Towards Context-Aware Retail Environments: An Infrastructure Perspective

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ABSTRACT
In this paper we discuss means of realizing future retail environments based on the Internet of Things (IoT). Such environments provide consumers with a context-aware shopping experience allowing for premium services such as the provision of targeted product information or dynamic pricing based on estimated product quality. We believe that from an infrastructure perspective it is important to deal with heterogeneity not only on device or protocol level, but also on middleware level. We focus our discussion on the future infrastructure in the retail store that is aimed at integrating mobile and stationary devices such as digital signage, electronic shelf labels, or sensor networks. We present a corresponding future shopping scenario that showcases the implications of IoT and mobile technologies in the store and discuss a work-in-progress demonstrator setup to be deployed in a retail-specific living laboratory.

Author Keywords
Retail, Internet of Things, Context Awareness, Mobility

General Terms
Design, Experimentation, Human Factors, Standardization

INTRODUCTION
With the emergence of large scale mobile internet services, the proliferation of barcode and NFC reading capabilities of consumer phones, and the various initiatives aimed at converging domain specific IoT approaches [1] we are on the verge of a new era: Location-centric services in retail stores are being augmented with real-world information from all kinds of different sources. Not only consumers are enabled to use their mobile devices to access information systems provided by the store [2] as well as Internet platforms with product reviews, community ratings, competitive prices, or even context / location aware services that point to other offerings in the physical vicinity of the consumers. The retail stores themselves can also profit by these technological advancements, as some of the physical products might offer product centric services that inform about the product's lifecycle, quality status, maintenance records, or handling rules [3]. Based on the interpretation of the actual status information from the physical environment, pricing or stock management might be optimized for a retailer within specific retail stores. The complexity of the various physical and digital information sources, the users' profiles and situational preferences, impose challenges for an effective context processing to provide value-added services within a retail environment. With this paper, we would like to motivate the potential of context aware real-world services in the retail domain, not only for the consumer, as many existing approaches focus on, but also for the retailer and his store infrastructures.

STATE OF THE ART
IoT technologies in retail are gaining momentum in a similar pace as consumer smartphones are proliferating and becoming increasingly used for consumer shopping support. Consequently, many recent research initiatives center on mobile phone product recommender systems. For instance, [3] discusses how communities of users can easily review products and share recommendations among each other. While this approach has a strong focus on creating ratings via the phone, complementary works such as [4] similarly use mobile phones for recommendations, but focus more on generating ratings based on personal profiles and properties of the products themselves.

As our approach deals more with a retail infrastructure consisting of mobile and stationary devices operated by the retailer, the existing work on ubicomp retail platforms is highly relevant, such as [5] who already address the issues of linking mobile and stationary devices leveraging the capabilities of more powerful information exchange with larger information systems.[6] discusses mobile advertising applications that deliver promotional information to consumers based on their preferences and location, thereby also linking the physical aspects of the retail store and the mobile device the consumer brings to the store. While we acknowledge the existing body of work and its mostly consumer-centered rationale, we position our approach of using mobile and IoT technologies as components of a retailer infrastructure. This is implied in the motivating scenario presented in the next section.

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MOTIVATING SCENARIO

In order to illustrate how context aware IoT services can be utilized for the benefit of both the consumer and the retailer, we briefly discuss a motivating scenario that shows how mobile consumer applications and the store infrastructure can interact. The scenario is derived from a project use case [7] and shows how sensors monitor perishable goods in a store. The sensor infrastructure measures are used for estimating the quality of a rare and expensive form of Chinese orchids. Depending on the luminance, humidity, and temperature of the environment, the estimated future quality of the orchids is determined and prices are reduced, even before a perceivable degradation of quality occurs. By applying this sensor based quality control and combining it with dynamic pricing, it is ensured that the goods are sold before the quality degradation.

The scenario starts with a conscious consumer who has opted in to the store's information systems on her mobile app. This application conveys product information, special offers, couponing, and also allows the store infrastructure to identify her during her physical shopping visits to the store based on Bluetooth communication [9, 10]. Upon entering the store, the mobile application points her to a special offer of non-food items, namely rare and fragile orchids from China. Just as she approaches the shelf with the orchids, she realizes their price going down by 10%. Happy about the price reduction, she picks an orchid and continues shopping.

The realization of the scenario is based on a sensor platform that continuously monitors certain environmental parameters crucial for the quality of the fragile orchids to be in a certain range, so that neither dryness nor inundation, neither warm nor chill, nor non-optimal luminance harms the quality of the orchids. As it is difficult to maintain optimal conditions in a supermarket, the sensors would only send alerts to the Store backend system on severely inappropriate conditions, but the average conditions over time are still measured to calculate the estimated point in time for a perceivable degradation in quality. As the store management focuses on delivering the highest quality possible, prices are reduced already *before* a degradation of quality can be perceived by the consumer. From a business and industry perspective, the scenario demonstrates two important retail related concepts: Dynamic pricing and quality control of perishable goods. Dynamic pricing as a real-time tool for price optimization strategies has always been crucial for profit maximization. In contrast to the state of the art, dynamic pricing in the featured use case is not performed on static information such as best before end dates in the transaction data of the backend Enterprise Resource Planning (ERP) system, but it is based on real time IoT data gathered from a sensor infrastructure. As a significant amount of perishable goods never reach the consumer, but are disposed of before, either in the store or in the supply chain, the utilization of IoT sensors is also an interesting concept to implement quality control of perishables and thus reduce waste and increase profits at the same time.

CONTEXT INTEGRATION PLATFORMS

The retail domain is notorious for its heterogeneous IT infrastructures with many legacy information systems and physical devices. The dawn of mobile consumer phone integration will unlikely improve this situation, as there are already four major phone operating systems out today further adding complexity to an IoT infrastructure. We therefore decided to demonstrate the interoperability of IoT platforms by distributing functionality to two different platforms:

Context Management Framework

The NEC Context Management Framework (CMF) is a platform that simplifies the development of context-aware applications. It supports semantic access both of sensors and actuators and has been applied to many application areas – in particular to pervasive advertising and Digital Signage [9, 10]. For the purpose of the previously described scenario we focus on CMF's capability in managing sensor and context information.

As depicted in Fig. 2 the CMF consists of multiple *Context Agent*s grouped in clusters. The CMF can further be organized in clusters of clusters. Each agent provides access to information stored locally and at connected agents. Agents also enforce policies that define which applications and other agents can access which entity/attribute pairs.

A *Context Agent* offers information to applications from any of the following three sources: sensors accessed by *retrievers*, persistent context available from the *storage component* and *processing units*.

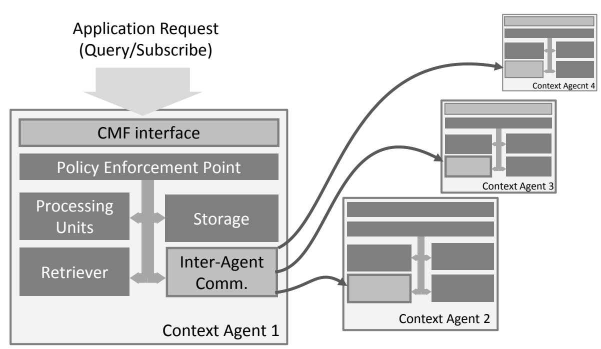

Fig. 2: High level architecture of the Context Management Framework consisting of coordinating Context Agents

Applications typically access the CMF using the *CMF Interface* on a local Context Agent, i.e. an agent deployed on the same computing node as the application. The CMF Interface offers access via a declarative *Context Access Language* (CALA) that operates on entity/attribute based data structure. Entity/attribute pairs model real world objects like orchids, shelves, the retail store and their properties. CALA supports query, subscribe, insert, delete, and update operations that are executed on a cluster of

Context Agents. Thus applications can access information in a fully declarative way and do not need to address individual agents directly. They are able to use a unified interface to access information generated by any sensor.

The CMF is OSGi based [11] and runs on most devices that support a Java virtual machine, ranging from regular computers to embedded PCs – as used in professional Digital Signage displays – to Windows Mobile and Android mobile phones, home gateways and set top boxes. The programming interface is based on XML-RPC, and its main concepts are currently being standardized as part of the Context API in the Open Mobile Alliance (OMA) Next Generation Service Interface (NGSI) [12].

Real World Integration Platform

The corresponding second middleware that we utilize for the realization of the scenario is SAP's "Real World Integration Platform" [8] which is an OSGi [11] based framework like CMF that facilitates the development of applications integrating real-world entities. Generally, this integration is performed by agents, which are specifically designed for each entity type. Furthermore, an agent can implement certain programming logic, not integrating any real world entities at all.

The overall architecture of the middleware is depicted in Figure 3. The Site Manager is used at design time for configuring the participating nodes and the distribution of the needed agents to these nodes. Additionally, the configuration of the agents itself is done in the Site Manager. All configuration data and agent code is stored in a central repository referred to as *Central Instance*.

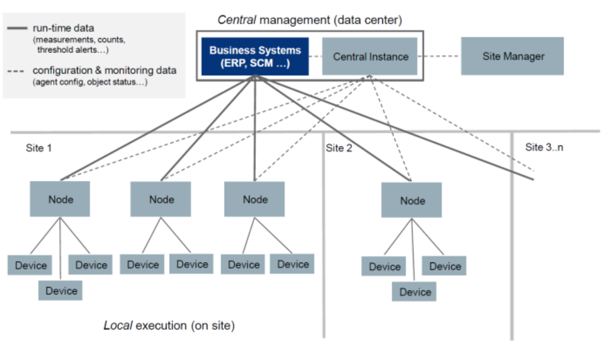

Fig. 3: Real World Integration Platform

At run time the nodes load the agents and their configurations from the *Central Instance* and execute them. In order to reach a common goal, the agents communicate via messages, which are defined within them. These messages can be handled synchronously or asynchronously by the agents, constituting request-response-protocols or event-based communication.

Integration

On implementation level both platforms are comparable as they utilize a lightweight component-based OSGi approach for representing IoT devices such as sensors or actuators. The RWIP has a stronger focus on static, design-time system configuration through the Site Manager and the *Central Instance*, allowing e.g. the modeling and central monitoring of different retail stores with individual nodes representing different stores. Through the declarative CALA interface the CMF decouples applications from sensors and actuators. It is therefore more appropriate for integrating highly dynamic IoT entities such as mobile phones that are not predefined in a static system configuration that RWIP offers. Consequently, within the realization of the demonstrator, for certain parts such as the identification of consumers via their mobile phones CMF is used [9, 10], whereas parts of the statically available store infrastructure such as the radio-controlled Electronic Shelf Labels are integrated with RWIP agents.

DEMONSTRATOR SETUP

As Figure 4 shows, the two middleware platforms are used to reflect different parts of the scenario's functionality. In general, the CMF is more concerned with sensing context information such as the identification of the user and the interpretation and abstraction of temperature information via dedicated physical sensors. A *Price Processor* component in the CMF utilizes the sensor information to realize the dynamic pricing of the product, conveying the price back to the CMF and making it available for querying to external parties such as a dedicated RWIP agent. For demonstration purposes a digital signage display is controlled by the CMF as an actuator that explains the rationale of the dynamic, quality based pricing of the orchid.

The Display Application is utilized to show unpersonalized advertisement and product information in a default mode and personalized, targeted advertisement, whenever a user (identified via the Bluetooth signal of his mobile phone) comes near. Additionally, by using an RFID reader in conjunction with tagged products) specific product information can be shown on the public display, when the product is placed on the reader.

On the RWIP side, the demonstrator comprises four agents: The CMF Bridge Agent, the Groovy Logic Agent, the Image Generator Agent, and the ESL ZBD Agent. The CMF Bridge Agent is especially designed for the cooperation with the CMF. It queries the CMF via its XML RPC interface for entity/attribute pairs which can be set in the agent configuration. An RWIP event is triggered on every change of the attribute. The Groovy Logic Agent can be configured to execute arbitrary scripts, written in the groovy language. These scripts can react to specified RWIP events or participate in request-response communication. The Image Generator Agent is designed to generate images dynamically. The configuration is done via XML files, which define the layout of the desired images. Each section in this layout can be configured to contain text or an embedded image. The ESL ZBD Agent integrates the

Bounce Application from ZBD [13] with the RWIP. It thereby provides the possibility to add and remove Electronic Shelf Labels (ESL) and update the content they are showing. In the demonstrator setup, a groovy script is executed on receiving a price change event. It requests an image with the new price from the Image Generator Agent and calls the ESL ZBD Agent to display it on the Shelf Labels

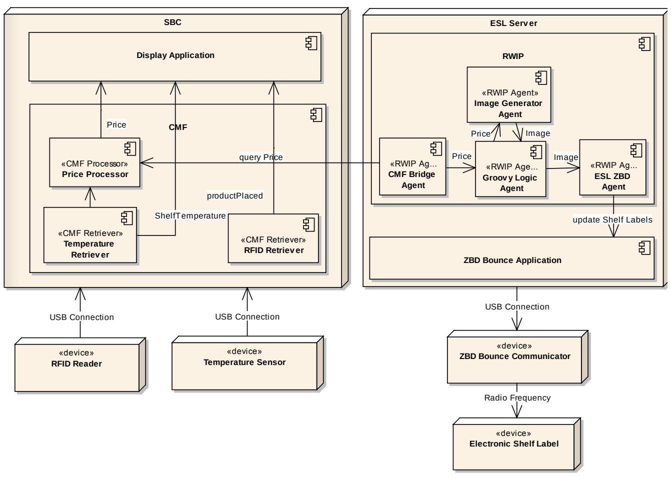

Fig. 4: Demonstrator Setup

The demonstrator setup shows how different mobile and stationary artifacts in a retail store can be integrated in order to provide context-aware services for the retailer. As the infrastructure is governed and controlled by the retailer, further information systems such as an ERP system can potentially be integrated as well, although the current state of the implementation does not yet provide backend integration.

The demonstrator will be shown at the IoT-Week event [14] before the MIRE workshop, so that we expect to provide our experiences with the live demonstration at IoT-Week and also discuss some feedback from the participants and future potential of IoT and mobile integration in retail.

CONCLUSIONS

With this paper we have discussed our current work in progress about using IoT and mobile technologies within a retailer's store infrastructure to realize value added services such as dynamic pricing based on product quality. While the demonstrator discussed in this paper is only a first step for making use of real-world context in retail, we believe that there are plenty more scenarios that can benefit from a more conscientious retail infrastructure such as targeted advertisement, queue control, or improved workforce distribution in the stores. We will continue to let our platforms evolve and converge in order to simplify the complex processes of real-world integration, thus facilitating the realization of future scenarios.

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