A Dynamic Approach to Multi-transfer Container Management

Sarita Bassil
Département IRO, Université de Montréal
C.P. 6128, succursale Centre-ville, Montréal, Québec, H3C 3J7, Canada
fax: +1 514 985 4039, e.mail: bassil@IRO.UMontreal.CA

Benoît Bourbeau
CIRANO, Montréal, Québec, Canada

Rudolf K. Keller
Zühlke Engineering AG, Schlieren, Switzerland

Peter Kropf
Département IRO, Université de Montréal

Abstract

This paper introduces a dynamic approach to manage the processing of client requests in a multi-transfer container transportation (MTCT) system. At the operational level, this type of system is faced with a continuously changing environment. In this context, the need for dynamic creation and adaptation of solutions is of utmost importance. The adopted approach is based on a two-layer framework that exploits workflow technology. The latter proposes a formalism to describe sequences of activities to be enacted when processing requests, hence reducing the need for manual, time-consuming management and organization. The proposed two-layer framework has a workflow layer that encapsulates the set of concurrently running workflows associated to client requests. A coordination layer is mainly responsible for the instantiation of new workflows to be inserted in the workflow layer and for modifications of running ones. These modifications are motivated by resource sharing issues or triggered by unanticipated/unexpected events. According to this two-layer framework, an implementation of a prototype for a MTCT system is finally presented.

Text

As described by Crainic [3], fleet management (FM) covers the whole range of planning and management issues from procurement of power units and vehicles to vehicle dispatch and scheduling of crews and maintenance operations. This type of management can be tackled under various lengths of planning horizon and levels of details: the strategical, the tactical and the operational level. The latter involves a short planning horizon and the level of details is relatively high. Nowadays, a growing number of companies are facing FM issues and are forced to cope with highly constrained environments while always maintaining a satisfactory level of efficiency. Specifically, there is ample evidence that the FM at the operational level is highly dynamic when applied to a variety of sectors. Funk *et al.*, for instance, tried to address the dynamism problem by proposing an approach based on the multi-agent technology [4].

Among the sectors in which FM represents a challenging issue, the *multi-transfer container transportation* (MTCT) – that could be extended to the multi-modal freight transportation – has gained in interest in recent years [3]. We talk about multi-transfer container transportation when a container is moved from terminal to terminal with the possibility to shift it from vehicle to vehicle before delivering it to the final destination. In this paper, we focus on the MTCT at the operational level, in which a close follow-up of activities must be achieved to ensure a good client requests satisfaction.

In the context of the MTCT management, it appears that the processing of a client request can be

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achieved by a specific sequence of interdependent activities: e.g., transfer an empty container to a vehicle, move the empty container to origin location, load container, move container to terminal, transfer container to depot, etc. Moreover, the MTCT requires to dynamically create the sequence of activities needed to accomplish a request. It also requires a high degree of adaptation of ongoing activities' sequences to deal with unexpected events (e.g., delayed vehicles, crew members desistance, technical problems, etc.).

Taking into account these observations, it seems natural to exploit the *workflow technology* [6] to model and to manage the processing of client requests. Indeed, workflow management systems (WfMS) can be helpful to concurrently manage a set of workflow instances associated to the different client requests. Unfortunately, most of the current WfMS fail to deal with dynamic aspects coming from real-world applications. These systems, often in conformity with the workflow reference model (WfRM) [7], are designed to manage static workflows where instances cannot be dynamically changed.

Consequently, using a proposed extension of the WfRM that covers the management of dynamic modifications of workflows, we introduce an original transportation system framework adapted to the MTCT application [2]. This framework is conceptually divided into two main layers: a *workflow layer* and a *coordination layer*.

The workflow layer essentially gathers a set of concurrently running workflow instances, each of them being associated to a specific client request. Knowing that a workflow instance is composed of a sequence of activities and that the state of these activities is known at any time, it is hence possible to determine the set of resources that are used.

Since we are dealing with activities to be achieved by humans, the dispatching of the appropriate crews at the appropriate time plays an important role. It seems natural to take advantage of the worklist concept to ensure this task. Worklists (which form part of a WfMS) are used to show which activity needs to be carried out. Crews have their personal worklist to quickly identify their assigned activities. On the other hand, it should be possible for crews to transmit feedbacks to the coordination layer about the state of their ongoing activities (e.g., normal termination, abnormal termination due to technical problems, etc.).

The coordination layer is responsible for a certain number of tasks that ensure the efficient allocation of resources. It is responsible to receive the new requests, to instantiate new workflow instances, to ensure the follow-up of activities and to react accordingly to unexpected events by sending modification orders to the workflow layer. In brief, the coordination layer gathers a set of components. Among these components, we apply operations research algorithms and heuristics that are used for the dynamic management of resources, as well as a registry service that keeps track of instantiated workflows along with a blackboard that contains the resources scheduling.

The instantiation of new workflow instances is considered as a complex and critical part of the transportation system, especially for the MTCT sector. Each newly arriving request instantiates a high-level basic workflow. The resulting instance is dynamically enriched using a repository of activity templates. Specific activities are thus scheduled within the instance. Attributes related to the activities are determined by using the specifications of the request (e.g., pickup/delivery date/address, weight/volume of the goods, etc.) as well as the information extracted from the registry service component.

It is possible that the resulting instances are not fully predefined. A typical example is when the attributes related to some of the activities are not set from the beginning, mainly because of their unavailability.

We propose a “just-in-time” mechanism where the setting of attributes is done when the needed information becomes available. For this purpose, a follow-up process of activities is continuously executing in the background of the coordination layer to set the attributes when possible, and hence to ensure that the necessary information is available when it is required.

Following the occurrence and reception of unexpected events, and if an operations research algorithm or even a user indicates that changes must be brought to ongoing workflow instances, the coordination layer is able to notify the workflow layer that some (i.e., one or more) of its workflow instances need to be modified. These notifications are typically of three types: suspension/postpone notifications, attribute updating notifications and structural modification notifications. The first notification type allows (1) to react to the lack of availability of resources or (2) to free some planned resources to reallocate them to priority activities. The second notification type allows to react to strategic adjustments that tend to improve the efficiency of the global processing. Finally, the third notification type allows to modify the sequence of a workflow instance by inserting a new activity or by deleting an existing one.

Taking into account the two-layer framework presented above, we propose a prototype based on an extended existing WfMS (ADEPT [5]) that supports challenging dynamic aspects [1]. These aspects include the automatic modification, the insertion of new activities from already defined templates, the setting/updating of an attribute as well as of the user (i.e., crews) assignment, and the updating of worklists. Automatic modifications of workflow instances and new instantiations are event-oriented. A rule-based approach for the detection of events and for the specification of the required operations (e.g., modification of instances, instantiations, etc.) is used. Finally, we simulate the results that could be provided by operations research algorithms and heuristics. These results are generated following the detection of events, and they call for specific operations.

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