Grand Challenges in Cyber Physical Systems
The Next Generation Embedded Systems

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Core Embedded Systems

• Dependability
• Cost of Validation/Verification
• Real-Time Support
Trend 1: Confluence of Networking, Personal Computing and Embedded Systems

- Clusters, Farms, Grids, WWW
- Embedded Everywhere
  - Transparent
  - Context-aware
  - Mobile
  - Miniature
  - Ubiquitous
  (Smart attire, smart spaces, …)

Autonomic Computing
Privacy
Networking

Trend 2: Newly Emerging Deeply Embedded Systems
(Sensor Networks)

- Sensor Network Applications
- Precision Agriculture
- Habitat Monitoring
- Emergency Response
- Disaster Response
- Border Control

- Features
  - Ad hoc deployment
  - Massive distribution
  - Interaction with a physical environment
  - Unattended operation

- Target Tracking
- Infrastructure Protection

American Border Patrol
Trend 3: Global Integration
From Smart Dust to Global Information Grids

- Low end: ubiquitous embedded devices
  - Large-scale networked embedded systems
  - Seamless integration with a physical environment

- High end: complex systems with global integration
  - Examples: Global Information Grid, Total Ship Computing Environment

Integration and Scaling Challenges

Low End High End

Emerging Challenge 1: An Internet for Embedded Devices

Observation: Human I/O bandwidth is bounded
Eventually, traffic growth is due to embedded devices

- Present Internet
  - Connecting people
  - Interface: Human centric, query/polling based (e.g., music download, google search, ...)
  - Applications: Web, e-mail, peer-to-peer multimedia, ...

- Future Internet
  - Connecting devices
  - Interface: Device centric, notification based (e.g., mine for patterns, alert to anomalies)
  - Applications: environmental monitoring, emergency response, ...

Issues: New architecture, new protocols for embedded devices, new addressing schemes, ...
Emerging Challenge 2: 
Integration at Scale

- Component integration has always been a problem
  - Scalability
  - Correctness (hidden mismatches breed bugs)
- We must now take it to the next level
  - Wide-area distributed embedded systems
  - Large-scale sensor/actuator networks
  - Billions of lines of code interacting across a network infrastructure

Emerging Challenge 3: 
Distributed Middleware for the Physical World

- Distributed middleware paradigms
  - Abstract distributed communication
  - Provide location transparency
- Middleware paradigms for deeply embedded computing
  - Represent the physical world to the programmer
  - Abstract distributed interaction with the physical environment
Emerging Challenge 4:
Interdisciplinary Problems

Summary

- Trends
  - Confluence of networking, personal computing, and embedded systems
  - New technologies (e.g., sensor networks)
  - Global integration

- Challenges
  - Wide-area embedded networks
  - Integration complexity
  - Middleware for the physical world
  - Interdisciplinary research