RFID Breadcrumbs for Enhanced Care Data Management and Dissemination

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Abstract- Conventionally, RFID tags are used to uniquely identify objects whose data can then be accessed over the network. This implies that the data storage capacity (up to 4K) of HF RFID has usually been neglected. In contrast, this work follows the *data-on-tag approach*, combining RFID and NFC technologies, with the aim of improving care-data management in assistive environments. It analyses the potential and feasibility of writing and reading small *breadcrumbs* of information at/from residents' RFID wristbands, as a solution to the inherent difficulties of gathering, processing and disseminating data within a multi-user, multi-stakeholder assistive environment such as a residence or a caring home. As a result of this, an AAL platform is extended to deploy what we have termed as the "*RFID breadcrumbing*" interaction metaphor.

Keywords- AAL, NFC, RFID, Real-time Web, Intelligent Environments

1. Introduction

RFID technology is proving as a key enabler of the Internet of Things (IoT) [18] [22], since it is a low cost solution to uniquely identify objects or even encode a URL from which an object's representing service or data can easily be accessed and operated on. The *data-on-network* approach, i.e. using RFID tags to encode a link or ID to a remote network accessed data repository or service, is the most commonly adopted approach. However, this work pursues the *data-on-tag* approach since it makes much more immediate the access to the touched or pointed object's metadata and its exploitation. Furthermore, it does not impose the existence of a perpetual back-end data link (pure data-on-network approach), which may not be desirable or possible in certain situations, e.g. rural environments with low coverage. Still it does not hinder the adoption of a hybrid approach which occasionally accesses a back-end system in order to synchronise or enrich the data stored on the tag with additional information.

The core of this paper is to propose and assess the benefits of adopting passive RFID tags as tiny personal databases where the life-log of a tagged entity (e.g. the care-log of a person who is about to lose its autonomy) can be stored, so that other authorized users (e.g. caretakers) aided by their NFC mobile devices, independently of whether they have access to an Internet link or not, can read, process and manipulate data in them. In other words, this paper proposes leaving small traces of information or *information breadcrumbs* in user-worn RFID wristbands or object-bound tags so that the cooperation of different user collectives or even objects gathering those breadcrumbs and adding new ones is enabled. The main idea is that through these information breadcrumbs personalised services can be triggered, consumed and provisioned within intelligent environments.

The *breadcrumbing* metaphor has its origins in the trail of breadcrumbs left by Hansel and Gretel in the popular fairytale. In computing, such metaphor has been successfully applied to human computer interaction, where a breadcrumb trail refers to a navigation aid used in user interfaces that gives them a way to keep track of their locations within programs or documents. Besides, GPS breadcrumbs refer to the idea of leaving notes or information associated to certain locations. A similar idea was already explored in early works on context-aware computing such as the stick-e note framework [2]. However, those works did not exploit the potential and advantages of making this metaphor reality through current NFC and RFID technology.

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In this work, the RFID breadcrumbing interaction metaphor is introduced as a novel way of enhancing data management and distribution among user collectives. Particularly, this work focuses on analysing the potential of applying this novel way of gathering, generating and disseminating information in the scope of assistive environments [1][12], concretely elderly people residences and homes. Such environments are good examples of heavily instrumented (sometimes intelligent) environments where big amounts of data must be gathered to be able to follow the progress and incidents regarding the daily routine of elderly people. Furthermore, the data gathered in such environments is not only of high relevance to caring staff but it must be communicated, in a daily basis, to the relatives or friends of the people being taken care of, so that they are aware of issues regarding their health, development or general well being. This imposes for the need of efficient real-time data dissemination mechanisms that only disclose the right information to the right people, i.e. they are *privacy aware*.

In summary, the hectic and not always easily regulated caring work prevents staff from being able to gather data in reports, and exploit them, in a timely and reliable manner. Often, those reports are collected at the end of the work shift and rely on the care staff good memory for transcribing the daily events and activities accurately. No provision is usually made to propagate part of that information to maintain a continuous feedback loop with relatives and interested people. In response to these issues, we propose the *RFID breadcrumbing metaphor* which should help alleviating this inefficient information gathering and dissemination process in multi-user, multi-stakeholder environments.

2. Related work

NFC [13] is a prevalent technology, available in some of the last generation smart phones (e.g. Google's Nexus S and Nexus devices), which combines the functionality of a RFID reader device and a RFID transponder into one integrated circuit. It operates at 13.56 MHz (HF – high frequency band). As an integral part of mobile devices (e.g. mobile phones or smart phones), the NFC components can be accessed by software to either act as a reading/writing device or to emulate a RFID tag. NFC devices feature three modes of operation:

a) *Smart Card Emulation*. When using the card-emulation mode, an NFC enabled device emulates an ISO/IEC 14443 or FeliCa compatible smart card. Among others, this mode enables the use of the NFC device as contact-less credit card or electronic ticket;
b) *Peer-to-Peer*. NFC devices can use the peer-to-peer mode defined in ISO/IEC 18092 to transfer data such as electronic business cards between two NFC enabled devices; and
c) *Read/Write*. The read/write mode allows NFC devices to access data from an object with an embedded RFID tag. It enables the user to initiate data services such as the retrieval of information or rich content (e.g. trailers and ring tones). This is the operation mode exploited in this work.

Increasingly, RFID applications are seeking to incorporate custom data directly onto RFID tags [17], eliminating the need to use the RFID tag value simply as a unique identifier to look up additional information in a backend system or database. For example, a company might want to store data such as an expiration date, original manufacturer, last maintenance check, or other relevant data about an asset directly on its RFID tag so that this valuable information is always available. Although the EPCglobal has specified a stack of specifications that enable a standardized identifier (Electronic Product Code – EPC [19]) to be stored on the RFID tag and all object related data to be kept on the network, such a standardized concept does not yet exist to store object related data on RFID tags. In fact, very few systems do store any more information that an ID or URL within a tag. Anyhow, although NFC and EPC tags are both RF technologies, they operate on different frequency bands and cannot yet be used together [23].

The adoption of new technologies to Healthcare environments has not been very effective due to the difficulty of integrating the proposed technologies in these heterogeneous places and their low user acceptance. In fact, a high percentage of clinical or caring staff is reticent to modify their daily work patterns even knowing the practical benefits that these technological approaches may offer. Consequently, the use of smart phones or tablets in those environments has not achieved the expected results. In [21], Roy Want analyzed the gap between computational advances in healthcare and their actual applicability, posing the question of whether computers

work efficiently in hospitals. However, we believe that innovative more user-centred research on Ubiquitous Computing, Context-Awareness and Natural Interaction should reduce that gap and help in the final user acceptance.

Despite the so far experienced difficulties to adopt ICT in healthcare, there are other studies [12] about the daily workflow of hospital nurses, medical interns and physicians that show that the time spent by these health workers in information management represents 20% of their shift time. This reduces the time that healthcare professionals dedicate to their patients in a face-to-face way, causing a loss of contact with patients and residents. By integrating technological solutions that implicitly, or explicitly but highly intuitively, acquire information of the user activities, it is possible to reduce this problem and, thus, increase the time dedicated to face-to-face healthcare of patients. This fact explains why the combination of NFC technology, RFID tags and mobile devices has been suggested in the last few years in several research projects related to medicine and caretaking [4][3][11][15][16].

This work aims to bring about a more usable easily deployable and intuitive technical solution, based on NFC and RFID technologies, which is targeted to solve the data management inefficient issues identified in elderly people caretaking, but extendable to other multi-user, multi-stakeholder environments such as machinery maintenance, industrial greenhouse keeping or cattle caring. In our opinion, direct access, through NFC, to a resident's medical record and the care procedures earlier applied by other caring staff, stored in residents-worn RFID wristbands, can significantly reduce the time spent in accessing clinical and caring records and thus enhancing the overall quality of resident caretaking. Our solution focuses on helping, through an NFC-extended platform, caretaking professionals so that they can take decisions based on their cooperatively gathered and published data (information breadcrumbs) over RFID tags worn by residents. Still, our solution wants to keep up-to-date relatives and friends of the elderly people evolution through social private-aware dissemination means.

3. RFID breadcrumbing

The *modus operandi* of the *RFID breadcrumbing interaction metaphor* is explained as follows. A stakeholder's (e.g. a caretaker) NFC-mobile touching a tag associated to an entity (e.g. a person or object) with a known profile at a given time and location (e.g. home, hospital or care centre), gives place to a set of predefined and standardised message or breadcrumb suggestions (e.g. ate breakfast, took pill), as the ones shown in Figure 7's bottom part. Such breadcrumbs can further be explicitly annotated with some attributes (e.g. what pill she took exactly) and implicitly with some context data, such as who performed the operation (the NFC mobile owner), where, when it did take place or the privacy level associated (see section 0) to the generated breadcrumb. Importantly, those breadcrumbs are directly stored by an NFC mobile in a person's own RFID tags (e.g. in the form factor of wristbands or watches), so that other authorised NFC equipped users can then review the information recorded and offer services which take into account the traces left by earlier visiting users. Furthermore, after providing a service, those interacting users can also leave other traces or breadcrumbs in the visited user's RFID tag.

Notably, a *redundant data forwarding process* is proposed in order to prevent data loss. User mobiles writing data may immediately or after a while propagate its generated breadcrumbs through a 3G, Wi-Fi or Bluetooth communication link. On the other hand, every NFC mobile application updating an RFID tags' contents will gather the oldest breadcrumbs currently stored in that tag whenever there is a need to gain sufficient space to store a newly created breadcrumb. Such device will then also be responsible to forward the collected breadcrumbs to a centralised database. Since every breadcrumb is uniquely identified, different agents publishing the same breadcrumb will not create a problem to the underlying breadcrumb database.

Breadcrumb consumption is not only targeted to local users, i.e. those touching the annotated entity or reviewing the gathered breadcrumbs at a given centre's database. This metaphor also enables for authorized users to remotely consume the gathered breadcrumbs. Logs gathered at the centralised database are selectively, taking into account privacy issues, disseminated to external services from which interested users can review parts of the life-log of an RFID wearing entity. Thus, breadcrumbs will reach to all interested parties, those directly collecting them and those remote users interested on them.

In an earlier work [6], we used the term Cookext to refer to the contents stored by an NFC device on an RFID tag, then retrieved by the very same device. The RFID breadcrumbs approach is thought, however, for the case where several users create, collect and share a range of information breadcrumbs left in HF RFID tags. *RFID breadcrumbing* is about creating, reading, collecting and disseminating information breadcrumbs stored in RFID tags by a group of users in a given domain (e.g. caretaking) so that more personalised and adapted services (e.g. better care services) can be offered to the RFID tag wearers.

4. Applying RFID breadcrumbing to AAL scenarios

This section explains how 13.56 MHz HF RFID tags combined with NFC technology can give place to the proposed RFID breadcrumbing metaphor. Particularly, it gives details on how the proposed interaction mechanism can be applied to AAL scenarios.

Figure 1. Mifare Standard 1K (wristband and card) and 4K (watch) tags and Nokia NFC 6131 used in the evaluation.

4.1. Creation of a portable personal RFID-based databases

In an earlier work [10], we assessed the suitability of using HF RFID tags for storing data. For that, we carried out a three-step process: a) *selection of NFC-compatible wearable tags with as big storage capacity as possible*. Figure 1 shows some of the Mifare 1K and 4K tags selected, together with the NFC device used in our experiments; b) *identify the maximum number of useful bytes storable in the selected tags.* Results obtained through a custom built Java ME application showed that the maximum useful bytes that can be recorded in a 1K Mifare Wristband are 705, whilst using a 4K Mifare Combi Watch, 3196 bytes can be recorded. Notably, the time spent writing these tags is about 2 seconds for the 1K tags and 7 seconds for the 4K tags, implying a small usability problem for the case of the 4K tags; and c) *develop a efficient mechanism to store data on HF RFID tags*. Since Java object serialization is not possible in Java ME, a custom object serialization mechanism was devised that allows for efficient binary encoding of data.

Our data encoding and storing solution [10] offers a special purpose compressed serialization method, sketched in Figure 2, which is undertaken by a Java ME application running on an NFC mobile phone. After the objects to be written are serialized, this method compresses them with a Range Encoding Compression algorithm. Besides, a Blowfish-based symmetric encryption process can be optionally applied to enhance the privacy of the written data.

Figure 2. Data transformation.

4.2. Data gathering issues at care centres

For the purpose of analysing the real possibilities of the RFID breadcrumbing interaction metaphor, the domain of dependant people caretaking has been chosen, which represents a challenging data management domain since:

- *Residents do not always stay and sleep at the care centre*. Some of them stay during the day and return home at the end of the day. Others occasionally stay with their families. Therefore, it is common that the care centre does not have control and is informed of every noticeable event or activity carried out beyond their premises. As a consequence, it is important to reconcile the information supplied by the resident's relatives with the information gathered in a regular basis at the residence.
- *Data capture is not highly prioritised*. Unfortunately, care staff is overloaded and they often postpone the report filling task until the last moment of their working shift. This implies that they record everything they remember about every resident they interacted with. Thus, a best-effort data gathering process is applied within the residence.

Analogously, the data supplied by the resident's family members when they take them out and back to the care centre premises is highly inaccurate and only based on the good will of both relatives and residence staff. If an immediate record of the information supplied by the relative is not supplied, that information is usually lost.

- *IT support at care centres and family homes is diverse*. Most of the care centres do have an IT system which keeps data about the personal and health details of the residents. However, most of the daily events and activities are only recorded in paper forms and then archived. In most cases, only a portion of that data is transferred to the back-end system, since caretakers are often not familiar with computing and are overloaded. On the other hand, relying on families to report via Web on the activities, events and noticeable facts while the elderly people are with them is not realistic. Besides, it cannot be assumed that relatives have an Internet-connected computer or a data plan in their mobile devices to do so. In conclusion, even at care centres those systems are not extensively used.

4.3. Information captured and transferred during caretaking

Several interviews involving staff from an elderly care centre in Bilbao were carried out in order to identify the data actually gathered and then used to enhance the services offered to elderly residents in care centres and homes. Such interviews revealed that three categories of care data reporting are clearly distinguished, as depicted in Figure 3:

1. *Report of daily regular activities.* These reports correspond to the activities carried out every day by a resident usually following a strict time pattern. Examples of these are:
   a. Time and status when the patient woke up, went to sleep, went to the WC, or had any food.
   b. Data about the different medical treatments applied to the patient, including medicines, rehabilitation exercises, or any other. Daily biometrical measures taken from a resident such as heart rate, glucose level or blood pressure are also stored.
2. *Report of non-daily, non-scheduled activities*. These gather data such as:
   a. Visits received by a resident, their duration, number of visitors, their relationship with the resident, and so on.
   b. Incidents with other patients or staff, medical incidents, technical incidents.
3. *Report of activities outside the centre, such as:*
   a. Externalization or transfer of a resident, visits by external doctors or special diagnosis equipment.
   b. Spending time home or out of the residence, such as holidays or outdoor activities.

Apart from what to record, another very important aspect is when to transfer the collected data to the residence's back-end. As previously mentioned, the fact that those events are manually reported several hours after they actually happened implies that data is often lost or is useless once reported. To address this issue, this work proposes that residence staff, relatives and external care staff read and record caring data using the intuitive RFID breadcrumbing interaction metaphor, where caring staff review and modify residents' RFID wristbands through NFC mobile phones. As previously mentioned, care breadcrumbs are recorded by touching a resident' RFID wristband with an NFC mobile and then quickly selecting by two or three clicks on the mobile application's user interface the concrete care action to log.

Recording caring data through an Internet-connected PC is unadvisable outside a caring centre. Often, relatives or external carers do not have Internet access, they are not computer literate, and, in case of having access to a PC, they often postpone the data reporting process. Even within a residence, care record reporting through a PC makes the reporting process a non real-time activity prone to the loss of many details on the way. Therefore, the review and recording of caring logs *in situ* and *ipso facto* through an NFC mobile phone and an intuitive mobile logging application interface, as suggested by the RFID breadcrumbing interaction metaphor, is a much more feasible approach for suitable care data logging.

4.4. HF RFID tags as daily care breadcrumb repositories

Figure 4 shows the actual data stored in a user-worn HF RFID tag. This is, her personal database including a set of life logs

or breadcrumbs. The `PersonalDB` class embodies all these data and consists of the following elements: a) an instance of class `Person` including a set of generic personal attributes (`name`, `birthdate` and so on), agnostic to the application-domain, a `type` attribute indicating the name of the class derived from `Person` (e.g. `Resident`) where additional application specific personal details are stored and serialized into the `contents` attribute (e.g. a reduced version of an Electronic Patient Record (EPR) including pathologies, allergies and latest measured biometrical values), b) a collection of information breadcrumbs or logs where each message includes a serialized instance of a class derived from `Breadcrumb` including the following attributes: `timestamp` it was created on, who created it (`loggerID`), where it was created (`locationID`), the `type` of message, i.e. the name of a class derived from `Breadcrumb` used in the serialization (e.g. `es.deusto.eldercare.daily.sleep.Awake`) and the actual message `contents`, in this case the time when it happened. It may look strange to have to include the `type` attribute in every breadcrumb stored, but this is necessary due to the fact that Java ME does not support reflection as already pointed out in section 0. Notice that an extra implicit parameter, namely `privacy_level` is defined for each breadcrumb which states the privacy nature of a given breadcrumb type, e.g. only visible by caring staff or also available for relatives or friends. Section 0 will explain how this attribute is exploited to enable privacy-aware real-time relay of breadcrumbs to different interested parties.
Notice that if the breadcrumb iteration metaphor was applied to other domains, e.g. machinery maintenance carried out by a group of mechanics, the mentioned `PersonalDB` would be transformed into a `MachineDB` and rather than enhancing `Person` information with breadcrumbs we would be enhancing `Machine` information. However, the `BreadCrumb` class is generic enough to be reused in any other application domain.

While profiling the data encoding process mentioned in 0 and detailed in [10], it was found that the optional encryption step does delay the recording and reading of a breadcrumb around 20%. The analysed care log dataset (a total of 234) presented some redundancies, e.g. the same caretaker leaves several care breadcrumbs during a day over the same resident's RFID wristband, most of the logs are recorded at the same location (e.g. residence or home) and so on.

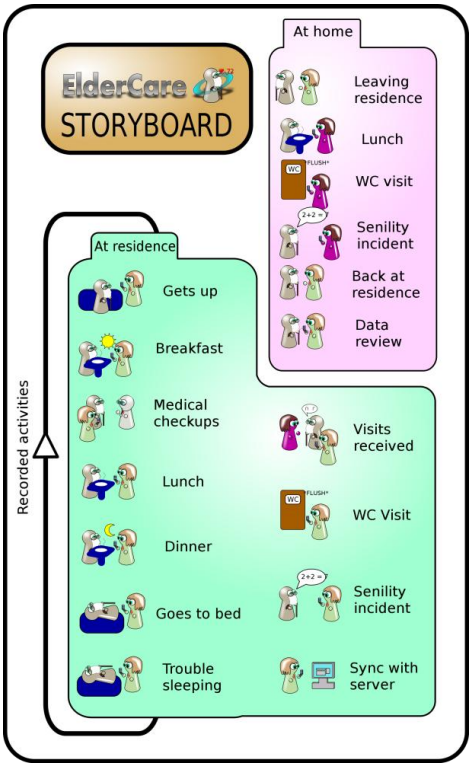

Figure 3. Storyboard with events collected by ElderCare.

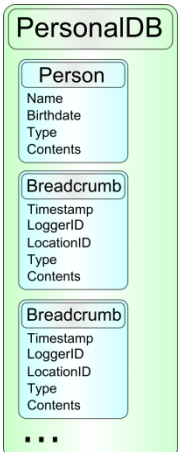

Figure 4. Data encoded on a tag.

Thus, compressing all the breadcrumb information together makes the total storage needs much smaller than storing each breadcrumb one by one. According to the care taking experts interviewed, the 34 and 64 messages store capacity found for the 1K and 4K cards, respectively, is sufficient, even in the 1K wristbands' case, to store all the logs gathered for a resident in a day.

5. An NFC-supported AAL platform for caretaking

The ElderCare platform described in [9] has been extended to accommodate the RFID breadcrumbing interaction metaphor and thus cope with the following issues associated to data gathering in a residence:

- *Different people (e.g. staff, family members, physical trainers) at different moments*, in different places (e.g. centre itself, at home, other hospitals) report data regarding a resident's daily care activities and events.
- *Collected data is only synchronized or transferred to the IT system on a best effort basis*. Usually, family members do not report directly to the IT system, they explain by voice anything relevant to the resident while being outside. Caretakers do not usually report the care related data in real time. They usually do it at: a) the beginning of their shift, b) whenever they receive the entries of residents and c) at the end of the shift, transcribing everything that was annotated or memorized during the shift.
- *An effective new mechanism to log care data must be easy to use and widely available*. A mobile device is a suitable device to log care data in real-time only if the data recorded can be easily selected by simply performing two or three clicks on a mobile application and introducing some numeric values. Furthermore, details such as who performs the log, for whom, with what privacy level, at what time and where have to be implicitly obtained by the application as result of touching the RFID tag with an NFC phone. Therefore, the NFC touch computing approach' benefits have to be combined with an intuitive graphical user interface on the mobile phone to select the appropriate care log to perform.

Figure 5 shows the architecture of the NFC and RFID-enabled ElderCare platform. The back-end system is composed of:

- *A web server* which hosts the care centre web application maintaining all relevant data about caretakers and residents in a relational MySQL database.
- *A synchronisation server* which transfers all the care breadcrumbs, related to caring events affecting different residents and harvested by caretakers' mobile devices from residents' wristbands or watches, into a MySQL database recording the necessary data to enhance the caretaking quality within the residence; and
- *A DAO component* which mediates all the data exchanges between the web application and synchronisation server, and the MySQL database; and relays non privacy sensitive breadcrumb information to external third-party services.

On the client side (left hand side of Figure 5), residence staff may use either an advanced web front-end based on GWT (Google Web Toolkit) to perform any generic data management in a residence (see Figure 6), or a Java ME application, which enables mobile users in an easy manner to both add new care breadcrumbs to a resident's wristband (observe Figure 7) and to extract them (*harvest*) with the purpose of reviewing them and optionally transferring them into the care centre back-end. Remember that whenever a caretaker tries to make a new annotation and the storage capacity of the resident's RFID tag has been exhausted, it is the caretaker's mobile application's responsibility to collect the data available until that moment (harvest it) and dump it later to the back-end system. Whenever data is harvested from a RFID tag only the oldest breadcrumb or breadcrumbs necessary to fit the new one are deleted, flagging the remaining ones as already harvested, preventing other ulterior user's from re-harvesting them. A backup of all breadcrumbs recorded by a given mobile is also kept and propagated to the back-end by the Java ME application, to avoid potential loss of data due to RFID failure. Therefore, there is a redundant breadcrumb propagation process in place.

Both the web and mobile clients are very intuitive since they offer easily browseable menus with a predefined, customizable set of annotations which can be parameterized (e.g. `Diagnosis with [normal; swine] flu`), and still offer the user the chance to insert free text annotations.

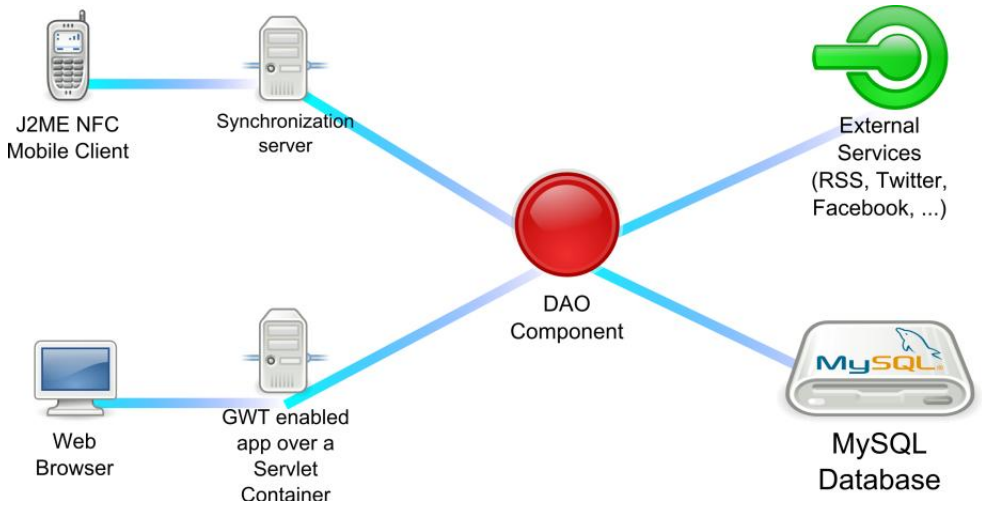

Figure 5. ElderCare Architecture.

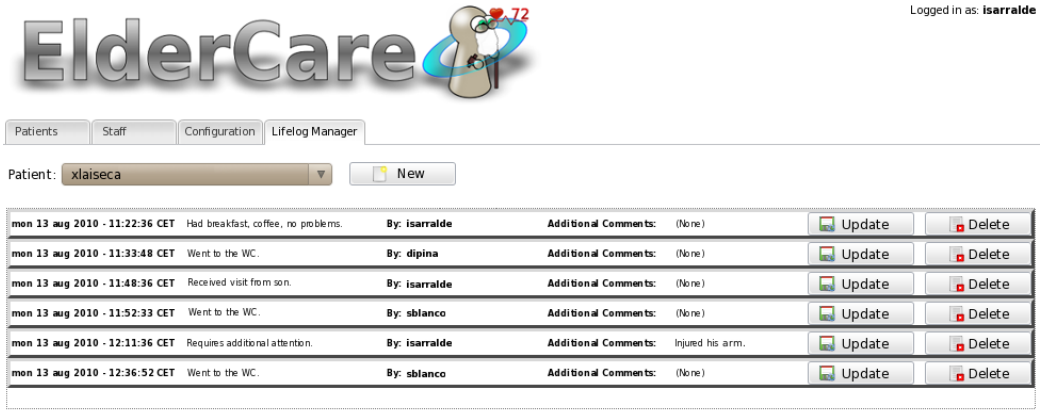

Figure 6. GWT front-end for ElderCare.

6. Relaying privacy-aware care data to the real-time web

An important collective not usually targeted by AAL platforms is people concerned with or interested in the elderly people, e.g. relatives or friends who are not directly involved in caretaking. The breadcrumb interaction paradigm is though to cope with this type of scenarios since it promotes both local and remote consumption of information breadcrumbs. Consequently, its implementation in the ElderCare platform supports different notification mechanisms to keep interested parties up-to-date (e.g. email, SMS, RSS or Twitter) about dependant people evolution. In other words, the ElderCare platform does not only keep custom data to enhance the daily caring activities and reduce errors in a care centre but it also exports part of that data to external real-time web services from which relatives and friends can follow dependant people's life log in a residence or in a monitored care home.

ElderCare is very sensitive to the private nature of many of the gathered care logs in a residence. For this reason, care breadcrumbs are filtered taking into account privacy concerns and then posted to a given resident's relatives and friends through different notifications mechanisms (see Figure 8). For instance, a post may be done to a resident's Twitter page, configured as a protected Tweet account so that only authorized followers can see the published tweets. Alternatively or simultaneously, the same breadcrumb may be published on a Facebook wall, an SMS message sent to relatives and friends of a resident, or an email with a report digest of the daily care breadcrumbs of a resident sent to their authorized relatives and friends.

Figure 7. ElderCare Mobile client.

Figure 8. Relying data to external services.

The care breadcrumb privacy-aware notification module devised is based on log4j[1], a very popular Java framework for flexible programming logging, where a log is a text message usually written to console such as `[main] INFO MyApp - Entering application.` In ElderCare, care breadcrumbs are classified according to different privacy levels which indicate the restrictions upon which some care logs may be relied to external services after they have been stored in ElderCare's central server.

Table 1 shows the four privacy levels that have been defined. Remember from section 0 that a breadcrumb is represented by an instance of a class derived from `Breadcrumb`. Such class provides an attribute named `privacy_level` which states in what level (according to the descriptions of Table 1), a breadcrumb should be forwarded through real-time dissemination mechanisms.

The class responsible for relying care breadcrumbs within the ElderCare platform is called `Disseminator`. Such class follows the behaviour of a log4j `Logger`, i.e. if the privacy level of a class representing a breadcrumb is not defined then it inherits its parent's privacy level. As in log4j several `Appenders` or output destinations can be assigned to a `Disseminator` instance. The derived classes `TwitterAppender`, `FacebookAppender` and `SmsAppender` have been implemented. For instance, the `TwitterAppender` class uses the twitter4j library, a Java implementation of the Twitter API, to send update messages to a protected Twitter account, where only authorized followers can view the tweets.

As an example, Figure 9 shows the automatically posted tweets for a resident by a `TwitterAppender`. Observe that the tweet creation timestamps, location and creator's username are implicitly inserted since every care procedure or care event annotation on a resident's wristband is qualified by the context attributes when, where and who performed it. On the other hand, notice that the synchronization process

[1] http://logging.apache.org/log4j/1.2/manual.html

occurs whenever caretakers initiate a Bluetooth, Wi-Fi or 3G session to upload into the care centre back-end all the residents' breadcrumbs that have been harvested from their identifying wristbands into the caretaker's mobile. This explains why in the Twittter snapshot the logs appear to have been uploaded all at once.

Table 1. Privacy levels associated to care breadcrumbs.

Level	Description
PRIVATE	Only medical or caring staff within a residence can see this care breadcrumb. It will never be relied to any external notification service. It will only be stored in ElderCare's central server's DB, where every care breadcrumb, independently of its privacy level, is stored.
CARER	Only the set of users which act as external carers (either professional or family members outside the residence) will be notified about these logs.
RELATIVE	Authorized relatives and friends may receive notification of residents' care breadcrumbs labelled under this privacy level. Users who do not perform caring tasks but will obviously be interested on the evolution of a resident fall in this category.
PUBLIC	Any care breadcrumb labelled with this public level will be automatically relied to the chosen real-time notification systems by the residents or their families.

7. Conclusion and Further Work

The main contribution of this work has been to prove that the data-on-tag approach of RFID combined with NFC mobile devices enables a new human-to-human interaction metaphor, namely RFID breadcrumbing, which can be very useful in scenarios with data management and dissemination problems. The resulting NFC-based platform allows caring staff to harvest the traces (breadcrumbs) left by others and to add new information breadcrumbs so that others can benefit from them. Furthermore, those information breadcrumbs are stored in a permanent manner on a central database and also forwarded through privacy-aware notification services so that interested people can also follow the whereabouts of residents.

The ElderCare platform prototype has been deployed in a residence in Bilbao where a reduced set of carers (2) have assessed the suitability and advantages brought forward by the RFID breadcrumbing interaction paradigm when interacting with residents (3 in the study). The positive feedback received in the questionnaires and the low-investment costs associated to its deployment will hopefully lead the residence management to request a full deployment in due time.

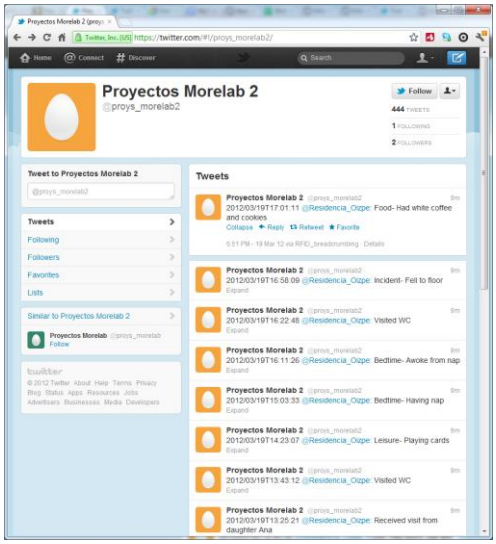

Figure 9. Care breadcrumbs forwarded to Twitter.

Further work on techniques to improve even more the amount of data stored or semantically annotate the stored information in the very tags will also be considered. In addition, our platform will be ported to other multi-user scenarios where different stakeholders cooperate on tasks or procedures applied to RFID labelled objects and people, e.g. cattle monitoring or industrial greenhouse keeping.

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References

[1] Ambient Assisted Living Joint Programme, http://www.aal-europe.eu, (2012)

[2] Brown, P.J. Bovey, J.D. Xian Chen.: Context-aware applications: from the laboratory to the marketplace. IEEE Personal Communications, vol. 4, no. 5: 58-64, (1997)

[3] Carroll R., Cnossen R., Schnell M. and Simons D.: Continua: An Interoperable Personal Healthcare Ecosystem. IEEE Pervasive Computing, vol. 6, no. 4, (2007)

[4] García-Vázquez J.P., Rodríguez M.D., Andrade A.G. and Bravo J.: Supporting the strategies to improvement elders´ medication compliance by providing ambient aids, Personal and Ubiquitous Computing Journal (ISI-JCR), vol. 15, no. 4: 389-397, Springer DOI: 10.1007/s00779-010-0363-z (2011)

[5] Haselsteiner E., Breitfuß K. Security in near field communication (NFC)PDF (158 KB), Philips Semiconductors, Printed handout of Workshop on RFID Security RFIDSec, (2006)

[6] Hervás R., Chavira G., Nava S., Villarreal V., Bravo J. In 12th International Conference on Knowledge-Based and Intelligent Information & Engineering Systems. LNCS, pp. 757-764. ISBN:978-3-540-85562-0 - Springer. Zagreb, Croatia, (2008)

[7] Langheinrich M. A Survey of RFID Privacy Approaches. Personal and Ubiquitous Computing, vol. 13, No. 6, Springer, pp. 413, (2009)

[8] López-de-Ipiña D. and Vazquez J.I., Simplifying Human to Environment Interaction through Touch Computing, Ambient Intelligence and Smart Environments (AISE) series, Volume I, Ambient Intelligence Perspectives, Selected Papers from the First International Ambient Intelligence Forum (AMIF) 2008, IOS Press, ISBN 978-1-58603-946-2, vol. 1, pp. 153-165, 15-16, (2008)

[9] López-de-Ipiña D., Blanco S., Laiseca X. and Díaz-de-Sarralde I., ElderCare: An Interactive TV-based Ambient Assisted Living Platform. Actas del II International Workshop of Ambient Assisted Living (IWAAL 2010), p.p. 75-82 Valencia, Spain, ISBN: 978-84-92812-67-7, (2010)

[10] López-de-Ipiña D., Díaz-de-Sarralde I. and García-Zubia J., An Ambient Assisted Living Platform Integrating RFID Data-on-Tag Care Annotations and Twitter, Journal of Universal Computer Science (J.UCS), ISSN: 0948-695X, vol. 16, no. 12, pp. 1521-1538, (2010)

[11] Mei H., Widya I., van Halteren A., Erfianto B.: A Flexible Vital Sign Representation Framework for Mobile Healthcare, Pervasive Health Conference, November 2006.

[12] Mejía, D.A.; Favela, J.; Moran, A.L.: Understanding and Supporting Lightweight Communication in Hospital Work, IEEE Transactions on Information Technology in Biomedicine, vol. 14, no. 1, pp. 140-146, (2010)

[13] NFC Forum.: NFC Forum Website. http://www.nfc-forum.org, (2012)

[14] NFC Forum: NFC Data Exchange Format (NDEF) Technical Specification, http://www.nfc-forum.org/specs/spec_list/, (2012)

[15] Preuveneers D. and Berbers Y.: Mobile phones assisting with health self-care: a diabetes case study, International Conference on Human Computer interaction with Mobile Devices and Services, MobileHCI '08. ACM, New York, pp. 177-186, (2008)

[16] Roy N., Pallapa G., and Das S.: A Middleware Framework for Ambiguous Context Mediation in Smart Healthcare Application, IEEE International Conference on Wireless and Mobile Computing, Networking and Communications, (2007)

[17] Teskey M: Turning RFID Data into Information, http://www.devx.com/enterprise/Article/32251/1954, (2007)

[18] Thompson, C.W.: Smart devices and soft controllers, Internet Computing, IEEE vol. 9, no. 1, pp. 82 – 85, (2005)

[19] Tribowski C., Spin K., Günther O., and Sielemann O.: Storing Data on RFID Tags: A Standards-Based Approach, Proceedings of the 17th European Conference on Information Systems (ECIS 2009), Verona, Italy, (2009)

[20] Varshney, U.: Pervasive Healthcare Computing. 288p. ISBN 978-1-4419-0214-6, (2009)

[21] Want, R. People First, Computers Second. in IEEE Pervasive Computing, (2007)

[22] Welbourne, E. Battle, L. Cole, G. Gould, K. Rector, K.Raymer, S.Balazinska, M. Borriello, G.: Building the Internet of Things Using RFID: The RFID Ecosystem Experience, Internet Computing, IEEE, vol. 13, no. 3, pp. 48-55, ISSN: 1089-7801, (2009)

[23] Wiechert T., Thiesse F., Michahelles F., Schmitt P., Fleisch E: Connecting Mobile Phones to the Internet of Things: A Discussion of Compatibility Issues between EPC and NFC, http://www.autoidlabs.org/single-view/dir/article/6/291/page.html, (2008)