# Challenges in designing information processing sensor networks

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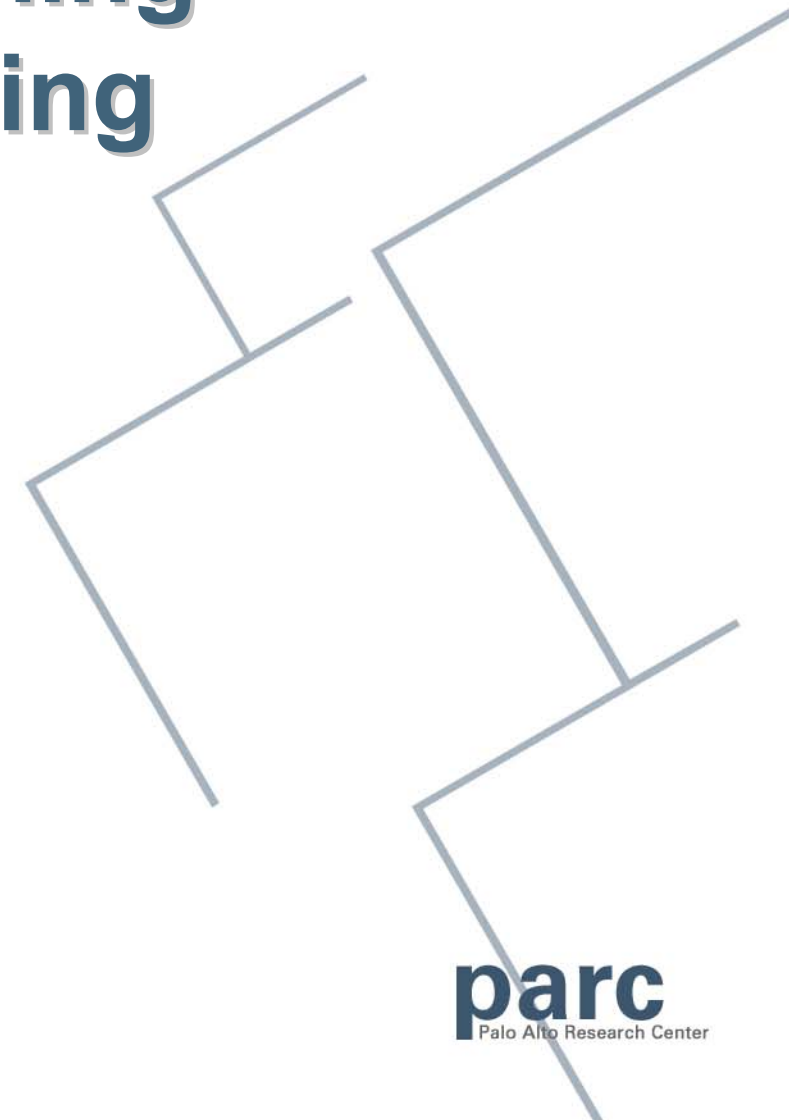

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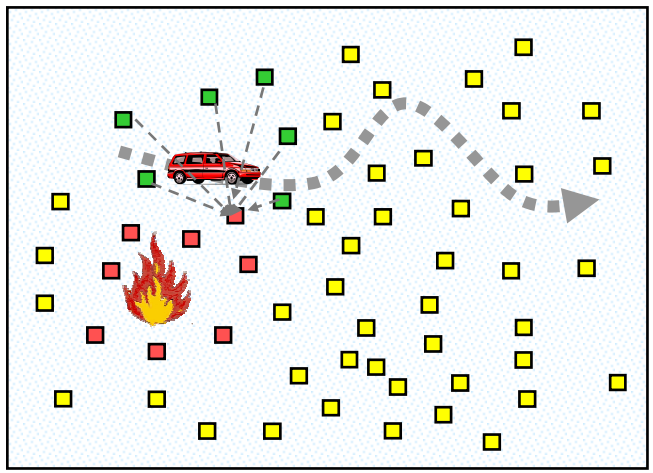
# Collaborative processing in sensor networks



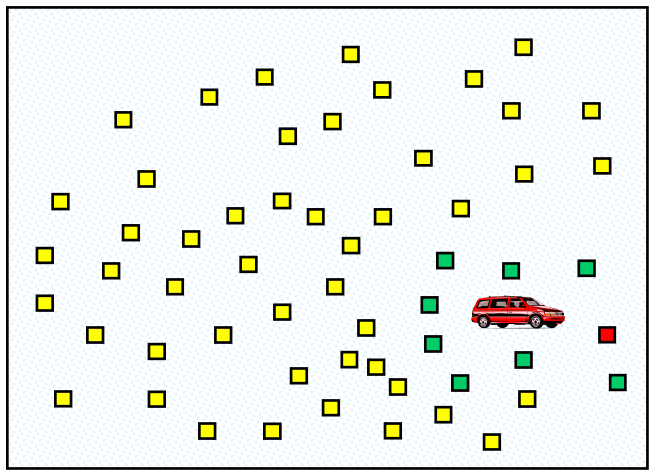
- What information to gather and communicate? And how often?
- Which nodes should participate in sensing, processing, or communication?
- How should the information be migrated?
- What is routing or querying in this context?

Moving from complexity-centric view of algorithm design to utility-based design:

- What information is critical for the high-level tasks?
- What is the cost of accessing the information?

# Collaborative processing

## – Group formation in sensor networks



- Information needs and resource constraints define who should participate in the processing groups
- Group membership (e.g. location) defines the behavior of a node

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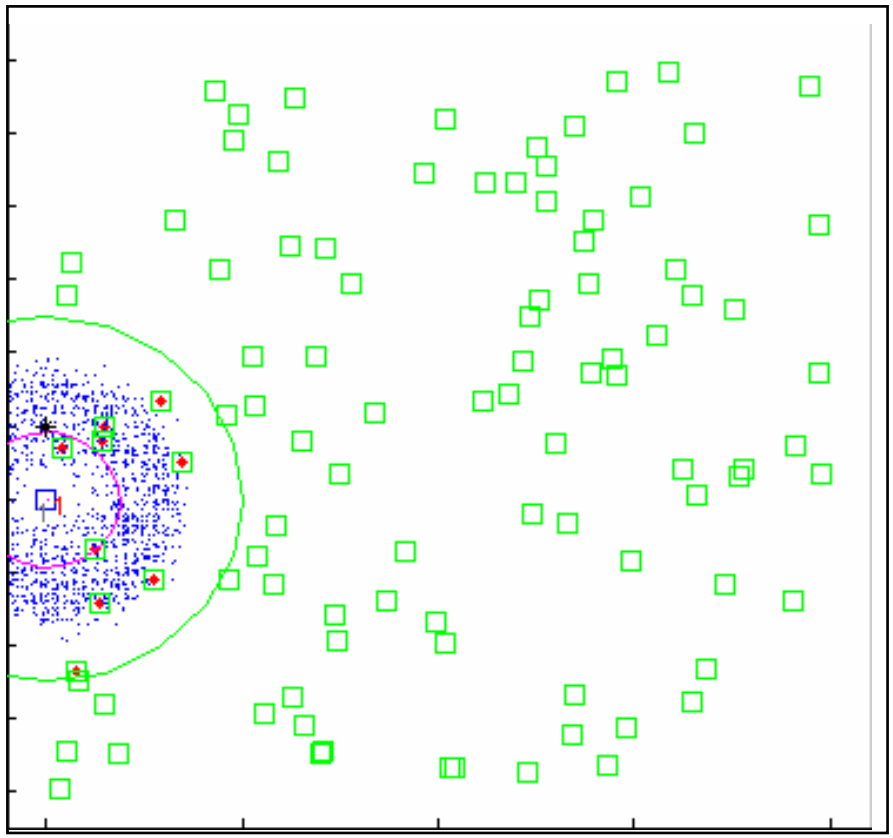
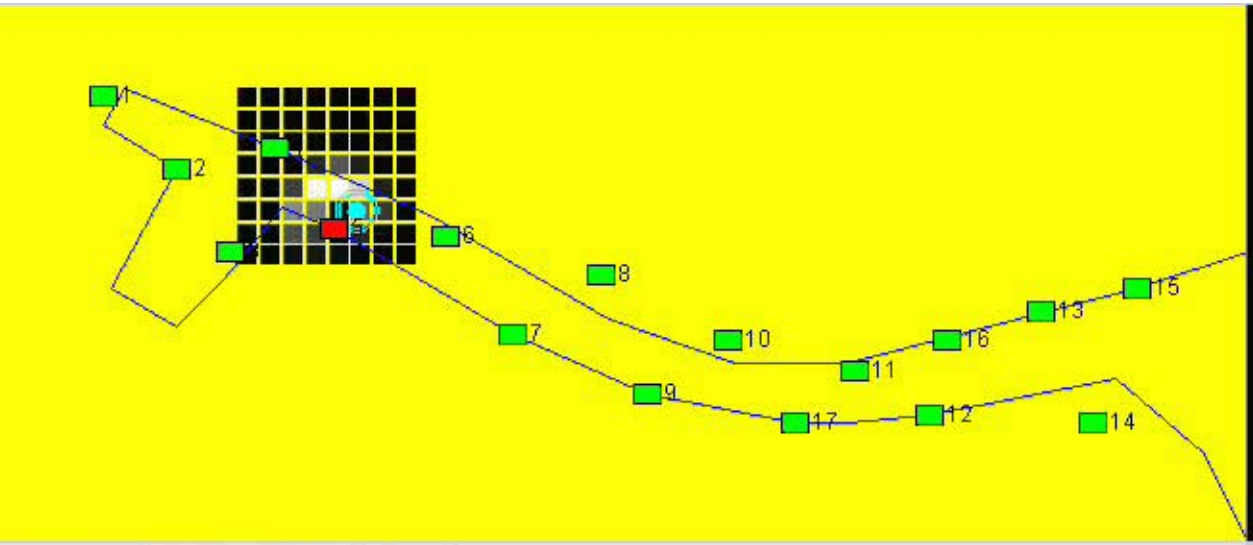
# Information-based group formation

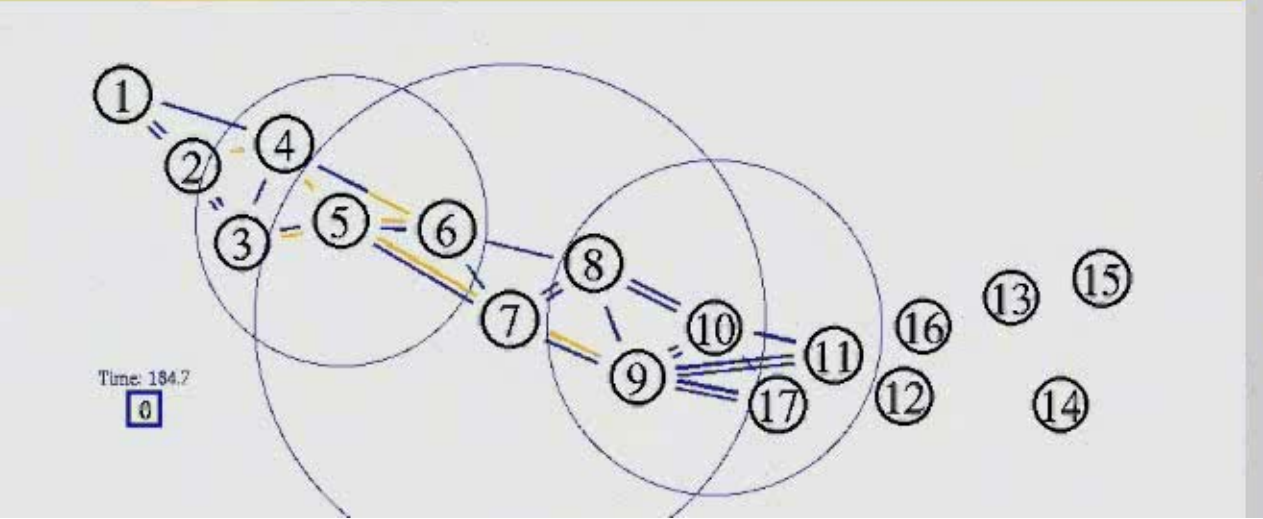


A leader node (blue square) carries belief state

- Choose sensor in the neighborhood with good information
- Hand off current belief to chosen sensor (new leader) and update

# An example of collaborative groups




Leader Node

Non-leader Node

GPS ground truth

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ISI

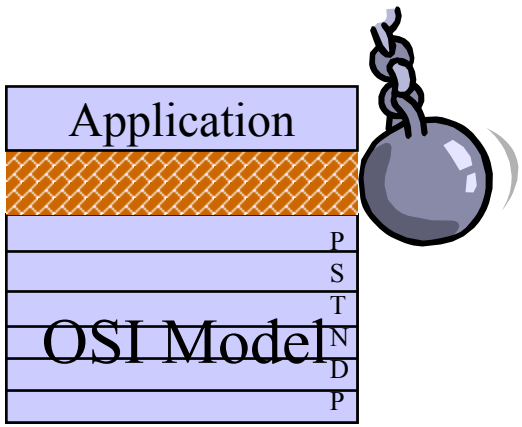
Data Packet

Control Packet

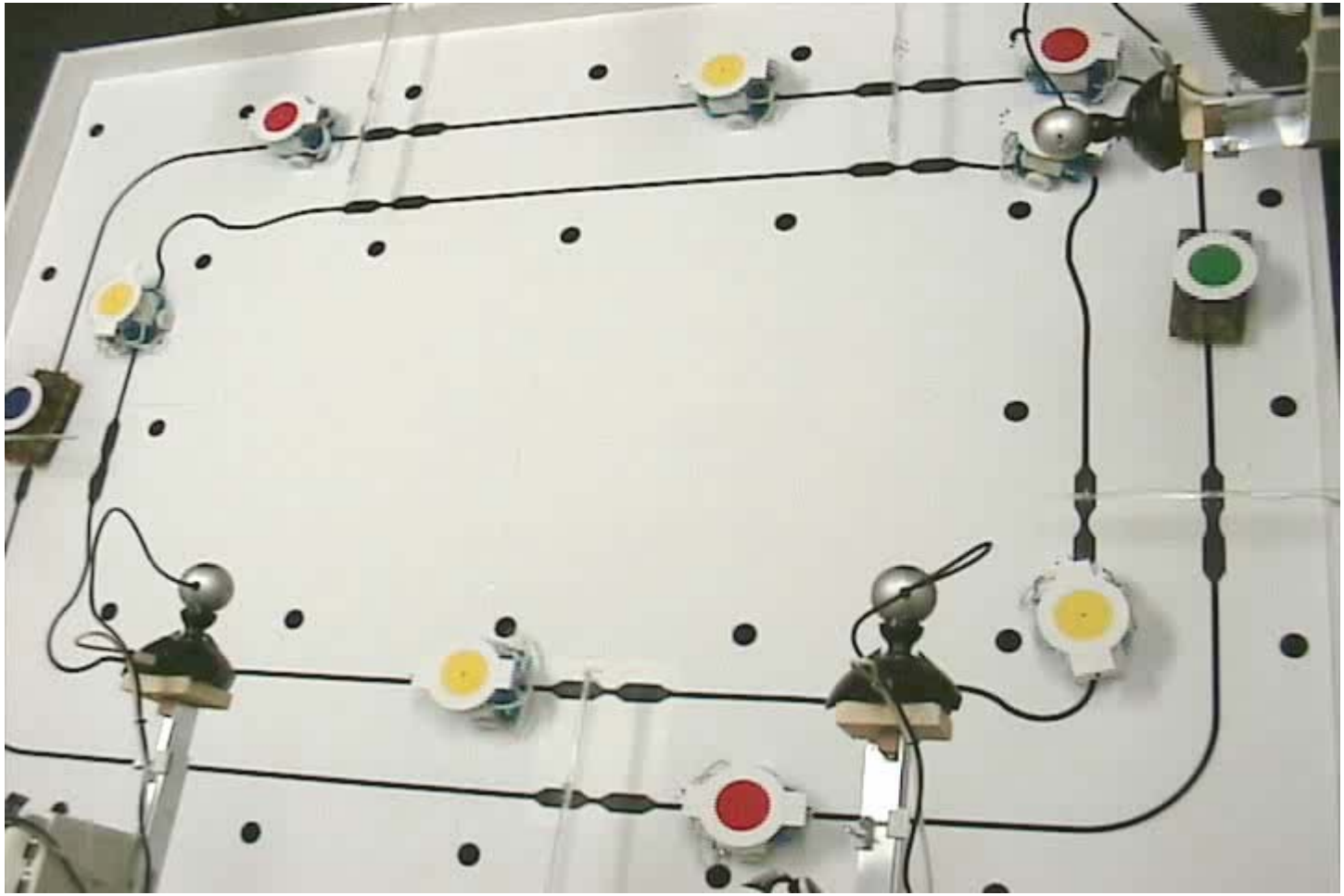
Broadcast control

# Cross-layer interactions

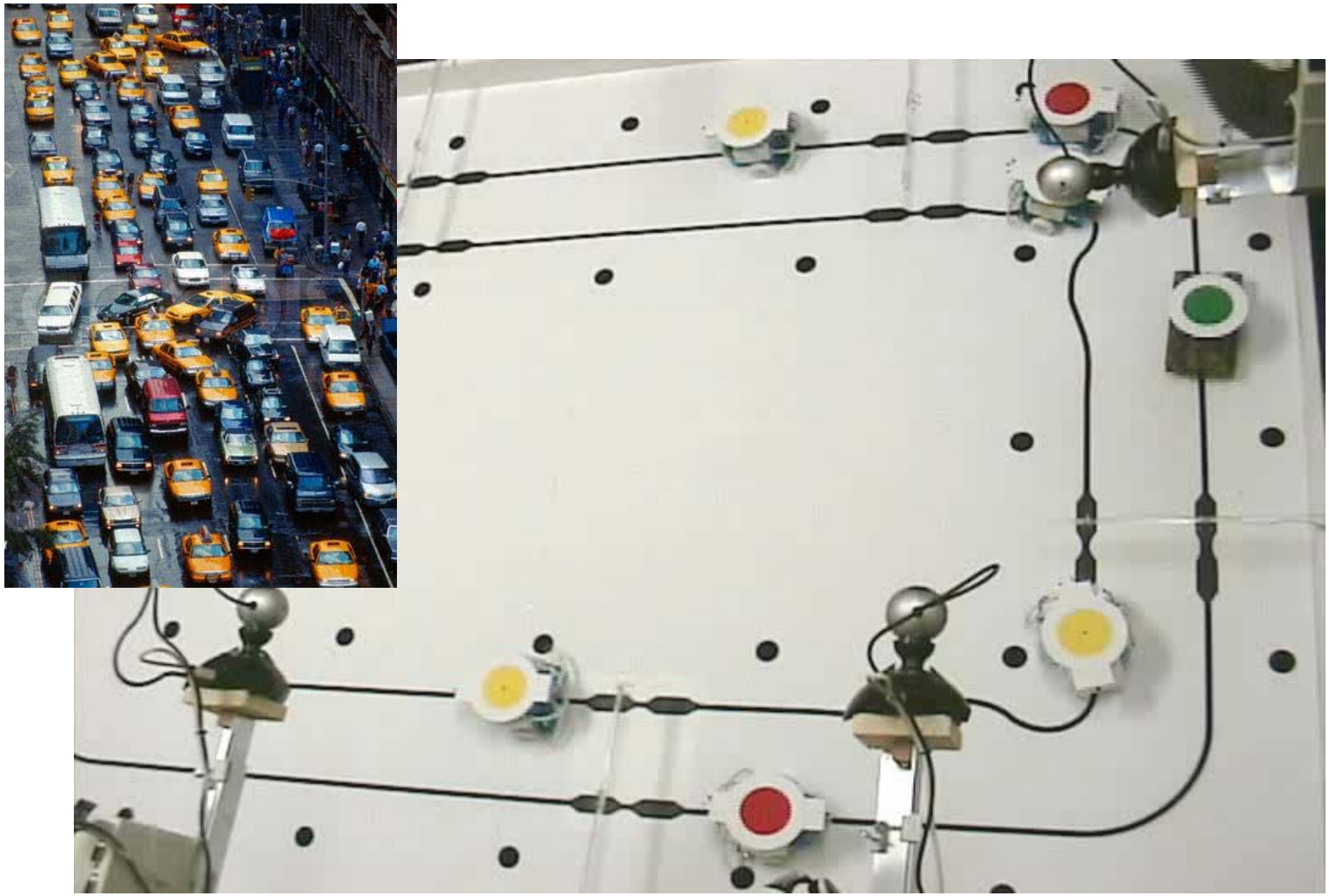
In sensor networks, networking is intimately coupled with sensing, interaction, and control needs and hence application semantics




- Break down traditional barriers of network stack
  - Consider both communication cost *and* application requirements to plan routes and task sensors
- Data-centric and ad-hoc
  - Address nodes based on geography and capability, not by name
- Group management vital to scalability
  - Limit data propagation to sensors relevant to measurement at hand



**What objects to pay attention to? What to ignore? Which aspects of the objects (e.g., location, identity) are of interest to the high-level tasks?**



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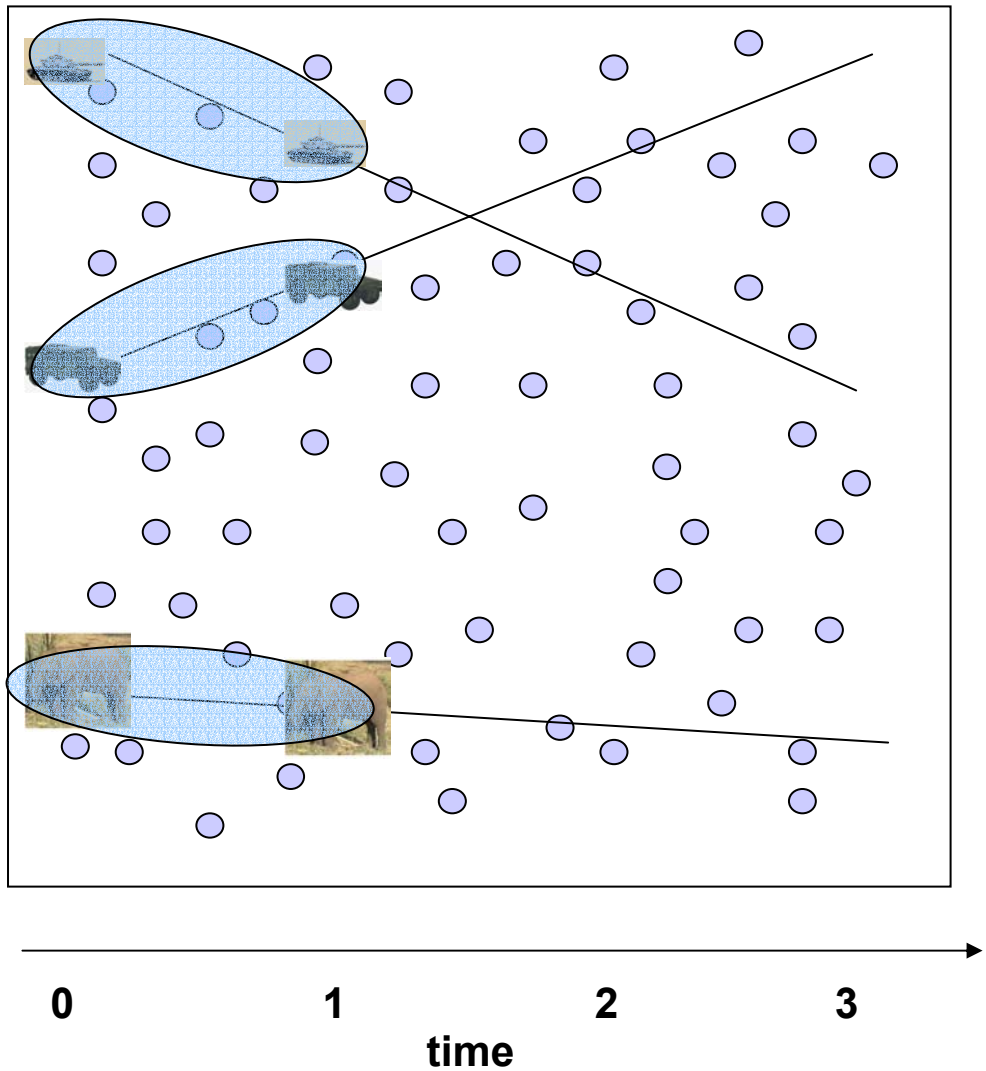
# Mixing of events

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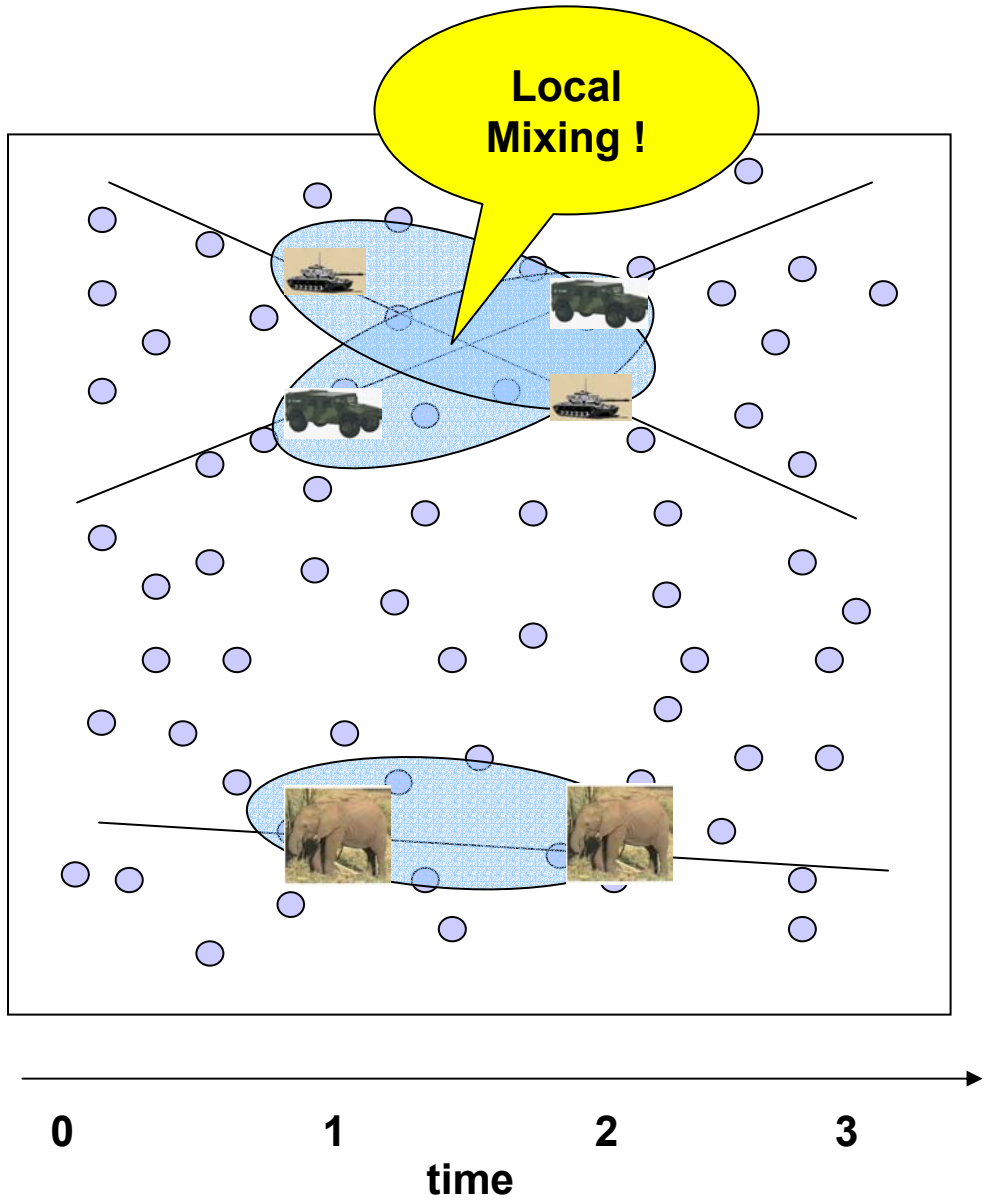


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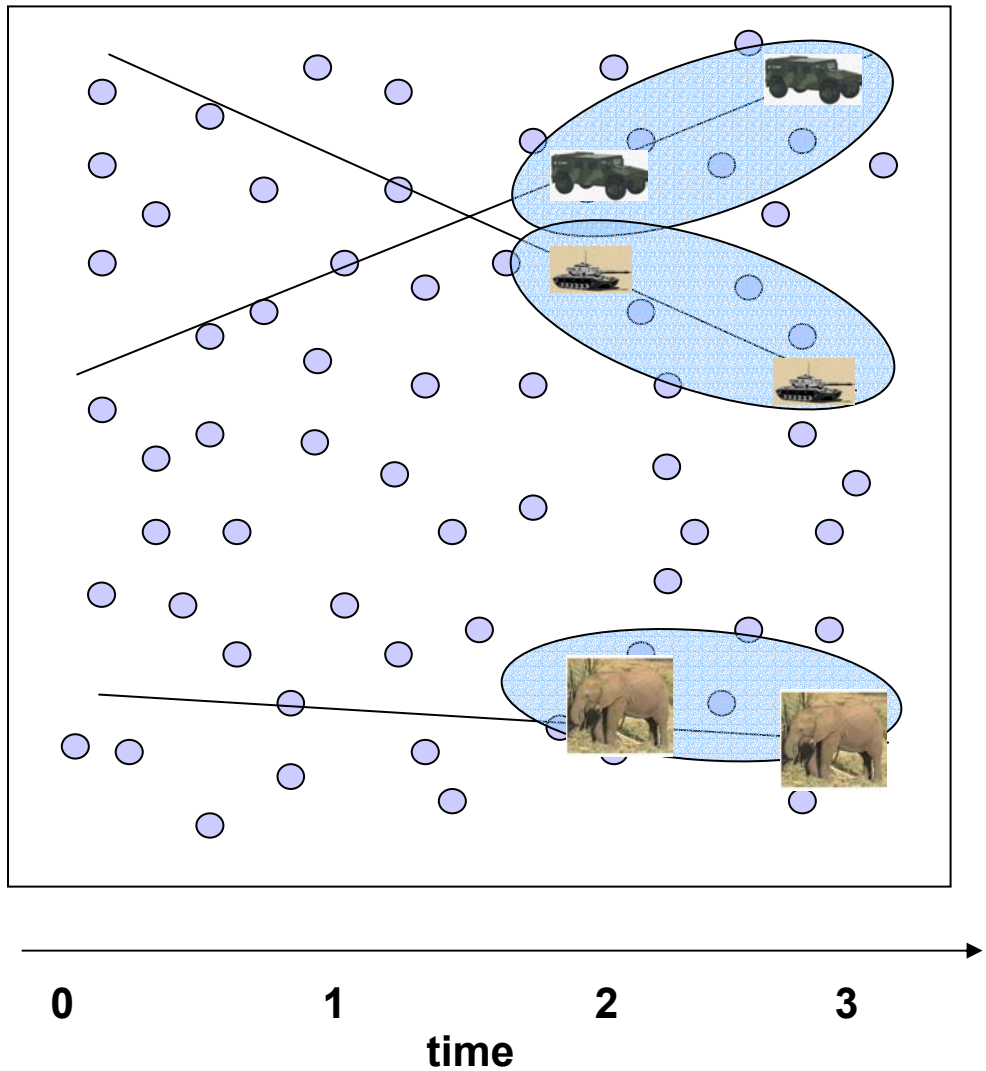


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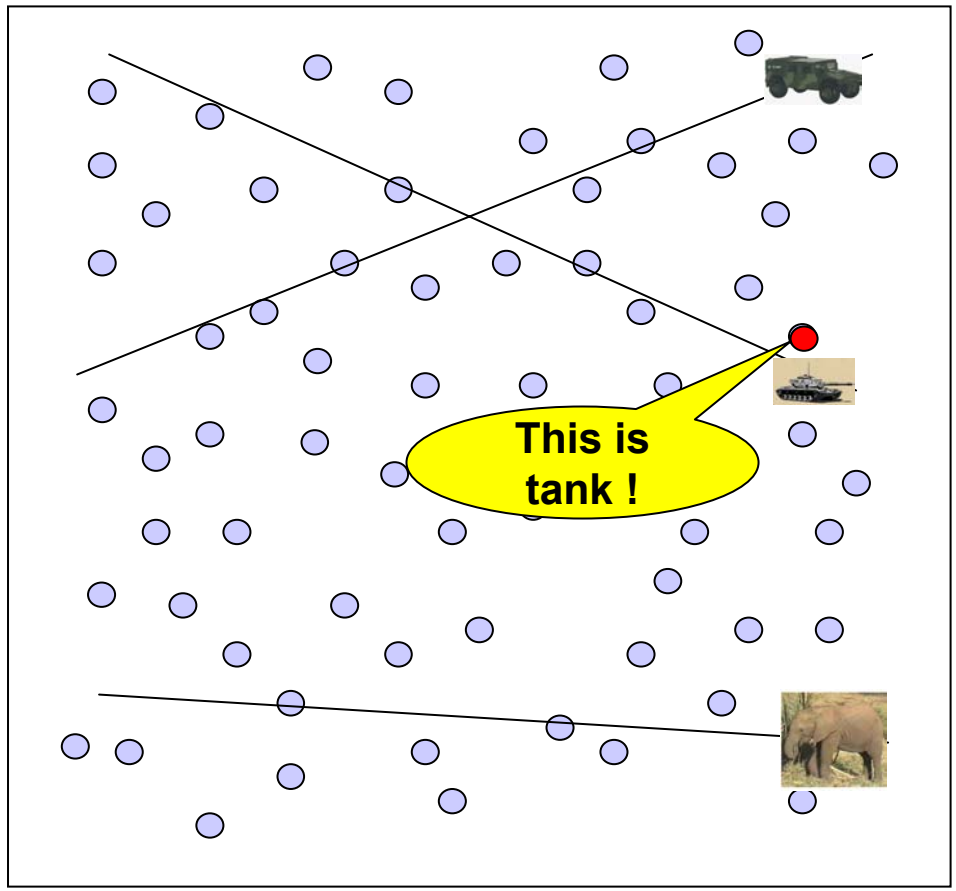


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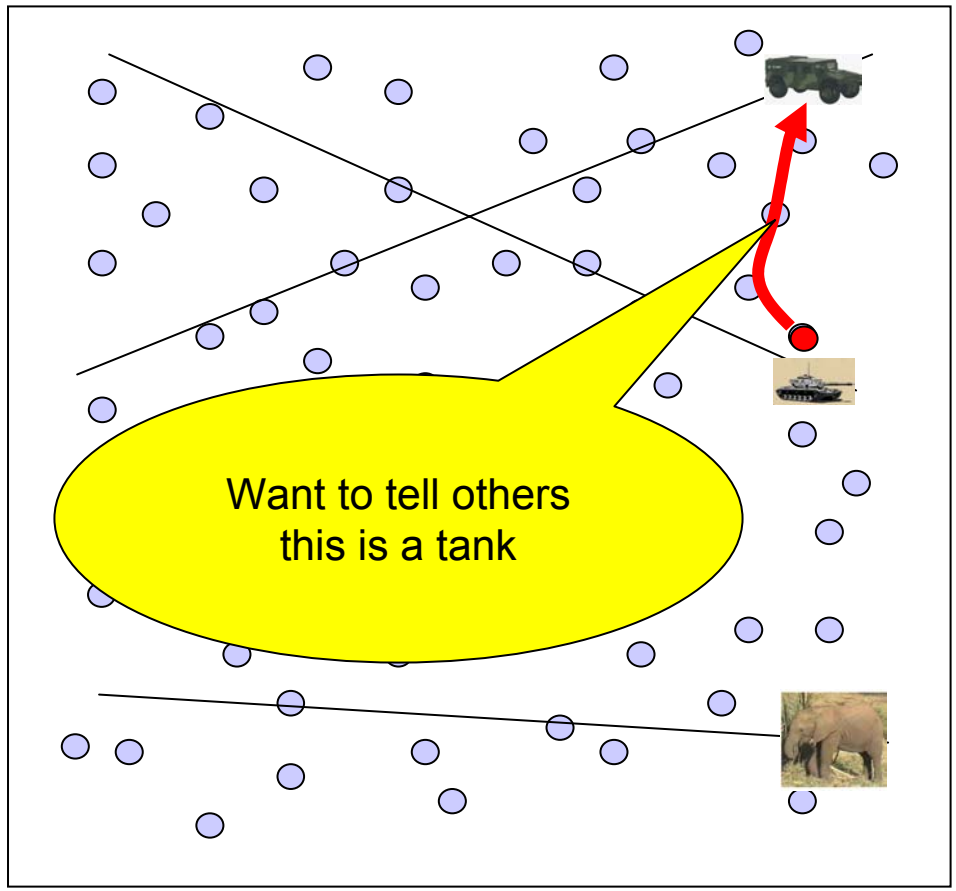
# De-mixing of events





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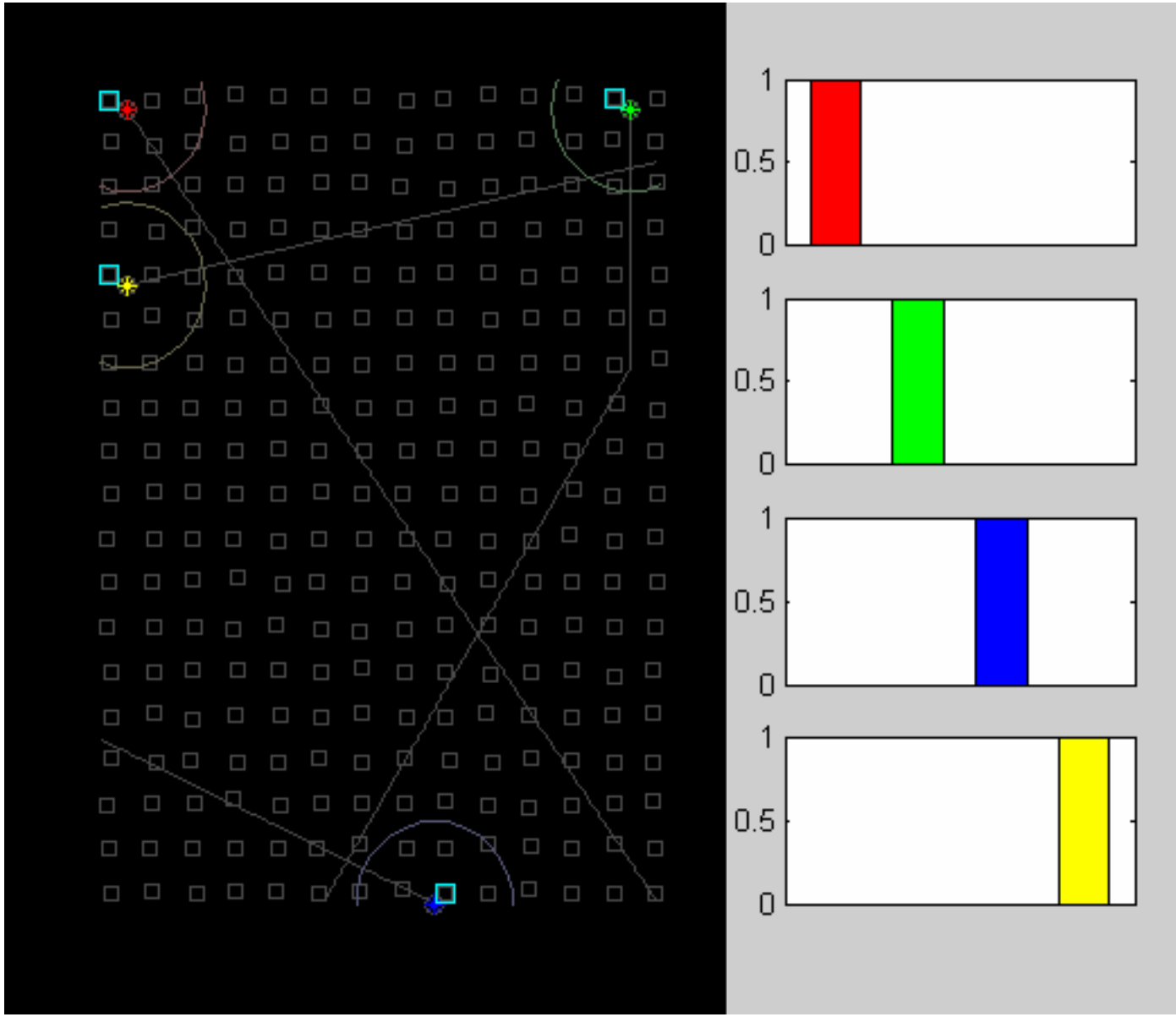
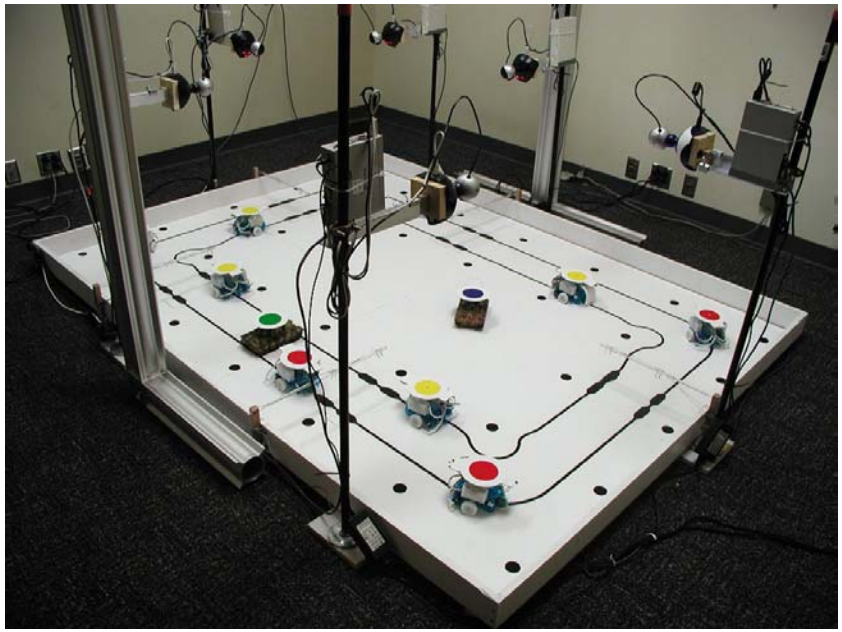
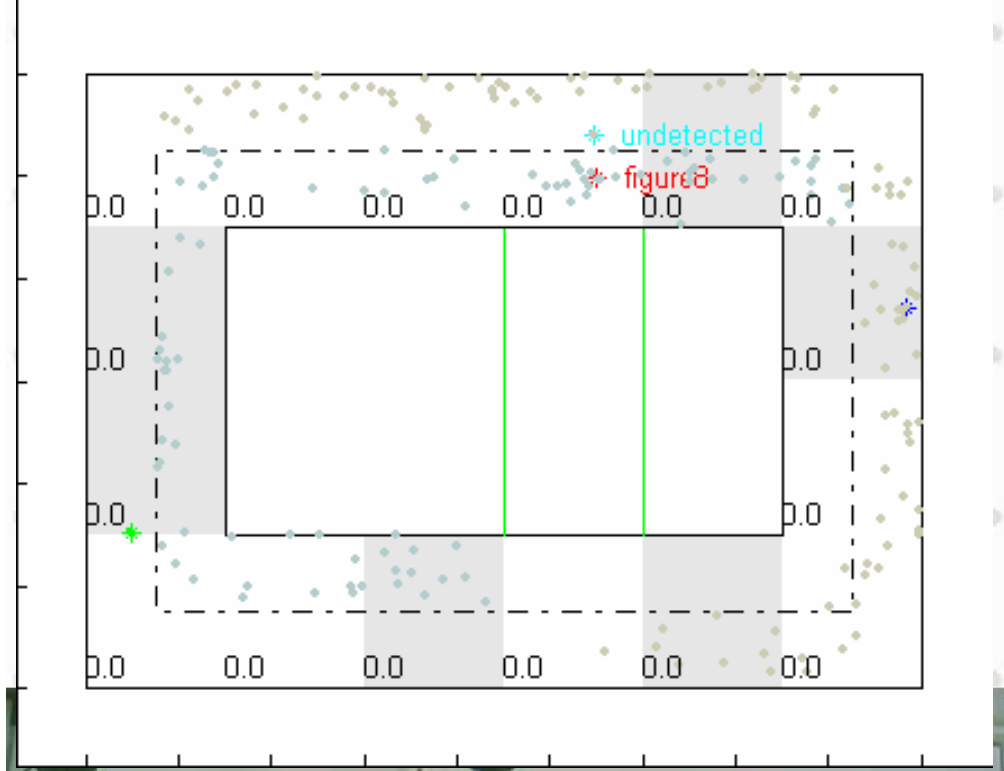
# Another example of tracking multiple, interacting events

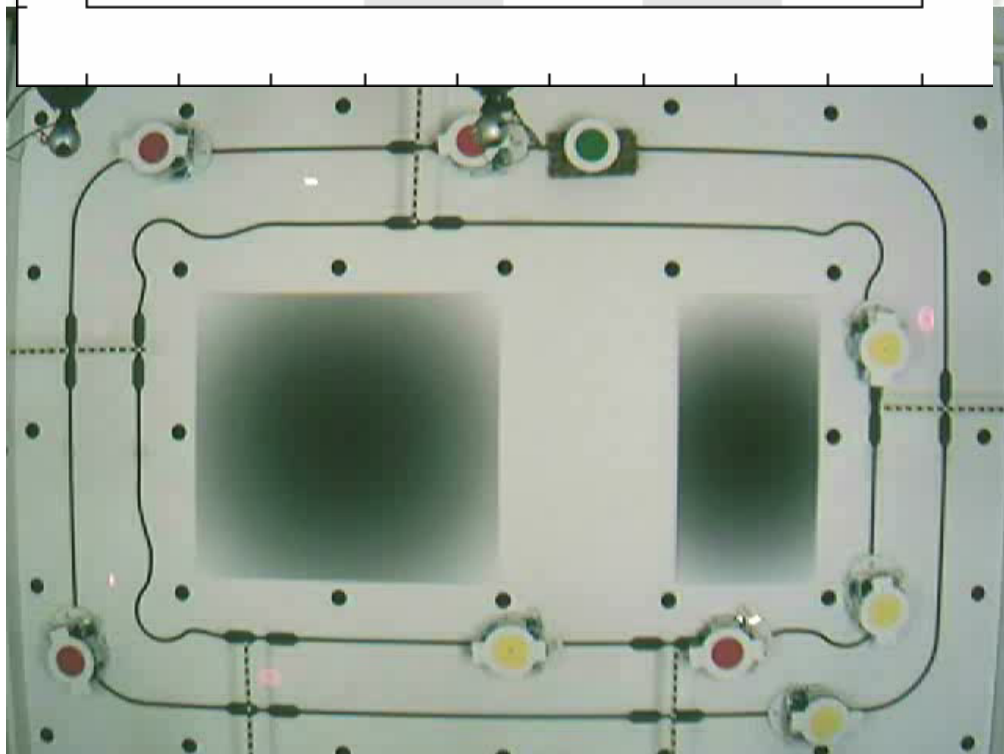




**Video sensor network testbed**

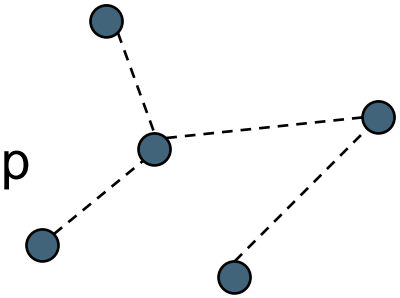
- 6 networked pan-and-tilt cameras
- FOV of cameras; each camera can see two FOV's on either side; overlapping FOVs
- Calibration points (1.5" diameter)
- Robot tracks (thickness 3/8")



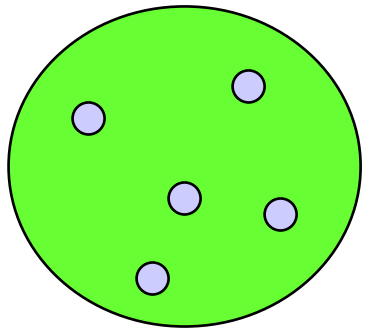



# Examples of Group-Based Communication Patterns

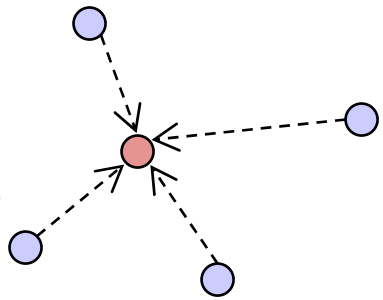
- Acquaintance group
  - Roaming members keep persistent connectivity



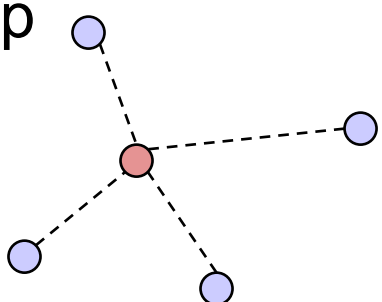
- Geographically constrained group
  - Defined by geographic extent



- Publish-subscribe group
  - Defined by producers and consumers of shared interests



- N-hop neighbor group



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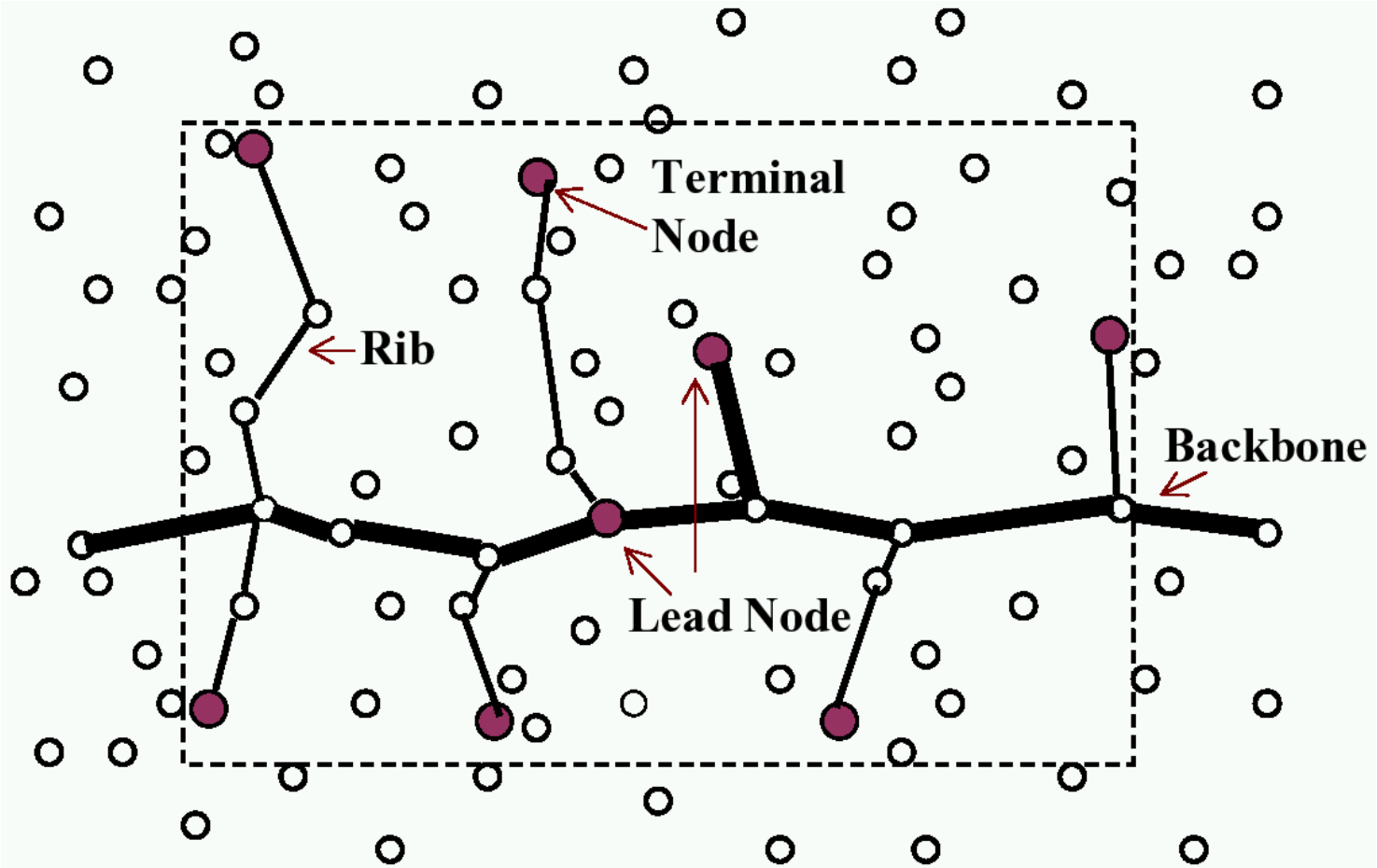
# RoamHBA: maintaining connectivity among roaming agents



# Any-time algorithms for sensor networks

- Incremental behaviors are important
  - Nodes may die, links may drop
  - Resources may be depleted
  - Stopping criteria may not be known a priori
- Quality of information should monotonically improve as more data become available
  - Without the need to re-compute from scratch every time
  - More graceful degradation
- Examples: localization, tracking

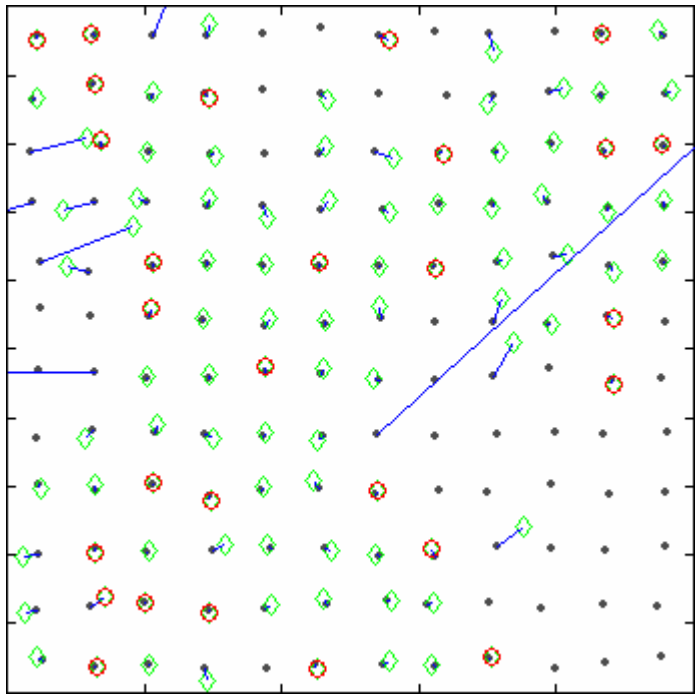
# An Example: Incremental localization

- Least square formulation of localization

$$z_i = f(|x_t - x_i|) + \Delta z_i \quad \Rightarrow \quad a_i^T x_t = b_i$$

- Can be solved incrementally.
  - Each node only needs to pass a 2x2 matrix and a 2-vector, regardless of mote count
  - Incremental, anytime algorithm

- iLS node localization:
  - Propagate location information from small number of known anchors to non-anchor nodes.
  - Error control avoids overweighting of single measurement by propagating error estimates
- iLS Tracking
  - Identical algorithm



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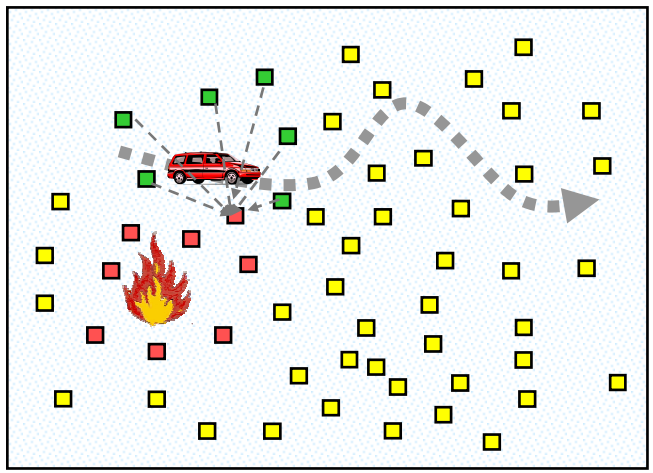

**Information-centric design**:

- What information is critical for the high-level tasks
- What is the cost of accessing the information
- Which nodes should participate in sensing, processing, or communication?
- How should the information be migrated?

The information processing needs largely determine the roles of and are supported by other layers of a sensor network

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