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Research Article

A Two Proposed Peer to Peer Approach Based on Locality Awareness and Replica Method to Disseminate and Manage Data in Vanet

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ABSTRACT

Peer-to-peer (P2P) systems are widely used in applications such as information dissemination and voice over IP, eliminating the need for a client-server model. In vehicular ad hoc networks (VANETs), high mobility leads to frequent topology changes and disconnections, making data availability a key challenge. To address this, we introduce a Distributed Hash Table (DHT) based on structured P2P networks, offering self-organization, scalability, and decentralization. This paper proposes two approaches to enhance data availability and lookup success rates. The first method utilizes data replication to improve availability and reduce lookup delay without adding significant network overhead. The second approach incorporates locality awareness to optimize search success and minimize lengthy routing issues. Both solutions are evaluated through simulations in urban environments, considering metrics such as lookup success ratio, logical hop count, and delay. The results demonstrate the effectiveness of the proposed approaches in improving data retrieval efficiency in VANETs.

Keywords: Structured Peer to Peer Systems (P2P); Distributed Hash Table (DHT); Vehicular Ad-hoc Network (VANET); Replication; Locality Awareness.

INTRODUCTION

Vehicular Ad Hoc Networks (VANETs) integrate next-generation wireless communication into vehicles, enabling continuous, reliable connectivity and efficient vehicle-to-vehicle communication without fixed infrastructure. Their primary goal is to enhance road safety, traffic management, and driving comfort while supporting applications such as entertainment, gaming, and internet browsing (Hussein et al., 2022).

VANETs share characteristics with Mobile Ad Hoc Networks (MANETs), including self-management, self-organization, low bandwidth, and shared radio transmission media. However, a key distinction is VANETs' predictable vehicle motion, which makes them more manageable. Despite this, efficient information dissemination remains challenging due to frequent topology changes caused by node churn. Structured peer-to-peer (P2P) overlays, built on Distributed Hash Tables (DHT), offer scalable routing and self-organization capabilities, making them a reliable foundation for VANET applications. These overlays use a consistent hash function to assign unique identifiers to peers and shared resources, ensuring efficient data distribution and retrieval. The function cited before maps resource IDs to a single node, this latter is tasked with storing this resource and/or its reference. Therefore, when searching for a specific resource, the requesting node has to find the full path until the responsible node holds the desired resource. To facilitate this process, every node maintains a routing table containing information about a set of peers to find the complete path of search requests. Well-known structured peer to peer protocols include Chord (Stoica et al., 2003), Pastry (Rowstron & Druschel, 2001), CAN (Ratnasamy et al., 2001), and others. The comportment of Vanet network is highly dynamic, with vehicles can join and leave the network at any moment. This dynamic nature greatly reduces data availability and con-tributes network instability. To cope with this critical issue,

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a proposed solution involves a data replication mechanism. This mechanism involves replicating the data across multiple nodes instead of single node. This paradigm is fundamental for augmenting data availability and enhance load balancing among vehicles, ultimately reducing both the lookup path and delay.

A key limitation of structured peer-to-peer overlays is the inefficiency caused by the mismatch between the physical (underlay) and logical (overlay) networks. In structured P2P networks, node IDs are assigned randomly, disregarding their actual physical locations. Consequently, adjacent nodes in the overlay may be physically distant, leading to delays and redundant traffic (Figure 1). To address this, we propose a modification in ID construction for Chord on VANET, incorporating physical node placement—an approach referred to as Locality Awareness. This paper presents two structured P2P-based data dissemination solutions using the Chord protocol: a replica-based method and a locality-awareness-based method. This work extends our previous research (Guezzi et al., 2020) with enhancements and additional simulation metrics. Simulation results demonstrate the scalability and effectiveness of the proposed solutions across various scenarios. The paper is structured as follows: Section 2 discusses structured P2P systems, location awareness, and the replica method. Section 3 reviews existing methodologies and related work. Section 5 analyzes performance through simulations, and Section 6 presents conclusions and future research directions.

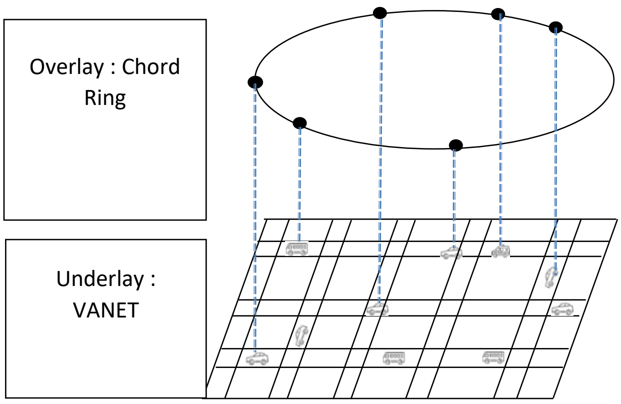

Figure 1. DHT of Vehicles

2. BACKGROUND NOTIONS

2.1. Replication Method

When using structured peer-to-peer networks, the procedure of hashing an object's IP address or its name in order to generate the key of the object is used to identify each resource or item. Following that, this key is assigned to be stored in a specific node with the nearby identifier to this key in the overlay. The node in which the key is stored is commonly referred to as the root or master node. The replication approach involves duplicating this key in other nodes. Replication method serves to enhance data availability, reduce response time, and achieve other benefits.

To enhance data availability in VANET, data replication has proven to be a robust approach for efficient data delivery. Various replication mechanisms have been proposed, broadly categorized into two classes:

Fixed Replication Number:

In this class of approaches, a predetermined replication number is assigned to each data. This places a restriction on the number of copies that can be made of each individual item of data. An example of such an approach is Spray-and-wait (Spyropoulos et al., 2008).

Metric-Based Replication:

The second category of methods involves the replication of data depending on a metric that has been computed. The process of replication takes place when certain requirements on the metric are satisfied, and the copies of data that are produced as a result are independently sent. Examples of this class include RAPID (Balasubramanian et al.,

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2009), trajectory-based (Wu et al., 2011), inter-contact time (H. Zhu et al., 2011), and path likelihood (Burgess et al., 2006).

Nevertheless, it's important to note that data replication comes with the drawback of consuming additional bandwidth, which is already a limited resource in vehicular ad hoc networks. On one hand, insufficient replication may fail to achieve the desired performance improvement. On the other hand, too much replication can result in poor band-width utilization, negatively impacting performance in such environments. Striking the right balance is crucial for optimizing the efficiency of data replication strategies in vehicular ad hoc networks.

2.2. Locality Awareness Method

As was mentioned before, the assignment of keys to nodes in structured peer-to-peer network overlays does not take into consideration the physical position of peers. As a result, two nodes that are physically close to one another may be located in the overlay at a great distance from one another. This critical mismatch poses a significant problem, causing the routing path length for the majority of requests to be excessively long. This issue substantially increases end-to-end delay, thereby degrading network performance.

To address the challenge of synchronization amongst the logical overlay and the physical position of nodes in network, a solution known as the Locality-Awareness mechanism has been proposed. In essence, this mechanism involves establishing location-aware overlay links rather than relying solely on node IDs. By doing so, this solution mitigates the issue of long paths. The construction of the logical topology is grounded in underlying physical information, aiding in the reduction of route length for query operations.

Locality awareness enables the presence of neighbor nodes in the logical network (overlay) that are also physically close. This condition results in a more rapidly and more efficient lookup process. Various methods can be employed to construct the overlay to implement the Locality Awareness approach, including clustering and node-ID assignment (Cherbal et al., 2015), broadcasting, and others. The Locality Awareness approach has the potential to accelerate the lookup process, enhance the success ratio of lookups, and provide other benefits.

3. RELATED WORKS

3.1. Locality Awareness

The establishment of an overlay network in distributed P2P system applications has been accomplished by a number of researchers through the utilization of structured peer-to-peer protocols such as Chord, CAN, and Pastry. The performance of structured peer-to-peer protocols on wired networks has been deemed to be impressive. As a result of the fact that the overlay links in VANET networks may cover multiple hops, the physical pathways that query search packets take are lengthened significantly. To mitigate this challenge, building an overlay based on locality awareness, rather than relying solely on node IDs, proves to be a viable solution. There is a substantial body of related research ad-dressing the issue of locality awareness for overlay construction in VANET networks, and a few pertinent works are discussed here.

In (Rybicki et al., 2009), Rybicki et al, presented an approach for a traffic information system called Peertis, which is constructed on a structured peer-to-peer protocol. This approach facilitates data sharing among vehicles. Peertis creates an overlay structure through an internet connection.

Peertis utilizes the CAN (Ratnasamy et al., 2001) protocol as a peer-to-peer network protocol in its overlay. In Peertis, roads are collected into road segments, each assigned a unique ID utilized as a key identifier in the Distributed Hash Table (DHT) overlay. Each segment has a designated vehicle serving as a master, responsible for all the data associated with that particular segment. The authors suggest maintaining proximity between neighboring road segments in the resulting overlay. The hashing function is switched with neighboring coordinates in the underlying topology in order to accomplish this concept that has been proposed.

In (Le-Dang et al., 2013), the authors introduced a location-aware based on Chord protocol called WILCO, specifically designed for wireless environments. In WILCO, all peers establish the logical structure (overlay) with their successor

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and predecessor using their IDs built with geographical location information of peers. This is done to enhance the quality of service in wireless networks. Additionally, modifications to the finger table are proposed to improve the new overlay based on location-awareness method. On the other hand, this strategy is fraught with difficulties because of the movement of peers, which results in frequent alterations in geographical locations. This mobility-induced instability can negatively affect the scalability of the network.

The MANETChordGNP, as proposed in (Fantar & Youssef, 2009), is based on constructing the overlay while considering the underlay topology using the Chord protocol. The GNP (Global Network Positioning) system is utilized to assign IDs to peers based on their geometric coordinates. A set of nodes is designated as landmarks to assist other nodes in joining the network. If a landmark node displaces or disconnects, the node with the closest logical ID takes its place. Each node is assigned a unique temporary ID to define its location in the overlay. The resource location and lookup procedures in MANETChordGNP are similar to the basic Chord protocol.

There are a number of papers that have been published on the topic of locality awareness in VANET that provide approaches that are based on the principles of cluster-ing. The latter method entails arranging cars into sets, taking into account a variety of parameters like velocity, direction, and physical location during the process. For example, in (Santos et al., 2004), the concept of cluster-based location routing (CBLR) is presented. In this system, vehicles communicate their whereabouts by sending HELLO signals to one another. Furthermore, CBLR is further improved in (Burgess et al., 2006) and (Kayis & Acarman, 2007), and the authors recommend that clusters should be formed based on the velocity of vehicles.

For a more in-depth understanding of locality awareness approaches in wireless mobile networks, readers are encouraged to refer to (Cherbal et al., 2015).

3.2. Replicat

In (Akila & Iswarya, 2011), the authors introduced V-PADA (Vehicle-Platoon-Aware Data) in VANETs environment. In this strategy, all of the vehicles gather together to create a platoon. Vehi-cles that are part of the same platoon are encouraged to set aside a portion of their buffers in order to retain a copy of data for other vehicles in the platoon. This allows for the shar-ing of information among the vehicles in the platoon. In the event that a vehicle becomes disconnected from the platoon, it is necessary for that vehicle to forward pertinent data to other vehicles that are part of the same platoon. This ensures that other vehicles will con-tinue to have access to the data. There is, however, a potential drawback to the V-PADA system, which is that the frequent joining and leaving of vehicles within the same platoon may result in additional computation overhead in the network.

In (Park & Lee, 2012), Park and Lee presented an effective approach in which data is replicated in Road Side Units (RSU) with the goal of achieving rapid information dissemination and improving data accessibility in VANETs. For the purpose of selecting the data items that ought to be replicated in the RSUs, their strategy takes into consideration driving patterns as well as data access patterns. It is possible for vehicles to make direct requests for the replicated data that is kept in the RSUs without first establishing a connection with the RSUs that are responsible for storing the original data. Nevertheless, one of the most significant drawbacks of this method is that the process of replicating the data could take a substantial amount of time, particularly when dealing with huge amounts of data being replicated. Additionally, the approach is limited to environments where RSUs are available.

In (Ghavifekr & Khosrowshahi, 2015), the authors proposed a scheme to achieve high data availability in VANET based on the replica method. In this method, each vehicle replicates its data to other vehi-cles inside the same parking lot while it is doing so. For instance, when a vehicle stops in a parking lot, it replicates its data to other vehicles simultaneously. In addition to this, if the vehicle goes to a different parking lot, it will also copy its data to other automobiles that are located in that new establishment. While this approach can aid in data dissemination in VANETs, it requires specifying which data should be replicated.

In (Fan et al., 2018), Fan et al, presented R-DRA. In this latter, they consider the processing and storage capabilities of all vehicles. They propose a replication-based method utilizing a distributed randomized algorithm, where the total

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number of disseminated data copies in the network is manageable. The authors' method, outlined in (Fan et al., 2018), involves controlling and limiting the number of replicated data, and each vehicle is assigned a specific threshold value indicating the quantity of data replicas disseminated by that vehicle. While the proposed approach seems practical, it is noted that the conditions assumed for the approach may be unattainable in the entire environment.

In (Wu et al., 2013), the authors introduce a routing protocol so-called CCR, designed for data dissemination in VANETs environment. CCR employs a capacity-constrained approach to replicate data, with CCR each vehicle adjusting its replication limit based on the fluctuating network capacity. While CCR achieves a high delivery success lookup ratio, it is noted that it introduces increased overhead in the network.

In (Zhu et al., 2018), a distributed data replication approach named EDDA is presented. The central concept in EDDA involves allowing the master or holder node to disseminate and copy data to multiple nodes, accelerating the dissemination process. The subsequent step is to compute the number of communication steps required in the network to reach a stable state, ensuring that the data becomes accessible to all vehicles.

4. PROPOSAL

4.1. Assumed Scenario

In the presented approach, it is assumed that the VANET operates in an urban environment. Within this supposed setting, all vehicles are assumed to be equipped with a wireless network interface (NIC) that is based on IEEE 802.11p, featuring a fixed range for establishing connections between vehicles. IEEE 802.11p is commonly known as Dedicated Short-Range Communication (DSRC) (Kenney, 2011), and it is an endorsed enhancement of the IEEE 802.11 standard designed to incorporate Wireless Access in Vehicular Environments (WAVE).

Also, in this supposed environment, all vehicles are expected to exchange information about themselves, including details about direction, speed and position. In fact, all this relevant information is conveyed through the Beacon messages. This latter is a type of single-hop short-range periodic message broadcasted between vehicles.

In this proposal, the Chord protocol is employed due to its simplicity in design, provable correctness, and high performance. It's worth noting that the proposed approach is applicable to any DHT-based scheme, such as Pastry (Rowstron & Druschel, 2001) and CAN (Ratnasamy et al., 2001), as these overlays also utilize ID-assignment for building the overlay.

4.2. Replication Proposed Method

The Chord protocol is employed in this proposal, as mentioned earlier. Each node retains additional routing information, known as the finger-table in Chord DHT (Stoica et al., 2003). For an identifier space that is m bits in length, the finger table is a routing table that can have a maximum of m lines included. Noting that the identification of the node that succeeds n by at least 2(i-1) on the identifier circle is included in the ith item of the finger table of any node n, it is important to note that the range of values for i is from 1 to m noted that all operations are calculated with modulo 2m.

To leverage the resilience of the query routing mechanism inherent in the Chord protocol, especially between a node and its set of finger nodes, a proposition is made to replicate data in the finger nodes list of the owner or master node. The objective is to address the challenge of data loss caused by node churn in the peer-to-peer overlay in VANET. In response to this, a novel data replication method named Finger Node Replication (FNR-VANET) has been introduced.

In this approach, data in master node is replicated into the group of its finger nodes. By adopting this strategy, the likelihood of locating a replica node in a network characterized by continuous changes in overlay topology is increased. The FNR-VANET approach enhances data availability in the vehicles' network, leading to a higher lookup success rate. Moreover, FNR-VANET has the potential to decrease the number of hops necessary for locating the requested data.

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The pseudocode of replicating data in a finger node is in the following:

Algorithm 1: Data Replication Algorithm.

```
For each received Item (resource);
    // Retrieve the id of this item
        ID = hash(item),
    //Firstly, Put Item_id in the master(owner) node
    Master Node = Successor(ID)
    //Then put Item_id in the set of replica nodes
     For k==1 to m do
        Replicat_Node_k = Successor((key+2^(k-1)) mod2^m)
```

The stabilization of the VANET (Vehicular Ad-Hoc Network) is significantly impacted by the addition and removal of nodes. To manage this dynamic environment, the Chord protocol employs a stabilization mechanism. To minimize any additional network overhead caused by the proposed replication approach, the replication of data is seamlessly integrated into the stabilization process. Consequently, whenever a node updates its list of finger nodes, it promptly replicates its data in these nodes. For a more in-depth understanding of the stabilization mechanism within the Chord protocol, interested readers have to refer to (Stoica et al., 2003).

During the lookup procedure, upon receiving a request, a node initiates the process by checking whether it is the designated owner or has a replica for the requested data. If the node is indeed responsible or has a copy of the requested data, it can resolve the re-quest locally. However, if the node neither holds the data nor has a copy of the data, it forwards the original request to the node with the largest ID in its finger table, which is less than or equal to the requested data key.

The steps of the Lookup Procedure are outlined in the following algorithm:

Algorithm 2: Lookup Procedure Algorithm.

```
For every received request(R);
    // asking node n to find the successor of R
     successor = n.find_successor(R)
       If R in (n,successor]
          return successor;
       else
            n′ = closest_preceding_node(id);
            return n′.find_successor(id);
    // searching in the local finger table for the highest predecessor of R
    n.closest_preceding_node(id)
      for i=m downto 1
        if finger[i] in (n,R)
          return finger[i];
      return n;
```

As an example, in Figure 2, if the key being looked up is 3, the designated node responsible for key=3 is 4. Node 4, being responsible, includes nodes 8 and 12 in its finger nodes. Consequently, the data associated with key 3 is copied in these nodes (8 & 12).

In the scenario where Node 8 is searching for key=3, it finds that it already contains key 3 as a copy. In this situation, Node 8 doesn't need to transmit the request further, as it has the necessary data locally

As depicted in Figure 2, in the standard Chord protocol, the lookup request traverses the nodes 8, 0, 4 respectively. On the contrary, with the introduced replication method, Node 8 already possesses the desired object, resulting in a significantly shortened lookup path and a decrease in the number of hops. This is achieved through the suggested

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replication approach, FNR-VANET. It's worth noting that reducing the logical hop count also implies a reduction in the physical hop count.

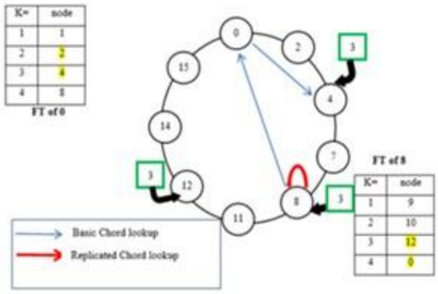

Figure 2. Example of a lookup path both before and after applying the replication approach.

4.3. Locality Awareness Proposed Method

In the Chord protocol overlay, all nodes acquire their IDs randomly, such as by hashing their IP addresses. This approach disregards the physical locations of nodes, leading to a lack of alignment between physical and overlay neighbors. To address this discrepancy, a solution known as Locality Awareness in VANET, or LA-VANET, has been proposed. LA-VANET considers the physical positions of nodes in the underlay when constructing the overlay network. Implementing the locality awareness method results in an overlay where nodes correspond with their physical neighbors. Nodes that are neighbors in the physical underlay topology have closely aligned IDs, positioning them as neighbors in the logical overlay structure, as illustrated in Figure 4.

This paper introduces a novel approach called LA-VANET, based on Locality Awareness in VANET. The primary objective of this method is to change the ID definition of nodes by incorporating the physical positions of nodes and adapting it to the VANET environment.

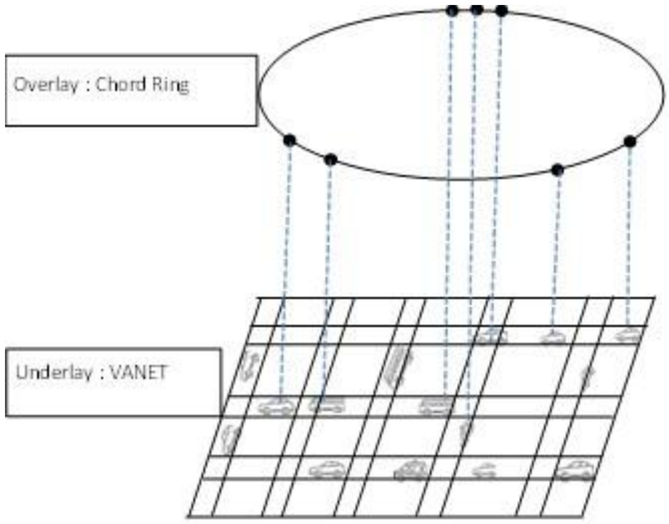

Figure 3. The application of locality awareness on Chord within VANET

To initiate the construction of the overlay, the most stable vehicles on the road are designated as Bootstrap Vehicles (BV). In this context, public transport vehicles such as city buses and taxi services are identified and assigned as bootstrap vehicles in the over-lay. Their selection is based on stability criteria, and their identifiers, such as physical ad-dresses, are utilized in the vehicle-ID calculation step. In addition, it is assumed that only Bootstrap Vehicles are able to reply to join call requests that are started by other vehicles.

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Each Bootstrap Vehicle (BV) computes its hash ID using the following equation:

BV_ID = Hash (MAC Address of BV) mod 2^k ⊕ hash (IP Address of BV) mod2^{m-k} (⊕ denote the concatenation)

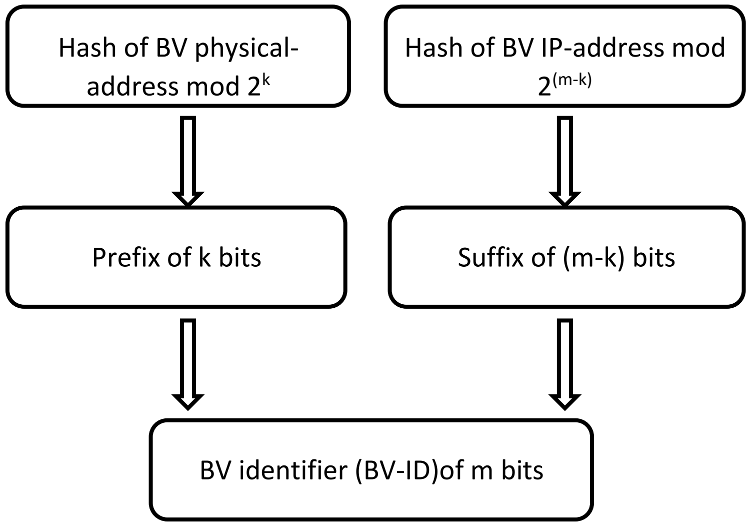

Figure 4. The calculation of Bootstrap Vehicle Identifier (BV-ID)

Furthermore, within LA-Vanet, all regular vehicles compute their ID using the following equation, relying on the ID of a previously elected Bootstrap Vehicle (BV).

The selection of the Best Bootstrap Vehicle (BBV) is determined based on various properties such as velocity, direction, and category. This strategic selection aims to extend the lifespan of the connections between vehicles and their BBV within the presented LA-VANET approach. Also we proposed to elect a backup of BBV (BBBV) for more net-work-stabilization.

Each vehicle calculates its hash ID using the following equation:

Vehicle_ID = hash (BBV_Mac_Address) mod 2^k ⊕ hash (Node_IP_Address)mod2^{m-k} ⊕ denote the concatenation)

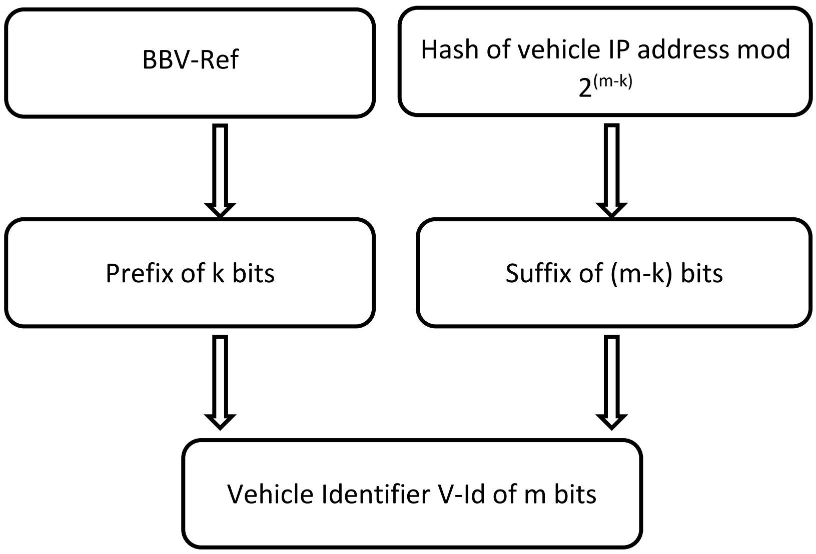

Figure 5. The calculation of Vehicle-Identifier

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The vehicle joining procedure is summarized as in the following pseudocode:

Algorithm 3: Locality Awareness Algorithm.

1. A newly arriving vehicle (Vnew) initiates the joining process by sending a join request to its 1-hop neighbors
2. All 1-hop neighboring existing Bootstrap Vehicles (BVexist) respond to the request by providing details about their existence.
3. Vnew selects the Best Bootstrap Vehicle (BBV) and Backup Best Bootstrap Vehicle (BBBV) based on predefined information, including velocity, direction, and vehicle type.
4. Vnew calculates its Vehicle_ID (hash ID) based on the chosen Best Bootstrap Vehicle (BBV).
    a. Prefix = The hash of the BBV Mac-Address
    b. Suffix = The hash of the Vnew IP-Address
    c. Vehicle_ID = Prefix ⊕ Suffix (⊕ denote concatenation)
5. Updating finger tables, set of predecessors, and successors of the existing overlay that are affected by the joining of Vnew.,
6. Transferring content objects to Vnew from its successors.

When Vnew calculates its reference ID, the subsequent stabilization process is governed by the DHT overlay maintenance processes of the Chord protocol, as detailed in (Stoica et al., 2003). Periodically, each node in the DHT overlay executes a stabilization procedure to maintain the consistency of the overlay. Within this procedure, the node verifies its successor and inspects details about its predecessors. This ensures that any newly entered node is discovered within a predefined period. Additionally, each node conducts a fix-finger procedure at regular intervals to refresh its finger-table. Further details about the stabilization processes and fix-finger procedure can be found in (Stoica et al., 2003).

4.3.1. BBV Move or Departure

In LA-Vanet, when the Best Bootstrap Vehicle (BBV) exits the network, all nodes associated with it must identify a new BBV and subsequently reconstruct the overlay. Consequently, all vehicles will be assigned new IDs calculated with respect to the reference pro-vided by the new BBV. Moreover, if the BBV undergoes a change in its position, it does not need to alter its ID unless there is a modification in its IP address.

In LA-Vanet, when the Best Bootstrap Vehicle (BBV) departs from the network, the Backup Best Bootstrap Vehicle (BBBV) assumes the role of the BBV. Consequently, all nodes associated with the old BBV detect the change and initiate the process of identifying a new BBV, followed by rebuilding the overlay. This results in all vehicles acquiring new IDs calculated in reference to the new BBV. In the event of the BBBV transitioning to the role of the BBV, a new Backup Best Bootstrap Vehicle (BBBV) is elected within the overlay to ensure the continuity and stability of the network.

4.3.2. Vehicle's Move or Departure

In LA-VANET, when a vehicle's departure is predictable, the vehicle takes proactive steps by informing its successor list and transmitting its objects to them. Simultaneously, it informs its predecessor to update both the finger table and successor's list, ensuring a smooth transition. On the other hand, if the departure of the vehicle is unpredictable, the entire overlay network will discover the new topology during the subsequent steps of the stabilization procedure within the maintenance process of the Chord protocol. This process helps the network adapt to changes and ensures the continued efficiency of the over-lay structure despite unexpected departures of vehicles.

If a vehicle's Best Bootstrap Vehicle (BBV) becomes unreachable, vehicles within the network must update their reference ID based on the new BBV, which is the previously elected Backup Best Bootstrap Vehicle (BBBV). This circumstance may arise when the BBV reaches its final stop on its route or comes to a halt due to various reasons, surpassing a specified threshold time limit, for example. In such cases, the overlay network needs to adapt by recognizing the change in BBV status and adjusting the reference IDs according-ly, ensuring the continuity and stability of the overlay network despite the unavailability of the original BBV.

5. SIMULATION ENVIRONMENT AND RESULTS

In this section of the present paper, we begin by introducing the parameters and environment of the simulation. Subsequently, we outline the performance metrics employed. Finally, we provide the evaluation results.

Our proposed approach has been simulated utilizing Oversim (The OverSim P2P Simulator, n.d.) on the OM-NeT++ (OMNeT++ Discrete Event Simulator, 2024) platform. Additionally, the Traffic control Interface (TraCI) (Wegener et al., 2008b) client that was de-signed for the OMNeT++/MiXiM (Sommer et al., 2008) framework was also utilized in the simulation. OMNeT++ framework is an open-source, discrete event simulation environment and component-based. The alternative framework, known as OverSim, is an open-source simulation framework that was developed expressly for peer-to-peer overlay networks. It is intended to be integrated with the OMNeT++ simulation environment.

To facilitate the creation of structured peer-to-peer networks, Oversim contains a number of different modules, such as Chord, Pastry, and Kademlia. For the purpose of simulating the Distributed Hash Table (DHT) of cars, we made use of the Chord module in our simulation. MOVE, which stands for Mobility model generator for vehicular net-works (Karnadi et al., 2007), was the tool that we utilized in order to produce realistic vehicle motions. The micro-traffic simulator known as SUMO (Simulation of Urban MObility) (Krajzewicz et al., 2002) serves as the foundation which MOVE is based upon. This combination allows for a comprehensive simulation environment that considers both the structured peer-to-peer system aspects and realistic vehicle mobility patterns.

The application of the IEEE 802.11p standard is incorporated into OMNET++. The IEEE 802.11p standard is the protocol that is particularly applicable to environments that involve vehicles. The graphical user interface (GUI) that is offered by the MOVE simulation environment is used to simulate the movement of vehicles. Through the use of MOVE's graphical user interface (GUI), it is possible to effectively portray a variety of characteristics, including the departure time of vehicles, their velocity, routes, and so on, in order to simulate the mobility of vehicles.

TraCI, which stands for Traffic Control Interface, is a client-server architecture that offers a TCP connection. In this scenario, MOVE/SUMO serves as the TraCI server, and OMNET++/INET serves as the TraCI client. This allows for the exchange of commands between the two of them through the use of TCP connections. This setup enables effective communication and coordination between the mobility and the network simulation components.

In this section, we begin by comparing the performance of the proposed replica method with other essential data dissemination schemes, specifically EDDA and CCR. The evaluation is conducted in terms of lookup hop count, lookup delay time, and lookup success rate. Subsequently, we compare the suggested approach based on the locality awareness method with the original mobile Chord algorithm, utilizing the same metrics for assessment

5.1. Lookup Hop Count

The logical hop counts, which are a reflection of the lookup speed, are represented by this metric, which is the average hop count or the number of vehicles browsed in every successful lookup within the overlay. This metric is an essential measure in the VANET environment. The average hop count is calculated as follows:

$$\boldsymbol{O} = \frac{\sum_{k}^{r} \boldsymbol{Hk}}{\mathbf{R}} \tag{1}$$

where:

$R - the\ total\ number\ of\ lookup\ requests,$

$Hk - the\ number\ of\ vehicles\ selected\ for\ each\ lookup,$

5.2. Lookup Delay Time

Certainly, the calculation for the average lookup latency or file discovery delay could be expressed in the following way:

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$$D = \frac{\sum_k^l Tk}{L} \qquad (2)$$

where: $Tk -$ $\quad the\ delay\ that\ is\ conveyed\ by\ one\ lookup\ request\ from\ the\ source\ to\ the\ final\ node$

$L -$ $\quad the\ number\ of\ all\ lookup\ rquests$

5.3. Lookup Success Rate

This ratio provides an indication of the effectiveness of the lookup process by deter-mining the proportion of successful lookups out of the total number of resource lookups occurred in a portion of time predefined. This equation is used to determine the success ratio, which is as follows:

$$E = \frac{R*100}{L} \qquad (3)$$

where: $R -$ $\quad the\ number\ of\ successful\ lookup\ requests$

$L -$ $\quad the\ number\ of\ all\ ressource\ lookups$

Parameters' simulation used are demonstrated in Table 1.

Table 1. Simulation parameters

Traffic type	
Number of vehicles	100, 200, 300, 400, 500
Vehicle properties	
Maximum speed of vehicles	70 km/hour
Maximum speed of BV	50 km/hour
Maximum speed of BBV	50 km/hour
Number of BV	15% of total vehicles
Number of BBV	15% of total vehicles
Maximum number of requesters at a time	35% of total vehicles
Ad hoc communication properties	
Protocol used	802.11p
Transmission range of vehicles	180 meters
DHT communication properties	
Protocol used	Chord
Underlying protocol	TCP/IP
Fix-finger period	3s
Stabilization period	3s

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5.4. Simulation Results

As we have mentioned before, we have proposed two approach for data dissemination in Vanet based on structured peer to peer communication, using replica and locality awareness method, so we simulate and analyze each one separately.

5.4.1. Replica method

5.4.1.1. Lookup Success Rate

We examined the lookup success rate while varying the number of from 100 to 500 vehicles. The simulation results, presented in Figure 6, illustrate that the lookup success rate achieved by our proposed replica method, FNR-Vanet, surpasses that of the other protocols, CCR & EDDA. As the number of vehicles increases, a common trend is observed – the success rates decrease. However, FNR-Vanet shows a slower decrease compared to CCR & EDDA. These findings confirm the effectiveness of the proposed method in terms of enhancing data availability in VANET.

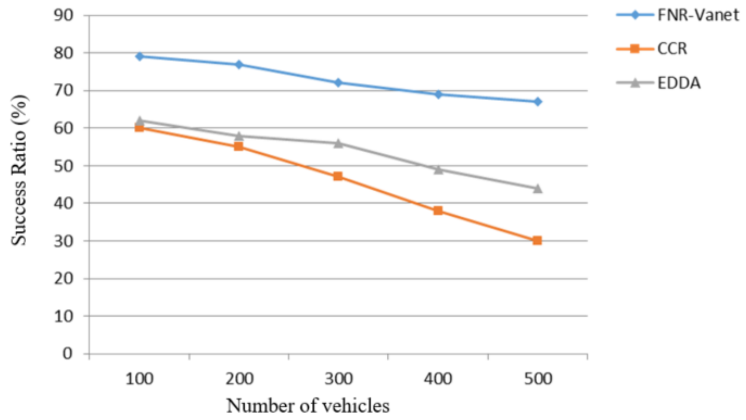

Figure 6. Lookup success rate with an increasing number of vehicles.

5.4.1.2. Lookup Hop Count

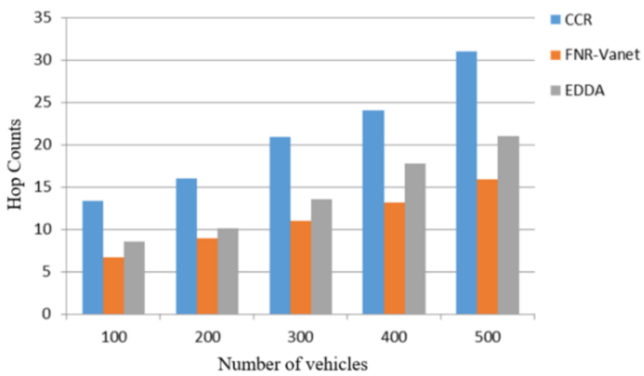

Figure 7. Lookup hop count: FNR-VANET versus CCR & EDDA

The primary goal of the proposed replica method FNR-VANET is to offer more availability of resources in VANET environment. To evaluate this, we examine the lookup hop count in the FNR-VANET approach in comparison to CCR & EDDA as the network size is varying from 100 to 500 vehicles. As depicted in Figure 7, the average number of hops in the proposed FNR-VANET approach is consistently lower when contrasted with CCR & EDDA. Furthermore, the

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hop count still experiences an increase with the rise in the number of vehicles, which aligns with expectations as more peers are involved in lookup requests.

5.4.1.3. Lookup Delay Time

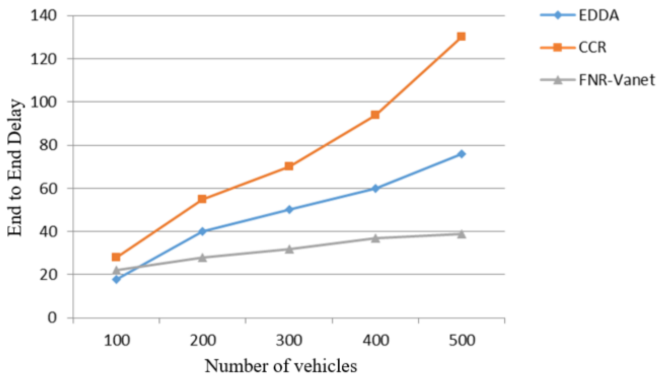

Figure 8. Lookup delay time: FNR-VANET versus CCR & EDDA

We conducted various lookup process scenarios with an incremental number of vehicles ranging from 100 to 500. The simulation results, presented in Figure 8, demonstrate that our method, FNR-Vanet, outperforms EDDA & CCR significantly. Specifically, latencies in FNR-Vanet range between 22 and 39 seconds, compared to 18 and 130 seconds in EDDA & CCR. This superior performance is attributed, on one hand, to the availability of data in the closest holder in the overlay and, on the other hand, to the consideration of physical topology during the overlay building phase. This consideration contributes to a reduction in end-to-end delay. The widening gap between the lookup latency of EDDA & CCR and our proposed method, FNR-VANET, becomes more pronounced as the number of vehicles increases.

5.4.2 Locality Awareness

5.4.2.1. Lookup Success Rate

The effectiveness of the system is illustrated in Figure 6 through a comparison of the lookup success rate. In the scenario that is assumed, the number of cars ranges from 100 to 500. The graph illustrates that the lookup success rate generated by the proposed approach, LA-VANET, surpasses that of Mobile Chord. Additionally, the success rates de-crease gradually as the number of vehicles increases, which is expected. These results validate the effectiveness of the proposed method LA-VANET, in terms of enhancing data availability.

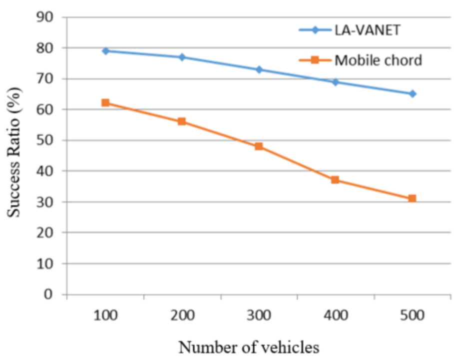

Figure 9. Lookup success rate: our approach versus mobile chord

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5.4.2.2. Lookup Hop Count

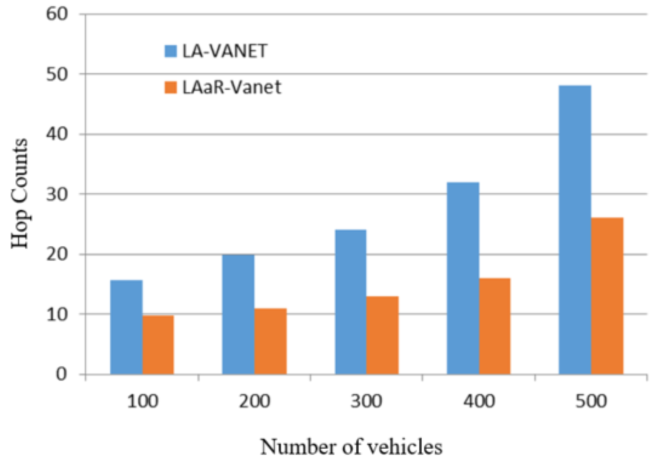

Figure 10. Lookup hop count: our approach versus mobile chord

The key of the locality awareness approach lies in considering the underlay topology when constructing the overlay structure. In our simulation, we investigate the lookup hop count in the proposed approach, LA-Vanet, as compared to Mobile Chord, with the number of vehicles ranging from 100 to 500. Illustrated in Figure 7 is the observation that the average number of hops in LA-Vanet is lower in contrast to Mobile Chord. Furthermore, this count still experiences an increase with a decreasing number of vehicles in the sys-tem, a trend aligned with expectations as there are more peers to browse through during lookup requests.

5.4.2.3. Lookup Delay Time

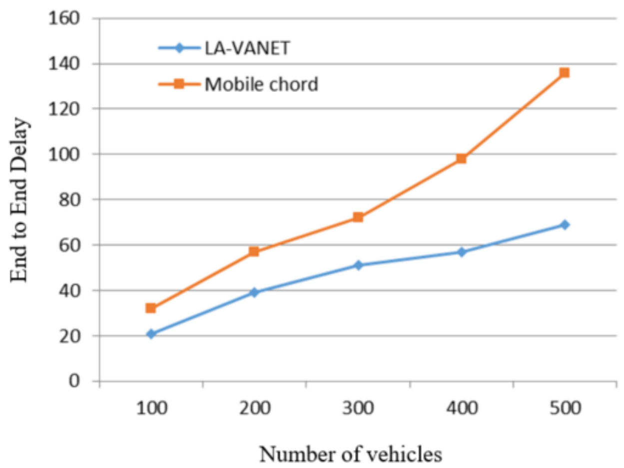

Figure 11. Lookup delay time: our approach versus mobile chord

We conducted various lookup scenarios with an increasing number of vehicles from 100 to 500. The simulation results, presented in Figure 8, illustrate that LA-VANET outperforms Mobile Chord significantly. In our approach, latencies range between 21 and 68 seconds, compared to 33 and 138 seconds in Mobile Chord. This improvement is attributed to the consideration of the physical topology during the overlay building process in LA-VANET, which contributes directly to a reduction in end-to-end delay.

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6. CONCLUSION

In this study, we have introduced and assessed two P2P-based approaches for da-ta dissemination in VANET. The first approach involves the replication method, which entails duplicating data across multiple holder or master nodes to address the challenge of data availability in VANET. The second approach is centered around locality awareness, which entails constructing an overlay that aligns with the underlay or physical topology. This method aims to minimize the number of hops required for each lookup operation. Our experiments have demonstrated the efficacy of both proposed approaches. The results indicate a decrease in the number of hops traversed during each lookup, an improvement in the success ratio of lookups, and a reduction in end-to-end delay. The performance of these approaches has been benchmarked against state-of-the-art algorithms, including CCR, EDDA, and mobile Chord. In future re-search, we plan to incorporate additional parameters to further enhance the proposed approaches. Additionally, we intend to implement these proposals in practical re-al-world scenarios to validate their effectiveness in a practical context.

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