Vehicular Cloud Computing: A Survey

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OUTLINE OF TOPICS

- INTRODUCETION AND MOTIVATION
- TWO-TIER VEHICULAR CLOUD ARCHITECTURE
- VEHICULAR SERVICE TAXONOMY AND APPLICATIONS
- OPEN ISSUES
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INTRODUCETION AND MOTIVATION

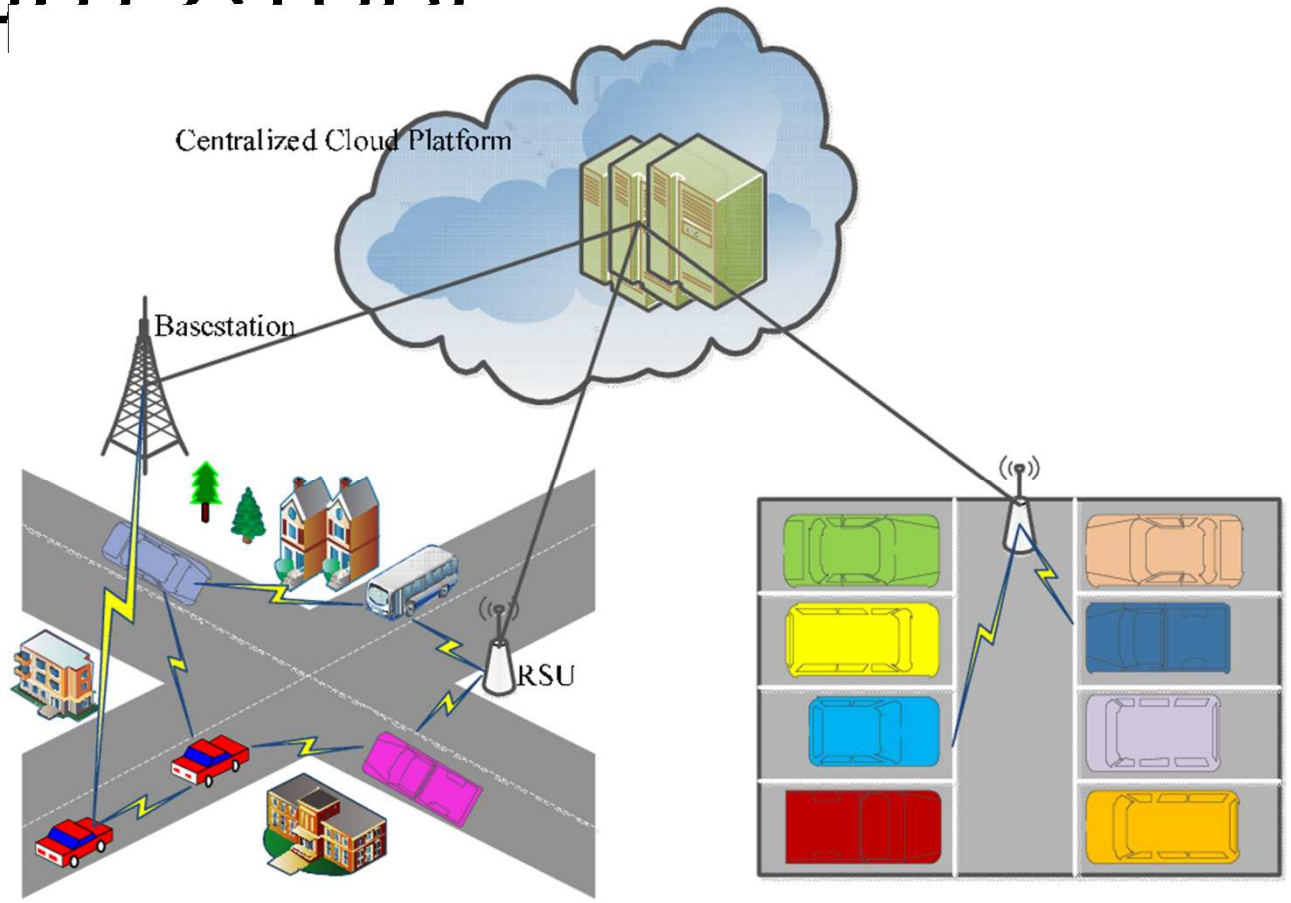
Motivation:

- ``Computer-on-wheels'' : on-board computer, storage device, GPS device, radio transceiver, short-range rear collision radar device, even sensing devices.
- Developing cloud services and increasing users.

Therefore, pioneering researchers take them into the concept of cloud computing as service providers.

- Current related studies in vehicular cloud.
- To exploit the benefit of Vehicular Cloud Computing.

TWO-TIER VEHICULAR CLOUD ARCHITECTURE



TWO-TIER VEHICULAR CLOUD ARCHITECTURE

- Features
  - **Instability**: vehicular cloud is the volatile resource availability since there is no guarantee on the vehicles behaviors, or the resource availability.
  - **Heterogeneity**: different vehicles manufactured by different companies are usually with different platforms.
  - **Resilience**: vehicular cloudlet can work on two different communication modes, i.e., V2V and V2I.
  - **Selflessness**: a vehicle's role in vehicular cloud is ambiguous as it could be either a service provider or a service consumer.
  - **Greenness**: leveraging excessive resources on vehicles such that unnecessary hardware deployment and investment are avoided.

VEHICULAR SERVICE TAXONOMY AND APPLICATIONS

- Service Taxonomy
  - Network-as-a-Service
  - Storage-as-a-Service
  - Sensing-as-a-Service
  - Computation-as-a-Service
- Potential Applications
  - Autonomous Driving Management
  - Intermediate Cache
  - Participatory sensing

VEHICULAR SERVICE TAXONOMY

- Network-as-a-Service examples:
  - PVA (parked vehicle assistance): promotes the network connectivity by incorporating parked vehicles as static nodes into traditional vehicular networks.
  - ParkCast: leverages roadside parking to distribute contents in urban VANETs.
  - LoadingZones: leverages parked cars to behave as relays and to provide opportunistic access to non-time-sensitive applications for moving vehicles.
  - Malandrino et al. address the cooperative content downloading in vehicular networks.
  - Acer et al. study the timely data delivery issue by exploring the opportunistic contacts between WiFi-enabled buses using two different routing policies.

VEHICULAR SERVICE TAXONOMY

- Storage-as-a-Service examples:
  - Arif et al. develop a framework for analyzing the behaviors in a long-term parking lot of an international airport under an infinite parking capacity assumption. They also mention the idea of using the parking lot as a data center but they do not specify how to use the storage resources.
  - Gu et al. trade the vehicular storage resources in parking lots for communication cost and propose a two-tier data center system that consists of both stable first-tier and unstable second-tier storage resources to lower the total data access cost.

VEHICULAR SERVICE TAXONOMY

- Sensing-as-a-Service examples:
  - Yu et al. investigate a cooperative data sensing and compression approach for urban environment surveillance in vehicle sensor networks (VSNs).
  - Eckhoff et al. propose the utilization of parked cars to sense the vehicles that are not in line-of-sight to improve driving safety.
  - Liu et al. develop a system called POVA for traffic light sensing in large-scale urban areas.
  - Ma et al. propose a user-driven Cloud Transportation System (CTS) which employs a scheme of user-driven crowdsourcing to collect user data for traffic model construction and congestion prediction including data collection, filtering, modeling, intelligent computation and publish.

VEHICULAR SERVICE TAXONOMY

- Computation-as-a-Service examples:
- At the beginning of vehicular cloud computing, some work has started to figure out how to utilize the opportunistically available computation.

  - Shi et al. investigate the computing in cirrus clouds where the connectivity between the service providers and users is intermittent.

VEHICULAR POTENEIAL APPLICATIONS

- Autonomous Driving Management
  - Autonomous driving requires a great quantity of information and intensive computation. Basically, we may outsourcing all the computation tasks to the distant cloud platform.
  - With the introduction of vehicular cloud, many tasks actually can be handled by the proximate vehicular cloudlet, without resorting to Internet cloud.
  - In this case, vehicles perform as both information collector and processing units. This not only saves much communication bandwidth but also makes the autonomous driving management resilient to the Internet availability.
  - Some prototypes using robots already have been developed.

VEHICULAR POTENEIAL APPLICATIONS

- Intermediate Cache
  - The recent rapid development of smart devices like smartphone has posed a heavy burden on existing network infrastructure.
  - To deal with the insatiable data access needs, e.g., dense base-station deployment, wider bandwidth allocation, new physical techniques, etc.
  - It is suggested that an efficient way is to trade the intermediate cache to the communication cost by deploying many distributed caches.

VEHICULAR POTENEIAL APPLICATIONS

- Participatory sensing
  - All the vehicles, no matter in mobility or in parking, can be utilized to conduct participatory sensing.
  - An important application of vehicular participatory sensing is to construct augmented maps of different phenomena (e.g., traffic condition, temperature, road condition, etc.).

	V2I	V2V	Computation	Storage	Sensor	Internet Cloud Independency
Smart Traffic Cloud		√	√		√	
Cloud Transportation System	√				√	√
Cloud Robotics	√	√		√		√
Datacenter At the Airport	√		√			√
Carcel	√	√		√	√	
CRoWN	√			√		√
CarSpeak	√	√	√		√	√
MobEyes		√		√		√
VAM		√	√		√	√
PVA		√				√
LoadingZones	√	√				√
POVA	√				√	

OPEN ISSUES

- Resource Modeling
  - For vehicular cloudlet without resources availability guarantee, it is essential to model the dynamics of the resources.
  - Previous studies on vehicular networks mainly focus on the mobility models of vehicles. This provides a solid foundation to model the dynamics of the resources in mobile vehicular cloudlet.
  - However, recall that vehicular cloud also includes static vehicular cloudlet consisting of vehicles in a parking lot. The behaviors (e.g., arrival and departure) in the parking lot deeply influence the resource availability and it is essential to clearly describe such dynamics.

OPEN ISSUES

- Resource management strategy: heterogeneity and instability of vehicular resources
  - For heterogeneity, there is a need to build a resource description format to effectively represent diverse resources in a uniform way. To cope with the autonomous management, the description model shall be simple enough for exchanging between vehicles.
  - For the instability issue, a critical question is how to accurately and timely capture the dynamics of the resources on a communication channel which may also be unreliable.

OPEN ISSUES

- Resource allocation: in static vehicular cloudlet
  - Multiple co-existing vehicular cloudlet providing the same services.
  - The resource allocation shall be made according to both the requirement characteristics and resource availability dynamics to provide fine-grained tuning of vehicular resources.
  - Furthermore, such resource allocation will be considered from two aspects, intra-parking-lot tuning and inter-parking-lot tuning.
    - Intra-parking lot mainly deals with the mismatch between the local resource availability and the requirement.
    - Inter-parking-lot tuning is to systematically consider the resource allocation across different parking lots.

OPEN ISSUES

- Offloading
  - To guarantee the completeness of the offloaded task under intermittently available resources, one may offload multiple replicas of the same task to different vehicles with the hope that at least one of them can be completed.
  - Furthermore, both the service providers and tenants shall consider how to balance the computing between local, vehicular cloudlet and Internet cloud so as to achieve different goals.

OPEN ISSUES

- Security and Privacy
  - A user could participate in a role as either service provider or service consumer, he/she shall must be safe in offloading his/her jobs and contributing his/her vehicular resources to the vehicular cloud.
  - The privacy and security of the vehicle's owner should be preserved.
  - Security and privacy of the customers who rent these resources must also be preserved.
  - Furthermore, the openness of vehicular cloud computing makes the malicious attacker also be a part of the vehicular cloud.

CONCLUSION

- An introduction of vehicular cloud and present a two-tier architecture.
- Classify the services into four categories.
- Some potential applications of vehicular cloud are also summarized.
- List several challenges that we have to face for the realization of vehicular cloud computing.

We believe that vehicular cloud computing is expected to become an important model for mobile applications and be an essential part of our daily life in the future.

Thank you!