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Fondul Social European
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OIPOSDRU

Universitatea
POLITEHNICA
din Bucuresti

INSEED: Creating IT Competencies for the Service Industry

(Service-oriented Computing, Cloud Manufacturing)

University Politehnica Bucharest

Program Strategic pentru Promovarea Inovarii în Servicii prin Educaţie Deschisă, Continuă (INSEED)
POSDRU/86/1.2./S/57748
Proiect cofinanţat din Fondul Social European prin Programul Operaţional Sectorial Dezvoltarea Resurselor Umane 2007-2013

FONDUL SOCIAL EUROPEAN
Investeşte în
OAMENI

InSeED

Agenda

- Services in Manufacturing Advances within INSEED
- Service Oriented Enterprise Architectures Masters Class
- Service Oriented Integration Patterns in Manufacturing
- SOA-enabled Devices
- Vertical Integration of the Manufacturing Enterprise
- Service-oriented Agents in MES Implementations
- MES Virtualization
- Dissemination of Research Results (SOHOMA workshops)

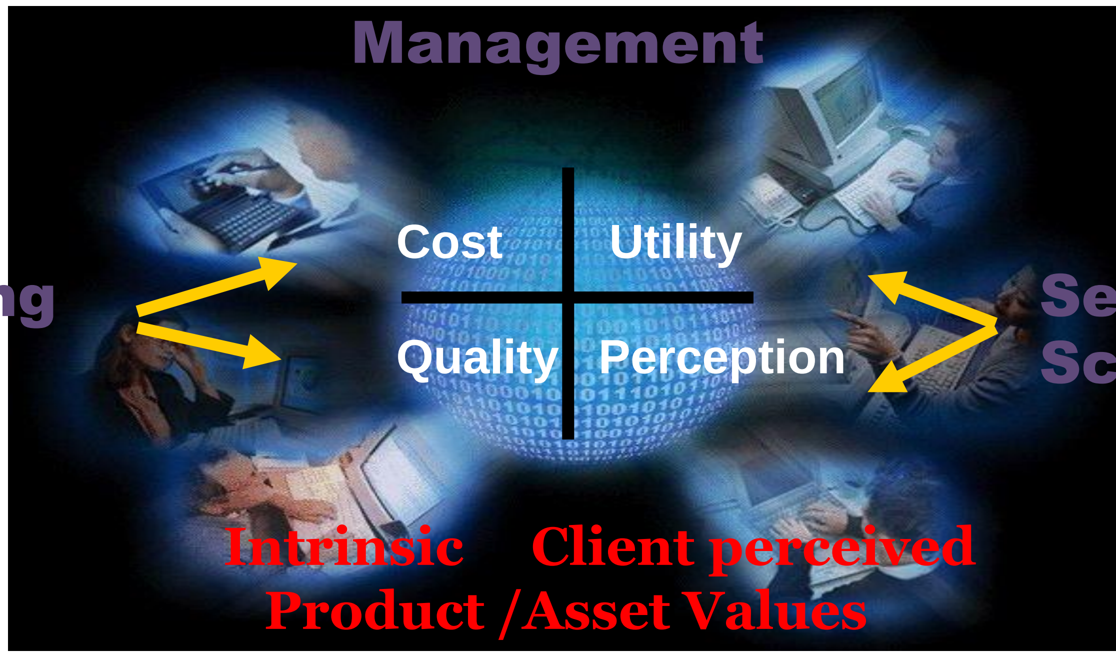
Value Creation: Engineering vs. Service

HOW VALUES ARE CREATED?

- Services focus on creating Utility Value or Perceived Value for a product/asset
- They are in contrast with Engineering which focuses on Cost and Quality
  Service Oriented Architectures in Manufacturing

Client-focussed

Engineering Science



Services Science

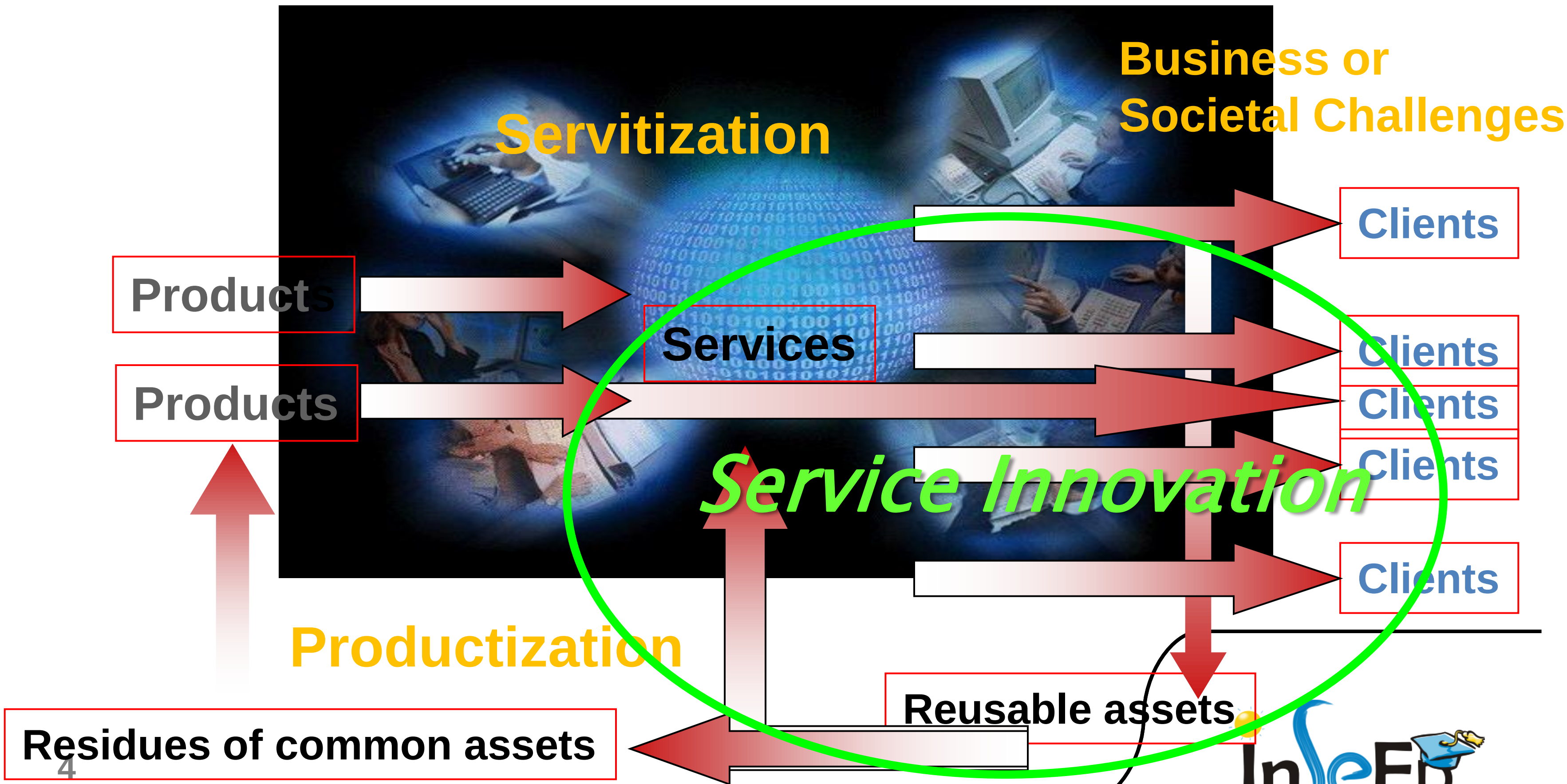
Value from enhancing the capabilities of things (customizing, distributing, etc.) and interactions and integrating between things (functionalities, availability, results, etc.)

Product-focussed

Science and Humanity Disciplines

Route to Market: Servitization vs. Productization

- Service: non mass producible – labor intensive
- Product: mass producible – capital intensive
- Service/Product: mass customizable – labor/capital intensive



IT Competencies in Service Oriented Enterprise Architectures Masters Class

- **Semester I:**
  - » C11: SCADA and PLC Networks
  - » C12: Wireless Sensor Networks for Product-Driven Automation
  - » C13: Information Systems Security
  - » C14: Requirements Management and Business Process Modelling
  - » C15: Data Flow Modelling and Computing Networks
- **Semester II:**
  - » C21: Software Design and Implementation
  - » C22: Service Oriented Architecture and WEB Technologies
  - » C23: Fundamentals of Service Science
  - » C24: Enterprise Resources Planning
  - » C25: Business Analytics and Optimization for Enterprise
- **Semester III:**
  - » C31: Applied AI and Rapid Deployment Automation
  - » C32: Enterprise Modelling and Integration
  - » C33: Supply Chains and Logistics
  - » C34: Multi-Agent Systems for Enterprise Control
  - » C35: Distributed Data Bases and Knowledge Bases for Production

- **Total didactic activities: 54 hours x 14 weeks = 756 hours**
- **Total R&D activities: 30 hours x 14 weeks = 420 hours**

Service Oriented Integration Patterns in Manufacturing

- At the aggregate level of a manufacturing enterprise, SOA is the standard for business process modeling and management [Forrester Research 2005]
- The integration of the shop floor processes in the enterprise business processes requires service orientation to fill in existing technological gaps and solve legacy problems.
- An end to end integration, from the initial offer request to the manufacturing execution system and supply chain, provides enterprises with the ability to gain agile control of all activities, allowing flexibility and constant improvement.

General Services Orientation Concepts at Enteprise Level

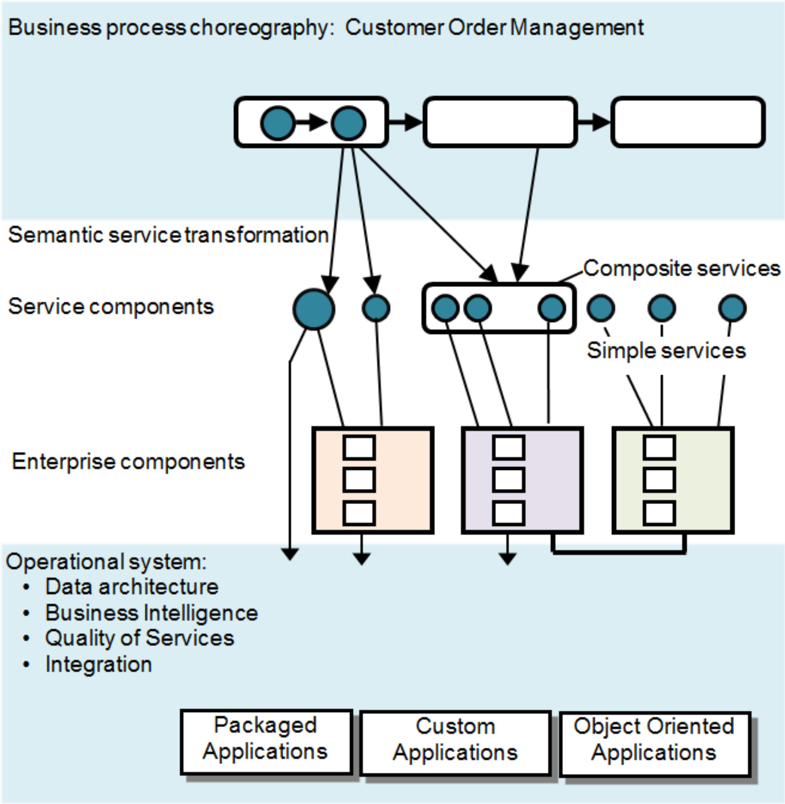
- ❑ The primary goal of Service Oriented Architecture in the context of manufacturing enterprises is to align the business layer information flow with the technology specific information flow
- ❑ The latter being partitioned on two layers:
  - ❑ (1) the business layer (management of customer orders);
  - ❑ (2) the shop floor layer (execution of customer orders).
- ❑ SOA is an IT system model providing flexibility to the enterprise in the way business applications are created.

General Services Orientation Concepts at Enteprise Level

- The major components of SOA are:
  - services;
  - services bus;
  - process choreography - composite applications;
  - message transformation, mediation and routing;
  - services registry

Service Oriented Enterprise Architecture (SOEA)

- Service Oriented Enterprise Architecture (SOEA) for the generic business layer of a manufacturing enterprise



Business processes

- Business processes should be treated as compositions of other business processes and services and therefore be decomposed into their subordinate sub-processes and services.
- Services (including business processes as services) can then be detailed in service components - converted into a detailed set of definition metadata that will describe that service to the information system.

Enterprise Service Bus (ESB)

- ❑ The Enterprise Service Bus (ESB) is a flexible connectivity infrastructure for integrating applications and services.
- ❑ An ESB performs the following actions between requestor and services:
  - ❑ Intelligent message routing between parties
  - ❑ Conversion of transport protocols between service consumer and service provider
  - ❑ Transformation of message formats between service consumer and service provider
  - ❑ Handling business events from various sources

Manufacturing alignment with SOA

- Almost all industries by now strive to achieve SOA architecture, either by starting from scratch or by slowly migrating the legacy applications and more importantly legacy processes towards this goal.

- So, how are the manufacturing enterprises reacting to this trend?

- First of all the manufacturing enterprises have to move in this direction also.

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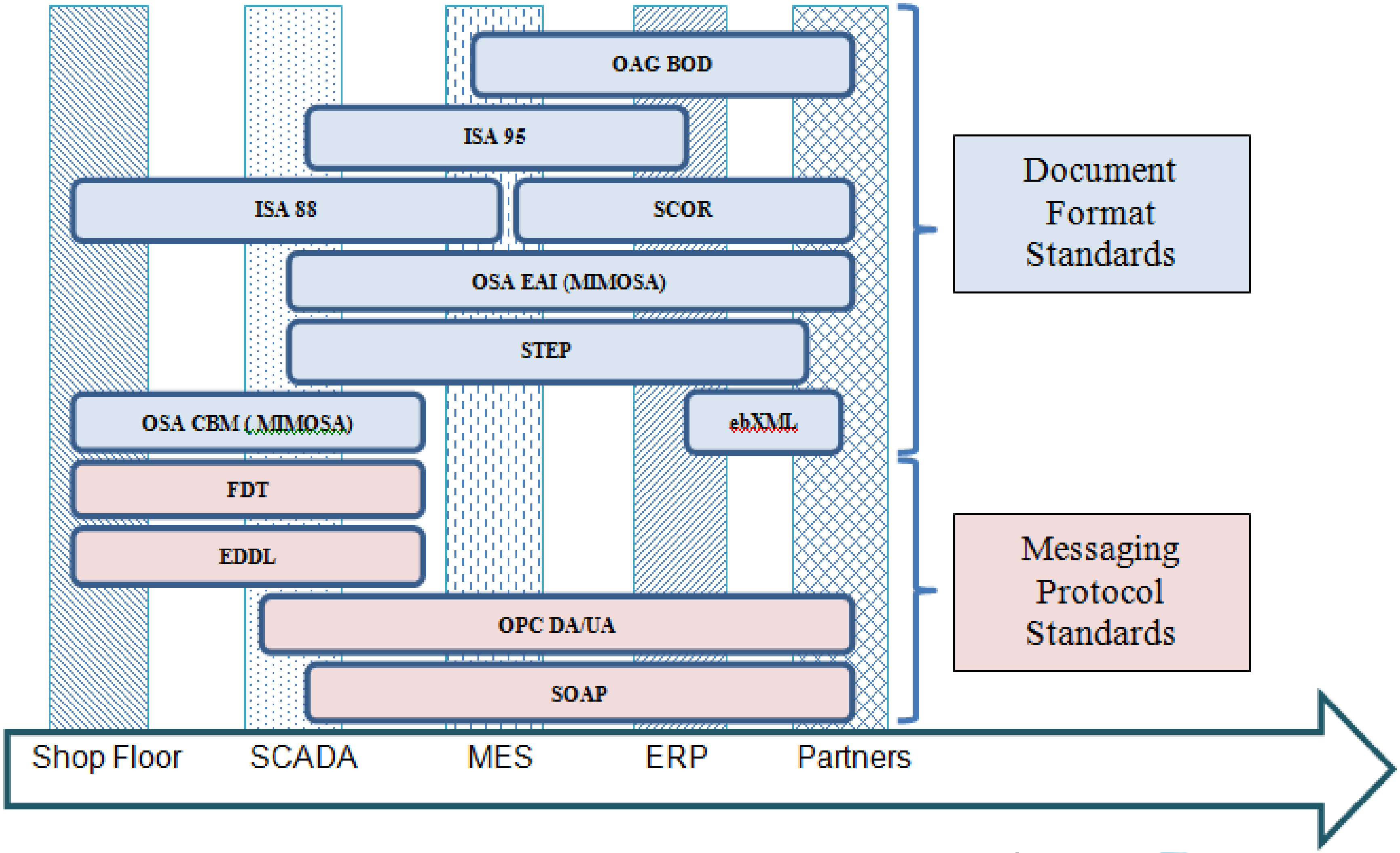
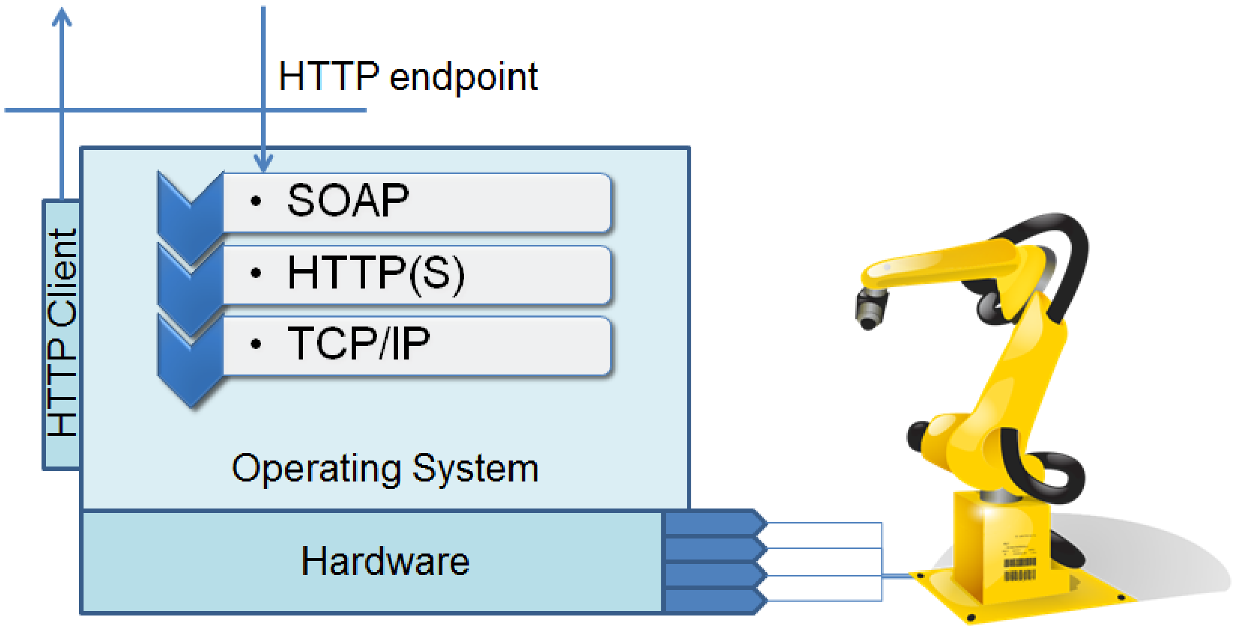
Manufacturing Standards



SOA Enabled Devices

- ❑ Distributed intelligence and alignment to industry standards are two main prerequisites for organizing shop floor activities based on SOA paradigms



Class I: Workstation assisted shop-floor device

- Is represented by the physical device and the associated workstation.
- In this case the workstation is a standard computer equipped with a dedicated card for connecting to the device.
- The software is most of the time proprietary and allows programmatic control of the physical device.
- The communication protocol between the workstation and the device is proprietary and usually is a low level signal based protocol.

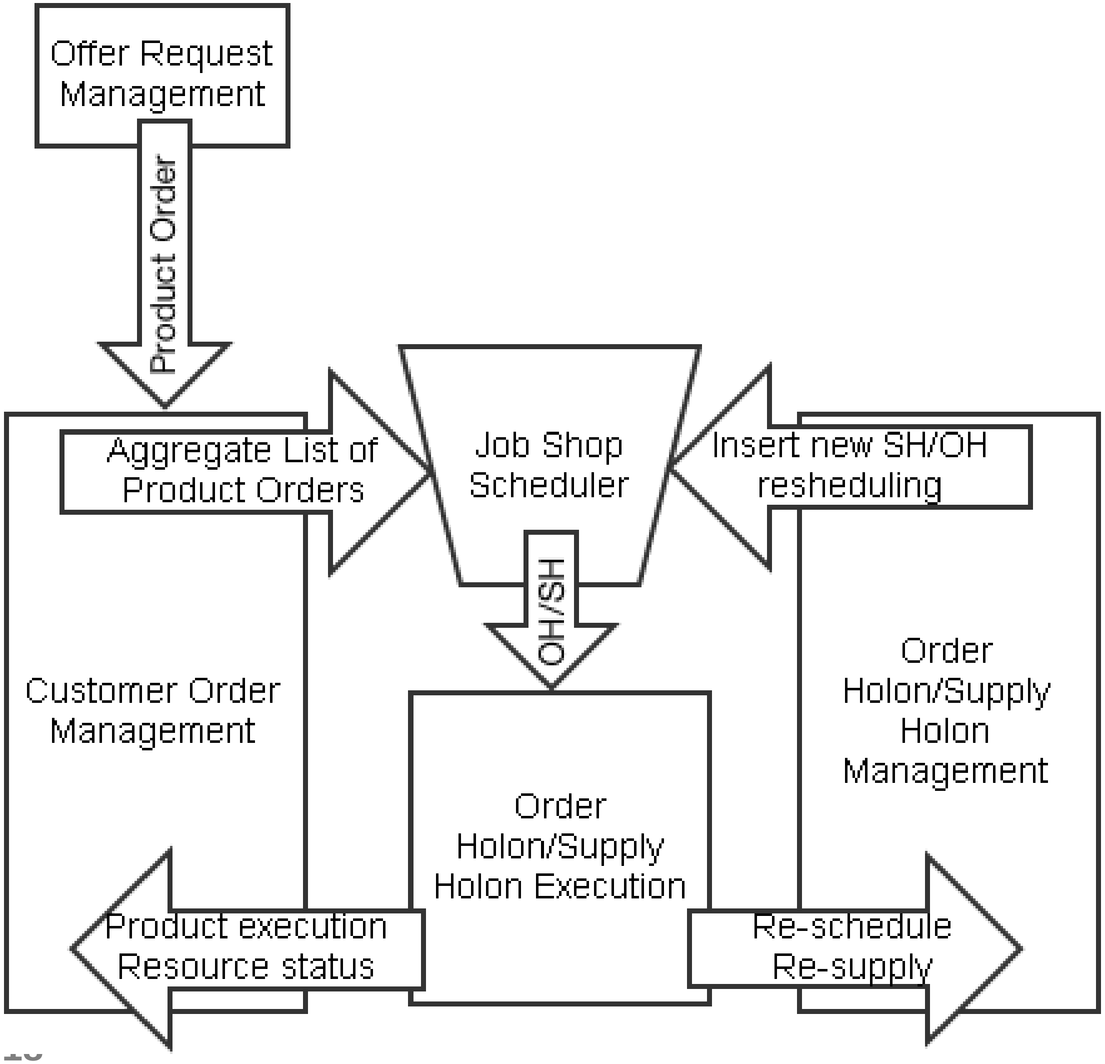
Class II: Embedded OS shop-floor device

- Is constructed by a hardware environment capable to run an embedded Operating System attached to the shop floor physical device.
- The requirements for this class of devices are to implement a full HTTP stack, capable to run both a HTTP server for hosting web service endpoints and a HTTP client for calling external web services.
- The web service in this case is only to expose the existing functionality in an SOAP format, or in other words it performs data transformation only.

Class III: Intelligent shop-floor device

- This category of devices is able to run Data and CPU intensive applications in order to implement an intelligent behavior.
- These devices are able to run a full Java Virtual Machine on top of the embedded OS and have enough memory and processing power to be able to execute complex algorithms that allow them to make intelligent decisions, such as Genetic Algorithms for scheduling, Neural Networks for decision making and so on.

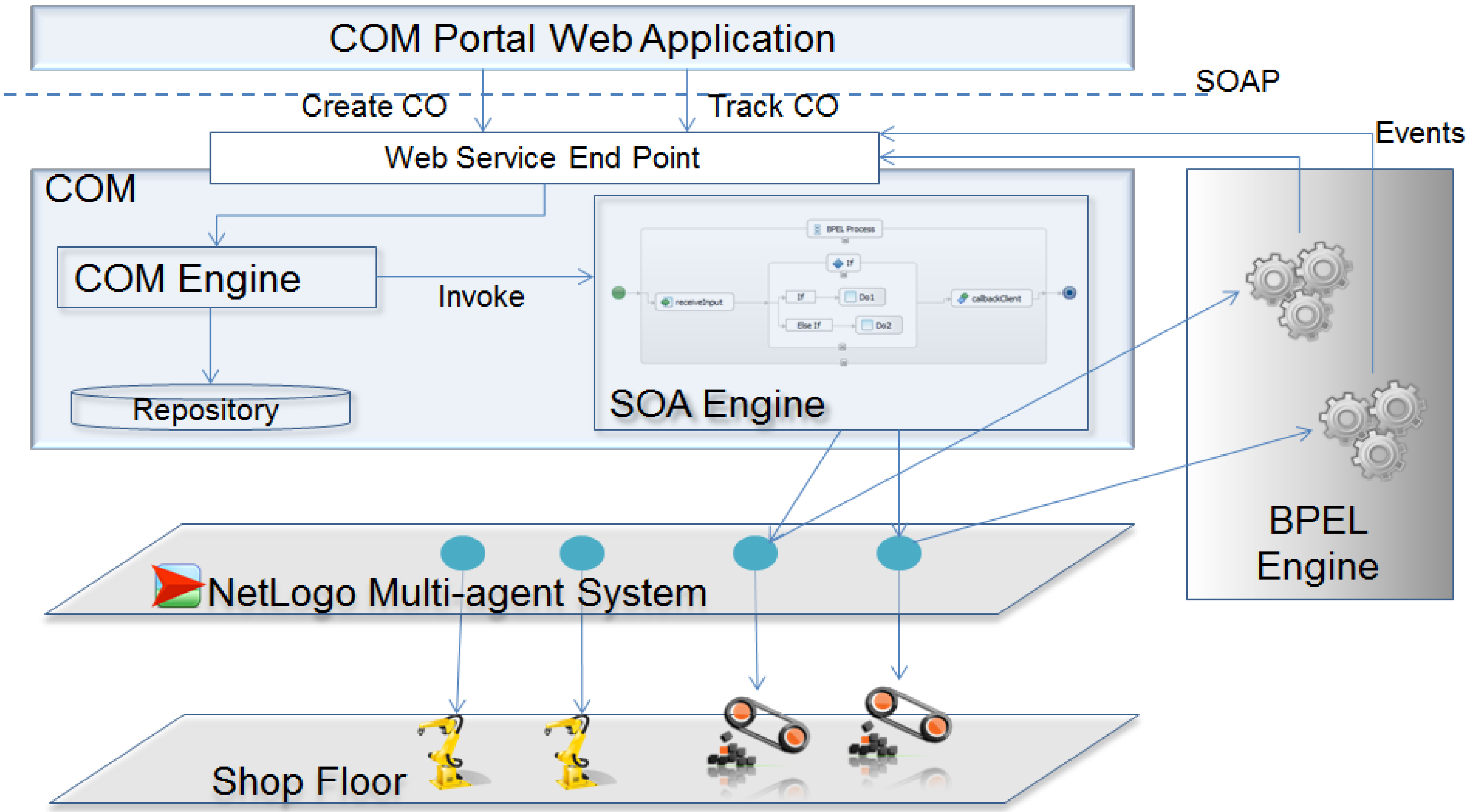
Vertical Integration of the Manufacturing Enterprise



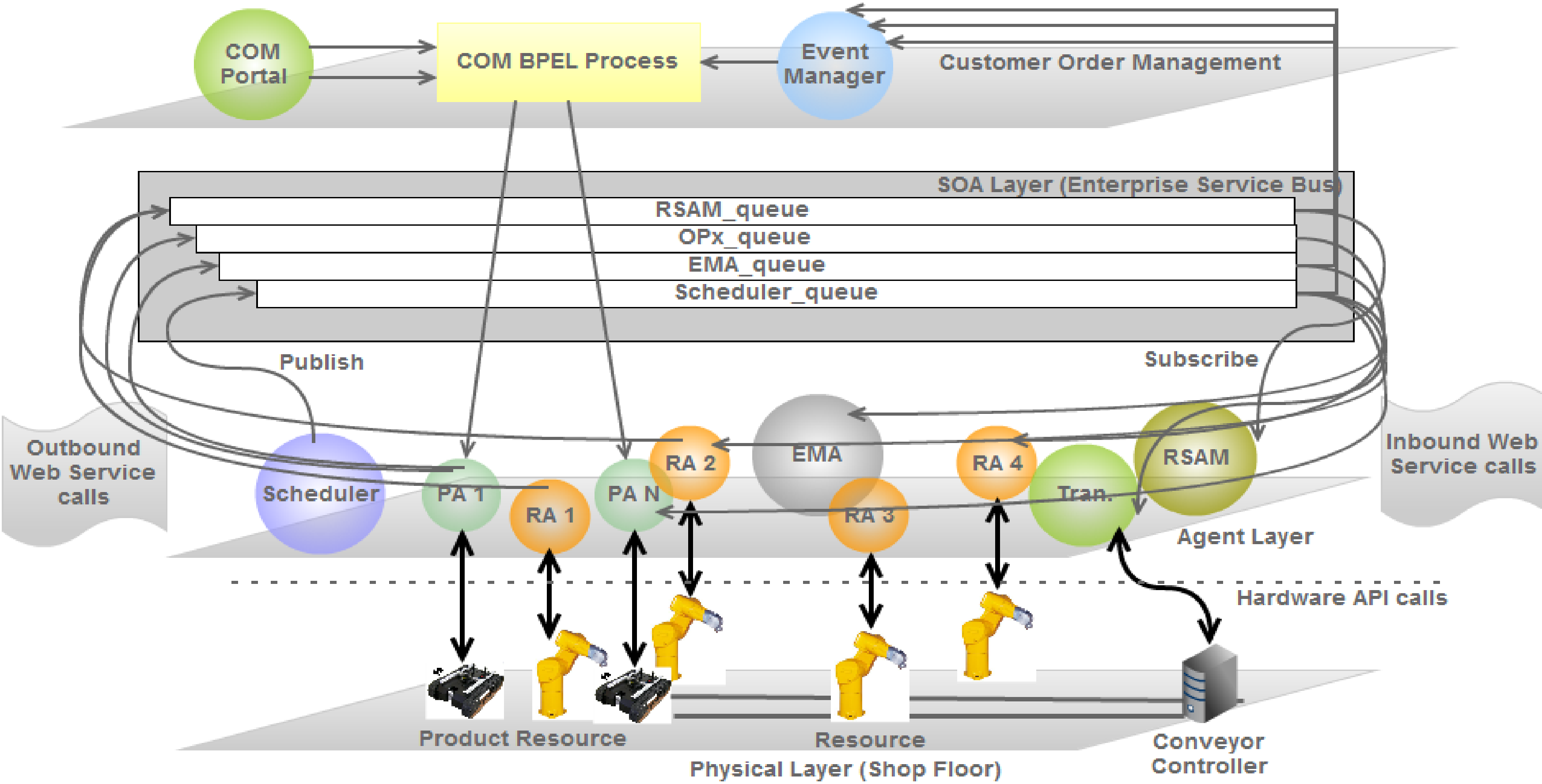
Vertical Integration of the Manufacturing Enterprise

- **Offer Request Management** - is responsible for managing the request for offers by evaluating the capability and cost to complete the product batch in the requested timeframe
- **Management of Client Orders** - has as input the customer order, computes the aggregate list of product orders (APO).
- **Order and Supply Holon Management** - schedules product execution and allocates resources from the APO using order- and supply holons in the Holonic Manufacturing Execution System (HMES).
- **Order Holon Execution and Tracking** - deployment of the order- and supply holons (OH/SH) for product execution and tracking the status of these processes performed through services provided by shop-floor resources (CNC machines, assembly robots, PLC - driven conveyor, machine vision inspection).

Customer Order Management Integration in Manufacturing Systems



Manufacturing Execution System with Multi-agent System implementation



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Agent interaction model

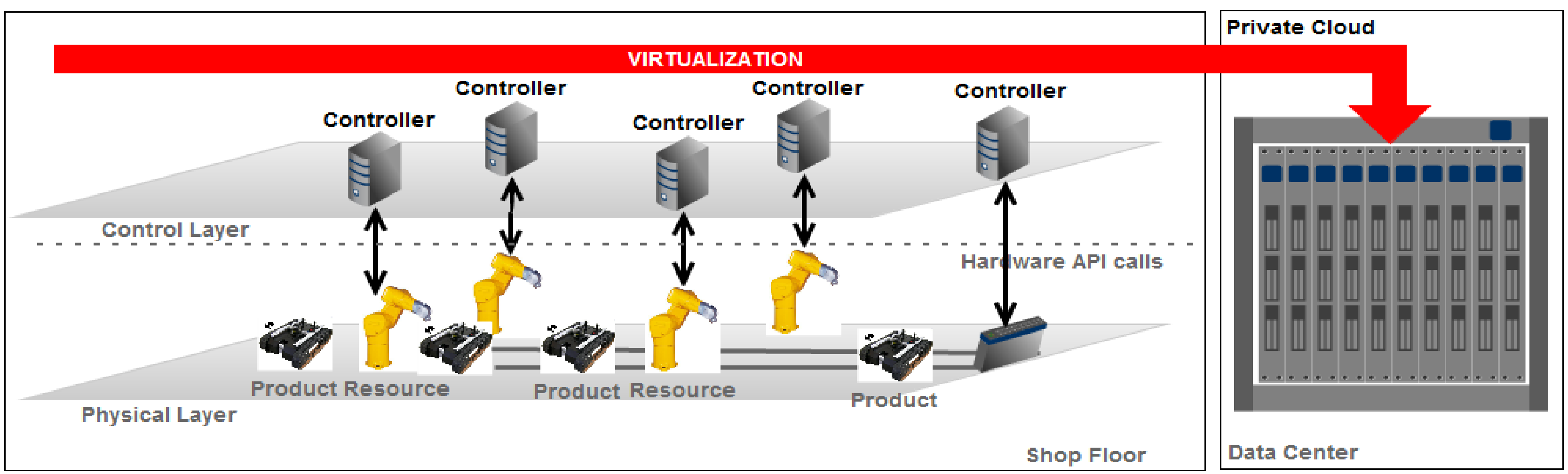
- **Product Database:** agent that stores and retrieves data from a structured storage containing information about products and operations associated with the manufacturing process.
- **Resource Service Access Model (RSAM):** agent that acts as a resource broker, where resource agents (RA) can publish their state and capabilities. This information is used by product agents (PA) during execution.
- **Execution Monitoring Agent (EMA):** agent that centralizes PA states. The proposed framework introduces EMA agent for execution process monitoring at PA level. The EMA agent is responsible for generating periodic events that are sent through the ESB and consumed by the Customer Order Management module.
- **Scheduler:** agent incorporating the production planning functionality. This agent creates and stores the execution schedule and sends continuous commands to the RAs and PAs driving the fabrication process according to the generated BPEL processes for each product.

Agent interaction queues

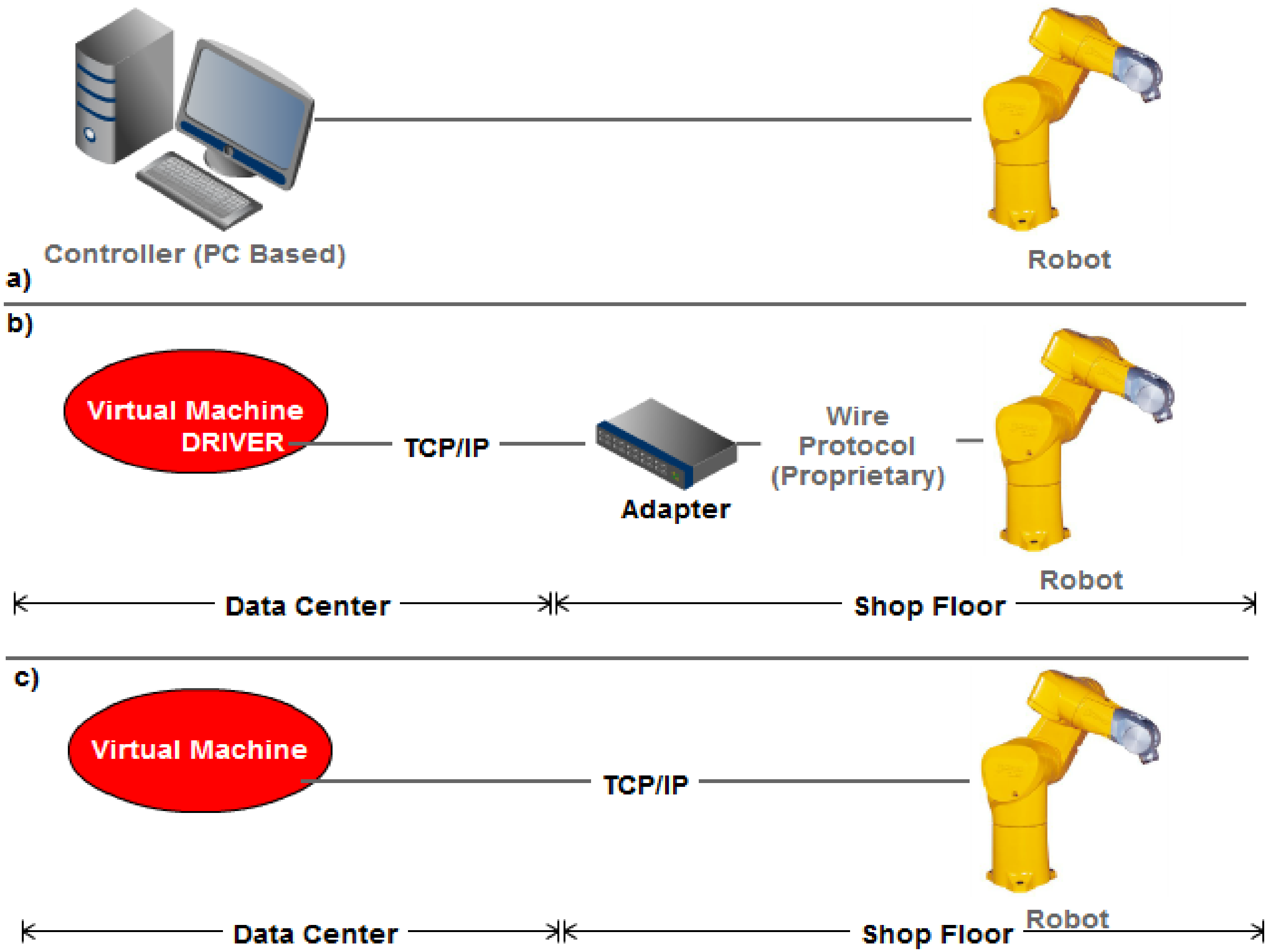
- **RSAM_queue:** is used by the resource agents to register with the RSAM agent. The publishers to this queue are all the resource agents. The subscriber to this queue is the RSAM primary agent and the backup RSAM agents.
- **EMA_queue:** is used by the products in execution (WIPs) to publish their states. The subscriber to this queue is the EMA agent. The EMA agent consumes these messages and stores the current production state, performing the production tracking role.
- **OPX_queue:** is created at runtime by the resource agents (RAs) for each supported operation. The RA creates the queue and subscribes to it. The PAs are publishing messages to the corresponding OPx queue, when an operation is required. This is the queue used by the PAs to communicate with RAs in order to execute the next operation.
- **Scheduler_queue:** is used by the scheduler to publish messages to the RAs and PAs.
- **Error_queue:** is used to signal an error on the production line. This error can be posted by PAs or RAs and is received by RSAM, EMA and Scheduler agents.

MES Virtualization

- The basic concept of MES and shop floor virtualization involves migration of all workloads that were traditionally executed on physical machines located on the shop floor to the data centre, specifically to the private cloud infrastructure as virtual workloads.
- The idea is to run all the control software in a virtualized environment and keep only the physical devices on the shop floor.
- This separation between hardware and software provides high flexibility and agility to the manufacturing solution



Shop Floor Resources Binding to Virtualized MES

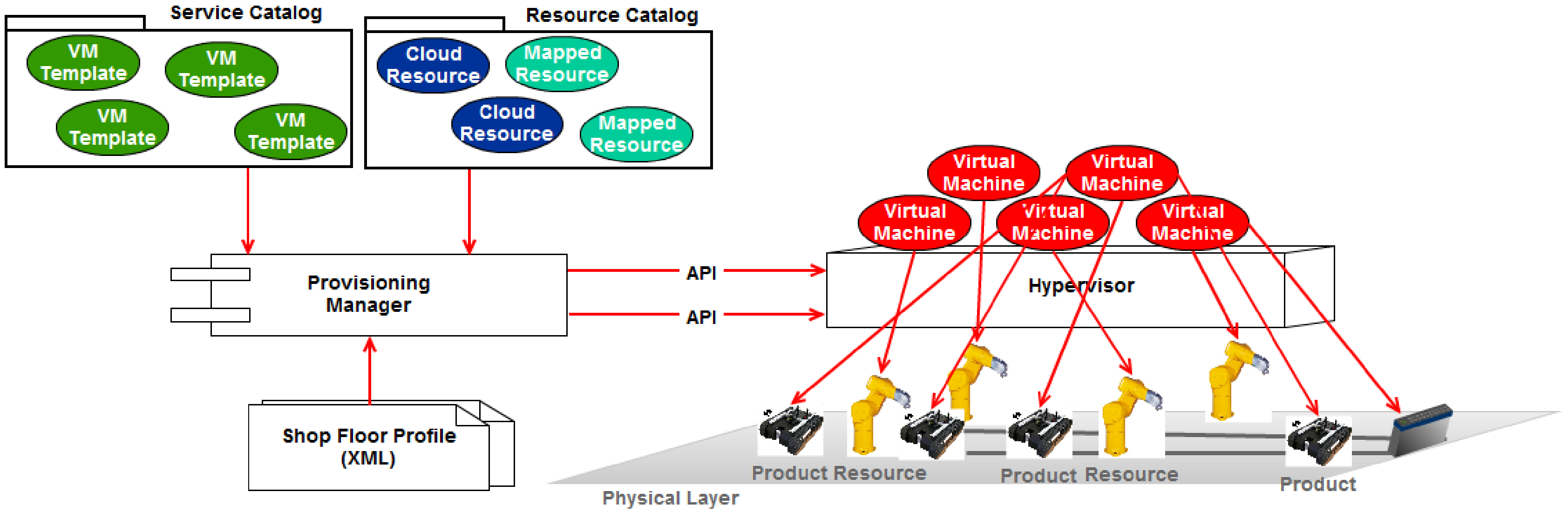


Shop Floor Resources Binding to Virtualized MES

- a) is the initial state without virtualization
- b) and c) are the two alternatives to workload virtualization.
- In case the resource can be accessed by TCP/IP directly, the virtualization is consists in virtualizing the workload directly and mapping a virtual network interface to it, which will be used to control the resource.
- In case a proprietary wire protocol is used, the virtualization process is more complex, as it would involve a local controller on the shop floor that would provide the physical interface for the wire protocol.

Shop Floor Profiles

- ❑The binding between workload templates and virtualized resources is done using shop floor profiles.
- ❑Shop floor profiles are XML files and contain a complete or partial definition of the manufacturing system virtual layout and mappings.
- ❑The shop floor profile is workload centric and basically contains a list of workload definitions

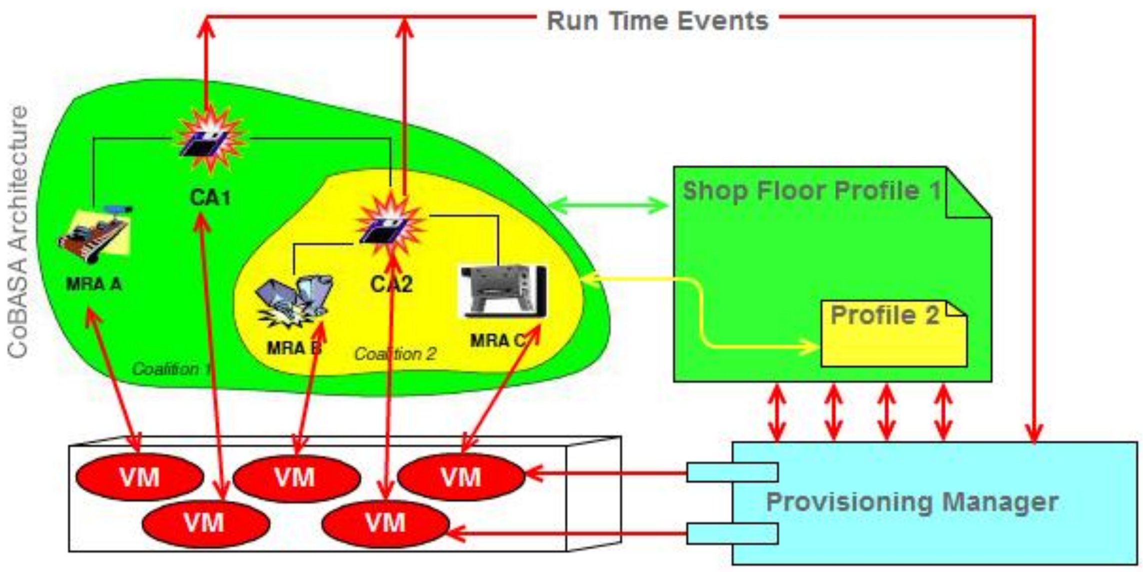


Provisioning Manager (PM)

- ❑The shop floor profiles are loaded by the provisioning manager (PM) component.
- ❑The provisioning manager is responsible for parsing the shop floor profiles and creates the workload instances based on their definition, in the private cloud environment.
- ❑The PM also maps and binds the virtualized resources to the VMs deployed in the cloud, running on the virtualization blades by using either standard network drivers, for TCP/IP accessible resources or by using custom drivers for proprietary communication protocols.
- ❑To do so, the PM calls the hypervisor APIs.

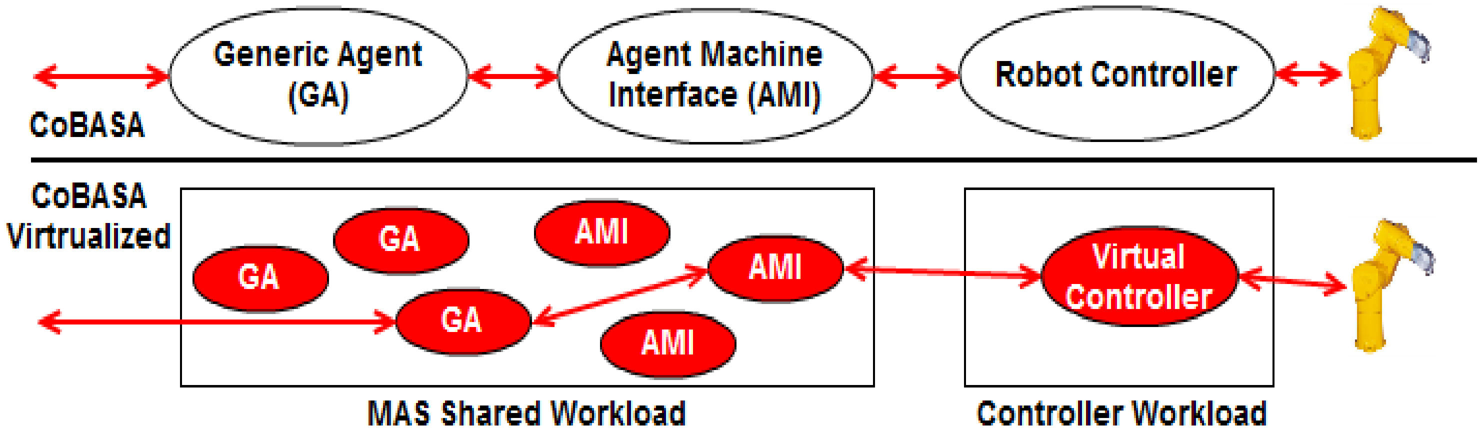
Implementation Example - multi-agent MES based on CoBASA architecture

- The CoBASA architecture (Barata et al., 2003) introduces an agent-based control architecture in which cooperation regulated by contracts is proposed as a flexible approach to dynamic shop floor re-engineering.
- It describes the dynamic and flexible cooperation of manufacturing agents representing resources (here robots), and how they can be created from a generic agent template.
- The flexibility is assured by the resource (robot) consortium concept defined in the CoBASA architecture.



Implementation Example - multi-agent MES based on CoBASA architecture

- CoBASA vs. Virtualized CoBASA architecture



Benefits of Virtualized MES

- Virtualization brings many advantages also on the manufacturing system reliability by allowing full system snapshots and backups and quick recovery in case of failures, as well as providing built in redundancy.
- Most private cloud implementations offer these features by default and can be directly adopted.
- Resource controller virtualization allows a separation or decoupling between the physical resource and the information system.
- The most important advantage introduced by decoupling is the possibility to have multiple versions of the virtual controller with different configurations and switch between them as needed.

Research Results

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SOEA – the internationalization context

SOHOMA 2011-2013 [http://www.sohoma{11, 12, 13}.cimr.pub.ro]

SOEA – the internationalization context

SOHOMA Editions & Literature [ISI recognized]

SOHOMA editions

2011 Edition

SOHOMA11 Photo Gallery

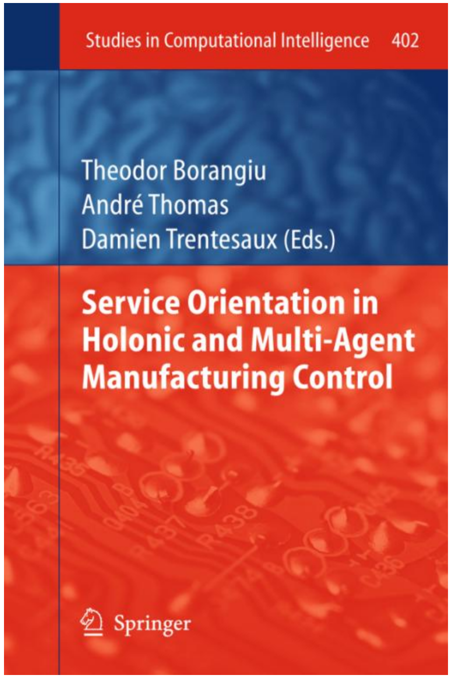
2012 Edition

SOHOMA12 Photo Gallery

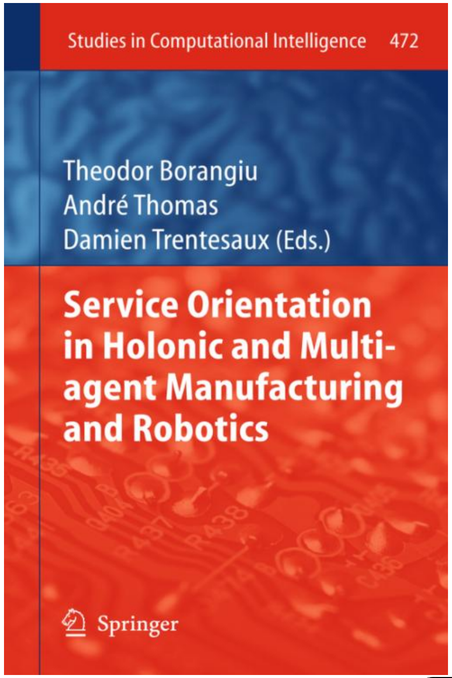
2013 Edition

SOHOMA13 Photo Gallery

SOHOMA'11 Proceedings Volume



SOHOMA'12 Proceedings Volume



SOHOMA'13 Preprints Volume

Q/A

- Thank you!