Uses of RFID and NFC technologies in AAL Communications for Health: A Literature Review

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Abstract — **During the last years, there has been an increasing interest for the Ambient Assisted Living (AAL) communications, since life expectancy and population aging have been incrementing thanks to the advances in medicine and health care. This paper presents an academic literature review of the use of RFID and NFC technologies for AAL communications and also proposes a new original system of the use of NFC in health. The search systems and databases used were IEEE Xplore, Scopus, Web of Science and PubMed. The search returned a total of 48 papers. The new system proposed consists of two modules, one for high risk patients and other for emergency services. The module of the patient involves a NFC tag embedded in a garment he always wears. When placing it next to his mobile phone, the garment activates an application that makes a call and sends his location and relevant data of his health condition to the emergency services. There is very little research done in RFID and NFC applied to AAL compared to other application fields and the most researched applications are monitoring systems and tools for medication control and prescription.**

Keywords - AAL communications; mobile health (mHealth); NFC; review; RFID.

I. INTRODUCTION

RFID is a technology that allows wireless non-contact data transfer for identification using radio-frequency (RF). The fundamental of this technology is using a spectrum of radio-frequency to transmit identification information between two devices. The range of frequencies can be low frequency (LF), 125 KHz-148MHz; high frequency (HF), 13.56MHz or ultra-high frequency (UHF) 868MHz, 915MHz. Usually, the communicating devices are two: RFID tags and RFID readers. The tags can be either passive, active or battery-assisted passive, and they are composed at least by an antenna and an integrated circuit. The system works this way: A reader transmits an encoded radio signal to interrogate the tag and the RFID tag replies with its identification and other information when receives the message. Commonly, RFID tags tend to be integrated into a mobile object (e.g. ID card) and readers are stationary. It has several advantages compared with other identification systems, such as longer working distance, faster reading ability, lack of battery management, wireless localization and accuracy in measurement [1-3].

According to the NFC Forum, Near Field Communication or NFC is "a standards-based short-range wireless connectivity technology that makes life easier and more convenient for consumers around the world by making it simpler to make transactions, exchange digital content, and connect electronic devices with a touch" [4]. It works in the free frequency band of 13.56 MHz and builds upon RFID systems by allowing short-range and simple safe two-way communication between smart objects just by bringing them close together. The separation of the devices should be less than 4 centimeters and the maximum communication speed that NFC offers is 424 kbps. NFC is commonly used for establishing connections with other wireless technologies such as Bluetooth or Wi-Fi. The most important advantages of NFC are the following: it is interoperable, security-ready, inherently secure (due to its short range communication), versatile, open and standard-based [3-5].

The two mentioned technologies have several applications: access control (e.g. toll gate system), tracking of objects (e.g. car tracking), commerce (e.g. payment by mobile phones), machine readable travel documents (e.g. plane tickets), human identification, or health care, among others. In the field of health care, AAL is one of the issues more researched lately because of the continuous aging of the population, especially in industrialized countries where life expectancy is on the rise and the birth rate is in decline. Aging societies have to face many challenges and the capability of elderly people to autonomously master their own life will play a significant role than ever before. In the context of increasing the quality of life, the need of technological assistance grows more and more imperative and it is important to supply tools and methods to

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allow elderly or impaired people to perform individually, without the help of others, tasks of their daily life, both in their own house and in public spaces [6]. For this reasons, the pervasive use of short range wireless communication technologies can play a fundamental role in improving health care delivery and ensuring cost-effective and patient-centered disease management and prevention [7].

As Dohr *et al*.[8] mentioned in a work, AAL applications "include services, products and concepts to increase the quality of life, wellbeing and safety of elderly people". The main goal of AAL is to achieve benefits for the individual (increasing safety & wellbeing), the economy (higher effectiveness of limited resources) and the society (better living standards) [8]. For achieving this objective, AAL applications are mainly focused on health, safety, independence, mobility and social contact.

The main aim of this paper is to perform a review of all the research done in AAL using RFID and NFC communications. For this objective a search of related works will be executed in several academic databases and systems. The authors have selected these technologies among other wireless sensor network technologies such as Bluetooth, Zigbee or wireless sensor networks since RFID and NFC are no power consuming, their working distance is shorter than the others and they are less researched academically.

Additionally, a new innovative and original proposal of use of these tools for AAL, concretely NFC, will be suggested, which will be different from those studied but will also complement them. Hence, the main contributions of this work will be obtaining the state of the art and the tendencies in the use of these technologies for AAL, and motivating other researchers by the new proposal to develop it or a similar application to make easier contacts with emergency services and save essential minutes in critical situations.

II. METHODS

A review of the published works related to the application of RFID and NFC technologies in AAL was developed and took place up October 2016[4]. The methods used for this review were the same as those used in previous works [9-11]. Hence, the review was a literature study where several academic systems and databases were used. These systems were IEEE Xplore, Scopus, ISI Web of Science (previously named ISI Web of Knowledge) and PubMed. The combinations of words utilized as search strings were the following: *rfid AND aal; rfid AND ambient assisted living; nfc AND aal; nfc AND ambient assisted living*. There were no limitations in date publication, so each and every related research was obtained independently of the date of its development or publication.

All the systems returned a total of 143 results, of which 74 were duplicated or with an irrelevant title for this research. The majority of those were duplicated, being very few those with irrelevant titles. Hence, of the remaining 71 papers, 7 were dismissed after reading their abstracts or the whole paper if necessary, resulting a total of 64 relevant works.

The requisites to include a paper as relevant are the following: the paper must be written in English, it has to involve one or more applications or systems using NFC or RFID technologies for an AAL environment and it can include other communications technologies such as Wi-Fi, Bluetooth, ZigBee, etc. As there are very few requisites, almost every paper found (not duplicated) was included in the relevant results. This was done on purpose in order to obtain the biggest number of papers related to this search.

The process of selection of the papers was done by reading the titles and the abstracts of the results obtained by one of the authors. When there were doubts about the inclusion of a paper, the author indicated this issue to the rest of the authors and the whole article was read by all of them in order to reach an agreement to make the decision of including or not the paper. Finally, a classification of the papers was obtained by reading their abstracts as well as the whole article when required. Once this process was completed, a new revision of the obtained classification was done and similar categories were merged to obtain a more condensed classification.

III. RESULTS

A. Literature Review of the Use of RFID and NFC for AAL

As mentioned in the Methods section, a total of 48 relevant papers were found. Their publication dates are spanned from 2008 to 2015, not finding papers before 2008. Figure 1 shows the number of papers published each year and Table I contains a classification of the different types of papers published and the number of papers found for each type.

TABLE I. CLASSIFICATION OF THE RESULTS OF THE REVIEW.

Type of system/application	Papers
Indoor position tracking system	10
Monitoring system	9
Medication control system	7
Link of sensors in a monitoring system	5
Link of sensors and ID detection in a monitoring system	4
System for aiding impaired individuals to perform routine tasks	3
Surveillance system	3
Identification system in a residence/hospital	2
Medication and prescriptions control system	2
Medication prescription system	2
System to couple antennas	2
Biometric access control system	1
Brain rehabilitation system	1
Complete AAL system to improve quality of life	1
Data transmission using NFC	1
Diabetes therapy system	1
Digital agenda for elderly	1
EHR system using NFC	1
Monitoring system and navigation assistant system	1
Link of sensors and user interaction in a monitoring system	1
Physical training motivation system	1
Robotic furniture system	1
Robots integration in a house	1

Some types are very similar and their differences should be clarified. A monitoring system is a system to monitor and

check some vital signs of the patient whereas a surveillance system uses cameras and other devices in order to watch the patient continuously. The type "Link of sensors in a monitoring system" and "Link of sensors and ID detection in a monitoring system" are papers more focused on the connection of sensors to a monitoring system rather than the system itself.

A medication control system is used for managing the doses and the intakes of medicines whereas a medication prescription system is designed for aiding patients to request medication prescriptions to their doctors from home. Finally, a robotic furniture system is a system composed by furniture that automatically adjusts its configuration to the needs of the patient, whereas "Robots integration in a house" is about the introduction and integration of robots in the living environment of a patient.

In the following paragraphs there are presented some examples of the most researched type of works. An indoor position tracking system used in AAL applications is the one proposed by Nazemzadh et al. (2013), which uses a position tracking estimation that will be used in a smart rollator to assist elderly or impaired people to navigate securely in big locations such as airports or railway/bus stations. This technique is based on an extended Kalman filter that processes data from sensors and a RFID reader which will detect a limited amount of passive RFID tags stuck in the tiles to correct the trajectory of the user [12].

Schmid *et al.*,[13] designed an analog scale for capturing and quantifying subjective health parameters such as pain or well-being in the context of a monitoring system. This scale is integrated into a smart NFC transponder activated by the reader's device. The patient only needs a mobile phone with NFC available and the necessary software in order to esteem the related health parameter by placing the phone at the corresponding spot of the NFC scale, everywhere and at any moment. This device ensures precise data capturing that can also be forwarded to a telemonitoring center [13].

An illustration of medication control system is the proposed by Jara *et al.* [14] which define a knowledge-based system to check drugs in order to detect Adverse Drugs Reaction (ADR) and allergy interaction. To do this, the patient can use either barcode or NFC through mobile devices such as mobile phones or laptops. The information obtained is sent to a Pharmaceutical Intelligent Information System to detect if a drug is compatible or not with the patient's allergies stored in his Electronic Health Records (EHR) [14].

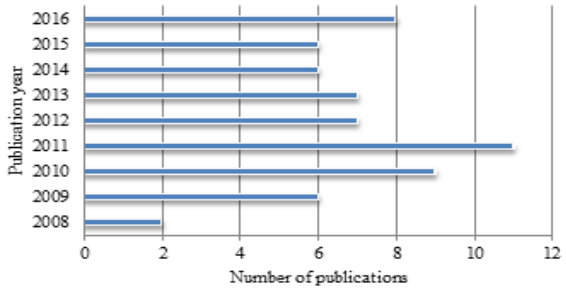

Figure 1. Number of papers found per publication year.

Zerawa *et al.* [6] developed a system for aiding impaired individuals to perform routine tasks using RFID identification cards. With this card, an impaired or elderly person can identify himself before performing a task using a card reader and the reader system will remember the task executed, such as pressing a floor button in an elevator. This way, the next time the person will do the task after identifying himself, the system will recommend him the task that he performed the last time (the floor he went), which will be probably the task he wants to do [6].

Finally, an example of surveillance system is the one proposed by Villacorta *et al.,[*15], who combine several modules to develop a complete system. It consists at least of a control module, a sensor network with acoustic sensors, video cameras and a RFID module. The RFID module is used for identification and access control of the people living in a house. Each of them will wear a bracelet with a passive RFID device and the bracelet will interact with the RFID readers distributed on the doors of each room, identifying the rooms where each person is, which complements the acoustic and video modules [15].

B. Application of NFC for fast response in emergency situations

The motivation of the authors is creating a system that could help in emergency situations in order to make faster the assistance of the patients suffering the situation and therefore improving their chances of obtaining a proper treatment at the right time. After the review of the NFC and RFID applications for AAL and their classification, the position is excellent to think and propose a use of these technologies with this objective.

Following this motivation and based on the works of Marcus *et al.*[16] and Jara *et al.*,[17], the system conceived uses NFC technology in order to make emergency calls when the user is suffering a critical incident, such as an infarct or an allergy attack. The system consists of two modules, involving both patients and emergency staff.

From the point of the patient, he will utilize a pervasive device that he usually carries everywhere such as a NFC-enabled mobile phone and a passive NFC tag that he will also carry at any moment. The NFC tag will be embedded in a garment that he will always wear such as a bracelet, a watch or a necklace. It will be programmed to activate a mobile application installed in his mobile phone, which automatically will call the emergency systems, sending also the location and several relevant data of the health status and problems of the user.

On the other hand, the emergency services will have available a mobile application in a mobile phone or device they use that will receive the calls and the data sent by the patients' phones when an emergency situation is happening. This way, the emergency services can know exactly the location and relevant information about the patient before they go the place where the incident is occurring, saving vital time in the gathering of information from the patient.

Supposing that the NFC tag is embedded in a bracelet of a patient with hypertension and high risk of fatal heart

malfunction, the system will function as follows: initially, the patients should introduce in the app provided some personal information about them, such as they name, age, social security or insurance number, address and contact person. It will also introduce relevant clinical information such as his hypertension condition, known allergies, history of surgery and relevant parameters (cholesterol levels, diabetes, etc.). If, by chance, the patient feels bad and he thinks he is suffering a heart attack or a serious crisis, he will move the mobile phone closer to the bracelet (less than 4 centimeters [3]). Then, the NFC tag will activate the app sending the data stored and the location obtained by the GPS of the phone to the emergency services module, starting also a communication between them. The emergency staff will immediately receive these data and will be able to talk to the patient if he can. They will be capable of moving to the location sent without asking the patient and will be provided with significant information about him that will prepare them to the scenario they will find.

The proposed system has several limitations and problems to take into account: it is important to place the NFC in a garment that will normally be away from the patient's mobile phone in order to avoid false alarms to the emergency system. The information will be sent using Wi-Fi or 3G (or 4G if available) connection, which means that the data cannot be sent when there is no available link. However, the call will be done since it does not need data sending (if the phone is in range). Finally, the data stored and sent in the patients' application are very sensible and need to be protected and secured against external attacks, but there are several techniques to solve this problem.

IV. Discussion

Several findings can be obtained from the literature review of the use of NFC and RFID for AAL. Only 64 results were obtained, which is extremely low, compared to the 673 results returned by IEEE Xplore when searching "NFC" alone or the 10,814 results for "RFID". The reasons for this are two: on one hand, there are much more research done in other fields, or just focusing on the technologies themselves; and, on the other hand, there are some researches that can be applied to AAL but this fact is not mentioned and, hence, these researches are not returned when searching for AAL. Nevertheless, in light of these numbers, there is very little research focused on AAL applications.

Focusing on Figure 1, it can be seen that there was a progression of the interest in these technologies for AAL, spanned from 2008 to 2010, and then, from 2010 to the present day, this interest remained almost constant, with slight fluctuations.

As Table 1 shows, there is an application of RFID and NFC commonly researched, which is their use in monitoring systems, either focusing on the whole system or on specific parts of it. A total of 13 studies found related to monitoring systems prove that. Another focus of interest shown by researchers is the application of these communications on medication control and medication prescriptions systems, with a total of 8 related researches. Systems used for surveillance or tracking and aiding the navigation of elderly and impaired people are also fields of interest. The rest of the types of applications found are less researched and equally distributed with only 1 or 2 papers per type.

Focusing on the new application of NFC proposed, there are several points to be discussed. First of all, the system is only an idea and has not been developed yet (although it is in progress), but it is thought that it will aid both patients and emergency services. The system is only recommended for patients with high risks of suffering serious incidents that can cause death or significant disabilities, such as heart attack, hypoglycemia, strokes, etc. These people will benefit of the easiness of contacting the emergency services by only moving their mobile phone closer to the NFC tag, which will save vital minutes that a normal call suppose. It can be especially useful for attacks that involve quick loss of conscience.

On the other side, the emergency services can be also benefit from the system because they will receive relevant data in addition to the call. The situation of the emergency will be displayed on the device as well as personal and clinical data from the patient, essential to understand the emergency and know what can be happening even before answering the call. This way they can get going without delay just viewing the location received and can also talk to the user who called as if it was a normal call. To save additional time, they can study the data of the patient on the run to the emergency location. Thus, when arriving, they just need to ask a couple of questions if necessary, or know what to do in case of the patient is unconscious, in light of the data received.

Not only time will be saved with this system, but also lives and costs. Lives can be saved specially in the mentioned emergency scenarios where the patient had lost his conscience before the emergency staff arrived. They are not able to communicate with the patient, but they have at least information of him and can guess what could have happened, which can mean saving his life. The costs savings are derived from the promptness of delivering the help by the emergency staff, which can result in a quicker recovery of the patient, reducing hospitalization times and, hence, costs from the sanitary system.

V. Conclusion

Despite these benefits, there are some drawbacks mentioned in the results section that must be overcome. The most problematic one can be the involuntary moves that can get the mobile phone and the NFC tags enough close to activate the application and send a false alarm. For avoiding this, a confirmation button can be displayed or an acoustic signal can sound in order to warn the user about the approach before sending the alarm.

For future work, the system can be developed in collaboration with the local emergency services in order to determine the efficacy of its use and evaluate the benefits-costs comparison of the system. Another research line derived from this study can be the incorporation of the use of NFC tags in a mobile application for people with heart conditions, which is being developed by the authors. The idea will be similar to the system proposed: to integrate a tag in a garment the user will wear permanently to use it for calling the emergency services.

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