5.13 Programming Beyond Individual Nodes

- Sensor-actuator network systems offer some unique advantages. Dense networks of distributed sensors can improve perceived signal-to-noise ratio by reducing average distances from sensor to physical phenomena.
- In-network processing and actuation shorten the feedback chain and improve the timeliness of observation and response. Untethered network nodes and infrastructure less mesh network topologies reduce deployment costs. However, the greatest advantages of networked systems are improved robustness and scalability.
- A decentralized system is inherently more robust against individual node or link failures because of network redundancy. Decentralized algorithms are also far more scalable in practical deployment; they might be the only way to achieve the large scales needed for some applications. Because of decentralized systems spatial coverage and multiplicity in sensing aspect and modality, the detection, classification, and tracking of moving, nonlocal, or low-observable events require cross-node collaboration among sensors.

Target tracking as a motivating example

- Tracking is a canonical problem for sensor networks and essential for many commercial and military applications such as traffic monitoring, facility security, and battlefield situational awareness.
- Given a moving point signal source or target in a 2D sensor field, a tracking system's goal is to estimate target state histories, such as spatial trajectory, on the basis of sensor measurements.
- From a tracking expert's point of view, each sensor node provides a local measurement useful in estimating the target state. However, in most cases, only a relatively small subset of sensors contribute significantly to the estimation, owing to sensing-range limitations. In this case, a good solution is a leader-based tracking scheme, such as Information-Driven Sensor Querying (IDSQ), to fuse information from only the sensors that provide high-quality measurements.

- As Figure 5.7 illustrates, at any time instant t, IDSQ designates a single node, located close to the target, as leader. The leader node fuses these high signal-to-noise ratio measurements and updates its current target location estimate, referred to as the belief.
- For most sensor types, owing to the physical properties of signal propagation, the sensors with high signal-to-noise ratio will be within a limited range of the leader node. So, we can minimize the communication cost and latency for gathering sensor data.
- As the target traverses the sensor field and the belief evolves to follow its motion, the most "informative" sensors might no longer be those closest to the current leader. A nearby sensor might then be selected to replace this leader on the basis of the updated belief and a criterion combining resource constraints with some measure of sensing utility (such as mutual information). The current leader then hands off the belief to this sensor, which becomes the next leader at time $t + \delta$, where δ is the communication delay. The process of sensing, estimation, and leader selection repeats.

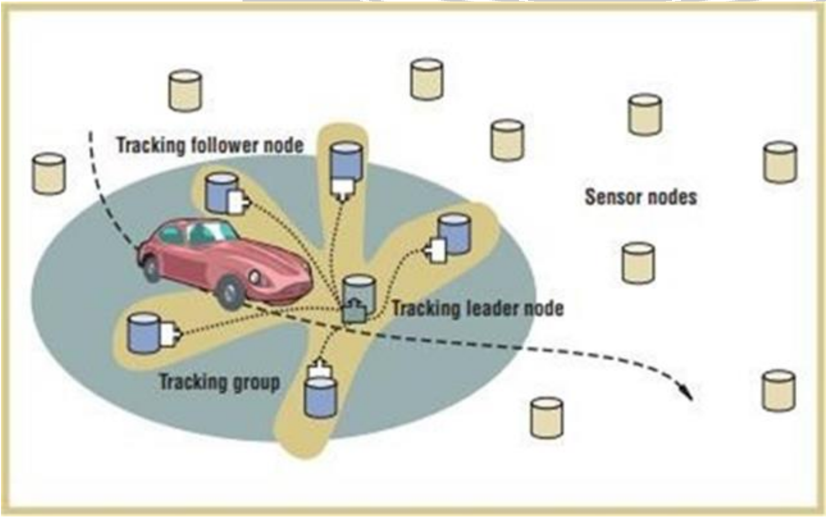

Figure 5.7. Collaborative processing in a leader-based object-tracking scenario. Source : Protocol and Architecture for Wireless Sensor Networks by Holger Karl , Andreas willig

- As a vehicle moves through a sensor field, nearby sensors detect it. An elected leader node aggregates data from the active sensors and migrates the information from node to node as the vehicle moves.
- The sensor nodes collaborate primarily to improve sensing accuracy, and acceptable estimation quality might be achieved using only a subset of the sensors.
- One node, the leader, plays a key role in fusing others' sensor measurements. If no leader is present, all sensors that form the contour are equally important. Each node might locally update and repair its observation of a contour section, but the global state can only be assembled from observations of many nodes along the entire contour. Hence, System designers must explicitly write code to

- Maintain sensor connectivities in a neighbourhood
- Discover the best node for handoff
- Invite neighbour nodes into the group
- Handle communication delays and failures