Secure and Scalable QoS for Critical Applications

Marc Wyss, Giacomo Giuliari, Markus Legner, and Adrian Perrig

ETH zürich

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Objective

Communication guarantees for **Critical-yet-Frugal (CyF) applications**:

- Critical: requires high availability
- Frugal: low traffic volumes

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Current solutions

Leased lines
+ Strong QoS guarantees
- High cost
- Low redundancy
- Does not scale

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Bandwidth reservations over the Internet
+ Low cost
- Does not scale (e.g., IntServ)
- No bandwidth guarantees (e.g., DiffServ)
- Centralized (e.g., SDN)
- Not secure (almost all existing protocols)
- Limited deployment

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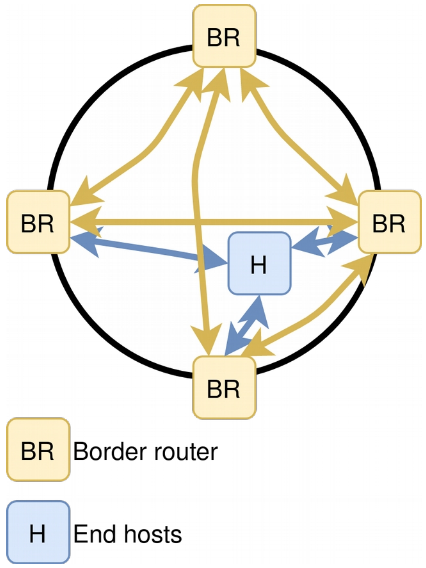
Our contribution: GLWP

Network model

- Internet consists of autonomous systems (ASes)



Network model

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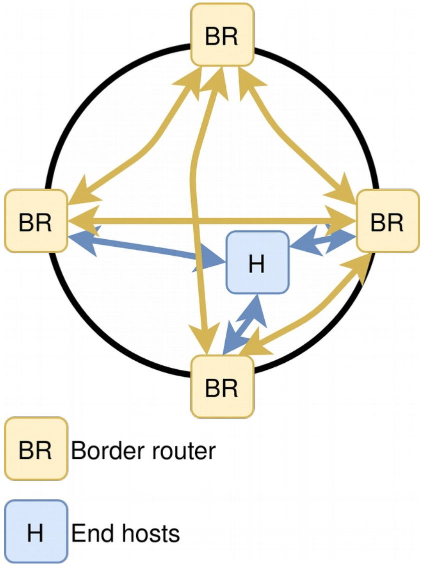
- Every AS has a local secret key known by all its services and border routers



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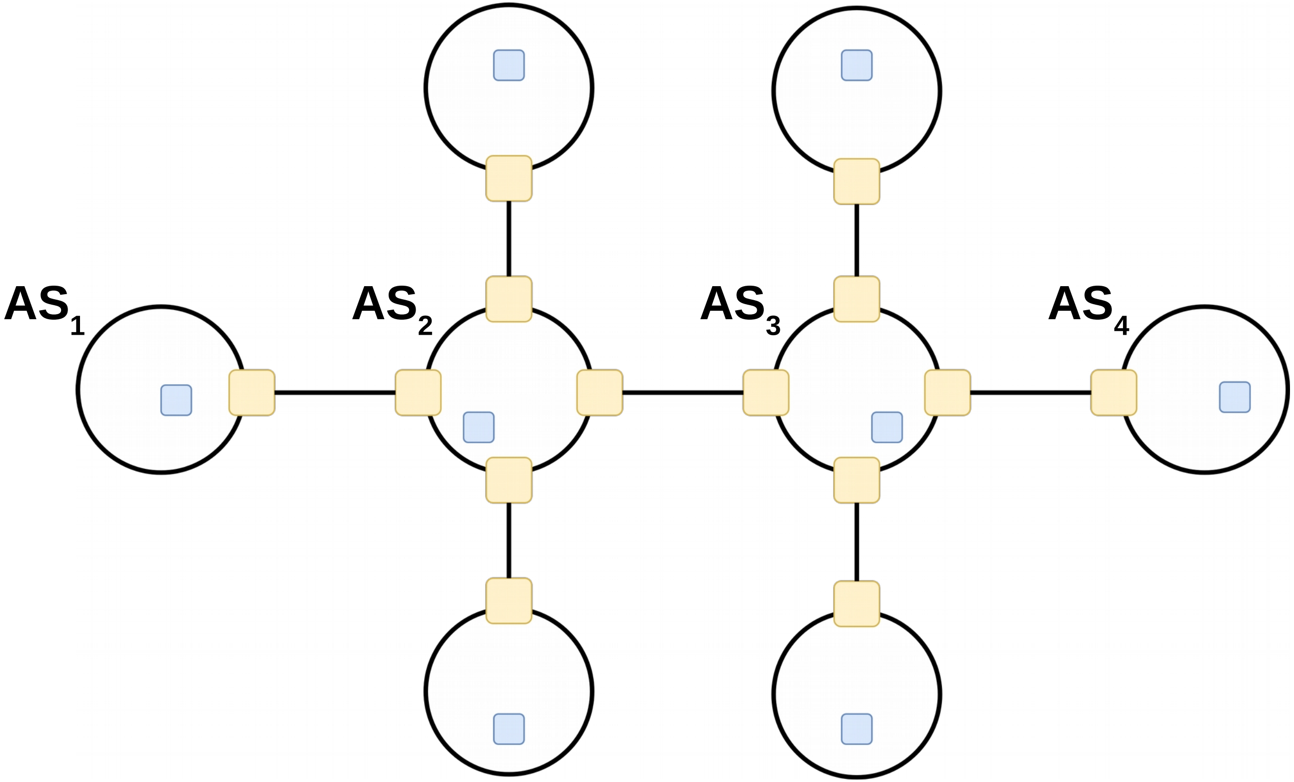
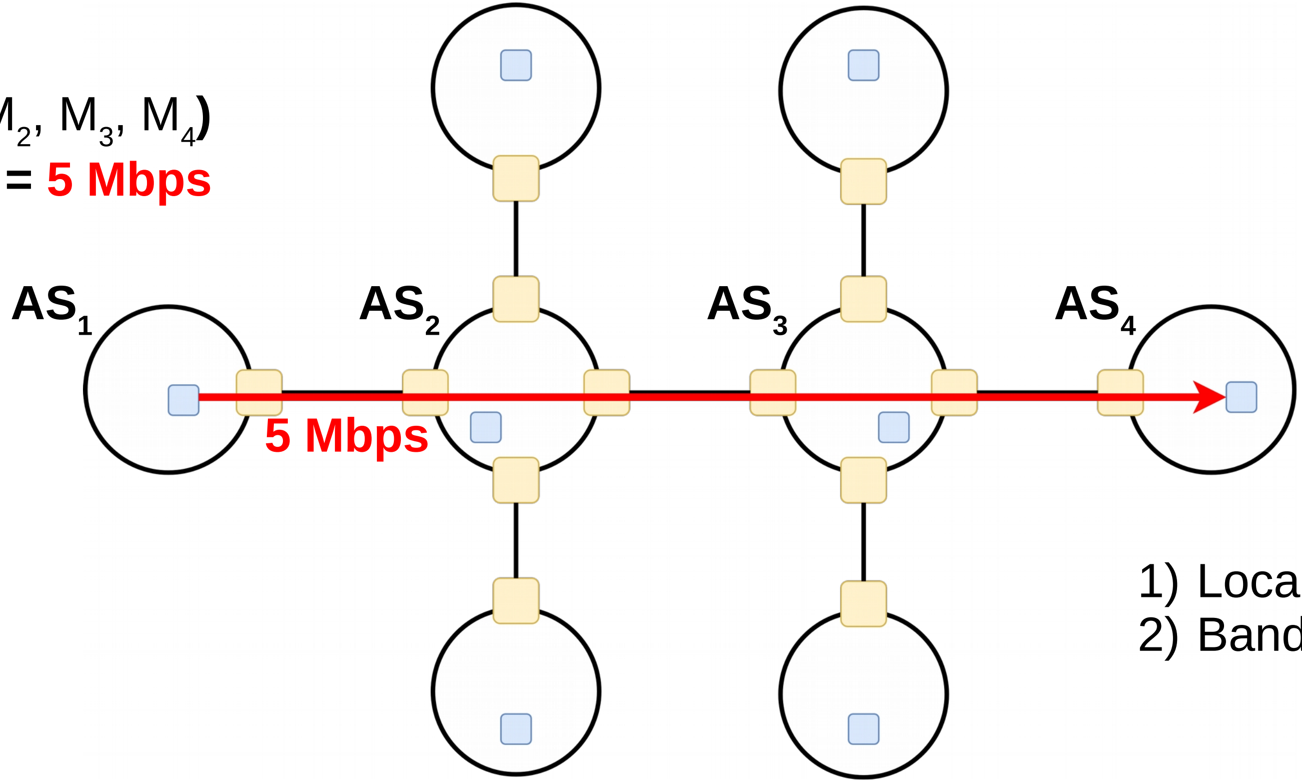
- Path stability (e.g., using SCION)

Calculating allocations: GMA



Calculating allocations: GMA

GMA(M_1, M_2, M_3, M_4) **= 5 Mbps**



1) Locality
2) Bandwidth > 0

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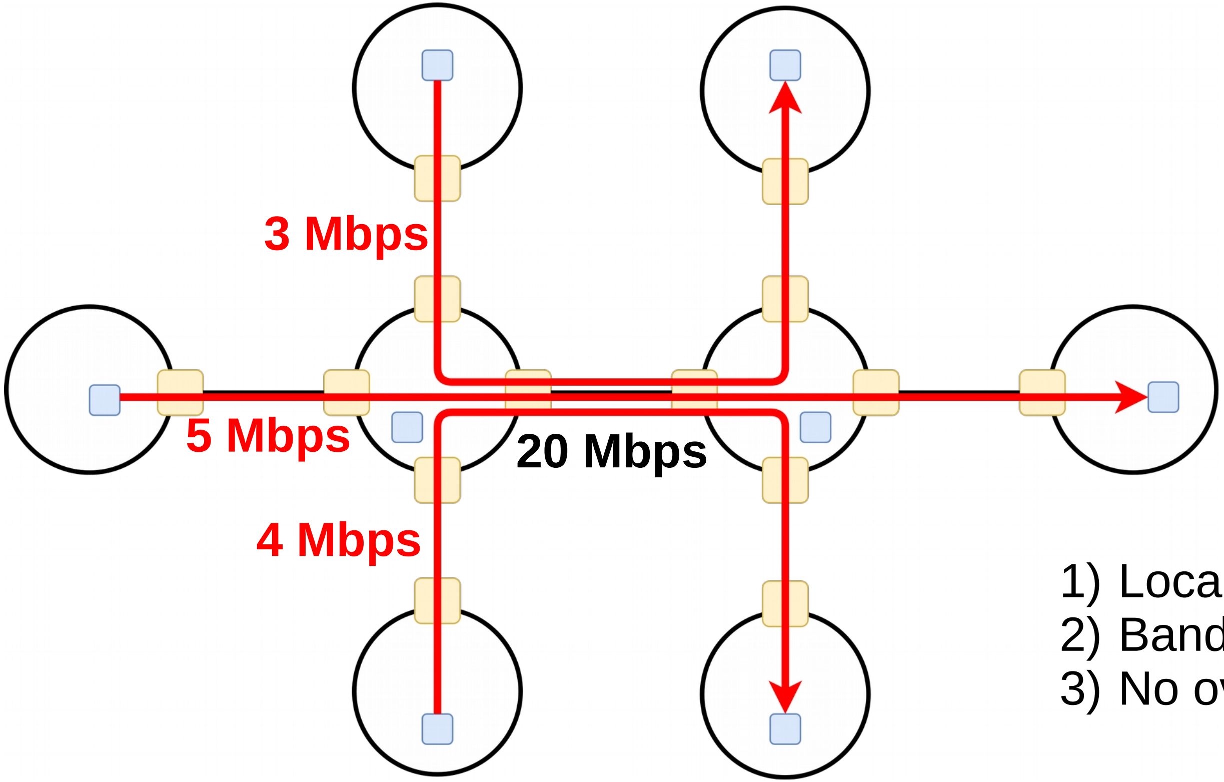


1) Locality
2) Bandwidth > 0
3) No over-allocation

GLWP

“GMA-based light-weight communication protocol”

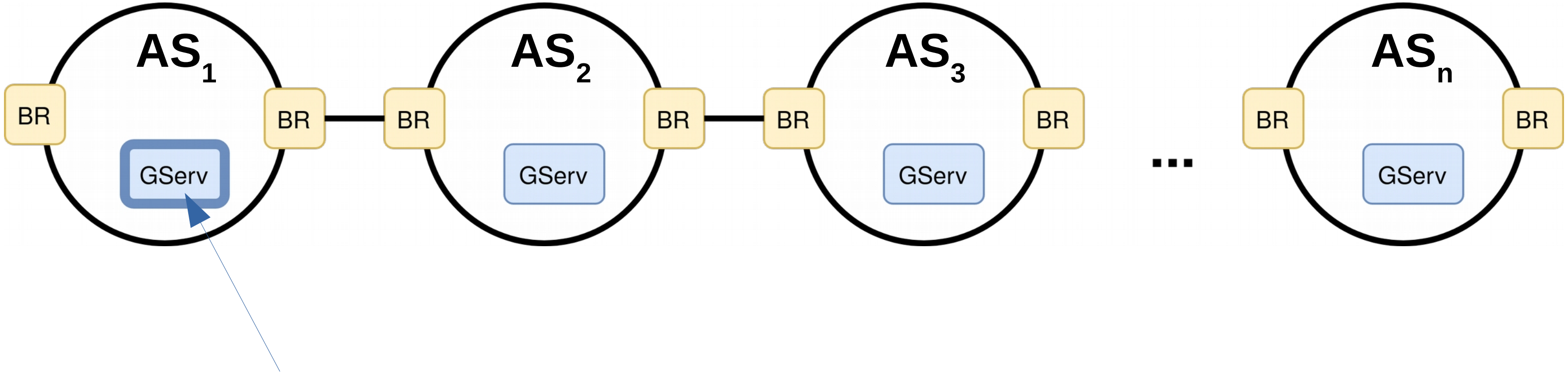
Discovery-phase

- Source AS selects path
- Collect reservation information of every AS on the path
- Every AS on the path calculates bandwidth using GMA

Transmission-phase

- Send data traffic over the reservation
- Protect traffic from congestion and DDoS

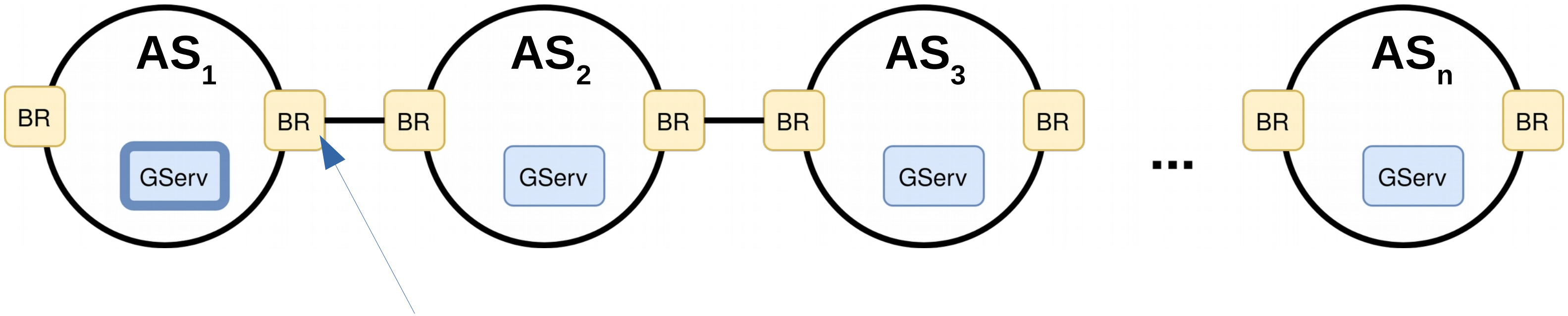
GLWP: Discovery phase



GLWP Service

- M_1
- Shared symmetric keys with every other AS
- Secret key K_1

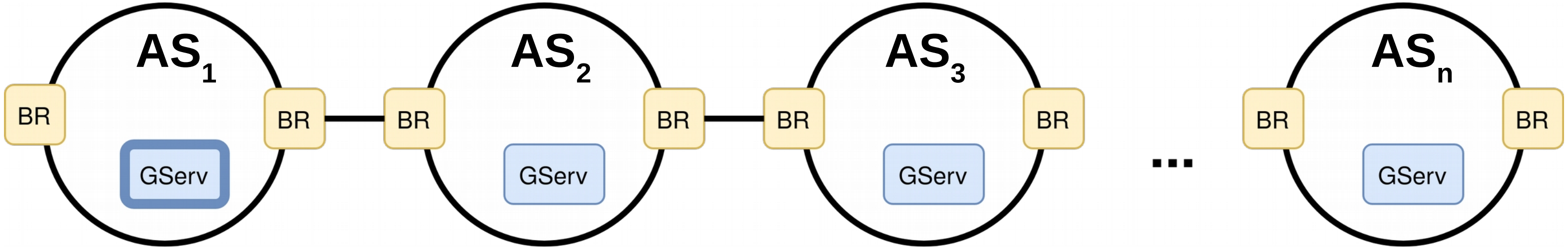
GLWP: Discovery phase



Border router

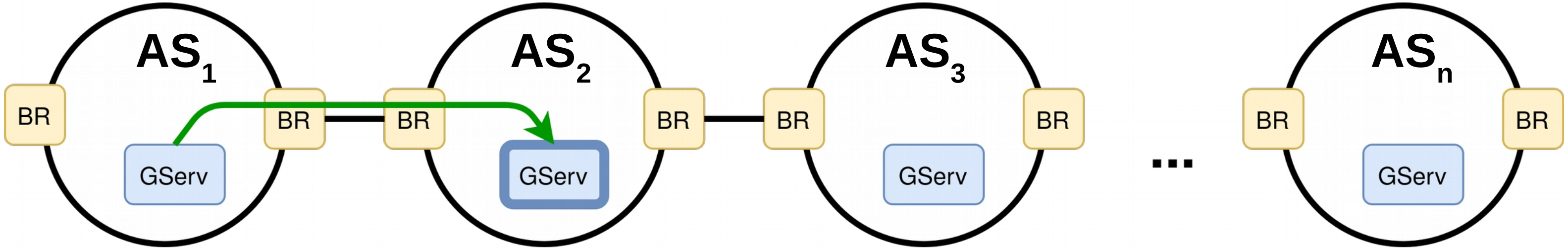
- Secret key K_1

GLWP: Discovery phase



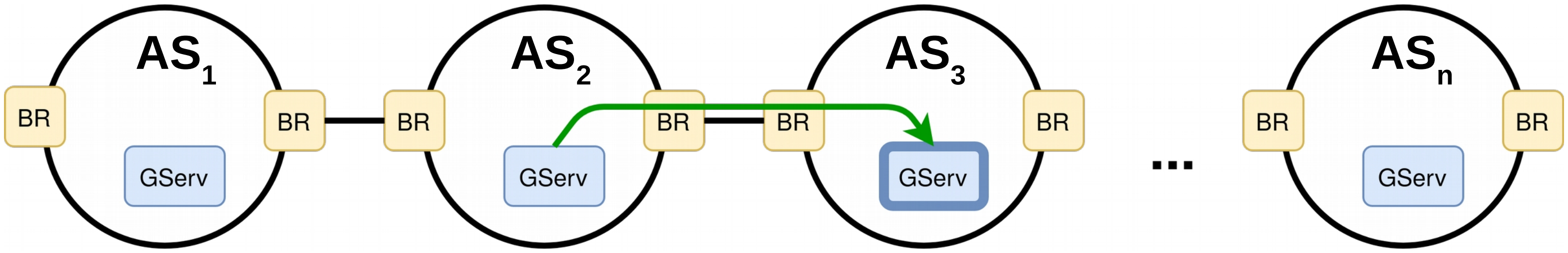
Packet = [Path, M_1]

GLWP: Discovery phase



Packet = [Path, M_1, M_2]

GLWP: Discovery phase



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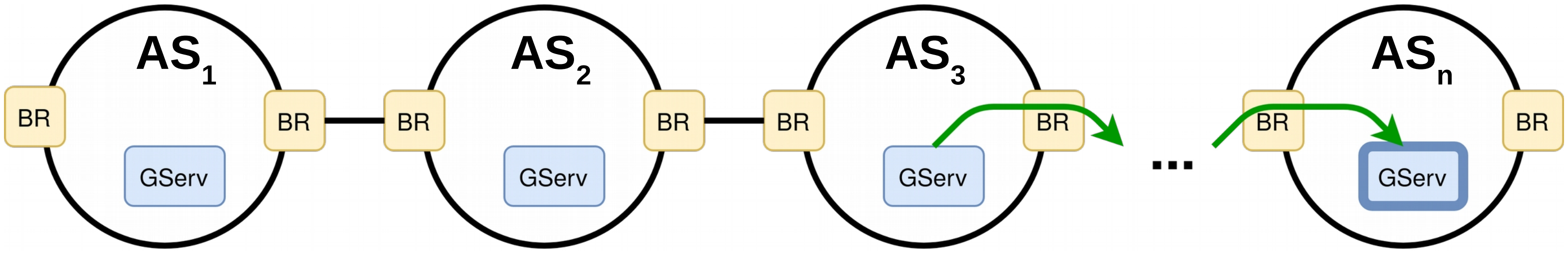

Packet = [Path, M_1, M_2, M_3, …, M_n]

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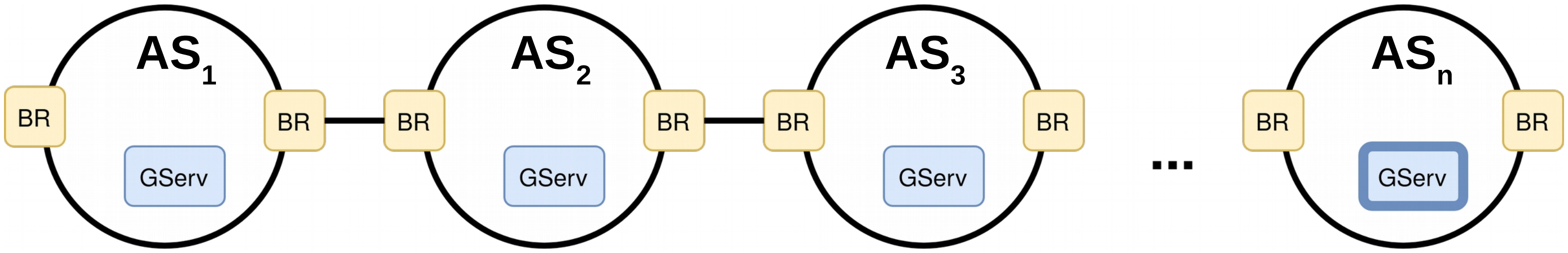
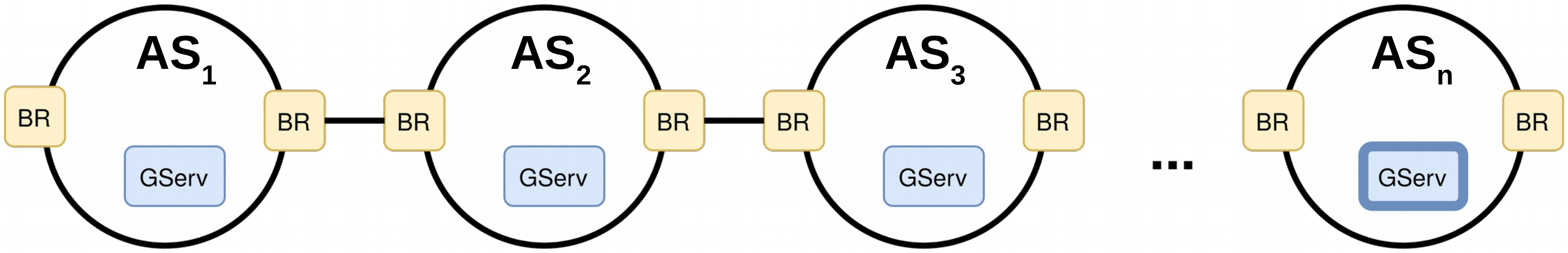


Packet = [Path, M_1, M_2, M_3, …, M_n]

- Bandwidth: $BW = \mathbf{GMA}(M_1, M_2, \ldots, M_n)$
- Hop Key of AS_n: $HK_n = \mathbf{MAC}_{K_n}(BW, Path, TS_{exp})$

GLWP: Discovery phase



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Secret key of AS n

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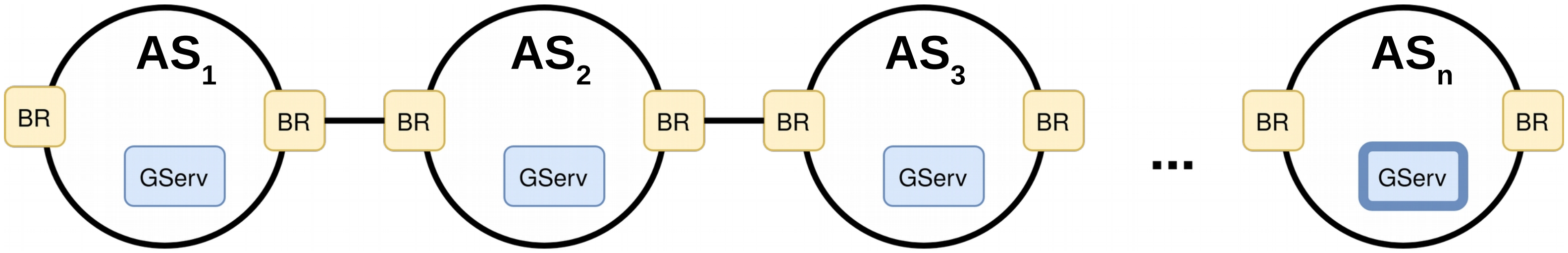

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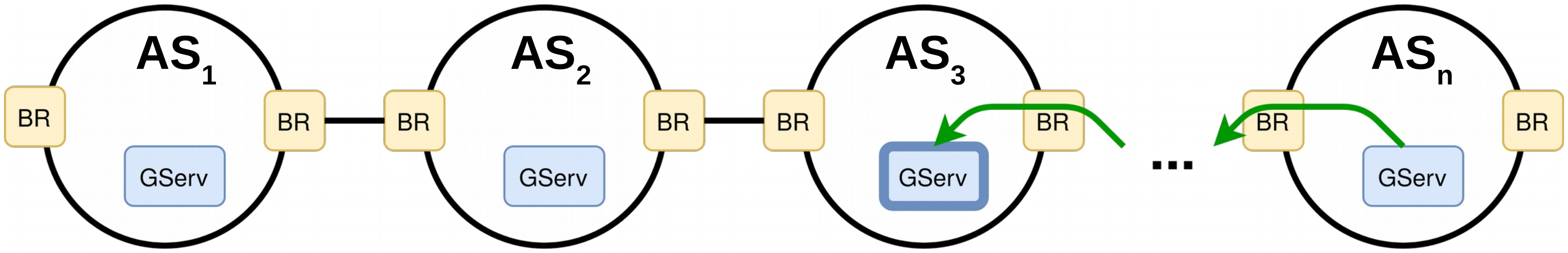

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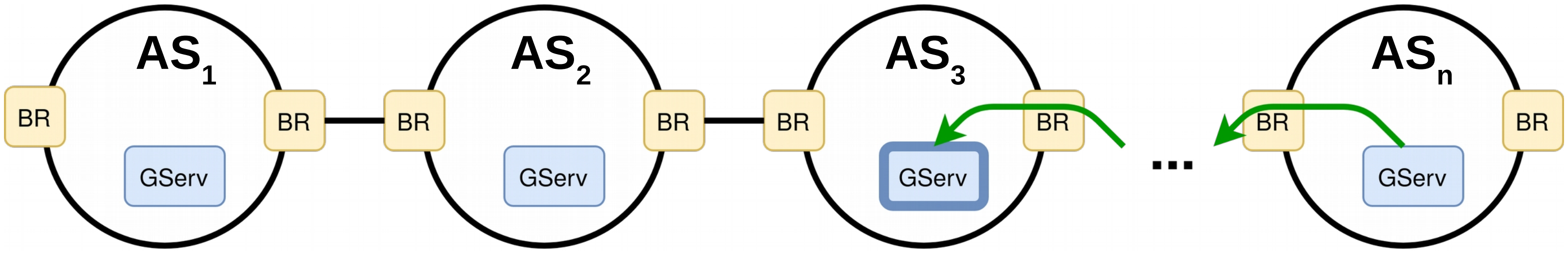
- Bandwidth: $BW = \mathbf{GMA}(M_1, M_2, \ldots, M_n)$
- Hop Key of AS_3: $HK_3 = \mathbf{MAC}_{K_3}(BW, Path, TS_{exp})$

Secret key of AS 3

GLWP: Discovery phase



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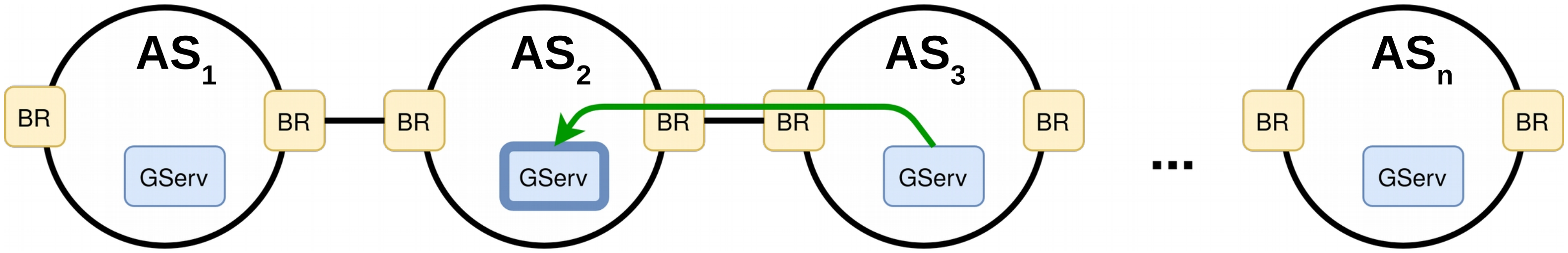

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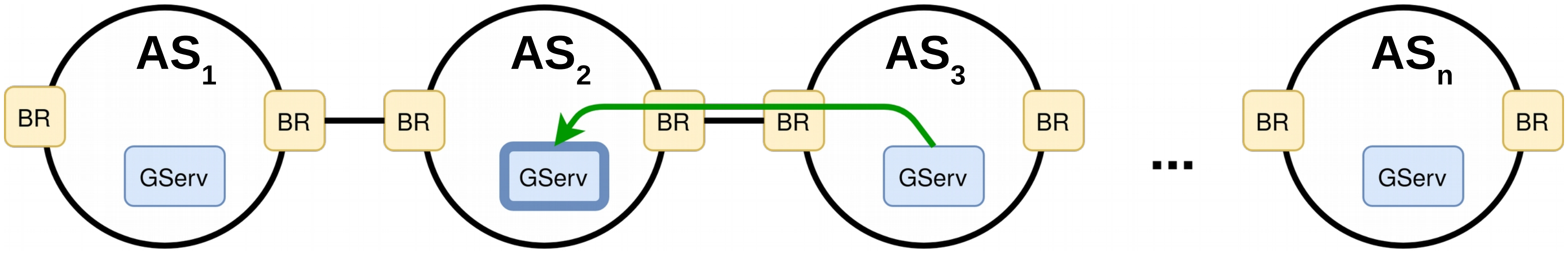
- Bandwidth: $BW = \mathbf{GMA}(M_1, M_2, \ldots, M_n)$
- Hop Key of AS_2: $HK_2 = \mathbf{MAC}_{K_2}(BW, Path, TS_{exp})$

Secret key of AS 2

GLWP: Discovery phase

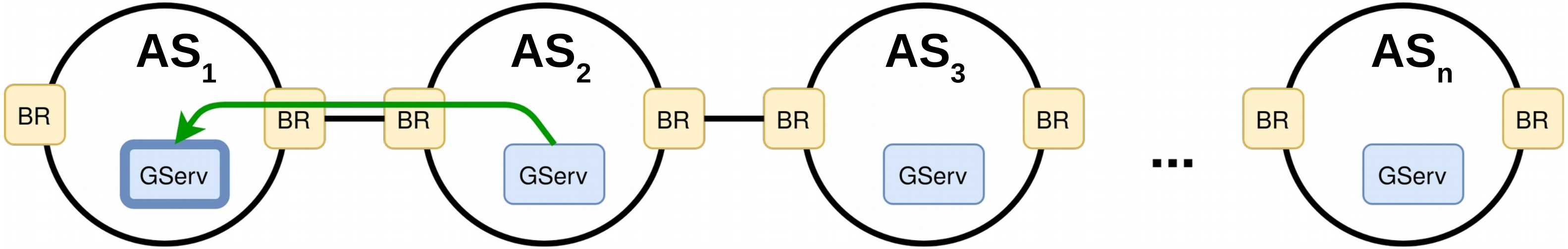


Packet = [Path, M_1, M_2, M_3, …, M_n, HK_n, … HK_4, HK_3, HK_2]

- Bandwidth: $BW = \mathbf{GMA}(M_1, M_2, \ldots, M_n)$
- Hop Key of AS$_2$: $HK_2 = \mathbf{MAC}_{K_2}(BW, Path, TS_{exp})$

Secret key of AS 2

GLWP: Discovery phase



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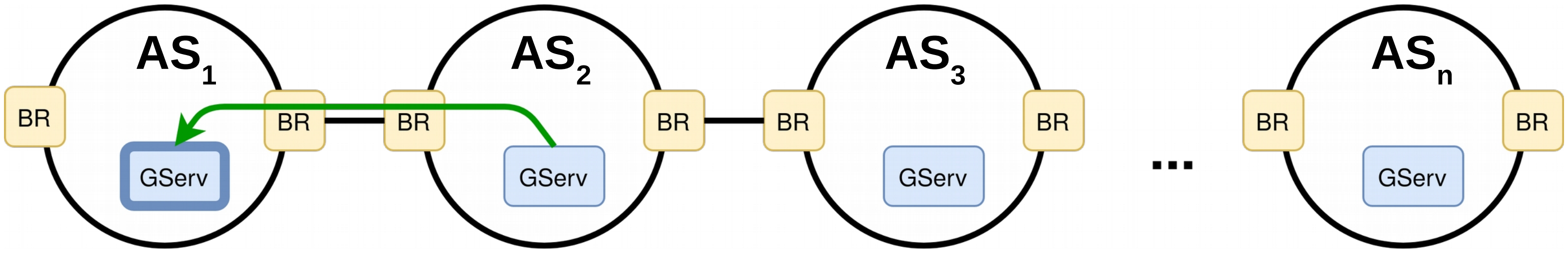
- Bandwidth: $BW = \mathbf{GMA}(M_1, M_2, \ldots, M_n)$
- Hop Key of AS_1: $HK_1 = \mathbf{MAC}_{K_1}(BW, Path, TS_{exp})$

Secret key of AS 1

GLWP: Discovery phase

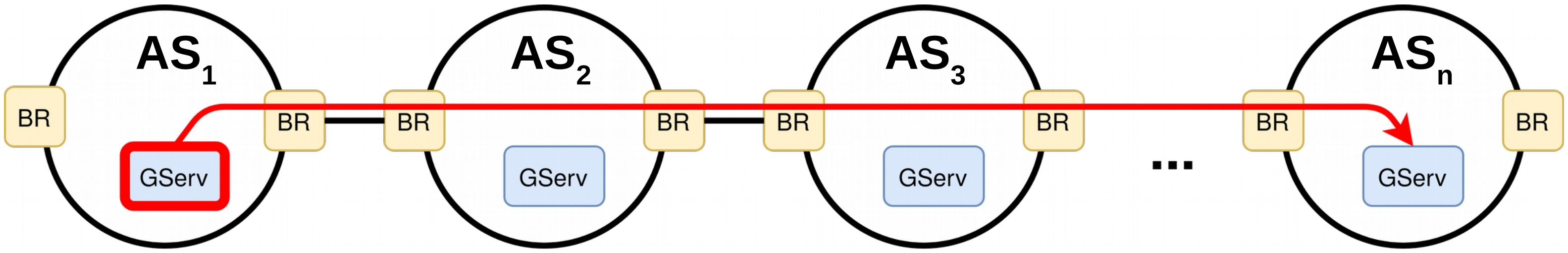


Packet = [Path, M_1, M_2, M_3, …, M_n, HK_n, … HK_4, HK_3, HK_2, HK_1]

- Bandwidth: $BW = \mathbf{GMA}(M_1, M_2, \ldots, M_n)$
- Hop Key of AS$_1$: $HK_1 = \mathbf{MAC}_{K_1}(BW, Path, TS_{exp})$

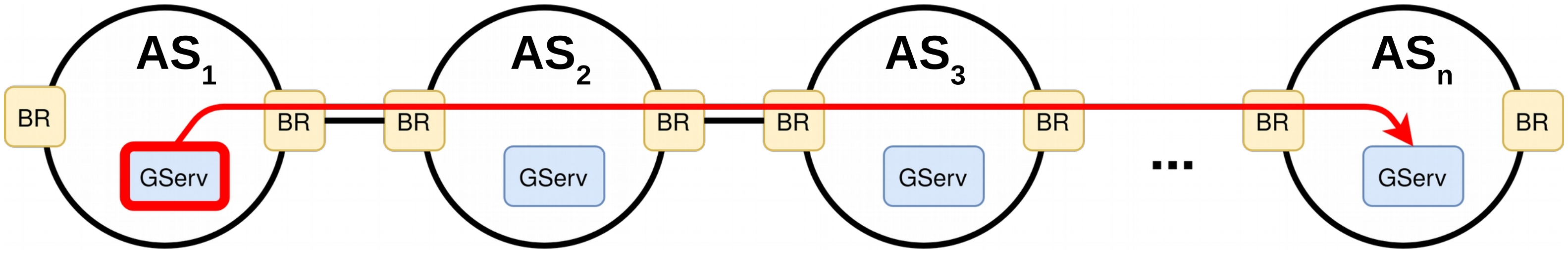
Secret key of AS 1

GLWP: Transmission phase



Packet = [Path, BW, TS_{exp}, TS_{pkt}]

GLWP: Transmission phase



Packet = [Path, BW, TS_{exp}, TS_{pkt}]

Hop authenticators:

$$HA_1 = \mathbf{MAC}_{HK_1}(AS_1, TS_{pkt}, length[pkt])$$
$$HA_2 = \mathbf{MAC}_{HK_2}(AS_1, TS_{pkt}, length[pkt])$$
...
$$HA_n = \mathbf{MAC}_{HK_n}(AS_1, TS_{pkt}, length[pkt])$$

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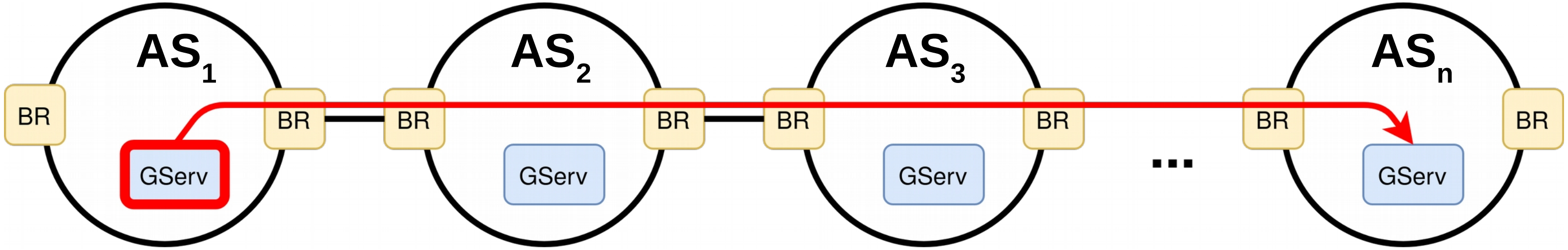

Packet = [Path, BW, TS_{exp}, TS_{pkt}, HA_1, HA_2, …, HA_n, payload]

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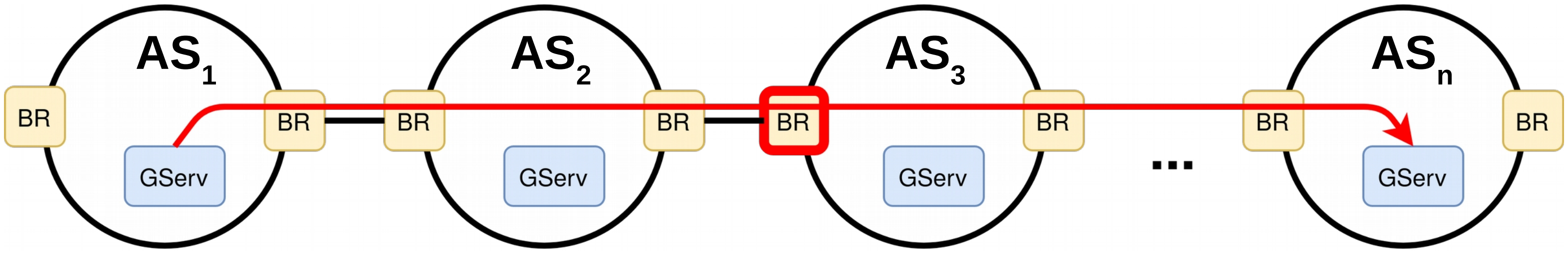
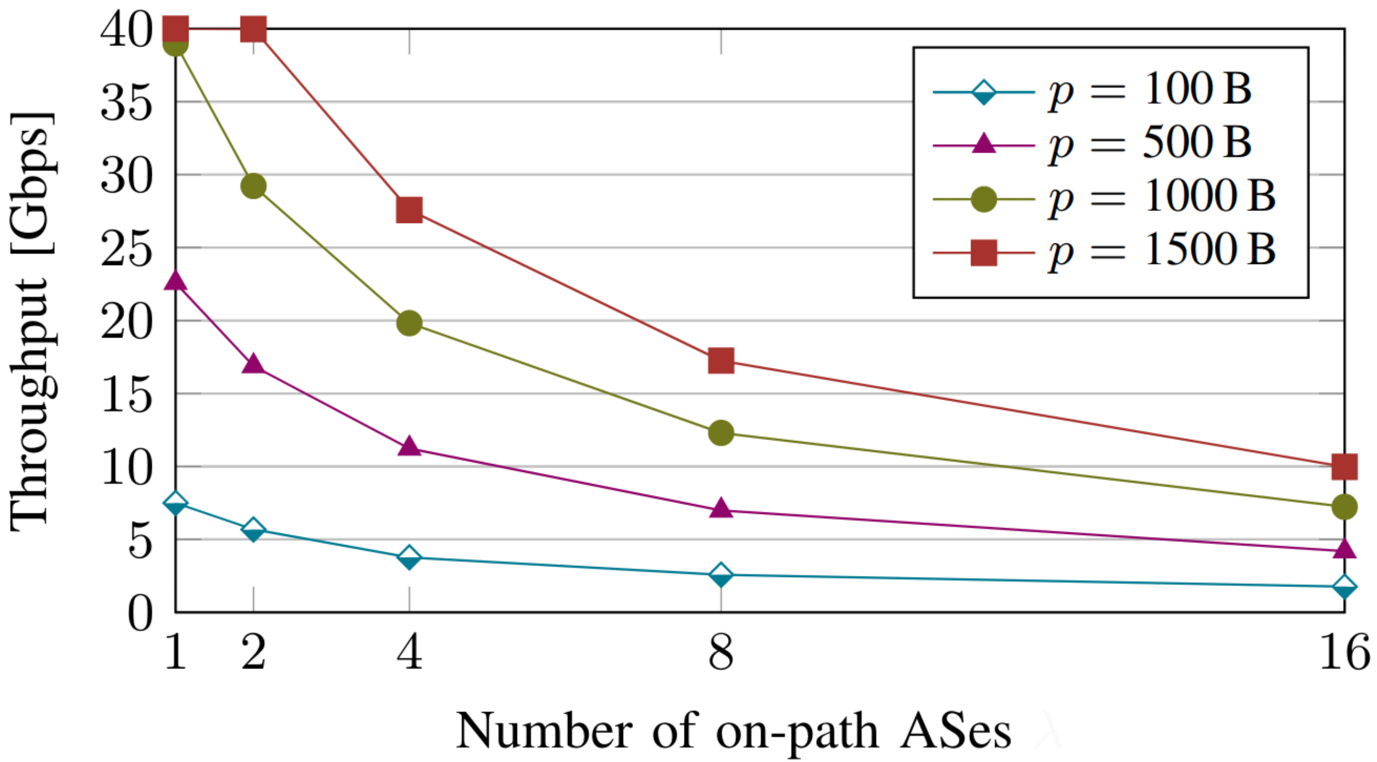


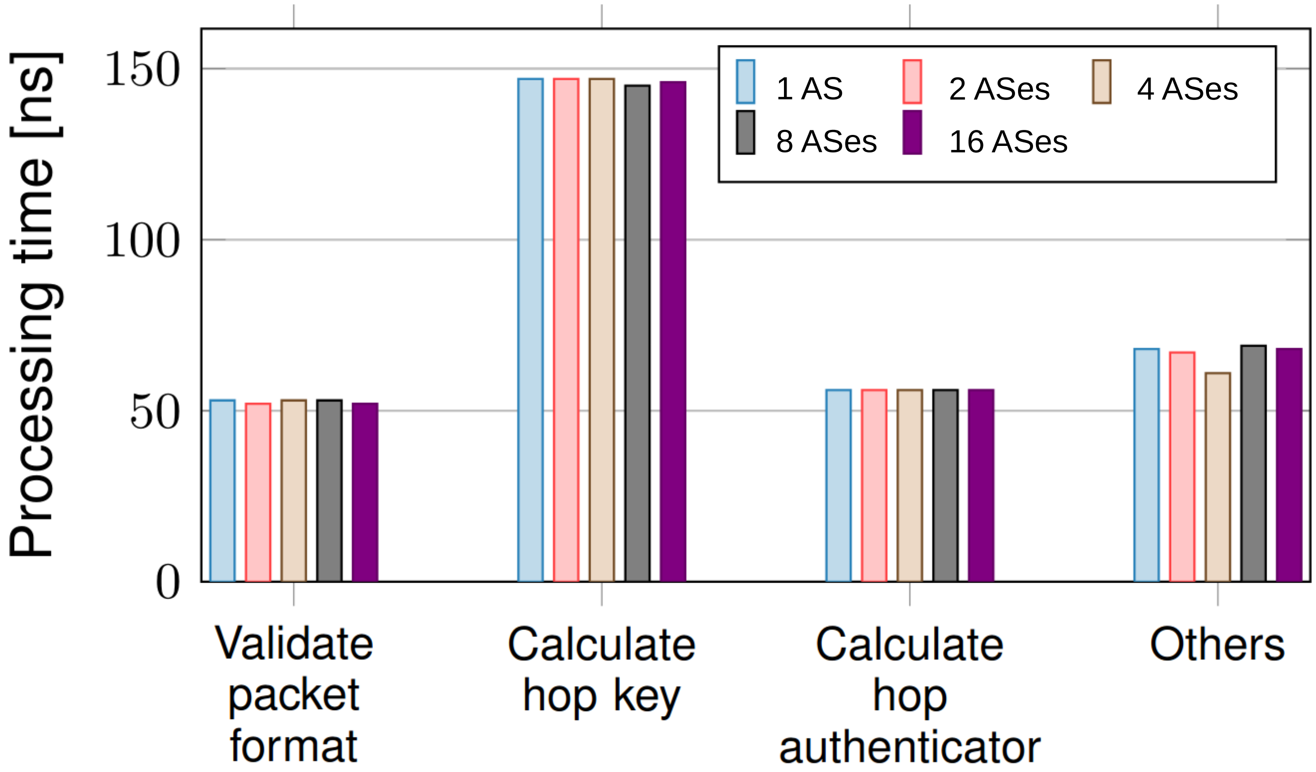
Packet = [Path, BW, TS_{exp}, TS_{pkt}, HA_1, HA_2, …, HA_n, payload]

- Recalculate hop key: $HK_3 = \mathbf{MAC}_{K_3}(BW, Path, TS_{exp})$
- Recalculate hop authenticator: $HA_3 = \mathbf{MAC}_{HK_3}(AS_1, TS_{pkt}, length[pkt])$
- Compare calculated hop authenticator the the one in the packet.
- Check packet using **replay suppression system** and **bandwidth monitor**.

Evaluation: GServ



Evaluation: Border Router



Security of GLWP

GLWP is secure against:

- Malicious GMA parameter announcements
- Path manipulation
- Request multiple reservations over the same path
- Reservation overuse
- Framing attacks
- Volumetric DDoS attacks
- ...

Conclusion

- **Critical-yet-Frugal applications** need guaranteed communication (QoS).
- Existing solutions cannot provide this.
- We present **GLWP**:
  - Strong QoS guarantees
  - Decentralized
  - Secure
  - Low communication and computation overhead
  - No per-path or per-connection state
  - Scales to large networks

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Thank you!

Email: marc.wyss@inf.ethz.ch

References

Name	Use in GLWP	Reference
GMA	• Bandwidth calculation • Locality property allows GServ to be stateless	“GMA: A Pareto Optimal Distributed Resource-Allocation Algorithm” SIROCCO, 2021
PISKES	• Efficient symmetric key distribution	“PISKES: Pragmatic Internet-Scale Key-Establishment System” ASIA CCS, 2020
SCION	• Path stability • (Multipath)	“SCION: A Secure Internet Architecture” Springer, 2017