IOT BASED SMART RESTAURANT SYSTEM USING RFID

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Abstract

Technologies of identification by radio frequencies (RFID) contribute in many IOT application scenarios, such as healthcare systems and smart retails. This paper proposes a system for smart restaurant. In a four layered architecture the RFID technology is used to handle the order delivery activity. The protocol used is the hypertext transfer protocol (HTTP) and the application service relies on a representational state transfer (REST) web service. This system has been demonstrated to be realizable by some simulation using the Raspberry pi board and the ITEAD PN532 NFC module.

1 Introduction

With the explosion of internet based services, it has become easy to build and exploit information's platforms for numerous purposes; now, the internet is extending to physical object with embedded electronics, making them smart. This phenomenon is called "IOT (The internet of Things)". The achievement of this extension involves the extension of supporting technologies and concepts such as RFID (Radio Frequency Identity), sensors, etc. The RFID technology, being one of the most important enabling technologies in IOT, supports a lot of convenient applications such as supply chain management [1], health care[2, 3, 4, 5], smart retails, smart house, smart hospital [6, 7], object localisation [8, 9], security systems. Those examples don't restrict the possible applications where it can be applied [10, 11, 12]. The RFID technology can also be used to support numerous applications in the smart city's scenario [13]. This paper is a proposal of system for smart restaurant based on IOT paradigm and using the RFID Technology. In section 2, we define a scenario and the different components of the system, and explain the system's architecture. Then in section 3, we discuss the technologies supporting the proposed solution. Further in section 4, we show the setup used to experiment the proposed system and also reveal the results obtains from some simulations.

2 Methodology

The proposal made in his paper stands on the following scenario:

2.1 Scenario

A customer comes in the restaurant and seats at a table. The table offers him a board through which he can browse the menu of the restaurant. The customer selects his dishes and submits his order which is wirelessly routed to the kitchen for procession. The kitchen team treats the order and the waitresses carry the order to the customer's table. As soon as the order is brought to the customer's table, the delivery of the order is notified in the system.

2.2 System components

Out of the scenario defined previously, we distinguish the following components:

2.3 Plate

The plates are used for the order delivery service. The unordinary thing is that they are incrusted with RFID chip, thus have an identity registered in the system through which they can be tracked.

2.4 Smart table

The smart table consists of a table equipped with an embedded Wi-Fi enabled touchscreen board with an RFID reader. The on-board software allows the user to browse the menu, submit an order, follow the process, and eventually pay. The RFID reader is for the purpose of identifying plates (orders) and notifying delivery. Another feature that could be added would be the ability to sense customer's presence. But for this work, we restrict the features to the order submission and the delivery notification.

2.5 Order monitor

The order monitor would be a large screen showing a dashboard on which the currents orders are displayed. Some extended features would be the display of the measurement of the staff productivity performance.

2.6 Delivery assignment machine

This machine is in charge of the assignment of plates for delivery; it would consist of a conveyor, an electronic board and a RFID reader. The board provides embedded software allowing the selection of the order to be delivered with a specific plate placed on the conveyer. In other words, it is the mean through which the system knows which given plate is carrying which given order or order item. And since one order is related to one specific table, it makes the table to be able to reject or accept a delivery accordingly. Figure 1 gives an illustration of this machine.

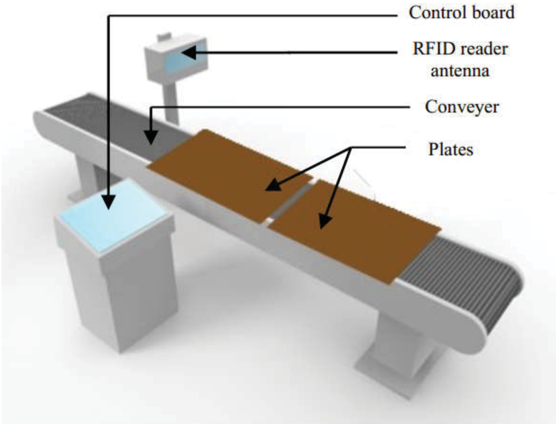

Figure 1: Illustration of the delivery assignment machine.

2.7 Application server

The application server (middleware) is the core component of the system. It consists in a Server machine running a RESTful Web service managing the data produced and exchanged by the other components of the system. Data are sent to and queried from it.

2.8 System architecture

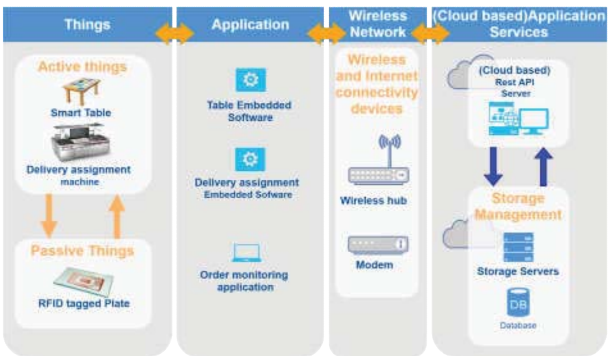

Figure 2: Description of the system's 4 layered architecture.

Figure 2 shows a four layered architecture and the way they interact with each other.
The things layer contains 2 groups of things. One is the group of active things, i.e. devices able to sense other things and collect data, while the second group categorizes things that are not able to produce data. The active things sense the inactive ones then produce data. e.g.: The smart table, would sense a plate used to carry one order.
In the application layer, we find programs that control the active things as well as programs exploiting the collected information.
The network type used is a Wireless Local Area Network (WLAN). It is the medium by which the data are conveyed to and from the middleware.

The application service layer regards the application supporting the system. It can be cloud-based. The type of application proposed is a RESTful web service because it offers more flexibility to interact with operational databases, which is a main component in business support software. This thus implies taking in account the weaknesses and the possible attacks in HTTP (Hypertext Transfer Protocol). It is clear that choosing a dedicated IOT protocol like MQTT (Message Queue Telemetry Transport) would improve the speed of information transfer and reduce the workload of the devices since it is a fast, lightweight and asynchronous protocol as compared to HTTP. However, it would still require in this case building a separated application server subscribing to relevant topics and also intelligently publishing some messages: which would be complex thus difficult to manage and maintain in this system.

2.9 Explanation of the system's operation

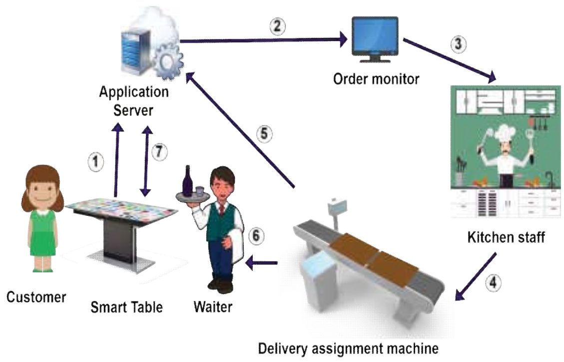

Figure 3: Illustration of the system's operation.

As shown in figure 3, the system's operates in 7 steps.
In the step 1, a given customer accesses the dishes menu through the embedded software of the smart table and emits his order; the order is sent to and register in the application server. After the order has been registered, it is then displayed on the order monitor; step 2. In the step 3, the members of the kitchen staff get the order information from the monitor and process it. The ordered dishes are then sent to the delivery officers when ready; step 4. Then in step 5 and 6, the delivery officers choose a plate to deliver the dishes. The chosen plate's RFID tag id is read by the delivery assignment machine and the officers, using the on-board software, identify the order and assign a delivery with that specific plate. This information is sent to the application server and the order is delivered to the due table by the waiters. Finally, when the plate is brought at the customer's table, the table reads plate's RFID tag id and initiate a lookup request to the application server.

```
Algorithm 1      : Delivery confirmation algorithm
Input            : plate_tag_id /*Plate's Tag ID*/
                   table_id /*Table unique id*/
1       del = SELECT * from Deliveries D
            WHERE D.plate_id = plate_tag_id AND
2       D.delivered = false
3       IF del NOT NULL THEN
            order = SELECT * FROM Orders O
4                   WHERE O.table_id = table_id AND
5       O.id = del.order_id
6           IF order NOT NULL THEN
7                   Confirm Delivery for order
8               ELSE
                    Reject delivery
            END IF.
9           ELSE
10                  Reject delivery.
11      END IF.
```

Figure 4: Algorithm of the delivery confirmation process.

The look up process is described in the algorithm shown in figure 4. In line 1, the application server tries to find a not yet delivered delivery assigned with the plate and reject the delivery if it doesn't find one. But if the delivery record is found, it then tries in line 3 to find an order matching with both the table and the delivery to confirm it, otherwise it is rejected. Practically, this lookup can be achieved by only one query with the order id, and the plate id as parameters.
The technologies that mainly contribute in the system we propose in response to the defined scenario are the RFID technology and the IOT prototyping boards.

2.10 RFID

The RFID technology is a strategic enabling component in this system. A passive RFID system is composed of a digital device called tag, embedding an antenna and an IC-chip with unique identification code (ID), and a radio scanner device, called reader [14]. The tags are commonly used to give an identity to objects or persons. The tags are categorized in battery-less tags and self-powered tags and operate in different frequency band. For this system, we focus on RFID battery-less tags (i.e. RFID passive tags) operating in the Ultra High Frequency (UHF) band (860–960 MHz). The RFID UHF passive tags have a minimum read distance of over 1 meter; which can be advantage depending on the way it is used or disadvantage considering the possible attacks from malicious entities. The High Frequency (HF) passive RFID Tags operates in 13.56 MHz and have a maximum read distance of 1.5 meters but can be read with a reader of more than 1 Watt RFID output power. Using the RFID HF passive tag could be a better alternative in the sense that in the proposed system, it is not that much required to have the possibility to read tags from very long distances and it would also impose some restriction to the distance from which the tags can be read. An RFID reader, also known as an interrogator, is a device that provides the connection between the tag data and the business system software that needs the information. The reader communicates with tags that are within its operation range. The reader uses an attached antenna to emit signals to the tags and also receive from. It exist many different sizes and types of RFID readers. They can be affixed in a stationary position in a store or factory, or embedded in electronic equipment or devices. To have reader embedded in the device is the solution we opt for regarding the smart stable. For the delivery assignment machine, both solutions can be considered.

2.11 IOT prototyping boards

An important role is played by IOT prototyping boards. These boards simplify the process of prototyping IOT projects. They consist in inexpensive computing hardware boards combining microcontrollers and processors with Ethernet port, wireless chips and other components in a pre-built, ready-to-program package. We do find on the market a variety of size depending on the manufacturers, the computational power as well as the pre-built-in components. The choice of the board is made according to the requirement of the system.

3 Results

In this part of the paper, we expose the methods used to experiment the system that we propose, as well as the results we obtained after doing some simulations.

3.1 Simulation setup

3.2 Hardware

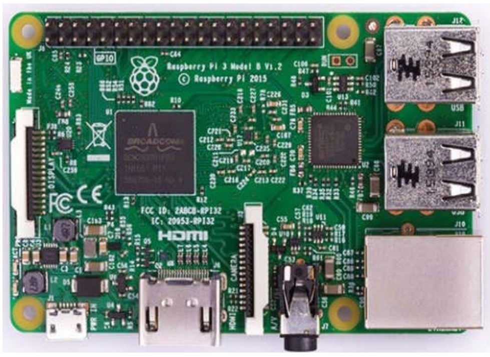

Figure 5: Picture of the Raspberry Pi Board Model 3 B.

Table 1: Specifications of the Raspberry Pi Model 3 B.

CPU	RAM	Accessories
1.2GHz 64-bit quad-core ARMv8	1GB	802.11n Wireless LAN Bluetooth 4.1 Bluetooth Low Energy (BLE) 4 USB ports 40 GPIO pins Full HDMI port Ethernet port Combined 3.5mm audio jack and composite vid-eo Camera interface (CSI) Display interface (DSI) Micro SD card slot VideoCore IV 3D graphics core

The IOT prototyping board we used to simulate this system is the Raspberry Pi 3 model B. The Raspberry Pi is a low-cost, basic computer contained on a single circuit board. The figure 5 and the table 1 show respectively a picture of it and its specifications. For the display, we used the Raspberry Pi 7 inch touchscreen. Attached to it, we used the ITEAD PN532 NFC module, which allowed simulating the RFID reader. As its name implies, the ITEAD PN532 NFC module is based on a PN532 chip and used for 13.56MHz near field communication. It is equipped with an on-board antenna and can be wired-up with the Raspberry board using SPI, IIC or UART communication interface.
So, combining those three elements (the board, the touchscreen and the NFC module), we made 3 units: 1 used to simulate the delivery assignment machine and the 2 others to simulate smart tables.
Then for the plate simulation, we used 20 UHF RFID labels. The application server was simulated using a laptop with a 2.40GHz i7 CPU and 8GB RAM running Windows 10. Another laptop with a 2.13GHz i3 CPU and 4GB of RAM capacity was used to simulate the order monitor.

3.3 Software

We used Raspbian Jessie, an operating system based on Debian Jessie to drive the Raspberry pi board. And since it supports the Java Virtual Machine, the embedded programs were implemented using the javaFX framework for the GUI and the Pi4j java library to interact with the NFC module. The javaFX framework has also been used to implement he order monitoring dashboard. And regarding the application server, we developed a Java Spring based JSON RESTful Web Service working with a MySQL database.

3.4 Network architecture

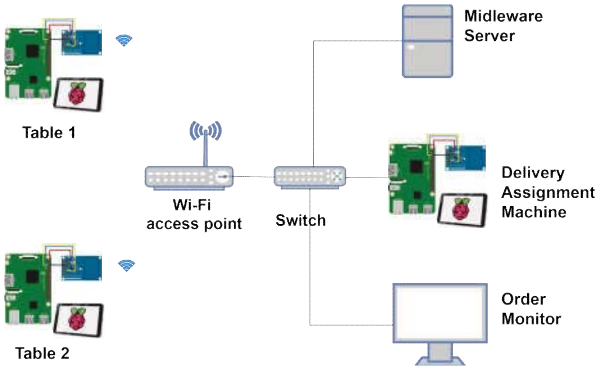

Figure 6: Simulation network architecture.

The figure 6 describes the network architecture used for the simulation. The middleware server, the delivery assignment machine and the order monitor, were connected to the network via Ethernet cables while the smart tables were connected via Wi-Fi through a Wi-Fi access point.

3.5 Results

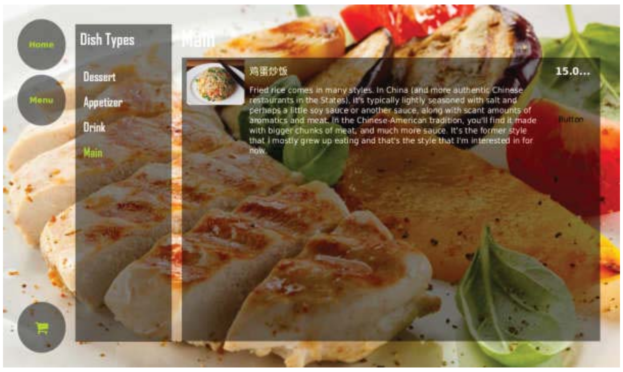

Figure 7: Screenshot of the dishes selection interface.

Figure 7 shows a screenshot of the smart table's embedded software, precisely the dishes selection interface.
To evaluate the performance of the system in terms of time, we simulated series of simultaneous order submission.

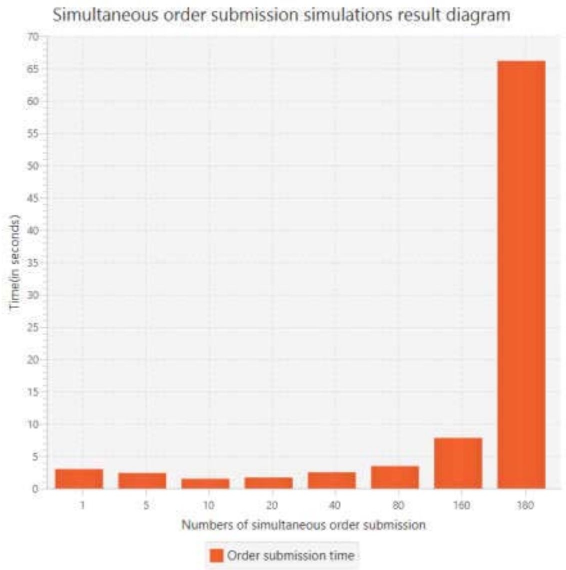

Figure 8: Result diagram of the simulation of simultaneous order submissions.

The time considered is the time gap between the moment the order is emitted from the table and the moments it is received by the application server.
As we can see in figure 8, this simulation showed that the lowest time it takes for an order to be emitted is averagely 1.5 seconds; when 10 orders are emitted simultaneously. In the worst case, it would take over 1 minute; i.e. when 180 orders are emitted simultaneously. But the emitting time for just 1 order is 3 seconds.
The same simulation principle has also been applied for the delivery lookup process. The time taken into consideration in this case is the gap between the moment the RFID Tag of the plate carrying an order is read by the table's RFID reader, and the application server's response moment after the lookup. The result is displayed in the diagram of figure 9.

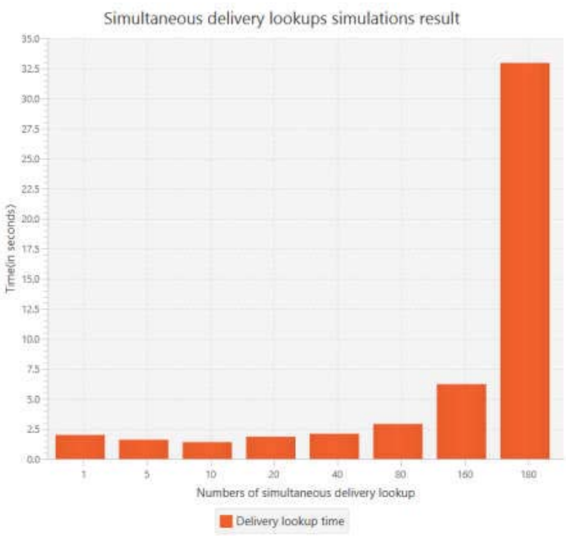

Figure 9: Result diagram of the simulation of simultaneous delivery lookups.

The lowest consumed time during the lookup process is averagely 1.4 seconds; also when 10 lookups are processed simultaneously. For a single lookup, it takes 2 seconds. For 180 lookups, it takes 33 seconds, i.e. half the time consumed for the same number simultaneous order submission.
These results demonstrate that the lookup process consumes less time than the order emission process. Also, in both cases of order submission and delivery lookup, the response time increases significantly when the number of simultaneous requests exceeds 160. We therefore conclude that for this particular setup, we can have a guarantee of low response time if the number of simultaneous request doesn't exceed 160.

4 Conclusion

We have proposed a system based on IOT paradigm in response of a scenario for smart restaurant. The key technologies supporting our proposed system are the RFID technology, as it is one of the main enabling technologies used in IOT, and also the embedded electronics. Further than proposing, we also created an environment to simulate and experiment this system. The challenge we met while realizing this work was to find suitable hardware that could be used to do a simulation most close to real life. A further extension of this system would be to add an analytic layer with the aim of providing a decision support tool for administration purpose. And as regards the protocols usage, to study on the way it could be possible to integrate the MQTT protocol would be a good step in the attempt to find a more efficient architecture. Also, another aspect that we did not focus on in this work, but nevertheless very important, is the security and privacy aspect: analysing the possible issues related to security and privacy and the possible ways to handle them.

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