# Vehicular Cloud

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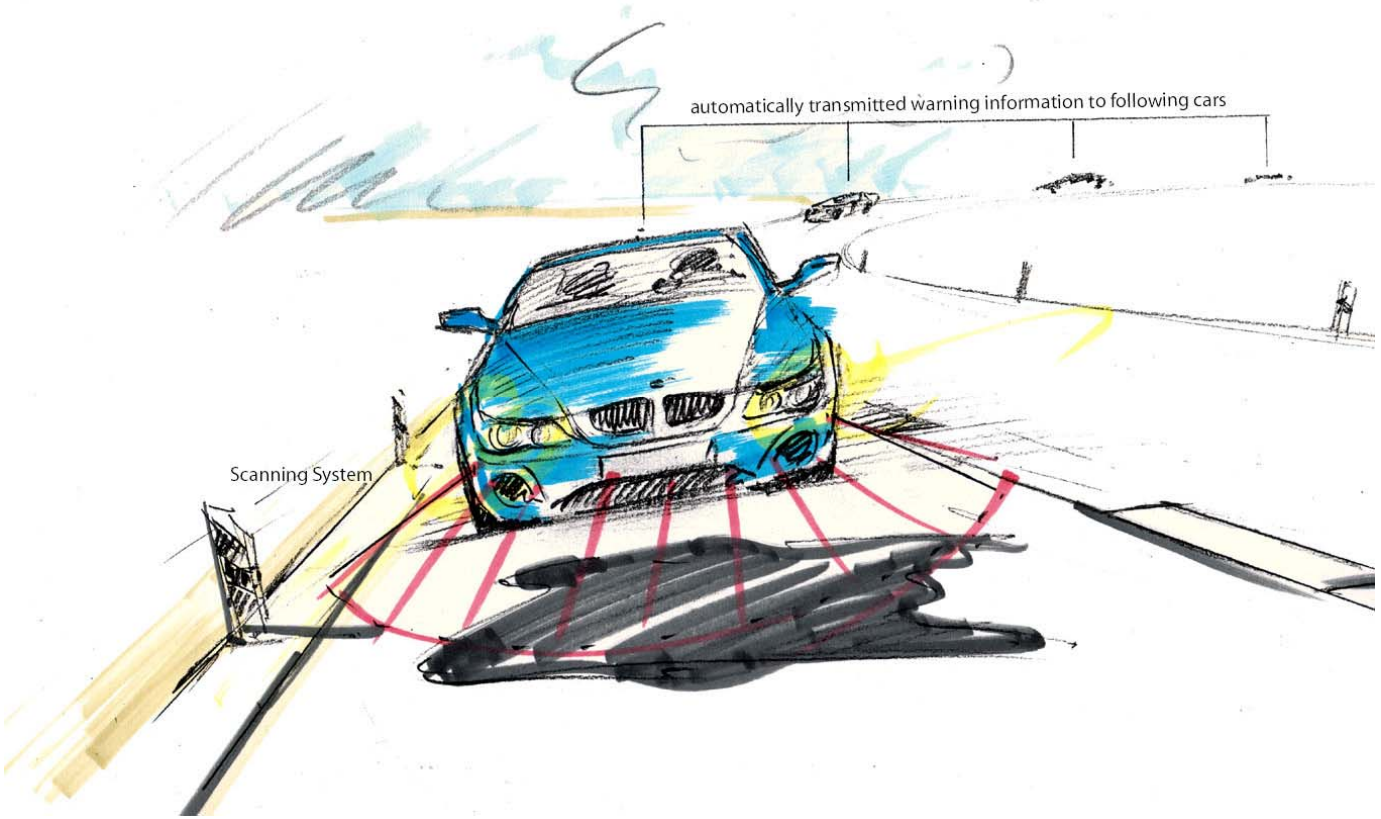
# Outline

- VANET
- Cloud computing
- Vehicular cloud: motivation and concept
- Application scenarios
- Challenges: architecture/security
- Data forwarding
- Questions

# VANET

- **Deliver timely information to drivers** in a cost-effective manner



# VANET – in a nutshell

- Main characteristics
  - uses vehicles as network nodes
  - vehicles move at will relative to each other but within the constraints of the road infrastructure
- Communications
  - Vehicle-to-Vehicle (V2V)
    - zero-infrastructure
  - Vehicle-to-Infrastructure (V2I)
    - roadside devices

# Smart vehicles (1)

- Vehicles are becoming more sophisticated
  - powerful on-board computing capabilities
  - tons of on-board of storage
  - significant communication capabilities
  - no power limitations
- Computations capabilities supported by
  - hosts of sensors and actuators
  - on-board radar and GPS

# Cloud Computing

- A paradigm shift suggested by
  - low cost high-speed Internet
  - virtualization
  - advances in parallel and distributed databases
- Basic idea: why buy when you can rent
  - exactly what you need
  - exactly when you need it
- Appealing to startups and other players
  - no upfront investment
  - no maintenance costs

# Cloud Services

- Software as a Service (SaaS)
  - customers rent software hosted by the vendor
- Platform as a Service (PaaS)
  - customers rent infrastructure and programming tools hosted by the
  - vendor to create their own applications
- Infrastructure as a Service (IaaS)
  - customers rent processing, storage, networking and other
  - fundamental computing resources for all purposes

# Vehicular cloud – motivation (1)

- parking lot of a typical enterprise on a typical workday
  - hundreds/thousands  cars go unused for hours on end
- Why rent computational/storage  resources elsewhere?
  - you have them in your own backyard

# Vehicular cloud – motivation (2)

- Dedicated Short Range Communications (DSRC)
  - Allocated by US Federal Communications Commission
  - 75MHz of spectrum (5.850 to 5.925 GHz)
  - In support of vehicular networking
- Roadside infrastructures
  - Inductive loop detectors
  - Video cameras
  - Acoustic tracking systems
  - Microwave radar sensors
  - Access point

# VC – vehicular cloud

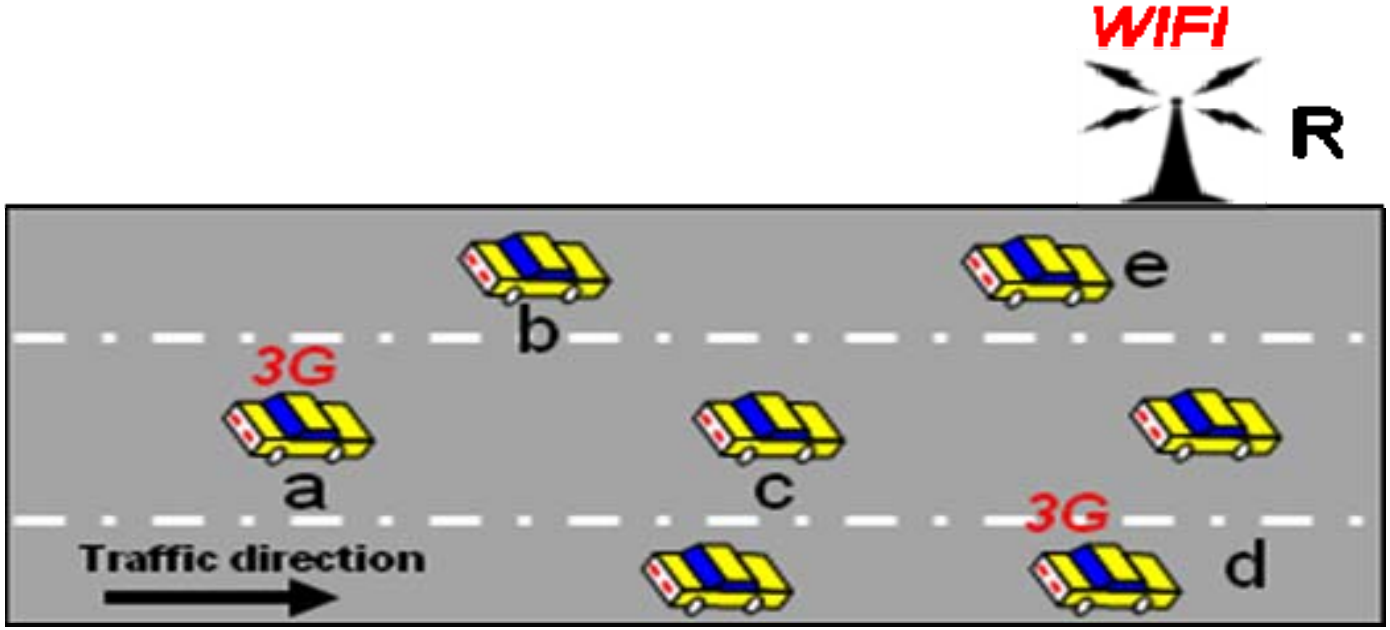
- ***A group of vehicles whose corporate computing, sensing, communication and physical resources can be coordinated and dynamically allocated to authorized users***
- How are VCs different from the classic clouds?
- Mobility: close proximity to an event is often un-planned
  - pooling of the resources in support of mitigating the event must occur spontaneously
- Autonomy: for the decision of each vehicle to participate in the VC
- Agility:  ability of VCs to tailor the amount of shared resources to the actual needs of the situation in support of which the VC was constituted

# Storage as a Service (SaaS)

- Computers in cars will have multiple terabytes of  on-board storage
- Data center in mall/airport/parking lot

# Network as a Service (NaaS)

- Most cars don’t have internet connection
- Small relative speed between cars on the same direction: traditional MANET



# Cooperation as a Service (CaaS)

- Drivers behind the wheels: suitable for human interaction tasks
  - Weather?
  - Road condition?
  - Best restaurant around a specific place?
- Publish/subscribe mechanism

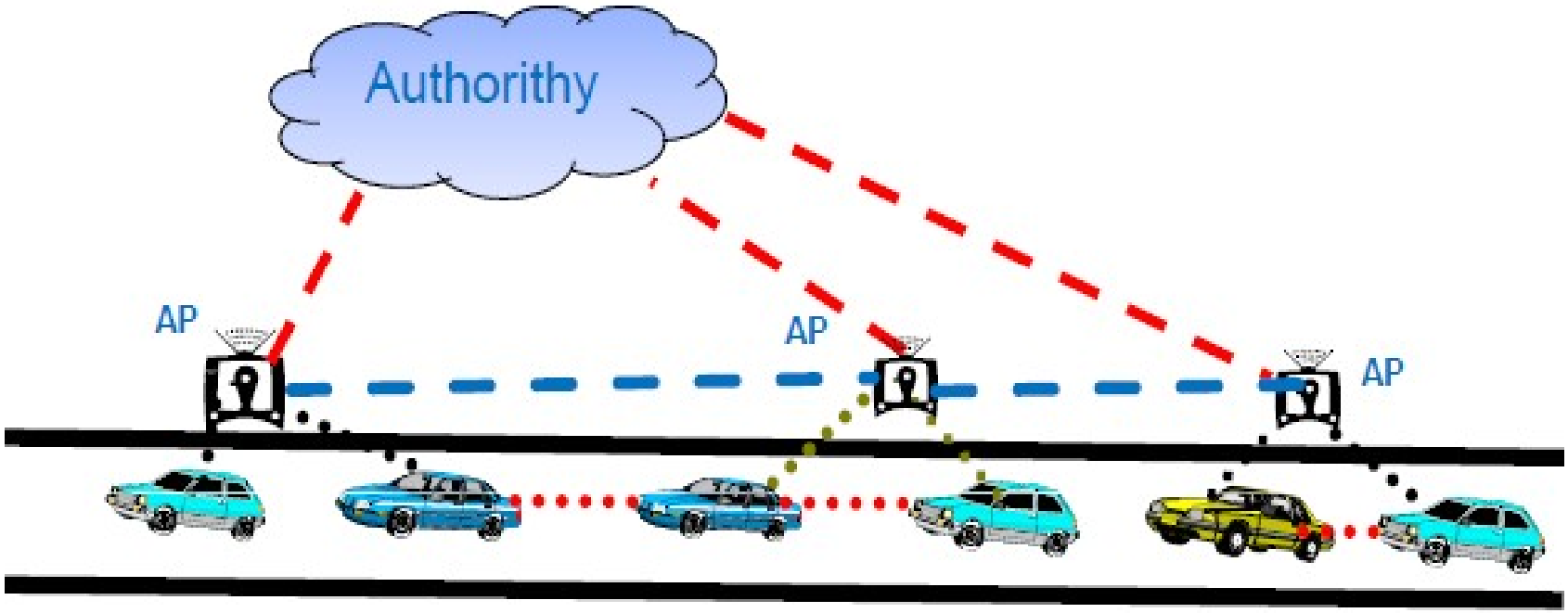
# Dynamically reschedule traffic lights

- The municipality
  - has the authority and the code but does not have the hardware
- The cars
  - have the computational power but lack the authority and the code

# Planned evacuation

- Several inter-operating VC of vehicles involved in evacuation coordinated the emergency management center
- The emergency managers learn and upload real-time information about open gas stations, shelters, open medical facilities etc

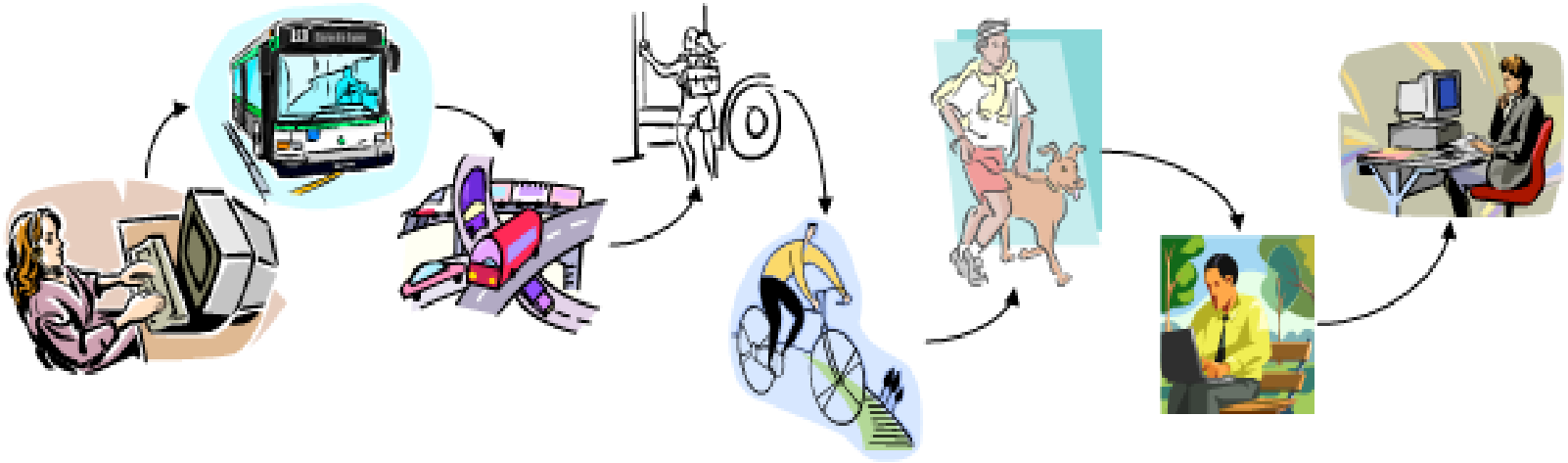
# Possible AVC architecture



# Security and privacy in VC

- Not yet addressed in literature
  - High mobility
  - Intermittent short-range communication
  - Attacker is hard to identify due to virtualization
- Proposition: mobile device/social network
  - Calgary Airport authority uses Facebook Connect to grant access to WiFi
  - Geographic information of mobile phone and vehicle must match

# Opportunistic network

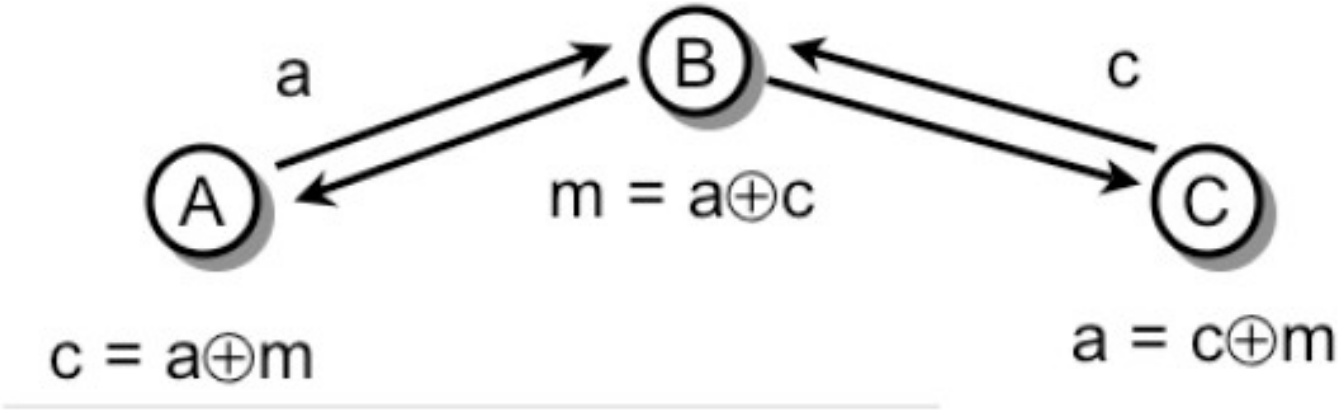


# Routing without infrastructure

- Dissemination-based routing
  - Work well in highly mobile networks
  - Tend to limit message delays
  - Suffer from high contention
  - May lead to network congestion
- ***Epidemic Routing*** protocol

# Routing without infrastructure

- Network-coding-based routing
  - Outperform flooding
  - Deliver information with fewer messages



# Routing with fixed infrastructure

- Instead of flooding the message, a message is kept until it comes within reach of a base station (RSU) belonging to the infrastructure
- Variation: both V2I and V2V communications are allowed
  - Delivers the message ***opportunistically*** to a near vehicle

# Routing with mobile infrastructure

- Carrier-based routing
  - Carrier functions as data disseminator/collector
  - Carrier can increase connectivity in sparse network
- How to choose carrier
  - Availability
  - Number of vehicles it meets
  - Community

# Question 1

- Epidemic routing is flooding-based in nature, as nodes continuously replicate and transmit messages to newly discovered contacts (with a possibility to infect these contacts) that do not already possess a copy of the message. In the most simple case, epidemic routing is flooding; however, more sophisticated techniques can be used to limit the number of message transfers. How can we improve Epidemic Routing protocol? (alleviate contention/congestion)

- ✓ *Impose a maximum number of relay hops to each message*
- ✓ *Limit the total number of message copies present in the network at the same time*
- ✓ *Choose relays based on the probability to successfully deliver to destination (recent history of meetings and visits)*

# Question 2

- If we view the structure of VC as an opportunistic network (delay-tolerant network, lack of connectivity, resulting in a lack of instantaneous end-to-end paths), what are the limitations of the routing algorithms designed for opportunistic networks when used to provide cloud computing service?
- ✓ *All the routing algorithms are designed for opportunistic network, efforts are made to limit message delay, but it is inevitable, thus makes them inapplicable for real time applications (such as voice/image recognition etc.)*

# Question 3

- If a VC utilizes carrier-based routing (carriers are selected among the nodes, and other nodes can only communicate with carriers, while carriers can communicate with each other), how is the performance related to the number of carriers?

✓ *When there are too few carriers, high delay / failure of delivery may happen because of the poor connectivity of the network, when there are too many carriers, since each one only carries partial result, they have to find a way to communicate among each other, the overhead it causes may result in poor performance.*