

Grand Challenges in Cyber Physical Systems

The Next Generation Embedded Systems

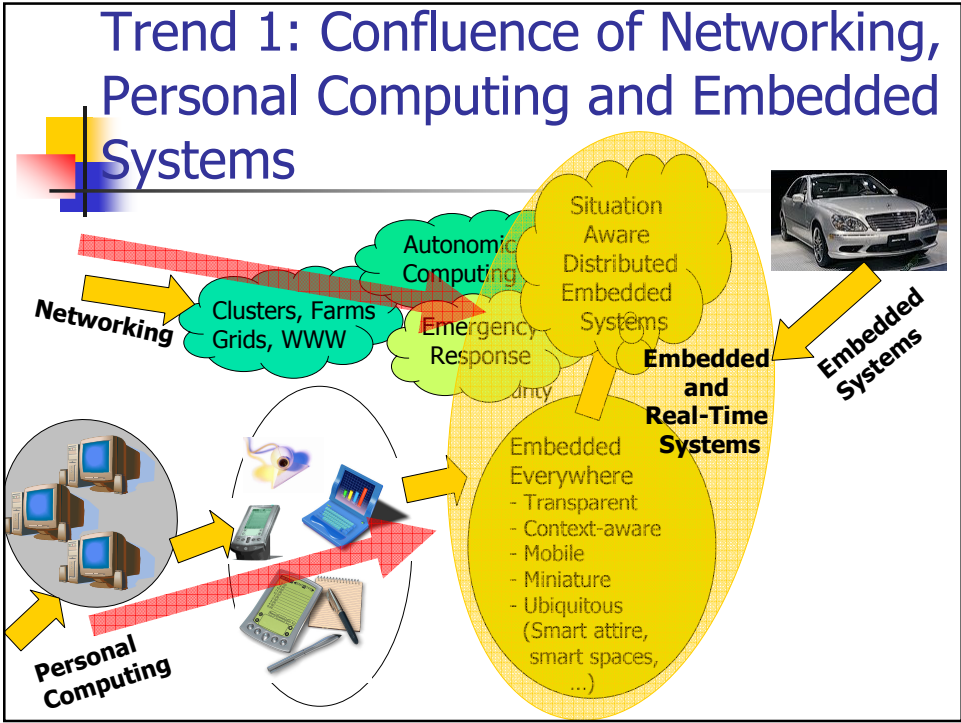
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Core Embedded Systems



- Dependability
- Cost of Validation/Verification
- Real-Time Support



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

Sensor Network Applications



Habitat Monitoring



Precision Agriculture



Disaster Response



Target Tracking



Infrastructure Protection



Border Control
American Border Patrol

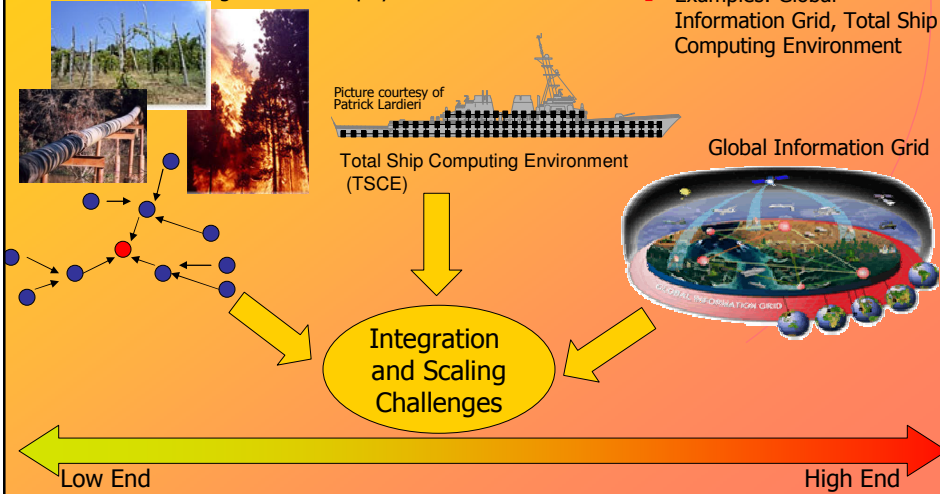
Features

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

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



Emerging Challenge 1: An Internet for Embedded Devices

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

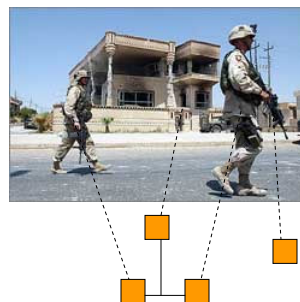
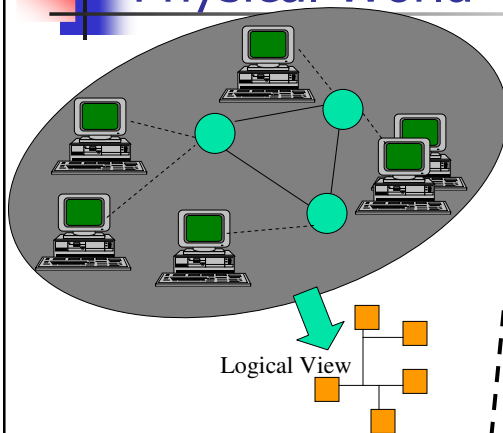
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|--|---|
| <ul style="list-style-type: none"> ■ Present Internet <ul style="list-style-type: none"> ■ Connecting people ■ Interface: Human centric, query/polling based (e.g., music download, google search, ...) ■ Applications: Web, e-mail, peer-to-peer multimedia, ... | <ul style="list-style-type: none"> ■ Future Internet <ul style="list-style-type: none"> ■ 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

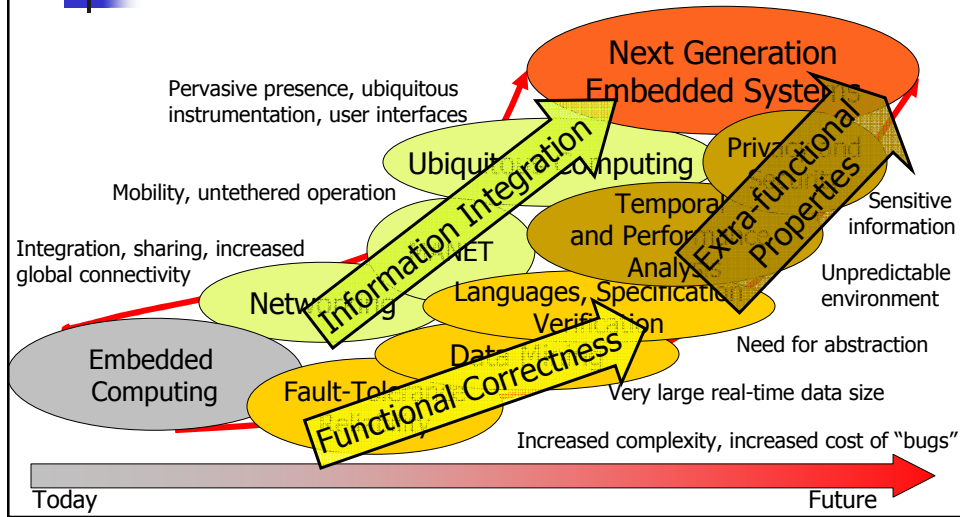
- Component integration has always been a problem
 - Scalability
 - Correctness (hidden mismatches breed bugs)
- We must now take it to the next level
 - Wide-area distributed embedded systems
 - Large-scale sensor/actuator networks
 - Billions of lines of code interacting across a network infrastructure

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