
# Software-Defined Networks Supporting Time-Sensitive In-Vehicular Communication

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# Outline

1. TSN & SDN in Vehicular Networks
2. Concepts on Implementing TSN + SDN
3. Timing & Latency Analysis
4. Conclusion & Outlook

# TSN & SDN in Vehicular Networks

**Why TSN?**

- Quality-of-Service traffic classes with timing guarantees
- Synchronous (scheduled TDMA) and asynchronous (reserved bandwidth) traffic

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**Why SDN?**

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- Global network knowledge

**Why TSN + SDN = TSSDN**

- Central (re-)calculation, verification and (re-)configuration of timings during runtime
- Robust safety and security methods

# Our Contributions

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Combine switching modules of SDN and TSN

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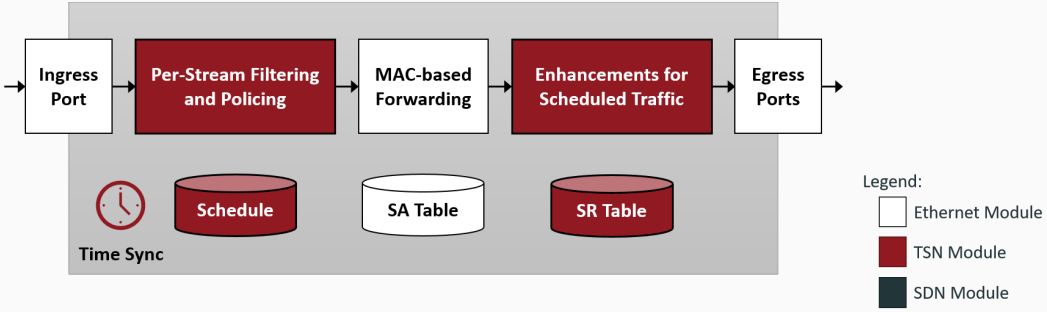
Define OpenFlow matching of time-sensitive flows

# Combining Switching Modules of SDN and TSN



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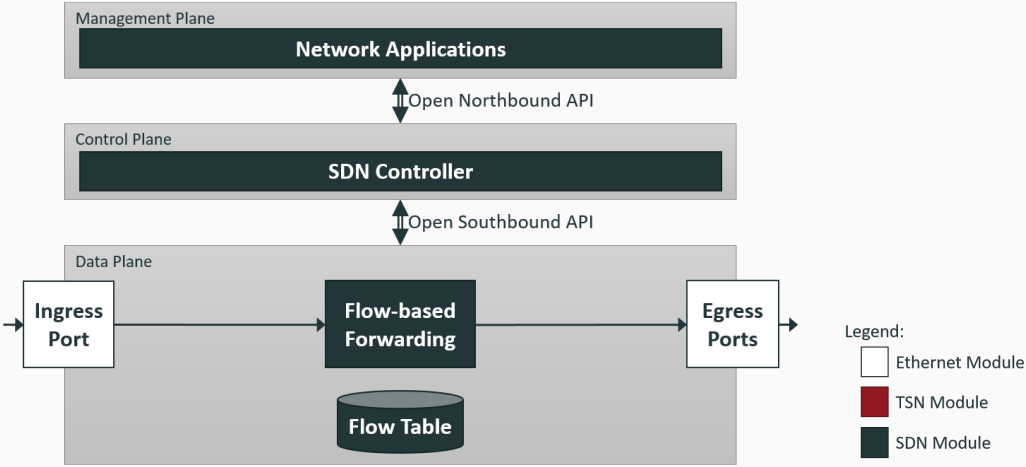

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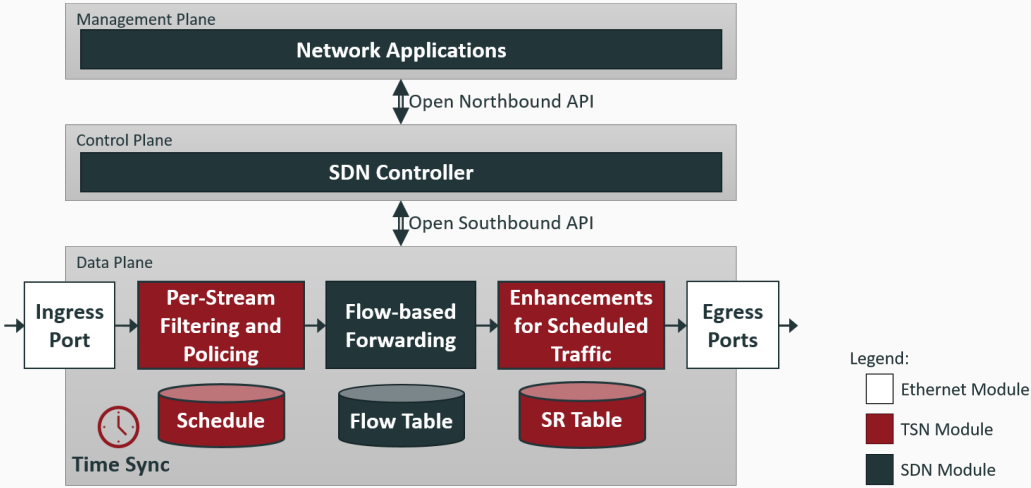

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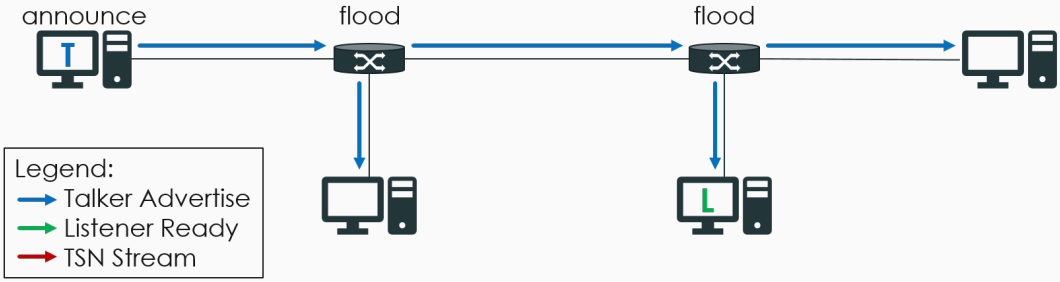

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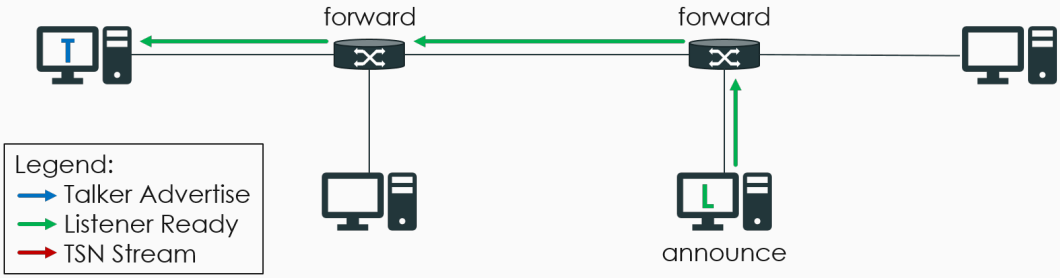

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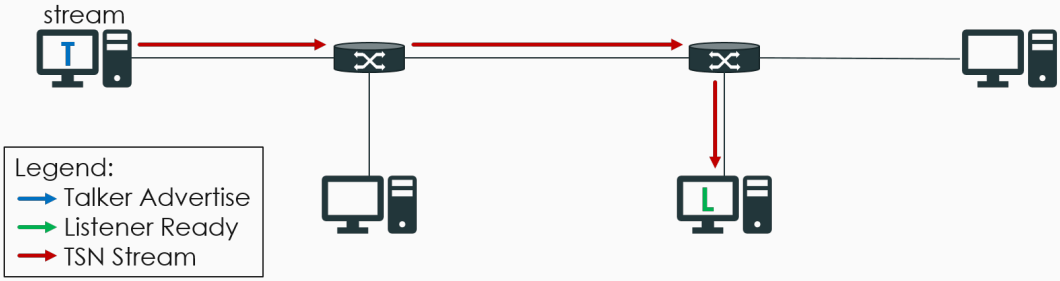

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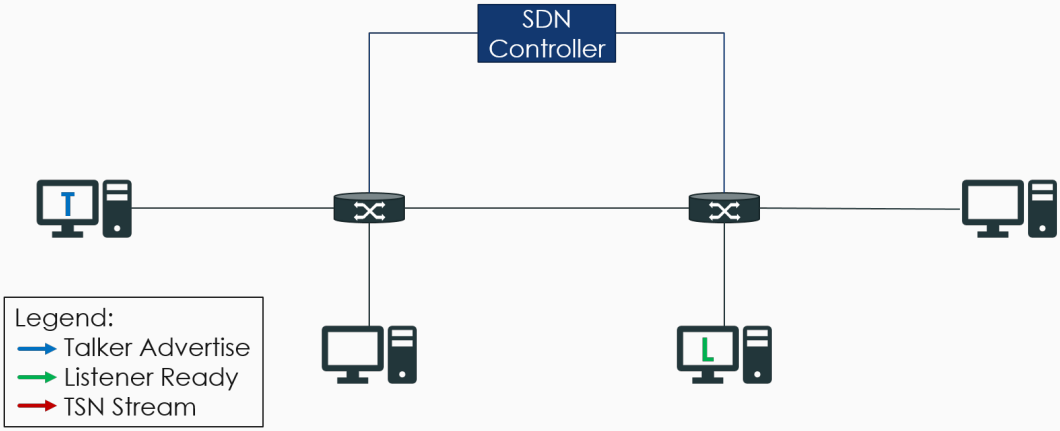

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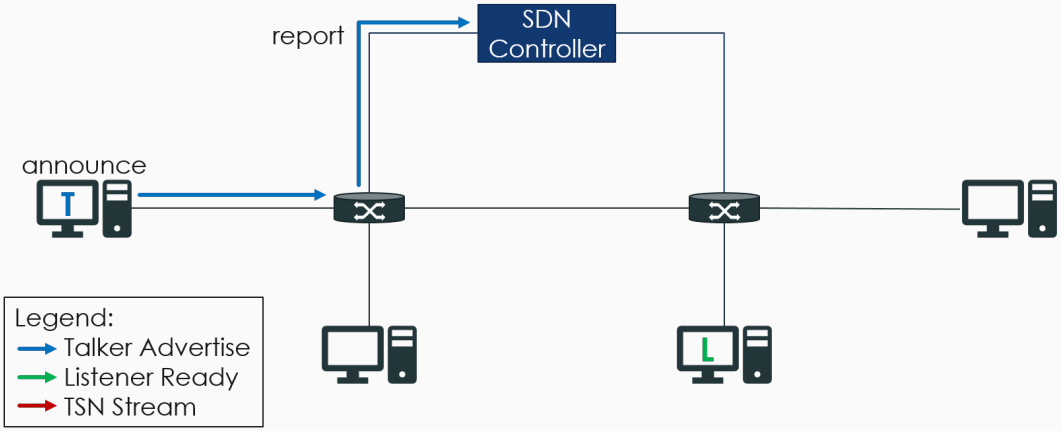

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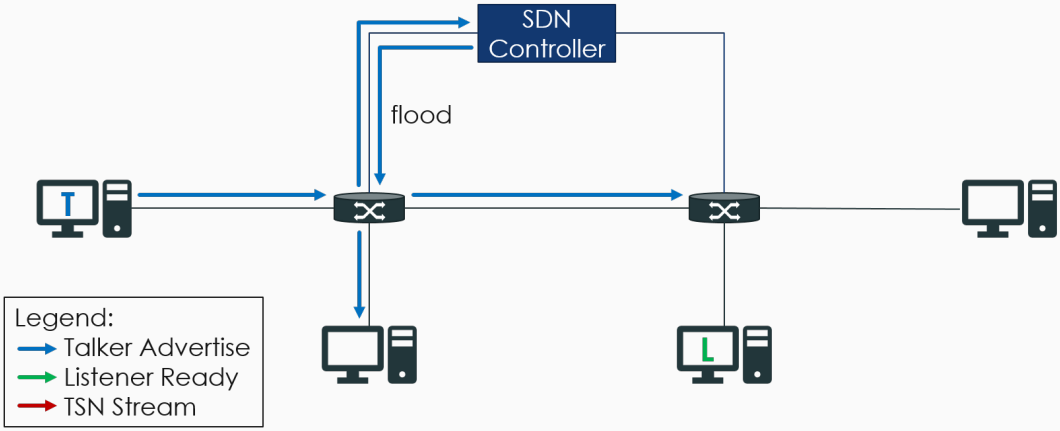

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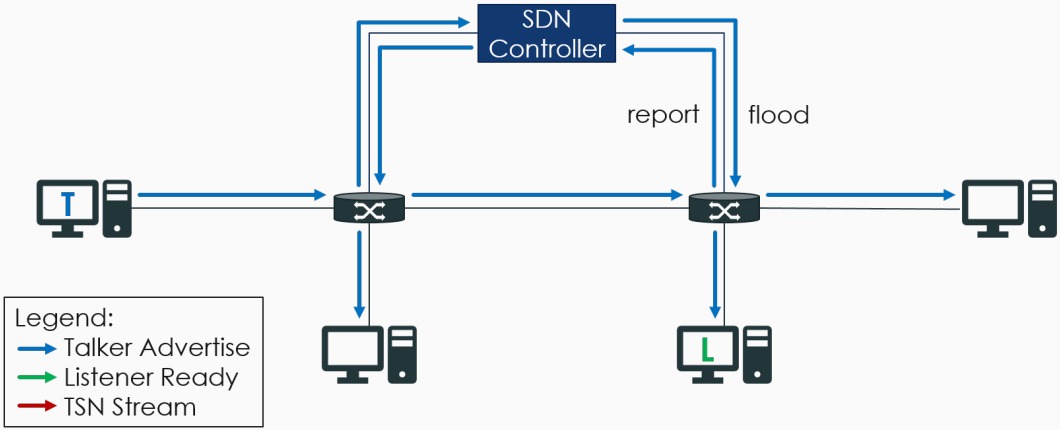

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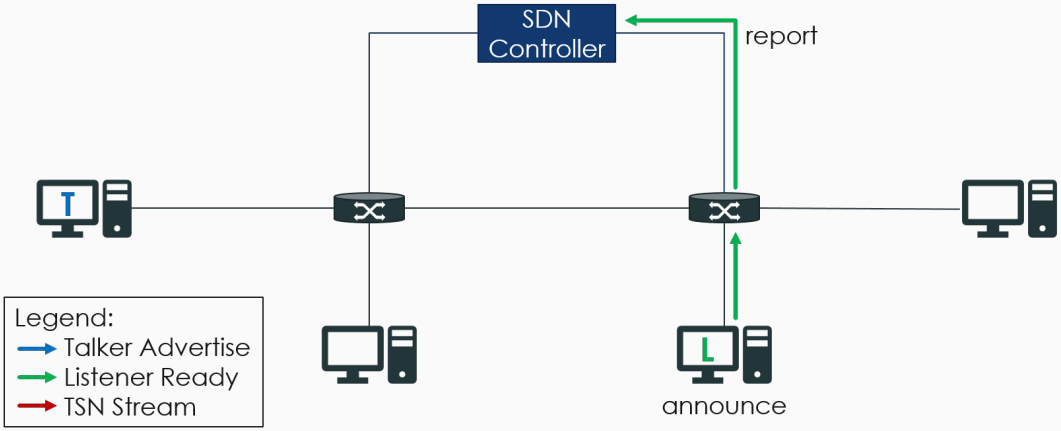

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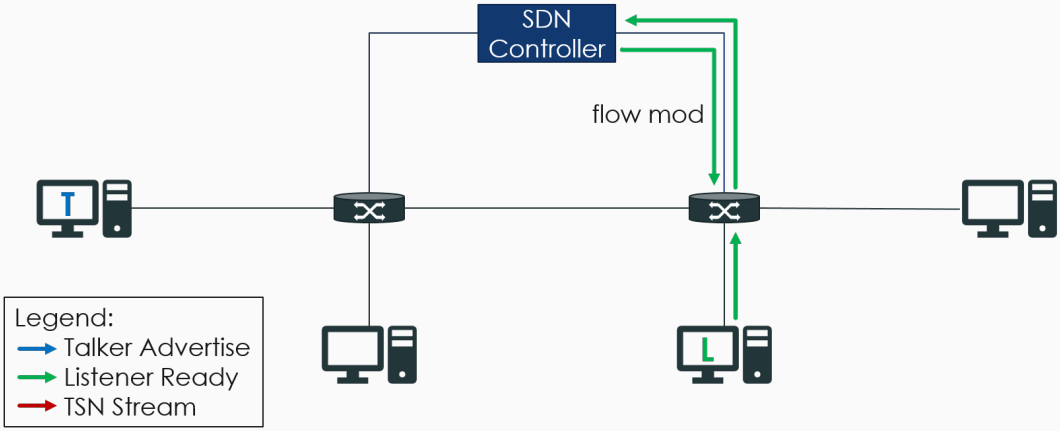

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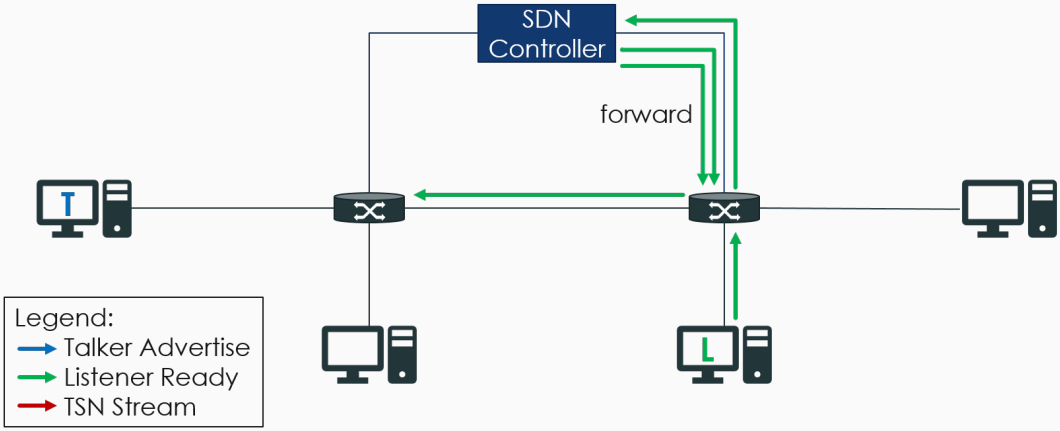

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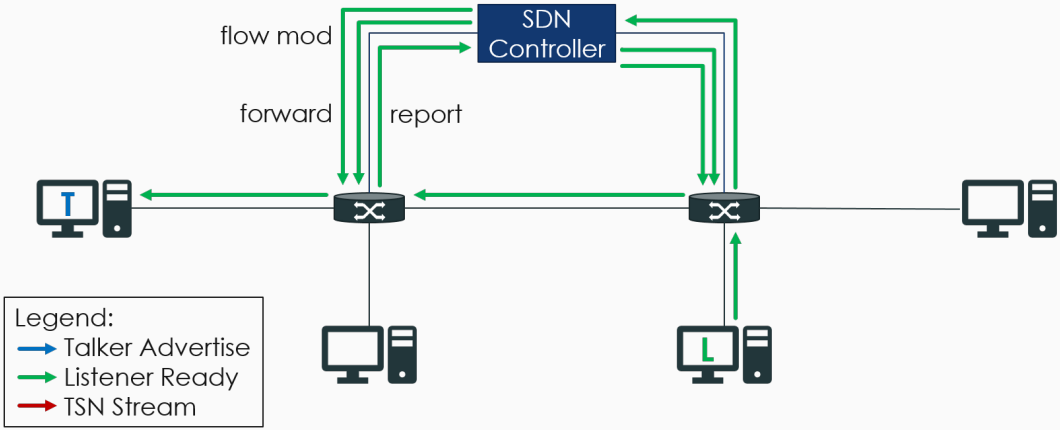

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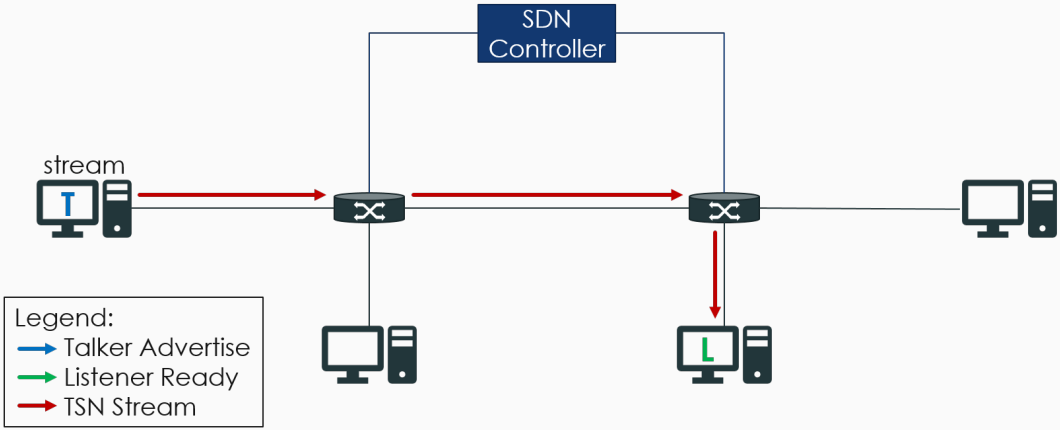
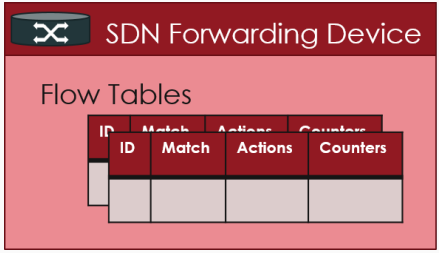
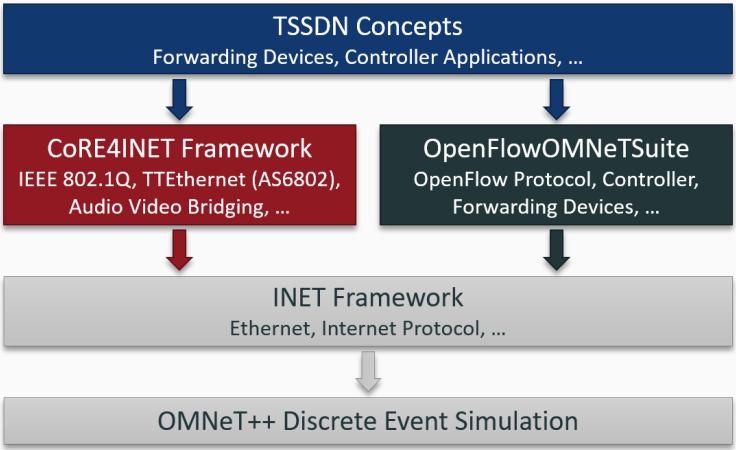


# Defining OpenFlow Matching of Time-Sensitive Flows

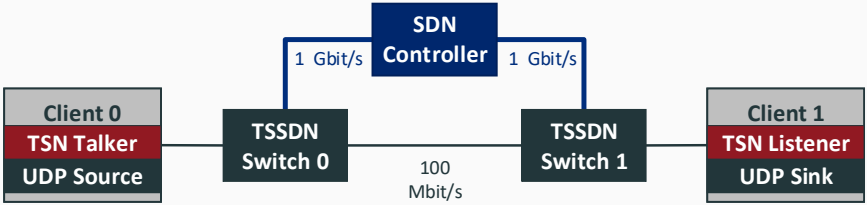
Match {
  Listener Multicast **Ethernet Destination Address**,
  Talker **Ethernet Source Address**,
  Switch **Ingress Port**,
  VLAN ID **802.1Q ID**,
  Stream Priority **802.1Q PCP**
}



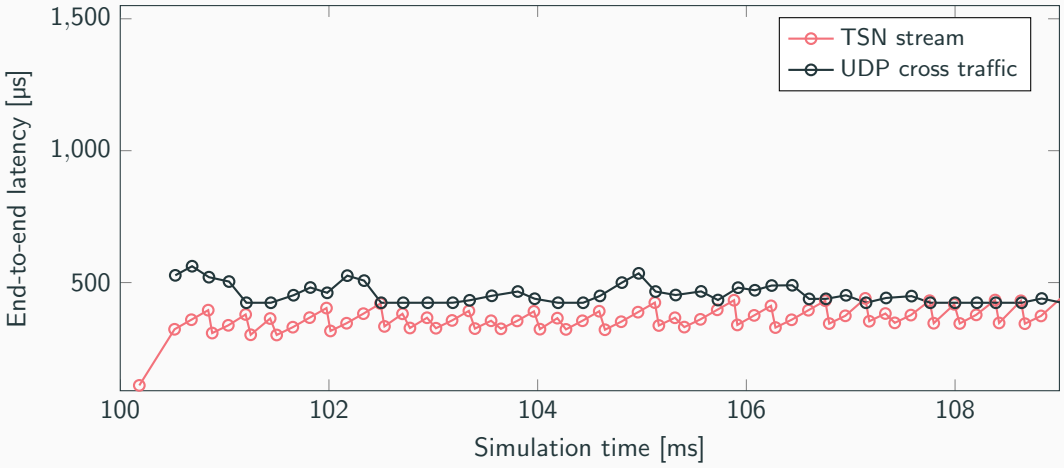
# Simulation Environment



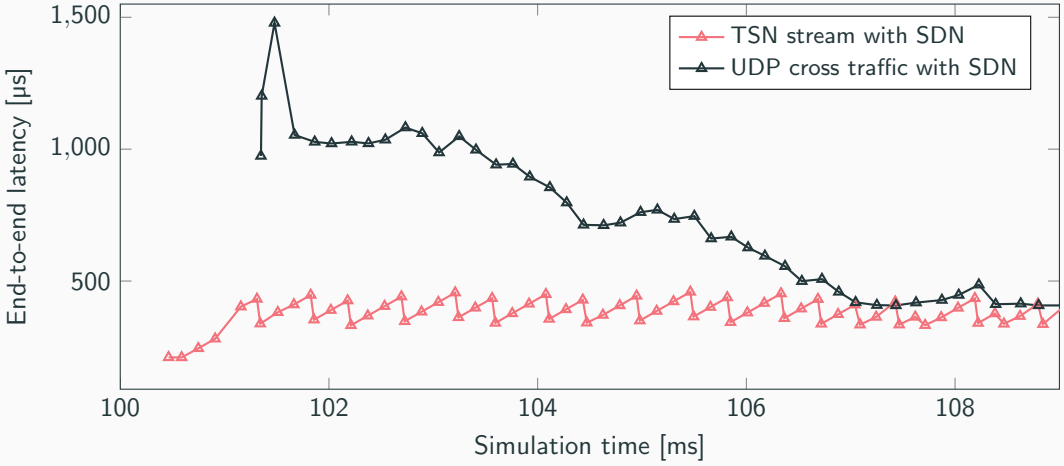
# Simulation Case Study



# Latency Measurement of TSN



# Latency Measurement of TSSDN



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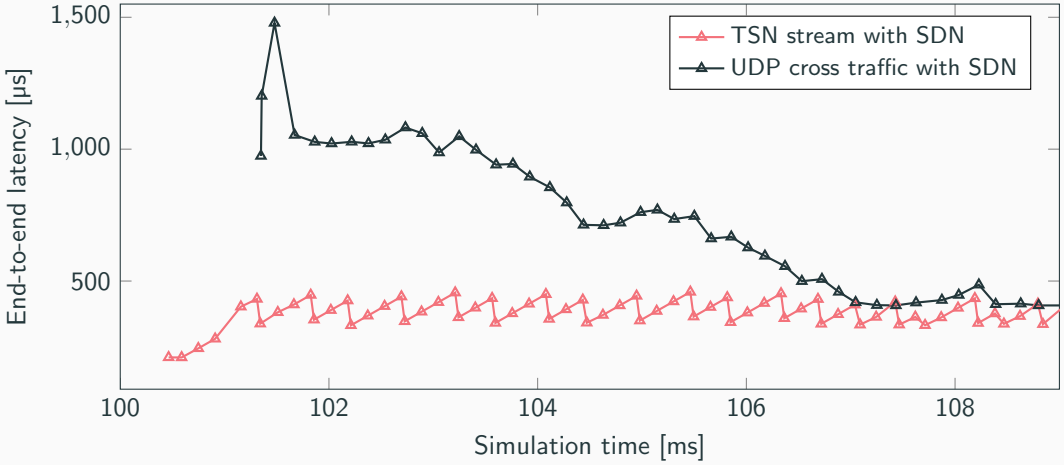
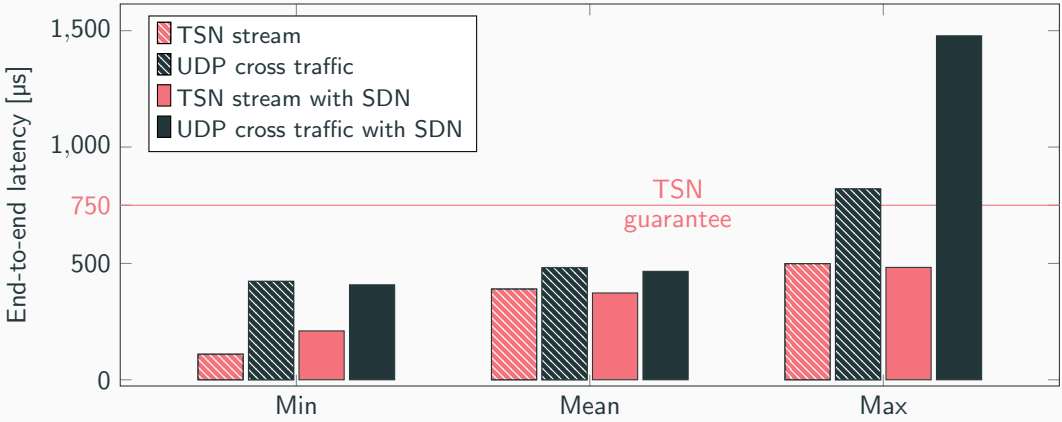



→ **No delay penalty for time-critical flows, while taking advantage of SDN in vehicles**

# Comparing Maximum Latency



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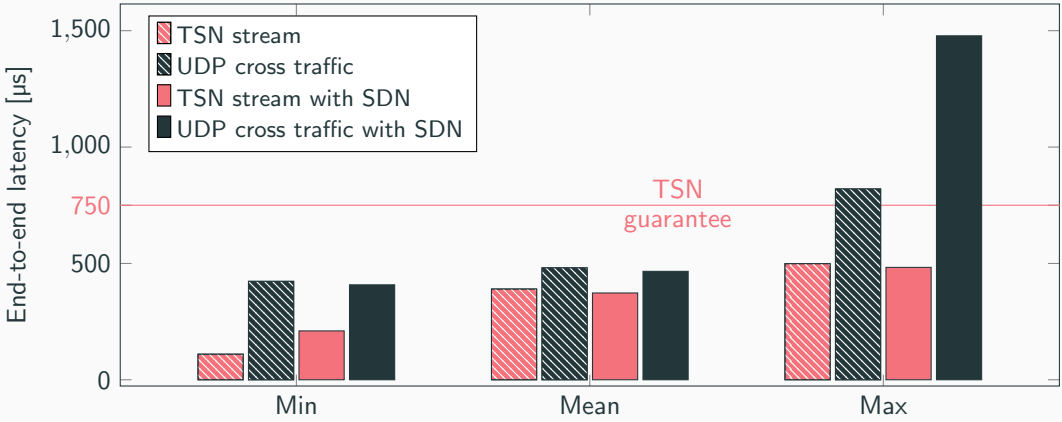


→ **The timing guarantees are met for time-sensitive flows**

# Conclusion & Outlook

Summary

- Combined TSN and SDN without a delay penalty for real-time traffic
- Presented our switching methodology that combines SDN and TSN
- Defined potentials of time-sensitive software-defined in-vehicular networks
- Opened the field of TSSDN in cars

Future Work

- Transfer more of TSNs control logic to the SDN controller
- Analyse the effect of SDN on synchronous TDMA flows
- Show potentials of TSSDN for vehicles including improvements on robustness and security

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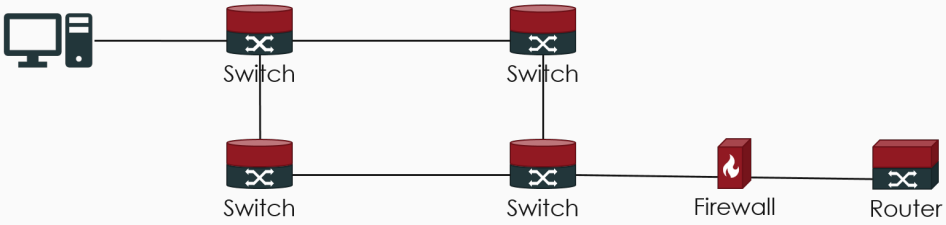
# Backup slides

# Time-Sensitive Networking

- Set of standards defined by the TSN task group of the IEEE
- IEEE 802.1Q-2018 extends Ethernet with the ability to forward concurrent real-time and cross traffic
- Different Quality-of-Service with several real-time traffic classes.
  - Synchronous, Time Division Multiple Access (TDMA)
  - Asynchronous, such as TSNs predecessor Audio Video Bridging (AVB)
- IEEE P802.1Qcc draft introduces a controller for central network management
- However, this controller is only a centralised configuration unit
  - No vendor neutral standardised interface between the controller and the switches
  - No functionality of the network devices extracted into the control plane

# Software-Defined Networking



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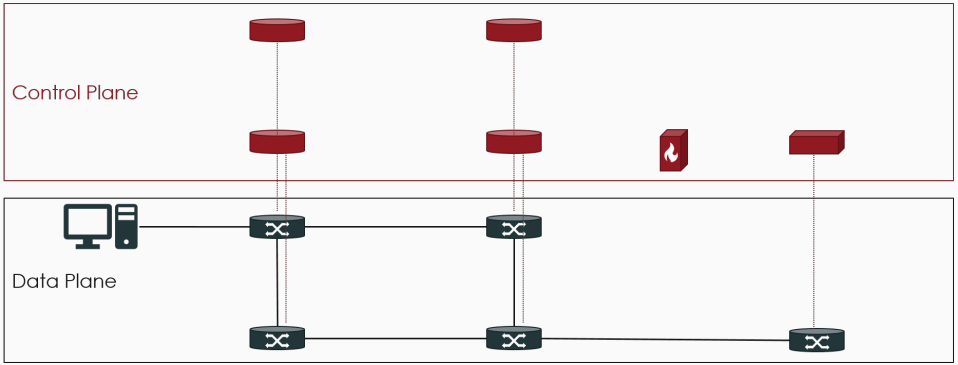

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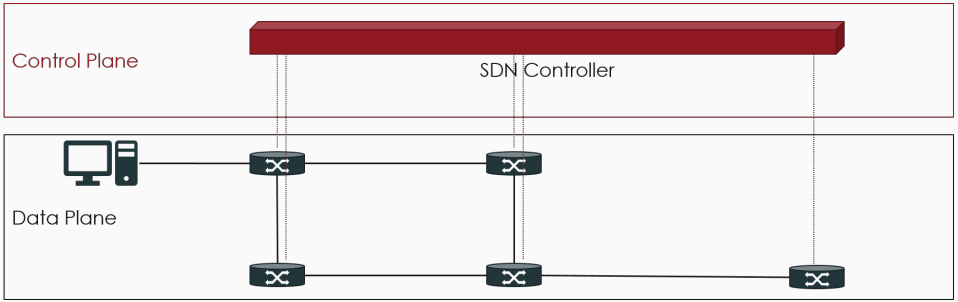

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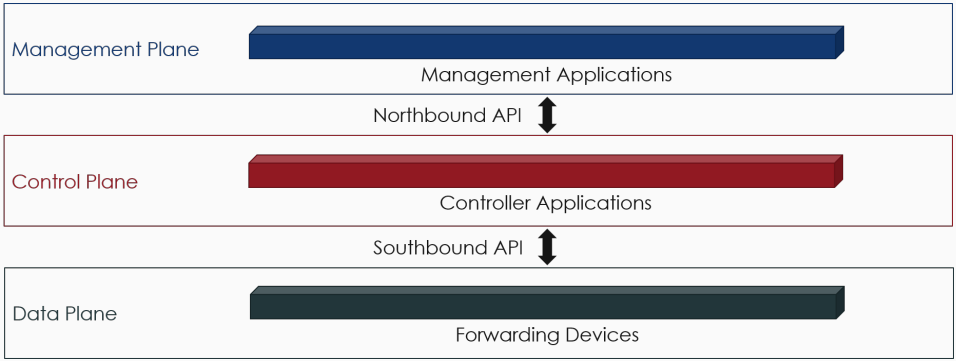

# The Case for In-Vehicular TSSDN

- OpenFlow standard and a centralised control logic
  - Vendor neutral selection of controller logic and forwarding devices
  - Allows for simple, exchangeable, inexpensive, and future proof forwarding devices
- Global network knowledge
  - Efficient route determination and re-routing
  - Central (re-)calculation and verification of timings over multiple links during run time
  - Central point for configuration and updates
- Robustness
  - SDN supports arbitrary network topologies
  - Combined with global network knowledge this is an enabler for robust safety methods
  - Network Security applications can be added to the SDN controller

# TSN maximum latency calculation

- Calculation by counting port scheduling processes.
- For a 100 Mbit/s link with a maximum delay of 250 µs for the highest priority