Agent/Space-based Computing and RF Memory Tag Interaction

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Abstract. As devices become more ubiquitous and information more pervasive technologies such as Semantic Web and Space-Based computing come to the fore as a platform for user-interaction with their environment. Integrating technologies such as advanced RF memory Tag with mobile devices and combining this with computation platforms such as those supporting Semantic Web principles provides for the user innovative and novel applications.

1 Introduction

The integration of mobile devices, RF memory tags and semantic web style information sharing and management will open new opportunities for the ad hoc gathering, sharing of information and for more interactive applications built on top of these concepts.

RF memory tag systems will have the ability to store large quantities of information coupled with high-bandwidth radio connections and even contain local processing capabilities. Mobile devices, such as mobile telephones, have access to ubiquitous connectivity solutions, eg: WLAN, GSM, UMTS networks, as well as sophisticated media and processing capabilities as well as many local sensors such as GPS etc.

Semantic Web technologies provide canonical information representation formats, in particular XML for the representation, RDF for the expression of semi-structured, linked and linkable information and languages such as OWL for the specification of those structures. This allows much easier integration and interoperability between applications, agents and devices through standardising many features and providing a basis for reasoning technologies leading to, at least, weak-AI capabilities.

Combining these technologies together provides a platform for highly interactive, viral information sharing applications that can be applied in many situations: such a platform has been implemented as in [10]. For example: mass memory tags are used as a distribution point of information in a certain locations such as office or shopping center information points, news stands, tourist attractions etc; even individual physical items can be tagged - an application particular relevant in the medial sector. Applications of a system would provide enahancements to existing service-oriented technologies.

In this paper we describe the technologies and an implementation which leads to framework that supports such applications and interactions. Firstly we provide descriptions of the technologies, then an overview of the types of applications with examples, then a discussion on a specific interaction case which highlights particular interesting areas of the RFID-Device-Space interaction and finally a discussion of the future direction and issues of this technology.

Jantunen J., Oliver I., Boldyrev S. and Honkola J. (2009).
Agent/Space-based Computing and RF Memory Tag Interaction.
In *Proceedings of the 3rd International Workshop on RFID Technology - Concepts, Applications, Challenges* , pages 27-38
DOI: 10.5220/0002172900270038

2 Background

We focus on the integration of three major technologies: the Semantic Web, RF memory tags and mobile devices. Within these categories we specialise on the notion of ‘Smart Spaces’, the distribution and integration of information and a particular mass-memory, high-bandwidth form of RF memory Tag.

2.1 Semantic Web and ‘Smart Spaces’

The Semantic Web [13] is a vision for the improvement of personal computing through the exposition and sharing of information based upon common representation formats, ontologies and semantics. The idea is that information would become *globally* ubiquitous and interoperable.

However much information is not ubiquitous in the global sense; it is personalised, hidden, private and is interpreted locally - this information tends to be the personal, highly dynamic information that one stores about oneself: contact lists, friends, media files, ‘my’ current context, ‘my’ family, ‘my’ home etc and the interweaving and linking between these entities through ad hoc personal structures.

To address this issue we have implemented a system based around larger, more user or personal focussed structured which we term ‘Smart Spaces’ [14]. Within a ‘Smart Space’ (or just space) a user can encapsulate all of their information and interact with that information according to their personal semantics and needs.

Spaces have the ability to be distributed across the user’s devices (mobile phone, media center, personal computer etc) as well as more centralised providers. Synchronisation between these distributed, individual repositories of information is asymmetric to address device and network capabilities as well as the user’s needs in terms of security etc.

Interaction with spaces is nominally by ‘agents’ which encapsulate fine grained functionality which themselves may be distributed across any number of devices that have access to the user’s space. Spaces themselves can interact through merging and projection enabling larger spaces to be constructed either on permanent or temporary basis.

Further interaction between users is enabled through one user granting access to their space (or spaces) to another user’s agents or even by directly sharing the contents of their spaces through the asymmetric distribution mechanisms.

A space can transcend over many of the user’s devices leading to the distribution of information and queries upon that information. For any agent accessing this information the physical location of it and the information is irrelevant: an agent sees the ‘totality’ of all information in that space. This requires sophisticated distribution algorithms that actually preserve a degree of assymetry of information depending upon the stability, connectivity and other properties of a particular information repository.

2.2 From Rfid to Rf Memory Tags

Radio frequency identification (RFID) technologies have been used for decades in extensive variety of applications [1]. In the simplest RFID applications the tags embedded into objects only provided 1-bit presence information when exposed to the electromagnetic field transmitted by a reader. Identification of tags with individual ID codes started from active tags and read only memories and it has become commodity also for passive tags. Recently, especially the mainstream development of passive RFID technologies has been steered by applications such as logistics [2], and mobile payment [3]. In these applications the tags may include also some amount of non-volatile memory. Thus, a bi-directional communication link between reader and tags is required to enable also writing of data to tags instead of read-only access. Recently, respective reader capabilities have been also integrated into mobile phones [4]. That provides a possibility to use RFID tags as part of Smart Space applications by using mobile phone readers as a gateway.

One development branch of RFID technologies is focusing on applications where passive RF memory tags will contain increasingly large non-volatile memory capacity (in scale of mega- to gigabytes) [5]. Such tags would enable storage of digital content exactly to the point where it is used e.g. into objects and physical locations. This approach is totally opposite to the network databases traditionally used in RFID systems where tags may store only a link to the databases. The visions behind this research are based on the foreseen development trends especially on the field of non-volatile memory technologies according to which the power consumption, physical size and price of (non-volatile) memories are continuously decreasing. TSuch his enables development of passive RF memory tags which can be accessed wirelessly, for example, with mobile phones and which can be used as ubiquitous storage capacity in Smart Space applications.

In RFID systems the physical interaction is usually based on back-scattering of narrow-band RF signals [7]. The reader device provides a continuous wave signal which is used by the tag to extract supply voltage.

The communication from the tag to reader is possible thanks to modulation of back-scattered signal from the tag, whereas the communication from reader to tag can be done for example with simple amplitude or phase modulation methods respecting the power extraction needs in the tag. Small memory capacity can be implemented with EEPROM and the whole functionality is usually controlled by a simple finite state-machine (FSM). However, when the storage capacity of tags increases significantly back-scattering method based on a single frequency band may be insufficient to achieve data-rates high enough. According to current regulations wide enough frequency bands are not available on low frequencies and the efficiency of wireless power transfer decreases on high RF frequencies. Thus, either data-rate or communication range is somewhat limited. Therefore dual-band systems have been proposed for data centric Ambient Intelligence (AmI) applications, such as, the ones used in Smart Space context [6]. An exemplary (complete) block diagram of an RF memory tag is presented in Figure 1. In such a system one frequency band is dedicated for wireless power transfer and one wider band for high data-rate communication.

Section 3 categorizes groups of interactions between RF memory tags and Smart Spaces. Depending on the category the required computational power of tag may range from mere memory access (a simple FSM is enough) to hosting of an agent or a space (requiring MCU or even CPU). In the two 'classic' ways it is sufficient that the tag is capable of transferring the data defined by the reader with the highest possible efficiency to achieve user-friendly interaction. The reader device is responsible of defining which data is read and/or written, and basically in the tag there is no need to process the content itself. Even the file-system can be maintained in the reader side if it is first copied from tag to reader in the beginning of interaction and then updated version is written to tag after the payload data in the tag has been modified.

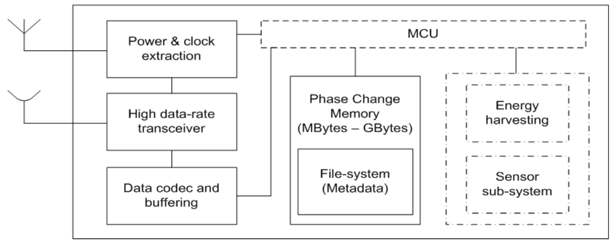

Fig. 1. Block Diagram of RF memory Tag.

In more sophisticated cases where tags are capable of hosting an agent or running a space it may be necessary to have sufficient processing capabilities in the tag itself. If fully active tags are excluded from the study, to achieve easy and low cost maintenance, the remaining alternatives are fully passive tags and semi-passive tags. In the passive solution the data is processed fast in the tag during the reader-tag interaction. In the semi-passive solution the data is processed over a long period of time (as a background process) by using a dedicated power source e.g. the power harvested from the environment and only the high data-rate communication requires wireless powering provided by the reader. In semi-passive case the tag may also function as a data-logger by slowly collecting a huge amount of samples from a low-power sensor over a long measurement period. However, these applications require extremely low power consumption what comes to the memory accesses, data processor and sensors but also required data-rate is extremely slow.

Altogether, the ongoing development on many technological fields will in the future enable utilization of RF memory tag systems in Smart Spaces. Actually, Smart Space applications may become one of the main drivers for the technological development of aforementioned RF memory tag systems.

2.3 Distribution

The scope of distribution and corresponding infrastructures in case of RF memory tag systems can be analysed in terms of two areas:

- physical environment, e.g. associating of the RF memory tag with direct or indirect functionality provided by the physical environment, and
- ubiquitous device architecture, e.g. impact to the internals of a particular mobile device

Considering further, the following can be seen:

- RF memory tag is dumb memory block and has just mechanisms for bidirectional wireless operations (read/write)

– RF memory tag has enough computational power on board, but still external power is needed, or it can be provided on a volatile basis

Therefore, the range of potential application can be variate from simple “just-in-place” and “just-in-time” file storages coming to distributed ad hoc storage systems [9] and going beyond asynchronous computation engines. Projecting such features to the Smart Spaces architecture RF memory tag system enables use cases when information related to the particular physical environment can be delivered in-place on-demand or even by estimation, in a very power and computation efficient manner. By saying “delivered” the whole process of extraction, recovery, storing and computing should be understood. Since using RF memory tag system it is feasible to produce a distributed snapshot of Smart Space which is tied with the particular physical environment by storing the run-time environment and corresponding contexts with data/information within the RF memory tags, it also becomes possible to revoke the system once it would be demanded by any user. In other words the distributed process of booting, suspending and resuming of the Smart Space now becomes more flexible, reliable and less physical context dependant.

Smart Space application infrastructure benefits from RF memory tag system as well. Since RF memory tags infrastructure provides distributed grained approach for execution context and information handling, Smart Space application can be constructed by traversing the RF memory tags and retrieving demanded parts of execution context and corresponding information.

In terms of ubiquitous device architecture, as it is presented by Figure 1, RF memory tag system can enable computationally constraint device with memory extension, distributed memory architecture, or, rich context data analysis and corresponding information generation, which then can be uploaded to RF memory tag system.

The problem of memory management (both, execution and mass memory) in distributed environment, when substantial amount of the devices are using RF memory tag system technology, converges to the efficient and sustained context execution which is essential part of whole computing environment, such as Smart Space. Especially because of high dynamics and constrains the amount of memory on board the mobile devices in Smart Space.

The approach of efficient and sustained distributed memory utilization by means of RF memory tag illustrates the solution of such problem. Consider the computing environment where memory is integrated with RF memory tag based architecture, and several distributed memory modules are dispersed around the Smart Space(s). Therefore they are considered as one stackable memory unit by means of corresponding combination of memory blocks of the environment.

Putting environment where memory is integrated with RF based memory tag architecture and several distributed memory modules are dispersed around the Smart Space(s). From the Smart Space perspectives and corresponding functionality is provided by distributed RF memort tag based infrastructure, at least following cases described in section 3 can be seen.

3 Interaction with Tags

In this section we describe the various modes by which spaces and agents interact with the RF Memory tags. We define four categories:

- Agents read from Tag
- Agents write to Tag
- Agents on Tag
- Space on Tag

The first two categories are the 'classic' ways of passively interacting with a tag and constitute simple information retrieval and sharing. The third and fourth cases involve much more 'active' interaction based requiring specific features of the agent/space architecture. We explain these in the following sections with an addition discussion of the actual physical interaction between devices and the RF memory tags.

3.1 User Interaction

As mentioned in the previous section, in the context of Smart Spaces many new requirements for the future enhanced RFID-like technologies are set. In Smart Space environment also the user interaction is in a critical role [6] since the fast data connection is enabled only if user voluntarily accesses RF memory tags. Therefore the system must be fast, flexible and reliable in addition to many other requirements. The need of bi-directional high speed data transfer is obvious to achieve convenient user experience when the storage capacity of tags increases. Flexibility can be understood as a requirement for practical communication range. Typical physical interaction is shown in figure 2.

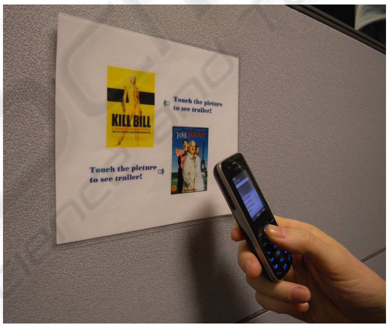

Fig. 2. Physical Interaction of Device and RF memory Tag.

From user's perspective it is needed especially to allow intuitive and convenient control through user interface of a mobile reader. Figure 3 presents a situation where mobile phone is used to interact with a tag which is part of a Smart Space. As can be expected, the communication range must be long enough to avoid need for accurate pointing of reader to tag in varying usage conditions. The communication link should also allow movement of the reader while the user makes selections through the user interface.

Reliability of the user interaction can be understood as the quality of data transfers i.e. low probability of errors on different levels but also as security and privacy aspects since obviously users cannot tolerate such infringements if the content stored to RF memory tags is private.

3.2 Agent Interactions

The "simple" read case is useful for applications where the tags provide relatively static local information, for example, maps, positioning information or even marketing information such as might be found in a shopping mall style scenario. One existing application is that found in museum environments [11, 12] and this is currently being investigated as an initial deployment of the technology described here.

The "simple" write allows the user to write to the tag. This enables sharing of user's information through copying information from the user's space to the RF memory tag. This case would be almost invariably used in conjunction with the read case. Typical applications here might be viral sharing of media or other information, for example, highly localized blogging and messaging. These classic cases are shown in figure 3.

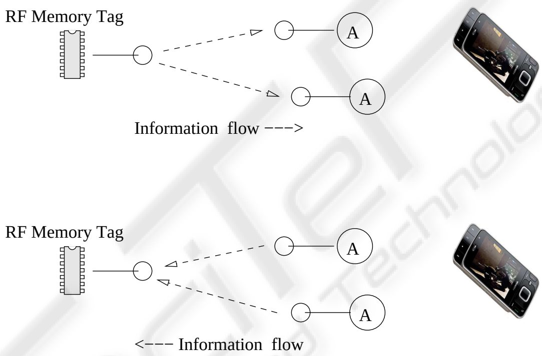

Fig. 3. Classic Interaction.

The third case shown in figure 4 requires the tag to have some computational capabilities. When the device with the reader is presented to the tag, it activates agents on the tag itself which then either request to join the user's space or are invited to the user's space for the duration of the time while the reader is in contact with the RF memory tag. The agents on the tag may provide additional reasoning or other data gathering/processing operations as well as supporting the classic read and write use cases described earlier.

The agents can access a Smart Space with five basic operations:

- *Insert*: Insert information into the Smart Space.
- *Remove*: Remove information from the Smart Space.
- *Update*: Update the information in the Smart Space. This is effectively an atomic remove and insert combination.
- *Query*: Query for information in a Smart Space.
- *Subscribe*: Set up a persistent query in a smart space. A change in the query results is communicated to the subscribing agent.

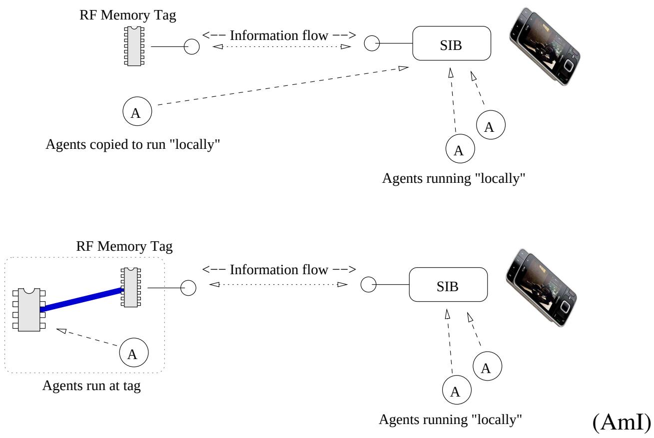

Fig. 4. Agent Interaction.

There are two individual cases to be considered here. First, where the RF memory tag has some computation capabilities, i.e. a CPU or MCU, and second, where the computation has to be made on the reader.

The first case is conceptually more straightforward, as the agents on the RF memory tag are executed outside the mobile device and need only access to the information stored in the space. This access may be limited by the space and thus the agents need not to be particularly trusted.

The second case would involve running arbitrary code on the mobile device, and presents a lot of additional problems to solve relating to security etc. Standard mechanisms related to e.g. downloading applications are probably not applicable, as the required interactions from the user should be kept to a minimum.

It should be noted that even as these cases differ on the implementation level and required infrastructure, but the end result regarding the information content in the space is the same.

This kind of “Agents on Tag” concept provides means to enhance the information content stored on the mobile device by adding localized, positional knowledge to the space. Furthermore, they may also utilize whatever information is available to them in the space, perhaps creating a history of interactions for subsequent processing etc.

3.3 Space Interactions

The fourth case is particularly interesting as it provides temporary (or even permanent) additional information for the user without resorting to agents. Any particular mobile device is part of Smart Space environment as it is presented above, in Section 2, and RF memory tag based infrastructure constitutes another Smart Space entity. This case can be addressed by any two (2) Smart Spaces merge process. Similarly to the previous agent interaction case there exist two distinct modes of operation, this time however referring to the location of the broker that enables the space; these are visualised in figures 5 and 6.

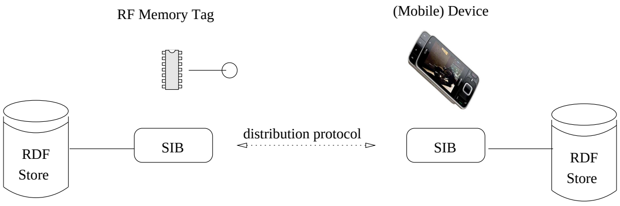

Fig. 5. Space Interaction (Tag hosting SIB).

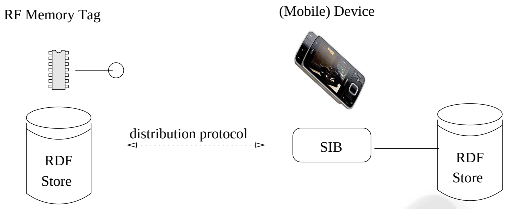

Fig. 6. Space Interaction (Tag not hosting SIB).

We would stick to the cases when RF memory tag based infrastructure is created by manageable and non-manageable RF memory tags, meaning that the computational capabilities of any RF memory tag are extended, e.g. with CPU or MCU, and limited, e.g. without CPU or MCU. To guarantee sustained data on the board of RF memory tag there are facilities provided by memory chip and RF control. To provide mechanism for proper allocation, management and removal of data, a recognizable list of data, ad hoc data management system is used.

Let us concentrate more on the technical details of the process when such mobile device would found any RF memory tag. To establish communication channel which should be considered of ad hoc type, mobile device should scan the environment to get the confirmation reply from any RF memory tag.

Once the physical connection is up and transport protocol is running, and RF memory tag can be mounted to be used as a storage space or it can begin to act as another Smart Space entity. To simplify our further considerations, let us denote the mobileThis work has been partially funded by TEKES ICT SHOK DIEM (www.diem.fi) and EU FP6 MINAmI projects (http://www.fp6-minami.org/). device's Smart Space as SS1, and the RF memory tag based Smart Space as SS2.

In case if RF memory tag was mounted as a plain storage space it can be used as an extent where, existed, SS1 keeps the data in raw (as it would be in case of any growable filesystem volume). And, therefore, any POSIX like procedures could be applied to gain the access and to store/remove the data on such volume. However, it is not really beneficial way in case of Smart Space environment.

Since one of the main points to use the Smart Space environment is to provide interoperable interaction between most of computing environment by exchanging high abstraction level information, by means of Smart Space's defined Insert, Remove, Subscribe, Unsubscribe and Query primitives and utilizing a certain reasoning mechanism over the different sets of that information, to extract the necessary one, the level of interaction between mobile device and RF memory tag is pushed up to high abstraction level of information exchange. Therefore, the rules of Smart Spaces merging process are applied. Those can be seen within the following flow:

1. let us assume that SS1 represent an active entity from energy perspectives, therefore it is assumed to be as a leading party (so defined master SIB or mSIB) which is driving the merging process as such
2. even SS2 represents a passive entity from energy perspectives, it might have either suspended SIB or RDF store facilities that can be merged with or utilized by the corresponding SS1 facilities, thus, one of the following can take place:
   (a) mounting as RDF store to SS1 facilities, providing passive information extent, meaning that reasoning over that extent should be provided by SS1 facilities
   (b) communicating as SIB-to-SIB, providing active information extent, meaning that reasoning over that extent can be provided by resumed SS2 facilities.
3. invoke SS2 to Join the SS1 by means of Join/Leave message exchange and corresponding Heartbeat message, to complete a handshake procedure
4. open communication as SIB-to-RDF (store) or SIB-to-SIB
5. prioritizing Query, Subscribe, Unsubscribe, Insert, Remove primitives to be issued over the RF memory tag based information extent
6. prioritization is driven by reasoning over either the information extent provided by SS1 or by SS2, thus the importance factor should be taken into account to leverage the flow of any needed information
7. proceeding with information exchange, this can be seen as a scheduler loop over the particular primitives queueThis work has been partially funded by TEKES ICT SHOK DIEM (www.diem.fi) and EU FP6 MINAmI projects (http://www.fp6-minami.org/).
8. finalizing communication as SIB-to-RDF (store) or SIB-to-SIB
9. leaving SS2 by Leave message from SS1 or invoking SS2 to send Leave message, suspending it due to the passive mode
   – any accidental power loss, which can be only due to the communication loss (due to the nature of RF memory tag infrastructure), is accounted by transactional model of any operations

Recombining cases above, to the better extent, a certain amount of agents could be stored at RF memory tag infrastructure as well. And, once SS2 is resumed, agents are retrieved from RF memory tag infrastructure along with information extent and the physical context dependant application in merged SS1 and SS2 entity is assembled. Logical flow above illustrates a strong potential of RF memory tag based infrastructure as Smart Space environment from the hardware perspectives. Therefore the cases above should not limit the scope of distributed RF memory tag infrastructure.

4 Issues

Any interaction in this kind of environment has security and in particular privacy issues. Because of the shared and thus viral nature of the information, the spread of incorrect, bad or otherwise information is made relatively trivial. There do exist methods for trust and policy but these still have to gain widespread acceptance.

One particular aspect is the provision of location and temporal information - because of the physical nature of the devices we can trivially infer location and the point in time when the interactions took place.

The trust of such a system ultimately resides with the users and the overall management of the information being interacted with and provided. However given the rise of social networking, microblogging and the very basic need to share information, many of these issues are not addressed there either. Nevertheless provision of security mechanisms such as authentication, encryption, private space and persistence etc can help in such matters.

Despite of these issues the benefits of such a mechanism for the user are tangible and specifically in the areas of marketing, advertising and the provision of specific and highly targetted temporal and location aware information.

Other concerns include the semantics and interpretation of the information contained within the various spaces - a detailed discussion of these issues and some of the solutions which are being implemented and investigated as part of the described architecture and system can be found in [15–18]

5 Conclusions and Future Work

In this paper we have introduced and analyzed a concept where RF memory tags form an extension to Smart Space infrastructure. Also most of the fundamental requirements set for RF memory tag systems in such a context have been covered. In the present work we have focused on interactions between the Smart Spaces and one individual tag.

The agent/space based system described in [10] provides a distributed infrastructure for context gathering; while the agents themselves provide end-points for service usage. Such services include those as provided by, for example: Nokia's OVI[1]. Sharing through physical access points such as RF memory tags provides additional and more novel interaction with these services. This conclusively supports the trend towards context gathering both in physical and virtual environments coupled with existing service-oriented paradigms and building future information management and sharing approaches.

The future work will further extend the concept so that a population of tags forms a platform for smart-space applications. This means that the SIB is implicitly shared among the population by scattering copies of collaborating agents to the tags. In other words, the tags collaborate with each other and form a SIB but due to the sporadic nature of the processing capabilities and communication link enabled by the readers, the tags have to rely on transfer of sporadic messages between each other.

Acknowledgements

This work has been partially funded by TEKES ICT SHOK DIEM (www.diem.fi) and EU FP6 MINAmI projects (http://www.fp6-minami.org/).

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