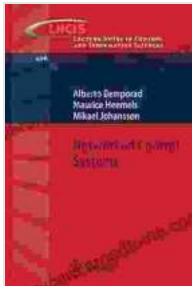


The Connected Future: Exploring Networked Control Systems



Networked Control Systems (Lecture Notes in Control and Information Sciences Book 406) by Alberto Bemporad

★★★★★ 5 out of 5

Language : English

File size : 9656 KB

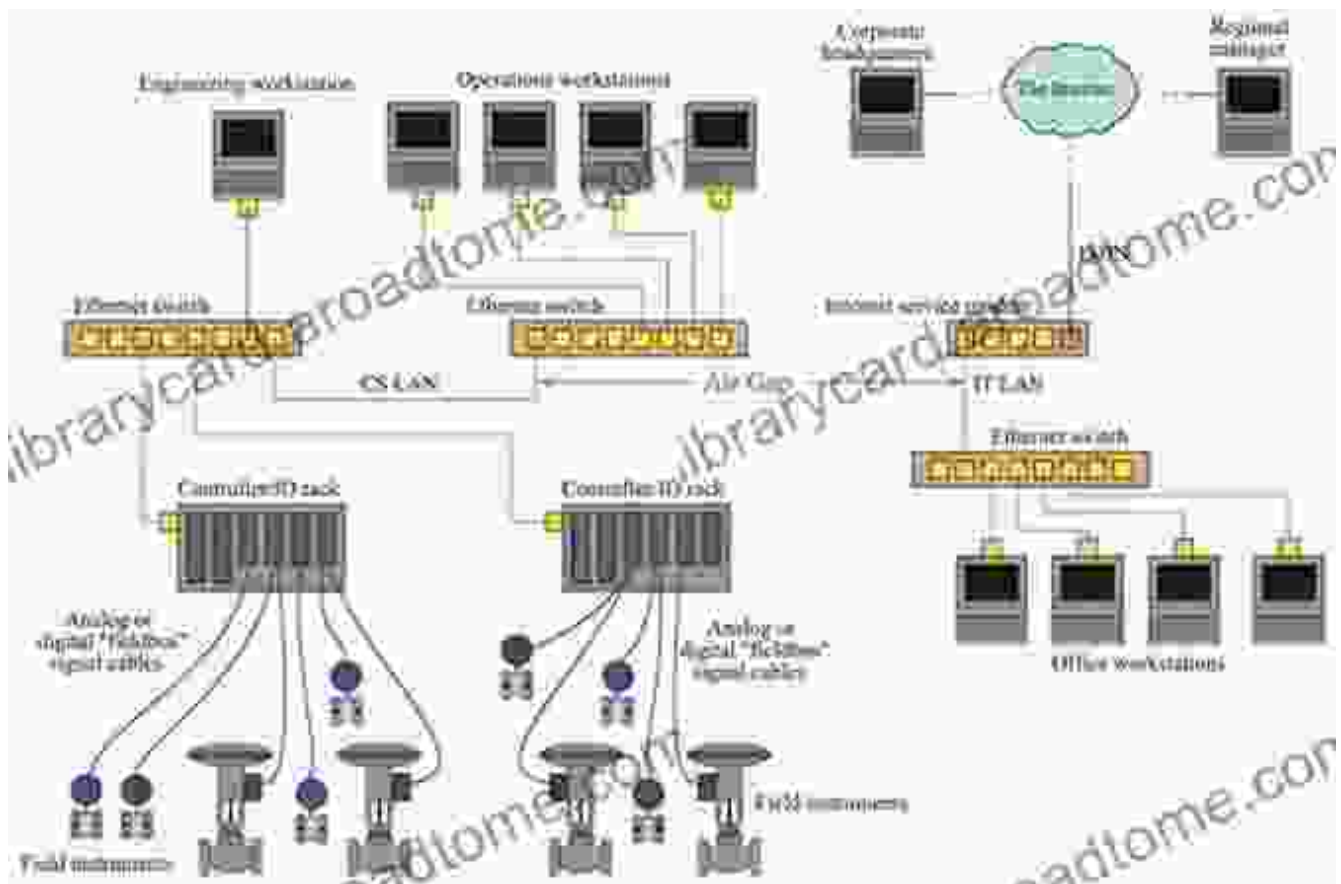
Print length : 380 pages



Welcome to the world of Networked Control Systems (NCSs), where interconnected devices and systems orchestrate intricate operations with unprecedented efficiency and flexibility. These systems have revolutionized industries, from manufacturing to healthcare, and hold the potential to shape our future infrastructure and services. In this comprehensive article, we provide a guided tour through the lecture notes of "Networked Control Systems: Lecture Notes in Control and Information Sciences 406." This acclaimed publication offers a deep dive into the theoretical foundations, practical applications, and cutting-edge research in this rapidly evolving field.

Delving into the Chapters

Chapter 1: Fundamentals of Networked Control Systems



Embark on a journey into the core concepts of NCSs. Understand the unique challenges posed by communication networks, such as delays, packet drops, and noise. Explore the architectural foundations of NCSs and gain insights into the interconnectedness of sensors, controllers, and actuators.

Chapter 2: Stability and Performance Analysis

Stability Analysis of Networked Control Systems Using a Switched Linear Systems Approach

M.C.F. Donkers, Student Member, IEEE, W.P.M.H. Heugens, Senior Member, IEEE,
N. van de Walle, Member, IEEE, and L. Huel

Abstract—In this paper, we study the stability of Networked Control Systems (NCSs) that are subject to time-varying transmission intervals, time-varying transmission delays, and communication constraints. Communication constraints impose that, per transmission, only one node can access the network, and send its information. The order in which nodes send their information is orchestrated by a network protocol, such as the Round-Robin (RR) and the Try-Once-Discard (TOD) protocol. In this paper, we generalize the mentioned protocols to novel classes of so-called ‘periodic’ and ‘aperiodic’ protocols. By focusing on linear plants and controllers, we present a modeling framework for NCSs based on discrete-time switched linear uncertain systems. This framework allows the controller to be given in advance time as well as its continuous time. To analyze stability of such systems for a range of possible transmission intervals and delays, with a possible nonzero lower bound, we propose a new procedure to obtain a convex overapproximation in the form of a polytopic system with norm-bounded additive uncertainty. We show that this approximation can be made arbitrarily tight in an appropriate sense. Based on this overapproximation, we derive stability results in terms of Linear Matrix Inequalities (LMIs). We illustrate our stability analysis on the benchmark example of a batch reactor and show how this leads to tradeoffs between different protocols, over different ranges of transmission intervals and delays. In addition, we show that the exploitation of the linearity of the system and controller leads to a significant reduction in conservatism with respect to existing approaches in the literature.

Index Terms—Communication Constraints, Networked Control Systems, Switched Systems, Stability, Time-Varying Systems, Convexity Systems

1 INTRODUCTION

NETWORKED Control Systems (NCSs) are systems in which control loops are closed over a real-time communication network. The fact that controllers, sensors, and actuators are not connected through point-to-point connections, but through a multipurpose network offers advantages, such as increased system flexibility, ease of installation and maintenance, and decreased wiring and cost. However, networked

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TABLE I. Relations that study non-networked induced line effects are simultaneously

Δ	max	min
min	100	100
max	100, 100	100, 100
min	100, 100	100, 100

the control system also introduces new challenges, caused by the packet-based data exchange between different parts of the network. Therefore, control algorithms are needed that can handle the communication imperfections and uncertainties caused by the packet-based communication. The related uncertainty is widely aware of this fact, as is explained by the formal analysis NCSs have received recently, see e.g. the overview paper [11–14].

In general, network-induced communication imperfections and uncertainties can be categorized into:

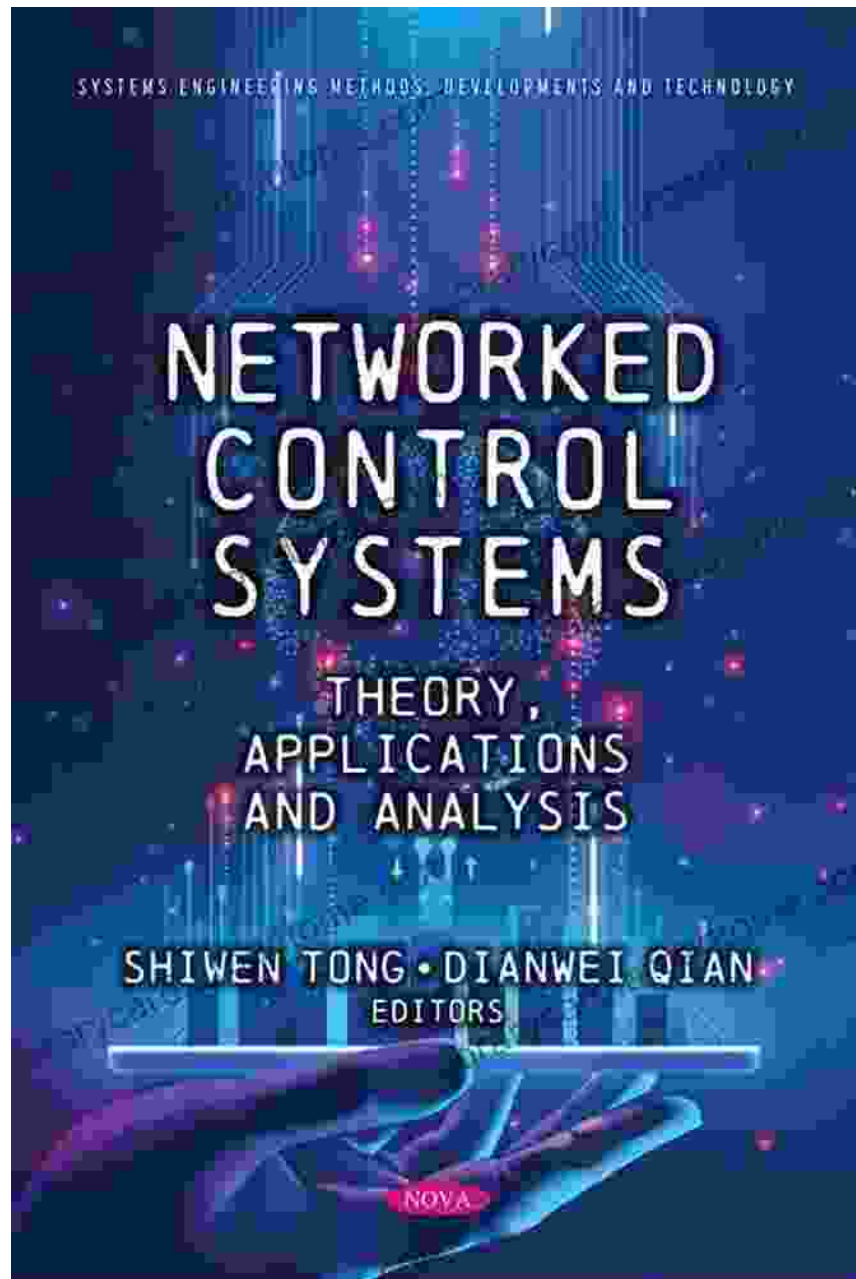
- (i) Quantization errors in the exchanged signals, due to the finite word length of the digital packets;
- (ii) Packet dropouts due to unreliable transmission lines. Variable length transmission intervals;
- (iii) Variable transmission delays;
- (iv) Communication constraints, i.e., not all sensor and actuator signals can be transmitted at the same time.

It is generally known that any of these phenomena can degrade closed-loop performance or, even worse, can hamper the stability of the control system. It is therefore important to know how these effects influence the stability properties.

Systematic approaches to analyze stability of NCSs subject to any one of these network-induced imperfections are well developed. For instance, the effects of quantization are studied in [15–19], of packet dropouts in [10]–[12], of time-varying transmission intervals and delays in [13]–[17], and [18]–[24], respectively, and of communication constraints in [25]–[28]. However, since in NCSs typically all the aforementioned imperfections and constraints are present simultaneously, it is relevant to study the consequences of all these phenomena in a common framework. Unfortunately, this is not a trivial task. The only combination of these imperfections that simultaneously consider, even for network-induced imperfections are given in [29]. Furthermore, [29] considers imperfections of type (i), (ii) and (iii) under type (iv) and (v) simultaneously. In this paper, we will focus on the stability of NCSs with time-varying transmission intervals and the presence of communication constraints.

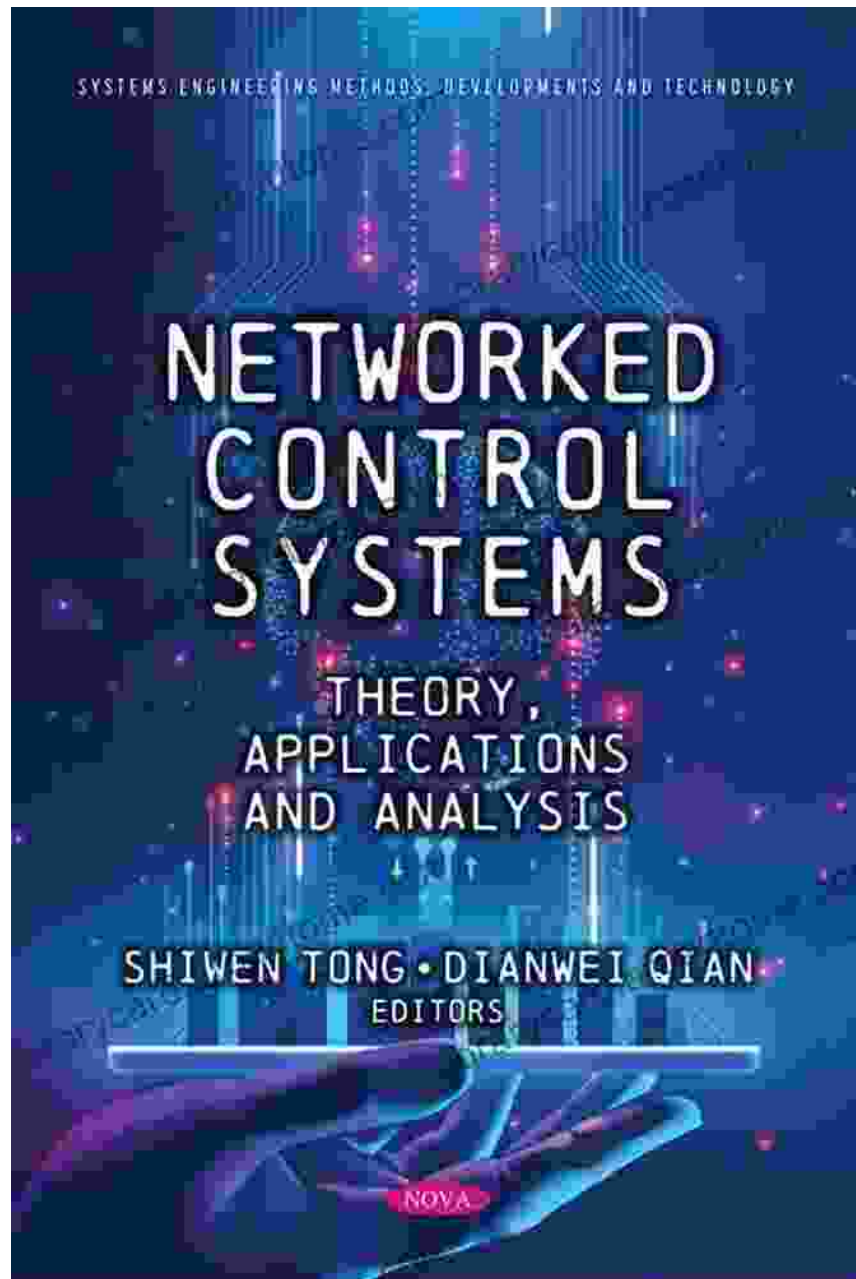
Delve into the intricate world of stability and performance analysis for NCSs. Master the techniques to determine whether a networked control system is stable and meets desired performance specifications. Learn about delay-dependent stability criteria and delve into the impact of network-induced uncertainties.

Chapter 3: Control Design for Networked Control Systems



Explore advanced control design techniques specifically tailored for NCSs. Discover how to design controllers that are robust to network imperfections and optimize performance under constraints. Learn about model-predictive control, event-triggered control, and receding horizon control.

Chapter 4: Applications of Networked Control Systems



Witness the transformative power of NCSs in a wide range of real-world applications. From industrial automation and transportation systems to smart grids and healthcare, uncover the practical benefits of networked control. Understand how NCSs enhance efficiency, safety, and reliability in diverse industries.

Chapter 5: Emerging Trends and Future Directions

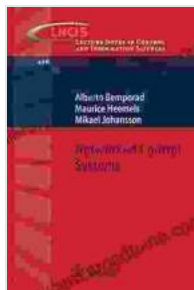


Peer into the crystal ball of NCSs and discover the exciting research directions that are shaping the future of the field. Explore the frontiers of distributed optimization, adaptive control, and machine learning for NCSs. Uncover the potential of 5G and beyond, cloud computing, and the Internet of Things in advancing NCS capabilities.

Embark on an intellectual odyssey with "Networked Control Systems: Lecture Notes in Control and Information Sciences 406." This comprehensive guide is the ultimate resource for students, researchers, and practitioners seeking a deep understanding of Networked Control Systems. With its accessible explanations, cutting-edge insights, and comprehensive coverage, this publication empowers you to navigate the

complexities of this interconnected world and unlock the full potential of networked control.

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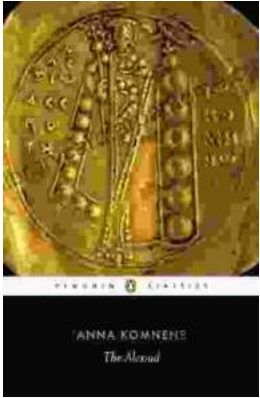
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