Application-based Management of Sensor Networks

Hervaldo Carvallo, Mark Perillo, Sameer Tilak,
Wendi Heinzelman and Amy Murphy

Center for Future Health
Department of Electrical & Computer Engineering
Computer Science Department
University of Rochester
http://www.futurehealth.rochester.edu
The Center for Future Health Vision

- Help people take better care of themselves everywhere on Earth

- Engineers, physicians, and social scientists working together to develop smart tools

- Consortium with industry, foundations, and government to bring products to market

- User friendly health technology for the home
Smart Medical Home

Medical Advisor

- Memory Assistance
  - R. Nelson, CS

- Gait Monitor
  - M. Tekalp, ECE

- Heart Monitor
  - H. Carvalho, CFH

MILAN Coordination Infrastructure

sensors/effectors
Applications

- **Objective:** describe events in the environment
  - Use sensor data as input

- **Performance:** varies as access to sensors change
  - May be based on current situation
  - May have minimum acceptable performance
  - Similar to application QoS requirements

- Multiple applications in same environment may interact according to user-defined mechanisms
Networks

- Network protocol manages channel resources
  - Bandwidth, transmission schedule, discovery of new and loss of old nodes
  - Bluetooth, 802.11, 802.15, application-specific

- Feasible sets of sensors that can be supported depend on
  - Network protocol
  - Channel conditions

- Nodes have certain cost when transmitting data to applications (e.g., energy)
MILAN: Middleware Linking Applications and Networks

Applications should not need to keep track of low-level sensors, but should influence how network is reconfigured over time.

MILAN:

- Takes input from
  - Application (on desires and performance)
  - Network (on physical limitations and cost)
- Uses information to determine appropriate network configuration
- Dynamically reconfigures network to
  - Satisfy application goals
  - Tradeoff performance for cost
Research Issues

- Application programming model
  - Follow a general framework for data fusion
  - Support individual, redundant, and multi-modal sensors
  - Low-level and high-level data fusion and analysis

- How to determine feasible sets?

- Cost-performance tradeoff among feasible sets
  - How to determine which subset of sensors to use?
  - How will appropriate subset vary over time?
Generic Data Fusion Framework

Redundant Sensor → R. pre-Processing m 1 → R. Data Fusion m 1

Independent Sensor 1 1 → I. pre-Processing m 1 → I. Data Fusion m 1

Mid-level Analysis

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Optimal Sensor Management

- Wireless sensor network
  - Energy constraint
  - Application is dependent on data from sensors monitoring the environment

- Not all sensor data is necessary
  - Redundant data

- Goal: maximize application lifetime while meeting application-specific QoS
Example Problem

Feasible Sets
- \( S_1, S_2 \)
- \( S_1, S_5, S_6 \)
- \( S_2, S_3, S_4 \)
Problem Formalization

- Feasible Sets $F_i$, $i = 1 \ldots N_F$
- Sensors $S_j$, $j = 1 \ldots N_S$
- Each feasible set $F_i$ is used for $T_i$ time
- Each sensor in $F_i$ must contribute $T_i \times P_{ij}$ units of energy toward utilization in $F_i$

- Energy constraint: $\sum_{i=1}^{N_F} T_i P_{ij} \leq E_j$
- Maximize $\sum_{i=1}^{N_F} T_i$
- Solve via linear programming
Improvement Using Optimal Sensor Management
Testbed: Heart Monitoring

- Multiple body worn, Bluetooth-enabled sensors

- Tradeoff: single sensor vs. multiple sensors
  - Increase reliability, increase overhead

- MILAN allows heart monitor to adapt network configuration to match application needs as
  - Available components change (e.g., sensors die)
  - Application focus changes (e.g., patient state changes)
Current/Future Work

- General “language” to allow applications to convey requirements to MILAN
- Incorporating multi-hop networks
- Distributing application computation among sensors
- Distributing MILAN decision-making
Summary: MILAN

• Networking/middleware solutions needed to intelligently manage large-scale networks with limited resources

• MILAN enables application-directed control of sensor network

• Initial MILAN centralized, but research plans to distribute both computation and network control