Impact of Pervasive Computing on Service Design in Hospitality

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***Abstract*—The economies of developed countries have significantly transformed from manufacturing based to service based, where the hospitality industry plays an important role. Within this context, new service design and service innovation are vital for maintaining competitive advantage. Recently, pervasive computing has emerged as a key enabler in various industries in support of service innovation by facilitating the design of new services. This study aims to investigate the benefits provided by pervasive computing in the hospitality domain for improved customer satisfaction, profitability, and operational efficiencies. First, an overview of pervasive technologies is presented. When reviewing existing applications in the hospitality domain, it is observed that most of the pervasive applications currently found in the hospitality market are primarily focused on the RFID technology, and managed by disconnected systems. Our aim is to propose an integrated pervasive computing framework supporting innovative services incorporating pervasive technologies for the hotel industry, and not being limited to RFID applications. Via the analysis of the framework, changes in business processes are exposed, and improvements obtained through the collected data on the framework integrated with the enterprise systems are discussed.**

***Index Terms*—hospitality, pervasive computing, service design, service innovation**

I. Introduction

Based on the nominal GDP (Gross Domestic Product) sector composition of 2010 [1], it is observed that in the developed countries like UK, USA, EU, and Japan, service sector has the highest contribution to the economies, by around 80%. Most developed countries' economies are dominated by the service sector as a result of its continuous expansion [2]. These economies are significantly transformed from manufacturing-based into service-based [3]. Progress in the tourism and hospitality sector is a key issue in this transformation. Many similar and easily substitutable services in the hospitality market result in higher customer expectation and increased competition. One of the main differentiation strategies is offering more innovative alternatives by integrating novel functionalities into the service. *Service innovation* is defined as introducing radical changes and developing new designs, procedures, methods and service concepts [4]. There are many examples proving how service innovation provides differentiation in the market and keeping up pace with the rapid changes in information and communication technology in the hospitality domain.

As one dimension of information and communication technology, pervasive computing aims to create human-centered environments saturated with computing and communication, and to increase the quality of life. The vision introduced by Mark Weiser in 1990s [3] is becoming a reality as a result of recent developments in technology, and pervasive computing is being utilized in various industries for introducing new services within the context of service innovation.

The purpose of this study is to introduce an integrated pervasive computing framework enabling innovative services for the hospitality sector. It provides data collection, analysis, and sharing capabilities to be used as part of the three main enterprise systems: Customer Relationship Management (CRM), Enterprise resource planning (ERP), and Supply Chain Management (SCM), which in turn results in increases in employee efficiency, profit, and customer satisfaction.

In Section 2, we provide an overview of pervasive computing. Section 3 highlights existing pervasive computing applications in the hospitality industry. We propose a pervasive computing framework and associated innovative services for the hotel industry in Section 4. The benefits provided by this framework are discussed in Section 5, and the conclusion is given in Section 6.

II. Pervasive Computing

Mark Weiser [3] coined the term "Ubiquitous Computing" in order to describe fundamentally the same position with the term "pervasive computing" as making many computing instruments, devices, resources and technologies available throughout the physical environment and making them structured, thoughtful and invisible to users. The idea of weaving computers seamlessly into the physical environments provides embedded computation everywhere while these technologies are vanishing into the background. As a result, people do not have to focus on the computer itself and carry out their work with the assistance of such a computing infrastructure. Weiser envisions a world full of connected computers in the form of tabs, pads and

Manuscript received January 20, 2013; revised March 21, 2013.

doi: 10.12720/joams.1.2.241-245

boards, cheap wireless networks and information accessible everywhere for serving much functionality in and out of the room.

When he wrote the article, this was a vision too far ahead of its implementation time. In the later decades, significant improvements regarding hardware, sensors, wireless communications, and global networking developments have had major impact on materializing Weiser's vision toward technical and economic viability. Such developments include fiber optics for data transmission providing nearly limitless bandwidth, human voice controlled systems used for new generation user interfaces, and discoveries on image processing. Similarly, improvements regarding wireless networking and cloud computing technologies facilitate flexible collaboration of connected devices.

Regarding the impact of pervasive computing technologies in the hospitality domain, the available examples are mostly in the form of Radio Frequency Identification (RFID) based deployments; hence integration with other pervasive computing technologies is missing. Oztaysi et al. [5] studies such innovative RFID technologies in hospitality, but is limited in scope regarding other important components of pervasive computing. In the current study, we intend to extend that work by incorporating those complementary technologies and services designed around them with the goal of providing service innovation through a more integrated pervasive computing framework for the hotel industry. The descriptions of these components together with the services they enable are provided in the next section.

III. The Proposed Pervasive Computing Framework

Our main objective in designing the proposed framework is to address automation issues related to pervasive computing systems within a multimodal and multimedia environment. We intend to automate services and application selection according to user and hardware profiles, and optimally configure them automatically, when possible.

The customer uses mobile devices such as smart-phones, tablets, or kiosks in the hotel, whereas the hotel-staff use hand-held devices given by the hotel for accessing the system. Components of the introduced framework (Fig. 1) are users (hotel customers and staff), device access manager, privacy manager, task manager, performance manager, information manager, services manager, application manager, server, profile manager and databases for tasks, services, and profiles.

A. Access Device Manager

The Access Device Manager (ADM) resides on devices that the users utilize to access the pervasive system. Access Device stands for devices such as smart phones, personal digital assistants (PDA), kiosks, and desktop computers. It manages a set of software agents: Notification Agent, Session Agent and Service Agent. The Notification Agent manages announcements sent to and received by the current user of the device. The Session Agent manages the user activities during the session. The Service Agent manages components needed to provide services to the current user's device. The utilized components are stored in a local cache, and provided on demand to the Session agent.

B. Security and Privacy Manager

The Security and Privacy Manager (SPM) uses pre-defined security policies based on user profiles for preventing non-authorized access.

C. Task Manager

This module is responsible for all tasks carried out by the hotel-staff. Based on the information collected from other manager modules, the Task Discovery Agent creates the tasks and assigns them to the corresponding hotel-staff based on their profiles.

D. Services Manager

This module is in charge of services available through the pervasive system. Service components are stored in a database, which the Services Manager will access when looking for a specific service. Upon demand, the Application Manager sends posts to Service Agents located on computing devices such as smart phones, tablets or kiosks, as well as to the Service Handler in the Services Manager module. The Services Manager communicates with the Information Manager, set-top box, and entertainment units in order to provide the service. Services are stored in the database communicating with the enterprise applications in the hotel such as ERP, CRM and SCM.

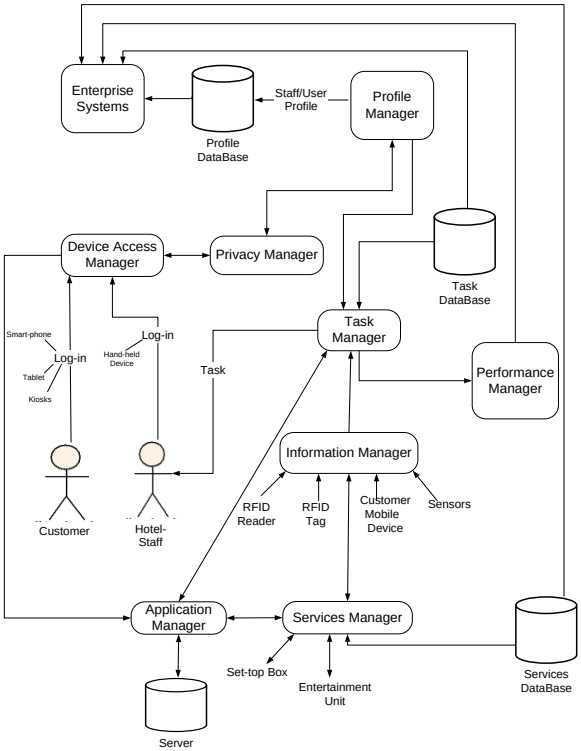

Figure 1. The proposed pervasive computing framework

E. Profile Manager

This module manages the user/hotel staff profiles database. It communicates with the Security and Privacy Manager in order to respond to requests on user profile information. It communicates with the service agent for providing users' preferences needed to adapt the services. Profile databases are communicating with the enterprise applications of the hotel such as CRM.

F. Information Manager

This module handles data received from various sensors and contains algorithms which transcribe the data received from sensors and send this information to the Services Manager.

G. Application Manager

This module manages applications installed on the computing devices with networking capabilities, e.g. smart phone, PDA, kiosks, desktop computer. The Notification Agent manages inputs sent to and received by the current user of the device. It communicates with the Service Manager if the input requires a service and with the server if updating data stored in the databases is necessary.

H. Services Supported by the Framework

We investigate possible applications of this pervasive computing framework in the hospitality industry. Candidate services provided by the proposed framework include self-check-in, concierge, identity recognition, in-room resource access, in-room ambience adjustment, in-room service access, personalization, contactless payment, information access, tracking children via RFID-enabled wristbands, smart waitresses, smart mini-bar, and employee performance management. Before starting to use these services, it is assumed that the user is authenticated, and the necessary profile information is loaded for adapting the services.

Self-Check-in is the process where a customer selects his room on his own through the application installed on his own mobile device or a kiosk in the hotel, which provides functionalities such as self-check-in and customized service interactions by offering different language options for foreign travelers. Similarly, by using the mobile application, *concierge* services are provided in the form of a hotel guide including descriptions of different facilities in the hotel such as spa, pool, fitness room as well as touristic places nearby. Multimedia content is used in order to obtain more comprehensive visualization. Customer requests to use the service through the web browser software installed on his mobile device. The notification agent in the application manager receives the request. For the check-in service, it establishes a connection to the server for updating room availability, and assigning the most appropriate room to the customer for the defined time period. Then, the customer is informed through the web browser.

Identity recognition is the system which identifies the customers and controls their access permissions, such as in the form of keyless room entrance. Each customer can enter his/her own room without using any key. Similar to the use of a smart card, a mobile device with integrated NFC module or infrared/wireless connectivity can be used as the key for a hotel room. The necessary information is loaded onto the mobile device of the customer securely after authorization. In the case of not owning a smart-phone, a smart card can be used for this purpose. The information manager communicates with the application manager through the service manager after receiving inputs from smart mobile devices or RFID readers. A confirmation is sent from the server in the application manager to the smart phone. Thus, upon arriving at the hotel, customers can go directly to their rooms and gain entry using their smart-phones or smart-cards.

In-room resource access is the system that intelligently adjusts comfortable temperature settings based on the outside temperature and personal preferences, as well as turning thermostat down at desired intervals, and the air conditioner off when no one is in the room. The information manager sends information gathered from various sensors located in the room to the service manager, and intelligent software modules in the service manager component provides adjustments of heating, cooling and lighting systems so that they respond appropriately according to the number of occupants in a room at any given time. The application manager provides remote monitoring and control of the room through the customer's mobile device. After receipt of the input from the mobile device browser by the notification agent, communication with the service manager occurs for transforming the request to a service.

In-room ambience adjustment is provided by smart walls which are inherently large displays. They can be turned into a video player or customizable wallpapers. Remote control is provided by the application manager. Mechanism works similar to the remote control function of in-room resource access.

Instead of calling the reception desk, *service access* by automatic voice recognition is used in the hotel for getting information regarding services such as breakfast/lunch time and menus, entertainment activities in the hotel. The information manager provides recognition of the voice commands through the customer mobile device and sends them to the task manager for translating them into corresponding tasks for the hotel-staff and to the services manager for informing the customer through the application manager. Customer is informed by the web browser installed on his mobile device.

Personalization is provided based on the past history of hotel guests regarding TV, climate, mini-bar usage, and consumed services stored in the profile database. After authentication, this information is loaded onto the server managed by the application manager which translates them to related services/tasks, and forwards them to the services and task managers. To illustrate; a created task can be replenishing the mini-bar in the room with preferred drinks of the customer during his stay. A

created service is adjustment of room temperature to preferred levels. As a result, when same guests enter the room next-time, the room environment settings are automatically adjusted, and the mini-bar orders drinks according to their preferences.

For the *smart waitress* service, hotel-staff working in the restaurant uses the software installed on his hand-held device for recommending menu items to the customers. A recommendation engine in the application manager uses customers' past preferences for lunch and dinner selections as well as their demographic information. All of this information is loaded on the server of the application manager, after authentication. All orders that are entered into the handheld devices by waiting staff are transmitted wirelessly to the printers in the kitchen and bar. They are also transmitted to the administrative terminal to log the order on the database. This communication is provided through the wireless access point, which acts as the bridging point between the printers, hand-held device and administrative server.

Contactless payment system is an automation service for in-hotel expenditures of the guests. Every expense is paid via smart phones or similar devices by using NFC technology. Also, in addition to smart phones, smart cards with predefined expense limits can be used by children so that their parents can control their expenses. Information manager receives the input data of user/card id from phones, smart cards, and amount of charge entered by the hotel-staff and transmits to the service manager which is responsible for updating balance in the card and phones corresponding to the user profile according to the charge.

Information access includes augmented reality applications which are used for viewing the hotel environment with virtual computer-generated overlay information in the form of sound and graphics on a mobile device. Notification agent in the application manager takes input from the camera of the phone, and intelligent software in the application manager overlays computer generated pictures in real-time, then sends processed information to the user in real-time, such as displaying the work hour information, and spa services when the user points the camera in the direction of the hotel spa.

Tracking children is performed by using RFID-enabled wristbands. The information manager takes the information regarding the exact location of the children in the hotel from RFID readers located in different places in the hotel and sends the data to the application manager to be seen on the parents' mobile phone or kiosks. Thus, the parents can trace their children through this service.

Smart mini-bars provide fast replenishment in the bar, automatic locking after check-out, and automatic billing. The information manager sends received inputs from sensors in the bar (e.g. data from the RFID reader in the mini-bar which reads RFID tags placed on the bottles) to the services manager for transforming the input into useful information about in-room consumption, corresponding charges and restocking needs, and to the task manager for transforming related information into a task for the hotel-staff, such as ordering of the consumed drinks. Related information stored in service and task databases is used for the SCM system.

Employee performance management is used to create measurable parameters for managing employees' performance. The information manager captures service time and waiting time in the queues through real-time information retrieved from deployed sensors and the software installed in the hand-held devices used by the hotel-staff and transforms them into related information for the performance manager through the task manager. To illustrate, this system can be used in the restaurant of the hotel. A waitress uses her hand-held device for entering ordering and service times. Sensors are used to measure the number of people and waiting time of a guest in the line. The information manager sends the information to the performance manager over the task manager in order to transform it into performance information to be used within the human resource module of the ERP system in the hotel.

IV. Benefits of the Proposed Framework

These systems provide increased customer satisfaction, customer loyalty, and employee efficiency, as well as decreased costs for inventory, labor, and energy consumption. As a result, the business revenue increases, and competitive advantage and brand differentiation are achieved.

Customer satisfaction is the key issue in the hospitality industry, and is increased by reducing waiting times in the queues with the deployment of the employee performance management service, by helping find information about locations in the hotel by using the augmented reality applications as part of the information access service, and by providing all preferred drinks in the smart mini-bar. In addition, personalization is achieved by capturing user preferences for the room environment (e.g. light, temperature), TV, and mini-bar usage results so that when the same guests enter the room next-time, the room environment is adjusted automatically, and the mini-bar is filled with drinks they prefer. Menu options are recommended based on the guests' past preferences, as well. These collected preferences are used in the hotel CRM system for customer segmentation in order to offer highly demanded packets, and inform customers about packets they prefer. These data are used for service innovation as well, which results in brand differentiation, competitive advantage, and loyalty.

The in-room resource access service reduces energy expenses of the building. The employee performance management and the smart-waitress service increase efficiency of the employees, and decrease labor cost. The self check-in service eliminates the process carried out by the receptionist. Thus, workload on the employees and labor costs are reduced. The smart mini-bars send messages for restocking to the hand-held devices of the employees, so that they don't have to physically enter every room. This reduces labor cost, as well. Smart mini-bars reduce inventory levels of the drinks based on actual

consumption, and trigger automatic ordering. Thus, inventory cost of the drinks is reduced.

V. Conclusion

Developers bring many innovative products in the domain of pervasive computing after its introduction in the 1990s. Pervasive technologies are still in the early-adoption stage in their product life cycle, and have not reached their maturity levels, yet. However, many enterprises have noticed the importance of these technologies because of their benefits. Therefore, the idea of using pervasive computing technologies in an integrated system in the hospitality domain brings many innovations as explained in this study. The proposed pervasive computing framework for the hotels provides reduced labor and inventory costs, as well as increased revenues, customer satisfaction, and operational efficiency.

Data collected within this framework are used as part of the three main enterprise systems; one of them is CRM, collected data is transformed into meaningful information in CRM in order to provide brand differentiation, competitive advantage and loyalty. For instance; customers' profile information is used for appropriate customer segmentation, and offering different campaigns based on this information helps increase the number of customers, and the revenue of the hotel. Using data captured in the personalization service provides customer satisfaction and loyalty.

Data such as real-time consumption, replenishment time, real-time stock levels are collectable through the integrated framework. The SCM system transforms these data into meaningful information in order to help reduce inventory costs.

The last enterprise system using the data gathered through the integrated framework is ERP, where captured data such as service time and waiting time in the queues are used for improving operational efficiency and hotel-staff performance in the ERP system.

Providing secure wireless connectivity between mobile devices and application manager is one obstacle of the proposed framework. Additionally, privacy and ethics related issues are another obstacle. These should be taken into consideration as part of the implementation of these systems.

For future studies, cost-benefit analysis of the proposed framework should be performed in order to assess the feasibility of deploying these technologies.

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