# DATA TRANSMISSION FOR PRIORITIZED SERVICES IN VEHICULAR AD HOC NETWORKS USING ACHIEVABLE ABILITY AWARE GENERALIZED INSTANTLY DECODABLE NETWORK CODE

*K. Lakshmi*, M. Soranamageswari*

## Abstract

In the Vehicular Adhoc Network (VANET), the foremost essential process is to transfer Emergency Messages (EMs) since their reliability is affected by the vehicle's high mobility and their positions. To combat this difficulty, a varied spider like Transmission Mechanism for Emergency Data with an Improved Restricted Greedy Forwarding (TMED-IRGF) protocol was recommended, which discovers the nearby vehicles based on trust values and forwards the messages via the optimal shortest path. Conversely, it needs more redundant transmission among vehicles owing to the rapid alterations of the network topology in the high-speed movement of vehicles. Therefore, this article combines the TMED-IRGF protocol with the network coding to avoid the redundant rebroadcasting of EMs. In this framework, a Rate-Aware Generalized Instantly Decodable Network Coding (RAGIDNC) scheme is proposed to encode and disseminate the EMs. It includes a reliable information transmitted over a communication channel of the different vehicles in the decision process of both the forwarded mixture of packets and the rates at which they are forwarded. The problem of forwarding EMs is initially investigated to identify the total number of transmissions. To reduce the number of transmissions, the vehicles apply the RAGIDNC graph model which integrates both the linear NC possible coded mixtures and the different transfer rates. Thus, the forwarding EM packet is highly valuable to the desired destination vehicles by reducing redundant transmissions among vehicles. Finally, the simulation findings show that the RAGIDNC achieves better effectiveness than the classical routing protocols in disseminating EMs in VANET.

**Keywords:** VANET, Emergency messages, TMED-IRGF, Priority, Network coding, Rate adaptation, Instantly decodable network coding, Packet forwarding.

## I INTRODUCTION

VANET is a useful system that connects people, channels, and locomotives in Intelligent Transport Systems (ITSs) using the innovative devices and wearable technologies and so on. The goals of ITS are divided into three categories: path confidentiality, traffic feasibility and data service [1-2]. To satisfy these goals, the VANETs cope with real-world transmission through different transmissions.

But, V2V transmission is only essential for the successful implementation of in-built devices. Similarly, Road-Side technologies are vital in V2R, but they are extremely difficult to build; creating administrations tend to restrict their accessibility, particularly in rural areas [3-4]. Furthermore, V2V is ideal in an emergency where conventional distribution systems and RSUs have collapsed. As a result, V2V is far more adaptable than V2I for implementation.

Overcrowding, information losses and end-to-end jitter will occur from data collected for these kinds of applications. The system data is categorized into normal and life security EMs, which has to be reduced to minimal possible lag to the desired vehicle. If conflict guidelines are followed, urgent

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Department of Computer Science,
Government Arts College, Coimbatore, Tamil Nadu, India
*Corresponding Author

signals must be provided to the target vehicle before the deadline expires. The text and multimedia data exchanged between rule authority guidance and rescue team vehicles is indispensable. As a result, the key obstacle to VANET is streaming urgent alerts that assist certain vehicles in avoiding crises and overcrowding [5]. Different criteria must be met to establish an effective network: 1) The interaction area should be sufficient to provide an acceptable warning period for probable vehicles, 2) The network should provide stronger distribution reliability so every vehicle receives the urgent alerts to ensure their anonymity and 3) the network should reduce the hop count required for propagating urgent alerts. As a result, data transmission protocols have been recommended to properly disseminate urgent alerts at the lowest cost.

In the past centuries, numerous data transfer protocols have been designed to accomplish the V2V interaction [6]. For considerable VANETs with high mobility, such protocols seem to be ineffective. From this perspective, Qiu et al. [7] developed an improved spider web-like Transmission Mechanism for Emergency Data (TMED). In this TMED, a noticeable message has been spread to decide the interaction link between an origin and target vehicles having the maximum reception percentage of urgent alerts. Also, an adaptive multi-priority data queue handling scheme has been integrated with the restricted greedy transfer protocol depending on the neighborhood prediction for disseminating urgent alerts. Nonetheless, the neighborhood prediction relied on only the data reception ratio of the link that was constructed by the neighborhood. This does not make sure that every neighborhood was trustworthy.

As a result, an Improved Restricted Greedy Forwarding (IRGF) protocol has been suggested to find the neighborhood using the trust measure in TMED. It has been concentrated on trustworthy neighborhood vehicles according to the desired information about all vehicles, including the vehicle's site, speed, direction and density. All vehicles disseminate urgent alerts for measuring the trust and reputation scores of all neighborhood vehicles. These scores have been evaluated with the threshold for deciding the trusted neighborhood vehicles and receiving the urgent alerts disseminated by them. Moreover, the vehicle's site, speed, density and Euclidean gap among vehicles were calculated. Such computed ranges were then provided to the fuzzy logic framework for deciding the highly trustworthy neighborhood vehicles as forwarding vehicles that disseminate the urgent alerts to the target vehicles. On the contrary, message rebroadcasting was needed in V2V transmissions because of the congested and slow urban road traffic scenario. Also, the efficiency was influenced by the rapid changes in the network topology because of the high-speed mobility of vehicles in the highway scenario. This reduces the message distribution effectiveness significantly. Hence, in this paper, a network coding framework is proposed with the TMED-IRGF protocol to prevent the redundant forwarding of messages. First, the problem of forwarding EMs is studied to analyze the total number of transmissions. Then, the RAGIDNC graph model is introduced to reduce the number of redundant transmissions by each vehicle during EM broadcasting[8]. This model considers the utilization of different vehicles of both the forwarded mixture of packets and the rates at which they are forwarded. According to this integration of the NC model with TMED-IRGF, the efficiency of EM broadcasting through VANETs is enhanced and the demand for message rebroadcasting is avoided efficiently.

This paper is structured as follows: Section II discusses the previous work associated with this research. Section III explains the concept of the proposed framework and Section IV exhibits its effectiveness. Section V summarizes the entire work and provides the future scope.

## II LITERATURE SURVEY

Vijayakumar and Joseph [9] concentrated on effective information distribution in VANET and considered real-time latency without imposing latency tolerance. Initially, an adaptive load balancing method was developed depending on real-world modification with the predicted and real-time implementation. Also, various real-world scheduling protocols were utilized to prioritize the requests to be analyzed. Moreover, the predicted transfer time was higher than the real transfer time for propagating the request to the respective vehicle was discussed. But it was only focused on fixed deadlines for requests and a single path.

Haider et al. [10] developed a new routing scheme called Direction Aware Best Forwarder Selection (DABFS) for distributing warning data in VANETs. In this scheme, directions, relative locations of vehicles and distance were considered for computing the vehicle's mobility direction by Hamming distance and finding the most suitable path among the available set of paths. Then, the warning data was disseminated via adjacent and the best paths. But, the network throughput was not effective.

Sathya Narayanan [11] developed a protocol for safe and authentic transmission in VANET. Initially, the network was created with several vehicles and the adjacent finding in WAVE protocol. Then, the in-build devices acquire the vehicle's data which was accumulated and registered in a gateway for special identification of every vehicle. Moreover, a cloud link was enabled for disseminating the urgent data to each vehicle. But it has a high processing time and transfer latency.

Ali et al. [12] suggested an information distribution method for transferring urgent data in VANETs depending on clustering and location-based transfer methods. In this method, the vehicles were dynamically grouped to control the transfer storm challenge and a location-based method was introduced to decrease the transfer latency, resulting in timely distribution of urgent data packets. But it needs more attributes related to the vehicle to improve the clustering robustness.

Srivastava et al. [13] designed a Fuzzy-based Beaconless Probabilistic Broadcasting Algorithm (FBBPA) for notifying vehicles about an event without broadcasting. It depends on the probabilistic scheme for transmitting the received data. The data was retransmitted only if their current priority was not equal to 0, if the traffic was only within the predefined region of interest and its traffic count was beyond the particular bounds. If such limits were met, then the receiver-oriented channel access method was adopted. Also, fuzzy logic was applied to analyze the broadcast chance related to all vehicles. But it needs the proper selection of fuzzy membership functions to improve network efficiency.

Berlin et al. [14] presented a full authentication of VANET transmission protocols using the SPIN model authenticator. In this study, an authentication framework was introduced to verify the correctness and develop errors of VANET transmission protocols using a model authenticator. This framework was employed to disseminate emergency-related data between vehicles and RSUs. On the other hand, its efficiency was not analyzed in terms of different metrics.

Wu et al. [15] suggested an information dissemination method depending on adjacent positions in VANET. In this method, 2 different information dissemination modes were presented. First, the actual velocity and location of the adjacent nodes were estimated to decrease the effect of vehicle mobility. After that, a highly efficient group of relay forwarding nodes was constructed to disseminate the information. But it was not able to solve the network partition issue influenced by the sparse network. Hammood et al. [16] developed an Adaptive Quantum Logic Gate (AQLG)-based NC in VANET for achieving reliable and effective multicasting. In this scheme, the trust-based graph optimization was executed by the cuckoo search algorithm for choosing the secure relay nodes. But it needs an improved NC scheme to further enhance the throughput.

## III PROPOSED METHODOLOGY

In this section, the TMED-IRGF with the RAGIDNC framework is explained briefly. The schematic representation of the presented framework is portrayed in Figure 1.

***Figure 1. Block Diagram of TMED-IRGF-NC Framework***

### 3.1 System Model

Initially, V2V network is established origin and end node discover its site and the route using the GIS. The existing model is applied to find the effective route with the negligible latency between the source and destination vehicles. Then the intersection nodes of both are determined. Then, each available path consisting of road segments between source and destination intersections is observed. According to the available paths, the origin node transmits notification message to the end node before the broadcasting of messages.

If the end node receives, then it sends an acceptance message to the origin node with the actual route. Added to that the transfer delay is calculated with the help of timer. Suppose the time exceeds the timer then try with another alternate route or use the same route later. The route which has the least transfer latency is selected as the transfer route for EM broadcasting.

After finding the transfer route, an IRGF scheme is executed depending on the vehicle site estimation for broadcasting messages. It determines the trust and reputation scores of every vehicle. These determined values along with distance, vehicle's site, velocity, direction and density are provided to the fuzzy logic to decide the site of forwarding (neighboring nodes) nodes. After that, the chosen forwarding node transmits the message to the chosen neighbor depending on its predicted site. The decision is made to find it as an intersection node or not. If it so then send beacon message to know its side details.

Generally, all the nodes are categorized as an intersection and ordinary nodes to forward messages between source and destination vehicles. The forwarding messages can be achieved by two types: i) from an ordinary vehicle and ii) from an intersection vehicle.

Also, the messages are separated into different priorities such as high, medium and low based on the emergency levels of the events generating the packets. Based on that different transfer routes are selected appropriately to mitigate the network congestion efficiently.

On the other hand, there are many redundant broadcastings of messages among vehicles which influences the throughput and latency. To resolve this problem, RAGIDNC scheme is integrated in each vehicle to encode and broadcast messages which results in less number of transmissions (i.e., prevents redundant broadcasting).

### 3.2 Rate-Aware Generalized Instantly Decodable Network Coding

During broadcasting, any ordinary vehicle determines its site details before any message transfer. When no intersection vehicles are available then send the message to the nearest ordinary vehicle. Otherwise check the current and next road form a long straight road or not. If so, then transmit the message to the nearby vehicles. Or else, transmit the message to the intersection node. This is repeated until it discovers the available next hop.

Similarly, the header details are determined for successive road segment in transfer route. After, the current vehicle can broadcast the message to its adjacent which is nearest to the consecutive intersection. At 50ms of Control Channel Interval (CCHI), a number of subframes are allocated by ordinary and intersection vehicles. Such vehicles will be active only on the allocated subframes. This defines that ordinary/intersection vehicle can broadcast messages only in its subframes; however, it can receive on every CCHI slots. All subframes are split into different timeslots and intersection vehicle has the chance to broadcast many times in similar subframe.

So, there are many redundant broadcastings of messages between vehicles which results in ineffective use of channels. To avoid this issue, the linear NC is utilized for broadcasting messages. In every timeslot, the vehicles broadcast a linear mixture of its message and every message delivered during the current subframe. Also, the random NC coefficients are applied for encoding the messages. The coefficients are chosen from Galois field (GF(ρ) ) with degree ρ. The coded message is a linear mixture of each actual message as:

α_(x-1) m^(x-1)+⋯+α_1 m^1+α_0 m^0 (1)

In Eq. (1), α_x denotes the random coefficient chosen in GF(ρ^x ) and m^x denotes the actual message produced from a vehicle x. The coefficients vector is added to the coded message which alleviates target vehicles to decode the actual messages. The transmission of messages using linear NC maximizes their success delivery by each adjacent. This is enhanced by creating the GIDNC graph which ensures the complete utilization of the channel resources in VANETs. It determines all probable packet mixtures and recognize the vehicles that can instantly decode every of such mixtures.

Consider that all vehicles are involved in accepting each message m ∈ M. At any given period, these messages are decomposed into 2 groups from x^th vehicle perception:

The Contain group C_x having the messages successfully accepted by x^th vehicle.

The Desire group D_x=M\C_x having the messages lost at x^th vehicle.

During broadcasting, each vehicle initially transfers uncoded messages with the achievable rates. The t^th message broadcasting is successfully accepted by x^th vehicle if R(t)≤R_x (t) where R(t) is the group of achievable abilities of each vehicle during t^th broadcasting and R_x (t) is the achievable ability of x^th vehicle during t^th broadcasting. On the other hand, each vehicle with abilities smaller than R(t) during t^th broadcasting loses the message. Once one complete cycle of broadcasting messages uncoded is finished, each vehicle uses the variety of Contain and Desire groups of vehicles to transmit exclusive coded mixtures of their lost messages. With a condition, decoding of message is done only if it present in the Contain group. Those vehicle may join with the accepted message to take out m. So according to the rule of GIDNC, a mixture contain at least two unrevealed messages will be eliminated.

Every possible mixture is determined and the vehicles are identified that can instantly decode each of these mixtures by constructing the RAGIDNC graph. This graph is created depending on the message requests containing set of vertices and edges. It facilitates the detection of packet mixtures, it is immediately decodable. The graph G(V,E) is built as follows: Considering vehicle x requests message m, this scenario is observed as a vertex v_u ∈ V. Likewise, vehicle y requests for m and it is observed as vertex v_y ∈ V. Every request of a vehicle is observed as a vertex in the graph and the weight of every vertex is allocated as the utility value. To create the group of vertices, the group of achievable rates is introduced R_x={R ∈ R|R≤R_x } for every vehicle x. For all vehicles, the set of feasible rate is considered as the highest rates. A node is provided for all feasible vehicles, where m is the requested message and r is the obtainable rate r from R_x. A set of edges E forms a bridge between any two vertices only on following the below criteria:

Criterion 1: r=r^'.

Criterion 2: m=m^'.

The connectivity criterion 1 guarantees that the exchange rate is constant for all adjacent vertices in the RAGIDNC graph. The criterion 2 indicates the immediate decodability criterion of GIDNC from the network-layer perception. Then, this is decomposed into m=m^'.

According to the abovementioned criteria, it can be eagerly inferred that all cliques in the RAGIDNC graph defines a transfer containing:

- The decodable mixture is determined by the cliques' vertices.
- Even if it is below its ability are detected by the clique's vertices.
- So, all cliques in G identifies the message arrangement that can instantly serve each vehicle including this clique's vertices. The vertices of G is categorized into 2 layers:
    - Upper-level graph G_U: It comprises each vertex from the desire group of each vehicle.

    - Lower-level graph G_L: It comprises each vertex that are not in the desire group of any vehicle.

For any communication, a clique k is chosen from G_U which will target a group of Desire vehicles. For the non-targeted Desire vehicles, the neighboring G_L to k is applied to deliver an unnecessary message to them without violating the instant decodability of the messages at the Desire vehicles. For non-targeted Desire vehicles, this step expands their Contain group and so maximizes the probabilities of having more coding chances in next communications according to criterion 2. As a result, the transfer defined by all cliques in the RAGIDNC graph is immediately decodable which are determined by the clique's vertices. Figure 2 illustrate the RAGIDNC graph for 3 vehicles and 3 messages. It shows that the clique {112,322} is chosen since it offers 4 bits/sec.

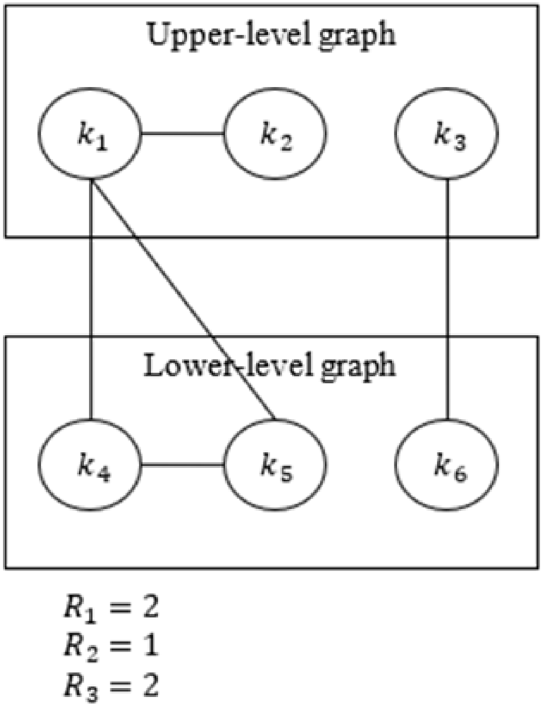

**Figure 2. Example of RAGIDNC Graph**

**Algorithm: TMED-IRGF-NC**

```
Begin
Initialize the number of vehicles;
Consider source and target vehicle to send the beacon messages with each other vehicles;
while(t≤T_total )
```

```
Split the vehicles into ordinary and intersection vehicles;
Determine the reputation score to discover the trustworthy vehicles;

Compute the distance between vehicles, density and velocity;
Execute the fuzzy logic system to decide the forwarding trustworthy vehicles;
Apply the RAGIDNC scheme to encode the EMs to be broadcasted by intersection vehicles between source and destination;
//RAGIDNC
for(k=1:n)
    1. Build the IDNC graph G(V,E) depending on the message requests;
    2. Search the maximum weighted clique in G(V,E) which contains the maximum achievable rate;
    3. Acquire the encoded message by XORing each message which are detected by the vertices in the maximum weighted clique;
    4. Broadcast the encoded EMs;
    5. Decode the EMs at the destination vehicles;
    6. Update the vehicle site details, service queues and G(V,E);
    end for
end while
End
```

## IV SIMULATION RESULTS

In this section, the TMED-IRGF-NC (RAGIDNC) framework is simulated in the Network Simulator version 2.34 (NS2.34) to analyze its efficiency. Also, the comparative analysis is presented between proposed and existing protocols: AQLG [16], EE-FMDRP [17] and TMED-IRGF regarding Mean Transfer Delay (MTD), Packet Delivery Rate (PDR) and Routing Overhead (RO). Table 1 presents the simulation parameters.

| Parameters | Value |
|---|---|
| Simulation region | 1500×1500m2 |
| Number of vehicles | 150 |
| Mobility model | RandomTrip |
| Beacon message size | 20bytes |
| Beacon interval | 5s |
| MAC protocol | IEEE MAC 802.11p |
| Interface chain | NewPriQueue |
| Interface chain length | 20 |
| Packet type | Constant Bit Rate (CBR) |
| Packet size | 5Kbyes |
| Packets generation speed | 1-10(packets/s) |
| Channel capacity | 2Mbps |
| Simulation time | 600s |

*Table 1. Simulation Parameters*

4.1 Mean Transfer Delay (MTD)

It is the average duration essential to broadcast the warning data from origin to the target vehicles.

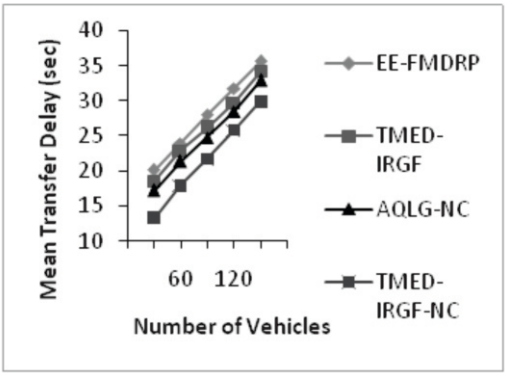

*Figure 3. MTD vs. Number of Vehicles*

Figure 3 illustrates the MTD (in sec) obtained for EE-FMDRP, TMED-IRGF, AAQLG-NC and TMED-IRGF-NC under different number of vehicles. It analyzes that the MTD of TMED-IRGF-NC using 30 vehicles is 33.83% less than the EE-FMDRP, 28.49% less than the TMED-IRGF and 22.67% less than the AQLG-NC. For 60 vehicles, the MTD of TMED-IRGF-NC is 25.1% less than the EE-FMDRP, 21.83% less than the TMED-IRGF and 15.96% less than the AQLG-NC. For 90 vehicles, the MTD of TMED-IRGF-NC is 22.5% less than the EE-FMDRP, 16.86% less than the

TMED-IRGF and 12.5% less than the AQLG-NC. For 120 vehicles, the MTD of TMED-IRGF-NC is 18.87% less than the EE-FMDRP, 13.13% less than the TMED-IRGF and 9.47% less than the AQLG-NC. For 150 vehicles, the MTD of TMED-IRGF-NC is 16.01% less than the EE-FMDRP, 12.57% less than the TMED-IRGF and 9.12% less than the AQLG-NC. So, this is concluded that the MTD of TMED-IRGF-NC is 15.29% relatively reduced compared to the other frameworks due to the encoding of the EMs which prevents the frequent message retransfer via the trusted forwarding vehicles.

### 4.2 Packet Delivery Rate (PDR)

It is the number of effectively received messages at the target vehicles within a unit period.

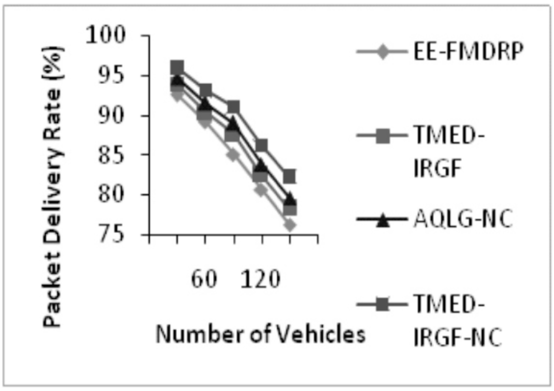

*Figure 4. PDR vs. Number of Vehicles*

Figure 4 demonstrates the PDR (in %) achieved for EE-FMDRP, TMED-IRGF, AAQLG-NC and TMED-IRGF-NC under varying amount of vehicles. It addresses that the PDR of TMED-IRGF-NC for 30 vehicles is 3.67% greater than the EE-FMDRP, 2.24% greater than the TMED-IRGF and 1.37% greater than the AQLG-NC. For 60 vehicles, the PDR of TMED-IRGF-NC is 4.37% higher than the EE-FMDRP, 2.99% higher than the TMED-IRGF and 1.75% higher than the AQLG-NC. For 90 vehicles, the PDR of TMED-IRGF-NC is 6.93% higher than the EE-FMDRP, 3.88% higher than the TMED-IRGF and 2.25% higher than the AQLG-NC. For 120 vehicles, the PDR of TMED-IRGF-NC is 6.82% greater than the EE-FMDRP, 4.48% greater than the TMED-IRGF and 2.74% greater than the AQLG-NC. For 150 vehicles, the PDR of TMED-IRGF-NC is 7.86% higher than the EE-FMDRP, 5.11% higher than the TMED-IRGF and 3.39% higher than the AQLG-NC. Therefore, it is summarized that the mean PDR of TMED-IRGF-NC is 3.17% comparatively higher than the other frameworks by preventing the packet loss and the regular retransfer of EMs through VANET.

### 4.3 ROUTING OVERHEAD (RO)

It is the percentage of sum amount of control message bytes i.e., Hello messages and sink messages to the sum amount of warning data bytes received by the target vehicles.

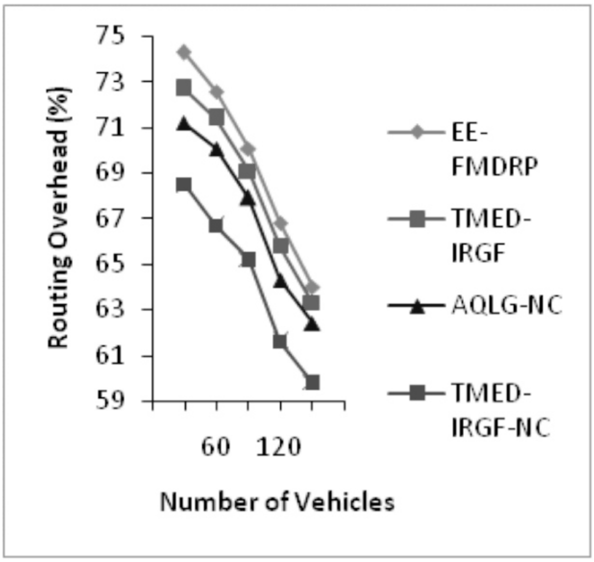

*Figure 5. RO vs. Number of Vehicles*

Figure 5 exhibits the RO (in %) for EE-FMDRP, TMED-IRGF, AAQLG-NC and TMED-IRGF-NC under varied amount of vehicles. It observes that the RO of TMED-IRGF-NC using 30 vehicles is 7.81% less than the EE-FMDRP, 5.78% less than the TMED-IRGF and 3.79% less than the AQLG-NC. For 60 vehicles, the RO of TMED-IRGF-NC is 8.13% less than the EE-FMDRP, 6.58% less than the TMED-IRGF and 4.85% less than the AQLG-NC. For 90 vehicles, the RO of TMED-IRGF-NC is 6.99% less than the EE-

FMDRP, 5.64% less than the TMED-IRGF and 3.98% less than the AQLG-NC. For 120 vehicles, the RO of TMED-IRGF-NC is 7.78% less than the EE-FMDRP, 6.38% less than the TMED-IRGF and 4.2% less than the AQLG-NC LNC. For 150 vehicles, the RO of TMED-IRGF-NC is 6.56% less than the EE-FMDRP, 5.53% less than the TMED-IRGF and 4.17% less than the AQLG-NC. So, this is concluded that the RO of TMED-IRGF-NC is 5.04% minimized than the other frameworks because of avoiding the rebroadcasting the EMs with the use of encoding scheme.

## V CONCLUSION

In this paper, the TMED-IRGF-NC framework was presented to prevent the frequent retransfer of EMs through VANET. First, the TMED-IRGF scheme was applied to choose the forwarding vehicles between the source and target vehicle. Then, the RAGIDNC-based method was applied for broadcasting the encoded EMs in the CCHI timeslots and different transfer rates. Eventually, the simulation findings realized that the TMED-IRGF-NC framework attains an overall MTD of 21.72sec, mean PDR of 89.72% and RO of 64.36% than the other frameworks. Even if it establishes effective simultaneous message transfer, the simultaneous transfer may create the broadcast storm challenge. Thus, the upcoming development of this research would concentrate on handling the broadcast storm challenge during EMs broadcasting through VANETs.

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