Internet of Things for Medication Control: E-Health Architecture and Service Implementation

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ABSTRACT

The use of Radio Frequency Identification technology (RFID) in medical context enables drug identification but also a rapid and, of course, precise identification of patients, physicians, nurses or any other health caregiver. Combining RFID tag identification with structured and secure Internet of Things (IoT) solutions, one can establish a ubiquitous and quick access to any type of medical related records, as long as one can control and adequately secure all the Internet mediated interactions.
This paper presents an e-Health service architecture, along with the corresponding Internet of Things prototype implementation, that makes use of RFID tags and Electronic Product Codes (EPC) standards, in order to easily establish in a ubiquitous manner a medication control system. The system, presented and tested, has a web interface and allowed for a first evaluation of the e-health proposed service. As the service is mainly focused on elderly Ambient Assisted Living (AAL) solutions, all these technologies - RFID, EPC, Object Naming Service (ONS) and IoT – have been integrated into a suitable system, able to promote better patient/physician, patient/nurse and, generally, any patient/health caregiver, interactions.
The whole prototype service, entitled "RFID-based IoT for Medication Control", and its web interface are presented and evaluated.

Keywords: Internet of Things, Ambient Assisted Living, Object Naming Service, Medication Control, E-Health, EPC, RFID.

INTRODUCTION

The Radio-Frequency IDentification, commonly known as RFID, is used in many applications (Sharma & Siddiqui, 2010; Ziegler & Urbas, 2011). 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, object or thing.

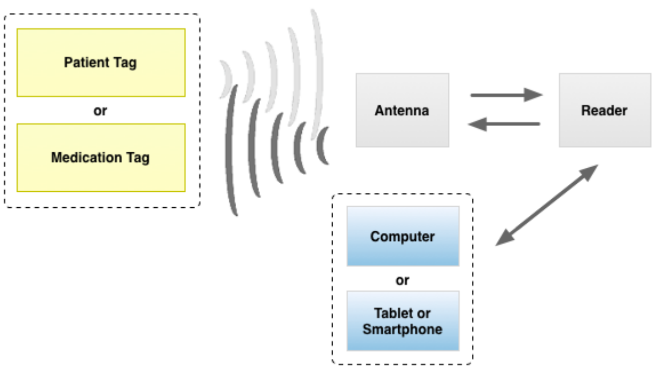
Using electronic devices that emit radio frequency signals, it is possible to perform an automatic capture of data, or a tag, from a reader. Therefore, RFID is an easy-to-use and versatile acquisition information technology.

RFID is a system where a radio signal is transmitted to a specific 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.

The tags contain silicon chips and antennas that allow it to respond to radio signals sent by a transmitter base. These elements are small proximity cards which can be found in different formats: passive, semi-passive, semi-active or active. Passive tags are not made up of a power source of their own and operate with the energy sent by the reader and transmitted through the antennas. As they do not require a battery, the manufacture of such tags is cheaper. Most existing RFID tags are this type. When the radio waves from the reader reach a passive tag, the spiral antenna within the tag creates a magnetic field; the tag draws power from the reader, transmitting power to its circuits, accessing the information encoded in the tag's memory and enabling it to communicate. Unlike passive tags, the active tags are made up of a power source, are more complex, have memories with higher capacity and they can store additional information sent by the transmitter - receiver. They have a small size (about the size of a coin), a practical range of ten meters and consist of a battery with several years' duration. The third kind of RFID tags, the semi-passive, have an operation very similar to the passive tags, however they consist of a smaller battery (which allows the integrated circuit of the tag to be constantly powered). Finally, the semi-active tags are only active when programmed to send a signal at previously predetermined intervals or in response to a specific event (Vacca, 2009).

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 (Ziegler & Urbas, 2011) to a host computer, a supporting information system and software programs to deal with all the data usages (Figure 1).

Figure 1. RFID system architecture.



Each of the components of an RFID system varies according to the frequency band defined for the system. Each frequency range has different characteristics and behavior. RFID tags are usually categorized into Low-Frequency (LF), High-Frequency (HF), Ultra-High-Frequency (UHF) and microwave transponders. Briefly, the LF tags exhibit a range of values between 125KHz to 134KHz. This type of RFID solution has a low rate of data transfer (only read one tag at a time and if they are passive) and a poor performance when near metal. They only work for short reading distances and are widely used for access control, animal identification and athletes, etc.. On the other hand RFID solution based on HF (13.56 MHz) show a good rate of data transfer, read multiple tags, work only with passive tags and display a reading distance of one meter. These solutions are used in hospitals (e.g. patient identification), access and food control, and libraries. In the range of 860MHz to 960MHz is where the ultra-high-frequency tags operate. This RFID solution is capable of performing readings up to 10 meters for passive tags, and 100 meters for active tags, has a high rate of data transfer and is made up of small size tags. Its main applications are traceability of items, vehicle identification, inventory management, etc.. Finally, the microwave tags (2.5 GHz) use active tags that allow a large reading distance and a high speed of data transfer. Due to the high cost of active tags, this type of system is used on toll roads on the highways (Hunt, Puglia, & Puglia, 2007)(Evdokimov, Fabian, & Günther, 2011).

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 (Viret et al., 2011) or even implant it under the skin of a patient (Rajagopalan & Rahmat-Samii, 2010). 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 (He et al., 2008). 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 (Rodrigues, 2009). In the pharmaceutical industry, the counterfeit drugs represent a costly and potentially deadly problem. One way to tackle this problem is to track and monitor drugs using RFID tags, keeping a record of the entire journey, from manufacturing to the pharmacy shelves. The RFID also helps to manage more efficiently the drugs that are in stock by providing updates on the inventories in real time (Pan, 2010).

The use of Internet to virtually enable links to information contained in tags is commonly known as *"Internet of Things"* (Tan & Wang, 2010; Wu, Lu, Ling, Sun, & Du, 2010). 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, an extended version of (Laranjo, Macedo, & Santos, 2012), 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, the paper presents the general IoT architecture, proceeding to the e-health service implementation and testing, then ending with some concluding remarks and future work.

RELATED WORK

Several studies on *Ambient Assisted Living* (AAL) to support elderly people in their daily routine have already been published. *Dohr et al* (Dohr, Modre-Opsrian, Drobics, Hayn, & Schreier, 2010) presented smart objects to facilitate generic tele-monitoring processes, Chun-Liang et al (Lai, Chien, Chang, Chen, & Fang, 2007) presented a framework for using RFID patient identification within the Taichung Hospital information system. More recently, other works such as (RMAIS) (Lee et al., 2011) have studied the integration of medication with patients and even some hardware products, such as special medication dispensers, arose (McCall, Maynes, Zou, & Zhang, 2010).

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 ubiquitous Internet of Things, associated 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 (Balakrichenan, Kin-Foo, & Souissi, 2011) while other works deal with specific security issues within EPC context, presenting Lightweight Public Key Infrastructures (Sun, Zhao, Xiao, & Hu, 2009) solutions.

The *Electronic Product Code* (EPC) (EPCglobal, 2007) 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 format chosen for the prototype development was the *Serial Global Trade Item Number* (SGTIN-96) (Finkenzeller, 2010) of 96bits.

Using the Internet as a basis, EPCs are encoded as URIs (*Uniform Resource Identifier* (Berners-Lee, Fielding, & Masinter, 1998), 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*) (Inc., 2007) 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.

Finally, the *Object Name Service* (ONS) provides a global search service that supports an EPC code, where it is translated into a URL (*Uniform Resource Locator*) (Berners-Lee, Masinter, & McCahill, 1994), thus having more information about the object to be found. It is also important to notice that this service can be built using the same technology as DNS (*Domain Name System)* (Mockapetris, 1987a). As mentioned, the ONS service can use the already existing DNS service, making use of the NAPTR (*Naming Authority Pointer*) (Mealling & Daniel, 2000) 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 and the fields used in the ONS are *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 any of these, one can get more information about the tag and its context.

It is important to notice that the ONS does not offer any extra information about the tag itself, indicating only the tag owner and also which *"service"* is to be used for data exchange.

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 for instance 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.

E-HEALTH CONTEXT

A study carried out in Portugal on *"Adherence to Medication Regimen in the Elderly"* (Henriques, 2011) (PhD thesis, in Portuguese) showed that a large majority of the elderly people need external help for managing medication.

Having carried out a detailed study with a population of elderly people, the study (Henriques, 2011) stated that *"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 that *"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 (Henriques, 2011)) 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, state reasons where semi-automated AAL systems, as the IoT-base e-Health Service proposed here, may be of invaluable help.

Table 1. Type of Help Needed by Elderly Patients. (Adapted from (Henriques, 2011)*).*

Type of Help Needed	Total Number	Percent. %
Manage Medication	119	36.1%
Get Info on Medication	63	19.2%
Explain Medication regime	44	13.3%
Interpreter Medication regime	26	7.9%
Monitor Medication regime	20	6.1%
Remembering Medication times	19	5.8%
Filling-up Drug-dispenser	10	3.0%
Reading Label	8	2.4%
Monetary Help	7	2.1%
Getting Drugs out of box	4	1.2%

INTERNET OF THINGS BASED SERVICE ARCHITECTURE

This paper presents a simple e-health service prototype for Ambient Assisted Living, based on available and well known IoT technologies, and evaluates the usage of RFID-based information systems in order to establish a real-time monitoring system, able to verify the compliance by patients of correct intake of the prescribed dosage of medications.

The prototype system 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 of them identified by means of RFID-tags. The main objective of these tags is not patient localization, as for instance (Yeung, Kwok, & Mui, 2011) 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 when 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 (Group, 2011), 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, with the correct doses at the correct time. 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 have. 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.

OBJECT NAMING SYSTEM

In order to support this IoT-based AAL system, we have developed a prototype ONS service that allows the registration, and retrieval, of information about physicians, patients, nurses, medicines, prescribed pharmaceutical drugs and recommended dosages.

The Object Name System service has been structured as exemplified on Table 2. Table 2 presents the domain configuration for a corporate Fully Qualified Domain Name (FQDN), entitled RFID-EPC.di.uminho.pt. Numerical parameters listed respect to the Data Base serial number (2013033001, expressing version 01 on 2013/03/30) and several Data Base timing parameters (in seconds, e.g., 14400 establishes 4 hours as the EPC Data Base resolution refresh time).

Table 2. Data Base Configuration file for a specific ONS for EPC resolution

RFID-EPC.di.uminho.pt.	**IN**	**SOA**				**master.RFID-EPC.di.uminho.pt. IT-EPC-manager.CCN.di.uminho.pt. (2013033001, 14400, 7200, 604800, 14400)**	
	IN	NS				master.RFID-EPC.di.uminho.pt.	
	IN	NS				slave.RFID-EPC.di.uminho.pt.	
master	IN	A				10.11.10.1	
slave	IN	A				172.16.111.222	
000001.0000001.sgtin.id	**IN**	**NAPTR**	0	**1**	**u**	**EPC+HTML**	!^.*$!http://server.drug-lab.org/drugs-info/Drugs-01!.
000011.0000001.sgtin.id	**IN**	**NAPTR**	0	**0**	**u**	**EPC+HTML**	!^.*$!http://server.ABC.org/CCN/hospital1!.
000002.0000001.sgtin.id	**IN**	**NAPTR**	0	**1**	**u**	**EPC+HTML**	!^.*$!https://server.ABC.org/CCN/hospital1/Doctors-Level1!.
000003.0000001.sgtin.id	**IN**	**NAPTR**	0	**1**	**u**	**EPC+HTML**	!^.*$!https://server.ABC.org/CCN/hospital1/Patients!.
000004.0000001.sgtin.id	**IN**	**NAPTR**	0	**0**	**u**	**EPC+HTML**	!^.*$!http://non-existent.page.fg/error-type!.
000001.0000001.sgtin.id	**IN**	**NAPTR**	0	**0**	**u**	**EPC+EPCIS**	!^.*$!https://MED-01.LAB-X.org:8080/epcis-repository/query!.
000011.0000001.sgtin.id	**IN**	**NAPTR**	0	**1**	**u**	**EPC+EPCIS**	!^.*$!https://MED-01.LAB-X.org:8080/epcis-repository/query!.
000021.0000001.sgtin.id	**IN**	**NAPTR**	0	**0**	**u**	**EPC+HTML**	!^.*$!http://server.ABC.org/CCN/hospital1!.
*.0000001. sgtin.id	**IN**	**NAPTR**	0	**0**	**u**	**EPC+HTML**	!^.*$!http://LOCAL.CCN.com/bad-id!.

This type of implementation of an Object Name System for Electronic Product Code resolution, takes full advantage of the distributed nature and resilience inherited from the traditional Internet DNS service (Mockapetris, 1987a, 1987b). This ONS service has no single-point-of-failure, as there will be several servers (at least one master and one slave, usually several slaves), with both topological and geographical distributions: every slave server (slave.RFID-EPC.di.uminho.pt. is an example of a slave server) for the domain (RFID-EPC.di.uminho.pt. in the above example) gets its EPC DataBase copy from the master server (master.RFID-EPC.di.uminho.pt.) and is able to independently deliver the service. This way, apart from contributing for the ONS service resilience, every other (slave) server is also able to share the work load:

as there is no real limitation to the number of slave servers for a single ONS domain, the system may grow seamlessly.

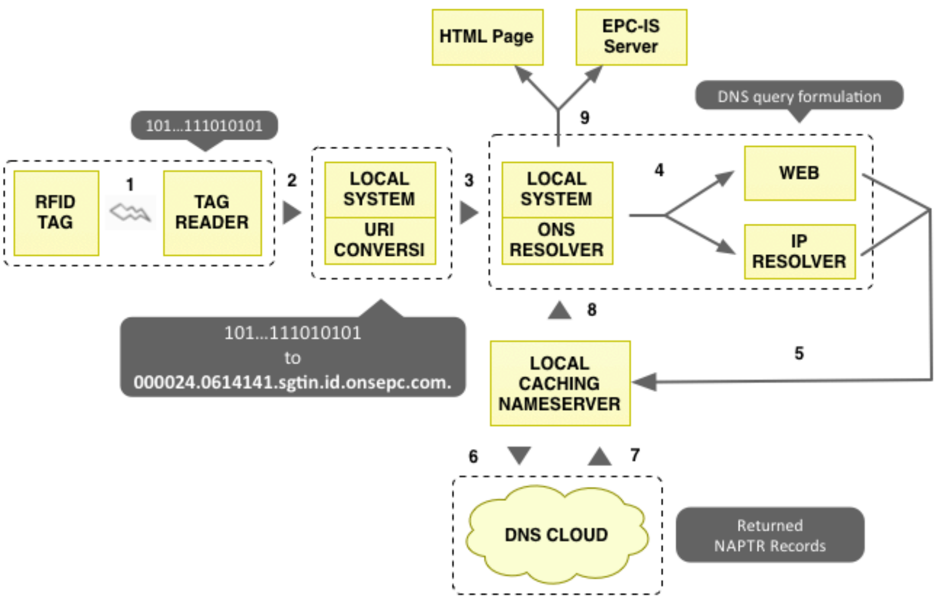
On the other hand, in spite of having the EPC Data Base replicated among several servers, it is still possible to assure that the whole distributed solution is completely secured. As the ONS FQDN zone transfers may, and in this case should, be authenticated, all the ONS servers for any EPC domain should have its own digital credentials and make use of those digital credentials both for server authentication and data encryption. This way one can assure strong authentication for EPC Data Base transfers from FQDN master to slave servers.

Also notice that ONS is mainly the service entry point, perhaps the most important service enabler for the Internet of Things approach presented in this paper: it enables relating the EPC identifier to the corporate, or universal, IoT related data. Notice that this approach enables a mixed corporate/universal IoT based service; the NAPTR resource records (Mealling & Daniel, 2000) that the EPC ONS service returns point either to corporate services, either to universal Internet based services. So, one may resolve EPC identifiers both to publicly available information (as it is the case of very generic drug information, e.g. http://server.drug-lab.org/drugs-info/) and corporate information (as it is the case of https://server.ABC.org/CCN/hospital1/).

EPC identifiers are divided into groups, which are in turn are divided into sub-groups. These groups, also called namespaces, are normatively defined in EPCglobal Tag Data Standards. Each sub-group has a slightly different structure depending on its task, what to identify and how to be used. In order to make good use of Internet-based technologies, the EPC are encoded as URI (Uniform Resource Identifier) which are basic schemes that enable to address the entire World Wide Web, ensuring that the EPC network is compatible with current developments of the Internet.

It is assumed that RFID tags are used to identify each one and all of these stakeholders. Besides that, it is also assumed that there is a ubiquitous and safe 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 2.

Figure 2. Schematic of the prototype service "RFID – based IoT for medication control".



SERVICE IMPLEMENTATION AND TESTING

Figure 2 outlines the e-Health Service prototype architecture and components, starting from the moment 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 (information on medications or pharmaceutical drug composition, as shown in Figure 3, is generally for public access).

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 others are part of the EPC Manager owner signature. In this study, we used a 96-bit length SGTIN format (Finkenzeller, 2010), whose structure is shown in Table 3. The length of the Company Prefix and Item Reference is variable depending on the value of Partition.

The Applet technology allows running java code in the client machine keeping the characteristic platform independence and mobility provided by web applications.

Such technology also allows the application to interact directly with the tag reader hardware to obtain the EPC. Other common web technologies would not enable this direct interaction. Beyond being automatic read from the hardware, the EPC can be manually inserted in both decimal and binary formats.

Table 3. 96-bit SGTIN Scheme. (Adapted form (Finkenzeller, 2010)*).*

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

This prototype 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 resource record whose general format is presented in Table 4.

Table 4. Example of NAPTR records.

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!

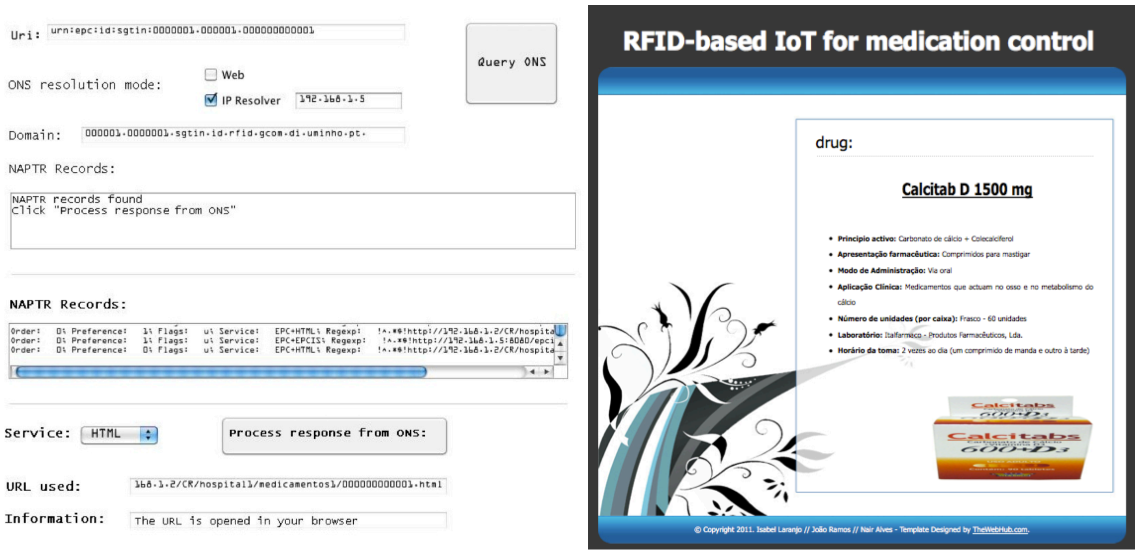
Our prototype application takes the *EPC* code in pure form *URI*, **urn:epc:id:sgtin:0614141.000024.400**, removes the prefix **urn:epc** and the serial number (**400** in this example) and adds the corresponding domain to get **000024.0614141.sgtin.id.onsepc.com**.

The result of a *ONS query* returns a set of records *NAPTR* (see Table 4) 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 3(a)).

Figure 3. (a) URL that is obtained from the NAPTR open in browser. (b) URL access open in browser



(a) (b)

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 3(a)).

The service prototype presented, developed in Java language, was set fully operational and tested. To support general ONS requests, some open source tools (see 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 (for security reasons the method *setCache* has been used so that ONS responses were not stored in cache); 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 "https://code.google.com/p/fosstrak/source/browse/") 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: graphical 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 3(a) and Figure 3(b) result from real captures from the prototype system and present an IoT - based medicine interaction: the RFID tag from a medicine has been read by the prototype system, its EPC led to the ONS resolution and from there, URI pointers led to the EPCIS available information; as one can see on the right (Figure 3(b)) one of the URIs returned has enabled the 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 information 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.

SECURITY ISSUES

In the context of this work personal and private information is accessed, most of which is protected by medical confidentiality. Therefore, this personal and private 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 does not yet include any strong security mechanisms, so it is still 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 and no information leak may occur. Also, the persistent stored information must be encrypted to prevent Data Base attacks.

CONCLUSIONS AND FUTURE WORK

Radio Frequency Identification technology may identify any object with a RFID tag via radio signals. Electronic Product Code, enabling a unique identifier for each object, establishes a simple means to access indexing data and consequently to obtain a URI address with all the information about the object. This technology has certain limitations which need to be overcome or minimized. One is endanger user privacy, another is the increased costs resulting from its implementation.

The implementation of a service based on RFID technology involves a complex set of tasks. Nevertheless, some useful and simple solutions are showing up enabling, for instance, to solve problems related with medication control.

The prototype system implemented and presented in this work, is able to get RFID EPC information associated with several e-health entities and objects: e.g. physician, patient, nurse, caregiver, drug, hospital, pharmacy, etc, assessing either public or private information. The prototype is able to translate EPCs (between binary and decimal format), query the ONS and process the returned NAPTR records, using its URI to access information from services such as a Web server and EPCIS.

The service was designed and implemented for medication control. The system prototype was tested with a simulated cycle: from medical prescription to patient drug control (correct medicine, correct dosages at right time). Everything is logged into the system. With a portable RFID reader and an Internet connection, this service becomes ubiquitous and can be used by mobile users.

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 are also envisaged. Event creation on a calendar with the schedule of dosages of drugs, may also help patients to self-regulate. Authors are also extending the system, enabling for entities/objects location (within corporate health facilities) and increasing the security levels of confidence in authentication and encrypted communications.

Also, at storage level, the system DataBases need to have its sensitive information encrypted. The access to the available information should be granted only to strong authenticated and authorized physicians or nurses. Despite the existence for a digital certificate for the applet, the web interface has still some security flaws. So, deeper security mechanism must be implemented, in order to assure the access control in some parts of the applet.

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