Chapter 72
New Transportation Systems for Smart Cities

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ABSTRACT

Poor traffic management in urban environments is responsible for congestion, unnecessary fuel consumption and pollution. Based on new wireless sensor networks and the advent of battery-powered vehicles, this chapter describes three new systems that affect transportation in Smart Cities. First, a Smart Parking system which assigns and reserves an optimal parking space based on the driver's cost function, combining proximity to destination and parking cost. Second, a system to optimally allocate electric vehicles to charging stations and reserve spaces for them. Finally, we address the traffic light control problem by viewing the operation of an intersection as a stochastic hybrid system. Using Infinitesimal Perturbation Analysis (IPA), we derive on-line gradient estimates of a cost metric with respect to the controllable green and red cycle lengths and iteratively adjust light cycle lengths to improve (and possibly optimize) performance, as well as adapt to changing traffic conditions.

INTRODUCTION

The term "Smart City" is used to capture the overall vision of an urban environment with well-managed processes such as traffic control and energy distribution; safer and more efficient services such as parking or emergency response; and a new generation of innovative services yet to be developed. From a technological point of view, at the heart of a Smart City is a cyber-physical infrastructure with physical elements (e.g. roads, vehicles, power lines) which are continuously monitored through various sensors to observe, for instance, air/water quality, traffic conditions, occupancy of parking spaces, the structural health of bridges, roads and buildings, as well as the location and status of city resources including transportation vehicles, police cars, police officers, and municipal workers. The data collected need to be securely communicated (mostly wirelessly) to information processing and control points. These data may be shared and the control points can cooperate to generate good (ideally, optimal) decisions regarding the safe operation of these physical elements (e.g. vehicles guided through the city). It is important to emphasize that what ultimately makes the city

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"smart" is not simply the availability of data but the process of "closing the loop", consisting of sensing, communicating, decision making, and actuating. Figure 1 is a high-level illustration of this process, which must take place while taking into account important issues of privacy, security, safety and proper energy management necessitated by the wireless nature of most data collection and actuation mechanisms involved.

In this chapter, our focus is on transportation aspects of urban settings and on new developments which promise to revolutionize how vehicles operate in a Smart City and how overall traffic is managed. At any given time, hundreds of thousands of vehicles are in constant motion through the roadway networks associated with any large urban area. Based on the 2011 Urban Mobility Report, the cost of commuter delays has risen by 260% over the past 25 years and 28% of US primary energy is now used in transportation. Congestion in such traffic networks is estimated to be responsible for 20% of fuel consumption in any significant urban area. A major source of frustration for our inability to improve traffic conditions is the realization that, even if we could determine a theoretical optimal operation point, there are extremely few controls currently allowing us to attain this point: they are mostly simple signaling schemes (traffic lights) and economic incentive mechanisms (tolls, speeding fines). At the heart of the problem is one of the well-known folk-principles from game theory: when a player (driver) lacks information about the behavior of other players (drivers), poor decisions are made (Braess et al., 2005). Consequently, even if a driver is "smart" and makes use of sophisticated data about the state of the system, his/her decisions may be driver-optimal, but not system-optimal.

In fact, poor or inadequate traffic management in urban environments is responsible not

Figure 1. Cyber-physical infrastructure for a Smart City