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Requirements Analysis and Performance Evaluation of SDN Controllers for Automotive Use Cases

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Outline

I. In-Vehicle Networks
II. Software Defined Networking
III. Requirements Analysis
IV. Performance Evaluation
V. Controller Applications
VI. Conclusion and Outlook

I.

In-Vehicle Networks

Present State of In-Vehicle Networks

- Functions and services through Electronic Control Units (ECUs)
- Different proprietary bus systems (CAN, MOST,...)
- Domain based network

Emerging In-Vehicle Networks

- Increased dynamic network traffic
  - Internet connectivity
  - Communication with environment (Vehicle-to-X)
- Switched Ethernet-based backbone
- Time-Sensitive Networking (TSN)

- Software Defined Networking (SDN) approach for dynamic network traffic

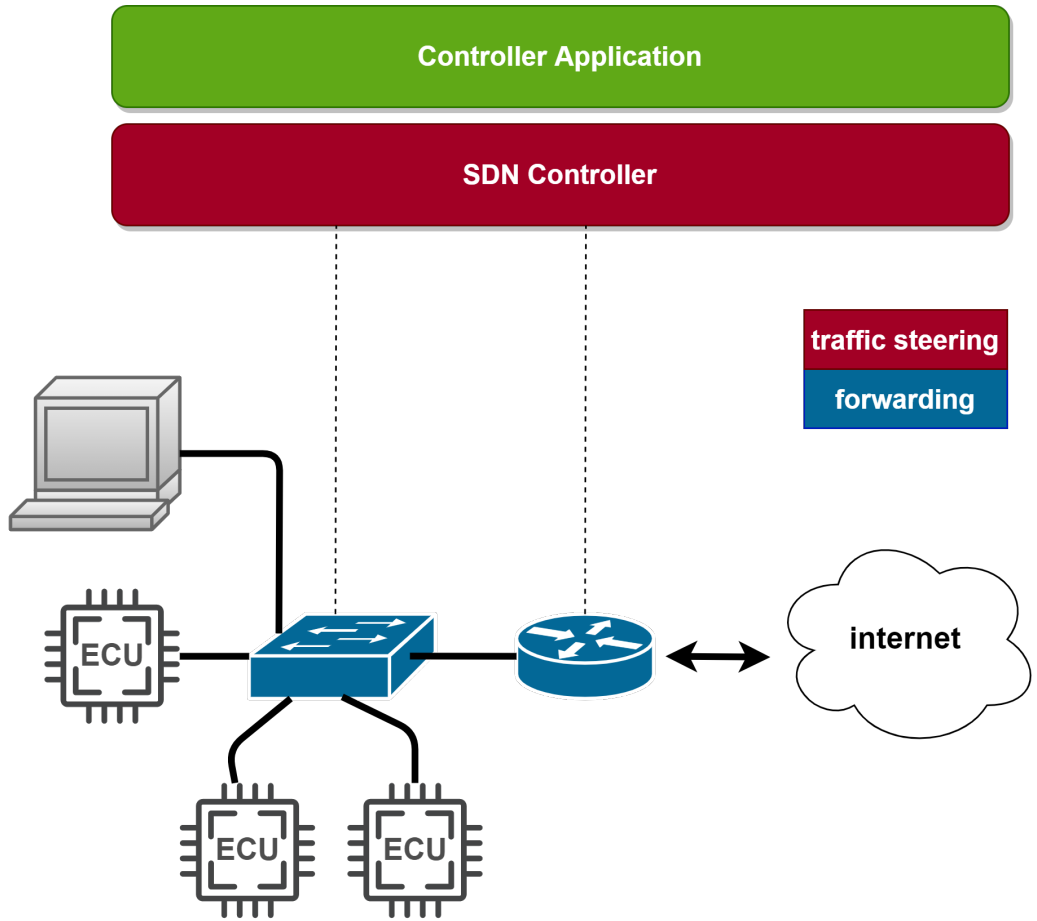
II.

Software Defined Networking

Software Defined Networking

- Logically centralized
  - SDN controller (Software)
  - Forwarding devices (Hardware)

- SDN controller
  - Global view on network
  - Steer network traffic
  - Development of controller applications



Research Questions

1. What requirements ?
2. How do SDN controllers perform ?
3. Can requirements be fulfilled by applications ?

1. Requirements analysis
2. Performance evaluation
3. Controller application examples

III.

Requirements Analysis

Requirements

Real-time

- Quality of Service
- Scheduled configuration
- Short Start-up time

Safety

- Link failure detection
- Transaction
- Controller Redundancy

Security

- Access control
- Network statistics

Remaining functional requirements

Remaining non-functional requirements

Evaluation Categories

- **Feature:** Function provided by the controller
- **Performance:** Must be measured in the performance evaluation
- **Application:** Can be fulfilled by a controller application

Candidate Selection Based on Feature Requirements

- Over thirty SDN controllers
- Selection of controllers by provided feature
- No single controller provides all wanted feature
- Only one feature not fulfilled by any controller
- Most promising controllers tested in performance evaluation

Controller Candidates

ONOS

- Java
- Open-Source

OpenDaylight (ODL)

- Java
- Open-Source

Lumina

- Java
- Proprietary
- Based on ODL

Ryu

- Python
- Open-Source

OpenMUL

- C/C++
- Open-Source

IV.

Performance Evaluation

Metrics

- Metrics are related to requirements

Quality of Service
- Asynchronous Message Processing Time

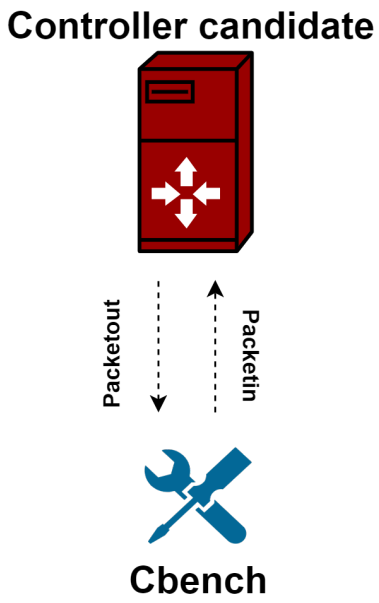
Short start-up time
- Start-Up time

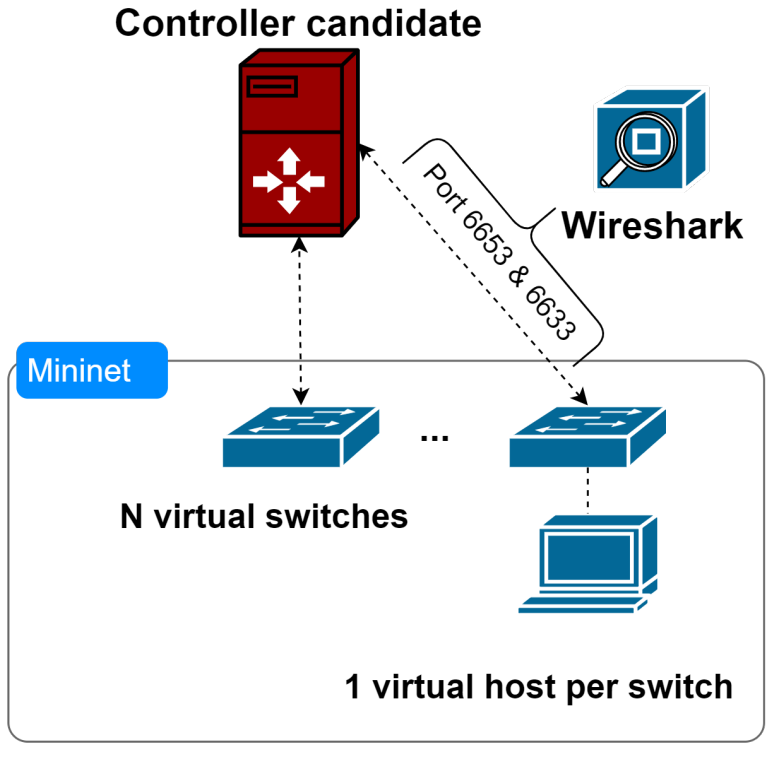
Link failure detection
- Topology Change Detection Time

Controller redundancy
- Failover Time

Testbed

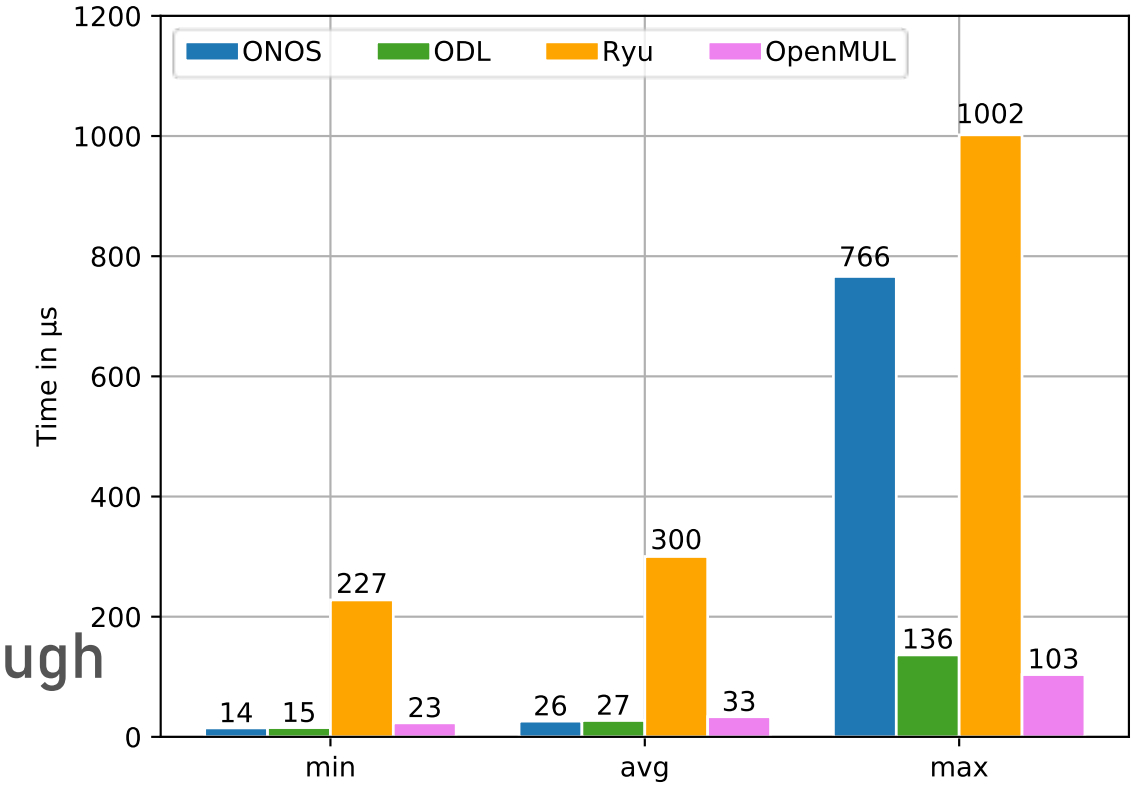
- Cbench: benchmarking application
- Mininet: network emulation
- Wireshark: packet capture





Quality of Service

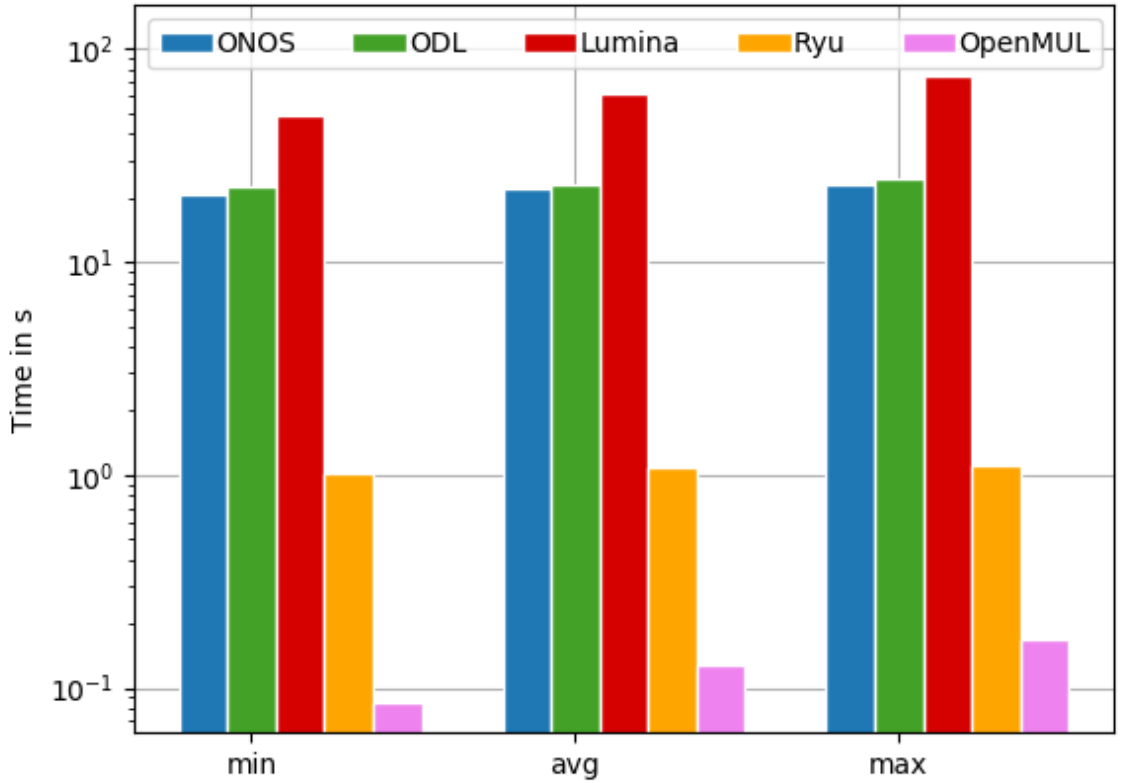
- Asynchronous message processing time
- Delay
  - arrival of asynchronous message
  - outgoing controller message
- Maximum end-to-end delay
  - 10ms control data
  - 150ms multimedia data
- Maximum processing time is low enough
- Extension for guarantees is needed



Short Start-Up Time

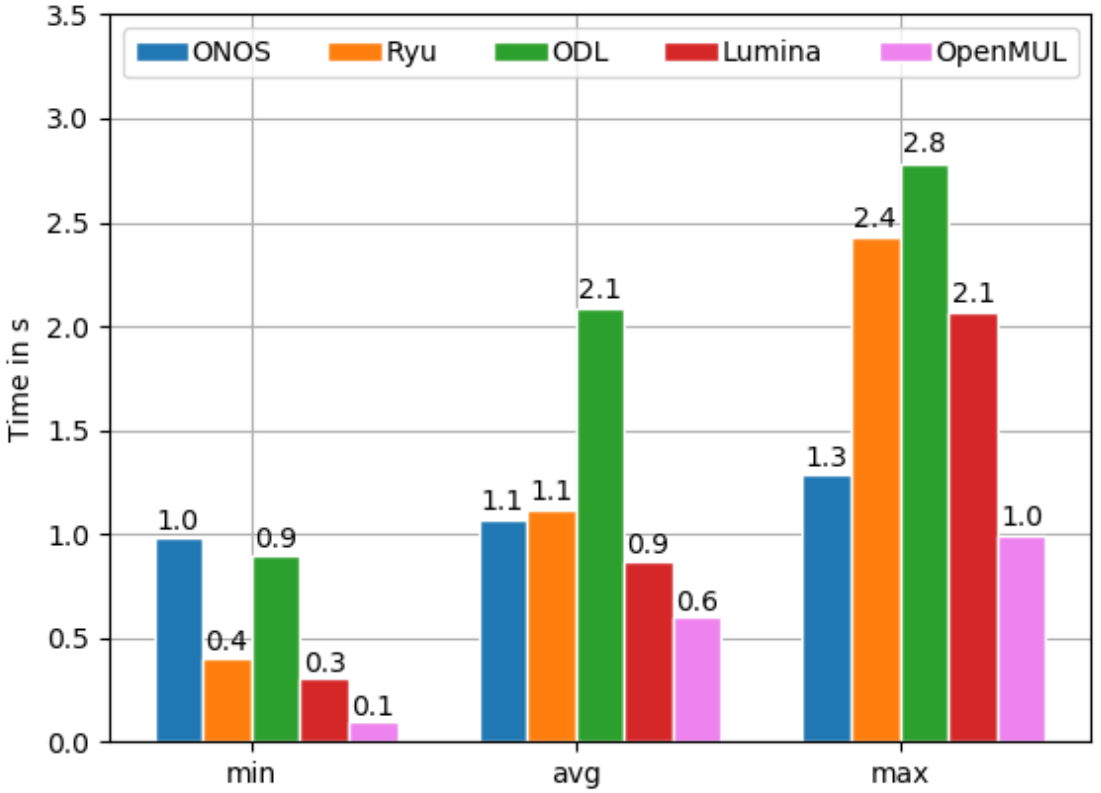
- Start-Up time
- Delay
  - Start of controller
  - Operational state

- Todays ECUs start-up time is under 200ms
- Except OpenMUL all needed multiple seconds
- C-based controller



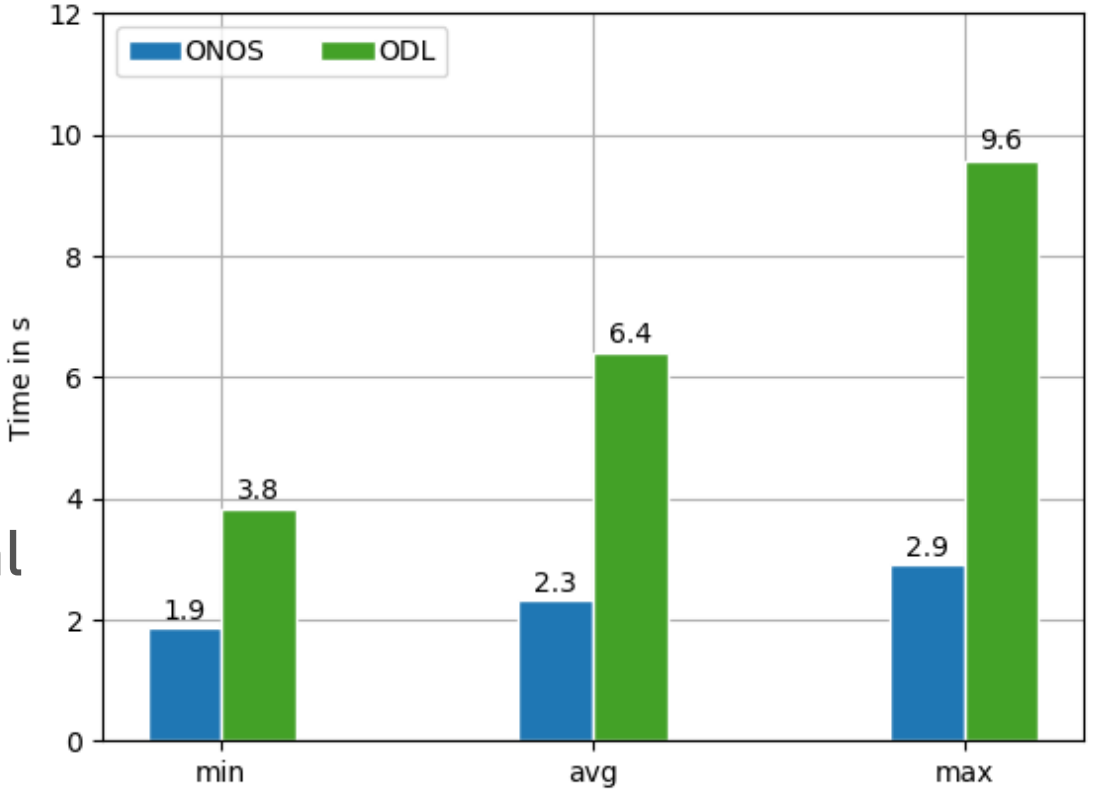
Link Failure Detection

- Topology change detection time
- Delay
  - Topology change
  - Detection
- Relevant for networks with redundant connections
- Maximum end-to-end delay
- Too high to be fallback strategy



Controller Redundancy

- Failover time
- Delay
  - Failure of controller instance
  - Replacement
- Important for management of safety critical traffic
- Failover time too long for safety critical traffic
- Pre-configured forwarding devices



V.

Controller Applications

Implementation Platform

- Requirements with controller applications
- Automotive specific applications
- ONOS
- Realistic in-vehicle network prototype

2016‘ Seat Ateca Prototype

Controller Application Examples

Quality of Service

- Priority Queues

Scheduled configuration

- Configuration with timestamps

Transaction

- Configuration list

Access control

- Access control list

Network statistics

- Report collection

VI.

Conclusion and Outlook

Conclusion And Outlook

- SDN controllers must undergo a redesign
  - Automotive specific features
  - Embedded system compatible
- Extensions are needed to boost performance
- Fulfilling requirements with controller applications

Future Work

- Development of automotive specific controller implementation
- Development of controller applications

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