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# Internet of Vehicle Speed Detection and Reporting System Based on RFID

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## *Abstract*

***A major cause of road accident in the world is excessive speed driving, which recent studies indicates that one third of road transport fatalities are results of inappropriate speed, and unexpected change in road way (road construction or maintenance and/or unexpected obstacles). Therefore, Monitoring vehicle speed is important to enforce speed limit laws. However, vehicle data collection has been traditionally approached using one of the following sensor based approaches: radar, induction loop detectors, and magnetic sensors, microwave sensors, etc. These are all difficult to install and maintain. Lately, video based vehicle data collection systems are being explored by commercial video detection systems which are not energy efficient and require adequate training to use. This research paper proposed a vehicle speed detection system model, based on RFID technology, leveraging on internet connectivity for reporting of detected vehicles violating speed limit traffic rule. Three recursive algorithms were designed based on the proposed mathematical formulae for obtaining the vehicle speeds, and the proposed system operation principles. A test case simulation was done, and the data obtained was analyzed further with bar chart, and it showed the accuracy and efficiency of the proposed RVSDS system model. The proposed model, promises full enhancement of internet of things (I.O.T) research when fully implemented and will also increase the number of things connected over the internet which in this case is road network and vehicles.***

**Key words:**Vehicle detection system, internet of things, RFID technology, Transportation

## 1.0 Introduction

In transportation, vehicle detection system may be defined as a system that has the capability to detect vehicles and measure traffic parameters such as count, speed, and incidents. Complex vehicle detection requirements are needed rather than many off-the-shelf vehicle detectors that use normal traffic-actuated controllers for traffic signals. Determining the speed of a vehicle is important for transportation management system in determining excessively speeding vehicle [1]. A major cause of road accident in the world is excessive speed driving, which recent studies indicates that one third of road transport fatalities are results of over speeding and unexpected change in road way (road construction or maintenance) [2].Decreasing the number of accidents and mitigating of their consequences are a big concern for traffic authorities, the automotive industry and transport research groups [3]. Therefore, Monitoring vehicle speed is important to enforce speed limit laws [4]. However, vehicle data collection has been traditionally approached using radar, induction loop detectors, magnetic sensors, and microwave sensors as one of sensor based approaches [5]. These traditionally approached sensor based data collection are all difficult to install and maintain [6]. Lately, video based vehicle data collection systems are being explored [7] and these are not energy efficient and software intensive.

This research paper presents a vehicle speed detection system based on radio frequency identification technology and internet network. This creates a new network solely chosen for vehicle speed detection and reporting and hereafter referred to as internet of vehicle speed detection and reporting system.

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## 2.0 Related Work

A work on image processing and analysis of the methodologies used as tools for developing traffic surveillance and controlling application was previewed in [8]. While the use of image background subtraction on image processing from video streams for a moving and stationary vehicle speed estimation technique was done in [1]. Its main advantage is the low cost effective approach, which is easy to install and maintain, when compared with other technique. Also, an alternative vehicle speed detection that is based on camera system, using several image processing technique as a more suitable replacement for existing radar system due to its draw backs in [6] was proposed in [9] and an enhancement over the system proposed in [1] which uses only one image processing technique. A video based vehicle detection system based on Harris-Stephen corner detector algorithm for determining vehicle counts and speeds at aerial road- ways and freeways was proposed in [5]. The algorithm performance accuracy and speed was evaluated, and concluded that it was better than the existing commercial video based vehicle detection systems. A video based vehicle speed detection and tracking system, using image analysis was proposed and experimented in [10]. They combined background subtraction, feature extraction, and vehicle tracking to determine the speed. Also, a new technique of zero-crossing detector (ZCD) algorithm for frequency calculation, which was implemented by amplifying the output of the Doppler radar such that it can be processed by a microcontroller for vehicle speed detection, without the need for a converter was proposed [11]. A wireless autonomous vehicle speed control system based on radio frequency for detecting and controlling vehicle speed in zones, such as schools and high ways was designed in [2]. Their model has an added feature for emergency object detection unit that informs the driver of object presence ahead of the vehicle and to slow down speed. Furthermore, a radio frequency modulation speed control system through keil simulation tool and embedded processor was designed in [3]. Later on, a vehicle speed intimation system, that inform drivers, of their current driving speed, as well as the road information, such as bends and hills, utilizing the MEMS, RF, GPS, GSM technology was designed in [12]. The system of [12] has the capability of detecting and reporting accident occurrences, which is an enhancement over the system developed by [3]. Then, a novel Infrastructure to Vehicles communication and control system for intelligent speed control using Radio Frequency Identification (RFID) technology for identification of traffic signals and a fuzzy logic controller was presented in [13].

All these systems did not consider reporting of vehicles violating speed limit, instead, concentrated on speed detection and techniques. But, without further actions leaves the fatalities resulting from excessive speed to continue prevailing. In order to stop its prevalence, Jyothi and Roy [4] developed a vehicle speed detection system that tracks a vehicle speed for speed limit violation using image processing technique. The system uses scene and reference point positions to calculate the vehicle speed. Also, Monika et al [14]designed an in-vehicle system, based on IR technology, that detects the speed of vehicles by calculating the time taken for the car to drive from one point to another and then alerting the police of speed limit violation by sounding an alarm signal using a buzzer.

These two speed detection and reporting systems are far from being a perfect solution because the system proposed in [4] will need to capture image of vehicle for better identification of the defaulted driver while the system developed in [14]will require the presence of traffic officials to be stationed on the road at strategic point to get the alert and arrest the defaulter.

Therefore, our proposed RVSDS system, promises to become the next generation vehicle speed detection system, which creates an internetwork designated for vehicle speed monitoring and reporting operation. The RVSDS spares no effort in timely detection and reporting of excessively speeding vehicles, thereby enhancing a guarantee prosecution of all offenders, storage of offenders' track record.

## 3.0 Architecture of RFID Vehicle Speed Detection System

The architecture of the proposed RVSDS model is shown in Fig1. The RVSDS comprise of four major components, each with specialised functions. They are;

### 3.1 Intelligent data acquisition unit (IDAU)

This is the main component of RVSDS, which needs to be installed on the roads. We propose a small design miniaturized system that is energy efficient. Its main task is to detect and monitor vehicle speed. While the other components assist in making it a complete system. IDAU is made up of three major components, which are:

**3.1.1 RFID Reader** is responsible for the communication at layer one, also known as the lower layer, where vehicle speed detection and identification is done, through the interaction between the Active RFID reader and the passive RFID tag attached to the vehicles. For energy efficient operation, the RFID reader remains in semi-active mode, while there is no vehicle in range.

**3.1.2 MCU** is likened to central processing unit of a general purpose computer system in terms of functional role. it is responsible for all the arithmetic, logical and memory operation of the RVSDS. it takes as input the time stamp of each communication between each vehicle RFID tag and the IDAU sub-unit (RFID reader), and computes the time taken for the vehicle to travel through the RFID reader 2meter reachable distance, then finally determines the speed by applying proposed time and distance algorithm. In order to ensure cost efficiency and feasibility in implanting the RVSDS, we used an 16bit MCU which is made from Atmel named atmel328.

**3.1.2 Internet Modem** connects each IDAU sub-system of the RVSDS that are distributed across distant road networks to the speed detection and monitoring server database for reporting of vehicles that were detected violating speed limit across the road network. The inclusion of Internet Modem creates an enterprise system with global expansion capability through seamless access to RVSDS information. To enhance energy efficiency operation of the RVSDS, the IDAU unit internet modem subsystem will always be in sleep mode, until there is need for data to be transmitted to the database.

**3.2 RFID Card/Transonder/Tag** uniquely identifies each vehicle, and also, communicates with the IDAU unit emplaced along road paths in the form of solar road reflectors, through its sub system RFID reader. This tag is an important component in the entire RVSDS operation. Thus, it is compulsory that this chip should be implanted on all vehicles. The installation style is either as a sticker on vehicle plate number. Also, due to the variety of RFID cards/tags, and their applicability and functionalities, the use of passive tags, which does not require extra power supply, but rely on the power received through radio frequency wave from the RFID reader was used.

**3.3 Offenders Database** is the storage component of the RVSDS that keeps all records of detected vehicles violating speed limit traffic rule. For onward retrieval, tracking and prosecution of vehicles and drivers in an hustle-free manner.

**3.4 Monitoring Interface:**the point where data is retrieved from the database, by both traffic personnel's on patrol duty in the field, and office personnel's in the monitoring interface unit

Therefore, in the RVSDS architecture (Fig1), the vehicle RFID transponder which holds each vehicle identity, communicate with the IDAU unit subsystem (RFID transceiver), hence generating input data for the system, amongst which includes, vehicle ID, time of communication start, time of communication end. These data are then collected by the embedded central processing unit which uses the data to determine the speed of vehicle and compute if vehicles violates speed traffic speed limit or not. Whenever a vehicle violates speed limit traffic rule as determined by the embedded central processing unit computation, the vehicle ID and other information relating to the offence are sent to the internet modem, for onward transportation to the road vehicle speed limit monitoring and data storage centre. The road vehicle speed limit monitoring and data storage centre consists of a well structured high-end sever infrastructure, equipped with database management system, with data analysis application, for structuring of the data of reported vehicles.

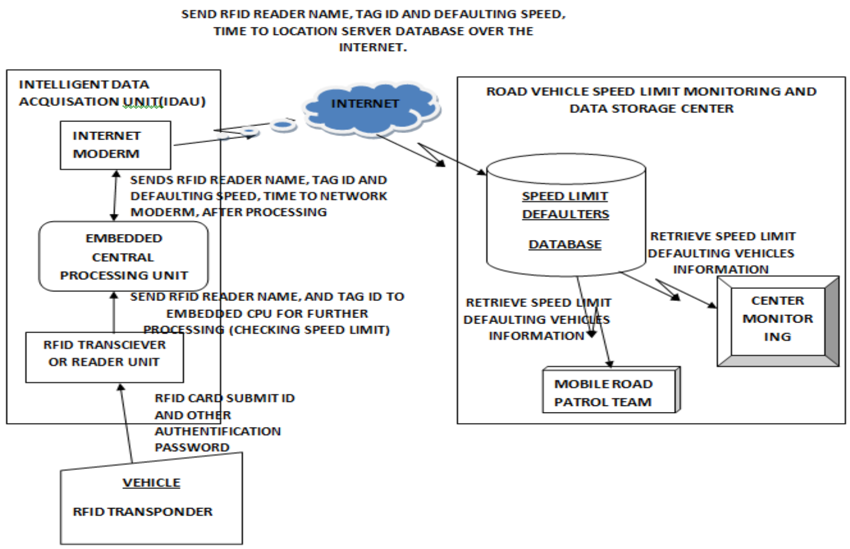


**Fig1:** RVSDS model architecture

## 4.0 Implementation of the Proposed Model

The proposed model comprises of two network communication layer; layer one responsible for identifying and communication with vehicles, within a short range of 2meters. While layer 2 handles long range communication of data transfer from layer one to through the central processor to the speed detection database. the technique used for determining the speed of vehicles is based on time and distance computation technique, obtained from the layer one communication between the user unit (RFID card or transponder) and the IDAU sub unit (RFID reader or transceiver), the entire system comprise of the following components, internet modem, RFID reader, RFID cards, embedded microcontroller, server computer, and database system. Each component collaborating to create a new internet network that enhances road safety and timely detection and punishment of driving speed limit violators.

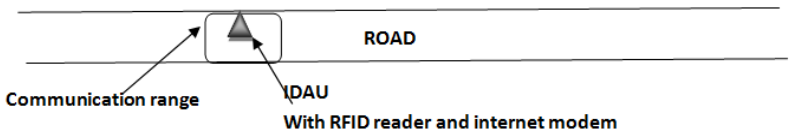


**Fig 2:** RVSDS emplacement/ installation and operation principles

Fig2 shows the IDAU system installation along a road path in a non-conspicuous manner. A small design form factor is used to enable its installation in the form of a solar road reflector to avoid the possibility of drivers detecting its presence on the road. Also, communication between vehicles and the system is ensured in a first come first serve queue system, enabling vehicle communication with the IDAU RFID reader unit, one at a time, preventing the issue of tag flooding the reader.

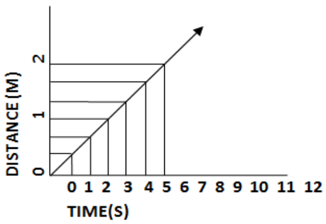


**Fig. 3:** Time and distance graph of RVSDS operation showing IDAU communication distance of Vehicle travel time

The time and distance graph in Fig3 explicitly shows the technique for detection of vehicle speed used by proposed system at a fixed time limit expected for every vehicle to travel the 2meter distance for each tag.

## 4.1 Proposed Algorithm and Mathematical Formula

Three algorithms are proposed for the RVSDS operation. The first two algorithm (eqn(1) and eqn(2)) allow computation of required speed for vehicles on a road segment and detect the speed at which a vehicle drives on a road segment under the grid of the RFID reader. The third algorithm perform the comparism logic to decide if vehicle over speeds or not and to report the vehicle unique identification number with other details or not.

The proposed algorithm determines the speed of vehicles using the timestamps from the beginning of the vehicle RFID tag communication to the end. This is within a fixed 2meter distance for RFID reader capability using the following steps:

- ***Step 1:*** Calculating the speed limit for a road section

The specified speed limit ($SSP_L$ )of each IDAU on each road segment relative to the fixed RFID transceiver subsystem communication range with vehicles RFID transponder is calculated by using eq.(1)

$$SSP_L = d / t \tag{1}$$

Where

d= coverage area of distance of the RFID reader in the IDAU subsystem of the RVSDS system (2meters)

t = time pre-defined to travel through the distance of the RFID reader coverage area

- ***Step2:*** Calculating the time taken($t_t$ )by vehicle to travel through the distance of the RFID reader coverage area ($t_t$)

The start time of vehicle tag communication with IDAU RFID reader ($T_{BCOM}$), subtracted from the end time of vehicle RFID tag communication with IDAU RFID reader($T_{ECOM}$.). It is calculated by the eq(2)

$$t_t = T_{ECOM} - T_{BCOM} \tag{2}$$

Where

$T_{ECOM}$= time stamp marking the end of communication between vehicle RFID transponder and IDAU RFID transceiver

$T_{BCOM}$ = time stamp marking the beginning of communication between vehicle RFID transponder and IDAU RFID transceiver

- ***Step 3:*** Calculating the speed of vehicle detected

The vehicle speed ($VSP_d$ )of each vehicle by the IDAU on each road segment relative to the fixed RFID transceiver subsystem communication range (d) with vehicles RFID transponder and the time taken($t_t$ )by vehicle to travel through it, is calculated by using eq.(3)

$$VSP_d = d / t_t \tag{3}$$

Where

d= coverage area of distance of the RFID reader in the IDAU subsystem of the RVSDS system usually 2meters

$t_t$ = the time taken ($t_t$ ) by vehicle to travel through the distance of the RFID reader coverage area

- ***Step4 :*** Determining the vehicle that violates speed limit

This is determined by simply comparing the result from eqn(1) and eqn(2), IF ($VSP_d$ ) m/s <= ($SSP_L$)m/s THEN vehicle did Not-Default / violate speed limit. Its details are transferred onward through the internet for further processingELSE IF ($VSP_d$ ) m/s > ($SSP_L$)m/s THEN vehicle defaulted speed limit traffic rule Transfer details through the internet for further processing.

### 4.1.1 Pseudo code for Determining Speed Limit

**Algorithm eqn (1) (**d, t**,** $SSP_L$**)**

```
{
Read: d
Read: t
SSP_L = distance / time
Return SSP_L;
End
}
```

### 4.1.2. Pseudo code for Determining time taken to travel through IDAU RFID reader reachable range and equivalent speed used by a vehicle combines Step2 and Step 3

**Algorithm eqn(2) (**$T_{ECOM,}$ $T_{BCOM}$, d, $t_t$ ,$VSP_D$**)**

```
{
read: distance
read;T_BCOM
read: T_ECOM
t_t = T_ECOM  - T_BCOM
VSP_D= d/ t_t
Return VSP_D
end
}
```

### 4.1.3 Pseudo code for Determining vehicle violation of specified speed limit using step4

**Algorithm SpeedDetect ($VSP_d$, $SSP_L$)**

```
{
Input: VSP_d
input: SSP_L
IF VSP_D > SSP_L
then
sendToDatabaseReport(
RFID tag number
+
RFID reader name// the named location where vehicle had defaulted
+
Communication details// start time, end time, time travelled, predetermined time by equ(1)
)
ElseIf VSP_D<= SSP_L
then
doNothing()
return
}
```

### 4.1.4 Pseudo code to Terminate after completing an operation for a vehicle

```
Return to 4.1.1
Repeat For all vehicles
```

## 5.0 Result of Findings

Given the four segment road A1 to A4 as shown in Fig4, varying specified communication range for each IDAU unit and estimated time for each vehicle to travel through were assigned. Beginning from communication between the vehicle RFID transponder, and the IDAU RFID transceiver, to the end of communication is recorded in Table1. The time stamp acquired by the IDAU for four vehicles (V1 to V4) travelling through segment A1, is given in Table3. Hence, applying the proposed algorithm and the mathematical formulas derived from the system model will determine the vehicles that violate the speed limit in road segment.

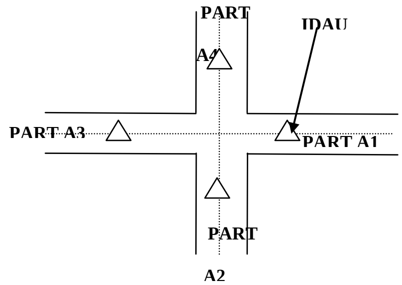


**Fig 4:** Four simulated emplacement of IDAU on road segments

Fig4 shows a four road segment, with IDAU placed along paths, anticipating incoming vehicles, to communicate with and determine their speed limit.

Table1 contains road segment information, and estimated time expected for each vehicle to travel on each road segment, over varying IDAU RFID unit, with varying communication range and estimated time to begin and end the communication within the specified communication range.

**Table 1:** IDAU emplacement and road segments information

| **Road Segment** | **IDAU RFID Reader Coverage / Or Road Segment Distance** | **Estimated Time For Vehicle To Travel The Distance Per Segment Of Road** | **Speed Limit For Each Road Segment ($SSP_L$)** |
|---|---|---|---|
| **A1** | 2M | 20S | ? |
| **A2** | 3M | 10S | ? |
| **A3** | 2M | 20S | ? |
| **A4** | 1M | 30S | ? |

The missing speed limit for segment A1 to A4 is computed as follows:

- **Step1**

We obtain the speed limit for each road segment as follows using eqn (1)

$SSP_L = d / t$

A1 =2/20 = 0.1M/S

A2 = 3/10 = 0.3M/S

A3 =2/20 = 0.1M/S

A4 =1/30= 0.03M/S

The computed speed limit for each road segment that a vehicle must comply to is known and fixed.

- ***Step2***

The time taken ($t_t$) by vehicle to travel through the distance of the RFID reader coverage areacan be computed given the detail of vehicle and IDAU communication timestamps, as shown in Table2.

**Table2:** vehicles travel time data obtained by IDAU RFID unit during communication with vehicles on segment A1 for four vehicles

| **Vehicle** | $T_{BCOM\ (sec)}$ | $T_{ECOM\ (sec)}$ | $t_{t\ (sec)}$ | $VSP_d$ |
|---|---|---|---|---|
| **V1** | 21 | 35 | ? | ? |
| **V2** | 50 | 80 | ? | ? |
| **V3** | 120 | 160 | ? | ? |
| **V4** | 180 | 200 | ? | ? |

Table2 contains timestamp information of communication between vehicles RFID transponders and IDAU RFID transceiver. The $t_t$ for the vehicles to travel through the IDAU RFID transceiver communication range for IDAU RFID transceiver on road segment A1 can be computed using eqn(2):

$t_t = T_{ECOM} - T_{BCOM}$

V1 = 35-21= 14S

V2 = 80-50 = 30S

V3= 160-120= 40S

V4=200-180 = 20S

Having obtained the time taken by vehicles (V1 to V4) travelling through road segment A1, the vehicle speed can now be computed using eqn(3).

- ***Step 3***

The vehicle speed is computed by the embedded central processing unit of the IDAU unit by applying eqn(3) of step three (3) of the proposed algorithm as follow;

$VSP_d = d / t_t$

$VSP_d$ v1 = 2/14 = 0.14m/s

$VSP_d$ v2 = 2/30 = 0.06m/s

$VSP_d$ v3 = 2/40 = 0.05m/s

$VSP_d$ v4 = 2/20 = 0.1m/s

**Table3:** Summary of all four vehicles travel/communication time and computed speed detected information

| Road Segment | Vehicle | $T_{BCOM\,(s)}$ | $T_{ECOM\,(s)}$ | $t_{t\,(s)}$ | $(VSP_d)$ m/s | $(SSP_L)$m/s | $(VSP_d)$ m/s |
|---|---|---|---|---|---|---|---|
| **A1** | **V1** | 21 | 35 | 14s | 0.14 | 0.1 | 0.14 |
| **A1** | **V2** | 50 | 80 | 30s | 0.06 | 0.1 | 0.06 |
| **A1** | **V3** | 120 | 160 | 40s | 0.05 | 0.1 | 0.05 |
| **A1** | **V4** | 180 | 200 | 20s | 0.1 | 0.1 | 0.1 |

- **Step4:** Determining the vehicles that violated the speed limit

The Table3 shows a brief summary of the result from the simulation of a single IDAU unit on road segment A1, with four vehicles travelling through a distance and the results of computed detected speed. Determining vehicles that defaulted traffic speed limit rule can be done using step4 comparative scheme as follows:

Defaulted = $(VSP_d)$ m/s > $(SSP_L)$m/s

Not-Defaulted = $(VSP_d)$ m/s< =$(SSP_L)$m/s

V1 0.14m/s <=0.1m/s = false = Defaulted

V2 0.06m/s<=0.1m/s =true = Not-Defaulted

V3 0.05m/s<=0.1m/s =true = Not-Defaulted

V4 0.1m/s <=0.1m/s = true = Not-Defaulted

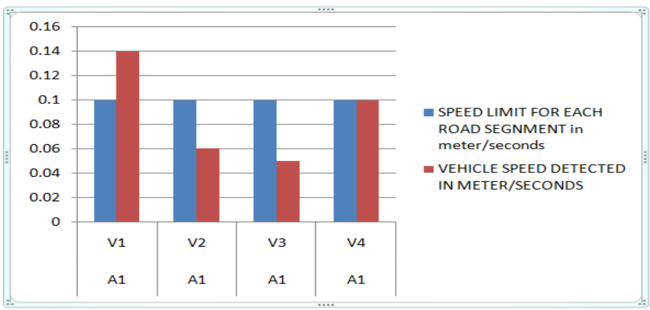


**Fig. 5:** Graphical representation of simulated four vehicle speed detection on road segment A1 by RVSDS

## 6.0 Discussion

Further analysis of the obtained vehicle data of Table3 is graphically represented in Fig5. The graph shows that vehicle V2, V3 and V4 travelled within the specified speed limit on road segment A1 as detected by the IDAU unit. Although, V4 travelled at the exact speed limit which is not dangerous, but not advisable because any slight increase in speed can registers the vehicle as a speed limit defaulter. V1 exceeded the speed limit on road segment A1, by driving at a speed of 0.14m/s, which is 40% higher than the stipulated speed limit. Thus, vehicle V1 information is collected and sent to the speed limit monitoring and data storage center by the embedded central processing unit, through the internet modem, for onward storage, and processing.

Therefore, the proposed RVSDS system promises to become the next generation vehicle speed detection system, which creates an internetwork designated for vehicle speed monitoring and reporting operation. the RVSDS spares no effort in timely detection, and reporting of excessively speeding vehicles, thereby enhancing a guarantee prosecution of all offenders, storage of offenders track record which in turn creates a disciplined society of drivers with the consciousness of always being spotted on excessive speed driving with commensurate punishment in an undetectable system which is similar to solar road reflectors.

## 7.0 Conclusion and Future Work

This paper presents a vehicle speed detection model that enhances internet of things, through the use of RFID technology. This approach will dramatically increase the number of things connected over the internet as already anticipated by lot of authors. It promises to be a perfect replacement for other existing expensive vehicle speed detection and reporting system. Therefore, the use of vehicle speed detection model will enhance its suitability in the future smart city transport system. Also the RVSDS will enhance road safety, inculcating the speed limit consciousness into all drivers. Due to its miniaturised design form factor, the existence of speed detection system will rarely be noticed. The RVSDS model, was designed, modelled, and simulated to obtain data. Its result shows the efficiency and accuracy of its operation, when fully implemented. Although, further test and proper design consideration, in ensuring the limitation of RFID reader communication range within 2meters, is highly required to avoid tag flooding.

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