Demo: Teaching How to Enable Industry 4.0 Applications using TSCH in Cooja Simulator

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CCS Concepts

• **Networks** → **Link-layer protocols**; • **Computing methodologies** → *Modeling and simulation.*

Keywords

TSCH, Cooja Simulator, Hands-on, 6TiSCH, Critical thinking

1 Extended Abstract

Industry 4.0 applications demand highly reliable and time-sensitive communication, especially where sensor feedback must be closely synchronized with control commands [2, 3]. Such stringent requirements cannot be met by traditional random access protocols like WiFi, LoRa, or Bluetooth, which offer no guarantees on latency or packet delivery. To address this, the IEEE 802.15.4 Time-Slotted Channel Hopping (TSCH) mode enables deterministic communication with predictable delays and high reliability—key enablers for industrial automation.

In this demo, we present three carefully designed assignments that provide students with hands-on experience of the TSCH protocol, laying the foundation for understanding its role in the Industrial Internet of Things (IIoT).

In the first assignment, students simulate a two-node network to understand the joining process in the 6TiSCH stack [4] and also to familiarize them with Cooja simulator. During the simulation, all nodes print debug information to the console, which students parse to fill in assignment tables—e.g., Enhanced Beacon (EB) size, frequency channels scanned before joining, etc. Students record per-packet delays and also calculate the average delay over multiple packets. In the final step, a star topology is simulated where two hosts transmit packets over a shared minimal cell, leading to collisions and packet loss. The next two assignments focus on dedicated cells allocation, both manually and using the 6top protocol. The latter enables nodes to negotiate dedicated cells in a distributed manner using add/delete/relocate transactions.

We designed these three assignments with a step-by-step approach to cover specific 6TiSCH features, instead of using standard Cooja examples:

- Minimal Configuration: Students start with a minimal configuration to understand the basic operation of the 6TiSCH stack, including the joining process, channel hopping and usage of minimal cell. The latter is a shared broadcast cell for control traffic, enabling other nodes to join the network.
- Linear vs Star Topology: Comparison of packet delays and losses in linear and star topology with minimal cell hints at the necessity of a scheduling function.
- Dedicated Cells: Students assign cells manually to hosts and analyze the impact on delay and reliability.
- 6top Protocol: Students learn how to negotiate dedicated cells in a distributed manner for scalable deployments (no central entity required).

Each assignment takes several hours to complete and concludes with a handout prompting critical reflection on parameter choices and their impacts. One of the main challenges for students was mapping theoretical concepts to events observed in the simulator, and interpreting the debug output correctly. For example, the following questions lead students to appreciate distributed cell assignment with 6top protocol, as explored in Assignment 3.

(1) When adding dedicated cells, what is the factor of reduction of average delay? Explain the reasons for this.
(2) To improve average end-to-end delays, is it better to add cells at nodes closer to the sink or those further away? Justify your answer.
(3) What are the pros and cons of the scheduling approach used in this example?

In this demo setup, participants can try all three assignments using the Cooja simulator. We also provide handouts to validate and interpret results. Assignments are also validated on real devices (OpenMote B). All our assignments and modified examples required for the simulator are available at [1]. As a general limitation, the assignments use a simplified unit disk radio model, which does not account for complex propagation effects. Also for larger networks, the parsing of the debug output becomes cumbersome, and students may need to focus on a subset of nodes.

We collected students' feedback per learning objective using a 1 "achieved completely" to 4 "not achieved at all" scale. Majority of votes were 1 or 2, indicating that the assignments were effective in teaching critical thinking about communication in the context of Industry 4.0, as well as fostering collaboration within international and interdisciplinary teams. Active participation in lecture break out sessions, repeated discussions of the learned materials as well as team-based work on assignments were the main driving factors for this success.

References

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