

3.13 On coordination problems of cooperating decentralized scheduling systems

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In multi-site scheduling environments (which can also be seen as production networks, supply chains) the need for a cooperation of previously independent scheduling authorities in order to achieve the common objectives has been widely accepted. A supply chain is usually built by a network of cooperating companies which provide some of the needed functions e.g. supplying, production, transport, for the whole network. The supply chain operations reference model shows that the planning and scheduling tasks are vital for the supply chain. But as they are also vital for the companies themselves, they usually have implemented an own system that plans for the local goals and therefore acts quite autonomously. Therefore it is an important task to find a kind of cooperation in multi-site scheduling scenarios that takes into account the global as well as the local objectives.

Especially if we haven't the chance to build multi-site scheduling systems from scratch the problem arises naturally because typically local scheduling systems already exist and these are acting independent trying to reach the goals of the local system. But also other problems of coordination have to be tackled. These will be examined in this paper. If we are going to develop a cooperating system consisting of decentralized scheduling systems we are faced with the following requirements:

- Networks are dynamic. This means that business units can easily join or leave a production network.
- Network optimisation in respect to local autonomy. The autonomous local scheduling systems keep trying to optimize the local objectives, but also the common global objectives have to be regarded.
- A business unit including all its scheduling behaviour can participate in more than one production network. But it is not necessary to inform the other networks of an engagement.
- No information disclosure: coordination should be possible without internal information.
- (Local) scheduling systems are viewed as black boxes. This is because the existing systems shall be used further on and the scheduling knowledge is hidden in the system.
- No hierarchy required among the planning authorities.

- Reactive scheduling is done to change an existing global schedule according to requirement changes.

Existing systems typically assume an environment that lacks one or more of the requirements above.

- APS systems assume a focal company that is responsible for the whole supply chain and therefore uses the scheduling system alone and gives the master schedule to the other systems [SK02].
- The MUST approach assumes a hierarchy among the scheduling systems that is used to decompose the scheduling problem. The integration of existing systems is difficult [Sau06].
- Agent-based approaches assume equal systems that act together in order to obtain the common objective thereby neglecting the local perspective and existing systems [Sch99, FSWZ03].

Therefore we are looking for a system that regards the following objectives:

1. Information hiding: local systems can be incorporated as black boxes, only minimal information is given to the other systems
2. Global objective: the cooperating systems try to optimize the common objective, but also do not neglect their local goals
3. Dynamic structure: the systems can dynamically work in several networks

On the basis of the requirements a system architecture has been proposed that consists of agents that are responsible for local scheduling authorities and additionally one coordinating agent that is responsible for the coordinative activities [SS05]. Fig. 1 shows the general architecture.

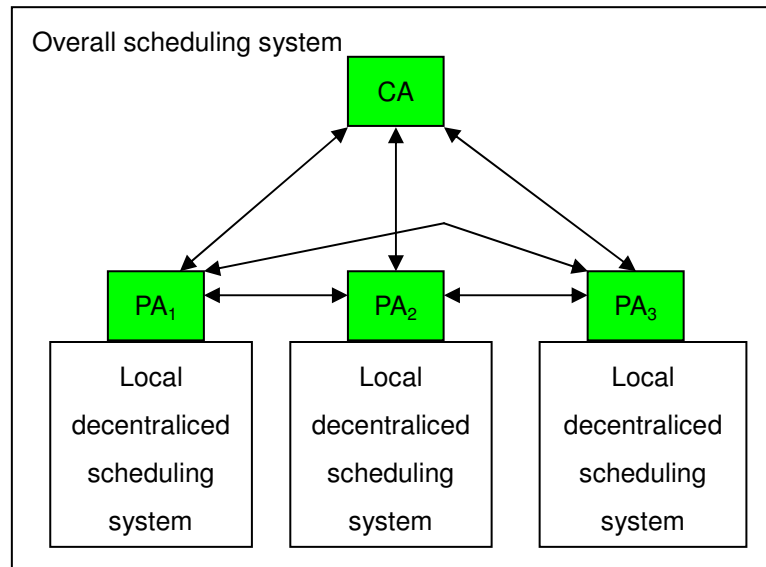


Figure 1. General architecture of cooperative decentralized systems

The local scheduling authority is an autonomous entity internally using a scheduling system which tries to achieve its individual goals while cooperating with other local scheduling authorities in one or more production networks. To maintain this autonomy in the coordination model, every scheduling authority is represented by an autonomous agent, a *planning agent* (PA), i.e. the local scheduling system is wrapped by the PA. A planning authority can participate in a number of networks simultaneously and can leave or enter networks at will. In respect to the flexibility of the PAs and to reduce the communication cost within a network a *communication agent* (CA) is used which provides infrastructure to the network. A network therefore consists of a set of PAs and one CA. Several protocols are used for coordination of predictive and reactive scheduling and schedule improvement. Predictive scheduling is done by a method similar to the contract net protocol. The communication server acts as the manager trying to contract activities to the agents. The rescheduling is based on the main idea of using an alternative PA for a given activity when the originally assigned PA can not fulfil its confirmation. Improvement discussions allow the improvement of the global schedule by discussions among the PAs.

If using independent local scheduling systems it becomes important to investigate collaboration resp. contracting possibilities where global as well as local objectives can be met. We propose a model where order agents are used to regard the global objectives and planning agents are representing the local scheduling systems as shown in fig. 1. The resulting scenario is shown in fig. 2.

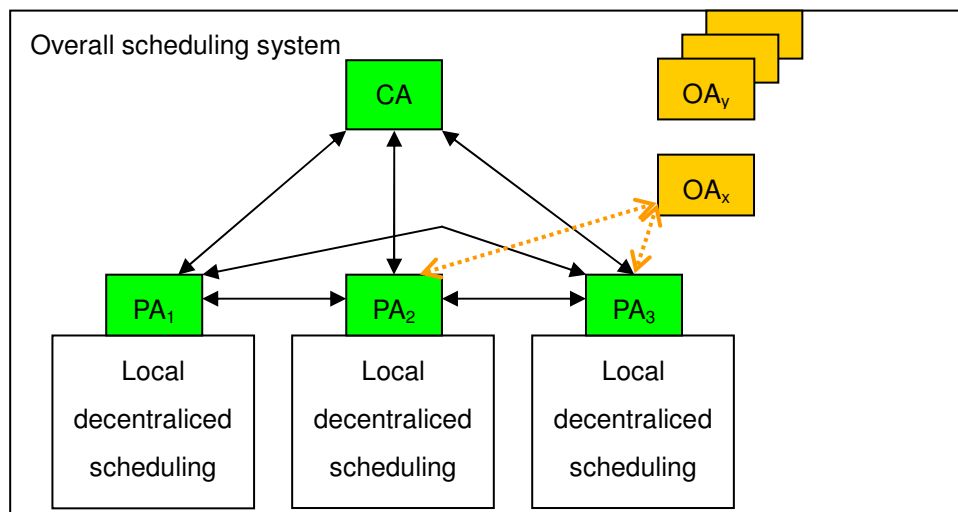


Figure 2. Coordination in mass customization scenario

Here the order agent (OA) is responsible for regarding the global objective coming with the external order, e.g. meeting delivery dates. The coordination mechanism includes:

- order agents that ask the PA for scheduling alternatives and select the best ones regarding their own objectives
- PAs that offer possible production intervals and resources while trying to optimize their local objectives.

We are actually evaluating the approach in a mass customization scenario [SS07].

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