Fundamental Research Challenges for IoT/CPS (a few from the many*)

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* See: Research Directions for the Internet of Things, invited paper, IEEE Internet of Things Journal, inaugural issue, Vol. 1, Issue 1, Feb. 2014, pp. 1-7.

Vision – A Smart World

Smart Buttons

Smart Homes

Smart textiles

Smart City

Smart World

IoT/CPS

Smart Watch

Smart Phone

Smart Skin

Smart Pills

Smart Swarms of Drones

Vision

- What will it really take to build a smart world?
- Human analogy
- CPS Technology (for next gen. IOT)
  - Safety, control, real-time, adv. signal processing/ML, …

From the Washington Post

Consumers don't find smart homes all that smart

ASSOCIATED PRESS FILE PHOTOS

ABOVE: Former Nest CEO Tony Fadell talks about his company's product updates during a 2015 news conference in San Francisco. BELOW: A Nest Cam surveillance video camera was released as part of Google's attempt to turn homes into yet another thing that can be controlled and tracked over the Internet.

tect smoke alarm hit early problems that required the company to disable its most innovative feature — the ability to wave your hand under the detector to stop the alarm. (It was a particularly attractive feature for bad or at least smoke-heavy cooks.) The company also fielded very public complaints about faulty software that, as The New York Times reported, literally left people in the cold. Then, earlier this year, Nest announced that it would stop supporting the Revolv, a smart home hub that it acquired along with a smart appliance firm of the same name in 2014.

All of these announcements served, in some capacity, to highlight problems consumers are having with the smart home market. It sounds pretty great to have thermostats, light bulbs, ovens and security systems that anticipate our every move. The reality has been something less wonderful — a fractured market of occasionally buggy appliances that work with some, but not all, of the systems out there.

And, perhaps most tellingly, despite the public problems Nest was facing, no single company has positioned itself as an alternative.

So, beyond the early adopters, consumers right

See **HOMES**, Page 11

A Long Way to Go

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2 Overarching Research Qs

- Systems of Systems
  - Direct and Indirect Dependencies and Conflicts <at run time>
- Scaling to 10-100s of trillions of devices and 100s of millions of apps

Smart Cities

- Many services across many domains

Emergency
- *Fire/Explosion Management*
- *Evacuation Aid*
- *Inclement Weather Alert*
- *Health-Care Dispatch*
- *Etc.*

Public Safety
- *Road Accident Management*
- *Risky Area Monitor*
- *Potential Terrorist Monitor*
- *Surveillance Drone*
- *Etc.*

Environment
- *Street Lights*
- *Robots Management*
- *Waste Management*
- *Pollution Control*
- *Etc.*

Transportation
- *Adaptive Traffic Light*
- *Emergency Vehicle Monitor*
- *Road Condition Monitor*
- *Traffic on Special Events*
- *Etc.*

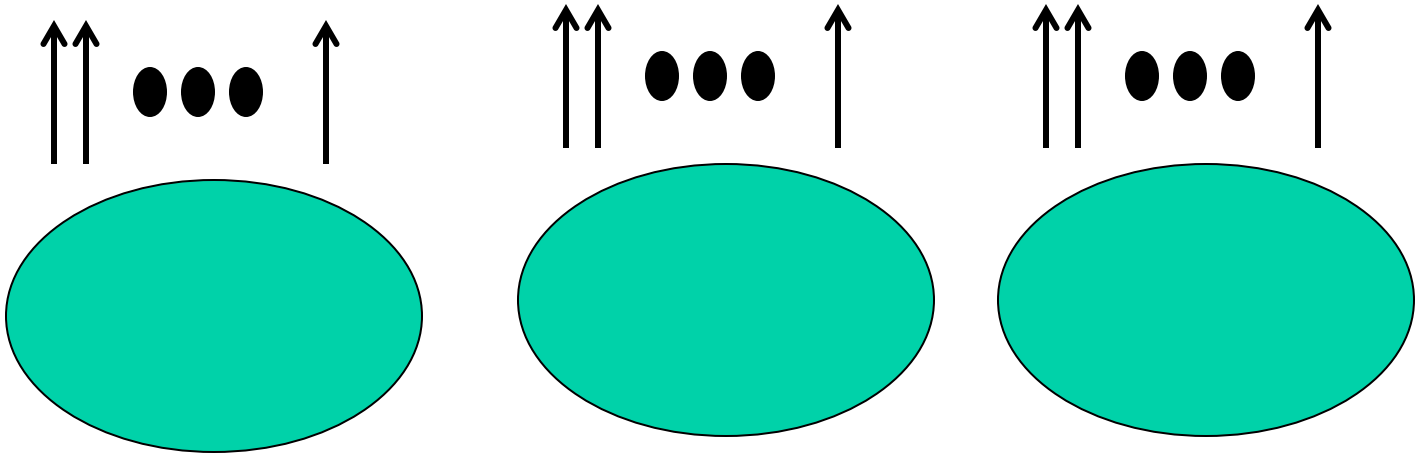
Energy
- *Water Usage Monitor*
- *Energy Usage Monitor*
- *Solar Energy Generation Optimization*

(New) System of Systems

- Operating in continuously evolving open environments
- 2nd ary effects on environment
- Multi-scale in time and space
- Humans-in-the-Loop: safety
- Real-Time
- Independently developed services and apps

Services in a Smart City

Output Signals



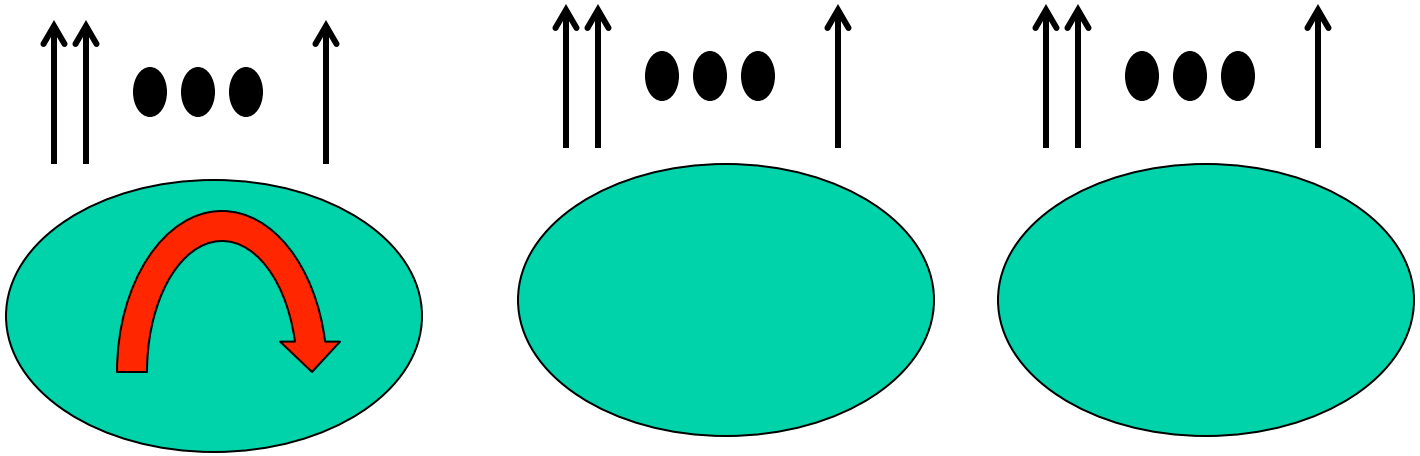
Transportation *Emergency* *Pollution*

SERVICES

Services

Research on : correctness, safety, security, privacy, realisms …

Output Signals



Transportation *Emergency* *Pollution*

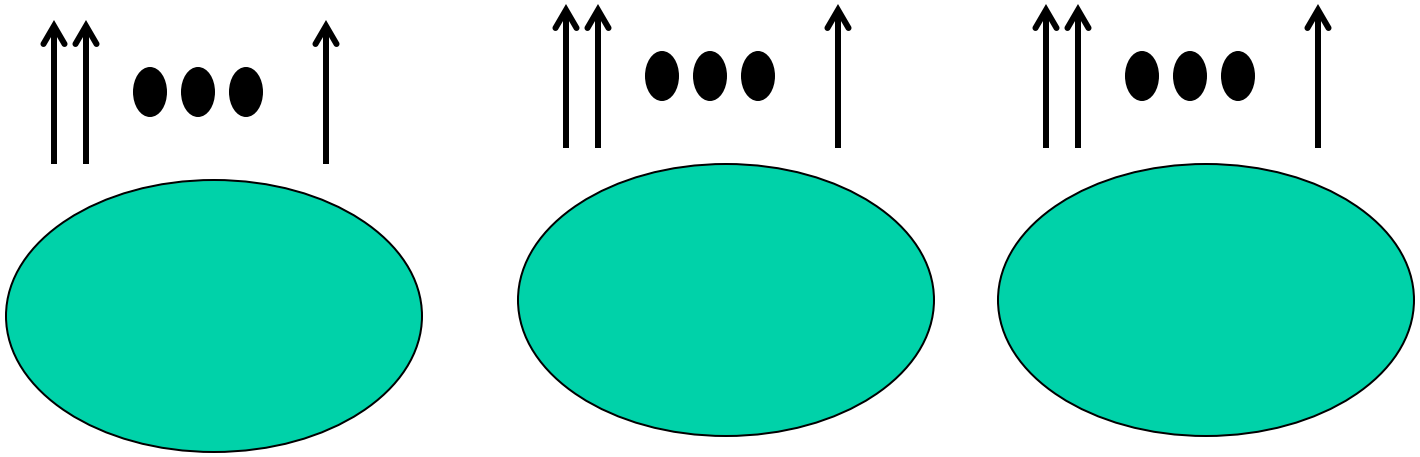
SERVICES

Services

Secondary/Implicit Impact

Impacts Pollution

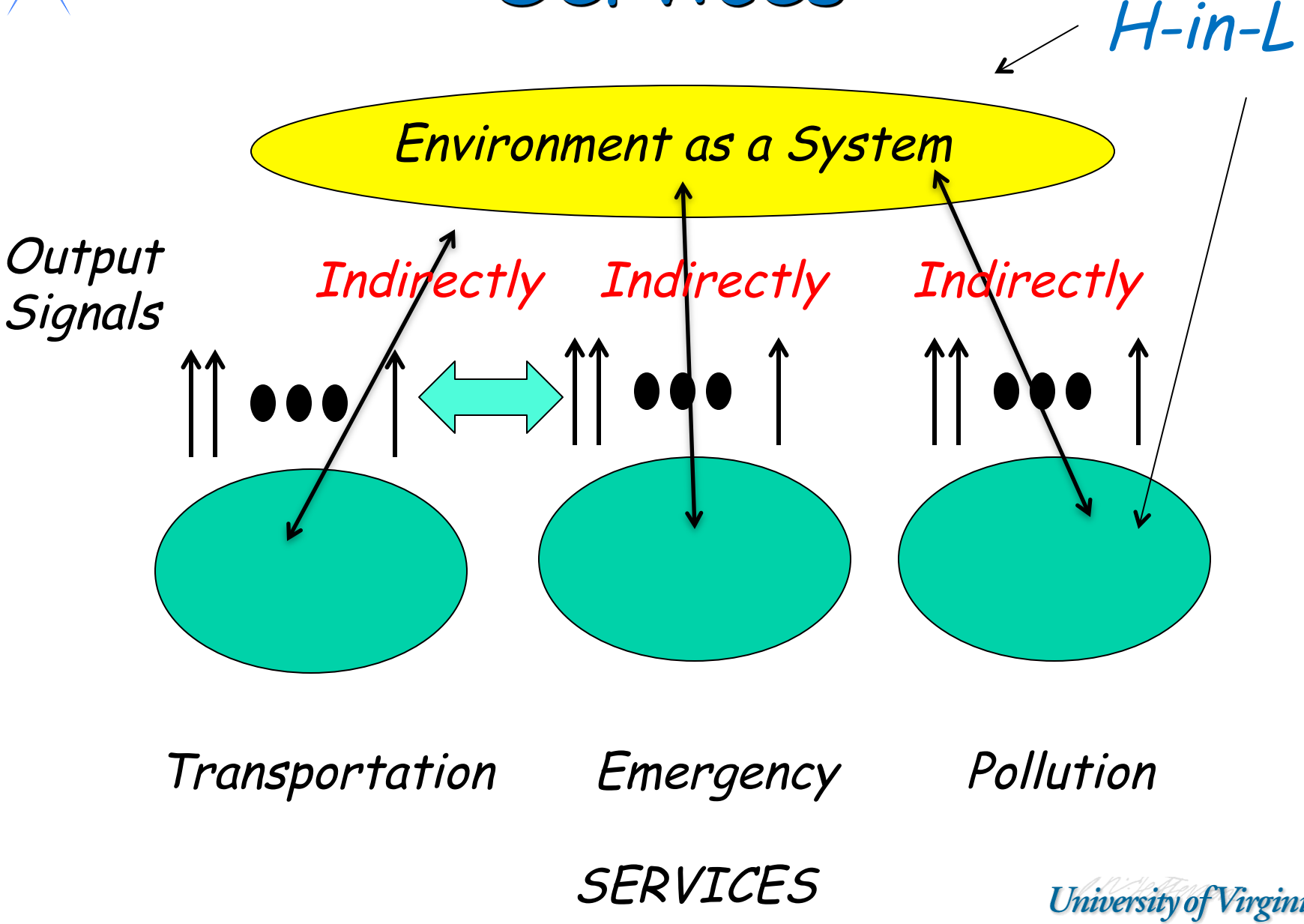
Impacts Transportation



Transportation *Emergency* *Pollution*

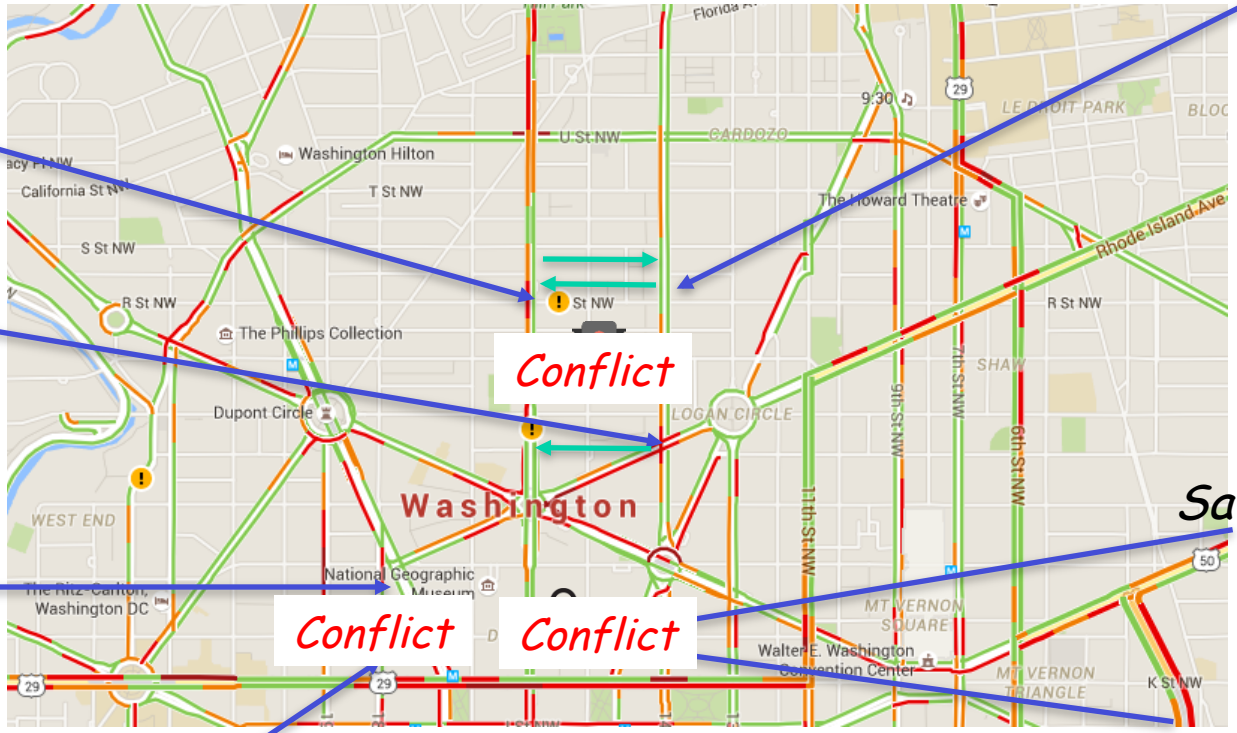
SERVICES

Services



Conflicts/Complicated

- Conflicts among Services in Smart Cities



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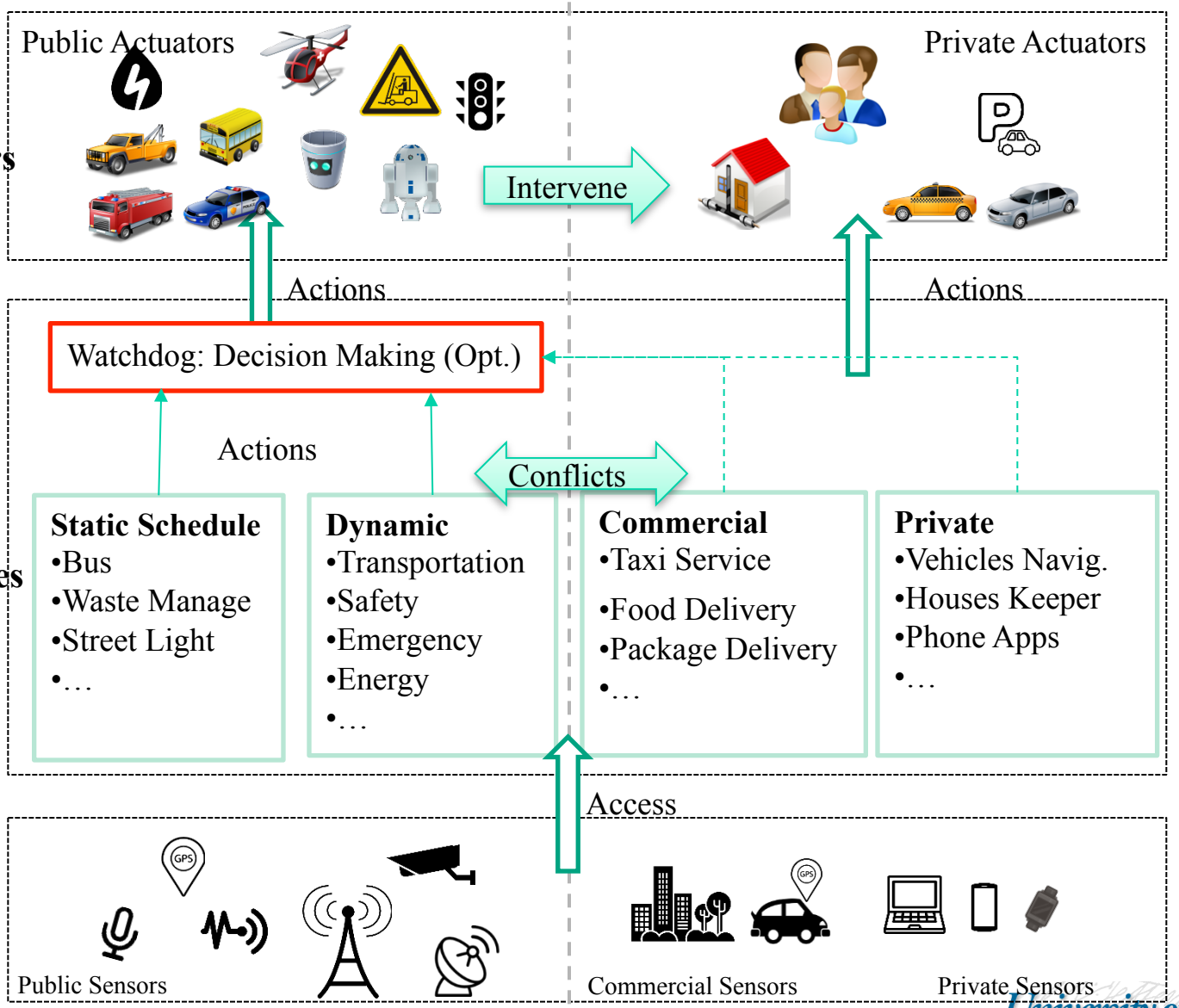
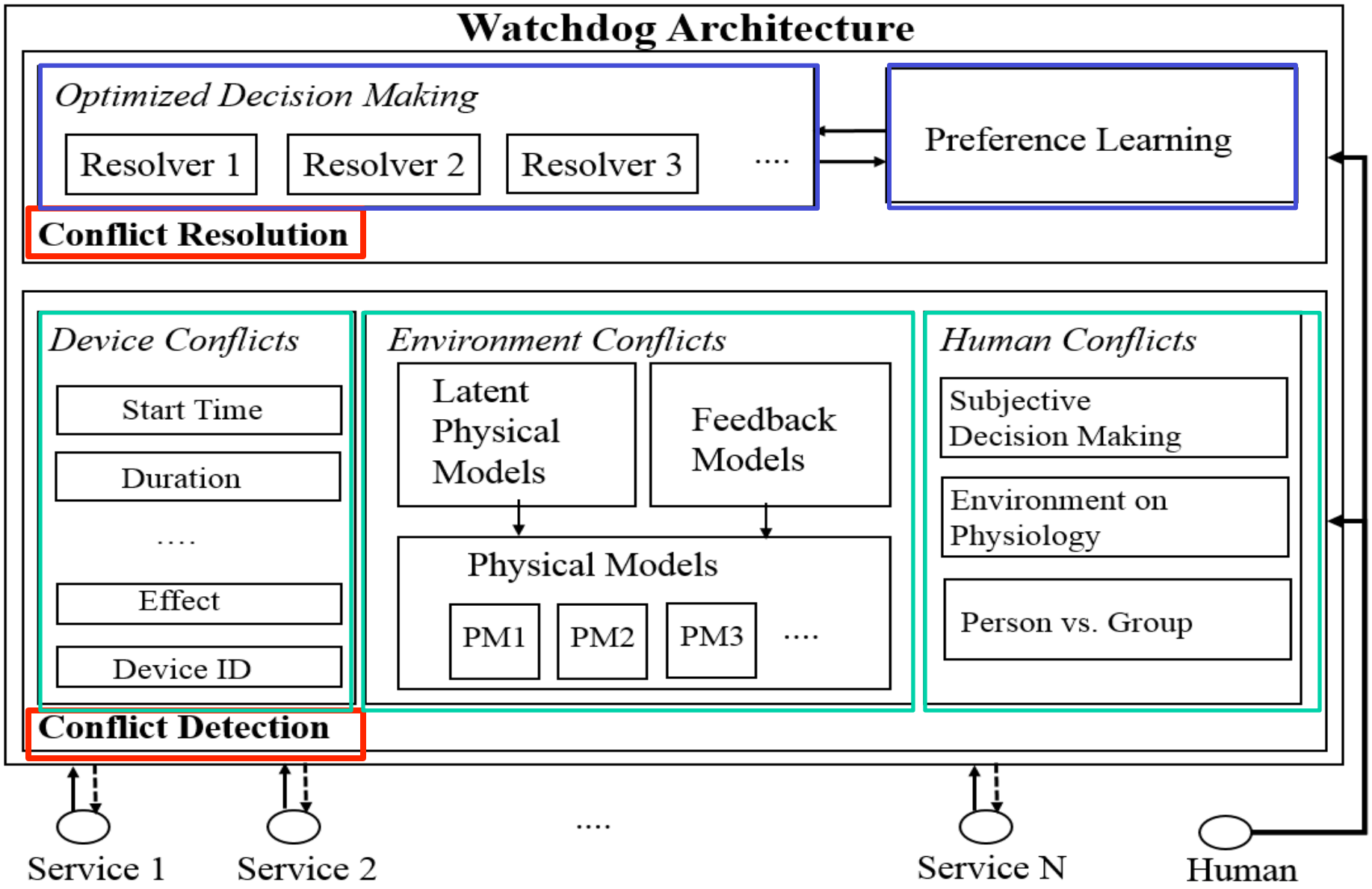
Smart Cities



Watchdog Architecture

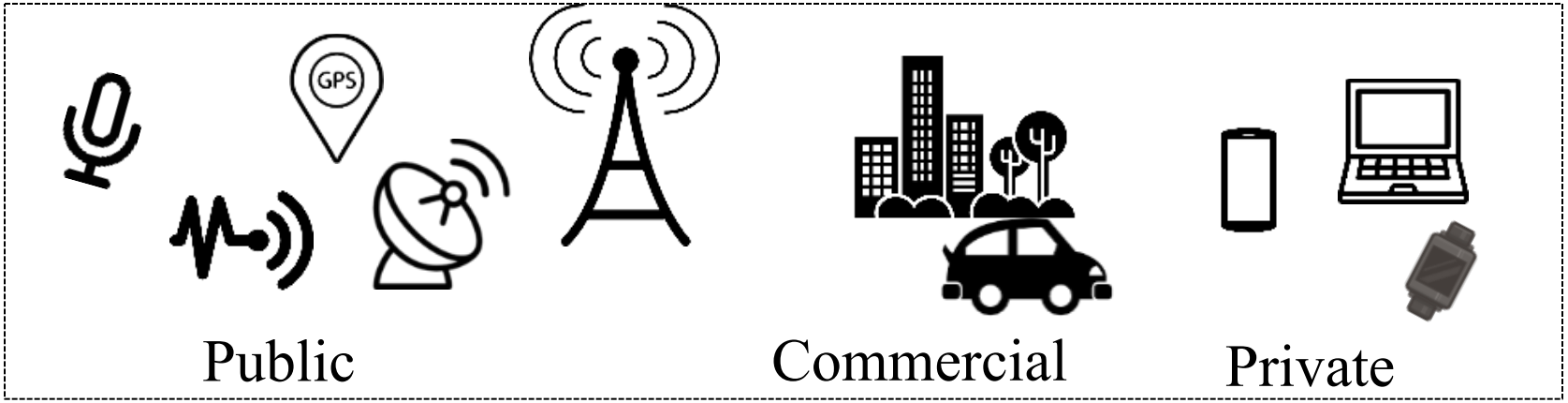


Scaling and Density Issues

- 10,000 devices/person
  - Ownership
  - Configuration and Reconfiguration
  - Management
  - Sharing –A sensing and actuation utility
- Runtime Dynamics Paramount
  - Interference/Conflicts
  - Safe
  - Operational

Need a S&A Utility

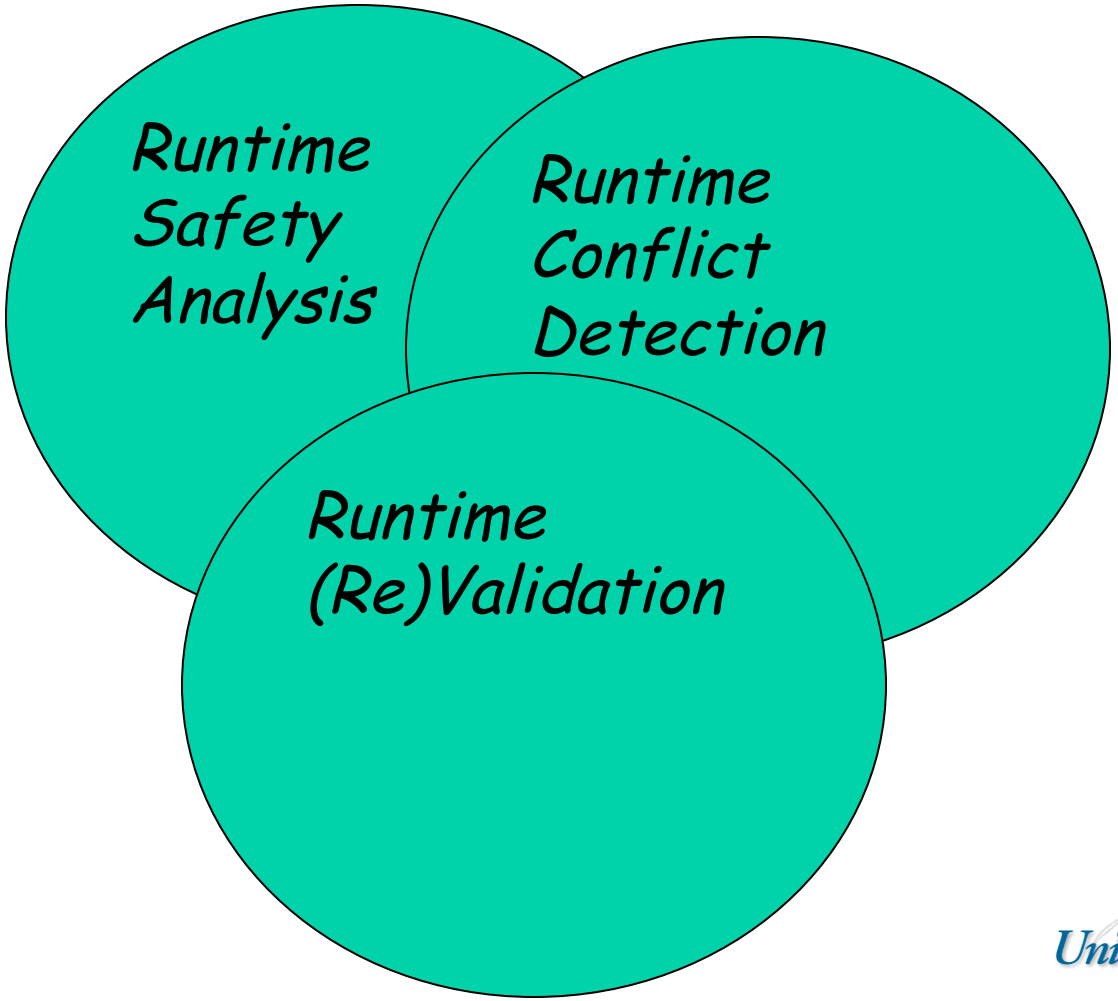
Sensor and Actuation Layer



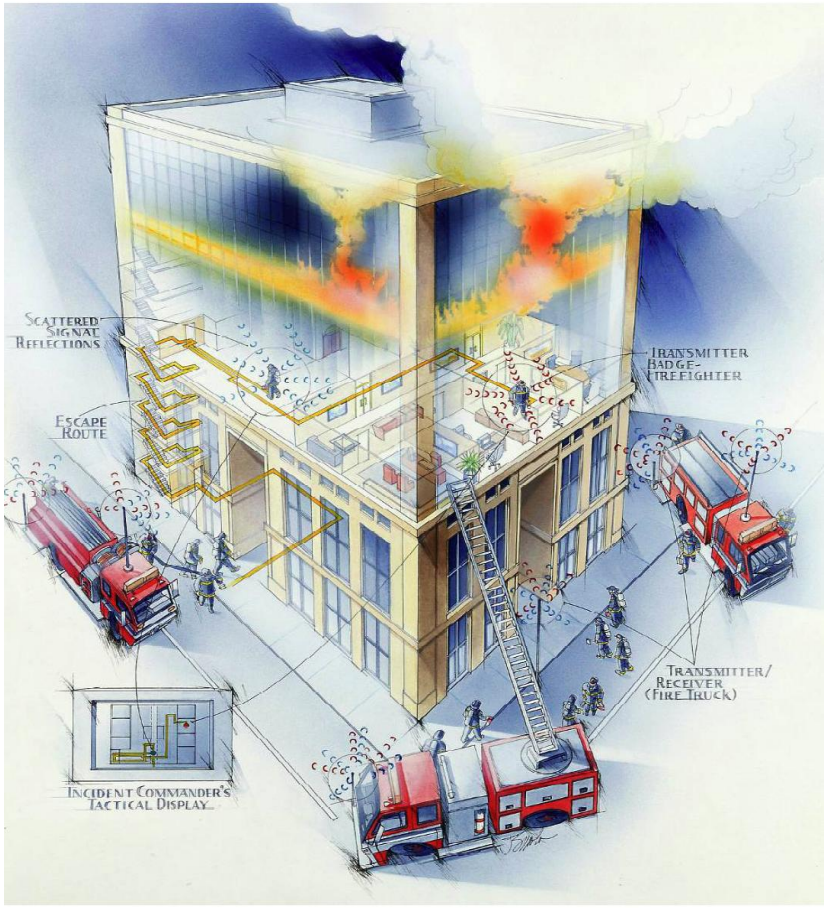
Ownership Sharing Management

Runtime Dynamics

Three related needs



(Re)Validate: Run Time Assurance (RTA)



- Safety Critical
- Long Lived
- Dynamics of Environmental Changes
- Influences Correctness

Validate-Aware Cyber

- Validate and Re-validate that system is still operational (at semantics level)
  - Emulate sensor readings
  - Reduce tests: focus on key functionality
  - Overlap tests and system operation
  - Evolve required tests
  - SW design for ease of RTA

See Run Time Assurance paper in IPSN 2010.

Summary: IoT/CPS

- Runtime Realisms are paramount
- Incredibly complex runtime dynamics
- Scale, density, uncertainty, runtime safety, validation and conflict detection, personalization, …