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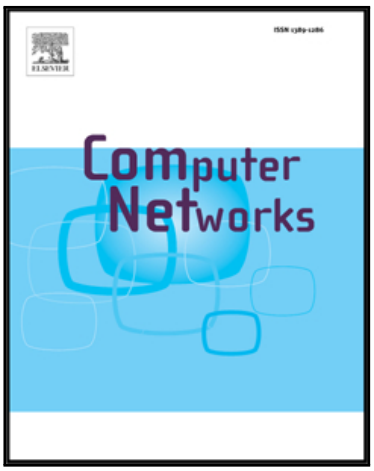

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Kalupahana Liyanage Kushan Sudheera, Maode Ma,
Peter Han Joo Chong

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Controller Placement Optimization in Hierarchical Distributed Software Defined Vehicular Networks

Kalupahana Liyanage Kushan Sudheera[a,*], Maode Ma[a], Peter Han Joo Chong[b]

[a] *School of Electrical and Electronic Engineering, Nanyang Technological University, Singapore*
[b] *Department of Electrical and Electronic Engineering, Auckland University of Technology, New Zealand*

Abstract

Recently, a new paradigm has emerged, named as Software Defined Vehicular Network (SDVN) which applies the concept of Software Defined Networking (SDN) in Vehicular Ad-hoc Network (VANET), to overcome the shortcomings in vehicular networks. With the introduction of SDN, VANET has been provided with flexibility and programmability along with a performance improvement. However, the improvement comes at a cost of higher operational delay because, the controllers are placed far away from the data plane in the existing SDVN architectures. As an alternative, we have previously proposed to bring the control plane down to Road Side Unit (RSU). In this study, we further extend this work and introduce a hierarchical distributed controller architecture where the top tier of controllers are regionally distributed on the Internet and the bottom tier of controllers are placed in several selected RSUs closer to the vehicles so that the latency induced by the system becomes low. We further present a novel controller placement model for the RSU level controllers based on the p-median facility location problem with the delay and the significance of the RSU location as the factors to achieve the optimization heuristically as an integer quadratic programming problem. With the help of the simulation results, we show that our proposed controller placement model can optimize the placements of controllers with a lower latency compared to other possible controller placement methods including the existing SDVN architectures and conventional VANETs.

Keywords: Architecture, Optimization methods, Software defined networking, Software defined vehicular networks, Vehicular ad-hoc networks

1. Introduction

The transportation industry has been facing several serious issues such as increasing traffic accidents, long traffic congestions and damages to public property and human lives, etc. Continuous increasing amount of vehicles, limited space in road infrastructure and bad driving behaviors can be stated as the root causes that drive these problems [1]. However, these critical threats can be minimized by establishing a proper communication among vehicles, which is one of the fundamental objectives of the Vehicular Ad-hoc Networks (VANETs) [2].

The VANETs emerged nearly a decade ago and since then it has been getting an increasing attention both from the industry and academia due to its unique challenges. In VANET, vehicles will be equipped with On Board Units (OBUs) which generally facilitates a GPS device and a Dedicated Short Range Communication (DSRC) radio-transceivers [3]. In contrast to other mobile ad-hoc networks, VANETs exhibit several unique characteristics such as predictable mobility patterns, large network size, frequent disconnections, and stringent delay requirements. Also, VANETs deploy unique stationary Road Side Units (RSUs) in the network with a purpose to disseminate important information such as road conditions, traffic light status, etc. to the passing vehicles [4].

But so far, VANETs have not been able to meet the desired expectations leaving a lot of challenges open such as inefficient information dissemination, security vulnerabilities, inability in coping with dynamic topology changes which result in low Packet Delivery Ratios (PDR) and high end to end delays, etc. [2, 5]. Some of these problems are very difficult to solve under current VANET architecture. Most importantly, current distributed VANET architecture cannot provide a sense of programmability to the system [6]. Therefore, it is very difficult to deploy and test new protocols and services in VANETs. A comprehensive reconfiguration in each vehicle is required for the purpose of deploying new services, prompting serious issues on the manageability and expandability of the existing VANETs.

In order to address these problems and enable programmability, researchers are focusing on incorporating Software Defined Networking (SDN) into VANETs [7, 8]. SDN has been brought forward to encourage innovation and provide programmability to traditional network sys-

*Corresponding author
Email addresses: KUSHANSU001@e.ntu.edu.sg (Kalupahana Liyanage Kushan Sudheera), EMDMA@ntu.edu.sg (Maode Ma), PETER.CHONG@aut.ac.nz (Peter Han Joo Chong)

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