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Emerging Technologies for Telemedicine

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This paper focuses on new technologies that are practically useful for telemedicine. Three representative systems are introduced: a Digital Video Transport System (DVTS), an H.323 compatible videoconferencing system, and Vidyo. Based on some of our experiences, we highlight the advantages and disadvantages of each technology, and point out technologies that are especially targeted at doctors and technicians, so that those interested in using similar technologies can make appropriate choices and achieve their own goals depending on their specific conditions.
Index terms: *Telemedicine; Education; Internet; Academic network; Technology*

INTRODUCTION

The term telemedicine refers to the utilization of communication and information technology for medical education and patient care through the transmission of images and sounds (1). Successive new technologies have emerged and the available systems for practical telemedicine are changing rapidly.

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We believe that many doctors and other medical staff understand the advantages of telemedicine. Not only can we save a great deal of time and cost in terms of physical movement, but scalability is another important point in that we can easily repeat the communication and invite participation of many other interested parties at remote sites.

Regardless of the fact that telecommunication is growing in the business and academic fields, it is not yet that popular in the medical community (2, 3). One of the main reasons for this is the high demand for image quality in medicine. It is essential that transmitted images have the highest quality to make adequate diagnoses and to provide satisfactory medical information. In addition, the need for transmitting moving images is quite high and important in various situations in medicine, such as showing surgery or new skills and procedures. This requirement gives rise to a serious technical challenge where moving images must be transmitted smoothly, as the size of these images is much greater than that of still images. Tele-radiology, tele-pathology, and tele-ophthalmology are successful examples of telemedicine using still images, whereas tele-surgery, for example, requires a completely different system to meet doctors' demands for streaming video (4-7). Additionally, cost is an important issue in telemedicine because it typically requires special equipment, which can be very expensive. Hospitals in rural areas and developing countries, where telemedicine is most necessary, may not have sufficient budgets to afford the necessary equipment.

During the past ten years there have been great advancements in technology, and there are now several practical options for healthcare providers to take advantage of telemedicine. Here we introduce some of the available systems based on our experiences, so that readers can make the best choices for their own needs.

Digital Video Transport System

Digital Video Transport System (DVTS) is a simple and inexpensive application for sending and receiving digital video (DV) streams using broadband Internet. This software was developed by the WIDE (Widely Integrated Distributed Environment) Project in Japan (8, 9). Although it is a powerful and internationally authorized program, it is freely downloadable (http://www.sfc.wide.ad.jp/DVTS/ software/). With DVTS, we can transmit high quality video with low latency, because the system skips the compression process, which inevitably degrades the quality and is time-consuming (10). To secure this high quality, however, we need stable Internet with at least 30 Mbps of bandwidth and a public IP address (Fig. 1) (11). The minimum devices needed are as follows: personal computer (PC), running either Windows, Linux, or Mac OS and equipped with a FireWire (IEEE1394) interface, DV camera or other video source with FireWire capability, and audio devices such as microphones and speakers (9, 12-15).

The biggest advantage of a DVTS system is the price. DVTS is definitely the cheapest of all telemedicine systems, but only if the appropriate Internet capability is available. DVTS software is free; a DV camcorder, microphone, speaker, and PC are all very common products, which the hospital may already have. Thus, this system does not require special and expensive equipment for use in telemedicine. Moreover, National Television System Committee/Phase Alternating Line conversion is automatically carried out between different color formats (16, 17). Additional advantages are easy handling, portability, and high compatibility with audio and video devices.

Due to skipping compression, the processing delay of DVTS, which is known as latency, is between 200 ms and 400 ms, which is good enough for interactive conversation (18).

Considering the disadvantages, the DVTS system consumes over 30 Mbps network bandwidth for the highest quality of communication. We cannot use the commercial Internet, but instead need an academic network (an Internet leased line with high bandwidth and high performance), as explained later. Although such a government-funded network is now available in many countries and connects many universities and academic institutions worldwide, it is not yet an easy task for certain developing countries or private hospitals to get connected to this network. Regarding equipment, DTVS is not a complete system although it is compatible with a variety of common devices. Therefore, users themselves need to ascertain the most suitable equipment. Nevertheless, the package of necessary equipment is illustrated for their

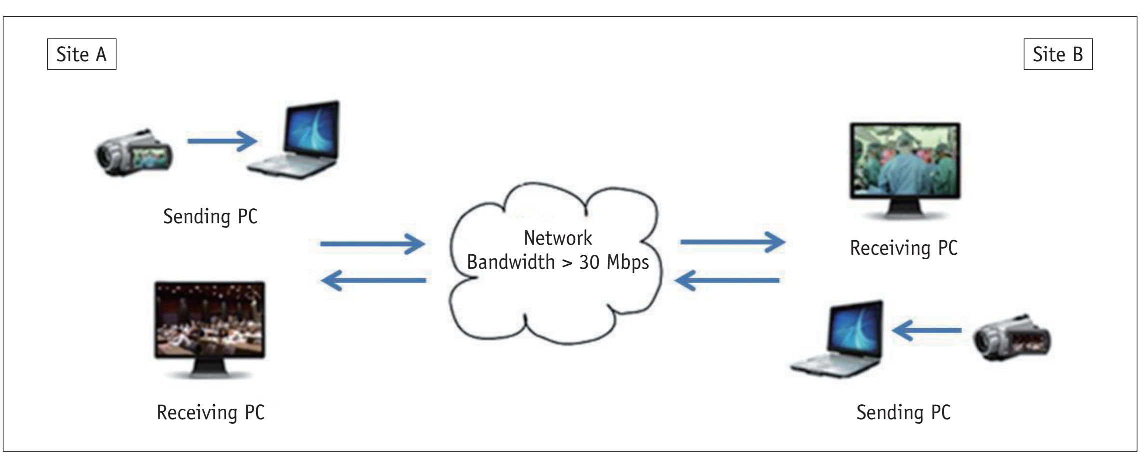

Fig. 1. DVTS system with point-to-point connections.

convenience (19). In addition, because the DVTS solution is free and without any technical support, the engineer needs to have appropriate knowledge and skills to set up, troubleshoot and optimize the system. As this system does not come with either an echo-canceller system or a quality of service (QOS) system, the local engineers need some experience to run it properly (20).

Referring to the issue of sound, the lack of echo-canceller integration is often a problem that needs to be considered (21). If one site has an echo problem, it causes echoes at all other stations. So we need to prepare appropriate audio devices, such as a unidirectional microphone or one with an on-and-off switch as an easy solution, or the freely available EchoDamp solution (http://echodamp.com/getechodamp.html). The good news is that an updated version of DVTS has just been introduced to solve some of these existing problems and to meet more demands (22).

To conclude, DVTS is a cheap and open system, and is becoming more and more complete. As such, it is attracting more users, and is most commonly used (23) (Fig. 2).

Fig. 2. Live endoscopy using DVTS at 4th Meeting of Society of Gastrointestinal Intervention on October, 2010 in Seoul, Korea.

Multipoint Control Unit for DVTS

A multi-point control unit (MCU) is a device used to bridge video conferencing connections. Either software or hardware can be used to provide the capability for multiple points to participle in a conference (24). DVTS software was originally developed to work only between two stations. Due to the high demands of connecting multiple stations, however, the following two MCUs are currently available.

Quatre/QualImage

Quatre optimizes high-speed video processing and enables meetings between multiple remote sites with DV at the original quality (Fig. 3). This system is most frequently used between 4 stations, and can be connected with a maximum of 7 stations, bringing constant quality when compared to point-to-point connections. It was developed in 2005 (Information Services International-Dentsu Ltd., Tokyo, Japan) (25). Compatibility only with the NTSC color

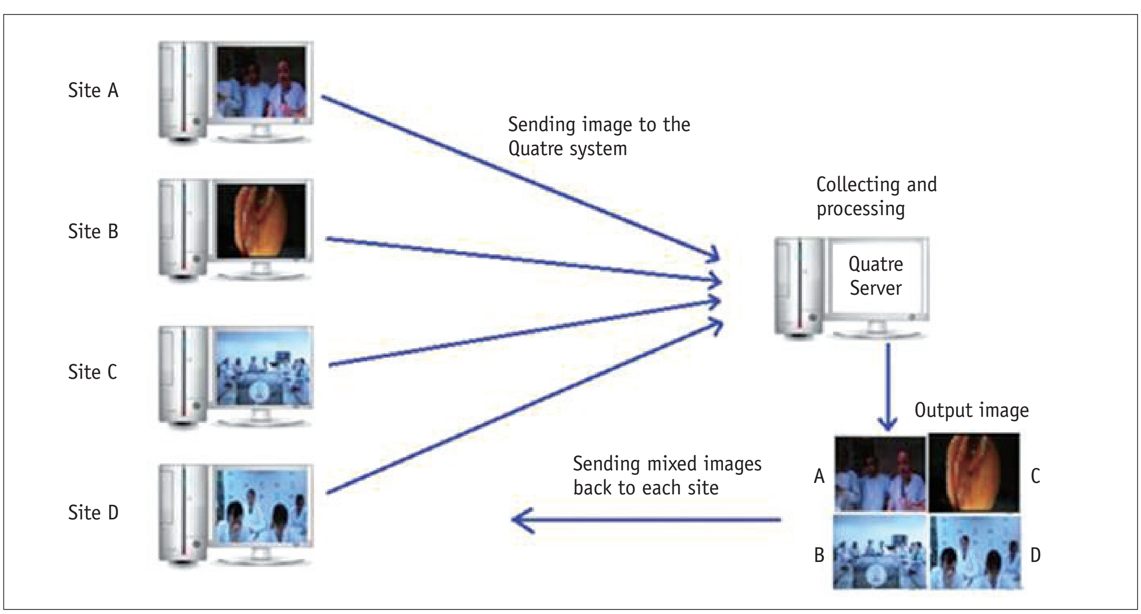

Fig. 3. Quatre, multi-point control unit for DVTS. Video image from each site is merged into one image by Quatre server, and is then sent back to original site.

system is a big disadvantage when organizing international conferences using this MCU because many countries use the PAL system. So they need to buy an NTSC camera or a PAL-NTSC converter if they want to join conferences with multiple sites (26). Another technical problem is that this system supports only a 16 bit sound standard; other standards do not work (27).

DVTS-Plus

The DVTS-Plus system is another multi-party conferencing system. It was developed in 2010 by the China Education and Research Network (CERNET), China (28). The developers claim more flexible management than Quatre, consideration of network sensitivity, time-consuming testing, automatic scheduling, and limiting the number of participants. Attendees can see thumbnails of all participating sites, and can choose any of these videos to show large images with DV quality. Thus, each attendee can talk to anyone in the conference who is connected through one of the 20 sites. The equipment needed for DVTS-plus is the same as for DVTS. Although this system is currently compatible only with NTSC, a PAL version is under development.

H.323 Video Conferencing Solution

The H.323 protocol is a recommendation from the International Telecommunication Union that defines the protocols for providing audio-visual communication sessions on any packet network (29). The H.323 standard addresses call signaling, multimedia transport, and bandwidth control for point-to-point and multi-point conferences. It is widely implemented by videoconferencing equipment manufacturers, is used within various Internet real-time applications, and is widely deployed worldwide by service providers and enterprises for both voice and video services over IP networks (30).

In contrast to DVTS, this system comes in an all-in-one package. All the necessary video and audio equipment for transmission is built into a set of hardware that performs compression of audio and video streams in real-time. The system is compatible with standard-definition (SD) video, which is referred to as 480p video mode, was developed in the early 1990s, and has become quite popular (31). The bandwidth required is 0.3-2 Mbps, much smaller than that for DVTS. Although this system has frequently been used for general teleconferencing and e-learning using slides without video presentations, it has never become popular in telemedicine mainly due to insufficient quality for video streaming (32). Nevertheless, a high-definition (HD) video conferencing system, an upgraded version of the SD system, has recently been developed and commercially released, providing much better quality video transmission, with 30 or 60 fps (frames per second) at resolutions of 1080i or 720p (33-35).

Currently, this solution is still quite expensive, and is not yet widely used in the medical community. However, with the expansion of HD medical devices in hospitals and a growing number of the upgraded videoconferencing system in companies and public institutions, this system is promising in telemedicine. The bandwidth required by this videoconferencing system is around 2 to 8 Mbps, which is not too large. Streaming images have sufficient quality and motion, and are attached to HD devices for input and output.

The all-in-one system provides easy handling and requires less preparation during setup. Sound quality with a built-in echo cancelling system is also an advantage. Another merit is that there are many suppliers of these products, and they are pretty much compatible with each other. Therefore, there is more choice and greater support from the vendors, such as Polycom Inc., LifeSize Communications Inc., Tandberg Inc., Sony Electronics Inc., Cisco System Inc., amongst others (36-40).

Despite all these advantages, this system also has some disadvantages. The first of these is the image quality with the SD version of the system. Although the number of HD systems is increasing in the market, the availability of this high-end equipment is still limited and many centers are working with the old version, which cannot provide smooth and clear video transmission. The problem is that when the two different versions are connected, the quality is downgraded to SD even in the HD-equipped centers.

As far as multiple connections are concerned, companies offer various solutions, from MCU software support for up to 6 station connections, to a hardware system supporting dozens of connection points (Fig. 4).

It should be noted that suppliers now also offer a software version of the H.323 video conferencing system. Using a normal PC and webcam, users can conduct point-to-point calling or join a multipoint video conference. This solution is simple and easy to use with acceptable quality for personal remote meetings. The main disadvantage is the quality of the shared content. H.323 software works well with still images and presentations; however, transmitted

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video has low quality, is noisy and loses frames.

Vidyo

Vidyo, a new company from the US, has developed its own videoconferencing system. This is one of the previously mentioned H.323 videoconferencing systems, but is based on the latest H.264 standard, which is currently the most advanced and effective compression technology as opposed to the conventional H.263 protocol (Fig. 5) (41, 42).

Vidyo provides low latency and high quality video conferencing from hardware devices, PCs, and mobile devices over the Internet (43). Using their new Vidyo network architecture, videoconferencing can be carried out over the commercial Internet or academic networks, even using a wireless or mobile network, thereby providing flexibility for users. Although the connection speed is limited to 8 Mbps, the transmitted image quality is perfectly acceptable with a good compression standard.

High-quality video communication means the Vidyo system is ideally suited to telemedicine. Vidyo provides a strong ability to connect from a PC, using VidyoDesktop software. Users can work on hardware and devices already owned, and the VidyoDesktop is compatible with other audio-visual devices, and is built to run on Windows, MacOS or Linux. Not requiring a global IP is another big advantage (44, 45).

As a new system with the many advantages mentioned above, there are good reasons to choose Vidyo for our

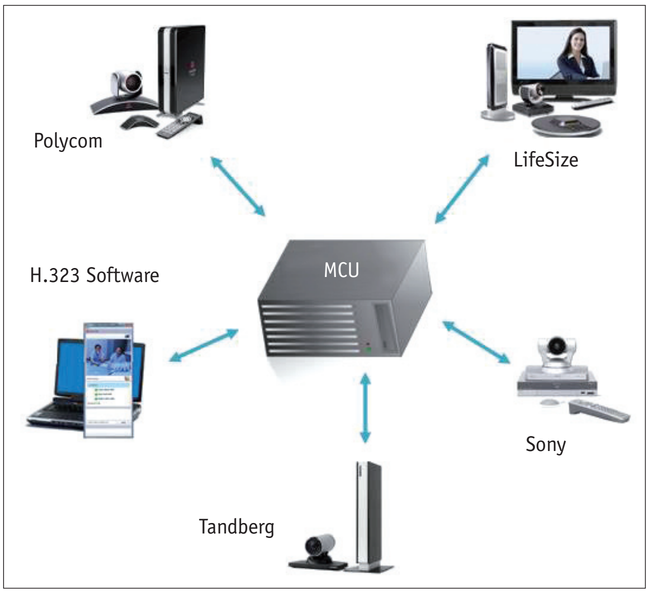

Fig. 4. H.323 video conferencing system: multi-site connections between different companies using MCU (multi-point control unit).

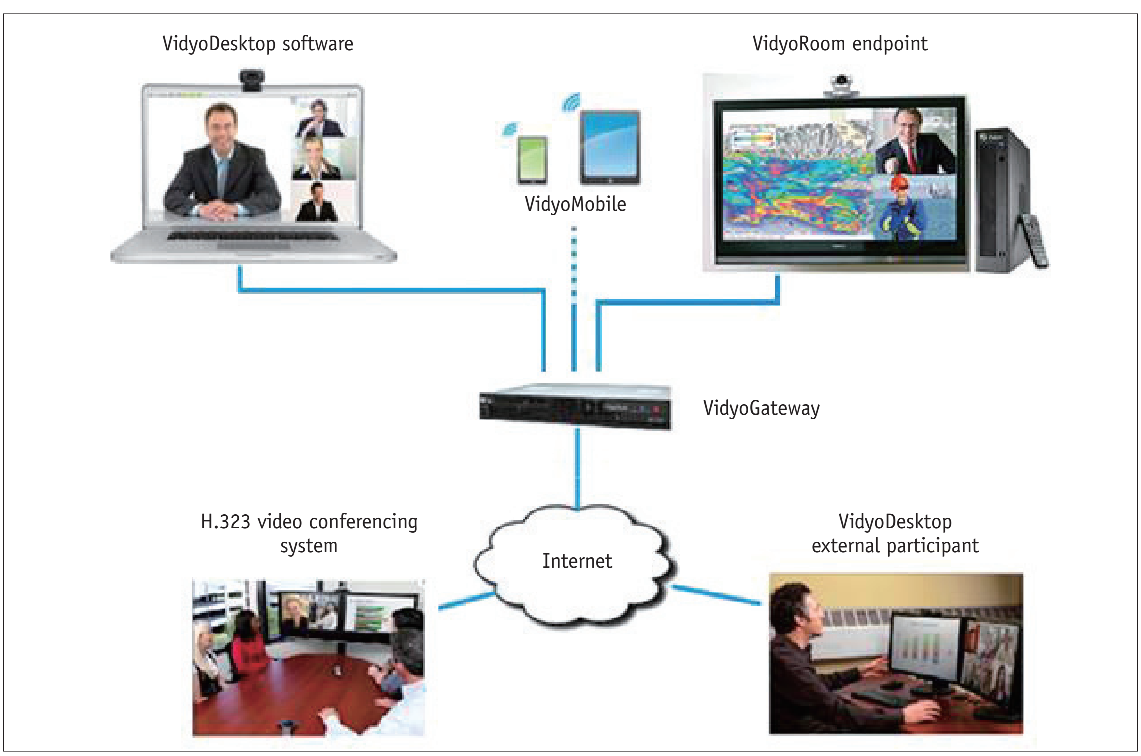

Fig. 5. Vidyo teleconferencing community, connecting users with Vidyo hardware device (VidyoRoom), personal computer (VidyoDesktop), apple or android smartphone, as well as H.323 system using VideoGateway.

telemedicine activities. However, there are also some disadvantages. One of these is the fact that this is a new system that is not that popular yet. This means that not many stations and engineers are familiar with it and the only support available is from the Vidyo company. Compared with companies that have had many years of experience, the Vidyo product is not entirely perfect, the features are less complete, and one still has to wait for the upgrades from the company. Although the VidyoDesktop is compatible with most audio visual devices, only recommended specialized equipment can be used with VidyoRoom, the hardware for this system. This is really a problem if one wishes to use one's own devices or create a flexible system.

The "community" can be a disadvantage with Vidyo, too. One needs to participate in a community of users, and thus, independent hospitals or individuals cannot use Vidyo. Moreover, as far as video transmission is concerned, the stations that can send a clear enough signal are restricted to those that have installed a VidyoRoom system, whereas stations without this system cannot send video clearly; they can only receive it.

In addition, the compatibility of Vidyo with other videoconferencing systems is not that good. Sometimes users have difficulty connecting to other H.323 videoconferencing systems that are already popular and widely accepted.

Vidyo has also developed a multi-point connectivity solution, called VidyoGateway, to bridge traditional systems with their Vidyo system and extend multipoint conferencing. The VidyoGateway supports Vidyo endpoints and other videoconferencing systems and MCUs from other vendors. However, the problem here is that the monitor only shows up to 9 stations, with the rest hidden, which is unsatisfactory for communication.

DISCUSSION

System Comparison

A comparison of the three systems is presented in Table 1 from various viewpoints. Which system is the most

Table 1. Comparison of Systems

Systems	DVTS	H.323	Vidyo
Cost	-US$ 2000	US$ 5000-20000	US$ 15000-30000
Camera	DV camera	HD camera	HD camera, webcam
Voice	External	Integrated or external	External
Echo canceller	Optional	Integrated	Integrated
Transmitted contents	Uncompressed SD	Compressed SD and HD	Compressed SD and HD
Anti-aliasing	No	Yes	Yes
Preparation and handling	More experience	Less experience	Less experience
Engineers in charge	1 or 2	1	1
Number of multiple connections	Quatre: up to 7 DVTS-Plus: 20 or more	25 or more	25 or more
Security for patient privacy	VPN routers required for IPsec	Integrated (Vendor original)	Integrated (Vendor original)
Network requirement	30 Mbps	384-1024 Kbs (SD), 1-8 Mbps (HD)	512 Kbps (SD) 1-8 Mbps (HD)
Time delay	200-400 ms	300-400 ms	150-300 ms*
Video input	One-to-one: NTSC, PAL Multiple: NTSC only	NTSC, PAL	NTSC, PAL
Audio input	One-to-one: All formats Quatre: 16 bit at 48 kHz	All formats	All formats
Pointer in the monitor	Yes (optional with Tele-pointer server†)	Yes (with optional devises)	No
Vendor support	No	Yes	Yes

Note.— *Reference from Vidyo Inc. (41). In fact, time delay very much depends on stability of network, †Tele-Pointer is software developed by ICT Research Division, INTEC Systems Institute Inc., Japan. DV = digital video, HD = high-definition, SD = standard-definition, NTSC = National Television System Committee, PAL = Phase Alternating Line

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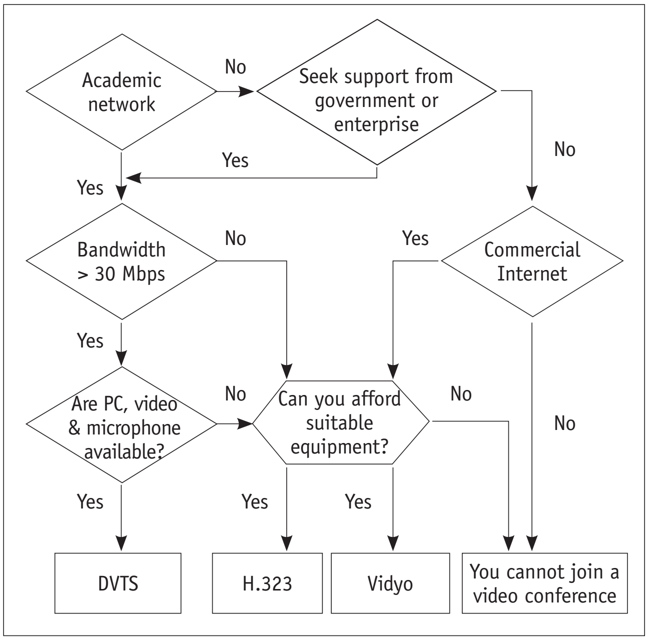

Fig. 6. Flowchart to assist in correct selection of system.

suitable for a hospital or institution depends on a variety of conditions including the available equipment, hospital network, human resources, number of connecting sites, etc. The flowchart in Figure 6 should be helpful in selecting the correct one, but this choice may also change according to the subject or content presented in the conference.

Academic Network Versus Commercial Internet

Commercial Internet is used everywhere in the world, with speeds ranging from hundreds of kbps to hundreds of Mbps (46). For many different purposes, millions of users share the limited bandwidth. Overloaded or unstable speed is very common. For general purposes, the commercial Internet is usually an asymmetric line, and so the download speed is many times greater than the upload speed (47). Under these conditions, browsing homepages or sending/receiving still images like X-rays or pathology should be acceptable because users can wait until the screen shows up or the pictures reach them. On the other hand, when moving images like surgery or endoscopy are transmitted, the streaming images are distorted by mosaic noise or sluggish movement (48-51). Therefore, for special purposes such as research, education, and health care, a leased line is necessary to ensure suitable video quality.

In contrast to a commercial network, which is open to the public, an academic network is a closed network that is for research and education purposes only (Fig. 7) (Table 2). It is government-funded and the main users are universities, hospitals and research institutes. As such, the general public cannot use it at home, nor can companies use it to earn a profit. There are also international backbone networks that connect these national research and education networks (REN) to each other and to other RENs around the world (52). The biggest advantage of this network is its independence. A high performance and symmetric network is designed for research and development activities. The REN provides high speed IP network bandwidth in the range of tens of Mbps to tens of Gbps, fully accommodating the advanced network services. So far, most of the developed and developing countries have their own RENs funded by the government. Research institutes, universities, and hospitals are always welcome to join this network according to the policy of each country (53).

The Korea Advanced Research Network (KOREN) is an example of the academic network in Korea, and there are more than 250 member institutions connected to this network (54). In China, the REN is called CERNET, and connects 2000 universities and research institutions. The US has Internet2 connecting 200 major universities, while GEANT2 connects over 3000 universities all around Europe (55, 56). There are similar situations in many other countries and continents.

SD Versus Compressed HD

Other important issues to consider in the evaluation of quality are image compression and aliasing.

Standard definition in DVTS has a resolution of 720 × 480 pixels while high definition for H.323 and Vidyo has a resolution of 1920 x 1080 pixels. One may think that it is clear that the latter two systems yield better quality than DVTS. But the issue is not that simple. These HD systems include a compression process which inevitably degrades the quality, whereas DVTS does not include this compression algorithm, thus preserving the best SD quality. Nevertheless, the reason that compressed HD images still yield high-quality images is mainly due to the aliasing function. Aliasing refers to an effect that causes different signals to become indistinguishable when sampled and to the distortion or artifacts that result when the signal reconstructed from samples is different from the original continuous signal (Fig. 8). These HD systems include an anti-aliasing effect to smooth the images, whereas DVTS does not. Bearing all this in mind, it should be noted that the final image quality is very much dependent on the eventual output devices, and so careful attention should also be paid to monitors and projectors. Further study is necessary to compare the quality between these systems theoretically.

Another system has recently been developed that can transmit HD videos without any compression (57, 58). There is no doubt that the quality of this system should be far better than that of any of the three systems mentioned above. However, this new system requires a stable network as large as 1.5 Gbps and very expensive equipment for encoding and decoding. Although it is currently an experimental system, we strongly hope that it will become more widely applicable to telemedicine with easier and more economical settings in the near future.

Security of Patient Privacy

Patient privacy is of the utmost importance, especially

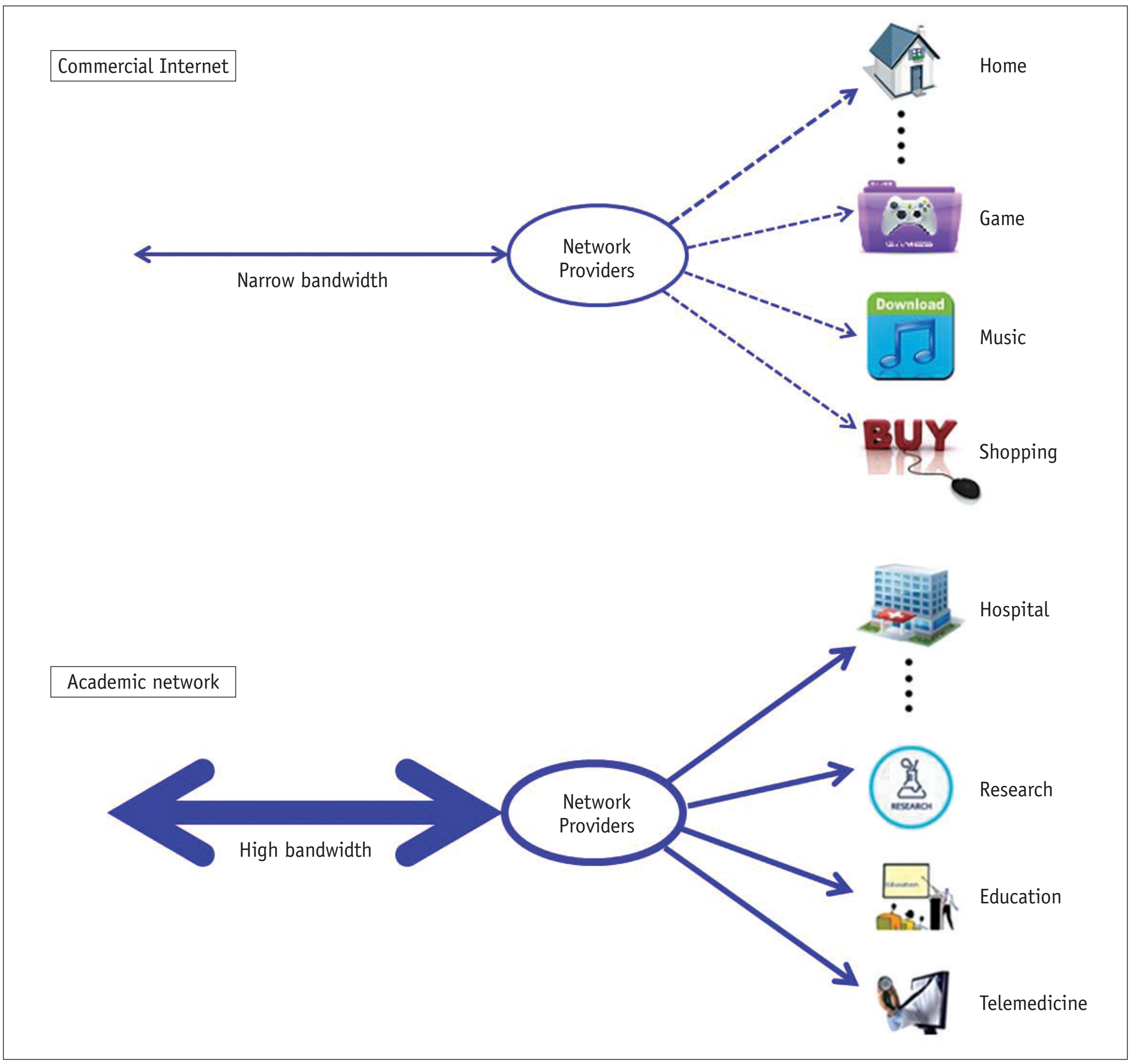

Fig. 7. Commercial Internet (top) versus academic network (bottom).

Table 2. Comparison between Commercial Internet and Academic Network

	Commercial Internet	Academic Network
Bandwidth	Hundreds of Kbps to tens of Mbps	Tens of Mbps to tens of Gbps
Download/Upload speed	Asymmetric	Symmetric
Stability	Unstable	Very stable
Activities	All purposes	Research, education
Cost	Self-funding	Government-funded
Users	Everyone	Priority for government institutions

Fig. 8. Aliasing problem: "aliasing" (top) versus "antialiasing" (bottom).

when live demonstrations are performed or a patient participates in a remote consultation broadcast over the screen. IPsec, an internationally authorized algorithm for encryption, is what is used with DVTS, and is accepted by our ethics committee (59). There are no import or export problems using this protocol as is the case with older programs like C4-VPN (Focus Systems Co., Tokyo, Japan). For H.323 compatible video conferencing systems, the vendors have developed their own security systems for installation, but appropriate evaluation should be carried out, because they are not necessarily accepted by formal Standards bodies, such as the Japanese government (60).

CONCLUSION

We have reviewed three major systems for telemedicine. They are all well accepted and promising solutions, but we should not forget that advancement of technology never stops and more convenient and less costly systems could become available at any time. We should keep our eyes open to such developments and work closely with engineering people to take full advantage of telemedicine for both healthcare providers and patients around the world.

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