A SCHOOL COMPUTER NETWORK MODEL

by

Mr. Somsak Sakdanuphap

A Final Report of the Six-Credit Course
CE 6998 - CE 6999 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

November 2002

St. Gabriel's Library, Au

A SCHOOL COMPUTER NETWORK MODEL

by
Mr. Somsak Sakdanuphap

A Final Report of the Six-Credit Course
CE 6998 – CE 6999 Project

Submitted in Partial Fulfillment
of the Requirements for the Degree of
Master of Science
in Computer and Engineering Management
Assumption University

November 2002

Project Title	A School Computer Network Model
Name	Mr. Somsak Sakdanuphap
Project Advisor	Rear Admiral Prasart Sribhadung
Academic Year	November 2002

The Graduate School of Assumption University has approved this final report of the six-credit course, CE 6998 – CE 6999 PROJECT, submitted in partial fulfillment of the requirements for the degree of Master of Science in Computer and Engineering Management.

Approval Committee:

(Rear Admiral Prasart Sribhadung)
Advisor

(Prof.Dr. Srisakdi Charmonman)
Chairman

(Dr. Chamnong Jungthirapanich)
Dean and Co-advisor

(Assoc.Prof. Somchai Thayarnyong)
MUA Representative

November 2002

ABSTRACT

Today's advanced information technology and global economy have created requirement for individual and business to gain competitive advantages in network management and to operate their business efficiently.

This project is concerned with details of the computer network system for high school, results and conclusions established for the summary of school network model. The results published here demonstrate an analysis for providing computer users and network administrators with appropriate telecommunication to access the Internet. It provides an overview of Internet service providers as a guideline for selecting alternative network or linking to Schoolnet by NECTEC.

ASSUMPTION UNIVERSITY OF THAILAND
BROTHERS of ST GABRIEL
LABOR OMNIA VINCIT
SINCE1969
มหาวิทยาลัยอัสสัมชัญ

ACKNOWLEDGEMENTS

I would like to express sincere gratitude to my Advisor, Real admiral Prasart Sripradung. His patient assistance, guidance, and constant encouragement have led me from research inception to the research completion. Without him, this project would not have been possible.

Above all, I am thankful to Archan Jira Tapviset, Computer center Chief in Sa-nguan Ying high school and Archan Jirat Jamsawang, Computer center Chief in Suankularb Nontraburi high school and also to my friends and to my family for their persistent love and support, without which nothing would be possible.

ASSUMPTION UNIVERSITY OF THAILAND
BROTHERS of ST GABRIEL
LABOR OMNIA VINCIT
SINCE1969
มหาวิทยาลัยอัสสัมชัญ

St. Gabriel's Library, Au

TABLE OF CONTENTS

ASSUMPTION UNIVERSITY OF THAILAND
BROTHERS of ST GABRIEL
LABOR OMNIA VINCIT
SINCE 1969
มหาวิทยาลัยอัสสัมชัญ

LIST OF FIGURES

ASSUMPTION UNIVERSITY OF THAILAND
BROTHERS of ST GABRIEL
LABOR OMNIA VINCIT
SINCE1969
มหาวิทยาลัยอัสสัมชัญ

LIST OF TABLES

UNIVERSITY OF THAILAND ASSUMPTION
BROTHERS of ST GABRIEL
LABOR VINCIT OMNIA
SINCE1969
มหาวิทยาลัยอัสสัมชัญ

I. INTRODUCTION

1.1 General Background

How will a new learning environment in the information society look like? It will be characterized by diversity, complexity, and flexibility for school network. Lifelong learning is rapidly becoming a reality rather than an aspiration. Flexible learning of online school networking aims to develop student's capabilities as a outdoor tool. The shape of online learning is mutating rapidly. In this environment of change and innovation, schools have begun to use information and communication, including the Internet. Online schools have become the new frontier. There is a need for in-depth research examining this adventure to discover its potential and pitfalls and provide guidance for future development in secondary high school.

In the past, most rural schools in Thailand have not been developed education along the new technology trend. At this moment, computer network system has become involved in people's daily life. We know that Internet can be expanded to world wide among many users. It has become necessary to admit this new trend into our real life so that we can communicate across the world. This system initiates as the simplest normally Local Area Networks which is known as LAN to connect various computer terminals together. It can save cost and it provides convenience in use and ensures reliability and accuracy of data.

National Electronics and Computer Technology Center (NECTEC) has implemented a schoolnet project that identifies the characteristics of a quality science education. Thai government has recognized the importance of providing students an opportunity to expand their experiences and has taken by supporting the school network. The government has realized the need to provide teachers and students access with information technologies that are becoming prevalent in industry and education. As a result, we use Internet for school as a tool like a computer information center that performs as online library to retrieve related resource, historical data and relevant information. Rural schools can get more benefit from their computer center as an information hub to students, teachers, and the public.

Therefore, we have to prepare minimum hardware requirement as IBM-compatible computers of Pentium-class level or better AMD technology, and Macintosh computers at Power PC level or better architecture. This also includes peripheral accessories such as working colour monitors, keyboards, mouses, printers, modems, and CD-ROM drives. Any application software should be related with Internet application such as Internet tools (i.e. Internet Explorer for web surfing, Eudora for email, etc.)

This project provides guidance to executives of information technology system on deploying of routing switches. It examines the context of the history of campus-area networking, and looks at the various issues involved in integrating digital communication based on today's global network.

We need to prepare high school students for their future by providing them access to the growing body of information and technology that is available. This will provide them more with the opportunity to research and explore current issues and hopefully instill the desire to be lifelong learners. We must actively ensure that the activities we provide are relevant to the student's lives.

However, we can know how to set up the computer network that is connected to Internet. But the speed for communication depends on the infrastructure of telephone line and network.

1.2 School Network Expansion

As one of the three main pillars of the IT-2000 plan, education is treated as the most important long-term investment for the nation. It is important to boost all schools to leap-frog their education technology with the Internet in order to tap the wealth of global knowledge available on the Internet. Without NECTEC's SchoolNet Thailand program, it is hard to say how 1,500 schools can be connected to the Internet in such a short time. The magic of this fast development was partly due to the existence of a wonderful information network we started in 1996 as the Golden Jubilee Network (http://goldenjubilee.or.th) which owns a comprehensive nationwide access service.

The Golden Jubilee Network, or Kanchanapisek Network in Thai, is another initiative of Her Royal Highness Princess Maha Chakri Sirindhorn. It is a place where NECTEC hosts mass of information in Thai language about His Majesty the King and his development projects. We ran the project in celebration of His Majesty's fiftieth year of accession to the throne in 1996.

With the royal permission and the support from TOT and CAT (Communications Authority of Thailand), SchoolNet was made accessible from anywhere in the country without incurring the long-distance call charge. In addition, Internet access to SchoolNet was provided free of charge to 1,500 schools everywhere. As of April 2000, the project managed to get 1,409 schools online and more than 460 of them have web presence. Some of them became very well known and very popular websites. So does the project's website: http://www.school.net.th.

In October 1999, the government of Thailand approved a massive expansion of SchoolNet to cover 5,000 schools. This means that all secondary schools (grades 6 to 12) will be getting free Internet access, and so would be more than a thousand schools at the primary level and kindergarten. This ambitious project is now under implementation by NECTEC/NSTDA.

Network interconnection for schools is only part of a story. We need to invest more on contents and teachers. For many schools in the rural area, we do not even think of a computer because kids do not have enough food to eat and have no uniform to wear. Therefore other forms of assistance are provided through other projects.

During the course of developing SchoolNet Thailand, it was found that major hindrance for schools in getting benefit from the global knowledge is due to four factors. These are: (lack of) computers, (lack of) access to the Internet, (lack of) relevant contents for schools in Thai language and (lack of computer-fluent) teachers. While the Ministry of Education is solely responsible for the first factor, i.e., it has to equip classrooms with computers and courseware, the other three factors are hardly provided by the ministry.

SchoolNet project has identified these problems since 1998. Lack of Internet access was quickly solved by the royal permission to use the Golden Jubilee Network to access SchoolNet. Almost all of SchoolNet budget at NECTEC, being very small, was directed to the contents creation program and teachers' training.

In January 2000, a digital library for SchoolNet was successfully created. The digital library consists of more than 1,000 articles in Thai language which are classified and searchable from the Internet. The articles were collected and prepared by schoolteachers who joined the course "Building Digital Library for SchoolNet" set up by Kasetsart University and the Institute for the Promotion of Teaching Science and Technology.

Apart from the digital library, several schools developed their web sites with useful information and excellent educational materials. NECTEC also promotes international cooperation projects such as the GLOBE program, ThinkQuest, and AT&T Virtual Classroom.

For teachers' training, NECTEC provided pilot courses and teaching materials for Rajabhat Institute, which, in turn, will teach schoolteachers in SchoolNet project. In addition to this normal Internet course, NECTEC also provides a special course on Linux-SIS, our own distribution of Linux for use as School Internet Server. SIS is very popular in Thailand due to its excellent documentation in Thai language, simple to install CD-ROM and web-based server management without the need to know UNIX commands. SIS training courses are always in constant demand from schools looking for reliable Internet server with the lowest cost.

1.3 Objectives of the project

In this section, we provide a content of methodology objectives of this report given as follows:

(1) To guide the principal of computer information center for schools to prepare the computer network.

(2) To classify the type of network, hardware and software requirement for school network.

(3) To implement necessary capabilities to end-users for relevant mission, for example, by training the users for progressive skills beyond information technology session.

(4) To examine the effectiveness of virtual schooling and configure some comparisons with conventional approaches.

(5) To identify common school network problems.

(6) To recommend and troubleshoot the problems of school network.

1.4 Scopes of the Project

This project provides guidance to school computer center on network development. It examines online connection in the context of the history of campus-area networking, then observes the various issues that involve network technology issues, are followed by a brief discussion of two typical migration scenarios, in which better network connection are added to existing networks or used to replace existing conventional network. The objectives of the project are given as follows:

(1) This project focuses on secondary high school.

(2) Boundary of target is around downtown district.

(3) Some implementation guidelines.

(4) Overview of school network infrastructure.

(5) Analysis of significant policy decision for school networking in the future.

1.5 Importance of Study

As bandwidth ad transmission speeds increase and compression technologies become more sophisticated, new opportunities are emerging for the convergence of existing and new media in the learning environment. Digital technologies are the catalyst and the means for enormous changes in the way of learning and teaching. They are shaping the time, place, and pace of education. Then, nationwide secondary high schools have the potential to increase the network capacity for accessibility of education to a huge number of people.

The content of this report is available to benefit of school network secondary high schools in order to suggest the high potential way to shape the use. Alternatives based on digital technologies are essential, not optional. In this new learning environment, knowledge becomes a modularized product. Therefore, school network is preferred for grasping this chance to gain educational advantages.

1.6 Statements of Problems

The statements of the project are given as follows:

(1) What is a comprehensive set of advanced school network for a secondary school?

(2) What is the best characteristic of school network in current technology?

(3) How do the today school networks running well for serving to all users?

(4) What findings can be used to inform network administrator of school network?

(5) Which types of network infrastructure are preferable in term of data communication to the outcome of the study?

(6) What are the best alternatives for secondary high school to enhance and implement their computer center into a school network?

ASSUMPTION UNIVERSITY OF THAILAND
BROTHERS of ST GABRIEL
LABOR OMNIA VINCIT
SINCE1969
มหาวิทยาลัยอัสสัมชัญ

II. LITERATURE REVIEW

2.1 Introduction of Network

Beginning of A.D. 2000 is the year of Information Technology. While the term "network" has many definitions, most people would agree that networks are collections of two or more connected computers through a cable or wire medium. Broadband services market is an apt industry to illustrate the importance of fair competition. Broadband Internet service has been available to the Thailand market for over a year. But unlike the competitive narrowband Internet market with over 18 licensed service providers, the number of broadband Internet service provider remains at a grand total of one plus that gets into the market. Lack of competition in this critical part of advanced service for Thailand is due to lack of economic incentive for any Internet service provider to offer broadband service from the only broadband telecommunication network available today.

Once their computers are joined in a network, people can share files and peripherals such as modems, printers, tape backup drives, or CD-ROM drives. When networks at multiple locations are connected using service available from phone companies, people can send e-mail, share links to the global Internet, or conduct videoconferences in real time with other remote users.

Every network includes:

(a) At least two computers (Personal Computers or Workstations)

(b) A network interface on each computer (a device that lets the computer talk to the network), usually called a network interface card (NIC) or adapter.

(c) A connection medium, usually a wire or cable, although wireless communication between networked computers and peripherals is also possible. (Telephone line, ISDN, ADSL, Cable Digital)

(d) Network operating system software, for example Microsoft Windows 98, Windows ME, Windows 2000, or Window NT series (i.e. NT 4.0, Windows 2000 Server), Novell NetWare, Appleshare, or Artisoft LANtastic.

Most networks-even those with just two computers also contain a hub or switch to act as a connection point between the computers.

Table 2.1. Thailand IT Market Growth Profile (in million baht).

Category	1998		1999		2000E	
1. Systems	2,465	-40%	2,704	+10%	2,612	-3%
2. PC and workstations	11,132	-53%	17,406	+56%	20,573	+19%
3. Packaged Software	5,126	-25%	6,289	+23%	7,744	+23%
4. Services	7,229	-12%	8,738	+21%	9,384	+7%
TOTAL	25,953	-39%	35,137	+35%	40,413	+15%

Note: The whole IT market in Thailand had a significant growth of 35% in 1999, mainly due to the Y2K conversion. In 2000, however, it was estimated that there would be some further 15% growth over 1999.

Source: ATCI/ATSI/CAT-VG 1999 (NECTEC, 2001)

2.2 Basic Networking Components

Most Networks consist of at least two computers, network interface cards, cabling, network operating system, and a hub.

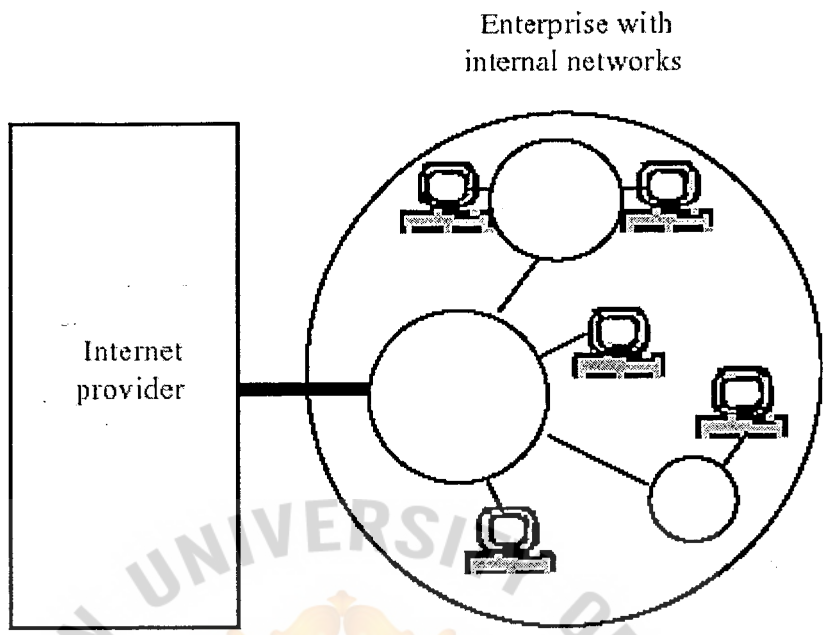

Figure 2.1. Networking Connections to users within organizations

2.2.1 Clients and Servers

Often, as the network grows and more computers are added, one computer will act as a server--a central storage point for files or application programs shared on the network. Servers also provide connections to shared peripherals such as printers. Setting up one computer as a dedicated server prevents you from having to outfit every networked computer with extensive storage capability and duplicate costly peripherals. The computers that connect to the server are called clients.

Note that you don't need to have a dedicated server in your network. With only a few computers connected, networking can be "peer to peer." Users can

St. Gabriel's Library, Au
2442

exchange files and e-mail, copy files onto each other's hard-drives, and even use printers or modems connected to just one computer.

But as more users are added to the network, a dedicated server can provide a central point for management duties such as file backup and program upgrades.

2.2.2 Wiring and Cable

There are three primary types of network wiring (also referred to as "media"): Twisted pair- the industry standard in new installations. This wire comes in several standards. Unshielded Twisted Pair (UTP) Category 3 wire, often used for phone lines, and UTP Category 5 wire are the current networking standards. Coaxial- resembles round cable television wiring.

Fiber optic- usually reserved for connections between "backbone" devices in larger networks, though in some very demanding environments, highly fault resistant fiber-optic cable is used to connect desktop workstations to the network and to link to adjacent buildings. Fiber optic cable is the most reliable wiring but also the most expensive.

Take care in selecting the cabling for your offices and buildings. You want to be sure the wires running through ceilings and between walls can handle not only your present needs, but also any upgrades you foresee in the next several years. For example, Ethernet can use UTP Category 3 wiring. However, Fast Ethernet requires at least the higher-grade UTP Category 5 wiring. As a result, all new wiring installations should be Category 5. You may want to explore plenum cable, which can be routed through many types of heating and cooling ducts in ceilings. Check with your architect or wiring contractor to ensure this process is fire code compliant.

St. Gabriel's Library, Au

2.2.3 Network Interface Cards

Network interface cards (NICs), or adapters, are usually installed inside a computer's case. With portable and notebook computer, the NIC is usually in the credit card-sized PC Card (PCMCIA) format, which is installed in a slot. Again, when selecting NICs, plan ahead. Ethernet NICs support only Ethernet connections, while 10/100 NICs cost about the same can work with either Ethernet or higher-performance Fast Ethernet connections. In addition, you need to ensure that your NICs will support the type of cabling you will use- twisted-pair (also call 10BaseT), coaxial (also called 10Base2), or a mixture of both.

2.2.4 Hubs

Hubs or repeaters are simple devices that interconnect groups of users. Hubs forward any data packets- including e-mail, word processing documents, spreadsheets, graphics, print requests- they receive over one port from one workstation to all of their remaining ports. All users connected to a single hub or stack of connected hubs are in the same "segment," sharing the hub's bandwidth or data-carrying capacity. As more users are added to a segment, they compete for a finite amount of bandwidth devoted to that segment.

For Example: To understand how a hub serves your business network, imagine a hotel with just one phone line available to all guests. Let's say one guest wants to call another. She picks up her phone and the phone rings in all rooms. All the other guests have to answer the phone and determine whether or not the call is intended for them. Then, as long as the conversation lasts, no one else can use the line. With a few guests this system is marginally acceptable. With a few guests, this system is marginally acceptable. However, at peak times of the day-say, when everyone returns to their rooms at 6 p.m.-it becomes difficult to communicate. The phone line is always busy.

2.2.5 Switches

Switches are smarter than hubs and offer more dedicated bandwidth to users or groups of users. A switch forwards data packets only to the appropriate port for the intended recipient, based on information in each packet's header. To insulate the transmission from the other ports, the switch establishes a temporary connection between the source and destination, then terminates the connection once the conversation is done.

For Example: A switch would be like a phone system with private lines in place of the hub's "party line." Jane Tipton at Berkley Hotel calls Bill Johnson in another room, and the operator or phone switch connects the two of them on a dedicated line. This allows more conversations at any one time, so more guests can communicate.

2.2.6 Routers

Compared to hubs and switches, routers are smaller still. Routers use a more complete packet "address" to determine which router or workstation should receive each packet next. Based on a network road map called a "routing table," routers can help ensure that packets are traveling the most efficient paths to their destinations. If a link between two routers fails, the sending router can determine an alternate route to keep traffic moving.

Router also provides links between networks that speak different languages-or in computer speak, networks that use different "protocols." Examples of protocols include Internet Protocol (IP), Internet Packet Exchange (IPX) and AppleTalk. Router not only connect networks in a single location or set of

St. Gabriel's Library, Au

buildings but they provide interfaces – or "socket" – for connecting to wide-area network (WAN) services. These WAN services which are offered by telecommunication companies to connect geographically dispersed networks, are explained in more detail in the next chapter.

For Example: To understand routing, imagine the Berkley Hotel and all other fellow hotels in its chain have trained their operators to be more efficient. When guest Jane Tipton at the Berkley Hotel call guest Rita Brown at the Ashton Hotel, the operator at the Berkley knows the best way to patch that call through. He sends the call to the Pembrook operator, who passes it to the Ashton. If there's ever a problem with the switchboard at the Pembrook, the operator at the Berkley can use an alternate route to get the call through- for example, by routing it to another hotel's switchboard, which, in turn, sends the call to the Ashton.

2.2.7 Cable Modems

Cable Modems offer extremely fast and relatively inexpensive access to the Internet. A cable modem connects directly to the same line that provides cable TV service to a home or business, and then to an Ethernet network interface card (NIC) in a PC.

While a traditional dial-up modem provides access at speeds up to 56 Kilobits per second, a cable modem can deliver transmission rates of up to 10 megabits per second-nearly 200 times as fast. And unlike dial-up modems, cable modems have a connection to the Internet that is "always on." In other words, you won't face busy signals or delays while your computer connects to the Internet.

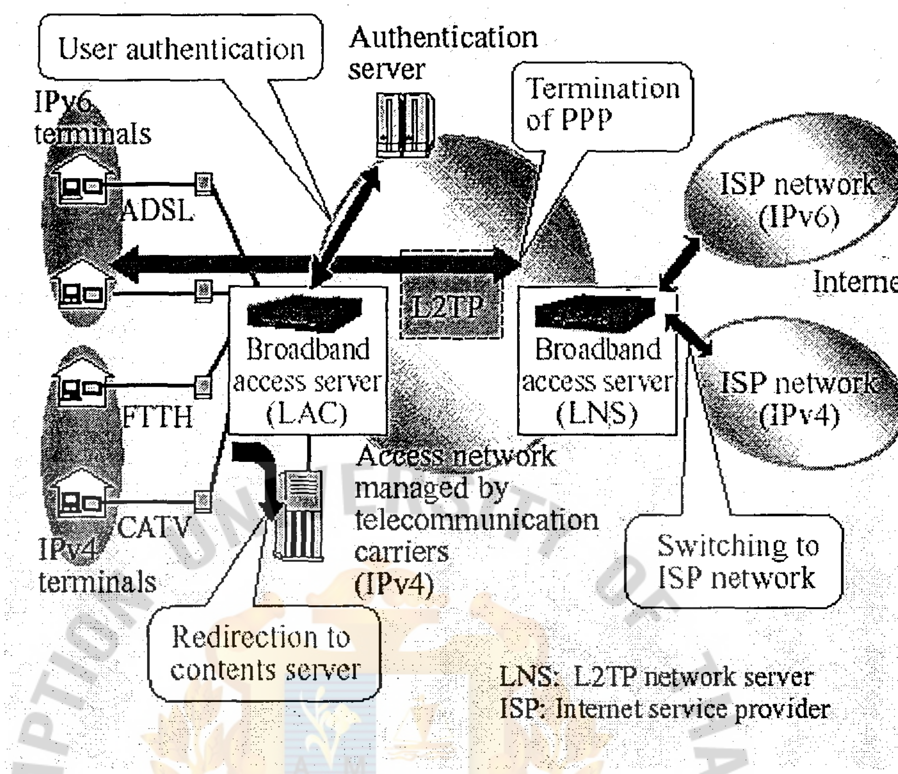

Figure 2.2. Broadband Access Network.

By the same token, since you are sharing the connection with multiple users on your cable system, your performance will depend on how many users are online at once. Another caution: in today's cable modem systems, users on a single segment of cable are essentially connected to a single local area network (LAN). To prevent neighbors from accessing files on a computer, that computer's file sharing options should be turned off. Ready to sing up? You might need to be patient. About 65 million locations in the U.S. alone have cable service, but only a small percentage of those links are cable modem-ready; the rest will require upgrades to handle the two-way traffic of Internet surfing.

Upsides:

(a) Extremely fast transmission rates for downloading Web pages and files (uploading to the Internet- mostly mouse clicks and e-mail- occurs at a slower but still quick speed of up to about 2Mbps).

(b) Inexpensive service- about $50 per month today or close to the cost of basic cable TV.

(c) Minimal requirement- all you need to make the connection is a relatively new PC, a cable modem (often leased from the cable company), an Ethernet card in the PC, and a connection point from your cable service provider.

Downsides:

(a) Limited availability- at the writing, only about 10 per-cent of the U.S. has access to the upgraded cable systems needed to support cable modems. The experts say it will be about five years before the technology is widespread.

(b) Extra installation steps- gaining Internet access today can be as simple as installing a modem and browser software and calling your Internet Service Provider's access number. With a cable modem, the Cable Company most likely will need to send out a technician to check your writing quality and install the device. You also will need to have an Ethernet card installed in the PC, if it doesn't already have one.

2.2.8 Digital Subscriber Line (DSL) Service

Digital Subscriber Line or DSL technology is a high-speed service that like ISDN, operates over ordinary twisted pair copper wires supplying phone service

St. Gabriel's Library, Au

to businesses and homes in most areas. DSL is often more expensive than ISDN in markets where it is offered today.

Using special modems and dedicated equipment in the phone company's switching office, it offers faster data transmission than either analog modems or ISDN service, plus- in most cases- simultaneous voice communications over the same lines. This means you don't need to add lines to supercharge your data access speeds. And since DSL devotes a separate channel to voice service, phone calls are unaffected by data transmission.

There are several flavors of DSL. ADSL delivers asymmetrical data rates (for example, data moves faster on the way to your PC than it does on the way out to Internet). Other DSL technologies deliver symmetrical data (same speeds going in and out of your PC).

The types of service available to you depend on the carrier operating in your area. Because DSL works over the existing telephone infrastructure, it should be easy to deploy over a wide area in relatively little time. As a result, the pursuit of market share and new customers is spawning competition between traditional phone companies and a new breed of firms called Competitive Local Exchange Carriers (CLECs). If you choose DSL service for connecting your business to the Internet or for giving remote sites and users high-speed access to your central network, your carrier will help you install the appropriate hardware.

2.2.9 Integrated Service Digital Network (ISDN)

ISDN is an acronym for Integrated Services Digital Network. It is a completely digital telephone system that provides high speed, high quality voice and data transmission of up to 128kbps. You can plug an ISDN adapter into a wall jack and get a faster connection with no line noise and data transmission is extremely fast and reliable.

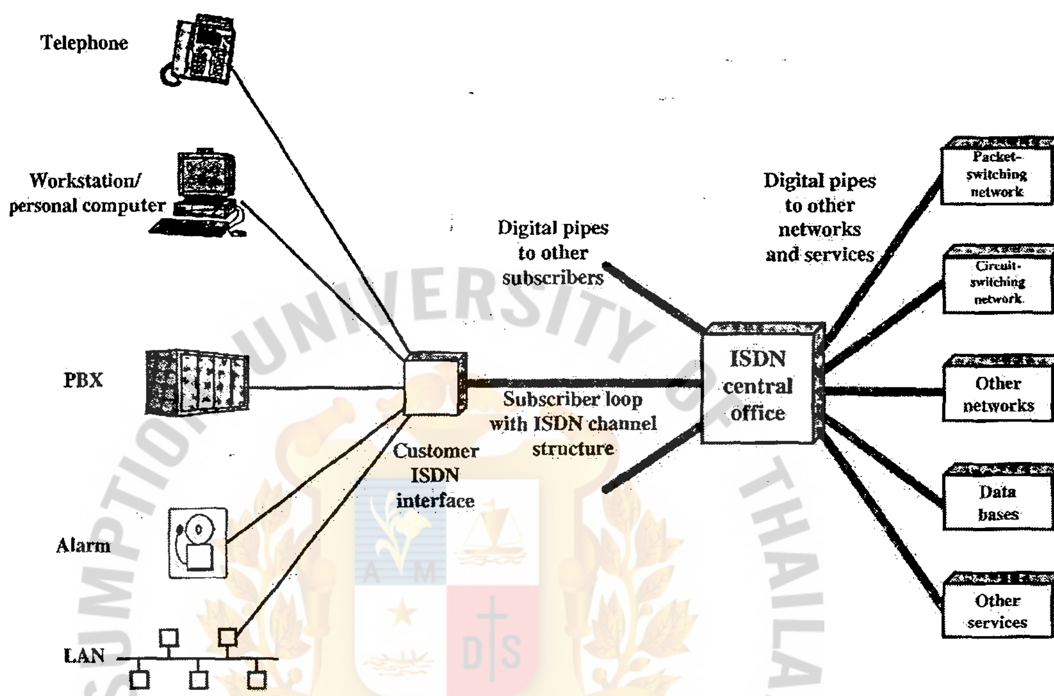

Figure 2.3. ISDN network system.

ISDN Access offers high quality and high speed Internet access speed at 64 kbps. Applications for ISDN include Internet, e-mail, database access and file transfer. Videoconferencing is an emerging ISDN application that is growing fast in popularity, and ISDN is currently the practical way of making it happen. We strongly recommend this cost-effective solution for a small network up to 20 PC users.

ISDN is designed to replace existing public telecommunication networks and deliver a variety of services. The ISDN is defined by the standardization of user interfaces and implemented as a set of digital switches and paths supporting a broad range of traffic types and providing value-added processing services. Practically, there are multiple networks, implemented within national boundaries, but from the user's point of view. There is a single accessible, worldwide network. ISDN is also the integration of voice and data transmission (and other formats such as video and graphic images) over a digital transmission network. This network configuration is proposed by numerous common carriers. (such as TOT)

2.3 Overview of Networking Technologies

(a) Local-Area Network: Ethernet and Fast Ethernet

Ethernet has been around since the late 1970s and remains the leading network technology for local-area networks (LANs) or networks contained in building or on a single site. Ethernet is based on a standard referred to as carrier sense multiple access with collision detection (CSMA/CD). (See Token Ring in the Glossary section to learn about another basic style of network communication.)

Simply put, an Ethernet workstation can send data packets only when no other packets are traveling on the network- when the network is "quiet." Otherwise, it waits to transmit, as a person might wait for another to speak during a conversation. If multiple stations sense an opening and start sending at the same time, a "collision" occurs. Each station then waits a random amount of time and tries to send its packet again. After 16 consecutive failed attempts, the original application that sent it must start again. As more people try to use the network, the number of collisions, errors, and subsequent retransmits grows quickly, causing a snowball effect. Collisions are normal occurrences, but too many can slow and software the network. When more than 50 percent of the network's total bandwidth is used, collision rates begin to cause congestion. Files take longer to print, applications take longer to open, and users are forced to wait. At 60 percent or higher, the network can slow dramatically or even grind to a halt.

As noted in the previous section, Ethernet' s bandwidth or data-carrying capacity (also called throughput) is 10 megabits per second (Mbps). Fast Ethernet works the same way-through collision detection,-but it provides 10 times bandwidth, at 100 Mbps.

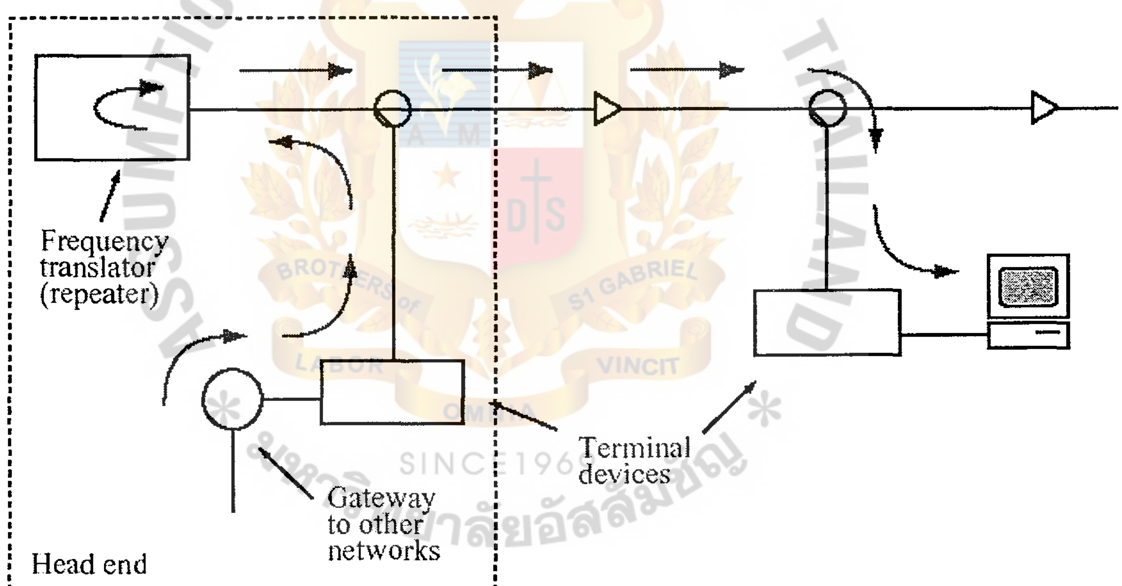

Figure 2.4. Data Transmission.

(b) Remote Access and Wide-area Networks

LANs accommodate local users-people within a building or on a campus. Wide-area networks (WANs) connect users and LANs spread between various

St. Gabriel's Library, Au

sites, whether in the same city, across the country, or even around the world. "Remote access" refers to a simple connection, usually dialed up over telephone lines as needed, between an individual user or very small branch office and a central network.

Your business gains access to the Internet through some type of remote connection. A single user can dial up an Internet service provider (ISP) via modem. Multiple users within a campus might choose to rely on a router to connect to the ISP, who then connects the campus to the Internet.

In general, LAN speeds are much greater than WAN and remote access speeds. For example, a single shared Ethernet connection runs at 10 megabits per second (Mbps) (Mega means "million"). Today's fastest analog modem runs at 56 kilobits per second (Kbps) (Kilo means "thousand")-less than one percent of the speed of an Ethernet link. Even the more expensive, dedicated WAN services such as T1 lines don't compare (with bandwidth of 1.5 Mbps, a T1 has only 15 percent of the capacity of a single Ethernet6 link). For this reason, proper network design aims to keep most traffic local-that is, contained within one site-rather than allowing that traffic to move across the WAN.

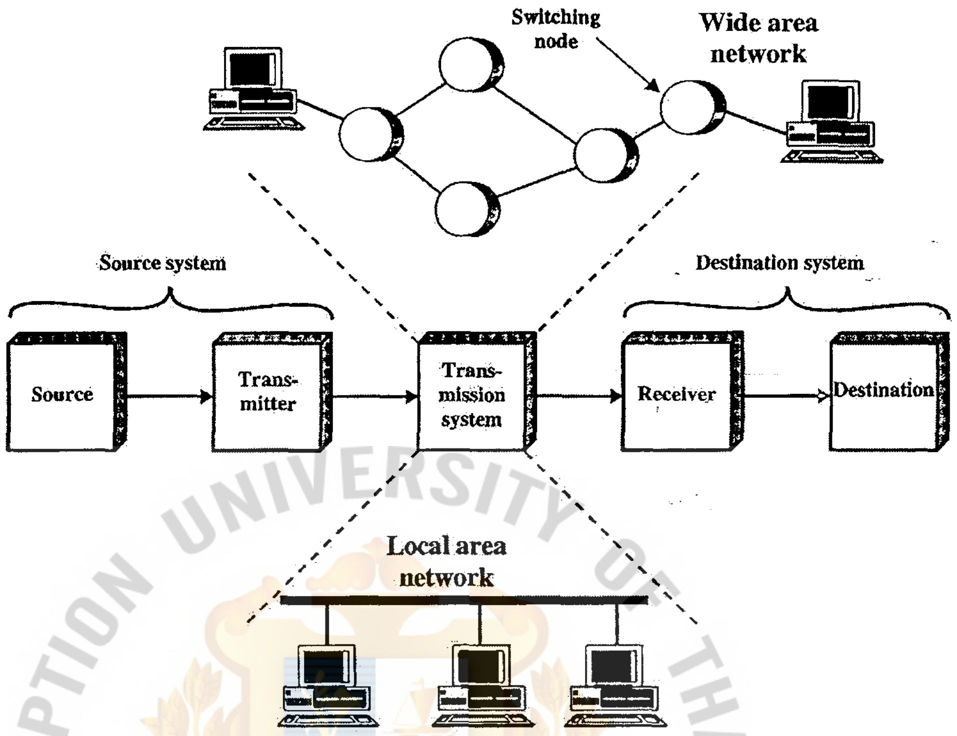

Figure 2.5. WAN connection.

(c) Virtual Private Networks: A Cost-effective Alternative to Building Your Own WAN

As businesses grow, they need to connect a rising number of remote offices and individuals to their central network to share information and resources electronically. Traditionally, this has been accomplished by building a private wide area network (WAN), using leased lines to connect offices, and dial-access servers to support mobile users and telecommuters. For a small or medium-sized business, a traditional private WAN can be costly to build and manage. The leased lines, telecommunications services and equipment needed to interconnect offices can be expensive, and each added location requires a new leased line. Individuals or small branches dialing into a central site via the public telephone network incur long-distance charges, and managing dial access servers at the central site can be resource-intensive and complex.

Nowadays, people, business and government have an alternative for connecting remote sites and users to main company network- virtual private networks (VPNs). A VPN offers the security and full data access of a private wide area network, but since it runs over the Internet, it is more affordable and flexible.

(a) *More Affordable*:- Remote users can connect with central network resources through a local link to an Internet Service Provider, at the price of a local call. This is a much more cost- effective method than making a long distance call to the central site.

(b) *More Flexible*:- New sites can be added easily, without need for extensive new equipment or an additional, dedicated private line. VPNs also simplify the task of creating an {extranet}, which gives customers or suppliers password- protected to a portion of a private network- for example , to order products, check status of shipments, or submit invoices.

(c) *More Reliable*:- VPN leverage the equipment and full-time expertise of the vast public network infrastructure and the companies that oversee it.

2.4 Ethernet (CSMA/CD)

The most commonly used medium access control technique for bus and star topology is carrier sense multiple access with collision detection (CSMA/CD). The original baseband version of this technique was developed by Xerox as part of the

Ethernet LAN, and this work formed the basis for the IEEE 802.3 standard. (William S. 2000)

As with other LAN standards, there is both a medium access control layer and a physical layer, which are considered in turn in what follows.

(1) IEEE 802.3 Medium Access Control

It is easier to understand the operation of CSMA/CD if we look first at some earlier schemes from which CSMA/CD evolved.

(2) Precursors

CSMA/CD and its precursors can be termed random access, or contention, techniques. They are random access in the sense that there is no predictable or scheduled time for any station to transmit; station transmissions are ordered randomly. They exhibit contention in the sense that stations contend for time on the medium.

The earliest of these techniques, known as ALOHA, was developed for packet radio networks. However, it is applicable to any shared transmission medium. With ALOHA, when a station has a frame to send, it does so. The station then listens for an amount of time equal to the maximum possible round-trip propagation delay on the network (twice the time it takes to send a frame between the two most widely separated stations) plus a small fixed time increment. If the station hears an acknowledgement during that time, fine; otherwise it resends the frame if the station fails to receive an acknowledgement after repeated transmissions, it gives up. A receiving station determines the correctness of an incoming frame by examining a frame-check-sequence field, as in HDLC. If the frame is valid and if the destination address in the frame header matches receiver's address, the station immediately sends an acknowledgement. The frame may be invalid due to noise on the channel or because another station transmitted a frame at about the same time. In the latter case, the two frames may interface with each other at the receiver so that neither gets through: this is known as a collision. If a received frame is determined to be invalid, the receiving station simply ignores the frame.

Because the number of collisions rises rapidly with increased load, the maximum utilization of the channel is only about 18 percent..

To improve efficiency, a modification of ALOHA known as slotted ALOHA, was developed. In this scheme, time on the channel is organized into uniform slots whose size equals the frame transmission time. Some central clock or other technique is needed to synchronize all stations. Transmission is permitted to begin only at a slot boundary. Thus, frames that do overlap will do so totally. This increases the maximum utilization of the system to about 37 percent.

Both ALOHA and slotted ALOHA exhibit poor utilization. Both fail to take advantage of one of the key properties of both packet radio and LANs, which is that propagation, delay between stations is usually very small compared to frame transmission time. Consider the following observations. If the station-to-station propagation time is large compared to the frame transmission time, then, after a station launched a frame, it will be a long time before other stations know about it. During that time, one of other stations may transmit a frame; the two frames may interfere with each other and neither gets through. Indeed, if the distance is great enough, many stations may begin transmitting, one after the other, and none of their compared frame get through unscathed. Suppose, however, that the propagation time is small compared to frame transmission time. In that case, when a station launches a frame, all the other stations know it almost immediately. So, if they had any sense, they would not try transmitting until the first station was done. Collision would be rare because they would

St. Gabriel's Library, Au

occur only when two stations began to transmit almost simultaneously. Another way to look at it is that a short delay time provides the stations with better feedback about the state of the network; this information can be used to improve efficiency.

The foregoing observations led to the development of carrier sense multiple access (CSMA). With CSMA, a station wishing to transmit first listens to the medium to determine if another transmission is in progress (carrier sense). If the medium is in use, the station must wait. If the medium is idle, the station may transmit. It may happen that two or more stations attempt to transmit at about the same time. If this happens, there will be a collision; the data from both transmissions will be garbled and not received successfully. To account for this, a station waits a reasonable amount of time after transmitting for an acknowledgement, taking into account the maximum round-trip propagation delay and the fact that acknowledgement station must also contend for the channel to respond. If there is no acknowledgement, the station assumes that a collision has occurred and retransmits.

One can see how this strategy would be effective for networks in which the average frame transmission time is much longer than the propagation time. Collisions can occur only when more than one user begins transmitting within a short time (the period of the propagation delay). If a station begins to transmit a frame and there are no collisions during the time it takes for the leading edge of the packet to propagate to the farthest station, then there will be no collision for this frame because all other stations are now aware of the transmission.

2.5 Gigabit Ethernet

In late 1995, the IEEE 802.3 committee formed a High-Speed Study Group to investigate means for conveying packets in Ethernet format at speeds in the gigabits per second range. A set of 1000-Mbps standards have now been issued.

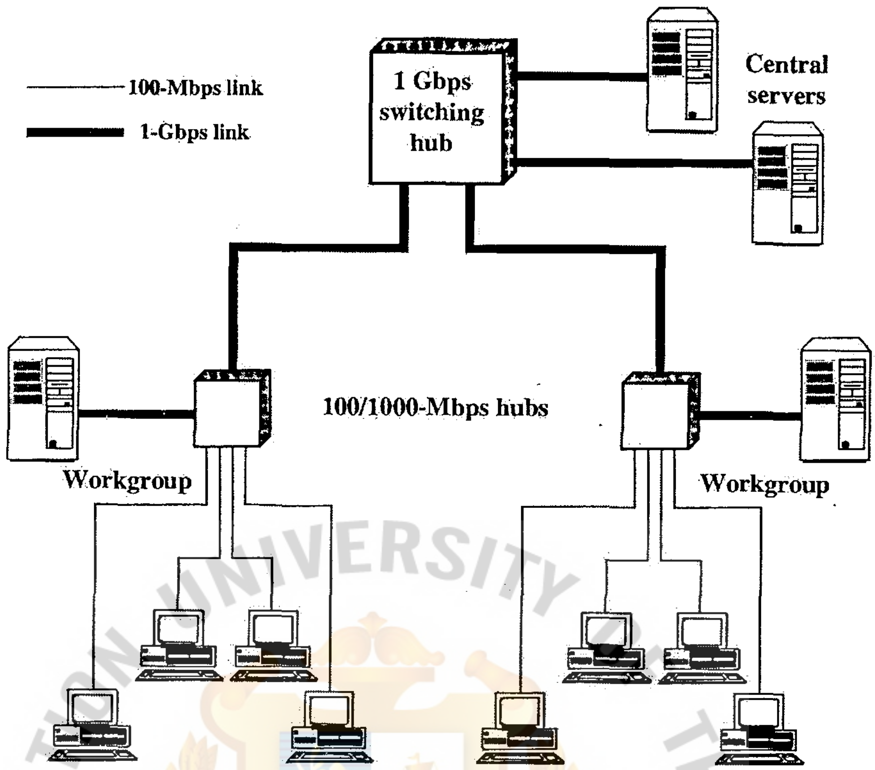

Figure 2.6. Example of Gigabit Ethernet Configuration.

The strategy for Gigabit Ethernet is the same as that for Fast Ethernet. While defining a new medium and transmission specification, Gigabit Ethernet retains the CSMA/CD protocol and Ethernet format of its 10-Mbps and 100 M-bps predecessors. It is compatible with 100BASE-T and 10BASE-T, preserving a smooth migration path. As more organizations move to 100BASE-T, putting huge traffic loads on backbone networks, demand for Gigabit Ethernet has intensified.

Figure 2.6 shows a typical application of Gigabit Ethernet. A 1-Gbps switching hub provides backbone connectivity for central servers and high-speed workgroup hubs. Each workgroup hub supports both 1-Gbps links, to connect to the backbone hub and to support high-performance workgroup servers, and 100-Mbps links, to support high-performance workstations, servers, and 100-Mbps hubs.

ASSUMPTION UNIVERSITY OF THAILAND
BROTHERS of ST GABRIEL
LABOR OMNIA VINCIT
SINCE 1969
มหาวิทยาลัยอัสสัมชัญ

III. NETWORK ANALYSIS AND DESIGN FOR SCHOOL NETWORK

This paper describes our unique solution for the design and construction of a network that delivers Internet access to students everywhere in the country with a local telephone call. Under several constraints – a severely limited budget and limited network resources and manpower – we derived a solution that delivers reliable network access, which can be used with a high utilization factor despite the "synchronous" nature of classroom activities during class hours.

3.1 Introduction of SchoolNet Thailand Model

Starting in February 1998, schools all over Thailand were given free access to a specially designed IP network through the SchoolNet Thailand project. With cooperation from local telephone companies and a government policy to boost the nation's educational infrastructure, this large network was set up in 1997 to cover the country, which is the size of Texas. The work was an initiative of Thailand's Princess Maha Chakri Sirindhorn.

The SchoolNet Thailand project was launched in 1995. We (the National Electronics and Computer Technology Center (NECTEC)) ran it as a pilot project. The early network was based solely in Bangkok; schools outside the capital city had to shoulder the high cost of long-distance telephone calls or leased-circuits in order to get connected. As a result, only a few schools outside Bangkok participated in the early SchoolNet Thailand project. Even at the peak of Thailand's economic growth, government funding to support SchoolNet was unavailable.

The advent of the Internet has had a significant impact on every aspect of our lives including the education of our young. Thailand, though regarded as a developing country, was among the first in South-East Asia to venture into cyberspace. Early efforts were focused on an academic TCP/IP-based network called the Thai Social/Scientific, Academic and Research Network (ThaiSarn). ThaiSarn has had continuous growth, both in number of nodes and bandwidth, since 1992. The success of ThaiSarn and the growing importance of the Internet have prompted the demand for Internet access in Thai schools.

In 1996, the year of celebration of the fiftieth anniversary of His Majesty the King's accession to the throne, there was a great opportunity to use information technology to join the celebration. During the fifty years, there had been many successful projects of His Majesty with information available in print but hardly any with information available on the Internet. It was a good time to start making such information available there. As an initiative of Princess Maha Chakri Sirindhorn, who is an advocate of education development in Thailand, the Golden Jubilee Network project was implemented as a program to create Thai content on the Internet for mass education in Thailand.

The network consisted of two parts: the content and the access network. Content-creation tasks were assigned to eleven organizations which had served the country through many successful projects due to His Majesty's initiative. The project task was subjectively to make available electronically existing knowledge and useful information for access by Thai people. SchoolNet would manage the design and implementation of the access network. The design specifications were to give free, local, PPP access to everyone who wanted to read the contents.

St. Gabriel's Library, Au

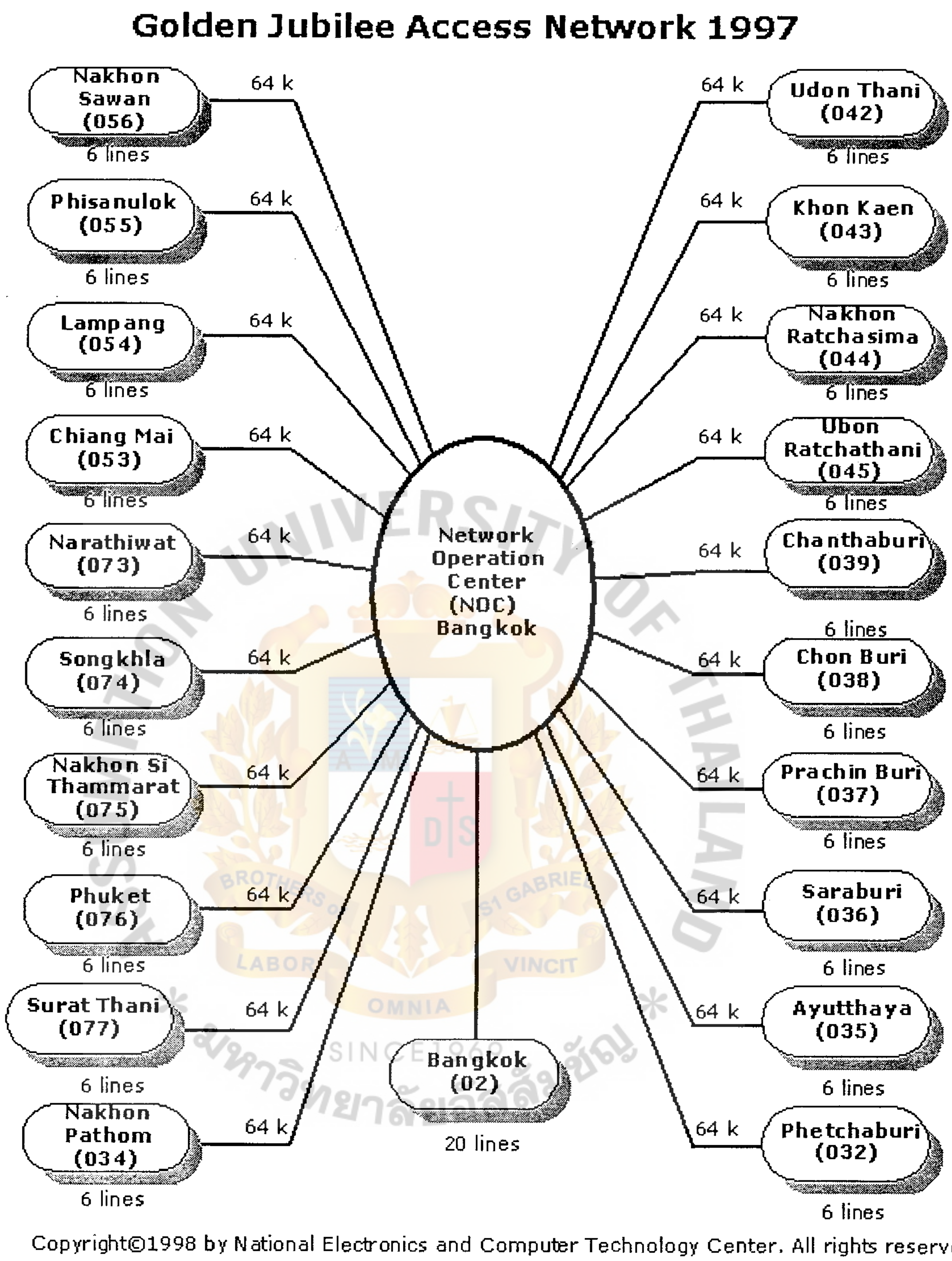

Figure 3.1. Golden Jubilee Access Network 1997.

The SchoolNet solution was a special bulletin board system using TCP/IP and web technologies. The network allowed access to a web site containing biographies, royal speeches, information on development projects under royal initiatives and royal activities as well as other information related to His Majesty. The web site of the Golden Jubilee Network was accessible by the Internet as well as by dial-in PPP telephone lines. The telephone number 1509 was used for these lines; it was billed as a local call in Thailand. 21 points of presence (POPs) were established throughout Thailand for access from all 76 provinces. Each POP had 6 modems and was connected by a 64K bps (bits per second) leased circuit to a main hub in Bangkok. Due to the non-commercial nature of the service, the network did not allow any users to use email or transit to the global Internet.

Therefore, at the end of the celebration year 1997, we had successfully completed three crucial components for Thailand's mass-education program on the Internet: school awareness, Thai language content and a nationwide access network. The three components were then integrated in 1998 to form the national SchoolNet network.

Needless to say, NECTEC should be viewed as just an incubator of the early effort to introduce Internet in Thai schools. The project's eventual success will depend on many more factors including the creation of content, training, better network infrastructure and a sincere effort on the part of the government to improve the overall education of its citizens.

It is clear that no single organization in the country can accomplish this task alone. Thailand urgently needs a joint effort by different government ministries if it really wants to see that every student has a chance to get online.

3.2 Network Congestion

Congestion is the networking term for too much traffic clogging network pathways. Common causes of congestion in today's networks include:

(1) Too many users on a single network's segment or collision domain.

(2) High demand from networked applications, such as groupware (for scheduling and appointments) and e-mail with large attached files.

(3) High demand from bandwidth-intensive applications, such as desktop publishing and multimedia.

(4) A rapidly growing number of users accessing the Internet.

(5) The increased power of new PCs and servers.

3.3 How to Spot Network Congestion

Some common indicators of network congestion include:

(a) Increased Network Delay

All networks have a limited data-carrying capacity. When the load is light, the average time from when a host submits a packet for transmission until it is actually sent on the LAN is relatively short. When many users are vying for connections and communicating, the average delay increases. This delay has the effect of making the network appear "slower," because it takes longer to send the same amount of data under congested conditions than it does when the load is light.

In extreme circumstances, an application can fail completely under a heavy network load. Sessions may time-out and disconnect, and applications or operating systems may actually crash, requiring a system restart. But remember that many factors contribute to application performance (for example, CPU speed, memory, and disk performance). LAN is only one of several possible bottlenecks.

(b) Higher Network Utilization

One important measure of congestion is "channel utilization," which is the percentage of time that a channel is busy carrying data. It is directly related to the traffic load. While many network management software programs offer visual displays of this information, special network monitoring equipment, such as protocol analyzers or remote monitoring (RMON) devices, may be required. There are many variables to consider when trying to determine what constitutes acceptable utilization, including the number of stations on the LAN, software or application behavior and network traffic patterns, In other words, is most traffic between users and a local server, or are users reaching out of their own segments across the network and creating congestion. For most small business environments, any of the following utilization levels can be used as "rules of thumb" for determining when an Ethernet LAN is approaching excessive load:

(1) 20 percent of full capacity, averaged over an eight-hour work day.

(2) 30 percent averaged over the worst hour of the day.

(3) 50 percent averaged over the worst 15 minutes of the day.

(c) Dissatisfied Users

Network speeds are partly subjective: the ultimate measures of LAN congestion is whether users can get their work done efficiently. If users are dissatisfied with network performance, there is a problem- regardless of statistics indicating the network is doing just fine. Note that user dissatisfaction with performance may not indicate network congestion problem. The slowdown may be due to applications, computer CPU speeds, hard disk performance, servers, and WAN access devices (slow modems or WAN connections)

3.4 Advanced Network Solution

The key to advance network solution is how to enhance or re-grade up the existing network towards the current technology. In properly designed school network environment, 80 percent of the traffic on a given network segment is local, and not more than 20 percent of the network traffic should need to move across backbone. Backbone congestion can indicate that traffic patterns are not meeting. In this case, rather than adding switches or upgrading hubs, it may be easier to improve network performance by the following:

(1) Maintaining and implementing computer resources (applications, software, and files from one network service to another, for example) to contain traffic locally within a computer workgroup.

(2) Transferring users/staff so that the computer network group more crossly reflect the actual traffic patterns.

(3) Boosting the internal and external network bandwidths that users can access locally without lagged down.

After ensuring to design proper network and resource layout, the next step is to determine the optional technology to enhance the network system.

3.5 Giving Network a Performance Boost

Most computer networks run as shared Ethernet networks, with all users sharing a single segment. Obviously, as more users plug into a network and as they download larger files across network, the traffic loads rise. With this example, we demonstrate how to furnish a network into high capabilities or separate collision domains could alleviate congestion. How to boost up the networking performance:

St. Gabriel's Library, Au

(a) For sustained traffic with smaller files, the performance difference between the network technologies is relatively minor. In this case, the congestion is caused by a constant stream of small files through backbone networks.

(b) Sporadic traffic with large file transfers and power users running high-bandwidth applications require a different approach.

(c) Dedicated bandwidth to workgroup. As demanding new applications such as desk top multimedia or videoconference become more popular, all school may choose to give certain individual desktop computers their own dedicated 100-Mbps links to the networks.

(d) Finally, for school network environments running streamed multimedia application (such as video training over the network), the large overall bandwidth of Fast Ethernet switches and high-end digital communication line are the best solution.

3.6 Network Analysis for School Network

The connection of the first 1,500 schools cost some 50 million baht (US$ 13 million), a large part of which was supplied by Golden Jubilee Network fund. With support from TOT, schoolNet provides free Internet access to schools across the country. While Schoolnet provides the dial-up services, the schools itself are responsible for the provision of computers, course training, and implementation plans for information center. It is often difficult to motivate catch to use application to catch their attention.

How to boost up the school network's performance depends partly on what networking equipment is connected beneath the data communication line? Nowadays, there are many broadband items available on market such as ISDN, ADSL, and Cable modem in order to increase the bandwidth access for Internet. All broadband devices are additional tools for enhancing the access connection of school networks.

Table 3.1. Thailand at School.
(Number of primary and secondary schools, university, students, teachers, and Access to ICT (in percentage), 2000)

Level	Institution	Teachers/ Professor	Students	Number of Institution with PCs	Number of Institutions with Internet
Primary Schools	30,715	361,967	4,654,080	23,698 (77%)	686 (2.2%)
Secondary Schools	2,669	126,385	2,580,759	2,430 (91%)	1,182 (44%)
Universities	50 Private 24 Public	340 (in 1999)	1,013,888	(100%)	(100%)

Source: ITU adapted from NECTEC and Ministry of Education (2000).

Benefits for School Networking:

(a) Accommodate New, More Demanding PCs and Workstations –Today's personal computer can increase the number of filing transfer, connection access, and large file storage. The speed and bandwidth of desktop computers, the size of popular internet files and educational files, and the magnitude of attachments sent via e-mail are increasing continually. School network bandwidth must grow to keep up with advances in technology.

(b) Make Existing Application Run Faster – The important reason to increase the school network's capacity is to gain higher performance of the existing client/server application. Adequate bandwidth also ensures that school can add this technology as necessary.

(c) Deploy Powerful Internet Applications – Internet applications promise a more self-sufficient and productive workforce – major's advantages in today's competitive school network. High-bandwidth also impose radically different demand on school network infrastructure. For example, more network traffic travels over backbone instead of remaining within existing medium.

3.6.1 How Each Broadband Should Keep up with School Network

Offering access to your internal network through the Internet might seem like a recipe for data disaster. However, VPNs use tunneling and encryption to protect your private traffic. Tunneling creates a temporary, point-to-point connection between the remote and central sites, blocking access to anyone outside. Encryption scrambles the data on the sending end and reassembles it on the receiving end, so it cannot be read or changed while in transit.

3.6.2 What You Need to Build a Networking for School

You can build and maintain your own VPN, but most small and medium-size business will find it easier to rely on a Service Provider. In this case, you simply connect to the Service Provider using routers (for sites with multiple users or heavy- duty usage) or modems (for individuals or branch offices with light usage) – just as you might connect your central site and remote users to the Internet. Note that there are two types of VPNs- dial VPNs and dedicated VPNs. This means VPNs can leverage the low cost of ordinary dial-up services, or, where a high-speed, high-capacity remote link is needed, they can operate over frame relay services or leased lines.

Once you implement a VPN, the offices in your network will need a firewall to act as a "sentry" to protect your network from unauthorized users. This firewall can be stand-alone device, but for small networks, firewalls can be integrated into a server or router, simplifying management and lowering capital cost.

Keep in mind that using a VPN means relinquishing some control over your network. Be sure to find a Service Provider who can provide a strong service level guarantee (99 percent uptime or better) and support the protocols you are using (most likely, IP or Internet Protocol) with minimal latency of traffic delay. If you have sites in multiple countries, you also may want to look for a Service Provider that already has- or is planning to have- local points or presence in the nations where you operate. This keeps your costs down by minimizing long-distance charges: your sites connect using local calls.

Analog Lines- Using analog lines to dial out to other networks or to the Internet- or to allow remote users to dial into your network- is a straightforward solution. Most ordinary phone lines are analog lines. Connect a modem to your computer and to a wall jack, you're in business. You pay for a connection as you would pay for a phone call- by the minute, or at set rate per local call (long-distance charges are the same as for a long-distance telephone call).

At present, the fastest analog modems operate at 56 Kbps for transferring data. With today's larger file sizes and graphically sophisticated Web sites on the Internet, you should choose modems that operate at a minimum of 33.6 Kbps (also called V.34) and that have V.42bis (data compression) capabilities.

While modems offer a simple solution for dial-out connections to other LANs and the Internet, they do not scale well as your network grows. Each modem can support only one remote "conversation" at a time, and each device that wants to connect with the outside world needs a modem, (Find more information in the Small Business Networking Examples section about overcoming this limitation by installation a router for wide-area communications and your Internet link.) " Dial-on-demand" routing is sometimes used as a compromise between the dialup method of connecting and full-fledged routing. With dial-on-demand routing, the router establishes (and is charged for) a connection only when the connection is in use. This solution uses a basic router paired with either a modem or an ISDN line, and makes the calls as requested by router.

ISDN operates at 128 Kbps and is available from your phone company. Charges for ISDN connections usually resemble those for analog lines- you pay per call and /or per minute, usually depending on distance. ISDN charges also can be flat rate, if they are linked to a local CENTREX system.

Technically, ISDN comprises two 64 Kbps channels that work separately. Load balancing or "bonding" of the two channels into a 128-Kbps single channel is possible when you have compatible hardware on each end of a connection (for example, between two of your sites). What's more, as a digital service, ISDN is not subject to the "line noise" that slows most analog connections, and thus it offers actual throughout much closer to its promised maximum rate.

You can make ISDN connections either with an ISDN-ready router or with an ISDN terminal adapter (also called an ISDN modem) connected to the serial port of your router. Again, modems are best for single users, because each device needs its own modem, and only one "conversation" with the outside world can happen at any one time. Your ISDN router, modem or terminal adapter may come with analog ports, allowing you to connect a regular telephone, fax, modem, or other analog phone device. For example, an ISDN router with an analog phone jack would allow you to make phone Leased Lines- phone companies offer a variety of leased-line services, which are digital, permanent, point-to-point communication paths that are "open" 24 hours a day, seven days a week. Rather than paying a fee for each connection, you pay a set amount per month for unlimited use. Most appreciate leased lines for school network range in speed from 56 Kbps to 45 Mbps (a T3 service). Because they all work the same way, choosing the right line for you depends on the number of users and the amount of remote traffic the network will carry (and how much bandwidth you can afford). A common service for business with substantial WAN usage is a T1 line with 1.5 Mbps of bandwidth.

By "point-to-point," we mean that leased lines use a direct, physical connection from your school or campus to the phone school's switch, and then to your other schools. Often, the phone or data services school may need to install new cabling.

Table 3.2. Transfer Rate for a 10-Megabyte File.

Modem Speed/ Type	**Transfer Time**
14.4-Kbps* Telephone Modem	1.5 hours
28.8-Kbps Telephone Modem	46 minutes
56-Kbps Telephone Modem	24 minutes
128-Kbps ISDN Modem	10 minutes
1.54-Mbps* T-1 Connection	52 seconds
4-Mbps Cable Modem	20 seconds
10-Mbps Cable Modem	8 seconds

Note: *kbps = Kilobits per second
*Mbps = Megabits per second

Table 3.3. Broadband Connectivity.

Connectivity Method	Description	Bandwidth
"Terrestrial"		
Dial-up Internet	Connecting to the Internet through a modem and telephone lines	56 Kbps modems give reasonable connnectivity
ISDN	A circuit-switched digital technology used to create point-to point links to Internet service providers (for dedicated connections) or between buildings	Basic rate ISDN supports two 64 Kbps digital channels. Can be bonded together to create one 128 Kbps pipe
Dedicated connections	A connection between a school and an Internet service provider	Varies from 64 Kps to 45 Mbps(T3)
ADSL	High speed Internet services presently offered by several companies; can also be used to connect buildings	Asymmetrical bandwidth of about 1 Mbps into the school and 300 Kbps out of the school
Cable-based modems	Offered by TelecomAsia through CATV.	Asymmetrical bandwidth capacity of about 30 Mbps into the school and up to 10 Mbps out of the school. Shared bandwidth means that speed into the school is actually about 1 Mbps
Fiber optics	Unused carrier fiber or fiber installed by school board is used to transmit data between schools and school board office	Depends on the electronics installed to transmit data: up to 1 Gbps
Ethernet, hub or switched LAN	Applicability depends on the age and architecture of the school – running cables through ceilings and walls can be problematic	Cables installed should support 100 Mbps Ethernet even if less is needed at present
Powerline technology to connect computers in a school together to form a LAN	Uses existing electrical wiring to transmit data – new technology	

The more times your answered “yes,” the more likely it is that you need to move up the scale of connectivity choices-away from analog lines to ward ISDN, DSL, or even leased lines.

It is also possible to mix and match services. For example, urban school from which a student is dialing in from computer center might connect to network using ISDN or DSL, while the main connection from the computer center to the Internet would be a T-1.

IV. SCHOOL NETWORK EVALUATION

4.1 Advanced School Network

SchoolNet Thailand model for national school has been a lunched by NECTEC in 1995. The early network was based solely in Bangkok; schools outside the capital city had to shoulder the high cost of long-distance telephone calls or leased-circuits in order to get connected. As a result, only a few schools outside Bangkok participated in the early SchoolNet Thailand project. Even at the peak of Thailand's economic growth, government funding to support SchoolNet was unavailable. Nowadays, there are 4,630 schools nation wide those and become members of school network.

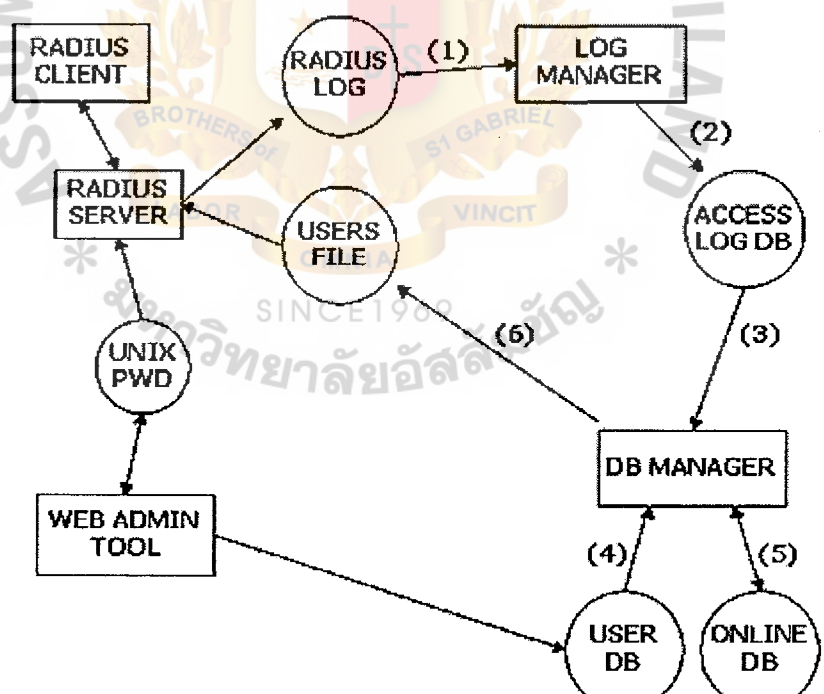

Figure 4.1. Interaction of Different Modules for Dynamic Authentication.

St. Gabriel's Library, Au

The network consisted of two parts: the content and the access network. Content-creation tasks were assigned to eleven organizations that had served the country through many successful projects due to His Majesty's initiative. SchoolNet task was to make available electronically existing knowledge and useful information for access by Thai people. This also managed the design and implementation of the access network. The design specifications were to give free, local, PPP access to everyone who wanted to read the contents.

The system needed up-to-date information to decide whether to allow a user to access the network and how many minutes to grant the user for that particular session. That meant that we needed a system that could manage user accounts and accesses. The system also required a minimum amount of human intervention because of the limited resources and manpower in this project. The challenge then was how to automate this whole process.

To handle users' telephone calls for assistance and support it was necessary to set up a help desk for SchoolNet. At present, there are three tools that support this operation. First, when responding to inquiries concerning unsuccessful log-ons, the help desk staff can verify a user's password through a standard web browser interface. Second, in addition to the email alert that the system sends to the team in case a network link is unreachable, the help desk staff also have, at their disposal, a link status web page that indicates whether a particular link is up or down and additional data about packet loss and round-trip time. Third, information is available for the staff to check how many accounts a school has, what the login names are, and to which categories and classes the accounts have been assigned.

This paper has so far only described the dial-in access part of SchoolNet. Although constituting a smaller part, some relatively advanced and financially well-to-do schools are connected to the SchoolNet backbone in Bangkok by permanent leased circuits. These schools number around 14. They all have their own campus LAN and a dedicated teacher-student team to operate routers as well as Internet servers.

However, as previously mentioned, most schools outside Bangkok cannot afford to pay for such leased circuits. To solve this problem, we plan to allow provincial schools to connect to our nearest POPs via a leased circuit. Due to limited resources, currently each POP can only accommodate one leased-circuit connection. SchoolNet is in the process of drafting a policy for selecting which schools can connect in this way. The criteria will likely be based on the technical potential of the school to operate an Internet node and the level of school activities on the Net.

SchoolNet also plans to expand the dial-in access part of SchoolNet so more schools can be brought online and more users can be handled. The target is to have 5,000 schools connecting to SchoolNet by the year 2001 and each school eligible for five Internet accounts instead of three. Moreover, the online time will be increased from 40 hours per month to 80 hours per month so students will have more time to explore the web. The number of modem lines in each provincial POP will be increased from fifteen to sixty and in Bangkok from one hundred and twenty to four hundred and fifty to accommodate more SchoolNet users.

In addition, we felt reasonably that technology could not produce sufficient growth of the network. Therefore, we would rather give examples for guidelines to implement the existing school network. There are key competencies for development of SchoolNet as follows:

(a) Network Configuration

(b) Data Library for Database Function

(c) Speed Bandwidth

(d) Hardware/Software Resources

(e) Network Access

(f) Help Desk Support Tool

4.2 SchoolNet Study

As we see in this case study, the most significant element underpinning Thailand's school network is a strong collaboration of Thai engineers from NECTEC. The engineers shared a common vision - Thailand must have a national network for the benefit of all Thais.

To gather primary resource data, we interview A. Jira Tapviset, The chief of computer center of Sa-nguan Ying high school, and A. Jirat Jamsawang, The director of computer school network (IT division) of Suankularb Nontraburi high school. We made a summary of the survey into two cases as follows:

(1) Case Study A: Computer School network model – Sa-nguan Ying High School

There are 2,800 students at comprises the academic level of all Mathayom 1 – Mathayom 6 (M.1-M.6). Computer centers consist of 75 sets in computer learning lab and 100 sets for all sections connected to LAN network. In total 175 sets are used for entering student profile into database record system, grading evaluation processing, and registration.

Right now the schools set up only a server to connect to Schoolnet/NECTEC via connection with 56K dial up modem, then all downloaded information would be kept in database server with Linux OS. Whoever needs to search the website will upload it from the server.

(a) M1-M3: Core courses studying the basic about how to use computer and Operation system by Microsoft, Microsoft Office97, etc.

(b) M4-M6: Core courses studying about Programming, Internet connection, Networking system, Multimedia, HTML to build homepage, etc.

Computer Hardware configuration for network administrative purpose for connecting to Internet:

(1) CPU: Pentium 4 -- 1.6GHz

(2) Memory: SDRAM 256MB

(3) Hard disk: IDE 10GB

(4) Floppy disk: 1.44MB, CD-ROM 52X

(5) Monitor 15"

(6) Keyboard, Mouse, Speaker

(7) Ethernet card 10/100 Mbps

Computer Hardware configuration (General purpose):

(1) CPU Pentium Celeron 733MHz

(2) Memory: SDRAM 128 MB

(3) Hard disk: IDE 6GB

(4) Floppy disk 1.44MB, CD-ROM 40X

(5) Monitor 15"

(6) Keyboard, Mouse, Speaker

(7) Ethernet card 10/100 Mbps

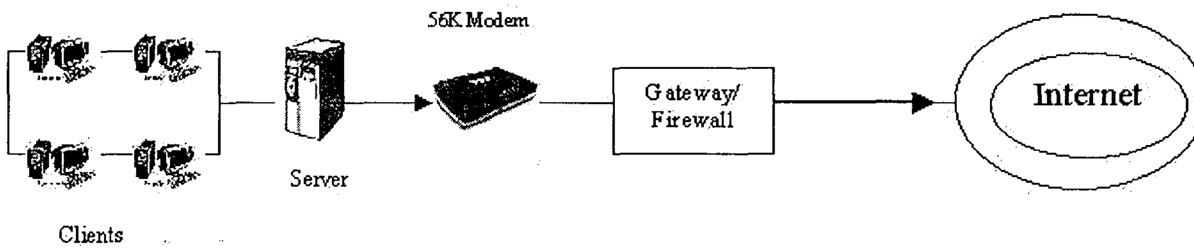

Figure 4.2. School Computer network for Sa-nguan Ying High School.

Solution for Case A:

Based on the number of students, specification of personal computer for both workstations and servers, and size of bandwidth modem, this project would rather suggest the alternatives for upgrading the existing school network of Sa-nguan Ying high school. The school connects to Internet with 56k dial-up modem that accesses via KSC. This amount of bandwidth is not adequate for the number of students if they are online at the same time. This causes bottleneck of streaming lines, for example, if large number of files are downloaded, the server would be down for those transactions requested by the clients. Time response would be increased without allocating the functional resources. Therefore, we advice technically configuring an on-line network of the school network to prevent unexpected events. Firstly, the school could replace a 56 Kbps dial-up line with a higher broadband to handle the number of clients. For example, in term of data rates available to ISDN subscriber, ISDN at 128 Kbps is reasonable to provide data transmission for video and audio lab. If clients download applications of video streaming package for multimedia class with 56k modem that is unable to access with full performance there can be time delay. ISDN will be an application to help teachers with assistant teaching multimedia whose purpose is for new technology education.

Recommendation to improve network connection speed up:

As a future plan, we have been planning for a next step development to increase speed up network improvement. Then, the school may consider a new medium line such as a leased line that accesses bandwidth at 128 kbps that is connected directly to Schoolnet by NECTEC. Therefore, outcome of increasing speed up and bandwidth for computer school network will be directly proportional to the benefit of students and teachers in this school. For example, the teachers can gain more knowledge and that affects their students. The students can directly access the network, which means the ability to learn from the internet will increase also.

(2) **CASE B:** Example of Schoolnet model - Suankularb Nontraburi School

Suankularb Nontraburi High School has 3,800 students at levels of Mathayom 1 – Mathayom 6 (M1-M6). There is a computer center for managing grades, student profile database, registration files, financial management and accounting, etc.

Computer rooms for education can be defined as below:

(a) Learning Computer Lab. = 160 computers (for surfing the Internet)

(b) Sound Lab (English) = 50 computers

(c) Thai language program = 25 computers

(d) Mathematics program = 25 computers

(e) Multimedia Lab = 35 computers

(f) Administration center for computer processing = 5 computers

Computer hardware configuration is as follows:

(1) CPU: Pentium 4 -- 1.6GHz

(2) Memory: SDRAM 256MB

(3) Hard disk: IDE 40GB

(4) Floppy disk: 1.44MB, CD-ROM 52X

(5) Monitor 15”

(6) Keyboard, Mouse, Speaker

(7) Ethernet card 10/100 Mbps

In total, 300 computers are connected via computer network by LAN- Local Area Network with Leased line 56 Kbps and Satellite link 256 Kbps via Internet service provider CS Internet for full time access to Internet.

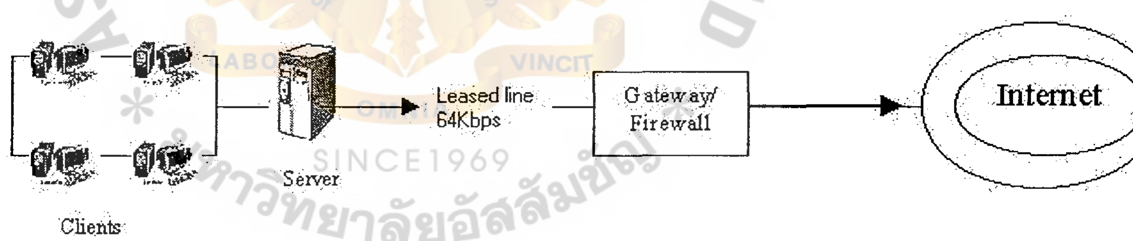

Figure 4.3. School Computer network for Suankularb Nontraburi High School.

Solution for Case B:

The school computer network of Suankularb Nontraburi compreises of leased line 64 Kbps and Satellite link 256 Kbps, which has a variety in connecting to the Internet. It means that it has high efficiency for speed up which is good enough to download large files through the Internet. There is high performance control to uplink/downlink stream data via satellite as well. The student can connect to Internet online for surfing the website in one click.

This school is a good example of school network that not only already has a high performance network but also has some plan for improvement in the future. Even though it is a good example for all schools but not all schools can follow such a high cost of improvement for the network. If there is enough budget for investment in network construction.

Recommendation to Improve network Connection speed up:

In the future plan, they are developing an intranet of small network in their section in order to be independent and not depending on the main server. Also, there is a plan to implement hi-speed transfer of data via optic fiber cable network to improve the capacity of internal network and manage the database on their own. The outcome of this effective plan will be an advantage in planning and developing their connection through the network in the future.

4.3 SWOT Analysis of School Computer Network

Table 4.1. SWOT Analysis of Sa-nguan Ying High School.

Strength: Easy to control and develop hardware/software with a small network in keeping database record management	**Opportunity:** To setup network with less overhead cost. Suitable for rural school for beginning a network model.
Weakness: Inconvenience in downloading and updating information on time. We have to link with 56k dial up connection.	**Treat:** Bandwidth is limited.

Table 4.2. SWOT Analysis of Suankularb Nontraburi High School.

Strength: Students are able to connect to Internet and search library data on time. High-speed network can be demonstrated in class that is easy to emphasize system configuration.	**Opportunity:** There are 2 options to connect to Internet via leased line and satellite link. Student has more clearly defined knowledge about network can be developed to high speed.
Weakness: Complicated to understand how to develop networking connection.	**Treat:** If problem occurs in the complexity network, there must be one specialist for monitoring surveillance.

4.4 Approach for Upgrading Planning

This section provides step-by step instructions for planning an upgrade. The first part is intended for high schools with 1,000-2000 students that currently use an Ethernet hub. The second part addresses the concerns of high school with over 2,000 students. This high school may presently have an Ethernet hub, 10-Mbps Ethernet switch or a combination.

This section will help high schools to consider whatever they need for the development of school network. This will also help the schools select high technology features that will be useful for school network environment.

LAN for Small High School:

This section copes with 500-1000 students to review the discussion in the previous section to decide whether a Fast Ethernet hub or an Ethernet switch best meets the performance requirements and budget needs. Basically:

(1) Either a hub or a switch improves performance if current network utilization is high.

(2) Switched Ethernet provides more total bandwidth.

(3) Fast Ethernet hubs are less expensive than Fast Ethernet switches.

To locate resource efficiency, workstation should be placed in the same segment as the servers they access in order to minimize unnecessary traffic. Then, each segment should be its own collision domain. The devices in a segment do not need to be physically collocated. For example, you might create one segment each for finance, registrar office, and administration department. Creating logical segments not only reduces network traffic, it also increases security by restricting confidential traffic to one segment of the network.

If you are upgrading to an Ethernet or Fast Ethernet switch, you can optimize LAN performance by placing workstations on the same logical network as the servers they access most often. This setup reduces the amount of traffic that must travel over a network backbone, which is the network segment that connects switches.

With planning to use existing hub in school, the network could gain the advantage of existing 10-Mbps hubs. The technical advice is connecting each workstation to a 10-Mbps segment, and connecting servers to 100-Mbps segment. This network management would boost up the performance of school network and create advantages for users.

4.5 Cost Benefit Analysis

The cost-benefits of intranets are meant to be self-evident. After all, the set up costs appear to be minimal and the benefits although largely intangible are , by all accounts, substantial. So why not just get on with it and see what happens?

St. Gabriel's Library, Au

(1) Why is Cost-Benefit Analysis Necessary?

For many people, the process of measuring the costs and benefits of an intranet is one that, with any luck, can be avoided. After all:

(a) "There are so many intangibles, it's impossible to do."

(b) "The benefits of an intranet are so obvious, there's no print."

(c) "An intranet is so cheap to set up that there's no requirement to justify it"

(d) " An intranet is just a basic tool, like fax and word processing, that can be taken of granted."

(e) " The figures are far too complex to calculate."

Pual Korzeniowski writes in Info world Electric: 'Rather than carefully evaluating bottom-line benefits, corporations are plunging headfirst into the intranet waters. New applications have sprung up in months or even weeks and top management approval is often assumed rather than requested.'

So why spoil this cost situation and go to all the trouble of a proper analysis?

Because even relatively intangible costs and benefits can be measured if you are prepared to approximate.

Because the benefits of an intranet may be obvious to you, the up-font direct costs of an intranet may be relatively low, but the human costs of setting it up, populating it with content and then maintaining that content are considerable.

Because even word processing and fax had to be justified when they were first introduced (don't say anything- if they weren't, they should have been!).

And because, if you're prepared to follow a straightforward step-by-step procedure, you'll find the calculations are not complicated at all.

Perhaps the strongest argument for conducting a proper assessment of the costs and benefits of an intranet is that this should provide you with the ammunition you need to do the job properly, with an appropriate budget and realistic timetable. If it doesn't, then at least you will be forewarned enough to drop the subject quietly or look to get a job with another organization, where an intranet is going to be of more use.

(2) Scoping Your Intranet

It is not possible to conduct a meaningful analysis without a clear indication of what you want your intranet to achieve. There are many ways of categorizing what an intranet does. The following is one way of doing it.

Information publishing: using the intranet to deliver news and other information in the form of directories and web documents.

(a) **E-mail:** implementing an e-mail system that integrates seamlessly with the intranet, allowing information to be both 'pushed' and 'pulled'.

(b) **Document management:** using the intranet to allow users to view, print and work collaboratively on office documents (word-processed documents, spreadsheets, presentations, etc.).

(c) **Training:** using the intranet to deliver training at the desktop.

(d) **Databases and other bespoke systems:** using the intranet as a front-end to organization-specific systems, such as corporate databases.

(e) **Discussion:** using the intranet as a means for users to discuss and debate issues.

Pretty well every organization will implement the first of these information publishing. The majority will have ambitions to extend their intranet to cover the rest of the list at some stage. Don't be distracted into predicting too far into the future- apart from anything else it will make your calculations more difficult and less useful. Concentrate on what you expect to achieve in the first major wave of implementation- let's say the first year.

(3) Establishing some basic facts and figures

To make your calculations later you will need to gather some basic facts and figures about your audience:

(3.1) The size of your intranet target population and, if appropriate, the proportion this represents your organization's total projected intranet user population.

(3.2) The number of people within the target population who will need new PCs, the number who are currently not networked and the number who will be provided with access to the Internet.

(3.3) The average annual salary and benefits of the target population, the average working hours in a day and working days in a year (used to calculate labour saving and productivity gains).

(a) Analyzing costs

The next step is to analyze the costs that will be incurred in setting up and running your intranet. There are two main categories of cost:

Capital costs: hardware and software costs that will be met by the organization's capital budget and normally, written off over a number of years.

Revenue cost: other costs that are likely to be borne by the organization's normal expense budget.

It is also necessary to make a distinction between the one-off costs associated with start-up and on-going maintenance costs. Here are some ideas for what to include in each case:

(b) Start-up capital costs

(1) These costs form a major part of your up-front investment. Because, as fixed assets, they have a useful life of several years and a resale value, they are normally written off over three or four years.

(2) New PCs – for providing intranet access to employees without their own PCs.

(3) Providing network connections to PCs not currently networked.

(4) Web servers and server software.

You also need to provide for the cost of software applications, whether they are developed on a bespoke basis (in-house or outside) or purchased off-the-shelf. You can pay considerable prices for 'industrial strength' applications, but much cheaper or even free application can be obtained with a little research. What you will need will depend on what you are using your Intranet for:

(1) Information publishing: examples of automated applications include directories (phone, employees, products, services, locations, etc.) and application that automates the production of news pages, classified ads or newsletters.

(2) E-mail: Intranet e-mail is typically provided with a single off-the shelf application, plus individual client licenses.

(3) Document management: typically one main application.

(4) Training: for ease of calculation, assume that an intranet training application represents one hour of self-instructional material.

(5) Databases and other bespoke systems: include any application that provides users with an Intranet front-end to a major, existing bespoke corporate system.

(6) Discussion: there will typically be one application to allow users to debate topics over Intranet.

(c) Start-up revenue costs

These also form part of your up-front investment, but are more likely to be written off in the first year of implementation:

(1) Design consultancy: the cost, whether internal or external, of creating a structural, navigational and graphical design for the part of the Intranet being analyzed.

(2) Promotion: the cost again, internal or external, of launching the Intranet to your target population.

(3) Training: the total cost per user, of providing training in both how to use the Intranet and how to provide content.

(d) Some money will have to be reversed each year, from year 2, for upgrades to your server hardware and software and to your off-the-shelf applications. Perhaps the best way of estimating this will be as a percentage of the initial cost – say 25%

(e) Ongoing revenue costs

A considerable amount of the effort is required to maintain and continuously improve your Intranet. These costs need to be budgeted from year one:

(1) Editorial and design personnel: the people required to administer Intranet policies and act as overall content editors for your target population. Remember to include salaries, benefits and expenses.

(2) Technical personnel: the people required by the organization as a whole to keep your intranet up and running from a technical perspective.

(3) Internet access: the cost of providing lines out to the Internet. A simple way of estimating this is to make a small annual allowance, say $50, for each employee who will have access.

The following costs apply after the first year of implementation:

(1) Ongoing consultancy: continuous modifications and improvements to your Intranet design, expressed as a percentage of start-up design consultancy costs.

(2) Ongoing promotion: continuing promotion of the Intranet to your target population expressed as a percentage of start-up promotional costs.

(3) Ongoing training: a percentage of start-up training costs, largely to account for employee turnover.

(4) Maintenance of bespoke applications: assuming this work is not carried out by the technical personnel listed above, make an allowance for continuing development of your bespoke applications, say 25% of the initial cost.

(4) Forecasting benefits

Not many people have trouble calculating costs. It takes a little more ingenuity to pin down the benefits. There are three main categories of benefit:

(a) Direct cost saving: saving in expenditure other than labor-print, paper, telephone, travel cost, etc. – that can be directly attributed to the introduction of the intranet.

These can usually be calculated in three steps: (1) the number of incidences of expenditure in the time period, (2) the cost of each incidence and (3) the proportion of these that could be eliminated using the Intranet. For example, if the number of pages of formal printed material received per person per year was 500, the cost in pence per page, including printing and delivery, was 6P and the percentage of these pages that could be delivered on-line was 70%, the saving in pounds would be 500 X (6/100) X 70% X the size of the population.

(b) Labor savings: saving in the amount of time required to carry out tasks as a result of introducing the Intranet. These can be expressed in minutes per person per day. To calculate the saving, divide the number of minutes saved by the number of minutes in the day (60 X the number of working hours) and multiply by the size of the population and the average salary.

(c) Productivity increases: increase in output per person attributable to the introduction of the Intranet, expressed as a percentage. Because personal productivity has such a wide range of implications from job to job and organization to organization, it is probably easier to convert these to simple labor saving. For example, if the total productivity gains were 3%, calculate the saving as (3/103) X the size of the population X the average salary. The actual effect of higher productivity, such as increases in sales, could well be much larger and, if you can estimate these, then you should.

4.6. Analyzing the Results

Before you can make any conclusions from your findings, you 'll need to total up your costs and benefits.

(a) Summarizing Costs

If your target population is a subset total Intranet population, then you need only to take a proportion of the costs that are borne centrally. The following costs are likely to be central:

(1) Server hardware and software

(2) The purchase, development, maintenance and upgrades to software applications provision of technical personnel.

Remember that you only need to take account of the cost of applications that are required to support your initial Intranet implementation.

(b) Summarizing Benefits

Total up the benefits for each Intranet category under the three benefit headings: direct cost saving, labor saving and productivity increases. Before making your calculation, it is necessary to determine the proportion of the target population that is affected by each of the Intranet categories.

For example, the whole population may be affected by the use of the Intranet for information publishing, but only 30 % for document management and 40% for workflow. If you don't make these distinctions, you are likely to over-estimate your benefits.

We can setup network operation shown in table 4.1 with a small-size school at 1,000~2,000 students for 50 computers.

UNIVERSITY OF THAILAND ASSUMPTION
BROTHERS of ST GABRIEL
LABOR VINCIT OMNIA
SINCE 1969
มหาวิทยาลัยอัสสัมชัญ

St. Gabriel's Library, Au

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This school network model has described a good project for starting plans to setup a network. Initially, we can suggest how to grasp this network model as described in Chapter 4 about the effort to introduce Internet in Thai schools. This project concept can be easily applied in a developing country that is planning to set up an educational network in medium size high schools.

Many high schools have to study to set a budget with minimum cost and be effectively useful in application of network performance.

This report has two good examples for all schools to follow with pros and cons. The first one (Sa-nguan Ying High School) is a good example on economic cost that most schools in up country always use. The second (Suankularb Nontraburi High School) is a good example of larger schools that can be done, according to the price of all network that is still expensive at present

In the future, the cost of all equipments such as PC, Network card, Hub, Switches, and Modem will be cheaper. This is the main reason to improve the efficiency of their network. I hope that this is not only a dream for all up country students to have some opportunity to study and find some information through the Internet. To become a reality depends on the vision of all the leaders.

5.2 Recommendation

Nowadays, LAN Bandwidth is inexpensive. The cost for increased LAN bandwidth has stayed relatively constant over time. Over-provisioning bandwidth in LAN eliminates network performance tweaking, vastly reduces the effects of latency, and reduces the probability of congestion. It also increases operational efficiency by

St, Gabriel's Library, Au

V. CONCLUSION AND RECOMMENDATION

5.1 Conclusion

This school network model has described a good project for starting plans to setup a network. Initially, we can suggest how to grasp this network model as described in Chapter 4 about the effort to introduce Internet in Thai schools. This project concept can be easily applied in a developing country that is planning to set up an educational network in medium size high schools.

Many high schools have to study to set a budget with minimum cost and be effectively useful in application of network performance.

This report has two good examples for all schools to follow with pros and cons. The first one (Sa-nguan Ying High School) is a good example on economic cost that most schools in up country always use. The second (Suankularb Nontraburi High School) is a good example of larger schools that can be done, according to the price of all network that is still expensive at present

In the future, the cost of all equipments such as PC, Network card, Hub, Switches, and Modem will be cheaper. This is the main reason to improve the efficiency of their network. I hope that this is not only a dream for all up country students to have some opportunity to study and find some information through the Internet. To become a reality depends on the vision of all the leaders.

5.2 Recommendation

Nowadays, LAN Bandwidth is inexpensive. The cost for increased LAN bandwidth has stayed relatively constant over time. Over-provisioning bandwidth in LAN eliminates network performance tweaking, vastly reduces the effects of latency, and reduces the probability of congestion. It also increases operational efficiency by enabling less sophisticated support requirements and allowing more focus to be placed on applications instead of network bottlenecks. A campus backbone built out of only two 24-port Gigabit Ethernet switches that are trunk clustered could cost as little as US 60,000 and it would deliver nearly 1000 times the bandwidth of a shared FDDI ring as well as maintain the resiliency benefits.

5.3 Further Recommendation

As performance requirements and the size of school network increase, networks are becoming increasingly complex and more prone to failure and outages.

Since businesses can quickly shutdown if their networks fail, planners must install fault tolerant devices at key points within their networks. Conventional switches and routers do little to ensure network availability. The overall objective is to:

(a) Ensure that the core of the network is protected against any potential single point of hardware failure.

(b) Provide mirrored linkes for LAN and WAN traffic.

(c) Replace conventional switches and routers that tie transaction processing clients to server farms with non-stop devices.

BIBLIOGRAPHY

1. William Stallings, “Data and Computer Communications”, sixth edition: Prentice Hall, 2000
2. Jeffrey A. Hoffer, Joey F. George and Joseph S. Valacich, "Modern Systems Analysis and Design.", 2nd edition: Prentice Hall, 1999
3. Kenneth C. Laudon and Jane P. Laudon, "Management Information System", sixth edition: Prentice Hall, 1997
4. Israel Borovits, "Management of Computer operations", Prentice Hall, 1984
5. James R. Mensching, "Managing an information system", England cliffs, NJ07632, USA: Prentice Hall, 1991
6. Russell, Roberta S. And Bernard W. Taylor, III, "Production and Operations Management", Englewood Cliffs, NJ 07632, USA: Prentice-Hall, 1995
7. Jay heizer and Berry render, "Operation Management", 6th edition or International edition: Prentice Hall, 1996
8. Hamdy A. Taha, "Operation Research: An Introduction", 5th Ed., Prentice Hall, 1997.
9. Charles P. Pfleeger, "Security in Computing", 2nd edition: Prentice Hall, 1997
10. Dieter Gollmann, "Computer Security": John Wiley, 1999
11. William Stalling, "Cryptography and Network security: Principle and Practice", 2nd edition: Prentice Hall, 1999
12. David A. Stamper, "Business Data communication", 4th edition: Benjamin Cummings, 1994

St. Gabriel's Library, Au