ÇUKUROVA UNIVERSITY
INSTITUTE OF NATURAL AND APPLIED SCIENCES

MSc THESIS

Muhammed Yakup YILMAZ

DESIGN AND IMPLEMENTATION OF A CAN COMMUNICATION LINE DIAGNOSIS SYSTEMATIC FOR ROAD VEHICLES

DEPARTMENT OF ELECTRICAL AND ELECTRONICS ENGINEERING

ADANA, 2014

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We certify that the thesis titled above was reviewed and approved for the award of degree of the Master of Science by the board of jury on 28/02/2014.

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Director Institute of Natural and Applied Sciences

ÖZ

YÜKSEK LİSANS TEZİ

KARAYOLU TAŞITLARI İÇİN CAN HABERLEŞME HATTI ARIZA TESPİTİ SİSTEMATİĞİ TASARLANMASI VE UYGULANMASI

Muhammed Yakup YILMAZ

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: Prof. Dr. Mehmet TÜMAY
: Doç. Dr. Mutlu AVCI

Bu çalışmanın amacı araçların CAN hattından okunup uzaktaki bir merkeze iletilen verilerin işlenmesini sağlayacak bir Hata ve Veri Yönetim Sistemi tasarlamak ve geliştirmektir. Merkezde toplanan verilerin ulaşılabilirliğini sağlayacak bir veritabanı ve sunucusu tasarlanacaktır.

Araca entegre edilmiş modül tarafından araçtan okunan ve GPRS üzerinden uzak kontrol merkezine iletilen veriler tasarlanan Hata ve Veri Yönetim Sistemi aracılığı ile analiz edilebilecek, sınıflandırılabilecektir. Belirli bir bölge, bir model veya bir komponent hakkında alınan gerçek araç verileri Veri Yönetim Konsolu sayesinde operatörün belirleyebileceği farklı kombinasyonlara göre filtrelenerek gerçek verilere dayalı raporlar hazırlanması sağlanabilecektir.

Anahtar Kelimeler : Uzaktan Diyagnoz, Veri Yönetimi, Veri Sınıflandırma, Otomotiv CAN Bus, GPRS&GPS.

ABSTRACT

MSc THESIS

DESIGN AND IMPLEMENTATION OF A CAN COMMUNICATION LINE DIAGNOSIS SYSTEMATIC FOR ROAD VEHICLES

Muhammed Yakup YILMAZ

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Supervisor : Asst. Prof. Dr. Murat AKSOY
Year: 2014, Pages: 102
Jury : Asst. Prof. Dr. Murat AKSOY
: Prof. Dr. Mehmet TÜMAY
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The purpose of this study is to design and improve a Failure and Data Management System which provides to process the data which is read from vehicle CAN line and transmitted to the remote center. A server and a database which provides the availability of stored data will be designed.

The data which is read from the vehicle and sent to remote center by the integrated remote diagnosis module will be analyzed and classified by the designed Failure and Data Management System. The real vehicle data which is collected about a specified region, a model or a component will be filtered according to the different combinations that the operator is able to set off. The field feedback reports which are based on the real vehicle data will be able to prepared through the Data Management Console.

Key Words : Remote Diagnosis, Data Management, Data Classification, Automotive CAN Bus, GPRS&GPS.

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I would like to send my greatest thanks to Deniz TANRIÖVER who supported me in this tiring period.

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LIST OF ABBREVIATIONS

A/C : Air Conditioner
ABS : Anti-lock Braking System
ACK : Acknowledgement (Data Networking)
ARM : Advanced RISC Machines
CAN : Controller Area Network
CM : Conversion Method
CPU : Central Processor Unit
CS : Coding Scheme
DLC : Data Length Code
DP : Data Page
DTC : Diagnostic Trouble Code
DTCO : Digital Tachograph
EBS : Electronic Brake System
ECAS : Electronically Controlled Air Suspension
ECS : Electronic Stability Control
ECU : Electronic Control Unit
EDGE : Enhanced Data rates for GSM Evolution
EDP : Extended Data Page
EOF : End of Frame
FMI : Failure Mode Identifier
GPRS : General Packet Radio Services
GPS : Global Positioning System
I-CAN : Instrumentation CAN
ID : Identifier
IDE : Identifier Extension
INT : Intermission
M-CAN : Multiplexer CAN
MOKI : Modular Cluster
NM : Network Management

OC	: Occurence Counter
P	: Priority
P-CAN	: Powertrain CAN
PG	: Parameter Group
PGN	: Parameter Group Number
PLC	: Programmable Logic Controller
REDI	: Remote Diagnosis
RISC	: Reduced Instruction Set Computing
RTR	: Remote Transmission Request
SA	: Source Address
SAE	: Society of Automotive Engineers
SOF	: Start of Frame
SPN	: Suspect Parameter Number
SQL	: Structured Query Language
SRR	: Substitute Request Bit
ZR2-E	: Central Controller

1. INTRODUCTION

The quality and the cost of aftersales services became very important recently for all industries. This is one of the main factors that effects directly the sales amount in the market. The importance of the quality and the cost of aftersales services are seen obviously in automotive industry, especially in commercial vehicle market. When there is a breakdown on a vehicle with full of passenger and if it is not possible to have the vehicle back on its way in a short time, the future sales will be effected evenly.

The service networks, road assistances are being improved however the root cause -human factor- still effects the progress. A person checks the bus first when there is a breakdown and a person intervenes in the failure as a road assistance member.. etc. Therefore, the quality and cost of the application is directly proportional to the technical qualification of these people.

On the other hand, it is a big amount of money and time to reach to the place of vehicle breakdown or to tow away the vehicle to the workshop for diagnosis and solution.

The system which is developed in this study resolves the problems "distance to the event's location" and "insufficient qualification of the technical member". Human and distance factors are eliminated with a remote communication system to the vehicle directly.

And also all data which is collected with this system is stored in a center and it is possible to use this data and analises for the future designs as a firsthand feedback from the field which is also a valuable information for the manufacturer. The process flow before this study for failure management is shown in Figure 1.1.

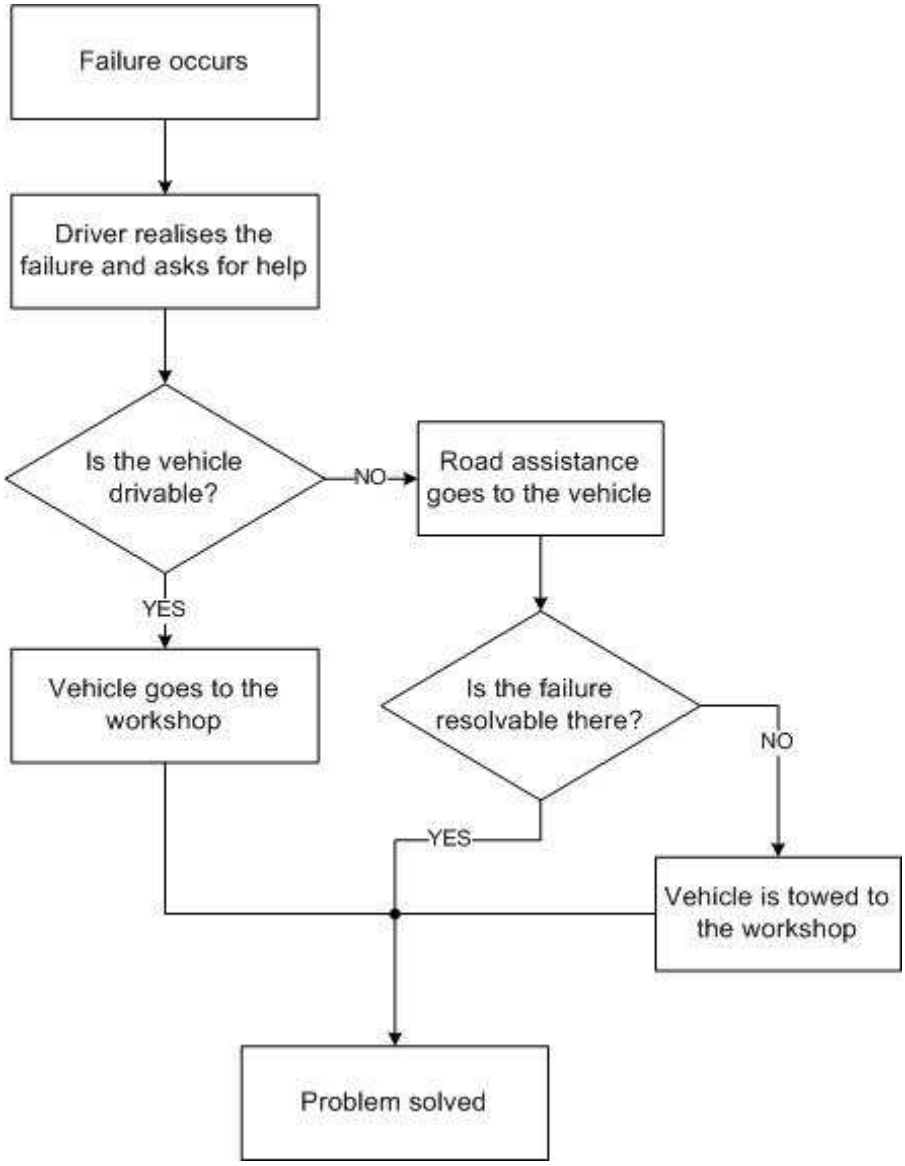


Figure 1.1. Current Process Flow For Fault Diagnosis and Solution

The process flow after this study for failure management is shown in Figure 1.2.

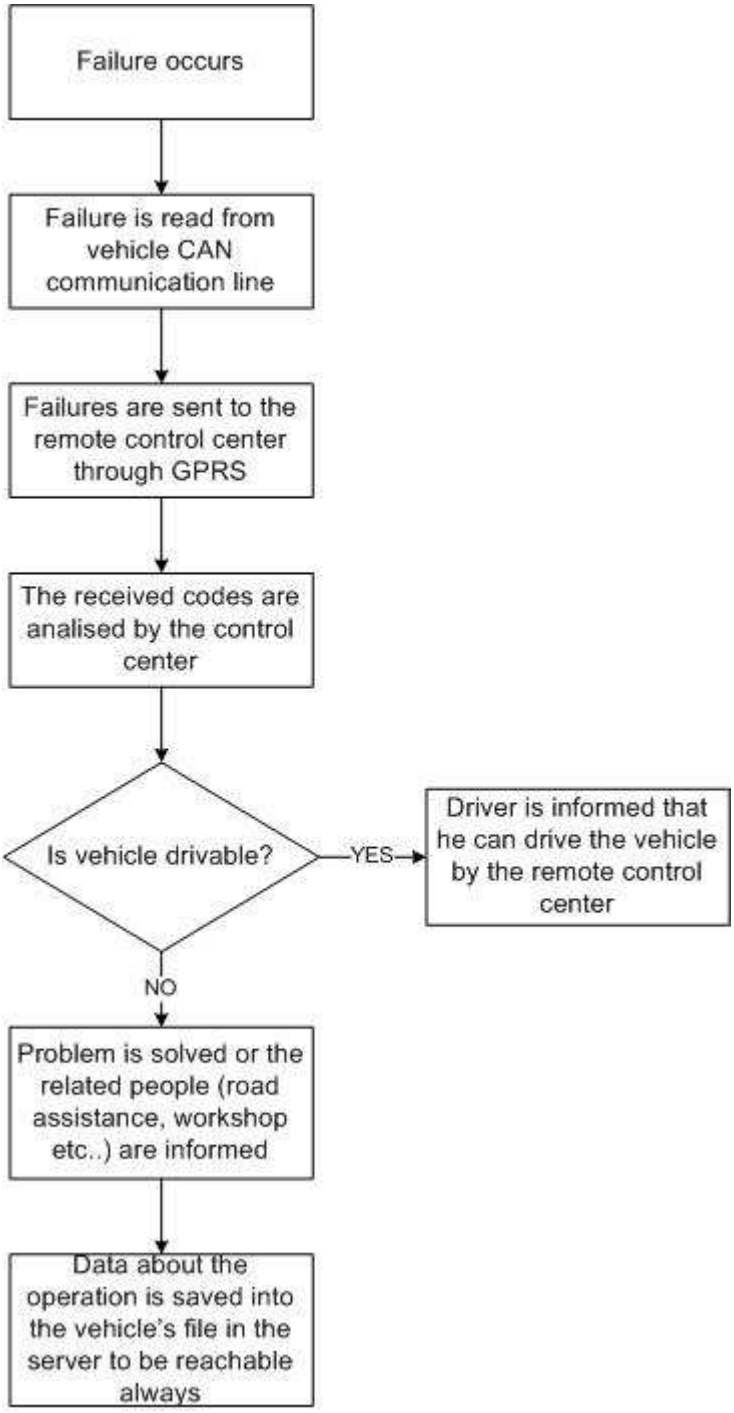


Figure 1.2. The process flow after this study

In this study a fault management system and a systematic for analyzing the data is developed. The main steps which are studied :

- Data management system design for the data or fault which is read from the vehicle communication line.
- Designing a hardware and a software for sending the data from vehicle to the data control center through GPRS.
- Designing and improving a data analyze systematic on a data control center
- Designing a remote fault control and response systematic

Material and Method: Electronic Control Units (ECU) which electronically controls the functions of the components such as engine, gearbox, Air Conditioner etc. need to communicate with each other. As an example engine speed information has to be sent to gearbox ECU from engine ECU. This communication is provided through a data network which is called CAN (Controller Area Network) and according to the SAE (Society of Automotive Engineers) J1939 automotive standard.

All data which is coming out from these ECUs are available in this data network. There are some special messages on CAN network for failures also.

When there is a failure on the vehicle it is read from CAN network directly and sent to the remote center through GPRS. Failure is analized according to a fault management systematic and responded back.

A project called Remote Diagnosis (REDI) which contains the works below;

- Reading data from CAN network
- Sending data to a remote center through GPRS
- Analysing the data
- Responding from the remote center
- Monitoring the data from the web server

is completed to manage all these data and failures from a remote center.

In this study “sending the data to a remote center”, “analaysing the data”, “responding back” and “monitoring the data” sections of this project designed, tested and applied. The general structure of REDI (Remote Diagnosis System) is shown in Figure 1.3.

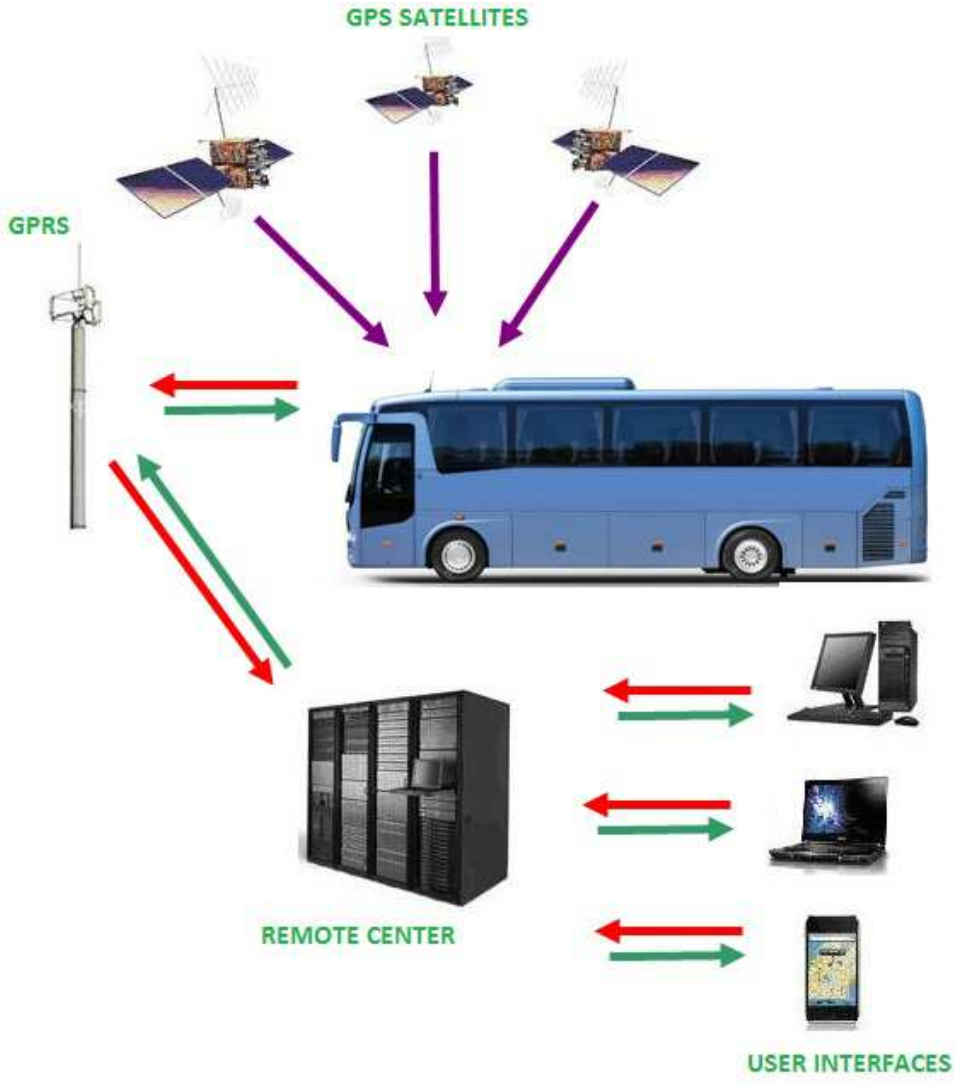


Figure 1.3. REDI Structure

The works for developing REDI in this study are listed like below:

- A hardware and a software for sending the data to the remote center
- A software for receiving and transmitting the data on the remote center
- A systematic for analaysing the data
- A web server for monitoring the data

2. PREVIOUS STUDIES

There are some studies completed about each developement section of this project such as data transfer through GPRS, determining the location through GPS satellites, communication with CAN network.

This study is related especially with the automotive applications of remote data transfer. So the previous works which are detailed below are generally about vehicle electronic diagnostic and mobile communication.

Schwinke had a patent in 2009 for a System and Method for Communicating Vehicle Diagnostic Data via an inactive telematics unit. In his study a serious diagnostic condition detected in the vehicle was used to trigger a call from the telematics unit to a call center using a cleared number. During the call, diagnostic data could be transmitted to the call center and a temporary number could be provided by the call center to the telematics unit to permit temporary communication. Additional diagnostics could be run and reported using this temporary number. General structure and the process flow of this system are shown in the Figures 2.1 and 2.2. Schwinke has used telephone calls for the remote data transfer. In this study data transfer is provided via GPRS.

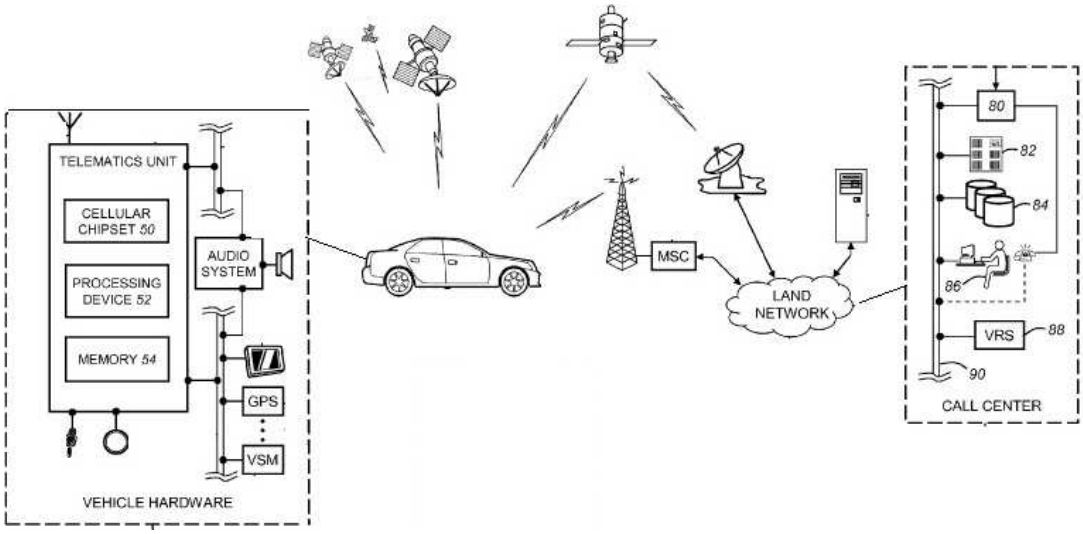


Figure 2.1. Schwinke System Structure (Schwinke, 2009)

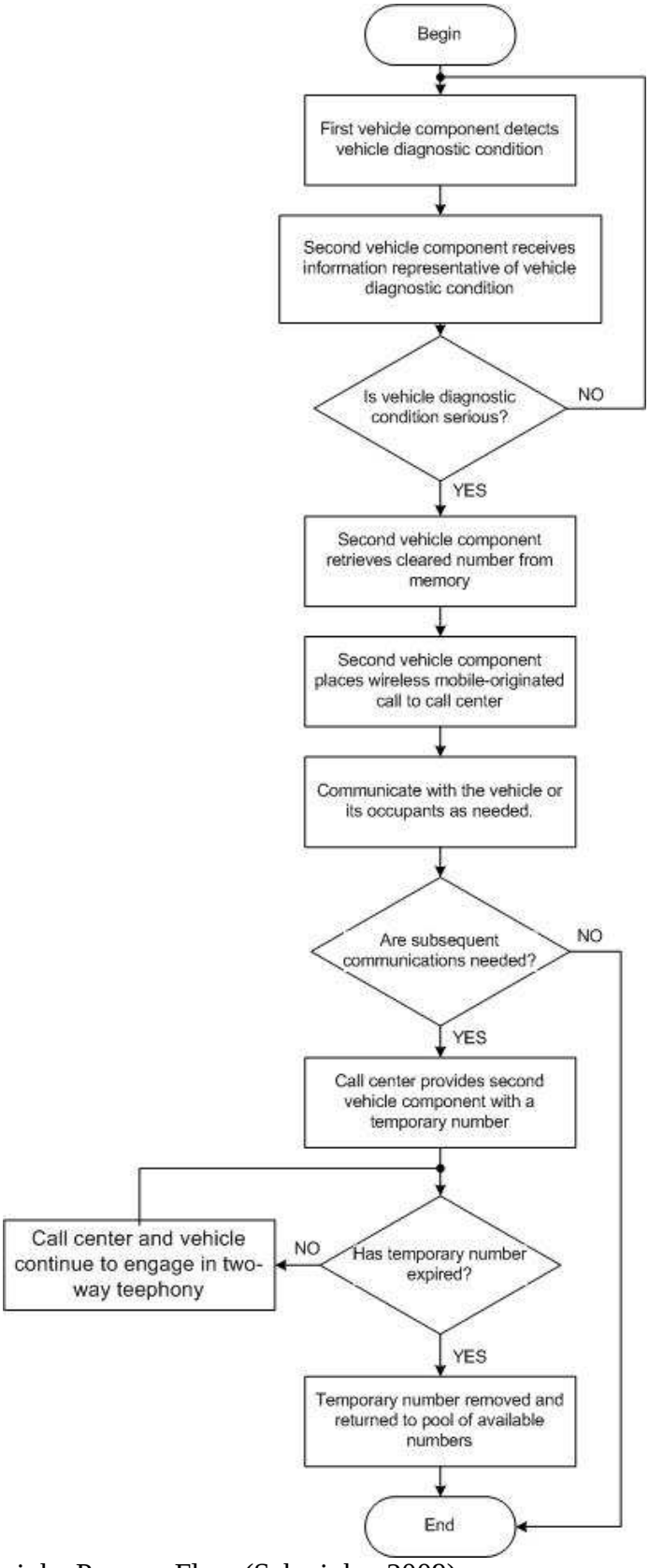


Figure 2.2. Schwinke Process Flow (Schwinke, 2009)

Faus and Ram have developed a system for monitoring CAN Bus information. Their study was very similar with a Fleet Management System. They have designed a method and system of monitoring CANbus information across an integrated wireless equipment management system and a mobile wireless communications system. Main idea of their study was to provide the selective vehicle information which is read from CANbus to a terminal of the integrated wireless equipment management system. General structure of their study shown in the Figures 2.3 and 2.4.

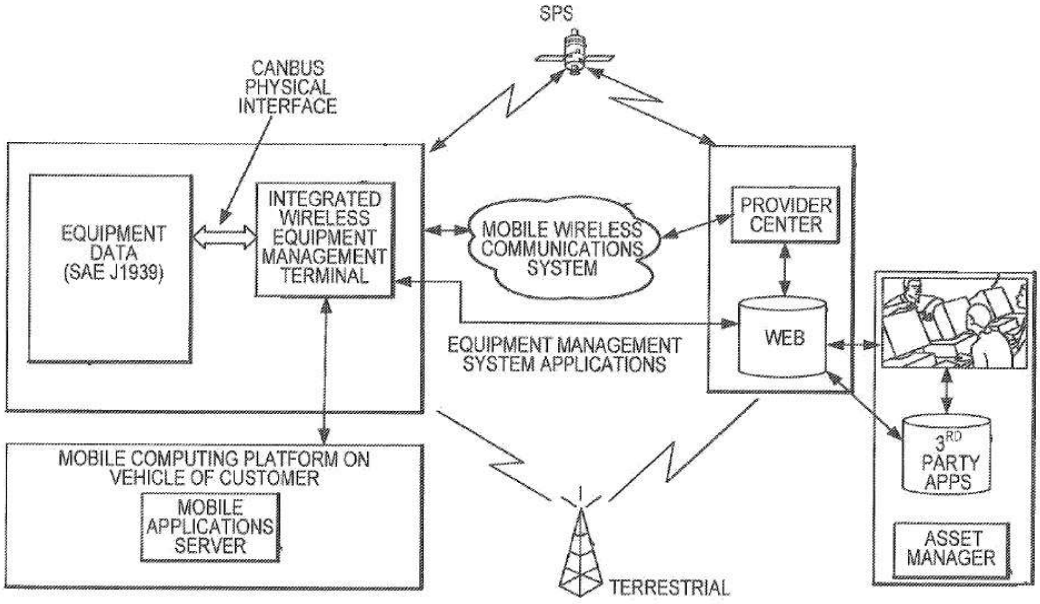


Figure 2.3. Faus System Structure (Faus, 2009)

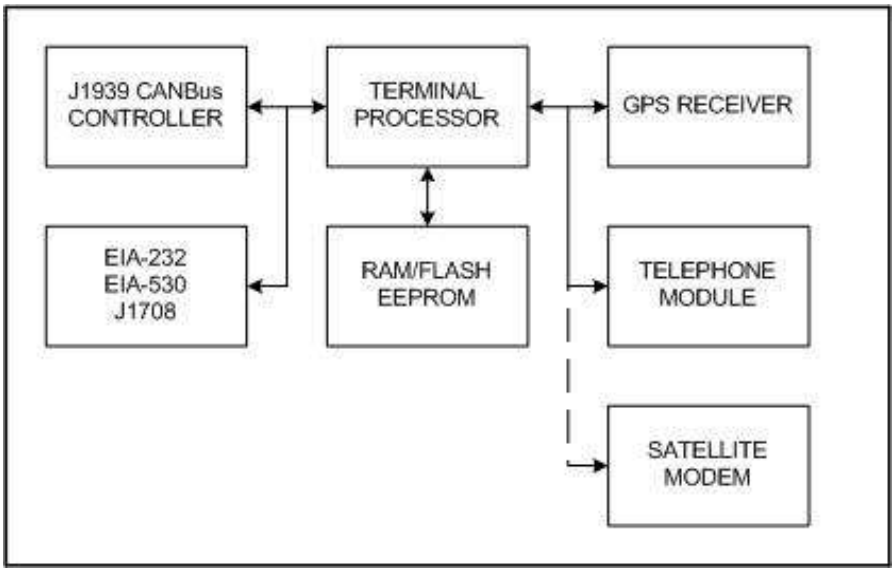


Figure 2.4. Faus System Block Diagram (Faus, 2009)

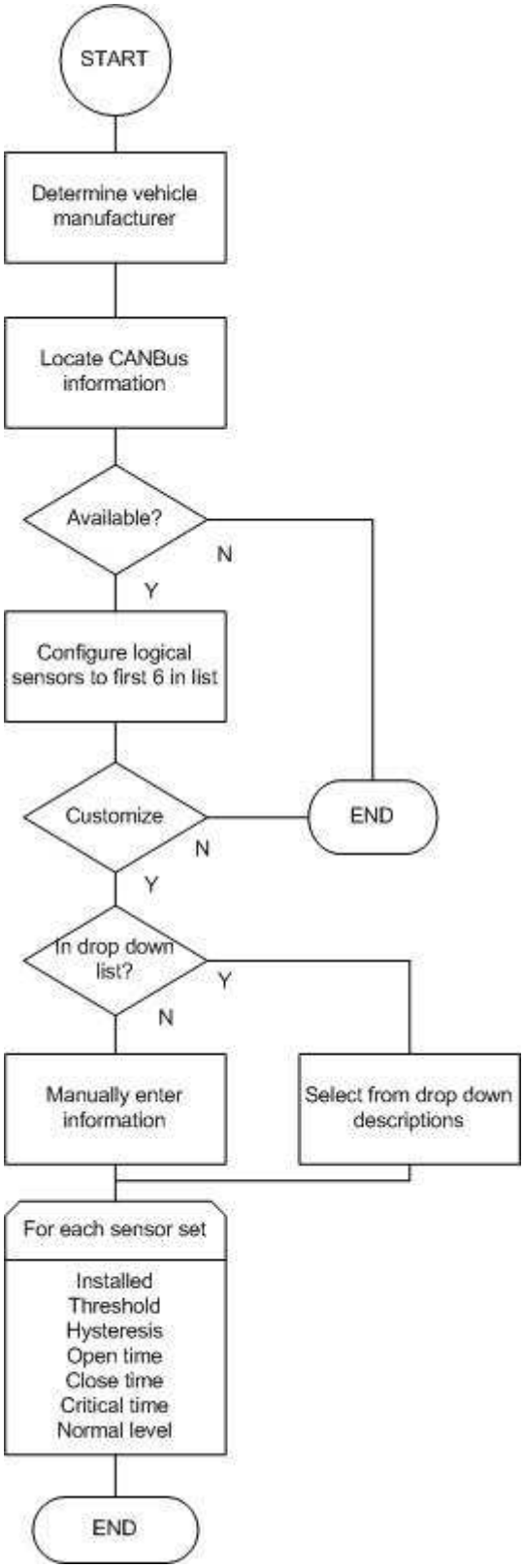


Figure 2.5. Faus Process Flow (Faus, 2009)

Hodges had a patent in 2010 for a System and Method for Performing Vehicle Diagnostic which included an aspect included a system for monitoring a vehicle's healt status. He has created a system that comprised a vehicle monitoring computer system configured to receive information associated a cell phone with a vehicle, receive vehicle diagnostic information including vehicle conditions, automatically determine a severity status for the vehicle conditions based on pre-defined severity status values, and if the severity status for any vehicle condition exceeds a pre-defined severity threshold value, automatically transmit a text message to the cellular phone. General structure and process flow of this study are shown in the Figures 2.6 and 2.7. Hodges created some severity status according to the vehicle conditions were pre-defined. In this study a more complicated data management system is designed.

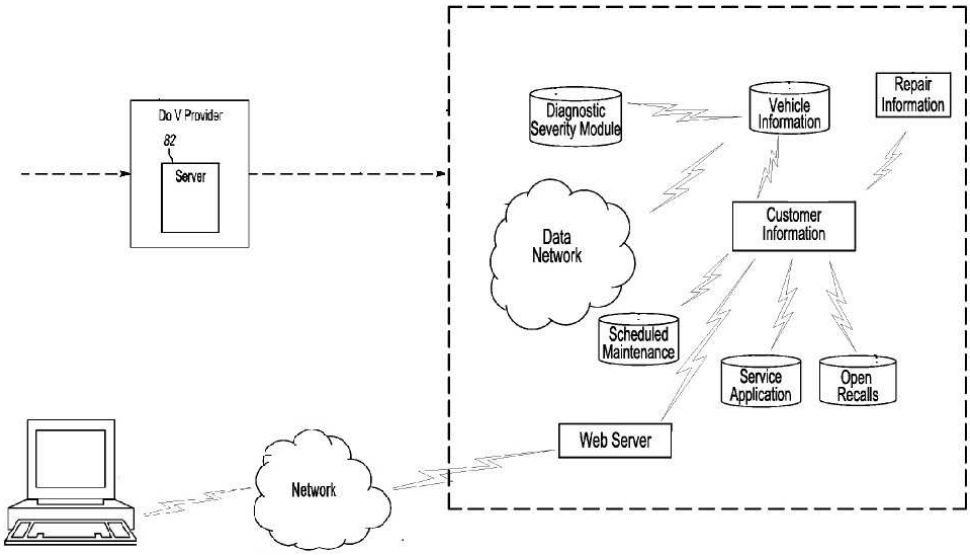


Figure 2.6. Hodges System Structure (Hodges, 2010)

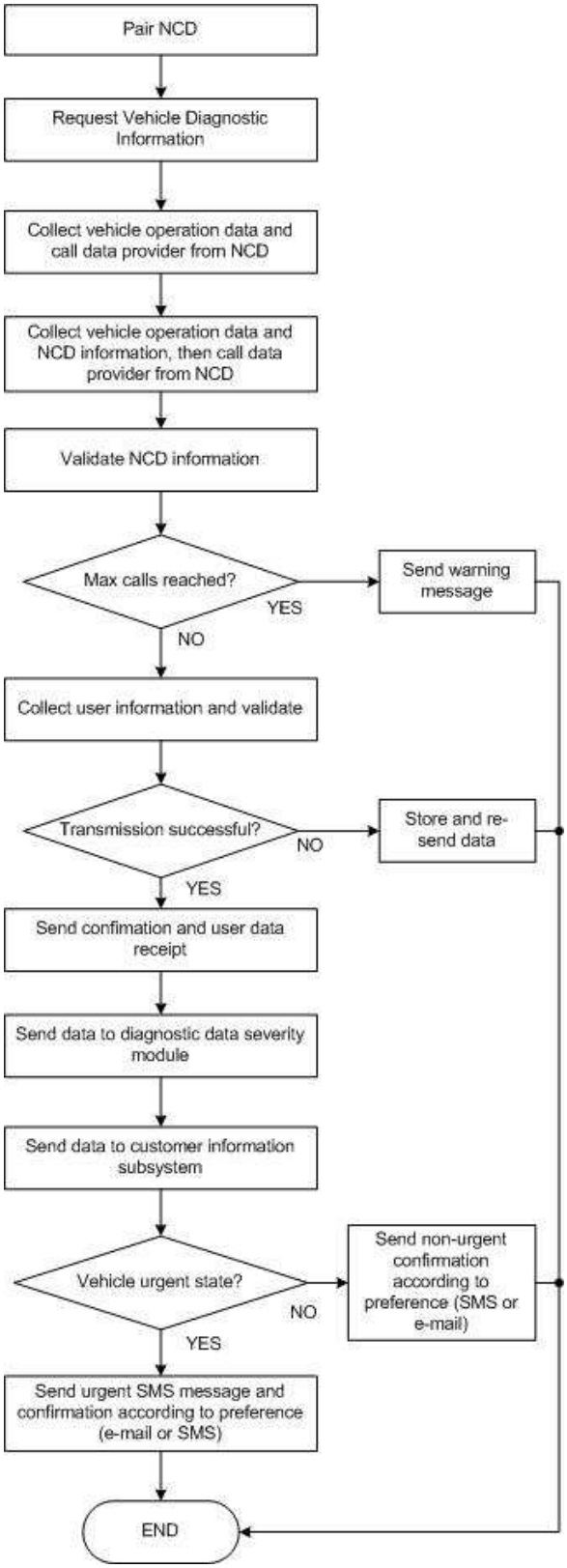


Figure 2.7. Hodges Process Flow (Hodges, 2010)

Chenn has developed a vehicular diagnostic communications system, and components thereof, were provided for an apparatus and technique for communicating vehicular diagnostic information over a cell-phone network. The system included a code reader having a vehicle diagnostic port connector for receiving vehicle diagnostic information from the vehicle diagnostic port. The code reader in this system also had a local connectivity network circuit for communicating vehicle diagnostic information between the vehicle diagnostic port connector and a local connectivity circuit. A cellphone was arranged in communication with the local connectivity network for communicating vehicle diagnostic information between the code reader and a cellular telephone network.

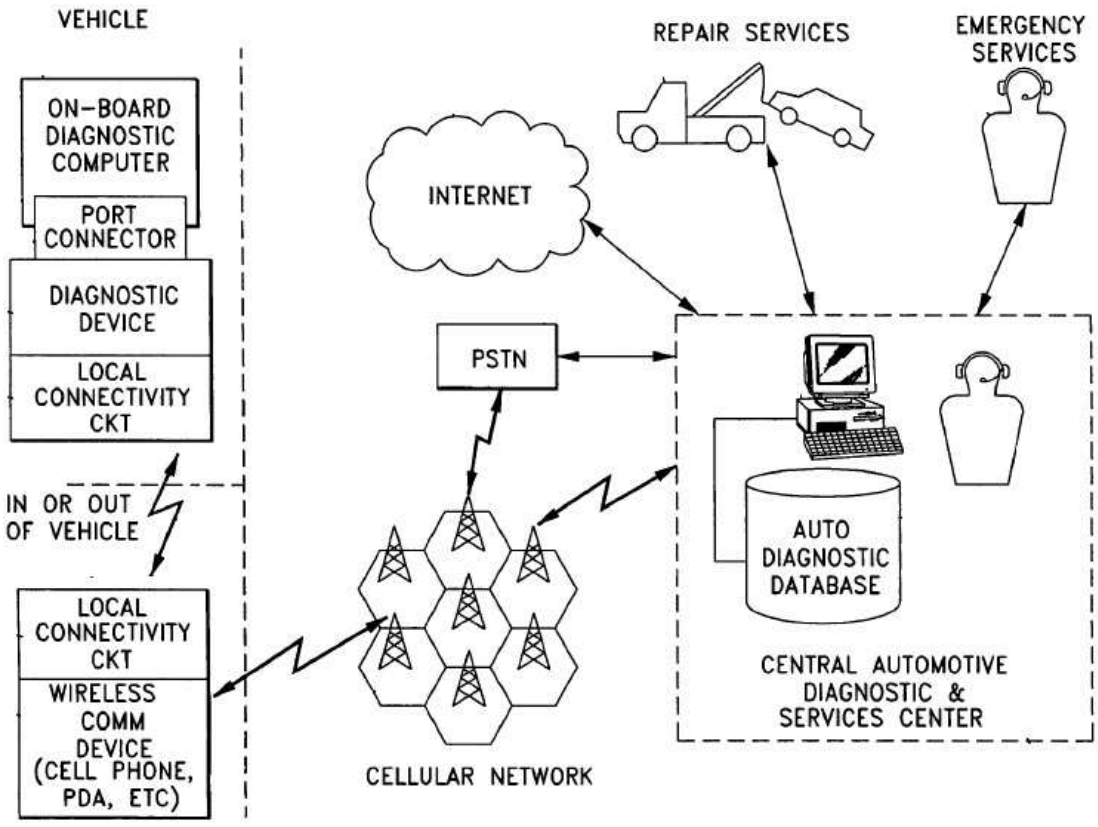


Figure 2.8. Chenn System Structure 1 (Chenn, 2011)

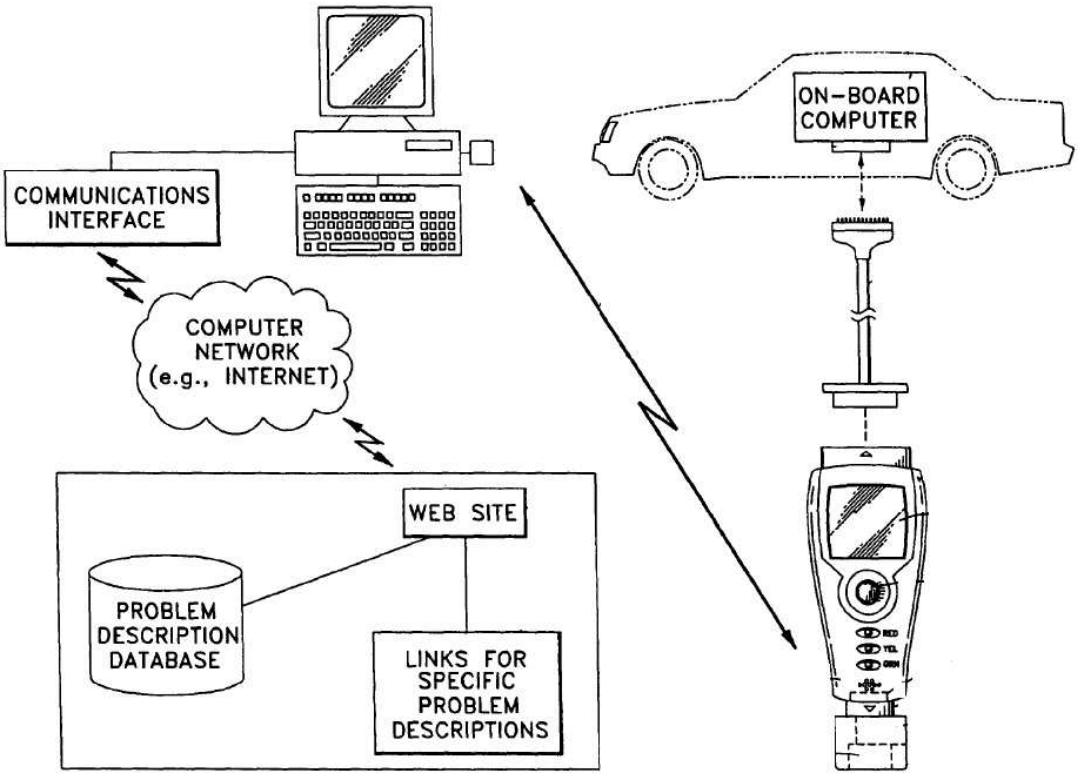


Figure 2.9. Chenn System Structure 2 (Chenn, 2011)

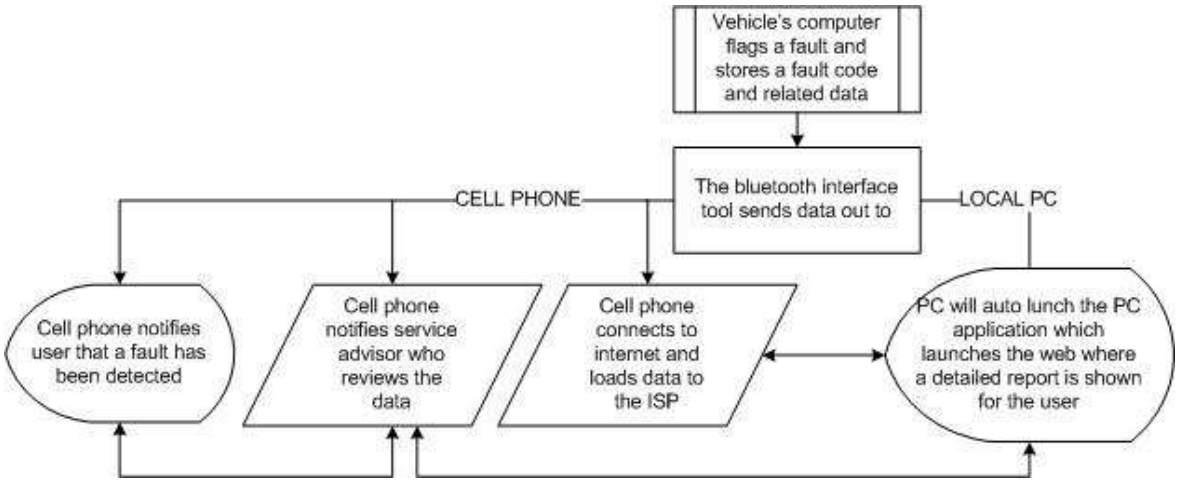


Figure 2.10. Chenn Process Flow (Chenn,2011)

3. MATERIAL AND METHOD

3.1. Vehicle Data Communication

The main components on a vehicle are controlled via Electronic Control Units (ECU) and the Electronic Control Units need to communicate with each other. This communication is provided with a CAN (Controller Area Network) line. It is just like the blood vessels on a living organism and the organs of this living organism are the main components of the vehicle. A Central Proccessor is located in the center of this network such as a brain. All this structure is called as Multiplex System. The diagram (Figure 3.1.) shows a sample of Vehicle Multiplex System.

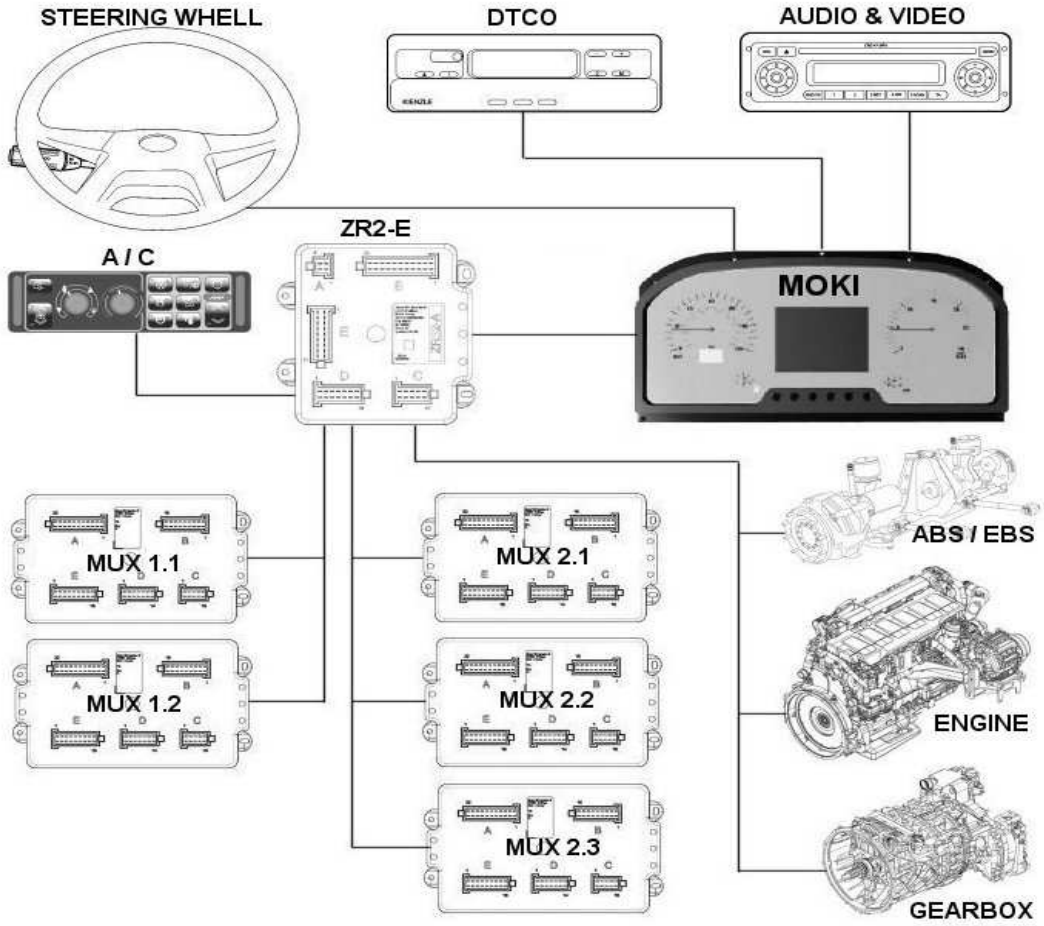


Figure 3.1. Vehicle Multiplex System Block Diagram

All input and output signals are flowing on this line and having a direct connection to CAN line means that you have a direct communication to all ECUs on the vehicle and all ECUs means all data of the vehicle.

The programming of Vehicle Multiplex System is held by an automotive application of PLC (Programmable Logic Controller) which includes the central proccessor and the multiplexers.

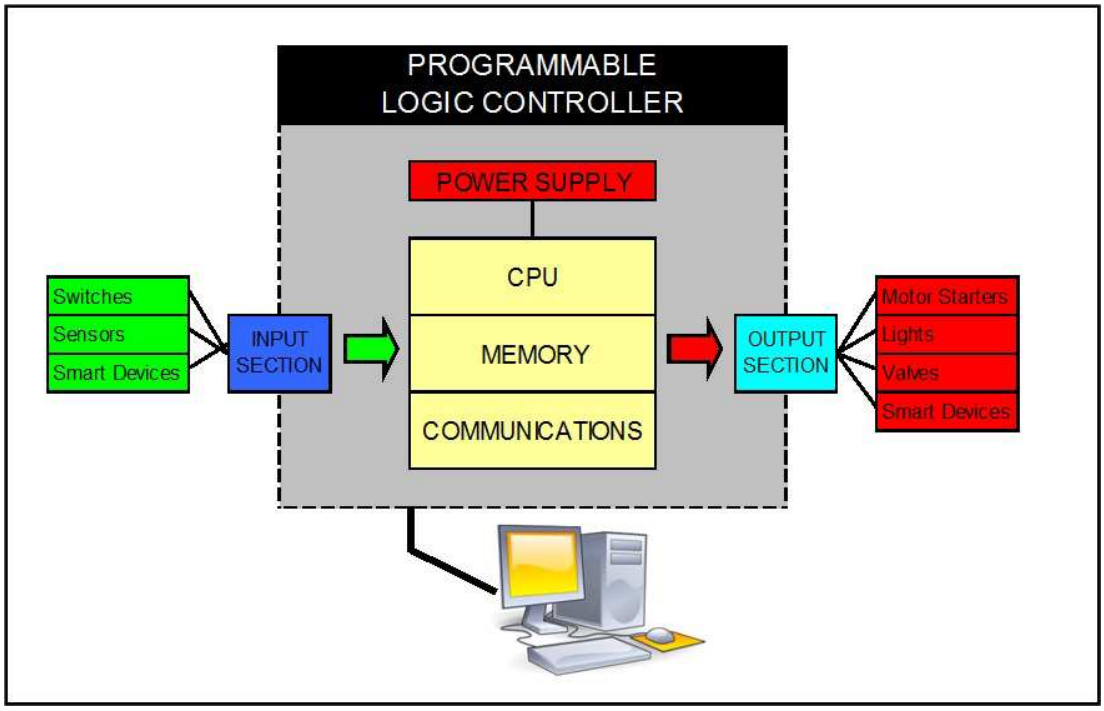


Figure 3.2. Basic Structere of a PLC Sytem

3.1.1. CAN BUS (Controller Area Network)

CAN Bus is a vehicle bus standard designed to provide the communication between the devices with each other within a vehicle without a host computer. CAN Bus is a message-based serial communication protocol which is designed specifically for automative applications. CAN bus was first developed by Robert Bosch in 1983 and was officially released in 1986 at the Society of Automotive Engineers (SAE) congress. A single line made of two twisted cables are used for the connection on CAN line. And there are two 120 Ohms resistances on both two ends of CAN line.

There can be more than one CAN line on a vehicle according to the purpose and the transmission rate depends on the purpose. Some CAN lines are explained below;

Instrumentation CAN (I-CAN) provides the communication between the Central Processor Unit and Instrument Cluster, Tachograph. The transmission rate is 250Kbps.

Multiplexer CAN (M-CAN) provides the communication between the Central Processor Unit and the Multiplexers. The transmission rate is 125Kbps.

Power Train CAN (P-CAN) provides the communication between the Central Processor Unit, Engine, Transmission, Brake, Suspension, Retarder and Engine Cooling Systems. The transmission rate is 250Kbps.

A sample of a vehicle CAN lines is shown in Figure 3.3.

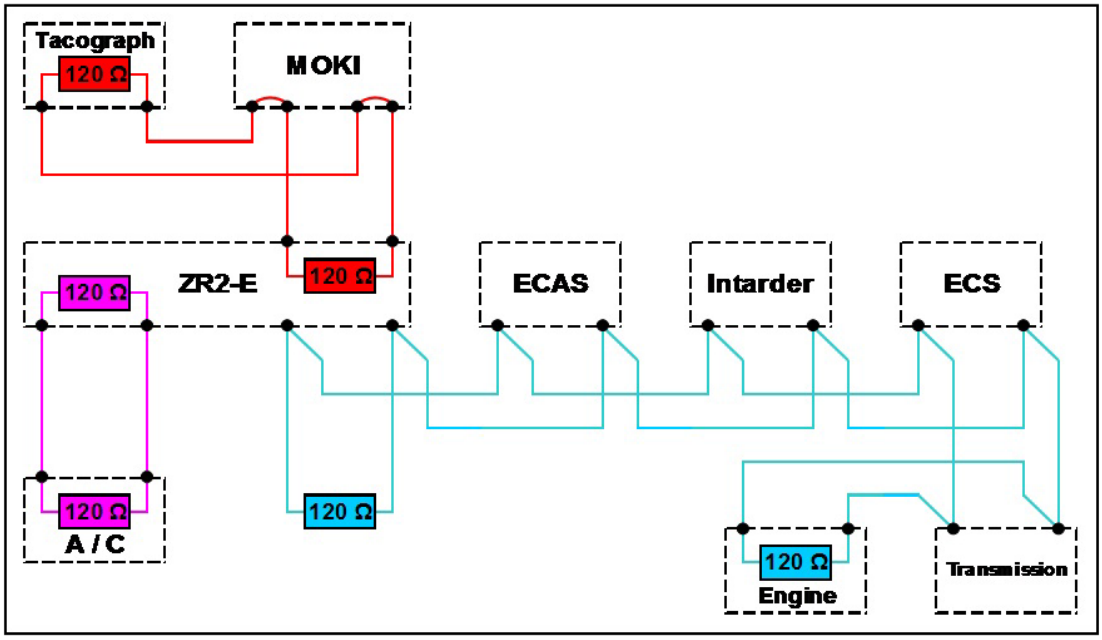


Figure 3.3. Vehicle CAN Bus Block Diagram

3.1.2. SAE J1939 CAN Communications Standard

The J1939 is a communication protocol which comes from the international Society of Automotive Engineers (SAE) and works on the physical layer with CAN-highspeed. The application focus is on the power trains and chassis of commercial

vehicles. The protocol is used in heavy vehicles for on-street and off-road operations (construction machines).

J1939 is a multimaster system with decentralized network management without channel-based communication. It supports up to 254 logical nodes and 30 physical ECUs per segment. The information is described as parameters (signals) and combined on 4 data pages in parameter groups (PGs). Each parameter group can be identified via a unique number, the parameter group number (PGN). Irrespective of this, each signal is assigned a unique SPN (suspect parameter number).

The majority of the communication usually occurs cyclically and can be received by all ECUs without explicit request of data (broadcast). In addition, the parameter groups are optimized to a length of 8 data bytes. This enables very efficient use of the CAN protocol. Particular information such as configuration data or diagnostic data can be exchanged exclusively between two ECUs (peer-to-peer). The specification of the communication, broadcast or peer-to-peer, is a property of the parameter group used. Thus, in addition to the definition of which parameters are transmitted, the transmission type also depends on the parameter group.

So that peer-to-peer communication is possible on a CAN network, each ECU must be assigned a unique address in the range from 0 to 253. To avoid the mistaken occurrence during operation of two ECUs with the same address, a clever strategy is required – the network management (NM). With J1939, the NM is organized decentrally. That is, each ECU must implement a minimum functionality of the NM. The tasks of the NM are:

- Resolution of address conflicts (minimum requirement)
- Ongoing check as to whether ECU addresses are assigned in duplicate on a network (minimum requirement)
- Change of the ECU addresses at runtime
- Unique identification of an ECU with the help of a name that is unique worldwide
- This name also serves to identify which functionality an ECU has on the network (Vector, 2010)

3.1.2.1. SAE J1939 CAN Message Standards

CAN messages in J1939 standard are not required to be addressed to a specific destination on the network. This allows to connect new ECUs to the CAN Bus without any additional software design. Any ECU can receive the messages from network only with being connected. The figure shows a sample of 2-nodes CAN line. The number of nodes can be increased without any message implementation. Special messages which require specific destinations can also be addressed with message identifiers.

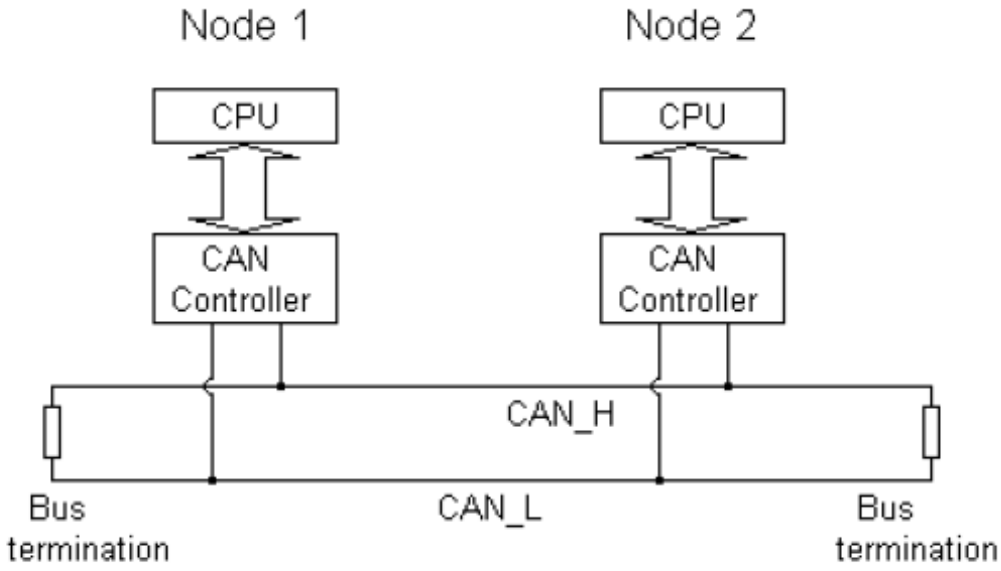


Figure 3.4. Sample CAN Bus with 2 nodes

1939 uses CAN 2.0B protocol which you can find its structure in Figure 3.5. CAN Standard 2.0A was extended to 2.0B to allow a 29-Bit Identifier according to J1708 and J1587.

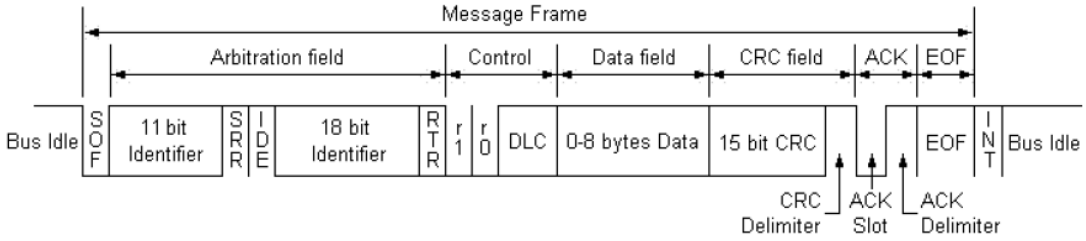


Figure 3.5. Sample CAN 2.0B format

SOF : Start of frame (start bit)

ID : Message identifier (indicates msg priority)

RTR : Remote transmission request

IDE : Identifier extension bit (2.0A or 2.0B)

r0 : Reserved bit. Sent as dominant.

DLC : Data length code. Valid range 0 – 8.

CRC D : CRC delimiter. Marks end of CRC field.

ACK S : Used for receiver to ACK msg. Sent as recessive.

ACK D : Marks end of ACK field.

EOF : End of frame. (stop bit). Sent as 7 recessive bits.

INT : Intermission. Sent as 3 recessive bits.

SRR : Substitute request bit. Sent as recessive. This is simply a placeholder bit to ensure compatibility between 2.0A and 2.0B because 2.0A has RTR.

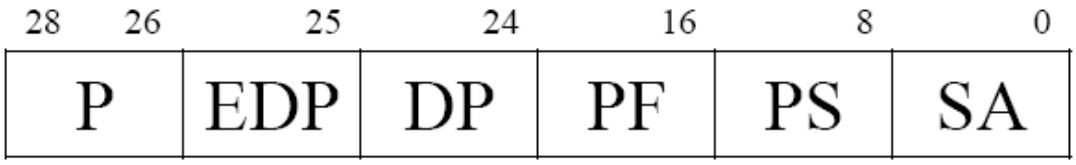


Figure 3.6. CAN ID Mapping

P : Message priority. Must come first.

EDP : Extended data page. J1939 devices must set to 0.

DP : Data page. Used to create a second page of PGNs.

PF : PDU format:

< 240, PS is destination address. (PDU1 format)

>= 240, PS is group extension. (PDU2 format)

PS : PDU specific. Either destination address or group extension.

SA : Source address of controller application (CA).

SAE J1939 Message format is explained in the Figure 3.7;

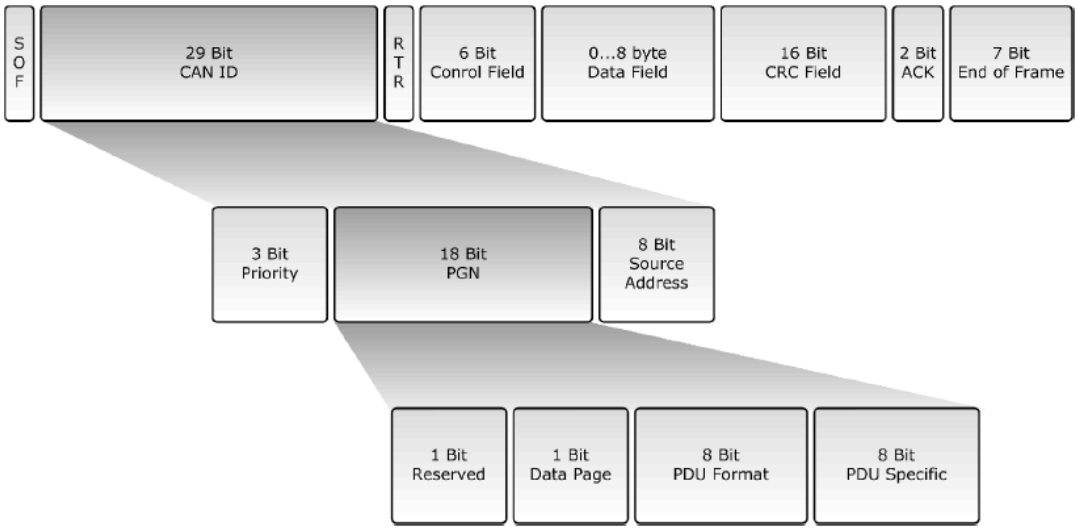


Figure 3.7. SAE J1939 Message Format (ESD Electronics, 2010)

Paremeters embedded in the 29-Bit message identifier are divided into three sections:

- Priority
- PGN (Parameter Group Number)
- 8 Bit Source Adress

Parameter Group which points to information of parameter assignments within 8 byte CAN data field, repetition rate and priority, is identified by Parameter Group Number.

Priority: During arbitration process priority is represented by first three bits. Eight priority levels are provided. A value of 0(000) has the highest priority, a value

of 8(111) has the lowest priority. High priority messages are assigned to time critical data such as torque control data from transmission to engine. Lower level priorities are suitable for non-time-critical data such as engine configuration data.

Although CAN is centered aroung the ID, J1939 is centered around PGN (Parameter Group Number). PGN is defined by the CAN ID. CAN ID for PGNs of broadcast message and addressed message are shown in Figures 3.8. and 3.9.

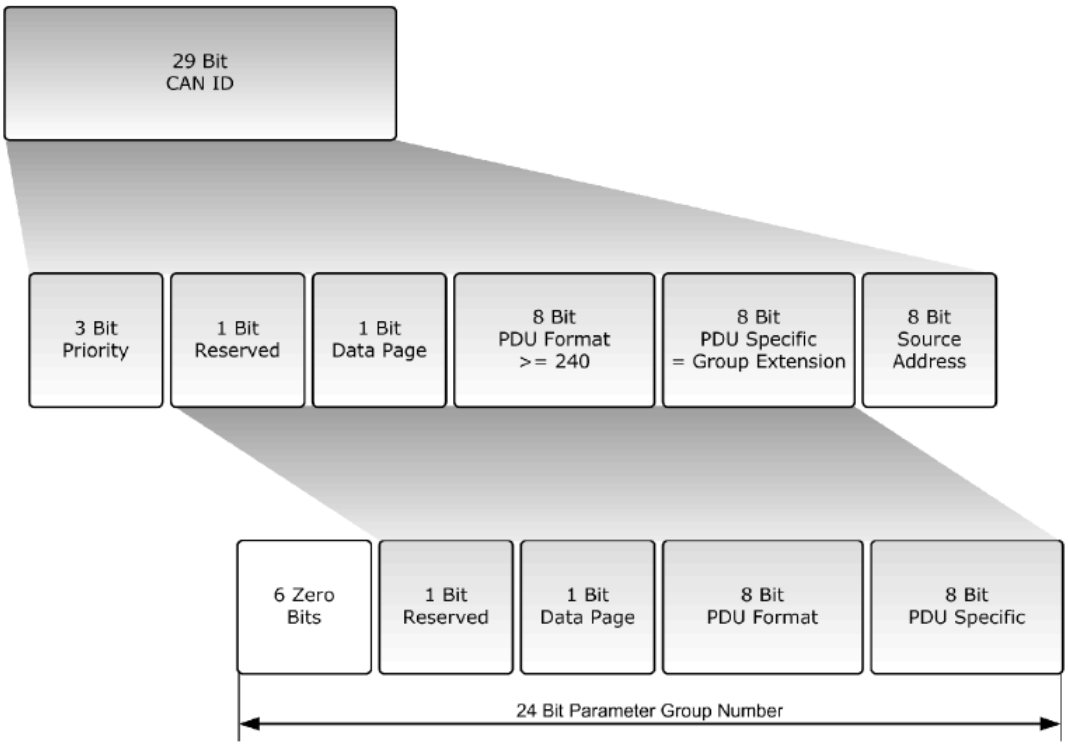


Figure 3.8. PGN for Broadcast Communication (ESD Electronics, 2010)

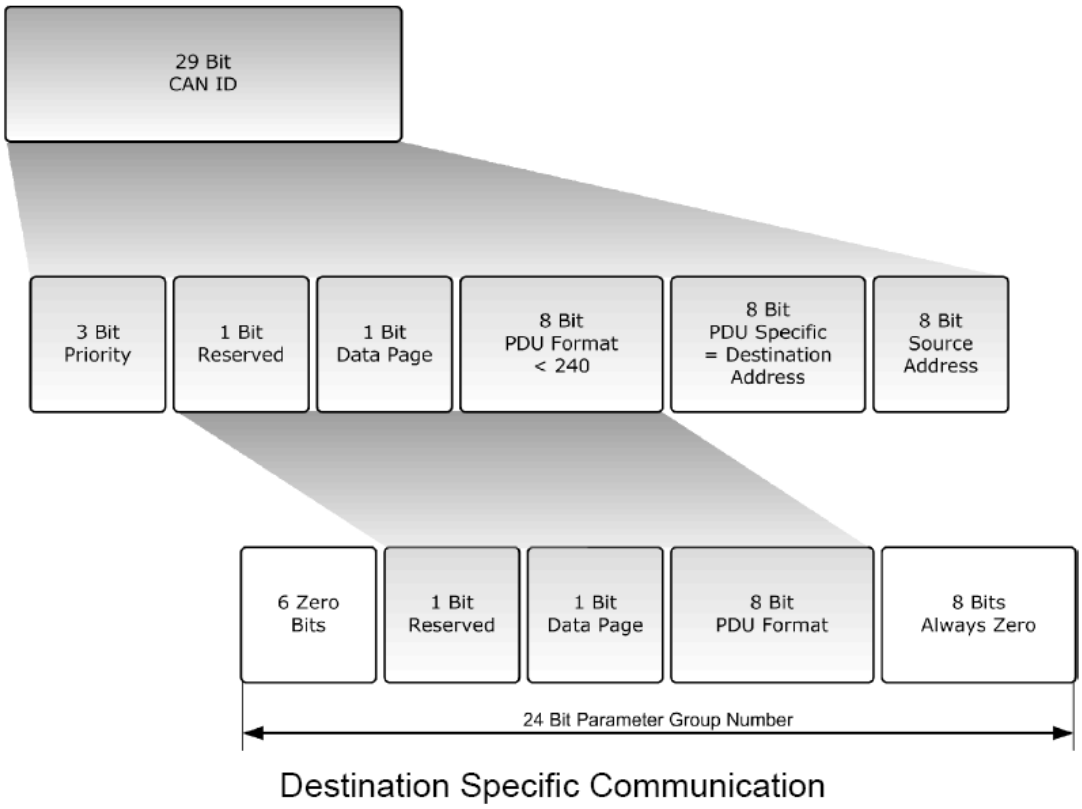


Figure 3.9. PGN for Destination Specific Communication (ESD Electronics, 2010)

3.1.3. Diagnostic Trouble Codes

Diagnostic Trouble Code (DTC) is a code which you have from vehicle CAN network when some important report messages required. Diagnostic Trouble Code is generated by four information which are explained below. These different fields give detailed information about the reported message and better explanation is provided.

Table 3.1. Diagnostic Trouble Code (DTC) Structure

Suspect Parameter Number (SPN)	19 Bits
Failure Mode Identifier (FMI)	5 Bits
Occurence Counter (OC)	7 Bits
SPN Conversion Method (CM)	1 Bit

Suspect Parameter Number (SPN) : is used to identify the reported diagnostic message. This message can be a repairable failure on a subsystem, a hard

failure on subsystems and assemblies which may exhibit abnormal operating performance, definition of a specific issue, a report of a component and non-standard failure mode.

SPNs are assigned to each individual parameter in a Parameter Group and to items that are relevant to diagnostics but are not a parameter in a Parameter Group. SPNs are independent of the source address for the message. However, the source address may be necessary to determine which controller on the network performed the diagnosis. (SAE, 2000)

A sample of PGN and SPN is shown in Figure 3.10.

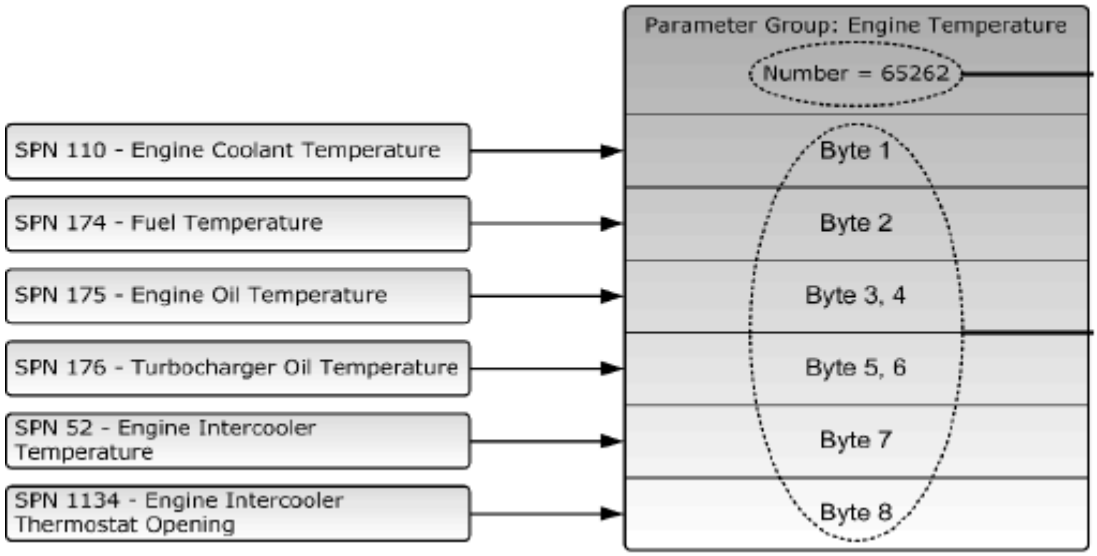


Figure 3.10. PGN and SPN Relationship (ESD Electronics, 2010)

Engine Temperature which is shown as an example in Table 3.2. has a PGN and Engine Coolant Temperature has a SPN under this Parameter Group.

Example:

Table 3.2. PGN Engine Temperature

PGN 65262	**Engine Temperature**
Transmission Rate	1 sec
Data Length	8 bytes
Data Page	0
PDU Format (PF)	254
PDU Specific (PS)	238
Default Priority	6
PG Number	65262 (FEEEhex)

Table 3.3. SPNs Related with Engine Temperature

Description of Data			**SPN**
Byte	1	Engine Coolant Temperature	110
	2	Fuel Temperature	174
	3,4	Engine Oil Temperature	175
	5,6	Turbocharger Oil Temperature	176
	7	Engine Intercooler Temperature	52
	8	Engine Intercooler Thermostat Opening	1134

Table 3.4. SPN Engine Coolant Temperature

SPN 110	**Engine Coolant Temperature** (Temperature of liquid engine cooling system)
Data Length	1 Byte
Resolution	1 deg C / Bit
Offset	-40 deg C
Data Range	-40 to 210 deg C
Type	Measured
Reference	PGN 65262

Failure Mode Identifier (FMI) : is the field which defines the type of the failure that is reported in the subsystem assigned by an SPN.

Occurance Counter (OC) : is the field which indicates the number of failure repeating.

Diagnostic Trouble Code (DTC) is created with the integration of these four fields. A code number is not created but the required information about the failure report is supplied by each field.

Some samples of DTCs and explanations of an engine manufacturer are shown in the Table 3.5.

Table 3.5. DTC samples for Cummins Engine

SPN	FMI	Faulte Code	SPN Description
629	12	111	Engine Control Module Critical Internal Failure - Bad Intelligent Device or Component
612	2	115	Engine Magnetic Speed/Position Lost Both of Two Signals – Data Erratic, Intermittent, or Incorrect
102	16	124	Intake Manifold 1 Pressure – Data Valid but Above Normal Operational Range – Moderately Severe Level
91	3	131	Accelerator Pedal or Lever Position Sensor 1 Circuit - Voltage Above Normal, or Shorted to High Source

3.2. Integrated Module

The electronic hardware which you can find the general structure in Figure 3.11. of is integrated to the vehicle electrical system.

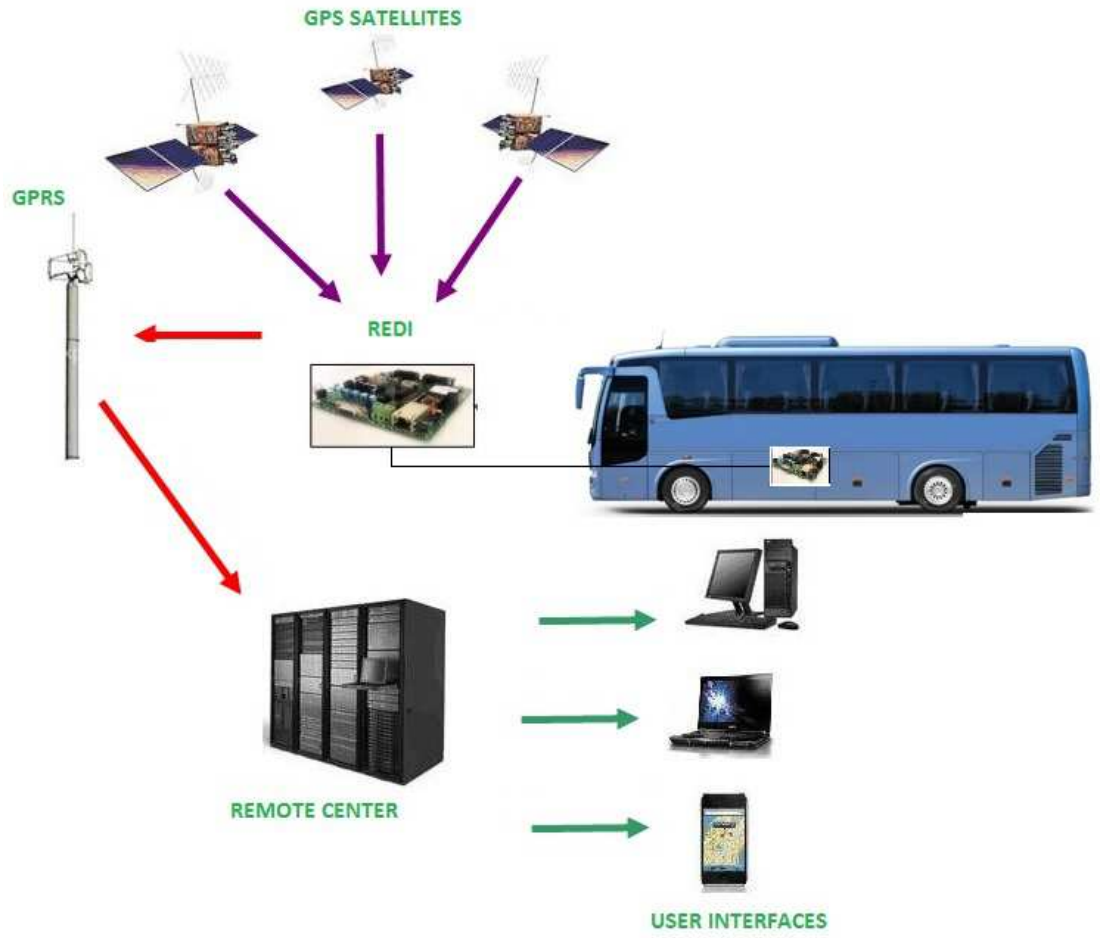


Figure 3.11. General Structure of the System

The integrated module is developed as 3 independent modules. Then these 3 parts are put together and the integrated module is created. These 3 modules are listed like below:

- CAN Communication Module
- GPS Module
- GPRS Data Transfer Module

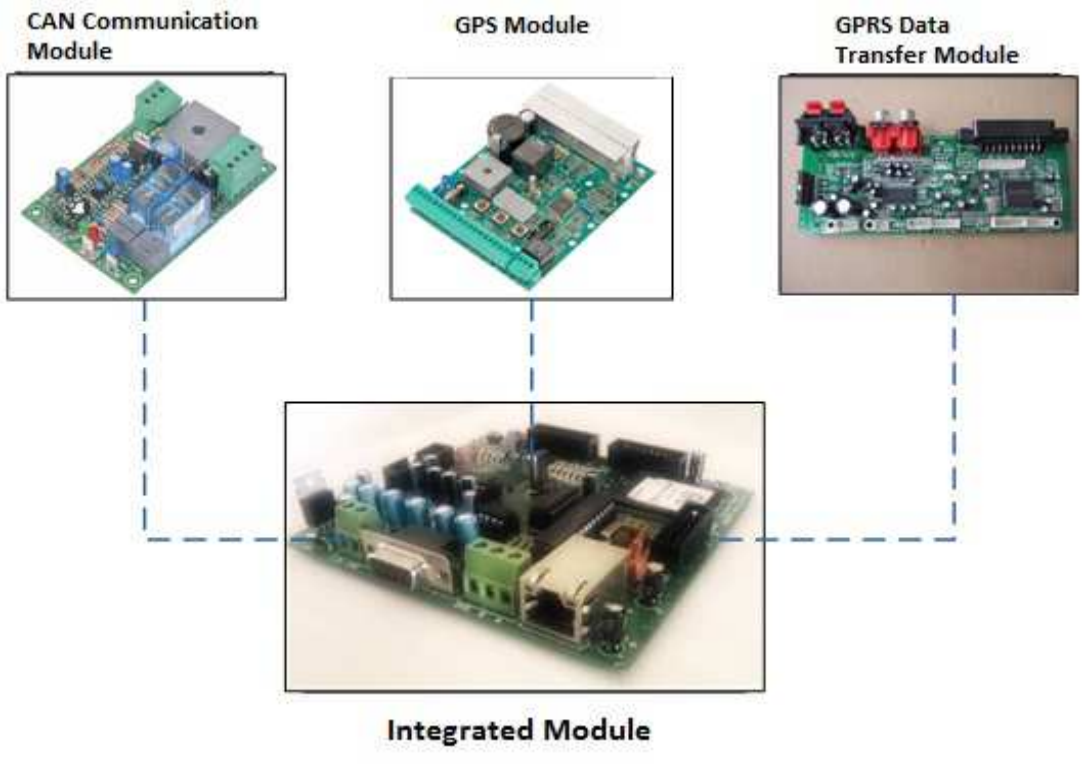


Figure 3.12. Basic Structure of the Integrated Module

3.2.1. CAN Communication Module

An ARM based microcontroller is used to communicate with the vehicle CAN Bus. ARM processors are developed by Advanced RISC Machines and a type of 32-bit reduced instruction set computer (RISC) microprocessors. Acorn Computers Ltd. designed the original architecture of ARM in the 1980s. Since then, it has become one of the most popular microprocessors, especially used in consumer electronic devices such cellphones, multimedia players, calculators and tablet computers.

ARM processor features include:

- Load/store architecture
- An orthogonal instruction set
- Mostly single-cycle execution

- A 16x32-bit register
- Enhanced power-saving design.

With the latest years ARM has become a microprocessor manufacturer which is leading in the market. ARM has developed microcontrollers for lots of electronic sector in the market. CAN Bus communication microcontrollers are also one of these products. An ARM based CAN controller may have more than one independent CAN controllers on board the chip. LPC11C00 series is an example of a CAN microcontroller which is designed with an ARM Cortex-M0.

A sample CAN microcontroller connection is shown in Figure 3.13.

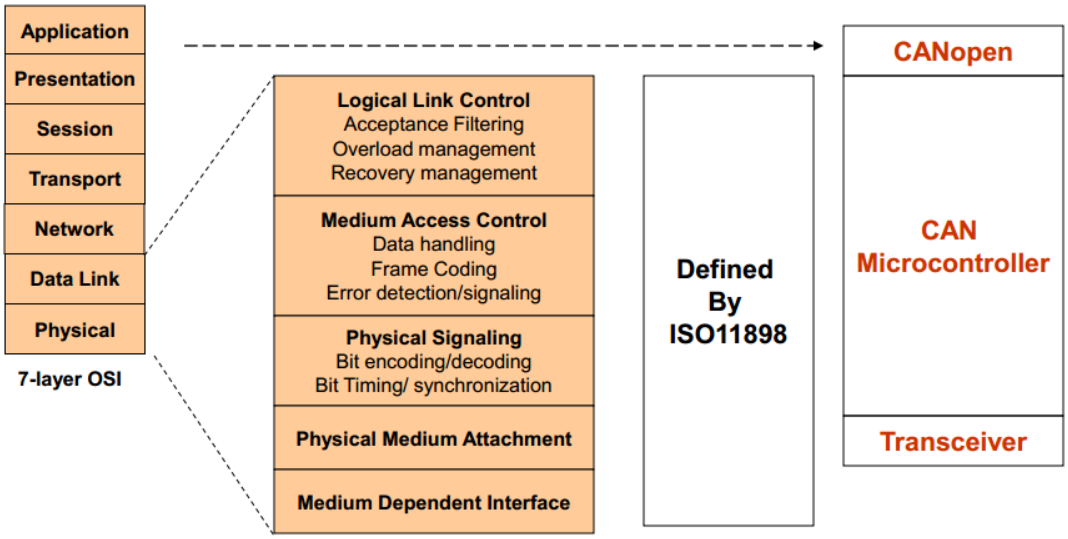


Figure 3.13. CAN Microcontroller Connection (NXP, 2011)

The block diagram of LPC11C00 CAN microcontroller is shown in Figure 3.14.

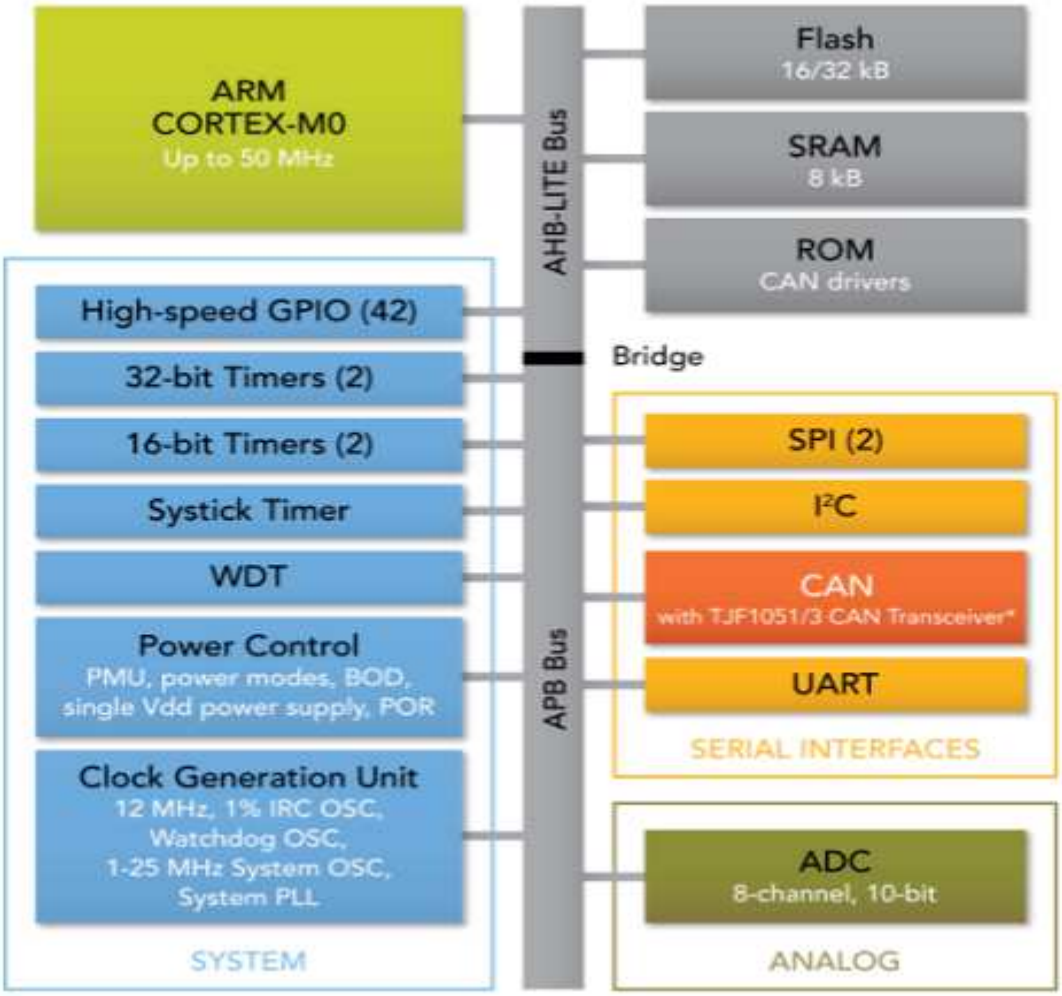


Figure 3.14. Block diagram of LPC11C00 (NXP, 2011)

The components shown in microcontroller block diagram and the specifications are listed below:

- 50 MHz Cortex-M0 processor with SWD/debug
- 32KB/16KB Flash, 8KB SRAM
- Dedicated Interrupts on up to 13 GPIOs
- CAN 2.0 B C_CAN controller with on-chip CANopen drivers, integrated transceiver
- UART, 2 SPI & I2C (FM+)
- Two 16-bit and 2 32-bit timers with PWM/Match/Capture and 24-bit system

timer

- 12MHz Internal RC Oscillator with 1% accuracy over temperature and voltage
- 8-channel high precision 10-bit ADC with ±1LSB DNL
- 36 fast 5V tolerant GPIO pins, high drive (20 mA) on select pins
- High ESD performance: 8kV (Transceiver) / 6.5kV (Microcontroller)
- Low Electromagnetic Emission (EME) and high Electromagnetic Immunity (EMI) CAN transceiver

More than one CAN lines exist on the vehicle which services to different purposes. P-CAN, I-CAN, M-CAN are some examples for vehicle CAN lines. As it is explained before P-CAN (Powertrain CAN) line provides the communication between the ECUs of powertrain components such as engine, gearbox, brake control etc. This is a CAN network for powertrain components. Besides I-CAN (Instruments CAN) line provides the communication between the central processor units, Digital Tachograph, instrument cluster etc. This is also another CAN network on the vehicle. Both of them belongs to vehicle CAN network but at the same time they are seperated from each other. The CAN communication module of the integrated remote diagnostic module needs to have more than one independent CAN communication ports to be able to communicate with these CAN lines seperately. The CAN connection of the remote diagnostic module is shown in Figure 3.15.

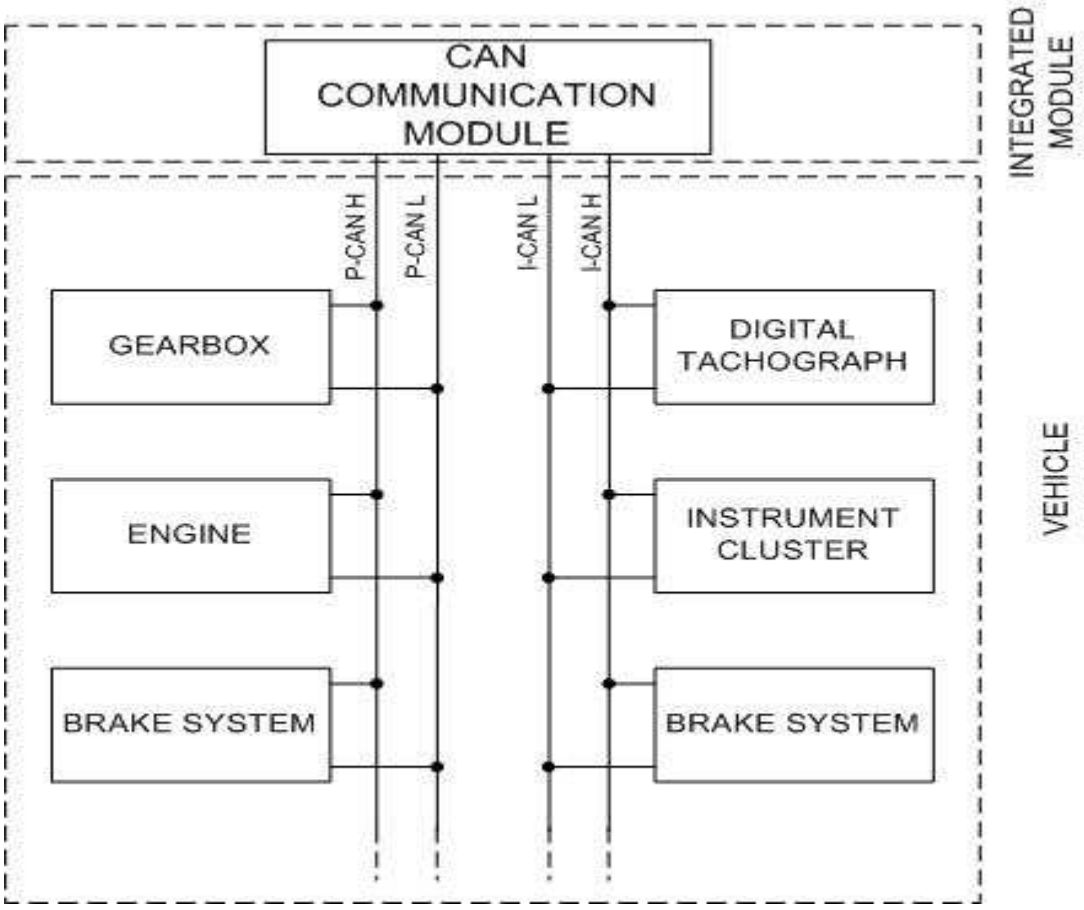


Figure 3.15. CAN Connection of Communication Module

As an example the CAN communication module will receive gearbox failure messages from Gearbox ECU through P-CAN network, besides that it will receive vehicle speed signal from Digital Tachograph through I-CAN network.

As it is explained before each CAN line has two 120 Ohms resistors in both ends of line to provide 60 Ohms equivalent resistance. The communication module is connected to the CAN lines as an other branch line. Because of that the equivalent resistance remains constant and no more termination resistances are required on CAN communication module.

3.2.2. GPS Module

A GPS Module is integrated to the Remote Diagnosis module for locating the vehicle in all over the world. The location of the vehicle is important for a better

aftersales service in case of a break-down and the data which is collected from the vehicle communication network is meaningful according to the vehicle region for future design configurations.

The Global Positioning System (GPS) consists of a satellites network which involves about 25 satellites. Each satellite is orbiting the Earth and the altitude is about 20,000 km. US government first developed the system for the military navigation applications. But today the radio signals which the satellites broadcast can be received by anybody with a GPS device. Satellite navigation tools, handheld GPS units and mobile phones are some examples of these devices. The physicist Fierwardt Winterberg performed a general relativity test (for time slowing in a strong gravitational field) in 1956. He placed accurate atomic clocks in orbit inside artifical satellites. And later, he made some calculations by using general relativiy to determine the Earth observations of the clocks which are placed in the satellites. GPS design is based on the corrections of these observations. The first man-made satellite Sputnik was launched by The Soviet Union in 1957. The radio transmissions of Sputnik has been monitored at Johns Hopkins's Applied Physics Laboratory by two American physicists, William Guier and George Weiffenbach. They could pinpoint the location of the satellite on its orbit because of Doppler effect. The required heavy calculations have been done in Applied Phsyics Laboratory with the permission of he Director. Guier and Weiffenbach were asked to investigate pinpointing the user’s location on the earth by the deputy director of the APL, Frank McClure. At the same time the Navy was working on a project of submarine-launched Polaris missile and they needed to know the location of submarine. And then the Navy and APL worked together and developed the Transit System. ARPA (renamed DARPA in 1972) has played also a role in Transit’s development in 1959.

The first successful tests of Transit (first satellite navigation system) have been performed in 1960 by the United States Navy. Five satellites have been used to provide a navigational fix once per hour. Then U.S. Navy worked on the Timation satellite in 1967 and they could be able to locate accurate clocks in space which is a necessary technology for GPS. Omega Navigation System has become the first worldwide radio navigation system in the 1970s. It is based on phase comparison of

signal transmission from pairs of stations. These systems showed that a more universal navigation solution is required because of its limited accuracy.

3.2.2.1. How GPS Locates Position

A GPS receiver recieves the signals sent by GPS satellites above the Earth and calculates its position by timing the signals exactly. The messages which includes the informations listed below are broadcasted continually by each satellite.

- the time (when the message was transmitted)
- the satellite position (at time of message transmission)

The messages transmitted by the satellite and received by the GPS receiver are used to determine the transmission time of a message and this time is used to calculate the distance of the point on Earth from the satellite by the help of the speed of light. GPS receiver receives messages from all of the satellites which it could see. Each satellite creates a sphere of message transmission. And all the satellite spheres which transmits message to the GPS receiver intersect in one point on Earth. This point gives us the location of the GPS receiver. This is how navigation equations compute the location of a point on Earth. Figure 3.16. shows an example of locating a point on earth with 3 satellites. At least three satellites are required to designate a location.

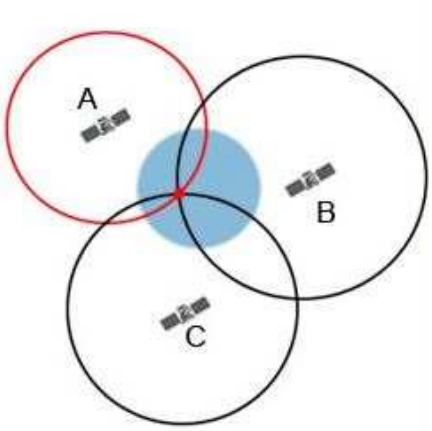


Figure 3.16. GPS Satellite Location

Then the calculated location is displayed with a map or the latitute and longitude information of this point is used. Altitude information which is calculated according to the height of satellite above the geoid may also be included as a data.
GPS section of integrated Remote Diagnosis module locates the point and transfers this information to the data management server. The location of the vehicle is stored and brought in to use of different interfaces.

3.2.2.2. GPS Receiver Design

Main features of a GPS Module are listed below;

- Autonomous GPS receiver controlled by the following options:
  Host Device
  G24-Java
- Mini USB type AB connector
- SIM card holder
- 70 pin connector for G24 Module family connection
- On/Off button
- UART1 (8 lines)
- UART2 (4 lines)

- The GPS Module Reference Design board is supplied with an external antenna Cirocomm type: 0300130033A0800

The block diagram of GPS module is shown in Figure 3.17.

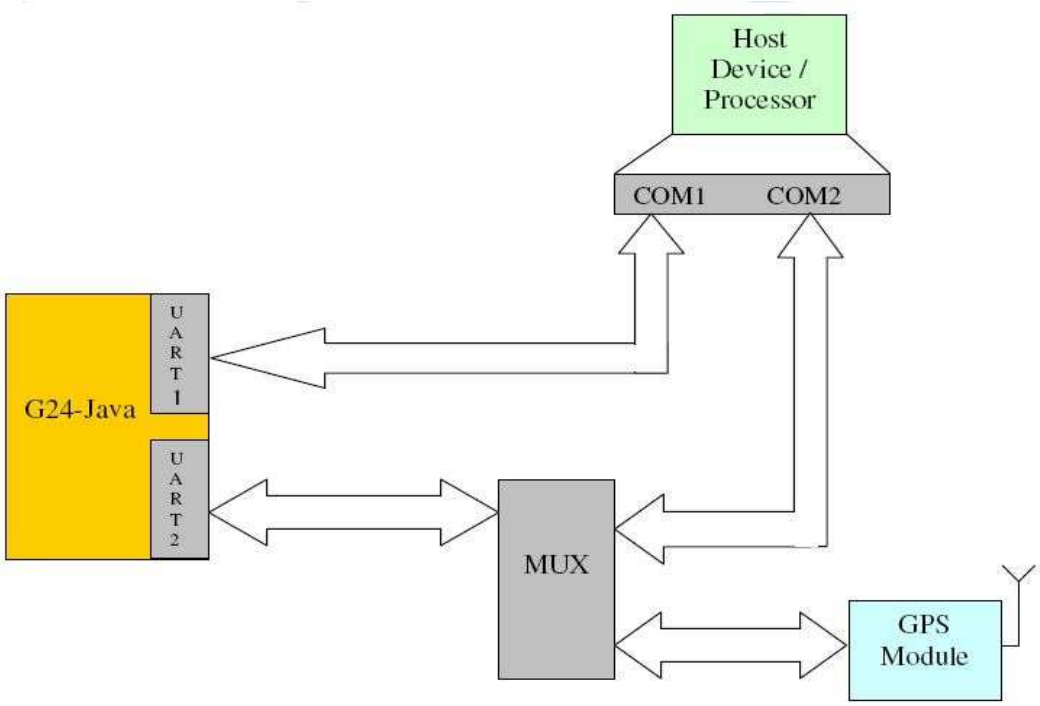


Figure 3.17. Block Diagram of GPS Module (Dror, 2007)

Reference design board description for GPS module is shown in Figure 3.18.

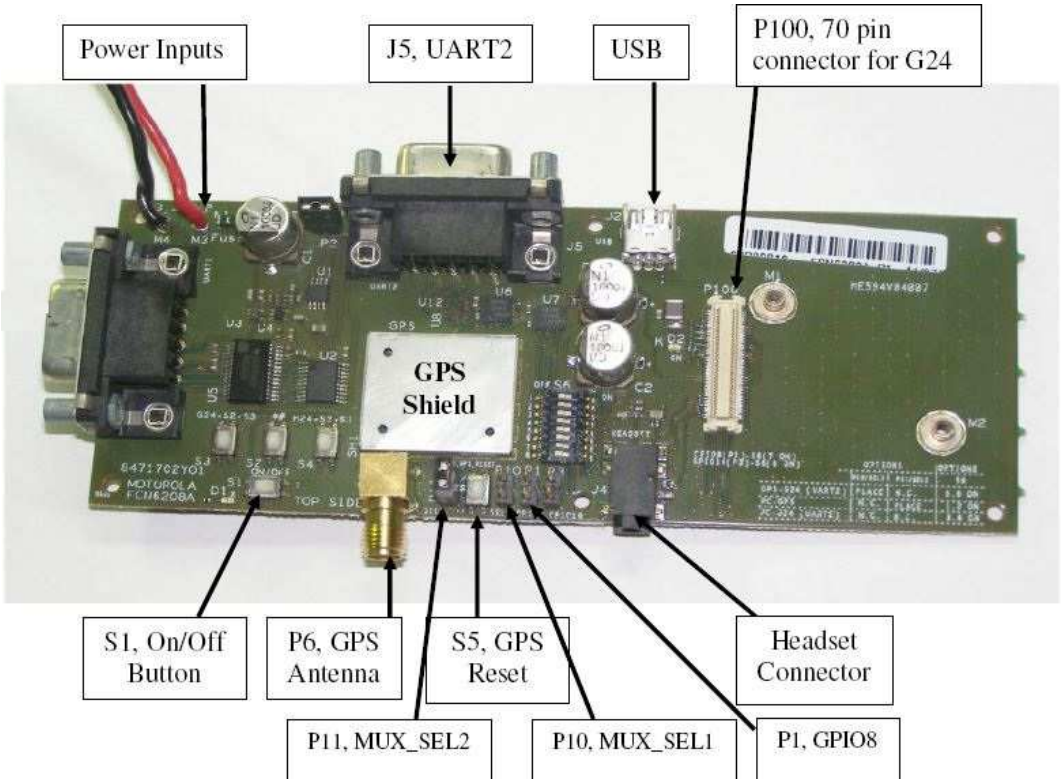


Figure 3.18. Reference Board Design of GPS Module (Dror, 2007)

The process flow diagram of a vehicle position locating is shown in Figure 3.19.

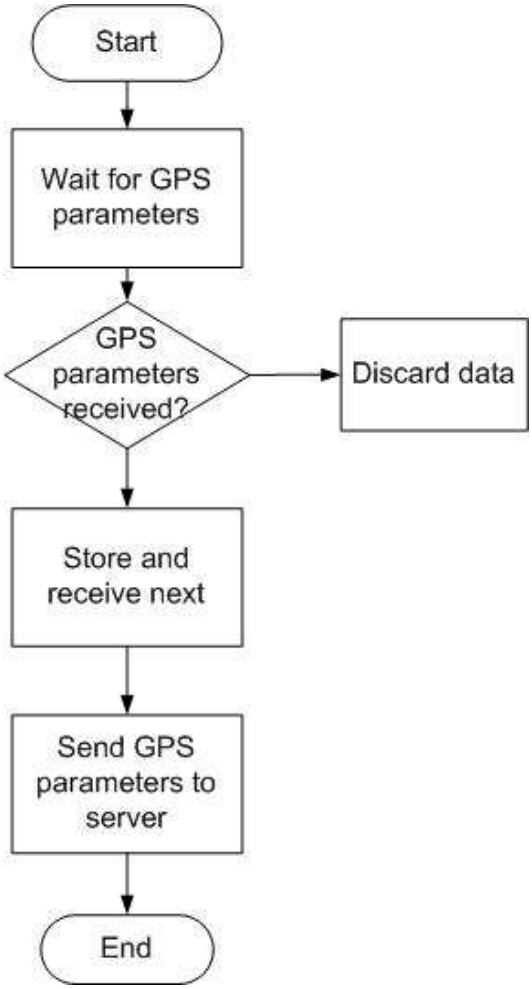


Figure 3.19. Process flow of Position Locating

3.2.3. GPRS Data Transfer Module

The data collected from the vehicle CAN network is forwarded to the remote control center over a GPRS module which is also integrated to the remote diagnosis board. GPRS is a kind of data communication layer which is designed over GSM transmission link. GSM (Global System for Mobile Communications) is a communication standard which is developed by European Telecommunications Standards Institute (ETSI). ETSI developed this standard to define the communication protocols for the second generation (2G) digital cellular networks. These are the networks which were used by mobile phones and the standard was described to take the place of the first generation (1G) analog networks. First it was

developed to be a digital, circuit switched network for a qualified voice telephony. But by the time it has been improved for data transfer communications together with voice telephony. The digital network data communication started with circuit-switched transport and then packet data transport over GPRS (General Packet Radio Services) has been improved on this protocols. Later on EDGE (Enhanced Data rates for GSM Evolution) became a more efficient way of data transfer on GSM, especially for the data rates. In the last couple of years 3rd Generation Partnership Project (3GPP) which is a partnership organisation between the telecommunication companies, has become together to make a third generation (3G) GSM based mobile phone system. This has been a globally applicable mobile phone communication system. And now fourth generation (4G) mobile communication is being developed over 3G. This generation of mobile communication system is to provide more efficient internet access but not designed on GSM. Remote diagnosis module sends the data which is read from vehicle CAN network to the remote center as data packets over GPRS.

3.2.3.1. How Data Sent Via GPRS

There are 8 time slots and 4 coding schemes. And these coding schemes (CS) have different data transmission rates such as 9.05 kbit/s, 13.4 kbit/s, 15.6 kbit/s and 21.4 kbit/s. The total data rate is 171.2 kbit/s when all these time slots and coding schemes used. The connection is not occupied all the time, it is only used while the data packet is being sent to the remote center.

GPRS data transfer system needs the below components basically;

- GPRS modem connected application
- An active GSM/GPRS network
- A sim card with active GPRS service
- A remote center with access to internet.

The system requirements and the relationship is also shown in Figure 3.20.

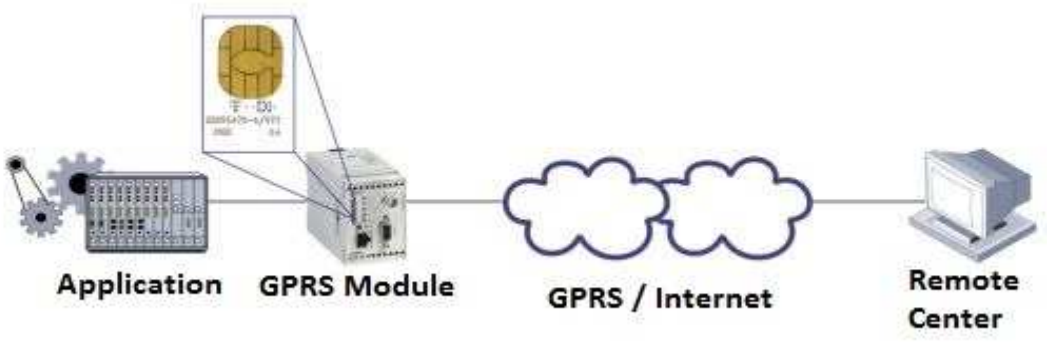


Figure 3.20. GPRS Data Transfer Schema

In remote diagnosis module the firmware which is written in the GPRS data transfer module drives the application. And the application activates the GPRS connection and sends the data. When data reaches to the internet via GPRS, remote center takes part in the process and receives the data which is transmitted from GPRS module.

A block diagram of GSM/GPRS module is shown in Figure 3.21.

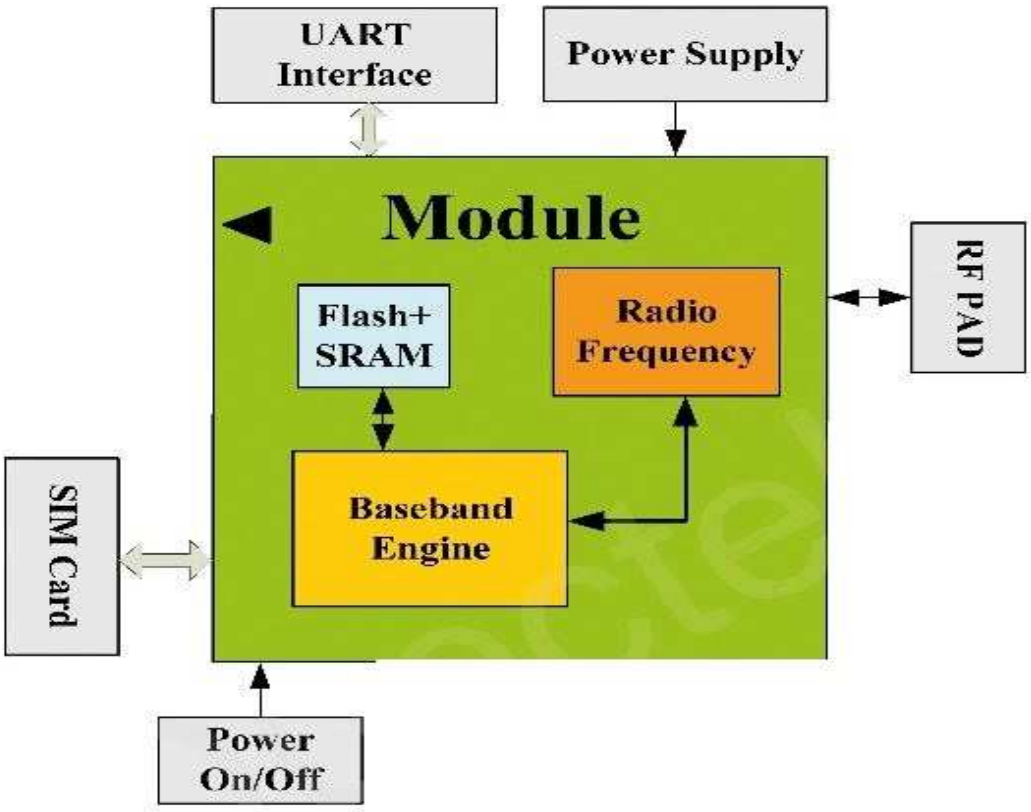


Figure 3.21. GSM / GPRS Module Block Diagram (Open Electronics, 2011)

GPRS data transfer module is integrated to the remote diagnosis module and supplied from the integrated board. The communication between the GSM/GPRS module and the remote diagnosis is provided with RS232 serial communication protocol. Data transmission speed is 300bps.

Remote diagnosis module will be integrated to every vehicle if requested. The storage unit in the module saves the data and brings them together to make a packet data. After that data is sent to the remote center via GPRS. The vehicle data which is decided by the remote center to be received, is read from CAN network continually and stored to the memory unit. And the period of transmitting the stored data is controlled by the remote center due to the requirement.

3.3. Remote Center

A SQL based web server is designed to be used as a remote data management center. SQL (Structured Query Language) is a special-purpose programming language designed for managing data held in a relational database management system (RDBMS) (International Business Machines, 2006). SQL consists of two different pupose of languages. These are ;

- Data definition language
- Data manipulation language

SQL programming language is designed on the principles of relational algebra and tuple relational calculus. SQL is used to be a complete data management system. The features of the language are inserting data, query, update and delete, creating schema and data access control.

IBM engineers first developed SQL in the early 1970s. They called the language as SEQUEL (Structured English Query Language) which is designed to manage the data stored in IBM's management system. The name SEQUEL then is changed to SQL because of a same named trademark.

The data management center of remode diagnosis system is designed with Microsoft SQL 2008 which is also a ralational database management system developed by Microsoft. The main purpose of this system was to store and retrieve data due to the requirements of other software applications. These sofware applications can be the ones on the same computer (such as the current vehicle manufacturer internet database), or the ones running on another computer across a network like internet (called as different user interfaces in remote diagnosis system). Microsoft bought first SQL code base from Sybase SQL Server and entered to the database market. And SQL Server 2008 was released on August, 2008. The main purpose of this version was to focus on the tuning, organizing and maintaining the data management by itself.

General architecture of the SQL Server 2008 is shown in Figure 3.22.

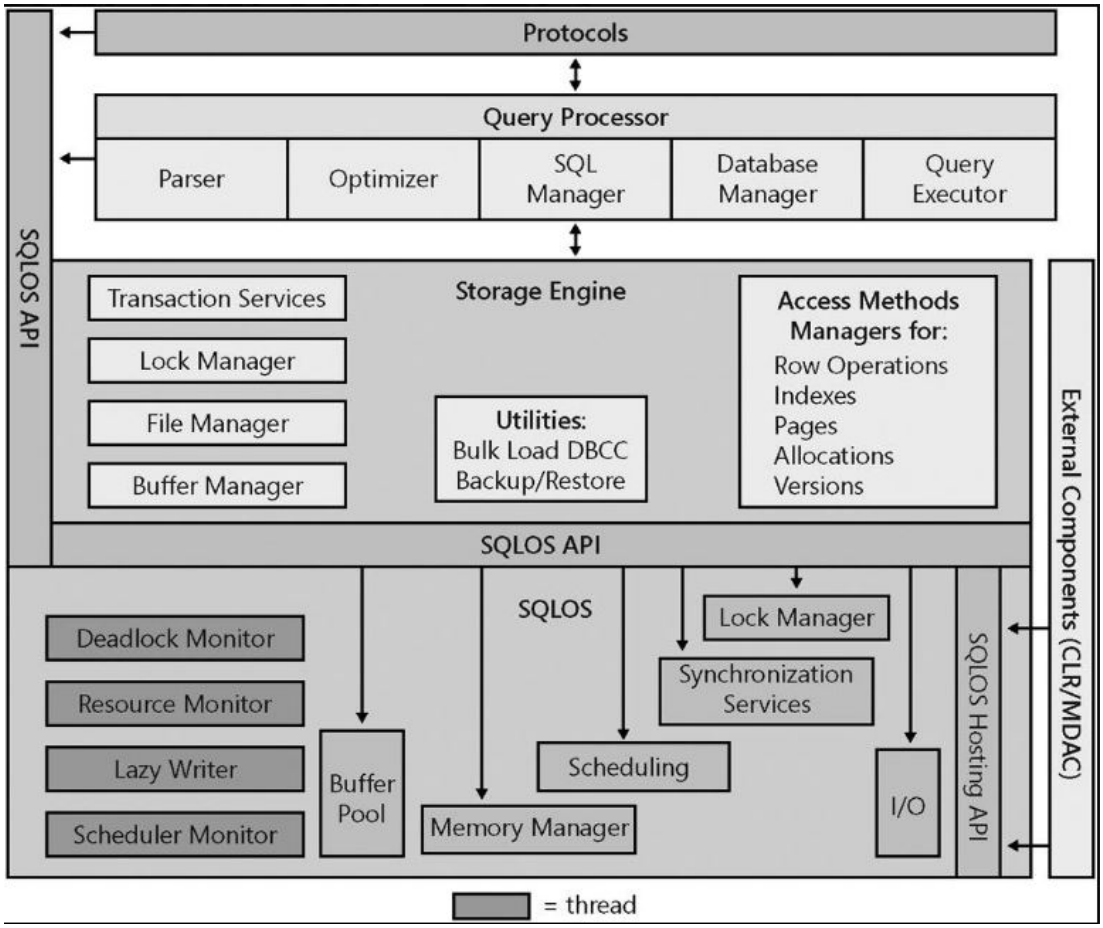


Figure 3.22. SQL Server 2008 Architecture (Jain, 2011)

SQL server has four main components which are listed below;

- Protocols
- Relational engine (It is also called as the Query Processor)
- Storage engine
- SQLOS

All data which is sent to the SQL server should interact with these four components listed above. The purposes of these four components in SQL server are basically explained below and a simple block diagram is shown in Figure 3.23. for a better understanding.

Protocols are standing for the Entry and the Exit of the server. The requests of the customer is received and translated for the relational engine. And the respond from the server due to the customer request (if a result exists) comes out of this component for the customer. In remote diagnosis system the Protocols meet the data which is transmitted by the GPRS communication module and converts it to an appropriate format for the relational engine. Vehicle data first meets Protocols section of SQL server on remote center.

Relational Engine is standing for the main data processing unit of the server. The data which is converted by the Protocols section is accepted in relational engine. The relational engine checks this data and decides what to do with it according to the designed algortihm. The data which is transmitted by the remote diagnosis integrated module is managed in this section. Vehicle data management system basics are created in here.

Storage Engine is standing for the memory unit of the server. The data which is executed by the relational engine is sent to the storage engine if required. This component manages all data access. Vehicle data which is transmitted by the Remote Diagnosis integrated module is saved and stored in this section.

SQLOS Layer is standing for the operating system of the server. All system activites including memory management, thread management and synchronization are handled by this section. This component is especially working for the server itself on the background.

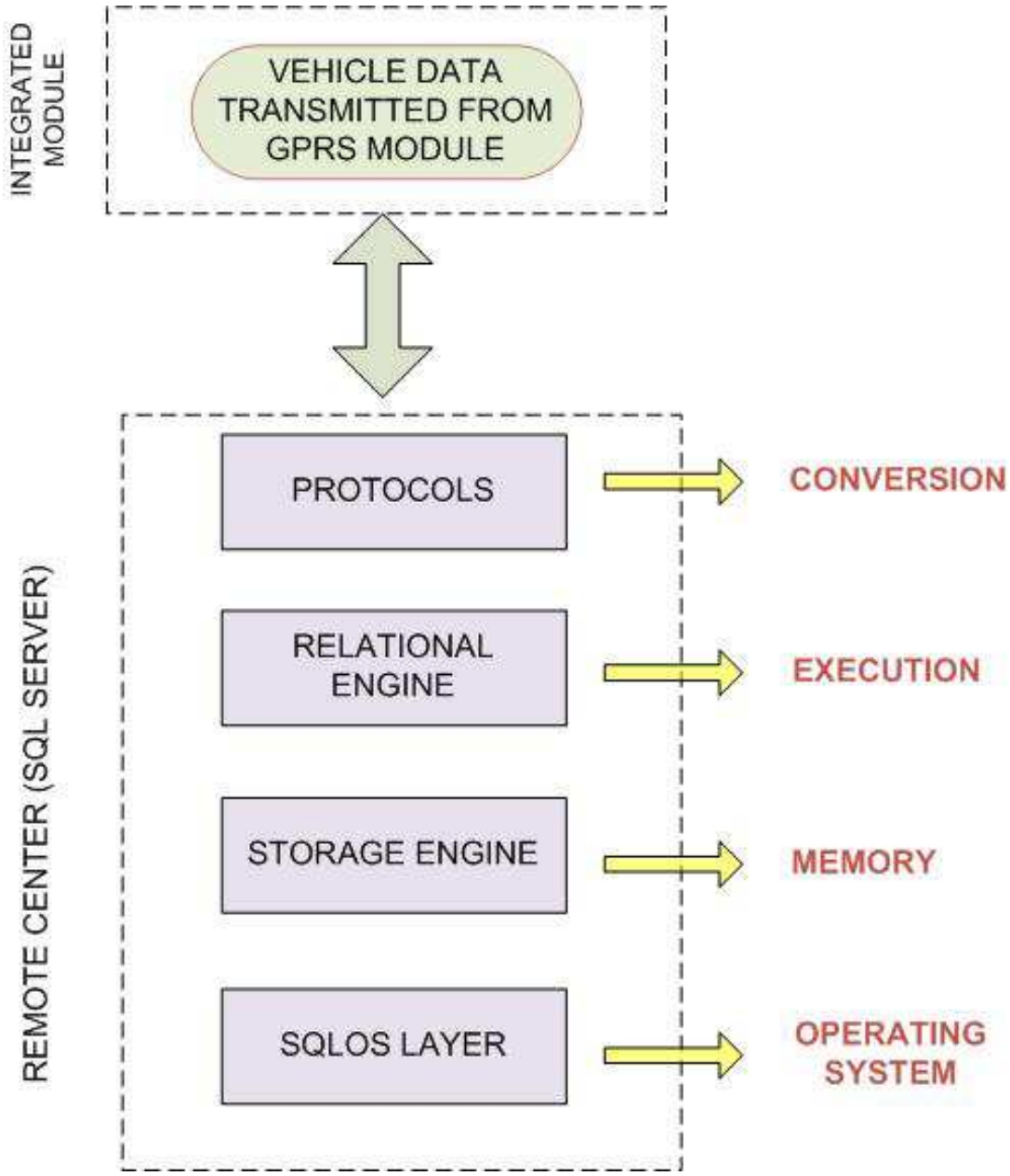


Figure 3.23. SQL Server Components and Tasks

3.4. Data Flow and Data Management

The data which is flowing in vehicle CAN line is received by the remote diagnosis integrated module and served to the end user who is related with the data. The transmission of the data begins in the vehicle network and first received by the CAN communication section of Remote Diagnosis Module. The received data is

converted to a GSM/GPRS data format to be able to sent through GPRS data transfer section of Remote Diagnosis Module. The data which is transmitted by GPRS module is received by the web server which is the entrance of the Remote Data Management Center. The data is processed in the remote center and served to the end user with proper interfaces. The entire system which is examined in this study is shown as a block diagram in the Figure 3.24.

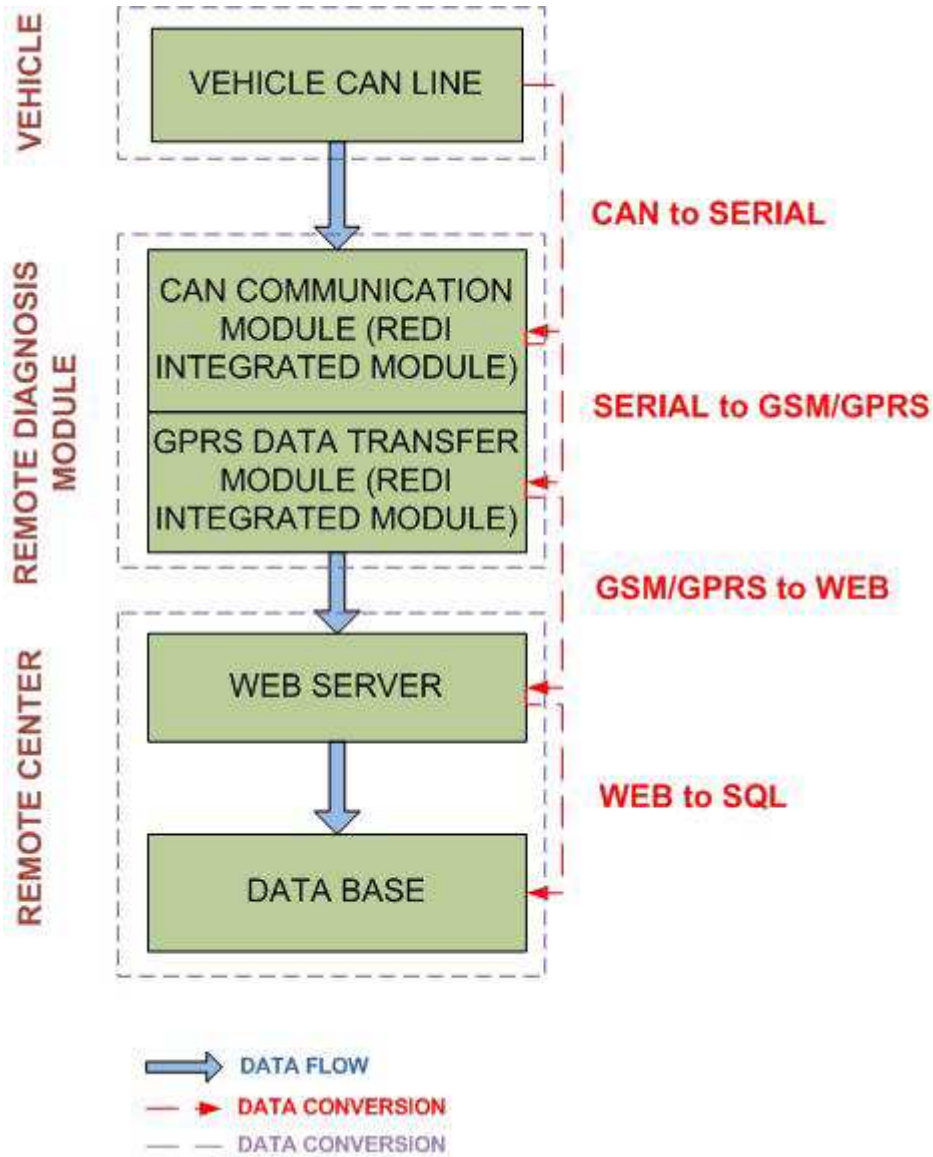


Figure 3.24. Remote Diagnosis System Data Flow Diagram

3.4.1. How Remote Diagnosis Module Reads Data From Vehicle CAN

All the CAN messages which are flowing in vehicle CAN Bus are called as “data” in this study. These messages can be some failure messages which belongs to the several ECUs or real time vehicle information messages which gives idea about the conditions of the vehicle. Vehicle CAN Bus is an open network and all the messages are available to the any demanding (except secure messages). Remote Diagnosis Module is connected parallel to vehicle CAN line as an ordinary ECU and became a part of the network. And then all the CAN messages began to flow into the module too. The requested messages such as the failure codes or some specific information messages are selected and these messages are converted into a proper format for GPRS data transfer.

The failure messages of engine ECUs are standard. Each engine broadcast the same CAN message to the network. That’s why first of all engine model is read from the CAN line and then failure message. The meanings of the failure codes are standard but the explanations about the failures depends on the brand. Because of that the failure codes analyzed by considering the engine model. An example of an engine Diagnostic Trouble Code CAN message is shown in Figure 3.25.

Figure 3.25. A Sample Engine DTC Message

3.4.2. How Remote Diagnosis Module Sends Data To Remote Center

The data which is received by CAN communication module is transmitted to the remote center in packet data format. This packet data includes the message received from vehicle CAN network and some more vehicle. Figure 3.26. shows the packet data format to be send over GPRS.

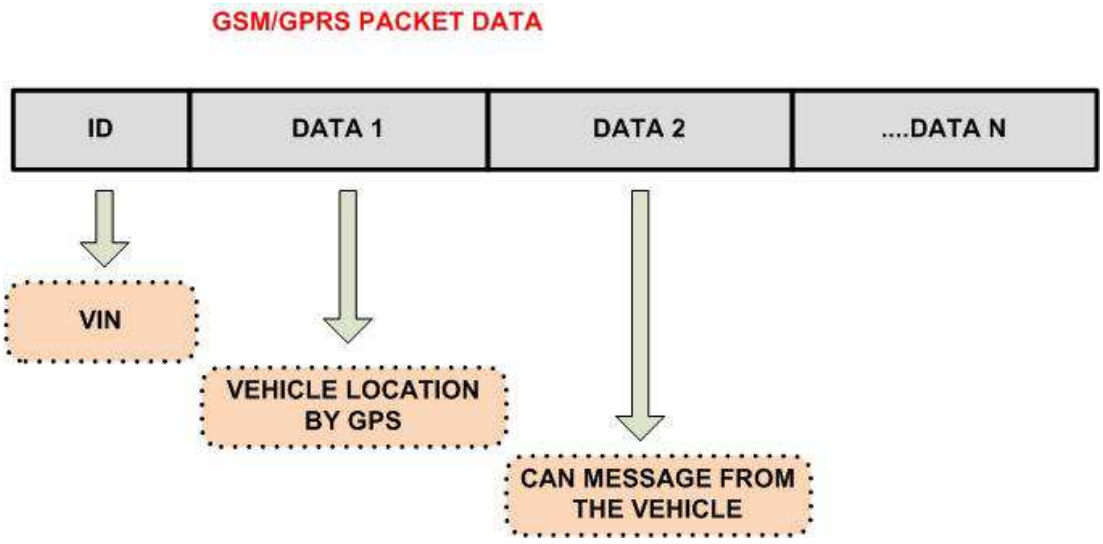


Figure 3.26. GPRS Packet Data

Each part of this packet has its own purpose and when remote center receives the data packet, classifies due to the sectors, processes and stores in the database.

3.4.2.1. ID

The first sector ID determines the name of the data. In this study VIN (Vehicle Identification Number) is sent as the ID to the remote center. Vehicle Identification Number (VIN) is mostly known as Chassis Number. Every manufactured vehicle has its own VIN given by the manufacaturer. All the information about the vehicle is kept in the manufacturer's internal database due to the VIN. This number is also written on the ECUs while the installation in the production line. When you read the CAN messages from the CAN line of the bus

VIN is also received from the network. By the VIN the vehicle which the failure code or the real time information is received from, is known. The data is stored in the remote center due to the VIN and it is matched with the internal manufacturer database. When somebody needs to check something about this vehicle the only required information will be the VIN.

3.4.2.2. Vehicle Location By GPS

The longitudes and the latitudes are received by the GPS module while the data transmitted to the remote center. The vehicle location is also learnt with this information and stored to the database on the remote center. It is named as data1 in this data packet.

3.4.2.3. CAN Message From The Vehicle

This sector is for the main data in this study. The failure code or the vehicle information (such as the speed of the vehicle) are transmitted to the remote center in this sector.

An example of what is sent to the remote center is shown below;

ID : NLTRJUA8L01010067

LOCATION : Latitude 51°01′N

Longitude 04°28′E

CAN MESSAGE : 18FECA00x

The process flow of GSM/GPRS data transmission is shown in Figure 3.27.

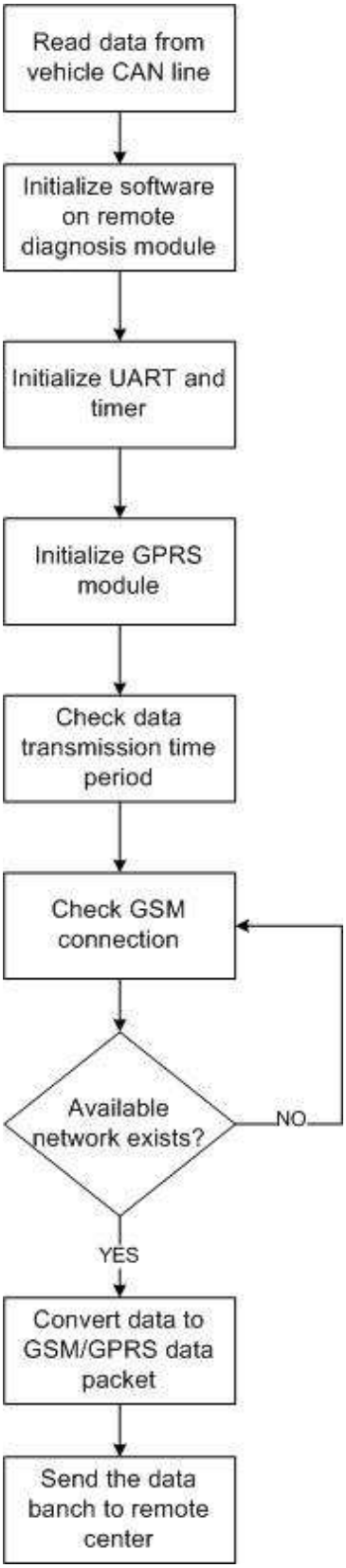


Figure 3.27. GSM/GPRS Data Transmission Flow Chart

3.4.3. How Remote Center Receives And Stores Data

The data which is transmitted from the remote diagnosis module is first received by the web service of the remote center. Web service receives the data and classifies due to the ID. If it is an active diagnostic trouble code, the responsible people are informed. If it is just an ordinary information to be stored, it is sent to the database. All these management is provided with an data management interface which is in communication with the web service and the database. The components of the remote center and the relationship between them is shown in Figure 3.28.

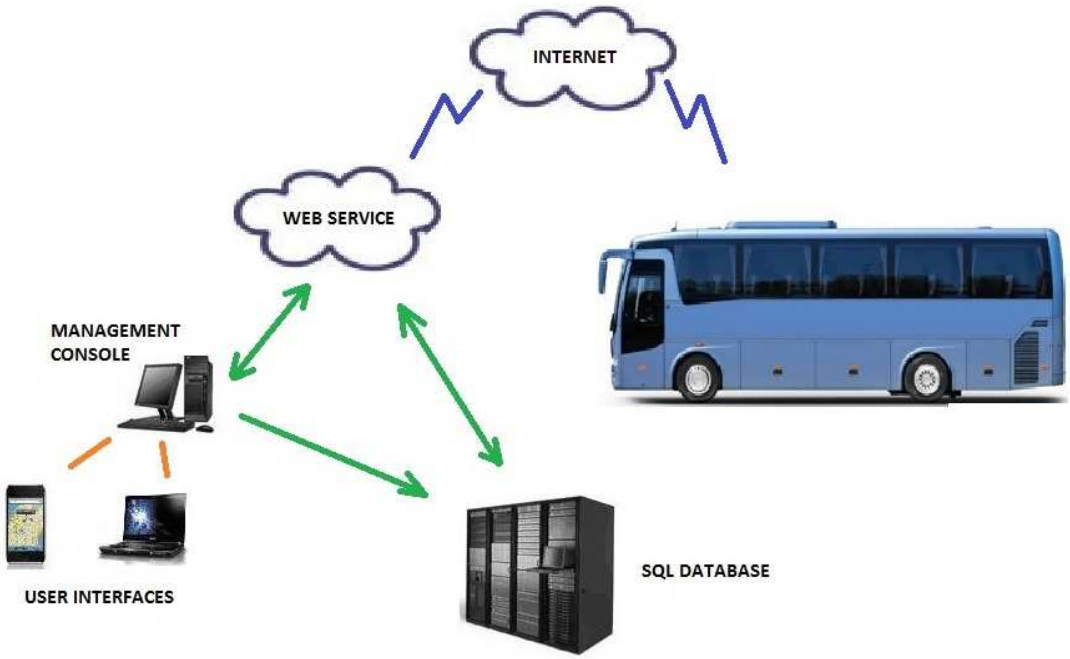


Figure 3.28. Remote Center System Structure

Web Service, Management Console and SQL Database generates the Remote Center. Web service is the first communication section with the remote diagnosis module. SQL Database stores the data and Management Console processes every data and manages all the info. The process flow for the remote center data receiving ana managing is shown in Figure 3.29.

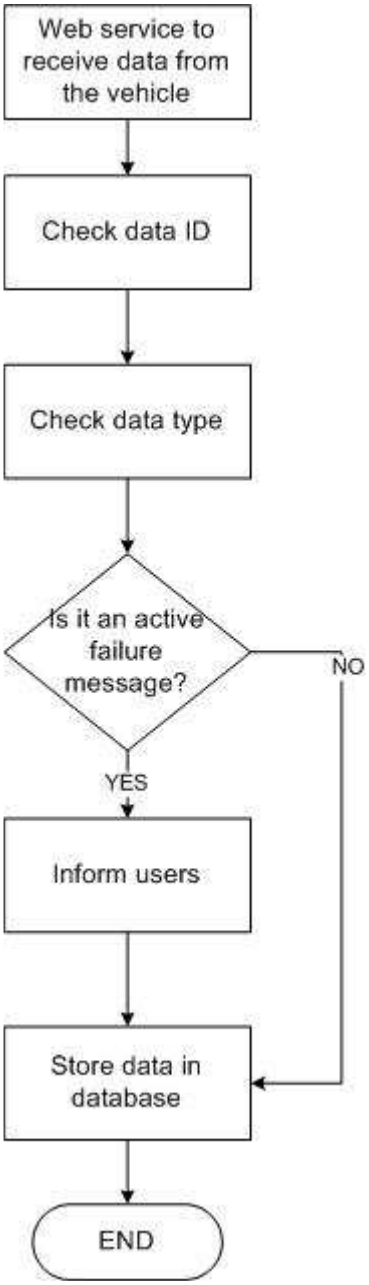


Figure 3.29. Remote Center Data Flow and Management

3.4.4. Analyzing The Received Data On Remote Center

This CAN message (engine diagnostic trouble code) has a meaning about the failure. These informations are classified as SPN and FMI. This message is converted to a packet data format and included into the batch which will be sent to

the remote center. Due to the data management algorithm this can message will stand for and engine failure and lead the user to proceed as required.

The message that we receive from CAN line can be also an information about the real time vehicle conditions. Such as ;

- Speed of the bus
- Engine coolant liquid temperature
- Revolution of the engine
- Average running time of the engine ... etc.

In this study a data management system is created on the remote center. When an active failure which means a dangerous situation is received from the remote diagnosis module the reponsible people are warned with different interfaces such as e-mail.

And also in the same database selected vehicle information data is stored to be able to used for different purposes such as future designs. As an example if the information data listed above are stored periodically from the vehicle which are in different regions, a foresight can be achieved about the topography of the region and the usage of the vehicle. These informations are stored and served to the users anytime and will help to classify the future vehicle design configurations. As an example; if the engine coolant liquid and the revolution of the engine is always more than the average values, it means that the vehicle is running on a mountain region. And the new vehicle model which will be designed for this region will have an engine with more torque according to the previous one.

The data which is received by the remote center includes the data group below;

- VIN (Read from vehicle CAN line
- Location (Received from GPS module)
- Data (Failure or vehicle information which is read from CAN line)
- Date of occurence (Read from CAN line together with data)

This data receives to the remote control center as in their real format and are sent to the database which is also classified due to this data format. The database stores these informations under the titles;

- VIN
- Vehicle Class
- Vehicle Model
- Territory
- Country
- Day
- Month
- Year
- Time Interval
- Component
- Priority
- Failure Code
- Code Explanation
- Selected vehicle information (such as “Engine Coolant Temperature”)
- Response State

Two sample databases for vehicle failures and vehicle information are shown in Figure 3.30. and Figure 3.31.

VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	COMPONENT	PRIORITY	CODE	EXPLANATION	RESPOND
NLTRUA8L01010067	TOWN	MD 9 LE	EUROPE	FRANCE	2	1	2013	10:30-11:00	ENGINE	1	111	Intake Manifold 1 Pressure Sensor Circuit - Voltage below normal, or shorted to low so	YES
NLTRUA8L01010068	TOWN	AVENUE LF	EUROPE	GERMANY	5	2	2013	08:30-09:00	ENGINE	1	115	Intake Manifold 1 Pressure -Abnormal rate of change.	NO
NLTRUA8L01010069	TOWN	AVENUE CNG	EUROPE	FRANCE	4	3	2013	12:00-12:30	ENGINE	2	125	Intake Manifold 1 Temperature - Data Valid But Below Normal Operating Range - Mode	NO
NLTRUA8L01010070	TRIP	MD 9 IC	USA	USA	1	4	2013	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating Range -Least Severe Level. Low	NO
NLTRUA8L01010071	TRIP	PRESTIJ SD	EUROPE	BELGIUM	14	5	2013	12:00-12.30	ENGINE	2	168	Engine Misfire Cylinder 3 -Condition Exists.	YES
NLTRUA8L01010072	TRIP	LD IC	EUROPE	SWITZERLAND	1	4	2013	21:00-21:30	TRANSMISSION	1	3008	System Voltage High	NO
NLTRUA8L01010073	TRIP	LD SB	EUROPE	NETHERLANDS	29	7	2013	23:00-23:30	TRANSMISSION	1	3017	Actuator Supply Voltage 1 High (HSD 1 batt)	NO
NLTAPL55L01000057	TOUR	MD 9	USA	USA	1	8	2013	18:30-19:00	TRANSMISSION	2	3116	Pressure Control Solenoid (PCS) 6 Control Circuit High	NO
NLTAPL55L01000058	TOUR	SAFIR	NON-EUROPE	SYRIA	4	9	2013	20:30-21:00	TRANSMISSION	1	3121	Lost Communication with ECM / PCM "B"	YES
NLTAPL55L01000059	TOUR	HD C12	EUROPE	NETHERLANDS	15	5	2014	16:30-17:00	TRANSMISSION	2	3122	Gear Shift Module 2 State of Health	YES
NLTAPL55L01000060	TOUR	LD	EUROPE	TURKEY	8	11	2013	22:00-22:30	TRANSMISSION	1	3126	Gear Shift Module 2 invalid Data	NO
NLTAPL55L01000061	TOUR	T5 30	USA	USA	9	12	2013	18:30-19:00	TRANSMISSION	1	3109	Kickdown Input Switch Circuit	NO
NLTAPL55L01000062	TOUR	T5 35	EUROPE	BELGIUM	12	4	2013	21:00-21:30	TRANSMISSION	2	3079	Engine Coolant Temperature Sensor 2 Circuit High	NO
NLTAPL55L01000063	TOUR	T5 45	USA	USA	15	5	2014	22:00-22:30	BRAKE CONTROL	1	4903	Wheel Sensor ABS Axle 2 Left / specialinstructions	NO
NLTAPL55L01000064	TOWN	MD 9 LE	EUROPE	FRANCE	18	6	2014	22:00-22:30	BRAKE CONTROL	2	4915	Wheel Sensor ABS Axle 3 Left / voltage above normal or shorted high	YES
NLTAPL55L01000065	TOWN	AVENUE LF	EUROPE	ITALY	22	7	2014	16:30-17:00	BRAKE CONTROL	1	4931	Pressure Modulation Valve ABS Axle 1Left / voltage above normal or shorted high	YES
NLTAPL55L01000066	TRIP	LD IC	EUROPE	NETHERLANDS	24	8	2014	14:30-15:00	BRAKE CONTROL	1	5020	Lining Wear Sensor Axle 2 Left / voltageabove normal or shorted high	YES
NLTAPL55L01000067	TRIP	LD SB	NON-EUROPE	ISRAEL	25	9	2014	08:30-09:00	SUSPENSION CONTROL	2	6041	2/2 solenoid valve front axle right /Current above normal or grounded circuit	YES
NLTAPL55L01000068	TOUR	LD	NON-EUROPE	CAMEROON	23	10	2014	16:30-17:00	SUSPENSION CONTROL	1	6068	Level sensor front axle right / Data erratic, intermittent	YES
NLTAPL55L01000069	TRIP	MD 9 IC	EUROPE	SWEDEN	30	12	2014	20:30-21:00	SUSPENSION CONTROL	2	6089	Pressure sensor front axle left / Current above normal or grounded circuit	NO
NLTRJTA8L01010123	TRIP	SAFARI HD	EUROPE	BELGIUM	3	5	2014	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating Range -Least Severe Level. Low	NO
NLTTMSA7L01000156	TRIP	SAFIR	EUROPE	LITHUANIA	22	5	2014	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating Range -Least Severe Level. Low	YES
NLTTMSA7L01000158	TRIP	MD 9 IC	NON-EUROPE	ISRAEL	25	7	2014	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating Range -Least Severe Level. Low	NO
NLTRJTA8L01010129	TRIP	AVENUE	EUROPE	ITALY	13	8	2013	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating Range -Least Severe Level. Low	YES

Figure 3.30. Sample Received Failure Database

VIN	VEHICLE CLASS	VEHICLE MODİ	TERRITORY	COUNTRY	DAY	MINTH	YEA	TIME	VEHICLE SPEED	ENGINE COOLANT TEMPE	ENGINE OIL TEMPE	ENGINE RPM	CURRENT GEAR
NLTRUJA8L01010067	TOWN	MD 9 LE	EUROPE	FRANCE	2	1	2013	10:30-11:00	105	85	80	2000	7
NLTRUJA8L01010068	TOWN	AVENUE LF	EUROPE	GERMANY	5	2	2013	08:30-09:00	85	65	70	1550	5
NLTRUJA8L01010069	TOWN	AVENUE CNG	EUROPE	FRANCE	4	3	2013	12:00-12:30	30	60	40	900	3
NLTRUJA8L01010070	TRIP	MD 9 IC	USA	USA	1	4	2013	14:30-15:00	55	57	43	1250	2
NLTRUJA8L01010071	TRIP	PRESTIJ SD	EUROPE	BELGIUM	14	5	2013	12:00-12:30	70	62	52	1360	5
NLTRUJA8L01010072	TRIP	LD IC	EUROPE	SWITZERLAND	1	4	2013	21:00-21:30	72	63	35	1350	6
NLTRUJA8L01010073	TRIP	LD SB	EUROPE	NETHERLANDS	29	7	2013	23:00-23:30	43	65	86	1750	4
NLTAPL55L01000057	TOUR	MD 9	USA	USA	1	8	2013	18:30-19:00	12	80	95	1800	2
NLTAPL55L01000058	TOUR	SAFIR	NON-EUROPE	SYRIA	4	9	2013	20:30-21:00	58	81	36	1865	3
NLTAPL55L01000059	TOUR	HD C12	EUROPE	NETHERLANDS	15	5	2014	16:30-17:00	65	87	58	1250	2
NLTAPL55L01000060	TOUR	LD	EUROPE	TURKEY	8	11	2013	22:00-22:30	92	100	0	1360	1
NLTAPL55L01000061	TOUR	TS 30	USA	USA	9	12	2013	18:30-19:00	53	103	86	1350	5
NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	12	4	2013	21:00-21:30	69	105	95	1750	6
NLTAPL55L01000063	TOUR	TS 45	USA	USA	15	5	2014	22:00-22:30	43	90	35	1800	5
NLTAPL55L01000064	TOWN	MD 9 LE	EUROPE	FRANCE	18	6	2014	22:00-22:30	65	84	58	2020	6
NLTAPL55L01000065	TOWN	AVENUE LF	EUROPE	ITALY	22	7	2014	16:30-17:00	92	86	50	1865	4
NLTAPL55L01000066	TRIP	LD IC	EUROPE	NETHERLANDS	24	8	2014	14:30-15:00	53	57	66	1250	2
NLTAPL55L01000067	TRIP	LD SB	NON-EUROPE	ISRAEL	25	9	2014	08:30-09:00	69	80	75	1360	3
NLTAPL55L01000068	TOUR	LD	NON-EUROPE	CAMEROON	23	10	2014	16:30-17:00	43	99	78	1865	2
NLTAPL55L01000069	TRIP	MD 9 IC	EUROPE	SWEDEN	30	12	2014	20:30-21:00	82	45	63	1250	4
NLTRJTA8L01010123	TRIP	SAFARI HD	EUROPE	BELGIUM	3	5	2014	14:30-15:00	65	63	68	1550	5
NLTTMSA7L01000156	TOUR	SAFIR	EUROPE	LITHUANIA	22	5	2014	14:30-15:00	73	61	71	1780	5
NLTTMSA7L01000158	TRIP	MD 9 IC	NON-EUROPE	ISRAEL	25	7	2014	14:30-15:00	44	74	83	1650	4
NLTRJTA8L01010129	TOWN	AVENUE LF	EUROPE	ITALY	13	8	2013	14:30-15:00	86	86	75	1900	7
NLTAPL56L01000101	TRIP	MD 9 IC	EUROPE	GERMANY	12	6	2014	16:30-17:00	75	82	70	1700	6
NLTAPL56L01000102	TRIP	MD 9 IC	EUROPE	GERMANY	13	6	2014	14:30-15:00	45	101	82	1650	4
NLTAPL56L01000103	TRIP	MD 9 IC	EUROPE	GERMANY	15	7	2014	21:00-21:30	68	79	65	1500	5
NLTAPL56L01000104	TRIP	MD 9 IC	EUROPE	GERMANY	17	9	2014	22:00-22:30	82	95	86	1300	7
NLTAPL56L01000105	TRIP	MD 9 IC	EUROPE	GERMANY	18	11	2014	08:30-09:00	35	80	48	1450	2

Figure 3.31. Sample Received Info Database

All these data are serviced to the opearator with a Data Management Console and the operator processes the data with this console. Each operator has got his own authorization. For example; some operators are allowed to delete the failures some not. So in the main page it is asked for the operator access information just like shown in Figure 3.32.

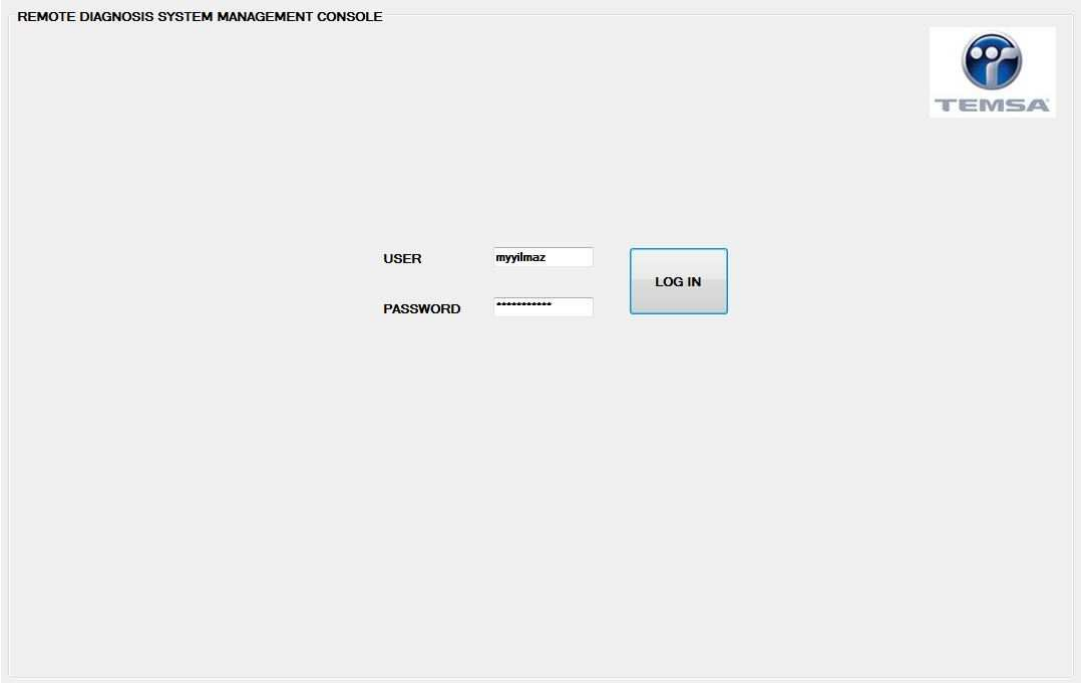


Figure 3.32. Management Console Login Page

After log in the main page gives you eight function buttons. These buttons control different parameter filtering types.

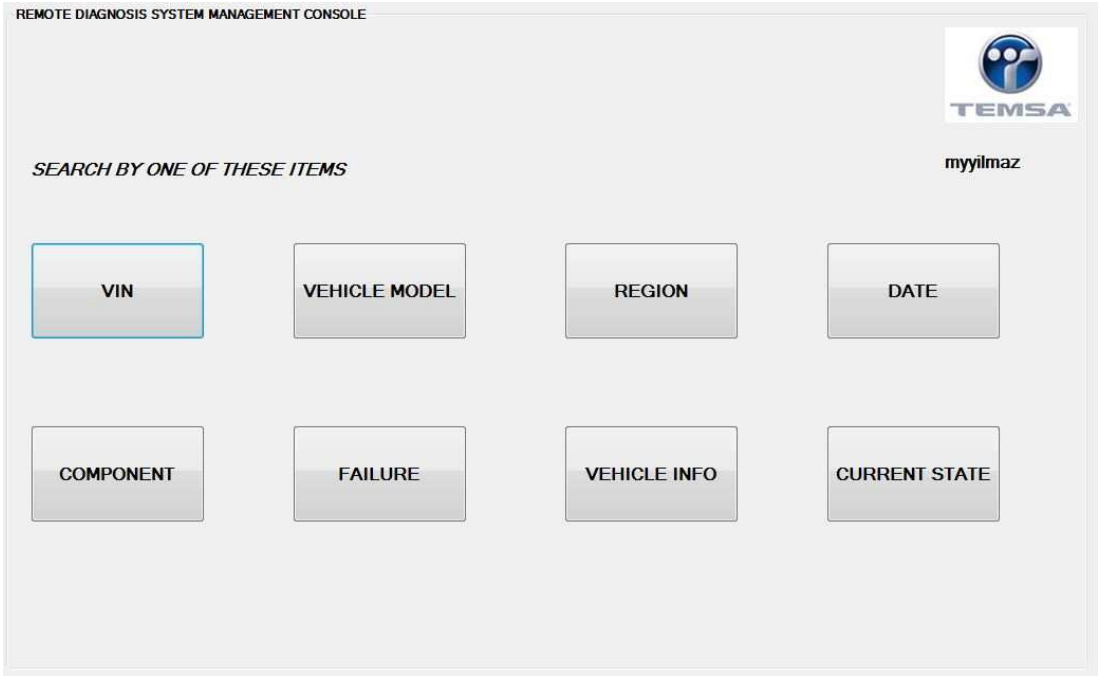


Figure 3.33. Management Console Main Menu

The data can be filtered according to the all possible combinations in the management console. The data or failures can be listed by typing in a VIN, or selecting a special country. A combination with a country and a vehicle model can be also displayed. This ability allows us to analyze a data or a failure and helps us to have an idea about the failure, vehicle configuration, or topography of the region.

Each function button is explained;

VIN means the Vehicle Identification Number (as explained in previous chapters). When this function button is selected, all the received failures and all the received vehicle information can be displayed as a list. It only lists according to the entered VIN.

Figure 3.34. VIN Based Searching Failures 1

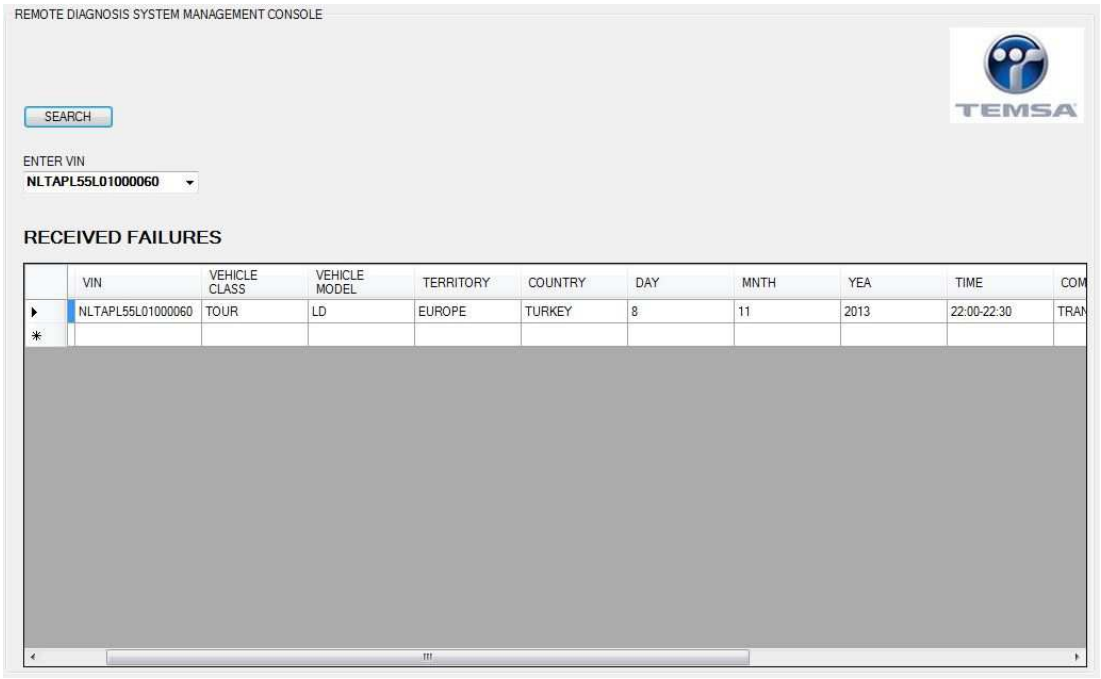


Figure 3.35. VIN Based Searching Failures 2

VEHICLE MODEL button is standing for filtering according to the Vehicle Class and the Vehicle Model. Vehicle data can be filtered for a class (such as Tour Class which is used for intercity passenger transport) or only for a specified vehicle model can be the reference for filtering the data.

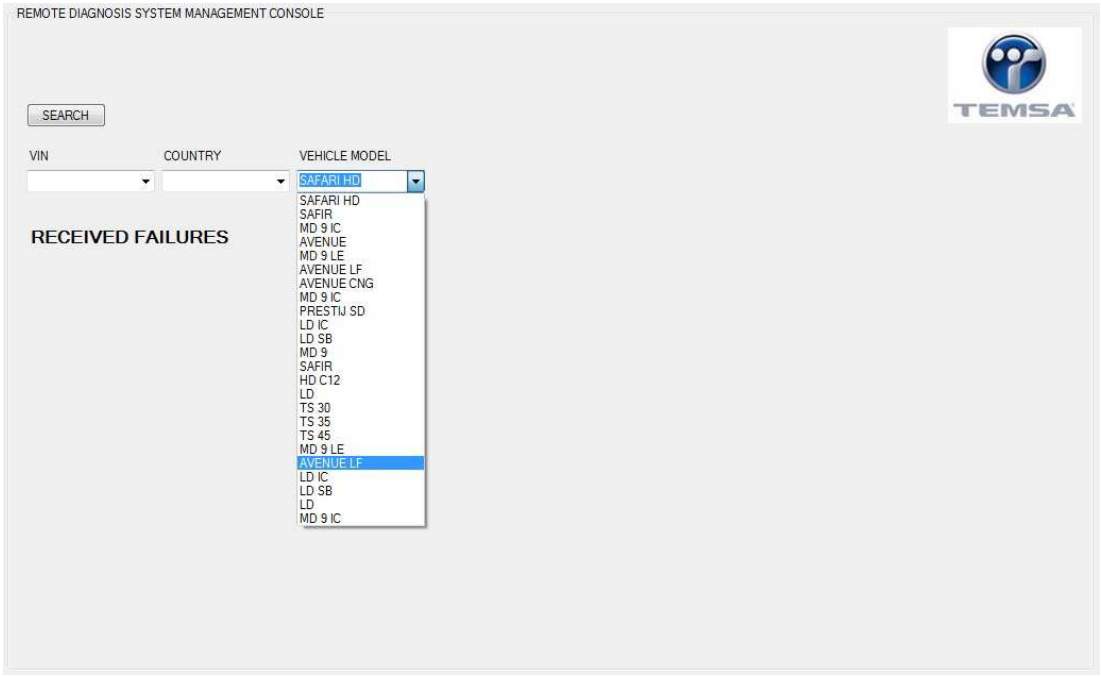


Figure 3.36. Vehicle Model Based Searching Failures 1

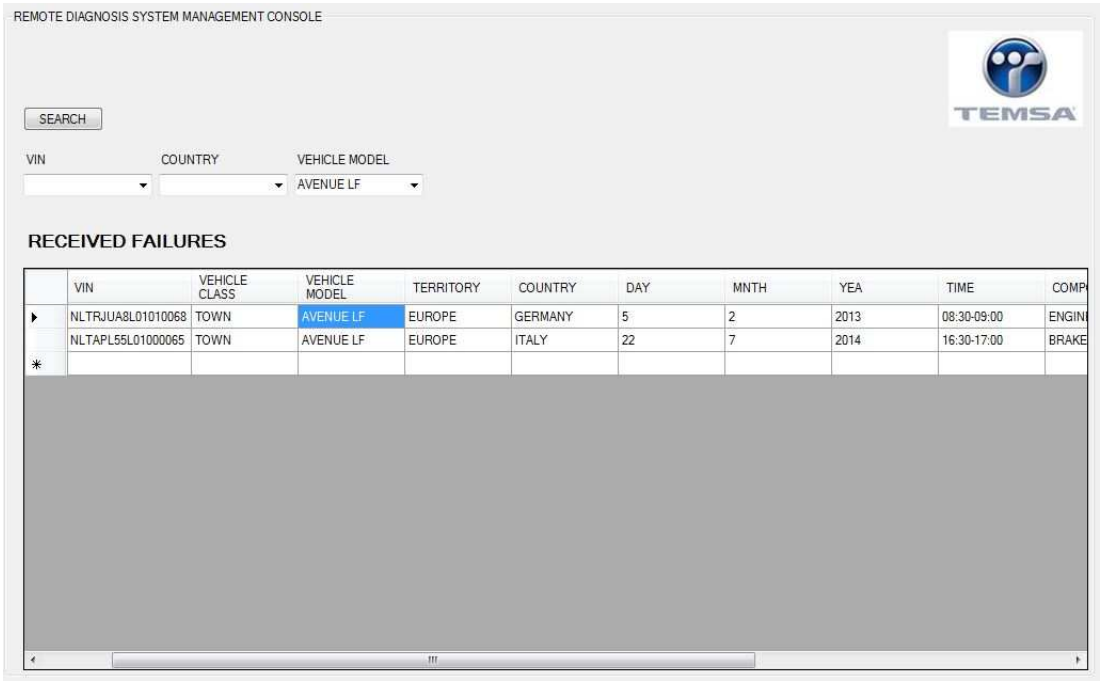


Figure 3.37. Vehicle Model Based Searching Failures 1

REGION includes both Territory and Country for the classification of the failure. A specified country or a region on the world can be selected to display the received vehicle datas. As an example the data coming from Germany can be displayed but at the same time it can be filtered as Europe which includes Germany and some more countries.

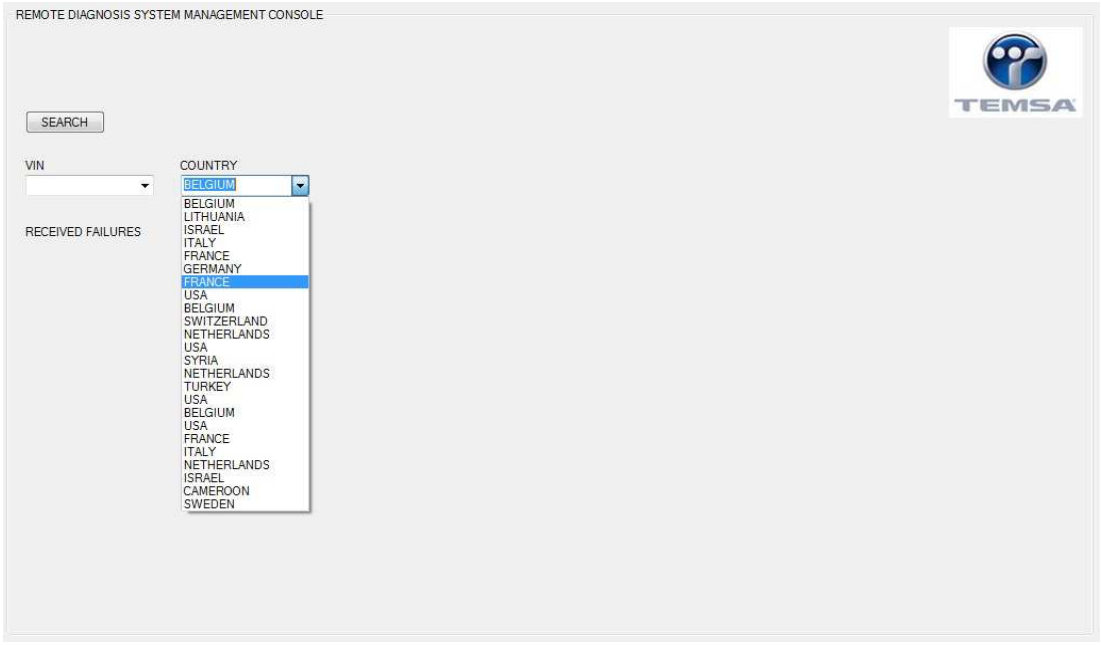


Figure 3.38. Country Based Searching Failures 1

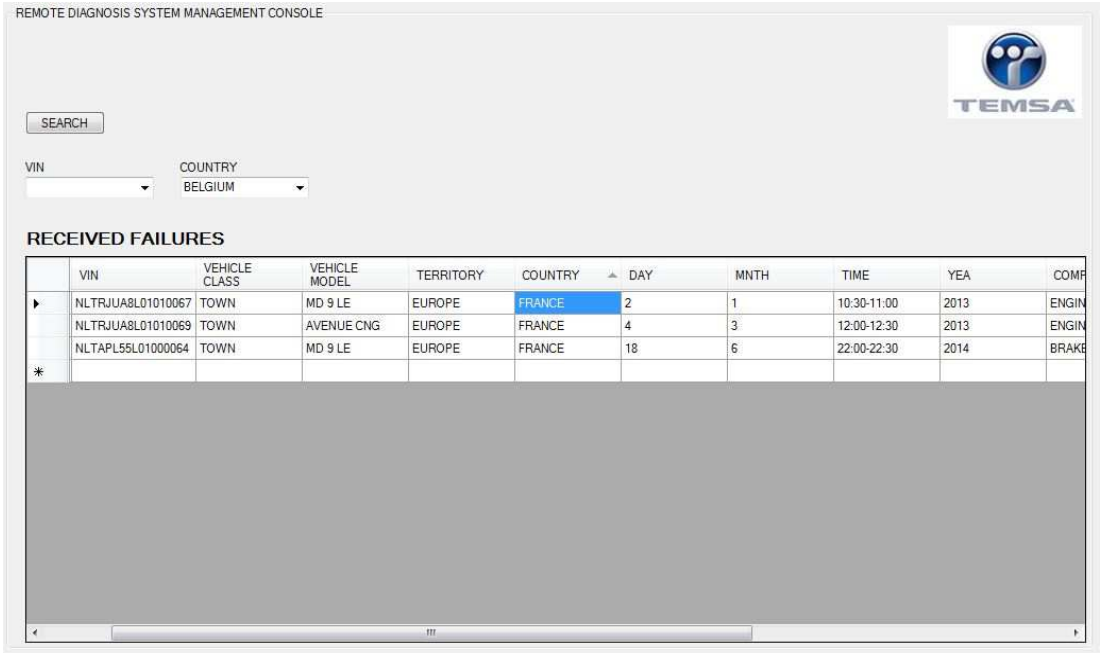


Figure 3.39. Country Based Searching Failures 2

DATE stands for the data receiving time for the filtering. A specified date, a month, a specified preiod of time... etc can be selected for filtering the failures or data. According to the occurence date and time of failure or data, currency of data is followed.

Figure 3.40. Date Based Searching Failures 1

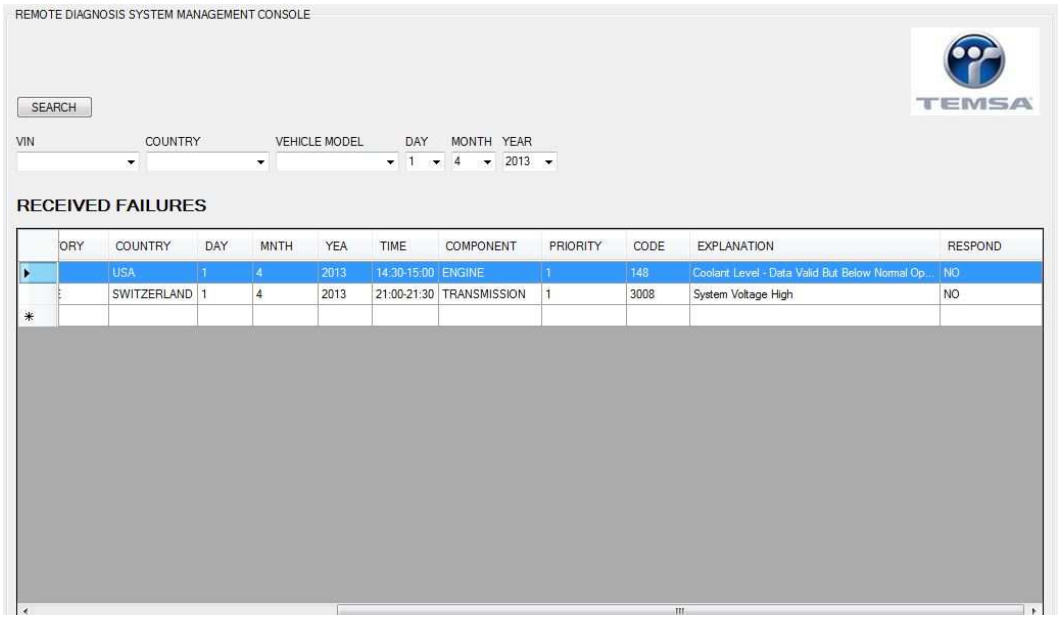


Figure 3.41. Date Based Searching Failures 2

COMPONENT based on searching means to filter the data according to the vehicle components such as engine, transmission, brake system.. etc. As an example when all received failures or data are filtered according to a specified vehicle model and a vehicle component, the behaviour of this components on that specified model can be observed with real values.

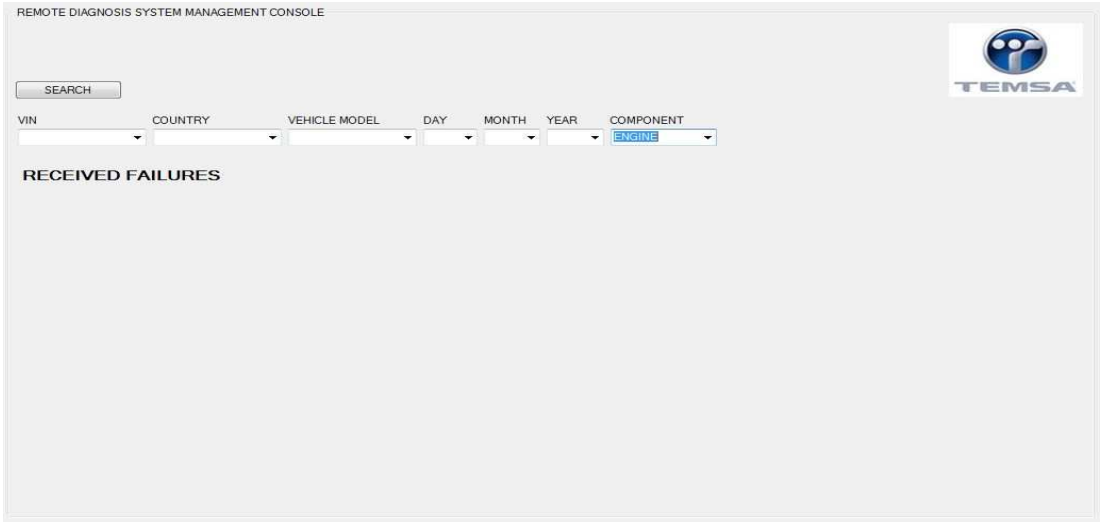
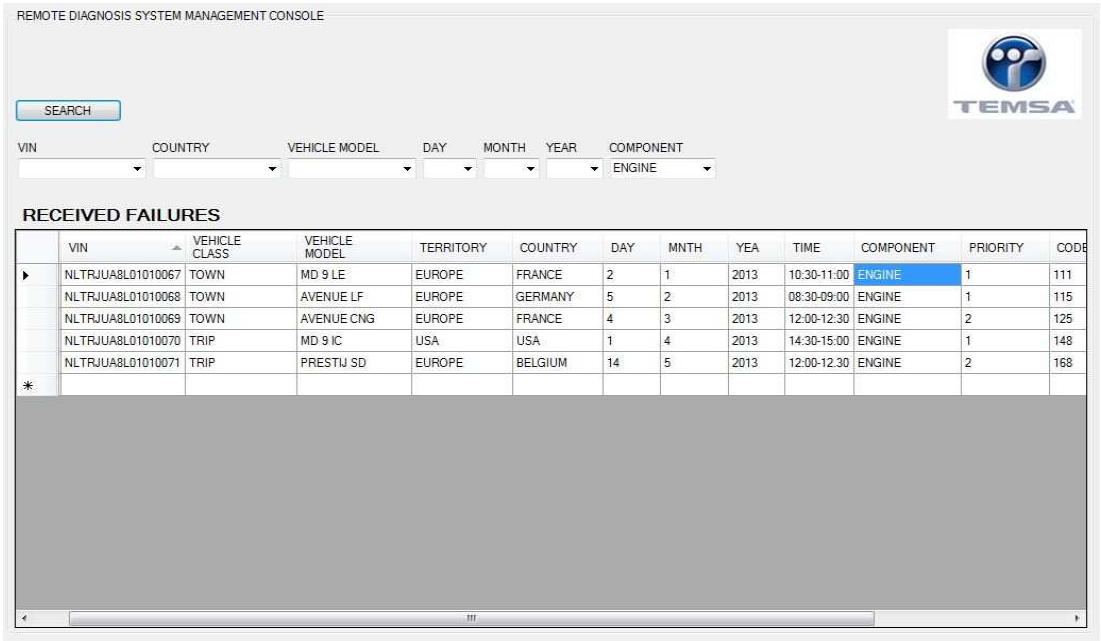


Figure 3.42. Component Based Searching Failures 1



VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	COMPONENT	PRIORITY	CODE
NLTRJUA8L01010067	TOWN	MD 9 LE	EUROPE	FRANCE	2	1	2013	10:30-11:00	ENGINE	1	111
NLTRJUA8L01010068	TOWN	AVENUE LF	EUROPE	GERMANY	5	2	2013	08:30-09:00	ENGINE	1	115
NLTRJUA8L01010069	TOWN	AVENUE CNG	EUROPE	FRANCE	4	3	2013	12:00-12:30	ENGINE	2	125
NLTRJUA8L01010070	TRIP	MD 9 IC	USA	USA	1	4	2013	14:30-15:00	ENGINE	1	148
NLTRJUA8L01010071	TRIP	PRESTIJ SD	EUROPE	BELGIUM	14	5	2013	12:00-12.30	ENGINE	2	168

Figure 3.43. Component Based Searching Failures 2

FAILURE CODE based searching stands for to the reference of failure code, code explanation and the priority of the code. Any code can be checked due to the priority or a common failure can be observed in all vehicles by filtering due to the code.

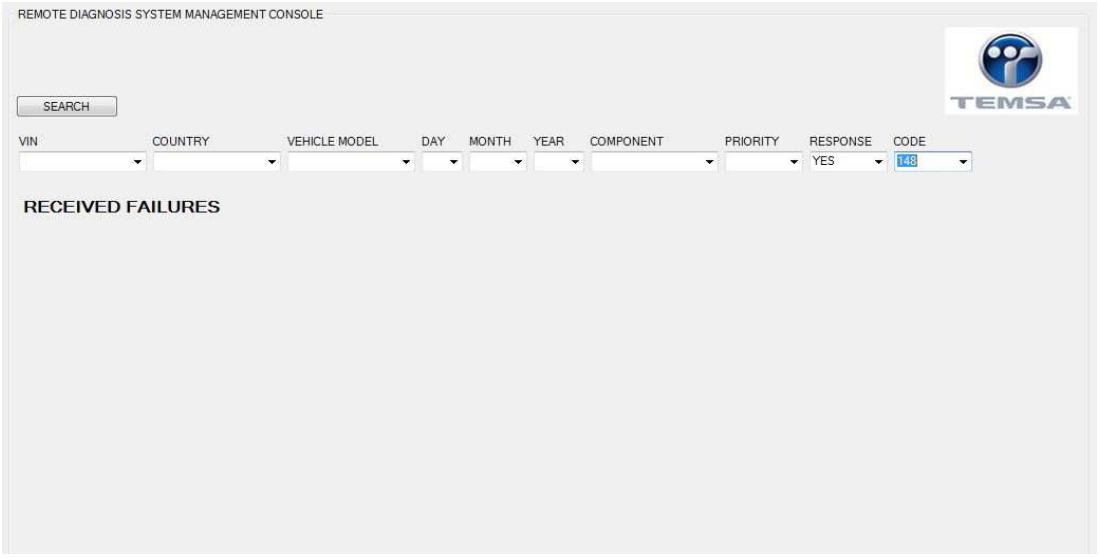


Figure 3.44. Code Based Searching Failures 1

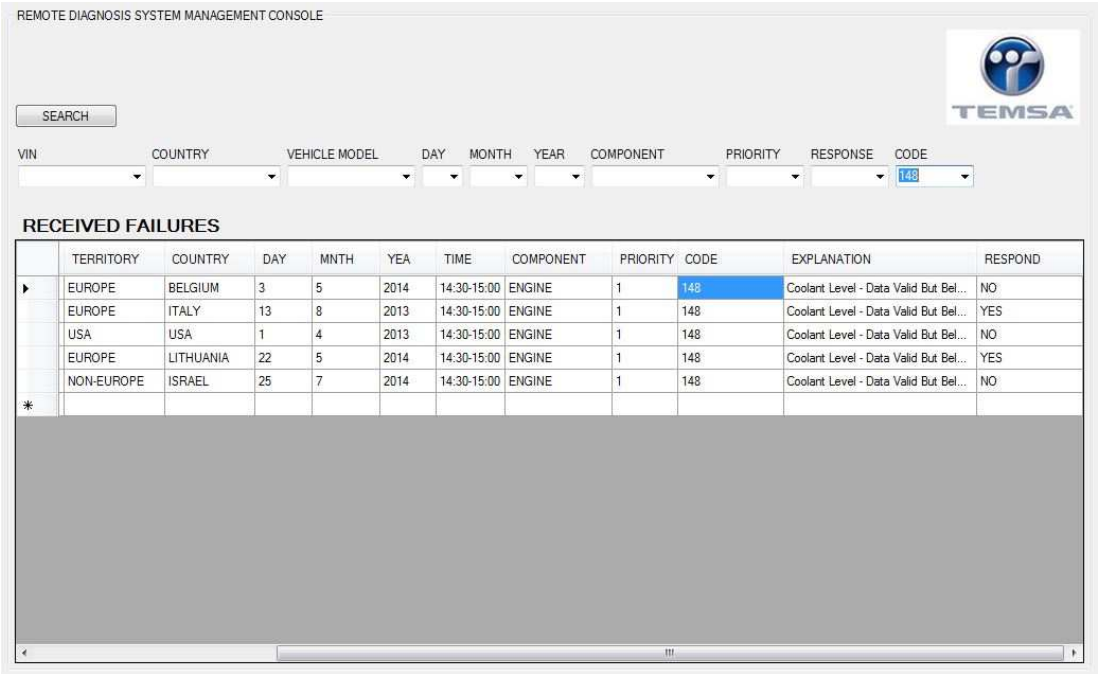
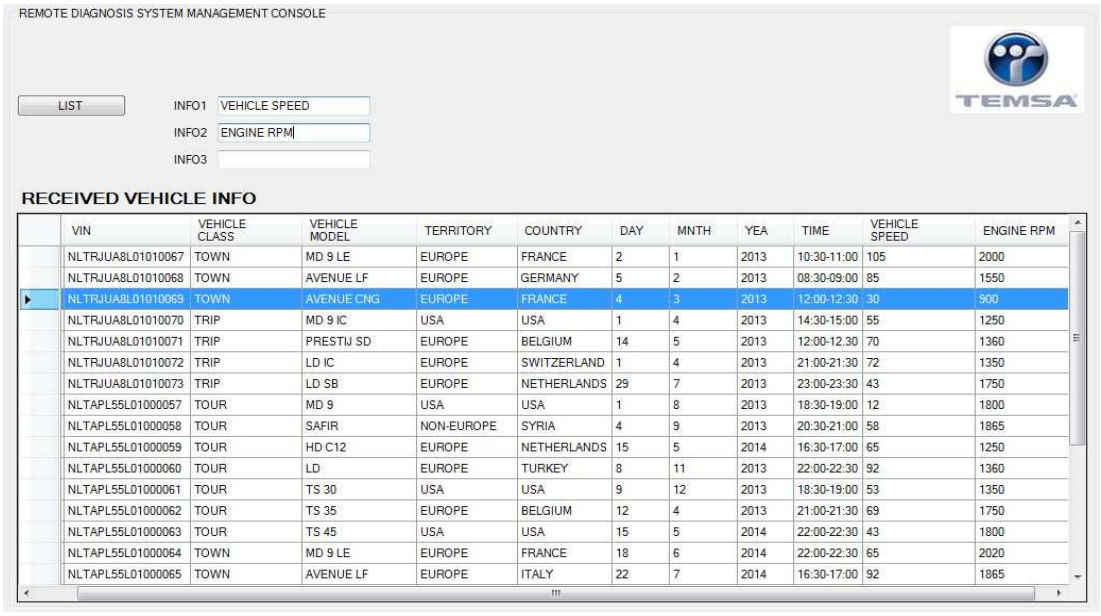


Figure 3.45. Code Based Searching Failures 1

VEHICLE INFO means the data which is received from the vehicle as a vehicle parameter. This information doesn't mean an active diagnostic trouble code or not a failure at all. But it gives idea about the vehicle conditions such as engine speed, coolant temperature, oil temperature... etc. When a report is created about these parameters, the fault which occurs on the vehicle can be evaluated better.

Figure 3.46. List Vehicle Speed & Engine RPM 1



VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	VEHICLE SPEED	ENGINE RPM
NLTRJUA8L01010067	TOWN	MD 9 LE	EUROPE	FRANCE	2	1	2013	10:30-11:00	105	2000
NLTRJUA8L01010068	TOWN	AVENUE LF	EUROPE	GERMANY	5	2	2013	08:30-09:00	85	1550
NLTRJUA8L01010069	TOWN	AVENUE CNG	EUROPE	FRANCE	4	3	2013	12:00-12:30	30	900
NLTRJUA8L01010070	TRIP	MD 9 IC	USA	USA	1	4	2013	14:30-15:00	55	1250
NLTRJUA8L01010071	TRIP	PRESTIJ SD	EUROPE	BELGIUM	14	5	2013	12:00-12:30	70	1360
NLTRJUA8L01010072	TRIP	LD IC	EUROPE	SWITZERLAND	1	4	2013	21:00-21:30	72	1350
NLTRJUA8L01010073	TRIP	LD SB	EUROPE	NETHERLANDS	29	7	2013	23:00-23:30	43	1750
NLTAPL55L01000057	TOUR	MD 9	USA	USA	1	8	2013	18:30-19:00	12	1800
NLTAPL55L01000058	TOUR	SAFIR	NON-EUROPE	SYRIA	4	9	2013	20:30-21:00	58	1865
NLTAPL55L01000059	TOUR	HD C12	EUROPE	NETHERLANDS	15	5	2014	16:30-17:00	65	1250
NLTAPL55L01000060	TOUR	LD	EUROPE	TURKEY	8	11	2013	22:00-22:30	92	1360
NLTAPL55L01000061	TOUR	TS 30	USA	USA	9	12	2013	18:30-19:00	53	1350
NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	12	4	2013	21:00-21:30	69	1750
NLTAPL55L01000063	TOUR	TS 45	USA	USA	15	5	2014	22:00-22:30	43	1800
NLTAPL55L01000064	TOWN	MD 9 LE	EUROPE	FRANCE	18	6	2014	22:00-22:30	65	2020
NLTAPL55L01000065	TOWN	AVENUE LF	EUROPE	ITALY	22	7	2014	16:30-17:00	92	1865

Figure 3.47. List Vehicle Speed & Engine RPM 1

CURRENT STATE is stands for defining the open or close cases. If a failure has been solved on the vehicle or when a response is given back to the vehicle, the current state is defined as close. The received failures list can be filtered based on not reponsed cases in a country and by this way an overall list about a country can be created.

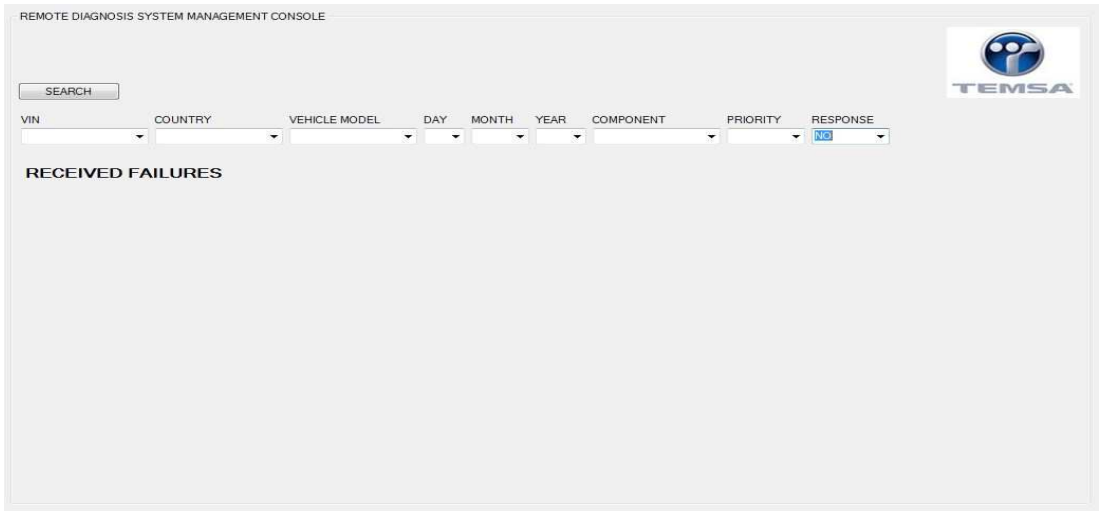
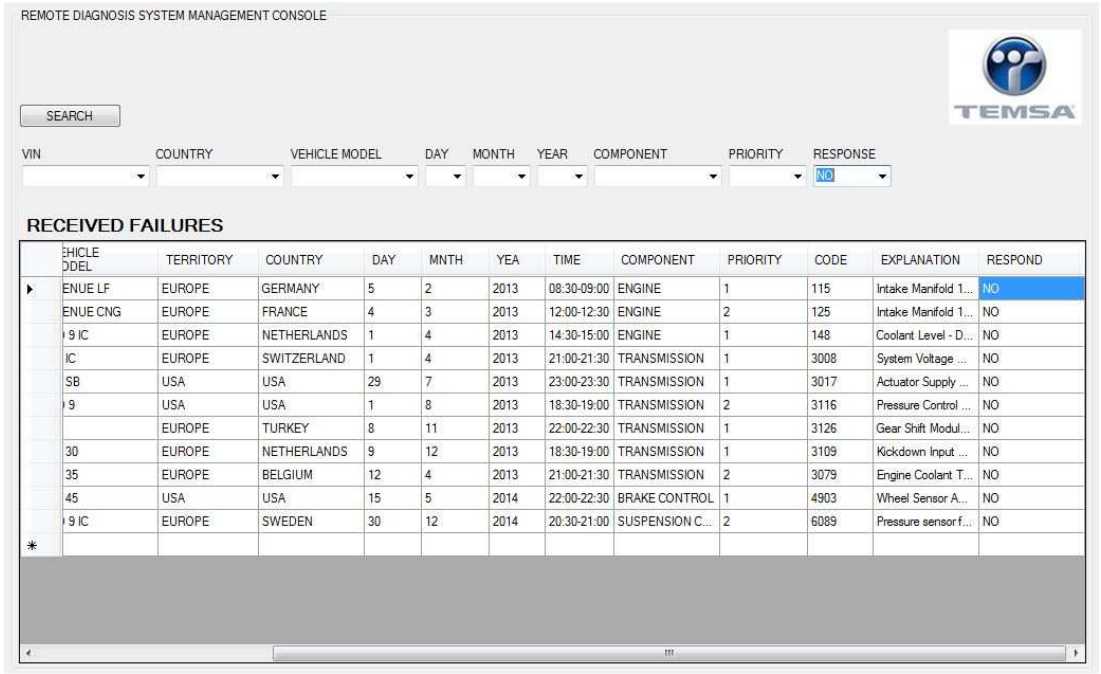


Figure 3.48. Response Based Searching Failures 1



HICLE ODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	COMPONENT	PRIORITY	CODE	EXPLANATION	RESPOND
ENUE LF	EUROPE	GERMANY	5	2	2013	08:30-09:00	ENGINE	1	115	Intake Manifold 1...	NO
ENUE CNG	EUROPE	FRANCE	4	3	2013	12:00-12:30	ENGINE	2	125	Intake Manifold 1...	NO
9 IC	EUROPE	NETHERLANDS	1	4	2013	14:30-15:00	ENGINE	1	148	Coolant Level - D...	NO
IC	EUROPE	SWITZERLAND	1	4	2013	21:00-21:30	TRANSMISSION	1	3008	System Voltage ...	NO
SB	USA	USA	29	7	2013	23:00-23:30	TRANSMISSION	1	3017	Actuator Supply ...	NO
9	USA	USA	1	8	2013	18:30-19:00	TRANSMISSION	2	3116	Pressure Control ...	NO
	EUROPE	TURKEY	8	11	2013	22:00-22:30	TRANSMISSION	1	3126	Gear Shift Modul...	NO
30	EUROPE	NETHERLANDS	9	12	2013	18:30-19:00	TRANSMISSION	1	3109	Kickdown Input ...	NO
35	EUROPE	BELGIUM	12	4	2013	21:00-21:30	TRANSMISSION	2	3079	Engine Coolant T...	NO
45	USA	USA	15	5	2014	22:00-22:30	BRAKE CONTROL	1	4903	Wheel Sensor A...	NO
9 IC	EUROPE	SWEDEN	30	12	2014	20:30-21:00	SUSPENSION C...	2	6089	Pressure sensor f...	NO

Figure 3.49. Response Based Searching Failures 1

Some filtering combinations are shown in Appendix 1.

LAYOUT function stands for sending e-mails or printing the filtered list. When the list is needed to be sent to somebody else or just needed to be printed out to be saved as a harcopy the layout function is available under every list.

The flow chart of the filtering progress of Data Management Console is shown in Figure 3.50. This flow process flow explains basically the background working principle of Data Management Console.

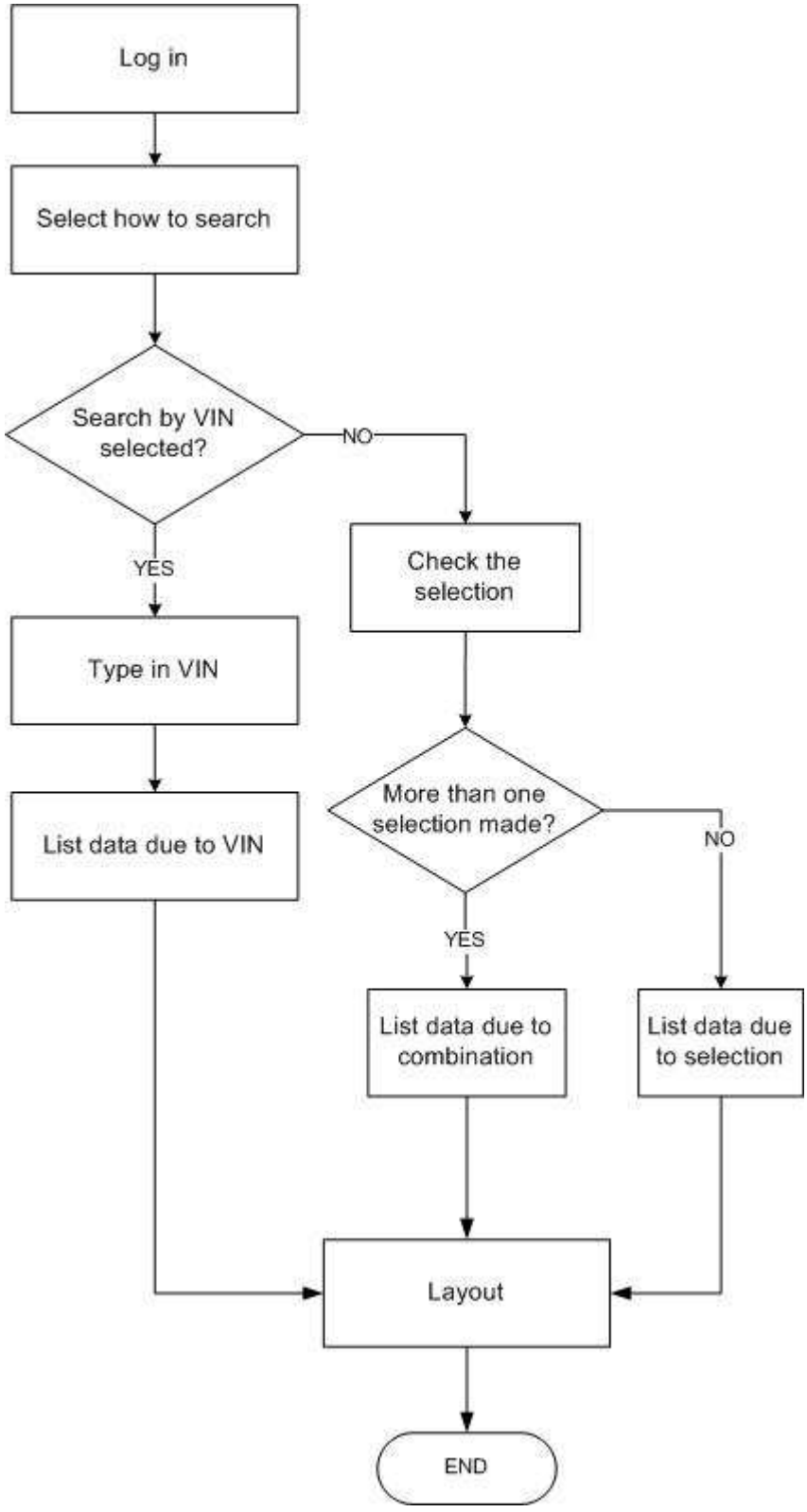


Figure 3.50. Data Management Console Searching Process Flow

4. RESULTS AND DISCUSSION

As a result of this study implementation of Remote Diagnosis Module (REDI) and design of Data Management System have been achieved successfully. REDI board is integrated to the vehicle multiplex system. The adaptation of REDI to the vehicle multiplex system has been tested for different vehicle models, with different type of CAN messages.

A CAN analyzer software has been used to create unreal vehicle data messages. The messages have been sent to remote center by the help of a GPRS module. All type of CAN messages including the failure codes and the vehicle real time conditions have been sent to the remote center and has never seen any problem of the data transmission.

Tests have been performed while the vehicle was standing still and also while the vehicle was on the road. The data transmission was successful for both these two conditions. The location of the vehicle has been detected successfully while performing GPS module test in different locations.

All steps of developing a data management system have been realized with this study. The specifications of the basic system sections have been decided. The integration of REDI to vehicle network and remote remote center has been developed and tested. A database have been created and the communication between this remote center and the vehicle have been tested with several data banches. There haven’t been any problem on database and server.

The entire system data management system have been tested with several failure and information messages which are transmitted by REDI. Possible field events have been classified and simplified according to the feedback received from a local bus& coach manufacturer. These possible events were included into the management system, the progress on the management system due to these events have been tested and the user satisfaction of the remote center has been observed successfully.

REDI board has been connected to the test vehicle (Temsa Safir) as shown in Figure 4.1. and Figure 4.2.

Figure 4.1. Test Vehicle (Temsa Safir)

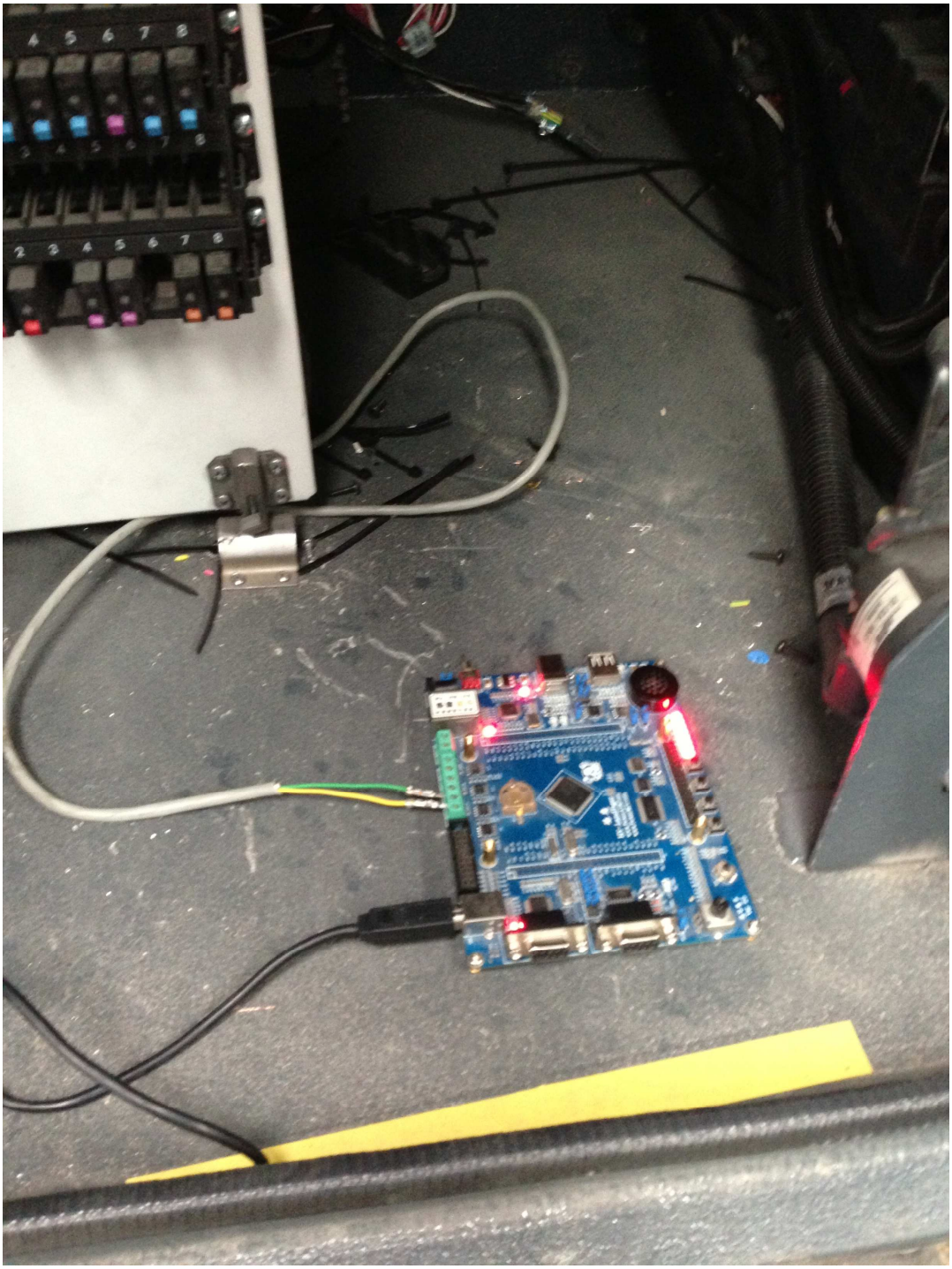


Figure 4.2. REDI Board Integration to the Vehicle Harness

After REDI is integrated to the bus successfully vehicle real time information have been observed while the vehicle is standing still. After REDI is connected to the vehicle multiplex system all CAN message begins to flow over REDI too. Some

informations such as engine RPM, engine coolant temperature, etc. have been observed through REDI.

There is always a data flow in vehicle CAN line while the power is on and REDI reads these messages always too. But the data transmission with the remote center is provided when there is and active failure diagnostic code or a requested vehicle information. A failure message has been created on vehicle to perform a failure message transmission test. As an example the intake air pressure sensor electrical connector has been taken out and an active diagnostic trouble code was created. CAN message explanation of the failure which is read with CAN analyzer software is shown in Figure 4.3. SPN and FMI explanations of the active diagnostic trouble code is seen in figure.

Figure 4.3. Active Diagnostic Trouble Code by CAN Analyzer

International standard failure codes have been matched with a special manufacturer diagnostic trouble code. The apperance of the related active diagnostic

trouble code on vehicle's instrument cluster is shown in Figure 4.4. These codes are stored in database as a table. The related part of this table is shown in Table 4.1.

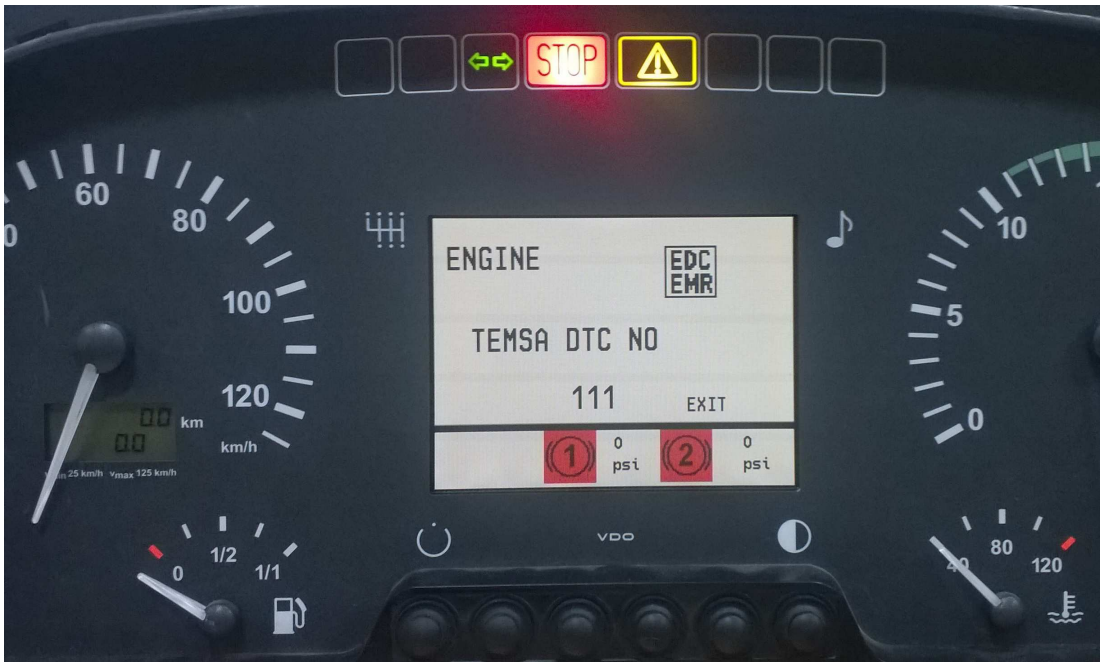


Figure 4.4. Active Diagnostic Trouble Code on Instrument Cluster

Table 4.1. DTC 111 Explanation

SPN	FMI	Temsa DTC	Manifacturer	Definition
102	4	111	CUMMINS	Intake Manifold 1 Pressure Sensor Circuit - Voltage below normal, or shorted to low source. Low signal voltage or open circuit detected at the intake manifold pressure circuit.

This message was received from the vehicle CAN network by REDI and sent to the remote center. The remote center receives the code "111", checks on the database and sends a warning message to the responsibles as it is shown in Figure 4.5. and Figure 4.6.

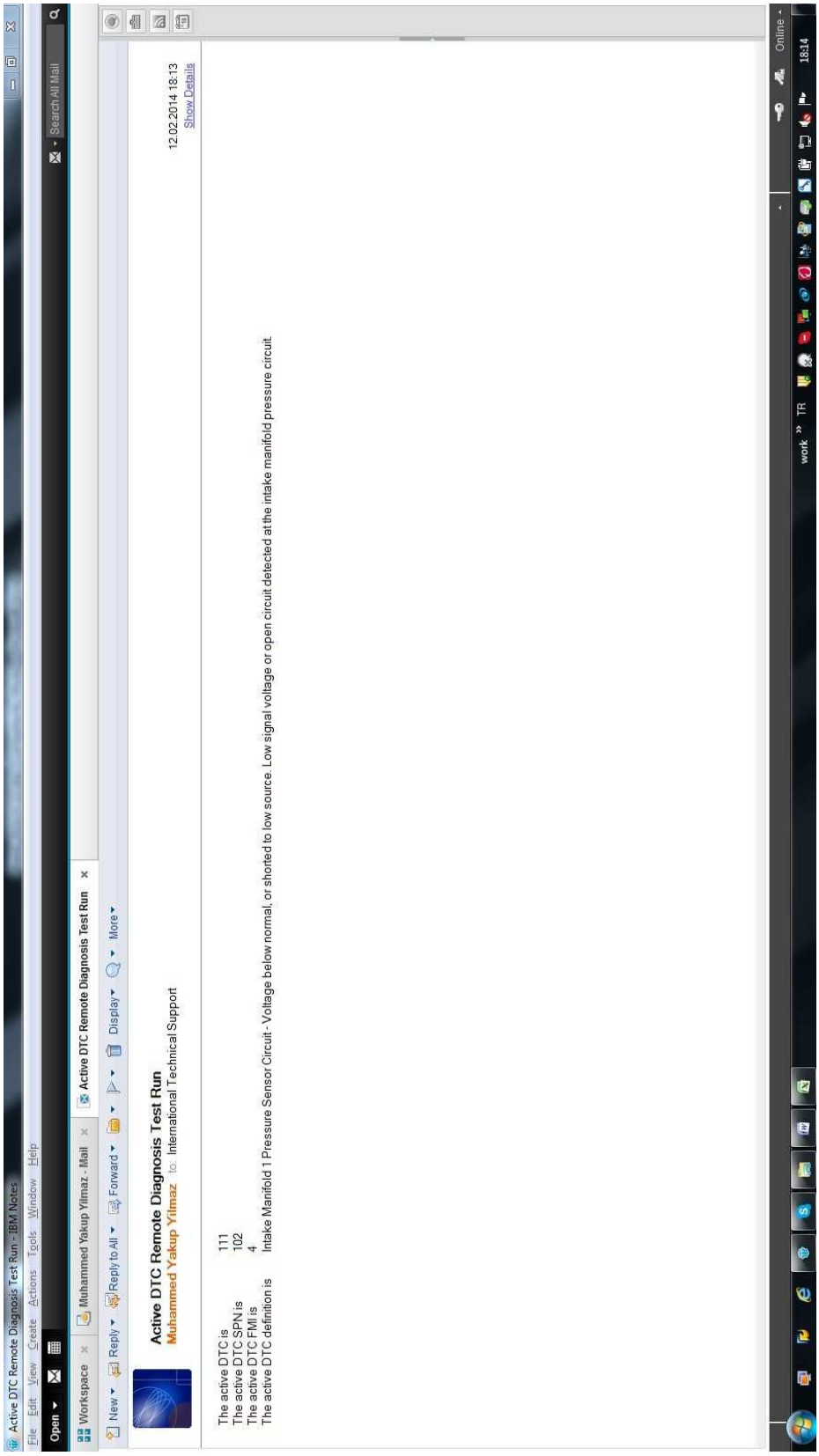


Figure 4.5. Warning message DTC 111

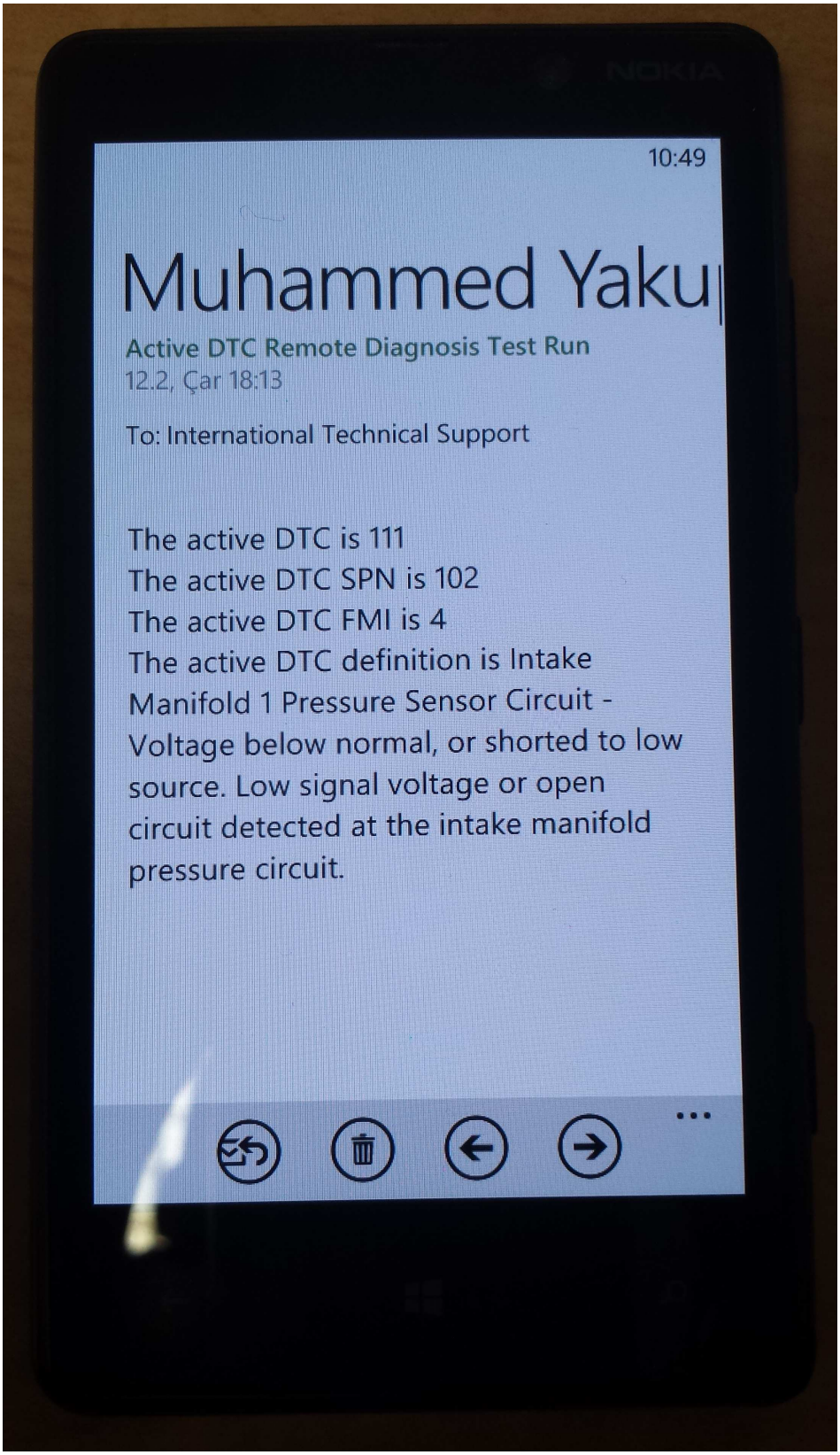
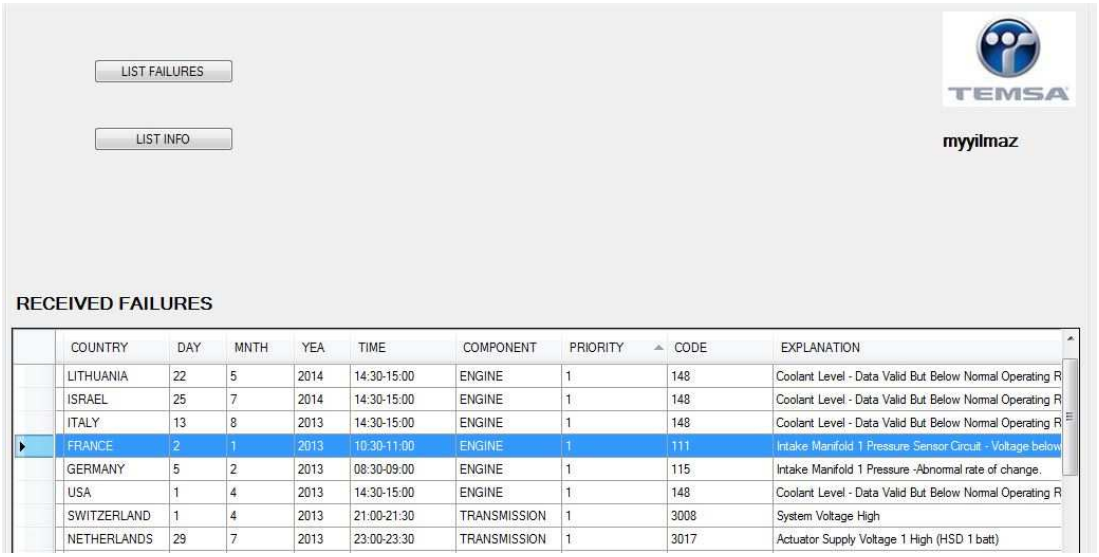


Figure 4.6. Warning message DTC 111 on Mobile Phone

The active diagnostic trouble code “DTC 111” has directly been sent to the responsible e-mail addresses. The next step of this process is to display and analyze the active diagnostic trouble code in Data Management Console. The responsible people have received the e-mails to be warned about the active diagnostic trouble code. The same process has been set off by the operator through the Management Console. The all received failures in the remote center has been listed and DTC 111 which has a 1st degree priority has been observed by the operator. (Figure 4.7)



COUNTRY	DAY	MNTH	YEA	TIME	COMPONENT	PRIORITY	CODE	EXPLANATION
LITHUANIA	22	5	2014	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating R
ISRAEL	25	7	2014	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating R
ITALY	13	8	2013	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating R
FRANCE	2	1	2013	10:30-11:00	ENGINE	1	111	Intake Manifold 1 Pressure Sensor Circuit - Voltage below
GERMANY	5	2	2013	08:30-09:00	ENGINE	1	115	Intake Manifold 1 Pressure -Abnormal rate of change.
USA	1	4	2013	14:30-15:00	ENGINE	1	148	Coolant Level - Data Valid But Below Normal Operating R
SWITZERLAND	1	4	2013	21:00-21:30	TRANSMISSION	1	3008	System Voltage High
NETHERLANDS	29	7	2013	23:00-23:30	TRANSMISSION	1	3017	Actuator Supply Voltage 1 High (HSD 1 batt)

Figure 4.7. DTC 111 On Management Console

There are several ways for the operator to proceed about this diagnostic trouble code. First one is to inform the responsible people with an e-mail again. Operator decides to inform a authorized workshop in the location that the failure occurs. And the authorized workshop related area has been informed with an e-mail through the management console.

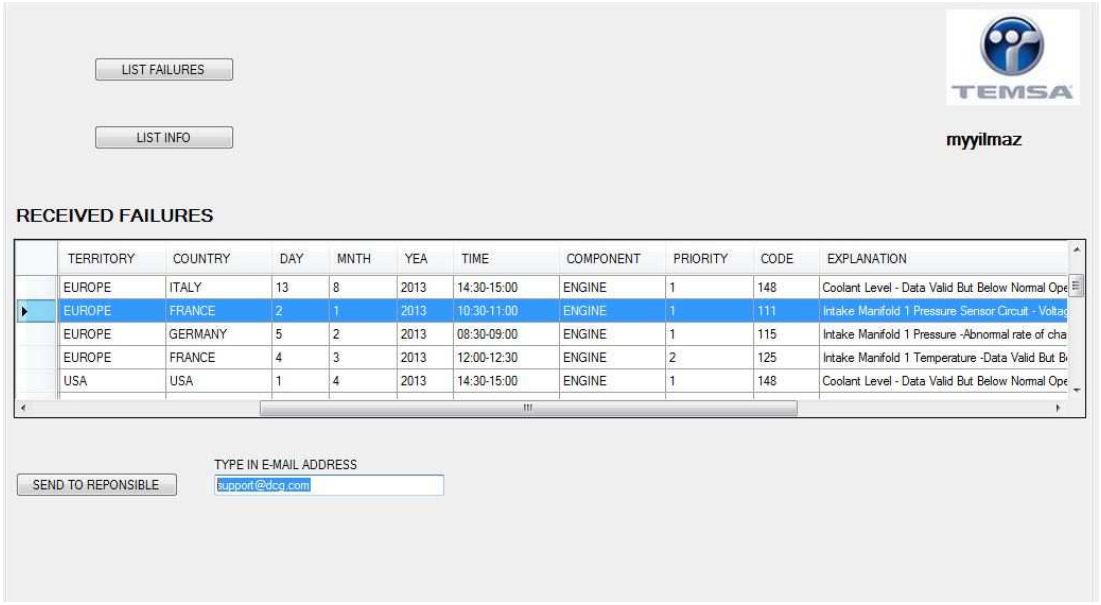


Figure 4.8. Send Warning to the Responsible

Another function on the management console was to send a warning to the driver. It depends on how dangerous the failure is. If it is an urgent issue, playing a warning sound command was sent to the vehicle to inform the driver and he was warned that this is a safety issue.

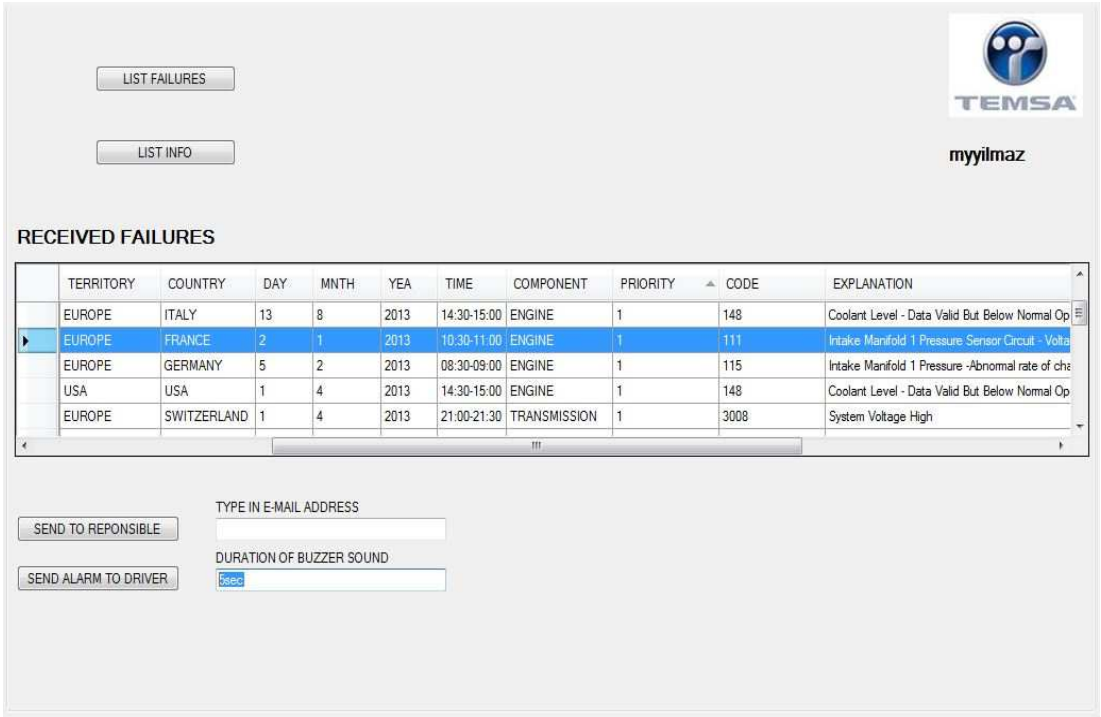


Figure 4.9. Send Warning to the Driver

In an other test performance receiving the vehicle information by the management console has been performed. The failure which was received from the vehicle was DTC 3079 “Engine Coolant Temperature Sensor 2 Circuit High”.

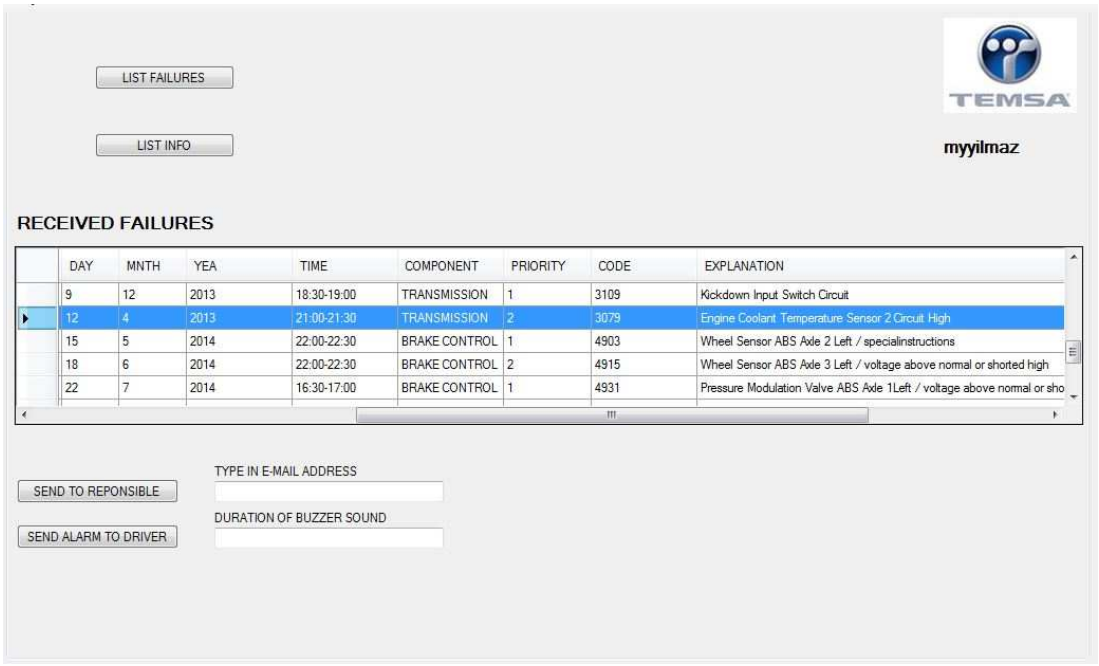


Figure 4.10. DTC 3079 On Management Console

The operator analyzed the failure and decided to receive the Engine Coolant Temperature information for a whole day from this vehicle.

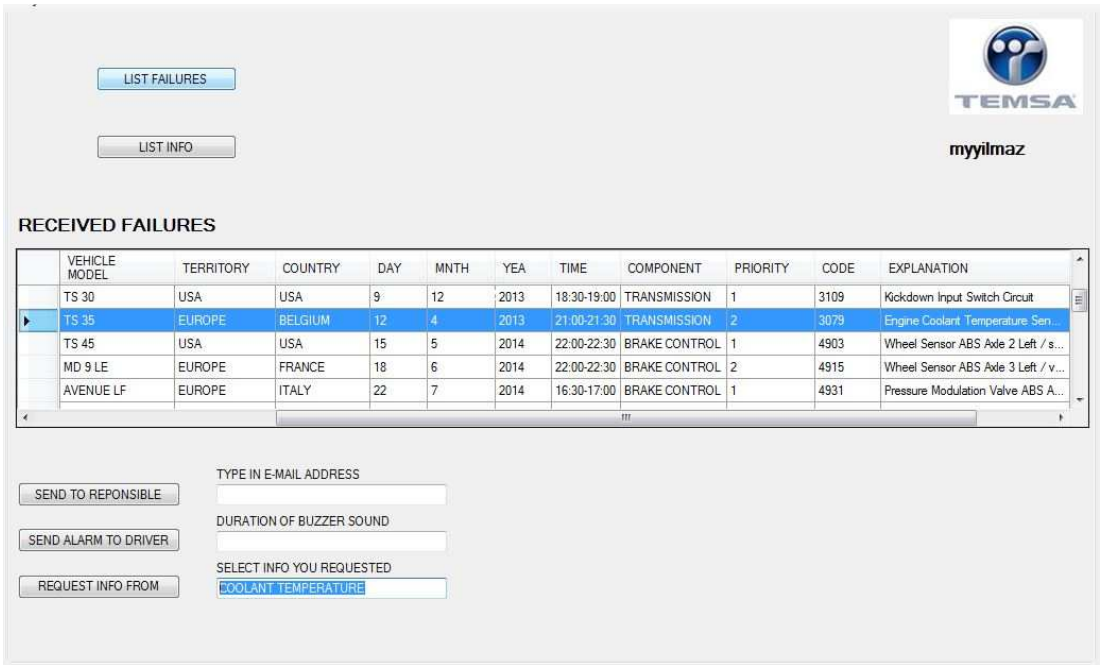


Figure 4.11. Request Info From Vehicle Function

The requested info “Coolant Temperature” only for this vehicle is received by the remote center and displayed on the management console.

RECEIVED VEHICLE INFO

ID	VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	ENGINE COOLANT TEMPERATURE
1	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	08:00-08:30	65
2	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	09:00-09:30	80
3	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	10:00-10:30	101
4	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	11:00-11:30	104
5	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	12:00-12:30	103
6	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	13:00-13:30	95
7	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	14:00-14:30	98
8	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	15:00-15:30	102

Figure 4.12. Coolant Temperature From Vehicle NLTAPL55L01000062

The operator checked engine coolant temperature values due to the time in the same day and analyzed the failure DTC 3079 based on these parameters.

5. CONCLUSION AND FUTURE WORK

In this study, remote diagnosis system (REDI) for a commercial vehicle which is designed on CAN Bus architecture, were studied by using the present technologies. A vehicle data management system which would suggest a solution to a very important aftersales services requirement “fastest response to a failure on the field”, is developed. A sample test for REDI Data Management System has been achieved. The test drives of the vehicle with the integrated module and the management of the remote center have successfully been completed.

During the study, the hardware and the firmware of REDI which is used to communicate with the vehicle CAN Bus, receive the CAN messages and send data to remote center, were studied. Some difficulties which have been faced during the banding together study of CAN Communication Module, GPS Module and GPRS Data Transfer Module, have been handled successfully.

The system has been evaluated as one of the cornerstones of the aftersales services products. Especially for the commercial vehicle manufacturers who doesn’t have a wide aftersales network. Easy and efficient integration of the module to the vehicle has been designated as the most useful characteristic of the system. It can be applied to all commercial vehicles with CAN Bus technology with a proper modification.

In the future, data management system of this study can be simplificated and bring in compliance with the usage of smaller field networks such as local transport companies. And also the data storage and the management of the system can be improved and be used as an international advice center for the future designs of any commercial vehicle manufacturer.

REFERENCES

AMOR_SEGAN, M., 2011. A Framework for Health Monitoring of Automotive Electrical and Electronic Control Systems. Vehicular Netwoking Conference, 2011, Pages 177-184.

BETTA, G., CAPRIGLIONE, D., PIETROSONTO, A., 2005. A Methodology to Test Instrument Software ; An Applicaiton to the Diagnostic in Automotive Systems. Instrumentation technology Conference, Ottawa 2005.

BITEUS, J., 2011. Distributed Diagnosis Using a Condensed Representation of Diagnoses With Application to an Automotive Vehicle. Systems, Man and Cybernetics, Part A: Systems and Humans, IEEE Transactions, Page(s): 1262-1267

CROSSMAN, J., GUO, H., 2003. Automotive Fault Diagnosis Part: I. IEEE Transactions on Vehicular Technology Vol:52, July 2003.

CHENN, I.C., 2011. Cellphone Based Vehicle Diagnostic System. US 2007/0005201 A1, USA.

COSTANTINO, N., 2011. Design and Test of an HV-CMOS Intelligent Power Switch With Integrated Protections and Self-Diagnostic for Harsh Automotive Applications. Industrial Electronics, IEEE Transactions on, Page(s): 2715 - 2727

CHEN, Y., 2011. Applications of Bayesian Network in Fault Diagnosis of Braking System. Intelligent Human-Machine Systems and Cybernetics (IHMSC), 2011 International Conference, 26-27 Aug. 2011, Page(s): 234 – 237.

CHENG, A., 2011. ECU Loader Design of in-vehicle CAN Network Based on ISO15765. Information Science and Technology (ICIST), 2011 International Conference, 26-28 March 2011, Page(s): 1215 – 1217.

DROR, D., AVITAL, R., ZAMALIN, A., 2007. Initial Version of GPS Reference Design Document. Motorola Wireless Modules Version 1.0., November 2 007.

EBERL, M., 2012. Considering Diagnosis Functionality During Automatic System Level Design of Automotive Networks. Design Automation Conference (DAC), 49th ACM/EDAC/IEEE, Page(s): 205 – 213.

ESD ELECTRONICS, 2010. Serial Control and Communications Vehicle Network. webpage: http://www.esd-electronics.us

FAUS, J., RAM, S., 2009. Method of Monitoring Canbus Information. US 2009/0192662 A1, USA.

GUPTA, A., 2011. Model Based Failure Detection of Diesel Particulate Filter. American Control Conference (ACC), 2011, June 29 2011-July 1 2011, Page(s): 1567 – 1572

HODGES, T.A., 2010. System and Method for Performing Vehicle Diagnostic. US 2010/0256861 A1, USA

JIANSEN, Y., KONGHUI, G., HAITAO, D., BIN, X., 2010. The Application of SAE J1939 Protocol in Automobile Smart and Integrated Control System. International Conference on Computer, Mechatronics, Control and Electronic Engineering, 2010.

JENKINS, W., LEWIS, R., LAZAROU, G., PICONE, J., ROWLAND, Z., 2009. Real-Time Vehicle Performance Monitoring Using Wireless Networking. USA

JOHANSON, M., DAHLE, P., SÖDERBERG, A., 2011. Remote Vehicle Diagnostic over the Internet Using the DoIP Protocol. ICSNC 2011: The Sixth International Conference on Systems and Networks Communications, Sweden

JAIN, 2011. SQL Server 2008 Architecture. Webpage: http://4sqldba.blogspot.com/2011/01/sql-server-2008-architecture.html

LEE, M., 2010. Automotive Network Gateway to Control Electronic Units Through MOST Network. Consumer Electronics (ICCE), 2010 Digest of Technical Papers International Conference on, Page(s): 309-310

LIU, H., WU, J., CHU, L., 2011. Design of Remote Monitoring and Fault diagnosis System for Electric Vehicle. 2011 International Conference on Electronic & Mechanical Engineering and Information Technology, 2011.

LIYUAN, T., GUIHE, Q., JINDONG, Z., 2010. Remote Diagnosis System of Vehicle Based on Telematics. 2010 International Conference on Computer, Mechatronics, Control and Electronic Engineering, 2010.

LI, J., XU, Y., 2009. Remote Monitoring Systems based on Embedded Database. Third International Conference on Genetic and Evolutionary Computing, 2009.

MAUDERER, A., 2012. Efficient Digital Design for Automotive Mixed-Signal ASICs Using Simulink. Design and Diagnostics of Electronic Circuits & Systems (DDECS), 2012 IEEE 15th International Symposium, 18-20 April 2012, Page(s): 372 – 377

MURPHY, Y., CROSMMAN, J., CHEN, Z., CARDILLO, J., 2003. Automotive Fault Diagnosis Part II: A Distributed Agent Diagnostic System. IEEE Transactions on Vehicular Technology Vol:52, July 2003.

NXP, 2011. Cortex-M0 Integrated CAN Solutions. web page: www.nxp.com/cortex-m0

OPEN ELECTRONICS, 2011. GSM Module-M10. web page: http://www.open-electronics.org/gsm-remote-control-part-5-m10/

PRODANOV, W., 2009. A Controller Area Network Bus Transceiver Behavioral Model for Network Design and Simulation. IEEE Transactions on Industrial Electronics, Vol 56, No:9, September, 2009.

POHRONSKA, M., 2011. Embedded System Architecture for Real-Time Rule Based Reasoning. Engineering of Computer Based Systems (ECBS-ERC), 2011 2nd Eastern European Regional Conference, 5-6 Sept. 2011, Page(s): 85 – 91

QUANQI, W., JIAN, W., CHU, L. 2011. Design of Vehicle Bus Data Acquisition and Fault Diagnosis System. Consumer Electronics, Communications and Networks International Conference, 2011.

SCHWINKE, S.p., 2009. System and Method for Communicating Vehicle Diagnostic Data. US 2009/0248236 A1, USA SAE, 2000

SERAFINI, M., 2011. Application-Level Diagnostic and Membership Protocols for Generic Time-Triggered Systems. Dependable and Secure Computing, IEEE Transactions on, Page(s): 177 – 193.

SANKAVARAM, C., PATTIPATI,B. , KODALI, A., PATTIPATI, K., AZAM, M., KUMAR, S., PECHT, M., 2009. Model-based Data-driven Prognosis of Automotive and Electronics Systems. 5th Annual IEEE Conference on Automation Science and Engineering India, 2009.

TAHAT, A., 2012. Android-based Universal Vehicle Diagnostic and Tracking System. Consumer Electronics (ISCE), 2012 IEEE 16th International Symposium, 4-6 June 2012, Page(s): 137 – 143

YUN Y., ZHIHUA, F., 2010. Design of a Link Layer Controller for High Speed Serial Bus, ICISE, 2010 2nd International Conference 2010.

YAN, X., ZHANG, Y., SHANG, C., YUAN C., 2010. Study on Remote Fault Diagnosis System Using Multi Monitoring Methods on Dredger, PHM'10, 2010.

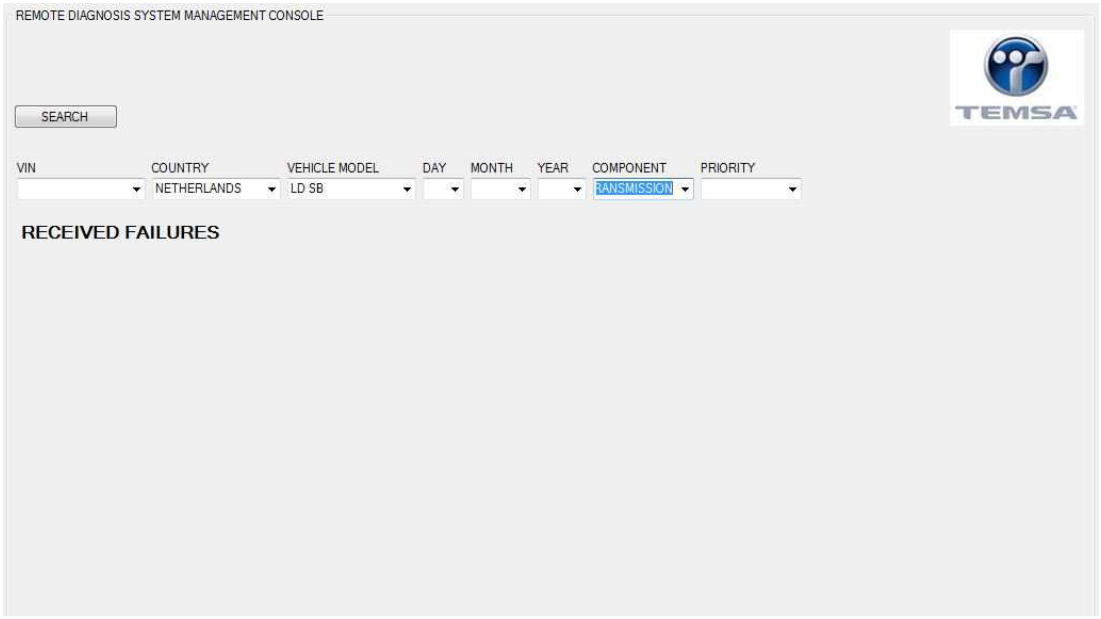
ZHANG, X., 2010. Fault Diagnosis of Automotive Electric Power Generation and Storage Systems. Control Applications (CCA), 2010 IEEE International Conference 8-10 Sept. 2010, Page(s): 719 – 724.

BIOGRAPHY

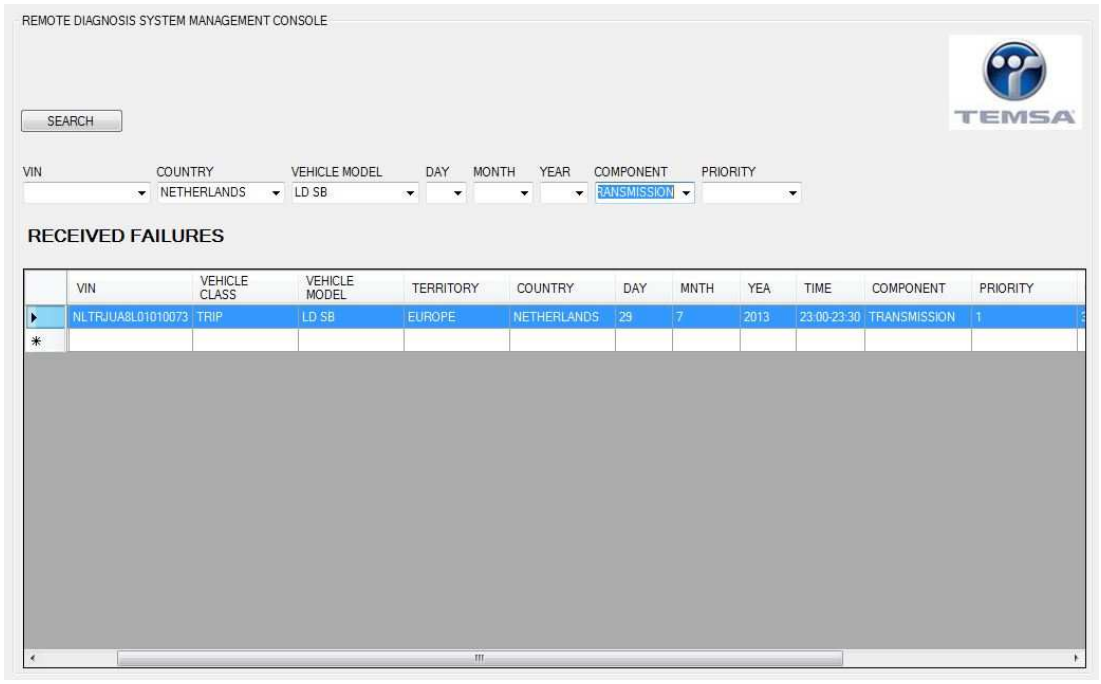
Muhammed Yakup YILMAZ was born in Tokat in 1984. He completed his primary, secondary and high school educations in Tokat. He graduated from Cukurova University Electrical and Electronics Engineering Department in 2008. He is working as an Electrical and Electronics Engineer in an automotive company in Adana since 2009.

APPENDIX

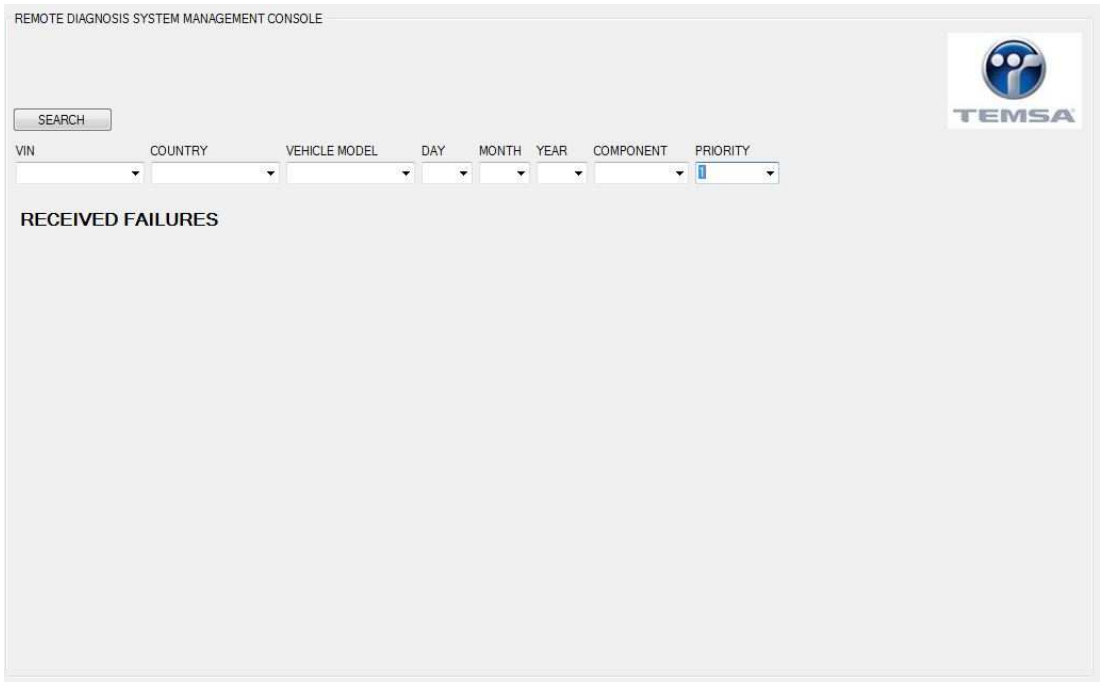
Appendix 1 : Several Combinations of Searching Failures and Information on Management Console



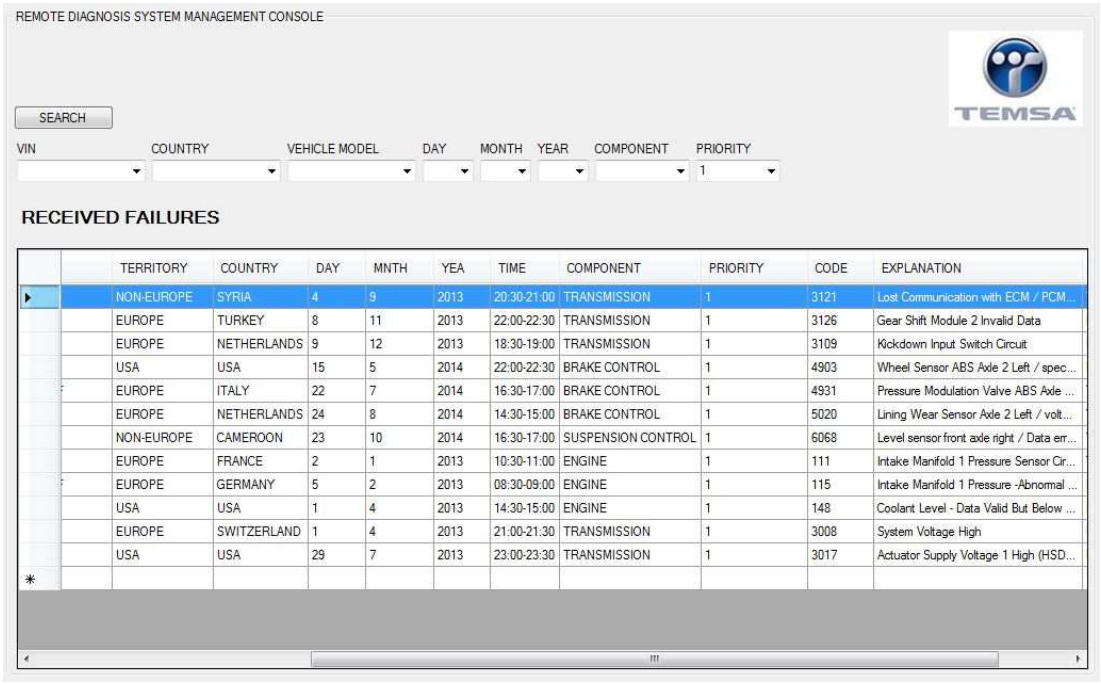
Model & County & Component Combination Sample 1



Model & County & Component Combination Sample 2

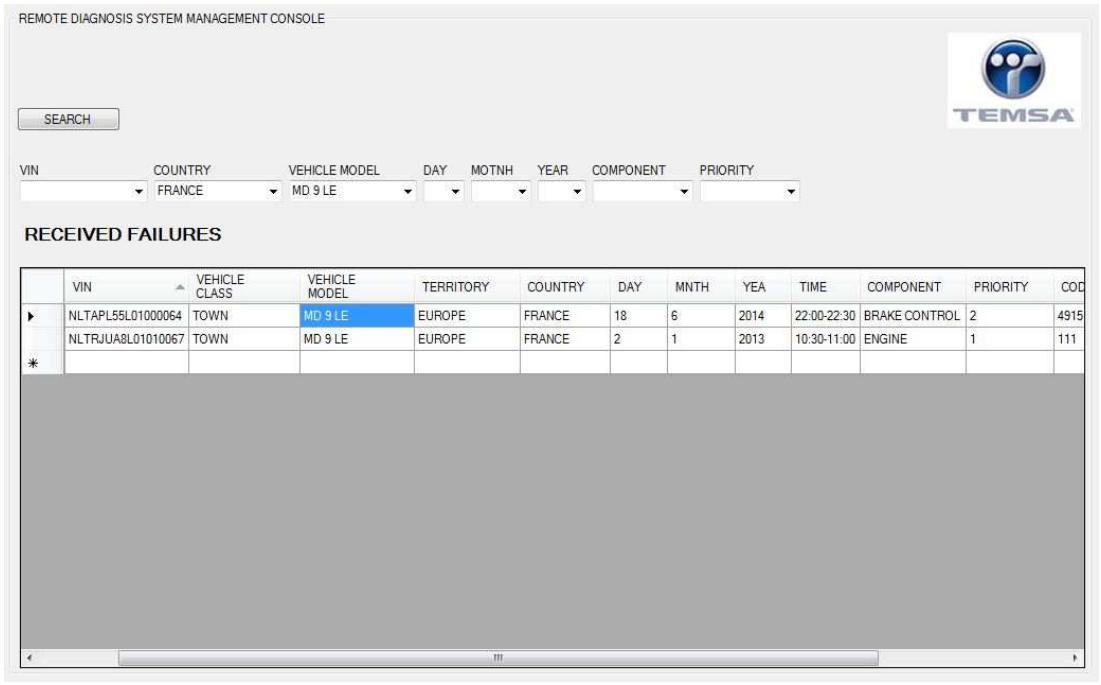


Priority Based Searching Failures 1

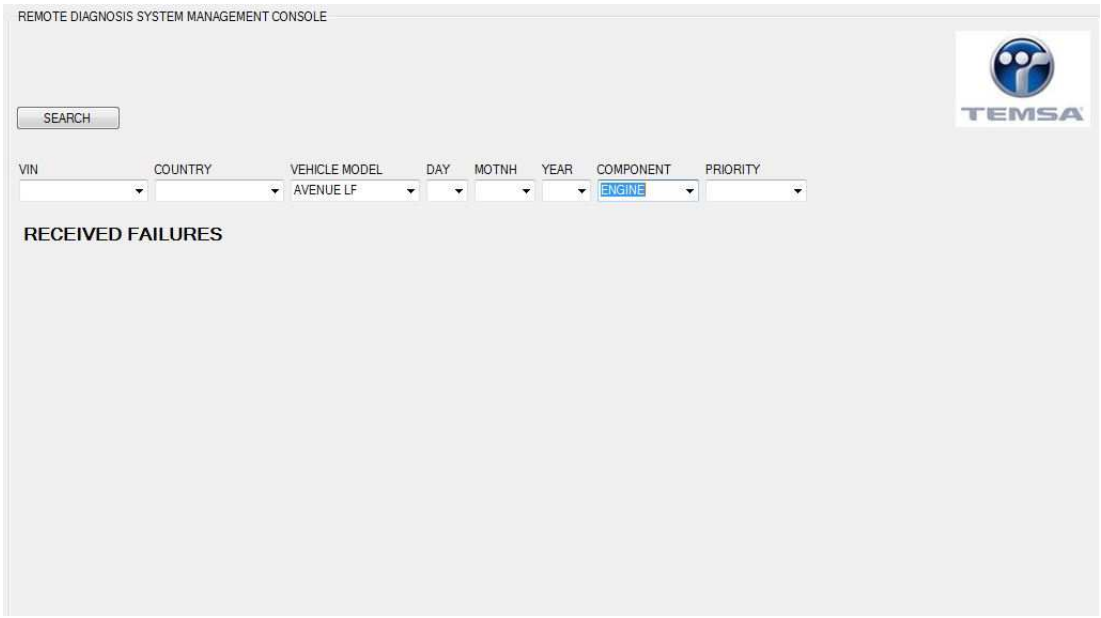


Priority Based Searching Failures 2

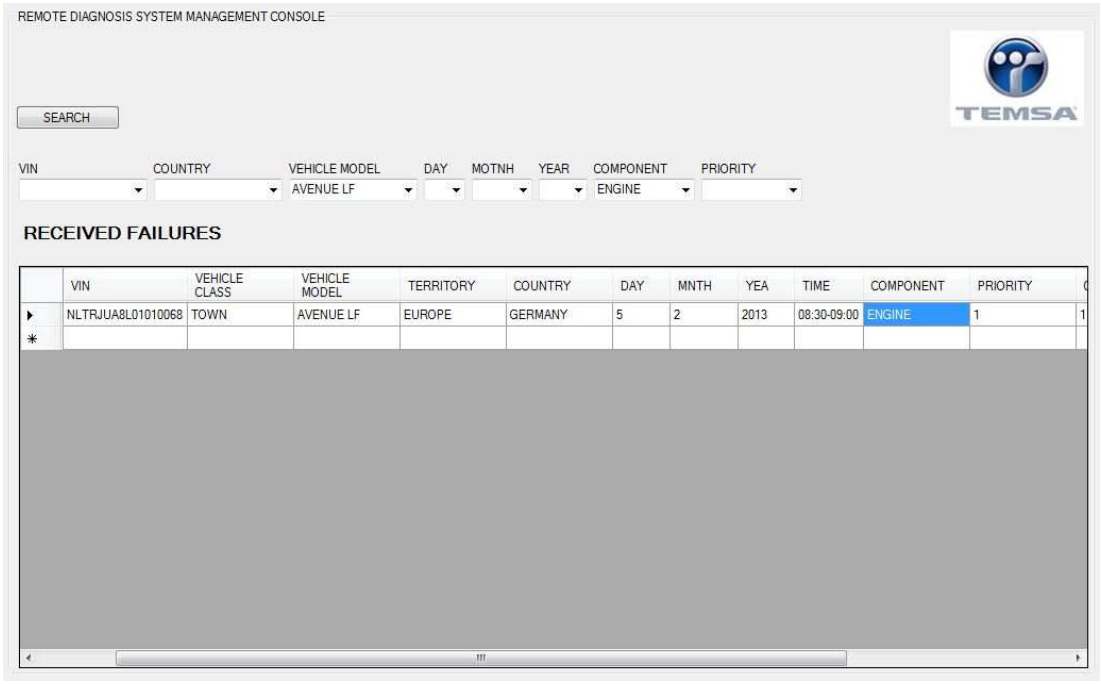
Model&Country Based Searching Failures 1



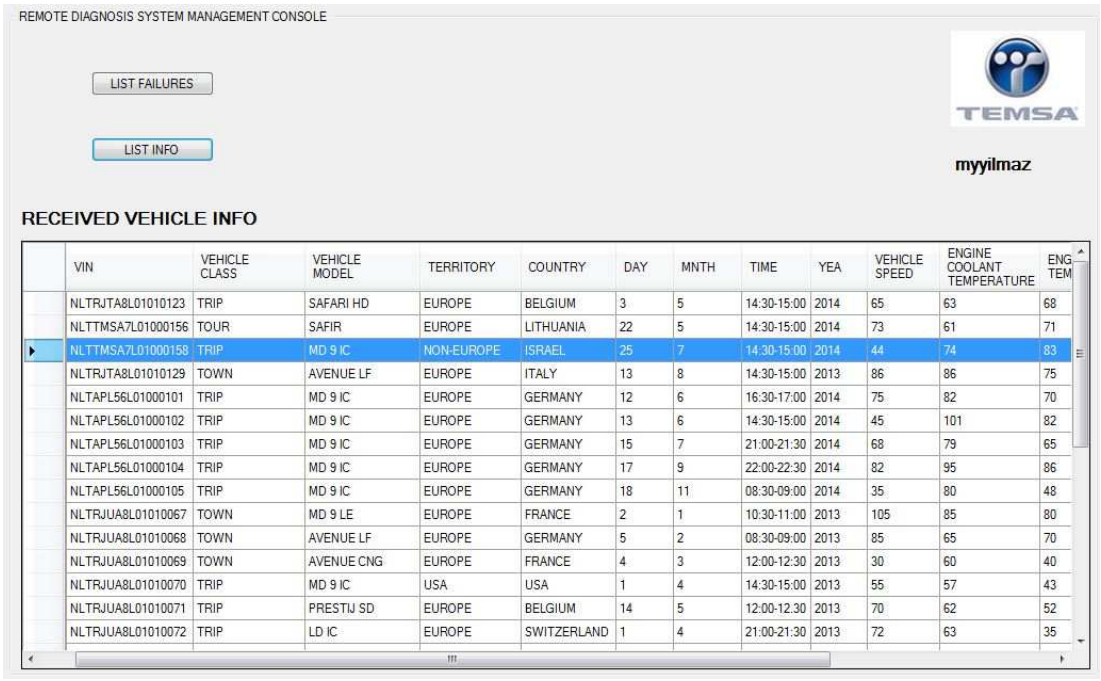
Model&Country Based Searching Failures 2



Model&Component Based Searching Failures 1

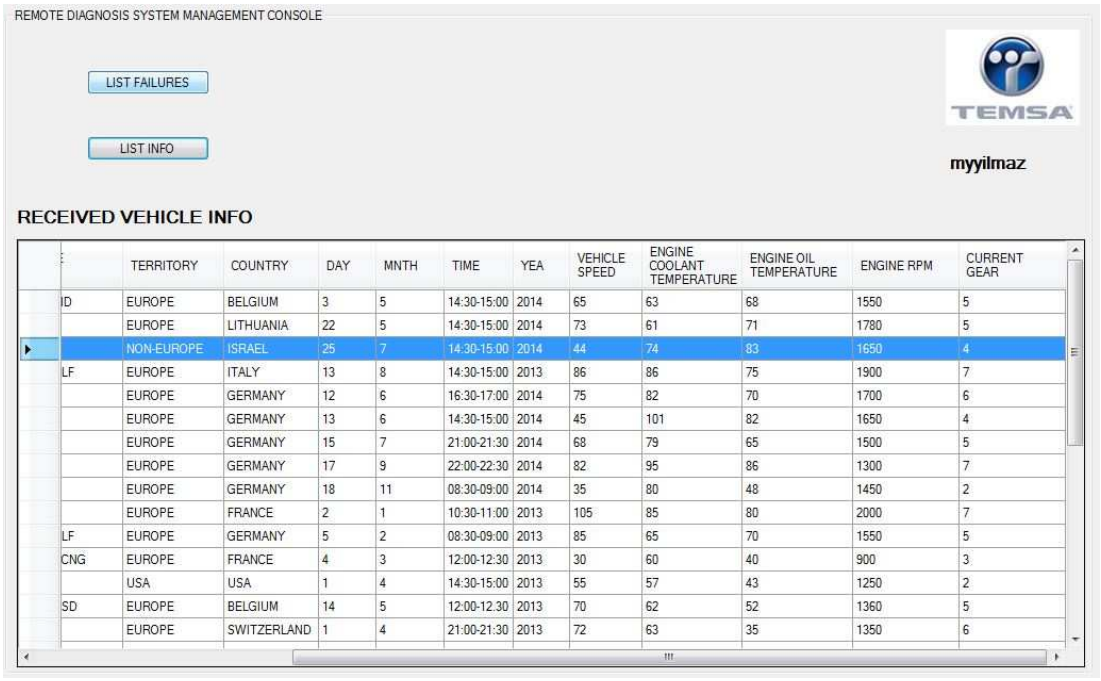


Model&Component Based Searching Failures 2



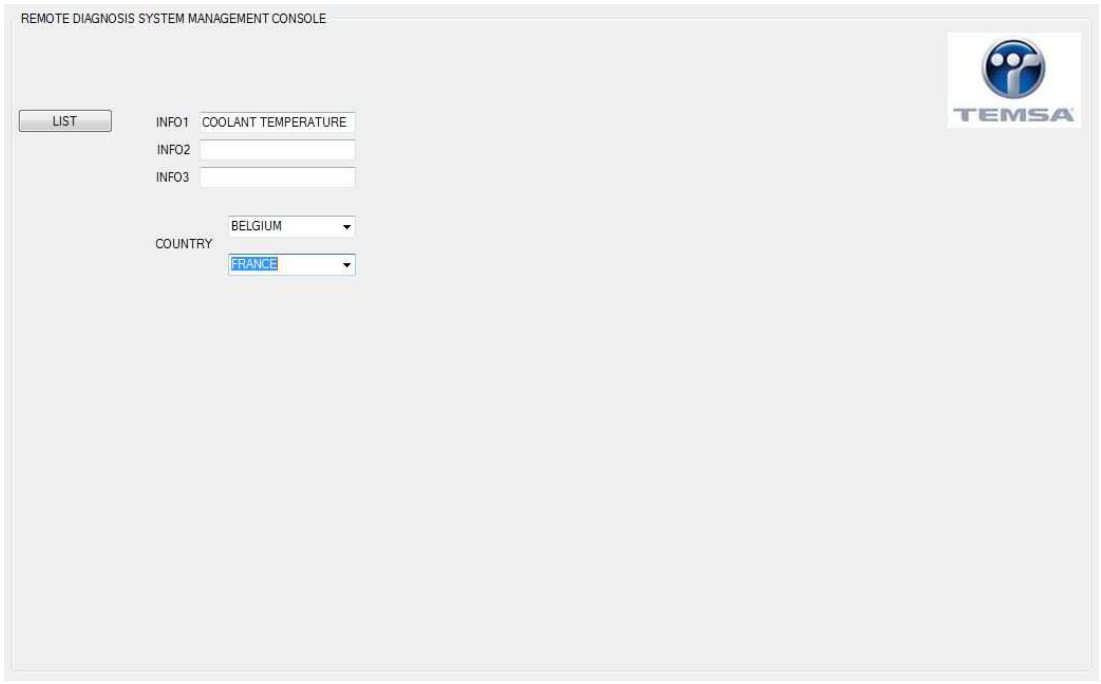
VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	TIME	YEA	VEHICLE SPEED	ENGINE COOLANT TEMPERATURE	ENG TEM
NLTRJTA8L01010123	TRIP	SAFARI HD	EUROPE	BELGIUM	3	5	14:30-15:00	2014	65	63	68
NLTTMSA7L01000156	TOUR	SAFIR	EUROPE	LITHUANIA	22	5	14:30-15:00	2014	73	61	71
NLTTMSA7L01000158	TRIP	MD 9 IC	NON-EUROPE	ISRAEL	25	7	14:30-15:00	2014	44	74	83
NLTRJTA8L01010129	TOWN	AVENUE LF	EUROPE	ITALY	13	8	14:30-15:00	2013	86	86	75
NLTAPL56L01000101	TRIP	MD 9 IC	EUROPE	GERMANY	12	6	16:30-17:00	2014	75	82	70
NLTAPL56L01000102	TRIP	MD 9 IC	EUROPE	GERMANY	13	6	14:30-15:00	2014	45	101	82
NLTAPL56L01000103	TRIP	MD 9 IC	EUROPE	GERMANY	15	7	21:00-21:30	2014	68	79	65
NLTAPL56L01000104	TRIP	MD 9 IC	EUROPE	GERMANY	17	9	22:00-22:30	2014	82	95	86
NLTAPL56L01000105	TRIP	MD 9 IC	EUROPE	GERMANY	18	11	08:30-09:00	2014	35	80	48
NLTRJUA8L01010067	TOWN	MD 9 LE	EUROPE	FRANCE	2	1	10:30-11:00	2013	105	85	80
NLTRJUA8L01010068	TOWN	AVENUE LF	EUROPE	GERMANY	5	2	08:30-09:00	2013	85	65	70
NLTRJUA8L01010069	TOWN	AVENUE CNG	EUROPE	FRANCE	4	3	12:00-12:30	2013	30	60	40
NLTRJUA8L01010070	TRIP	MD 9 IC	USA	USA	1	4	14:30-15:00	2013	55	57	43
NLTRJUA8L01010071	TRIP	PRESTIJ SD	EUROPE	BELGIUM	14	5	12:00-12:30	2013	70	62	52
NLTRJUA8L01010072	TRIP	LD IC	EUROPE	SWITZERLAND	1	4	21:00-21:30	2013	72	63	35

List All Vehicle Information 1

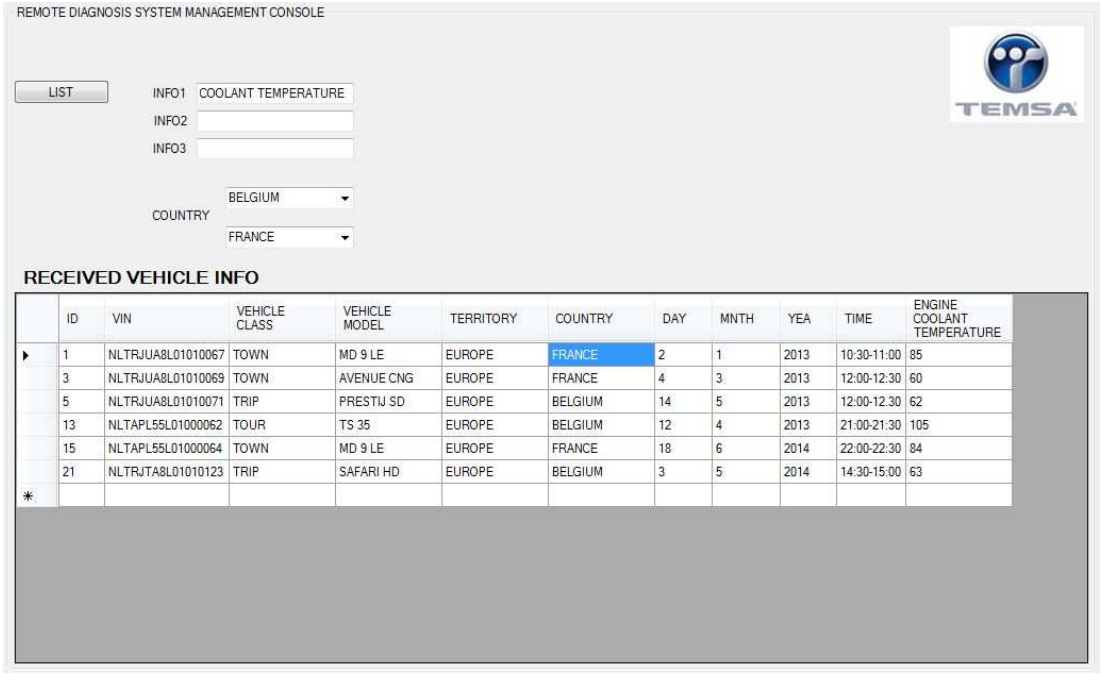


	TERRITORY	COUNTRY	DAY	MNTH	TIME	YEA	VEHICLE SPEED	ENGINE COOLANT TEMPERATURE	ENGINE OIL TEMPERATURE	ENGINE RPM	CURRENT GEAR
ID	EUROPE	BELGIUM	3	5	14:30-15:00	2014	65	63	68	1550	5
	EUROPE	LITHUANIA	22	5	14:30-15:00	2014	73	61	71	1780	5
	NON-EUROPE	ISRAEL	25	7	14:30-15:00	2014	44	74	83	1650	4
LF	EUROPE	ITALY	13	8	14:30-15:00	2013	86	86	75	1900	7
	EUROPE	GERMANY	12	6	16:30-17:00	2014	75	82	70	1700	6
	EUROPE	GERMANY	13	6	14:30-15:00	2014	45	101	82	1650	4
	EUROPE	GERMANY	15	7	21:00-21:30	2014	68	79	65	1500	5
	EUROPE	GERMANY	17	9	22:00-22:30	2014	82	95	86	1300	7
	EUROPE	GERMANY	18	11	08:30-09:00	2014	35	80	48	1450	2
	EUROPE	FRANCE	2	1	10:30-11:00	2013	105	85	80	2000	7
LF	EUROPE	GERMANY	5	2	08:30-09:00	2013	85	65	70	1550	5
CNG	EUROPE	FRANCE	4	3	12:00-12:30	2013	30	60	40	900	3
	USA	USA	1	4	14:30-15:00	2013	55	57	43	1250	2
SD	EUROPE	BELGIUM	14	5	12:00-12:30	2013	70	62	52	1360	5
	EUROPE	SWITZERLAND	1	4	21:00-21:30	2013	72	63	35	1350	6

List All Vehicle Information 2

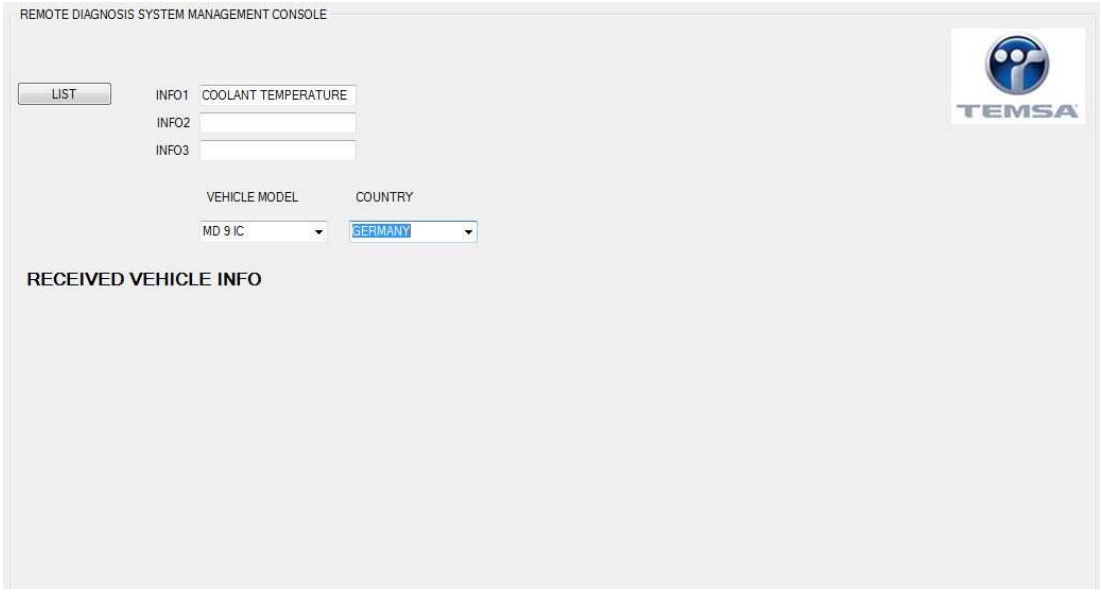


List Coolant Temperature Based on Country 1

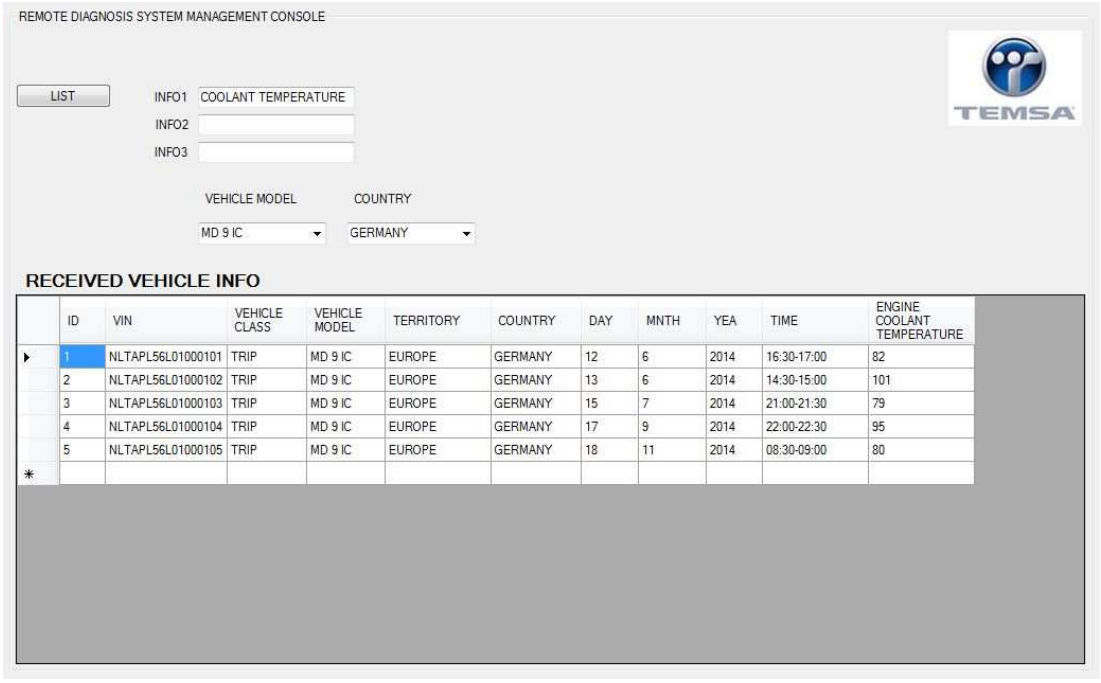


ID	VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	ENGINE COOLANT TEMPERATURE
1	NLTRJUA8L01010067	TOWN	MD 9 LE	EUROPE	FRANCE	2	1	2013	10:30-11:00	85
3	NLTRJUA8L01010069	TOWN	AVENUE CNG	EUROPE	FRANCE	4	3	2013	12:00-12:30	60
5	NLTRJUA8L01010071	TRIP	PRESTIJ SD	EUROPE	BELGIUM	14	5	2013	12:00-12.30	62
13	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	12	4	2013	21:00-21:30	105
15	NLTAPL55L01000064	TOWN	MD 9 LE	EUROPE	FRANCE	18	6	2014	22:00-22:30	84
21	NLTRJTA8L01010123	TRIP	SAFARI HD	EUROPE	BELGIUM	3	5	2014	14:30-15:00	63

List Coolant Temperature Based on Country 2

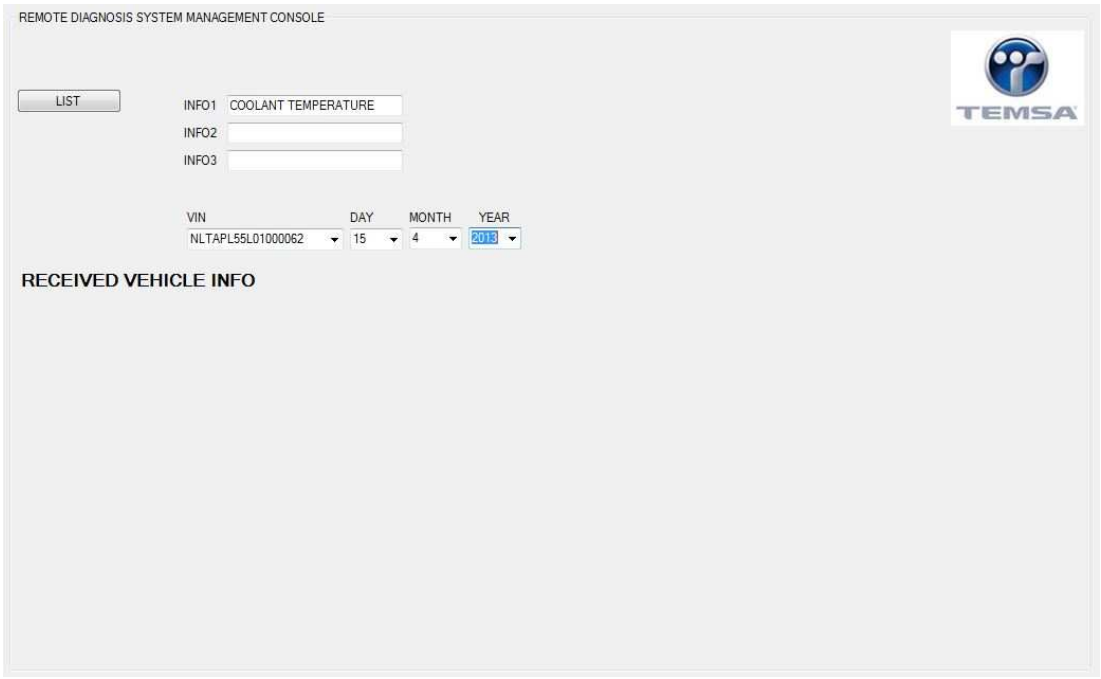


List Coolant Temperature Based on Model & Country 1

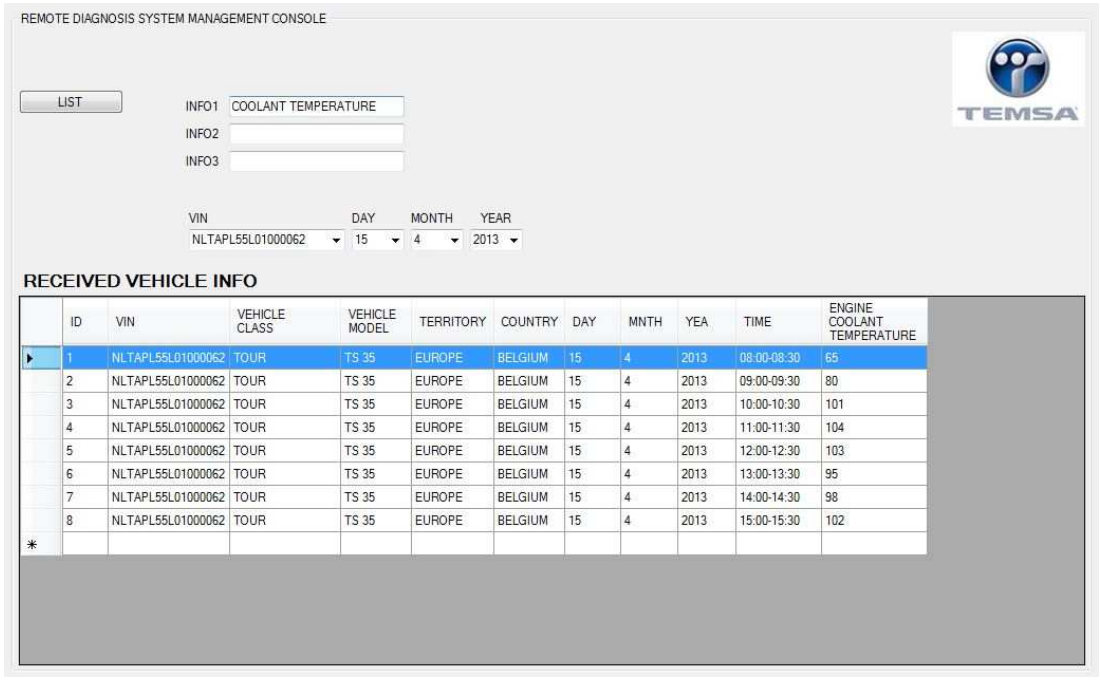


ID	VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	ENGINE COOLANT TEMPERATURE
1	NLTAPL56L01000101	TRIP	MD 9 IC	EUROPE	GERMANY	12	6	2014	16:30-17:00	82
2	NLTAPL56L01000102	TRIP	MD 9 IC	EUROPE	GERMANY	13	6	2014	14:30-15:00	101
3	NLTAPL56L01000103	TRIP	MD 9 IC	EUROPE	GERMANY	15	7	2014	21:00-21:30	79
4	NLTAPL56L01000104	TRIP	MD 9 IC	EUROPE	GERMANY	17	9	2014	22:00-22:30	95
5	NLTAPL56L01000105	TRIP	MD 9 IC	EUROPE	GERMANY	18	11	2014	08:30-09:00	80

List Coolant Temperature Based on Model & Country 2



List Coolant Temperature Based on Time 1



ID	VIN	VEHICLE CLASS	VEHICLE MODEL	TERRITORY	COUNTRY	DAY	MNTH	YEA	TIME	ENGINE COOLANT TEMPERATURE
1	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	08:00-08:30	65
2	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	09:00-09:30	80
3	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	10:00-10:30	101
4	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	11:00-11:30	104
5	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	12:00-12:30	103
6	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	13:00-13:30	95
7	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	14:00-14:30	98
8	NLTAPL55L01000062	TOUR	TS 35	EUROPE	BELGIUM	15	4	2013	15:00-15:30	102

List Coolant Temperature Based on Time 2