DETERMINISTIC6G

IEEE 802.1 Interim Meeting

Simulation Framework for Wireless 5G/6G TSN Bridges with OMNeT++/INET

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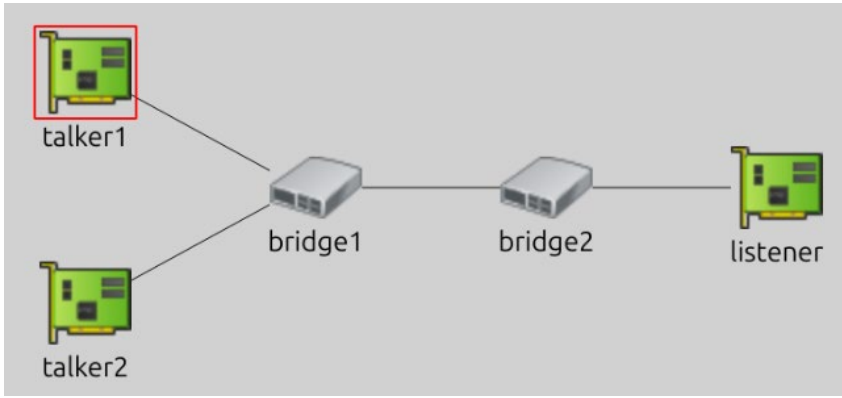
Agenda

- Converged 6G/TSN networks
- DETERMINISTIC6G Simulation Framework
- Demo
- Conclusion
- Outlook

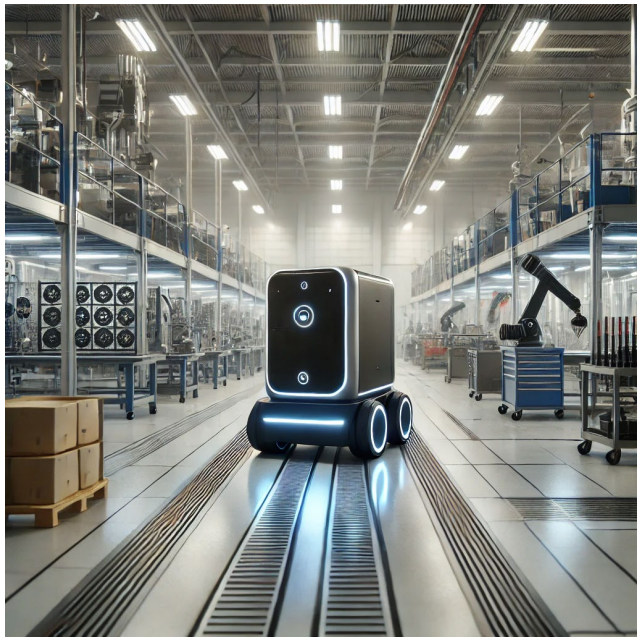
Converged 6G/TSN Networks

TSN networks:

- Devices (endpoints and bridges) implement TSN features
- Ethernet-links:
  - Constant link speed
  - Low packet loss



Converged 6G/TSN Networks



Images generated by DALL-E

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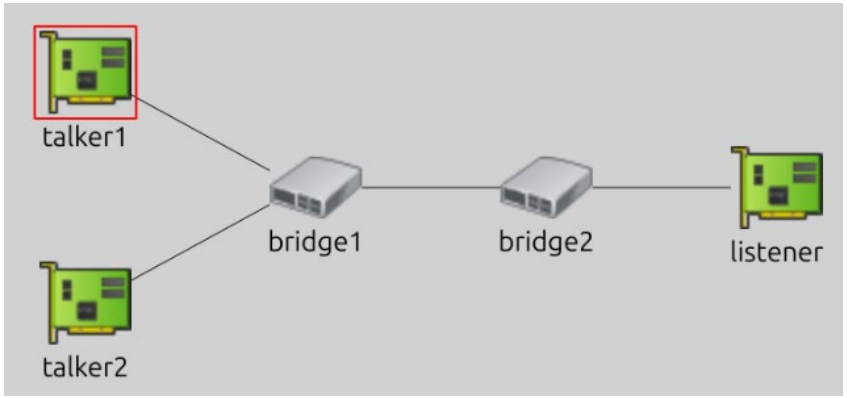

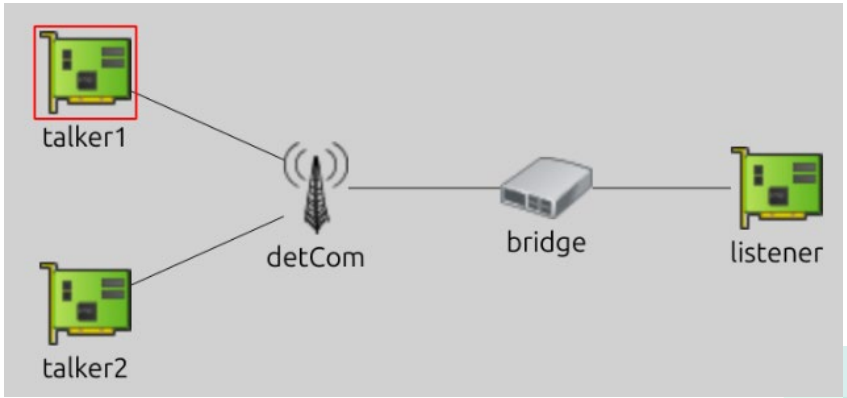

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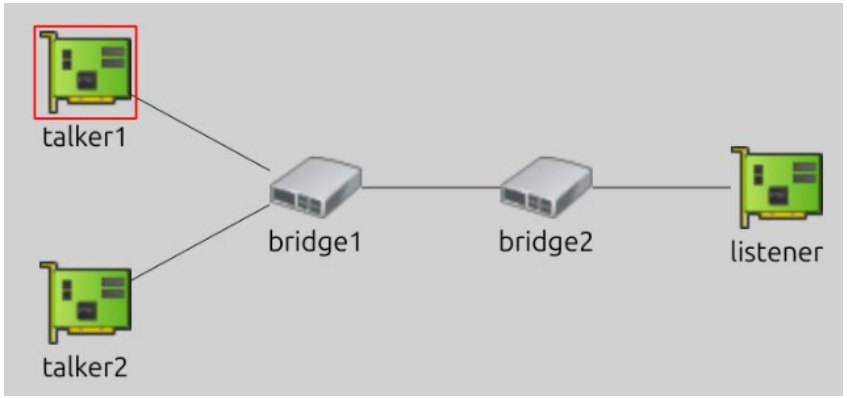
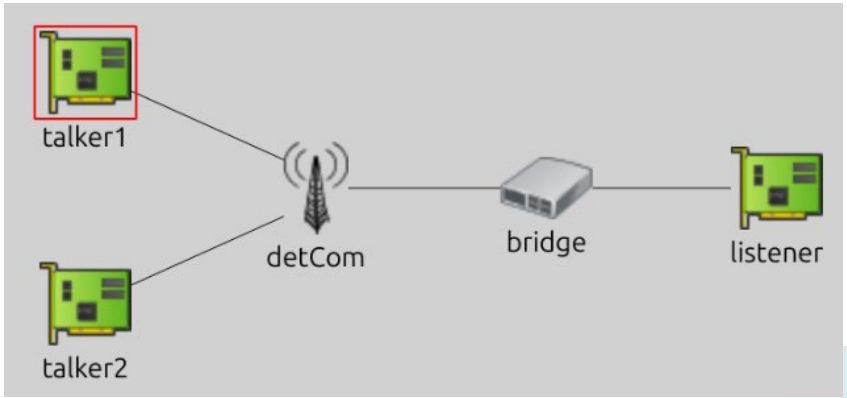


Converged 6G/TSN networks:

- DetCom node needs to provide TSN features
- Wireless Links:
  - Variable packet delay
  - Higher packet loss



Converged 6G/TSN Networks: Current Simulation Frameworks

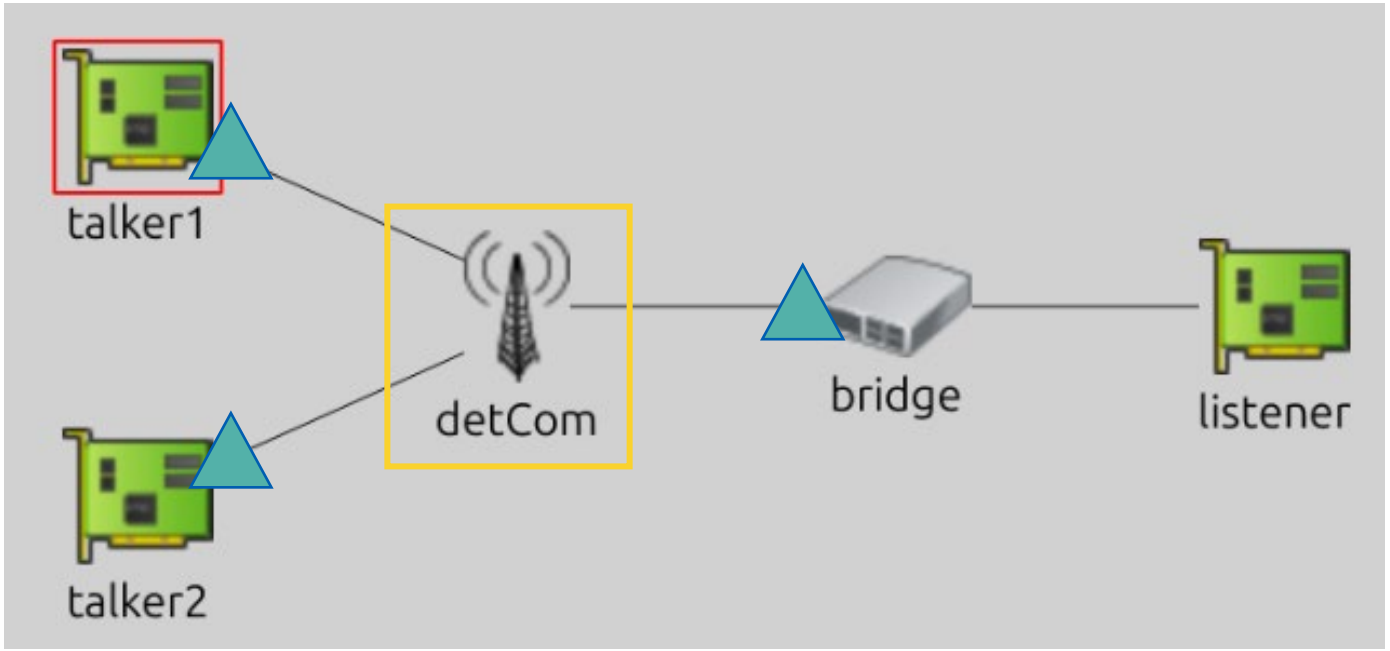
Existing simulation frameworks:

- Wired TSN networks:
  - e.g. NeSTiNg from USTUTT and INET
  - ➔ No 5G/6G features
- Wireless 5G/6G networks
  - e.g. Simu5G
  - ➔ No deterministic communication mechanisms

Problem: There is no existing simulation framework to simulate converged 6G/TSN networks.

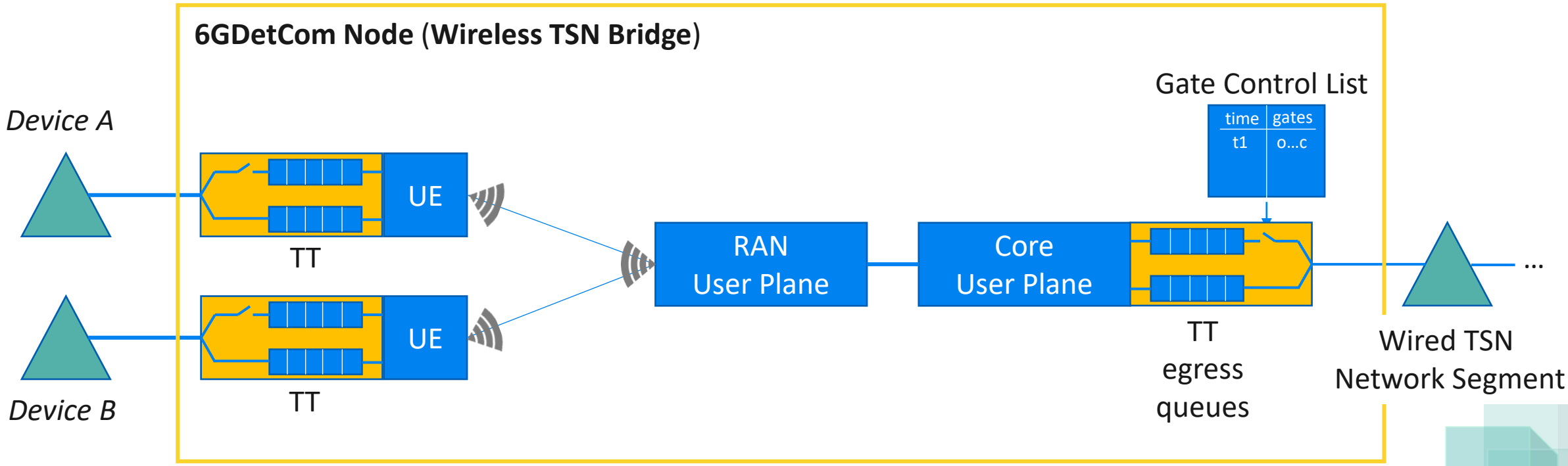
Goal: Evaluation platform for analysis of end-to-end deterministic communication (TSN/DetNet) in converged 6G/TSN networks.

Converged 6G/TSN Networks



Deterministic6G Simulation Framework: Architecture

TT: TSN Translator
UE: User Equipment
RAN: Radio Access Network
PD: packet delay



3GPP TS 23.501

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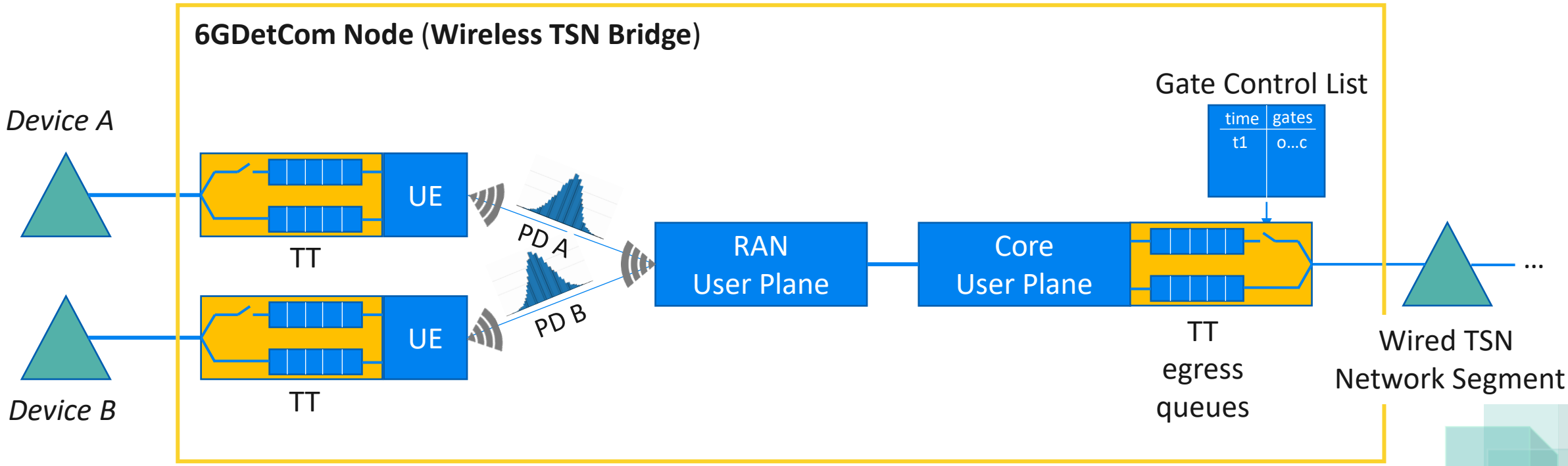
6GDetCom Node: Wireless TSN Bridge with characteristic packet delay (PD) for 6G



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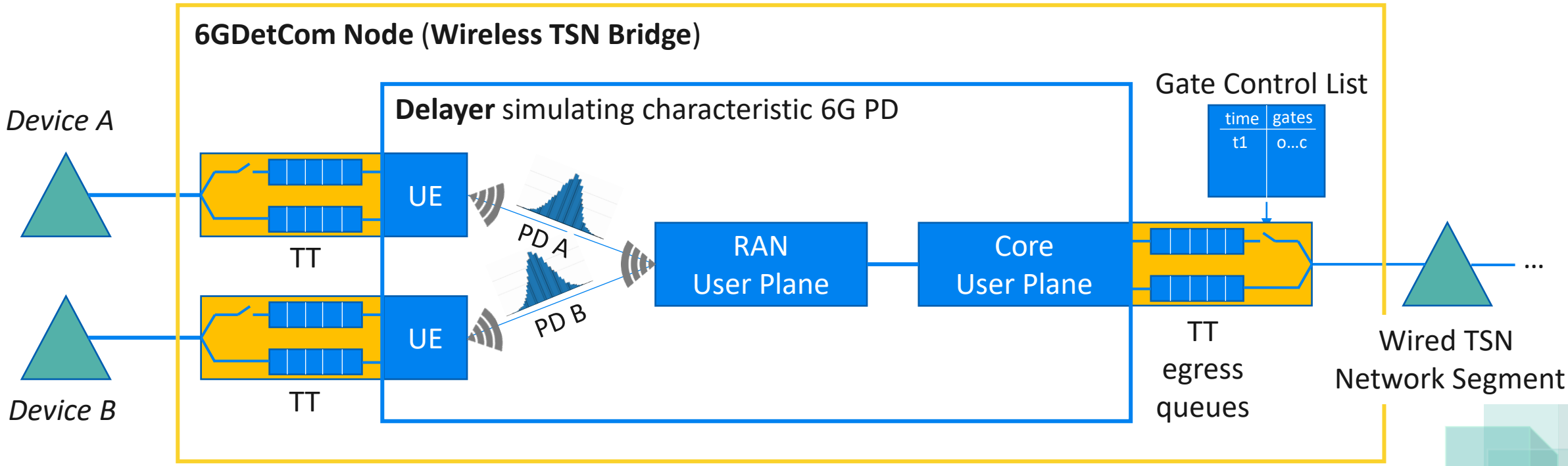

Deterministic6G Simulation Framework: Overview

- Novel **data-driven** simulation approach**:**
  - Integrating real 5G measurements into TSN simulator
  - Only possibly through joint (contributions of various project partners)
  - Validation at very early stage of 6G development possible

- Based **OMNeT++/INET** simulator (open-source release of extensions)
  - Most popular platform for TSN simulations

➔ Enables **realistic quantitative** validation of DETERMINISTIC6G concepts

Deterministic6G Simulation Framework: Overview

Simulation of characteristic Packet Delay (PD):

- PD distribution functions (e.g., a normal distribution)
- Stochastic processes (e.g., a random walk process)
- Histograms from PD measurements (see below)

Available PD models and data sets[1]:

- 5G experimental platform (KTH Stockholm)
- 5G testbed of industrial shop floor (Ericsson)
- Wired TSN bridge (University of Stuttgart)

[1] Available on Github: https://github.com/DETERMINISTIC6G/deterministic6g_data

Deterministic6G Simulation Framework: Overview

6GDetCom Node features most relevant TSN mechanisms

TSN mechanisms inherited from wired TSN bridge model of INET:

- Shaping:
  - Time-aware Shaper
  - Credit-based Shaper
  - Asynchronous Traffic Shaper
- Per-stream Filtering and Policing
- Frame Replication and Elimination
- …

Deterministic6G Simulation Framework: Implementation

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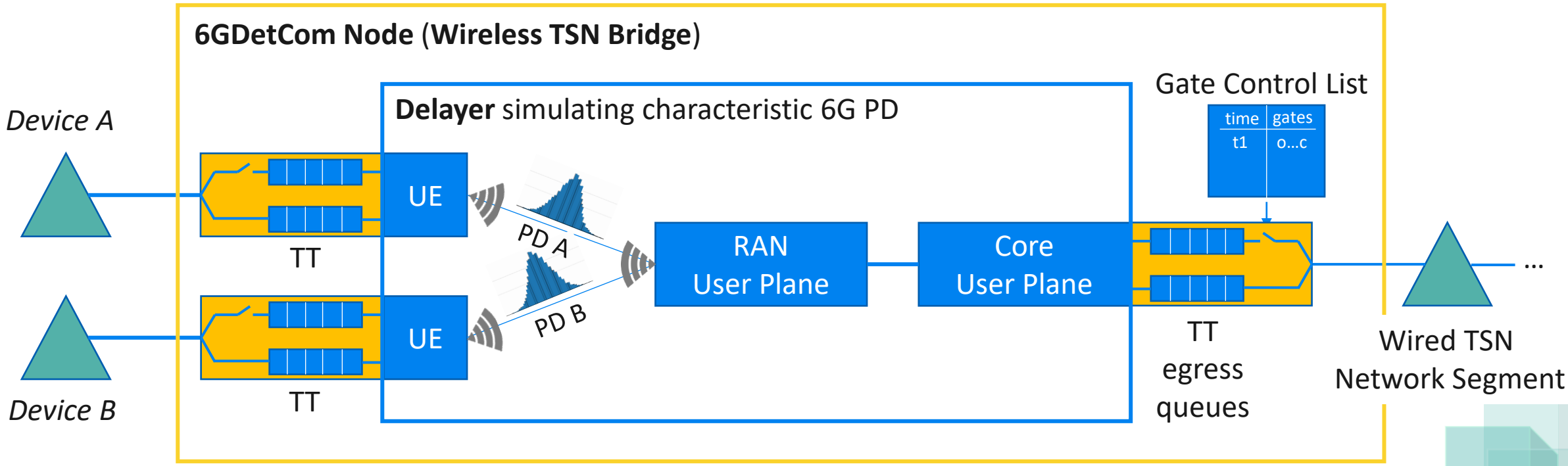

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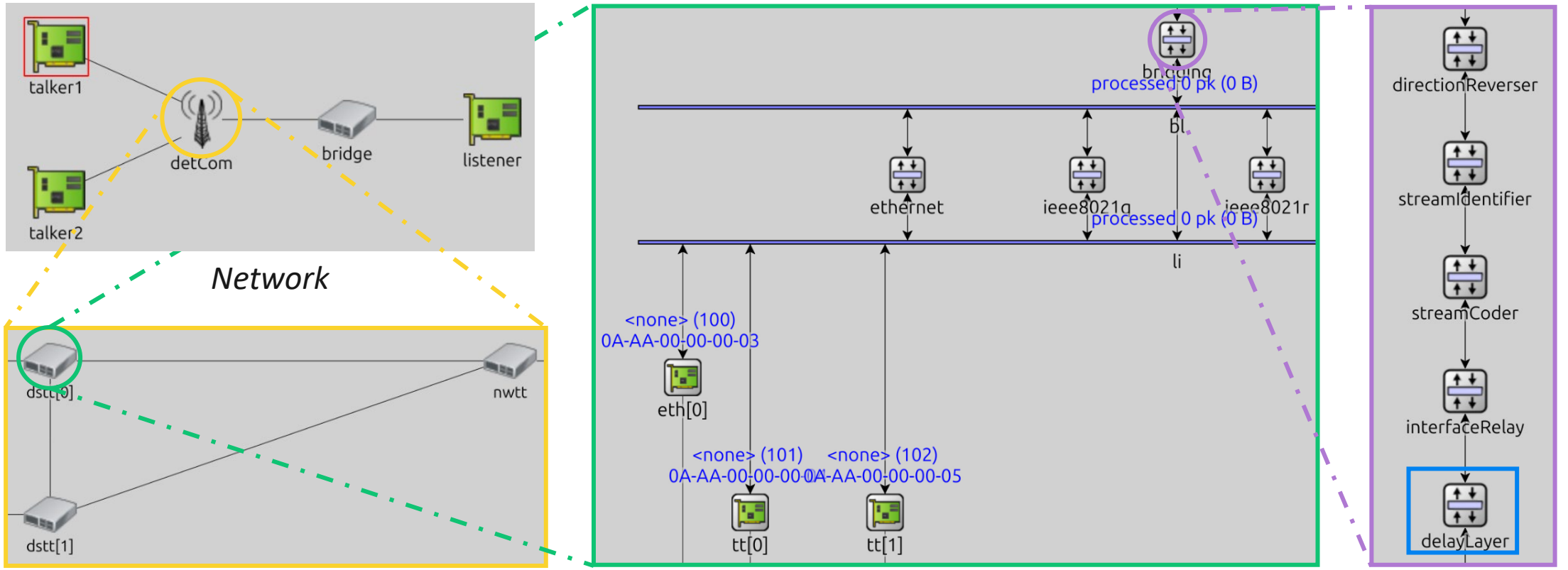
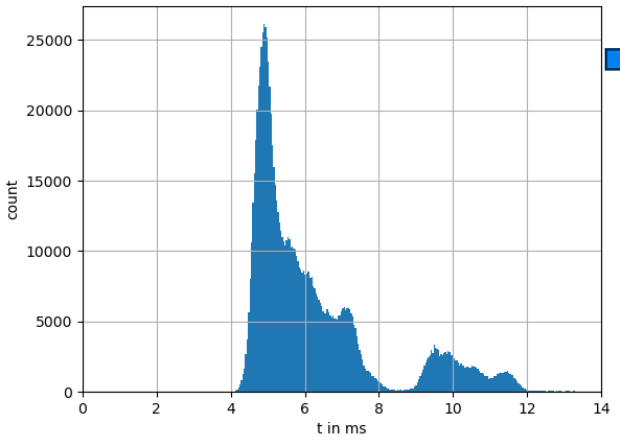
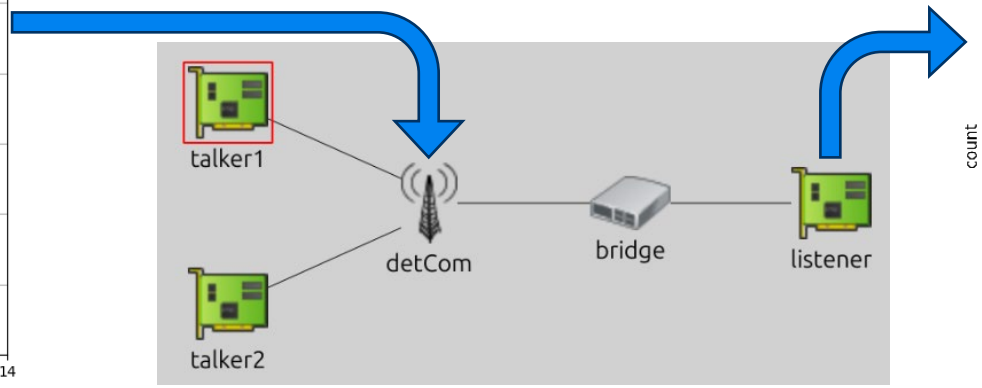
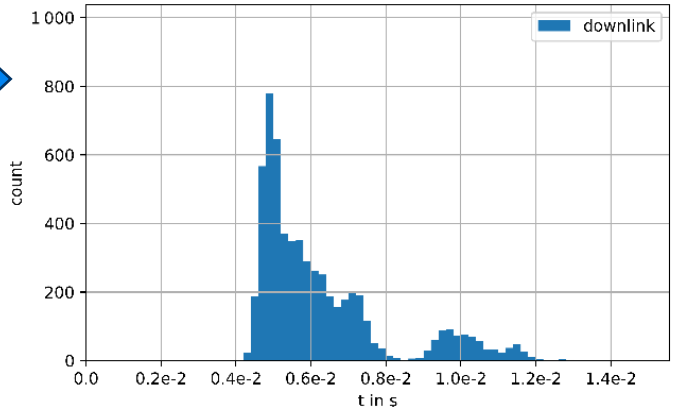


Deterministic6G Simulation Framework: Usage







Simulation Input

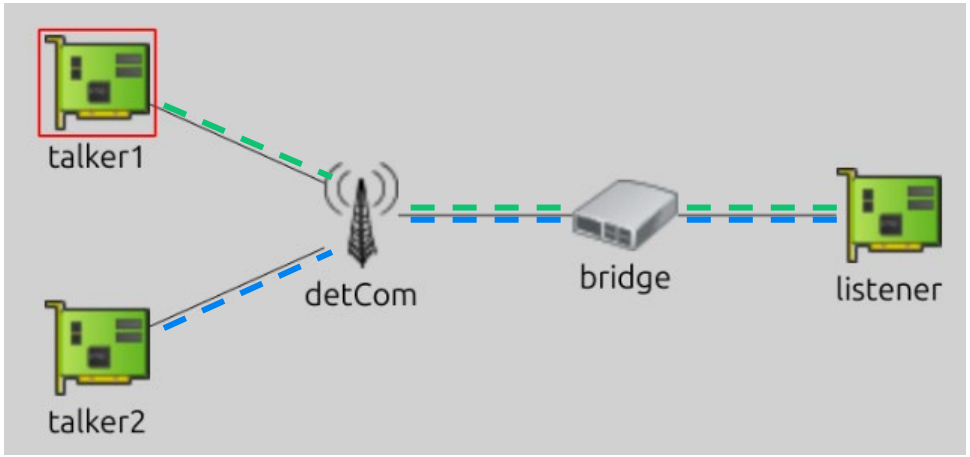
```
*.histogramContainer.histograms =
{uplink: "uplink.xml"}

*.detCom.dstt[0].delayUplink =
rngProvider("histogramContainer","uplink")
```

Resulting end-to-end delay in simulation

Demo

- Two Streams: (Stream 1 and Stream 2)
  - Cycle: $10\ ms$
  - Max. Delay: $10\ ms$
  - High Packet Delay Variation (PDV)



- Analyze two different schedules

Conclusions

- **Simulator:** 1st release publicly available
  - Data-driven simulations based on realistic delay models from measurements
  - Data plane simulation models
    - TSN mechanisms
    - Characteristic packet delay

➔ Ready for end-to-end simulation in converged 6G/TSN networks

Open Source Code & Data

GitHub

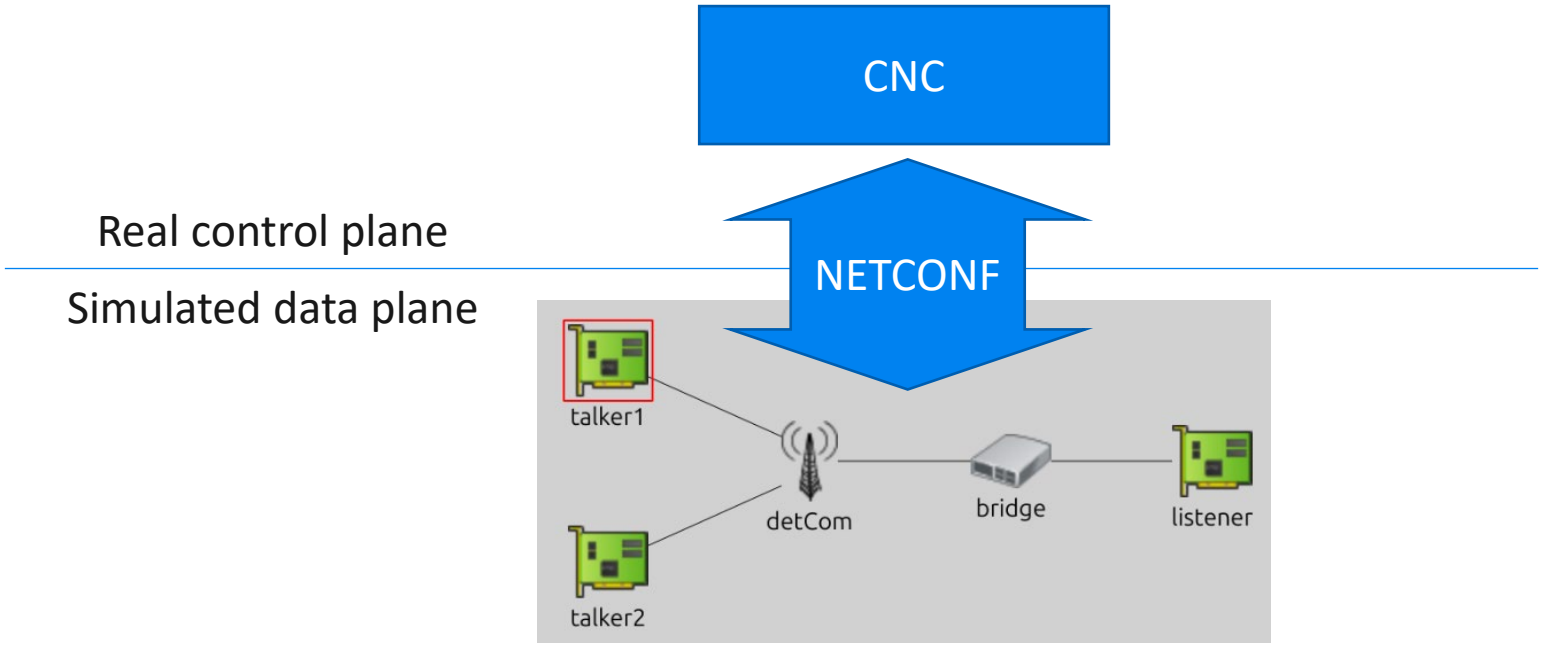
https://github.com/DETERMINISTIC6G

zenodo

https://zenodo.org/communities/deterministic6g/

Outlook

- **Time Synchronization**
- **Control plane simulation models** for dynamic adaption of data plane
- More…



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