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Investigating the positive effects of packet dropouts on network-based H_∞ control for a class of linear systems

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Abstract

This paper investigates the positive effects of packet dropouts on network-based H_∞ control for a linear system that cannot be stabilized by a non-delayed static output feedback controller, but can be stabilized by a delayed static output feedback controller. By intentionally inserting a lossy network between the system and the controller, and embedding a logical packet-selecting algorithm that produces some packet dropouts in the actuator module, the networked control system is modeled as a system with an interval time-delay, which is stable with some *nonzero* time-varying delay, but is unstable without a time-delay. By constructing a complete Lyapunov–Krasovskii functional and discretizing both the lower bound and the upper bound of the interval delay, some new delay-dependent criteria for H_∞ performance and controller design are derived in terms of linear matrix inequalities. It is shown through an example that (i) proper packet dropouts can produce a stable control effect; (ii) utilizing the discretization of the lower delay bound can reduce the conservatism of the H_∞ performance criterion; and (iii) the proposed design result is effective in achieving satisfactory H_∞ control performance.

1. Introduction

The use of communication networks in feedback control systems sparks increasing technology and methodology research on networked control systems (NCSs) [1–4]. Several advantages

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including low cost, high reliability, flexible structure and remote control, promote the development of a number of applications, for example, vibration control of offshore platforms [5,6], and coordinated control of unmanned surface vehicles [7]. In many practical situations, network-induced delays and packet dropouts may lead to performance degradation, which is regarded as deteriorating or negative effects on the stability and system performance. Using an H_∞ norm as a performance index to describe the effect of exogenous disturbance on controlled output, various H_∞ control and H_∞ filtering problems are studied for traditional control systems [8–10]. For NCSs, networked H_∞ control [11–15] and networked H_∞ filtering [16–18] are considered by taking network-induced delays and/or packet dropouts into account. Besides, other networked control issues such as input–output control [19] and fault detection [20,21] are concerned with in the presence of network-induced delays and/or packet dropouts. It should be mentioned that the aforementioned works only deal with the negative effects of network-induced delays and/or packet dropouts on stability and performance of NCSs. However, it is shown in [5,6,22] that proper network-induced delays can be purposefully produced in the feedback control loop to achieve a stable and satisfied tracking effect for a class of systems that cannot be stabilized by non-delayed static output feedback controllers, but can be stabilized by delayed static output feedback controllers. In this situation, network-induced delays are of the positive effects on system performance. Such systems occur in several practical systems, such as damped harmonic oscillators [23], structural systems [24,25], and delayed resonators [26]. For these systems, some questions paralleling to investigating the positive effects of network-induced delays on NCSs in [22] naturally arise to be necessarily concerned with: whether or not packet dropouts can be used to achieve the stability or improve system performance? If the answer is positive, how to embed packet dropouts in selecting proper control signals and how to establish a rational NCS model by taking the positive effects of packet dropouts into account? How to develop some corresponding analysis and design methods for such NCSs? Answering these questions motives the current study.

Note that for systems in [22–26], a complete Lyapunov–Krasovskii functional (LKF) together with a discretization scheme of delay bound is a common way for achieving stability and performance criteria. For a system with constant time-delay, a sufficient and necessary delay-dependent stability condition can be derived by using a complete LKF, which is further discretized by partitioning the delay bound to obtain a testable stability criterion [27–29]. For a system with time-varying delay, a mixed complete LKF is proposed to obtain a sufficient delay-dependent stability criterion based on the partition of the upper delay bound [22,30,31]. It should be mentioned that information about partition of the lower delay bound is ignored in [22,30,31], which leads to some conservatism. In this paper, we will attempt to construct a new complete LKF that makes use of both the lower and upper bounds of the time-varying delay, and then fully utilize information about partition of both lower and upper delay bounds in deriving some less conservative delay-dependent stability and performance criteria.

Different from the work on the positive effects of network-induced delays in [22], in this paper, we focus on the positive effects of packet dropouts on H_∞ control over a communication network for a system that cannot be stabilized by a non-delayed static output feedback controller, but can be stabilized by a delayed static output feedback controller. For such a system, a stable control cannot be ensured by a non-delayed static output feedback controller, but can be achieved by purposefully inserting a lossy packet network between the system and the controller. From the theoretical point of view, a key idea in this paper is transforming equivalently the effects of packet dropouts into the positive effects of delays on the system stability [22]. In order to do so, a logical packet-selecting algorithm is embedded in the actuator module to determine when and