CORNELL DATA NETWORK FUTURES

Background Information:

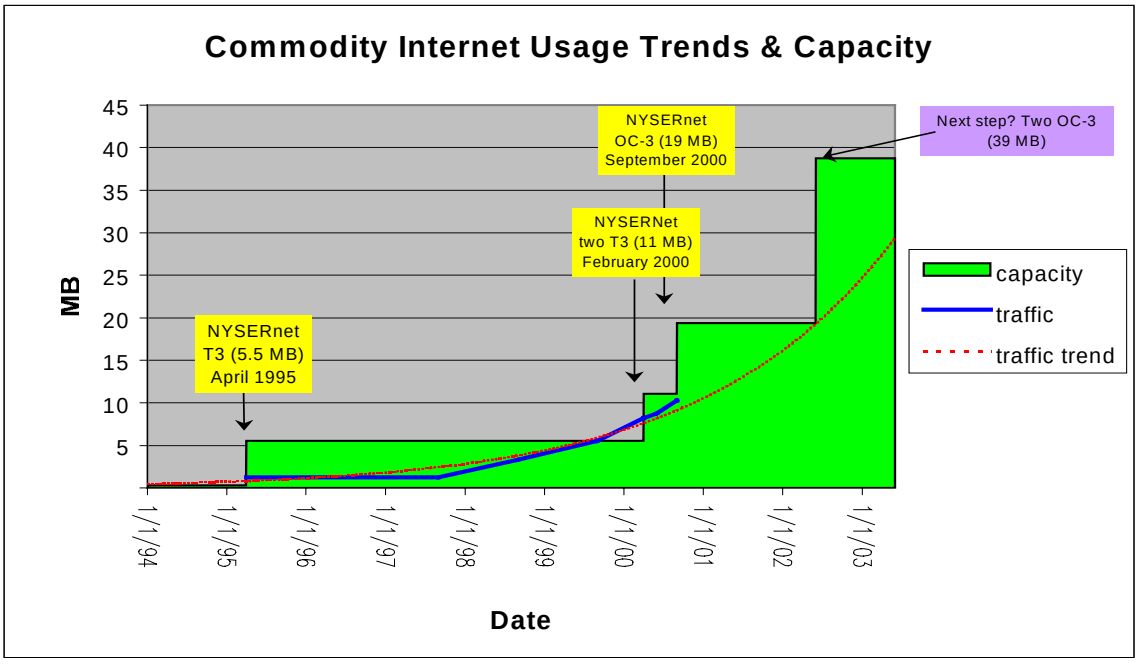
The current campus network services close to 110 buildings and interconnects over 700 local area networks supporting in excess of 23,000 end user work stations and desktop computers. Access to commodity Internet service is provided by an OC-3 link. In addition, a second OC-3 connection provides access to the NYSERNet 2000/ Internet II research infrastructure.

Deployment of a ubiquitous ethernet data network infrastructure began in the mid 1980's with the installation of Proteon routers and edge hardware[1] manufactured by David Systems.

Through the end of 1996, bandwidth growth was primarily driven by new connection demands. Now, increasingly, the need for additional bandwidth is tied to the changing nature of the information that is being exchanged. Frequent access to World Wide Web resources, large electronic mail files, larger file size transfers within fixed time windows, digital library services, distributed learning requirements, and high quality audio, telephony and video services: all these uses and more now drive Cornell's growing demand for aggregate and peak bandwidth provision and assured quality of service. [2]

In response to growing demand for bandwidth, Cornell Information Technologies (CIT) reengineered the campus backbone in 1999. As a result of this upgrade, backbone infrastructure is now much better positioned to meet projected demand within the life cycle of the hardware.[3] In addition, Cornell has acquired additional bandwidth from Internet Service Providers over time to meet patron demands.

(Fig 1)



[1] "Edge hardware" is a term commonly used to describe equipment placed in building phone closets to provide individual connections to the network service. The Cornell campus network is comprised of "core" backbone routers and "edge" phone closet ethernet repeaters.

[2] GartnerGroup projects peak user traffic demand increase by a factor of 100 between 1999 / 2001. R-08-9117

[3] Current campus backbone use is ~3% of capacity.

Nevertheless, providing ample core backbone capacity to a wide array of Internet resources has not removed fundamental constraints imposed by the aging edge equipment and obsolete twisted pair "Category 3" media plant.

Three scenarios for data networking investment at Cornell and their service level implications:

Investment Scenario #1: No new investment.

Context:

Over two thirds of the installed edge equipment is antiquated shared 10Mb/sec ethernet hardware.[4,5] More than half of the installed edge equipment is over five years old. Recent data collected by CIT indicates that the demand for bandwidth exceeds the capacity of over half of the installed base of shared networks during peak periods of usage.

Service Ramifications of Investment in Scenario #1:

BENEFITS*:*

- None.

LIMITATIONS:

- Without any additional investments, users on 10Mb/sec shared connections will see increasing number of service failures due to the aging equipment. In fact, the vast majority of the currently installed edge equipment is long past the industry standard replacement cycle for such equipment.[6]
- Service quality will diminish exponentially as a function of increasing demand. Multiple classes of commodity desktop workstations now have the ability to saturate a shared 10Mb/sec network. Projected growth in aggregate network loads over time will exacerbate this trend.
- Insufficient bandwidth —along with no predictable or assured quality of service—effectively eliminates the network's ability to support new voice or video services. (see Ethernet Data Rate/Service Table on page 4)
- Highly insecure default broadcast of data packets to all participants on such a shared resource.
- Limited data acquisition tools to fine tune and adequately predict future use demands.
- Over half of the campus wire plant phone closets are insecure, often allowing public access to equipment.

[4] Current networking engines provide "switched" or dedicated non shared services at rates up to 1,000 Mb./Sec. On a "shared" ethernet multiple users share a single 10Mb/Sec connection. In a switched environment each user has a dedicated ethernet link – non-shared.
[5] CIT has limited resources for short-term "remediation" to replace critical but highly congested shared networks.
[6] Depending on information source, recommended network replacement cycles range from 12 months to 3 years.

Conclusions and summary statement for investment scenario #1

Failure to invest additional funds will not only limit the network's ability to deliver or receive new services such as voice over IP and packet video but will relegate users to *decreasing* service levels on an inherently insecure technology provided over an insecure wire plant.

Investment Scenario #2: Replacement of edge hardware. No new investment in wire plant.

Context:

Replacement of shared edge equipment with commodity 10/100Mb/sec, Level 3-aware[7] switching gear would eliminate the vast majority of bandwidth limitations, and, at the same time, create an infrastructure capable of prioritizing bandwidth based on service need. The cost per port is extremely favorable when compared to the original investment per port for David Systems hardware, the port price dropping from well over $100/port to less than $100/port while enabling a 100+ increase in capacity delivered to connected user.

While the replacement hardware would support switched 10Mb/sec or switched 100Mb/sec rates to the desktop, the installed Category 3 wire plant will only support 10Mb/sec data rates. As there is no significant price advantage to purchase 10Mb/sec only switched hubs, ports will be configured to provide 10Mb/sec only services.[8]

Service Ramifications of Investment Scenario #2:

BENEFITS:

- New hardware will replace aging edge infrastructure equipment, eliminating projected increases in equipment failures and associated downtime.

- Installation of a switched 10/100Mb/sec edge hardware limited to a switched 10Mb/sec rate is predicted to meet 99% of network service demands within a CIT-targeted three year equipment replacement cycle of the installed hardware. Where new twisted pair "Category 5" wire runs allow, potential 100Mb/sec rates will provide utility well beyond the average network equipment life span standards.[9]

- Switched 10Mb/sec rates are of sufficient bandwidth to support high quality audio and good quality video services.

- Level 3 capabilities of switching gear will allow the development of integrated quality of service (QoS) mechanisms to prioritize data transfer on campus. QoS infrastructure improves the look, sound and feel for latency and jitter-sensitive applications such as audio and video. Other critical data transfers for security or e-business applications would also benefit.

[7] "Level 3 aware" implies technology capable of allocating bandwidth priorities as a function of service level flags within IP packets.
[8] 100Mb/sec rates over Category 3 wire will cause unpredictable results and network service errors.
[9] It is difficult to predict campus bandwidth requirements over extended periods of time. 100Mb/sec services will allow multiple HDTV streams. Unless there is an unforeseen "killer" application, 100Mb/sec rates as a base standard for Cornell may be sufficient well into the future.

Ethernet Data Rate/Service Table

Shared 10	Switched 10 Level 3 Aware	Switched 100 Level 3 Aware
General Internet Use →	General Internet Use →	General Internet Use →
File/Server Transfers MB →	File/Server Transfers GB →	File/Server Transfers TB →
Limited Audio	Audio / QoS	Audio / QoS
Limited Video	Video / MPEG 2, 4 / QoS	Video / MPEG 2, 4 / QoS
	Teleconferencing / QoS	Teleconferencing / QoS
		Video HDTV / QoS

- 100Mb/Sec service rates implied for locations with Category 5 or better wire installed.
- Limited default broadcast of data improves security.
- Improved data collection tools for performance and service growth projections.

LIMITATIONS:

- Installed wire plant remains insecure and limits service rates to switched 10Mb/sec.

Conclusions and summary statement for investment scenario #2

Replacement of edge equipment whether driven by increasing demand for bandwidth or the requirement to replace the aging infrastructure will create a robust and moderately enhanced campus-wide data service for a minimal capital investment.

Investment Scenario #3: Replacement of edge hardware. Replacement of wire plant.

Context:

Nearly a fifth of the current campus wire plant fails to meet the minimum specifications for Category 3 wire installations. Over half of the "phone closet" locations are shared with non-CIT equipment and custodial supplies, etc. While to date creative wiring and equipment placement has allowed CIT to work around the distance limitations for installed Ethernet hardware. And, while misplaced broom handles disrupting service from a shared custodial / data networking closet are annoying – the security ramifications should not be underestimated.

The integrity of Cornell's intellectual and administrative information, from genomics research to student records is at risk. *The monetary value and liability for the information exchanged at Cornell during any given day is enormous.* Although it is true that encryption offers a means to navigate an insecure infrastructure, it is not widely leveraged by our patron base. And there is a common misunderstanding that information exchanged between locations on the Cornell campus is reasonably secure. The gravity of this problem was recently highlighted in the Cornell Audit of CIT's services and remains a concern of the

Office of Information Technologies (OIT).[10] However, quantifying the value of a comprehensive campus rewiring project at this time is difficult as it is dependent on timing and the "strategic" potential seen, vs. the alternative costs and limited data-rate ramifications of simply securing the existing phone closets.[11]

Service Ramifications of Investment Scenario #3:

BENEFITS:

- All benefits outlined in Scenario #2.
- Secure wire plant.
- Enables switched 100Mb/sec and future higher data rate services. Large utilization of individual 100Mb/sec Ethernet connections *is not* expected within 3 years. Large utilization and demand for 100Mb/sec links to support server and backup engines within departments / colleges *is* projected in the near term. 100Mb/sec will be required for point to point HDTV video conferencing and high bandwidth visualization applications.
- Strategically positions Cornell to quickly respond to unforeseen application demanding very high bandwidth delivery.
- Wire plant utility is estimated to be 15 years.

LIMITATIONS:

- Cost. (Total wire plant replacement will increases data service cost by ~ 10%)
- Limited initial utility for the vast majority of patrons.

Conclusions and summary statement for investment scenario #3

Replacement of edge equipment and twisted pair wire plant would be a strategic investment for Cornell University at this time, creating an enhanced network infrastructure that would be among the best in the nation. The installed network will provide a secure, manageable, and non-restrictive campus resource capable of supporting the most aggressive new uses of information technology as envisioned by Cornell faculty, students, and administration.

[10] Audits office report # 00020 Network infrastructure and operations audit report.
[11] A formal cost benefit study of Category 5 wire plant investment timing is planned.