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Distributed Manufacturing Control with Extended CNP Interaction of Intelligent Products

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Summary

1. Introduction
2. Structure of the control model
3. Extended CNP for order holon execution
4. Information architecture

Introduction

- Manufacturing domain is suitable for decentralization of the control because it features physically highly distributed processing systems

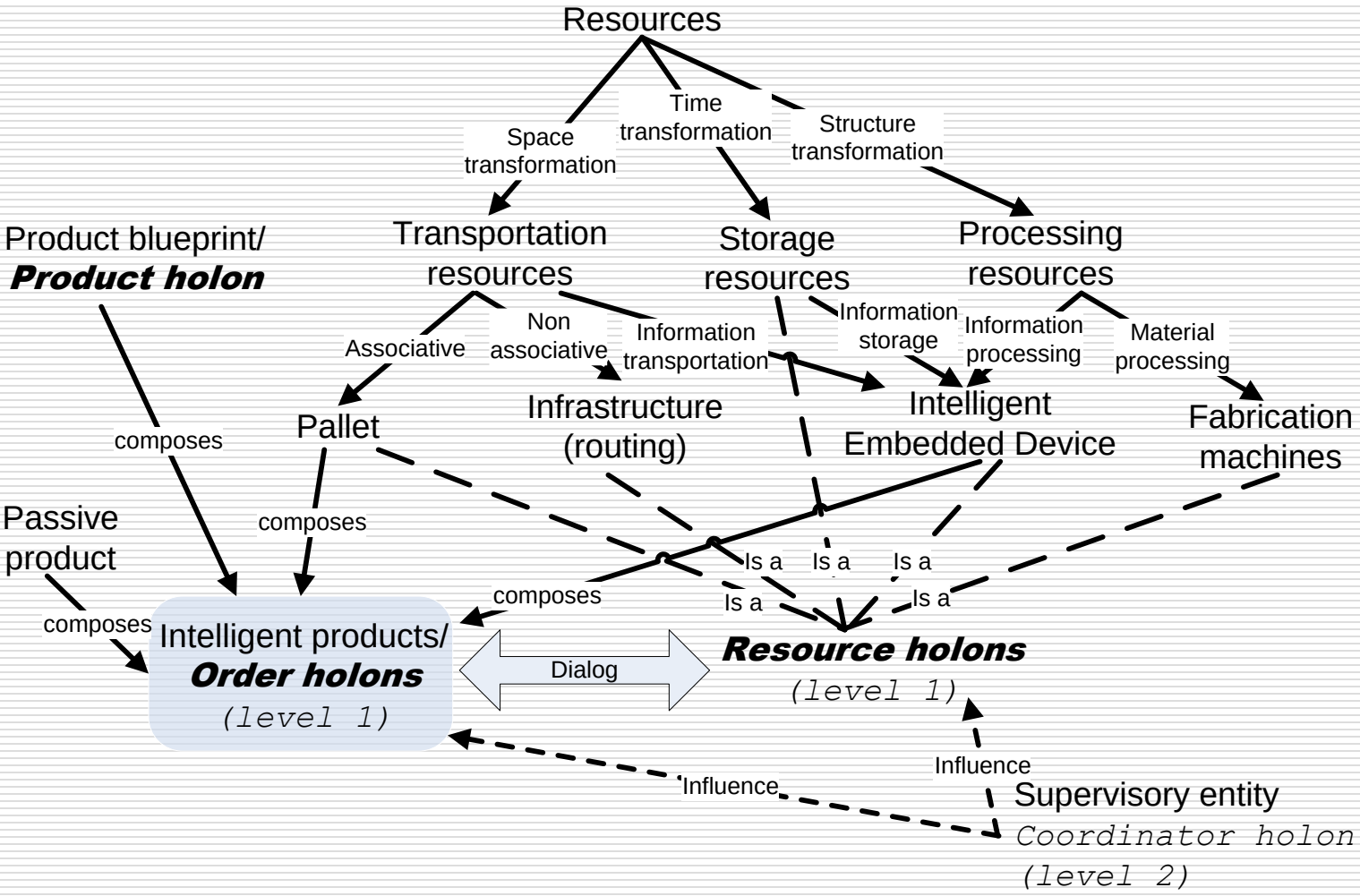
- Production environment is not always deterministic, centralized approaches rapidly become inefficient when the shop floor cell must deal with disturbances or uncertainties => switch the primary objective of a designed system from global optimization to adaptability at perturbations and real-time optimization

- Intelligence is highly distributed in sensing and local analysis of physical properties

- Distributed intelligence paradigms:
  - Product-driven automation
  - Intelligent product (McFarlane et al., 2002, Meyer et al., 2008)
  - Multi Agent control (Bellifemine et al., 2007)
  - Holonic Manufacturing Systems (Babiceanu et al., 2004, Borangiu et al., 2009)
  - Result: dynamic reconfiguration to provide agility to frequent changes in production, fault-tolerance to resource breakdowns and adaptability to material flow variations.

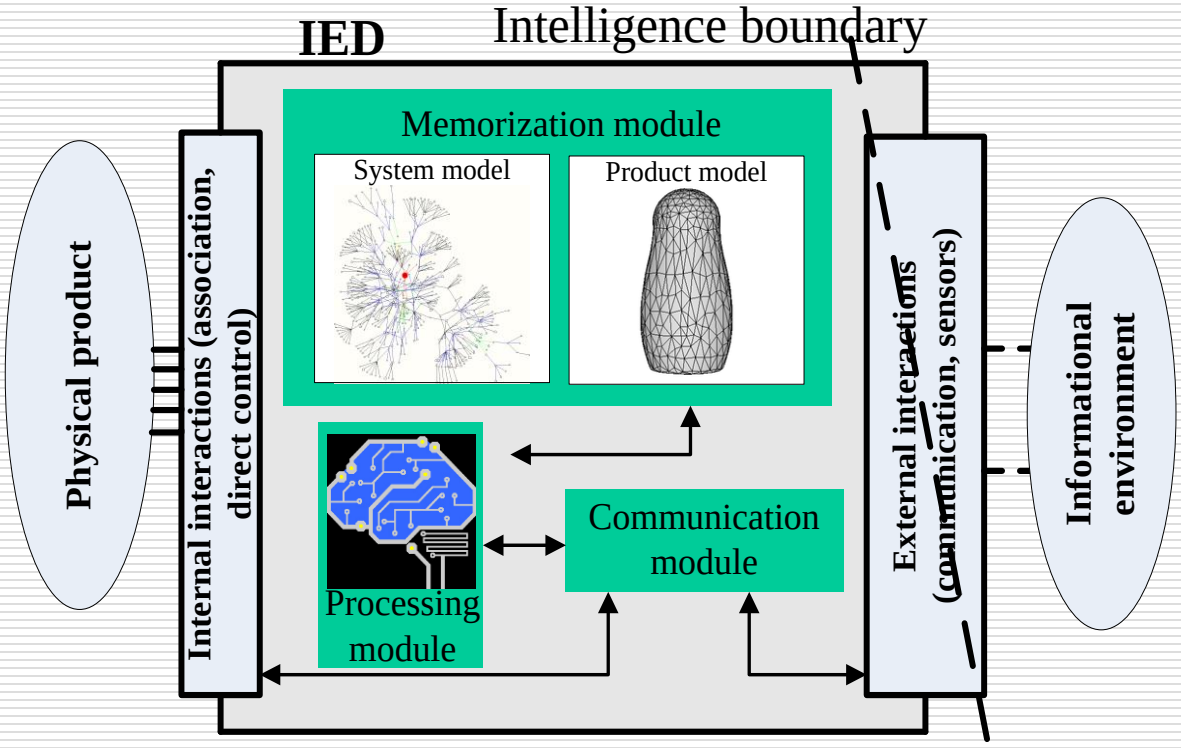
- Reduce the myopia (Leitao et al., 2010) through a combination of the two control modes - hierarchical and heterarchical

Structure of the control model



Structure of the control model

- Order holon
  - represent the client's orders
  - composed of: product, pallet carrier and IED



Structure of the control model

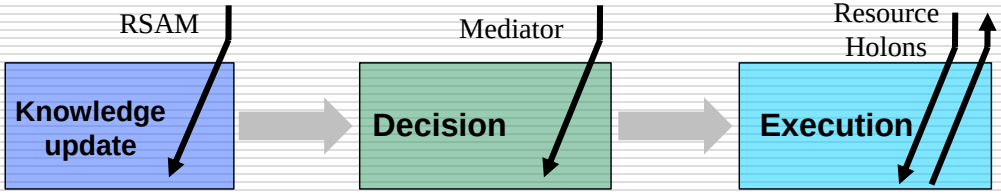
- The proposed structure of the control system is completed with two additional elements which help ease the access to information
  - Resource Service Access Model (RSAM): distributed fault-tolerant entity in charge of collecting resource information during their usage and offering it in a concise manner when taking the decision of resource allocation.
  - Mediator: agent in charge with conflict resolution during active OH bidding.

Extended CNP for order holon execution

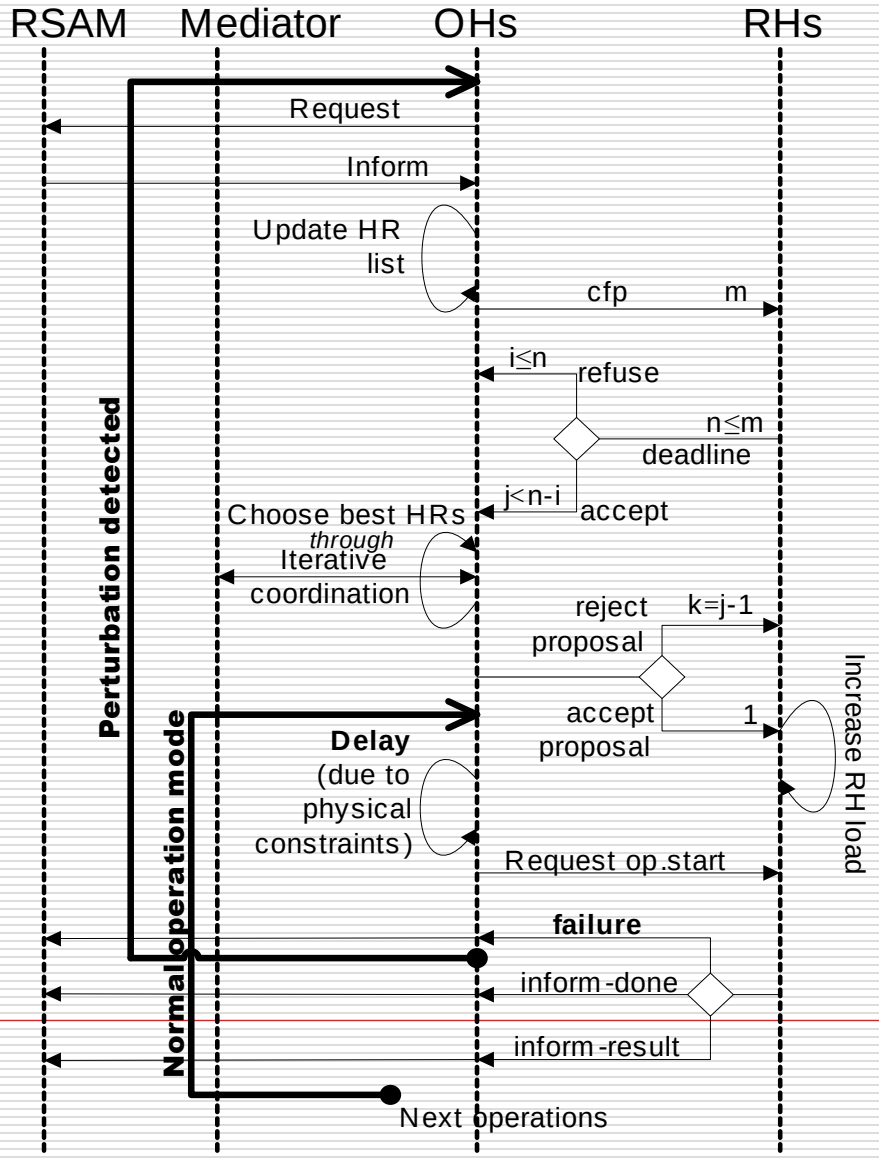
- Semi-heterarchical strategy

Strategy	Description	Expected results
Hierarchical	Planning and scheduling for a batch are centralized done at the high layer	Minimize the makespan at batch level
Negotiated **Heterarchical**	Schedules of each active OH are computed through communication with the other active OHs.	Minimize the makespan at packet level
Non-Negotiated **Heterarchical**	There is no global scheduling and the next operation is selected on the first free resource found	Minimize the perturbation impact

- When executing a product the decisional module should provide an answer to the following questions: "What is the next operation to be performed? What is the resource that will do that operation? How do I bring the product there (which is the route)?"



Extended CNP for order holon execution

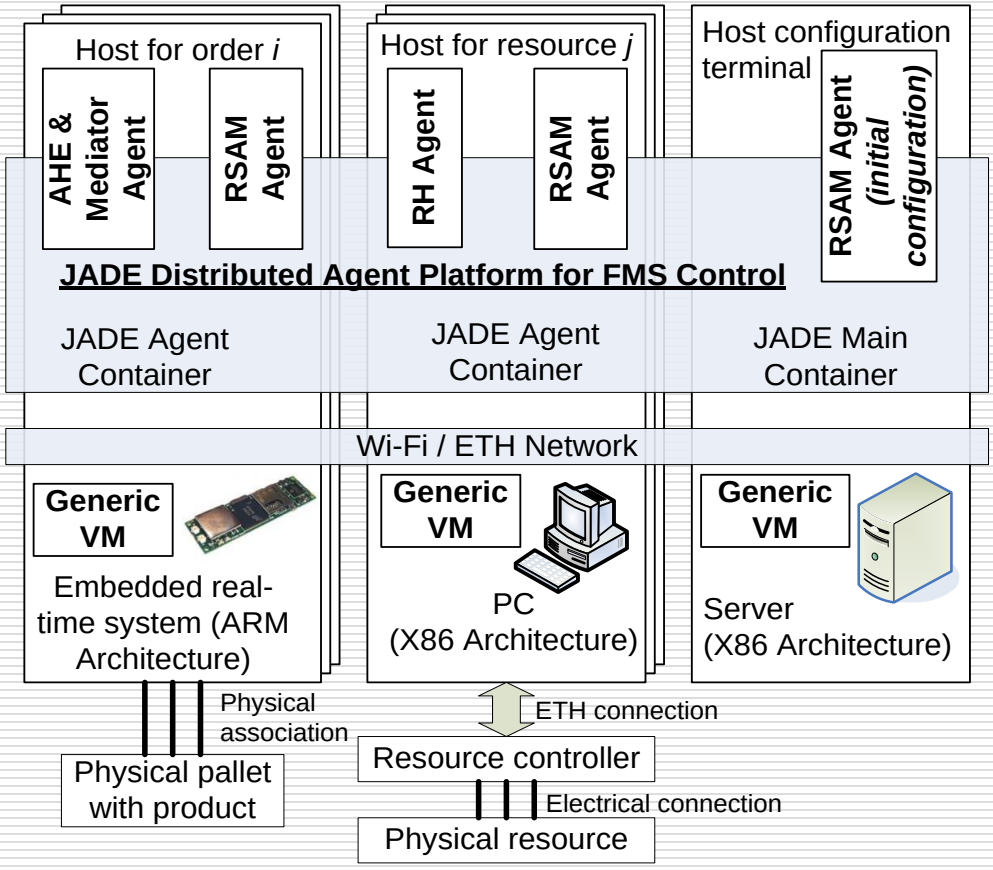


Information architecture

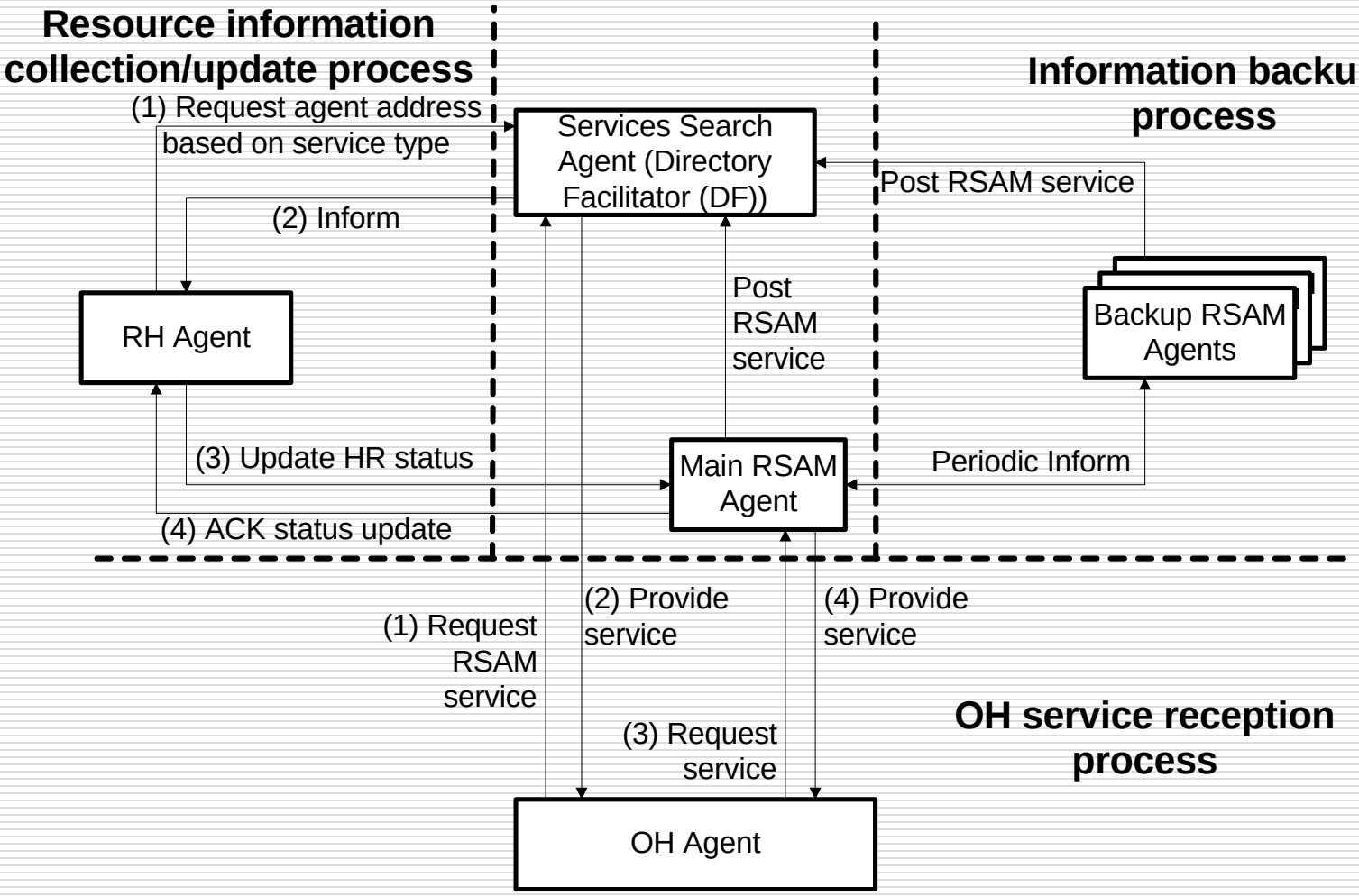
Generic control model: based on JADE framework

Composing agents

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



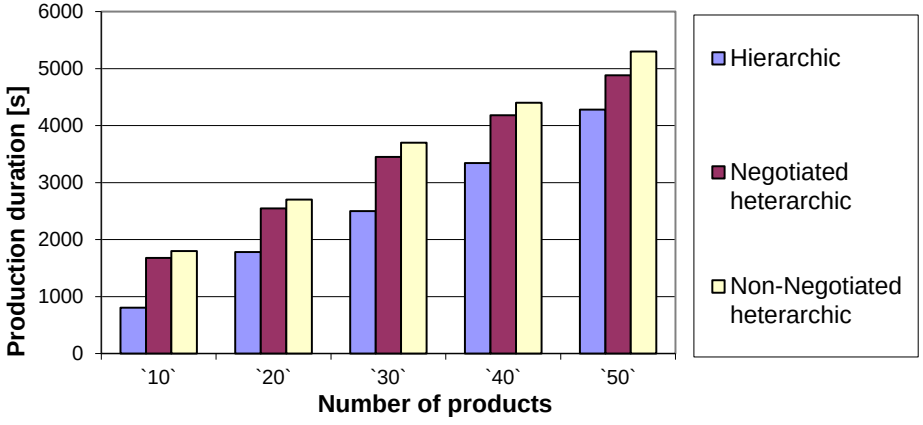
Information architecture

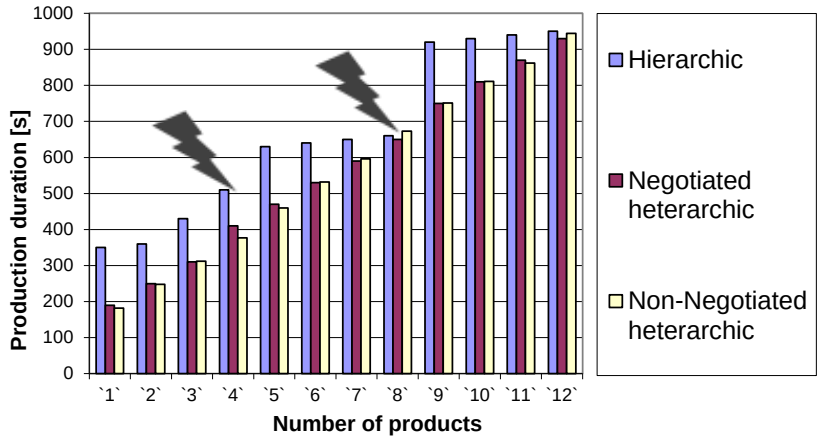


RSAM High Availability Architecture

Conclusions

- Experiments have been done using the three proposed control strategies
- In a non-perturbed environment the hierarchical strategy offers the best production time (global optimization), followed by the negotiated heterarchical (local optimization) and finally by the non-negotiated heterarchical (no optimization).
- In a perturbed environment (resource failures (flash) the results prove that the hierarchical strategy becomes inefficient compared with a heterarchical (negotiated of non-negotiated) strategy





Conclusions

- Advantages of using a semi-heterarchical strategy whose scope is to switch between hierarchical (stable FMS) and heterarchical (frequent disturbances) control.