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Advanced Medical Video Services through Context-Aware Medical Networks

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***Abstract*—The aim of this paper is to present a framework for advanced medical video delivery services, through network and patient-state awareness. Under this scope a context-aware medical networking platform is described. The developed platform enables proper medical video data coding and transmission according to both a) network availability and/or quality and b) patient status, optimizing thus network performance and telediagnosis. An evaluation platform has been developed based on scalable H.264 coding of medical videos. Corresponding results of video transmission over a WiMax network have proved the effectiveness and efficiency of the platform providing proper video content delivery.**

I. Introduction

A number of telemedicine applications are based on the transmission of medical video over wired and wireless network infrastructures. Such applications include remote medical action systems (e.g., remote surgery systems), patient remote telemonitoring facilities (e.g. homecare of chronic disease patients) and transmission of medical video for educational purposes. In all cases perceived video image quality is high for the insurance of proper diagnosis and/or assessment. The medical video quality requirements are translated into high bandwidth, low delay and jitter requirements for the underlying networks. However, both wired and wireless network infrastructures cannot often guarantee the efficient delivery of the video content, especially in the case where public wide area networks are involved and 'best effort' resource schemes are applied. In addition, telemedicine systems can often require the constant transmission of medical video even in unnecessary cases (e.g., in case of patient monitoring when patient status does not require medical attention), consuming this way a great amount of resources.

Context-aware medical networks can overcome the aforementioned issues, through performing appropriate content adaptation. This paper presents an improved patient state and network aware telecare and telemonitoring framework. The scope of the framework is to allow medical data transmission only when determined necessary and encode the transmitted data properly according to the network availability and quality, and to the patient status. The framework's architecture is open and does not depend on the monitoring applications used, the underlying networks or any other issues regarding the telemedicine system used. A prototype evaluation platform has been developed in order to validate the efficiency and the performance of the proposed framework. WiMax [9] infrastructure has been selected for the networking of the involved entities. The latter wireless technology provides wide area network connectivity and Quality of Service (QoS) for specified types of applications. It is considered thus suitable for delivering scalable coded medical video services, since the QoS classes can be associated with scalable compression schemes. Through the concomitance of the advanced scalable video coding and the context-awareness framework, medical video delivery can be optimized in terms of better resources utilization and best perceived quality. For example, in the case of patient monitoring, where constant video transmission is required, higher compression schemes in conjunction to lower QoS network classes might be selected for the majority of content transmission, whereas in case of an emergency event, lower compression and high QoS classes provide better content delivery for proper assessment.

The rest of the paper is organized as follows; Section 2 provides background information on telemedicine and telecare systems adopting the context aware and personalization concept, among with a brief literature overview of proposed schemes and implementations. Section 3 describes the architecture of the proposed framework, provides implementation details and presents its main functionality. Performance aspects in the context of data coding using scalable H.264 and transmission are presented in Section 4. Finally, Section 5 concludes the article and discusses future work.

II. Related Work And Background Information

Despite the numerous implementations and proposals of telemedicine and e-health platforms found in the literature (an indicative reference collection can be found in [1]-[8]), only a few works include context awareness. The main goal of context aware computing is to acquire and utilize information about the context of a device to provide services that are appropriate to particular people, place, time, events,

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etc. ([12]). The work presented in [13] describes a context-aware mobile system for inter-hospital communication taking into account patient's and physician's physical location for instant and efficient messaging regarding medical events. J. Bardram presents in [14] additional use cases of context-awareness within treatment centers and provides design principles of such systems. The project 'AWARENESS' (presented in [15]) provides a more general framework for enhanced telemedicine and telediagnosis services depending on the patient status and location.

To our best of knowledge, there is no other work exploiting context awareness for optimizing network utilization and efficiency, within the context of medical video delivery services. The presented medical video services context aware framework is based on the active services concept presented in [10] and the context-aware telemedicine framework in [11]. Active services can dynamically adapt themselves to various underlying networking environment conditions, according to the instruction of appropriate networking entities and the requirements posed by the end user. Context awareness can provide information regarding the type of service required, the data coding and the time frame.

In our case, the active services consist of the patient monitoring tools that can dynamically adapt the coding of medical video (in terms of rate, compression and/or encryption used) to both underlying network conditions and the patient status itself. A more detailed description of the discussed context-aware medical framework is provided in the following section.

III. The Context-Aware Medical Video Delivery Platform

The architecture of the proposed context-aware medical video services framework is illustrated in Figure 1. The major modules consisting the proposed framework are; a) the Network Status Monitoring module that determines the current network interface used and the corresponding status, b) the Patient Status Monitoring module that collects patient data and determines the patient status, c) the Video Coding module which is responsible for properly coding (i.e. compressing) the transmitted medical video, according to instructions given by d) the Medical Broker (i.e. usually a repository containing predefined or dynamically defined threshold values for determining patient and network status).

The patient state can be determined through a number of biosensors (i.e. heart rate and body temperature sensors) and corresponding vital signals. Defined threshold values in the latter signals determine the case of an immediate video data transmission with better quality (alarm event) to the monitoring unit. In case of normal patient status, periodical video transmission might occur at lower video quality. Video coding and transmission can also vary according to network availability and quality: The framework can be also used in cases of remote assessment or telesurgery; according to the network interface used, appropriate video coding is applied on the transmitted medical data, avoiding thus possible transmission delays and optimizing the whole telemedicine procedure.

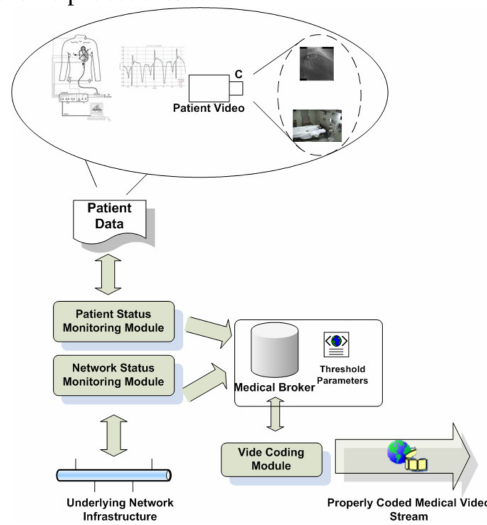

Figure 1. Architecture of the proposed context-aware medical video services framework

The framework's architecture is open and does not depend on the monitoring applications used, the underlying networks or any other issues regarding the telemedicine system used. For this purpose, Web Services ([16], [17]) have been used as a communication mechanism between the major framework components and the external patient monitoring applications used. The message exchange has been implemented through SOAP [18], a simple yet very effective and flexible XML-based communication mechanism. The latter involves the session initialization (which more precisely includes user authentication and service discovery) and the exchange of status and control messages. The status messages include information regarding the patient data as generated from the monitoring sensors and the underlying network status and quality, whereas the control messages contain instructions regarding the proper coding of the transmitted data. It should be noted that the involved modules for the aforementioned communication (see Figure 2) can all reside at the patient's site, or alternatively the Medical Broker can reside at the remote treatment site for the direct collection of medical data and the reactive instruction's provision.

IV. Framework Evaluation Using Scalable H.264 Video Coding

In order to validate the developed medical video services platform, an evaluation platform has been implemented based on H.264 ([19], [20]) video coding. The main components that the platform consists of are: the attached biosensors on the patient, the software modules responsible for collecting the corresponding signals and determining the appropriate video coding depending on the patient and network status, and the simulated WiMax network infrastructure for data transmission to the monitoring units (e.g., a treatment center, an ambulance or a physician at a remote site). An illustration of the platform and the main components is presented in Figure 2.

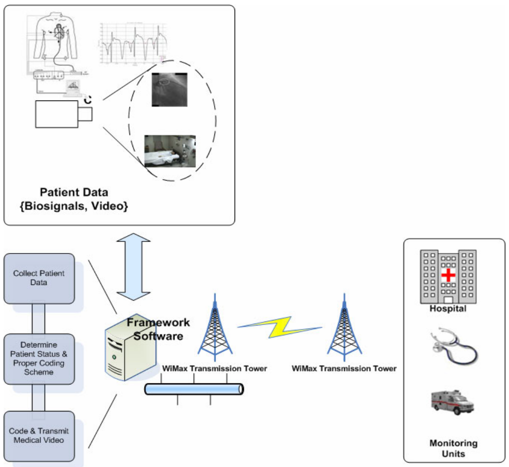

Figure 2. The presented Framework Evaluation Platform

Two patient states have been defined; normal and urgent. The patient data that are monitored through corresponding sensors are: ECG, BP (Non invasive Blood Pressure), PR (Pulse Rate), HR (Heart Rate) and SpO2 (Hemoglobin oxygen saturation). Table I presents the data levels-thresholds that indicate the patient status.

TABLE I
PATIENT DATA AND DATA LEVELS INDICATING AN URGENT STATUS

ACQUIRED PATIENT DATA	DATA LEVELS INDICATING AN URGENT STATE
ECG (Electrocardiogram, 3 leads)	ST Wave elevation & depression T-wave inversion
BP (Non invasive Blood Pressure)	90 mm Hg > systolic > 170 mm Hg
PR (Pulse Rate)	50/min > PR > 110/min
HR (Heart Rate)	50/min > HR > 110/min
SpO2 (Hemoglobin oxygen saturation)	< 90 (%)

Two video sequences have been used for transmission corresponding to the two defined patient status. The Media Access Control (MAC) layer of 802.16 enables the differentiation among traffic categories with different multimedia requirements. The standard [22] supports four quality-of-service scheduling types: (1) unsolicited grant service (UGS) for the constant bit rate (CBR) service, (2) real-time polling service (rtPS) for the variable bit rate (VBR) service, (3) non-real-time polling service (nrtPS) for non-real-time VBR, and (4) best effort service (BE) for service with no rate or delay requirements.

The evaluation testbed includes a simulated WiMaX wireless network of 1Mbps with the following rate allocation for the supported traffic classes: 200Kbps for the UGS class, 300Kbps for the rtPS class, 300kbps for the nrtPS class, 200Kbps nrtPS classes, and 200Kbps for the BE class. Each group of pictures (GOP) is consisted of I, P and B frames structured by repeating sequences of the period IBBPBBPBB. The GOP contains 25 frames per second, and the maximum UDP packet size is at 1000 bytes (payload only). A scalable extension of H.264/AVC encoder and decoder was used, provided by [23]. A number of background flows are also transmitted in the simulated network in order to fill in the respective WiMaX class capacity in the link. The background traffic is increased from 210Kbps to 768Kbps leading the system in congestion. For evaluation purposes we adopt a simpler QoS mapping policy, by using direct mapping of packets to WiMaX classes. All packets are formed into three groups, according the type of context that they contain, and each group of packet is mapped to one WiMaX class.

The first simulation scenario refers to the normal patient status. The corresponding video sequence has been used with a single layer H.264 transmission; rtPS for transmitting I frames and nrtPS and BE for transmitting P and B frames are used respectively. The second simulation scenario refers to the urgent patient status and concerns a scalable H.264 stream transmission consisting of two layers; the Base Layer (BL) packets are encoded using the scalable extension H.264/AVC codec at 128kbps and two Enhancement Layers (EL), (i.e. EL1 and EL2), encoded each at 256kbps respectively. The correlation between the video frames, the H.264 layers and the network classes is presented in Table II.

TABLE II
VIDEO FRAME, H.264 LAYER AND WIMAX CLASSES CORRELATION FOR EACH SCENARIO

VIDEO	FRAME TYPES			H.264 LAYERS		
SEQUENCES	I	P	B	BL	EL1	EL2
A	rtPS	BE	BE	128 Kbps	-	-
B	rtPS	nrtPS	BE	128 Kbps	256K bps	256Kbps

The experimental results prove better network resources utilization in case of the normal patient status and acceptable video quality in case of the urgent patient status. PSNR and Structural Similarity Index (SSIM) [21] have been used as quality metrics. In the case of normal patient status (Video sequence A, higher compression and low network quality class used) PSNR and SSIM were calculated at the receiver at 23.456 and 0.762 respectively. In the case of the urgent patient status (Video sequence B, better video coding and higher network quality class used) PSNR and SSIM were calculated at 29.012 and 0.918 respectively.

TABLE III
RECEIVED PACKET AND FRAME STATISTICS FOR THE EVALUATION EXPERIMENTS

Frame Type	***Packet Delay (ms)***	***Frame Delay (ms)***	***Packet Jitter (ms)***	***Frame Jitter (ms)***	***Packet Loss (%)***	***Frame Loss (%)***
			Video Sequence A			
I	302.85	323.45	6.23	7.19	3.2	0.1
P	339.87	322.89	7.14	8.09	12.4	11.1
B	973.86	962.32	9.31	9.43	47.6	47.1
			Video Sequence B			
I	302.85	323.32	6.71	7.27	3.2	0.1
P	340.81	323.59	7.29	8.17	11.9	11.1
B	942.43	969.36	7.62	8.27	43.7	43.3

Table III presents corresponding results regarding the packet and frame statistics at the receiver side for each frame type (i.e. I, P and B). There is a significant decrease of frame delay, loss and jitter for the second video sequence. The latter is translated into the both better network resource utilization and proper video quality when context-awareness indicates the proper video coding and transmission schemes.

V. CONCLUSION

Medical video transmission is a key issue for the successful deployment and usage of telemedicine applications. Video compression schemes have been introduced in order to achieve better content delivery and quality preservation at the same time according to the requirements of the corresponding e-health application. An innovative telecare and telediagnosis platform has been developed, that considers both network and patient status for proper coding of medical video data; unnecessary data transmission is thus avoided, unless an urgent case is detected or it is required by the medical personnel. Scalable data compression is applied optimizing transmission, when network conditions are considered inadequate. Future work includes the establishment of the innovative context-aware telecare and telediagnosis platform into a real patient-care environment, providing helpful information regarding the assessment of the platform in use.

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