Algorithms of Networked Control System Design

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Abstract –**This paper discusses design of Networked Control Systems (NCS). NCS are distributed control systems whose sensors, actuators and controllers are interconnected by shared industrial network. The major NCS problem is network-induced delays. These delays caused by the sharing of communication medium can be constant, bounded, or even random and can degrade system's performance. The main goal of the paper is to present the methodology of NCS design and the behaviour algorithms for individual NCS nodes. Finally, the control methods suitable for NCS are shortly presented.**

Keywords - **control system, control design, communication networks, delay compensation, algorithms.**

Industrial networks and their applications have been developing rapidly in the last two decades. On the side of automation, new requirements for control systems which include modularity, control decentralization, integrated diagnostics, fast and easy operation and easy maintenance limit the use of traditional analogue way of interconnection in industrial control. Thus use of industrial networks in area of high performance control and automation is promising application and research task. Feedback control systems wherein the control loops are closed through the industrial network are called Networked Control Systems (NCS). This implementation of a network into the control loop has several advantages as lower cabling price in comparison with the analogue connection, easier installation and maintenance, easy diagnostics of system, increasing of control architecture flexibility, increasing of system reconfiguration etc. But this network interconnection has also some disadvantages as communication constraints, dependability of control from network faults, asynchronous elements of control, unpredictable network faults etc. All of mentioned disadvantages lead to network induced delays. The implementation of communication networks into control system loops has motivated a number of researchers (Walsh, *et* a/., 2001; Barger, *et* a/., 2002) to analyse negative impact of the network to control systems stability and performance. Many of them designed effective methods to compensate effect of network delays, but those systems require more complex approach then just some, event the most sophisticated, control algorithm. This paper is focused to design of NCS from implementation point of view. The problem solved is, how to change control strategy (sampling period, regulation constants, configuration of individual NCS nodes, etc.) after implementation of network interconnection between several control nodes.

Apart from NCS problems mentioned in introduction of the paper, NCS have many problems connected to their configuration and control algorithm. This chapter shows NCS specific features, those are the a reason of the special approaches in case of the NCS.

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The performance chart shown on Fig.l (Lian, *et al.*, 2002) depicts sampling phenomenon of NCS. The chart is the comparison of control performance versus sampling period for continuous control, digital control, and networked control. For a fixed control law, the worst, acceptable, and best regions can be defined based on control system specifications. Since the performance of continuous control is not a function of sampling period, the performance index is constant. For the digital control case, the performance only depends on the sampling period assuming no other uncertainties. The performance degradation point A (sampling period PA) in digital control could be estimated based on the relationship between control system bandwidth and sampling rate. For the networked control case, point B needs to be determined by further investigating the characteristics and statistics of network-induced delays and device processing time delays. As the sampling period gets smaller, the network traffic load becomes heavier, the possibility of more contention time or data loss increases, and longer time delays result. This situation causes the existence of point C in networked control.

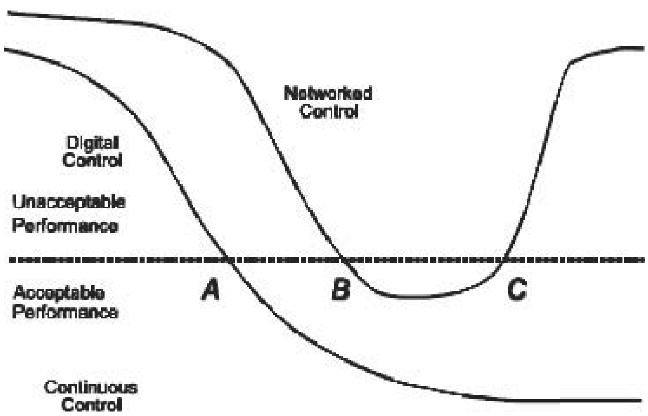

Fig. 1. Performance comparison of continuous control, digital control, and networked control cases.

Smaller sampling period results in high frequency communication and may degrade the network *QoS* (Quality of Service). The degradation of network *QoS* could further worsen the control *QoP* (Quality of Performance) due to longer time delays when the network is nearly saturated. Due to the interaction of the network and control requirements, the selection of the best sampling period for a NCS is a compromise.