Scheduling for Multi-modal Cyclic Transport Systems

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Abstract: This paper concerns the domain of the multimodal transportation systems composed of buses, trains, trams and subways lines and focuses on the scheduling problems encountered in these systems. Transportation Network Infrastructure (TNI) can be modeled as a network of lines providing cyclic routes for particular kinds of stream-like moving transportation means. Lines are connected by common shared change stations. Depending on TNI timetabling the time of the trip of passengers following different itineraries may dramatically differ, e.g. the same distances along the north-south, and east-west directions may require different travel time. So, the mine question regards of TNI schedulability, e.g. the guarantee the same distances in arbitrarily assumed directions will require approximate traveled time. Considered timetabling problem belongs to NP-hard ones. The declarative model of TNI enabling to formulate cyclic scheduling problem in terms of the constraint satisfaction one is our main contribution. At last, the simulated results manifest the promising properties of the proposed model.

Keywords: cyclic scheduling, multimodal transport system, multimodal processes, declarative modeling, constraints programming

1. Introduction

A cyclic schedule [2, 8] is one in which the same sequence of states is repeated over and over again. In the case of Multimodal Transportation Systems (MTS) the appropriate cyclic scheduling problem has to take into account the constraints implied by the considered Transportation Network Infrastructure (TNI), e.g. see fig. 1. Assuming the transportation lines considered are cyclic and connected by common shared change stations a network can be modeled in terms of Cyclic Concurrent Process System (SCCP) [2]. Assuming each line is serviced by a set of stream-like moving transportation means (vehicles) and operation times required for traveling between subsequent stations as well as semaphores ensuring vehicles mutual exclusion on shared stations are given, the main question regards of SCNI timetabling, for instance guaranteeing the shortest time of the trip for passengers following a given direction. In systems of that type transportation means (agents) moving along the same route. Depending on SCNI timetabling the time of the trip of passengers following different itineraries may dramatically differ. In that context the considered cyclic scheduling directly regards of multimodal processes encompassing passengers’ itineraries, and indirectly regards of modeling them SCCPs. The TNI schedules sought have to follow vehicles (agents) collision- and deadlock-free flows as well as the passengers’ itinerary optimization requirements. The problem considered belongs to NP-hard ones [3].

Literature review. So far there is no research paper on cyclic scheduling of multi-modal processes modeled in terms of above defined TNI. The existing approach to solving the SCCPs scheduling problem base upon the simulation models, e.g. the Petri nets [5], the algebraic models, e.g. upon the (max,+) algebra [4] or the artificial intelligent methods [6]. The SCCP driven models assuming a unique process execution along each cyclic route, studied in [1, 2, 4] do not allow to take in to account the stream-like flow of local cyclic processes, e.g. buses servicing a given city line. So, this work can be seen as a continuation of the investigations conducted in [1, 2, 4, 7].

New contributions. The declarative models employing the constraints programming techniques implemented in modern platforms such as OzMozart, ILOG, [1], [2] seems to be well suited to coup with SCNI scheduling problems. In that context, our contribution is a formulation of SCNI cyclic scheduling problem in terms of the constraint satisfaction one [2].

Organization. The paper is organized as follows. In Section 2, an illustrative example of TNI and its cyclic scheduling problem statement are provided. In Section 3, a cyclic processes network is modeled. In Section 4, the selected case of multimodal processes is discussed In Section 5, we draw the conclusion.

2. Problem formulation

The TNI with distinguished vehicles and stations, shown in Fig. 1, is modeled in terms of the SCCP shown in Fig. 2. Four local cyclic processes are considered: \( P_1, P_2, P_3, P_4 \). The processes follow the routes (composed of transportation sectors and separating them stations) while providing connections in two directions i.e., the north-south and the east-west, for the two multimodal processes \( mP_1, mP_2 \) and \( mP_3, mP_4 \), respectively. \( P_1, P_2 \) contain two sub-processes \( P_1 = \{ P_1^1, P_1^2 \}, P_2 = \{ P_2^1, P_2^2 \} \) representing trains (agents) moving along the same route.