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Locating Agents in RFID Architectures

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Abstract. The use of software agents can create an "intelligent" interface between users' preferences and the back-end systems. Agents are now able to interact and communicate with each other, forming a virtual community and feeding back the user with suggestions. Innovative systems related to *Asset Tracking*, *Inventory* and *Shelving* architectures are more often involving advanced communication techniques (e.g., RFID); these systems are responsible for user authentication and objects verification. RFID systems could have jamming situations where many objects are moving at the same time and in the same direction. Moreover, other disadvantages have also been observed, such as hindering further implementations, privacy and security issues problems, in addition to the system's disruptive behavior in case of crowd checkouts (e.g., Supermarket and Airports). Addressing these disadvantages, this paper proposes a possible integration between a Multi-Agent framework and an RFID-based application (back-end). This integration would allow objects (such as passports or goods) with RFID tags to better check-out through airports or supermarket gates that contain RFID-readers.

1. Introduction

Software agents are characterized by two major functions: self-containment and interaction. In a certain application that is using agent-oriented programming techniques – located in a particular environment or a network – users expect this application to fulfill a set of requirements that are difficult to realize by other techniques. Previous research has demonstrated that Agents can efficiently fulfill a given requirement or task independently from extra user involvements. For example, in ToothAgent [1] a mobile user is able to get a mobile agent on his/her cellular phone. This mobile agent carries all of the user's requirements or a required service with its specifications. ToothAgent performance relies on Used Books requisitions. Using Bluetooth allows, user has his/her cellular phone communicating with a different network server located in a different environment (e.g., university campus), and finally unload this agent. Consequently, a task is realized on behalf of the user and the results are communicated using almost a bottom-up module.

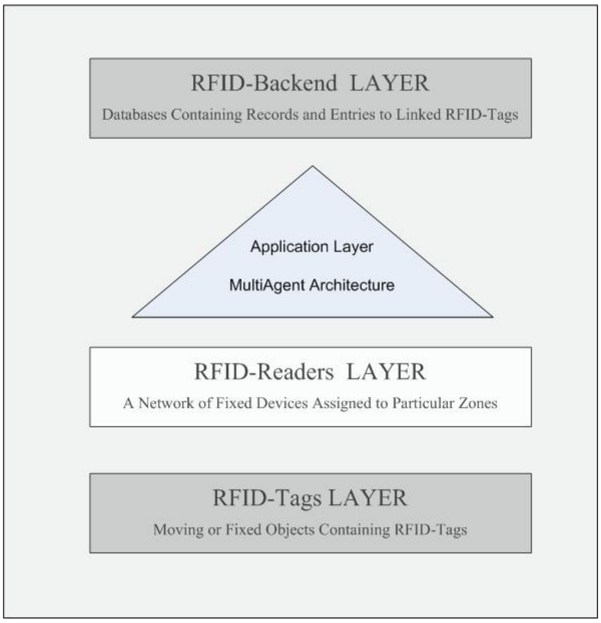

Fig.1: Positioning MultiAgent Architecture inside Standard RFID Design.

ToothAgent and similar implementations have always been involving the use of advanced communication methods such as Bluetooth and Wi-Fi in order to construct an overall architecture that finally delivers a certain service to a specific user in the simplest way. Another advanced and promising communication method, which is increasingly used in many markets and research areas, is Radio Frequency Identification (RFID). Indeed, this technology is efficient and cost effective. Basically, using an RFID-Reader, standard radio frequencies are used to read information on small devices or chips, better known as tags. Some of these tags are sophisticated, editable, and used for vital applications such as E-Passports [2]. Other tags have simpler architectures and they are one-time edited upon manufacturing, and, accordingly they are used only for cost-effective models such as Supply Chain Management.

A simple RFID architecture may contain three main parts: 1) *The Tag* that identifies a specific object (e.g., an animal [3] or a product); 2) *The Reader* that reads whatever data edited or pre-installed on the tag, and 3) *The Back-end System* that usually contains a single or a network of databases that converts the tag contents into useful application entries. Finally, RFID is another technology that can be integrated within a range of computer-based applications. This integration would improve the identification of surrounding objects, and establish a sort of communication with fixed or moving system entities that play a fundamental role in explicit service architecture (see Figure.1).

To elaborate, and following the above-noted examples, bar-coding technology is the most commonly used method in computers in stores (to identify and checkout goods) and at airports (for passengers' check-in and check-out and secure passports and visas). Yet in both cases human personnel is still employed in the process to follow up and control the data. An alternative way that would both facilitate data processing and decrease the costs of operation is to replace the bar-coding and human personnel with RFID.

For example, if all of the products in the supermarket are RFID-tagged, all what a costumer will have to do is to pick what s/he wants and pass through a gate that is RFID-Readers enabled. At the gate, the system will quickly read the RFID-tagged information that the products have, identify objects, and electronically charge the costumer's credit card or any other pre-defined payment method. Advantages (such as avoiding long queues and the automation of several daily life tasks) and disadvantages (such as the lack of privacy and security) are both considered whenever RFID is an option. This paper's core reflection is concerned with integrating software agents throughout RFID-based applications, so that it can be of use for people in such situations as easily and quickly checkout from supermarket or airport gates. This paper proceeds as follows: Section.2 explains the newly recommended architecture for agents to better establish virtual community-like systems. Section.3 introduces the integration between Agent-Islands and RFID-based Systems. Section.4 describes the advantages of such integration. Finally, we briefly demonstrate some of the related work.

2. RFID Application

The RFID system design is basically about the communication established with mobile tags that are attached to all of the objects located in a zone, which is covered by RFID-Readers. These RFID-Readers are able to establish a channel of communication, read the tags and, and trace the move of these objects within a certain range – the coverage area. Data stored on these tags can later be converted into a machine-readable format and accordingly used by the machine. When an object carrying an RFID tag is checked into the back-end system, it corresponds to a particular set of data that distinguishes the tag-holder and an object's specific characteristics from others. Since the locations of these objects are already known, we can easily refer to each set of tags (e.g., using serial number or MAC address) according to the location.

Let us consider the example of a situation in a store where different product categories are arranged in different locations according to their origin and prices. It is quite common that a customer would go into a supermarket and to find all of the crackers in one side and the soda drinks in another, and so on for the rest of the goods. It is like having the floor of the store marked with different areas and each area has its own belongings. In a real-world situation, an RFID-Reader is located on top of a block of shelves and it communicates with the products located within its coverage area, so if the customer leaves the detergents section and he/she searches for a product in the sweets' one, the product he/she has picked first is no longer belonging to coverage range of the former RFID-Reader and now is located within the coverage range of another RFID-Reader (Freq. 13.56 MHz with Less than 5 M or Freq. 915 MHz with read range of5 Meters).

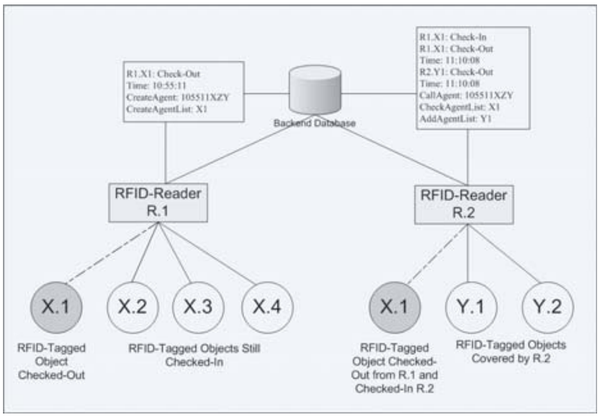

Fig.2: RFID Agents-*based* early check-out scheme.

When an object containing an RFID tag is scanned by one of the Readers, the data on this tag is communicated with the back-end system and verified for accuracy and, sometimes, related tasks are launched to determine some other characteristics (e.g., price, expiry date and size). This communication usually takes place when a product is being checked out of the system, or whenever an object is signed to be located out of the architecture coverage range. This process of sign-in and out can be adopted in similar smaller phases within the purchasing process. As we explained in the above-mentioned example, the RFID reader responsible for each zone sign the goods in and out depending on the availability of these objects within its marked area. A reader will be launching a review process for the assigned objects within a pre-defined timeframe (the average time for someone to decide about obtaining a product). Once a product is not available or is added to the list of assigned ones, the reader automatically recognizes the check-out or in for an object. Software agents can play a central role in this process by monitoring the check-outs and check-ins within a single RFID Reader whenever it is time to communicate with the back-end system to verify the new situation (see Figure.2).

During this communication with the back-end system a platform of agents can be installed. These agents will carry the data of the checked-out items from the list of assigned products of a specific RFID reader, and then hang in the network waiting for the same data to be checked somewhere else. This process can be realized by implementing a method that compares the data that the agent carries with the newly checked-in data within the overall system. This will help accumulate the objects list within a system having check-out from a zone and check-in from another, all in the exact time, which refers to a certain purchaser moving with his/her cart from a zone to another.

2.1 Agents Performance and Organization

Considering the above-mentioned example, in which each product will be assigned an agent able to maintain its future and present statuses within a single environment (e.g., a supermarket), the agent will have to coordinate with other agents to form Islands of Agents which, would create a profile of a certain group of moving products – and accordingly identify a specific customer and his/her interests – and link the products checking in time and zone with the rest of the products having the same. We finally shape a group of agents that are able to communicate and benefit the shopper in several ways. One advantage is reviewing the customer’s accumulated product list and accordingly communicates with the customer through, for example, a Bluetooth mobile communication about similar promotions or newly-offered products. Another advantage is that agents, while checking out, will be managing to have most of the products going through the checking out module on-the-fly with the customer move in a specific zone. This can take place simply by reviewing the already existing list every pre-defined time and update the list with the new products. Consequently, whenever it is time for the customer to be located near to the checkout gate, RFID-Readers close to the checkout gate would launch a final comparison process of the two product lists; the one that the agents managed to establish while the customer moves in the zone and the other that the customer is leaving the place with. Therefore, a jamming by the checkout gates will be avoided.

An RFID-based early check-out system will be basically concerned with fulfilling two main functions. One is the RFID-tagged object that is checking-out of a certain zone and, the other is the RFID-tagged object that will be checking-in in another zone. System inputs and outputs will be given, sent, and generally exchanged among these two actors. In turn; the connection between back-end system, RFID-Reader and RFID-Tag should be well-established and robust. The same applies to the communication between the back-end systems, integrated with the Multiagent layer, and the zone-walker, providing the user with extra services (e.g. passport checkout gate directions and new product offers and promotions). A mobile-based application is chosen for these types of human-objects interactions, thus, standard mobile phones relations are taken as a method of communication. Nevertheless, and autonomous agents will be negotiating the check-out/check-in details and finally communicating the final results with the mobile user. Similar architecture – selling used books for student – was described by scholars [1].

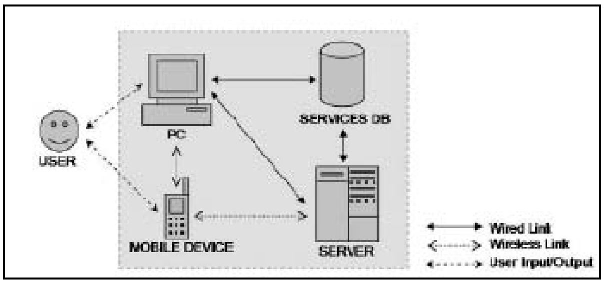

Fig.3: ToothAgent Interactions of System's Components [1]

2.2 Algorithm Anticipation

Autonomous agents that take part of a Multi-agents environment for mobile based applications are well-known with their capabilities to achieve difficult organization and negotiation tasks within a certain community. Consequently, the use of autonomous agents in RFID early check-out systems is essential. Our suggested scheme will be using any-time algorithm suggested by scholars [7] that is expected to help us solve the problem of tasks allocation, which accordingly will help the check-out/check-in requests routing within a community of autonomous agents. As a result, agents are expected to shape an alliance to better perform a certain Tagged-Object request between multiple zones.

2.3 RFID Architecture Modifications

The RFID Architecture in this case composes of customized RFID features and new integration of technologies and capabilities on the software layer, like Autonomous and MultiAgent systems, and on the hardware layer which consists of two components: the Device Layer and the Network Layer. On the Device Layer, it consists of the actual hardware and software of the individual RFID devices on the network. These devices can be any number of RFID-Readers and Location Servers. The increase of the number of the Readers available can be observed, as each reader will be responsible for a particular zone. The method of communication between the reader and the location server will be reliable enough not only to update object details, but also to exchange information requests and queries related to the move and the combination of a set of objects.

On the Network Layer, a middleware platform will be implemented, as it supports objects checking in and out, reading, writing, filtering, grouping and routing of data generated by RFID-Readers. Within this layer, the expected Multi-agent application would be developed so that readers can communicate with each other throughout the interactions and coordination of Agents, as if Agents are the language spoken among RFID-Readers. So at the end it is all made clear that the objects grouped in this shopper/walker profile are checking out of the system and they are adequately verified.

3. Agents RFID Integrations

Integration between cellular phones and RFID infrastructures is feasible. A previously proposed framework, SpatialAgent [4], aiming at providing mobile users with services based on their locations, utilized an RFID-based location model to identify objects and users' locations, and a location-information-servers (LISs) to manage location sensing systems and agent devices. In this system, agents have a graphical interface that allows their interaction with users who can freely customize them. Also, a related research, "follow-me" [5] – conducted by Cambridge University's Sentient Computing Project – assumed that a space is equipped with tracking systems (e.g., RFID Network) that help the location identification process of both users and objects.

These integrations open a window of opportunity for developing a service-oriented framework that can help a walker within a certain environment to better explore the surroundings. On the other hand, another window is open wide in offering commodities and showing promotions, which will help improve the management of a certain environment.

3.1 User-Profile Adaptation

Tools to set up an accurate customer profile may include: 1) knowing what a shopper is interested in; 2) understanding what sort of products combinations he/she makes; 3) analyzing the sequence of moves he/she makes within a specific area, and 4) sound techniques of analysis. These tools will lead the RFID application layer to better manage the tagged objects to best fit in user profiles. Other advantages can also be realized. For example, assume that the system record shows that three different shoppers in a supermarket have picked a certain tomato paste from zone A, that they have included in their list of objects a certain pasta brand from zone F, and that the same shoppers usually move from zone A to zone F and never the other way around. Based on this record, a restructuring process for the locations of the products can be made to facilitate the movement for shoppers, such as replacing zone F with zone B. On the RFID application layer, one of the possible integrations can be made with the Profile Extractor (PE) [6] which is a module that classifies users using supervised learning techniques. It can be used to discover users' preferences by analyzing data relevant to a user's interaction or data that are gathered from different sources (e.g. data warehouse or transactions), this happens so the system could suppose a set of regulations that help in relating this user's behavior.

3.2 Concept Generalization

The RFID tags can transmit in different frequencies, a characteristic that makes it readable from different distances. A 13.56-MHz tag can be found by a RFID-Reader within 10 inches, but a 915-MHz tag can be read up to 10 feet away. This increases the probability that an object would be scanned on-the-run. Similar to WiFi networks or cellular phones, RFID tags are relatively easy to jam when using power at the right frequency. The electromagnetic or electrostatic coupling in the RF (radio frequency) part of the electromagnetic spectrum is used to transmit the signals. This coupling makes the RFID jamming occurs usually at the airport gates, as all arriving passengers rush to the exit at the same time.

A checkout process at airports is another area of interest where Agent-islands can be applied.

If a RFID-Tagged passport holder is moving from a zone to another inside the Arrivals Hall and the system records these movements and creates an Electronic-Passport (E-Passport) holder profile, an early checkout can be predicted and initiated. Moreover, a pre-defined checkout path can be taken into account, as mentioned above, by intelligent agents recording and learning from the frequent moves of E-Passport holders. When it becomes clear that a passenger is moving from point X1 to X2 and then checkout at X3, the system will be able to assume the probability for the check-out of this passenger, as if agents have their own virtual communities in which they learn from each other and facilitate the actions to be taken by the general framework. Also, agents will be able to predict passengers' movements within limited environments such as airports.

Conclusion

This paper introduced a preliminary outline of Agent-Islands, a new technique for providing location-based services. This idea of islands of Agents came about from a pre-defined list of RFID-Tagged objects moving within a bordered zone. An agent is created for each walker or shopper, adding to its profile the objects he/she is picking, correlating the RFID tags check in and check out time from different zones with the moves taken inside this environment. We have discussed how this technique can be applied within a Multi-agent based architectures in order to facilitate the mission of concurrent customers check-out, avoiding the disadvantage of RFID-Reader Gates Jamming within a network of linked Readers and Back-end Systems. We illustrated a scenario where RFID technology is used to specify users' locations, then, finally, we demonstrated the possibility of Agent-Islands to integrate with RFID structures to offer the customer an improved set of value added services.

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