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Utilizing IoT to Enhance School Bus Transportation Safety

Hasnaa Waked
College of Engineering,
EFFAT University
An Nazlah Al Yamaniyyah, Jeddah, 22332, Saudi Arabia
hawaked@effatuniversity.edu.sa

Awateef Qusti
College of Engineering,
EFFAT University
An Nazlah Al Yamaniyyah, Jeddah, 22332, Saudi Arabia
ahqusti@effatuniversity.edu.sa

Nejoud Alassiri
College of Engineering,
EFFAT University
An Nazlah Al Yamaniyyah, Jeddah, 22332, Saudi Arabia
nealassiri@effatuniversity.edu.sa

Zain Balfagih
College of Engineering,
EFFAT University
An Nazlah Al Yamaniyyah, Jeddah, 22332, Saudi Arabia
zbalfagih@effatuniversity.edu.sa

Lamis Almohamadi
College of Engineering,
EFFAT University
An Nazlah Al Yamaniyyah, Jeddah, 22332, Saudi Arabia
lhalmohamadi@effatuniversity.edu.sa

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Abstract:

Public transportation with IoT deliverable that is a smart bus that is capable of performing calculations on number of the passengers, alert them when they arrive to their destinations, as well allowing passenger's families to track the bus movements by interacting to a user-friendly website that provides them with such services. This study has focused on tracking features within the platform form the three perspectives: guardians, administrator and bus driver. The implementation taken from two perspectives first is the web application implementation, which is going to be a website that the users can interact with the system through it. The second perspective is the system implementation through demonstrating a small model of a smart bus. The model will be powered with an IoT Architecture implemented to it, which will show how all the pieces should be operating together in one infrastructure.

Keywords: *IoT Architecture; smart bus; tracking features*

1. Introduction

Internet of Things (IoT) is a system provided with an exceptional identifier and the capability to transfer data over a network without demanding human-to-human or human-to-computer interaction [1]. IoT also refers to the networked interconnection of everyday and objects [2]. The connection of physical things to the internet makes it possible to access remote sensor data and to control the physical world from a distance [3].

Vehicles play a big role in the safety and travel. To consider the human benefit the technology now is drifting to the concept of IoV [4]. Internet of Vehicle innovation is a mobile communication system that allows the vehicles to connect thru the public network using Vehicle-to-Vehicle (V2V),

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Vehicle-to-Road (V2R), Vehicle-to-Human (V2H) and Vehicle-to-Sensor (V2S) interaction [5]. Maji et al. (2017) defines that smart buses are the non-stationary components of the Smart Bus System (SBS) and the normal buses can be converted into smart buses with the incorporation of intelligent sensors and IoT devices [6]. The ideal idea about transforming everything into smart through the use of internet is evolving. Besides that, RFID also been implemented to study the school transportation for children's movements from home to school entrance, trying to solve a little part of the school-age children's security problem [7].

In Saudi Arabia, most schools are providing bus services without implementing any solutions that ensures student's safety and same issue goes to third-party school bus companies. This results in parents avoiding the need of using school bus services, and tends to hire a private driver or deliver their children by themselves to school to ensure their safety. Yet, none of these options are operating in a smart way. Accidents and deaths are increasing; traffic jams are becoming a norm. This project aims to develop a smart bus and the integrity of local buses as a source of school transportation, in order to overcome the problems and the tragedy of students that explained above. The suggested solution will be expected to address these problems as reducing the number of accidents, grow trust between parents and buses, and spread awareness of using school buses among children (or pre-schooler) and young students.

2. Methodology

The functional and non-functional requirements is representing a form of documentation that explains how the elements of a system are present, and how to determine to back-end users what build the system, and what completes the system.

2.1 The main components in the SPT IoT architecture are:

IBM Bluemix: is a cloud computing platform that offers both platform as a service (PaaS) and infrastructure as a service (IaaS). This component will be reserved for dealing with storage and analysis of the SPT data [8].

API: Application programing Interface (API) services is used to build, manage and run application that handles user requirements.

IBM Watson: IBM Bluemix cloud platform supports access to other IBM cloud tools and services, including IBM Watson. A gateway in IoT architecture is the factor that will provides the sensors attached to the system with a single point of contact with external networks by using Wi-Fi or any other type of connectivity [9].

MQTT: MQTT is an abbreviation for Message Queueing Telemetry Transport. Specifically, it is a "machine-to-machine (M2M)/"Internet of Things" connectivity protocol". The need of MQTT can be presented within the need of establishing connections with remote locations where a small code footprint is required and/or network bandwidth is at a premium (MQTT.org, 2014). The need of MQTT in SPT can be presented by the fact that the project deals with passing many information at a certain time for different factors.

2.2 Hardware Components:

Intel Chip (Edison): the Intel Edison is a computer-on-module. The reason for choosing Edison in particular is for its capabilities in wearable devices, Internet of Things devices, and communicating via Bluetooth and Wi-Fi.

Arduino (Breakout): used in the demonstration of the IoT model for the smart bus as the Arduino will represent the brain that controls the system functions (Programming Electronics Academy, 2015).

WiFi Dongle (Huawei E303): to virtualize the presence of a wide area network with an internet connectivity that will operate on an entire city or certain environment that has the buses with the SPT system powered with.

NMEA-based GPS (Parallax #28506) is a GPS receiver communicator and a provider of real time position information that supports microcontroller projects. Hence, based on searching for previous IoT implementation, it has been shown that many projects that dealing with GPS are using Parallax #28506 for this task (Parallax Inc, 2012).

Zigbee Controller: the ZigBee will be used to deliver position attributes such as latitude and longitude to the bus GPS in order to make the NMEA display it for the actors interacting with the GPS interface.

2.3 Functional Requirements

1. The platform will have a section called personal information for the guardian where user can view and edit some of the personal information entered by the admin. The edited values will be: Password, Email, Phone Number, Alternate phone Number, and location.
2. The system will have a database for registering users (students, guardians, bus drivers) by school administrator. This is needed to give the end user access to the SPT platform. The administrator will also need the database for adding buses, and monitor access by setting passwords to guardians and bus drivers.
3. The system will have a tracking platform that uses real time navigation and GPS tracking, which will allow guardians to know what the current location of the bus and their children.
4. The system will have a tracking platform that uses real time navigation and GPS tracking, which will allow bus drivers to explore the timeline that consist of passenger's arrival points in order to deliver passengers efficiently to their homes.
5. The system will have a tracking platform that uses real time navigation and GPS tracking, which will allow School Administrator to explore bus movements and location in case of an emergency or a bus breakdown incident.
6. They system will have an image processing camera that works as a counter. This camera will be in charge of counting passengers within the bus, and update the remaining number of passengers left, to ensure that the bus driver won't forget any student within the bus.
7. The system will have a voice calling unit that will stream the passenger's name when he/she arrives to the destination point. This to ensure that no one has passed their stop while they are on the road. Hence, no need for the bus driver to keep calling names.
8. The platform will include a feedback section provided to end users who have access to the platform (guardians and bus drivers). This is needed to enhance user experience and customer service from a business perspective. By allowing users to share their concerns, feedbacks and recommendations.
9. The school admin will be allowed to have a function called generate reports within the admin panel, in order to create reports for the admin that helps in understanding how the system performs from a business perspective, and how to improve if any gaps or issues found within the operation.

2.4 Non-Functional Requirements

1. The users will need to have the platform to be translated in both Arabic and English. Priority is given to Arabic language due to the fact that most users are old and they tend to be more user-friendly with platform that supports Arabic

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as their mother tongue language which is easy to follow to them.

2. When guardians log in for the first time, the will be asked to reset the password for security purpose. So that each guardian can have a unique password.
3. The calculation accuracy in people counting camera must be high and tested on many different scenarios before actual implementation to ensure passenger's safety.
4. Every log in session made by the users or the administrator must have an end if no activities are made during the session at a certain time.
5. If the guardian or bus driver forgot their password they will have forgot password option on the login page where they can reset their password by entering their email or phone number as an authorization factor to send the password to.
6. All the data during registration must be entered correctly to avoid confusion or information leakage of other elements of the system.
7. The platform must use an HTTPS connection for the sake of security.
8. The platform (which is a website) should have a responsive web design which allows end users to explore the website easily from different devices like mobile phones and tablets.
9. The platform GUI needs to be efficient and user friendly.
10. The users will need to have the server running at all times in order to access the platform whenever they need. Hence it will require an internet connection to access that server.

A sea level use case, which deals with users and their general functions that they need to operate while they are on the system. This level is consisted of one use that has all the general functions for guardian, bus driver and admin which shown in Figure 1.

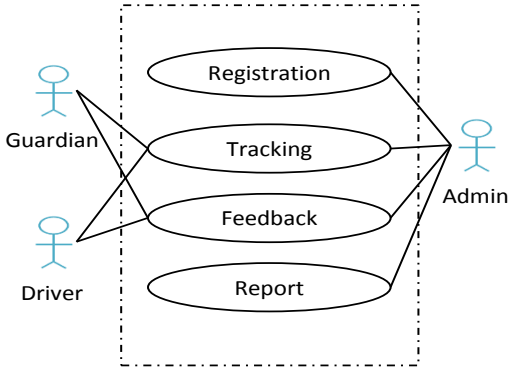

Figure 1. Sea Level Use Case (General)

Guardian logs in into the system using credentials given by the school administrator. Guardian required resetting the password and logs in again. In SPT platform, the guardian can view/edit personal information within the account. Guardian chooses the child (passenger connected to Guardian) to track. This is if the guardian has more than one child, who is a student and subscribed to the bus system. Besides that, they can explore tracking platform and checks the status of the bus that has his/her child on as well as sends feedback report to school administrator in case of a concern or any other issue. Guardian logs out from the system, or system will do a logout automatically within 30 minutes if no actions are made by the user.

Bus driver logs in into the system using credentials given by the school administrator. Bus driver required to enter the bus ID which associated with. In SPT platform, the bus driver explores tracking platform that is provided with a timeline representing each passenger's arrival point. Bus driver displays the counting cameras which will calculate the number of passengers entering and leaving the bus together with the voice calling unit to notify the passenger with their names when they arrive to their destination. Besides that, the bus driver sends a feedback report to administrator in case of concern or any other issue. Bus driver logs out from the system, or system will do a logout

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automatically within an hour if no actions are made by the user.

Administrator allows connecting to bus server. In SPT admin panel, administrator can access to the entire servers. Administrator can modifies physical buses into the database with a unique ID and general information about it and modifies users by registering them and specifies if they are guardians, students or bus drivers, also generate the relation between each table. Administrator can generate passwords access to bus drivers and guardians in order access the platform. Besides that, the administrator receives feedback from users and reports them to higher authorities if needed. The system is capable to generate reports from all the different units within the system to analyse operations. Administrator can access tracking platform by tracking buses in case it is needed. Administrator logs out from the system, or system will do a logout automatically within 30 minutes if no actions are made by the user.

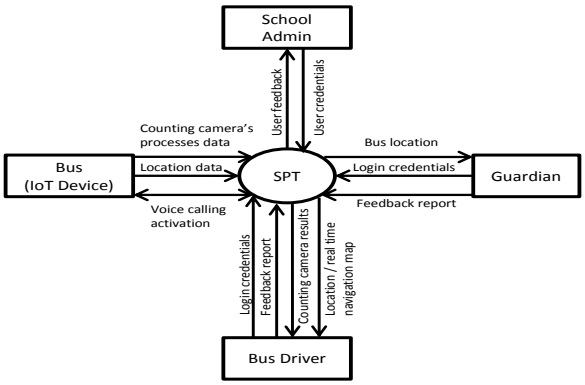

Figure 2. Context Diagram

2.5 System access

The concept of securing a system does not only controlling user access. There should be security architecture to the system as well to ensure that even of a breach happened to the data, it will be only for a certain layer and not to be fully on the system.

2.6 Web Application Servers

The web security architecture includes the web server, application server, and a database server. Hence, this requires a defence in depth mechanism to secure the system by implementing each server separately on different user within the machine. This will enhance the security implementation for the system.

2.7 Sessions Connection

Human errors and their reckless behaviour toward security cannot be fixed only by setting rules and policy on their side, there should be an automatic process that forces them to be more committed to security. Such requirement is measured in controlling users' sessions. The three kinds of session ending are:

1. Guardian will be logged out automatically if no actions are made within 30 minutes.
2. Bus driver will be logged out automatically if no actions are made within one hour.
3. Administrator will be logged out automatically if no actions are made within 30 minutes.

2.8 Encryption:

Internet of things deals with the concept of opening many ports and protocols, which mean many backdoors, can be available to attack the system. A basic step to use secure hypertext transfer protocol HTTPS to encrypt the connection. Secondly, to encrypt user's password using hash functions this will be defined on the back-end development using PHP. Also specify special ports to connect with the platform.

2.9 Passwords:

In user access controls, a requirement in guardians' access is defined, which is that when they log in for the first time, they will need to reset their passwords. However, another security requirement is needed in order to force them to not use a weak

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password. So, the guardian's password should consist of both numbers and letters, and it should be not less than 6 characters.

3. Result and discussion

3.1 Phase one: Building the database

The database is the foundation of any application. The main step is to design the conceptual and logical view of the database. Next, is to develop these diagrams physically through the database server, which is MariaDB. The code development was made using MySQL, which is a relational database management system language. The code has three phases. First, the Guardian_seq table which will have the last part of the customized ID, so for instance, in 'GID001' the last number is taken from Guardian_seq. Second, the main table that has guardian information such as firsname, lastname email and so on. Lastly, the trigger is connects to the customized ID within the condition for auto incremented number in Guardian_seq tabe.

3.2 Phase Two: Implementing Guardian Interface

First step was to create login and user account page. The login page will also have sub-categories where in case the guardian forgot his/her password so a reset process needs to be made in order to restore the password. The login page is shown in figure. The administrator and bus driver will have the same login page the difference will be in the past variables and the queries.

A forgot password option is available to take the guardian to a reset page. Where he/she can type the email they are registered with to send the reset password link to it. In order to send the reset link, a PHP mailer class library was used in generating the code that sends an email to the user.

The password is taken by the password function in PHP to convert the password into a one-way hash. That way the password will be stored in an encrypted format for security matters. An example for one of the hashed passwords:

Plain text password:	Effat12345
Encrypted Password:	$2y$10$Cx7niDQ3Pt6KcjREYiWyvetg8NfZsMu2mABR67fQtRRdSRHDvTx6G

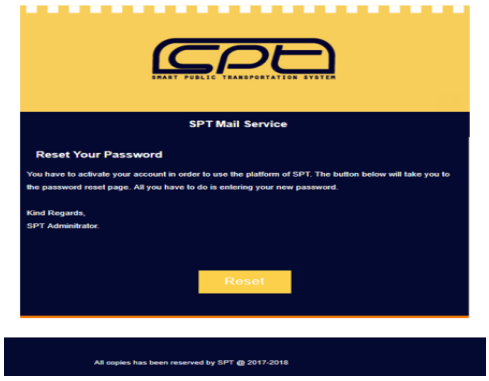

Figure 3. Reset page and the reset email for guardian

The guardian will be able to see his children and know about their subscription information within the bus, and track the bus if a trip is active. Other options allowed for guardian is to see when the last time he/she accessed the system was, view/edit account information, send a feedback, plus changing the website language. The page has four elements. First element is for student general information; second element for current trip information, third element is for bus and bus driver information in case of an emergency. And finally the fourth element, which is the tracking map.

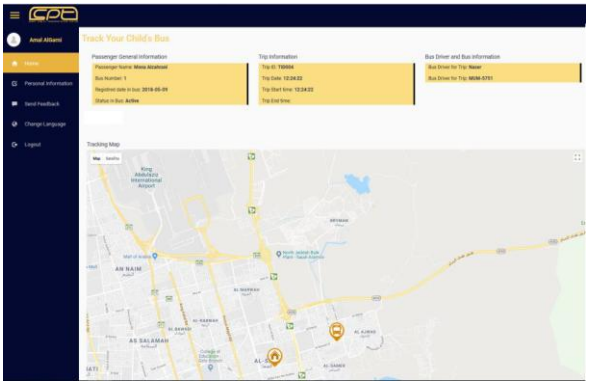

Figure 4. Tracking page for guardian

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3.3 Phase Three: Implementing School Administrator Interface

The dashboard was designed the same way of designing the guardian page only with different options. The admin can choose any of the four assets to explore, or on the right bar the admin can either explore tracking platform to track buses, view and reply to received feedbacks, view reports of the system as a whole, and view his personal information.

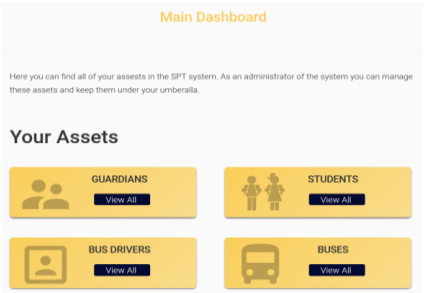

Figure 5. The admin dashboard

For guardians, the admin can view all guardian and some of their general information, this is made through the use of data tables. If a guardian wants to see the whole information about a guardian he/she can click on the guardian id for viewing, editing, or deleting the guardian. The admin can add the guardian to student and the guardian may receive an email of his ID and the linked needed for him/her to visit in order to activate the account. For student, there are student information such as emergency contact and destination point of the student. Therefore, admin can manage the bus for the student. Next is buses, the admin can see the bus history for student for which bus she is currently in, and which bus she was in before. To see more details about buses we go to the buses page which will have same general data table about buses. For the driver, general information of the driver and the history within the trip is recorded. New driver can be added here by admin, and the driver may accept the email to activate the driver platform.

Next element for admin feature is the tracking platform where admin can see all buses that have active trips within the map. In addition, the report of each area can be generated in graphical format.

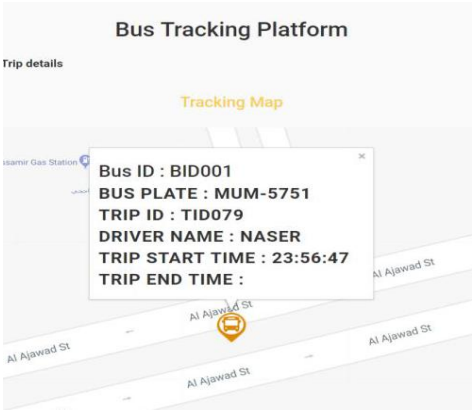

Figure 6. Tracking platform for administrator

3.4 Phase Four: Implementing Bus Driver Interface

The extra element in login page for driver is to enter the bus id he is going to drive within this trip. By entering bus id, a get variable will be used throughout the rest of the pages to maintain the bus value beside the driver session, so the $BID = $_GET['BID']; will act like a second session with the driver session.

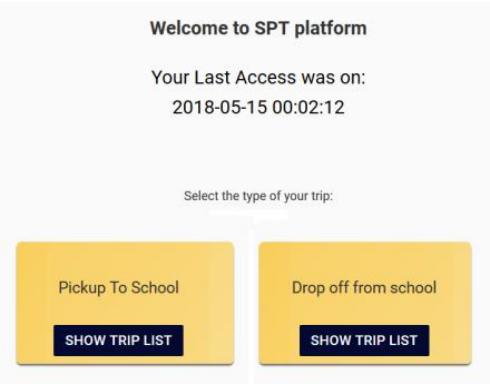

Figure 7. Driver home page

The driver will select either if he is going to make a trip that is from home to school 'Pick Up to school' or from school to home 'Drop off from school'. These two statements indicate that in the pickup option we're going to make they query get all the student who do not have a status equal to

'Active PM', while the exact opposite is made for drop of by selecting student who do not have a status equal to 'Active AM'. These two statements will result in displaying in each option a page that contains the list of students who are added to this bus and are matching the select statement.

3.5 Hardware development

The tested real-life model of the School Public Bus Transportation hardware is conducted. This hardware will be placed inside the school bus and it is connected to the school system where the bus current location and time stamp will be stored and send to the website of the school. Another feature of this device is that it provides the system administrator and the kid's guardians to have the ability to know the current location of the bus that has their kids.

Circuit Components:

- ESP8266
- GPs
- Breadboard
- Arduino Software (IDE) and library

To get the current coordinates of the bus location, the GPS receive this data from the satellite and send the signals to the ESP8266, the ESP8266 decode the signals and transmit it via the internet connection to the database website.

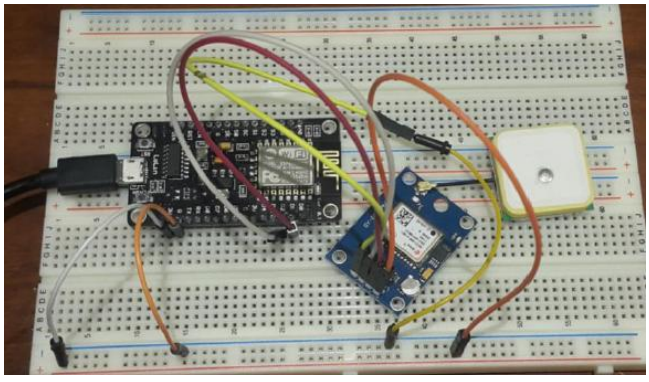

Figure 8. Hardware set-up for school bus

4. Conclusion

This study successfully develops and implemented the SPT system to address the problem of school transportation by establishing a better and safe environment for the students in the Kingdom of Saudi Arabia. The SPT system is presented as an advanced solution based on recent technologies that will take a part in enhancing society's awareness about internet of things in the future.

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