INF

FAKULTÄT FÜR
INFORMATIK

Enabling Path Awareness for Legacy Applications through SCION-IP Translation utilizing eBPF and Tofino

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Structure

1. Background – SCION
2. Motivation for a SCION IP Translator
3. Concepts – Translating IP addresses to SCION
4. eBPF & P4 Implementation on Tofino
5. Evaluation of Performance and Resource Usage
6. Conclusion & Future Work

1. Background: SCION Architecture

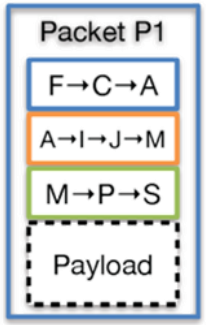
Path-based Network Architecture

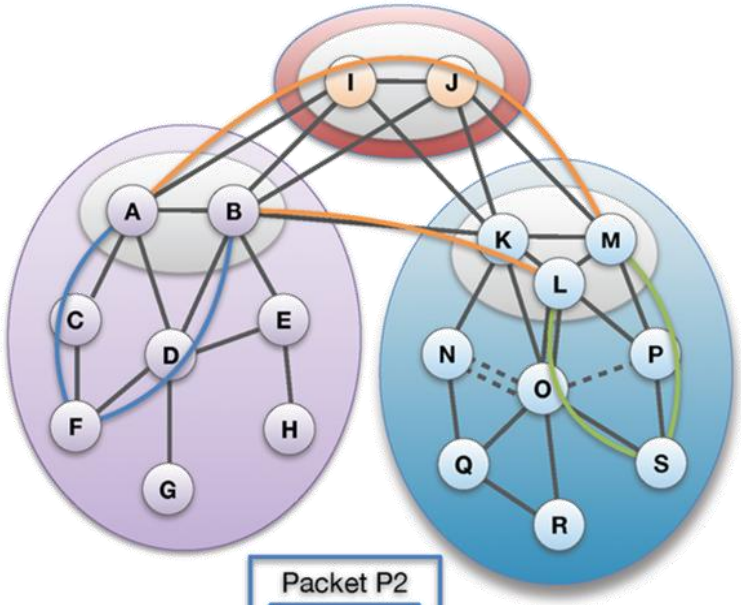
Control Plane - Routing

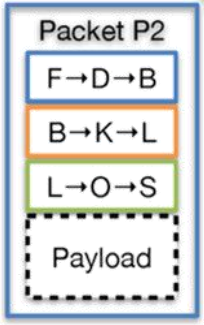
- Constructs and Disseminates Path Segments

Data Plane - Packet forwarding

- Combine Path Segments to Path
- Packets contain Path
- Routers forward packets based on Path
  - Simple routers, stateless operation



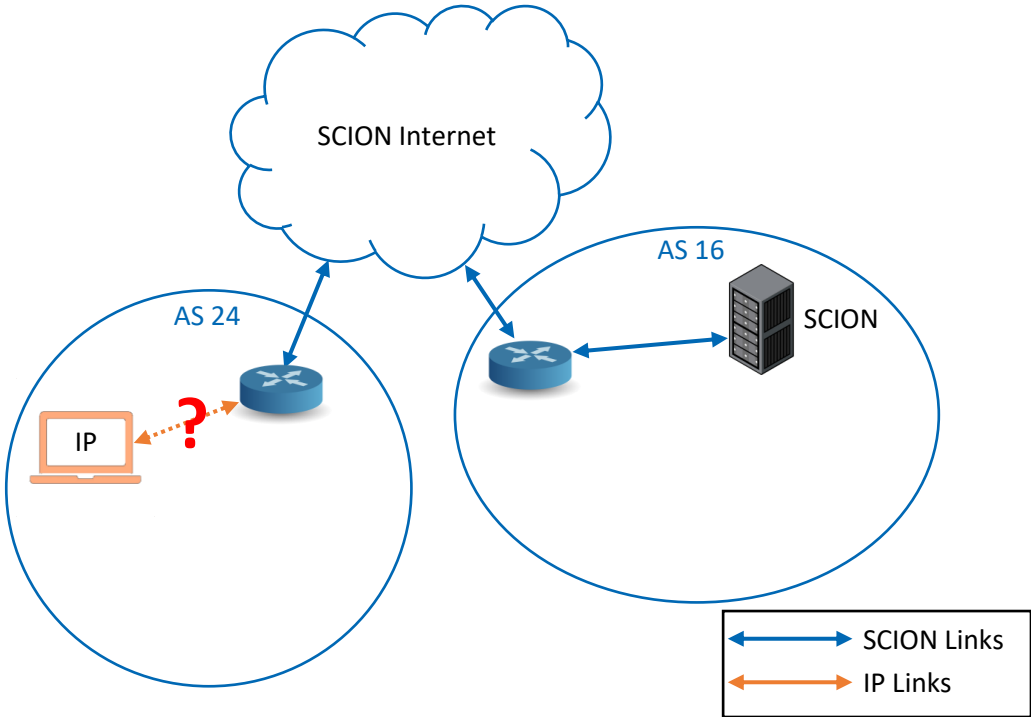




SCION

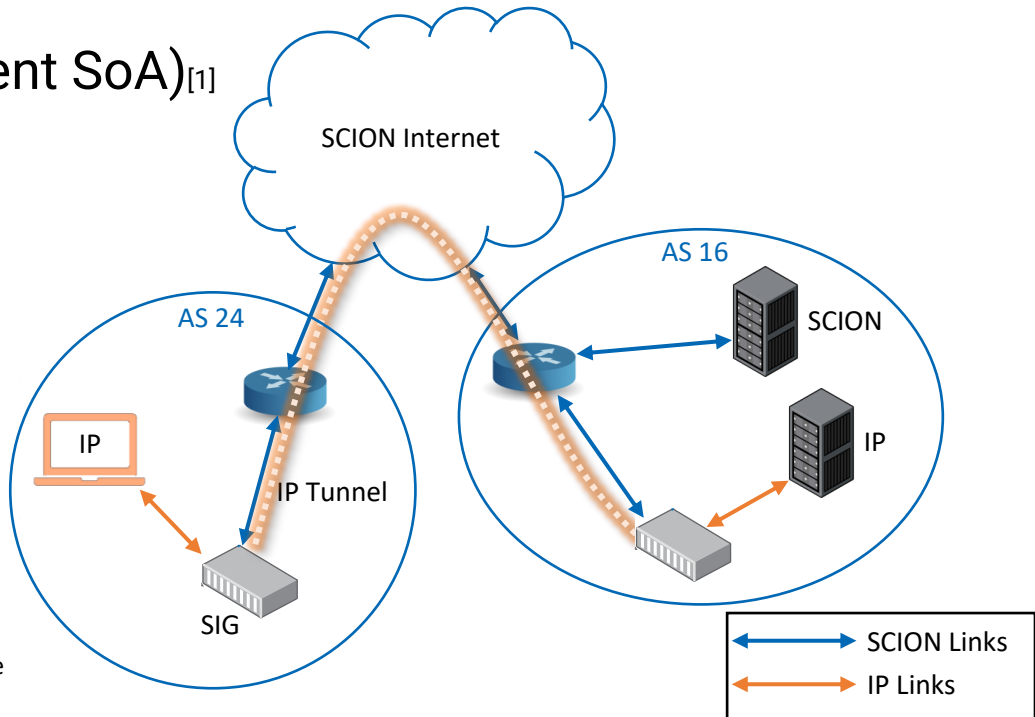
2. Motivation

- SCION solves many issues of today's Internet
- How can legacy IP applications use the SCION network?



2. Motivation

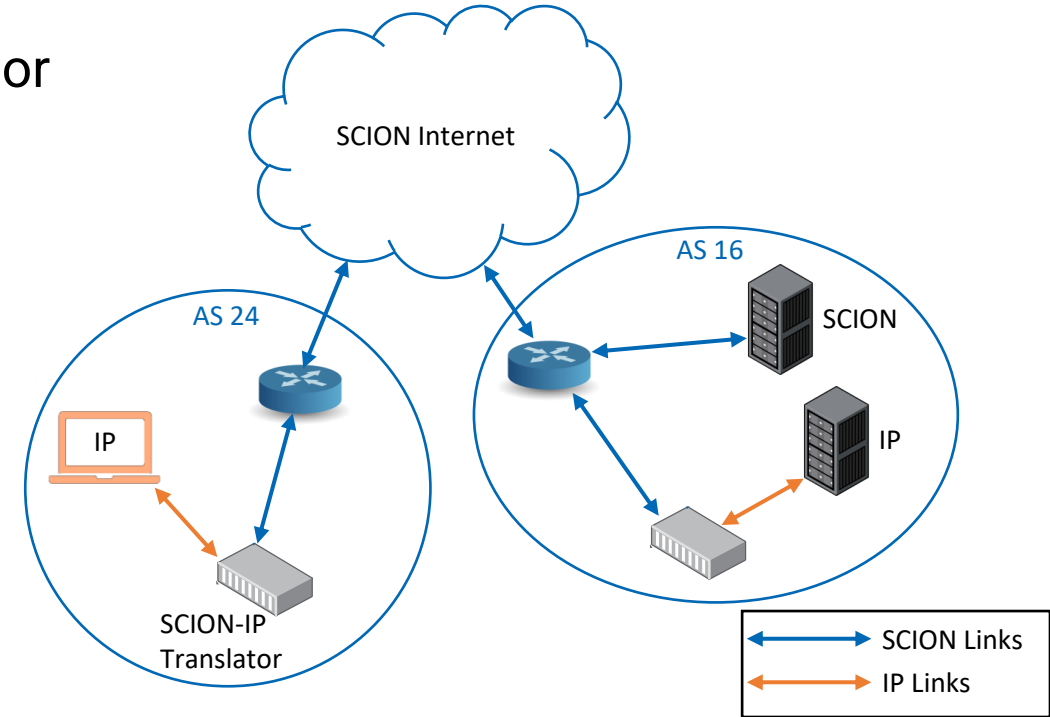
- SCION solves many issues of today's Internet
- How can legacy IP applications use the SCION network?
  - Use SCION-IP-Gateway (SIG) (Current SoA)[1]
  - Tunnels IP over SCION
  - Complex encapsulation
  - Have to exchange IP routes with each other
  - No communication between SCION and IP apps



[1] L. Chuat, M. Legner, D. Basin, D. Hausheer, S. Hitz, P. Müller, and A. Perrig, The Complete Guide to SCION. Springer, 2022

2. Motivation

- SCION solves many issues of today's Internet
- How can legacy IP applications use the SCION network?
  - We propose the SCION IP Translator
  - Allows IP applications to use the SCION network
  - Enables interoperability between SCION and IP implementations of an app
  - No encapsulation overhead



3. Concepts - Translating IP addresses to SCION

- SCION addressing: ISD – AS – Host Address
  Example server: 1 18 fd00::0d93
- Encode SCION addresses in IPv6 (“SCION-mapped IP”)

IPv6:

128-bit IPv6 address					
8 bit	12 bit	20 bit	24 - m bit	m bit	64 bit
global routing prefix				subnet ID	interface ID
SCION prefix	ISD	ASN	local routing prefix	subnet ID	interface ID

IPv4:

128-bit IPv6 address					
8 bit	12 bit	20 bit	24 bit	32 bit	32 bit
global routing prefix				interface ID	
SCION prefix	ISD	ASN	0	0x0000ffff	IPv4 address

3. Concepts - Translating IP addresses to SCION

- SCION addressing: ISD – AS – Host Address
  Example server: 1 18 fd00::0d93
- Encode SCION addresses in IPv6 (“SCION-mapped IP”)
  fc
  - 8 Bit global SCION prefix

IPv6:

128-bit IPv6 address					
8 bit	12 bit	20 bit	24 - m bit	m bit	64 bit
	global routing prefix			subnet ID	interface ID
SCION prefix	ISD	ASN	local routing prefix	subnet ID	interface ID

IPv4:

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SCION prefix	ISD	ASN	0	0x0000ffff	IPv4 address

3. Concepts - Translating IP addresses to SCION

- SCION addressing: ISD – AS – Host Address
  Example server: 1 18 fd00::0d93
- Encode SCION addresses in IPv6 (“SCION-mapped IP”)
  fc00:1
  - 12 Bit ISD number because currently assigned from range 64-4094

IPv6:

128-bit IPv6 address					
8 bit	12 bit	20 bit	24 - m bit	m bit	64 bit
	global routing prefix			subnet ID	interface ID
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- SCION addressing: ISD – AS – Host Address
  Example server: 1 18 fd00::0d93
- Encode SCION addresses in IPv6 (“SCION-mapped IP”)
  fc00:1000:18
  - 20 Bit ASN because current BGP allocation from block below 2^19

IPv6:

128-bit IPv6 address					
8 bit	12 bit	20 bit	24 - m bit	m bit	64 bit
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3. Concepts - Translating IP addresses to SCION

- SCION addressing: ISD – AS – Host Address
  Example server: 1 18 fd00::0d93
- Encode SCION addresses in IPv6 (“SCION-mapped IP”)
  fc00:1000:18xx:xxxx::0d93
  - 64 Bit Interface ID for simple host address assignment

IPv6:

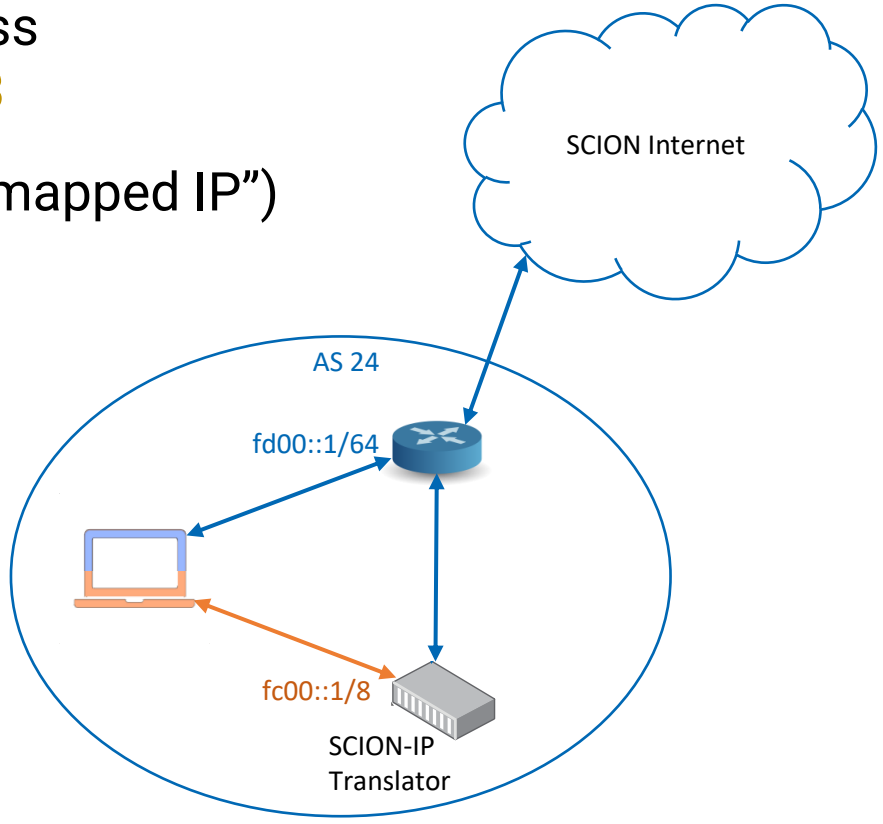
128-bit IPv6 address					
8 bit	12 bit	20 bit	24 - m bit	m bit	64 bit
global routing prefix				subnet ID	interface ID
SCION prefix	ISD	ASN	local routing prefix	subnet ID	interface ID

IPv4:

128-bit IPv6 address					
8 bit	12 bit	20 bit	24 bit	32 bit	32 bit
global routing prefix				interface ID	
SCION prefix	ISD	ASN	0	0x0000ffff	IPv4 address

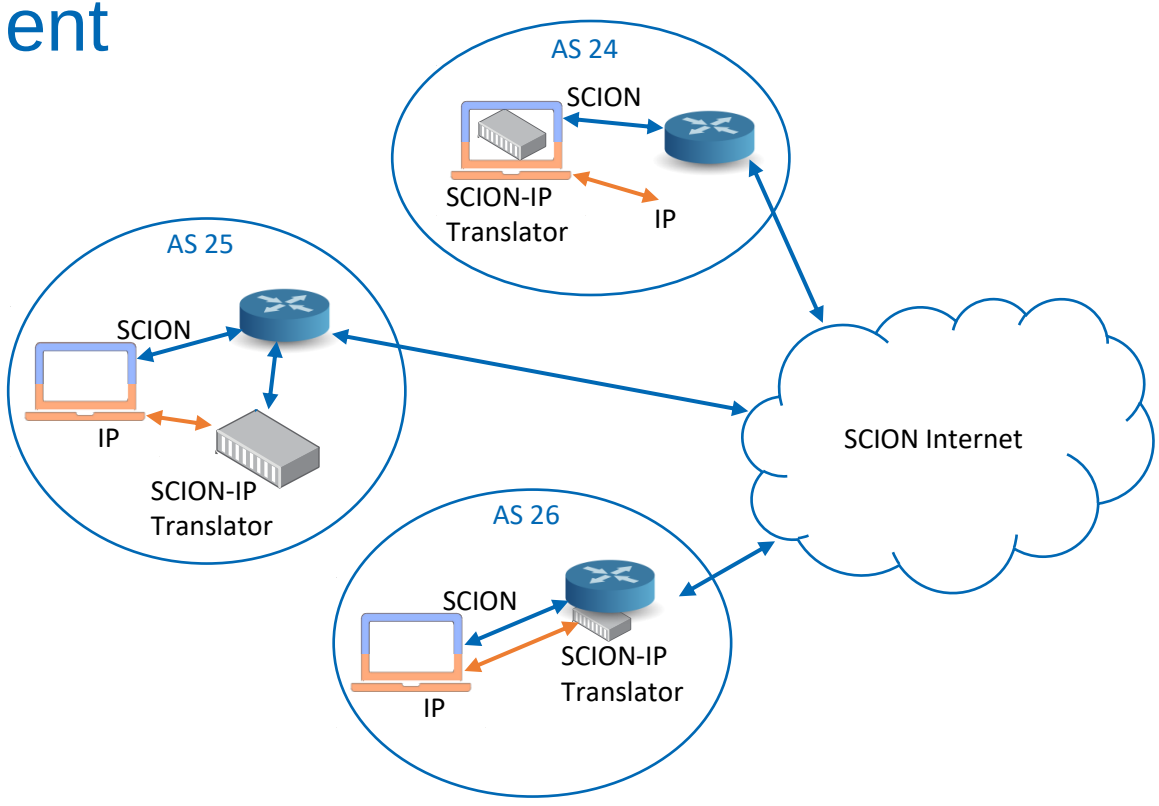
3. Concepts - Translating IP addresses to SCION

- SCION addressing: ISD – AS – Host Address
  Example server: 1 18 fd00::0d93
- Encode SCION addresses in IPv6 (“SCION-mapped IP”)
  fc00:1000:18xx:xxxx::0d93
- All hosts need a SCION-mapped IP additionally to its existing IPv6
  - Legacy SCION traffic to fd00::1
  - IP traffic to SCION mapped IPv6
    fc00:1000:18xx:xxxx::0d93



3. Concepts - Deployment

- At the host
  - Kernel (eBPF)
  - User Space
  - NIC
- At the Local Gateway Router
- At the Border Router/As Network Service (P4 switch)



3. Concepts - Deployment

- At the host
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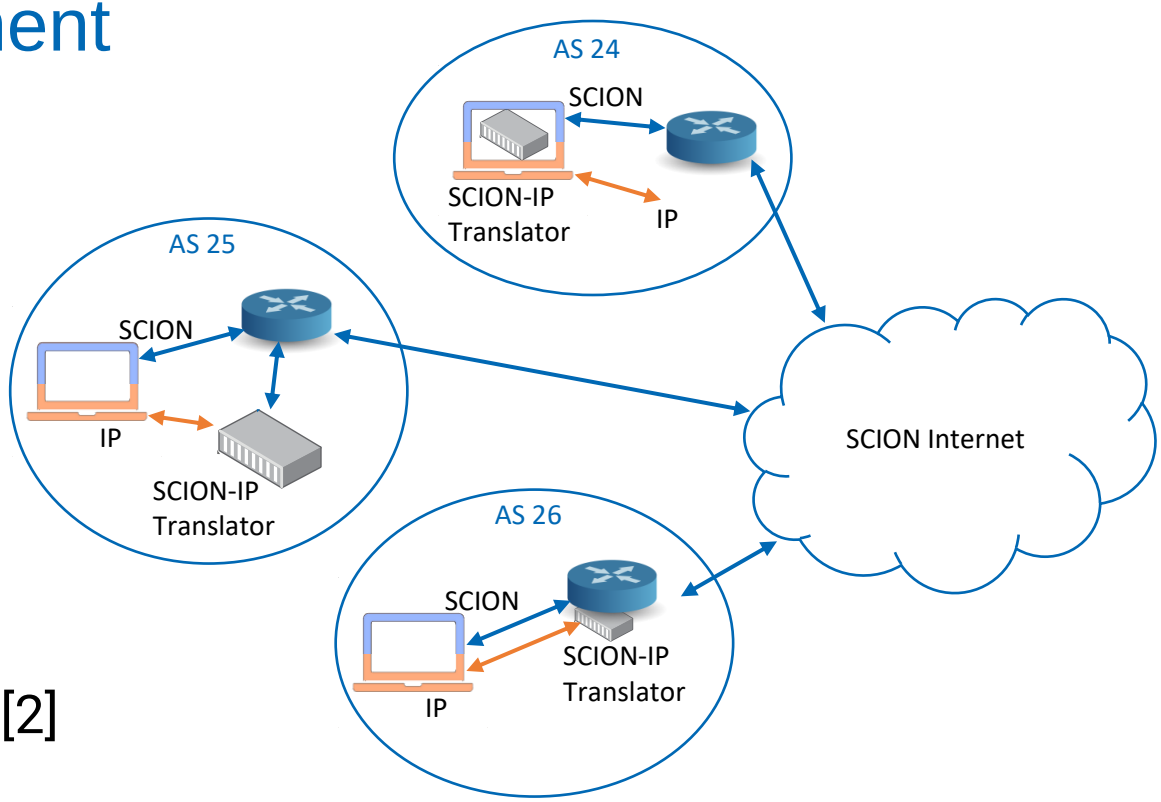
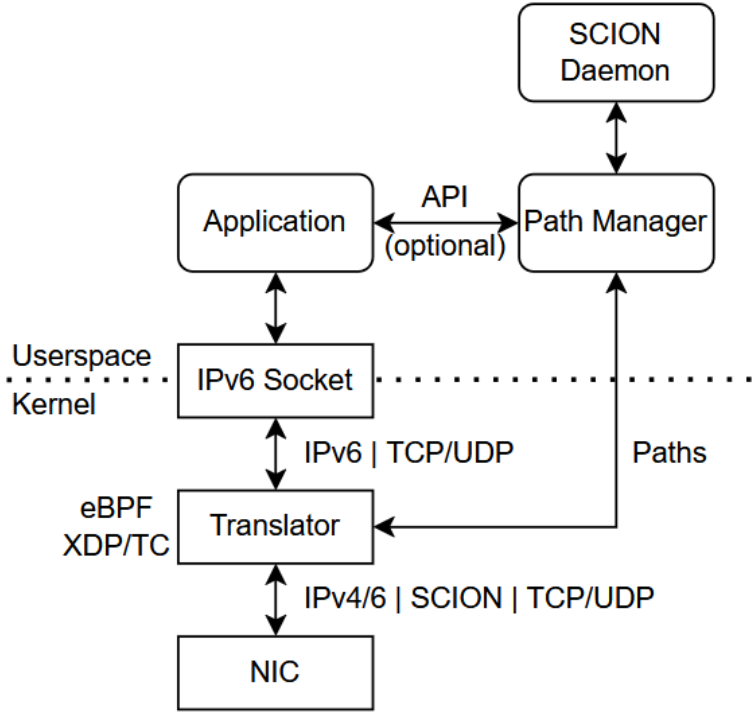


[1] Schulz, et al.: **Unlocking Path Awareness for Legacy Applications through SCION-IP Translation in eBPF.** *SIGCOMM eBPF Workshop 2024.*

[2] Schulz et al.: **Scion Edge Router for Legacy IP Applications based on Intel Tofino.** *ICNP EuroP4 Workshop 2024.*

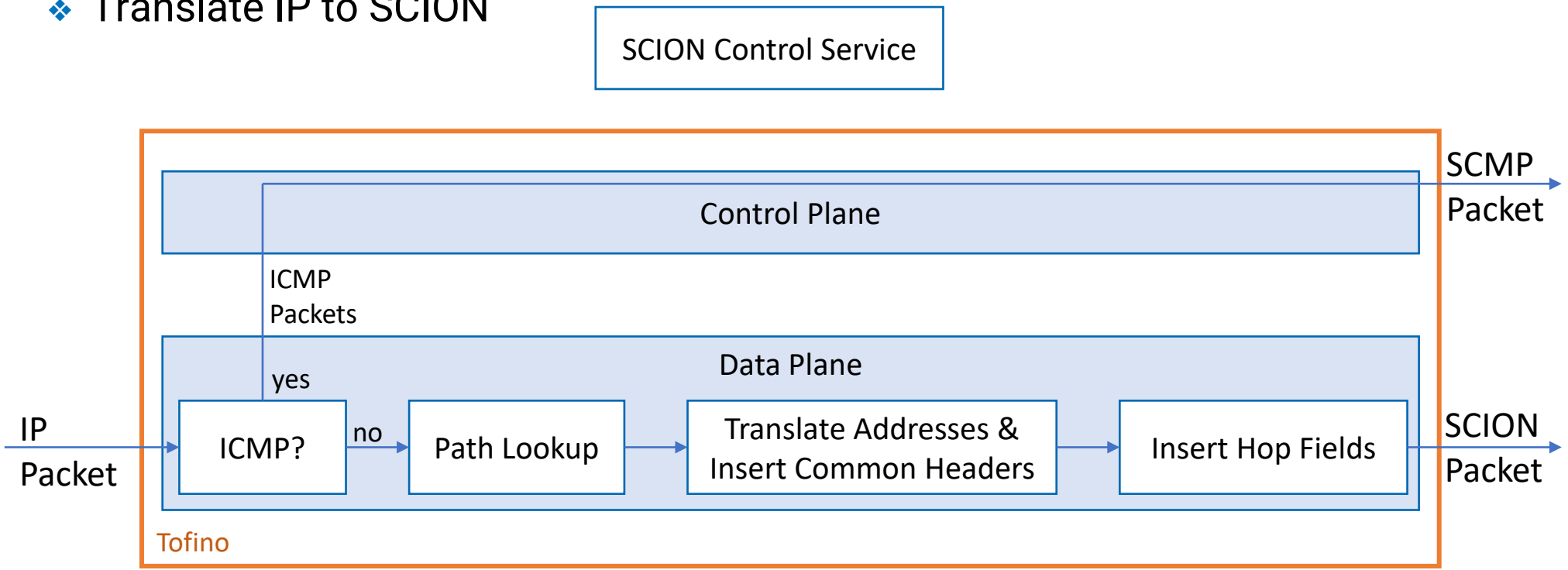
4. Implementation – eBPF for XDP/TC

- Linux: Kernel module
- Windows: Packet interception driver (Not implemented yet)
- Control Plane in user space (path manager daemon/service)



4. Implementation – Tofino

- P4 implementation targeting Tofino 1 & Tofino 2
- Translate IP to SCION



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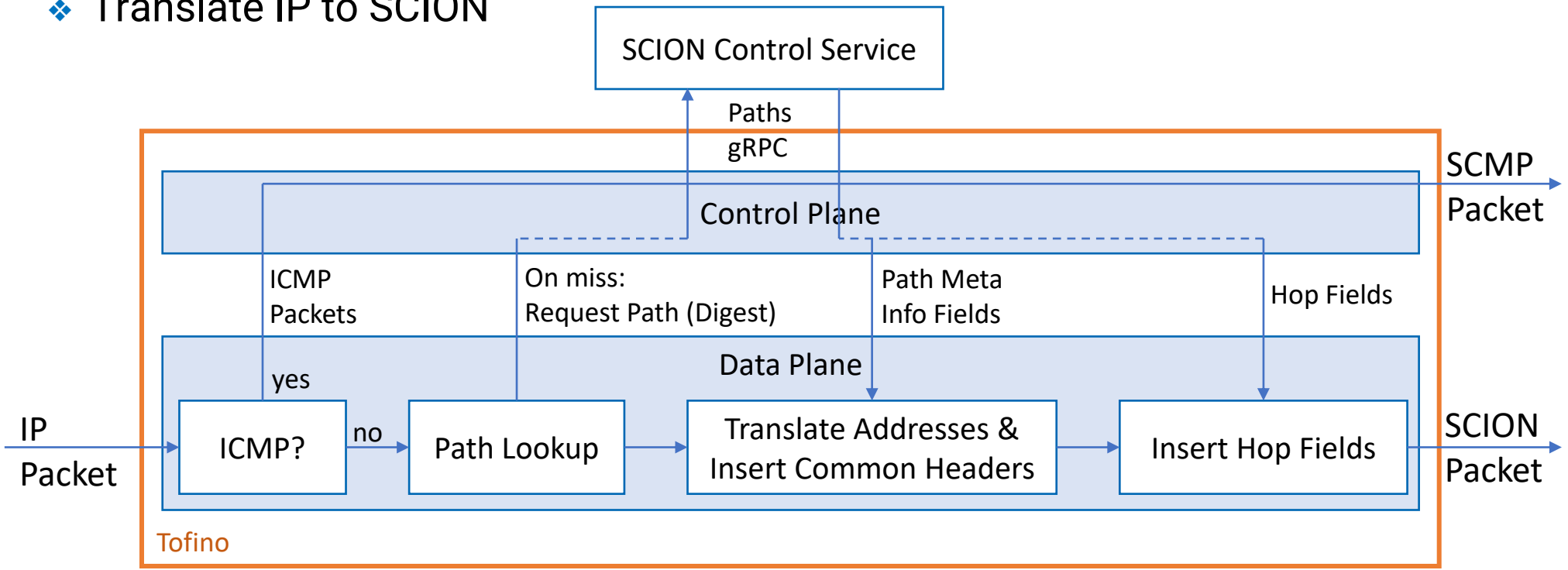
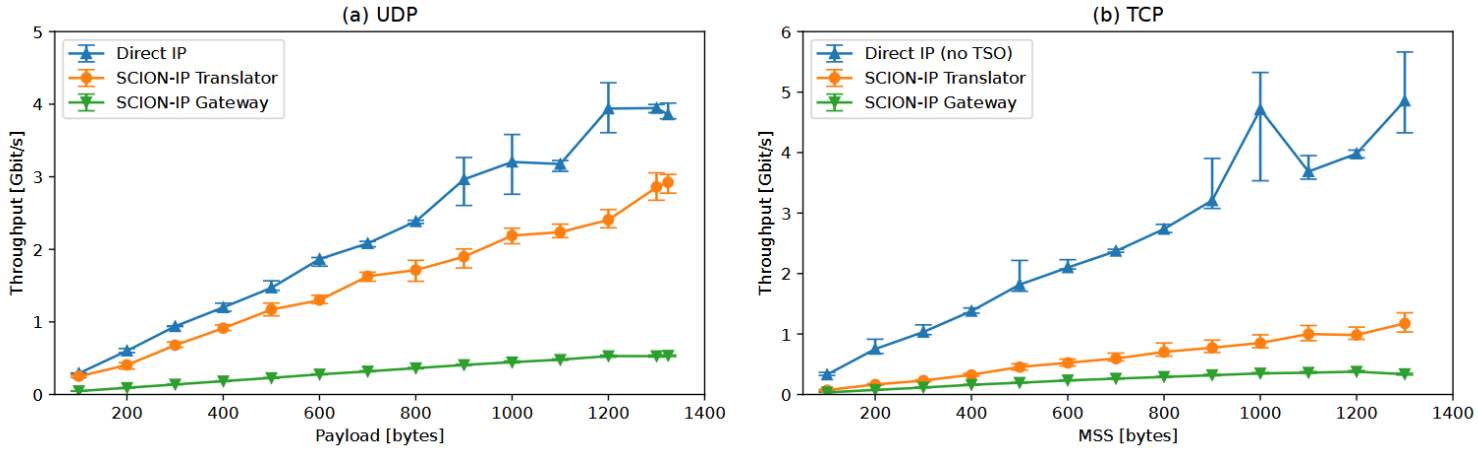


5. Evaluation

Throughput

- For eBPF (Server with AMD EPYC CPU (32 core) and Mellanox ConnectX-5 100GbE, traffic generated with iperf3 on 100 Gbit/s links):



- For Tofino: 400 Gbit/s (i.e. regular line rate performance)

5. Evaluation

Resource Consumption in Tofino

Translation Direction	Performance Criteria	Switch Generation	
		Tofino 1	Tofino 2
IP → SCION	Max. insertable hop fields per pass[1]	16	24
SCION → IP	Required recirculations for MAC validation	5	2

[1]Only restricted by PHV registers, as every inserted hop field requires 12 byte

6. Conclusion and Future Work

The SCION-IP translator…

- Enables legacy IP applications over SCION
- Allows interconnection between IP and SCION implementations of an application
- Is easier to implement than the SIG (or rewriting applications to SCION)
- Is implemented in eBPF (user path choice) & Tofino (higher performance)

We plan to…

- Improve path selection for Tofino to meet specific applications requirements
- Implement the other translator concepts as well

Thanks for your attention!

Papers: [1] Schulz, L.C., Gallrein, F., Hausheer, D.: **Unlocking Path Awareness for Legacy Applications through SCION-IP Translation in eBPF.** In: *Proceedings of the ACM SIGCOMM 2024 Workshop on EBPF and Kernel Extensions*. p. 68–70. eBPF '24 (2024) https://doi.org/10.1145/3672197.3673437

[2] Schulz, L.C., Wehner, R., Hausheer, D.: **Scion Edge Router for Legacy IP Applications based on Intel Tofino.** In: *7th European P4 Workshop (EuroP4'24)* (2024) https://ieeexplore.ieee.org/document/10858525

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