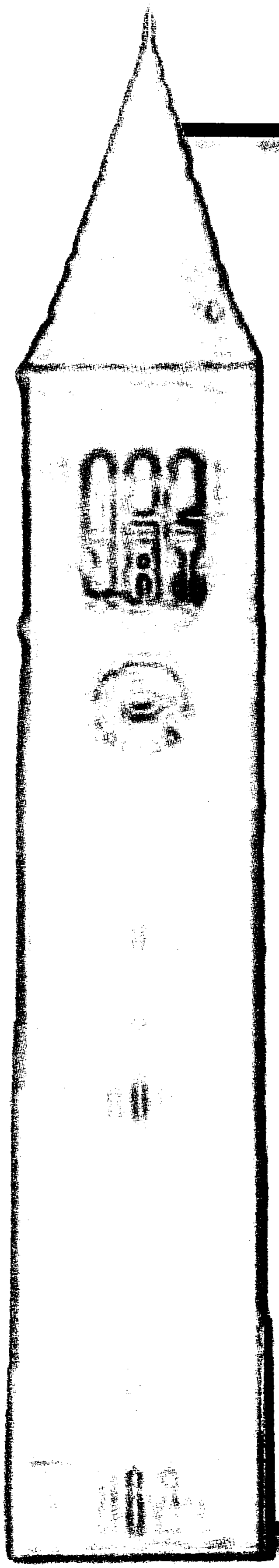


Network Cost Recovery

Task Force Report

November 2001

CORNELL

Contents

This report provides detail and recommendations of the Network Cost Recovery Task Force, including:

Executive Summary

The Task Force was formed to evaluate how best to charge users of Cornell's data network resources. Since the user population's consumption patterns vary greatly, there is no simple solution.

After studying various options, the Task Force developed a rate structure recommendation for academic and administrative users with four components:

- Network Access Fee: There are two flavors of Network Access Fees.

    - Network Port Access Fee: for access to the Cornell backbone and the Internet. The fee covers access for a single user.

    or

    - Single Port Gateway Fee: for access to the Cornell backbone and the Internet for schools and departments that provide their own Local Area Network service. A port access fee, higher than the single user fee, covers access for many users.

- Backbone/Wireless Service "Tax": Recovers the cost of the Cornell's backbone network since a portion of the traffic remains within the Cornell network. This headcount-based tax is intended to cover part of the costs of maintaining and improving the Cornell network. It is recovered by assessing a tax to departments and units based upon the number of employees and students.

- Public Port Access "Tax": Public network ports would have the cost of their use recovered through a student headcount-based tax assessed to the departments or colleges to whom the students using these public ports are accountable.

- Tiered Wide Area Network Consumption Fee: Based on actual incoming and outgoing usage that crosses the border between Cornell network and the larger Internet. There would be a tiered-fee structure to support those users (or groups of users behind a single port gateway) who generate a much higher volume of traffic. The needs of more than half of the users would be met by the terms of the lowest tier.

Taken together, these four components cover all of the academic and administrative network infrastructure cost.

The Task Force recognizes that the ResNet recovery mechanism may require modifications to the recommended structure. The operational strategy to implement the spirit of this report may be different for ResNet in comparison with general campus network services.

Members

The Task Force and invited participants met seven times over three months and included the following Cornell University Members:

Rohit Ahuja	Director, Finance, Budget, and Planning, Office of Information Technologies (Task Force Chairman)
Michael D. Anthony	Manager, Indirect Cost (Representing Joanne M. DeStefano, Acting Vice President, Financial Affairs & University Controller), Division of Financial Affairs
Richard J. Duell	Associate Director, University Budget Office
Edna R. Dugan	Assistant Vice President, Student & Academic Services
Marge H. Ferguson	Associate Dean for Business Administration, Hotel Administration Accounting Services
Ray G. Helmke	Director, Computing Facility, Laboratory of Nuclear Studies
Charles W. Kahle	Customer Services Director, Cornell Information Technologies
Dean B. Krafft	Computing Facilities Director, Computer Science Department
Joe M. Lalley III	Business Operation Director, Facilities Services
Kellie A. Page	Business Services Director, Campus Life
Jason Rhoades	Communications Products Director, Cornell Information Technologies
Robert J. Swieringa	Dean, Johnson Graduate School of Management
R. David Vernon	Director, Information Technologies Architecture, Office of Information Technologies

Background

Polley McClure, Vice President, Information Technologies, formed a Network Cost Recovery Task Force to evaluate specific mechanisms by which Cornell recovers the costs of providing data network services on campus. Cornell Information Technologies (CIT) incurs a cost of providing network services to the Cornell user community, and the general guidance from central administration has been for CIT to recover all enterprise network costs. The Cornell user community includes employees, students, and visiting scholars. The current rate structure focuses on data ports and assumes that there is one user for each network connection and that each port uses the same amount of CIT "services." However, this is not the case. Many subscribers have increased the number of users and devices per data port via "hublets" or wireless access points and a few users consume a vast majority of available Wide Area Network (WAN) resources. This complicates cost recovery, undermines notions of fairness, and results in network fragmentation. The Task Force was asked to recommend a rate structure that is fair to all and promotes scholarship.

Mission

The mission of the Network Cost Recovery Task Force is to recommend a network cost recovery process at Cornell University that will support Cornell's mission as "the best research university in the country for undergraduate students" and as an institution "where any person can find instruction in any study."

Guiding Principles

The Task Force identified the following principles as the base conditions to judge the value of any given network cost recovery process:

- Cost should be assigned to the unit incurring the cost.
- Rate structure should support a unified campus network architecture.
- Users should have an opportunity to select from multiple levels of service:
  - Universal and affordable access to basic services; and
  - Premium levels of services to allow world-class research and education.
- Network that is competitive in features, performance, and cost with
  - Our peer institutions; and
  - Commercial service providers.

Recommendations

It was the consensus of the Task Force that the guiding principles could be best met by a hybrid network cost recovery process segmented into four components.

These components are:

1. Network Access Fee: either
   a. Fixed Network Port "Access" Fee
      or
   b. Single Port Gateway (SPG) Fee
2. Backbone / Wireless Service Headcount "Tax"
3. Public Port Headcount "Tax"
4. Tiered Wide Area Network (WAN) Consumption Fee

<u>1a. Fixed Network Port "Access" Fee</u>

To assure the best network architecture, the fees which departments pay for edge Ethernet port access should not encourage the ad hoc use of multi-port repeaters (hublets). The Task Force recommends that the network port fee reflect only the barebones edge costs. In addition, to assure fair use of backbone resources, only one user will be allowed access to any one port contracted from CIT. For example, a single contracted port cannot be used to support more than one user, but can be used to support more than one device. If more than one user wants access to a single port, the contracting party would need to purchase an "SPG" class port, outlined next (component #1b).

<u>1b. Single Port Gateway (SPG) "Access" Fee</u>

Some colleges or departments at Cornell elect to provide their own Local Area Network Service. These colleges or departments require Cornell's backbone and WAN services only. For these patrons there would be a monthly SPG access port fee plus a tiered rate-based WAN fee for the aggregated use of WAN resources by represented users. SPG port cost should only reflect cost associated with supporting SPG ports. The tiered rate-based fees for SPG ports and single user ports could be the same, although the lowest tier appropriate for an SPG port would be at a significantly higher volume of traffic.

As with fixed network port charges, all SPG users' colleges or departments will be assessed backbone (component #2) and public port (component #3) taxes.

<u>2. Backbone / Wireless Service Headcount "Tax"</u>

Backbone:

Currently 40 percent of the backbone is consumed by client access to the Internet; the remaining 60 percent is consumed by local client/server traffic. As there is currently no way to associate the cost of Cornell-to-Cornell backbone use to individual users, and as there is little correlation between total port count and backbone costs, a "headcount tax" for allocating local use of the backbone was seen as the best solution. This tax would be billed to each school or department based on the percentage of total "heads" (faculty, staff, and students) attributable to each department. The remaining 40 percent of backbone costs will be linked to WAN consumption fees outlined later (component #4).

Wireless:

The Backbone / Wireless tax should be computed to include all costs for the Red Rover wireless service. All users who have paid a fixed network port access fee or SPG access fee may use Red Rover services without additional fees. A Red Rover user who has no "wired" connection should be charged a port access fee. It is important to note that the CIT Red Rover wireless service is not intended for fixed-location use or for high-bandwidth server and client applications, but targeted to provide limited mobile network client access for the Cornell Community.

3. Public Port Headcount "Tax"

There are many public ports that provide services not easily associated with any one sponsoring college, academic department, or unit. The Task Force recommends that these facilities costs be recovered through a student headcount tax. This process would be similar to the backbone / wireless tax but would only use the student headcount as the denominator and would only be billed to colleges or academic departments to whom these students are accountable.

The Task Force recommends that a committee with appropriate campus representation be created to assure proper identification of ports to be covered by this tax by reviewing and approving any public port classification requests.

4. Tiered Wide Area Network (WAN) Consumption Fee

Internet network access costs are high and consumption can vary greatly from user to user, and the Task Force concluded that it was important to provide users cost "feedback" for WAN resource consumption. In order to allow stable budgeting at the department or individual level, it was considered critical that users be allowed to purchase tiered service based on their expected level of need. In turn, CIT would track the WAN usage for each contract, and if consumption exceeded the contracted level, the patron, within a reasonable time, would be required to reduce their consumption or "upgrade" the existing service contract and pay any new applicable fees. Where technologically feasible, CIT may jointly develop an arrangement with the departments and units which would like to limit their consumption.

Inherent in the tiered service is the notion of a universally affordable base service contract that would address the needs of 50 to 80 percent of users.

Associated Conditions and Notes

The Task Force considered the following conditions.

Campus Rewire Costs:

The Task Force generally believes that any expense associated with the campus wire plant should not be reflected in network costs charged to colleges or departments. This belief is based on the following three observations:

- Some colleges or departments on campus have already capitalized upgraded wire from alternative funding sources and therefore any general network cost associated with the backbone or WAN rates would unfairly "double bill" them.
- Including wiring costs associated with selected building fixed network port fees would inflate port costs and encourage the proliferation of "hublets."
- It is difficult to predict applications that would require an enhanced physical infrastructure in the future. Hence the re-cabling of the campus buildings falls into the category of "future-proofing" or investing in future capability. Given this, many colleges or departments believe that they should be allowed to set their own cost priorities relative to any rewiring project.

If it is determined that the campus will move forward with a campus-wide rewiring project, the Task Force recommends that a new committee be formed to consider cost allocation options, i.e., the potential for the building wire to be recovered through a central source or incorporated back into the network rate.

Cost-to-Cost Causer Relative to ResNet Services:

It was the consensus of the Task Force that ResNet expenses should not be recovered through inflated general campus network cost recovery charges. CIT should continue to adjust ResNet rates to the point of market acceptance. The remaining deficit should be covered by the central administration and other mechanisms identified by EBG.

Implementation of Headcount Tax:

The Task Force acknowledged that some members are concerned about the implementation of headcount tax for employees who have no direct access to or need for network resources. The Task Force further noted that it is important to recognize that every employee indirectly consumes network resources through our administrative systems. A majority of Task Force members supported an equal headcount tax charge across all employee classes. The Task Force recommends that CIT make every effort to ensure that implementation of the headcount tax is fair and no one is counted twice.

Operational Complexity:

The Task Force recognizes that tiered rate billing will require additional operational overhead and associated costs. The Task Force also recognizes that the operational strategy to implement the spirit of this report may be different for ResNet than for general campus network services. Information about current costs and the recovery of those costs under this proposal can be found in Appendices B and C.

Sample Bills

The following hypothetical charges depict the above network cost recovery process. These are for illustrative purposes only. The actual charges will reflect the network cost and consumption at the time the network cost recovery process is implemented. However, it is important to recognize that the Task Force shaped its recommendations in the context of these and similar hypothetical charges.

Standard Network Service Bill

Sample number 1:

Account number: XXXXX Department: YYYYY	
Monthly port fee:	$ 7.50
Tier **one** WAN service agreement:	$ 5.50
Total monthly bill:	$ 13.00

Sample number 2:

Account number: XXXXX Department: YYYYY	
Monthly port fee:	$ 7.50
Tier **three** WAN service agreement:	$ 60.00
Total monthly bill:	$ 67.50

SPG Service Bill

Account number: XXXXX Department: YYYYY	
Monthly ISP port fee:	$ 45.00
Tier **eight** WAN service agreement:	$ 650.00
Total monthly bill:	$ 695.00

Public Port Tax Bill

Account number: XXXXX Department: YYYYY	
Total student headcount applicable:	250
Cost per head:	$ 1.90
Total monthly bill:	$ 475.00

Backbone Tax Bill

Account number: XXXXX Department: YYYYY	
Total headcount applicable:	300
Cost per head:	$ 4.35
Total monthly bill:	$ 1,305.00

Appendices

A. Scenarios Considered by the Task Force

B. Current Enterprise Network Costs

C. Proposed Academic/Administrative Cost Recovery

D. Network Billing Strategies at Cornell

E. Cornell Data Networking Future

Appendix A — Scenarios Considered by the Task Force

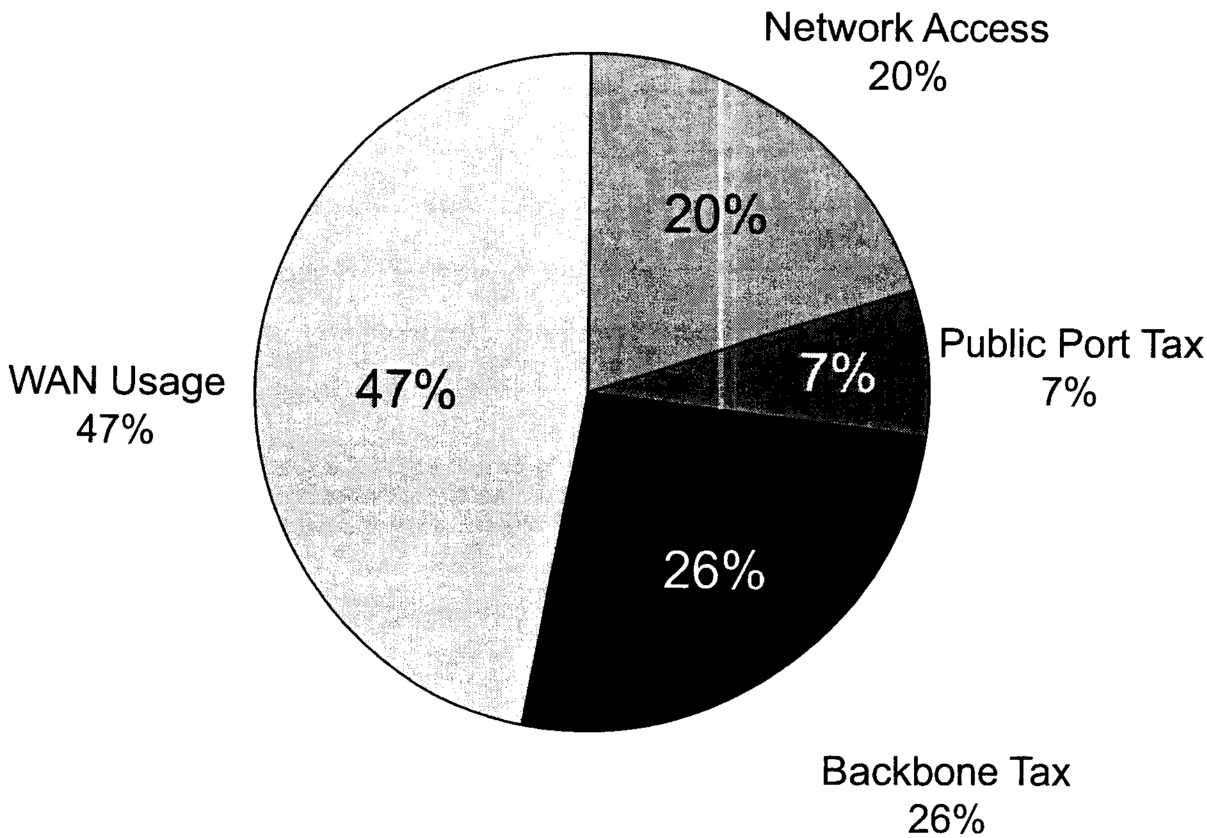
	Advantages	Disadvantages
Full recovery via **Fixed Network Port** Access Fee (Current process at Cornell)	• Operational simplicity • Continuity with current practices • Fixed port counts provided near term revenue and cost predictability	• Creates economic incentive to install multi-port repeaters (Hublets) and thereby fracture network • Erodes CIT revenue stream over time • No feedback to customer for excessive consumption • Obfuscates relation between consumption and needed resource investment over time. • Only partially documents and justifies expansion of CIT resources (e.g., purchase more Internet bandwidth)
Full recovery via **Headcount Tax** (Fixed monthly charge to departments based on number of faculty, staff, and students associated with the department)	• Operational simplicity • No economic incentive to disconnect ports and thereby fracture the network • Provides revenue and cost predictability	• No feedback to customer for excessive consumption • Obfuscates relation between consumption and needed resource investment over time. • Does not document and justify expansion of CIT resources
Full recovery via **Usage-based Billing** (Variable charge to departments that is based upon users' consumption)	• Feedback to customer for excessive consumption • No economic incentive to disconnect ports and thereby fracture the network • Fully documents higher fees based on use • Allows demand to justify expansion of CIT resources	• Unpredictable revenue stream • Operationally complex and expensive • Limited ability to reduce cost due to decline in consumption in the short term
Full recovery via a **Hybrid** of the above solutions	• Provides some revenue stability • Minimal economic incentive to disconnect ports and thereby fracture the network • Feedback to customer for excessive consumption • Mostly documents increased charges based on use • Allows demand to justify expansion of CIT resources	• More operationally complex than fixed network port fee or headcount tax based systems but less complex than a pure usage-based billing system.

Appendix B — Current Enterprise Network Cost ($ 1000)

Cost Category	FY02 Forecast
Wiring	$ 74
Edge	1,869
Backbone	2,471
Internet	1,007
Network Operations Center	634
Maintenance	1,631
Administrative & Billing	866
Total	$ 8,552

Note: these figures include ResNet costs (~ $2.6M), which are not depicted in the recovery chart Appendix C). The Task Force recognizes that the ResNet recovery mechanism may require modifications to the recommended structure to address ResNet-related items.

Appendix C — Proposed Academic/Administrative Cost Recovery



Note: This chart does not include ResNet costs.

Office of Information Technologies

IT Architecture Initiative

REV1.

NETWORK SERVICE BILLING STRATEGIES AT CORNELL

Introduction

As part of the IT Architecture Initiative, the Office of Information Technologies (OIT) is producing a series of papers outlining directions in information technology architecture. In the spirit of RFCs, the papers are intended to facilitate understanding of and open dialogue about information technology trends at Cornell, with the ultimate goal of improving the utilization and interoperability of information technology services throughout Cornell.

Synopsis

This document outlines the Cornell network design and related costs to provide context for an exploration of network cost recovery strategies. It includes:

- Network elements overview
- Network resource consumption relative to the elements outlined
- Client impact on network resources as a function of application type
- Cost modeling alternatives
- Closing thoughts and observations

Network Elements Overview

In order to explore and develop funding models for network services at Cornell and have them broadly supported by the patron base there must be a common understanding of the elements that drive the cost of network services. For the IP data network at Cornell there are many elements that contribute to the cost of the services. In addition, there is a great variety in the impact that client applications have on the network.

In order to model costs it is helpful to view the network as being comprised of three integrated network services, each with its own cost ramifications. These network services are:

- Local Area Network services (LAN)
- Campus Area Network services (CAN)

Appendix D — Network Service Billing Strategies at Cornell

• Wide Area Network services (WAN)

Local Area Network:

Though there is a fair amount of variation in how people define "LANs," for the purposes of this paper LAN services are defined as all client equipment interconnected by "switching" hardware. Switches are low price devices with limited "intelligence" that operate at very high speeds to interconnect devices within a single ethernet broadcast domain.[1] Though it is beyond the scope of this paper to go into great detail about network hardware, the nature of the network data traffic movement "switches" perform is fairly finite when compared to network "routers." Therefore switches are much less expensive to build per port and per aggregate network capacity provided. Switch cost is also driven down by their "commodity" nature. They are a product sold in massive volumes by multiple hardware vendors. Most building intraconnections of hardware at Cornell are supported by low cost, very high speed (up to 100 Mbs), "commodity" switch network hardware. Often people define switches as "level 2" devices and routers as "level 3" devices. These "levels" are references to the OSI model for network services at large.[2]

In brief review, LAN's are comprised of "level 2," low cost, high speed, switched interconnected clients. Patrons of network services can think of switched LAN's as "cheap," "dumb," and "FAST" when compared to the network cost associated with level 3 devices often utilized in CAN and WAN network provisioning.

Campus Area Network

The Campus Area Network at Cornell is comprised of level 3 "router" hardware interconnected by very high speed data links that in turn interconnect campus switched LAN's. The cost per "port" on routers is orders of magnitude more expensive than the cost per port on network switched devices. This high cost is a function of lower product demand and the additional data manipulation routers perform. These advanced router functions require powerful processing engines to assure fast interconnection -- thus driving up the price of these core devices.

While there is some variation in the number of level 3 devices deemed critical in Campus Area Network design, the use of routers in the Campus Area Network to interconnect LANs instead of low cost switches is driven by the administrative and operational control routers enable. In addition to others, these controls include improved security and limiting the ability of users within one LAN broadcast domain from stealing the IP numbers of a user in another domain.

In brief review, Campus Area Networks at Cornell are comprised of "level 3," interconnected, high cost per port routers. Routers are desired because they enable administrative control over the campus network not enabled by low cost network switches. While there is a bit of debate on the number of these devices needed at Cornell, to date CIT has elected a conservative approach that maximizes the number of router ports required in order to provide high operational control over the larger network.

Wide Area Network

Like the Campus Area Network, Cornell's connection to the "Internet" is provided by a routed interface. However, the primary element that drives cost in the wide area is the expense of the data links that Cornell leases from Internet service providers. The cost of "internet bandwidth" is orders of magnitude more

[1] Broadcasts from one host are seen by every other host in a given "broadcast domain."
[2] Seven layer model for networking protocols and distributed applications developed by the International Standards Organization (ISO).

expensive than the aggregates cost of data services provided by the Campus Area Network hardware. For example a dedicated 100Mbs switched port in a LAN, if capitalized over 3 years would cost ~ $30 a year.[3] In turn, a 155 Mbs Internet link currently costs ~ $800,000 per year!

Base Costs Associated with All Network Services

There are two additional classes of costs associated with network use: media and general service costs. These are described in the two sections that follow.

Media (Copper/Fiber) and Costs:

Implied in the above outlines of CAN and LAN hardware costs is the additional cost associated with the media used to transport the signal to and from devices. On the Cornell campus LAN connections to clients are based primarily on TP copper, and CAN interconnection is done by fiber. Generally fiber is capable of carrying larger amounts of data longer distances than TP copper and therefore is ideal for interconnecting distant locations. In turn, copper is excellent for horizontal building distribution where distances tend to be less than 100 meters. The cost of provisioning and maintaining these media plants are part of the larger network service delivery costs. Fortunately the usable life span of fiber and copper is very long so the capital costs can be spread out over an extended period (in excess of 15 years). Unfortunately at Cornell the building wire installed is very old (more than 15 years) and limited in the total speeds at which it can carry data to ~ 10 mbs. In addition, despite the relatively long life and low cost per port when capitalized over 15 years, network services fees have not reflected any media expense to date. Given these facts, Cornell is faced with the quandary of how to best replace the existing older "cat 3" wire. If this were to be done en masse the total one time costs could be significant and would impact any final rate structure. For additional information about campus rewire directions please see http://www.cit.cornell.edu/oit/Cornell_Network_Futures.pdf.

Other Associated Costs

In addition to media expenses, it can be argued that there are general service costs directly associated with network service delivery. These often include:

"Middle Ware" such as:

- Traditional network Name Services (DNS).
- General directory access tools such as LDAP.
- Network authentication and encryption tools – such as Kerberos / PKI.
- Dynamic IP number allocations tools such as DHCP.

General support services such as:

- Network Operations Services (NOC).
- Security / incident response.
- Network Help Desk Support.
- Network Research and Development
- Maintenance

While some may debate what should or should not be included as a general network cost, once defined the final list is universal and must be reflected in any network costing model along with CAN/LAN/WAN hardware and media expenses. Clearly a failure to maintain currency in evolving middle ware applications or evolving network service demand will impact Cornell's ability to participate in larger "global" exchange

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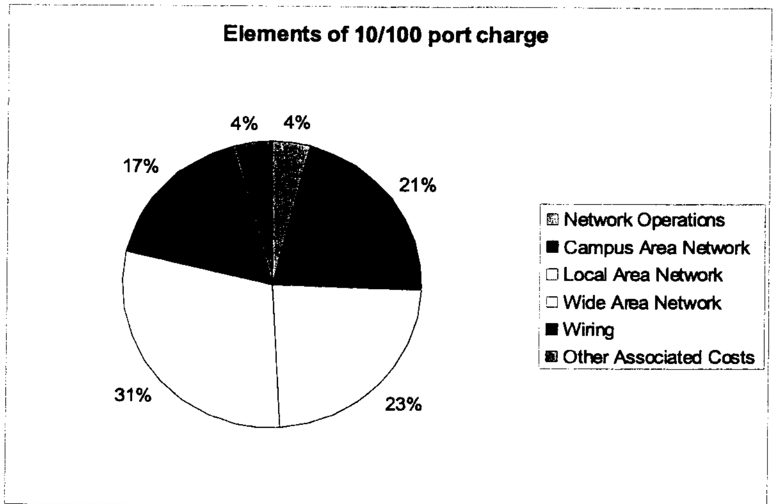
[3] Port fee does not reflect media and associated costs such as middle-ware, etc.

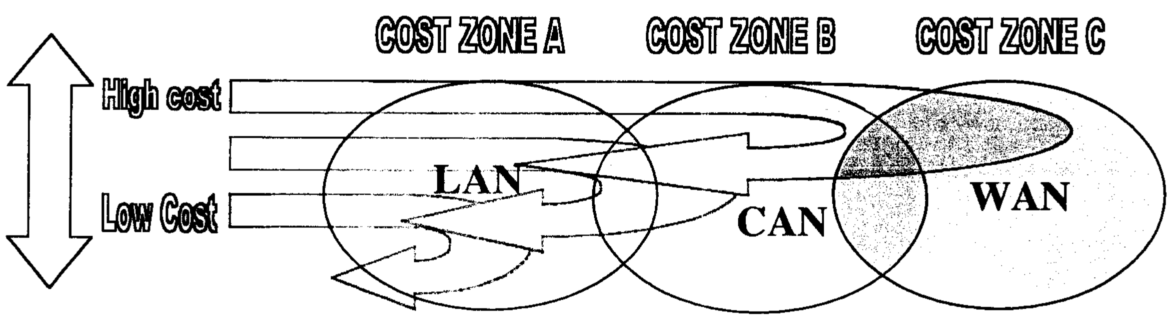
of information with peer institutions. For example, unless Cornell participates in the development of "standards" based inter-domain authentication schemas, Cornell will not be a "trusted" peer allowed to exchange "authenticated" information. The ongoing research and development of these tools and related expense is an assumed part of the larger middle-ware base universal expense of Internet service provision at Cornell.

Estimated network port provision element costs as a % of total expense is as follows:[4]



With the above outline of the nature of LAN/CAN/WAN deployments, it is self evident that the cost of a given network services at Cornell is a function of the path a given data communication takes, plus any other associated networking costs. If a patron of Cornell's network only communicates within a switched LAN, the cost of service can be VERY low, however, the same amount of data pushed across the CAN and WAN will be much higher.

Conceptually these cost zones can be modeled as follows:



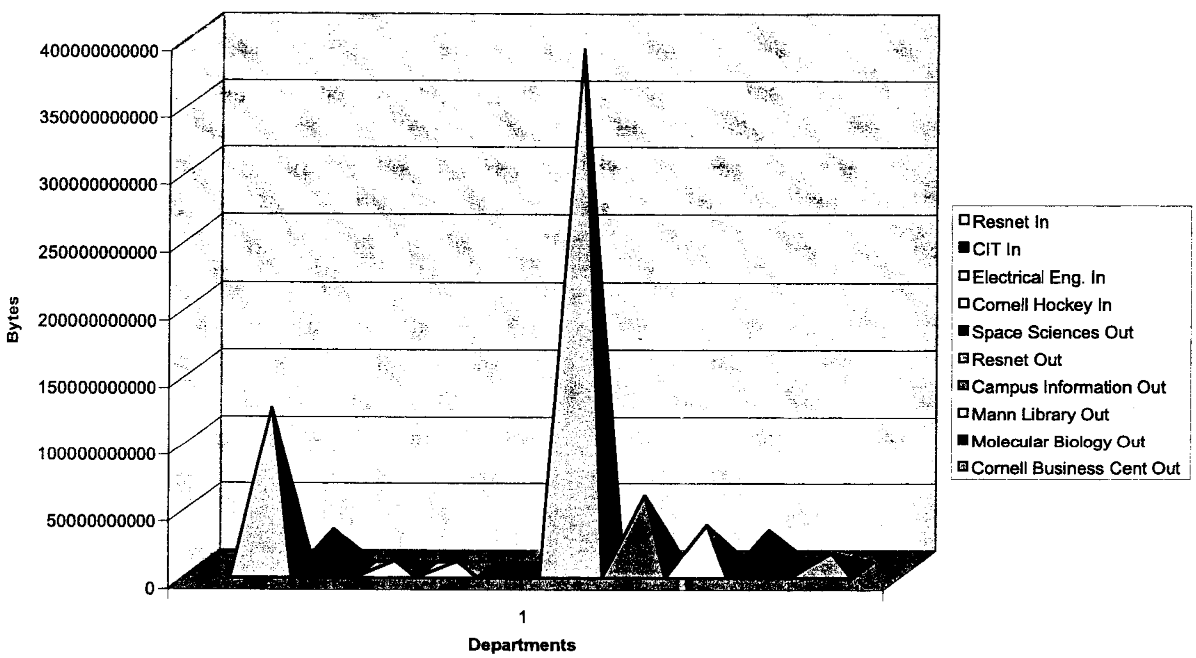
[4] Graph represents % total cost associated with *deployed* hardware not % of "capacity" for WAN/LAN/CAN resources.

Client Impact on Network Resources as a Function of Application Type

In addition to the varying costs based on network zones, not all clients with the same connection to the campus network impact the network equally. The point is not to belabor the obvious notion that a "video" application running on a computer connected to the network would use more than the same computer simply running a mail client, but to note the fact that a computer with a "100 Mbs" connection to the network viewing a video from a remote location, may often use *fewer* WAN resources than a "server" or multi tasking computer connected to the network with only a 10 mbs connection. TCP communications across high latency Internet links may actually penalize connections attempting to run a single large bandwidth tasks.

In short, due to the nature of TCP/IP, compounded by a given Internet latency[5] and Non QoS enabled network hardware[6], when it comes to a client's ability to consume WAN resources, the number of unique network connections per client can often be more important in determining impact on WAN resources than the size of the LAN port connected to the client. A wonderful example of this phenomenon is the impact of "shared" 10 Mbs connected "Napster" servers in the residence halls and their consumption of outbound Cornell WAN resources.

Top Campus Departments For Incoming and Outgoing Traffic On 3/29/01



[5] See: http://citeseer.nj.nec.com/cache/papers2/cs/1206/http:zSzzSztesla.csl.uiuc.eduzSz~madhowzSzpublications zSzton97.pdf/lakshman96performance.pdf

[6] See: http://www.cit.cornell.edu/oit/videodistribution.html

Multiport Repeater Impact on CAN and WAN Resources

Adding complexity to modeling data transmission costs is the growing use of multi-port repeaters, or "hublets" by departments to increase the number of connections within an office to support additional devices. Hublet impact on a given network WAN/CAN resources parallels that of multitasking vs. single tasking clients. If hublet installation enables multiple communication connections across the campus CAN / WAN the impact on campus and Internet resources will be high. However, if the hublet is used to interconnect devices within an office, such as a computer and printer, then the traffic is local and there is no additional impact on the larger campus resources. However, it is arguable that every device connected to a hublet, regardless of local vs. remote data paths, still consumes "base line" service, i.e., DNS, Security, Helpdesk support, etc. And data network connections connected to hublets consume more resources on average than data network connections connected to single clients. But of course, like single clients, the nature of the use can dramatically change the quantity of CAN and WAN resources hublets consume.

Cost Modeling Alternatives

As is apparent from the above overview, determining the true cost of a given network connection at Cornell is not as simple as charging based on the quantity and size of a given LAN connection. Network consumption or cost per user is a function of network port speed, datapath, application type, the technical nature of the IP Wide Area Network resources used to transmit IP plus any universal base support costs.

Summary of Current Average Cost Model

To date, cost recovery at Cornell has been rooted on a simple average cost model that takes the total number of network users and divides that into the total cost of the network service to determine the network "bill" per connection. Clearly this does not reflect actual consumption -- it does not attempt to do so, it only reflects the average cost of the larger service per activated jack. Some patrons are getting a great deal, others are paying far more than they are utilizing. OIT and CIT are exploring refinements to the current average cost model, but the fundamental premise remains the same.

Complications in the Average Cost Model

One of the first challenges of setting up an average cost recovery process is the attempt to find the best measure for total user count. This is not as straightforward as one might initially assume. To date CIT has elected to use active ports as the base number (divisor) to determine average cost. However, with the growing use of hublets in departments to connect additional resources to a single "billed" port, the average cost derived income is gradually becoming threatened. To aggravate matters, the use of average "port" charge has placed a false economic incentive for departments to lower their total network costs by accelerating the installation of hublet and wireless repeaters[7] to lower total port counts they are billed for. Clearly the continuation of this practice will prove unsupportable by Cornell at large as it undermines the ability to deliver advanced network services such as e2eQoS[8] and required funding streams to maintain base, wire, CAN, & WAN network infrastructure.

Other Average Cost Models

Given the failings of the use of ports to determine the divisor for average expense, thought has been given to alternative average cost schemas. These include:

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[7] See (need link to wireless paper when online)

[8] See http://www.cit.cornell.edu/oit/videodist.html

- Total IP number count
- Total MAC address count
- Total head count

Each has weaknesses as outlined below:

Total IP Number Count: While using IP numbers may well be a better current measure than port counts it is easily subverted by the use of NAT enabled hublets. NAT or "Network Address Translator" enabled devices[9] would present only one IP number to the larger campus resource while supporting multiple hidden IP numbers to the installing departments. Again, as the port count schema seems to have stimulated the installation of hublets, using IP numbers as the base count would likely stimulate the use of NAT devices. For an IP count process to be effective there would have to be a university policy that made it illegal to use NAT devices and a process to police network installations.

Total MAC address count: Each hardware device on an Ethernet network has a unique identity, known as a MAC address. It is possible to write applications that "sweep" or "police" the network and to get a total device count. However, you can only assure sweeps through routers are controlled by CIT. In addition, MAC addresses could be hidden by NAT devices. Therefore to be effective CIT would have to mandate access and control of all network routers on campus and have the authority to sweep networks within departments to get accurate device counts.

Total Head Count: This process is based on the assumption that on average the cost per person is a good measure of average network consumption at large. The advantage is creating a process that does not encourage "cheating" or false economic incentives to hide total network utilization. The disadvantage is this billing process is often perceived as a central "tax" on departments for a service they may argue they do not use or that does not provide enough value to justify the tax. In addition, head count or tax systems often encourage abusive consumption, as there is no direct economic consequence for excessive utilization.

Though alternative divisor count strategies are still being actively considered, at this time it is not clear that changing to MAC or IP count strategies would offer enough value to justify the operational expense incurred.

In the near term CIT and OIT has elected to address the proliferation of hublet installation and the higher average cost per network port they create by advocating a higher fee for ports supporting hublets. This has been referred to as a "single circuit gateway" rate. This higher fee is based on the assumption that on average hublets will consume more network resources than a single client does. Unfortunately as with clients, there is tremendous variation in the actual consumption of resources by hublets and, in turn the proposed "ISP" fee for hublets and or wireless repeaters has been meet with considerable community angst. This angst is not, per se, unjustified as many higher performance servers supporting multiple WAN sessions connected to a single port can and will use the same amount of network resources as a hublet supporting multiple "average" clients. This fact is not lost on many departments.

But, somewhat antithetically it is also true that multiple departments have installed hublets precisely to connect "average" clients with the sole purpose of lowering local networking costs. This process violates the fundamental fairness of average rate based billing fees to the larger Cornell community.

The bottom line is that all average rate based cost models are fundamentally limited and in turn subject to legitimate criticism. However, it is also clear that departments have been installing hublets and wireless systems simply to avoid legitimate network fees. If any average cost system is to succeed, Cornell must face the realties and limitations of this billing strategy and in the spirit of a larger community "play fair" and pay their fair share, once a process is adopted.

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[9] See http://www.ietf.org/html.charters/nat-charter.html

Alternatives to Average Cost Models

Despite all hope and good will, history at Cornell has taught us that departments will go to extraordinary lengths to figure out how to pay the lowest network fees possible regardless of the impact on the larger community. This is not meant to be a derogatory comment about departments, it is natural for departments to attempt to lower costs, and average cost billing based on ports, IP numbers, and MAC addresses creates a clear incentive to do so. Given this, short of a mandated head count based average cost system, Cornell may have to enable a non-average rate based system or a system that penalizes or limits collective abusers of the inherent weakness of a given average rate fee.

Proactive Identification of High-Use Users and Departments

In order to provide fairness within an average cost based billing system, there is active consideration of policing connections and if abuse is found, restricting access to broader CAN and LAN resources. An alternative but similar theme would be to average the "income" associated with a given LAN and then allow access to CAN and WAN resources reflecting that % of the total income. For example RESNET patrons would be allotted CAN and WAN resources to reflect the % of the total CAN and WAN expense RESNET subscriptions cover. This same model could be applied to all Cornell departments. If departments persist in the deployment of hublets or use excessive amounts of CAN and WAN resources, the larger department connection to the campus could be limited to the share funded via official port subscription.

Of course this is a rather draconian approach to network cost recovery. It implies an active policing process and would punish all members of a given "department" regardless of individual use. Alternatively there is a growing belief that short of a head count based cost recovery system, only a true "consumption based" or "rate based" approach to network fees will be viable in the long run.

Rate-Based Billing Applications

Cornell has recently entered into an agreement with Apogee Corporation[10] to acquire Apogeeís rate based billing application. Once fully deployed this application will allow CIT a fine tuned understanding of network traffic flows on campus. In turn, this information could be the basis for generating usage based network "bills." Depending on the final configuration, usage charges can be a function of:

Time of day
Class of users
Data Type
Prorated utilization of the three network cost zones (outline earlier in this paper)

An advantage of rate based billing not enabled by average based billing schemas is the proactive feedback it provides to consumers. It is empirically clear to all who bother to dig beneath the network covers a bit at Cornell that a significant percentage of networking costs are related to activities that departments may not desire to fund. For example, with rate based billing, departments would be empowered to encourage users who stream audio content across the Internet to "buy a CD player" as the CD player cost far less than the network resources used to provide the same. A little proactive communication within a department might have a dramatic effect on a given departments network bill. In turn as departments rationalize their network use, CIT could rationalize its future network development and optimize its investments.

There is a recognized concern that a rate based billing model might exacerbate the notion that "rich departments" will be able to consume all resources needed while "poor" departmentsí access to Internet

[10] See: www.apogee.com

resources will be stifled. In addition, some members of the community have expressed concern that a rate based billing model might have a "chilling" impact on the scholarly use of network services at Cornell. This general debate over the network as a "common good" vs. a more capitalistic approach of allocation is sure to cause interesting dialog. Regardless, it is also clear that the existing models for network billing based on average rates have failed to assure long-term funding for this critical Cornell resource. Possibly, if the Cornell community is unwilling to move to a more inviolate "head count" billing process, rate-based billing, despite the impact it may have on given departments access to internet resources, may be the only viable alternative.

Closing Thoughts and Observations

There is a spectrum of approaches that could be applied to network cost recovery systems. These range from simple and effective fees derived from total headcount, to the implementation of a rate based billing application. It should now be clear that given the nature of IP networking and the great variation in network consumption by given applications, average port fee models may always be challenged by individual users.

Pragmatically, if Cornell elects to maintain an average rate billing system, only a total head count (or general "tax") model may be immune from the enterprising individual attaching additional ports or hiding IP numbers in an attempt to lower network costs. Alternatively Cornell could embrace an empirically defensible rate based billing system for network service delivery.

For any funding system selected it is important to understand its inherent limitations and ramifications. Traditional port/IP/Mac count based systems encourage ad hoc deployment of network hardware by departments that in turn threaten required income streams and future advanced network services. In addition, loss of income diminishes Cornell's ability to underwrite the cost of middle-ware and general support requirements of all network users. Simply stated, attempts to avoid paying legitimate costs impact advanced network services development--services that will be commonly delivered at every other major research university.

To avoid a failure to maintain prudent investments in the network infrastructure at Cornell, OIT, CIT and departments must work together to forge and fund an advanced network that has the potential to deliver new services and has a fair and supported process for cost recovery. Once network costs, application use, and the limitations of alternative models are understood, the best cost recovery system may well be limited to either rate-based billing or a simple "head count" based fee.

Appendix E — Cornell Data Network Futures

CORNELL DATA NETWORK FUTURES

Background Information:

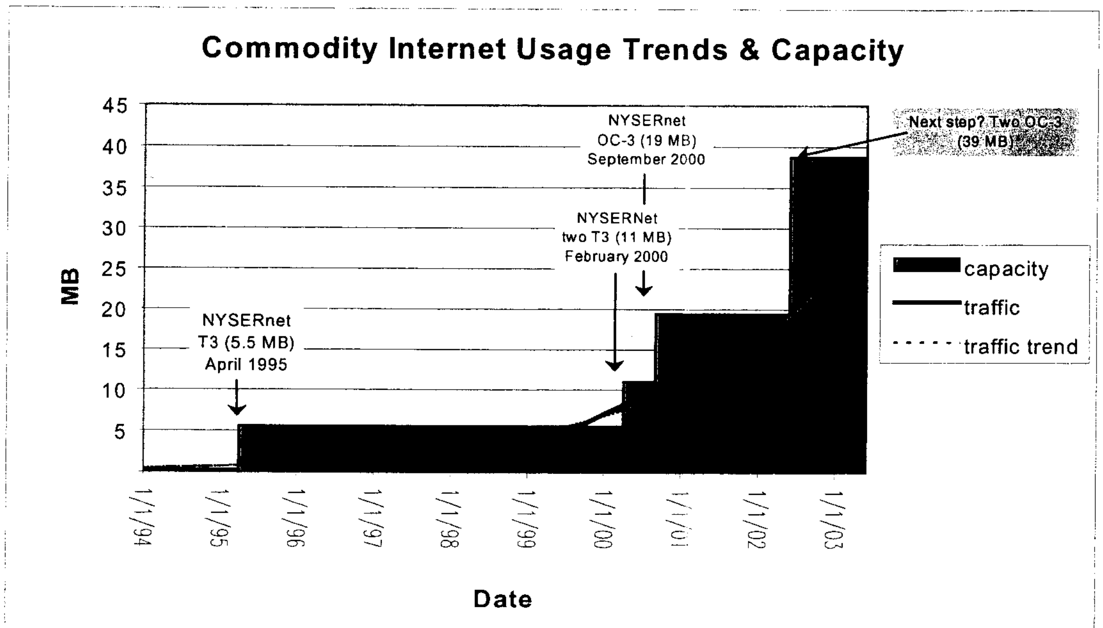
The current campus network services close to 110 buildings and interconnects over 700 local area networks supporting in excess of 23,000 end user work stations and desktop computers. Access to commodity Internet service is provided by an OC-3 link. In addition, a second OC-3 connection provides access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

<u>Three scenarios for data networking investment at Cornell and their service level implications:</u>

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.

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[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.

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[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 [illegible]	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.