Enabling Software-Defined Networking Technologies in Carrier Networks

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***Abstract*-Adopting software-defined networking (SDN) in carrier networks is now gaining momentum. Carriers and vendors are rushing into this new domain, hoping to solve some most urgent problems which arise along with the process when fixed high-speed data access and mobile broadband (MBB) get increasingly popular across the globe. To the same end, this paper elaborates novel software-defined fixed networking (SDFN) and software-defined mobile networking (SDMN) architectures, leveraging a set of emerging and promising technologies including SDN, clouding computing, network virtualization (NV), network functions virtualization (NFV), and dynamic service chaining. Furthermore, in the light of the irreversible trend towards fixed mobile convergence (FMC), this paper also proposes a forward-looking software-defined converged networking (SDCN) architecture. The three proposed architectures can effectively help carriers to reduce cost and enhance service performance, and therefore can serve as a good reference for the next-generation carrier network designing.**

Keywords: Next-Generation Networking Architecture, Network Design, Software-defined Networking (SDN), Carrier Network, Fixed Mobile Convergence (FMC).

I. INTRODUCTION

SDN refers to an emerging network architecture, which decouples the network control plane and data/forwarding plane. Particularly, control plane is designed to be implemented in software, while data plane is implemented in commercial-off-the-shelf hardware. The industry has already witnessed the successful application of SDN in the fields of data center networking. At present, adopting SDN in carrier networks is gaining gigantic momentum. Carriers and vendors are rushing into this new domain, expecting to solve the most urgent issues and challenges which arise along with the process when fixed high-speed data access and MBB become increasingly popular around the world. More precisely, carriers are mainly annoyed by:

- Ever rising capital expenditure (CAPEX) due to continuous updating of network infrastructure;
- Extremely high operational expenditure (OPEX) owing to complex operation, administration, and maintenance (OAM) tasks in legacy networks;
- Revenue loss as a result of competition with over-the-top (OTT) applications operated by Internet companies;
- Hard to provide finer-granular and differentiated services for both subscribers and applications, since the current carrier networks are not flexible, intelligent and agile enough.

Consequently, the overall challenges from carrier's perspective are to decrease the total cost (CAPEX & OPEX) while enhancing service, so as to increase the revenue.

To help carriers solving the aforementioned problems, quite a few research efforts have been carried out or are ongoing. In industry, Ericsson recently published its Service Provider SDN approach [1], aiming to extend virtualization and OpenFlow with three additional key enablers, i.e., integrated network control, orchestrated network and cloud management, and service exposure. Huawei has also unveiled its SoftCOM strategy [2] for applying SDN and cloud computing in carrier networks. Juniper has developed JunosVContrail SDN product line [3] for carrier networks. In academia, Bansal et al. [4] from Stanford established OpenRadio project, targeting at a programmable wireless network data plane. Li et al. in [5] sketched out a software-defined cellular network architecture called CellSDN. Naudts et al. in [6] conducted a techno-economic analysis of SDN as architecture for the virtualization of a mobile network. In [7], Gudipati et al. recently proposed SoftRAN, a centralized control plane for radio access network (RAN). Pentikousis et al. in [8] introduced the SDN-based MobileFlow architecture.

Many existing proposals only concern one or several specific parts of a carrier network, more detailed holistic solutions for enabling SDN in carrier networks are highly desirable. In order to bridge the gap, this paper elaborates novel SDFN and SDMN architectures for carrier fixed network and mobile network, respectively, leveraging a set of emerging and promising technologies i.e., SDN, clouding computing, network virtualization [9], NFV [10], and dynamic service chaining. Furthermore, in the light of the irreversible trend towards future FMC, the paper proposes a forward-looking SDCN architecture for carriers. It is believed that, as the major contribution, the proposed SDFN, SDMN, and SDCN architectures are of great help for carriers to keep profit and sustainability. Meanwhile, they can significantly enhance both capacity and efficiency regarding network OAM, as well as accelerate business innovation to new application fields.

The remaining part of this paper proceeds as follows. The SDFN and SDMN architectures are proposed in Sections II and III, respectively. In Section IV, this paper further elaborates a future-facing SDCN architecture following both SDN and FMC concepts, aiming to reduce cost while

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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IMPROVE CHANNEL AVAILABILITY IN VEHICULAR IPTV SYSTEMS BY A HYBRID TRANSMISSION SCHEME

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Abstract: One important factor restricting the capacity of IPTV service over vehicular-to-infrastructure (V2I) networks is the limited radio resource reserved on the road-side-units (RSUs). This paper elaborates a hybrid video transmission scheme to improve the channel availability in vehicular IPTV systems. The advanced scalable video coding (SVC) technique is applied to encode TV channels. SVC layers are transmitted in different modulation and coding schemes (MCSs), so as to provide differentiated robustness and resource utility efficiency. The hybrid transmission scheme intelligently delivers SVC layers to vehicles via either pure V2I or inter-vehicle relay connections. Comprehensive simulation experiments are conducted and show that, compared to the legacy V2I transmission scheme, the proposed hybrid scheme can effectively enhance user quality of experience (QoE) by significantly increasing channel availability, with only slightly deteriorating the transmission delay for the enhancement layers.

Keywords: network modeling, multimedia applications, resource management, QoE, channel availability

1 Introduction

IPTV service in vehicular networks can provide passengers with live TV access on-the-road, and is regarded as one of the most promising multimedia applications in the future intelligent transportation systems. Communications in vehicular networks can typically be classified into V2I and vehicle-to-vehicle (V2V) modes. Firstly, the V2I mode relies on a series of RSUs which are built-up along the roads and can be accessed by vehicles via wireless communications. Secondly, the common manner to establish V2V communications is to build MANET, which in the context of vehicular network is called VANET.

Stemming from the fact that vehicular IPTV is a live video streaming service, which has to be delivered to users in real-time, i.e., with strictly limited transmission delay, service providers prefer to transmit the TV channels in pure V2I mode. However, the radio resources on RSUs are usually quite restricted, and when i.e., increasingly more TV channels are provided, radio resource shortage will pose a tough challenge. The users may consequently suffer from deteriorated channel availability and degraded QoE. Aiming at solving this problem, this paper adopts the advanced SVC technique to encode every IPTV channel in multiple SVC layers (including one base layer and at least one enhancement layer). Since different SVC layers typically possess non-identical weights, RSUs transmit SVC layers in different MCSs, so as to provide differentiated robustness and resource utilization efficiency. The major contribution of this work is attributed to the elaboration of a hybrid IPTV transmission scheme with the purpose of improving the channel availability in a resource restricted vehicular network. The hybrid scheme intelligently delivers SVC layers to different vehicles via either pure V2I or inter-vehicle relay connections (including both V2I and V2V communication modes). Comprehensive simulation experiments are carried out and the results show that, compared to the pure V2I transmission scheme, the proposed hybrid scheme can greatly enhance user QoE by effectively improving channel availability, with only slightly increasing the transmission delay for the enhancement layers.

The remaining part of this paper proceeds as follows. Sect. 2 introduces the related work. Then, the basic vehicular network architecture and the user behaviour model are discussed in Sect. 3. After that, as the paper's major contribution, a hybrid video transmission scheme for vehicular IPTV system is derived in Sect. 4. In Sect. 5, the performance of the hybrid scheme is evaluated by means of simulation. Finally, summary and outlook are given in Sect. 6.

2 Related work

Channel availability is an essential QoE performance metric in IPTV systems, which is closely related to call blocking probability (CBP). Earlier publications have already provided well-known exact or approximate analytical algorithms for the CBP calculation in the context of unicast and multicast scenarios. In addition, simulation based evaluation serves as another option. In Refs. [1-2], J. Lai et al. proposed a link state-vector-based model to simulate IPTV systems in detail. Besides, a TCAC scheme [2], Ref. [3] was also proposed to decrease the CBP and to improve the channel availability in both static and peak-hour scenarios. Those works, however, focused on IPTV in fixed wireline / wireless networks, where users rarely move while watching.

In vehicular networks, video steaming transmitted via

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Profiling Driver Behavior for Personalized Insurance Pricing and Maximal Profit

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Abstract*—Profiling driver behaviors and designing appropriate pricing models are essential for auto insurance companies to gain profits and attract customers (drivers). The existing approaches either rely on static demographic information like age, or model only coarse-grained driving behaviors. They are therefore ineffective to yield accurate risk predictions over time for appropriate pricing, resulting in profit decline or even financial loss. Moreover, existing pricing strategies seldom take profit maximization into consideration, especially under the enterprise constraints. The recent growth of vehicle telematics data (vehicle sensing data) brings new opportunities to auto insurance industry, because of its sheer size and fine-grained mobility for profiling drivers. But, how to fuse these sparse, inconsistent and heterogeneous data is still not well addressed. To tackle these problems, we propose a unified `PPP` (Profile-Price-Profit) framework, working on the real-world large-scale vehicle telematics data and insurance data. `PPP` profiles drivers' fine-grained behaviors by considering various driving features from the trajectory perspective. Then, to predict drivers' risk probabilities, `PPP` leverages the group-level insight and categorizes drivers' different temporal risk change patterns into groups by ensemble learning. Next, the pricing model in `PPP` incorporates both the demographic analysis and the mobility factors of driving risk and mileage, to generate personalized insurance price for supporting flexible premium periods. Finally, the maximal profit problem proves to be NP-Complete. Then, an efficient heuristic-based dynamic programming is proposed. Extensive experimental results demonstrated that, `PPP` effectively predicts the driver's risk and outperforms the current company's pricing strategy (in industry) and the state-of-the-art approach. `PPP` also achieves near the maximal profit (difference by only 3%) for the company, and lowers the total price for the drivers.

***Index Terms*—Driver behavior profiling, personalized insurance pricing, company profit, trajectory data mining**

I. Introduction

Insurance is designed to protect the people and things we value most. Among it, auto insurance is one important category that provides financial protection against damages and liability resulting from car accidents. How to profile driver behaviors and devise pricing models, plays an essential role for insurance companies to gain profits and attract customers (drivers).

There has been considerable research on understanding the driver behavior and auto insurance pricing in the last decade. Traditional approaches, e.g., generalized linear models [1], [2], rely on drivers' static demographic information (e.g., age, gender and vehicle type) to compute the insurance price, but usually neglect the driving risk. Usage-Based Insurance (UBI) [3] based methods [4], such as Pay-As-You-Drive model [5] and Pay-How-You-Drive model [6], are introduced to model the driver mobility factors like time, mileage and speed for improving insurance pricing.

TABLE I: Drivers' claim statistics.

Driver Type	Driver Percentage	Accident Percentage
Claim count $= 0$	72%	0%
Claim count $= 1$	11%	20%
Claim count ≥ 2	**17**$\%$	**80**$\%$

However, the above solutions have the following drawbacks. 1) They are able to model only coarse-grained driving behaviors, resulting in inappropriate pricing, and incurring potential profit decline or even financial loss. As reported in 2016, over 70% auto insurance companies in China were in financial loss [7]. Table I shows the real-world claim data offered by a mainstream insurance company (due to the privacy concern, we omit the name) for the year 2016. Note that 17% of the drivers cause 80% of the accidents and claim indemnity. These drivers' risk behaviors necessitate further investigation at a finer-grained level. 2) The existing approaches cannot capture the time-variant driving risk. According to the survey conducted by the same company mentioned above, the number of overlapping accident-involved drivers between 2016 and 2017 is only about 3% (2.8% between 2015 and 2016). This indicates that driver risk behaviors often change over time. Thus, capturing the temporal risk patterns is crucial to build an accurate pricing model, which is required by the company as personalized and flexible. 3) Traditional models fail to link driver behaviors and pricing models with the ultimate goal of maximizing company profits, especially under the real-world enterprise constraints.

Recently, the rapid development of telematics [2], [8] in auto insurance industry has enabled to collect large amounts of fine-grained mobility data, like vehicle speed, acceleration, engine speed and so on, to better profile drivers' risk for pricing. With these telematics data, traditional methods [9] are usually leveraged to compute the insurance price, e.g., Pay-How-You-Drive model [10]. Although the mass of new telematics data has great potential to model driving behaviors more accurately and improve the granularity of risk prediction, it also poses new research challenges. First, telematics data

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PBE: Driver Behavior Assessment Beyond Trajectory Profiling

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Abstract. Nowadays, the increasing car accidents ask for the better driver behavior analysis and risk assessment for travel safety, auto insurance pricing and smart city applications. Traditional approaches largely use GPS data to assess drivers. However, it is difficult to fine-grained assess the time-varying driving behaviors. In this paper, we employ the increasingly popular On-Board Diagnostic (OBD) equipment, which measures semantic-rich vehicle information, to extract detailed trajectory and behavior data for analysis. We propose PBE system, which consists of Trajectory Profiling Model (**P**M), Driver Behavior Model (**B**M) and Risk Evaluation Model (**E**M). PM profiles trajectories for reminding drivers of danger in real-time. The labeled trajectories can be utilized to boost the training of BM and EM for driver risk assessment when data is incomplete. BM evaluates the driving risk using fine-grained driving behaviors on a trajectory level. Its output incorporated with the time-varying pattern, is combined with the driver-level demographic information for the final driver risk assessment in EM. Meanwhile, the whole PBE system also considers the real-world cost-sensitive application scenarios. Extensive experiments on the real-world dataset demonstrate that the performance of PBE in risk assessment outperforms the traditional systems by at least 21%.

Keywords: Driver behavior analysis · On-Board Diagnostic (OBD)

1 Introduction

Nowadays, the number of traffic accidents increases rapidly every year [6,16]. Meanwhile, researchers have found that the driver behavioral errors caused more than 90% of the crash accidents [13], served as the most critical factor leading to the crash accidents. Therefore, how to effectively analyze the driver behavior

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