

Real-Time Services in Packet-Switched Networks for Embedded Applications

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Abstract

Embedded applications have become more and more complex, increasing the demands on the communication network. For reasons such as safety and usability, there are real-time constraints that must be met. Also, to offer high performance, network protocols should offer efficient user services aimed at specific types of communication.

At the same time, it is desirable to design and implement embedded networks with reduced cost and development time, which means using available hardware for standard networks. To that end, there is a trend towards using switched Ethernet for embedded systems because of its high bit rate and low cost. Unfortunately, since switched Ethernet is not specifically designed for embedded systems, it has several limitations such as poor support for QoS because of FCFS queuing policy and high protocol overhead.

This thesis contributes towards fulfilling these requirements by developing (i) real-time analytical frameworks for providing QoS guarantees in packet-switched networks and (ii) packet-merging techniques to reduce the protocol overhead.

We have developed two real-time analytical frameworks for networks with FCFS queuing in the switches, one for FCFS queuing in the source nodes and one for EDF queuing in the source nodes. The correctness and tightness of the real-time analytical frameworks for different network components in a single-switch network are given by strict theoretical proofs, and the performance of our end-to-end analyses is evaluated by simulations. In conjunction with this, we have compared our results to Network Calculus (NC), a commonly used analytical scheme for FCFS queuing. Our comparison study shows that our analysis is more accurate than NC for single-switch networks.

To reduce the protocol overhead, we have proposed two active switched Ethernet approaches, one for real-time many-to-many communication and the other for the real-time short message traffic that is often present in embedded applications. A significant improvement in performance achieved by using our proposed active networks is demonstrated.

Although our approaches are exemplified using switched Ethernet, the general approaches are not limited to switched Ethernet networks but can easily be modified to other similar packet-switched networks.

Keywords: embedded systems, real-time communication, packet-switching, switched Ethernet, FCFS and EDF scheduling, schedulability analysis, active networking, protocol overhead