EMbedded MONitoring (EMMON)

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Project outline

• Full title: EMbedded MONitoring
  – Duration: 01.03.2009–29.02.2012 (36 months)
  – Budget: 2.576 M€
  – Project Web Site: www.artemis-emmon.eu

• Sponsored by 7th Framework Programme (7FP), ARTEMIS Joint Undertaking initiative:
  – Industrial Priority Seamless connectivity and middleware
    – https://www.artemis-ju.eu/
    – https://www.artemisia-association.org/
Partners

• Industrial Partners

• Research Centres
  – Centro de Estudios e Investigaciones Técnicas de Gipuzkoa

• Universities
  – Instituto Superior de Engenharia do Porto, Trinity College of Dublin, Aristotle University of Thessaloniki
Goal

“Create an integrated framework for large scale and dense wireless sensor networks that allow effective monitoring for more than 10 000 devices.”

– Solve the scalability problem of WSN, a major challenge as embedded objects scale from a few dozens to thousands (and millions) of interconnected objects.
Motivation

• The vision of smart locations is of significant societal interest today!
  – SP3. Smart environments and scalable digital services
    • Smart locations (smart city, smart homes, smart public spaces, ...). A smart city can monitor its levels and distribution of air pollution and give recommendations to Civil Protection
    • Monitor large or dense areas detecting abnormal variations and reacting in accordance (water quality in pipelines, pollution and fire hazards in cities and forests, building environment)
  – SP7. Embedded technology for sustainable urban life
    • Achieve greater efficiency in use of resources, better comfort, more flexibility in the provision of resources, energy-efficiency in buildings and better situation awareness for the citizen
Areas of Application

• **Integrated generic framework**
  – Applications that requires continuous, periodic, large scale monitoring of the environment. Changes are reported by triggering of actions (alarms, alerts, actions)
  – E.g
    • Regional climate/marine monitoring;
    • Urban quality of life monitoring (pollution, air and noise);
    • Forest fire monitoring;
    • Natural resources monitoring;
    • Precision agriculture;
    • Industrial plant monitoring;
    • Dense monitoring deployments;
    • …
Innovation

• Sensor networks **widespread barriers**
  – Unreliable communication systems
  – Not easy to use
  – Low battery life / Short lifetime and system lifetime
  – Scalability problems -> Leads to small deployments
    -> Hard to adapt
  – Available solutions too tailored and specific
    – Cost
  – Security gaps, limitations (on data and sensors)
Innovation

• Develop a WSN system architecture capable of scaling up to 10K nodes
  – New embedded middleware with better overall energy-efficiency, fault-tolerance, and reliability;
  – Horizontal and generic network architecture for multiple applications and scenarios
  – New efficient and low-power communication protocols;
  – Develop network planning and deployment tools for Large Scale WSNs;
  – Provide integrated framework of technologies to enable Large Scale WSNs.
Challenges

• Middleware
  – End-user requirements
    • Easy-to use scalable programming abstractions
    • System services that implement these abstractions, including:
      – Scalable data acquisition, gathering, aggregation and storage
      – Reliable code management, deployment and update
      – Fault-tolerance support and resource discovery
      – Efficient resource management
  – Non functional properties
    • Scalability
    • Acceptable and predictable performances
  – Usually middleware is application specific
Challenges

• Programming abstractions
  – A data-centred, fully geographical, highly-scalable API
    • Simple yet powerful
    • Supports both functional and non-functional requirements

• Scalable data acquisition, aggregation and storage
  – Scalable positioning
  – Time synchronization
  – Application-customisable user-controllable in-network aggregation
    • Performed by every tier of the hierarchy, and even within tiers.
  – Web services integration
Challenges

• Reliable code management, deployment and update
  – A custom-designed Over The Air Programming (OTAP) algorithm

• Fault-tolerance support and resource discovery
  – Distributed fault-tolerance component
  – A new reinforcement-learning based routing component

• Efficient resource management
  – Node level duty-cycling
  – A novel energy saving component based on Bayesian inference
Challenges

• Middleware architecture

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Challenges

• Scalable communication architecture
  – the number of nodes, the spatial density, or the size of the region covered.
  – Easily/transparently adapt with no or negligible degradation of overall system performance

• A hierarchical, multi-tier network architecture
  – IP at the higher-levels
  – IEEE 802.15.4 standard is adopted as short-range communication protocol
    • A clustered WSN architecture
Challenges

• The synchronized version of IEEE 802.15.4 is used at the lowest tiers
  – Divide time into active and sleep periods
  – This enables to find the best delay/throughput vs. energy trade–off.

• WSN nodes are organized into a ZigBee–based Cluster–Tree network model rooted at a gateway
  – Collisions between clusters is avoided by scheduling in a non-overlapping fashion using the Time Division Cluster Scheduling
Challenges

- Scalable communication architecture
Challenges

• Integrated Toolset
  – Many work on WSNs has focused on protocols or applications
    • lack of easy/ready-to use WSN integrated tools for planning, implementing, testing and commissioning WSN systems
  – There exists a plethora of works about network planning and deployment
    • But little help to match coverage requirements with network performance evaluation
  – Important to provide integrated Toolsets!
Challenges

- Integrated Toolset

Network Deployment Simulator (JIST/SWANS tool)
  Inputs:
  - Field’s size
  - Sensing coverage
  Outputs:
  - Number of WSN Patches
  - Number of SNs
  - Nodes’ positions

TDCS scheduler (MATLAB tool)
  Outputs:
  - Parent <-> Child
  - Cluster scheduling

Worst-Case analyzer (MATLAB tool)
  Outputs:
  - Worst-Case E2E delay Real Time

Network Protocol Simulator (OPNET model)
  Outputs:
  - E2E delay Best-Effort
  - E2E delay Real-Time
  - Packet loss
  - Energy consumptions

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Test-bed

• DEMMON1
  – 300 m² test-bed with 303 motes
  – 3 WSN patches, 12 clusters each

• Toolset
  – deployment planning
  – network dimensioning
  – worst-case performance analysis
  – protocol simulation
  – …
Pilot Deployment

• WSN deployment @ SANJOTEC
  – Building of a Science & Technology Park
    • Industrial Living Lab
    • http://www.sanjotec.com
  – 400 physical nodes and 9600 virtual nodes
    • Scalability of middleware and command and control
Pilot Deployment

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Related Deployment

- EMMON technology related
  - Energy-efficiency in data centers using WSNs
    - monitoring physical conditions (temp./hum.)
    - controlling HVAC, computing/load balancing
    - to reduce (huge) energy consumption
  - Test-bed at a small data centre room
    - 60 Nodes in 10 m²
    - 8 racks, temp+hum at 3 heights, front+back
    - 1 cluster per rack, 1 WSN patch

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Summary

• EMMON tackles the scalability of WSN systems
  – Middleware abstractions for large-scale monitoring
  – Robust, reliable and scalable network infrastructure
  – Network planning and deployment toolset to assist real deployments
  – Based on COTS components

• Validation
  – Live deployments of more than 400 nodes
    • Scaled with Emulation of 9600 virtual sensors
  – Experimental performance analysis of protocols/middleware within test beds
Thank you!

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