Universität Rostock

Traditio et Innovatio

Institute of Applied Microelectronics and Computer Engineering

A Simulation Model of IEEE 802.1AS gPTP for Clock Synchronization in OMNeT++

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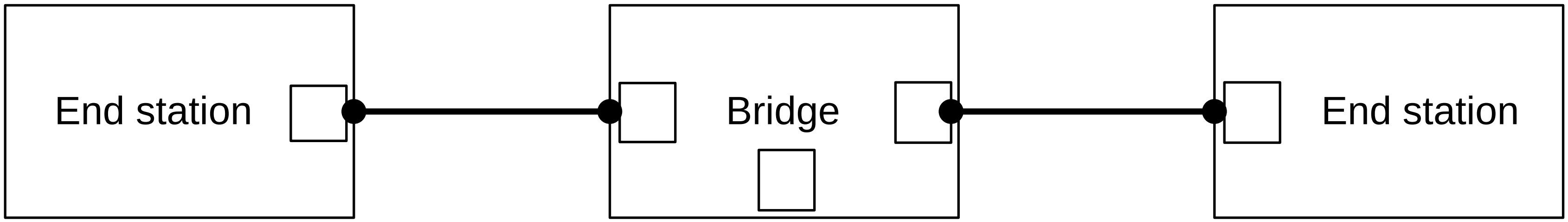
1. Motivation

- Real-time Ethernet systems
  - No open standard established
  - Only proprietary solutions (expensive)

- A standard-based approach is required
- IEEE 802.1 Time-Sensitive Networking (TSN) Task Group
- gPTP is a part of TSN standards (for sync)

2. Basics

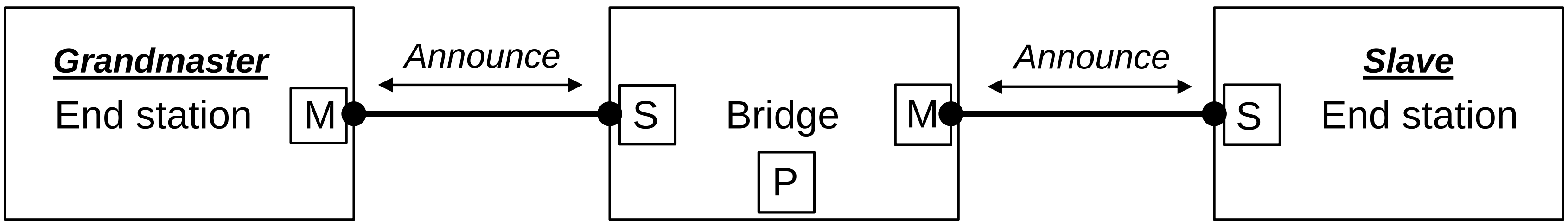
- **Overview of gPTP protocol**



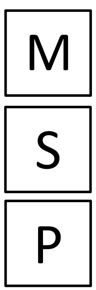
- Types of time-aware systems
  - End stations, bridges
- Types of ports
  - Master, slave, passive
- Time-aware systems only communicate gPTP information directly with other time-aware systems
  ➔ Hop by hop synchronization

2. Basics

- **Best master clock selection (BMCS)**



- All time-aware systems participate in BMCS
- Announce message: time-synchronization spanning tree vector
- Automatic changeover to a secondary grandmaster



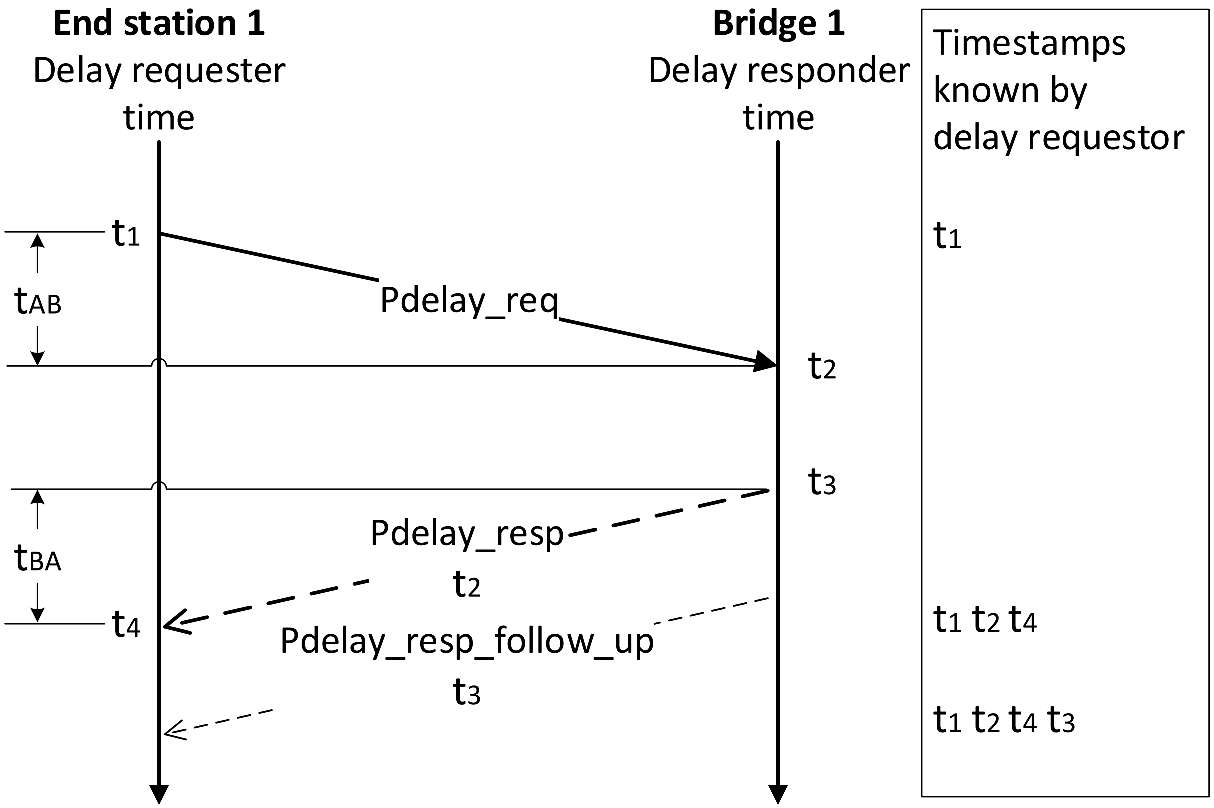
Master port

Slave port

Passive port

2. Basics

- **Propagation delay measurement**

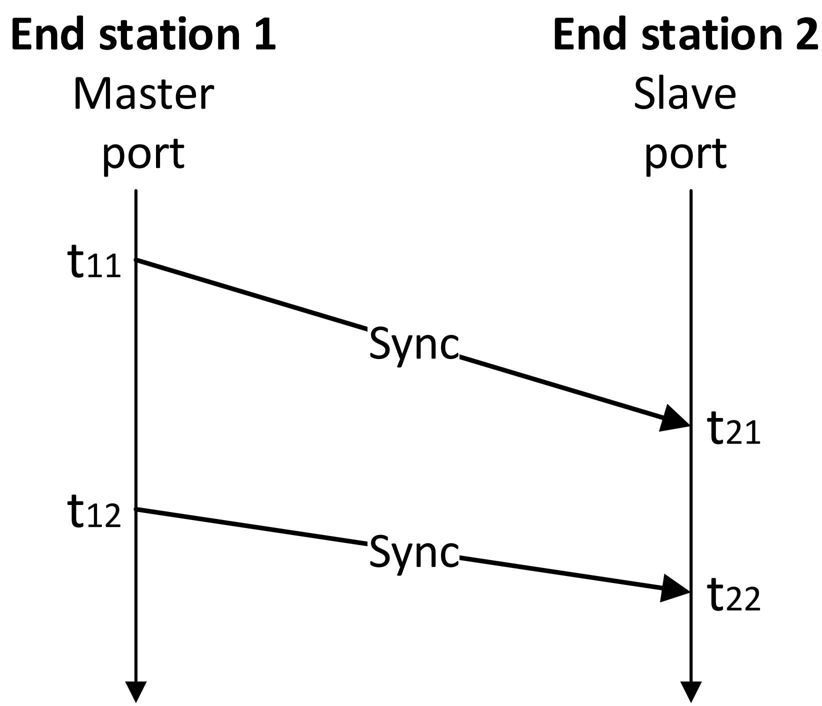


$$P_{delay} = \frac{(t_4 - t_1) - r \cdot (t_3 - t_2)}{2}$$

$$r = \frac{f_{requestor}}{f_{responder}}$$

2. Basics

- **Propagation delay measurement**
  - Rate ratio



$$(t_{12} - t_{11}) \neq (t_{22} - t_{21})$$

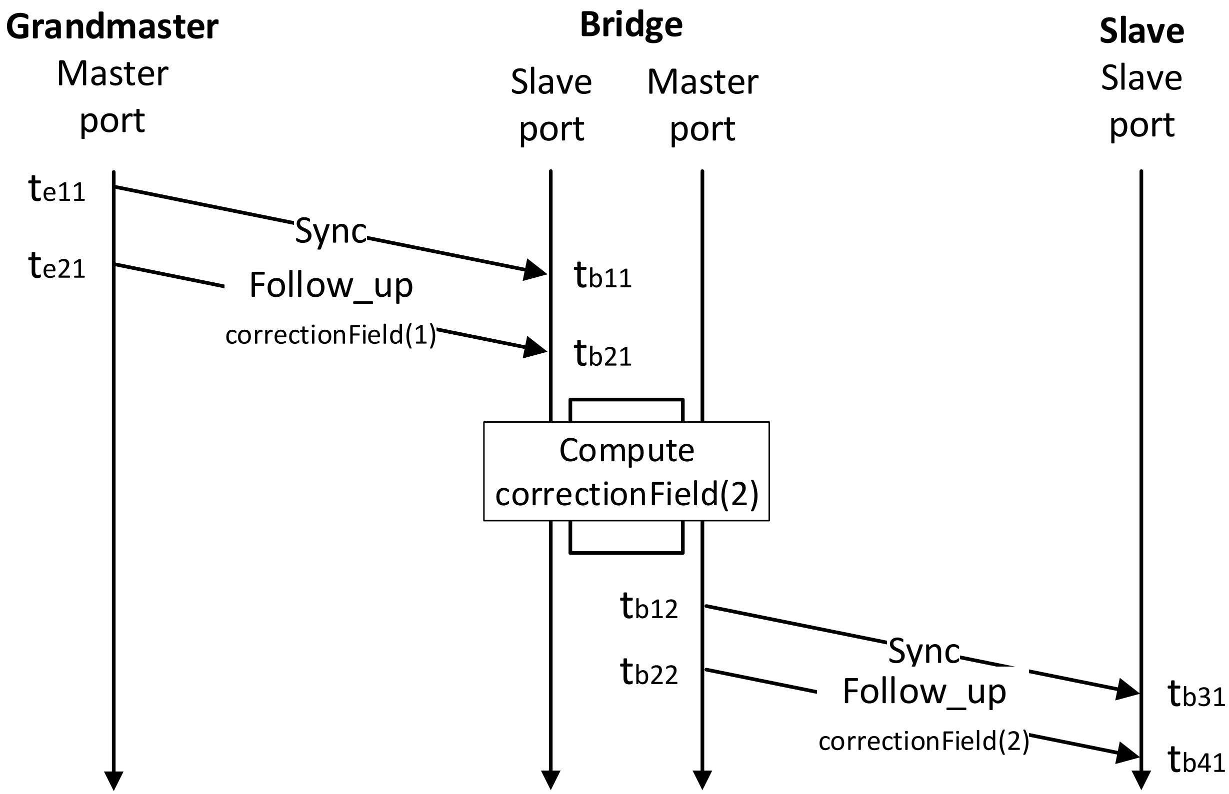
$$r = \frac{(t_{12} - t_{11})}{(t_{22} - t_{21})}$$

$r = 1$ $\quad Clock_{es1} = Clock_{es2}$

$r < 1$ $\quad Clock_{es1} < Clock_{es2}$

$r > 1$ $\quad Clock_{es1} > Clock_{es2}$

2. Basics: Transport of Sync. Information



- correctionField: Composed of propagation delay and residence time
- Slave: preciseOriginTimestamp + <delayToGM> ➔ Synced to GM time

3. Implementation

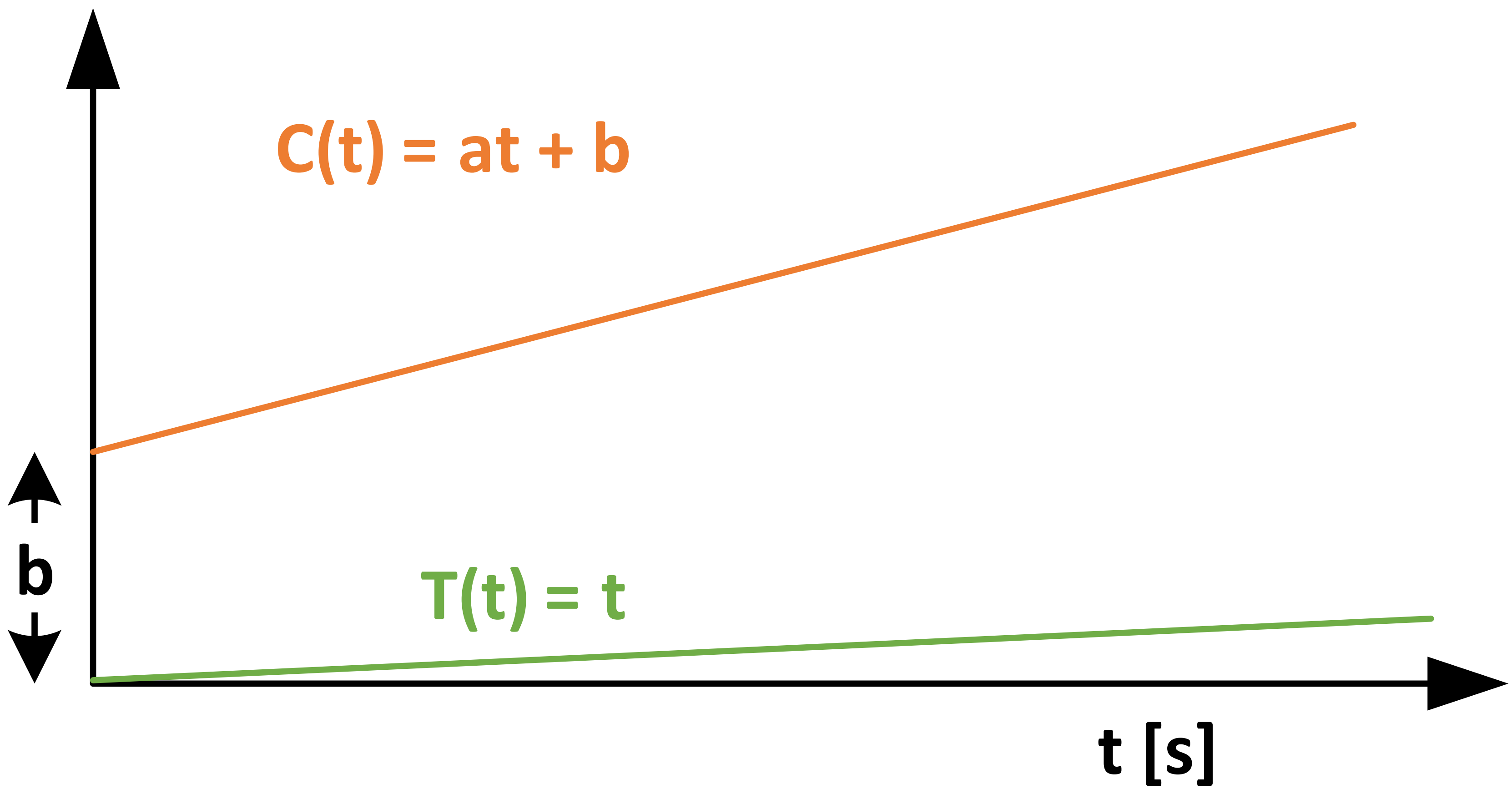
- **Scope of the project**

  gPTP simulation model in OMNeT++ using the INET library

  - Integrate gPTP model seamlessly with other protocols from INET
  - Implement only time synchronization and propagation delay measurement
  - Best master clock not part of project
    Assumption: GM shall no be selected randomly
  - Implement simple clock with constant drift

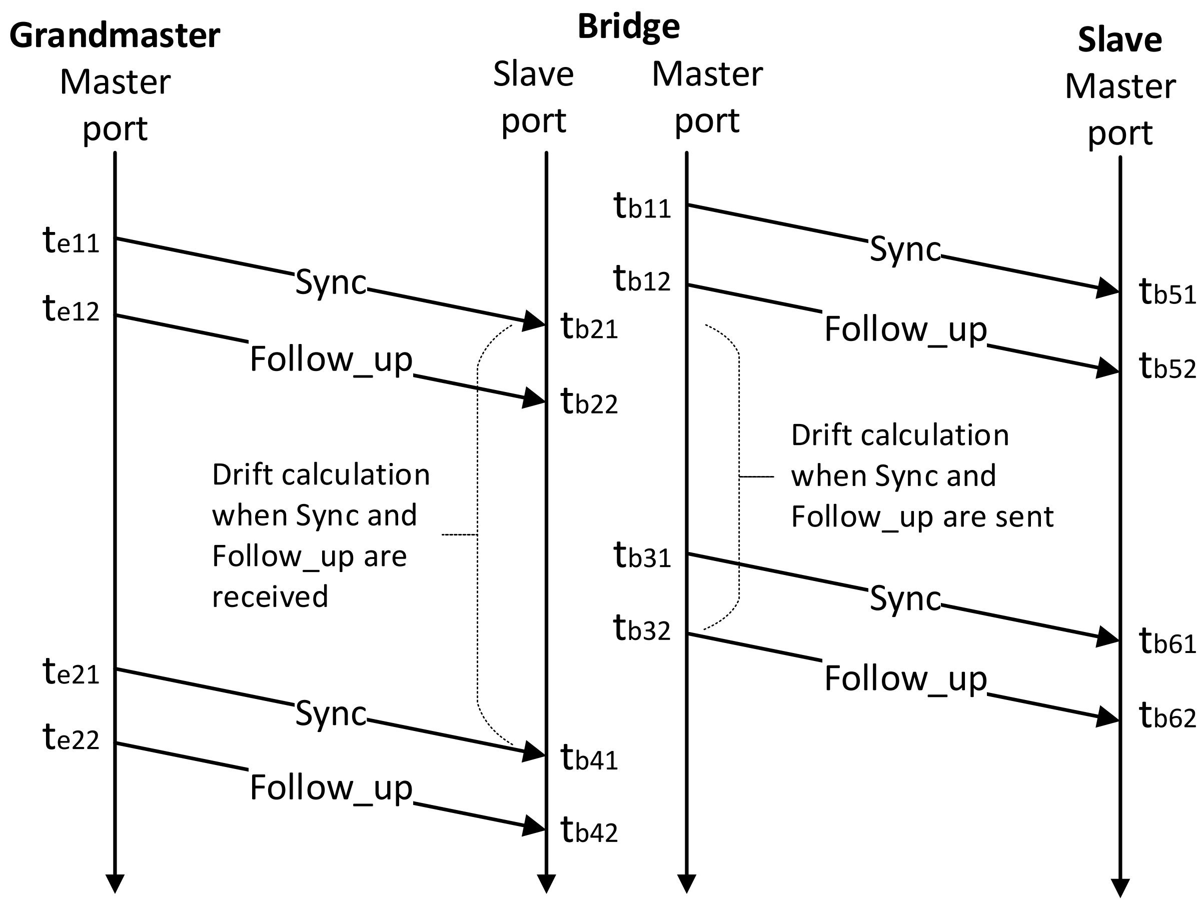
3. Implementation

- **Model of clock with constant drift**



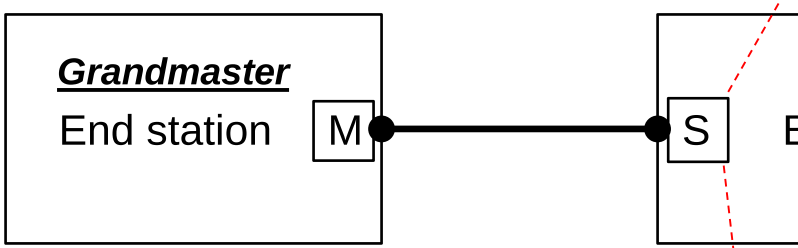
3. Implementation

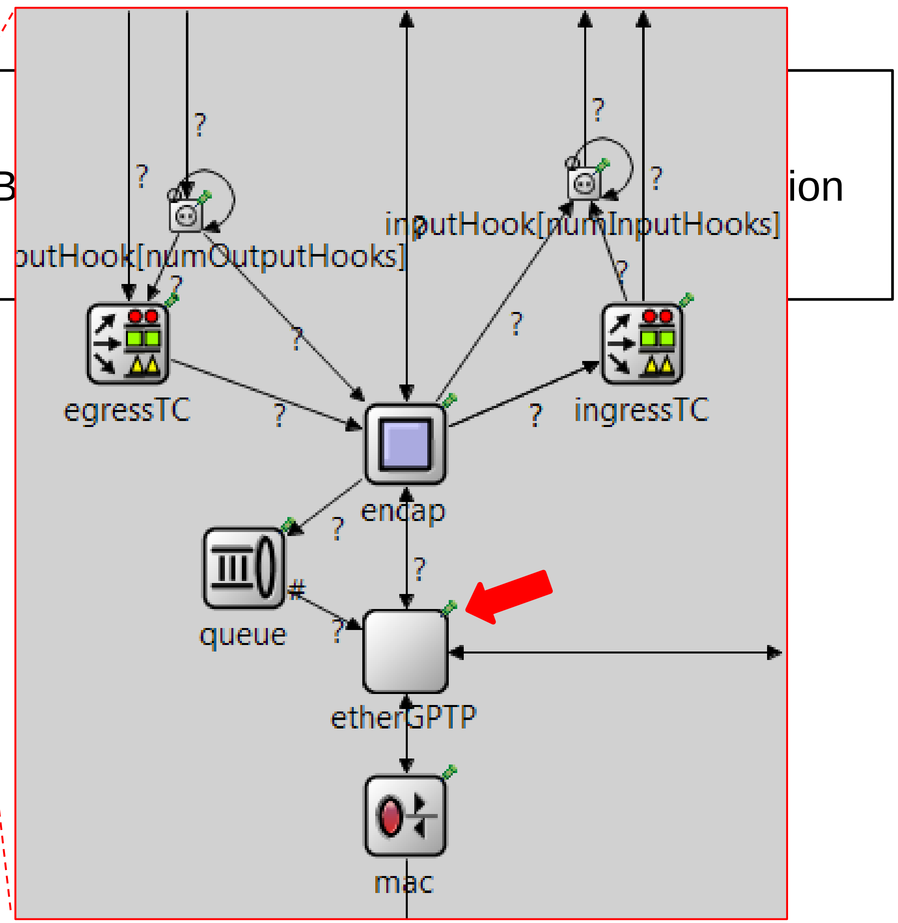
- **Model of clock with constant drift**



3. Implementation

- **Model of gPTP functionalities**

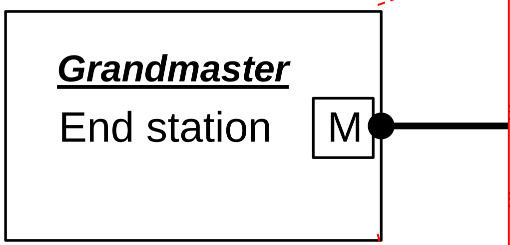


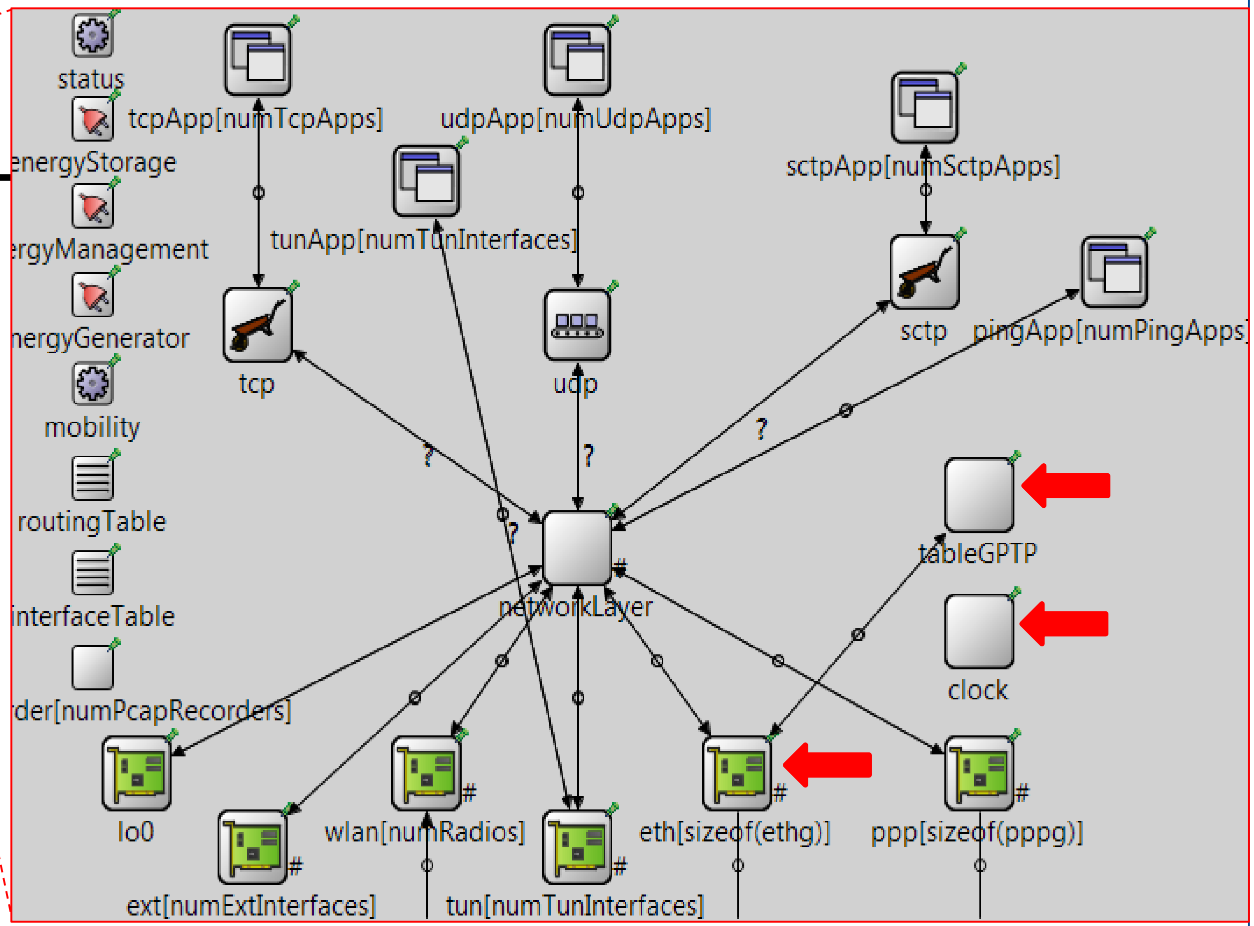


- Eth. interface with gPTP support: *EthernetInferfaceGPTP*
- Simple module for gPTP functions: *etherGPTP*

3. Implementation

- **Model of time-aware systems**

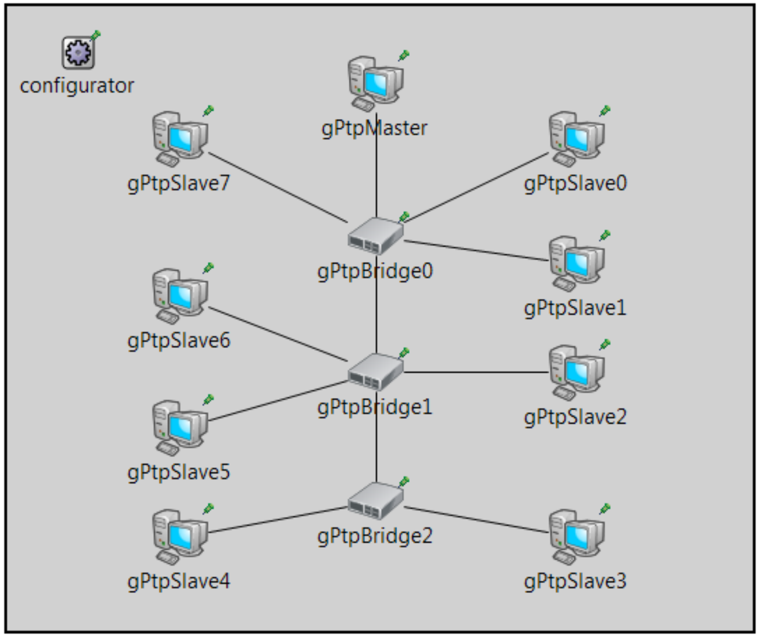




- Simple module *tableGPTP*
- Simple module *clock*
- Compound module *EthernetInferfaceGPTP*

4. Evaluation: Simulation Setup

- Same setup as Lim et al.* (BMW + TUM)
- Evaluation:
  - Propagation delay measurement
  - Time difference to GM (before resynchronization)



Clock drift of time-aware systems in domain [ppm]											
Master	Bridge0	Bridge1	Bridge2	Slave0	Slave1	Slave2	Slave3	Slave4	Slave5	Slave6	Slave7
0	30	-15	20	-50	10	50	-5	-50	40	-15	-35

*Hyung-Taek Lim, Daniel Herrscher and Lars Volker “IEEE 802.1AS Time Synchronization in a switched Ethernet based In-Car Network”, IEEE VNC 2011

4. Evaluation: Propagation Delay Measurement

- Converge to 25 ns (absolute difference < 0.5 ns)
- Lim et al.: +/- 10 ns acceptable

Node	Propagation delay[ns]	Error (%)	Absolute difference [ns]
Slave 0	25.43	1.72%	0.43
Slave 1	25.43	1.72%	0.43
Slave 2	24.78	-0.88%	0.22
Slave 3	25.29	1.16%	0.29
Slave 4	25.29	1.16%	0.29
Slave 5	24.78	-0.88%	0.22
Slave 6	24.78	-0.88%	0.22
Slave 7	25.43	1.72%	0.43
Bridge 0	25	0.00%	0.00
Bridge 1	25.43	1.72%	0.43
Bridge 2	24.78	-0.88%	0.22

4. Evaluation: Time Difference to GM

- Time difference to GM (before resynchronization)
- As expected: e.g., for 125ms and +/- 50ppm ➔ +/- 6.25us

Node	Time difference to GM before resynchronization in our implementation [µs]	
	Sync interval 62.5 ms	Sync interval 125 ms
Bridge 0	2.36	4.24
Slave 0	-3.12	-6.25
Slave 1	0.63	1.25
Slave 7	-2.19	-4.37
Bridge 1	-0.94	-1.87
Slave 2	3.13	6.25
Slave 6	-0.94	-1.87
Slave 5	2.50	5.00
Bridge 2	1.25	2.50
Slave 3	-0.31	-0.63
Slave 4	-3.12	-6.25

5. Conclusion

- We have contribute
  - Simulation model of gPTP
  - Models for time-aware systems: end-station and bridge
  - Simple clock model with constant drift
- Comparisons of results to literature
- Useful in simulating any networks based on the gPTP
- Entire system is publicly available*
- Future work: Utilize other the clock models

* https://gitlab.amd.e-technik.uni-rostock.de/peter.danielis/gptp-implementation

Thank you for your attention.

Questions?