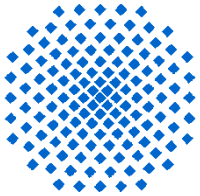

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ZeroSDN: A Highly Flexible and Modular Architecture for Full-range Network Control Distribution

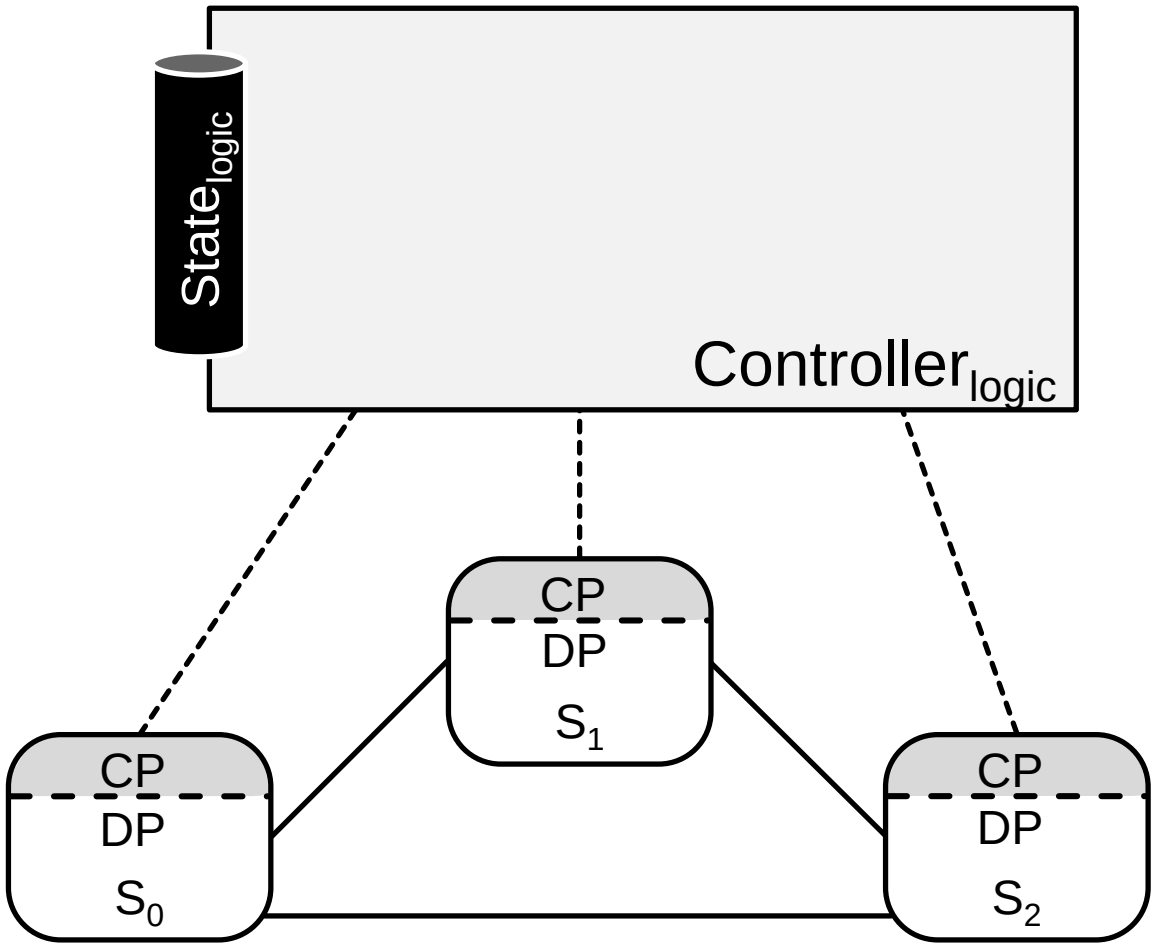
Thomas Kohler, Frank Dürr, Kurt Rothermel

October 12th, 2017

KuVS Fachgespräch
“Network Softwarization”

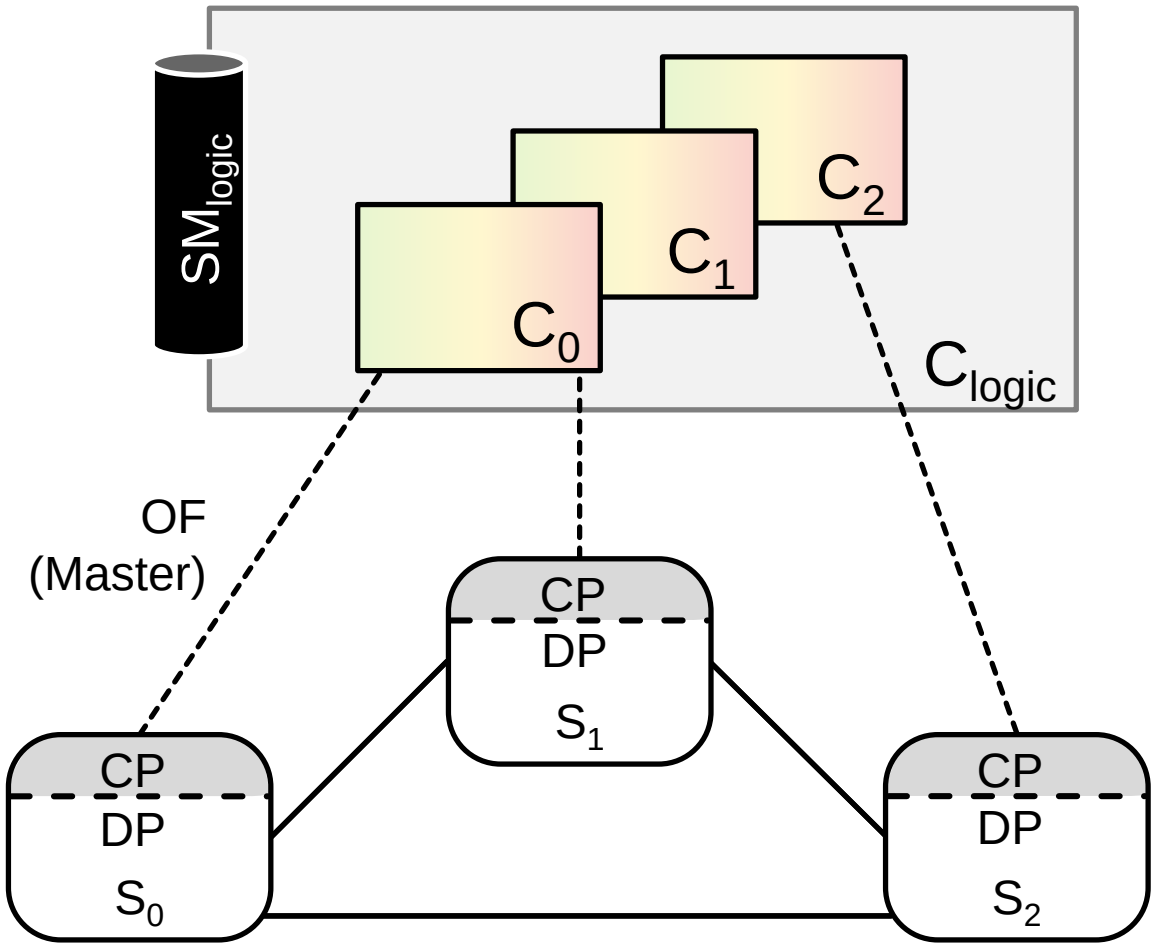
dSDN
distributed
Software-Defined
Networking

Introduction – Control Plane as a Distributed System



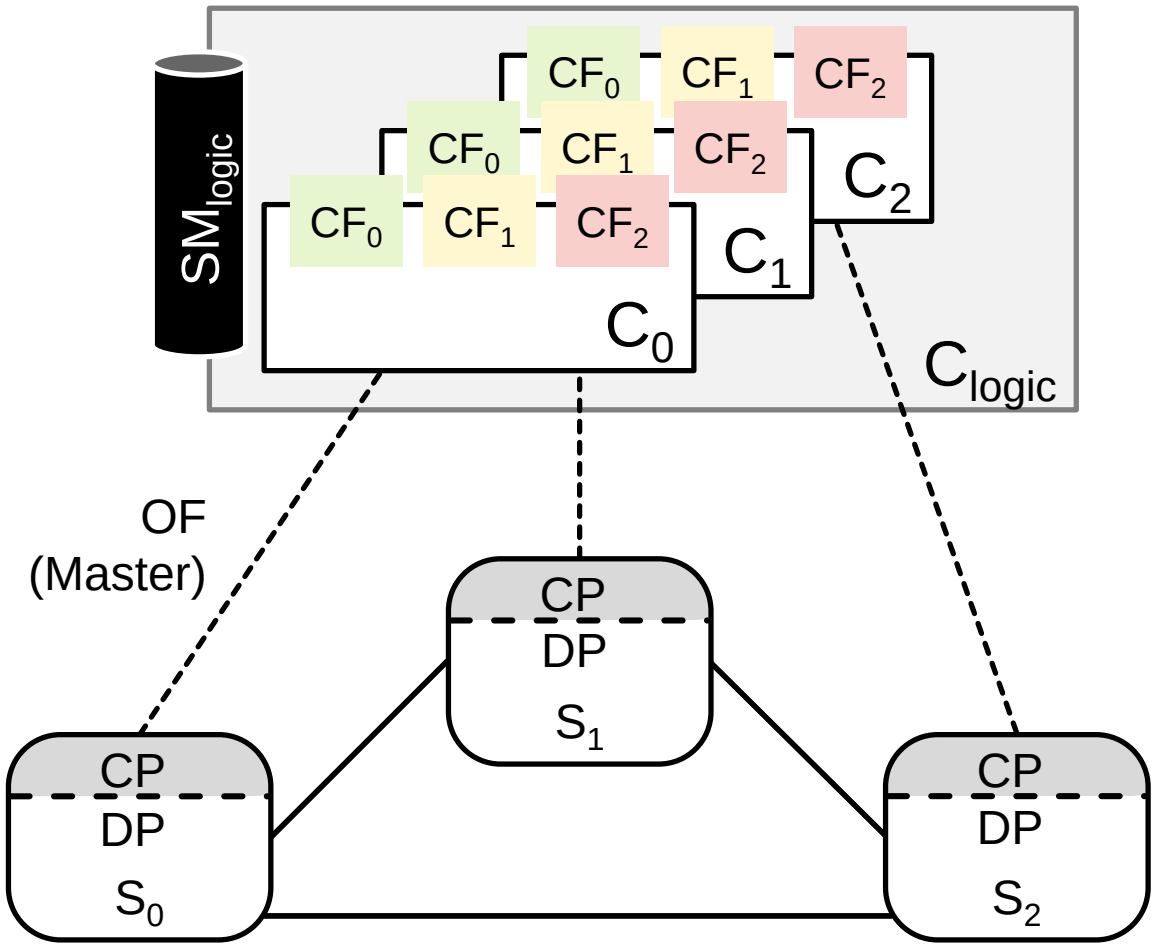
- SDN paradigm
  - Separation of control plane and data plane
  - Logically centralized control
    - → Global view
    - → Distribution transparency

Introduction – Evolution of SDN Controller Architectures



- Control Plane (CP)
  - Monolithic
  - Replication support
- Data Plane (DP)
  - Fixed controller-instance assignment (master / slave)

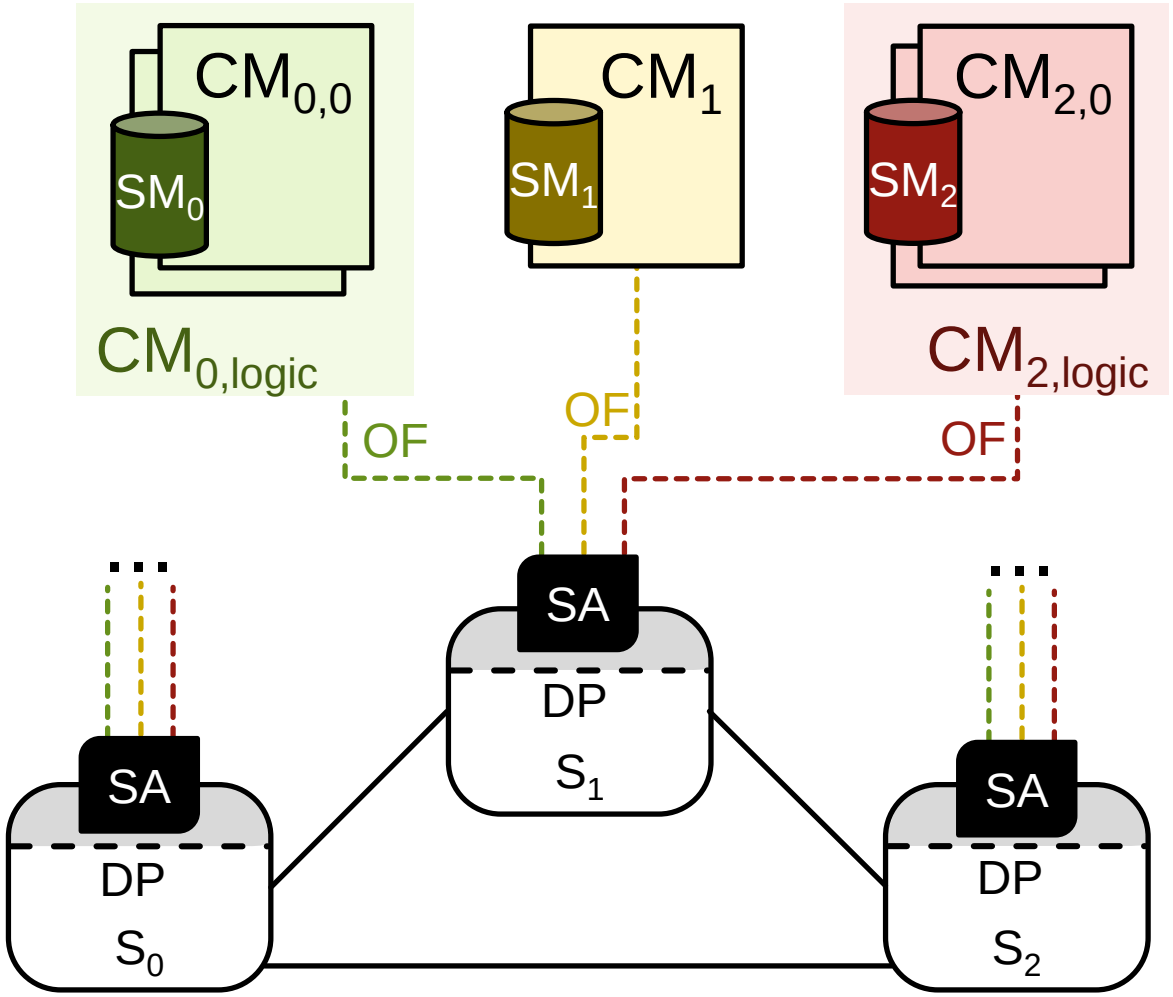
Introduction – Evolution of SDN Controller Architectures



- CP
  - **Modular**
  - Monolithic
  - Replication support
- DP
  - Fixed controller instance assignment (master / slave)

Onix, Hyper Flow, ElastiCon, Beehive

Introduction – Evolution of SDN Controller Architectures



- CP
  - **Modular**
  - **Distributed**
    - **Partitioning**
  - Replication support
- DP
  - CF partitioning

    → $n:m$ controller mapping
  - Dynamism

DevoFlow, Kandoo

Introduction – Evolution of SDN Controller Architectures

- Observations & Shortcomings
  1. Fully (logically) centralized control model
     - No control communication between switches
     - No switch-local logic (decision making)
  2. Heavyweight controllers
     - Modularization frameworks typically heavy-weight
     - Lightweight controllers do not have distribution capabilities
  3. Tight switch-controller coupling
     - Fixed mapping
     - No module dynamism

Outline

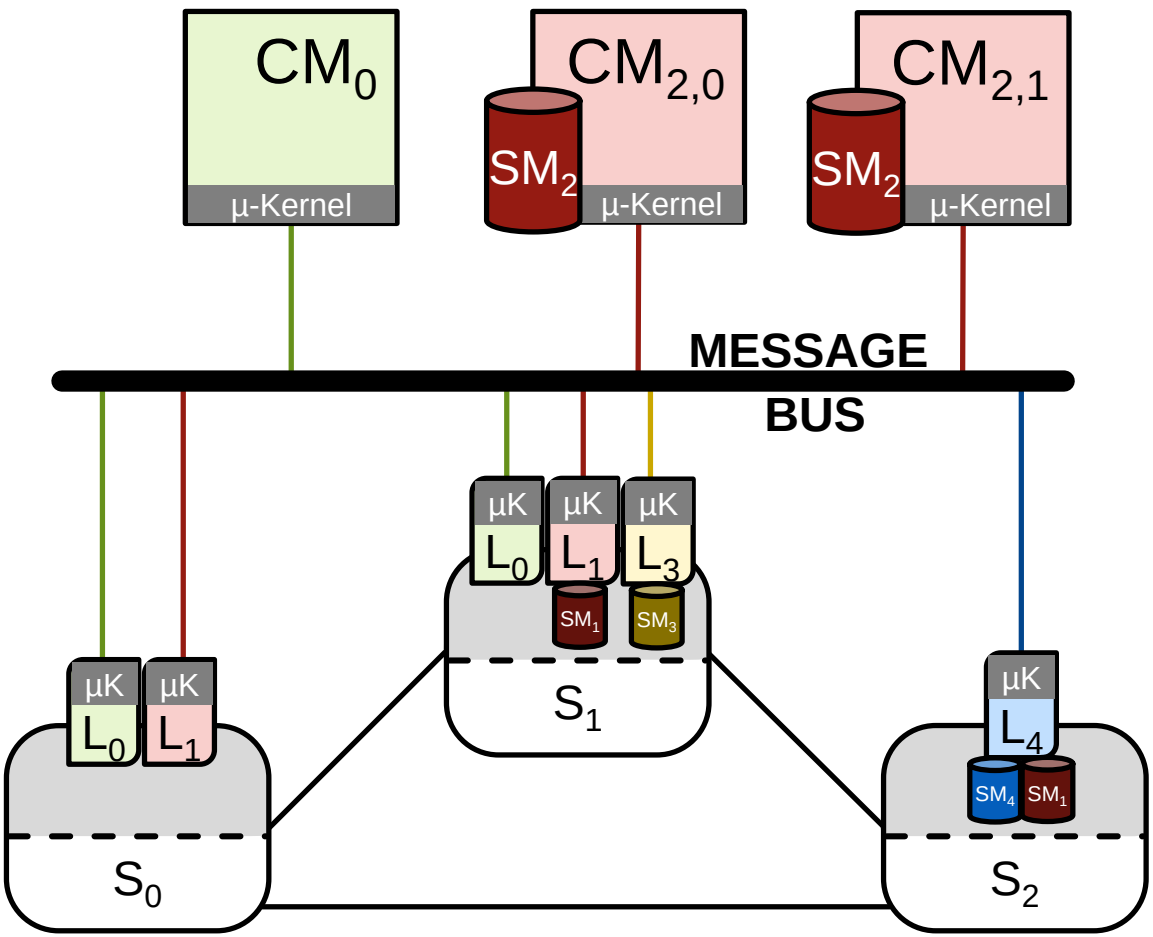
- Introduction – Evolution of SDN Controller Architectures
- **Architecture for Full-range Network Control Distribution**
- Highly Flexible Control Plane Distribution
- Implementation & Evaluation
- Roadmap to a Highly Scalable Holistic System Control Plane
- Conclusion

Contributions

"*ZeroSDN [...]*", Kohler, Dürr, Rothermel
ANCS'17

- SDN Controller Architecture with high flexibility in distribution
  - From logically centralized to fully decentralized control
- Micro-Kernel controller architecture for distributed light-weight controller modules (controllets)
- Pushing down network control to switches (local logic)
  - While leveraging global knowledge
- Decoupling of controllets through a message bus
  - Content-based filtering of *data- & control plane events*

Architecture for Full-range Network Control Distribution



- µ-Kernel architecture
- Modularity
- Full distribution
  - Local & remote controllets
- Replication
- Message bus
- Event-based network control

Message Bus – Decoupling Event-based Controllets

- Data- / Control- plane events
  - Packets or state changes of switches and data plane end-hosts (*DPE*)
  - Control coordination messages and control state changes (*CPE*)
- Message bus paradigm
  - Routing of events to subscribers w/ content-based filtering
  - Emulation of P2P, multicast communication patterns
  - Transparently implement arbitrary delivery semantics

Ravana: Controller Fault-tolerance in SDN; Rexford et al. **SOSR'15**

Outline

- Introduction – Evolution of SDN Controller Architectures
- Architecture for Full-range Network Control Distribution
- **Highly Flexible Control Plane Distribution**
  - Fully Distributed Control
  - Local Logic: Local Data Plane Event Processing (LDPEP)
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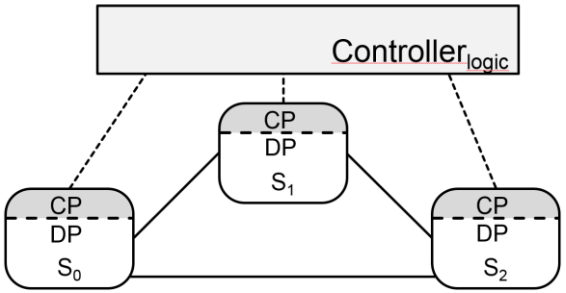
Highly Flexible Control Plane Distribution – Fully Distributed Control

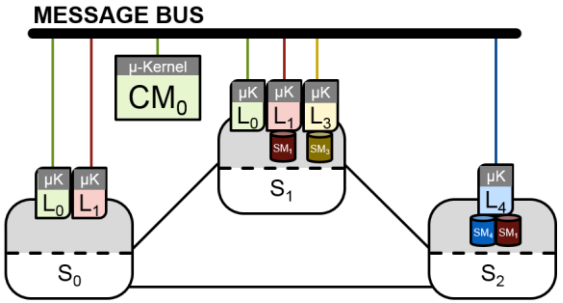
- Network control distribution
  - Top end:

    full centralization (majority of current SDN controller architectures)



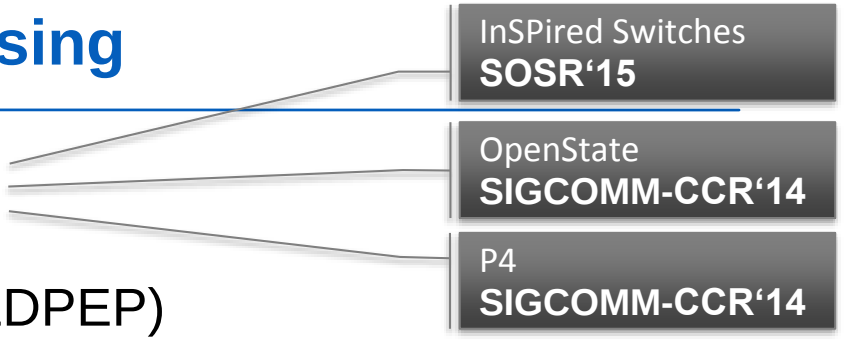
  - Bottom end:

    full distribution of network control

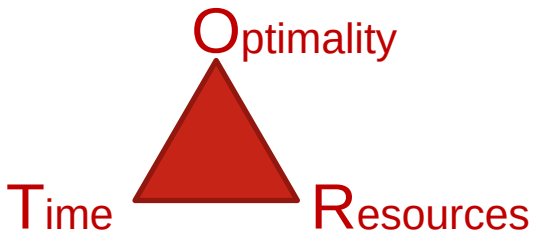


- Our approach: offer full range of distribution

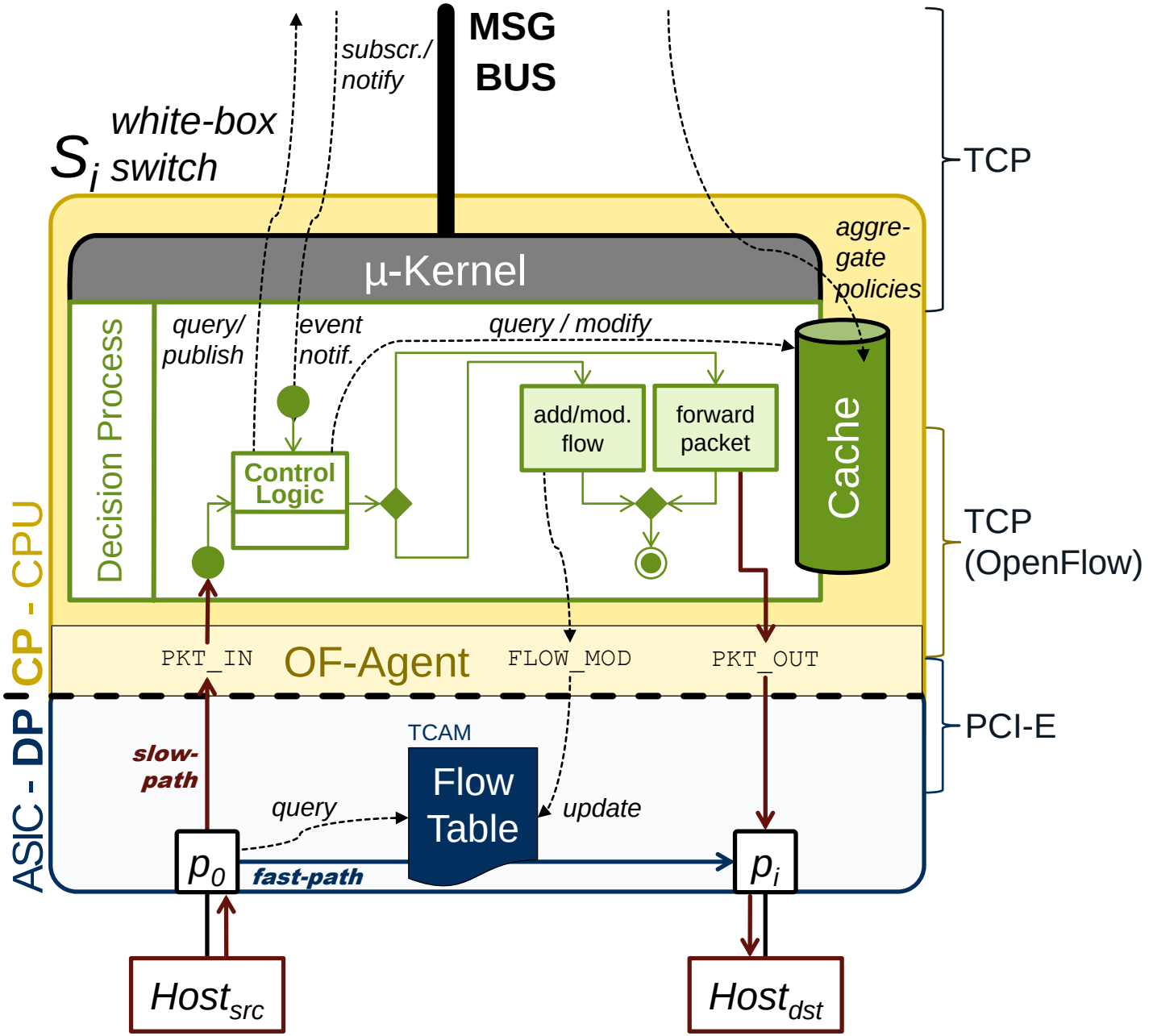
Highly Flexible Control Plane Distribution – Local Data Plane Event Processing



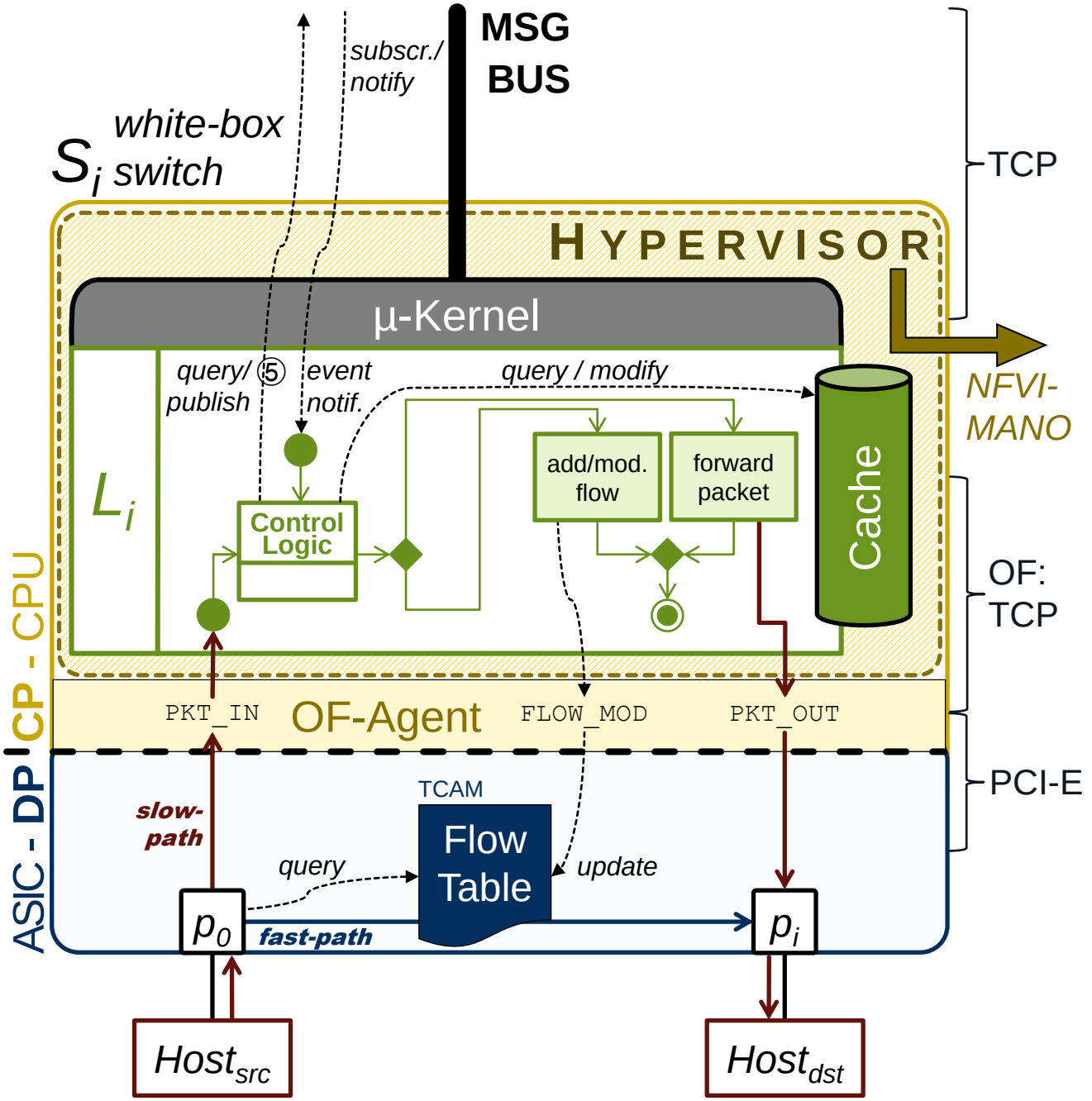
- So far: enhancing switch capabilities
- Local Data Plane Event Processing (LDPEP)
  - Running controllets (decision making) on switch hardware
  - Increased resilience against controller-failures, inherent load balancing
  - Ideally: entirely local decision making → most timely reaction
  - .. while having access to neighbours and global knowledge → optimality
  - Scale scope of local control with available computing resources
  - Trade-offs (*intermediate procedures*)



Local Data Plane Event Processing



LDPEP – Isolation Requirements



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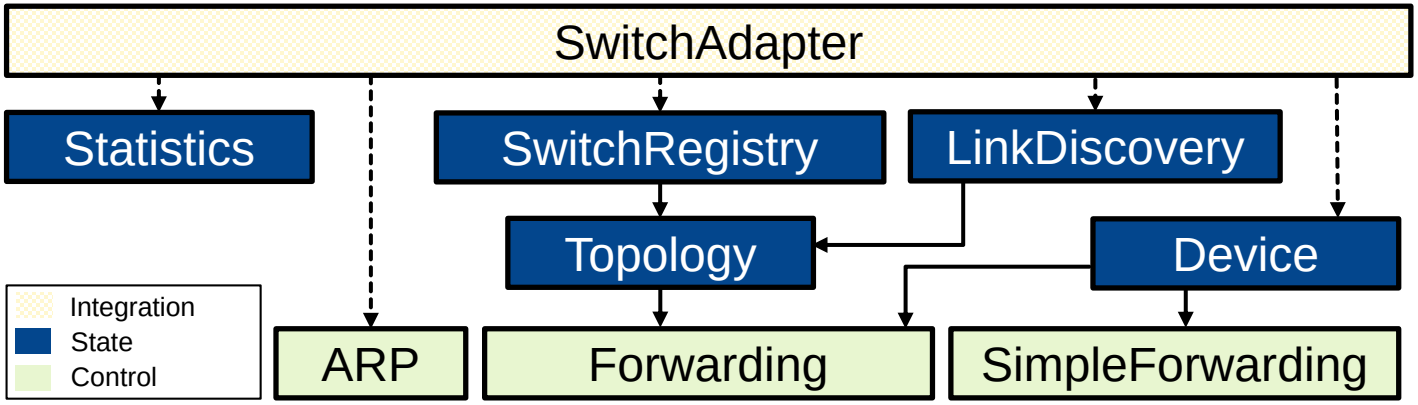
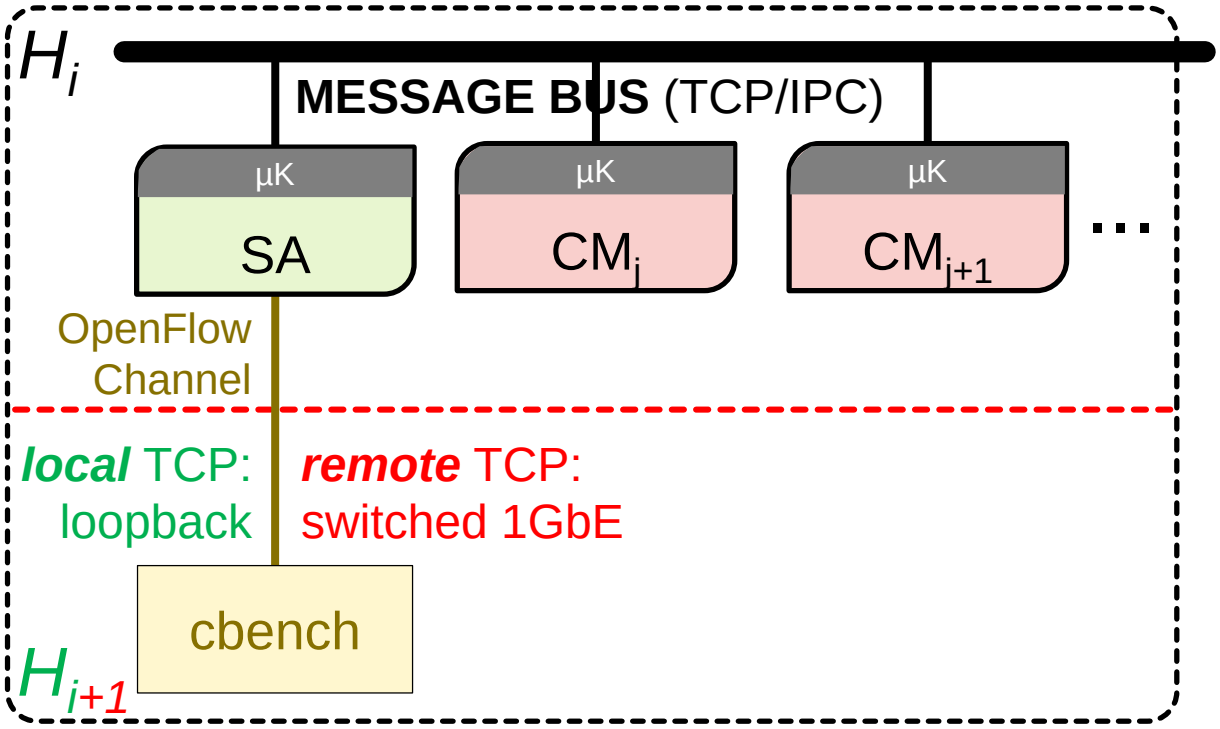
Implementation

- ZMF: modular execution framework http://zerosdn.github.io/
  - Dependency and life-cycle management
  - Message bus: communication middleware: ZeroMQ
- ZeroSDN: distributed SDN controller application
  - Message de-/serialization: Google Protocol Buffers
  - Core controllets implemented (OF 1.0 - 1.3)



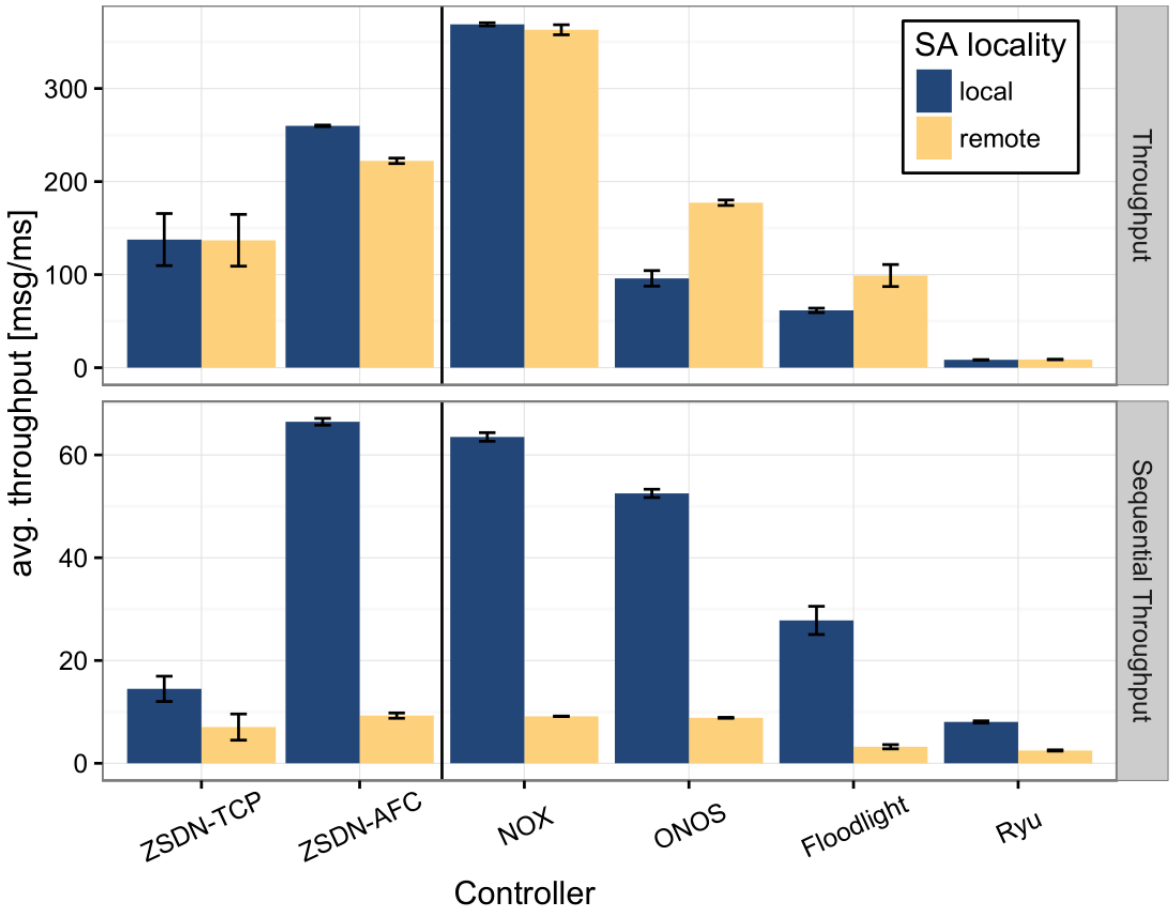
Evaluation – Raw Controller Performance – Methodology

- Raw controller performance
  - 12 nodes (Xeon, 4 x 3.4GHz), 1GbE *local*
  - 6 node pairs *remote*



- cbench emulates switches
- # emulated switches $s = 1$
- # end hosts $e = 10000$
- Observation time $T = 12min$

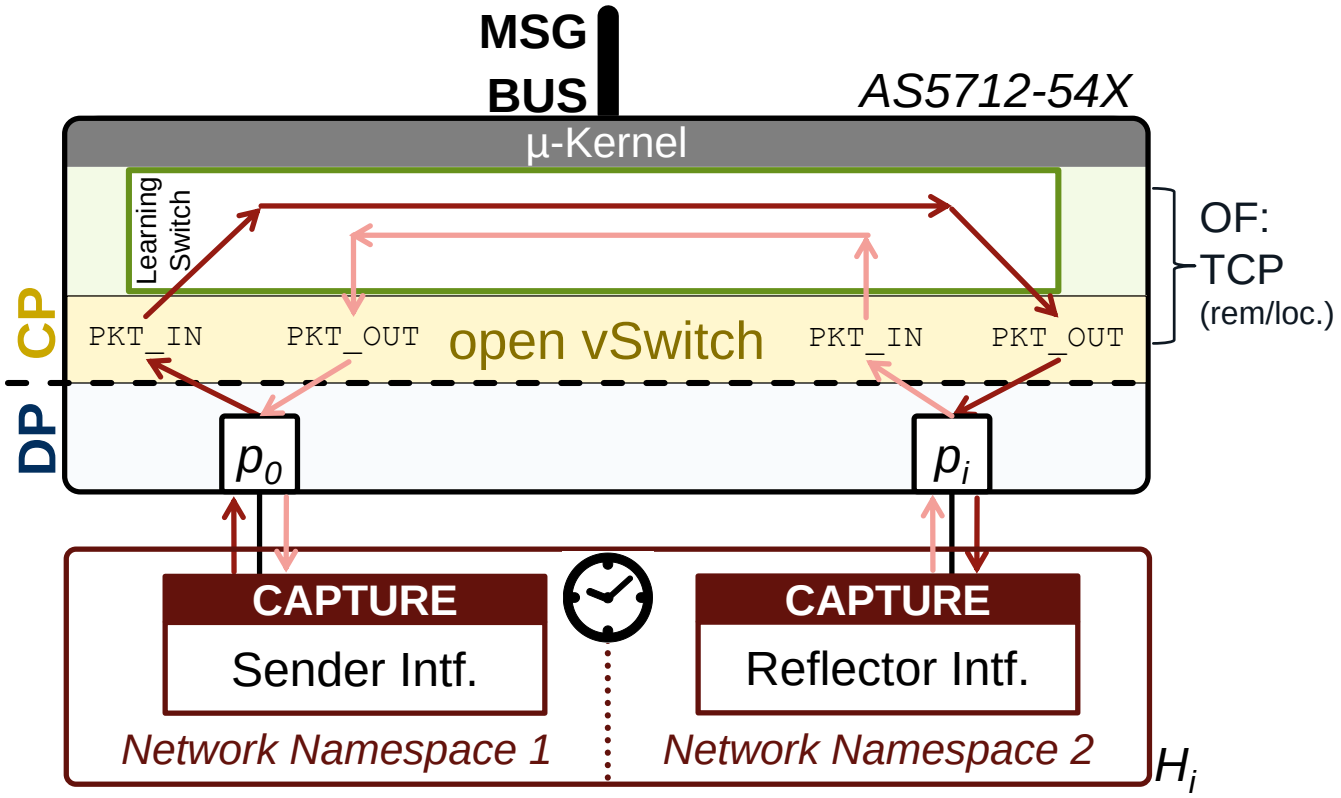
Evaluation – Raw Controller Performance – Results



- Distribution impact on throughput
  - factor 0.5
- Moderate locality impact on throughput
- Remote vs. local latency
  - factors 2 to 6

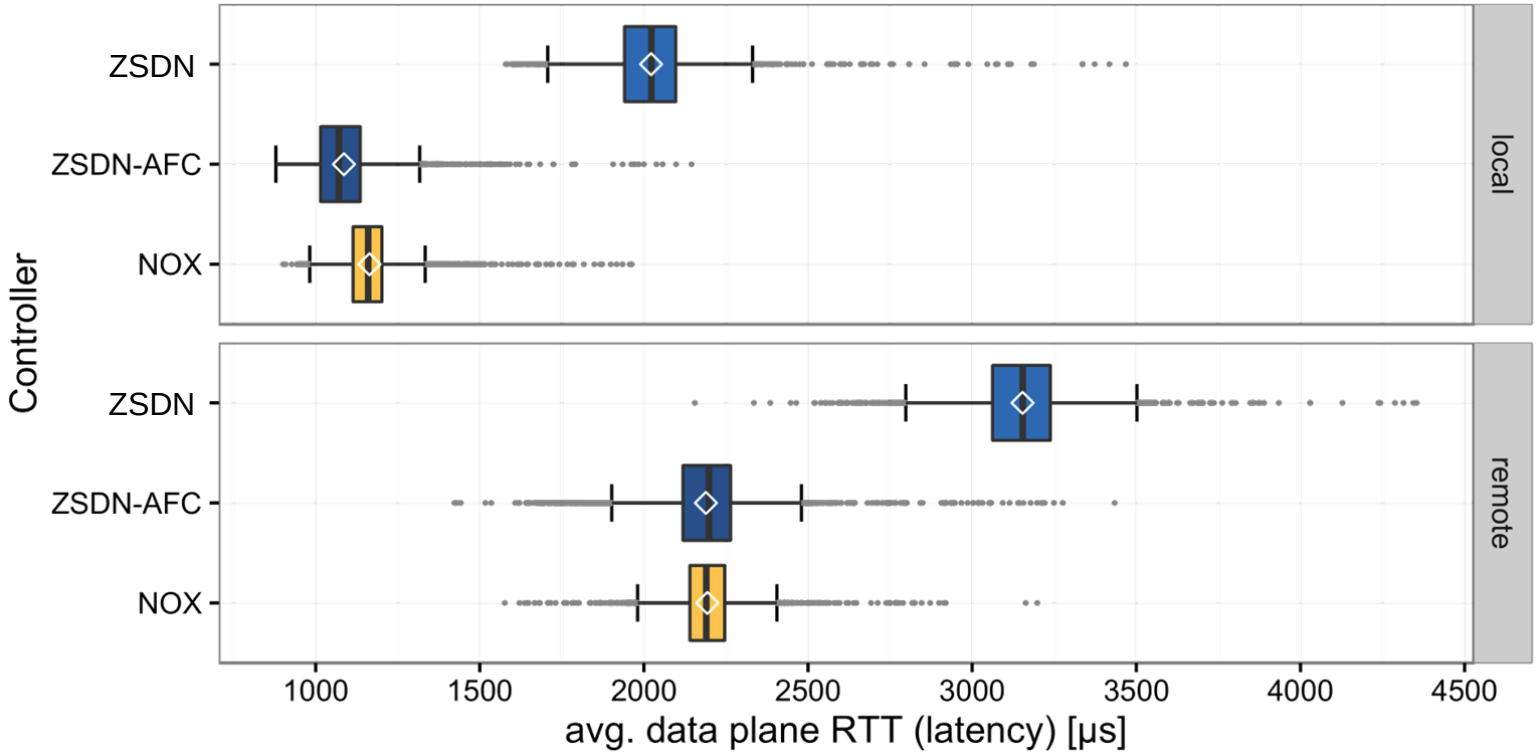
Evaluation – Hardware Switch – Methodology

- Performance on a Whitebox-Networking Hardware Switch



- Provoke packet processing in switch control plane
- Measure data plane RTT

Evaluation – Hardware Switch – Results



- Remote TCP connection latency impact factors:
  2 (ZSDN-AFC), 1.9 (NOX), 1.5 (ZSDN)

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Roadmap to a Highly Scalable Holistic System Control Plane (Future Work)

- Complex network event processing
  - Predicate logic for evaluation of events
    - logical operators
    - timing constraints
    - sequences of events absence of events
  - Distributed evaluation of complex events in controllets, subscribing to relevant simple events (DPE & CPE)

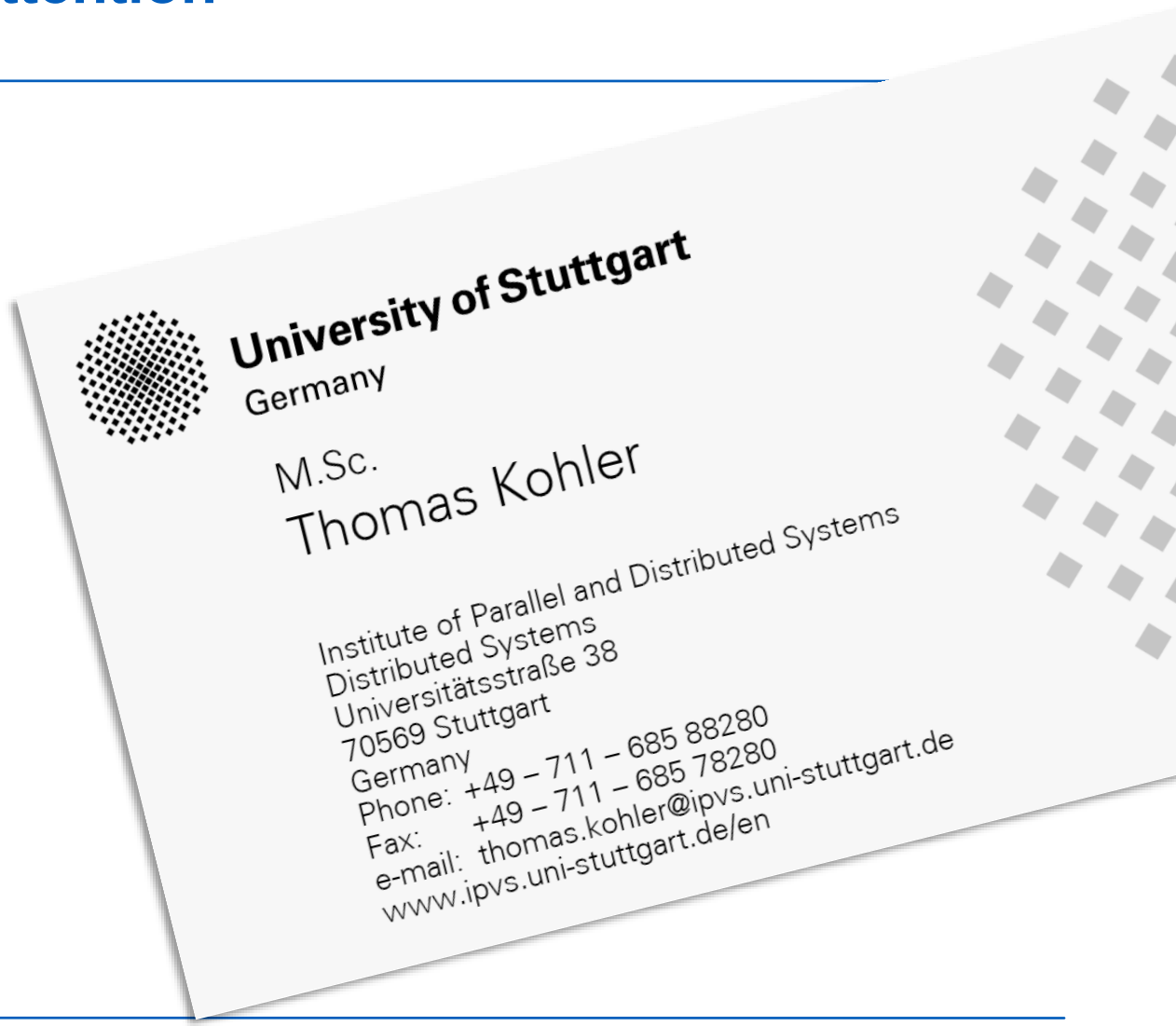
- Holistic system control plane:
  Application layer events & end-host control
  - NFVs, end-systems (including VMs), applications
  - Execute complex system management workflows

Conclusion

- Highly flexible & modular architecture for full-range network control distribution
- Lightweighted micro-kernel approach
- Decoupling of controllets through a message bus
  - Content-based filtering and hybrid processing of control plane and data plane events
- Exploiting locality of switches along with global knowledge

Thanks for your attention

Any Questions?



Contact &
further information:

https://goo.gl/tYWSgW