



Optimal tracking performance and design of networked control systems with packet dropouts[☆]

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Abstract

The optimal tracking problem for single-input–single-output (SISO) networked control system over a communication channel with packet dropouts is studied in this paper. The tracking performance is measured by the energy of the error signal between the output of the plant and the reference signal. It is shown that the optimal tracking performance is constrained by nonminimum phase zeros, unstable poles, the characteristics of the reference signal and packet dropout probability, and the optimal controller is obtained. It is also shown that when the communication constraint does not exist, the optimal tracking performance reduces to the existing normal tracking performance of the control system without a communication channel. The result shows how the packet dropouts probability of a communication channel may fundamentally constrain a control system's tracking ability. Some typical examples and simulations are given to illustrate the theoretical results.

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1. Introduction

Networked control systems (NCSs) have found successful applications in a wide range of areas such as industrial automation, distributed/mobile communication, and unmanned vehicles [1,7,19,27,30,36,37]. While NCSs have received increasing research attention, they have also given

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rise to new challenges due to inherent network-limited bandwidth. Among all the challenges that emerged, the intermittent data packet dropouts [5,20,21,32,38] and the signal-transmission delay [6,9–12,14–16,24,28,29], are known to be two of the main causes for the performance deterioration or even the instability of the NCSs. The problem of controller design for NCSs over digital communication is studied in paper [13]. The stabilizability problems of NCSs with multiple quantizers are studied in paper [23]. The problem of stabilization about uncertain NCSs with random but bounded delays is discussed in paper [35]. The present paper focuses on modeling of the NCSs and stabilization analysis. The problem about stabilization of NCSs with network-induced delay and packet dropout is investigated in paper [39]. In spite of the significant progress in those studies, the more inspiring and challenging issues of control optimal performance under such network environment remain largely open; for example, optimal tracking design and attainable tracking of the performance of NCSs constrained by the communication links in the feedback loop. Various information transmission constraints, such as data-rate limit, quantization precision, bandwidth constraint, time delays and data packet dropouts, are all likely to have a negative effect on the tracking performance of NCSs.

Optimal tracking performance in control system design has been an important area of research for many years [2,3,25,31,40–42]. The paper [2] studied a tracking step signal performance problem for multi-input multi-output (MIMO), linear, time-invariant systems by using unity feedback control scheme. The analysis method of an optimal tracking performance is proposed for MIMO linear time-invariant (LTI) systems under disturbance rejection in paper [40]. The results focus on the study of the optimal performance achievable by feedback control, and especially on how the performance may be intrinsically constrained by the properties of the plant, whereas knowing such relationship is in assessing the limitation of the plant, in understanding the trade-offs in the design task, and in knowing the fundamental design limits. However, all these mentioned works have not taken into account the effects of networks, which would make the study of the optimal performance much more challenging. In recent years, the topic of optimal tracking performance has been extended to NCSs [8,17,22,43]. The optimal tracking performance problem had been studied for MIMO linear time-invariant discrete-time control systems with communication constraints in [8]. The optimal tracking performance of a linear time-invariant system with a quantized control signal is studied in [17]. The results showed that the quantization limits the system tracking performance. A tight lower bound on the data rate required to stabilize an unstable system is proposed in [18]. The stability of a SISO continuous-time LTI unstable plant with time-delay over an ACGN communication channel is studied in [22]. The optimal tracking performance problem has been discussed for SISO NCSs with SNR constraints in [43]. But the study of optimal tracking performance is seldom based on considering packet loss in previous results; and the packet dropouts are important parameters to influence the network control system stability and performance. This paper studies the optimal tracking performance of SISO linear time-invariant system over a communication channel with packet dropouts.

Without loss of generality, we consider the case where the system sensor is far away from the plant but the controller is close to the plant in this paper. We study a SISO NCSs optimal over communication channel by considering the constraint of packet dropouts. The proposed model will be applied in many realistic systems, such as remote monitoring robot surgery, where patient is the plant, robot is the controller, the remote experts obtain information by the network transmission, information of experts will be returned to the robot by the network transmission. Some information will be lost because of communication constraints.

In this paper, we study the optimal tracking performance issues pertaining to single input single output (SISO) feedback control systems over the communication channel by considering

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