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Real-time guaranteed cost control of MIMO networked control systems with packet disordering

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ABSTRACT

This paper discusses guaranteed cost control for multi-input and multi-output (MIMO) networked control systems (NCSs) with multi-channel packet disordering. Considering the time-varying and bounded network transmission delay, packet dropout and packet disordering, a novel model of NCSs is proposed by introducing the concept of packet displacement. It is worthwhile mentioned that this model can fully describe the dynamic characteristic of network and always guarantee the newest control input executed by the plant, which makes that the plant can be controlled in real time. The resulting closed-loop systems are jump linear systems due to the newest signals executed subject to Markovian chains. A real-time controller is designed for uncertain and certain NCSs based on Markovian theory combined with linear matrix inequality (LMI) techniques such that the closed-loop cost function value is not more than a specified upper bound that varies according to Quality of Services (QOS). Finally, numerical examples are given to illustrate the effectiveness of the proposed method.

1. Introduction

As is well known multi-input and multi-output (MIMO) networked control systems (NCSs) are the feedback systems wherein multi-sensors, multi-actuators and multi-controllers (or one controller) are distributed and connected over a network medium as illustrated in Fig. 1[1]. Due to the sharing network and multi-channel transmission, all of the sampled data can not arrive at the controllers and actuators synchronously, and packet dropout, packet disordering and other nonideal facts are always inevitable, which will degrade control performance of the systems greatly and make the analysis and design of MIMO NCSs complex compared to single-input and single-output (SISO) NCSs. However, as pointed by [2], the multi-channel transmission policy as opposed to the single-channel transmission policy may be increasingly required due to network or system requirements in the practical control systems. For example, under a packet exceeding the limitation of the packet size of the communication channel, the packet has to be broken into multiple packets. Moreover, MIMO systems have potential to improve data rate and channel capacity of network communication systems (see [3]). Then, the multi-channel transmission policy has to be adopted. Therefore, it is of importance to fully understand and minimize the effect of network transmission delay, packet dropout and packet disordering, etc. on stability and performance of the systems for the multi-channel transmission policy.

Recently, much research has been done on the analysis and synthesis for MIMO NCSs [1,2,4–13]. Necessary and sufficient conditions for stability of discrete-time NCSs subject to packet loss under a multiple-packet transmission policy were obtained, and the packet dropping margin formula was derived in [2] wherein, however, controller design is not discussed. Other literature dealing with packet loss of MIMO NCSs also can be found (see [4,5]). Considering the sensors and controller are time-driven, and the actuators are event-driven, [6] proposed discrete-time models of plant and controller dynamics and LQR controller was designed under assumption of constant sensor and actuator delays. In [7], a typical asynchronous dynamical system (ADS) was modeled, the exponential stability conditions were given similar to [8]. However, network transmission delay was assumed as shorter than one sampling period. [9] compensated the time delay and packet dropout for NCSs with multiple communication channel by multiple controllers. Moreover, PID control, scheduling method and architectures of MIMO NCSs have been investigated by many researchers, such as [1,10,11]. More recently, in [12], a technique, by which non-interacting multiple loops with same/different sampling time requirements can be integrated over a non-deterministic

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