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Pre-hospital Videoconferencing Telemedicine: Are We There Yet?

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Abstract

Aims

Pre-Hospital telemedicine has the potential to save lives. This study examined the challenges in the development of a mobile audio-visual telemedicine platform for the pre-hospital telemedicine component of the European Commission funded LiveCity project.

Methods

Open source software and off-the-shelf hardware elements were used to build a wearable field unit for the paramedic to communicate from the scene of an emergency via live video with the Emergency Department hub over a Third Generation (3G)/High Speed Packet Access (HSPA) network.

Results

Videoconferencing from the scene was compromised in all but one of thirty-four telemedical consultations. Significant challenges in software and hardware suitability, durability, and reliability were identified. The 3G network was unable to provide for an uninterrupted high-quality mobile video link between the paramedic and the Emergency Department.

Discussion

Improvements in hardware and software design with bespoke telemedicine equipment appropriate to the pre-hospital environment as well as investment in fourth (4G) and fifth generation (5G) networks with more extensive coverage will be required to further enable the widespread adoption of optimal telemedicine in pre-hospital care.

Introduction

In a world where videoconferencing from a mobile phone is readily available many ambulance services still communicate with Emergency Departments (EDs) via ambulance control switch boards or Citizens Band (CB) radios.[1] Whilst communication with the hospital has been an element of pre-hospital practice for many years the adoption of technological developments into this environment has been slower than many would have expected.[2,3] Real time high-definition audio-visual transmission can improve communication and enhance medical care.[4,5] These video transmissions are data-intensive applications that require high speed uninterrupted internet access. As part of the LiveCity project we had previously established the acceptability of an audiovisual link to the hospital for patients, paramedics, emergency medicine nurses and doctors.[6]

This research examined the feasibility of providing pre-hospital telemedicine between the on scene paramedic and the Emergency Department Doctor using a wearable kit developed from integrating off the shelf hardware, and modifying open source software and with transmission over an upgraded 3G network to communicate directly with a teleconferencing hub in the ED. The LiveCity project integrated wireless and wired broadband with the aim of creating an ideal communication platform for implementing pre-hospital audio-visual communication.

Methods

The research and ethics committee of Beaumont Hospital agreed to the performance of the prospective feasibility study. Approval was obtained from the Data Protection commissioner. Funding was received under the Competitiveness and innovation framework program seven of the European Commission.

The LiveCity Consortium consisted of 18 partners from seven EU member states. The telemedicine element of the LiveCity Project brought together experts in telecommunications, software development, network engineers, pre-hospital care and emergency medicine.

The developers of the hardware and software solutions and network providers collaborated with the Emergency Medicine health professionals and the Health Service Executive Ambulance service to describe and address the end users' requirements. From a user device point of view the initial strategy of the project had been to use common off the shelf devices with integrated cameras and wireless modems to connect the paramedic with the emergency department. The actuality was that the project built and tested a new wearable video solution as there were no suitable off the shelf solutions available that met the end users' requirements.

The fifth prototype of the field based-wearable kit which was deployed for the patient recruitment phase of the study consisted of a head mounted Contour camera with its own power supply and an ear piece and microphone linked by High Definition Multimedia Interface (HDMI output)cabling to a VIA Atom Microcomputer with video encoding software installed. Data transmission was through a HSPA/3G Modem. The computer and a two-hour battery pack were stored in a backpack along with a HDMI acquisition card, a power management unit and a 3G Universal Serial Bus (USB) dongle. Rugged buttons and feedback audio and Light Emitting Diode (LED) systems were attached to the arm straps of the backpack via cabling from the computer with heavy duty connectors (Figure 1).

Figure 1: Telemedicine Emergency Department Interface (TEDI) backpack.

Notification lights above the control buttons were developed to indicate when 1.the unit was powered on, 2. it was connected to the hub, and 3. it was live streaming. This camera back pack system collected the video and audio, and compressed it using the H.264 standard for video compression, encrypted the video and sent it over the air interface to the High Speed Packet Access (HSPA) base stations which are located at various locations around Dublin (Figure 2).

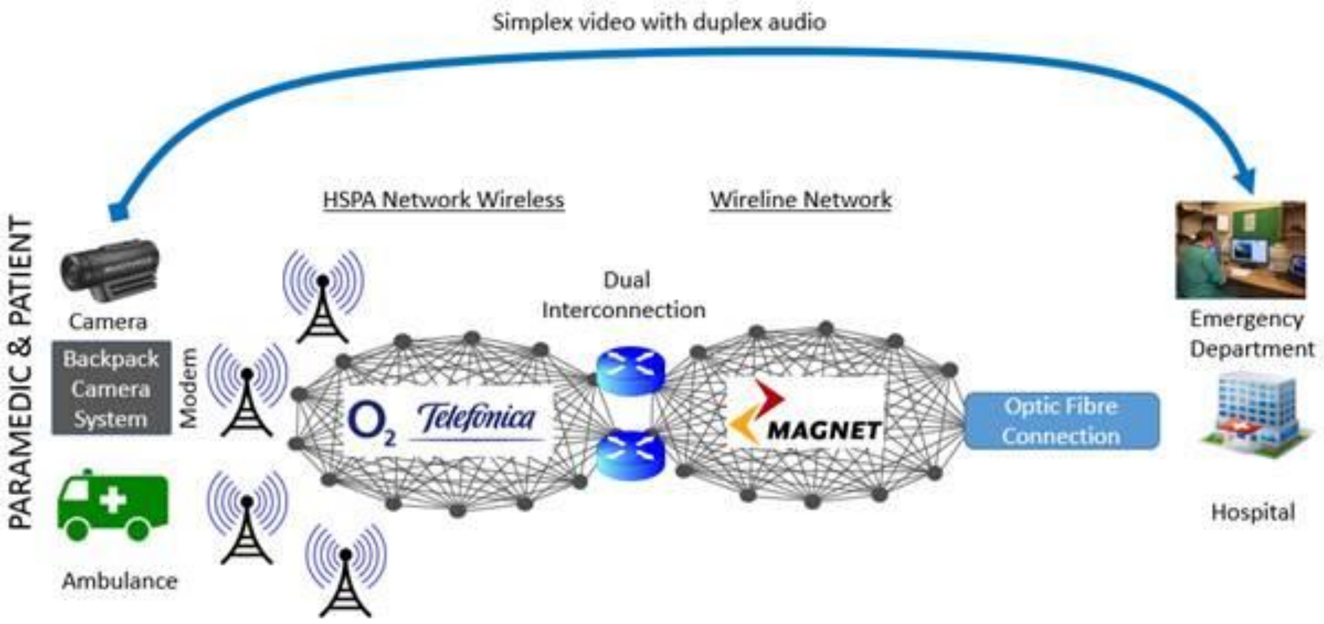

Figure 2: Network Deployment Overview.

From the base station the traffic was carried over the backhaul network to two interconnection points with the wireline network. The backhaul network included dual path redundancy as is common in 3G networks. An access point name (APN) with a private addressing scheme dedicated to the LiveCity project was used. The APN was configured for additional quality of service features to give a higher level of priority compared to other traffic on the uplink. The traffic arrived at the network and was carried in a virtual private network (VPN) to the hospital. A dedicated optic fibre was installed, in partnership with a third party who already had circuits in the area, into the hospital emergency department at Beaumont hospital. The dedicated hub office included a 27-inch LG Television monitor (Model 27EA33) and a Toshiba Satellite Pro L850-1P8 laptop computer with a headset with earpiece and microphone.

Results

Forty-seven field tests of the platform were performed prior to patient recruitment and subsequently 34 patients consented to and experienced an attempted pre-hospital telemedicine consultation.

We noted technical challenges in 33 of 34 telemedicine consultations. The technical problems are discussed under the headings of hardware challenges, software challenges and network challenges.

Hardware challenges

There was a need for detailed instructions for starting up the Telemedicine Emergency Department Interface (TEDI) device which included an eight-point standard operating procedure. The backpack itself could not be worn whilst seated in the ambulance as it placed the paramedic too far forward in the seat and as such had to be put on after arrival at the scene. The computer battery generated a lot of heat to the point of becoming uncomfortable for the person wearing it and this also caused overheating of the hard drive such that it would crash and fail to reboot. This necessitated the design of vents within the backpack which only partly resolved the issue. The hardware had multiple USB connections with cables going to a dongle, switch devices, and other cables to microphones and earpieces as well as a HDMI cable to the camera. During patient testing USB attachments broke, the HDMI cable became disconnected, a dongle broke, the cable into the back of the camera broke. The subscriber identity model (SIM) card in the hard drive tended to click up and out of position. There was a very frequent need to re-boot the hardware to ensure the camera was being recognised by the hard drive. The hard drive and camera both had separate power sources with separate chargers the camera having a usable time of about two hours whilst the hard drive could be up to 4 hours which necessitated carrying multiple spare batteries for each. There were repeated equipment breakdowns such as the hard drive casing cracking, cables fracturing and connections breaking that required progressive rebuilds with more durable material. The backpack potentially could catch on items. The camera on the head band tended to tilt upwards and could become uncomfortable with prolonged wearing of same. In short the provided hardware in prototype phase 5 still did not meet the requirements of the end users when deployed in the pre-hospital arena, such that when deployed the TEDI camera was worn by a member of the research team to avoid interrupting the paramedic in their work.

The software challenges

The modified open-source software was used to create an audio-visual software application with an end user interface (Figure 3) in the hub used by the hospital-based doctor.

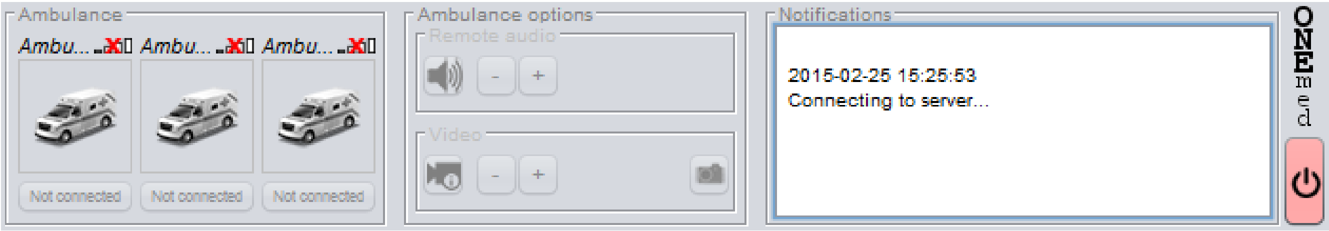

Figure 3: (software interface allowing up to 3 ambulances to interact with the physician who could manipulate audiovisual quality and take high definition still images).

The software development included full video to video re-engineering for improved integration and stability to allow up to 3 ambulances to be supported, preview image acquisition, Ambulance status and selection buttons, a notifications area, remote sound management and video quality management, still picture support and improved stability and resilience.

Due to the sensitive nature of data transmitted end-to-end encryption was required leading to data intensive transmission. Software resilience was suboptimal in enabling recovery especially during signal handover from mast to mast while transiting through a region with poor network signal. There was a need to re-boot the camera and hard drive to establish a video link which invariably took longer than establishing the audio link and it was often necessary to reduce video quality to try and establish a video link. At times the taking of a screen shot seemed to help start a video stream and at times if the video stream was established and a screen shot was taken the video stream would either freeze or be lost. Audio quality was poor whilst persistent echoing made it quite difficult to communicate. The Doctor manning the communication hub heard their own voice up to about five seconds after asking a question of the camera wearer due to the encryption process. In the event of a dropped or lost signal the Doctor at the hub heard the last sound from the field repeatedly until the connection was lost completely or re-established. This was due to the repetition of the last data parcel as a result of the looping of the signal. There was an issue of delay between the audio feed and the video feed and a delay created by the encryption of both. There was freezing of images, pixilation of images, degradation of sound quality and loss of signal with movement as well as looping of the audio signal. All of these made real time communication challenging and necessitated the Doctor at the hub speaking at a slower rate than would be optimal in an emergency situation.

The Network challenges

Due to the data-intensive nature of this application we experienced persistent signal drop that led to significant difficulties in real time audio-visual communication. Communication via the platform when the patient was in doors or in a moving vehicle was frequently associated with loss of signal. Notionally HSPA can have uplink speeds of several megabits (Mbps) per second.

In practice the pilot measured speeds in the range less then 1Mbps. During testing uplink speeds in the range of 500 kilobits (Kbps) to 1Mbps were found to be useful for transmitting video.

Discussion

Prehospital telecommunication has been used to expedite care in patients with stroke, myocardial infarction and trauma.[7-10] It is regarded as cost effective and increases the specialist's sense of safety with respect to the advice they are giving.[11-13] Its use has been advocated in situations as diverse as facilitating advanced airway management and major incident management.[14,15] In previous work paramedics expressed concerns about the reliability of the equipment available to facilitate teleconferencing.[6] Having light weight, compact, robust, reliable, intuitive, unobtrusive, low maintenance equipment that works rapidly first time and every time and is appropriate to the environment is essential if video conferencing from the pre-hospital environment is going to be used more frequently. The technology must facilitate not impede the delivery of pre-hospital care.[16] The equipment must be designed for the environment taking all of the end users requirements into account.[17] Bespoke hardware and software solutions must be developed to enable mobile video conferencing to facilitate paramedics in optimizing the usefulness of telemedicine consultations. The head mounted camera, earpiece and microphone should link wirelessly with the computer and from there to the communication hub. Our research has confirmed the work of others that data intensive transmission such as encrypted multimedia limits the utility of 3G for real-time on site mobile telemedicine application.[18] Even with higher network speeds that are available in 4G and even 5G networks priority access to all available networks will be required for optimum telemedicine functionality. Network providers must cooperate and allow access for pre-hospital telemedicine across all available networks. Satellite facilitated telecommunications from the pre-hospital environment has been suggested by others.[19] Getting the right patient to the right place whilst they are having the right treatment requires the right technology. We are not there yet when it comes to the provision of optimal pre-hospital video telemedicine technology but the goal of providing specialist advice where they can see and hear what the paramedic is dealing with is worth pursuing.

Declaration of Conflicts of Interest:
The involvement of the research partners was part funded by the European Commission under the FP7 initiative. The technical partners are commercially involved in telecommunications delivery.

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