

Wireless Monitoring of People in a Home Environment

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Abstract—The consistent increase in the world's elder population has been putting a lot of challenges regarding national development, sustainability of families and the ability of health care systems to provide for ageing populations. As wireless sensing technology continues to evolve, devices integrating low-power, low-bandwidth radios and a modest amount of storage, emerge due to considerable reduced costs. Wireless sensors based home monitoring systems provide a safe, sound and secure environment for elder people, enabling them to live in their own home as long as possible. This work introduces the Elder Monitoring System (EMoS), a MiXiM based framework, in which an Ad hoc On-demand Vector Routing (AODV) protocol has been implemented together with a modified HORUS system, for tracking and monitoring, in a home environment, elder people or people with special needs. The results obtained from this research demonstrate the feasibility to build a monitoring system for elder care using a simulated environment in which several aspects of the hardware commercially available have been also discussed.

Index Terms—Sensor Networks, Elder Care, Routing Protocols, Indoor Location, MiXiM, OMNeT++

I. INTRODUCTION

IN recent years, the increase in life expectancy has been putting a lot of challenges regarding national development, sustainability of families and the ability of health care systems to provide for ageing populations. During recent years the number of people in the world above 60 years has increased from 200 million in 1950 to 670 million, an ageing group that represents already 20% of the world's total population in developed countries [1].

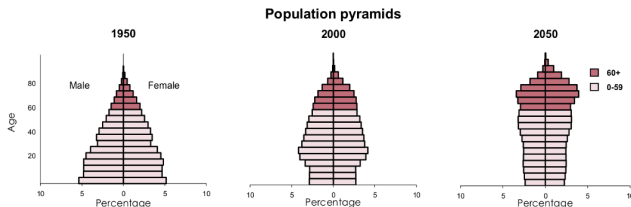


Fig. 1. Demographic pyramids for Portugal between 1950 and 2050 [1].

With the relocation of young people to the suburbs and the low birth rate, the number of elder people who live home alone is increasing. This situation creates a huge anxiety in all

the people involved, resulting many times in early institutionalization in caring homes or other elder care facilities. Also people with physical or mental disabilities present identical caring needs. For example, people with mild mental retardation usually achieve sufficient social and vocational capabilities for minimal self-support. Problems with these people occur because they have trouble getting in/out of bed on time. The lack of overview and planning skills to see that they have to go to bed on time in order to be able to go to work on time the next day.

Creating a system able to monitor people in this situation would allow specialized professionals to dedicate their work to other types of scenarios where a larger dependency would exist freeing costly and rare resources. As wireless sensor technology continues to evolve, devices integrating low-power, low-bandwidth radios and a modest amount of storage emerge with a considerable low cost. With a vast number of existing sensors, ubiquitous applications can emerge as a low cost alternative with huge added value for monitoring people in a home environment, providing a huge symbiosis between man and machine.

This work suggests the development of a system, where one or more persons, carrying a node with wireless capabilities, move around an environment where other wireless sensors exist. The system should be able to identify each individual and allow for communication with a central base station in a bidirectional way.

The rest of this paper is organized in the following manner. In Chapter 2 a research about the state-of-the-art solutions is made with reference to systems that employ video, wearable sensors and home appliances sensors to monitor people in a home environment.

Chapter 3 talks about the related work, focusing on elder people needs in healthcare, through a study where interviews were made to Case Managers (CMs). This chapter also refers to the usage of wireless sensors for tracking and compares routing protocols.

In chapter 4 the work environment for the simulation is presented together with the difficulties in getting a simulator that can achieve a high degree of accuracy while simulating movement, obstacles and wireless sensor networks.

In chapter 5 the Elder Monitoring System (EMoS) is presented together with an evaluation of real hardware options commercially available, capable of implementing the system in real

conditions.

Chapter 6 discusses and analyses results from the simulation. Conclusions and future work are presented in chapter 7.

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II. STATE OF THE ART

A. Monitoring using Video or Audio

Current smart home environments consist of several appliances and other devices, with sensors, actuators and/or biomedical monitors. These systems are used by the residents in a daily basis. In some situations the house is monitored using video and audio technologies, even tho they present some disadvantages like: high costs due to sophisticated equipments and specialized deployment, the need for a large bandwidth or privacy issues. Several state-of-the-art solutions were reviewed. In [2] falls are detected. In order to reduce the number of false alarms, the system integrates a WSN and a video system. Cameras activated by a wireless sensor tracking mechanism, are able to interpret the video signal and make decisions whether to call an emergency number or not. A voice communication IEEE 802.15.4 is also discussed through the usage of state-of-the-art radios capable of transmitting voice. In [3] and [4] an installed surveillance system is used to infer about the position of a resident. No interaction with the system is needed in order to locate the person. The usage of *Smart Cameras* allows to resolve the privacy issue of data transmission through air, with the possibility of spoofing, which would present serious security concerns to the user.

[5] deploys another monitoring application in a care home. It refers to the need for more healthcare professionals and the small amount of time that each one of them has available for each elder. The volume of biomedical data gathered can improve the way that the case manager follows it's dependent. [6] refers to the term *aging in place* which represents a movement where elders live in an independent and safe manner in their own homes. Monitoring of falls but also utilitarian functionalities are implemented such as object detection, calendar, video-conference and address book. [7] uses video and audio to correctly deduce if a fall has happen.

B. Monitoring using Wearable Sensors

The reduction in size of wireless sensors is bringing to the market solutions that can track a person's health, independently of his location or activity. The possibility of smart clothes with built-in sensors sufficiently small and light to be carried without any discomfort, enable the mass usage of such equipments in a medium term. In [8] the Body Sensor Network (BSN) is addressed, as a solution to early detect heart problems with sensors capable of measuring temperature, acceleration or building an electrocardiogram all connected to a central coordinator node using Bluetooth (Figure 2). [9] discusses the need for three types of priorities for messages in a WBAN: *On-demand* requested by a doctor or physician in order to monitor the patient vital signs, *Emergency* initiated by the sensors when some critical threshold has been exceeded and *Normal* with the lowest priority. In [10] it is discussed the problems that arise from the usage of Zigbee in a crowded

WLAN environment. An algorithm is suggested to solve this issue in which the Zigbee forces an AP to leave from an occupied frequency.

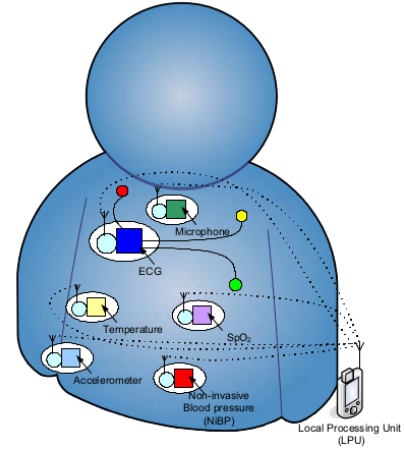


Fig. 2. Example of a Body Sensor Network (BSN) [8].

[11] suggests the integration of several networks into one integrated platform able to track a person in the interior or exterior enabling all the case managers to be constantly aware of their patient. The same paper also refers the need to develop sensors that don't present any discomfort to theirs users, since that might be a very strong reason for not wearing sensors during a long period of time.

C. Monitoring using domestic sensors

In this type of monitoring, information is gathered anonymously, using sensors with very minimal computational capabilities. Proximity sensors or sensors installed in home appliances are accessed in order to understand if the person is at home or has passed through a certain corridor. This type of monitoring has less granularity, which can be a problem if more information is needed. [12] uses pressure sensors to help Alzheimer's patients reaching their destination inside house through the use of TV screens. *MediaCup* is introduced in [13] as fully ubiquitous device. With a battery capable of charging using an electromagnetic field, the *MediaCup* is fully hidden from user and coupled with a few sensors that can track, for instance, movement or acceleration (

A lot of research has been done focusing falls, vital signs tracking and ubiquitous computing. The recent development in BSNss has brought to the scene new sensors and new concepts that can even be used for entertainment. Also the need for unobtrusive equipments and the lack of privacy of devices that store too much information, like cameras is a problem to be discussed.

III. RELATED WORK

A. Elder Home Monitoring

In study named 'The Activities of Daily Living Study' presented at [14] several questionnaires were delivered to Case Managers (CMs) (professionals that give assistance to elder people living at home). This study refers to the existence of a

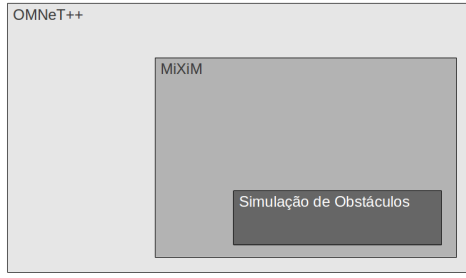


Fig. 5. Modular overview of the work environment.

capabilities. Some of the reasons that make OMNeT++ the most obvious choice are: the modular hierarchical design, which can be combined for reuse and flexibility, the Object Oriented approach, the C++ internal structure, Network Description (NED) language for module building and a auto-animated environment. MiXiM in turn provides a complex channel losses model, which for indoor environments allow us to achieve close to real values and several MAC and NIC models for the IEEE 802.15.4. Finally the simulation of obstacles was obtained using a MiXiM modification [26] that implements a simple obstacle model given by:

$$L_{obs}[dB] = \beta n + \gamma d_m \quad (1)$$

with attenuation per meter βn and attenuation per wall γd_m configurable using a XML file.

In this work the following values were used:

Profundidade(cm)	β (dBm)	γ (m)
20	106.3	0
10	26.575	0

TABLE I

V. SYSTEM ARCHITECTURE

A. Elder Monitoring System EMoS

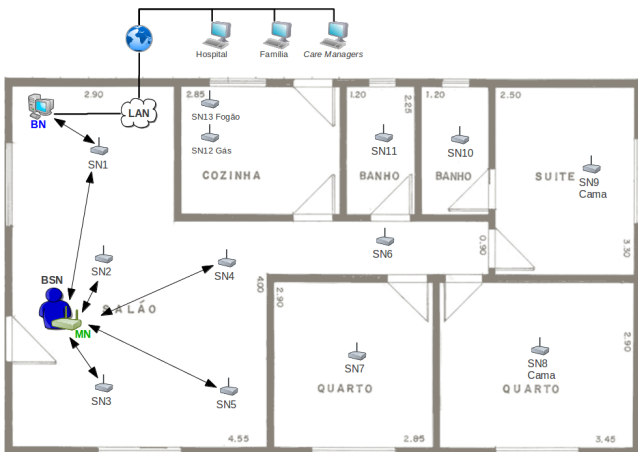


Fig. 6. Model structure of the Elder Monitorization System (EMoS).

EMoS is comprised of three types of nodes: Static Node (SN), Mobile Node (MN) and Base Node (BN). These nodes

all have distinct roles in the network.

The MN is a sensor equipped with two radios, one IEEE 802.15.4 and another Bluetooth for connection with a BSN. It can be installed in a walker or a wheelchair. It has the ability to communicate with all the other nodes in the WSN and to record static node signatures for localization tracking.

The SN is a sensor equipped with one radio IEEE 802.15.4 capable of sending messages when connected to a stove or a bed pressure sensor and establishing communication with all the other nodes in the WSN. All static nodes are connected to the power network and don't need any batteries.

The BN is a USB IEEE 802.15.4 gateway and is connected to a PC. It has the largest computational capability in the network. It is responsible for coordinating all the WSN, communications with the exterior and tracking all the mobile nodes detected.

All nodes share the same CSMA MAC layer and have an AODV custom build for this simulation Network Layer. The application layer differs accordingly to the node role.

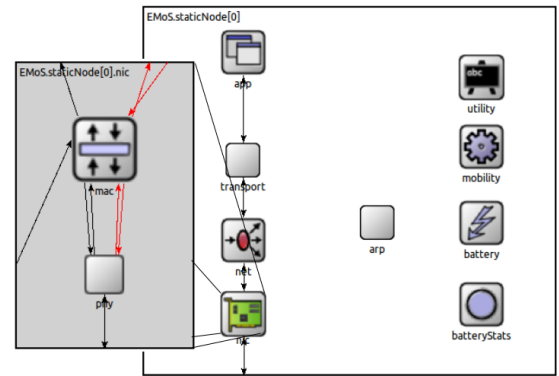


Fig. 7. Internal structure of a EMoS node.

Two types of radios exist in the simulation: the *Texas Instruments CC 2420* and the *Digi XBee*, with the following parameters, which are used to configure the NIC in each node:

Parâmetro	Valor
Modulation	O-QPSK
Receiver Sensitivity	-92 dBm
Transmit Power	1mW
Sleep Current	<10 uA
Current Consumption RX	50 mA
Current Consumption TX (P=0dBm)	45 mA

TABLE II
RADIO *Digi XBee*.

Parâmetro	Valor
Modulation	O-QPSK
Receiver Sensitivity	-95 dBm
Transmit Power	1.1mW
Sleep Current	0.02 uA
Current Consumption RX	18.8 mA
Current Consumption TX (P=0dBm)	17.4 mA

TABLE III
RADIO *Texas Instruments CC2420*.

In the online phase the MN collects all the signatures during a certain amount of time. When that time is over it calculates the mean signal strength for each static node received and sends the result to the closest SN.

The SN in turn sends to the BN (Base Node). Note that if no route is available the network layer will find one using AODV. When the message with the static nodes samples arrives to the BN it will be used to infer the MN position. This will be made using firstly a discrete-space estimator and afterwards a continuous-space estimator. The discrete-space estimator can only determine a position available in the radio map while the continuous-space estimator allows all the other points.

All correlations modules are simple mean operations.

Therefore when the message arrives to the discrete-space estimator it's joint probability is calculated as:

$$P = \prod_{j=1}^n P_i \quad (5)$$

where P_i is:

$$P(s_i \leq 0.5) = P(Z \leq \frac{s_i + 0.5 - \mu}{\sigma_i}) \quad (6)$$

The position with the largest probability wins and is considered the position where the mobile node is. But, because the discrete-space estimator only allows the positions stored in the radio map it is necessary to use the continuous-space estimator to improve the accuracy of the estimated value.

Two techniques are applied: Center of mass of the positions and Time-averaging in the physical space.

The first uses the other smaller probabilities calculated to triangulate a new position, using the following equations:

$$x = \frac{\sum_{j=1}^{\min(N,P)} x_i P_i}{\sum P_i} \quad (7)$$

$$y = \frac{\sum_{j=1}^{\min(N,P)} y_i P_i}{\sum P_i} \quad (8)$$

The second uses previous stored estimated positions to get a mean value of the new position:

$$x = \frac{\sum_{j=1}^K x_i}{K} \quad (9)$$

$$y = \frac{\sum_{j=1}^K y_i}{K} \quad (10)$$

This makes a reasonable approach to the real positions. HORUS authors affirm to get 0.86 m in 90% of the cases in a real test-bed.

VI. CONCLUSION

In order to get a simulation the closest to reality, it was necessary during the course of this thesis, to find solution that would me limited to simulating isolated aspects of the problem, but all the complete set of functionalities that would allow for a close to real simulation.

A big part of this problem was solved by finding MiXiM, but the lack of a good routing protocol and node tracking system, made it clear that it was necessary to find such a solution.

This thesis allowed the development of a fully integrated system, called EMoS that would allow further work and resolve the issues that arose.

In the future a better solution for the tracking system can be found, removing the need for an offline process, which would be very time consuming in real conditions.

Another possibility is the implementation in the node of parallel stack of layers that would allow the same node to communicate with a bluetooth network, extending the simulation to a BSN network simulating biologic events like heartbeat or blood pressure.

The improvement of the obstacles model could also be achieved in order to get better simulation parameters.

ACKNOWLEDGMENTS

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