

## Modelling issues of Wireless LANs for Accident and Emergency Departments

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*Abstract* - The paper provides an overview of the application scenarios and modelling issues of Wireless Local Area Networks (WLAN) in hospital and clinical ward environments and presents the concept of MedLAN system, dedicated to these environments. Furthermore, it discusses the potential problems when implementing such systems.

### I. INTRODUCTION

Mobile telemedicine is a new and evolving area of telemedicine that exploits the recent developments in mobile networks for telemedical applications in general [1], [2]. The aim of this paper is to present an overview of the main design and development elements of an integrated mobile WLAN dedicated to accident and emergency (A&E) departmental building structures and the anticipated challenges from both the telemedical and telecommunications point of view.

In typical scenarios, WLANs are very practical in hospital environments for several reasons:

- Older hospital structures and buildings that are not suitable for cabling and wired LAN applications.
- Mobility issues, where staff on the move can access their patients from different access points in complete roaming capabilities.
- The installation and long term running cost of WLAN systems will be cheaper and easier to upgrade.
- Installation flexibility as the network can reach places the wire can not.
- Scalability, as the network can be configured to various topologies to suit the changing needs of a hospital [3]

Presently, a project named "MedLAN" is developed to accommodate these medical needs. The system design and research methodology of it, is divided into three main tasks representing the pyramid development procedures of such applications:

- Modelling and simulation to define the biomedical digital signal processing requirements for second and third generation mobile telecommunication systems [4], [5];

- System hardware and software design to implement a mobile MedLAN system capable of transmitting several channels of medical data and information;
- Clinical testing and evaluation of the prototype MedLAN model, radio link and data acquisition server.

### II. MedLAN: DESIGN CONCEPTS AND CHALLENGES

A schematic of the MedLAN system, is shown in Fig. 1. It consists of two main parts: A mobile trolley that exists in the Accident & Emergencies ward "majors" ward area and a consultation point, within the hospital.

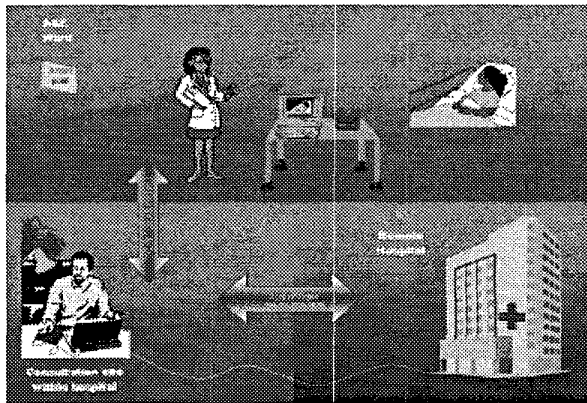


Fig. 1. Representation of the MedLAN project

The mobile trolley consists of a high-end laptop computer that is equipped with a WLAN PCMCIA card initially using the IEEE802.11b protocol that will permit total **mobility** within the A&E room and beyond. An access point within the A&E acts as a wireless hub for the network data to be transmitted to and received from the rest of the network. A high quality digital camcorder is connected to the laptop and with the use of the IEEE1394 protocol, **high quality** video and audio is transmitted. Additional medical instruments (like otoscopes, dermoscopes etc) are also connected to the system and their output is send over the air.

In the consultation point (that can be at any location in the hospital) the consulting physician can have a choice of

teleconferencing either from a fixed computer within the existing hospital network, or a mobile laptop, sharing the same mobility advantages as the former laptop. It can even transmit video to a PDA pocketsize computer [Fig. 2].

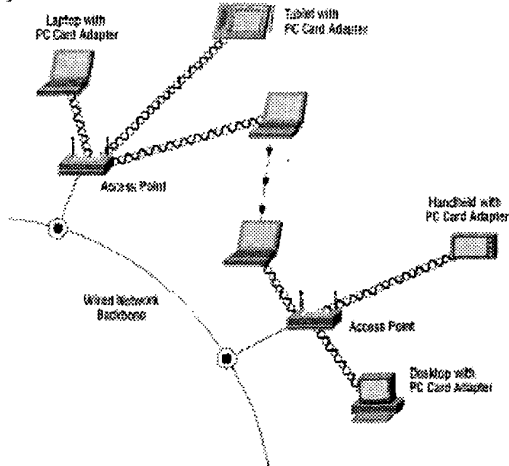


Fig. 2. Connection between the WLAN and the existing wired hospital network. Laptop computers can have roaming capabilities between the various access points

In a later scenario, data can be transmitted from one hospital to another, or even to a doctor's home. Fibre optics, DSL or even WLANs can be used for that purpose. [6]

The amount of medical data sent depends on whether IEEE 802.11 TGB or IEEE 802.11 TGA standards are to be used. The latter provides a better choice but is more prevalent in the US. With the dissemination of the HiperLAN/2 standard, there will be a greater opportunity for uniformity.

### III. MODELLING MedLAN

For the modelling purposes of this project, OPNET Modeler 7.0 was chosen. This software package includes a radio library that permits simulation of Wireless networks.

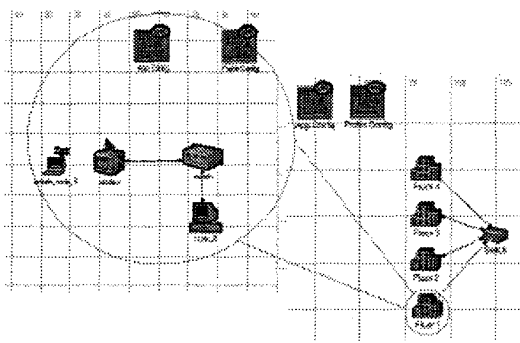


Fig. 3. MedLAN model using OPNET Modeler

Fig. 3 shows the model created. It consists of a wireless node (mobile\_node\_0) that represents the laptop computer that roams around the A&E ward, an access point that will probably be placed in the centre of the ceiling of the A&E ward (wireless), a fast switch responsible for distributing the data (switch) and a desktop computer (node\_0) that will be placed in the consultant's office. All the possible applications that the units can use are stored within "App Config" while the settings for the applications that were used in this specific model, are within "Profile Config".

The figure also represents the link between the A&E ward and the consultation point. This can be expanded to accommodate all the floors of the hospital (Fig. 2).

For this scenario, there is an assumption that only one audio / video link between the A&E ward and the consultation point exists.

### IV. SIMULATION RESULTS

Two alternative scenarios were simulated: one transmitting low quality video (128x120x10 fps) and a VCR scenario that transmits high quality video (352x240x30 fps), in order to investigate the response of the existing network to the additional load of the wireless network. Both scenarios use ten minutes of audio / video communication (with variable load) out of the one hour of total communication while the existing wired network runs with a normal load (normal ftp, light web browsing and normal email).

Out of the numerous graphical outputs that the OPNET Modeler can produce, the interesting ones are those who determine the quality of the service (QoS). By that we mean the combination of resolution, delay, frames per second (fps) and general stability of the system and the video throughput.

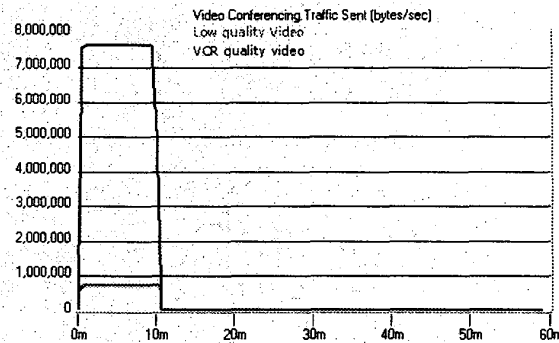


Fig. 4. One hour of simulation measuring the video conferencing traffic created for both scenarios (low video and VCR)

Fig. 4 contrasts the videoconference traffic between the two scenarios (low video and VCR). The first scenario has a peak value of less than 700 Kbps out of the 11 Mbps that the WLAN can offer in its best case but severely degrades the image quality (from 720x576x30fps to 128x120x10fps). In the second case the value is a little more than 7Mbps producing an image output of 352x240x30fps.

Fig. 5 shows the end-to-end delay of both the videoconferencing systems. This is the accumulation of the

various delays introduced to the link (IEEE1394 port, WLAN, access point, Ethernet, videoconferencing software).

As expected, the lower video quality demands much less bandwidth and introduces fewer delays and inconsistencies to the system. However, proper diagnosis would be difficult (or even impossible) using a system like that.

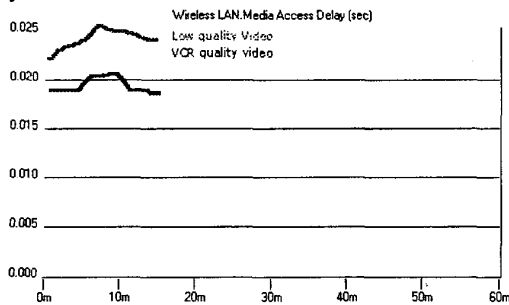


Fig. 4. One hour of simulation measuring the video conferencing delay created for both scenarios

### V. MODELLING CHALLENGES

Unfortunately most of the modelling software packages can not take into account the various unique details that each system has. The specific model was proven poor on taking into account the bandwidth fluctuations of the existing wired LAN (especially in a large hospital).

It also assumes that there are no fluctuations due to the movement of the WLAN cart within the A&E ward, even though the IEEE802.11b protocol will constantly change its speed out of the available range: 1, 2, 5.5, 11 Mbps. Accordingly, when positioned in a "difficult" area, it would fall back to a lower speed to ensure data integrity.

Various obstacles (walls, metallic objects that can reflect radio signals, etc) were impossible to model, not only because of the software limitations, but mostly of their constantly changing nature and position.

Security of the system is also not addressed within the modelling software. IEEE802.11b supports three modes: unsecured, 40 bits and 128 bits Wired Equivalent Privacy (WEP). Using any type of encryption is bound to increase the load of the network.

Finally, interference with existing appliances and other radio technologies could not be accommodated into this model, although they could severely affect the system's performance. As the IEEE802.11b system operates at 2.4GHz, both microwave ovens and Bluetooth devices can deteriorate signal quality and reduce its speed, even though the system uses spread spectrum techniques to eliminate such interference.

### VI. DISCUSSION

- IEEE1394 a very promising new serial bus that can deliver up to 400Mbps of uncompressed video and audio protocol, was chosen to transmitting the picture from the camera and the various medical instruments. Unfortunately this is much higher than any commercial WLAN technology will be able to handle for the next few years. In its "standard mode", IEEE1394 has a throughput of 100Mbps, which is a **much higher** than the IEEE802.11b can transfer.

- As there is not such available bandwidth, the developer is called to compromise with one of the following solutions: either reduce the picture size / fps or **compress** the image.

- Although compressing the signal is a more viable solution, it will introduce a further delay to the signal that can reach up to 2 sec in a LAN. This delay is explained, as the time necessary for the compressing algorithm to try and find similarities between a number of frames. The higher the number of frames that it compares and packs, the higher the rate of compression. Unfortunately the same applies for the delay. Furthermore, it will lose some of the original information, that could be necessary for a proper diagnosis.

- High fluctuations on the existing wired network load, introduce both latency and quality degradation on the signal transmitted as, less bandwidth results in more compression.

- As mentioned above, the variable speeds that the IEEE802.11b can choose from, force the developer to select a "preferable" speed for the implementation of the project. Accordingly, the compression algorithm will be chosen to be able to cope with that speed. Therefore, one has to make a site survey of the area that the WLAN exists, in order to determine if there are spots on that area that would reduce the "preferable" speed even more.

- Finally, the top **privacy** and security goal for any Healthcare facility is not to allow people to be inadvertently associated with their unique health characteristics or personal identifiers. That is why a number of position statements have been issued to help members protect their medical information [7]. The developer must design the system in that respect, making sure that even though wireless, the system does not have security "holes".

### VII. FUTURE TRENDS

The future commercialisation of a new WLAN protocol, **HiperLAN/2**, will improve the specifications of such systems.

HiperLAN/2 supports both higher speeds (up to 54Mbps) and, most importantly, QoS. Accordingly, the delays of the video transmission will not only be reduced due to the increased speed, but also due to the fact that the user can choose which applications will have priority over others.

Finally, HiperLAN/2 offers core compatibility with the emerging IEEE1394 protocol. This way, it avoids unnecessary data conversions that result in fps fluctuations.

## VIII. CONCLUSIONS

This paper presents the major concepts of the design and development of a MedLAN system dedicated to a typical A&E ward system.

The research carried out so far has concentrated on modelling a system that allows the transmission of the above data.

It was proven by simulation that due to the enormous amount of data to be carried over the air link, the developer must resort in compression techniques to be able to accommodate a signal more than 100Mbps into a 11Mbps (at the best) channel.

The compression technique to be chosen, must take into account the maximum data rate available; something that is specified by a detailed site survey of the area to be used.

OPNET Modeler 7.0 was proven to be a valuable simulation tool, although there were several factors that it could not take into account.

The next step for the MedLAN project will be the hardware / software implementation of the prototype followed by the clinical testing in the real life environment.

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