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Lowering the Barriers to Non-Safety Applications in Cloud-Based Vehicular Networks

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Abstract: Intelligent transportation systems non-safety applications reply on resource-constrained RoadSide Units (RSUs). Strengthening the vehicles in the VANETS with a cloud access aims to interconnect On-Board Unit (OBU) and RSU resources into the cloud for computing tasks. With cloud computing, cloud-based vehicular networks can support many unprecedented applications. However, deploying applications of cloud-based applications with low latency is not a trivial task. It creates a burden to the vehicular network's designers because rapid development and communication technologies, gradual changes in cloud-based vehicular networks evolve into a revolution in the process. In this study, we try to reveal the barriers hindering the scale up of applications based cloud-vehicular networks and to offer our initial cloud-based vehicular networks as a potential solution to lowering the barriers.

Key words: Cloud-based vehicular networks, software defined network, cloudlet, roadside units, virtual private mobile networks, communication

INTRODUCTION

The cloud architecture for vehicular (Yu *et al*., 2013) is in the progress of merging with the internet as a fundamental platform for Intelligent Transportation System (ITS). The cloud architecture for vehicular networks consists of three interacting layers: vehicular cloud, Road Side Unit (RSU) cloud and central cloud. The RSU is accessible only by the nearby vehicles. RSU components are described as a highly virtualized platform that provides the computation, storage. Similar system typical known as edge computing (Kai *et al*., 2016) such as cloudlets (Satyanarayanan *et al*., 2009) are emerging at the RSU as a small-scale operational site that offers cloud services to bypassing vehicles. The software defined network are among applications scenarios for fog computing for VANETS (Boucetta *et al*., 2017) that has been given much attention to many researchers interested in the application of cloud-based vehicular networks.

With powerful cloud computing, cloud-based vehicular networks (Yu *et al*., 2013) can support unprecedented applications such as multimedia applications, video conferencing and real-time navigation. Typically the Road Side Units (RSU) in cloud-based vehicular networks host an application that provides services. A vehicle will access a roadside by V2R scommunications. The On-Board Unit (OBU) is equipped with the vehicle. This OBU allows Dedicated Short Range Communication (DSRC) communications with other OBUs or RSUs. The RSU can be highly virtualized, able to provide computation, storage and networking services between the vehicles and the central cloud. The RSU acts as Fog computing. Fog computing appears as a good candidate for a cloud-based vehicular network that requires delay-sensitive, connectivity, mobility and location-awareness services which could satisfy the demands of future cloud-based vehicular networks applications (Kai *et al*., 2016).

The SDN (Liu *et al*., 2013) is a growing computing and networking concept. SDN separates control plane and data plane entities. It executes the control plane software on general purpose hardware. It has a well programmable data planes. SDN concept together with fog computing would resolve the main issues in vehicular networks irregular connectivity, packet loss rate. The architecture of SDN controlled VANET can improve resource utilization, selection of best routes and facilitate network programming.

VANET/internet of the vehicle with SDN and Fog Computing is the hottest technology within recent years. Salahuddin *et al*. (2015) present an n RSU cloud as a vehicular cloud for the computational and communication infrastructure supporting vehicle grid on the Internet of Vehicles (IoV). Their novel contribution is about the

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architecture of RSU CRM and RSU micro-datacenter. They model the CRM as a multi objective optimization problem for minimizing VM migrations, control plane overhead, number of service hosts and infrastructure delay. No virtualization of physical mobile network proposed for reduces delay. Truong *et al*. (2015) propose a new promising VANET architecture called FSDN which combines SDN and fog computing; the latter additionally brings capabilities for delay-sensitive and location-awareness services. The solution covers V2V, V2I and Vehicle-to-base station communications.

We take the position that a vehicle changes location and switches between RSU cloudlet units. The vehicle needs to wait for service re-initiation time to resume the current cloud service. Therefore, cloud-based vehicular applications demand a much more delay to access computation resources located in the cloud. Second, this need of satisfying benefits of software-defined VANETs that are classified in three area such as path selection, frequency/channel selection and power selection (Kreutz *et al*., 2014) is best met by fully exploiting the flexibility provided by the SDN concept and network virtualization functionality. Third, that such SDN functionalities provide for the ability to better accelerate the deployment of applications of cloud-based vehicular networks and software-defined VANETs applications.

What limits the scaling of applications of cloud-based vehicular applications and software-defined VANETS? In this study, we explore this issue and propose an architecture solution. We then explore different layers included in the proposed architecture.

Obstacles to applications of cloud-based vehicular network: The idea of roadside cloud which is composed of two dedicated local servers and roadside units is not new. Yu *et al*. (2013) propose a vehicular cloud in vehicular networks which is composed by a vehicular cloud, roadside cloud and central cloud. The roadside cloud was composed of dedicated local servers virtualize physical resources and acts as a potential cloud. In their concept, the roadside cloud is accessible only by vehicles located within the radio coverage area of the cloud site's roadside units. The roadside cloudlet refers to a small scale roadside cloud that offers cloud services to bypassing vehicles.

The first obstacle is about re-initiation service on the roadside cloud as the vehicle switch on the roadside unit's cloud away from its coverage area. A vehicle can select a nearby roadside cloudlet and customize a transitory cloud. This transitory cloud can only serve the vehicle for a while. When a vehicle considered as a mobile node customizes a transitory cloud from the roadside cloudlet, it is offered by virtual resources in terms of Virtual Machine (VM). Figure 1 shows the customization of the transitory cloud from a roadside cloudlet. This VM consists of base VM in the roadside cloudlet and the overlay VM in the vehicle. This interaction of these two components (base VM and overlay) is the first step. The base VM is a VM with just a resource template that holds on the operating system installed on VM. Once the vehicle starts requesting cloud service through roadside cloudlet, the VM becomes a VM instance for the vehicle. A VM overlay is the compressed binary difference between the base VM image and the VM instance. The overlay contains the customized VM and its resources requirements. A vehicle delivers the VM overlay to a roadside cloudlet that already possesses the base VM from which this overlay was derived. The roadside cloudlet decompresses the overlay, then applies it to the base VM and finally delivers a complete customize dedicated VM instance.

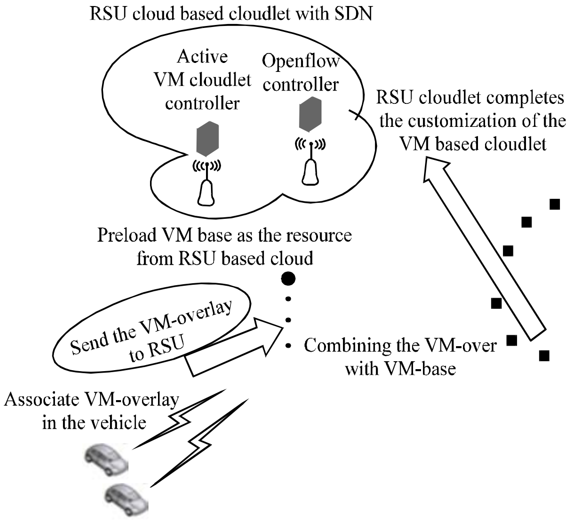

Fig. 1: Dynamic VM synthesis approach to instantiate a VM for transitory cloud service at roadside cloudlet SDN units

If the vehicle moves along the roadside and switch between different roadside unit cloudlet, the vehicle needs to wait for service re-initiation time to resume the current cloud service. During the service re-initiation time, the current transitory cloud service is temporarily disconnected. Since, the roadside cloudlet unit is one hop away from the bypassing vehicle, only a minimum delay will be experienced as long as the bypassing vehicle remains in the communication range of the roadside cloudlet unit. If the bypassing vehicle changes location and relies on the cloud service, the bypassing vehicle needs to wait for service re-initiation time to start the customization of the transitory cloud. This obstacle starts when the current serving roadside cloudlet unit's IP address is changed. A new IP address for roadside cloudlet unit closes the established TCP connection with the current VM instance associated with the current transitory cloud.

Establishing a multipath TCP is a method for performing a single IP address source node in a wireless communication. Teka *et al*. (2016) uses Multi Path TCP (MPTCP) transport layer. With the MTCP, it is possible for the connection to remain established after a Mobile Device (MD) changes its IP address which can significantly reduce the delay. This solution cannot solve the issue of single IP address unless another method such live migration of the current instance of the VM from the current cloudlet to the next cloudlet is explored. While, this can beneficial to a small roadside's site units with only one or two roadside cloudlet units, it imposes a big problem for a long road such as highway with a hundred of roadside cloudlet units. The configuration is notably hard because nearly every device (communications devices) needs to be set up separately, not to mention to update the whole roadside's site units for some new global policies. The solution is to extend the existing roadside cloud (roadside cloudlet unit) by adding Software Defined Networking (SDN) solutions. For example, a roadside cloudlet can switch between different roadside units without the VM instance changes the IP address in a centralized vehicular network or forwarding messages across roadside cloudlet units.

The second obstacle is how to reroute traffic process to improve network utility and reduce congestion in order to make software defined VANET applications more benefits in the three individual areas of path selection, frequency/channel selection and power selection (Kreutz *et al*., 2014). For path selection traffic of software defined VANET applications can become unbalanced, either because the shortest path routing results traffic focusing on select some nodes or because there is some application which involves big bandwidth such as video. For frequency/channel selection when the cellular network does not have multiple available wireless interfaces or configurable radios, there would be a lack of channels for emerging traffic for VANETS emergency services for instance. The selection of channels at which time with what type of traffic will be used and which radio interface is also an issue. When these situation elaborated above are discovered by the networking operators, it can start to reroute traffic process to improve network utility and reduce congestion by adopting new technology, especially when the technology has the ability to modify the function of the network.

Ultimately, all two of these obstacles are ramification of deployment model of applications of cloud-based vehicular networks and software-defined VANETs applications where rapidly deployment and provide services quickly with a minimum of latency requires a separation of data and control plane with well-defined programmable interface to provide a centralized global view of network and use virtualization and partitioning technologies to enable new services, especially, when these functionalities are combined with emerging cloud computing and mobile devices technologies. To overcome these obstacles, we must rethink the structure and deployment of model used in vehicular network and SDN based VANETS architecture.

MATERIALS AND METHODS

Proposed solution: We propose a vehicular network architecture deployment model built around two core design principles: RSU cloud based cloudlet-SDN to provide a centralized global view of RSU cloud and enable an easier way to configure and manage it using a central controller and roadside's devices only responsible for simple packet forwarding. Virtual Private Mobile Networks (VPMNs) (Liu *et al*., 2013) based on Long Term Evolution (LTE) and Evolved Packet Core (EPC) mobile technology. VPMNS allows networks resources to be considered a flexible pool of assets which can be dynamically utilized as needed.

System architecture: In this study, we discuss the architecture of the proposed vehicular network architectural implemented with the SDN. In the rest of the study, we use Edge-SDN vehicular architecture to refer to the proposed solution. As illustrated in Fig. 2, our architecture incorporates the following computing components: RSU cloud based cloudlet with SDN; it includes traditional RSUs and micro datacenters that host the services to meet the demand from the underlying OBUs in the mobile vehicles. Traditional RSUs are fixed roadside infrastructure. Network operator using LTE-EPC features VPMN: mobility with the Virtual Private Mobile network at the operator network using LTE-EPC. Central cloud computing: a cloud established among a group of dedicated computing servers on the internet. A vehicle will access the central cloud by vehicle-to-roadside units or by network cellular communication (network operator).

RSU cloud based cloudlet-SDN: RSU cloud based cloudlet-SDN includes traditional RSUs and micro datacenters that provide the services to meet the demand from the underlying OBUs in the mobile

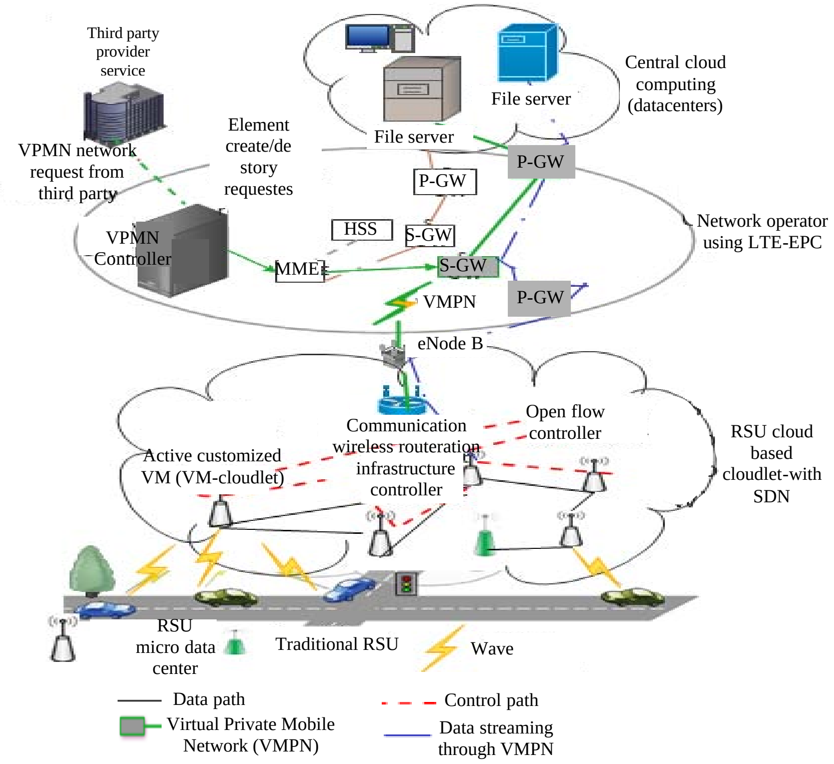

Fig. 2: Overview of the proposed vehicular architecture-based edge-SDN with latency reduction

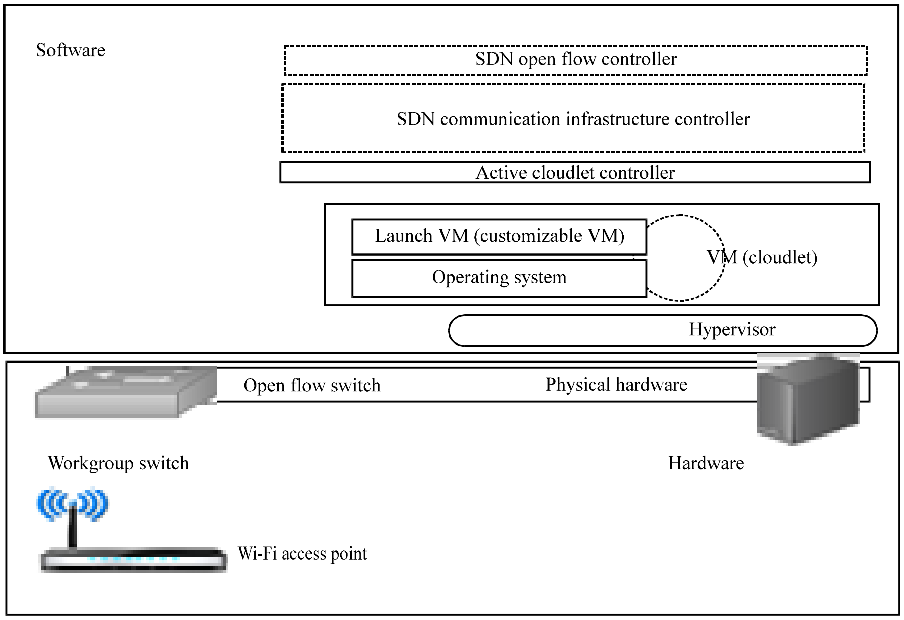

Fig. 3: Micro-datacenter in RSU cloud based cloudlet with SDN

vehicles. Traditional RSUs are fixed roadside infrastructure that can perform V2I communication using WAVE. A fundamental component of the RSU clouds is the RSU micro-datacenter.

The RSU micro-datacenter in the RSU based cloudlet and SDN is proposed is shown in Fig. 3. The RSU micro-datacenter hardware consists of a computing device and an openflow Wi-Fi access point and switch. The software components on the computing device include the host operating system, a hypervisor and a Cloudlet VM. A hypervisor is a low-level middleware that enables virtualization (Vohra, 2016) of the physical resources. This allows abstraction of various VMs on a single device. It is a technique widely employed in traditional datacenters that improve resource utilization, portability and fault tolerance (Baliga *et al*., 2011). In this manner, VMs can host services by efficiently sharing resources. VMs also enable service migrations and replications onto other VMs on disparate physical devices. Optionally, one or more of the micro-datacenters will have additional software components, namely, active cloudlet controller's, SDN communication infrastructure controller's and SDN openflow controller. The active cloudlet controller controls the next migration service. The SDN communication has the role to select the wireless communication infrastructure when central cloud or RSU resume cloudlet instance. The SDN openflow controller controls SDN controller.

Cellular communication based LTE-EPC: Evolution (LTE) connects base road side cloud based cloudlet and SDN to the central cloud. The LTE connects base stations (eNode B) to the internet using IP networking equipment. The user Equipment (EU) connects to a base station which directs traffic through a Serving GateWay (S-GW). The S-GW serves as a local mobility anchor that enable seamless communication when the user moves from one base station to another. The S-GW tunnels traffic to the Packet data network GateWay (P-GW). The P-GW also connects to the internet and other cellular data networks and acts as a firewall that blocks unwanted traffic (Vohra, 2016).

The advantages of edge location, cloudlets (fog computing) have the ability to support applications with low latency requirements. For example, gaming, augmented reality, real time video stream processing based on the cloudlet based server and cellular communication near the cloudlet datacenter. Edge computing is still the first age in its development. In the literature, five vehicular network applications based on edge computing are for instance smart traffic light and connected devices, software defined networks, parking system, content distribution and decision support systems. This research focuses on the SDN based VANETs applications. The SDN supports vehicle to vehicle with a vehicle to infrastructure communication and main control.

RESULTS AND DISCUSSION

In this study, we consider the scalability of the VPMNS solution to be included in the network operator for the proposed edge SDN vehicular architecture for the vehicular network. The proposed cellular network in the architecture extends the vision of VPMNS with SDN cellular based on the SoftRAN (Liu *et al*., 2013) to control the private end-to-end services (Fig. 4).

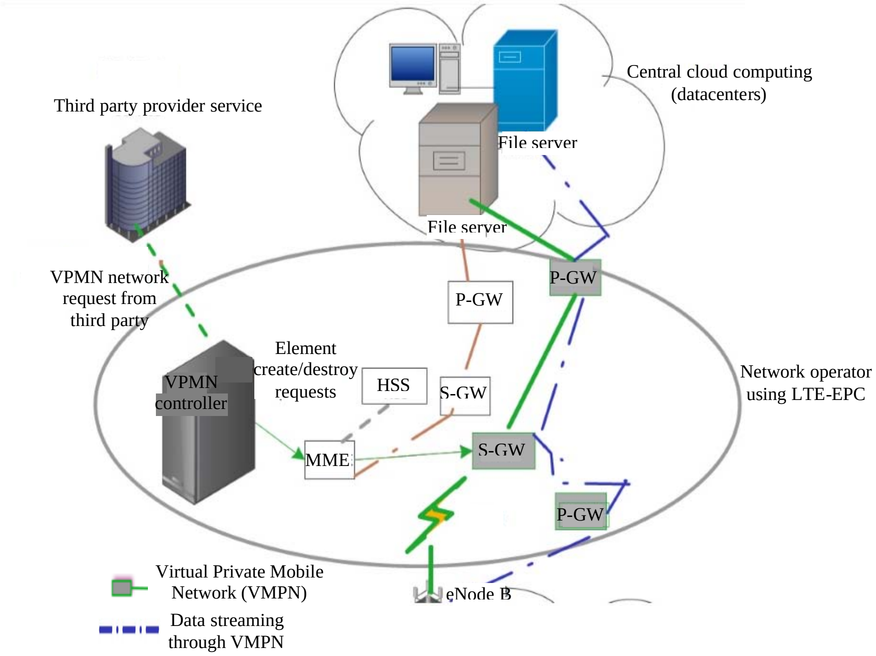

Fig. 4: VPMN-based which consists of a P-GW co-located with the cloud infrastructure and an S-GW

We consider use case to illustrate the presence of cellular network based LTE-VPMN and SDN in the proposed architecture. The use case is about the real-time car navigation. In real time car navigation, the driver in the car needs to access the resources in the third party provider services. Vehicles may offer services that use the resources that are outside of they own computing ability. In the extreme case, the vehicles may use computation resources in the central computing that is utilized for traffic data mining. In our scenario, the third party service provider also, on occasions, needs to make use of computing resources from a cloud computing provider. We further assume that the vehicles need to utilize the functions that the third party service provider hosts in the cloud.

Figure 4 shows a VPMN-based solution to this scenario. In this case, we assume that the VPMN consists of a P-GW co-located with the cloud infrastructure and an S-GW (or more likely a number of S-GWs to ensure geographic coverage). Traffic between vehicles and the cloud infrastructure can now follow the more direct path.

CONCLUSION

The study presents obstacles that limit the scaling of applications of cloud-based vehicular applications and software-defined VANETS. From an operational perspective, this architecture allows RSU cloud-based cloudlet-SDN to solve the problem of connectivity when the bypassing vehicle moves away from the current range of communication. Applying SDN to the roadside cloudlet enable the centralized system to have a better consistency since the controller has a global view of the network. A roadside cloudlet can switch between different roadside units without the VM instance changes the IP address in a centralized vehicular network or forwarding messages across roadside cloudlet units.

RECOMMENDATIONS

The key open question we are investigating in the future is whether there is a “minimum delay” in terms of live migration of the VM instance customized for transitory cloud service. We envision the VPMN-SDN in the cellular operator approach to enable SDN VANETS applications, especially where services or application need to interact with the roadside cloudlet-SDN units more closely. However, simulating the proposed architecture at scale is the topic for our ongoing research. The virtual resource migration due to the vehicle mobility must be investigated in our future research.

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