Intelligent Cokes and Diapers: MyGROCER Ubiquitous Computing Environment

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Abstract. Over the past years, significant developments in mobile technologies and associated economies of scale via mature manufacturing processes have made the construction of ubiquitous computing applications possible in specific domains. This paper presents the business rationale and the architectural framework of an innovative ubiquitous computing application for the grocery sector (MyGROCER). MyGROCER exploits the opportunities provided by emerging wireless and mobile commerce technologies, coupled with automatic product identification technologies (RF-Id), in order to enable an efficient home replenishment schema, enhance the quality of service provided by retailers, and ultimately add value to the end-consumer. We present the architectural elements of the application by identifying the design challenges and the way they were dealt with. The paper concludes with a critical appraisal of ubiquitous computing applications in supermarket environments and identifies future research challenges.

1 Introduction

Ubiquitous computing (ubicomp) was first introduced by Weiser as "*the method of enhancing computer use by making many computers available throughout the physical environment, but making them effectively invisible to the users*" [39]. Abowd (2000) enhances that definition by stating that ubiquitous computing inspires application development that is "off-the-desktop" implying that the interaction of the users with the system will not resemble the traditional mouse/keyboard interfaces [2]. According to Abowd (2000), application-driven research in ubiquitous computing includes three axes of investigation: *natural interfaces*, *context-awareness* and *automated capture and access*.

Over the past years, there have been many experimental applications that applied the aforementioned principles in different environments. Examples include: The Active Badge and the Xerox ParcTab, both location-aware appliances that provide automatic call forwarding for a phone system and automatically updated maps of user locations in an office [37] [38]; Classroom 2000 which investigates the impact of ubiquitous computing on university education [3]; Cyberguide and GUIDE which provide information services in a tourist based on his current location [27] [4] [14]; MusicFX which collects music preferences of people working out in fitness centers and determines the best music to play at any given time [28]; HyperAudio and HIPS which implemented hand-held electronic museum guides that adapt their behaviour to that of the individual visitor [30] [9]; The Conference Assistant which allows conference participants to take notes at distributed presentations through a PDA given by the conference organizer [15].

All of the above applications aimed to facilitate an "every-day" activity of our life. Nevertheless, little research work has been conducted in the field of grocery shopping in terms of developing a ubiquitous computing prototype. Our research has identified two prototypes that aim to enhance the shopping experience in supermarkets: MyGROCER [26] and Shopping Assistant [5].

This paper aims to present the architecture of a prototype ubiquitous application in the grocery sector. The paper is motivated by the results of the MyGROCER research project (Mobile Shopping of Electronically Referenced Products) which is funded by the European Commission (IST Programme). In the following sections, we will present the business rationale behind the MyGROCER concept and the general design principles we used during the specification of the system's architecture. Section four presents briefly the concept of MyGROCER in terms of application scenarios while sections five and six depict the overall system architecture. Finally, section seven concludes with a critical appraisal of the overall solution and identifies areas for further research.

2 Motivation

Our primary motivation for the implementation of this research project does not come from the point of view of mobile computing systems but rather from a different perspective, namely optimising the efficiency and effectiveness of business processes [25] [32] [36] within the supply chain of the grocery sector. Although the focus of pervasive systems is primarily on disappearing computing infrastructures and assisting every-day life instead of overwhelming it [1], the information collected has significant repercussions for the operation of businesses and for conducting commerce. Indeed, rather than having a supply chain terminating at the supermarket checkout, it is now possible to extend its reach in the consumer household. Of course, this has significant effects both on the consumer experience and on internal processes of commercial organisations.

Indeed, the integration of Internet technologies in retail practices has transformed the sector in a matter of a few years. This transformation has not only affected the way retailers interface with their clients but has touched all areas of their activities. The fundamental aim remains of course the same, that is, to provide services increasingly cost efficient and consumer-oriented. This trend has generated a new generation of Internet based collaborative and cross-organisational supply chain models. The Holly Grail of these developments is the unification of the supply chain as a direct, shared and cost efficient channel from raw material all the way to the customer. This objective generates a novel kind of service, which is on demand, ubiquitous and personal and for that matter a perfect match for pervasive computing.

The current situation is quite different. On one hand, the grocery value chain does not have data beyond the supermarket shelf and the checkout, which in turn results in significant inefficiencies in a market sector where margins are minimal. For example, it has been estimated [24] that in a typical supermarket out of stock conditions cause up to 3 percent loss of revenue due to loss of sales. Furthermore, 53 percent out of stock conditions are due to store replenishment inefficiencies. Even worse, a further 8 percent of on the floor out of stock conditions occur despite the fact that the necessary supplies are in storage on site.

On the other hand, retailers (namely supermarkets) are also focusing on enhancing the consumers experience in their retail outlets. Indeed, supply-chain management and consumer behaviour researchers have identified numerous issues that affect the so called "shopping experience". Baker (1986) [7] referred to environmental conditions (temperature, scent music and so on), while Fram (1994) emphasized on time-pressure as a factor that influences the shopping experience [17]. Aylott et al (1998), contributed to the list of problematic issues during a "grocery shopping transaction" through the conduction of a research in the UK comprising 29 focus groups with a total of 239 respondents [6]. The results indicated that the majority of the respondents considered queuing (especially during check-out) as the most important stressful factor. Additional factors included information overload (mainly through in-store promotions or advertisements [8] [23] [29]), fragmentation of information and inability to continuously monitor the total price of the products in their shopping cart.

Up to now, researchers have been focused either on the supply-side (upstream) or the consumer-side (downstream). The Collaborative Planning Forecasting and Replenishment program supported by ECR [16] – a strategic initiative among the stakeholders of the grocery sector – has tried to answer the problem of visibility and collaboration among the supply-side [33] [22]. Regarding the enhancement of customers experience within the supermarket, besides the research prototypes mentioned in the previous section, several commercial solutions have been introduced allowing the consumers to monitor their shopping transactions. All of them are based on barcode identification and offer basic services during the shopping trip (displaying the price of each scanned product) and during check-out (displaying the total price of all scanned products and printing a receipt that was handed to the cahier). An example is the Symbol Portal Shopping System used in several supermarkets including Finast (USA), Safeway (UK), Tenglemann (Germany) and Albert Heijn (The Netherlands) (http://www.symbol.com). Nevertheless, although these solutions offer automation of the check-out process, they are proprietary to each manufacturer and cover only part of the problems since (1) they demand substantial integration overhead with each retailer's back-end system, (2) they lack security mechanisms and (3) they are unable to extend the grocery value chain beyond Point Of Sales data (POS), namely to incorporate the consumer's household to the replenishment lifecycle [26].

A potential solution to the aforementioned problems is the implementation of an integrated application that enhances the shopping experience in-store and at the same time operates as an information hub among the value chain stakeholders. The following section discusses the design requirements we followed when specifying the proposed system architecture.

3 Ubiquitous Computing Design Requirements

Proposing a ubiquitous application for the grocery sector presents significant challenges due to the fact that shopping is considered both as an "every-day activity" and a "leisure-time-activity" [31]. To this end, traditional design theories (capable to design applications for desktops) fail to grasp the actual requirements that such applications impose in terms of users' interaction, enhancement of the overall shopping experience and so on.

This gap can be bridged by ubiquitous computing design requirements. According to Abowd et al (2000) [2], ubiquitous computing applications must incorporate graphical interfaces that support more natural human forms of communication, which are easy to use and provide a fast learning curve. This statement is extremely important for our case if we consider that supermarket shoppers belong to different age groups and may be unfamiliar with technology. To this end, a graphical interface that allows the smooth operation of the system is mandatory. Furthermore, ubiquitous computing applications must be context-aware. Context awareness refers to the incorporation of several attributes (identity, location, time, history and environment) into the business logic of the application. Abowd et al (2000) and Truong et al, (2001) argue that the aspect of location can be described by answering the following questions [2] [35]: who is using the system? What is he/she doing? Where is he/she located? When does the interaction take place? Why is the user doing that specific action? Applying the concept of context awareness in supermarket environments we can argue that:

- Context aware applications in supermarket environments must know the identity of the shopper in order to provide *personalized services*.
- They should also identify what the user is placing inside the trolley and consequently identify the *actual contents* of the shopper's shopping cart.
- Furthermore, identification of the shopper's location could enable the provision of *alternative* or *promotional* products that are positioned near the shopper's location.
- Identification of the time dimension could enable the provision of informative or *promotional messages* to the shopper in specific instances.

It should be noted that as context-aware systems offer increased personalization, privacy concerns for the capture and later processing of context information is required. To this end, sophisticated mechanisms that ensure this trust, privacy and security must be implemented. These issues will be further addressed in the final section of the paper. Finally, automated capture and access refers to the capability by the application to store specific information that is crucial to the end-user and enable its playback at the time it is needed. In the case of supermarket applications, we project this concept to the capability by the application to keep track of the shopper's past purchases and to suggest him/her of a shopping list that matches his / her needs. The following table summarizes the design requirements by giving emphasis to specific applications in the supermarket environment:

Table 1: Ubiquitous computing applications design requirements - Applicable for supermarket environments

Application Requirements	Design Principles	
Natural Interfaces	• The application should provide easy to use interface • The application should provide easy to learn interfaces	
Context-Awareness	*Who*	The application should identify the identity of the consumer
	What	The application should identify the actual contents of the shopper's shopping cart
	Where	The application should identify the current

		location of the shopper in the supermarket and propose alternative products or promotional products
	When	The application should identify when a product has attached a promotional rule and display a notification message to the shopper
	Why	The application should identify if the specific shopper's action is related to a specific event (e.g. the consumer is on a diet)
Automated Capture & Access	• The application should keep track of the shopper's purchases • The application should remind the shopper of his/her shopping list • The application should incorporate privacy mechanisms	

Most of these general design principles have been addressed by MyGROCER. It should be noted that MyGROCER is still on its development phase and this paper presents the architectural solution of the initial prototype. A future version of the system will incorporate an innovative location identification mechanism based on GPS specially modified for indoor environments. We address our future plans in the final section of the paper. The following section presents briefly the functionality of MyGROCER.

4 Ubiquitous Computing in the Supermarket

4.1 The MyGROCER Concept and Functionality

MyGROCER is an innovative information system aiming to exploit the opportunities that emerging wireless technologies (such as Bluetooth and WLAN) and automatic product identification technologies provide to the grocery sector. The main objective of the system is to introduce advanced B2C oriented E-services upon intelligent mobile access devices, enabling full interactivity, personalization and automation of home replenishment activities for products in the grocery retail sector with clear future extent to the retailing sector in general. The main functionality of MyGROCER can be summarized in three collaborative scenarios: the in-store scenario, the on-the-move scenario and the smart-home scenario. These scenarios are in accordance with the generic design requirements presented in the previous section.

4.2 In-Store Scenario

Innovative wireless networking schemes are implemented inside the supermarket in order to enable the provision of MyGROCER's value-added services. RF-Tags, which comprise of small labels, are replacing traditional barcodes. RF tags uniquely identify each product and are constantly transmitting the "presence" of the product to RF-receivers, effectively positioned on the shopping cart. When the consumer enters the supermarket he logs in MyGROCER through his cart. The system identifies the user and displays his shopping list (missing products) to the shopping cart's display screen. While shopping at the supermarket, the consumer selects products from the shelves as usual. The readers on the shopping cart can understand when the products are placed in and with the necessary application logic, can also retrieve their price and other information and update the consumer's shopping list from the retailers' servers. The shopping cart may also display in-store promotions that are based on previous consumer buying behaviour or cross-selling product associations. At the check-out counter, there is no need to scan the products again. Instead, the "smart" shopping cart notifies the cashier, sends the shopping-list data to the check-out system and the payment receipt is issued, while the store inventories can be updated. The customer's shopping list information is maintained in the system as point of sales data to be used for future promotional activities.

4.3 Smart-Home Scenario

Similar to the supermarket scenario, key-storing locations in the household are inter-networked with RF-Id readers. If the consumer wants to keep track of his house inventory, he must place the products he bought from the supermarket to these locations. The RF-Id readers register the "presence" of each individual product and update the inventory in regular intervals. To save energy, readers will be powered-off for the most part of the day and periodically (e.g. every 1-2 hours) will wake-up and scan all items within range. The home scenario prerequisites a “Home Server”, either a normal PC or a modified set-top-box with capable storage capability and application logic in order to store the home inventory. As soon as the products are removed from their original location, and not reinstated within specific period of time (possibly defined by the user), a “replenishment” signal is transmitted to MyGROCER over Internet connection. The consumer can then retrieve his shopping list either through his mobile phone in order to conduct mobile shopping transactions or through the shopping cart in-store as a reminder of which products must be purchased.

4.4 On-The-Move Scenario

Consumers can have access to the automatically generated shopping list (which comprise of products that the system has identified as “missing from the house”) through their wireless access devices (PDA, mobile phone etc.). Consumers will be able to administer the shopping list (modify quantities, add new products etc.) and receive at any time information about the total amount they should pay for the selected products. Then, consumers might wish to have home delivery or submit their shopping list to a set of registered supermarkets in MyGROCER database initiating reverse auctioning sequences. Additional value-added services that fall to the on-the-move scenario include notification about products that have ran out-of-stock either at the moment MyGROCER realizes the product’s absence or at certain predefined times, advanced product recommendations based on consumers’ profile and past buying behaviour, fully automated payment services and on-the-fly management of their profile where the consumers can inform the system about their preferences (e.g. I am vegetarian etc.), definition of high-priority products (for notification reasons), minimum safety-stock product quantities etc.

The collaboration between the 3 scenarios can be depicted in the following figure in terms of data exchange among them. In particular, the following figure (figure 1) displays the lifecycle of a transaction in MyGROCER.

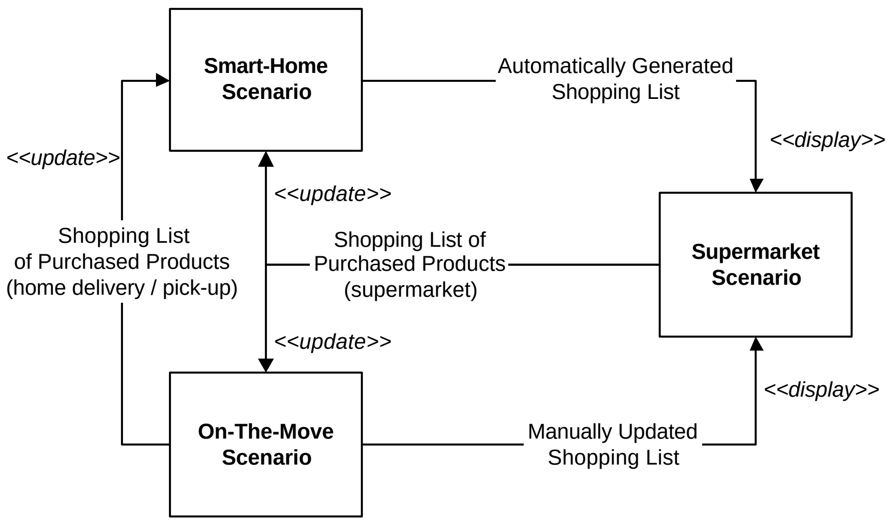

Figure 1: Collaboration among the three scenarios of MyGROCER

5 System Architecture

From the application scenarios presented above, it is apparent that MyGROCER operates as an intermediary, integrated with the retailer’s back-end systems and capable to interface with a variety of heterogeneous devices ranging from palm PCs running EPOC OS or Windows CE to WAP-enabled mobile phones. More specifically the system will interface with the following devices shown in the context diagram below (figure 2).

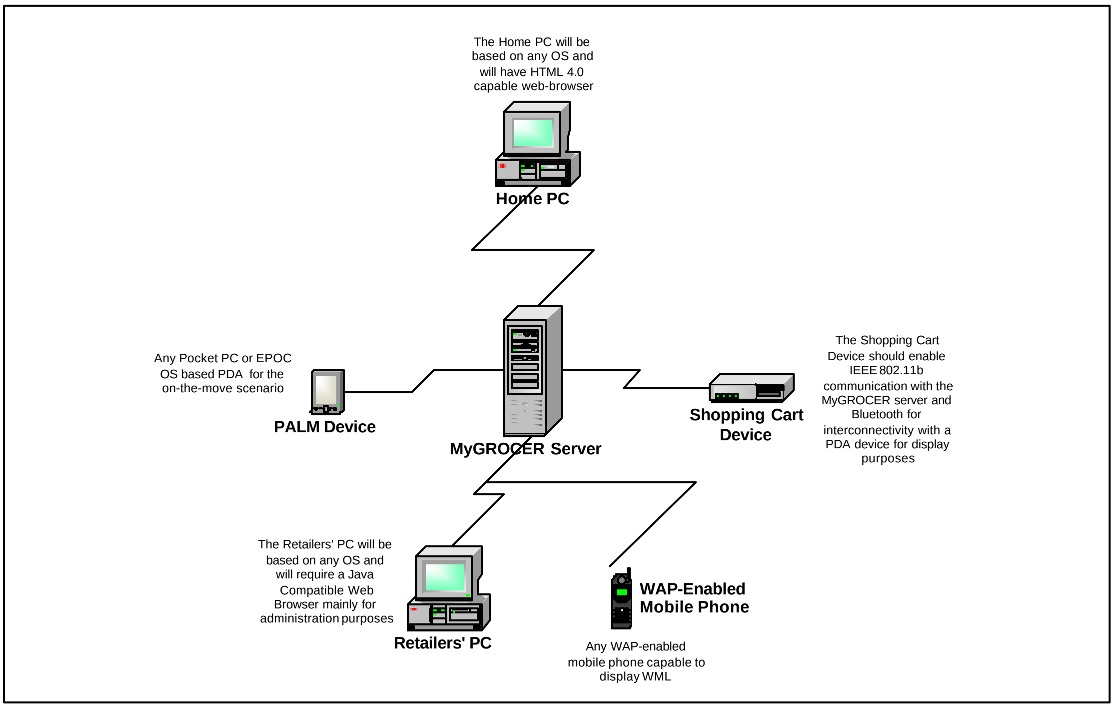

Figure 2: Integration of MyGROCER with different devices

This collaboration among heterogeneous devices introduced additional requirements to our architectural approach. Tandler (2001) suggests that in such cases, the application designers should propose a software infrastructure that is open for different styles of interaction and able to adapt the visual interface accordingly [34]. To this end, we used a Content Transformation server (CTS) capable of transforming the data from XML using XSL to either HTML or WML depending on the target platform. In addition, we used an Application Server which stored the business logic of our application and communicated with the retailers' back-end systems and the CTS in order to interface with the shopping carts in-store.

The application server was used for providing access services to the carts including session management, location tracking, personalisation and caching. Our primary motivation for developing this architecture was the requirement that traffic on the wireless network should be kept to minimum, as should the hardware requirements on the computing device mounted on the shopping cart. However, by introducing this design we also inherited what proved to be a more reliable, secure as well as faster method for device support. To this end, most of the processing is performed at the applications server with the cart-mounted device employed primarily for rendering the presentation layer elements. We believe this is a reasonable design for two reasons:

- First, user sessions share a large amount of data traffic between client and back end server (for example catalogue queries and product offers) and
- Second, the processing capabilities of the end user device are too restricted to provide acceptable performance levels for the more demanding tasks (for example real time recommendations based on consumption profiles).

The Application Server communicates with the Content Transformation Server through SOAP in order to ensure smooth communication over protected networks (through a firewall), which in turn communicates with a Web Server (for communication with the shopping carts over IEEE 802.11b) and a WAP Gateway (for transmission of the content in WML-enabled wireless devices). The overall system architecture in the supermarket environment can be depicted in the following figure (figure 3).

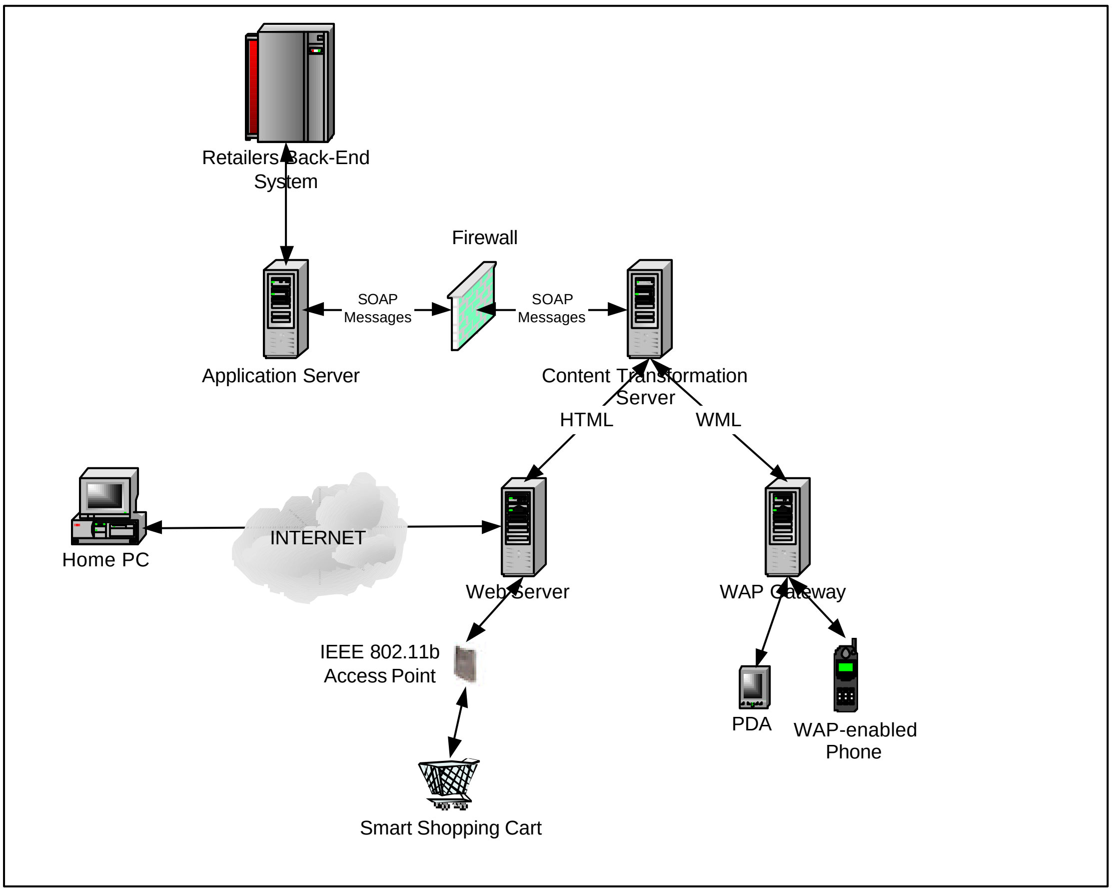

Figure 3: Overall MyGROCER Architecture

The following section discusses in detail, the architectural solutions for the shopping cart and the smart-home / on-the-move scenarios.

6 Implementation Details

6.1 Overview of RF-Id solution

The core technological innovation of the proposed solution is the use of Radio-Frequency (RF) technology for the products' identification as a barcode replacement. Indeed, current practices in product identification entail the use of barcode: barcodes are self-contained messages with information encoded in the widths of bars and spaces in a printed pattern attached on the product itself. This information is retrieved through optical readers that can transform the pattern into data. However, the actual interpretation of the data is an altogether different issue: there are several competing standards including several versions of UPC and EAN, JAN, MSI, CODABAR, Code 39, H-P, Code 11, Code 128 and so on. On the other hand, all of them share one common feature: they can identify a class of products but not specific instances of them. For example, all 330ml cans of Coke have the same barcode printed on them. Finally, in most cases the barcode only identifies the specific product class but not product class classification or category. RF technology provided a solution to this problem by introducing unique product identification which enables continuous monitoring of each individual product among the supply chain [10].

There are many researchers that have identified the benefits of RF-Id technology as a replacement of barcodes from both the business [10] [26] [32] and technical [18] perspective. All of them summarize RF-Id benefits in comparison to barcodes in terms of transparent data capturing for the shopper (no line-of-sight between tag and reader is required), efficient operation in hostile environments (excessive dirt, dust, moisture, poor visibility), unique product identification and provision of Electronic Article Surveillance (Anti-Theft) capabilities. The use of RF technology in MyGROCER can be summarized in a two-fold perspective: the RF-system of the shopping cart / smart-home and the role of the RF-tags themselves.

6.2 The Shopping Cart Architecture

In order to design the most efficient architecture to support the automatic identification of products and at the same time design a system that will be friendly to use and easy to learn. To this end, we had to face two major design challenges.

Figure 4: The prototype RF-Reader for the shopping cart

The first design challenge we had to overcome when specifying the shopping cart architecture was the selection of the most appropriate mechanism in order to efficiently read the products when placed in the trolley. Our choice of RF-Id solution was based on the IONAS chip design by Atmel Corp. The IONAS operates at 13.56 Mhz and is ISO/IEC 14443-2 compliant. It has a capacity of 320 EEPROM bits, divided into 10 pages of 32 bits. It supports password and write lock protection, programmable send and receive protocols and multiple tags read (anti-collision mechanism). The chip itself contains an internal tuning capacitor and thus for a complete tag only an external antenna is required. The IONAS can store an identification of length between 4 and 19 bytes. The corresponding RF-Id reader is a custom design by Ordicam. The reader used in this application is based on the commercially available Ordicam model V61 and it is built on the Microchip PIC16F876 processor. However, the V61 has only 3cm effective reading range and is therefore unsuitable for this application. This short read limit is due to safety and environmental requirements that restrict the power output of radio frequency equipment. The custom model with a corresponding antenna design, while honouring the regulations, has an effective read range of approximately 20cm. A longer range would introduce the problem of false identification of products by nearby shopping-carts or even the shelves of the supermarket. The reader is 100x50x15 mm and weights 2.5kgs with battery included. Finally, it is equipped with a serial RS-232 interface for connection with the shopping cart. The prototype reader can be depicted in figure 4.

Since one of the main objectives of the system was total transparency for the consumer, the original requirement suggested that the readers should be able to cover the complete volume of the shopping cart, which is approximately 80x40x60 cm. In that case, the system would be able to automatically identify every product inside the trolley and inform the consumer about its contents. However, this solution presented several drawbacks:

- Given the range of the reader and the fact that readers may only be attached to the trolley sides we came up with a design requiring at least 12 readers per cart
- The increased number or readers required an extremely high power consumption which in turn required a special modification of the trolley that would provide sufficient power supply (embedded batteries)
- Even this design did not provide any guarantee that every orientation and part of the shopping cart would be eventually covered
- The time it takes the system to register and identify all the tags increases with the number of tags in a probabilistic manner. For large number of tags this time can become unpredictable
- The packaging material of the products themselves might absorb the signal of the tags preventing the reader(s) from registering some products
- Finally, from a financial point of view, the increased number of readers would make our solution unfeasible in terms of total cost. Current estimations on the retail price of RF-Id readers indicate an average €500 – 600 cost per unit.

Our second attempt approached the problem from a different point of view: rather than aiming to monitor the presence of items everywhere at the full volume of the shopping cart we opted instead to monitor only entry and exit of products. To this end, only four readers should be installed on the top of the shopping cart with the purpose to identify products when they are placed into it. Each reader covers only a part of the top, open space of the cart, and by that means the combination of all four creates a *thin two-dimensional layer*. As a result, when a consumer places a product inside the cart, the system reads its tag once and the shopping cart application modifies a flag that stores the current *"state of presence"* for this product. Furthermore, the system parses the ID of the tag, extracts the barcode and transmits it to the retailer's database in order to identify the description and price of the product. If the consumer wishes to remove the product from the cart, the thin layer on the top reads again the tag and performs the same operations but identifies that the product has been already scanned (through the "state of presence" flag), therefore must be removed from the consumer's shopping list. It should be noted that in order to minimize the transmission of barcodes to the central database, a *cache memory* implemented locally on the shopping cart application stores gradually the association of barcodes and prices. The cache memory is automatically cleared at the beginning of each day. The proposed solution can be depicted in figure 5:

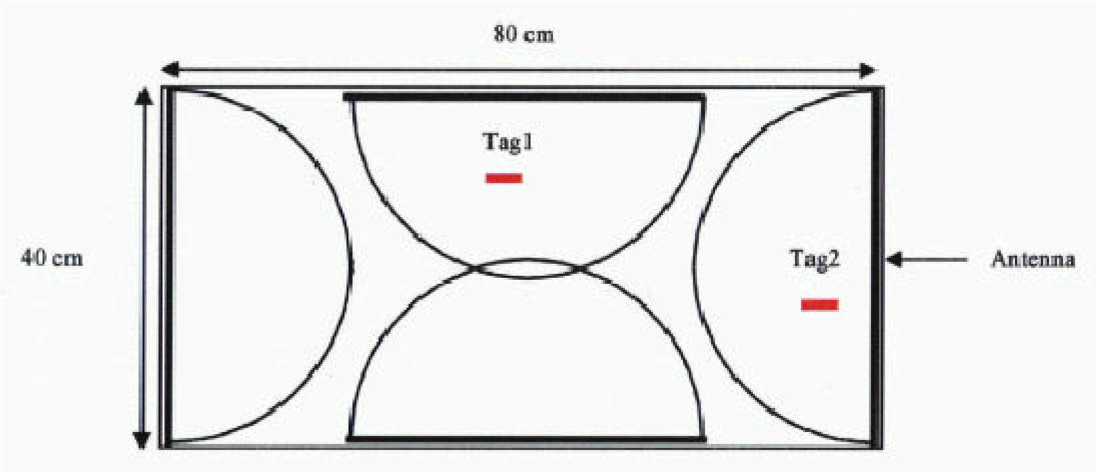

Figure 5: Shopping cart top coverage with four readers

The second design challenge we had to overcome when specifying the shopping cart architecture was the interconnectivity between the shopping cart and the supermarket server, RF-Readers and correspondent display device. Our initial approach was to design an architecture that allowed the product barcode (extracted from the RF-tag) to pass instantly from the shopping cart to the main server via IEEE 802.11b wireless Ethernet. The server can use this information to dispatch personalized promotions and display of products' related information (such as price, short description, image and so on). Furthermore, the display device of our prototype solution would have to be based on the following requirements: (1) the device would have to be resistant to its operational environment (supermarket floor, outdoor storage area), (2) it should be able to connect to the RF-Id readers on the one hand and to the wireless network infrastructure on the other (3) it should offer a good display capability for consumer interaction, (4) it should be perceived as fast enough from the user and (5) it should offer an open and extensible operating environment suitable for its capabilities. However, the overall architecture presented several problems:

- We needed a device equipped with four RS-232 interfaces in order to communicate with all readers and an additional PCMCIA port to interface with the WLAN card
- That device required increased processing power
- The implementation of such a proprietary solution would increase substantially the cost of each shopping cart resulting to an unfeasible market solution.

To this end, our architectural solution was based on a distributed approach. The consumer will use a Bluetooth-enabled PDA (provided either by the supermarket or using his own one) in order to monitor his shopping cart and use the MyGROCER services in-store. The PDA will communicate through Bluetooth with an embedded terminal device in the shopping cart which in turn will communicate with the RF-readers and the supermarket server through RS-232 and IEEE 802.11b respectively. The embedded terminal device will have the necessary business logic to process the information from the supermarket server and dispatch it to the consumer's PDA (figure 7). This solution presents significant advantages in terms of total cost, portability (each consumer can use his own PDA) and future extensions. The shopping cart architecture can be depicted in figure 6:

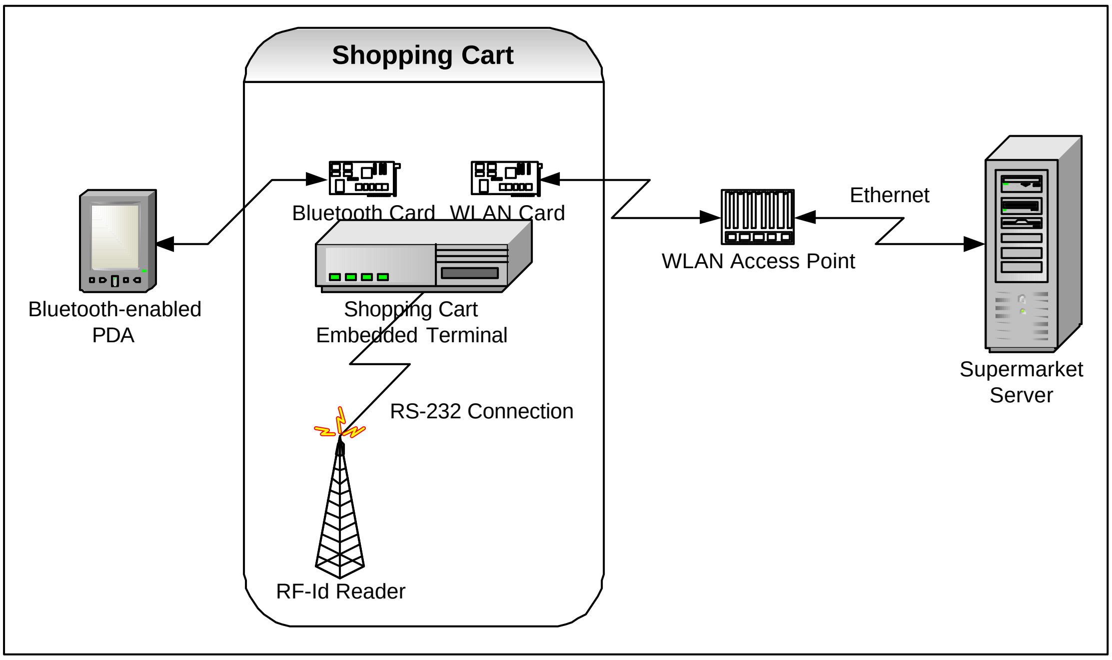

Figure 6: Overall shopping cart architecture

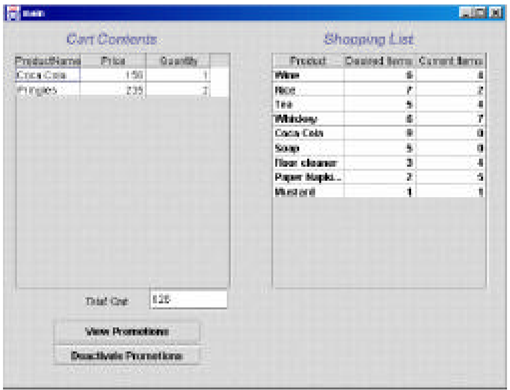

Figure 7: Main screen of MyGROCER application in-store. Shopping cart contents (left) and integration with home inventory (right)

6.3 RF-Tags Specification

Passive, self adhesive tags with significant memory capabilities (19 bytes) have been used for our prototype solution. The contents of each tag follow the guidelines stated by international standards organizations and global working groups (such as the Global Commerce Initiative – GTAG project [20] and the Electronic Product Code of the MIT - Auto-ID Center [11]). Nevertheless, since these results are not yet finalized, we have decided for our prototype to initially store inside the tag the barcode and manufacturer of each product. Furthermore, each tag will contain a unique serial number in order to ensure that each product will be uniquely identified. Finally, for security reasons, at the time an item passes *initially* through the top of the cart, the reader transmits a command that disables a *security bit (EAS)*. To this end, the system ensures the legitimate possession of the item by the consumer even outside the store. If the consumer changes his mind and wants to return the item back on the shelf, the item is removed from the shopping list as described above, and the reader re-enables the security bit as the item passes in front of it. The RF-Tags used for our prototype can be depicted in the following figure (figure 8):

Figure 8: Self-Adhesive RF-Tags of MyGROCER prototype

6.4 Smart-Home and Mobility

The smart-home scenario was built around the concept of a home networking architecture based on X10 with connectivity provided through a hub which transmitted the data received into a home server. The home server is capable to store instances of the home inventory and at specific time frames (predefined by the consumer) transmit the current inventory level to the retailer's server through the Internet (using DSL, ISDN or a simple V90 modem). The aforementioned architecture can be depicted in the following figure (figure 9).

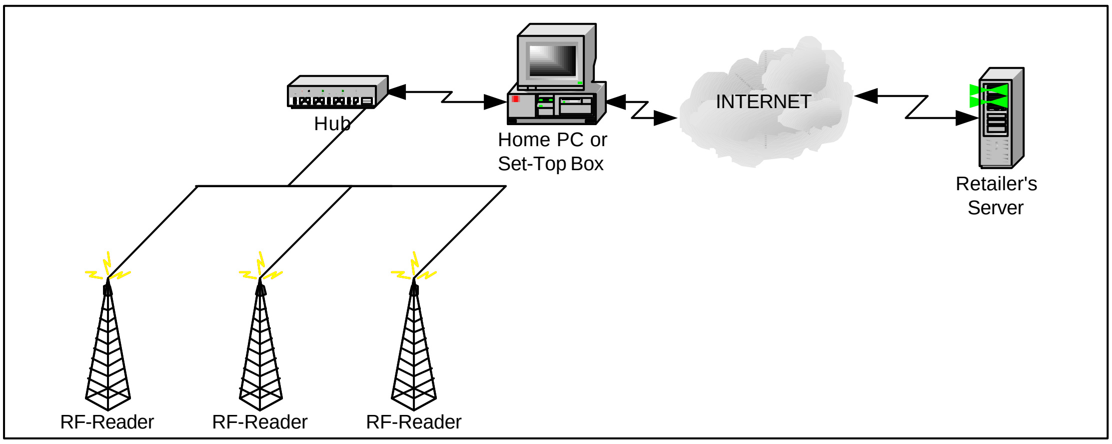

Figure 9: Smart-Home Architecture

For simplicity reasons, we have implemented our prototype using only one reader interconnected through RS-232 with a PC running a Java-enabled Application Server. It should be noted that the smart-home scenario presents additional requirements for security and privacy. To this end, we implemented a mechanism that enables consumers to fully administer the smart-home infrastructure in terms of products that will be monitored by the RF-Readers, time cycle between replenishment signals and automatic notification on products that have either expired or have been out-of-stock (Figure 10, middle).

Finally, access to the service from mobile devices was available through a WAP gateway operating at MyGROCER Service Provider. The consumer was able to view and modify his automatically generated shopping list and place an order through his mobile phone or PDA. Out of stock alerts are sent as SMS messages to the registered users. We have implemented the on-the-move scenario in a WAP-enabled phone (Figure 10, right) and PDA (Figure 10, left).

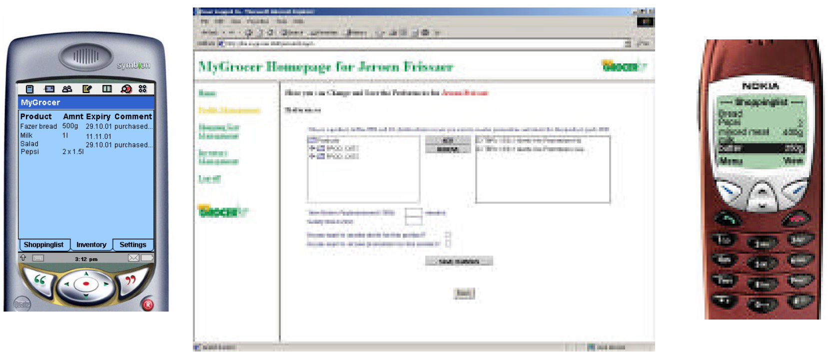

Figure 10: Administration of shopping list - PDA version (left), Management of Home Inventory (Middle), Administration of shopping list - WAP version (right)

7 Conclusions and Future Research Directions

This paper presented the architectural solution of MyGROCER, an integrated ubiquitous computing application for the grocery sector. The project has already developed an initial prototype and is currently implementing an enhanced version of it which will incorporate additional functionality in terms of location sensitivity. In particular, the second prototype will incorporate a modification of GPS to work in indoor environments. It should be noted that the GPS signal does not typically work indoors because the signal strength is too low to penetrate a building [12]. Nevertheless, Indoor GPS solutions can be applicable to wide space areas where no significant barriers exist such as a supermarket environment. According to Giaglis et al (2002), the navigation signal is generated by a number of *pseudolites* (pseudo-satellites) and is designed to be similar to the GPS signal in order to allow pseudolite-compatible receivers to be built with minimal modifications to existing GPS receivers [19]. The signal generated by the pseudolites is monitored by a number of *reference receivers*. The small footprint combined with ultra-low power consumption and low cost make it feasible to apply indoor GPS positioning technology in mass-market applications for the first time. In our second prototype we will install a set of pseudolites in the supermarket including Indoor GPS receivers to the shopping cart embedded terminal in order to monitor the consumer's path and offer true location-based services.

Nevertheless, during our attempt to develop a fully functional ubiquitous computing environment for the provision of next generation retail services we have identified numerous research challenges regarding the possibility of commercial deployment for such systems. First, we have found that the need for open standards is more important than ever before. Although RF-Id technology promises significant benefits for the retail sector in general, still the existing standards are immature. Furthermore, in order to provide a seamless user experience, similar systems must be interoperable irrespective of location, hardware and software manufacturer, service provider and person. This interoperability suggests solid integration between the different components of the application and among the retailers' back-end systems and significant administration overhead. Indeed, our experience in this area has led us to conclude that the retailers' infrastructure has been developed incrementally over a rather long period of time and thus its current architecture has been evolved rather than designed. To this end, access to such systems is rarely transparent and requires significant integration overhead.

In addition, ubiquitous computing systems being indistinguishable from the environment they operate in must provide guarantees regarding their functionality and operation so that users trust them with their intimate personal data. For this reason, access control and trust management must be embedded from the very beginning into the systems and not constitute an add-on "feature". The issue of trust and privacy is extremely important especially if we consider that we constantly need information regarding the consumers' current location in-store, past consumption patterns, household information, demographic data and so on in order to provide fully personalized services. This issue becomes more important in the smart-home scenario where the consumers should allow the installation of RF-Readers in their household. An initial critical appraisal of this situation would indicate that ubiquitous computing application designers must make some compromises on the extent they offer personalized services (especially in case of commercial solutions). Traditionally, data protection legislation in most EU countries prohibits the capture and storage of any person-related data and only allows exceptions for clearly defined purposes after which the data must be destroyed [13]. In our case, we allowed consumers to deactivate the provision of personalized services and at the same time participate to the system without providing their full set of personal information. However, this is not the solution to the general problem of trust and privacy. We expect that users will eventually be willing to adopt such applications only if they perceive that they are getting better value in return for letting go some of their privacy. As a result, we need to develop better and more valuable applications that meet the consumers' expectations.

Finally, there is need for a viable economic and business model. This is the most important reason why such applications have not been already deployed in real environments and remain in prototype forms. Several questions need to be answered: Who will be the owner of the application? Is it possible for such applications to generate revenue? Will the consumers use them? Will the consumers pay for them? Consumers might pay to live in a ubiquitous world, but no one expects them to pay for any application or add-on feature unless it proves to be a "killer-one" [13]. To this end, extensive market research is demanded in order to identify (1) appropriate target groups that will use such systems and

(2) the most feasible revenue models that would ensure break-even for the potential investors. Still, RF-Technology presents significant drawbacks in terms of total cost: the cost of each RF-tag is currently estimated to be between €0,15 and €1 depending on production volumes [21] making RF-tags cost-ineffective for low-priced products.

In order to identify a first impression on the potential commercial deployment of such systems, we completed a consumer survey based on focus groups during the initial phases of the project. The survey aimed to provide an understanding of how consumers perceive our proposed concept in comparison to their customary way of shopping. The results of the survey were very optimistic and gave an initial confirmation on the potential of strong commercial success of such solutions. The in-store scenario presented identifiable benefits for the consumers who perceived it as an innovative service ("shopping of the future"), under the scope of making shopping easier, well informed, more amusing and less time-consuming. On the contrast, consumers were reluctant to use the smart-home scenario due to privacy reasons although they acknowledged its clear benefits for specific market niches such as disabled people. Nevertheless, it was extremely interesting that among the interviewed consumers, only the younger ones identified the issue of privacy and the value of their personal data. We attributed this observation to the fact that younger people are more familiar with new technologies and are aware of potential dangers. Regarding the on-the-move scenario, it was considered as useful especially for people with limited time or physical disabilities. As a conclusion, upon establishment of the in-store scenario, the smart-home and on-the-move propositions could be re-examined at a time when there is evidence that shoppers are well familiarized and appreciative of the new hi-tech shopping/ replenishment procedures.

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