AUTHORS
Konstantinos A. Banitsas
E&CE, School of Engineering and Design,
Brunel University, West London, England
E-mail: konstantinos.banitsas@brunel.ac.uk

Konstantinos Perakis and Dimitrios Koutsouris
Biomedical Engineering lab,
National Technical University of Athens, Greece

Theodoros K. Kalyvas
GERCO LTD, Athens, Greece

By Konstantinos A. Banitsas, Konstantinos Perakis, Theodoros K. Kalyvas and Dimitrios Koutsouris

3G Technology in Telemedicine

Mobile phones used for telecommunication between ambulance and hospital

In Greece there are on average 461 000 ambulance calls every year. Only in the general Athens area, an average of 730 ambulance calls are logged each day. 27% of those calls result in transportation to an A&E ward (category A responses). An ambulance takes on average 17 minutes to reach its destination in the city of Athens.

Patients in critical condition would benefit from a faster diagnosis, which cannot be provided by the ambulance crew. In 1998 the National Technical University of Athens developed project "Emergency 112", whose objective was to reduce treatment times, improve medical diagnosis, and minimise costs by providing wireless communication between the moving ambulance and a medical expert.

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Transmission of critical bio-signals (ECG, BP, HR, SpO2, Temperature) and images to an emergency call centre enabled physicians to direct pre-hospital care more effectively.

However, as the system was using a 2G, its speed of 9.6 Kbps, allowed only low-resolution static images and patient data in text form to be transmitted. When General Packet Radio Service (GPRS) was introduced it offered a bandwidth of about 50 Kbps, which allowed transmission of modest quality static images. 3G systems utilise the Universal Mobile Telecommunication Services (UMTS) technology and support higher data rates, enabling a range of new applications.

When conventional 2G mobile terminals move from one cell to another, they have to dissociate from the old cell and associate to a new cell, causing small gaps in communication that can severely affect time sensitive processes. UMTS, on the other hand, uses "soft handover" where a mobile terminal switches from one cell to another in such a way that at a point in time it communicates with both cells.

That results in a more stable data flow, essential in real time applications. When a mobile terminal gets out of a 3G-coverage area it falls back into GPRS speed, until it regains a 3G signal. This introduces considerable delays in communication and data transfer. As an alternative, access points supporting WLANs can be used by the system described in this paper. These offer a faster connection at a lower cost, compared to the 3G.

How we did it

In total 17 trial runs were conducted in Athens, a city with quite high traffic load, where a 3G mobile telephony network was recently deployed.

The ambulance used for the trials had the following equipment fitted:

- A high-end laptop computer.
- A quality camcorder capable of focus and white balance under various lighting conditions. This could also take high-resolution still photos.
- Either a PCMCIA card supporting 3G communication between a laptop and a 3G network or a 3G phone acting as a modem (via USB or bluetooth).

The laptop had a standard videoconferencing programme installed, which allowed point-to-point communication with the base station, located in a hospital where either a doctor or a consultant could use a standard computer to estab-

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lish a link with the moving ambulance. The base computer was equipped with a web camera allowing two-way videoconferencing. This enabled the consultant to visually demonstrate a method to the ambulance crew, but lowered the quality of the ambulance-to-base station link.

The ambulance moved in both UMTS and GPRS coverage areas: only about one third of the geographical area of Athens is covered by 3G cells. For the remaining areas, the system fell back to GPRS, lowering considerably the available speed. Several road speeds were tested, from a stationary position to a top speed of 140 km/h, in different routes, including road tunnels and urban canyons.

To monitor network performance on the mobile side of the system, two separate network monitoring programmes ran continuously, measuring channel utilisation, packet size, protocol usage and network speed.

What the results showed

Engineering

The videoconferencing sessions produced relatively clear video, using the H.263. The bandwidth was adequate for a satisfactory video of 10-15 fps and resolutions of up to 640x480 pixels. The initial speed of 384 Kbps, (3G coverage) was stable with negligible fluctuations. When connected to a 2.5G cell, the speed dropped to about 40 Kbps exhibiting relatively heavy fluctuations. Transition between 3G cells was very smooth and virtually transparent to the user.

When the system handed over from 3G to 2.5G, there were some delays of five to 15 seconds. In one case, communication was lost for over one minute and the whole session had to be re-established. In a total period of 23 hours and over an area of about 180 km^2, in nine recorded instances, communication fell back from 3G to 2.5G lasting a total of 17 minutes.

In cases where the patient did not need to be transferred to an A&E ward, a different approach could be followed: the same laptop computer can also accept a WLAN card, enabling it to connect to the hospital site, via a Wi-Fi hotspot. This increases the speed of communication dramatically up to 2.5-3.5 Mbps and allows for lower compression rates resulting in a clearer videoconferencing session.

This was tested as an alternative to the 3G link and the results were encouraging. The disadvantage of this option was that the ambulance and staff should be relatively stationary to maintain connection to the access point.

Telemedicine

Experiments were conducted over seven days, involving a number of doctors, patients and other personnel:

- A total of 17 patients were transferred with the ambulance, which carried this system.
- Four consultants were asked to make a prognosis based on patient data sent by the system (video, image and sound).
- Two engineers continuously researched the communications properties of the system.

All the test cases produced acceptable results both in terms of videoconferencing and still imaging. According to questionnaires the overall quality of the outputs was: poor 4.2%, acceptable 25.4% and good 70.2%.

Sound quality was acceptable, although the relatively high background noise caused by the ambulance movement lowered the quality of videoconferencing. Transmission of still images was straightforward using the same high quality camcorder that was used for videoconferencing.

A still image of 1Mpixel took about 10-15 seconds to be transmitted. The fluorescent lighting inside the ambulance had no significant effect on the quality of the images. Transmission of films (x-rays, CT, MRI, etc) proved to be the most difficult task, although there was little actual need for it. Finally, the system could also act as an on-line terminal, allowing access to the hospital database (patient records, drug prescriptions, etc.).

Expanding on our results

When the ambulance was within a 3G-coverage area, the system had an acceptable videoconferencing quality. In GPRS areas the bandwidth was not enough to accommodate the load. Sound and still imaging quality was very satisfactory even in GPRS areas, expanding the system's usefulness.

The cost of the additional hardware that needs to be installed on an ambulance, does not exceed €6 000. Most test sessions lasted three to 10 minutes and transmitted 3-15 MB of data, at an average cost of €5-20 per session. The overall cost of the system (installation and running costs) is low enough to allow its massive deployment.

A Virtual Private Network (VPN) was used to create a secure tunnel from source to destination, utilising the software that was provided with the PCMCIA 3G card.

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This system can also be installed in a mobile vehicle (the consultant's car for example) and allow for communication between the car and the A&E ward, offering a whole new range of applications.

Conclusion

Participating doctors largely agreed that this system produced solid results that could be used for improving the quality of service to the patients. All prognoses made using the system agreed with the final diagnoses of the patients, even though further tests were required to confirm each diagnosis.

Overall, it is evident that a high quality, low-cost system like this can considerably reduce the time needed for a patient to get primary consultation and effectively save lives.