A Run-Time System for Predictably Low Age of Information in Networked Cyber-Physical Systems

Stefan Reif, Timo Hönig, Wolfgang Schröder-Preikschat
Friedrich-Alexander-Universität Erlangen-Nürnberg

Andreas Schmidt, Pablo Gil Pereira, Thorsten Herfet
Saarland Informatics Campus

Novel application domains like the Internet of Things (IoT) and inter-connected cars have initialted a transition from deeply embedded cyber-physical systems to collaborating systems. Such networked cyber-physical systems no longer operate in isolation, but communicate over shared resources to cooperate.

One of the key challenges is to ensure that all system components operate on "fresh" data. The age of information depends on data dependencies, scheduling, function execution times, and network transmission times. In complex systems, information processing chains are so long that various sources of non-determinism accumulate, and potentially cause system components to operate on outdated or even inconsistent data.

The main reason for non-determinism is the dynamic behavior of networked cyber-physical systems. Besides varying network channel conditions in the Internet or wireless links, node performance depends on available resources, for example due to power constraints in embedded nodes, or contention on edge-located computing nodes.

This talk proposes cross-layer pacing, a dynamic approach for predictably low age of information. It minimizes queueing delays, which are a main source of latency and jitter in large-scale networked systems. This talk further presents X-Pace, a prototypical run-time system which implements cross-layer pacing. To minimize latency and jitter, X-Pace measures component performance metrics at run-time, utilizing recently developed networking algorithms. These measurements allow our system to detect the current bottleneck component, to communicate the bottleneck pace through the entire system, and to enforce the correct speed at all layers in the system, including the application. X-Pace achieves a significant reduction in latency and jitter at application level in real-world scenarios.