Universität Rostock Traditio et Innovatio

A Simulation Model for Investigating Clock Synchronization Issues in Time-Sensitive Networks

3. KuVS Fachgespräch "Network Softwarization"

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Introduction and Motivation

- Realtime (RT) communication for process control and manufacturing systems is mandatory for modern industrial automation
- IEEE 802.1 Time-Sensitive Networking (TSN) task group defines a set of standards for time-sensitive data transmission over Ethernet
- Many applications in the (Industrial) Internet of Things
- Production robots working together in a production line must be precisely synchronized in a smart factory

Industry robots made by Kuka

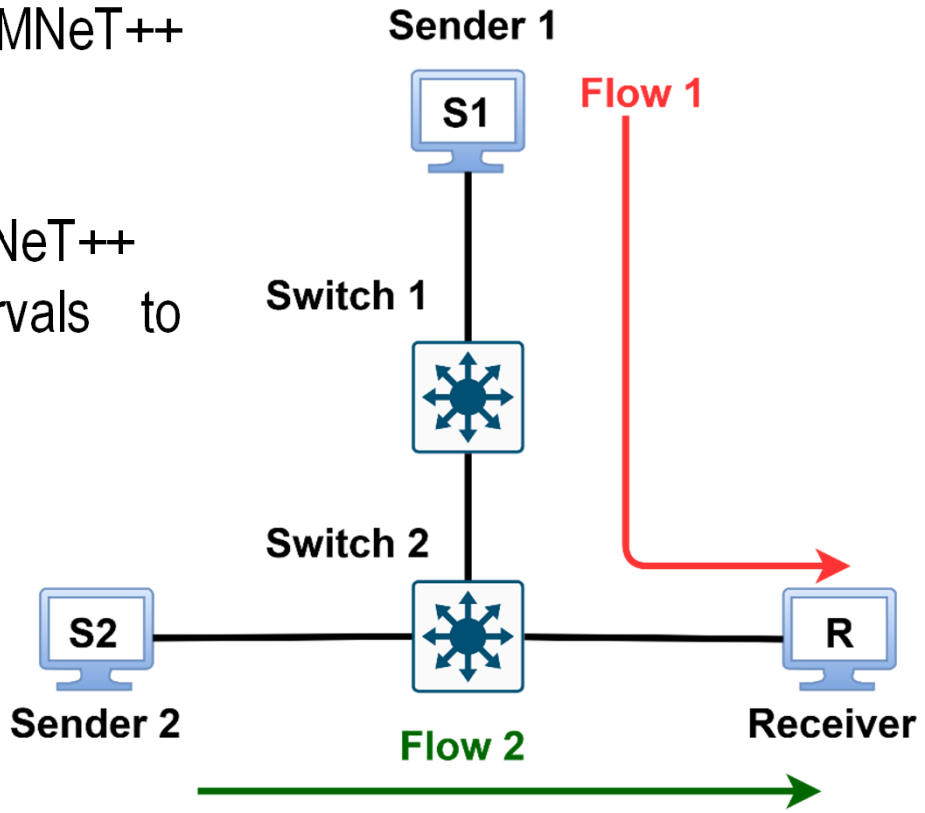
Time-critical communication when handing over work pieces.

Basics of IEEE 802.1AS

- To enable RT communication, time synchronization is required
- IEEE 802.1AS generalized Precision Time Protocol (gPTP) describes mechanisms to synchronize the clocks of network components
- Two types of systems: time-aware bridges and time-aware end stations
  - Time-aware end station can be selected as grandmaster (GM)
  - GM provides the timing information to all time-aware systems

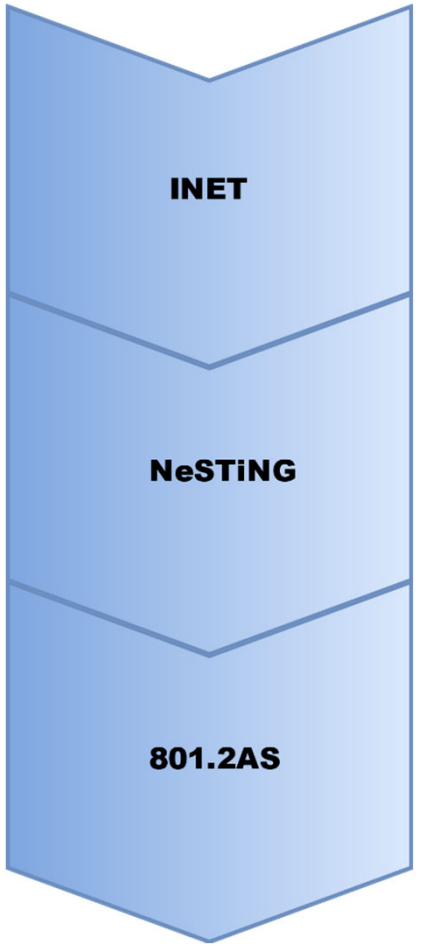
Contributions

- Integration of a simulation model that implements IEEE 802.1AS in the OMNeT++ framework NeSTiNg
- Simulation of a clock model with drift
- Proof of concept and evaluation in OMNeT++
- Analysis of resynchronization intervals to compensate clock drift



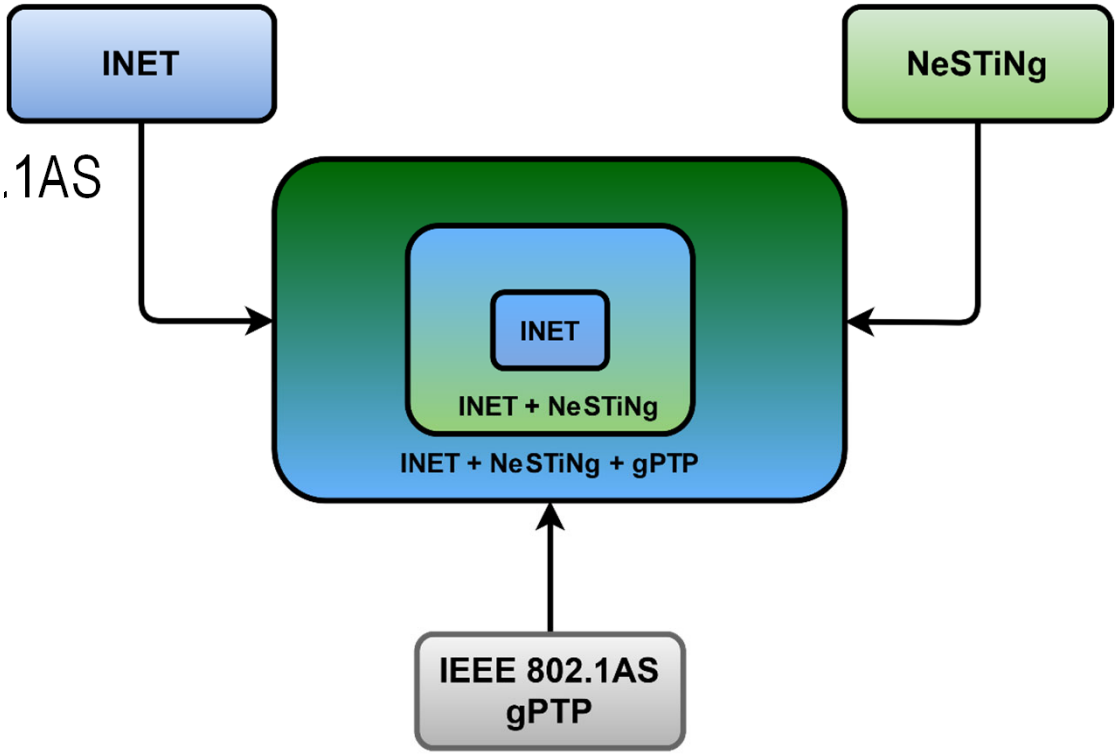
Methodology

- INET
  - INET contains models for many protocols and standards
  - Implemented the basic model of IEEE 802.1Q
- NeSTiNg
  - Scheduling
  - Routing
  - Queueing
  - Prioritization
- Simulation model IEEE 802.1AS (gPTP)
  - Time synchronization
  - Propagation delay measurement



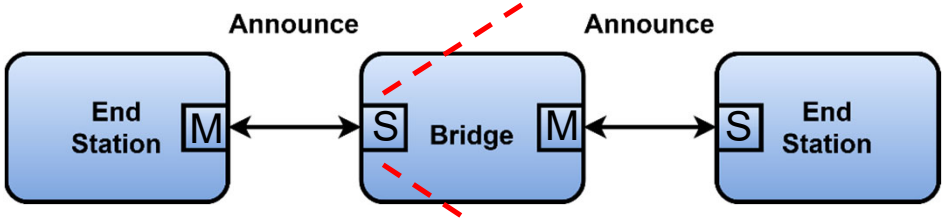
Methodology

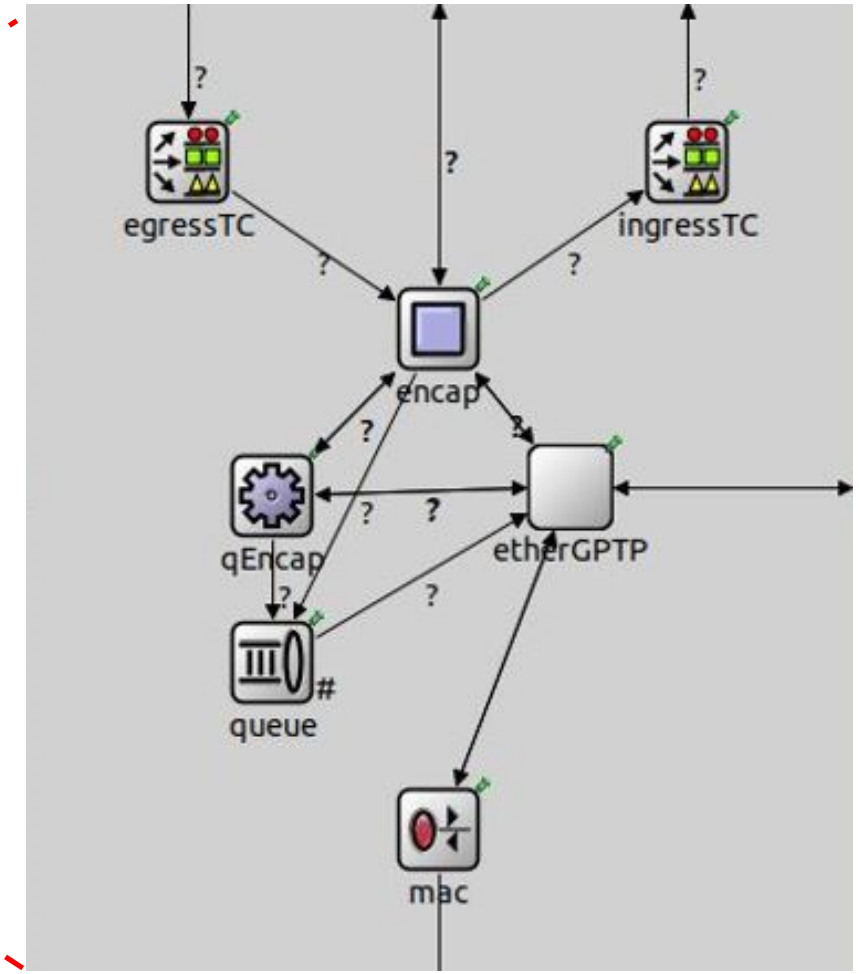
- OMNeT ++ 5.6.2
  - INET 4.1.2
  - NeSTiNg
  - Simulation model IEEE 802.1AS



Implementation

Integration of gPTP in NeSTiNg



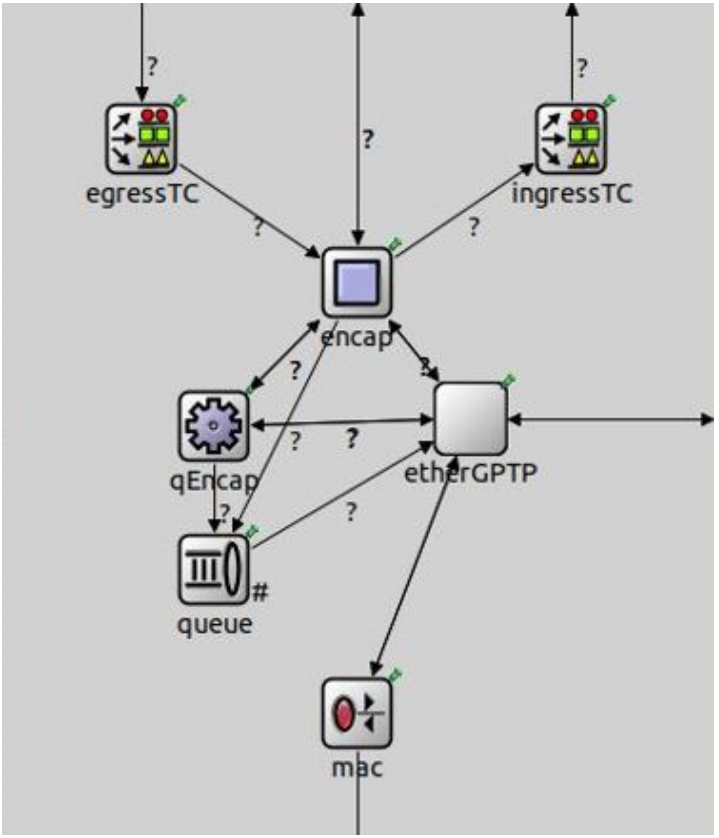


Implementation

Integration of gPTP in NeSTiNg

- EtherGPTP
- If the message type is gPTP
  - processes it based on a type of the gPTP message

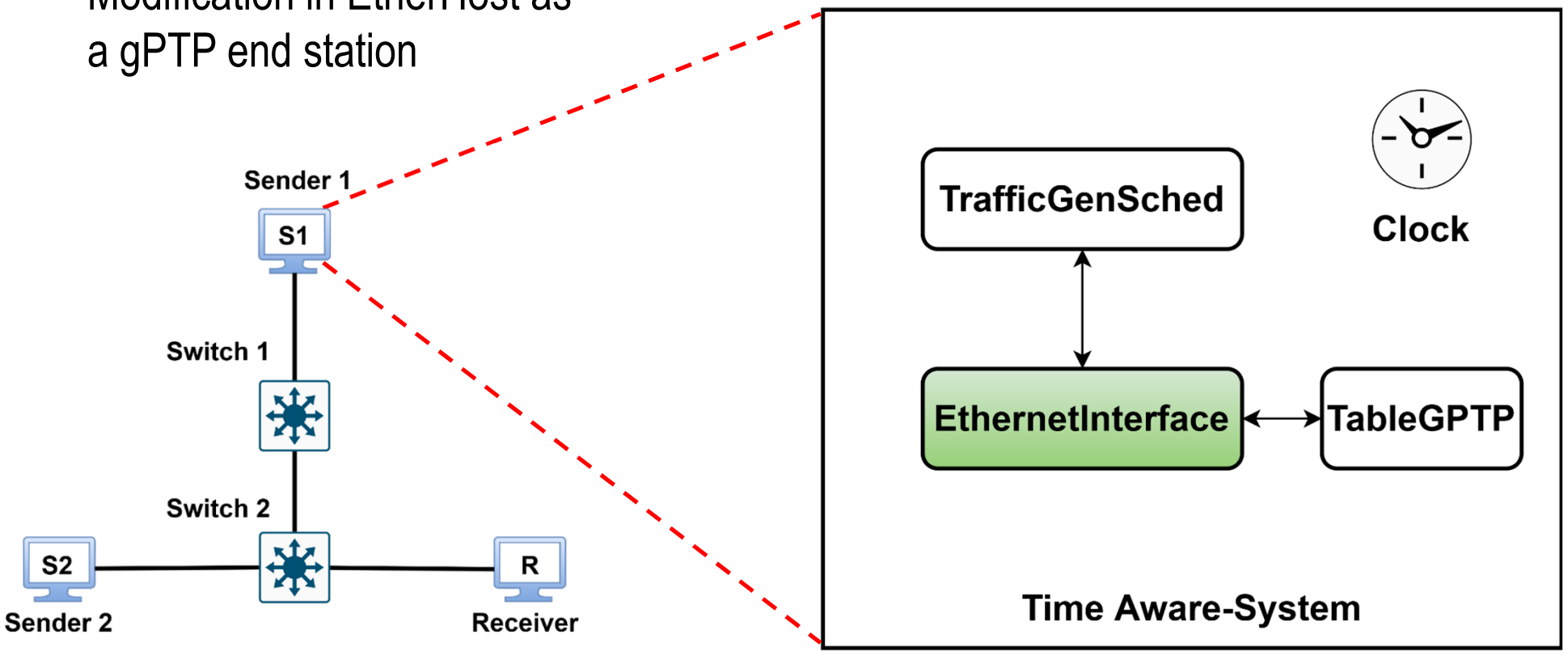
- If the message type is not gPTP
  - forwards it to the upper layer without any modification



Implementation

gPTP End Station

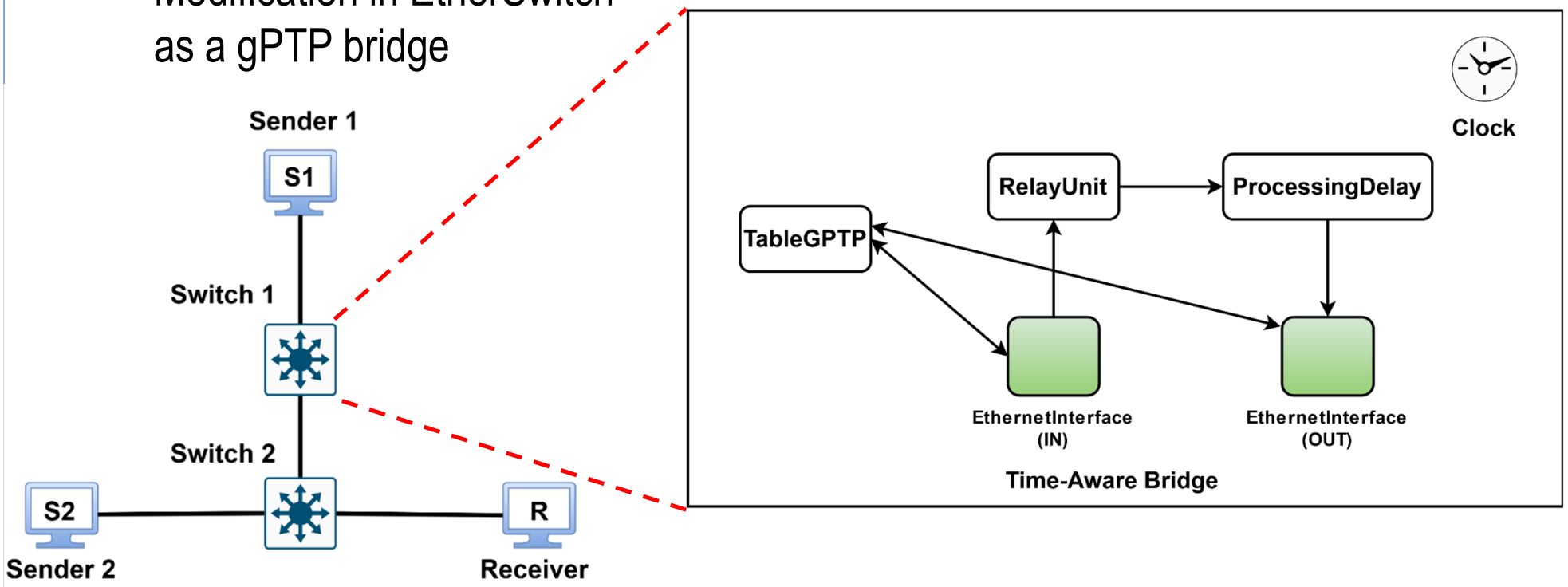
- Modification in EtherHost as a gPTP end station



Implementation

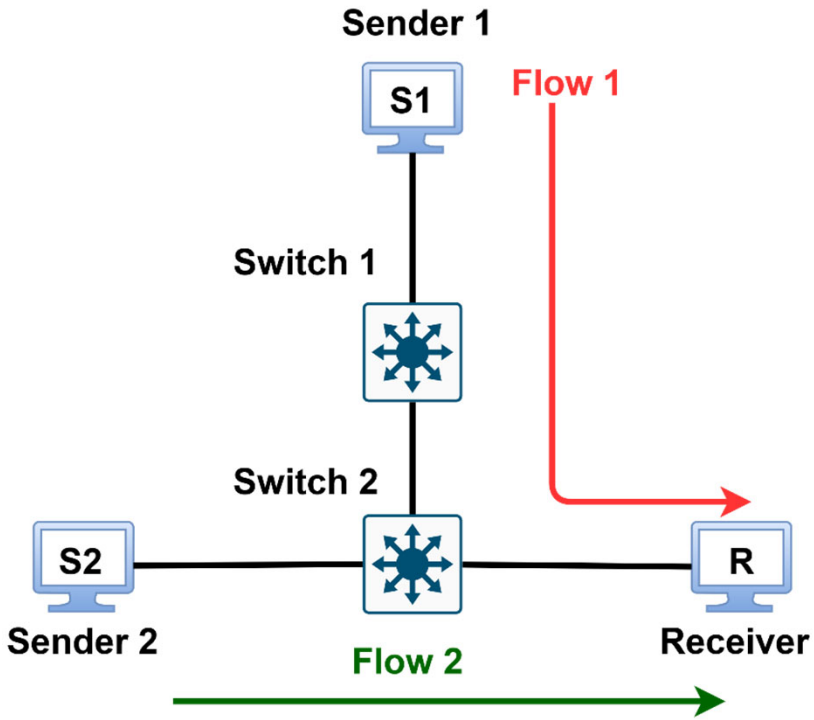
gPTP Bridge

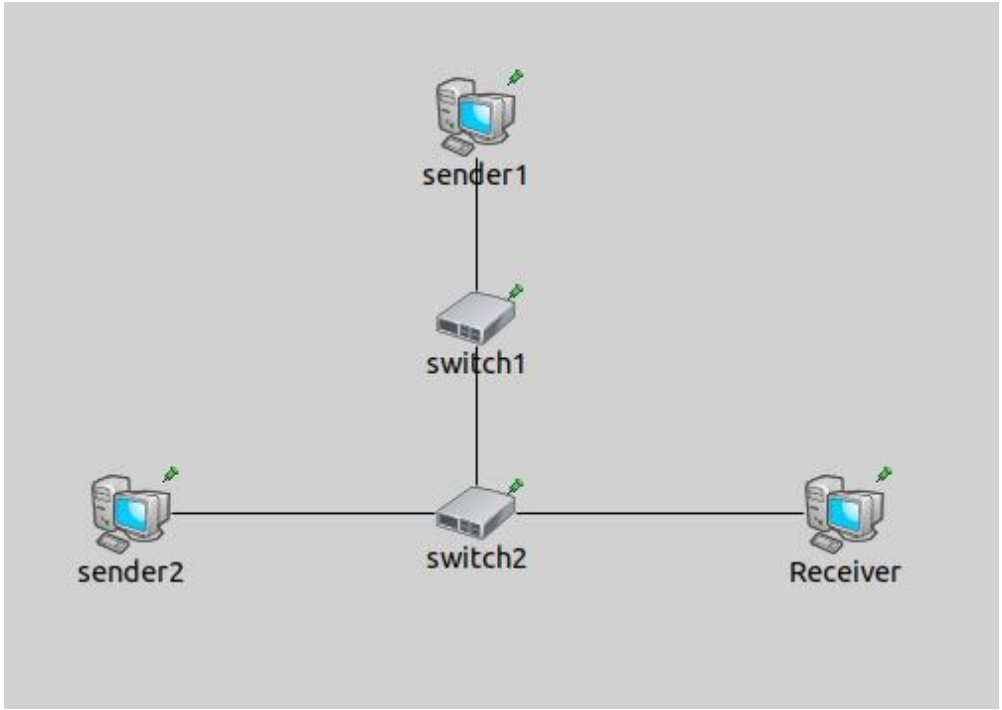
- Modification in EtherSwitch as a gPTP bridge



Implementation

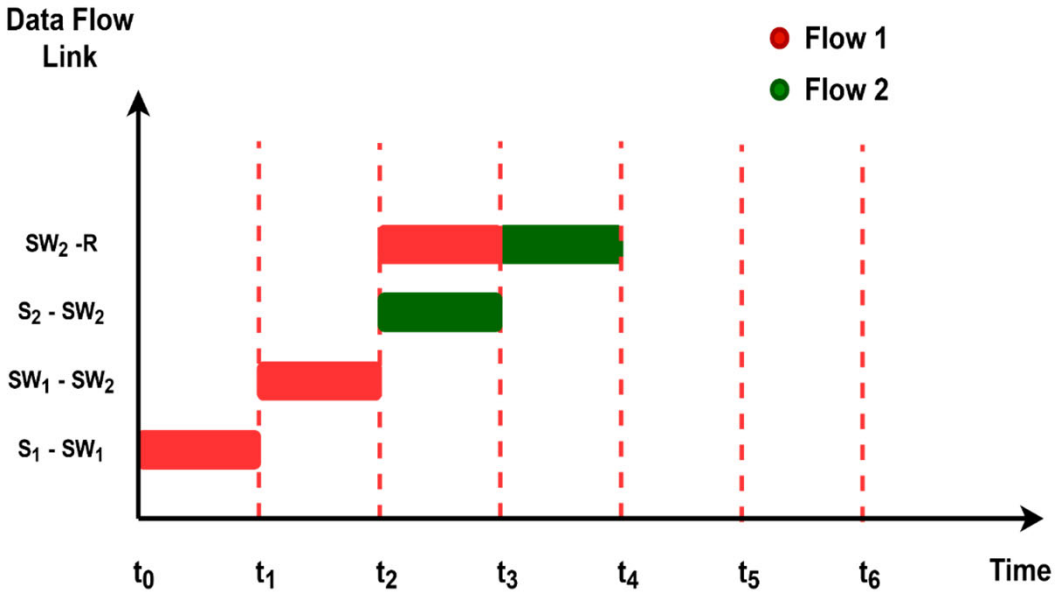
Network Topology

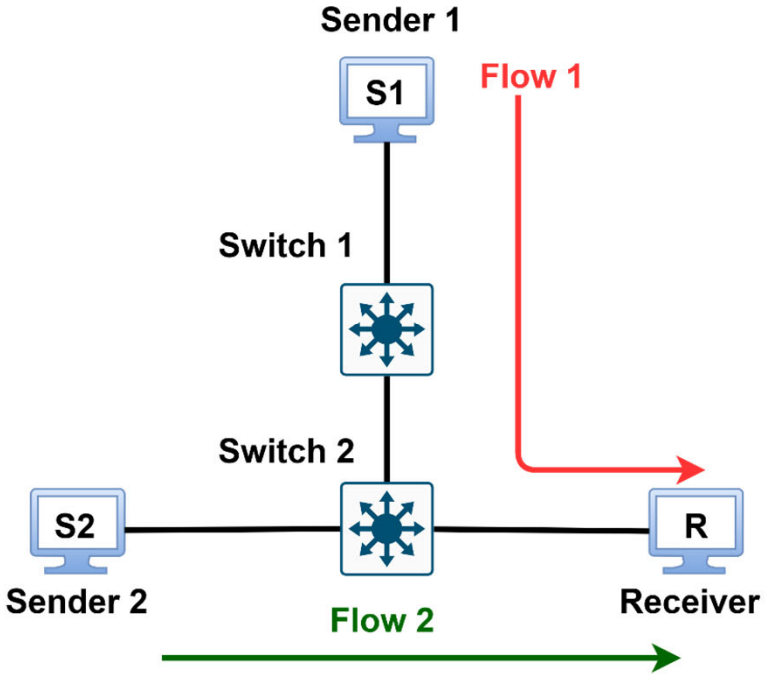




Implementation

Ideal Scenario

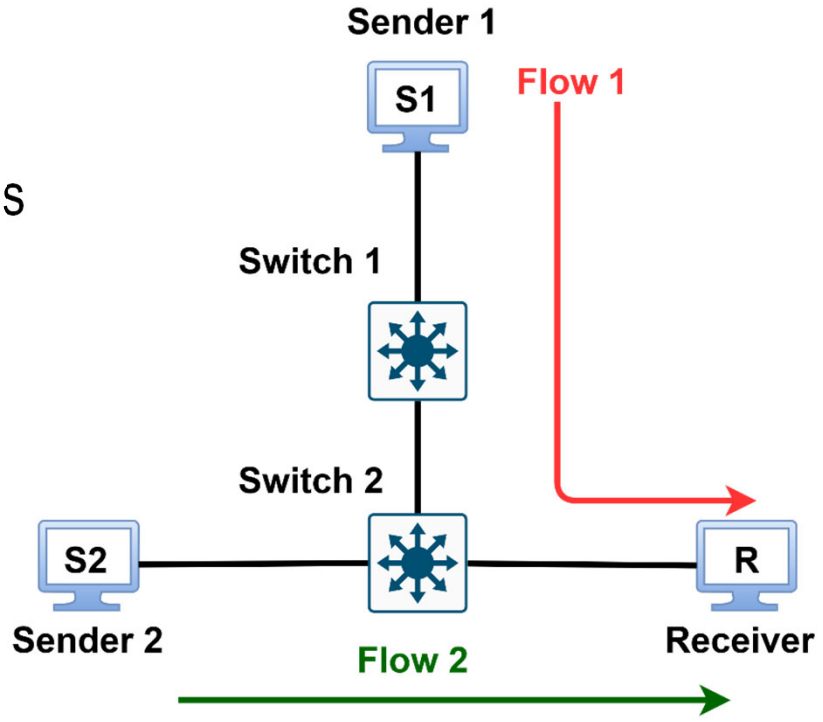




Results

Test parameter

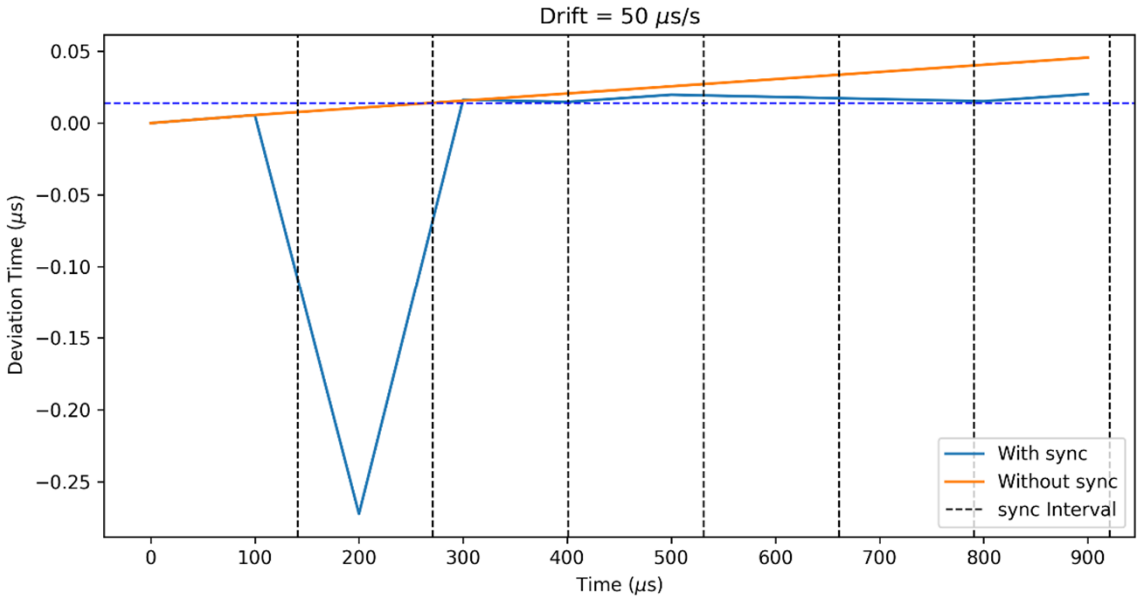
- Sender 1 act as a master
- Sender 2 has clock drift
- No drift in the switches
- The data packets are sent after every 100 µs
- The re-sync interval 130 µs



Results

- Sender 2 clock drift = 50 µs/sec

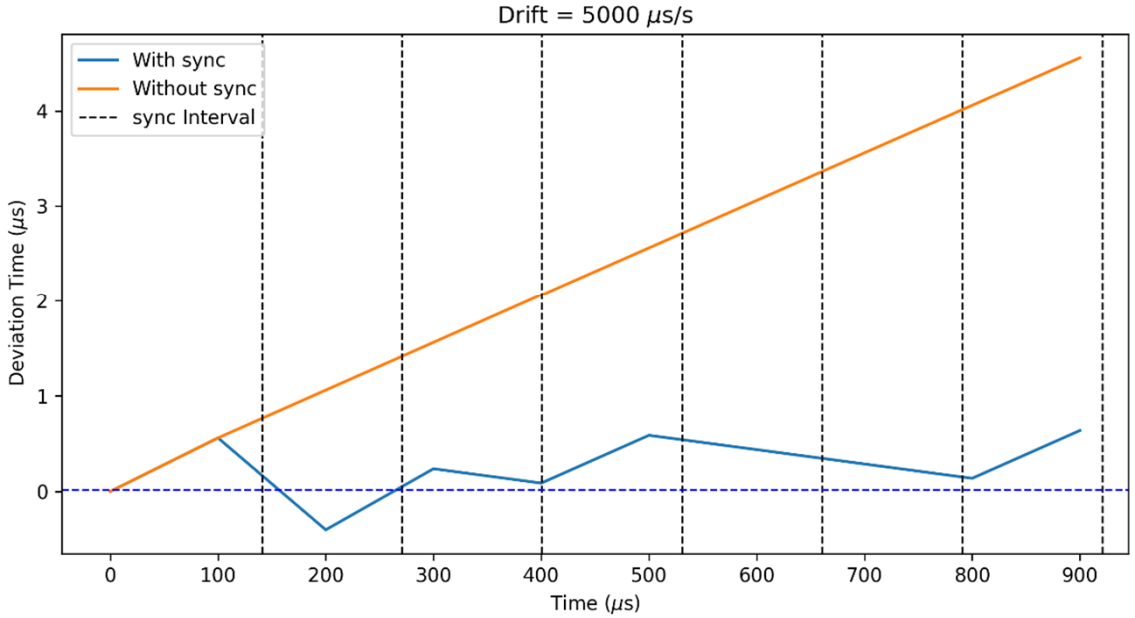
Packet No.	Sender 2 time without sync (µs)	Sender 2 time with sync (µs)
1	0	0
2	100.0056	100.0056
3	200.0106	199.272295
4	300.0156	300.016232
5	400.0206	400.014732
6	500.0256	500.019732
7	600.0306	600.018232
8	700.0356	700.016732
9	800.0406	800.015232
10	900.0456	900.020232



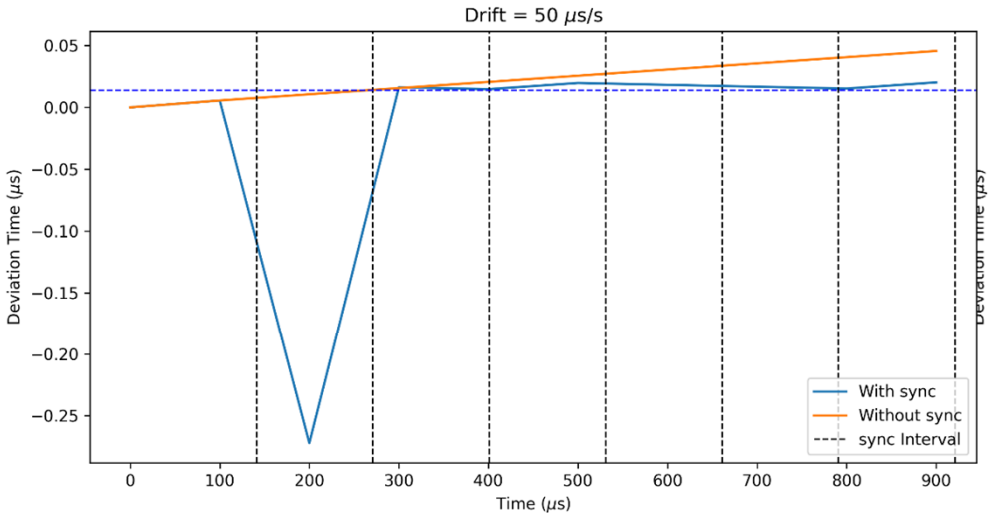
Results

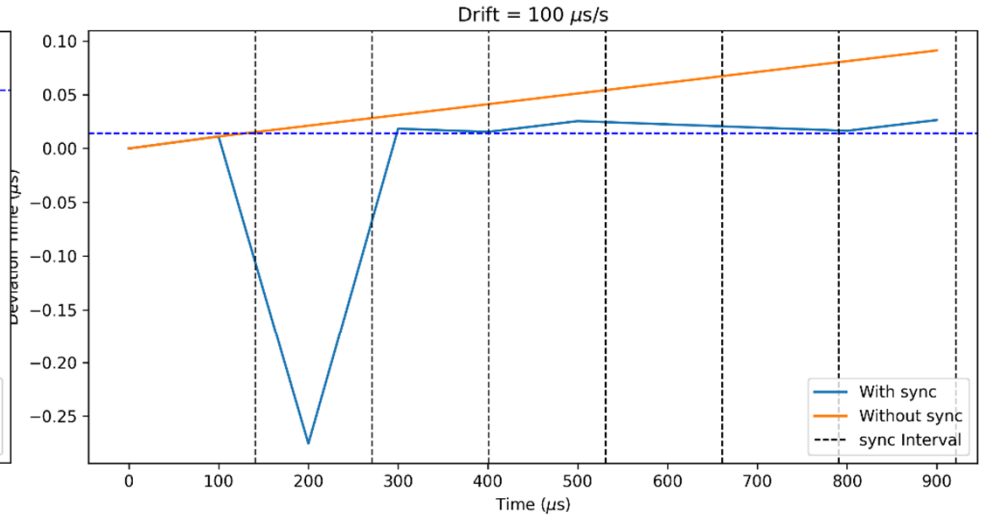
- Sender 2 clock drift = 5000 µs/sec

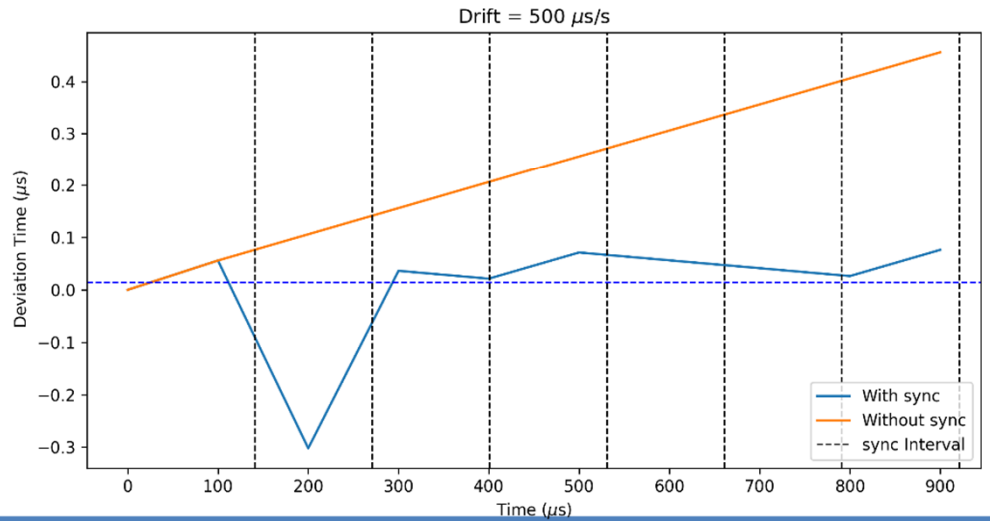
Packet No.	Sender 2 time without sync (µs)	Sender 2 time with sync (µs)
1	0	0
2	100.56	100.56
3	201.06	199.598545
4	301.56	300.23717
5	402.06	400.08717
6	502.56	500.58717
7	603.06	600.43717
8	703.56	700.28717
9	804.06	800.13717
10	904.56	900.63717

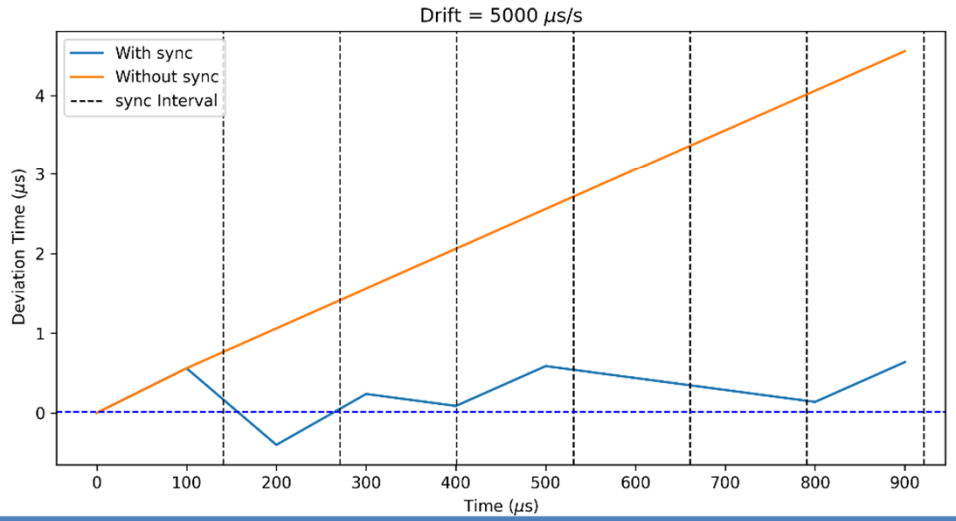


Results


Drift = 50 µs/s
Deviation Time (µs)
Time (µs)
With sync
Without sync
sync Interval


Drift = 100 µs/s
Deviation Time (µs)
Time (µs)
With sync
Without sync
sync Interval

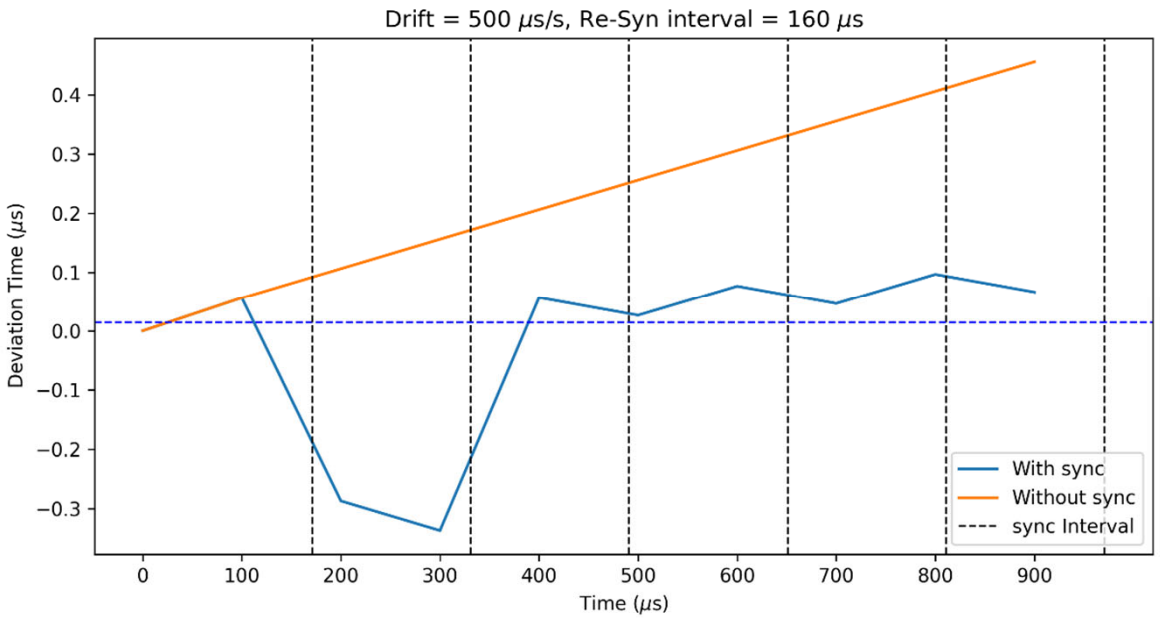

Drift = 500 µs/s
Deviation Time (µs)
Time (µs)
With sync
Without sync
sync Interval


Drift = 5000 µs/s
Deviation Time (µs)
Time (µs)
With sync
Without sync
sync Interval

Results

- Sender 2 clock drift = 500 µs/sec
- The re-sync interval 160 µs

Packet No.	Sender 2 time without sync (µs)	Sender 2 time with sync (µs)
1	0	0
2	100.056	100.056
3	200.106	199.286954
4	300.156	299.336955
5	400.206	400.056327
6	500.256	500.026327
7	600.306	600.076327
8	700.356	700.046326
9	800.406	800.096327
10	900.456	900.066326



Conclusion

- gPTP functionality is integrated in the NeSTiNg project
- Realistic clock model is used
- Proof of concept in OMNeT++
- Re-synchronization mechanism is analysed

Future Work

- Simulate more realistically and with more complex topologies

Thank you for your attention!

Questions?