ORNET
A Network for the Operating Room of the Future

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For most of the history of medicine, physicians relied on the direct evidence of their senses (primarily vision and touch). Increasingly, however, physicians find themselves relying on ever more sophisticated artificial sensing devices, both to facilitate the performance of diagnostic and therapeutic procedures, and to monitor the condition of patients. Some, like the cameras used in minimally invasive procedures, augment the traditional senses. Others, like pulse oximetry, capnography, or depth-of-anesthesia monitoring, provide entirely different kinds of information.

Unfortunately, the technology used to correlate and process patient data has not kept up with the ability to collect it. During a procedure, medical personnel typically monitor separate streams of data through various 'legacy' proprietary configured devices, often one for each sensor.

Clearly, the "configured device connected by wires paradigm" will not scale as the number of sensors and the number of kinds of sensors increases. We are currently working, with clinicians from the Massachusetts General Hospital, at combining technologies from our previous NTT sponsored research (SpectrumWare and WIND) to attack this problem.

SpectrumWare-based Medical Instruments

The SpectrumWare project was originally aimed at building wireless communication systems

- Can adapt rapidly to specified changes in their functionality or to dynamic channel conditions, and
- Be easily modified to perform unanticipated functions.

It did this by moving the hardware/software and analog/digital boundaries close to the antenna, and then doing all of the digital signal processing in software running on commodity workstations. We believe that this basic idea can be extended to a variety of medical instruments. Consider, for example, an ultrasound machine. It consists of a transducer, hardware and algorithms for processing the signal produced by the transducer, a display, and a user interface.

The SpectrumWare approach suggests that a better way to achieve the same (or better) functionality is to connect the transducer to an A/D converter and a wireless transmitter, put the sample stream on a network, and do everything else in software on PC's sitting on the network. This introduces economies by allowing sharing of resources, e.g., multiple devices can use the same processor and display. It also facilitates innovation by decoupling the algorithms used to process signals from the hardware used to generate the signals. Finally, it opens up the possibility of generating synthetic medical instruments by fusing the signals from multiple sensors.

Wind-based Operating Room Sensor Network

Many sensors are used in the course of a complex surgical procedure, and the number is steadily growing. Not only do the wires connecting these sensors to displays introduce a huge amount of clutter into the operating environment, but also connecting them is increasingly time consuming. Furthermore, in the course of a medical procedure it often becomes desireable to add additional sensors. If the sensors are all to be networked, as suggested above, the process of adding and removing sensors must be made as easy and quick as possible.

The WIND project, which has been funded by NTT, is developing middleware and protocols that will enable applications networks of devices, sensors, and computers to communicate with each other with minimal manual or *a priori* configuration. Many of the ideas in WIND can be readily applied to building our ORNet.

We will use an intentional naming system to help connect applications to appropriate device proxies and device proxies to appropriate devices. We will use location dependent networking techniques to deal with the fact that patients must be monitored not only in the operating room, but also prior to and after surgery. Finally, we will use adaptation techniques developed as part of WIND (and SpectrumWare) to deal both with the fact that an operating room is a relatively hostile environment for wireless communication and the need to reduce energy consumption at the sensor.

Status

Over the nine months, we have established strong working relationships with clinicians and the bio-medical engineering department at the Massachusetts General Hospital. Working with this group, we have developed a preliminary layered ORNet architecture. This is described in an attached working document. A prototype implementation of this architecture is currently underway.

We have also started work on some simple SpectrumWare-based medical instruments. The furthest advanced of these projects is an invasive blood pressure device. Though far from ready for clinical use, we have established a wireless connection from the sensor to the network and demonstrated the ability to track a pulse over the network.