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(a) **Title of the research item: Virtual Trauma Team**

(b) **Subject area: The Added Value of Applications and Services in the Wireless World**

(c) **Objectives of the required research (Why has the topic been chosen? Where will the results be applied?)**

The clinical motivation for Virtual Trauma Team is to improve quality of care in trauma care in the vital first "golden hour" where correct intervention can greatly improve likely health outcome.

The motivation for Virtual Homecare Team is to improve quality of life and independence for patients by supporting care at home. The economic motivation is to replace expensive hospital-based care with homecare using wireless technology to support the patient and the carers.

Results will be applied by international partners in healthcare services

Introduction

We present in fact two healthcare applications: Virtual Trauma Team and Virtual Homecare Team. The Virtual Trauma Team application involves wireless communications between members of the trauma team, namely ambulance teams (paramedics possibly accompanied by a trauma team doctor) and the hospital (Emergency Room (ER) team and in some cases also the surgery team). The Virtual Trauma Team is supported by a Hospital Virtual Private Network (HVPN) which extends the hospital intranet into the community. The Virtual Homecare Team application is also supported by the Hospital Virtual Private Network extended into the patient's home in the form of a specialised electronic home environment. The following fictional application scenario illustrates the applications. The scenario is patient centred and follows one episode of care. The 'chain of care' begins in the community with the emergency services attending an accident, the patient receives treatment in hospital and then returns home to continuing support centred on the home.

The Application Scenario

Vic is walking along a country lane when he unfortunately suffers a road traffic accident. A vehicle collides with him at low speed. He is knocked down but conscious, he has some injuries and feels pain in his right leg and in his chest. The driver of the car calls the ambulance and waits with him. Very soon the ambulance approaches and stops nearby. One of the paramedics from the ambulance kneels down and talks to Vic, asking him what happened and where he feels pain. The paramedic explains that he is in contact with the hospital and is at the same time talking to the specialist in the hospital emergency room, who can see and hear what is going on. The paramedics have already called up Vic's hospital records and GP records to check his history, his problem list, his current medication and whether he has allergies to certain drugs. The paramedic performs an examination and talks through what he is doing. Then the hospital specialist makes some comments to the paramedic and instructs him to administer pain killing drugs immediately. When this is done the paramedics move Vic into the ambulance and they set off. During the journey various machines in the ambulance monitor Vic's vital signs and display them in the ambulance and simultaneously to the ER specialist and also to the surgeon in the hospital. In the ambulance Vic can see the ER specialist on a TV screen and they talk directly during the journey to the hospital. The hospital specialist is also giving further instructions to the paramedics. Vic is vaguely aware that the hospital doctor is also talking to someone else but doesn't realise that the other person is the surgeon in the operating theatre (who is currently operating on another patient). The journey takes them back along the country lane and then they speed along the highway, then into the city and to the hospital. Meanwhile the ER room is prepared to receive the patient and the operating theatre is also made ready. Vic is prepped for surgery whilst still in the ambulance and within minutes of arriving is undergoing life saving chest surgery. Following surgery Vic undergoes a period of post-operative care followed by rehabilitation. On discharge from hospital he is cared for at home. Healthcare continues with home visits by members of the Virtual Homecare Team including the homecare nurse and the physiotherapist. These health professionals are equipped with mobile computers and can interact via wireless communications with their base whilst out and about or whilst in patients' homes. Thus they can communicate with other members of the Virtual Homecare Team who may be located in the same city or indeed anywhere in the world. Vic is provided with a personal area network - a patient PAN - a wearable set of miniature sensors which monitor his vital signs and other physiological signals and can detect unusual situations (such as a fall or accident, or a clinical event) send alerts and summon help. The patient PAN communicates over wireless link with the eHome platform and thence to the hospital. The set of sensors and devices can be customised to the needs and health problems of the individual patient. Vic can also directly communicate with the hospital by phone and if tele-consultation is needed this is also available via the eHome video conferencing system.

Network Architecture

Hospital VPN

The hospital VPN (Virtual Private Network) simulates a private network over a public network such as the Internet. It appears as a private regional network to the hospital, but physically shares for example backbone trunks with other customers. The security level of the VPN is the same as the private network, achieved by means of access control and encryption, protecting it against the threat of hacker and other attacks. The major advantages of a hospital VPN over a privately owned network are the economies of scale and built-in management facilities of large public networks.

The proposed hospital VPN consists of three basic network types: Hospital Intranet, Trauma Team Network and the eHome (see figure 1). The Hospital Intranet is the hospital's in house LAN, with strict access and security rules. The ambulance and paramedics form a Trauma Team Network. This network is connected via a wireless link (e.g., IEEE 802.11, GPRS, UMTS) to the Hospital Intranet. The eHome represents the patient medical care network, and could be connected to the Hospital Intranet via a wired (e.g., ADSL, cable modem) or wireless link (e.g., IEEE 802.11, GPRS, WLL).

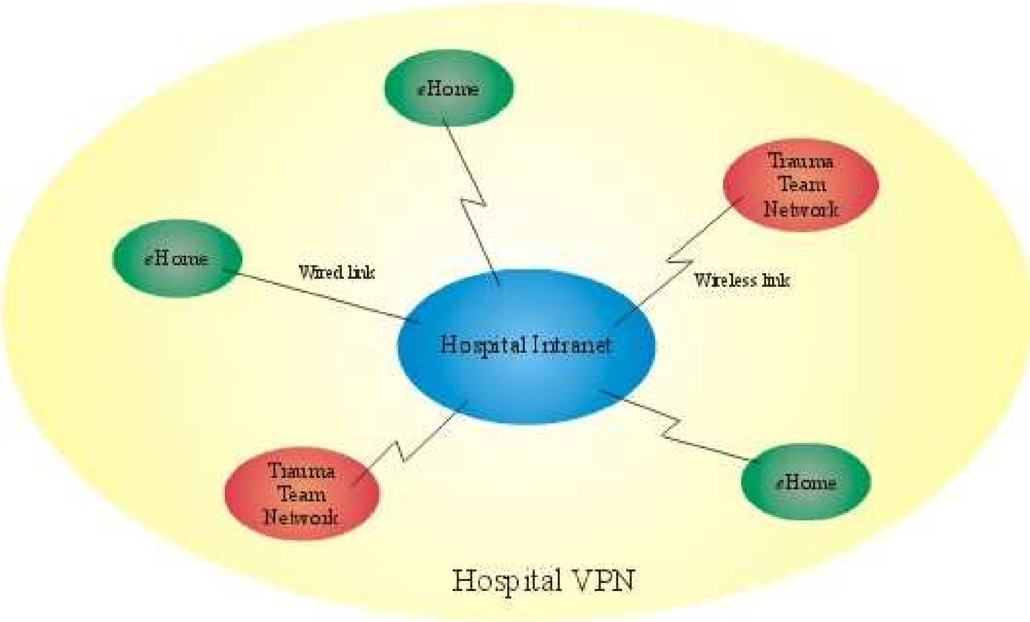

figure 1

The Trauma Team Network key node is the ambulance (see figure 2). It houses a VAN (Vehicle Area Network) that has connections to the Hospital Intranet and paramedics PANs (Personal Area Networks). Typically the VAN interconnects a group of medical devices (e.g., active body sensors, bio-belt) equipped with wired and/or wireless network interfaces. The network technology used for the VAN could be Bluetooth (version 2) or IEEE 802.11, with an appropriate gateway to interconnect to the Hospital Intranet and the paramedics PANs. If the paramedics are working outside the ambulance, their PAN has a wireless connection with the VAN. The PAN could be based on Bluetooth (version 1 or 2) devices with an Bluetooth version 2 or IEEE 802.11 link to the VAN.

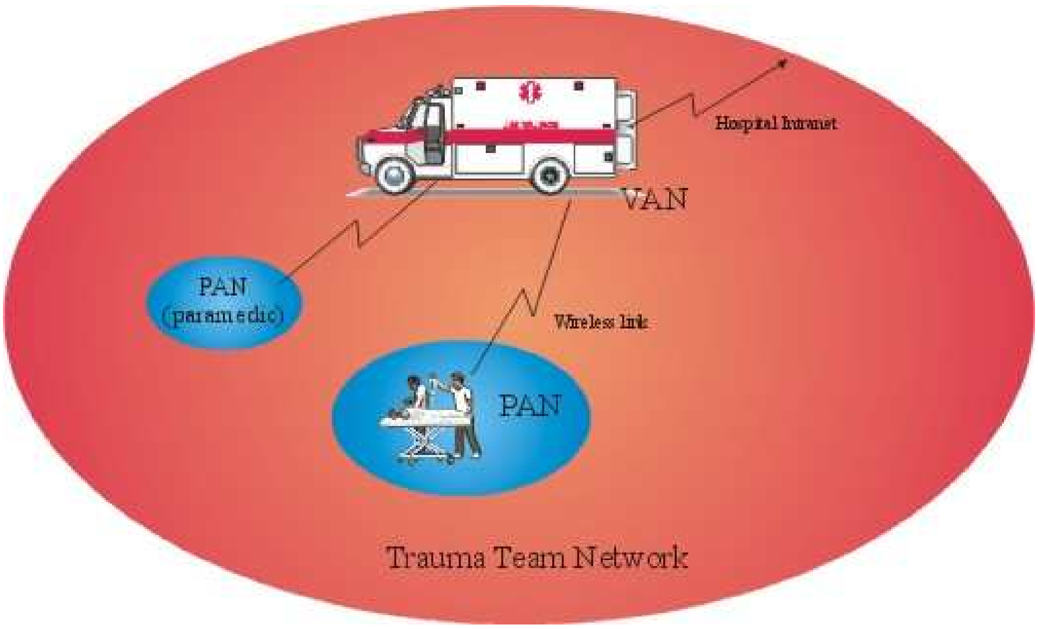

figure 2

Once the patient is stabilized and transported to the ambulance by the paramedics, the ambulance rushes to the hospital. The VAN to Hospital Intranet connection will be fully operational during this time. Depending on the wireless networking technology used, rapid and seamless horizontal handover from one cell to another should be supported. It is also possible that the ambulance VAN traverses different wireless networks (e.g., IEEE 802.11 to GPRS, and back to IEEE 802.11). In that case rapid and seamless vertical handover should be supported.

The patient's eHome network (see figure 3) consists of wired and wireless devices (e.g., digital cameras, microphones, loudspeakers) and the patient PAN. The network central device is a base station with a wired (e.g., ADSL, cable modem) or wireless link (e.g., IEEE 802.11, GPRS, WLL) to the Hospital Intranet. The patient is free to move in the eHome (premises), but his PAN stays connected.

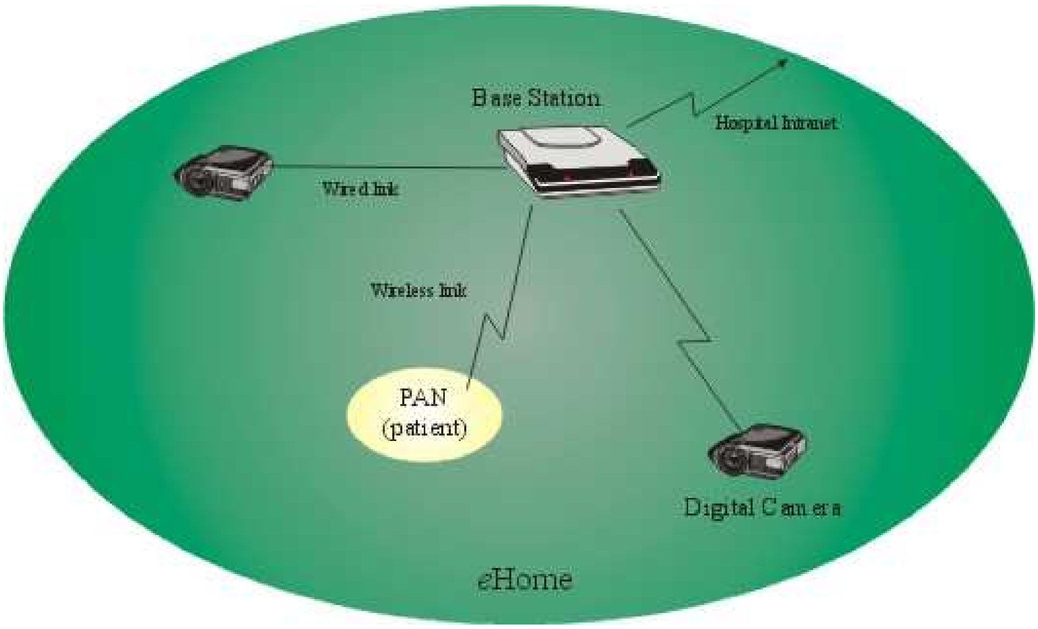

figure 3

In the special case that paramedics give medical care to a patient in the eHome, the patient and paramedics PANs could be interconnected in an ad hoc way. Here an information routing decision should be made: use the eHome or VAN link to the Hospital Intranet.

The overlay network should be IPv6 based. This emerging protocol provides the necessary address space for small mobile devices. It also has good support for stateless (host) configuration, IP mobility and security (e.g., IPsec).

Research Issues

These applications generate many research issues relating to wireless networking technologies. In this WG we focus on the Application perspective: here the research issues include:

Proactive Quality of service (Policies, Management,Measurement, Mechanisms): How to supply end-to end QoS guarantees for

- Always-on, streaming video (including on-the-move) between ambulance and hospital

- Two way audio link, telephone quality (thus full duplex audio)

How far should applications be network aware?
Should the application itself be aware of and adapt to changing QoS capabilities (eg. caused by horizontal handover (eg from relatively empty to relatively busy cell) and vertical handover (eg. from WLAN to GPRS). Location awareness would enable anticipation of changing QoS capabilities for fixed wireless network infrastructures but not for eg, ad hoc networks.

Lightweight Application Protocols are needed to support persistent mobile internet applications to achieve:

- Robustness of applications
- Recovery in face of temporary network failure
- Dynamic adaptation to network performance degradation (eg strategies in the *application* for adapting to/compensating for packet loss, increased delay, jitter etc.)
- Security (encryption, identification, authentication)

(d) State of the art in the area (including important references)

MIT Project Oxygen, http://oxygen.lcs.mit.edu/KnowledgeAccess.html

Guardian Angel: Personal Lifelong Active Medical Assistant, http://www.ga.org/ga/

MediLink -- A SmartCard-Assisted Wearable Data Acquisition and Communication System for Emergency and Mobile Medicine (T. Koval et al) Nov., 1998, Preprint (INABIS-98; published on web at www.inabis.org and www.mcmaster.ca/inabis98)

Dudziak M, Koval T, Developing A Practical Wearable Telemedicine System for Emergency and Mobile Medicine, htttp://www.silicond.com/research/transpacpres/ppframe.htm

Curry GR, Harrop N, The Lancashire telemedicine ambulance., J Telemed Telecare 1998;4(4):231-8

Domotica.it: Risorse on-line: La casa intelligente, introduzione all' home automation, http://www.domotica.it/

Pitsillides, A, G. Samaras, M. Dikaiakos, DITIS: Collaborative Virtual Medical team for home healthcare of cancer patients, http://www.ditis.ucy.ac.cy/Reports/reports.html

Samuel K. Moore, Unhooking Medicine, IEEE Spectrum January 2001 Volume 38 Number 1, http://www.spectrum.ieee.org/pubs/spectrum/0101/1_4a_medi.html#sb2

New York City Department of Health, Tuberculosis Control Program, TB and The Law http://www.ci.nyc.ny.us/html/doh/html/tb/tb-law.html

Applied Informatics (TIIAP #36-40-94065), Final project report, http://informatics.cpmc.columbia.edu/appldinf/final.txt

(e) Possible approach

The first phase is to prototype the eHome hardware infrastructure using available technologies. The research component at this phase will involve network management issues and application design and development issues. The eHome platform and the patient PAN experiments will provide a proof of concept in a stationery environment. Phase 1 results will feed into Phase 2, where we add the complications of vehicle mounted systems and fast roaming.

In Phase 2 we will experiment with the technologies needed to implement a fast roaming platform (the ambulance application is a specific instance of the general case of vehicle mounted systems).

(f) Expected results

- Prototype eHome - electronic home platform for homecare
- Protoypes of experimental PAN (generic patient PAN, trauma team PAN)
- Experimental data from experiments with fast roaming vehicle mounted high bandwidth applications
- A QoS framework to map user QoS parameters onto network QoS for heterogeneous network environments (including a combination of wired and wire free, also combinations of different wireless transport systems).
- Performance prediction method based on performance analysis techniques
- Measurements of actual QoS to test the performance modelling methodology and QoS framework and mechanisms
- Security recommendations for wireless communications in the healthcare domain
- Comprehensive evaluation of the technology and applications

(g) Time frame to get the expected results

We expect preliminary eHome and PAN results in 2 years. The remaining research issues arise from a 'far horizon' vision and are partially dependent on first results. Hence the exact time frame is difficult to predict.