

„We’ve got realtime networking at home“

Why many systems are moving to TSN so slowly

Johannes Zink – j.zink@pengutronix.de



\$whoami

- Kernel Developer at Pengutronix since 2022
- Former System Engineer, mostly worked on Realtime Networking



- Embedded Linux consulting & support since 2001
- ~6000 patches in Linux kernel

Agenda

- Application examples
- Application requirements for realtime networking
- Legacy implementation approaches
- Brownfield migration towards TSN
- The role of Linux networking
- Outlook



Application Examples

- Machine Control
- Audio Video Bridging
- Aerospace
- Automotive
- ...



Application Requirements

- Time Synchronization

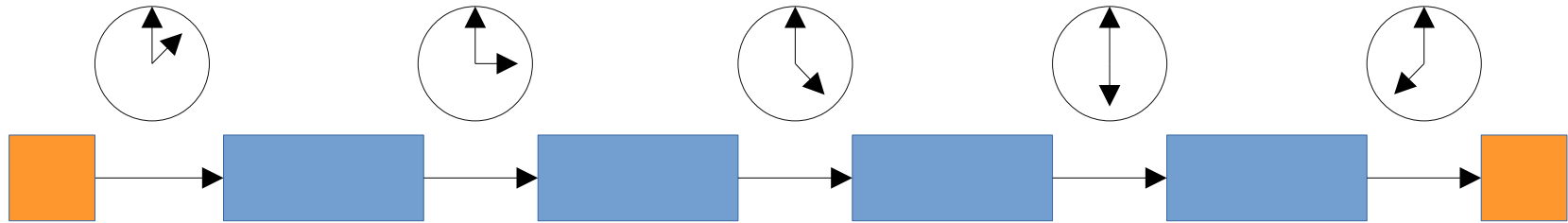


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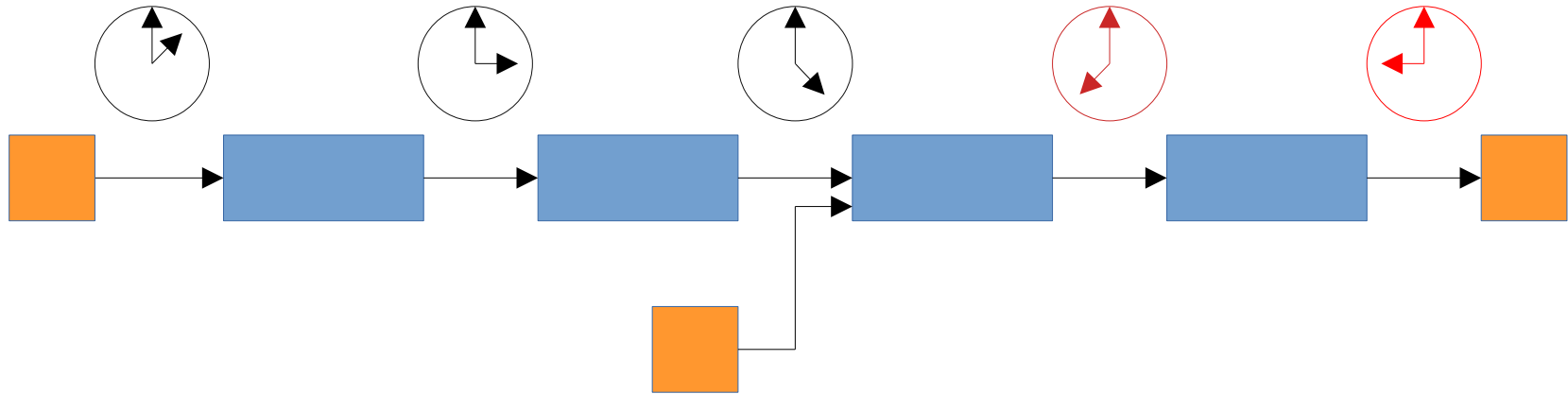
Application Requirements

- Time Synchronization
- Bounded Transmission Latency



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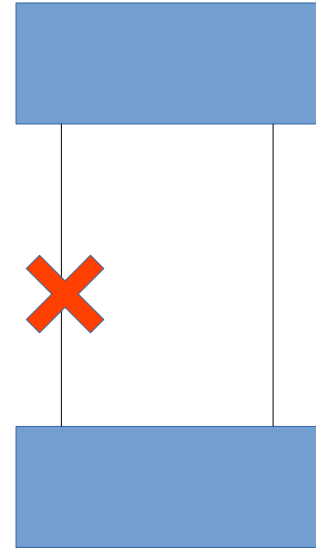
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- Time Synchronization
- Bounded Transmission Latency
- Quality of Service



Application Requirements

- Time Synchronization
- Bounded Transmission Latency
- Quality of Service
- Additional Features
 - Physical Layer Redundancy



Legacy Implementation Approaches

- Time Synchronization
 - PTP or PTP-ish
- Bounded Transmission Latency
 - Best effort
 - Engineered setups
- Quality of Service
 - Traffic segregation
 - DSCP



TSN

- Standard set fixing most requirements
 - gPTP
 - Traffic Shaping
 - Network management
 - Physical Layer Redundancy (partially solved with PCR and FRER)
- Some requirements are out of scope
 - Routing



Brownfield Migration Strategies

- Deployed devices often cannot be upgraded
 - Hardware requirements
 - Often cannot converge with TSN
- Replacing entire systems often too expensive
- Upgrading subsystem and using gateways instead
- TSN capable hardware for replacements, extensions or new deployments



The role of linux networking

- Required standards and components are supported in mainline
- Excellent basis for development (thank you for all your effort!)
- Userspace Interface and documentation
 - API design
 - Daemons, Services, Configuration, Default Settings
 - Examples, reference designs help a lot pushing technology in the field
 - Test tools
- TSN is only the start for Deterministic/Realtime Networking



Outlook, Call for Action

- TSN fills lots of gaps, but remaining issues need to be addressed
 - DetNet will fill more of these gaps
 - Higher level protocols
- Future challenges will include providing good interfaces with sane default settings
- Integrators and users will need help to push technology forward
 - Examples
 - Reference designs
- Debugging and Validation Tools



Thank you for your attention

Are there any Questions?



Bonus slide – War stories from the field

- PTP sync issues in large TV production setup due to skype calls being routed on critical paths
- Broken audio streams on large concert recording due to bad switch setup
- Audio dropouts on a >10k audience venue due to last minute network layout changes
- Production line crashes due to football game being streamed over machine networks
- Radio stations transmitted as multicast and a bad IGMP configuration of a switch at the manufacturing plant causing DoS on synchronous movement of a PnP robot
- Firmware updates causing DoS in machine realtime operation
- ...

