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Point of Disconnect
Internet Traffic and the U.S. Communications Infrastructure

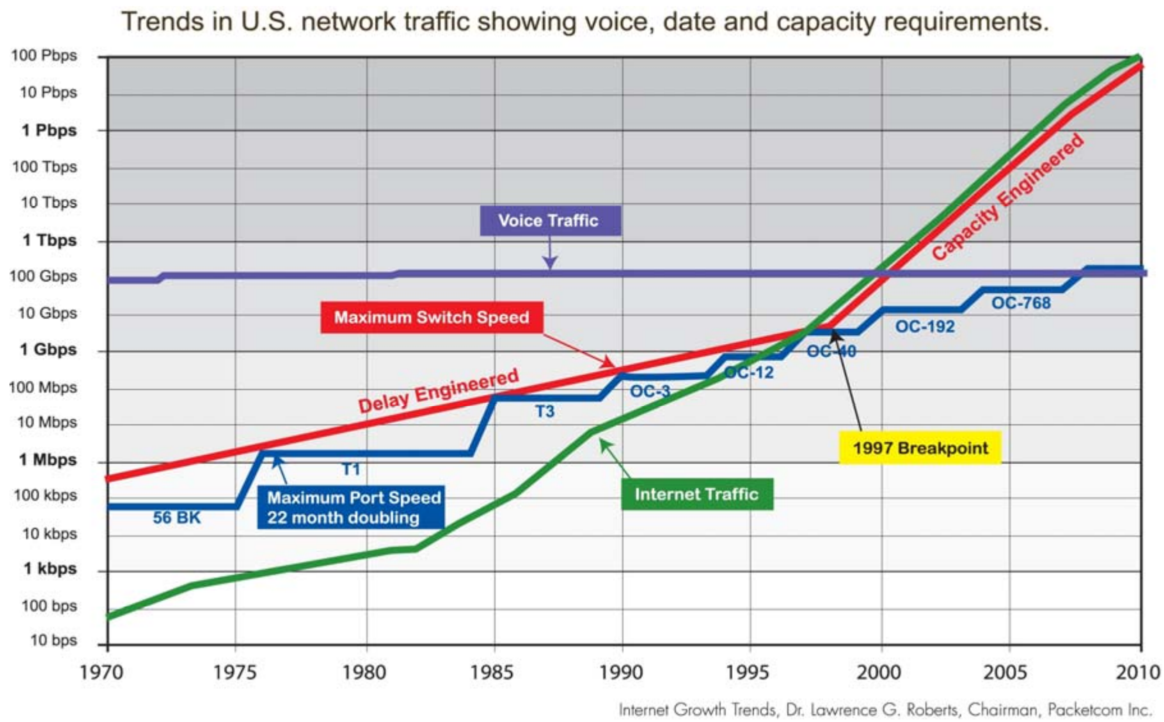
MICHAEL KLEEMAN
University of California, San Diego

We've Reached a Point of Disconnect

The public communications infrastructure in the United States is largely invisible to all but a few engineers and operations personnel. Were it visible as a road system, it would appear to be excellent in some places, but showing wear with potholes in others — heavily congested at many times and locations, and in need of massive investment and redesign to support new vehicle types. It is as if most of the drivers in the country rushed out and traded in their cars for massive 20-wheeled trucks, blocking and slowing traffic everywhere they went.

We have reached a point of disconnect between the traditional voice, Internet and broadcast video network architectures and the needs of today's customers. This disconnect is driven largely by emerging multimedia and multimodal Internet-based traffic and our infrastructures and their underlying economics are struggling to catch up.

There is, or should be, little debate about the importance to all sectors of the economy of our communications infrastructure keeping pace. Accordingly, seeking a better understanding — and even a rough consensus — about the sources and nature of this disconnect is important in identifying solutions.



U.S. Internet traffic became the principal driver of new network capacity in 1997 and exceeded voice traffic in 1999. Significantly the demand for voice traffic is much slower than Internet traffic, which is driven by multimedia and video traffic.

We're Using the Internet Differently

The Internet was initially designed to help transfer files from one computer to another and for simple messaging. People used little bandwidth at home because it was largely unavailable. People used a little more at work. Delay was acceptable because one or two seconds of jitter, delay, or latency has virtually no impact on how a consumer experiences an e-mail or file transfer. And, the infrastructure we have — and the economic arrangements underlying that infrastructure — were more than capable of handling this sort of demand.

Then the demand started growing. It is easy to see why. One example: the most popular YouTube video download as of July 2007 was "Evolution of Dance," a six-minute video added in 2006, which had over 52 million downloads. This one video generated traffic roughly equivalent to a month of data network traffic in 2000.[1] YouTube currently serves more than 100 million videos per day and thousands are added each hour to the online library.

- ***The number of new videos uploaded daily on YouTube.com jumped from 20,000 in the beginning of 2006 to 65,000 in the beginning of 2007.***
- ***iTunes usage grew 47.5% in 2006 alone.***
- ***9.2 million Americans have downloaded a podcast; 5.6 million downloaded video.***
- ***Video requires at least ten times the bandwidth of voice.***

But "more traffic" only tells part of the story. There have also been changes in the types of traffic and the quality of service (QoS) that this traffic requires, and where the traffic is originating and going to — each contributing to the disconnect.

***Users want to do more with their connection independent of location*.** In under ten years, we went from e-mail and simple services to full-blown high quality video, music sharing, real time chat and voice and video conferencing, often all at the same time both at home and on the road. And as users became more sophisticated with their computers and cameras do it yourself (DIY) media emerged, which is what has made it possible for 52 million people to download "Evolution of Dance" on places like YouTube.

***Big files move from computer-to-computer instead of originating on central servers*.** The technology commonly used for audio and video file transfers (applications like Limewire and BitTorrent, for example) that now make up the largest volume of traffic on the Internet breaks up large files and stores parts of them on participating users' computers. Then it uses these computers to deliver the file to the next user. It would be as if truckers started using surface streets instead of the highway system, stressing parts of the network not designed to carry such traffic.

***Latency, jitters, and low quality-of-service became unacceptable*.** The Internet has gone from a complement to everyday activities to a principal platform for business and personal activities. In the event of a major network outage, people have trouble getting their news and chats, but more

[1]YouTube uses compression technology to reduce the network traffic it generates (and pays for) to a peak of 300,000 bits/second. YouTube videos are uploaded by users to the company site.

importantly, doctors cannot view medical charts and x-rays remotely and increasingly many businesses effectively shut down their sales and marketing activities.

What This Means for the Network

These changes in user demand have resulted in corresponding changes in network requirements. Contrasting this customer-driven demand for service with voice provides a good comparison. Voice traffic was virtually all point-to-point and utilized a dedicated network resource for its duration which no other users could access, and all calls used the same protocol (which was 64,000 bits/second without any compression to reduce the capacity required — about the speed of a basic dial-up connection).

Contrast this with the Internet. The Internet is a packet-based network, where multiple traffic streams share the connection, and if one user uses increased network capacity it can degrade the quality of the service for other users. In order to meet demand, the communications infrastructure must do each of the following:

Deliver more traffic. The speed needed to deliver traffic is increasing. Sending a video, even a small picture on YouTube, uses five-to-six times more capacity than a traditional voice call. Expanding that to high-quality full screen video, even with high compression ratios requires ten to 20 times as much capacity.

Deliver traffic quicker — upstream and downstream. Now, traffic goes upstream and downstream (e.g., you used to download websites, now you also make VoIP calls) and is extremely time–sensitive — when you're using the Internet for voice a two-second delay is maddening. The traffic is also more likely to be running at higher speeds for longer periods as we listen to radio or watch TV over our connection or act as a remote music server for Limewire.

Deliver traffic anytime and anywhere. Planning a network where the high-speed content servers are in known locations (and connected to the backbone network via high quality, premium priced connections) was a relatively straightforward process. Now, any user (connected to a low-cost residential broadband connection) might be sending out video streams, using mobile devices, and running applications that will keep their network connection running at a high-load for hours, vastly complicating the design and investment decisions.

Deliver traffic around "moving chokepoint." For example, as the networks connecting businesses and homes increase in speed and quality, this will put greater stress on the main backbone networks. When mobile networks are utilized more heavily, then these will begin to slow and the wireless users' experience may suffer.

Manage interdependencies. Complicating all of this is the reality of the Internet. That it is not one network but a "network of networks" where traffic often terminates on a different network, run by a different operator, than where it began. While one carrier might maintain the highest quality service on their network, the peered network where the traffic needs to terminate or the peering point might be congested.

What Does This Mean?

To return to the highway analogy, it is as if a new major shopping center is built next to a residential neighborhood one day and then two months later ten others are built 20 miles away in different areas, and then the entire neighborhood changes from cars to massive 20-wheeled trucks. In a case like that, where do you invest and how do you prevent your investments from becoming stranded?

These dynamics lead to a situation where the current and projected requirements for communications services have outgrown the architecture, traffic management and economic requirements of today's networks.

Network operators now need to undertake integrated planning, incorporating all expected applications as well as wireless and wired networks into their forecasts. And they need to plan for much higher speeds in all areas of the network — a challenge when most residential network connections were designed for voice-only and require electronic equipment[2] at each end to carry some degree of high-speed data.[3] In planning the network, consideration needs to be made for ***residential demand*** for services that exceed that of a ***major business location*** less than five years ago. The network of the future will need to be flexible, expandable and support high traffic loads at multiple locations to ensure that the high activity of one user does not degrade the service to others.[4] This means moving away from copper as the primary end-to-end residential access medium to an increase in deeper fiber optic penetration in the network — (fiber optic cables can carry millions times the traffic over longer distances than copper wires and can be used to bring very high-speed services closer to the customer where copper pair, coax, fiber or wireless technologies can provide the last mile) and increased use of symmetrical higher speed services that can guarantee QoS for voice, video and other demanding applications.

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[2] Typically ADSL equipment, providing asymmetrical digital subscriber line services, is optimized to use copper cable to provide as much speed as is economical, and provides more 'downstream' to the residence than 'upstream' from the residence since this asymmetrical traffic was typical of the customer demand ten years ago.

[3] The definition of high speed has varied over time. When most data traffic was text 10-20 thousand bits per second, that was considered high speed. Today, .5 to 1 million bits per second, 100 times faster, is the minimum that is considered high speed. In some countries, it is 10-20 times faster than that. As new applications emerge that consume network capacity, the definition of high speed will change, shifting upwards.

[4] The basis for this paper is a longer study I am currently completing for AT&T on just these issues.

What Happens If Communications Infrastructure Doesn't Keep Up?

It is a complex undertaking, expensive, and carries with it technical and commercial risks. But, clearly, the risks of not managing these issues are greater. Technologically, the price of not keeping up is slower access to websites and greater risk of dropped packets. The typical user will not know what the problem is, only that their video will not download quickly or their phone calls sound noisy or drop. That, in turn, will affect consumer behavior, which impacts businesses. Obviously, the success of YouTube would be unlikely in a world where dial-up was the norm. Unless we ensure an adequate supply of quality bandwidth at reasonable prices, many current and future business models will be stranded, which will have serious implications for economic growth and national competitiveness in the Internet sector.

Solutions

All these complications in network design and construction will require the development and adoption of new techniques and technologies. There are three core strategies available to help us overcome the core disconnect between infrastructure and demand.

Build extra capacity. The simplest approach is to build more capacity, which is happening. Of course, building extra capacity is expensive, time consuming and may often not meet the full set of needs of the customers as demand continues to increase and bottlenecks move. Additionally, traffic often needs to transit across multiple networks operated by multiple providers and more capacity in one place does not guarantee sufficient capacity end-to-end.

Compression technology. Traffic, especially video, can be compressed to reduce the network demands created by an increasing video usage.[5]

Triage and prioritization. Core routers, the switches of the Internet, can become increasingly sophisticated. They can speed time-sensitive traffic through the Internet more quickly than, for instance, e-mails which can be delivered a few seconds later without consumers noticing or caring. And there are a myriad of new technologies emerging to both meet this need for a quality network and to challenge it by adding new functionality and applications onto the network.

Bringing these solutions online requires a massive mobilization of resources, most of which can and will come only from the private sector. Each of these solutions will require investments in new

[5] Video can consume a large amount of network capacity. Uncompressed regular (non-HD) broadcast TV requires more than 100 million bits/second (megabits per second), but can be compressed down to less than 1% of that demand and still be presented with acceptable quality on a typical TV. However the uncompressed version is still much better, as DVD TV viewers know when they compare their picture with that from a satellite or digital cable provider.

capacity and technology — and not just in the new hardware or software. Each new system will need to be integrated in with the existing gear, monitored and managed. Equipment, cables and software all need to be installed and maintained. And if there is one thing we have learned from the Internet it is that there is no end game; that the process of invention, adaptation and evolution will continue.

It will impact not only the network operators but also the firms that supply them. It will impact customers — business and residential — and the firms that supply them, from consumer entertainment electronics to networking hardware and software to telephones, videophones, computers and monitors. It will drive innovation and create work for the network operators to continue to meet the demands of their customers.