

Real-Virtual fusion Manufacturing Systems

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Introduction: research fields

- Manufacturing & Service Systems Design
 - Environment adaptive manufacturing systems
 - Autonomous and decentralized system
 - Emergent synthetic methodologies
 - Synthetic approach for social system
 - Service science / engineering
 - Open innovation (hackathon, ideathon)
 - Urban system design based on IoT

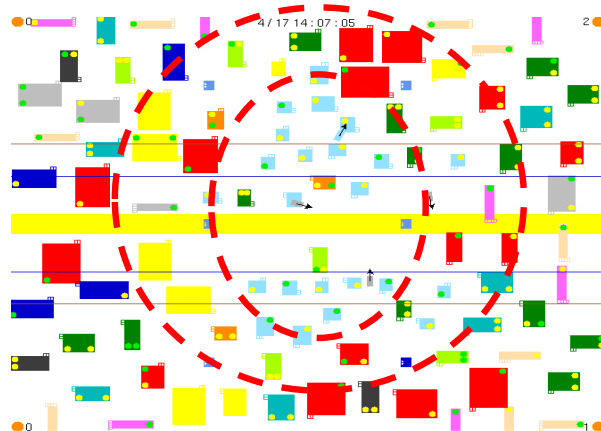


Fig: Self-organization based layout design of semiconductor production

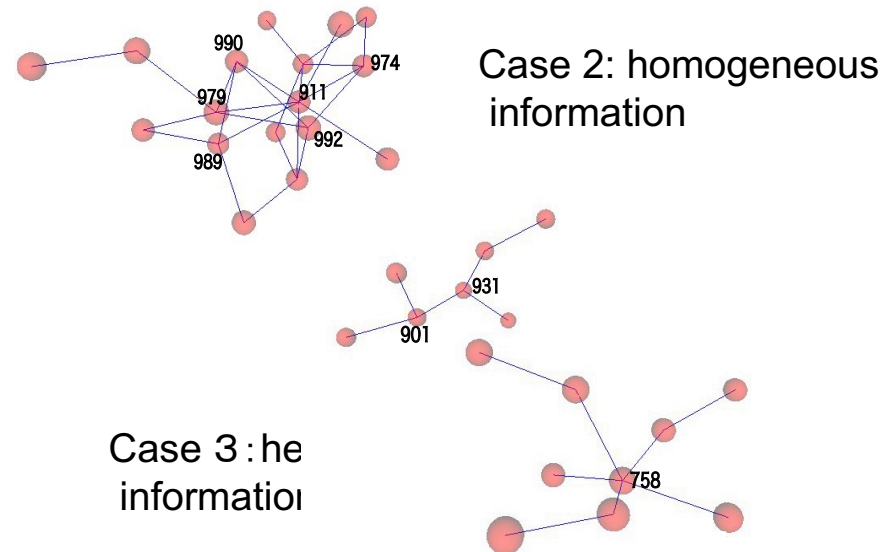
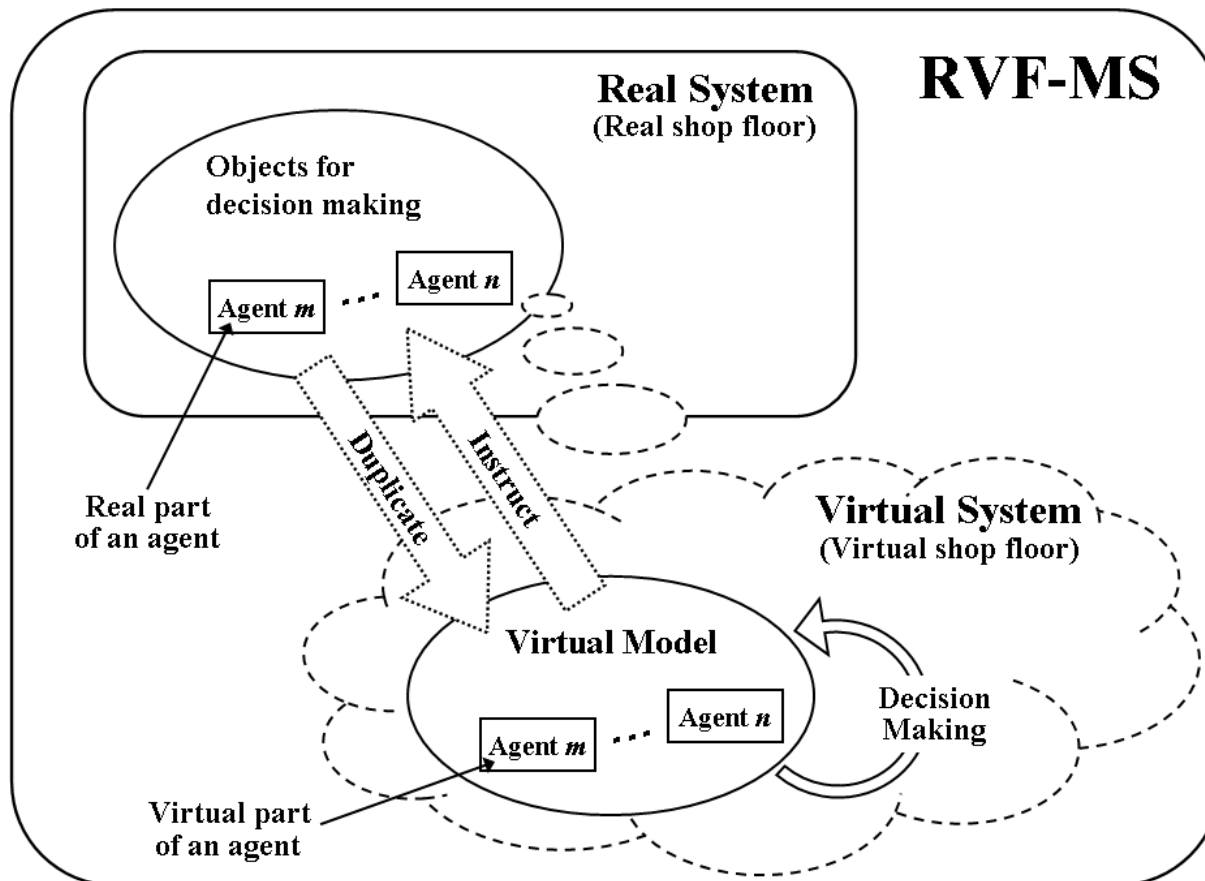


Fig: Emergence of consumer networks

Real-Virtual Fusion Manufacturing System (RVF-MS)

- RVF-MS aims to
 - adaptively and effectively deal with both external and internal fluctuations
 - couple the real production shop floor (real system) and the digital manufacturing model (virtual system)



Multi-agent system based configuration is adopted to realize *dynamic construction of virtual systems* so as to balance between system optimality and adaptability.

Production Scheduling in RVF-MS

□ Planning Phase

- Virtual system is constructed by the communication of **all the agents**
- to achieve **global production optimization**

□ Operational Phase

- Virtual system is constructed only by the communication of **partial agents** which are necessary for rescheduling
- Rescheduling using partial components can
 - *Not destroy the initial schedule frequently*
 - *be executed faster to give a quick response for fluctuations*

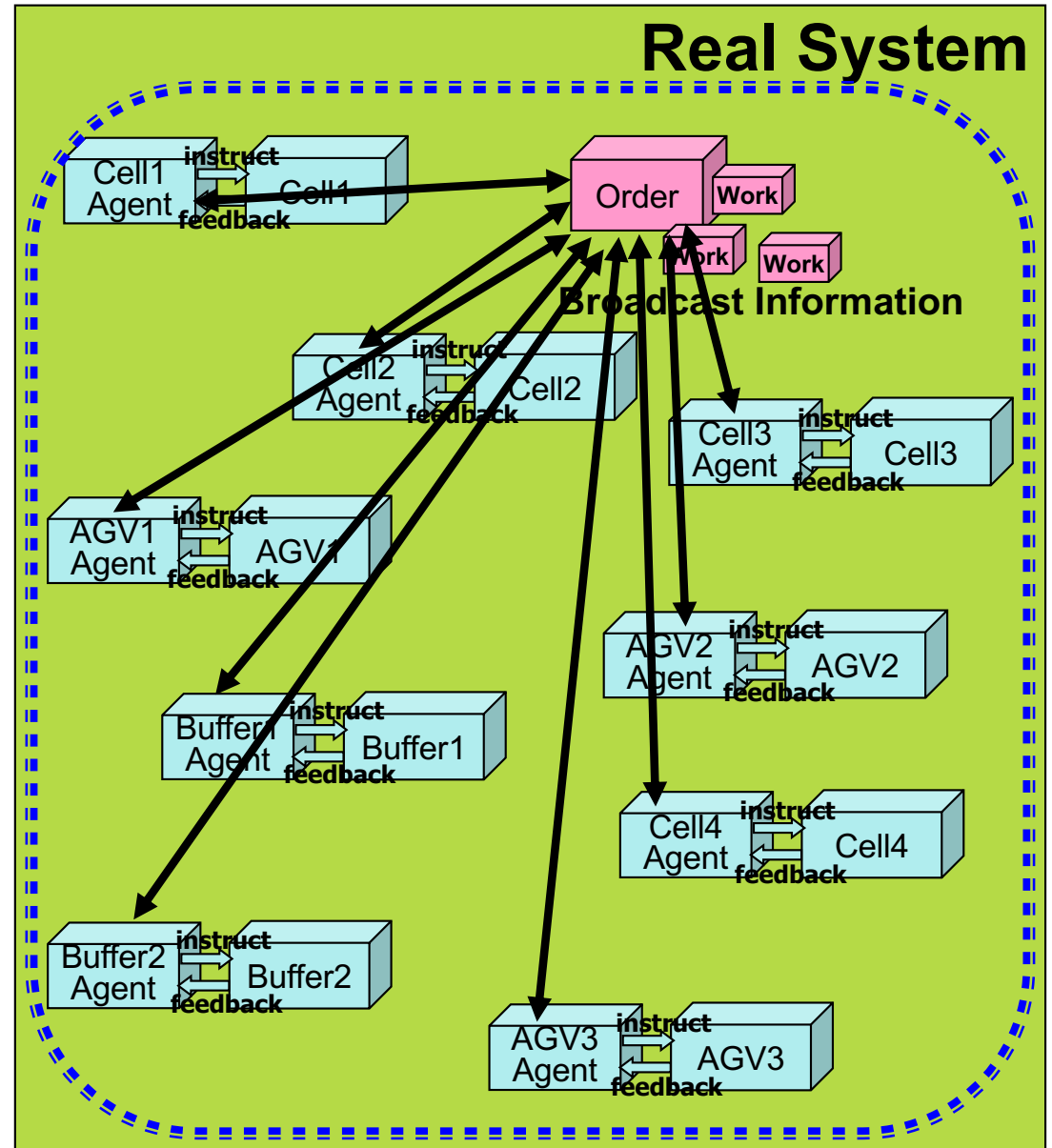
A social contract based approach, named Combinatorial Auction is applied

Scheduling in RVF-MS

(planning phase)

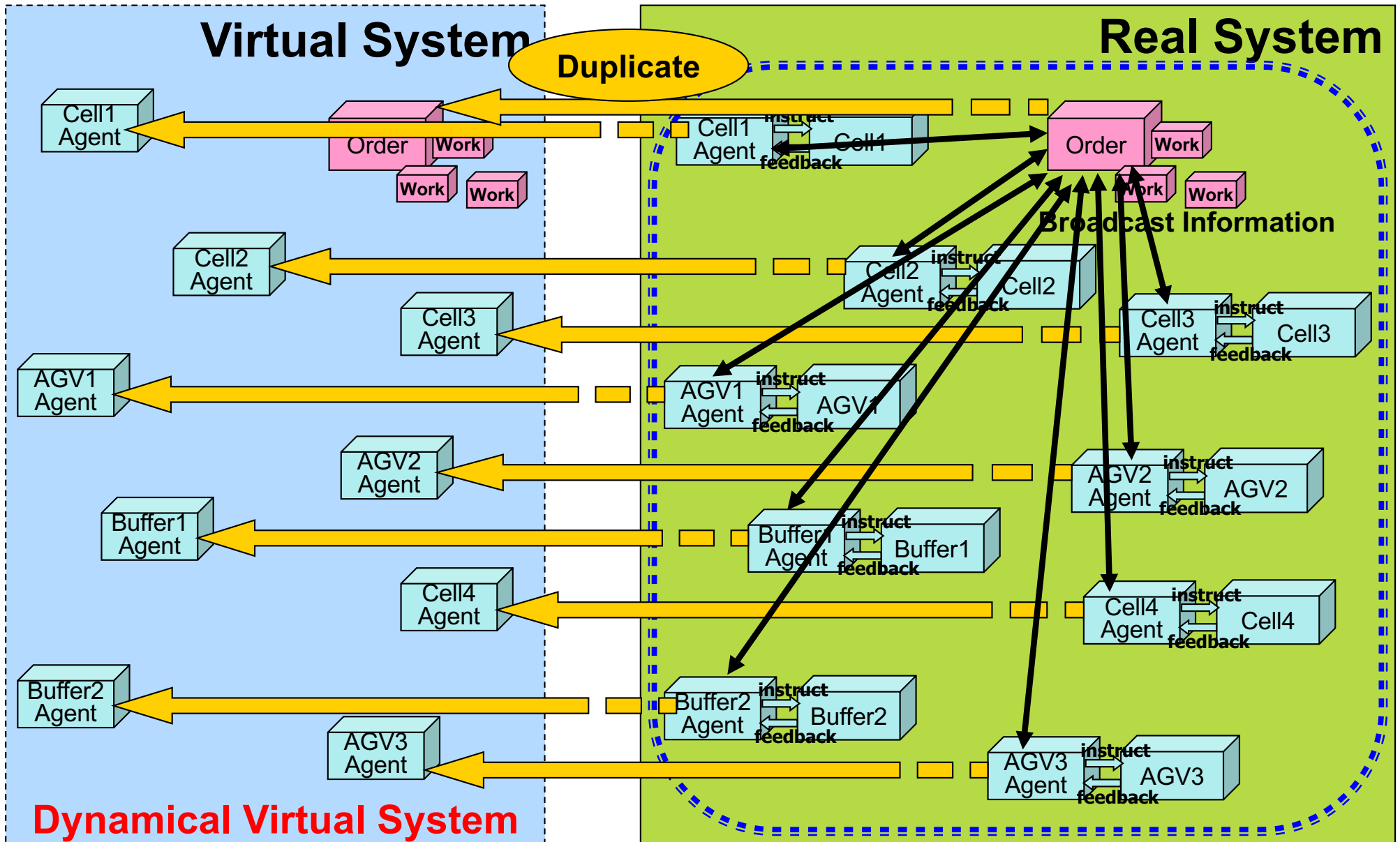
Virtual System

Dynamical Virtual System



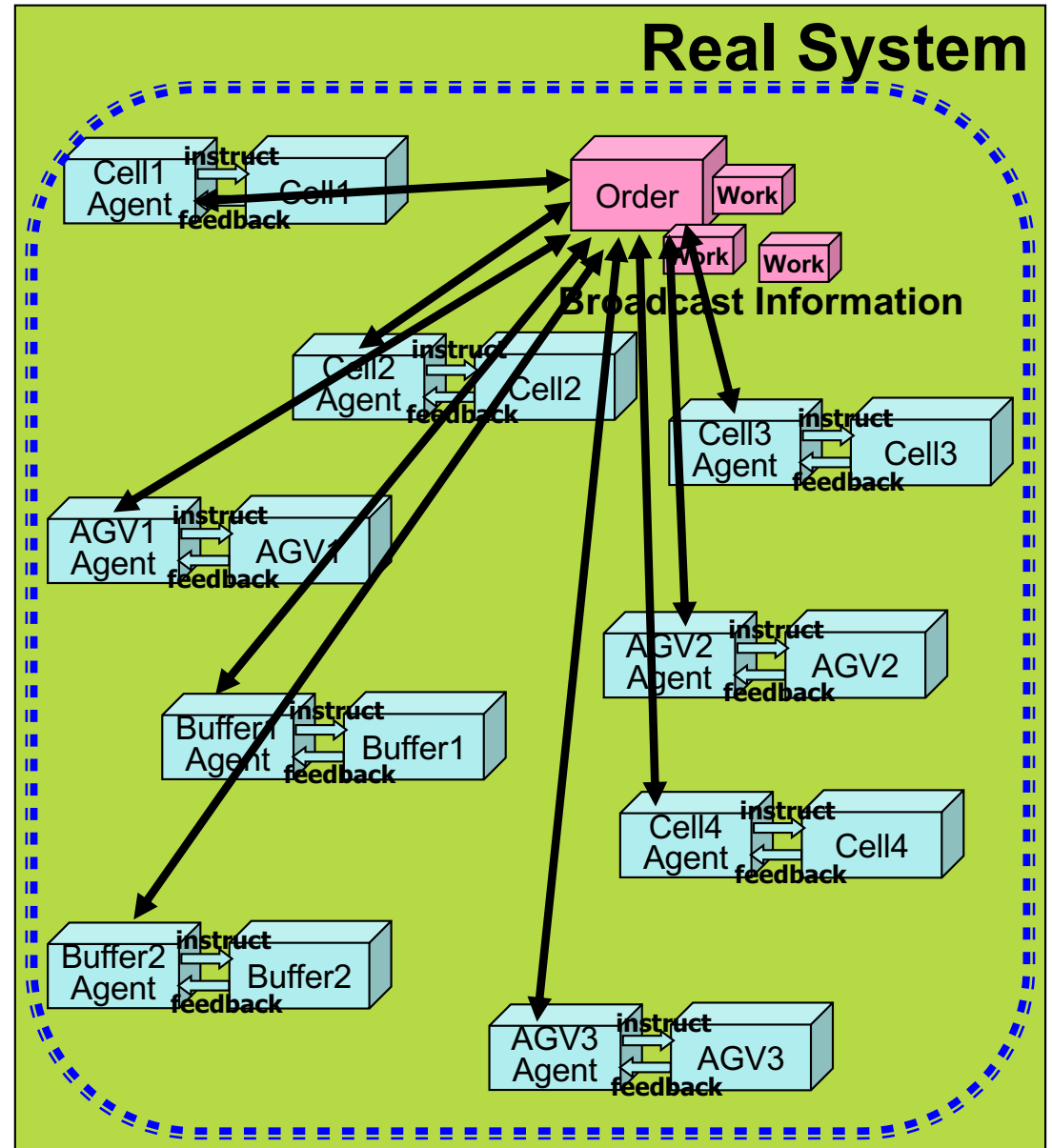
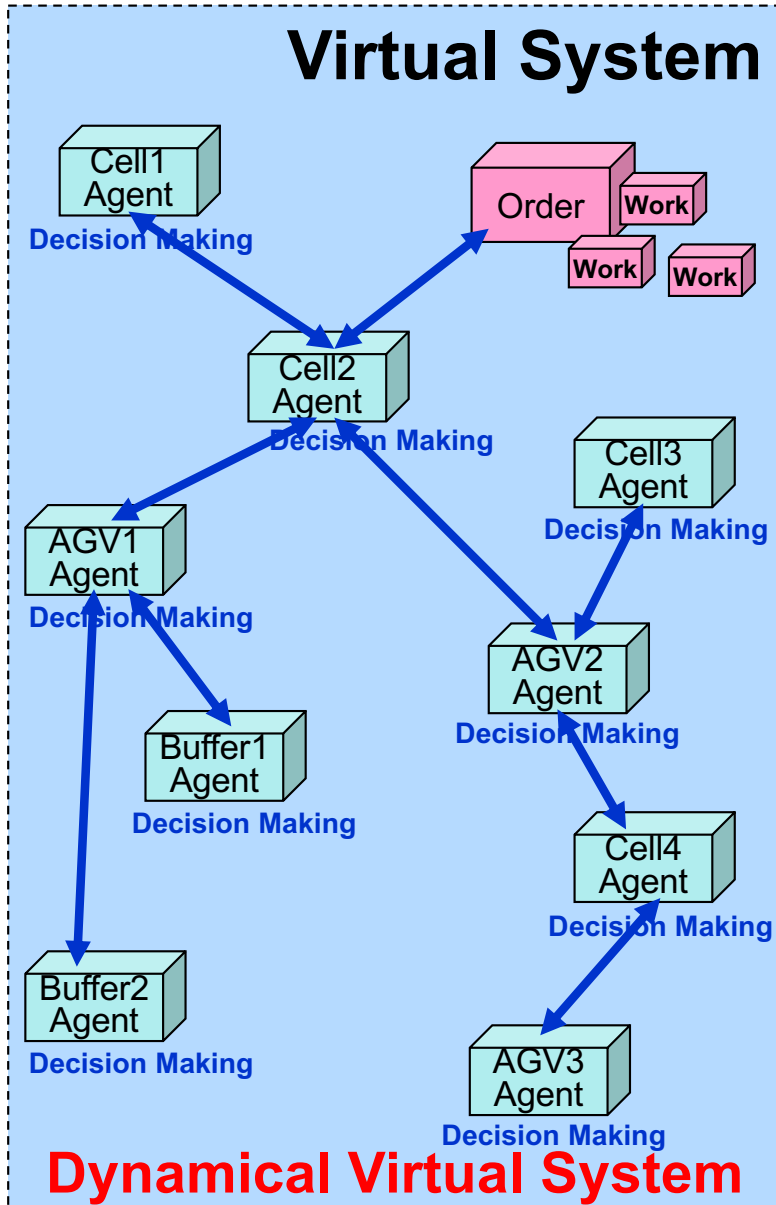
Scheduling in RVF-MS

(planning phase)



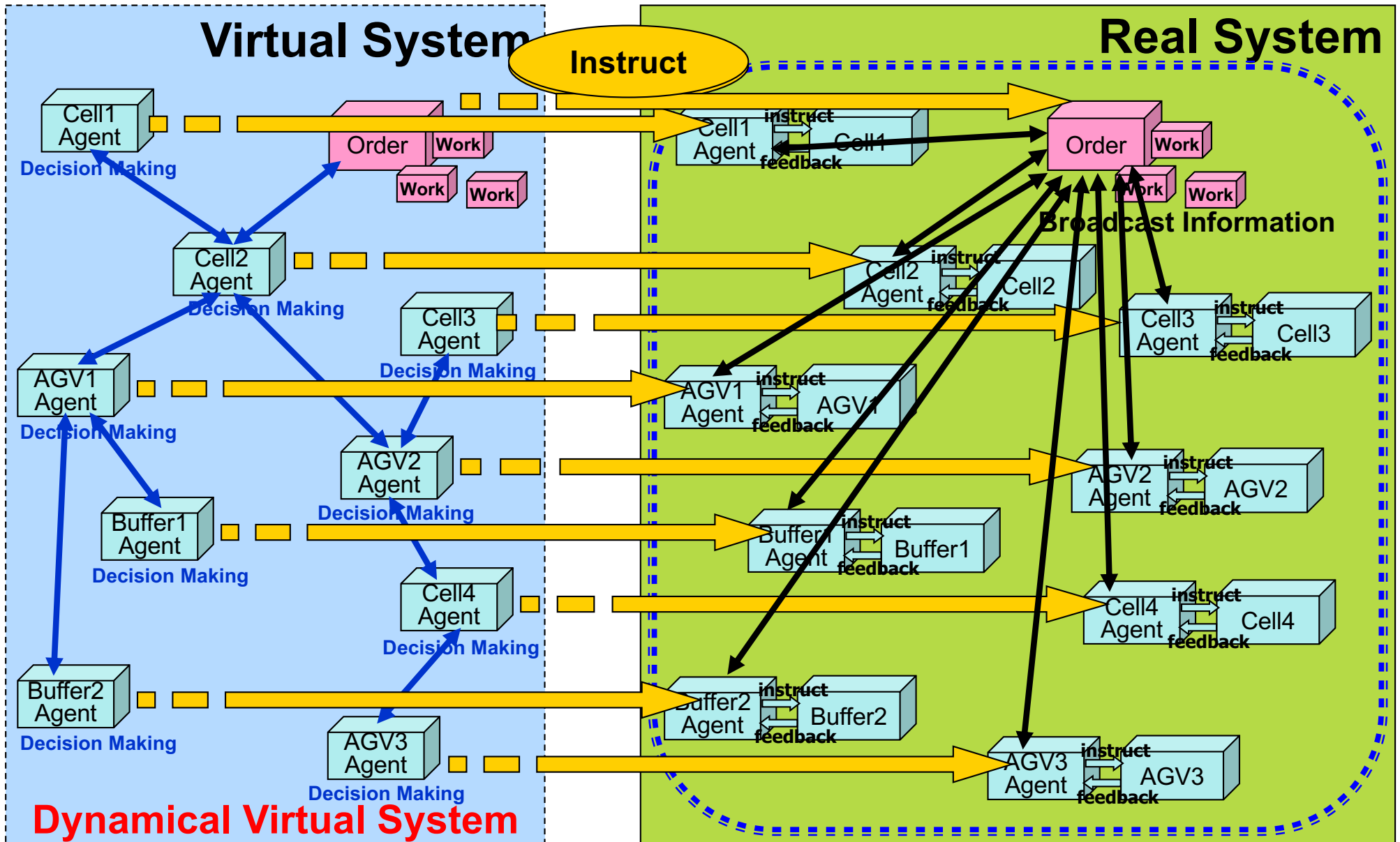
Scheduling in RVF-MS

(planning phase)



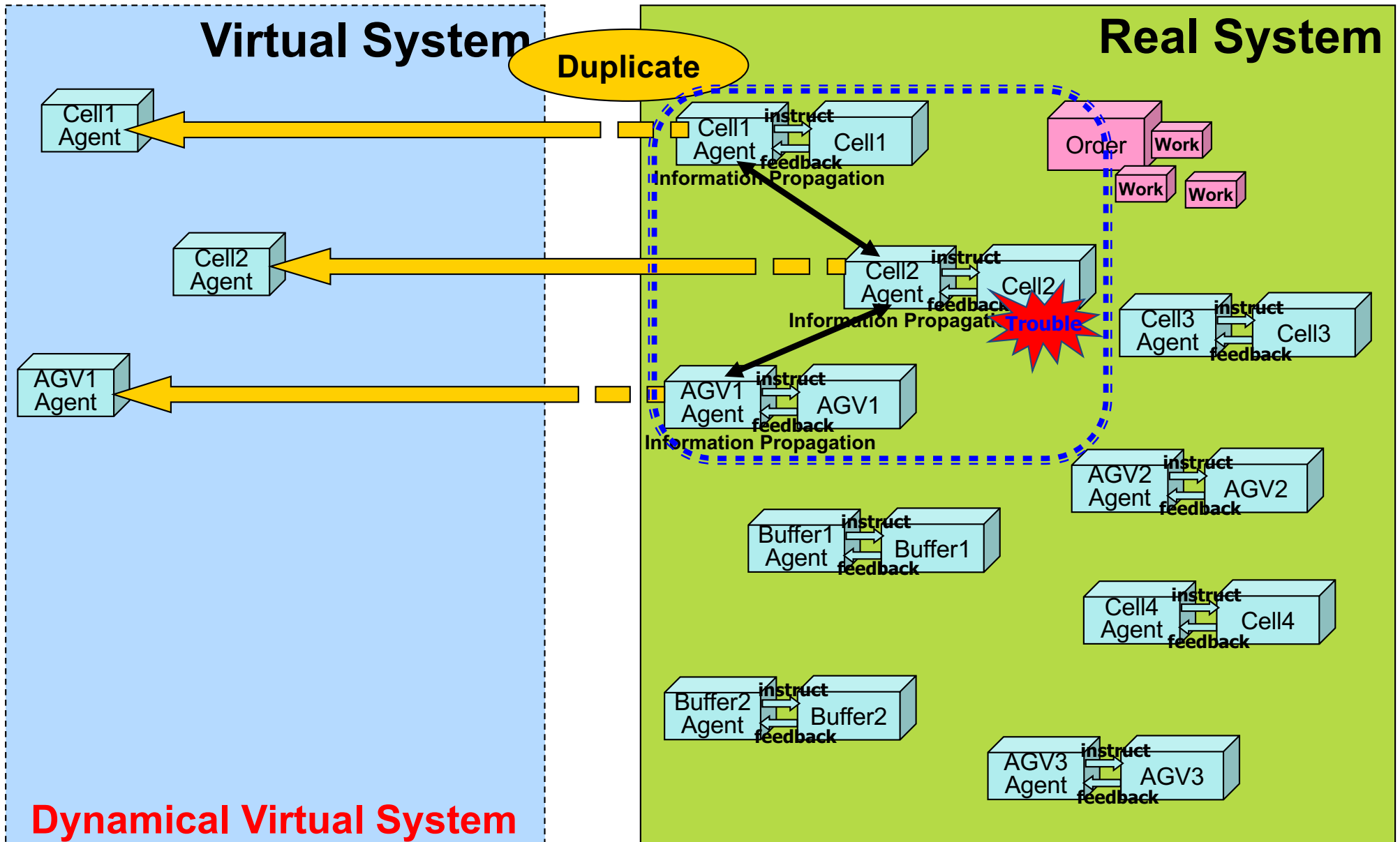
Scheduling in RVF-MS

(planning phase)



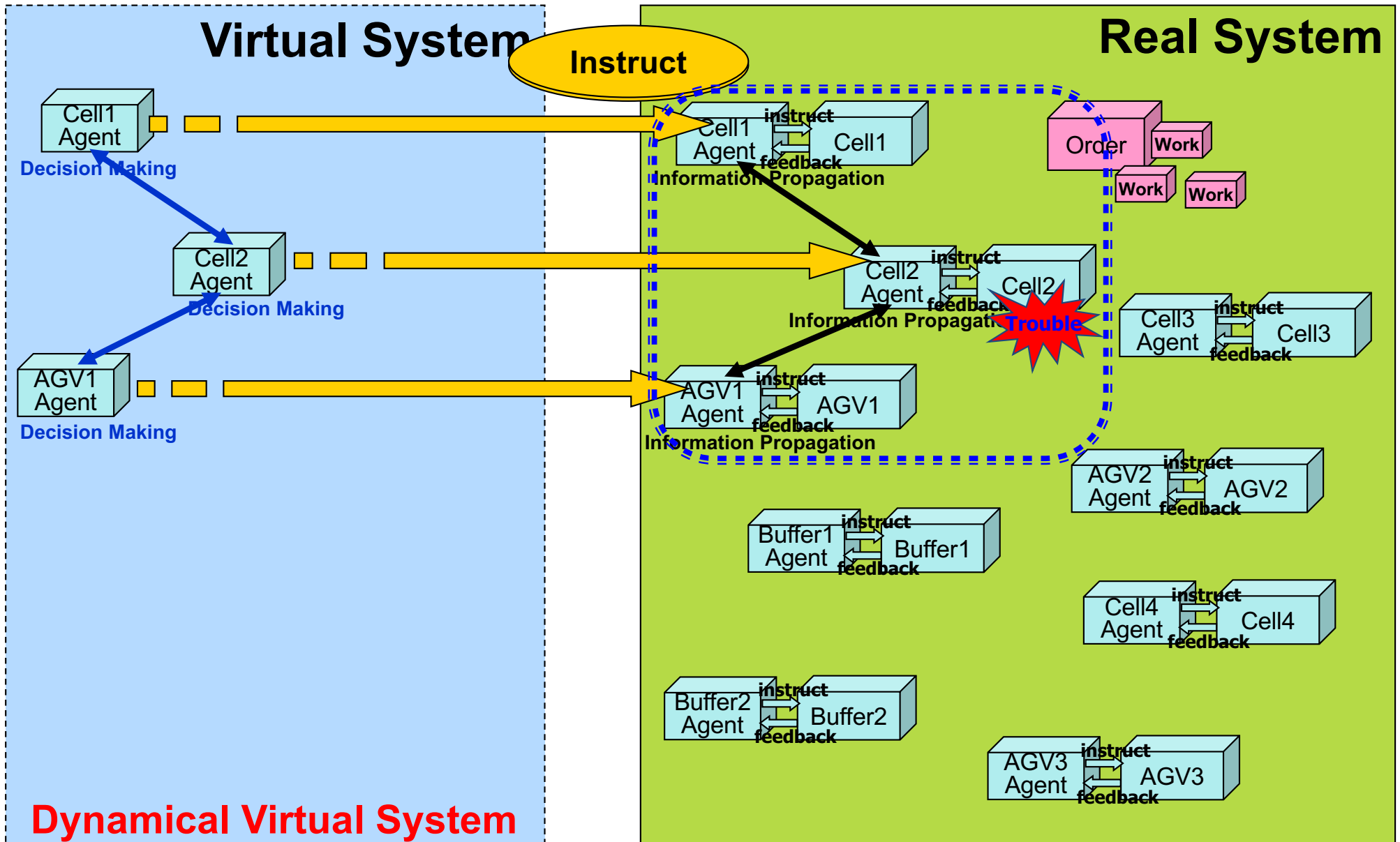
Scheduling in RVF-MS

(operational phase)



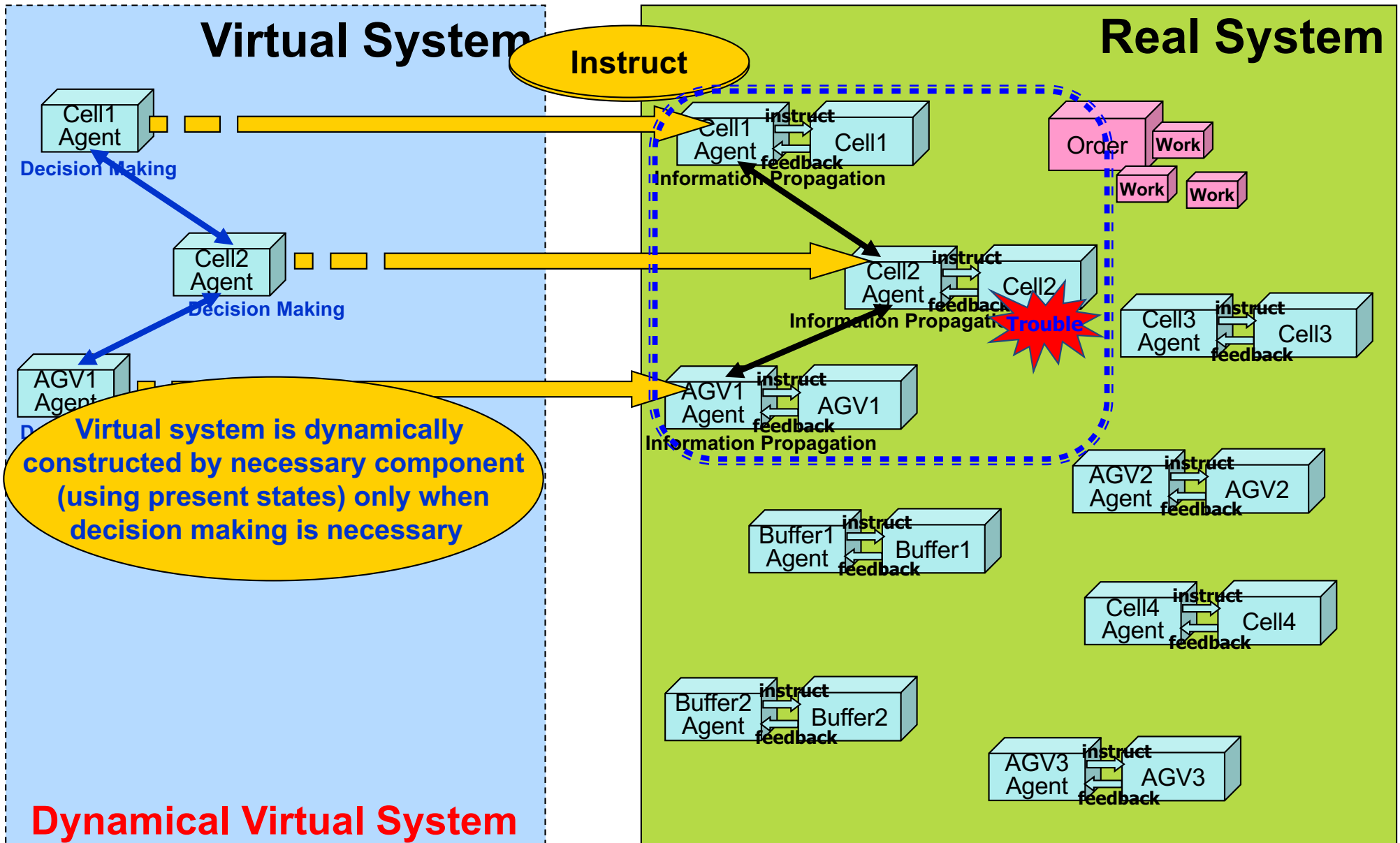
Scheduling in RVF-MS

(operational phase)



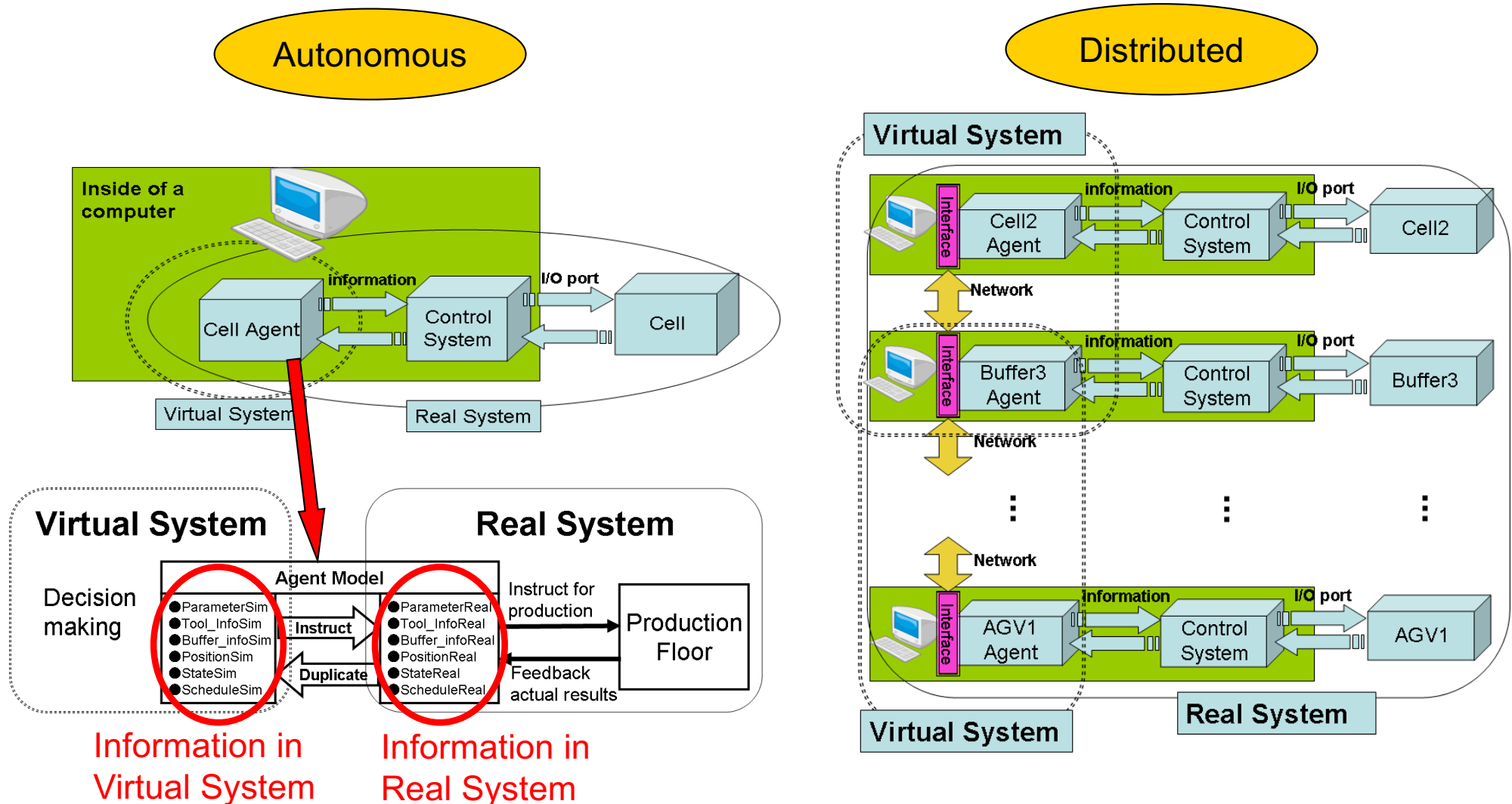
Scheduling in RVF-MS

(operational phase)



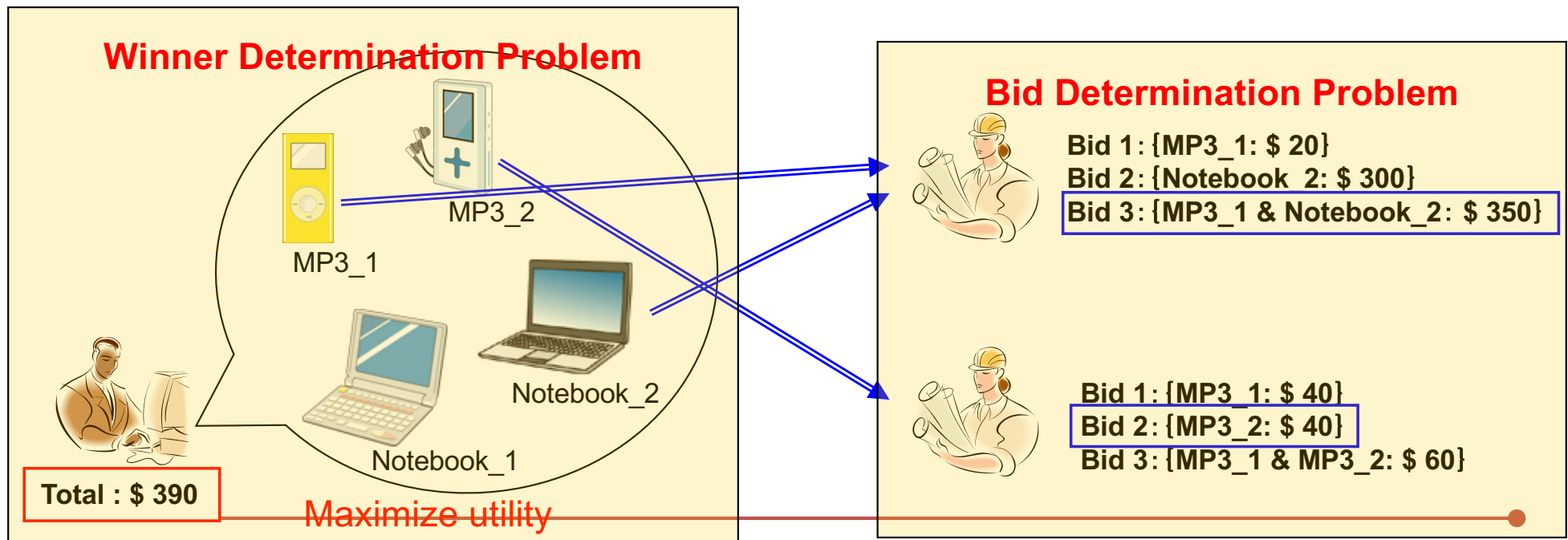
Implementation of RVF-MS

Multi-agent System paradigm



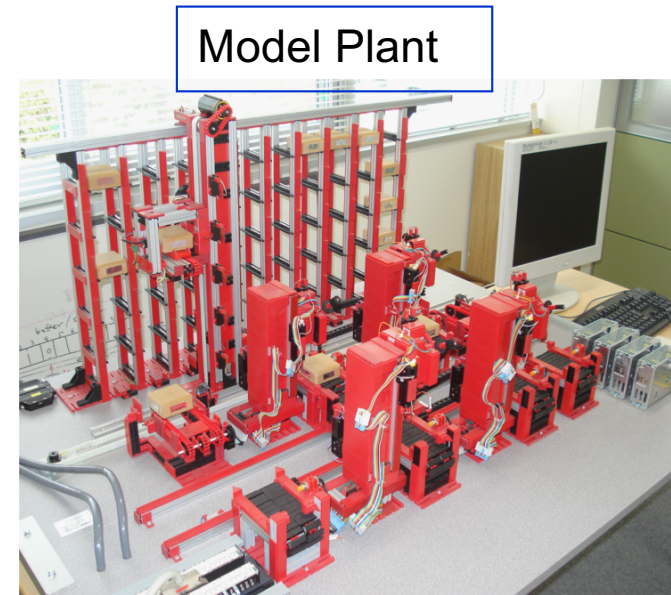
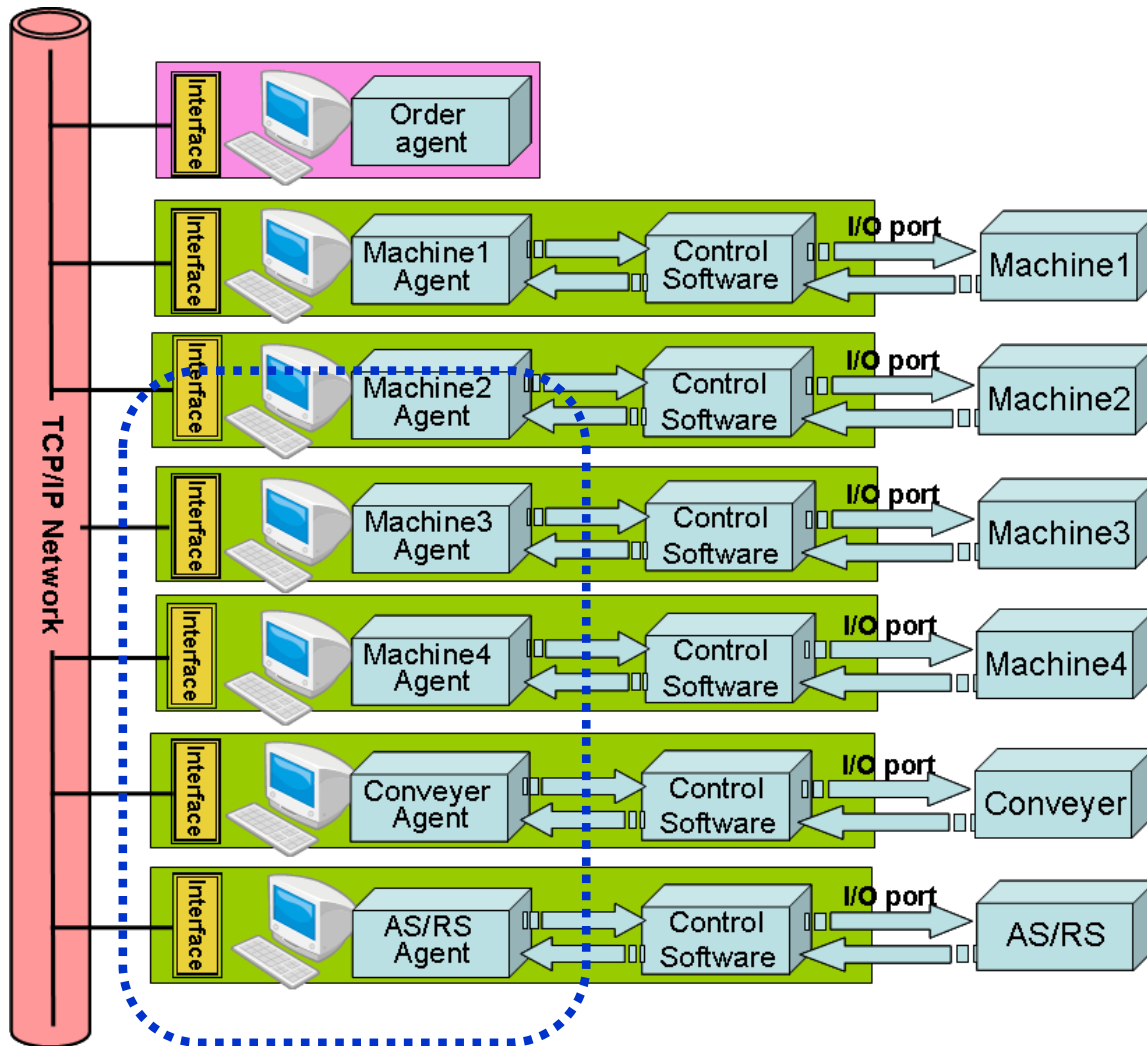
Combinatorial Auction (CA)

- CA is a type of social contract based approach, in which participants can place bids **on combinations of discrete items**, rather than just individual items or continuous quantities.
- Relationship such as **complementarity** and **replacements** among items can be represented in CA, so that efficient allocation of items can be realized.
- **BDP**: determine efficient placement of bids and submit to the auctioneer
 - All-bids: bids by all of the jobs' combination (*Although Optimum solutions can be obtained, combination explosively increases along with the large scale*)
 - Part-bids: bids by only a part of the jobs' combination (it is effectiveness by using *utility restriction and local search to give an efficient search space*)
- **WDP**: determine efficient allocation of items to bidders, to maximize the auctioneer's utility.



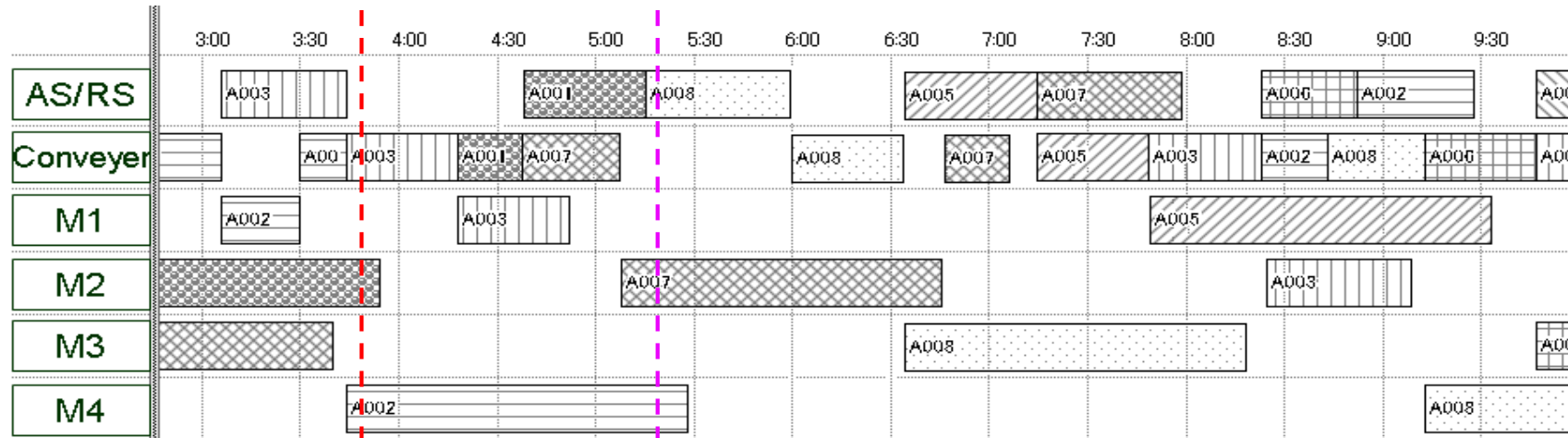
System configuration of RVF-MS

- There are motors, sensors, actuators, and control systems in each part of model plant.

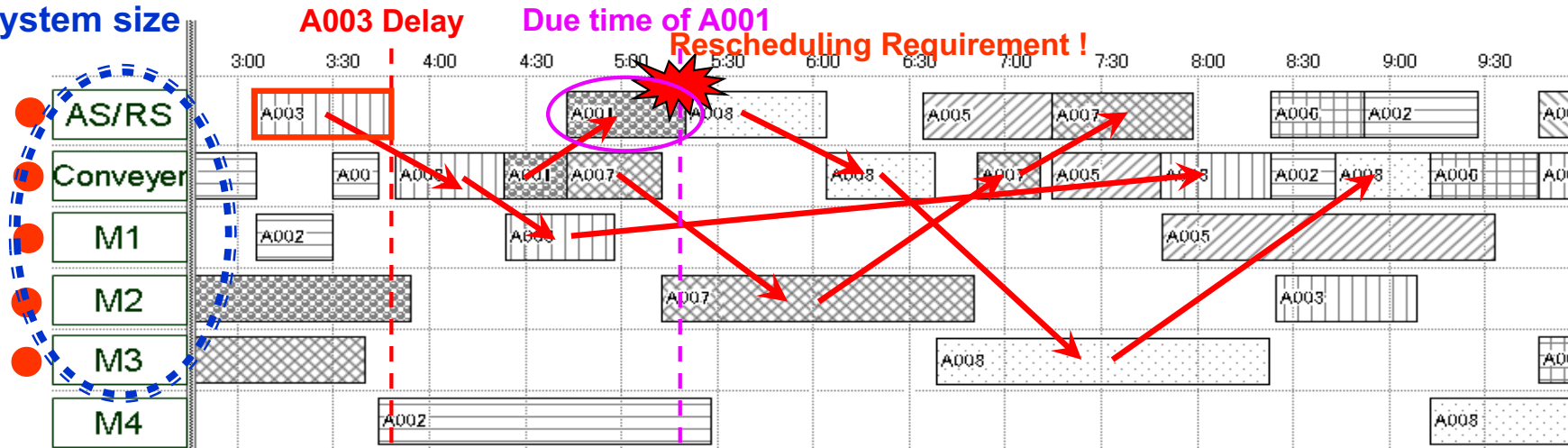


- Milling Machine: 4
- Transportation Conveyer: 1
- Buffer Conveyer: 4
- AS/RS (Automated Storage and Retrieval System)

Experimental result



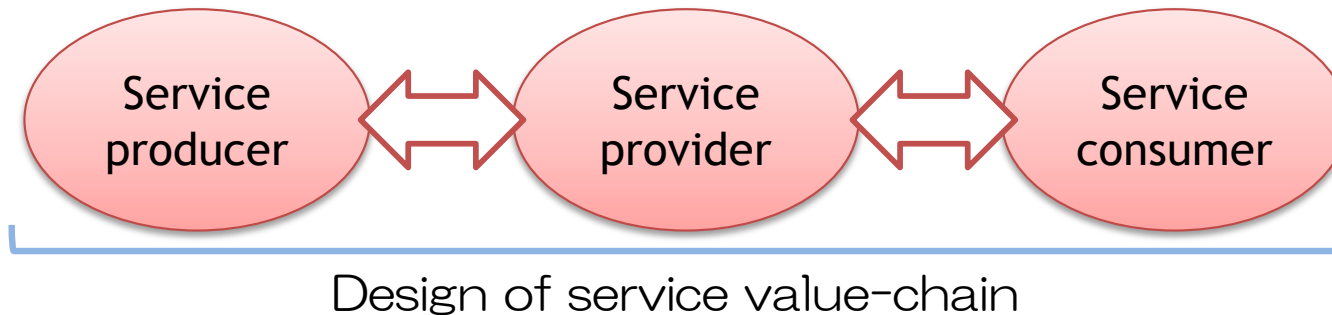
Decision of virtual system size



Decision of virtual system generation timing

Toward Service Systems Design

■ Service systems



- Building service system design methodologies
 - Re-design from viewpoints of “service”
 - Service Dominant Logic (Vargo & Lusch, 2004)
 - Integration of production/provision/consuming stages
 - Sustainable system design by maximizing Customer Satisfaction (CS), Employee Satisfaction (ES) and Management Satisfaction (MS)
 - Value co-creation by Service producer, provider and consumer