- Preventing users from accessing specific media file types that exceed a maximum value.

[34] Source: RIM, "BlackBerry Enterprise Server for Microsoft Exchange, Version: 5.0, Administration Guide."

- Specifying the maximum file size that can be downloaded.
- Controlling the maximum file size for attachments that users can receive.
- Preventing users from viewing certain attachment file formats.
- Limiting the maximum file size for attachments that users can send.
- Controlling which connections can be used for upgrading BlackBerry device software.

Protocol Resiliency

BlackBerry communications protocols were designed originally for slow networks, such as Mobitex, which ran at 0.1% of the throughput rate of today's fastest mobile-broadband networks with significantly higher communications delays. This heritage makes them highly bandwidth efficient and particularly resilient in congestion situations with today's modern networks.

RIM's network operations center (NOC) architecture means that there is only one connection for a device to maintain no matter how many services the device is communicating with, compared with competitors' approaches in which TCP connections need to be maintained for every service. This results in significant reduction in overhead for BlackBerry connection maintenance.

RIM's proprietary communication protocols further reduces the connection maintenance overhead compared with TCP.

Others agree with the BlackBerry advantage. A research note from Peter Misek at Canaccord Adams states that the BlackBerry service can send 11 times more emails per 500 Mbytes of data capacity than an iPhone. Alternatively, the Blackberry can deliver 7,000 Web pages versus 3000 for the iPhone. "We believe that in a scarce spectral environment, RIM's NOC/BES architecture and compression technology will be worth tens of billions of dollars to global operators."[35]

Financial Benefit of Efficiency

Given the cost of mobile bandwidth, greater efficiency translates directly to saving for both users and for operators.

User Savings

Users on "unlimited" plans may not see any costs savings from more efficient applications, but they still experience other benefits such as battery life, and more reliable operations. Meanwhile, those on usage-based plans could see significant savings, as shown in Table 6, which projects some typical usage scenarios. Common usage-based pricing plans today range from 50 cents to $2 per megabyte. BlackBerry e-mail traffic volume is typically less than one half of other solutions, and Web traffic is typically one third.

[35] Source: Rethink Wireless, "Data caps could give RIM a new day in the smartphone sun," November 5, 2009, http://www.rethink-wireless.com/article.asp?article_id=2108 .

Table 6: User Email Cost Savings Based on Different Profiles

		Light User	Medium User	Heavy User
Email Usage				
	Emails per Month	100	300	1000
	Size per e-mail body (Kbyte)	5	5	5
	Percentage with attachments	10%	10%	10%
	Average size attachment (Mbyte)	1	1	1
Message Body Consumption				
	Total body per month (Kbytes)	500	1500	5000
	BlackBerry data volume (Mbytes)	0.335	1.005	3.35
	Typical non-BlackBerry data volume (Mbytes)	1	3	10
Attachment Consumption				
	Total attachment volume (Mbytes)	10	30	100
	BlackBerry data volume (Mbytes)	5	15	50
	Typical non-BlackBerry data volume (Mbytes)	15	45	150
Total Data Volume (body + attachment)				
	BlackBerry (Mbytes)	5.335	16.005	53.35
	Typical non-BlackBerry (Mbytes)	16	48	160
Monthly Savings with BlackBerry				
	Assuming 50 cents/Mbyte usage plan	$5.33	$16.00	$53.33
	Assuming $1/Mbyte usage plan	$10.67	$32.00	$106.65
	Assuming $2/Mbyte usage plan	$21.33	$63.99	$213.30

One can do a similar savings analysis for Web browsing, as shown in Table 7. These are for relatively low-usage scenarios. User streaming video, for example, can generate far more traffic than what is calculated.

Table 7: User Web Browsing Costs Savings Based on Different Profiles

		Light User	Medium User	Heavy User
Web Usage				
	Pages Viewed Per Month	100	300	1000
	Typical Mobile Web Page Size (Kbytes)	100	100	100
	Total Volume Web Traffic (Mbytes)	10	30	100
Data Consumed on Mobile Device				
	BlackBerry (Mbytes)	4.2	12.6	42
	Typical Non-BlackBerry (Mbytes)	12.5	37.5	125
Monthly Savings with BlackBerry				
	Assuming 50 cents / Mbyte usage plan	$4.15	$12.45	$41.50
	Assuming $1/Mbyte usage plan	$8.30	$24.90	$83.00
	Assuming $2/Mbyte usage plan	$16.60	$49.80	$166.00

Actual savings clearly depends on actual volume and actual service plans. But across a wide range of assumptions, users will experience significant benefits from lower data consumption in usage-based pricing scenarios.

Mobile Broadband Network Costs

The savings are also dramatic for operators. Assuming a per megabyte cost of HSPA of $.03 Euros[36], the e-mail and Web browsing volume of a medium user from the above tables, 4 million BlackBerry users out of a subscriber base of 50 million, an operator could save more than 100 million dollars a year in operating costs.

Table 8: Savings to Operator from BlackBerry

Total subscribers	50,000,000
% Using Smartphones	20%
% Smartphones that are BlackBerry	40%
Total BlackBerry Devices	4,000,000
Montly Data Saved (MBytes, Medium User)	56.9
Total Monthly Data volume saved (Mbytes)	227,580,000
Operator cost per megabyte ($) HSPA	0.042
Montly savings	$9,558,360
Annual savings	$114,700,320

Conclusion

The mobile-broadband industry is experiencing tremendous success, yet its very success is undermining its ability to deliver a consistent, trouble-free experience. As the number of users increases with ever more demanding applications, it is inevitable that there will be ever more cases in which the volume of traffic in different coverage areas exceeds capacity, resulting in congested operation.

More efficient applications not only reduce the likelihood of congestion occurring in the first place, but they also are inherently more resilient, since they require less time and data to operate. They also reduce battery consumption, and most importantly for users, reduce costs, especially with usage-based pricing plans.

Beyond user benefits, greater application efficiency results in significant savings for operators including lower costs in the radio network, lower costs in backhaul, lower infrastructure costs and the need for less new spectrum.

[36] Source: UMTS Forum, "A White Paper from the UMTS Forum Mobile Broadband Evolution: the roadmap from HSPA to LTE," February 2009.