iSAFT Test Tool for deterministic on-board Ethernet Networks

(ESTEC CONTRACT NUMBER 4000127688)

ESA Final Presentation Days - May 2020

teletel

Presentation Contents

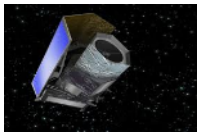
- Company Overview & relevant iSAFT product line
- Project Overview
- Participants and Main Roles
- Main Work Areas / Project Timeline
- Main Work Packages Description
- Conclusions

teletel

Company Overview

25 years SME based in Athens-Greece, Aerospace and Defence Design and Development house, offering the following space products/services.

- On-board and Ground SW design and development



- iSAFT product line for the validation of on-board data networks

- Unit Testers, Test Benches (EGSE/SCOE) and Automated Test Equipment (ATE)

- AIT Support Services

teletel

iSAFT Product Line
Interface Cards, Software, Integrated Testers/Recorders

SpaceWire

SpaceFibre

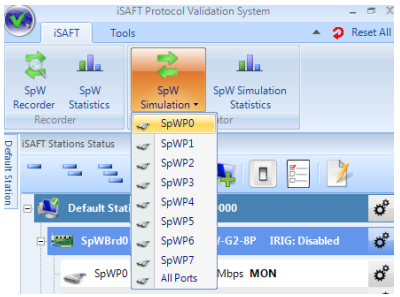
CAN

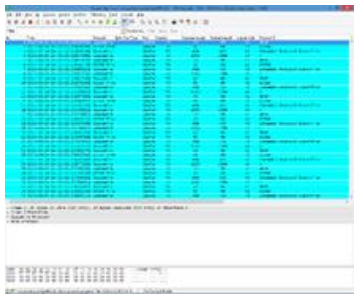
CANopen

MIL-STD-1553

TTEthernet

UART, SPI, I2C, other





teletel

iSAFT Product Line – All-in-one test systems

Cost-effective on-board data networks testing with robust integrated systems.

Multiple network interface cards (SpW, 1553, CAN, SpFi),

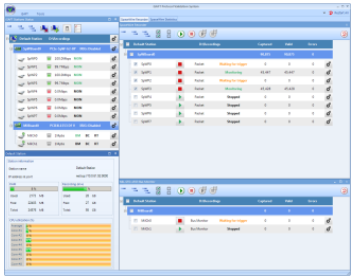
SpaceWire

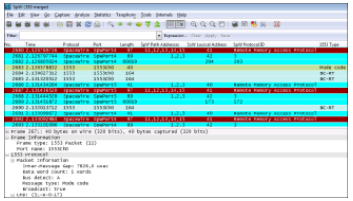
MIL-STD-1553

CAN/CANOpen

in a **single** Integrated System, avoiding different devices in your testbed,

with **unified** Control, Simulation & Recording SW





teletel

Example: iSAFT SpaceWire Simulator / Recorder

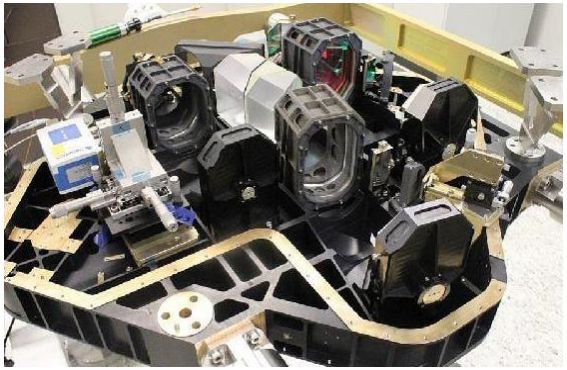
iSAFT SpaceWire Simulator / Recorder

Central Checkout System (CCS)

EDEN, C&C CCSDS

iSAFT SpaceWire Simulator / Recorder

4 – 8 SpW Links



Satellite Payload / Instrument

3rd Party Software (C#, C++, Python APIs)

Web Services / TCP/IP

Local / Remote Control GUI

Example use case

teletel

On-board data networks trends

- Increase the quantity of high-speed instruments and resulting TM data
- On-board DHS become more complex and need high data rates
- Integrate in the same network critical and non-critical data

➢ Clear need for mixed-criticality networks supporting multi-gigabit instrument rate, low jitter time distribution, guaranteed QoS for C&C applications

Project Overview – Ethernet in space technologies

Time-Triggered Ethernet

- Candidate deterministic network for on-board communications
- Already selected for Ariane6, MPCV Orion, Cis-Lunar gateway

Time Sensitive Networking

- Supported by ground industries (automotive, rail, industrial control)
- IEEE based standards
- Can be used for high speed time-critical data delivery

teletel

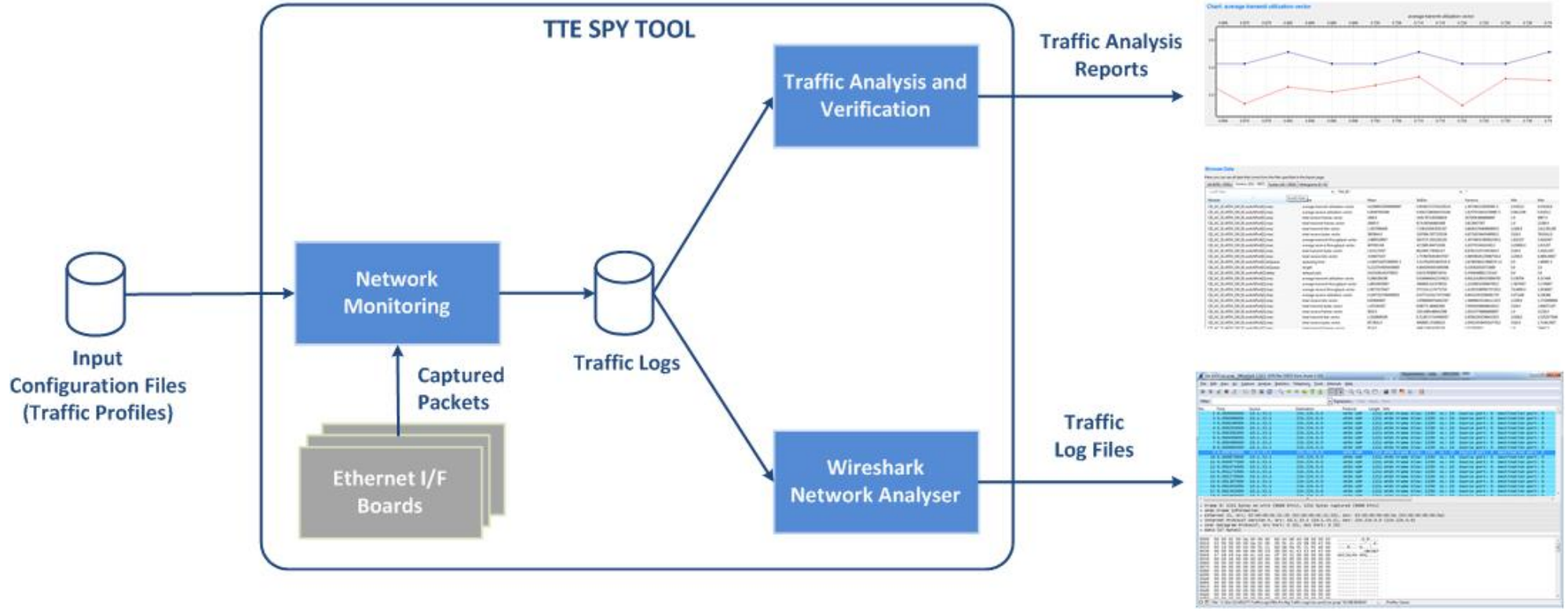
Extend iSAFT with Time Triggered Ethernet interface

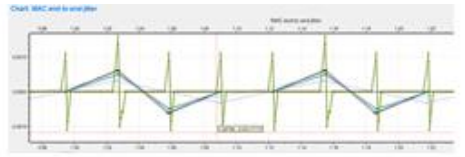
Main contractor: Teletel

Sub-contractors: Ariane Space, AIRBUS Defense & Space

- Phase 1 (project completed in 2018)
  - Task 1: Implementation of a TTEthernet VERIFICATION/SPY Tool
  - Task 2: Assessment for the implementation of a TTEthernet End System IP Core based on open TTEthernet standards
- Phase 2 (not started – on-hold):
  - Full Implementation of a TTEthernet End System IP Core
  - iSAFT PVS Tool extension: Implementation of TTEthernet ES simulation and traffic generation + fault injection tool (based on FPGA boards using the IP Core)

iSAFT TTE Verification/SPY Tool features





teletel

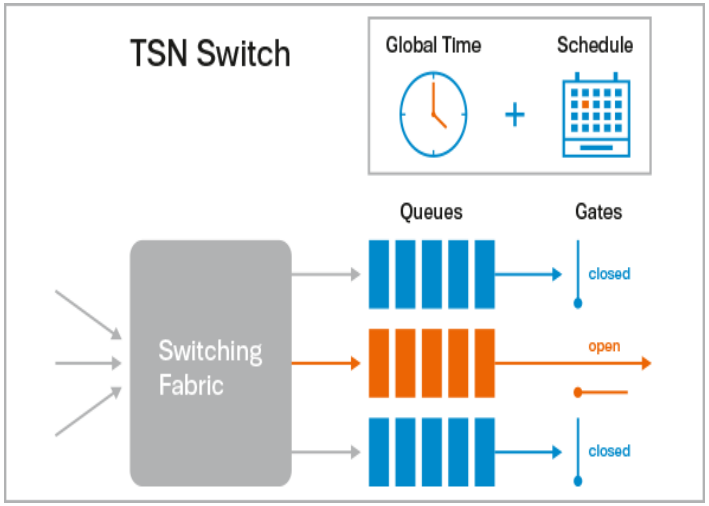
- But in the meantime …..
- A new promising player has appeared in the space domain -> TSN
- Before proceeding to develop a TTE IP Core and the subsequent test tool, TELETEL wants to secure further developments.

- Decision to execute a new GSTP Phase-1 project (de-risk)
  - *analyse, evaluate and compare TTE with TSN, mainly for network verification*
  - *identification of possibly common TTE/TSN building blocks,*
  - *prototyping in VHDL/FPGA technology and demonstration in a typical TTE/TSN testbed.*
  - *Use the existing iSAFT TTE Verification/SPY tool to verify the developments*

Project Overview – TSN main features

Time Sensitive Networking offers a way to send time-critical traffic over a standard Ethernet

- Message latency is guaranteed through switched networks
- Critical and non-critical traffic can be converged in one network
- Higher layer protocols can share the network infrastructure
- Real-time control can be extended away from the operations area
- Sub-systems can be integrated more easily
- Components can be added without network or equipment alterations
- Network faults can be diagnosed and repaired faster



teletel

Participants and Main Roles

- **TELETEL S.A. (Greece) - prime-contractor**
  - Analysis of TTE/TSN commonalities
  - Development of VHDL IP blocks
  - Setup of a TSN testbed
  - Verification and demonstration
  - Definition of the roadmap for a fully fledged TTE/TSN Test Tool

- **AIRBUS Defense & Space (Toulouse) - subcontractor**
  - Requirements for the use of TSN in future missions
  - Identification of mandatory & optional TSN standards
  - Bring system level requirements from existing and future missions, assuring the wider and more complete requirements definition, consolidation and review.
  - Roadmap for future Ethernet based test tools for space

teletel

Main Work Areas

- Analyze the TSN / IEEE related standards and define the required blocks for a TSN capable controller - identify possibly common building blocks between TTE and TSN (e.g. scheduler, etc.)
- Requirements definition for TSN Test Tool supporting End System simulation, traffic generation & fault injection functionalities
- Selection of the core blocks for a TSN controller and HDL implementation, integration in a PCIe FPGA board
- Setup of a TSN testbed and demonstration
- Definition of the roadmap for deriving a generic TTE/TSN Ethernet test and validation tool & production of a detailed Proposal for a subsequent Phase

teletel

Project Timeline

- **Project Kick-Off**
  - Date: September 2nd, 2019
- **Requirements for a TSN Test Tool, identification of common blocks with TTE**
  - Milestone: SRR
  - Date: December 2019
- **Selection of TSN controller blocks and initial experimentation**
  - Milestone: PDR
  - Date: March 5th, 2020
- **Integration of TSN controller blocks in a PCIe FPGA board, testbed setup and initial results**
  - Milestone: CDR/TRR
  - Date: April 2020
- **Demonstrator and Test Results Synthesis, roadmap and proposal for future developments**
  - Milestone: FAR - pending
  - Date: End May 2020

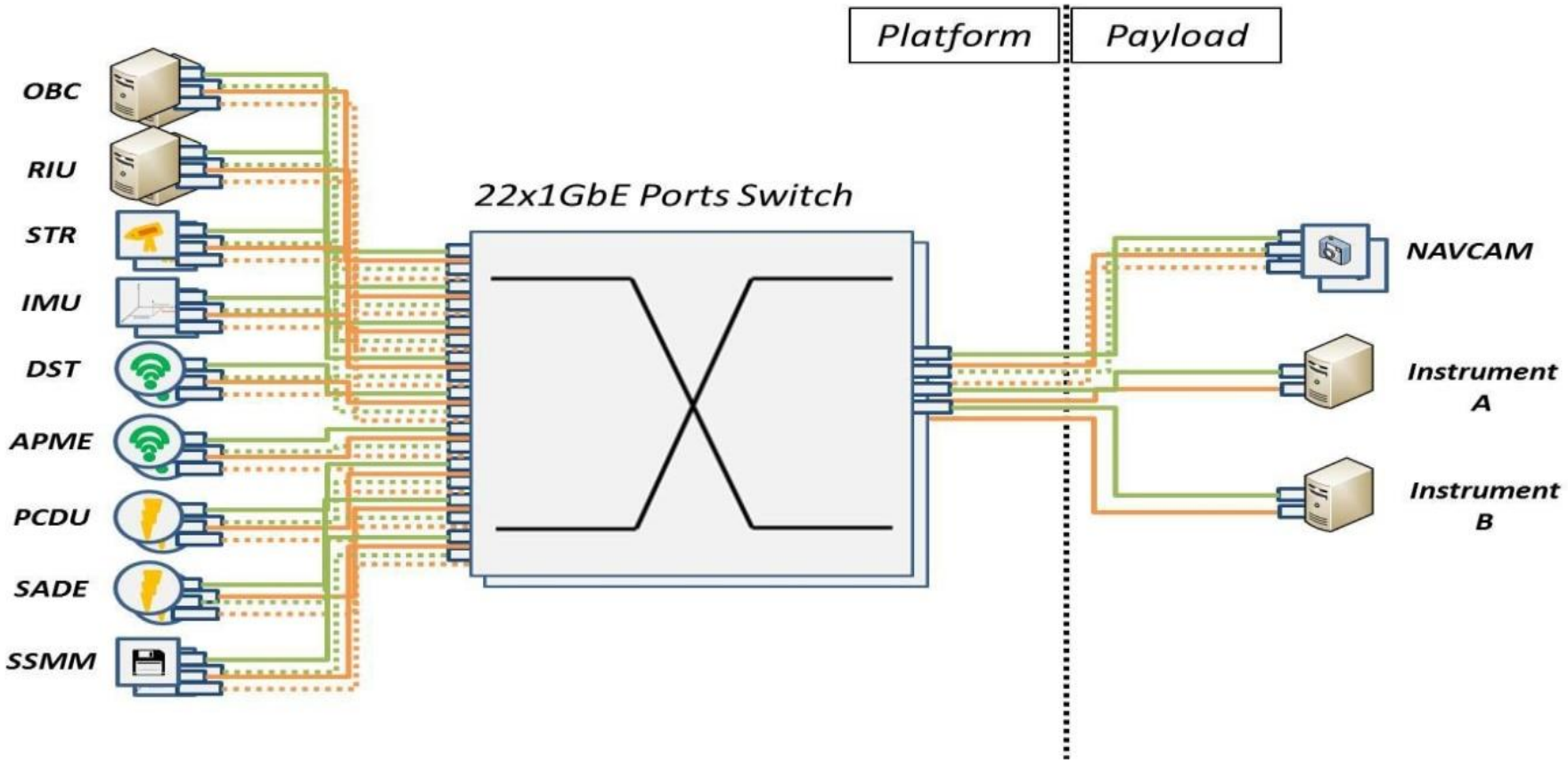
teletel

WP1 – TSN standards of interest

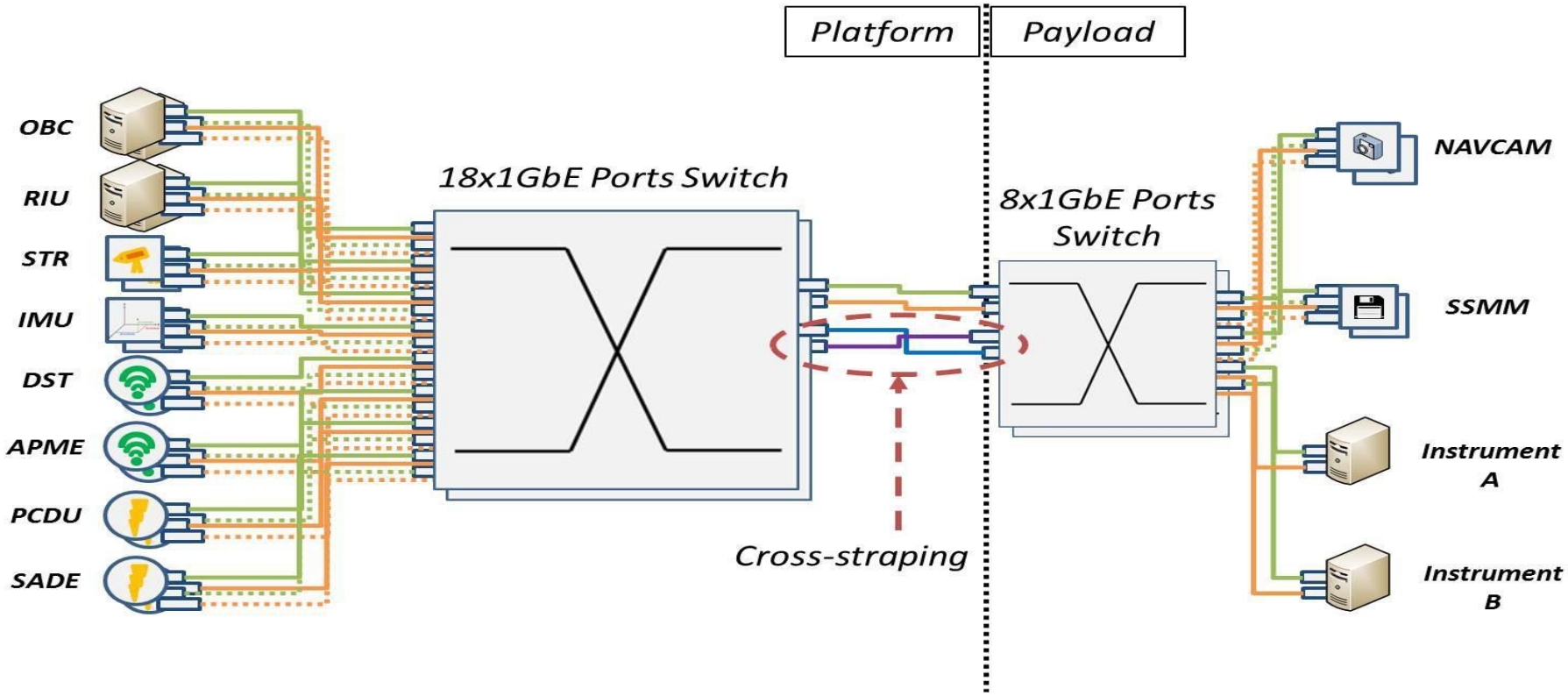
Ref.	Name	Target	Rationale
IEEE 802.1AS-Rev	Timing and Synchronization	mandatory	Sharing a common date + delay measurements
IEEE 802.1Qci	Per-Stream Filtering and Policing	mandatory	Policing + QoS management at Layer 2
IEEE 802.1CB	Frame Replication and Elimination (FRER)	mandatory	Availability of the network and the system (RAMS)
IEEE 802.1 Qbv	Scheduled Traffic	mandatory	For scheduled traffic, TBC
IEEE 802.1Qav	Credit Based Shaper	mandatory	For Quality of Service
IEEE 802.1 Qcc	Time Sensitive Network Configuration	mandatory	Static configuration part is mandatory
IEEE 802.1Qbu & IEEE 802.3br	Frame Preemption	optional	Needs for ultra-low jitter still under consolidation
IEEE 802.1Qch	Cyclic Queuing and Forwarding	optional	It is actually a combination of other standards
IEEE 802.1 Qat	*Stream Reservation Protocol*	*not required*	*Dynamic (re)configuration hence not targeted for space avionics*
IEEE 802.1 Qca	*Path Control*	*not required*	*Dynamic (re)configuration hence not targeted for space avionics*
IEEE 802.1 Qcc	*Stream Reservation Protocol Enhancement*	*not required*	*Dynamic (re)configuration hence not targeted for space avionics*

teletel

WP1 – Topology 1 for ORION with a PL/PF switch

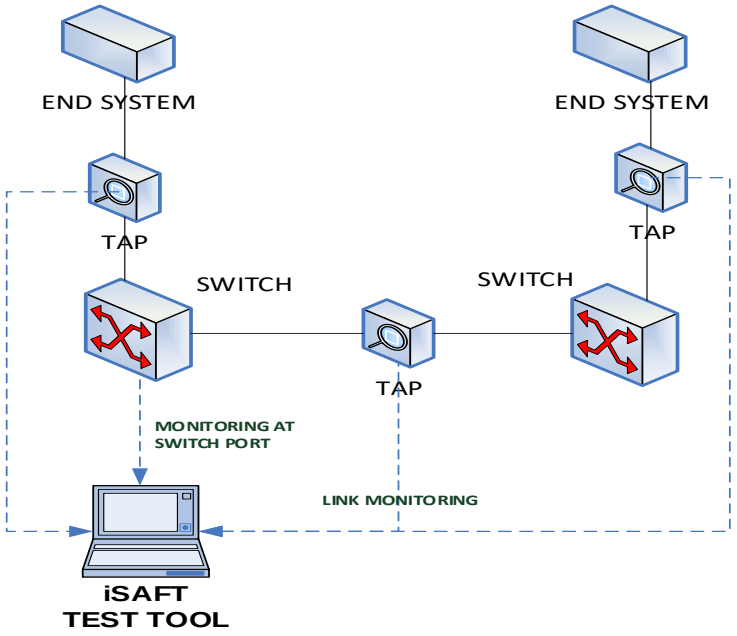


WP1 – Topology 2 for ORION with one PL and one PF switch

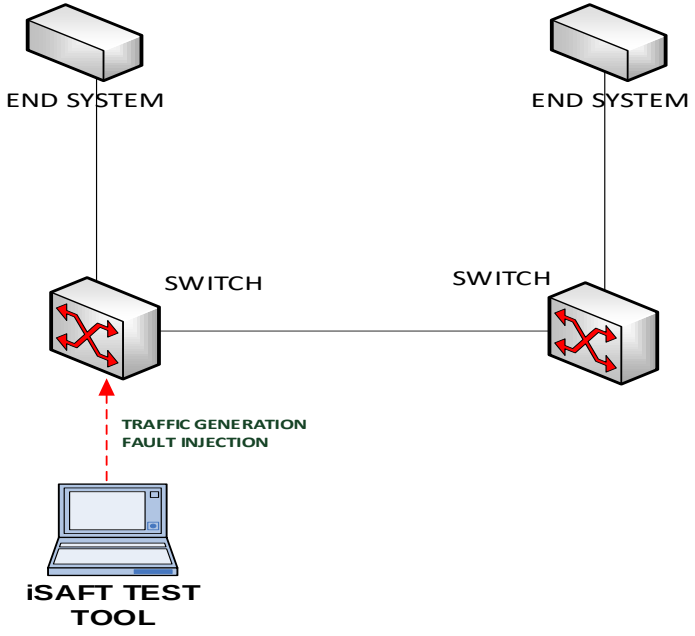


teletel

WP1 – TSN Test Tool Requirements



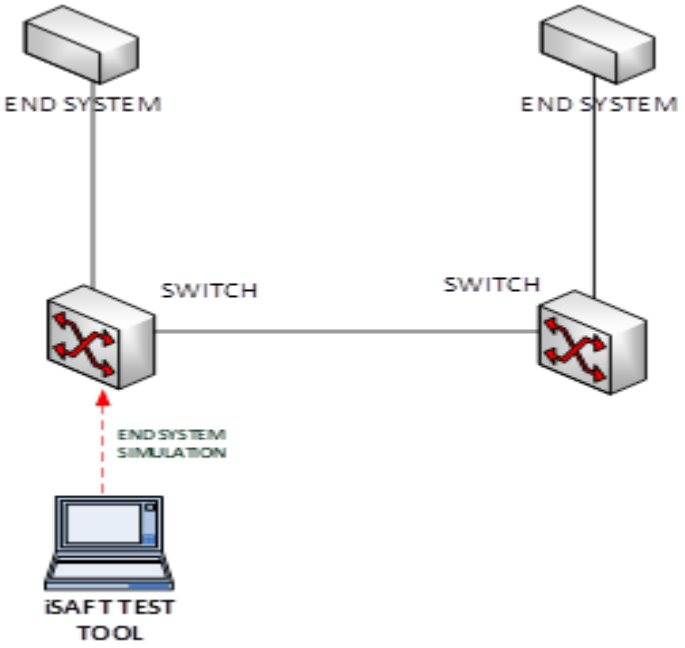
Network Monitoring



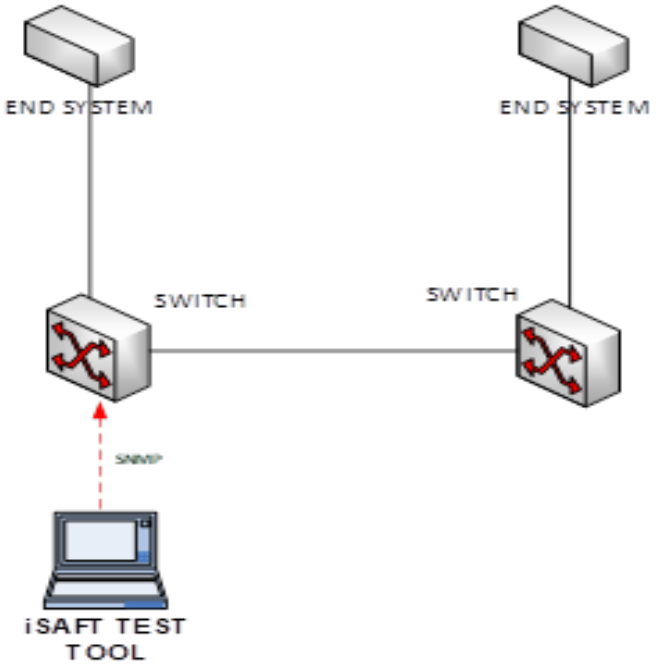
Traffic Generation

teletel

WP1 – TSN Test Tool Requirements



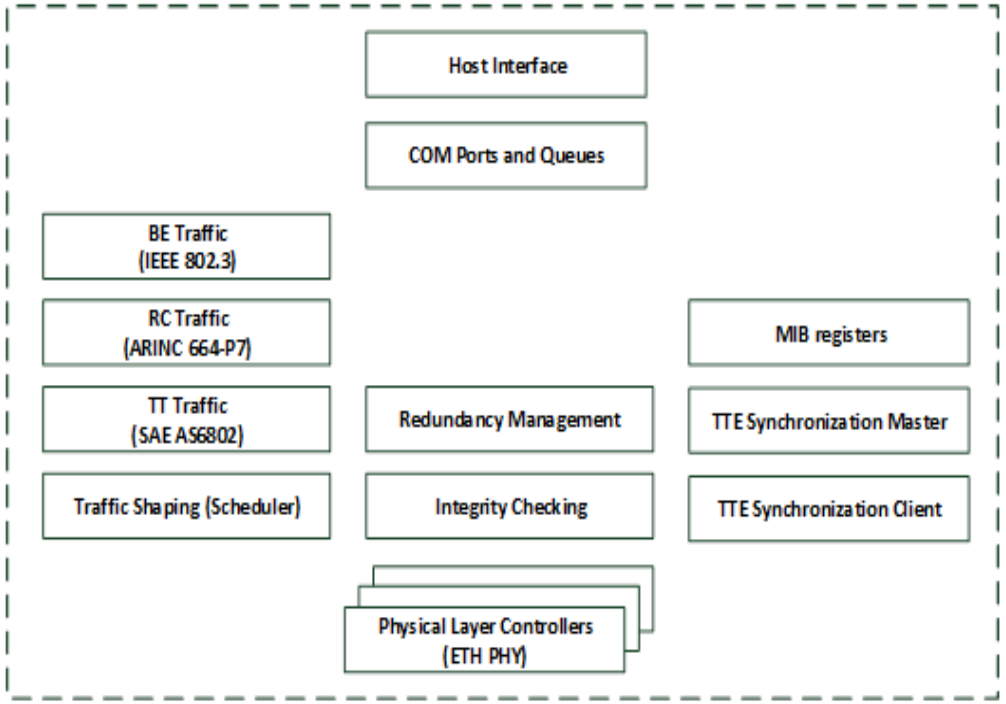
End System Simulation



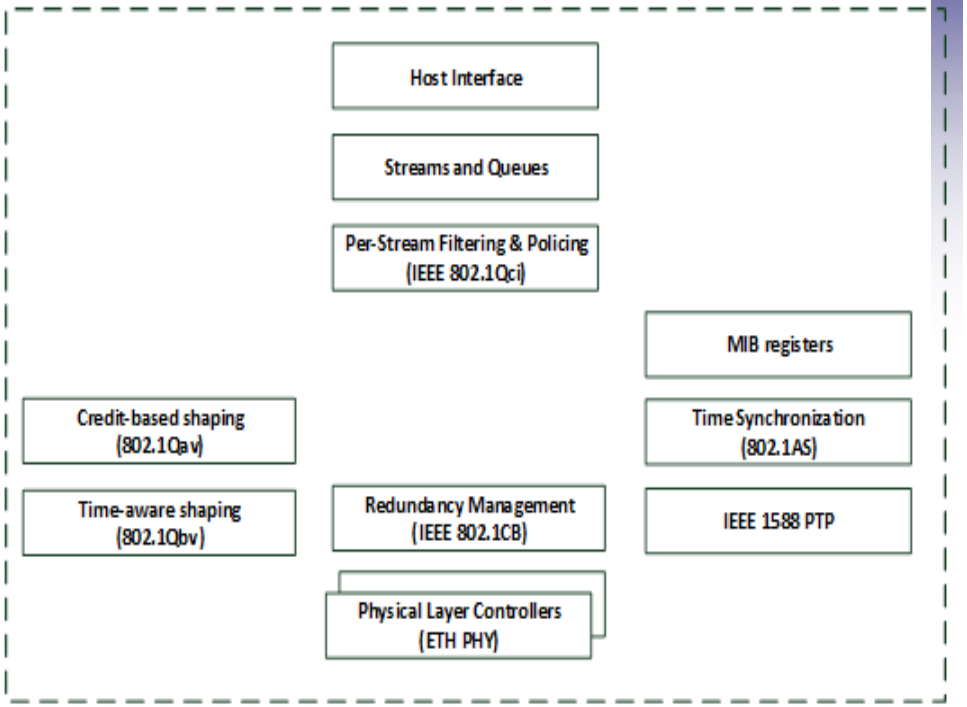
SNMP Network Management

teletel

WP1 – Common building blocks between TTE & TSN



TTE End Node



TSN End Node

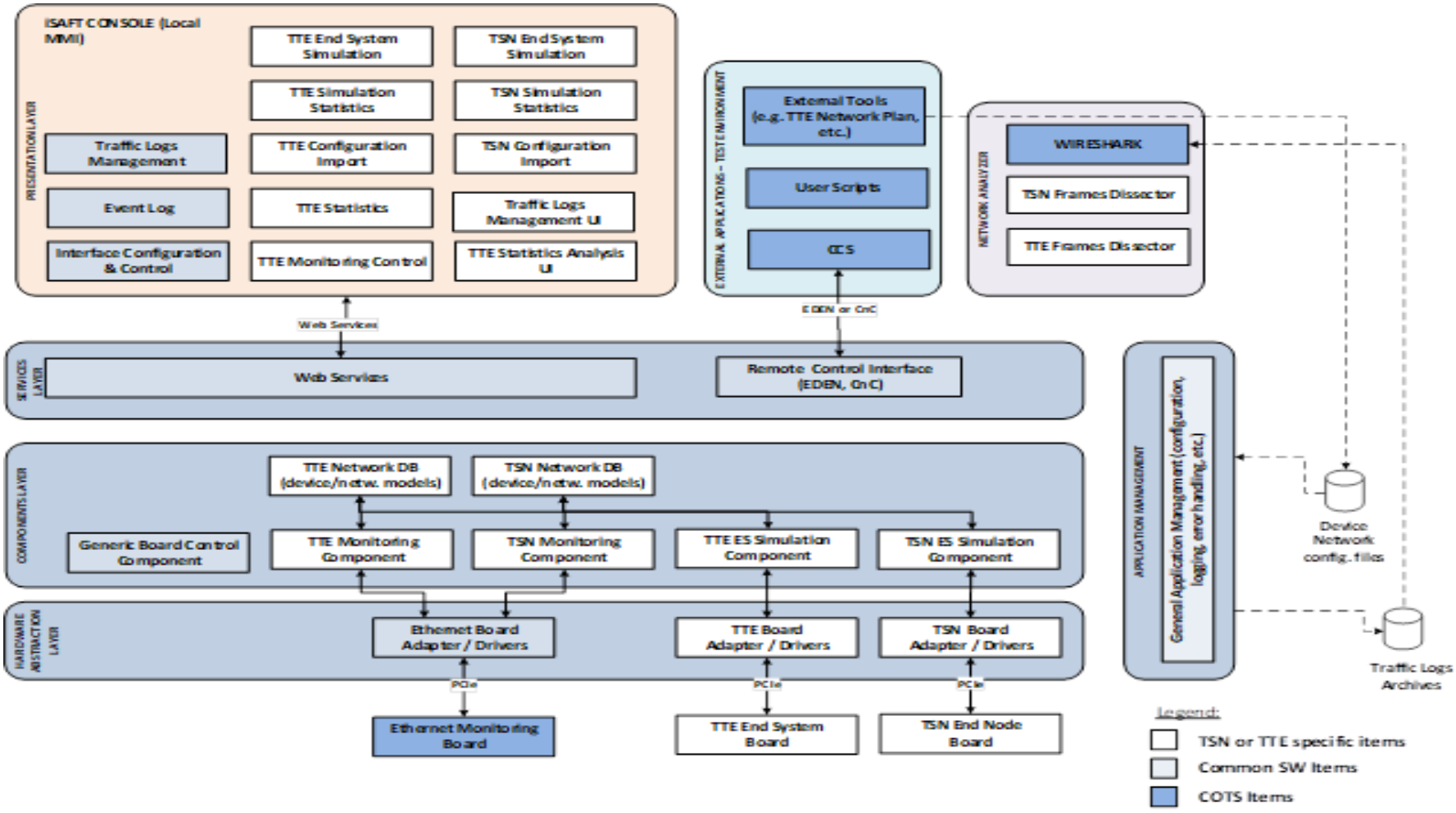
teletel

WP1 – Common IP Core blocks between TTE & TSN

TTE	TSN	Notes
Time Synchronization		
Synch. Master / slave protocol SAE AS6802	PTP 802.1AS IEEE 802.1AS, IEEE 1588	Different frames (PCF / PTP) different algorithms
Transmission traffic shaping		
TT traffic class SAE AS6802	Time-aware shaping IEEE 802.1Qbv	Different scheduling algorithms
RC traffic class ARINC 664-P7	Credit-based shaping IEEE 802.1Qav	Different scheduling algorithms
BE traffic class IEEE 802.3		
Redundancy management		
Synchronous Redundancy management SAE AS6802	Frame Replication and Elimination for Reliability IEEE 802.1CB	Different frames streams / identification and handling, different algorithms for redundant frames identification
Asynchronous Redundancy management ARINC 664-P7		
Communication Ports		
COMM ports per VLID ARINC 664-P7	Per-Stream Filtering & Policing IEEE 802.1Qci	Different frames streams / identification and handling (per VLID or per stream identifiers)

teletel

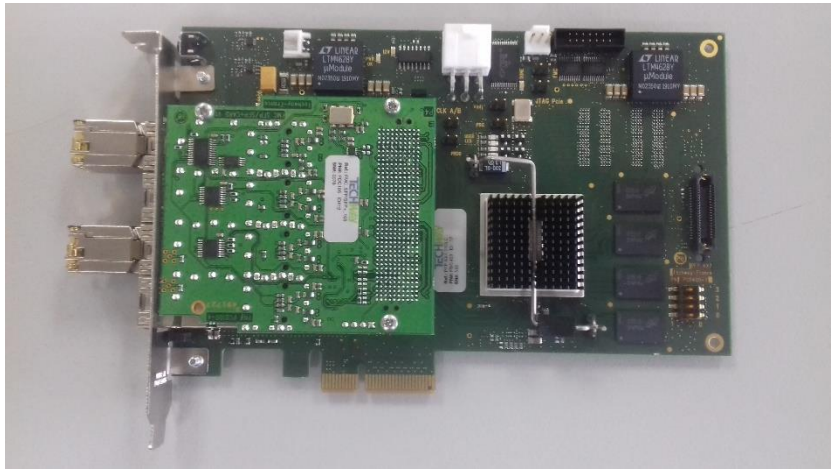
WP1 – Common SW blocks between TTE & TSN



teletel

WP2: TSN End Node IP Core Prototyping

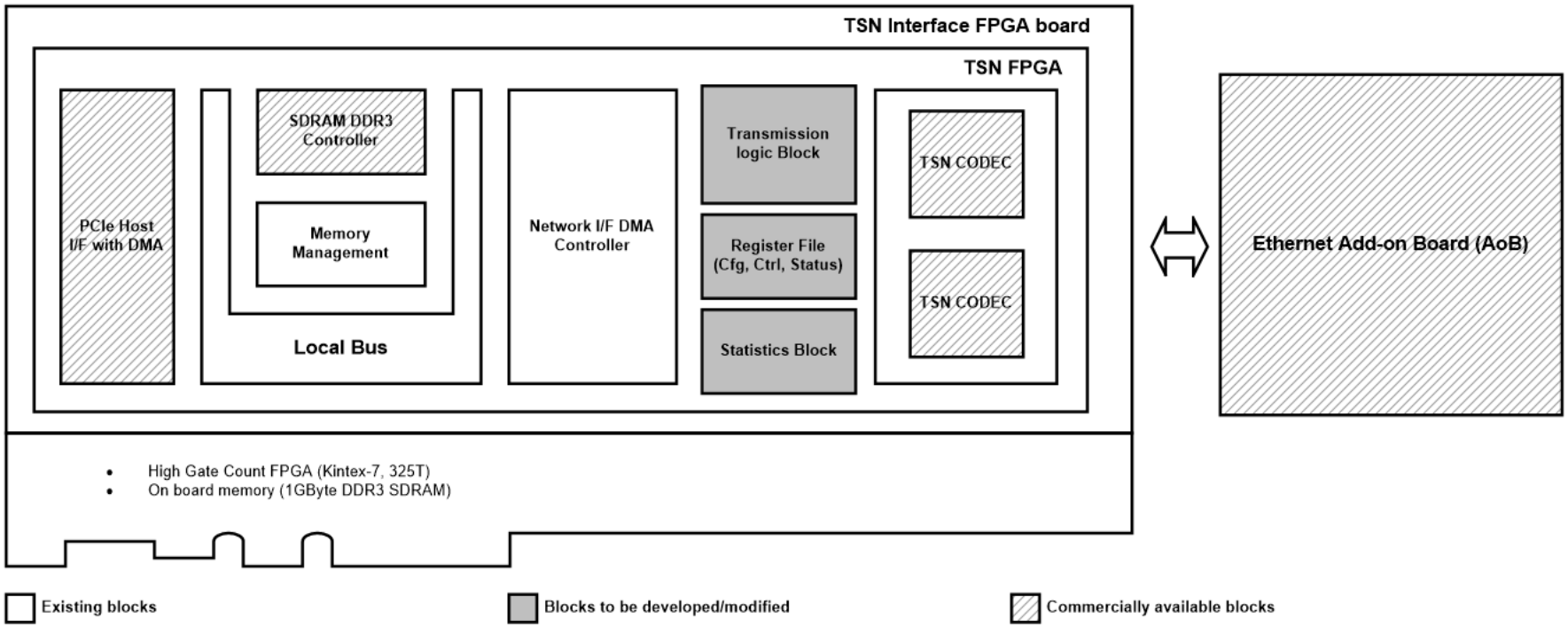
- TSN Board Consists of :
  - TechWay PFP-KX7 FPGA board (hosts Kintex7-325T device)
  - TechWay SFP/SFP+ FMC board hosting 2x 10/100/1000BASE-T SFP modules



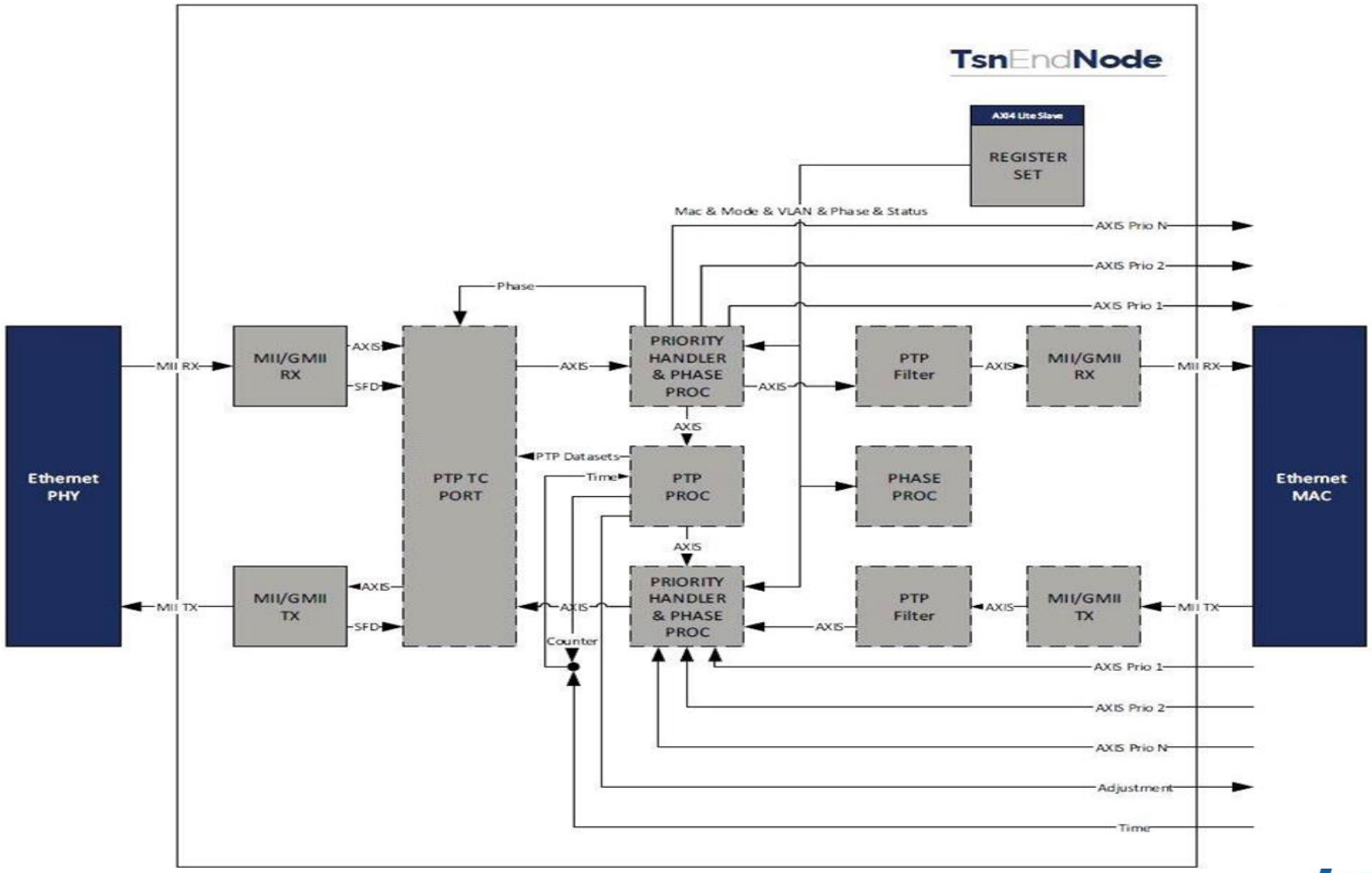
  - Each board hosts 2x NetTimeLogic TSN End-Node IP cores

teletel

iSAFT TSN PCIe FPGA board



TSN End Node IP (NetTimeLogic)



TSN IP Core FPGA Utilization

- The NetTimeLogic End-Node IP core utilization in the Kintex7-325T device is the following:
- The IP core war configured with the following characteristics:
  - 8 Priority Queues
  - Max Cycle Time (1ms)
  - IEEE 802.1AS, IEEE 802.1bv, IEEE802.1av enabled

Resource	Estimation	Available	Utilization ...
LUT	44755	203800	21.96
LUTRAM	384	64000	0.60
FF	22287	407600	5.47
BRAM	166	445	37.30
DSP	37	840	4.40
IO	2519	400	629.75
BUFG	1	32	3.13

Single IP core utilization

Resource	Utilization	Available	Utilization %
LUT	154808	203800	75.96
LUTRAM	19497	64000	30.46
FF	93358	407600	22.90
BRAM	405	445	91.01
DSP	91	840	10.83
IO	114	500	22.80
GT	6	16	37.50
BUFG	23	32	71.88
MMCM	4	10	40.00
PCIe	1	1	100.00

Total TSN board utilization (2x IP cores, Platform Logic)

teletel

Comparative FPGA Utilization for Data Networks

FPGA device: Xilinx Kintex7 (XC7K-325T)

- SpaceWire: 8-port implementation (Data transmission/reception capabilities for up to 400Mbps)
- SpaceFibre: 4-port / 4-VC per port implementation (Data transmission/reception capabilities for up to 3.125Gps)
- TSN: 2-port / 8-priority queues per port implementation (Data transmission capabilities at 1Gbps)

Resource		Utilization (%)		
Type	**Available**	**SpaceWire**	**SpaceFibre**	**TSN**
LUT	203800	48.30	53.69	75.96
LUTRAM	64000	12.26	22.46	30.46
FF	407600	28.57	34.05	22.90
BRAM	445	56.63	71.57	91.01
DSP	840	1.31	1.31	10.83
IO	500	54.40	39.80	22.80
GT	16	25.00	50.00	37.50
BUFG	32	65.63	96.88	71.88
MMCM	10	70.00	40.00	40.00
PCIe	1	100.00	100.00	100.00

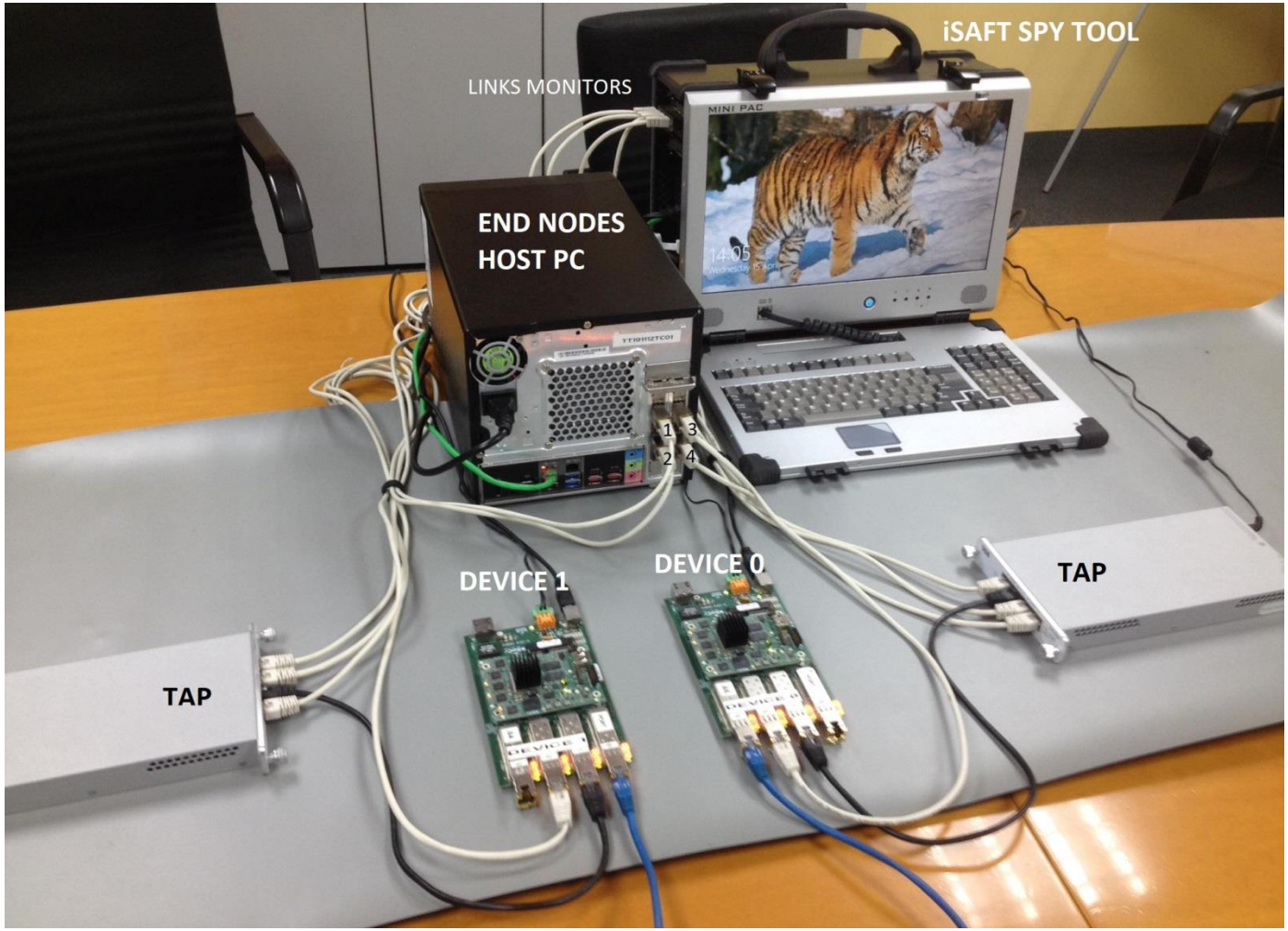
teletel

WP3: Demonstration setup 1/3

- 2x TSN boards are hosted in an iSAFT System providing a total of 4x TSN End-Nodes

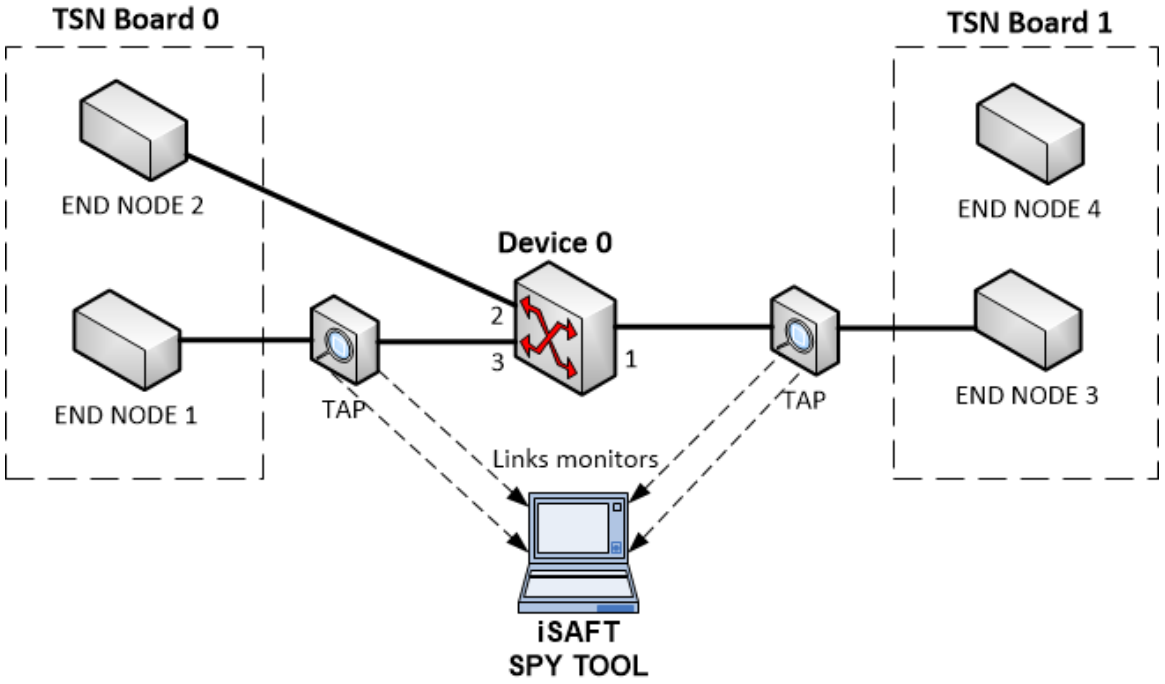
teletel

WP3: Demonstration Setup 2/3



teletel

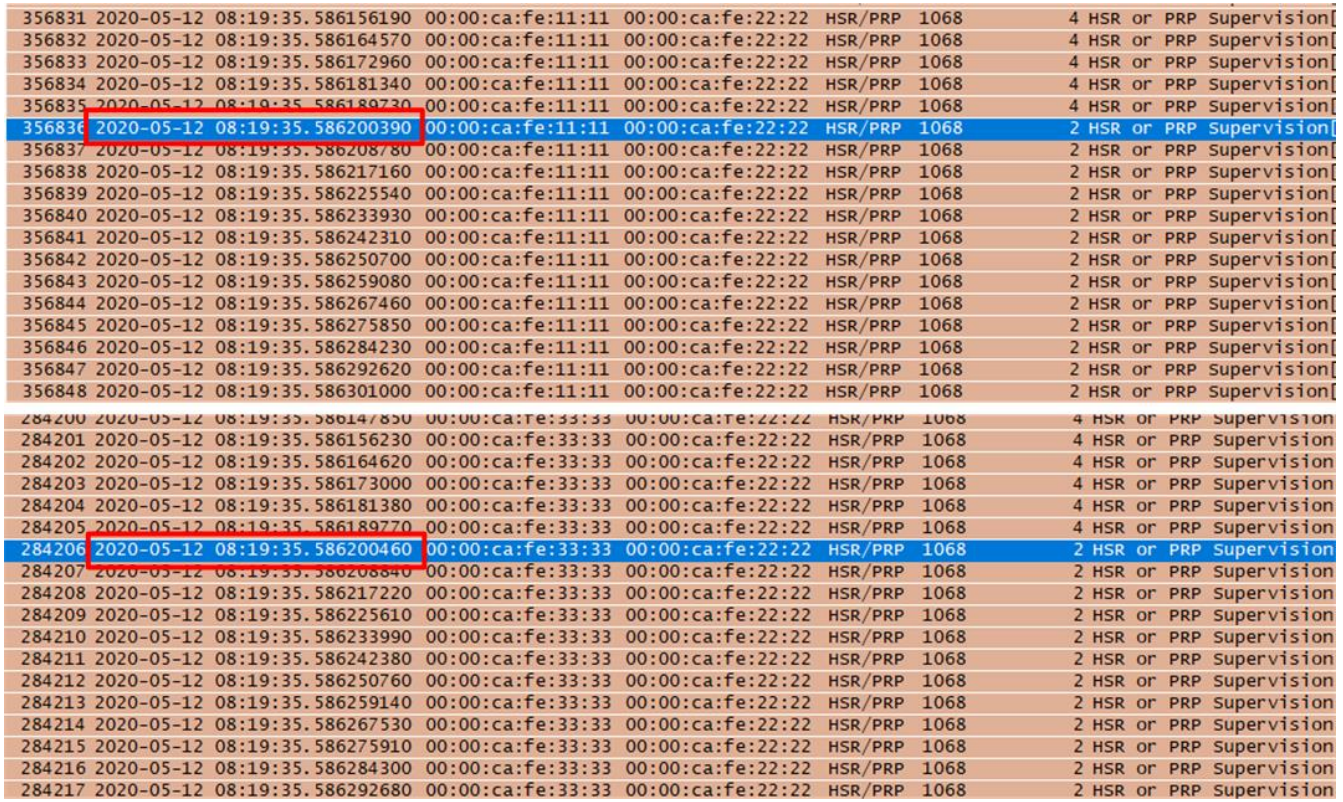
WP3: Demonstration Setup 3/3



- Three end nodes (EN1, EN2 and EN3) are connected to a TSN Switch
- Links between EN1 and the Switch, and between EN3 and the Switch are monitored with TAP devices using iSAFT SPY tool
- IEEE802.1AS (PTP Synchronization), IEEE802.1bv (scheduling), IEEE802.1av (credit based shaping) functionalities are demonstrated

teletel

WP3: PTP synchronization



356831	2020-05-12 08:19:35.586156190	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
356832	2020-05-12 08:19:35.586164570	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
356833	2020-05-12 08:19:35.586172960	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
356834	2020-05-12 08:19:35.586181340	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
356835	2020-05-12 08:19:35.586189730	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
356836	2020-05-12 08:19:35.586200390	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356837	2020-05-12 08:19:35.586208780	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356838	2020-05-12 08:19:35.586217160	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356839	2020-05-12 08:19:35.586225540	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356840	2020-05-12 08:19:35.586233930	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356841	2020-05-12 08:19:35.586242310	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356842	2020-05-12 08:19:35.586250700	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356843	2020-05-12 08:19:35.586259080	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356844	2020-05-12 08:19:35.586267460	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356845	2020-05-12 08:19:35.586275850	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356846	2020-05-12 08:19:35.586284230	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356847	2020-05-12 08:19:35.586292620	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
356848	2020-05-12 08:19:35.586301000	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision[
284200	2020-05-12 08:19:35.586147850	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision
284201	2020-05-12 08:19:35.586156230	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision
284202	2020-05-12 08:19:35.586164620	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision
284203	2020-05-12 08:19:35.586173000	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision
284204	2020-05-12 08:19:35.586181380	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision
284205	2020-05-12 08:19:35.586189770	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision
284206	2020-05-12 08:19:35.586200460	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284207	2020-05-12 08:19:35.586208840	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284208	2020-05-12 08:19:35.586217220	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284209	2020-05-12 08:19:35.586225610	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284210	2020-05-12 08:19:35.586233990	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284211	2020-05-12 08:19:35.586242380	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284212	2020-05-12 08:19:35.586250760	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284213	2020-05-12 08:19:35.586259140	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284214	2020-05-12 08:19:35.586267530	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284215	2020-05-12 08:19:35.586275910	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284216	2020-05-12 08:19:35.586284300	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
284217	2020-05-12 08:19:35.586292680	00:00:ca:fe:33:33	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision

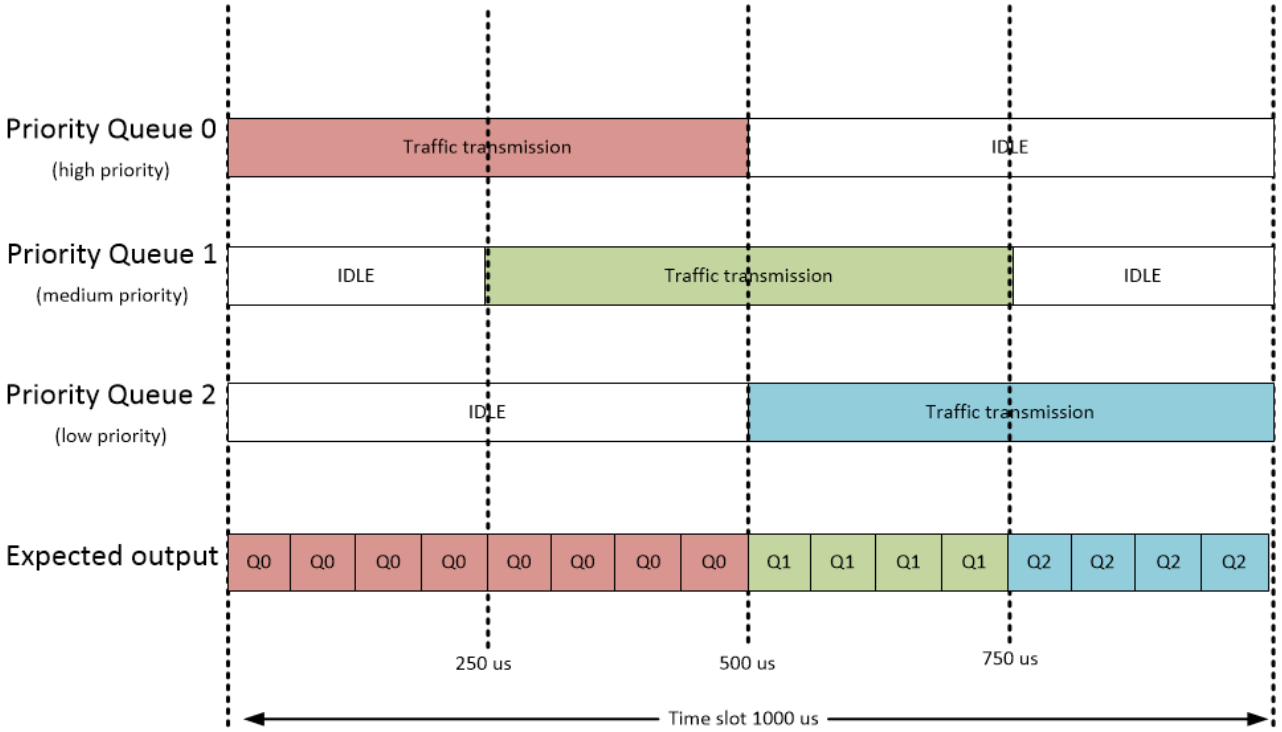
Start of cycle on EN1

Start of cycle on EN3

- **Switch is the PTP synchronization master**
- **The same scheduling (time slot / phases) is applied to EN 1/3 (transmitting at the same time)**
- **Links from EN1/EN3 monitored with common timestamping**
- **Both nodes are synchronized (beginning of cycle) with a time difference under 100 ns**

teletel

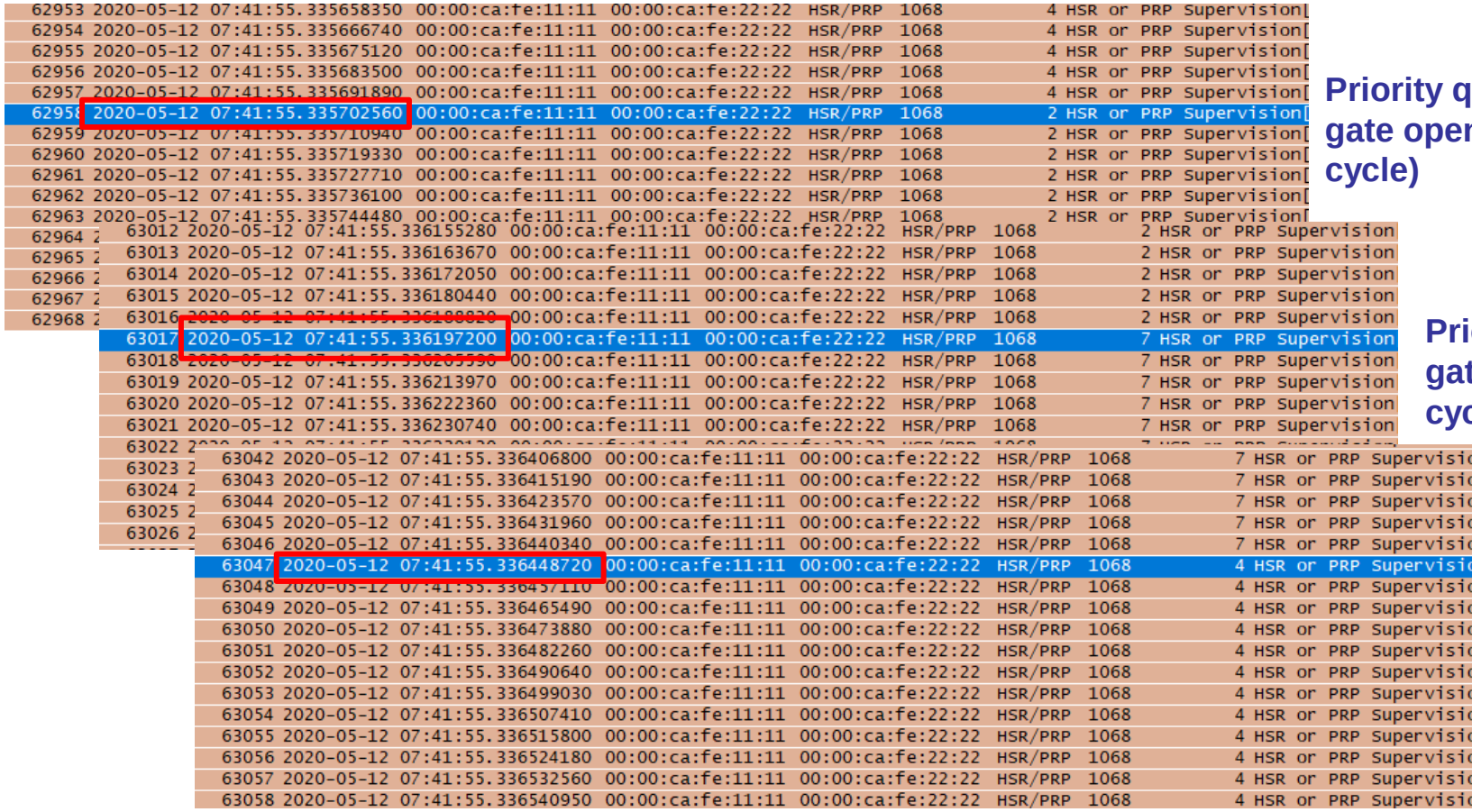
WP3: TSN Scheduling 1/2



- **Time slot duration is 1000 us**
- **Priority queue 0 can transmit from t = 0 to t = 500us**
- **Priority queue 1 can transmit from t = 250us to t = 750us**
- **Priority queue 2 can transmit from t = 500us to t = 1000us**
- **Expected output is according to priority precedence**

teletel

WP3: TSN Scheduling 2/2



Priority queue 0 gate opens (start of cycle)

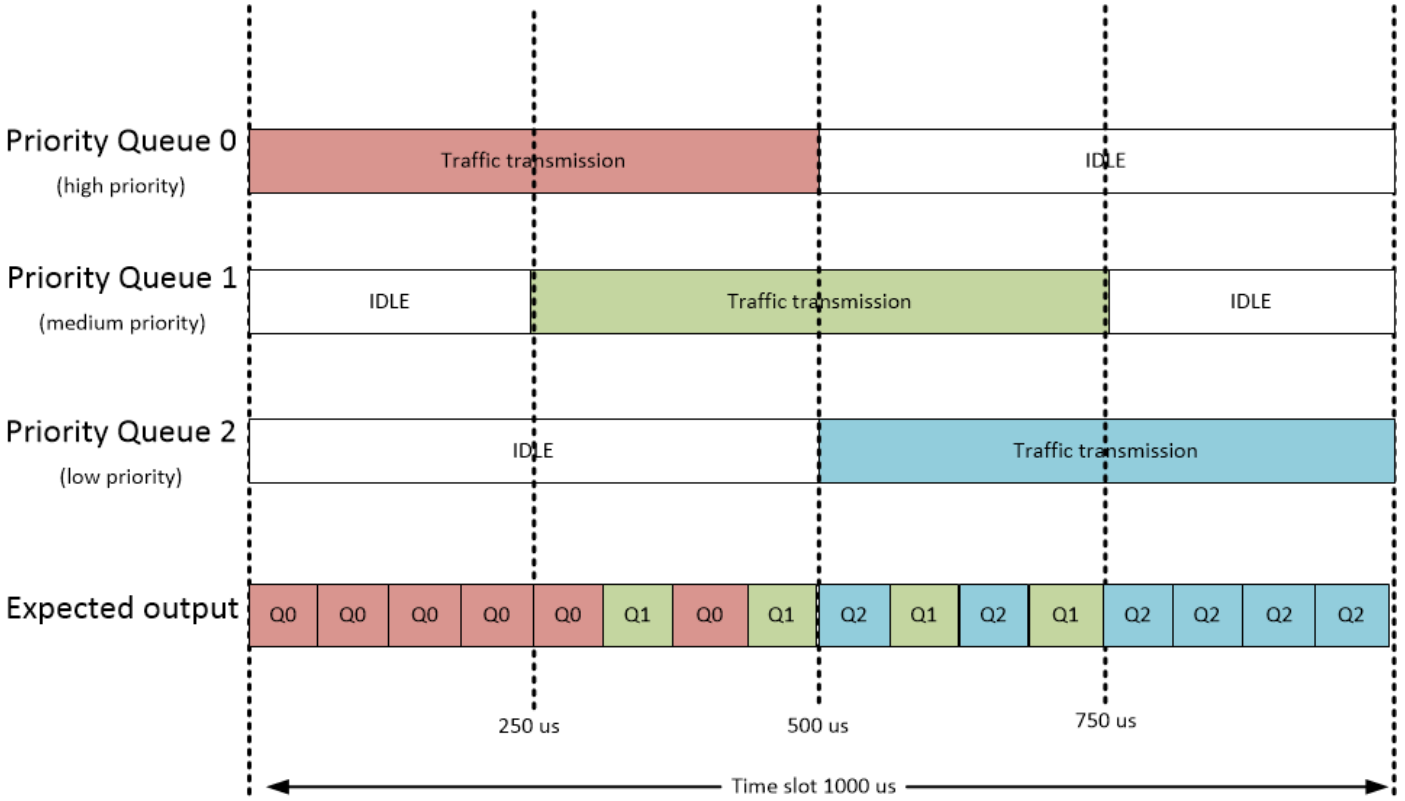
Priority queue 1 gate opens (start of cycle + ~500us)

Priority queue 2 gate opens (start of cycle + ~750us)

- **Timestamping results verify the expected transmission schedule**

teletel

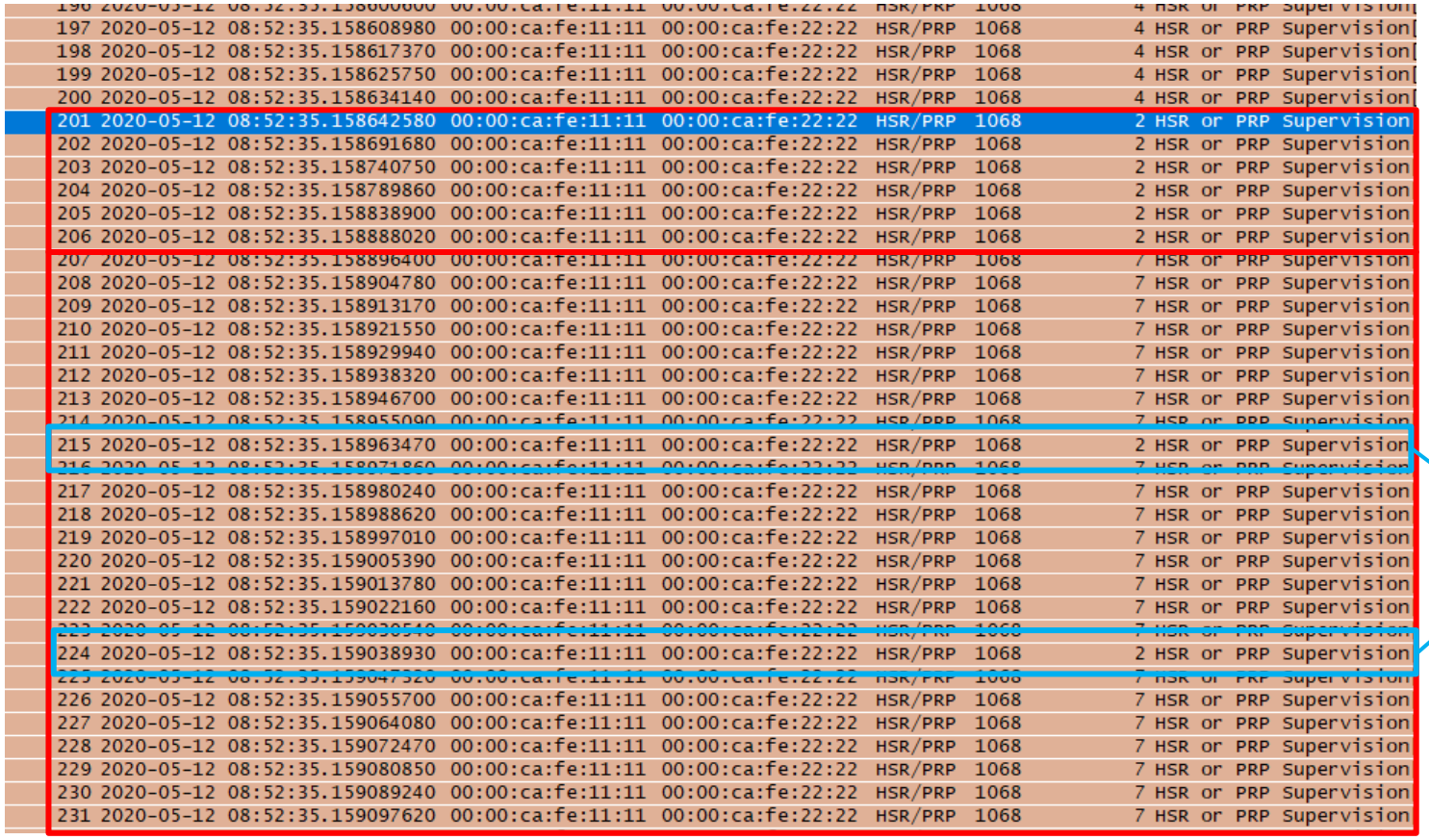
WP3: Credit Shaping 1/2



- **Priority queue 1's credit slopes (inc/dec) are configured for higher bandwidth than queues 0 and 2**
- **Expected output on overlapping phases is according to credit shaping (Queue 1 shall have more BW)**

teletel

WP3: Credit Shaping 2/2



197	2020-05-12 08:52:35.158608980	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
198	2020-05-12 08:52:35.158617370	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
199	2020-05-12 08:52:35.158625750	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
200	2020-05-12 08:52:35.158634140	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	4	HSR or PRP Supervision[
201	2020-05-12 08:52:35.158642580	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
202	2020-05-12 08:52:35.158691680	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
203	2020-05-12 08:52:35.158740750	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
204	2020-05-12 08:52:35.158789860	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
205	2020-05-12 08:52:35.158838900	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
206	2020-05-12 08:52:35.158888020	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
207	2020-05-12 08:52:35.158896400	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
208	2020-05-12 08:52:35.158904780	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
209	2020-05-12 08:52:35.158913170	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
210	2020-05-12 08:52:35.158921550	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
211	2020-05-12 08:52:35.158929940	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
212	2020-05-12 08:52:35.158938320	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
213	2020-05-12 08:52:35.158946700	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
214	2020-05-12 08:52:35.158955090	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
215	2020-05-12 08:52:35.158963470	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
216	2020-05-12 08:52:35.158971860	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
217	2020-05-12 08:52:35.158980240	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
218	2020-05-12 08:52:35.158988620	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
219	2020-05-12 08:52:35.158997010	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
220	2020-05-12 08:52:35.159005390	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
221	2020-05-12 08:52:35.159013780	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
222	2020-05-12 08:52:35.159022160	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
223	2020-05-12 08:52:35.159030540	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
224	2020-05-12 08:52:35.159038930	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	2	HSR or PRP Supervision
225	2020-05-12 08:52:35.159047320	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
226	2020-05-12 08:52:35.159055700	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
227	2020-05-12 08:52:35.159064080	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
228	2020-05-12 08:52:35.159072470	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
229	2020-05-12 08:52:35.159080850	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
230	2020-05-12 08:52:35.159089240	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision
231	2020-05-12 08:52:35.159097620	00:00:ca:fe:11:11	00:00:ca:fe:22:22	HSR/PRP	1068	7	HSR or PRP Supervision

Start of cycle (Queue 0 transmits only)

Queue 1 starts transmission with higher BW allocation

Queue 0 transmits with lower BW allocation due to credit shaping

- **Credit Shaper allows for precise bandwidth allocation scenarios in overlapping phases**

teletel

Conclusions

- **TSN seems to be an open and promising technology for mixed criticality Ethernet networks in space, supported by multiple players**
- **Early availability of test and simulation tools will assist the technology take-up**
- **Initial prototyping proved the concepts and reduced the development risks**
- **The project results pave the way for the development of a fully fledged TSN Test System**
- **A future activity shall also be the development and qualification of a TSN IP Core for flight use, ideally on a European FPGA (BRAVE).**

teletel

Contact

teletel

- 124 Kifissias Avenue
- 115 26 Athens, Greece

- Tel: +30 210 6983393
- Fax: +30 210 6983391

- email: rtd@teletel.eu
- http://www.teletel.eu