

An overview of videostreaming on the internet and its application to surgical education

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Abstract. The Information Age has endowed mankind with a wealth of new technologies. Applications of these technologies are being developed to facilitate content exchange between individuals and institutions. Internet streaming is an exciting new technology that allows multimedia content to be stored and sent over the Internet, and medical educators are challenged to harness the potential of streaming for educational enhancement. This article helps to define streaming, examining its potential for surgical education.

Key words: Computer networking — Distance education — Internet — Videostreaming

We are currently well into what many call the Information Age, an era that has been compared with the industrial revolution. During the industrial revolution, a quantum leap was made in technological innovation, and applications for this new technology were quickly realized. The result of this unprecedented effort was an exponential advancement in the global standard of living. It is not unreasonable to assume that the Information Age will have a similar impact. One cannot help but be impressed by the ever-increasing processing speeds and capabilities of computers and the use of robotics in mainstream society. In addition, the World Wide Web and modern telecommunications are rapidly transforming the world into one large community.

As one considers these new technologies, it is perhaps natural to place an inappropriately high value on them. Despite impressive performances by hardware and software, it is “content” that will rule the 21st century. Technology serves only as a vehicle to enable content transfer. Technology by itself cannot have an impact on lives. Streaming data is a method that allows content providers to send real-

time audio and video over the Internet. Internet users can immediately access audio and video content and receive educational programming on demand. This article helps to define streaming, discussing its potential value in surgical education.

How streaming works

Streaming technology has been recognized as a significant milestone because it overcomes the restriction of limited bandwidth over the Internet. The term “bandwidth” is used to describe how much data you can push across a network. The wider the bandwidth, the better [1]. Modems allow 56,000 bytes per second (56 kbps) to be pushed. Because one frame is approximately 10 kb, at most, 5.6 frames are received per second. Therefore, normal video feeds of up to 30 frames per second cannot be achieved.

Fortunately, other devices exist besides modems to increase the rate of data transfer. Cable modem access allows 1.2 to 14 mbps (megabytes per second) to be transferred depending on the server, but transmission difficulties can result if too many people are accessing the same server. Digital Subscriber Lines (DSL) overcome this hurdle by giving everyone his or her own line at approximately the same speed as cable modem access. Currently, T-1 links and the T-3 link, which can carry data at 1.544 and 44.746 mbps, respectively, are being used as well. These make it possible to achieve real-time video of the desired 30 frames per second.

The transfer of large multimedia content files through a limited bandwidth conduit was traditionally a slow and painful downloading process. With the introduction of streaming, this hurdle to real-time distribution of multimedia content on demand can be eliminated.

Streaming works by a client-to-server method of communication over the Internet (Fig. 1). Understanding this concept, requires a firm grasp of how a local area network (LAN) functions. One of the most common LAN concepts is demonstrated by linking numerous computers to one printer to fulfill the printing needs of an entire office cost effectively.

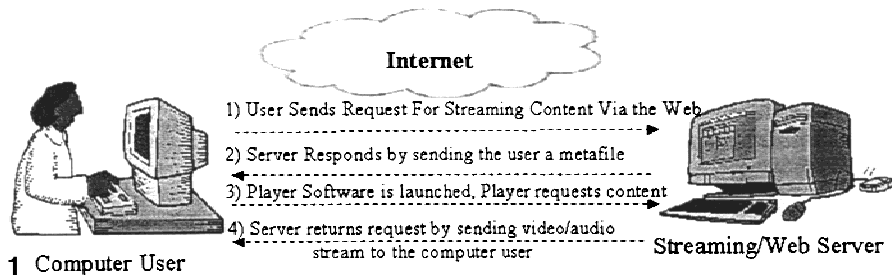


Fig. 1. Standard communication for streaming video. **1** The computer user clicks on a link on a web page. **2** The server responds by sending the user a "metafile" that contains the location of the streamed content. **3** Once the metafile is received, the user's streaming player software will be launched automatically, and the player sends a request for content to the server designated in the metafile. **4** The streaming server is contacted; the file is located; and the streaming process is started back to the computer user.

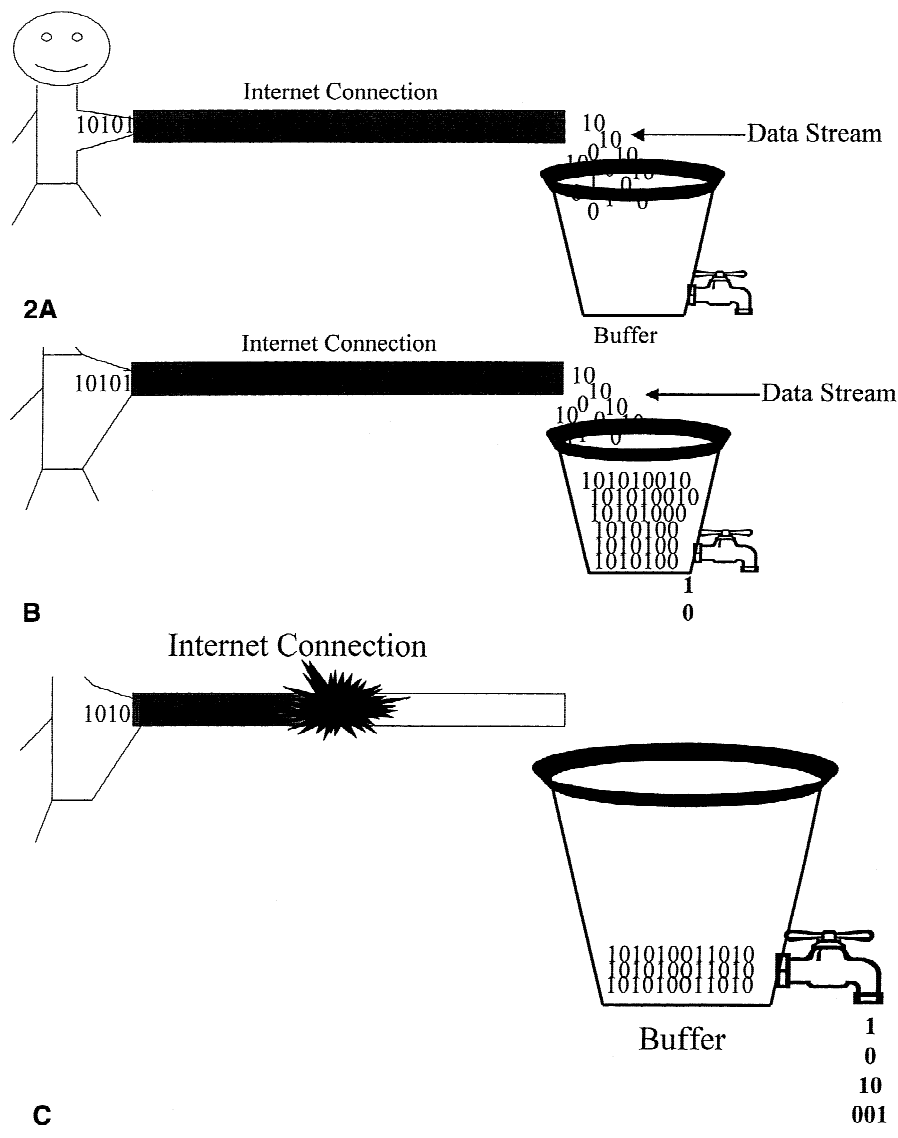


Fig. 2. Example of a buffer. **A** Think of the stick figure as the whole movie waiting to be streamed (part by part it is transferred to the buffer). Data flows from the Internet connection to buffer. **B** Once buffer is sufficiently full (some of the movie has been built up in the clients RAM), the data stream is released and viewed by the user. **C** If data transmission is interrupted, display to user continues until buffer is empty.

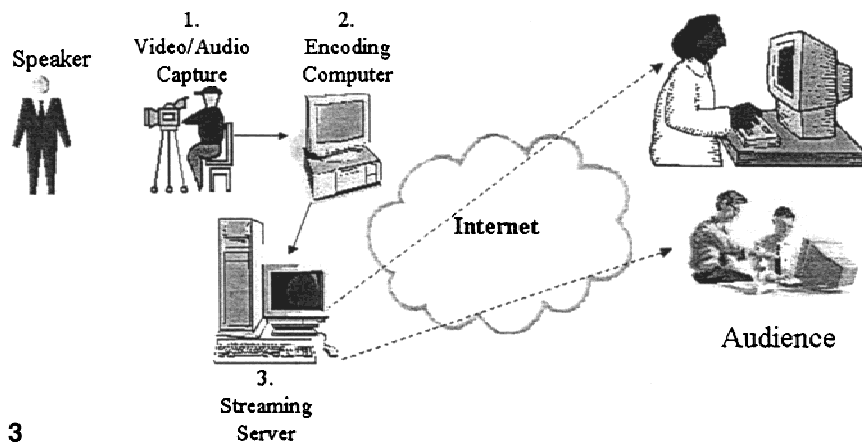


Fig. 3. Live broadcast using streaming technology. **1** For a live broadcast to take place, an individual will be recording the event using a video camera and microphone. **2** The signal from the video camera is sent to a video capture card on a PC. The PC uses software such as Real Producer to encode the incoming video signal to streaming video. **3** The streamed video is sent to a streaming server where it will be broadcast to anyone on the Internet.

A LAN physically links several personal computers (PCs) to each other, and often to a mainframe or minicomputer. This is accomplished with a variety of materials: twisted-wire cables, fiber optics, telephone lines, and even infrared light and radio signals. There are many ways to link PCs, but each configuration must perform the same tasks.

The most common situation dealt with by a network involves transmission of a message from one PC to another (e.g., a data query, instructions to run a program stored on the network, or a message to be forwarded to the Internet). Data or a program may reside on a PC used by a coworker or on the network. It may also reside on a file server (client server), which is a specialized, high-performance PC with a large hard drive that is not used exclusively by any individual. It exists to serve the other PCs on the network, which are called clients, by providing rapidly accessible data storage. A network also may have a server that links the LAN to the Internet. If a network does not have a specific server, it is a peer-to-peer network, which means that each computer acts as a server to all the others, which in turn are acting as servers. All LAN servers must receive requests from the individual PCs (nodes) and be able to deploy responses rapidly to the other PCs on the network. This is accomplished in a variety of ways. The most frequent types include Ethernet, token ring, and star, which account for most LAN client-server configurations, the specifics of which are beyond the scope of this article [4].

The streaming process is initiated when the computer user's streaming program sends a request for content to a streaming server. After the server receives the request from the client, it starts to send the requested information from the server to the client. As the client begins to receive the content from the server, the client software sends this data to what is known as a buffer (Fig. 2). The buffer is a portion of the computer's random access memory (RAM) that contains the first few seconds of the datastream. Once the client has an adequate amount of media content in the buffer, the software program starts to display the content to the computer user. As the client software continues to play, content is constantly added to the buffer. Thus, if there is Internet congestion during transmission, the buffer allows continuous content display and smoothes out inconsistencies. If data had to flow continuously from the server through the network to the client, transmission difficulties would cause breaks in the content. With some of the data already in the buffer, however, the datastream does not suffer. This process of simultaneous display and reception of media content continues until the media content is finished or terminated by the computer user. If the content is live audio or video, it must be passed through an audio or video capture expansion card, which turns the analog signal into digital information (Fig. 3).

Audiostreaming

When one clicks on a word or picture linked to an audio clip on the Internet, the Web browser being used contacts the Web server holding the web page link. The server sends the Web browser, such as Netscape Navigator (Netscape Communications, Mountain View, CA) or Microsoft Internet Explorer (Microsoft, Redmond, WA), a small file called a

metafile, which indicates where the browser can find the sound file, tells the PC how to play the file, and tells the Web browser to launch the appropriate audioplayer (a plug-in designed to work with certain Web browsers that can be downloaded from the Internet). The audio player contacts the audio server providing the sound file and tells the server exactly how fast the Internet connection is. Depending on this speed, the server sends one of several versions of the audio file. The faster the Internet connection, the higher the audio quality will be [4].

The sampling frequency determines the limit of which audio frequencies can be reproduced digitally. One of the most important rules of sampling is Nyquist's theorem, which states that the highest frequency that can be represented accurately is one-half of the sampling rate. Therefore, if one desires a full 20-kHz audio bandwidth, the sample must be at least twice that fast (i.e., more than 40 kHz). Real video will encode its audio at 22 or 44 kHz. A presentation with audio encoding of 44 kHz will have superior sound quality, but will require more bandwidth than a presentation with audio encoded at 22 kHz.

The server sends the audio files in user database protocol (UDP), which permits an occasional packet of information to be lost, with only minor sound disruption. When the information packets arrive at the PC, they are decompressed and decoded, and the results are sent to the buffer. The buffer is housed in a small portion of random access memory (RAM) in the CPU central processing unit (CPU) and holds a few seconds of sound. When the buffer is full, the audioplayer processes the file through the PC's sound card, which plays the audio, while the server continues to send the rest of the audio file. If the buffer becomes empty, there will be a pause in the audio until the PC accumulates enough data to keep on playing. If the sound is from a live source, the player will skip the portion that it misses, whereas if the sound is prerecorded, the playback will continue from the point at which it stopped [4].

Videostreaming

Videostreaming operates much the same as audiostreaming. However, there are several important differences. A video capture expansion card receives the analog video signal from its original source (e.g., a live camera or a recorded video) and turns it into digital information. Next, the digital information is sent through a codec (coder-decoder), which exposes the datastream to compression/decompression algorithms. Several methods may be chosen to compress video and audio data, which work on the axiom that if the data does not change, one does not have to send it. If duplicated data is not sent, the datastream is much smaller and therefore can flow through the bandwidth pipe faster. This provides smoother voice and audio reproduction without a prolonged downloading process. Interframe compression compares adjacent frames of the video and transmits only the data that changes from one frame to the next. Therefore, less information is required if the background of a video is not constantly changing. Intraframe compression also works by reducing the amount of data necessary to represent a single frame of video information, but it accomplishes this in a different fashion. Intraframe compression captures and compresses every part of every frame [4].

Two types of transmission protocols can be used to transmit video and audio signals: Internet provider (IP), multicast information packets, or user database protocols (UDP). The IP protocol uses less bandwidth because it sends a single signal to a computer acting as a multicast server, which in turn duplicates the signal for all client PCs attached to it. Video delivery by UDP is more common because it does not require special network hardware (a multicast server), and it is more efficient in preventing gaps and pauses in the audio part of the signal. However, this also requires more bandwidth because individual video signals must be sent to all client PCs. The PC receiving the information decompresses the video and loads it into the RAM buffer, just as with audiostreaming. The signal is split into video and audio components and sent to video and audio cards. As with audiostreaming, videostreams skip packets of information that cannot be handled in real time. A defective video packet causes a glitch in the feed, which will carry over to other frames. The computer corrects these errors by comparing new frames with old frames [4].

Streaming software

There are two major software providers for streaming: Real Player G2 (Real Networks, Seattle, WA) and Windows Media Player (Microsoft). Real Networks is the more popular software platform. Therefore, we shall concentrate on its properties. Real Network's Real Player 5.0 (first generation) is credited with the development of real-time Internet multimedia content. Now, Real Network's G2 Player (second generation) systems have greatly enhanced audio and video quality by overcoming previous limitations of streaming technology and have added new features to the streaming environment that facilitate multimedia presentations. These improvements set the G2 system apart from all past streaming systems [2].

Audiovisual streaming quality over the Internet has been improved by G2 streaming in two distinct ways. The G2 music codec enhances frequency response by 80% for 28.8 kb/s users, which means that audio quality for the vast majority of streaming technology users is greatly increased [2]. Audiovisual quality has been improved through the use of "Surestream" technology, which automatically scales Real Audio and Real Video files to all bandwidths by dynamically adjusting the bitrate (the amount of "information packets" per time segment) to match available bandwidth (the amount of information that can be accessed efficiently at once by a streaming program). Thus, if the bandwidth changes, there is no break in the media content display while rebuffering occurs [2].

Also, G2 streaming has greatly enhanced the way multimedia presentations are delivered. Real Player G2 has the capability to support synchronized multimedia integration language (SMIL). This computer language allows authors to create media content that combines scrolling text (Real Text), high-resolution images, and powerful transition effects with audio, video, and even animation [2]. The content author has the ability to create as many windows as necessary for effective content delivery. Because it allows the advantage of multimedia presentation techniques, SMIL is a powerful streaming tool.

Examples of surgical education using streaming technology

Internet streaming is used by a number of different media content providers. However, most streaming is used for the presentation of daily news and entertainment. Unfortunately, medical educators have been slow to harness the potential of streaming as an educational tool. However, in several recent examples, the streaming platform was used to present medical content. On June 16, 1998, a live birth was broadcast over the Internet, which raised questions regarding whether such broadcasts enhance education or merely feed the American public's appetite for sensationalism. Since then, America's Health Network [5] has broadcasted live open-heart surgery, hair transplantation, cataract removal, knee replacement surgery, cerebral aneurysm clipping, among others [1]. This past July, Carrie Phillips' (formerly of the musical group Wilson Phillips) bariatric surgery was broadcast by A Doctor in Your House [7]. Despite the marketing and public informational format of these streaming milestones, they have effectively demonstrated the potential impact of this medium for educational purposes. Therefore, it is important for surgical educators to seize the opportunity to use videostreaming for content production and advancement of continuing education goals.

Baylor College of Medicine, Houston, Texas, has integrated Internet streaming into its curriculum and currently offers four courses for continuing medical education credit [6]. Some course titles are Current Recommendations on the Treatment of Hypertension: Who and How, Diagnostic Approach to Cardiac Tachyarrhythmias, Diagnostic Approach to the Patient With Chest Pain, and Management of Patients with Acute Myocardial Infarction: From Admission to Discharge and Beyond. The courses are each worth a maximum of 0.5 hour in category 1 toward the American Medical Association (AMA) Physician's Recognition Award. Each course consists of a Power Point slide show with the course instructor narrating the slides (audio transcripts are also available), but no video of the speaker is shown. At the end, a 10-question test is given, which is submitted to the physician conducting the cybercourse.

Earlier this year, the University of Texas-Houston Medical School began to use streaming technology to deliver live lectures over the Internet using standard PCs and modems. The lectures were presented as live media content and simultaneously recorded, which allowed future playback. The lecture format was similar to Baylor's in that it included slides with audio synchronization [3].

We began using Internet streaming for educational purposes here at Yale 2 1/2 years ago. Seminars in Surgery is a distance-learning project now in its second year of existence. The goal of this project is to make the Surgical Grand Rounds and the Surgical Science lectures from the Department of Surgery at Yale University School of Medicine available to the world via the World Wide Web. Like the other institutions, we are using Real Video for this project.

The Surgical Grand Rounds and the Surgical Basic Science Lectures are 1-h lectures delivered each week by either faculty of the Yale Department of Surgery or special guest lecturers of the department. Each lecture is recorded using a digital video camera. Once the lecture has been recorded, the digital videocassette is taken to the multimedia lab,

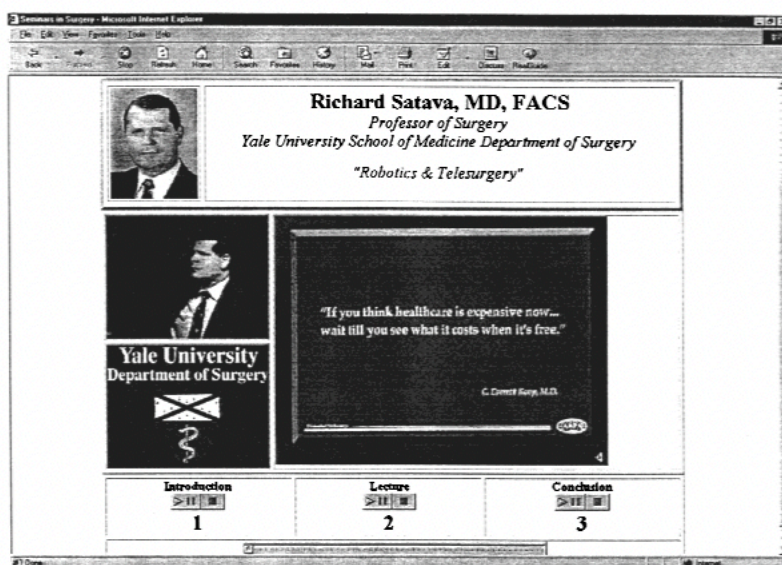


Fig. 4. An example of streaming video integrated into A web page for Seminars in Surgery.

where it is converted into a digital computer file, which then is edited digitally. Video and audio segments showing the introduction of the lecturer and concluding remarks also are created. Once complete, the file is exported to the Real Video encoder. The encoder software produces a real media file, which can be streamed on the World Wide Web, provided the file resides on a Real Video server. Once the file is encoded on the server, it is possible to hyperlink to that file from a web page, thus enabling the media content to be broadcast over the Internet. Fig. 4 shows an example of our web-based interface for this project.

In Fig. 4 three real video windows are being used. In the upper left window, there is an introduction and video segment of the initial part of the speaker's presentation. After the first clip is completed, the next section will show the speaker's slides in the larger window on the right side. The user cannot see the speaker, but hears his or her voice narrating the slides. The final part, which appears in the lower right corner, is a video of the speaker giving a conclusion to his or her lecture. This interface does not use SMIL technology. We currently are converting all presentations to the G2 format. The G2 upgrade with Surestreaming allows the use of a more robust multimedia presentation platform.

Discussion

Two years ago the Society of American Gastrointestinal Endoscopic Surgeons (SAGES) performed an initial investigation into the use of streaming as a way to export educational content. At the end of this evaluation, it was concluded that this technology was not ready to be used. The small pixelized images that displayed erratic synchronization of the speaker's lip movements and audio presentation were very distressing. Currently, this technology is being revisited, and over the past 2 years, previous shortcomings have been very successfully addressed. The advent of the

Real G2 format has produced unprecedented advantages that can be exploited by content developers. Even a portion of the scientific session from the SAGES 2000 meeting was broadcast over the Web for a few months.

Despite these improvements, content providers and streaming users must continue to participate actively in maturing this medium, so that it may be introduced into mainstream medical education. Skeptics remain concerned about some aspects of Internet streaming. Content providers have strong feelings about how they prefer to present their materials. Many fear the extra work that is involved in converting their analog data into digital information. Others contend that surgeons and other medical professionals are in the early stages of developing universal computer literacy. In addition, many cautious educators warn that streaming multimedia presentations over the Internet is not a substitute for live instruction.

In fact, streaming should not be seen as a substitute for live instruction, but rather as a way to enhance medical education. Streaming is excellent for delivering information on very specific topics that address areas of widespread concern for clinicians, especially if the topic covered helps to hurdle significant diagnostic, procedural, or treatment issues successfully. Lecture topics that are not well attended in the real-time situation also may not be well attended in cyberspace because they will not assist the clinician in dealing with day-to-day challenges. Subsequently, these types of products have limited marketability and poor revenue-producing potential.

Streaming is not so effective in providing large volume and diverse educational content. It is most effective in presenting very focused subject matter. An example of this strategy can be seen in the tutoring services a professor must provide for a very large biochemistry class. It often is very difficult for that professor to address the specific tutoring needs of each individual in his or her class. The streaming of focused multimedia tutorials covering the most fre-

quently asked questions generated by a specific body of information could be very effective in improving the performance of the class as whole, while time delivering needed special attention to poorly performing students who require additional help. Another example involves a surgeon who is preparing to perform a para-esophageal hernia repair. The patient has a totally intrathoracic stomach, and the physician has limited experience with this problem. A streaming presentation on the particulars surrounding the successful approach to this rare problem could be very beneficial.

Critics often comment that the same experience can be replicated with videocassettes. On initial review, that assessment may appear correct, but when studied more closely, it can be seen that streaming offers more knowledge transfer options with a more cost-effective profile. Currently, 60% to 70% of Americans either own or have access to a computer. The software necessary to view streaming presentations can be downloaded free of charge from the Internet. Streaming content eliminates the cost of videocassettes, videocassette recorders, and the need to transport materials from one place to another, which drastically decreases costs. Also, 24-h-a-day access to the Internet allows the participant boundless use capabilities. Because all content is digitally created, it can be updated easily, whereas the traditional use of videocassettes cannot. Thus, update production costs are decreased, and the shelf life of the product is extended.

Despite the significant multimedia presentation capabilities offered by Internet streaming, it does not provide the ultimate solution to the continuing education dilemmas we face. It is best used as an important component in a multi-pronged strategy that features several platforms. For medical educators, the challenge is to embrace this technological medium and learn to exploit its strengths. For clinicians, the challenge involves being willing to "point and click" in order to explore a new and exciting knowledge-transfer technique that can help to overcome the challenges of continuing medical education.

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