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Feasibility Study of MongoDB and Radio Frequency Identification Technology in Asset Tracking System

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***Abstract*—**Taking into consideration the real time situation specifically the higher academic institutions, small, medium to large companies, public to private sectors and the remaining sectors, do experience the inventory or asset shrinkages due to theft, loss or even inventory tracking errors. This happening is due to a zero or poor security systems and measures being taken and implemented in their organizations. Henceforth, implementing the Radio Frequency Identification (RFID) technology into any manual or existing web-based system or web application can simply deter and will eventually solve certain major issues to serve better data retrieval and data access. Having said, this manual or existing system can be enhanced into a mobile-based system or application. In addition to that, the availability of internet connections can aid better services of the system. Such involvement of various technologies resulting various privileges to individuals or organizations in terms of accessibility, availability, mobility, efficiency, effectiveness, real-time information and also security. This paper will look deeper into the integration of mobile devices with RFID technologies with the purpose of asset tracking and control. Next, it is to be followed by the development and utilization of MongoDB as the main database to store data and its association with RFID technology. Finally, the development of a web based system which can be viewed in a mobile based formation with the aid of Hypertext Preprocessor (PHP), MongoDB, Hyper-Text Markup Language 5 (HTML5), Android, JavaScript and AJAX programming language.

***Keywords*—**RFID, asset tracking system, MongoDB, NoSQL.

I. Introduction

RFID technology is one of today's emerging technologies due to its competence to identify multiple objects that are tagged with unique IDs and the ability to obtain real-time information of the tagged objects. The development and implementation of RFID technologies have already moved closer to most daily applications. The utilization of RFID technologies might be seen as an opportunity and a possibility to substitute QR (Quick Response) codes, barcodes and GPS technologies. In addition, many real-time applications with RFID technology have been implemented in many real stores with the aid of wireless connection to perform data retrieval and can be accessed in the form of web-based applications or mobile based applications. The implementation of RFID technology in a typical system composed of two main components known as the readers and the tags. The function of a reader is basically to read and write tags while a tag stores data and consist of a unique identification (ID). The purpose of a reader is simply to generate signals and provide power for the tag. The tag that receives power from the reader will enable it to execute any commands sent by the reader. In return, the tag will send back a signal to the reader. It is this signal that contains the unique ID) of a tag which then will be used by the reader to look up in the database in order to ascertain the identity of the respective objects. The acquired information will be either in a form of object's name, serial number, location and cost among others.

In present day, more modern RFID tags and readers are being enhanced and developed which certainly offer more benefits. For instance, it provides greater frequencies, read-speed performance rate, better data transmission, multiple ID, real-time information and so forth. Due to these capabilities as well as RFID tags are getting smaller in sizes and relatively cheap, many business operations and healthcare management have been implementing RFID technology almost everywhere either as a standalone system or applications that works in many growing research areas such as in security and access controls, supply chain management and many more. Such reliability has grabbed the attention of many researchers to study the diversification of RFID technology into another level such as the integration of RFID system as a mobile application in smartphones.

MongoDB is one of the most popular NoSQL type of database engine. It has gained attraction amongst the database designer communities over the relational databases [1]. It is a document database which consists of collections which are preferably known as tables in the traditional relational type of database. The rows or tuples in MongoDB are known as documents. Basically, the usage of MongoDB can simply host multiple databases and it serves much functionality such as providing high performance, flexibility, availability, simplicity and easy scalability. Due to that, MongoDB is well-suited to be utilized for any system that requires large and dynamic database experience.

Mobile applications (mobile apps) are quite popular particularly in today's business and market share operations. This is because it serves as accessibility, mobility and user-friendly to all users. This mobile app is aided with the use of wireless or 3G connections in order to perform sending and receiving data from other similar or integrated devices. Many manual or existing systems have been enhanced into a mobile based application or mobile apps as it allows user to access it anywhere at any time while obtaining real-time information. Such flexibility and accessibility helps to increase profit or revenues of organization since mobile app can be used to

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promote the organization's branding name while at the same time helps promoting offers or sales to customers through mobile apps with the help of other integration software such as Push notifications. With such features, mobile app serves many privileges to customers, vendors and organization in many ways. And regular attendance are the prerequisites that are commonly imposed in most schools. They are connected to emerging character behaviors such as initiative, respect, integrity and responsibility.

The presentation of this paper is organized in the following sequences. A related background study is compiled and discussed. Next, a detailed system design and workflow is proposed. Subsequently a discussion on the findings is portrayed and finally a conclusion is drawn.

II. Related Background Study

The uses and applications of RFID have gained prominence recently. Most of the works were focused on healthcare [2], asset tracking [3], shopping environment [4], mobile devices [5]-[9]. On the religious aspect of application, majority of the researched works had focused on the uses of RFID to control crowd management [10]-[12].

Many papers have begun to be published in the use of RFID in the healthcare sector [13]-[15] due to its large inventories. Besides identifying and tracking assets locations using RFID, the need of mobile technologies such as in a form of mobile application can aid the system for convenience purposes while relying on web application at the same time. Therefore, the necessity of having both web and mobile application can solve the problems on accessibility, efficiency, mobility and availability issues.

The burgeoning RFID technology usage together with the use of wireless networks and mobile technology, a more comprehensive asset tracking and monitoring system can be well established [16]-[17].

RFID technologies and mobile application can definitely work closely and communicate with each other which help to solve problems especially for matters such as accessibility, mobility, efficiency and real-time information aspects. The use of RFID technology is capable of integrating and communicating with other platforms interchangeably.

The potential of this asset tracking system can increase the number of inventories to be tracked and increase the range of detection thus, alerting the authorities. Subsequently it increases the benefits of better portability, user-friendly and increase efficiency.

III. Research Approach

This section reports a system methodology for developing the RFID asset tracking system utilizing MongoDB as the prime NoSQL DBMS for data repository.

A. System Architecture

This system is a web-based system that can be viewed in a mobile-based application which integrates with RFID technology. It utilizes MongoDB as the main database engine which automatically retrieves and stores data from RFID reader into the database. Basically, this system is developed to track available tagged assets within the range of the area where RFID reader is being placed as shown in Fig. 1 in accordance with the software development established methods [18] and techniques [19]. The ability of viewing the system in a mobile based application form can simply help the user to monitor and track the tagged assets at any time as long as the user stays connected to the same wireless connection that the main system is connected to. For this system, it is the admin user who is responsible to maintain the system. Hence, the admin user can add and edit new and existing tagged assets. Furthermore, admin user can use the mobile based application to scan a room in order to access and track the availability of the tagged assets in a room. Moreover, an admin user can check and view the log history of in and out of the tagged assets for future references. Besides that, this system has other feature such as notifications that mainly alerts the admin user and secondary user through emails whenever a tagged asset is taken out from a certain room or laboratories. Another obvious feature is the ability for the admin user to add and edit details of the tagged assets. Updating the availability of the tagged assets runs every 10 seconds that simply added new tagged assets into the database while updating the existing tagged assets in terms of date and time. With the above mentioned features, it simply helps to reduce certain problems while enjoying data retrieval in a real-time manner.

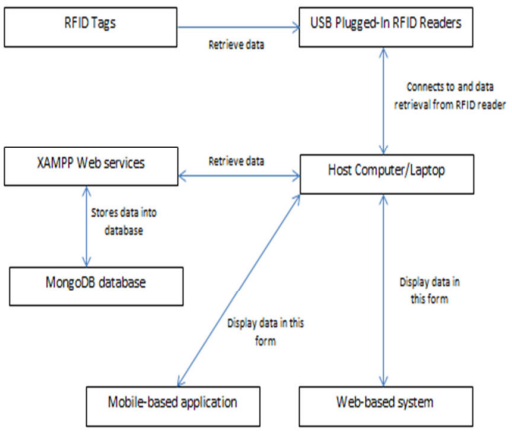

Fig. 1 Overall system architecture

First of all, the RFID tags will be attached to an asset or item which then to be readable by an RFID reader. For this project, the RFID reader is a USB typed of reader that connects to either a computer or a laptop. Once connected to the laptop or computer, running the system will basically retrieve and sent data which will be auto stored into the database using a local host web server known as XAMPP server. A user then can freely access and view the system by either a mobile-based application or in a web-based system. In order for the user to retrieve this information, the user needs to access the same Wi-Fi connection that the main computer is connected to. If the user connects to different Wi-Fi

connection, then the user will not be able to perform the available options provided in the system. This is because of system that will be displayed via smartphones is in web view form as shown in Fig. 2.

Fig. 2 Image form of the system architecture

The overall structure of this system is the ability for user to access the system either by using a web-based system or mobile-based application. It allows user to request and retrieve data directly from the database while adding new information of a particular tagged asset into the database. The system will have auto update for every 10 seconds whenever the system runs the prototype RFID reader. Therefore, any new tags will auto inserted into the database while existing tagged assets will remain closely updated

B. System Workflow

There are various research methods that can be applied in today's real-time application depending on the aims of the research studies. This is because the need to solve existing problems.

The research method for this project will be using qualitative research method as a way to determine the benefits of utilizing MongoDB, RFID technologies and mobile application technology in a real-time situation for example in School of Computing and Informatics faculty in Institut Teknologi Brunei (ITB), Brunei. Fig. 3 shows how data are collected and analyzed from the data sources available.

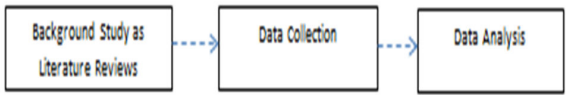

Fig. 3 Workflow of system method

C. System Design

The system design is divided into two main areas which are the mobile application (mobile app) and the web-based version to prototype RFID operations. The mobile web application acts as the front–end for the admin user who basically responsible for managing the application. Meanwhile, the web-based version of RFID reader is a prototype for testing the application.

The mobile app has been designed that are based on simplicity. It basically consists of simple buttons for user interaction with the mobile app. Buttons are designed using the 'LinearLayout' in a vertical layout with silver colored. Each of the buttons has different actions. Meanwhile the background has been designed with mosaic background in silver colored for modern and fresh appearance purposes. Besides that, this mobile app can only be accessed by the administration (admin) user only. Hence, the admin user has all privileges in accessing and managing the mobile app. The design layout for this mobile application basically is the main focus of this project.

Fig. 4 A local host web-based screen for Room A

Acquiring an RFID reader can be very costly. This is because there exist various brands, types of RFID readers in terms of frequencies and their functionalities. Furthermore, it is also due to the variation in distances. The longer the reading distance that can be readable by a RFID reader, the higher the price. Besides that, implementing RFID technology devices in a real environment such as in schools, hospitals and others can be very expensive since it needs to cover wide areas. Therefore, a web-based site version was designed to imitate the work flow of RFID reader specifically for reading data purposes.

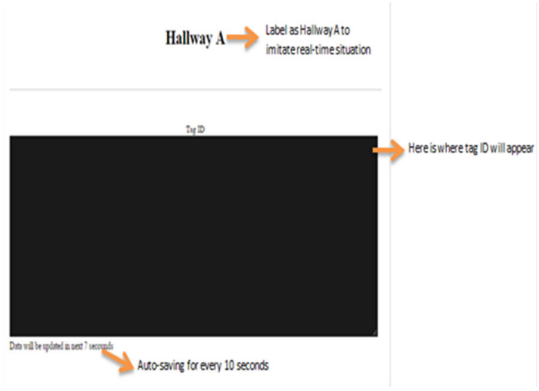

Fig. 5 A local host web-based screen for Hallway A

D.System Development

The first stage of the system development was to connect between the usages of MongoDB with the web-based system. This web-based system acts as a prototype that shows the action process of RFID reader. Besides that, two local host web-based screens have been developed as to assume that RFID reader is being installed in one of the rooms as in the two web-based screens. The first screen is representing as a room while the second screen representing as the hallway. Therefore, the room screen is labeled as Room A while the hallway screen is labeled as Hallway A. Both web-based screens have the same functions as depicted in Figs. 4 and 5 respectively.

```
$.post('dataB.php',{txt_area:$('#dstr').val()},function(r){
    $('#upd_div').html("Last Updated: "+r);
$('#timer').html('Saved.. Data will be updated in next 10 secounds');
s = setTimeout('timePicker(' + 10 + ')', 5000);
return false;
```

Fig. 6 Auto-saving Function for Room A and Hallway in PHP language

As shown in Fig. 6, the implementation process at this stage involves the auto-saving function that is basically an auto-saved the Tag ID of the RFID tag. It is able to auto-save the time and date of the tagged asset being scanned by the RFID reader. So every time a tagged asset is being scanned by RFID reader, the tag ID will be displayed on the local host website screen. The auto-saving function will save the data into MongoDB database every 10 seconds. An auto-refresh function will refresh the webpage every 30 seconds. Furthermore, when an existing Tag ID is being scanned, the time and date will be auto-updated. Meanwhile, if the RFID reader has scan a new tag ID, it will be added into the database. Fig. 7 shows the snippet codes for auto-set time in JavaScript language while auto-saving and auto-updating function is written in PHP programming language.

```
<?php
if((!count($count)) && (strlen($link) == 8) ) {
    //Save the New user
    $user_data=array('content'=>$link,'date_created_in'=>date('Y-m-d H:i:s'),
    'date_last_modified_in'=>$date_last_modified,
    'room'=>"Room A",'status'=>"IN", 'status_out'=>"NONE");
    $collection->save($user_data);
    echo "<center></center>";
}
?>
```

Fig. 7 Auto-save any new tag IDs

```
else{
    $collection->update(array('content' => $link),array('$set' => array('content' => $link,
    'date_last_modified_in' => $date_last_modified,'room'=>"Room A",'status'=>"IN",
    'date_created_in'=>date('Y-m-d H:i:s'),'status_out'=>"NONE")));
    echo "<center></center>";
    }
```

Fig. 8 Auto-update any existing tag IDs

```
$mail->addAddress('fypassignment@yahoo.com', 'fypassignment');  //primary user
$mail->addAddress('fypassignment@gmail.com', 'fypassignment');  //secondary user
```

Fig. 9 Manual edit the user's email address via coding

```
public function isMail()
    {
        $this->Mailer = 'mail';
    }
public function isQmail()
    {
        $ini_sendmail_path = ini_get('sendmail_path');

        if (!stristr($ini_sendmail_path, 'qmail')) {
            $this->Sendmail = '/var/qmail/bin/qmail-inject';
        } else {
            $this->Sendmail = $ini_sendmail_path;
        }
        $this->Mailer = 'qmail';
    }
```

Fig. 10 Sending Email using PHP's mail and G-mail functions

```
WebView mWebView = (WebView) findViewById(R.id.webview);
mWebView.clearCache(true);
mWebView.getSettings().setJavaScriptEnabled(true);
mWebView.loadUrl("http://192.168.1.101:80/LATEST-FYP/");
mWebView.setWebViewClient(shouldOverrideUrlLoading(view, url) -> {
        view.loadUrl(url);
        return false;
});
```

To load local host website

Fig. 11 Web view function and use of URL

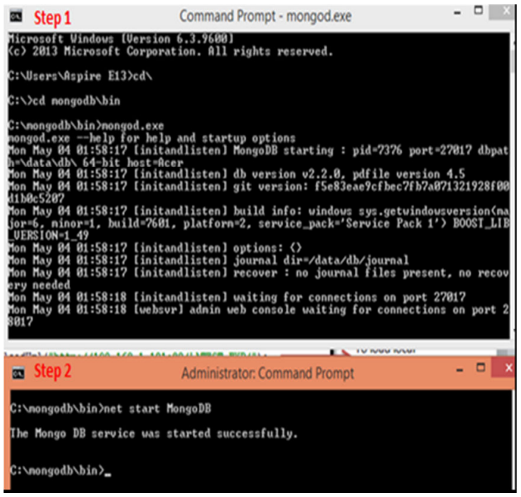

Fig. 12 Steps 1 and 2 to start and use MongoDB database

Next is on the use of auto-notification function. This function is to basically to auto-alert or notify the admin user via E-mail if a tagged asset is found within the range of the RFID reader that are being applied in Hallway A area. This notification is in E-mail form due to free, accessible and easier

to program it as compared to SMS (Short Message Service) and Push notification. Furthermore, this function will mainly alert two users which are primary user and secondary user. A primary user is the admin user while the secondary user is a person who is always around or closer to the area or building such as a security or a technician support staff. The idea for doing this is due to petty theft issues. If there happened a theft occurrence and the tagged asset is to be stolen and found in Hallway A area, thus both users will be automatically alerted and secondary user can then rush to the incident area. Besides that, an admin user can only edit the E-mail address manually through the coding itself. There is no edit user interface for changing the E-mail addresses. In reference to the written coding, this function is aided by the PHPMailer java class in order to send it to the auto-alert. Fig. 10 shows the snippet code for editing the user's e-mail address and the E-mail notification function. Meanwhile, the second stage involves the connection of database with a mobile application (mobile app). This mobile app has been built originally using PHP language that is displayed originally as a local host website. In order for the website to be able viewable in a mobile application form, we have used the WebView function that requires Android Studio for the mobile layout working successfully. This can be said as native mobile app and it is much simpler to implement the web view function in order for the website to become a mobile app. Moreover, since we have used the WebView function, it requires URL that allows access to the local host website on the computer. Hence, we have added the IP address of the computer and the location of the local host website of Tracking Asset folder as shown in Fig. 11. Furthermore, the mobile device that the admin user uses do need to access to the same Wi-Fi connection as the local host website on the computer is connected to. This is because to allow for the mobile app to be successfully working on the mobile device, to retrieve information and access the local host website on the computer.

Moving on to the usage of database, basically the adding, editing and saving the data into the database were all in MongoDB formed or language. It is just using the XAMPP which provides web services for windows. With such features, it enables to apply add, edit and saved functions into the system as a whole. Viewing the collections and documents created in MongoDB can be done using a command prompt. It can be viewable using Robomongo software which provides the user interface in order to access, view, create, add, edit and delete the existing or new collections and documents created using the Robomongo. Below are the steps to start and use of MongoDB application.

The main important in installation of MongoDB is the downloading and installing of PHP-MongoDB driver. This is only applicable for those who want to use PHP language, phpMyAdmin and XAMPP to program the coded scripts. Be aware that the involvement of php.ini and 'ext' folder under PHP folder.

The 'ext' folder will require the download of php_mongo.dll while in php.ini is for setting the extension for php_mongo.dll under the Dynamic Extensions as shown in Fig. 14.

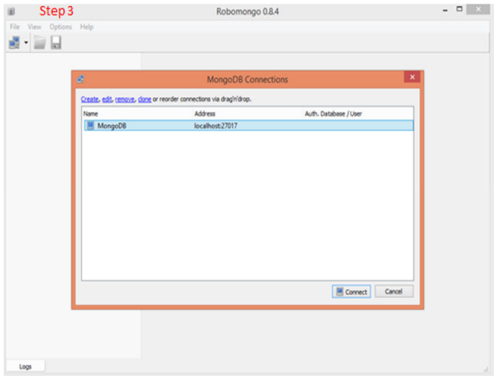

Fig. 13 Step 3 Use of Robomongo for user interface

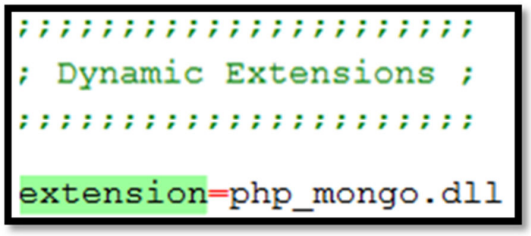

Fig. 14 'ext' folder in php folder of xamp folder

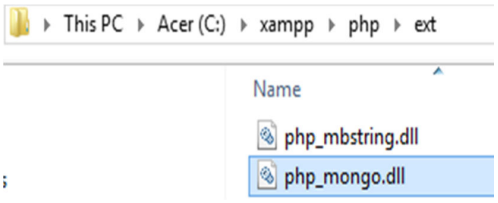

Fig. 15 mongo.dll in 'ext' folder

IV. Experimental Result and Analysis

At this stage, the web-based RFID site and the mobile application (mobile app) has been tested couple of times. Most of the core functions successfully working. These are the functions, software and applications that had been tested in a real-time environment.

1. Testing the system based on location: The system does not require to be tested in specific places such as in the School of Computing and Informatics in Institut Teknologi Brunei (ITB). This is because the RFID reader device is portable, light and it is a USB plug-in type of reader. Hence, it only requires a laptop or a desktop for the reader to be utilized once connected to the laptop/computer.
2. Testing mobile app on a mobile device: In terms of mobile app, it does need a mobile device for the application to successfully functional. Hence, we have tested the mobile app using Samsung Note 3 mobile device. Basically, we used a Samsung USB cable and connected it to the mobile device and uploaded the mobile app via Android Studio and it does work as expected.

3. Testing Auto-Email notification: For email notification, we have tested it by using two of my emails to represent the primary and secondary users. It did auto-sent the emails to the email addresses that we have provided.
4. Testing the web-based RFID site with MongoDB: This part is about the site that acts as the RFID reader. We have tested the RFID reader to scan the RFID tags and it basically able to retrieve and store the tag IDs into MongoDB database.
5. Testing the scanning function in mobile app: This scanning function in the mobile app has been tested and it basically is able to retrieve data directly from the database.
6. Testing the purchased RFID software: The RFID software included the RFID reader, tags and a USB cable. The software that is used for writing programs or coding did not work due to errors. Hence, we have to create a web-based version using PHP language to replace the software.

Based on the functions mentioned above, those were the results after being tested which basically produced some success results and a few were not performing as expected due to the complications that occurred during the development phase.

V. Conclusion

The study of this project hopes that the implementation of the system which replicates the integration of technologies in a real-time environment enable for individuals and organizations to see the big picture of the advantages that can be benefited from it. The integration of these technologies such as RFID technologies, MongoDB database engine and mobile applications can serve many advantages in various ways such as profit increases, real-time updates, mobility, accessibility, efficiency and many more.

The idea of putting these studies into a project research and implementing a prototype version is to have a better understanding that these technologies are powerful on its own while providing services that could aid in a daily life basis for better management. Tracking assets can surely be applied practically in healthcare management and business operations. With that, it can be clarified that the integration of these technologies can be used and well suited for tracking assets either for personal use or organization operations.

The usability of this whole system can be further expanded and improved for future research studies. The areas which can be enhanced to provide better functionalities based on the features are the use of better RFID technologies such as Wi-Fi enabled UHF RFID reader with an auto-alert or notification using SMS or PUSH notifications. The use of a Direct scanning together with mobile apps to RFID reader provides security enhancement for the applications. These functions will further expand the scope to a wider research studies such as the usage of an enhanced video cams to detect and record the occurrences and detection of user access in and out of the rooms, using enhanced RFID technologies and request for access into the system once register should be applied with user level status to enable admin user for granting or deny the user access into the system.

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