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Telemedicine Systems and Telecommunications

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1. Introduction

The practice of telemedicine can be divided into two distinct categories: realtime and store-and-forward. Realtime telemedicine involves synchronous interaction between the parties concerned. For example, a health-care professional and a patient may interact by videoconferencing. While realtime telemedicine is often effective in terms of consultation and patient satisfaction,[1][2] it presents challenges. Foremost is the scheduling of the parties concerned, because there are usually two health-care providers involved in the consultation (the local provider and the remote physician), and they both need to be available at the same time.

In contrast, store-and-forward (S&F) telemedicine is an asynchronous interaction, so that a clinical query, for example, can be transmitted by the referrer and then answered by a specialist at a convenient time. Email is a common example of this type of telemedicine. Although diagnostic accuracy may be lower with S&F telemedicine, it is advantageous from the point of view of cost, complexity and convenience.[3]

The field of telemedicine encompasses more than clinical interactions, of course. Having the technology to connect remote sites also allows distance learning. This may involve training or information sharing for health-care professionals that does not directly involve patients but still enhances care.

2. Essential Components of a Telemedicine System

Successful telemedicine requires appropriate equipment and some kind of telecommunications medium. However, successful telemedicine requires more than just technology. The three essential components are:

1. the personnel,
2. the technology,
3. a liberal measure of perseverance.

2.1 Personnel

For any telemedicine system to work in practice - in a real clinical situation - suitable, committed personnel are essential. People with the necessary skills to undertake the clinical components are required at both ends of any telemedicine link. This means that there must be trained staff at the referring end of the link who are able to handle the patient contact required. They must be comfortable with this mode of care delivery and they will probably need prior training, since telemedicine will represent a clinical situation that they are not normally exposed to. Unless this is planned in advance, the technology may be underused (or even ignored entirely) by staff who may be uncomfortable with the new processes.

At the specialist, or consulting, end of a telemedicine link, different characteristics are required of the personnel. The two most important factors are the reliability of the equipment and the availability of the appropriate personnel. Use of a telemedicine system will decrease if the patient information is available but the link is unusable, either for technical reasons or because the appropriate staff are not available at the diagnostic end. It is essential to ensure that there are sufficiently trained personnel and the schedules are carefully planned to enable links to be used with minimum delays, even in emergencies. Training is a very important factor in successful telemedicine.[4]

2.2 Technology

The technology is in many ways the most straightforward part of a telemedicine system and, once a working link has been established, it can largely be ignored. Much of the equipment required may already be available for other functions, and can be shared if planned properly. Reliability is a requirement for all medical equipment and telemedicine equipment is no exception. For telemedicine, all the equipment needs to function properly, since any malfunction will break the chain required for a successful link. Although modern computers and operating systems are fairly reliable, the integration of components still requires close attention to ensure reliability and ease of use. Unreliable technology is likely to cause the system to be under-used or even ignored.

2.3 Perseverance

Finally, it is important to mention one crucial component, without which a telemedicine system will not function. Experience shows that at least one dedicated and committed individual is needed with the perseverance to overcome the inertia inherent in all established clinical routines, and the commitment to champion the new system until it can demonstrate its usefulness. This mentor or champion of the system will help to drive the implementation and to deal with problems as they arise.[5]

3. Clinical Requirements

The technology required for a telemedicine link can be divided into three categories:

1. equipment to capture the clinical information at each site,

2. the telecommunications link needed to transmit this information between the sites,
3. equipment to display the information at each site.

Before the technology can be selected, it is necessary to consider the nature of the information to be transmitted between the sites, because this will determine the choice of equipment and the telecommunications network. Factors to be considered include:

1. the types of information to be transmitted,
2. the quantity of information to be transferred,
3. security and privacy (e.g. in Europe and the USA there has been recent legislation about data security).

3.1 Types of Information to be Transmitted

Different clinical situations generate very different types of clinical information (Table 1). Hence, there are many possible sources of data that can be used in telemedicine applications. In some cases this can be relatively simple information, such as concentrations of a metabolite (e.g. a high blood glucose concentration may suggest diabetes), whereas in others more qualitative and subtle information is needed, as in psychiatric assessments, where observations of posture, speech and mental state are required. Not all information will be needed at every site. For example, a telepsychiatry application will probably require ordinary commercial videoconferencing equipment instead of very high-quality audio or video signals and a telemonitoring service will require only data and text transfer, without audio and video.

Information Source	Type	Typical File Size
Electronic Stethoscope	Audio	100 kByte
ECG Recording	Data	100 kByte
Chest X-Ray	Still Image	1 MByte
Fetal Ultrasound Recording (30 s)	Moving Image (video)	10 MByte

Table 1: Examples of Clinical Information

The clinical need for any telemedicine project must be carefully assessed before making decisions about what equipment will be required. In the past, projects have been established on the assumption that it will be necessary to transmit all possible types of information. This can lead to disproportionately high set-up and maintenance costs that may not be justified by the actual telemedicine use. In general, it is preferable to limit the initial system to a defined clinical goal and so minimize the costs.

3.2 Quantity of Information Transferred

The units in which the quantity of digital information is measured are the bit and the Byte (Box 1). One method by which the total volume of information can be reduced is to compress it first, and then decompress it on reception. This is not always an acceptable technique for medicolegal reasons (i.e. only the original raw signal may be considered acceptable).

A careful assessment of the above needs will determine the quantity of information that must be transmitted between the project sites, and the time frame over which it must be sent to achieve the desired clinical goals. In S&F applications, the transmission time may not be important; in realtime applications, the transmission time is usually critical.

Once this fundamental aspect has been established, it will then be possible to assess whether there is a technically feasible means of achieving it. In practice, some solution is almost always possible, but the costs may not be justified by the clinical benefit.

Box 1: Bits and Bytes

A Byte of digital information corresponds approximately to a single character of alphabetical text. So, for example, a page of text comprising 50 lines, each of 60 characters (and spaces), contains 3000 characters altogether. It can therefore be represented in a computer by approximately 3000 Bytes of information, i.e. about 3 kByte. A floppy disk commonly stores 1.4 MByte (i.e. 1400 kByte) of information and PC hard disks often have capacities of 10-40 GByte (i.e. 10,000-40,000 MByte).

Each Byte is normally represented in the computer by eight binary digits or bits (0 or 1 signals). To transmit 3000 Bytes of information, a total of 24,000 bits of data would have to be sent. Telecommunications line speeds are usually quoted in bit/s. For example, a modem connected to the telephone network can normally transmit information at speeds of 28-56,000 bits per second. The 3000 Bytes representing a page of text would therefore take something like 1 s to send (the actual speed of information transmission is always much lower than the theoretical speed, because of the necessity for transmission line protocols).

Authors should distinguish carefully between bits and Bytes, which represent a frequent source of confusion in telemedicine.

4. Information Capture

The types of information that are relevant to telemedicine can be divided into five broad categories:

- documents,
- electronic medical records,
- still images,
- audio,
- video.

4.1 Documents

Documentary information (e.g. reports, letters or static medical records) can be transmitted in digital form, if the information already exists as a computer text file. Alternatively, paper documents can be digitized using a flatbed scanner or a document camera, and then transmitted as still images (see below). Note, however, that, for non-urgent cases, copies of written records can be posted to the consultant end of the link in advance, or paper documents can be faxed before or during a telemedicine session. Even in the age of digital telemedicine, the use of the postal service can represent a very cost-effective way of transferring large quantities of information from one place to another; the disadvantage involves the delay and the human interaction required.

4.2 Electronic Medical Records

Traditional paper-based records are gradually being replaced by electronic medical records (EMRs). At present, the EMR is a hodge-podge of heterogeneous, proprietary systems that rarely interoperate successfully. Efforts are underway to create a highly interoperable EMR system, where data can flow across the health-care continuum seamlessly.[6][7] EMRs will allow instant access to a patient's record, including the business operations such as billing and reimbursement.

4.3 Still images

Two major classes of image are important in telemedicine - those of unspecified quality and those where the diagnostic needs (and hence legal consequences) dictate a particular image quality (Figure 1). The difference can best be appreciated by considering the difference between photocopies of images and the originals - a photocopy may be perfectly legible and acceptable for many purposes, but fine detail present in the original may have been lost. For some types of image this can be crucial, and the requirements have been particularly well studied for radiographs.[8]

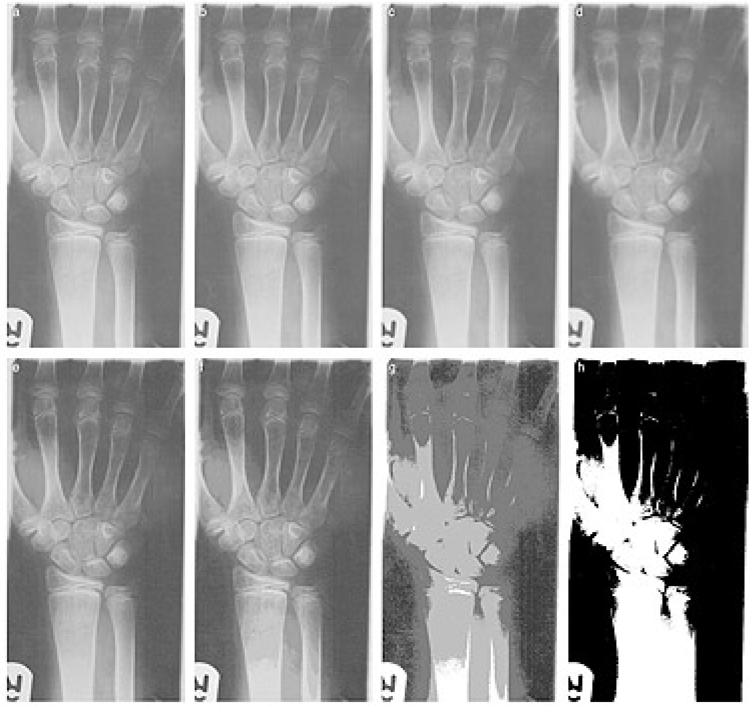

Figure 1: Image quality in a still picture is usually defined in terms of the numbers of picture elements in the image (pixels) and the numbers of their black and white - or colour - levels. (a-d) show the same X-ray image digitized at different resolutions: 240, 120, 60, 30 dots/inch. (e-h) show the same X-ray images displayed with different numbers of grey levels per pixel: 255, 15, 5 and 2.

For many telemedicine purposes, a simple photographic image may be sufficient. For instance, low-cost digital cameras now provide very good imaging quality and may be adequate to capture an image of a skin lesion for teledermatology or a view down a microscope for telepathology.[9] Alternatively, an inexpensive flatbed scanner can be used to digitize photographs or charts such as electrogram (ECG) traces (Figure 2). If the scanner is equipped with the appropriate transparency attachment, then 35mm slides or X-ray films can also be scanned. Where relatively simple diagnoses are required, such basic equipment may be more than adequate, e.g. for emergency room assessment of X-rays of a simple fracture.

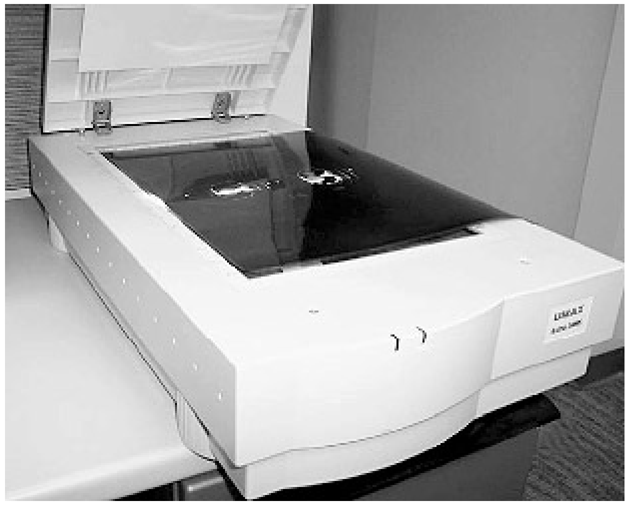

Figure 2: A flatbed scanner can be used to digitize a paper record. With a suitable backlight, X-ray films can also be digitized (photo credit: B. Harnett).

Another inexpensive method is to capture still images using a video camera, possibly one that is specially designed for imaging documents (Figure 3). In addition, many diagnostic instruments now provide a video output, for example ultrasound scanners. Still images can be recorded with a video capture card on a personal computer (PC) and a suitable screen capture program.

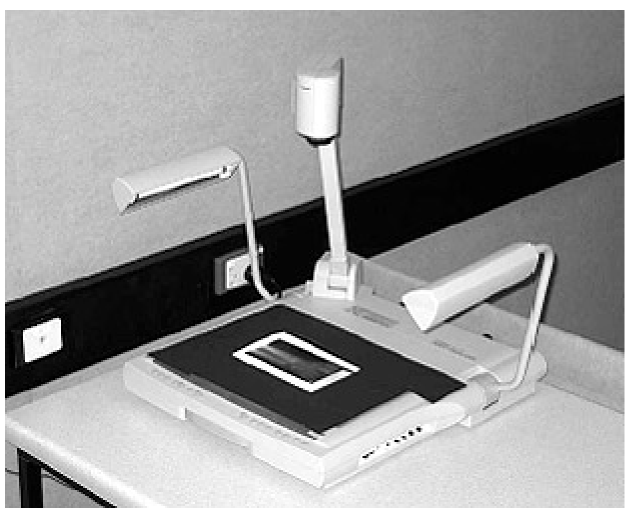

Figure 3: A document camera is an alternative method of digitizing X-ray films. Note the use of black cardboard masks around the region of interest.

When high-quality diagnostic images are required, the equipment involved can be costly. Modern diagnostic imaging devices are often equipped with digital outputs, which allow images to be transmitted between sites. However, it is common for telemedicine links to be set up in situations where the patient side of the link has old or outdated equipment. In this case, it may be necessary to purchase specialized equipment, such as high-resolution X-ray film digitizers, which are much more expensive (10-20 times) than flatbed scanners designed to work with PCs.

Digital Imaging and Communications in Medicine (DICOM) is an established standard for digital image transmission in radiology; it defines how images of clinical quality are distributed via networks.

4.4 Audio

At its simplest, voice transmitted by telephone or radio can be used for some remote diagnoses. Although the telephone system has been designed for voice transmission, it is not necessarily ideal for all types of medical sound transmission. Telephones use analogue (Box 2) transmission, which is therefore susceptible to noise and loss of quality, particularly over long distances. Digital signal transmission offers many advantages, particularly since digital signals can be transmitted over networks for long distances without degradation. It is also possible to process a digital signal in various ways, including compressing it so that a live or recorded voice requires less data to be transmitted than the original signal (see below for further information about compression).

Most modern PCs are equipped with a sound card that is suitable for capturing audio for telemedicine purposes. No special equipment is required other than a suitable microphone. In some cases, it is also possible to connect these cards directly to the equipment that is being used; for example, the audio output of an ultrasound scanner can be connected to the PC. Another option is simply to use an ordinary telephone line as the audio portion of the session. This frees up more bandwidth for video.

Box 2: Analogue and Digital

An analogue signal is one whose magnitude is continuously variable. For example, an electrical signal might have a magnitude of about 1.2 V (measured with an inexpensive voltmeter), while a more expensive instrument might show it to be 1.2345 V. The value measured depends on the resolution of the instrument.

In contrast, a digital signal can vary - or be measured - only in discrete steps. The digital representation of the same voltage might show it to be 1.2 V the adjacent levels being perhaps 1.0 V and 1.4 V. Increasing the sensitivity of the measurement does not alter the value.

To transmit an analogue signal requires, in principle, a perfect transmission path. In the case of an electrical voltage, any resistance in the transmission path will reduce the voltage at the receiver site. Analogue transmission, such as between the subscriber's house and the telephone exchange, is therefore susceptible to the introduction of noise. In contrast, the transmission of a digital signal is perfect. The huge advantage from the perspective of telemedicine is that transmission quality becomes independent of distance: a telemedicine transmission between two locations in the same city will work as well as transmission between two locations on different continents.

4.5 Video

A common view of telemedicine is that it only involves realtime video images transmitted between remote sites for the purposes of consultation between a doctor and a patient. This is certainly one form of telemedicine, although it is by no means the only one. In cases where video transmission is considered appropriate, the issue arises of what video quality is required, since unsurprisingly the higher the quality, the higher the cost of the equipment and the transmission. In the majority of applications, commercial videoconferencing units provide the most straightforward solution to the problem of transmitting video pictures for telemedicine. Generally speaking, such units provide video pictures that are not as good as broadcast quality television (TV), although in many clinical applications this does not seem to matter.[10] When considering this question, it is worth bearing in mind that the users' opinions will be influenced, even if subconsciously, by the domestic TV that they are used to watching (Box 3).

A wide range of telemedicine equipment and accessories is available commercially. A benefit of using commercial suppliers is the technical assistance that they can provide, which includes setting up the working connection and (in most cases) a help desk for technical problems. Many suppliers can perform software upgrades and fault-finding by logging on to the equipment from their home base. For those without technical knowledge or access to in-house technical support, this may be important to the success of a telemedicine project.

Box 3: Video Standards

There are two common broadcast TV video standards: National Television Standards Committee (NTSC), which is used in Japan and North America, and Phase Alternating Line (PAL), which is used in much of Europe. The two systems have different display characteristics:

1. 525 lines/picture at 30 pictures/s (NTSC),
2. 625 lines/picture at 25 pictures/s (PAL).

The standard called common intermediate format (CIF), which is widely used for videoconferencing, was introduced to provide compatibility between the two video standards. Thus, it is possible to videoconference between the USA (where the camera and monitor operate to the NTSC standard) and say Europe (where the camera and monitor operate to the PAL standard). CIF is 288 lines/picture at 30 frames/s. The resulting quality of a CIF video picture is not very different from that of a normal TV picture.

4.6 Compression of Video Signals

Commercial videoconferencing units all use compression techniques to reduce the quantity of data being transmitted, and therefore the communication costs. This means that the units at either end of a link must be compatible, i.e. the same compression and decompression algorithms must be employed. To ensure that equipment from different manufacturers is interoperable, international standards have been defined by the International Telecommunication Union (ITU) (Table 2). Provided that each telemedicine site has a system embracing the proper standards, it is possible to conduct videoconferencing sessions between pieces of equipment supplied by different manufacturers. This applies not just to the basic transmission of video and audio, but also to additional features such as the control of cameras at the remote site, and the exchange of data between PCs that are being used in the videoconferencing session. Equipment that does not adhere to standards should be avoided.

Compression is a rapidly developing area of computing science, where the objective is to maximize the file compression and minimize the information loss.

Protocol	Purpose
H.320	The oldest of the multimedia communication protocols. Defines a videotelephone operating on ISDN.
H.324	A newer protocol defining videotelephony for the standard telephone network (PSTN). Poorer-quality pictures, because of the restricted bandwidth of the PSTN compared with ISDN. Since H.324 can also be used on ISDN, it may supersede H.320 in due course.
H.323	A newer protocol defining videotelephony for LANs and the Internet.
T.120	A family of protocols to allow computer-supported cooperative working in conjunction with videotelephony.

Table 2: ITU Protocols

4.7 Videoconferencing Equipment

Videoconferencing has traditionally required equipment which was expensive to buy and to run, and was large and complicated to operate. At first it could be used only in fixed studio installations, but miniaturization made possible the development of the 'rollabout' unit, which could be moved between rooms within a building. The basis of the equipment is the CODEC (coder/decoder), which handles the compression of video pictures prior to transmission, and the decompression of the received pictures prior to display. Rollabout units are still widely used, particularly in business, and generally deliver highquality video pictures (up to 2 Mbit/s transmission) on large display monitors with high-quality sound.

More recently, as the trend to miniaturization has continued, portable videoconferencing units have appeared, in which all the components except the display screen are integrated into a single unit. Such 'set-top' units require only connecting to a domestic TV to form a good-quality videoconferencing system (Figure 4).

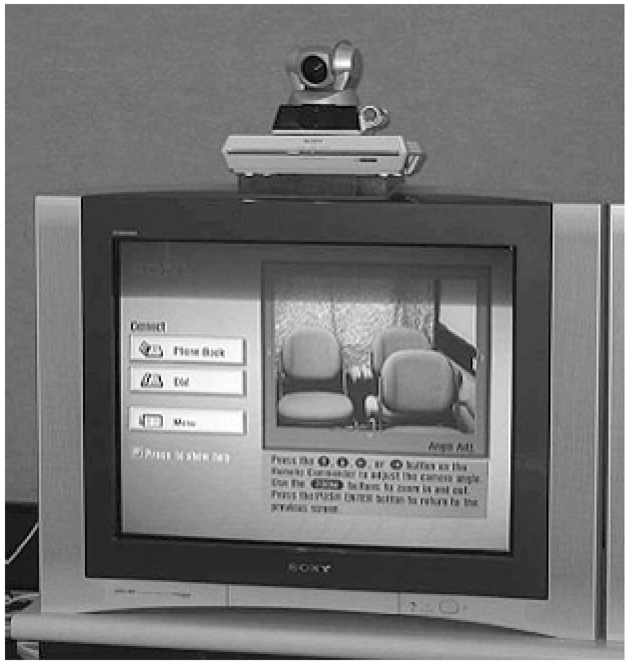

Figure 4: A set-top videoconferencing unit.

Further technological development has resulted in the videoconferencing functions becoming available on a plug-in card for PCs. This means that an ordinary PC can be used as a personal 'desktop' videoconferencing workstation delivering reasonable quality video on a smaller screen and with generally lowerquality sound; nonetheless, these may be adequate for many purposes. It is also possible to use the PC's own processor to encode video for transmission, i.e. the PC operates as a software CODEC (Figure 5).

Figure 5: Desktop videoconferencing software (photo credit: B. Harnett).

The merits of the different families of videoconferencing system are summarized in Table 3.

Type	Quality of Video & Audio	Cost	Usage
Studio	High	High	Large Group
Rollabout	High	High	Small Group
Set-Top	Low/Medium	Low	Personal/Small Group
Desktop	Low/Medium	Low	Personal
PSTN	Low	Low	Personal

Table 2: ITU Protocols

Much of the technology to capture the different types of information required in telemedicine will be available in any well-equipped modern office, but most telemedicine applications aim to provide services to poorly equipped remote sites that may not have even the most basic computer equipment. A major part of the overall cost of setting up a telemedicine system may be purchasing such straightforward items for the patient consultation end of the link.

5. Information Transmission

All of the above relates to videoconferencing equipment using digital telecommunications. It is also possible to transmit video pictures using the ordinary telephone network, but, because a very high degree of image compression is required, the picture quality is rather poor.

In terms of network coverage, the conventional telephone is now widely available, even in the developing world; it is also a relatively inexpensive form of communication. More sophisticated digital telecommunications, such as ISDN, have more restricted coverage and higher costs, though they have major advantages over conventional telephony in terms of reliability and bandwidth. Satellite communications solve the coverage problem - providing truly global access - but remain expensive.

The choice of transmission method for any telemedicine application is, in practice, a compromise between what one would like and what one can afford. In practice, various trade-offs have to be made, which include:

- cost,
- availability of the service (i.e. the coverage),
- bandwidth, reliability and quality of service.

5.1 Cost

Telecommunications costs generally are falling. In most parts of the world, there is increased competition in the telecommunications industry, because of the privatization of previously government-run departments and deregulation. Another factor in falling prices is technological development. Nonetheless, telecommunications costs may still represent a significant proportion of the cost of a given telemedicine application.

5.2 Availability of the Service

Despite the wide availability of network services, a common problem in telemedicine is the availability of network services over the 'last mile'. The 'last mile' describes the connection from the actual site of practice to the nearest telecommunication access point, such as the local telephone exchange. Providing a connection over this last mile is often where telecommunication becomes very expensive.

5.3 Bandwidth, Reliability and Quality of Service

An important factor in telemedicine is the time frame in which the information is required. For some applications rapid information transfer is needed, for example when telemedicine is being performed for emergency management. However, in less urgent cases information can be stored and transmitted at a slower rate, for later examination.

Bandwidth is the data-carrying capacity of the communication medium used. It is measured in bits per second (bit/s, often abbreviated to bps) and ranges from 1200 bit/s for some types of mobile phones to more than 1000 Mbit/s for transmission through a fibre-optic cable. Successful telemedicine has been carried out using a wide range of bandwidths.

The clinical information to be transmitted will dictate the minimum network bandwidth that can be used.[11] How this bandwidth is obtained between the sites involved in the study depends on a variety of different factors. The main questions will be what infrastructure is already in place at each site, and what communications are possible between the sites (both physically and through local telecommunication companies). Rural areas where patients are often most in need of telemedicine services are often those where network communication may be limited. Providing high-bandwidth connections to such sites can be very expensive.

Generally speaking, the problems of network reliability (in the sense of communications being possible or not), exemplified by the traditional telephone network with electromechanical switching, have been solved by the move to digital telecommunications. In fact, substantial portions of the telephone network are already digital, which is partly why the call quality has improved dramatically over the last 20 years.

A related aspect to the general reliability of a telecommunications link is the quality of service that can be guaranteed for the user. For networks in which the user is provided with a circuit from end to end (such as ISDN or the PSTN) there is little difficulty, but for networks in which the bandwidth is shared (such as the Internet) the bandwidth available to the user can be severely affected by what other users are currently doing. In some networks with shared bandwidth, it is possible to reserve bandwidth for the user at the start of the connection and then release it to the general pool at the end. Such quality-of-service techniques have yet to be standardized.

5.4 The Internet

Most people are now familiar with modem access to the Internet via the telephone network, and this method of communication can be used for telemedicine.[12-15] Such systems have the advantage of accessibility, since anyone who can access the Internet can reach the required sites (limiting access to legitimate users may then be a problem, and security issues may become important). The Internet is particularly useful for situations where a clinician may require access to data from home (such as a radiologist viewing an X-ray image) before giving some clinical advice, e.g. a consultant advising on a fracture seen by a junior doctor in the emergency department. It may also be possible to use these systems from areas where analogue telephone lines are the only ones available, which may be particularly helpful for remote sites where other means of communication are limited.[16]

Web servers on the Internet store data for subsequent distribution to users. This is a client/server architecture, which is a useful approach for telemedicine. The Internet can also be used to provide a virtual private network (VPN), i.e. to provide a private (secure) connection between two sites. A VPN offers a method of securely linking sites. The limitation is that both sites must have connection to the Internet at the desired bandwidth. Many remote sites do not yet have Internet service providers (ISPs) with sufficient bandwidth available, although in cities this type of connection is worth considering. The alternative to a dial-on-demand connection is a dedicated or permanent circuit.

5.5 Standard Telephony

The conventional telephone system is the public switched telephone network (PSTN). The standard analogue telephone line is a readily available form of communication, obtainable almost anywhere in the world. Unfortunately, the bandwidth available to users is limited to a maximum of 56 kbit/s and is likely to be much less if the telecommunications infrastructure is poor. Nonetheless, this type of connection can be suitable for some telemedicine applications that do not require either realtime data transmission or large file sizes. For applications such as teledermatology and telepathology, a modem connection may be sufficient to let two sites view images simultaneously, while discussing them via a separate telephone line.

5.6 Mobile Phones

Mobile phones are becoming commonplace, and can be used to transmit digital data, albeit at low rates of data transfer (similar to the PTSN). For applications where realtime transfer is not needed and access to a standard modem is not possible, they are ideal. Mobile phones may be useful to connect with a specific individual who is travelling, and has access to a mobile phone and perhaps a laptop computer. Computerized tomography (CT) scans[17] and ECG recordings[18] have been reported in this way. In many developing nations, mobile phone networks are being deployed instead of upgrading and expanding the traditional telephone network.

5.7 ISDN

The digital counterpart of the PSTN is ISDN, which is now available in most metropolitan areas in industrialized countries. It is completely different from the PSTN and offers end-to-end digital connectivity. This has two main advantages: greater reliability due to the digital nature of the data traffic, and higher bandwidth per line. Two standard types of ISDN connection are available to customers: a basic-rate line and a primary-rate line.

A basic-rate ISDN line offers the user a bandwidth of 128 kbit/s in two separate 64 kbit/s data channels. Basic-quality videoconferencing can be conducted using commercial equipment over a single basic-rate ISDN line. For higher-quality videoconferencing, multiple basic-rate ISDN lines can be used. For example, three lines aggregated together (providing six data channels) are commonly used, resulting in a bandwidth of 384 kbit/s. Primary-rate ISDN lines offer the user a bandwidth of up to 2 Mbit/s, thus allowing very high-quality video pictures to be transmitted.

ISDN connections are commonly used for telemedicine, because of their security, bandwidth, quality of service and relatively wide availability. Another advantage is the potential for adding capacity to these networks by renting additional lines. The major drawback of ISDN is that line rentals and usage charges can be high, although itemized billing allows the actual cost of telemedicine use to be readily evaluated.

A recent trend is to use existing local area networks (LANs) for telemedicine data transmission using Internet Protocol (IP). The principal disadvantage for realtime work is the problem of guaranteeing bandwidth for the telemedicine application.

5.8 Satellite

Generally speaking, fixed satellite connections are expensive to install and costly to use. They offer similar bandwidth to microwave links and the ISDN, but have the advantage of global coverage. Traditional satellite connections use geosynchronous satellites. Several telemedicine projects have used satellite linkages to connect mobile sites (such as military units or ships at sea) which would be impossible to reach in any other way.[19][20] As costs fall in the future, satellite transmission may become competitive with ISDN, particularly for remote areas. See Lamminen for a recent review.[21]

Another option is the use of a low earth orbiting satellite (LEOS). A LEOS offers the advantage of very inexpensive, hand-held receivers, not much larger than a standard mobile phone. They can be used nearly anywhere in the world, but currently have one significant drawback: very low data rates, of the order of 2.4-3.0 kbit/s. This may be acceptable if you need to send only a small file.

5.9 Leased Lines

Leased lines are an alternative to using ISDN, in which a permanent digital connection is established between two locations. The user pays a fixed rental for the line, which includes the cost of all calls. The line is leased for an agreed term (usually annually) and is thus paid for regardless of use. In contrast, the cost of dial-ondemand services like the PSTN or ISDN depends on the actual usage of the circuit. Clearly, there will be a point at which a leased line becomes cheaper than a dial-on- demand connection, which will depend on the usage. However, the leased line option limits the user to transmission between the two locations that have been connected (e.g. two hospitals), unlike the use of ISDN, in which any other institution with an ISDN connection can be called, just as with a telephone.

5.10 Digital Subscriber Lines (DSL)

DSL technology, which is often referred to as 'broadband', provides an IP connection to the user. DSL connections come in a variety of types, such as symmetric and asymmetric - in the latter case, it is called ADSL. The generic acronym is xDSL. The important thing about DSL is that it uses the existing copper telephone wire that is usually already present in the facility. The main drawback is that the facility must be located within about 5 km of the telephone company's switch. ADSL usually provides more downstream bandwidth (i.e. to the user) than upstream. This is fine for downloading data, but is not necessarily suitable for realtime videoconferencing.

5.11 Cable Modems

Cable TV is common in many metropolitan areas. The cable network represents a robust wiring system, which connects to homes and businesses. The same cable can be modified to act as a gateway to the Internet. Like xDSL, cable uses an inexpensive modem to provide more bandwidth than can be obtained with the

PSTN. The principal drawback is that cable systems usually provide access through regional gateways, which means that if many people in a local area are using the service, the available bandwidth per user may decrease. Cable modems - like xDSL - also provide asymmetrical bandwidth to the user. However, their cost and bandwidth make cable and xDSL attractive options for low-cost telemedicine applications.

5.12 Microwave

Microwave connections are expensive to install, but inexpensive to maintain. The bandwidth available using microwave connections is high, 2-10 Mbit/s being common. However, microwave links are only feasible for sites that are relatively close together. Sites require direct line of sight to each other and must be less than about 30km apart (less if the visibility is poor). For longer distances, repeater stations can be used, but the cost rapidly becomes prohibitive. The advantage of a microwave link is that there are virtually no running costs - the bandwidth is essentially free following installation. The disadvantage is that a microwave link connects just two locations, point to point.

5.13 ATM

ATM transmission was designed to take advantage of the characteristics of fibre-optic cables. Very high bandwidth transmission is therefore possible, the latest equipment operating at rates of gigabits per second. However, ATM is used primarily in the 'backbone' of a network. Thus, the major telecommunications carriers use ATM for long-haul transmission. While ATM has advantages in terms of capacity and quality of service, it is very uncommon for ATM to be directly connected at the user level, and few telemedicine applications have used ATM networks directly.

Network options for telemedicine are summarized in Table 4: ITU Protocols

6. Information Display

The method of information display will depend mainly on the format in which the information is originally captured. For example, audio information will usually be 'displayed' in the form of sound. Several options are available for displaying images. Videoconferencing units commonly use standard TV sets as their display, while still images are often displayed on PC monitors. However, PC monitors are sometimes used instead of TV screens for viewing video, and TV screens are sometimes used for viewing the output from a PC. This is more than a matter of simply connecting them together, because PC display monitors and TV screens operate in a fundamentally different way (see Squibb for a review).[22]

Many items of medical equipment have a PC built-in, the output of which can be directly displayed on another PC but not viewed with a TV. In such cases, it may be necessary to use a specific video output (often designed for connection to a video recorder) to acquire an analogue signal suitable for a TV display. Such PCs do not always use bulky cathode ray tubes, but increasingly use flat screen displays (as in laptop computers). These types of display are still expensive, but are becoming increasingly popular due to their smaller overall size and lower power consumption. PC screens also come with different resolutions (the number of dots per unit area). High-resolution screens are used for detailed work, but are more expensive. Most telemedicine applications (other than radiology and pathology studies) do not need high-definition images. For instance, a standard magnetic resonance image (MRI) has a resolution of 512 x 512 pixels.

7. Training

Equipment and the telecommunications are a necessary, but not sufficient, prerequisite for a successful telemedicine programme. The right people are also required and they must be properly trained. Since many telemedicine programmes often begin incrementally, training users can also be done incrementally. Numerous universities and private companies offer telemedicine training, as well as the equipment vendors, although this sort of training tends to focus on the capabilities of specific devices. If you decide to implement a telemedicine programme, training must be part of the plan.

8. Conclusion

About 10 or 15 years ago, the technology for telemedicine was not readily available. Much early telemedicine work involved modification of expensive equipment, which was originally designed for other purposes. Now, however, the technologies such as robust telecommunication networks and video equipment are widely available, and much more affordable. Telemedicine users now have a plethora of choice. Most manufacturers offer products that adhere to industry standards which ensure interoperability with other devices. The situation in medical informatics is less developed and efforts continue to ensure the seamless integration of data between different systems. This is important in health care, where patient data-sets need to be available when required.

While the right technology is essential for a successful telemedicine programme, it is essential not to overlook the human factors. In particular, a local 'champion' will be required, and there will be a continuing requirement for user training.

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