A Channel Popularity Oriented Transmission Scheme in Vehicular IPTV Networks

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***Abstract*-IPTV services in vehicular networks are currently attracting increasingly more attentions. One essential challenge is to efficiently utilize the limited radio resources in vehicular access networks. This paper assumes that scalable video coding (SVC) is used to encode TV channels. Since TV channels usually possess different popularities, the paper proposes a novel transmission scheme, which employs differentiated modulation and coding scheme (MCS) profiles for channels of different popularities. The principle is to use more robust MCS profiles for more popular channels while to adopt higher efficient MCS profiles for less popular channels. Comparative simulation experiments are conducted and show that the proposed scheme can effectively and efficiently improve the gross channel availability (GCA) up to 10% compared to the baseline method.**

Key words: wireless multimedia networks, IPTV, vehicular networks, scalable video coding (SVC), channel popularity

I. INTRODUCTION

Intelligent transportation system (ITS) mainly focuses on two categories of applications, i.e., security related and entertainment related. The vehicular IPTV service is regarded as one of the most promising multimedia entertainment applications, since it can provide passengers with live TV access on-the-road. Communications in vehicular networks are classified into *vehicle-to-infrastructure* (V2I) and *vehicle-to-vehicle* (V2V) modes [1]. The V2I mode is implemented with a set of road-side units (RSUs) built-up along the roads and can be accessed by vehicles via wireless links. The common manner to establish V2V communications is to build MANET or VANET (in the context of vehicular networks).

Vehicular IPTV is a live video streaming service, which implies high bandwidth demands and strictly limited transmission delay. Service providers, therefore, prefer to transmit TV channels in pure V2I mode. However, radio resource on RSUs is usually quite restricted. When it cannot support the concurrent transmission of all the channels, users may consequently suffer from deteriorated channel availability, one of the most important QoE metrics. SVC is a solution to mitigate this problem. In particular, SVC is employed to encode TV channels. Due to the fact that a lower SVC layer typically takes more weight than a higher SVC layer from users' perspective, more robust *modulation coding schemes* (MCSs) are used for lower SVC layers, while higher efficient (less robust) MCSs are employed by higher SVC layers. By this means, differentiated robustness and radio resource utilization efficiency can be provided. Chen et al. [2] proposed a scheme to deliver layered video information through wireless heterogeneous vehicular networks, where the mobile stations failing to receive all layers can learn the layer information from neighbors and regain the information through relaying using VANETs. Xing et al. [3] derived an adaptive video streaming scheme for video streaming services in the highway scenario. Relying on cooperative relay among vehicles, a vehicle can download video data using a direct link or a multi-hop path to the RSUs. Momeni et al. [4] investigated the TV channel availability in vehicular IPTV services with different traffic intensities and a varying number of TV channels offered to find out the acceptable availability of TV channels or the CBP. Hu et al. [5] investigated the BPRA problem for the layered video multicast in VANETs.

This paper elaborates a novel TV channel transmission scheme to further enhance the radio resource utilization. The major contribution attributes to the fact that the proposed transmission scheme is TV channel popularity oriented, which has rarely been studied in previous literature. Comparative simulation experiments are conducted and illustrate that the proposed scheme can effectively improve the GCA up to 10% compared to the baseline method where all the provided TV channels are transmitted with the same MCS profile.

The remaining part of this paper proceeds as follows. Section II gives a brief on IPTV services in the vehicular networks. Then, as the paper's major contribution, a novel transmission scheme concerning channel popularity is elaborated in Section III, with the discussions on its advantages and disadvantages. After that, in Section IV, the performance of the proposed scheme is evaluated by means of simulation. Finally, conclusions are given in Section V.

II. IPTV SERVICES IN VEHICULAR NETWORK

A. Typical vehicular IPTV network architecture

A typical vehicular IPTV network has been illustrated in Figure 1, which hierarchically consists of three different levels, namely backbone, aggregation, and access networks. *Video head-end office* (VHO) is attached to the backbone network via very-high-speed fibers, and is the source of all the provided TV channels. It can also be the source of other *video-on-demand* (VoD) resources. The backbone and the aggregation levels are typically tree-topology-based; the underline physical links can be either wire-line or wireless depending on practical capacity demands and budgets. In the access network, a number of RSUs are linearly deployed along

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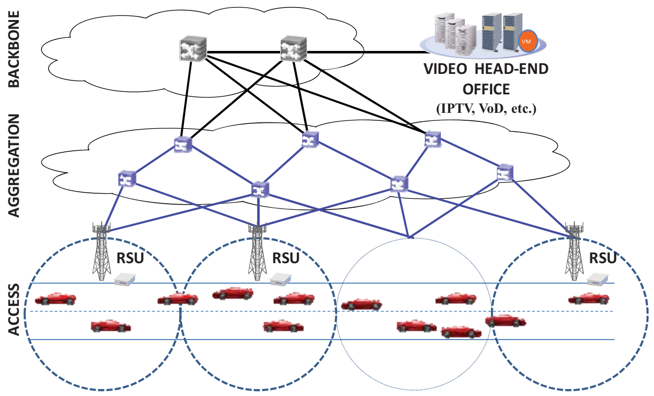


Figure 1. A typical vehicular IPTV network architecture.

the road where the IPTV service is offered to the vehicles. Different from the conventional cellular networks, the signal coverage areas of RSUs are linear along the road. The coverage zones of two neighboring RSUs are tightly adjacent to make sure vehicles will not experience signal disruptions when crossing the boundaries in between.

In the access network, vehicular network supports two types of communication modes, i.e., V2I and V2V. To avoid excessive transmission delay, service providers usually adopt the V2I mode, which means that, all the IPTV channels are directly transmitted from the RSUs to vehicles by means of IP multicast, without any intermediate relay facilities.

B. TV channel popularity distribution

Empirical measurements expose the fact that subscribers' interests are not evenly distributed on all the TV channels, i.e., at a random instant, the majority of users may watch a relative small portion of the offered channels, which indicates non-identical popularity for different TV channels. Typically, channel i's popularity can be measured by channel access frequency, which is the ratio of the requests for channel i among all the channel requests, generated by a set of users during a certain period of time.

In practice, channels popularity can be derived from a practical traffic trace, or can be modeled by different probability distributions. One most frequently used distribution is the Zipf-like distribution, with the PDF:

$$f(k;s,N) = 1/k^{s} \Big/ \sum_{n=1}^{N} (1/n^{s}) \qquad (1)$$

where N is the number of provided TV channels, k is the popularity rank, s is the value of the exponent characterizing the distribution. This paper further classifies the TV channels into different categories, so as to apply the same e.g., access control strategy to all the channels in each single category. One example is given in Figure 2, where 40 channels are offered, and are following the Zipf-like distribution. These channels are further divided into four categories, namely A (most popular), B (popular), C (unpopular), and D (least popular) groups. It is noted that satisfying channel requests of the first two groups may be of greater importance, especially in a radio resource limited system (as is considered here).

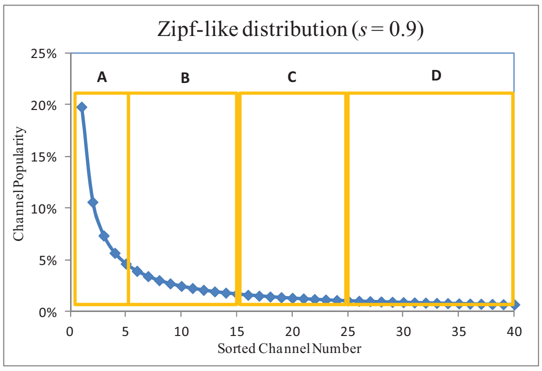


Figure 2. Zipf-like TV channel popularity distribution.

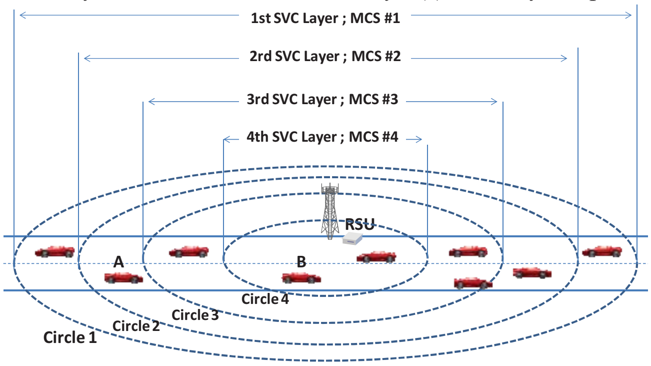
III. Transmission Scheme Concerning TV Channel Popularity

This paper focuses on a resource restricted vehicular IPTV system, which means the radio resource reserved on each RSU cannot support the simultaneous transmission of all the TV channels in a full cell-coverage mode. In order to better utilize the radio resource, service providers can use SVC technologies to encode each TV channel into multiple layers. More robust MCSs are used for the lower SVC layers, based on the consideration that those layers typically contribute more to user QoE than the higher layers. For all the offered TV channels, the same MCS profile is used. This conventional SVC transmission method is defined as the *baseline scheme*. Figure 3 demonstrates one such example.

To further improve the radio resource utilization, this paper elaborates a channel popularity oriented transmission scheme, on the basis of the above baseline scheme.

A. Principle of channel popularity oriented transmission scheme

The popularity oriented channel transmission scheme assumes that, all the provided TV channels are encoded by SVC techniques. SVC decomposes a higher quality video stream into multiple subsets, representing a lower quality in spatial resolution, a lower video signal quality, a lower temporal resolution, or a combination thereof. Assume that each TV channel is divided into L SVC layers, including one base layer and L-1 enhancement layer(s). Usually, a specific



MCS No.	#1	#2	#3	#4
MCS	QPSK, 1/2	QPSK, 2/3	16QAM, 1/2	64QAM, 2/3
Coverage Rad.	800 m	600 m	400 m	200 m

Figure 3. The legacy SVC-based channel transmission method.

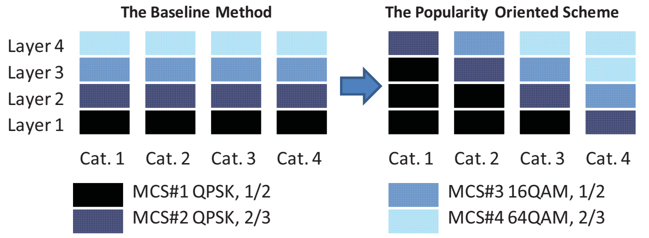


Figure 4. An example of popularity oriented transmission scheme.

enhancement layer *i* can be decoded only with all of its lower layers (i.e., layer *1* to *i-1*), since decoding an upper layer needs the information derived from one or more of its lower layers.

There are in total *N* channels provided, which according to the channel popularity are classified into *C* categories, with the 1^{st} category as the most popular group and the C^{th} category as the less popular group. Different from the baseline method, which chooses the same MCS profile for all the channels, the popularity oriented TV channel transmission scheme employs differentiated MCS profiles for channels in different popularity categories. Precisely, for channels in the 1^{st} category, more robust MCSs are used for the SVC layers, while for the C^{th} category, more efficient MCSs are adopted. Figure 4 illustrates one such example to better explain the scheme's principle.

B. *Advantage and disadvantages*

Compared to the baseline scheme, the channel popularity oriented transmission scheme can enhance the user QoE by increasing the GCA in radio resource limited systems. The improvement mainly attributes to the fact that the proposed scheme adopts more robust MCS profiles for the popular channel categories, which tends to assign a larger amount of radio resources to those popular channels, and consequently satisfies a larger number of channel requests. On the contrary, since the total radio resource is fixed, availability of the unpopular channels will be negatively influenced, which is the disadvantage of using this popularity oriented scheme.

IV. Performance Evaluation

This paper mainly considers the gross channel availability (GCA) as the performance metric. In addition, the availabilities of different channel categories, denoted as CCA_i , are also evaluated in order to provide more insights in detail. GCA is defined as the average ratio of the period that the weighted SVC layers of all the provided channels are successfully received & decoded by a vehicle when driving in the simulated zone, and is evaluated by:

$$GCA = \sum_{i=1}^{L}\sum_{j=1}^{K} t_{i,j}\cdot \omega_i \Big/ \sum_{j=1}^{K}\tau_j \qquad (2)$$

where *K* is the total number of IPTV users driving through the road during simulation, and *L* is the number of SVC layers; τ_j is the time user *j* spends on going across the simulated zone, while $t_{i,j}$ denotes SVC layer *i*'s available time period for user *j*. Since each SVC layer contributes to a different extent to the gross video quality, w_i denotes the weight of the *i*th SVC layer.

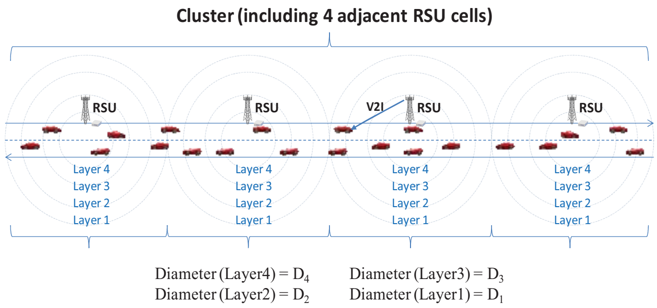


Figure 5. Illustration of simulation scenario.

CCA_i possesses the similar definition as GCA, the only difference is that CCA only considers the channels in the *i*th popularity category.

A. *Simulation Introduction*

This paper resorts to simulation to evaluate the aforementioned performance metrics. The simulation scenario is shown in Figure 5, which contains four adjacent RSU cells, which form a multicasting cluster. In the cluster, TV channel multicasting in all the cells is synchronized. Vehicles drive along the road bi-directional with constant speed *V* and exponentially distributed inter-vehicle distance *d*. Besides, the notations and simulation parameters are given in TABLE II.

TABLE II

Notations and simulation parameters

Notation	Description	Value
N	Total num. of IPTV channels	40
B	Number of lanes	4 (2 in each direction)
L	Number of SVC layers	4
w_i	Weight of SVC layer *i*	0.4,0.3,0.2,0.1
p_i	Popularity of channel *i*	Zipf distr. *s*=0.9
a	Prob. of vehicle using IPTV	0.5
D_i	Coverage radius of MCS#i	cf. Figure 3
V	Vehicle speed in each direction	20,40,60,80,100, 120,140,160km/h
D_{cell}	Diameter of each cell	1600 (m)
$D_{cluster}$	Diameter of each cluster	6400 (m)
d_{avg}	Average distance between two neighbouring vehicles	14, 18, 22, 26, 30, 34, 38, 42 (m)
d_{max}	Maximal distance between two neighbouring vehicles	18, 22, 26, 30, 34, 38, 42, 46 (m)
d_{min}	Minimal distance between two neighbouring vehicles	10, 14, 18, 22, 26, 30, 34, 38 (m)
T_{sim}	Simulated time duration	7200 (s)
C	Number of popularity categories	4 (cf. Figure 2)
TD	Traffic Density: average num. of vehicles in each lane per direction	$TD = D_{cell} / d_{avg}$

A dedicated *Monte Carlo* simulator written in pure C language has been developed, and the *LoadSpec* tool [6] is used to generate aggregate traces of channel switching events for the vehicular IPTV users. LoadSpec is an artificial load generator for different interfaces and it is capable of producing realistic network traffic with different characteristics in a very simple and flexible manner. The simulation logic is as follows:

- **Step_1**. Use LoadSpec to generate a set of single traces for all the simulated vehicles. Align and combine them in time axis to form the aggregate trace, with considering the different instants when those vehicles enter into the simulated cluster. The aggregated trace contains two types of events, namely *channel switching* (CS) and *boundary cross* (BC) events (i.e., a vehicle drives across cell boundaries and different SVC layer coverage circles).
- **Step_2**. Start to conduct the simulation according to the aggregate trace. When the BC events happen, the system will check issues such as whether the SVC layers of the watched channel is still available, or whether higher SVC layers are currently available for that vehicle. When a CS event arrives, the vehicle will first leave the currently watched channel, and then will join into and receive the highest available SVC layers of the newly requested channel, depending on its current location.
- **Step_3**. After the simulated system changes from transient-state to steady-state, a set of variables and arrays are used to record the statistics such as the SVC layer available time per layer per user, etc.
- **Step_4**. When the simulation time is up, calculate the performance metrics, i.e., GCA and CCA_i, according to the recorded statistics in Step_3.

B. *Experimental Results*

Experimental results are plotted in Figures 6 and 7 (in which the confidence intervals given are based on a confidence level of 95%). Particularly, Figure 6 presents GCA against traffic density with and without using the proposed scheme. As can be seen, the popularity oriented transmission scheme can considerably increase the GCA up to 10% (from 66%to 76% when the TD is round 457). Figure 7 further illustrates the CCA curves for the four different channel popularity categories with and without applying the proposed transmission scheme. Note that, for channels in popular category A and B, the CA will be increased after using the proposed scheme, while, in contrast, the CCAs of categories C and D degraded. This means that the scheme scarifies the CA of unpopular channels to increase the CA of popular channels and consequently to significantly enhance the GCA and QoE.

V. Conclusions

This paper focused on improving the GCA of vehicular IPTV systems, where TV channels encoded by advanced SVC technologies are transmitted directly from RSU to vehicles (V2I mode). As the major contribution, this paper elaborated a TV channel popularity oriented transmission scheme to enhance the radio resource utilization. The proposed scheme employs more robust MCS profiles for popular channels with the purpose of serving more users, while providing more efficient MCS profiles for unpopular channels to save the resource. Comprehensive simulation experiments demonstrated that, compared to the baseline transmission scheme, the channel popularity oriented scheme can substantially optimize QoE by increasing the GCA up to 10%

The planned work in the future is to establish a mathematical model to determine the globally optimized MCS profiles for each individual TV channel so as to further enhance the performance of the proposed transmission scheme.

References

[1] Momeni, S., Wolfinger, B.E. (2013) Availability of IPTV Services in VANETs Using Different Access Network Technologies, Proc. of IEEE ITST 2013, Tampere, Finland.

[2] Cheng, HY., Gau, V., Huang CH., and Hwang, JN. (2012) Adaptive Video Streaming with Inter-Vehicle Relay For Highway VANET Scenario ,Expert Systems with Applications, vol. 39, pp. 8356-8368.

[3] Xing, M., and Cai, L. (2012) Advanced Formation and Delivery of Traffic Information in Intelligent Transportation Systems, Proc. of IEEE ICC 2012, Ottawa, Canada, pp. 5168-5172.

[4] Momeni, S., Lai, J., Wolfinger, B.E. (2013) Availability Evaluation of IPTV Services in Roadside Backbone Networks with Vehicle-to-Infrastructure Communication, Proc. of IEEE IWCNC 2013, Cagliari, Sardinia, Italy.

[5] Hu, M., Zhong, Z., and Chang, CY.(2013) A Multicast Scheduling Approach for Layered Video Service in Vehicular Ad Hoc Networks, Proc. of IMIS 2013, Taichung, Taiwan, ROC.

[6] Kolesnikov A. and Heckmüller S. (2008) LoadSpec - ein E-Learning Werkzeug zur Lastspezifikation im Bereich der Telematik, E-Learning Baltics, eLBa 2008, Rostock, 17.-19. Juni 2008.

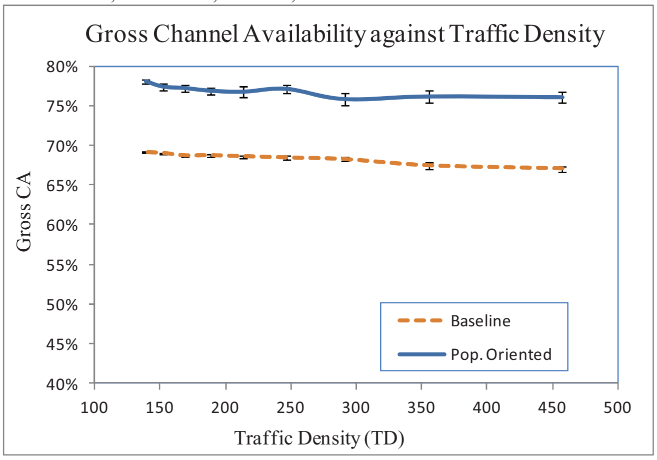


Figure 6. Gross channel availability (GCA) against traffic density.

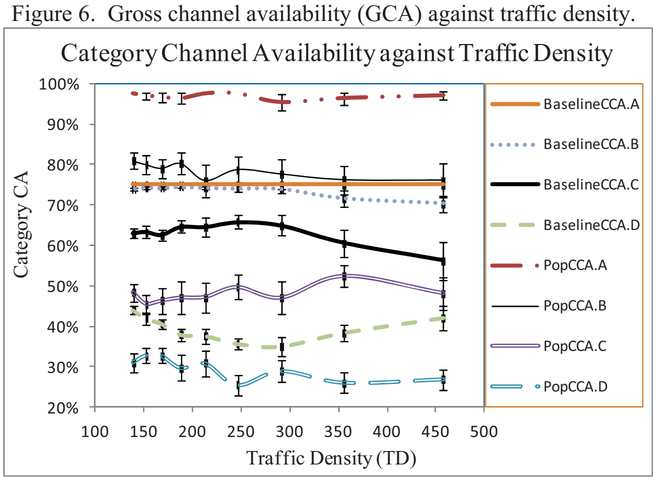


Figure 7. Category channel availability (CCA) against traffic density.