CPS: TTP Option: Synergy: Traffic Operating System for Smart Cities

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Overview

- **Goal**: Develop a network *traffic operating system (TOS)* with 3 levels of feedback control:
  - **Network Level Control:** demand management with information dissemination
  - **Road Link Level Control:** signal timing, lane allocation, speed advisory
  - **Vehicle Level Control:** V2X, platoons, speed/lane adjustment
- This project takes a holistic, cross-layer approach to:
  - Maximize network mobility throughput
  - Enhance safety with connected vehicle technology Enhance safety with connected vehicle technology
  - Minimize environmental impact through fuel economy and lower emissions

- **Major Accomplishments:**
  - TTP: 3-car platoon demonstration on an arterial roadway (V2V and V2I)
  - Demonstrated conditions under which increase adoption of vehicle autonomy leads to overall network mobility improvements

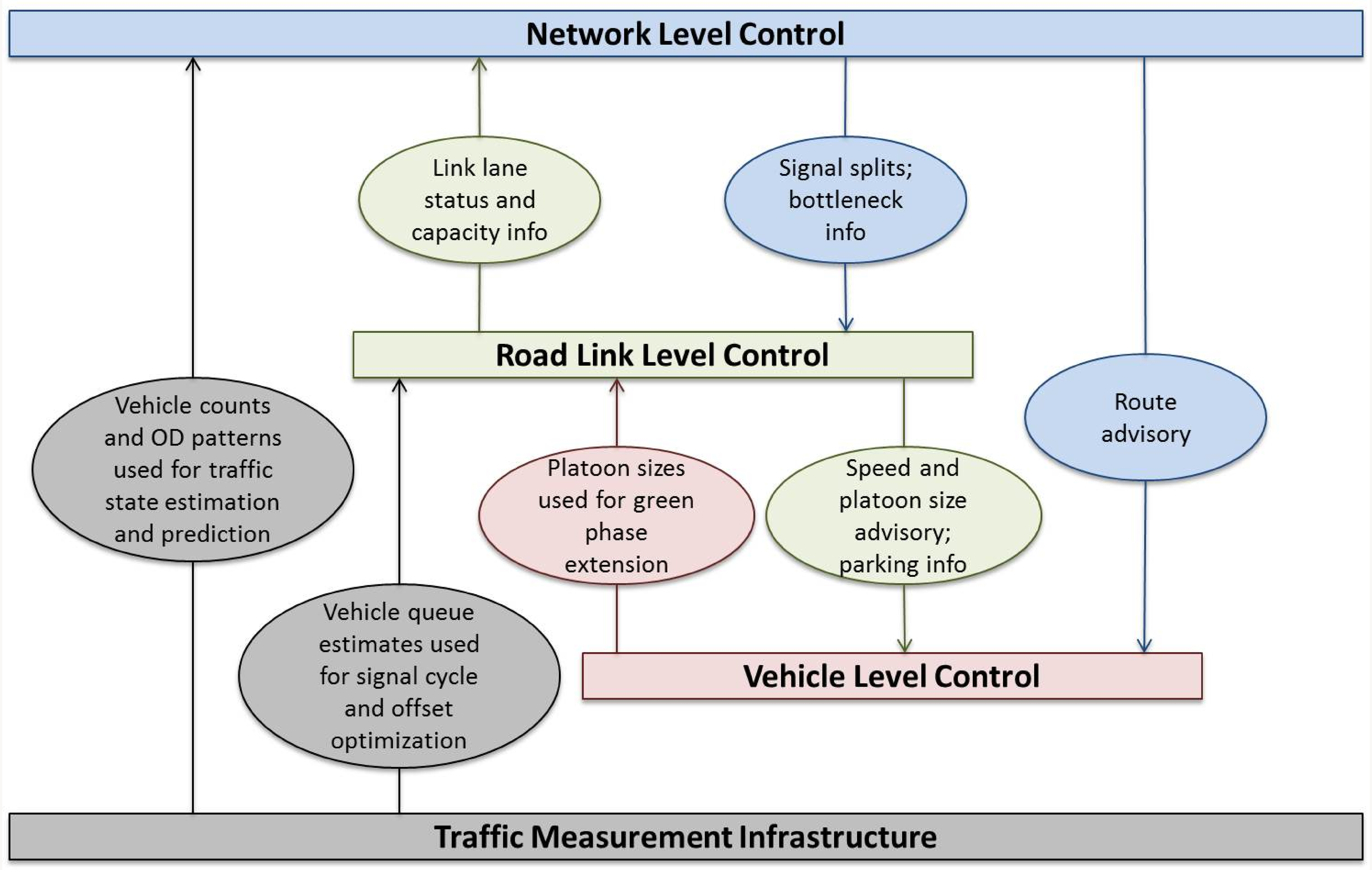

Figure 1: Diagram illustrating information flow in the TOS

Traffic Management

Network Level Control

- Game-theoretic capacity analysis of road link and networks with mixed autonomy
  - Increasing roadway throughput through vehicle autonomy does not inexorably lead to overall network mobility improvements
  - Vehicle headway (roadway throughput) can and should be controlled to guarantee increase network throughput
  - It is possible to introduce differential pricing in networks with mix autonomy to maximize network mobility

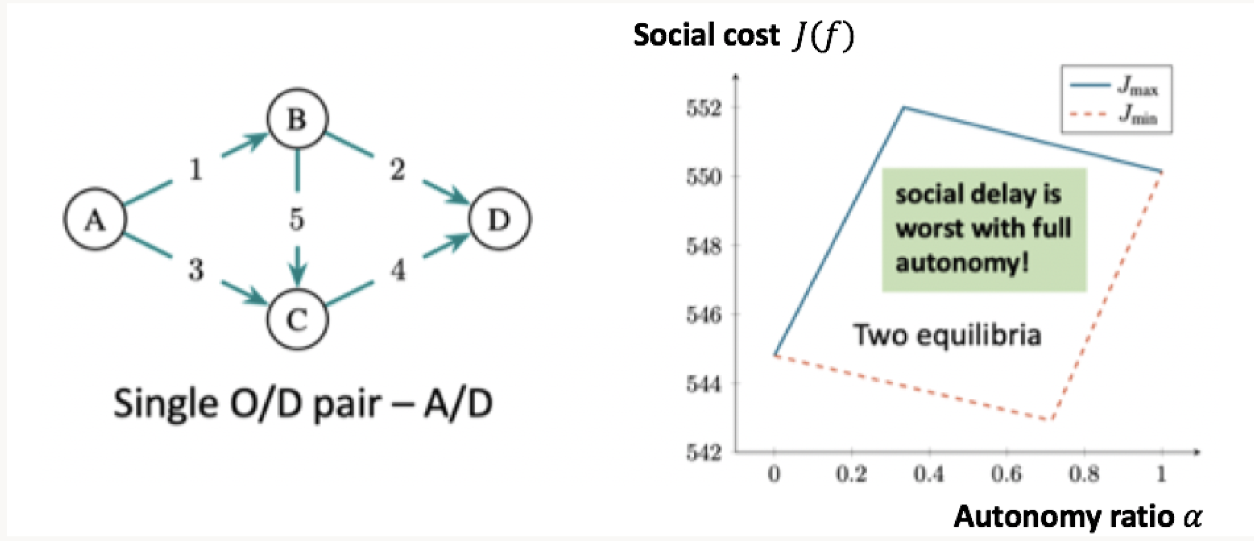

Figure 2: Full autonomy exacerbates the traffic conditions

Road Link Level Control

- Increase the accuracy of sensor data and improve road occupation efficiency by:
  - Infrastructure sensor optimal placement
  - Merging infrastructure, mobile sensor data and real-time prediction algorithms for state estimation
  - Joint perimeter and signalization control and signalization bandwidth maximization

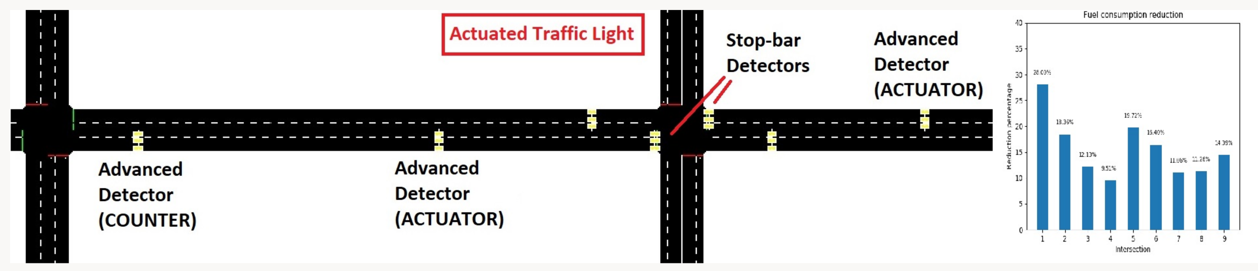

Figure 3: Traffic light phase length estimation for fuel consumption reduction

Vehicle Level Control

- We platoon vehicles via *cooperative adaptive cruise control* (CACC) technology, increasing intersection throughput & highway capacity. Particularly, we explore:
  - Dynamic formation of platoons
  - Joining and split maneuvers

Transition to Practice

Arcadia Demo: 3-car platoon testing

- Goal: Showed that forming platoons improves traffic efficiency
  - Reduction in acceleration delays when light turns green
  - Platooning vehicles drive closely together, improving road capacity and throughput
- Use of connected vehicle technology:
  - V2V: velocity forecast from front and leader vehicle
  - V2I: signal, phase and timing (SPaT) information from upcoming traffic light

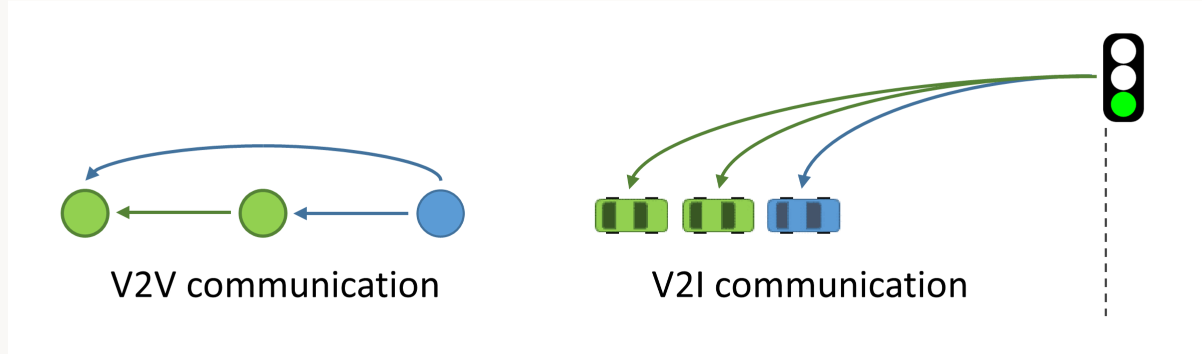

Figure 4: Diagram of V2X communication used in platooning demo

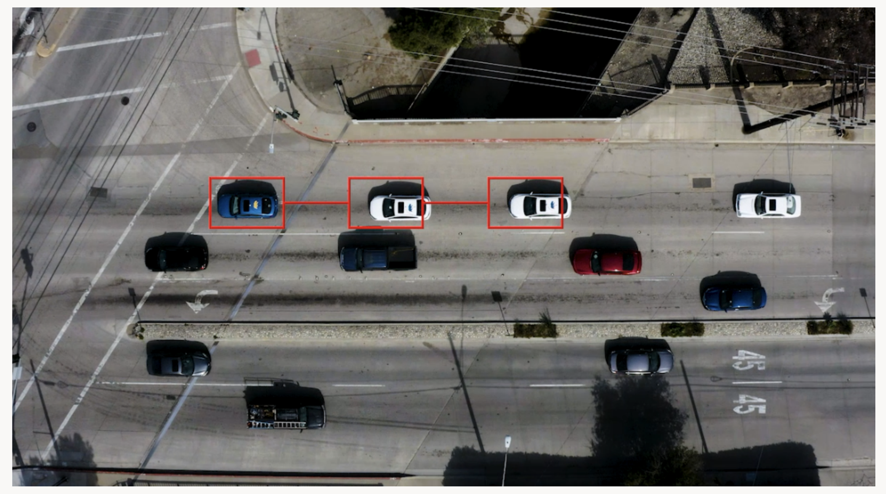

Figure 5: Platooning demo: 3-car platoon testing in the Live Oak Corridor in Arcadia, California. Feb. 2020. Video available online: https://youtu.be/xPYR_xP3FuY

Selected Publications (2020)

[1] Ruolin Li, Negar Mehr, and Roberto Horowitz.
The impact of autonomous vehicles' headway on the social delay of traffic networks.
In *2020 59th IEEE Conference on Decision and Control (CDC)*, pages 268–273.

[2] Stanley W Smith, Yeojun Kim, Jacopo Guanetti, Ruolin Li, Roya Firoozi, Bruce Wootton, Alexander A Kurzhanskiy, Francesco Borrelli, Roberto Horowitz, and Murat Arcak.
Improving urban traffic throughput with vehicle platooning: Theory and experiments.
IEEE Access, 8:141208–141223, 2020.

[3] Mikhail Burov, Negar Mehr, Stanley Smith, Alexander Kurzhanskiy, and Murat Arcak.
Platoon formation algorithm for minimizing travel time.
In *2020 IEEE 23rd International Conference on Intelligent Transportation Systems (ITSC)*, pages 1–6. IEEE, 2020.

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