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SPECIAL ISSUE ON PERFORMANCE ANALYSIS AND SYNTHESIS OF COMPLEX NETWORKED SYSTEMS WITH COMMUNICATION SCHEDULING

PART II: CONTROL

Over the past few decades, research of complex networked systems has attracted rapidly growing interest, benefiting from their easy maintenance and installation, large flexibility and low cost. A key feature of such a complex networked system lies in that various system components/devices are mutually connected via communication cables or wireless communication medium. Numerous results on performance analysis and parameter design of complex networked systems have been reported. It is worth noting that data exchanges among various system components/devices are usually governed by suitable communication scheduling protocols with an aim to offer advantages in resource-constrained applications, such as improved communication bandwidth usages, reduced computational cost, lower sensing/actuation frequencies, and so on. As such, complex networked systems with communication scheduling find wide applications in the resource-limited execution of sensing, actuation, and decision-making in the field of cybernetics, especially in signal processing and control across industrial systems. There is no doubt that the system performance analysis and control design of these systems become much more complex and challenging than the ones already studied in non-networked scenarios due mainly to the communication induced asynchronous coupling, periodic switches, accumulated delays, as well as unknown-but-bounded disturbances. Therefore, it is of great significance to understand how to integrate advanced communication scheduling techniques with novel modeling, filtering and control methodologies in complex networked systems.

The purpose of this Special Issue is to advance the application of communication scheduling technology and methodology in complex networked systems, and further promote the research activities in filtering and control subject to communication scheduling, insecure data transmission, unreliable communication as well as communication induced phenomena. After a rigorous and careful peer-review process, 17 high-quality papers have been selected from the submissions for this Special Issue, where each paper has

been reviewed by at least two reviewers. However, this Special Issue is by no means complete. It is expected that the Special Issue will stimulate further related research and applications in this significant and timely subject.

In this Special Issue, we have divided the papers into two parts: Part I: Filtering of complex networked systems with communication scheduling; Part II: Control of complex networked systems with communication scheduling.

CONTROL OF COMPLEX NETWORKED SYSTEMS WITH COMMUNICATION SCHEDULING

Networked control represents an important topic in recent years due to limited network resources which usually result in some additional constraints on data exchange. This group consists of 8 high-quality papers, which have been classified into four subgroups as follows.

Performance analysis and synthesis under communication scheduling

In practical applications, it is essential for networked systems to adopt some communication protocols, which can effectively reduce resource consumption while achieving the desired performance. In light of this consideration, the paper entitled "*Event-triggered output consensus for linear multi-agent systems via adaptive distributed observer*" by Zhang *et al.* resolves the cooperative output regulation for heterogeneous linear continuous-time multi-agent systems, where a set of closed-loop estimators is constructed and implemented on each agent to reduce the triggering times and the undesirable Zeno behavior can be excluded via the designed scheme. In the paper entitled "*Modelling and optimal control of networked systems with stochastic communication protocols*" by Zhu *et al.*, the finite and infinite horizon optimal control is investigated by resorting to stochastic analysis and dynamic programming, where optimal state-feedback gains are presented by the solutions of coupled algebraic Riccati equations.

Performance analysis and synthesis under cyber-attacks

The information flow through the communication network can be deliberately blocking or manipulated due to the openness and vulnerability of the communication network, which leads to the security issue of complex networked systems. This subgroup consists of three papers, which deal with challenging issues regarding Stachelberg game analysis, consensus control and adaptive control, respectively. In the paper entitled "*Switched Stachelberg game analysis of false data injection attacks on networked control systems*" by *Huang et al.*, a receding-horizon switched Stackelberg strategy on the controller is derived, which, together with the corresponding best response of the attacker, constitutes the switched Stackelberg equilibrium. It is shown that the closed-loop system achieves the asymptotic stability if the switching signal satisfies a certain average dwell time. Considering heterogeneous multi-agent systems subject to uncertain deny-of-service (DoS) attack, the paper entitled "*Consensus of heterogeneous multi-agent systems with uncertain DoS attack: Application to mobile stage vehicles*" by Yu *et al.* provides a design

scheme of the expected controller dependent on the solution of some matrix inequalities, where the attack duration is assumed to be upper bounded and the occurrence of the attack describes by a Markovian jumping process. The paper entitled "*Observer-based adaptive secure control with nonlinear gain recursive sliding-mode for networked non-affine nonlinear systems under DoS attacks*" by Yang *et al.* investigates the adaptive secure control by introducing the recursive sliding mode dynamic surface, where several adaptive laws are developed to estimate the ideal weight value of adopted neural networks, and the dynamic surface control approach is utilized to simplify the control design.

Performance analysis and synthesis under cyber-attacks and event-triggered scheduling

There is no doubt that the complexity of system dynamics and performance analysis increases in the simultaneous presence of cyber-attacks and limited communication resources. In this sense, the main challenges may include the heterogeneous switching dynamics, adversarial influences of cyber-attacks and intermittent triggering instants. This subgroup consists of two papers, which focus on false data injection attacks and denial of service attacks, respectively. For cyber-physical systems with the dual-terminal event triggered mechanisms, novel stability and stabilization criteria are derived by exploiting the Lyapunov-Krasovskii theory, and a dynamic output feedback security control is designed to reduce the impact from false data injection attacks in the paper entitled "*Dual-terminal event-triggered control for cyber-physical systems under false data injection attacks*" by Wang *et al.* In the paper entitled "*Event-triggered control of cyber-physical systems under asynchronous denial of service attacks*" by Peng *et al.*, a general attack model is developed to conveniently model the asynchronous denial of service attacks within measurement and control channels in a unified framework. Based on the developed model, sufficient conditions are derived for guaranteeing the input to state stability by utilizing the traditional switching control mechanism.

Performance analysis and synthesis under heterogeneous delays

Time-delays are inevitable in practical networked systems due to the limited bandwidth and are generally heterogeneous for complex systems consisting of multiple nodes or subsystems. As such, it is necessary to develop an effective control approach to disclose the effect of heterogeneous transmission delays on the control performance of complex networked systems. In the paper entitled "*Consensus of a multi-agent systems with heterogeneous delays*" by Rehák *et al.*, a consensus algorithm is developed with the help of a Lyapunov-Krasovskii functional, and the dimension of the resulting convex optimization problem is proportional to the dimension of one agent only but does not depend on the number of agents, thereby guaranteeing the requirement of scalability.

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