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Communication Networks

P4-LISP: A P4-Based High-Performance Router for the Locator/Identifier Separation Protocol

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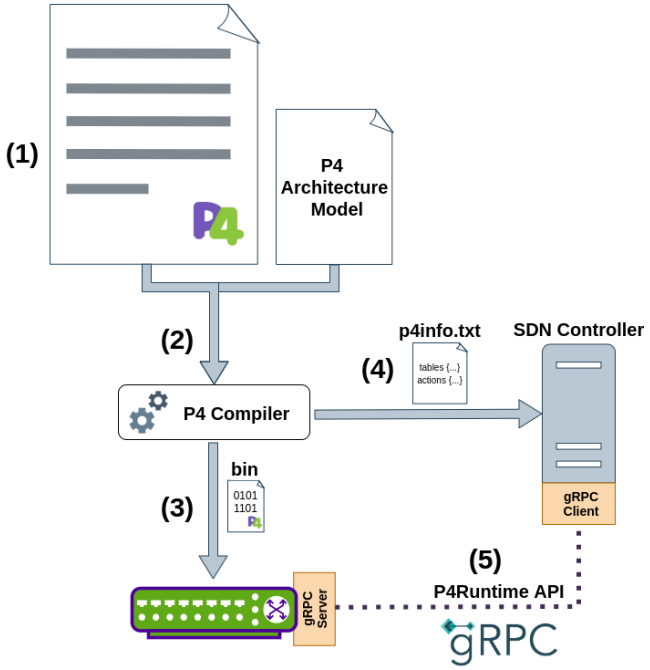
http://kn.inf.uni-tuebingen.de

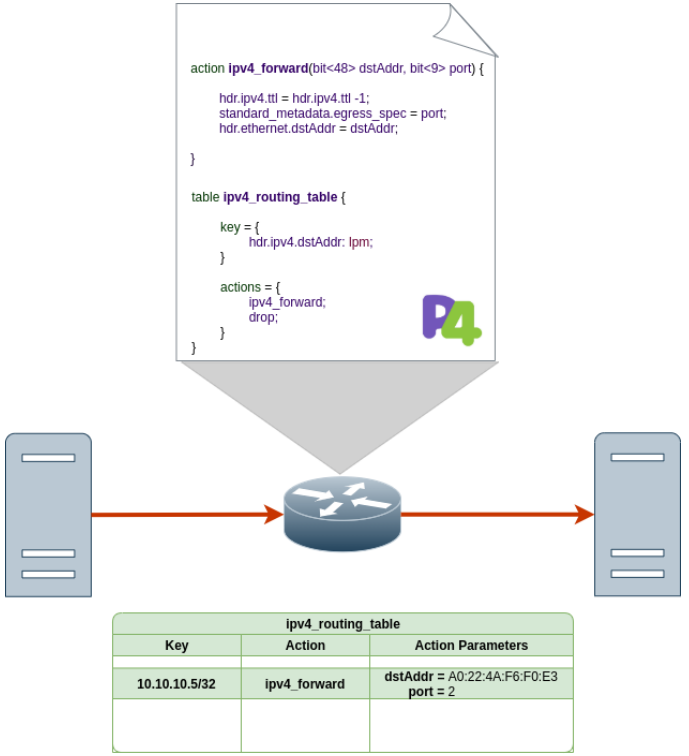
Outline

- What is P4?
- P4-LISP router architecture & components
  - LISP control plane lispers.net
  - Local P4 controller
  - P4 data plane
- P4-LISP evaluations

Data Plane Programming with P4

- P4 = Programming Protocol-independent Packet Processors
- Programmable header processing
- Deployable on high-performance hardware
- More: see P4 survey [2]

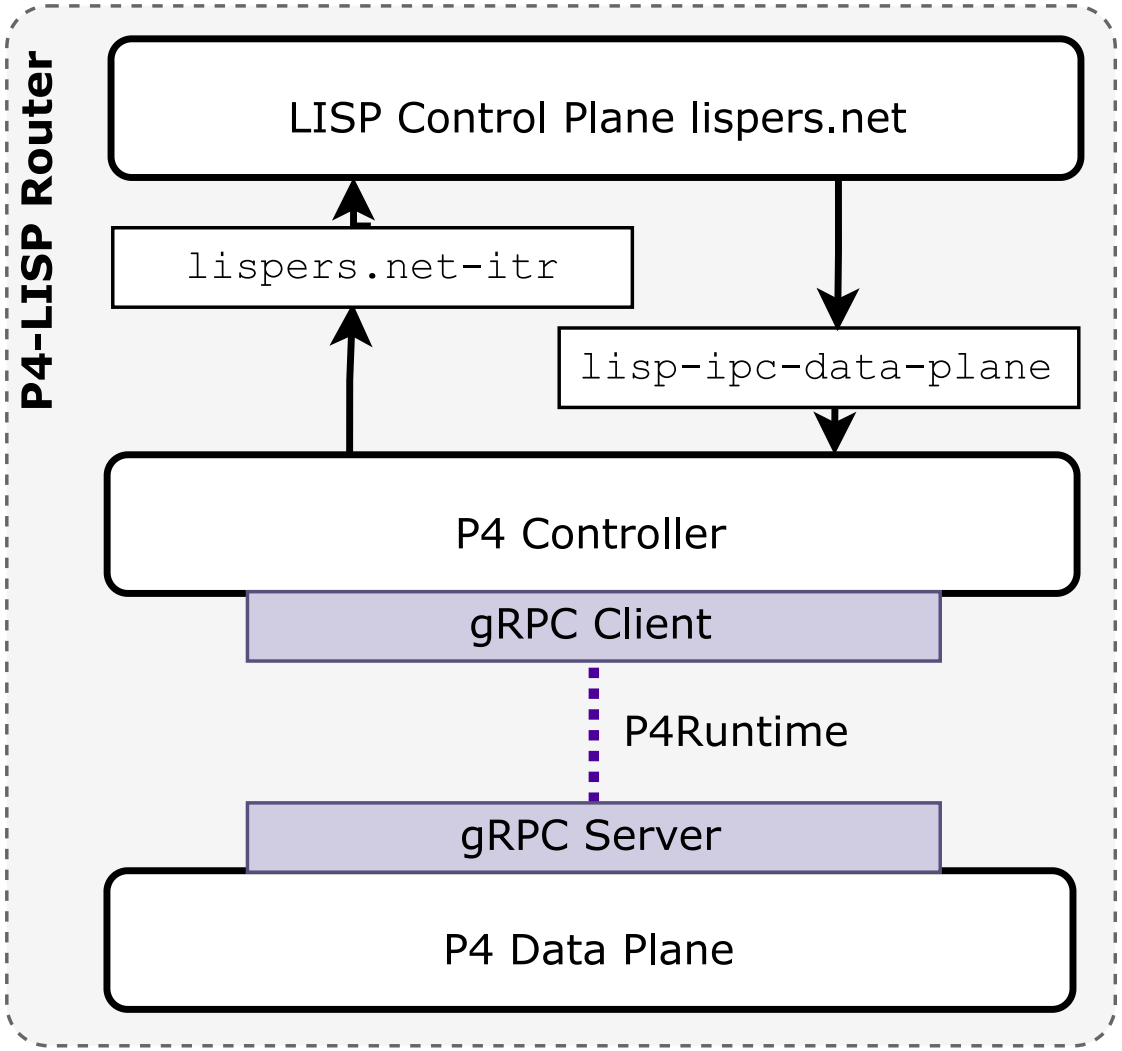




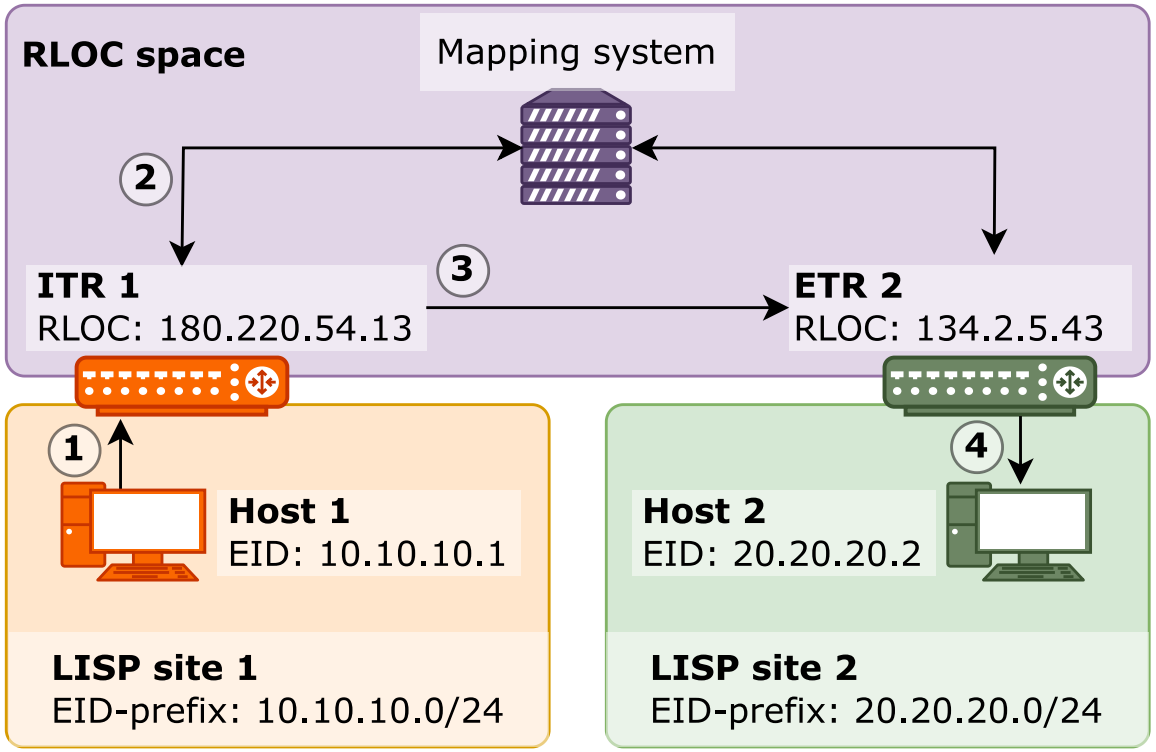
[2] F. Hauser et al., “A Survey on Data Plane Programming with P4: Fundamentals, Advances, and Applied Research,” Journal of Network and Computer Applications, vol. 212, 2023.

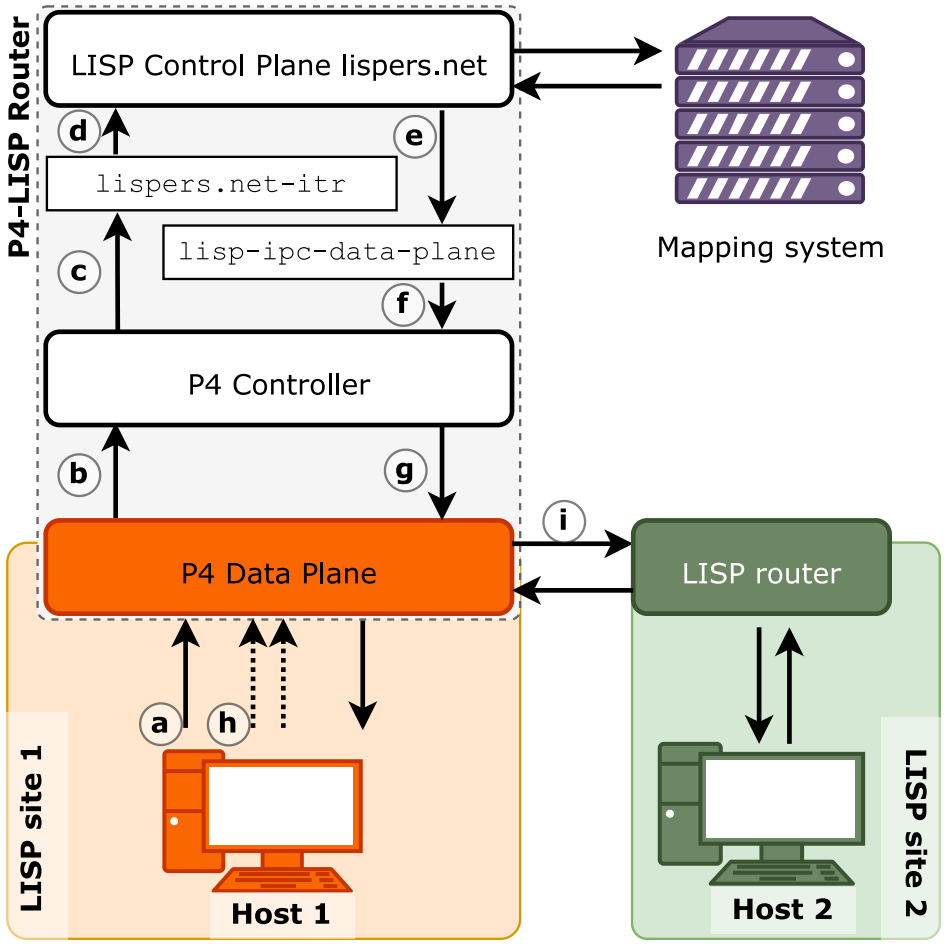
P4-LISP Router Architecture

- Forward packets to P4 controller where no table-entries / mappings are available
- (P)xTR: encapsulate, decapsulate
- RTR: re-encapsulate
- NAT-Traversal and LISP-NAT
- Mobile Node support: double encapsulation
- Security measures
  - Rate-limit packets to P4 controller to 1pps, to not overload the P4 controller
  - Process packets originating only from registered source EIDs
  - Process packets destined only to valid destination EIDs

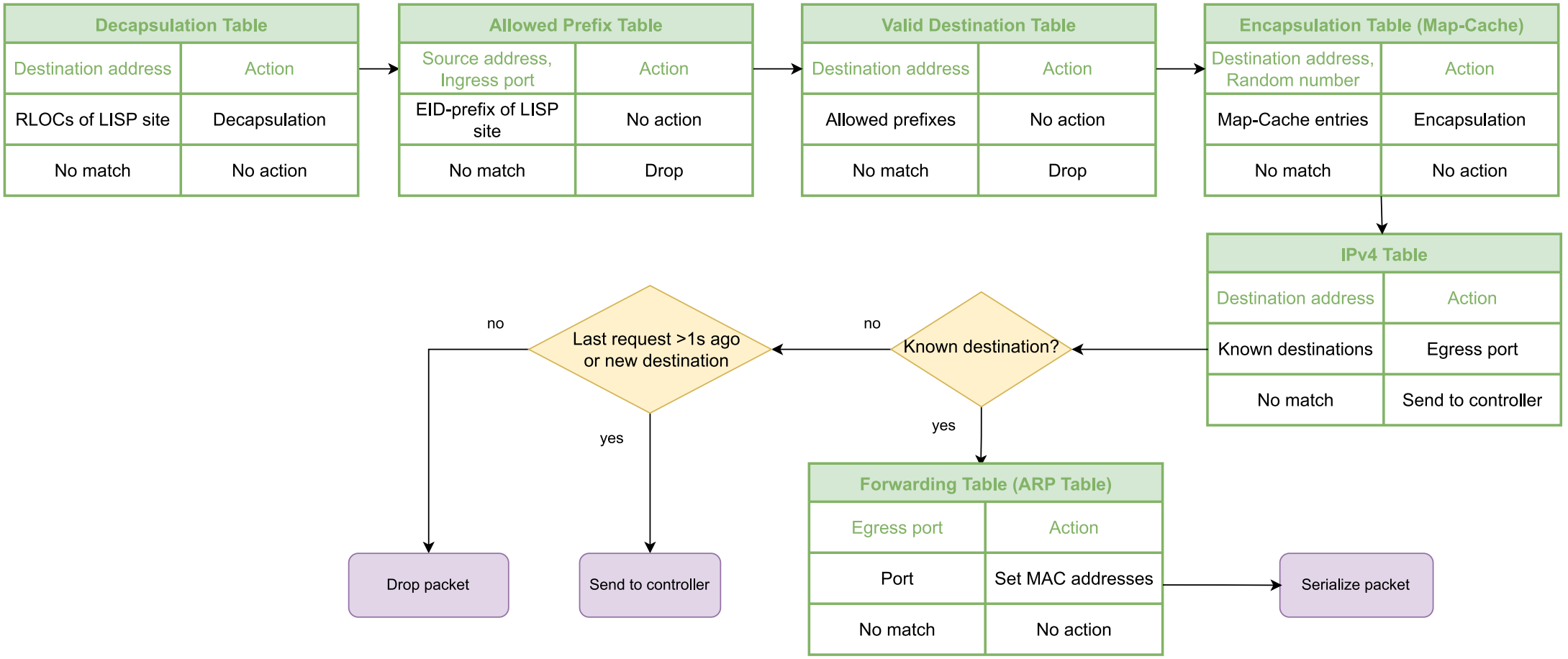


P4-LISP – Example Packet Flow

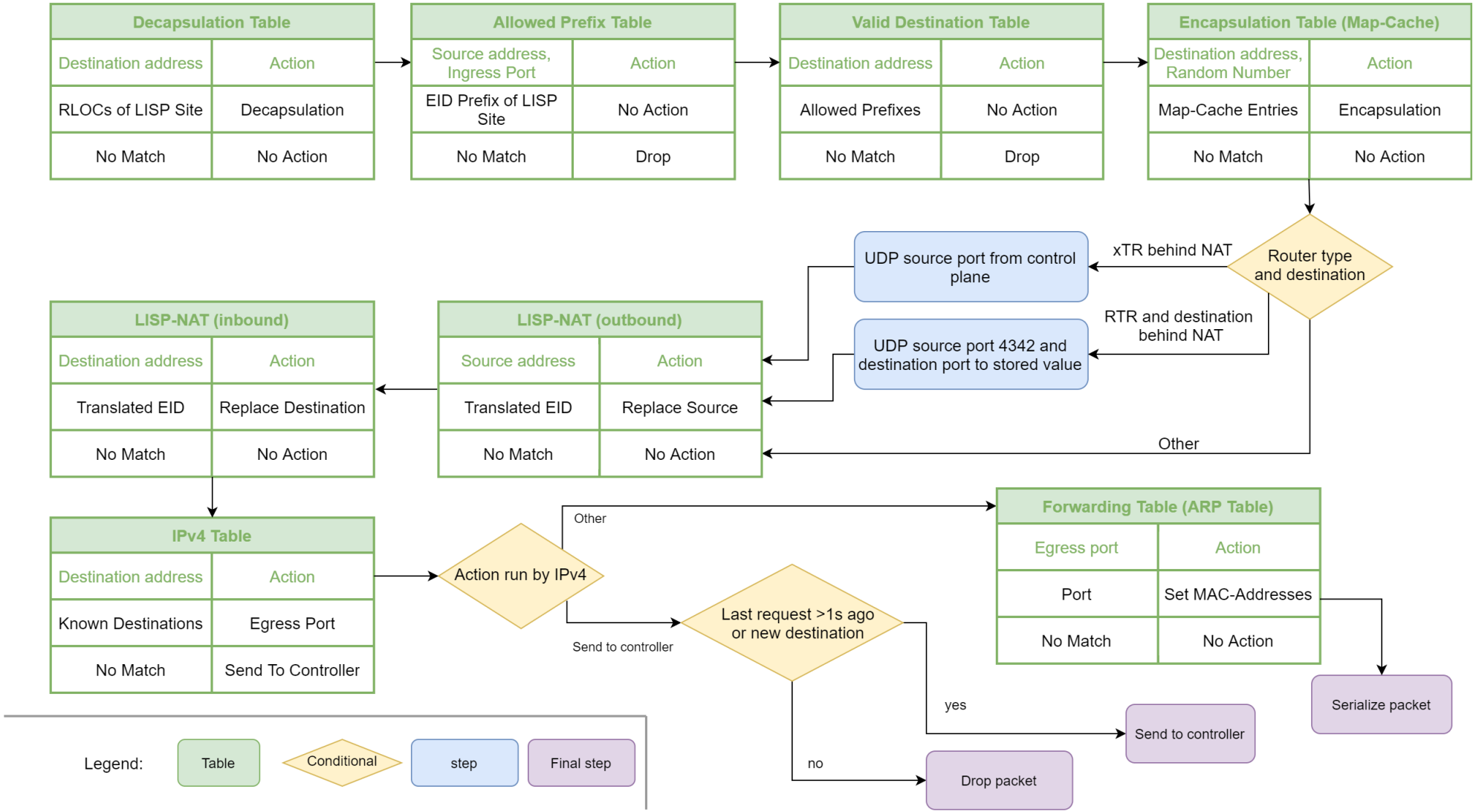




P4 Data Plane – Simplified xTR MAT Flowchart



P4 Data Plane – Simplified MAT Flowchart

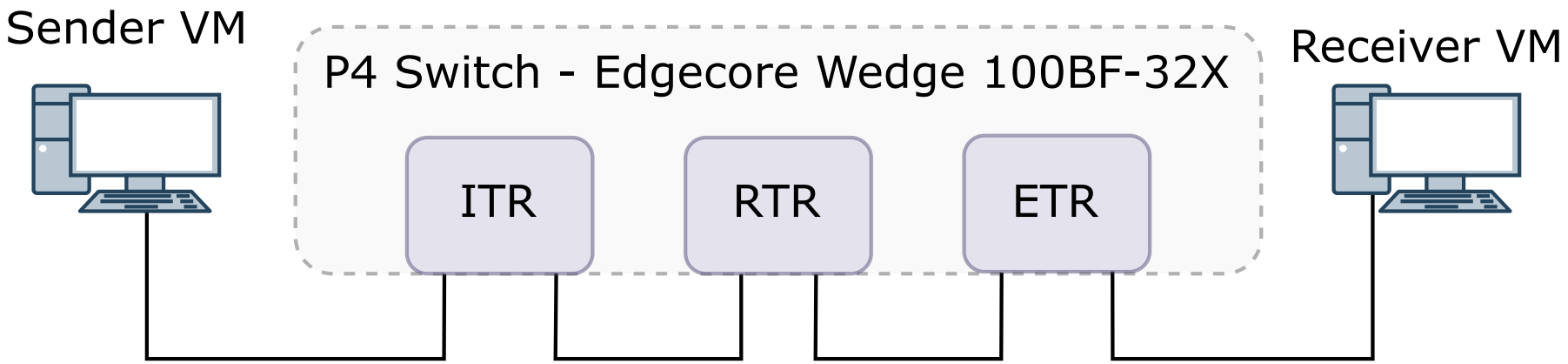


Evaluations

- Bandwidth evaluation
- Functional unit tests
- Latency analysis
- P4 controller performance

Data Rate Evaluation

- Data rate evaluation with re-encapsulation performs with around 100 Gbit/s
- Evaluations using P4TG [3]



[3] S Lindner, M. Häberle, and M. Menth, “P4TG: 1Tb/s Traffic Generation for Ethernet/IP Networks”, IEEE Access, 2023.

Functional Unit Tests

- Different scenarios were tested (xTR, PxTR, RTR)

- Many extensions are supported
  - NAT traversal
  - Mobile Node
  - LISP-NAT
  - …

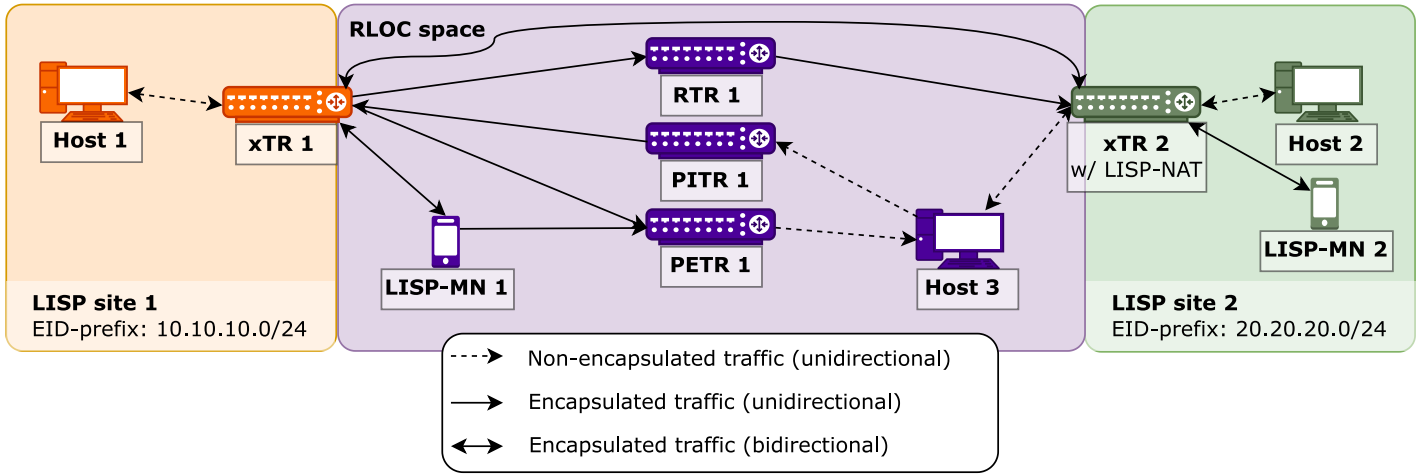


TABLE I
UNIT TESTS FOR DIFFERENT LISP ROUTER TYPES.

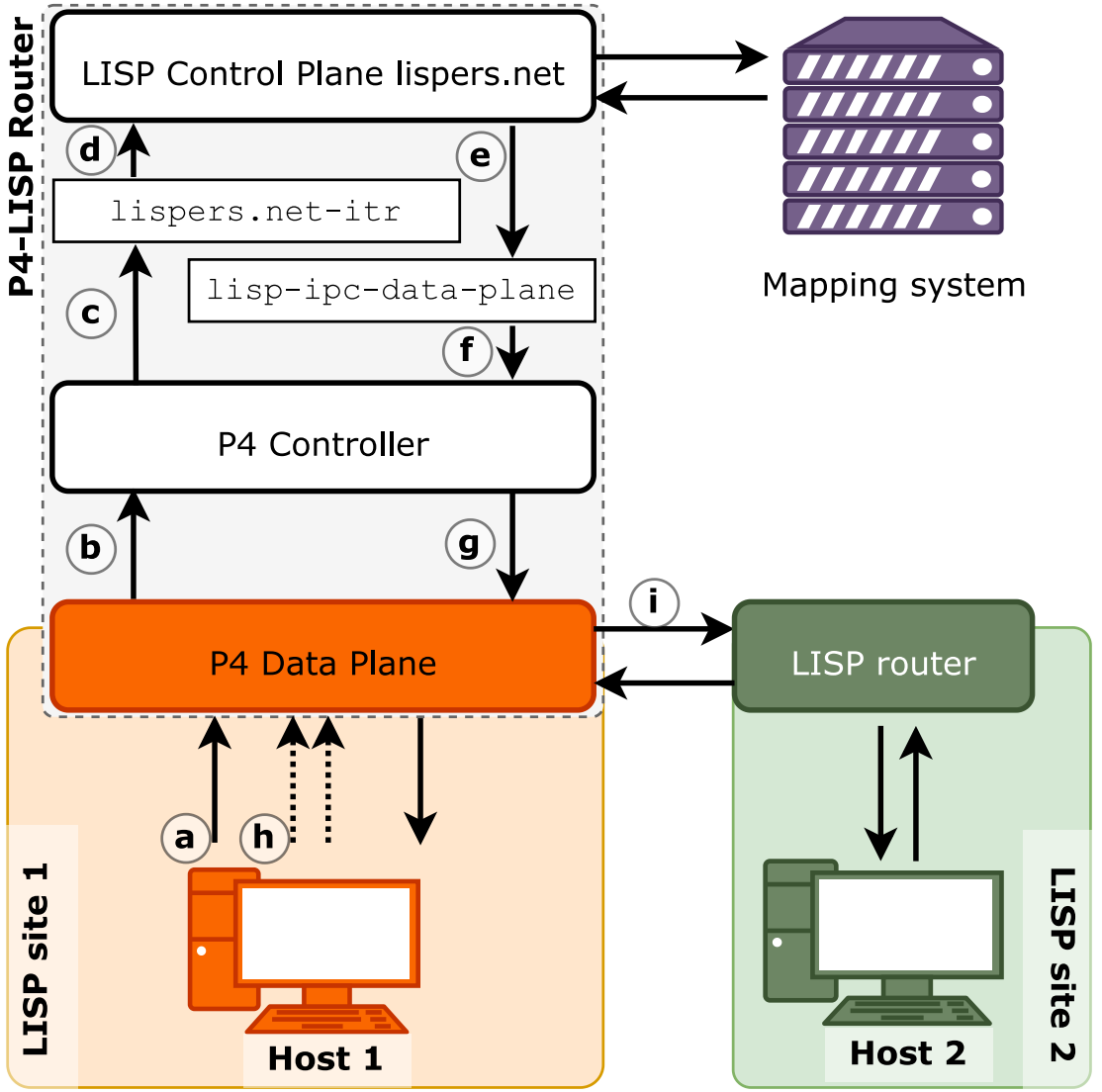
Router	No.	Test description
xTR	1	Packet encapsulation
	2	Packet decapsulation
	3	Load balance to multiple ETRs
	4	Drop packet with invalid source address
	5	Drop packet towards disallowed destination
	6	NAT traversal
	7	LISP-MN to lisp node
	8	LISP-MN to non-LISP endpoint
	9	LISP-MN to LISP-MN (EID)
	10	LISP-MN to LISP-MN (RLOC)
	11	Node to LISP-MN in other LISP domain
	12	LISP-MN receives packet
	13	Native Forwarding without encapsulation
	14	LISP-NAT outbound traffic
	15	LISP-NAT inbound traffic
PITR	16	Encapsulate for non-LISP host
	17	Encapsulate from LISP-MN (RLOC)
	18	Encapsulate from non-LISP host to LISP-MN (EID)
	19	Drop packet with invalid source outside
PETR	20	Decapsulate packet with one encapsulation
	21	Decapsulate packet with two encapsulations
	22	Drop encapsulated packet with non-registered source address
	23	Drop twice encapsulated packet with non-registered source address
RTR	24	Send packet towards node behind NAT
	25	Send packet towards LISP-MN behind NAT
	26	Receive packet from node behind NAT for encapsulation
	27	Receive packet from node behind NAT for encapsulation to LISP-MN
	28	Receive packet from node behind NAT to forward without encapsulation
	29	Drop packet if neither source nor destination is known

Latency Analysis

- How large is the latency introduced by different components in P4-LISP?

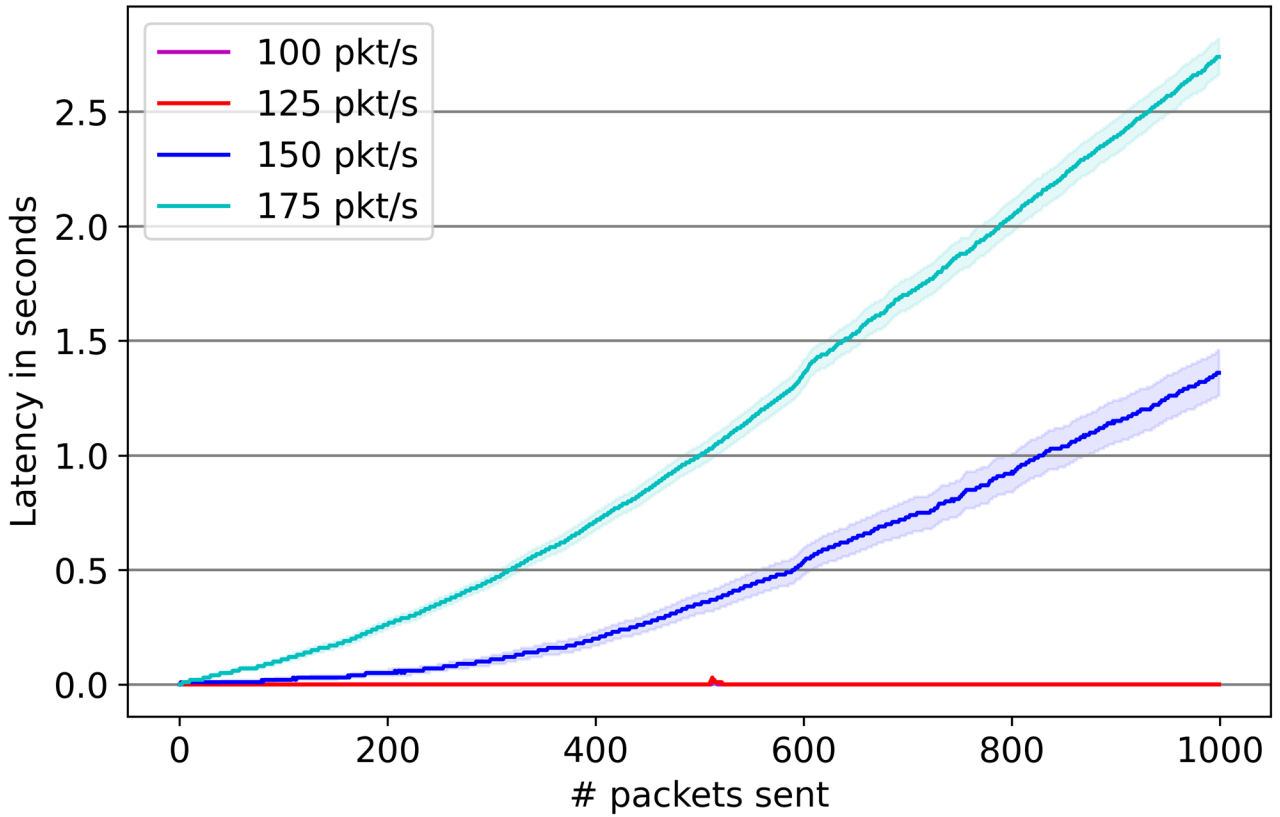
TABLE II
MEAN AND STANDARD DEVIATION (SD) OF THE LATENCY CAUSED BY A CACHE-MISS IN THE P4-LISP DATA PLANE.

Steps	Mean (ms)	SD (ms)	Description of the steps
a-i	19.74	0.81	Worst-case latency: First packet sent by source until received by destination.
a-c	4.45	0.16	P4 controller delay for issuing discovery message.
d-e	12.61	0.72	Control plane delay.
f	0.80	0.10	P4 controller delay for processing control plane answer.
g-i	1.78	0.20	P4 controller delay for inserting table entry, until packet reaches destination.



P4 Controller Performance

- Send 1000 packets with different destination IP addresses where no mapping is available
  - Using *nping* [4]
  - All of these packets are forwarded to the local P4 controller
  - Different packet rates are examined
- Overload at ~150 pps
  - Latency rises
  - No packet drops observed



[4] https://nmap.org/nping/

Conclusion

- P4-LISP is a high-performance LISP router implementation for data rates ~100 Gb/s
  - Open-source: https://github.com/uni-tue-kn/P4-LISP
  - Leverages open-source control plane lispers.net
  - All LISP tunnel router types are implemented in a single P4 program (ITR, ETR, PITR, PETR, RTR)
  - RTR can perform re-encapsulation at line rate
  - Double encapsulation also at line rate, e.g., for LISP-MN
  - Some security features against DoS attacks

- Supports multiple extensions
  - LISP Mobile Node
  - NAT-Traversal
  - Interworking mechanisms (e.g., LISP-NAT)
  - Multihoming, load-balancing, and traffic engineering