

OPPORTUNITIES AND CHALLENGES FOR INTEGRATED H- CPS PLATFORMS AT SCALE



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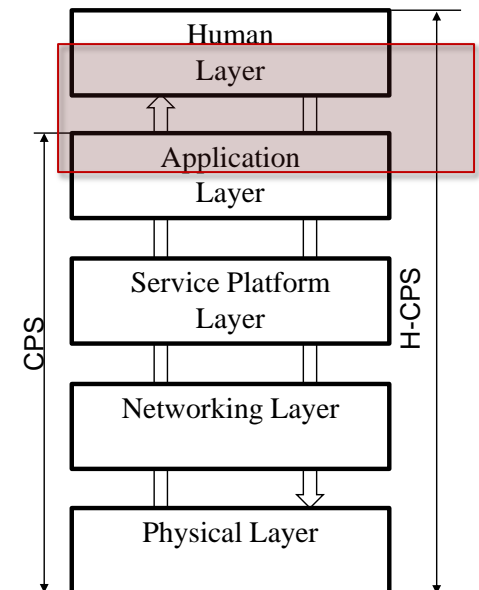
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Human Cyber-Physical Systems

- CPS are engineered systems where functionality and salient characteristics emerge from the interaction of
 - Physical system
 - Control
 - Management Software
 - Network
- Human – CPS : Control loop is closed through the Human Layer with support from: - e.g. - smart cities
 - decision support systems
 - user interfaces
 - incentives



Dynamic Integrated CPS Platforms

- Built not as a single use, single function network, but as networked (wireless) platforms that can be used by many, possibly concurrent users
- Physical configuration/topology affects the available computational resources.
- Physics imposes timing constraints on the computational and communication activities.
- Applications span multiple nodes, for reasons related to the availability of resources.
- Think of it as a Computational Cluster with Physical Constraints.



Dynamic Integrated Human CPS at Scale



Interconnected cars able to perform limited autonomous driving, e.g. that are able to park autonomously in a parking facility.



- Real-time tracking of buses.
- Synchronized Transit Simulation
- Notification support based on pre specified route
- Incentive comparisons between different trip options.
- Integration of real-time bus tracking with ridership information.

Context-aware and individualized travel planning simulation for residents using the transit services.

And many more applications....

Key Challenges

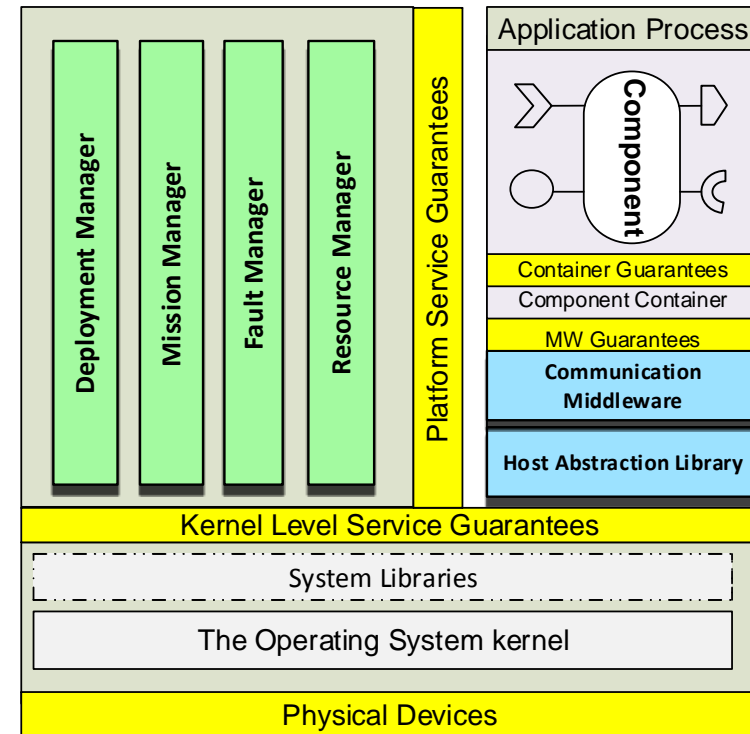
- **Good user interfaces** are necessary – understanding how to present information without overwhelming the person is important.
- **Decision Support Systems** - integration of multi-domain simulation and analytical platform.
- Dynamic, yet physically **constrained computing environment**
- **Support operation across Levels of Autonomy** while ensuring safe decisions across a wide range of scenarios
- **Personalized analytics** based on stream processing across multiple data silos and over multiple timescales
- **Interactions across CPS domains** which require interoperation across multiple system dynamics, constraints and communication technologies.
- **Heterogeneity:** a number of devices and networking technologies exist and have to be incorporated.

Approach for solving these challenges

- Architecture for managing the scale and heterogeneity.
- A well-defined component model for designing applications that support strong time specification and correctness specifications.
- Integrated Simulations to create a Decision Support System
- Smart City Hub as a collection of interface points.

Managing scale and heterogeneity

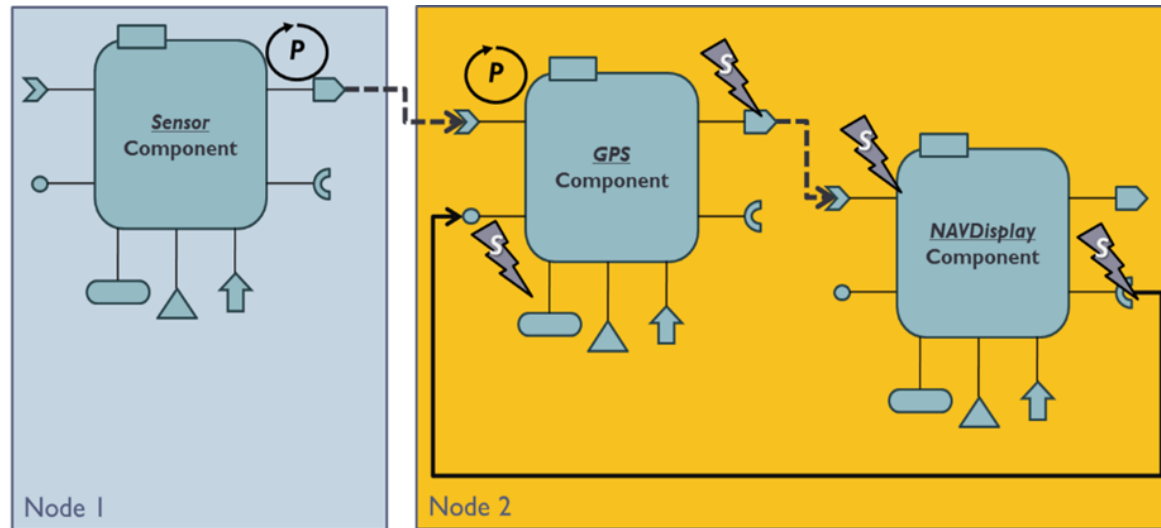
- *Interactions across engineering domains which require interoperation across multiple system dynamics, constraints and interactions:*
 - Well-defined interaction semantics and support of cross platform robust middleware
 - Support for well-defined data model.
- *Tradeoffs between Privacy, Security and Safety from both theoretical and operational perspectives:*
 - Good analytical tools
 - Built-in support across the layers for privacy and security
- *Distribution of Adaptive and Autonomous Platform Management:*
 - Support for adaptive deployment, configuration and application management architecture
- *Timely Dissemination of Massive Amounts of Information Reliably, Securely and Scalably:*
 - Support for enforcing quality of service and strong implementation of time synchronization protocol such as IEEE Precision Time Protocol.



*More information is available on
Drems.isis.vanderbilt.edu*

Component Model – Time-Driven Data Stream Processing

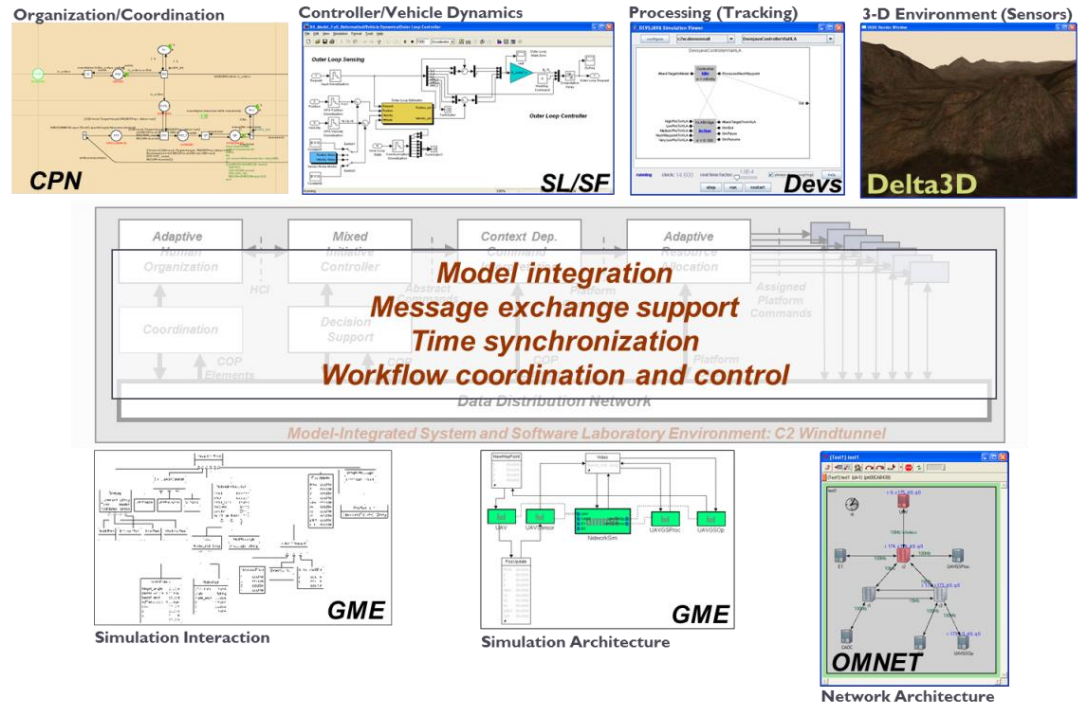
- Support for composition of on demand application workflows.
- Resource and service driven application deployment and configuration.



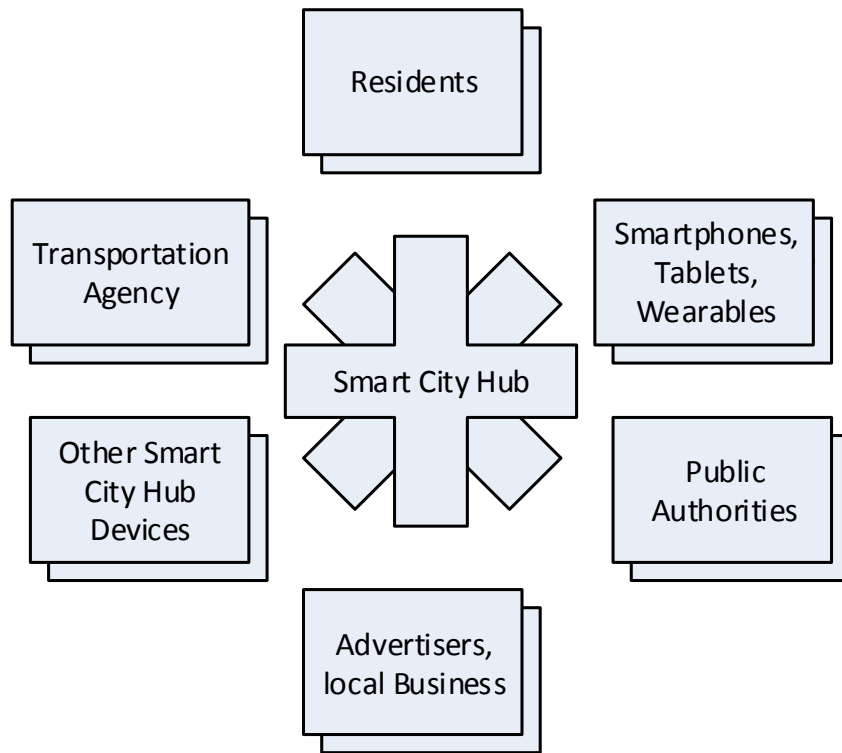
- Time triggered and event triggered operations with support for stream processing.
- Strict deadline monitoring of the activities.
- Precondition, Invariant and Post condition specifications for each component firing rule.

Decision Support Systems

- Integrating simulation engines.
- Technology used is based upon the **Vanderbilt's** Command and Control (C2) Wind Tunnel
- **Vanderbilt's** Command and Control (C2) Wind Tunnel is a virtual laboratory for experimentation with simulated worlds that include both *physical* and *cyber* elements that are tightly coupled and interact. It has been used to evaluate C2 systems for the military, and to experiment with cyber defenses in industrial control (SCADA) systems. The tool is open source and is used in various research projects and in the industry.



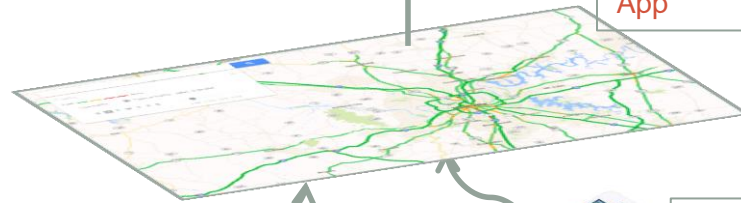
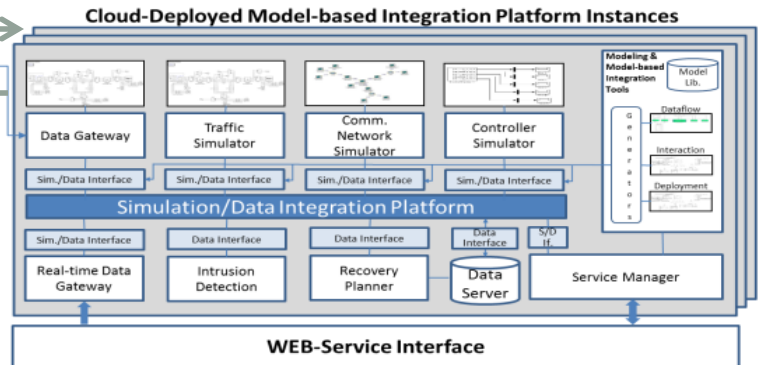
City Hub



Smart city hub Framework provides a platform for information integration and providing an interactive experience to city residents with the purpose of enhancing their quality of life.



Example - Smart Transit Application



City hub integration with the App

Google Traffic Data + Route information

Smart phones with Apps

Sensors for tracking Bus Location

Beacon + phone

Provided Services:

- Real-time tracking of buses.
- Synchronized Transit Simulation
- Support for future simulations
- Notification support based on pre specified route
- Incentive comparisons between different trip options.
- Integration of real-time bus tracking with ridership data collection.

AVL units



Summary

- Good user interfaces - Siemens Smart City Hub
- Decision Support Systems - C2 Wind tunnel
- A resilient application architecture that can be deployed and configured across different environments.
- Integrated Remote Management Services such as deployment Manager, fault Manager.
- Support for well-defined execution triggers and support for defining workflow participant stages using a novel application model.