

Experiments on Combination of DetNet and TSN

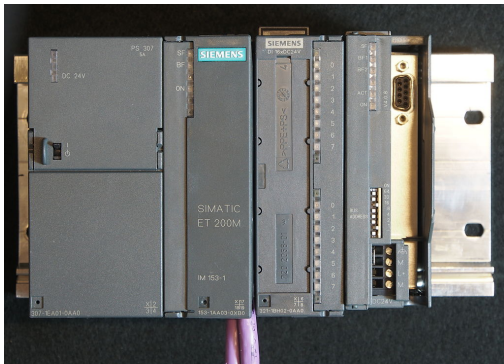
DetNet - TSN Workshop

Dr. Florian Kauer

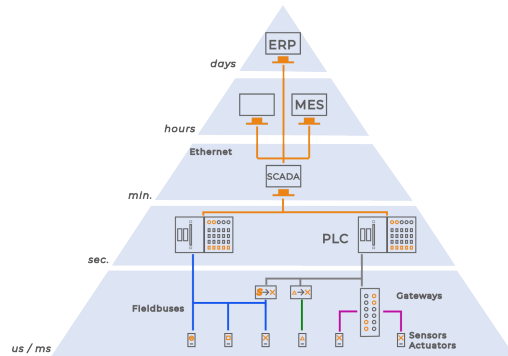
Linutronix GmbH

2025-07-26

Industrial Automation today

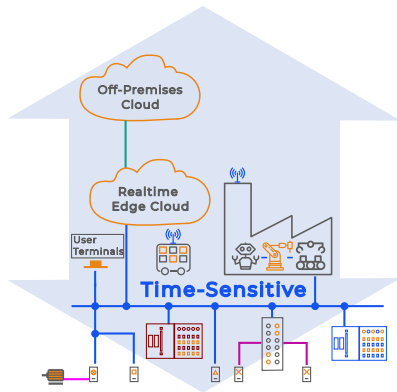


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**Dedicated programmable logic controllers (PLCs)
scattered over factory floor**

Virtualized Edge Cloud Compute Platforms (Future)



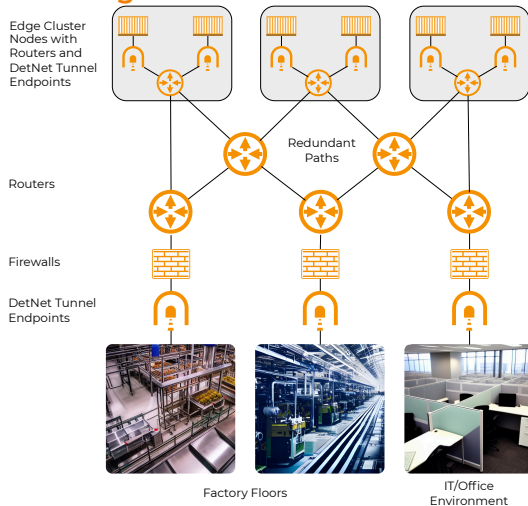
Convenient data exchange between
field level and upper levels



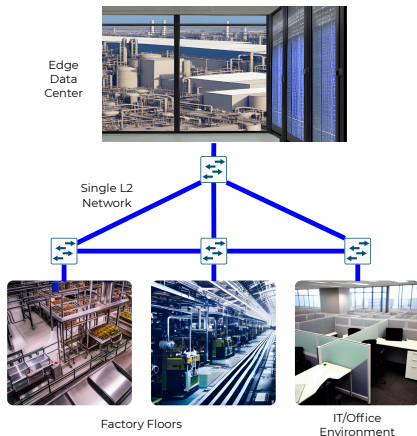
AI impression of a central data center in an industrial park

Redundant compute capacity available
on demand without hardware changes

DetNet from Field Level to Edge Cloud



Why not just deploy a single large TSN?



- ❑ Huge number of devices → Performance issues
- ❑ Multiple trust domains → Security issues
- ❑ Intertwined network management

TSN in the Linux Ecosystem

Real-Time Task Scheduling

- PREEMPT-RT (mainline since last year)

Traffic Shaping (Qbv/EST, Qav/FQTSS)

- TAPRIO and CBS qdisc
- Software emulation and full hardware offload (for Intel i226 and many others)

Frame Preemption

- Supported by Linux kernel at least for Intel i225/i226

Time Synchronization

- LinuxPTP and many related Linux kernel features

TSN Validation

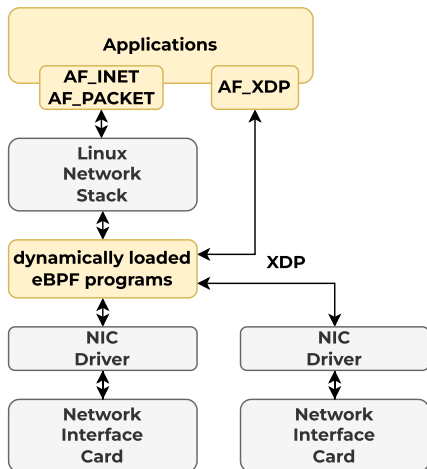
- RTC-Testbench

Sockets with low latency and jitter

- AF_PACKET and AF_XDP

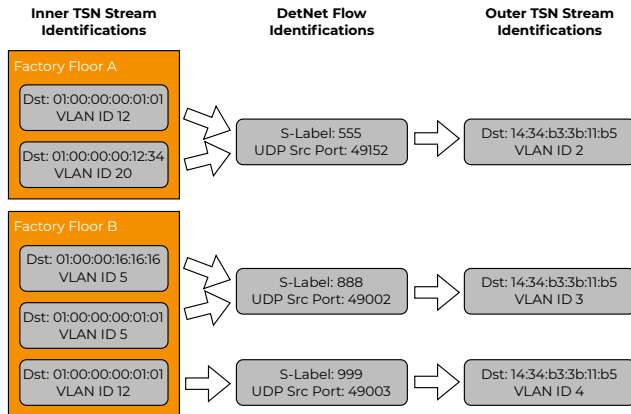
eXpress Data Path

- ❏ Versatility of Linux Network Stack induces latency and jitter
- ❏ OT traffic structure usually known ahead
 - Load dedicated program (eBPF) at runtime allows to bypass Linux Network Stack
- ❏ Still, control over NIC stays with kernel (in contrast to DPDK)
- ❏ Suitable for fast experimentation



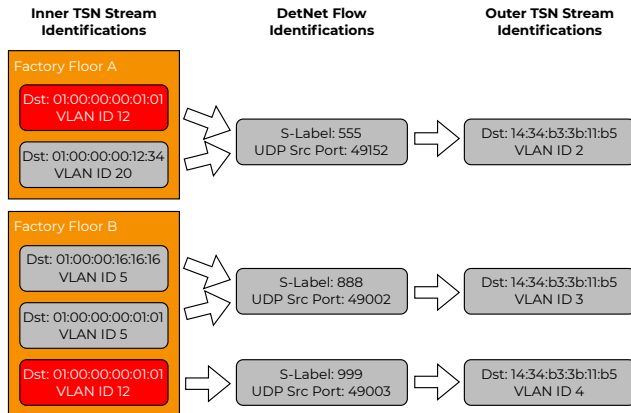
DetNet Tunneling over TSN-aware Networks

- Encapsulate TSN streams into MPLS and UDP/IP to maintain network segregation
- Map DetNet flow to dedicated TSN streams
- Provide guaranteed bounded latency and zero congestion loss end-to-end



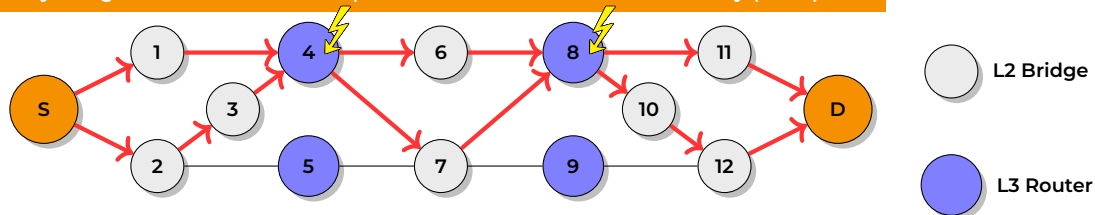
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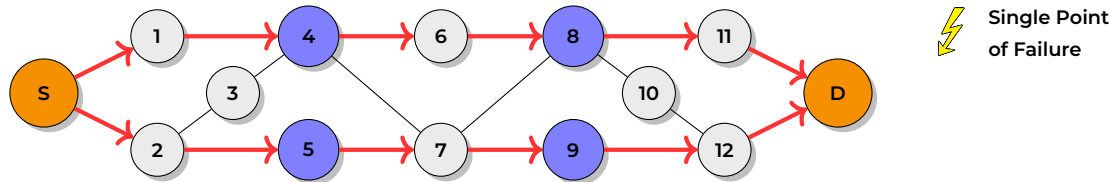


Service Protection Beyond TSN Sub-Networks

Only using IEEE 802.1CB Frame Replication and Elimination for Reliability (FRER)



Using DetNet's Packet Replication, Elimination, and Ordering Functions (PREOF)



How to orchestrate TSN and DetNet in Linux?

detnetctl Open Source Framework

 github.com/linutronix/detnetctlConfiguration
Interfaces

Static YAML File

NETCONF / YANG

D-Bus



Setup of

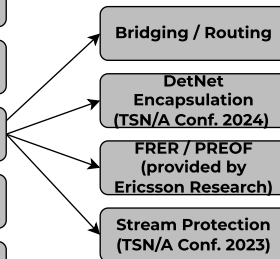
Physical and Logical
InterfacesTAPRIO qdisc for
Time-Aware Shaper

eBPF/XDP programs

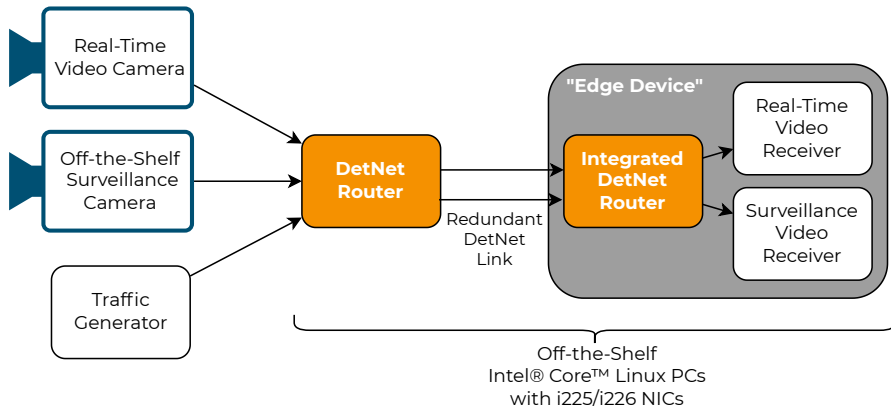
Network
Namespaces

PTP

Bridging / Routing

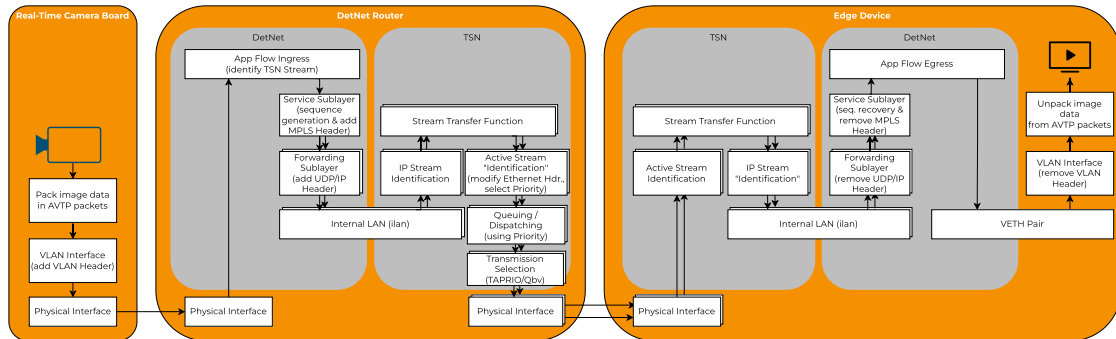
DetNet
Encapsulation
(TSN/A Conf. 2024)FRER / PREOF
(provided by
Ericsson Research)Stream Protection
(TSN/A Conf. 2023)

detnetctl Demo



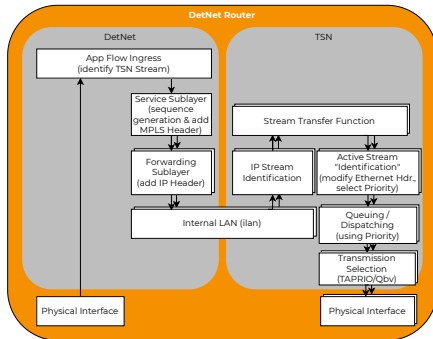


Logical View

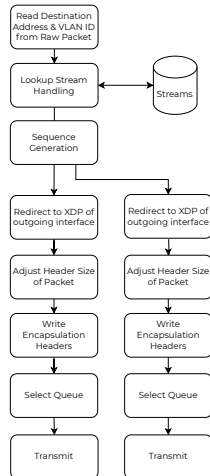


Implementation with Linux eXpress Data Path (XDP) and eBPF

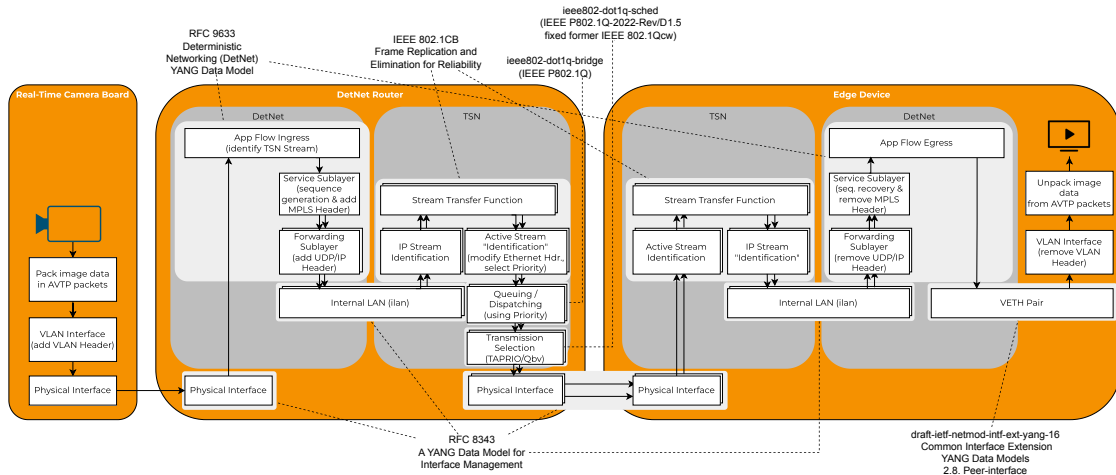
Logical View



Implementation View



Configuration via YANG



Note: Related YANG instance data is attached to this PDF

Conclusion

- 📁 Industrial automation is moving towards virtualized control in edge clouds
- 📁 DetNet is suitable to converge multiple TSNs for edge cloud infrastructure
- 📁 Existing standards are suitable to deploy actual TSN over DetNet over TSN networks
- 📁 Linux and eBPFs are a good fit for both experimentation and real-world deployments

 github.com/linutronix/detnetctl