University of Toronto
Department of Computer Science

Internet of Vehicles:

From Intelligent Grid to Autonomous Cars and Vehicular Clouds

Presenter: Yasaman Rohanifar

MSc Student, Department of Computer Science
DGP Lab, University of Toronto

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About this paper

- 2014 IEEE World Forum on Internet of Things (WF-IoT) Conference
- 159 Citations

About the Authors:

- Mario Gerla - UCLA
- Eun-Kyu Lee - UCLA
- Giovanni Pau - UCLA + Sorbonne
- Uichin Lee - KAIST

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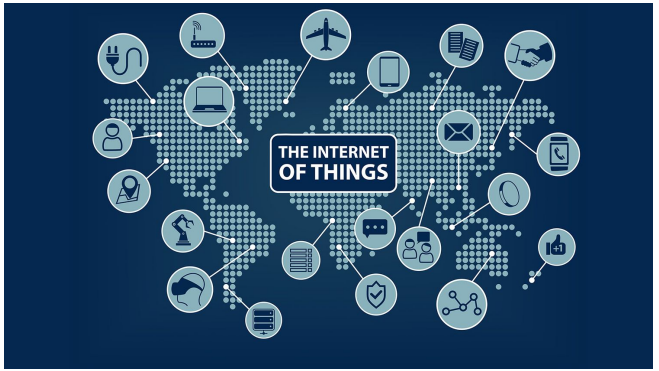
From Individual Vehicles to the Cloud

Collection of sensor platforms (GPS, ...) ➔ Cloud ➔ Network of Autonomous Vehicles

Utility Function of Autonomous Vehicles:

- Prompt delivery of the passengers to destination
- Maximum safety and comfort
- Minimum impact on the environment

Same evolution from **Sensor Web** to the **Internet of things**!



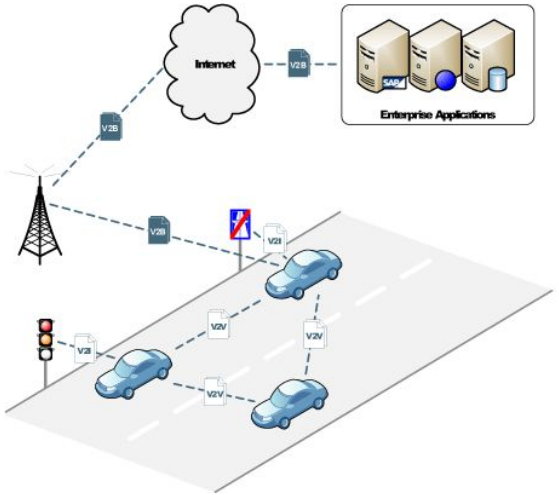
From Individual Vehicles to the Cloud

Visionary: The vehicles will be better than human drivers!

- Less Pollution
- Lower Delays, Smoother Traffic
- Better Driver and Passenger Comfort

Handling catastrophes:

- Efficient communication with other vehicles
- Discover needed sources
- Necessity of secure communication
- Distributed Processing Environment

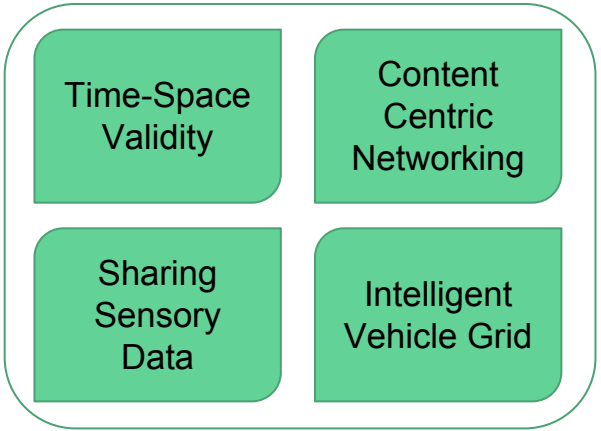


Vehicular Cloud

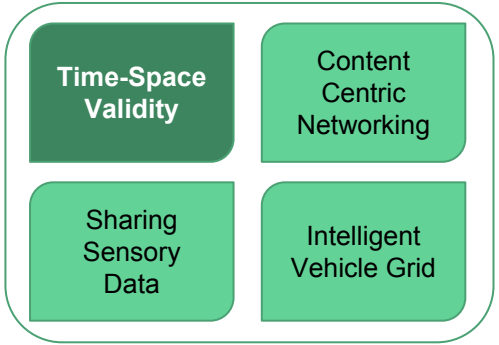
Emerging Applications on Wheels

Characteristics observed in Vehicle Applications:

- **Application Content Time-Space Validity**
- **Content Centric Networking**
- **Vehicle Collaboration Sharing Sensory Data**
- **Intelligent Vehicle Grid and Vehicular Data**



Emerging Applications on Wheels



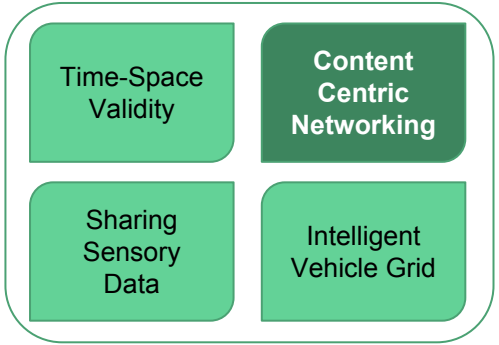
- **Application Content Time-Space Validity**

  Vehicles as rich data “prosumers”

  - Local Validity
  - Explicit Lifetime
  - Local Interest

- Time-Space validity of data ➔ Scalability of data collection/processing/storage
- Data should be kept on the vehicle rather than uploading to the internet!
  - Enormous Spectrum Savings

Emerging Applications on Wheels



Interest in content not the provenance!

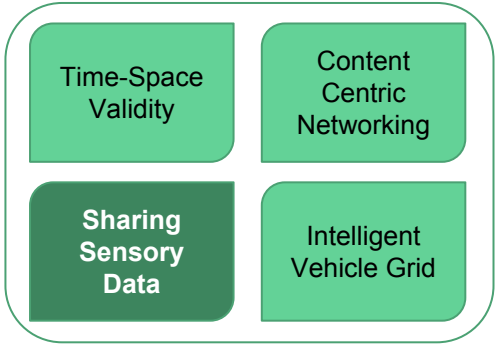
Flooding query messages to local area

Accepting responses regardless of the identity of the provider

Content Centric Networking ➔ Management and Control of AUVs

- AUVs travel at high speed and short distance from neighbors ➔ Up to date info
- In case of accident, the AUV must alert the driver

Emerging Applications on Wheels



Producing value-added services

- **MobEyes:** Forensics, Witnesses for traffic accidents
- **CarSpeak:** Direct access to neighbor car's sensor data

  Running autonomous driving applications
- **Intelligent Transportation System:** Exchanging traffic congestion and road conditions constructing up-to-date road conditions database

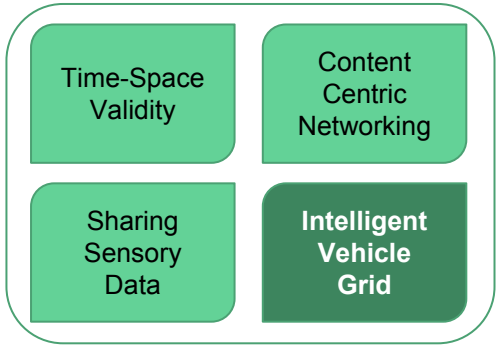
Collaboration ➔ Ensuring stability of autonomous fleet

Emerging Applications on Wheels

Generated Data from Vehicles

Smart Dust + RFID Tags + Microcontrollers

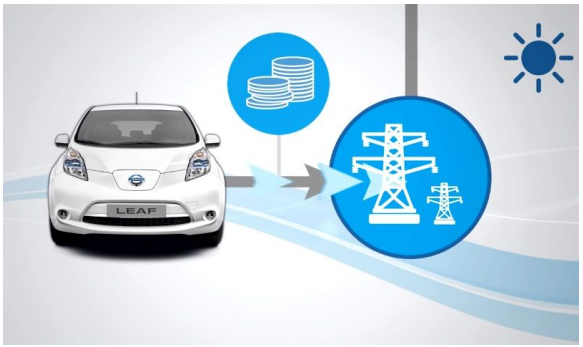
Vehicle Grid



Vehicular Cloud: Instantiation of Internet of Vehicles

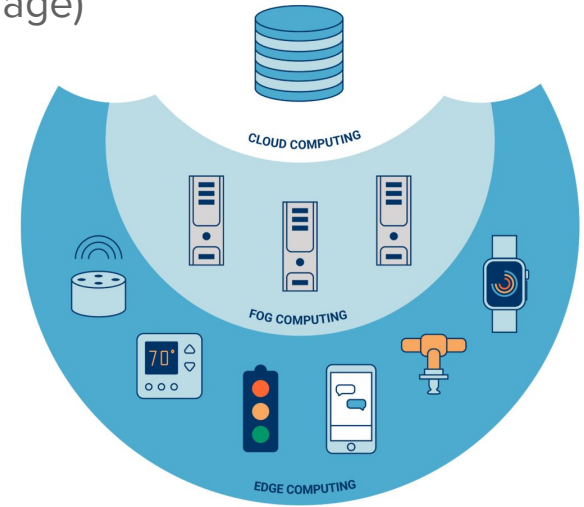
(protocols, services, etc to make vehicle grid work)

Vehicular Cloud Architecture → Autonomous Driving



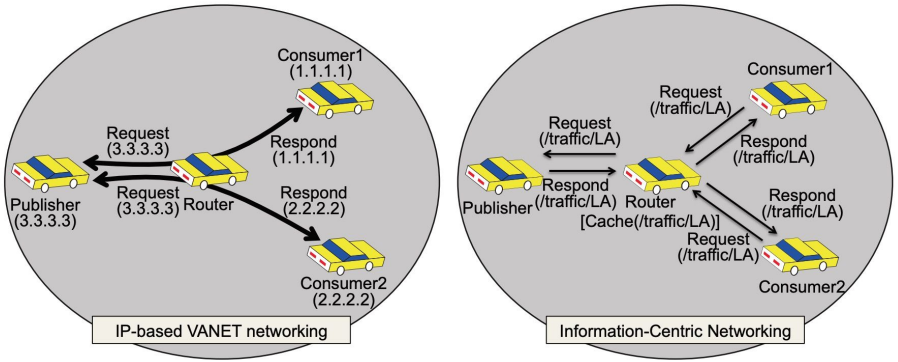
Vehicular Cloud

- **Vehicular Computing**
  - Conventional CC ➔ Mobile CC ➔ Vehicular CC
  - Mobile nodes with limited resources (computing + storage)
    - Cost to upload
    - Time-consuming to search and download
    - Local relevance
  - Edge Computing



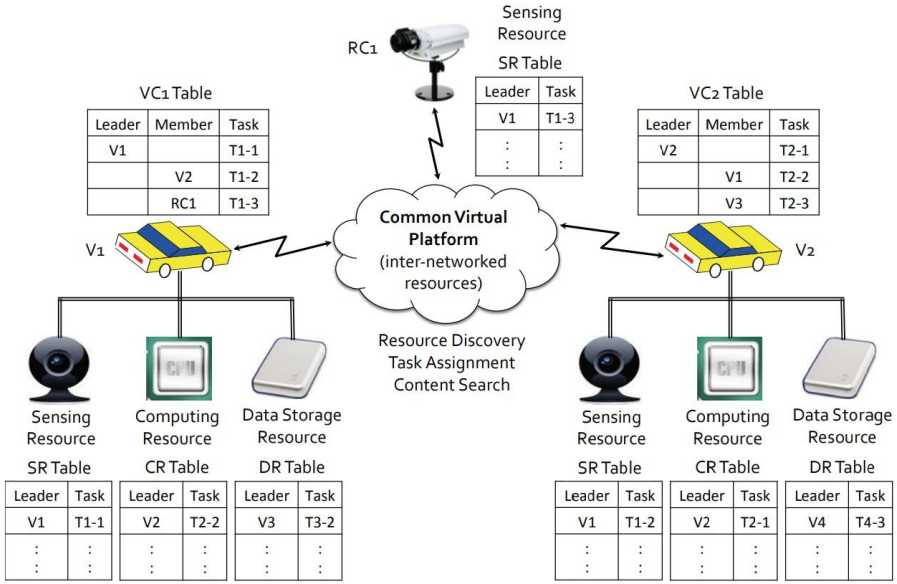
Vehicular Cloud

- **Information Centric Networking**
  - ICN focuses on what (content) instead of where (host)
  - Uses **content names instead of IP** addresses so that the
    - DONA (Data-Oriented Network Architecture)
    - PSIRP (Publish-Subscribe Internet Routing Paradigm)
    - NetInf (Network of Information)
    - NDN (Named Data Networking)
      - Interest from consumers
      - Data from publishers
      - Content name for routing



Vehicular Cloud

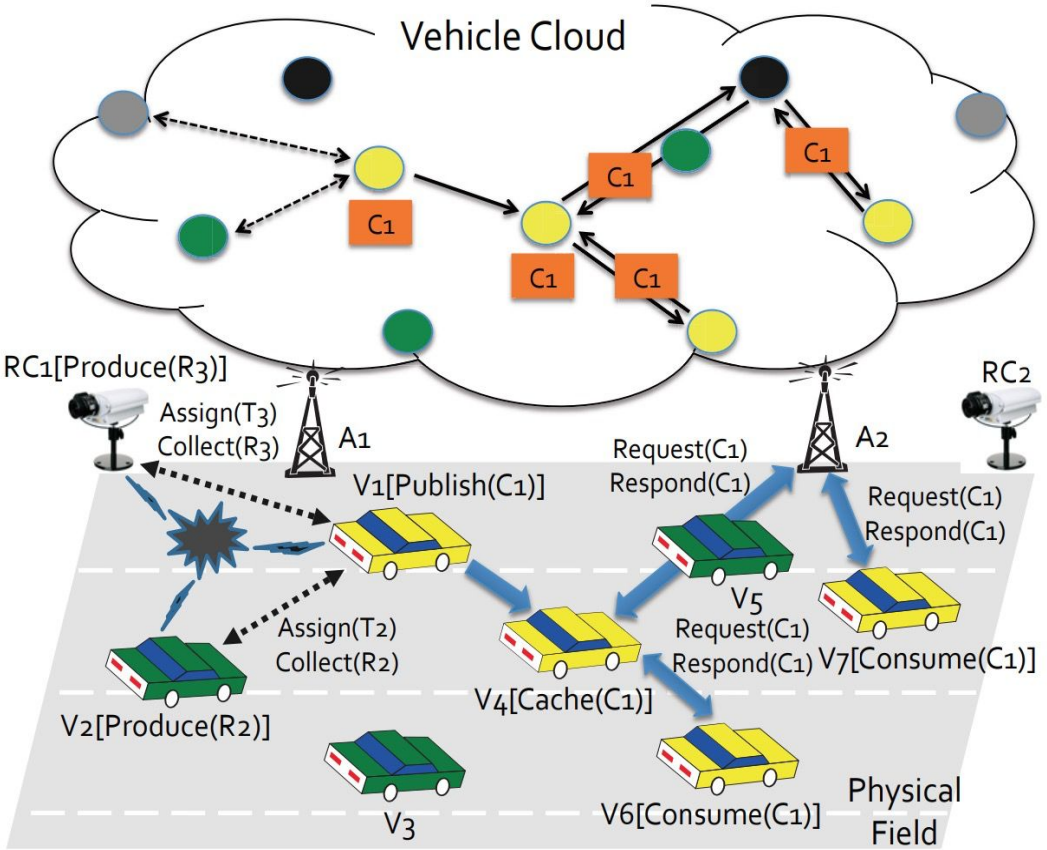
- **Cloud Resources**
  - Internet Cloud Vs. Vehicular Cloud
    - Storage, Sensor, Computing
    - Inter-networked resources via purely p2p connections
    - Negotiating the level Of resource sharing (brokers)
    - RSUs as stationery good negotiator role



Vehicular Cloud

Case Study

1. Cloud resource discovery
2. Cloud formation
3. Task assignment & result collection
4. Content publishing & sharing
5. Cloud maintenance **(?)**
6. Cloud Release



Vehicular Cloud and AUV Challenges

- **NDN Network Layer**
  - VCC's "narrow waist" network layer is NDN
  - Content found by **exploiting geographic relevance** more than **naming hierarchy**

- **Beacons and Alarms**
  - Sensors alone are not sufficient
    - Maintaining stable operations in high speeds
    - Extremely reduced inter-vehicle spacing
  - V2V communications are necessary
    - Lead cars facing 4-stop intersections
    - Finding out about road conditions ahead

Vehicular Cloud and AUV Challenges

- **Intelligent Transport**
  - Using the existing highway network more efficiently
  - Managing automatic charges
  - Awareness of other mobiles sharing the road

- **Infrastructure Failure Recovery**
  - Gray period of human takeover
  - Losing knowledge of neighbors beyond sensor range
  - Maintaining a V2V supported propagation of traffic conditions and congestion

Vehicular Cloud and AUV Challenges

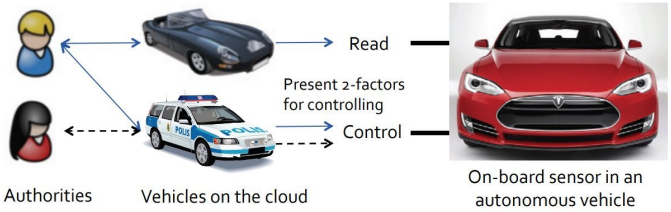
- **File and Media Downloading**
  - Entertainment - Marketing Strategy
  - Bittorrent techniques via V2V support
  - Broadcast only supported by V2V communications
  - LTE would introduce too much latency and would not scale

- **Cognitive Radios and Spectrum Data-base Crowdsourcing**
  - Need for V2V between AUVs
  - DSRC 75 Mhz spectrum exhausted by the basic safety applications
  - V2V requirements supported by the WIFI spectrum

Vehicular Cloud and AUV Challenges

- **Virtualization**
  - AUVs might need to do “data mining”
    - Expensive computations must go to cloud
    - Privacy of the drivers + sensitivity of the application
  - Customization of the sensor platform to different applications

- **Security**
  - DDoS, Privacy, Confidentiality
  - Attacks targeting the steering or the brakes system
  - Access to the cars’ internal mechanism
    - On-Board Diagnostics (OBD) & CAN
  - Multi-factor protection strategy



Summary

P1	Evolution of o the Internet of Autonomous Vehicles communications, storage, intelligence and learning capabilities
P2	Vehicular Cloud, the equivalent of Internet Cloud for vehicles the core system environment that makes the evolution possible
P3	Vehicular Cloud and AUV Challenges

Thank you for your attention!

Questions?

Discussion Points/Questions

Q1	Is Information Centric Networking secure enough?
Q2	Security and Safety, Adversarial Attacks
Q2	How does self-organizing cloud take place? What about Cloud maintenance if there's no other candidate?