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Product-driven automation in a service oriented manufacturing cell

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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

3. Dynamics of the control model: the resource allocation process
   - Real-time decentralized resource allocation

4. Implementation of the generic control model
   - Composing agents
   - RSAM distributed infrastructure and agent interconnection

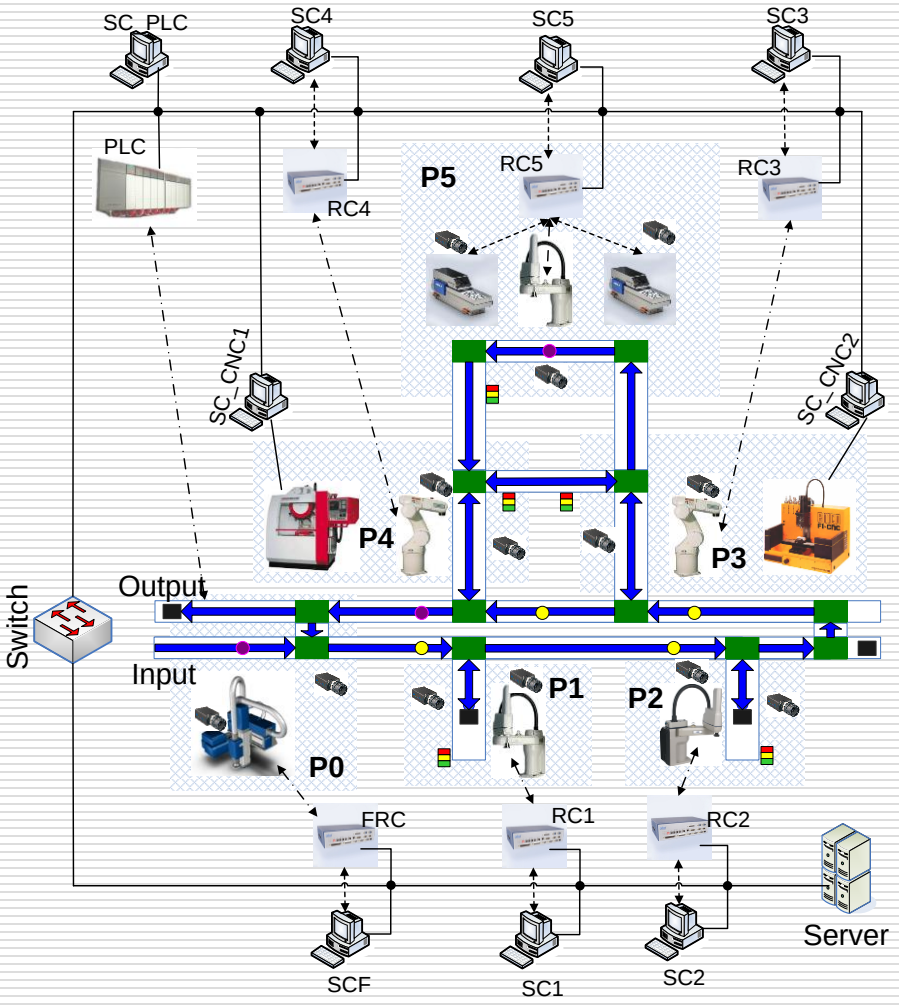
Introduction

- Current demands in FMS control: best performance and predictable over time
- Solution:
  - off-line schedule generated by a central entity
  - central or hierarchical control structure
- Problem: perturbations (e.g.: stock depletion, rush orders, etc) that invalidate the central planning and scheduling
- 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)

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**



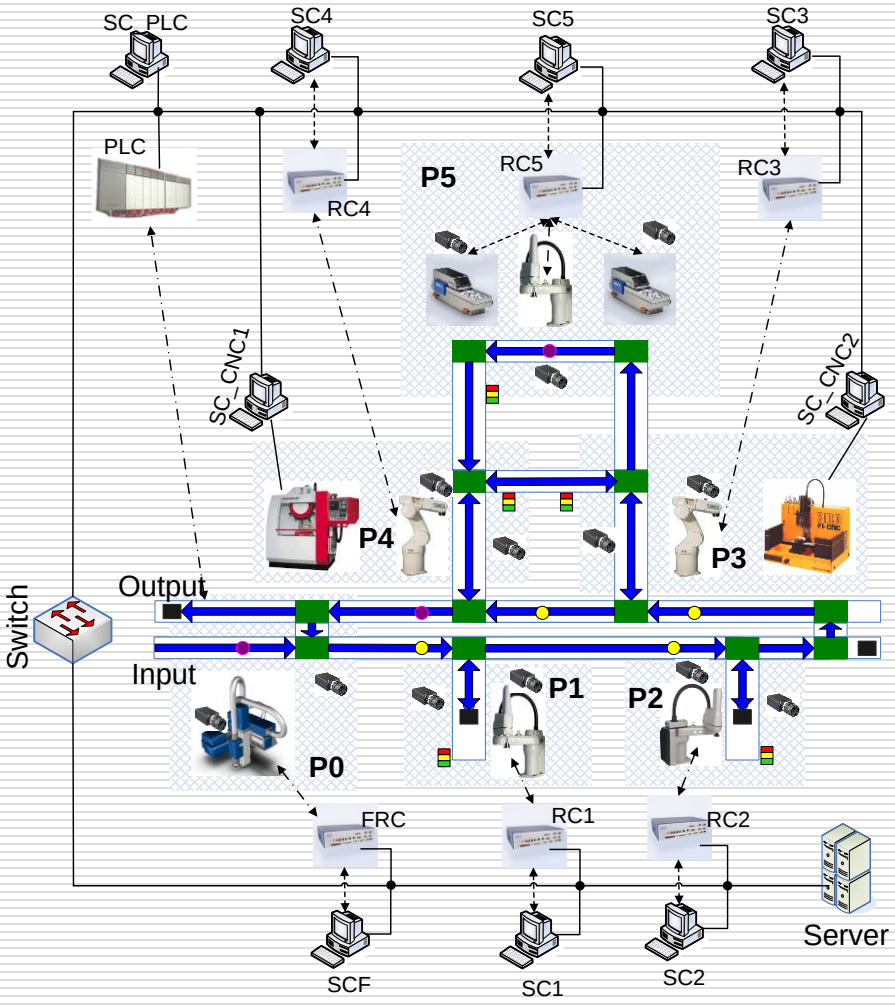
Structure of the control model

Objectives:

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

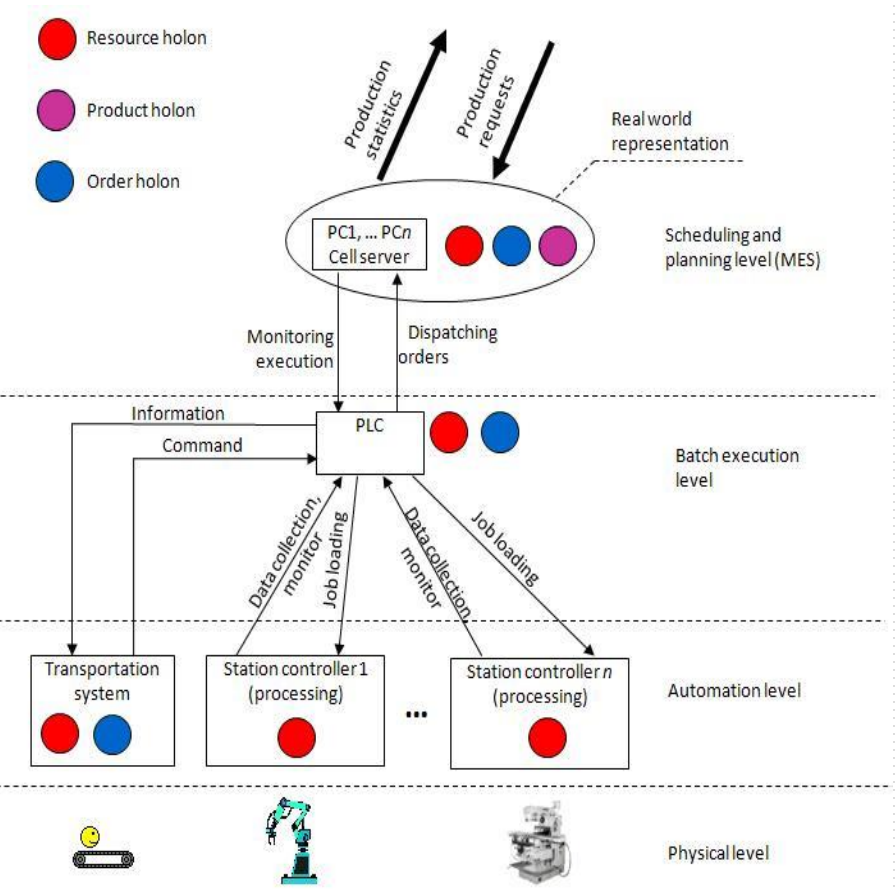
Solution:

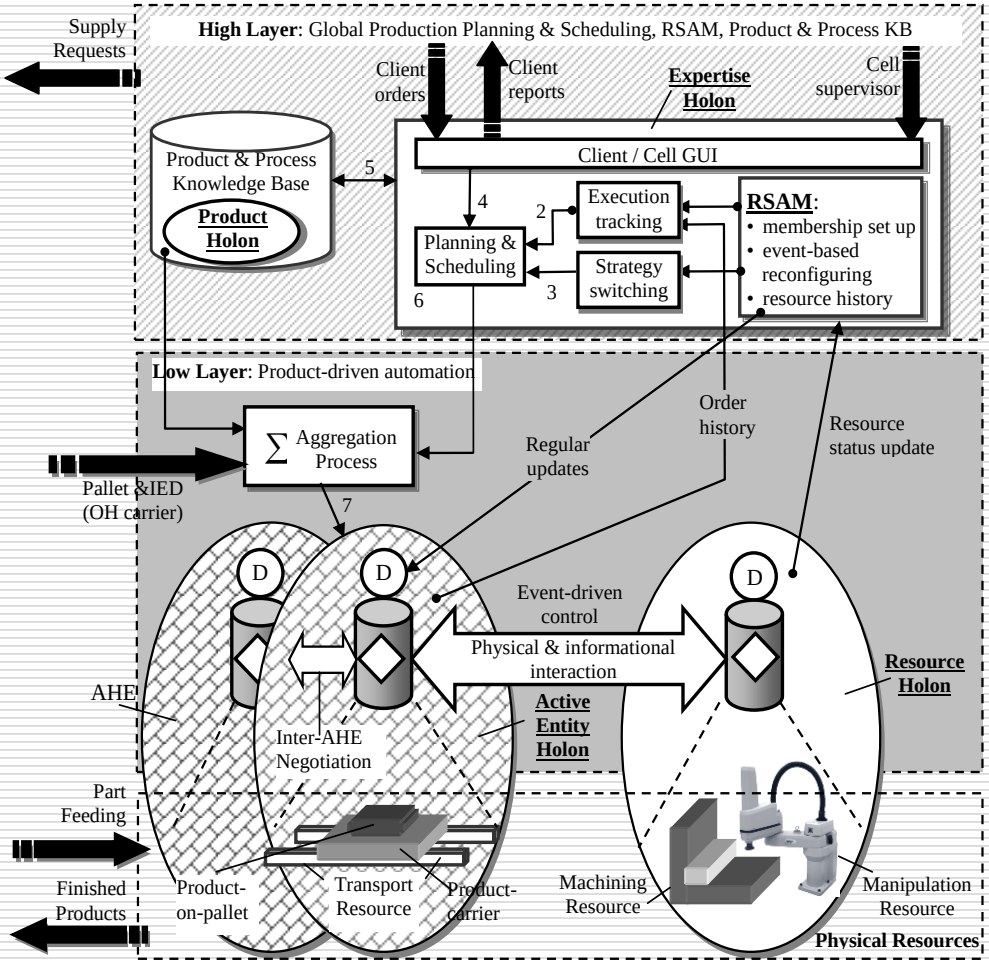
➢ Semi-heterarchical control architecture inspired from the HMS



Structure of the control model

Old control model VS New control model

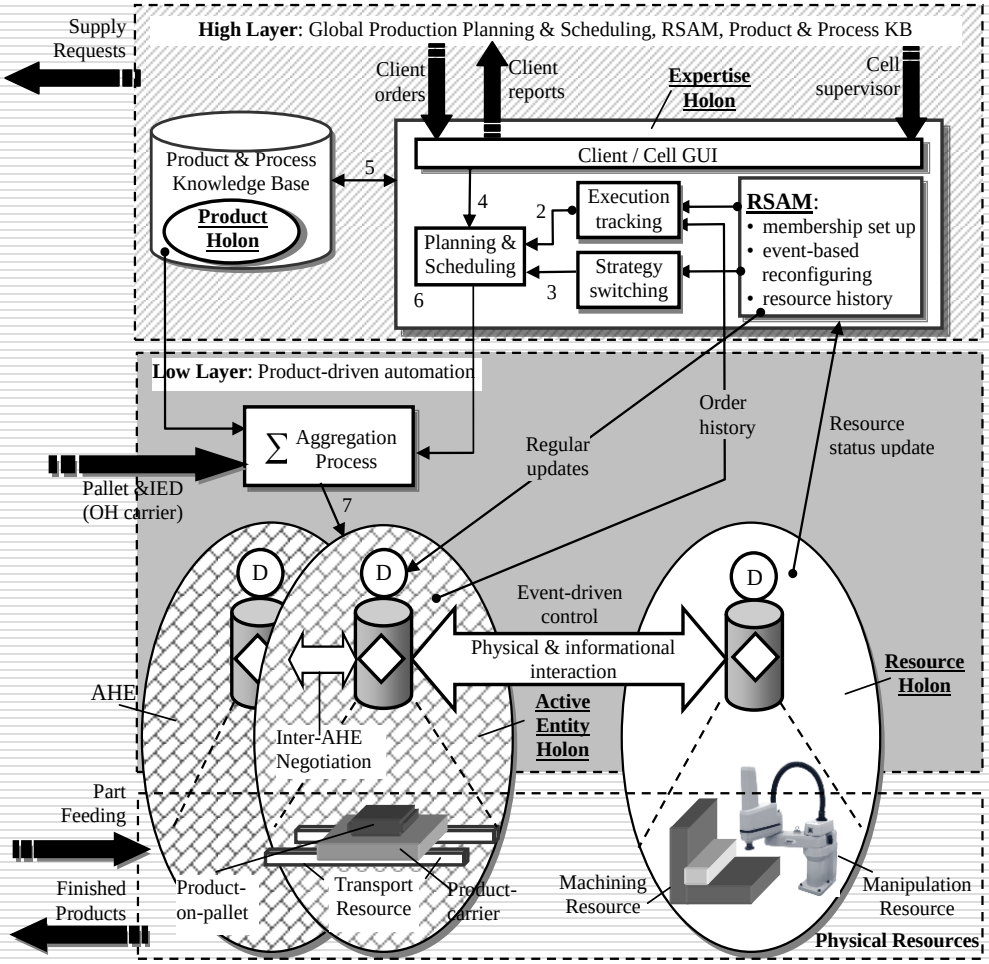




Structure of the control model

2-layer generic architecture for semi-heterarchic shop-floor control with resource service access reconfiguring

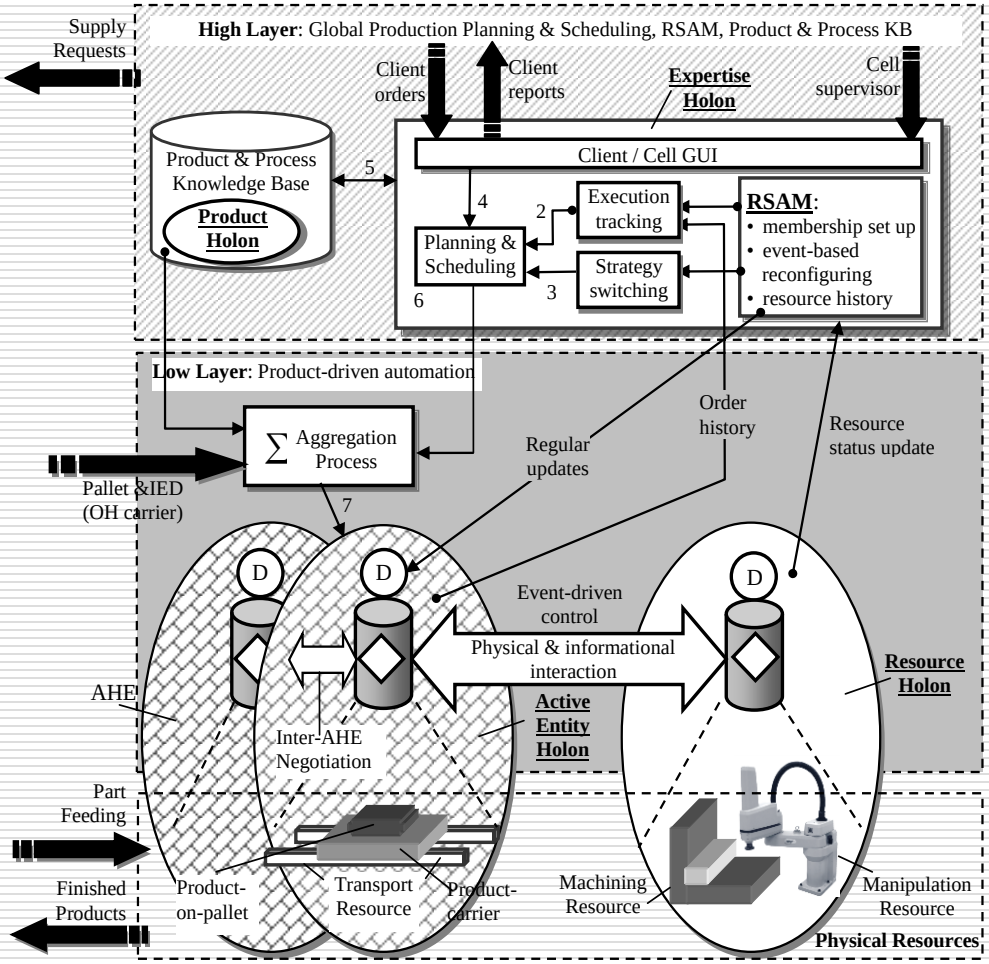
- **High layer: client and cell GUI, global production planning and resource allocation, strategy switch, execution tracking, RSAM (re) configuring**
- **Low layer: Product-driven automation (product routing, resource monitoring, product history) + packet resource allocation**



Structure of the control model

Composing entities / holons:

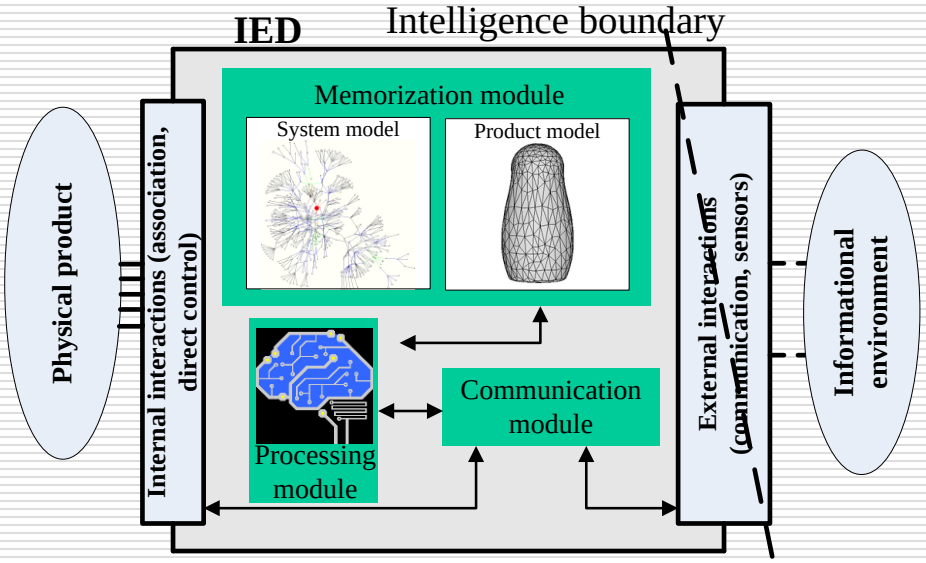
1. **Expertise Holon (EH): global production planning, scheduling, coordinator, GUI and production strategy decider;**
2. **Active Holon Entity (AHE): an aggregate intelligent entity in charge of taking real-time decisions;**
3. **Resource Holon (RH): physical resources together with the control counterpart;**
4. **Product and Process Knowledge Database (PPKB): stores the operations structure for the products;**
5. **Resource Service Access Model (RSAM): distributed autonomous entity in charge of collecting resource information and offering it in a concise manner.**



Active Holon Entity structure

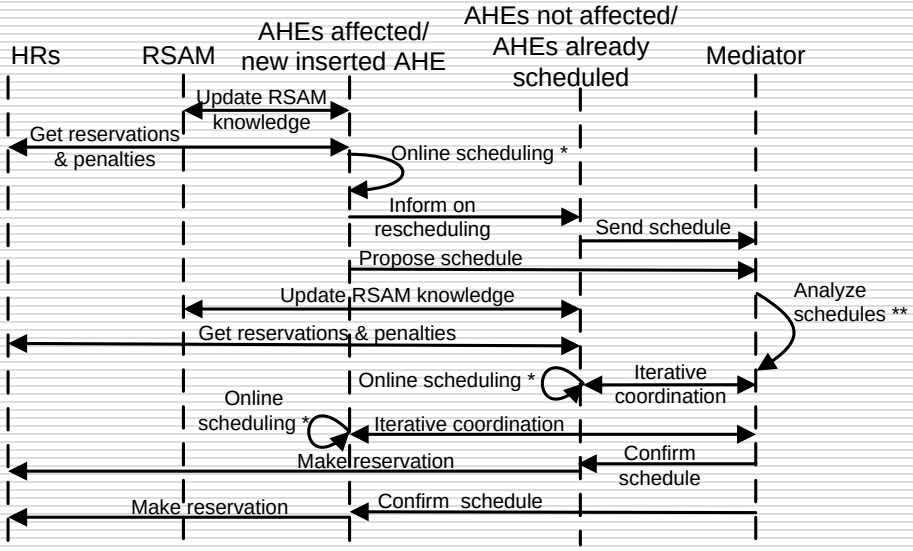
- *Embedded intelligence*, handles:
  - ✓ the updated model of resource services access (RSAM);
  - ✓ the product model;
  - ✓ a set of resource allocation algorithms (real-time scheduling);
  - ✓ an inter-agent communication protocol;
  - ✓ product-driven automation:
    - "Next-operation" scheduling;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

lifecycle



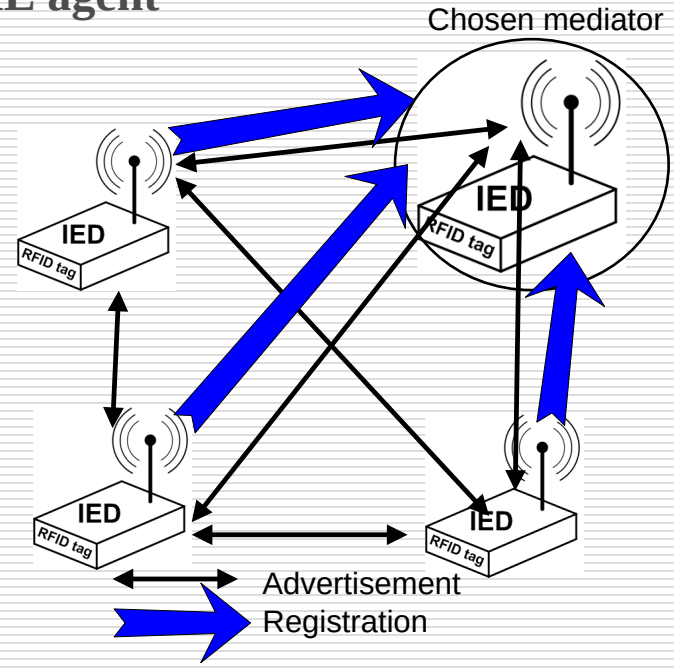
Dynamics of the control model: allocation process

- **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**

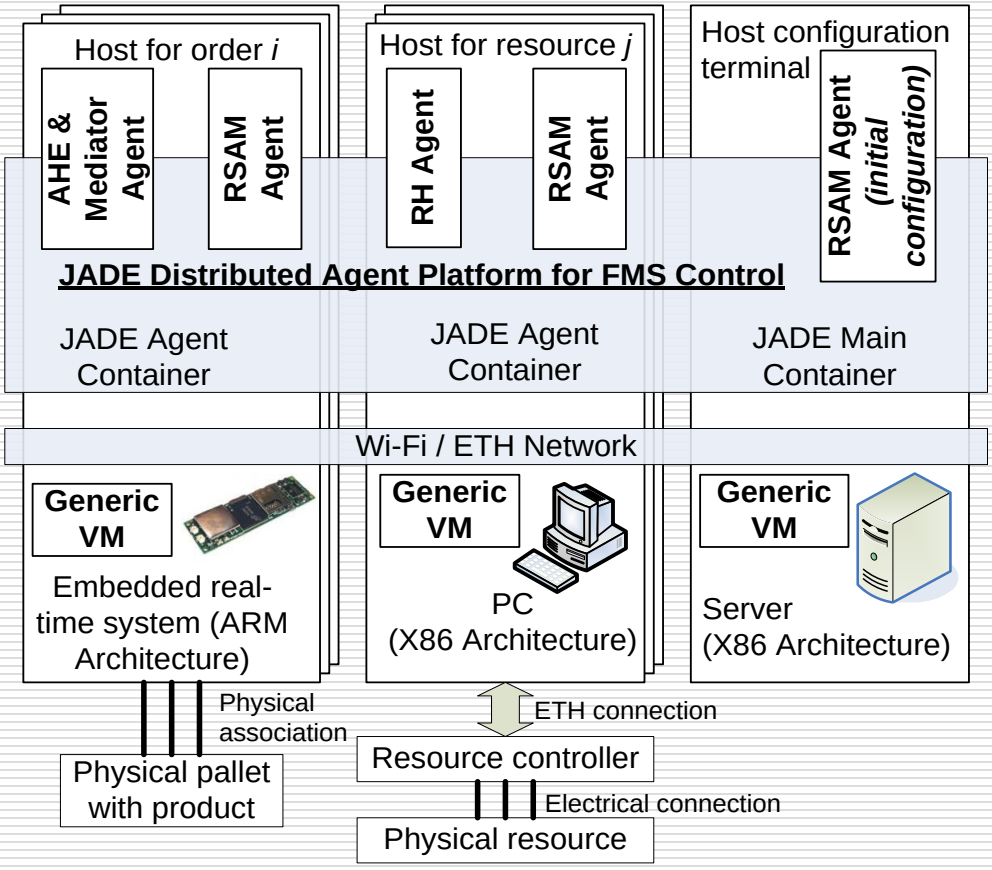


Implementation of the generic control model

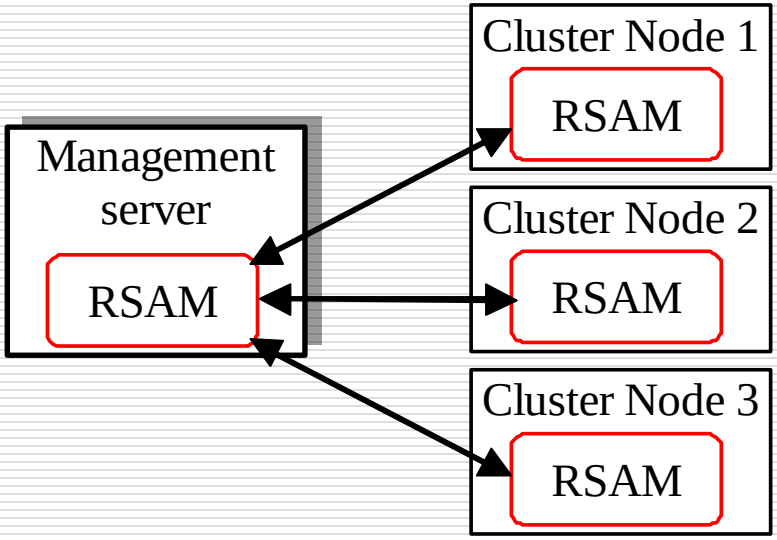
Generic control model: based on JADE framework

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



RSAM distributed infrastructure and agent interconnection

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