Simulating 6TiSCH Stack for Avionic Wireless Sensor Networks in OMNeT++

OMNeT++ Community Summit 2022

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Agenda:

1. Introduction
2. Background
   Challenge
3. Implementation
4. Demos
   Network Bootstrapping
   Adapting to Traffic
   Interference Avoidance
5. Conclusion & Outlook
1. Introduction
Wireless Sensor Networks

Figure 1: Wireless Sensor Networks (WSNs) examples.
Wireless Sensor Networks

Figure 1: WSNs examples.

Challenges
• Reliability
• Scalability
• Interoperability
• Energy-efficiency
Figure 2: Protocols based on IEEE 802.15.4 standard for low-rate wireless personal area networks.
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Timeslotted Channel Hopping (TSCH)

Figure 3: TSCH schedule example for a 4-node network.
IPv6 over the TSCH mode of IEEE 802.15.4 (6TiSCH)

<table>
<thead>
<tr>
<th>Apps</th>
<th>CoJP</th>
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<tbody>
<tr>
<td>CoAP / OSCORE</td>
<td>6LoWPAN ND</td>
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<tr>
<td>UDP</td>
<td>ICMPv6</td>
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<td>6LoWPAN HC / 6LoRH HC</td>
<td>Scheduling Functions</td>
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<tr>
<td>6top Sublayer + 6top Protocol (6P)</td>
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<td>IEEE 802.15.4 TSCH</td>
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Routing, applications
Transport
Network
Medium Access Control (MAC)

Figure 4: IETF 6TiSCH.
Figure 5: Routing Protocol for Low-Power and Lossy Networks (RPL) Destination-Oriented Directed Acyclic Graph (DODAG)
Minimal Scheduling Function (MSF)

Figure 6: TSCH schedule under MSF.
2. Background
Wireless Avionics Intra-Communication (WAIC)

Current Aircraft Communications:
- Safety-related
  - HF/VHF/Satellite comms
- Non-safety related
  - Passenger connectivity

Communications with ground

Operational Communications
Internet Connectivity

WAIC Systems:
- Safety-related applications:
  - Sensors/Actuators
  - Wireless redundancy for wired communications

Figure 7: WAIC use-cases

1Aerospace Vehicle Systems Institute. 2011
Quality of Service (QoS) in 6TiSCH

Figure 8: QoS challenges in a WAIC network using 6TiSCH.
Quality of Service (QoS) in 6TiSCH

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## Solution

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Figure 9: 6TiSCH stack with cross-layer information exchange (6TiSCH-CLX)[1].
Results

Figure 10: Mean end-to-end delay of a safety-critical application (smoke alarm) under default 6TiSCH stack and cross-layer improvements.
3. Implementation
Implementation Overview

**Network Layer**
- IPv6NetworkLayer:
  - Configuration parameters, interface to upper layers
- ipv6:
  - Core IPv6 functionality
- ipv6RoutingTable:
  - Destination cache management, routing table access
- IPv6NeighborDiscovery:
  - Neighbor discovery and cache management

**Routing Sublayer**
- Rpl:
  - Rpl instance maintenance
- TrickleTimer:
  - Control messages broadcast interval
- ObjectiveFunction:
  - Parent selection interface
- TschSpectrumSensing:
  - Issues channel sense requests
- TschLinkInfo:
  - State information per neighbor
- TschMsf:
  - Minimal Scheduling Function
- TschSf:
  - Generic interface for scheduling functions
- Tsch6TopSublayer:
  - Transaction management

**McM Sublayer**
- TschMac:
  - MAC FSM
  - Based on IEEE802.15.4 INET implementation
  - Retransmissions
- TschSlotframe:
  - Management of all links
- TschLink:
  - Cell representation: location, type, options
- TschNeighbor:
  - Queue management per neighbor
- TschVirtualLink:
  - Extends TschLink with priorities
- TschHopping:
  - Channel hopping sequence

**Phy Layer**
- WacPhy:
  - Extension of IEEE 802.15.4 PHY with 40 channels in 4.2-4.3 GHz band
- Ieee802154NarrowbandDimensionalRadio:
  - Configurable implementation of IEEE 802.15.4 PHY
- RadioMedium:
  - INET 4.2 radio medium interface
Implementation – RPL

**RPL**
- Joining/leaving DODAGs
- Route discovery (DAOs)
- Loop detection and repair
- DODAG version control (sink)

**TrickleTimer**
- Maintaining trickle intervals
- Triggering DIO broadcasts

**ObjectiveFunction**
- Preferred parent selection from candidate list
- Rank computation using link metrics

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3 RFC 6206. [https://www.rfc-editor.org/rfc/rfc6206](https://www.rfc-editor.org/rfc/rfc6206)
Implementation - TSCH

6TOP SUBLAYER

Tsch6TopSublayer
Transaction management

TschLinkInfo
State information per neighbor

TschMsf
Minimal Scheduling Function

TschSf
Generic interface for scheduling functions

MAC LAYER

TschMac
- MAC FSM
- Based on IEEE802.15.4 INET implementation
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4. Demos
Network Bootstrapping

Figure 11: Network bootstrapping
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Adapting to Traffic

Figure 12: MSF adapting number of scheduled cells to the traffic load (1 pkt/sf).
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Interference Avoidance

Figure 13: MSF relocating interfered cells after HOUSEKEEPING_PERIOD duration.
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5. Conclusion & Outlook
Conclusion & Outlook

• Modular 6TiSCH-stack implementation with MSF
• Cross-layer communication to achieve QoS
• Highly extensible
Conclusion & Outlook

• Modular 6TiSCH-stack implementation with MSF
• Cross-layer communication to achieve QoS
• Highly extensible

Missing:
• Proper integration with ICMPv6
• Upper layers (CoAP)
• Fragmentation layer (6LoWPAN)
• Migration to OMNeT++ 6.X, INET 4.4
• Testing (unit, end-to-end, …)
Thank You very much
References


