IoT applications in Smart Hotels

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Abstract: - With the rapid development of the Internet of Things (IoT), new applications and research related to IoT are booming. Smart homes, smart cities, smart agriculture and smart world are becoming a reality with an increasing number of services and new devices being available every day. The hotel industry has realized the potential impact of the IoT research, with many hotel chains conducting research in IoT to implement their proprietary solutions. The application of IoT in the hotel industry focuses on providing the guests with personalized services to improve the guest's experience.
One of the major challenges that faces IoT applications in the hotel industry is the respect of the guest's privacy. In fact, guests are not willing to provide the hotels with information to customize IoT applications that could potentially expose private information of the guest's habits and relationships with other guests.

This paper describes a new IoT architecture that uses intelligent agents and fuzzy rules to customize the IoT services without exposing the private information of the guest. This IoT architecture provides an inexpensive mean to implement IoT in the hotel industry to build advanced services, thus improving the guest's satisfaction and retention rates.

Keywords: - Internet of Things; Smart Hotel; Fuzzy logic; Multi-Agents; AI.

1 Introduction

Since the emergence of the concept of the Internet of Things (IoT), more devices are being connected to the Internet. These devices can sense environment, share information and execute requests. IoT is becoming available in people's daily life [1-2] and is making their life more comfortable [3].

The number of things connected to the Internet is increasing every day. Gartner [4] back in 2013, has predicted that the revenue of IoT will exceed 300 billion $ by 2020. Iot-analytics [5] has stated that the number of connected IoT devices in 2018 has reached 7 billion and it is expected to grow to 21.5 billion by 2025. The revenue of the global IoT Market was $151 Billion in 2018 and it is forecasted to grow to $1,567 Billion by 2025.

IoT has attracted a lot of research due to the potential revenue of IoT. It has been used in an increasing number of new applications that make use of the enormous amount of data generated by such devices and their potential interoperability to provide new services to citizens, companies, and public administrations [2].

In this paper, we propose an architecture that uses multi-agents and IoT devices to build more sophisticated services on top of IoT in hotels. These services are adapted to the guest's preference while maintaining the privacy of the guest's habits, parameters and custom rules.

The rest of the paper is organized as follows: Section 2 provides an overview on the related works. The system architecture is presented in section 3 followed by the conclusion in section 4.

2 Related Work

The term IoT was first used by Kelvin Ashton in 1999 [6]. IoT provides connectivity to IoT devices to authorized users from any place [7-8]. The concept of IoT can be realized by having a wide variety of technologies around us such as RFID, sensors, engines, mobile phones, middleware and computing cloud [9]. IPv6 is often used with IoT devices due to the large address space of IPv6 versus that of IPv4 [10]. IoT has been adopted in different areas and applications such as smart cities, smart agriculture, smart healthcare, smart manufacturing, and others [11].

Smart cities [12-13] is a new approach for managing the complexities and challenges growing cities are facing and for providing better services for its citizens [14]. The main objective of a smart city is connecting the physical infrastructure, the ICT infrastructure, the social infrastructure and the business infrastructure [15]. A smart city uses components like smart phones, networks and sensors to connect citizens, to provide them with better use of public resources, to increase efficiency, to improve the quality of services offered to the citizens and to reduce the operational expenses for the public administrations [16 - 17]. Smart cities has many applications such as smart transport, smart energy, smart health, ambient-assisted living, crime prevention and community safety, governance, condition monitoring and maintenance of infrastructure, disaster management and emergency, smart homes and smart tourism [18].

Tourism and travel is one of the world's largest industries with a global economic contribution of over 7.6 trillion U.S. dollars in 2016 [19]. The hotel industry is the cornerstone of tourism. Hotels provide their guests food and beverage services as well as other different recreation, relaxation and leisure programs [20]. Competition between hotels is becoming more intensified every day. The major challenge that is facing hotels' operators is to find means to retain regular customers while attracting new ones [21-22].

The authors in [23-24] concluded that guests' privacy is one of the major concerns of guests. Guests' privacy in this context refers to protecting them from an unauthorized intrusion of information such as the guests' locations, their environment, their preferences, their relations with other guests and the activities they are performing.

The author in [25] focused on the problem of privacy versus intelligence in intelligent systems. In fact, there is often a trade-off between the customers' right to protect their privacy and the data that must be collected about the customers to be able to customize the functions of the system to make it "smart" and adapted to the customers' needs.

Applying IoT to smart hotels has recently been attracting a lot attention [26] with the announcing of Hilton in 2017 that it has been working on a proprietary IoT solution and a similar announcement by Marriott [27]. Moreover, companies have started to offer IoT based solution to the hotel industry, such as Interact-lighting [28], which has recently offered an IoT based solution to manage the lighting of hotels to save cost and to adapt it to the guests' preferences.

The research in [20] examines the tourism demand readiness to accept the use of new technologies in tourism. They have conducted surveys, randomly sampling 106 hotel guests in the city of Zadar. The result of the survey has proven that young highly educated guests are more inclined to adopt new technologies.

The authors in [29] purposed a three-layer architecture that is intended to be used in smart hotels' environment. The top layer is the central server responsible for handles data from the middle layer which hosts the subsystems. The top layer might be running on the physical hardware present inside the hotel or it may be hosted on a cloud service connected to the hotels via low latency high-speed Internet connection. The primary objective of subsystems is to read sensory data from the lowest layers which host the modules. The authors described scenarios in smart hotels during the three phases of the guest's stay in a smart hotel: that is, arrival, stay, and checkout. All of the scenarios that were described are able to be implemented today with the existing portfolio available on the market. For maintain the privacy of the guest, the system contains the possibility to turn off the non-critical server communication in case some of the guests do not want the data about their stay to be recorded and analyzed.

The authors in [30] presented one of the applications of smart hotels called Intelligent Hotel Room (iHR). This application delivers "intelligent" and personalized services to the guests by monitoring their activities, locations and the smart objects within their rooms. The iHR provides guest with the ability to control electronic appliance via a Universal Remote, to use an intelligent laundry hanger for automatically requesting the laundry service and an intelligent touch panel for requesting the room cleaning service or room service. The application monitors the environment and the guest's actions to extrapolate potential habits, adapt the room's behavior and to store the collected data.

The iHR provides an interesting framework but may be considered an invasion on the privacy of the guests.

The author in [31] presented a system called Android Robot Controller (ARC). The ACR is a bare-bones network-based robot control system that works on mobiles, wearables and full-fledged computers. In addition to controlling robots, the ARC system could be used as a replacement for the room's access key through the use of the NFC technology that is available in the guest's smart phone. The paper also suggests collecting data about the guest, such as the guest's heart rate, to provide him/her with lighting and music that would encourage him/her to continue playing at casinos. The paper also suggests using a wearable device to measure the temperature in the area surrounding the guest and to adjust the air conditioner accordingly to keep the temperature within the limits of the guest's preference. These application ideas may be interesting, but some of them are a clear invasion of privacy that the customers will not accept.

3 System Overview

The main goal of this research is to provide the guests with more sophisticated services based on the IoT devices available in the hotel. In this paper, we will discuss two such services: extending room access to friends and building a customized wakeup service.

To be able to implement these services without disclosing the guest's private information, such as his/her preferences and his/her relationship with other guests, the use of a multi-agent architecture was chosen. In fact, the system starts by authenticating the guest and it retrieves the ids and the information about the IoT devices that are available in the guest's room. The guest will use her/his smart phone to retrieve this information. A smart agent acting on behalf of the guest will run on the guest's smart phone and will negotiate with the smart agents representing the IoT devices to adapt them to the preferences and rules of the guest. This is done without disclosing the rules, preferences and relations stored on the guest's smart phone. An overview of the system is presented in Fig1.

Each guest will have a smart agent acting on the guest's behalf, which is called the Guest's Smart Agent (GSA). The GSA will run on the guest's smart phone and can be customized by the guest. The guest defines her/his relationship with other guests in the hotel using the application shown in Figure 2. The guest defines the type of relationship with the other guests (family member, friend or acquaintance) and their closeness to him/her. The closeness is a fuzzy concept that will be fuzzified and used in the fuzzy rules controlling the GSA. For example, the user may define a rule (RULE1) stating that if the relationship-type with another guest is a friend and that the closeness is high and the room-status is empty then allow access to this guest. Such a rule will provide close friends with the ability to enter the guest's room when they are not in the room using the NFC capability of the friend's mobile phone.

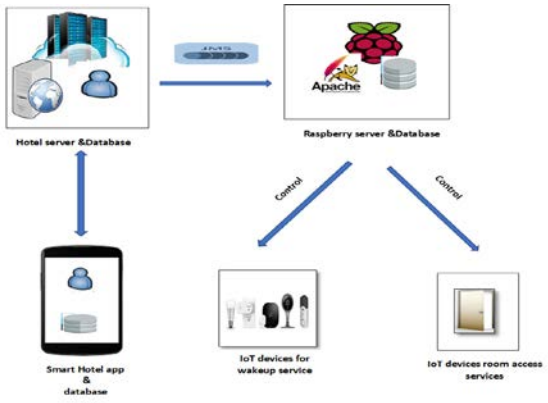

Figure 1: System Overview

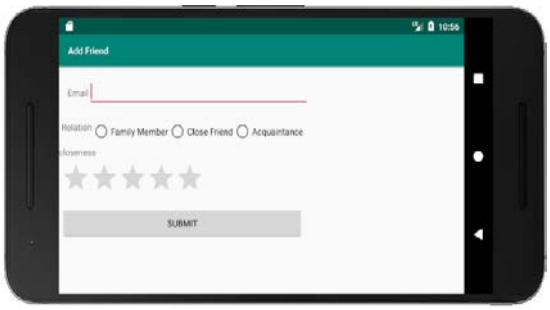

Figure 2: Defining the guest's relationship with other guests

The guest also defines his/her schedule as shown in Figure 3. The guest states the date of the activity, the start time, the end time, whether this activity is in the room or outside, the importance of the activity and the privacy of the activity. The user can define another rule (RULE2) stating that if the relationship-type with another guest is family-member and that the closeness is medium or high and the room-status is occupied and the guest-privacy is medium or low then allow access to this

user. This rule means that if the guest is in the room and that his/her current privacy level is medium or low, which is a fuzzy parameter indicating the level of privacy of the activity the guest is currently performing, and that a family member whose closeness to the guest is at least medium, then the room will grant him/her access.

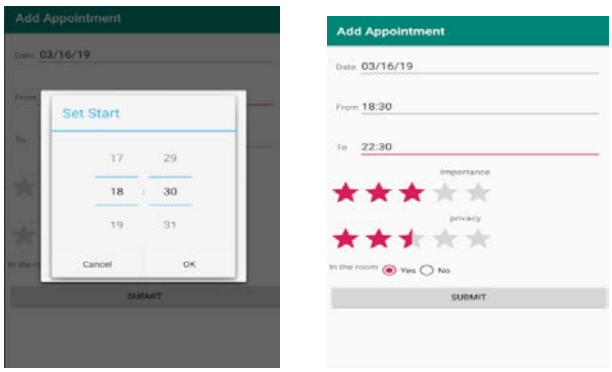

Figure 3: Setting Schedule

When the user defines a new activity, the GSA will use the set of fuzzy rules to determine the list of guests that will be accorded access to the room during this time, if any. The GSA will send the list to the hotel backend. This information will be propagated to the Raspberry Pi device that controls the room using Java Messaging Service (JMS); The Raspberry Pi will accord access to the other guests to the room accordingly. For example, when the guests indicate that he/she will be out of the room in the evening from 4 to 8 PM, this information will be used in conjunction with RULE1 to grant all close friends of the guest access to the room during this duration. The hotel server will not be informed about the type of relationship between the two guests or whether the room is empty or occupied. The hotel will only be informed that the guests may access the room from 4 to 8 PM, thus respecting the privacy of the guests.

If the guest requires to be woken up at a specific time, the GSA will communicate with the hotel server to get the list of IoT devices available in the guest's room that may contribute to the process of waking-up the guest. The hotel server will communicate to the GSA the ids of these IoT devices, their description and the level of contribution to the waking-up process. The level of contribution to the waking-up process is a fuzzy parameter that reflects the effectiveness of using this device to wake up the guest. For example, an alarm clock will have a higher level of contribution then a music player. The devices that could contribute to the waking-up process may include devices such as an electric curtain, a music player and a light switch.

Depending on the guest's preference, the GSA may send instructions to these IoT devices through the hotel servers to open the curtains, to play music with a low voice and to open the light with low intensity half an hour before the wakeup time of the guest. The GSA will send instruction to increase the music level and the light intensity periodically. If the guest confirms through his/her smart phone that he/she is awake, further instruction to the devices used in the wakeup process not be executed. If the guest doesn't confirm that he/she are awake till the wakeup time, only then the alarm will ring. This means that guest will probably be awaken slowly using music and light instead of being awaked on the annoying buzz of the alarm. This is an example of how the mix of artificial intelligence and IoT can allow the hotel to build new sophisticated services that were not available before.

To control the IoT devices of the hotel, the guest's GSA will send instructions to the hotel's server indicating the device id, the start time and the intensity chosen if the device provides an intensity control. The hotel's server will send this information to a Raspberry Pi that controls this IoT device. The Raspberry Pi will authenticate the agent representing the hotel and will store these instructions on a MySql running on the Raspberry. A java application continuously running on the Raspberry will send the corresponding instructions to the IoT device when the time of the event occurs.

4 Conclusion

In this paper, we presented a framework that could be used by hotels to implement the concept of smart hotels. This framework allows the hotels to offer sophisticated services to their guests while respecting the guest's privacy. We presented two examples of how sophisticated services could be offered through the integration of smart agents and IoT devices. The first service allows the guest to provide access to other guests in the hotel to his/her room depending on their relationships with the guest and the guest's schedule. The second service enables the guest to be awakened gradually using music and light instead of the annoying buzz of an alarm clock.

This research is also an example of how the integrating between AI and IoT technologies could provide customers with a better quality of service, thus increasing the customers' satisfaction and increasing the rate of returning customers.

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