International Journal of Scientific Advances
ISSN: 2708-7972
Volume: 3 | Issue: 3 | May - Jun 2022 Available Online: www.ijscia.com
DOI: 10.51542/ijscia.v3i3.31

Research on Route Pre-caching Based on Content Type Awareness

Muhammad Awais Javeed[1] and Jiang Xingfang[2*]

[1]School of Computer Science and Artificial Intelligence
Changzhou University, Changzhou, Jiangsu, China, 213164

[2]School of Miccroelectronics and Control Engineering
Changzhou University, Changzhou, Jiangsu, China, 213164

E-mail: javedawais704@gmail.com; xfjiang@cczu.edu.cn

*Corresponding author details: Professor Jiang Xingfang; xfjiang@cczu.edu.cn

ABSTRACT

In order to improve cache hit efficiency and reduce network response delay in Vehicular Named Data Networking (VNDN) environment, a routing strategy based on content type awareness and a collaborative content pre-caching strategy based on content popularity prediction for probabilistic caching were proposed. Firstly, an appropriate route-forwarding strategy is selected according to the message characteristics and whether the destination node is known. Then, unsupervised learning topic model Latent Dirichlet Allocation (LDA) is used to dynamically predict the request preference of vehicle users. Secondly, the topological relationship between different devices in the Internet of vehicles and the predicted vehicle user preferences are used to accurately and effectively predict the popularity of content, so as to reduce the redundancy of content files cached by network devices and maximize the cache hit ratio. Simulation results show that compared with other content caching strategies, this content pre-caching strategy can effectively improve cache performance.

Keywords: vehicle named data network; content perception; content popularity prediction; the cache

INTRODUCTION

In recent years, with the continuous maturity of autonomous driving technology, the related technology of intelligent connected vehicles has attracted widespread attention in the academic world. Due to the particularity of vehicle AD hoc network, the traditional TCP/IP network architecture cannot adapt to the technical and application requirements of intelligent connected vehicles. However, the content-oriented named data network architecture NDN ADAPTS to the high-speed movement of vehicles and its in-network cache characteristics can quickly respond to the requests of vehicle users, thus becoming popular vehicle network architecture in the academic world. Vehicle named data network is the network architecture NDN loaded in the intelligent vehicle unit, so that the vehicle can sense the surrounding environment, and realize the data communication with the surrounding vehicles (V2V), pedestrians (V2P), roadside facilities (V2I), on the premise of ensuring driving safety to enhance the driving experience, improve traffic efficiency.

However, with the development of vehicle-mounted communication technology, vehicle users have put forward higher requirements for travel experience. Different service types have different requirements. Secure message services have higher requirements on delay and positioning accuracy. Non-secure entertainment, advertising and other information services not only increase the diversity of content, but also raise requirements on improving data transmission efficiency and enhancing user experience.

Car named data network based on vehicle ad-hoc network, the network architecture based on NDN, content-oriented communication mode, the network cache feature, alleviate the IP address assignment of traditional network architecture, system scalability and robustness problems, greatly improve the communication efficiency of intelligent snatched the vehicle service system and data transmission stability. Data routing and caching in VNDN are two key factors determining the quality of network service. Although there have been many researches on relevant strategies, they still cannot meet the explosive growth of data types and diversified needs of user services, and are completely suitable for the complex environment of modern urban intelligent transportation network. This paper studies the routing and forwarding pre-cache strategy based on content awareness, and improves the data transmission efficiency and node cache performance.

RESEARCH STATUSES

At present, there are several data forwarding schemes for intelligent transportation network connected vehicles: clustering, backbone network and geographical location based forwarding schemes. Huang et al [1] proposed cluster-based mobility prediction (COMP) collaborative cache to build intra-cluster and inter-cluster communication and reduce the impact of vehicle mobility on data transmission. Wang et al [2] proposed a backbone based forwarding network, a push data propagation algorithm and a pull data retrieval algorithm, a forwarding network based on the mobility of vehicle nodes to improve the stability of the network, and a reverse path repair algorithm to improve the success rate of data reception. Wang et al [3] proposed to use NDN feature backbone node to carry out data transmission aggregation and obtain data in unicast mode by relying on forwarding table to improve the efficiency of data transmission and reduce transmission cost. However, in backbone network, the request and transmission of all kinds of messages depend on backbone nodes, whose selection is very important for data transmission. Ravi et al [4] proposed a random network optimization scheme of multi-hop routing, which uses AODV routing protocol to solve the problem of route interruption and queue waiting and realize data transmission. Qiu et al [5] designed a spider web transmission mechanism for emergency data in vehicle-mounted AD hoc network to effectively alleviate the transmission delay of high-priority data. A data forwarding strategy based on vehicle driving trajectory is proposed. In this strategy, the roadside unit acts as the data publisher and the data forwarder to provide data services for vehicle nodes. This study considers the characteristics of the content and the combination of paths to provide differentiated routing and forwarding schemes for different message services.

Existing studies on cache strategy can be divided into two dimensions, node and content, according to the different objects of concern. In the study on cache strategy of concern node, the design mainly considers the social attributes and moving track between nodes to select cache nodes. Wei et al [6] proposed to use the social attributes of partners and couriers to determine cache nodes, so as to maintain relatively reliable communication links and improve the transmission quality of multimedia and video messages. In this study, the implicit Dirichlet distributed LDA model was constructed for different request service messages, and the content popularity was accurately predicted by dynamically predicting the request preferences of vehicle users and the communication topology of nodes, so as to optimize the cache performance of nodes and the network load of intelligent networked vehicle system.

ROUTING AND FORWARDING POLICIES BASED ON CONTENT AWARENESS

Scenario Description

Intelligent snatched vehicle technology matures, produce all kinds of car services, covering safety travel, perception, leisure entertainment, a variety of applications such as road conditions but vehicle nodes in the dynamic variation of the topological structure of high speed Internet, which makes the users of these requests to the service of real-time, accuracy, diversity, and higher requirement are put forward.

The scenario model for this section is shown in Figure 1. The scenario includes vehicle nodes running on the road and roadside units (RSUs) deployed on both sides of the road. The vehicle node is equipped with vehicle-mounted unit to support vehicle-vehicle communication and vehicle-roadside communication. Roadside units have certain computing and communication capabilities, and can preferentially obtain the demand and data holding status of vehicle nodes within the communication range. As the best relay nodes, roadside units can match the supply and demand of vehicle nodes and complete data transmission.

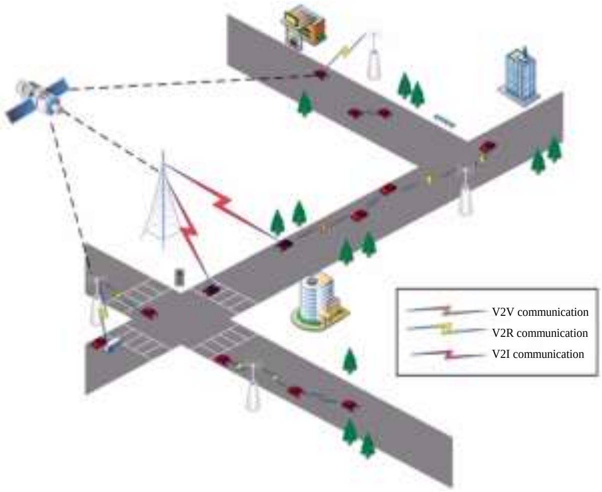

FIGURE 1: Scenario diagram of route pre-caching based on content awareness

Data Packet Format Reconstruction

(1) Data naming and data format design

In order to better adapt to the routing and forwarding policy proposed in this section, the hierarchical naming format of the original NDN packet is modified. The data is named as follows:

/ Type / Data name / Road ID / Data part / timestamp

Where, the Type field represents the packet Type, which is divided into Interest packet and data packet. The data name field represents the name identification of the packet carrying specific content, namely beacon, Interest name and data name. The Road ID field is specific to the packet type of the known destination and represents a segment ID binary group {destination segment, request segment}. The Data part field indicates what messages exist, and the timestamp field indicates the timestamp generated by the interested packet or packet. Set its field to 1. The specific beacon packet format is

/ Interest / beacon / Road ID / (buffer, inter, Geolocation, Velocity, Node-degree) / timestamp

(2) Neighbor and PIT tables

In order to adapt to the routing policy proposed in this section, the PIT table of NDN data structure loaded by road equipment RSU should be modified before the routing policy design, and a neighbor table should be maintained by vehicle nodes and RSU themselves, including node ID, node location, speed, bridge center degree and the road section. The specific data form is shown in Table 1 and Table 2. The Table 1 is Neighbor Table; The Table 2 is The PIT table of RSU

TABLE 1: Neighbor Table (NT)

ID	Geo Location	Velocity	BC	Road ID
V2	(346.57, 760.99)	(0.888594, 1.50761)	0.16	2
V13	(390.83, 714.88)	(-1.77495, -0.58092)	0.075	-2
……	……	……	……	……

TABLE 2: The PIT table of RSU

Interest	Incoming Road ID	Consumer Node
Road ID 1	Road ID 1	V_1, V_2
Road ID 1		
……		
Road ID 1	Road ID 2	V_3, V_4

Where, the PIT table of RSU is specifically described as: Assuming that the vehicle node (located at Road 0) obtains the Road conditions of Road0 /Road 1/Road 2/Road 3, it will forward to the PIT entries stored in RSU: The value of Interest Road ID is Road 1, Road 2, and Road 3, the value of Incoming Road ID is Road 0, and the value of Consumer Node is .

(3) Content-aware Routing and forwarding Policy

Vehicle nodes exchange information by sending beacon packets every second and the broadcast information is to nearby RSUS, including their own location notification and cache content sharing information. Since every vehicle on urban roads is equipped with GPS navigation system and digital map of the city where it is located, the vehicle can obtain the CURRENT Road Sequence ID and Geo Location through GPS and digital map. The specific flow chart of content-aware routing policy is shown in Figure 3

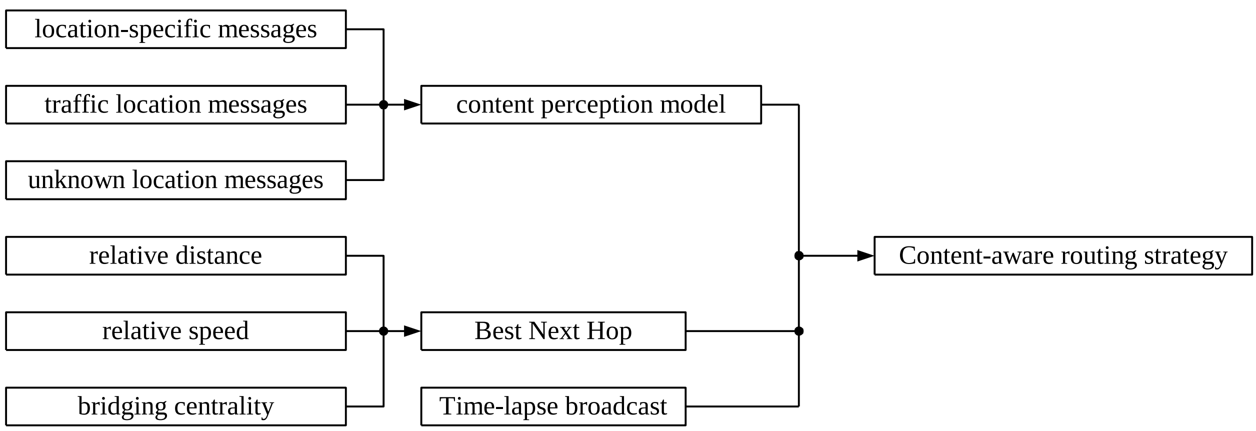

FIGURE 3: Content-aware routing policy framework diagram

Table 3 shows the core pseudo codes of the routing and forwarding policy known to the destination node V_i

TABLE 3: The core pseudo codes of the routing and forwarding policy

Algorithm 1 Forwarding strategy known of the destination node

Input：Node V_i， NT， Interest Packet， Producer V_p

Output：Interest Packet are delivered to the Producer node

```
Node V_i receives Interest packet
  while (Content NOT in CS) then
    if Interest Packet is requesting Special LoactionMessiage then
      if V_p in NT then
send Interest Packet to V_p
else
        if V_i in Destination Road then
          Next node ID = -1
            broadcast Interest Packet
        else
          calculate and send to best Next node ID in Next Road
        End if
      End if
```

```
    else
      find and send to the nearest RSU
      if Next Road hasn't Node then
        store Interest Packet and wait Node appear
        re-planning New Road Sequence and update Interest Packet
        send New Interest Packet to New Next Road
      else
        send Interest Packet to Next Road
      End if
      RSU self-checking CS
    End if
  End while
  send Data Packet
End
```

In the actual Internet of vehicles, the movement of vehicles is not completely random, but in a fixed path within a certain period of time. As shown in Figure 4.

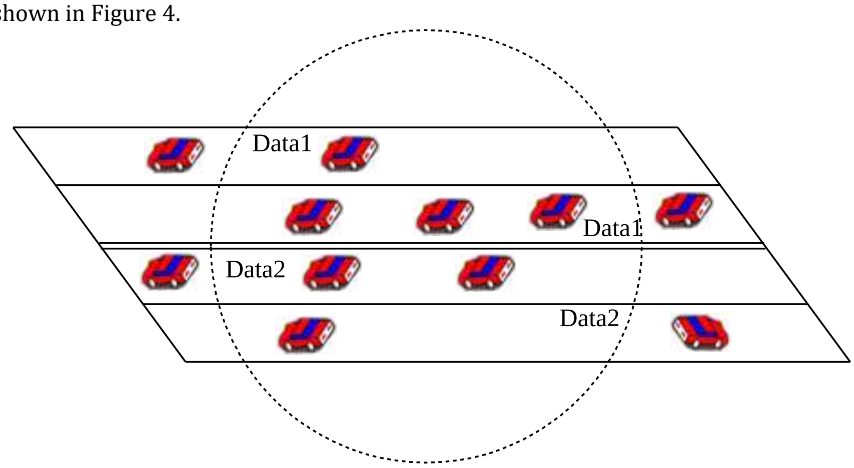

FIGURE 4: Schematic diagram of node centrality scenario

In the VNDN environment where the destination node is unknown, the data exchange of the vehicle node depends on the match between the packet and the prefix information of the interest packet.

PRE-CACHE STRATEGY OF VEHICLE NODES

Problem Description: Caching data on all nodes will lead to a large amount of data redundancy. Selecting only cached data will greatly increase the construction cost. In addition, different types of service data have different priorities. Secure service data focuses on minimizing delay while non-secure service data focuses on data transmission efficiency and cache utilization efficiency. Therefore, when considering cache data, the priority of data type should be considered first, and then the cache location should be considered to reduce data redundancy and improve the utilization of cache space. Therefore, this study caches the content near the vehicle node and the predicted location.

(1) Prediction of vehicle node path position

When the vehicle returns: Path prediction: based on the position $\boldsymbol{P}_{t_{k-1}}$ and speed $v_{t_{k-1}}$ of the last moment, assuming that the speed of the vehicle node is constant during the period when the interest packet is sent and the data packet is returned, then the node position

$$\boldsymbol{P}_{t_k} = \boldsymbol{P}_{t_{k-1}} + v_{t_{k-1}} \Delta t \text{ , } \Delta t = t_k - t_{k-1} \qquad (1)$$

at the current moment. When applied to predict the return of data packets, the position of consumers should be

$$\boldsymbol{P}_{\text{pre}} = \boldsymbol{P}_{\text{send\_interest}} + v_{\text{send\_interest}} \Delta t \text{ ,} \qquad (2)$$

Where, $\Delta t = t_{\text{current}} - t_{\text{send\_interest}}$.

(2) Location selection of cache contents

Packet returns, the packets are cached in the best the next-hop node, reduce the network traffic load, also due to the interference of mobility, the contents are cached in the road and bridge center with high degrees of vehicle nodes, the neighbor node center degree value is greater than average degree of vehicles to determine node with high degrees of vehicle bridge center node. Note: The optimal next hop node here is not necessarily the vehicle node with the highest centrality. The optimal next hop vehicle node is obtained based on the comprehensive score of the three attributes of relative distance, relative speed and bridging centrality.

(3) Cache content prediction

Considering the limited storage capacity of network data transmission equipment and the uncertain change of vehicle users' preferences over time, it is necessary to filter data and cache more valuable data, so the popularity of cached content should be predicted. In order to improve the accuracy of prediction, the strategy deeply determines the similarity between the request contents, and pays more attention to the semantics of the contents besides the repetition rate of the words in the request contents. LDA is an effective topic model in semantic mining. Therefore, the pre-caching strategy is designed to predict popular content using the topic model LDA.

(4) Model building

According to the design requirements of the pre-cache strategy, a communication cache model is established under the environment of intelligent vehicle network connection. The popularity prediction model is designed according to literature [8] to deploy N vehicles, that is, set $V = \{V_1, V_2, \cdots, V_i, \cdots V_N\}$.

The m road test unit RSU, namely set $M=\{\mathrm{RSU}_1, \mathrm{RSU}_2, \cdots, \mathrm{RSU}_i, \cdots, \mathrm{RSU}_m\}$, cache f content, namely popular content set $F=\{F_1, F_2, \cdots, F_i, \cdots, F_f\}$, in addition, the maximum communication range of vehicle nodes is set as d_V, and the maximum communication range of RSU is set as d_m. As for the location of content cache, choose cache in vehicle node and RSU, that is, vehicle users can not only share their cached files with each other, but also get the content files they are interested in from base station RSU. The content is initially cached on the web server. The topological relationship of various network devices (vehicle nodes and RSU) is represented by matrix $A=[a_{ij}]_{(M+V)\times(M+V)}$. The two devices are within the communication range $a_{i,j}=1$, otherwise $a_{i,j}=0$, specifically

$$a_{ij}=\begin{cases}1 & i,j\in V, d_{i,j}\le d_V\\ 1 & i\in V, j\in M, d_{i,j}\le d_m\\ 1 & i,j\in M, d_{i,j}\le d_m\\ 0 & \text{other}\end{cases}. \quad (3)$$

The effectiveness of the cache strategy is measured by the cache hit ratio, that is, the average probability of vehicle users obtaining content request files within a limited time range, represented by variable P,

$$P=\frac{\sum_{v_i\in V}\sum_{f\in F}\sum_{j\in(V\cup M)} g_{v_i}P_{v_i,f}a_{v_i,j}c_{j,f}}{N}, \quad (4)$$

Where, parameter g represents the probability of vehicle user v_i sending the request content file; $P(v_i,f)=P(f\mid v_i)$ represents the probability that the vehicle user v_i requests the file f; $g_{v_i}=\sum_{f\in F}P_{v_i,f}\le 1$ and $P(v_i,f)\in[0,1]$; The $c_{j,f}$ parameter indicates whether the content file f is cached locally (vehicle nodes and RSU). The problem description is as follows.

Considering the finiteness of cache space, the content cache optimization problem is constructed with the maximization of cache hit ratio as the objective function and the communication distance between network devices as the constraint condition. The mathematical expression of the optimization problem is as follows:

$$\max\_P=\frac{\sum_{v_i\in V}\sum_{f\in F}\sum_{j\in(V\cup M)} g_{v_i}P_{v_i,f}a_{v_i,j}c_{j,f}}{N}, \quad (5)$$

Where, parameters g_{v_i}, $P_{v_i,f}$, $c_{j,f}$ are coupled with each other, making the content cache optimization problem become NP-hard problem (knapsack problem) and increasing the difficulty of P optimization of the objective function.

To solve the above cache optimization problem, the content cache probability P is obtained by predicting the user preference of vehicle users and predicting the popularity of content.

(5) Dynamic prediction of vehicle user preferences based on LDA (implied Dirichlet distribution) model

In order to effectively predict the preferences of vehicle users, the user preference matrix U, $U=[\mathrm{P}_{v_i,f}]_{V\times F}$, represents the preferences of all vehicle users, is introduced. In LDA model, assuming that each file has one and only one theme, the theme of the multiple files a theme collection Z, namely $Z=\{z_1, z_2, \cdots, z_i, \cdots, z_N\}$, here is the theme of the divided into safety class (such as weather, traffic, driving service class topics) and entertainment (movies, songs, news topics), the g_{v_i} probability of said vehicle user request. The $P(z_i\mid v_i)$ represents the conditional probability that the vehicle user's request message is subject z_i; the $P(f\mid z_i)$ represents the conditional probability that the request message of the vehicle user is subject z_i and the file is f. In the topic model above, the initial values of the above parameters can be obtained from the history matrix N, which is obtained from the history matrix $N=[n_{V,f}]_{V\times f}$, where the parameter $n_{V,f}$ represents the total number of file f requested by the vehicle user v_i in a finite time.

In summary, the joint probability of file f requested by vehicle user v_i is

$$P(v_i,f\mid\alpha,\beta)=g_{v_i}\sum_{z\in Z}p(f\mid v_i,\beta)p(f\mid\alpha), \quad (6)$$

$$P(f\mid v_i,\beta)=\int P(f\mid v_i,\varphi)P(\varphi\mid\beta)\mathrm{d}\varphi=\prod_{f=1}^{F}\frac{\Delta(n+\beta)}{\Delta\beta}, \quad (7)$$

$$P(f\mid\alpha)=\int P(f\mid\theta)P(\theta\mid\alpha)\mathrm{d}\theta=\prod_{f=1}^{F}\frac{\Delta(n+\alpha)}{\Delta\alpha}, \quad (8)$$

Where, $g_{v_i}\in G$ and G represent the probability matrix of all vehicle user request files $G=[g_{i,j}]_{V\times F}$. α, β are prior parameters derived from experience, and φ, θ are parameters of implicit Dirichlet distribution.

The unknown parameters in the above formula are estimated by Gibbs sampling to make the LDA model algorithm converge. The posterior probability of the topic model variable is

$$P(z\mid v_i,f)=P(f\mid v_i,\beta)P(f\mid\alpha). \quad (9)$$

EXPERIMENT

(1) Experimental Settings

In order to verify the performance effect of the proposed strategy, the traffic simulator SUMO and ndnSIM were used to build an experimental platform, and the vehicle movement situation was simulated in the real expressway and city scenarios to realize the NDN communication model.

A $1000\mathrm{m}\times1000\mathrm{m}$ map of Xi'an urban area was captured by OpenStreetMap and the NETCONVERT tool provided by SUMO was used to easily import OpenStreetMap map data. Six Rsus were evenly deployed at 500m intervals. Distribution of 50 and 300 vehicles in two different network sizes, with 10 and 1024 sizes of data packets to distinguish security and entertainment data, simulated a real traffic scene, cache evaluation default street on both sides of the RSU cache all content. Specific parameter Settings are as Table 4.

TABLE 4: Specific parameter Settings

Parameters	Value
Total Cache Size	40%
Network Size	50, 300 vehicles
Content Size	10, 1024
Simulation Time	200s~1200s
Vehicle Speed	1m/s~10m/s
RSU Transmission Range	500m
Vehicle Transmission Range(R)	200m
Period of broadcasting beacon	1s

(2) Analysis of experimental results

In order to verify the performance proposed in this study, COMP [2] and MPFS [9], two classical predictive forwarding strategies, were used as comparison, simulation time was taken as independent variable, and five performance indicators including packet arrival rate, average delay, average hop number, cache hit ratio and network cost were used for comprehensive and reasonable performance analysis. In this experiment, 50 vehicles and 300 vehicles were selected to distinguish the two scenarios of expressway and urban road. In order to minimize errors, repeated experiments were carried out. The average value of the experimental results was taken, and the specific simulation results were analyzed as follows.

As can be seen from Figure 5, as the number of vehicle nodes increases, the packet arrival rate of the three strategies increases, which is due to the in-network caching feature of NDN architecture. Vehicle nodes will selectively cache the received packets to meet the subsequent request requirements. As can be seen from the figure, when the number of nodes is 50, the packet reach rate of single node of R-Pre-cache strategy proposed in this study has reached 54%, while the other two strategies are lower than 50%, because this strategy is optimal node and broadcast cooperative forwarding, while the other two strategies are single node forwarding and data retrieval delay. When the number of nodes increases to 300, both R-pre-cache policy and MPFS policy can reach about 80%. This is because although the three strategies all take movement prediction into account, the frequent changes of COMP clustering lead to data transmission delay and low packet arrival rate.

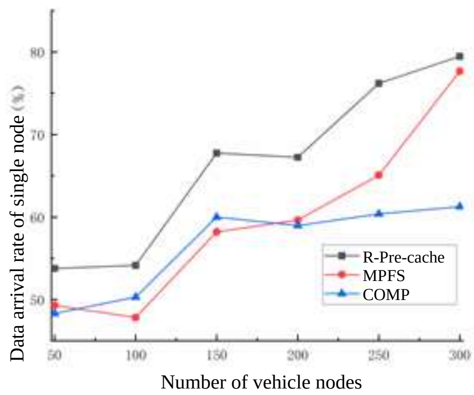

FIGURE 5: Change of packet arrival rate of single node with simulation time

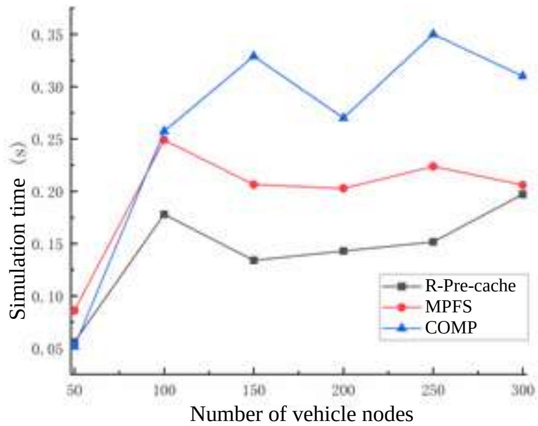

FIGURE 6: Variation of average time delay per vehicle volume

As shown in Figure 7, the simulation compares the influence of different number of vehicle nodes on the average hop count of R-Pre-cache, MPFS and COPM. It can be seen from the figure that the average hop numbers of the three factors have little influence on the change of vehicle node number. Individually, because of the clustering factor, data is cached in cluster-head nodes within 2 or 3 hops in COMP strategy, so the average hop number is stable at about 2 hops. The R-Pre-cache policy detects different data and forwards the cache accordingly. Therefore, the average hop count can be maintained at about 2 hops. The MPFS policy does not specify the cache location and the cache is based on the forwarding path by default. Therefore, the average hop count is slightly higher than that of the other two policies. In general, the three strategies incorporate prediction, and the data packets are cached near the request nodes, so that the data requests can be satisfied more quickly.

As shown in Figure 8, as the number of vehicle nodes increases, the cache hit ratio increases slightly at the beginning. When the number of vehicle nodes is greater than 200, due to the limitation of simulation time and the increase of vehicle node requests, the amount of data in the network is too large, and the cache hit ratio decreases slightly. When the number of vehicle nodes is 300, The cache hit ratio of the three strategies is maintained at 30%-40%. When the number of vehicle nodes is 50, the R-Pre-cache strategy proposed in this study achieves a cache hit ratio of more than 50% when the number of nodes is small, because the optimal next-hop node and broadcast cooperative forwarding are considered, and the RSU cache near the predicted location is considered when the data packet is returned. Because data is cached along the forwarding path, the MPFS policy has better performance in cache hit ratio.

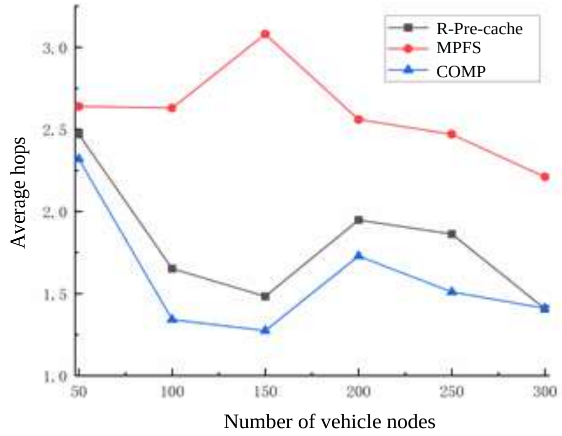

FIGURE 7: Change of average hop numbers with vehicle numbers

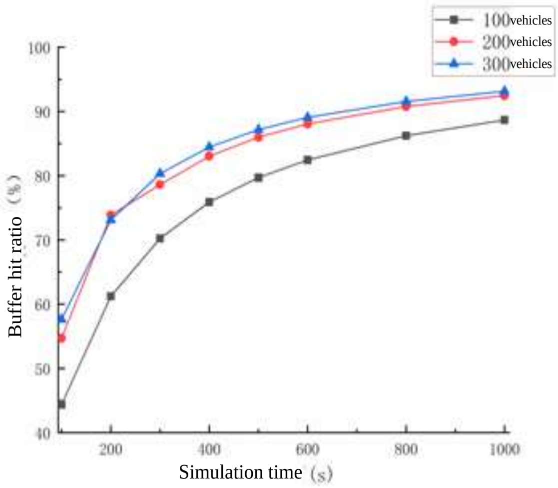

FIGURE 8: Cache hit ratio changes with the number of vehicle nodes

CONCLUSION

A routing strategy based on content type awareness and a cooperative content pre-caching strategy based on probability caching considering content popularity prediction are proposed. According to the message characteristics and destination nodes, an appropriate route-forwarding strategy is selected, and the Latent Dirichlet Allocation (LDA) is used to dynamically predict vehicles, which basically meets the user's request. Furthermore, the topological relationship between different devices in the Internet of vehicles and the predicted vehicle users are used to accurately and effectively predict the popularity of content, so as to reduce the redundancy of content files cached by network devices and maximize cache hit ratio. In contrast, content precaching strategies based on content type awareness and considering content popularity prediction can effectively improve cache performance.

REFERENCES

[1] X. Wang and S. Cai, Efficient Road Safety Data Retrieval in VNDN, in IEEE Systems Journal, vol. 15, no. 1, pp. 996-1004, March 2021, doi: 10.1109/JSYST.2020.2977388.

[2] W. Huang, T. Song, Y. Yang and Y. Zhang, Cluster-Based Cooperative Caching with Mobility Prediction in Vehicular Named Data Networking, in IEEE Access, vol. 7, pp. 23442-23458, 2019, doi: 10.1109/ACCESS.2019.2897747.

[3] X. Wang, Z. Wang and S. Cai, Data Delivery in Vehicular Named Data Networking, in IEEE Networking Letters, vol. 2, no. 3, pp. 120-123, Sept. 2020, doi: 10.1109/LNET.2020.2994906.

[4] B. Ravi, J. Thangaraj and S. Petale, Stochastic Network Optimization of Data Dissemination for Multi-hop Routing in VANETs, 2018 International Conference on Wireless Communications, Signal Processing and Networking (WiSPNET), 2018, pp. 1-4, doi: 10.1109/WiSPNET.2018.8538353.

[5] T. Qiu, X. Wang, C. Chen, M. Atiquzzaman and L. Liu, TMED: A Spider-Web-Like Transmission Mechanism for Emergency Data in Vehicular Ad Hoc Networks, in IEEE Transactions on Vehicular Technology, vol. 67, no. 9, pp. 8682-8694, Sept. 2018, doi: 10.1109/TVT.2018.2841348.

[6] W. Quan, C. Xu, J. Guan, H. Zhang and L. A. Grieco, Social cooperation for information-centric multimedia streaming in highway VANETs, Proceeding of IEEE International Symposium on a World of Wireless, Mobile and Multimedia Networks 2014, 2014, pp. 1-6, doi: 10.1109/WoWMoM.2014.6918992.

[7] L. C. Liu, D. Xie, S. Wang and Z. Zhang, CCN-based cooperative caching in VANET, 2015 International Conference on Connected Vehicles and Expo (ICCVE), 2015, pp. 198-203, doi: 10.1109/ICCVE.2015.24.

[8] F. Jiang, J. Wang and C. Sun, Deep Q-Learning-Based Cooperative Caching Strategy for Fog Radio Access Networks, 2021 IEEE/CIC International Conference on Communications in China (ICCC), 2021, pp. 922-927, doi: 10.1109/ICCC52777.2021.9580239.

[9] M. Duan, C. Zhang, Y. Li, W. Xu, X. Ji and B. Liu, Neighbor Cache Explore Routing Protocol for VANET based on Trajectory Prediction, 2018 IEEE 3rd Advanced Information Technology, Electronic and Automation Control Conference (IAEAC), 2018, pp. 771-776, doi: 10.1109/IAEAC.2018.8577903.