iLAND: mIddLewAre for deterministic dynamically reconfigurable Networked embedded systems

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- Context and motivation
- Approach overview
- Validation domains
- iLAND architecture
- Time-deterministic reconfiguration
- Conclusions
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Introduction

- iLAND is an ARTEMIS call 1 project
- March 1st, 2009 – February 28th, 2012
- 9 partners:
  Spain, The Netherlands, France, Portugal, and U.S.A.

- Coordination: Visual Tools, S.A. (Spain)
- Technical coordination:
  Universidad Carlos III de Madrid (Spain)
Integrated LAND
(cyberphysical inspiration)

- Heterogeneous nodes
- Decoupled interaction
- Configuration changes at any time.
- Timely data transmission
Subsystems of different nature can be far apart.

Subsystems need timely communication to perform cross-processing of data.

Data bulks.

Functionality changes are possible by adding or removing subsystems or individual nodes.

Software-level functionality changes are possible.

Triggers for reconfiguration come from any part of the system at any time.

Real-time operation (data/event transmission and node operation) are a clear added value.
Integrated LAND

- Infrastructured NES
  - Communication guarantees

- Ad-hoc NES
  - No guarantees
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MAIN CHALLENGE:

- Supporting timely reconfiguration
- Decoupled interaction model
- Real-time communication

APPROACH:

- Composition strategies based on services
- Asynchronous communication paradigms (standard-based)
- Vertical view of real-time execution support
- Service-based application architectures
Approach overview

Integrated LAND

- Middleware focus with key issues:
  - Time-deterministic reconfiguration
  - Real-time (and QoS-based) communication

- Service-oriented software model:
  - Application-level services
  - Middleware-level functions/components
Service-based applications

- A service is defined in a simplified way:
  - A self-contained functionality piece of an application that:
    - Has clearly defined input and output interfaces that
    - Resides in a remote node in the network, and that
    - Receives and sends messages

- An application is a set of services in the form of a graph:
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Validation domains

- High-availability video surveillance in critical areas
- Health monitoring system
- Early environmental warning system
High-availability video surveillance in critical areas

- **Supervised control systems**
  - remote control of physical processes
  - to improve the interaction with humans
  - to develop control strategies closer to the human behaviour.

- **Security surveillance in critical areas**
  - Real-time image processing and event detection
  - Real-time transmission of data and alarms
High-availability video surveillance in critical areas

Premises under surveillance

Several geographical premises remotely distributed

DVRT

LAN

Local operator

Video wall

Remote monitoring and control room

Remote operator’s console

Internet

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High-availability video surveillance in critical areas

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High-availability video surveillance in critical areas

MAIN FUNCTIONS:

- Video acquisition
- Video image analysis and data extraction
- Video and data transmission
- Presentation of results

THE SAME FUNCTIONS IN DIFFERENT APPLICATION CONTEXTS EXHIBIT DIFFERENT TIMING REQUIREMENTS
High-availability video surveillance in critical areas

NODE TYPES:
- High capacity servers and embedded processors with cameras
- Cameras (image sensing) and other sensors:
  - Limited amount and usually “mono-modal” detection
  - Activated by a reduced set of triggers
  - Relatively simple but robust for the intended detection
  - Little semantics and stateless behavior

COMMUNICATION LINKS
- Wired: servers - cameras
- Wireless: sensors - cameras

CONTROL ALGORITHMS
- Control loops, image processing, etc.
High-availability video surveillance in critical areas

RECONFIGURATION TRIGGERS:

- New requested functionality
- Stop running functionality
- Sensing event
- Alarm detection from image analysis
- Internal monitoring events controlling the infrastructure state:
  - Load balancing
  - Infrastructure optimization decisions
  - Node/functionality crash
High-availability video surveillance in critical areas

RECONFIGURATION RESPONSES:

- Activate/stop video streaming from selected camera(s)
- Activate/stop recording from selected cameras(s)
- Hand over for object-tracking
- Actuation decision upon alarm detection (initiate real-time streaming/recording, generate operator alarm, etc.)
- Hand over responsibility of some cameras to other server nodes (NVRs)
eHealth: Nursing home

MAIN FUNCTIONS:

- Remote monitoring of critical patients
- Alerting medical staff
  - Detect health concerns and inform in real-time
- Physical follow up of patients

DEPLOYMENT:

- Medical equipment
- Room manager
- Control center
RECONFIGURATION VALIDATION

- **External triggers:**
  - New patient enters/leaves a room
  - Health concern
- **Internal triggers:**
  - Overload of some node
  - Some functionality (service) is not available

**DURING NORMAL OPERATION:**

- The control center staff must receive periodic logs and sporadic events (e.g., alarms).

**DURING RECONFIGURATION**

- Periodic logs and alarms should continue to be sent at suitable frequency.

- **Actions:**
  - Reconfigure sensing infrastructure for patient follow-up
  - Immediate reporting to medical staff
- Potential of using DAM to detect, diagnose and predict health-related events.
- Network of sensors around the home provide data to identify activities concerning: mobility, self-care, domestic life.
- Analysis of evolution of predefined activity indicators (starting time, duration, continuity, quality of results, etc.) can potentially provide additional information.
Remote monitoring and early warning using public transportation

- Remote monitoring system

- Large unpopulated areas with no access to broadband

- Opportunistic use of the public infrastructure to convey large volumes of sensor data to a central environmental analysis center.

- Large forests, coast lines, water defenses and dikes in floodplains.
Remote monitoring and early warning using public transportation

- It allows
  - Notification of threatening conditions
  - Quick response to prevent disasters or costly damages
- Signals are sent to subscribers in real-time in advance
  - People can take response actions
  - Also suitable automatic response actions are triggered
- Operational phases:
  - Detection; the geographic area equipped with appropriate detection and sensing
  - Analysis; continuous processing of the information discriminating by areas
  - Warning; alert signals to emergency agencies and citizens
ARCHITECTURAL APPROACHES:

- **Centralized analysis;**
  - A central unit collects data from the observed area and merges it with data from other sources (as satellite observations)
  - Prohibitively expensive in unpopulated areas

- **Local analysis;**
  - Local application collects data and decides based on local info.
  - Simplest solution
  - Limited effectiveness since the global view is lost

- **Distributed analysis (the hybrid case);**
  - A local application performs the monitoring and analysis
  - A central application complements the local ones, receiving all monitored data (not necessarily in real-time), and tuning data for the prediction models used by local applications
  - Less restrictions to the communication infrastructure
Wild fire detection

- Several WSNs distributed over a large wild area.
- Total area subdivided into several regions.
- Each region is supervised by a local analysis and processing unit (LAPU).
- Sensors communicate with LAPUs via wireless mesh nodes using one or more hops.
- Connectivity with infrastructure:
  - Opportunistic communication (high throughput, high latency)
  - Low latency and relatively low throughput channel.
RECONFIGURATION VALIDATION:

- Data readings; Local applications *periodically* collect data on temperature, CO₂ concentration, light, pressure, smoke, humidity, etc.

- *Spatial and temporal resolution* are set to detect potential risky situations maximizing the life time of the WSN.

- *Sensor activation*
  - In normal situations, not all sensors are active.
  - Upon alarm detection, activation of sensors and data exchange among LAPUs is done in real-time.
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iLAND architecture

- iLAND Core Functionality
  - Service Management
  - Application Management
  - QoS global communication settings
  - Compositional logic
  - Application control

- iLAND Communication Backbone
  - Data-centric Publish/Subscribe paradigm
  - Standards-based solutions (DDS)
Real-time communication

- Decoupled interaction following data-centric middleware paradigms
  - DDS (Data Distribution Service for Real-Time Systems)
  - ICE (Internet Communications Engine)
  - Observed RT-CORBA and Distributed RTSJ

- Network protocols
  - Real-time communications with Time-Triggered paradigms
  - Combined use of level 3 protocols for QoS communication
iLAND service model

iLAND: middleware for deterministic dynamically reconfigurable NES

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TECHNIQUES

- Graph search
  - Complexity threats
- Admission control
  - Correct characterisation of QoS and real-time properties
  - Resource consumption and requirements

APPLICATION DOMAINS

- On-line: fast response (time-bounded solution)
- Off-line: optimization
Graph search vs Admission control techniques

- Graph based composition
  - Heuritic utilization
  - * algorithms
  - Linear complexity algorithms: one way search (no way back)
  - Selective search: partial way back.

- Schedulability analysis
  - Worst-case
  - Average-case
  - Budget assignment
iLAND prototypes

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To summarize...

- iLAND targets networked embedded systems with:
  - Heterogeneous nodes
  - Decoupled interaction
  - Needs for reconfiguration in a timely manner

- Use of standard-based solutions for communications backbone (such as DDS)

- Build reconfiguration functionality on a service oriented structure for applications

- iLAND middleware architecture provides a flexible solution to integrate different node types and meet objectives

- iLAND concepts will be validated in different domains.
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