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Medical Video Server Construction

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The paper discusses two implementation options for a Digital Video Library, a repository used for archiving, accessing, and browsing of video medical records. Two crucial issues to be decided on are a video compression format and a video streaming platform. The paper presents numerous decision factors that have to be taken into account. The compression formats being compared are DICOM as a format representative for medical applications, both MPEGs, and several new formats targeted for an IP networking. The comparison includes transmission rates supported, compression rates, and at least options for controlling a compression process. The second part of the paper presents the ISDN technique as a solution for provisioning of tele-consultation services between medical parties that are accessing resources uploaded to a digital video library. There are several backbone techniques (like corporate LANs/WANs, leased lines or even radio/satellite links) available, however, the availability of network resources for hospitals was the prevailing choice criterion pointing to ISDN solutions. Another way to provide access to the Digital Video Library is based on radio frequency domain solutions. The paper describes possibilities of both, wireless and cellular network's data transmission service to be used as a medical video server transport layer. For the cellular network based solution two communication techniques are used: Circuit Switched Data and Packet Switched Data.

Introduction

Interpersonal communications has been experiencing a lot of changes during few last decades, however, almost all solutions and techniques were suited for voice transmission. Many experts and visionaries expect that in the next years the age of video communications will come with some transitional period of extensive spreading of digital video distribution. The key issue in the area of digital video distribution is development of Digital Video Libraries being a sophisticated repository of video content that has been indexed, abstracted, and can be browsed and streamed to many users in simultaneous sessions.

It is quite obvious to expect that Digital Video Libraries will be dedicated to specific applications and one of the most promising is telemedicine where a massive and well organised video content should be stored for education and documentation purposes.

Compression Formats for Telemedicine Purposes

Digital Video Libraries, constructed for Telemedicine Systems, usually utilise three compression techniques: DICOM, MPEG-1 and QuickTime. The DICOM format gives the best quality as it is based on a lossless (or almost lossless) compression. On the other hand, as DICOM streams usually exceed 3 Mbit/s, this format can be used in really high bandwidth networks (25Mbit/s, 155Mbit/s) only like in [5]. A lossy compression with the lower bandwidth requirements (about 1Mbit/s) can by achieved using the MPEG-1 compression. The post compression video quality is almost perfect; however, during several networking trials it has been revealed that the achieved throughput was in some cases limited to 2 - 3 frames per second. Real-time video performance should be possible once Internet2 or other high-bandwidth networks become available for world-wide telemedicine purposes [6]. The third popular video format is QuickTime. While using the internal Sorenson Video compression scheme, serious bandwidth savings can be gained for narrowing streams even to 300kbit/s. Those saving are of course ransomed with lower picture quality, achieved by a reduction of the picture resolution, frames-per-second ratio, and number of colours. Such prepared videos may be available on different platforms, e.g. at the web telemedicine vortal [7].

Video Server

Design of a medical video server consists in the choice of the most appropriate components and their integration into the digital video library. The two most important choices to be decided on are: a video compression format and a video streaming.

The Choice of the Video Compression Format

Design of effective medical video content streaming and storing procedures in a video database has to be preceded by an analysis of several available video formats features. The following formats have been inspected:

- DICOM
- RealMedia Video
- Windows Media Video
- QuickTime
- MPEG-1/2
- MPEG-4 (DivX, AngelPotion)

Each of the above formats has some advantages and disadvantages. In telemedicine applications it is justified to assume that the original motion picture is being delivered in the **DICOM** format. Compression and post processing of a motion picture is a follow-up of a limited transmission bandwidth between the database and end users. The additional challenge is a simultaneous streaming of many video streams while keeping a support for download and play out of data. When such restrictions do not exist it seems possible to upload movies to the video database in their original DICOM format, unless some other user options have to be provided (indexing and abstracting the video content).

DICOM

DICOM is a commonly approved standard for medical (motion) picture data formatting. Therefore **DICOM** allows for data exchange between heterogeneous computer systems without decompressing or transcoding. **DICOM** should make medical system users' life easier; however, it does not make programmers' tasks easier. Currently, several companies try to implement the **DICOM** standard in their systems; all of them assure the 100% **DICOM** compatibility of their hardware.

The **DICOM** format is internally compressed. The compression (lossless or a little bit lossy) ratio is not perfect. The typical motion picture: 512x512 in 256 greyscales, 12.5 frames-per-second generates a stream of about 3.6Mbit/s.

RealMedia Video

RealMedia is the most popular and the most advanced system for multimedia streaming over Internet. It allows for real-time transmission of audio, video and complex multimedia presentations. **RealMedia** consists of three basic building blocks. The first one is a **RealProducer** coder that transforms audio and video data into the **RealMedia** format. The second block is a **RealServer** for data streaming; a user part of the application is known as a **RealPlayer** [4].

The coder allows preparing files for transmission to end users over communication links in several set-ups. It is possible to use modem links like: 28.8kbit/s (analogue), 56kbit/s (analogue-digital) or 64/128kbit/s ISDN (digital). Support for leased links like: 256kbit/s, 384kbit/s or 512kbit/s is provided as well. Unfortunately, the last bandwidth setting is the best quality available in this coder; by setting to 512kbit/s the quality still is lower than in case of the **MPEG-4** format (described further).

Windows Media Video

Encoding **DICOM** signals to the **WMV** format causes a problem at the very beginning stage - it is necessary to add an extra audio track to the **DICOM** video. The next encoding stages are rather intuitive and consist of choosing the coders/decoders, the bandwidth required, the picture resolution, and the frames-per-second ratio. The research performed revealed that the minimum bandwidth for the acceptable picture quality is 512kbit/s. For the 1Mbit/s throughput the quality is very high and it does differ from the original one insignificantly. Unfortunately, the achieved compression ratio is located close to 1:20 what is not a perfect result. Moreover, controlling the encoding process in the automatic manner is not performed from a command line but with a support of additional SDK software.

QuickTime

Encoding video streams into the **QuickTime** format seems to be a better solution than **WMV**; at first, several play out and conversion plug-ins are available, including those converting the stream directly from **DICOM**. At second, the compression method is very effective as the quality achieved after the compression was comparable to the quality of **WMV** and **RealMedia Video** while a file size was much smaller. At third, no **WMV**-like problems with audio track have been observed, and **QuickTime** format streams are susceptible to indexing and broadcasting easily. Unfortunately again, there are no command line options provided for a direct control of movie processing and storing.

MPEG-1/2

The **MPEG-1** standard is a rather old (1992) video compression format. It was constructed mainly for life recorded video content and for streaming flows about 1Mbit/s. Later, its more advanced version (**MPEG-2**) has become a standard as a result of support both for higher bandwidths (necessary for high resolution television) and bandwidth scaling as well. Though both standard versions are much related, the **MPEG-2** is not fully compatible with its predecessor. The **MPEG-2** standard requires the decoder supporting both **MPEG-1** and **MPEG-2** video formats.

Both versions enforce high quality of the final content with the minimal throughput of 1Mbit/s and the minimal frames-per-second ratio of 24.

MPEG-4

MPEG-4, the next member of the MPEG standards family, is still subject to the design. The object approach applied there allows for moving and scaling of individual components of a movie. In the **MPEG-**4 format, additional compression algorithms are available (including wavelets) apart from those based on the DCT transform.

Apart the classical **MPEG-4** format its several modifications are available. The most popular ones are: **DivX (DivX;-)**, **OpenDivX/DivX 4**) family and **AngelPotion**.

DivX;-) is a "hacked" Microsoft **MPEG-4** coder/decoder. The original coder/decoder was a commercial product. **DivX;-)** is some form of jeer of commercial products [2].

AngelPotion MPEG-4 codec is a little bit faster then the **DivX** coder/decoder. It allows for encoding and decoding higher quality files as well.

The file compression carried out revealed that as far as the subjective feelings are considered, the coder/decoder for **AngelPotion** format offers the best results. The quality coming with the 512kbit/s bandwidth is difficult to distinguish from the original one.

The Choose of the Video Streaming Server

There are many video servers existing on the market. The Table 1 presents their overall comparison including cost, available video formats, billing possibilities, performance and others.

From the very first review of the table it can be realised that there is no best choice for any environment. A proper solution for the end-user can be Real Networks Server. The client software for this system (called Real Player, earlier known as Real Audio Client and Real Video Client) is very popular among Internet users. It is free and can be easily downloaded from Internet file servers. Some versions of Microsoft Windows or Netscape Communicator Web Browsers have it already implemented. Client software has the automatic update option so there is no need for administration task after new software modules or protocols are introduced. RealNetworks software has its own disadvantages as for example a low number of standard file transfer formats being supported. Fortunately, there are converters on the market available.

Free Apache Web Server (considered for specific medical environment) presents almost the same quality as a previous solution. Its main advantages are popularity and easy management. The key feature is a public available source code and modularity. The additional modules can be created and integrated with existing ones easily.

When designing the digital video library we have to consider a disk space. The Apache Web Server is so common that it is possibly already installed on a target server giving disk space, memory and processing power savings. While choosing the web server the native medical video format - DICOM can be utilized.

TABLE 1

Video server comparison

Server:	OVS[1]	RNS[2]	DSS[3]	HTTP[4]
Server price per client, from:	$70	$0	$0	$0
Streams served number[5]:	Thousands	Thousands	Thousands	Hundreds
Source authorization[6]:		×		×
Advertisement module:		×		Option
Playback authorization:	×	×	×	×
RA files:		×		×
RM files:		×		×
RAM files[7]:		×		×
AVI files:	×	×		×
WAV files:	×	×		×
MOV files:	×	×	×	×
MPEG files[8]:	×		×	×
Converters included[9]:		×		
Real-time transmission:	×	×		×
Video on demand:	×	×	×	×
Graphical administration interface:	×	×		×
VCR-like functions:	×		×	×
Databases integration:	×			×[10]
On-fly streams mixing:	×			
Available platforms:	9[11]	11[12]	5[13]	29[14]
Available protocols:	7	3[15]	3[16]	2[17]
Analogue data:	×			
Play-list:	×		×	
Multicast:	×	×	×	
Logging:	×	×	×	×
Billing:	×			
Own disc matrixes:	×			
Bandwidth scaling:	×	×		
Fast preview:	×		×	×
Bandwidth management:	×	×	×	

[1] OVS = Oracle Video Server
[2] RNS = RealNetworks Server
[3] DSS = Darwin Streaming Server
[4] Typical free WWW server, most data based on Apache Web Server
[5] Informational, estimated for high performance server
[6] Possibility of inserting the author identification markers
[7] RA, RAM and RM formats using RealOne Player software with HTTP protocol
[8] AVI, MOV, WAV and MPEG formats using Quick-Time plug-in with HTTP protocol
[9] Different file formats to supported by video server format converters
[10] Semi-automatic
[11] Microsoft Windows NT on Intel (Pentium class), Sun Sparc, Hewlett Packard HP9000, Digital Alpha, Silicon Graphics, IBM AIX , nCube, Siemens Nixdorf and Pyramid
[12] Including: Windows 2000, Windows NT, Linux, Solaris, HP/UX, AIX, IRIX, Compaq Tru64 UNIX 5.1 I FreeBSD
[13] Mac OS X Server 10.0, Free BSD 3.5, Red Hat Linux 6.2, Solaris 7, Windows NT Server/Windows 2000 Server
[14] AIX, Aux, BEOS, Bs2000-osd, BSDI, CYGWIN, DARWIN, DGUX, Digital Unix, Free BSD, HPUX, IRIX, Linux, MACOSX, MACOSX Server, Net BSD, NetWare, Open BSD, Os2, Os390, Osf1, QNX, Reliant Unix, Rhapsody, SINIX, Solaris, SunOS, UnixWare, Win32
[15] RTSP, PNA i HTTP
[16] HTTP Fast Start i RTP/RTSP
[17] HTTP i FTP

The access to medical video content has to be secured because it contains confidential patients' data. That is why a combination of following authentication and authorisation methods has to be implemented (presentation order from the weakest one).

1. Password access - no random access to file server on the basic level; very low security against organized attack.
2. IP protection - access is allowed only from given IP addresses; possibility of IP spoofing, difficulty with sharing or changing IP.
3. One-way encrypted password - higher protection; transmission and password can be caught and changed.
4. Digital signature and certificate - the client-server authorization and authentication - protects against content modification and allows hardware independent verification.
5. Transmission encrypting (encrypted tunnels) - tapping protection with crypt overhead.
6. PGP file encrypting - no access to files even after server hacking; key can be lost or forgotten, what equals file destruction.

ISDN as the Backbone Technique

Providing access to digital video library between medical parties with a satisfactory quality requests transmission over a broadband backbone network. Many potential possibilities do exist such as:

- private (corporate) network LAN/WAN,
- leased lines (channel 2Mbit/s),
- satellite links,
- radio channels,
- ISDN network.

An ISDN network was chosen in the presented design because of requested availability. This technique is useful in terms of transferring digital data signals as well as ensuring good quality of service like throughput, delays, and jitter. Nowadays, when people would use several devices attached to a single telephone line, ISDN could be recommended as the best way of provisioning a connection of mixed media streams (voice, video, and data). If subscriber owns analogue equipment, he can get advantage in the ISDN network also. However, an additional set-up is needed in such a case (so called an NT adapter).

The best way to connect subscriber to digital video library services is to use ISDN lines with owned telephones (hospitals usually have analogue devices) with a PC based digital library client. Connections are established from time to time only and for a specified period of time when access to digital video library is required. In this case it is also possible (not only when connection is provided via leased-line) obtaining time-to-call less then 1 second. This method is much cheaper than leasing digital lines from a telecommunication operator that could be an important point for hospitals and other medical parties.

Two types of access connection have been defined:

- Basic Rate Access (BRA) - channel 2B+D, throughput of 144kbit/s,
- Primary Rate Access (PRA) - channel 30B+D, throughput of 2Mbit/s.

Both interfaces can be configured on simple copper twisted pair, so no special activities from operator's point of view are required (which also means adapting existing connections to medical parties). Considering access to a digital video library, we have to realise that a BRA interface provides to low throughput and on the other hand a PRA interface is too expensive. The optimal solution can be unification of at least two basic channels. Such a data rate (256kbit/s) is sufficient for transmitting video, audio and data stream from medical video server. Full multimedia stream can be established using two or more BRA interfaces through ISDN router connected to the lines and PC (used as a digital video library terminal).

For correct configuration of connection between end user and medical video server it is required to apply few devices in the ISDN network. The list includes:

- digital telephone - enables easy to use and good quality end-user device to proceed voice calls; it also enlarges list of possible network services, so a subscriber can customise them; each telephone consist of numeric keys and LCD display, to increase quality of use;
- videoconferencing modules - entire set of devices enabling videoconferencing between involved parties;
- digital "modem" - enables data transmission in 1 B or 2 B channels which means rates of 128kbit/s available for the end user;
- ISDN router - it allows a connection through an ISDN network for a specified period of time; this way, time channels from 64kbit/s up to 256kbit/s are available (practically to each point in the world where ISDN system is active); this solution is more profitable than leased lines especially for firms using the link periodically.

As there are different techno-economic options available for medical parties we can suggest three ways of accessing a digital video library sketched in the Figure 1.

In each solution TP S.A. leased line is applied (due to its penetration in the area around Krakow) so TP S.A.'s network exchange with two BRA lines is used. As suggested above, 256kbit/s streams are minimum requirement for good quality video transmission.

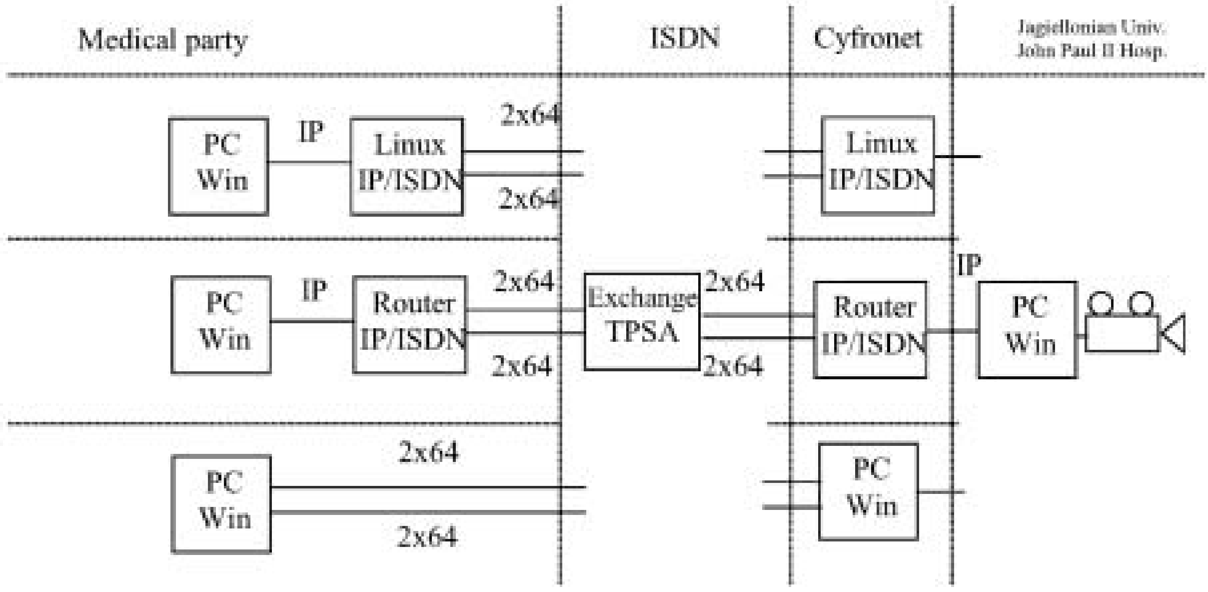

Fig. 1. The ISDN backbone network architecture.

First mode operates on a computer node with a Windows operating system. This setup requires using an additional node for splitting stream into two BRA lines. This service is able to run on a simple Linux system aimed to work only as the conference bridge and route IP packets from PC. Benefits rising from using Linux system are very important as long as it remains free of charge and non hardware-consuming. Upgrading standard installation with ISDN4 LINUX module system can be regarded as a specialised traffic bridge for conferencing purposes.

Second proposal suggests using ISDN router instead of an additional PC with Linux inside. There is advantage that such a router can be running in the medical centre already and will be accommodated for video connections only and IP traffic accompanied by them. Supplementary improvement is achieved in terms of management and configuration of this router. It is possible to configure service more precisely assuring better safety conditions as before. Unfortunately, higher cost of ISDN router, in case of necessity of buying it for access to a digital video library, reduces possibilities of using this system.

A third solution requires the least job to be done in accommodating own system for accessing a digital video library. This system allows execution of all processes to be done on a single computer with Windows operating system. Windows NT is capable to execute mixing and splitting more than one BRA channels into a video data stream.

In our project we have decided to use the second option as of putting the stress on the quality and flexibility of achieved streamlined communication, using owned OptiBase video encoding cards, and already running computers with Windows. Approximated cost of installation of a single point of access to a medical video server with full capabilities is 6,700 PLN (1,860 euro or $ 1,670) which includes router, PC and ISDN connection lines (plus camera and capture card).

A monthly fee for connecting to a medical video server (at present rates) is estimated to be about 1,900 PLN (530 euro or $475) with session duration equal to 2h, 8 - 9 times a month, but much cheaper scenario (session duration 1h, 4 times a month) will cost medical party about 400 PLN (110 euro or $100).

Radio Access to the Video Server

Introduction

In particular cases it is impossible to access the Video Server through a dial-up (ISDN, POTS) or a leased wire connection. The problem arises both for:

- consultations in Healthcare Units connected through low-speed lines, and
- consultations within local area networks accessed via wireless connections.

Because of its functionality a GSM based solution is very attractive. At present, all hospitals in Poland are under the radio coverage of two most popular providers. The transmission speed in a GSM network until very recently was equal to 9.6kbit/s, and was insufficient even for services like e-mail or WWW. Nowadays two more efficient transmission techniques are available:

- General Packet Radio Service (GPRS),
- High Speed Circuit Switched Data (HSCSD).

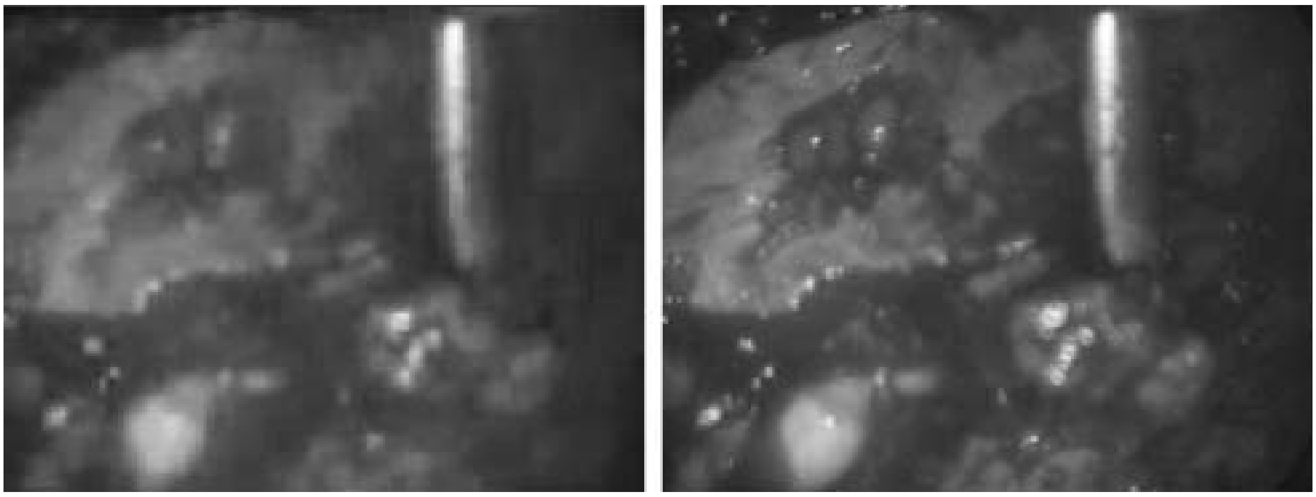

Fig. 2. The video stream 40kbit/s (left) and the original (right).

The transmission speed for both techniques is about 40kbit/s and is close to the highest one offered in POTS (56kbit/s).

HSCSD

Circuit Switched Data (CSD), the oldest transmission technique available in a GSM network, offers 9.6kbit/s only. Every time slot (i.e. transmission channel) in a TDMA frame can be used with throughput as follows:

- low 4.8kbit/s,
- normal 9.6kbit/s,
- high 14.4kbit/s.

The plain CSD technology uses the normal throughput. The HSCSD technology can utilise the high one and offers more than one time slot for one subscriber for data transmission. At present, up to 3 or 4 time slots are available for one HSCSD session. Transmission speed varies from 40 to 50kbit/s. From a subscriber's point of view the most significant difference between the CSD and HSCSD is:

- the increased throughput, and
- charging (for example one of the Polish providers charges HSCSD the same as CSD).

GPRS

CSD based solutions are GSM versions of plain data transmission techniques used in POTS or ISDN. Subscriber needs to dial an access number. Charging is proportional to a holding time. A transmission channel is unavailable during the connection time even if no data are sent.

GPRS offers a different method. A subscriber is connected continuously to a GPRS packet network. The transmission channel is busy only when data is transmitted and fees are proportional to amount of data sent and received in the transmission channel.

Theoretically, up to 8 transmission channels are available for transmission of one packet. Every transmission channel offers throughput equal to 14.4kbit/s, so subscriber is connected via a 115.2kbit/s channel. In practice throughput depends on a coding method being used and is lowest for the CS1 coding and highest for the CS4 one.

EDGE

In the near future a new transmission technique, Enhanced Data Rates for Global Evolution (EDGE), is intended to be introduced. The transmission speed for EDGE is 384kbit/s and is greater than the maximum expected for POTS with use of any modulation technique. The idea of EDGE is similar to GPRS but EDGE uses a more efficient modulation 8PSK (8 Phase Shift Keying) instead of GMSK (Gaussian Minimum-Shift Keying).

WLAN

Usage of radiowaves as a physical layer is a basic concept of a wireless local area networks based on the 802.11 standard. WLAN allows workstations to communicate between each other and provides access to wireline networks. The wireless LAN can be:

- a standalone computer network, or
- an extension to the existing wired LANs, i.e. twisted pair Ethernet.

According to the physical layer of the WLAN network, the coverage area strongly depends on a radio signal strength and propagation environment. The simplest topology of WLAN network is an ad-hoc workgroup configuration (called cell) created by a few devices equipped with the WLAN's interfaces. In general, the cell shape can be described as a circular area. The traffic management function coordinates the communication between devices. Cell is managed by a one specific station,

TABLE 2
Video stream transmission test results

Video stream	Total downloading time [s]	Number of packets	Average packet size [bytes]	Frame per second	Original video file size [MB]
40kbit/s	11.1	1448	1508	5.9	0.901
100kbit/s	27.1	3960	1508	9.92	5.690
1Mbit/s	46561.9	46949	1508	24.82	65.775

which plays a role of a network Access Point. The Access Point manages the traffic within the cell, and is a gateway to another Access Point (another cell, as well) or wired Ethernet network. WLAN networks allows remote user to move from one cell to another with the handover procedure, which is not noticeable to the user. Nowadays the WLAN equipment operate in the 2,4GHz frequency range and offers the transmission speed ratios up to 11Mbit/s in area radius up to 200m. The WLANs mobile character and relatively high transmission speed ratios imply the usage in the telemedical area of applications, such as medical video sequences browsing.

Radio Access Tests

There are two possibilities to access resources of the Digital Video Library through a GSM or WLAN links:

- *offline* - download a file and watch it remotely, and
- *online* - open a file from server and watch it during download.

The second solution saves the connection time but requires a video stream not greater than the available throughput. We examined some typical examples, and the video stream not greater than 40kbit/s (for GPRS and HSCSD) was not sufficient for consultations (Fig. 2).

We propose to deploy the offline solution. The video client software intended to operate in wireless environment should be equipped with some additional mechanisms to overcome data throughput limitations. Basically a video quality management system is necessary. There are two concepts of quality management mechanism proposed in this paper. Both of them are based on highlighting of the most important parts (from the user's point of view) of the video stream combined with decrease a frame throughput. Usage of the additional mediation layer that is intended to fit the video stream to the character of the transmission medium is the common feature of both approaches. This layer is divided in two parts located on the server and client's side. The mediation layer covers tasks connected with indexing, transmission and caching of the video stream.

The first approach an offline solution, which uses indexing of the video stream of decreased quality and framing throughput, enables user to select the parts of the stream to be viewed with a normal quality. Due to the simplicity of the method presented above its implementation seems to be feasible without interference in the structure of the video stream produced by the video server. However repeated transmission of the same video sequences with different quality cannot be avoided which is the main disadvantage of this method.

The second approach is based on indexing the original image combined with decreasing the frame throughput. The user is enabled to increase the indexing frequency thus increasing the frame throughput. The video stream is assembled and cached by the client side of the mediation layer. This approach requires processing the video stream resulting in increase of a complexity of the mediation layer that has to compress and decompress video streams.

Testing procedure was performed within the WLAN (11Mbit/s) network using the packet analyzer software. Three different video streams were taken under consideration: 40kbit/s, 100kbit/s, 1Mbit/s. Video streams were produced in the QuickTime video format and were viewed using the QuickTime plug-in in the MS IE on PIII 800MHz computer. The radio signal level was -73dBm. The obtained results are shown in Table 2.

Conclusions

Digital Video Libraries are a heart of any digital video distribution system. A lot of design problems deserve attention of engineers and researchers in order to provide an effective and flexible platform for video storing and accessing.

The most important are video content indexing that allows for a fast access to a requested content and video abstracting enabling accelerated content browsing.

In view of different available transmission technologies it is important to inspect as well which of them are suited for a digital video distribution from an integrated techno-economic viewpoint. A special attention has to be paid to mobile and wireless services.

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