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Cooperative content caching among RSU's and vehicular edge nodes by considering content popularity and the Probability of visiting the hot zones.

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Abstract

Improving the performance of content distribution in vehicle networks is possible via the use of RSUs (Roadside Units) and edge nodes that work together to cache data/ content . By taking into account content popularity and the likelihood of visiting the hot zones, we give a complete evaluation of previous experiments on cooperative content caching in this study. In this study, we evaluate and contrast several strategies for enhancing content delivery performance that have been presented in the literature. Cooperative caching has been shown to increase the Quality of Service (QoS) and decrease the latency of content delivery in vehicular networks, according to the evaluated research. We also stress the significance of popular material and the likelihood of visiting the hot zones when it comes to content caching. Exploring more effective caching algorithms and assessing the effectiveness of cooperative caching in real-world circumstances are two potential next steps for researchers in this field.

Key words: Cooperative, RSU, vehicular edge content, Probability, zone etc.

Introduction

The need for content delivery in vehicular networks has skyrocketed in recent years, thanks to the proliferation of linked vehicles. Caching is a possible solution to the problem of inefficient content delivery. By bringing frequently accessed data closer to where it is needed (where users are), caching may drastically cut down on both latency and network congestion. In this study, we survey the existing literature on cooperative content caching between Roadside Units (RSUs) and Vehicular Edge Nodes, taking into account the data/ content popularity and the likelihood of users visiting the hot zones.

This study provides a thorough analysis of current research on RSUs and vehicle edge nodes that caches content cooperatively. The authors evaluate and analyse the many strategies proposed in the literature to improve the efficiency with which content is delivered. Based on the reviewed literature, cooperative caching improves QoS and reduces latency in vehicular networks by storing frequently requested content locally.

One of the biggest challenges of content caching is deciding what to cache and where to cache it. Many studies have proposed different algorithms based on content popularity and movement patterns as a means of fixing this issue. Some studies used machine learning methods to predict

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what data would be most often accessed and stored that copy in RSUs or edge nodes. The chance of users reaching the hotspots must also be included into content caching. The hotspots are the areas where there is a heavy traffic volume and a strong demand for certain content. Several methods have been proposed in the literature for predicting how often users would be in hotspots and storing their data. Cooperative content caching is a topic of interest in the field of vehicular network research because of the increasing prevalence of internet-connected vehicles and the consequent need for widespread data dissemination. In the present work, we review the state-of-the-art research on cooperative content caching between RSUs and vehicular edge nodes, taking into consideration content popularity and the possibility of visiting the hot zones.

Background and motivation:

In order to increase road safety, traffic efficiency, and passenger experience, intelligent transportation systems, enabled by vehicular networks, have emerged as a viable technology. However, it is still difficult to provide consistent and dependable communication services in highly dynamic and mobile settings. By storing regularly requested Content in a more convenient location for the vehicular uses , content caching may decrease delivery delay and congestion in vehicular networks. In this study, we suggest a cooperative content caching method that makes use of roadside units (RSUs) and vehicle edge nodes to store data in anticipation of users' likely visits to high-traffic areas.

Review of Literature

(Yao et al., 2021) Studied "*Cooperative Caching in Vehicular Content Centric Network based on Social Attributes and Mobility*" After investigating the impacts of channel fading and irregular network connection on communications in vehicle ad hoc networks (VANET), researchers found that VANET are vulnerable to performance degradation. Growing VCCN, or the Vehicular Content Centric Network, shows potential in addressing content needs and easing communication bottlenecks in VANET. To be more precise, increasing the cache hit ratio and decreasing the access time of information retrieval may be aided by picking the appropriate vehicles to cache the frequently accessed data items. The right vehicles might be the key to success here. In this piece, we propose a CCSAMP (Cooperative Caching with Social Attributes and Mobility Prediction) approach for VCCN. The CCSAMP was created from the realisation that drivers with similar or shared interests tend to circulate in similar circles and interact with one another.

(Chen et al., 2020) Studied "*Cooperative Edge Caching with Location-Based and Popular Contents for Vehicular Network*" It found that consumers and government officials are both looking forward to the era of autonomous autos, which has been ushered in by recent developments in automotive technology. However, relying only on on-board sensors might be challenging when trying to meet the stringent requirements of autonomous vehicles in hazardous environments. One such circumstance is trying to avoid a collision while visibility is poor. Sharing information with different groups is essential for things like warning the public about potential dangers and maintaining high quality standards.

(Nam et al., 2021) Studied "*Adaptive Content Precaching Scheme Based on the Predictive Speed of Vehicles in Content-Centric Vehicular Networks*" After doing some preliminary study, we came to the conclusion that Content-Centric Vehicular Networks (CCVNs) provide a promising approach to efficiently distributing and exchanging content among vehicles in environments with vehicular traffic. Multimedia data, in particular, may be rather large, making it difficult for a car to download the whole information while still staying within the range of its current Roadside Unit (RSU). In order to solve this issue, several studies have used mobility-based content precaching in succeeding RSUs throughout the vehicle's trajectory. A constant speed is used, such as the current speed of the vehicle looking for the content or the average speed of Vehicular in the next RSU, to calculate how much of the content has been precached.

(Oh et al., 2022) Studied "*Optimized Distributed Proactive Caching Based on Movement Probability of Vehicles in Content-Centric Vehicular Networks*" We looked at CCVNs, which are networks focused on transporting content, and found that they have considered distributed proactive caching as a promising method of ensuring that new services are delivered promptly. Cars that use naïve caching methods only save their data with a single RSU after making a request. This is done so that during data collecting, as little time as possible is lost between the data source and the cars. Vehicle networks could only manage a finite number of Vehicles and a finite amount of Content due to the high cost of deployment for RSUs, resulting in a decline in the cache hit ratio. The percentage of successful cached requests also dropped.

(Guo et al., 2020) Studied "*A zone-based content pre-caching strategy in vehicular edge networks*" and took great pleasure in it as mobile network technology and devices have rapidly advanced over the last decade, mobile data has proliferated at an unprecedented rate. Cisco predicts that by 2021, global mobile traffic would increase at a rate of 7.2 exabytes per month. By using remote core networks with centralised cloud servers, we are able to handle mobile requests. Cloud computing technologies provide for this functionality. However, a centralised computing paradigm is no longer suitable for serving the vast dispersed and dynamic edge demands in networks like MANET (mobile ad hoc network) and VANET (vehicular ad hoc network). Both mobile and car networks fall under the category of "ad hoc networks" (VANET).

(Choi & Lim, 2023) Studied "*Deep Reinforcement Learning for Edge Caching with Mobility Prediction in Vehicular Networks*" Researchers found that when cars are connected to the internet, both the driver and the passenger may take use of additional features. However, if all the vehicle users' requests are sent to one far-off server, the transmission delay will increase, and the delay restriction may not be met. Performing caching closer to the Vehicular user might reduce latency by distributing requests more uniformly throughout the network. With this, we can address the problem at hand. By placing data storage closer to end users, a mobile edge computing (MEC) server installed in the RSU and an on-board unit (OBU) installed in the car may act as cache nodes. Mobile edge computing (MEC) servers are the specialised hardware at the network's periphery.

(Wu et al., 2021) Studied "*A Comprehensive Review on Edge Caching from the Perspective of Total Process: Placement, Policy and Delivery*" and learned that more nuanced CDN technologies and effective caching solutions are needed to accommodate the increased demand for services through mobile networks. This is because of the ever-increasing demand for mobile data and the concomitant decrease in available bandwidth and power. As the number of networking services available increases, so does the demand for higher-quality content, putting immense strain on both the central network and the backhaul.

(Gupta et al., 2023) Studied "*An edge communication based probabilistic caching for transient content distribution in vehicular networks*" They found that VCNs, or Automotive Material Networks, are a crucial enabling solution for the entirely decentralised distribution of content for in-vehicle entertainment systems. Content caching in a VCN is handled by both the vehicles' on-board units (OBUs) and fixed locations' RSUs. This guarantees that content required by moving vehicles may be delivered promptly. However, as RSUs and OBUs have limited caching capability, only selected content may be cached.

(Amadeo, 2021) Studied "*A Literature Review on Caching Transient Contents in Vehicular Named Data Networking*" and found that the unique information-centric Vehicular Named Data Networking (VNDN) architecture was developed with cars in mind. Name-based forwarding and local caching set it apart. Numerous caching algorithms, all of which work when confronted with static data packets like those found in standard Internet content, have been proposed for VNDN. The development of IoT and IoV applications, however, has led to the prediction that massive collections of vehicle contents would be transient in nature. This implies that they will expire at some point in the future after serving their purpose.

(Han et al., 2022) Studied "*MEC-Based Cooperative Multimedia Caching Mechanism for the Internet of Vehicles*" and observed that it is projected that multimedia apps will find broad deployment on car networks. Edge caching is used to decrease the quantity of traffic on a network and the length of time it takes for data to be transferred in order to meet the demands that multimedia applications have for low-latency and high-speed data transmission. Because the edge cache server has a specific amount of storage space, the success of the content management strategy plays a vital role in deciding how effectively the edge cache will perform.

(Zhang et al., 2020) Studied "*A joint optimization scheme of content caching and resource allocation for internet of vehicles in mobile edge computing*" for a high-speed free-flow situation, we describe a combined optimization technique for content caching and resource allocation using mobile edge computing in the Internet of Vehicles. In order to implement car-cloud collaborative cache, it is necessary to estimate the route that a vehicle will follow. Vehicles making data requests enjoy reduced latency thanks to simultaneous data capture from both V2V connections and V2I links. This is made feasible by edge cloud networks storing incoming vehicle data and the business data of cars that have made a request.

Content caching in vehicular networks:

Congestion and latency in vehicle networks may be mitigated with the use of content caching. The performance of content distribution may be enhanced by caching by storing frequently requested content in close proximity to users. Choosing what data to cache and where to store it might be difficult. Caching is more difficult in vehicular networks due to the mobility of cars and the dynamic nature of the network.

Cooperative content caching among RSUs and vehicular edge nodes:

Improving the performance of content delivery in vehicular networks may be possible via cooperative caching between RSUs and edge nodes in vehicles. RSUs can store the data in a cache and send it to passing cars, and edge nodes in vehicles can do the same. However, the mobility of cars and the restricted communication range provide significant difficulties for RSU collaboration with vehicular edge nodes.

Content popularity-based caching algorithms:

Several researchers have developed techniques for caching material depending on its popularity. These algorithms make use of machine learning methods to determine which pieces of content will be the most popular and then store copies of these items in the most frequently visited nodes (RSUs). To further enhance caching efficiency, some research has suggested a hybrid strategy that takes into account both content popularity and mobility patterns.

Mobility pattern-based caching algorithms:

Algorithms for caching data based on vehicle mobility patterns take into account the locations of moving vehicles when making storage decisions. These algorithms make advantage of vehicles' past movements to forecast their future whereabouts and store data in those anticipated hotspots. In order to optimise caching performance, some research has suggested a hybrid strategy that takes into account both content popularity and mobility patterns.

Hot zone-based caching algorithms:

When deciding where to store cached data, algorithms that take into account hot zones take into account the likelihood of users accessing certain areas. The term "hot zones" refers to places with a high vehicle density and a high likelihood of requesting a certain content type. These algorithms calculate the likeliness of returning to popular areas and store data there in advance.

Selection of Multiple RSUs among Multiple RSUs

The information will be distributed across many RSU candidates and cached to several RSUs. Reference was able to increase the cache hit ratio by retaining the mobility information table and so enhancing the accuracy of its mobility prediction. The Content Routing Technology (CRT) will routinely revise its popularity to give more weight to more recent requests, while the Non-Persistent Caching (NPT) and Rate-based Hierarchical Caching (RHT) will keep the vehicle in good working shape and revise its range and range duration. The NPT and RHT kept track of where the vehicle would go and how long it would be on the road, respectively, while the CRT kept track of its popularity by giving priority to the most recent requests. Since the RSU is where a request ultimately lands, pre-fetching the most frequently accessed data there improves the cache hit ratio. A mobility probability table associated with a Next Application Processor (AP) and a timeframe for staying in an Application Processor (AP) are both used when deciding where and how much pre-fetching is done. They improved user satisfaction by increasing the cache hit ratio, which reduced latency and traffic. The Mobility First project would be utilised to conduct the evaluation, and the expected AP would pre-fetch the data in advance. optimises the download process to boost its success rate. In order to determine the possibility of a successful delivery, their method in incorporates historical data on vehicle velocity, wireless bandwidth, and RSU position. Caching is accomplished using two distinct algorithms. The RSU will keep a cached version of the data that has the highest chance of being successfully sent. An RSU will also think about how well received the information is and whether or not any updates have been made.

Comparison of existing schemes:

Location-based caching, in which material is stored in RSUs close to the requesting cars, is one of the most used caching strategies in vehicular networks. While this approach is straightforward and efficient at decreasing access latency and network congestion, it has a low throughput and may struggle under heavy load. Caching that takes into account how often certain content is been requested in the past is another approach. While this approach may increase the hit rate and decrease the access latency, it may not take into account the variations in traffic and content demand in different geographies.

Cooperative caching scheme

- **Architecture and components:**

Both roadside units (RSUs) and mobile edge nodes (Men) play a role in the proposed cooperative caching method (VENs). Mobile nodes with limited storage space and the ability to interact with RSUs and other VENs are contrasted with stationary nodes, RSUs, that are linked to the infrastructure network. Cooperative caching's structural design.

- **Two-phase caching approach:**

The popular content and the likelihood of users visiting certain hotspots inform the first part of the cooperative caching scheme's caching process. In the first stage, RSUs store copies of the most frequently accessed data. The quantity of requests made for a content during a certain time period is indicative of its popularity. In order to increase the hit ratio and decrease the network congestion, RSUs store the most popular content first.

In the second stage, VENs store data in their caches according to the likelihood that they will be visiting hotspots. Vehicles' past paths may be used to estimate how likely it is that they will

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enter a danger zone. Intersections, toll booths, and parking lots are all examples of "hot zones," or places with high traffic density and frequent pauses. Content that is regularly viewed in a hot zone will be cached on VENs that are likely to visit that hot zone in the future. By doing it this way, we can minimise access latency by keeping material closer to the cars that need it.

Content popularity and hot zone probability calculation:

RSUs gather and analyse request records from vehicular to determine how popular certain Contents are. The logs document events such content ID, time/date, and asking vehicle position. Using this data, RSUs may determine which Content is most often accessed and save it locally. Both the time frame and update interval are flexible in how popularity is determined. VENs utilise their GPS and communication features to share data with other VENs and RSUs in order to determine the likelihood of visiting in a hot zone. Vehicle paths and RSU locations are gathered to calculate the likeliness of passing through a danger zone. Considerations like traffic volume, time of day, and weather may all play a role in the probability's calculation.

By combining RSUs and VENs, the proposed cooperative caching strategy may cache frequently requested information and improve its placement depending on popularity and the likelihood of hot zones. In the following paragraphs, we will discuss the simulation approach used to assess the efficacy of the suggested strategy.

Conclusion

In this study, we surveyed the latest research on RSUs and mobile edge nodes working together to cache material. According to the experiments analysed, cooperative caching dramatically improves content delivery speed on vehicular network. The report also emphasised the significance of popular content and the likelihood of visiting the hot zones when deciding where to cache information. Exploring more effective caching algorithms and assessing the effectiveness of cooperative caching in real-world circumstances are two potential next steps for researchers in this field.

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