Paper

Wireless communication for medical applications: the HEARTS experience

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Abstract— Wireless networks provide all the functionality of wire-line networks without the physical constraints of the wire itself giving an interesting alternative to phone-line and power-line wiring systems. With a wireless network, physicians can actively monitor a patient's vital signs from anywhere in a hospital. HEARTS (health early alarm recognition and tele-monitoring system) is a research project having the major aim to provide support for prevention and monitoring heart disease, based on advanced technology. The HEARTS idea is to gather biometric and environmental data coming from patients during both hospitalization phase and in their normal lifetime activities, using wireless networks. The wireless network and its composing devices are called personal health network (PHN). WPAN and WLAN technologies have been investigated, each with its pros and cons, for use in health monitoring activities inside hospitals and at home, for improving patient mobility, and to provide patients for "last interconnection hop" to the infrastructure network. Technological and operational problems have been addressed concerning bluetooth, IEEE 802.11b (WiFi), GSM/GPRS/UMTS wireless transports, all of them tested and some of them concretely adopted inside the HEARTS framework.

Keywords— bluetooth, wearable 802.11b, wireless networks, sensor data, DSP, medical devices, dehospitalization.

Wireless networks provide all the functionality of wire-line networks without the physical constraints of the wire itself giving an interesting alternative to phone-line and power-line wiring systems. With a wireless network, physicians can actively monitor a patient's vital signs from anywhere in a hospital.

Wireless technologies are generally based on radio transmissions within a network area; radio transmissions comprise of two distinct technologies, using narrowband or spread-spectrum radio. Most wireless networking products are based upon the spread-spectrum technologies. There are three types of network, each one with a different coverage area suitable for different applications:

- wireless personal area network (WPAN);
- wireless local area network (WLAN);
- wireless wide area network (WWAN).

The bluetooth technology, suitable for WPAN, is the result of a cooperation between leaders in the telecommunication and computer industries; it delivers opportunities for rapid ad hoc connections using a low-cost, short-range radio link built into a single microchip.

Bluetooth radios establish radio links in the unlicensed ISM band at 2.4 GHz, using a low RF power of some milliwatts; designed to operate in a noisy radio frequency environment, bluetooth radio modules operate using FHSS (frequency hopping spread spectrum) transmissions, avoiding interference from other signals by hopping to a new frequency after transmitting or receiving a packet. A collection of digital appliances that are connected to a home network via bluetooth technology is called a piconet. A piconet is composed of up to eight devices with one acting as master; all devices participating on the same piconet are synchronized to the same hopping sequence, determined by master. The range of a bluetooth device for typical uses is about ten meters.

Bluetooth has a maximum shared data capacity, in a piconet, of about 1 Mbit/s, which translates to a real throughput of 780 kbit/s once the protocol overhead is taken into account; according to link type and number of other active devices, each device in a piconet will have a capacity varying from 64 to 780 kbit/s.

Specific characteristics or common applications for the bluetooth standard are called bluetooth profiles; examples of profiles are: dial-up networking (DUN), serial, local area network (LAN), headset, file transfer.

The IEEE 802.11 is the worldwide adopted standard for wireless LAN communications, since 1999; the 802.11b extension operates in the 2.4 GHz unlicensed ISM band; with an RF power of 30 mW it can reach 100 m of operating range; it uses a direct-sequence spread spectrum (DSSS) transmission type, and reach data rates of 11 Mbit/s in a single operating frequency; interoperability of different brands 802.11b devices is certified from WECA (Wireless Ethernet Compatibility Alliance) consortium tests; products that pass these tests are stamped with a WECA seal of approval, called WiFi (pronounced Y-Phi) for "wireless fidelity".

The health early alarm recognition and tele-monitoring system (HEARTS) is a research project having the major aim to provide support for prevention and monitoring heart disease, based on advanced technology; the objective of using wireless communications in HEARTS is to reduce the amount of cabling necessary to collect sensor data, and therefore increasing the user mobility in his real-life activities.

The HEARTS idea is to gather biometric and environmental data coming from patients during both hospitalization phase and in their normal lifetime activities, using wireless networks. The wireless network and its composing devices are called personal health network (PHN).

The serial profile used in the personal health network is an emulation of serial communication (RS-232) over a wireless link. Bluetooth modules implementing serial profile can exchange data at a distance up to 10 m.

The wearable device is mainly a data acquisition subsystem, collecting all the data coming from biomedical and environmental sensors; it also apply some basic computation to the collected information, such as filters and data normalisation algorithms.

The bluetooth connectivity in wearable device is realized by mean of customized bluetooth modules; these modules implements serial profile functionalities and are controlled by a set of AT commands. An embedded microcontroller provide both the data acquisition, normalization, digital filtering and bluetooth connectivity logic.

The discovery protocol embedded in bluetooth modules give to the entire personal health network an high degree of adaptivity, because new sensor sets could be seamlessly activated and added to the network at runtime.

The *master station* of the personal health network is called integrator device. It acts like a gateway between the personal health network and the HEARTS core services; it can be deployed on a PDA or a panel PC and provides a link with infrastructure network by mean of a wired (Ethernet) or wireless (WiFi) link. When needed, it could show ECG signals directly to the medical expert, acting like a traditional monitor; no significant interferences were found during the simultaneous usage of bluetooth and WiFi interfaces in HEARTS system.

The combined use of bluetooth technology and WiFi infrastructure, at home, in the office, or in a hospital, is capable to cover all possible monitoring scenarios:

- patient lie on his bed in a hospital room (typical of intensive care units);
- different patients are followed in a limited area (like a cardiology unit room).

Patient not only can lie in a bed, but is also capable to walk across a limited area (like an apartment, a hall, or a court).

Different solutions have been prototypically implemented, in order to evaluate the different scenarios, taking into account the typical throughput produced by a PHN, generally up to 15 kbit/s per second throughput produced by a full-featured personal health network; a single WiFi access point is capable to collect up to 10 PHN data, and when using a 100 Mbit network infrastructure the entire system is capable to collect up to 50 patients data (typical coverage of an entire cardiology unit).

Several WWAN technologies, like GSM/GPRS/UMTS are theoretically suitable for PHN operations, but due to limited bandwidth or technical limitations on using it, like asymmetrical bandwidth of GPRS, implemented to privilege the download functionality more than the upload, they don't perfectly fit HEARTS needs. Even the cost of these technologies is an hard obstacle to the deployment of continuous remote monitoring systems.

The major challenges for the future of the remote monitoring systems like HEARTS are substantially:

- easy setup of network connections and handover (especially for PDAs);
- more computational power for next generation handheld devices (data compression, smart DSP);
- remote control of terminal node (PHN) operations;
- remote control of wearable devices acquisition rate and DSP stuff;
- agreements with major telecom providers to guarantee at-home monitoring using existing and new broadband access at lowest possible costs.

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