University of Pennsylvania

CAUSE94

November 28, 1994

Designing and Implementing a Network Architecture Before it Becomes Obsolete

Dr. Noam H. Arzt *(arzt@dccs.upenn.edu)*
Ira Winston *(ira@cis.upenn.edu)*

With the rapid advances in networking technology and the exploding demand for network access, resources, and services, Penn finds itself needing a new network architecture as it works to complete its present one! Through the work of a small but dedicated group, the campus is following a careful, structured methodology to develop its next-generation network. A partnership was forged among individuals responsible for major campus-wide client/server initiatives, representatives of the major schools, and the separate organizations responsible for telephony and data/video communications. To keep the campus community informed, World-Wide Web is used to publish not only finished products of the project, but work-in-process as well.

Introduction

Networking has changed significantly at Penn since the early days of Gandalf boxes and IBM 3270 terminals. It took decades for the telephone to be considered an essential instrument appropriate for ubiquitous deployment. In a mere twenty years, data networking has evolved to become as mission critical to the academic enterprise as any core piece of Penn's infrastructure. Consider:

> *Virtually every school at Penn uses the campus network, PennNet, in its teaching, from simple electronic messaging and conferencing to promote student-faculty and peer interaction, to entire electronic courses taught for credit. Faculty, however, often will not use the network during class presentations until it is as reliably as their overhead transparencies.*
>
> *Data communications are now essential to research in many, if not all, academic disciplines as a means to quickly exchange data or ideas, submit proposals to sponsors, or harness the appropriate resources for experimentation and inquiry. And research continues to push the envelope of technology every day.*
>
> *Telecommuting and mobility will become increasingly important to students, faculty and staff as the University seeks ways to become more energy-, environment-, and efficiency-conscious. Robust data communications, integrated with better telephony and video, will enable this location independence.*

But also consider that PennNet was never architected to provide services as reliably, quickly, or broadly as users have come to expect. To meet this challenge, the Network Architecture Task Force was charged in March, 1994 to assess the current state of data, voice, and video networking at Penn, and to make recommendations for changes to these architectures during a three to five year planning cycle.

Membership and Organization of Task Force

The Task Force is made up of individuals from across the University. One of its two chairpersons comes from the central computing group, the other is the computing director at one of Penn's major schools. This sense of partnership is critical to the success of the project, since PennNet is a campus-wide asset. The other members of the committee, while not selected for strict purposes of representation, represent a broad set of individuals from around the University with differing technical backgrounds. Two important criteria guided the selection: individuals either needed to have something concrete to contribute, or had something they needed to learn.

For perhaps the first time, the Office of Telecommunications, which is responsible for telephony at Penn and reports through a different Vice President than data communications, is a full participant in this planning process. The University's contract with Bell Atlantic for Centrex services expires during the course of the planning period, so the Task Force is examining options for its replacement. Other members of the committee include additional networking directors from other schools (Arts and Sciences, Wharton School), computing directors from other units (like the Library), as well as other individuals from various central computing departments (networking, academic computing services, central MIS group).

The Task Force was charged by Penn's Network Policy Committee, a subcommittee to the campus' computing advisory board. This committee not only receives regular updates, but is available to grapple with policy questions that have the potential to slow the Task Force's progress.

A small sub-committee of the Task Force was formed to craft the architectural alternatives (see methodology section below), since this step is best performed by a relatively small group initially with its work exposed over time to more and more individuals. The two co-chairpersons, along with the Manager of Network Operations and Manager of Network Engineering in the central networking department formed this sub-committee.

It is important to recognize the overlap with other efforts at Penn, and the coordination that is constantly required of the Task Force chairpersons. At Penn, the network architecture is seen as just one piece of a larger, inter-related architectural puzzle. Similarly, some sections of the network architecture are being developed primarily by other Task Forces and groups. Some relevant efforts include a recently-started DCE Task Force; our ongoing Project Cornerstone, which focuses on administrative systems and processes; Access 2000, our initiative in the area of library systems; and our E-mail Task Force, which focuses on a number of electronic mail, netnews, and office automation issues.

Technical Architecture Methodology

Network planners often believe they "know what is best" for the campus without bothering to ask. Many, in fact, have turned as conservative as the data center manager of the 1980's who safely bought "whatever IBM had to offer." In the 1990's, the once-"maverick" network manager is playing it "safe" by buying whatever CISCO and Cabletron have to offer.

Definition

A technical architecture is a blueprint for making technology choices. In the words of the GartnerGroup, it is a process and not a product. The crucial objective is to improve the performance of the enterprise. A technical architecture is *not* a platform from which to preach a certain methodology or justify a predetermined technical direction.

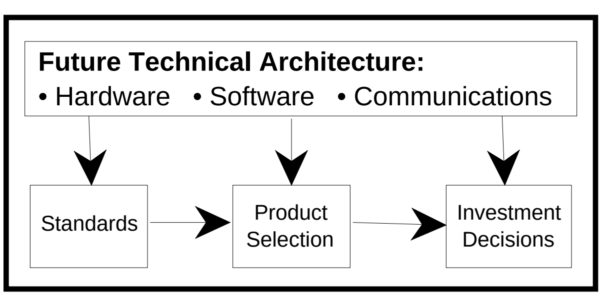

Figure 1 - **Components of a Technical Architecture**

Generally speaking, a technical architecture consists of the hardware, software, and communications components of an organization. From the architecture flows the standards (including policies and procedures), product selections, and ultimately the investment decisions of the enterprise.

Developing a Technical Architecture

According to the methodology being followed at Penn, four major factors are considered when developing a technical architecture:

- University Direction and Business Requirements - First and foremost, the technical architecture must satisfy the University's needs. It must support the University's academic and administrative objectives. Care needs to be taken not to deploy technology simply for technology's sake.

- Principles - The University has developed a set of principles, or beliefs, that together provide direction for information systems and technology. Project Cornerstone, Penn's multi-year effort to improve administrative information and systems, developed principles in the administrative domain. A set of principles which apply to academic information technologies is currently being developed. Generally, principles are meant to remain relatively stable, unless major changes in University philosophy or direction occur.

- Current, or *de facto* Architecture - Regardless of how it came to de deployed, the current, or *de facto* architecture is nonetheless the major starting point for any new architectural initiative. The existing architecture must be documented and understood, for both its strengths and weaknesses, before work on a new architecture can begin. The current architecture of PennNet , the University's telephony network, and the University's video network have been documented.

- Industry and Technology Trends - To assist in identifying the new architecture it is necessary to have a base of information about the technologies and industry trends that are both popular and emerging in the marketplace. Vendors, as well as experts and consultants, have been invited to supply this information via briefings and reports. The Task Force has been collecting and synthesizing this material from a number of sources:

  - Regular review of material from the GartnerGroup, the Internet and other sources.
  - Briefings from major network technology vendors, with an engineering rather than marketing focus, during the summer/fall of 1994, including Fore Systems, Cabletron, DEC, and AT&T.
  - Formal and informal exchange of information with experts and our counterparts at other institutions.

This set of data assists the team in developing a set of architectural alternatives which are presented to University management with a cost/benefit analysis and recommendations for implementation.

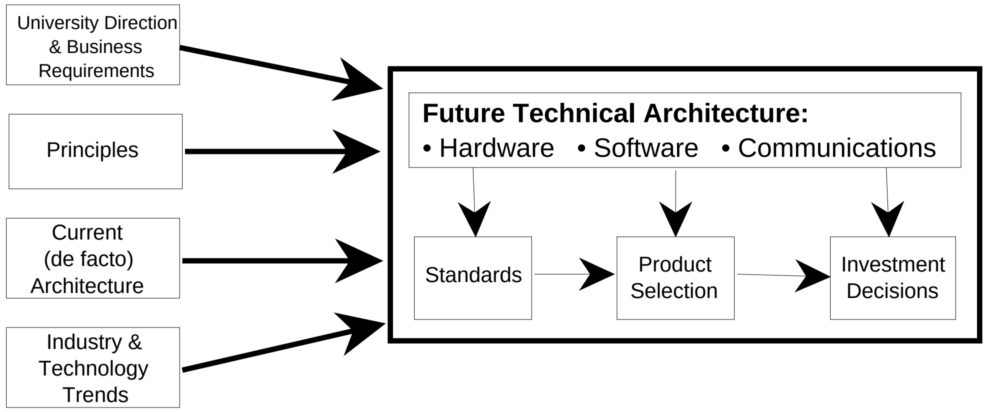

Figure 2 - **Developing a Technical Architecture**

<u>Scope of the Architecture</u>

The technical architecture is made up of a number of components. At Penn, the network architecture will not define every component at the same level of detail. It is expected for the current effort that data networking will be more developed than either voice or video. Other efforts will have to follow in these two areas to define their architectures in more detail.

Data networking will include models for both the physical networking topology (from Internet gateway to the desktop device) and the services that use that physical network (e.g., protocol stacks, LAN strategy, DCE, end-user networking products). From these models will flow the standards and supported product lists to be adopted campus-wide.

It is important to provide an architecture that enables access to the network and its services to as close to 100% of the University community as possible, while recognizing that a small percentage of aggressive users will likely require more sophisticated connectivity or services than the mainstream, and a percentage of less sophisticated users will be satisfied with substandard facilities.

The potential convergence of video, voice and data technologies is high on the minds of task force members. Relevant factors include:

- Increased digitization of services (versus more traditional analog implementations) leading to increasingly common media and wiring standards
- Arrival of multimedia technologies that will synchronize data, audio and video in a single application
- Increased interest in and use of video conferencing
- Increased potential and use for voice-response system integrated into traditional business applications
- Crossover in offerings beginning in the commercial marketplace among traditional data, voice and video providers

The Task Force is monitoring these developments and assessing their impact on the architecture.

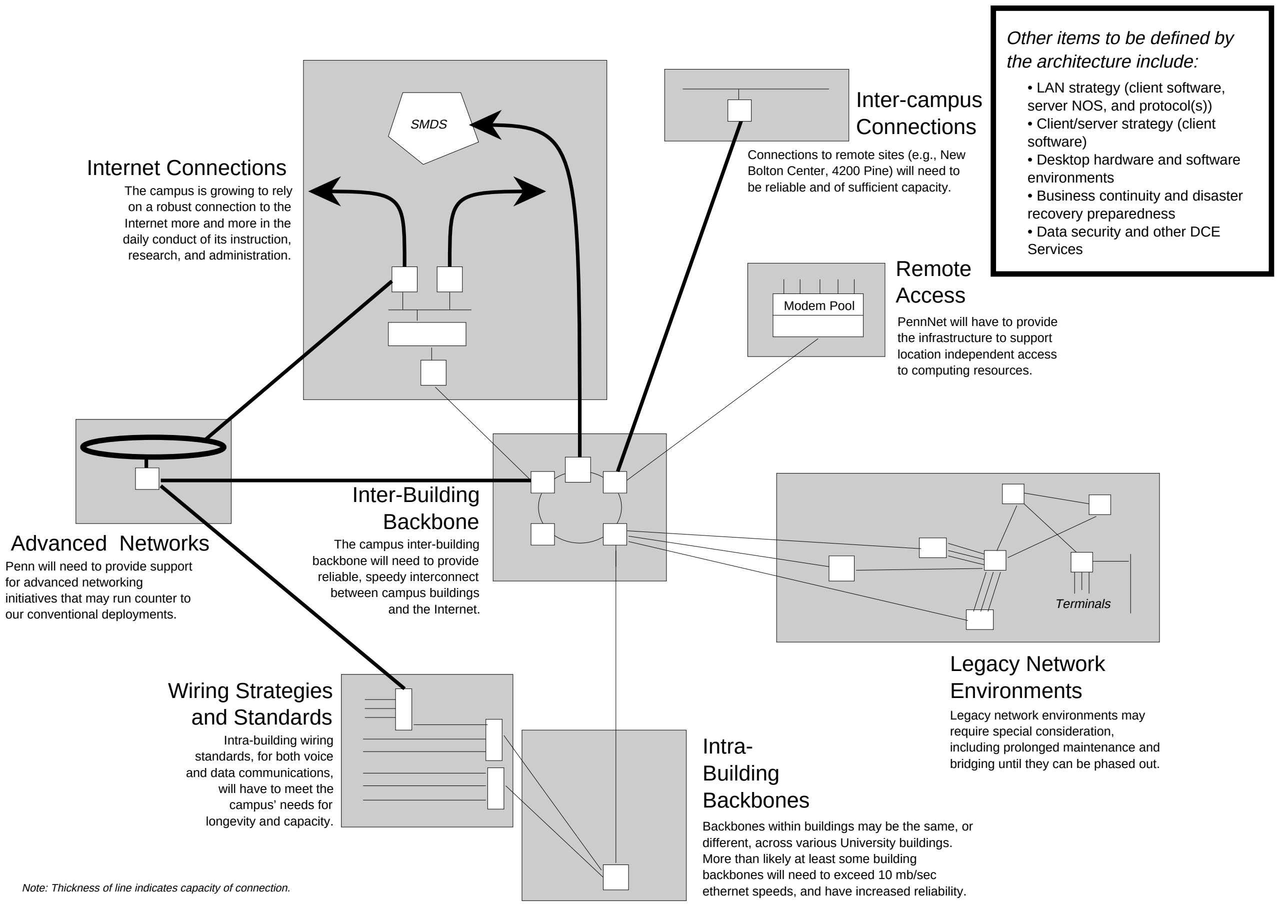

Figure 3 - **Network Architecture Template**

A template for the network architecture is found in Figure 3. The goal of the architecture effort is to define alternative strategies for each of these areas. Major components of the architecture include:

- Connection to the Internet and other wide-area networks
- Inter-campus backbone (e.g., New Bolton Center, Center for Judaic Studies)
- Inter-building backbone
- Intra-building backbone
- Wiring and media standards (e.g., wireless)
- Workgroup computing strategy, including appropriate client and server software, Network Operating Systems (NOS), and protocols
- Enterprise computing and communications strategy, including appropriate desktop software to be compatible with various enterprise-wide initiatives
- Institutional file system that might be required by workgroup or enterprise computing strategies
- Remote access strategy, for home and "on the road"
- Desktop hardware and software environments for networking
- Business continuity planning and disaster recovery preparedness
- Network information security, including network-wide authentication services
- Role of legacy network environments (e.g., ISN, terminal servers)

Developing and Articulating Needs

The Task Force spent considerable energy in an initial analysis of the campus' needs for networking technology and services. Wider discussion of these points is now required. While it is tempting to simply say "more *whatever* is better," the Task Force has attempted to be more precise in anticipating the campus' needs and describing those needs relative to each other. Two important points need to be made:

Elements out of Penn's Control	Elements, like the reliability and capacity of the Internet beyond the campus' boundary, that are out of Penn's control can have a substantial impact on users. Steps can be taken in some cases to either minimize Penn's reliance on these resources, or provide redundant or back-door methods of securing reliable service.
Test Bed for Experimentation	Given the rapid changes in information technology, and the rapid expansion of our collective knowledge base, Penn must be positioned to use new technology in an appropriate and timely manner for the greatest pay-back from the most prudent investment. Penn must have a formal mechanism for testing new technology for potential production use or campus-wide deployment

Figure 4 below displays a framework for understanding these desired network functions which are described below. The four core needs -- accessibility, reliability, capacity, and capability -- appear close to the center of the diagram. Their supporting needs appear around them. The main categories are defined as follows:

1. **Accessibility**: The ability to access network resources whenever and wherever desired. To use a metaphor from another utility, electrical power is available and accessible by-and-large whenever and wherever it is needed, and both the power companies and builders accordingly work together to anticipate and meet needs.

2. **Reliability**: The consistency and quality with which the network performs its tasks and provides its services. An important component of Reliability is the set of services that allow the network to be managed and that allow for prompt trouble-shooting and maintenance. We currently lack clear language that allows customers and service providers to even consistently understand what constitutes a network "outage" or "failure." We also lack clear measures that allow us to determine whether the network is living up to its expected or planned targets of operation, while recognizing that individual services provided by departments may become unavailable regardless of the state of the network.

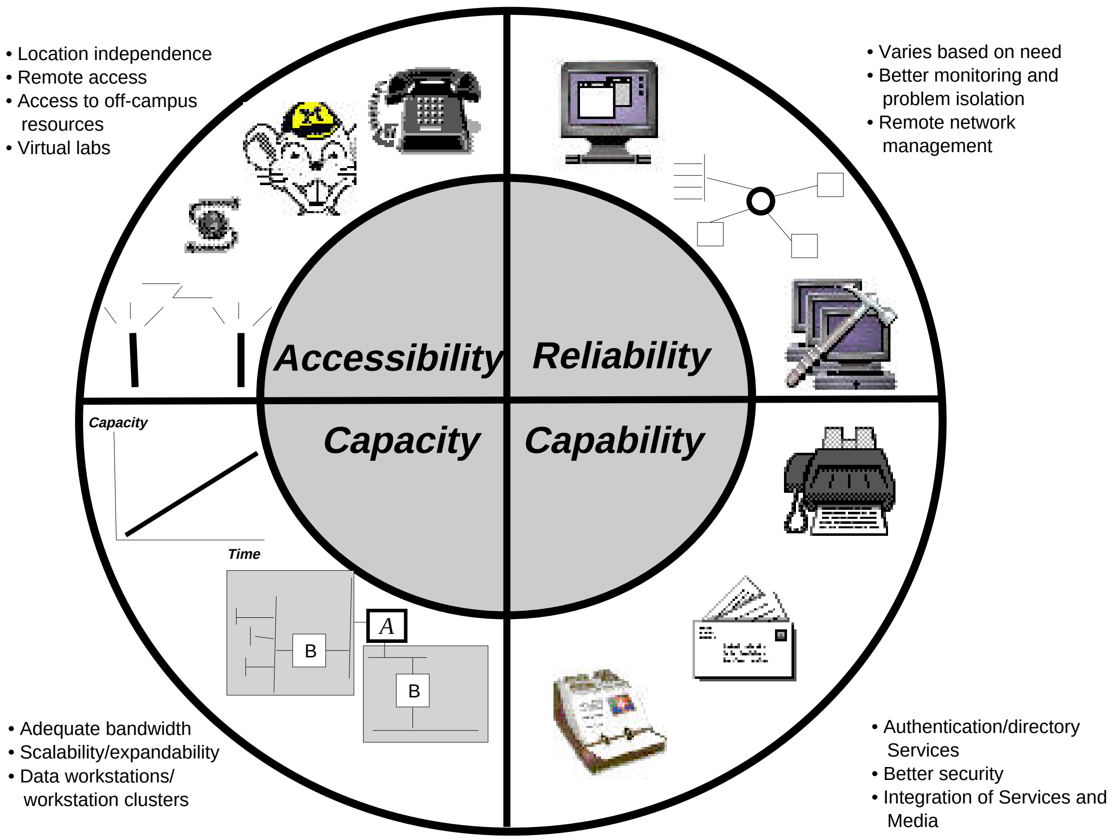

Figure 4 - **Desired Network Functions**

3. **Capacity**: If the network is thought of as a highway (or pipe), and bandwidth as its capacity for travel or use, the goal is to ensure sufficient ability to travel on or use this highway with an acceptable level of performance to complete a given operation. The new architecture must be sufficiently scalable to accommodate a connection for *everyone* while recognizing that new users will phase in over time.

4. **Capability**: Given sufficient capacity, the network must have the capability to support the necessary services. Authentication/directory services control access to network resources, and inform users about where to find those resources and other users. In an evolving multi-media world, PennNet must provide services using less traditional media, and recognize the convergence of traditional data, audio and video services.

Assumptions help to bound the set of possible architectures to a more reasonable set, and help focus the search for solutions. The Task Force developed a set of working assumptions that continue to evolve as the project evolves. Some examples include:

TCP/IP	TCP/IP will continue to be the enterprise-wide networking protocol. OSI protocol is not, and will not, become significant.

Higher Bandwidth to Homes	The choice of offerings of infrastructure to provide higher bandwidth to homes will become increasingly available during the planning period.
Dorm Connectivity	All dorms will be wired by the end of the planning period.
Bandwidth Demand	Demands for network capacity and services will continue to increase at a dramatic rate (estimated to be at least 50% per year) for the foreseeable future. Sudden increases in demand due to discrete events or new capabilities will require a quick response in added capacity to meet demand.
"Killer Apps"	"Killer Apps" (perhaps desktop video-conferencing?) will change network usage patterns in ways we cannot predict.
Inter-building Communication	The campus per-building subnet model still seems valid.

<u>Developing Alternatives: "Myths" of Network Planning</u>

Penn has found that a small group of individuals must work closely to develop alternative architectures. Using the template (Figure 3 above), a sub-set of the Task Force worked on brainstorming different levels of the architecture: inter-building communications, intra-building communications, migration strategies, etc. The vendor presentations helped to inspire critical thinking and visioning. Interestingly, these discussions highlighted a number of common misconceptions, or myths, about network planning in the 1990's:

Myth 1: Ethernet is Obsolete

It appears that ethernet has life in it yet, evidenced by the movement toward switched (versus shared) ethernet, and the likely dominance of greater-than-10MB ethernet over the next several years.

Myth 2: Network Electronics can "Trickle Down"

The market for network electronics is changing rapidly. It is common today to assume that these components have a useful life of three to five years, and that they can be migrated from sites requiring more aggressive solutions to sites requiring less aggressive solutions to prolong their life. Product lifecycles are shrinking quickly, and it appears that old network electronics, especially electronics that cannot be remotely managed, have no place in the infrastructure.

Myth 3: When in doubt, always lay fiber

The jury is still out on whether fiber to the desktop is necessary or even wise. The market seems to have embraced category 5 twisted pair copper wire as the standard, with potential for transmission speeds exceeding 100MB/sec on this wire.

Myth 4: ATM will dominate in the next few years

It is not clear how soon virtual circuit networks (like ATM) will become the new paradigm in networking. While virtual circuit networks support real-time services better than packet switching networks, they fail to run today's protocols robustly enough to support the large installed base of applications.

Myth 5: An Architecture can last for five years

Various components have very divergent lifecycles making network planning increasingly challenging. Product lifecycles are now measured in weeks and months instead of years. An architecture that takes too long to implement is destined to become obsolete before its time. It is useful to plot a technology migration path within which one is able to skip steps in order to minimize obsolescence.

These are just some of the issues the Task Force has struggled with, and about which, in some cases, has not yet reached a conclusion.

Building Consensus and Marketing the Architecture

A critical piece of the architecture process is building consensus as recommendations develop. Penn is an especially decentralized campus with strong, independent schools who will build their own infrastructures if they do not feel well-served by the central computing group. Additionally, the central computing group is ultimately dependent on the schools to fund its activities.

Technical architecture efforts face the double problem of needing to keep technical managers around the campus informed and up-to-date, while figuring out how to market the ideas to the financial and business managers who ultimately need to be "sold" on the need for the investments. It is common for managers, especially when the investments are big, to consider the problem "taken care of" after a one-time purchase. At Penn, the original network infrastructure was funded through a bond purchase whose repayment extends until 1999, though the equipment purchased is already obsolete. Managers must be educated to view investments in technical infrastructure as ongoing, evolving purchases.

The Task Force chairpersons decided to use the World-Wide Web as a vehicle for documenting the process and outcome of Task Force activities. Works in process as well as draft and final "products"of the task force are maintained in a WWW server available for wide viewing on campus and across the Internet. This goal of "full disclosure" removes any fear that a given constituency may have about not being included in the process - all they have to do is consult the on-line documentation and comment as appropriate. All meetings are announced in the Web. Agendas are made available before meetings, and notes are made available after meetings. All products of the task force are immediately available for comment, and are likewise accessible by vendors to assist them in preparing for technical sessions on campus.

The project became amazingly self-documenting. When it became clear that a traditional needs document was necessary to effectively explain the objectives and interim conclusions of the Task Force to the various advisory boards and business managers, it became very easy to make the leap from notes to a formal document since all the important information had already been electronically "published" via WWW. This step of marketing early to financial decision makers is critically important: first it is necessary to explain the project, then prepare cost estimates in ways they can understand.

Conclusion

Developing a network architecture is an ongoing process. Market pressures and short lifecycles make decisions about directions, standards, and products increasingly difficult. The key to avoiding obsolescence is to plan continuously, keep abreast of technology developments, and engage the campus whenever possible.

Penn is currently developing its architectural alternatives, building its cost model, and developing the necessary recommendations to present to the campus early in 1995. Progress can be monitored in the World-Wide Web with the URL **http://www.upenn.edu/ITI/it-initiatives.html**, Information Technology Architecture branch.