CS428: Information Processing for Sensor Networks

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Key Research Challenges at the Node and System Levels

The setting:
- power conservation is important:
  - untethered node operation
  - communication far more expensive than computation (sensing, too)
- *ad hoc* deployment in noisy, adverse environments
  - self-initialization, self-configuration
  - robustness to individual node failure
“Semantic” Routing and Networking

- We want to address spatial locations or information, not individual nodes
- “Content” and “address” in a message get intermixed
- How do we help information providers and clients find each other?

Directed diffusion
Geo-routing
In-Network Processing

- Information aggregation on the way to the destination
- Need to balance quality of paths with quality of information collected
- Are there “application-independent” paradigms of information aggregation?

Temperature aggregation
Power-Aware Sensing and Communication

- Variable power systems
- Let most sensors sleep most of the time; paging channels
- Exploit correlation in readings between nearby sensors
- Load-balance, to avoid depleting critical nodes
Sensor Tasking and Control

- Decide which sensors should sense and communicate, according to the high-level task – a non-trivial algorithmic problem.
- Direct sensing of relations relevant to the task – do not estimate full world state.
Enable Data-Base Like Operations

- Data only available right after sensing operation
- Dense data streams must be sampled, or otherwise summarized
- Must deal with distributed information storage – "where is the data?"

(a) Lossless Isobars

Field isolines
Self-Configuration for Ad-Hoc Deployment

- Network size makes it impossible to configure each node individually.
- Environmental changes may require frequent re-calibration.
- Network must recover after node failures.

Iterative localization
New System Architectures

- Resource constraints require close coupling between the layers
- Can we define application-independent programming abstractions for sensor nets?

A sensor net stack?

<table>
<thead>
<tr>
<th>User queries, external databases</th>
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<tbody>
<tr>
<td>In-network: application processing, data aggregation, query processing</td>
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<tr>
<td>Data dissemination, storage, caching</td>
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<tr>
<td>Adaptive topology, geo-routing</td>
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<tr>
<td>MAC, time, location services</td>
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<tr>
<td>Phy: comm, sensing, actuation, SP</td>
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Various Issues

- Integration of sensors with widely different modalities
  - High data-rate sensors (cameras, laser scanners)
- Sensor mobility
- Actuation

Distributed robotics
Conclusion

Ubiquitous networked sensors provide a dense spatial and temporal sensing of the physical world.

They potentially provide low-latency access to information that is highly localized in time and space, and thus provide a way to sense and act on the physical world beyond what has been possible up to now.

Sensor networks raise many research issues at the physical node level, the system architecture level, and the algorithm deployment level.