MTSFB TR 1:2018

TECHNICAL REPORT

VEHICLE DIAGNOSTIC MONITORING SYSTEM (VDMS)

Preface

Vehicle Diagnostic Monitoring System (VDMS) is developed to provide a connected, data-rich monitoring environment. Using the VDMS, transportation providers will be able to monitor real time information such as location and current task of their vehicles, as well as vehicles' health status. The system is also developed to provide details which can be used in financial planning such as fuel consumption and in assessing the vehicles' enviromental impact such as vehicles' carbon emission.

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Abbreviations

AAC	Automatic Air Conditioning
ARM	Advanced RISC Machine
ARTC	Automotive Research & Testing Centre
CAN	Controller Area Network
DTS	Dedicated Transport System
ECU	Engine Controller Unit
EMS	Engine Management System
EPB	Electric Parking Brake
EPS	Electric Power Steering System
FMS	Fleet Management System
GHG	Greenhouse Gas
GPS	Global Positioning System
SPI	Serial Peripheral Interface
VDMS	Vehicle Diagnostic Monitoring System

VEHICLE DIAGNOSTIC MONITORING SYSTEM (VDMS)

1. Introduction

Rapid development in urban areas requires the general public to travel daily. With current inter-town connectivity via public transportation, there is constant increase of public transportation users as they find such mode of transportation affordable and convenient. With this development, public transportation providers, such as bus and taxi operators, need to ensure that their services and vehicles are up to standards and efficient to remain relevant in the industry.

The Vehicle Diagnostic Monitoring System (VDMS) provides a connected, data-rich monitoring environment. The VDMS device captures real-time data from vehicles (buses, taxis and trucks) which provides detailed vehicle status to the transportation providers. Through the system, service providers can monitor location and current task of their vehicles, vehicles' health status, fuel consumption and carbon emission among others.

2. Target groups and benefits

This technology targets public transportation providers, such as bus and taxi operators, to whom vehicle close tracking and monitoring are vital to assess the standards and efficiencies of their service.

The major benefits of adopting this technology include:

a) Improving service performances and efficiencies by closely monitoring activities of the vehicles;

b) Improving safety by monitoring drivers' driving practice while at the same time ensuring good work discipline among the drivers;

c) Assisting transportation service providers to drill down on daily fuel consumption of the vehicles thus identifying the elements in reducing cost and fuel consumption;

d) Supporting green technology by monitoring carbon emission of vehicles - ensuring that the vehicles adhere to the carbon emission limit for cities they travel to; and

e) Providing the transportation service providers with vehicle health status at any given time and to alert them on any emergencies.

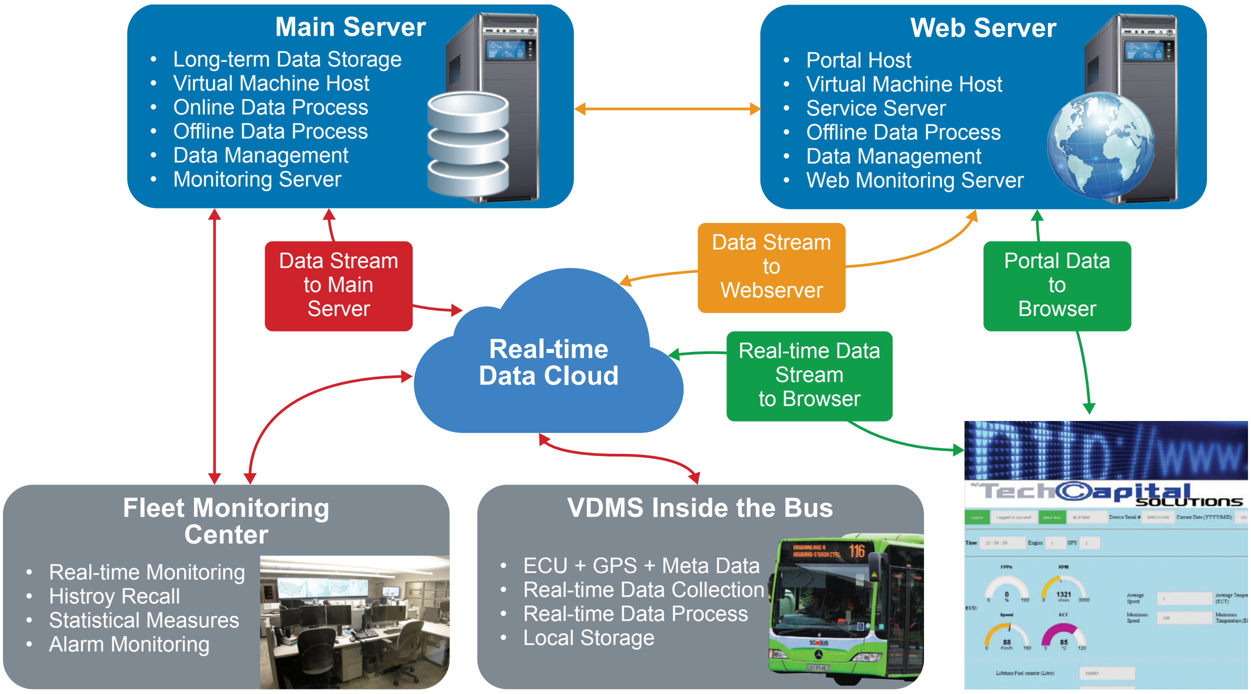

Figure 1. VDMS overall structure

The VDMS device will automatically install the VDMS system equipped with MCP2515 controller, ARM Based NanoPC, ECU Communication Interface, Smart Power Supply, GPS and 3G communication module on to the vehicle's Engine Control Unit (ECU).

This connectivity gives instant access to the vehicle status. The system then connects to a cloud data hub through wireless connection. Users can then access the vehicle status information through a portal. The visual interpretation of the overall architecture of VDMS is presented in Figure 1.

3. Objectives

The main objectives of this technology implementation are:

a) To monitor the speed, location and route of vehicles via GPS module;

b) To improve service performance and efficiency by monitoring vehicle activities (location and time of start/stops);

c) To monitor fuel consumption and CO_2 emission; and

d) To provide accurate and reliable real-time information on vehicle activities through access portal.

4. Scope of work

The scope of work for this project is as follows:

a) Phase 1:

i) Project planning

b) Phase 2:

i) Hardware implementation on sample bus: connecting the hardware to the vehicle's ECU, collecting sample data from the VDMS device;

ii) Submission of purchase orders to Designated Transport System (DTS); and

iii) VDMS device installation and data integrity acceptance by DTS.

c) Phase 3:

i) Data collection study: to ensure the VDMS values are accurate and within the designated range; and

ii) Submission of final project report and data sample for DTS' approval.

5. Methodology

The four elements of VDMS are:

a) VDMS hardware

i) The VDMS hardware comprises of MCP2515 controller, ARM Based NanoPC, ECU Communication Interface, Smart Power Supply, GPS and 3G communication module; and

ii) The VDMS hardware is installed on to vehicles and connects directly to the vehicles' ECU.

b) Data collection and interpretation

c) Channelling of processed information to the cloud data hub

i) This process is done over 3G wireless connection. Through this cloud data hub, users can access the status of the vehicle from any location and at any time through internet connection.

d) Data visualisation

i) The analysed data is presented through a user-friendly dashboard.

5.1 System hardware components

Figure 2. VDMS hardware system

Figure 2 above depicts the VDMS hardware. The VDMS is enclosed in a black box of 13.3 cm (length) x 10.6 cm (width) x 7.0 cm (height).

The VDMS is connected to the ECU of the vehicle through the C471 connector indicated by a circle in Figure 3 which is located under the central electric unit in the instrument panel of the bus via a round 2 positions sockets, of part No. 1-1719434-1 from TE connectivity as shown in Figure 4.

The main components inside the VDMS are the ARM Based NanoPC, ECU Communication Interface, Smart Power Supply, 3G communication module and MCP2515 controller.

Figure 3. The connection point to the ECU at C471 connector

Figure 4. The connection to C471 connector using part No. 1-1719434-1 socket

Once the VDMS is connected to the ECU, the VDMS extracts the ECU data on the vehicle status. The SCANIA bus (the bus model used for this project), similar to every other modern vehicle, had a communication system that connects and communicates with the different components of the vehicle.

The communication system used by SCANIA bus is called Controller Area Network (CAN) bus. Another standard system, the Fleet Management System (FMS), manages the CAN bus data management and monitoring. The VDMS collects vehicle data from the CAN bus, interprets and analyses the data into understandable information and displays this information on the system dashboard.

5.1.1 SCANIA's CAN bus

SCANIA

TECHNICAL PRODUCT DATA **1731923**
Controller Area Network Specification
Bus Chassis System (BCS) external CAN bus

CAN bus is a rigid digital bus (communication system) which is designed to communicate with many computers/micro-controllers without the need of host computer.

The hardware and software (protocol) are designed to connect together many controlling units such as engine control unit, auto transmission, airbags, ABS, power steering, advance audio systems and air conditioner. For example, if the driver changes the gear to reverse, the CAN bus will activate the rear camera, brake lights and rear sensor and assist the vehicle reversing process.

Figure 5 shows the example of CAN bus connection functioning as a communicator between multiplex wiring system of different components in a vehicle.

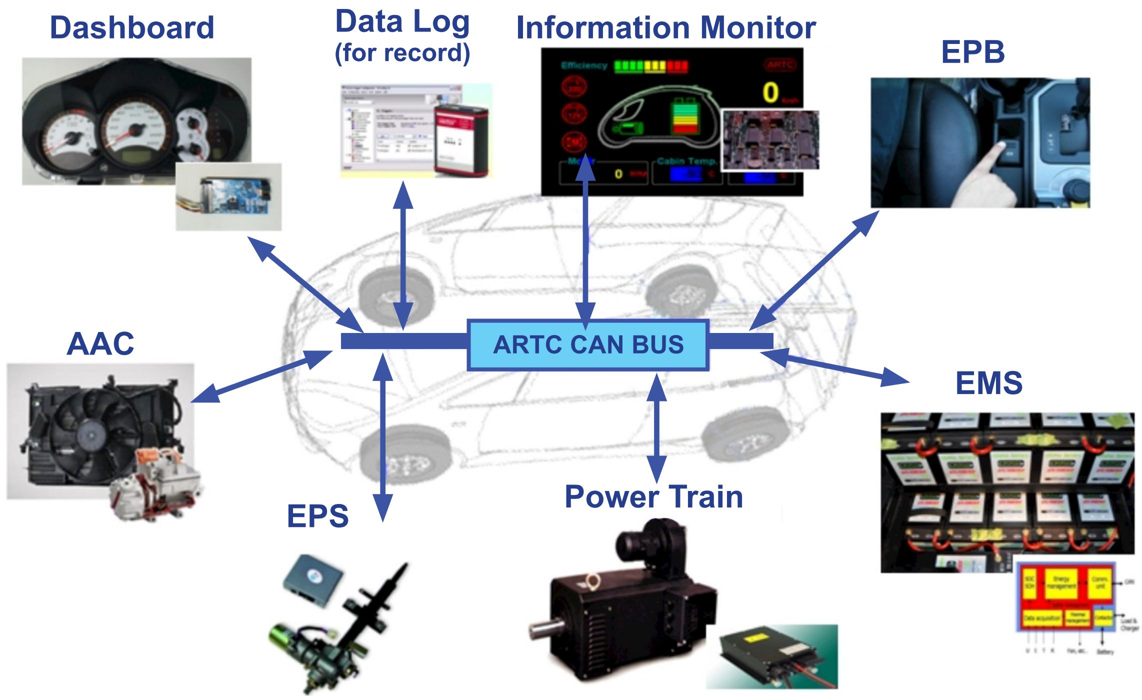

Figure 5. CAN bus connection functions

Data collected by the CAN bus comprises of many parameters as shown in Table 1. The parameters are identified through their unique identifiers and filtered as per VDMS requirements.

Unique identifiers are standardised across CAN buses using FMS.

Table 1. Sample of CAN bus parameters and respective identifiers

No	Parameter	Identifier [Hex]	DLC	DATA 0	DATA 1	DATA 2	DATA 3	DATA 4	DATA 5	DATA 6	DATA 7
1	Total fuel used	18FEE900x	8	FF	FF	FF	FF	11	CC	07	00
2	Engine coolant temperature	18FEEE00x	8	79	FF	FF	FF	FF	FF	FF	FF
3	Vehicle distance	18FEC1EEx	8	08	94	98	07	FF	FF	FF	FF
4	Wheel based vehicle speed	18FEF100x	8	F3	C9	05	54	03	FF	FF	FF
5	Engine speed	0CF00400x	8	F0	7D	85	3A	10	FF	FF	FF
6	Accelerator pedal postition	0CF00300x	8	F0	38	1A	FF	FF	FC	FF	FF

5.1.2 MCP2515 controller

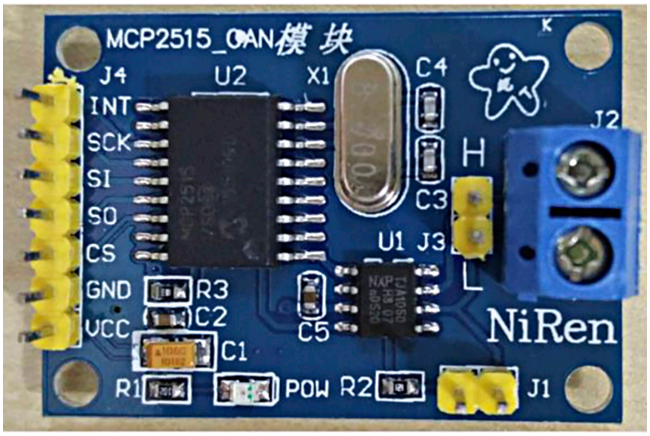

Figure 6. MCP2515 controller

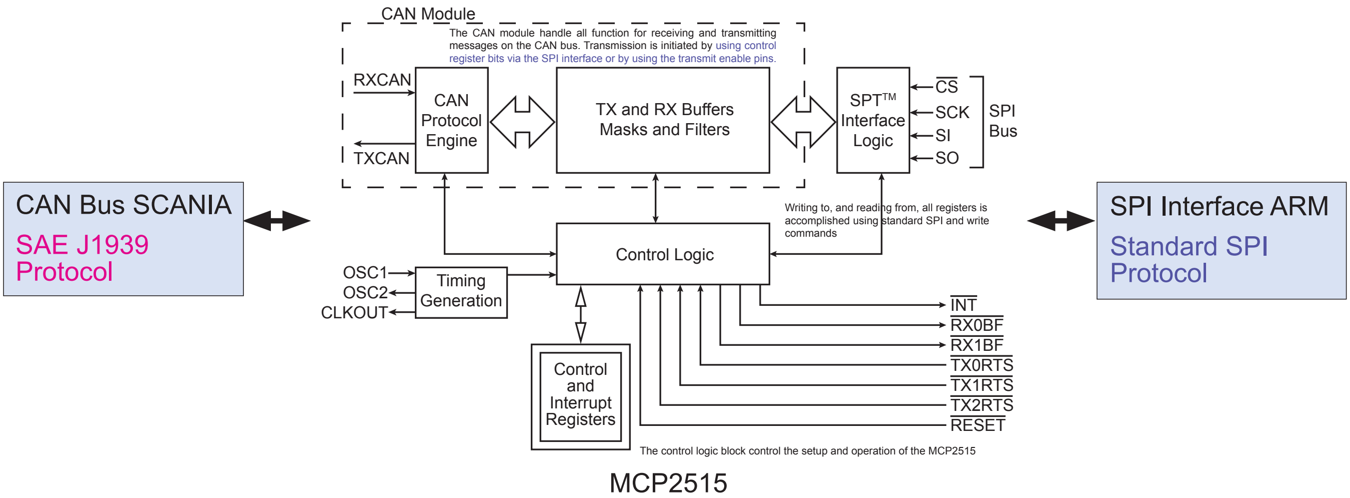

Figure 7. ARM block diagram

MCP2515 controller as shown in 6, is used to convert the CAN bus SCANIA (SAE J1939) protocol to the standard SPI protocol as described in Figure 7. The ARM Based NanoPC processor is used to process the CAN bus data into user readable data.

However, the data for CO_2 emission is not displayed in the CAN bus data. CO_2 emission of the vehicle is calculated based on *GHG Protocol-Mobile Guide (03/21/05) v1.3* [(1)].

CO_2 emission is calculated using the following equation:

$$CO_2\ (kg) = \text{fuel used (litre)} \times \text{heating value}\left(\frac{GJ}{litre}\right) \times \text{emission factor}\left(\frac{kg\ CO_2}{GJ}\right)$$

where

Fuel used = readily obtained from CAN bus data (litre)
Heating value = 0.0371 GJ/litre
Emission factor = 74.01 kg CO_2/GJ

5.1.3 ARM Based NanoPC

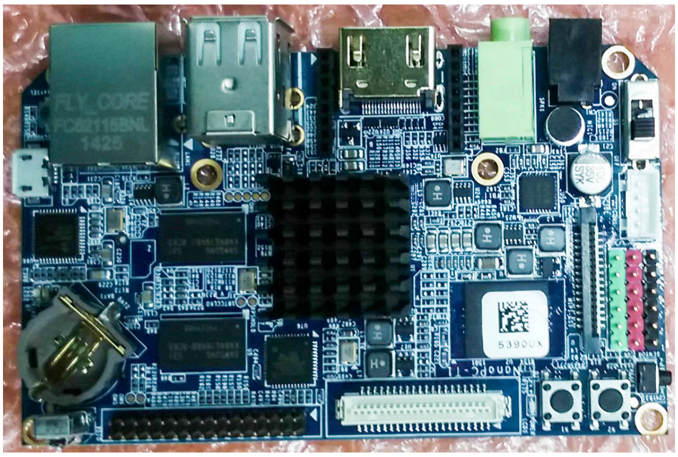

Figure 8. ARM Based NanoPC

The ARM Based NanoPC as shown in Figure 8, processes the data received from the CAN bus or the vehicle. The java program written to extract and calculate the CAN bus data is embedded in the Samsung Cortex-A9 Quad-core Exynos 4412, 1.5G Hz.

The detailed description of the ARM Based NanoPC as shown in Figure 9.

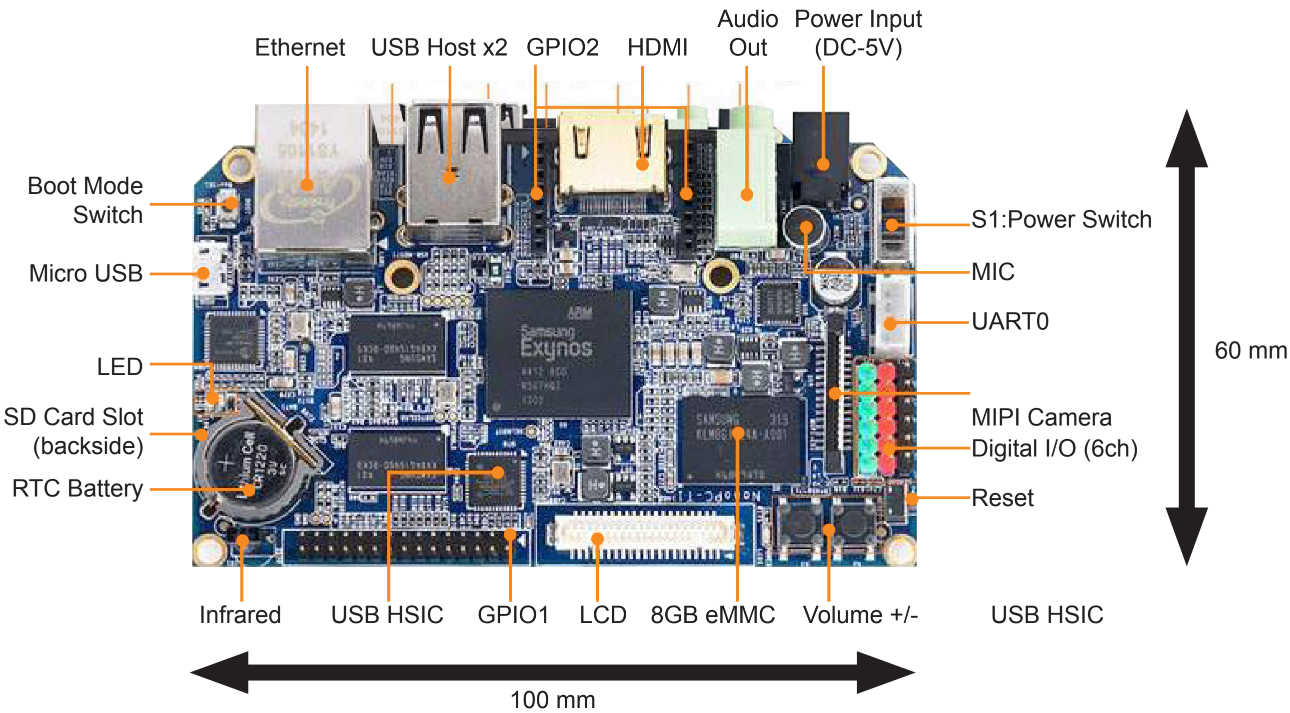

Figure 9. ARM Based NanoPC with labelling

Specifications:

a) Samsung Cortex-A9 Quad-core Exynos 4412, 1.5G Hz

b) RAM: 1 GB DDR3 RAM, 32-bit data bus

c) Flash: 8GB eMMC flash

d) HDMI output resolution: 1080P (1920 x 1080)

e) LCD: TFT LCD interface

f) USB OTG: One microUSB interface

g) USB Host: Two USB Host 2.0 interface

h) Ethernet: 100 Mhz Ethernet, RJ45

i) SD card slot

j) Audio In: One MIC in box

k) One Audio Out in jack

l) IR: One infrared receiver

m) Two users keys

n) Two user LED

o) Six digital sensor I/O

p) CMOS camera interface

q) MIPI interface: Support HD camera

r) GPIO1-34Pin: UART x 2, SPI x 1, I2C x 1

s) GPIO x 13 GPIO2-16Pin: UART x 1, GPIO x 2, SDIO x 1, USB Host 2.0 x 1

t) Android 4.2.2 & 5.0

5.1.4 Smart Power Supply

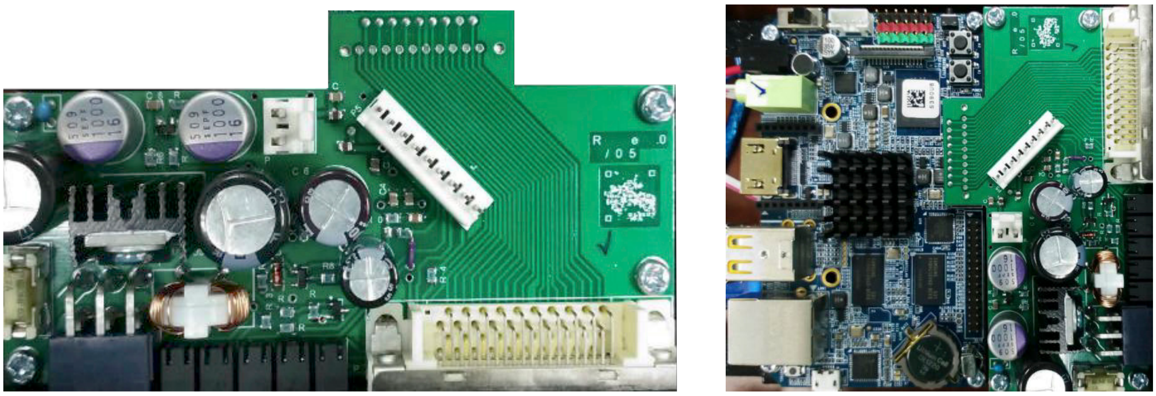

Figure 10. Smart Power Supply

The power regulator or Smart Power Supply as depicted in Figure 10, is another essential part of the device. This component not only helps to protect the device from over voltage and short circuit, but also oversees the status of both the hardware and software in case of crash or loss of connectivity. In such instances, the board is able to reset the device automatically.

The following is the description of this integrated board:

a) Wide range voltage input

b) Reverse polarity protection

c) Over voltage protection

d) Short circuit protection

e) Independent watchdog timer to detect non-running software so that power can be reinstated to restart the unit and to remove faults

f) ECU communication interface

g) RS232 interface

h) Surge protection

i) Status indicators

j) Power ON

k) ECU connection

l) GPS status

m) 3G status

n) Software status

o) LCD connector (debugging purpose)

5.1.5 3G Communication module

Figure 11. 3G Communication module

The VDMS is connected to the virtual dashboard/web portal through 3G connection by a 3G communication module as per Figure 11. GSM-based connection is used via the telecommunication network provider.

5.2 System

A java programme extracts the information from the CAN bus through the MCP2515 controller. The data is then converted, calculated and channelled to the cloud data hub.

The java programme is written in Android Studio using Android Open Source Project (AOSP) as its operating system. Screen shot of the java programme is as per Figure 12.

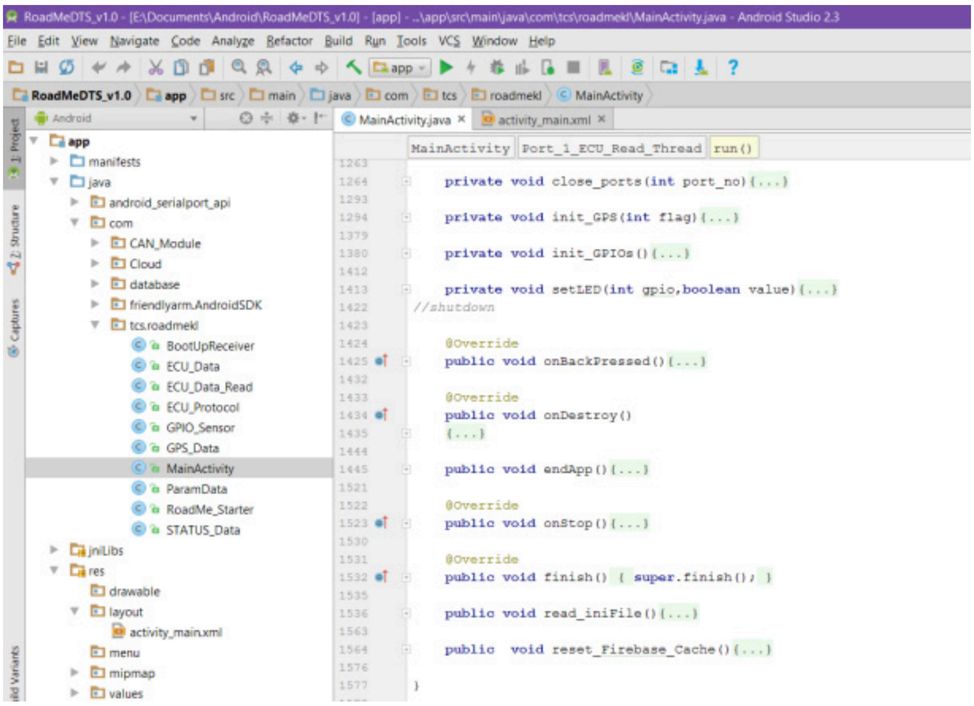

Figure 12. A screenshot of the java program for ARM Based NanoPC

5.3 Portal development

The vehicle information is displayed through a dashboard or web portal. This website is designed using HTML environment.

To use this portal:

a) Log in to the website and select the vehicle to be monitored; and

b) The portal will then load the current status of the vehicle such as the vehicle RPM meter, speed meter, engine temperature and fuel used.

Screenshot of the HTML codes as shown in Figure 13.

```
<!DOCTYPE html>
<html>
<head>
    <title> DTS Real-time Demo</title>

    <meta charset="utf-8" />
    <link rel="stylesheet" type="text/css" href="css/stylesheet.css">
        <link rel="icon" href="images/favicon.ico" type="image/x-icon"/>
        <link rel="shortcut icon" href="images/favicon.ico" type="image/x-icon"/>

    <script async defer src="https://maps.googleapis.com/maps/api/js?key=AIzaSyABvHSEtsexct-DGRmSx-8eKDK6S5cZRYY&"
            type="text/javascript">
        google.maps.event.addDomListener(window, 'load', init_map);
    </script>
        <script src="js/raphael-2.1.4.min.js"></script>
    <script src="js/justgage.js"></script>


</head>

<body>

    <ul class="topnav">
        <li><a href="#home">Home</a></li>
        <li><a href="#contact">Contact</a></li>
        <li><a href="#about">About</a></li>
        <li class="icon">
            <a href="javascript:void(0);" onclick="myFunction()">&#9776;</a>
        </li>
    </ul>

    <img src="images/header.png" alt="TechCapital Solutions Sdn Bhd" style="width:auto;" style="display: block; margin-left: auto; margin-right: auto;">
        </br>

    <!--Login-->
    <button onclick="loginButtonClick()" id="loginButton" style="width:auto;">Login</button>
    <input type="text" id="loginStatus" disabled maxlength="20" size="15" style="width:auto;">
```

Figure 13. Screenshot of the HTML codes

Dashboard login interface is as per Figure 14.

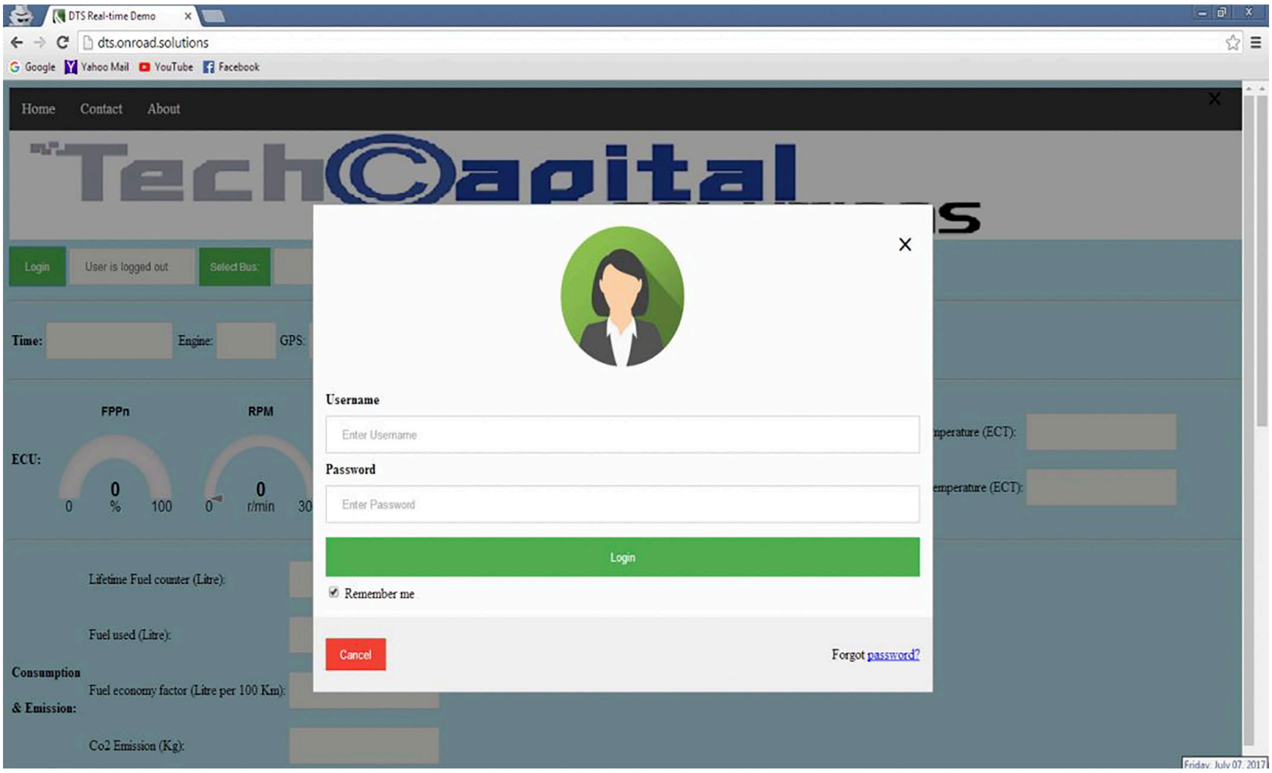

Figure 14. Dashboard login interface

Design of the VDMS dashboard is as per Figure 15.

Figure 15. VDMS dashboard

6. Progress status

The sequence of VDMS system installation onto SCANIA bus is tabulated in Figures 16 to 22:

Figure 16. DTS bus

Step 1
The sample bus for VDMS installation and testing.

Figure 17. ECU bus

Step 2
ECU to power source and CAN bus cable connection.

Figure 18. Cables installation

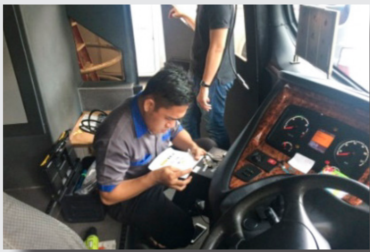

Figure 19. Bus dashboard

Step 3
ECU to power source and CAN bus cable connection.

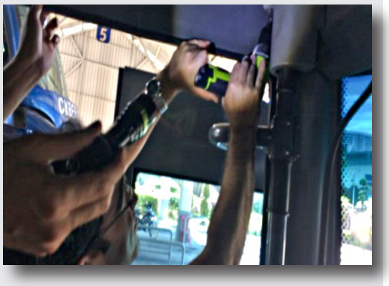

Figure 20. Drilling holes

Step 4
Wiring works in progress to connect the cable from the bus ECU to the second floor of the bus.

Figure 21. VDMS compartment

Step 5
VDMS is installed into this front compartment on the second floor of the bus.

Figure 22. VDMS installation

Step 6
VDMS is wired to the ECU.

7. Result analysis

Table 2 shows data collected from VDMS for test period between 1 to 9 July 2017. Data will be extracted from the VDMS dashboard at the end of each day as stated in the table. The location column shows the last GPS location of the bus at 23:59:59 with the first set of numbers indicating the longitude and the second indicating the latitude.

The tachometer reading column shows the total distance travelled by the bus since its first day of operation and reading will be added up for every travel.

The remaining columns travel (km), max speed (km/h), max temperature (°C), fuel consumption for the day (litre), fuel counter (litre), and CO_2 emission (kg) record the bus engine status for the day. For instance, on 2 July 2017, the bus travelled a distance of 108 km with max speed of 108 km/h and max engine temperature of 104°C. On this day, the bus used 370 litres of diesel with a total fuel counter of 268,987 litres used. Also, for that amount of diesel and engine activity, the bus emitted 1,014.56 kg of CO_2 emission.

Table 2. Data collected from VDMS for period 1 – 9 July 2017

No	Date	Time	Location	Tachometer (km)	Travel (km)	Max Speed (km/h)	Max Temp (°C)	Fuel Consumption for the day (litre)	Fuel Counter (litre)	CO_2 Emission (kg)
1	Saturday, 1 July 2017	23:59:59	2.856931686401367, 101.75530242919922	668135.9375	0.5	0	54	0.5	268617.5	1.37
2	Sunday, 2 July 2017	23:59:59	4.829001426696777, 103.41488647460938	669012.8125	876.88	108	104	369.5	268987	1014.56
3	Monday, 3 July 2017	23:59:59	2.920471668243408, 101.65157318115234	669540.1875	527.38	108	104	225	269212	617.80
4	Tuesday, 4 July 2017	23:59:59	2.970950126647949, 101.5840072631836	669820.8125	280.63	108	104	139	269351	381.66
5	Wednesday, 5 July 2017	23:59:59	2.920754909515381, 101.65181732177734	669820.8125	0	108	104	1	269352	2.75
6	Thursday, 6 July 2017	23:59:59	2.9204182624816895, 101.65215301513672	670126.75	306	108	104	158	269510	433.84
7	Friday, 7 July 2017	23:59:59	2.920330047607422, 101.65203857421875	670299.5	173	108	104	92	269602	252.61
8	Saturday, 8 July 2017	23:59:59	2.9204649925231934, 101.65204620361328	670310.8125	11	108	104	9	269611	24.71
9	Sunday, 9 July 2017	23:59:59	2.920316696166992, 101.65206146240234	670578.25	268	108	104	143.5	269754.5	394.02

Figure 23. VDMS dashboard user interface

Figure 23 above is a snapshot of the VDMS dashboard. Through this dashboard, users can access current status of the vehicle by logging in to the portal and entering the vehicle plate number (through field located at the top row). The portal will then load the status of the vehicle such as the vehicle RPM meter, speed meter, engine temperature and fuel used. Figure 23 shows that the speed of BLG7808 at 23:59:59 is at 88 km/h and the engine temperature at that time is 85°C.

8. Conclusion

This technology is developed to monitor the speed, location and route of the given vehicles through the GPS module. The module is implemented by the VDMS that is able to monitor the information through 3G communication module.

The real-time monitoring functionality of VDMS will improve the service performance and efficiency by monitoring the vehicle activities (location and time of start/stop) and users are able to check the activities of the vehicle at any time through the web portal.

The VDMS monitors the fuel consumption and CO_2 emission and other environmental impact of the vehicle via the website portal. Information on fuel consumption and CO_2 emission rate would enable service providers to strategise routes for better fuel consumption hence reducing CO_2 emission rate.

The VDMS provides accurate and reliable real-time information on vehicle activities via the website portal and able to fulfil the needs through its sophisticated engineering.

9. References

[1] *Calculating CO_2 Emission from Mobile Sources. GHG Protocol - Mobile Guide (03/21/05) v1.3. Retrieved from http://www.ghgprotocol.org/guidance-0*

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