Enterprise Co-operation Leads To Extended Products

And More Efficiency

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Abstract

Internet enables collaborative planning of enterprise networks, however co-operation between businesses has been constrained due to information hiding. Companies are afraid that knowledge about available capacity and forthcoming demand will be misused by the partners in the supply chain.

Different levels of information sharing are possible: (1) from the default in which the subcontracting company only returns a fixed lead time and quotation for an order request or (2) a scenario in which the subcontracting partner supplies a set of available production time slots upto (3) full resource schedule information including tracking of rolling stocks.

A recently developed collaborative planning methodology – PPC – is documented and obtainable efficiency improvements are shown by simulation.

The paper concludes with a reference to ongoing work on the usage of the methodology in the microelectronics and automotive industry. The conclusion also touches the theme how new "extended products" become feasible as a result of intensified enterprise collaboration.

Introducing The Network Enterprise Perspective In Virtual Enterprise Planning

Emerging e-marketplace concepts today are only discovering the opportunities enabled by collaborative planning techniques.

See Figure 1

Current WEB marketplaces mimic real markets "buy and sell" behavior as illustrated in phase 1 (figure 1). At t^0 (the current time) the market contains products that have been delivered by suppliers and can be bought by customers. If a customer is another enterprise and the product is an 'intermediate product' we already have the virtual enterprise structure and the supplier can be seen as an (optional) subcontractor in the model. If the supplier also provides information about products that will be available on the market place at different instances in the future (t^0, t^1, …, t^i, … , t^n) and the customer expresses his needs at time instances in the future the actors on the market can synchronize work based on the ATP (available to promise) information at the marketplace. When the market place uses resource capacity models and work in progress combined with products in inventory information the two stage optimization methodology described in this paper becomes a driving force on this e-market place.

The Stepwise Collaborative Optimization Methodology - PPC

This paragraph provides a short summary of the two step PPC methodology [Frederix 2000] capable to plan the workloading in a virtual enterprise (network) . PPC (illustrated in Figure 2) creates in the first step (1 – in figure) a "rough feasible" plan. A plan that can be generated quickly and consists of a set of first routings of the orders in the virtual enterprise with order due dates for the different enterprise entities and the total cost of the schedule. This "rough feasible plan" can be used to answer questions about the feasibility to deliver products to the customers at a pre-specified due date. The planner can accept this solution that will be feasible but not at an optimal cost or reject it and ask for a better solution. When he asks for a better solution or when the methodology is used to create a fine optimized schedule, sets of "rough feasible plans" based on the rules defined by the planner or other heuristic procedures will be generated.

If a "rough plan", part of this set is "promising" the methodology will search for a (3 in figure) local optimum in the neighborhood of this "rough" solution using the "fine optimizer" of the methodology. The "fine optimizer" works on the whole collaborative manufacturing chain and looks at the available free slack in the orders at any point in the process routes and is in this way able to improve the given rough schedule.

The combination of an optimization algorithm with heuristics at the "rough planning" and "fine planning" phase creates more flexibility for the enterprise network planner and also permits, depending on the chosen heuristics, to select between an integrated optimal plan up to loosely coupled almost independent plans for the different collaborating enterprise entities. Because the "rough schedule" that can be randomly generated, based on dynamic or static heuristics or other methods, is improved using the fine optimizer that works enterprise wide it is likely that the methodology will create better solutions than obtainable with one of the optimization techniques alone.

The rough optimizer. Steps (1) and (2) shown in figure 2 generate a feasible schedule. For these steps it is currently only possible to use a heuristic method. This is because (1) the complexity of a collaborative enterprise does not allow to compute exact solutions in reasonable time and (2) optimization is performed on approximate models of a real world. Most of these heuristic techniques deliver not one solution, but – depending on the parameter settings – different rough solutions. Another rough solution can be the result of another start sequence of Jobs (e.g. in the case of dynamic dispatching heuristics), another partitioning of entities (hierarchical decomposition and static scheduling) or the result of adding some randomness in dynamic dispatching decisions. The PPC methodology uses Simulated Annealing to execute a random walk (or walk driven by defined heuristics) in the first phase (the rough optimizer) of the optimization process. Algorithms that work more in an incremental way (steepest descend, tabu search) are less capable to sample the same large solution space in the available optimization time.

See Figure 2

The fine optimizer using the “total float algorithm” [Frederix 2000] starts from solutions provided by the rough optimizer and searches in the local neighborhood if better solutions are available. Minimizing makespan will imply that total floats have to be minimized. The aim of this transition mechanism is to identify pairs of critical operations processed on the same resource and prioritize the operation with the least total float between the two. The net result of this operation will be reduced idle time of the resource between these two operations. Such an action will result into a new critical path and therefore a new solution. It is obvious that there may be more operations that satisfy the previous rule. The algorithm will compute for all this operation sets (i and j) the difference $f_i - f_j$ (only positive floats) and sort in descending order.

The total float transition mechanism [Frederix 2000] can be extended to create a collaborative manufacturing chain schedule that delivers orders at due date. This objective is reached when the total float is not calculated starting from the end date of the latest job (the makespan definition) but from the due date set for the corresponding orders. In the initial iterations of the fine optimizer algorithm it is possible that the intermediate schedule of an order passes the due date. This results in negative floats for the different tasks or operations of this order. The drawback of the method described in this paragraph expects that all orders can be delivered at their due date. If this seems impossible the methodology will use the enterprise network to find additional capacity. (Part of methodology not documented in this short paper)

Experiments

64 typical data sets of Fischer and Thomson [Fischer et al. 1963], Adams, Balas and Zawack [Adams et al. 1988], Applegate and Cook [Applegate et al. 1991], Lawrence [Lawrence 1984], Storer, Wu and Vaccari [Storer et al. 1992] and Yamada and Nakano [Yamada et al, 1992] with fixed sets of constraints have been used to benchmark the PPC methodology. This larger set of benchmark exercises, some of them known for the issues that arise when you try to solve them, has been selected to obtain statistical significant results.

See Figure 3

In a first exercise scheduling results have been obtained using “dynamic dispatching” rules referenced in recent literature [Tipi 1999] [Sabuncuoglu 1998]. Scheduling the exercises using dynamic dispatching rules is comparable with the best behavior of every virtual enterprise entity on its own, not using the additional virtual enterprise network information. The real world case will even be worse, because the “local” virtual enterprise entity has only access to local available information and in the benchmark – the dynamic dispatching rules have access to all process steps in the chain. A set of 7 different dynamic dispatching rules have been used to schedule the exercise: First In First Out (FIFO); Last In First Out (LIFO); Shortest Operation Processing Time first (SOPT); select job with Most Remaining Work first (MRW); select job with Least Remaining Work first (LRW); select operation with smallest ratio of the operation processing time to the total remaining processing time (ODT); and select the operation with the smallest ratio obtained by multiplying the operation processing time by the total processing time (OMT).

These results have been compared with the schedules generated by the PPC methodology starting from a randomly generated start sequence for the jobs. The included graph (Figure 3) shows the sum of the obtained solution rankings, based on the makespan value, for every dispatching method applied to the set of exercises. It illustrates that the PPC methodology starting from randomly generated start sequences (RANDOM) outperforms the best performing rule (ODT). However the remark has to be made that the dynamic dispatching rule that performs best strongly depends on the selected set of exercises, and this is much less the case for the PPC methodology that does a global optimization based on free slack and free float calculations.

The PPC Methodology in e-Market Places

Every partner at the market place is a VE entity who has its local production optimization needs and the core VE will use the information at the dynamic WEB marketplace to run a global optimization pass. The described model supports VE entities that deliver (1) a complete dynamic model with resources, process routes and work in progress ; and the other VE entities – commonly known as subcontractors - (2) who limit visibility on the available information (product lead time, global production capacity).

Often the VE product is only a part (intermediate product) used in other virtual enterprise(s). This is the so called multi-tier architecture found in the automotive and other industries. The described methodology also offers the option to combine the information available in this type of multi-tier virtual enterprise and removes some the disadvantages of traditional supply chains as described in Lee’s [Lee et al. 1997] paper “Information Distortion in a Supply Chain: The Bullwhip Effect”.

See Figure 4

Figure 4 illustrates that one VE unit can be part of more than one virtual enterprise. These virtual enterprise entities will optimize their local schedules first. The methodology can then use the collection of different local VE entity schedules to build a rough plan and the fine pass optimizer can start from different rough solutions to build the fine virtual enterprise wide plan.

Conclusions

(1) The improvement of the virtual enterprise network schedule is based on the availability of “free task float” information at the different virtual enterprise entities and the ability of the methodology to dynamically reconfigure the work schedule for these entities.

(2) Internet application service provider (Asp's) can use the PPC methodology to enable a more efficient loading of the virtual enterprise and provide network solutions that outperform standalone planning solutions.
(3) The methodology is applicable on one virtual enterprise, a multi-tier virtual enterprise and a virtual enterprise network. A flexibility not often found in other heuristic optimization techniques.

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The Imperial College of Science, Technology and Medicine – University of London, has supported the "Enterprise Co-operation Methodological work. The encouraging results obtained so far in simulations have initiated enough momentum to start the a larger research project (www.co-operate.org) [Co-operate 2000] that will produce a prototype of distributed, but co-operatively inter-operating, business processes of a dynamic network of companies for the microelectronics and automotive industry.

New collaboration rules and processes that will be developed in the Co-operate project [Sousa et al. 2000] will combine co-operation in the network with the independence and flexibility of the individual virtual enterprise entity. This project shall provide more knowledge with respect to (1) what co-operation models are possible in the virtual enterprise environments and (2) explore the advantages that can be obtained by linking several customer – subcontractor tiers over a larger part of the value chain.

In a similar way the more efficient enterprise collaboration that becomes feasible in the network economy has become a driving force behind so-called extended products. These products will have a shorter time to market, offer additional advantages to the customers – e.g. deferred personalization to a few days before delivery …, and include new characteristics – e.g. remote diagnostics, network based features,…. . The reflection that the digital economy has on extended products will be investigated and documented in the "Extended Products in Dynamic Enterprises" [Expide 2000] project (www.expide.org) driven by Bremen University in Germany and the University of Galway in Ireland.

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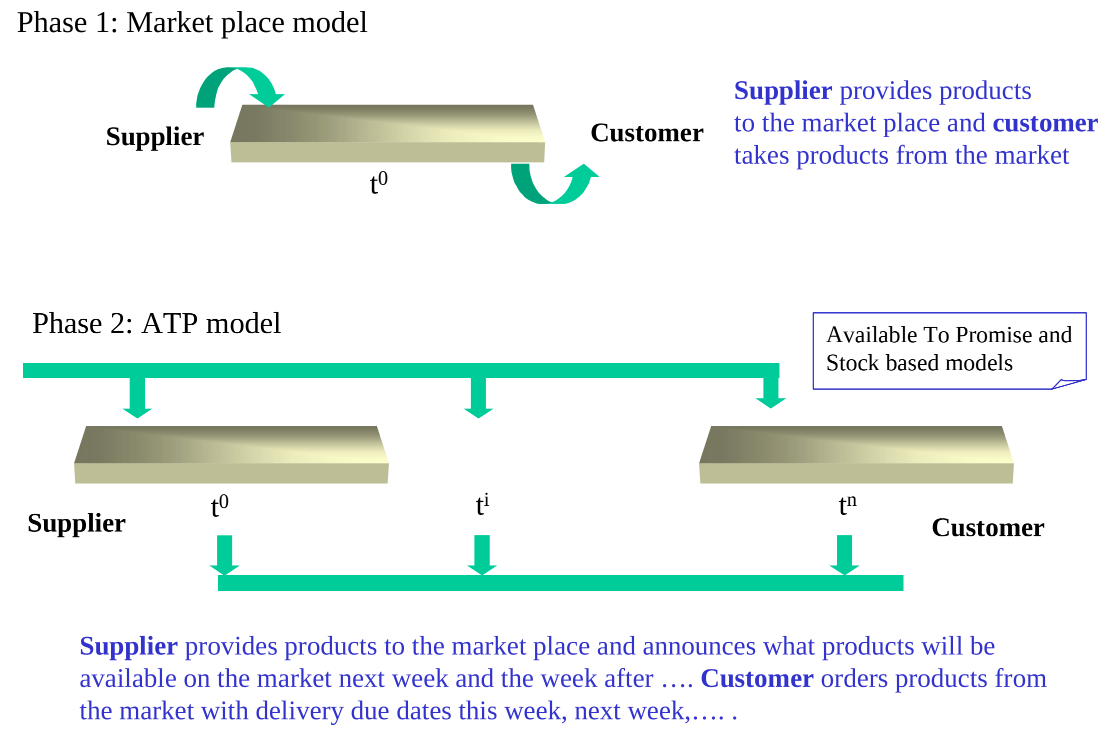

Figure 1 The WEB marketplace - an exploitation enabler

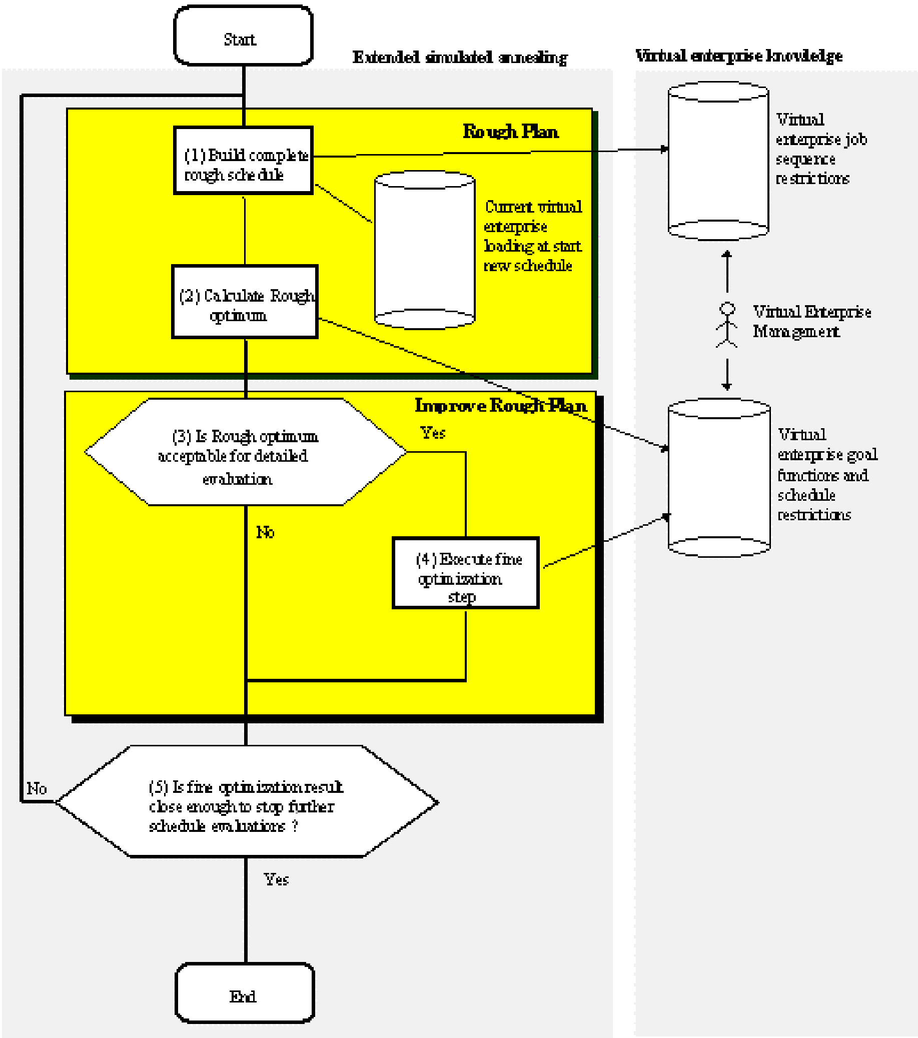

Figure 2: Concept Design of Proposed Solution

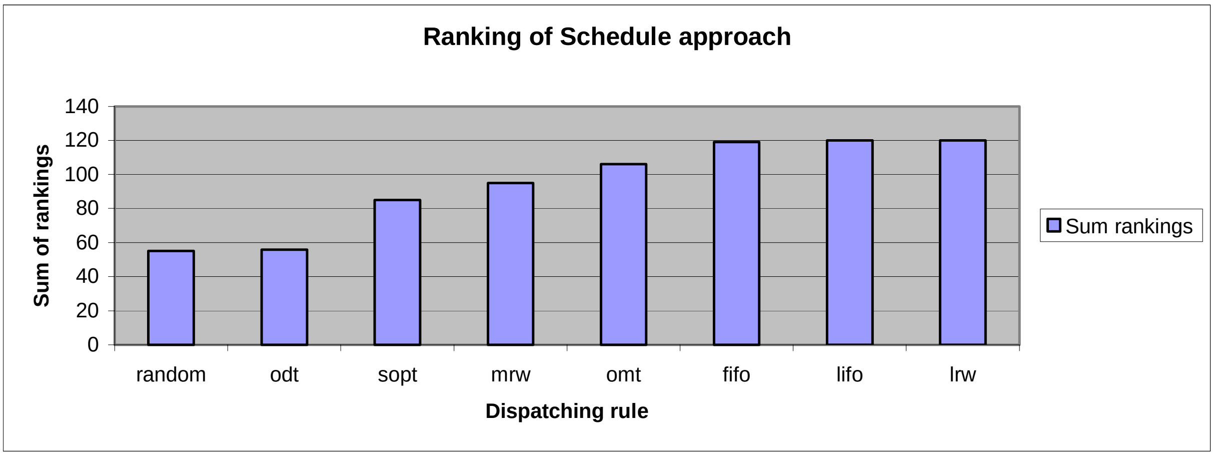

Figure 3:Ranking dynamic dispatching and PPC's performance

The VE unit part of more than one virtual enterprise

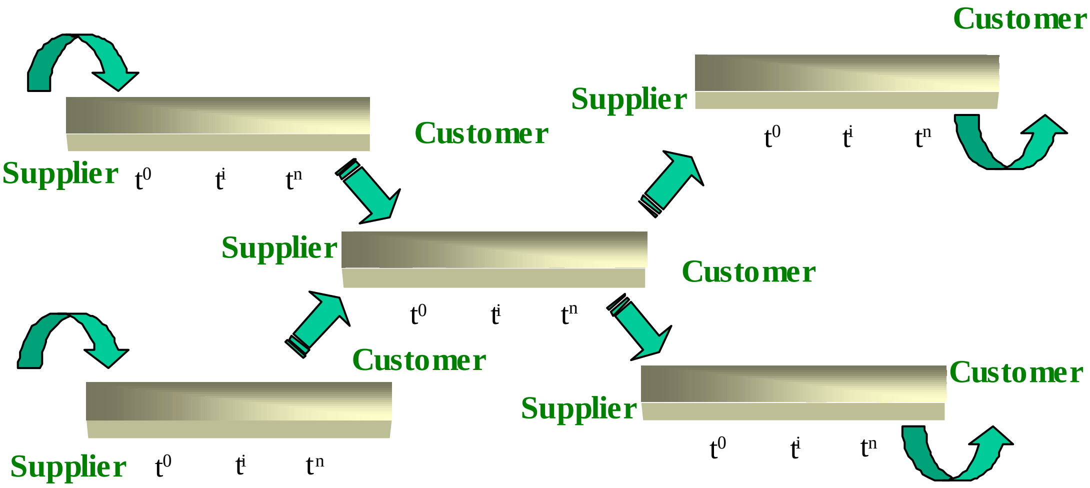

Figure 4 The dynamic n - Virtual Enterprise WEB marketplace