An Integrated Communications Platform for Advanced End-to-End Distant Medical Education Services

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***Abstract* - In this article, we propose the implementation of an integrated platform for the provision of advanced tele-medicine services over satellite, specifically tailored to the continuing medical education and training of health professionals on new surgical techniques. The system will enable the transmission of live - high quality - surgical video from operating rooms, including both panoramic and endoscopic view, in order to facilitate a) training of surgeons and/or students on advanced surgical techniques through the observation of live procedures using the daVinci system and b) mentoring/proctoring of novice surgeons during their initial laparoscopic procedures. The system also provides interaction between trainees and local surgical tutors via videoconference. It is aimed at implementing an end-to-end solution, which will offer horizontal integration of the proposed tele-medicine service, with the offer of equipment and broadband satcom/telecom services, in a scalable and adaptable manner that can be easily replicated on a wider scale.**

Keywords: Robotic assisted Surgery, Tele-mentoring, Tele-training, Satellite link, HDTV, DVB-RCS standard.

I. INTRODUCTION

Laparoscopic surgery, also called minimally invasive surgery (MIS) (or keyhole surgery) is a modern surgical technique in which operations in the abdomen are performed through small incisions (usually 0.5-1.5 cm) as compared to larger incisions needed in traditional surgical procedures.

Laparoscopic surgery includes operations within the abdominal or pelvic cavities, whereas keyhole surgery performed on the thoracic or chest cavity is called thoracoscopic surgery. Laparoscopic and thoracoscopic surgery belong to the wider field of endoscopy. The key element in laparoscopic surgery is the use of a laparoscope. There are two types:

- a telescopic rod lens system that is usually connected to a video camera
- a digital laparoscope where the charge-coupled device is placed at the end of the laparoscope, eliminating the rod-lens system.

Conceptually, this approach is intended to minimize post-operative pain and speed up recovery times, while maintaining an enhanced visual field for surgeons. Due to improved patient outcomes, in the last two decades, laparoscopic has been adopted by various surgical sub-specialties including gastrointestinal surgery, gynecologic surgery and urology. Based on numerous prospective randomized controlled trials, the approach has proven to be beneficial in reducing post-operative morbidities such as wound infections and incisional hernias (especially in morbidly obese patients), and is now deemed safe when applied to surgery for cancers such as cancer of colon.

The restricted vision, the difficulty in handling of the instruments (new hand-eye coordination skills are needed), the lack of tactile perception and the limited working area are factors which add to the technical complexity of this surgical approach. For these reasons, minimally invasive surgery has emerged as a highly competitive new subspecialty within various fields of surgery. Surgical residents who wish to focus on this area of surgery gain additional training during one or two years of fellowship after completing their basic surgical residency.

At this point we would like to mention a few facts related to the daVinci robotic surgical system. It is designed to enable complex surgical procedures using a minimally invasive approach. Moreover it is the only operational robotic system for clinical applications. The robot is of a master-slave type architecture which operationally means that the surgeon controls the robot from a consol using “joy-sticks” and “foot-pedals”. It is capable of providing 3-D vision with an amplification of 10 times with a steady picture and high tremor reduction. Additionally the daVinci instruments offer six degrees of freedom at the robotic tip and an additional seventh degree is supplied by the action of the instrument itself. In overall the system provides remarkable possibilities for high precision surgical tasks within the field of robotic – assisted surgery.

II. THE NEW EDUCATIONAL OPPORTUNITIES - EXISTING LIMITATIONS

While there is a strong believe in the prominent role of laparoscopy and robotic-assisted surgery in the mid-long future, surgeons' training is still a major challenge, with access to training facilities being insufficient in most of the cases. The development and evolution of the proposed platform coincides with the success of laparoscopic and robotic-assisted surgical procedures. Since approximately 1992, in varying levels and degrees, the surgical specialties of orthopedics, general surgery, neurosurgery, urology, pediatrics and plastic surgery have used and exploited the capabilities of advanced telemedicine in various surgical procedures. Numerous studies see for instance [4], [8] have investigated the feasibility of surgical tele-consultation, tele-mentoring (surgical instruction), tele-proctoring (overseeing surgical procedures) and remote or virtual presence surgery (active control of remote surgical instrumentation). These studies have demonstrated the vigorous interest in applying novel communication systems in the surgical community, proving amongst others the effectiveness and acceptable levels of safety of the approach and associated technologies. Trials have shown that tele-mentoring and tele-proctoring are feasible techniques that can actually enrich and enhance surgeon's education and at the same time decrease the likelihood of complications which could be attributed to inexperience with new operative techniques.

A. Surgeons' Training

While MIS techniques have been shown to provide tremendous advantages for patients, novice laparoscopic surgeons developing their skills face challenging learning curves. Unfortunately only a few laparoscopic surgical experts (expert mentors) exist relative to the number of surgeons needing training in laparoscopic surgical techniques (e.g. cholecystectomy) since most of them are concentrated in relatively few centers and are not readily available at remote locations, see [1], [3-4] etc. Furthermore, because operating the *daVinci* robot requires unique surgical skills, surgeons are required to participate in a special training program with proctorship before they can start utilizing the system during surgery. Also Robotic surgical assistants, such as a surgeon or physician's assistant, also require special training; see [6-8]. The surgical assistants and operating room nurses must also be trained on utilizing the robot at the patient's bedside in the operating room, see [5].

B. daVinci Robotic Training

The *da Vinci* System basic training is comprised of two parts:
(i) On-Site Training (Surgeons and Support staff attend a half-day training session at the hospital) and
(ii) Off-Site Surgical Skills Training (One surgeon and his/her surgical assistant learn and practice procedural surgical skills using the robotic system at a regional or remote training center)
The next step is Proc Training, including Live Procedure Observation. Live surgery provides the opportunity for novice *daVinci* professionals to observe experienced, independent *daVinci* surgeons. The end result is a better understanding of robotic assisted surgical applications and techniques, including patient indications and selection, robotic-assisted surgical techniques, anatomical reference, patient preparation, surgical positioning, port placement and instrumentation applications. Notice that with conventional laparoscopy, the surgeon must look up and away from the instruments, to a nearby 2D video monitor to see an image of the target anatomy. Furthermore the surgeon must also rely on his/her patient-side assistant to position the camera correctly. In contrast, the *da Vinci* System's ergonomic design allows the surgeon to operate from a seated position at the console, with eyes and hands positioned in line with the instruments.

C. Surgeon Proctoring

Traditional surgeon education begins in clinical residency programs, which rely heavily on peer-to-peer education. Independent *daVinci* surgeon proctoring facilitates the development of robotic surgical skills by providing opportunities for novice *daVinci* surgeons to work under the supervision of experienced professionals during their initial procedures. Currently, medical doctors are required to fulfil most of their educational needs by attending events such as seminars, workshops and congresses at both national and international levels. Technological advances in communications are enabling surgeons to procure expertise quickly and efficiently, see [2], [9-10] etc.

In this respect the proposed communications platform could be an invaluable tool in providing instantly available expertise to novice surgeons during laparoscopic procedures, in a cost and time effective manner.

III. METHOD - DESCRIPTION OF THE PROPOSED INTEGRATED PLATFORM

An innovative low cost platform is proposed for educational purposes. It is based on the integration of existing and mature Information and Communication technologies, products and tools, which have been successfully utilized in various application fields for the provision of innovative broadcast services. Regarding the communications part the existing satellite infrastructure at a national level provided by HellasSat operator will be used. HellasSat owns and operates the HelasSat-2 geostationary satellite which provides IP and Video broadcast services through its operational DVB-RCS system. Within our proposed solution Hellas Sat will be the operator who can establish the backbone satellite communication link and also provide the required channel capacity as well as its DVB-RCS Hub infrastructure and satellite terminals (SIT's). Thus it will enable the restoration and installation of wide area telecommunications for the provision of advanced telemedicine services and especially those related to robotic assisted surgery.

System Architecture:

The system comprises of two basic components:

- The Base Station which is installed to the Medical Service Provider (see *figure 1*), and
- The Remote Client which is installed to one or more of the remote sites (clinics, hospitals, medical schools, etc) (see *figure 2*).

The whole system will be implemented using "off-the-shelf" hardware and tools. For the implementation of the proposed services, the following equipment can be used:

***A.** At the Medical Service Provider (Base station):*

- HD Videoconferencing Unit (VCU).
- Videoconference equipment (PTZ cameras, microphones, monitors) at the mentor's office.
- Videoconference equipment at the *daVinci* Operation Room.
- 3D Encoding and Streaming Server.
- HD 3D video-over-IP broadcast server.
- Leased telecommunication line to Hellas SAT broadcast center (DVB-RCS Hub).

***B.** At the Remote Clients (clinic, hospital, medical school etc):*

- HD Videoconferencing Unit (VCU).
- Videoconference equipment (HD PTZ cameras, microphones, HD monitors and/or projectors) at the training room and laparoscopic operation room.
- Module for receiving input from the endoscopic camera (laparoscopic procedures).
- Telecom equipment (DVB-RCS terminals).

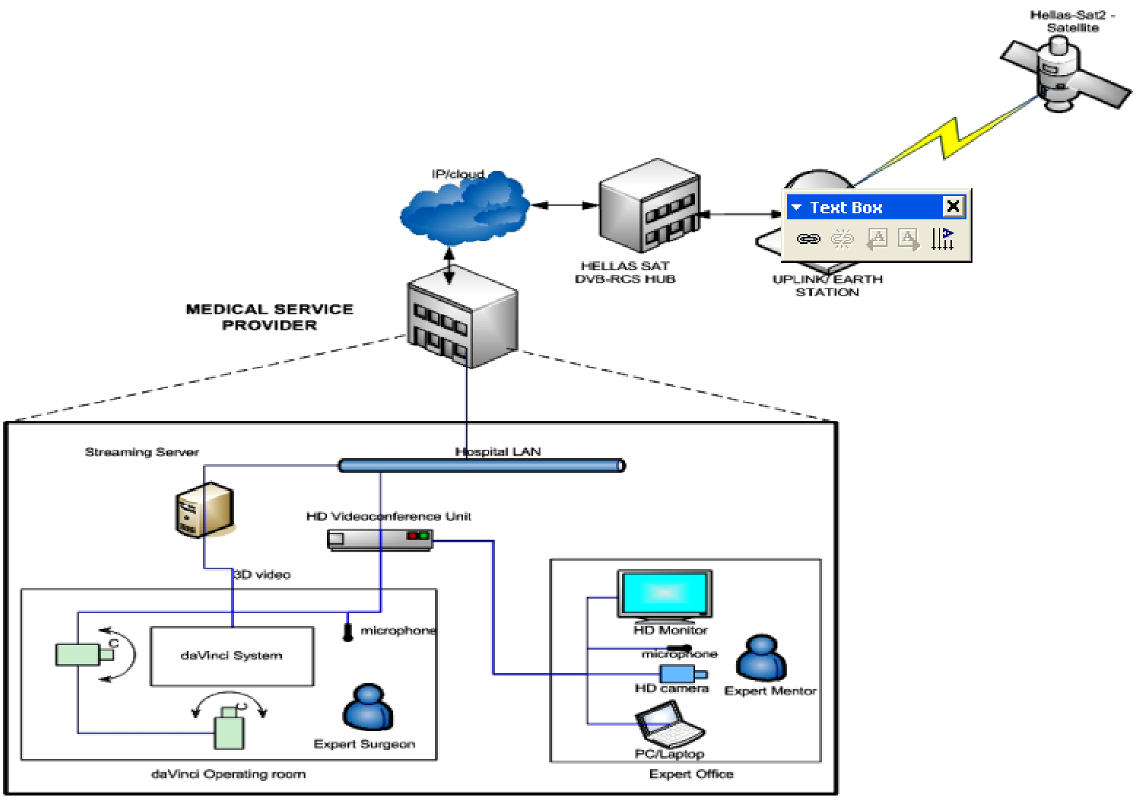

Figure 1: Central Part of the network

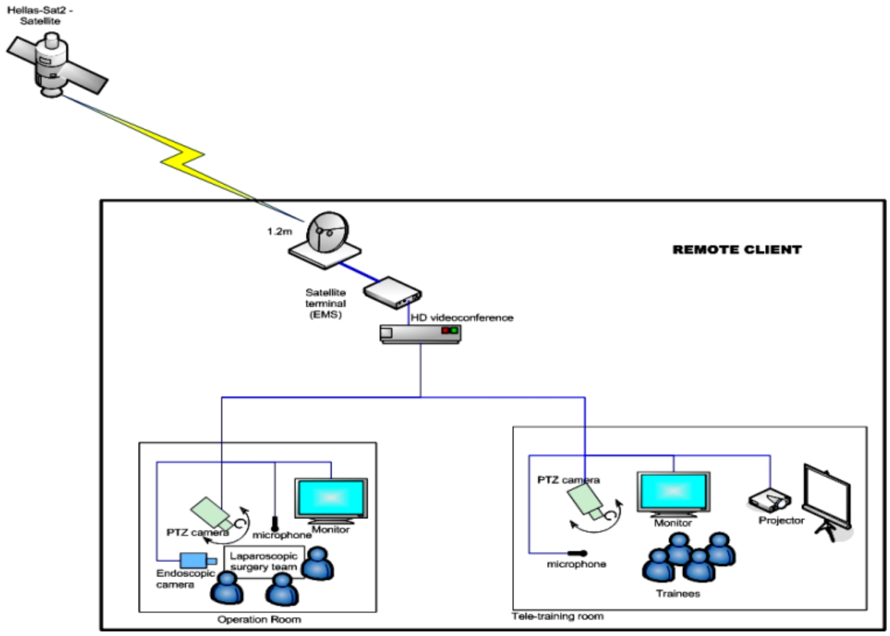

Figure 2: Remote part of the network

As it is readily seen the architecture of the proposed system comprises of at least two pilot sites (central and remote). The central site transmits High Definition (HD) image and sound from the Operation room as well as additional content pertinent to the education of the students. The latter will be transmitted using DVB-RCS Technology. Hellas Sat 2 carries the HD signal to the remote sites for reception as well as the data part of the system.

The application management server at Hellas Sat headquarters is an optional capability inserting extra content to the carrier if applicable. The pilot sites are capable of receiving the transmitted HD videos from the other side as well as data and therefore a closed-loop high quality teleconference can be established.

The central site can either transmit directly to the satellite using a local infrastructure (expensive) or send the signal through internet VPN to the Hellas Sat ground station for uplink.

The architecture is in effect combining a HD audio/video link as well as a DVB-RCS data link (see *figure 3*). The table below summarizes the traffic rates of the Satellite Interactive Terminals (SITs) used for the data link (educational content). The HD channel uses a different link through the same satellite. The latter will carry high definition image and sound directly from the operation room. The two columns on the right side of the table illustrate the equipment used for the satellite link on the sites. The power of the Block Up-converter and the dish diameter ensure a stable link in all weather conditions.

Site	**Location**	**Outbound Data Rates (Kbps)**	**Inbound Data Rates (Kbps)**	**BUC (W)**	**Dish Diameter (m)**
Sit 1	Athens	512 (on site)*	2048	2	0,96
Sit 2	Thessaloniki	512	2048	2	0,96
Sit 3	Patra	512	2048	2	0,96
Forward	Athens	1024 (H.S.)*	2048	750	4,8

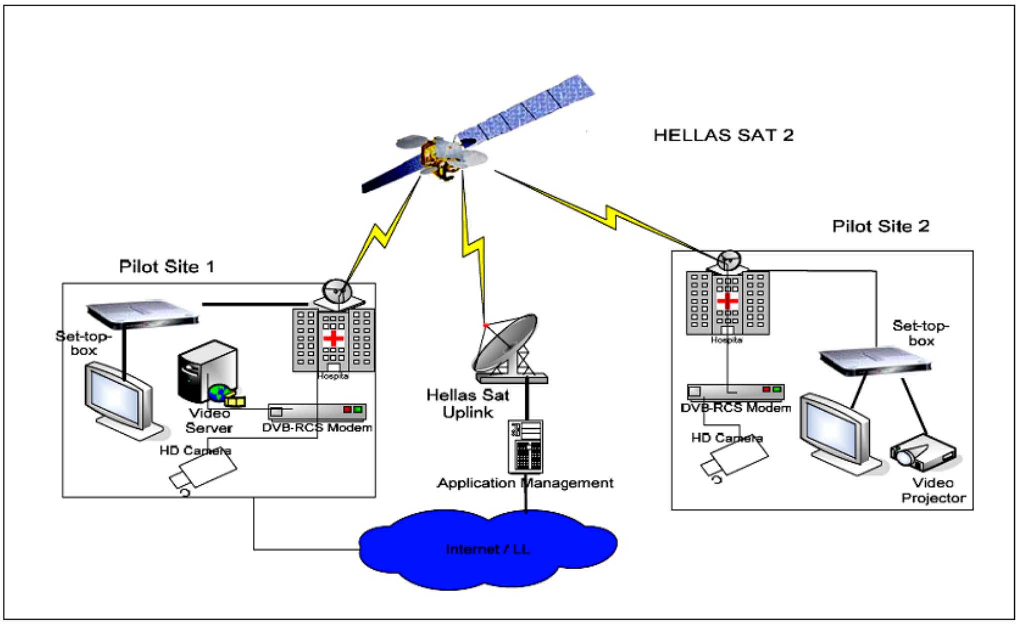

Figure 3: Platform architecture with Satellite Component

The HD content will be carried using mpeg4 image encoding and DVB-S2 encapsulation. The modulation can be either QPSK or QAM. It is estimated that the transmission of a single channel of high quality video needs approximately 10 MHz of analogue bandwidth on the satellite e.g. 5 times more that on a conventional 2Mbps SD (Standard definition) transmission. For bandwidth-saving purposes, no image will be transmitted from the remote to the central sites. Any sound and data needed on that direction will be carried through the DVB-RCS data link.

The role of the satellite component is a crucial one. Despite the wide popularity and applicability of wired or wireless terrestrial networks and services in the developed and less developed countries, vast geographical regions remain uncovered by any broadband communications services. In many situations where distant locations are in regions where there is no adequate terrestrial infrastructures, satellite communications appear to be the best and most efficient technical solution. In that respect the following key technical advantages are offered:

- Accessibility.
- Security.
- Broadband communications capability.
- Broadcast/multicast capability.
- Quality of Servivce (QoS): Satcom offers a quality of service comparable and in some cases superior to terrestrial broadband technologies.
- Flexibility.

IV. APPLICATION AREAS AND SERVICES

In this subsection the provided services of Continuing Education of Health professionals are analyzed. Indeed the implementation of the proposed platform will enable the provision of services in the following application areas:

1. Tele-mentoring of novice laparoscopic surgeons.
2. Tele-training of surgeons on advanced surgical techniques (daVinci System).
3. Tele-presence and tele-proctoring of novice surgeons using the daVinci System.

1. Tele-mentoring service will allow novice surgeons, with no formal advanced laparoscopic training, to be remote mentored and assisted by an expert that can be located at a distant site during the initial phase of laparoscopic procedures or for realizing new techniques. For example an expert surgeon located at his office such as the Athens Medical Center will be able to watch novice surgeons performing laparoscopic procedures at the branches of Thessaloniki or Romania. The expert mentor will be able to watch High Definition (HD) video from the remotely cameras at the operation theater (panoramic view), along with video from the endoscopic camera, thus having a clear view of the procedure. He will also be able to interactively communicate with the novice surgeon in order to provide consultation and mentoring services (see *figure 4*).

2. Tele-training of surgeons on the daVinci Robotic Surgical System: An expert surgeon will perform robotic-assisted procedure using the daVinci system at the Athens Medical Center. The trainees surgeons located at the branches of Thessaloniki and Romania will be able to receive live high definition (HD) video from cameras at the operation room (panoramic view), along with 3D stereoscopic video from the system camera, thus having a clear view of the procedure. They will also be able to interactively communicate with the expert surgeon in order to ask questions etc (see *figure 5*).

3. The Tele-Proctoring application will enable novice surgeons during their initial procedures of the daVinci system the tele-presence of an expert proctor. An independent daVinci proctor located at his remote office will be able to watch High Definition

(HD) video from the operation room located at the Medical Service Provider's premises including both panoramic views as well as 3-D stereoscopic video from the endoscopic camera. As with previous applications interaction is accomplished and facilitated via videoconference sessions between the daVinci Operating Room and the Proctor's Office at the remote Hospital or clinic.

V. CONCLUSIONS - FURTHER RESEARCH

The daVinci robotic system located at a local private entity such as the Athens Medical Center, Athens, Greece, is used as the basic key element. Moreover surgeon proctoring within the same framework is presented. Hellas Sat is the operator providing the communications infrastructure while specific services are proposed to be implemented such as Tele-mentoring and Tele-training of surgeons at remote locations. Furthermore the proposed platform will be open to support the deployment of new tele-medicine applications in the future while it could be further used as a pilot for the performance of remote live operations using da Vinci robotic set-up. This achievement will require the co-operation of doctors and other personnel to overtake any technical obstacles related mainly to the elimination of the "latency" problem over the satellite medium.

Thus, in this paper the overall objective could be further broken down into the following two sub-objectives:

- *To design the platform architecture and implement the necessary components*
- *To deploy the pre-selected applications in a pilot base, evaluate their performance with the involvement of real end-users and fine-tune the platform.*

At this stage further research efforts are required. Furthermore, based on the existing satellite infrastructure, the Medical Service Provider can deploy various types of "traditional" telemedicine services, including Tele-radiology, Tele-monitoring or even eHealth applications.

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