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Pervasive communications in healthcare

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ABSTRACT

The evolution of wireless communication technologies opened the way to the definition of innovative eHealth systems aimed at providing a continuous and remote support to patients and new instruments to improve the workflow of the medical personnel. This paper presents a survey of wireless communication technologies currently applied in eHealth systems, deeply analysing communication standards, protocols and performance results achieved in this field. The analysis of advantages and drawbacks of current technologies introduces also the definition of new research issues and possible solutions for future eHealth systems.

1. Introduction

In the last few years advances in wearable computing and wireless sensor networks have paved the way to new definitions of eHealth systems, moving from telemedicine to the integration of existent specialized medical technologies with pervasive wireless networks. The innovations provided by these new-generation systems are twofold: on the one hand, the development of continuous monitoring features for the patient and, on the other hand, the improvement of workflows and productivity of medical personnel in the facilities. In both cases the users (patients, doctors and formal/informal caregivers) must be able to communicate and exchange data as much as possible, anywhere and anytime, assigning to pervasive communications a fundamental role in the system. Currently several wireless technologies are involved in eHealth systems, mainly depending on their application scenarios and related system architectures. Patient remote monitoring, ambient assisted living (especially for elderly people), emergency interventions, workflow optimization, instruments localization and inventory represent some of the main application domains. They involve different kind of users and have different system requirements generally identifying two categories of eHealth systems: "*patient-centered*" and "*hospital-centered*" systems. In the first case, all the system components are focused on the patient, by providing him/her with continuous monitoring and medical feedback in the daily life. In the latter case, the final target is to provide additional technological instruments to the medical personnel to improve their performances and workflow organization. To achieve these targets, patient- and hospital-centered systems are characterized by two different system architectures, involving different technological and communication issues. In this paper we present a survey of wireless and mobile communication technologies and protocols currently used in these systems, highlighting main issues, advantages and drawbacks of specific solutions and possible hints for future proposal. To better address the communication part, firstly we present a general description of the system architectures and their evolution in the last few years (Section 2). Then, we deeply analyze wireless communication technologies, protocols and their performances in this application domain (Section 3). Finally, in Section 4, we present eHealth standardization issues and the new proposal of a Bluetooth Medical Device Profile as the new standard for personal eHealth mobile devices that should guarantee the maximum interoperability among Personal Health Systems and their effective implementation in National Health Systems.

2. eHealth systems evolution

Patient- and hospital-centered eHealth systems largely differ in the design and development of their architecture as shown in Figs. 1 and 2. Patient-centered systems are generally characterized by a three-tier architecture composed of: (i) body-worn or implanted sensors, with which the patient is equipped for personal monitoring of multiple parameters; (ii) a Hospital Information System (HIS) for storage and management of health data, generally located in the medical facility, and (iii) a mobile device that generally acts as a personal gateway between the previous two entities. IBM introduced this model in [1] defining the gateway as Personal Mobile Hub (PMH) in order to promote an open standard-based architecture and to encourage manufacturers to build wearable healthcare devices provided with a general application platform. Initially, the main requirement of PMH was to support multiple wireless protocols and inter-device communications. Later its role has been extended, acting also as personal repository to store

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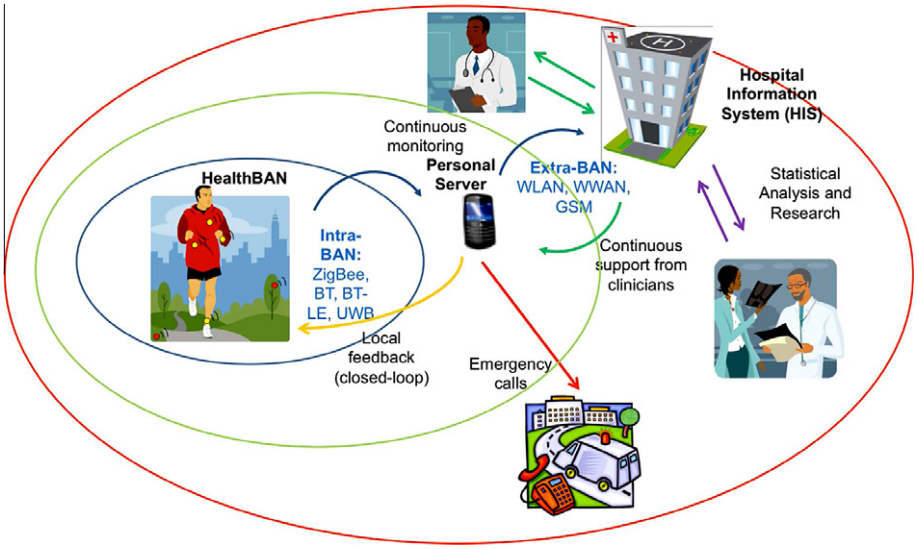

Fig. 1. Patient-centered system.

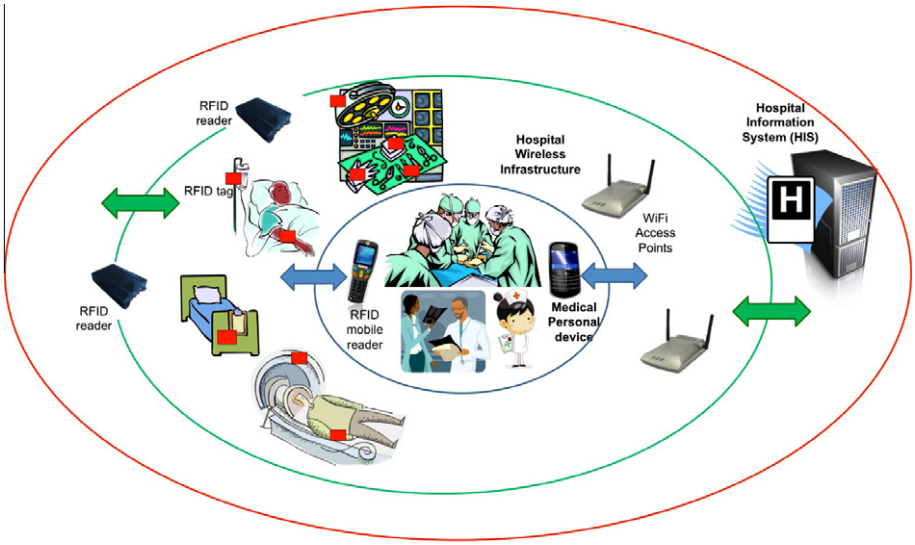

Fig. 2. Hospital-centered system.

several users information (from the usual address book to electronic health records), and enhanced with algorithms of data fusion, aggregation, and elaboration, necessary to give a preliminary interpretation of sensed data, becoming thus a Personal Server (PS) [2]. This model has paved the way to the most part of pervasive healthcare systems designed for remote health monitoring, opening the field to various research areas, from hardware innovations, as new wearable technologies and wireless networking, to new data fusion and elaboration algorithms, making the Personal Server able to provide a preliminary feedback to the patient (e.g., life style suggestions, programming the next check with the physician). In this case event-processing middleware and expert systems have been proposed to develop automated decision support systems (DSS) implementing thus a *closed-loop* approach among the patient, doctors and the PS. In addition, as highlighted in Fig. 1, it is possible to implement a continuous and remote monitoring of the patient, providing him/her with periodical feedback on the health status and possible care plan updates. The use of this kind of systems allows the reduction of clinical checks and hospitalization costs. Moreover, the collection of health data from different patient-centered systems represents a wide and fundamental source of information for the medical research in terms of statistical and epidemiological studies. In fact, the HIS can exploit personal monitoring data of different patients' categories to provide additional diagnostic instruments to the medical personnel.

Even though the architecture of patient-centered systems is so well-defined, actually most solutions proposed in literature mainly focus on specific features, like hardware integrations or dedicated applications designed for specific sets of patients and diseases. Usually they do not provide general features like adaptability to different system configurations and application scenarios. Each system should be able to support the increasing or variable number of involved sensors and devices, generally developed by different companies, and to use different wireless standards and protocols. In addition, only few solutions propose a complete system, addressing issues related to all the layers of the architecture. MEDIC [3] is one of them, presenting a general architecture for a wearable sensor system that can be customized on the individual patient's needs, and a middleware platform aimed at managing