E-Scheduling

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INTRODUCTION

Collaboration between business partners can take many forms, ranging from simple exchange of elementary data to collaborative work on product development and division of labor in production and distribution processes. This article describes concepts, systems, and experiences with computer-aided collaborative scheduling.

Scheduling is the allocation of resources over time to perform a collection of tasks (Baker, 1974). A schedule maps activities to resources, together with their planned start and end times. It determines what activities will be realized with what resources at what time.

Scheduling is traditionally seen primarily as an activity geared to a specific workshop or factory. Increased division of labor and globalization of manufacturing activities demand the coordination of distributed production activities. As scheduling decisions are often short term and taken close to execution, real-time information exchange, seamless task collaboration, and contingency management among geographically dispersed factories may be beneficial (Jia, Fuh, Nee, & Zhang, 2002).

E-Scheduling can be defined as the application of computer and network technology as devices for coordinating tasks that are somehow related. With the evolution of the Web, eScheduling systems also became available for use in business-to-business (B2B) and business-to-consumer (B2C) relationships, for coordinating appointments, meetings, and reservations. In the remainder of the article we discuss e-scheduling first in production systems and then in office and service environments.

BACKGROUND

At the core of scheduling problems there is a coordination issue: Resources must be available for working together at the same time, and mostly also at the same place. Information and tools may be needed to execute the tasks and have to be considered in the scheduling process. Thus, several resources must be available at the right time at the right place in the right quality, resulting in a typical logistical problem.

Scheduling procedures have traditionally been regarded primarily in a manufacturing context. Several objectives may be relevant in scheduling. Much effort has been spent on developing algorithms for solving the associated assignment and sequencing problems. Mathematical complexity theory has shown that most sequencing problems are NP-hard (Lenstra, Rinnooy Kan, & Brucker, 1977). Therefore research has been focused on developing heuristics and interactive systems for finding good, but not necessarily optimal solutions.

Some operations management concepts recommend segmenting shops into autonomous work groups (Baines, 1993; Schuring, 1992). These groups are scheduled to execute certain tasks within predetermined time frames (e.g., 1 week). The assignment of tasks to certain members of the group and machines and the sequences in which the tasks are executed on them are not decided centrally but by some member(s) of the group. Experience has shown that the actors in the groups are heavily interdependent in their activities and, as a consequence, spend a great deal of time on coordinating and negotiating their activities. This is also true for relationships with other working groups, central planners, purchasing agents, process support technicians, and others. In many situations, the actors had no efficient means of supporting this interaction. They kept a number of "private" logbooks, but little was based on well-defined procedures and supported by tools (Carstensen & Schmidt, 2005). Results like this show that there is a need for a well-defined collaboration on the shop floor and for coordinating schedules in distributed systems.

From an information systems viewpoint, scheduling is part of or closely related to manufacturing resource planning (MRP II) and enterprise resource planning (ERP) systems. Earlier MRP systems either excluded detailed scheduling tasks or proposed detailed but inflexible schedules in the form of lists, which might have been updated only once a week. When PCs with graphical user interfaces became available, systems were developed that allowed an interactive definition and improvement of schedules, for example by presenting machine- and task-oriented Gantt charts and allowing schedule modifications by drag-and-drop. These systems originated in Germany, and the German term *leitstand* (Adelsberger & Kanet, 1991; Kurbel, 1993) is sometimes also used in English for such an electronic control unit. Leitstands work as part of a computer hierarchy, receiving short-term data from the ERP system, supporting the scheduler interactively in his tasks, acquiring data from the shop floor, and transmitting basic data or data aggregates to the ERP system. In a medium-sized or large enterprise, typically several control units are implemented for scheduling different workshops. These decentralized leitstands are usually not directly connected and do not offer other schedulers real-time information that may be relevant for their decisions.

Manufacturing execution systems (MES) are designed for shop floor control, statistical process control, and management of work in progress (Chang, 2005). Scheduling is sometimes seen as functionality offered by MES. Some sources mention potential advantages of communication between MES (Kratzer & Erhard, 2004).

Some vendors do not provide functionality for detailed scheduling in their ERP system but offer a supply chain management (SCM) system that includes an advanced planning and scheduling (APS) system. For instance, SAP's APO (advanced planner & optimizer) includes a "production planning/detailed scheduling" (PP/DS) module, which allows scheduling of production orders with very fine granularity. Although such modules are offered as part of an SCM system, they are not designed for collaborative use by several units, but provide their advanced functionalities primarily for one particular unit.

COLLABORATIVE PRODUCTION SCHEDULING

In this section, we assume that scheduling decisions of one unit influence the schedules of other units. These units may be different shops at a certain plant or different plants within a group or different companies within a supply chain. The units depend on their suppliers to provide the right materials at the right place at the right time and in the right quality. Owing to this dependence the schedulers of the receiving unit may wish to know details of how the preceding production and distribution operations have progressed. We distinguish between a simple exchange of information between these units and more sophisticated types of collaboration.

Information Exchange

The SCM literature emphasizes the importance of information exchange, among other reasons to avoid the bullwhip effect (Lee, Padmanabhan, & Whang, 1997). Information exchange is discussed primarily for point of sales data, inventory data, and machine utilization data.

Information needed to support scheduling decisions may be exchanged via reports about (potentially real-time) data that are published on a Web site or sent to a PDA. Such reports may be designed to present production data by time-frame, stock-keeping unit, production area, and operation.

In contract manufacturing the schedule of transports may determine production schedules and a need for exchanging information between distribution and production schedulers' results (Chang & Lee, 2004; Chen & Vairaktarakis, 2005). With respect to distribution schedules and their fulfillment, Track&Trace systems (Hannon, 2004) have become quite popular. They show the progress made in bridging the spatial distance between supplier and recipient, allow the recipient to prepare for arrivals, but also to adjust production schedules if the item required should arrive too late.

The customer may receive information about successfully finished operations and when the remaining operations are scheduled for execution. As usual, this could be done via alerting mechanisms (e.g., sending e-mails), by providing information on the Web, or even by allowing access to (parts of) the scheduling system. Visibility of real-time data for business partners is regarded as one of the main properties of the "real-time enterprise" (Rabin, 2003).

In the chemical industry, changes in the schedule of one plant can affect several other plants, and ripple effects may increase the magnitude of changes in plants downstream. For instance, in the Bayer company the plant schedules are highly interdependent. The results of the nightly centralized scheduling run are broken-

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