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Segmentation-based Vehicle Location Detection (SVLD) Mechanism for Network Dwelling Range Extension and RSU Load Reduction in VANET V2R Communication

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Abstract

Vehicular Ad hoc Networks (VANETs) are specialized vehicle networks designed to provide diverse applications and services for vehicles in mobility. Nevertheless, VANETs face several challenges such as dynamic network structure, rapid changes in velocity of vehicles in various directions, data overload, and limited duration of connectivity, all of which can result in poor proficiency in delivering services to the vehicles. This hinders the progress of meeting the requirements of time-sensitive applications which could not tolerate much delay. Deploying a vehicular infrastructure such as the Roadside Unit (RSU) is crucial for improving the efficiency of data distribution in VANETs. The dynamic nature of the vehicle environment in VANET leads to constraints in data delivery, such as problems with high density and connectivity duration. Vehicles in high velocity can enter and exit the transmission range area of an RSU in Vehicle-to-Roadside (V2R) communication without obtaining all the data they requested. This sets added processing and load on the RSUs and leads to greater rates of dropped requests, delays, and reduced responsiveness. Furthermore, in extensive networks characterized by frequent and rapid changes in connectivity and dynamic network structure, such as urban highways, V2R communication experiences brief periods of connectivity when traveling at high speeds. Additionally, for V2R communication, vehicles does not receive any services when outside the Network Dwelling Range (NDR) of an RSU. This study introduces the Segmentation-Based Vehicle Location Detection (SVLD) mechanism that involves fragmenting the NDR of RSUs into overlapping segments and identifying vehicles within these segments. Experiments have been conducted in simulation using OMNeT++, SUMO and Veins with the goal of expanding the NDR and increase the duration of connectivity in V2R communication. Additionally, it aims to alleviate the burden on the RSU by facilitating a smooth transfer of workload to the next RSU. The results demonstrate a substantial expansion of the NDR using the RSU's NDR overlapping approach, as well as a reduction of 36.4% in the RSU's load.

1. Introduction

Due to the challenges posed by VANETs, such as dynamic topology, high vehicle speeds in different directions, and short connectivity lifespan, V2V communication may exhibit suboptimal performance in collecting and transmitting vehicle-provided data. This significantly complicates the development of delay-sensitive applications on VANETs. Deploying a vehicular infrastructure such as the RSU and enabling V2R communication is an essential approach for enhancing message distribution performance in the VANET, in order to address these requirements.

RSU placement refers to the process of identifying the most suitable arrangement of RSUs inside a specific target region based on provided characteristics in order to meet specific goals, such as optimal connectivity, maximum coverage, and finest network performance [1- 2].

The communication modes in VANET, as implemented in technical design, are susceptible to numerous vulnerabilities. Vehicles as nodes that are naturally dynamic in their mobility are defined by their ability to communicate with other nodes or infrastructure via short-ranged wireless-based communication. This technical requirement itself presents various challenges due to dynamic topology, fast interchangeable mobility, velocity and density, limitations of capacity, as well as intricate road layout. These factors collectively contribute to the prevalent issues in VANET, particularly in the realm of data communication [2-4].

The effectiveness of V2R communication, for example, greatly depends on the connection with the roadside infrastructure or RSU for network access and other resources. Nevertheless, this dependence can give rise to complications when RSUs are inaccessible or not deployed in particular regions, leading to deficiencies in coverage and connectivity problems [5-6].

The communication capability of V2R is also constrained by the limited communication range with the RSU, which spans a mere 1000 meters [7].This limitation results in connectivity challenges, particularly when managing data from swiftly moving vehicles [2,8-9]. Consequently, rapid-moving vehicles have the potential to swiftly exit the coverage range of a RSU, resulting in network disconnections and service disruptions [10]. This restricted transmission range poses a barrier to maintaining uninterrupted connectivity, which is vital for ensuring safety applications and accessing the mobile Internet [11-13].

Apart from RSU placements and V2R communications, road layout also presents a complex challenge to VANET [12, 14-15], and it directly influences the distribution of vehicles and network topology due to the bounded movements of the vehicles on it. The urban highway for instance presents the unique challenge of having a greater number of lanes [16], hence holding a higher density of vehicles, and intersections are usually located at distinct places [17] usually far apart from each other.

In a typical vehicular traffic congestion on an urban highway, VANET would be facing high to maximum vehicular density during standing traffic events, and with RSU placements with non-overlapping NDRs, vehicles that are located outside of an NDR during a standstill traffic congestion would not be getting any VANET services. Hence, it is imperative to elucidate the characteristics of road layouts and their influence [16, 18] Figure 1 depicts a situation where vehicles are located outside the RSU's NDR, resulting in their inability to access services provided by the VANET. These vehicles are trapped in traffic and are not within the coverage area of the RSU. Therefore, there is an essential need to extend the RSU's transmission range, and at the same time ensure effective NDR for all vehicles on the urban highway.

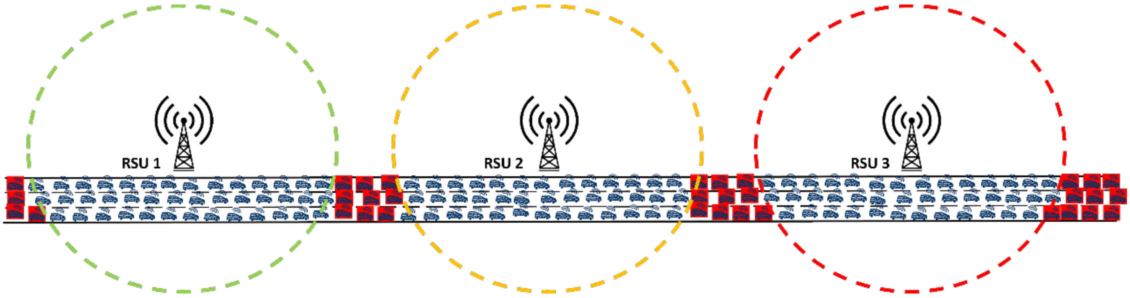


Fig. 1 *Vehicles not in the RSU's NDR excluded from VANET Services*

The placement of RSUs is indeed an important factor to be considered in designing a method to address the resource capacity handling issue. For example, in downloading or retrieving information from the edge node, certain applications may necessitate that the average time it takes for a round-trip to occur is lower than a specific threshold, while others may enforce criteria on the latency of the slowest responses based on where they are placed while in operation [19]. Additionally, certain applications may possess a superior priority level compared to others, with the priority being determined based on their QoS [20-21]. The issue at hand is the efficient allocation of resources to these applications, with the goal of minimizing operational expenses for edge servers while yet maintaining the desired quality of service for the applications.

Numerous strategies for deploying RSUs in vehicular networks have been proposed to enhance coverage, minimize costs, and improve communication quality, with each approach targeting distinct challenges in various environments. Huang and Jhang, [22] identified the most congested area through mapping the vehicular traffic with Voronoi Graph in pursuit to analyse the best fitting place for V2R communication. Huo et al. [23] present a multi-objective approach for RSU deployment that incorporates reliable coverage analysis and accounts for various communication environments. The optimization of cost and Quality of Service (QoS) is achieved through an algorithm that integrates packet delivery ratio (PDR) in VANET performance to improve coverage reliability across diverse scenarios. Chaabene et al. [24] propose a spatio-temporal deployment method aimed at cost reduction and coverage maximization which identifies high-utility locations from vehicle trajectory data, ensuring that minimal RSUs are utilized for optimal coverage, while similarly, Zhang et al. [25] analyse the integrated deployment of RSUs and dedicated lanes in a mixed autonomy context, focusing on optimizing infrastructure placement to effectively support both human-driven and automated vehicles while adhering to budget constraints.

Gu et al. [26] employ a hierarchical clustering approach for the deployment of RSUs in complex networks, emphasizing cluster heads as critical deployment locations. This approach emphasizes areas with significant connectivity, thus improving data transmission and optimizing RSU resources. A similar deployment mechanism based on node popularity is proposed by Mao et al. [27] that maximizes coverage ratio by adjusting traffic parameters and adding the inhibition distance coefficient to improve service capacity for vehicles.

On the other hand, Astudillo León et al. [28] investigate the placement of RSUs in urban environments, emphasizing distinct urban features such as street configuration and vehicle density, rather than merely targeting high-traffic zones. This method decreases the quantity of RSUs required while preserving coverage quality through the alignment of RSU placement with urban topology. Iturbe-Olleta et al. [29] present an adjusted propagation model for ITS-G5 communications that modifies RSU placement according to environmental characteristics that aims to optimize coverage while minimizing the number of units deployed, thereby balancing deployment costs with coverage requirements.

Other related approaches were presented by Liu et al. [30] that investigate cooperative localization involving RSUs and vehicles, employing millimeter-wave (mmWave) sensing to enhance localization accuracy. This approach is particularly advantageous in high-speed vehicular contexts, where precise localization is essential for safety and efficiency. Feng et al. [31] propose a deployment strategy based on spectral clustering for vehicular edge computing environments. The proposed method clusters areas of high demand, optimizing the number and locations of RSUs to balance computation offloading with communication requirements, thereby enhancing task completion times and reducing deployment costs.

Bang, et al. [32], Saleem et al. [20], Saad et al. [33] and other similar, and recent works manipulates the edge node transmission range to calculate the task offloading time that is suitable in V2R communication, and many researchers [34-36], are utilizing V2V communication in order to lessen the burden of data overload and the connectivity gaps of V2R communication. However, through V2V, not all vehicle nodes are willing to offer their computing power to other vehicles and the owner may be reluctant to contribute resources without the appropriate incentives [37] and moreover, these approaches are not evaluated in a heavily congested urban highway, where traffic congestion are severe up to a standstill, immobilizing vehicles for a certain duration of time.

In light of this fact, this paper proposes the Segmentation-based Vehicle Location Detection (SVLD) mechanism for V2R communication on VANET urban highway mobility that aims to extend the RSU's NDR and at the same time provide a seamless handover among RSUs to ensure an extended NDR with prolonged connectivity time for all vehicles by using a segmented overlapping NDR between two RSUs. The objective of this mechanism is to extend the NDR and prolong the duration of connectivity and to provide network coverage to all vehicles on the highway.

2. Methods

The Segmentation-Based Vehicle Location Detection (SVLD) mechanism is proposed based on the hypothesizes that the RSU could save resources by not having to process and transmit data or task requests to vehicles that by the time of delivering the processed data or task, had exited its NDR. It also proposes that in the event of the situation is predicted, the task will be handed over to the next RSU where the vehicle might have moved and connected to. Therefore, this research proposes that the transmission range of the RSU be segmented and proposes that handover to the next RSU proactively materializes within the last segment. This would prevent unnecessary processing and transmission of data from the current RSU, hence promote optimization. Based on our previous experiment conducted on segmenting the RSU's NDR [38], the establishment of RSU's segmented NDR are as shown in Table 1.

Table 1 *RSU's NDR segmentation*

Segment	Coordinates (x, y)	Distance (m)
Segment A	(1592.22, 2331.55)	249.92
Segment B	(1839.49, 2367.83)	249.94
Segment C	(2084.22, 2418.62)	249.95
Segment D	(2329.51,2466.64)	249.94

2.1 Overlapping of RSU's NDR Segments

This section revolves around investigating the effects of overlapping RSUs, specifically overlapping Segment D of an RSU with the next RSU's Segment A. This topology aims to promote proactive handover between RSUs, hence extending the NDD, and prolonging the NDT for V2R communication in VANET. Figure 2 illustrates the overlapping of three RSUs that is placed by shifting the RSU's coordinates to overlap the two segments; Segment D of RSU 1 with Segment A of RSU 2, and Segment D of RSU 2 with Segment A of RSU 3. In severely or frequently congested areas, especially the urban highway where vehicles can experience standing traffic, this topology is predicted to cover the stretch of the areas that are not within any NDR with the support of several overlapping RSUs.

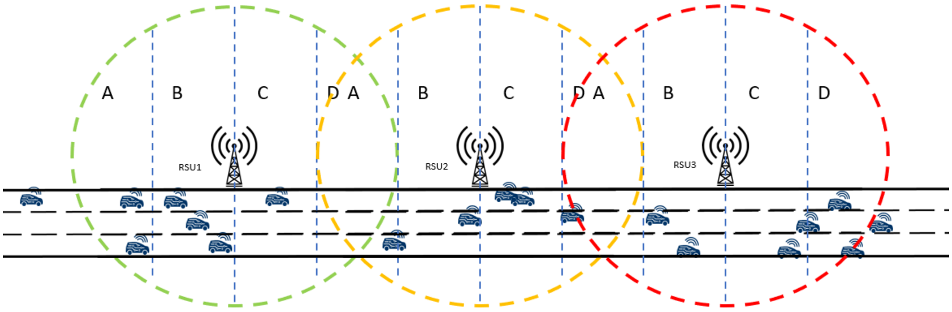


Fig. 2 *Overlapping NDRs of three RSUs in urban highway setting*

Fig. 3 *Snapshot of the overlapping NDRs of three RSUs in OMNeT++*

The coordinates of the three RSUs are presented in the following Table 2, and the illustration of the overlapping NDRs, together with a snapshot of this arrangement in OMNeT++ is presented in Figure 2 and Figure 3 respectively.

Table 2 *RSU coordinates*

RSU	Coordinates (x)	Coordinates (y)
RSU 1	2070	2330
RSU 2	2820	2480
RSU 3	3570	2480

2.1.1 Experiment 1: Overlapping RSU Segments

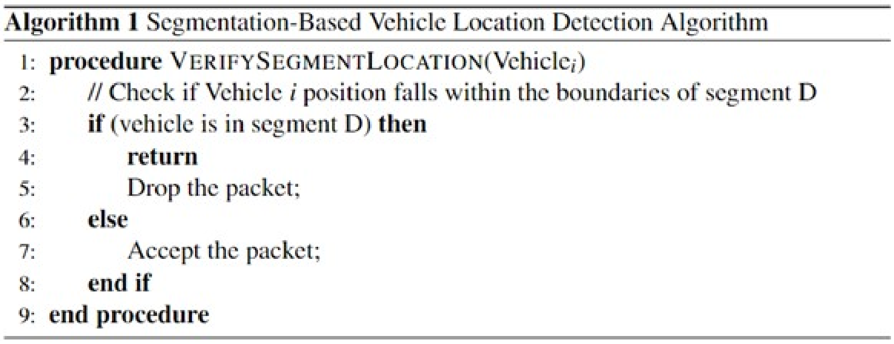
This experiment is aimed at overlapping Segment D and Segment A of two consecutive RSUs based on the coordinates of the three RSUs presented in Table 2. All three RSUs are set with a transmission radius of 500 m. To test the detection of the overlapped segments, only 1 vehicle is utilized, with velocity level of 100 kmph. The size of the data packet is set to 10 MB per unit with beacon rate of 1s and data rate of 6 Mbps. The V2R communication event log between the vehicle and the other three RSUs are recorded to extract the time and data transmission taking place within the overlapping segments.

2.1.2 Data Duplication Control and Proactive Handover in Overlapping RSUs

In VANET environment, especially in V2R communication, the association of a vehicle with an RSU as it enters the RSU's transmission range will require some delay. This is due to the need of include or to register the vehicle in the RSU's communication schedule. A vehicle must alert the RSU to its presence as soon as it reaches the RSU's transmission range to be included in the RSU's schedule. Only then will it be able to partake in collision-free communication and be inquired for data by the RSU [39-40].

Creating a concise association or connection configuration is particularly difficult in a VANET setting where vehicles are constantly traveling at high speeds and frequently changing positions. The utilization of the RSU in conjunction with the overlapping segmentation approach appears to extend the NDR of V2R communication. However, it has been demonstrated to generate message duplication, leading to unnecessary processing and subsequently overloading resources' capacity resulting from the overlapping of NDRs in experiment 1.

To further address the issue, it is imperative to resolve the problem of message duplication. This section discusses the methodological approaches to configuring the RSU to withhold or reject the processing and transmission of messages from a vehicle that is anticipated to leave the NDD. In this scenario, it refers to any vehicle that is currently located in Segment D that is sending requests for data processing or task offloading. The SVLD algorithm as presented in Figure 4 is utilized whereby the algorithm is coded in Veins' Tracimobility RSU Module.



Algorithm 1 Segmentation-Based Vehicle Location Detection Algorithm

```
procedure VerifySegmentLocation(Vehicle$_i$)
    // Check if Vehicle $i$ position falls within the boundaries of segment D
    if (vehicle is in segment D) then
        return
        Drop the packet;
    else
        Accept the packet;
    end if
end procedure
```

Fig. 4 *SVLD algorithm - acceptance of packets by RSU*

This algorithm, however, does not completely reject or deny the message, as Segment D of the current RSU overlaps with Segment A of the next. This would cause one RSU to reject the message, which would then be seamlessly received by the next RSU, resulting in the acceptance of only one RSU. As a result, there would be no duplication of processing.

2.2.1 Experiment 2: Data Duplication Control in Overlapping RSUs' NDR

To eliminate the processing of redundant broadcast data and task requests in the overlapping NDRs, it is necessary to amend the default packet acceptance procedure of the RSU. The RSU that receives data from vehicles within its NDR's Segment D must discard the packet. The following RSU, which has an overlapped Segment A within its NDR with the previous RSU will then accept and process the packet.

This approach enables the acceptance of the broadcast packet by only one of the two RSUs, hence preventing two RSUs from simultaneously processing the same packets. To provide a seamless and proactive handover, the transition from the current RSU should be initiated in its last segment, Segment D, while the handover to the next RSU should occur in its first segment, Segment A. This mechanism is expected to reduce the processing time as well as the usage of capacity in RSUs, and to achieve this objective, it is necessary to configure the RSU module so that every RSU could react and accept the vehicle's data, except when the vehicle is located in Segment D.

The first step in experiment 2 is to program the SVLD algorithm in the Veins' Tracimobility RSU Module and replicate the simulation settings from SVLD Experiment 1. The V2R communication log and extract the segment identification, handoffs, and handovers between the RSUs are then recorded and analysed.

2.3 Evaluation of SVLD Mechanism

The evaluation for the overall effectiveness of SVLD mechanism is undertaken to collect the comprehensive outcomes of the SVLD mechanism for evaluation and analysis. In order to achieve this objective, experiment 2 is repeated, and evaluation matrices are established for data collection. The evaluation criteria include the extension of NDR, and the effectiveness of the handover between RSUs in V2R communication. The expected outcome is evidence of prolonged NDR in length and time, and extended V2R communication due to overlapping RSU transmission ranges. Therefore, it is anticipated that there will be a decrease in the number of received data packets at the RSU, as the data that is supposed to be processed in the packet transmitted from within Segment D is discarded and handed over to the next RSU. To validate these presumptions, it is necessary to compare a simulation scenario with SVLD against a simulated scenario without SVLD. Figure 5 depicts the connectivity time in V2R for VANET without SVLD's RSU overlapping NDR and Figure 6 depicts the same with SVLD's RSU overlapping NDR. These scenarios were executed, and their results were subsequently compared.

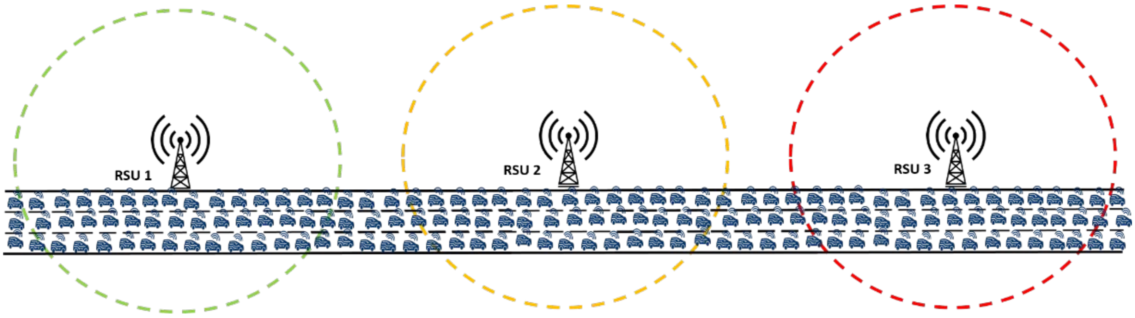


Fig. 5 *VANET topology without SVLD RSU segmentations*

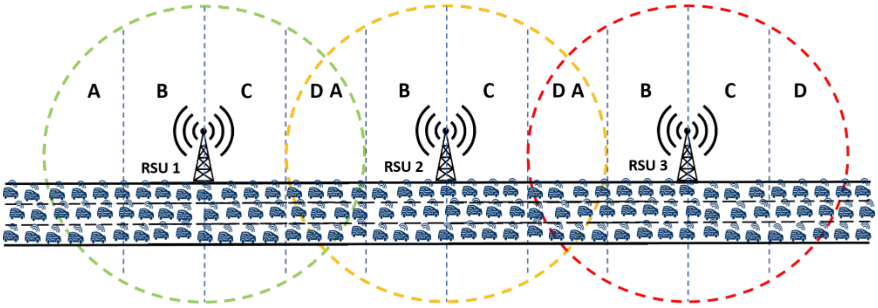


Fig. 6 *VANET topology with SVLD RSU segmentations*

2.3.1 Experiment 3: SVLD and Extended NDR Evaluation

The final experiment is conducted by firstly replicating the simulation settings from SVLD Experiment 2. The evaluation matrixes are set to include throughput, delay, and PDR. The simulation is run and the V2R communication log is extracted to analyse the segment identification, handoffs, and handovers between the RSUs. This first set of experiment gathers the results of SVLD effects. A second set of experiment needs to be run to compare a similar VANET scenario without SVLD. Therefore, the VANET architecture in this second set must exclude the overlapping NDR of the RSUs. Hence, the three RSUs are separated through a gap of 1000 meters to ensure no overlapping of NDRs. The V2R communication log is again extracted, and finally, the results of both sets of experiments are compared to determine the effectiveness of the SVLD mechanism.

2.3.2 Experiment 4: SVLD and Reduction of RSU's Load

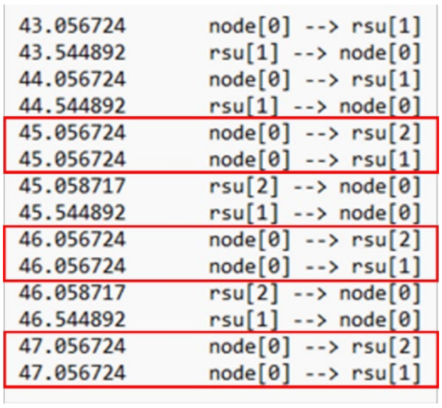
The experiment was conducted by repeating the settings of Experiment 3, but with an additional specification, which is the vehicular density. Vehicular density is increased and repeated at each run at 20, 40, 60, 80 and 100 vehicles, while beacon rate of 1s and data rate of 6 Mbps is maintained. This is to simulate an increase in the amount of data packets that is transmitted to the RSUs. The effects of SVLD are expected to reduce the amount of data packets received by the RSUs, hence reducing the processing load of data or task requests submitted by the vehicles.

3. Results and Discussion

3.1 Results of Experiment 1: Overlapping RSU Segments

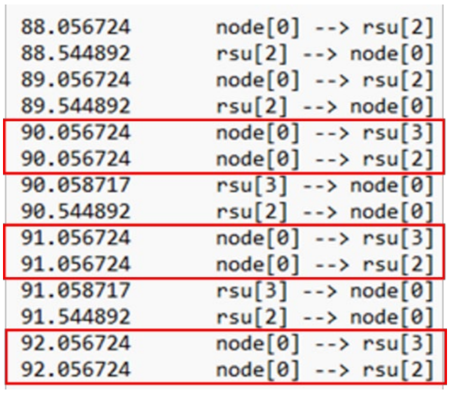
The effects of the overlapping NDRs extracted from the V2R communication event log for the overlapping of NDR of RSU 1 and RSU 2 are presented in Figure 4, while Figure 5 presents the extraction V2R communication event log for the overlapping of NDR of RSU 2 and RSU 3. The lines within the highlighted box in both figures indicate an identifiable transmission of data from the vehicle to both RSUs within the overlapping NDRs. Figure 7 exhibits the transmission of identical data to both RSU1 and RSU2, whereas Figure 8 depicts the same scenario for RSU2 and RSU3.

Both figures indicate that within the overlapped areas of Segment D and Segment A between the two RSUs, the vehicle would be transmitting or broadcasting the exact data to both RSUs. While it is comprehended that this is normal in V2R communication, this duplication is inevitable when the RSUs are overlapped together. Although this topology of overlapping RSUs prolonged the connectivity time of the V2R in VANET, it also resulted in duplicated data processing at the RSU. This duplication does not have a favourable impact on resource management or capacity reservation.



```
43.056724        node[0] --> rsu[1]
43.544892        rsu[1] --> node[0]
44.056724        node[0] --> rsu[1]
44.544892        rsu[1] --> node[0]
45.056724        node[0] --> rsu[2]
45.056724        node[0] --> rsu[1]
45.058717        rsu[2] --> node[0]
45.544892        rsu[1] --> node[0]
46.056724        node[0] --> rsu[2]
46.056724        node[0] --> rsu[1]
46.058717        rsu[2] --> node[0]
46.544892        rsu[1] --> node[0]
47.056724        node[0] --> rsu[2]
47.056724        node[0] --> rsu[1]
```

Fig. 7 *Duplication data transfer in overlapping segments of RSU 1 and RSU 2*



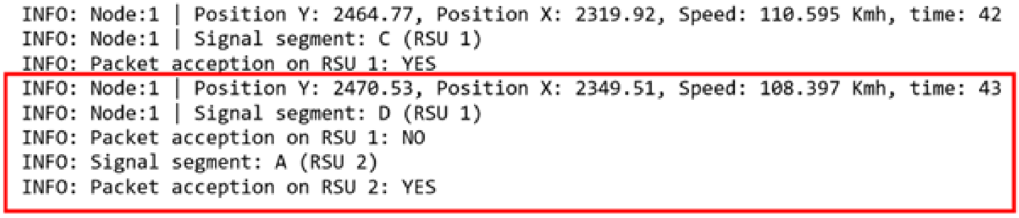
```
88.056724        node[0] --> rsu[2]
88.544892        rsu[2] --> node[0]
89.056724        node[0] --> rsu[2]
89.544892        rsu[2] --> node[0]
90.056724        node[0] --> rsu[3]
90.056724        node[0] --> rsu[2]
90.058717        rsu[3] --> node[0]
90.544892        rsu[2] --> node[0]
91.056724        node[0] --> rsu[3]
91.056724        node[0] --> rsu[2]
91.058717        rsu[3] --> node[0]
91.544892        rsu[2] --> node[0]
92.056724        node[0] --> rsu[3]
92.056724        node[0] --> rsu[2]
```

Fig. 8 *Duplication data transfer in overlapping segments of RSU 2 and RSU 3*

In order to efficiently resolve this matter, it is necessary to implement an additional control mechanism that can remove redundancy and extend the NDR without wastefully overwhelming the capacity of the RSUs. The SVLD mechanism is therefore to address this issue. The topic will be further explained and analysed in the section that follows.

3.2 Results of Experiment 2: Data Duplication Control in Overlapping RSUs' NDR

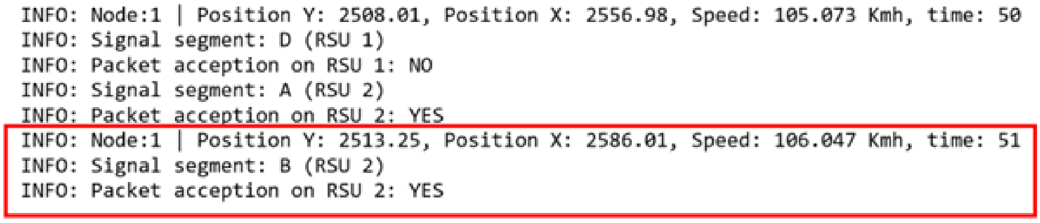
Experiment 2 results are analysed through the simulation event log of the V2R communication. The relevant snippets from the event log are presented in Figure 9 and Figure 10, which depicts the detection of location (segment) and time recorded for a vehicle upon entering and exiting an RSU. In relation to the event log extracted in Figure 9, at time t=42, the vehicle's presence is detected through its beacon coming from Segment C, and the current RSU, which is RSU 1, is still accepting packets. At time t=43, when the vehicle advances to the next segment, which is Segment D of RSU 1 that overlaps with Segment A of RSU 2, there is a handoff from RSU 1 to RSU 2, resulting in a "takeover" by RSU 2. This signifies that only 1 RSU is accepting the data within the overlapping segment, thus preventing any data duplication.



```
INFO: Node:1 | Position Y: 2464.77, Position X: 2319.92, Speed: 110.595 Kmh, time: 42
INFO: Node:1 | Signal segment: C (RSU 1)
INFO: Packet acception on RSU 1: YES
INFO: Node:1 | Position Y: 2470.53, Position X: 2349.51, Speed: 108.397 Kmh, time: 43
INFO: Node:1 | Signal segment: D (RSU 1)
INFO: Packet acception on RSU 1: NO
INFO: Signal segment: A (RSU 2)
INFO: Packet acception on RSU 2: YES
```

Fig. 9 *Event log as the vehicle enters the overlapping segments of RSU 1 and RSU 2*

Furthermore, it demonstrates a seamless handover between RSU 1 and RSU 2 in receiving messages from the vehicle. During this period of overlap, RSU 2 receives and handles messages from the vehicle, and has complete authority over the vehicle's actions as it completely leaves RSU 1's jurisdiction at t=51. Presently, the vehicle has been located within section B of RSU 2, as depicted in Figure 10.



```
INFO: Node:1 | Position Y: 2508.01, Position X: 2556.98, Speed: 105.073 Kmh, time: 50
INFO: Signal segment: D (RSU 1)
INFO: Packet acception on RSU 1: NO
INFO: Signal segment: A (RSU 2)
INFO: Packet acception on RSU 2: YES
INFO: Node:1 | Position Y: 2513.25, Position X: 2586.01, Speed: 106.047 Kmh, time: 51
INFO: Signal segment: B (RSU 2)
INFO: Packet acception on RSU 2: YES
```

Fig. 10 *Event log as the vehicle exits the overlapping segments of RSU 1 and RSU 2*

3.3 Results of Experiment 3: Extended NDRs

Figure 11 and Figure 12 presents the comparison of V2R communication between the vehicle and the RSUs along the simulated urban Federal Highway. The simulation is conducted twice, once with non-overlapping NDRs and another run with overlapping NDRs in Experiment 3 as illustrated in Figure 4 and Figure 5.

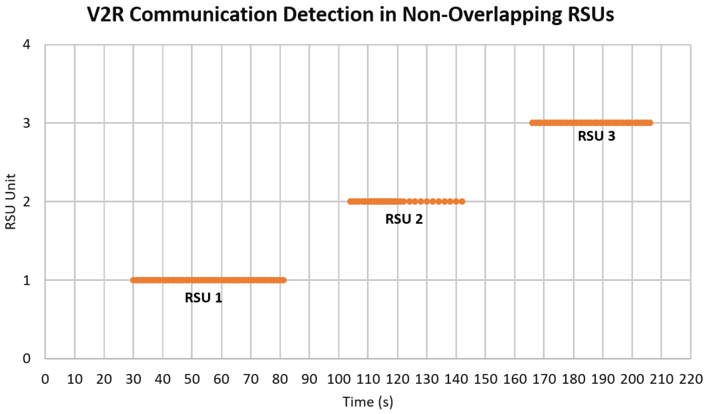


Fig. 11 *V2R communication within NDR in non-overlapping RSUs*

The V2R communication recorded for non-overlapping RSUs in Figure 11 demonstrates a period of time where there is no NDR coverage, indicating a discontinuity in V2R communication. This means that no data is being shared between the RSUs when the vehicle is outside the RSU's NDR. By comparing with Figure 12, it is evident that there are no gaps between RSUs. This emphasizes a continuous V2R connection as the vehicle passes each RSU. This highlights the extensive and prolonged utilization of the NDR, which entails the overlapping of the NDRs of the RSUs while also enabling a smooth transition between RSUs during handover.

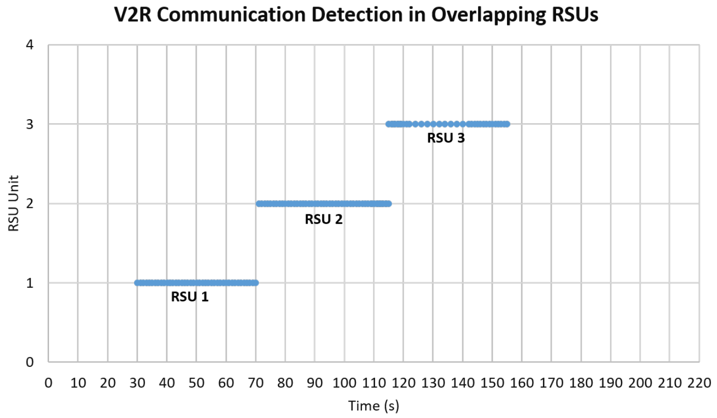


Fig. 12 *V2R communication within NDR in overlapping RSUs*

Consequently, the anticipated result of the SVLD development has been accomplished, as evidenced by the expansion of the NDR for the anticipated SVLD mechanism to increase the duration of connectivity. The absence of any interruption in V2R communication between the RSUs indicates a successful handover and continuous V2R coverage.

3.4 Results of Experiment 4: Reduction of RSU's Load in Received WSM Messages

Observation to compare the number of data packets received in effect to the SVLD overlapping RSU topology design is tabled out in Table 3 and visually presented in a histogram graph in Figure 13. The application of SVLD has led to a reduction in the quantity of received data packets by the three RSUs across various vehicle densities. The percentage reduction in received data packets with the implementation of SVLD remains substantial across different vehicle densities, ranging from approximately 34.15% to 41.43% within the density levels of 20 to 100 vehicles. This signifies that VANET could benefit in the overloading problem of the RSU with an average reduction rate of 36.40%.

Table 3 *Reduction rate in effects of SVLD in VANET V2R communication*

Density	Data packets received with SLD	Data packets received without SLD	Reduction rate (%)
20	454	710	36.10
40	1056	1803	41.43
60	1967	2987	34.15
80	2819	4351	35.21
100	3516	5418	35.11

Based on the simulation experiment results, it has been demonstrated that the use of SVLD in both topology and algorithm design is effective in eliminating gaps between RSUs, hence, facilitating proactive handovers, extending the NDR, and preventing message duplication. These factors collectively help to address the resource capacity problem in VANET.

Apart from implementing a control mechanism based on the positioning of the RSU, it is important to acknowledge that resource capacity may still be impacted during periods of high vehicular density, leading to traffic congestion on urban highways. In the event of severe traffic congestion, it is anticipated that the high volume of vehicles may generate an excessive number of messages to the RSU, potentially causing it to become overwhelmed and unable to fulfil any V2R task requests. Nevertheless, the presence of overlapping NDRs of the RSUs has already resulted in a decrease in the amount of data and task requests that can be handled. This is because when 25% of the NDRs overlap, it enables the transfer of 25% of the data from vehicles in the overlapping area to be seamlessly handed over to the next RSU, and evidently reduced an average of 36.40% of RSU's load.

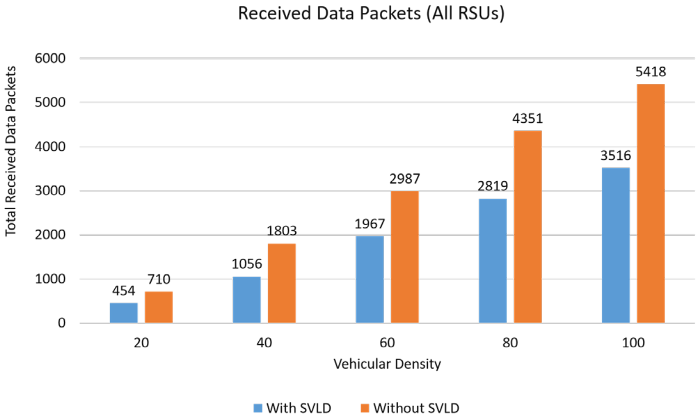


Fig. 13 *Reduction of total received data packets comparison*

4. Conclusions

In contrast to other works, the issues of V2R in the restricted 1000-meter RSU transmission range are an integral part of V2R communication in VANET architecture and are being addressed in this study. An overlapping RSU's NDR set on the urban highway is designed to provide V2R communication to any vehicles accessing the highway either in low or high velocity. Moreover, SVLD is proposed for vehicles to be able to receive the processed tasks it has given to the RSU even in mobility. SVLD bridges the perceived gap between RSU transmission ranges that would prevent vehicles from sending or receiving data or processed tasks, and eventually reduces the load of the RSU by 36.40%. This significant reduction reduces the chances of the RSU being overwhelmed with data packets especially during high vehicular density situations such as traffic congestion on an urban highway. In addition to vehicular density, the performance of V2R communication in VANET is significantly influenced by the data rate of the RSU and the size of data received from vehicles. These parameters also contribute to the impact on V2R performance as well as resource capacity. Therefore, additional factors, such as delay, throughput, packet delivery ratio, and most importantly resource capacity is recommended to be thoroughly examined and researched to enhance the suggested solution.

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Conflict of Interest

The authors declare that there is no conflict of interests regarding the publication of the paper.

Author Contribution

The authors confirm contribution to the paper as follows: ***study conception and design:*** *Nurshahrily Idura Ramli, Mohd Izani Mohamed Rawi, Mohd Faisal Ibrahim;* ***simulation and data collection:*** *Nurshahrily Idura Ramli, Mohd Faisal Ibrahim;* ***analysis and interpretation of results:*** *Nurshahrily Idura Ramli, Mohd Faisal Ibrahim;* ***draft manuscript preparation:*** *Rosanita Adnan, Noorhayati Mohamed Noor, Nur Atiqah Sia Abdullah. All authors reviewed the results and approved the final version of the manuscript.*

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