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Rethinking Vehicular Communications: Merging VANET with Cloud Computing

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***Abstract*—Despite the surge in Vehicular Ad Hoc NETwork (VANET) research, future high-end vehicles are expected to under-utilize the on-board computation, communication, and storage resources. Olariu et al. envisioned the next paradigm shift from conventional VANET to Vehicular Cloud Computing (VCC) by merging VANET with cloud computing. But to date, in the literature, there is no solid architecture for cloud computing from VANET standpoint. In this paper, we put forth the taxonomy of VANET based cloud computing. It is, to the best of our knowledge, the first effort to define VANET Cloud architecture. Additionally we divide VANET clouds into three architectural frameworks named Vehicular Clouds (VC), Vehicles using Clouds (VuC), and Hybrid Vehicular Clouds (HVC). We also outline the unique security and privacy issues and research challenges in VANET clouds.**

***Keywords*-VANET; Cloud Computing; VANET Clouds; Security and Privacy; VANET Cloud Architecture;**

I. Introduction

The basic idea of VANET (Vehicular Ad Hoc NETwork) is to take the widely adopted and inexpensive Wireless Local Aarea Network (WLAN) technology, with a few tweaks, and install it on vehicles. Nevertheless, despite the surge in VANET research, security and privacy issues have been the root cause of impeded momentum in VANET deployment. One of the many goals of VANET is to support traffic safety and make the driving experience more safe and comfortable. In VANET, Vehicles and RSUs (Road-Side Units), i.e. network nodes, will be equipped with on-board computation and communication modules to make sure fruitful communication possible among them [1-4].

According to statistics from US Department of Transportation (DoT) in 2008, a staggering amount of roughly $75 billion are lost in worker productivity and around 8.4 billion gallons of fuel is wasted [5]. Let alone, half of all congestion events occurred by highway incidents rather than by rush hours which is a common perception [6]. Looking at these statistics, the need for new infrastructure such as VANET seems to be inevitable.

US Federal Communication Commission (FCC) has allocated a rich 75MHz of spectrum (5.850-5.925GHz band) for the exclusive use of Dedicated Short Range Communication (DSRC) also knows as WAVE 802.11p. A number of authors pointed out in their work that the allocated bandwidth exceeds far more than the requirements for VANET safety applications [7]. Thus the surplus bandwidth opened the doors for new opportunities along with the normal functionality of VANET [8].

Cloud computing has changed the computation and communication mindset by decoupling computational assets from physical infrastructure thereby enabling virtualization [9]. The main motive of cloud computing is to "*exactly what you need and when you need* ".

Recently Olariu et al. [10] envisioned the idea of vehicular clouds by taking traditional VANET to the clouds [11]. The main driving force behind their idea of vehicular clouds is that in the near future, the huge vehicular fleets on our roadways, streets and parking lots will be recognized as abundant and under-utilized computational and communication resources. These resources could be used elsewhere that could earn a comparable revenue as well. Though Oraliu et al. [10] for the first time, proposed the idea of vehicular clouds, but they did not discuss the potential structural framework for vehicular clouds.

In this paper we put forth, for the first time, the taxonomy of future VANET clouds. We propose the potential framework architecture for different types of cloud scenarios in VANET. It is, to the best of our knowledge, first effort to propose such architectural taxonomy for VANET clouds. Additionally, we also discuss unique challenges from architectural, security, and privacy standpoint in VANET clouds. The structure of the rest of the paper is organized as follows. Section II summarizes the state of the art regarding vehicular clouds. We provide the readers with a bird's view of cloud computing as a baseline for our proposed architecture, in section III. Section IV presents our proposed VANET clouds architecture. Section V describes the research, security, and privacy challenges in VANET clouds following by concluding remarks in section VI.

II. State of the Art

In this section we outline the state of the art and previously proposed schemes about VANET clouds.

In the very near past, Oraliu and his collegues envisioned combining VANET with cloud computing [10, 11]. They proposed Autonomous Vehicular Clouds (AVC) offering potential applications to VANET users. The authors also discussed research challenges in vehicular clouds briefly. Abuelela et

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al. [11] suggested to take conventional VANETs into the cloud and envisioned that in future, the under-utilized VANET resources could be utilized by combining VANET with cloud computing [10]. Taking a step ahead, Bernstein et al. [12] proposed a Platform as a Service (PaaS) model for mobile vehicular domain with possible potential applications. Yan et al. [13] outlined the security and privacy challenges in vehicular clouds. They discussed the challenges resulted by the features of vehicular clouds, e.g. authentication of high-mobile vehicles and the complexity of trust relationships among multi-players caused by intermittent short range communication.

All being said, the infant vehicular clouds still needs rigorous research activities to make it through the deployment phase. One advantage is that, no additional infrastructure is needed for deployment since the infrastructure is already there. Olariu et al. [10] carried their work mostly from applications standpoint. Our contribution is different from the aforementioned authors. We put forth a solid taxonomy of the VANET clouds based on the type of applications and modes of communication. Moreover we define different architectural frameworks for VANET cloud based on the vehicular-based cloud computing taxonomy. It is, to the best of our knowledge, very first approach to take the vision of Olariu and his co-workers, a step further towards VANET based cloud computing.

III. Cloud Comupting- A Bird's View

Cloud computing is also known as utility computing which is based on pay-as-you-go service [9]. The scenario could be easily compared with our daily life, where we use gas and electricity in our homes as much as we need and at the end of the month we pay for exactly what we have used, neither more nor less.

The core of the cloud services is comprised of three basic delivery models in the form of layers. The top layer is known as Software as a Service (SaaS). This layer delivers applications to consumers (either individual or enterprise) in a multitenant fashion. The by far best example of this service suit is Google Docs which is an equivalent to Microsoft Office. Google provides the aforementioned service to its consumers for free.

Platform as a Service (PaaS) is the second type of service in the layered stack which means, instead of installing development tools/softwares on host computers, deliver the development environment as a service to the consumers. This makes the consumers capable of doing their development remotely by using only the services provided by the service provider. Normally this kind of service works well at enterprise level and the best example is Google App Engine.

At the bottom of the layered stack, cloud computing provides Infrastructure as a Service (IaaS). Instead of application or environment, in this paradigm, physical resources are delivered to consumers as a service. These resources include servers, connections, and related tools necessary to build an application environment from the scratch. Consumers have virtually unlimited resources according to their budget. They can rent processing, storage, networks, and other fundamental computing resources on which the consumers then deploy and run arbitrary software (both application and system). Amazon is providing such services on rent through its elastic computing called EC2.

The baseline of VANET and cloud computing being discussed, we move onto our proposed VANET clouds architectural framework in the next section.

IV. Proposed VANET Cloud Architecture

Olariu et al. [10] for the first time, coined the term Autonomous Vehicular Clouds (AVC) as, *"A group of largely autonomous vehicles whose corporate computing, sensing, communication, and physical resources can be coordinated and dynamically allocated to authorized users"*. We take a step forward to broaden the idea of VANET clouds by first defining a communication paradigm for VANET clouds and then put forth the potential cloud services from VANET standpoint.

A. Service Architecture in Clouds

As illustrated in Fig. 1, VANET clouds are suitable for IaaS and SaaS only, whereas PaaS does not seem to be logically appropriate for VANET environment. At IaaS level, the potential services provided by VANET clouds might be Network as a Service (NaaS) where a vehicular node moving on the road might be used as a wifi access point gateway to the internet. The vehicles could rent their resources if the users intending to use the services, are will to pay. At SaaS level, real-time VANET information could be shared with the subscribed users. Additionally, infotainment services and P2P applications are suitable to be used as SaaS.

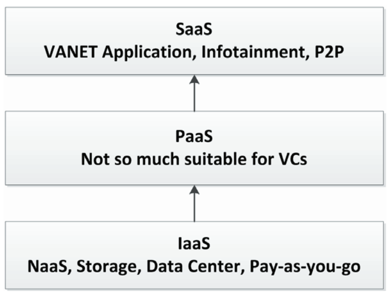

Fig. 1. Service architecture in VANET clouds

B. VANET Clouds Taxonomy

Fig. 2 illustrates the brief VANET clouds taxonomy. We divide VANET clouds into three major architectures namely Vehicular Clouds (VC), Vehicles using Clouds (VuC), and Hybrid Clouds (HC). VC is further divided into two scenarios from movement standpoint. Static clouds refer to the stationary vehicles providing cloud services. For instance a virtual super computer formed by the collaboration of vehicles parked in a big organization or enterprises parking lot [11]. In case of static VANET clouds, the infrastructure (communication, storage, and process) can be rented out to make revenue as well. IaaS and data storages services are feasible for such

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arrangements. On the other hand, dynamic clouds are formed on demand in ad hoc manner. VuC connects the VANET to traditional clouds where VANET users can use cloud services on the move such as infotainment, traffic information, and CAA. In HC, vehicular clouds will interact with traditional cloud for services exchange. The vehicles and RSUs will serve as gateways on the VANET part thereby communicating with the gateways of traditional clouds. Each section is further elaborated in the following sub-sections.

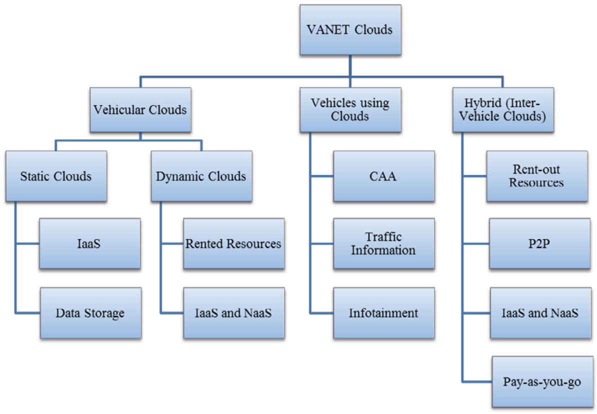

Fig. 2. Taxonomy of VANET Clouds

1) Vehicular Clouds (VC): The main players in VC include VANET infrastructure itself, gateways, and brokers as shown in Fig. 3.

Note that the vehicular nodes serve as service providers in this paradigm. VC is formed in the following manner. First, the vehicles initiate a protocol to select broker(s) among them and identify the boundaries of the clouds following by electing an Authorized Entity (AE) among the brokers to ask for authorization in order to form a cloud. After brokers and AE are elected, then AE invites the vehicular nodes in the premises of the cloud boundary to take part in cloud. Interested vehicles will reply with an ack. If the number of interested vehicles is above certain threshold, then AE will ask higher authorities about permission to form a cloud and provide the potential resources. Upon getting permission, the participants of the cloud will pool their resources to form a rich virtual environment. AE sends the schedule plan to higher authorities and gets implementation authorization. Note that the job in hand can be handed over to the cloud by higher authorities in exchange of some incentives to the participants. AE dissolves the cloud after the job is done. It is worth noting that this strategy is different in some sense from that of Olariu et al.s [10] scheme in the way that, it is better practice to first look for the volunteers before asking authorities for permission. It would save the bandwidth and communication if the number of volunteers for dynamic cloud formation was not enough and in case if it was not possible to form a cloud.

The most appropriate example for dynamic clouds is dynamic traffic lights scheduling. Consider a national sports event in a downtown stadium watched by thousands of viewers. When the event is over, everybody wants to go out first and it will create catastrophic traffic jams. The usual traffic lights

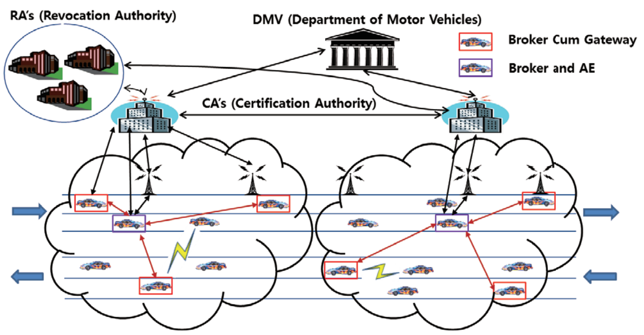

Fig. 3. Vehicular Clouds (VC)

would not be a suitable option to fade the traffic jam away. The better solution would be to re-schedule the scheduled traffic lights in a real-time. In worst case, it would include not only traffic lights in the stadium vicinity, but also the effect of changing one traffic light would affect many others thereby demanding re-scheduling the traffic lights on a large scale. In the aforementioned scenario, AE sends the traffic signals re-scheduling plan to the municipality and hence the traffic jams issues can be resolved in a timely manner.

2) VANET using Clouds (VuC): Fig. 4 depicts the architecture of VuC where VANET uses cloud services on the move. The virtualization layer is provided by the gateways. Note that RSUs act as gateways for vehicles to the cloud services. High speed wired communication can be used from RSUs to the cloud services. As depicted in the taxonomy of the VANET clouds, the services offered by VuC include CAA, real-time traffic information, and infotainment.

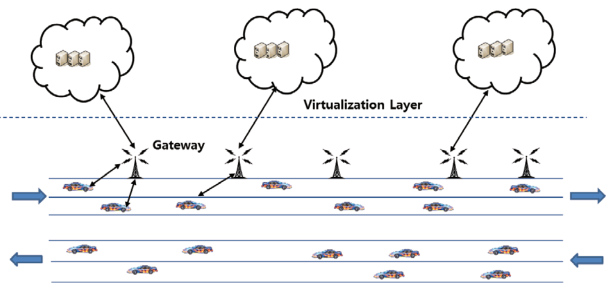

Fig. 4. Vehicles using Clouds (VuC)

3) Hybrid Clouds (Inter-Vehicle Clouds): HC is the combination of VC and VuC where VC serves as both service provider and consumer at the same time. HC architecture is shown in Fig.5. The motivation behind HC is that, vehicles moving on the road might rent their resources and might want to use cloud services at the same time. NaaS and P2P are the most suitable examples for such scenarios. Nevertheless due to the ephemeral nature of VANET, connection among vehicular nodes is very intermittent. But yet it can be argued that usually for P2P applications, the size of the files is fairly small making it suitable for short time connection. Other potential applications for this architecture include IaaS in case of VC.

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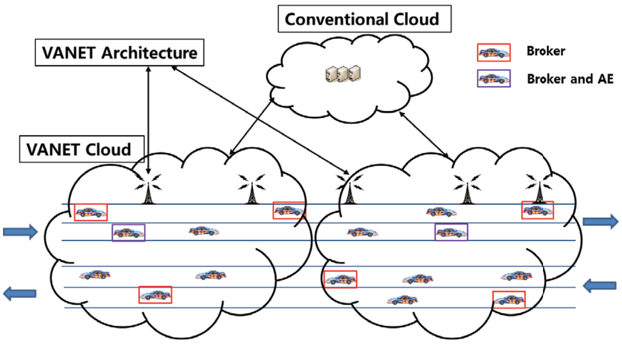

Fig. 5. Vehicles using Clouds (VuC)

V. Security Challenges in VANET Cloud

There are many risks involved with renting virtual resources in cloud environment or storing data in cloud thereby releasing control over data. One concern that many users are aware of is loss of privacy and data storage security [14, 15]. Logically VANET clouds inherit their parental long-chased security and privacy issues from both VANET [4,16] and cloud computing [14,17]. We take a different road towards security issues in VANET clouds. Unlike Yan et al.'s scheme [13], where the authors discussed spoofing of identities, repudiation issues, DoS and so forth, we believe that potential solutions to such issues have been put forth by VANET community already. These issues better be taken up with the VANET community and cloud computing comunity whichever necessary. The same argument holds for traditional cloud architectural issues.

The security and privacy challenges faced by standalone VANET and cloud computing will remain unchanged even if the two technologies are merged to form VANET clouds.

The main challenges for VANET clouds are expected to be *gossip interval, mobile authentication, conditional anonymity and virtualization, insiders and outsiders, renting out resources, autonomy, control, and cooperation middlewares*.

VI. Conclusions

In this paper, we put forth the vision of combining two emergent fields, VANET and cloud computing. In the recent past, the core idea of vehicular clouds was suggested for the first time in the literature but to date, there is no architectural framework proposed. To this end, only applications are emphasized in vehicular clouds environment. To the best of our knowledge, ours is the first effort to suggest a concrete VANET clouds architecture from services standpoint. A brief taxonomy of VANET clouds is outlined. We divide VANET clouds into three architectural frameworks namely Vehicular Clouds (VC), Vehicles using Clouds (VuC), and Hybrid Clouds (HC). Moreover we also put light on the security challenges unique to VANET clouds.

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