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Stochastic Distribution Control Strategy with Application to Networked Control Systems

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Abstract- **In this paper, the minimum error entropy criterion has been utilized to design controller for non-linear networked control systems (NCSs), where time delays in the communication channels are of random nature. A recursive optimization solution has been developed based on the recently developed stochastic distribution control strategy. The local stability condition of the closed loop NCSs has been established. A simulation example has been given to show the effectiveness and applicability of the proposed approach.**

***Index Terms*—Networked control systems, delay, stochastic, optimization**

1. INTRODUCTION

In some practical engineering applications, the measurement and control commands need to be transmitted over communication networks, such as: automotive industry, teleautonomy, teleoperation of robots and automated manufacturing systems. These networked control systems (NCSs) are spatially distributed systems in which the communication between sensors, actuators, and controllers occurs through a shared communication network.

With the fast development of network technology, NCSs can offer many advantages in terms of modularity, integrated diagnosis, quick and easy maintenance, and low cost. Recently, network standards such as Hartbus, Fieldbus and industrial Ethernet have been widely used in various industrial sectors so as to achieve reliable measurements and effective distributed control structure. In this context, considerable effort has been made to incorporate the network into closed-loop control systems.

A communication network inserted into the feedback loop makes the analysis of NCS much complex. More and more attention has been drawn to the development of a general theory for NCSs, which considers control and communication issues simultaneously. Network induced delays, one of major issue in NCSs, is inevitable and typically deteriorates the NCS's performance. As such, it is important to develop control strategies that can cope with the closed loop control when the actuator and sensor channels are subjected to time delays. Some methodologies developed to deal with network delays have been highlighted by several survey papers [1-3]. An augmented state vector method [4] was proposed to control a linear system over a periodic delay network. Fuzzy control method [5] was used to analyze and design NCSs. Predictive control strategy was reported in [6]. In addition, robust control method was proposed in [7].

Some stochastic control methodologies have been proposed. Queuing mechanism was developed to reshape stochastic delays to deterministic delays by utilizing some probabilistic information of NCSs [8], however the result is more conservative. In [9-11], the induced delays are modelled as Markov chains such that NCS becomes a jump linear system with one mode or two modes. Hidden Markov model was utilized to analyze NCS with shorter delay [12], however, it is difficult to identify the number of the states of Markov chains and their transient probability in practice. An LQG controller was presented in [13-15], in which the induced delays with known probabilities are independent and identically distributed (i.i.d). In addition, LQG optimal controller was also employed when the communication delays are assumed to be independent random variable with known probability density function (PDF) in [16, 17].

When a continuous-time signal is transmitted over a network, the overall delay between sampling and eventual decoding at the receiver can be highly variable because both the network access delays and the transmission delays depend on highly variable network conditions such as congestion and channel quality [1]. In most cases, the network induced delays are usually non-Gaussian random variables, moreover, the noise in NCS is probably non-Gaussian random variables as well. In recent years, random network delays have been modelled by using various formulations based on probability and the characteristics of sources and destinations of signals passed in the networking area [2, 16].

Since the probability density function (PDF) of the induced random delays in NCSs may not obey Gaussian distribution, hence the NCSs based on stochastic control theory might achieve high performance. However, it is noted that hitherto, the developed stochastic NCSs mainly investigate linear systems. Moreover, the assumed condition on various induced delays may be a little bit strict or conservative.

In this paper, we propose a novel approach to design controller of NCSs utilizing stochastic distribution control strategy reported in [18–23]. NCSs are put into more

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