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SMART SCHOOL BUS MONITORING AND NOTIFICATION SYSTEM USING RFID AND GPS

MASTER'S DISSERTATION

Submitted in partial fulfilment of the requirements for the award of

MASTER OF SCIENCE IN INTERNET OF THINGS

WIRELESS INTELLIGENT SENSOR NETWORKING

(MSC in IoT-WISENET)

Submitted by

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APRIL, 2021

DECLARATION

I, UMUHIRE Cedric, herewith state that this dissertation report is my original work and has not been submitted before for any academic award in the either University of Rwanda or other higher learning institutions for academic publication or any other purpose.

UMUHIRE Cedric

26 Jan 2021

BONAFIDE CERTIFICATE

This is to indorse that the project entitled "Smart school bus monitoring and notification system using RFID and GPS" is the genuine work of Cedric UMUHIRE registered to 219013712 in partial fulfilment of the requirement for the award of a Master's degree in Internet of Things - Wireless Intelligent Sensor Networking (MSc in IoT-WISeNet) from College of Science and Technology at University of Rwanda, Academic year 2019/2020

This work has been submitted under the guidance of Dr. Jean Baptiste MBANZABUGABO as main supervisor and Dr. Louis SIBOMANA as co-supervisor.

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DEDICATION

I dedicate this dissertation …

To my wife Ange and my children Audrey, Nornha, and Horma without whom this dissertation would have been completed.

To Mom, Who took me to the school!

To my close friend, Who supported me a lot during my master's studies!

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ABSTRACT

Smart education is conceived as using technology in the classrooms and school administration, yet there are other factors outside the classroom and school administration, that need to be automated such as assuring parents while sending their children to schools. One key challenge in the City of Kigali is that no trustworthy system in place, which can monitor school buses and be able to provide real-time information for children's locations while commuting to school. This remains an issue for many parents, as there is no solution, which can connect parents, their children, bus drivers, and school administration.

Considering the Internet of Things (IoT) and its technology's benefits and advantages, monitoring the child's location on their way to and from school can be realised in real-time and reduce parents' worries besides raising the confidence level of children's safety.

Within this research, the design of an IoT-based solution of smart school bus monitoring that provides SMS notification in real-time has been proposed together with its prototype development. The system allows parents and schools to track the condition and safety of children. This is done by using a combination of Radio Frequency Identification (RFID) and Global Position System (GPS) technologies connected to a remote server using GSM/GPRS technologies through Arduino Uno and Arduino IDE.

To accomplish the objectives of the research, further readings on the adopted technologies were made through and a three-layered IoT system architecture model was selected in the designing and development of the prototype. This resulted in a Smart School Bus (SSB) system consisted of six (6) main components and seven (7) sub-components. For the software side, the SSB is comprised of six main components too in three modules namely identification, tracking, and notification. The entire system is implemented under the N-Tier deployment style. The technical discussion highlights system requirement fulfilment, plus how the real system can be implemented as the next step after this research and the business case analysis of SSB were elaborated.

The practice of diverse devices, communication rules for software features, and security instruments was a hard encounter which SSB system faces and should balance to provide its features and ensure responsive services.

KEY WORDS

RFID, GPS, SMS, notification, tracking, bus monitoring, children, IoT, Internet of things.

LIST OF ACRONYMS

AC:	Analog Converter
App:	Application
ASIC:	application-specific integrated circuit
DC:	Digital Converter
DPWS:	Device Profile for Web Service
DPWSim:	Device Profile for Web Simulation
Dr.:	Doctor (Ph.D.)
EDI:	Electronic Data Interface
EPC:	Electronic Product Code
Et al.:	is short for the Latin term “et al,” meaning “and others.”
EU:	European Union
Fig.:	Figure
FM:	Frequency Modulation
GCM:	Goal Constraints and Module
GLONASS:	Global Navigation Satellite System
GPRS:	General Packet Radio Service
GPS:	Global Positioning System
GSM:	Global System for Mobile Communications
HEC:	High Education Council
HF:	High Frequency
IC:	Integrated Circuit
ICSP:	In-Circuit Serial Programming
ID:	Identifier
IDE:	Integrated Development Environment
IoT:	Internet of Things
ITU:	International Telecommunication Union
KB:	Kilobytes
LAN:	Local Area Network
LCD:	Liquid Crystal Display
LED:	Light-Emitting Diode
M2M:	Market to Market

MEMS:	Microelectromechanical systems
MRLM:	Multimodal Representation Learning-based Model
MSc:	Master of Science
NAVSTAR:	Navigation System with Time and Ranging
NFC:	Near Field Communication
NMEA:	National Marine Electronics Association
NXP:	next experience
OBD:	On-Board Diagnostics
PCB:	Printed Circuit Board
PCs:	Personal Computers
QoS:	Quality of Service
RF:	Radio Frequency
RFI:	Radio Frequency Interface
RFID:	Radio-Frequency Identification
RPM:	Revolutions Per Minute
RTC:	Real-Time Clock
SMS:	Short Message Services
SOA:	Service-Oriented Architecture
SoC:	System-on-Chip
SSB:	Smart School Bus system
TTFF:	Time-To-First-Fix
UHF:	Ultra-High Frequency
UI:	User Interface
USA:	United State of America
USB:	Universal Serial Bus
UTP:	Unshielded Twisted Pairs
Wi-Fi:	Wireless Fidelity
WiMAX:	Worldwide Interoperability for Microwave Access
WISeNet:	Wireless Intelligent Sensor Networking
WSN:	Wireless Sensors Network

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CHAPTER 1: INTRODUCTION

1.1. Introduction

Every day millions of children need to travel from home to school and vice versa. For parents to obtain safer transport for their children is sometimes a critical issue. Crime against children is increasing every day, especially in developed countries [1]. Children in the world employ an excessive time travelling to and from school.

In the United States of America, more than 25 school bus tracking apps are in place in 2019 [2], to help concerned parents about their children to know where their children are located. Those platforms provide school bus information of their children to parents: a bus is running late, to get an estimated time of its arrival, bus map location, notification if it is behind the schedule, and alert in case of emergency [3].

With specialised trackers, all children transport stakeholders could continuously see where their children are, if are non-violent, and so on. As an alternative to providing the information just to parents, these apps offer services to school administration of keeping track of their students, and bus companies use them to expand their safety and to provide better service.

In South Africa, vehicle tracking services represent a multimillion-rand industry including solutions for tracking children to school [4]. “TrackSchoolBus” is one of them and is currently used. The platform has a parent app with the following key features: School bus attendance to view complete and precise school bus attendance of the children anytime from anywhere without contacting authorities. Real-time location and notifications help you to pick the children from their respective bus stops at right time and generates complete details of the school bus journey of the children. Leave management to apply leave for the children if needed without contacting school management. View schedule route to visualize the detailed view of the scheduled route of the school bus trip and receive a notification of any changes or updates in the scheduled route. Bus stop re-assignment to change the pickup/drop-down point of the children via an app without much hassle if any relocation is needed. Lastly provides communication with school management and drivers via an app [5].

In East African region, specifically in Tanzania solution like School bus tracker is in place [6]. Children's whereabouts at your fingertips provide child safety as a top priority to any concerned parent. Parents need to know their children are safe while in transit to and from their respective schools. It makes sense to have a GPS vehicle tracking system installed in school buses to ensure the safety of children to add value to education services [6].

In Rwanda, during school time everyday children risk many challenges like extended travel times, overloaded buses, long bus stop waiting times, late arrival and departure, taking the wrong bus, get out to the wrong bus stop, etc. These challenges faced by children during their trip to and from school result in a problem to many parents due to lack of enough information on their school bus system. The only solution parents have for those challenges is to make calls to different individuals like a bus driver, teacher, school administration, other parents, neighbours, or doing nothing and wait until the children returned home safely in the evening. In some cases, this can result in blaming children when they are late yet it is not their fault, while in some cases they have waked up early. Such situation is one of the factors that can affect the performance of students and leads to the poor quality of education in general.

Some parents prefer to use their own cars to take their children to/from school but this also is a delinquent to them as they are mostly late to their office or to take their children from school [7].

The authority of Kigali City also recognizes children's transport to/from school as a big challenge within the city, but it is still seeking a general solution, as now school transport is an issue between school administration and parents [8].

Some private companies or individuals and/or schools tried to respond to children’s transport problem within Kigali by providing coloured yellow school buses to indicate that they are dedicated to school transport only, however, issues persisted as no system provides information in real-time to allow parents to track where their children are located during the school time.

Another challenge of children transport within Kigali city is its topology that affects at large the way of going and coming of children to and from school definitely, as it is difficult to track school bus due to traffic jam caused by limited and small roads. According to Smart City Rwanda Master Plan [9], an integrated transport app will help to enhance the reliability of public transport including children transport's while also acting as a strategic tool for designing routes and intervals to assist in children safety.

The Internet of things (IoT) as a paradigm promises to make things including consumer electronic devices or home appliances such as medical devices, fridges, cameras, and sensors part of the internet environment. This paradigm opens doors to innovations that will build a novel type of interactions among things and humans and enables the realisation of smart cities, infrastructures, and services for enhancing the quality of life and utilisation of resources [10]. IoT can be used in many applications, but in this research, the focus is monitoring children’s location during their trip to and from school.

The research aims to design and develop a prototype for an IoT-based monitoring system to enable all concerned bodies to have a reliable and secure school transport service to guarantee the security of the children. The system tracks children’s locations among the following locations: home, bus stop, inside the bus, and school. It combines RFID and GPS technologies and connects them to a remote server using a GSM/GPRS module and their technologies and provides real-time notification.

Different reports showing attendance, incident, pickup time and location, etc. may be generated by the system from the real-time data and make them available through a system to schools, parents, and other stakeholders who are concerned for bus comfort, safety, and attendance, toward providing complete visibility into conditions from home, inside school bus up to school and the way back to school. The system intends to monitor the children's location and provide related information by sending notifications through emails and/or SMSs to different bodies per demand by default and automated notifications as optional.

1.2. Definition of technical terms

The proposed system uses a combination of RFID and GPS technologies to connect them to a remote server using a GSM/GPRS technology integrated with Arduino.

RFID (Radio-Frequency Identification) is an automatic identification and data capture system comprising one or more RFID readers and one or more RFID tags in which data transfer is achieved through suitably modulated inductive or radiating electromagnetic energy. A tag is attached to the item to be identified, and a transmitter/receiver unit interrogated the tag and receives identification data back from the tag [11].

GPS is a continuous space-based, all-weather radio system for navigation, positioning, and time-transfer which provides extremely accurate three-dimensional position and velocity information together with precise common tome reference to suitably equipped users anywhere on or near the surface of the earth [12].

GSM (Global System for Mobile Communications) a digital cellular phone technology that is the predominant system in Europe, but is also used around the world. GSM defines the entire cellular system, from the air interface to the network nodes and protocols [13].

GPRS (General Packet Radio Service) is an enhancement to the GSM mobile communications system that supports data packets. GPRS enables continuous flows of IP data packets over the system for such applications as web browsing and file transfer [13].

Arduino is an open-source Arduino Software (IDE) that makes it easy to write code and upload it to the board. This software can be used with any Arduino board [14].

1.3. The scope of the research

The scope of the research is to design a hybrid IoT multimodal and simulate or develop its prototype system that can track the movements of a child and keep monitoring his or her location to respond to the parents' concerns after sending their children to school. Technically the system designed combines the technologies of RFID, GPS connected to the remote server through GSM/GPRS technologies. The system should be able to send a notification to parents and school administration per demand via email and/or SMS with the option of automated notification. The system should be able to provide interaction with users through the web app and mobile app and store its data into the cloud on the server-side.

1.4. Problem statement

It has been shown by Raja et al. [1] that the use of the applicability of RFID technology for tracking and monitoring children during their trip to and from school in school buses, considering its advantage of efficient tracking capabilities, low cost, and easy maintenance can contribute in identifying the presence of children at school. Then that information could be communicated to the parent and school via the GSM module. But the research did not take into consideration the use of email which is efficient in terms of cost-effectiveness and keeping records.

Children tracking systems are currently adopted in different places worldwide. A system that allows the parents to be notified when their ward alights or boards the bus is developed by Raj and Sankar [15]. The developers made use of RFID and GPS technologies to identify each student and locate a vehicle respectively and connect them to a remote server over Wi-Fi using an ESP8266 microcontroller. The information can be accessed by the parents through a mobile application and this helps parents track their wards effectively. The school administration can also access the application to ensure student safety and contact a driver or a parent. However, the system does not consider child safety between home and bus stops.

The big challenge for parents and different stakeholders concerning children's safety while to and from school is tracing where they are whenever they are not with them. Therefore, considering the local context specifically in the urban area of the City of Kigali, the standalone solution to the above problem is calling individuals or moving to school to inquire about their children’s conditions. This is not the viable solution with the current advanced technology as instead, it is time and money consuming. But so far, there is no other solution. To solve this problem, it needs to provide an adequate real-time platform in Kigali City that can generate information for all those concerned about children's safety while commuting to/from school.

It is in this line, to address the above issue, the researcher thought to design a solution with an IoT based smart school bus monitoring and notification system that tracks children from their home to school and the way back and be able to send information about the location of children given local context. The system should be able to communicate in real-time via SMS and email in both directions between the system and parents or school administration or bus driver or any other entity concerned. The advantage of the proposed system is providing interaction among all concerned bodies of the children transport given the IoT multimodal technology to be adopted and the capabilities of providing the children location information from home to school.

1.5. Literature review and rationale

Raja et al. [1], introduced a system with the use of RFIDs to track children, but the information from RFID cannot provide information on the dangerous situation of the children inside the bus. The platform devised a method to identify the student by using a combination of RFID and GPS technology to track the student locations and alert parents with sent notifications via SMS. System notifications are set to be sent automatically which may be a challenge due to the many notifications received nowadays.

Sridevi et al. [16], presented a system that provides the relevant information about bus numbers from users’ source and destination along with the route details and real-time location. Their system used GPS attached with the bus. In their project, UNO is used to program with a real-time clock (RTC), and all information related to the bus (source and destination), can be accessed by users through the android application. Their system could be only consumed by children who know how to use the information generated by the system.

Emad et al. [17], proposed a similar system “IoT based school bus tracking and monitoring system” where each school bus contains a variety of modules including an On-Board Diagnosis-II (OBD) Module, an RFID Module, and an RFID for each child, DHT22 and a smartphone that acts as a mobile hotspot. This system uses publish/subscribe mechanism. A parent to benefit from it, needs to subscribe each time they want to use the system feature of publishing/subscribe mechanism, which can be considered as a limitation for some parents, it is not user friendly.

Jisha et al. [18], developed a school bus monitoring system capable of tracking students in a school bus using a combination of RFID/GPS/GSM and GPRS technologies. In addition to the tracking, a prediction algorithm is implemented for the computation of the arrival time of the school bus. Through an Android application, parents can monitor the bus route and forecast arrival time for the bus. This system did not consider the safety of students between the bus and home.

Raj and Sankar [15], proposed a system that provides real-time information about various parameters of the vehicle like the location, the route, the speed, the list of passengers, the adherence of drivers to schedule, and much more. The system further allows the parents to be notified when their ward alights or boards the bus. In this system, they made use of RFID and GPS technologies and connected them to a remote server over Wi-Fi using an ESP8266 microcontroller. This system starts counting when passengers enter into the bus, out of the bus it is not its business.

Zhenhua et al. introduced a novel multimodal representation learning-based model (MRLM) with two closely related modules trained simultaneously. The global feature representation learning and multimodal feature representation learning. After MRLM is converged, items’ multimodal features could be used to calculate users’ preferences on items via cosine similarity. Through extensive experiments on two real-world datasets, MRLM remarkably improved the recommendation effectiveness in IoT [19].

Son N. et al. introduced Device Profile for Web Simulation (DPWSim), a simulation toolkit to support the development of service-oriented and event-driven IoT applications on top of devices with secure Web services capabilities and seamless integration into the existing World Wide Web. DPWSim allows developers to prototype, develop and test IoT applications using the Device Profile for Web Service (DPWS) technology without the presence of physical devices. It also can be used for collaboration among manufacturers, developers, and designers during the new product development process [20].

1.6. Aims and objectives

This research aims to develop a hybrid IoT multimodal system and simulate it or develop its prototype. The system should be able to help all concerned bodies especially parents to have information related to the location of their children when they commute to and from school in a real-time manner. The notification is sent via email or SMS and indicates the children's location. The novelty of the system is to put in place another method of communication on top of the standalone solution of making calls to track the location of the children from home to/from school and allows the communication from both directions between system and parents or school administration or bus driver.

The specific objectives are the following:

1. To review the literature on RFID, GPS technologies, and IoT based systems;
2. To design a hybrid IoT multimodal of RFID and GPS technologies connected to the remote server (cloud);
3. To develop an algorithm that guides the implementation of the developed multimodal;
4. To simulate the proposed system or develop the prototype of the proposed system.

1.7. Methodology

To achieve the aim of this research, different methodologies are used to realise the specific objectives.

For the first objective, further readings from different sources of documentation were conducted mainly using the internet and gathered related information to the topic of the research.

To design an IoT multimodal different hardware and software modules were required. These include the RFID and GPS sensors, GSM/GPRS module, Arduino UNO microcontroller, Arduino IDE, and cloud platform enabled architecture as data engine and Proteus simulator for simulation. The above-mentioned modules being hardware or software were tested before being used. An IoT system architecture approach specifically a three-layered system architecture was adopted for the second objective.

RFID and GPS sensors are located at the perception layer and serve as data collection for the system. RFID with its technology for child identification using RFID tag and RFID reader installed in different locations along the way the child passes.

GPS sensor installed in the bus, with its technology, generated the coordinates for each school bus location.

GSM/GPRS module was used positioned at the network layer and its role was to send the collected data to the remote server for further processing and send SMSs.

Arduino UNO microcontroller integrated all system components being components at perception layer, at the network layer, and an application layer. The work of the Arduino UNO microcontroller together with Arduino IDE is executed at application layers to serve the system purpose.

It was planned to do a system survey research, however, due to time constraint, the researcher did not get the chance to carry out interviews with a sample of twenty parents and ten children picked randomly from Les Hirondelles de Don Bosco primary school located in Kicukiro District and the management of the school to inquire challenges wherein school, parents and children face associated with children transport. For a deep understanding of the real problem of a school bus system, the researcher was supposed to collect data from ten individuals who are key players in children's transport explicitly school bus drivers and bus owners. The information wanted are like how and what mechanism used to attribute a bus to a route or vice versa, time of pickup of children, number of the children per bus, time to commute, number of bus stops, etc. but due to time limit, this activity was not achieved.

After gathering all required information for the proposed system design, the researcher proceeded in the IoT prototype development concerning the three-layered IoT system architecture.

To realise the third and fourth objectives, the software architecture by modularity and the Goal Constraints and Module (GCM) process to predefine all pathways of the IoT prototype were adopted as the approaches to complete the two objectives.

1.8. System architecture

The system architecture of the proposed system is composed of 6 main units: Child unit, Home unit, School bus unit, School unit, Cloud unit, and Parent unit.

1) **Child unit**: Consisted of the child with his/her RFID card: a card with RFID embedded technology that serves to identify the child. Each child wears his or her card in a manner way it can serve its purpose.
2) **Home unit**: Consisted of RFID reader and connectivity to a remote server through connectivity. This unit serves to read the RFID tag on a child while he leaves home and returns home.
3) **Bus unit**: Consisted of a GPS sensor to track the movement of the bus and the speed limit and GSM/GPRS module to provide a connection to the remote server, of GPS and RFID reader and a mobile app of the driver for interactive with the application.
4) **School unit**: Consisted of RFID reader to read the RFID tag on a child while entering and exiting the school premises and connectivity to a remote server through connectivity, mobile app, and web application for communication and management with the system.
5) **Cloud unit**: data engine of the system that provides cloud services such as data storage, security, privacy, and execution of an instruction. It gives the view of data to end-users.
6) **Parent unit**: contained a mobile app and/or a web application connected to the remote server through the internet to allow a parent to use the application.

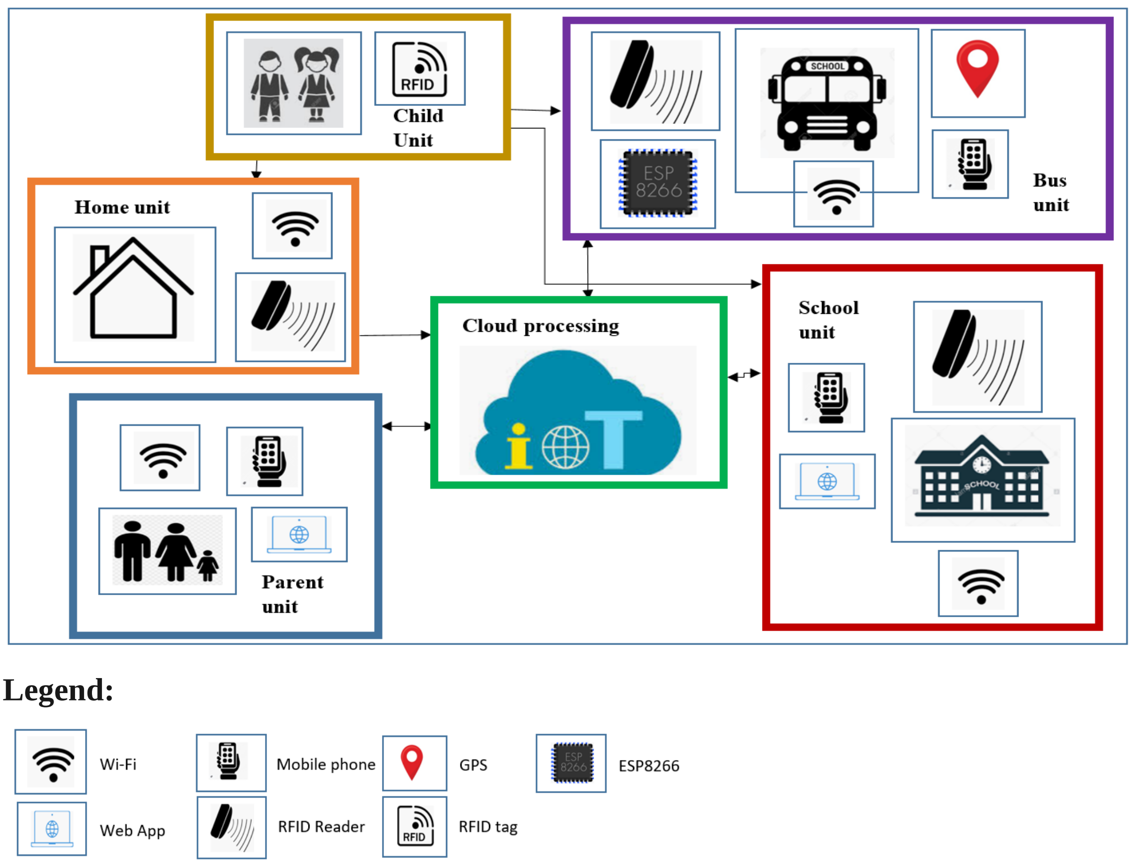

Figure 1: The proposed system architecture

1.9. System design

The system combines different components with different technologies; therefore, the system design adopted the multimodal IoT system design which consists of linking different devices, protocols, applications, and platforms. This provided the required interoperability, data privacy, security, interfaces of those different components of the system. The design defined all requirements of the system such as data type to be collected, how the communication among all system's components and system management.

The system design defined the process specifications that the system followed and the information model used by the system.

The system design also defined the services of the monitoring system: service types, service inputs/outputs, service endpoints, service schedules, service preconditions, and service effects. The system design defined which IoT level suitable for the proposed system.

Initially, the system initiated two modules: RFID and GPS modules when it starts, and puts ON GPS inside the bus and activates all RFID readers to be ready to communicate with the server. For the RFID module, the system created encrypted data of the children in the database to identify each child and generated code for each child. The encrypted data is then written to the tag that is carried by the children (the portable card to each child for his/her identification). The RFID module also verified the value on the tag until all tags are successfully encrypted. Once the tag approaches the RFID reader, it compares the card information to the data stored in the database.

This happens when a child passes his or her card to an RFID reader. At that stage, two services are executed, either the tag's value matches with one from the database, then the child is identified and the system recognises the action and sends the information to the remote server and goes to the next tag, or the tag value is not recognised and the RFID reader notifies the system and the card's owner that the wrong tag is used and go to the next tag. All communications are done through the Arduino microcontroller and GSM/GPRS module or Wi-Fi. All information is stored and executed to the remote server where notification is generated if requested.

For the GPS module, once the GPS is ON, it calculates the location by using the triangulation technique and then sends the information about the bus (location, the engine starts or shut down, speed limit) to the server through the connectivity from GSM/GPRS module or Wi-Fi if the bus has Wi-Fi inside. From the server-side, the notification module with its capabilities sends a notification to the dedicated destination when requested.

1.10. System algorithm

The system has the objective of monitoring the children while commuting to and from school and send a notification message containing the child's location. To achieve the system target, the system needs to perform three main tasks: identify the child, track the location of the child and send a notification.

To realise the purpose of the system, the three main modules are integrated into one microcontroller before sending all data to the server: RFID module for child identification, GPS module for bus tracking, and GSM/GPRS module to provide connectivity.

RFID module uses two objects: RFID tag for child identification and RFID reader to read the data from the tag and send them to the server. The RFID tag is configured with encrypted data in such a way the system recognises it through an RFID reader. If the tag used is not from the system, the RFID reader should be able to provide a notification of a not recognised tag if else it reads the information and sends it to the remote server through connectivity.

GPS module uses GPS sensor to track bus location and GSM/GPRS module to send location data to the server. Once the bus engine turns on, immediately the GPS starts to calculate the bus coordinates and the status of the bus engine (engine starts or shut down) and speed limit then sends the information to the remote server.

On a remote server, the application was designed to run all types of instructions/commands from the system’s components. If a child's location is requested, the application compares the identification of the child's location request in the database and provides the feedback accordingly.

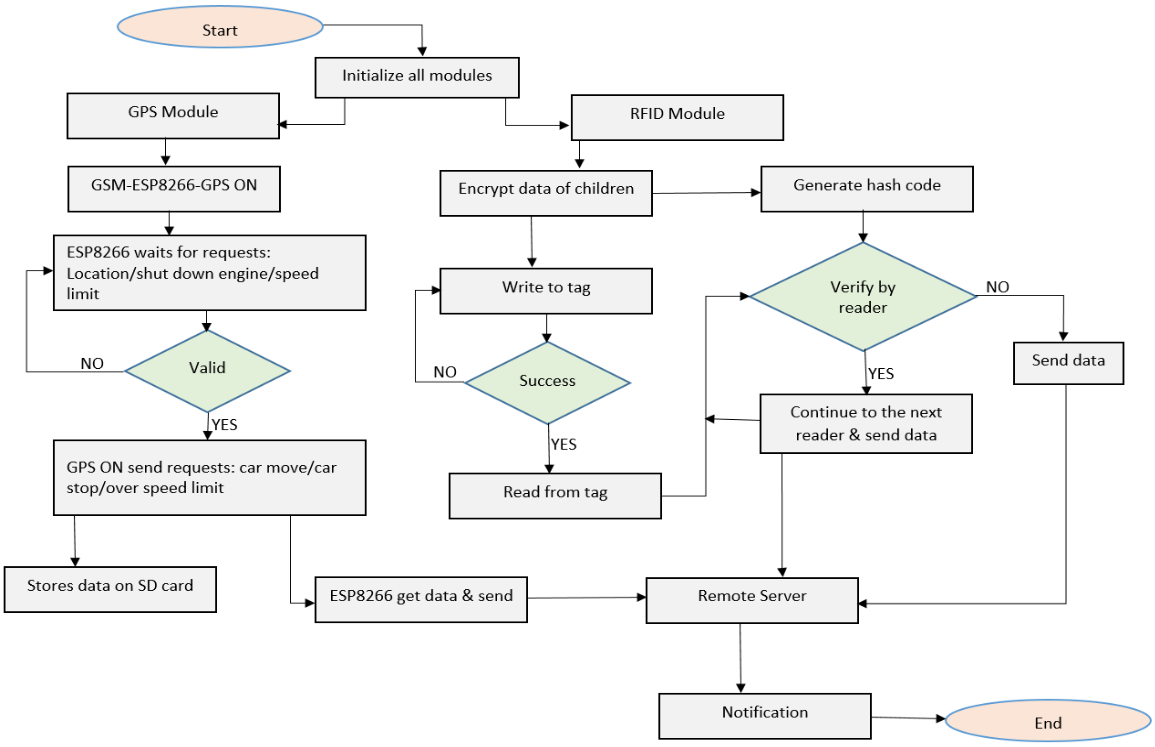

Figure 2: The proposed System algorithm

1.11. System prototype development

One of the specific objectives of this research is to simulate or develop the system prototype instead of developing the end product due to time constraints. Proteus simulation was supposed to be used as a simulator. But due to the simulation of a multimodal IoT system was a challenge with Proteus, the research switched the simulation into real prototype development even if there was a budget constraint. The prototype developed consisted of the following IoT components: The RC522 RFID module, NEO-6M-0-001 GPS module, SIM800L EVB, and Arduino Uno microprocessor. The prototype development was based on the system architecture, system design, and algorithm.

1.12. Anticipated outputs

This research work resulted in the following outputs:

- A literature review on RFID and GPS technologies to IoT based systems;
- An IoT multimodal of RFID and GPS technologies integrated into one application on a remote server;
- An algorithm of the system to guide the implementation of the developed multimodal.

- A simulation/prototype of IoT-based smart school bus monitoring and notification system.

1.13. Potential impact

To know where your beloved ones are located is essential especially when it is done in real-time and links parents and their children. It is noticeable that at the end of the research, different stakeholders of children transportation were happy to hear that there is a system that can help them, particularly parents who are concerned about their children's transport. The notification sent to parents positively affects parents as they can obtain in real-time information related to their children's location. School management gains the capability of monitoring and tracking the buses and bus drivers, and this can contribute at large children's safety while they go and come to and from school.

Data generated by the system would contribute to further studies or/and future researches. School bus transportation system is improved towards Smart transport which is a component of Smart Kigali the vision of our capital city.

CHAPTER 2: LITERATURE REVIEW

2.1. IoT overview

Back in 2015, Karen et al. [21] published "The Internet of Things: an overview". In their document, they defined the Internet of Things as an emerging topic of technical, social, and economic significance. Consumer products, durable goods, cars and trucks, industrial and utility components, sensors, and other everyday objects are being combined with Internet connectivity and powerful data analytic capabilities that promise to transform the way we work, live, and play. They continued by providing projections for the impact of IoT on the Internet and economy as impressive, with some anticipating as many as 100 billion connected IoT devices and a global economic impact of more than $11 trillion by 2025.

At the same time, however, they raised significant challenges of the Internet of Things that could stand in the way of realizing its potential benefits. The Internet of Things engages a broad set of ideas that are complex and intertwined from different perspectives [21].

The Internet of Things (IoT) is an important topic in the technology industry, policy, and engineering circles and has become headline news in both the specialty press and the popular media. This technology is embodied in a wide spectrum of networked products, systems, and sensors, which take advantage of advancements in computing power, electronics miniaturization, and network interconnections to offer new capabilities not previously possible [21].

On the other hand, the Internet of Things (IoT) as defined by Xiaolin Jia et al. [22] is a global network infrastructure, linking physical and virtual objects through the exploitation of data capture and communication capabilities. It will offer specific object identification, sensor, and connection capability as the basis for the development of independent cooperative services and applications. These will be characterized by a high degree of autonomous data capture, event transfer, network connectivity, and interoperability.

2.2. Human monitoring

2.2.1. Human monitoring – information background

The human activity monitoring technology is one of the most important technologies for ambient assisted living, surveillance-based security, sport and fitness activities, and healthcare of elderly people. The activity monitoring is performed in two steps: the acquisition of body signals and the classification of activities being performed [23].

2.2.2. Monitoring technology

Published by OSHwiki [24], monitoring technology systematically observes, keeps an eye on, or oversees and checks the progress or quality of something or someone over a while, based on a sensor or a set of sensors (e.g., sensing audio, vision, location, and biosignals). Regarding people, monitoring technology, or lifestyle or behavioural monitoring as it is sometimes called, forms a sub-set within a wider and more general model of remote technology as in telecare and security.

Sensors are installed on or in people and their environments, and they provide data from which their physiological state and behaviour can be derived. Often, normal physiological states and behaviour are distinguished from the unusual. In the unusual, we should at least distinguish between sudden anomalies (a heart attack or a fall) and gradual changes (e.g. slowly increasing stress levels) [24].

Monitoring technology can take several shapes, which can be roughly characterised using the modalities used [24]:

- Audio based (e.g. automatic speech recognition);
- Bio signals (e.g. electrocardiogram);
- Vision based (e.g. facial expressions);
- Text (e.g. Twitter messages);
- Blood samples (e.g. hormone levels);
- Interaction based (e.g. mouse and keyboard interaction, pressure sensors, a global positioning system (GPS));
- Questionnaires (e.g. using 5-point Likert scales); and
- Interviews (e.g. using a chatbot).

OSHwiki continued to inform that combinations of these are surprisingly rarely applied. The collection or capturing of such (big) data, however, is only part of the equation. Most likely, it is the simplest part. Subsequently, storage, sharing, and analysis are needed. Of the latter, in particular, the analysis itself already embodies a complex processing pipeline. Additionally, searching the data for patterns and decision support are often needed or at least preferred [24].

The commute of students from home to school and back has always been a source of concern for parents. Students often get on the wrong buses and get off at the wrong stops. Bus drivers may not be able to identify all the students and do not know in time if a student is missing. Parents have no way of knowing if their ward is safe until the evening when the bus returns.

While some schools have already implemented GPS tracking of buses using GSM and other means, they do not ensure absolute safety. Some of these devices do not give real-time information whereas some are too expensive to be a ubiquitous solution. A tracking system that does not identify individual students may also lull the guardians into a false sense of security [15].

2.3. Identification – RFID

The first thing to do before anything being monitored is to identify it, this allows to differentiate one from another. Ullah Aman [25] defined RFID as self-regulating technology which is used for various systems to help them carry out their functions based on object identification, data recording, and various objects controlling. An emblematic RFID system consists of two parts: tags (transmitters/responders) and readers (transmitters/receivers). The tag contains a microchip that is attached to an object, under tracking, and it works as an identifier of that object. On the other hand, RFID reader exchanges information with RFID tag regularly by using radio waves.

He continued by introducing the biggest advantage of RFID technology [25] as automatic object identification, data capturing, and cost reduction across a wide scale of business activities. The RFID technology had got momentum in the past decade due to the cost constraint in its implementation across a variety of businesses. RFID will bring many opportunities which will innovate the entire world politically, economically, and geographically.

RFID readers, distributed throughout the world, follow correct routing protocols to connect to the Internet. Afterward, a reader can exchange information for identification, tracking, and monitoring of objects based on tags they carry.

On the other hand, IoT means particular identifiable objects which are called “things” and their virtual presentation in IoT architecture. RFID is a prerequisite for the successful functioning of IoT systems. Objects in everyday life can be radio-tagged so that they could be identified and their information could be stored in real-time databases for research, analysis, planning and many more purposes [25].

2.4. IoT and RFID technology

2.4.1. Internet of Things architecture

The IoT system architecture is generally divided into three layers: the perception layer, the network layer, and the service layer (or application layer), as shown below figure [22] .

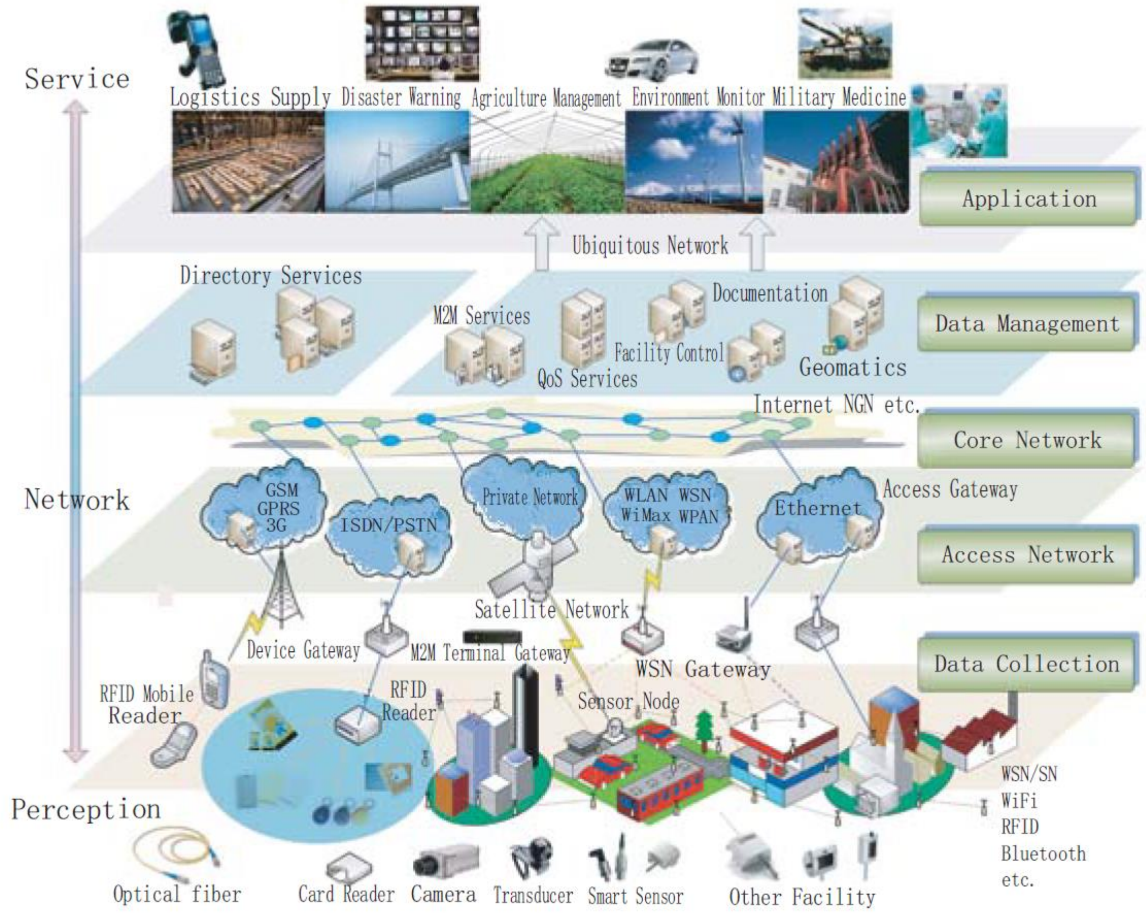

Figure 3: Internet of Things Architecture (Source [25])

Perception layer: It is the information origin and the core layer of IoT. All kinds of information of the physical world used in IoT are perceived and collected in this layer, by the technologies of sensors, wireless sensors network (WSN), tags and reader-writers, RFID system, camera, global position system (GPS), intelligent terminals, electronic data interface (EDI), objects, and so like [22].

Network layer: This layer, also called the transport layer, including access network and core network, provides transparent data transmission capability. By the existing mobile communication network, radio access network, wireless sensor network (WSN), and other communications equipment, such as a global system for mobile communications (GSM), general packet radio service (GPRS), worldwide interoperability for microwave access (WiMax), wireless fidelity (WiFi), Ethernet, etc., the information form perception layer can be sent to the upper layer. At the same time, this layer provides an efficient, reliable, trusted network infrastructure platform to the upper layer and large-scale industry applications [22].

Service layer: This layer, also called the application layer, includes the data management sub-layer and application service sub-layer. The data management sub-layer provides processing complex data and uncertain information, such as restructuring, cleaning, and combining, and provides directory service, market to market (M2M) service, Quality of Service (QoS), facility management, geomatics, etc. by service-oriented architecture (SOA), cloud computing technologies, and so on. The application service sub-layer transforms information into content and provides a good user interface for upper-level enterprise applications and end-users, such as logistics and supply, disaster warning, environmental monitoring, agricultural management, production management, and so forth [22].

2.4.2. RFID System

The RFID system is composed of three main components:
RFID tags, reader, application system [22] [25], as shown in Fig. 2.

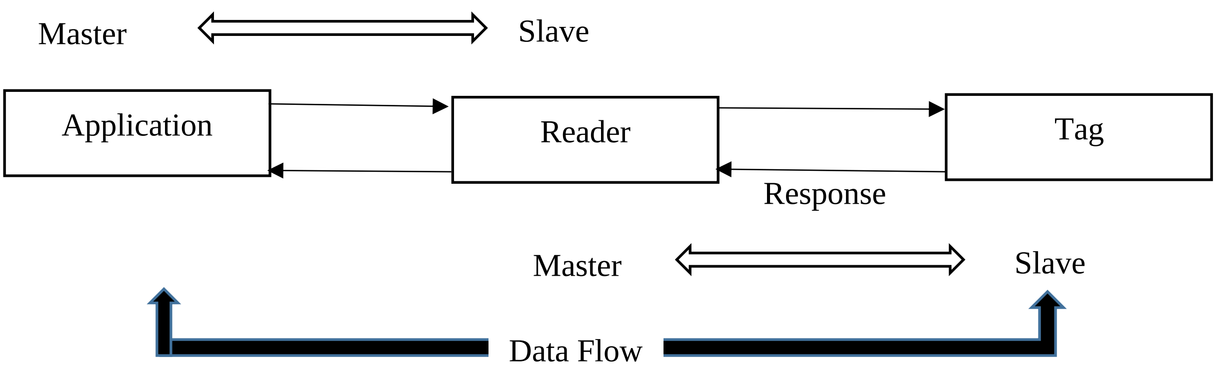

Figure 4: RFID Components

RFID tags: also known as transponders (transmitter/responder) are attached to the objects to count or identify. Tags could be either active or passive. Active tags are those that have partly or fully battery-powered, can communicate with other tags, and can initiate a dialogue of their own with the tag reader. Passive tags, on the other hand, do not need any internal power source but are powered up by the tag reader. Tags consist mainly of a coiled antenna and a microchip, with the main purpose of storing data.

Reader: also known as a transceiver (transmitter/receiver) made up of a radio frequency interface (RFI) module and control unit. Its main functions are to activate the tags, structure the communication sequence with the tag, and transfer data between the application software and tags.

Application system: also called data processing system, which can be an application or database, depending on the application. The application software initiates all readers and tags activities. RFID provides a quick, flexible, and reliable way for electronically detecting, tracking, and controlling a variety of items. RFID systems use radio transmissions to send energy to an RFID tag while the tag emits a unique identification code back to a data collection reader linked to an information management system. The data collected from the tag can then be sent either directly to a host computer, or stored in a portable reader and uploaded later to the host computer.

2.4.2.1 RFID Tags

RFID tags come in many different shapes, sizes, and capabilities. When an RFID solution is designed, the solution's architect must take into account both business and technology requirements before choosing the type of RFID tag to use [25]. All RFID tags have the following essential components in common: antenna, integrated circuit, printed circuit board (or substrate) [22].

The main responsibility of the antenna of the RFID tag is to transmit and receive radio waves for communication. The antenna is also known as the coupling mechanism, which can transform the energy in the form of electromagnetic radiation. This is the way the tag and reader communicating with each other. In a suitable environment and proximity to an RFID reader, the antenna can collect enough energy to power the tag's other components without a battery [22].

The integrated circuit (IC) is a packaged collection of discrete components that provide the brains for the tag. The IC in an RFID tag is much like a microprocessor found in any cellular phone or computer, but it is usually not very sophisticated. For many RFID tags, the IC component has only a single purpose, to transmit the tag's unique identifier (ID). If the tag has any peripheral components, the IC is also the master controller that is responsible for gathering any extra information and transmitting it along with the tag's ID [25].

The printed circuit board (PCB) is the material that holds the tag together. The circuit board may be rigid or flexible and is composed of many different types of materials, depending on the type and purpose of the tag. For example, tags that are used for tracking components on an assembly line where extremely high temperatures may be encountered would tend to be much more rigid and are usually placed inside a protective enclosure. Tags are built to comply with a categorization called a class [22].

Classes progressively have a greater capability. Electronic Product Code (EPC) global has defined six classifications for RFID tags (0 to 5). A general description of functionality that each class is required to comply is as follows [22] [25].

Class 0/class 1: These classes provide the basic radio frequency (RF) passive capability. Class 0 is factory programmed. Beyond class 0, including class 1, the tags are user-programmable.

Class 2: Additional functionality is added, which includes encryption and read-write RF memory

Class 3: Batteries are found onboard that will power logic in the computer circuit. Class 3 provides longer range and broadband communications.

Class 4: Active tags are part of the definition of class 4 tags. Peer-to-peer communications and additional sensing are also included.

Class 5: Class 5 tags contain enough power to activate other tags and could be effectively classified as a reader.

Passive tags, which have no built-in power source and the power is provided by the radio frequency wave created by the reader, are usually classified in the class 0 to 3 range. Class 4 describes active tags, which have an internal power source (a battery), that provides the necessary power for the operation of the tag over some time. Class 5 is reserved for tag readers and active tags that can read data from other tags.

2.4.2.2 RFID Reader

RFID readers are also referred to as interrogators because they query tags as the tags enter their read range. The reader is responsible for orchestrating the communication with any tags in its read range and then presenting the tags' data to an application that can make use of the data.

Readers in all systems can be reduced to two fundamental functional blocks: the control system and the high frequency (HF) interface, consisting of a transmitter and receiver, as shown in Figure below. The entire system is controlled by an external application via control commands [25].

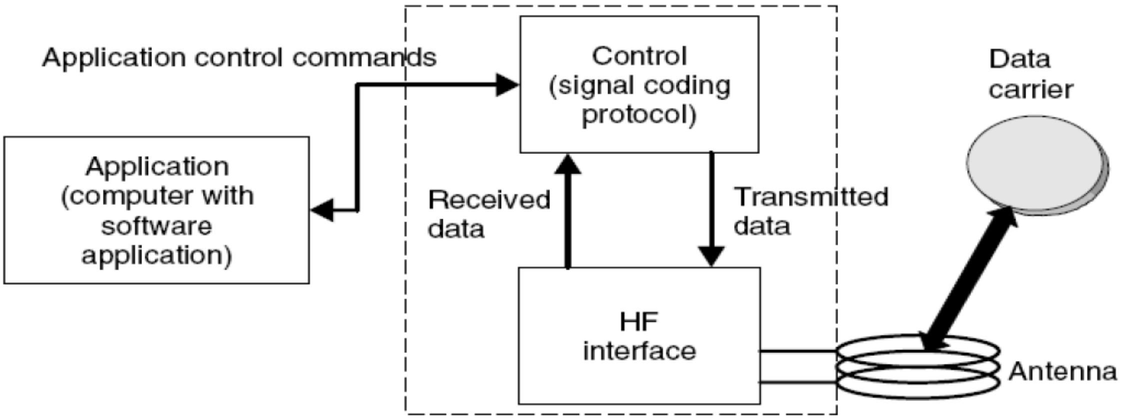

Figure 5: Control system and HF interface of RFID Reader (Source [22])

The reader's HF interface performs the following functions [22]:

a) Generation of high-frequency transmission power to activate the transponder and supply it with power;
b) Modulation of the transmission signal to send data to the transponder;
c) Reception and demodulation of HF signals transmitted by a transponder.

The reader's control unit performs the following functions [25]:

a) Communication with the application software and the execution of commands from the application software;
b) Control of the communication with a transponder (master-slave principle, as shown in Fig. 4);
c) Signal coding and decoding. In more complex systems the following additional functions are available:
d) Execution of an anti-collision algorithm;
e) Encryption and decryption of the data to be transferred between transponder and reader;
f) Performance of authentication between transponder and reader.

The control unit is usually based upon a microprocessor to perform these complex functions. Cryptologic procedures, such as stream ciphering between transponder and reader, and also signal coding, are often performed in an additional ASIC (application-specific integrated circuit) module to relieve the processor of calculation-intensive processes.

2.5. Vehicle tracking

2.5.1 Vehicle tracking - Information background

Historically, vehicle tracking has been accomplished by installing a box into the vehicle, either self-powered with a battery or wired into the vehicle's power system. For detailed vehicle locating and tracking this is still the predominant method; however, many companies are increasingly interested in the emerging cell phone technologies that provide tracking of multiple entities, such as both a salesperson and their vehicle. These systems also offer to track calls, texts, and web use and generally provide a wider range of options [26].

A vehicle tracking system combines the use of automatic vehicle location in individual vehicles with software that collects these fleet data for a comprehensive picture of vehicle locations. Modern vehicle tracking systems commonly use GPS or global navigation satellite system (GLONASS) technology for locating the vehicle, but other types of automatic vehicle location technology can also be used.

Vehicle information can be viewed on electronic maps via the Internet or specialized software. Urban public transit authorities are an increasingly common user of vehicle tracking systems, particularly in large cities [26].

On the other hand, tracking vehicles can be defined as monitoring the location of a truck, car, or any moving vehicle using the GPS. Widely deployed to keep track of truck fleets, vehicle tracking ensures that the vehicles are being used properly and that they can be recovered in the event they are stolen [27].

2.5.2 Vehicle tracking – GPS

Vehicle tracking relies both on the Global Positioning satellites (GPS) and a cellular system. A tracking module in the vehicle continuously picks up the GPS coordinates that indicate the real-time location of the vehicle. Using a cellular data service, the coordinates are immediately transmitted to the tracking system located somewhere. Customers log in to the tracking system website to see their vehicles on road maps, similar to in-dash and handheld GPS-based navigation systems [27].

A small unit containing a GPS tracker for cars, or a GPS tracker for trucks is installed in each of the fleet’s vehicles. This unit allows to monitor the movement of all vehicles: where they are, where they were, when they began the journey, where they stopped and for how long, and so on [28].

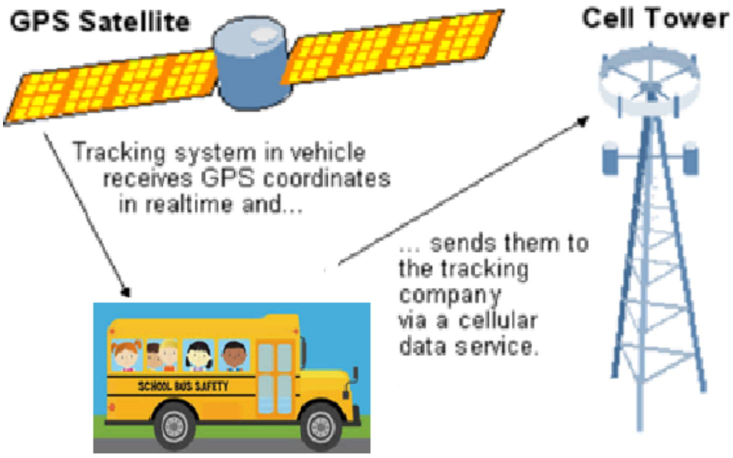

Figure 6: Vehicle tracking system

2.5.3 Offline vehicle monitoring

There are non-real-time tracking systems in which the in-vehicle module records the coordinates, but does not relay them for real-time monitoring. The data are downloaded from the module when the vehicle is returned at the end of the trip [27].

2.5.4 Two types of tracking

Several types of vehicle tracking devices exist. Typically, they are classified as "passive" and "active". Passive devices store GPS location, speed, heading, and sometimes a trigger event such as key on/off, door open/closed. Once the vehicle returns to a predetermined point, the device is removed and the data downloaded to a computer for evaluation. Passive systems include auto download types that transfer data via wireless download. "Active" devices also collect the same information but usually transmit the data in near-real-time via cellular or satellite networks to a computer or data centre for evaluation [26].

Many modern vehicle tracking devices combine both active and passive tracking abilities: when a cellular network is available and a tracking device is connected it transmits data to a server; when a network is not available the device stores data in internal memory and will transmit stored data to the server later when the network becomes available again.

2.5.5 GPS technology

Major constituents of the GPS-based tracking are [29]:

GPS tracking unit: The device fits into the vehicle and captures the GPS location information apart from other vehicle information at regular intervals to a central server. Other vehicle information can include fuel amount, engine temperature, altitude, reverse geocoding, door open/close, tire pressure, cut off fuel, turn off the ignition, turn on the headlight, turn on taillight, battery status, GSM area code/cell code decoded, number of GPS satellites in view, glass open/close, emergency button status, cumulative idling, computed odometer, engine RPM, throttle position, GPRS status and a lot more. The capability of these devices decide the final capability of the whole tracking system; most vehicle tracking systems, in addition to providing the vehicle's location data, feature a wide range of communication ports that can be used to integrate other on-board systems, allowing to check their status and control or automate their operation.

GPS tracking server: The tracking server has three responsibilities: receiving data from the GPS tracking unit, securely storing it, and serving this information on demand to the user.

User interface: The UI determines how one will be able to access information, view vehicle data, and elicit important details from it.

2.5.6 Use case

Vehicle tracking systems are normally used by fleet operators for fleet management functions such as fleet tracking, routing, dispatching, on-board information, and security [26]. Some vehicle tracking systems are hustled with or interface with fleet management software. Along with commercial fleet operators, urban transit agencies use the technology for several purposes, including monitoring schedule adherence of buses in service, triggering automatic changes of buses' destination sign displays once the vehicle approaches the bus terminus (or other set location along a bus route such as a particular bus stop along the route), and triggering pre-recorded (or even synthetic speech) bus stop, route (and its destination) or service announcements for passengers.

The American Public Transportation Association estimated that, at the beginning of 2009, around half of all transit buses in the United States were already using a GPS-based vehicle tracking system to trigger automated stop announcements [30]. This can refer to external announcements triggered by the opening of the bus's door at a bus stop, announcing the vehicle's route number and destination, primarily for the benefit of visually impaired customers, or to internal announcements to passengers already on board identifying the next stop, as the bus approaches a stop or both; the latter is often also displayed on an internal LED display or LCD monitor connected to the system while the loudspeakers play them.

Data collected as a transit vehicle follows its route is often continuously fed into a computer program which compares the vehicle's actual location and time with its schedule, and in turn produces a frequently updating display for the driver, telling him/her how early or late he/she is at any given time, potentially making it easier to adhere more closely to the published schedule [26].

Such programs are also used to provide customers with real-time information as to the waiting time until the arrival of the next bus or tram/streetcar at a given stop, based on the nearest vehicles' actual progress at the time, rather than merely giving information as to the scheduled time of the next arrival. Transit systems providing this kind of information assign a unique number to each stop, and waiting passengers can obtain information by entering the stop number into an automated telephone system or an application on the transit system's website [31].

Other applications include monitoring driving behaviour, such as an employer of an employee, or a parent with a teen driver.

Vehicle tracking systems are also popular in consumer vehicles as theft prevention, monitoring, and retrieval device. Police can simply follow the signal emitted by the tracking system and locate the stolen vehicle. When used as a security system, a Vehicle Tracking System may serve as either an addition to or replacement for a traditional car alarm. Some vehicle tracking systems make it possible to control the vehicle remotely, including block doors or engines in case of emergency. The existence of a vehicle tracking device then can be used to reduce the insurance cost, because the loss-risk of the vehicle drops significantly [26].

2.6. Proposed tracking system based on IoT concept

Vehicle tracking systems are widely used worldwide. Components come in various shapes and forms but most use GPS technology and GSM services. Newer Vehicle tracking systems also use the latest Narrowband - IoT technology [26] that can provide low power consumption and optimized data transmission rates. Furthermore, these systems may also feature short-range data communication systems such as Wi-Fi. While most will offer real-time tracking, others record real-time data and store it to be read, in a fashion similar to data loggers. Systems like these track and record and allow reports after certain points have been solved.

Examples of the system based on IoT concept:

1. IoT-based Vehicle Tracking & Vehicular Emergency System [32]: system consists of three main units, which coordinate with each other and make sure that the ambulance reaches the hospital without any time lag. It has three main components:
   - The vehicle unit and the ambulance unit
   - The Traffic unit
   - Main Server

The vehicle unit consists of a controller, ADXL sensor, GPS. The vehicle unit is installed in the vehicle and every vehicle should have a vehicle unit. The vehicle unit consists of a controller, MEMS sensor, GPS.

The vehicle unit installed in the vehicle senses the accident and sends the location accident to the main server. The vibration sensor used in the vehicle will continuously sense for any large-scale vibration in the vehicle. The sensed data is given to the controller. GPS module finds out the current position of the vehicle which is the location of the accident and gives that data to the IoT Web server. The accident location is then conveyed to the main server unit that houses the database of all the nearby hospitals and sends an ambulance to the accident spot. This information to the main server is conveyed by the GPS module. The location information is given to the ambulance which helps it to reach the accident location immediately to save the casualties. The web-based tracking system is a system designed using a combination of several modern information and communications technologies. The system comprises vehicle-mounted tracking devices, a central server system, and a web-based application.

2. Vehicle Detection and Tracking System IoT based [33]: system model makes use of Raspberry Pi interfaced with USB or Pi camera instead of using powerful workstations, traffic surveillance cameras. This system is portable. Raspberry pi is accessed by remote computers, android devices, or laptops and makes provision for view selection. Because of the static IP address assigned to the Raspberry system, it enables them to communicate it with other remote computers.

2.7. Human and vehicle monitoring summary

Human safety is an important issue due to the sudden rise of crimes and accidents. To resolve this issue a proposal of a Human Tracking System based on GPS (Global Position System) and Internet of Things (IoT) that has dual security features was initiated. The proposed systems incorporate the available technical know-how in sensors (RFID, GPS, etc.) to track, monitor, and assist a child in different situations. The proposed systems may be utilized by children in school buses. The proposed concept of developing such a device is to create an environment where a child can be located at any time thus reducing the cost and efforts involved to track them by several means.

CHAPTER 3: SYSTEM DESIGN AND ARCHITECTURE

3.1. Architectural System

The architecture of a system is a high-level description of the entire system that explains the required architecture elements and their services as well as the principles that the elements shall maintain while communicating and working together [34].

IoT is well-rooted to embedded systems as well as several technologies like pervasive systems and sensor networks [35]. IoT is a system where the “things” used as an individual or as a group are connected via a network (over Internet protocol) to collaborate and perform some tasks while interacting with the digital and physical world. [35]

To design the Smart School Bus (SSB) monitoring and notification system using RFID and GPS in short SSB, the IoT architecture model was adopted.

3.1.1. IoT architecture

The development of a complete IoT system and service includes several components. A key aspect of the IoT Architecture is the data sampling [35], which can be:

– **Periodic sampling**: based on digital signal processing and control with time-series data. Power is needed for sensing and communication; while wireless communication requires large amounts of power. Bandwidth demand is high since data from the sensor has to be communicated at every k^{th} period, regardless of the data quality.

– **Aperiodic sampling**: based on event; hence useful to relax the resource (e.g. power and bandwidth) constraints. Sampling here refers to the acquisition of data from the environment which reflects a certain state that is relevant for the system (input), e.g., temperature, motion, speed, etc.

The Smart School Bus system can be categorised as aperiodic sampling because it reacts when the child passes nearby the key point (RFID reader) or anyone requests information from the system at any time.

Important considerations in IoT development may include power and bandwidth constraints, as well as data validation and verification: Is the data valid to be sent? (What is the relevance of reporting the same value at every k^{th} period if the value is not changing)? Is the data coming from the right source?

The data captured at the sensor might need filtering, and need to be pre-processed before sending it for use (application).

Since the application of IoT is not limited to a particular domain, the complexity and requirements also vary across various systems. In some applications, it may need to monitor the various remotely deployed devices and also make use of cloud computing, while for some applications this only sensing and actuation are enough [34]. For example, an IoT system meant to control home appliances in a smart-house may not has the same requirements as a smart irrigation system that make use of whether information processing (using cloud service).

IoT requirements can be broadly classified to [35]:

- **Perception**: collecting data from the physical world with less or no intervention of the user, hence various sensors are used.
- **Pre-processing**: collected data can be pre-processed before relayed over a network; this also includes data filtering.
- **Communication**: different entities, the “things” need to accomplish the task, need to communicate using various protocols and standards.
- **Application**: the data collected and communicated ultimately need to be processed to meet the end-user (business/individual user) needs while improving the user experience. This may include taking action with less or no intervention by the user, hence actuators can be used.
- **Monitoring**: it is important to monitor the environment and resource (a scarce resource).

These requirements can be addressed if architectural elements are delivering the respective service, and the architecture of IoT systems may vary across the application domain.

Though no particular consensus on the architecture, the layered approach has become predominant in IoT, particularly three-layered or five-layered.

Table 1: Generic system requirements in IoT

Feature	**Description**
Flexibility	The system should ensure its services components and services reusability and composability
Compatibility	Integrate numerous information from several devices and protocols in an easy way
Responsiveness	Respond and/or allow rearrange IoT platform components.
Security	Take security measurement of IoT system

Privacy	Allow access to personal information to only authorized users.
Service-Oriented	Offered services in front.

Table 2: Generic user requirements in IoT

Goal	**Description**
Usability	User friendly
User experience	Enjoyable to use
Personalisation	Allow customisation
Unobtrusiveness	Not remarkable
Minimum user input	Minimum possible inputs from the user

3.1.1.1 Three-layered model

This architecture organizes the services needed to meet the requirement into three levels [35]:

– **Perception Layer**: Responsible for delivering application-specific service.
– **Network Layer**: Responsible for connectivity and processing the raw data captured from sensors in such a way it is meant for use.
– **Application Layer**: Capturing information from the environment. Predominantly sensors are used to sense and gather information from the physical environment.

1. **Perception Layer**

Any computing is about collecting data (input), processing, and delivering information for further processing or action (output). But how the data collection, processing, and actuating the action might vary across technologies and computing principles [34].

Data can be collected explicitly as user input or implicitly by observing the environment (physical environment, user environment, and/or the digital environment). In IoT, sensors are widely used to collect data from the physical environment, human or digital.

Sensors (electrical sensors) are key players at the perception layer, they are the bridge between the physical world and the digital world. The phenomena in the physical world, which is made of atoms, are in the form of physical variable and is based on analog signals. Whereas, the computing world demands information to be digital. Sensors bridge this gap as they can devices that convert a physical variable into an electrical signal [35]. Sensors are a type of transducer that converts some physical phenomenon such as heat, light, sound, humidity, etc. into electrical signals. Any device which can convert one form of energy into another form is called a transducer [35]. For example, even a speaker can be called a transducer as it converts the electrical signal to pressure waves (sound).

A wide range of variables can be perceived from the environment for digital processing (temperature, humidity, soil moisture, light intensity, sound, pressure, wind (speed, direction), position, proximity, displacement, acceleration, orientation, heath, smoke, motion, vibration, RF, water (level, flow, quality, turbidity, PH, pollution, particulates), gas, radioactivity, etc.).

2. Network Layer

Stimuli from the environment can be received by the sensor and will be converted into digital information, however, this information has to be interpreted in such a way it is meaningful to the desired application. The information (often after interpretation) shall be communicated for decision making and/or further processing [34]. In the three-layered model, the network layer is mainly responsible to connect the "things" and process the data captured from the sensor and communicate the data to the upper layer.

3. Application Layer

The data after captured and interpreted in the context of the user can be then used to make a decision and/or as input for further processing, and this is done at the application layer [34]. For instance, in the ultrasonic, the calculated distance may require actuation on a vehicle brake system.

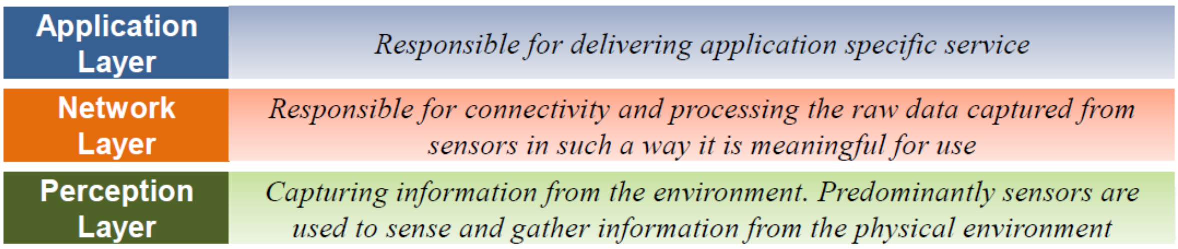

Figure 7*:* The three-layered model Diagram adapted *[36]*

3.1.1.2 Five-layered model

In the five-layered model, the services provided at the network layer of the three-layered model split into two layers – the Transport Layer and Processing Layer. Also, a Business Layer is newly added as management would become important when the IoT system becomes wider and complicated [35].

1. Transport Layer

This layer transport data from the perception layer to the application layer. Various wireless and/or wired mediums could be used such as UTP-LAN, Bluetooth, RFID, Wi-Fi, NFC, etc. [34].

2. Processing Layer

Data processing as per the user (system) requirements is done at this layer. The processing may employ various storage and computing models and technologies; such as cloud computing, web services, big data, database systems, etc. [34].

3. Business Layer

As the IoT system becomes complex, management will become an important aspect to consider. All four layers focus on responsibilities to meet the functional requirements

- Perception layer – data input
- Processing layer – does the processing
- Application layer – information output as specific service
- Transport layer – connecting and three layers to relay data between the layers

The management on the other hand handles the non-functional requirements aspect to assure the proper delivery of the functional requirements. Therefore, the business layer is responsible for managing applications, remotely devices (e.g., does the device function properly), business and process models, and privacy and security [34].

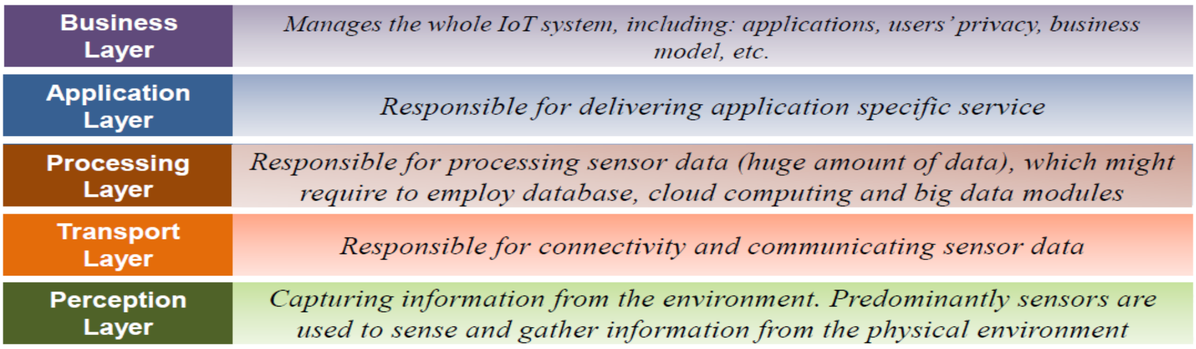

Figure 8: Five layered model Diagram adapted *[36]*

The processing segment may include various processing strategies such as distributed or centralized. Cloud computing has become one important platform to support processing demands in IoT, especially when the processing comes to large and complex data processing. This often demands to follow a client-server model where the clients are thin-client. However, the system requirement might demand faster processing and response time. In such case, additional layers could be required to do additional processing, storage, and monitoring; and also, to maintain security [35].

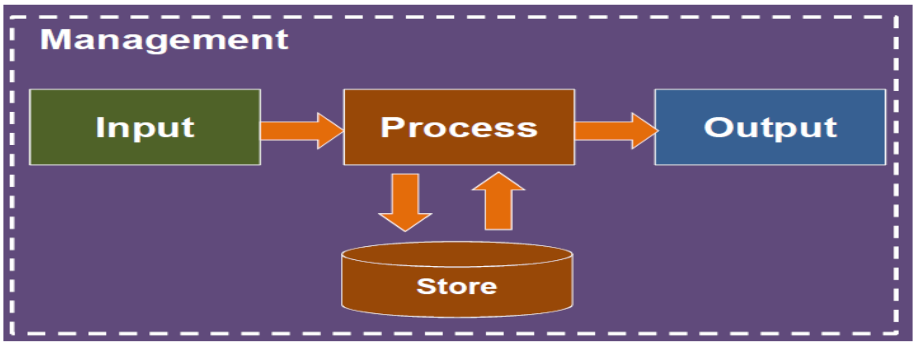

Figure 9: Von Neumann Architecture

The additional layers, while creating fat-client or servers at the edge of networks, they also lead to the Fog Computing model. Monitoring and pre-processing are done at the gateway level on the edge of the network before the data is sent to the cloud. These layers come between the transport and the perception (physical) layers [35].

Security Layer: Performs encryption/decryption and ensures data integrity and privacy.
Temporary Storage Layer: Provides storage functionalities such as data replication, distribution, and caching.
Pre-processing Layer: Performs data filtering, processing, and analytics over sensor data.
Monitoring Layer: Monitors power, resources, responses, and services.

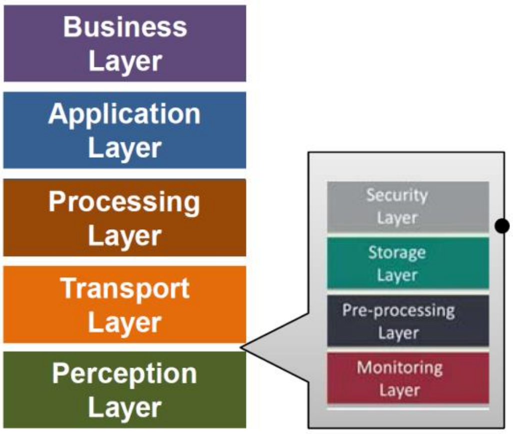

Figure 10: Another architecture model useful to IoT

3.1.2. SSB three-layered architecture

From the above perspective of IoT architecture, the Smart School Bus Monitoring and Notification System using RFID and GPS in short SSB adopted three-layered architecture as its IoT architecture with its three layers distributed as follows:

The SSB system high-level architecture consists of sensors at the perception layer, wireless communication at the network layer, and cloud services at the application layer.

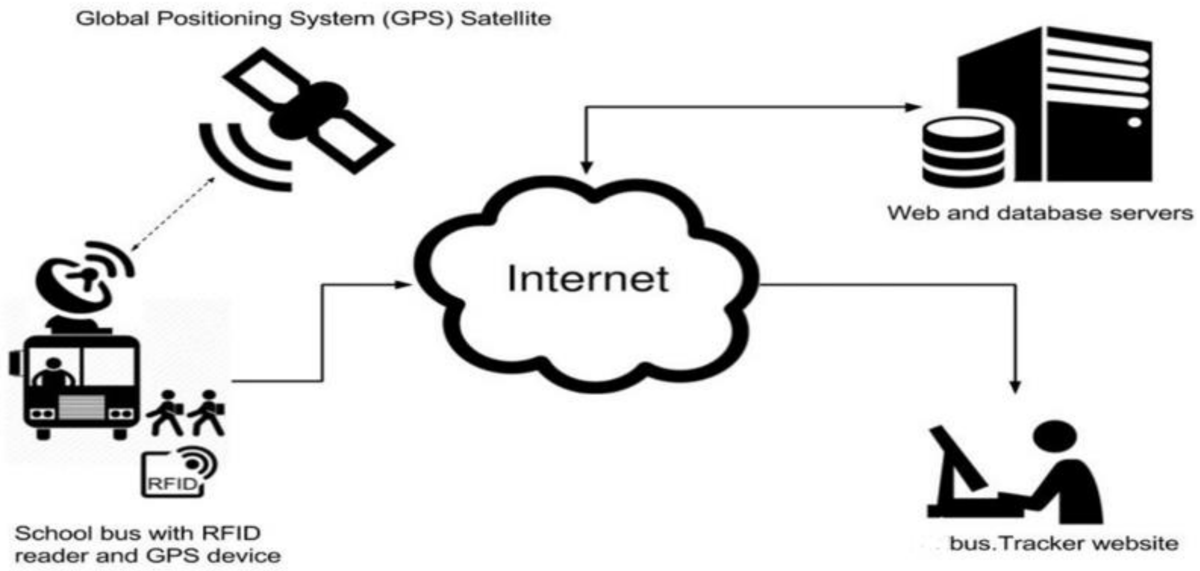

Figure 11: RFID - GPS Bus Tracker System Architecture

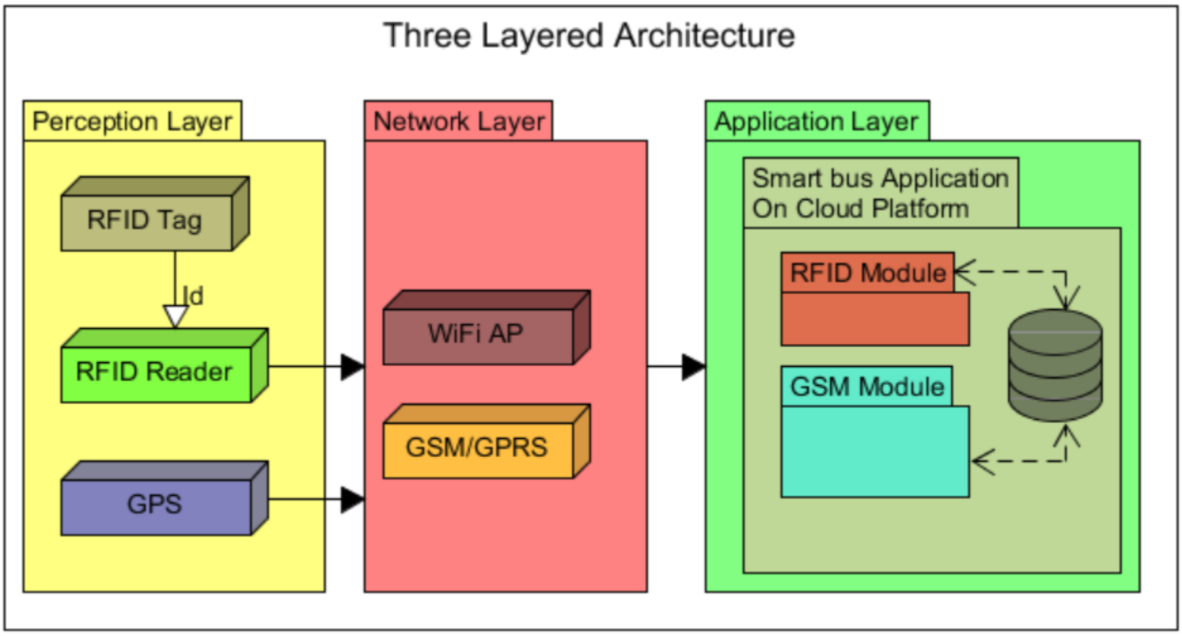

Figure 12: SSB three-layered architecture

The three-layered architecture of the SSB system is composed of six (6) main components and seven (7) sub-components connected all together in three layers: Child component, Home component, School bus component, School component, Cloud component, and Parent component.

1. **Child** component: RFID card or a smart card: a card with RFID embedded technology that serves to identify the child. Each child wears his or her card in a manner way it can serve its purpose. Different scenarios can be observed on the way the child would carry it. It can be attached to the bag, carry it on hands… To be determined at the implementation stage.
2. **Home** component: composed of an RFID reader and connectivity to a remote server through Wi-Fi, this unit serves to read the RFID tag on a child while he leaves home and returns home.
3. **Bus** component: composed of GPS sensor to track the movement of the bus and the speed limit and GSM/GPRS module for sending GPS data to the remote server, RFID reader to read the RFID tag on a child while entering and leaving the bus and connectivity to a remote server through a connection and mobile phone of the driver to provide communication with the core application.
4. **School** component: composed of the RFID reader to read the RFID tag carried by the child while entering and exiting the school and connectivity to a remote server through Wi-Fi, mobile phone, and web application for communication and management with and of the system.
5. **Parent** component: composed of either a mobile app or a web application or both and connectivity to the remote server through the internet to allow parents to monitor their children through the application.
6. **Cloud** component: data engine of the system from cloud services such as data storage, security, privacy, and execution of the instructions.

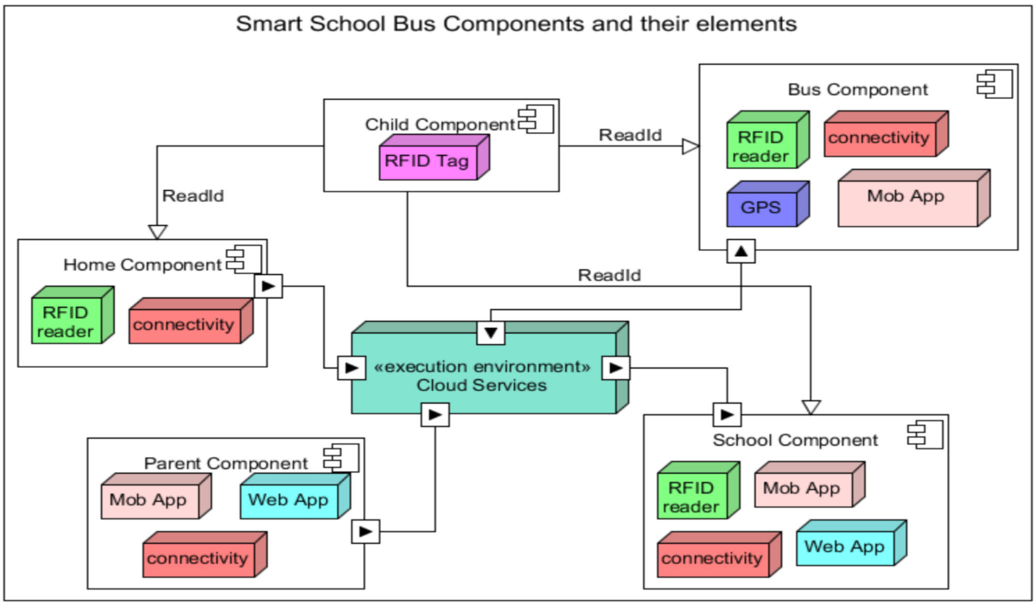

Figure 13: Smart School Bus Components and their elements

3.1.3. SSB System Design

The SSB system is a hybrid system, it combines different components with different technologies, and this gives the system be heterogeneous design system. The system design is likely to be intelligible and does not necessitate explicit familiarity or working out. The main SSB feature allows a programmed way of thing fitting together, and at the same time, it delivers straight or circuitously always responsive services because it offers unified interconnectivity between computation and non-user interface devices.

3.1.3.1. Comparison between the SSB system to others IoT Systems

The comparison was conducted in two system features: device-based and user-oriented systems.

Device-based system: Associating the SSB with a typical device-based system (see Table 1) some resemblances can be highlighted as the sturdiest characteristics were used as a fundamental basis for designing the SSB system. The system is with enlarged complexity that includes identification mechanisms, reliable privacy, tracking notification management. In assessment to other school bus systems, the SSB system enables child identification by identity data management.

User-oriented system: The SSB is a user-friendly system that has user uniqueness and this identity is achieved by including in the architecture Item Registration component. To offer autonomous broadcast of communications utilizes notification component. The SSB inquiry option with its algorithm outspread tracking abilities to pursue and discover children's location and provides to requester built on pre-defined configurations. The SSB system is web-based access to services. The required pre-communication relationship established between the parties is also present in both user-oriented systems.

3.1.3.2. Main components of SSB

The SSB system has six main components and seven sub-components or elements dispatched as follows:

Table 3: SSB Components and their elements

System component	**System elements**
Child	RFID tag

Parent	Mob App, Web App, and Connectivity
Home	RFID Reader and Connectivity
Bus	RFID Reader, GPS Receiver, Connectivity, and Mob App
School	RFID Reader, Connectivity, Web App, and Mob App
Cloud	Cloud Services

1. **RFID tag**

A tag (also called a transponder or transceiver) is a small device equipped with a microchip carrying data and an antenna. There are two types of tags; active and passive.

Passive tags require no power and are much more common. Incoming radio waves induce an electrical current in the antenna, just strong enough to feed the tag’s circuit and send out a response. Due to constraints in the on-board power supply, passive tags have a relatively short range of operation (from about 10 mm up to about 5 metres, but typically a few centimetres) and can only transmit a limited amount of information. Yet, the lack of a power supply gives passive tags their unique and main selling point, that they can be very small in size. One of the smallest passive RIFD chips, Hitachi’s "μ-chip", is only 0.4mm x 0.4mm in size and barely visible with the naked eye. It contains a unique 128-bit number that is written onto the chip during the manufacturing process and cannot be changed [37].

Active tags function the same way as their passive counterparts, except that they have their power source and thus longer ranges (dozens of metres) and more memory. Because of this power source, active tags today are bigger and more expensive. Becoming smaller and cheaper, they might be the choice of the future. For example, a new generation of active tags called "Dice" was presented by YRP Ubiquitous Networking Labs in April 2005. They are about 15mm x 15mm x 15mm and according to the manufacturer, the battery will last for 2 years and 3 months if the tag communicates every 5 minutes. If manufactured in volume, the price of a "Dice" tag will be at the “lower end of several dollars" [37].

Depends on the vendor, the application, and type of tag, but typically a tag carries no more than 2 kilobytes (KB) of data—enough to store some basic information about the item it is on. Simple “license plate” tags contain only a 96-bit or 128-bit serial number. The simple tags are cheaper to manufacture and are more useful for applications where the tag will be disposed of with the product packaging. The aerospace industry wants to store parts histories on high memory tag, which has led to the introduction of passive UHF tags that store 4KB or 8KB of data [38].

2. RFID reader

A reader communicates with a tag to capture the data stored in the tag. The reader usually sends a low-power radio signal to activate the tag and the tag then sends data back to the reader. Most readers are – as their name suggests – only capable of reading data, although some also can write to certain tags. Normally, readers forward the data to other systems (such as PCs) for subsequent processing. In comparison to tags, readers consume more power, are larger and more expensive. RFID systems use radio signals to communicate, but only certain frequency bands are available for license-free use. There is international variation in the frequencies and power levels available for RFID systems. Due to different national regulations, an RFID system produced in one country may not work in another country. Four different kinds of frequencies are currently used: Low frequency (125 to 134 kHz), High frequency (13.56 MHz), Ultra High Frequency (868 to 956 MHz), and Microwaves (2.45 GHz). The main differences are in the Ultra High-Frequency band, where for example the EU (865-868 MHz, 869.4-869.65 MHz), the USA (902-928 MHz), Korea (908.5-914 MHz), Australia (918-926 MHz) and Japan (950-956 MHz) use different frequencies and the power limits [37].

3. GPS receiver

Global **P**ositioning **S**ystem (GPS) is a satellite-based system that uses satellites and ground stations to measure and compute its position on Earth. GPS receivers are generally used in smartphones, fleet management systems, military, etc. for tracking or finding a location. GPS is also known as Navigation System with Time and Ranging (NAVSTAR) GPS.

GPS receiver needs to receive data from at least 4 satellites for accuracy purposes. GPS receiver does not transmit any information to the satellites. GPS receiver uses a constellation of satellites and ground stations to calculate accurate location wherever it is located [39].

These GPS satellites transmit information signals over radio frequency (1.1 to 1.5 GHz) to the receiver. With the help of this received information, a ground station or GPS module can compute its position and time. GPS receiver receives information signals from GPS satellites and calculates its distance from satellites. This is done by measuring the time required for the signal to travel from the satellite to the receiver. To determine distance, both the satellite and GPS receiver generate the same pseudocode signal at the same time. The satellite transmits the pseudocode; which is received by the GPS receiver. These two signals are compared and the difference between the signals is the travel time.

Now, if the receiver knows the distance from 3 or more satellites and their location (which is sent by the satellites), then it can calculate its location by using the trilateration method.

4. **Connectivity**

Connectivity is one of the chief units of an Internet of Things (IoT) infrastructure, along with sensors/devices, data processing & user interface. For a device to step into the realm of the Internet of Things, it must be able to communicate with other devices. Different applications demand different sets of properties of connectivity, and fortunately, there's an overwhelming number of options (with the availability of multiple providers for each) and the count is still on the rise. The connecting technologies differ in their trade-offs among power consumption, range, bandwidth, security, and cost [40].

In an ideal world, the ultimate one-size-fits-all connectivity solution would offer extremely low-power consumption for the devices while retaining the ability to quickly transmit huge chunks of data over long distances, with all of this provided at prices low enough for the smart businesses to remain economically viable. However, given the inherent heterogeneity of use cases within the Internet of Things, the sad truth is that no existing or near-future communication protocol will be able to accommodate all the possible smart applications while granting them no compromises in terms of the above-mentioned crucial IoT connectivity factors [41].

Choosing the right wireless technology is critical, thus, finding the best solution for a given project always involves negotiating a balance between three fundamental connectivity parameters: range, bandwidth, and power consumption. Consequently, the ability to recognize project requirements in every stage of its deployment and in-depth knowledge of the IoT use case specifics will greatly support the process of choosing the best-suited connectivity network for the smart enterprise [41].

3.2. Software Architecture

Ultimately, the software is used at the business layer for management, control, security, etc. (i.e. adding new supplier on the smart gas controller system or registering assets in the system on the asset tracking system) at the application layer to meet the requirement by exercising the use case and at processing layer for data filtering, aggregation, etc. [34].

Software architecture is therefore important to be considered, especially to describe the structure of the system at the upper layers.

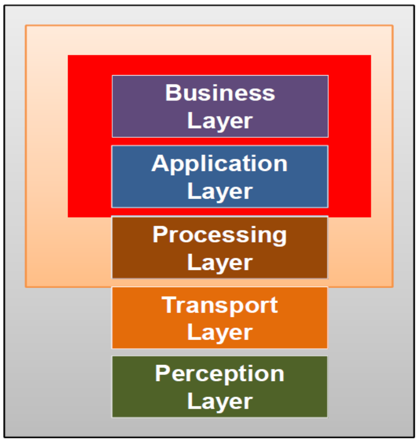

Figure 14: Upper layers responsible for Software Architecture

Software architecture mainly is based on modularity and the concept of modules may vary between programming languages:

- The module can refer to the encapsulation of data and functions;
- In some cases, it might also refer to the collection of several functions/classes, which is also referred to as a package.

Whichever concept is considered, it is about the decomposition of the larger system into smaller and manageable systems, which can be called a subsystem.

Modularity is about a logical partitioning of a system considered as a technique for systematically slicing complex software to be manageable for implementation and maintenance. The logic of partitioning, often, is based on functional dependency or data dependency [34].

Decomposition might focus on the grouping use cases related to specific actors, and common use cases can be grouped into subsystems based on the various cohesion and coupling consideration or the functional relationship of the use cases. Note that an actor can have roles in unrelated functions. Subsystem creation can be applied by grouping classes as an approach. Mainly subsystem is characterized by the service it provides [34].

A system needs to be modularized yet the modules need to be interdependent. A good system is required to be loosely coupled with highly cohesive, this means that the extent to which modules are interdependent and the extent to which all instructions in a module related to a single function [34].

The coupling can be done either by *data coupling* with parameter = unit data, by *stamp coupling* with parameter = data structure, by *control coupling* based on control flags passed between modules, or by *common coupling* with global variable or by c*ontent coupling* with passing by reference [34].

While cohesion can be smoothly done either *functional*, *sequential*, where instructions within are related to data, communicational where sequence does not matter, procedural where instructions sequence matter plus the flow of control or instructions within the module can be related to other modules, temporal where instructions are related through the flow of control but the order, doesn't matter or instructions are not functionally related but appears at the same time, *logical* where it consists of several sets of instructions, but the particular set that is executed is determined from outside the module or flag that specifies what to do is passed in from outside, *coincidental* where instructions have no relationship, the worst type of cohesion result of disorganized programming [34].

3.2.1. Definition of Software Architecture

Software architecture is a high-level description of the software focus on how the low-level design elements (modules/subsystems) are arranged, how the structured solution meets all of the technical and operational requirements while optimizing common quality attributes such as performance, security, and manageability.

K. Philippe et al. derived and refined a definition of architecture based on work in [42]. According to their definition software architecture is about describing how the software is organized. The description may include the structural elements and their interfaces by which the system is composed; behaviour as specified in collaboration among those elements; composition of these structural and behavioural elements into larger subsystems and an architectural style that guides this organization.

Architecture focuses on how the major elements and components within an application are used by or interact with, other major elements and components within the application at low-level design, selection of data structures and algorithms, or the implementation details of individual components are the concerns. However, some of the low-level design concerns could be dictated by the high-level decision.

Architecture and Design concerns very often overlap, in some cases, decisions are more architectural, in other cases, the decisions are more about design, and how they help to realize that architecture.

Architecture helps to provide a solid foundation for the software, though failing to consider key scenarios may affect functionality, failing to design for common problems - may affect end-user criteria, failing to appreciate the long-term consequences of key decisions – may affect dependability and maintainability. Such failures put your application at risk.

3.2.2. SSB Software Architecture

The SSB software architecture and design took into consideration for the users: who are going to use it, system: the IT infrastructure and its cost, and business goals: provide the real location of the children while commuting to and from school.

For each of these areas, the system architecture outlined key scenarios by identifying important quality attributes (e.g., reliability or scalability) and key areas of satisfaction and dissatisfaction (e.g. usability).

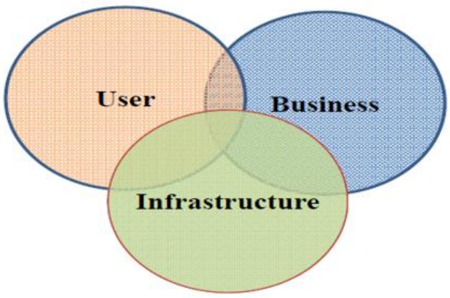

Figure 15 Key considerations in Software Architecture

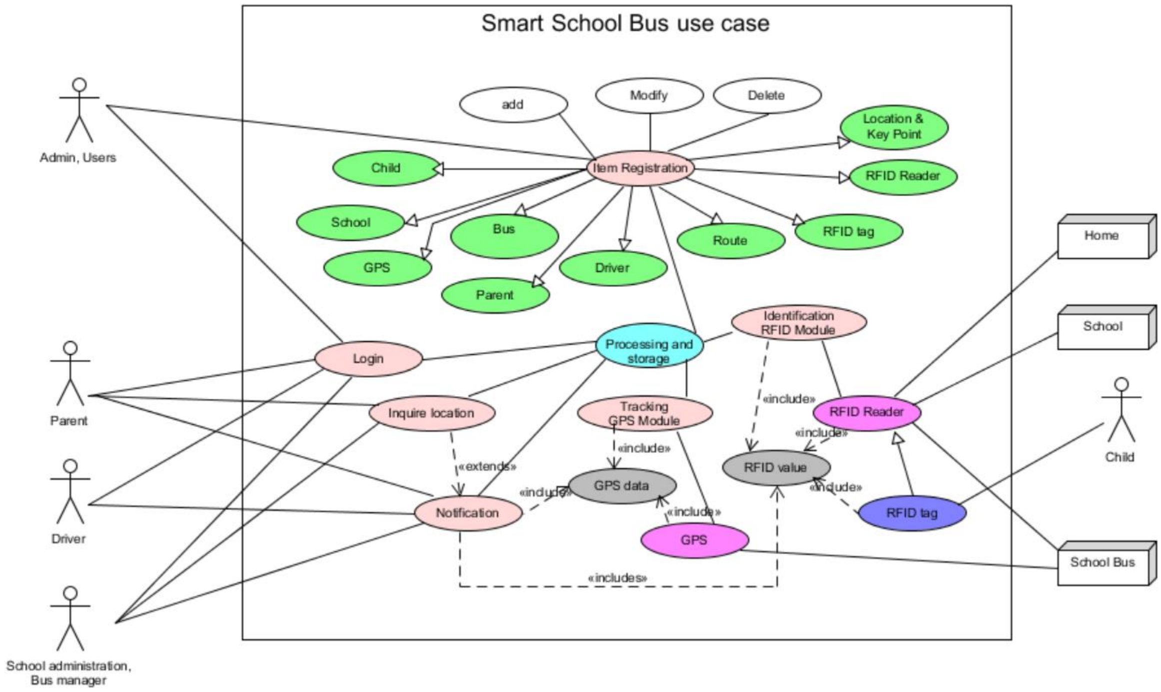

Figure 16: Smart School Bus use cases

From the use case design, it is shown that the SSB has six (6) main components where *identification, tracking,* and *notification* are the basis of the goal plus one core component in terms of software architecture. The six components are:

1. Item registration component
2. Identification component from RFID module
3. Tracking component from GPS module
4. Login component
5. Inquire location component
6. Notification component

In addition, the seventh component that is the core component of the system is the processing and the storage.

With the above 7 components, the SSB met the requirements at a different level and balancing trade-offs following high-level concerns to be considered when thinking about software architecture.

3.2.2.1. SSB Software Components

1. **Item registration component**

SSB items are well described before their registrations. The SSB item registration offers identity to each item for its uniqueness in the system. Once a registration option is selected provides program items in the system as follows: In the SSB area, select Add Item. Enter in the general information for the item by selecting item type and entering an item name and all related information. The code must be alphanumeric and allow uniqueness among all recorded items in the database.

2. **Identification component from RFID module**

In SSB the identification is done by the RFID module based on the RFID technology. RFID module uses two objects: RFID tag for child identification and RFID reader to read the data from the tag and send them to the server. The RFID tag is configured with encrypted data in such a way the system recognises it through an RFID reader. If the tag used is not known from the database, the RFID reader should give notification of not recognised tag if-else it reads the information and it sends the information to the remote server through connectivity inside the bus and wireless or wired connectivity in other locations.

3. Tracking component from GPS module

The SSB uses a GPS module to track the bus location. GPS module uses GPS sensor to record bus coordinates and GSM/GPRS module for communication to the server. Once the bus engine turns on, immediately the GPS starts to calculate the bus location, the status of the bus engine (engine starts or shut down) and speed limit then sends the information to the remote server at the interval of every 30 seconds.

4. Login component

The login component serves to authenticate a user before getting services from the SSB. When the user wants to log in, he sends a login request, the server then encrypts a message of some sort (the challenge) and also generates the correct response (i.e. encrypts the challenge using the stored hash). The user logs in by entering the collect username and password.

5. Inquire location component

This component serves to allow anyone with permission to request child location. With the child identification provided after its validation, the system can locate the child's location and respond to the notification selected.

6. Notification component

In SSB, a notification system is a combination of child identification and his/her current location determined by the pre-determined key locations provides a means of delivering a message to a set of recipients. A notification can be either an e-mail or an SMS but also as the system is linked with Google Map, the response of the current child location can be seen on Google map.

7. Processing and storage component

This is the SSB core component, it provides the calculations of the entire system and storage capabilities. All components of the system are interconnected in these components. The monitoring service of the whole system is given by this component. All responses from the system are provided through the processing and storage component.

3.2.2.2. SSB Software Architectural Style

An architectural style, also known as an architectural pattern, is a set of principles or a coarse-grained pattern that provides an abstract framework for a family of systems.

Architectural style describes deployment patterns, structure and design issues, and communication factors [34].

Regarding the structure, the SSB is layered style architecture focus on the structural configuration of the software, such as functionalities. This implies every data request should be validated before access to the data is permitted.

About the deployment, the layered SSB architecture resides in N-tiers situated on the cloud side and communicates with sensors via the internet. This categorises SSB architecture to service-oriented architecture (SOA) applications. Services are provided to the other components by application components, through a communication protocol over a network.

Concerning the communication aspect, the SSB architecture uses different protocols for data transmission and interlayers communication.

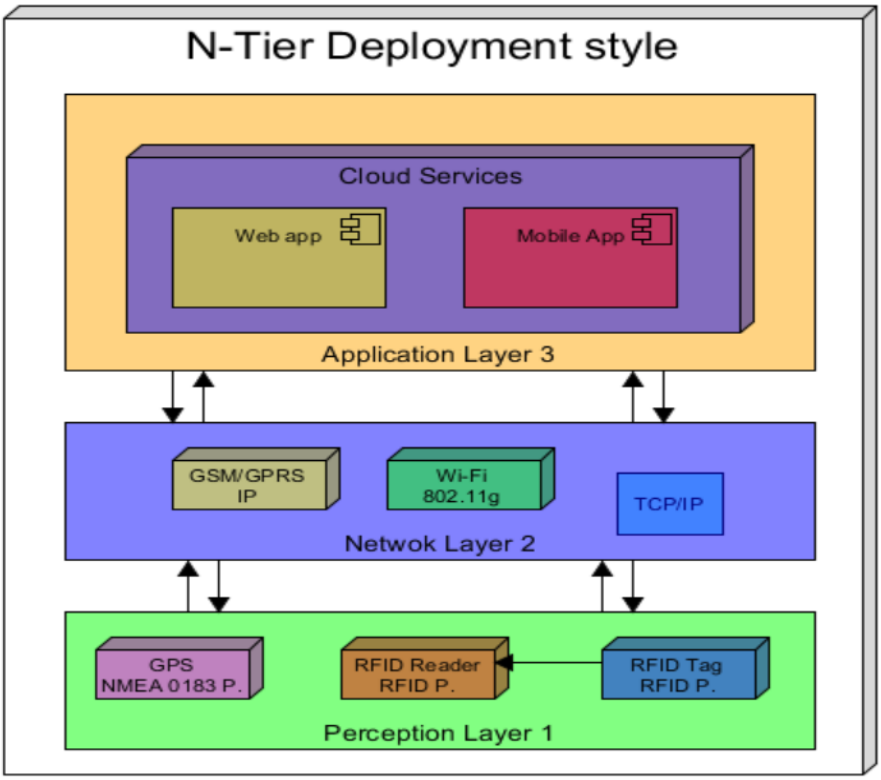

Figure 17: SSB N-Tier Deployment style

Specifically, the above architectural style determines the vocabulary of components and connectors that can be used in instances of that style, together with a set of constraints on how they can be combined [42].

The components in each layer communicate with components in other layers through well-defined interfaces.

SSB adopted the layered architecture style due to its benefits:

– *Abstraction:* Layers allow changes to be made at the abstract level.
– *Isolation:* Allows to isolate technology upgrades to individual layers to reduce risk and minimize the impact on the overall system.
– *Manageability***:** Separation of core concerns helps to identify dependencies, and organizes the code into more manageable sections.
– *Performance*: Distributing the layers over multiple physical tiers can improve scalability, fault tolerance, and performance.
– *Reusability*: Roles promote reusability.
– *Testability*: This is achieved as the result of decomposability Component-Based

3.2.2.3. SSB system algorithm

The system has the objective of monitoring the children while commuting to and from school. To achieve the target, the system needs to carry out three main tasks: identify the child, track the location of the child and send the notification.

SSB system algorithm is guided by its architecture. It has three main software modules integrated into one application on the server: RFID module for all related for child identification, GPS module for bus tracking and its related bus information, and notification module to provide interaction between the system and end-users.

1. **RFID software module**

RFID software module uses two hardware objects: RFID tag carried by the child and RFID reader located at home, inside the bus, and at school premises. The communication between the two hardware objects and the module is the internet.

An RFID tag is configured with encrypted data in such a way the system recognises it through an RFID reader. All RFID tags should be pre-configured before their use, and their data should be kept in the RFID database. If the tag used is not from the RFID database, the application should give notification of not recognised tag if else it matches the tag value and the data in the RFID database, the information is sent to the server through internet connectivity and the data can be shared through other software modules.

2. GPS software module

GPS software module uses GPS sensor to track bus location and GSM/GPRS module for communication to the server. Once the bus engine turns on, immediately the GPS starts to calculate the bus coordinates, the status of the bus engine (engine starts or shut down) and speed then sends the information to the remote server. All about bus tracking-related information are done in this module like routes, drivers, buses...

3. Notification module

On the server, the application runs instructions/commands from all components of the system. It uses the notification module to respond to any request for child location by SMS or email or Google map response depending on the choice from the client. If a child's location is requested, the application compares the identification of the child's location request in the database, and if found it looks for his current location and provides the feedback accordingly.

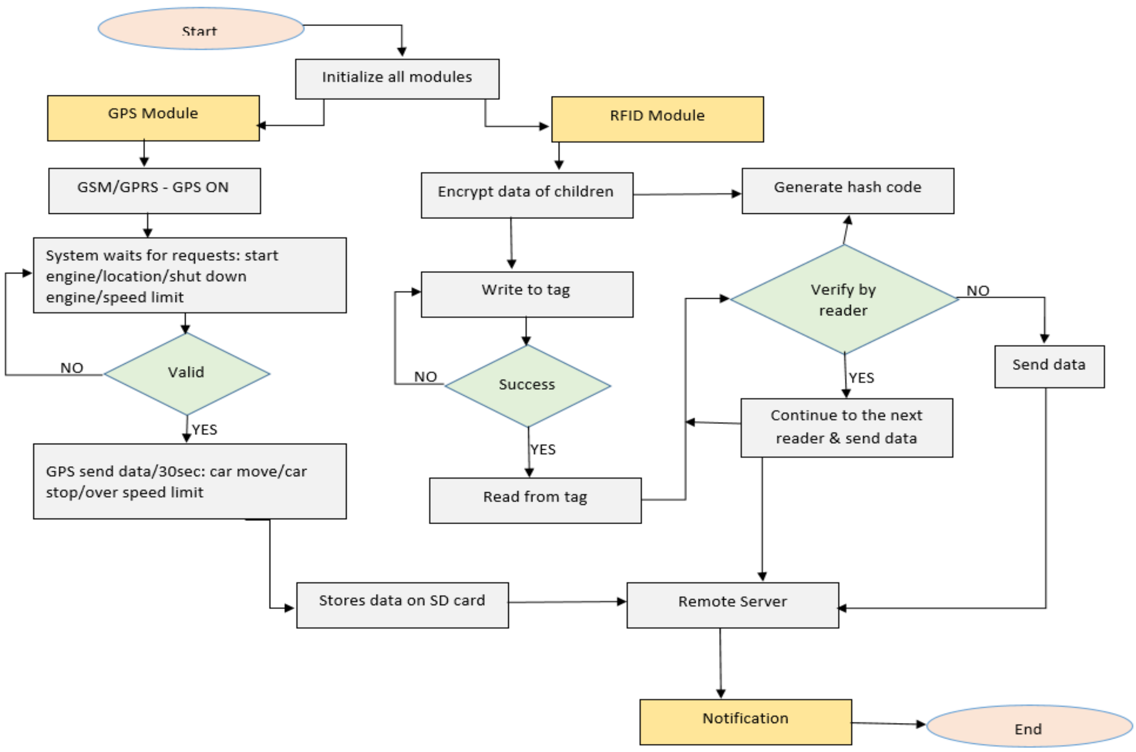

Figure 18: SSB system algorithm

From the notification module the system can generate school bus attendance to view complete and precise school bus attendance of the children, details of the school bus journey of the children, to apply absence for the children if needed, view schedule route to visualize the detailed view of the scheduled route of the school bus trip, notification of any changes or updates in the scheduled route, bus stop re-assignment, change the pickup/drop-down point of the children, and live communication with school management and drivers.

3.3. SSB Prototype

Initially, the plan was to simulate the proposed system with the Proteus simulator due to budget constraint and it was one of the objectives of the thesis, however with the limited time given to complete the thesis and needed skills to mature how to use Proteus, keep in mind the simulation of a hybrid system like SSB that combines different devices and modules and their technologies associated with them, it was an unachievable task. For the above reason, the researcher decided to develop a prototype of the proposed system with the minimum budget he had. Although procuring all required components to develop a prototype that works as the proposed SSB should work was not possible due to budget limitation, nevertheless, the researcher came up with a prototype that can at least provide the three key services of the SSB.

3.3.1. IoT prototype

Prototyping is a critical piece of IoT product development. However, without properly defining the goals, constraints, and modules of the IoT prototype, determining how and where to start the prototyping process can be daunting.
Using the Goal Constraints and Module (GCM) process to predefine all pathways of the IoT prototype provides clarity on the prototype goals and can act as a compass in selecting the proper tools to rapidly get started in a rewarding and obstacle-free prototyping process [43].
Once all of the functional modules of the device are identified, scoping out the correct hardware from online vendors becomes much quicker.

3.3.2. SSB prototype

To develop the SSB prototype, the researcher used the GCM process to predefine all about the prototype with clarity on prototype goals, constraints and modules to be used.

3.3.2.1. The goal of the SSB prototype

The SSB system has the objective of monitoring the children while commuting to and from school. To achieve the goal, the system needs to perform three main tasks: identify the child, track bus location along the way and send the notification to all concerned.

To realise the SSB prototype, only based to test the three main tasks of the system, therefore it requires three main modules integrated with a microprocessor. Those modules are the following: RFID module for child identification and has two main parts: RFID tag for object identification and RFID reader to read the data from the tag, GPS module for bus location tracking and GSM/GPRS for sending the notification to registered numbers and/or sending data to the server-side (cloud). The devices communicate with the Web App and Mobile App via cloud services.

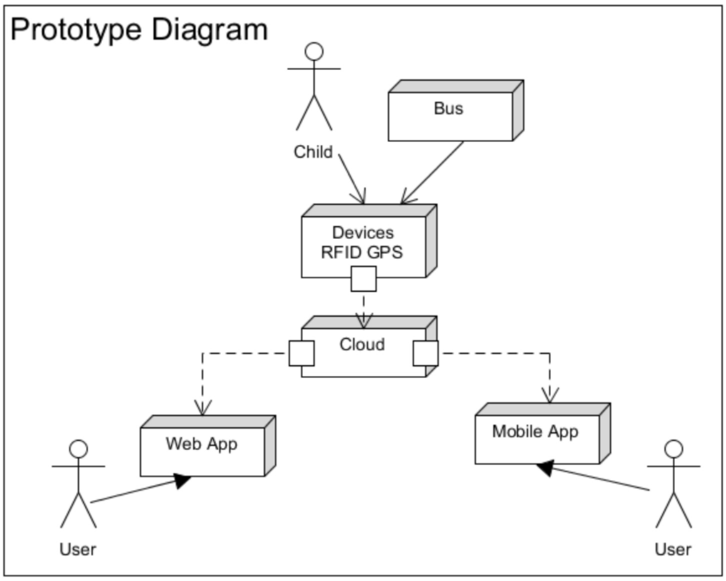

Figure 19: SSB Prototype Diagram

3.3.2.2. Constraints of SSB prototype

SSB constraints can be discussed in the following terms:

1. ***Size***: the prototype cannot give the real image of the system as it cannot cover the size of the entire system i.e. functionalities, all required prototype components are not obtained. In other words, the prototype is small in size compared to the SSB system.
2. ***Power***: The GSM/GPRS module needs to be on with a separate power source to be able to operate correctly.
3. **Cost**: The budget allocated for the prototype was not sufficient to get all the required prototype components.
4. **Functionality**: the prototype was not able to provide all functionalities as the end product, only three main functionalities to be tested with the prototype.
5. **Memory**: The prototype did not have the required memory to store more data, e.g. SMS messages only SIM memory can be used and free cloud services memory can be used.

6. **Security**: There is no way to test the security aspect from the prototype itself as it cannot test all functionalities.

3.3.2.3. Modules of SSB prototype

As above mentioned, the SSB prototype tested the three tasks: identification, tracking, and send a notification. To test three main tasks of the system, the prototype is composed by RFID module for child identification and has two main parts: RFID tag for object identification and RFID reader to read the data from the tag, GPS module for bus location tracking, and GSM/GPRS for sending the notification to registered numbers and/or sending data to the server-side (cloud). All three modules are interconnected by an Arduino microprocessor.

The RFID module selected for the SSB prototype is the 13.56 MHz RC522 S50 keychain S50 card RF RFID IC card MFRC-522 sensor module. The package includes two kinds of tags (card and keychain). Reader Module - that sends signals to the tag and reads it back

MF RC522 is applied to the highly integrated read and write 13.56MHz contactless communication card chip, NXP launched by the company for the “table” application of a low-voltage, low-cost, small size of the non-contact card chip to read and write, smart meters, and portable handheld devices developed better choice. The MF RC522 use of advanced modulation and demodulation concept completely integrated with all types of 13.56MHz passive contactless communication methods and protocols. 14443A compatible transponder signals. The digital part to handle the ISO14443A frames and error detection. Besides, support rapid CRYPTO1 encryption algorithm, terminology validation MIFARE products. MFRC522 supports the MIFARE series of high-speed non-contact communication, two-way data transmission rate up to 424kbit/s [44].

Specifications

Input Voltage:	DC 3.3V
Current:	13-26mA
Idle Current:	0-13mA or DC 3.3V
Sleep Current:	<80uA
Peak Current:	<30mA
Operating Frequency:	13.56MHz
Supported Card Types:	Mifare1 S50, mifare1 S70, mifare ultralight, mifare Pro, mifare desfire product

Dimensions: 40mm - 60mm

Operating Temperature: -20-80 degrees Celsius

Storage Temperature: -40-85 degrees Celsius

Relative Humidity: 5 percent -95 percent

Module interface SPI parameters: Arm/AVR/Pic/Arduino

Data Transfer Rate: Maximum 10Mbit/s

Package Content: 1 x Board, 1 x S50 card, 1 x Keychain, 2 x pin header.

To identify more children, the researcher bought four more S50 cards.

Figure 20: The RC522 RFID module

The GPS module selected for the SSB prototype is from the NEO-6 module series which is a family of stand-alone GPS receivers featuring the high-performance u-blox 6 positioning engine. These flexible and cost-effective receivers offer numerous connectivity options in a miniature 16 x 12.2 x 2.4 mm package. Their compact architecture and power and memory options make NEO-6 modules ideal for battery-operated mobile devices with very strict cost and space constraints.

The 50-channel u-blox 6 positioning engine boasts a Time-To-First-Fix (TTFF) of under 1 second. The dedicated acquisition engine, with 2 million correlators, is capable of massive parallel time/frequency space searches, enabling it to find satellites instantly. Innovative design and technology suppress jamming sources and mitigates multipath effects, giving NEO-6 GPS receivers excellent navigation performance even in the most challenging environments.

GPS receiver module gives output in standard (National Marine Electronics Association) NMEA string format. It provides output serially on Tx pin with default 9600 Baud rate.

This NMEA string output from the GPS receiver contains different parameters separated by commas like longitude, latitude, altitude, time, etc. Each string starts with '$' and ends with carriage return/line feed sequence.

Figure 21: The NEO-6M-0-001 GPS module

The GSM/GPRS selected for the SSB prototype is the SIM800L EVB version, is a complete Quad-band GSM/GPRS solution in an LGA type which can be embedded in the customer, it has a set of TTL level serial interface, a set of power supply interface. Besides, there is a set of antenna interfaces on this module [45].

Features:

- Supply voltage range 3.4 ~ 4.4V and
- The current of 1A or more (the current is very important)
- It features Bluetooth, FM, and Embedded AT (AT commands)
- Quad-band 850/900/1800/1900MHz
- Operation temperature: -40 ~85-degree Celsius

Applications:

- SIM800L support Quad-band 850/900/1800/1900MHz, it can transmit Voice, SMS, and data information with low power
- Due to its size, it can fit into the slim and compact demands of customer design.

Figure 22: The SIM800L EVB for SSB prototype

The microprocessor selected for the SSB prototype is Arduino Uno which is a microcontroller board based on the ATmega328P. It has 14 digital input/output pins (of which 6 can be used as PWM outputs), 6 analog inputs, a 16 MHz ceramic resonator (CSTCE16M0V53-R0), a USB connection, a power jack, an ICSP header, and a reset button. It contains everything needed to support the microcontroller; simply connect it to a computer with a USB cable or power it with an AC-to-DC adapter or battery to get started.

"Uno" means one in Italian and was chosen to mark the release of Arduino Software (IDE) 1.0. The Uno board and version 1.0 of Arduino Software (IDE) were the reference versions of Arduino, now evolved to newer releases. The Uno board is the first in a series of USB Arduino boards and the reference model for the Arduino platform [46].

Technical Specifications

Microcontroller	ATmega328P
Operating Voltage	5V
Input Voltage (recommended)	7-12V
Input Voltage (limit)	6-20V
Digital I/O Pins	14 (of which 6 provide PWM output)
PWM Digital I/O Pins	6
Analog Input Pins	6
DC Current per I/O Pin	20 mA
DC Current for 3.3V Pin	50 mA
Flash Memory	32 KB (ATmega328P) of which 0.5 KB used by the bootloader
SRAM	2 KB (ATmega328P)
EEPROM	1 KB (ATmega328P)
Clock Speed	16 MHz
LED_BUILTIN	13
Length	68.6 mm
Width	53.4 mm
Weight	25 g

Figure 23: Arduino Uno microprocessor for SSB prototype

3.3.2.4. The realisation of the SSB prototype

To realise the SSB requires connecting all modules with the microcontroller Arduino UNO, and this requires jumper wires, breadboard, and extra power source for the GSM module.

Before making the SSB prototype, testing each module separately was the first step, if all modules tested positively worked, the next step was to realise the prototype goals set which are identifying the child by the RFID module, tracking the bus coordinates with the GPS module and send notification per SMS with the GSM module.

Table 4: SSB Prototype pin connection

RFID-RC522 Pin	**Arduino Uno Pin**
SDA	10
SCK	13
MOSI	11
MISO	12
IRQ	Not connected
GND	GND
RST	9
3.3V	3.3V
NEO 6M - GPS	**Arduino Uno Pin**
VCC	5V
GND	GND

Tx	2
Rx	3
SIM800L-GSM	**Arduino Uno Pin**
5V	5V from another power source
GND	GND from another power source
VDD	Not connected
Tx	6
Rx	7
GND	GND
RST	Not connected

Below is the wiring image that illustrates how the modules are interconnected.

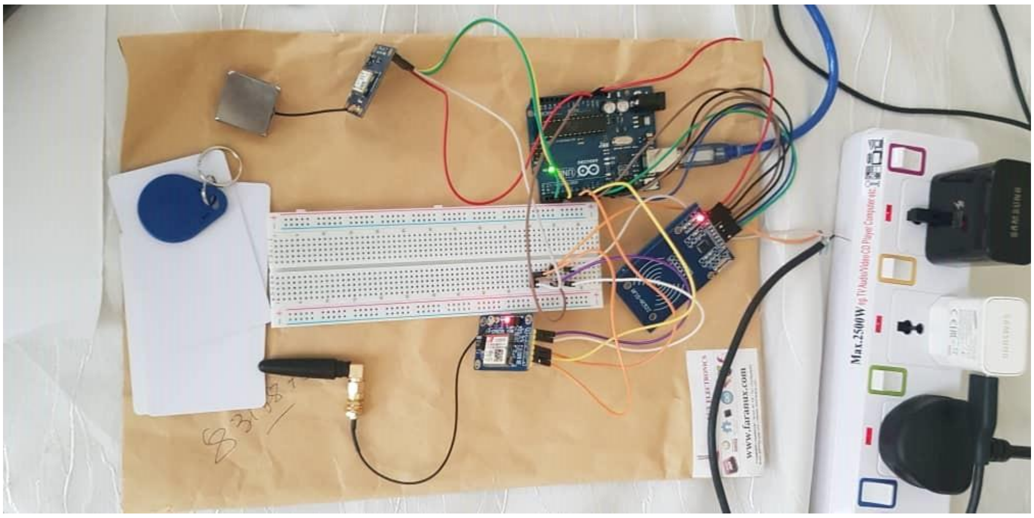

Figure 24: SSB prototype

3.3.2.5. The SSB data set analysis

As mentioned above, the SSB system provides three key services: identify the child, monitor the bus movements and send the SMS notification to concerned stakeholders.

To identify the child, the system should read the RFID tag assigned to the child and recorded in the identification table through the identification module. The system uses RFID reader to read the tags, and the data captured with the reader is compared with the data stored in the database for child identification. Once the reader captures the tag information, the system goes to the next step of SMS notification.

From the prototype realisation, with five different tags, the system can identify four children recorded in the system as these four tags are linked with known children by the system. The fifth tag was kept for an unknown card used to be able to test how the system could react with strange tags. All five tags are identified by the system.

To monitor the bus movements, the SSB system should recognise the GPS module installed into the bus and communicates with it via a GMS/GPRS module to retrieve the bus coordinates. The system also stores all known locations coordinates like child's home, nearest bus stop and school premises in the GPS table through GPS software module to be used while tracking the child's movements. The system is able to capture the coordinates from the GPS module.

The SSB to be able to send an SMS notification, first of all should identify the child through his or her identification and his or her location with its coordinates via tracking module. It should also know the parent or any other concerned stakeholder mobile number to send to the SMS. Once all three mandatory information are received by the notification module, the SMS is sent to its destination indicating where the child is located.

The next section provides results obtained from the SSB prototype.

3.3.2.6. Results obtained

The prototype is able to identify the child with his/her name linked with the RFID id assigned to the child.

With the help of the GPS module, the prototype can track the school bus movements and provides the bus coordinates to the system.

The last prototype goal is to send the SMS notification to all registered stakeholders.

During the test the SMS notification was sent successfully from the system to its destination. The GSM module was assigned the 0784701459 SIM card number and SSB SMS was coming from that number.

Below are the images of the results obtained:

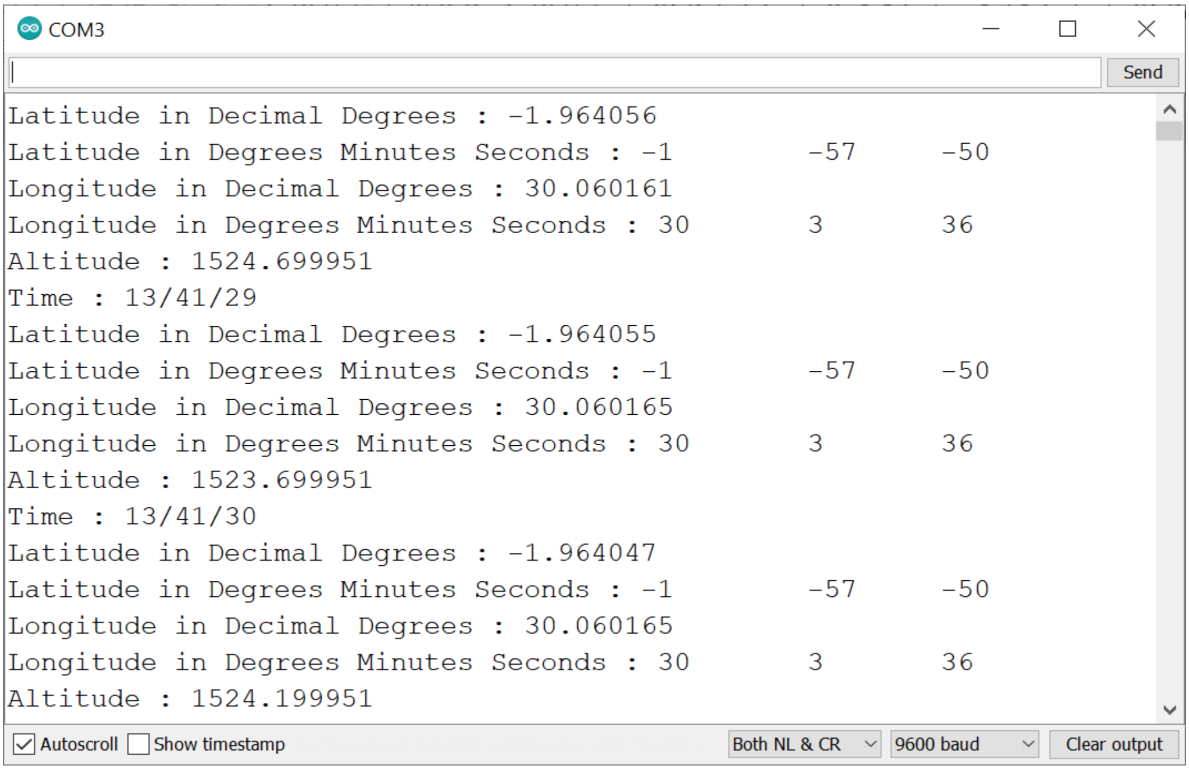

Figure 25: Obtained GPS coordinates

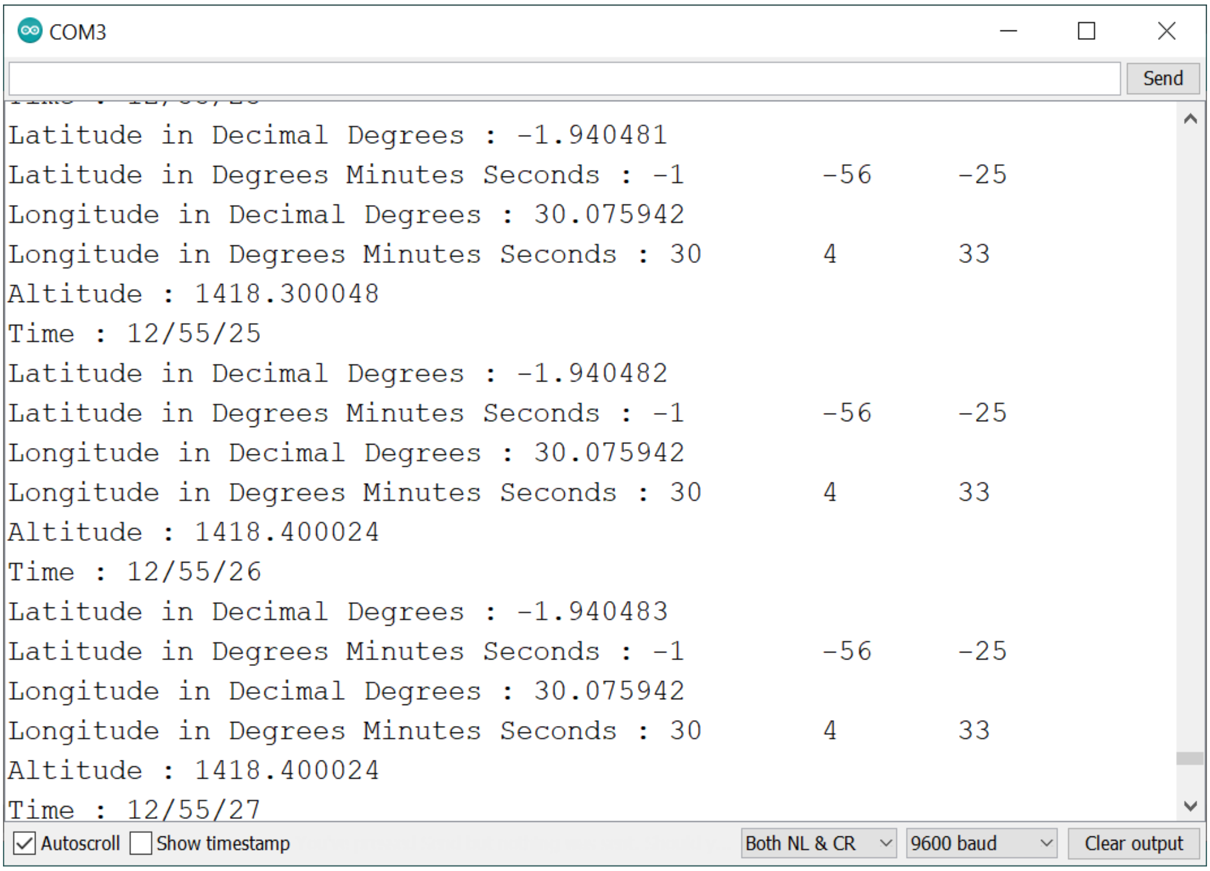

Figure 26: Obtained GPS coordinates on different locations

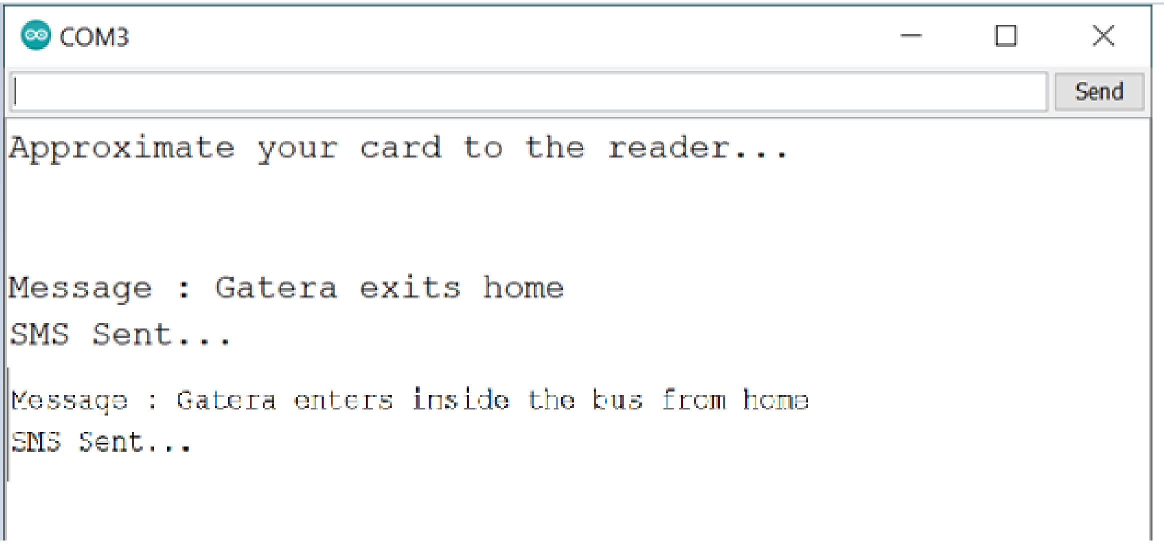

Figure 27: The Child Gatera is identified by the system

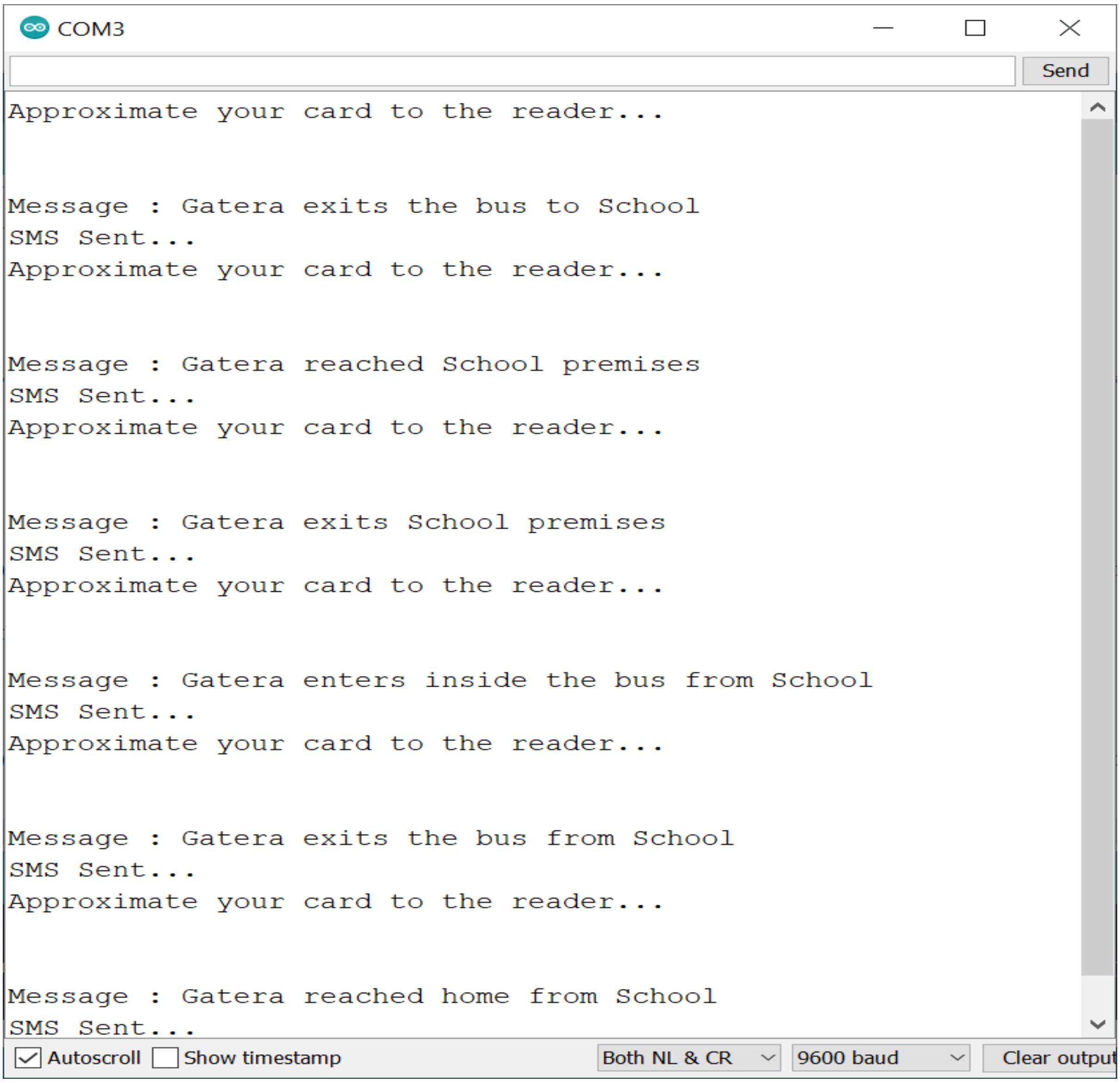

Figure 28: The Child Gatera is monitored from his movements by the system

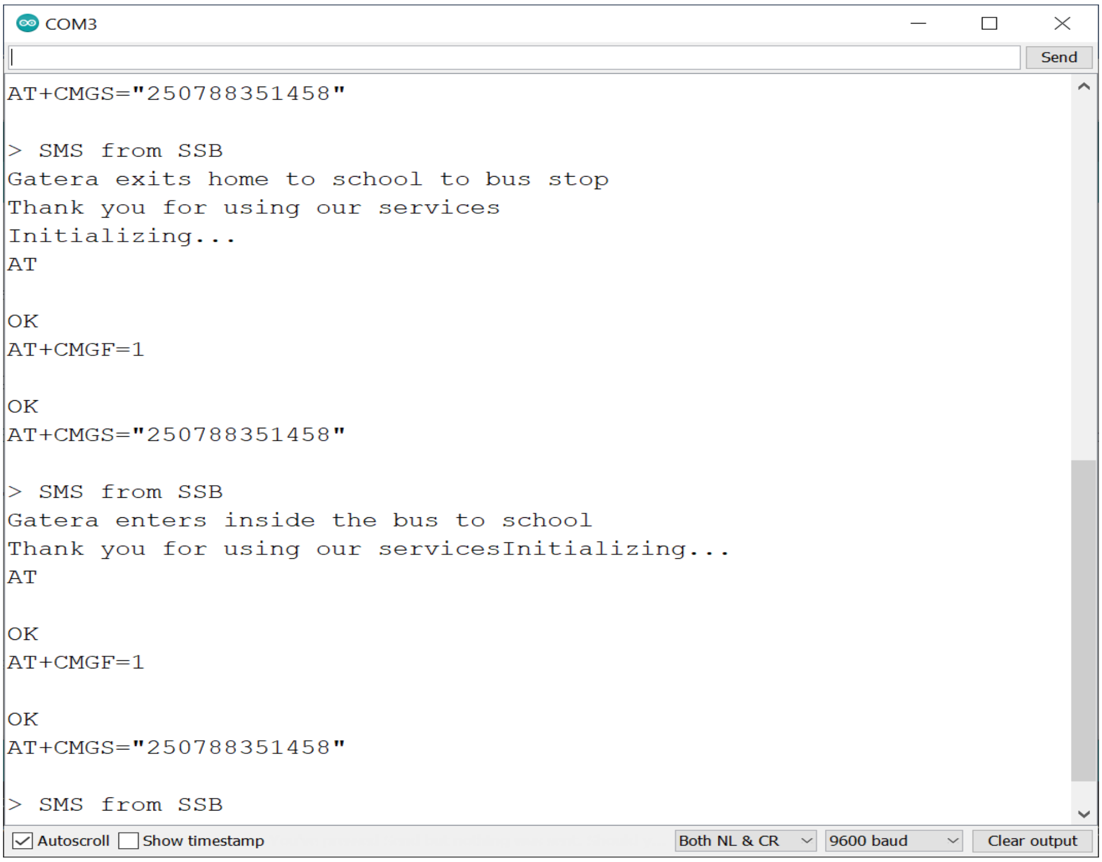

Figure 29: SMS notification is sent from the system going to school

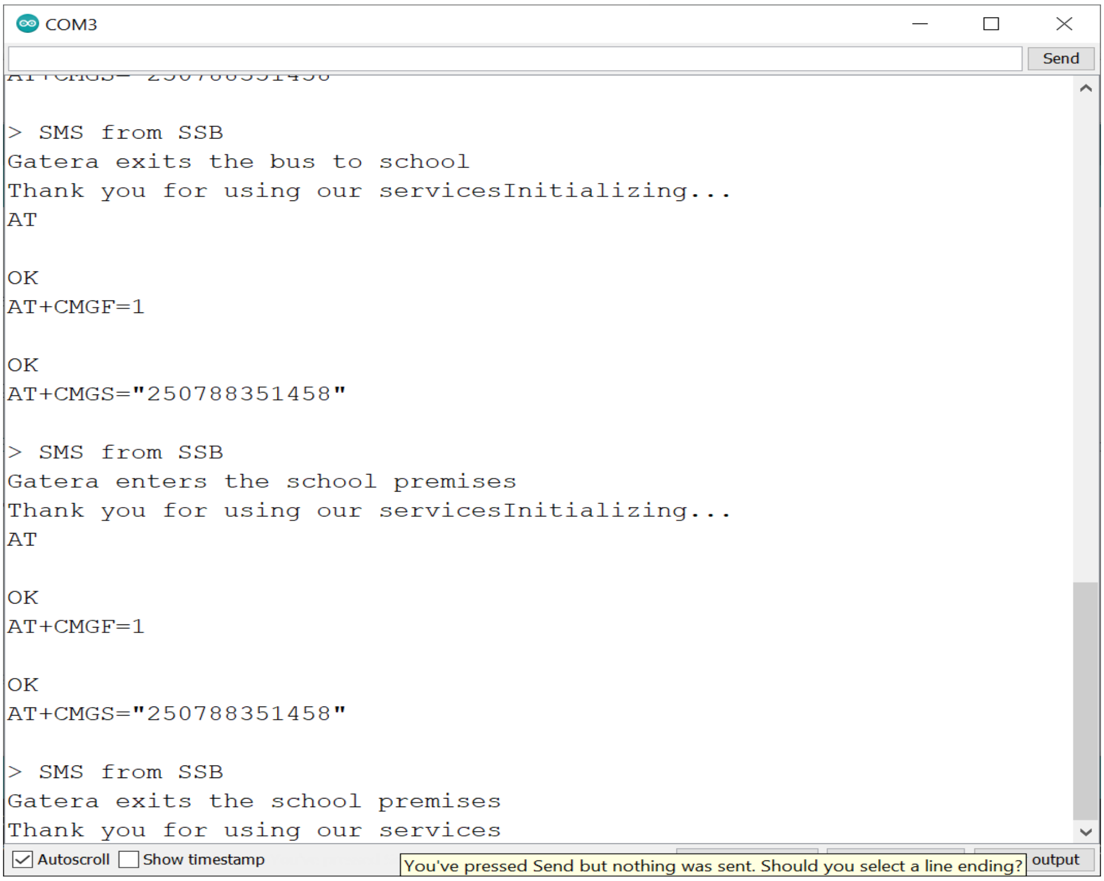

Figure 30: Different SMS notifications are sent from the system per events to school

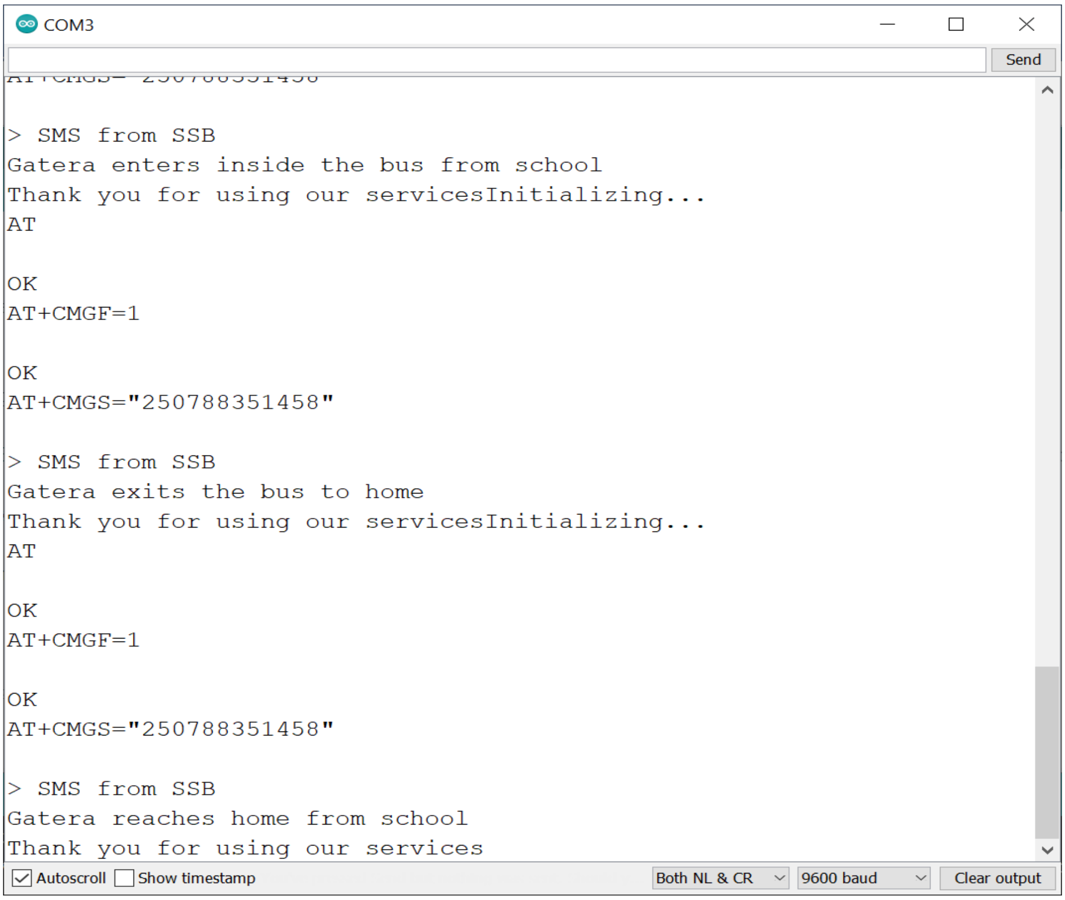

Figure 31: Different SMS notifications are sent from the system per events to home

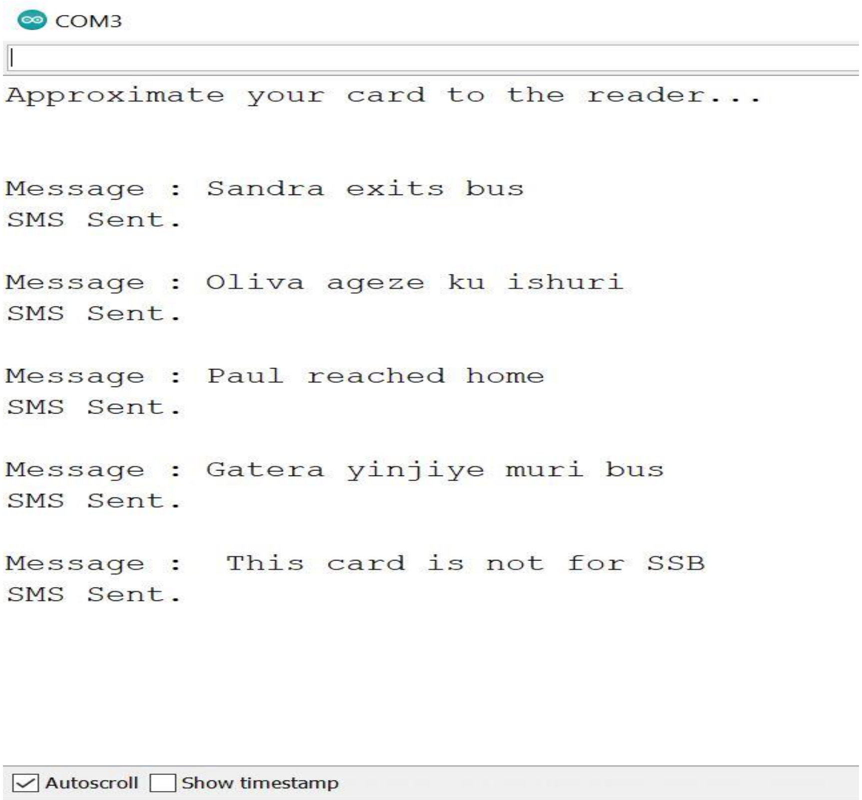

Figure 32: The system can identify different children

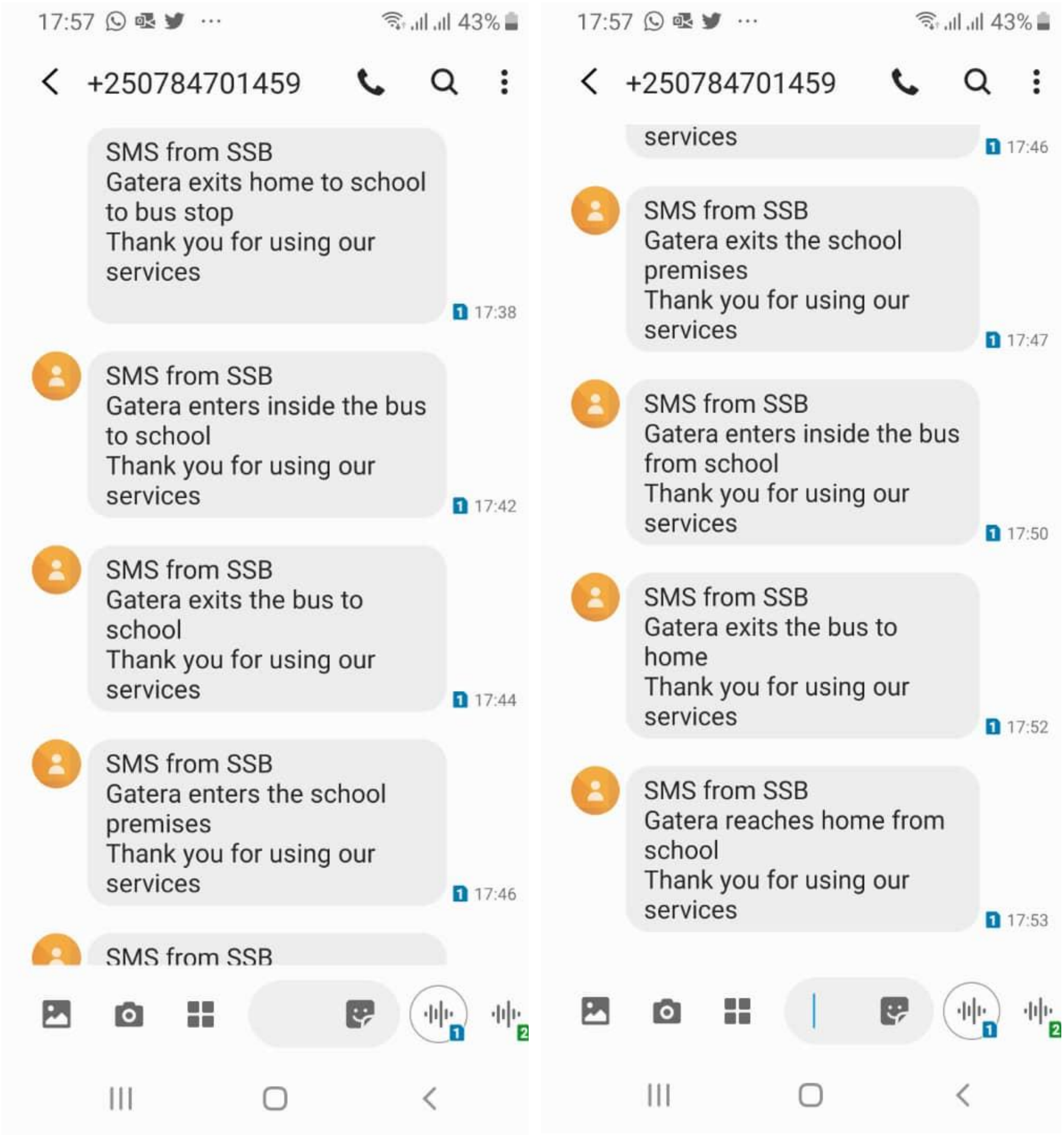

Figure 33: SSB SMS notifications to their destinations

3.3.2.7. Challenges faced during the prototype realization

The realisation of the prototype faced different challenges. Let highlights some of them:

1. Foremost, getting the budget of prototype modules was not an easy thing;
2. To find a shop where you can get IoT devices was not straight forward as this field is new in the Kigali market;

3. To get help from anyone like a colleague or anyone else, was impossible due to the pandemic of Covid 19, the college was closed, so it requires to ask by a call which is not easy to know who to call and budget for it;
4. To get internet for further reading and documentation was a major concern and costly;
5. The time dedicated to completing the thesis including the prototype was limited, hence I did get time to realise the application part namely web app and mobile app, and complete the prototype as it was planned or it should be.

3.3.2.8. Benefits from the prototype development

While realising the prototype, I gained a lot as benefits:

1. It helped me to understand more how the IoT projects are built and developed;
2. I get the opportunity to experience Arduino IDE and all related to and increase the knowledge in coding;
3. The modules used are now well known technically and conceptually;
4. From the reading, I got a lot of information on different technologies. Huge improvement in terms of IoT skills;
5. The realisation of the SSB prototype allowed me to understand the theoretical modules learned from the class

3.4. Discussion

3.4.1. Technical discussion

The technical discussion part discussed system requirements realisation technically.

3.4.1.1. System requirements fulfilment

The SSB system and its components are essential to confirm advanced means of monitoring human being based on identity. SSB technical proposal is built on the easiest way of think identification empowered by RFID technology and movement tracking provided by GPS techniques, the two features improved by searching, find and notification algorithm via computation done at cloud level. The SSB system is designed considering the mentioned above requirements for IoT system architecture in IoT at all layers.

In the relation to system flexibility, the SSB-designed system provides a web and mobile user-friendly interface to facilitate human interaction with the system. The communication among all SSB components is enabled by internet connectivity through various protocols such as Wi-Fi, GSM/GPRS, and wired network. Moreover, the SSB management done in the cloud is the additional principle for ensuring mobility and scalability.

The SSB system is built to work with any type of device from any vendor as well as it is compatible with the system, thus the SSB system does not have limitations on the devices' type or vendor.

The SSB system hypothetically could be evaluated as unfailing based on its data flow model structures for suitable connections among the logical objects. The reputed use case scenarios reflect the system's SSB process failure or different user preferences. The absence of all-inclusive system functional, integration, and testing at a large scale does not let to entitlement the reliability requirements are met with full extend of inevitability.

The SSB system obliges user authentication to allow any service operating within the application therefore the privacy of the data is a crucial concern for the SSB. The core component of SSB controls the access rights to the system services through user identification.

3.4.2. Implementation

To implement the SSB system, the first thing to do is to complete the development of all its components mainly its Web app, mobile app and hosting it on cloud. Thereafter, testing it in real mode and analyse the devices and user's behaviour on system performance. The prototype's purpose was for demonstrating system functionalities testing for academic research purpose.

3.4.3. Business case analysis

The business analysis of the system comprises brief and debating the most important ethics of the system from the business aspect.

The following factors are identified as essential for successful business models involving the latest IoT trends [47]:

- *Real-time data and analysis*: The business models should be designed to accelerate data capturing and analysing operations to process data from diverse data centres, assemble, analyse and deliver results in real-time.
- *Intelligent operations*: IoT industry needs to involve intelligent operations to control data from diverse endpoints.
- *Diverse revenue streams*: The IoT business models should be created to produce novel services, software, and devices in extending the existing products to generate new revenue sources.
- *Turn on and turn off features*: Another cornerstone of building IoT business models is the feature of turning off and on in diverse orders and getting additional values of devices and committed software for those devices.

Take into consideration a business point of view, the SSB offers tools to make simpler the process of child monitoring through his or her identification and provide his/her location via an SMS notification services.

Values and competitive advantages of the SSB system:

- Reducing the parents' worries while they send their children to school;
- Increase of children safe during the trip to and from school;
- Time-saving process and cost reduction to know the current location of the child;
- Ease child identification using RFID features – children attendance;
- Always responsive services no matter time and place;
- User-centred applications services;
- Context-aware applications.

3.5. SSB System Design and Architecture summary

In this chapter, the Smart School Bus system design and architecture were presented. Also, the system and user requirements have been identified. The introduction of the SSB prototype concept was defined. The description of the main functionalities and actions in the system such as SSB notification via SMS sent by GSM, GPS monitoring, and RFID identification modules were presented. The evolution of the proposed SSB from technical to business aspects was discussed to identify the advantages of the system and find out future research fields.

CHAPTER 4: CONCLUSION AND RECOMMENDATIONS

4.1. Research contributions

The dissertation presented some of the significant encounters for children transportation to and from school in the form of the global, regional and local context. The research proposed an extended and different vision for child monitoring from home to school which allows computerised connection among several objects in IoT which is time and effort saving for the end-user. Similarly, it ensures always responsive services to the end-users. The presented SSB system is an answer addressing the communication and interactions among all stakeholders involved in the school bus system with the help of IoT provision automation solutions. The SSB feature serves the possibility of monitoring the children using a school bus from home to school by notifying primarily their parent or anyone else with the permission per request and automatically as an option.

4.2. Conclusion

The commute of children from home to school and back has always been a source of concern for parents. Bus drivers may not be able to identify all children and do not know in time if any child is missing. In local context parents have no way of knowing if their ward is safe until the evening when the bus returns.

As an output of the dissertation, the proposed Smart School Bus (SSB) is among the first systems in IoT in Rwanda if not in the region to address child monitoring from home to school mostly in Kigali. The proposed attractive solution aims to provide in form of SMS notification per request of the current child location in real-time. The user’s role and the proposed system functionalities are meaningful in terms of child monitoring during his/her trip to school. Therefore, the proposed system contributes to the evolution of the internet towards being part of the Internet of People and the Internet of Everything. The notification to parents will positively affect parents as they can obtain information in real-time related to their children's location. The school management also gains the capability of monitoring and tracking the buses and bus drivers, and this can contribute at large children's safety while they go and come to and from school.

Data generated from the system would contribute to further studies or/and future researches. School bus transportation system will be improved towards smart transport which is a component of Smart Kigali the vision of our capital city.

4.3. Recommendations

4.3.1. General

The IoT centre should avail the required materials (IoT modules) timely to facilitate the prototype development to meet the project objectives.

During theoretical learning, the time for practical assignments should be increased as well as practical works. This can contribute a lot to the moment of project realisation.

The university should look for means of helping students to realise their projects done during their final project module after their presentation, to serve the purpose as they are proposed to solve different problems. At least the top ten projects; can be an encouragement for students to work better.

4.3.2. Specifics

The SSB development should be completed to its full operation to serve its purpose. The functional set of the SSB system will depend on changes in ICT technologies that offer: security policies, data storage, heterogeneous networks communication, dedicated software artefacts, and functionalities, etc. From that perspective, the information alliance model among multiple parties is needed as well as some functional and logical components beyond the scope of the proposition which means the design is open for several technological implementations and further development. During the implementation process, there may be other components not considered while proposing the SSB system that could improve the functionalities of SSB, those components should be added using adequate design.

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