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RESEARCH ARTICLE

Data Flow Control for Network Load Balancing in IEEE Time Sensitive Networks for Automation

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ABSTRACT IEEE time sensitive networks (TSN) offer redundant paths for automation networks that are essential preconditions for network load balancing (NLB) or distribution. They also provide several traffic shapers and schedulers with different impacts on the data flow control. The selection of the right traffic shaper or scheduler for an automation network is challenging. Their influence depends on various network parameters such as network extension, network cycles, application cycles, and the amount of data per traffic class and network cycle. In this study, data flow control for NLB in automation TSN using different traffic shapers and schedulers was investigated. The effects of the network parameters on the shapers and schedulers were derived and imported into the data flow control model of the automation network. The sample networks were simulated, and performance comparisons were made. The results show that the enhancements for scheduled traffic (EST), strict priority queuing (SPQ), and the combination of SPQ with frame preemption (FP) are better scheduler selections in connection with larger networks, fast network cycles, and fast application cycles. The cyclic queuing and forwarding (CQF) shaper and asynchronous traffic shaper (ATS) are rather an alternative for load control in small networks or in conjunction with slow applications.

INDEX TERMS Automation networks, data flow control, load balancing, time sensitive networks.

I. INTRODUCTION

The continuously increasing communication demand in the industry has resulted mainly from the ''Industry 4.0'' industrial revolution. This implies a significant expansion in the digitalisation of the production process and vertical communication connectivity from cloud-based servers down to the sensor level in an industrial plant. This increase implies not only a growing demand for data volume and communication speed, but also a higher need for reliable and deterministic data transport. These developments have led in a first step to the develoment of the Audio Video Bridging (AVB) standard [1] and finally to the creation of a ''Time-Sensitive Networks (TSN)'' [2], [3] Task Group (TG) as part of the IEEE 802.1 Working Group (WG). TSN is defined by the associated IEEE standards extending the IEEE 802.1 standard [4], [5], [6], [7], [8], [9], [10], [11], [12], [13], [14] and is still under further development. AVB and TSN define various new functionalities and different traffic shapers and schedulers, such as the credit based shaper (CBS) [6], the enhancements for scheduled traffic (EST) [8], the cyclic queuing and forwarding (CQF) [11], the asynchronous traffic shaper (ATS) [13], the strict priority queuing (SPQ) [5], and frame preemption (FP) [7], to achieve highly efficient and deterministic data transport. TSN also allow for the use of multiple communication paths, primarily to provide seamless media redundancy according to IEEE 802.1CB [32], which defines ''Frame Replication and Elimination for Reliability (FRER)''. Classical, non-TSN networks for Internet or campus communications, both wired and wireless, are typically set up as multi-paths networks. In addition to the advantages of redundancy, the availability of multiple paths has led to the use of load-sharing and load-balancing concepts since the late 1990s. These non-TSN networks are usually

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