Information Centric Networking Based SVC Video Proactive Caching in VANET

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Abstract

In this paper, we have proposed a mechanism for proactively caching the user requested video in Vehicular Adhoc NETwork (VANET). The proposed mechanism find out the location of vehicles and Road Side Unit (RSU) in the transmission range in next time frame and the chunk of the video vehicle will request. The network proactively caches before the user requests it. The formulated optimization problem is linear programming combinatorial optimization problem. We presented matching game based algorithm to solve this problem. The evaluation results show that our proposed mechanism significantly improve the video quality.

1. Introduction

Recently, the wireless access network technology has achieved significant improvement in giving high bandwidth to the end user. However, Users demand for bandwidth-thirsty applications has increased more rapidly than the advancements in the wireless access network technology.

In Content Centric Networking (CCN) user generates request packet (called Interest) for getting his desired content and get Data packet as a reply [1-3]. CCN nodes are intelligent that cache the important contents, avoid forwarding duplicate requests and take forwarding decisions on longest prefix matching of the hierarchical naming of the CCN content [6-8]. On the other hand, h.264/SVC, also called layered video, encodes the content in a mandatory Base Layer (BL), mandatory for encoding any video, and multiple optional Enhancement Layers (EL). ELs are used to improve the video quality.

In this paper, we propose a mechanism to predict the vehicle location in the future time frame and its neighboring vehicles and the RSU the vehicle is falling in its range, in that specific future time frame. Then, we find out the part of the video that vehicle will request in that time frame. After that, the proposed mechanism proactively caches the different layers of the video in neighboring vehicles in such a manner that maximizes the utility and maintain a minimum QoS. Our formulated problem is linear programming combinatorial optimization problem, for which's solution we presented algorithm based on matching game. In the evaluation scenario, we show that the proposed mechanism achieves significant performance improvement.

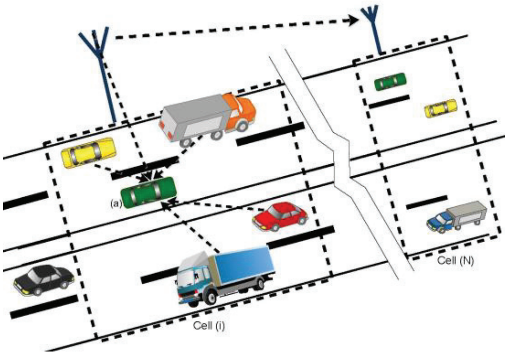

Figure 1: *System architecture*

2. System Architecture and Assumptions

Fig. 1 is showing system architecture for our proposed mechanism. The road is divided into equal length cells and vehicles within a cell can communicate to one another as well as to the Road Side Unit (RSU), the current cell is falling in. One RSU can cover multiple cells because of having powerful antenna. RSU is connected to the backbone network either via wire or wireless. RSUs can communicate with each other and they share the vehicle movement and active session information. Vehicles generate Interest for desired content. There are total $Z^K = \{Z_1^K, Z_2^K, ..., Z_Y^K\}$ contents in the content provider server.

3. Problem Statement

The important thing is, locating the cell the vehicle will be traveling in at time t + 1, so that to pre-cache the vehicle requesting video content at time t + 1 in vehicles and RSU of the cell. Vehicles locations are determined by the method used in [4]. There are $V = \{V_1, V_2, \dots, V_N\}$ vehicles on the highway.

$p(v_{ni}^{z_y^K})$ is the probability that $v_n^{z_y^K}$ (vehicle v_n playing chunk z_y^K at t+1) will get this content from vehicle $v_m^{z_y^K}$, which has pre-cached it, calculated as follows [4]:

$$p(v_{mnc_j}^{z_y^K}) = p(v_{nc_j}^{z_y^K}) * p(v_{mc_j}^{z_y^K}) \qquad (1)$$

Where $p(v_{nc_j}^{z_y^K})$ and $p(v_{mc_j}^{z_y^K})$ are the probabilities that the requester and provider will be in cell c_j at time t+1 respectively. Next important is to find the video chunk y that it will be requested at t+1 i.e., $z_{y,n_{c_j}}^k$. It is rather simple and can be calculated from the playback time of the video.

The received data rate of the user can be calculated as follow:

$$r(v_{nc_j}^{z_y^K}) = r(v_{nc_j}^{z_y^k})^{RSU} + r(v_{nc_j}^{z_y^{k'}})^{V2V} \qquad (2)$$

Where $r(v_{nc_j}^{z_y^k})^{RSU}$ is the data-rate user gets in downloading the k layers of the video from RSU while $r(v_{nc_j}^{z_y^{k'}})^{V2V}$ is the rate achieved in downloading the remaining k' layers of the video from another vehicle.

4. Proposed Solution

Our objective is to maximize the utility by providing more and more ELs of the video to the requester. To ensure minimum QoS, BL is always cached and provided by the RSU unless there are some uncovered cells. The ELs are proactively cached in the RSU covering c_j as well as in other vehicles that will be traveling in the same cell at time t+1. In order to estimate the chunk quality that is forward via a candidate card, we use a utility function for soft real-time applications versus rate allocation [9]. This function estimates QoS satisfaction following rate of V2V communication. A hybrid traffic includes both inelastic and elastic traffics streams emerged from real-time and delay-tolerant applications, whose QoS conductively modeled by sigmoidal at the time slot t+1 is determine as follows:

$$q_{v_{nc_j}^{z_y^K}}(\alpha_{nm}) = c\left(\frac{1}{1+e^{-a(r(v_{nc_j}^{z_y^K})(\alpha)-b)}} - d\right) \qquad (3\text{-}1)$$

Here, $d = \frac{1}{1+e^{ab}}$, $c = \frac{1+e^{ab}}{e^{ab}}$. is the sigmoidal application utility with parameter a =1, b = 25 estimates another real-time application with the inflection point r = 25. In [3-1], $r(v_{nc_j}^{z_y^K})$ is determined as follows:

$$r_{(v_{nc_j}^{z_y^K})}(\alpha) = \sum_{m=1}^{M} \alpha_{mn} p_{mn}^{z_y^K} r_{mn}^{z_{y,n_{c_j}}^k} + r(v_{nc_j}^{z_y^k})^{RSU} \qquad (3\text{-}2)$$

Utility of the system is maximized by the following optimization problem:

$$OPT-1:$$

$$\sum_{n=1}^{N}\sum_{m=1}^{M} \rho_n \frac{q_{v_{nc_j}^{z_y^K}}(\alpha_{nm})}{K} - \alpha_{nm}\delta_m \qquad (4)$$

$$Subject\ to:$$

$$\sum_{m=1}^{M} \alpha_{nm} \le 1, \qquad \forall n \qquad (5)$$

$$\alpha_{nm} \in \{0,1\}, \qquad \forall \in n, m. \qquad (6)$$

$$\sum_{n=1}^{N} \alpha_{nm} \le 1, \qquad \forall m \qquad (7)$$

Where α_{nm} is representing that receiving vehicle and providing

Algorithm 1: Video chunk proactively caching at time t+1

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1-  Initialize: $v_n^{z_y^K}, v_m^{z_y^K}, z_{y,n_{c_j}}^k$
      - RSU evaluate $p(v_{nc_j}^{z_y^k})$ and $p(v_{mc_j}^{z_y^{k'}})$
      - Each car n computes utility values, sorting decrement and build
    $\succ_n$ based on
                $U_n^{v_{nc_j}^{z_y^K}}(m) = \frac{q_{v_{nc_j}^{z_y^K}}}{K}$
      Swap matching operation to find stable matching $\mu^*$
2-  Each car n sends a bit to car m in the first entity in its preference list.
          If n = argmax{ ∀ n→m} $\frac{q_{v_{nc_j}^{z_y^K}}}{K} - \delta_m$ then,
                Pre-cache $z_{y,n_{c_j}}^{k'}$ in Vm, or $\alpha_{nm}$ =1
          Else
                drop the layers (k')
                $\alpha_{nm}$ = 0
                delete m in preference list of car n
        Go back to step 2
Outputs: $\alpha^*$ and Stable matching $\mu^*$ [5]
```

vehicles are in the same cell. ρ_n and δ_m are the rewards the content provider getting from requesting node and the provider node from the content server respectively. The constraints are ensuring that at a time one sender is connected with one provider and vice versa. The above optimization problem is linear programming combinatorial optimization problem. Solving this problem for a modest set of vehicles is not possible in the limited time. Therefore, we are presenting matching game base solution to this problem in the Algorithm1.

5. Performance Evaluation

We take a scenario that there are total 18 vehicles traveling in a section of highway which are divided into two categories, cars and trucks. All the vehicles in a category moving with the constant speed during the time of evaluation. The RSU provide the BL of the video and ELs are delivered via V2V communication. RSU having 4 resource blocks for assigning to the V2V communication. We have changed the ratio of content providing nodes and content requesting nodes. The results are shown in Fig. 3. In the figure, we can see that, initially the downloaded video quality increases with the increasing number of providing nodes. However, in 3:1 and 1:4 the video quality is not increasing. Reason for this is the network saturation i.e., there are content providing nodes but network resources are not available for the V2V communication.

6. Conclusion and Future Work

In this paper, we presented scalable video streaming proactively caching in VANET with V2V communication. We divided the road into cells and found out vehicle's location and the part of the video it will be watching in next time slot. We preload that part of the video in other vehicles that will be in the transmission range of the requesting vehicle. Our formulated problem is linear programming combinatorial optimization problem. We presented matching game to solve this problem. In the evaluation scenario, we showed that our proposal increases the video quality in limited resources network. In future, we aim to extend our formulation to make it concrete and evaluate the proposal in realistic environment.

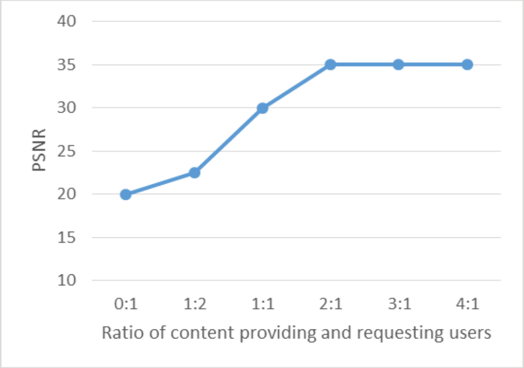

Figure 3: Average quality of the downloaded video

7. Acknowledgement

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