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H_∞ Controller Synthesis for Networked Control Systems with Time Delay System Approach

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Abstract—**In modern control systems, physical plant, controller, sensors and actuators are difficult to be located at the same place, and hence these components need to be connected over network media. When feedback control system is closed via a communication channel, then the control system is classified as a Networked Control System (NCS). The introduction of communication network gives significant advantages, such as reduced installation and maintenance cost and increased system agility. In the other hand, the use of communication network will lead to intermittent losses or delays of the information and may decrease the performance and cause instability.**

This paper investigates the problem of H_∞ controller synthesis for (NCS). It is well known that H_∞-norm constraint can be used to provide a prespecified disturbance attenuation level, and alternatively to analyze robust stability of dynamical system.The NCS is modelled as a time delay system. The physical plant and controller are in continuous time. Two network features are considered: signal transmission delay and data packet dropout. Our objective is focused on the design of state feedback controller which guarantee asymptotic stability of the closed-loop systems. The proposed methods are given in the terms of Linear Matrix Inequality (LMI). If this LMI conditions feasible, a desired controller can be readily constructed. Finally, we consider an unstable system for numerical example. It is shown that the state feedback controller proposed here make the closed-loop system stable with or without input disturbance.

Keywords— **H_∞ Controller, Networked Control Systems (NCS), Time Delay systems, Linear Matrix Inequality (LMI)**

I. Introduction

Time delay is the property of a physical system by which the response to an applied force (action) is delayed in its effect. When information or energy is physically transmitted from one place to another, there is a delay associated with the transmission [8]. It is well known that the presence of time-delay is a source of instability [9]. Xia et al. [6] presents some basic theories of stability and synthesis of systems with time-delay, in the form of $\dot{x}(t) = Ax(t) + A_d x(t - \tau(t))$, where $\tau(t)$ represents time-varying delay. Wu et al. [7] presents a method referred to as the free-weighting-matrix (FWM) approach for the stability analysis and control synthesis of various classes of time-delay systems. In [3], a new model for time delay systems is proposed, that is $\dot{x}(t) = Ax(t) + A_d x(t - \tau_1(t) - \tau_2(t))$. The new model is motivated by practical situation in Networked Control Systems (NCSs), where $\tau_1(t)$ is the time-delay from sensor to the controller and $\tau_2(t)$ is the time-delay from controller to the actuator. Based on such a system representation, [3] derived the stability condition. Gao et al. [2] presented a new stability condition and investigated the problem of H_∞ performance analysis. Dey et al. [1] constructed a new Lyapunov-Krasovskii functional in obtaining the stability condition for such system, and provided less conservative delay upper bound, as compared to the conditions in [2,3].

In modern control systems, physical plant, controller, sensors and actuator are difficult to be located at the same place, and hence these components need to be connected over network media. When feedback control system is closed via a communication channel, then the control system is classified as a Networked Control System (NCS) [10,13]. NCS has been attracted much attention due to significant advantages, such as reduced installation and maintenance cost, increased system agility, and so on [12]. There have many researcher to conduct research on the topic of NCS. To mention a few, [11] addressed the problem of quantized feedback control. Result on state feedback control could be seen in [2, 15]. Stability analysis, and stabilization of NCS are investigated in [12, 13] and the references therein.

Motivated by [1], in this paper we continue the preliminary result derived in [1] to the NCS problem. Our objective is focused on the design of H_∞ controller NCS. It is well known in systems and control community that H_∞-norm constraint can be used to provide a prespecified disturbance attenuation level, and alternatively to analyze robust stability of dynamical system.

Notation. The notation $X > 0$ denotes a symmetric positive definite, asterisk (*) represents the elements of symmetric term in the symmetric block matrix. The superscripts "T" and "-1" represent the transpose and inverse matrix, respectively. $L_2[0, \infty)$ is the space of square integrable functions on $[0,\infty)$.