Efficient Mapping and Management of Applications onto Cyber-Physical Systems

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Motivation

- Cyber-Physical Systems: Richly heterogeneous devices (mobile devices, home electronics, taxis, robotic drones, etc.) that together gather sensor data, analyze it, and coordinate large-scale actions in response to it.
- Challenge: How to program CP Systems?

Prior Approaches

- Simplifications to reduce complexity.
  - Assume homogeneous systems
  - Program for one particular deployment
- Current approach leads to "brittle" systems.
  - Deployments with multi-generation devices
  - Multiple scenarios with different mobility capabilities

1. How to meet performance and accuracy goals while managing power and other scarce resources?
2. How to select which devices to use? From a static or dynamic pool of resources.
3. How to support dynamic adaptivity within a single deployment? How to support portable operation across different deployments?

Our Project

1. Abstraction layer to allow CPS applications to express application needs
   - Coverage and sensing requirements
2. Device attribute catalog to summarize local nodes and their capabilities
   - Sensing capabilities, probability of success, accuracy, etc.
3. Model, Prediction and Control mobility of nodes
   - Different types of motion (people, fixed sensors, robot, etc.)

Acknowledgments

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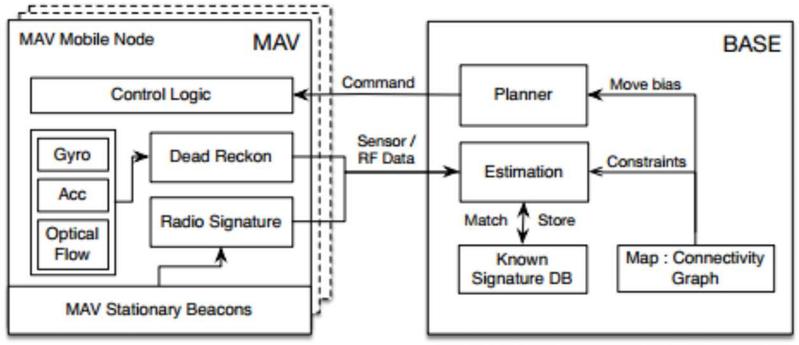
Testbed: Minimalistic Controlled Mobile Sensor

- Test Nodes Adapt to changing environment, reassign task base on node capabilities and localized failures
- Hardware testbed for indoor Micro Aerial Vehicles (MAV)
- Dynamic coverage estimation: by obtaining in-network relative path signatures, then assign task to multiple nodes to compute signature paths

Adaptive Motion Planning and Deployment

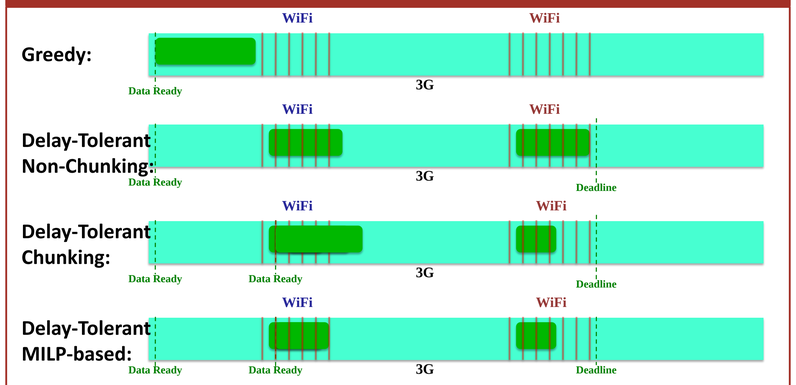


- Determine deployment/coverage/location status using macro and micro changes in environmental signatures in the system.
- Macro: Utilizing landed nodes to determine if the sensor is in new or old areas, to incrementally increase deployment coverage of a building.
- Micro: Sensing coverage estimation by obtaining
  - 1) relative motion path signatures
  - 2) dead resigning signatures,
  - 3) similarity between prior signatures.
- Dynamic allocate task allocation allow nodes to more efficiently coordinate and predict the current sensing coverage of an area.
  - Bias motion to areas of lower coverage (application needs) and higher demand (system needs).

Select Media Coverage

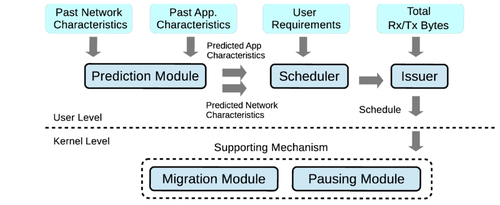
- Michigan Radio "Could drones detect leaks at oil and gas sites?", Mar 2015. http://michiganradio.org/post/could-drones-detect-leaks-oil-and-gas-sites#stream/0
- NBC News "Swarms of Drones Could be the Next Frontier in Emergency Response", Jan 2014.
- Mark van der Feyst, Eric Wissner & James Petruzzi, "Residential Fire Rescue", Cengage Learning, Delmar, March 2013.

Predictive scheduling for Low-Energy Comms.

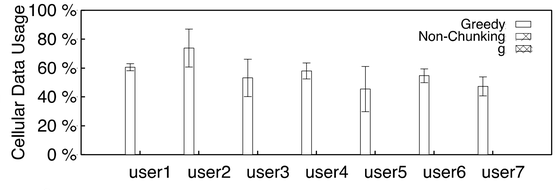


- Approaches vary in reliance on workload and environmental predictions, and in degree of delay tolerance.

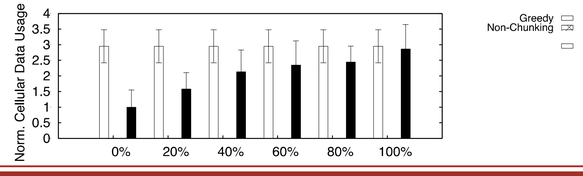
Comms Optimization: Android Implementation



Perfect Prediction



Effect of Prediction Errors



Select Publications

- A. Purohit, S. Carpin, P. Zhang. Adaptive Planning for Deployment of Micro-Aerial Sensor Swarms. Intl. Workshop on Robotic Sensor Networks, CPSWeek, 2014.
- O. B. Yetim and M. Martonosi. Adaptive Delay-Tolerant Scheduling for Efficient Cellular and WiFi Usage. IEEE Intl. Symp. on a World of Wireless Mobile and Multimedia Networks. June, 2014.
- A. Purohit, Z. Sun, S. Pan, P. Zhang, "SugarTrail: Indoor Navigation in Retail Environments without Surveys and Maps", IEEE SECON 2013.
- D. Mir, S. Isaacman, R. Caceres, M. Martonosi, and R. Wright. DP-WHERE: Differentially Private Modeling of Human Mobility IEEE BigData, Oct. 2013