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An Efficient On the Run in-Vehicle Diagnostic and Remote Diagnostics Support System in VANET

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Abstract: The existing Vehicular Ad hoc NETwork (VANET), is being an emerging field of interest for researchers, business community of OEMs and suppliers (community of automotive components' manufactures (ACMs)) and vehicle owners/users (transporters). The VANET based applications/services on road environment (RE) sophisticates the mentioned vehicular community of members (VCMs) and introduces encouraging road side assistances and new business models with certainty based applications development with Intelligent Transport System's (ITS) support. The congestion control application using VANET is widely used by transporters and is being successful application in RE with effective events dissemination in between vehicles and road side unit(s) (RSU). The growth of Internet-enabled devices in vehicles, the reduced cost in utilizing the Internet services and reliable, feasible performance of infotainment devices, attracts the VCMs, to involve in certainty based Vehicle Diagnostic Support System's (VDSS) development and deployment in VANET. With available new diagnostic concepts, standards and solutions, this paper focusses on development of On the Run in-Vehicle Diagnostic and Remote Diagnostics Support System (ORiVD-RDSS) to the vehicles, which are involving in production on the road. In VANET, as events dissemination, the diagnostic trouble codes (DTCs) of a vehicle is disseminated with nearby RSU on RE and the same/other RSU transfers trouble fix solution(s) (TFS) to the specific vehicle with the help of Service Base Station(s) (SBS). In the proposed work, Request/Transfer/Respond (RTR) framework with Remote Diagnostics Support (RDS) protocol with in ORiVD-RDSS is introduced and improved reliability, performance and efficiency of events dissemination are tested in an urban simulation environment and the comparative analysis with the existing framework and protocol is presented as results. The DTC:TFS pair matching from vehicle to RSU and RSU to vehicle with SBS and the events dissemination effectiveness is presented in this paper to emphasis the importance of RDSS on the road environment. In the field of vehicle diagnostics support, this is the first work in VANET, using RTR framework and RDS protocol, which focuses on, remote diagnostics support, even the vehicle is in running condition on RE.

Key words: In-vehicle diagnostics · Remote diagnostics support · VANET · RTR Framework · RDS Protocol

INTRODUCTION

The integration of heterogeneous technologies into a single form to frame a VANET, which includes vehicles as nodes. The nodes are equipped with an on-board unit (OBU) as a mobile computing device with internal sub units as GPS, GSM(2G/3G)/4G communication services and a mobile computing [1]. In VANET, the challenges are communication among fastest moving nodes, communication between infrastructure to vehicle (I2V), vehicle to infrastructure (V2I) and vehicle to vehicle (V2V). The Internet of Things (IoT) provides the possibility as vehicles with internet to communicate and exchange various information, related to in-vehicle (InV) services, passenger safety, travel sophistication and effective travel with VANETs, which is treated as Internet of Vehicles (IoV) [2]. In both urban paved RE (URE) and rural unpaved RE (RRE), a transporter is subjected to drive the vehicle, to reach the destination. With the conventional mode of travel (ask and get), a transporter in URE is free from troubles to access the services for a vehicle of any kind. In RRE, the lack of access or no

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vehicle related services are easily accessible. The VANET equipped RE and its applications cum services provide, the transporters to utilize various vehicle related services and among one is the remote diagnostics services [3].

In an URE, the ITS with VANET based services provide various advanced applications to the transporters and are optimized over conventional transportation system. The applications and services are indicating the locations of hospitals, hotels, markets, gas stations, schools, stadium, etc. Such relevant services are provided through V2V and V2I event dissemination with publish-subscribe framework [4, 5]. The framework is based on the need of the commuters and the published events are subscribed from the vehicles, through human machine interaction (HMI). One of the main unit of ITS is VANET and ITS acts intelligently to assist transporters on various services and is being an expert system [6]. In expert systems, providing a solution to the problem of specific situation in a domain is the act of selecting optimum solution from alternatives and is accomplished with its strong knowledge base (KB) and strong experience level in that specific domain. The ORiVD-RDSS is an expert system, which is equipped with intelligent programs on SBS, to make right decisions on selection of efficient solutions from the alternatives. In this system, the problems are DTCs of InV domains and are identified with OBD-II standards. From the source vehicle (SV), the DTCs are disseminated to nearby RSU (nb-RSU) and the nb-RSU, again requests the SBS with the collected DTC. This forms the two-tier client/server architecture [7]. The SBS searches and finalizes with trouble-fix solution (TFS), which is an exact pair of DTC:TFS. The finalized TFS is transferred to the SV through the nb-RSU (at present). The SBS consists several databases and are vendor (vehicle) specific DTCs and TFSs collection [8]. The uniquely classified DTCs and its matching TFSs, the SBS acts the role of second tier server role in this network communication. From the SBS, the right TFS for a specific DTC is disseminated to the SV by identifying the nb-RSU. The SV is performing progressive travel towards its destination. Due to the fast-moving characteristics of the nodes in VANET, the requested nb-RSU by SV and the transferring nb-RSU by SBS may or may not be the same one. In this context, the current nb-RSU is the one, which is in the SV's range of communication on the RE.

In InV network architecture, the electronic control units (ECUs) are increasing day by day. This drives the ACMs to follow a common standard in this architecture and among one is the AUTOmotive Open System ARchitecture (AUTOSAR) [9]. The various domains of InV system are effectively monitored and controlled by ECUs and networked ECUs are being nodes on the network [10]. To control, coordinate and bring all ECUs towards centralized operation, the software components are used and this enables the network operations with the help of software. In an automotive system, the software are device drivers, firmware, middleware and services cum applications oriented. These are managing InV network's components ECUs, sensors, actuators and automobile platform [11]. The sensors are used to acquire the data from various domains of the InV system and based on the need of the operations, the processors are manipulating them. This InV network is possible with wireless communication and the power source for the wireless transceivers are not a reliable one. In many cases, this characteristic yields complexity and inefficiency and the hard-wired network communication is preferable [12].

In the InV system, the effectiveness of the domain operations is measured with the threshold value and which is the key factor to identify, whether the malfunction occurred in the domain or not [13]. The diagnostics services cum applications software are used with the system, to identify DTCs. The threshold values' plus or minus value with a specific range is specified in the software as a tolerance level of a specific domain variable. The DTCs are generated, if the domain operations' fault tolerant capabilities are exceeded beyond the tolerance level. In the InV, all available domains are monitored with ECU based application software and the domains' variables are verified with its specific threshold values, to generate DTCs based on onboard diagnostics standard II (OBD-II) [14]. The computing activities like, monitoring, verifying and decision making are major key activities of the InV diagnostics software based on OBD-II, which are developed by automotive service/application software developers [15]. The software development for automotive in-vehicle network has two classifications as like conventional software development and are system and application software. To activate ECUs and synchronize them with centralized control of in-vehicle networks, the system software is used and are as device drivers, firmware and middleware. In-vehicle network based middleware acts the role of operating system and further takes care on the network related operations of ECUs with in in-vehicle. Using networked ECUs and operating system, the possibilities of collecting various in-vehicle domains' data are highly possible to enable diagnostics application related services with the proposed system.

Further, this article's flow is organized as follows. In the immediate next section, the proposed system based related work is narrated. The next successor section describes about the ORiVD-RDSS, which is the proposed system. The same section is sub divided and stated with system components, RTR framework, functions, a mathematical model, RDS protocol and its algorithm. The next section presents results and discussion of ORiVD-RDSS, which is enhanced with details, simulation results, analysis and the last section concludes with feasible possibilities of future scope of this work.

Related Work: Cooper *et al*. [1] were represented the challenges and problems in the routing protocols' of VANETs, which are clustered and functions based on efficient algorithm and with it, a group for vehicular channel is proposed, that can serve as the foundation for incident or accident detection, congestion detection, information dissemination and entertainment applications in RE. For a large scale, urban RE networks, an intelligent vehicular traffic information system using VANET was proposed by Zhang *et al*. [3] and they addressed solutions by considering the problems such as the large volume of data transmission, long duration with standability of network coverage, instability in communication and the need for an automatic generation and update method for environment information in a large-scale URE network. The event dissemination in VANET with the fixed capacity of events on a single RSU and the concept of placing RSUs in uniform distance on road side, with various kinds of service providers to maximize the events dissemination and minimize the total cost spent on a RSU are presented with Mukherjee *et al.* [5]. Uhlemann [16] presented a complete anatomy about connected cars and focused on connected-vehicle safety applications and further elaborated to take necessary remedies to overcome the incident/accident situations (due to in-vehicle network components malfunction); the situation awareness is communicated through V2V and V2I communications with the predecessors and successors of on road vehicles. The importance of C-ITS, Standardization of vehicular communications and communications access for land mobiles, dedicated short range communications and distributed congestion control are addressed in her work.

Gozalves [17] described about the network service providers and their range of services for smart devices, multi-systems and business models focusing on future and their expansion due to demand and need. Further the assurance about the new technology NB-IoT, which provides accessibility to commuting devices, even they are in hard to reach areas by communication medium. Telford *et al*. [18] were presented the work with fault classification and diagnostic system for unnamed aerial vehicle, which is resulted with high classification of troubles and diagnostic accuracy on the vehicle malfunctions. The Sundström *et al*. [19] were represented the industrial standard act of maintaining a lookup table for various operations to overcome fault and make the system as fault free system by reducing the cost spent on maintenance. Liu *et al.* [20] were presented a software defined network concept for RSU in VANET. The Cooperative data scheduling is the work done by the team and proved with maximizing the number of vehicles that retrieve their requested data with RSU. The high-speed mobility nature of vehicles on road, the multimedia content distribution to vehicles as an infotainment application services, by using VANET is proposed by Sarakis *et al.* [21] and they analyzed the application layer performance for video-streaming which uses standardized, IEEE 802.11p and ETSI ITS protocol stack. The hybrid-VANET-enhanced ITS is introduced and the real-time path planning algorithm for a vehicle to avoid traffic congestion with improved optimum cost of travel using stochastic Lyapunov optimization technique was discussed by Wang *et al.* [22]. VANET communication Security and intelligent decision making on vehicle operations, confidential authentication with trusted authority based message dissemination using dual authentication and key management was presented by Vijayakumar *et al.* [23]. Using an integer linear program with center particle swarm optimization in a hybrid VANET sensor network and its cost minimization problem on deployment of RSUs on road side is focused on Lin *et al*. [24].

The disability of CSMA/CA based IEEE 802.11p MAC layer protocol based message dissemination of VANET during high speed message dissemination on vehicles, request-to-send/clear-to-send mechanism's inability in high data rate conditions are overcome with orthogonal frequency-division multiple-access (OFDMA)-based MAC protocol for VANETs (OBV) were presented by Bazzi *et al*. [25]. The higher quality of video streaming with low overhead and fewer collisions on unicast video streaming in VANETs, which is based on a balance between link stability and geographic advancement of nodes are proposed and proved with a novel protocol named VIRTUS by Rezende *et al*. [26]. The category of non-safety applications' communication protocol named Stable CDS Routing Protocol in VANET was proposed with the work of Togou *et al*. [27]. The Service Oriented IoT was the major discussion of In-Young Ko *et al*. [28] and presented user-centric services to utilize IoT on urban environments. The pragmatic solution for VANET's and its involvement in multidisciplinary areas of communication standards, routing, security and trust were presented as survey results by Mukesh Saini *et al*. [29]. The characteristics of content delivery in VANET and its architectural design were discussed and techniques and strategies based solution description was provided by Silva *et al*. [30].

These applications are focusing on various services for the transporters such as safety travel on road, internet connected vehicle services, comfort and fastest travel, reduction in travel time, reduced cost spent on travel, informed road environment, congestion avoidance and remote diagnostic support, etc. Among such comfort and sophisticated application related services by VANET, this paper describes about vehicle remote diagnostics support system.

The Proposed Efficient ORIVD-RDSS System: The proposed system, functions with three basic components as vehicles, RSUs and SBS, which are mainly focusing on diagnostic support to the running vehicles on the road. In in-vehicle (InV) networks, the components such as ECUs are provided by the VCMs with firmware. The concept of updating the firmware/ flashing the firmware during malfunctioning of software components in such devices are focused on proposed work and the remote support is facilitated through VANET infrastructure. The modern vehicles are equipped with many ECUs to control and coordinate the InV operations towards sophistication. The ECUs are hardware units combined with software to synchronize and stabilize the vehicle operations. The fault tolerance capabilities of the InV network system, is taken as a major factor to develop this system, in which the vehicles, RSUs and SBSs are bounded with wireless communication. On the SBS, the vehicle's DTC:TFS pairs, are classified on the basis of vendor's specific make, model and its variants. The outer layer of this classification is various vendors of vehicles; the immediate next inner layer of classification is the vehicle's make and the next inner layer of classification is the vehicle model and the deepest inner most layer of classification is the vehicle model based variants. The database and the tables of DTC:TFS pairs are following the similar way of classification through which the possibilities of organizing the data made simple and effective.

Proposed System Components: InV OBU: In vehicles, the On-Board Unit (OBU), which is a mobile computing device which performs the role of communication cum computing enabled activities and enables the in-vehicle operations from traditional mode to smartness mode of operations. Most of the VANET applications are wireless communication oriented and proposed system with VANET and ITS operates with 2G/3G/LTE communication support. The Fig.1(a) represents, the OBU's organization on its internal hardware/software components.

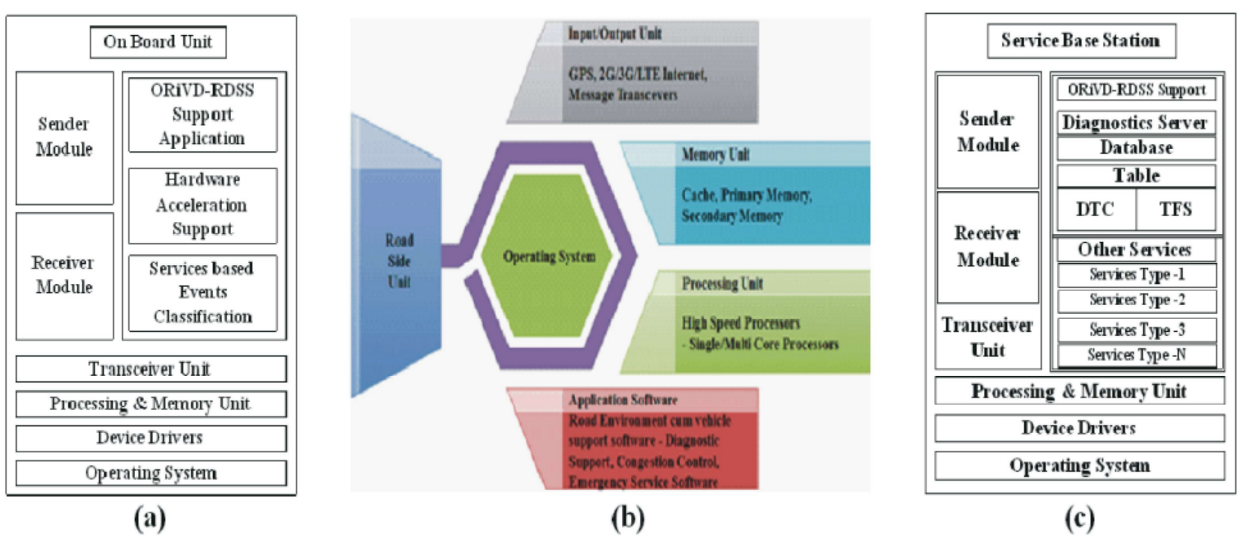
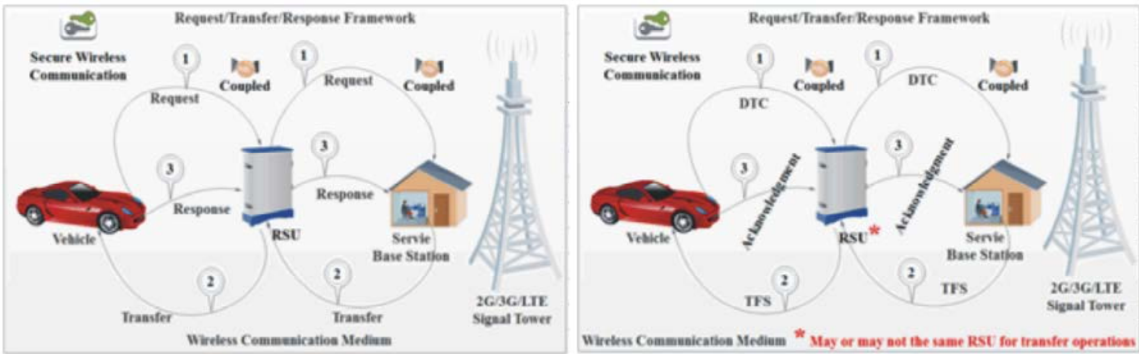


Fig. 1: (a) Organization of InV OBU; (b) Organization of an RSU; (c) Organization of SBS.



(a) (b)

Fig. 2: (a) Conceptual - RTR framework in ORiVD-RDSS; (b) RTR framework operations of system.

An RSU: The RSU is similar like OBU and is being a computing device and in VANET, the role of RSUs are vital. The Fig.1(b) presents, the RSU's organization of software and hardware components. The complete unit is equipped with efficient high speed processors which meets the fastest needs of on run vehicles on the RE. These units address the requests from vehicles and in case of non-availability of resources, further they request with other servers to provide services to the vehicles with in its range of accessibility. SBS: In ITS services, the base stations act the role of resource/content providers to RSUs and vehicles, where these nodes in the network are not having sufficient storage capacity and lack to keep the resources within their physical architecture and in Fig.1(c), the organization of SBS is provided. On growing importance in smartness among the components, the transporters are transforming from traditional to smartness and the needs of transporters on the RE are increasing day-by-day.

RTR Framework: The system ORiVD-RDSS is an application based services providing platform on road side to vehicles and vendors. The vehicles are utilizing the service to fix their errors before they propagate them as fault. In this work, we coined a new RTR framework, which defines the system operations in terms of requests, transfers and responses. The conceptual representation of RTR framework is given in the Fig.2(a).

Request: The vehicle drops the request for TFS using DTC with the nearby RSU on RE. The current RSU collects it and validates the request details and further transfers the DTC request with the SBS. During the request operation, the request flows through Vehicle to RSU (V2R) and RSU to SBS (R2S) communication and the communicating devices are tightly coupled. The received DTC is further scrutinized at SBS to identify the right TFS and the identified TFS is transferred to the vehicle through the same RSU or the next successive RSU, where the vehicles are on road and involves in production (moving towards destination).

Transfer: During transfer operation, the vehicle's TFS transfer flows with S2R and R2V communication. The participating RSU may or may not be the same, where the vehicle dropped its DTC request. Due to the fast-moving nature of vehicles on RE, vehicle drops the DTC request on nearby RSU and moves on towards the destination and may or may not lost the wireless signal range of last RSU and reach next successor RSU. In this scenario, the SBS is the responsible component under ORiVD-RDSS, to transfer the right TFS from SBS to vehicle through RSU. While entering into the availability range of new successor RSU, vehicle updates the RSU's vehicle-status table with its presence (vehicle-id) on the current RSU. This vehicle-status updating activity on all successor RSUs continue, to SBS to transfer TFS to the vehicle, where the vehicle is towards its destination.

The SBS is updating its Vehicle-RSU status table with regular time interval to transfer the TFS to the current RSU, where the vehicle is travelling at present on the road. By holding the vehicle's current RSU status, the SBS transfers TFS. Response: During response operation, the vehicle's status on fixing the errors with accessed TFS, on the specific in-vehicle domain components and the complete history about the diagnostic fix and the details of RSU involved in the bringing back the quality of operations of in-vehicle components are forwarded to SBS in the form of an acknowledgement. The acknowledgement has the complete history of the diagnostics and trouble fix, which are maintained as for business and history purpose for a specific vehicle. The Fig.2(b) represents, the operations of the proposed system with RTR framework.

1. Function on in-vehicle diagnosis and reporting to OBU

```
Function VDA (ECU_P, ECU_TH, TI) returns DTCs
    Inputs: ECU_P, a percept that holds values of ECU's Software components
            ECU_TH, the threshold value of ECU software component to function
                in normal performance
            TI, the time interval of checking parameter values of ECUs

    if ((ECU_P< ECU_TH) OR (ECU_P>ECU_TH))
            {
            problem identified on particular ECU
            report to OBU with OBD-II Standard DTCs
            }
    else
            {
            wait to perform the VDA on ECU at next time interval season begins
            }
End Function
```

2. Function on OBU to drop DTC with nearby RSU

```
Function ODR (DTC_I, RSU_NB, V_ID)
    Inputs: DTC_I, an identified DTC that holds values of error intensity
            RSU_NB, a near by RSU with its ID
            V_ID, the vehicle Id, to identify TFS on SBS
    if (nearby RSU is identified)
            {
            drop DTC with RSU using V2R communication standard
            wait until the TFS received
            }
    else
            {
            wait to identify the nearby RSU
            }
End Function
```

3. Function on RSU to transfer DTC with SBS

```
Function RSDS (DTC_VID, SBS_NB, RSU_ID)
    Inputs: DTC_VID, a DTC with vehicle ID that holds error code and vehicle ID
            SBS_NB, a near by SBS with the communicating RSU
            RSU_ID, an RSU's ID, to identify RSU on ORiVD-RDSS
    if (nearby SBS is identified)
            {
            transfer DTC with vehicle ID using R2S communication standard
            verify if the vehicle is moving or waiting on the same location
            if (vehicle continues its travel towards destination )
                    { get ready to collect other vehicles DTC to receive }
            else
                    { wait for the vehicle to access TFS }
            }
End Function
```

4. Function to transfer TFS from SBS through RSU

```
Function Transfer-TSR (TFS_DTC-S, RSU_NB-V, V_ID) returns TFS to vehicle
    Inputs: TFS_DTC-S, a DTC specific TFS from SBS
            RSU_NB-V, the details of vehicle holding RSU from SBS
            V_ID, a vehicle's ID, to identify vehicle on ORiVD-RDSS
                to transfer TFS
    if (vehicle holding RSU is identified by SBS )
            {
            Transfer TFS with vehicle-hold RSU using S2R standard
            Transfer TFS with vehicle from RSU using R2V standard
            }
End Function
```

5. Function to collect TFS and Fix the diseased ECU (On OBU)

```
Function OBU-Fix-ECU (ECU_Disd, DTC_I, SWI_TFS) returns
acknowledgment
    Inputs: ECU_Disd, an ECU details, which is diseased during
                request operation
            DTC_I, the identified DTC, during request operation
            SWI_TFS, a software image, which is the trouble fix
                for diseased ECU

    identify the diseased ECU on the in-vehicle network with DTC_I

    apply the TFS software image to the vehicle, which is on running
    generate the acknowledgment to send to SBS
End Function
```

6. Function on OBU to send acknowledgement with SBS through RSU

```
Function OSR (ACK_TFS, RSU_NB, V_ID)
    Inputs: ACK_TFS, an acknowledgment with status of trouble fix details
            RSU_NB, a near by RSU with its ID
            V_ID, the vehicle Id, to identify TFS on SBS
    if (nearby RSU is identified)
            { drop ACK_TFS with the RSU using V2R communication standard
              stop the current RTR operation
            }
    else
            {
            wait to identify the nearby RSU
            }
End Function
```

Fig. 3: ORiVD-RDSS functions.

Functions: The SBS is an expert system, involves with superior decision making support and serves the correct TFS to the vehicle through RSU. In ORiVD-RDSS, RSU is the middle component which collects the vehicle requests in the form of DTC and transfers the same request to SBS for identifying right TFS. The right TFS from SBS is accessed by the vehicle through RSUs on the RE. In this context, the two-tier client/server architecture is introduced with the system. During requesting operation, the vehicles and RSUs are acting as clients and while transferring the TFSs to the vehicle, the SBSs and RSUs are acting as server.

The proposed system's functions are (1) Function on in-vehicle diagnosis and reporting to OBU; (2) Function on OBD to drop DTC with RSU; (3) Function on RSU to transfer DTC with SBS; (4) Function to transfer TFS from SBS through RSU; (5) Function to collect TFS and Fix the diseased ECU (On OBU); and (6) Function on OBU to send acknowledgement with SBS through RSU. The Fig.3 represents the functions on ORiVD-RDSS.

Mathematical Model: In ORiVD-RDSS, the system components are Vehicles, RSUs and SBSs. They can be defined with set theory. In a particular domain, the members in a set have several functions associated with them. The vehicles are coming under a set; and are having their own members of its domain and the set is defined as,

$V_i = \{v_1, v_2, v_3,...\}$, of "$n$" tuples, where "$V$" denotes set of vehicles, "v" denotes an individual vehicle, "i", denotes the vendors of vehicle make and "n" denotes the DTCs of in-vehicle domains.

$V_{ij} = \{v_{11}, v_{12}, v_{13},...\}$, where "$j$" denotes a specific model of vehicle, which belongs to a specific vendor and the set can further have classified with variants of the specific vehicle model.

Every vehicle has their own sub domains of operations associated with them. These domains are power train, body, chassis, active safety, passive safety, telematics, diagnostics and OBU. Such sub domains are being members in a vehicle set. Positively, in-vehicle set can be defined with its in-vehicle sub domains and each in-vehicle domain members are defined with their own parameters and every in-vehicle domain parameter are collected by diagnostic domain and is validated with the threshold value of the domain standard, to identify the DTC. The second component of the proposed system is RSU, which functions in the system with the wireless communication medium and is defined as,

$R_i = \{r_1, r_2, r_3,...\}$, where "$R$" denotes a set of RSUs in ORiVD-RDSS, "r" denotes a single RSU and "i" denotes serial order number of RSU on the road side which are within a cluster.

The 3rd component of the system is SBS, which is defined with its members in a set called "S" and as,

$S_i = \{S_1, S_2, S_3, ...\}$, of "$m$" tuples, where "$S$" denotes a set of distributed SBS on the RE, "s" denotes a single SBS, "i" denotes serial order number of SBS on the RE and "m" denotes the TFSs available on SBS for each vehicle on ORiVD-RDSS.

The entire system components are defined in a family of set and is,

$F_{ORiVD\text{-}RDSS} = \{V, R, S, A\}$, under the condition $n \leq m$. where "V" denotes a set of vehicles, "R" denotes a set of RSUs, "S" denotes a set of SBSs, "A" denotes an association set and all are members of set $F_{ORiVD\text{-}RDSS}$.

In set "A" the members are associations of DTCs and their exact TFSs. This is the mapping from vehicle (DTC) to the SBS (TFS), which is the main goal of the system that provides right TFS for the DTC's sent by the vehicle through RSU. The set V and its member variables can be mapped into set S in terms of DTC and TFS and provides a relation called "u" and which is abided by the condition $n \leq m$. ($u \sim v$), if and only if ($u_i = v_i$), for 3 consecutive models of the same vehicle and this satisfies reflexivity, symmetricity and transitivity. Therefore, with the relation ~ the equivalence classes may be defined as a set A and is,

$A = \{[u_1], [u_2], [u_3], ..., [u_t]\}$, such that $t \leq n$ and $t \leq m$ and is an association set of all mapping classes in sets V and S. For example, the DTC from the vehicle and its equal TFS on SBS. For example,

$A = \{[DTC_1 = TFS_1], [DTC_2 = TFS_2], [DTC_3 = TFS_3], ..., [DTC_d = TFS_d]\}$

In addition to this,
$[u]$ add $[v] = [u$ add $v]$ for all $[u]$, $[v]$ and
$[u]$ multiply $[v] = [u$ multiply $v]$ for all $[u]$, $[v]$,

This shows the possibility of operators on relations. The function mapping for the DTC to TFS, matching is given below,

$f = A \rightarrow S$ and $f([u]) = [u^*]$, such that $[u^*]$ belongs to S and $[u^*]$ is the image of $[u]$, where it is a diseased one on vehicle, the $[u^*]$ is an image on SBS, which replaces the diseased one with fresh software (SW) component.

The f is a well-defined function, which gives the equivalence mapping of diseased to fresh image SW component with appropriate searching technique for matching. The mathematical model and its definition on the environment for the system gets the dimension of finite domain. On this basis of definition for the system, the application software development for ORiVD-RDSS in terms of client/server end are fixed with finite number of requirements to fulfill the system related operations to be accomplished with crisp and towards certainty of operations.

RDS Protocol: The remote diagnostics support protocol is introduced in the proposed work. This protocol is the dynamic routing protocol, performs routing of packets, based on distance vector cum link state routing methods and is used in vehicle's remote diagnostics support, which enables the communication between vehicles, RSUs and SBS in the ORiVD-RDSS. VANET is an environment where large number of nodes are evolving and are having fastest movement on the road. The RSUs and SBSs are fixed units and are placed nearby the road sides and they provide services to running vehicles based on the context of the applications' need (diagnostics support) of the vehicles. Routing Table (RT): This protocol uses IP addressing for indicating source and destination nodes on the network and the nodes may be vehicles, RSUs and SBSs. The source node is the one, which is having trouble in its internal units and requests with DTC and is treated as a source vehicle (SV). The destination node is the one, which is having DTC:TFS pairs and serves the SVs on request. The RT of RDS extends with necessary fields and are given in (Table 1).

The first field specifies the vehicle identity, treated as SV, which initiates the communication. The second field indicates DTC of the SV and consists in-vehicle's diagnostic detail. The third filed is the IP address of nearby RSU (nb-RSU) of the SV on the RE, where the vehicle is performing travel towards destination.

Table 1: Fields of RDS protocol routing table.

1	2	3	4	5	6	7	8	9
V_ID	DTC	RSU_IP	RSU_SEQ	SBS_ID	LU_V	LV_RSU	RT_FLW	RT_LT

RDS Routing Algorithm

Prior State: Vehicle identifies the DTC (OBD-II Standard) with in-vehicle diagnostics support.

```
    Step 1: The vehicle drops the DTC with nearby RSU (using TFSREQ).
    Step 2: RSU verifies DTC with its RT records.
        if (RSU¶s RT field - DTC matches)
            {Collect the LSU¶s identity with RSU¶s on the VANET
             Identify the location of LSU
             Calculate and find the shortest distance between SV to LSV
             if (Distance between SBS and SV < Distance between SBS and from LSV)
                 {Stop}
             else
                 {RSU, requests TFS from its SBS}
            }
    Step 3: SBS searches the DTC:TFS pair on its database.
        If (requested DTC is available on SBS RT record)
            {Move to the record on main DB of DTC:TFS pair
            Collect TFS and append with TFSTFR
            Find and fix the SV¶s current RSU}
        else
            {Search requested DTC with main DB of DTC:TFS pair
            Collect TFS and append with TFSTFR
            Find and fix the SV¶s current RSU}
    Step 4: SBS transfers TFSTFR to the RSU.
    Step 5: RSU transfers TFS to SV.
    Step 6: SV collects and fixes its trouble with TFS.
    Step 7: SV responses SBS with the acknowledgment message ACKRES through RSU.
```

Post State: Vehicle uses TFS and recovers from trouble.

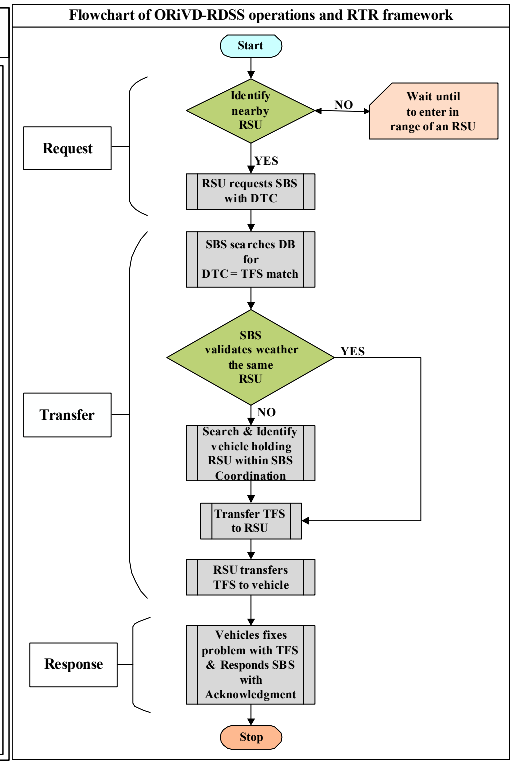


Fig. 4: (a) RDS routing algorithm; (b) ORiVD-RDSS operations and RTR Framework.

The fourth filed denotes the sequence number of nb-RSU on a specific cluster of the system, which belongs to a specific SBS. The fifth filed consists the details of SBS and has two parts, they are IP address and sequence number of SBS. As for sequence number of SBS, if the cluster consists more than one SBS, the sequence number is applicable or the cluster consists only one SBS with it and the default value is one. If more than one SBSs present in a cluster, the sequence order number is assigned. In combined mode of sequence number and the IP address of the SBS is included in the fifth field and is treated as SBS_ID. The sixth field is the last used vehicle's (LUV) ID. In recent past, the LUV acted as a SV and used the same DTC, to fix its trouble with DTC:TFS pair in successive mode. The seventh filed is the LUV's current nb-RSU, which holds active status of the LUV. The eighth field is the details of complete route, which is the record of the SV, consists utilization details of SBS or LUV to complete the DTC:TFS match, to fix the trouble on SV and success hit of matched pair. The last field is the lifetime of the specific route information (a field on a RT) and it is restricted with time span.

In ORiVD-RDSS, each component consists, its own RT and the field values for the source and destination varies. The lifetime validity of a record in RTs of vehicles (SV, LSUs), RSUs and SBS are restricted with specific time interval 30 minutes, 60 minutes and lifetime of the vehicle on the ORiVD-RDSS, respectively. A record's lifetime as 30 minutes on a vehicle specifies, that the recently trouble fixed vehicle may in running condition, it may cross 50 kilometers (if the speed of travel is 100 kilometers/hour approximately). The lifetime of an RSU's RT record is 60 minutes. The extended time limit provides the SV to access the details of SBS. On SBS, the lifetime of RT record is lifetime of the vehicle. This indicates, the validity period of the vehicle to be a part as node in the ORiVD-RDSS. There are three types of packet formats in RDS protocol. They are based on the RTR framework operations and are request, transfer and response. The names of the packets are TFSREQ, TFSTFR and ACKRES. The TFSREQ is the message, which carries DTC with it from SV to intermittent RSU to SBS. The trouble fix solution request is initiated at SV end. The TFSTFR message is the one, which is used during the transfer of TFS from SBS to SV through intermittent RSU. The trouble fix solution transfer is initiated from SBS. The ACKRES is the message, used for acknowledgment response. This is initialized by SV and appends the details of applied TFS on SV. This is treated as a response from SV to SBS.

The Fig.4(a) represents, the RDS routing algorithm. The algorithm starts with DTC, by assuming the prior state as the vehicle's in-vehicle diagnostics provides DTC. The vehicle drops the DTC with nearby RSU. The RSU requests SBS for TFS with collected DTC. With intelligent programs on SBS, DTC:TFS pair is identified and SBS searches with in its coordination range of RSUs for identifying the current RSU, which holds the live status of the SV. Then TFS is transferred to the current RSU. The current RSU transfers the TFS with the vehicle. The algorithm ends with acknowledgment responses to SBS through RSU from SV, by confirming the post state as the SV utilized TFS and recovers from the problem. The Fig.4(b) represents, the ORiVD-RDSS operations and RTR framework.

RESULTS AND DISCUSSIONS

In the proposed system RTR framework and RDS protocol, the V2V communication is limited to propagate TFS packets by specifying minimum lifetime value with in vehicles RTs. The TFS for a vehicle is specific and cannot be same with all sort of vehicles on the road. With this condition, the V2V based DTC:TFS pair finding is avoided in overall mode and relays on specifiers and the protocol forces the vehicle request to reach SBS's cache to collect TFS through RSU. This act of RDS regulation, eliminates the time delay of packets to reach the destination or finding route to destination through RSUs. The DTC request, TFS transfer and the acknowledgment responses are tested in simulation environment which yields comprehensive progress comparing to the existing protocols on VANET communication. The comparison based simulation results are prepared and validated with ns2 with the following conditions and the variations on the generated results of existing protocols to the proposed protocol shows the saturated improvement in VANET based communication.

As for the performance measure, we present the test case in the form of simulation and the comparison between AODV protocol to our proposed RDS protocol. This simulation is performed with the Simulation Urban Mobility (SUMO) tool. The simulation parameters are listed in the (Table 2).

Results and Discussions:
Access Delay: It is the time spent by a network interface waits, before it can access a shared VANET resources, in milliseconds; Jitter: It is the simple unsteadiness in the packets delivered to the nodes and is measured in seconds; Packet Delivery Ratio (PDR): It is a ratio of actual packets delivered to the total packets sent from one node to another node; Throughput: It is the number of packets per bytes received by a node per unit time and is measured in milliseconds.

The Fig.5(a) represents, the clarity of RDS protocol over AODV and its packets transmission within RTR framework operations by considering the nodes as SV, RSU, SBS, LUV and nb-RSU are yielding reduced access delay. When nodes are 10 in numbers, both RDS and AODV access delay are similar and increase in nodes on VANET, which are involving in communication, the RDS protocols' node access delay considerably reduces. This shows the scalability is not a problem with RDS, when number of communicating nodes are increasing in VANET for remote diagnostics support. The Fig.5(b) shows that the RDS protocol performs better over AODV, when the speed of the vehicles is increasing, the access delay with RSU, nb-RSU, SBS, LUV are reduced. When communicating vehicles, speed is same in both the protocol's communication (at beginning), access delay is same and RDS improves it performance when the vehicle's speed increases. The request, transfer and response based communication operations on ORiVD-RDSS, due to RDS is improved 35% over AODV.

Table 2: SUMO simulation parameters.

Simulation parameters	Values	Simulation parameters	Values
Bandwidth	2 MB	Network area	40 X 60
Packet size	1000 bytes	Traffic rate / type (Node / min)	CBR / 1
Buffer Length	50 packets	Network Size (N)	50
Receiver energy	0.01	Number of senders	2, 4, 6, 8,10
Transmitter energy	0.02	Routing protocol	RDS Protocol
Initial energy	100j	MAC	IEEE802.15.4
Propagation model	Two-way ground	RF output power/receiver sensitivity	-4dBm/-84dBm
Antenna type	Omni directional	Sim time in seconds	3500 seconds
Mobility model	Random way point model	Transmitter range	250

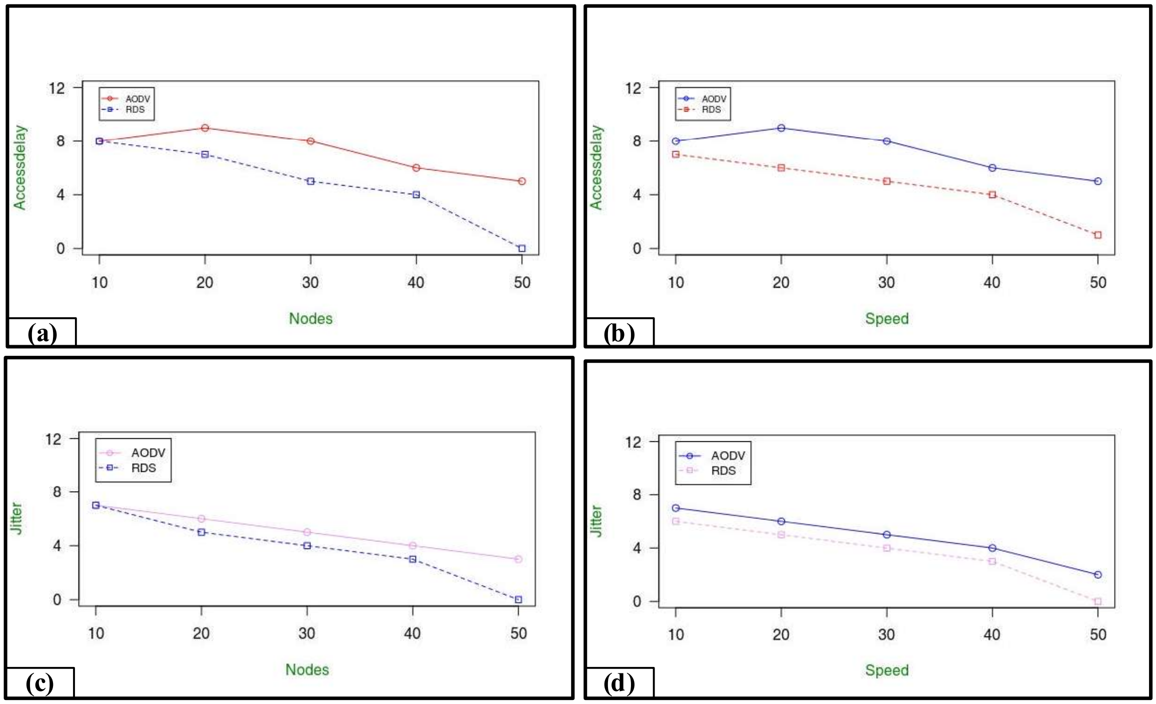


Fig. 5: (a) Node and access delay; (b) Vehicle speed and access delay; (c) Jitter and nodes; (d) Jitter due to vehicle speed.

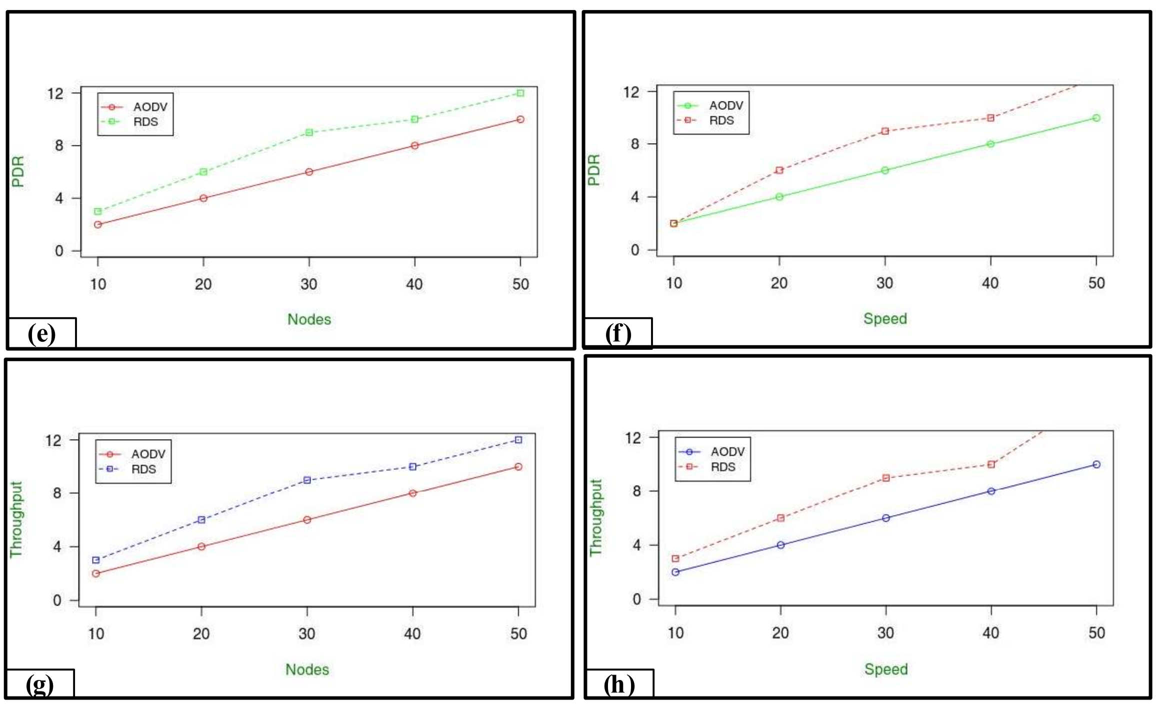


Fig. 5: (e) Nodes and PDR; (f) Vehicle speed and PDR; (g) Nodes and throughput; (h) Vehicle speed and throughput.

The Fig.5(c), clearly states that the jitter reduces, when nodes are increasing and with Fig.5(d), the speed of the vehicle increases.

The Fig.5(e) specifies that the packet delivery on the nodes during communication and the ratio is increasing when the number of nodes are increasing. By comparing with ADOV, which holds the path details and identifies the route with neighbor nodes on VANET suffers comparatively with RDS protocol. The Fig.5(f) yields the view on vehicle speed and it increases, the packet delivery ratio increases. The Fig.5(g) represents, the throughput with number of nodes increasing and Fig.5(h) shows, the increase in throughput, while the speed of the vehicle increases.

The given analysis report is a comparative study with AODV, where in which the complexity of identifying route involves and the RDS protocol relays on nb-RSU and SBS on the specific cluster. The V2V communication is purposively avoided to overcome such communication drawbacks (are in existing) and the simulation result proves the RDS protocol's effectiveness, even the VANET node increases or the speed of the vehicle increases the performance on event dissemination increases. The heterogenous route finding option is eliminated in RDS protocol. Identifying a vehicle to request or transfer operations are avoided by specifying very less time interval in its RT entries. The dynamic nature of RT entries on SV and LUV are only used, when the DTC request reaches with in the RT record's lifetime expires in RSU and LUV. The increase in nodes as well as increase in vehicle speed, never disturbs the performance of RDS and the scalability problem never arises in RTR framework based operations with RDS protocol on VANET based ITS.

CONCLUSION

The complexity in identifying the DTCs with OBU details the necessities to follow a common architecture for the in-vehicle networks. It is very important to follow a common InV network architecture by ACMs and the complexities on ORiVD-RDSS can considerably reduce. The convergence of traditional to smart vehicles, are attracting the ACMs, OEMs and VCMs for betterment of services. In this work, vehicle operations are subjected to uncertainty of act and generates DTCs and disseminates with RDSS and ORiVD-RDSS operations are subjected to certainty of act, which fixes the troubles with appropriate TFSs. In such scenario, the introduced systems with their applications and services attracts the transporters society.

The emerging trend of VANET development platform and demanding needs of application related activities in it, drives the field towards various innovations' possibilities. The world of IoV and their relevant applications, services can be proposed with social welfare projects and can be tested and implemented as further work. On completion of this proposed work, the software components for ECUs and their malfunction details are accounted to replace with the fresh copy or image of the same ECU's software components, in the mode of flash/reinstall. In future, as for our extension from ORiVD-RDSS, it is considered that the number of RSUs reduction or elimination is evaginated.

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