The Ohio State University

College of Engineering

CONNECTED VEHICLES

Semi-Autonomous, Collaborative Vehicular Systems

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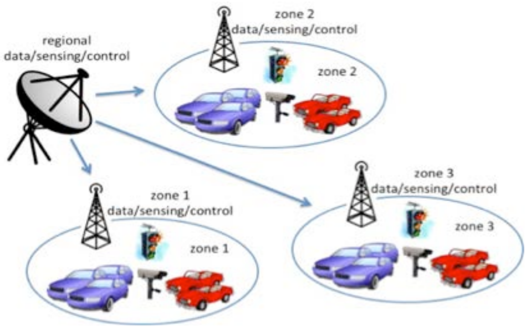
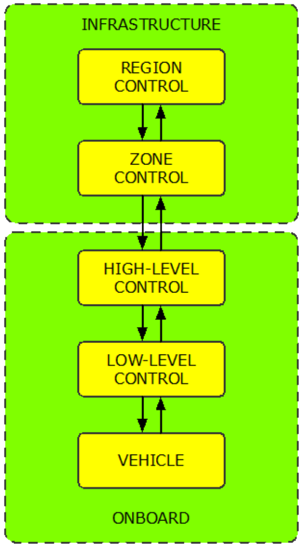
INTRODUCTION

- Semi-Autonomous, Collaborative Vehicular Systems:
  - a network of human-driven, semi-autonomous, and fully-autonomous vehicles participating in a transportation system in a safe and efficient way
- Crucial Aspects:
  - **Collaboration:** A particular concern is safe cohabitation of the traffic network with human-driving, non-communicating vehicles, and other vehicles with varying CPS capabilities via cooperative situation awareness.
  - **Scalability:** Proposed approaches needs to be compatible with real-world scenarios involving thousands of participating CPS entities. Here we propose a structured architecture to tackle challenges relating to scalability issues.
  - **Testability:** Focus is placed on the development fully and partially virtual environments for rigorous testing of CPS components before real-world tests and deployments.

VISION

- In the future, most vehicles are going to have V2V & V2I communication, onboard GPS, access to map databases, and access to “cloud” resources.
- We predict that from these unstructured resources will emerge a structured hierarchy of local and remote capabilities.
  - Which CPS components should be deployed on the vehicle, and which on the infrastructure and the “cloud”?
- Our proposed CPS model is capable of handling both intermediate stages as well as the final fully-integrated stage.
  - an effective functional mapping for the deployment of various CPS components enabling efficient usage of communication and computation resources
  - a modular and non-restrictive structure for the development and integration of new components





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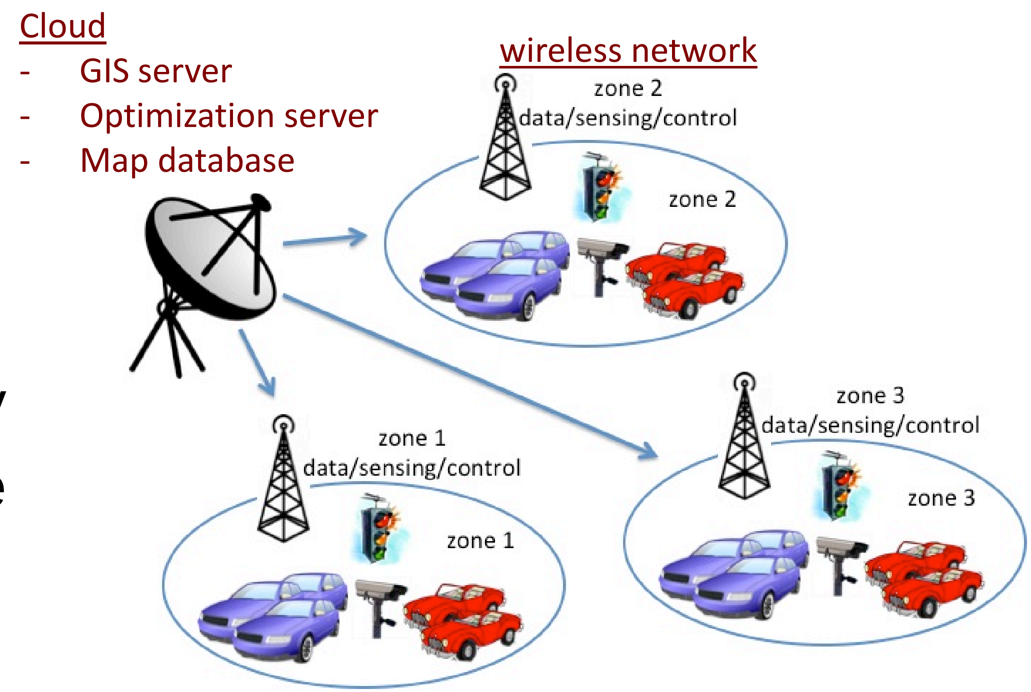
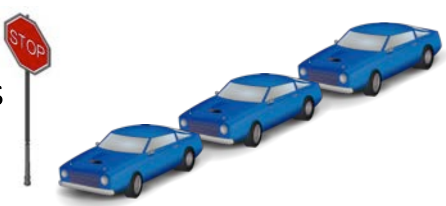
ENERGY-AWARE INTELLIGENCE

- Generating driving advice:
  - Cloud based
  - Energy optimal
  - Real time
- Cloud resources at the highest level of the hierarchy
- Wireless infrastructure at the zone level
- Generate driving advisory at the vehicle level, utilizing low-level vehicle fuel-consumption dynamics.

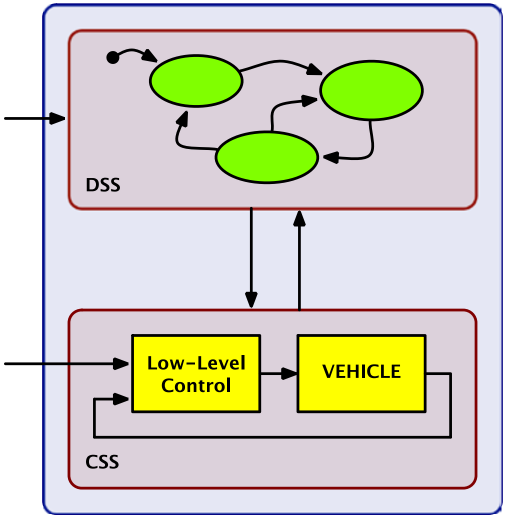


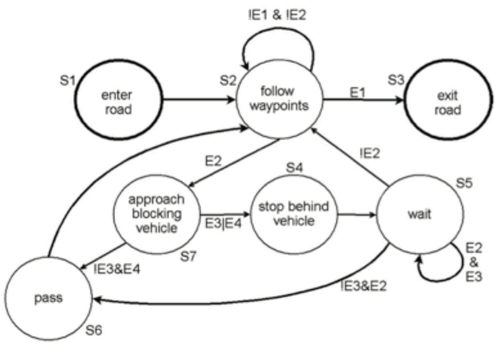
Coordinated urban convoys
through intersections
and city traffic rules



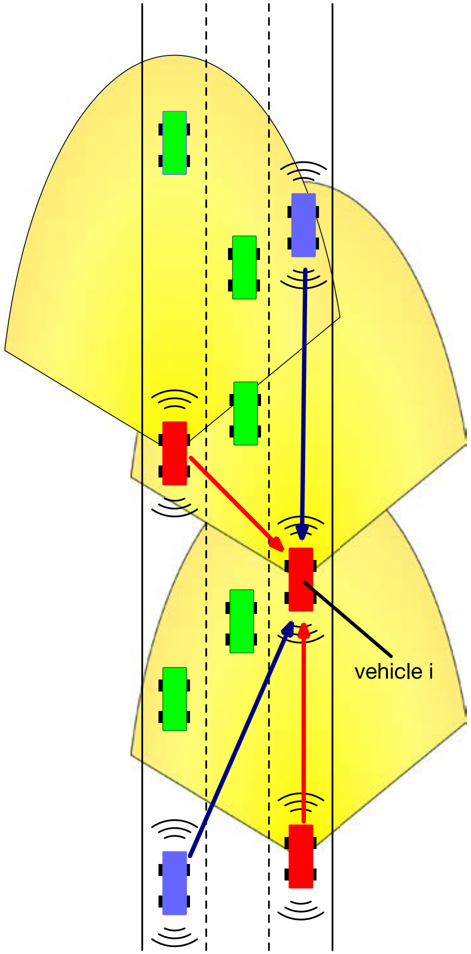
RESEARCH SUBTOPICS

- We envision the utilization of hybrid-state systems as a central modeling paradigm for cyber-physical interactions.
  - Autonomous vehicle control
  - Semi-autonomous vehicle control functionalities
  - Cooperative multi-vehicle behaviors
  - Regulation of the traffic within zones and regions through the infrastructure

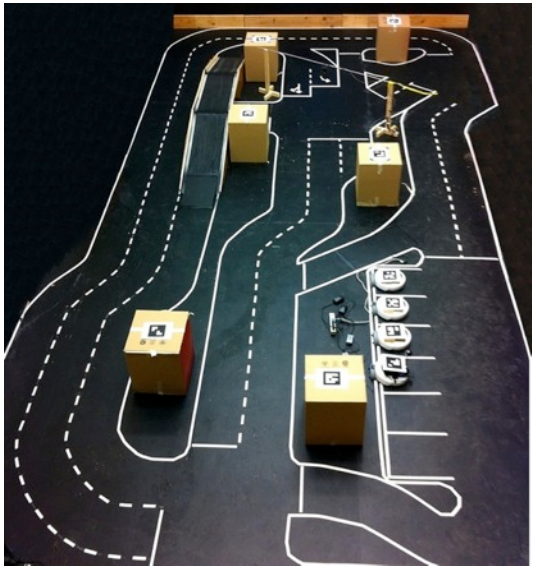




- Cooperative situation awareness becomes a crucial aspect in collaborative vehicular networks with varying CPS capabilities.
- We categorize vehicles based on their capabilities:
  - Non-equipped vehicles: vehicles without V2V capability, not participating in the vehicular network.
  - V2V-equipped vehicles: vehicles have v2v capability, but without external sensing to enable object detection (such as non-equipped vehicles, static obstacles, pedestrians, bicycles).
  - Fully-equipped vehicles: vehicles with both v2v and external sensing (e.g. vision, lidar) capabilities.
- Cooperative information sharing and integration is achieved through:
  - Development of efficient real-time V2V information sharing approaches that ensure the transfer of all relevant data to all relevant CPS entities participating in the network (beyond safety message)
  - Development of information integration approaches that would fuse information coming from various sources into a coherent scene representation—onboard sensing and v2v information sharing.



- Another concern is the study of the benefits and limitations of partial and full virtualization on cyber-physical system testing, on the specific example of collaborative driving.
  - Cooperative multi-vehicle situation awareness and decision making
    - Traffic simulator and indoor testbed (integrated with the simulator, with optional virtual entities)
    - Outdoor tests (with optional virtual entities)
  - Interaction between human driver and semi-autonomous vehicle functionalities
    - Driving simulator for modeling driver behaviors
    - Development and testing of cooperating semi-autonomous functionalities (e.g. lane keeping)



TESTING AND TESTABILITY

- Test tracks for fully controlled environments
- Parking lots for simpler, slower tests
- Time, weather, logistics, safety…
- Testing even a single experimental vehicle for a single capability takes a significant amount of person hours.

CONNECTED VEHICLE TESTING

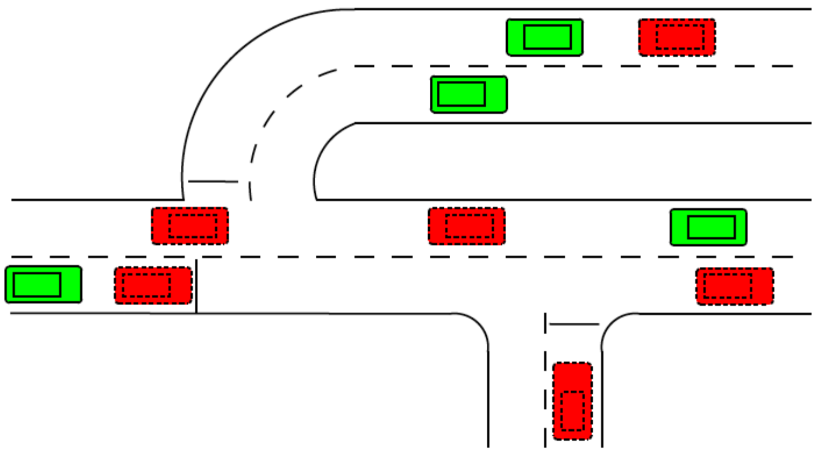
- Dedicated Short Range Communication (DSRC) Testing:
  - Many vehicles
  - Connected infrastructure
  - Data collection centers
  - Maintenance
- Safety Pilot Model Deployment

ITS World Congress 2008 closed a five block section of of 11th Avenue[1]. Current model deployment program covers a significant portion of Ann Arbor, MI[2].

1: NHTSA 2008 Second Annual Report (DOT HS 811 466)
2: UMTRI Safety Pilot website (http://www.umtri.umich.edu/)

ALTERNATIVE: SEMI-VIRTUAL TESTING

- Similar to HIL simulation
- Full-size vehicles interacting with the simulation
- Simulated agents, scenarios, even sensors
- Much lower cost, and safer



Connected vehicle tech enables a unified and easy to implement interface between virtual and physical.

FIRST EXPERIMENTS

- Connected autonomy experiment:
  - Two semi-autonomous, two manual vehicles with radios
  - DSRC-equipped traffic light
  - Convoying and regrouping
- Simulated/physical interaction experiment:
  - Real and simulated mobile robots
  - Indoor testbed
  - DSRC emulation over WiFi