EdgeMap: CrowdSourcing High Definition Map in Automotive Edge Computing

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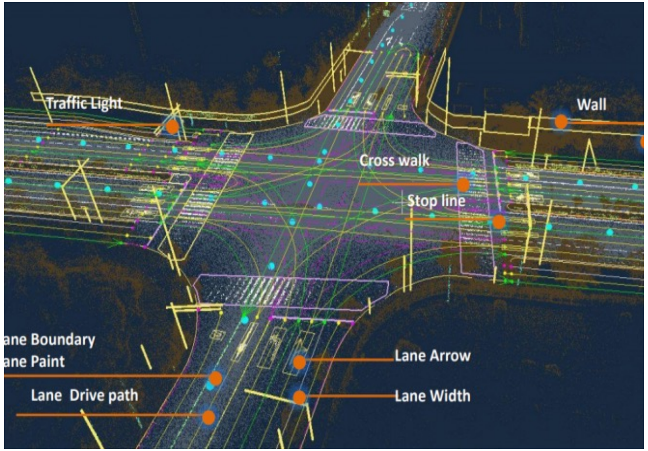
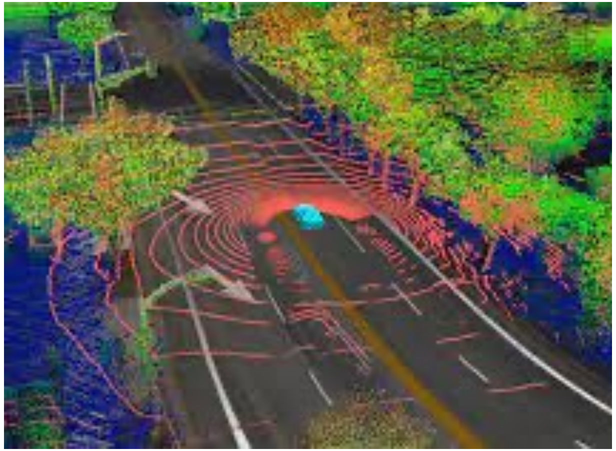
IN OUR GRIT, OUR GLORY™

High-Definition Map

- HD map enables Autonomous Driving and ADAS
  - Accurate and high precision presentation of the roads
  - AV and ADAS rely on HD map for relocalization, e.g., SLAM

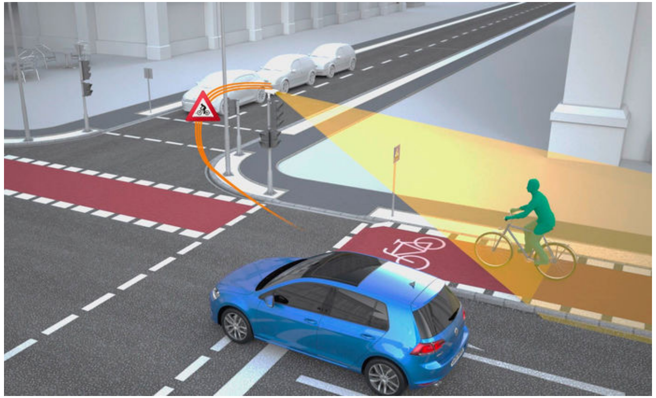




High-Definition Map

❖ HD map needs up-to-date information

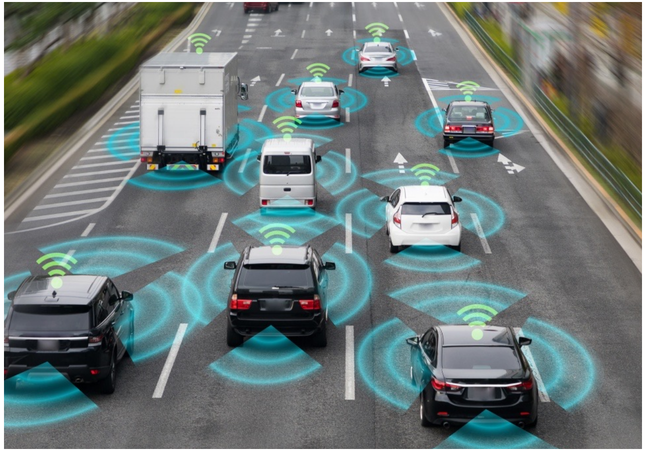
- Transient information on the road, e.g., constructions and accidents
- Infrastructural sensors have limited coverage and angles

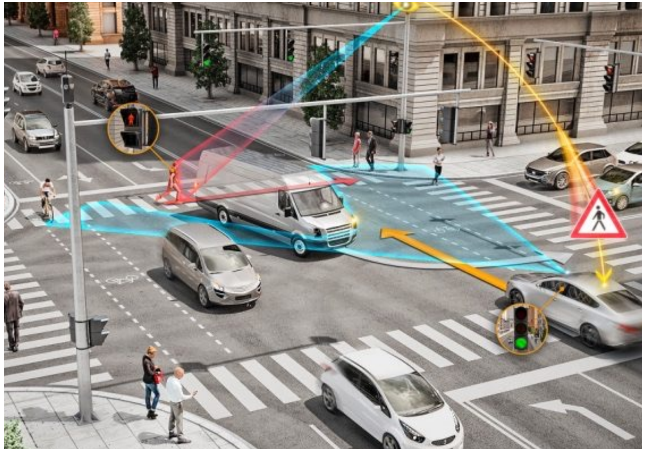


Connected and Automated Vehicles

❖ CAVs connect vehicles wirelessly with Edge Computing

- Allow information sharing and vehicle collaborations
- Crowdsourcing data from rich sensors in CAVs for updating HD map





Challenges

- Enormous UL/DL radio transmission needs
  - Raw sensor data can be up to 100Mbps per CAV
  - Soaring operating expenses (OPEX) for service providers
- Fast-changing network dynamics
  - High-velocity of vehicles, e.g., channel condition and traffic
  - Complicated resource demands

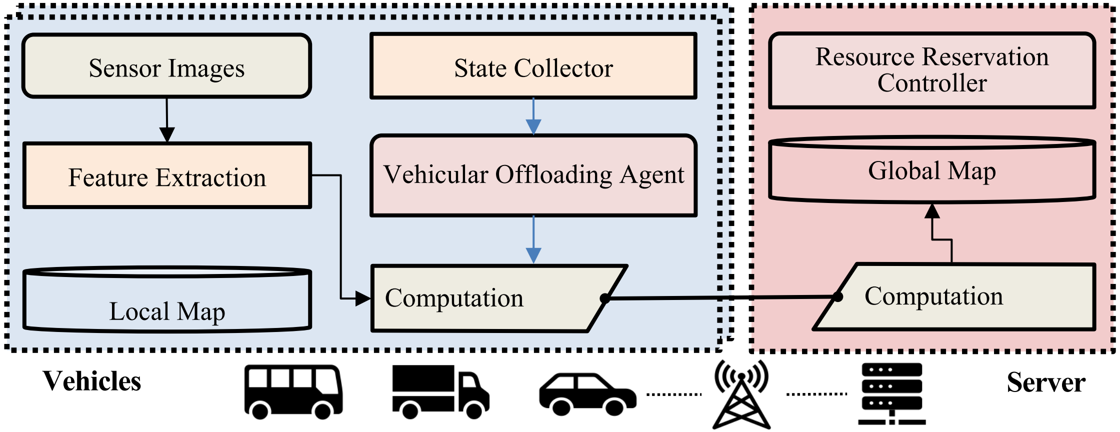
SLAM
>100Mbps

Speed
>30kph

* Ahmad, F., et. al., Carmap: Fast 3d feature map updates for automobiles. NSDI 2020

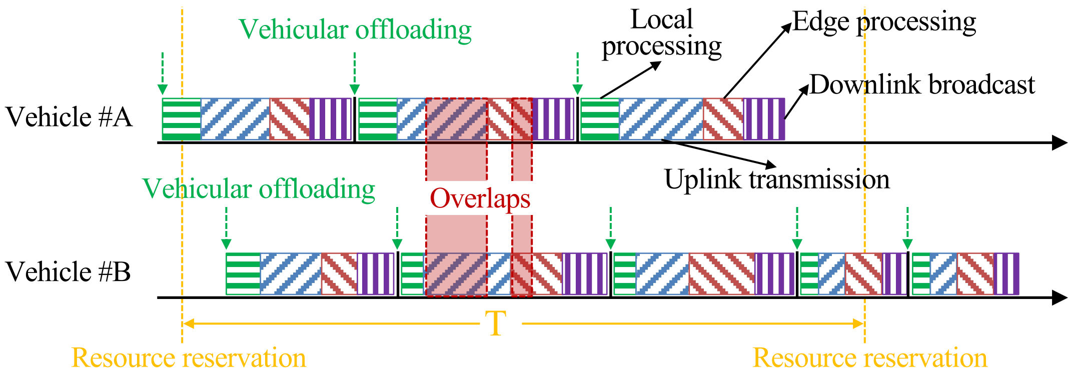
EdgeMap

- Objective: minimize resource usage of crowdsourcing HD map
- Adaptive vehicular offloading
  - Observation: the more pre-process onboard, the less data to be transmitted
  - Reduce the latency of vehicle offloading according current network states
- Learning resource reservation
  - Learn to reserve network resources from network operator
  - Satisfy the latency requirement of vehicular offloading, assure up-to-date HD map



Vehicular Offloading

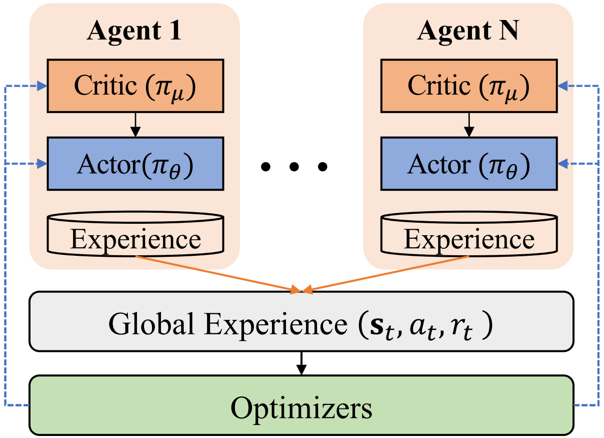
- Asynchronous distributed offloading from individual CAVs
  - Reduce transmission overhead and action delay in centralization scheme
- Challenge: overlap offloadings
  - Unpredictable overlapping among vehicular offloadings
  - Four stages: Local processing, UL transmission, Edge processing and DL broadcast



Vehicular Offloading

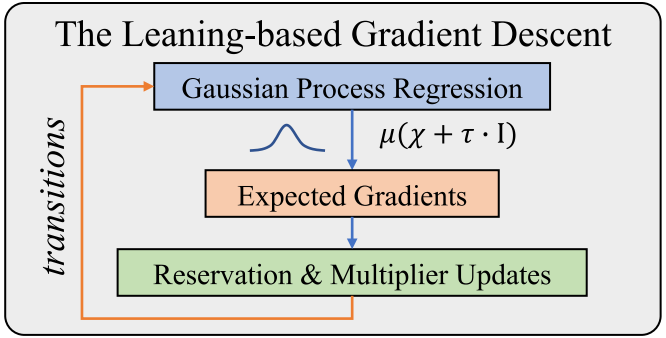
❖ Asynchronous Multi-Agent Deep Reinforcement Learning

- Create individual DRL agents in CAVs
- Follow centralized-learning-distributed-execution
- **State space**: local vehicular states (CPU, speed, radio) and system status (server workload)
- **Action space**: vehicular offloading partition [0,1]
- **Reward function**: the latency of the vehicular offloading



Resource Reservation

- Learn to reserve network resources
  - The vehicular offloading policy is static in this large time scale, e.g., hours
- Challenge: unknown resource demands
  - Changing vehicular offloading policy
  - Coupling cross-domain resource correlations
  - Limited data samples
- Solution:
  - Create Gaussian Process Regression (GPR)
  - Define the expected gradients from GPR model
  - Gradually update current resource reservation



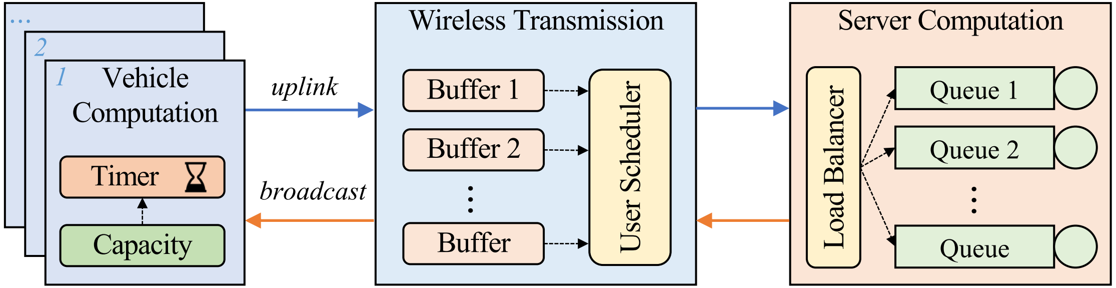
Simulation

End-to-End Network Simulator

- Time-driven, with 5G UL/DL and queue-based edge computation
- Packet sizes and computing time are collected from real experiments

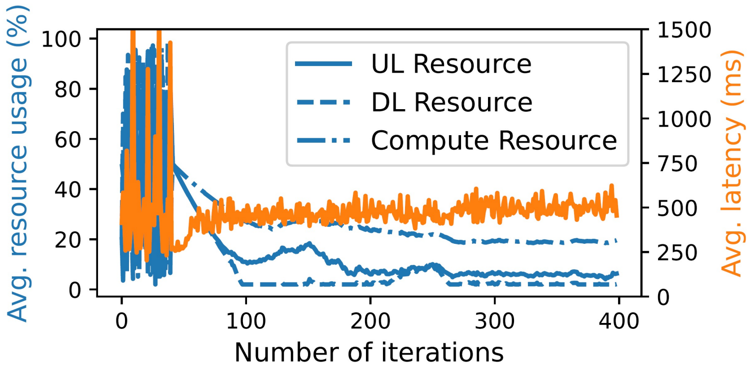
Other Parameters

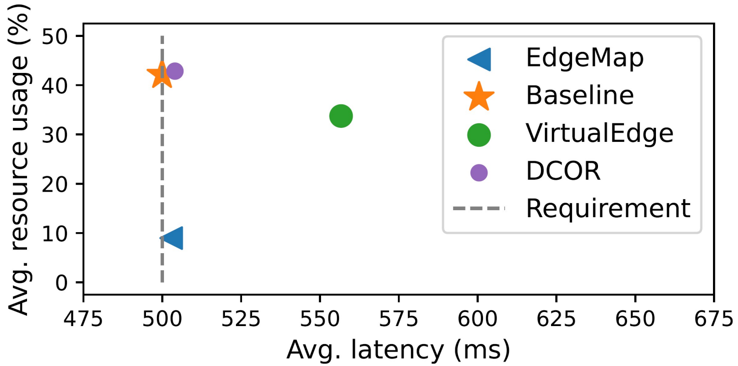
- Use PPO agents with 3-layers of 128 neuros
- Use scikit-learn to build GRP model
- Measure ORB-SLAM3 in both Laptop (Intel i7, 2.5GHz) and Desktop (AMD 3600, 3.8GHz)



Results

- **EdgeMap convergence**
  - The sample-efficient GPR model accelerate the convergence
  - The multiple PPO agents of EdgeMap converges as well
- **EdgeMap outperforms others**
  - EdgeMap achieves lowest resource usage and meet latency requirement
  - VirtualEdge fails to meet the latency requirement
  - DCOR obtains higher resource usage





Summary

- HD map needs up-to-date road information while crowdsourcing approach overwhelm cellular network with enormous data transmission
- We proposed EdgeMap to minimize the resource usage while meeting the latency requirement of HD map
- We design asynchronous distributed vehicular offloading solution to reduce offloading latency under existing resource reservation
- We design sample-efficient learning-based resource reservation solution to lower the resource demand under static offloading policy
- We evaluate and validate EdgeMap in an end-to-end network simulator

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