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On delay stable communications in asynchronous networks

Abstract:
This dissertation defines a frame forwarding technique offering a fixed delay to a subclass of traffic in closed industrial control networks. In these networks bandwidth is dedicated to periodic traffic supporting tight inter-process control and control loop communication.
Ideally periodic traffic arrival will have minimal delay-jitter with constant realized delays. This simplifies the implementation of connected control devices. Furthermore networks are simplified with asynchronous node and switch operation. Switch designs are simplified as there is no dependence on adjacent switch clock operation. Correct network function only relies on switches directly traversed by each flow and is not dependent on complex clock synchronization mechanisms.
Existing packet scheduling schemes that attempt to minimize delay-jitter, suffer from either requiring inter-switch clock coordination (i.e. RCSP-DJ), or maintain a fixed priority so that the highest priority flows must contend without regard to past frame arrival treatment (i.e. RCSP-RJ). In this dissertation the FlexTDMA protocol is defined which supports closed network communication.

FlexTDMA will be enhanced to accommodate real-world networking conditions (FlexTDMA+) and will be enhanced to support simultaneous multicast (FlexTDMA++). The FlexTDMA scheduling algorithm delivers frame data on each flow nearly at the maximal delay bound with minimal delay-jitter in an asynchronous network. Industrial control switching network systems will benefit from FlexTDMA when the complexity of system level synchronization is unacceptable, but the component switches must operate independently. FlexTDMA does not require synchronous network clock coordination and preserves the data content of frames. FlexTDMA+ includes three improvements: baseline preemption, partial baselining and baseline deadline density control, which are used to support real-world conditions of node periodic on-off transmission, clock drift, frame loss and bandwidth load. FlexTDMA++ supports simultaneous multicast under real-world conditions of switch failures, node periodic on-off transmission, clock drift, frame loss and bandwidth load.