

A Smart System to Support Proximity-Based Solidarity in Corsica

SmartAngels

Eric Innocenti, Dominique Urbani, Marielle Delhom, Pierre Regis Gonsolin, Paul-Antoine Bisgambiglia

Abstract — The purpose of this paper, is to provide a solution to the issue of dependence for elderly people in the context of an ageing population phenomenon. In rural areas with a low population density, isolation has negative impacts on everyday life. In France, the ageing population raises the fear of a serious increase in the number of persons suffering from disabilities and in need of assistance. In Corsica, population ageing is substantially increasing. Given this critical context we are trying to develop a system of connected objects called *SmartAngels* to support proximity-based solidarity. It consists of a meshed network of autonomous ZigBee microcontrollers, in which various actors can exchange information by means of an accurate interface design. Its main task is to support both proximity-based solidarity and social relationships in rural environments. Moreover, the SmartAngels device grid ensures optimal neighbourhood solidarity in case of a serious problem by creating a community of actors. First aid can be provided by neighbouring people alerted by the system, thus allowing to efficiently handle the distance to civil protection assistance, and to overcome technical limits in areas where telecommunication networks are either underdeveloped or saturated. In this work, we present a *SmartAngels* system prototype allowing to handle the social link and launch alerts in rural environments with a low density of population.

Keywords — Connected objects, WSNs, ZigBee application, *SmartAngels* system.

I. Introduction

An overall improvement of living conditions and health are the main causes of the process of population ageing. This phenomenon affects populations all over the world in developed countries. The number of elderly people over 60 is the most rapidly developing. Currently, most countries have completed their population's demographic transition, *i.e.* when populations with high birth and death rates meet the threshold of populations with low birth and death rates. In theory, all populations in all countries will evolve according to this trend. When the natural increase becomes negative, it leads to the population ageing problem, sometimes even to a population decline.

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In the next few years the whole world population will have to face this issue. While all nations achieve their population's demographic transition as a result of the steady progresses of medicine and a longer life expectancy, the population ageing process causes major social effects as regards economics and health. For example, there is a deep restructuring of consumption related to these older consumers. In fact, the consumption relations change with year-classes and life-stages such as birth, studies, divorce, retirement, health, etc. There is an increasingly strong emergence of individualisation of demands, especially in terms of health. In this paper, we are more particularly interested in solving the issue of dependence for elderly people in relation to the ageing population process phenomenon in Corsica. *Wireless Sensor Networks* (WSNs) are a promising technology for in-house tele monitoring of patients [8, 19, and 20]. They are usually based on a technology relying on small range communications *ZigBee/802.15.4* [9, 21] for the implementation of a network. The main advantages of *ZigBee* are its low cost and low power consumption, as well as its ability to pay great attention to energy efficiency and communication extra costs in network service applications [10, 11, and 12]. In this paper we are developing a *ZigBee*-based tele monitoring system for elderly people in low population density areas in Corsica. We present a connected objects system called *SmartAngels* consisting of a meshed network of autonomous *ZigBee* microcontrollers, in which various actors can exchange health-related information. This paper is organized as follows: section 2 gives the context overview of this research. The *SmartAngels* project is presented in section 3. An overview of the ZigBee standard, hardware design and perspectives, are presented and discussed in section 4. The current work is concluded in section 5.

II. Corsican demographics

In France, population ageing raises the fear of a serious increase in the number of people suffering from disabilities and needing assistance. More and more people are to face the need of assistance for his or her partner. It will be more and more difficult to assume this dependency. The uses of professional help or specialized institutional placements tend to develop. In Corsica, population ageing has been increasing since 1999 and the process of population ageing is greater than at the national level [1]. On January 1, 2009, the Corsican population amounted to 307,000 inhabitants, with 35.4 people per square kilometre.

TABLE I. CORSICAN POPULATION EVOLUTION THESE LAST YEARS [1].

Period	Percentage	Total population
1990 to 2009	+ 61.73 %	+ 11 709
1990 to 2000	+ 17,71 %	+ 3 359
2000 to 2009	+ 37,4 %	+ 8 350

This population density is the lowest in metropolitan France. There is clearly a need to consider an increase related to dependency due to the growth of dependent elderly people (cf. Table I).

There is a widely positive demographic trend of people aged over 60. In particular, we observe a consequent increase of elderly people over 75 in the last ten years. This increase is 2.5 times more important than the one that occurred between 1990 and 2000 [1]. This phenomenon is more pregnant in the male population where the demographic evolution substantially increased between 2000 and 2009. This, related to the fact that the number of elderly people between 40 and 74 years also tremendously increased, suggests a growing increase of older people over 75 in the next decades. This will result in an increasing number of dependent elderly people in Corsica.

At the same time, in our modern societies, people live more in cities, they leave country sides, and small businesses are progressively vanishing. In rural areas with a low population density, people isolation increases and has negative impacts on daily life (isolation, sickness, etc.). For elderly people, there is a higher risk of dependence, and home care is difficult and often not suitable. Moreover, in these areas, it is frequent to observe the disappearance of solidarity, or at least, a proximity-based solidarity reconfiguration [2]. Over the last few years, the emergence of technologies related to connected objects has seemed to give technical solutions to these issues related to both an ageing population and isolation [3, 4]. The use of these technologies reassure by allowing people to be monitored. However, they must be used in addition to a human presence. In fact, other people's attention remains a necessary condition, in particular in the case of home care services for elderly people. In this case, connected objects are sources of opportunity and innovation for companies [5, 6]. They are now available and generate huge amounts of data [7]. Connected objects all converge in many areas: computer science, networks, electronics, Big Data, usability, marketing and sociology. However, among these connected devices, few can be run in countryside areas, where access to telecommunication networks is limited or absent. In this work, we present the *SmartAngels* system so as to manage the social link and alerts in rural areas with low population density. Our design and build approach (from electronics to mobile applications) will allow to identify the main difficulties related to the development of connected objects.

III. The SmartAngels project

A. Description

SmartAngels is a system based on connected objects, aiming at easing home care for elderly people, and allowing an immediate intervention of neighbours if necessary. *SmartAngels* is designed to be used in « blank areas », in the case of an interruption or saturation of cellular networks. It may also be used by first aid teams in case of a major disaster such as earthquakes. Currently, all existing home care solutions available on the market depend on landlines. In case of emergency, the person activates the system by means of a button, a watch or a connected pendant, and a phone dialling system contacts rescue services over a landline. The drawbacks of current systems are:

- The need to use a landline phone service in working order;
- Varying first-aid response times;
- Congestion of both first-aid and phone networks, in case of a disaster;
- Person dehumanization and isolation, whose security depends on machines.

The *SmartAngels* system allows the following enhancements:

- A network service operating despite the unavailability of landline phone network;
- Neighbours' intervention, improvement in response times, and if needed emergency call;
- Fighting against social isolation and dehumanization, creating solidarity-based communities;
- A system adapted to countryside areas and urban centres where many persons live alone.

The *SmartAngels* system allows to sustain proximity-based solidarity and launch critical alerts needing quick first aid intervention with emergency devices (emergency buttons, GPS-ZigBee *AngelWatch*, etc.). Fig. 1 is a picture of our latest prototype device.

B. SmartAngels Specifications

The *SmartAngels* system is a prototype network of connected objects. It relies on a meshed network of autonomous *ZigBee* microcontrollers, in which various actors can exchange information in Corsican mountain areas.



Figure 1. SmartAngels prototype device.

For that, we use two telecommunication networks that are both redundant and autonomous. On the edges of coverage areas, the gateways are connected to reachable public telephone networks (2G/3G/4G/5G?). They allow to communicate in case of emergency. The *SmartAngels* community actors can take action to provide first aid while waiting for civil protection assistance. Thus, thanks to network meshing, the *SmartAngels* system ensures an optimal neighbourhood solidarity, and the actors – or first responders – of the system can efficiently help to coordinate emergency management during a crisis. The *SmartAngels* system allows to overcome technical limits in areas where telecommunication networks are underdeveloped. An example of *SmartAngels* system architecture is illustrated in Fig. 2.

C. SmartAngels Device

SmartAngels are small, autonomous, configuration-free devices, powered by rechargeable batteries. Mobile devices can incorporate a *GPS* chipset. They can be connected to alert triggering devices such as bracelets or pendants. These objects communicate with each other using a meshed *ZigBee* network. Each device can communicate directly with a smart phone using *Bluetooth* to send or receive messages from other devices which are then forwarded by the *ZigBee* network. Each device has an *LCD* screen displaying essential information, interface buttons (command and SOS), sensors (smoke, CO, CO₂, temperature, humidity, luminosity), cf. Fig 1.

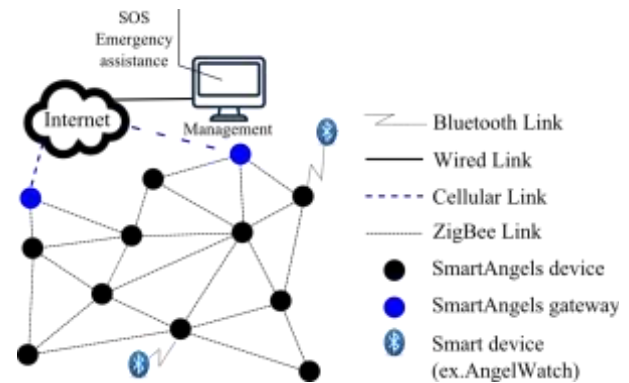


Figure 2. The SmartAngels system infrastructure.

D. SmartAngels Gateway

SmartAngels gateways communicate with devices using *ZigBee*. These nodes are connected to the Internet via a gateway module (Ethernet, GPRS) in order to call first-aid services or simply to have communication with a device outside the area (cf. Fig 2). A *SmartAngels* gateway is used as a back office to centralize alerts, to manage collected data and to monitor the system.

IV. Experimentation

A. Overview of the ZigBee standard

The *ZigBee* technology aims to seek short distance communications between many devices, such as that dedicated to remote controls. Its protocol describes a wireless communication which is standardized by the Institute of Electrical and Electronics Engineers (IEEE). It uses the 802.15.4 standard and globally operates in the 2.4 GHz frequency band, thus it is not country-specific. *ZigBee* supports three different network topologies (star, tree, mesh). Each of them has its own advantages and can be adapted according to its final application. When the protocol is implemented with a power-saving application mode and with the low data rate of 250 Kbps, it allows *ZigBee* devices to have a low energy consumption. *ZigBee* technology is chosen in this work because it is cheaper and easier to develop than the other competitor technologies for low power wireless devices. For interested readers, see [13, 14, 15, and 18] for more precise comparison information on wireless device technologies. The main features of the *ZigBee* standard are summed up in Table II.

B. Hardware design

We built a system of 12 *SmartAngels* prototype devices for experimental purposes. The development of efficient *SmartAngels* devices involves real *in situ* experiments. In fact, *ZigBee* material, environment and configuration should be very different, but also very decisive to guarantee the operation efficiency of a wireless system [16].

TABLE II. ZIGBEE KEY TECHNICAL FEATURES.

Technical feature	ZigBee
Memory requirements	4-32 KB
Bits per second	20-250 Kbps
Max. Theoretical Signal range	10-100 metres
Power consumption	35.706 mW
Number of nodes	More than 64,000
Bill of materials (BOM)	about \$10

To evaluate the feasibility of our system in its intended application, we will perform a number of experiments from November to December 2017. We will use *SmartAngels* devices in a remote rural village of Corsica. The usual sets of experiments will be conducted to study: (1) node connectivity, (2) packet loss rate and (3) transmission rate.

The scenario consists in monitoring the evaluation of performance for the two topology networks: star and mesh (cf. Fig.3). The system will include several nodes carrying data from temperature and humidity sensors. Our main purpose is to show that *SmartAngels* can work well in a real environment over an extended period of time. For the test, 24 sensors will be deployed in different rooms of houses. One of the nodes will be a coordinator, and all the others will be sensors with routing capability. Each *SmartAngels* prototype is equipped with the open source electronics prototyping popular platform *Arduino Uno*. This later adopts an *ATmega328* single-chip Atmel© microcontroller combining the Atmel 8-bit AVR RISC-based microcontroller, 32 KB ISP flash memory, 1 KB EEPROM, 2 KB SRAM, 23 general purpose I/O lines (for more features [22]). The visual user application interface includes 2 buttons (a red one and a green one). The red button is used to send SOS messages (cf. Fig. 1). An LCD display is used to show system messages and error codes. The RF module of each device is designed using the IEEE 802.15.4 compliant transceiver *Digi XBee®* series 1 connected to an on-board 2.4 GHz chip antenna. The 2.4 GHz band is used because it has the highest data rate with more channel options, and consumes the lowest amounts of power [16]. The RF module can be switched to an external antenna via a standard SMA connector for a better performance if needed. A sensing module with two sensors for temperature and humidity is in charge of detecting environment conditions. *SmartAngels* will be powered with Li-Ion battery with a DC input range from 3.5 to 5.5 V. The experimental results will be presented in a next paper.

C. Perspectives

A lot of work shows that the *IEEE 802.15.4/ZigBee WSNs* is a promising alternative to wired systems for patient monitoring [8, 17, 20, and 21]. In this context, we will work on carrying data from wearable electrocardiogram (ECG) sensors with the *SmartAngels* system.

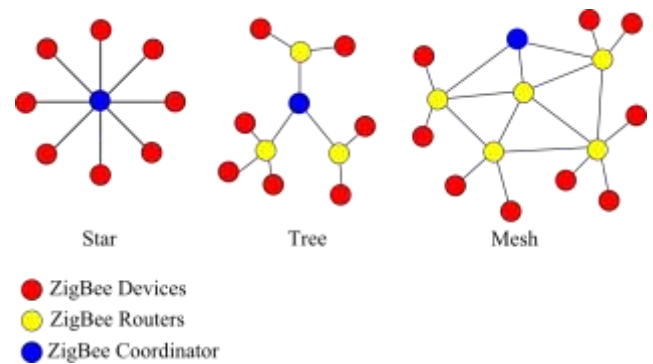


Figure 3. ZigBee network topology.

For that, we plan to develop connected clothes (*SmartClothing*), using *Bluetooth Low-Energy (BLE)* technology. *BLE* as a low energy version of *Bluetooth* is a promising technology [18]. Isolated persons presenting a high risk of cardiovascular diseases will be rapidly helped. Then, the *SmartAngels* system will fully play its role by ensuring proximity-based solidarity.

V. Conclusion

This paper proposed an intelligent system prototype to support proximity-based solidarity and social relationships in rural environments with a low density of population. Real-time detection of *SmartAngels* prototypes shows a potential for it to be used as an information and communication technology platform also allowing the delivery of healthcare services. Our future works will have to meet the challenge of sending healthcare data such as the ECG of monitored patients with cardiovascular issues. From November to December 2017, we will use *SmartAngels* devices in a remote rural village of Corsica to conduct a set of experiments. Results will be published in a future paper.

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