A Wireless Sensor Network for Ambient Assisted Living

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Abstract. This paper introduces a project for PhD Thesis about ubiquitous wireless network infrastructure to support an Ambient Assisted Living (AAL) system. The system integrates a set of smart sensors which are designed to provide care assistance and security to elderly citizens living at home alone. A first approach has been reached by designing and implementing a non intrusive full featured WSN for this specific purpose. This development results were successful but not optimal and opened several new research lines. An step forward is to be taken in the following fields: (1) AAL purpose specific network protocol witch optimizes the power consumption. (2) New adaptive bed/chair occupancy detector based on ElectroMechanical Film (EMFi) transducers to avoid furniture characteristic dependence. (3) Door passing through detector for monitoring always opened doors and avoiding pet disruptions. (4) Optional wearable device that incorporates accelerometers and S.O.S. button for minimizing the system response time. (5) Extended featured PIR sensor for further activity monitoring. (6) Low power *CO* and gas sensors to prevent accidents.

Keywords: Ambient Assisted Living, AAL, ubiquitous monitoring, wireless sensor networks, smart sensors.

1 Introduction

Increasing health care costs and an ageing population are placing significant strains upon the health care system. Small pilot studies have shown that meeting seniors' needs for independence and autonomy, coupled with expanded use of home health technologies, and provide improved social welfare. Difficulty with reimbursement policies, governmental approval processes, and absence of efficient deployment strategies has hampered adopting non-obtrusive intelligent monitoring technologies.

In this field, DIA project - Intelligent Warning Device, from Spanish *Dispositivo Inteligente de Alerta* - aims to develop devices which detect behaviour

patterns from their users and use them to take alert actions when significant variations happened. This project is leaded by the company Ambiental Intelligence and Interaction S.L.L. (Ami2) [1] in collaboration with the Technical University of Cartagena - UPCT, from *Spanish Universidad Politcnica de Cartagena* -, at the sensory layer of the system [6], and with the University of Murcia - UMU, from Spanish *Universidad de Murcia* - at the reasoning and context extraction layers [3]. The first implementation of the system has been brought to market under the brand Necesity [2].

The system integrates a set of smart sensors which are designed to provide care assistance and security to elderly citizens living lonely at home. It facilitates privacy by performing local computation, it supports heterogeneous sensor devices and, at a first step, it provides a platform and initial architecture for exploring the use of sensors with elderly people. A first approach has been reached by designing and implementing a non intrusive full featured WSN for this specific purpose. This development results were successful, but not optimal, and opened several new research lines.

Projects on home health monitoring and telemedicine have been performed for two decades. In the paper of Choi et al. [4], Figueredo and Dias [7] or Eklund et al. [5], Virone et al. [13, 12] home care system project was described. In this paper, we describe an ubiquitous assistential monitoring system at home. We have focused on the unobtrusive habitual activities signal measurement and wireless data transfer using XMesh technology.

2 Current State of the Research

A first prototype scenario has been developed in which a user will have a home assistance system that is able to monitor his or her activity in order to detect incidents and uncommon activities. The prototype house or scenario has a bedroom, a hall, a corridor, a toilet, a kitchen, and a living room. Movement sensors are installed in each location. Moreover, in the bedroom there is a pressure sensor in bed; in the hall, a magnetic sensor to detect the opening and closing of the entrance door, and in the sofa of living room another pressure sensor. All sensor boards have a complementary temperature sensor. The data is gathered from sensors mounted in the home. The sensor events are transmitted by the wireless sensor network to the base station by means XMesh technology (similar to Zigbee). A gateway is also included in the system to allow continuous monitoring. The gateway receives the events from the sensors through base station and decides what the appropriate action to take will be. Options could include querying the user to check on their status, storing (or forwarding) data on the event for future analysis by a assitential care provider, placing a telephone call to a care provider, relative or health care service, or other options.

The main idea consist in monitoring the person living alone in his home without interacting with him. To start, it is needed to know if he is at home in order to activate the ubiquitous custodial care system. It is easy to know by the context if a resident is at home knowing that the entrance door was opened and

movement in the hall was detected. By means of distributed sensors installed in each room at home we can know the activities and the elderly location. On the other hand, as the pressure sensors are located in the bed and the favourite sofa in the living room, we can know more of where he is even if he is not in movement. All this sensory assembly will be ruled by an artificial intelligent software which will allow to learn of elderly diary activities. If the system detects a suspicious event, i.e., movement in any room at 12 a.m and pressure in the bed, then the system give an alert to the caregiver.

The sensor network consists of a set of sensor nodes, to be distributed ubiquitously at home, and a special node that acts as a base station to the PC. The sensor nodes implement the minimum architecture to carry out environmental monitoring activities, develop messages with information about events that occurred and to form a wireless network with mesh topology over which the messages are taken to the PC. These nodes comprise a microcontroller and a radio transceiver specifically for low-power, as well as a set of commercial sensor devices able to pick up the activity at home in a non-intrusive and safe way. In particular, passive infra-red (PIR) sensors are used to monitor the location of the user, pressure-detecting mats under the mattress to detect the presence in bed and magnetic contact sensors to signal the opening of the front door of the house. As introduced, the base station is a node with special characteristics. In this case, no sensors devices are integrated but a USB-UART transceiver to provide the node connectivity to the driver via USB virtual serial port.

The sensor nodes microcontroller is programmed with an application that performs a dual function. On the one hand, the node monitors the activity and pre-processes information captured by sensors to shape events in context. On the other hand, the node acts as a focal point for the transmission of multi-hop messages, forming a whole network with mesh topology. The base station does not perform environmental monitoring but acts as a network coordinator node.

3 Lines of Research in Progress

The current version of the wireless sensor infrastructure uses a general purpose multi-hop network protocol, called XMesh, capable of hopping radio messages to a base station where they are passed to a PC -or other possible client-. It integrates three kinds of commercial sensors that support the basic monitoring needs. These are: passive infra-red (PIR) sensors for activity monitoring, pressure mats for bed/chair occupancy and magnet contact for door opening detection. An specific application is programmed on the nodes to perform a power efficient monitoring for AAL purposes. An step forward is to be taken on the following fields:

1. AAL purpose specific network protocol which optimizes the power consumption. Some features supported by the generic network protocols are not relevant on this specific scenario but increase the power consumption. Primarily, the mesh topology (multi-hop feature) simplifies and guarantees the coverage

in an undefined and potentially wide area. However, supporting the mesh is the main source of power consumption at the nodes, since verifying if another node is attempting to transmit consumes almost the same as transmitting a message. Most of the scenarios of the AAL applications can be covered using a star topology network. The aim of this research line is to design an adaptive network protocol witch began using a mesh topology and attempt to reduce it into a star topology if possible.

2. New adaptive bed/chair occupancy detector based on ElectroMechanical Film (EMFi) transducers to avoid furniture characteristics dependence. The pressure mat is a simple way of detecting occupancy at a bed or chair, but a proper work is dependant on the user weight and some characteristics of the furniture, i.e. the mattress softness or the kind of bed base. The objective is to design a new sensor based on EMFi to provide an analogical weight measurement with a minimal power consumption.
3. Door passing through detector for monitoring the always-opened doors and avoiding pet disruptions. Some users, specially at rural areas, are used to keep some exterior doors opened even when they are not at home. If they leave the house though one of these doors then the system is unable of be aware of it. By the way, the presence of free pets at the house disrupts the user location inference. These two problems are attempted to be solved by using a low power passing through detector for the doors. The application is obvious for the first case and, for the second one, the new detector would be installed at a certain height at every door in the monitored rooms to enable a pet tolerant tracking system.
4. Optional wearable device that incorporates accelerometers and S.O.S. button for minimizing the system response time. This AAL System is designed to work even when the user carries nothing with him. However, the response time can be drastically decreased when wearing a small device that allows the user himself to claim for help if he is conscious and, besides, incorporates a 3-axes accelerometer which provides the reasoning layer with some extra information to make decisions.
5. Low power *CO* and hydrocarbon gas sensors to prevent accidents. There already exist on the market stand alone sensors for this purpose. The aim of this line is to integrate them into the ALL sensor infrastructure. Standard gas sensors typically implies a power consumption issue when integrating them into WSNs. New releases of low power sensors are being studied and adapted to the node architecture.

4 Results

The system has been validated in terms of functionality and acceptance by the user group. This validation was performed using a pilot project of twelve months with one hundred of systems installed in homes of elderly people residing in different towns of the Region of Murcia. It was carried out under contract with the IMAS - *Instituto Murciano de Acción Social* - with the collaboration of social

services from seven municipalities of the Region of Murcia and help from home care companies operating in this territory. Besides, partial results have been achieved in several of the new research lines, introduced at Section 3.

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