Hybrid VITS: Real Time Path Planning and Data Dissemination Mechanism in Urban Scenario

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A dissertation submitted to the department of Computer Science, Bahria University, Islamabad, as a partial fulfilment of the requirements for the award of the degree of Master's in computer sciences.

Session (2017-2019)

Thesis Completion Certificate

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Thesis Title: **Hybrid VITS: Real Time Path Planning and Data Dissemination Mechanism in Urban Scenario**

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I bestow my thesis work specifically to my husband and to all my beloved family fellows.

Acknowledgement

First of all, I am extremely thankful to God, who is the creator of the whole universe. He is the one who gave me power, strength and knowledge through which I am able to complete this research work. I would like to thank Dr. Awais Ahmad for his guidance and knowledge and his help during every step of my thesis. I will also like to acknowledge the support from my husband every step of my degree. I would not be able to complete this without his support. Thank you for your motivation and support. I owe you more than what I can mention. I am grateful to my mother for her prayers without which I can never achieve anything in life. Thanks to my whole family for their support.

Declaration of Authentication

I, Summia Taj hereby state that my MSCS thesis titled "**Hybrid VITS: Real Time Path Planning and Data Dissemination Mechanism in Urban Scenario**." is my own work and has not been submitted previously by me for taking any degree from this university

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At any time if my statement is found to be incorrect even after my Graduate the university has the right to withdraw/cancel my MSCS degree.

Name of scholar: Summia Taj

Date: 11-June-2019

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ABSTRACT

Vehicular Ad hoc Networks (VANETs) have fascinated remarkable interests due to their great applicability and viable significance. Path planning in VANETs based on efficient collection of real time data, which effectively mitigate the traffic congestion problems in urban areas. Real time data is shared in VANETS by using an effective sharing mechanism to avoid redundancy of collected information. However, dynamic path re-planning and effective sharing mechanism based on real time data are the still challenging problems. Therefore, first we proposed a novel data dissemination technique for information sharing among the roadside units (RSU) in hybrid VANETS intelligent transportation system (VITS). hybrid-VITS is comprised on VANETs, vehicular-traffic-server (VTS) and cellular system. Then, considering the traffic congestion in urban areas, optimal path is calculated to re-plan the path based on K-shortest path algorithm and RSU based load balancing technique is adopted to avoid further congestion generation. Furthermore, to validate the results information dissemination mechanism is implemented $C^{\#}$ and simulation is carried out in Omnet^{++} to assess the proposed path planning algorithm, by using real time traffic set-up and the map of Berlin city from urban area. The results demonstrate the proposed solution outperform the prevailing methods.

CHAPTER 1

INTRODUCTION

1.1 Introduction

As of late, development of VANETs have cemented the new ways for implementation of Intelligent Transportation System (ITS) [1]. ITS has picked a broad enthusiasm in academia and industrial investigation and it is the across the board solution for real time traffic management systems that incorporate the real time data collection and cooperation among the entities (vehicles, RSUs, and sensors) which collectively creating VANETs [2]. As VANETs are the auspicious factor of ITS for assisting abundant kinds of applications to recuperate traffic conditions i.e., preventing traffic congestion, road safety and finding optimal path to travel. Particularly, traffic congestion has converted to an emergent problem to be unraveled with the higher number of private cars in growing economy [3]. There is a need for high coordination among public transportation system and VANET because both influence the traffic condition. Conventional approaches are unable to resolve promising issues i.e., sudden congestion, real time information acquisition and so on [4].

In VANETs vehicle are outfitted with on board unit (OBU) and an RSU generally deployed at intersection of road [5] [6]and exhaustive communication capabilities are enabled among the vehicles and RSUs via V2V, V2R R2R to enable the efficient data delivery and information sharing [7] [8]. The efficient path planning relies on real time information acquisition and dissemination in non-neglectable delay [9] [10]. Conventional methods are infeasible due to utilizing historical data. Aforementioned methods are unable to provide information about sudden situations. It arises a high need for effective information collection and dissemination in a mobile environment. Transmitted information might be useless due to delay in information sharing. Consequential aggregated information can be used for real time vehicles path planning [11] [12], traffic flow management [13] [14], traveling time estimation [15] and localization of vehicles [16] [17]. However, the majority of the related works revealed the solutions dependent on strict suppositions i.e., perfect data delivery, well balanced RSUs capacity to handle requests and perfectly balanced traffic after re-planning the path, but in real scenarios this cannot be incorporated. Due to delay sensitive nature of VANETs information sharing delay is non neglectable. Furthermore, most of the existing solutions incorporate real time data to discover the ideal route individually for each vehicle in uncoordinated manners [18]. Which may lead to further congestion generation. Similar problem can be face after re-planning the path if appropriate mechanism is not used for balancing the traffic [19]. Although, the main concern of re-planning the path is to avoid the congestion by balancing the traffic. Therefor it is highly need for such solution which can accommodate these imperfections jointly i.e., algorithms for optimal path with load balancing to avoid the congestion and an effective sharing mechanism to avoid the repetition of transmitted information and instant delivery [20] [21].

To this aim, foremost we propose a novel real time data dissemination mechanism with minimum redundancy, lower complexity and rapid data delivery by assimilating numerous kinds of communications in VANETs i.e., V2R, R2R, V2V and V2S. Furthermore, a real time path re-planning technique that exploit K-shortest path algorithm to calculate the path in coordinated way and load balancing to avoid further congestion which is due to same path selection by larger number of vehicles. After sense the congestion, Vehicle requests for path re-planning to the Server via RSU. Calculated K-Paths send to the RSU and RSU further distribute the path to the interested vehicles to avoid the congestion.

1.2 Motivation and Problem description

- Real time information sharing about accident/traffic congestion is delay sensitive. Delays in sharing can make the information useless for a vehicle. Normally delay arrive due to complexity and redundancy of information.
- Real time situation is mater a lot in calculating the traveling time. Without considering such information calculate traveling time accurately is impossible.
- Detours and choosing the same path in path planning algorithm generate the further congestion rather than avoiding it.

1.3 Research Contribution

- Initially, we propose a novel data dissemination technique based on RSUs in Hybrid VITS by assimilating numerous kinds of communications in VANETs i.e., V2R, R2R, V2V and V2S, and provide minimum redundancy, lesser complexity and rapid data delivery.

- A realistic time calculation method is proposed which is based on density of vehicles on each road segment. The corresponding RSU will acquire the traffic information of road segment related to itself and calculate traveling time for that road segment.
- An RSU based Congestion avoidance method is proposed which consider the total road length and density of vehicles as the important metrics for measuring road capacity. And then distribute the calculated path among vehicles according to the capacity of road.
- Finally, we design an algorithm to calculate optimal path after congestion generate. Which calculate the alternative paths based on real time traffic information and digital map. We exploit K-shortest path algorithm to calculate the path and load balancing to avoid further congestion which is due to same path selection by larger number of vehicles. After sense the congestion, Vehicle requests for path re-planning to the Server via RSU. Calculated K-Path sends to the RSU and RSU further distribute the path to the interested vehicles to avoid the congestion.

1.4 Thesis Organization

The organization of thesis is as follows. Chapter 2 presents state of the art, that has carried out for the information sharing mechanism, real time path planning and traveling time estimation in VANET. Furthermore, limitations from each solution is portrayed. Chapter 3 highlight the methodology of the proposed scheme. Chapter 4 determines the validity of proposed scheme by showing the results and its comparison with state-of-the-art algorithms.

CHAPTER 2

LITERATURE REVIEW AND BACK GROUND

2.1 Background

VANET is the subcategory of MANETs (mobile ad hoc networks). It plays an important role in cooperative traffic managing. Traditionally, every vehicle in VANETs act a separate router or participating node. nodes connect to other nodes as come in communication range of each other, as vehicles fall out of communication range drop out the network and new nodes fall in communication range and get connected.

Traditional VANETs comprised on vehicles, RSU and communication links between both of them V2R, V2V and R2R, and vehicles are deployed with OBU. VANETS are aiming at transportation life more intelligent, luxurious and convenient i.e., traffic monitoring, early warnings about congestion and accidents. Entertainment facilities, stats about economic concerns like fuel consumption etc.

- **Application of VANETs**

  Some of the important application are summarized as follow:

  - **Safety in traveling**

    One of the major applications of VANET is safety. To avoid or reduce number of injuries and fatalities early warning about upcoming hazards, congestion and about risk of accidents are used to make traveling safer.

  - **Efficiency in traveling**

    Avoid congestion, lesser consumption of fuel and reduce traveling time are the major applications which may achieved via VANETs for efficient and safer traveling.

  - **Convenient traveling**

    Convenient traveling includes comfort and luxurious service via VANETs, which may make traveling more convenient like, collection of E-toll, advanced travelers information system etc.

- **Characteristics of VANETs**

Some of the important characteristics are summarized as follow:

- **Variant topology**

Topology is always dynamic in VANETs. Connecting nodes may make different topology every time due to high mobility of nodes in network. nodes connect to each other for a very little time due to high speed and mobility.

- **Variation in connections**

High mobility and rapid topology change cause the higher variation in connections among the node. So many disconnections in links between the vehicles may arrive.

- **Mobility constraints**

For realistic implementation of VANET a mobility model is very crucial which must show the realistic patterns of mobility of node/vehicles in different traffic scenarios.

- **Foreseeable mobility**

In VANETs road and highways are pre-defined so mobility can be predictable. Which make network design more convenient and flexible.

- **Integration of new technology**

Adoption and integration of new technology in VANETs is beneficial. Like security cameras, GPS etc. make more convenient and reliable.

- **Free of power constraint**

VANETs are luckily have privilege of long-lasting battery life for efficient and better processing capabilities i.e., routing in network.

- **Delay sensitive constraints**

In case of any emergency VANETS are responsible for delivering the critical messages to the corresponding society without any hassle. To provide urgent aid and to save human lives.

2.2 State of the Art

Conventional ITS owns lots of challenges which includes traffic congestion due to accidents or density of vehicles on road, information sharing delays and so on. Which arises many other challenges related to aforementioned problems i.e., late arrival, extra energy consumption and unbalanced usage of ITS resources etc. However, these issues can be overcome by optimal path planning, accurate and rapid information sharing among different entities of ITS. Many works presented in literature to solve the aforementioned issues [13,16]. For example, Delay in traffic information sharing in VANETs can be reduce by employing traffic signal operation in bidirectional roads [22] [23]. The developing of VANET creates the swift real-time traffic information sharing achievable in ITS. Traffic information sharing in real time is swifter and more competent by exploiting V2V and V2R communication [24] [25].

An information sharing technique is proposed with lower complexity and redundancy in the distributed transportation system for sharing data among the RSUs. Furthermore, a dynamic path planning algorithm based on Traveling Time Estimation (TTE) is presented to escape the traffic congestion, which is based on drift-plus-penalty-framework and backpressure policies. To achieve the optimal results in revising and re-planning the path vehicles are assigned with weights. Vehicles with higher weights are dispatched first which is impractical in real scenarios [9,11] [26]. In VANETs sharing information among entities is a delay sensitive application that require efficient & accurate sharing. To resolve the matters like longer latency and higher collision, an efficient data broadcasting system is proposed established on clustering and probabilistic broadcasting [27] [28].

To reduce the path length and travel time a path planning strategy is proposed. Traffic information collected in real time is used to dynamically calculate the path that provide the shortest path with minimum travel time. RSUs are connected to a central server which calculate the shortest path on request. Proposed method is evaluated on the root of vehicles density based on travel time and end-to-end delay. Non presence of effective data dissemination, lack of reachability, higher end-to-end delay are some open issues to resolve [29].

Another real time approach is used on the base of path planning to escape traffic jam and congestion in urban areas. Thus, an intelligent traffic system CHIMERA is proposed with a congestion prevention system through a traffic taxonomy and a re-routing algorithm, it expands the whole spatial utilization and decrease the vehicle's average travel. Along with these achievements some open concerns are still there i.e., un-cooperative routing, Localized communication range among RSU and vehicle, unconnected RSUs and Detour in re-planning the path [30].

A Lyapunov optimization-based path planning algorithm, which exploits the real time data for planning to achieve the maximum spatial utilization and minimum average vehicle's travel cost [14,18]. Similarly, to overcome the traffic congestion at the road intersections adaptive and intelligent traffic lights scheduling method is proposed by using the traffic light sensors information as a response to lessening time of red light. By considering the vehicular density, average speed and position an appropriate red-light time is obtained [31] [32]. Table 1 represent the comparative analysis of state-of-the-art solutions.

Table 1: comparative analysis of different Real rime path planning in VANETs.

Sr. No	Ref	Objective	Technique/Method	Advantages	Drawback
1	[9,11]	• Real Time path planning • Information sharing method	• Drift-plus-penalty • Backpressure policies	• Lower complexity • Lower redundancy	• Limited RSU capacity • Detour • Unfair path distribution
2	[17,29]	• Real time Path Planning	• Bellman-ford	• Reliable route	• Broadcast storm • Congestion after re-planning
3	[18,30]	• CHIMERA	• K-NN • K-shortest path • Boltzmann probability distribution	• Detect congestion • Balance distribution	• Un-cooperative routing • Unconnected RSUs • Detours
4	[14,,18]	• Hybrid-ITS • Real time path planning	• Lyapunov optimization	• Improved spatial utilization • Reduce average vehicle travel cost • Avoid congestion	• Evaluation is made on strict assumption. • Increased AMD in density • Redundant information collection at server
5	[19,27]	• Data Dissemination scheme	• Clustering • Probabilistic forwarding algorithm	• Good performance in term of average message delay & packet delivery	• Traffic intensity influenced the results
6	[16,,22]	• Data delivery delay reduction	• Routing Choice Algorithm in Grid Topology	• reduce the data delivery delay	• Not considered RSUs
7	[15,19]	• (CBL) among RSUs	• on-demand real-time scheduling algorithm	• minimum load transfer rate	• higher overall request drop rate.
8	[22,33]	• MCBL	• on-demand real-time scheduling algorithm	• maximization of system performance	• requests deadline miss ratio in higher work load

CHAPTER 3

METHODOLOGY

In this chapter a methodology of real time path planning and information sharing mechanism is discussed in detailed. Intending at specifying real time information collection and sharing, and path planning for vehicles, a network architecture is exploited via global perspective in the intelligent transportation system. furthermore, traffic flow model, road network and other basic assumptions are elaborated. In Table 1 the summary of notations used is given.

Table 2: Summary of notations

Symbol	Details
I	Set of all intersection
S	Set of road segments
R	Set of RSUs
V	Set of Vehicles
TTx	Calculated traveling time
δ	Congestion indicator
$O_{vi}(T)$	Outflow rate of vehicles on intersection i in sample time T.
$I_{vi}(T)$	inflow rate of vehicles on intersection j in sample time T.
σ	Speed constraint
t^{w}_{r+g}	Traffic signal time
t_o	Interval for path re-planning
t_d	Time Interval for A-periodic updates
τ	Congestion removal time

3.1. Overview

The proposed work aims to develop a path re-planning algorithm based on real time data to prevent congestion. Furthermore, a novel real time data dissemination mechanism is proposed to achieve minimum redundancy, lower complexity and rapid delivery of data among RSUs in the hybrid VITS. While taking into account the real time information, traveling time is calculated using proposed method which depict the realistic traveling time for a source to destination. While state of the art solutions have plenty of imperfections which includes information sharing mechanism at RSU share data redundantly and in a complex manner, congestion generation due to choose the same path by a large backlog of vehicles which leads to change the congestion from one road to another rather than avoiding it. We exploit K-shortest path algorithm to find the optimal path and avoiding the congestion. To avoid the redundancy and complexity, a novel information dissemination method is proposed to achieve the rapid data delivery. Figure 3.1 illustrating the whole system process.

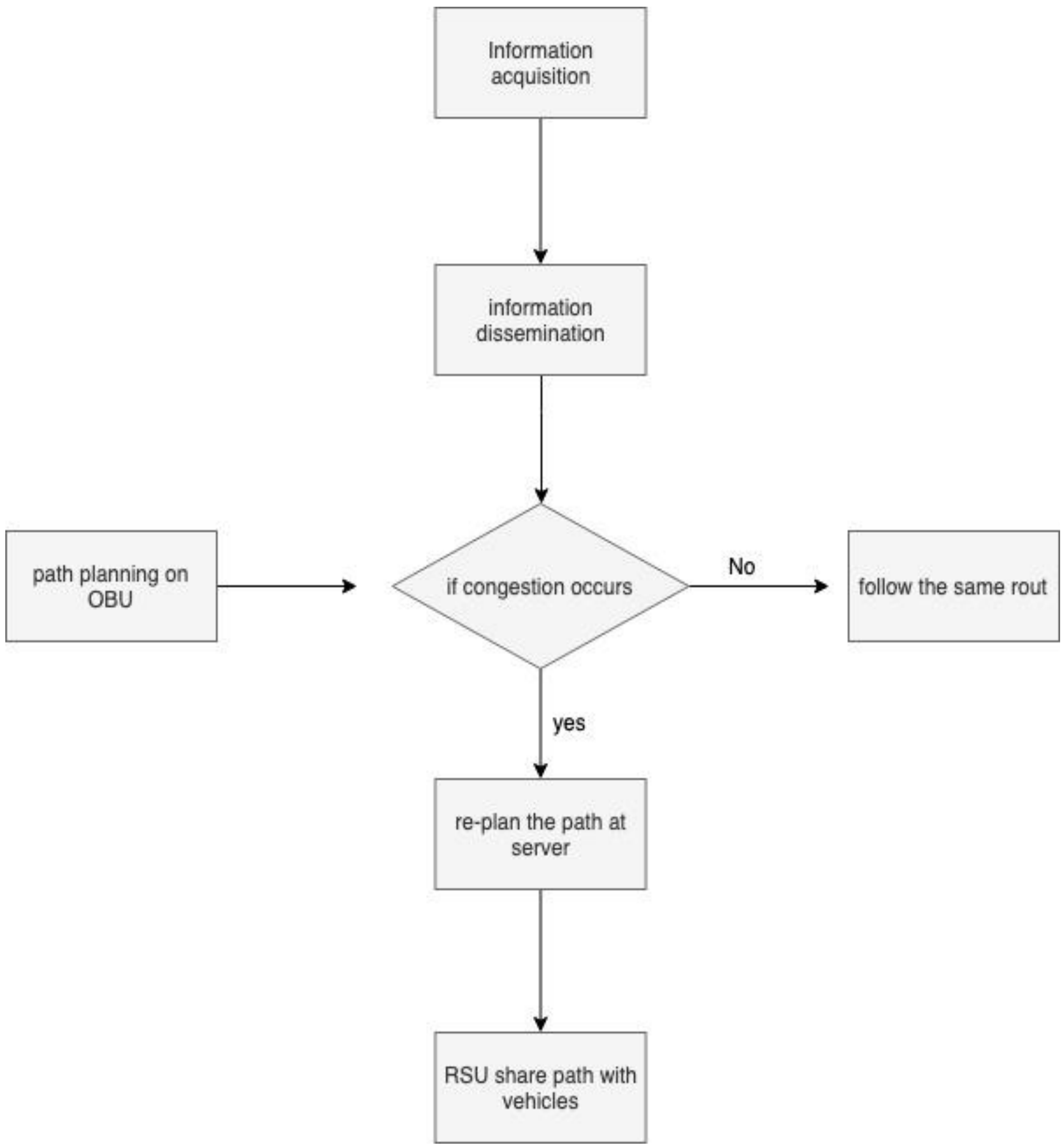


Figure 3.0.1: illustration of system process

The Hybrid VITS comprising of following major parts:

- Vehicles
- RSU (road side unit)
- Vehicular-traffic-server
- Taxi (super-node)
- Cellular BS (base station)

Real time path planning and efficient information sharing are important factors of ITS. Plenty of research has been carried out to achieve the beneficial results in terms of optimal path planning to avoid the congestion and rapid information sharing while minimizing the delay to achieve rapid data delivery among the vehicles, RSUs and entities of public transportation system. In spite of such development many concerns are open for further investigation.

3.2. Hybrid-VITS (VANETs Intelligent transportation system)

Considered hybrid VITS architecture is shown in Fig 3.2, comprising of vehicles, RSUs, VTS and a cellular base station (BS). Vehicles are attired with OBU, which is responsible for V2V and V2R communication among vehicles and RSU. Vehicles sense and send the periodic information (i.e., vehicles velocity, density and location) to the vehicles and with the nearest RSU as well. Furthermore, a cellular [18] public transportation system which consists of mobile telemonitoring and management of Taxies is also implicate. Once the vehicles sense the congestion, a warning message will be generated and shared among RSUs. If a Taxi (super node) gets the warning message it directly uploads the warning alert to the BSs and BS forward the message to the VTS. While RSUs share the warning message (containing road segment ID and congestion indicator) to other RSUs by our proposed sharing mechanism and to the VTS.

The RSUs are installed at each road intersections, responsible for real time information collection via V2R communication. R2R communication is adopted to share information among RSUs by exploiting our proposed sharing mechanism. Two type of information stored in RSU's cache i.e., periodic (length of road segments in digital map, information of road intersection and traffic lights intervals) and A-periodic (accident/congestion) information. A-periodic information is shared proximately while periodic information is shared after a scheduled time.

Vehicles enters at a road segment and request for information to the RSU. speed cameras, loop detectors deployed along with RSU are used to gather information. Periodic information will be obtained via V2R communication. All entities of system are supposed to use 5G cellular system for communication among each other.

Initially vehicle calculate the path from source to destination in OBU by using GPS and digital map and follow it until an A-periodic information is not received by nearest RSU. When vehicle received a warning message it will send request for re-plan the path to the RSU and RSU forward the requests to the server. The server will calculate the alternative paths and send back to the RSU and RSU will dispatch the vehicles backlog according to load balancing method.

When a vehicle sense the congestion, warning message is send to the server by two mode to ensure the reliability. First, if vehicle find a closer super-node considering as a relay node. Secondly vehicle share this information with the RSU to ensure the message delivery to the server. If multiple taxies are there in the range of a vehicle, the closer super-node will be find to make a relay node. This is beneficial in case when a vehicle is not in an RSU 's communication range. In case when nor an RSU neither Taxi are there in the communication range then vehicle will adopt the carry and forward mechanism to share the information.

Moreover, the road network is categorized as four components N= {I,S,V,R}, where I denote the set of all intersection, S be the road segments in road network, bidirectional road are considered. V is a set of vehicles and R defines the all RSUs respectively. Table 1 shows the description of notations.

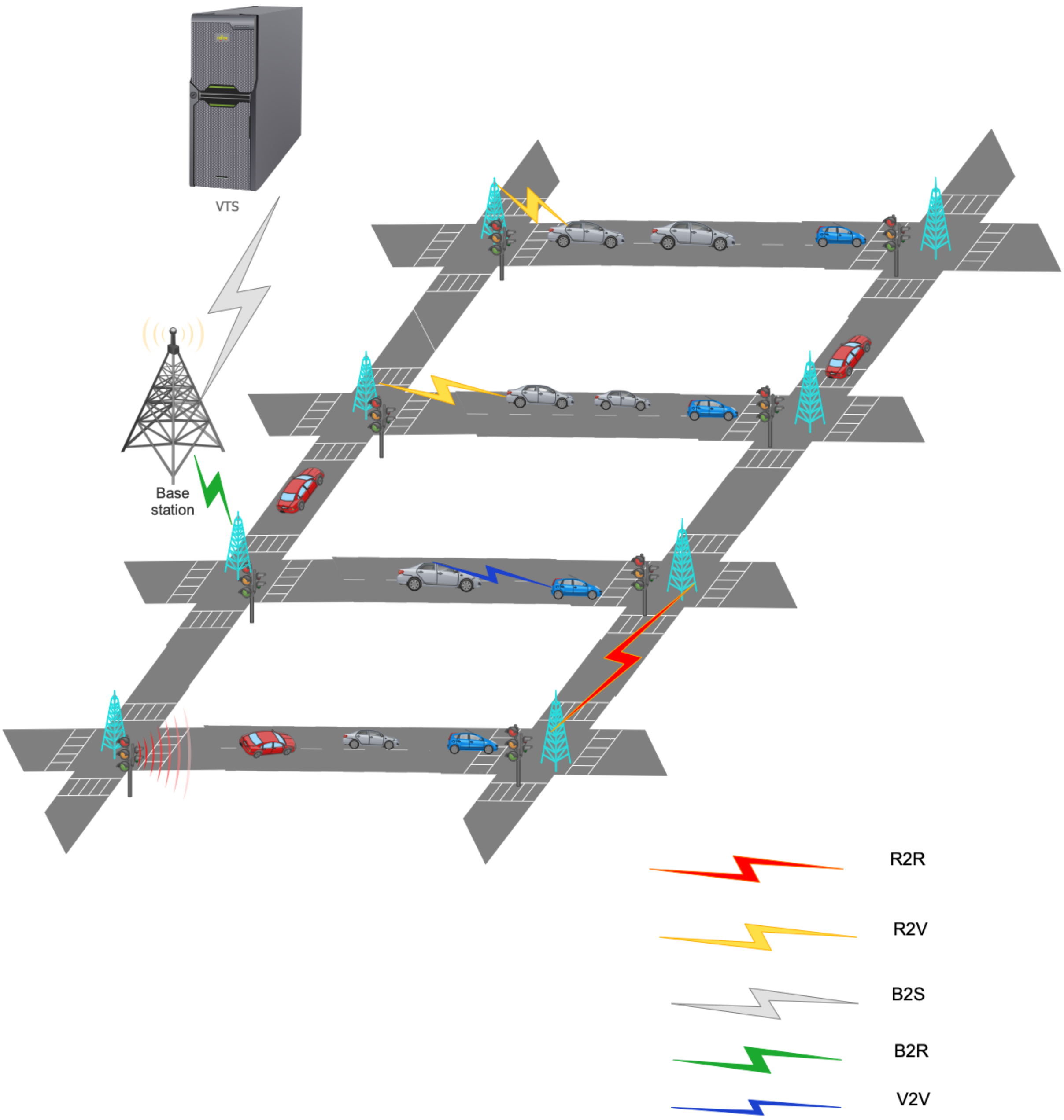


Figure3.0.2: Hybrid-VITS system architecture

3.3. Traffic Flow Constraints and assumptions

Congestion indicators are used to send warning message to the VTS. Two types of congestion are considered in the scenario accidental and non-accidental. It takes the two values 1 and 0. 1 for accidental and 0 for non-accidental.

$$\delta = \{1,0\} \quad (1)$$

Congestion removal time τ is defined as the expected time to remove the congestion. τ is for accidental congestion is 15 minutes and of non-accidental τ is 9 minutes.

$$O_{vi} = \text{outflow rate of vehicles}$$

$$I_{vi} = \text{inflow rate of vehicles}$$

For smooth traffic on road segments the traffic flow constraints need to be satisfied. Inflow rate on intersection i and out flow rate on intersection j for a road segment i to j must be equal in a sample time T.

$$O_{vi}(T) = I_{vi}(T) \quad (2)$$

It must be satisfied for each road segments. RSUs are known with full road capacity and traveling time of road segment *i to j* in average speed.

3.4. Real Time Data Dissemination Scheme

In this section, a real time data dissemination scheme is presented. Information sharing among VANETs is very crucial due to its delay sensitive nature and importance of real time information acquisition and sharing among the whole network. Late arrival of information can't be affordable. Real time data dissemination scheme is used to share data among RSUs which are deployed at road intersection in the road network. The presented mechanism is low in redundancy and complexity.

3.4.1. Algorithm Desighn

Two type of information kept at RSU cache categorizes as periodic information and A-periodic information. Periodic information is referred to as the static information which contains road segment ID, length of road segment and traffic light status. After some intervals this information is shared among RSUs in the whole network. For A-periodic information (i.e., accident or congestion), the RSUs share immediately as it received rather than waiting for updating interval. The conventional method of information sharing is broadcast, which lies few imperfections which include redundancy of shared data at RSUs. Every RSU receive redundant information packets from all RSUs over the network. It is also higher in complexity and increased sharing delay due to which for some RSUs information become useless when it received. To this aim, we proposed a data dissemination mechanism to share the information among RSUs in a unique way. It works on the base of direction parameters. first sharing originated by source RSU will be in two directions to the RSUs in upstream and downstream intersections. The receiver RSUs further share information in one direction, The RSU in upstream direction will share information in upstream and the one in downstream will forward in the downstream, assure the coverage, non-redundancy and rapid delivery. Upstream and downstream are defined on the basis of RSU 's ID. At each interval only two RSUs receive the information assures the coverage, rapid delivery and avoid the useless sharing.

Algorithm1. Information dissemination scheme among RSUs.

```
begin
input RSU= {R1, R2, R3,...Rm*n}
Empty S= {S1, S2, S3,....Si} //sharing table
input source RSU= Rs
if Update period=0
{
       //first time sharing
       If (each Ri is in grid topology)
          s1={Rs+1, Rs-1}


        //i+1th sharing
       For(i>=1:i<=m*n;i++)
               {
                Rk=Rs+1
                If (Rk>Rs)
                 Si={Rk+1}
                 Rk=Si
                }


       // i-1th sharing
           If (each Ri is in grid topology)
              For (j<=Ri: j>=1; j--)
                 {
                   Rp=Rs-1
                   If (Rp<Rs)
                   Si={Rk-1}
                   Rk=Si
                  }
output sharing table S= {S1, S2, S3, .... Si}
 }
```

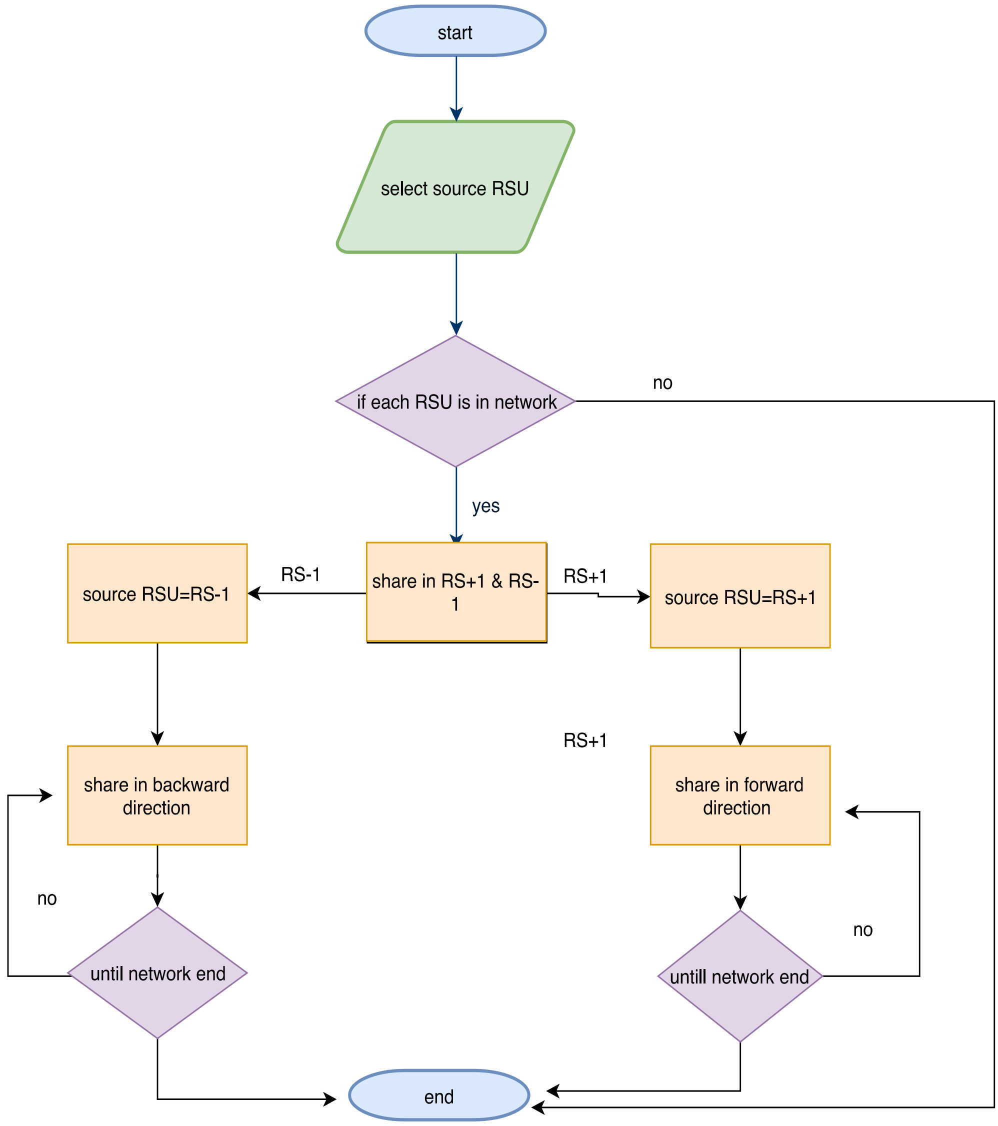


Figure 3.0.3 : information sharing process illustration

3.4.1. Information dissemination scheme steps

The information sharing scheme have four steps.

1. **Set the network parameters and RSUs will be define in this step:**

Consider an *n × m grid* road topology, as discussed RSU will deployed at each intersection it means n × m RSUs in the topology. RSU id is the number of RSU in grid topology and it is assigned row by row. For example, RSU1 to RSU n × m. The beacon message send by source RSUs contains Last RSUid, current RSUid, road 's ID where congestion is generated and the congestion removal time τ.

a. **First sharing:**

the source RSU_s share the message in two directions only. For example if receiver RSUs are RSU_a and RSU_b , source RSU_s decide the next RSUs by $RSU_a = RSU_s (ID) +1$ & $RSU_b = RSU_s (ID) – 1$.

b. **Second sharing:**

Second time sharing will be originate by RSU_a & RSU_b , which means the receiver RSUs in first sharing will be the source in next sharing. In this step RSU will forward the message to only one direction. The receiver RSU check the sender RSU's ID if it is greater than its own ID it will share in downstream, and if it is larger than its own ID it will share in upstream.

c. **Look forward for next RSU:**

   a. the receiver RSU must be the part of topology, we assume that each RSU have prior information about grid topology. for each Ni $\in$ {R}.

   b. the distance between existing road segment and the source (the road segment where initially warning message generated must be less than the congestion removal time, as it assures that the sent message is useful for a road segment or not $\sum_{k=s}^{i} TTx\text{k} < \tau$

c. repeat the steps 3 and 4.

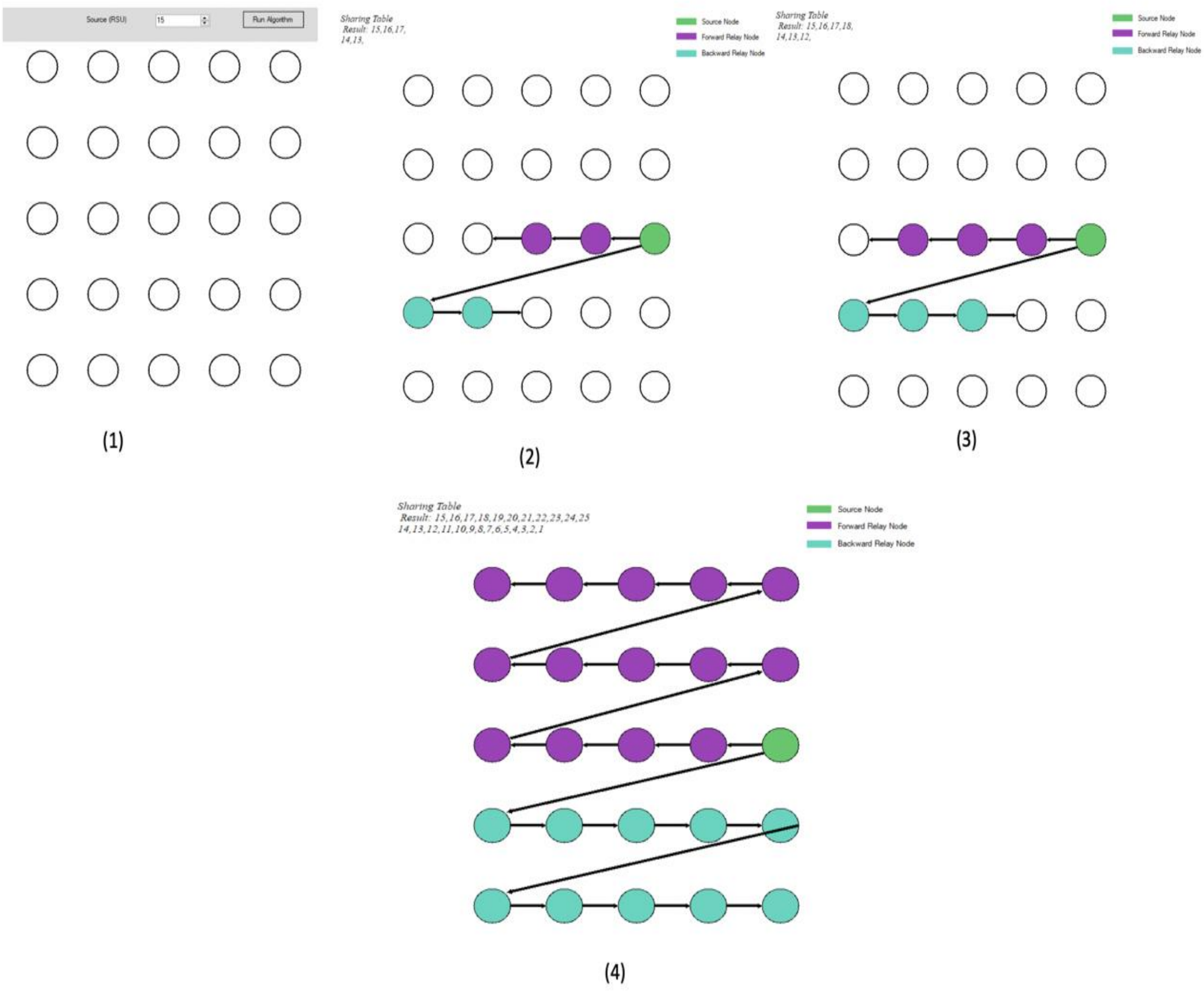


Figure 3.0.4: Data Dissemination scheme in 5 × 5 grid topology. (1) shows the Grid topology of RSUs (2) The RSU disseminate the data in two RSUs in the first iteration. (2) next two RSUs forward the data to only one direction. (3) similarly, process will continue (4) shows the complete sharing directions and sharing table.

3.5. Traveling Time Calculations

Once the vehicle enters on the road, it acquires real time information from the RSU about the downstream road segments. On the basis of acquired information the OBU calculate the optimal path from source to destination as shown the whole process of traveling time in figure 3.6. The real time information is gathered at RSU which is comprised on calculated Traveling Time.

Traveling time is calculated from intersection to intersection considering the vehicle's density on road segments. RSUs use the speed cameras deployed along the road segment. RSUs acquire average vehicles speed over the time interval on corresponding road segment. On the basis of which density is decided. So, the traveling time is considered the length of road segment, density of vehicles and speed metrics acquired by speed cameras. The realistic vehicles speed gathered on real time gives the accurate information and help out the calculating realistic traveling time.

It uses the two metrics for calculations as shown in figure 3.5.

A. traveling time on road segment t_{ij}.
B. waiting time at each traffic light t^{w}_{r+g}.

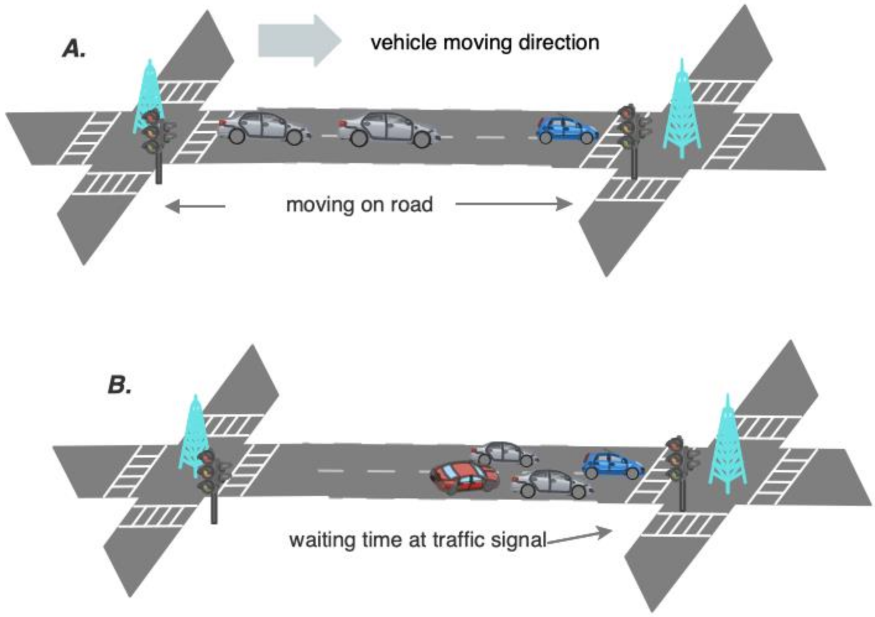


Figure 3.0.5 Illustration of traveling time calculation on a road segment

3.5.1. Traveling time on road segment

In the traditional method traveling time is calculated on the base of road segment length and number of vehicles on that road segment. It does not consider the realistic variations in density on that road segment. Density effects the velocity of vehicles. It may lessen or increase the traveling time. Density is decided on run time by acquisition of real time vehicles velocity by speed cameras. It is assumed that RSU is known by the average capacity of corresponding road segment and that average capacity is considered the threshold for density measurement. The RSU acquire real time information about density and update it on each interval. Traveling time is calculated on the basis of density of vehicles on road, if the density is high traveling time on road segment *i to j* take more time than average time. On average density it takes the average time to travel and in case of lower density it covers the distance in lesser time.

Density is defined on the bases of speed constraint σ, which take the tree values α,β,γ .

σ (α) = if speed is between (10km/h-20km/h) → high density

σ (β) = if speed is between (20km/h -40km/h) → average density

σ (γ) = if speed is between (40km/h-70km/h)→ low density

Aforementioned speed constraints are assumed for the traveling time on straight road segment R_{ij}. The traveling time on a road segment R_{ij} is calculated based on real time information is

$$t_{ij} = \frac{L_{ij}}{1 + vij(\sigma)} \tag{3}$$

Here, t_{ij} is the traveling time on road segment R_{ij}. L_{ij} is the length of road segment

When RSU acquired real time information from road side speed cameras on certain time intervals. Furthermore, processed acquired information to find the outcome in terms of traveling time on that road segment. If average speed is between 10-20, it indicates that vehicles density is high. Similarly, if average vehicles speed at a time interval is 20-40, it shows the average density on road. In case of 40-70 speed outcome is low density. If we consider the traveling time for a road segment R_{ij} in case of average speed is 8 minutes. For same road segment if density is low traveling time will be reduced accordingly from 8 minutes to 5 minutes and increased from 8 minutes to 11 minutes in case of higher density.

- **Waiting time on traffic signal.**

Waiting time at a traffic signal is time of red light + green light. Status of red light and green light is demonstrated by a Boolean function

$$\xi(t)\begin{Bmatrix} 0, \ green \\ 1, \ red \end{Bmatrix} \qquad (4)$$

It is assumed that the waiting time for a traffic light t_1 period is fixed, and if the waiting time is exceeded than t_1, congestion is considered to be occurred at that intersection. Congestion can be occurred along the road segment due to heavy density and traffic accidents.

- **Waiting for 1 traffic light period**

If the vehicles wait for only one traffic light period, then waiting time is measured as

$$t_j^w = t_1 - t_s \qquad (5)$$

Where t_1 is time of red light plus time of green light, and t_s is the start time of traffic light period.

- **Waiting for more than 1 period at traffic light**

when the vehicles waiting time is exceeded than t_1 . congestion is considered to be occurred, so its time is added to the total waiting time. As we mentioned earlier congestion indicator δ takes the two value 0 and 1. 0 is for accidental and 1 for non-accidental. Congestion removal time is also assumed to be fixed, for accidental congestion 9 minutes and 6 minutes for non-accidental.

$$t_j^w = (t_1 - t_s) + \tau \quad (6)$$

Here, τ is the congestion removal time. t_s is the starting time of traffic light interval. And t_1 is the total time taken by red and green light.

Aggregately, they traveling time is combination of traveling time on road segment and waiting time on traffic lights at road intersection. Thus, the traveling time calculation is

$$tt_c = \sum \left[\frac{L_{ij}}{1+vij(\sigma)}\right] + \sum[(t_1 - t_s) + \tau] \quad (7)$$

The equation 7 ttc represent the traveling time calculation strategy on a road segment ito j. The first half of equation $\sum \left[\frac{L_{ij}}{1+vij(\sigma)}\right]$ is representing the traveling time on road segment. L_{ij} is the length of road segment and $vij(\sigma)$ is the density of vehicle is on that road segment. 1 is the adjustment parameter. Similarly, remaining part of equation is elaborating the time spent on traffic signal and the estimated time for congestion removal. If the congestion indicator is on the parameter τ will take the congestion removal time, which is predefined, and it takes 0 if the congestion indicator is off.

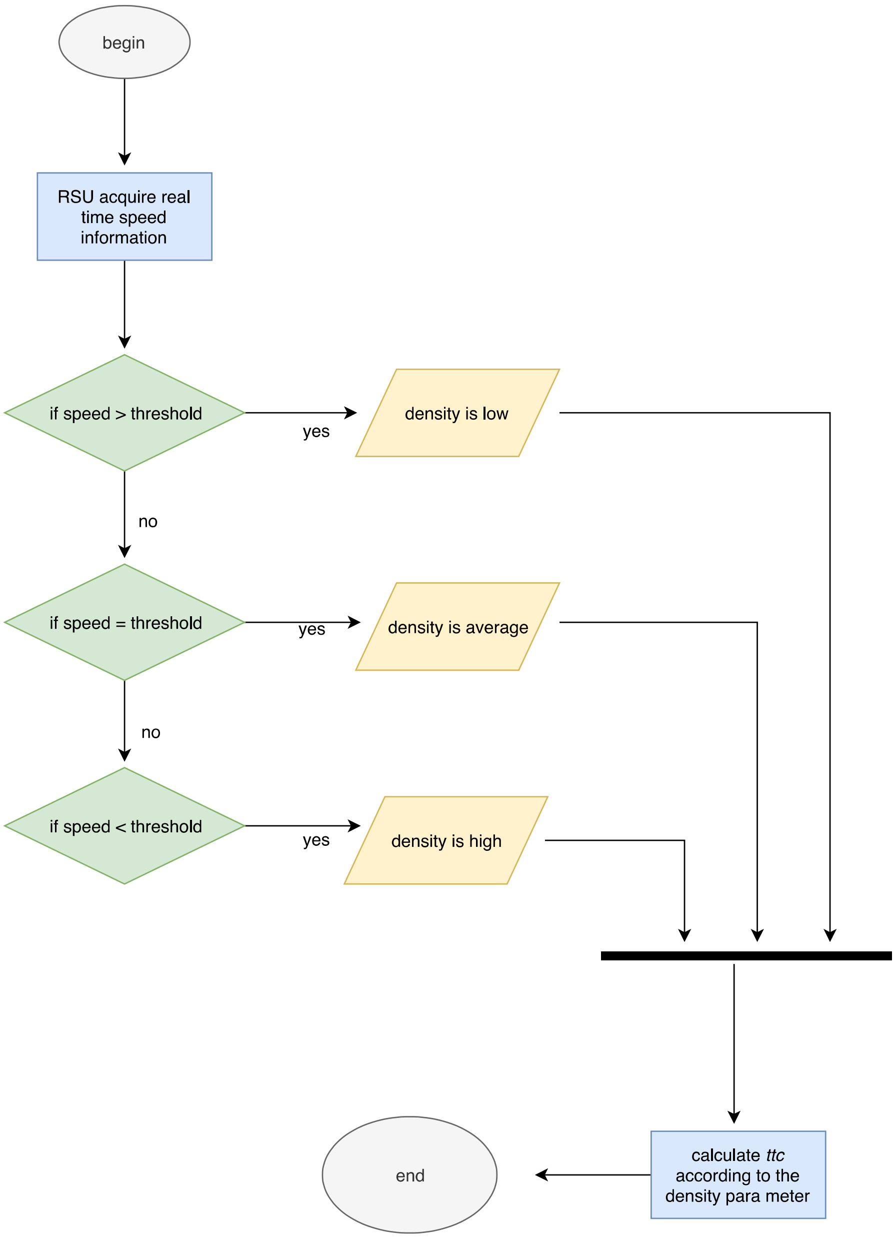


Figure 3.0.6 traveling time calculation process flow

3.6. Real Time Path Planning

In this section, real time path re-planning is proposed to provide the assistance of re-planning the path via sending a rout re-plan request to the VTS via nearest RSU. As it is mentioned earlier initially path is planned on the OBU individually by each vehicle while path re plan is calculated on VTS cooperatively by considering the real time information about road side i.e., vehicles density road capacity and other emergency situations. Which will helpful to avoid further congestion. Existing systems have such imperfections that they re-plan the path individually for each vehicle so it may create further congestion due to choosing the same path. On receiving the congestion alert VTS plan the path conferring to the real time traffic information acquired by RSUs and Vehicles. The latent issue of choosing the same path selection by a heavy backlog of vehicle cause the further congestion on new selected road segment is addressed as well.

3.6.1. Algorithm Design

Once the vehicle gets the congestion information it requests to VTS for revising the path, request will be forward by nearest RSU. VTS re-plan the path based on real time data collected by RSUs. Sudden accidents or congestion information is shared among RSUs by using proposed dissemination mechanism, it also shared with server. Upon receiving request server calculate the k-shortest paths and dispatched to the corresponding RSU, Now RSU dispatch these paths to the vehicles stuck in congestion on the bases of first come first serve. Additionally, RSU will use a counter if it dispatches the vehicles to the same route with same destination according to the road capacity (assumption: RSU knows each road capacity) and further vehicles will assign the next calculated path. Thus, further congestion will be avoided by using this mechanism.

Path re-planning is used only when A-periodic information will be updated.

$$t_0 = t_d$$

t_0 is the interval of path re-planning, where t_d is the updating time for A-periodic information.

Based on assumption real time path re-planning can be formulated as:

a) Assumed:

1) N={T}, N road network set is given, which provide basic road information.

2) Updating frequency $t_0 = t_d$.

3) Source and destination point.

b) Objective:

1) Find the K-paths K* from source to destination.

c) Subject to:

1) For all K$\subseteq$N

2) TT_χ is calculated for all road segments

3) K* paths must be satisfying:

$TT_\chi K = min_{s \to d}(TTx_{K1} \ldots \ldots TTx_{Kn})$

Path planning algorithm works on re-planning the path only when A-periodic information is updated. It uses the traveling time on a road segment as the main metric for calculation of total traveling time from source to destination, by taking into account traveling time of each participant road segment from source to destination. The traveling time is calculated according to the equation 7. Algorithm 2 shows sketch of proposed path planning algorithm.

Algorithm 2: Path re-planning using k-shortest path

begin
//initialization//
Input road network topology N= {S, T}
A contender set of intersections $I_C = \emptyset$;
for each intersection $i \in I$ **do**
  Acquire ttc_{ij} of contender intersection;
    update the set $I_C \leftarrow I_C \cup \{i\}$.
end for

// get real time information from RSUs of participants road segments

Input I_C set of contender intersections
Get real time information of requesting vehicle (s, d, velocity, current position)
s → current position

  //update time of A-periodic information
    if(td==true)

      Find K* Shortest path (s --> d)
        K* paths must be satisfying:
          $TT_{\chi}\kappa = min_{s \rightarrow d}(ttc_{K1} \ldots \ldots ttc_{Kn})$
  share path with requesting RSU

    end if
end

3.7. Congestion Avoidance

Congestion avoidance is a very crucial part of traffic management and path planning. Traditional path planning methods do not consider the congestion removal while planning a path, which cause the further congestion generation or in other words congestion is moved to another place rather than avoiding it.

Besides the path re-planning, we present an RSU based method for congestion avoidance. As discussed earlier, vehicle request for alternative path to the closest RSU when got a warning alert about congestion, accrued due to accidents or traffic jam etc. The RSU further pass the path request to the server, and server re-plan the path by combining the road segments having lesser traveling time from prescribed source to destination. It calculates the K paths and forward them to the requesting RSUs. Now RSU got the k calculated paths while k=3 in our scenario. The shortest path will get the higher priority and remaining are followed by it according to the priority.

It is assumed that each RSU in the network have prior knowledge of road capacity. Road capacity is defined as the possible maximum number of vehicles on a road segment, which can utilize that road segment without any delay or hassle.

$$R.C = \sum_{i=1}^{n} \frac{ln^{ij}}{V^{ij}} \quad (8)$$

R.C defined as the road capacity. l^{ij} is the length of a road segment. And summation of length of each lane on a road segment. For example. A road segment R_{ij} have four lanes and each lane capacity is 10 vehicles on a time interval. So total 40 vehicles can utilize that road segment in a time interval. In a specific time interval, if 40 vehicles assigned with that road segment, indicates that if more vehicles utilize that road segment cause the higher risk of congestion. Which is strictly needed to avoid.

So, if a road capacity is 15 vehicles, and RSU distribute the 1^{st} shortest path among 15 vehicles and furthermore vehicles are requesting for path, RSU will switch to the 2^{nd} shortest path and so on.

Congestion avoidance method is formulated as:

Given:

1) N={T}, N road network set is given, which provide basic road information.
2) Calculated K paths
3) Source and destination points

Objective:

1) Distribute K paths among interested vehicles

Subject To:

1) For all K paths
2) RSU distribute k^1 path to interested vehicles until R.C is not full
3) When R.C is full RSU switch to K^2 path, similarly until its capacity is not.
4) So on.

CHAPTER 4

SIMULATION, RESULTS & DISCUSSION

4.1. Simulation setup

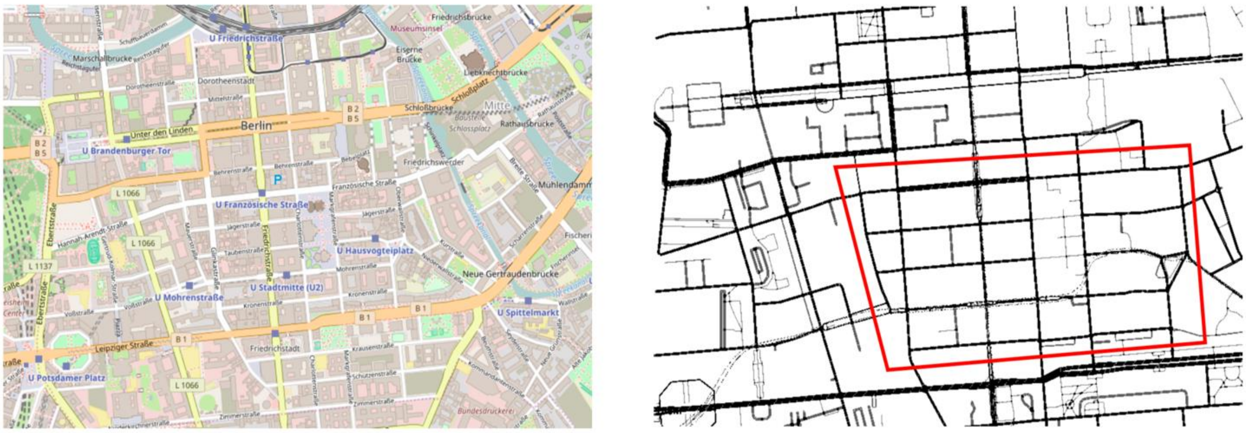
We contemplate an urban scenario in Berlin city for simulation, as depicted in fig 7. For real time information dissemination method, we develop a platform in $C^{\#}$ to investigate the performance of proposed method. A real time microscopic simulator SUMO (Simulation of Urban Mobility) along with $Omnet^{++}$ are used to evaluate the path re-planning strategy. The simulation parameters are elaborated in table II.

4.1.1. Simulation setup of information dissemination method in $C^{\#}$

Real time information dissemination method is simulated in $C^{\#}$. 25 RSUs are set into the grid type of road network. the source RSU is picked randomly. The RSUs are connected to each other via wired communication links. 25(5 x 5) RSU in the grid network means 5 RSU in Rows and in column respectively. The packet volume and delivery duration are used as the performance metrics.

4.1.2. Simulation of path re-planning in $Omnet^{++}$

Numerous simulation environments are executed to assess the performance of proposed path re-planning algorithm. To this aim, initially SUMO a realistic and microscopic simulator for road traffic is exploited to simulate the real time traffic in real time urban scenario. Furthermore, a network simulator VEINS is used to enable communication capabilities in VANETs. The VEINS is used along with $Omnet^{++}$ and SUMO correspondingly. The proposed path re-planning algorithm is evaluated under different densities based on IEEE 802.11 p/WAVE standard. We consider the realistic urban scenario of Berlin city. Vehicles are deployed in the area of 3000 x 3000 m for simulation. Which contains 25 road intersection and 40 road segments. RSUs and traffic lights are deployed on each intersection and traffic light interval is set to 100 second, 50s for red light and 50s for green light. The mobility model Traci Mobility is used. The simulation time is set to 1000 second. In $Omnet^{++}$, mobile information of each vehicle is acquired on each 0.1 seconds.



(a) (b)

Figure 4.0.1: considered map for simulation

In table 4.1 simulation settings and simulation parameters are discussed in detail. Figure 4.1 shows the map considered for this work and 4.1(b) shows the extracted features of map.

Table 3 simulation parameters

Simulation Parameters	**Value**
Simulation length	*3000m*
Simulation width	*3000m*
Traffic light duration	*100s*
Green light duration	*50s*
Red light duration	*50s*
Number of Road intersection	*25*
Simulation time	*2000s*
Number of road segments	*40*
Trace recording interval	*0.1s*
Vehicular speed limit	*10/15/25 (m/s)*
MAC/PHY	*IEEE 802.11 p/WAVE*
Obstacle	*Yes*
Mobility generator	*SUMO*

4.2. Evaluation of Path re-planning algorithm

4.2.1. Throughput

In figure 4.2 throughput in kbps is shown with respect to vehicles density. As number of vehicles are increasing throughput is also increasing.

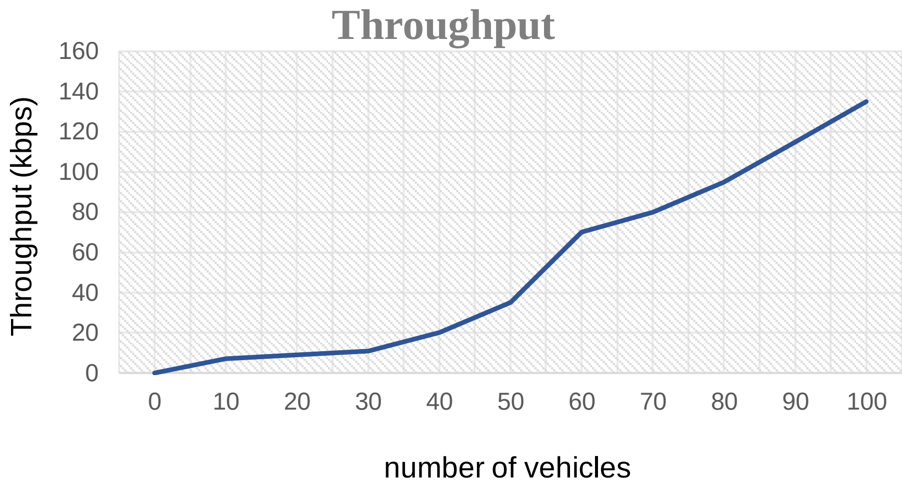


Figure 4.2: throughput of proposed system calculated in Omnet++

4.2.2. Traveling time Vs Number of vehicles

Figure 4.7 shows the traveling time of our proposed algorithm and static path planning algorithm respectively. Density of vehicles leave a deep impact on traveling time. We can observe, when the number of vehicles increasing the traveling is time is also increasing which depicts the realistic time calculation. While static path planning algorithm gives the static path, it does not consider the real time scenario that's why density wont impact it. It gives the static traveling time for vehicles even if the number of vehicles on a road segment is high. The proposed method calculates traveling time from intersection to intersection. Let say from I-10 to I-15, determine intersection 10 (source) to I-15 (destination). High density confines the vehicles 's speed.

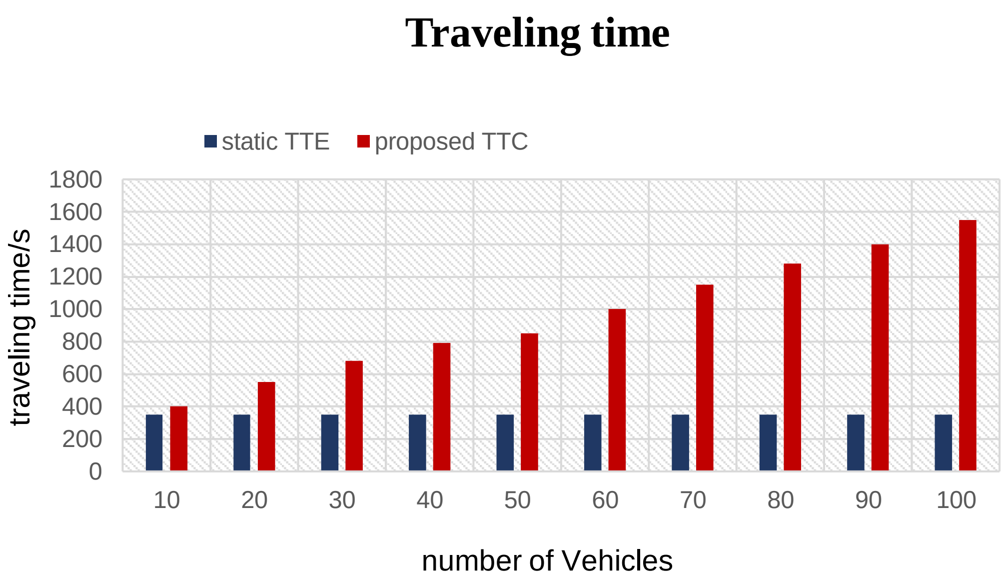


Figure 4.3: traveling time under different densities, static method vs proposed real time traveling time calculation method

- **Traveling time Path Re-Planning algorithm vs Static path planning**

Table 4: experimental results of path re-planning algorithm

S → D	*Path (intersection ID)*	*Traveling Time (s)*
0 → 15	0,1,2,3,4,6,8,11,15	436
3 → 9	3,4,6,9	267
6 → 13	6,7,8,9,10,13	389
01→ 14	1,2,3,5,7,8,11,13,14	524
10→ 3	10,9,8,5,4,3	398
11→ 25	11,14,15,16,17,20,22,24,25	589
25 → 30	25,26,29,30	458

Table 4.3 shows the experiment results of path re-planning from sources to destination. Consequently, figure 10 shows the traveling time taken by proposed path re-planning algorithm and static path planning algorithm. Our proposed algorithm takes more traveling time than static path planning algorithm, real time information is taken into account in proposed method which depicts the realistic traveling time. Static path planning algorithm do not consider the real time information which depicts the unrealistic traveling time.

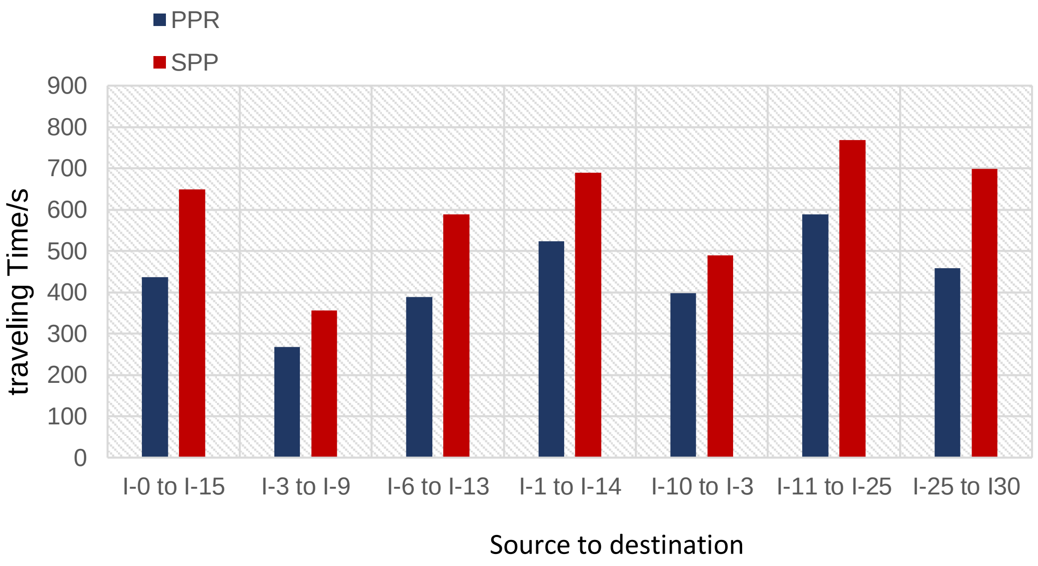


Figure 4 .4: traveling time from different source to destination

- **End-to-End delay**

The end- to -end delay of proposed system is shown in figure 4.7. when number of vehicles are increase the end to end delay is also increasing. But the as compared with the RSU based information sharing, the end to end delay is much less than that.

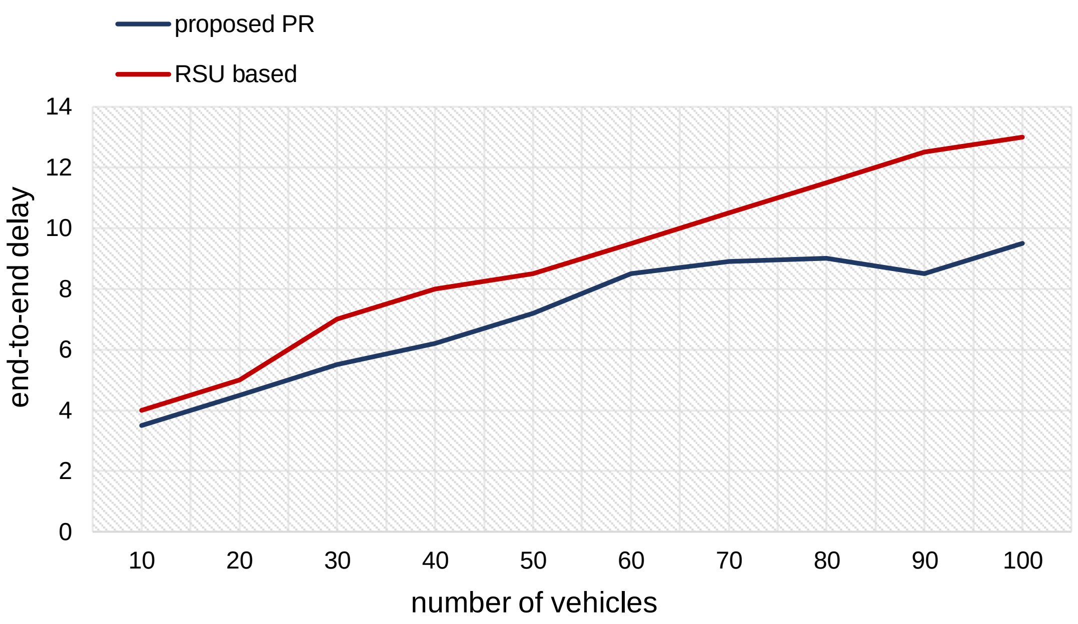


Figure 4.0.5: end to end delay of proposed system

- **Packet delivery ratio (PDR)**

In figure 4.7 packet delivery ratio is presented. PDR is calculated with the density of vehicles. When number of vehicles are less. The PDR is highest but with the increase in number of vehicles, the PDR is going to lower points. When number of vehicles are increasing, simply means number of hops are increasing that's why packet delivery ratio is gone lower.

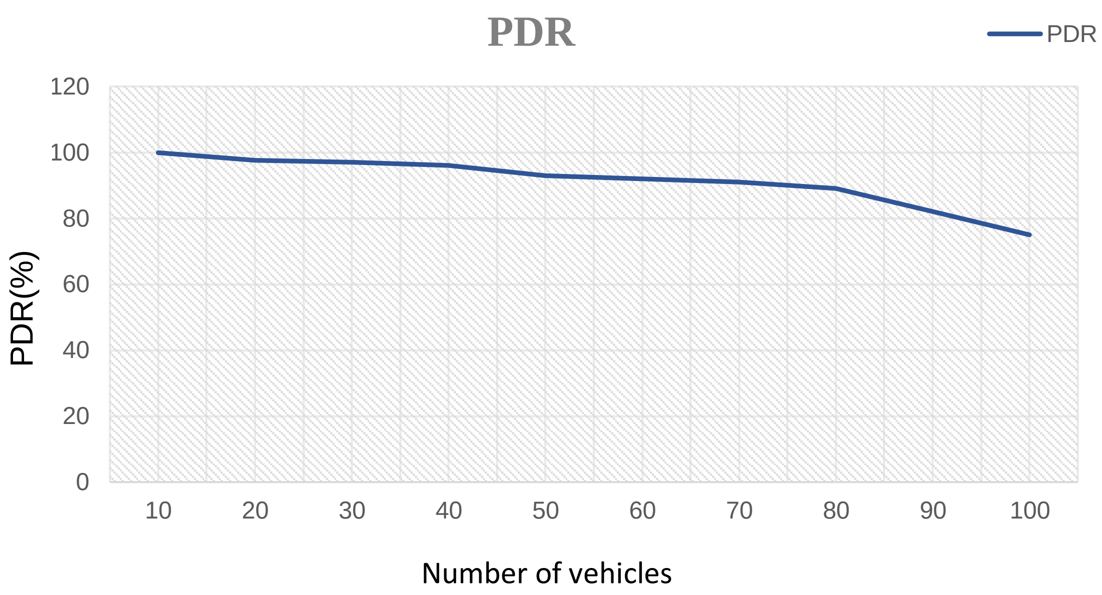


Figure 4.6: packet delivery ratio

4.3. Evaluation of information dissemination method

The proposed information dissemination method is evaluated in this section. The metrics used for the evaluation are packet volume, completed time for in edge and outer edge source node, complete time of proposed algorithm vs conventional broadcast method. Real time information dissemination method 's redundancy and complexity analysis are also presented.

4.3.1. Real time Information Dissemination Mechanism Redundancy Analysis and complexity analysis

Proposed real time information dissemination mechanism avoid the redundant transmission due to step 3 and 4. According to the mechanism each RSU gets the warning message only once. Consider if the RSUs are N in the whole grid topology and source RSU is picked randomly. In broadcast method messages are shared by flooding for that reason every RSU gets N-1 messages excluding itself. It is assumed that the network is n × m grid topology and time restriction is not considered of the real time. While in our proposed mechanism each RSU get only one warning message from another RSU either from upstream or downstream. The number of total shared message by broadcast method is $\frac{N(N-1)}{2}$, this is reduced by our proposed mechanism by $\frac{(N-1)\times(N-1)}{(N-1)N} \times 100\%$.

Packet volume is gone very higher in broadcast method. whereas in our proposed method it increases very slightly as compared to broadcast method.

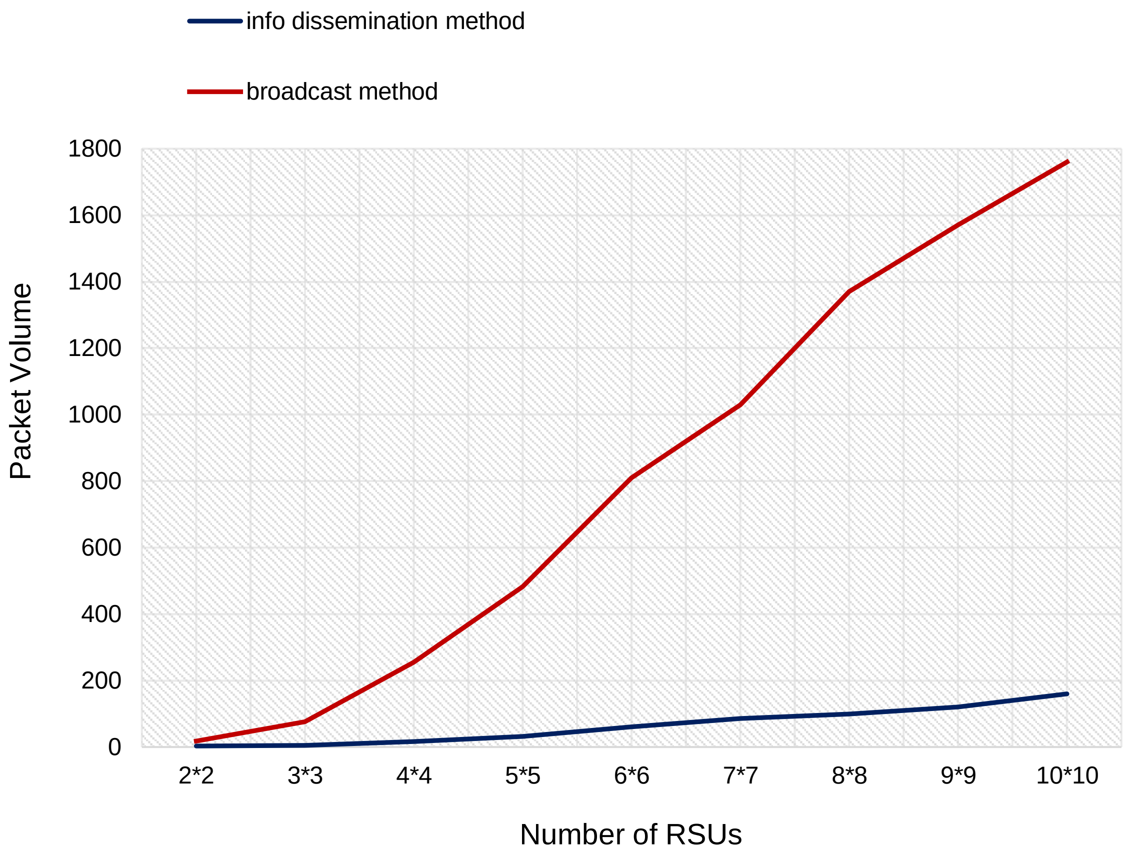


Figure 4.7: Information dissemination method completed time vs broadcast method complete time

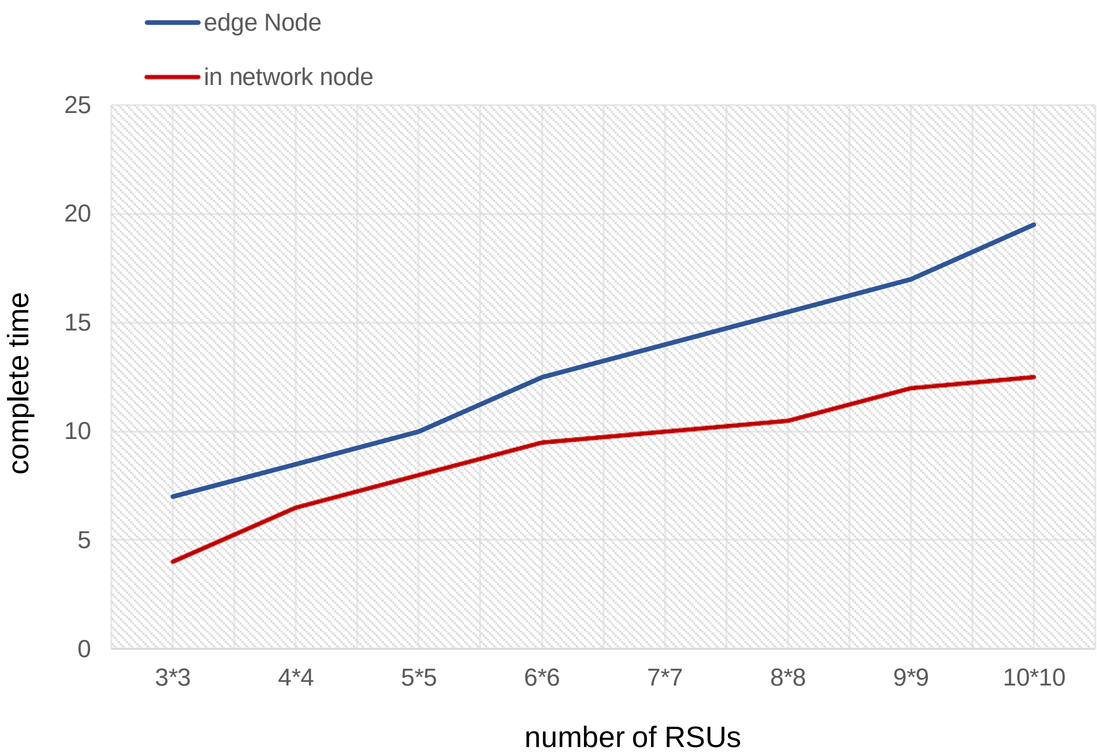


Figure 4.8: complete time for edge source and in network source node

Complete time for packet transmission among RSUs is vary on source node as shown in figure 4.9. If the source node is amongst the middle the complete time is low. on the other hand, in case of source node from edge takes higher time for completion.

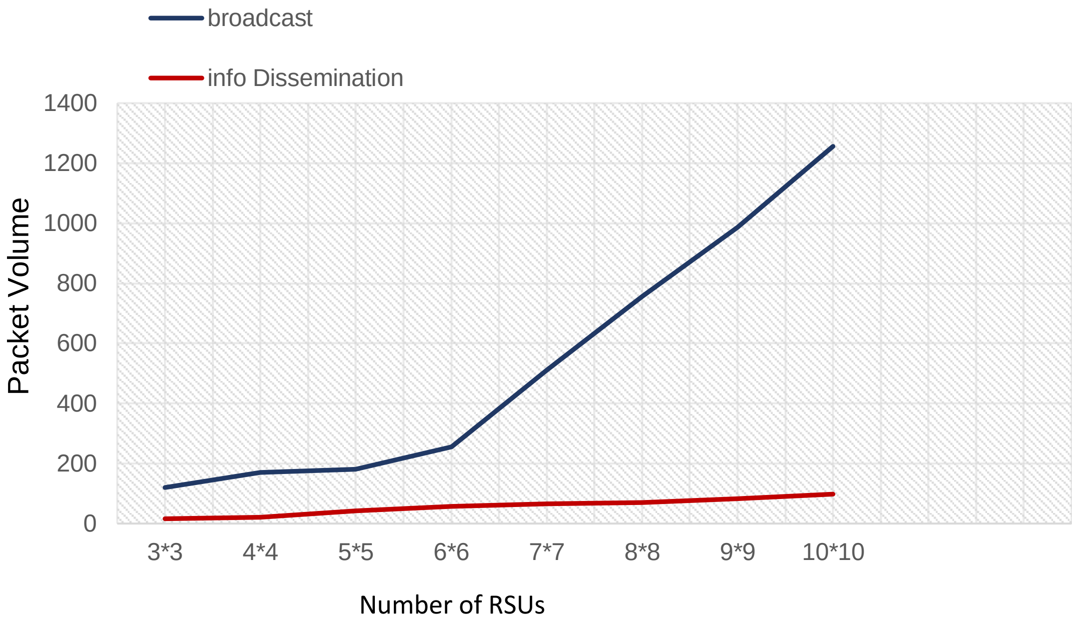


Figure 4.9: Packet Volume comparison among Information dissemination method and broadcast method

The figure 4.10 illustrate the comparison analysis of our proposed information dissemination mechanism among RSUs and the conventional method broadcast. The proposed method does not increase the packet volume even if the number of RSUs are increased as compared with the broadcast method.

4.4. Conclusion and Future work

In this, we have developed Hybrid-VITS to facilitate the vehicles by acuiring information and sharing among the network. Initially, we propoesd a Real time information dissemination mechanisim to share the information among RSUs by avoiding the redundancy and complexity. Then, desighn a realistic traveling time calculation method is used to measure the traveling time while considering real time information of vehicles and density. Furthermore, a realtime path planning algorithm exlpoiting the K-shortest path algorithm and fair distribution of calculated paths to the interested vehicles. Analytical analysis shows the performance in term of minimum end to end delay and throughput. In future, we re intended to extend the work in terms of large scale simulation based on real time data. Enhanced communicatoion capabilities among the RSUs componenets by applying 5G for communication in VANETS.

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