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An Ambient Assisted Living Platform Integrating RFID Data-on-Tag Care Annotations and Twitter

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Abstract: Although RFID is mainly used to identify objects whose data can then be accessed over the network, passive HF RFID tags do have significant data storage capacity (up to 4K), which can be utilised to store data rather than only IDs. This work explores the potential of storing, accessing and exploiting information on tags both, *theoretically*, by studying how much data can actually be stored in HF RFID tags, and *practically*, by describing an NFC-supported platform adopting the *data-on-tag approach* to improve data management in a care centre. Such platform illustrates two key aspects for AAL: a) RFID tags can serve as temporary repositories of care events whenever a continuous data link is not desirable and b) interactions between RFID wristbands worn by residents and care staff's NFC mobiles can improve care data management and keep relatives up-to-date with elderly people's evolution, through a Web 2.0 social service.

Keywords: RFID, NFC, IoT, AAL, Twitter, Web 2.0
Categories: C.2.4, C.2.6, D.2.2, D.2.6, D.2.11, D.2.12

1 Introduction

Ambient Assisted Living [AAL, 09] fosters the provision of equipment and services for the independent or more autonomous living of elderly people, via the seamless integration of info-communication technologies within homes and residences, thus increasing their quality of life and autonomy and reducing the need for being institutionalised or aiding it when it happens. This work explores this latter aspect of AAL, i.e. providing IT solutions once elderly people start losing their autonomy and stay either the whole day or partially in care centres.

RFID technology is proving as a key enabler of Internet of Things (IoT) [Thompson , 05] [Welbourne, 09], 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. Although 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 being successfully used, becoming the default RFID-based systems configuration, this work deems that adopting a data-on-tag approach may be even more suitable for IoT, 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, and it brings along important data traffic savings. Still it does not hinder the adoption of a hybrid approach which occasionally accesses a back-end in order to synchronise or enrich the data stored on the tag with additional information. Consequently, this work proposes the adoption of passive RFID tags as tiny databases where a lifelog of a person can be stored, so that other users with their NFC devices, independently of whether they have access to an Internet link or not, can access and manipulate the data in them, providing they are authorised to do so.

Elderly care centres are clear examples of 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 staff in order to offer a better service, but it must be communicated, in a daily basis, to the relatives of the people being taken care of, so that they are aware of issues regarding their health, development or general well being. Unfortunately, the hectic and not always easily procedurised caring work prevents staff from being able to gather data in reports in a timely and reliable manner. Often, those reports are collected at the end of the day and rely on the care staff good memory for transcribing the daily events and activities accurately. In our opinion, NFC technology could be used to alleviate this inefficient information gathering process. A caretaker's NFC-mobile touching a tag associated to a person, with a known profile at a given time and location (home, hospital or care centre), could give place to a set of predefined and standardised available logging suggestions (e.g. ate breakfast, took pill), which could 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 and when it did take place. More interestingly, those annotations would be stored in the residents' RFID wristbands, so that other authorised caretakers can review the caring procedures applied to a resident when they approach to her.

The structure of this paper is as follows. Section 2 reviews some related work on earlier research efforts regarding the two core contributions of this work: a) the use of RFID tags to encode data on them and b) the combination of NFC and RFID technology for aiding caretaking. Section 3 analyses the encoding capabilities of passive 15.56 MHz HF tags, both in terms of capacity and performance, in order to assess whether their use is recommended to improve data management in environments with high data capture and reporting demands. Section 4 analyses the challenging data handling duties in a caretaking environment and suggests an NFC-supported platform to alleviate them. Section 5 overviews a prototype implementation of such platform, namely CareTwitter, which also illustrates the integration of augmented objects (resident wristbands) with Internet services (Twitter). Finally, section 6 concludes the paper and details some future work plans.

2 Related Work

NFC [NFC Forum, 09] technology 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 PDAs), the NFC components can be accessed by software to either act as a reading/writing device or to emulate a RFID tag. The Nokia 6131 NFC SDK [Nokia, 07] allows developers to create and emulate Java applications (MIDlets) for the Nokia 6131 NFC mobile phone, one of the few worldwide available NFC mobile phones.

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).

Increasingly, RFID applications are seeking to incorporate custom data directly onto RFID tags [Teskey, 07], 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 [Tribowski, 09]) 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 [Wiechertm 08]. Notably, some researchers [Sample, 08] [Philipose, 05] are lately proposing an evolution of RFID tags where the power gathered from the reading device is used to read some data from the object/person to which they are attached and transmitted as if an ID had been read. The main novelty of this approach is that the data read is dynamically generated, giving place to RFID sensing tags.

The combination of NFC technology and RFID tags has been used in the last few years in several research projects related to medicine and caretaking [Bravo, 08]. Indeed, the adoption of mobile devices, as discussed by those works, is making caretaking easier. Although the usage of mobile devices like PDAs or laptops or even PCs can help in the caring process data management, those devices still demand traditional keyboard based data input mechanisms which are slow and cumbersome. The touch computing paradigm [Bravo, 06] brought forward by NFC makes the interaction between users and objects more immediate (by simply touching the required object). Mei proposes the development of a framework that depicts patients' vital signs [Mei, 06] and Tadj, with LATIS Pervasive Framework (LAPERF), provides a basic framework and automatic tools for developing and implementing pervasive computer applications [Tadj, 06]. Roy [Roy, 07] proposes a framework that supports the merge of efficient context-aware data for health applications that are regarded as an ambiguous context. More recently, Preuveneers researches how a mobile telephone platform can help individuals diagnosed with chronic illnesses like diabetes manage their blood glucose levels without having to resort to any additional system apart from the equipment they presently use, or without having to use additional activity sensors like pedometers, accelerometers or heartbeat monitors [Preuveneers, 08].

The Continua Health Alliance [Carrol, 07] is a non-profit, open industry group of healthcare and technology companies working together to improve the quality of personal healthcare. The Continua Health Alliance is working towards establishing a system of interoperable tele-health devices and services in three major categories: chronic disease management, aging independently, and health & physical fitness. The Continua Health Alliance design guidelines are based on proven connectivity standards, such as Bluetooth, NFC, Zigbee and USB, among others. Its reference architecture covers the whole personal healthcare management lifecycle from capture to aggregation and storage in health service management software.

3 Using RFID tags as Portable Databases

The storage of data in RFID tags is far from common. However, passive HF RFID tags do have considerable data storage capabilities which make them suitable to be used as low-cost object-bound databases.

Figure 1: Mifare Standard 1K and 4K tags and Nokia NFC 6131 used in the evaluation.

3.1 NFC Support for Data Encoding in HF RFID tags

The NFC Forum specifies a data-packaging format called NDEF (NFC Data Exchange Format) [NFC Forum, 06] to exchange information between an NFC device and another NFC device or an NFC tag. The specification defines the NDEF data structure format as well as rules to construct a valid NDEF message as an ordered and unbroken collection of NDEF records. Furthermore, it defines the mechanism for specifying the types of application data encapsulated in NDEF records. An NDEF record carries three parameters for describing its payload: the *payload length*, the *payload type*, and an optional *payload identifier*. Payload type names may be MIME media types, absolute URIs, NFC Forum external type names, or may be well-known NFC type names. The NFC RTD (Record Type Definition) is intended to support NFC-specific application and service frameworks by providing a means for reservation of well-known record types, and third party extension types. Record type names are used by NDEF-aware applications to identify the semantics and structure of the record content.

Wristband/ Card Mifare 1K			
Record Size (bytes)	**Number of stored records**	**Average writing time (ms)**	**Actual bytes written (record ID of 4 bytes)**
1	79	1902	395
2	71	1885	426
4	59	1844	472
8	44	1791	528
16	29	1747	580
32	17	1705	612
64	9	1639	612
128	5	1689	660
705	1	1732	709

Table 1: Analysis of the storage capabilities of a 1K Mifare wristband.

Mifare 4K Watch			
Record Size (bytes)	**Number of stored records**	**Average writing time (ms)**	**Actual bytes written (record ID of 4 bytes)**
1	372	8081	1860
2	335	7724	2010
4	279	7259	2232
8	209	6846	2508
16	139	6520	2780
32	83	6283	2988
64	46	6252	3128
128	24	6093	3168
3196	1	6214	3200

Table 2: Analysis of the storage capabilities of a 4K MifareCombi watch.

3.2 Analysing the Data Encoding Features of HF RFID Tags

In order to assess the suitability of using HF RFID tags for storing data, we have applied the following three-step process:

1. **Select a set of easily wearable tags with as much storage capacity as possible and still compatible with NFC and the Nokia NFC 6131 mobile.** Figure 1 shows the HF RFID selected for our experiment: a 4K MifareCombi Watch, a 1K Mifare wristband which can be easily attached to people, and 1K Mifare cards. All of them are ISO 15693-compatible, and therefore, readable and writeable by the Nokia NFC 6131 mobile used in our experiments. Furthermore, they have an ideal form factor to be worn by people.
2. **Identify the maximum number of useful bytes storable in the selected tags**. A Java ME application was developed that carries out a binary search in order to identify from an initial record size of 4Kbytes, how many records can be stored, how long it takes to write them, and how much actual useful data is encoded. Table 1 illustrates the maximum useful bytes that can be recorded in a 1K Mifare Wristband, as the one shown in Figure 1, i.e. a maximum of 705 useful bytes.

Table 2 shows the results obtained when using a 4K MifareCombi Watch, i.e. 3196 bytes. In both experiments a record identifier of 4 bytes was used within the NDEF record stored. Notably, the time spent writing these tags is about 2 seconds for the 1K tags and 7 seconds for the 4K tags. Besides, the mobile must be kept close enough to the tag in that period if data wants to successfully be written. This evidences a small usability problem whenever writing 4K HF RFID tags.

3. **Develop a new efficient mechanism to store data on HF RFID tags**. Once the storage capabilities of the selected tags were known, the final stage was to identify an efficient and flexible manner to store data on tags, according to the NDEF format. Taking into account the results obtained experimenting with different numbers of records, it was decided that only one record NDEF messages would be used. Furthermore, given that no standard on the data structures used by care centres to keep data on their interns was found, it was decided to make use of standard object serialization utilising the payload type field to identify the class name serialised. This latter fact is very important in the Java ME domain which lacks object serialization and Reflection. Consequently, a custom object serializer which works exactly the same way in Java SE and Java ME was developed. The only prerequisite for any class whose data is candidate to be stored in an RFID tag is to implement the `caretwitter.entity.utils.Serializable` interface (see Figure 5), which exposes methods to convert a class instance into an array of bytes and vice versa. Finally, rather that encoding the obtained byte streams directly into the tags, a compression process is undertaken to maximize the actual amount of data stored. For that, a Range Encoding Compression algorithm implemented in Java ME (http://www.winterwell.com/software/compressor.php) and released under LGPL license has been used.

4 Applying the Data-on-tag Approach for Enhancing Care Data Management

This work suggests that caretaking is a suitable domain for combining NFC technology and the RFID data-on-tag approach in order to enhance the data gathering process. This is because elderly people are looked after at different domains (elderly people's homes or their families', the residence itself), in different days (weekdays, weekends, during the day and night) and by different people (relatives or residence staff), making very difficult to reconcile the information gathered by all those people at those different places. Although a 3G mobile data link could be usedto transmit data from the device to a central server independently on whether the logger is within or outside the residence, cheaper communication schemes such as Bluetooth or Wi-Fi should be regarded. Unfortunately, the most popular and widely available NFC device, the NFC 6131, only enables 3G and Bluetooth communication. In order to use Bluetooth within the residence an intensive and cumbersome deployment of Bluetooth infrastructure should be deployed across the residence. In our opinion, it is very important to have access immediately to the latest caring records stored on the resident's own wristband, either inside or outside a residence, without being limited by the availability or not of a Bluetooth connection link, or being forced to use a more costly 3G connection link.

Apart from what to record, other very important aspects are who reads or writes care data, where, how and when they transfer the collected data to the care centre's back-end system. In this work, it is assumed that the residence staff and relatives or external care staff can record caring data whenever the resident is at the very residence or outside, respectively. Such care data recording is performed by touching a resident' RFID wristband with an NFC mobile and quickly selecting by two or three clicks on the mobile's user interface the concrete care action to log. We argue that recording caring data through an Internet-connected PC is infeasible 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, theyoften 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, this work proposes that recording caring logs *in situ* through an NFC mobile phone and an intuitive mobile logging application looks like a much more feasible approach for suitable care data logging.

4.1 Data Gathering Issues at Care Centres

The following points illustrate why the data gathering process in the elderly care domain is a challenging problem:

- **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 in 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 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 IT and are overloaded. On the other hand, counting 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 mobile device to do so. In conclusion, even at care centres those systems are not extensively used.

4.2 Data Collected at Care Centres and Outside

In order to identify the data actually gathered and then used in care centres, several interviews with care staff from a care centre in Bilbao, Spain have been carried out. The results of such interviews are shown in the storyboard depicted in Figure 2, where three categories of data reporting are clearly distinguished:

1. **Report of daily regular activities within the residence**. These reports correspond to the daily activities carried out by a resident usually following a strict time pattern (left-side logs in the "at residence" tab in Figure 2). Examples of these are:
   - What time did the resident get up or go to bed?
   - What did they have for breakfast/lunch/dinner?
2. **Report of significant non-regulated activities within the residence**. These reports gather data such as: doctors' visits and their corresponding assessment results, external visits received by a resident, their duration, number of visitors and their relationship with the resident, WC visits or any events or activities in which the resident was involved which are outside a fixed daily pattern (see right logs of the "at residence" tab).
3. **Report of activities outside the residence**. In this case, people taking the elderly outside the care centre have to record facts, otherwise recorded within the residence. Examples of such aspects are: WC visits and their times, any incidents or noticeable events which occurred, what and when the resident ate and so on.

Traditionally, there are two key moments when residence staff usually transfer data to the residence's IT system: a) whenever the resident enters the care centre and a voice report is given by the person accompanying the resident and b) at the end of the shift when the care centre staff carries out their daily reports. As previously mentioned, the fact that those caring events are manually reported several hours after they actually happened implies that a lot of data is lost. Consequently, the overall quality of the caring process and their associated report to the interested parties (doctors and relatives) is affected.

4.3 An NFC-supported AAL Platform

A useful data gathering system for a care centre has to take into account the following issues synthesized from the earlier discussion:

- **Different people** (e.g. relatives, staff) **at different moments** (e.g. entrance to centre, stay in centre, exit of centre) **in different places** (e.g. centre itself, outside) **report data** regarding a resident's daily care activities and events.
- **Collected data is only synchronized or transferred to the care centre 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. Furthermore, details such as who performs the log, for whom, 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, NFC touch computing paradigm benefits have to be combined with an intuitive graphical user interface on the mobile phone to select the appropriate care log to perform.

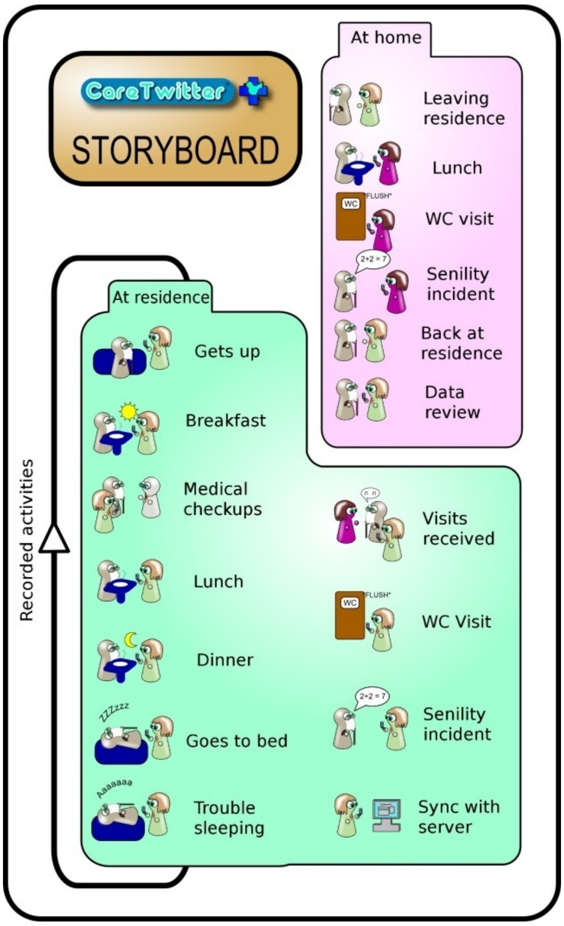

Figure 2: Most significant care logs recorded.

Figure 3 shows the architecture of the NFC-supported platform, namely CareTwitter, proposed to address the data gathering issues raised in the care centre scenario. The back-end system is composed of:

1. **A web server which hosts the care centre web application** maintaining all relevant data about caretakers and residents in a relational MySQL database.
2. **A Bluetooth synchronisation server** which transfers all the annotations, 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
3. **A DAO component which mediates all the data exchanges between the web application and synchronisation server and the MySQL database**. This latter component is also in charge of updating the Twitter accounts associated to residents with tweets regarding care activities which can be spotted by other users (relatives generally) following that twitter account. Importantly, the tweets published are only accessible to those other users who have been previously authorised by the resident or their relatives.

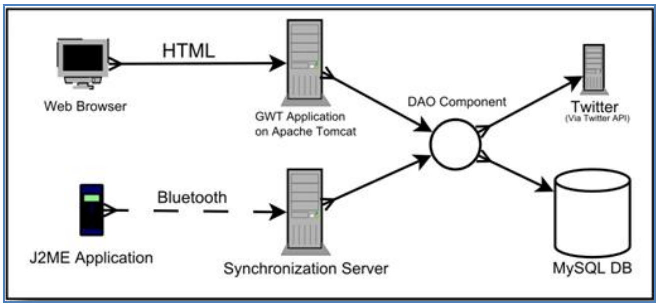

Figure 3: CareTwitter architecture.

On the client side, the caretaker may use either an advanced web front-end based on GWT (Google Web Toolkit) to perform any generic data management in the residence or a Java ME application, see Figure 4, which enables in an easy manner to both add new annotations to a resident's wristband (observe four first screenshots) and to extract them (*harvest*) (observe the last two snapshots) with the purpose of reviewing them and optionally transfer them into the care centre back-end. Note that whenever a caretaker tries to make a new annotation and the storage capacity of the resident's RFID tag has been consumed, 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 message or messages necessary to fit the new one are deleted, flagging the remaining ones as already harvested, preventing other ulterior user's from re-harvesting them. It is important to mention that at all time the resident's details are kept in the wristband, so that whenever the care staff member's phone harvests the caring annotations, the resident is clearly identified (see Figure 5). Both the web and mobile client are very intuitive since they offer menus with a predefined set of care annotations which can be parameterized with a set of predefined options or event free text. In particular, the mobile client prevents the user from imputing many data since these is gathered by the NFC interaction and simple selection of menu options in a mobile application through two or three clicks.

This NFC-aided platform architecture is suitable for a care domain since it addresses the following issues:

- **Assists the caretaker in the data gathering process**. Both relatives and residence staff are aided by intuitive menu options to rapidly and accurately select the suitable care log and parameterize it, if needed, with the minimum amount of data input. Furthermore, the annotations introduced are enhanced by certain implicit attributes such as the location where they are inserted, who inserts them and when. At all time, a resident's wristband will contain certain fixed details (name, surname, SSN, symptoms) to uniquely identify her.

- **Allows for anywhere at any time multi-user gathering of data**. Data gathered is temporally stored together with the resident's fixed data in the resident's wristband or watch (see Figure 1). No continuous data link is demanded between the caretaker's reading/writing NFC mobile device and the care centre back-end. Different caretakers may interact with the resident during the day, each of them leaving different annotations in the resident's wristband. Furthermore, not only staff in the care centre may annotate the resident's daily activities and events, but also their relatives will do so when they are with them at night or in the weekends.

Figure 4: CareTwitter mobile client.

- **Allows for asynchronous care data reporting**. Data gathered in a resident's wristband is transferred to the IT back-end or to the caretaker's device in the following cases:

- **Whenever a resident enters the care centre**, the receiving staff read with their mobile device all the annotations gathered in the resident's wristband, marks them as read, wipes out the last or latest ones and inserts a new log in the residents' tag recording who received the resident and when she arrived.
- **Whenever a resident leaves the residence**, in the case of only staying during the day or going away in weekends or holidays, all the data collected until that moment in the resident's wristband is recorded in the caretaker's mobile device.
- **Whenever care staff begins their shift**, they visit every resident to know their status and collect in their mobile devices all the care annotations issued by the previous shift's staff.
- **Whenever the care staff passes by their control room**, they will dump all the care data transferred into their mobiles, via Bluetooth to the care centre IT system. In order to simplify this process and prevent from timely Bluetooth discovery, the Bluetooth data link will be created upon care staff's touch of an RFID marker encoding the synchronisation server's Bluetooth MAC address.
- **Whenever care staff ends their shift,** they transfer their manually written notes about the residents or whatever they remember with the help of a GWT-based web front page. This same front-end is also used by the doctors to input their reports after having visited residents.

5 CareTwitter: an NFC-aided Lifelog System for AAL

This section reviews how data is encoded in the resident's RFID tags, and shows how and why such care logs are then transferred into a public micro-blogging service, namely Twitter.

5.1 Analysing the Data Encoding Features of Residents' HF RFID Tags

CareTwitter proposes a special purpose compressed serialization method in order to maximize the usage of HF RFID tags' storage capabilities. The following incremental data encoding formats are used internally in order to generate such data serializations:

1. **Stringified** – it generates a human readable string representing a care log. For example: `2009/10/08T09:57:00:35609912 @Home:Woke Up`.
2. **Encoded** – it is a transformation of a stringified care log into a more optimal representation. For example: `35609912#2##1254988620907#4`, where a "#" separates the original user ID, in the stringified version, from the location identifier (`2`), in this case the resident's home, the optional parameters, in this case empty, the date and time when the data log was issued and finally the ID of the care log (`4`). Internally, CareTwitter maintains a resource file mapping a unique numeric key to every possible care log, so that the amount of bytes consumed while logging are minimized.
3. **Serialized encoded** – it is a byte representation of a care log, corresponding to the byte serialization of class Tweet in Figure 5. As a matter of fact, the encoded format outlined is just a human readable representation of a care tweet, generated

by the `Tweet` class through the `PrettyPrint()` method. The serialized encoded format is generated through the `Serialize()` method.

4. **Compressed serialized encoded** – this format takes as input the concatenation of the tweet contents and resident's personal details resulted from the serialized encoded format and applies to it the Range Encoding compression algorithm mentioned in section 3.2.

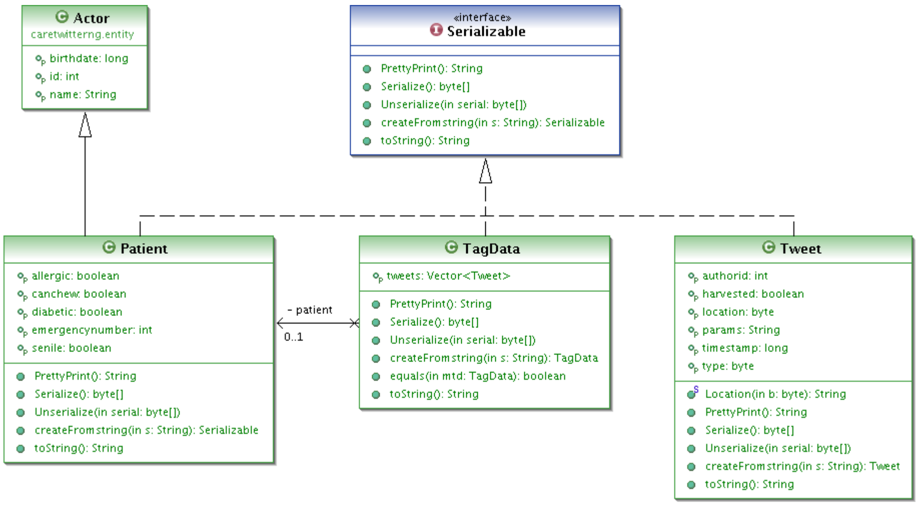

Figure 5: Care data encoding classes in CareTwitter.

Note that the contents that are actually stored in an RFID tag are the result of invoking the `Serialize()` method in class `TagData` of Figure 5. Such tag data is composed of: a) the resident's details, represented by the `Patient` class in Figure 5 and b) a collection of tweets issued by different caretakers. For example, if the following details and care logs are considered for a given resident:

```
Name: Carlos Sierra
ID #: 20142334
Birthdate: 1936/03/15T10:04:51
Diabetic?: true
Can chew?: false
Senile?: true
Allergic?: false
Emergency Phone #: 637648327
2009/10/08T09:57:00:35609912 @Home:Woke Up
2009/10/08T10:05:15:35609912 @Home:Food- Well
```

The following data in encoded format would be generated: `"20142334#Carlos Sierra#-1066571708750#true#false#true#false#637648327%35609912#2##1254988620907#4%35609912#2#Well#1254989115431#2"`.

We considered a sample of 234 care logs, taking into account common redundancies in care logging, in order to assess the capabilities of the proposed encoding format. For example, the same caretaker may perform several logs during a day, most of the logs will be at the same location, the same message (e.g. "visit to WC") may be taken several times in a day, and so on. Figure 6 compares CareTwitter's four incremental encoding formats. Considering care logs of an average size of 56 characters, a total of 34 and 164 messages could be stored in the 1K wristband and 4K watch tags, respectively, having discounted the 41 bytes occupied by the personal details of the resident. The size of the records used to store data in the 1K and 4K tags were 709 and 3200 bytes, respectively, bearing in mind the results shown inTable 1 and Table 2.

As conclusion, CareTwitter's*compressed serialized encoded* method reduces, on average, the size of a care log to 30% of its original size in stringified form, allowing a significant number of care logs to be recorded in a residence's 1K Mifare wristband or 4K Mifare watch, i.e. 34 and 164, respectively. According to care taking experts, such number of logs is sufficient, even in the 1K wristbands' case, to store all the logs gathered for a resident in a day.

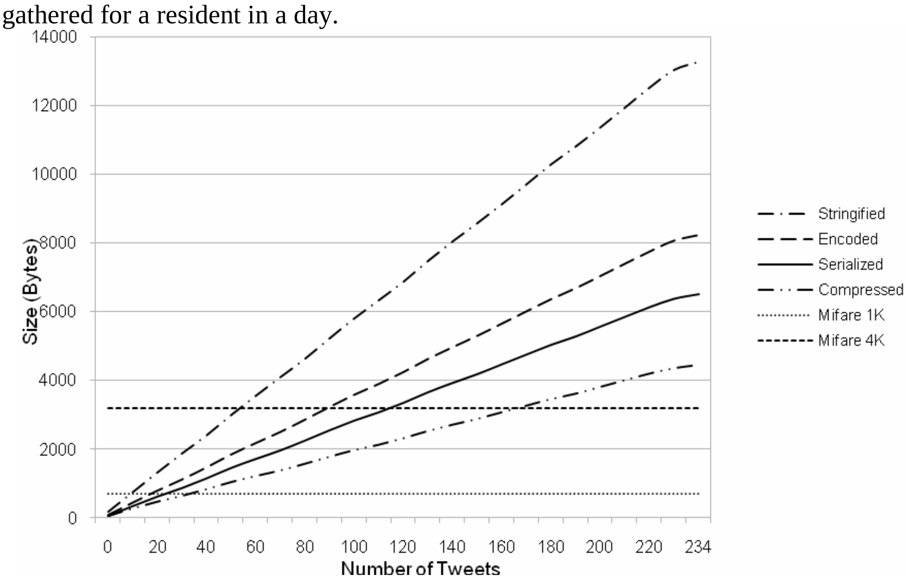

Figure 6: Storage performance comparison of CareTwitter's data serialization formats.

5.2 Populating Twitter with Care Logs

Notably, the CareTwitter AAL platform does not only keep custom data to enhance the daily activities in a care centre but it also exports part of that data to the external Twitter micro-blogging service from which relatives and friends can follow the *lifelog* of residents.

Twitter (http://www.twitter.com/) is a service that enables its users to send and read messages known as *tweets*. Tweets are text-based posts of up to 140 characters displayed on the author's profile page and delivered to the author's subscribers who are known as followers. Senders can restrict delivery to those in their circle of friends or, by default, allow open access. Users can send and receive tweets via the Twitter website, Short Message Service (SMS) or external applications. The Twitter API (http://apiwiki.twitter.com) specifies how to programmatically access via REST the Twitter service. The jTwitter library, a Java implementation of the Twitter API, is used by CareTwitter to send update messages from its back-end to the Twitter site. Remarkably, the tweets published by CareTwitter are never made publicly available. They can be followed only by users authorized by the residents or their family.

Thus, Twitter is a good alternative care log reporting solution because it enables anybody with Internet familiarity to follow what is happening with a relative at a care centre in real-time. The main advantage is that the usage of Twitter does not impose the installation of any custom-builtcare log following application. Nevertheless, it is also true that social Web 2.0 applications are still not widely used by people without significant Internet literacy. However, their usage is continuously expanding to different sectors of society, not necessarily being restricted to younger people. Notably, another interesting aspect about Twitter is that tweets viewing can be restricted, so that only authorized people have access to them. This fact can avoid certain resistance to get residents' or their families' allowance to publish their caring records on the web. Furthermore, CareTwitter care logs are classified in different confidentiality levels, so that the CareTwitters DAO Component (see Figure 3) only reports to Twitter messages from a resident's specified confidentiality level onwards. The approach followed is very similar to the one used in popular programming logging frameworks such as log4j.

As an example, Figure 7 shows the automatically generated tweets for a resident. 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 occurs whenever the care staff initiates a Bluetooth or 3G session to upload into the care centre back-end all the residents' data care logs that have been transferred from their identifying wristbands into the caretaker's mobile. This explains why in Twittter the logs appear to have been uploaded all at once.

This novel way of populating a Web 2.0 service with data generated from the interactions among caretakers' mobiles and residents' RFID wristbands is a clear example of the high potential of making augmented objects, not only people, to act as sources of Internet data.

Figure 7: Automatically generated care tweets of a resident in Twitter.

6 Conclusion and Further Work

The CareTwitter platform stores a log for every new care procedure applied on a resident's RFID wristband, following a data-on-tag approach. This new procedure of storing, reading and sharing care related data is possible thanks to the usage of RFID tags as mini databases. The storage capabilities of HF RFID tags is often neglected; they are mostly used only to record an ID which then requires to access related data over the network. CareTwitter makes data stay at any time with the resident and be available in real-time and without relying on wireless links (especially important outside the residence), often expensive or not available. Our experiments have proven that the storage capacity of either a 1K (wristband) or a 4K (watch) Mifare RFID tag, aided by CareTwitter's custom-built *compressed serialized encoded* data serialization format, is sufficient for storing the care logs of a whole day. Remarkably, the integration of CareTwitter with Twitter proves the high potential of using interactions with everyday objects or people to automatically publish data into Internet, in this case, the lifelog of residents in a care centre, so that their relatives and friends can be kept up-to-date about them. In conclusion, CareTwitter addresses the important data management issues associated to caretaking by proposing an NFC-based data logging platform which simplifies care data gathering and its dissemination to other caretakers and relatives, in this latter case through Web 2.0 social status reporting tools such as Twitter.

Future work should consider an evaluation of the system in a real residence in order to assess the foreseeable advantages of our distributed and asynchronous data collection, storage and publication mechanism. In addition, a key aspect will be to assess the foreseeable good usability of the NFC-supported mobile-mediated interaction of care staff with residents' RFID wristbands, against more traditional PC or PDA-based approaches. Finally, the security and privacy issues raised by the asynchronous collection of data distributed among different carer devices and forwarded, after applying privacy-aware filters, to public domain status reporting sites (e.g. Twitter) should be carefully addressed.

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