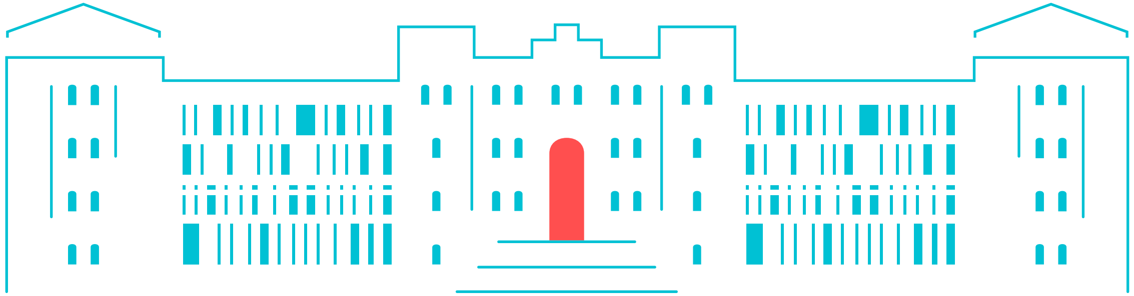
Simulating 6TiSCH Stack for Avionic Wireless Sensor Networks in OMNeT++

OMNeT++ Community Summit 2022

ComNets

TUHH Hamburg University of Technology

Institute of Communication Networks



Yevhenii Shudrenko, Koojana Kuladinithi and Andreas Timm-Giel

03.11.2022

Agenda:

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

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1. Introduction

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Wireless Sensor Networks

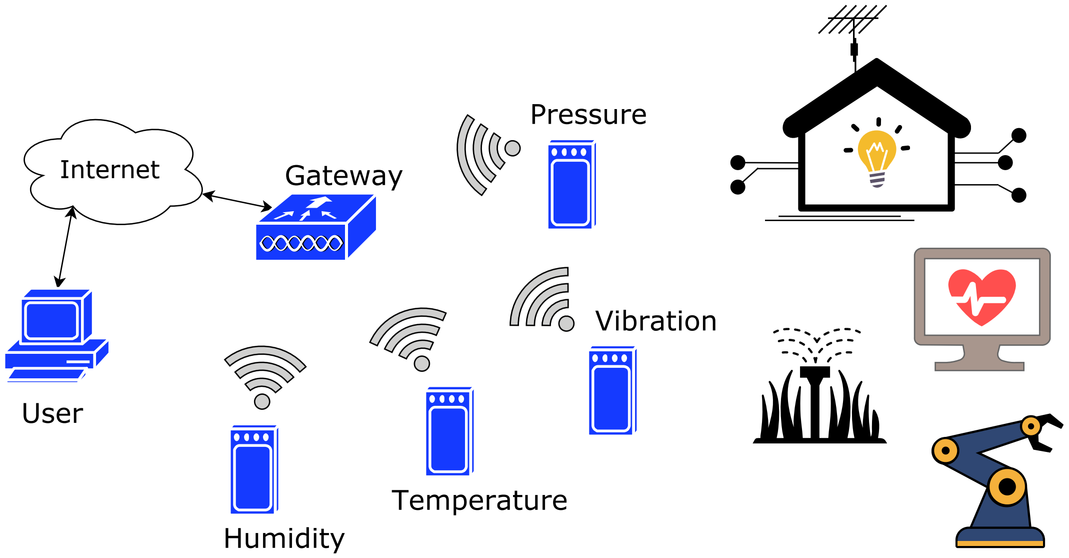


Figure 1: Wireless Sensor Networks (WSNs) examples.

Wireless Sensor Networks

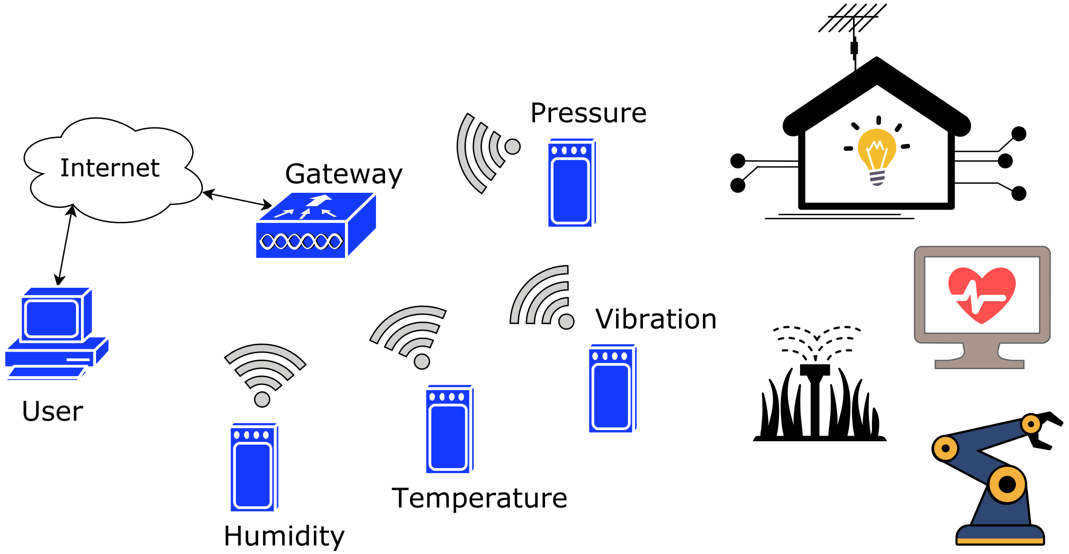


Figure 1: WSNs examples.

Challenges
- Reliability
- Scalability
- Interoperability
- Energy-efficiency

IEEE 802.15.4

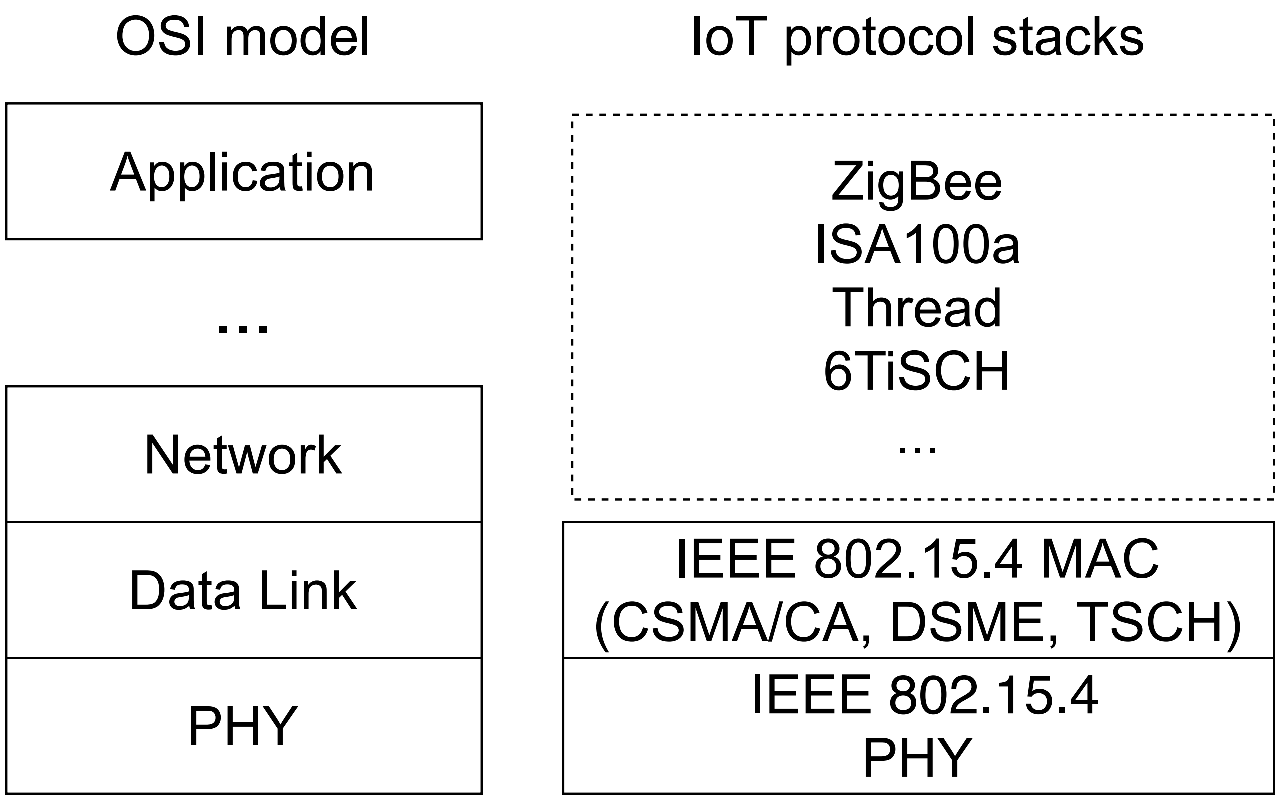
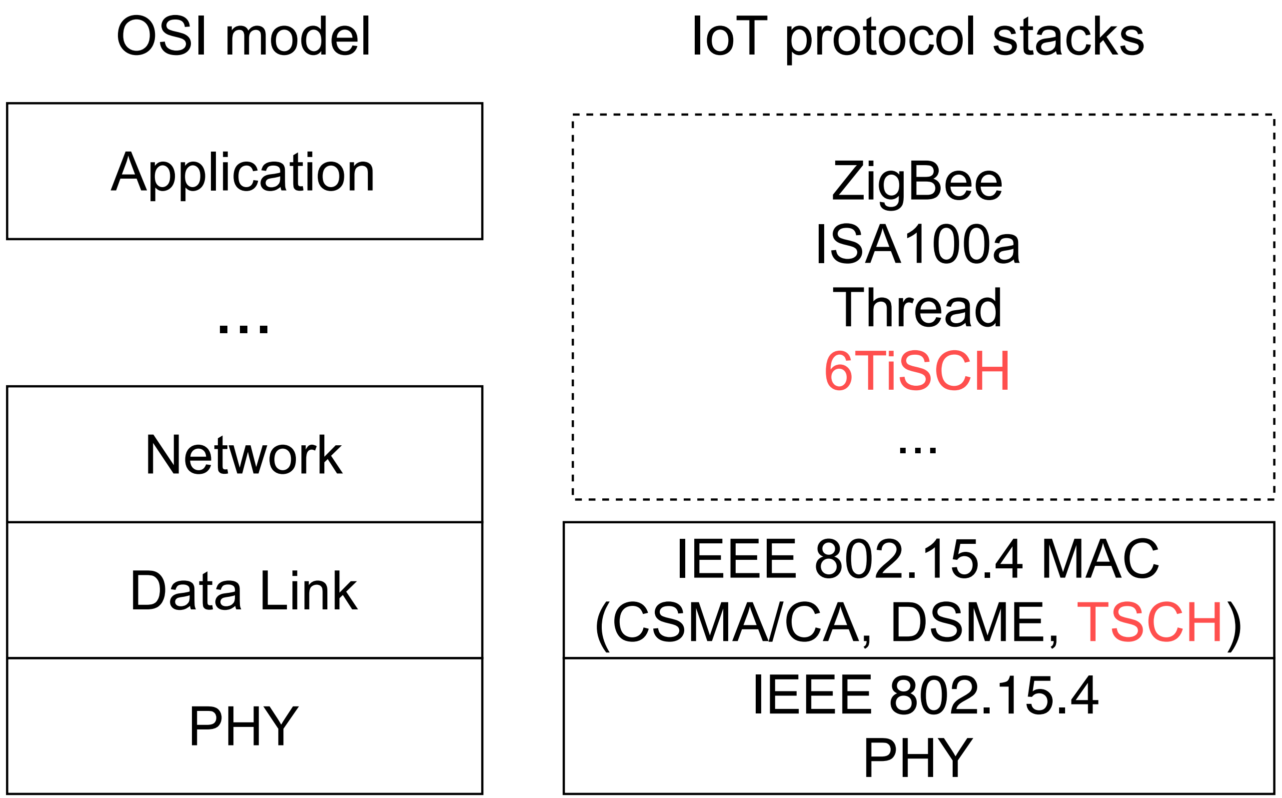


Figure 2: Protocols based on IEEE 802.15.4 standard for low-rate wireless personal area networks.

IEEE 802.15.4



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Timeslotted Channel Hopping (TSCH)

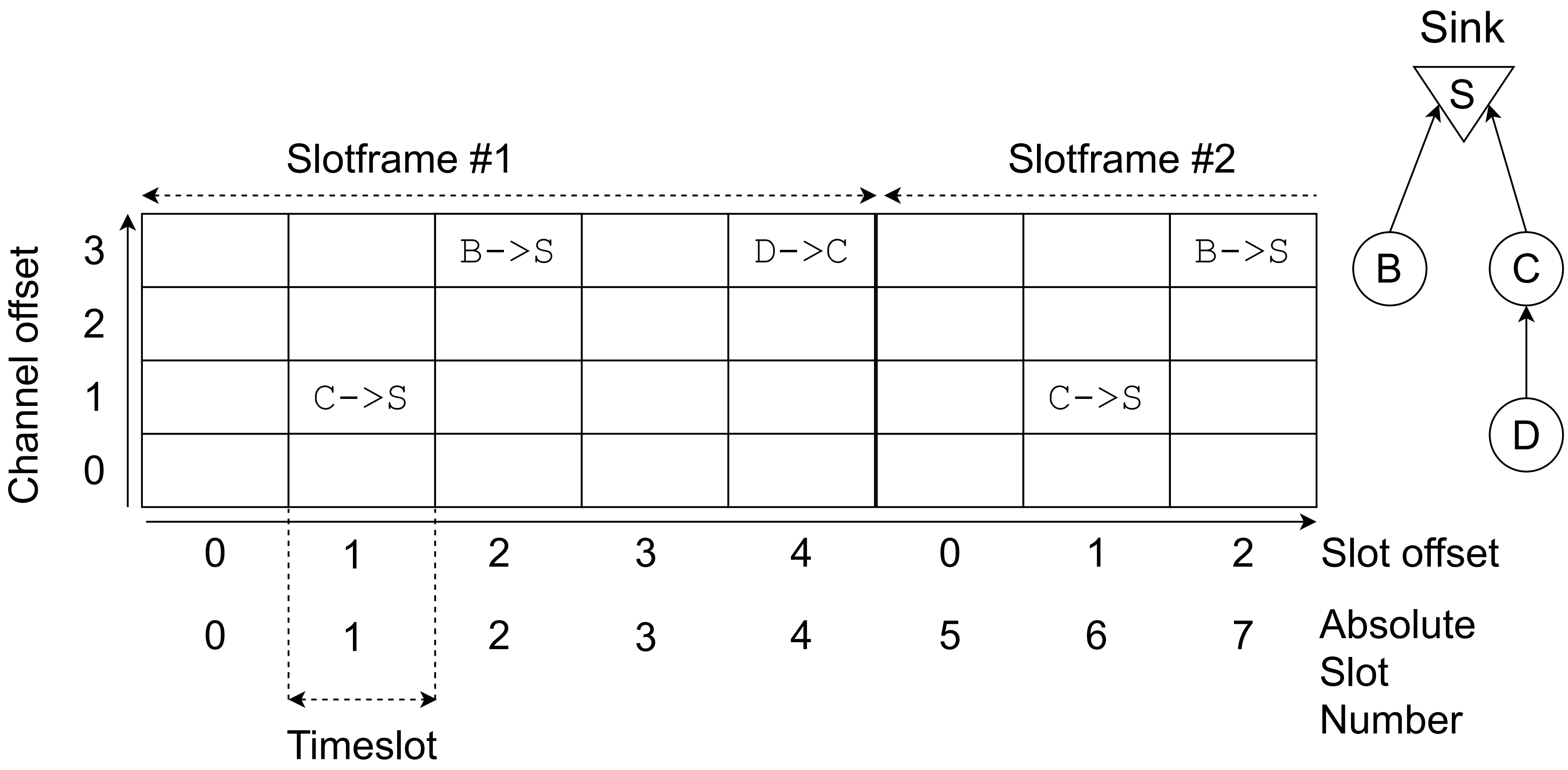

Figure 3: TSCH schedule example for a 4-node network.

IPv6 over the TSCH mode of IEEE 802.15.4 (6TiSCH)

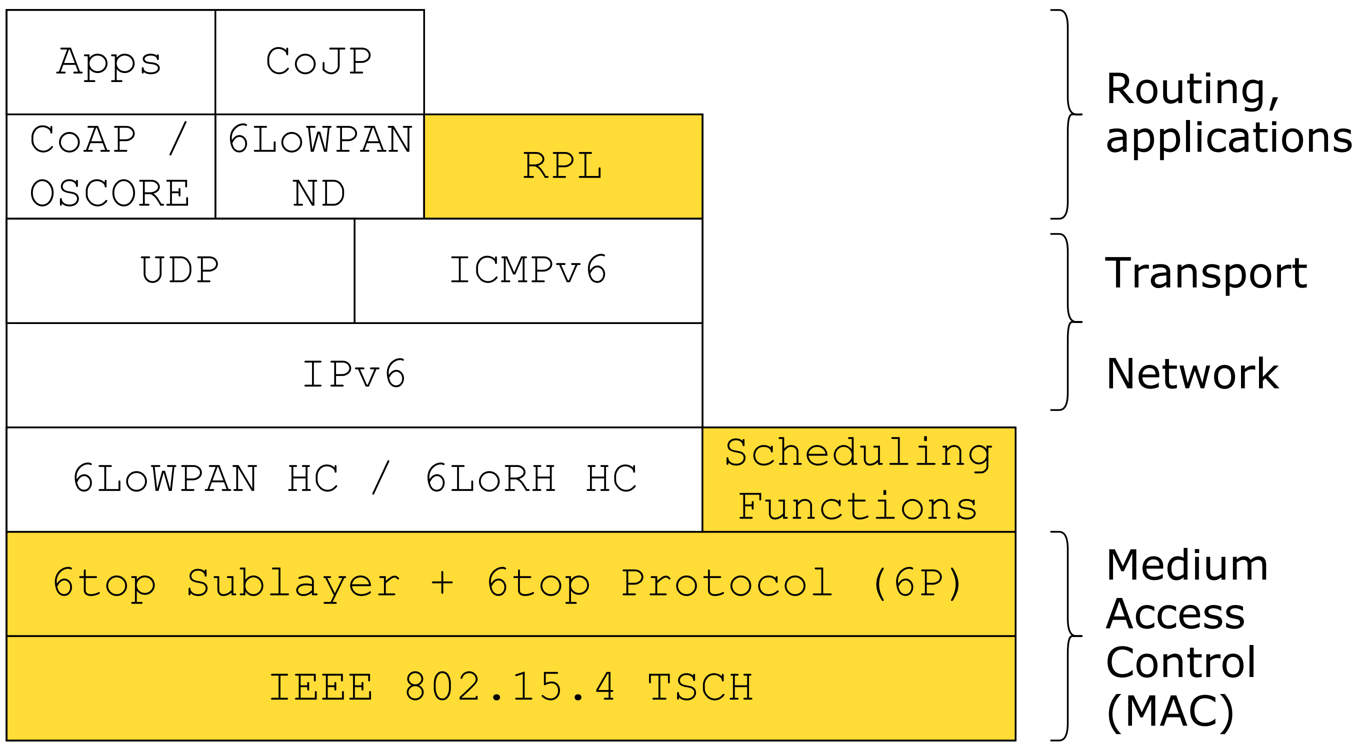

Figure 4: IETF 6TiSCH.

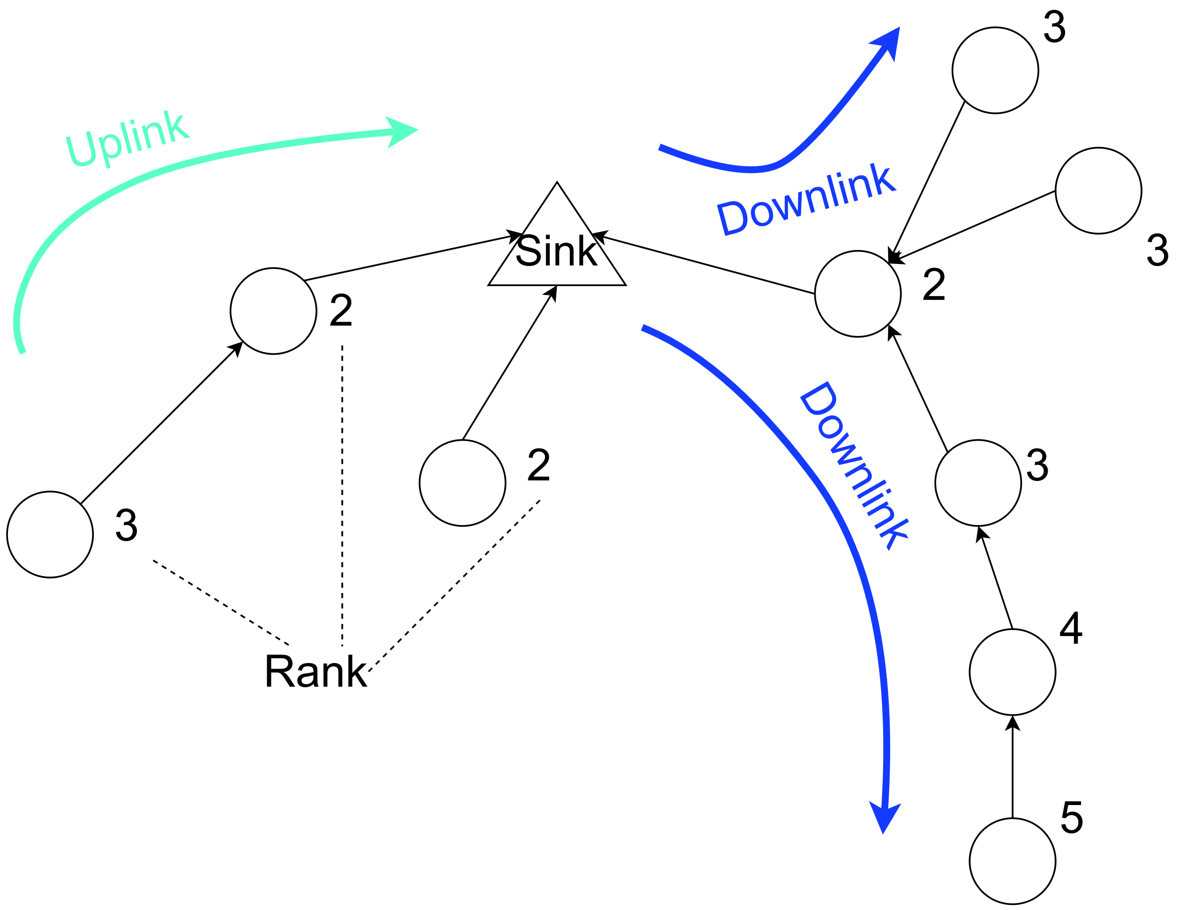

Figure 5: Routing Protocol for Low-Power and Lossy Networks (RPL) Destination-Oriented Directed Acyclic Graph (DODAG)

Minimal Scheduling Function (MSF)

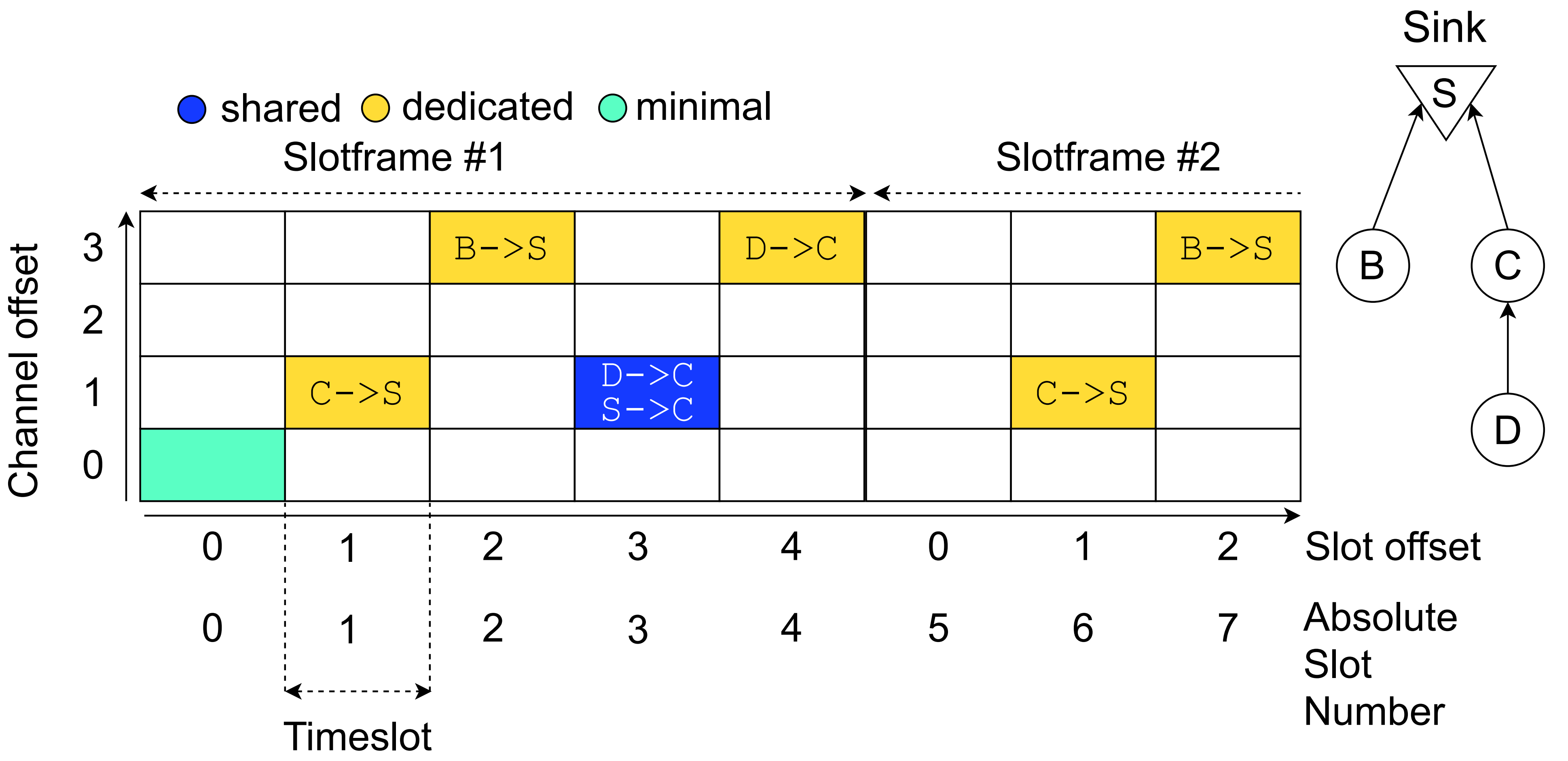

Figure 6: TSCH schedule under MSF.

2. Background

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Wireless Avionics Intra-Communication (WAIC)

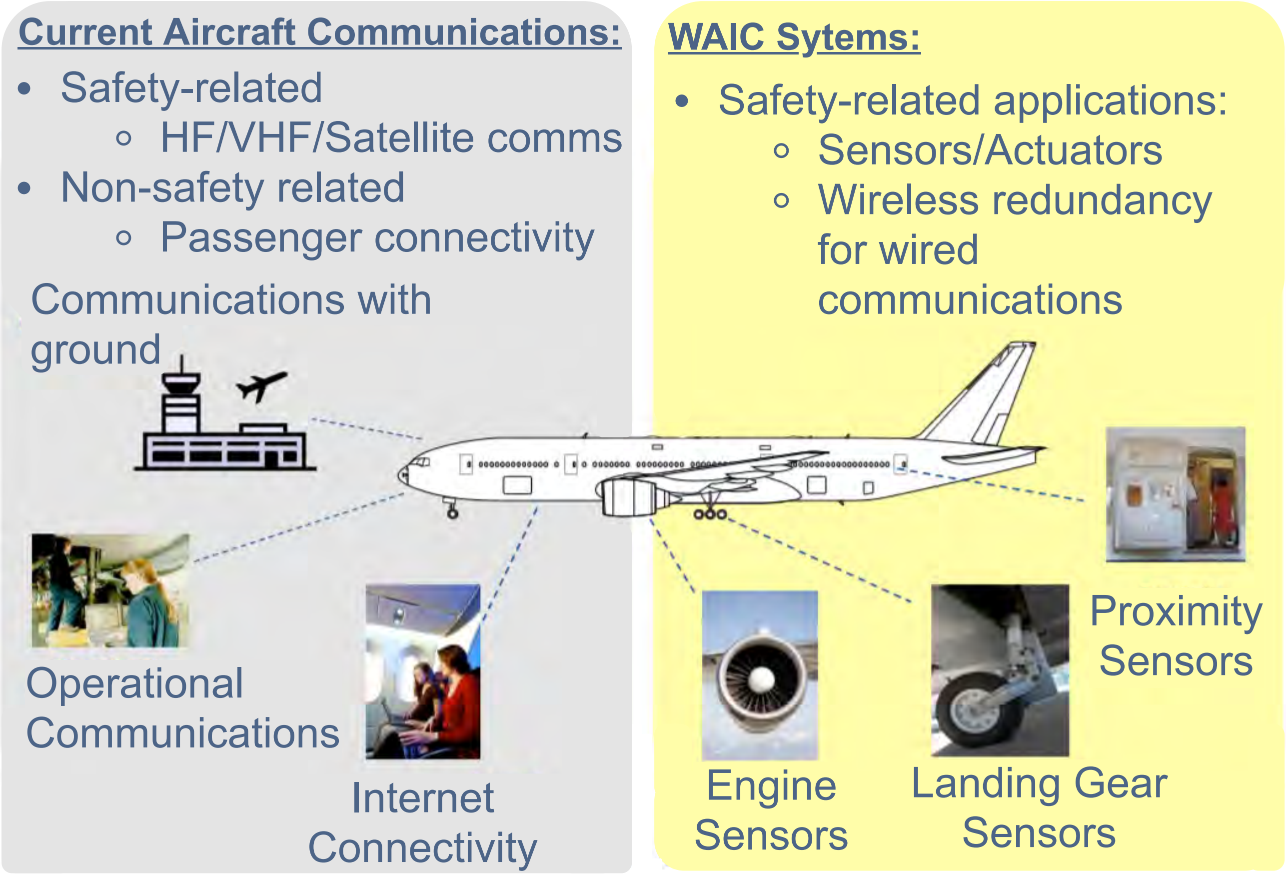


Figure 7: WAIC use-cases[1]

[1]Aerospace Vehicle Systems Institute. 2011

Quality of Service (QoS) in 6TiSCH

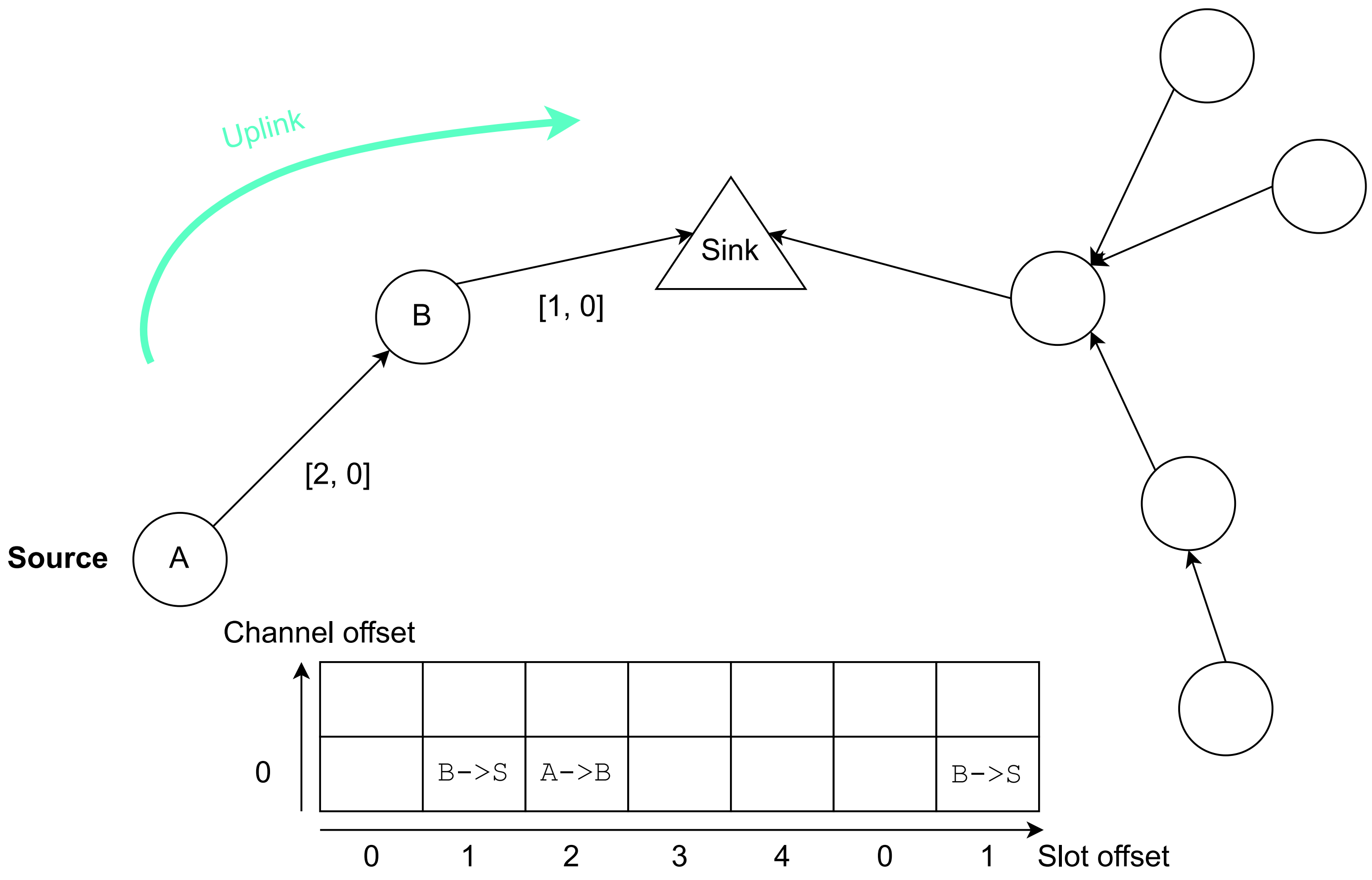
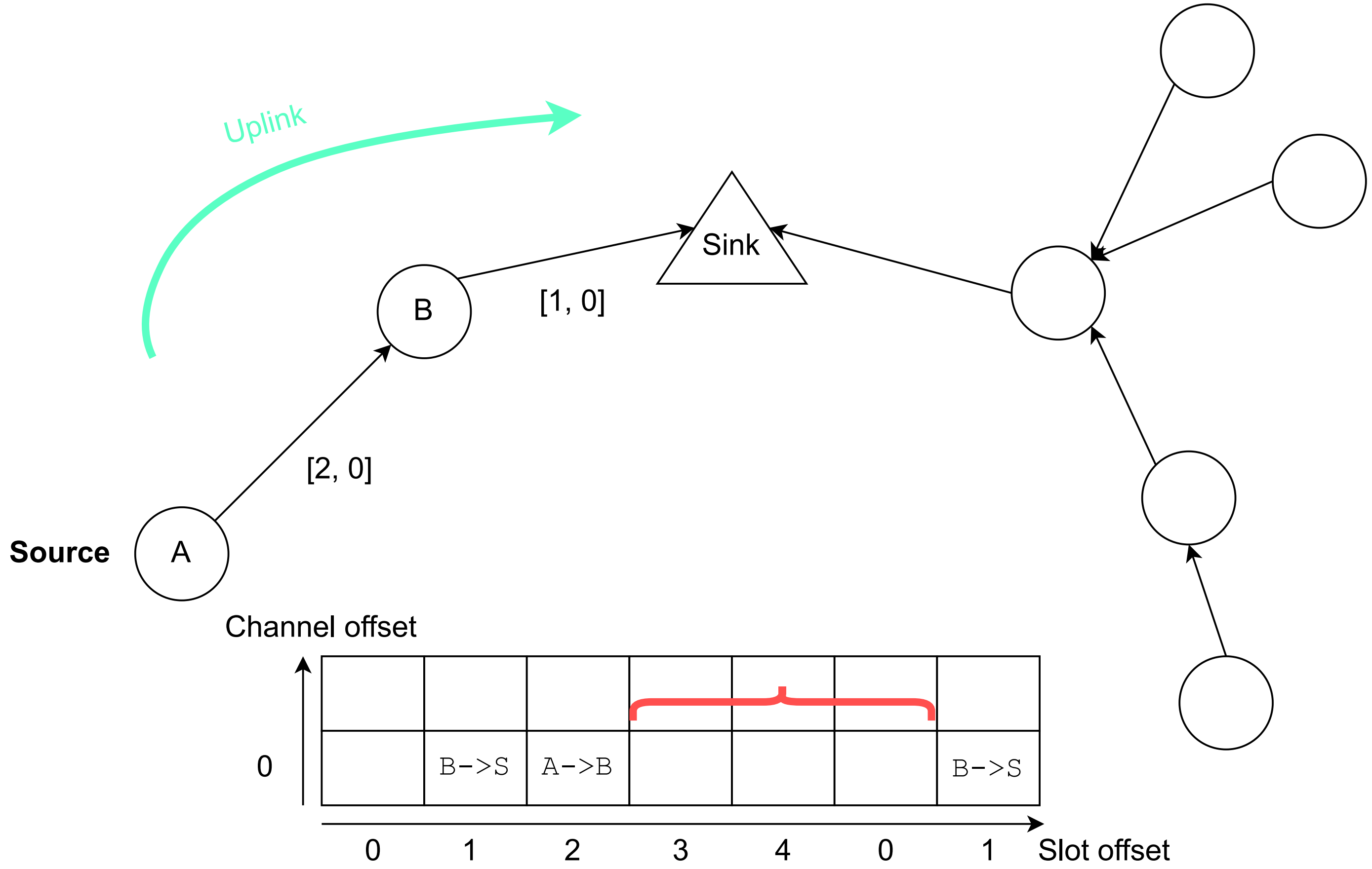


Figure 8: QoS challenges in a WAIC network using 6TiSCH.

Quality of Service (QoS) in 6TiSCH



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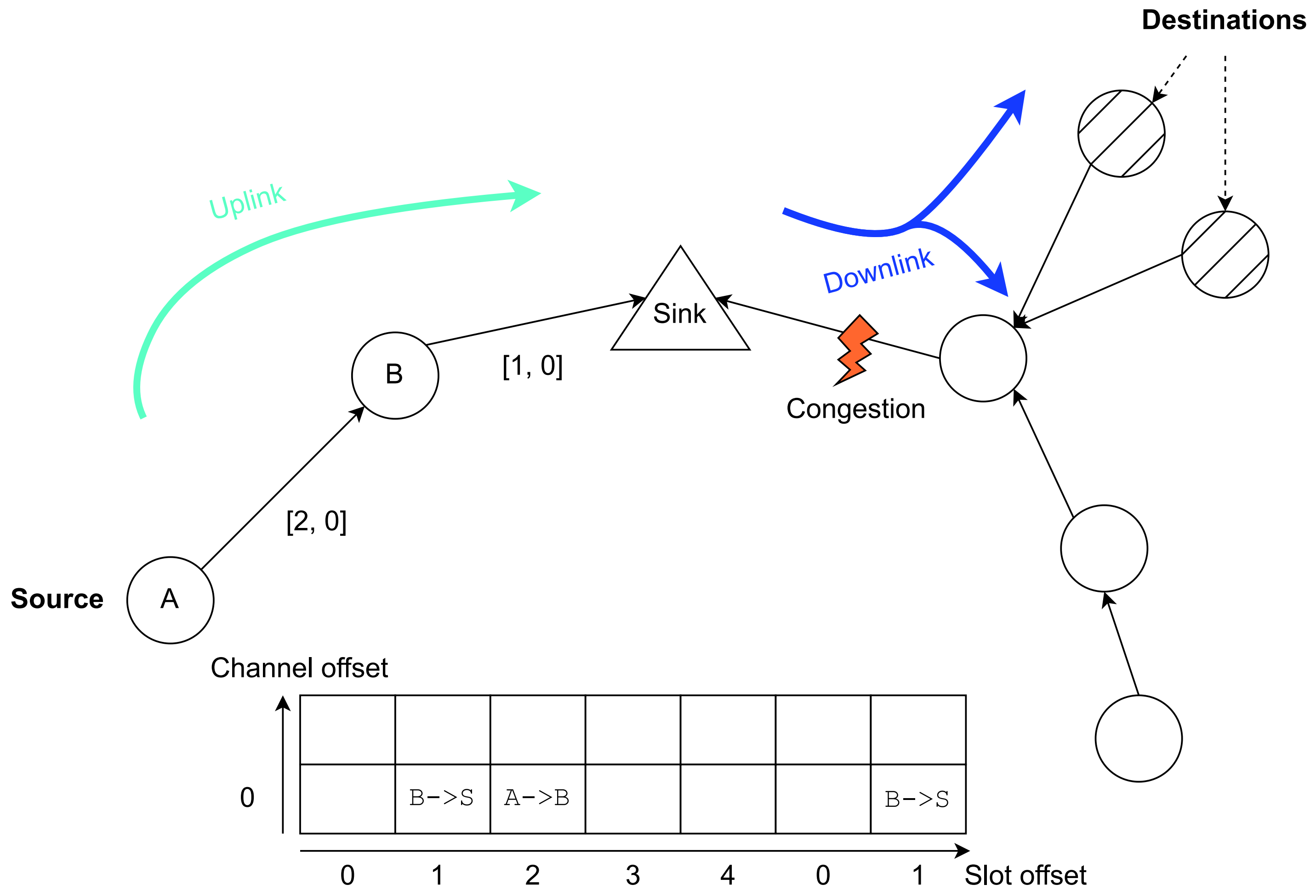

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Solution

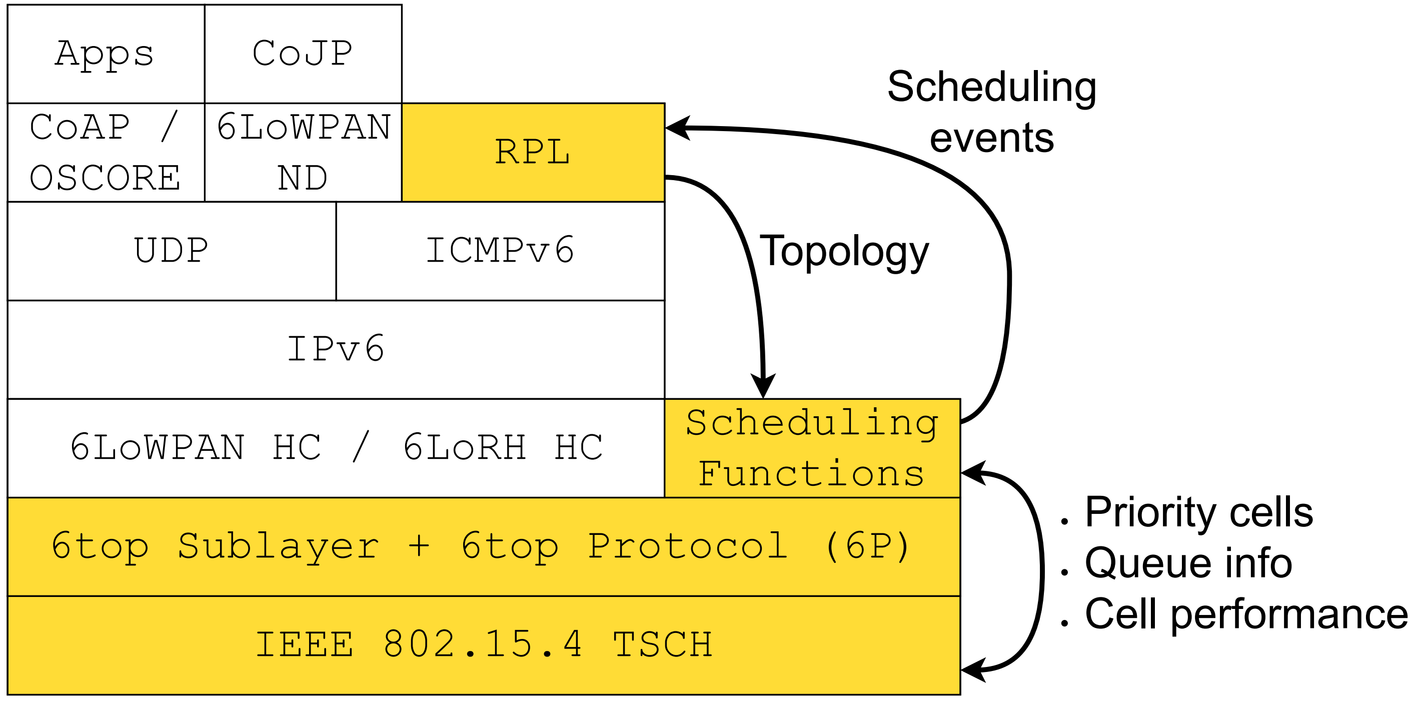

Figure 9: 6TiSCH stack with cross-layer information exchange (6TiSCH-CLX)[1].

Results

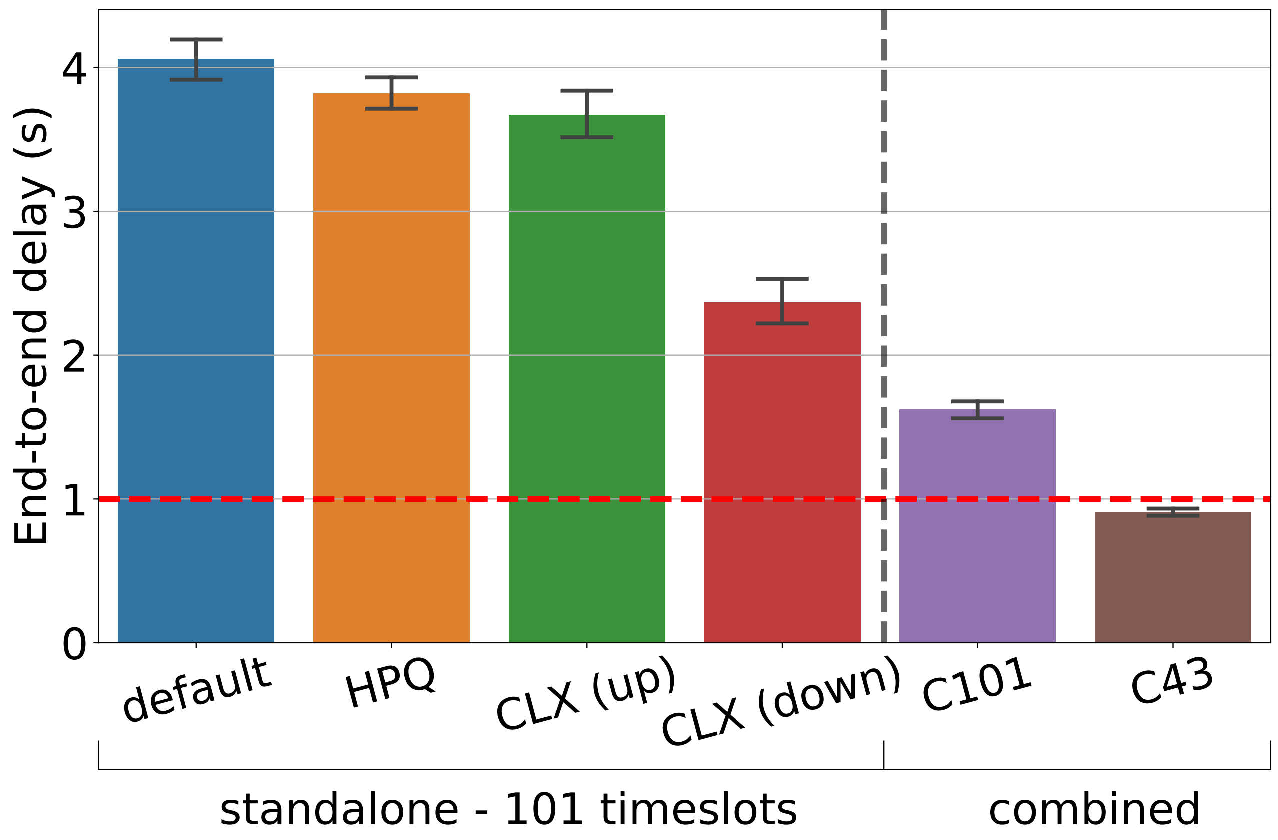

Figure 10: Mean end-to-end delay of a safety-critical application (smoke alarm) under default 6TiSCH stack and cross-layer improvements.

3. Implementation

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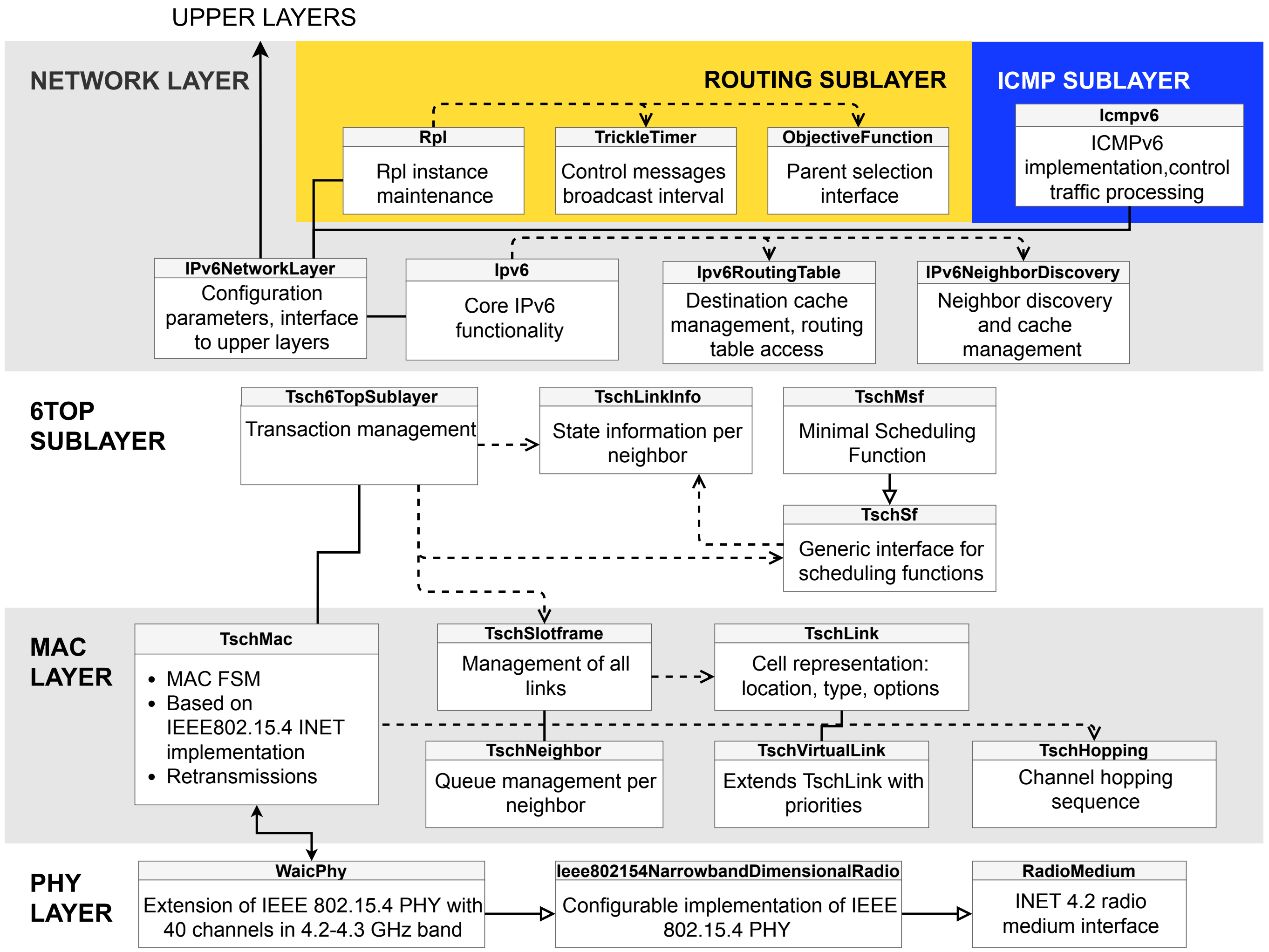
Implementation Overview



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Implementation - RPL

Rpl[2]

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

TrickleTimer[3]

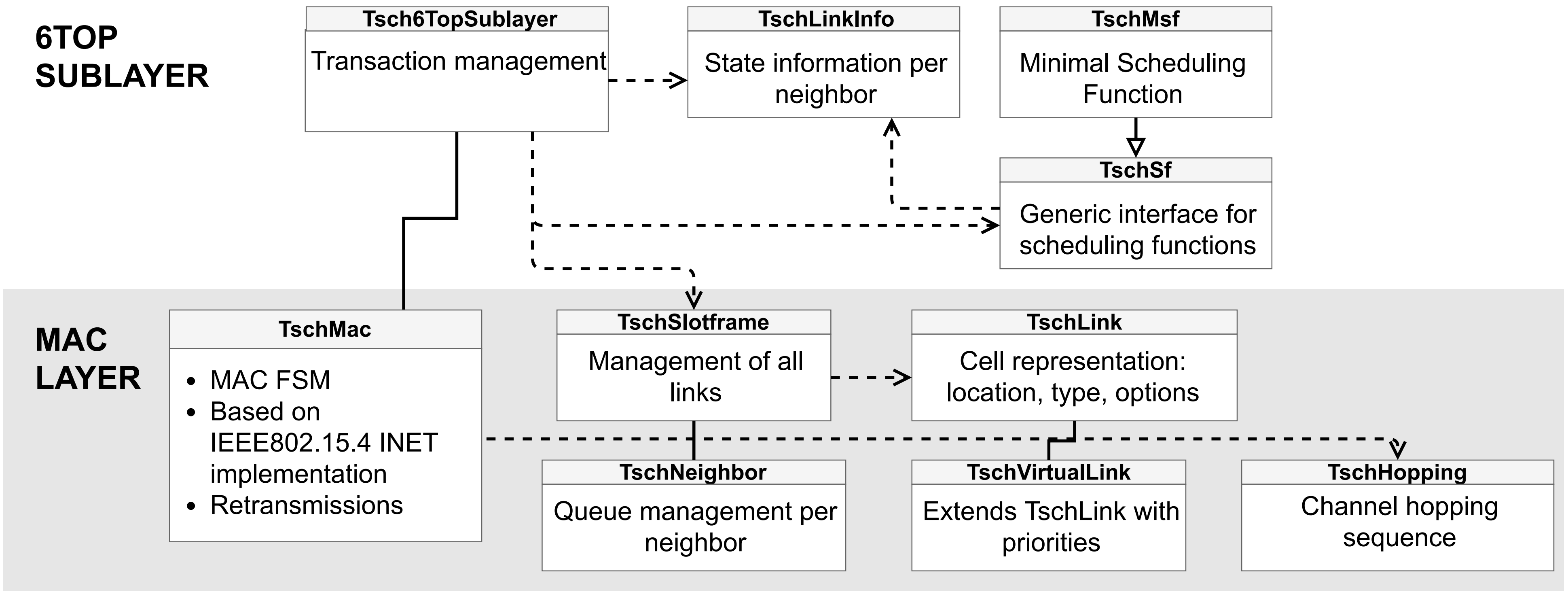
- Maintaining trickle intervals
- Triggering DIO broadcasts

ObjectiveFunction[4]

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

[2]RFC 6550. https://www.rfc-editor.org/rfc/rfc6550
[3]RFC 6206. https://www.rfc-editor.org/rfc/rfc6206
[4]RFC 6552. https://www.rfc-editor.org/rfc/rfc6552

Implementation - TSCH



4. Demos

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Network Bootstrapping

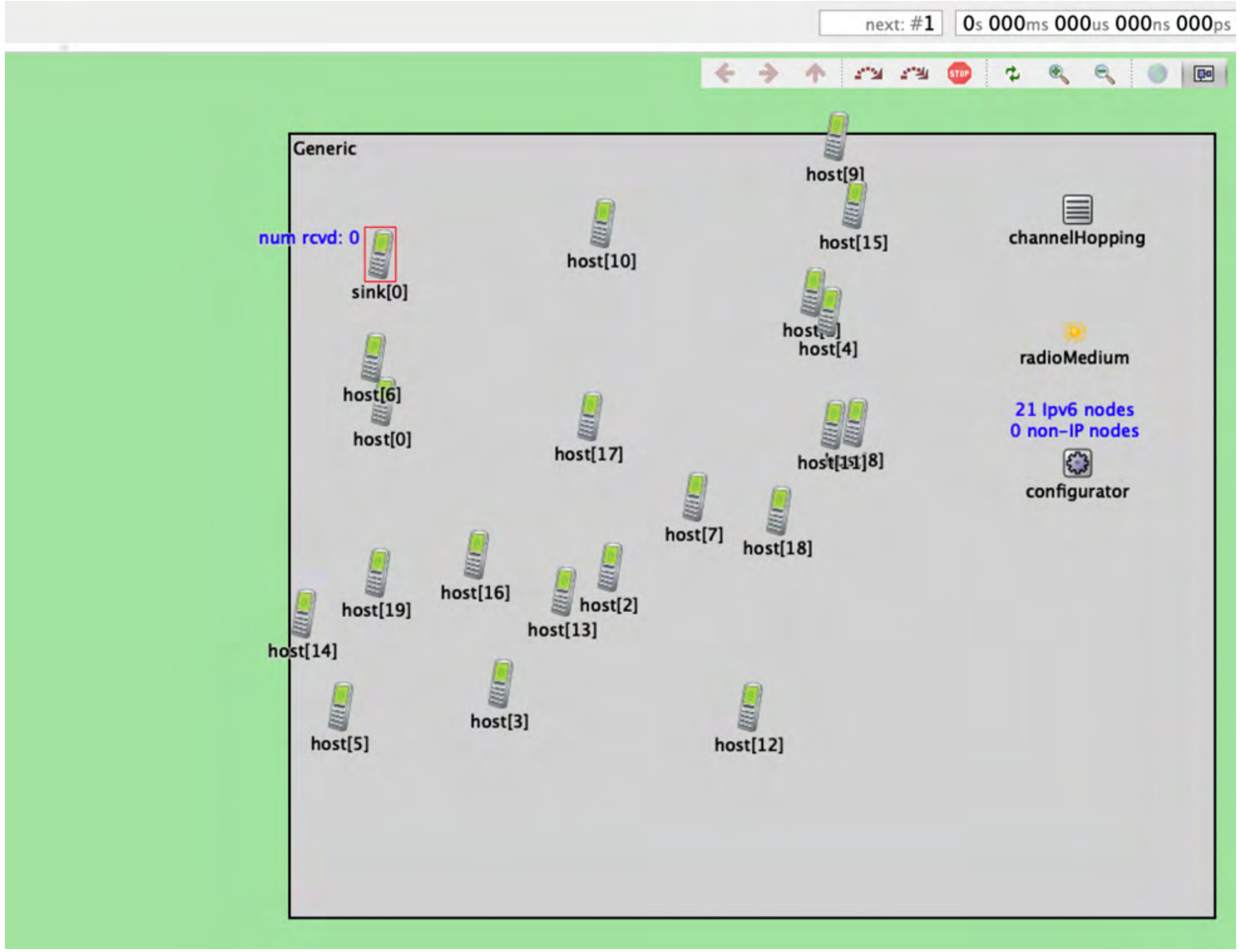
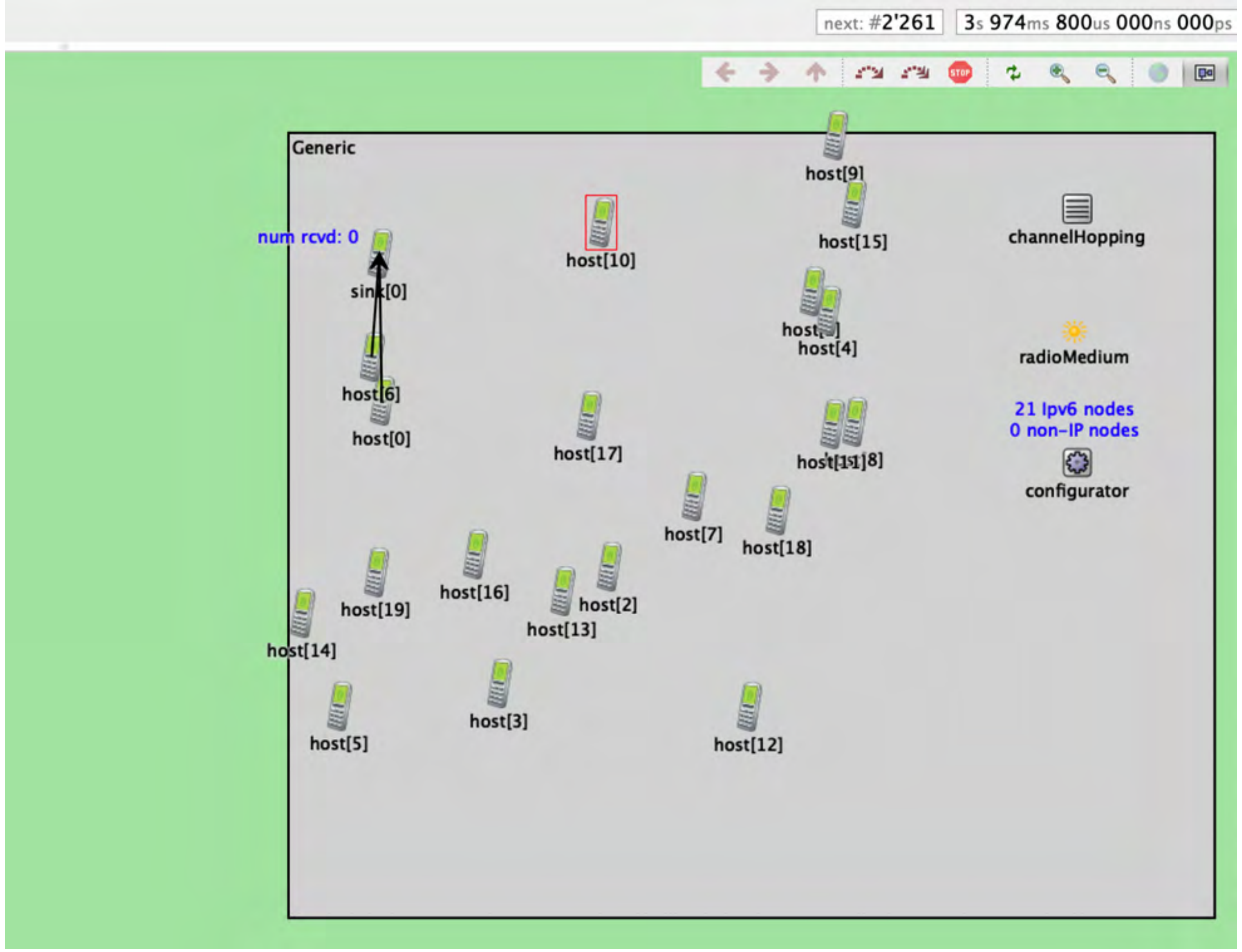


Figure 11: Network bootstrapping

Network Bootstrapping



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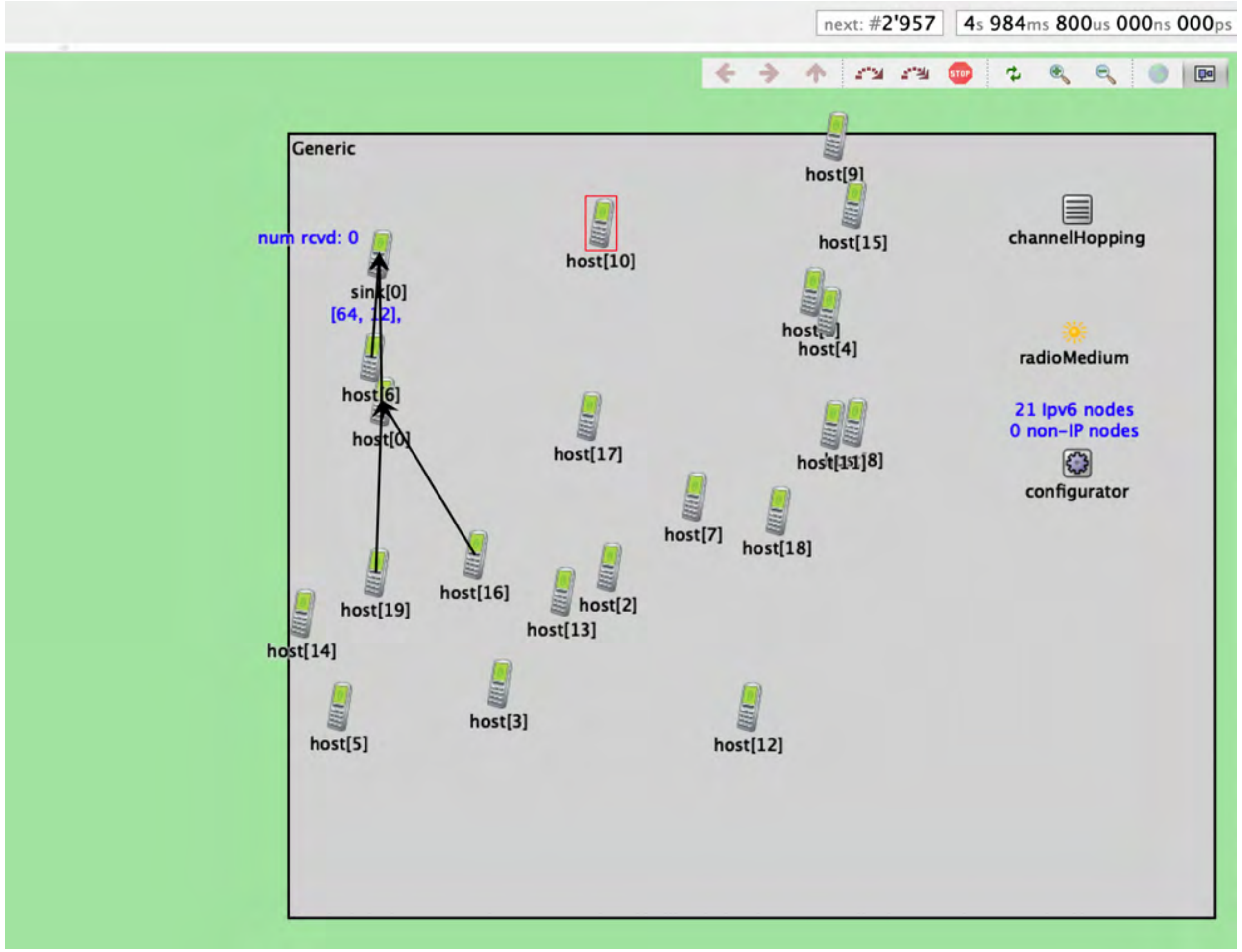

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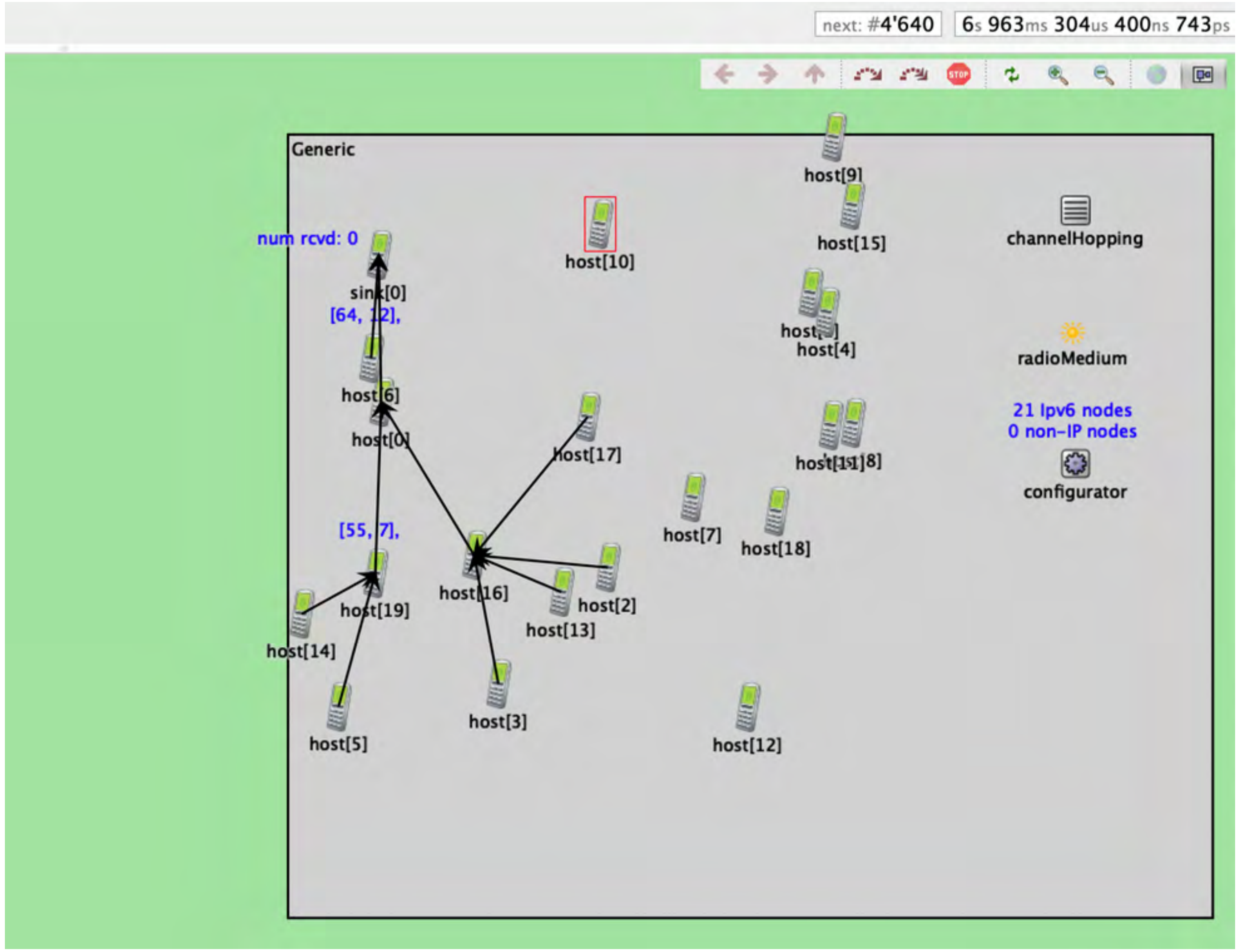

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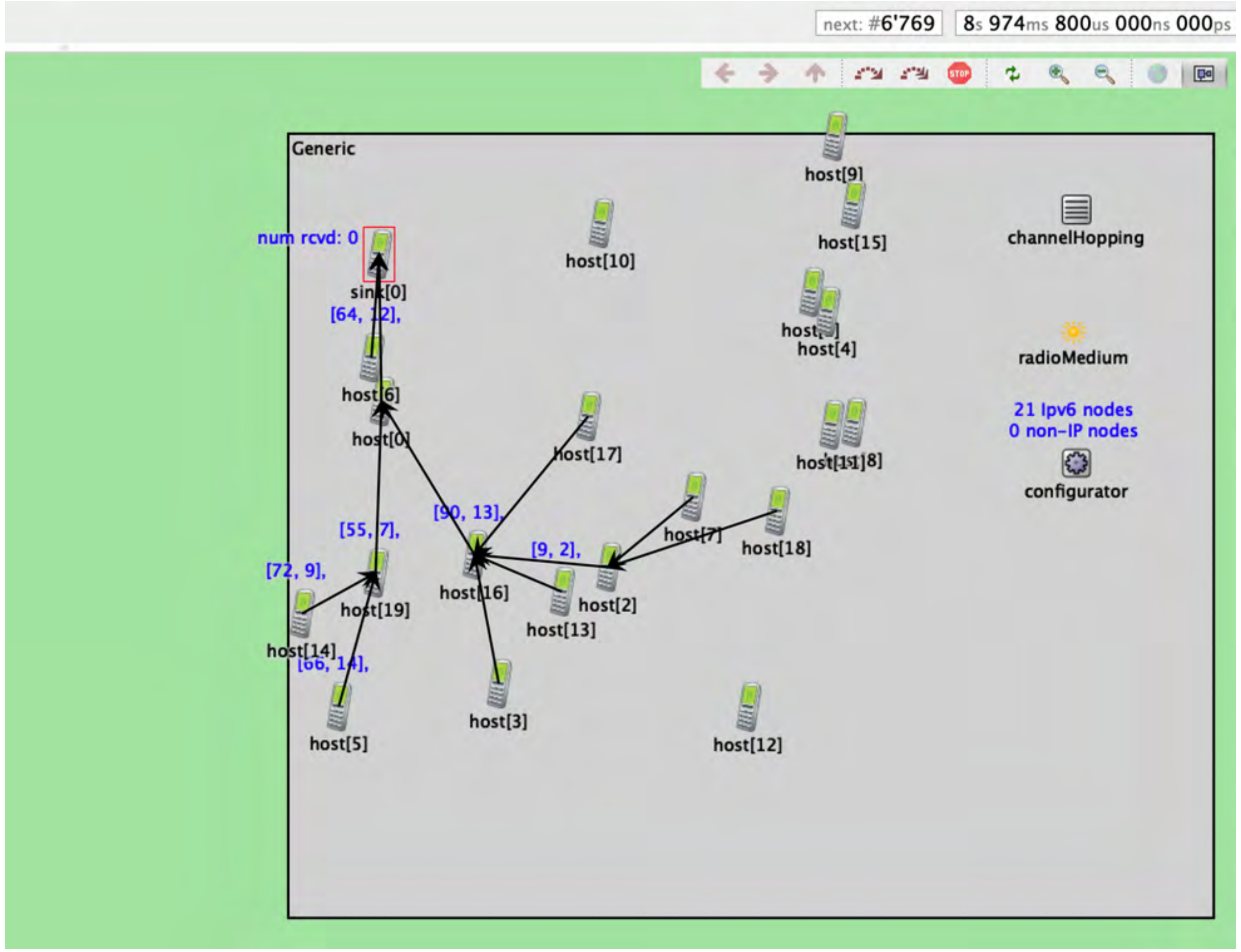

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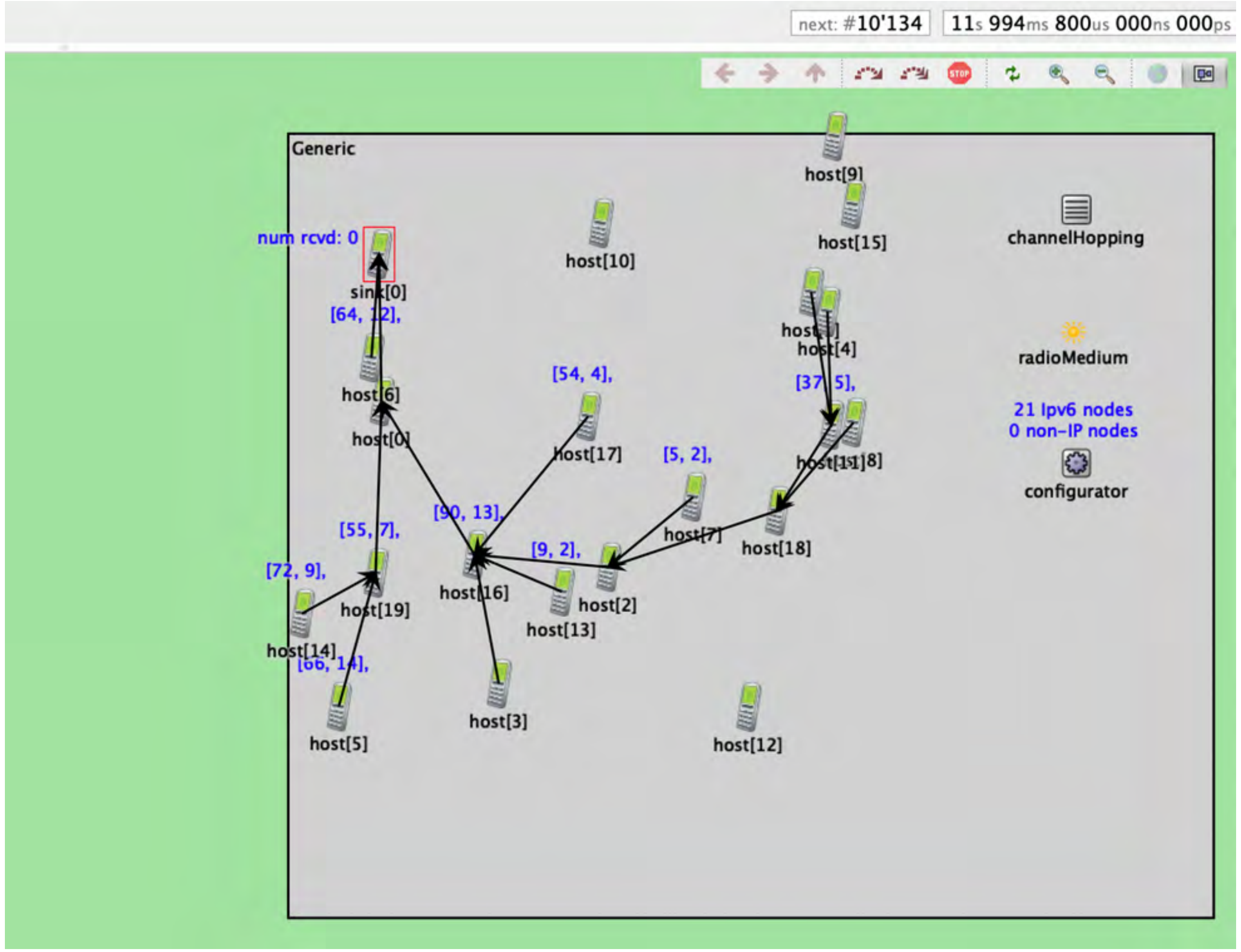

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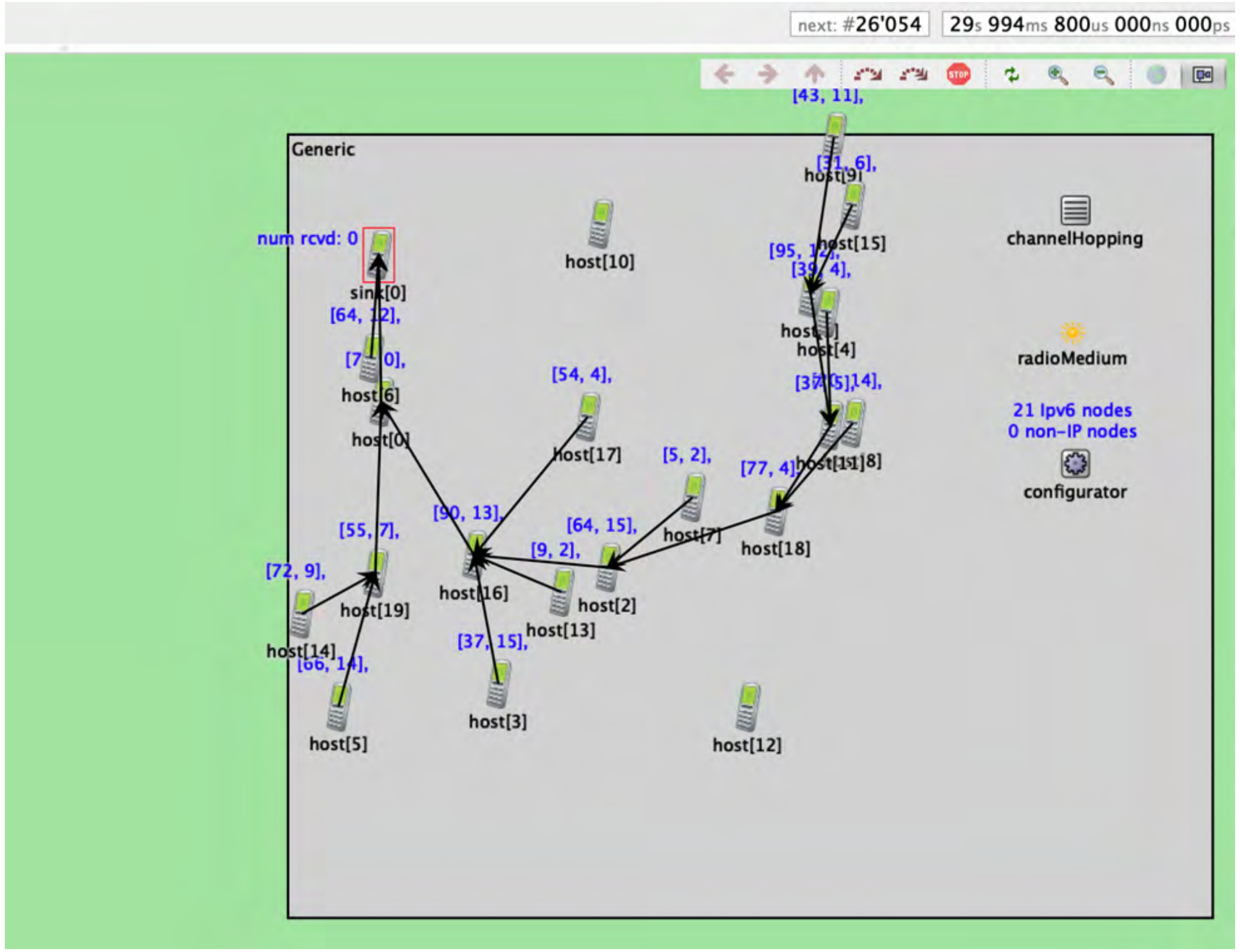

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Adapting to Traffic

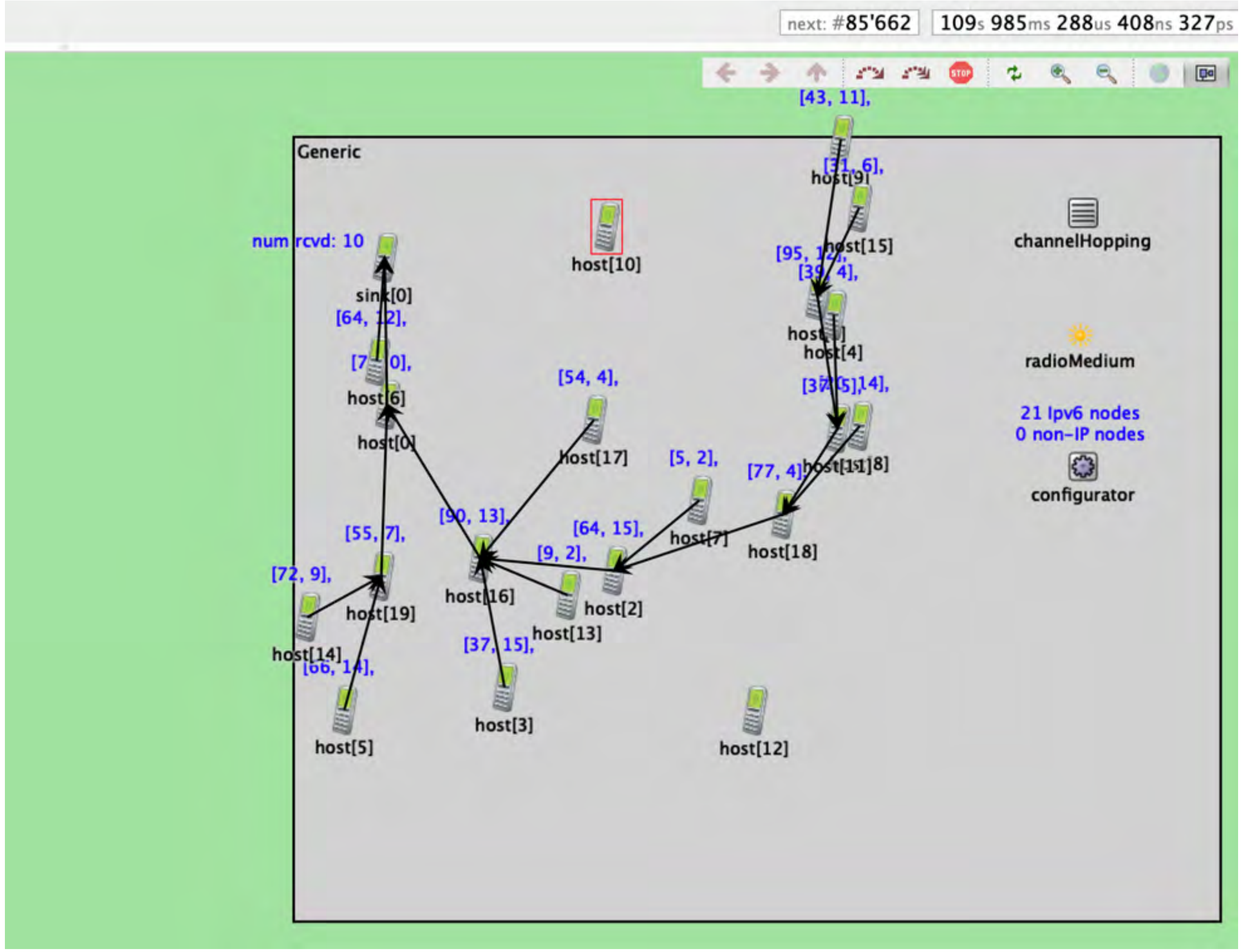
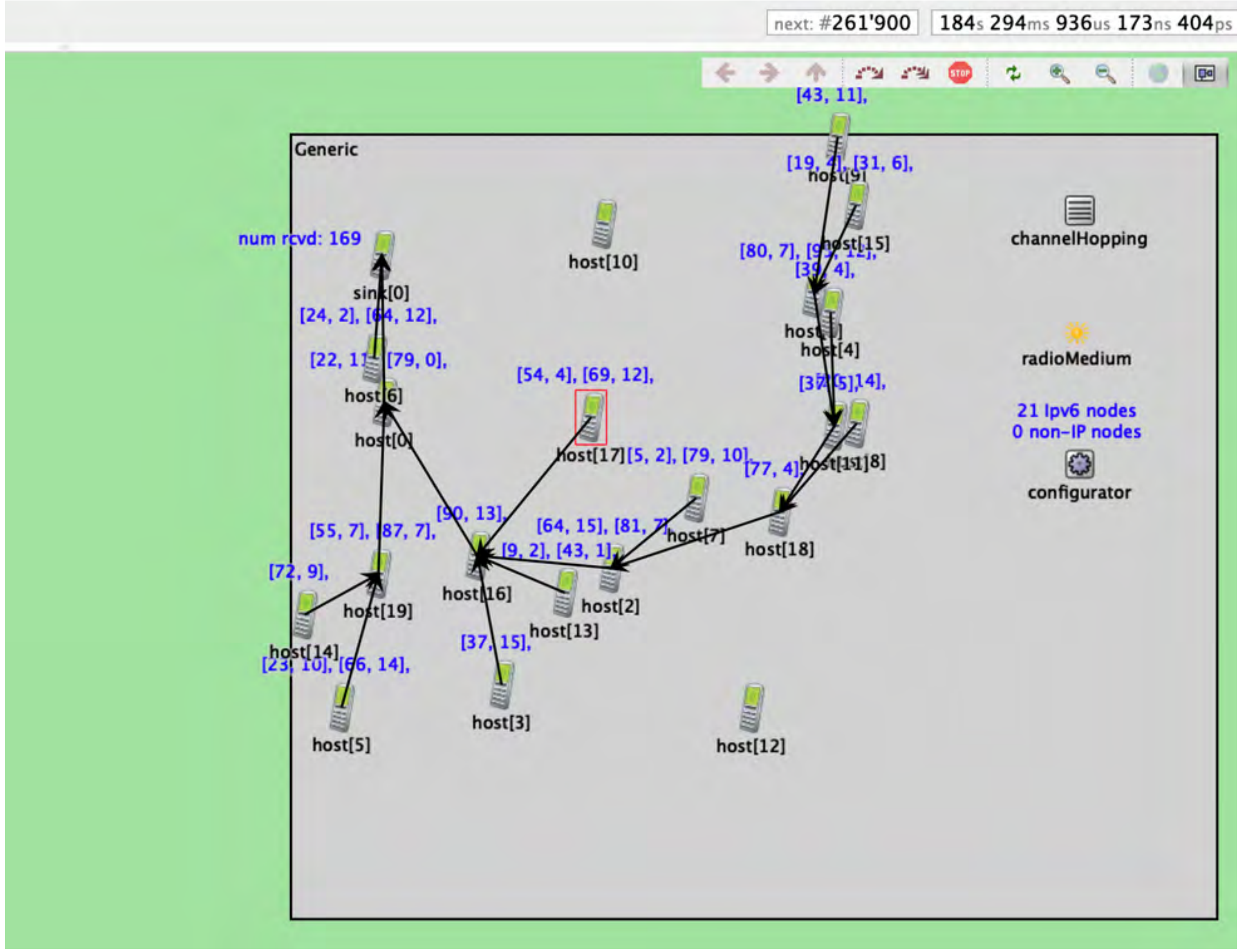


Figure 12: MSF adaptating number of scheduled cells to the traffic load (1 pkt/sf).

Adapting to Traffic



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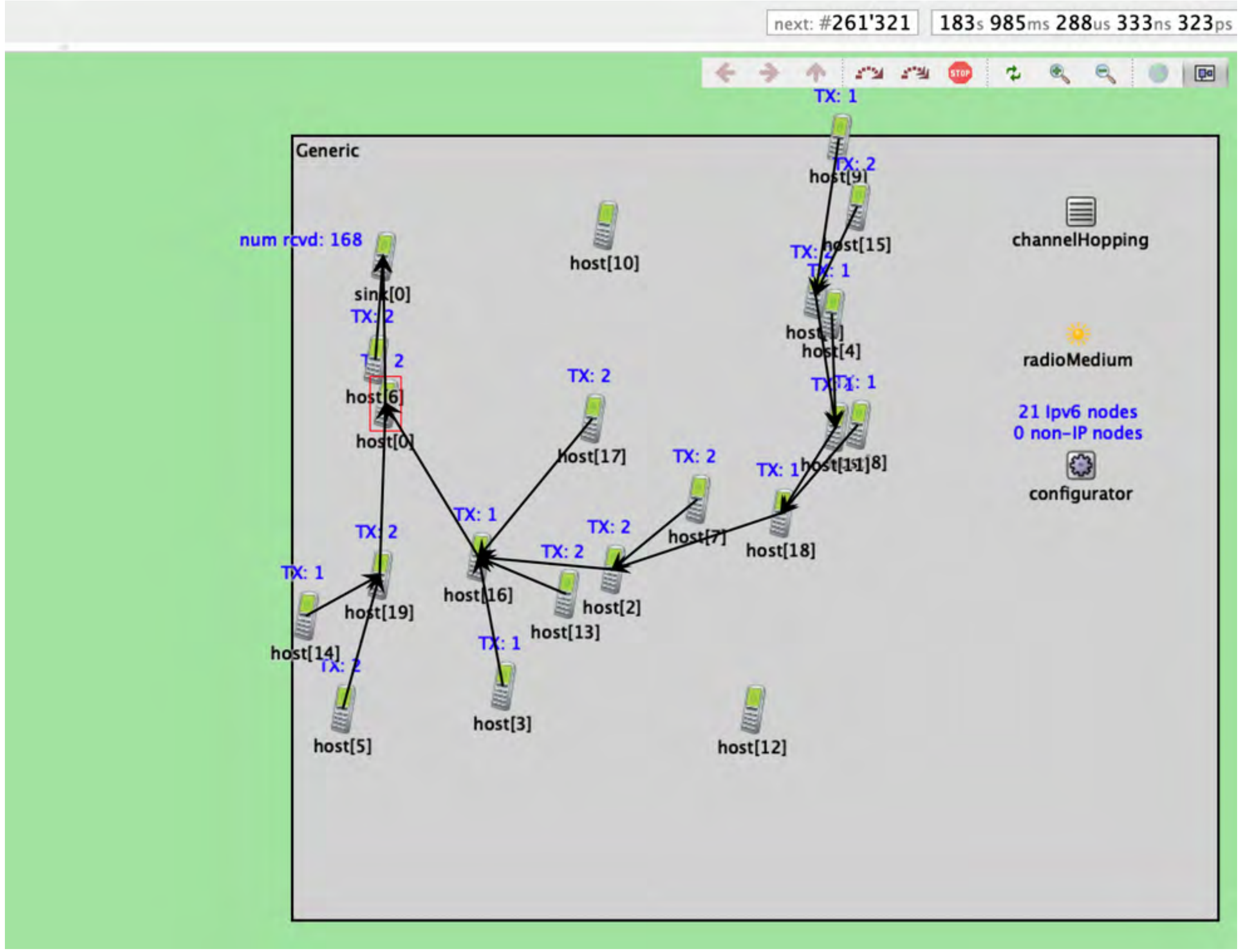

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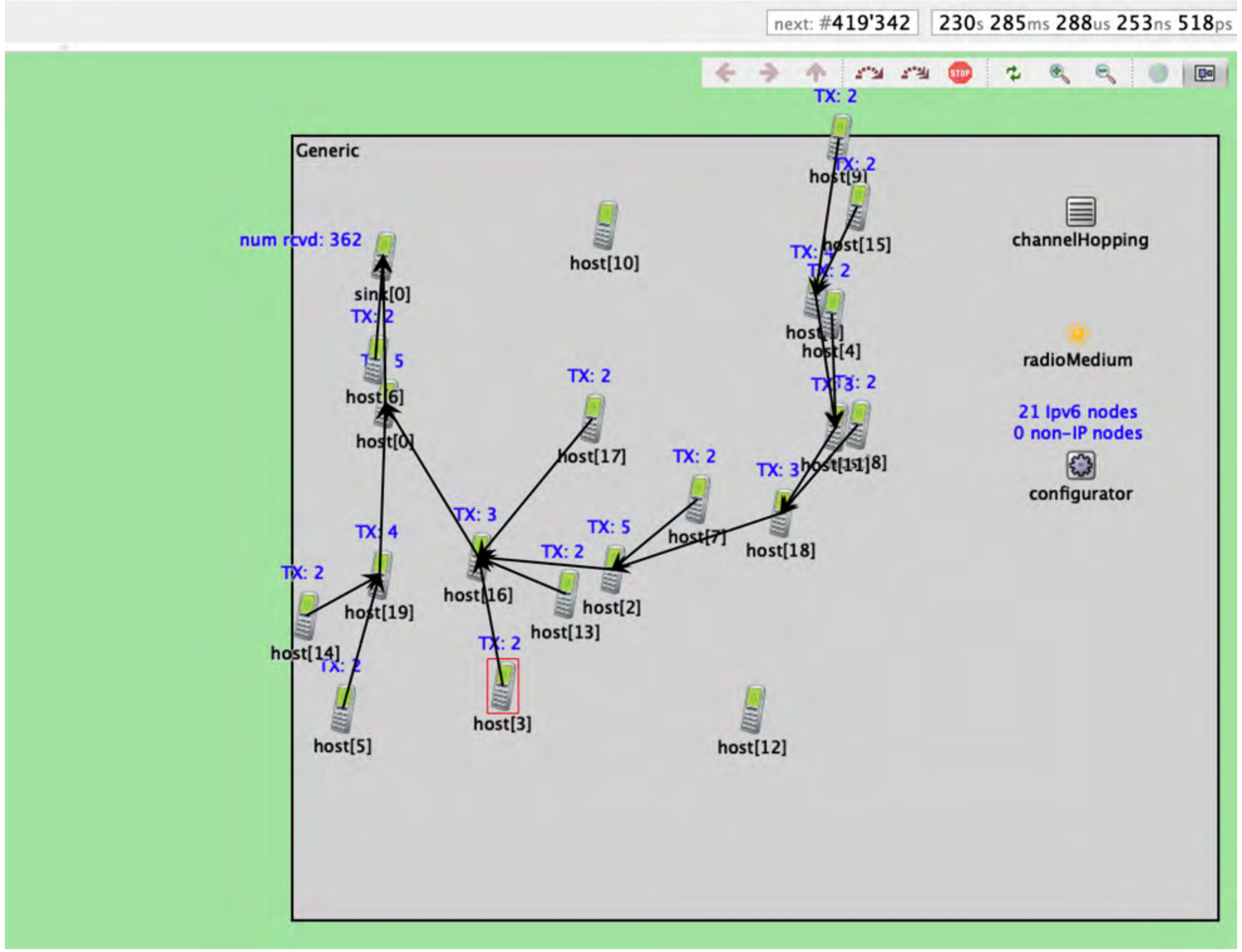

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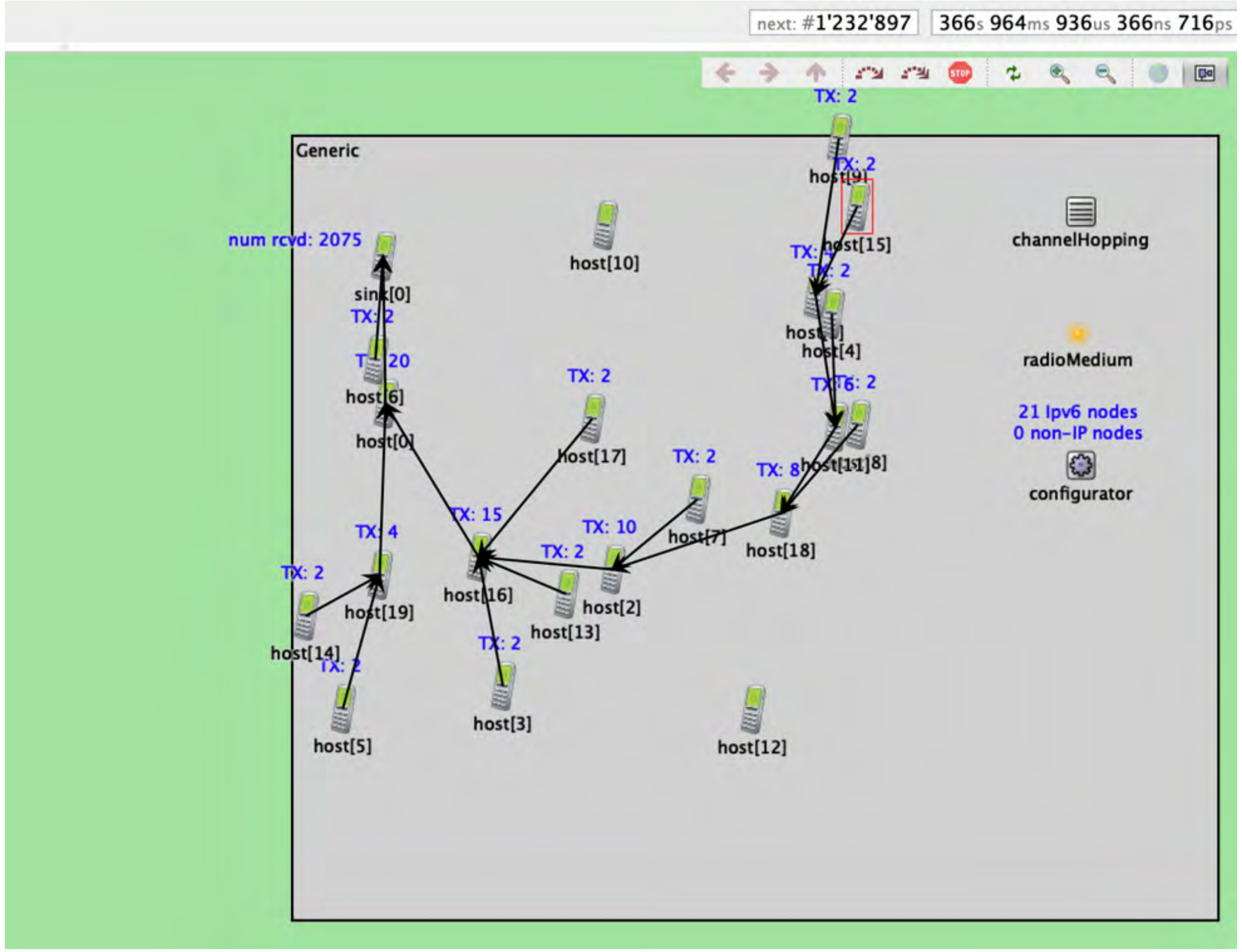

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Interference Avoidance

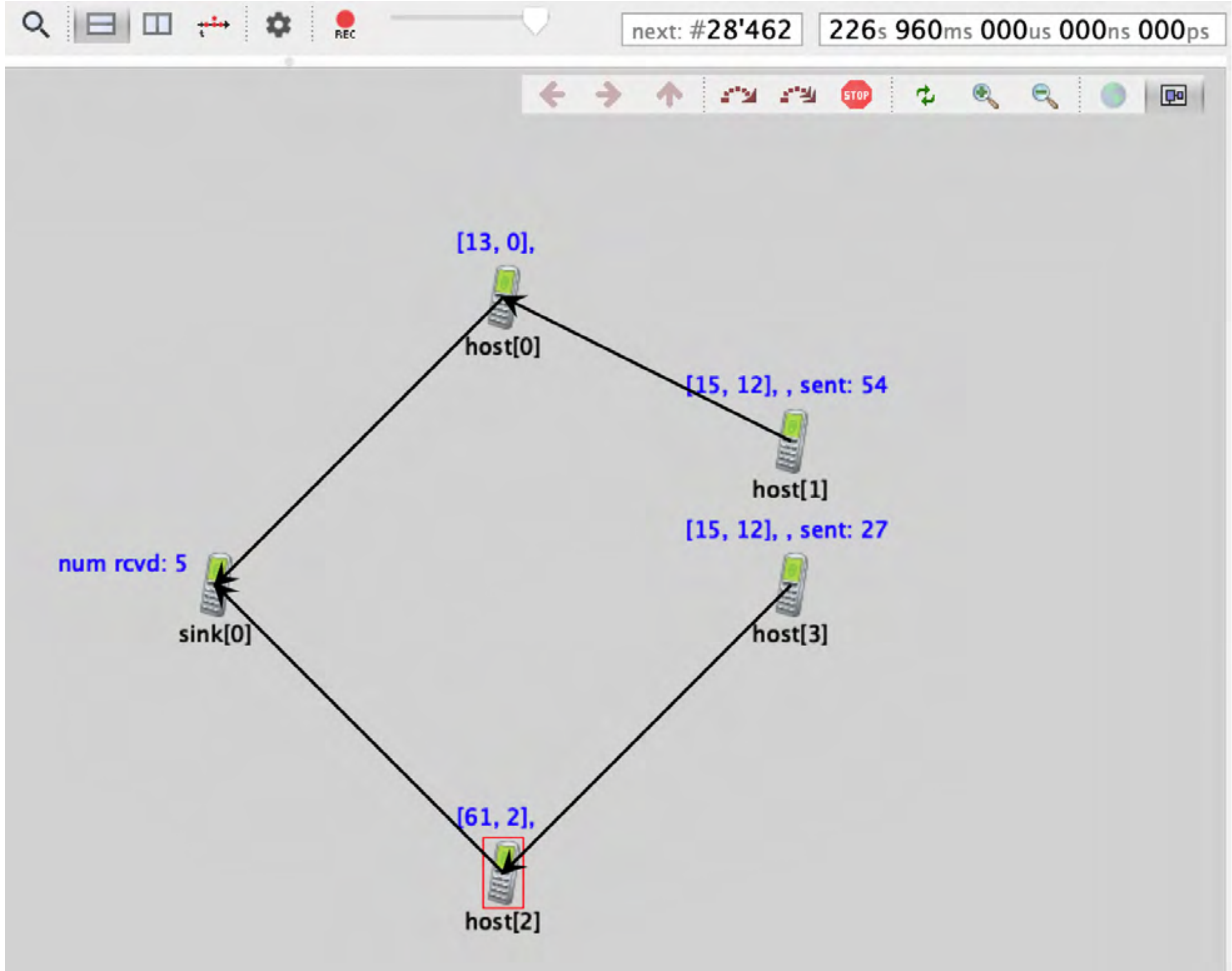
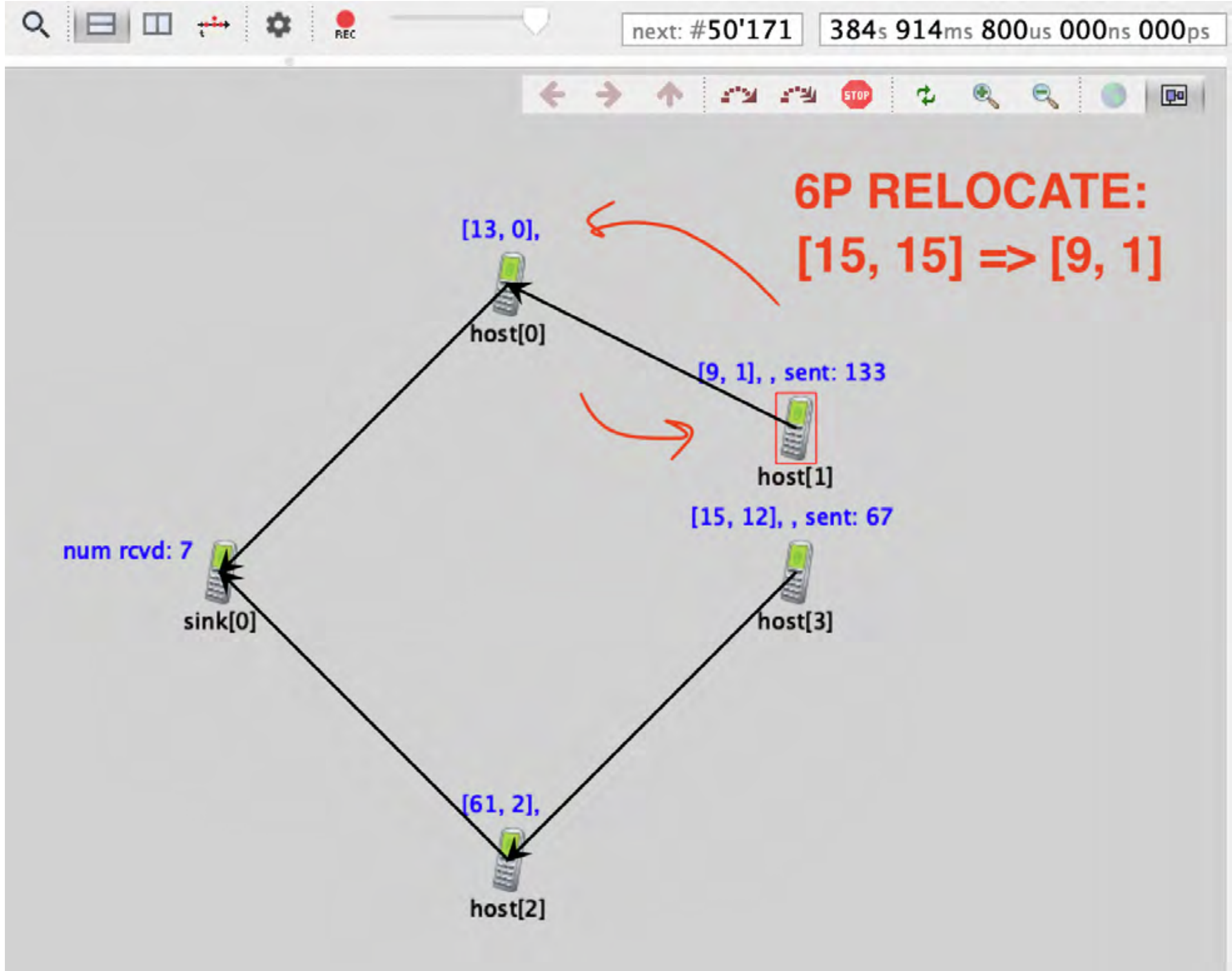


Figure 13: MSF relocating interfered cells after `HOUSEKEEPING_PERIOD` duration.

Interference Avoidance



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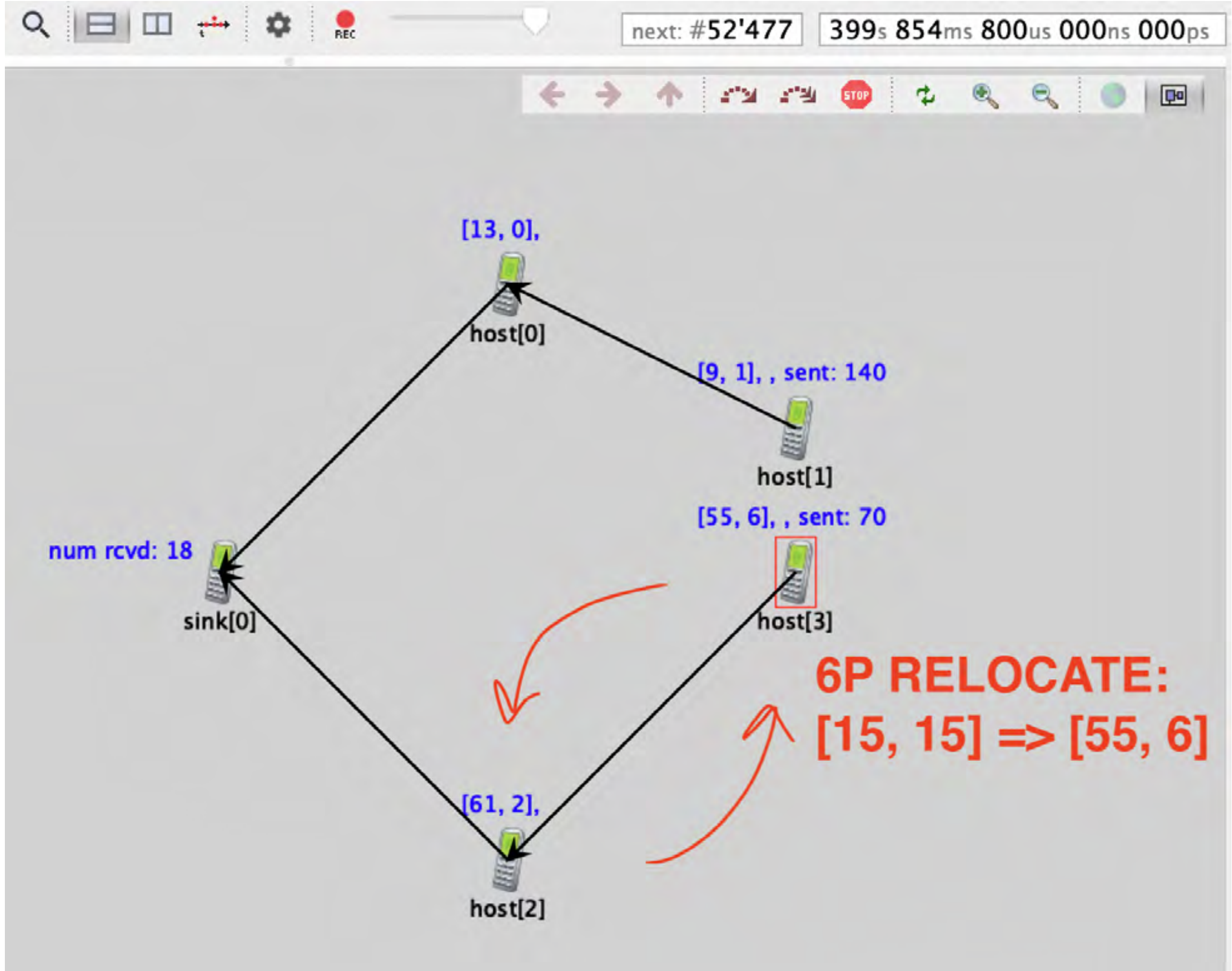

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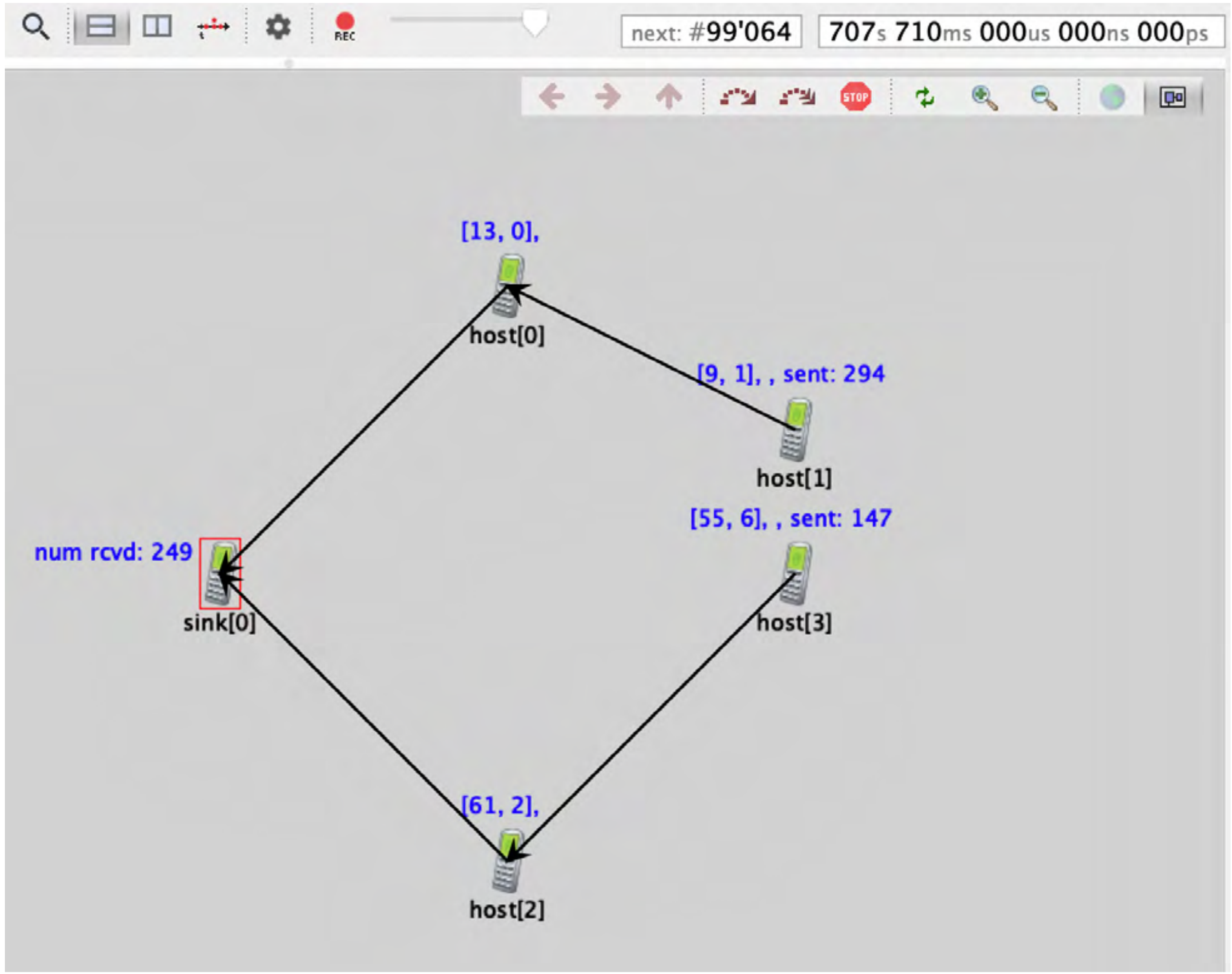

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5. Conclusion & Outlook

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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

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References

[1] Y. Shudrenko, D. Ploeger, K. Kuladinithi, and A. Timm-Giel, "A novel approach to enhance the end-to-end quality of service for avionic wireless sensor networks," *ACM Transactions on Internet Technology (TOIT)*, 2022.

[2] P. Thubert, *An Architecture for IPv6 over the Time-Slotted Channel Hopping Mode of IEEE 802.15.4 (6TiSCH)*, RFC 9030, May 2021. DOI: 10.17487/RFC9030. [Online]. Available: https://www.rfc-editor.org/info/rfc9030.

[3] ComNets, *Wireless Avionics Intra-Communications (WAIC) simulation model for OMNeT++, utilizing IEEE 802.15.4 Time Slotted Channel Hopping (TSCH)*, 2022. [Online]. Available: https://github.com/ComNetsHH/omnetpp-tsch/tree/6tisch.

[4] ——, *Routing Protocol for Low-Power and Lossy Networks OMNeT++ Simulation Model*, 2022. [Online]. Available: https://github.com/ComNetsHH/omnetpp-rpl.