Point of View: Wireless Point of Disconnect

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We're Reaching a Point of Disconnect

The *How Much Information? 2009 American Consumer Report* found that in 2008, Americans consumed 1.3 trillion hours of information, an average of almost 12 hours per day. Consumption totaled 3.6 zettabytes[1] and 10,845 trillion words, which corresponds to roughly 34 gigabytes and 100,500 words for an average person on an average day.

Much of this staggering amount of information is carried over communications networks. This report discusses whether our nation's wireless networks can deal with this traffic as it increasingly shifts from the wired to the wireless world and suggests next steps in preparing for a wireless future. In the same way that our wired networks have seen their capacity challenged by new demand, we are now seeing our wireless networks stretched to meet the consumer-generated traffic demands of the 21st century. While the drivers of demand are similar, the ability of the wireless networks to grow capacity is seriously limited. **For example, the throughput of the nation's wireless data network in 2010 was equivalent to less than one day of the nation's overall video consumption.**

Networks, and especially wireless networks, are not infinite in their capacity and when the demand outstrips supply, the result is degraded service quality, dropped calls and sessions and consumer frustration. To keep up with demand, U.S. wireless networks have traditionally doubled their capacity every 30 months[2] but this trend may not keep up with future demand. Upwards of 95 million Americans now have active smartphones and wireless-enabled PDA's and the volume of data traffic on U.S. networks is expected to increase by 1,800 percent over the next four years.

1800% increase in mobile data expected

- **More than 300 million** mobile devices in service in 2010
- **More than 95 million** active smarphones and wireless-enabled PDAs the U.S.
- **More than 94 million** laptops on the global mobile network
- **Machine-to-machine traffic** to increase 40-fold globally between 2010 and 2015
- **48 million people** worldwide have mobile phones but not electricity

The wireless communications infrastructure that makes cellular calling, smartphone applications and Netflix streaming possible is largely invisible to everyone except a few engineers and operations personnel. But if it were visible, it would appear as a traffic-clogged highway with rush hour about to begin. The shift to Internet-enabled phones and 3G and 4G services it is as if 30 percent of drivers rushed out and traded in our "voice" cars for massive 18-wheeled "data" trucks, blocking traffic and pushing other cars off the road everywhere we went.

We have reached a point of disconnect between the capacity of wireless networks and the emerging needs of today's customers. This disconnect is driven largely by multimedia and multimodal Internet-based traffic, real-time applications that operate independently of user transactions, and an explosion in the use of mobile video for calling, education and entertainment.

Our demand for quality high speed capacity enabled by wireless network infrastructure is growing exponentially and the technology and economics of wireless network capacity are struggling to catch up.

[1] A zettabyte is 10 to the 21st power bytes, a trillion gigabytes.
[2] Bernstein Research, June 14, 2010

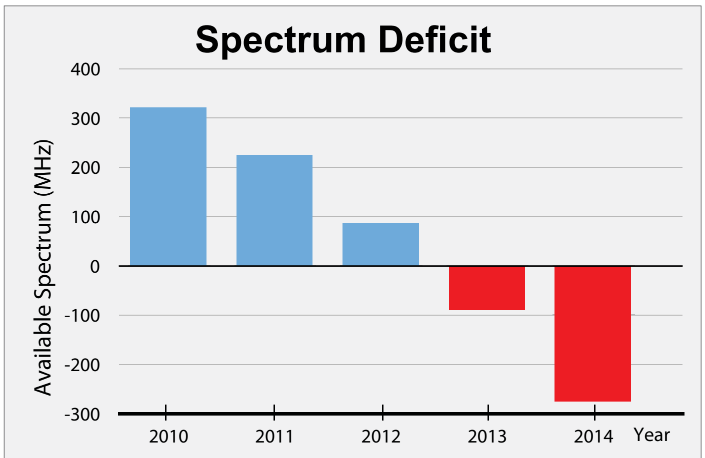
Why Wireless Networks Are Different – What This Means for the Network

Fiber optics is an amazing technology. It can send 40 billion bits per second 100 miles down a highly engineered, beautiful glass fiber by simply using pulses of laser generated light. Need to double the capacity? No need to add another fiber; just get another color laser and send multiple colors (or frequencies) of light down the fiber[3]. If you need more distance just add a booster to amplify the laser light and you can go thousands of miles via a medium that is protected from weather and other interference.

We are currently experiencing a mass migration from wired networks to wireless networks, which under the best of circumstances have far less capacity. For example, even with advanced Long Term Evolution (LTE) wireless technology, the theoretical capacity available to all network users in a given cell is less than 1/1,000th of the capacity of one fiber optic thread[4].

In the past, capacity on wireless networks was much less of an issue because almost all of the traffic was voice calls which used a small and fixed amount of network capacity. Since the capacity of each call was known and people could only make one call at a time, network demand was predictable—mobile voice calls used approximately 20 kilobits per second.

The next major product was texting, or SMS (short message service), which uses a tiny amount of capacity (160 characters or bytes) per message, less than one one-sixteenth of a second of voice traffic per message. For years, predictable demand patterns and relatively light traffic masked the severe limitations of wireless infrastructure.



The FCC projects a spectrum deficit by the year 2013

Wireless relies on a limited stock of spectrum. Applications such as military communications, aircraft control, broadcast television and radio, WiFi, mobile phones, and others, all compete for a small portion of the available spectrum. Ultimately, only a small portion of the spectrum that ***can*** be used for commercial mobile devices ***is*** licensed for such use. Recent estimates from the FCC indicate that the nation is running out of spectrum and will experience a spectrum deficit starting in 2013.

Wireless signals do not operate in the pristine world of fiber optics. Wireless signals are susceptible to interference from a variety of sources including other signals and electromagnetic noise, rain and snow, and steel and concrete buildings. This vulnerability makes it more difficult for signals to be sent and received reliably.

Wireless signals are distance sensitive. Wireless signal strength drops off the further the user is from the cell site, depends on the number of concurrent users in the area, is hampered by radio interference and gets weaker as a mobile user transitions from cell to cell. As with most digital modulation approaches, the further away from the source of the signal the lower the effective data rate (due to increased noise and error correction). Additionally, the higher the frequency the shorter the distance a wireless signal will travel.

Increasing capacity, given the limited radio spectrum, costs and constraints of smaller cell diameters and increased interference, is important in order to meet public demand. A common strategy for increasing capacity is to divide cells into three sectors, which provides more capacity but only temporary relief as the number of users continues to grow. The Federal Communications Commission recently made more spectrum available through auction. Adding new spectrum is the least expensive way to grow capacity because it can utilize much of the same infrastructure, e.g., no new towers, cell sites, generators, etc.

[3] Because this technique uses multiple different frequencies it is referred to as Wavelength Division Multiplexing, or WDM. When more than 10 or 20 frequencies can be sent over a single fiber (and today we can send over 100) it is referred to as Dense WDM or DWDM.

[4] The current capacity of a fiber pair is in excess of 1 terabit per second with systems that can carry over 100 optical channels each running 10 gigabit/second. LTE Advanced, yet to be deployed anywhere, is designed to run a 1gigabit/second *peak* download and 500 megabit/second *peak* upload. The current generation of 4G products run at about 1/10 that speed, or 10,000 times slower than a single fiber pair.

Engineers, manufacturers and operators have pushed to increase the amount of capacity available per hertz of spectrum: 3G gave us millions of bits per second in a radio channel and 4G and LTE give us tens and 100 million of bits per second. Providing 100 million bits per second to each user would create a considerable amount of capacity; however, if there are 100 concurrent users in a cell sector then in theory each has one megabit of capacity available even with LTE.

Once capacity is reached, the quality of service degrades to the point that downloads become slower or stall and calls start dropping. The networks were fine when Blackberries were sending email and performing Internet browsing but then hundreds and thousands of users began watching YouTube or now Netflix videos and running dozens of concurrent applications on their phones, iPads and TVs. In many cases, the network capacity to carry the new traffic wasn't (and in some cases isn't) available to meet the quality of service expectations of consumers.

Streaming traffic, like Netflix movies, differs from voice or email traffic in that it is a constant demand for a long time. Most users do not make phone calls for two hours without a break and even then there are pauses in speech which allow more efficient use of the network for voice. Streaming high quality video doesn't allow for such pauses.

Additionally, all users accessing a shared network – for example, a cable network or a mobile network – effectively compete with all of the others for a fixed amount of capacity. Without effective management and control, one user can destroy quality of service for everyone else. Mobile users can receive multiple video streams or, even worse, use their smartphones or laptop cards as peer-to-peer torrent devices, potentially using all available network capacity.

Evolution of Mobile Technology

1961

Mobile Telephone Service (MTS)

Available 50 years ago, customers had to spend thousands for the service and had a radio in their car with a handset. **When** a channel was free, customers would request a call and an operator would connect them with the other party. Less than a dozen calls could be made at the same time because the radio systems covered a given city from one tower with one set of frequencies.

1964

Improved MTS (or IMTS)

Allowing the customer to dial their own calls was the innovation of the Improved MTS (or IMTS) service. There was no operator. These suitcase (a large suitcase) sized devices were installed in the trunk of the car and used a rotary dial.

1984

1G (Cellular)

Starting in 1984, a number of smaller coverage antennae were installed in overlapping circle designs called cells. You could have hundreds in a city. These could be divided into sectors or slices (like a pie) and the same frequencies were reused across the city, radically increasing the capacity of the network. This was quite an invention but it was still only for voice and was analog.

1991

2G

Generation 2 increased capacity of the network and improved voice quality.

2000

3G

Generation 3 further increased the capacity of the network and allowed mobile data and voice traffic.

Present

4G or LTE

Even further increases the capacity of the the network.

Why Wireless Networks are Limited

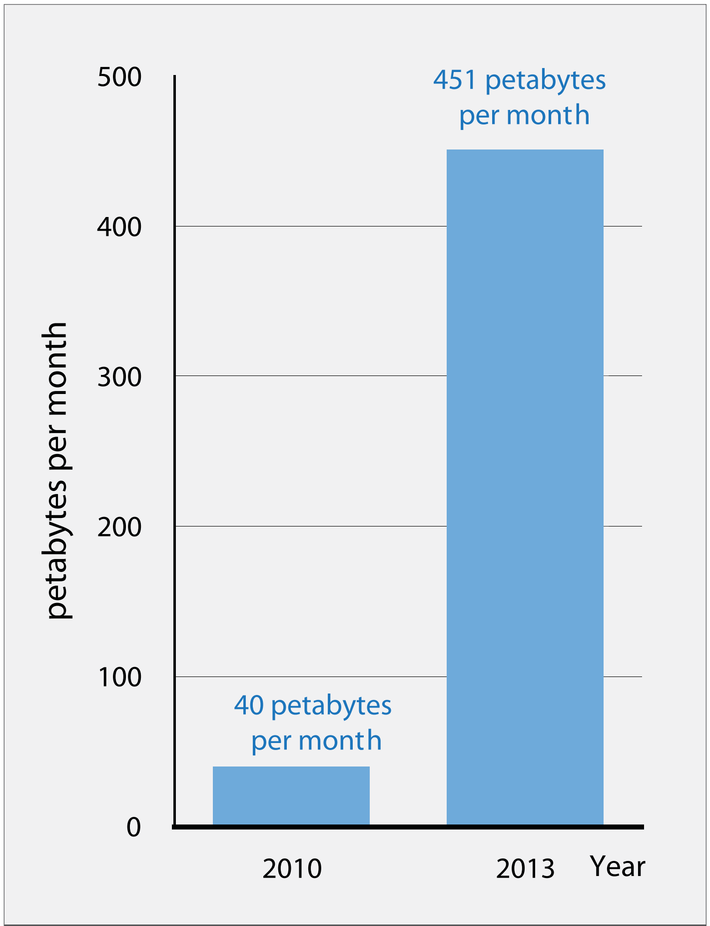
Ever since public data communications services began, demand has always been shaped by the supply and this is particularly true in wireless communications. Today, wireless networks offer enough speed to let consumers view high quality video, in addition to sending text messages and making calls. The demand load of all of this data traffic – ranging from two way video chat or conferencing to streaming video – is the primary consumer of capacity on wireless networks.

One industry analyst estimated in 2010 that U.S. mobile data traffic had grown at approximately 120 percent annual rate over the previous two years[5]. Data has now overtaken voice as the main application (by capacity consumed) on wireless networks, and by 2014 voice is projected to represent only 2 percent of the total wireless traffic[6].

More mobile devices. Smartphone penetration is approximately 30 percent in the U.S. One carrier reports that upwards of 60% of its post-paid customers use integrated devices. We all now understand that an iPhone uses more bandwidth than a non-smartphone – equivalent to 96 non-smartphones by one estimate. What we are now starting to learn is how fast the data consumption per smartphone is growing. The average amount of traffic per smartphone in 2010 was 79 MB per month, up from 35 MB per month in 2009[7].

Mobile replacement. As the speeds and capacity of wireless networks increase they become, in many cases, as fast or faster than the broadband many people have at home. In the same way that mobile phones have replaced fixed telephones for 25 percent of the population, so too is wireless data becoming a complete substitute for high speed data services, at home, on the road, and for many small business people at work.

Mobile video consumption. According to one recent estimate, today 10 percent of mobile users are watching video content on their devices and consuming 38 percent of data volume on mobile networks. By the end of 2011, video content will jump to 60 percent of network data volume[8]. According to another estimate, mobile video will more than double every year between 2010 and 2015 and account for two-thirds of the world's mobile data traffic by 2015.



Projected growth in mobile data traffic

Overall, the growth in wireless traffic is expected to be significant. According to estimates, mobile data traffic in the U.S. was approximately 6 petabytes per month in 2008, 40 petabytes per month in 2010, and it is expected to reach 451 petabytes per month by 2013[9].

- [5] Bernstein Research, June 14, 2010
- [6] Ibid
- [7] Cisco Visual Networking Index Global Mobile Data Traffic Forecast, February 1, 2011
- [8] Bytemobile Mobile Minute Metrics, March 21, 2011
- [9] Bernstein Research, June 14, 2010

To understand the impact that even minor shifts in consumer behavior – and especially shifts in our consumption of video – could have for the U.S. wireless network, consider the contrast between U.S. video consumption and the capacity of our nation's mobile networks.

U.S. viewers average nearly five hours of TV viewing per day (107,705 minutes per year) and as a nation we consume 1,266 **exabytes** of TV per year (1,266,000 petabytes). Compare this to the output of U.S. mobile data networks, which transmitted approximately .48 **exabytes** (480 petabytes) in 2010 over the course of the entire year. **That means the U.S. wireless data network's entire 2010 throughput was only sufficient to handle less than a day's worth of the nation's video consumption.**

Wireless networks carry more than just entertainment. They provide critical life-saving assistance by helping fire departments learn about hazardous materials in buildings they have to enter. They allow doctors to see patient medical images thousands of miles away. They let us communicate, conduct commerce, and have become an essential part of our personal and business lives.

Consumers expect wireless networks to be reliable and available, but the new demands of data threaten this reliability. If network capacity does not keep up with consumer use, more and more consumers will experience dropped calls, lack of access, and connection problems. Increasingly, such problems are not merely a consumer issue. According to the Centers for Disease Control, 26 percent of U.S. households are solely dependent on mobile phones, with no fixed-line phone in the home[10]. This percentage is highest in Mississippi and Arkansas, demonstrating that reliance on wireless communications is not limited to urban centers and technological hubs.

While there are many different types of cell sites, a "typical" cell site can handle about 120 iPad/iPhone users simultaneously streaming video. [11]

[10] Centers for Disease Control and Prevention National Health Statistics Report, April 21, 2011

[11] This is based on an assumption of three sectors per site with 24MB of capacity available per sector streaming standard definition video. This will vary from site to site but is based on theoretical sectors with good coverage and about 600 KB/second of video (but video streaming rates can vary significantly).

What This Means for Wireless Networks

Wireless networks will continue to be an increasingly important part of our lives, and wireless devices will become more pervasive. One might even say, wireless data is as integral to our society as the Internet. Making this network more capable should be a priority.

Carriers are investing billions of dollars to improve network capacity, but there are limits to what money and technology alone can provide. There needs to be a general understanding and acceptance of the trade-offs we will face for the convenience of accessing limited wireless capacity. Alternatively, as citizens we need to dramatically lower our expectations for wireless services in the future.

There are three core strategies to manage this disconnect between wireless infrastructure and demand.

More spectrum. The principal limiting factor is spectrum. As we have discussed, not all spectrum is effective for mobile services. The majority of that spectrum is not available for public wireless data services. Opening up more spectrum, and the right spectrum, is the easiest and least expensive way to increase network capacity. A combination of public and private strategies to optimize spectrum use will need to be employed and encouraged. However, many of the public solutions will take as much as a decade to implement.

Active network management. Planning a network with high speed services is complex work and all networks have finite capacity. Carriers will increasingly need to manage traffic and develop triage and prioritization protocols to ensure users are treated fairly and that users do not degrade the network experience for others. In the future carriers might utilize pricing based mechanisms with real time customer feedback to help manage network load, a sort of automobile peak usage pricing for mobiles.

Enable deployment of supporting infrastructure. Mobile services require towers and other support structures for antennas, lines and microwave dishes to “backhaul” the traffic from the cell site to the central network and switches, power, and secure locations for the equipment. Installing these facilities requires permits, construction and community support. The more we consume wireless data, the higher the number of cell sites will be needed to increase the capacity and improve reliability. If we want to continue to have access to reliable wireless services, we must be willing to support this construction. This needs to be an explicit choice made by the community.

Spectrum deficit solutions needed

Why We Should Care

Wireless networks have evolved from high-cost specialized voice networks used by a very few, to the most rapidly growing networks in history, both in terms of users and services. They are an essential part of personal and business life: used to pay bills; feed parking meters; call for help; make reservations; manage essential facilities; and connect with colleagues, customers, family, and friends. Wireless services are a major source of innovation and economic growth, yet the very capabilities and economies they provide require increases in capacity with a technology that is inherently capacity limited.

Continuing to expand the capacity of wireless data networks in an effective and economic manner is very much in the public interest. However, achieving the benefits will require active support and acceptance of some unpopular ideas, a willingness to prioritize and address this challenge, and the ability to lay aside traditional disputes in the interest of addressing this disconnect.