DRAFT

K-12 CONECTIONS TO THE INTERNET

by
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Introduction

We address establishing connectivity to the Internet for K-12 schools. In particular, our focus will be to connect school districts, i.e. we recommend providing only one connection per school district. The rationale here is that, once a single school in the school district becomes connected, the remainder of the school district will become connected after they see the value in the single connection (an element of "keeping up with the Joneses" exists here).

Indeed, we have observed just this situation with Rocky Mountain High School (RMHS) in Fort Collins, which became connected to the Internet in 1990 using donated equipment. Colorado SuperNet donated a Cisco MGS Gateway, and IBM donated two RS 6000's and one X-terminal. This project was so successful that the entire school district (the PR-1 School District) established connectivity through RMHS during the Fall of 1991, at a cost of almost $200,000! This large leverage ratio has existed for networking in general across the nation. During government fiscal year 1989, the higher education schools in the Westnet region spent $31 for every $1 of NSF investment in Westnet! It is absolutely critical to establish initial connectivity, as this catalyzes the rapid spread of technology.

Networking Growth Curves

The Rocky Mountain High School pilot program has followed a growth curve that initially was nearly vertical (see Figure 1). Having been deeply involved in the growth of the RMHS pilot program, we have gained much perspective. The RMHS experience provides valuable guidance as we assist other schools in connecting to the Internet. One of the main points that the RMHS project highlights is the issue of UNIX in the high school. The task of learning Internet protocols (telnet, ftp, etc.) and learning to manage a UNIX system proved, at times, almost too much for those involved in the project. The dedicated teachers at the high school spent many late evenings and long weekends of their own time coming up to speed in UNIX. By being located only a mile from the high school, CSU was able to provide "house call" service to assist with networking and UNIX difficulties. Presently, those involved in the RMHS project feel a glow of success, but they recall frequent, painful times that led to that success. Partially because of the experiences of the RMHS project and partially because of recent connectivity advances that allow fairly high quality network access without an on-site UNIX machine, we propose a less challenging model for the next wave of K-12 schools that we assist in connecting to the Internet.

The strategy is to provide the "plug" for their local Ethernet LAN (or asynchronous switch). We surmise that the growth of networking under such a model would appear as shown in Figure 2, over a five year period. Such a growth curve mandates a multi-year effort.

Since the RMHS pilot program was largely a "bootstrap" operation, few in-service training sessions were conducted. This was due partly to a lack of resources, and partly to a lack of a mature

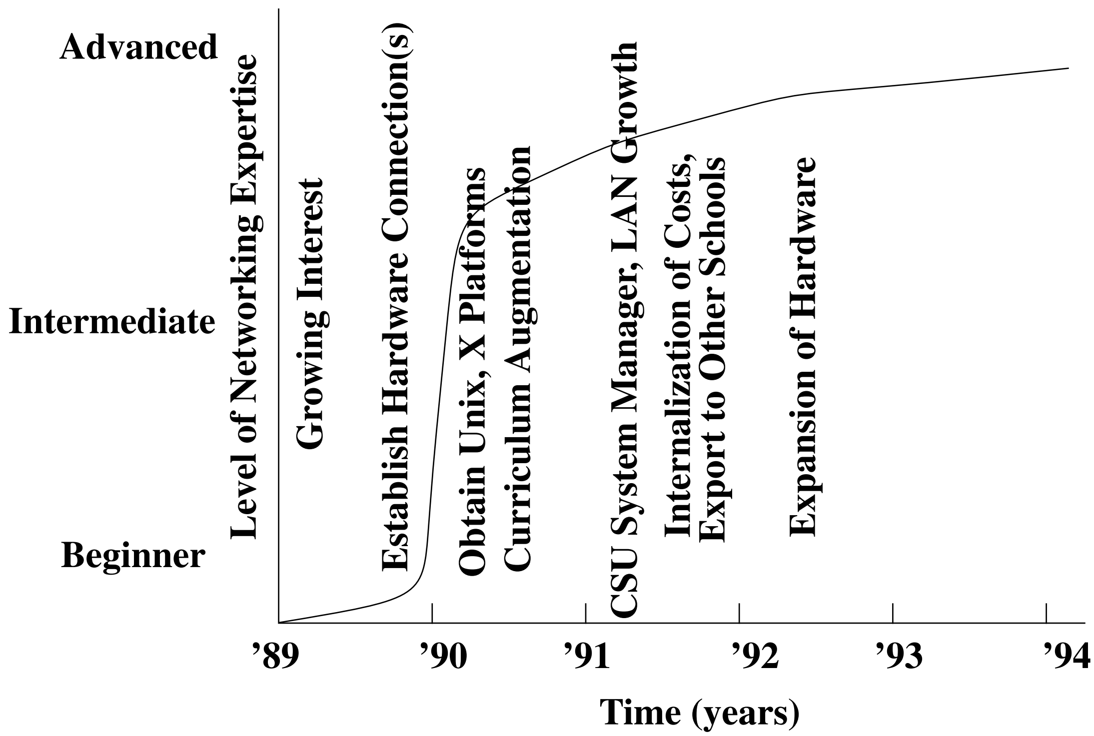


Figure 1 Rocky Mountain High School Networking Growth vs. Time

knowledge base for directing the RMHS program. Using the considerable knowledge and experience base gained from the RMHS effort, we now are in a position to infuse networking and associated educational aspects into schools as they join in our effort.

Technology

We propose three models, numbered 1 through 3, for establishing connections of individual sites to the Internet. We propose model 4 as the model most appropriate for connecting school districts. We now discuss these models.

Model 1 - Asynchronous Dial-In

Figures 3(a) and 3(b) depict these hardware options. Here, an asynchronous modem is used to connect one machine to a remote dial-in site. An automatic, "seeking" asynchronous switch may be used to "lock on" to a specific channel (i.e., machine). Such a switch with four input ports and one output port costs about $60. However, this allows only one machine to be connected at a time, and does not bring the network to the site. I.e., an account must exist remotely on the machine to which the asynchronous connection is established, and all files transferred via *ftp* are transferred to that machine (they can then be down-loaded using *xmodem* or some other protocol). This presents system management problems (accounts - sometimes in large number - must be managed and controlled for remote users). Also, it is a serious disadvantage for only one user to be connected at a time.

However, the advantage of this approach is the high transmission speeds available with relatively inexpensive technology. The recent emergence of v.32bis asynchronous modems permits effective (including data compression) transmission speeds approaching 50 kbaud. Devices of

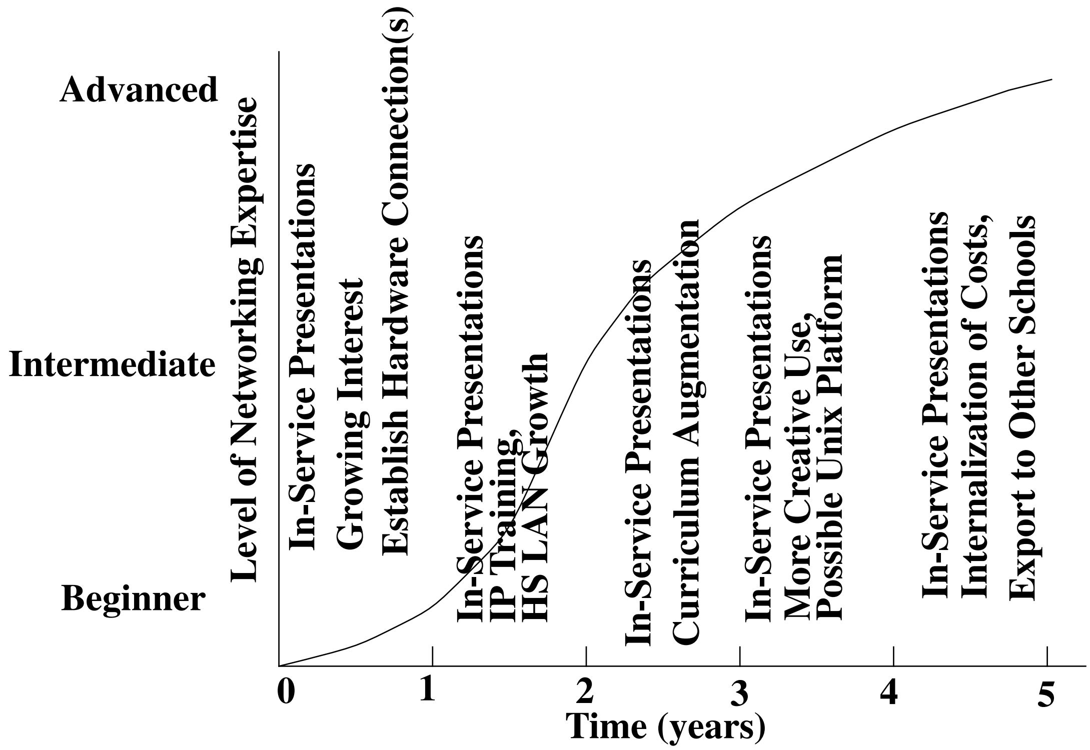


Figure 2 Typical High School Networking Growth vs. Time

good quality are available from Telebit (model T-3000) for about $585 each. Two identical asynchronous modems are required - one at the local (at the school) node, and one at the remote (Internet) node. Also, these devices use non-standard protocols for data compression and transmission (we may assume that they can "talk to themselves," but it may be problematic for them to "talk" to asynchronous modems manufactured by other vendors).

A variation of this model is shown in Figure 3(b). Here Appletalk Remote Access (ARA) can be used to make a remote network of Apple computers function as if they were local to the remote machine. We have little experience with this new technology, but it is advertised to aggregate multiple machines into one asynchronous connection.

Model 2 - Synchronous Dial-In

Technology is just evolving to the point where it is possible cheaply to bring the Internet to the school at a variety of levels. Instrumental in this is the emergence of the Network Applications Technology (NAT) IP router for $1,600. This router provides full IP connectivity for less than the cost of an 8-port terminal server! Furthermore, the circuit connection is able to be scaled using a variety of circuit interfaces, where dial-in using 9,600 baud (or above) synchronous modems (Model 2) is the most appropriate place to begin - an inexpensive, scalable approach. The cost of synchronous modems is decreasing dramatically (some at 9.6 kbaud now cost only about $400). Synchronous modems using standard protocols can achieve data transmission rates of up to 14.4 kbaud. A new standard (v.fast) is under development which will permit transmission speeds of up to 24 kbaud.

Also, synchronous modems implementing data compression are becoming available with data compression built in (although non-standard protocols are used). Two synchronous modems are required - one each at the local and remote nodes. Again, note that devices which use non-standard protocols for data compression and transmission may be problematic (we may assume two identical units will "talk between themselves," but they likely will not "talk" to synchronous modems manufactured by other vendors). Finally, note that a serial interface is required at the remote site. The synchronous modem at the remote site will “plug in” to this (typically via a v.35 interface). Cisco provides a card with 4 serial interfaces for about $2,700 - thus the per site cost is about $700.

Here, the circuit costs may be free, provided the call is local and local calls are not charged by time (depends on your local telephone company and category of service). If the call is long distance, it will be wise to assess typical charges versus purchasing a dedicated digital circuit, such as for Model 3.

Model 3 - 56 kbps Digital Connectivity

Model 3, depicted in Figure 5, is identical to model 2 except that the circuit is a dedicated, digital circuit of speed 56 kbps. For this, the synchronous modems must both be replaced with two CSU/DSU’s (Channel Service Unit/Data Service Unit) - much like a digital modem - at a cost of about $1,000 for each circuit. However, note that a 56 kbps digital circuit (even tariffed at the cheapest FCC#1 rate) will cost about $150 per month, while dial-in circuits may be free, or much lower in cost if they are not free (however, this depends on length of time connected and whether the call is local or long distance).

Again, a serial interface is required at the remote site, as in Model 2.

Model 4 - Connection to a School District

Here, we propose to install a larger Cisco gateway at the school district. The Cisco can then be used as the central hub for the school district. We advocate running the network from the school district to all high schools within the district via synchronous dial-in using NAT routers in the high schools, and establishing at all high schools dial-in for the junior high, middle and elementary schools. This model has worked effectively in the PR-1 school district.

Costs

Table 1 summarizes the hardware costs for each of the above models. Circuit costs will vary depending on location and type of service.

LAN Technology

There are several technologies for connecting computers to Local Area Networks. We recommend the use of Ethernet for Local Area networks for three reasons: (1) it is inexpensive, (2) it is fairly straightforward to manage, and (3) it is sufficiently fast to enable good transmission (it is rated at 10 mbps, but typically one gets only 2 to 3 mbps). Localtalk is Apple’s implementation, and is rated at 700 kbps (but, again, one gets only about 300 kbps). Internet Gateways come with a port (plug) for Ethernet. To implement Ethernet locally, one needs: (1) Ethernet cards for the computers ($100 for PC’s, about $200 for MAC’s), and wiring to connect all the machines together. Wiring for Ethernet comes in three forms: (1) Ethernet thick (we recommend against this), (2) Ethernet thin (we recommend in favor of this), and (3) twisted pair (this is acceptable for limited distances).

Acknowledgment

Much of the technical details for this article was provided by others (we are just collecting it). We thank Dave Menges (dcm@csn.org) of Colorado SuperNet and Bill Kamm (kamm@yuma.ACNS.ColoState.EDU) and Michael Moravan (moravan@yuma.ACNS.ColoState.EDU). In particular, Michael Moravan has tested the NAT router with our Cisco gateways, and assured that they inter-operate.

Comments

We invite comments on this article. We are not technologists - we just struggle with technology as a means to the end of providing Internet connectivity to the many schools within the Westnet region. We would be pleased to provide additional detail, and most pleased to receive corrections and comments on areas which require clarification. Please send us comments via electronic mail (our addresses appear on page 1 in the title area), or surface mail.

Glossary of Acronyms

Appletalk	- Apple's software implementation of local area networking
Asynchronous	- Data transmission where the devices are not required to be in lock-step (permits only one user at a time to access the Internet, except if a terminal servers or multiplexors.demultiplexers are used at both ends)
Asynchronous Switch	- Hardware allowing one computer at a time to connect to the local modem (locks onto a particular incoming channel).
ARA	- Appletalk Remote Access (software allowing multiple users at a time to connect across one modem connection).
Baud	- Binary Audial Digit (essentially one bit per second over a voice-grade circuit).
bps	- Bit per second (over a digital circuit).
Circuit	-Wire used to transmit data - of two types: (1) voice-grade phone lines accessed via dial-in using asynchronous and synchronous modems, and (2) dedicated digital line accessed via CSU/DSU's.
CSU/DSU	- Channel Service Unit/Data Service Unit (like a digital modem - hardware).
Ethernet	- Hardware implementation for LAN's (most common, high performance and inexpensive).
Gatorbox	- Hardware allowing conversion between Ethernet and Appletalk
Internet Gateway	- Hardware allowing multiple users to connect directly to the Internet.
kbps	- Thousands of bits per second.
LAN	- Local Area Network.
Localtalk	- Apple's hardware implementation of local area networking.
MAC	- Apple Macintosh Computer.
mbps	- Millions of bits per second.
NAT	- Network Applications Technology (manufactures Internet gateways).
PC	- IBM Personal Computer or Clone.
Synchronous	- Data transmission requiring timing for all devices to be in lock-step (in full synchronization); with a Gateway, permits multiple machines to access the Internet.
telnet	- Software allowing access across the Internet to remote computers.
Terminal Server	- Hardware allowing multiple users to access the network.
Telebit	- Company manufacturing modems.
V.32	- A communications protocol for modems.
V.32bis	- A communications protocol for modems with enhanced error correction/detection.
V.35	- Hardware interface (cabling) between a gateway and the synchronous modem (cabling, signal conditioning).
WAN	- Wide Area Network (Westnet, for example).

Table 1: Hardware Costs - Models 1 - 3

Model	Item	No. of Units	Unit Cost	Total Cost
1	Telebit T-3000 Modem	2	$585	$1,170
	Asynch. Switch	1	$60	$60
	TOTAL- Model 1			$1,230
2	NAT Router	1	$1,600	$1,600
	Serial Interface	1	$800	$800
	14,400 Synch. Modems	2	$700	$1,400
	TOTAL - Model 2			$3,800
3	NAT Router	1	$1,600	$1,600
	Serial Interface	1	$800	$800
	56 kbps CSU/DSU's	2	$500	$1,000
	TOTAL - Model 3			$3,400
4	Cisco MGS Router	1	$7,000	$7,000
	4S Serial Interface Card	1	$2,700	$2,700
	56 kbps CSU/DSU's	2	$500	$1,000
	TOTAL - Model 4			$10,700

FIGURE 3 MODEL 1: DIAL-IN
(a) Asynchronous Switch

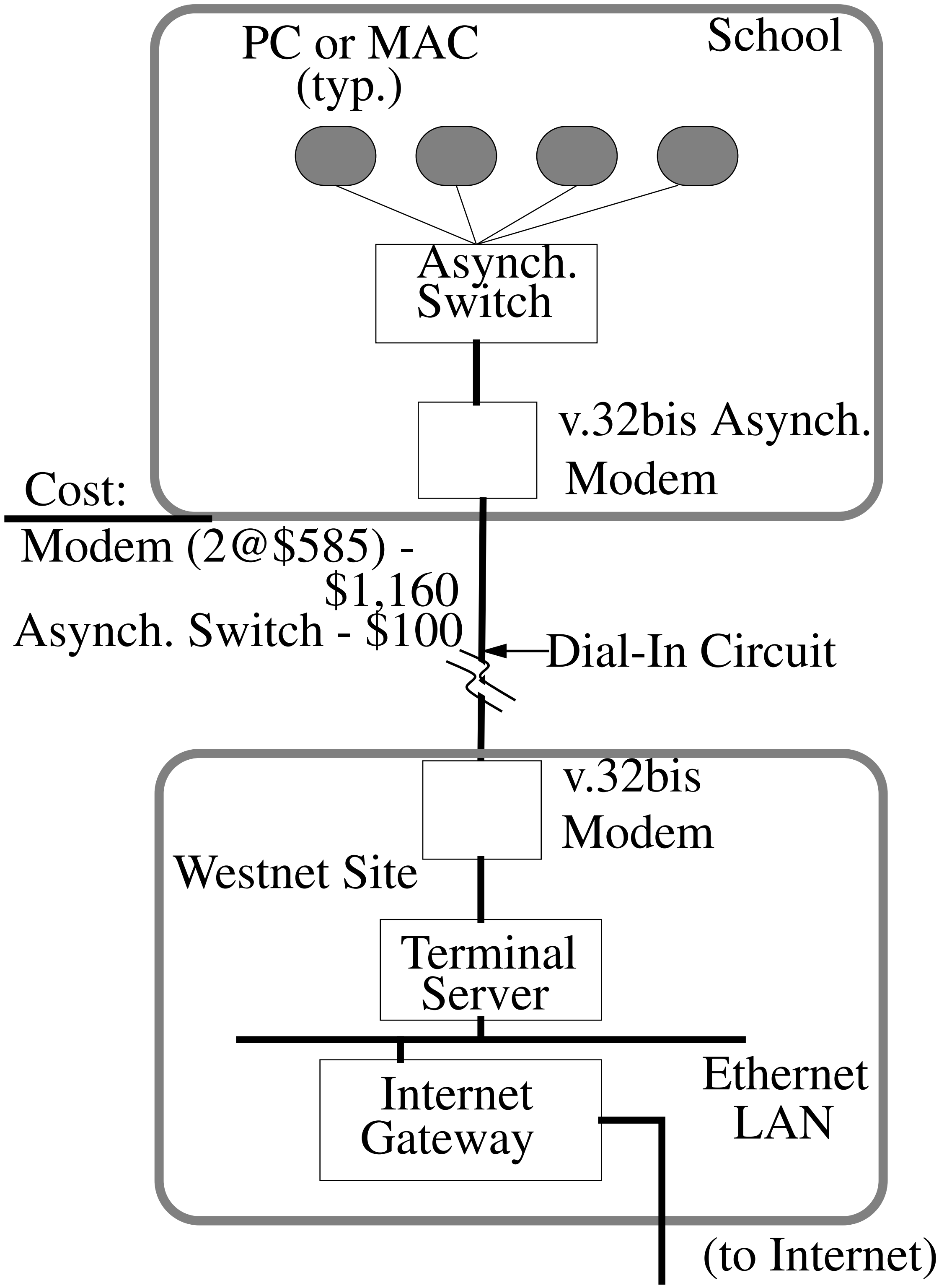


FIGURE 3 MODEL 1: DIAL-IN
(b) MAC's Running ARA

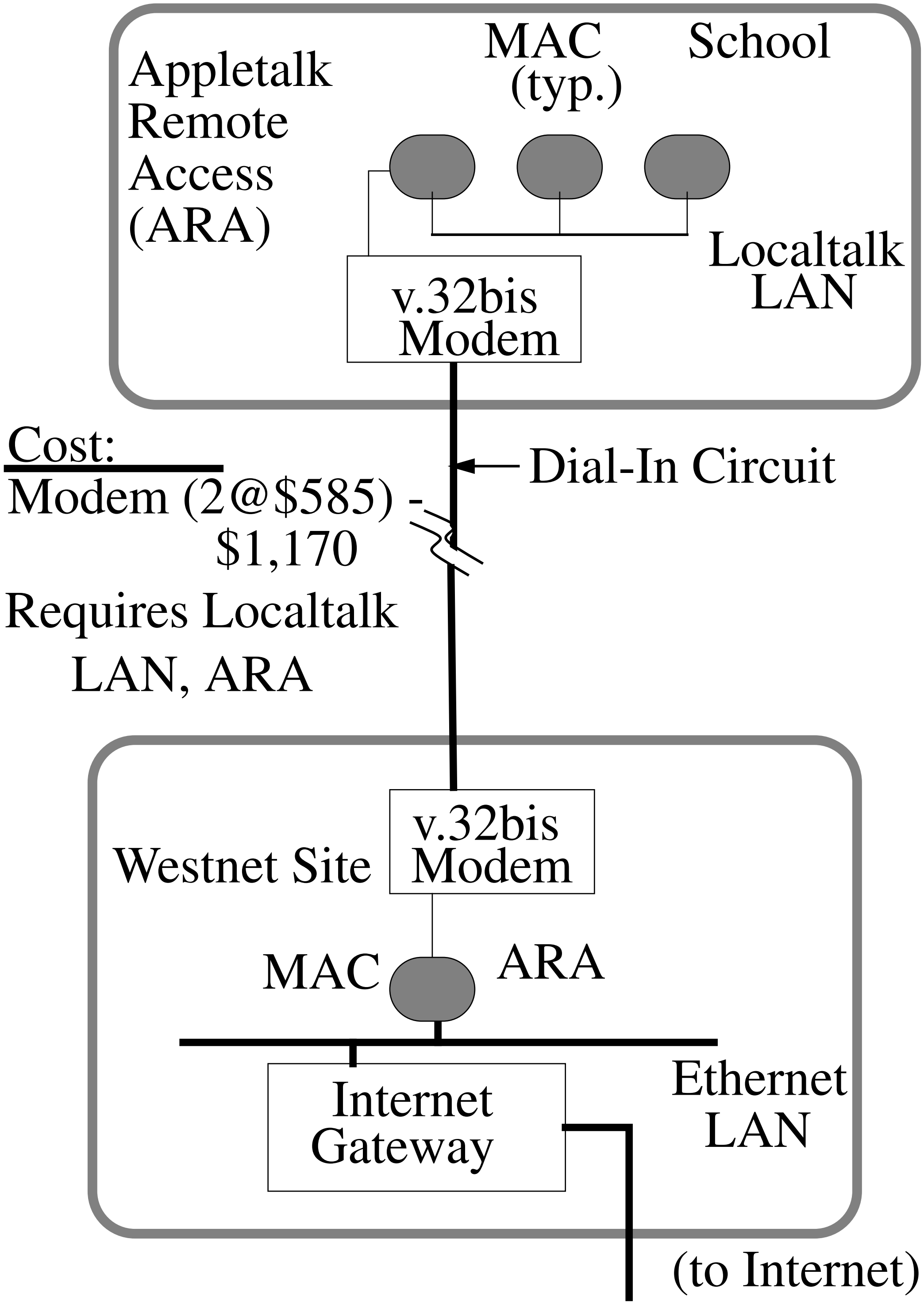
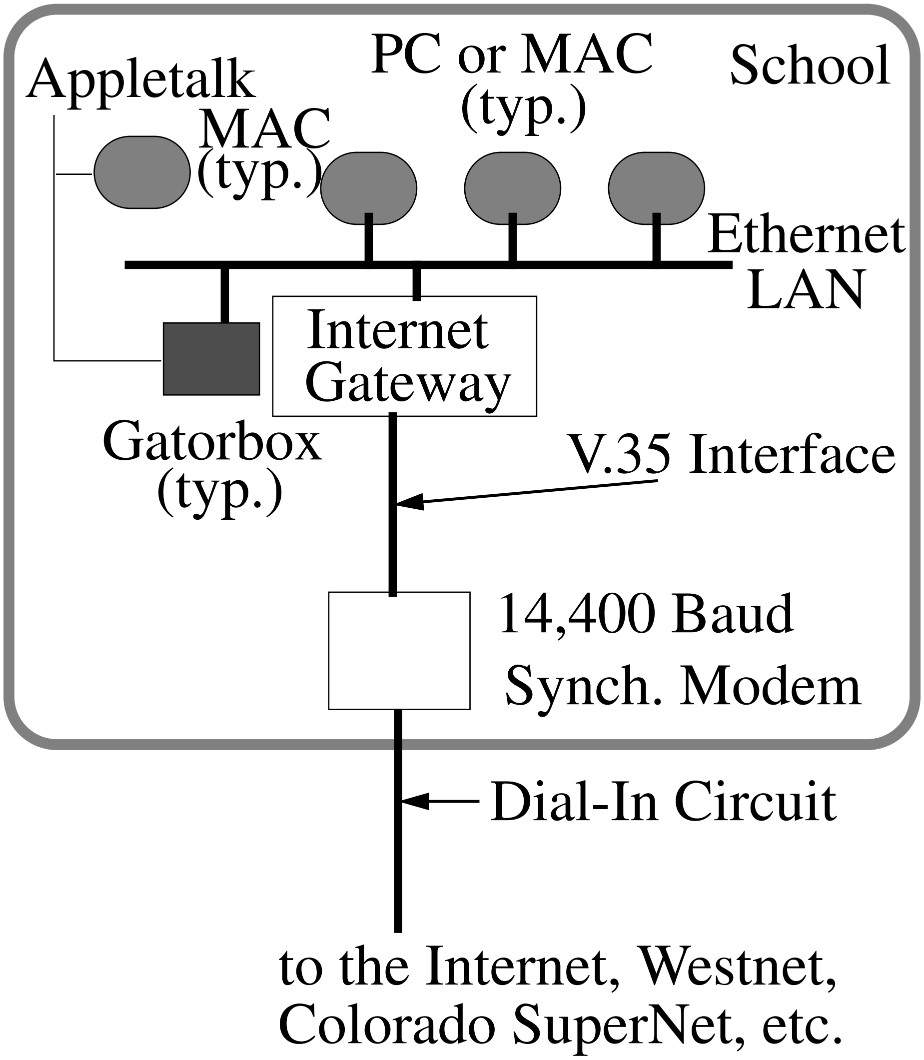


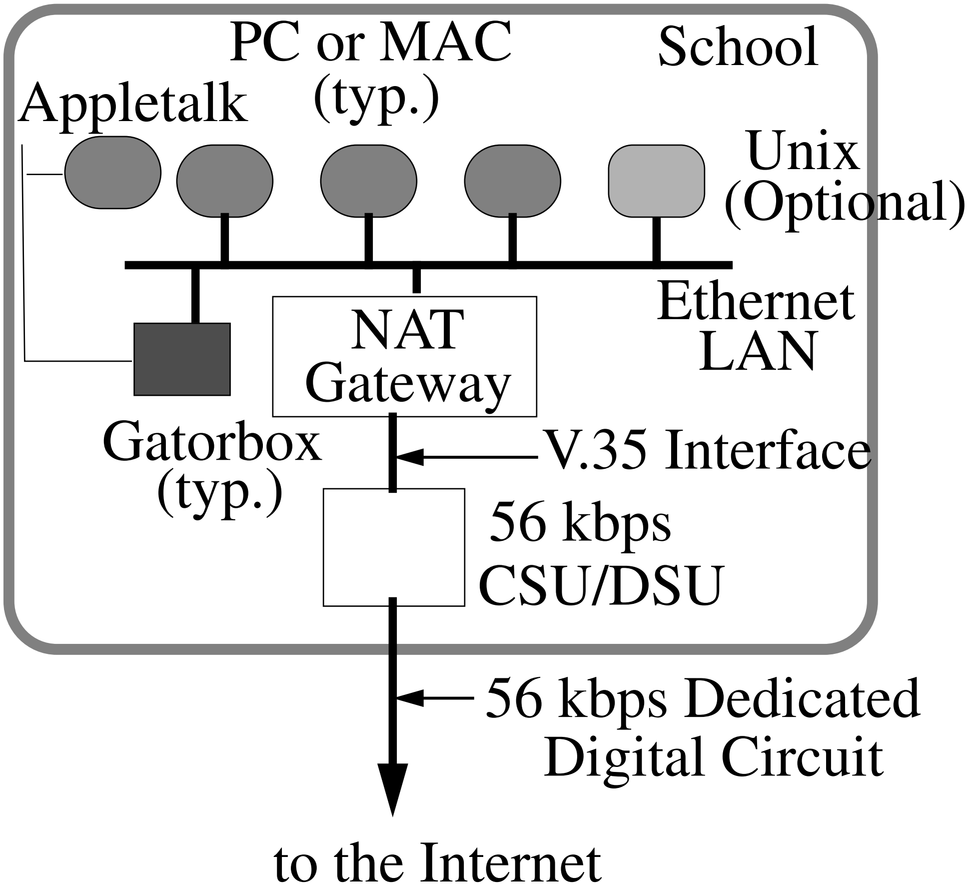
FIG. 4 MODEL 2: BRING THE NETWORK TO THE SITE - SYNCHRONOUS DIAL-IN



Cost:

NAT Gateway (1 ea.) - $1,600
14.4 kbaud Synch. Modem (2@$700) - $1,400
Gatorbox (or equiv.) - $2,100 (optional)
Requires Ethernet/Localtalk LAN at Site and
Serial Port (& Internet Gateway) at Remote Site

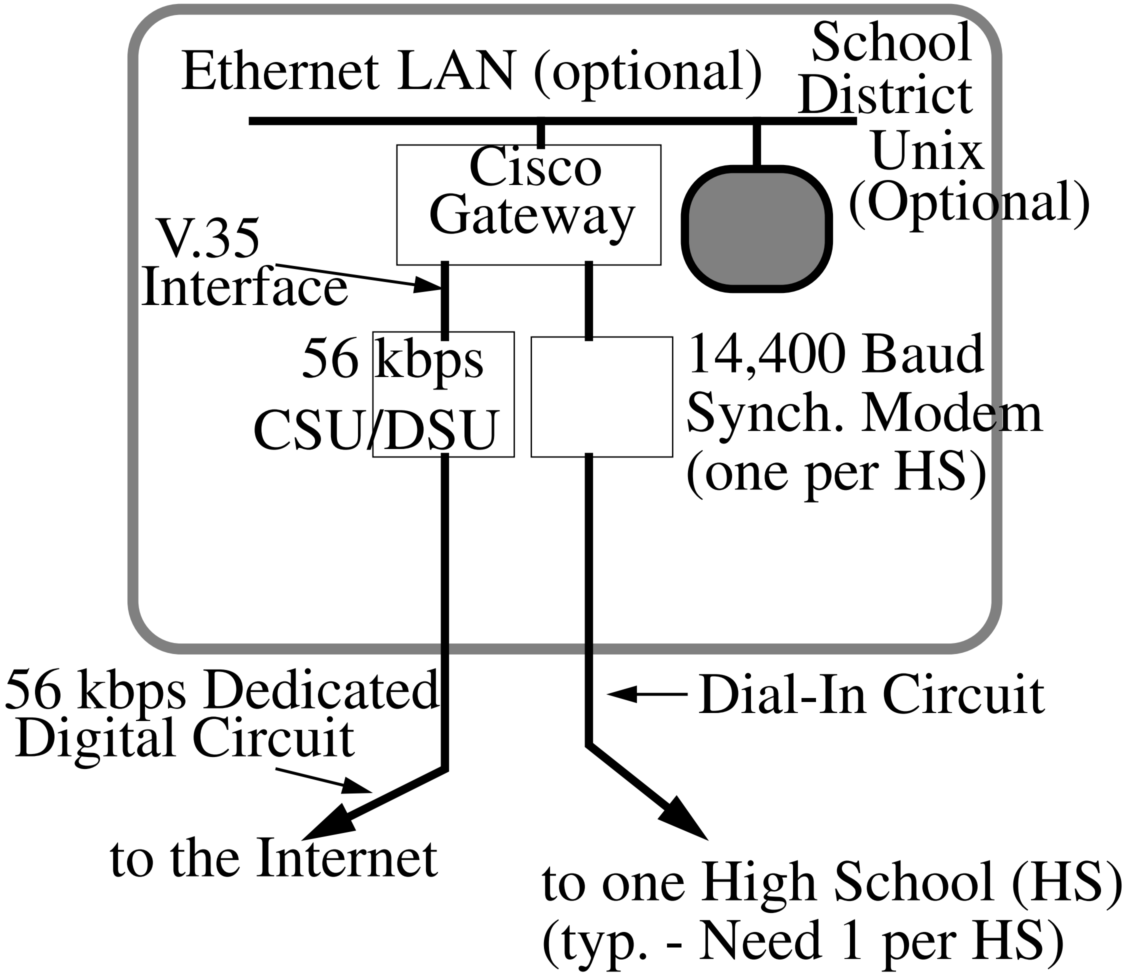
FIG. 5 MODEL 3: BRING THE NETWORK TO ONE SCHOOL - DEDICATED 56 kbps DIGITAL CIRCUIT



Cost:

NAT Gateway (1 ea.) - $1,600
CSU/DSU (2@$500) - $1,000
Circuit: $150/mo. (varies) + installation
Requires Ethernet/Localtalk LAN at Site and
Serial Port (& Internet Gateway) at Remote Site

FIG. 6 MODEL4: BRING THE NETWORK TO THE SCHOOL DISTRICT DEDICATED 56 kbps DIGITAL CIRCUIT



Cost:

Cisco Gateway (1 ea.) - $7,000
Serial Interfaces for the Cisco (4 ea.) - $2,700
Synchronous Modem (1 per HS) - $700 ea.
CSU/DSU (2@$500) - $1,000
Digital Circuit: $150/mo. + installation