HD VIDEO IN TELEMEDICINE
A Study of Local and Remote Video Distribution based on ITU-T H.264 Video Coding

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Abstract: Modern operating room devices produce several video streams at resolutions up to Full HD. Managing the high quantity of information produced during operating room activities requires a careful analysis and dimensioning of the video storage and streaming systems. A service for telemedicine and e-learning is proposed. The system is based on the ITU-T H.264 video coded for both storing and streaming medical video data. Different scenarios are compared in order to evaluate which solutions can better fit the video services deployment from operating rooms.

1 INTRODUCTION

Technological innovations in surgical operation and, in particular, in endoscopy is enabling minimally invasive procedures. Surgical operation augment their efficacy together with the patent's safety. Surgeon's risk is reduced by the use of most advanced technologies.

Integrated operating rooms can lead to a substantial improvement of surgical activities since last generation operating rooms will allow a simplified and secure management of innovative technologies and leave, at the same time, possibilities for future integration with communications and learning systems (Nocco,2008).

Current available systems are mainly closed. On the contrary, the introduction of open systems, and in particular based on standards, can reduce the dependence from proprietary solution augmenting the possibilities of development of the operating rooms with new and advanced technological products. This imply that with open systems it is possible to chose the technological solution that better matches the single needs (departments or operating room).

There is a rapid growth of mini-invasive surgery, new surgical methodologies as combined-surgery, natural orifice transumbilical endoscopic surgery and intra-operatory diagnosis. The effect is that new management needs are arising inside the operating rooms.

In particular there is a need for an harmonization of all the chain of surgical process in order to have an operating room as flexible as possible with respect to the different necessities that arise and change continuously (aa.vv. 2008).

Moreover, it is necessary to integrate the different IT systems that are available in the hospital, as for example:

- HIS, hospital information system: management of the information system: patient acceptance/discharge, case history, warehouse, statistics;
- RIS, Radiology Information System: gathering, distribution, radiology reports;
- DICOM**,** Digital Info and Communication Tecnology: possibility of sending, receiving, displaying, storing high resolution images and videos**;**
- PACS**,** Picture Archiving and Communication System: system of distribution, storing and

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displaying of images and video integrated with the other subsystems in the hospital network.

This paper focuses the attention to the transmission of high definition video originated by endoscopy instruments for supporting the surgical activity, and to the storing and distribution for additional services as, for example, teleconsulting or e-learning.

In particular, this paper presents the study of a system for storing and distributing high definition medical video of mini-invasive endoscopic surgery.

The paper is organized as follows. Section 2 presents the reference architecture. Section 3 presents the experimental tests performed on the reference application for exploring storing and streaming functionalities. Section 4 draws the conclusions.

2 REFERENCE SCENARIO

The reference scenario takes into consideration an operating room with video data produced by a single endoscopic column and a single scialitic lamp for endoscopic and laparoscopic surgery.

The endoscopic probe contains not only the surgical instruments but also a camera that can acquire high definition color images. In particular, the camera used for the experimental tests has a 3CCD wide megapixel providing a true acquisition in 16:9, with a frame aspect similar to the one perceived by the human eyes.

Such sensor is compose by three different CCDs providing, each one, a resolution of 1.12Mpixels (1.07 effective) devoted to the acquisition of the three different chromatic channels (Red, Green, and Blue). The advantage is a chromatic quality highly superior to the one achievable with a single CCD. The camera is enable to acquire video images in HD 1080i. The frame format is called 1080i60 meaning that a video frame has a resolution of 1920x1080 in interlaced mode and a video frequency of 30 fps.

On the scialitic lamp is installed a second camera that records the video of the operating room. In this case, the camera is SDTV and the videos can be used for teaching activities, legal medicine, for transparency and protection towards the patient. The video from the scialitic lamp is a 3CCD, 1/3", 800000 pixel, SDTV 576i50, with a frame resolution of 720x576 pixel, in interlaced mode and a video frequency of 25 fps.

Table 1 synthesizes the reference parameters used for setting up the experimental environment.

The reference scenario if composed by four operating rooms equipped for endoscopy.

The average duration of operation is established in 45 minutes.

A video stream HDTV, coming from the endoscopic probe, and a video stream SDTV, coming from the scialitic lamp are assumed to be continuously produced during the operation time.

Moreover, it is assumed that each room can operate at maximum five times per day for a total of 3 hour and 45 minutes of video stream data. Table 1 synthesizes the reference parameters for the analyzed scenario.

Figure 1 show the reference architecture for video storage and streaming.

Table 1: Video data reference parameters.

Operating rooms	4
Full HD Video (1080p)	1
Standard Video (PAL)	1
Video activity per day	225min

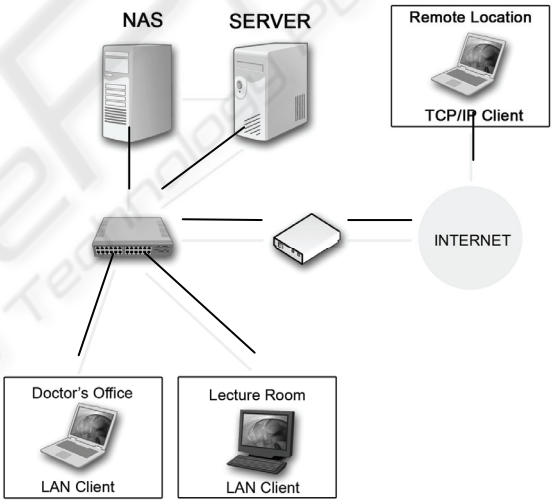

Figure 1: Reference architecture for video storage and streaming

The video coding architecture makes use of the ITU-T H.264 standard (Sullivan, 2004), (Wiegand, 2003).

H.264 is a state-of-the art video coding system capable of providing very good video quality at lower bit rates than previous standards (namely MPEG-2, H.263, MPEG-4 Part 2) without increasing the complexity of the design.

The Server receive through the LAN the video streams originated by the endoscopic camera and by the scialitic lamp. The video streams are encoded and stored into the NAS (Chen, 1994).

Referring to Table 1, the quantity of data produced for each surgical operation is equal to

7.5Gbytes. Table 2 reports the quantity of data produce considering full activity all day in each operating room, which is the worst case and the maximum amount of video information produced in a day.

Table 2: Video data produced each day in each operating room considering full activity (worst case).

Format	Bitrate (Mbps)	GB/gg/Room
HDTV	20	31.4
SDTV PAL	4	6.2

3 EXPERIMENTAL TESTS

Experimental tests have been conducted on a machine with the following characteristics: Processor, 2X Intel Xeon Dual Core X5460@3.16 GHz; Front Side Bus (FSB): Intel 500X, 1066MHz e 1333MHz; RAM: 4 GB DIMM DDR2 dual-Rank; SAS/SATA RAID 5, PERC5i controller for 1÷4 HDD; 3 HDD SATAμ, 3.5", 7.2K rpm, 1 TB; Network card: BroadCom BCM 5708 NET Extreme II GIGE. VideoLAN's VLC media player where used both as video streaming server and video client.

Several tests have been performed coding HDTV and SDTV videos at different bitrates and different coding modes in order to evaluate the coding speed and the average quality.

The objective video quality measure is the PSNR (peak-signal-to-noise-ratio) measured in dB.

Tables 3-5 report the result for the HDTV tests. Tests were performed encoding the HD video at three different bitrates (20Mbps, 10Mbps, 5Mbps) and at three different encoding modes (Max speed, Intermediate, Good quality).

Tables 3-5 show that the experimental set-up is able to encode in real time only if the Max Speed mode is chosen. Nevertheless, the quality improvements when using advanced modes as Intermediate of Good quality are not so purposeful.

Encoded video streams are stored in the Network Attached Storage and are available for further processing and applications. In particular the proposed system provides video transcoding and video streaming services. This allows a real time access at high/medium quality from the LAN clients and at medium/low quality from remote location outside the LAN. The main applications are teleconsulting and e-learning.

The transcoding experimental set-up considers two different scenarios.

The first one is based on the downsampling of the video resolution from HD (1920x1080) to PAL (720x576). PAL resolution allows streaming of video data at high/medium quality depending on the available bandwidth for a given service. Table 6 shows an example of the experimental tests. Four different bitrates were chosen: 2Mbps, 1Mbps, 700Kbps, 500kbps.

Table 3: HDTV Max speed mode.

Bitrate (Mbps)	Coding speed (fps)	PSNR (dB)
20	32.8	43.3
5	32.7	39.0
2.5	33.2	36.9

Table 4: HDTV Intermediate mode.

Bitrate (Mbps)	Coding speed (fps)	PSNR (dB)
20	17.5	43.6
10	21.2	41.0
5	24.6	39.8

Table 5: HDTV Good quality mode.

Bitrate (Mbps)	Coding speed (fps)	PSNR (dB)
20	11.8	44.2
10	14.0	41.8
5	17.9	40.0

Table 6: Downsampling HD video to PAL, example of video streaming quality at destination at different bitrates.

Bitrate (kbps)	PSNR(dB)
2000	41,6
1000	39,2
700	37,8
500	36,6

Table 7: Downsampling HD video to CIF, example of video streaming quality at destination at different bitrates.

Bitrate (Kbps)	PSNR (dB)
500	41,5
250	38,5
150	36,4
125	35,7

For bitrates lower than 1Mbps the quality at destination is poor and a real time video streaming becomes not reliable over network without guaranteed bandwidth as the Internet.

On the contrary, since modern LAN are able to accommodate gigabits of data, all the bitrates in Tables 6 will allow high/medium quality LAN video streaming.

The second scenario is based on the downsampling of video resolution from HD to CIF (352x288) format. CIF resolution allows streaming of video data at medium/low quality depending on the available bandwidth. Table 7 shows an example of the experimental tests. Four different bitrates were chosen: 500Kbps, 250Kbps, 150Kbps, 125Kbps. For bitrates lower than 150 Kbps the quality at destination is very poor. At these rates real time video streaming becomes feasible through the Internet even if, of course, the quality of service cannot be guaranteed. The application for this resolution/rates is mainly distance learning.

4 CONCLUSIONS

After the definition of a reference scenario it has been analyzed the activity of the video data flow production in order to set-up a multimedia storage and streaming system. A general architecture for storing and streaming the video data has been designed. The system is bases on the ITU-T H.264 video coding standard. The proposed system has been tested for different available network capacity in order to evaluate the loss of quality when streaming the content for tele-consultancy of e-learning.

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