PUBLIC KNOWLEDGE

Peak Paper World

Coping with a low-bit future.

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PEAK BANDWIDTH

The era of plentiful, low-cost bandwidth is approaching an end.[1] The supply of bits, the raw material of our information economy, is rapidly dwindling. The good news is that commercially viable mitigation options are ready for implementation. The bad news is that unless mitigation is orchestrated on a timely basis, the economic damage to the world economy will be dire and long-lasting.

Bandwidth is the lifeblood of modern civilization. It fuels most communication worldwide and is an input for entertainment, commerce, telemedicine and a myriad of other products used in everyday life. Dark fiber has been generous in yielding copious quantities of bandwidth to fuel world economic growth for over a century, but that period of plenty is changing.

Case Study: AT&T.

According to analyst David Burstein, "probably less than 1/100th of 1%" of AT&T DSL customers experience any impact from bandwidth congestion. AT&T is thus to be commended for capping DSL users at 150GB per month. Bandwidth conservation measures need to start today, before it's too late.

In the following, we describe the nature of the problem, options for mitigation, and required timing. The exact date of peaking is not known; some think it will be soon, others think a decade or more. However, the date is almost irrelevant as mitigation will take much longer than a decade to become effective, because of the enormous scale of world bandwidth consumption.

Background.

Bandwidth was formed by the tech bubble of the late 1990s and is typically found in strands of "dark fiber." The largest fibers are called "backbones," many of which were discovered next to railroad tracks. Since then, smaller pockets of bandwidth have been discovered in "last miles," in forms such as DOCSIS-enabled coaxial cable and FiOS brand fiber.

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[1] *See generally* Robert L. Hirsch, The Inevitable Peaking of World Oil Production, Oct. 2005, http://www.acus.org/docs/051007-Hirsch_World_Oil_Production.pdf.

Increasing strains are being placed on our bandwidth reserves. "Hogs" such as young people and cord-cutters are placing an unbearable strain on our bandwidth supplies, and "over-the-top" service providers like Netflix, Skype, Amazon, and Google consume copious amounts of bandwidth free of charge, without providing any valuable services in return.

"Once bandwidth is gone, it's gone."

In short, our tubes are being clogged with bits. While that may not seem like a major problem now, the long-term is bleak. We will look back fondly on the day our tubes were clogged. Once bandwidth is gone, it's gone. Used up bits are gone forever. They don't come back and can't be replaced. As a result important marketing messages, e-cards, and Facebook updates will be crowded out of the ever-shrinking supply of usable bits.

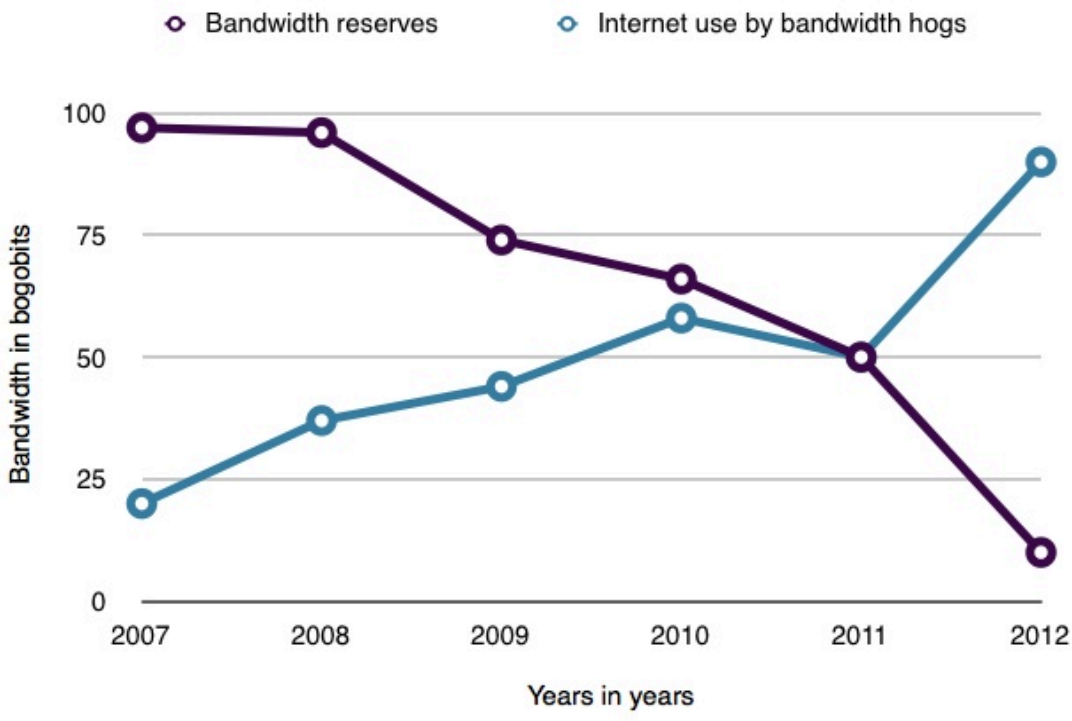

Fig. 1: An unsustainable bandwidth pattern.

Mitigation: Bandwidth Preservation.

An analyst from the hardcore band "Fouled Up" recently noted that Australia is suffering from a severe bandwidth shortage. He writes,

> Hey wally's [sic], sorry for the lack of up dates lately, we're in Australia and the internet here costs $15 an hour (I am not kidding) - it's like it just got invented here or they are all holding on to bandwith [sic] for when it becomes as valuable as crude or something. Either that or they all fell for the rumours about peak-internet that were going around a few months ago.[2]

Indeed, Australia's plans for a nationwide fiber network have been too little, too late. That nation has collapsed into chaos as rival gangs battle each other for control of scarce remaining bandwidth ("bandwizz" in the local dialect). While recent reports indicate that a "Bartertown" has arisen to create a form of bandwidth out of scrap copper, it is unlikely that these efforts will lead to the return of "Tomorrow-morrow Land."

But America still has time—and leadership from our dominant ISPs gives reason for hope. Forward-thinking companies like AT&T have found ways to promote bandwidth efficiency. With their innovative "caps," AT&T promises to extend its bandwidth reserves until we move towards alternative forms of communication that do not rely on non-renewable resources like bandwidth and capital expenditure. They are following in the footsteps of Comcast, who have already taken action against bandwidth "pirates" like BitTorrent users and Level 3 communications. There are other steps that can be taken to preserve our dwindling bandwidth resources:

- **More efficient file formats.**

Many multimedia formats are bloated and inefficient. For example, an MP3 file of Beethoven's 5th Symphony can approach 100 megabytes. By contrast, a MIDI file of the same exact music is only a few kilobytes. Similarly, ASCII art can replace most images online, and stick figure cartoons are an acceptable substitute for online video.

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[2] Looking for Gold, http://lookingforgold.blogspot.com/2011/03/heyo.html.

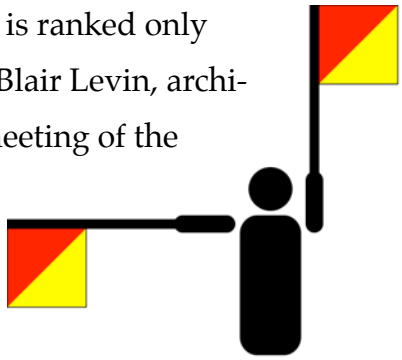
- **Low-flow devices.**

Bandwidth-efficient computers, smartphones, and e-toilets can reduce the amount of bandwidth needed for a communication, while only requiring one DNS cache flushing.

Going Forward: Renewable communications technologies.

- **Semaphore**.

Webster's Dictionary defines semaphore as "an apparatus for visual signaling (as by the position of one or more movable arms)." True—but the ability to send semaphore messages depends on the availability of flags and a clear line of sight, in addition to arms. Unfortunately, according to a recent OECD study the United States is ranked only 15th among industrialized nations in semaphore flag deployment. Blair Levin, architect of the FCC's National Semaphore Plan, suggested at a recent meeting of the NSIA that football referees and unimportant countries could be incentivized to give up their flags and help solve the looming "flag crunch."



- **Carrier pigeons.**

The standard for IP Datagrams on Avian Carriers has been in development for more than twenty-one years,[3] and is now robust and ready for widespread deployment. In a bandwidth-scarce era, carrier pigeons and other avian packet carriers have a particular advantage: they can fly right over congested information superhighways, providing reliable communications, nonfatal diseases, and adorable cooing sounds at low cost.

[3] *See* IETF Network Working Group RFC 1149, April 1 1991, http://www.ietf.org/rfc/rfc1149.txt.

•**Smoke signals**.

While best known as the title of an album by seminal hardcore band MDC, smoke signals are also a viable means of long-distance visual communication. Although ineffective in high-fog localities and subject to latency issues, smoke signaling is an effective way to roll out modern communications to rural communities.

•**Snail Mail.**

Thousands of years ago, gentleman and ladies would exchange "letters": words inscribed onto pieces of paper or parchment with an ink-pen, graphite marking stick, or an early sort of keyboard called a "type-writer." After stamping on them, these letter-writers would hand them off to a unionized government employee called the mailm'n to be delivered to its recipient, and neither snow nor rain nor heat nor gloom of night would stay this courier from the swift completion of their appointed rounds. Famous writers of letters include Abelard and Heloise (pictured), Ted Nancy, and the Unabomber. Aspiring belletrists, take note of Lord Chesterfield's dictum: "Politeness is as much concerned in answering letters within a reasonable time, as it is in returning a bow, immediately."

•**Sneakernet**.

It is possible to transfer large amounts of computer data and other cumbersomely large or heavy files by copying them to optical disks, USB flash drives, or portable hard disks. You then walk them down the hall to your colleagues: Thus, sneakernet. The sneakernet can be expanded by piggybacking on the US Mail or highway system. Top-flight hackers are hard at work expanding the capacity of the sneakernet. A Google Code project called "Sneakernet: A network architecture and

reference software implementation for free, low-cost Internet access," has broad ambition:

> Previous sneakernets have been simple point-to-point connections. Our sneakernet design uses a routing protocol that allows many-to-one connections between many end users and a single Internet access point. It allows messages to travel along the shortest possible transmission path through a cluster of interconnected couriers who overlap, and relay messages as they follow irregular and unpredictable paths. Software handles our routing protocol automatically so that users and couriers do not have to do any special route planning, they simply walk around normally and they 'gossip' when they meet. The messages flowing over the sneakernet are encrypted, and couriers and eavesdroppers can't read them. A data relay server accesses email and web pages from the Internet and then dispatches them through the sneakernet to the specific end users who have requested them, and sends email for them by proxy.[4]

Bandwidth Depletion Allowance.

A smart policy that would encourage new bandwidth exploration would be a "bandwidth depletion allowance." If bandwidth providers could deduct a reasonable percentage of the revenue from their residential service from their overall tax bill, they would be incentivized to stretch bandwidth further while simultaneously exploring alternative communication supplies. Quite simply, a bandwidth producer should figure percentage deple-

> *Never underestimate the bandwidth of a station wagon full of tapes hurtling down the highway.*
> *Andrew S. Tanenbaum*

[4] Sneakernet, http://code.google.com/p/sneakernet.

tion using a rate of 15% of the gross income from the property based on the average daily production of domestic crude bandwidth or domestic natural bandwidth up to its depletable bandwidth quantity.[5] Viola!

Conclusion.

Over the past century, world economic development has been fundamentally shaped by the availability of abundant, low-cost bandwidth. Previous communications transitions (speaking to writing, friendship to social networking, etc.) were gradual and evolutionary; bandwidth peaking will be abrupt and revolutionary.

The world has never faced a problem like this. Without massive mitigation at least a decade before the fact, the problem will be pervasive and long lasting. A number of technologies are currently available for immediate implementation once there is the requisite determination to act. Governments worldwide will have to take the initiative on a timely basis, and it may already be too late to avoid considerable discomfort or worse. Countries that dawdle will suffer from lost opportunities, because in every crisis, there are always opportunities for those that act decisively.

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[5] *See* IRS Publication 535,
http://www.irs.gov/publications/p535/ch09.html#en_US_2010_publink1000209050.

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