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Product driven manufacturing control with embedded decisional entities

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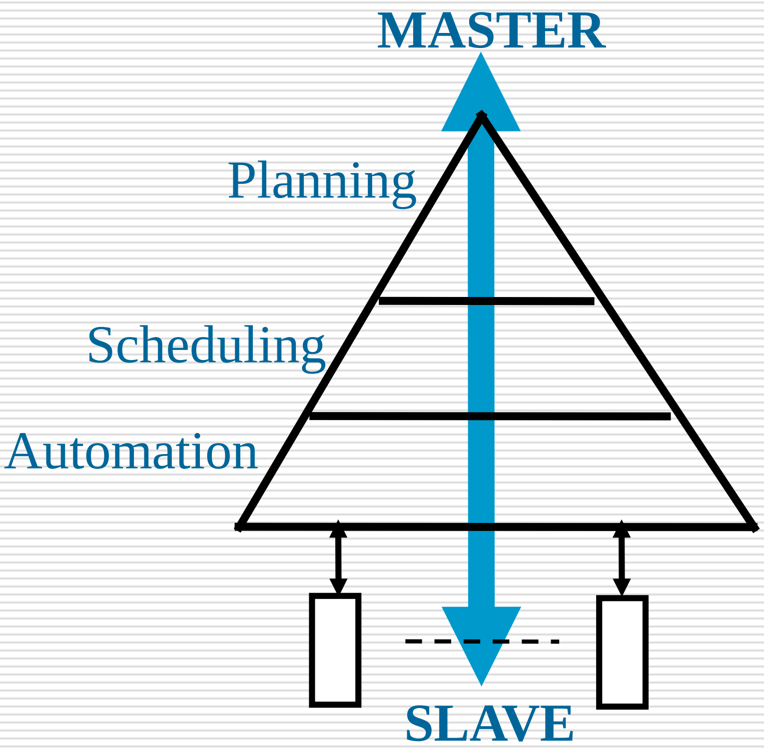
Summary

1. Introduction
    - State of the art in discrete, repetitive manufacturing control
    - From hierarchical to heterarchical control topologies
2. Structure of the control model
    - The physical infrastructure
    - Service-oriented control model with automatic reconfiguring
    - Structure of the generic building block
3. Dynamics of the control model
    - Using the Intelligent product for taking decisions in an industrial fabrication environment, switching between the different production strategies
    - Real-time decentralized resource allocation process
4. Implementation of the generic control model
    - Composing agents
    - RSAM distributed infrastructure and agent interconnection

Introduction

Centralized/hierarchical control approach



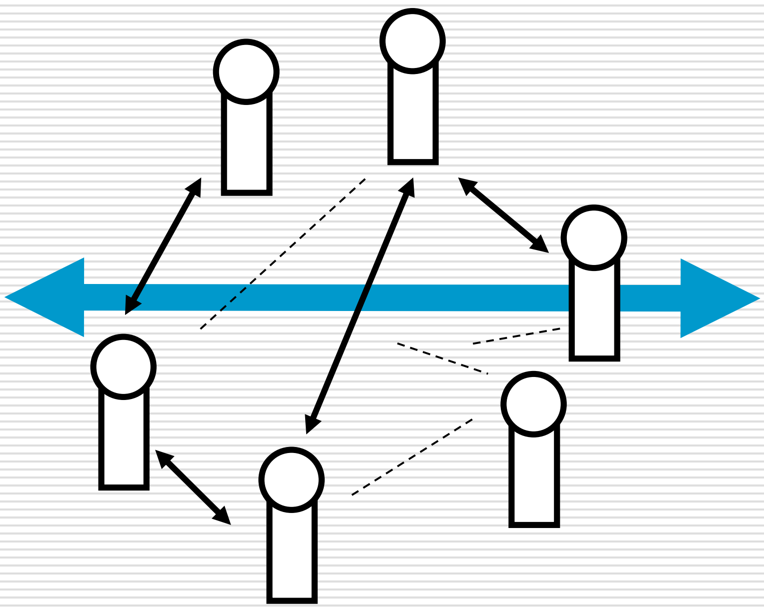
Computer Integrated Manufacturing

+ ***provides near optimal solution with hard assumptions***

- ***tends to become inefficient when the system must deal with stochastic behavior***

Introduction

Decentralized/heterarchical control approach



+ ***agile, reactive & able to adapt to the environment changes***

- ***lack of long term optimality even when the environment remains deterministic***

- Holonic systems (Van Brussel et al., 1998),
- Heterarchical systems (Trentesaux, 2007)
- Intelligent products (Meyer et al., 2008)

Introduction

- Current demands in FMS control: best performance, predictable over time and agile
- Classic solutions: centralized vs decentralized control architectures
- Intelligent products (Meyer et al., 2008) in a service oriented control architecture
- Holonic control (autonomous and cooperative entities)
- Objective: propose an architecture agile and optimized on long term

Objectives:

- Control system composed of autonomous and cooperative entities
- Fault tolerance
- Agile configuration of resources
- Long term / global optimization

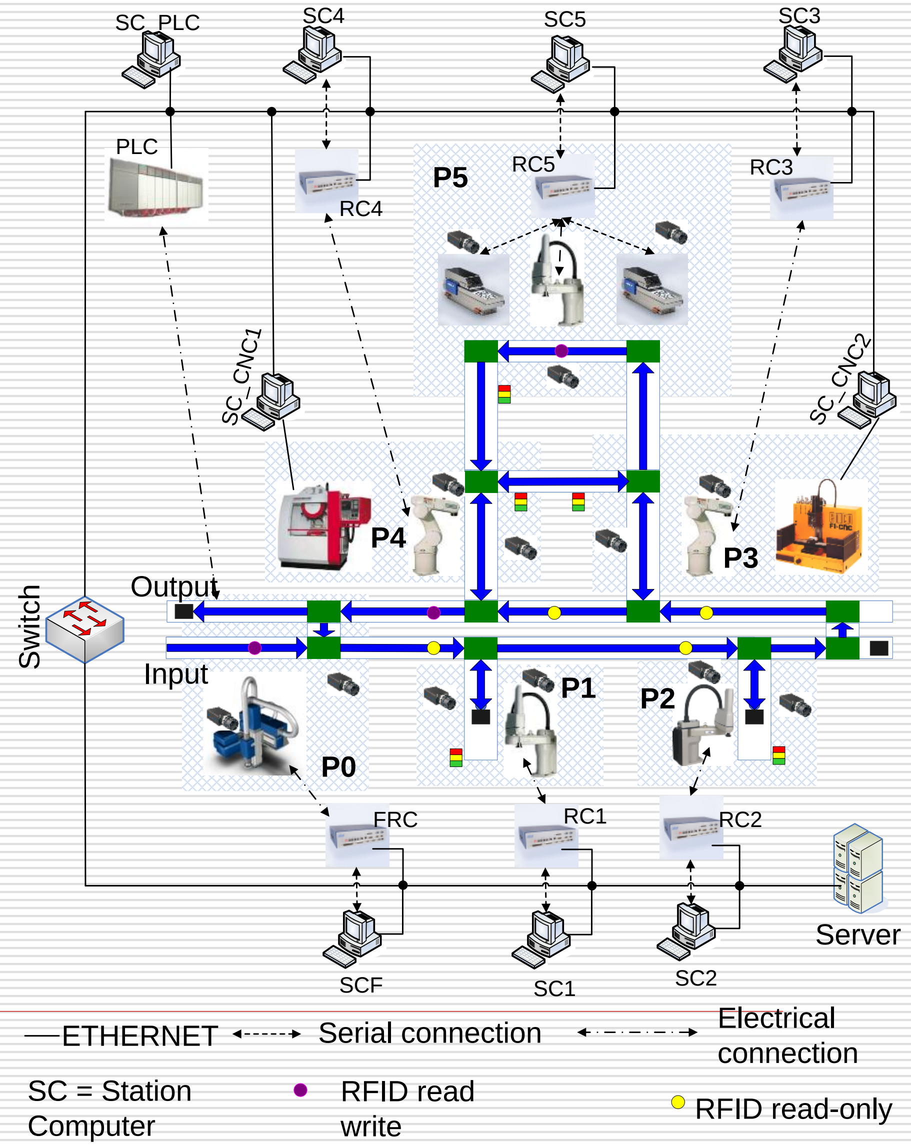
Solution:

- **Semi-heterarchical control architecture inspired from the HMS**

Structure of the control model

Shop-floor manufacturing structure:

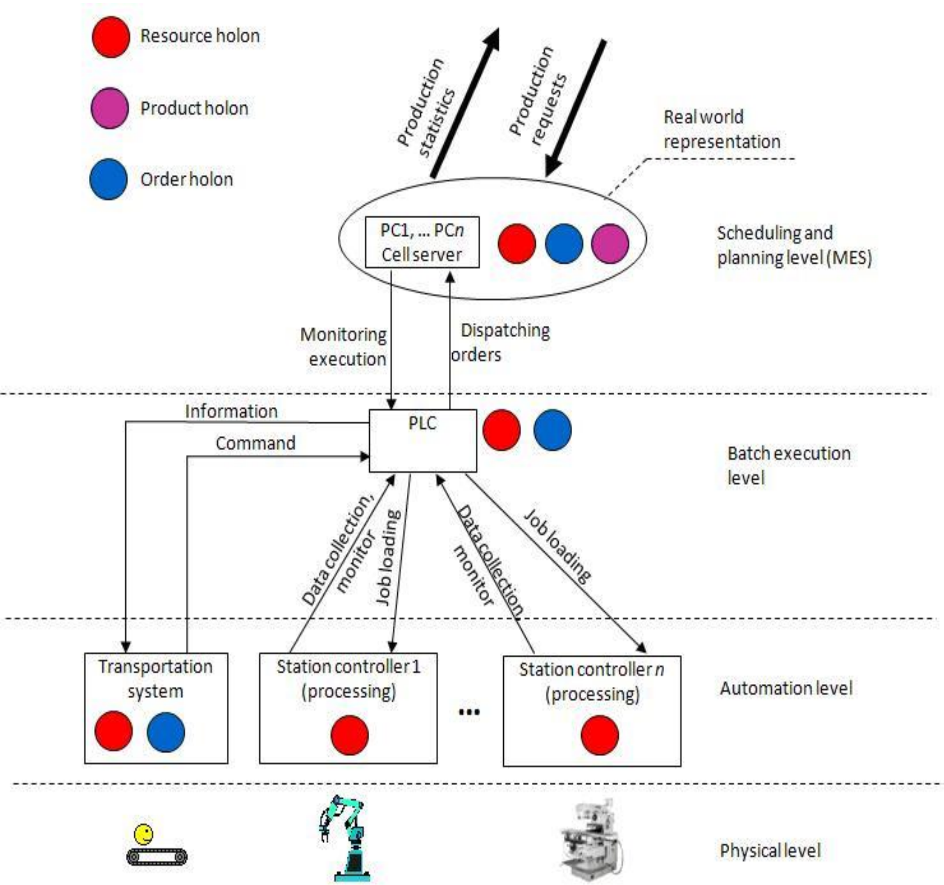
- 4-robot workstations (2 SCARA, 2 vertical articulated for assembly)
- 2 CNC milling machines serviced by vertical articulated robots
- 1 Cartesian robot workstation for pallet input / output
- 1 SCARA robot workstation with dual part feeding devices (vision-based AnyFeeders)
- Dual video cameras (stationary, down looking / mobile, arm mounted) for each machine vision system connected to robots in P0-P5

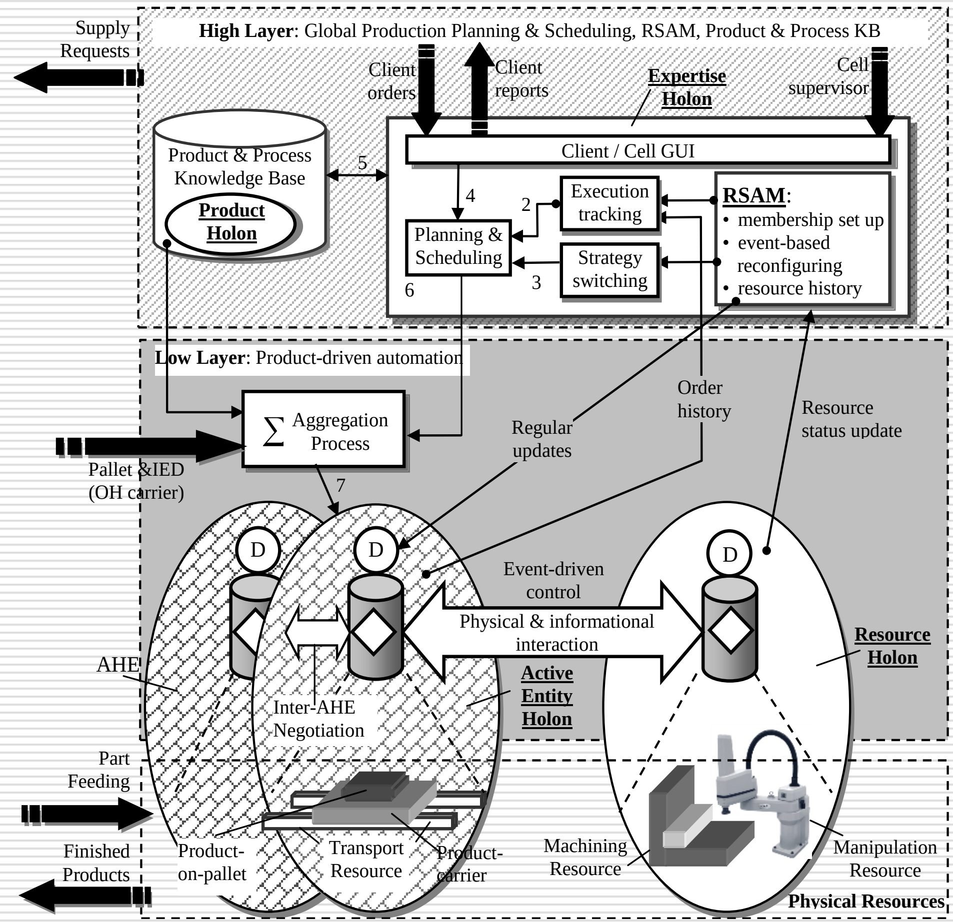


Structure of the control model

Old control model VS New control model

Composing entities / holons:



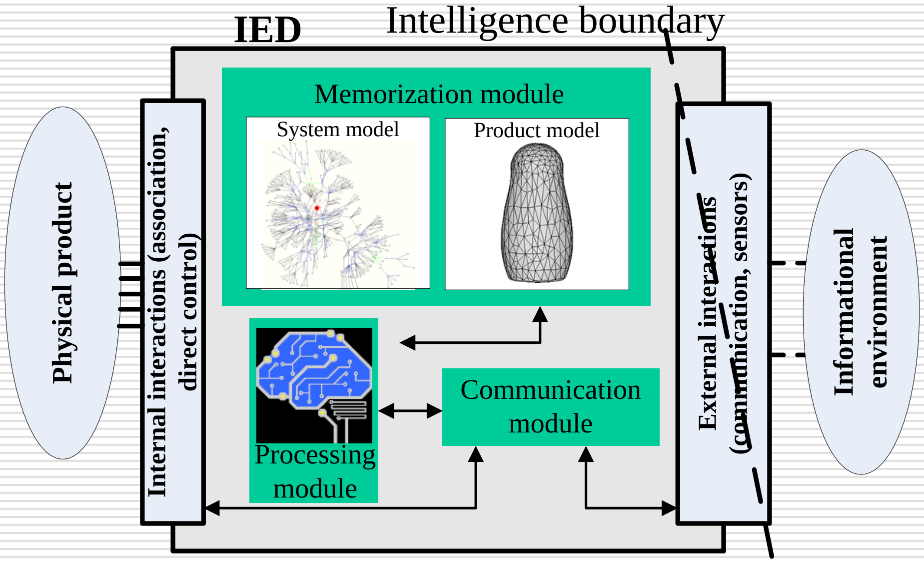


counterpart.

Structure of the control model

Active Holon Entity structure

- *Embedded intelligence*, handles:
  - ✓ the updated model of resource services access (RSAM);
  - ✓ the product model;
  - ✓ a set of resource allocation algorithms (real-time scheduling);
  - ✓ an inter-agent communication protocol;
  - ✓ product-driven automation:
    - - "Next-operation" scheduling;
    - - "Packet optimization" scheduling lifecycle



Dynamics of the control model

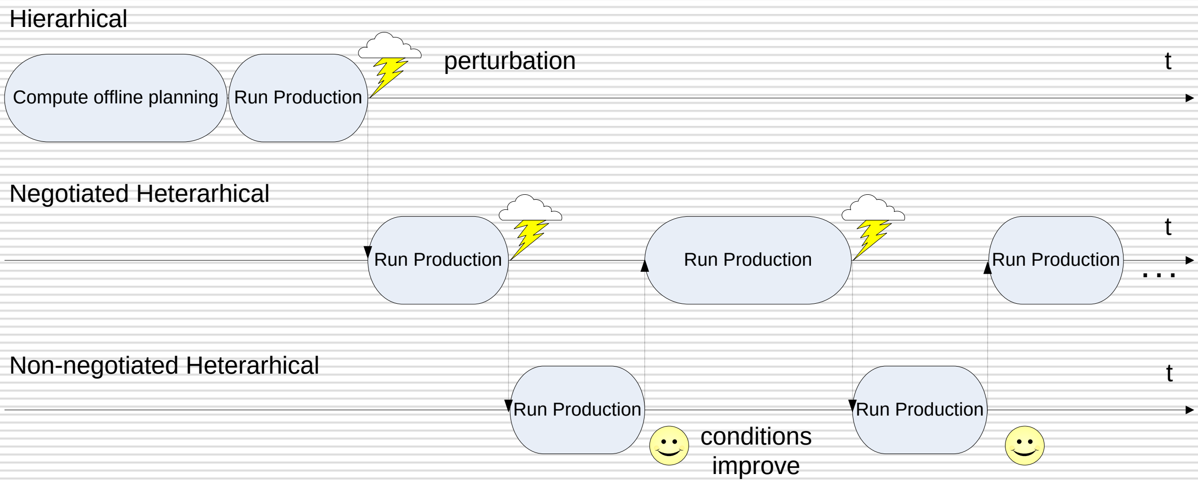
Switching between the different production strategies

1. **Hierarchical**
   - Offline planning and allocation

2. **Negotiated Heterarhical**
   - No planning
   - Packet level online allocation

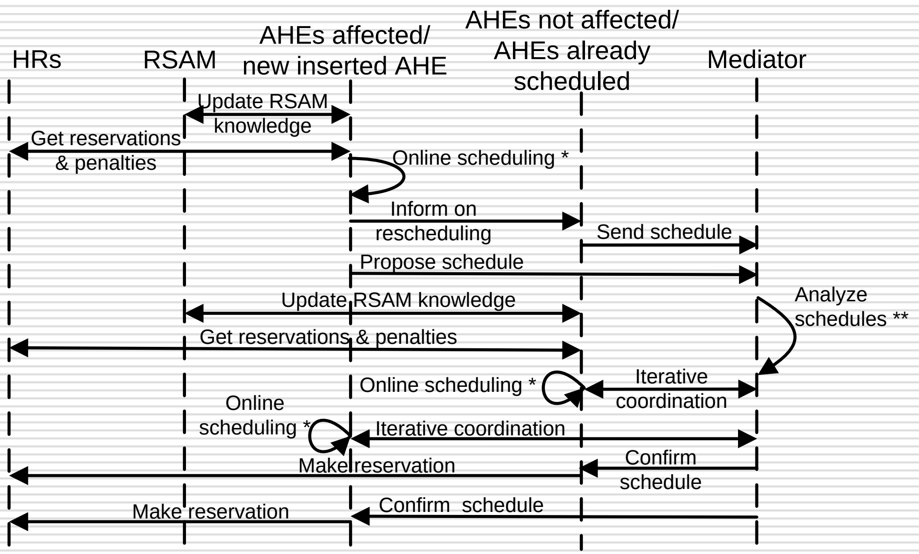
3. **Non-negotiated Heterarhical**
   - No planning
   - Next job level allocation

=> Semi-heterarchical strategy



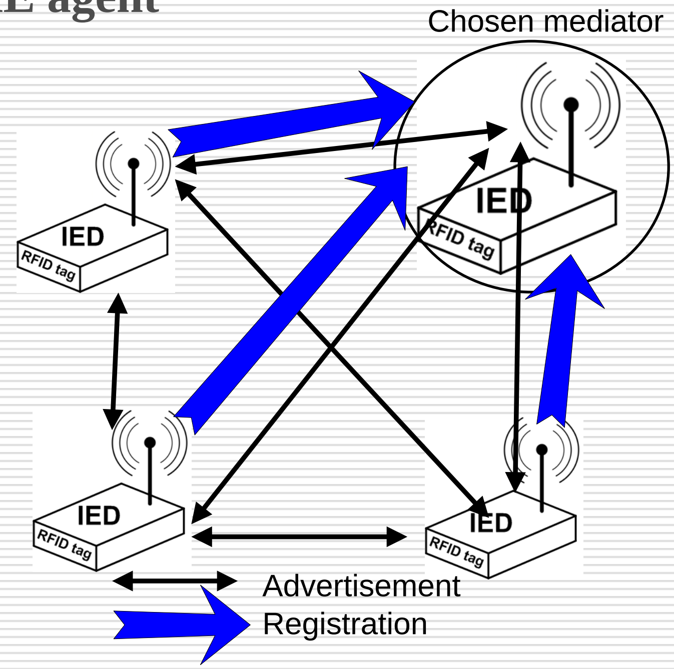
Dynamics of the control model: allocation process

- **Process objective:**
  - **Makespan minimization and equal resource utilization**
  - **Adaptability to perturbations**
- **Used strategies: hierarchical, negotiated heterarchical, non-negotiated heterarchical**
- **Real-time decentralized resource allocation**



Dynamics of the control model: Mediator

- **Mediator definition**
  - **Agent in charge with conflict resolution**
- **Selection process and lifecycle**
  - **Elected dynamically, after the current one leaves the system**
  - **Implemented as a functionality of the AHE agent**

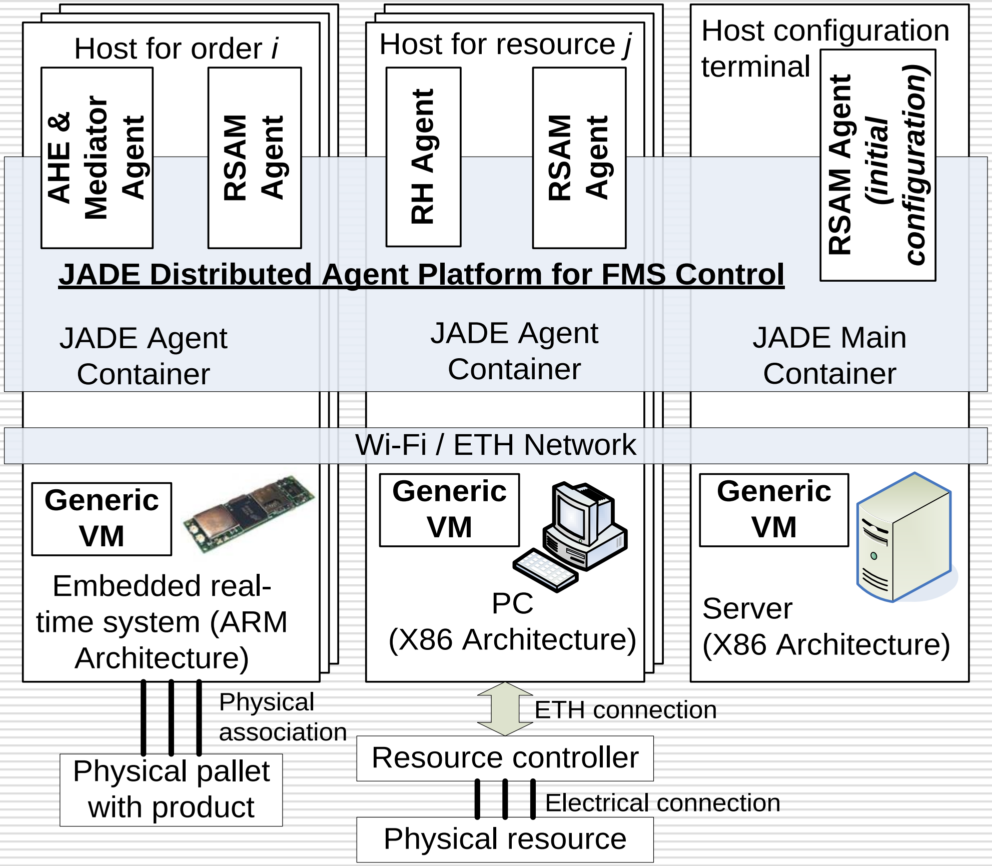


Implementation of the generic control model

Generic control model: based on JADE framework

Composing agents

- Active holon entity agent (Overo air)
- Resource holon agent (legacy equipment integration through MAS technology)
- RSAM agent



Implementation of the generic control model

Worst recovery time in case of perturbation [time units]	
Resource *i* failure: R*iF*	Restoring Local Storage *i* (LS*i*) at depletion
6.4 (R1F)	97 (LS1)
6.5 (R2F)	112 (LS2)
6.8 (R3F)	136 (LS3)
6.5 (R4F)	83 (LS4)

Conclusions

Paper goals:

- ✓ Definition of a generic service oriented control architecture
- ✓ Proposition of a method for decentralized resource scheduling using a mediator agent
- ✓ Proposition of an implementation framework which includes intelligent products and agentified resources

Advantage of the proposed approach:

- ✓ Scalable
- ✓ Reactive
- ✓ Easy resource (re) configuration

Current work and perspectives:

- ✓ Comparison with the previous control architecture
- ✓ Adding an ERP on top of the high control level