                    K-12 Internetworking Guidelines

Status Of This Memo

   This memo provides information for the Internet community.  This memo
   does not specify an Internet standard of any kind.  Distribution of
   this memo is unlimited.

I.  Introduction

   Many organizations concerned with K-12 educational issues and the
   planning for the use of technology recognize the value of data
   communications throughout the educational system.  State sponsored
   documents such as the California Department of Education's "Strategic
   Plan for Information Technology" recommend the planning of voice,
   video and data networks to support learning and educational
   administration, but they do not provide specific technical direction.

   The institutions that built the Internet and connected early in its
   development are early adopters of technology, with technical staff
   dedicated to the planning for and implementation of leading edge
   technology.  The K-12 community traditionally has not had this level
   of staffing available for telecommunications planning.  This document
   is intended to bridge that gap and provides a recommended technical
   direction, an introduction to the role the Internet now plays in K-12
   education and technical guidelines for building a campus data
   communications infrastructure that provides internetworking services
   and connections to the Internet.

   For a more general introduction to the Internet and its applications
   and uses, the reader is referred to any of the references listed in
   the following RFCs:

   1392    "Internet Users' Glossary" (also FYI 18)
   1432    "Recent Internet Books"
   1462    "What is the Internet" (also FYI 20)
   1463    "Introducing the Internet - A Short Bibligrapy of
           Introductory Internetworking on Readings for the Network
           Novice" (also FYI 19)

II.  Rationale for the Use of Internet Protocols

   In 1993, the Bank Street College of Education conducted a survey of
   550 educators who are actively involved in using telecommunications.
   (Honey, Margaret, Henriquez, Andres, "Telecommunications and K-12
   Educators: Findings from a National Survey," Bank Street College of
   Education, New York, NY, 1993.)  The survey looked at a wide variety
   of ways telecommunications technology is used in K-12 education.
   Their findings on Internet usage are summarized below.

         "Slightly less than half of these educators have access
         to the Internet, which is supplied most frequently by a
         university computer or educational service."

         "Internet services are used almost twice as often for
         professional activities as for student learning
         activities."

         "Sending e-mail is the most common use of the Internet,
         followed by accessing news and bulletin boards and gaining
         access to remote computers."

   The following chart shows the percentage of respondents that use each
   network application to support professional and student activities.

| Applications | Professional Activities | Student Activities |
|---|---|---|
| Electronic mail | 91 | 79 |
| News or bulletin board | 63 | 50 |
| Remote access to other computers | 48 | 32 |
| Database access | 36 | 31 |
| File transfer | 34 | 19 |

   The value of the Internet and its explosive growth are a direct
   result of the computer communications technology used on the network.
   The same network design principals and computer communications
   protocols (TCP/IP) used on the Internet can be used within a school
   district to build campuswide networks.  This is standard practice
   within higher education, and increasingly in K-12 schools as well.
   The benefits of the TCP/IP protocols are listed below.

Ubiquity         TCP/IP is available on most, if not all, of the
                 computing platforms likely to be important for
                 instructional or administrative purposes.  TCP/IP
                 is available for the IBM compatible personal
                 computers (PCs) running DOS or Windows and all
                 versions of the Apple Macintosh.  TCP/IP is
                 standard on all UNIX-based systems and
                 workstations and most mainframe computers.

Applications     TCP/IP supports many applications including, but
                 not limited to, electronic mail, file transfer,
                 interactive remote host access, database access, file
                 sharing and access to networked information
                 resources.  Programming and development expertise
                 is available from a wide variety of sources.

Flexibility      TCP/IP is flexible, and new data transport
                 requirements can be incorporated easily.  It can
                 accommodate educational and administrative
                 applications equally well so that one set of network
                 cabling and one communications system may be
                 used in both the classroom and the office.

Simplicity       TCP/IP is simple enough to run on low-end
                 computing platforms such as the Apple MacIntosh
                 and PCs while still providing efficient support for
                 large minicomputer and mainframe computing
                 platforms.  TCP/IP benefits from over twenty years
                 of refinement that has resulted in a large and
                 technically sophisticated environment.

Capacity         TCP/IP supports local area network and wide area
                 network services within the entire range of network
                 data rates available today, from dial-up modem
                 speeds to gigabit speed experimental networks.
                 Communications can occur reliably among machines
                 across this entire range of speeds.

Coexistence      TCP/IP can coexist successfully with other
                 networking architectures.  It is likely that offices
                 and classrooms that already have networks may be
                 using something other than TCP/IP.  Networks of
                 Apple Macintosh computers will probably be using
                 Appletalk; networks of PCs may be using any of the
                 common network operating systems such as Novell
                 Netware or LANManager.  Mainframe computers
                 may be using IBM's System Network Architecture
                 (SNA).  None of these proprietary protocols provides

broad connectivity on a global scale.  Recognizing
this, network technology vendors now provide many
means for building networks in which all of these
protocols can co-exist.

Multimedia          TCP/IP networks can support voice, graphics and
video as part of teleconferencing and multimedia
applications.

Compatibility       All of the major Universities, as well as
thousands of commercial and governmental
organizations use TCP/IP for their primary
communications services.  Commercial networks
such as Compuserve and America Online are also
connected to the Internet.  Many State Departments
of Education have sponsored statewide initiatives to
connect schools to the Internet and many K-12
school districts have connected based upon local
needs.

NREN                The High Performance Computing Act of 1991 and
the Information Infrastructure and Technology Act
of 1992 provide the foundation for building the
national telecommunications infrastructure in
support of education and research.  The National
Research and Education Network (NREN) will be
based upon Internet technology.

The benefits of internetworking technology have been demonstrated
through twenty years of use by thousands of organizations.  This same
experience also provides tested technical models for network design
that can be adapted to K-12 campuswide networking in schools of all
sizes and technical development.

III.  A Technical Model for School Networks

The vision of a modern communications network serving all primary and
secondary schools has been articulated and discussed in many forums.
Many schools and a few school districts have implemented ad hoc
network systems in response to their own perception of the importance
of this resource.  This section of the Internet School Networking
(ISN) Working Group RFC presents a standard network implementation
model to assist county offices of education and school districts in
their planning so that all such implementations will be compatible
with each other and with national networking plans intended to enrich
K-12 education.

The future goal of "an integrated voice, data, and video network extending to every classroom" is exciting, but so far from what exists today that the investment in time and dollars required to realize such a goal will be greater than most districts can muster in the near term.  We suggest that a great deal can be done immediately, with relatively few dollars, to provide modern communications systems in and between all schools around the nation.

Our present goal is to define a highly functional, homogeneous, and well supported network system that could interconnect all K-12 schools and district, county, and statewide offices and that will enable teachers and administrators to begin to use new communications tools and network-based information resources.  It takes considerable time to adapt curricula and other programs to take full advantage of new technology.  Through the use of standard models for implementation of current network technologies, schools can begin this process now.

Many states have already developed communications services for their schools.  A notable example is Texas which provides terminal access to central information resources from every classroom over a statewide network.  Modem-accessible systems are available in many states that serve to encourage teachers to become familiar with network resources and capabilities.  Although modem-access may be the only practical option today in some areas, it always will be limited in functionality and/or capacity.  In anticipation of emerging and future bandwidth intensive information resource applications and the functionality that they will require, we believe it is essential to provide direct network access to the National Research and Education Network (NREN) Internet (The Internet is a "network of networks" that interconnects institutions of higher education, research labs, government agencies, and a rapidly growing number of technology and information vendors.) from computers in every classroom.

The Internet communication protocols, commonly known as "TCP/IP," are the "glue" that will allow all computers to communicate.  As noted above, software that implements Internet protocols is available for all modern computers.  These protocols support a very wide variety of applications, from electronic messaging to client/server data access. The use of Internet protocols will ensure that all networked computers will have direct access to the vast range of existing information and education resources on the Internet, as well as to the emerging National Information Infrastructure.

Approach

   The implementation we suggest would use current proven and cost
   effective technology and would be expandable and upgradable to newer
   technology with minimum additional investment.  This approach
   requires careful, modular design to meet the following criteria:

   1) Any physical infrastructure development should be general and
      flexible enough to be reused as technology improves.  For
      example, a school office might have a simple terminal today
      which could be wired to a network adapter serving the school
      building.  Later a Macintosh, DOS, or Windows-based PC might
      replace the terminal, and the type of connection to the network
      would change accordingly.  However, the wiring between the
      office and the network "hub" site could remain the same if it
      is designed properly to begin with.  This is an important
      consideration since wiring typically represents 20 to 40% of
      the cost of individual network hookups;

   2) Existing computers and terminals in schools and district
      offices should be integrated as much as possible into the
      communication system.  This installed base represents a large
      investment, albeit in many cases a somewhat dated set of
      equipment.  Wholesale replacement of that base would be a
      large additional burden on funding resources.

      A consequence of the above is that the user interface and the
      services available will vary depending on the type of equipment
      used to access the network.  For example, DOS PCs, Macintosh
      computers, or Unix workstations would be connected directly to
      Local Area Networks (LANs) and would be provided with
      communications software to support a broad set of functions,
      many of which will have graphical user interfaces and will make
      use of client/server technology.  Apple-II computers, "dumb"
      terminals, or other such devices could be connected to
      intelligent network hubs that would allow access to network
      server computers or information resources, but almost certainly
      will not support the full range of functionality provided by a
      direct network connection.  In the short term, this is a
      limitation that we must accept;

   3) Network servers will be located where they can be managed and
      supported, and also provide access paths with adequate
      bandwidth.  A system of hierarchical servers should be created
      in larger school districts, with automatic transfer of common
      information from a central system to the secondary systems each
      night, or at appropriate intervals.  Local servers will allow
      each school to provide on-line information particular to its

programs and community.  This model optimizes use of network
bandwidth as well;

4) School interconnect topologies (links) must be both cost
   effective and manageable.  Communication between schools,
   district offices, county offices of education, and the State
   Department of Education must be reliable and of sufficient
   capacity to support the primary applications as well as allow
   development of new applications.

   Capacity is measured both by total data traffic volume and by
   response time when information is requested over the network.
   Reliability is measured by the percentage of time that the
   network is able to transport data.  Reliability should be well
   over 99.7%.  Capacity should be such that no more than 10% of
   the communications bandwidth is used during a typical work day.
   This is intended to leave adequate capacity for good response
   time to short term communication demands.

   Many schools already have some form of communications
   infrastructure in place.  In some cases this infrastructure can
   be adapted to newer technologies; in other cases it may have to
   be replaced over time.  These issues are explored further
   following presentation of the basic model that serves as a
   guideline for future communications system development.

Implementation Model

   There is no one "blueprint" for a network that will drop into every
   school.  Each school will have particular physical constraints,
   functional needs, an existing technology base, funding constraints,
   and opportunities for collaboration with vendors and support groups
   in its area.  What is presented here is a set of general guidelines
   that can be followed in the planning of a school network
   implementation.

   The strategic decision to use Internet protocols in developing school
   networks provides the opportunity to avoid the major expense of
   building new statewide backbone infrastructures in the near term.
   Interconnection of schools, districts, county offices of education
   and the State Department of Education can be accomplished by
   acquiring Internet connection service from any of the existing
   Internet service providers in the state.  ("Connecting to the
   Internet", Susan Estrada, O'Reilly & Associates, Inc. (ISBN 1-56592-
   061-9) lists Internet service providers in California and the
   nation.)  It is critical that Internet connection service meet
   criteria for reliability and capacity but connection to any Internet
   service provider will provide communication capability to all other

Internet subscribers within the state, the nation, and the world.

Internet technology is designed to allow very flexible intersite
topologies, but a hierarchical topology is the simplest to engineer.
Generally this will mean hierarchical connection of school facilities
to district offices, in many cases further aggregated at county
offices, and finally a link to an Internet service provider.
Coordination of circuit services and a single point of connection to
an Internet service provider serves both to minimize overall costs
and increase opportunities to make use of newer technologies.

The basic school network implementation model is quite simple: create
a local area network (LAN) within each school building or cluster of
buildings, provide at least one network server for that LAN,
interconnect that LAN with the local school district offices where a
similar LAN should be installed and where centrally managed
information resources should exist, and connect the district offices
to the nearest Internet service provider, possibly through the county
office of education.

Primary technical support for network monitoring and problem
resolution, and for managing network resource servers should come
from the district or county offices initially to avoid unnecessary
duplication at the local level.  As expertise is developed at the
local level, more of the responsibility for daily operation and
problem resolution can be assumed by individual schools.

It is impossible to cover all conceivable scenarios for
implementation of this model in specific schools.  However, it is
possible to state general principles that should be followed in
designing school network implementations.  The discussion below is
organized into sections corresponding to the basic model summarized
in the previous paragraph.  It includes a description of the general
principles that are important to each level of the implementation.

Step 1: School Local Area Network Implementation

A "school" is used here to mean a building or cluster of buildings
that are managed as a unit and typically are on contiguous, district
owned property.  Implementation of a LAN in this setting will involve
installation of a cabling system to distribute the network throughout
the structure(s), installation of premise wiring to support
connections of computers and terminals to the network distribution
system, installation of one or more network server machines in a
central location (Other protocols, such as AppleTalk or Novells IPX,
may be supported on a school's local area network (LAN) as needed for
local function such as printer sharing or local resource servers.),
and provision of a network router and telecommunications circuit or

radio link to connect that school to the district offices.

The most common LAN technologies in use today are ethernet and
LocalTalk.  (IEEE 802.5 Token Ring is not recommended for new
installations.  It is more expensive and it is not available for as
wide a range of computers.)  Both are quite inexpensive and easy to
install and maintain.  Ethernet is adaptable to most modern computers
and is built-in to high performance workstations such as Sun,
Hewlett-Packard, SGI, or Digital Equipment Corporation computers.
LocalTalk is built-in to all Macintosh computers and is adaptable to
DOS PC computers as well.  Ethernet is roughly 20 to 40 times faster
than LocalTalk.  Therefore ethernet is recommended for all computer
connections, when possible, and for the school LAN "backbone" or
network distribution system.

## 1.1  Network Adapters and Software

Individual computers will require network or communications adapters
and appropriate software.  Table 1 gives basic recommendations for
the computers most commonly found in schools.  Basic communications
software is available in the public domain for many personal
computers at no cost.  More sophisticated software is being developed
by a number of vendors for applications such as electronic mail,
distance learning, and multimedia database access.  For example, the
California Technology Project is developing very easy to use software
for Macintosh and DOS or Windows PC computers that will enable access
to a wide variety of information resources and services.  Schools
should look at all the available software and base choices on
required functionality and support costs as well as acquisition
costs.

In locations where computers will be purchased, the choice of
computer type should be driven by the availability of software for
the particular application(s) to be supported.  Almost all modern
computers can be attached to the type of network described in this
document.

| Equipment Type | Network Adapter | Communication Software |
|---|---|---|
| Simple terminal | "Network Access Server" located centrally. | Built-in to the networkaccess server. |
| Apple II, Amiga, Tandy, Commodore, older IBM PCs, etc. | Serial asynchronous port that will allow connection to the above. | Serial communications software that emulates a simple terminal. |
| Newer IBM PC | Ethernet adapter car with "10-base-T" port. "Thin-net" port may be used in lab clusters. | TCP/IP "TSR" software, for example "FTP Software" package. Additional software for special appl. |
| Older Apple Macintosh computers | PhoneNet adapter  MacTCP (external) and shared LocalTalk to ethernet router, for example the Shiva FastPath. | or equivalent plus "telnet" and "ftp". For example, NCSA Telnet.  Additional software for special applications, e.g., "electronic mail client." |
| Newer Apple Macintosh computers | May use same as the above.  For higher performance, use an ethernet adapter card with "10-base-T port. "Thin-net" port may be used in lab clusters. | Same as the above. |
| Unix workstations | Ethernet adapter card, if not already built in. | Typically comes with the basic system. Additional software may be needed for special applications. |

    Table 1:  Network Adapters and Software for Typical Computers

1.2  Premise wiring

   A major component of the implementation will be installation of
   cabling to connect individual computers or clusters of computers to
   the LAN.  The recommended topology is a "star" where each computer is
   wired directly to a "hub site" within the building as shown in
   Figures 1 & 2.  A cluster of computers, typically found in a teaching
   lab or library, may be interconnected within the room where they are
   installed, and the cluster connected to the hub site with a single
   cable as shown in Figures 3 & 4.

   The recommended premise wiring is "unshielded twisted pair" (UTP)
   wire that meets the Electronic Industries Association (EIA) category
   5 standards for high speed data communication service.  (See
   EIA/TIA-568 "Commercial Building Telecommunications Wiring
   Standard.")  While 2 pair cable may be adequate for most purposes,
   industry standards recommend installation of 4 pair cable.  The
   difference in cost is minimal so we recommend installation of the
   latter.  One end of each cable terminates in a category 5 RJ-45 jack
   (A standard RJ45 jack can be used for ethernet or lower speeds if
   initial cost is amajor factor.  Such jacks can be replaced with
   category 5 versions later as needed.) located near the computer.  The
   other end terminates on a standard "110 distribution block" (In older
   sites, M66 distribution blocks may already be installed.  These can
   be used for the time being but will not support newer higher speed
   technologies.) at the hub site utility closet.  A labeling scheme
   must be chosen and strictly adhered to so that cables can be
   identified at both ends later, as needed.

       [Figure 1:  Individual ethernet connection to the network]

           [Figure 2:  LocalTalk connection to the network]

   In most cases, the hub site utility closet will be shared with
   telephone services.  It is essential that a separate wall area be set
   aside within the closet for data service interconnections. Typically
   there will be a "field" of interconnect blocks for termination of all
   premise wires, another field for termination of trunk cables (used
   for low speed data terminals), and a third field for hub equipment
   ports.  Interconnections between premise wiring blocks and hub or
   trunk blocks are installed as needed in order to provide the
   appropriate service to each location where communication service is
   required.

       [Figure 3:  A cluster of computers connected to the network]

       [Figure 4:  A Macintosh cluster connection to the network]

Installation of wiring in a building typically is performed by a
qualified data wiring contractor.  This is a critical aspect of the
program and must be planned and installed professionally with both
current and future requirements in mind.  (See "Virtual Schoolhouse -
A Report to the Legislature on Distribution Infrastructures for
Advanced Technologies in the Construction of New Schools, K through
12" (Department of General Services, State of California, February,
1993) for example conduit and utility closet plans.)  To be prepared
for future distribution of video signals, school network planners
should consider installation of RG-59 coaxial cable to those
locations where video may be required at the same time that the UTP
premise wiring is being installed.  The coaxial cable would terminate
on a wall plate mounted "F" connector in the classroom, and would be
left unterminated in the utility closet.  Future technologies may
support video signals over other media so the installation of RG-59
cable should be limited to near term potential requirements.

It will be cost effective to install premise wiring to as many
locations as might ever serve a computer.  This will include
administrative offices as well as classrooms, laboratories as well as
libraries.  In high density locations such as offices, consideration
should be given to installation of two UTP cables to each outlet
location in order to provide the potential for several computers or
workstations.  Terminating both cables on the same wall plate will
add little to the overall wiring project costs and will add greatly
to the flexibility of the system.  Premise wiring that is not to be
used initially will not be connected to any electronics in the hub
site.

Hub sites should be utility closets or other protected, non-occupied
areas.  Hub sites can be created by construction of small closets or
cabinets in low use areas.  A hub site must be located within 300
feet of any connection.  Typically, multiple hub sites are required
in large or multi-story buildings.

1.3  Network Distribution System

All hub sites within a school must be interconnected to complete the
school LAN.  The design of this network distribution system will
depend greatly on the physical layout of the school buildings.  We
assume that ethernet technology will be used since higher speed
technology is still quite expensive.

               [Figure 5:  A complete small school LAN]

If all hub sites are within 300 cable feet of a central location,
then 10-base-T wiring can be used from a central hub to connect each
hub site, as shown in Figure 5.  If longer distances are required,

either thin-net or standard thick ethernet can be used.  Fiber optic
cable can be used if distance requires it and funding permits.  (If
fiber optic cable is installed, consideration should be given to
including both multimode fiber for current and future data
requirements and single mode fiber for video and future very high
speed data systems.) Specific design of the "backbone" network
distribution system will depend on the layout of the buildings to be
served.

With proper design as many as 250 computers can be connected to a
single ethernet segment.  Most often the practical maximum number
will be much lower than this due to the amount of data sent onto the
network by each computer.  For planning purposes, one can assume
100-125 computers per segment.  Beyond that size the network must be
subdivided using "subnetworks".  Design of a such a system is not
difficult, but is beyond the scope of this document.

The network distribution system cabling should include unshielded
multi-pair trunk cabling as well as ethernet trunk cabling.  The
multi-pair trunk cable will be needed to connect terminals or older
computers emulating terminals to a central "network access server"
(NAS).  A typical NAS can serve from 8 to 128 such connections.  It
is most cost effective to provide one per LAN, if needed.  The NAS
connects directly to the ethernet LAN.

## 1.4  Local Network Server

It is highly recommended that each school install a "network server"
to support local storage of commonly used information, software,
electronic mail, and other functions that may require high speed
communication to the users computer.  Since the connection to the
outside network will be much slower than the school LAN, it will be
most efficient to access information locally.  In particular,
software that is to be shared among the schools computers must be
stored locally since it would be very tedious to transfer it across
the slower external link.  The network server will be connected
directly to the ethernet network.

The location of the server should be chosen carefully to ensure its
protection from abuse and environmental damage.  Traditionally the
school library is the focus of information gathering and storage
activities and many school libraries have clusters of computers or
terminals already installed.  The library would be a very logical
place to locate the network server computer.  The Network Router (see
below) might also be located there if a suitable utility space is not
available.

The network server will be a small but powerful computer with a large
amount of disk storage capacity, typically 1-4 gigabytes.  It will
run software capable of supporting access by a large number of users
simultaneously.  It could also support dial-in access from teachers
or students homes using standard inexpensive modems.  (Access control
with user authentication is essential if dial-in service is to be
provided.)  If more than a few modems are to be installed, a NAS
might prove more cost effective.  If dial-in access is to be provided
to more than a few school sites within a district, a single central
modem pool maintainted at the district offices will be the most cost
effective.

## 1.5  External Connection

A single communication circuit will connect the school LAN to the
local school district offices.  In the school, there will be a
Network Router attached between the LAN and this circuit.  On the LAN
side, the connection will be a typical ethernet cable.  On the
external side, the connection will depend on the type of
communication circuit used, as discussed in step 2 below.

## Step 2: Interconnection of Schools with District Offices

All schools within a district should be connected individually to the
network router at the school district offices.  This "star topology"
will be much easier to manage and the capacity of each schools
connection can be increased appropriately as needs change.

Several standard communication circuit services may be used to effect
this connection.  The least expensive for situations where only
limited use is needed will be dial-up using high speed modems.
However, this type of connection is not recommended for serious usage
due to its very limited capacity.  Also, since most schools receive
telephone service under business tariffs, usage will be measured and
the cost will be dependent on how long the connection is maintained.
This will be true in general for other "switched services" as well
such as "switched-56" and ISDN.  Dedicated (permanently installed)
communications circuits are strongly recommended since they will
allow unattended access to and from the school network at all hours.
This will be particularly important if information files are to be
down-loaded during the night to local network servers or teachers and
students are to access the schools information resources from home.

Table 2 shows the most common options for dedicated circuit services.
Costs are indicated in relative terms since they vary greatly by
location and as tariffs are modified.  The exact costs must be
determined by contacting local communications service providers.
Total cost must take into account the equipment needed at each

location as well.

| Type of Circuit | Data Rate | Relative cost |
|---|---|---|
| Voice grade leased telephone line | 20 kilobits per sec (Kb/s) | modest* |
| ADN-56 | 56 Kb/s | high |
| ISDN, where available | 64 or 128 Kb/s | modest** |
| Low power radio | 64 to 256 Kb/s | high startup cost |
| Frame Relay | 56 Kb/s to 1.5 Mb/s | modest to high |
| DS1 | 1.5 megabits per sec | very high |

* Measured service charges must be taken into account.
** At this time, most ISDN tarriffs include message unit charges
   which can make theuse of ISDN prohibitively expensive for
   full-time connectivity.

Table 2: External Connection Communications Options

Frame Relay communication services are becoming available in many
areas.  Frame Relay is a shared, packet based data transport service.
A school site would contract for Frame Relay service as part of a
larger service group that includes the school district office and may
include the Internet service provider.  All members of that group
would share the communications capacity.  The advantage of this
service is that only one end of the circuit needs to be ordered (each
member orders a connection to the common service) and the capacity
offered to each member can be upgraded independently.  Also, in many
areas the cost of Frame Relay service is not dependent on distance to
the service provider which will make service to rural schools much
less expensive than equivalent services.  Overall system costs will
be minimized since the central router at the district office will
need fewer connections.

If Frame Relay is chosen, the overall service group must be carefully
engineered.  For example, since all schools would share the
connection to the district office (and possibly to the Internet
service provider), that must be a high capacity connection.  For the
initial design, the aggregate capacity of all school links should not

exceed the capacity into the district office (or the Internet service
provider) by more than a factor of 3 or there may be noticeable
congestion and variability in response times across the system.
There are many other factors that must be considered as well, such as
the virtual connection topology and how best to connect to an
Internet service provider.  Therefore, it is recommended that an
experienced network engineer be utilized to develop an operational
plan for Frame Relay if it is chosen as the school interconnection
service.

Future options for interconnecting schools and district offices will
include:

o        Community Access Television (CATV) cable systems offering
         either shared or dedicated bi-directional data communication
         services,

o        metropolitan area fiber optic communications service
         providers,

o        Switched Multi-megabit Digital Service (SMDS) providing data
         transport service at speeds up to 34 megabits per second.

o        Asynchronous Transfer Mode (ATM) connection services
         supporting voice, data, and video communications at speeds
         into the gigabit per second range.

(Many more options will become available as new technologies come to
market.)

The costs for the last three options are unknown at this time, but
may be generally higher than those indicated in Table 2.  The cost
for the CATV option may be negotiable as part of the local CATV
contract with the community.

As demands for network speed develop due to heavy use of multimedia
or other bandwidth intensive application, higher speed communications
circuits can replace the initial circuits with minimal change in the
equipment or LAN.  This gives great flexibility in tailoring service
to funding levels and application needs.

Step 3: School District Office LAN and Support Systems

The School District offices should form the focal point for
interconnection of all schools in the district.  Within the District
offices, network operations can be monitored and problem resolution
managed.  One or more network servers can provide essential network
support as well as central archiving of common information and

software.

A critical role of the district office will be to manage Internet
"Domain Name System" (DNS) (See STD 13, RFCs 1034, 1035 for the full
explanation of DNS, and also, RFC 1480.) service for the districts
schools.  DNS is required of all Internet networks.  It defines the
basic network level identity of each computer, workstation, server,
and active network component.  This function is described more fully
below under Network Management and Operational Monitoring.

The district offices should be wired in a manner similar to a typical
school, as shown above.  This will allow teachers, superintendents,
and principals to communicate and share information easily.  In
addition, an NAS connected to a central pool of modems could provide
dial-in access to the district network.

Step 4: Interconnection of the School District with the Internet

Connection of the entire school district to the Internet will take
place through the district office interconnect site, as shown in
Figure 6.  This hierarchical model can be extended another level to
interconnection of the school district offices through the county
office of education facilities.  Many administrative information
resources could be located at the county level, and there might be
cost savings if the entire county connects to an Internet service
provider through a single point.  The bandwidth required for this
single connection, however, will be much greater than that required
for each school district since traffic will be aggregated.

This hierarchical topology also provides a logical model for network
support and information resource management.  The school district or
county offices can provide continuous monitoring of the network and
provide high level technical expertise for problem resolution,
relieving the individual schools of this burden.  Interactions with
communications circuit providers and Internet service providers will
be more effective if handled through a central "trouble desk".
Similarly, it is highly desirable that network users have a single,
well known point of contact in case of problems or questions.

Internet service should be acquired from the most cost effective,
reliable Internet service provider.  Circuit services can be similar
to those shown in Table 2 above.  The higher speed services should be
considered if traffic demands increase and funding permits.  Circuit
costs usually will be lowest when connecting to the provider with the
nearest "point of presence" (POP), but newer technologies such as
Frame Relay and SMDS (At this time, SMDS services are not widely
available.) make circuit costs less dependent on distance.  The
Internet connection will require a high quality router that can be

configured to interact correctly with the service providers routers.
In most cases, this can be the same router used to support the local
school connections.

   [Figure 6:  Interconnection of schools to the Internet through local
                      School District Offices]

Integration of Existing School Networks

   Many schools have developed LAN systems in support of particular
   classroom activities or administrative functions.  In some cases the
   technologies used are not those recommended for new installations. If
   these older LAN systems are capable of transporting Internet
   protocols they may be integrated into a new LAN system and replaced
   later as funding permits.

   For example, IEEE 802.5 Token Ring is often used to interconnect DOS
   PC-type computers and IBM minicomputer servers.  Token Ring networks
   can transport Internet protocols and software is available for DOS
   computers to support basic Internet functions.  Many Internet routers
   support optional Token Ring adapters.  This is the recommended way
   that existing Token Ring LANs can be integrated into a wider school
   LAN system in order to extend Internet information resources to those
   PC users.

   Another example is a Novell Network system using ethernet as a LAN.
   The ethernet LAN, if implemented well, is perfectly capable of
   transporting Internet protocols as well as Novell protocols,
   simultaneously.  Each PC or Macintosh can be given software that will
   allow both Novell and Internet services to be used as needed. This
   coexistence is important so that, for example, a person using a PC
   that depends on the Novell server for disk file space can transfer a
   large file from a remote Internet server to the PCs pseudo-disk.  It
   also permits each user to run client software such as Eudora
   (electronic mail), Gopher (information services), and Mosaic (World
   Wide Web information services) which require direct Internet access.
   To integrate the Novell ethernet LAN into the wider school LAN system
   a simple ethernet repeater can be used in a manner similar to Figure
   3 above.

   An alternative to supporting both protocols that is sometimes
   suggested in cases such as the one cited above in which a network
   server already exists is to use the server as a "network application
   gateway".  This approach is strongly discouraged.  It is essential
   that each computer and workstation support Internet protocol data
   communication directly so that modern client/server applications can
   be supported where the server or servers may be located anywhere on
   the Internet.  The "gateway" approach severely restricts the

workstations potential ability to access multimedia and other
important information resources.

Some technologies, such as "arcnet," may not be capable of supporting
Internet protocols but may offer "terminal emulation" shared access
to something like a "modem pool".  The modem adapter might be rewired
to connect to ports on a network access server instead.  This would
provide simple access to information resources for the arcnet users.

In any case, older LAN technologies should not be expanded and should
be phased out as funding permits.  It is critical that there be a
relatively homogeneous installed base of technology in order that new
applications of information resources can be provided to the entire
school community.

Network Management and Operational Monitoring

All networks require some level of network management in order to
ensure reliable service.  Monitoring of the health of the network can
help identify problems before they become detrimental to network
users.  It also can help predict trends in traffic patterns and
volume.

Internet technology network management consists primarily of
determining the proper routing parameters for optimal and reliable
network operation, assignment of network Internet Protocol (IP)
addresses and maintenance of a network-accessible database of node
names corresponding to each address (See RFC 1480 for a discussion of
Internet naming conventions for school networks.), and monitoring the
daily operation of the network.  These functions typically are
performed by the staff of a Network Operations Center (NOC).

Domain Name System

The Internet Domain Name System (DNS) is the mechanism for
documenting and distributing information about the name and address
of each computer attached to the network (network nodes).  The DNS
service is provided by software that runs on the main network server.
It uses a database that is created and maintained by the NOC staff.

An Internet address is the numerical identifier for a node and it
must be unique among all nodes associated with the network.
Furthermore, if the network is to be part of the global Internet, all
addresses must be legitimate within the worldwide Internet system.

Associated with each numerical address can be one or more "node
names".  Although computers have no difficulty using numerical
addresses, it is often easier for computer users to remember and use

the node names rather than the numerical addresses.  In particular,
electronic mail addresses use node names.  DNS node names are
hierarchical and by appropriately using this hierarchy "subdomains"
can be assigned to each school site or district office.  In this way,
naming can be structured to be flexible as well as meaningful in the
context of the whole organization.

A plan for the assignment of IP network addresses and node names
should be developed early in the planning for the network
installation.  Initially, the database serving the DNS should reside
on the "district server" so that there is one site at which all
assignments are officially registered.  As the network grows and
expertise is developed, secondary DNS service can be run on the
servers at larger school sites.

The main DNS server for the district should be located as close to
the Internet connection (topologically) as possible.  This proximity
is to help ensure that network problems within the district network
will have minimal impact on access to the server.  This design is
illustrated in Figure 1 where the district server is on an ethernet
connected directly to the main distribution router.

Associated with the assignment of node names and addresses should be
a database of specific information about the computers connected to
the network.  When trying to resolve problems or answer user
questions, it is very important to know where the computers and other
nodes are located, what type of computer and software are in use, and
what type of network connection is installed.  With proper software
this database can be used to extract the DNS database discussed
above.

Network Monitoring

Internet network monitoring serves three primary purposes:

1) Constant observation of the "health" of the network, network
   components, and external network connectivity.  Standard Simple
   Network Management Protocol (SNMP) support is built-in to most
   active components today.  Even network servers and workstations
   can be monitored in this way.  Operations staff can be provided
   with network monitoring stations that will display alerts
   immediately upon detecting a wide variety of problems or
   anomalies;

2) Collection of statistics on the performance of the network and
   patterns of traffic in order to identify needed enhancements or
   re-engineering.  Using the same SNMP capabilities mentioned
   above, data on packet forwarding and total traffic volume can

be collected and used to generate periodic reports on network
utilization;

3) More rapid problem resolution.  When problems do occur, SNMP
   tools can help to pinpoint the source of the problem(s).  Such
   problems include transient routing anomalies, DNS query
   failures, or even attempts at breaking into network accessible
   host computers.

   Since network management and monitoring is a technically
   demanding task and requires special equipment and software, it
   should be a centralized function in the initial design of school
   network systems, as discussed above.

IV.  Network Support

Summary

The model for school network implementation described above is based
on broad experience with this technology in higher education and
administrative environments.  Many schools have already installed
networks very similar to this model.  We believe that it is a
practical first step towards bringing a powerful resource to bear for
enriching all of the nations school programs.

None of the suggestions above preclude or postpone in any way future
development of an integrated voice, data, and video network for the
nations schools.  Use of existing Internet carriers does not in any
way preclude future development of a separate "backbone" for the K-12
community if such a "backbone" is determined to be cost effective or
required for enhanced functionality.  Rather, the infrastructure
recommended above can be the foundation at the local level in
preparation for future high capacity networks.

The installation of a campuswide network or Internet connectivity
will also require a commitment to ongoing network support and its
related resource requirements.  There are two major areas of network
support, network operations and user services.  These support
functions are usually performed through the establishment of a
Network Operations Center (NOC) and Network Information Center (NIC),
however both functions can be performed by the same individual or
groups of individuals.

Network Operations Center (NOC)

   The Network Operations Center (NOC) oversees the performance of the
   physical network and some of its software support systems.  The staff
   may install networks, configure network devices and provide
   configurations for computers attached to an organization-wide
   network.  Real-time monitoring of the network can be performed using
   the Simple Network Management Protocol and many vendors produce
   monitoring systems that graphically display network performance, log
   events and usage, and produce trouble tickets.  The use of this type
   of network monitoring allows NOC staff to quickly detect problems and
   greatly reduces the personnel required to perform this function.
   Routine monitoring of the network can help to anticipate problems
   before they develop and lead to reconfigurations and upgrades as
   indicated.  If problems do arise, NOC personnel may go on-site to
   troubleshoot a problem and repair it.  If the problem is not local,
   NOC personnel will work with school district, County or regional
   network technical staff to resolve the problem.

   NOC personnel also assign addresses to network computers and devices
   and maintain the Domain Nameservice (DNS) for their organization.
   Domain Nameservice is a machine registry service that runs on a
   network server and enables access to machines by easy to remember
   names, rather than a network number.  DNS is required for any
   organization connected to the Internet and critical to the
   establishment of an electronic mail system.

   It is most cost effective to have the Network Operation Center serve
   an entire organization or region.  In order to ensure timely service
   all the way out to the most remote LAN, it is recommended that an
   organization assign local area network administration duties to on-
   site personnel to interact with NOC staff and assist with the
   maintenance of the network.  In the case of a school district,
   administrative support staff, teachers, librarians or school based
   technical staff can each take responsibility for a LAN or group of
   LANs.  If a problem arises, it can be reported to the LAN
   administrator.  The LAN administrator can determine if the problem is
   local or remote and if NOC staff need to be notified.  If so, the LAN
   administrator acts as the single point of contact for the NOC to
   provide a good communications channel for information and ensure
   efficient coordination of problem resolution.  This method of
   delegating responsibility provides for a high level of service for
   each LAN and optimally uses the time of NOC staff to provide
   economies of scale.

Network Information Center (NIC)

   The Network Information Center (NIC) provides information and support
   services to facilitate the use of the network.  The NIC often
   provides a help-desk service to answer questions about use of the
   network, references to useful resources and training in new tools or
   applications.  The NIC may also provide services such as an on-line
   directory of network users and their electronic mail addresses,
   bulletin board services of information and notices about the network
   and on-line training materials.  These NIC services could be provided
   on a school district or County level.  Most of the information would
   not be site specific and can be delivered electronically using
   electronic mail, electronic conferencing, on-line bulletin boards or
   other document delivery mechanisms.  These types of services may be
   well suited for a school or school district librarian.

   Other types of support services may be performed by NIC personnel
   such as maintenance of the electronic mail system or Postmaster
   duties, coordination of an on-line bulletin board or campuswide
   information system (CWIS) and management of an on-line conferencing
   system.  These duties are more technical in nature and will require
   technical staff to maintain them.

Postmaster

   Every organization which uses electronic mail should have an
   Electronic Mail Postmaster and a mailbox, postmaster, for the receipt
   of messages regarding use of the electronic mail system, mail
   problems and general inquiries about reaching people within the
   organization.  The Postmaster is responsible for reading postmaster
   mail and responding to inquiries.  These duties can be performed by
   non-technical staff with forwarding of messages to the appropriate
   technical support person as required.

CWIS Administrator

   Campuswide information systems or bulletin boards are one of the most
   useful applications on the network.  These systems allow people to
   share timely notices, documents and other resources with large groups
   of people.  These systems typically provide a hierarchical or tree
   like structure of menus that lead to on-line documents or other
   services.  Common types of information include deadline notices,
   grant announcements, training schedules, lists of available resources
   such as videos in a library or reference materials.

            [Figure 7:  Distributed Network Information Servers]

Information need not be stored all in one location.  Figure 7 shows a
set of distributed servers.  These servers can receive new
information automatically from a central server and can also contain
information generated locally that may pertain only to the local
school.  Users of the information need not know where the information
is stored: the information access software will present choices on an
integrated menu.

A CWIS or bulletin board must have an administrator or sponsor to
oversee the design and maintenance of the system so that it is easy
to navigate and find information, provides a professional
presentation of information and ensures that information remains
timely and relevant.  This function can be performed by NIC staff, or
trained librarians or administrative staff as appropriate.

Management of On-line Conferences

On-line conferences provide a way for groups of people to share
information, discuss ideas and pose questions.  Conferences usually
are set up to serve the needs of a group of people sharing a common
interest.  For example, an on-line conference might be established
for teachers to discuss a new science teaching framework or a teacher
may establish a conference for the discussion of the Civil War as
part of an American History class.  Some conferences are on-going and
may exist for years.  Others are short term and may exist for only
one semester.  Conferences may be created using the electronic mail
system or a facility called Usenet News.

On-line conferencing systems require a server computer on the network
that collects messages posted to a conference and distributes them
when requested.  Usually these systems are managed by a systems
administrator and someone must configure the system to establish and
delete groups upon request.  Other management duties include
scheduling the deletion of old messages and archiving especially
valuable conversations.  Typically these duties are performed by a
systems administrator or technical staff.

Staffing Considerations

The duties described above do not necessarily require hiring new
staff and they may be shared by people already within an
organization.  Small schools or districts may rely on County Office
of Education Information Systems staff to perform all functions.
Larger schools or districts may have staff to take on any combination
of duties and rely on the County Office of Education for others.
Access to the network and the use of electronic communications allows
people throughout the organization to perform these functions
remotely.  The assignment of responsibility for any of these duties

is flexible and should be approached with the goal of providing the
highest quality of service in the most cost effective and workable
manner.

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**VII.   Security Considerations**

   Security issues are not discussed in this memo.

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