2014 National Workshop on Transportation Cyber-Physical Systems

Session III: Infrastructure, Cloud-Based System, Green Approaches - Integration

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Agenda

- Integration
  - What? Why? When? How?
- Challenges
  - Architecture
  - Modeling
  - Composition
  - Scalability
  - Resilience & Security
  - Human in the Loop

What to integrate?

- Very big system to integrate
  - Various device (static/mobile); vehicles – manned, autonomous, semi-autonomous
  - Data format
  - Planned vs. ad-hoc
  - Modeling language and tools
  - Environment
  - Multiple networks
  - Humans and human behavior models

Why to integrate?

- Needed for functionality, needed for safety/ dependability
- To support cooperation, coordination & synchronization
- Can enable increased levels of system efficiency and performance
  - New systems (e.g. cloud) provide the opportunity for scalability
  - New technologies provide solutions but add challenges
- Meet high-level requirements
  - Decision support, efficient, robust, secure, safe, energy, easy to use …

When to integrate?

- Challenge – different timescales
  - day, hour, min, sec, …
- How much a priori?
- How much for near real-time decision support?
- How much for real-time control?

Principles for Integration

- Abstractions
- Standards
  - Open data formats
  - Open protocols
  - Open standards
- Layered middleware solution
  - Layered middleware & system middleware

Challenges - Architecture

- Need a structured methodology for integration that accommodates heterogeneity (e.g. through common APIs, standards)
- Designing a high level end-to-end architecture for integration of heterogeneous vehicles/ devices, built infrastructure, networks, environment, data, humans and human behavior models
- Integration
  - Vehicles/devices, networks, data, knowledge
- Cross-layer heterogeneity

Challenges - Modeling

- Must be able to
  - Integrated Cyber & Physical modeling
    - Sensing, Control, Actuation Loop
    - Theories to translate cyber(discrete) to physical (continuous)
    - In real-time?
  - Composition theory
  - Abstraction (right level) of information

Challenges - Modeling

- Must be able to go from digital capture of state to *dynamic* situational awareness for decision making and control
  - Device-level, inter-vehicle, system-wide
  - Multiple levels of SA are needed
- Multiple level loop with human (driver involved) system.
  - There are lots of interactions among components.
  - How to obtain develop effective modeling and tools to integrate those components.
- Validation and verification techniques
  - Simulation, co-simulation, testbed

Challenges – Modeling (cont.)

- Integration vs. interoperability
- Integrate system consider control loop cycles (of construction, deterioration and maintenance).
- Smart transportation infrastructure (new, retrofitted, or dynamically inspected) is needed that continuously monitors it's status without human intervention
  - That recognizes and alerts potential problems before they can lead to failures damaging lives and/or property

Challenges – Composition

- Integration of mechanisms to support composite itilities – dependability/safety, security, heterogeneity, privacy… and their composition, etc.
- The interaction with power grid and transportation system (multiple CPS interactions)
  - Integrate the vehicle drive pattern data with the roadway network information to obtain spatially-dependent energy requests;
  - The placement of the recharging, renewable and storage infrastructure to support a pre-defined penetration of EVs and PHEVs;
  - Connected EV energy and passenger transportation network is that EVs not only carry passengers, they also transport energy from renewable energy (solar or wind) plants to users that need power (e.g., charging stations and houses)
- Understand the complexity of integrated system and how to modify the system for future needs
- Backward compatibility and integration of legacy systems

Challenges – Scalability

- Modeling, planning, adaptation and control at scale
  - Big Control (industrial Internet)
  - Big Data (Geophysical, spatiotemporal, dynamic data)
    - For modeling, planning, adaptation, control
    - Role of cloud
  - How to analyze big data from various sensors and react to actors
    - Need to standardize ontology of data communication.
  - Mining mobility data to obtain regularity of transportation patterns, abnormal events, historical data to improve system operation efficiency and reliability
  - Integrating cloud that provide cheap storage and computation power relieving overhead on the vehicles
    - Develop storage and data streaming analysis to obtain pattern, similarity, abnormaly behavior

Challenges – Resilient & Security

- Big Control, heterogeneous big data, with high levels of assurance
- System integration needs to consider extreme situations
  - Whether it be a sudden increase in traffic due to phenomena such as mass evacuation
  - Influx of people to shelters, or when the transportation systems are damaged as a result of a large crisis.
- Security
  - Use information from physical system can validate security in cyber

Challenge – Human In the Loop

- Integration architecture that effectively engages the human and accommodates human behavior..
- Consider human (intent, decision) in the loop

- Grand challenge
  - How to support abstractions, layering, dependability, mobility in real-time???