Chapter 15

SELF-ORGANIZED CONTROL OF IRREGULAR OR PERTURBED NETWORK TRAFFIC

Dirk Helbing
Dresden University of Technology, Germany
Corresponding author
helbing@trafficforum.org

Stefan Lämmer
Dresden University of Technology, Germany
traffic@stefanlaemmer.de

Jean-Patrick Lebacque
Institut National de Recherche sur les Transports er leur Sécurité (INRETS), France
lebacque@inrets.fr

Abstract We present a fluid-dynamic model for the simulation of urban traffic networks with road sections of different lengths and capacities. The model allows one to efficiently simulate the transitions between free and congested traffic, taking into account congestion-responsive traffic assignment and adaptive traffic control. We observe dynamic traffic patterns which significantly depend on the respective network topology. Synchronization is only one interesting example and implies the emergence of green waves. In this connection, we will discuss adaptive strategies of traffic light control which can considerably improve throughputs and travel times, using self-organization principles based on local interactions between vehicles and traffic lights. Similar adaptive control principles can be applied to other queueing networks such as production systems. In fact, we suggest to turn push operation of traffic systems into pull operation: By removing vehicles as fast as possible from the network, queuing effects can be most efficiently avoided. The proposed control concept can utilize the cheap sensor technologies avail-

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able in the future and leads to reasonable operation modes. It is flexible, adaptive, robust, and decentralized rather than based on precalculated signal plans and a vulnerable traffic control center.

1. Introduction

Traffic control in networks has a long history. Early efforts have aimed at synchronizing traffic signals along a one-way, then a two-way arterial. There is still potential for improvement in this direction, as is attested by some recent research efforts [Stamatiadis and Gartner (1999)] or prompted by the development of new theoretical tools [Lotito *et al.* (2002), Mancinelli *et al.* (2001)]. Synchronization of traffic along arterials results in so-called green-waves, the aim of which is simply to ensure that traffic flows smoothly along main streets. Expected benefits of green waves are reduced fuel consumption and travel times.

The green-wave approach can be generalized to networks, yielding pre-calculated signal control schemes, such as TRANSYT [Robertson (1997)]. In principle such schemes are completely coercive: they force the traffic flow to comply with pre-calculated patterns, optimizing such criteria as the total travel time spent. Since traffic demand varies, the need for some responsiveness of the signal control was felt very soon. The SCOOT system [Robertson and Bretherton (1991)], an outgrowth of TRANSYT, allows for smooth change in the signal settings in response to changes in the traffic demand.

Among the strategies making use of precalculated controls, let us mention SCATS [Sims and Dobinson (1979), Lin and Chen (2004)], which relies on a library of controls (green durations, offsets, ...) according to traffic conditions. Even the optimization criterion depends on the traffic state. The system might, at night, minimize the number of stops, maximize throughput at day time under normal conditions, and aim at postponing the onset of congestion under heavy traffic conditions.

More recent developments stress greater adaptability. For instance UTOPIA [Mauro and Di Taranto (1989)] combines a regional control based on prediction of traffic flow through the main network arteries with the action of local intersection controllers. The regional control simply serves as a reference for local control.

OPAC [Gartner (1990)] optimizes queues in accordance with the "store-and-forward" concept [Papageorgiou (1991)], based on dynamic programming, with a rolling horizon. OPAC is fundamentally designed to manage intersections but extends to networks.

Even more decentralized and demand-responsive at a very local level, PRODYN [Henry and Farges (1989)] optimizes traffic at intersections by