

# Time-Sensitive Software-Defined Networking: A Unified Control-Plane for TSN and SDN

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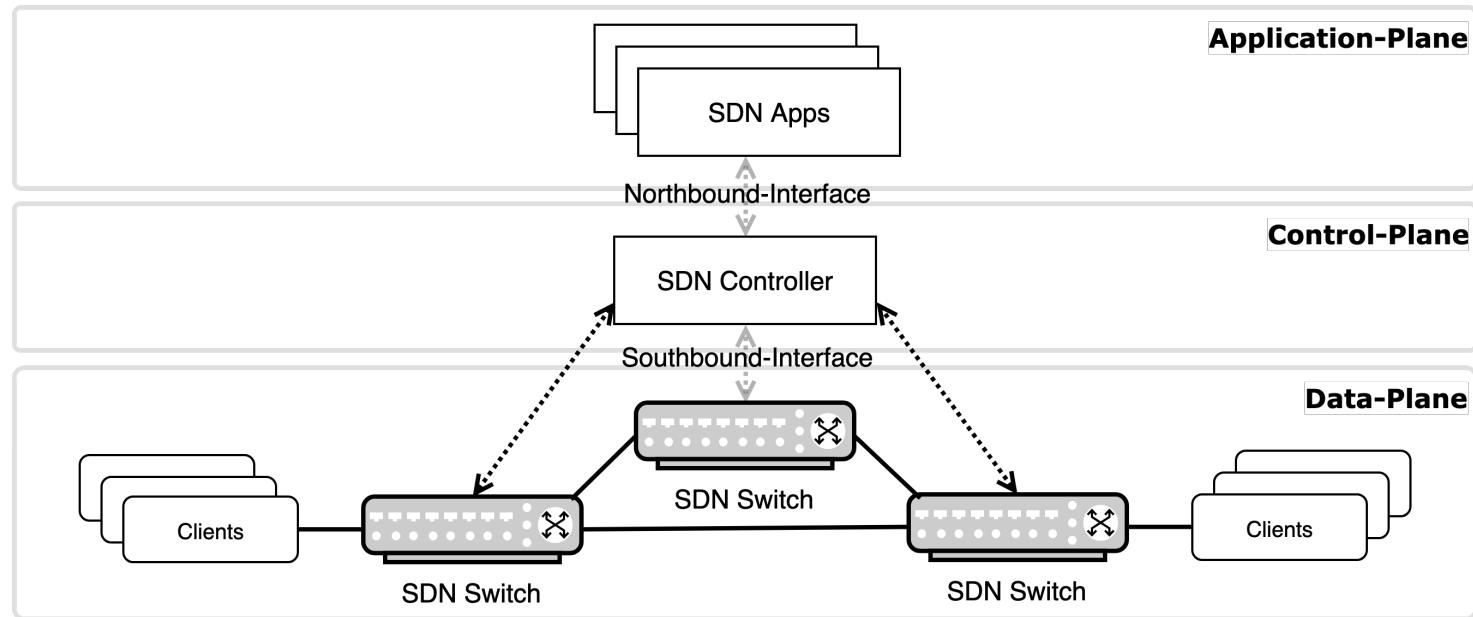
Funded by:

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# Agenda

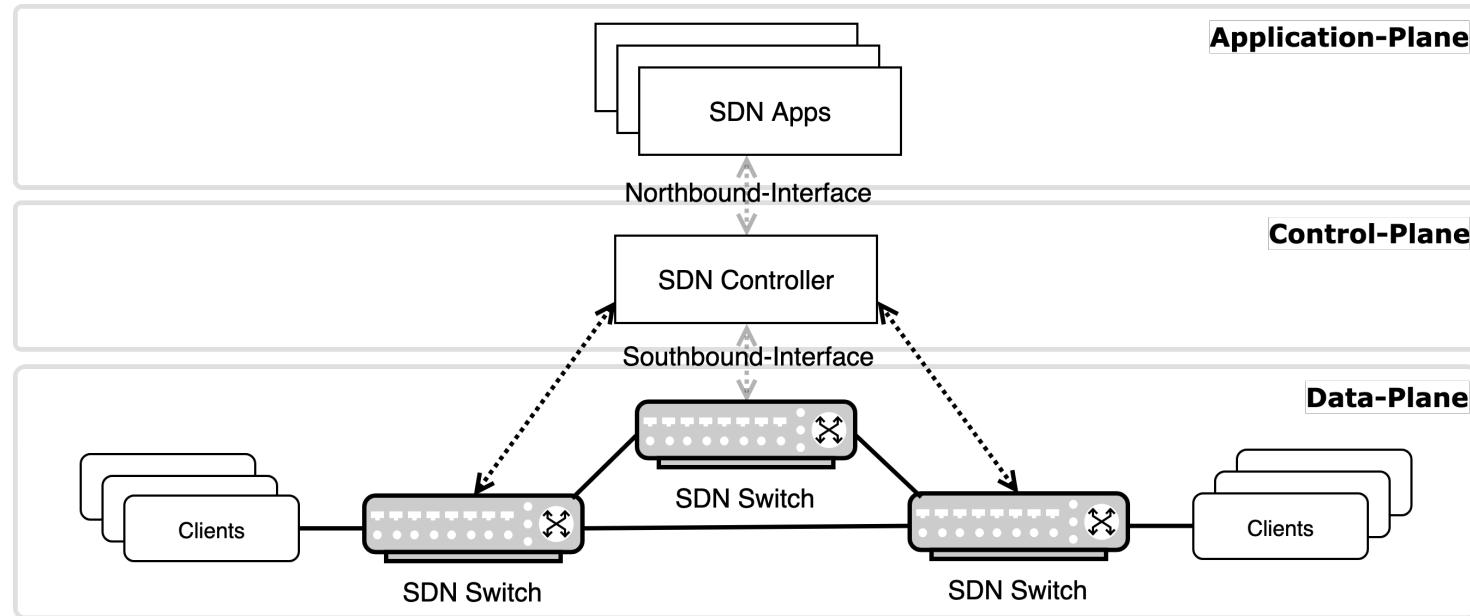
1. Introduction
2. Unified control-plane
3. Prototype & Testbed
4. Test cases and evaluation
5. Conclusion/Future work

# Introduction - Software-Defined Networking (SDN)

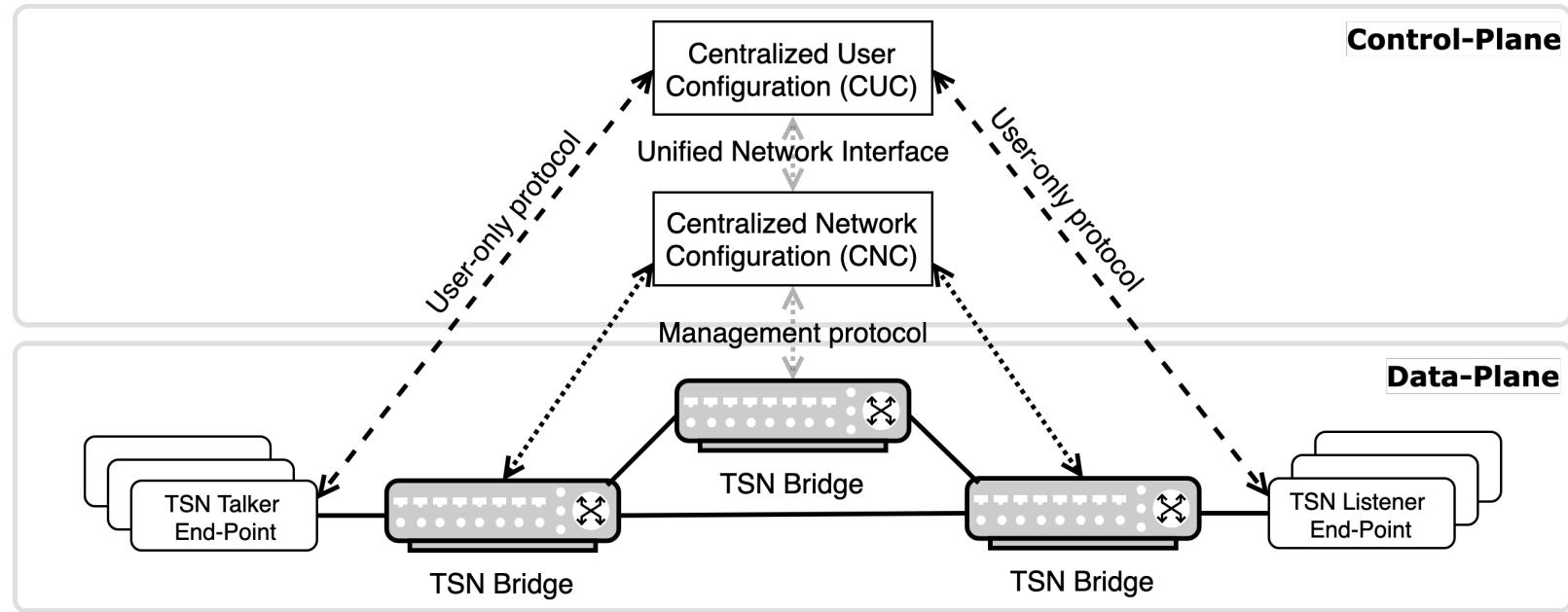


# Introduction - Software-Defined Networking (SDN)

- SDN for the 5G core network (5G-PPP)

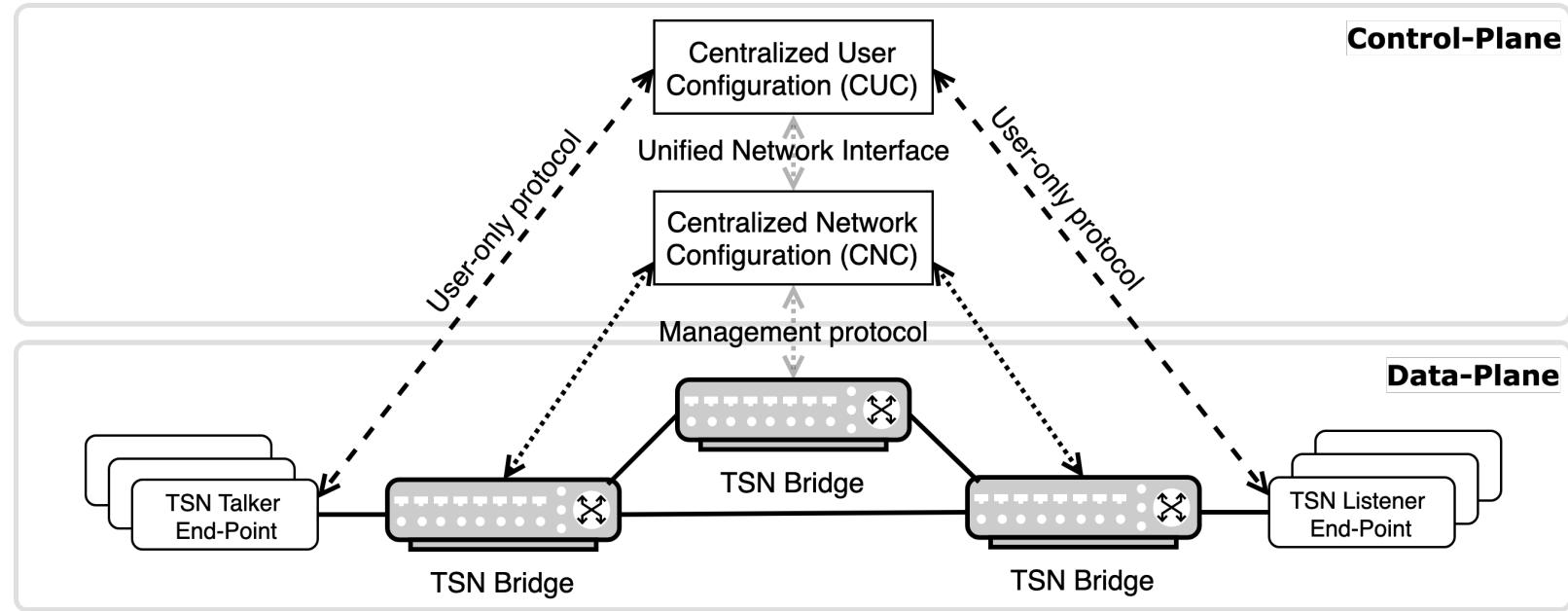


# Introduction - Time-Sensitive Networking (TSN)

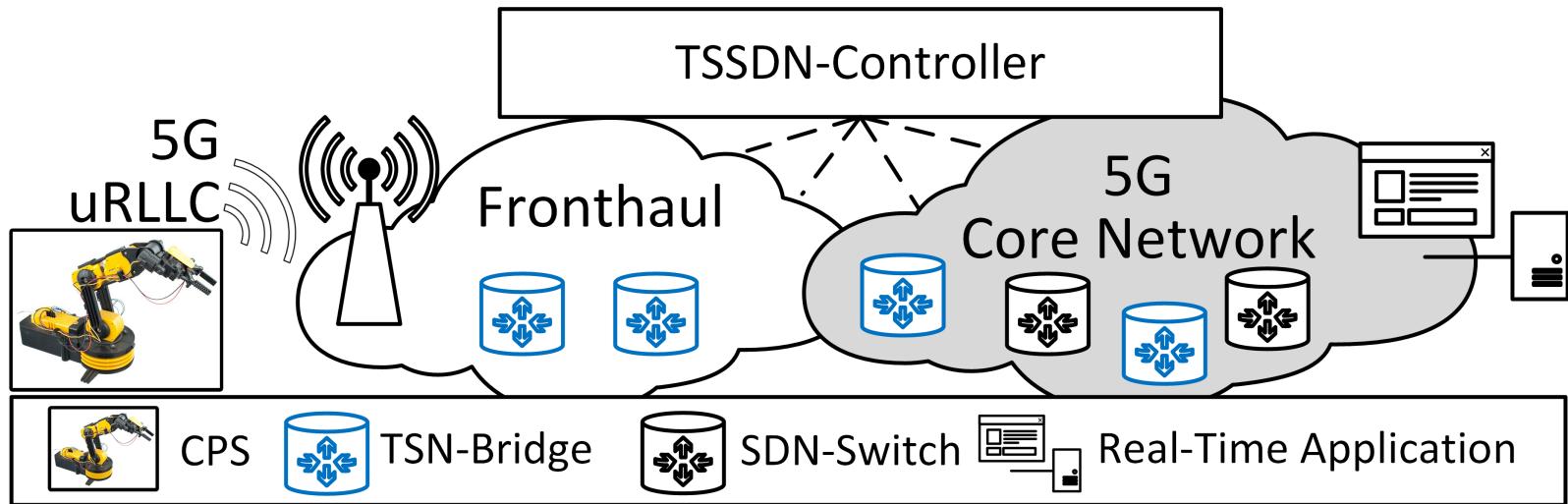


# Introduction - Time-Sensitive Networking (TSN)

- IEEE 802.1CM – Time-Sensitive Networking for Fronthaul



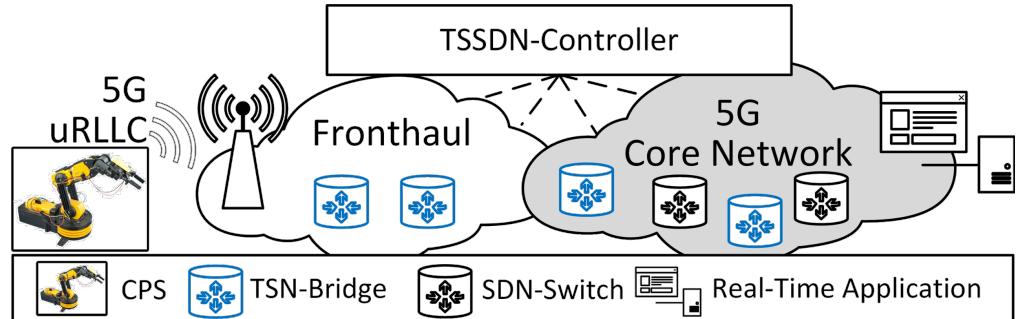
# Cloud-based Cyber-Physical Systems

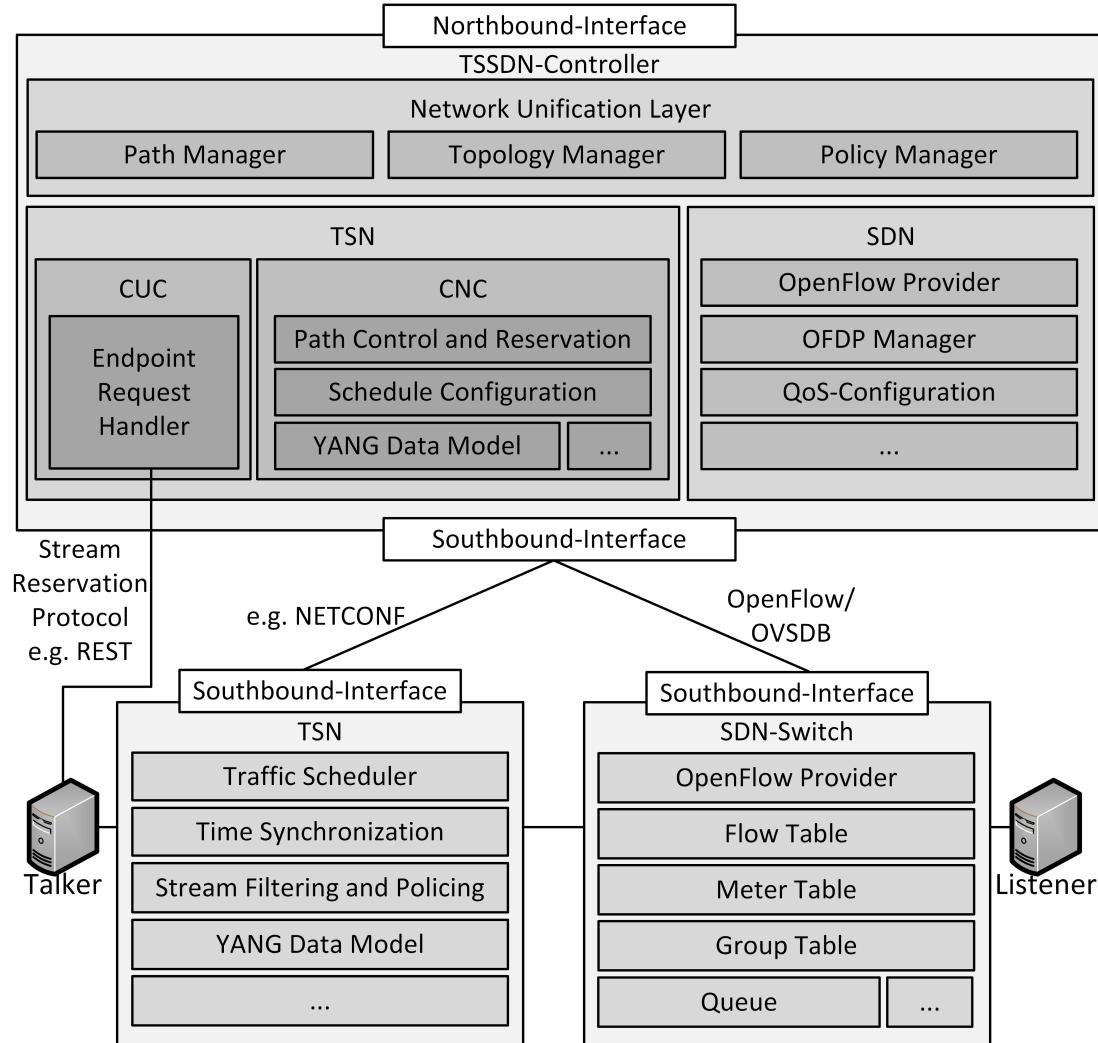


# Unified-Control Plane

## Time-Sensitive Software-Defined Networking

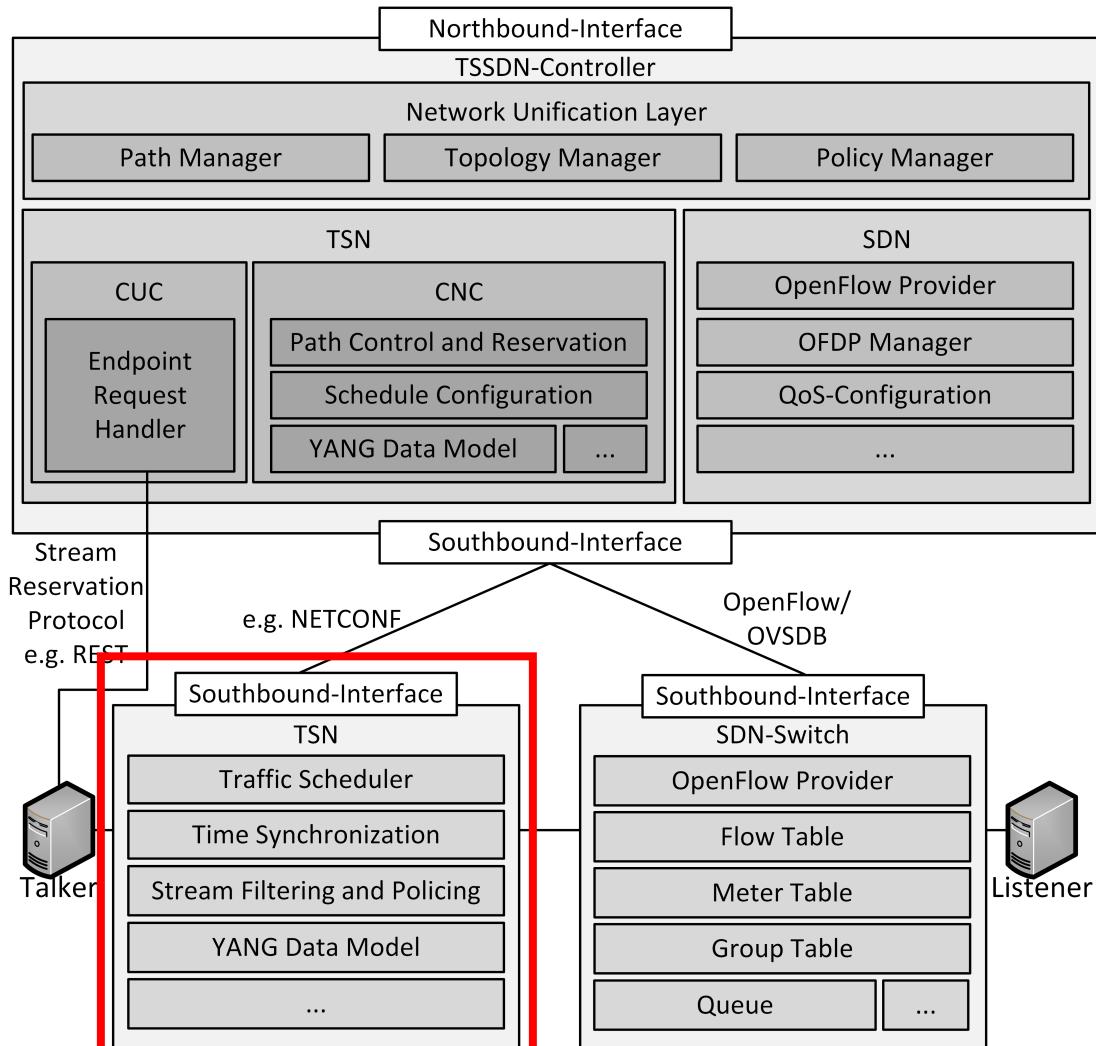
- One controller for TSN and SDN (TSSDN)
- Mixed network: TSN- and SDN-devices
- Deterministic paths
  - Only TSN-devices
- Non-deterministic paths
  - SDN-devices
  - Mix of TSN- and SDN-devices





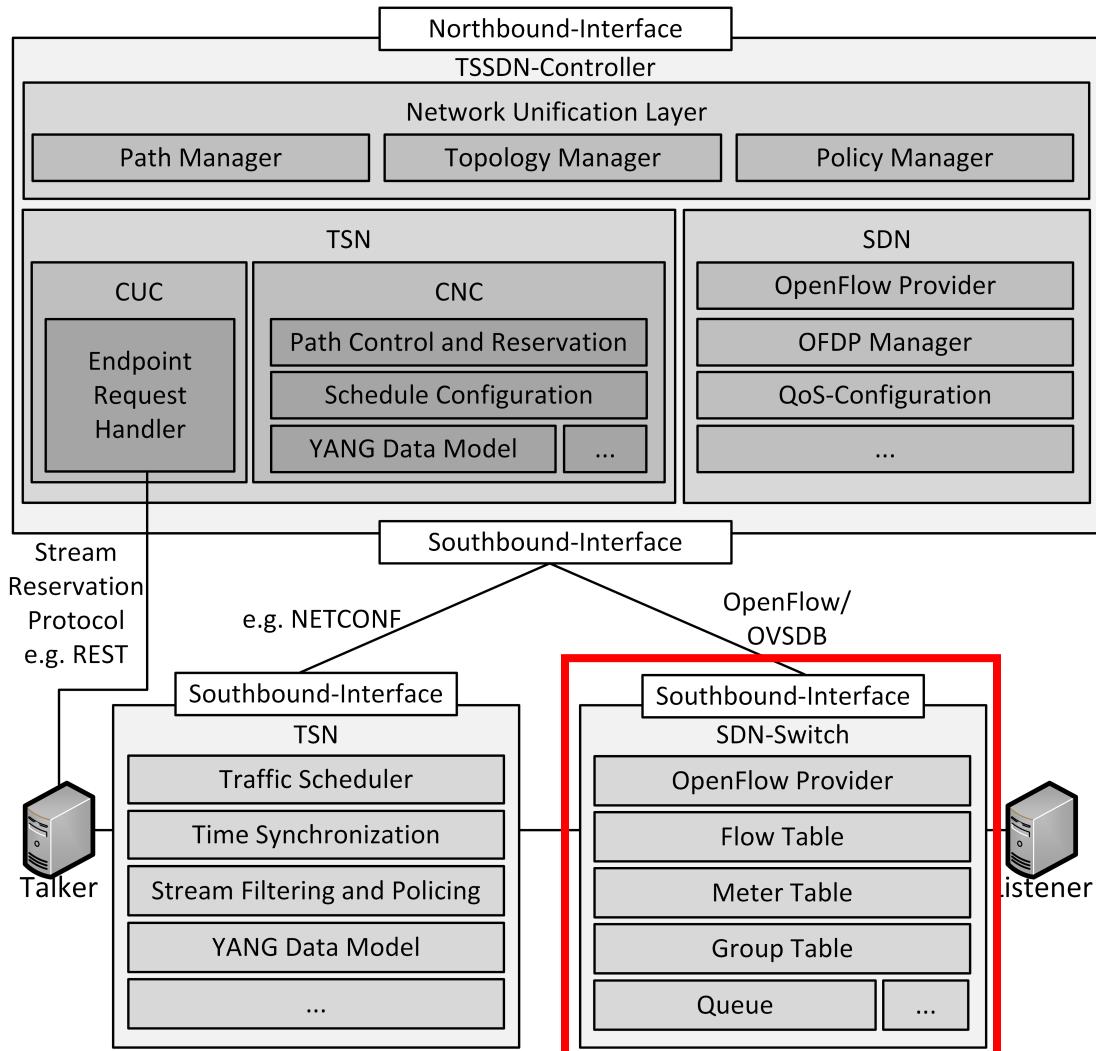
# Data-Plane

- TSN-Bridge
  - IEEE 802.1AS-Rev
    - „Timing and Synchronization for Time-Sensitive Applications“
  - IEEE 802.1Qbv
    - “Enhancements for Scheduled Traffic”
  - IEEE 802.1Qci
    - „Per-Stream Filtering and Policing“
  - IEEE 802.1Qcp
    - “Bridges and Bridged Networks Amendment: YANG Data Model”
  - ...



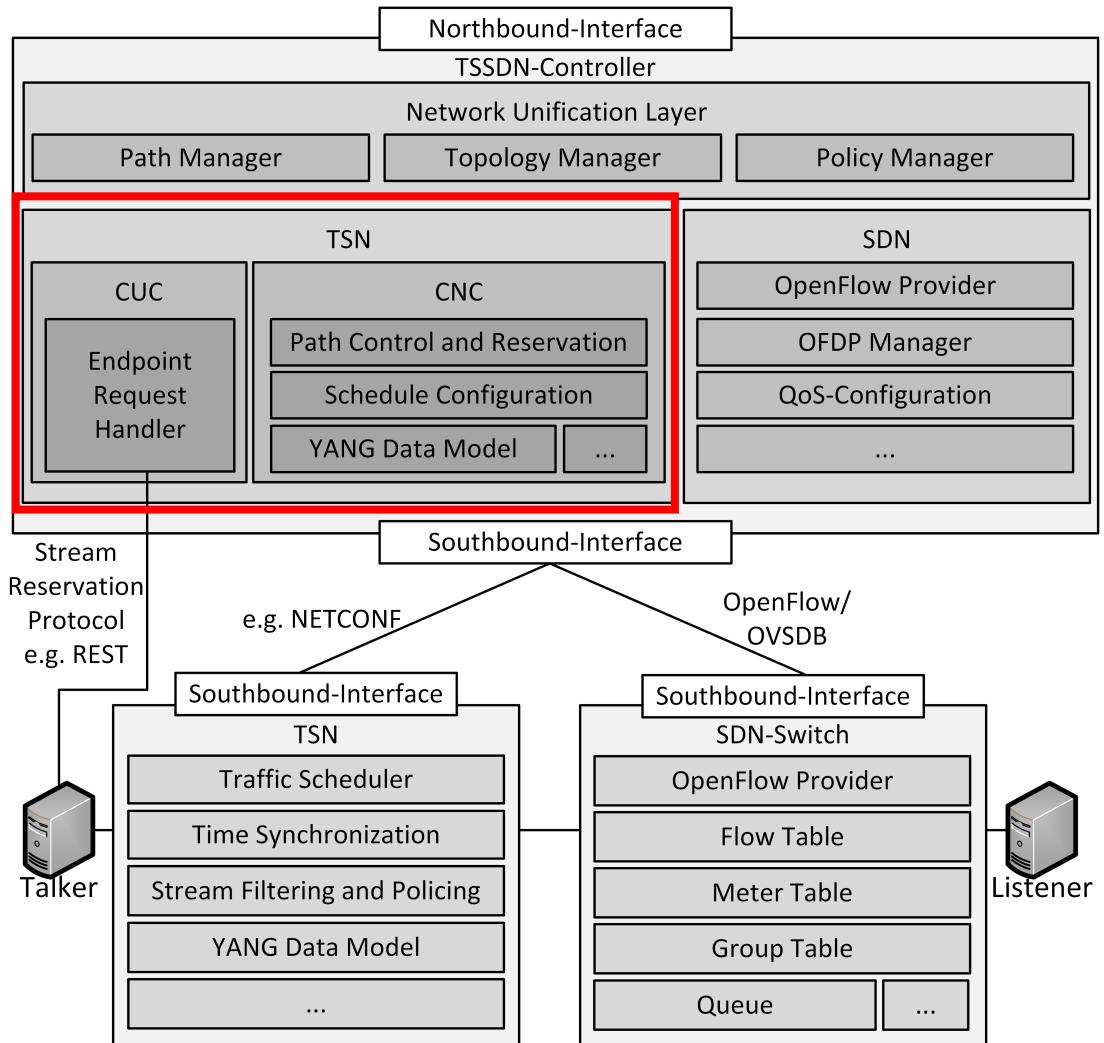
# Data-Plane

- SDN-Switch
  - OpenFlow
  - Flow Table
  - ...



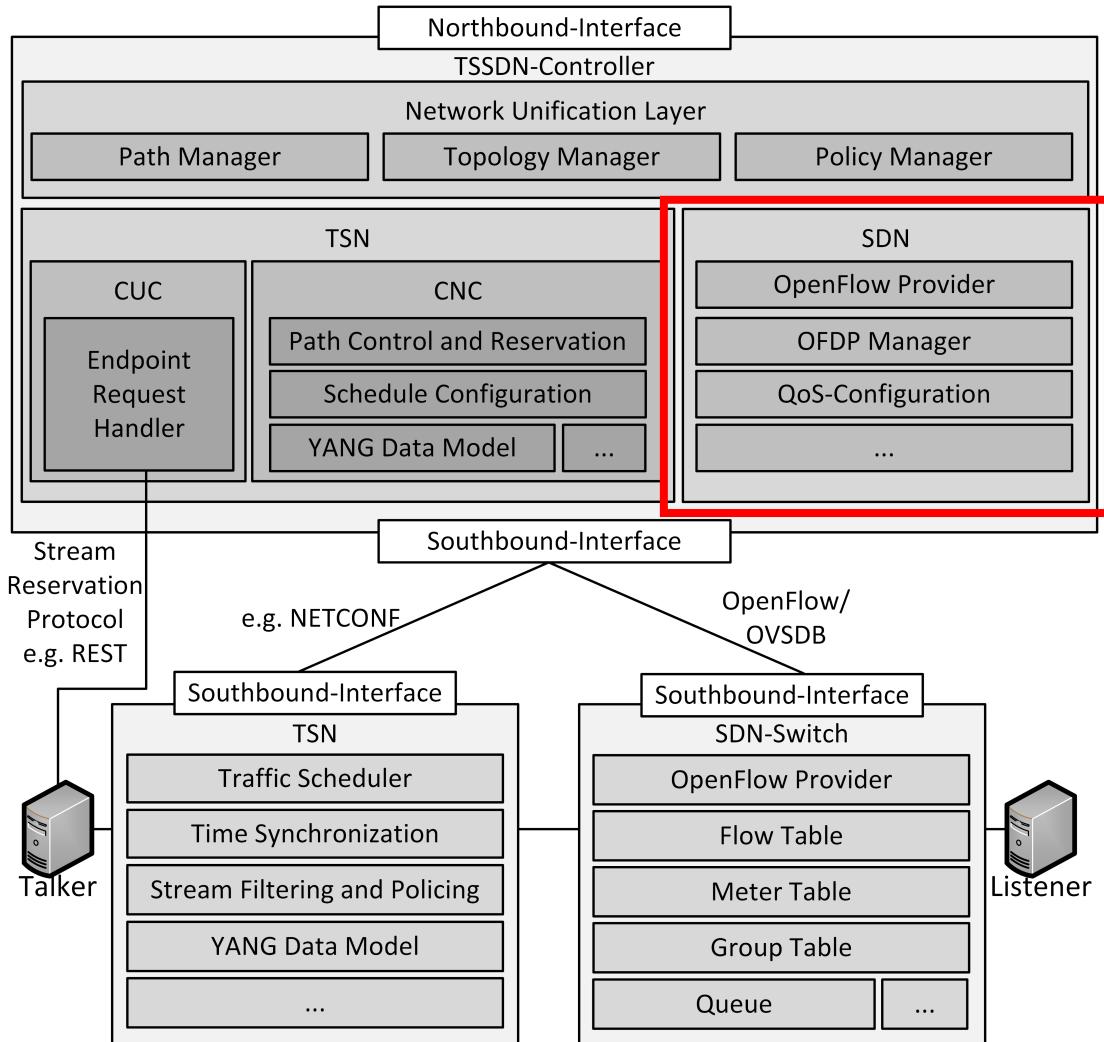
# Control-Plane

- TSN
  - Centralized User Configuration
    - Request connections
  - Centralized Network Configuration
    - Schedule calculation
    - Create device configurations



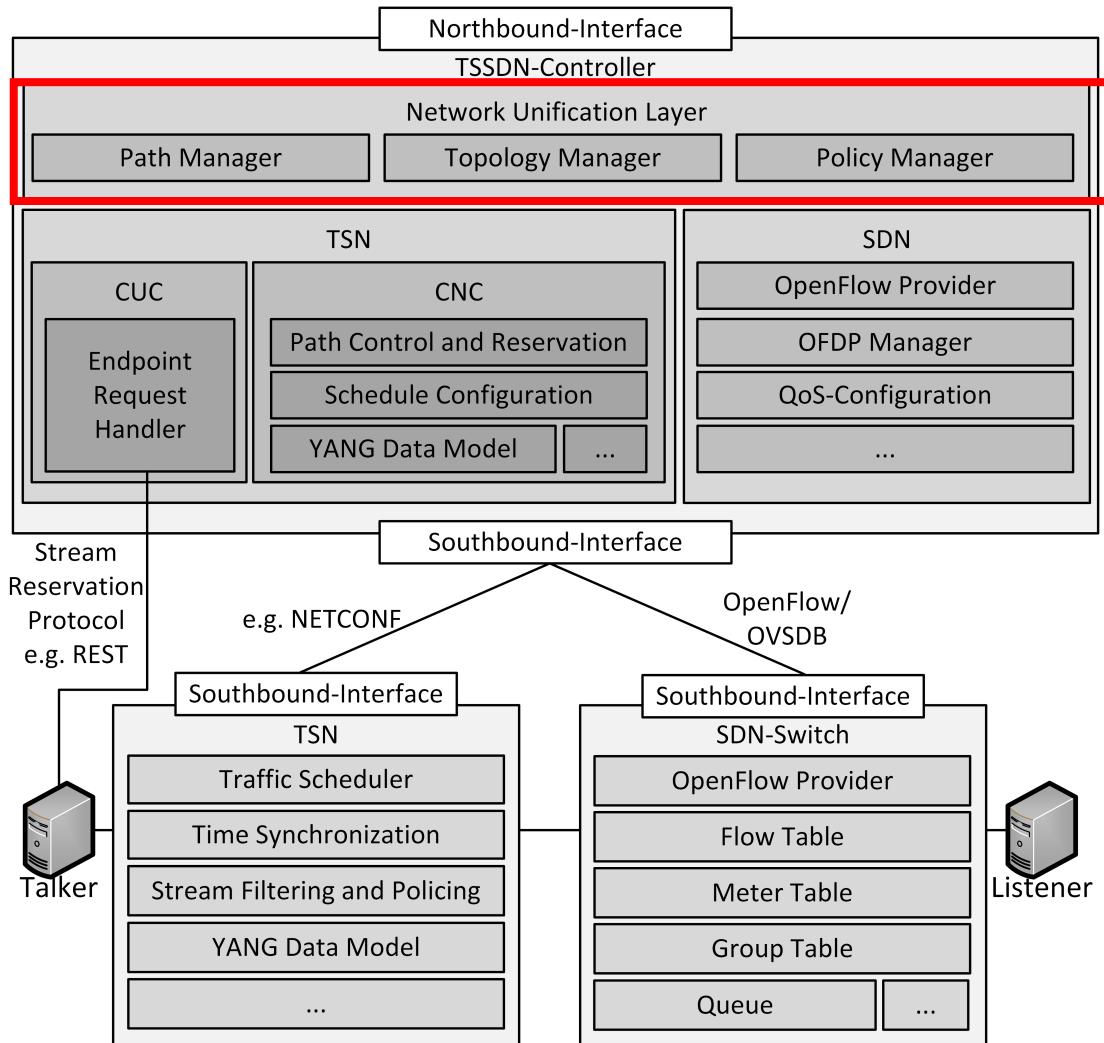
# Control-Plane

- SDN
  - OpenFlow Provider
  - OpenFlow Discovery Protocol (OFDP)
  - QoS
  - ...



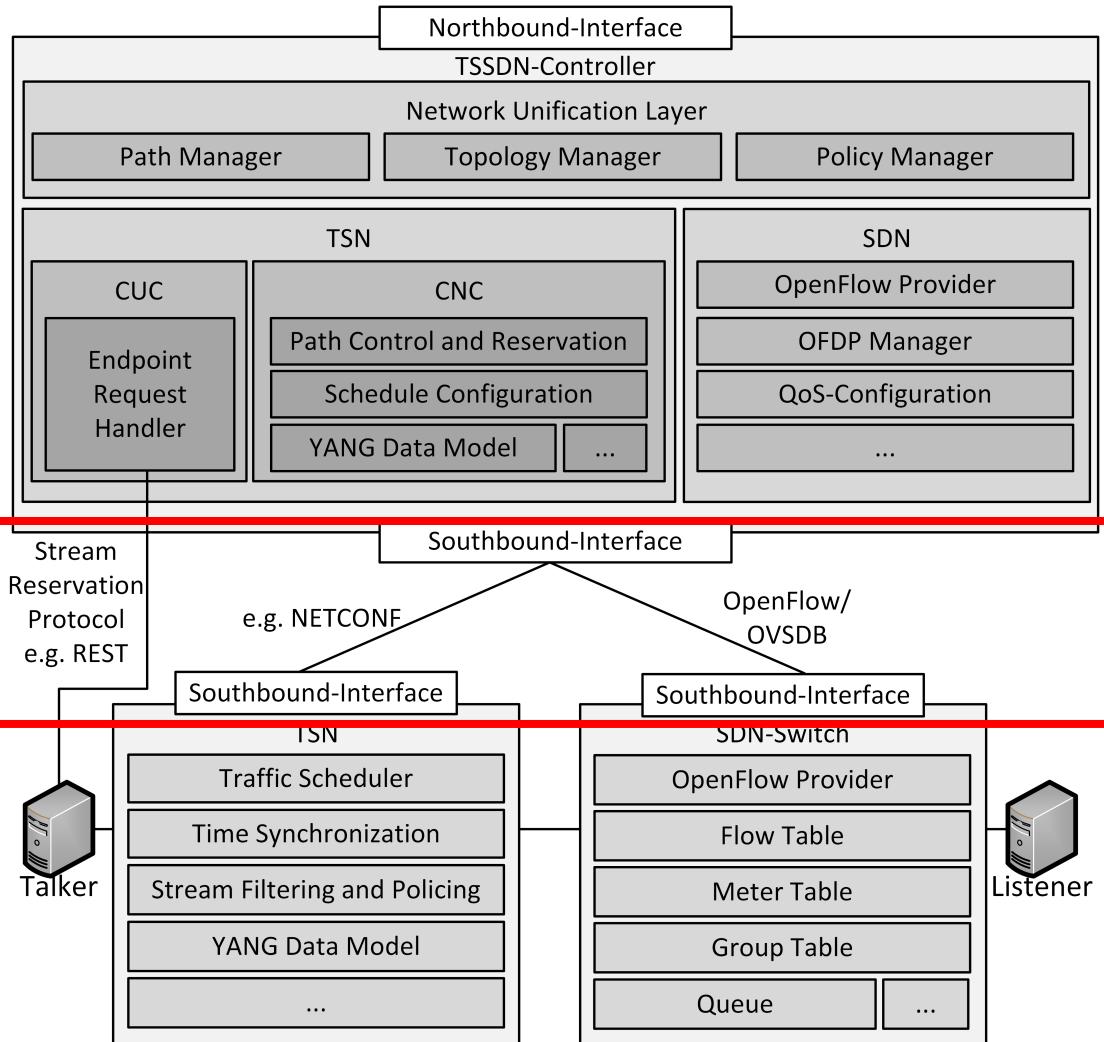
# Control-Plane

- Network Unification Layer
  - Orchestrate interactions
- Path Manager
- Topology Manager
  - Topology information from both technologies
- Policy Manager
  - E.g. Security policies



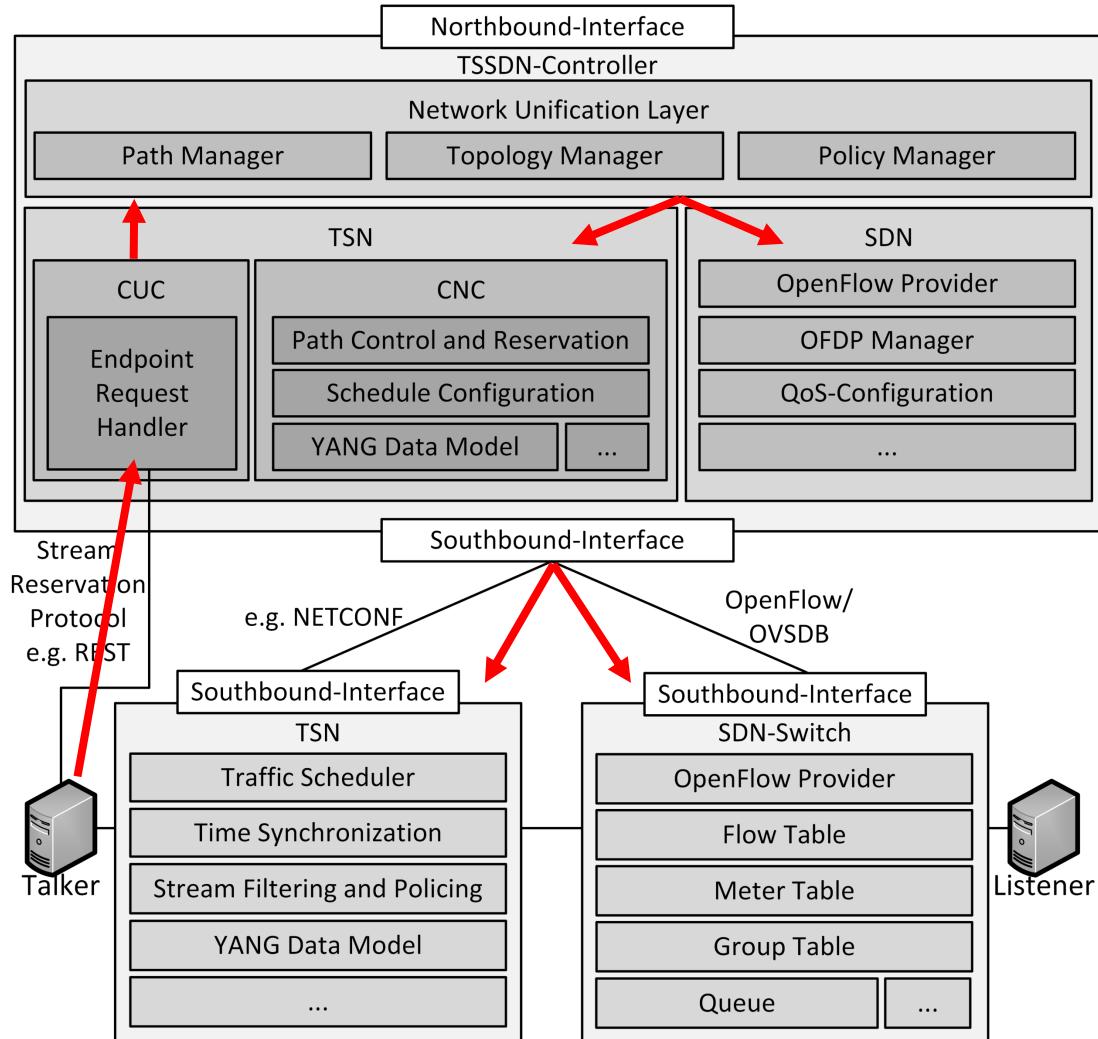
# Interfaces

- Connection requests
  - IEEE 802.1 Qcc
  - Interval of messages, amount of data, ...
- Southbound Interface
  - OpenFlow for SDN
  - E.g. NETCONF for TSN

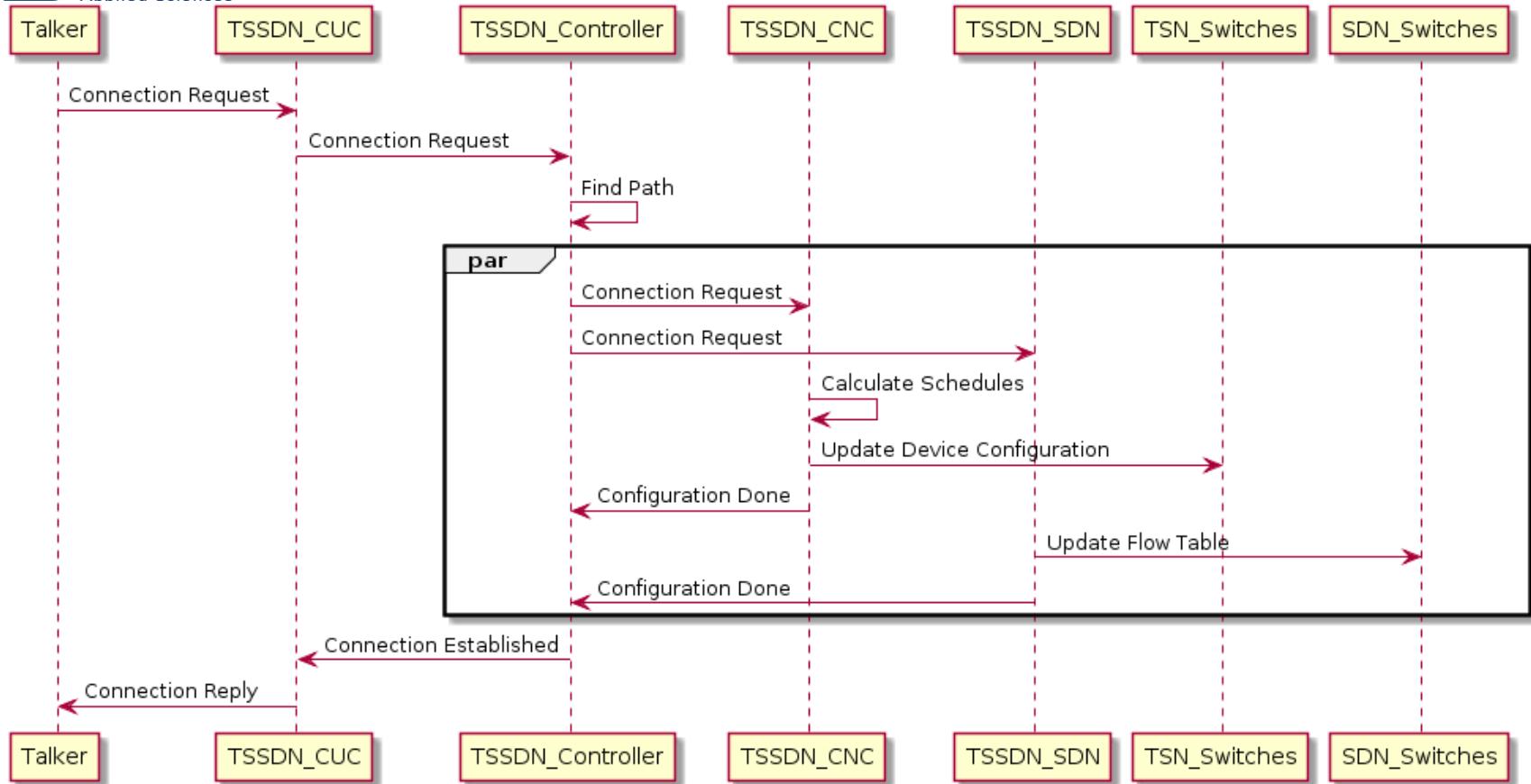


# Connection Request

- Talker requests a connection
  - Interval of messages
  - Amount of data
  - ...

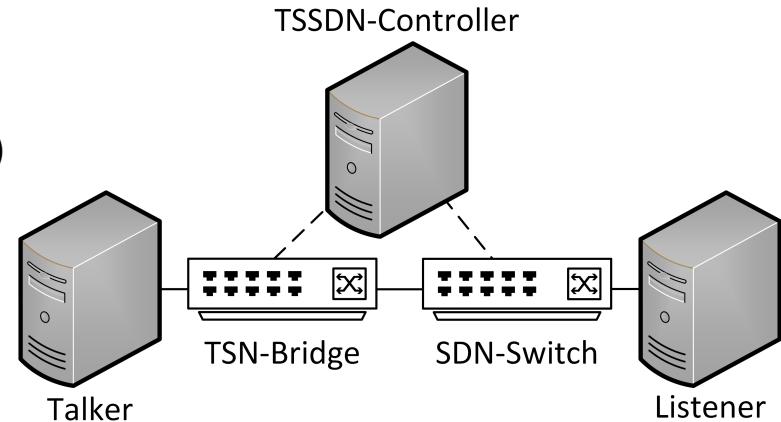


# Talker requests a non-time-sensitive connection



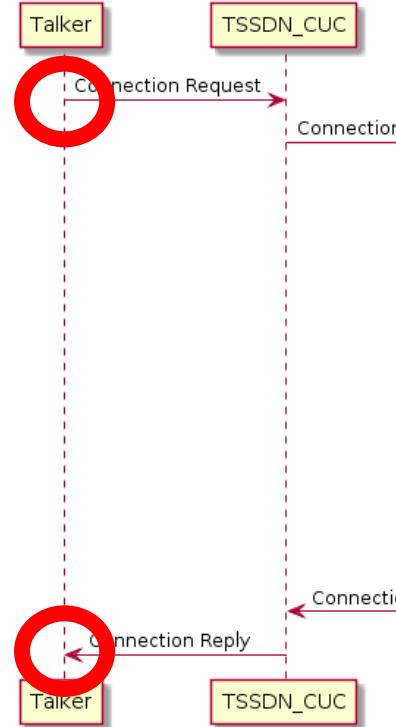
## Prototype & Testbed

- Based on Project Floodlight (SDN Controller)
- Modules for TSN and unification layer
- REST API for connection requests
- TSN Bridge: InnoRoute TrustNode
- SDN Switch: Edgecore AS4610-30T with PicOS



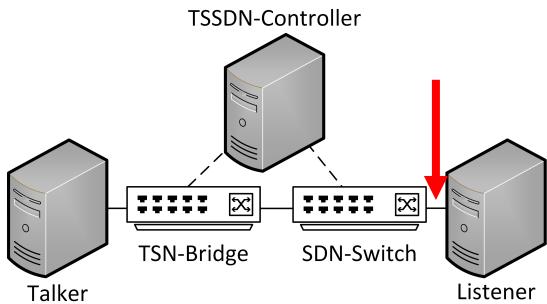
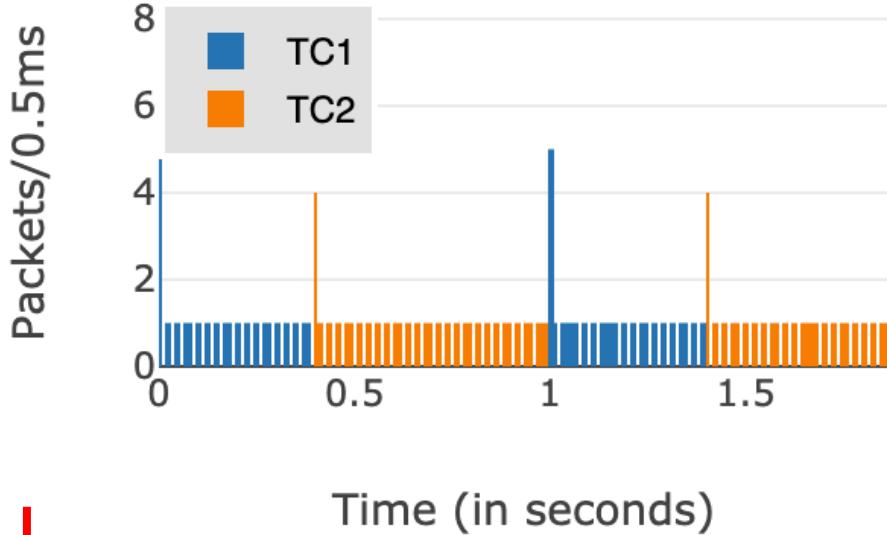
## Test Cases & Evaluation

- Setup time
- Talker requests a connection
- Response time for 1000 requests:
  - Average: 314,7ms
  - Minimum: 276,3ms
  - Maximum: 645,4ms
  - Standard deviation: 17,5ms



# Test Cases & Evaluation

- Correct scheduling behavior
  - 2 traffic classes (400ms / 600ms)



## Conclusion/Future Work

- Unified control-plane for TSN and SDN
- Non-time-sensitive and time-sensitive connections
- More realistic conditions (e.g. more network elements)
- More complex schedule calculation
- Applicability for large-scale networks