

Wireless Infrared Data Communication for an Intravenous Infiltration Detection System



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BACKGROUND

About 80% of hospital patients in the U.S. require intravenous (IV) therapy, and between 20% to 80% of IV lines fail due to infiltration, a clot in the cannula, an inflammatory response of the vein, or separation of the cannula from the vein.^{1,2} Infiltration of medications during infusion therapy results in complications ranging from erythema and pain to tissue necrosis requiring amputation. At present, visual inspection by the clinical staff is the primary means for detecting IV infiltration.

CW Optics has developed a noninvasive IV Infiltration Detection (IID) system capable of detecting changes in optical properties of the skin due to infiltration. The IID consists of a fiber sensor and an IID electronic module (IEM). The IEM provides the light source to and receives the detected signal from the fiber sensor.

OBJECTIVE

An 800-patient study of the IID system will be conducted at Virginia Commonwealth University Health System (VCUHS) in Richmond, VA, in Spring 2008. The IEM is designed to interface with a PDA (personal digital assistant) that will be carried by study nurses to allow for data collection in the hospital setting. The PDA enables the nurse to initialize patient runs and collect data stored in the IEM. The objective of this task is to develop a method for wireless communication, via an IrDA (Infrared Data Association) protocol, between the PDA and the IEM that ensures full compliance to the hospital's electronic data security standards. After retrieving data from the IEM, the PDA will transmit data to a laptop computer via a cradle and the laptop computer will send the data to a designated server located at CW Optics facility in Seaford, Virginia.

SYSTEM

IEM: It is a self-sustained bedside unit, can be powered by AC or three AA batteries. It contains an Atmel processor, a Zilox SIR transceiver with a microchip MCP2120 encoder/decoder, four Atmel DataFlash memory chips, a Truly 101x81 pixel LCD display, a serial port, an LED, and a detector. The IEM firmware was written in C. Figure 1 shows, from left to right, the IEM, the PDA, and a screenshot of the operating PDA.

PDA: The HP iPAQ hx2495 PDA has a 520MHz Intel PXA270 processor, Windows Mobile 5.0 operating system, IrDA communication, an USB docking cradle, and a rechargeable lithium-ion battery. It was programmed using Microsoft Visual C++ and the Microsoft Winsock Application Programming Interface (API) for IrDA.

Laptop computer: A Toshiba Satellite Notebook was chosen as the central station for PDA synchronization. It has a 1.6 GHz Intel Celeron M processor, three USB connectors, 192 MB RAM, an Ethernet network interface card, and Microsoft Windows XP. The PDA cradle can be interfaced with one of the laptop's USB ports for data synchronization.

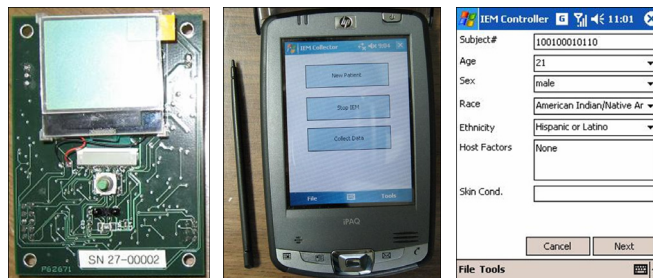


Fig. 1. Left: the IEM; middle and right: the PDA, running the operating software.

FIRMWARE and SOFTWARE

IEM Firmware: The MCP2120 only supports the IrDA physical layer (IrPHY). The IrDA Data specifications³ and IAR C-compiler were used to compile the IrDA communication protocol layers up to the InfraRed Link Management Protocol (IrLMP) layer and the Information Access Service (IAS) layer. The IrLMP layer defines device types and services, as well as transmission channels for the actual data transmission. This is where different devices are identified and perform their main functions. The IAS layer acts as the "Yellow Pages" for the devices. All of the services/applications available for incoming connections must have entries in the IAS which can be used to determine the service address. The IAR C-compiler also was used to compile the CWOptics custom protocol layer (IrCWOptics) which is placed above the IrLMP layer. The IrCWOptics layer supports the 2-way communication between the PDA and the IEM. Its service is specified in the IAS. Figure 2 shows the IrDA communication protocol layer stack and the CWOptics custom protocol layer (IrCWOptics).

PDA Software: An executable program that provides a touchscreen graphical-user-interface (GUI) on the PDA was compiled. It allows the study nurses to input pertinent patient characteristics, i.e., age, race, gender. Easy touchscreen buttons allow the nurses to start/stop a patient run and collect data files saved on the IEM.

Data Synchronization: The iPAQ PDA comes standard with the synchronization software, ActiveSync. A PC-based program was written to supplement ActiveSync for synchronizing data on the PDAs with the laptop. After synchronization, the program transfers the data over an AES-based (Advanced Encryption Standard) internet link to a designated server in CW Optics in Seaford, VA.

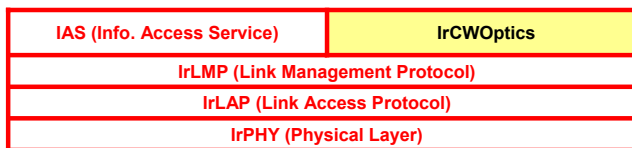


Fig. (2) IrDA Communication protocol layers and CW Optics custom protocol

OPERATION

A patient run is started by the user entering pertinent patient information to the PDA and selecting the start command, which sends the information over an IrDA connection to the IEM. The IEM then begins collecting data from the sensor for up to 72 hours. It is stopped by the nurse when the IV is terminated or when the nurse observes an infiltration. The completed patient run data are collected from the IEM (max. data size 700 KB). The PDAs are put in the cradles at the end of each work day to allow the transfer of data to the designated server and to recharge the PDAs.

The current system includes a laptop serving as the central docking station for the PDAs. It provides a means of communication for up to 10 PDAs, 99 IEMs, and one central docking station in the hospital. For the clinical trial, it is expected that two PDAs, 20 IEMs, one laptop, and one server will be utilized.

CONCLUSIONS

The incorporation of commands on top of the IrDA communication stack on the IEM and PDA results in a highly efficient, secure, and modular custom communication protocol, IrCWOptics. Using custom commands, the PDA can discover, start, stop, and collect data from an IEM.

The IEM will only respond to IrDA devices with pre-specified device names, device numbers, and a sequence of commands sent over the IrCWOptics layer. Authorized clinical personnel will be able to retrieve the encrypted patient data stored in the IEM. Unauthorized IrDA devices and users will not be able to establish communication links with the IEM. In order to demonstrate data security that satisfies HIPAA regulations, this system utilizes AES-based encryption, which is the standard most hospitals use for wireless networks.

This custom software can be adapted to other patient monitoring devices.

REFERENCES

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