Chapter 5
Constrained Average Design Method for QoS-Based Traffic Engineering at the Edge/Gateway Boundary in VANETs and Cyber-Physical Environments

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ABSTRACT

Cyber physical systems (CPSs) are software-intensive smart distributed systems that support physical components endowed with integrated computational capabilities. Tiered, often wireless, networks are typically used to collect or push the data generated or required by a distributed set of CPS-based devices. The edge-to-core traffic flows on the tiered networks can become overwhelming. Thus, appropriate traffic engineering (TE) algorithms are required to manage the flows, while at the same time meeting the delivery requirements in terms of latency, jitter, and packet loss. This chapter provides a basic overview of CPSs followed by a discussion of a newly developed TE method called 'constrained average', where traffic is by design allowed to be delayed up to a specified, but small value epsilon, but with zero packet loss.

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I. INTRODUCTION AND BACKGROUND

Cyber-Physical Systems

The term cyber-physical systems (CPSs) refers to an evolving generation of systems with integrated computational and physical capabilities that can interact with humans in a number of ways (Baheti & Gill, 2011; Song, Rawat et al.,2017; Romanovsky & Ishikawa, 2017). The term CPS was originally introduced in 2006 at a National Science Foundation (NSF) workshop in Austin, TX, where it was defined as "*a system composed of collaborative entities, equipped with calculation capabilities and actors of an intensive connection with the surrounding physical world and phenomena, using and providing all together services of treatment and communication of data available on the network*" (Quintanilla, Cardin et al., 2016). Some researchers now see a CPS as an orchestration of computers and physical systems where embedded computers monitor and control physical processes, usually making use of feedback loops, and where the physical processes affect computations, and vice versa (Lee, 2015; Sivakumar, Sadagopan et al., 2016; Hua, Lua et al., 2016). Thus, CPSs are systems of collaborating computational entities that are intensively connected with the surrounding physical world and its on-going processes, simultaneously providing and using data-accessing and data-processing services available on a cloud and/or on the Internet (Monostori, 2014; Zanero, 2017; Yu & Xue, 2016). CPSs therefore consist of computer networks and devices with built-in controllers that control (possibly, with human participation) physical processes by means of feedback; that is, physical processes exert influence on computations and computations exert influence on the choice and course of physical processes (Letichevsky, Letychevsky et al., 2017; Stankovic, 2017; Müller, Litoiu et al., 2016). Documented applications include but are not limited to: Vehicular Ad hoc Networks (VANETs), Intelligent Transportation Systems (ITSs), automotive systems, biomedical and healthcare systems, smart grid and renewable energy systems, manufacturing process control, military systems, air traffic control and safety systems, aircraft instrumentation, water management systems, physical security systems(access control and monitoring), asset management, and distributed robotics and drones (Baheti & Gill, 2011; Lee, 2015; Zanero, 2017; Letichevsky, Letychevsky et al., 2017; Massey, 2017). While some researchers consider CPSs as distinct from Internet of Things (IoT) systems, others broadly equate the two concepts, (e.g., Wang, Zhu et al., 2018, Thramboulidis & Christoulakis, 2016, Burg, Chattopadhyay et al., 2018, Antonino, Morgenstern et al., 2018, He, Maple et al., 2016, Blasch, Kadar et al., 2017), as a short list of references -- in fact, the National Institute for Standards and Technology (NIST) observes that "*CPS and related systems (including the Internet of Things, Industrial Internet, and more) are widely recognized as having great potential to enable*