Cooperative caching strategy for CCN dwell time based on V2V

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Abstract: As one of the development directions of the mobile Internet, the Internet of Vehicles is how to quickly and efficiently communicate between vehicles (V2V). Wireless communication is facing unprecedented challenges and opportunities. In CCN, network caching enables content to be cached on network nodes, reducing the delay for users to obtain content, and increasing the circulation of network content. This article proposes a CCN dwell time collaborative caching strategy based on V2V scenarios. It considers the mobility, relevance of vehicles in a connected vehicle, and the dwell time of content on network nodes under the request of Poisson arrival Collaborative caching. Through simulation, the cache hit rate, average delay, average hop count of the entire network is compared with the traditional CCN cache strategy, which effectively improves the network cache efficiency and network gain.

1. Introduction

In the Internet of Vehicles, smart vehicles can access the network through wireless communication. Among them, V2V communication scenarios are widely used, and any place where a vehicle is driving can constitute a V2V communication scenario. V2V communication is more suitable for vehicle-intensive scenarios. The characteristics of the vehicle-intensive scene are that the number of vehicle nodes is large and the storage content is rich, which makes the V2V communication network richer, and users are more likely to obtain the required content.

Content-Centric Networking (CCN) is one of the future network architecture research projects initiated by the National Science Foundation in 2010. One of the main features of CCN is the built-in cache of the network, so researchers have developed caching technology. I took a keen interest and researched caching strategies for different directions.

2. Related Work

In view of the lack of current cache solutions for vehicle mobility and content-intensive considerations in V2V scenarios, many literatures have proposed various approaches to network caches. [1]-[3] studied the use of cache technology in wireless networks Support user mobility and content distribution to reduce the network load; in [4] and [5], the author used a user prefix caching method to reduce the delay of users playing videos. However, most of these cache strategies are more suitable for static network scenarios, and for car networking scenarios, improvements need to be made based on basic cache strategies.

3. Problem Description

Vehicle-intensive intersections. There are many vehicles at this intersection, so there is more content and selectivity for car forwarding.Because it is an intersection, the speed of the vehicle is slow, and the direction of the vehicle is diversified. This article assumes that many vehicles are equipped with a radio frequency communication interface based on the IEEE802.11P protocol, GPS devices, sensors, computer control modules, and CCN modules.

Suppose that vehicle A sends a request for interest packet. By forwarding, the interest packet is forwarded to vehicle D through vehicle B and vehicle C. At this time, it is found that vehicle D has a data packet requested by vehicle A, and vehicle D receives the interest packet The matched data packet is then sent back to vehicle A according to the original interest packet forwarding path. The traditional CCN cache strategy is that the nodes on the return path will store the received and forwarded data packets. This strategy will inevitably cause data redundancy and serious waste of storage resources, reducing the performance of the entire network.

4. Cooperative caching strategy model based on V2V CCN dwell time

4.1 CCN packet design

In the traditional CCN, the nodes do not know the relative movement with other nodes. The main information is not suitable for the mobility of the Internet of Vehicles and the dwell time-based cache strategy designed in this paper. Therefore, first adjust the interest and data packets for the CCN. format. When a vehicle node requests to send an interest packet and receive a data packet, these data packets will carry the vehicle's ID information, location information, association information, direction information, and content dwell time information. As follows.

Table 1 Packet format

(a)Interest Packet format

Content	Select	Nonce	Position Info Table	Direction Info Table	Relatedness Info Table	Dwell time

(b)Data Packet format

Content	Signature	Signed Info	Data	Position Info Table	Direction Info Table	Relatedness Info Table	Dwell time

4.2 Vehicle importance analysis

In the Internet of Vehicles, the global topology of a node cannot be grasped, so consider calculating the correlation between each current intermediate vehicle node and other intermediate vehicle nodes to indicate the importance P_{Rn} of the intermediate vehicle node, where,

$$P_{Rn} = \frac{L_n}{Total} \tag{1}$$

Among them, n represents an intermediate vehicle node, L_n is the number of communication links within the V2V communication range of the intermediate vehicle node n, and Total is the number of communication links within the V2V communication range of all intermediate vehicle nodes.

4.3 Vehicle mobility analysis

The relative motion between two intermediate vehicle nodes has a certain effect on the decision whether to cache the content. In order to make the content as dispersed as possible in the network topology nodes, so that the nodes requesting the content can obtain the content in the range of the hops as small as possible, the vehicle mobility P_{Mn} is:

$$P_{Mn} = \frac{D_{ij}}{\upsilon \times R} \tag{2}$$

Wherein, D_{ij} when the intermediate vehicle node receives a Data packet, the distance between the intermediate vehicle node and the transmitting end, R is the communication range of the intermediate vehicle node, υ is a weight parameter, and υ is:

$$\upsilon=\begin{cases}20 & \textit{Node and sender are in the same direction}\\ 10 & \textit{Node and sender are not in the same direction}\end{cases} \quad (3)$$

The weight parameter υ is the representative value of the same direction and non-direction.

4.4 Analysis of content retention time

The location of content k is only related to the previous location, and is independent of the previous location, because the request arrived by Poisson, state 0 indicates that content k is not in CS, and state 1 indicates that content k is in CS At the top, state l indicates that content k is at the l-th position of CS. The transition rate from state l (l = 1, 2,…, dx) to state (1 + 1) is L, where (x + l) represents state 0, and each state l can transition to state 1 ($1 \neq 1$), the transfer rate is L (the arrival rate of content k).

Among them, $\beta=\lambda_k+\mu_k$.

For the content k satisfying $\lambda_k/\mu_k<1$, the corresponding Markov chain is non-periodic, irreducible and normally returning. Therefore, there must be a steady state probability, which can be solved by solving the following steady state equation:

$$\begin{cases}\pi_k Q=1\\ \pi_k e=1\end{cases} \quad (4)$$

Where is a (x + 1) -dimensional column vector, and e = (1,1, ..., 1) T is a (x + 1) -dimensional column vector, then:

$$\pi_{kl}=\frac{\lambda_k}{\mu_k}\left(\frac{\mu_k}{\mu_k+\lambda_k}\right), l=1,2,...x \quad (5)$$

$$\pi_{k0}=\left(\frac{\mu_k}{\mu_k+\lambda_k}\right)^x \quad (6)$$

Among them, π_k represents the probability that the content k is in the state 1 at the steady state, and from this, the formula of the average stay time of the content k in the buffer can be derived.

The content request received by the node cache follows the Poisson parameter λ' arrival, and the content k request follows the Poisson process parameter λ' (k = 1,2,… .., M). Content, the approximate formula for the average dwell time of content k in the buffer can be expressed as:

$$\mathrm{RT_k}=\frac{x}{\mu_k'}-\frac{1}{\lambda_k}\left(1-\left(\frac{\mu_k'}{\lambda_k+\mu_k'}\right)^x\right) \quad (7)$$

Among them, $\mu_k'=\lambda'-\lambda_k$

When the content k is not in the 0 state, the content to be cached in addition to the content k can be divided into two categories: a) uncached content and content below the content k; b) content above the content k; and if content k In the 0 state, no classification is needed. Obviously, only the arrival of a) content and content k will change the state of content k, and the arrival of b) content will not change the state of k.

ϖ_k Let be the dwell time of content k in the buffer, $\Pr\{\varpi_k>t\}$ indicating the probability that dwell time of content k is greater than t under the condition that content k is in state j, then:

$$\Pr\{\varpi_k>t\}=\sum_{j=1}^{x}\pi_{kj}\Pr_j\{\varpi_k>t\} \quad (8)$$

The difference between a request arrival sequence in a CCN network and a general queuing system arrival sequence is that the same request may arrive repeatedly before the previous request has been satisfied, so that the content will change from a) to b) Content; when content k is waiting to be replaced at the jth position of the buffer, within time t before the request for the next content k arrives, if and only if there are no less than (x-j + 1) different a) The content k will be replaced if the content content request arrives, that is, during the time period t, the dwell time will be greater than t if and only when the number of content content requests a) is less than (x-j + 1) Then there are:

$$\Pr_j\{\varpi_k > t\} = \sum_{i=0}^{x-j} e^{-u_k t} \frac{(u_k t)^i}{i!} \tag{9}$$

Substituting equation (9) into equation (8), we get

$$\begin{aligned}\Pr\{\varpi_k > t\} &= \sum_{j=1}^{x} \pi_{kj} \sum_{i=0}^{x-j} e^{-u_k t} \frac{(u_k t)^i}{i!} \\ &= e^{-u_k t} [\sum_{i=0}^{x-1} \frac{(u_k t)^i}{i!} (1-(\frac{\mu_k}{\mu_k+\lambda_k})^{x-i})]\end{aligned} \tag{10}$$

From equation (9), we can see that the expressions to the right of the equal sign are positively related to x and x, and they are consistent with the negative and expected correlations.

Further analyze the value of the downward transfer rate of the content k state. From the above, when the content k is in a non-fog state, only the arrival of a) content will increase the state value of content k by 1, and b) The arrival of content does not change the state of content k, so there are:

$$\mu_k^{upper} = \lambda' + \lambda_k \tag{11}$$

$$\mu_k^{lower} = \begin{cases} \lambda' - \sum_{j-1}^{x} \lambda_j & k<x \\ \lambda' - \lambda_k - \sum_{j-1}^{x-1} \lambda_j & k \ge x \end{cases} \tag{12}$$

When the content k is in the state 1, the maximum value is obtained; when the content k is in the state x, and there are the most popular (x-1) contents of the content type above, the minimum value is obtained.Since π_{k0} is an undecreasing function of μ_k the miss probability interval of the content k is:

$$[(\frac{\mu_k^{lower}}{\mu_k^{lower}+\lambda_k})^x, (\frac{\mu_k^{upper}}{\mu_k^{upper}+\lambda_k})^x]$$

The right-hand side of equation (4) is a non-increasing function. When the distribution of content requests is more uniform, that is, it is almost impossible to reach two or more requests for the same content in time t, and x (i) is much smaller than M. , B) The content of the class is small, so the approximate calculation formula for $\mathrm{RT_k}$ is:

$$\mathrm{RT_k} = \frac{x}{\mu_k'} - \frac{1}{\lambda_k}\left(1-(\frac{\mu_k'}{\lambda_k+\mu_k'})^x\right) \tag{13}$$

Among them, $\mu_k' = \lambda' - \lambda_k$.

Car networking based on the CCN distributed content retention time collaborative caching method calculation: According to the importance of vehicles in the network, the relative movement between vehicles and the dwell time of the requested content, the method of forwarding nodes to cache content s is:

$$\begin{aligned} p_k &= \alpha P_R + \beta P_M + \varepsilon RT_k \\ \alpha + \beta + \varepsilon &= 1 \end{aligned}$$

Among them, p_k is the probability that the intermediate vehicle node buffers the data packet; α, β and ε are the weights of vehicle importance, vehicle mobility, and content retention time, respectively. Due to the mobility of the connected car scenario, the nodes change in real time. The importance of the nodes cannot reflect its advantages in the connected car scenario, so $\alpha < \beta, \alpha < \varepsilon$.

5. Simulation results and analysis

The NS3 was used to simulate the CCN network in the V2V scenario. The simulation data was processed by NS3, and the comparison curves of LCE, LCD and this solution were made. The results prove that this solution has better hit rate, user acquisition delay, and overall network gain than the previous two solutions. There is a certain performance improvement in sex. See Table 2 for simulation parameters.

Table 2. Parameters Table

parameter	Value
Number of vehicle nodes N	80
Number of requested nodes ask_N	8
Number of requested nodes	80
ask_NVehicle node CS capacity C	10
V2V communication range R	100m
Speed v	3m/s
Node calculation time t_node	0.005s
Node forward time t_forward	0.002s
Maximum hop value n	7
Weighting factor α	0.1
Weighting factor β	0.3
Weighting factor ε	0.6

Figure 1 shows the change in the cache name rate over time. The cache hit rate increases with time. It can be seen that the LCE scheme has the best performance because the vehicle nodes have not changed much, In the early stage, the cache content is the most, but as time progresses, LCE caches too much content that is not needed at the node, causing its performance to deteriorate. As time advances, DTCCS can disperse content with a long stay time. In the entire network, the performance advantage of this solution is reflected.

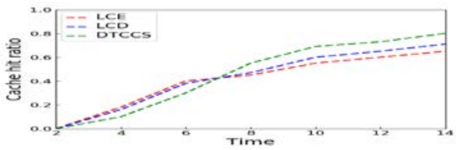

Figure 1. Graph of cache hit rate over time

Figure 2 shows the change of the average delay with time. As can be seen from the figure, the average delay obtained by the three solutions at the beginning is relatively long, because the previous content is obtained from the base station. In addition, the performance of this solution may not be good in the early stage, but as time progresses, the number of hops required for DTCCS requests will decrease and the average delay of the system will decrease.

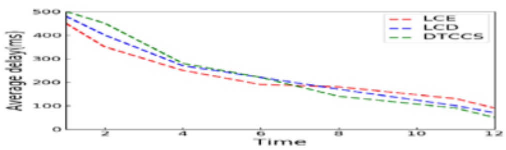

Figure 2. Plot of average delay over time

Figure 3 Comparison of average hop counts required by vehicle nodes for different numbers of vehicle nodes The larger the value, the greater the role of the overall system cooperation, the number of cached nodes increases, and the average number of hops for requesting nodes to obtain content decreases.

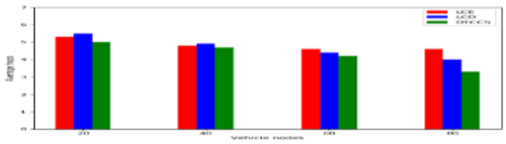

Figure 3.Change graph of average hops with number of nodes

6. Summary

This paper proposes a CCN dwell-time collaborative caching strategy based on the V2V scenario of the Internet of Vehicles. The goal of this strategy is to improve cache hit rate, reduce user acquisition delay, and improve overall network performance. By using cache hit rate, average delay, and average hop count, all three indicators have better performance. And by considering the dwell time of the content and the mobility of the nodes, it is more suitable for dynamic network environments.

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