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Casattenta: WSN Based smart technology

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Abstract: *"Casattenta" (Aware home, in Italian) is the demonstrator of a research project on "Ambient Intelligence", "Sensor Fusion" and "Wireless Sensor Networks". The result is a system composed of fixed and wearable sensor nodes, providing elderly people living alone in their house (but also persons in other situations and environments) with adequate and non intrusive monitoring in order to improve the quality of their life. The system consists of fixed smart sensors distributed in the environment and wearable ones monitoring inhabitants health and activity. The interaction between fixed and mobile nodes, based on the ZigBee wireless protocol, allows indoor tracking and identification of dangerous events. CR Categories: C.2.4 [Computer-Communication Networks]: Distributed Systems—Wireless Sensor Networks; J.m [Computer Applications]: Miscellaneous*

Keywords: *Ambient Intelligence, Smart Home, Wireless Sensor Networks*

I. Introduction

Thanks to the enormous progresses in many scientific fields, life expectation in many countries has markedly increased. In particular, in Europe the faction of over 65 y.o. persons reaches the 16% of the whole population [1]. Among these elderly people, about 90% qualifies as "autonomous community-dwelling", namely persons living at home and conducting independent life. Such people feel more comfortable in their familiar environment, in spite of the fact that, in general, they need some assistance, monitoring and companionship. From these points of view, their choice makes it difficult for their relatives to provide immediate help in case of need. In this context, Ambient Intelligence can play a great role in providing adequate (tele-) surveillance aimed at improving their quality of life, without compromising their privacy. In particular, recent technology advances in wireless communications, miniaturized sensors, intelligent garments [12] and low-power electronics [2][3][4] have made it possible to introduce significant amount of intelligence into the ambient, while ubiquitous computing and embedded systems for diagnostic and monitoring of both people and environments have been exploited to create assistive spaces [13]. In this context, several projects have been dedicated to the implementation of smart homes, in most cases new rooms or buildings [8] [9] [10], but the proposed electronic systems required considerable (and undesirable) deployment work. In such projects, often volunteers lived for some days of the week in a sort of sensorized accommodation, treating it as a temporary home, though it was really a living lab [11]. The work presented here, called "Casattenta" is an Ambient Intelligence system, applying Wireless Sensor Networks (WSN) technology to monitor elderly persons in their house in order to recognize events (falls, reaction incapacity, immobility,…) needing immediate assistance. Because of its WSN technology, the system proposed here does not require substantial installation work, hence it can be easily and economically deployed also in existing and even old houses.

The system is conceptually composed of two parts: a fixed and a mobile one. The former features a number of "Monitoring Nodes" (MNs) powered by the house main supply and implementing all functions normally required for home security and safety (anti-intrusion, gas leaks, temperature control...). Additional functionalities, in particular for energy savings could also be implemented. The system fixed component is able to communicate with the other part, formed by a few "mobile" nodes, here called "Active Keys" (AKs), each worn by one of the house inhabitants. These mobile nodes, of course powered by batteries, contain sensors aimed at capturing the wearer's activity, for instance aimed at specific pathologies, could be added if needed.

When a "scenario" possibly requiring attention (for instance, a fall followed by stillness or a voice call for help) is recognized, the system reacts making the interested AK to vibrate. If aware and not in need of help, the wearer can stop any further action by simply pushing a button. If this is not the case, after another trial to get a meaningful reaction, the system sends a message to a call center (and/ or to the wearer relatives) asking for attention and help. Up to now, Casattenta's hardware and control software has been developed as a prototype and only a few "scenarios" have been implemented. As far as data treatment is concerned, when no help is needed, no information is stored in order not to affect persons' privacy. However, if needed for medical treatment, continuous collection of data on the activity and habits of the monitored persons is possible. In this, and many other aspects, the Casattenta system could be expanded to cover an increasing number of needs, in

order to make houses safer, more comfortable and "aware" of the needs of its inhabitants. Furthermore, it can be suitably adapted to cover other applications, such as, for instance, monitoring of industrial or hospital environments; biomedical; logistics and transport. For these reasons, the interest of this work extends well beyond the limits of the specific, though important, application described in this paper.

II. System's General Description

The Casattenta system exploits sensors and wireless technologies to implement a concept of an indoor environment aware of significant events related to the ambient and/or inhabitants and capable to communicate remotely with interested observers. The system is mainly based on WSN technologies that can be easily deployed in existing and even historical building without major intervention in the house infrastructures. Furthermore, the main features of such networks are their capability of self-organization, scalability, low power consumption and relative low cost.

The overall system is flexible and easily adaptable to different requirements in terms of sensors' type, number and functionality. In addition, it makes use of low-cost standard heterogeneous technologies, such as a Wi-Fi infrastructure communicating with both ZigBee (Texas Instruments Platform) and TinyOS based motes (TmoteSky Platform) as well as, when required, with a GPRS gateway.

Casattenta was created for a home-like context in order to make the domestic environment interactive and safer. The system users (people particularly exposed to risk of domestic accidents such as elderly, but also impaired people, children...) will hereafter be called "interactive guests", because they can at every moment interact with the smart environment, for example sending out requests for help. Each of such "guests" is furnished with an AK, based on commercial components able to communicate wirelessly using a 2.4 GHz transceiver, compliant with the ZigBee standard. The AKs are also provided with some sensors and actuators allowing the interaction between the user and the Casattenta system that is able to identify the occurrence of particular events and react with appropriate responses.

The fixed part of the system is composed of MNs implemented with devices similar to the AKs, but featuring different sensors. Furthermore, the system features a central control and communication unit, hereafter denoted as "Home Gateaway" (HG).

The system is flexible and configurable in that it is possible to change kind, placement and number of sensors according to the need. The AKs and the MNs form the Casattenta's sensorial system, while the HG is the center for data collection and processing, constituted by a Java application which manages the graphic and sound interfaces and controls the whole system (Fig. 1).

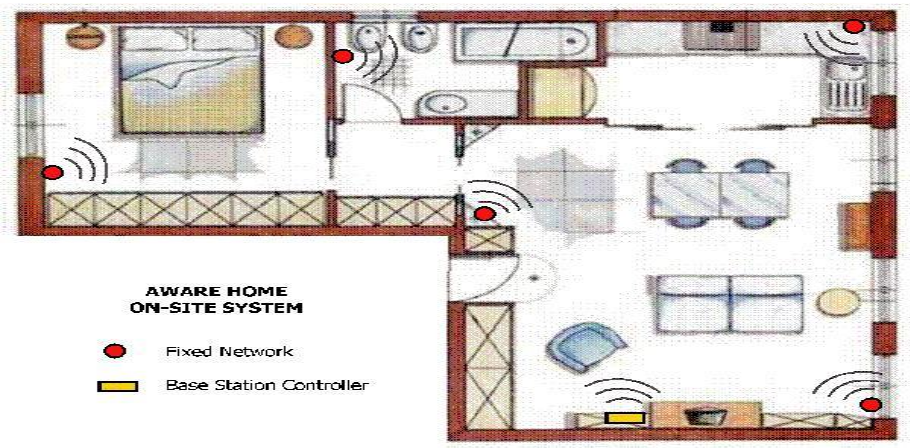

Figure 2 – Casattenta's Wireless Sensor Network architecture

III. Hardware and Software architecture

3.1 Fixed and Mobile Networks

The Casattenta MNs are installed in the house and allow all the monitoring functions of an advanced home system (e.g. access control, gas leaks, lightings, noises, opened windows, humidity, temperature, etc.). The system is easy expandable, reconfigurable and programmable to cover necessities that can emerge after installation.

The AKs are worn by users and enable to monitor the wearers' localizations, physiological parameters and activity. This part is made of small terminals worn unobtrusively in the pocket, on the belt, around ones neck, etc.

3.2 Hardware basic characteristics

The first implementation of the Casattenta system was based on the commercial wireless modules TmoteSky [5] that allowed to test and customize the WSN. TmoteSky modules are equipped with a Chipcon Wireless Transceiver (250kbps, 2.4GHz IEEE 802.15.4), an integrated antenna and a low-power microcontroller (TI MSP430). Moreover, they feature a few optional on-board sensors for humidity, temperature and light. Furthermore, it is possible to connect other kinds of sensors and actuators. In particular, we provided each AK with a MEMS tri-axial digital accelerometer (by ST Microelectronics) and a vibro-motor like those mounted on mobile phones (Fig. 2). Finally, a gyroscope (by Analog Devices) has also been added to implement a step counter.

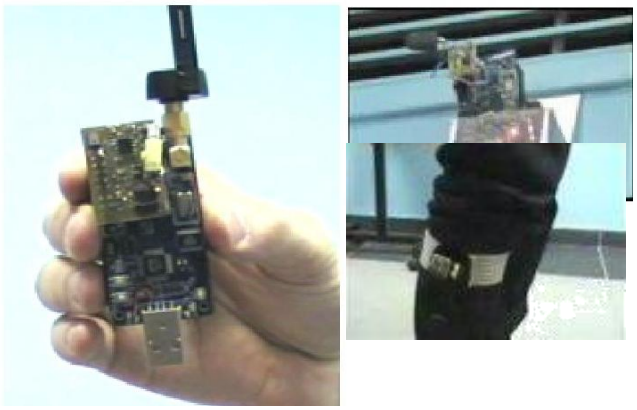

Figure 3.1 – On the left: A Tmotesky module equipped with vibro-motor and tri-axes accelerometer used as AK. On the right: up: MN with PIR sensor and microphone, down: AK with gyros fixed on the user leg.

Instead, the TmoteSky modules used as MNs have been equipped also with microphones (to capture unusual sounds and shouts for help) and Passive InfraRed sensors for presence detection (Fig.2). Naturally, other sensors can also be easily added and managed. From this point of view, some standard ones can be present in each MN, for instance in order to measure temperature, light, humidity and human presence. In addition each MN can also host specific sensors, such as, for instance, those for gas leakage in the kitchen and bathroom.

In a further development, the system was realized with a ZigBee WSN with the purpose to use a standard communication protocol providing significant advantages in terms of flexibility, self-reconfigurability, number of nodes and low-power characteristics. The hardware chosen for this purpose was the TI CC2430-based hardware modules bundled with the Z-Stack ™ [7] (Fig.3).

Naturally, the use of a standard protocol also helps in extending the system to other applications.

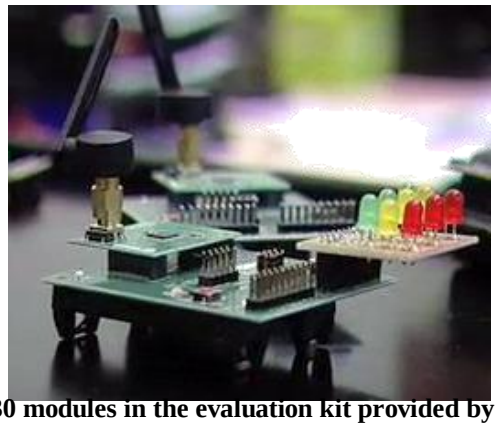

Figure 3.2 – A pair of TI CC2430 modules in the evaluation kit provided by Texas Instrument.

3.3 Software main features

The TmoteSky modules adopt the TinyOS operating system and their programming language, the nesC [6], while ZigBee nodes are equipped with Z-Stack™ and programmable in C**.** Casattenta's software is composed by the firmware running on each node (of both kind) and executed by the HG. The modules may be programmed according to their roles (AKs, MNs and data Collection Points CPs), and each module is identified by an unambiguous address. The HG must acquire and process the packets collected from each end-node.

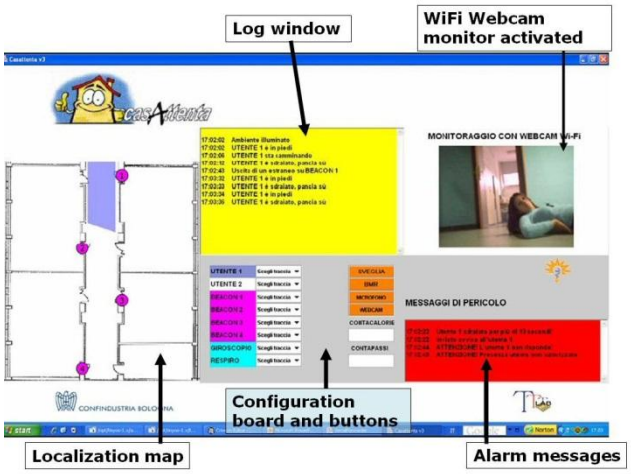

Figure 3.3 – A snapshot of the Home Gateway screen.

The HG is a Java application designed to present a graphical user interface (Fig.4). Several plug-ins enable the user to display real-time data collected from the sensors on each node. Furthermore, the HG enables to follow the real- time localization of all users wearing an AK, by means of a dynamic map. Other plug-ins provide graphical feedback on the main functionalities implemented, related to user-safety (e.g. fall detection), home surveillance (e.g. access control), environmental monitoring (e.g. comfort parameter monitoring such as temperature, humidity and lighting), social interaction (e.g. videoconferencing, activity recognition), setup of personal alarms and reminder of agenda events.

Furthermore, the HG enables the user to configure the system. For example, alarms can be configured to identify abnormal parameter behaviour (e.g. high temperature, gas leaks) and provide appropriate responses (e.g. activation of webcams, sound alarm, AKs' vibration).

Two different version of HG have been developed for the Casattenta system. The most advanced and complete one features a PC allowing remote internet connection as well as to dynamically configure and personalize the system functionality and services. Of course this solution offers a number of important advantages, in particular as far as further expansions and development are concerned. On the other hand, it is rather expensive and possibly difficult to be operated and accepted by elderly persons.

For this reasons, a second, simplified version of the system's external gateway has also been realized by means of a (cheap) GPRS gateway, allowing remote control by means of SMS or simple multimedia messages.

IV. Conclusion

Casattenta is a comprehensive "Ambient Intelligence" system conceived for a home scenario, that makes use of advanced Wireless Sensor Networks technology to make houses safer and more comfortable, particularly for elderly people (and similar type of persons) that like to live independently also when in need of occasional, but essential, attention and help.

The system has been realized as a prototype implementing only a partial set of all conceivable functions, particularly aimed at recognizing events that require immediate medical assistance (falls, immobility and shouts for help…).

However, further functionally could be easily added in the future. From this point of view, in particular, it would be interesting to include the possibility of friendly (and cheap) visual and oral communications with friends and relatives in order to improve the social wellness of the assisted people.

Although Casattenta has been primarily conceived for the application described above, it can easily be adapted for other interesting cases (museums, hospitals, industrial plants,…) where indoor tracking, seamless interaction among people and a smart environment are desired.

Looking at the future, new developments are planned in different directions, namely: expand the system including further functions; use more standard and easily available hardware; validation with "field trials" (i.e. within the houses of target people including the Digital Television, Figure 5).

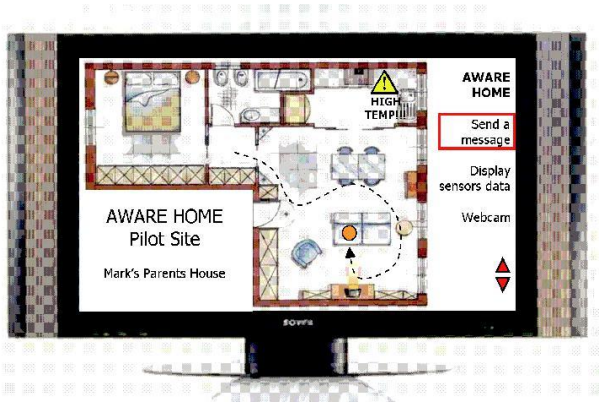

Figure 5 – A possible new implementation of Casattenta's "Home Gateway"

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