FabOS: Hooking up Container Platforms with Time-Sensitive Networks

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Challenging demands on Future Factories

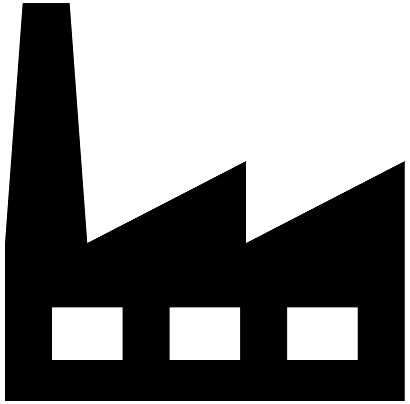
Flexible networking landscape

→ Adopt to changing Quality-of-Service requirements

Adoptive production

Frequent / daily floorplan adoptions

→ Changing setup of machines and factory OS



Real-time networking

Sustainability and compute efficiency

Flexible use of common of-the-shelf computing hardware

→ Virtual Programming Logic Controllers

Security

Security zones with real-time capabilities

→ Data-link layer access

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Do not reinvent the wheel!

kubernetes

- Cloud Container platform
- Flexible and efficient use of compute resources
- Easy container deployment

could become

→ ~~Is~~ the perfect compute environment for industry

Problems:

→ Container placement not aware of network requirements

→ No real-time network access

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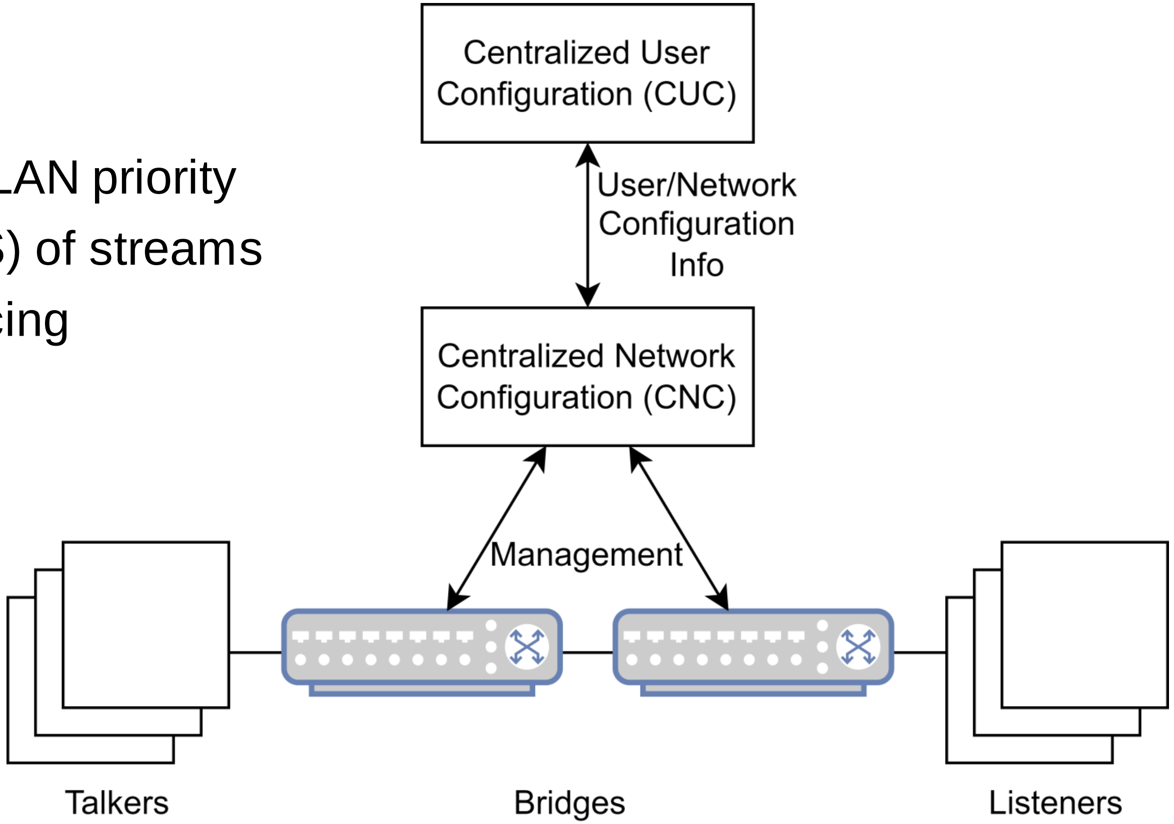
Time-Sensitive Networking (TSN)

- Promising solution for industrial networks
- Flexible network usage
- Stream detection via MAC address, VLAN ID, and VLAN priority
- Mechanisms for Guaranteed Quality-of-Service (QoS) of streams
  - E.g. Strict priority with per-stream filtering and policing
- Fully centralized model

Problem:

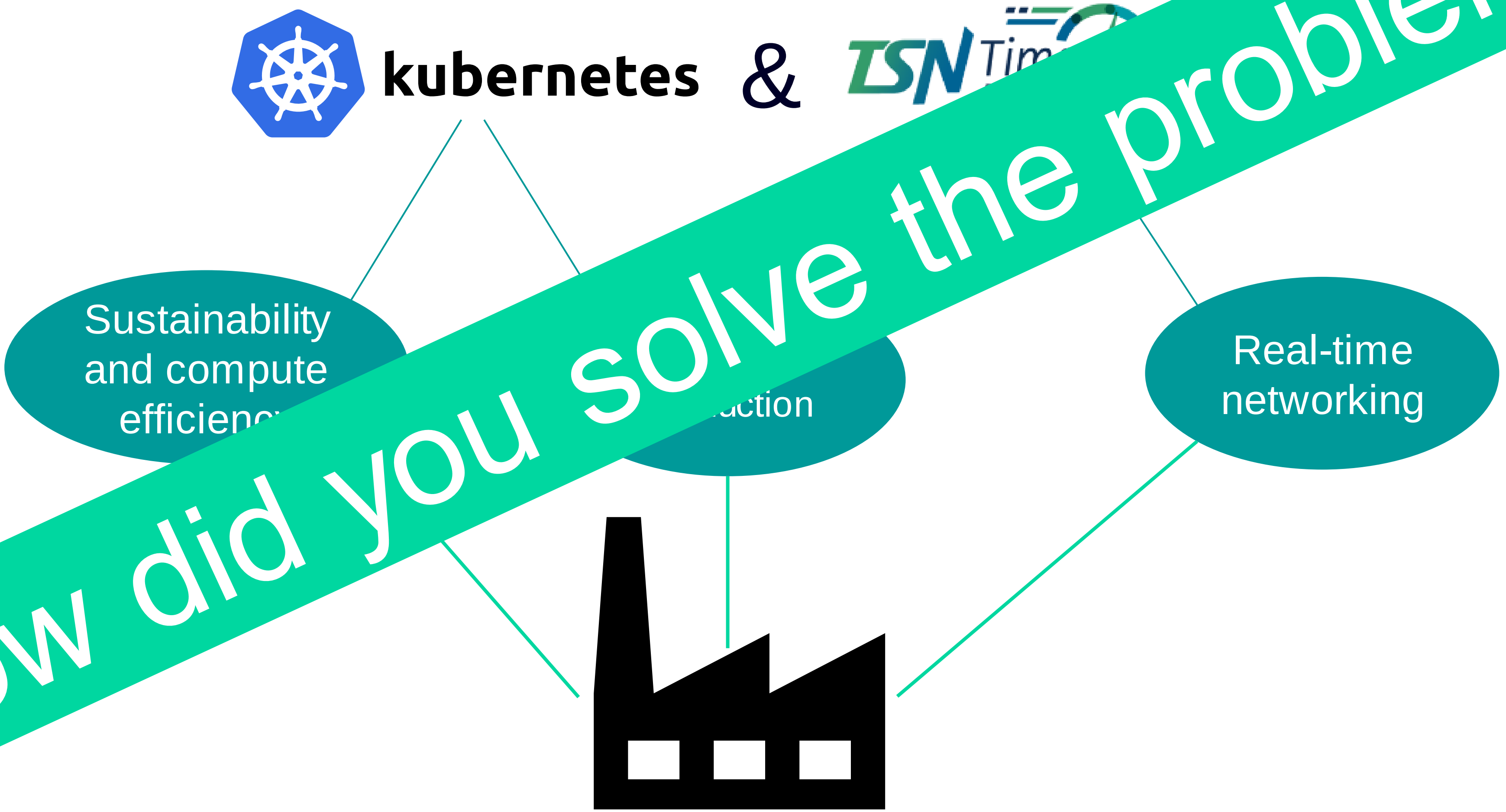
→ No implementation of CUC & CNC

→ No interface to Kubernetes



IEEE 802.1Qcc Fully centralized network model

The FabOS Architecture:
Hooking up Container Platforms with Time-Sensitive Networks



How did you solve the problems?

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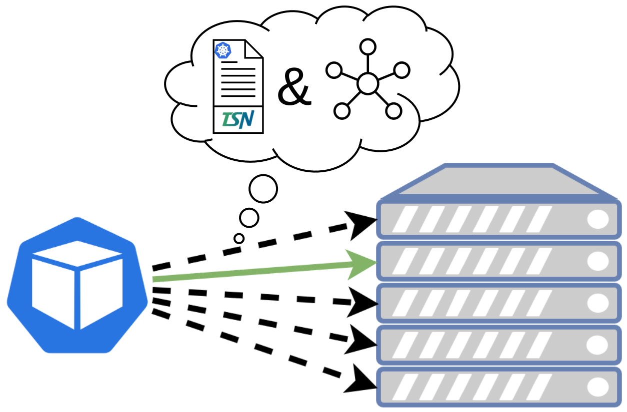
The proposed Architecture in 3 Steps

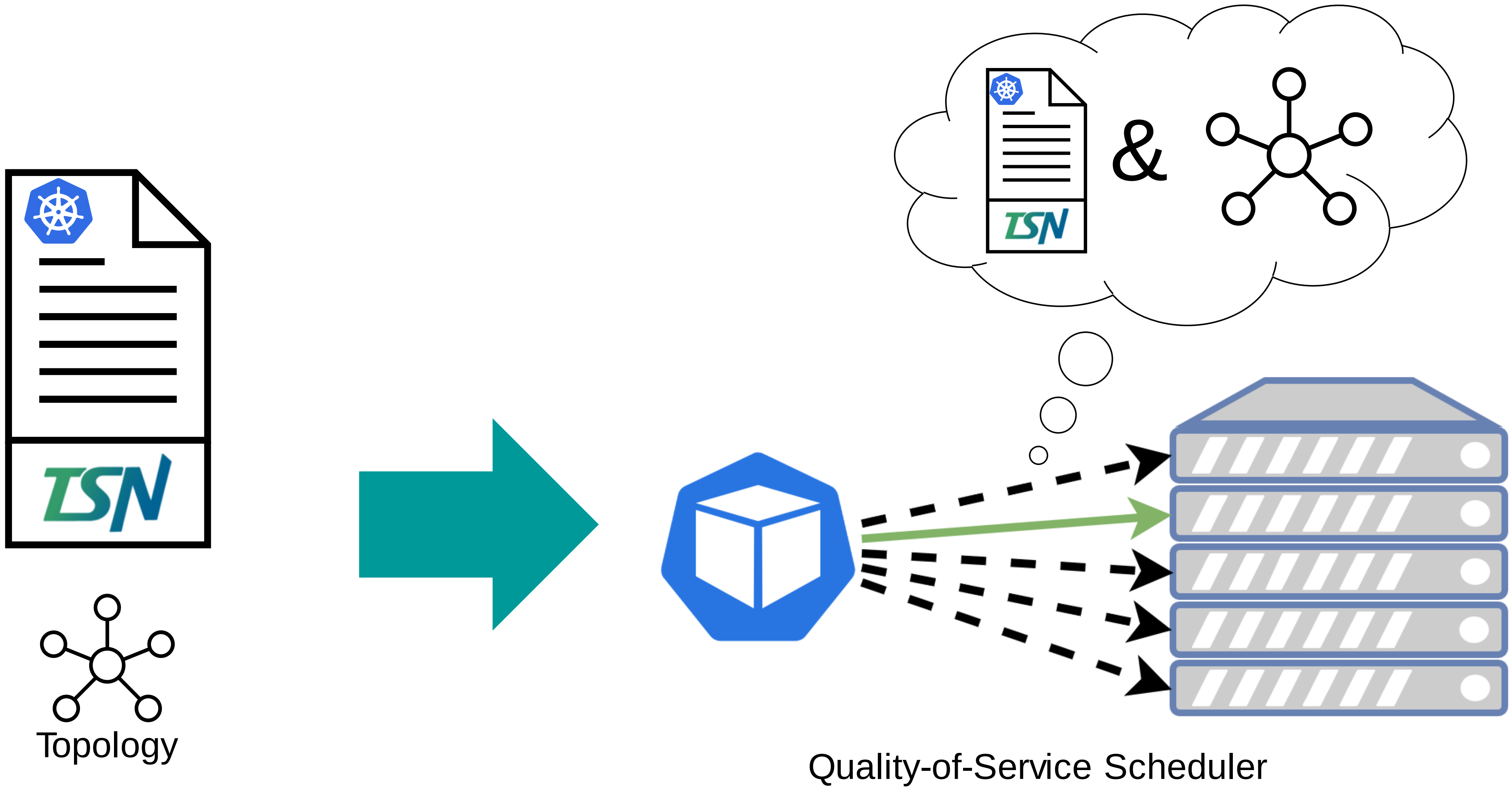
Step 1: Network aware Container Placement



Step 2: TSN Network Configuration

Step 3: Frame Tagging for TSN

Step 1: Network aware Container Placement



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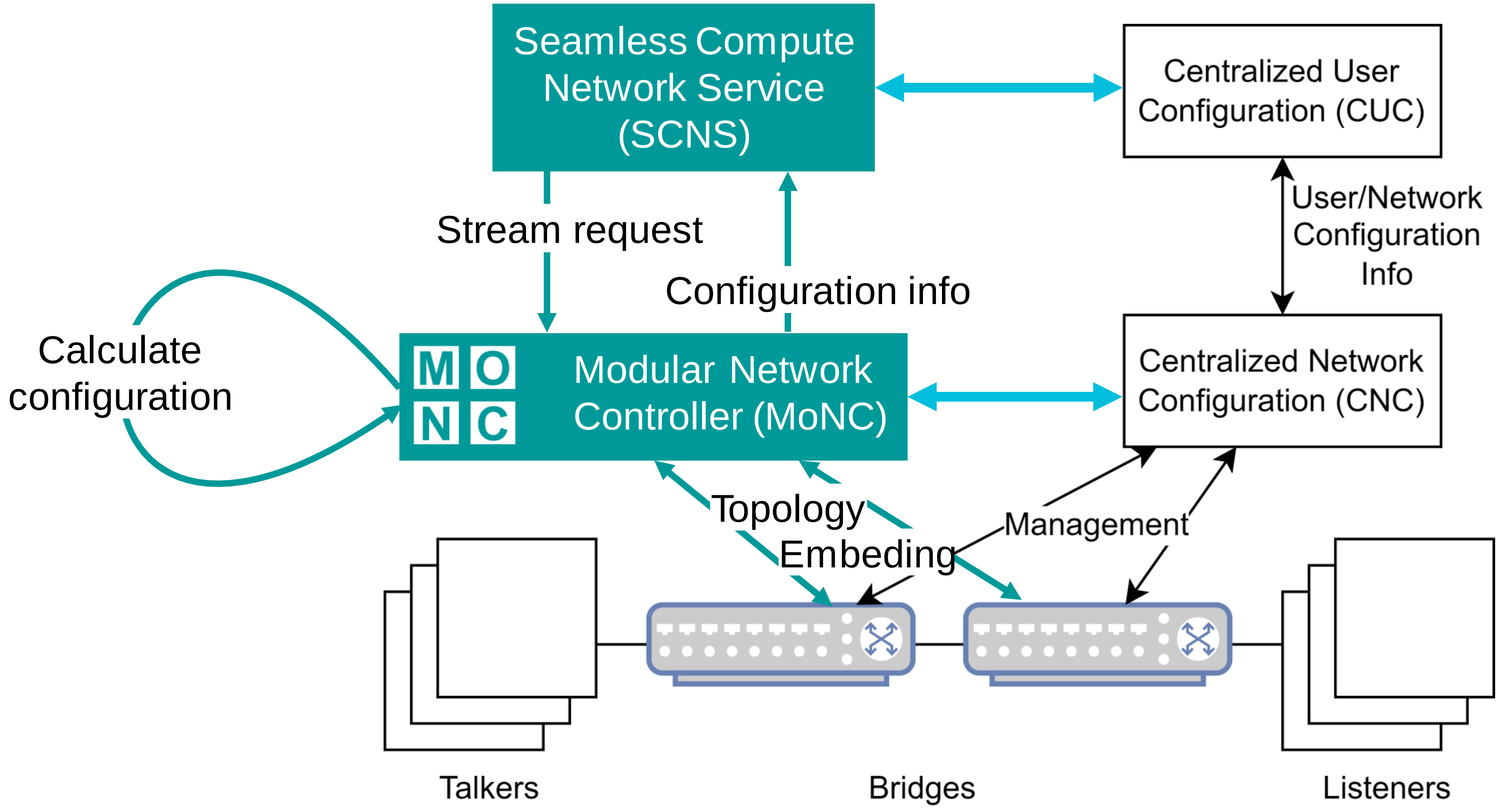
Step 2: TSN Network Configuration



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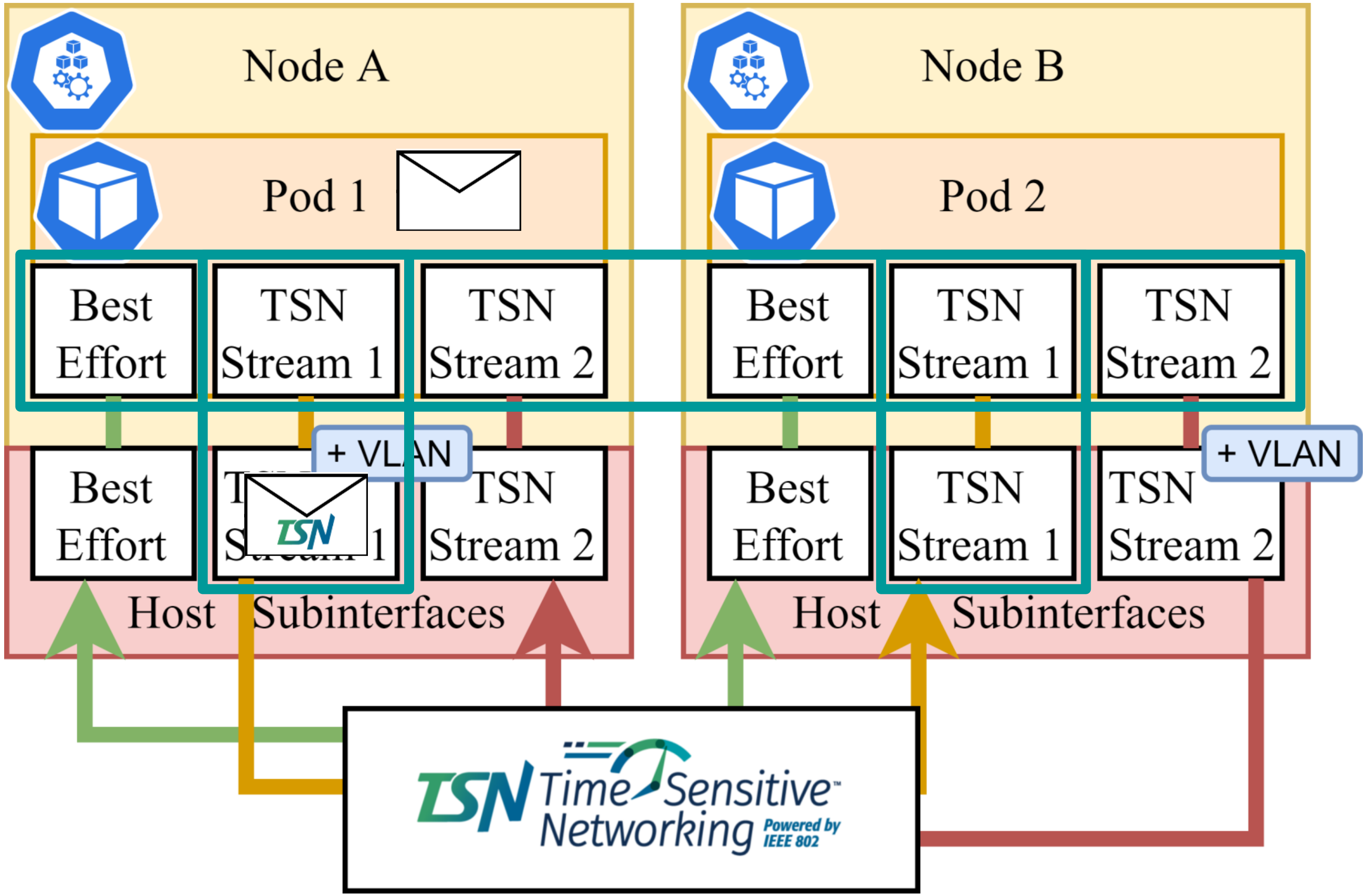
Step 3: Frame Tagging for TSN



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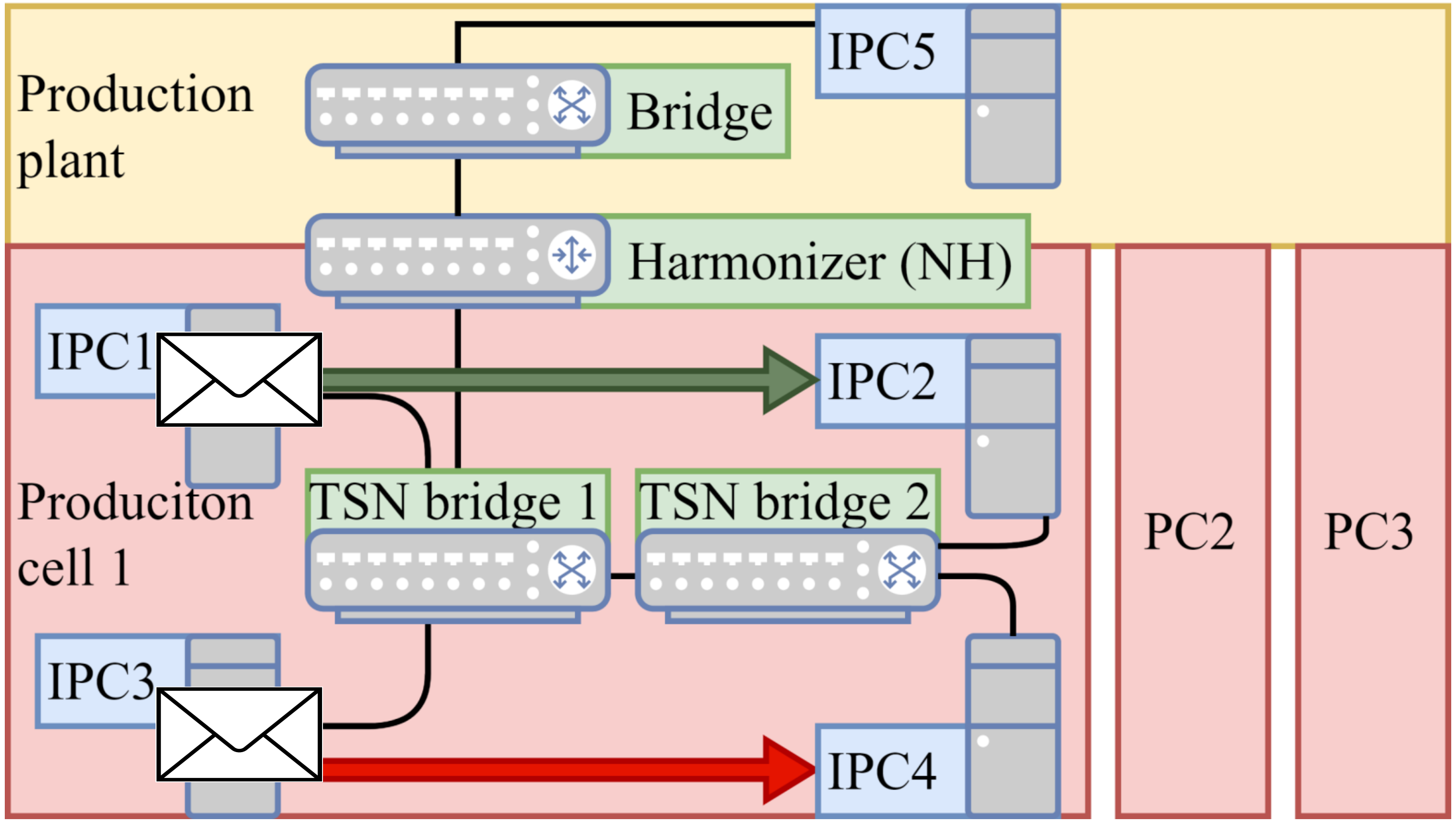
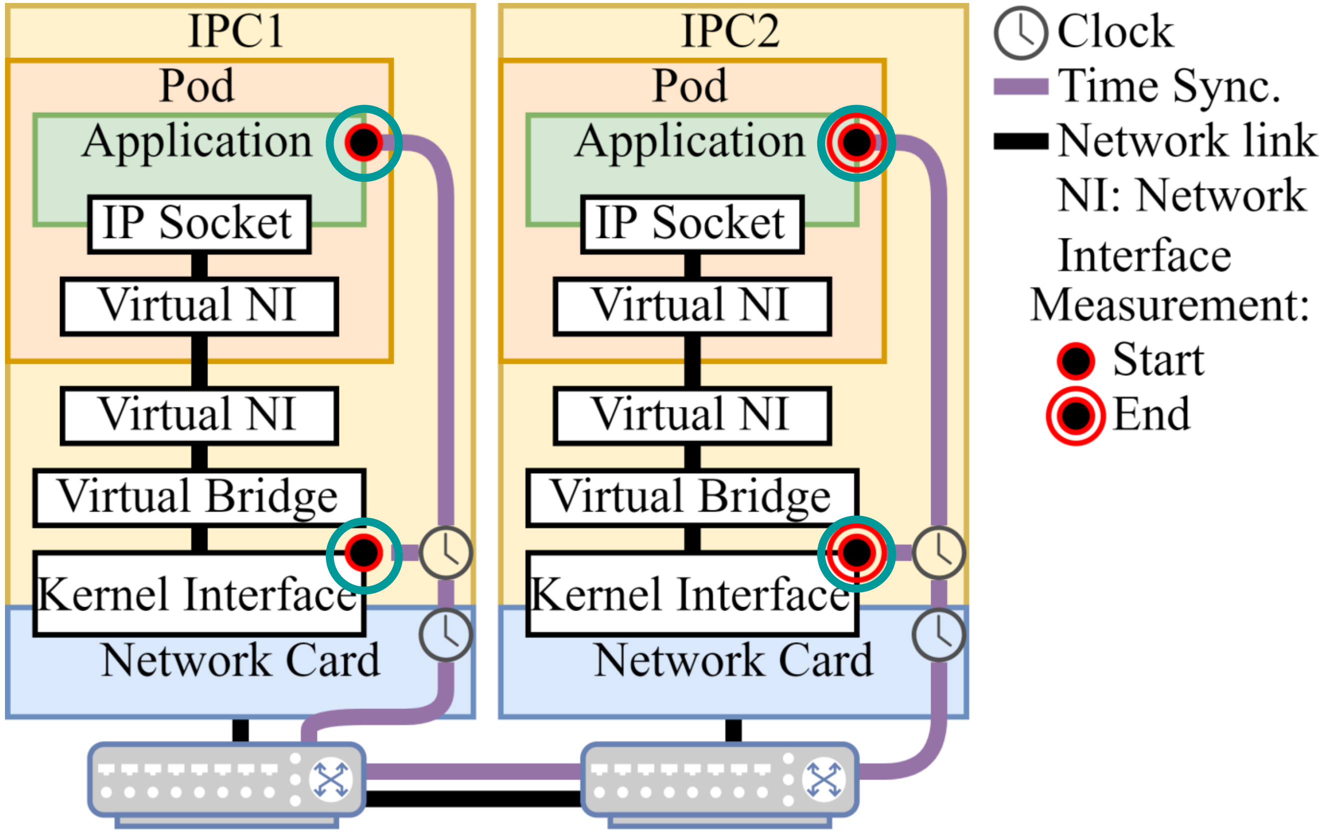
Proof-of-concept implementation



Evaluation – 3 Measurement setups



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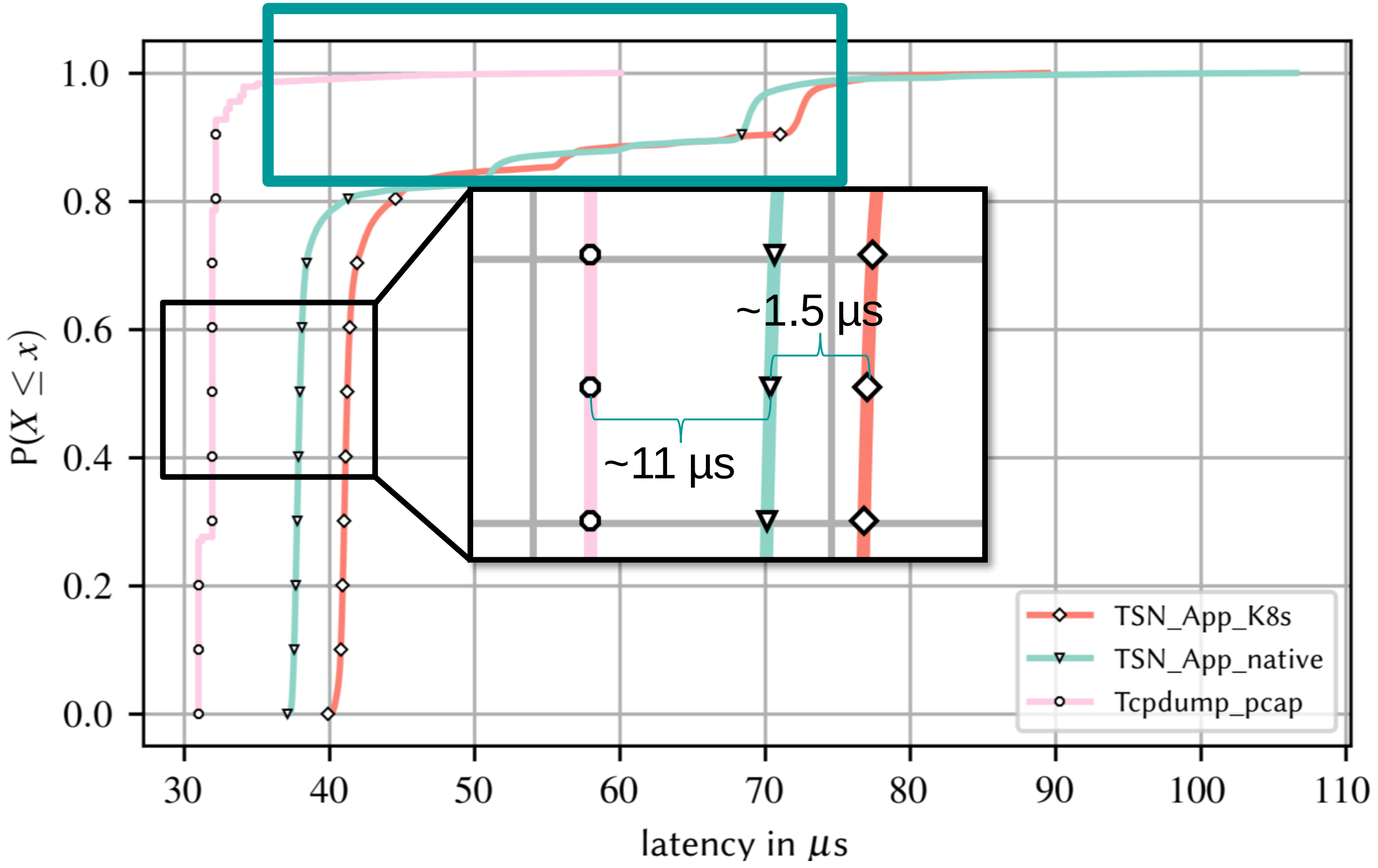
Evaluation – Virtualization Overhead



Latency overhead by application:

- ~33 µs Network (Linux to Linux)
- ~11 µs TSN Test App
- ~1.5 µs Kubernetes and Plugin

But:

- High Latency for over 10 % of Frames

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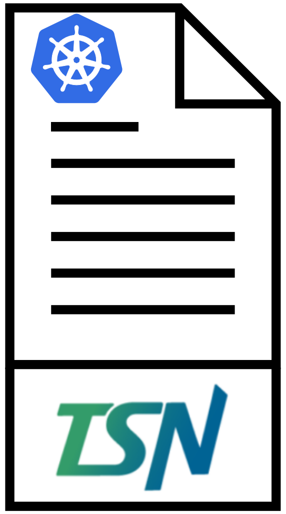
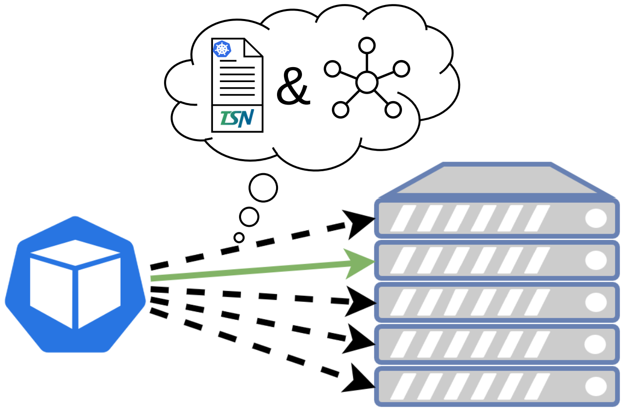
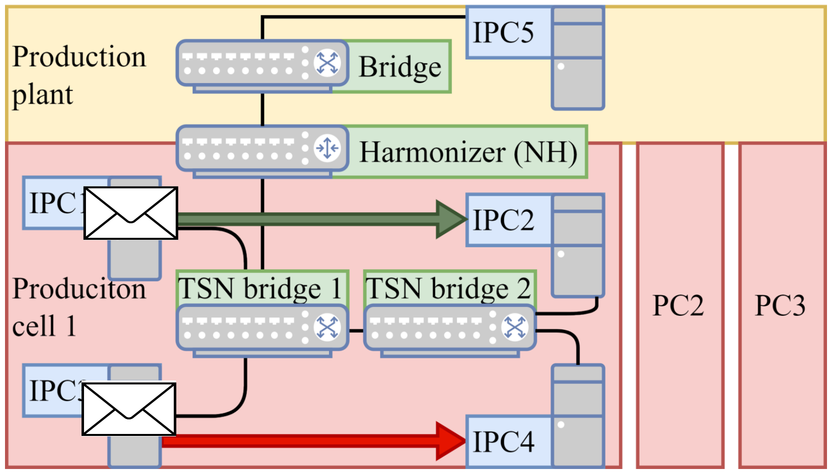
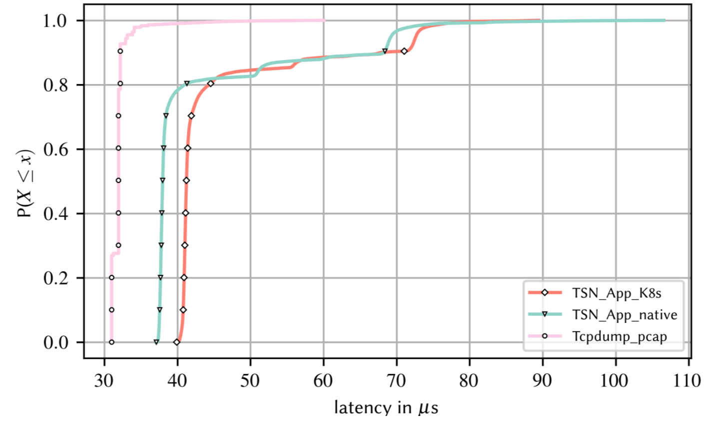
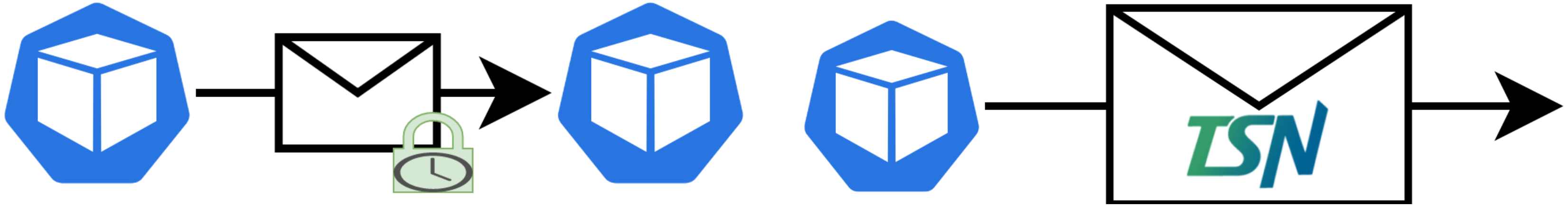
Conclusion











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Thank you !

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Interworking of Solutions with an example

Deployment Process of TSN application

1. Topology detection & storing (MoNC → Kubernetes)
2. Application request with communication requirements (User → Kubernetes)
3. Application Scheduling and Stream definition (QoS-Scheduler)
4. Stream request (QoS-Scheduler → MoNC)
5. Stream embedding (MoNC)
6. Application deployment (Kubernetes)

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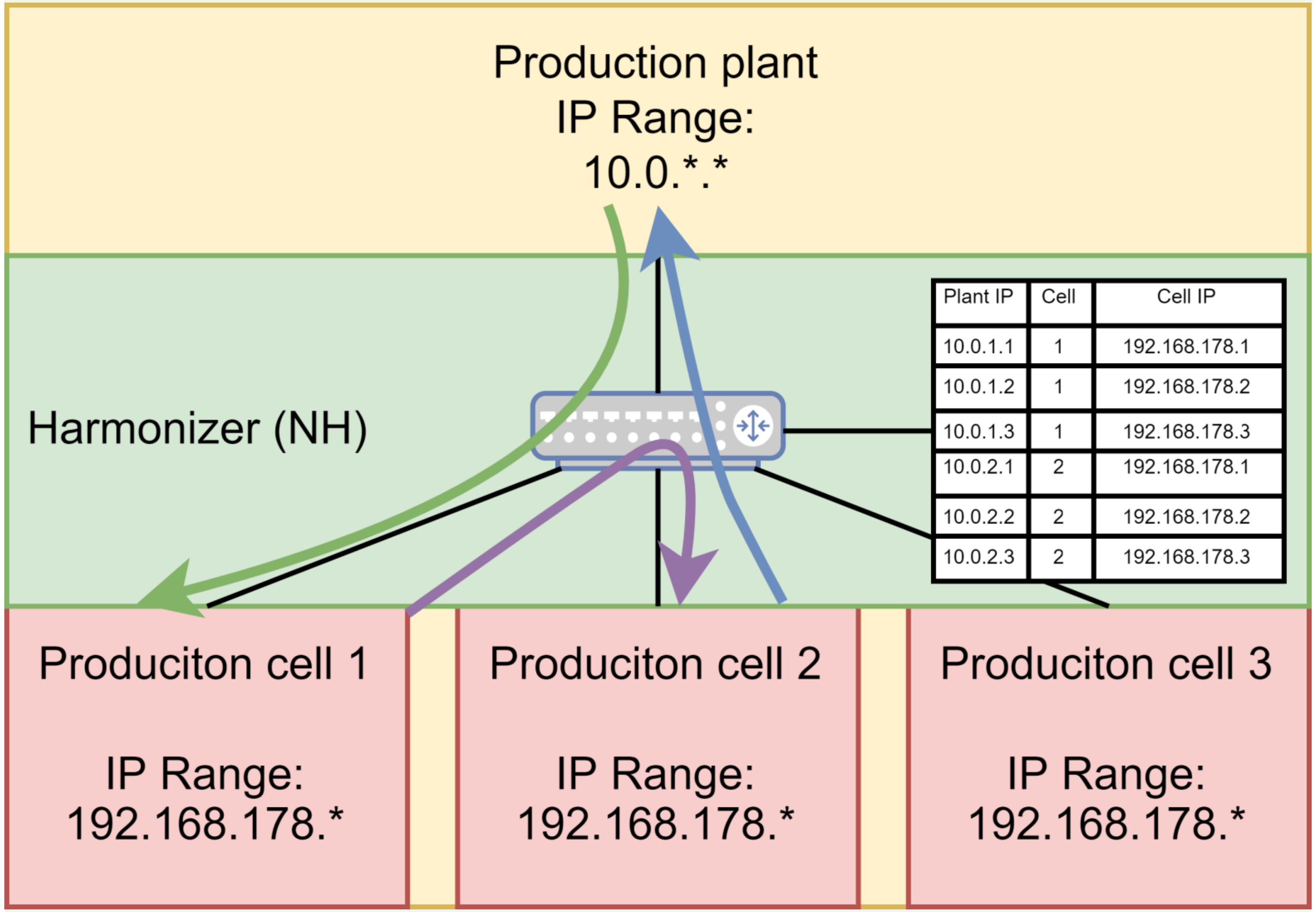
Solution 1: Network Harmonizer



Plant IP	Cell	Cell IP
10.0.1.1	1	192.168.178.1
10.0.1.2	1	192.168.178.2
10.0.1.3	1	192.168.178.3
10.0.2.1	2	192.168.178.1
10.0.2.2	2	192.168.178.2
10.0.2.3	2	192.168.178.3

Problem 1: Connect production cells with Data-Link layer access and low configuration overhead.

Function:

- „Fully transparent Router“
- Substitutes IP and MAC Addresses of passing packets.
- Substitutes sender-IP and target-IP of ARP packets
- Connecting production cells with identical IP/MAC configurations.

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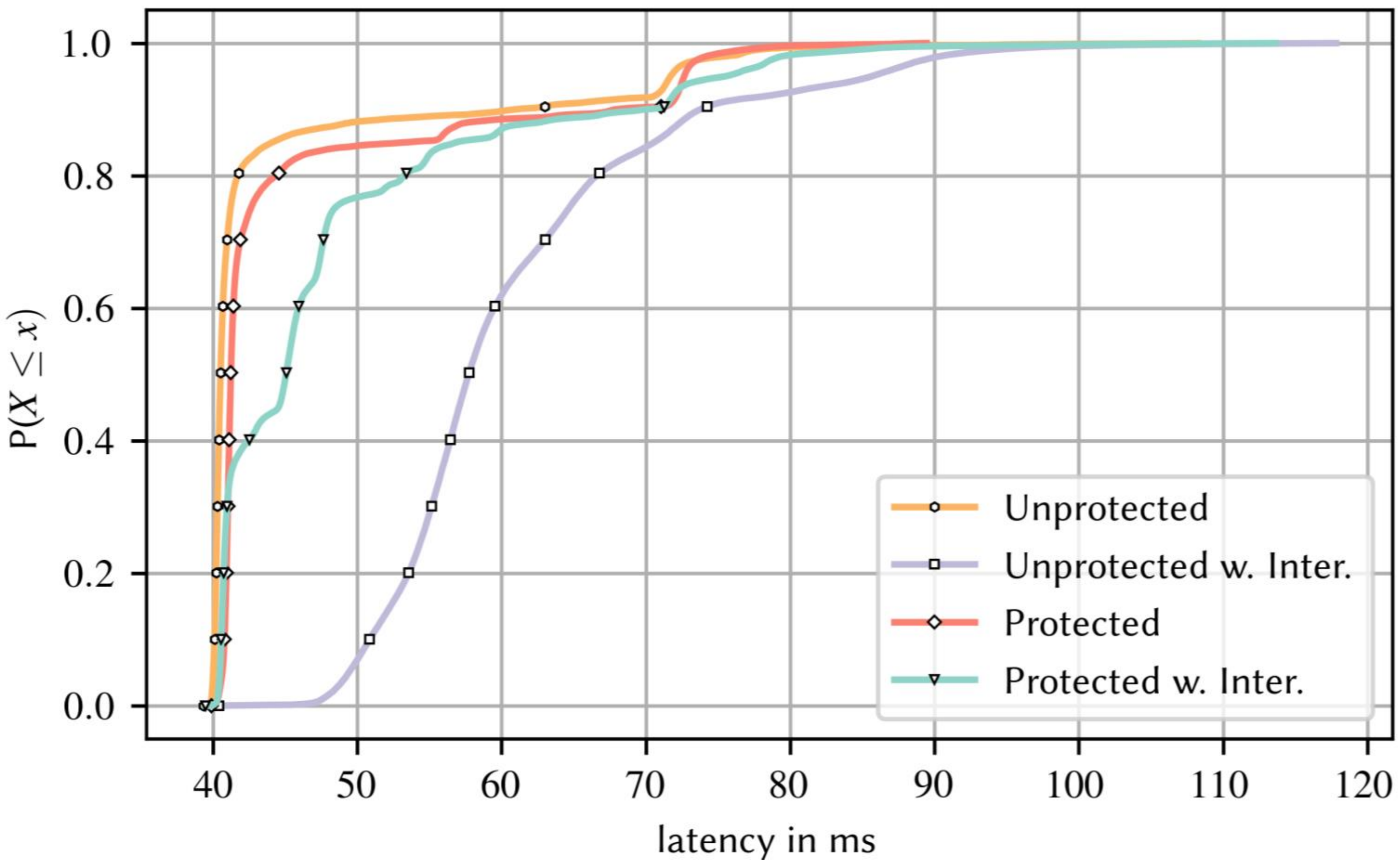
Evaluation – Interference Measurements



No Interference:

- Almost same Latency

With Interference:

- Unprotected Stream has Higher latency

→ Streams protected by PSFP

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Conclusion

Proof of concept shows

- Kubernetes adds small latency overhead
- QoS guarantees between Kubernetes Nodes possible

Next Steps:

- Investigate real-time Linux systems to reduce jitter
- Implement other Time-Sensitive Networking Algorithms