CYPRESS: Cyber-Physical RESilience and Sustainability

Dependability Techniques for Instrumented Cyber-Physical Spaces

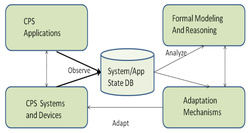
Grit Denker, Nikil Dutt, Sharad Mehrotra, Mark-Oliver Stehr, Carolyn Talcott, Nalini Venkatasubramanian

University of California, Irvine and SRI Intl.

OBJECTIVES

- Explores techniques for dependability and resilience and in cyber-physical spaces.
- Semantic foundations, cross-layer system architecture and adaptation services to improve dependability.
- Reflective (observe-analyze-adapt) Architecture

Digital state representation of ICPS guides a range of "safe" adaptations to achieve end-to-end ***infrastructure*** and ***information*** dependability



Infrastructure Dependability Techniques

Infrastructure component errors/failures - Device Failures, Network Failures, Overload, Congestion

Load Balancing for scalable processing

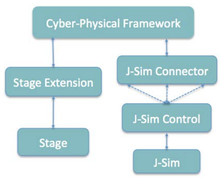
- Complex Operators required for event processing are scheduled to execute on processing units so as to minimize average processing latency
- NP-hard Problem: Hill-climbing heuristics, Histogramming techniques

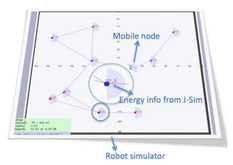
Using Multiple Access Networks

- Design of a multi-network management system that manages a hierarchical network structure with stable, resource-rich nodes closer to the root
- Scheduling mechanisms to avoid radio interference; cost-effective network state collection techniques; Lightweight query processing mechanisms

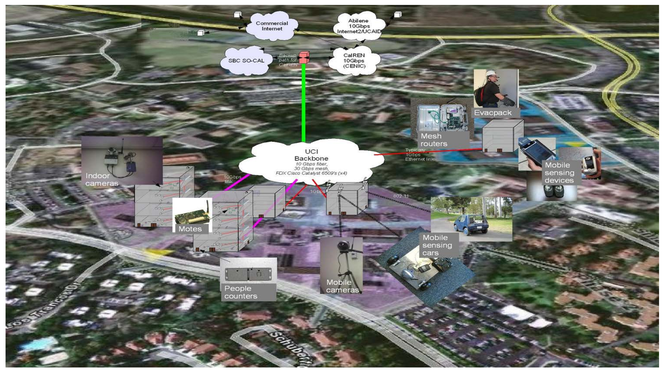
Exploiting Mobility

- Mobility brings adaptability, resilience, flexibility, sustainability etc. Compute trajectory for mobile nodes while balancing tradeoffs among energy, latency, buffer size, coverage and so on.
- Design of generalized simulation-based framework for mixed mobile/fixed sensing platforms: Integration of Stage Player (robot simulator) and network simulators;





CASE STUDY ---- Camera Surveillance and Fire Situational Awareness



Scenario 1: Room/Building Occupancy

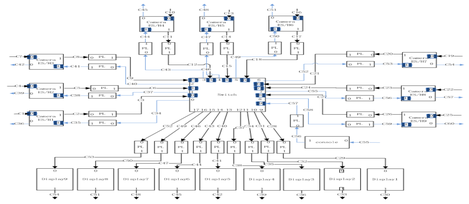
Problem: Hallway cameras cannot observe people trapped in offices.

Technique: Deduce number of people trapped, by determining entry/exit information for each room in real time.

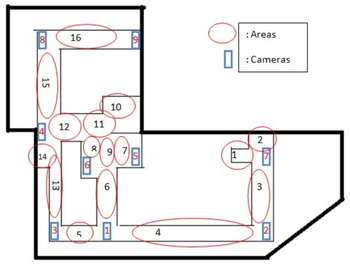
Scenario 2: Sensor Damage

Problem: Cameras might be burned, disconnected and/or destroyed.

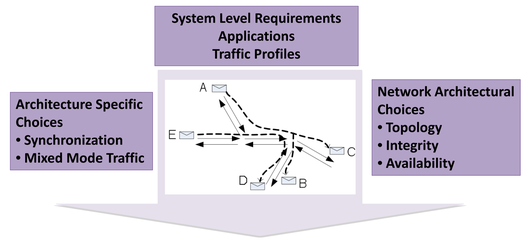
Technique: Leverage adjacent cameras and use reasoning principles to predict which areas people might be trapped in.



Scenario 3: Network Infrastructure Damage
• Fault analysis of camera network using formal methods; exploit camera storage and mobile collection; use semantics to ensure capture and coverage



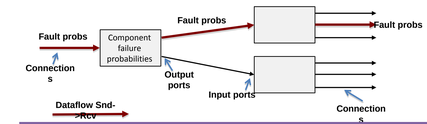
MODELING AND REASONING ABOUT RELIABILITY



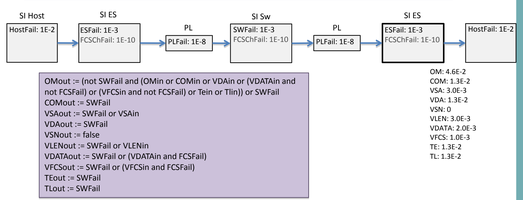
Performance Fault Free Analysis Tools
- Rate-Constrained: Check latency/utilization/ buffer size
- Time-Triggered: Check schedulability

Probabilistic Fault Analysis Tool
- Check Fault Tolerance Properties

- **Analyze selected points based upon a project's domain expertise**
- **Support architecture design choices through network architecture design space characterization at network components, hosts, and application level redundancy management**
- **Integrates latency, utilization, buffer size and fault tolerance analysis scalable to practical network architectures**

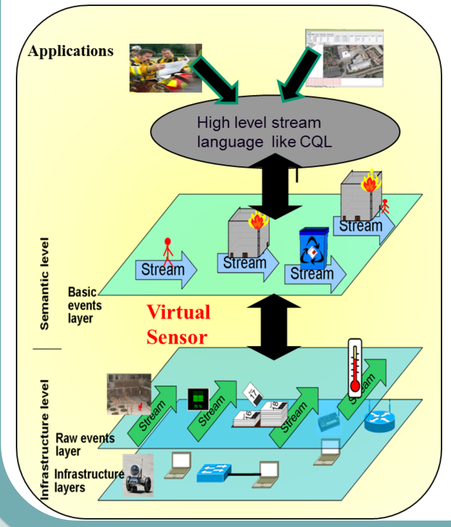


Analized Faults
Silent
Omission
Commission
Invalid (Src Adr, Dest Adr, Seq Num, Length, Payload/Data, Frame Check Seq)
Untimely (time early, time late)



Fault propagation/introduction rule: SI Switch, TT Traffic

Semantic Middleware for ICPS



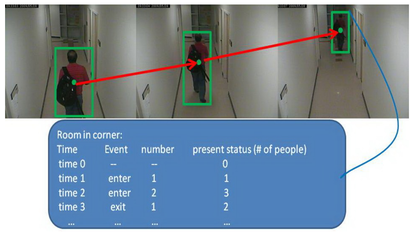
Information Dependability Techniques

Data Interpretation errors/failures - Uncertainty in Processing (e.g. speech/image processing), Contextual errors (e.g occlusions)

Data Cleaning via Entity Resolution

•Face Recognition is challenging in a resource-constrained environment

•Connect the problem of person identification with entity resolution using RelDC (a graph-based entity resolution framework)



Room in corner:

Time	Event	number	present status (# of people)
time 0	--	--	0
time 1	enter	1	1
time 2	enter	2	3
time 3	exit	1	2
...	...	...	...

Adaptive Actuation for Event Detection

•Balance event capture vs. accuracy

•Implement a lightweight, real-time scheduler applied in zoom-enabled camera network

•Modeled as Partially Observable Markov Model(POMDP)

Contact: Nalini Venkatasubramanian (nalini@ics.uci.edu)