Integration and Uses of RF Memory Tags with Smart Space Semantic Web Middleware

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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 innovative and novel applications for the user. In a way, information stored in Smart Spaces on RF Memory Tags could even create a sub-Internet of Things where users are the main information transport mechanism rather than the Internet.

1 Introduction

Novel methods of interacting, context gathering and integrating information can be obtained by the integration of mobile devices, advanced RF Memory Tags and Semantic Web [16].

RF Memory Tag systems 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, as well as sophisticated media capabilities and sensors.

Semantic Web provides information representation and reasoning technologies: RDF [10] for the expression of semi-structured and description and reasoning languages such as OWL for the specification of those structures.

Combining these technologies together provides for a platform for highly interactive, viral information sharing applications that can be applied in many situations. Such a platform has been implemented as described in [23, 22, 24]. Applications of a system would provide enahancements to existing service-oriented technologies [11, 25].

As an example of self-organizing and automatic collection of digital content one can imagine a use case where mass memory tag is used as a distribution point of information in a certain location (like a bulletin board, news paper stand, information point of tourist attraction etc.) [13]. As a starting point the content related to the topic is stored into the tag. During a period of time users download the content by using their mobile phones. However, during the same period of time the content in the tag may become out of date or some new information may become relevant. This new information may exist in the reader before it accesses the tag or the tag may even request for available updates of the content. Let us say that the tag is used as a distribution point to deliver news on a metro station. Every time when a user downloads the news from the tag, the tag may request for any updates within a certain category. If the new user has lately downloaded to his/her mobile phone some new information for example from the internet, that specific update may be uploaded into the tag automatically, and the user may for example get the news for free from the tag. With this method the content in the tag stays updated all the time. The method is useful especially in places where the number of users is large like in metro stations during the rush hours. The users may also be allowed to upload their own content to tags. In the news stand example the content could be for sale, announcements or a personal comment about the politics etc.

An additional use case of content exchange is a tag that may operate as a tool for social networking. This means that people accessing the tag has something common to share and they want to insert their comments and content so that other people can see the content. This can be easily imagined in case of tags which are linked to a certain physical location. Thus, people can use a certain tag as a blog. In that case a tag is the connecting node between readers and not another way around, which is the traditional case [12][18][8].

A tag may also use readers as information gathering devices. In that case the tag defines what kind of content the reader should gather for example from other tags. When the reader has a sufficient amount or some correct information defined by the tag, the reader may access the content collected by other readers. This way the tag may become an interesting content provider and the readers can access the tag only after collecting and uploading more of the interesting content. The tag may also provide to readers a program for the collecting of correct content, and the collecting may be done over a relatively long time period.

In this paper we describe the technologies and an implementation which leads to a 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 particularly interesting areas of the RFID-Device-Space interaction and finally a discussion of the future direction and issues of this technology.

2 Background

We describe briefly 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 [2] is a reality for the development of personal computing through the exposition and sharing of information. The idea is that information is *globally* ubiquitous, linkable and interoperable.

Spaces and space/triplestore-based computing [6, 20] has the ability to be distributed across the user's devices (mobile phone, media center, personal computer etc) as well as more centralised providers with the advantages of localising the user's information in terms of context and security.

Interaction with said spaces is by 'agents' [9, 27] 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) [3] 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 [7]. 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, and mobile payment [26]. 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 [28]. That provides a possibility to use RFID tags as part of Smart Space applications by using mobile phone readers as a gateway in similar ways e.g. as shown for Intelligent Products in [21].

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) [15]. 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.

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, a back-scattering method based on a single frequency band may be insufficient to achieve data-rates that are high enough. According to current regulations wide enough frequency bands are not available on low frequencies and the efficiency of wireless power transfer decreases at 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. 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.

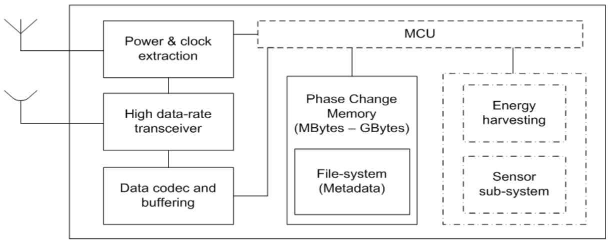


Figure 1. Block Diagram of RF Memory Tag

Section 3 categorizes groups of interactions between RF Memory Tags and Smart Spaces. Depending on the category, the required computational power of a 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 an updated version is written to the tag after the payload data in the tag has been modified.

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 the 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 a 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

Infrastructures made up from RF Memory Tags provide a distributed and fine grained approach for execution context and information handling. Smart Space applications 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, an RF Memory Tag system can enable computationally constrained devices with memory extension, a distributed memory architecture, rich context data analysis and corresponding information generation. The approach of efficient and sustained distributed memory utilization by means of RF Memory Tags can be considered as one stackable memory unit by means of corresponding combination of memory blocks of the environment.

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

3.1 User Interaction

In the context of Smart Spaces many new requirements for the future enhanced RFID-like technologies are set. In the Smart Space environment, user interaction is a critical role [17] 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 which shows a user downloading content from a piece of advertising. The example shown here is a user downloading approximately 20Mb of video content - in this case the advertising trailer for a movie.

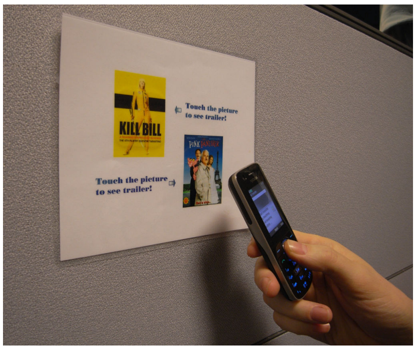


Figure 2. Physical Interaction of Device and RF Memory Tag

Figure 3 presents a situation where a mobile phone is used to interact with a tag which is part of a Smart Space. The communication range must be great enough to avoid the need for accurate pointing of the reader towards the tag in varying usage conditions - the RF Memory Tag is optimised for 10-30cm distance.

The communication allows 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. 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 cases are shown in figure 3.

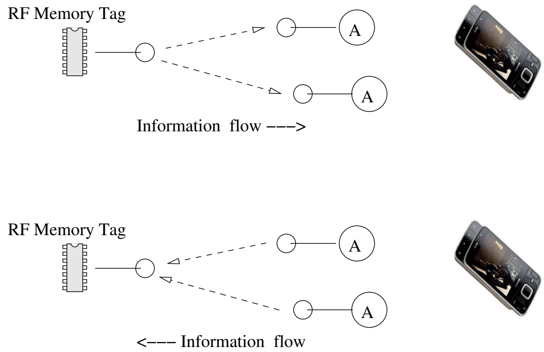


Figure 3. Classic Interaction

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.

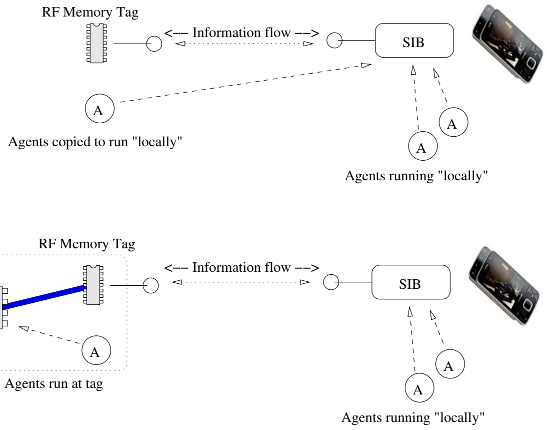
The agents can access a Smart Space with five basic operations:

- *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.

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.



(AmI)

Figure 4. Agent Interaction

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 a merge process for the two Smart Spaces. Similarly to the previous agent interaction case, there exists two distinct modes of operation, this time however referring to the location of the Semantic Information Broker (SIB) software. The SIB is the underlying softare that implements the space and the operations available on it as visualised in figures 5 and 6.

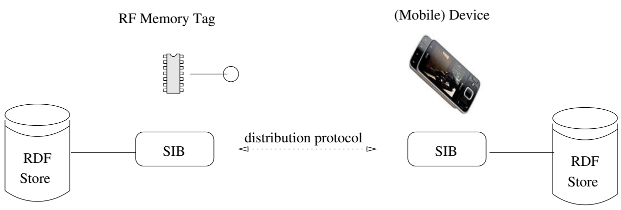


Figure 5. Space Interaction (Tag hosting SIB)

When a mobile device would find a RF Memory Tag it needs to establish a communication channel that should be considered of ad hoc type. Therefore the mobile device should scan the environment to get the confirmation reply from any RF Memory Tag.

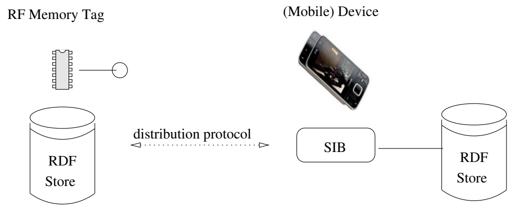


Figure 6. Space Interaction (Tag not hosting SIB)

Once the physical connection is up and the transport protocol is running, the 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 mobile device smart space SS1.

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

Since one of the main points to use the Smart Space environment is to provide interoperable interaction between the devices present in the computing environment by means of Smart Space operations (Insert, Remove, Subscribe, Unsubscribe and Query) 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 a 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. The mobile device is the active entity from an energy provider perspective, therefore it is assumed to be the leading party (so defined master SIB or mSIB) which is driving the merging process as such.

2. Even though the RF Memory Tag (with Smart Space contents SS2) represents a passive entity from an energy perspective, 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 for by the transactional models of any operations.

Recombining the 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 dependent application in merged SS1 and SS2 entity is assembled. The logical flow above illustrates a strong potential of RF Memory Tag based infrastructure as a Smart Space environment from the hardware perspective. Therefore the cases above should not limit the scope of distributed RF Memory Tag infrastructure.

4 Case Study: Tourist Services

Embedding agents on smart devices, including RFID tags is not a new idea [5][4]. The use of agent platforms in applications such as tourism has been studied e.g. in the Agentcities EU project. The use of RFID tags in tourist applications has also been proposed and implemented for identifying locations and objects, as well as linking to information sources related to them. However, the amount of information available on those tags has been restricted by memory size, it has not been writable and no on-board processing has usually been available. The use of RF Memory Tags could open radically new possibilities for implementing tourist services. We present here a simple case study based on the use of RF Memory Tags and Spaces within a tourist situation.

A tourist comes and visits an area where various sites and commercial services are proposed. Each of them is equipped with a tag that can interact with a mobile device handled by the visitor. In all cases, the visitor can read information about the proposed services, history, 3D visualisation or films about that particular location. In the ideal case, the mobile device would be the visitor's own mobile phone or some similar device. Otherwise such devices could be provided by the visited site.

Interaction is composed of identification, consumption tagging, spatial location, shared asynchronous memory, and distributed processing. For instance, the visitor's agent detects a museum entrance tag. This is achieved by the visitor allowing either his/her reader to active search for tags and respond to the requests to join or supply information - space-space communication, or by the visitor being pre-supplied with an agent that processes this information.

A first interaction verifies the identity of the agent and stores it in the local memory. Some information can be passed to the visitor's agent for local use. When the visitor leaves the museum, he can read a tag again to collect 'fidelity miles'. Agents in the museum's tag (or on the mobile device if that is more appropriate) could then check the amount of fidelity miles collected and propose various promotions and services that are available. Basic location information (i.e. 'was at museum') iscompared with other available sources, e.g. GPS or Indoor Mobile Positioning systems, for redundancy. Some messages transmitted to the tag toward various targets will be passed to future visitors that can be either receivers (identified by profile matching) or opportunistic messengers. One can think of this as being highly, physical location based micro blogging.

Tag-embedded agents could also analyse e.g. what information visitors have been the most interested in and modify what information is shown to them first, collect statistics on the number of visitors, gather feedback. For tourist groups, it could also be possible to leave 'traces' to other members of the group that indicate whether the place is worth visiting or not, where they went next etc.

This scenario exhibits some relevant issues: tagging of the environment, tagging of the mobile devices, location tag agents, pro-active tracking of visitors, pervasive cellular network with asynchronous memory. What is also essential to mention is that these scenarios can be implemented without any network connectivity, so no wireless network infrastructure or similar is necessary.

Tourism is obviously just one potential application domain for RF Memory Tags. Furthermore, the scenarios mentioned here only 'scratch the surface' because the number of scenarios enabled by such tags rapidly becomes enormous already for tourism only.

5 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 inconsistent information is made relatively trivial. Methods do exist for trust and security policies 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 don't seem to be a major obstacle in many cases. Nevertheless, provision of security mechanisms such as authentication, encryption, private space and persistence etc. can help in such matters.

Despite 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 targeted 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 [19, 1, 14].

6 Conclusions and Future Work

In this paper we have introduced and analyzed a concept where RF Memory Tags form an extension to a 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 pradigm and our implementation 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 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 form 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.

[1] www.ovi.com

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