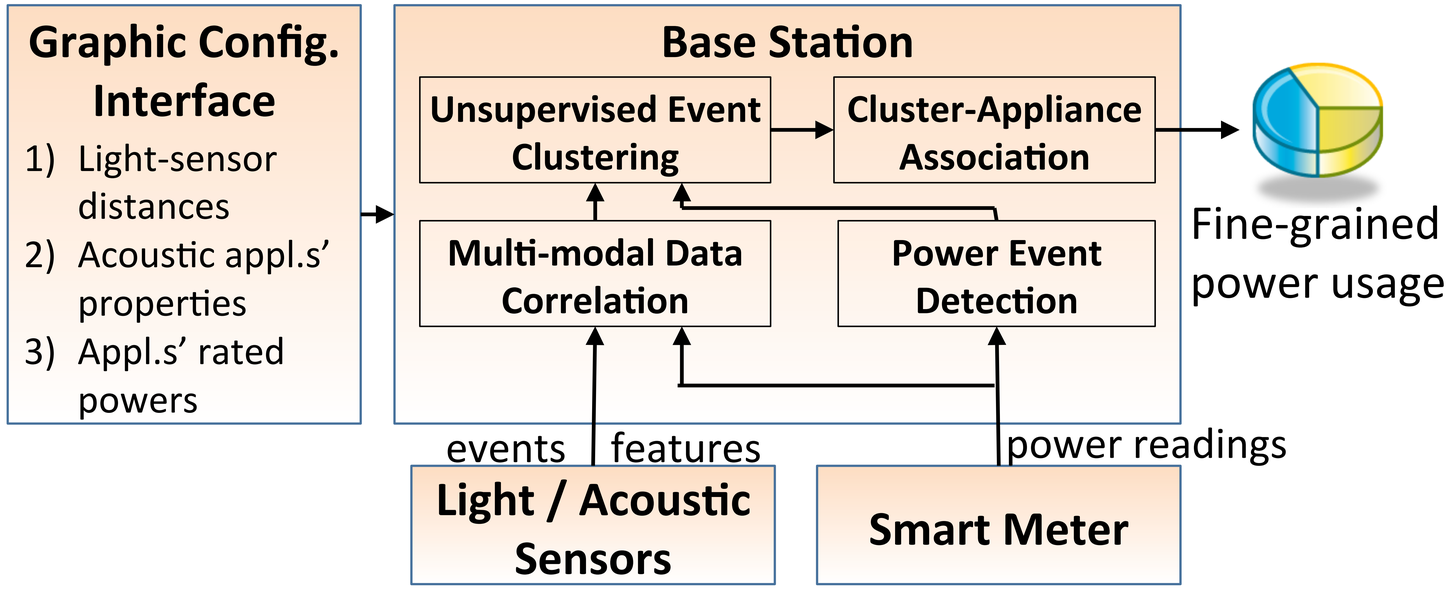
Supero: A Sensor System for Unsupervised Residential Power Usage Monitoring

Motivation

- Fine-grained power usage monitoring
  - *Direct sensing*: In-line meters is inapplicable to hardwired appliances
  - *Indirect sensing*: Labor-intensive training process
- 90% power consumption can be captured by light sensor + acoustic sensor + smart meter
- **Our goal: Ad hoc sensor deployment, training-free, easily obtained prior info**

System Architecture



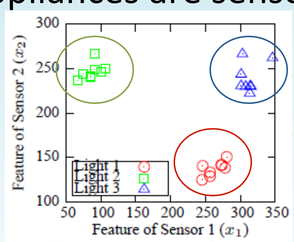
Challenges and Solutions

Environment dynamics and sensor errors

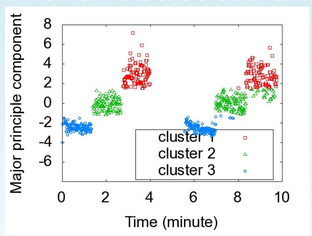
- Miss detections (due to weak signal)
  - Fusion among sensors in short moving window
- False alarms (window blinds events & conversations)
  - Discard event if the change of power is too small

Complicated sensor-appliance relation

- Appliances are sensed by different subsets of sensors



K-means on light intensity changes



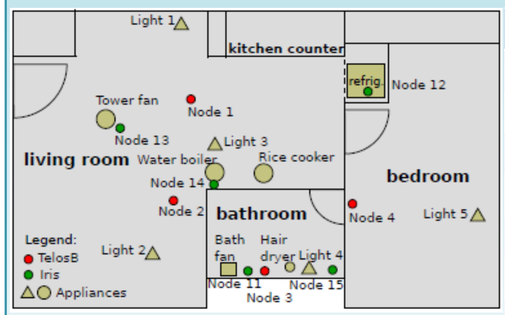
Clustering results for a 3-speed fan

- Which appliance causes a cluster of event?
  Linear assignment problem (Hungarian algorithm)

Implementation

- Sensors: TelosB & Iris from Memsic Inc.
  Smart meter: TED5000 Base station programs: GNU Octave
  Groundtruth meters: radio-enabled Kill-A-Watt

Deployments and Evaluation in 5 Homes



4 TelosB + 5 Iris in 40m² apartment for 7 days

Deployment time by volunteers

- One-bed room apt.: 1.5 hours
- 2-story house: 3 hours

Appl.	KAW	Supero			ViridiScope		
Name	kWh	Watts	kWh	Err (%)	Watts	kWh	Err (%)
Light1	4.14	154	4.17	0.5	152	4.11	0.9
Light2	4.96	150	4.96	0.1	149	4.92	0.8
Light3	6.15	155	6.24	1.4	155	6.25	1.7
Light4	1.45	62	1.45	0.1	63	1.48	1.7
Light5	0.39	105	0.39	0.2	110	0.41	5.5
Boiler	0.48	1493	0.48	0.5	0	0	100
T. Fan	0.15	30	0.21	50	24	0.24	66.2
Cooker	1.00	499	0.98	2.2	511	1.01	0.8
Dryer	0.09	467	0.07	19.2	3	0.02	73.2
Fridge	12.22	143	11.8	3.7	127	11.8	3.2
B. Fan	N/A	50	0.12	N/A	0	0	N/A
Router	2.12	12	2.03	4.3	18	3.04	43.3
Avg Err				**7.5**			**27.0**

Dennis E. Phillips, Rui Tan; Mohammad-Mahdi Moazzami; Guoliang Xing; Jinzhu Chen. Supero: A Sensor System for Unsupervised Residential Power Usage Monitoring. The 1st International Workshop on Non-Intrusive Load Monitoring, CMU, May 7, 2012.