Improved Telemedicine System using the H.265 Codec and 4G Networks

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Abstract— **This paper presents the exploratory stages of a project to develop telemedicine services in the Republic of Kazakhstan. The project intends to take advantage recent technological developments. It proposes a new video-encoding scheme as a replacement for other video codecs currently used in telemedicine systems. H.265 is suggested for telemedicine systems because it can support high-quality video streaming for telemedicine systems and at the same time it requires less bandwidth than its predecessor H.264. This perfectly fits within 4G wireless network capabilities such as WiMAX and Long Term Evolution (LTE) networks. The project targets patients whom cannot easily access the hospital to be monitored or be treated by a specialist even though this is needed for patient cases such as rehabilitation, and paraplegics. The proposed system could also be used for cases where patients are in ambulance on route to the hospital, as the system will convey patients' information and status to the hospital ward in order to prepare the necessary medical resources before the arrival of the patient, which increases the 'gold' rescue time. Using LTE and WiMAX to form the telemedicine framework means that the system could be used either from the home to monitor the patient or it could be used from mobile devices such as smart-phones, PDAs, or laptops. Future investigations are proposed for optimal streaming of H.265 over 4G wireless networks. In addition, a user-friendly interface is proposed that is suitable for mobile telemedicine.**

Keywords—H.265 Video Streaming, Long Term Evolution, Telemedicine, WiMAX.

I. INTRODUCTION

This paper reports on exploratory stages of a funded project to develop telemedicine services in the Republic of Kazakhstan (RoK), which is being developed under the leadership of the Nazarbayev University based in Astana. In a country as large as the RoK, there are bound to be rural areas without convenient access to local diagnostic facilities or to experts in a particular medical condition. For the same reason, though there may not be direct access to a wired network infrastructure, coverage by 3G, 3.5G and 4G wireless telecommunications systems is growing or about to be deployed in many rural areas, with satellite an additional possibility.

Telemedicine systems frequently use state-of-the-art technology and reliable communication systems to convey medical signals from the patient's location to a hospital (ward) for the purpose of monitoring the patient or preparing the required resources before the arrival of the patient. This period is called the golden period and is a critical time when saving a patient's life. Telemedicine systems can be implemented via wired or wireless networks. Wireless networks make it possible to deliver patient data and video images at any place and any time. However, wireless systems are not mature, because they are not yet able to convey high-resolution video capable of detailed examination in the hospital.

This paper proposes the use of 4G wireless networks to convey H.265 video for telemedicine purpose. 4G systems [1] such as Long Term Evolution (LTE) builds upon the existing 2G (GSM) 2.5G data extensions (GPRS, EDGE) and 3G data (HSDPA) cellular wireless infrastructure. WiMAX advanced [2], another 4G technology has developed independently of mobile phone networks and itself builds upon mobile WiMAX, which has been standardized by the IEEE as IEEE 802.16e. Therefore, it is more suitable for areas of the world without a pre-existing 2/3G mobile phone infrastructure, as well as those rural areas where 2/3G coverage remains sparse. Both 4G technologies (LTE and WiMAX) offer greater bandwidth for data than 3G data systems. Their wireless technologies have also converged, so that in general terms they are similar. For telemedicine, the principal attraction of 'broadband' access [3] is the enhanced bandwidths, allowing increased video streaming capacities (i.e. more simultaneous streams in the case of telemedicine). However, wireless bandwidth remains limited compared to wired access and the further 40 to 50% bitrate reductions offered by H.265 data compression becomes attractive.

Telemedicine systems are not only about biomedical engineering or medicine as they need the penetration of other disciplines such as computer engineering to create a framework to allow telemedicine systems to be used by a variety of mobile devices such as smart-phones, PDAs, and laptops/notebooks. In addition, there is a need to implement the required protocols for communication from the patient location to the hospital ward.

Data should be conveyed reliably and with high-quality in the case of images so that the ward can analysis the data and possibly use it later for educational purposes. Telemedicine systems were introduced in the late '80s over conventional telephone lines. However, mobile telemedicine systems started very recently [4-6] and were aimed at delivering the same services that are delivered by wired telemedicine systems regardless of the time or the place. An example system is shown in Fig. 1. In the Otello system [7-8] (see Fig. 1), developed in the EU, ultrasound video is collected remotely by a wireless-linked robotic camera that is controlled from a remote hospital. Notice that for a 4G system, the base stations can be connected together by microwave or for remote locations by means of satellite links.

In terms of emergency services, ultrasound images can also be of assistance in diagnosing strokes [9], as possible blood flow blockages can be visualized. Prompt attention to stroke victims can save lives and reduce impairments. More precisely ultrasound may help diagnose possible stenosis of the carotid artery. Having diagnosed a stenosis, the next step is to identify atherosclerotic plaque features (causing the stenosis), which can be tracked over time can aid in the prediction of the severity of. Intima media thickness (IMT) of the near and far artery walls can also help in this task. As Region of Interest (ROI) extraction or enhancement is possible (as other parts of the image are of less interest to a medical expert, how to create ROIs under H.265 (given its differing structure compared to its predecessor codec, H.264 (see Section II) is a research aim.

Mobile telemedicine systems can be utilized for emergency ambulance services, mobile hospitals, rehabilitation and paraplegic monitoring cases. Such systems are most effective when an ambulance is handling a patient on its way to the hospital. Ambulances carry paramedics but they only provide immediate medical care during the journey. Mobile telemedicine systems can send electrocardiograms (ECGs), still images, videos (including the aforementioned ultra-sound imagery), and other biomedical signals of the patient via a 4G network to the enable them to prepare the required medical resources to the hospital ward. The physicians in the ward will consequently obtain sufficient data about the status of the
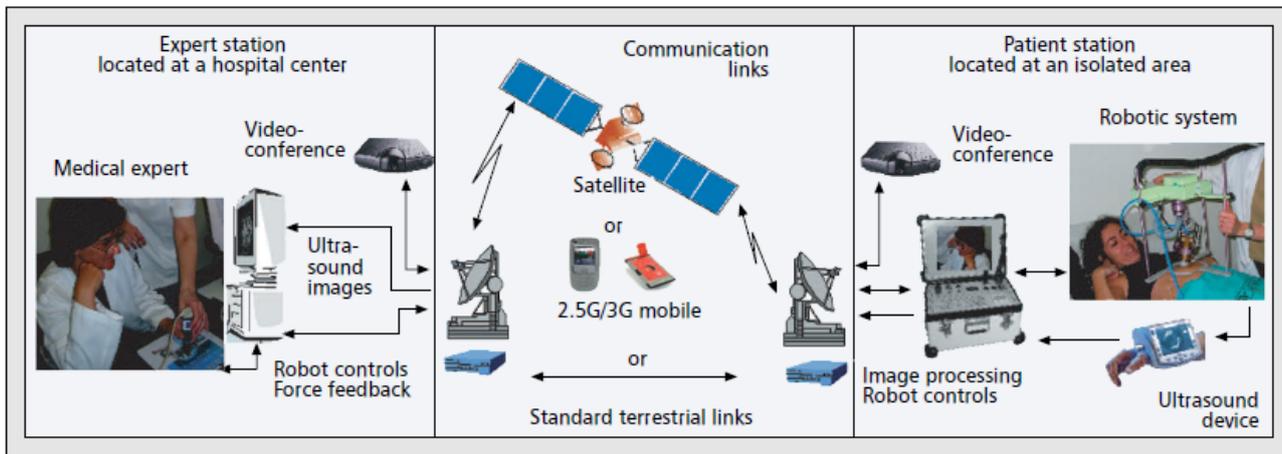

Figure 1: Existing Otello telemedicine system,
after [7-8].

patient, even though the patient remains in the ambulance. This will consequently allow medical resources to be assembled, before the patient's arrival at the hospital, thereby, increasing the gold rescuing time. The remainder of this paper discusses suitable emerging technology for video-enabled telemedicine systems.

II. H.265 FOR TELEMEDICINE SYSTEMS

Telemedicine systems still have limited support for high-resolution video that can satisfy the need for clinical examination. The reason for this is the lack of a video codec that can support both high-quality video streaming together with relatively low bandwidths available for the purpose of streaming it over wireless networks. Telemedicine systems should be able to stream videos similar in terms of their quality [8] to the video that is used in hospital examination screen from the resolutions and frame rates prospective

Therefore, this paper recommends H.265 [10] as a replacement to other video types used in telemedicine systems because of its features and suitability for 4G wireless networks such as WiMAX and LTE networks. WiMAX has significant deployment in areas without a limited existing 3G cellular phone network, such as India, while LTE has been recently rolled out in the U.S.A and parts of western Europe.

H.265 (otherwise known as High Efficiency Video Coding (HEVC)) is a video codec that was ratified in January 2013 by the ITU-T, following on from its predecessor, H.264. It has dramatically improved compression over H.264 [10-13] as it can stream video with approximately 40 to 50% less bandwidth, while maintaining the same or even better video quality as shown in Figure 2.

H.265 uses the concept of a block-based processing structure, similar to other previous encoding schemes after the H.261 codec, in which the pictures are divided into blocks
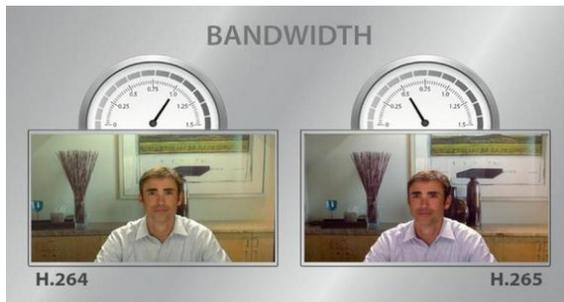
Figure 2: H.265 and H.264 comparison in term of bandwidth and video quality [10].

before the process of intra or inter coding. The new feature of H.265 [11-13] is that the structure of the block itself is different from other codecs. H.265 replaces macroblocks (MBs) with a coding tree unit (CTU). Within a CTU, H.265 has the capability to partition a picture into larger block structures of up to 64×64 pixels in addition to a variable sized partitioning capability for a picture, i.e. 64×64, 32×32, and 16×16, known as Coding Tree Blocks (CTBs). By applying the same coding to larger blocks the coding efficiency is improved at the expense of a less regular structure.

The architectural characteristics of the encoder together with the needs of its application environment will decide on the size of the CTBs. The size of those CTBs will have a consequent effect on the encoder/decoder delay characteristics, as well as memory requirements. A CTB is represented by a rectangular area (i.e. $N \times N$ samples) and the corresponding chroma CTBs cover each $N/2 \times N/2$ samples of each of the two chroma components. N could be 16, 32, or 64 and its size is signaled inside the bitstream. The luma CTB and the chroma CTBs with their associated syntax create a so-called CTU. The CTU is a basic processing unit which corresponds to a MB in previous standards and it is responsible for specifying the decoding process. As a result, blocks can be sub-divided into smaller coding blocks (CBs). A prediction unit (PU) is defined by a coding unit (CU) which originates from one luma CB and two chroma CBs. The PU is used together with a transform unit (TU) for intra and inter prediction (spatial and temporal prediction respectively). The CBs then have the capability [12][13-14] of similar or smaller sized prediction blocks (PBs) in addition to transform blocks (TBs).

The most important H.265 codec feature in terms of computational performance is its support for parallel processing through another data structure called tiles. The addition of tile tools makes it possible to partition the picture independently while decoding CTUs. In addition, wavefront parallel processing (WPP) is included to provide an even more computationally efficient encoding within multi-core processor environments. Because of the existence of dependent slices, the system can access tiles or WPP data more quickly than if the whole slice has to be decoded. The presence of independent slices helps in reducing the video encoding delay which consequently improves the real-time performance.

H.265's improved compression rate, which translates into a decreased bit-rate during transmission, comes at a cost when wireless transmission is involved. This is because the irregularly-shaped data structures make it difficult to devise [15] MB-based error resiliency structures from the tools available in H.265. In contrast, H.264, its predecessor, had many built in measures [16] to protect the fragile compressed video stream against the type of isolated and especially error burst that are commonplace during wireless transmission, due to the inherent nature of the wireless channel. Therefore, the error resiliency features and support for ROIs are not conveniently available for telemedicine applications as used in [9], requiring new research to find a way of compensating for this lack. What H.265 offers is support for reliable pseudo-streaming via MPEG-Dynamic Adaptive HTTP Streaming (DASH) [17]. However, MPEG-DASH not only requires pre-coding of multiple video streams but it can also lead to unpredictable streaming delays when congestion arises. Both these issues are clearly unacceptable for real-time, safety critical video delivery.

III.   TELEMEDICINE APPLICATIONS

The proposed telemedicine system aims at future scenarios for which where the existing wireless technology is not yet sufficiently mature to deploy the system, for instance, ultrasound video transmission [9] using WiMAX or LTE technology. Ultrasound video should ideally be streamed as high-definition video so that it could be relied on when it is received at the in hospital ward. To support such a resolution, H.265 should be used because of the reasons mentioned in the previous section. However, sending H.265 over an LTE network has not been investigated yet and this is necessary to find out the optimal video parameters that will lead to streaming the video at its best quality. In addition, the received video should be accepted through a clinical video quality assessment test. Nowadays, the videos that are used for telemedicine purposes are assessed for their quality by a neurovascular specialist. Medical specialists are the ones who decide [18] whether the resolution of the received ultrasound video is acceptable for diagnostic purposes or not depending on certain measurements and protocols.

The telemedicine system under development will utilize 4G networks. However, it is proposed to improve the telemedicine systems for many applications. For instance, the proposed system could be used in rural areas where there is no available specialized hospitals or specialist. In some cases, it is vital to have an instantaneous response from the specialist to the patient and *vice versa* for the purpose of diagnosis and this would not be possible without support for high-definition video resolution.

However, there are some cases where the time is not the only limitation factor for the patient to get into the hospital. In rehabilitation and paraplegia cases, it is difficult to access the hospital. Providing that type of patient with a telemedicine system capable of sending\and recording their information and videos will be essential for them. Other applications for the proposed systems are whenever an ambulance is dispatched or whenever there are emergencies. The system should be capable of conducting video streaming for patient and specialist

conversation in line with recording the compressed video, sending diagnostic ultrasound video, measuring blood pressure, providing real-time ECG signals, and other medical diagnostics.

IV. WIRELESS FOR TELEMEDICINE SYSTEMS

A fundamental feature of wireless systems is exposure to channel errors. As video compression aims to remove redundant information from each successive video frame, it is particularly susceptible to channel errors. Moreover, video display takes place at a rate of 24 or 30 frames/s, with high frame rates still for high-definition video (at least 1280×720 pixel/frame). The real-time rate implies that video is a delay intolerant service, which is disrupted if repair material is resent. While infotainment applications may tolerate intermittent delays, medical uses of video may not be so forgiving.

However, what one finds in the some existing literature on wireless systems for telemedicine [19] is a discussion of wireless technologies but limited simulation or testing for specific wireless systems. For example, in [3] though a WiMAX simulation was performed, the authors did not state what channel model was used and employed a non-standard wavelet codec, whereas in [9], no specific wireless technology was simulated and an unrealistic error pattern was tested. ROIs are also one way to avoid the demands of high-definition transmission, as only the salient part of each video frame is transmitted at high quality. Despite the title, in [16] the coding method for ROIs was apparently only tested for its ability to deliver an appropriate bitrate with the required quality for diagnostic purposes. No specific technology or channel error patterns appear to have been tested.

4th generation (4G) wireless systems, marketed as 'broadband' access, represent a significant improvement in a number of ways over 3G cellular systems. It is bandwidth and capacity that are of principle interest to video streaming, as compared to web access and speech/audio, video, even after compression represents a step increase in bitrate requirements. For example [3], a diagnostic sound signal consumes 32-250 kbps (after audio compression), 12 channels of ECG consume only 24 kbps, while sensor data (heart rate or blood pressure) only require 2-5 kbps. However, diagnostic video using MPEG-2 compression consumes 768 kbps–10 Mbps, depending on spatial resolution, frame-rate, and quality. The MPEG-2 codec is still employed in digital TV broadcasting, but for mobile wireless systems it has been largely replaced by H.264 (also known as MPEG-4 part 10) [20]. However, the data-rate for H.264 diagnostic video still remains high 640 kbps–5 Mbps. Hence the interest in the 40-50% bitrate reductions promised by H.265. Reducing bitrates in this way will still place strain on wireless links, especially if diagnostic video follows broadcast video and moves towards high definition (HD) video. HD video increases the spatial resolution, which leads to an increase in frame rate and signal-to-noise ratio (SNR) (finer quantization) to reduce the artefacts that otherwise become visible at high spatial resolutions. If the viewing distance is reduced (as it is on mobile devices) then ideally the frame rate and SNR should be increased, leading to

further increases in bitrate, apart from that just arising from an increase in spatial resolution. Common Intermediate Format (CIF) at 352×288 pixels/frame has become normal on mobile devices. However, standard definition TV is 576×420 pixels per frame and the smallest HD resolution (720p) is 1280×720 pixels/frame.

Therefore, 4G technologies represent an opportunity for telemedicine applications. For example, compared to 3G High Speed Downlink Packet Access's (HSDPA's) maximum data-rate of 10 Mbps, mobile WiMAX has a datarate ranging from 10 up to 50 Mbps (depending on range and configuration) [3]. WiMAX was designed as an Internet-based data transmission system, whereas 3G cellular wireless was originally intended for voice and data (i.e. Web) communication. In bare bandwidth terms, both LTE Advanced and WiMAX Advanced (IEEE 802.16m, which can coexist but is not backwards compatible with mobile WiMAX, IEEE 802.16e) offer peak datarates of about 340 Mbps on a 20 MHz channel [21][22].

The work in [23] presented a comparison of capacity between WiMAX Advanced and LTE Advanced. In simulations, there was 50% video traffic and 4×2 multi-user MIMO (an antenna technology that linearly increases bandwidth). It was found that streaming at a rate of 1.536 Mbps allowed 10 (LTE) or 11 (WiMAX) sessions to be supported. If the video rate could be decreased to 384 kbps the user capacity rose to 42 (LTE) or 44 (WiMAX). In effect the performance of these two 4G systems has converged and this should not be a surprise, as their transmission technologies have to some extent converged. For example, both employ Orthogonal Frequency Division Multiple Access (OFDMA). However, one area where WiMAX seems to have the edge is in power consumption [24], which is concentrated in the base stations (the terminals having been already optimized). For example, detailed comparison at a nominal datarate of 10 Mbps showed that mobile WiMAX compared to LTE had a power consumption per covered area of 10.2 compared to 25.06 mW/m^2. HSPA was 28% less efficient in those terms, demonstrating another advantage of moving towards 4G systems for telemedicine.

V. CONCLUSION

This paper proposed using the H.265 codec for the purpose of streaming patients' biomedical videos via 4G networks. A description of the advantages of H.265 video codec was given and its use in the telemedicine systems over other video encoding schemes was justified. In addition, the need for high-resolution video quality in telemedicine systems was explained and its relation to the clinical diagnosis by medical specialist was described. Finally, the telecommunication infrastructure used for the proposed telemedicine systems is suggested to be based on 4G network, as this is capable of providing the most bandwidth.

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