Network support for tele-education

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This paper discusses the state of the art in networking, and explains the way existing networks can support tele-education applications. Chapter 1 identifies which tele-education parameters have the biggest impact upon the underlying network, and proposes a classification of tele-education applications. Chapter 2 discusses the various networks that are used for tele-education purposes: Local Area Networks (LANs), Wide Area Networks (WANs) and Public Access networks.

1 Application demands

Of all application parameters that are relevant for the network, bitrate and delay are the most important ones. Bitrate indicates how much data the application offers to the network per time unit; bitrate is expressed in bits per second. Delay is the amount of time the network is allowed to take for the transport of a single piece of information; delay is measured in seconds. Based on these two parameters, tele-education applications can be divided into three categories:

- low-tech applications, which offer a limited amount of data and accept a large delay,
- medium-tech applications, which offer a medium amount of data and / or require a short delay,
- high-tech applications, which offer a high amount of data and require a short delay.

1.1 Low-tech applications

Typical low-tech applications do not offer more than a few hundred bytes per second and allow delays of multiple seconds. Existing networks usually do not have any problems to support these applications. Examples of low-tech tele-education applications are:

- Electronic mail (email). Emails may be exchanged directly between students and teachers, but can also be directed to a discussion list. For many courses such lists already exist; students who want to join such lists can subscribe by sending special requests to the managers of the lists.
- World Wide Web (WWW). Most existing tele-education courses take already advantage of the WWW. These courses rely on WWW browsers to down-load readers (which may include pictures) and exercises (which may use scripts and applets). The answers of exercises can be returned to the teacher via WWW forms, which are also useful in case new students want to get registered to a course or exam. The impact of the WWW is so dramatic, that it seems a good advise for programmers of new tele-education software to ensure that their new software will be able to cooperate with general purpose WWW browsers.

1.2 Medium-tech applications

Medium-tech applications are characterised by the fact that they can be supported by existing networks, provided that sufficient capacity is left. They typically generate up to hundreds of kbit per second, or demand short delays (less than one second). Examples of medium-tech tele-education applications are:

- Non-interactive voice. Besides text and pictures, WWW pages can also include voice. In tele-education environments, non-interactive voice will be particularly effective if it provides background information to pictures. Another use of a non-interactive voice is voice-mail.
- Non-interactive video. WWW pages can also be enriched with video fragments. In many cases the length of such fragments is limited to several seconds and the total number of bytes to be transferred does not exceed 1 Mbyte. Whereas the transfer of these segments may be possible with up-to-date networks, the transfer of complete video presentations of several hours will be problematic for most of the current networks.
- Interactive voice. An application that has bitrate as well as delay requirements, is interactive voice. Depending on the required quality and available compression techniques, the required bitrate may be between 10 and 64 kbit per second. The delay should be less than a second.
- Shared white-board. An application that may be particularly useful in combination with interactive voice, is a shared white-board. Although such applications do not generate substantial amounts of data, they demand for short network delays.

1.3 High-tech applications

High-tech applications are characterised by the fact that they can not be supported by most of the current networks. They typically generate more than 1 Mbit per second, and have strict delay requirements (fractions of a second). Examples of high-tech tele-education applications are:

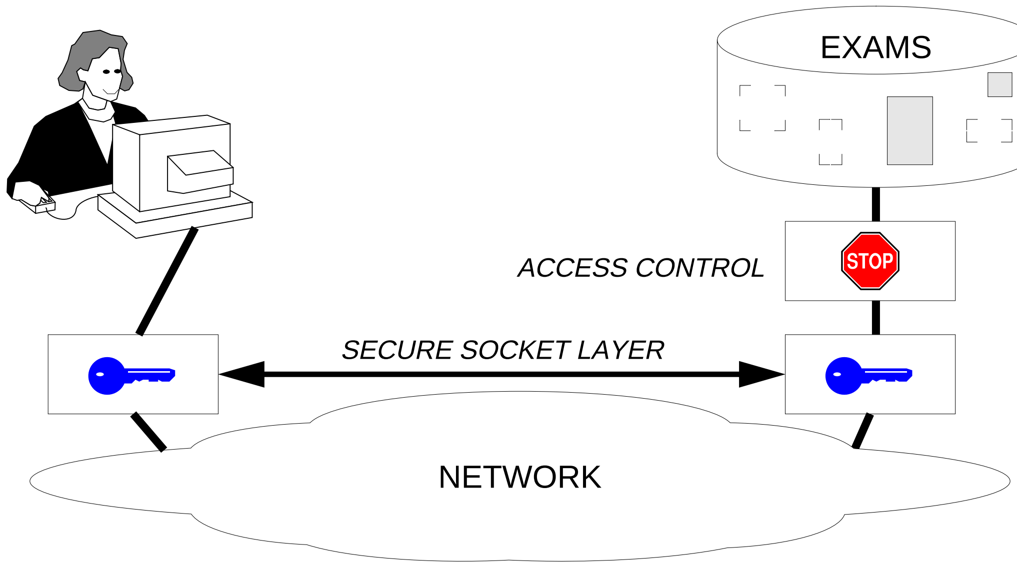
- Two-party video conferencing. This application allows individual students to interact with the (remote) teacher.
- Multi-party video conferencing. This application enables the creation of virtual classrooms. It allows teachers and students to be at different locations.

1.4 Security

If students are to be examined from remote locations, security becomes an important issue. Security includes authentication, confidentiality and access control. Authentication is needed to ensure that answers are actually created by the students who claim to be the composers. Confidentiality is needed to ensure that students can not see the answers that are composed by others. Access control is needed to ensure that students can not obtain the questions that belong to exams for which they did not register.

WWW browsers, such as Netscape, include Secure Socket Layer (SSL) software, which takes care of authentication and confidentiality. SSL is based on public key technology; because of US export restrictions the current software can only support limited size keys of 40 bits. Although all software is available, key management has not yet been solved and remains problematic.

WWW servers, such as NCSA and Apache, include built-in access control functions. These functions use a name - password mechanism to protect the access to files and directories (which contain the exams).



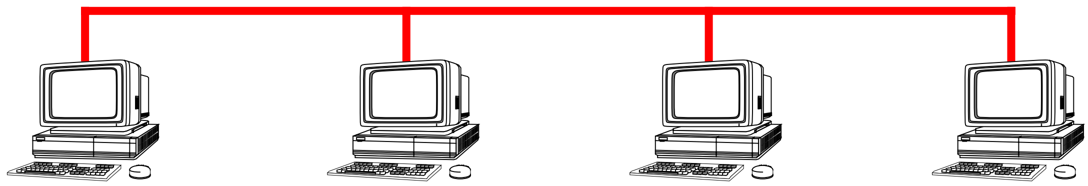
Secure tele-education

2 Network facilities

This chapter discusses the various types of networks that are being used for tele-education purposes: Local Area Networks (LANs), Wide Area Networks (WANs) and Public Access networks.

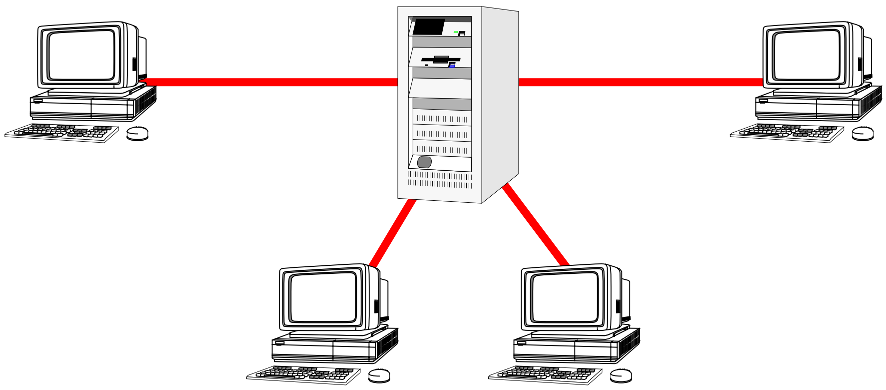
2.1 Local Area Networks

Local Area networks (LANs) are typically used to connect tele-education servers (for instance WWW and video servers), classrooms and, in case of the UT, students that live on the campus. The most popular LAN, which is also being used at our university, is Ethernet. Several versions of Ethernet exist. The traditional Ethernet, which has been standardized more than 15 years ago, is often used to connect between ten and hundred stations to a single medium. The topology of this network is the so-called *bus topology*. At each moment of time, only one of these stations will be able to transmit a packet over the bus. The length of a packet can be up to 1500 bytes; since the supported bitrate of Ethernet is 10Mbit per second, most packets can be transmitted within 1 millisecond.



Traditional Ethernet

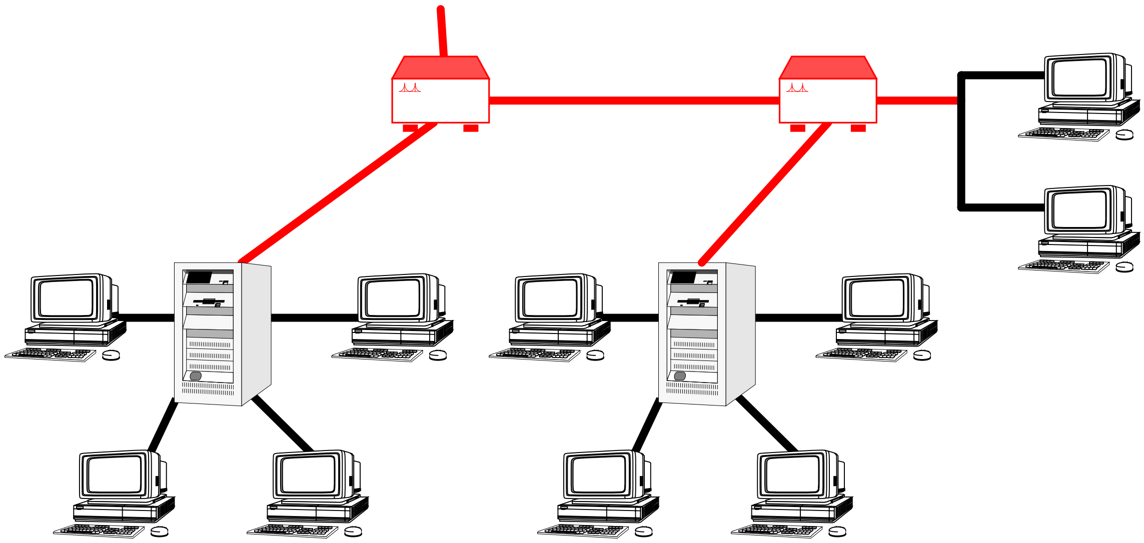
The traditional shared Ethernet, which is installed in many buildings of our university, can already get overloaded in case it has to support medium-tech tele-education applications. For such applications *switched Ethernet* will be the better solution. The topology of this Ethernet version is the so-called *star topology*. The centre of the star is formed by the Ethernet switch; each station is connected to this switch via a dedicated cable. Packets that arrive over a certain cable at the switch, are forwarded by the switch over the outgoing cable that connects the destination station; the packet is not transmitted over the other cables which can thus be used for the transmission of other packets. Switched Ethernet therefore allows multiple stations to transmit at the same moment of time.



Switched Ethernet

Although the 10Mbit version of switched Ethernet may be well suited for PCs and workstations that run medium-tech tele-education applications, it surely lacks the capacity to support high-tech tele-education servers, such as video-servers. If such applications are still needed, fast Ethernet, which operates at 100 Mbit per second, may be the solution.

Despite the introduction of switched and fast Ethernet, the number of stations that can be connected to a single Ethernet segment remains limited. If thousands of stations need to be connected, the creation of multiple Ethernet segments (each connecting between ten and hundred stations) becomes inevitable. To interconnect these segments, Internet Protocol (IP) routers must be introduced. A mistake that is commonly made, is that organizations save on this router infrastructure because the routers and the cables that connect these routers are not directly visible to the end-user.



Ethernet segments, interconnected by routers

If high-tech tele-education applications need to be delivered to many students that are living on a campus (LAN), the ideal network infrastructure may look as follows. Each student is connected to an Ethernet switch via a ten or hundred Mbit Ethernet line. Only a limited number of Ethernet lines are connected to a single switch. Switches are interconnected via IP routers. The line between switches and routers is a fast Ethernet or ATM line (ATM is discussed in the next section). The line between routers, and also the line to possible video servers, is a fast Ethernet or ATM line too.

2.2 Wide Area Networks

WANs are used to connect different universities, and allow students from one university to follow courses at other universities. The various universities within the Netherlands are interconnected via SURFnet, which runs the Internet Protocol and consists of several 34 Mbit/s rings. SURFnet is connected to other European countries via the TEN34 network at 22 Mbit/s, connections to the US will be upgraded in 1997 from 16 Mbit to 34 or even 155 Mbit/s. Plans exist to connect secondary schools too.

SURFnet topology

In January 1997 the new SURFnet4, which is based on a technology called Asynchronous Transfer Mode (ATM), has become operational. ATM has many interesting features; the most important being the possibility to set-up connections with guaranteed Quality of Service (QoS). In principle ATM is ideal to support high-tech tele-education applications, such as video conferencing. Unfortunately there are some problems that hamper the wide-spread introduction of ATM:

- Current ATM networks do not offer all necessary QoS support yet.
- There are not yet many applications that take advantage of the full power of ATM. Because of this lack, ATM equipment is sold in small quantities and remains expensive. But since equipment is expensive, there are not many companies willing to invest in ATM applications. In fact we are confronted with the traditional chicken and egg dilemma.
- QoS guarantees are primarily useful if they refer to the entire communication path. However, students, teachers and (video) servers are usually connected to LANs. Because of the relatively high costs of ATM, there are not many ATM-based LANs yet. Instead of investing in ATM, many organizations decided to base their new LAN infrastructure on fast Ethernet. Unless ATM technology becomes much cheaper for the local area, QoS guarantees can only be given for the WAN portion of the communication path.
- In principle ATM allows single students to reserve all available capacity. Without good management tools that detect and correct potential misuse, full introduction of ATM becomes risky.
- The impact of the Internet and IP has been underestimated. IP is constantly being improved and the new version of it (IPv6), in combination with a Resource Reservation Protocol (RSVP) and the Multicast backbone (MBone), fulfil already many of the promises of ATM.

To some extent the relation between ATM and IP can be explained in terms of the following analogy. ATM is OS/2, IP is DOS. Many people believe that OS/2 (ATM) is better than DOS (IP). Still most developments take place within the context of DOS (IP). DOS is also being upgraded to Windows '95 and Windows NT (IPv6, RSVP, MBone). As a result, the need for OS/2 diminishes.

Despite the various problems, we may still expect that ATM will play an important role as back-bone for IP. The advantage of using ATM, is that the high bitrates that are provided by ATM networks can be used by IP. Additionally, applications that are not sufficiently supported by IP (e.g. multi-party video conferencing), will still be able to use native ATM, although at a possibly higher price and, since connections may need to be manually configured, in a less dynamic way.

If we compare SURFnet with similar research nets in other countries, we may conclude that SURFnet is quite advanced and even supports, although at a small and experimental scale, the introduction of high-tech tele-education applications. However, it is not yet able to support such applications at a large scale, e.g. hundreds of courses with many thousands of students.

2.3 Public Access Networks

Public Access networks allow students that live in the city to connect to the infra-structure (e.g. the WWW and video servers) of the university. Examples of public access networks are the plain old telephone network, the Integrated Services Digital Network (ISDN), CAble TV (CATV). and Digital Subscriber Line (xDSL).

Until a year ago, the telephone network offered the only alternative for students living in the city to connect to the university's LAN. To transfer computer signals over the telephone line, modems are needed at both sides of the telephone line. In the last decade modems have been developed to communicate at 2.4 (V.22bis), 9.6 (V.32), 14.4 (V.32bis) and even 33.6 kbit per second (V.34). At this moment companies like Rockwell and US Robotics are even developing products that allow users to down-load information at 56 kbit per second (in the up-load direction the maximum bitrate is limited to 33.6 kbit per second). Modems slower than 33.6 kbit per second are only useful for low-tech tele-education applications. The new 56 kbit per second modems will also be able to support some of the medium-tech applications.

Nowadays it is also possible to connect to the university's LAN infrastructure via ISDN. ISDN enables computers to communicate at 64 kbit per second in a direct fashion, which means that computer information need not be modulated on an analog (voice) signal any more. Since a single ISDN interface enables the set-up of two concurrent connections, it is possible to a have simultaneous telephone call and computer connection. Another possibility is to set up two parallel computer connections, and communicate at 128 kbit per second. At such speed, ISDN will not have many problems with most medium-tech tele-education applications

The manufacturers and operators of the existing CAble TV (CATV) networks propose to extend their existing coaxial cable networks such that two-way data communication becomes possible. In this area a lot of research is going on, but standards are still missing (one of the groups working on such standards is IEEE 802.14). In the absence of standards, it is difficult to predict the impact of CATV for tele-education purposes.

The manufacturers and operators of the existing telephone networks are currently developing technologies like 'Asymmetric Digital Subscriber Line' (ADSL), 'High data rate Digital

Subscriber Line' (HDSL) etc. The key idea behind these technologies is to save the investments in the current copper-based telephone infrastructure by re-using the existing twisted pair telephone lines for high speed data communication. This year ADSL will already be introduced, although at a small scale, in the US. Once ADSL becomes available in the Netherlands, it will also (technically) be possible to support high-tech tele-education applications over public access networks.

Abbreviation	Name	Data rate
HDSL	High data rate Digital Subscriber Line	1.544 - 2.048 Mbps
SDSL	Single line Digital Subscriber Line	1.544 - 2.048 Mbps
ADSL	Asymmetric Digital Subscriber Line	Up: 16 to 640 kbps Down: 1.5 to 9 Mbps
VDSL	Very high data rate Digital Subscriber Line	Up: 13 to 52 Mbps Down: 1.5 to 2.3 Mbps

3 Conclusions

Three types of tele-education applications can be identified:
- Low-tech applications, which exchange email and WWW information.
- Medium-tech applications, which exchange voice and non-interactive video information.
- High-tech applications, which exchange interactive video information, possibly between multiple parties.

Under the assumption that the network is not heavily loaded, low-tech tele-education applications can be supported by all current network types. The characteristics of these applications (amount of traffic that is generated, acceptable delay) is similar to that of other applications. If the performance of other applications is acceptable, low-tech tele-education applications will show an acceptable performance too.

Medium-tech applications require state-of-the-art network technology. The LAN infrastructure, which connects students living on the campus, teachers and tele-education servers, should preferably be based on switched and fast Ethernet. The public access network, which allows students living in the city to connect to the LAN infrastructure, should be based on modems faster than 34 kbit per second, or ISDN. Using the Wide Area Network (WAN) infrastructure of SURFnet, medium-tech tele-education applications between universities should be possible too.

High-tech tele-education applications can only be performed as experiments in controlled environments. Given the current development in network technology, we may expect that further investments in this area enables us to give a limited number of high-tech tele-education courses within a few years from now.