Design Implementation and Adaptation of Sensor networks through Multi-dimensional Co-design

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Overview

- Wines 1 project
- Five collaborating institutions
  - ♦ University of Glasgow
  - ♦ University of Kent at Canterbury
  - ♦ University of Manchester
  - ♦ University of St Andrews
  - ♦ University of Strathclyde
- Primary focus – software/hardware engineering of heuristically optimal sensor network systems

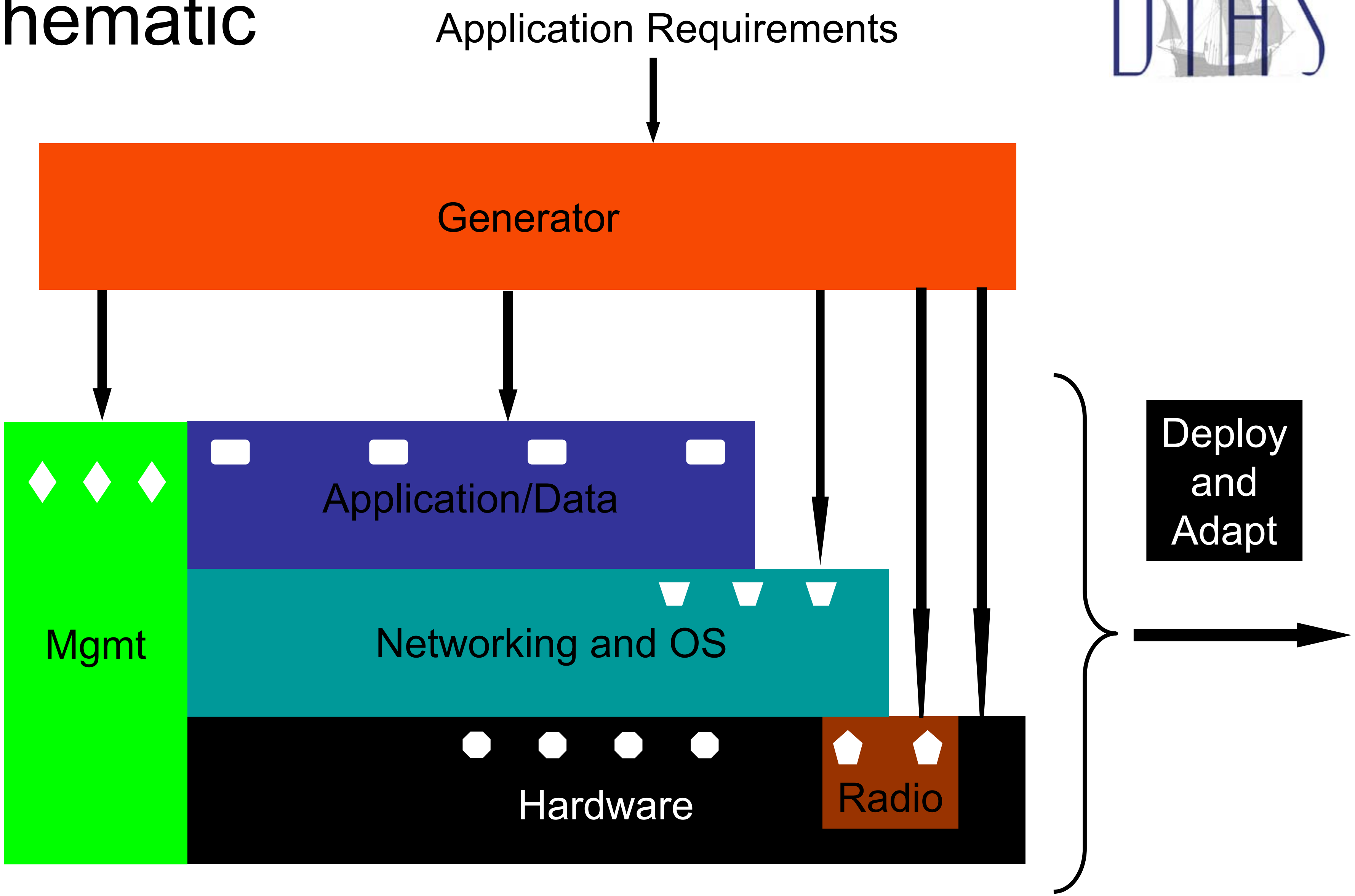
Sensor Network Co-design

- Employ generative programming techniques to construct sensor systems (using hw/sw co-design) that are:
  - Optimal with respect to a chosen global cost function
  - Formally validated with respect to required system properties
  - Adaptive to changing conditions in the field
- Co-design dimensions
  - Networking, operating systems, and hardware architecture
  - Radio communication
  - Network and system management
  - Application data management
- Approach
  - Generative programming and adaptation
  - Formally verify that the global adaptation has not violated any required, dimensional properties
  - Validate methodology through experimental systems

Methodology

1. Enumerate requirements for sensor network systems
2. For each dimension:
   - Deconstruct traditional components for system optimization
   - Define dimension-specific language(s) for requirement specification
   - Define cost function in terms of sensor net requirements
3. Generate designs from such orthogonally-produced specifications
4. Formally validate generated systems
5. Evaluate these systems in terms of the chosen global cost function in order to determine the optimal (or near-optimal) design
6. Construct an implementation platform upon which optimal designs can be constructed and deployed
7. Build, deploy, and operate two prototype systems using this platform to validate the methodology

Schematic



Application Requirements
Generator
Application/Data
Mgmt
Networking and OS
Hardware
Radio
Deploy and Adapt

Networking, OS, and HW Research Challenges

- Deconstruction
  - ♦ Componentized OS structure, e.g. TinyOS (esp. synthetic vs real hardware components)
  - ♦ Local sensor autonomy regarding meeting cost function and adapting to changing environment
- Optimization opportunities
  - ♦ Flatten communication layers
  - ♦ Aggregate transmissions to maximize bits sent each time the radio is fired up
  - ♦ Conversion between synthetic hardware components and real hardware components (traditional hw/sw co-design)

Radio Research Challenges

- Deconstruction
  - ♦ Determine the potential impact of a heterogeneous wireless environment on management of static and mobile sensor nodes, this will include security and data integrity
- Optimization opportunities
  - ♦ Cluster management in a heterogeneous wireless environment
  - ♦ Uplink cross layer integration techniques (transmission stack) for security and energy conservation
  - ♦ Demonstrator architecture for chosen radio interfaces

Management Research Challenges

- Deconstruction
  - ♦ Separately consider fault, configuration, accounting, performance, and security (FCAPS)
  - ♦ Push mode management traffic (as opposed to traditional pull mode)
- Optimization opportunities
  - ♦ The percentage of management traffic that can be piggy-backed onto actual data traffic
  - ♦ The amount of processing that can be performed on health-check measurements in the sensors

Application Data Management Research Challenges

- Deconstruction
  - ♦ Separate query processing strategies and models that are driven by a single dominant performance metric (e.g., response time)
  - ♦ Identify distinct actions that are solely justified by them (e.g., keeping intermediate results small)
  - ♦ Characterize each distinct motivation in current sensor network query processors (e.g., maximize lifetime, achieve graceful adaptation to node failure)
- Optimization opportunities
  - ♦ Explore caching and materialization in root/coordinator nodes for scalable compositionality
  - ♦ Compiling beyond concrete algorithms, down to machine-level, would open the way for better power/lifetime management

Expertise

- Project requires world-class expertise in the following areas:
  - ♦ Radio communications – Prof. J Dunlop
  - ♦ Networking, Sensor OS and HW – Prof. I Marshall, Mr. P Lee
  - ♦ Network and System Management – Prof. J Sventek
  - ♦ Application Data Management –Dr. AAA Fernandes, Prof. N Paton
  - ♦ Generative Programming – Prof. R Morrison, Prof. A Dearle, Dr. G Kirby, Dr. D Balasubramaniam
  - ♦ Formal methods – Dr. A Miller
  - ♦ Application domain – Dr. S Boult
- Industrial sponsors across spectrum of stakeholders
  - ♦ Xilinx: firmware in support of hw/sw co-design
  - ♦ Orange: gateway connectivity between sensors and back office
  - ♦ Intelisys: produces hydrochemical monitoring systems
  - ♦ Severn Trent Water: manages upland catchments for drinking water collection

Results to date

- Reports/papers (a partial list – each will be available on web site when it moves from draft to tech report status)
  - “Radio Transceiver: Design Choices and Cost Considerations”
  - “A Declarative Query Language for Sensor Networks”
  - “A Sensor Network Query Processor for Applications with Varying QoS Requirements”
  - “Sensor Network and System Management – a Survey”
  - “Concurrency on and off the sensor network node”
  - “Alternative scheduling mechanisms for TinyOS”