QoS-enabled Industrial Wireless Sensor Networks Testbed

Samuele Zoppi, Murat Gürsu, and Wolfgang Kellerer
Chair of Communication Networks
Technical University of Munich
{samuele.zoppi,murat.guersu, wolfgang.kellerer}@tum.de

Introduction & Background

Motivation

- Future industrial networked control systems (NCS) will be **wirelessly** interconnected
- Control loops pose strict **QoS requirements** on wireless communications
- Wireless Sensor Networks (WSN) can support NCS traffic and allow **centralized RRM** through scheduling (TSCH)
- **Goal**: Low-latency implementation of QoS provisioning in IWSN
- **Problem:** Current WSN devices are not designed for low-latency
- **Approach:**

1. Definition of a Network Architecture and QoS framework
2. Implementation of QoS-aware low-latency algorithms and protocols

Network Architecture

- Centralized, cellular architecture
- Network elements:
  - **Application (App.)**: industrial NCS application
  - **Network Manager (NM)**: entity that manages the Network Resources of the entire WSN
  - **Gateway (GW)**: interface btw the WSN devices, the NM and applications
  - **Sensor (S)**: WSN device representing the endpoint of the application

— Control links btw NM and WSN devices through the GW
- - - Data links btw App and WSN devices through the GW

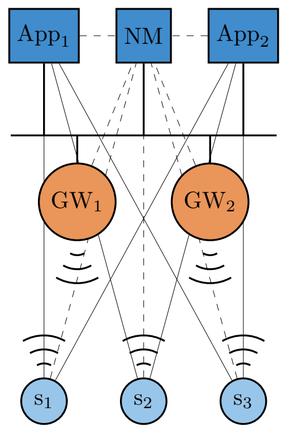


Fig. 1: Network architecture

QoS Provisioning Framework - Wireless DetServ

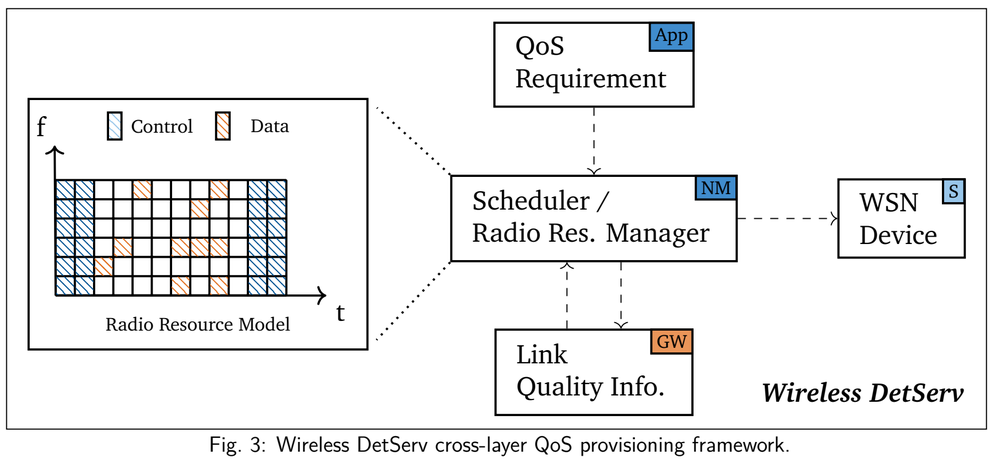


Fig. 3: Wireless DetServ cross-layer QoS provisioning framework.

- WDetServ collects application QoS requirements (latency, reliability, QoC, ...), Link Quality Information and allocates Radio Resources to the WSN devices
- RRM models the MAC Radio Resources to provide QoS
- RRM allocates RR for both Control and Data messages
- RRM allocates resources to retrieve Link Quality Information
- Simulation results of centralized dynamic scheduling in WSN s.t. latency and reliability constraits (Fig. 5)

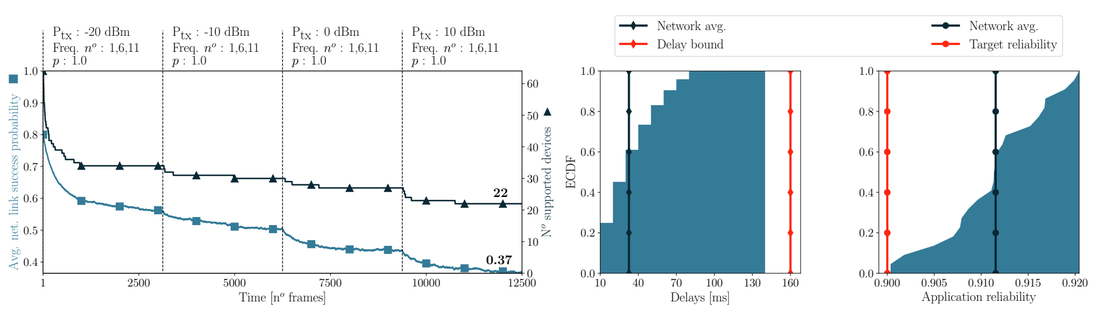
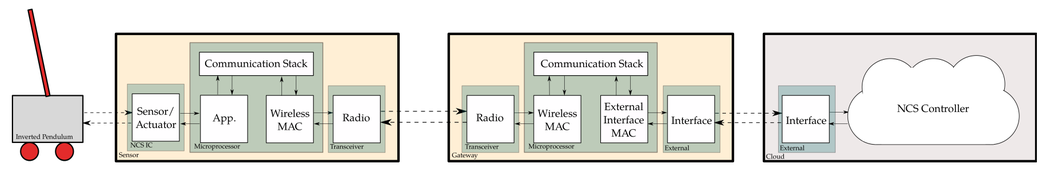


Fig. 5: Reliability-based scheduler performances in presence of increasing Wi-Fi transmission power (P_{tx})[4]. WDetServ detects the interference and adapts the radio resources guaranteeing the target reliability and delay bound.

IWSN Implementation



- **Goal:** Deployment of an IWSN NCS testbed based on Wireless DetServ
- **Problem:** several HW and SW latency bottlenecks
- **Approach:**

1. SW implementation of WDetServ cross-layer control link protocols
2. Development of bottleneck-free HW platforms

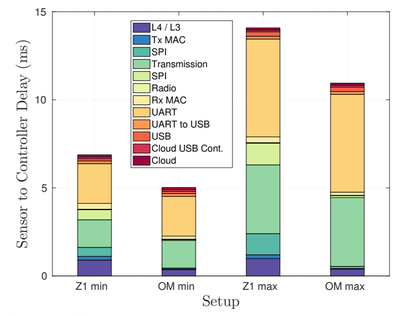


Fig. 8: Sensor-to-cloud delay measurements[3].

Software – Firmware

- Implementation of cross-layer control link protocols for:
  - Link Quality Information (PHY-MAC)
  - QoS requirement (APP-MAC)
  - Radio Resource Manager
- Possible frameworks: 6TiSCH and OpenWSN? Contiki?

Hardware

- Separate HW solutions for GW and WSN devices:
  - GW: high performance, multi-radio and multi-processor capabilities
    ⟶ low-latency, multi-channel SDR implementation
  - WSN devices: limited HW resources, single antenna, single/dual processor
    ⟶ Zolertia Z1/RE-Mote, TI SimpleLink

NCS Application – Inverted Pendulum

- Inverted pendulum as **benchmark** NCS application
- Control logic (controller) in the Cloud
- sensor-to-controller-to-actuator testbed
- Sensing and Actuation in the WSN device, options:
  ⟶ is the WSN device the pendulum?
  ⟶ is the WSN device a relay/forwarder/interface?

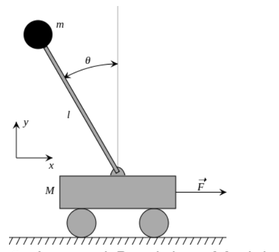


Fig. 9: Inverted Pendulum Model.

Conclusions and Current Work

- Wireless DetServ QoS cross-layer Framework can provide **QoS** (latency, reliability, QoC, ...) in WSN and support industrial NCSs
- Cross-layer **protocols** for dynamic RRM in IWSN will be implemented
- **Latency** is the major issue for HW implementation (radio, processing, ext. interface)
- Multi-radio, multi-processor, high-speed interface solutions will be implemented
- Standard NCS application will be defined for **benchmarking** purposes

Relevant references

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