Internet of Things for Medication Control: Service Implementation and Testing

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Abstract. RFID technology (*Radio Frequency IDentification*) enables putting an identification label (e.g. tag) into a certain object and, by means of a reader, get the information related to it without any physical contact. The use of these tags in medical context enables a rapid and precise identification of each patient and, by means of Internet of Things (IoT), enables a ubiquous and quick access to medical related records. These technologies, RFID and IoT, integrated within a suitable system, promote a better physician-patient interaction without any eye or other direct contact. A simple IoT-enabled system can send warnings to any physician, nurse or other health caregiver. Therefore, with a simple IoT architecture one may remotely monitor and control the patient's well being.

This paper presents an IoT architecture, using RFID tags, able to easily and remotely establish a medication control system, beginning from physicians prescription to pharmaceutical drug administration. The paper presents the implementation and analysis of a prototype service, with a web interface, allowing for a first evaluation of the proposed service. The prototype service - based on RFID, EPC (*Electronic Product Code*) and ONS (*Object Name Service*) - and its web interface are presented and evaluated. Some use cases are presented and evaluated using this prototype service entitled *"RFID-based IoT for medication control"*.

Keywords: RFID, IoT, EPC, ONS, EPCIS

1 Introduction

The Radio-Frequency IDentification, commonly known as RFID, is used in many applications [1, 2]. The use of this technology is constantly evolving, expanding at exponential rate. There are several methods of identification, although the most common is a microchip able to store a serial number that identifies the person, or object or thing. Using electronic devices that emit radio frequency signals, it is possible to perform an automatic capture of data, or a tag, from a reader. Therefore, RFID is an easy-to-use and versatile acquisition information technology. RFID is a system where a radio signal is transmitted to a specific

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transponder and to which it responds with another radio signal. Its aim is to carry data in suitable transponders (e.g. tags) and get it through by automatic reading, in the right place, at the right time, depending on the target application. Apart from the tags there is also the need for procedures to read or interrogate these tags (e.g. readers, antennas) in order to transmit the data [2] to a host computer, a supporting information system and software programs to deal with all the data usages. The main advantage of using RFID is the possibility of reading without physical contact or any other direct connection between the reader and tag. One can put the tag inside a product and read it without unpacking [3] or even implant it under the skin of a patient [4]. This technology has a very low response time and, therefore, in production processes, we need to get information from a moving tag. Fortunately the production price of tags has been declining over the last years. However, when users purchase an RFID-enabled item, they can face privacy loss [5]. Suppose that a consumer returns to the place of purchase using a clothing, in which the tag remains active. In such a scenario, users may be identified by the tag identification. This type of technology is used in security and access control, for example, controlling access to buildings/facilities, controlling the use of computers, preventing products replication, recovering stolen items, etc. In health there are devices that support RFID which are placed in patients suffering from Alzheimer's, diabetes, cardiovascular diseases, among others, that require complex treatment. The device placed on the patient only contains an identification number and, using a reader, the health professional, as long as he entitled with all the necessary authorizations, may access the hospital database and get information about the patient. Of course, whenever personal or private information is to be accessed, all the necessary security mechanisms must be present, protecting the data access. The use of Internet to virtually enable links to information contained in tags is commonly known as "*Internet of Things*" [6, 7]. This term is defined as objects carrying identity and virtual personality, which, while working in intelligent spaces, use interfaces to connect and communicate in a social, environmental and personal context.

Physicians can access all authorized health patient information using Internet of Things enabled access. A more extensive use of RFID-enabled *"things"*, either objects or persons, can improve several e-health services and specifically can foster patient medication control. Although a complete set of sensors can monitor the patient's health, a much simpler architecture may allow to automatically monitor and check if patients follow medical prescriptions: if patients had the recommended doses of the right pharmaceutical drug at the right time.

This paper presents a new e-health service architecture, using RFID tags and structured around the Internet of Things, to establish a remote medication control system, specially aimed at elderly people, for Ambient Assisted Living. After a brief review of related work in section 2, the paper presents the general IoT architecture in section 3, proceeding to the e-health service implementation and testing in section 4. Section 5 presents some concluding remarks and future work.

2 Related Work

Several studies on Ambient Assisted Living (AAL) to support elderly people in their daily routine have already been published. Dohr et al [8] presented smart objects to facilitate generic tele-monitoring processes, Chun-Liang et al [9] presented a framework for using RFID patient identification within the Taichung Hospital information system. More recently, other works such as (RMAIS) [10] have studied the integration of medication with patients and even some hardware products, such as special medication dispensers, arose [11]. These works rely on special hardware devices, either sensors for tele-monitoring, either special dispensers to interact with patients.

Nowadays, the generalized usage of mobile devices that elderly people are already using for voice communication, combined with the ubiquous Internet of Things, combined with well known Internet browsers interfaces, are a much more versatile and user friendly. That is our claim and consequently one should devise an integrated Internet of Things architecture able to accommodate users (doctors, nurses, caregivers and patients) and medications, either the real pharmaceutical drugs, either their virtual IoT presence.

In line with our approach one can find works on *Electronic Product Code* (EPC) and *Object Name Service* (ONS) evaluation [12] while other works deal specific with security issues within EPC context, presenting Lightweight Public Key Infrastructures [13] solutions.

The *Electronic Product Code* (EPC) [14] is a code number that gives the unique identification of a given physical object. The information about the object can be stored in databases located on the Internet or private networks. A RFID tag contains the binary representation of the EPC value that can be coded 64bits, 96bits or 198 bits long. There are different encoding schemes compatible with the EPC and the chosen format for the prototype development was the *Serial Global Trade Item Number* (SGTIN-96) [15] of 96bits. Using the Internet as a basis, EPCs are encoded as URIs (*Uniform Resource Identifier* [RFC2396]), which are a basic addressing scheme for all World Wide Web, thus ensuring that the EPC network is compatible with Internet developments. EPCIS (*EPC Information Services*) [16] is an EPCglobal standard for the interface that allows the effective share of data about an EPC. The EPCIS is concerned with information sharing, thus presenting a more distributed architecture. The *Object Name Service* (ONS) provides a global search service that supports an EPC code, where it is translated to a URL (*Uniform Resource Locator* [RFC1738]), thus having more information about the object to be found. It is also important to note that this service can be built using the same technology as DNS (*Domain Name System* [RFC1034]). As mentioned, the ONS service can use the already existing DNS service, making use of the NAPTR (*Naming Authority Pointer* [RFC2915]) resource record. Presently, ONS returns the URL(s) of services, where a customer can possibly get more information about the object identified by an EPC tag owner company. Such services may be web services or any other type of service provided by the EPC tag. The ONS can use the

NAPTR resource record that standardizes the requested services, protocols and resources connected to an entity.

The NAPTR resource records contain information enabling access to an EPCIS service. The fields used in the ONS are the *Regexp* and *Service*. The first one specifies a regular expression that indicates the service URL and the second one represents the service name that is found in the URL in question. From the *Regexp* field, both the initial and the ending character "!" are removed. When querying the ONS, a set of URLs are returned, directing the customer to a range of services. From these, one can get more information about the tag and its context. It is important to refer that the ONS does not offer any extra information about the tag, indicating only who owns the tag and also which *"service"* is to be used for data exchange.

3 e-Health Context and IoT Service Architecture

One of the health challenges in Portugal is to achieve a substantial decrease of elderly death due to medication errors. Those medication errors can occur on account of patient induced errors, due to miss-interpretations, or on account of mistakes from the health care system. No doubt, a very difficult situation can arise when two patients, with the same name and surname, share an health facility at the same time. Certainly, automated and secure ways of clear and unique identification, such as RFID tags, may be of invaluable help in reducing any type of mistakes or medication errors.

3.1 e-Health Context

A study carried out in Portugal on *"Adherence to Medication Regimen in the Elderly"* [17] (PhD thesis, in Portuguese) showed that a large majority of the elderly people need external help for managing medication. Having carried out a study with a population of elderly people, the study [17] stated *"as part of the reasons for non-adherence to medication, 60.5% of the patients indicated forgetfulness and 24.4% stated they did not have them with them at the time of intake"* and *"interventions (giving advise on pharmaceutical drugs, pharmaceutical drugs control and pharmaceutical drug education) are effective in increasing adherence"* to medication.

Table 1 presents a summary of the type of help that Portuguese elderly patients (older than 65 years, as published in [17]) said to be needing in order to adhere to medication. As one can notice, a large majority of the elderly need help in medication control, being that 82.8%, 265 $(119 + 63 + 44 + 20 + 19)$ out of grand total of 320, present reasons that can be fulfilled by semi-automated AAL systems, as the one proposed here.

3.2 IoT Service Architecture

This paper presents a simple e-health service prototype for AAL, based on available and well known IoT technologies, and evaluates the usage of RFID-based

Type of Help Needed	Number	%
Manage Medication	119	36,1
Get Info on Medication	63	19,2
Explain Medication regime	44	13,3
Interpeter Medication regime	26	7,9
Monitor Medication regime	20	6,1
Remembering Medication Hours	19	5,8
Filling Drug-dispenser	10	3,0
Monetary Help	7	2,1
Reading Label	8	2,4
Get Drugs Out of box	4	1,2

Table 1. Type of Help Needed by Elderly Patients (from [17])

information systems in order to establish a real time monitoring system able to verify the compliance by patients of the prescribed dosage of medications.

The prototype system here presented assumes that physicians, patients and medicines are to be identified by means of RFID-tags and that the whole process, from prescription to pharmaceutical drug administration, is to be monitored by means of an IoT-based information system.

The whole process begins at a health facility when the physician prescribes a set of pharmaceutical drugs to his patient, both identified by means of RFID-tags. Main objective of these tags is not patient localization, as for instance [18] research, but rather the establishment of an architecture and access control to the information system relating patients, prescriptions and medications.

It is assumed that the physician fill out the prescription where they include the dosage and time at which the medication shall be taken. This information is stored into the e-health system database, already linked to the RFID tag assigned to each patient.

These tags, following the general rules of RFID in Health-Care presented in [19], can be read by RFID readers placed in any specific hardware but also (and specially) by means of readers attached to general purpose mobile devices, such as smart phones, tablets, PDAs, etc. These tags are to be used to ensure that patients do get the correct medication, thus minimizing medical errors (the correct patient will get the correct medication). At an established time, determined by the posology, the patient, nurse, health assistant, or any-other caregiver, are to be notified to pay attention to the pharmaceutical drugs that each patient should take. The medicine itself, with its own RFID tag, can also be checked against the medical prescription. In this way, it is possible to minimize the errors in the amount of medication taken and the correct time of ingestion.

It is also assumed that every (prescribed) medicine can have its information available via any URI identifier, to be maintained by a national health service or by pharmaceutical companies and laboratories.

In order to support this IoT AAL system, we have developed a prototype OSN service that allows the registration, and retrieval, of information about physi-

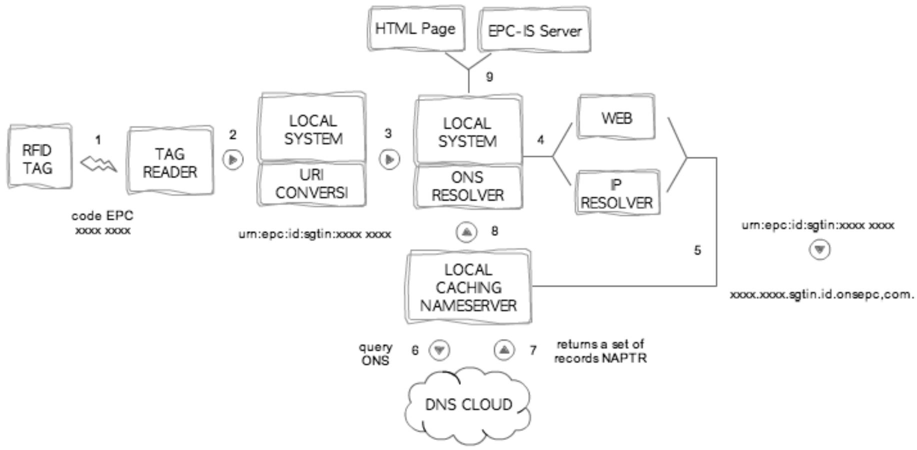

Fig. 1. Schematic of the prototype service "RFID-based IoT for medication control"

cians, patients, nurses, medicines, prescribed pharmaceutical drugs and recommended dosages. It is assumed that RFID tags are used to identify each one and all of these stakeholders. Besides that, it is also assumed that an ubiquous access to the data, via Internet enabled devices, to make queries from anywhere on the Internet about stored data. The global system architecture and the prototype main components are presented in Figure 1.

4 Service Implementation and Testing

Figure 1 outlines the e-health service prototype architecture and components, starting from the instant when an RFID tag is read and ending with the EPC information, got from either an EPCIS server, either form a generic WEB service. The global and generic WEB/HTML service can be used to access any non-private, or even public information[1].

The basic form of an EPC consists of a Header, EPC Manager Number, Object Class and Serial Number. The first two are part of the EPCglobal signing and the other is part of the EPC Manager owner signature. In this study, we used a 96-bit length SGTIN format [15], whose structure is shown in Table 2. The length of the Company Prefix and Item Reference is variable depending on the value of Partition.

The prototype service that we have implemented has been inserted into a Java applet that lies in a restricted, protected and secured area which can only be accessed by authenticated and accredited physicians or nurses to obtain the necessary information about the patient and his medication and dose. This pro-

[1] Information on medications or pharmaceutical drug composition (as shown in Figure 2) is generally for public access

Header	Filter Value	Partition	Company Prefix	Item Reference	Serial
8 bits	3 bits	3 bits	$20-40$ bits	$24-4$ bits	38 bits
00110000_2	8 (Max. decimal)	8 (Max. decimal)	$999,999$ $-$ $999,999,999,999$	$9,999,999$ $-$ 9 (Max. decimal)	$274,877,906,943$ (Max. decimal)

Table 2. 96-bit SGTIN Scheme (adapted from [15])

totype is able to translate between EPC's binary and decimal formats, make ONS queries and handle the received NAPTR records using its URL to access services such as HTML and EPCIS.

Main implementation steps and functions are now described in summary. The whole process begins reading a RFID tag (for instance, identifying a medicine) carrying an EPC (presented both in binary or decimal), then converted into the URI format, according to the syntax `urn:epc:id:sgtin:company.item.serial` and the system forwards it to the Local ONS Resolver. The system may use either a private or e-health corporate ONS service either a global Internet object name resolution service, for a globally accessible ONS service. It is obviously required the Fully Qualified Domain Name (FQDN, e.g. `rfid.gcom.uminho.pt.`) to be registered into the global DNS hierarchy. By ONS resolution, the application requests a NAPTR record whose general format is presented in Table 3. Our proto-

Pref	Flag	Service	Regexp
0	u	EPC+ws	!^.*!http://example.com/autoid/widget100.wsdl!
0	u	EPC+epcis	!^.*!http://example.com/autoid/cgi-bin/epcis.php!
0	u	EPC+html	!^.*!http://www.example.com/produts/thingies.asp!
0	u	EPC+xmlrpc	!^.*!http://gateway1.cmlrpc.com/servlet/example.com!
1	u	EPC+xmlrpc	!^.*!http://gateway2.xmlrpc.com/servlet/example.com!

Table 3. Example of NAPTR records

type application takes the `EPC` code in pure form `URI`. `urn:epc:id:sgtin:0614141.000024.400` removes the prefix *urn:epc* and the serial number (400 in this example) and adds the corresponding domain to get `000024.0614141.sgtin.id.onsepc.com`.

The result of a *ONS query* returns a set of records `NAPTR` (see Table 3) and allows extracting the URL from Regexp, being that the selected records are those that have the lowest value in the Pref (if all records have been tried without success, no service is available).

Finally, the local system contacts the (either e-health corporate, either global) EPCIS server, found in the URL, for the corresponding EPC.

The user client may select one of the available services: HTML or EPCIS. The user client is capable to do EPCIS queries and get information from a MySQL database, containing records of events related with the given EPC. Whenever a URL links to a valid service, this means that records of events related to the given

EPC are returned. These event logs are processed and subsequently presented to the user in text format (see Figure 2). If the user chooses the HTML service, the default browser is launched with the URL corresponding to the NAPTR record, presenting information related to the EPC (Figure 2).

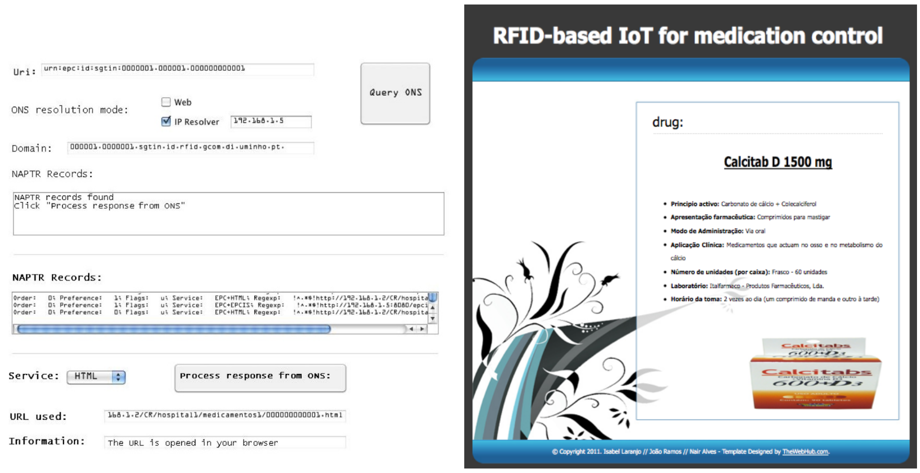

Fig. 2. URL that is obtained from the NAPTR open in browser

The service prototype presented in Section 4, developed in Java language, was set fully operational and tested. To support general ONS requests, some open source tools (`http://www.dnsjava.org/`) were used. Java classes developed enabled us to create a lookup object that performs queries to the DNS / ONS service. By default, this object attempts to resolve the query on the Web[2]; however, it is possible to create a local `SimpleResolver` object.

The RFID readers can be used for two main different objectives: get information about the current EPC or store information about a related occurring event. Thus, an important issue is the existence of an Information System (IS), capable of dealing with all these information exchanges, allowing easy, fast and secure access to it. This is achieved with EPCGlobal, which also standardizes the records of information exchanged between organizations or companies working in the same field (hospitals, for instance).

Open source implementation of the EPCIS standards (available at "`http://www.fosstrak.org/epcis/`") provide tools for an EPCIS and a MySQL database has been created using the schema proposed, in order to keep track of all the events linked with all the EPC's operations. An Apache Tomcat server has been setup to make all the information available on the network. After all the necessary settings established, two EPCIS interfaces are provided to the user: graph-

[2] For security reasons the method `setCache` has been used so that ONS responses were not stored in cache

ical interfaces to capture and search (query) information and classes for Java code developers.

The prototype system has been tested for some use cases, including tests for a complete workflow analysis and proved to be a useful tool. Physicians, patients and prescriptions have been inserted into the IoT experimental information system we have developed and the prototype system has been tested. Figure 2 results from real captures from the prototype system and presents an IoT medicine interaction: the RFID tag from a medicine has been put into the prototype system, its EPC led to the ONS resolution and URI pointers to the EPCIS available informations; as one can see on the right (Figure 2) one of the URIs returned enabled direct access to the pharmaceutical drug presentation.

The prototype system also permits reading a patient RFID tag, automatically linking the patient with his current prescription and generating alert informations on running medication hours also enabling, simply by reading any medication RFID tag, the patient (or caregiver) to identify if that one is the correct pharmaceutical drug he must have and also if now (current time) is within the time window for him to take it.

4.1 Security Issues

In the context of this work personal and private information is accessed, most of whicht is protected by medical confidentiality. Therefore, this personal information cannot be accessed by any non-authorized personnel. This means that, although the prototype integrates authenticated http access control and signed applet code, the current prototype doesn't yet include any strong security mechanisms, so it is necessary to make this e-health prototype service safer. Since granting security in information access is extremely important to protected e-health information, one must disallow any non-authorized access to non-public health information. Therefore, it is essential to have a security system with strong authentication, able to record the time and user identification of every access and detect misuses in case of any flaw in the system.

When using this prototype for testing it has been assumed that all e-health Information System is protected using cryptographic technics. Cryptographic keys should also be used by client applications (either accessed by physicians, by patients, or by any other health caregiver) and exchanged in a secure way. Using asymmetric encryption, and relying on public key infrastructure, secret key exchange can be done safely so that clients may connect safely to the service.

5 Conclusions and Future Work

RFID can identify any object with a RFID tag via radio signals. EPC, enabling a unique identifier for each object, also enables to establish a simple means to access indexing data and consequently to obtain a domain address with all the information about the object. The implementation of a service based on RFID technology presents itself as a complex set of tasks. Nevertheless, some useful and simple solutions are showing up enabling, for example, to solve problems related to medication control. The prototype system implemented and presented in this work, is able to get RFID EPC information associated with several e-health entities: e.g. physician, patient, nurse, caregiver, medicine, pharmaceutical drug, hospital, pharmacy, etc, assessing either public or private information. The prototype is able to translate EPCs (between binary and decimal format), to make queries to the ONS, to treat the received NAPTR records using its URL to access services such as HTML and EPCIS. Prototype service has been aimed at medication control and tested with a simulated cycle: from medical prescription to patient pharmaceutical drug control (correct medicine, due doses at due time) everything is logged into the system and can help patients even in mobility, as long as a portable RFID reader and an Internet connection is available.

In future implementations, these kind of systems can be attached to a calendar system and notify patients using messaging systems. Email messages, either to patients' care holders, nurses or physicians, and event creation on a calendar with the schedule of doses of pharmaceutical drugs, can also help patients to regulate themselves. In terms of security, the web interface has still some flaws, despite of already having a digital certificate for the applet and user authentication control. Nevertheless, deeper security mechanisms should be implemented in order to control the access some parts of the applet, because only strong authenticated and authorized physicians or nurses should have access to information in the database, where all sensitive information should be encrypted.

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