Embedded, Everywhere
A Research Agenda for Networked Systems of Embedded Computers
(Chapter 1)

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About the Book

- Written By: Estrin et al
  - Committee on Networked Systems of Embedded Computers
  - Computer Science and Telecommunications Board
  - Division on Engineering and Physical Sciences
  - National Research Council
- Published By: National Academy Press, 2001
- Available Online:
“Embedded, Everywhere explores the potential of networked systems of embedded computers and the research challenges arising from embedding computation and communications technology into a wide variety of applications—from precision agriculture to automotive telematics to defense systems.” -- NAP website
This Presentation

• Introduction
• Motivational Examples
• Understanding Networked Systems of Embedded Computers (EmNets)
• How EmNets Differ from Traditional Systems
• Why a New Research Agenda
• Related Topics Not Covered in Book
Introduction

• What is an EmNet?
• Current Trends
• A New Way of Thinking
• Research Challenges
Motivational Examples

- Automotive Telematics
- Precision Agriculture
- Defense Systems
Automotive Telematics

- Model year 2001
  - Between 20 and 80 Microprocessors
    - Engine
    - Breaking System
    - Airbag Deployment
    - Door Locks
    - Entertainment System
    - Etc.
  - Two Distinct Networks
    - Safety-Critical
    - Non-Safety-Critical
Automotive Telematics

• Move Away from Fully Engineered, Closed Systems
  – Disparity Between Design Cycles
  – Allow Easy Upgrade
  – Allow Owners to Integrate Other Devices

• Break Down Division Between Networks
  – Monitor for Upcoming Faults
  – Communicate Information to Manufacturer
Automotive Telematics

• Change from Self-Contained Network to a Node in a Much Larger Network
  – General Motors’ OnStar
  – Other Systems being Prototyped

• Web Sites of interest:
  – http://www.telematicsupdate.com
  – http://www.applied-telematics.net
  – http://www.telematicsdetroit.com
  – http://www.onstar.com
Precision Agriculture

- Solutions Based on Large-Scale Averages are Suboptimal
- Precision Agriculture Allows Much Finer and Automated Granularity
- Automatic Adaptation to Changing Environments
Precision Agriculture

• Future Applications
  – Early Detection of Bacterial Development
  – Monitor Livestock for Viral Contamination

• Web Sites of Interest:
  – http://www.precisionag.com
  – http://precision.agri.umn.edu
  – http://www.precisionag.org
Defense Systems

- Battlespace Surveillance
- Asset Management
- Smart Materials and Structures
- Health Status Monitoring of Personnel
- Make Information Available to Individuals
Defense Systems

• Web Sites of Interest:
  – http://www.eetimes.com/story/OEG20010717S0036
Understanding EmNets

• Characteristics
  – Multiple Interacting Nodes
  – Embedded in Control Systems Without Human Intervention
  – Purpose Other Than General Computing and Communications
  – Natural or Engineered Contexts
Understanding EmNets

• Useful Distinctions
  – Energy-Constrained Nodes vs. Non-Energy-Constrained Nodes
  – Fixed Topology vs. Flexible Topology
  – Safety-Critical Applications vs. Non-Safety-Critical Applications
  – Highly Engineered vs. Unconstrained, Ad Hoc Systems
EmNets vs. Traditional Systems

“Incremental improvement to today’s solutions will not suffice to realize the full potential of EmNets.”

- **Tightly coupled to the physical world** and each other in a
- **Resource-constrained environment** that will
- **Persist for long periods of time** while consisting of
- **Many interacting components** and being
- **Used and interacted with by non-expert users**
• Interact Strongly with the Physical World
  – Sense the Physical World
  – Communicate and Process Data
  – Cause Physical Actions to be Taken

• Usability Issues
  – Users Think of Themselves as Interacting with the Object, Not a Computer
  – Open Opportunity for Usability Research
Resource-Constrained

- Nodes are Likely Untethered
- Important Constraints
  - Nodes
  - Organization
  - System Policies
  - Hardware
- Limit the Amount of Computation and Communication
Long Lifetimes

- EmNets have Much Longer Lifetimes than Traditional Systems
- Older Systems Must Interoperate with New Developments
- Ability to Upgrade is Essential
- Battery Lifetime (*Not Mentioned In Paper*)
Size and Scale

- Potential for Networks to Grow Very Large
- Systems Designed to Work Properly at One Size, Often Fail at a Larger Size
- Cannot Develop EmNets Naively as Extrapolations of Existing Technology
Non-Expert Users

• Used by People with Little or No Systems Training
• Computing Systems Must Adapt to Users, Not the Other Way Around
• Expectations of Objects Different from Expectations of Explicit Computational Devices
• Potential Recipe for Disaster
Why a New Research Agenda?

- Characteristics of EmNets Demand New Kinds of Research
- Fundamental, Underlying Research Problems Must be Addressed
- Potential Impact Warrants Special Consideration
- Unique Technological Challenges
Why a New Research Agenda?

- Open Research Areas
  - Enabling Technologies
  - Ease of Construction
  - Self-configuration and Adaptability
  - Ensure Performance and Safety
  - Ease of Use

- Problems with Existing Solutions
  - Many Assumptions Don’t Apply to EmNets
  - New Research may Provide Benefits to Traditional Systems
Related Topics

- Advanced Sensors and Actuators
- Public Policy Issues
- Commercialization Issues, Standards, and Business Models
- Stand-alone Embedded Systems and Other Networked Information Systems