The Use of Body Area Networks and Radio Frequency Identification in Healthcare

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INTRODUCTION

Wireless sensor networks have been applied to monitor many phenomena. They were originally designed for monitoring natural phenomena over large geographic areas, such as the SOund SUrveillance System (SOSUS) network for ocean monitoring (Chee-Yee & Kumar, 2003); monitoring of ecological conditions (Szewczyk, Osterweil, Polastre, Hamilton, Mainwaring, & Estrin, 2004); non-invasive wildlife monitoring (Zhao & Guibas, 2004); and for monitoring traffic conditions (Hsieh, 2004). Technological improvements have enabled the creation of small low-power sensor nodes that can be placed on or in the body to monitor medical conditions. Such sensor networks are referred to as body area networks (BANs). Figure 1 illustrates a BAN that collects data from a person and their scale. These data are sent to a health information exchange or database. One example application is for the patient to use this information to help manage their diabetes.

This article will provide an overview of BANs and explain the design requirements for their successful deployment. The BAN provides the ability to locally monitor the patient, but to be effective, must provide this information to the healthcare provider or central medical information system, such as a hospital database. Next, description of security issues related to BANs is presented. The article concludes with a discussion of the areas for future work relating the BAN privacy and security.

BACKGROUND: BODY AREA NETWORKS (BANs)

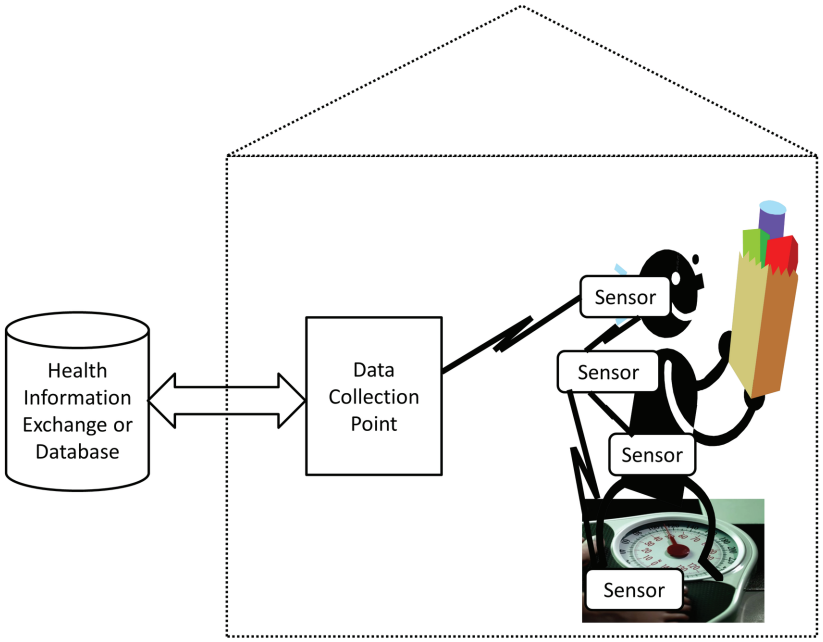
The key issues facing BANs are (1) size, (2) weight, (3) interconnection method, (4) operating lifetime, (5) privacy, and (6) security. Size and weight have been largely addressed by technological improvements in device fabrication for external devices. However, they remain challenges for implantable devices, along with the need for the device to be medically inert. Wireless communication provides a solution to the problem of connecting the nodes together without the use of wires and is especially useful for implanted devices to reduce the risk of infection caused by implanting wires to connect the nodes together. Operating lifetime is currently the most challenging issue facing BANs, especially for implantable components powered from batteries. Privacy is important from two standpoints: first, to prevent unauthorized disclosure of medical information; and second, to prevent cross-contamination of data from one person to another (i.e., person A's BAN reading person B's information and mistakenly acting on it). Finally, security is important from a data privacy aspect and to prevent malicious or unintentional alternation of medical settings within the BAN (e.g. on a pacemaker).

Node Size and Weight

BANs may be composed entirely or in part of nodes that are implanted inside the body. In the case of implanted nodes, the size of the node must be small enough so that the node does not cause physiological problems with the surrounding tissue and organs. While, the package size for integrated circuits (ICs) has been reduced to a level where it is feasible to design implantable nodes,

DOI: 10.4018/978-1-4666-5888-2.ch621

Figure 1. Example BAN to collect data about a patient for disease management



challenges are still present in shrinking the energy harvesting and/or battery pack to a sufficient size for the implantable node. Battery capacity technology has not provided the same size reduction as IC technology has. The battery pack is typically the largest component of an implantable medical device. Energy harvesting techniques such as radio frequency (RF) or thermal (temperature gradient) based techniques often require a large area. The antenna for RF energy harvesting must be sized appropriately to provide good reception at the desired frequency. The amount of energy harvested through thermal energy harvesting is dependent on the temperature difference over the energy harvesting components. Therefore, the thermal energy harvesting component must be large enough to obtain a sufficient temperature change. Thus, the size of the implantable BAN node must be small enough to not cause medical problems, but large enough to provide support for energy harvesting or battery capacity to provide the needed node lifetime.

The weight of the implantable BAN node is important from the medical standpoint and from the comfort standpoint. Medically, the node's weight must be small enough so that it does not put too much strain or stress on a joint, bone, or tissue. From a comfort standpoint, the weight must not make it too difficult for the patient to move.

BAN Interconnection Methods

The operating lifetime of a BAN is often defined as the time between battery replacement or recharging. This is a critical issue for BANs that provide continuous treatment or monitoring because it limits how long a subject can be away from their home (charging station) and significantly impacts quality of life. ZigBee (based on PHY and MAC layers of IEEE 802.15.4), WiFi (IEEE 802.11), WiMAX, GSM, GPRS, Bluetooth, and Bluetooth Low End Extension (Honkanen, Lappetelainen & Kivekas, 2004) are some wireless protocols used for BANs.

ZigBee provides support for a mesh network topology, which can handle the loss of nodes in the network and increase the assurance that messages will be received. This is especially useful in a BAN were the network topology may change due to movement or device failure.

WiFi is an attractive choice because it provides a simple means to connect to a home network (e.g. via a WiFi router). WiFi also provides support for fast data transfer, but is often seen as being too energy intensive for low-power devices, such as those in a BAN.

Bluetooth is another short-range protocol, but is limited in the number of devices that can participate