Connecting the Physical World with Pervasive Networks

CHEE-YEE CHONG, SRIKANTA P. KUMAR

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1 Introduction

- Networked microsensors technology is a key technology for the future.
- Smart disposable microsensors can be deployed almost anywhere.

- Ubiquitous wireless networks of microsensors probably offer the most potential in changing the world of sensing.
- Paper structure:
  - History of research in sensor networks
  - Technology trends
  - New applications
  - Research issues and hard problems
  - Some examples

2 History of Research in Sensor Networks

- The devbelopment of sensor networks requires technologies from three different research areas:
  - Sensing
  - Communication
  - Computing (hardware, software, and algorithms)

2.1 Early Research on Military Sensor Networks

- Can be traced back to Cold War.
- The sensor networks generally adopt a **hierarchical** processing structure where processing occurs at consecutive levels until the information about events of interest reaches the user.

2.2 Distributed Sensor Networks (DSN) Program at the Defence Advanced Research Projects Agency (DARPA)

- Modern research on sensor networks started around 1980 with the DSN program at the DARPA.
- R. Kahn, who was coinventor of the TCP/IP protocols and played a key role in developing the Internet, wanted to know whether the Arpanet (predecessor of the Internet) approach for communication could be extended to sensor networks.
- The network was assumed to havbe many spatially distributed low-cost sensing nodes that collaborate with each other but operate autonomously, with information being routed to whichever node can best use the information.
- Researchers:
  - CMU focused on providing a network operating system that allows flexible, transparent access to distributed resources needed for a fault-tolerant DSN. They developed a communication-oriented operating system called Accent (evolved into the Mach OS), whose primitives support transparent networking, system reconfiguration, and rebinding.
  - MIT focused on knowledge-based signal processing techniques for tracking helicopters using a distributed array of acoustic microphones by means of signal abstractions and matching techniques.
  - ADS[1] developed a multiple-hypothesis tracking algorithm to deal with difficult situations involving high target density, missing detections, and false alarms, and decomposed the algorithm for distributed implementation.

2.3 Military Sensor Networks in the 1980s and 1990s

- In platform-centric warfare: platforms own specific weapons,k which in turn own sensors in a fairly rigid architecture.
- In network-centric warfare: sensors donot necessarily belong to weapons or platforms. Instead, they collaborate with each other over a communication network, and information is sent to the appropriate shooters.

[1] Advanced Decision Systems, Mountain View, CA

2.4 Sensor Network Research in the 21st Century

- Latest technological advances boosted sensor networks development
- Sensor Information Technology (SensIT) program pursued two key research and development thrusts:
  - New networking techniques: sensor devices or nodes should e ready for rapid deployment, in an *ad hoc* fasion, and in highly dynamic environments.
  - NEtworked information processing.

3 Technology Trends

- Sensors, processors, and communication devices are all getting much smaller and cheaper.
- WIreless netowrkds based upon IEEE 802.11 standards can now provide bandwidth approaching those of wired networks.
- IEEE 802.15 standard for personal area networks (PANs) have a radius of 5 to 10 meters.
- In the future, the advances in MEMS technology will produce sensors that are even more capable and versatile.

4 New Applications

Examples:

- Infrastructure security
- Environment and Habitat Monitoring
- Industrial Sensing
- Traffic Control

5 Hard Problems And Technical Challenges

5.1 Ad Hoc Network Discovery

- Knowledge of the network is essential for a sensor in the network to operate properly.
- In planned networks, the topology of the network is usually known a priori.
- For ad hoc networks, the network topology has to be constructed in real time, and updated periodically as sensors fail or new sensors are deployed.
- In addition to knowledge of the topology, each sensor also needs to know its own location.

5.2 Network Control and Routing

- The network muse deal with resources that are dynamically changing, and the system should operate autonomously, changing its configuration as required.
- Without requiring IP addresses at each node is that one can deploy network devices in very large numbers.
- Survivability and adaptation to the environment are ensured through deploying an adequate number of nodes to provide redundancy in paths, and algorithms to find the right paths.

5.3 Collaborative Signal and Information Processing

- Collaborative signal and information processing over a network is a new area of research and is related to distributed information fusion.
  - Issue1: degree of information sharing between nodes and how nodes fuse the information from other nodes.
  - Issue2: tradeoff between performance and robustness.
  - Issue3: optimal data association is computationally expensive and requires significant bandwidth for communication.
  - meet mission latency and reliability requirements.
  - how to maximize sensor network operational life.

5.4 Tasking and Querying

- A sensor field is like a database with many unique features, and it is challenging for querying because of its instability.
- It is important that users have a simple interface to interactively task and query the sensor network.
- Mobile platforms can carry sensors and query devices. As a result, seamless internetwork between mobile and fixed devbices in the absence of any infrastructure is a critical and unique requirement for sensor networks.

5.5 Security

Sensor network should be protected against intrusion and spoofing.

6 Some Recent Results

6.1 Localized Algorithms and Directed Diffusion

6.2 Distributed Tracking in Wireless Ad Hoc Networks

6.3 Distributed Classification in Sensor Networks Using Mobile Agents