Scheduling the Supply Chain by Teams of Agents

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Overview

- Scheduling
- Supply Chain Management
- Supply Chain Scheduling Tasks
- Teams of Agents
- Application Framework
- Conclusions

Scheduling

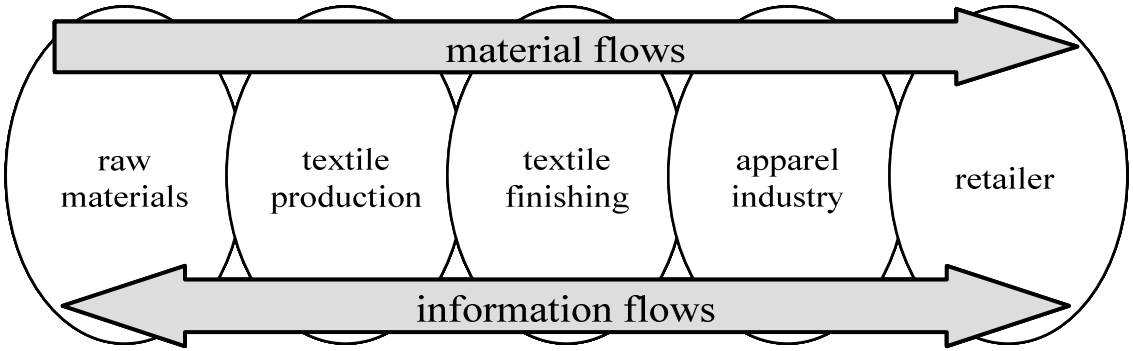
f(R, P, O, HC, SC, E, G, PL) → PL

- R: Resources,
- P: Products,
- O: Orders
- HC: Hard Constraints
- SC: Soft Constraints
- E: Events
- G: Goal functions
- PL: Schedule (Plan) [valid, consistent, optimal]

Predictive, reactive, interactive tasks

Supply Chains, SCM

- Supply Chain: network of organizations involved in producing products or services: from raw material to retailer



- Supply Chain Management:
  coordinated cooperation of independent organizations to achieve competitiveness

Supply Chain Scheduling

Tasks

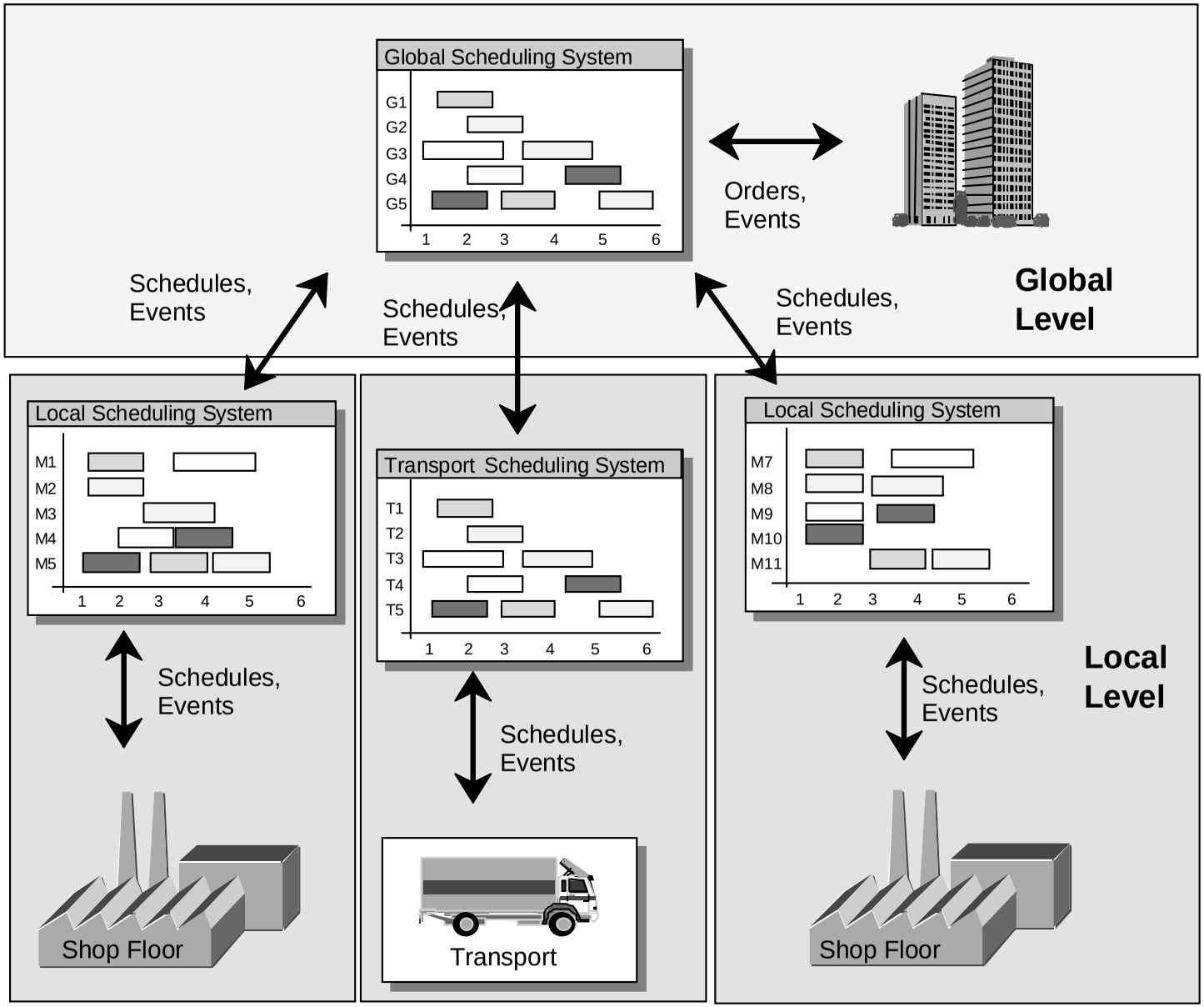
	source	make	deliver
Strategic			
Tactical			
Operational			

Supply Chain Scheduling

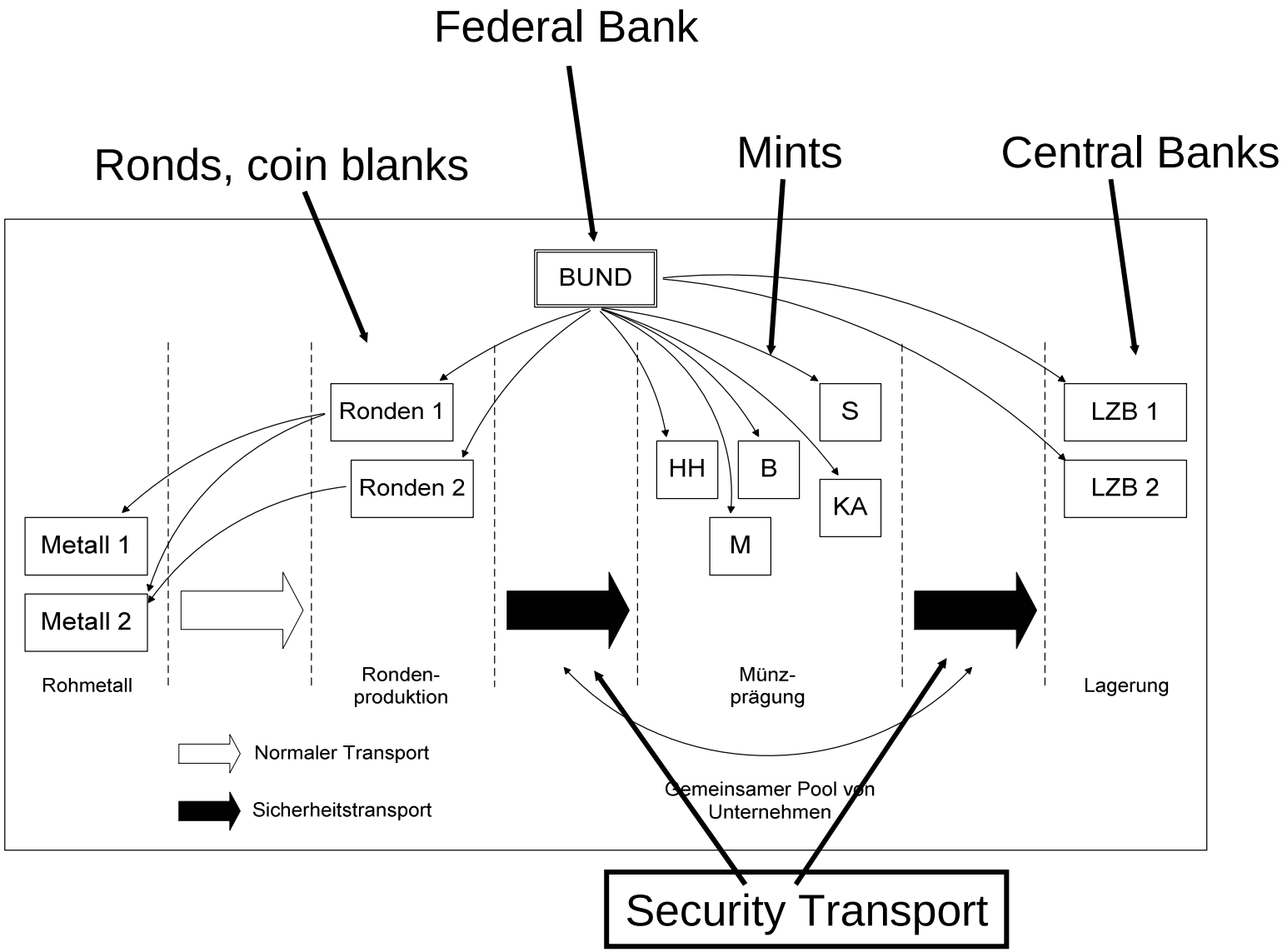
Decisions

- purchase, transportation, production, storage, inventory, coordination

Supply Chain Scheduling Problems



Example: Euro Coins



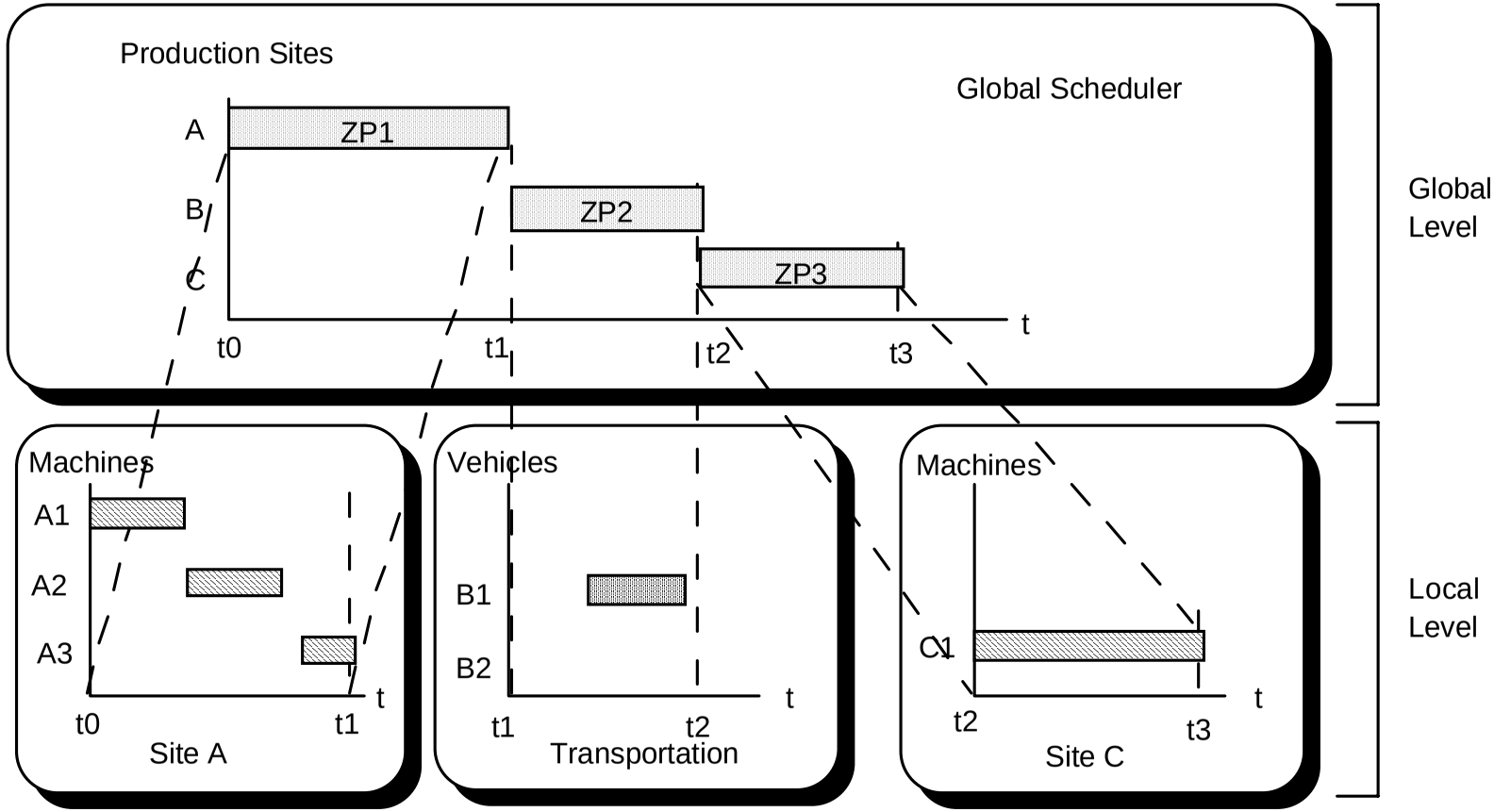
Supply Chain Scheduling: Challenges I

- **different production sites, transportation, storage**
- **global scheduling**: distribution of orders to production sites including transport, suppliers, storage => supply chain
  - complex interdependencies between the production processes performed in different plants (precedence relations, preferences, different costs, alternatives)
  - information is cumulative and not precise (e.g. durations, capacities), using all details is not manageable
- **predictive and reactive scheduling**: regarding all the events on the different levels

Supply Chain Scheduling: Challenges II

- **integration** of **local scheduling** (already existing on plant level)
- new scheduling tasks: **transportation/ storage scheduling**
- **coordination**: scheduling activities on two or more levels have to be coordinated, esp. in the case of events affecting each other
- **different goals**
    - on the global level, e.g. meeting due dates, early detection of capacity problems
    - on the local level, e.g. optimize machine utilization or work in progress times

Global and Local Scheduling



Modeling Scheduling Tasks

	Global Scheduling	Transportation Scheduling	Storage Scheduling	Local Scheduling
Resources	groups of resources, single plants	transportation vehicles	storage facilities	machines
Products	final products consisting of several intermediate products	transport of products using specific transportation vehicles	intermediate products, raw materials	intermediate products consisting of several production steps (operations)
Orders	external orders for final products	internal orders for transportation of intermediates	internal orders for storage of intermediate products	internal orders for intermediates
Hard Constraints	schedule all external orders, regard production requirements (one variant, precedence constraints, capacity)	schedule all orders, regard technical requirements (type of vehicle, transport capacity)	schedule all orders, regard storage requirements (place, type of facility, maximum duration)	schedule all orders, regard production requirements (one variant, precedence constraints)
Soft Constraints	meet due date, minimize transportation times/ costs, reduce inventory costs.	meet due dates, "optimal" vehicle utilization, minimize costs.	minimize inventory costs.	"optimal" machine utilization, meet due dates, minimize work-in-process
Events	global events, e.g. breakdown of machine groups	transport events, e.g. traffic delay	global events, e.g. capacity problems	local events, e.g. machine breakdowns
Goals	global goals, e.g. meet delivery dates	transportation goals, e.g. minimize costs	local goals, e.g. minimal costs	local goals, e.g. optimal machine utilization

Multi-Site Scheduling: Communication

LOGISTICS --> GLOBAL

- new/ changed orders
- other events (e.g. capacity changes)

GLOBAL --> LOCAL

- global schedule
  - order
  - product
  - intermediate to be produced
  - machine group or plant to be used
  - time window for production in local plant
  - amount of intermediate
- precedence relations to preceeding/ following intermediates
- rescheduling information (in the case the order has been replaced)
- events

LOCAL --> GLOBAL

- local realization
  - order
  - product
  - intermediate to be produced
  - scheduled time interval
  - machine group to be used
- events (e.g. breakdowns)
- (proposal for rescheduling)

SHOP FLOOR <--> LOCAL

- local schedule
- events (e.g. breakdowns)

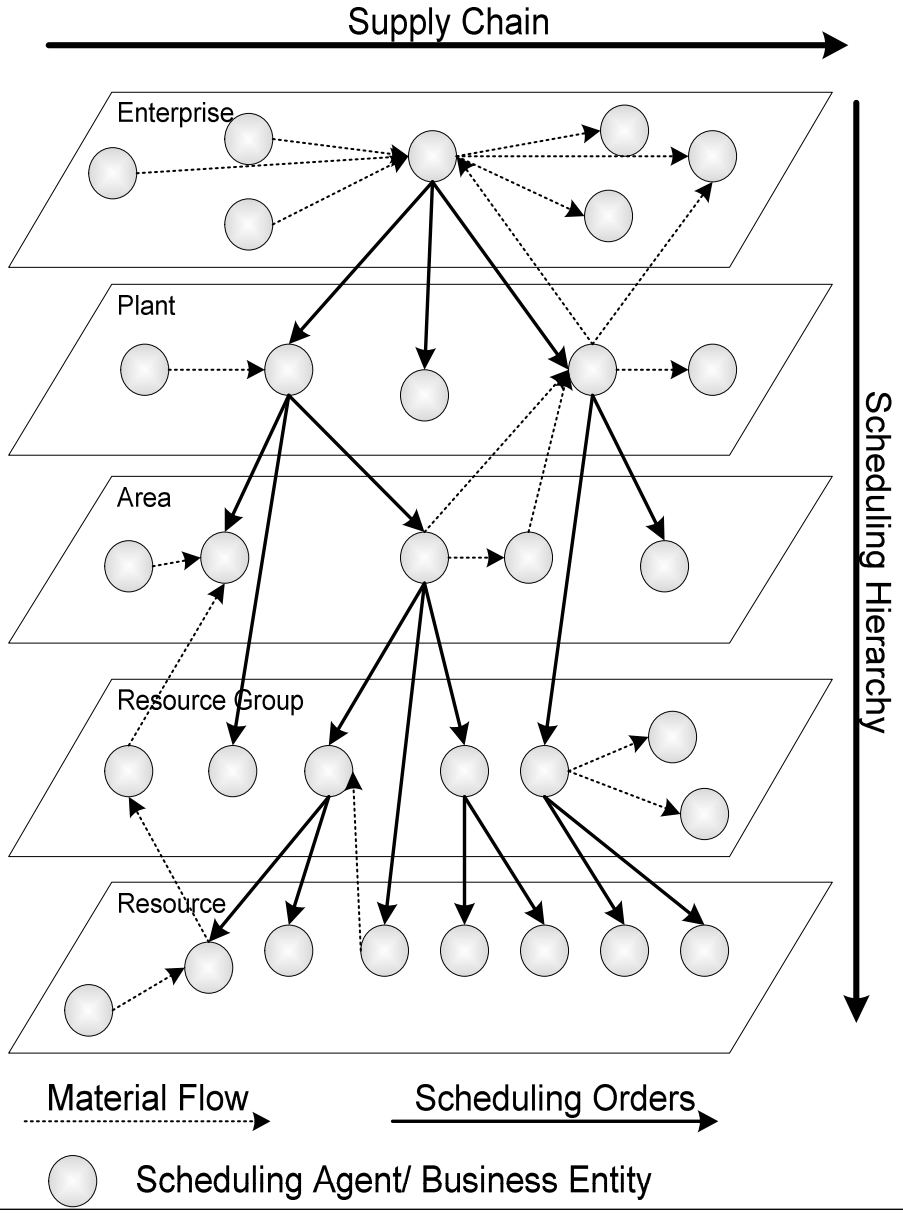
Agents

- Agent = Software system with:
  - **autonomy**: operates without direct interference by other systems, has control over its behavior and its internal state
  - **social capabilities**: agents behave and interact with other agents
  - **reactivity**: perceive their environment and react to changes
  - **proactivity**: capable of taking the initiative in a goal-directed fashion
  - **intelligence**: problem solving knowledge -> intelligent agent
- Multi-Agent System
  - set of communicating agents
- Problems
  - communication overhead
  - integration of user
  - local vs. global goals
  - control paradigm

Supply Chain Scheduling: Concept I

- Coordinated scheduling on different hierarchical levels
- Business units/ resources represented by scheduling agents
- Teams of agents solving scheduling tasks
- Each agent has specific scheduling knowledge
- Communication via contract net, direct communication or blackboard

Supply Chain Scheduling: Concept II



Teams of Agents

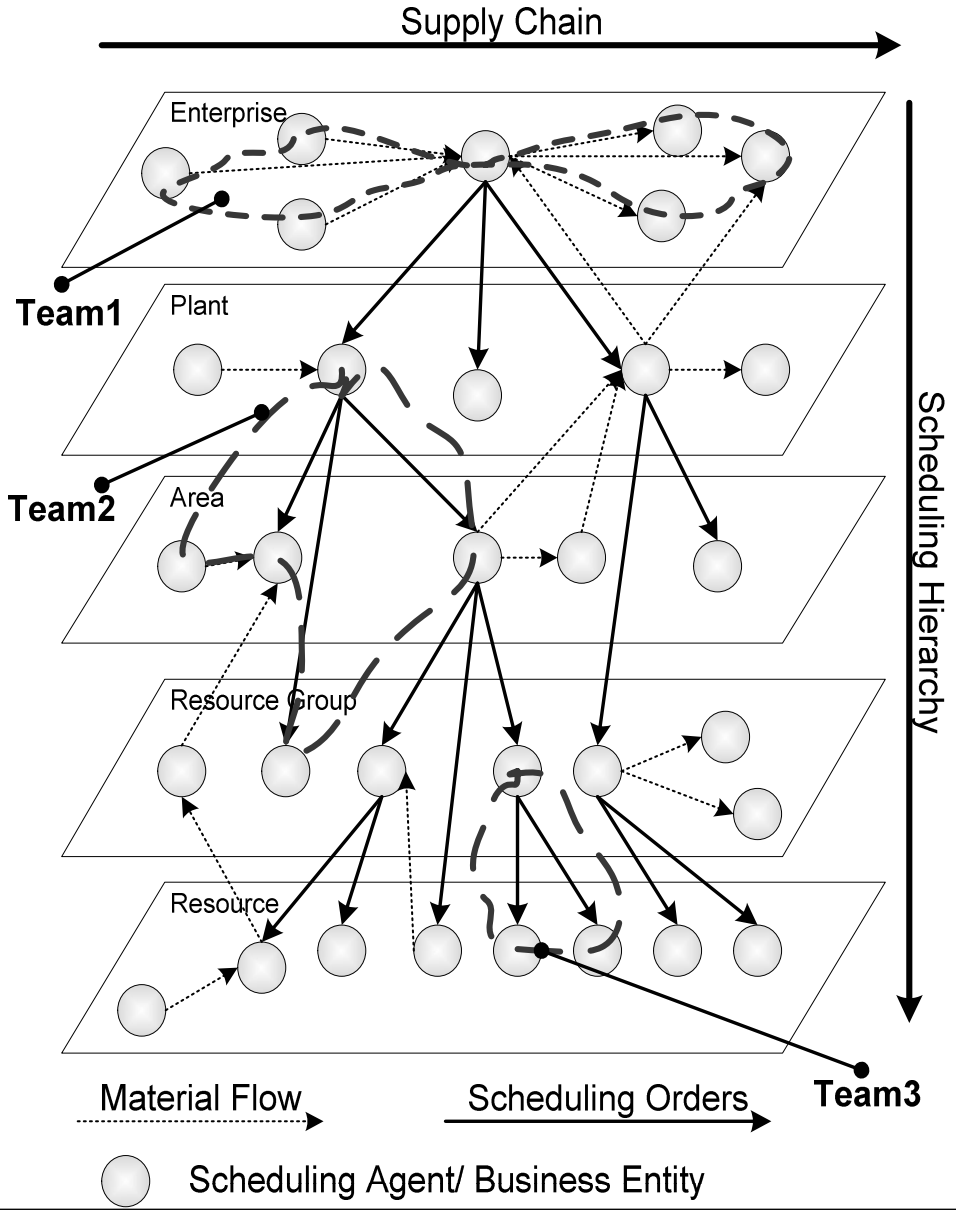
Definition:

Group of agents working together to solve a specific Problem

Advantages:

- Reduce communication overhead
- Design control loops
- Similarity to business structures
- Component based development
- Reduce complexity
- Different communication models within one system

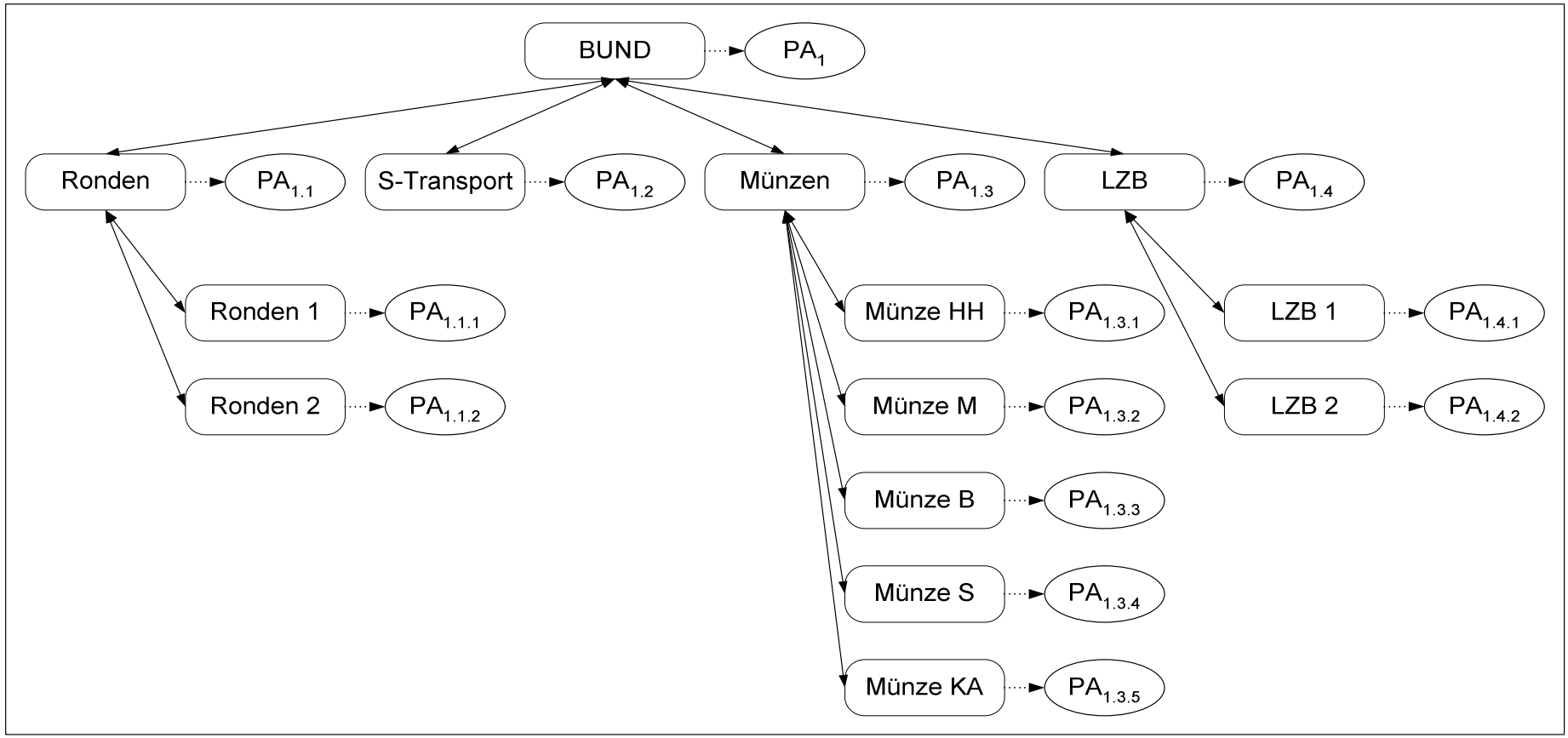
Supply Chain Scheduling: Concept III



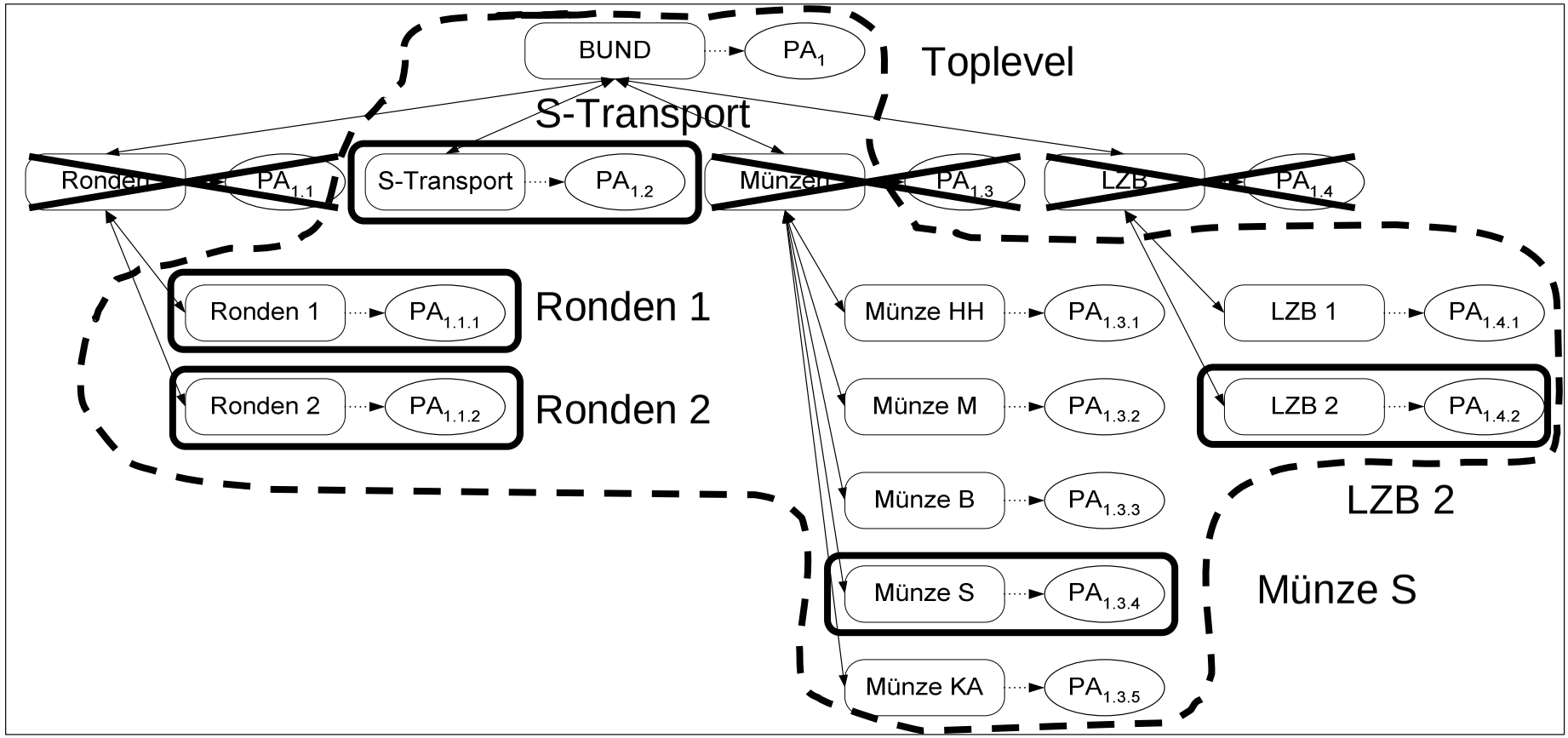
Process Model

1. Analysis of real world scenario
2. Mapping business units/ resources to agents
3. Adding associations and teams
4. Design of agents
5. Select agent platform
6. Implement agents
7. Integrate agents
8. Test

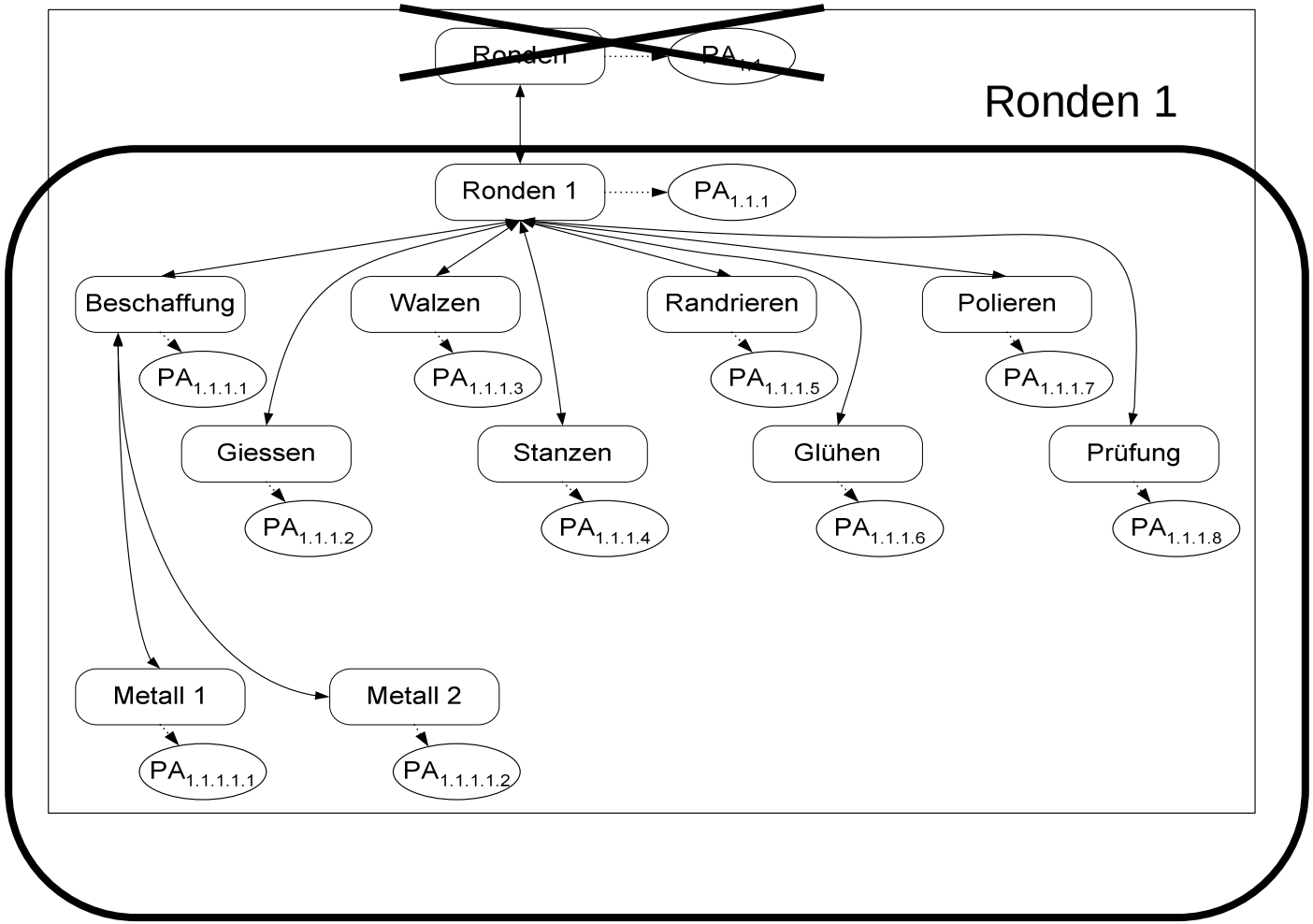
Steps 1 & 2: Mapping



Step 3: Teams (1) – Global Team



Step 3: Teams (2)



Step 4: Agent Template

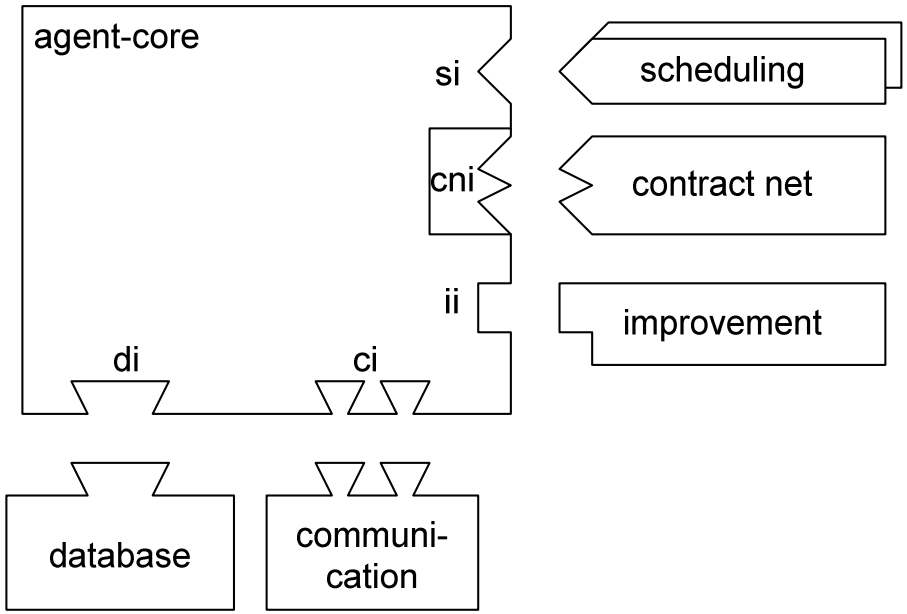
1. Agents Name
2. Agents represents:
   (focal company, machine group, …)
3. Responsibility:
   (global scheduling, coordination, …)
4. Team: to which team it belongs
5. Scheduling tasks
   (global schedule, transportation schedule, …)
6. Scheduling knowledge
   (view on database, specialized algorithms, …)
7. Scheduling strategy
   (EDD, avoid bottlenecks, …)
8. Cooperation: which kind of cooperation with which partners

Step 5: Scheduling Methods

Task	Methods investigated
Global Scheduling	Heuristics, Constraints, Genetic Algorithms, Fuzzy-Logic
Global Reactive Scheduling	Interactive, Heuristics, Genetic Algorithms, Constraints
Local Predictive Scheduling	Constraints, Heuristics, Genetic Algorithms, OR-Systems, Iterative Improvement (SA, TA, Grand Deluge), Neural Networks
Local Reactive Scheduling	Interactive, Heuristics, Constraints, Multi-Agent Systems
Transportation Scheduling	Heuristics, Constraints, OR-Systems
Storage Scheduling	Heuristics, OR-Systems
Coordination	Contract Net, Blackboard, (Direct, Indirect)

Step 6, 7, 8: Agent Platform

- Framework for scheduling agents
- Agent core with frozen and hot spots



Agent Framework

Agent core: basic features e.g. event handling, integrating components

- Database interface (di): connection to a relational database
- Communication interface (ci): basic communication (message passing) between agents and human schedulers
- Scheduling component interface (si): integration of different scheduling components implementing scheduling strategies to be used
- Contract net interface (cni): basic features of the contract net protocol are provided
- Schedule improvement interface (ii): improvement strategies for the schedule can be incorporated

Database: a relational database system, e.g. Oracle or MySQL

Communication: Messages are packed and unpacked, events are generated

Scheduling: all kinds of scheduling strategies

Contract: extensions of the contract net protocol needed

Improvement: all kinds of improvement strategies

Step 6, 7, 8: Agent Platform

Agent core with frozen and hot spots

- Main control cycle

IF new events THEN interrupt improvement AND event-handling

IF idle THEN schedule improvement

event-handling means:

IF database request THEN call database interface

IF scheduling task THEN call appropriate scheduling algorithm
AND perform negotiation if necessary

Conclusion

Supply Chain Scheduling Approach

- Scheduling decisions on the operational level
- Resource based hierarchical ordering of agents
- On each level sufficient knowledge to make good scheduling decisions
- Hierarchical ordering and teams of agents to reduce communication

Realization

- Java-based framework for scheduling agents