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Road Oriented Traffic Information System for Vehicular Ad hoc Networks

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Abstract Over the last few years, vehicular ad hoc networks (VANETs) have gained popularity for their interesting applications. To make efficient routing decisions, VANET routing protocols require road traffic density information for which they use density estimation schemes. This paper presents a distributed mechanism for road vehicular density estimation that considers multiple road factors, such as road length and junctions. Extensive simulations are carried out to analyze the effectiveness of the proposed technique. Simulation results suggested that, the proposed technique is more accurate compared to the existing technique. Moreover, it facilitate VANET routing protocols to increase packet delivery ratio and reduce end-to-end delay.

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1 Introduction

Vehicular ad hoc networks (VANETs) are rapidly gaining popularity and becoming one of the active research domains [1]. Applications contributing to VANETs popularity include safety applications [2], traffic monitoring, smart parking, route guidance, and vehicle related notification applications. These applications are building blocks of intelligent information system (IIS) [3,4] that require vehicular communication to propagate the data and events' information among vehicles. Data/information can be collected either by vehicle-to-vehicle communication (V2V), vehicle-to-infrastructure communication (V2I), or a combination of both.

The VANET architecture can be broadly classified into three categories [5] namely: (a) Cellular, (b) Ad Hoc, and (c) Hybrid. *Cellular or WLAN based VANETS* are usually designed to support infotainment related applications [6,7] such as, web browsing, news, parking information, and traffic statistics. However, it requires fixed infrastructure that is not always available. To address this issue, ad hoc networks are used that do not require fixed infrastructure support for propagation of information, but the nodes' limited transmission range and high mobility causes rapid topology changes [8]. Consequently, the network suffers from partitioning and routing link failure issues. *Hybrid architecture based VANETS* are combination of cellular and ad hoc networks, which are able to communicate via V2V and V2I links.

More to the point, *cellular* and *hybrid network based VANETS* rely on a centralized architecture in which traffic information is collected from the roads through access points. These access points are responsible to process the acquired information and make it available to the driver. The high cost of fixed infrastructure, in terms of hardware, installation, and maintenance is one of the major bottlenecks in the centralized approaches. Moreover, the centralized solutions only provide coverage up to areas, where the access points are installed.

To overcome the deficiencies of centralized approaches, decentralized traffic information systems are used. Information systems are best suited for ad hoc network based VANETS, where each vehicle is a source, destination, or intermediate node that relays the packets toward the destination. Unlike traditional MANETs, VANETs have unique characteristics such as, high mobility, shorter communication range, and network partitioning. Therefore, the decentralized traffic information systems are designed to consider VANETs characteristics.

To make accurate routing decisions, some VANET routing protocols for V2V communication require road vehicular density information [9,10]. For instance, as shown in Fig. 1, if vehicle A (source) wants to send some data to vehicle B (destination), then there are two available paths namely: path A and path B. As path A has low traffic density, it has more chances of network portioning and may suffer from high network delay. On the other hand, path B has higher vehicular density compared to path A that may lead to less network partitioning and lower network delay. Therefore, in this scenario, path B is more favorable for sending the data.

As illustrated in the above example, traffic density information is considered very useful and is used by multiple VANET routing algorithms namely: Greedy traffic aware routing protocol (GyTAR) [11], enhanced greedy traffic aware routing protocol (E-GyTAR) [12], and hybrid traffic aware routing protocol (HTAR) [13].

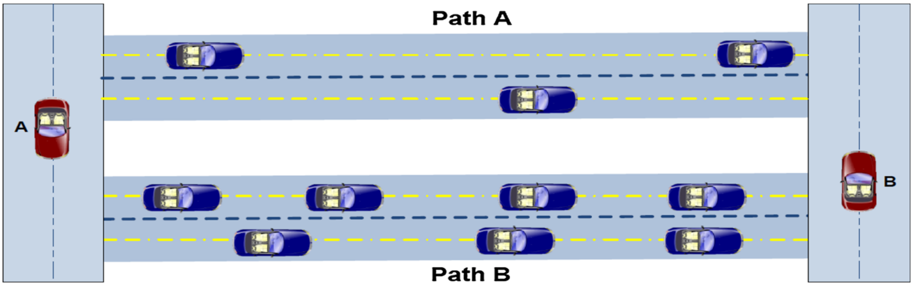

Fig. 1 Vehicular road density effect in VANETs

In this paper, we present distributed method for road traffic estimation named *"road oriented traffic information system (ROTIS)"*. It is exclusively designed for city environment and considers two-way multi-lane roads, their lengths, and junctions to precisely estimate the road traffic density. The proposed scheme is validated through extensive simulations and results are compared with contemporary existing scheme. Moreover, we have implemented ROTIS with VANET routing protocol to see its impact on the packet delivery ratio and end-to-end delay. The simulation results show that ROTIS exhibits improvement in existing scheme in terms of accuracy, packet delivery ratio, and end-to-end delay of the routing protocols.

The rest of the paper is organized as follows. Section 2 reviews related work. ROTIS operation is presented in Sect. 3. Section 4 contains simulation results and detailed analysis, and Sect. 5 concludes the paper.

2 Related Work

Considering the importance of road traffic density information, the researchers propose various methodologies. In *opposite stream vehicle communication approach* [14], each vehicle maintains a table that contains an average of road segment entry-exit time, also referred to as a *travel time*. The entry-exit time information is exchanged with neighbor vehicles that are moving in the opposite direction. In this process, the vehicles moving in identical direction are ignored, because they already have this information. The disadvantages of this approach include lack of accuracy and less scalability. Moreover, in sparse networks, opposite stream vehicle communication approach also incurs high delay in disseminating the updated information among vehicles [15].

Self-organizing traffic information system (SOTIS) [16] is another decentralized mechanism to estimate the vehicular traffic density. SOTIS maintains a table that consists of vehicle's current position and its average velocity. The table is periodically updated and exchanged with neighbor vehicles. Consequently, every vehicle becomes familiar with the position and average velocity of neighbor vehicles. The positional information is used to generate warning messages in critical situations (accidents) via in-car display [15]. Pitfall of this approach includes non-consideration of collaborative effort to process the information. Moreover, SOTIS is only designed for highway scenarios and depends on the traffic direction for exchanging tables among vehicular nodes.

TrafficView [17] is another technique that uses data aggregation for gathering and disseminating real-time road traffic information to the drivers. The scheme is similar to SOTIS in working. However, TrafficView periodically disseminates position and velocity of individ-

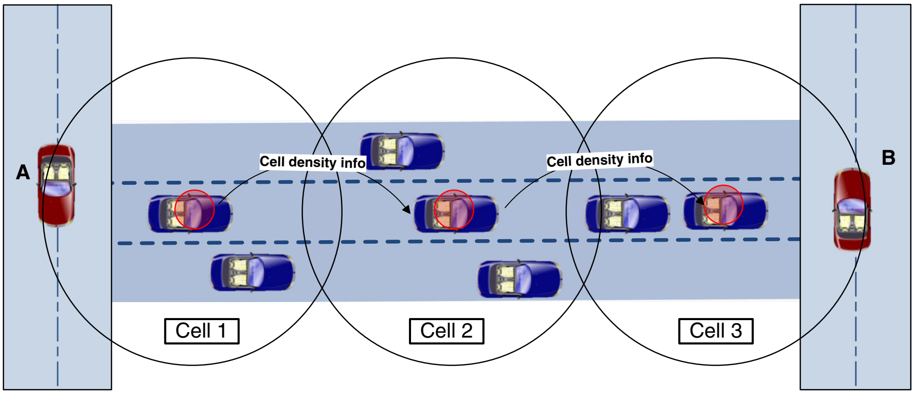

Fig. 2 Cells formation and group leader selection

ual vehicle node instead of the average velocities in the segments. TrafficView is a part of the project named e-Road [18] which helps to find suitable routes and important information about road conditions. TrafficView is only suitable for highway scenarios and does not consider the direction of vehicles while exchanging traffic information among vehicles.

In Tyagi et al. [18], the authors propose a traffic density estimation technique that bases on acoustic signal that is recorded by a microphone installed on a road side. The acoustic signal consists of multiple noise signals that includes but not limited to engine noise, tire noise, and air turbulence noise of vehicles. The signals are analyzed to determine the vehicular traffic density of the road segments using acoustic signal classifiers. The main drawback of this technique is that it is based on road side infrastructure and does not provide promising results in noisy areas.

The authors in Sen et al. [19] propose a traffic density estimation technique that based on video processing. To calculate the density of the road segments, live video feed is taken from multiple video cameras that are deployed on the road side. Later, the recorded video is processed using video processing tools to calculate the number of vehicles that enter or exit a particular road segment, where the difference of the numbers indicates the estimated traffic density. Similar to previous scheme, this technique also bases on road side infrastructure and suffers from average error of 11 % in terms of density estimation.

Infrastructure-free traffic information system (IFTIS) [15] is a decentralized vehicular density estimation technique that dissects each road into a number of fixed size cells based on transmission range of vehicles, as shown in Fig. 2. A vehicle closest to cell center is elected as a group leader that is responsible for estimation of cell density and forwarding the cell density information in form of *cell density packet (CDP)* to other cells. The group leaders add their cell density to the received CDP and forwards the CDP along the path until it reaches the junction. In this way, vehicular density of each cell is estimated and combined together to find the total vehicular density on a specific road segment. The calculated CDP information is available on the road junctions that plays important role in VANET applications and routing protocols. The drawback of IFTIS is the formation of fixed size (266 m) cells. Moreover, it does not consider direction of vehicles that can greatly affect the routing decisions due to carry-forward technique used by VANETs [20,21].

In Bilal et al. [12], authors proposed enhanced version of IFTIS that employs same concept for group formation and density calculation, as used by the IFTIS. However, in the enhanced version, the numbers of vehicles that move in the direction of destination are also considered.

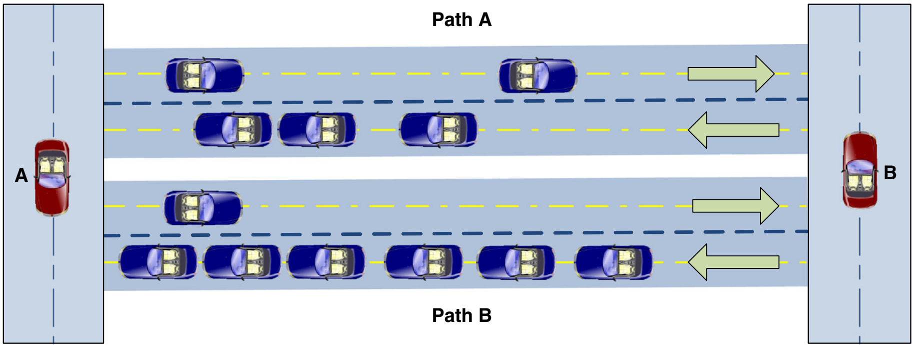

Fig. 3 Importance of vehicular direction in density calculation

The enhancement plays vital role in VANET routing protocols. For instance, if vehicle A wants to send some data to vehicle B, and path B has higher density compared to path A, then apparently path B is more favorable than path A,but it may not be necessarily the case. As shown in the Fig. 3, there are no vehicles at the end of path B. Therefore, the packets will not reach vehicle B and the last vehicle on path B will carry the packet towards the vehicle A. Alternatively, path A has less density, but it has vehicles that are moving in the direction of destination (vehicle B). Although, there are no vehicles at the end of path A, the last vehicle will store the data and carry it towards the upcoming junction (using carry-forward mechanisms [22,23]).

3 Road Oriented Traffic Information System

3.1 Problem Statement

The IFTIS density estimation scheme is based on fixed cell size. Therefore, if different road lengths are considered that are not multiple of 500 m, then vehicular traffic density is not calculated accurately as the cells do not fully cover the road segments or overlap the segments of other roads. Consequently, the estimated density is either under calculated or over calculated. Due to this reason, the authors in Bilal et al. [12] and Jerbi et al. [15] used road lengths of multiple of 500 m. In addition, the vehicular default transmission range was set to 266 m (including overlap (D_o) of 16 m), due to that the cells fully cover the road length. However, the assumptions, such as particular length roads (multiple of 500 m) and fixed size cells are unrealistic.

3.2 Problem Formulation

If we formulate the cell formation scheme of IFTIS, then the following derived equation can be used to determine the number of cells for a particular road length.

$$T_C = \lfloor R/(2 \times T) \rfloor + 1 \tag{1}$$

where, T_C is the number of cells formed, R is the road length and T is the transmission range of the vehicles.

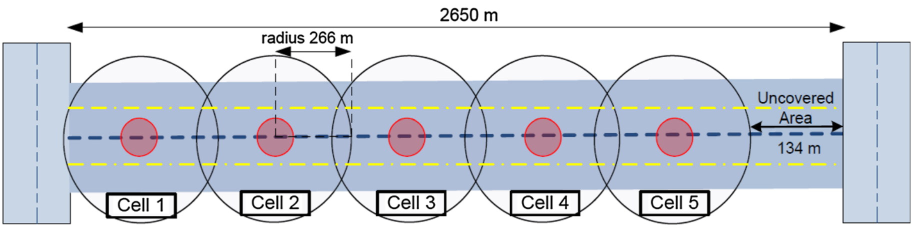

Fig. 4 IFTIS failure with uncovered road length

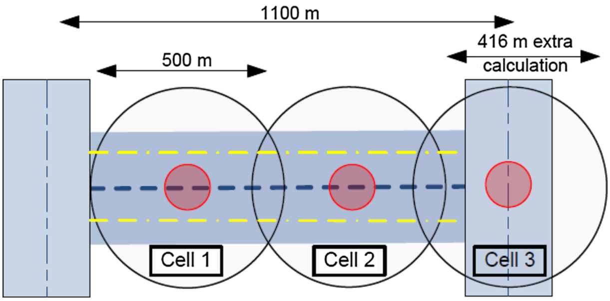

Fig. 5 IFTIS failure with overlapped road length

To find the cells' position on the road segment, let n be the cell number, D_o be the cell overlap, and T_o be the default transmission range of vehicle without the overlap. Using these variables, the position of each cell can be calculated using Eq. 3.

$$T_o = T - D_o \tag{2}$$

$$P(n) = (2 \times n \times T_o) - T_o \tag{3}$$

where, $0 > n \leq T_C$

3.3 Problem Verification

Assume roads of length 2,650 and 5,850 m. The number of cells and their positions can be calculated using Eqs. 1 and 3. It is clearly evident from Fig. 4 that some area remains uncovered.

For roads of length 2,650 and 5,850 m, the uncovered area is 134 and 334 m, respectively. Hence, by increasing the road length, uncovered area will also increase except for scenarios where the road length is a multiple of 500. Similarly, on decreasing the road length, extra cells will be formed that may overlap area of cells on other road segments. Consequently, extra vehicular density will be calculated that is not a part of same (identical) road, as shown in Fig. 5.

Similarly, for road lengths of 3,200 and 1,100 m, extra road length of 316 and 416 m is considered, respectively. Thus, decreasing road length also provides inaccurate vehicular traffic information.

3.4 Proposed Scheme

To address the issue elaborated in Sect. 3.3, a distributed technique named ROTIS is proposed. ROTIS ensures that the cell size is not defined statically and is adjusted dynamically by

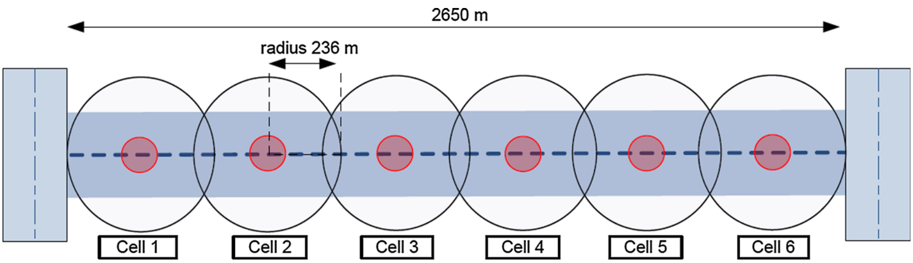

Fig. 6 ROTIS cell formation

considering the road length. To achieve this goal, the roads are dissected into small cells of same size. The cell size varies from road to road, but remains same on a single road segment. ROTIS uses variable transmission power during the cell formation phase that enables it to fully cover the road segments.

Similar to the existing routing schemes, ROTIS is based on the assumption that vehicles are equipped with on-board navigation system, global positioning system (GPS) device, and digital maps that enable the vehicles to get their geographic position and roads information. The vehicular information is exchanged with other vehicles (within transmission range) to maintain a neighbor table, that helps the vehicles to identify the geographic position, speed, and direction of the neighbor nodes. These tables are updated periodically through *hello* messages.

The working of ROTIS can be divided into two tasks, i.e., cell formation and density calculation.

3.4.1 Cell Formation

Unlike the previous techniques (discussed in Sect. 2), where road is dissected into fixed size cells, ROTIS is designed to form cells of any size considering the road length. ROTIS cell formation is shown in Fig. 6.

In ROTIS, vehicles are capable of changing their transmission power to form cells of different sizes. Therefore, during the vehicular traffic density estimation phase, each vehicle adjusts its transmission range according to the road length to fully cover the road segment. The algorithm steps are explained as follows:

Step 1: Get variable values
The algorithm gets road segment length (from a digital map), default transmission range of vehicles (250 m), and overlap distance that is used to connect cells and fully cover the road segments (16 m).
Step 2: Calculate total number of required cells
To fully cover a particular length road segment, required number of cells is calculated using the following equation:

$$T_C = \lceil R/(\mathrm{T_o} \times 2)\rceil \tag{4}$$

where, T_C represents the required number of cells, R represents the road length, and T_o is the default transmission range of vehicles.
Step 3: Calculate cells radius
Using default transmission range, the calculated number of cells may not cover the road segment accurately. Therefore, new cell size (radius) is calculated using the following equation:

Table 1 CDP message format

Cells density data packet		
Direction (optional)		
Road ID	Transmission time	Cell ID
Cell's center position	Cell's total density	Cell's directional density (optional)

$$C = \left\lfloor (R/T_C) \times \frac{1}{2} \right\rfloor \tag{5}$$

where, C represents radius of the cells.

Step 4: Adjust transmission range

Due to change in the cell size, the transmission range of the vehicles must also be changed accordingly to avoid over/under density estimation issues. This is achieved using the following equation:

$$NTR = \lfloor C + \mathrm{D_o} \rfloor \tag{6}$$

where, NTR represents the new transmission range, and D_o is the overlapping distance. Here, the maximum value of $C \leq T_o$, because the new transmission range cannot exceed the default transmission range.

Step 5: Form Cells

In this step, the road segment is virtually dissected into defined number of cells, in order to ensure make each vehicle can become part of a particular cell. To find the location of cells, the following equation is used:

$$P(n) = (2 \times n \times C) - C \tag{7}$$

where, n represents the number of cells that varies from 1 to T_C, and $P(n)$ represents center points of the cells.

3.4.2 Density Calculation

After the formation of cells, the next step is to calculate the road traffic density. Therefore, within each cell, one vehicle is elected as a group leader (cell leader) based on cell centrality. The group leaders are responsible for estimation of cell density that is performed by consulting the neighbor table. The number of vehicles in neighbor table represents the vehicular traffic density of the respective cell. Group leaders are also responsible for forwarding the CDP to other cells (via group leaders) of the identical road segment.

The main parameters of CDP message are shown in Table 1.

CDP message consists of road ID, transmission time, list of anchors (cell's center position), cell ID, new transmission range (NTR), and cell's total density (that is calculated by the group leader of each cell). The cell's directional density is an optional parameter that is used to measure the vehicular density in specific direction based on the required application.

When a vehicle enters a road segment, it calculates the number of cells (T_C, using Eq. 4) and their positions ($P(n)$, using Eq. 7), as per proposed method (discussed in Sect. 3.4.1). By doing so, the vehicle becomes aware of the cells' positions, and can declare itself as a group leader upon reaching the center of a particular cell. To calculate the total traffic density of a road segment, a vehicular node (F) (group leader of the first cell) generates a CDP. The group leader updates the total density (T_d) and directional density (D_d) parameters of the CDP by consulting its neighbor table (generated based on NTR using Eq. 6), and forwards it towards the end of the road segment (junction J_e). $\mathrm{N}_{ib,e}$ represents the number of vehicles in

Table 2 Pseudo code for CDP forwarding and density estimation

```
Begin
If $F$ is a group leader, then
    If $F$ is in first cell, then
        Create CDP
    end if
    $T_{d\,i} = N_{i\,b,e} + N_{i\,e,b}$
    $D_{di} = N_{i\,e,b}$
    NextAnchor = center of (cell i+1)
    if $F$ is not in the last cell, then
        Forward CDP to the next cell
    Else
        select neighbors ($N$) moving towards $J_e$
        If $\exists V \in N$ closer to NextAnchor, then
            Forward CDP to $V$
        Else
            Store CDP and carry it
        end if
    end if
    Broadcast CDP upon reaching $J_e$
end if
End
```

cell i moving from beginning of the road segment (b) to the end of the segment (e), whereas $N_{ie,b}$ represents the number of vehicles in cell i moving in the opposite direction.

When the CDP researches second cell, the packet is updated again and the process continues unless it reaches the last cell of the road segment. The group leader of the last cell calculates the mean and variance of the cells' density and propagates the estimated density to all the vehicles around the intersection. To do so, it searches for a vehicle (V) (within its neighbors N) that is moving towards the J_e. If such vehicle is found, it forwards the CDP to the vehicle (V) that broadcasts it around J_e. Otherwise, the group leaders of the last cell carry-forwards the packet and broadcast it upon reaching J_e. Consequently, the vehicles at the junction become aware of the road segment density by receiving the CDP message. Table 2 presents the algorithm for CDP forwarding and density estimation between two junctions, where Fig. 7 presents the flowchart of the process.

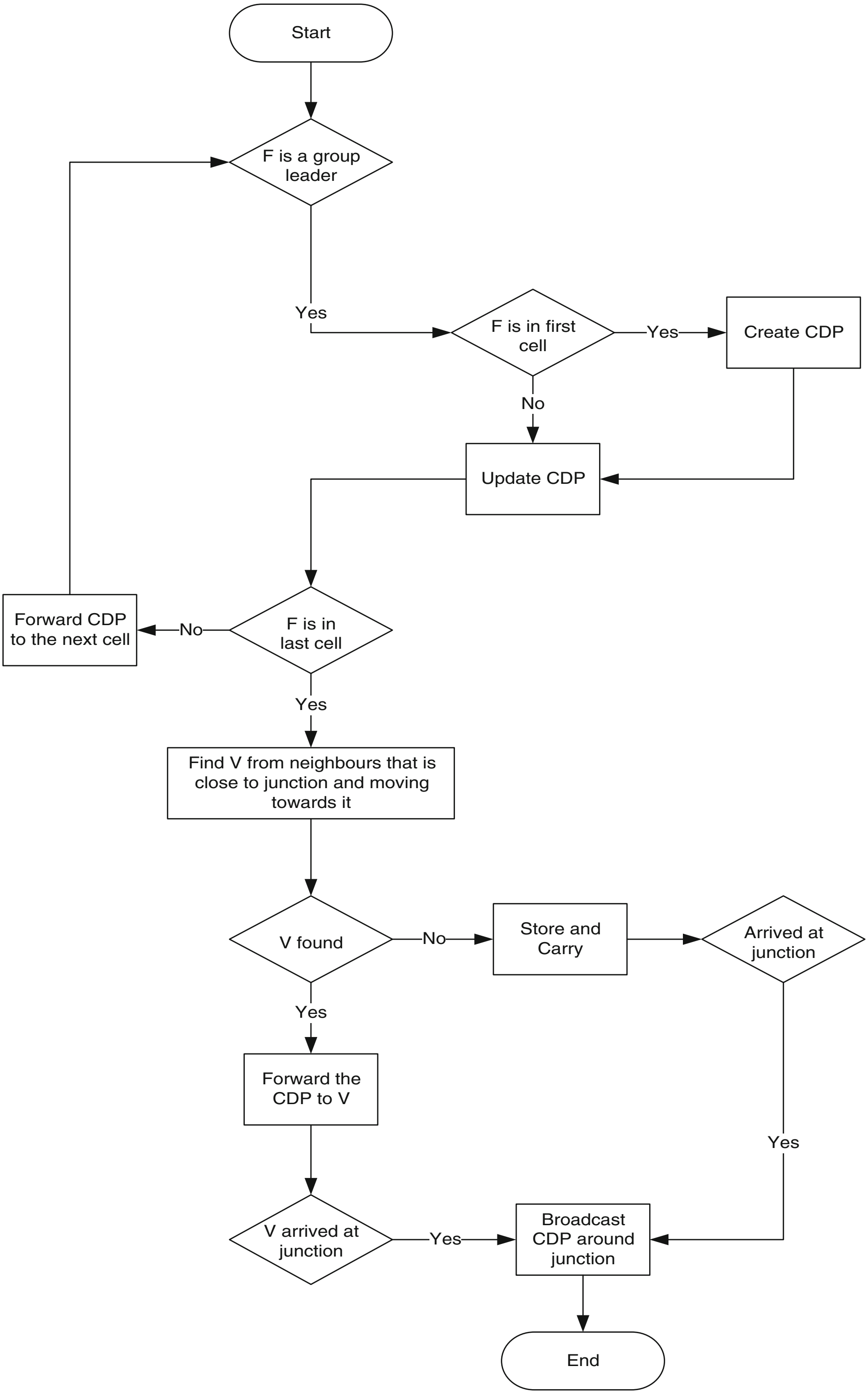

Fig. 7 Flowchart of CDP forwarding and density calculation

4 Simulation and Results

This section presents the performance comparison of ROTIS and IFTIS. The estimated densities of both the schemes are compared with the actual traffic density values (available in the simulator) over a period of time to evaluate the accuracy. Moreover, ROTIS is implemented in E-GyTAR routing protocol to investigate the effect on packet delivery ratio and end-to-end day. To get insight of detailed working of E-GyTAR routing protocol, the readers are encouraged to read [12]. The simulations are performed using GLObal MObile system SIMulator (GLOMOSIM) [24] that is specifically designed for the VANET environment.

4.1 Simulation Setup

The vehicles mobility patterns are generated using VanetMobiSim [25] that is a realistic mobility model for VANETs. The selection of realistic vehicular mobility generator is a crucial decision, as it plays pivotal role in the performance evaluation of protocols [26]. VanetMobiSim is based on CanuMobiSim [27] that supports both micro and macro level mobility [28]. Micro-mobility is associated with roads, speed, traffic lights, streets, bi-directional/multi-lane roads, and vehicular traffic flow. On the other hand, macro-mobility considers V2V communication, V2I communication, overtaking, and lane changing.

For the first experiment, 2,650 m straight road with multiple lanes in each direction is simulated. For the second experiment, city simulation area mentioned in Fig. 8 is used. The vehicles were positioned randomly over the road with bi-directional mobility, having speed of 35–60 km/h. Roads were dissected into different number of cells based on individual strategy. The key parameters of simulation setup are summarized in Tables 3 and 4.

4.2 Simulation Results

During simulation, we considered the case where some area of the road remains uncovered (in IFTIS). As discussed in Sect. 2, the issue occurs at the end of the last cell, when the road segment length is not a multiple of 500 m. For instance, for the road length of 2,650 m, IFTIS

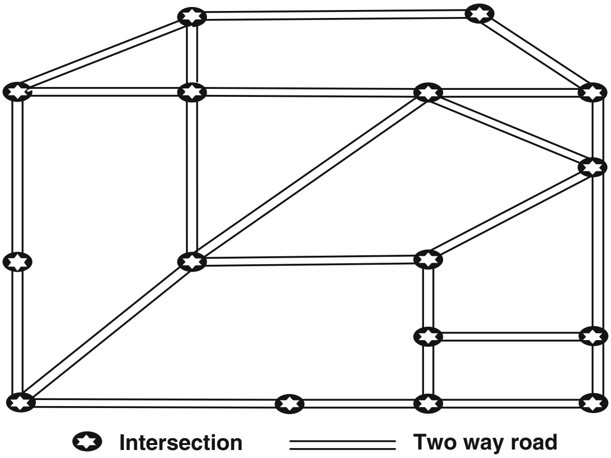

Fig. 8 City simulation area

Table 3 Simulation scenario/setup without routing

Parameter	Value
Simulation time	400 s
Map size	2,650 m
Mobility model	VanetMobiSim
Number of vehicles	140, 240–265
Vehicle speed	35–60 km/h
Pause time	2–5 s
MAC protocol	802.11 DCF
Default transmission range	266 m
Transmission range without overlap	250 m
Red zone radius	40 m
CDP sending rate	2 s
Overlapping distance	16 m

Table 4 Simulation scenario/setup with routing

Parameter	Value
Simulation time	200 s
Map size	$2{,}500 \times 2{,}000\,\text{m}^2$
Mobility model	VanetMobiSim
Number of intersection	16
Number of roads	24
Number of vehicles	75–200
Vehicle speed	35–60 km/h
MAC protocol	802.11 DCF
Channel capacity	2 Mbps
Transmission range using IFTIS	266 m
Transmission range using ROTIS	Variable
Traffic model	15 CBR connection
Packet sending rate	0.1–1 s
Weighting factor (α, β)	(0.5,0.5)
Packet size	128 bytes

creates five cells (with 266 m radius) while ROTIS creates six cells (with 236 m radius). The cell formation of IFTIS and ROTIS is shown in Figs. 4 and 6, respectively.

Figures 9 and 10 indicate the number of vehicles that are part of cell 1 and 5 with respect to time. There are two real traffic curves (one for IFTIS and other for ROTIS), because the cell formation techniques and cell sizes of both the techniques are different. Real traffic curves present the actual number of vehicles in a cell at a particular time. Note that real densities curves are not based on estimated traffic. This information is extracted from the mobility file using a script that shows the actual number of vehicles on a particular sub segment of a road (cell coverage area of IFTIS and ROTIS) at a particular time. For the road length of 2,650 m, the IFTIS cell size is slightly larger than the ROTIS cell size. Therefore, IFTIS cell contains more vehicles, which is evident from the real traffic curves of IFTIS and ROTIS in Figs. 9 and 10. The graphs show estimated density of cells (1 and 5) for ROTIS and IFTIS. In ROTIS the relative error for cell density estimation is 0–2 %, while in IFTIS the relative error

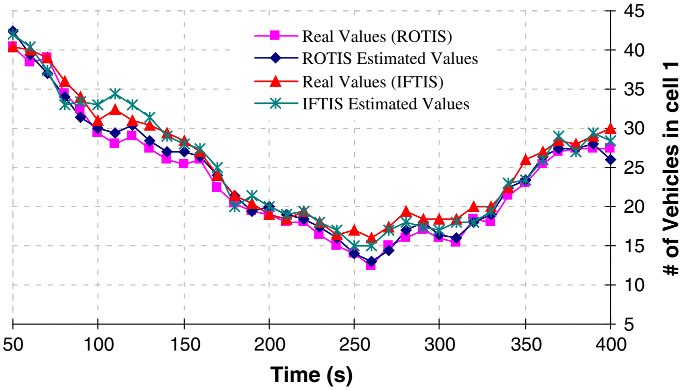

Fig. 9 Number of vehicles in Cell 1 with respect to time

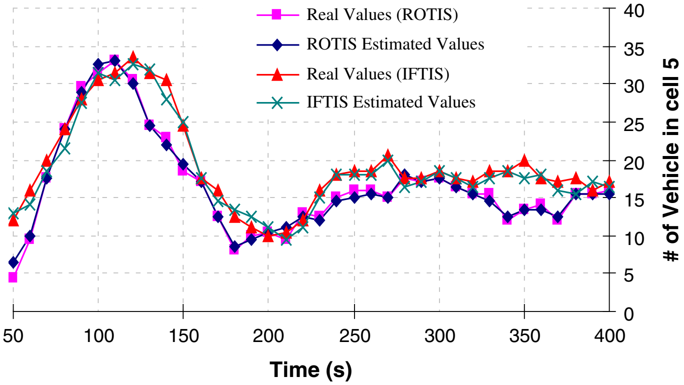

Fig. 10 Number of vehicles in Cell 5 with respect to time

is 0–3 %. Here, we only present the cell densities of cell 1 and 5, because in both the schemes the initial cells are formed accurately, and their relative error is quite low and identical.

Figure 11 demonstrates the main difference in both schemes. IFTIS dissects the road of length 2,650 m into five cells in which some area is left uncovered, whereas ROTIS dissects it into six cells and fully covers the road segment. In IFTIS, the transmission range of the last cell group leader covers the road up to 2,516 m. As the road's total length is 2,650, 134 m of road still remains uncovered.

Figure 12 demonstrates the total traffic density of a road segment (for cells 1 to 6). Result illustrates that the ROTIS estimated traffic density is very close to the real traffic curve, proving that ROTIS caters to the highlighted issue. On the other hand, the estimated traffic density of IFTIS varies from the real traffic curve to a large extent. The reason is that in IFTIS some area is left uncovered due to the flaw in cell formation technique. Consequently, the vehicles present in uncovered area are not counted, which ultimately results as wrong estimation of traffic density. At any given time, the IFTIS density estimation error depends on the size of uncovered area and number of vehicles present in that area. Therefore, to check the effect under high vehicular traffic, we explicitly increased the number of vehicles in this simulation ranging from 240 to 265 vehicles. It is evident that ROTIS is more accurate compared to IFTIS.

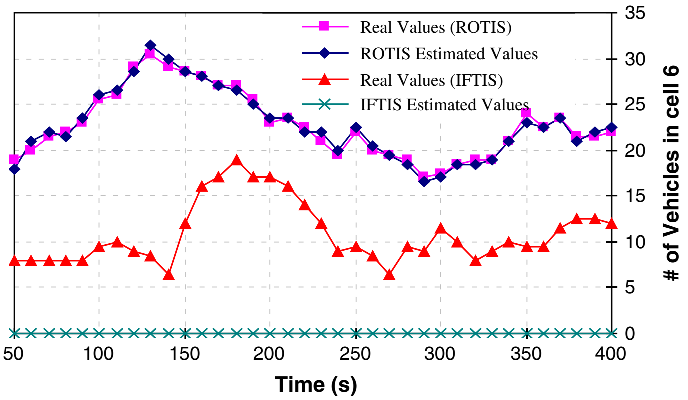

Fig. 11 Number of vehicles within Cell 6 with respect to time

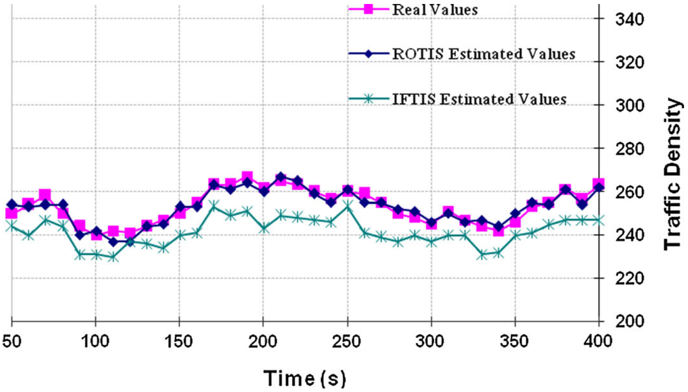

Fig. 12 Total road density with respect to time

Figure 13 shows the effect of ROTIS on packet delivery ratio of E-GyTAR routing protocol that is originally implemented using IFTIS scheme. The result demonstrates that the packet delivery ratio of E-GyTAR improves with ROTIS scheme. Moreover, it shows that the packet delivery ratio increases by increasing the number of vehicles. The increase in the packet delivery ratio of E-GyTAR (ROTIS) is due to optimal cell formation, which increases the neighbor tables' consistency and enables E-GyTAR to make accurate routing decisions.

Figure 14 illustrates packet delivery ratio with respect to variable packet sending rate. The result shows that variable packet sending rate has no major effect on the packet delivery ratio. However, GyTAR (ROTIS) has a minor edge over the GyTAR (IFTIS) due to the aforesaid reasons. In addition, ROTIS cell size is usually smaller than the IFTIS, due to which it contains fewer vehicles and has low chances of collisions during communications.

Figure 15 elaborates end-to-end delay of E-GyTAR protocol. The result shows that end-to-end delay decreases by increasing the number of vehicles. It is a fact because high number of vehicles improves network connectivity and reduces probability of network partitioning. Here, E-GyTAR (ROTIS) performs well because it makes optimal routing decisions due to precise density information and suffers less from the carry-forward issue due to optimal cell formation.

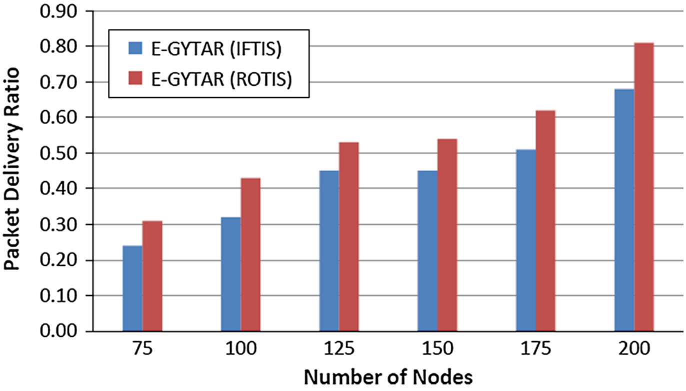

Fig. 13 Packet delivery ratio with respect to number of nodes at five packets/sec

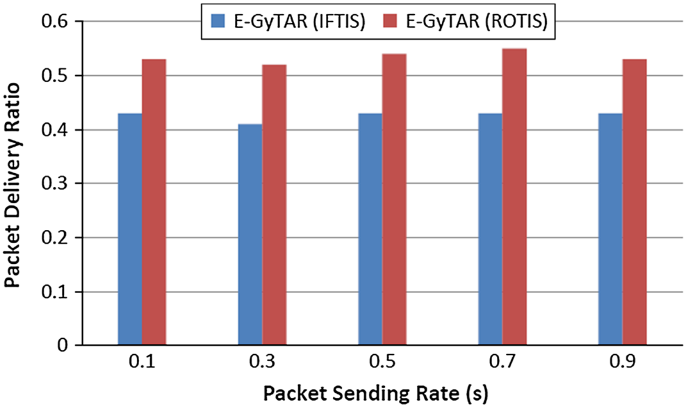

Fig. 14 Packet delivery ratio with respect to packet sending rate (175 nodes)

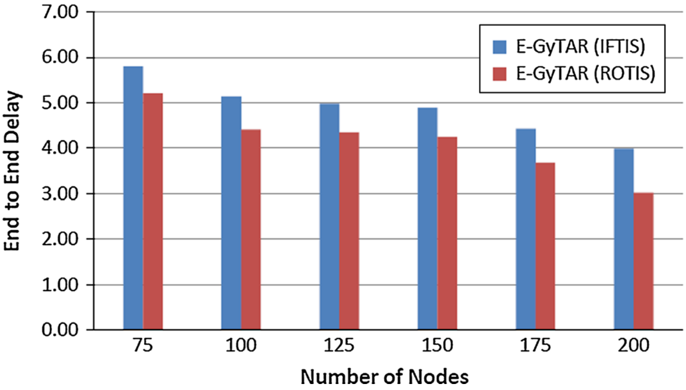

Fig. 15 End-to-end delay with respect to number of nodes at five packets/sec

Figure 16 shows end-to-end delay with respect to variable packet sending rate. The result shows that end-to-end delay decreases by reducing the packet sending rate. It is because high packet sending rate increases congestion in the network, which ultimately leads to increase in

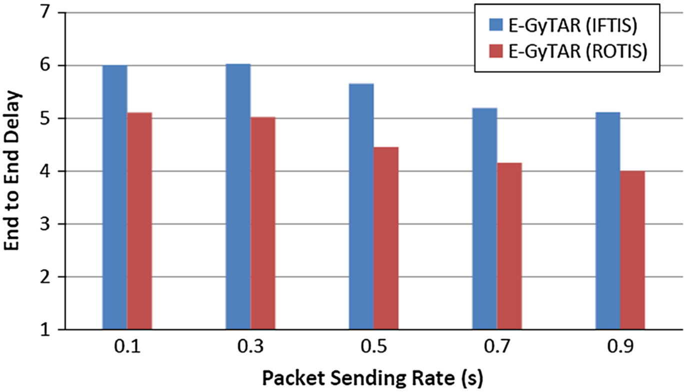

Fig. 16 End-to-end delay with respect to packet sending rate (175 nodes)

the end-to-end delay. However, GyTAR (ROTIS) incurs slightly less end-to-end delay due to optimal cell formation, accurate routing decisions, and fewer occurrences of carry-forward issue.

5 Conclusions

ROTIS is based on dynamic cell formation technique that fully covers the road segments and every vehicle becomes a part of a cell. ROTIS uses variable transmission power to form cells of different sizes that varies according to length of the road segments. The simulation results reveal that ROTIS density estimation mechanism is more accurate, especially when the road segments are of variable lengths that are not multiple of 500 m. The ROTIS traffic density preciseness is evident from that fact that it considers traffic of the last cell that is ignored in IFTIS. In addition, ROTIS is not affected by traffic over estimation issue, where traffic from adjacent cells is also calculated due to wrong cell formation. Nevertheless, when implemented in VANET routing protocols, ROTIS improves packet delivery ratio and minimizes end-to-end delay.

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