A Software-Defined Networking approach to enhance BGP security

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Outline

Objective & Goals

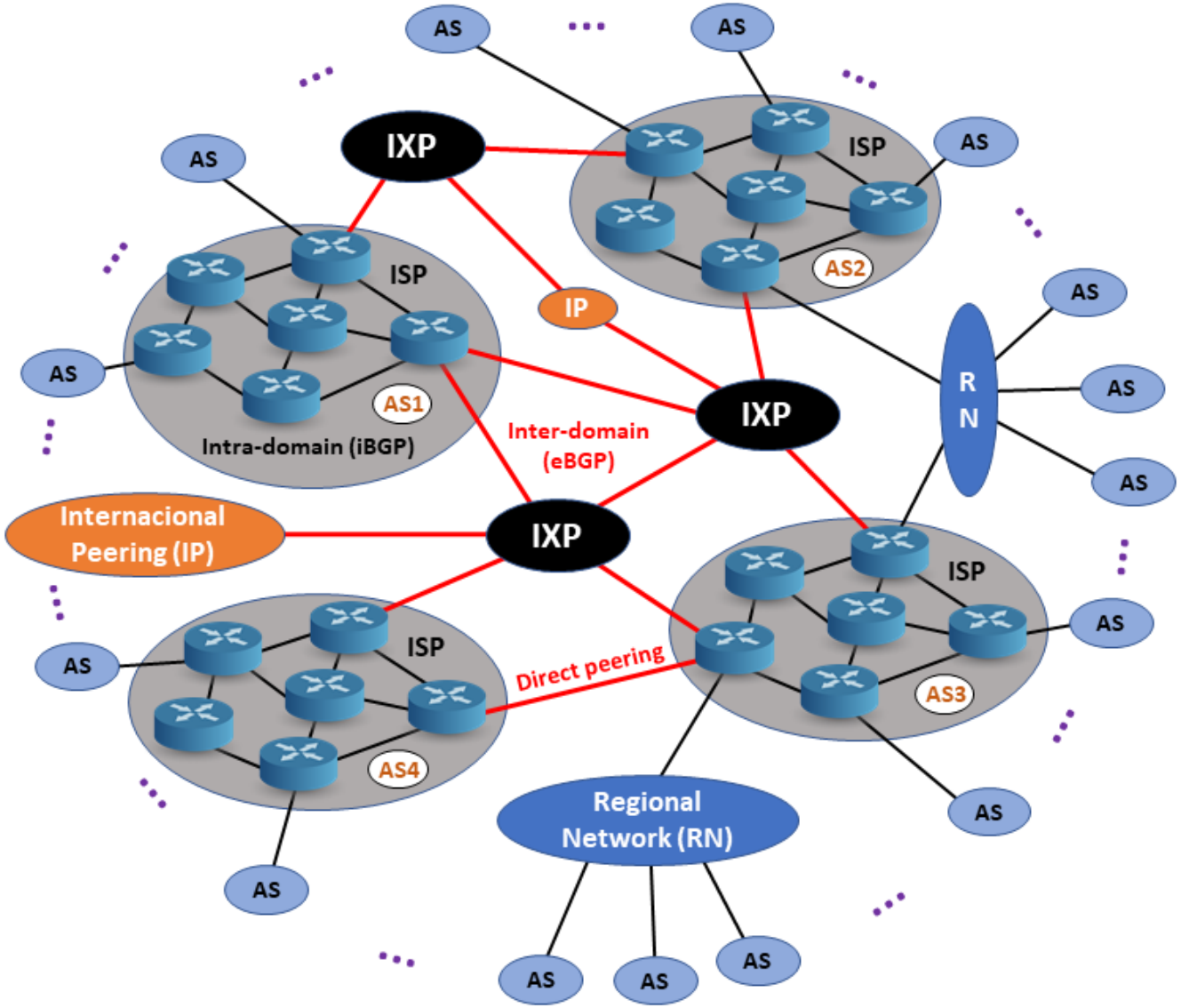
- Objective of this work: design, implementation and evaluation of an SDN-based architecture targeting Internet Exchange Points (IXPs) to enhance BGP security.
- Our goals:
  - Provide Origin Authentication and Path Validation to avoid prefix hijacks and other fake BGP announcements.
  - Promote deployment.

Motivation (BGP Security)

- Some solutions to improve BGP security having been proposed in the past two decades [ProcIEEE'10], but the most effective security solutions have not seen widespread deployment [SIGCOMM'14]:
  - Proposed solutions require changes to BGP.
  - Proposed solutions represent a high computational burden to routers.
  - Network operators are not given the right incentives to migrate to a secure solution, and have concerns about the disclosure of business relationships considered private.

Background - Internet infrastructure/routing

Internet interconnection



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IXPs around the world: **545 in May/2017** (source: peeringdb.com)

Continental Region	# IXPs	Continental Region	# IXPs
Europe	186	Africa	38
North Americ	131	Australia/New Zealand	27
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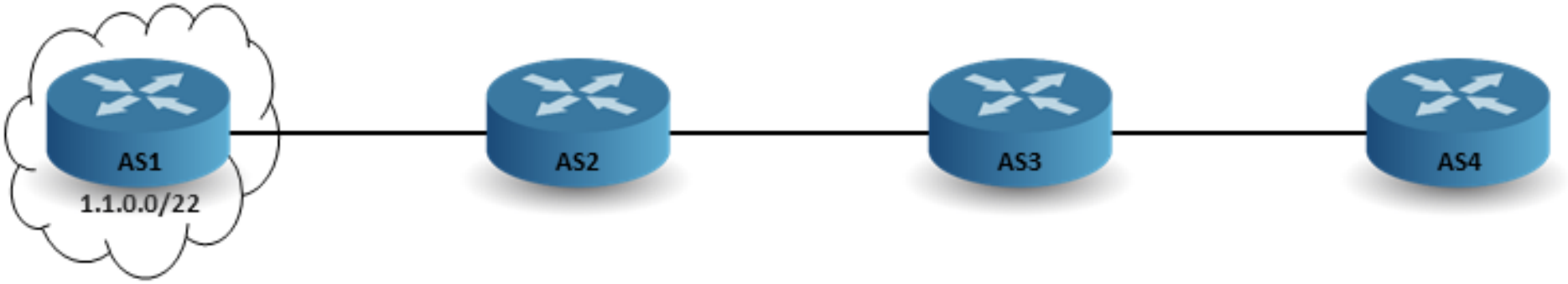
- DE-CIX has more than 600 connected networks.
- AMS-IX has more than 700 connected networks.
- CIX and AMS has each one a network traffic around 5 terabits/s.

Background (Internet infrastructure/routing))

IXPs visual distribution around the world (source: telegeography.com)

Background (BGP route announcement)

Route propagation along the path (**UPDATE** message)



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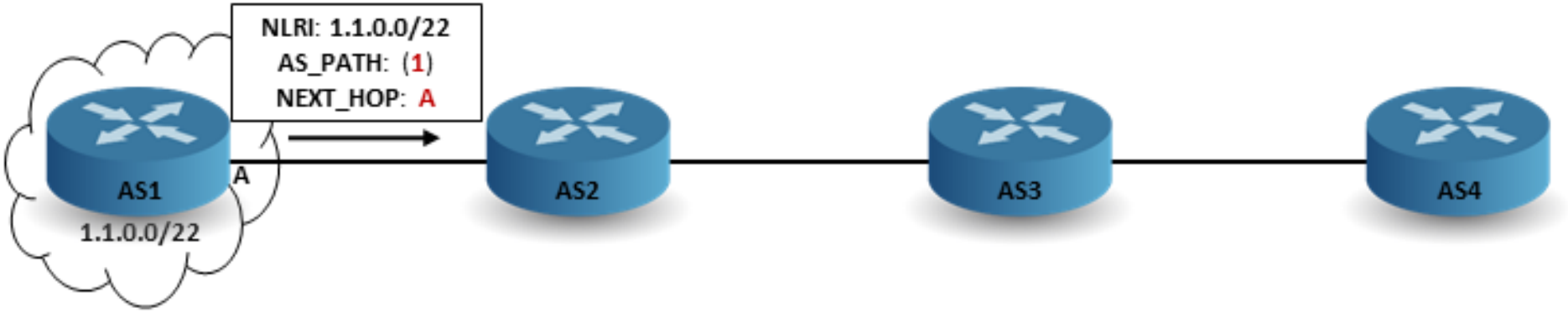

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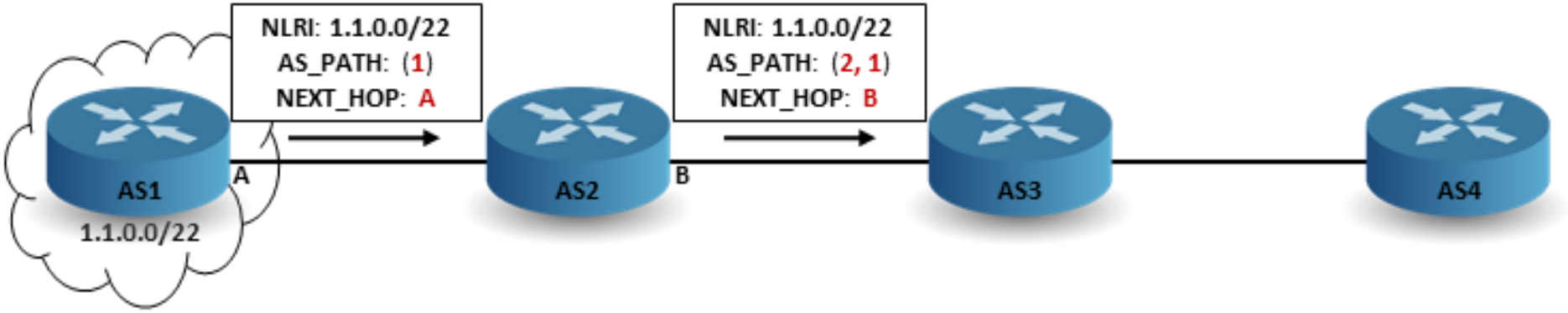

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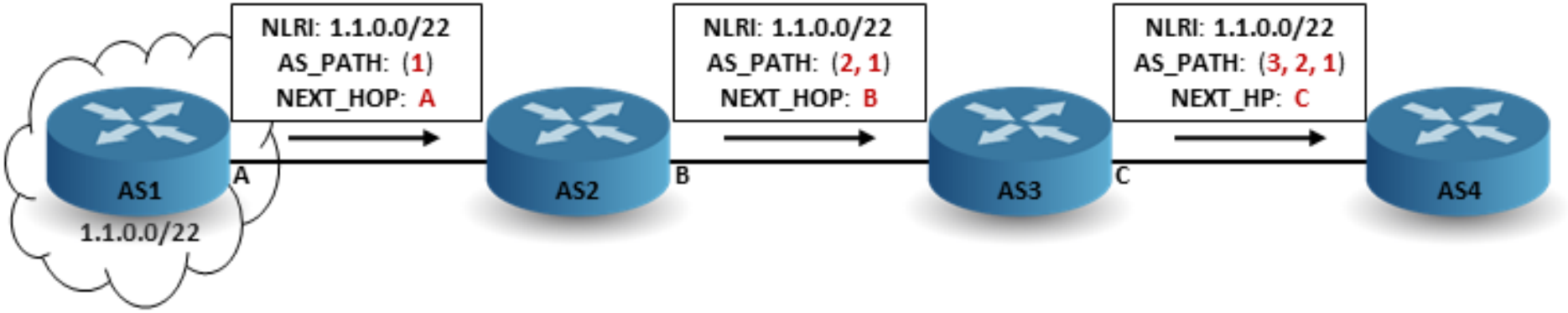
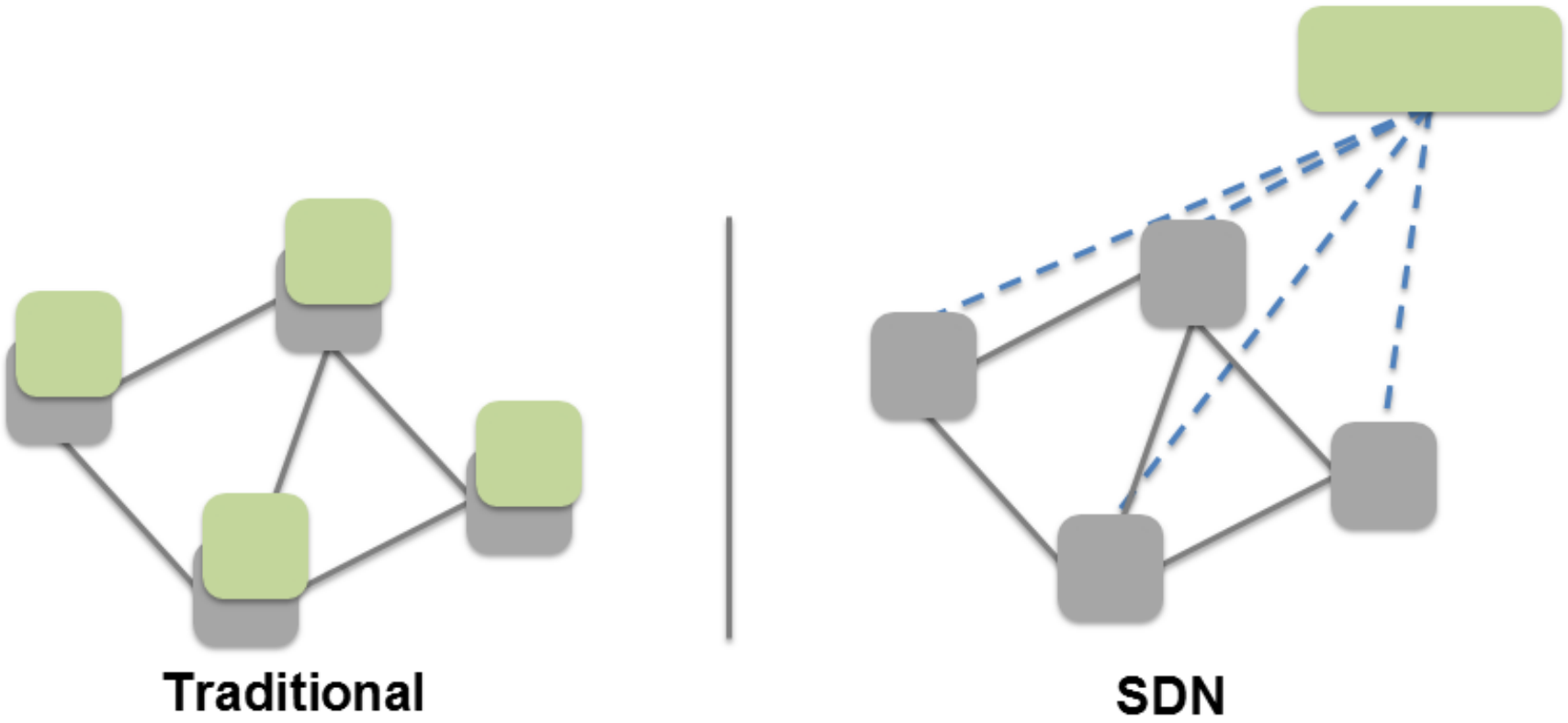
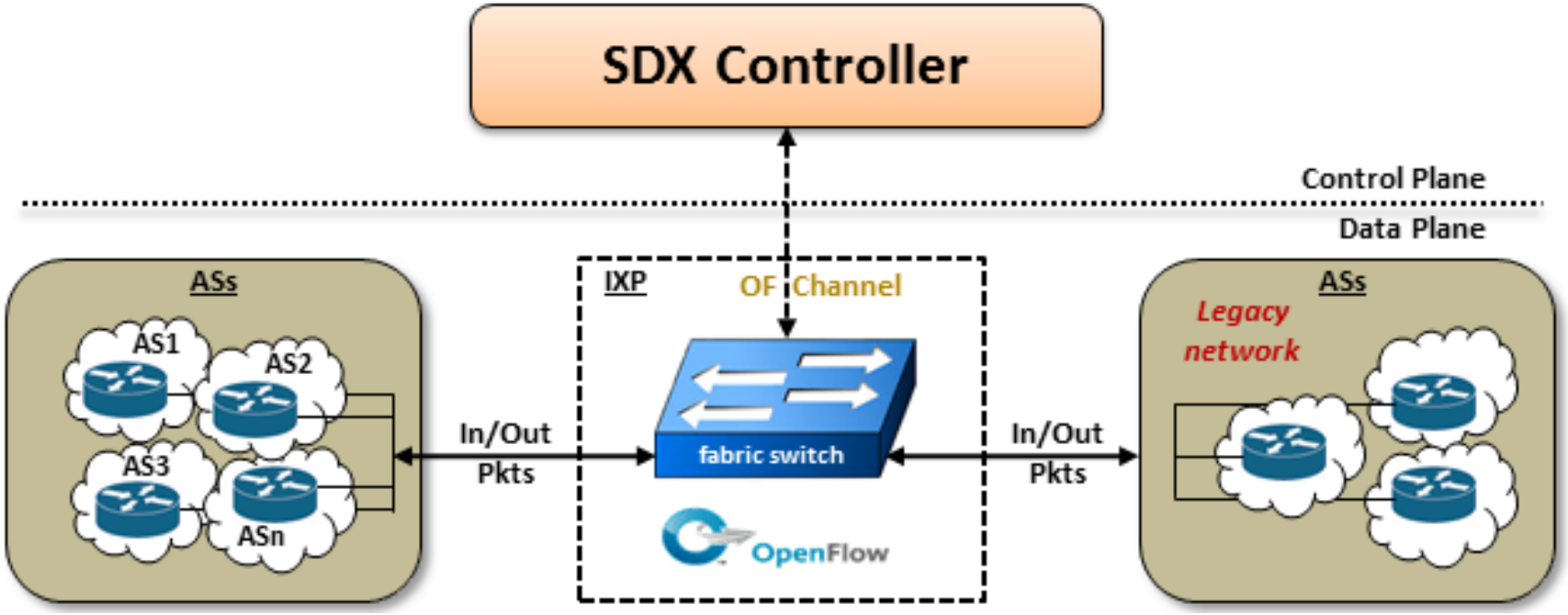


Background - Software-Defined Networking

Traditional and SDN network architecture

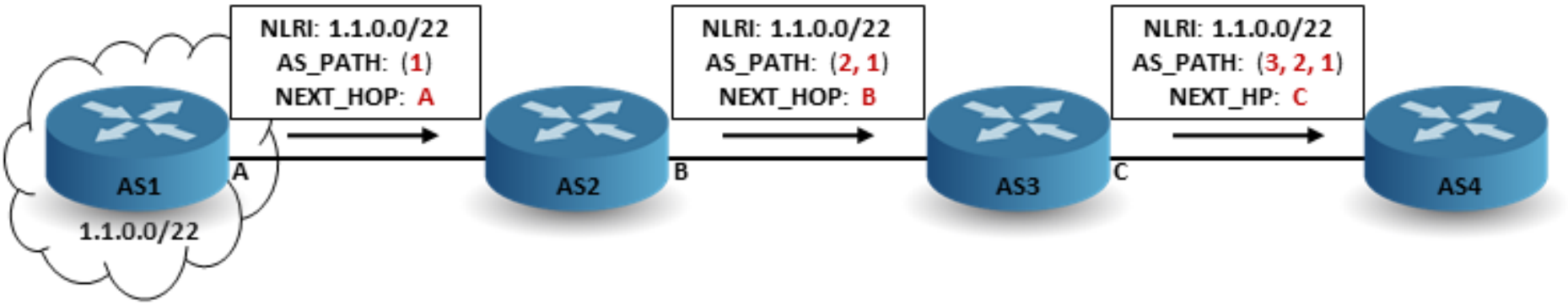


Software-Defined Exchange [SIGCOMM'14][NSDI'16]



BGP Security Problems - Prefix Hijacking

Prefix/Sub Prefix Hijacking



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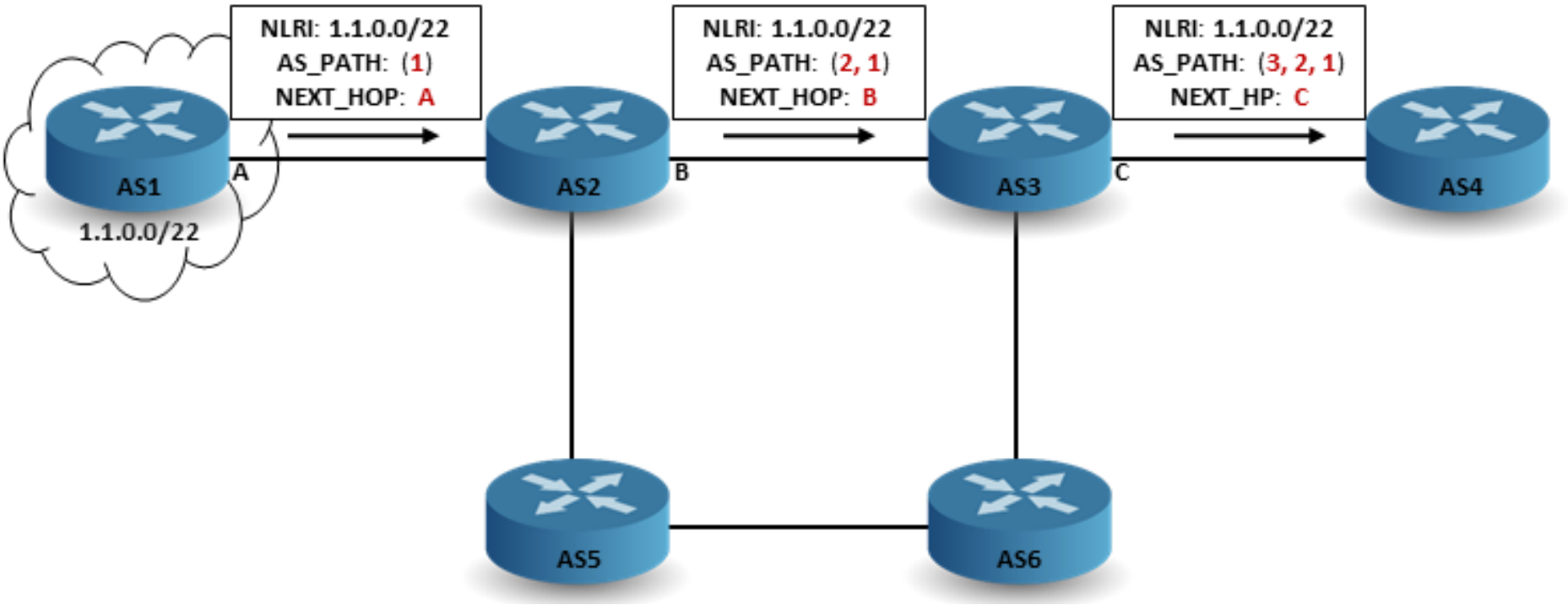

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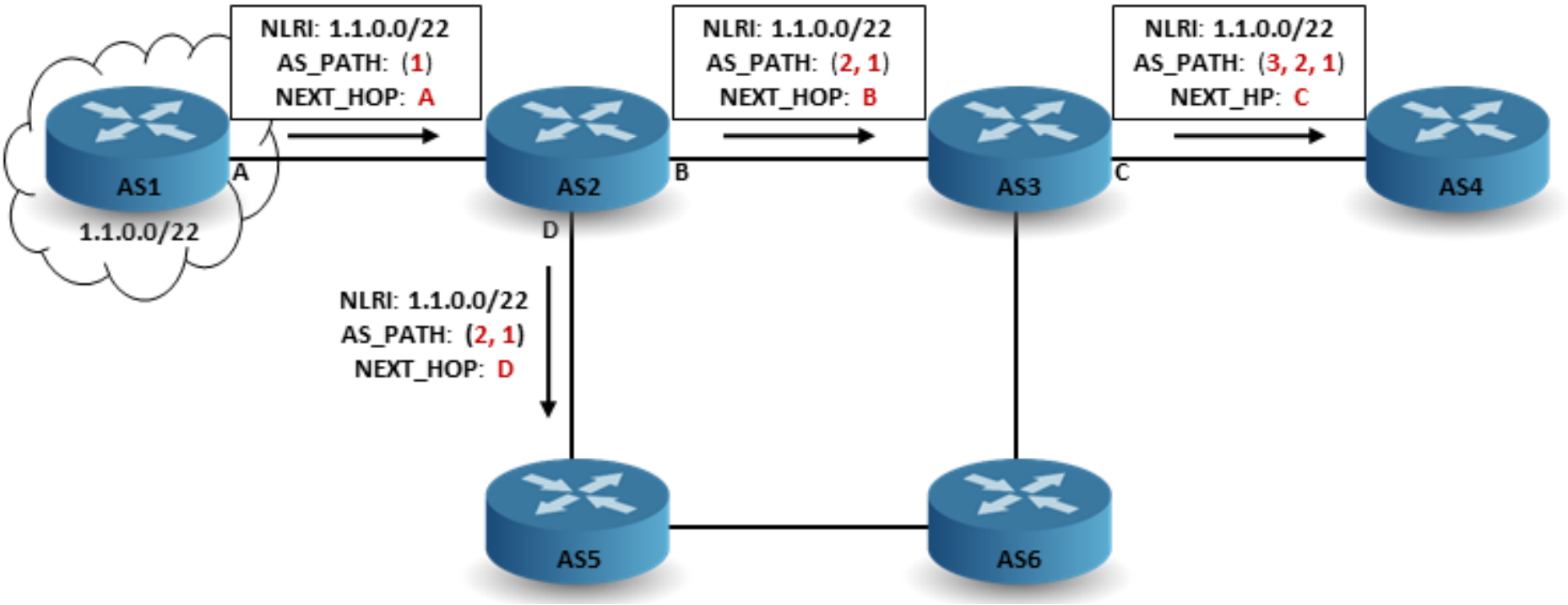

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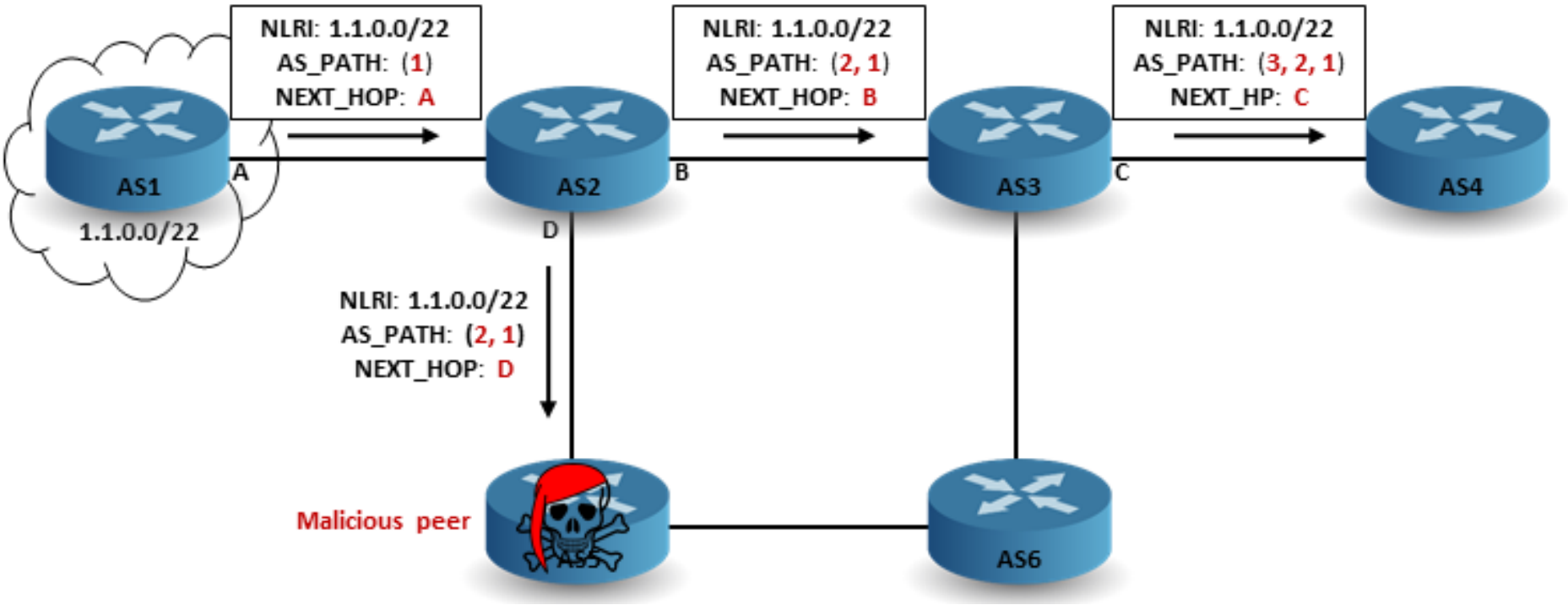

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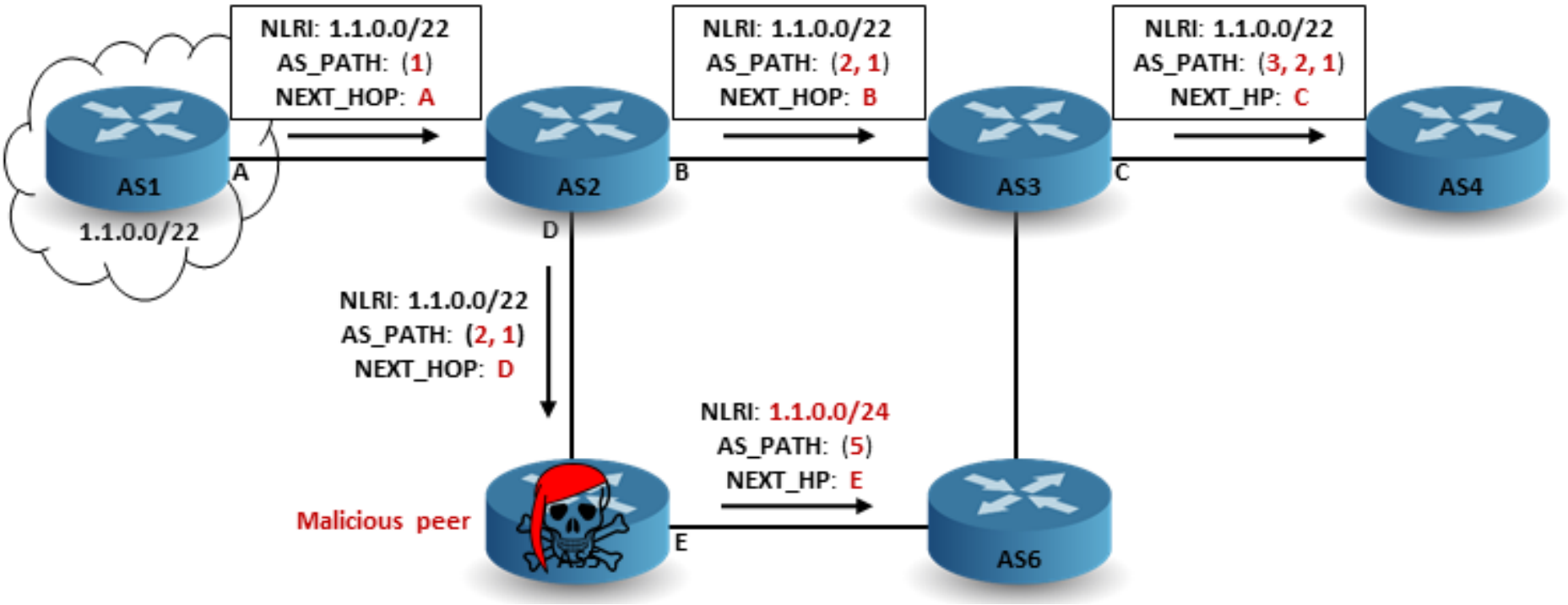

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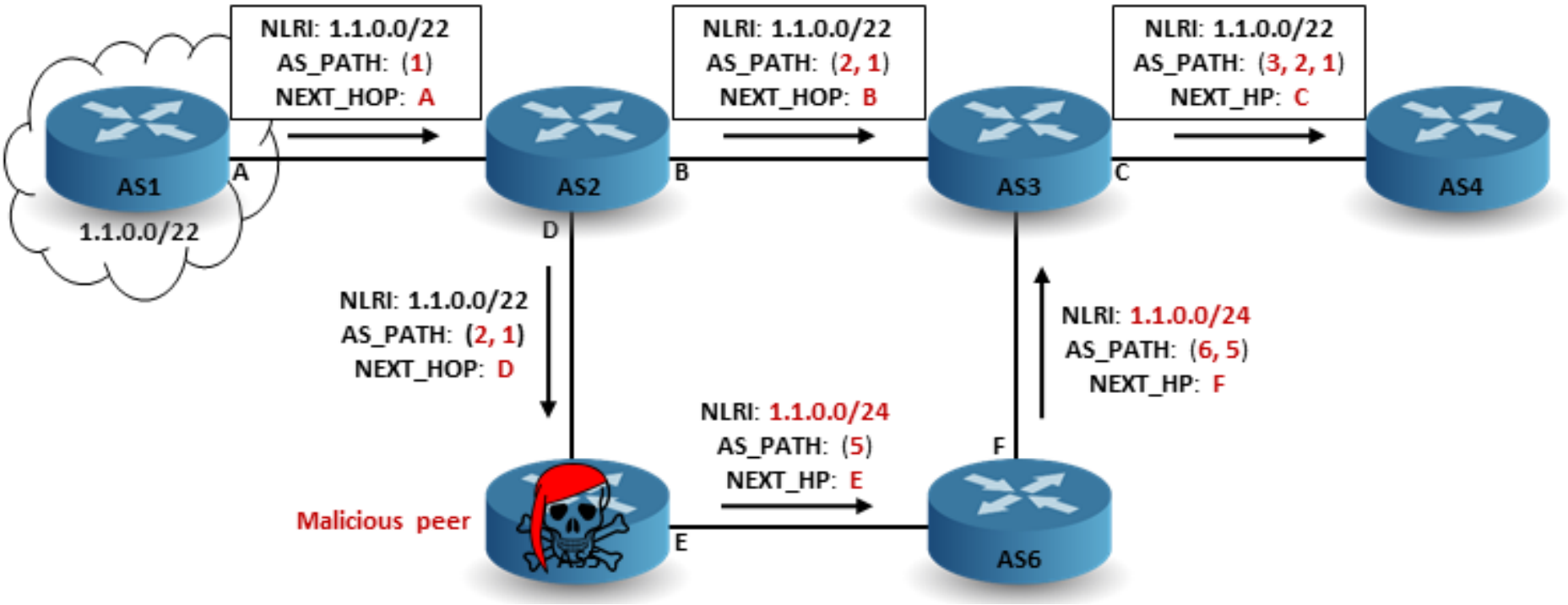

BGP Securiy Problemas - Path manipulation

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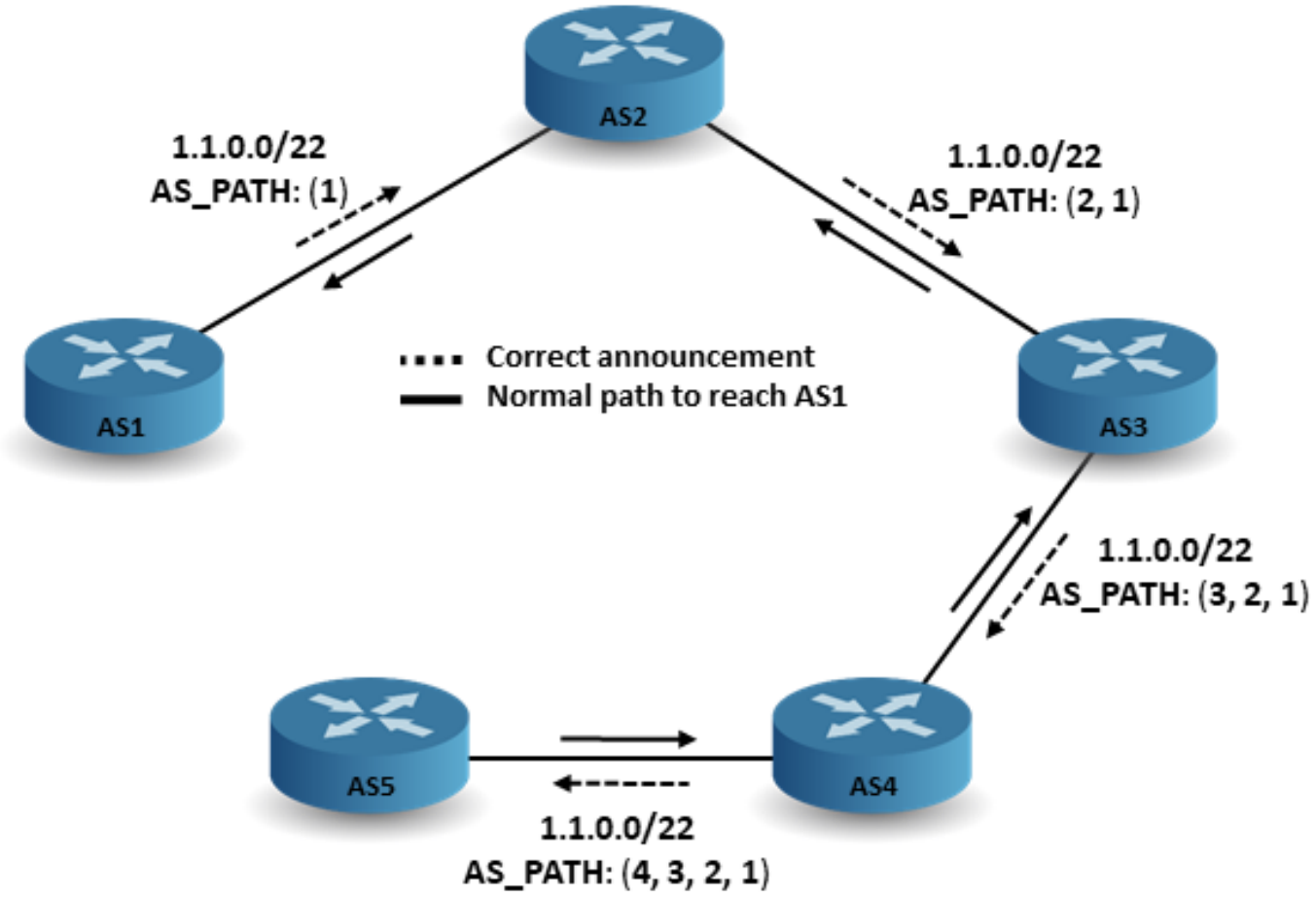

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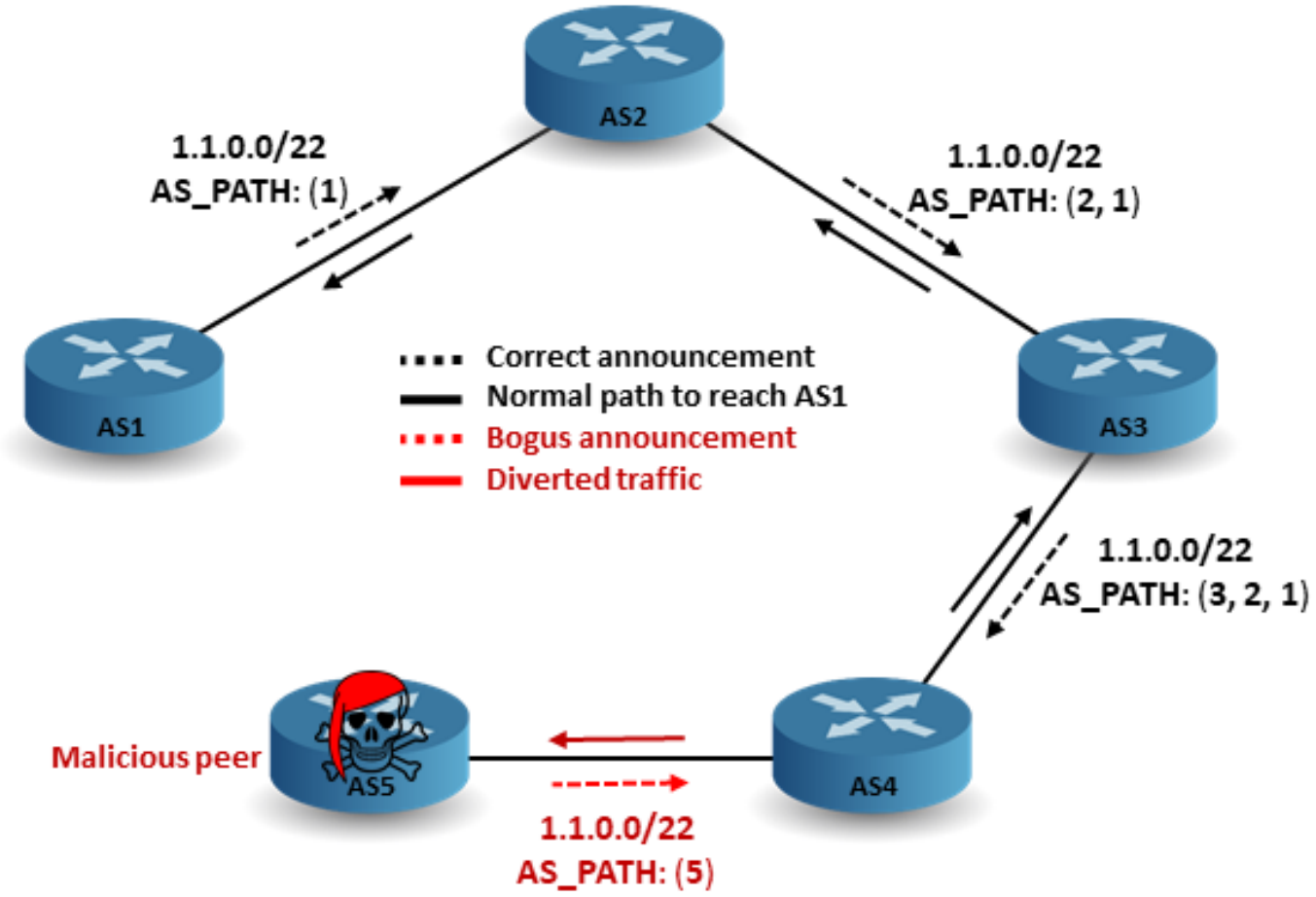
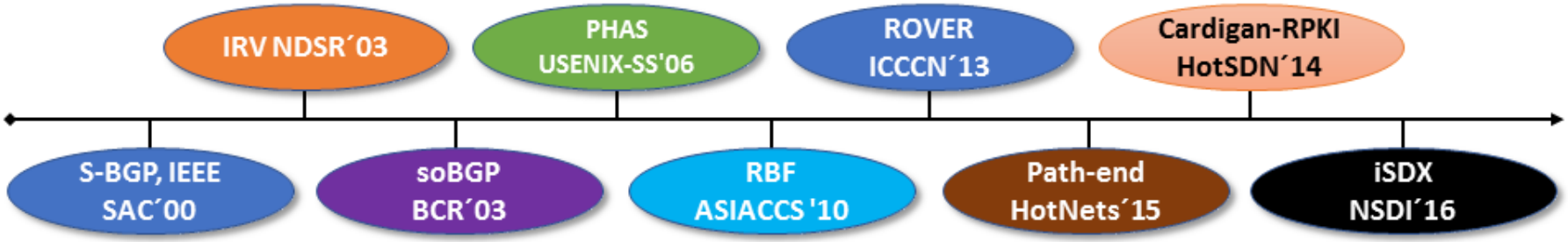


Related work



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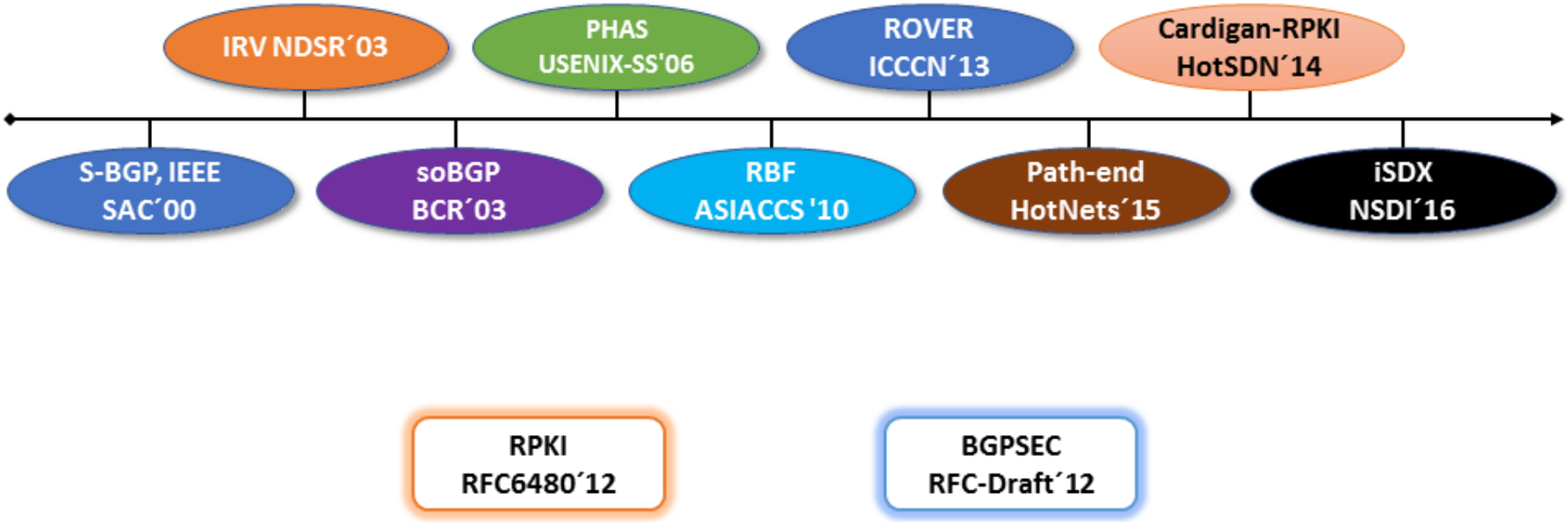

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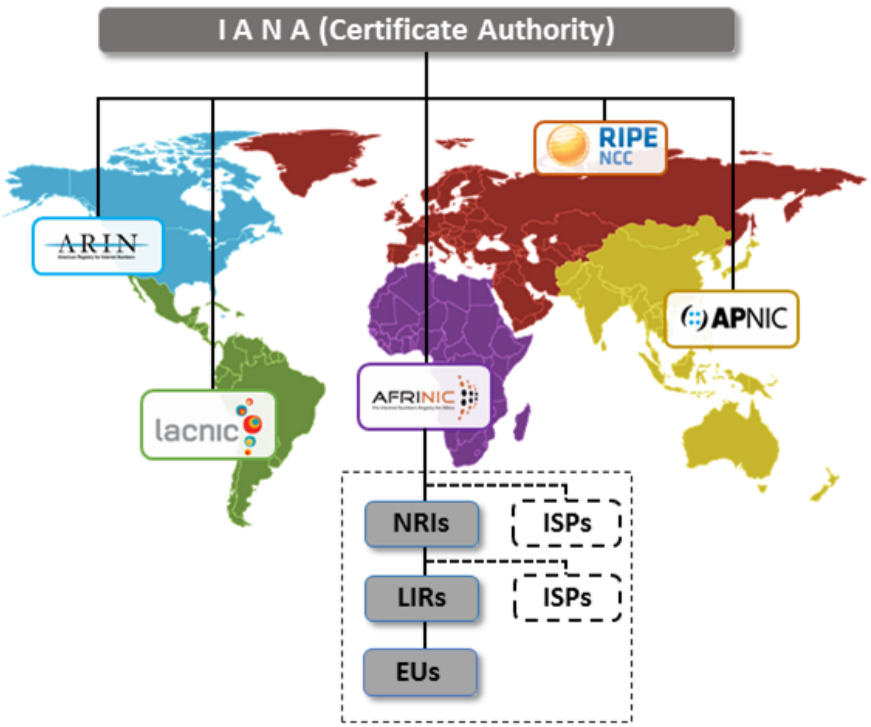

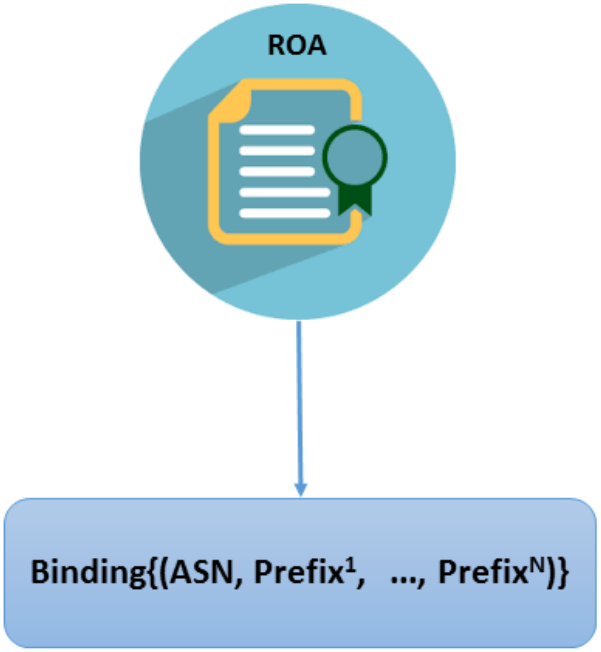

- A trusted DB is used to guarantee that an **AS cannot falsely claim** to be the rightful owner for an IP prefix (Route Origin Authorization - **ROA**) [RFC6482].
- The RPKI provides a trusted mapping - a **whitelist** - from allocated prefixes to ASes by establishing a cryptographic hierarchy of authorities.

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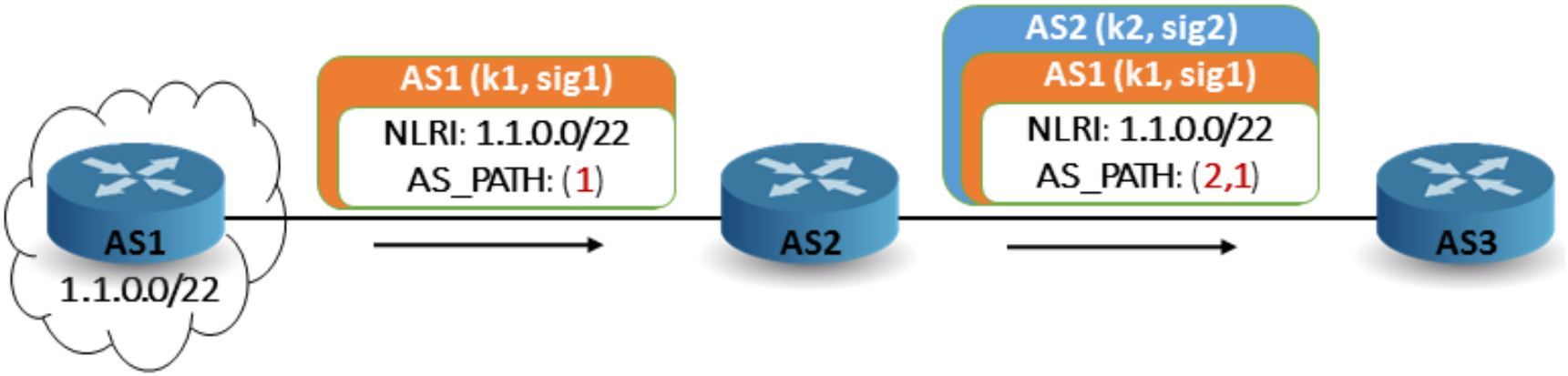
  - (-) RPKI coverage is small.

Related work: BGP securicy extension (BGPSEC) [RFC-Draft]



- In addition to origin authentication, it uses cryptographically-signed routing announcements to **provide path verification**.
- It comprises a set of nested signature which need to be verified.

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  - (-) Benefits only with large deployment.

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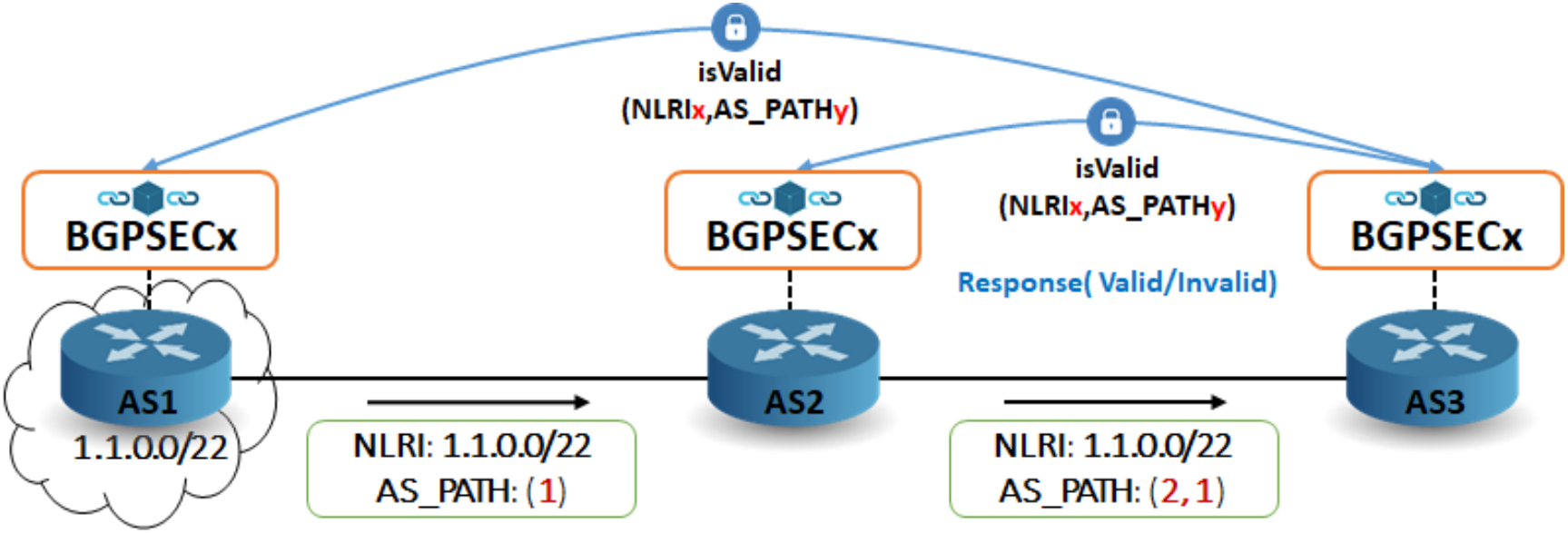
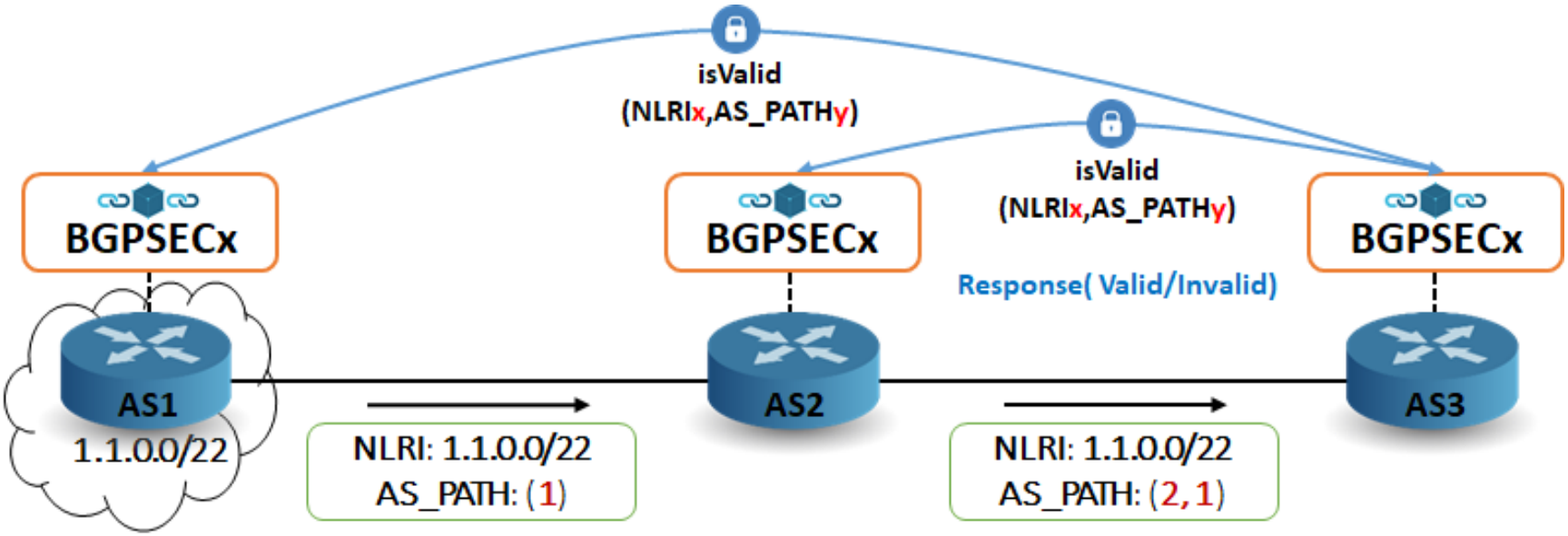
- Remove computational burden from routers.
- Creates incentives to ASes and removes disincentives.

BGPSECx design - (OA/PV on BGPSECx using Inter-IXP queries)



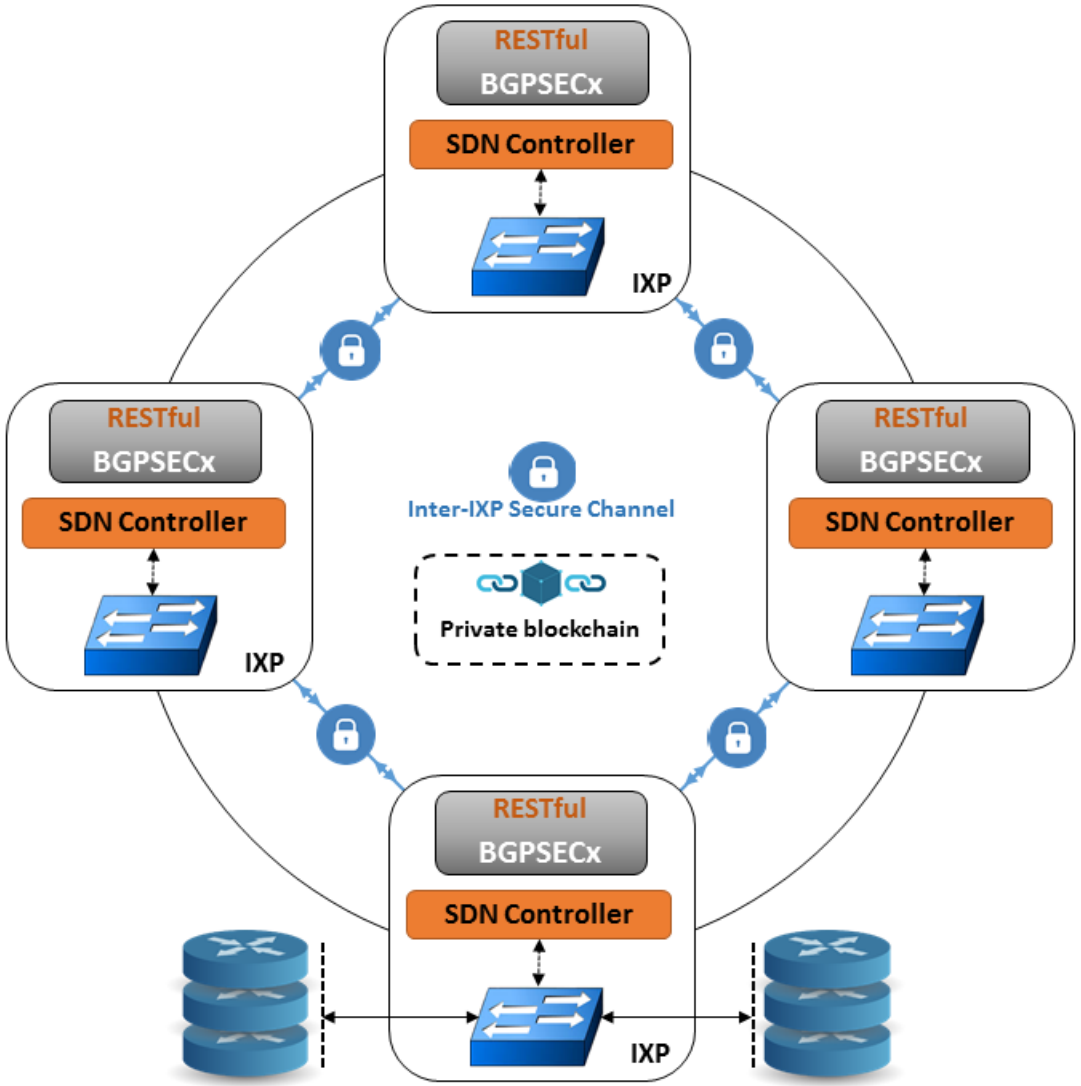
- Peer which receives the advertisement makes queries on each AS of the path to validate the announcement.
- In the queries, for a legitimate advertisement is returned VALID, otherwise INVALID.
- Queries uses RESTful over HTTPS.
- Queries in blockchain uses JSON-RPC (based in key/value).

BGPSECx design - (OA/PV on BGPSECx using blochchain)

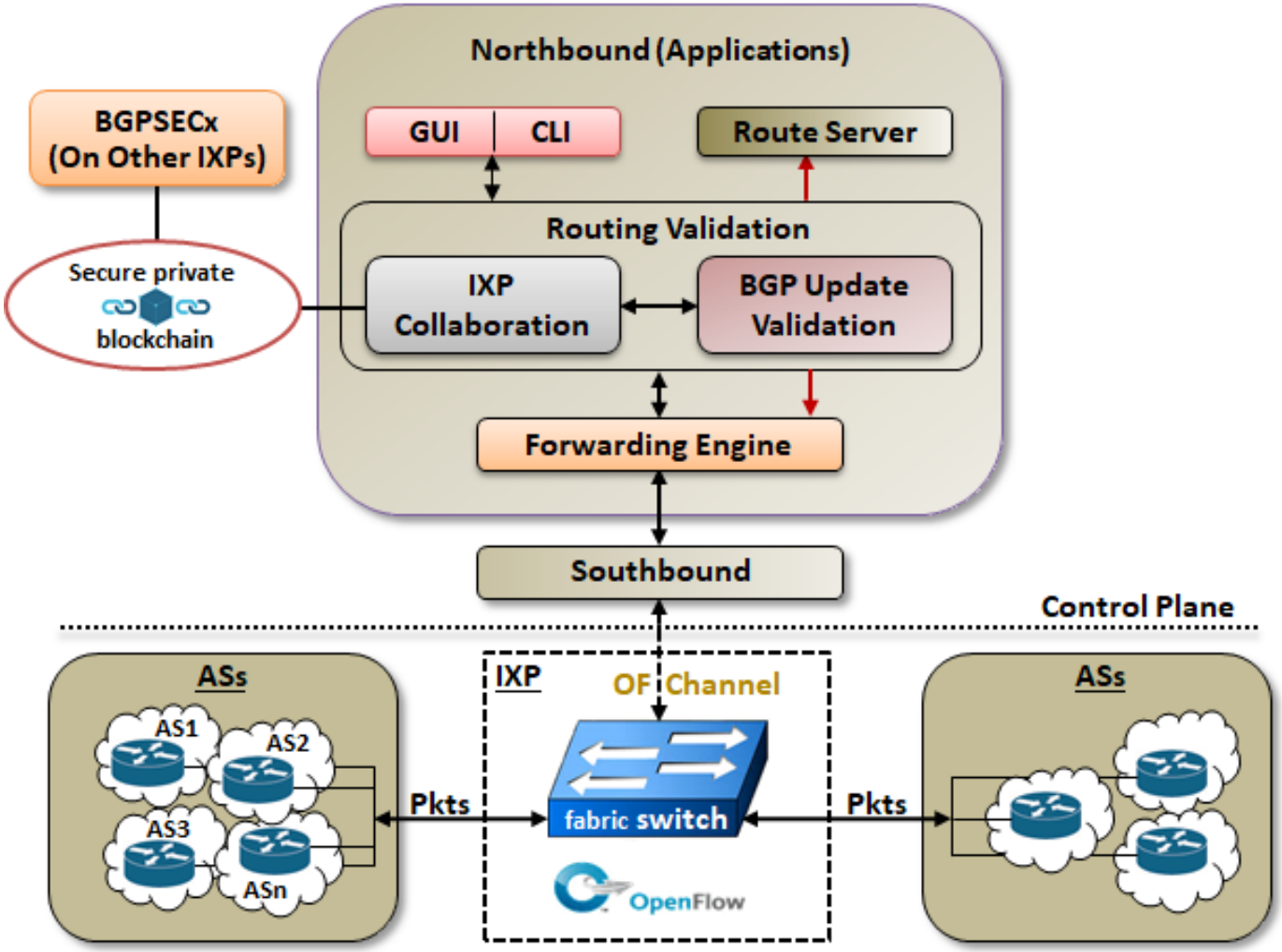


- Each peer have its blockchain and are synchronized with each other. No proof-of-work is required to include transactions. To avoid malicious peer is used a permission policy.
- To validate OA/PV, the AS makes queries in its own blockchain.
- To avoid synchronization problems, queries may be performed on the remote peer using JSON-RPC (HTTPS or SSL/TCP-Socket).

BGPSECx design (Inter-IXP queries)



Secure BGP for Internet Exchange Points - **BGPSECx**



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- Multichain approach to support blockchain.

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  - **(b)** Validating origin using BGPSECx
  - **(c)** Validating the full path using BGPSECx
- For BGPSECx we assume that:
  - Only the 10% largest IXPs use BGPSECx (it represents IXPs with more than 50 ASes, totalizing 4147).
  - Only a random set of X% of peers connected to each IXP uses BGPSECx: X = [1, **10**, 25, **50**, 75, **100**].
- Running each experiment 10 times.

Evaluation: routing dataset

Routing collector points and data volume (1/2)

IXP/Locality	# Updates	# Prefixes
RIPE (Amsterdam/NL)*	1176888	5886175
LINX (London/UK)	642095	3219512
AMS-IX (Amsterdam/NL)	802181	4021230
CIXP/CERN (Geneva/CH)	610684	2711758
VIX (Vienna/AT)	463082	2133931
JPIX (Otemachi/JP)*	141904	590750
NETNOD (Stockholm/SE)	918238	3350961
MIX (Milan/IT)	762713	3288810
NYIIX (New Yourk/US)*	897104	4344049

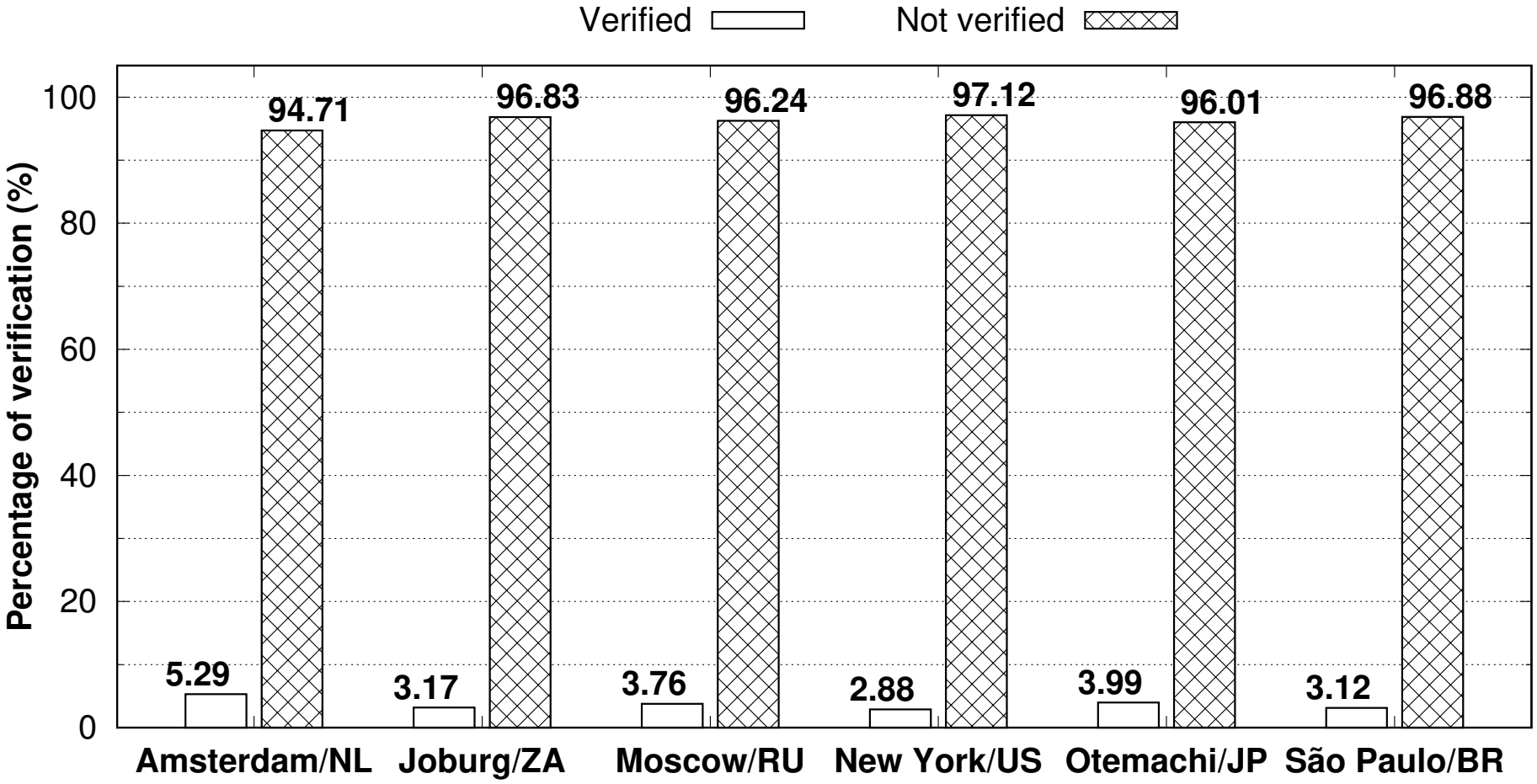
Evaluation: routing dataset

Routing collector points and data volume (2/2)

IXP/Locality	# Updates	# Prefixes
DE-CIX (Frankfurt/DE)	1524949	7004462
MSK/IX (Moscow/RU)*	1314165	4778407
PAIX (Palo Alto/US)	663323	3371273
PTTMetro (São Paulo/BR*	1896335	12324785
NOTA (Maiami/US)	259672	977813
CATNIX (Barcelona/ES)	**84222**	**278400**
NAP/JB (Johannesburg/ZA)*	437222	1820852
SwissIX (Zurich/CH)	**2015867**	**7900807**
FranceIX (Paris/FR)	1607568	7520597

Empirical analysis: simulation results

Verification results of **OA/RPKI** from NL, ZA, RU, JP and BR



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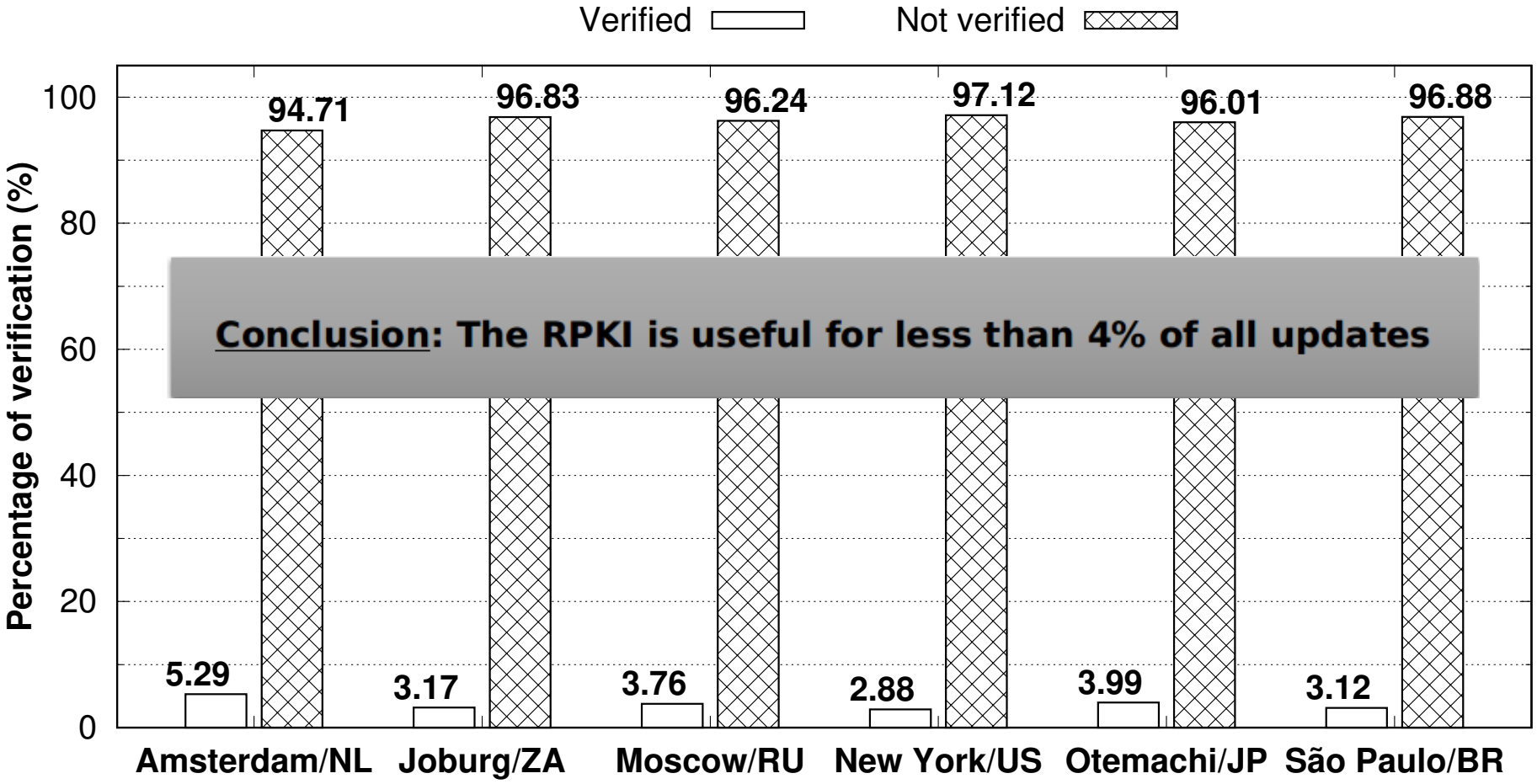

Conclusion: The RPKI is useful for less than 4% of all updates

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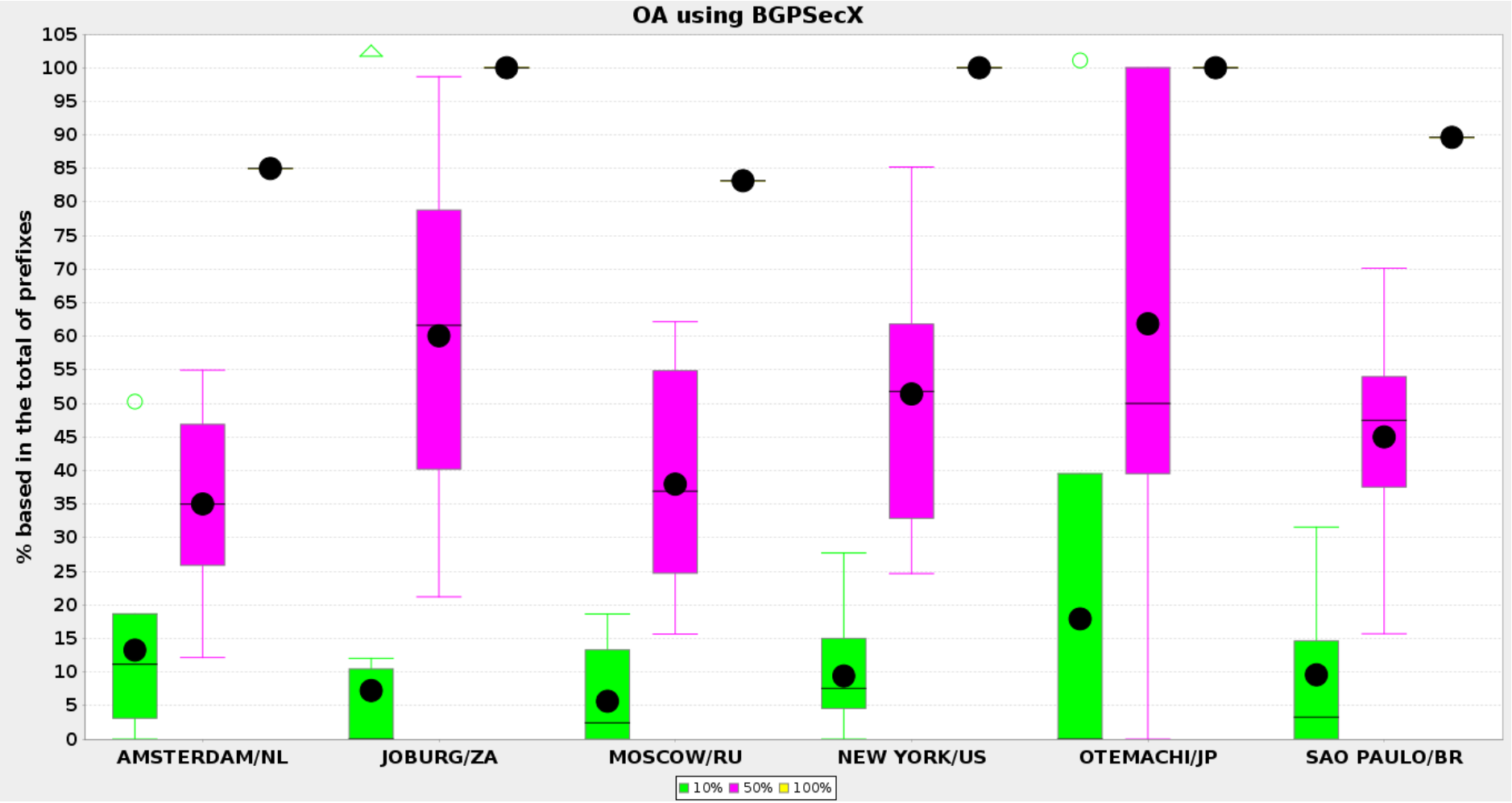

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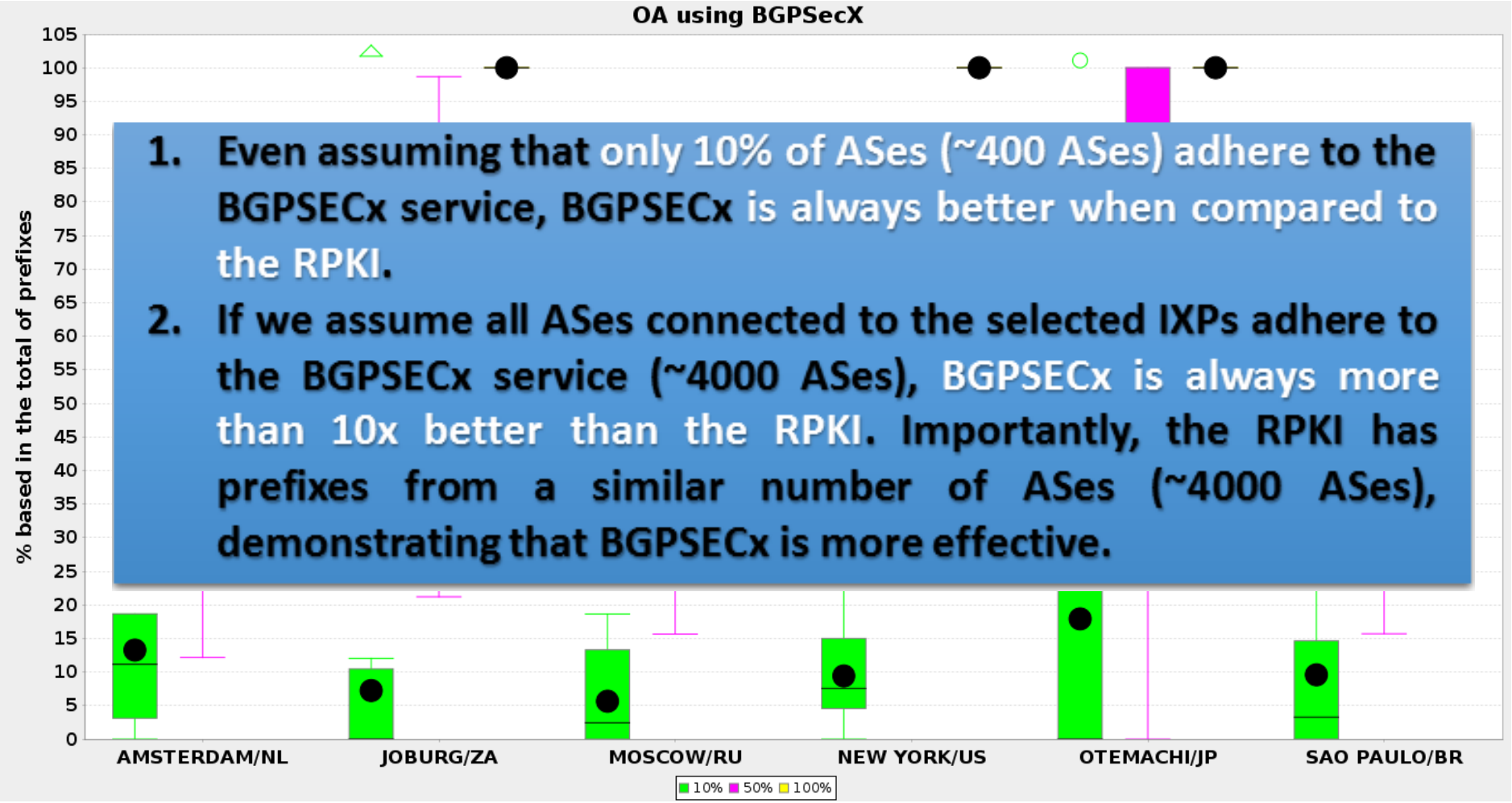

1. Even assuming that only 10% of ASes (~400 ASes) adhere to the BGPSECx service, BGPSECx is always better when compared to the RPKI.
2. If we assume all ASes connected to the selected IXPs adhere to the BGPSECx service (~4000 ASes), BGPSECx is always more than 10x better than the RPKI. Importantly, the RPKI has prefixes from a similar number of ASes (~4000 ASes), demonstrating that BGPSECx is more effective.

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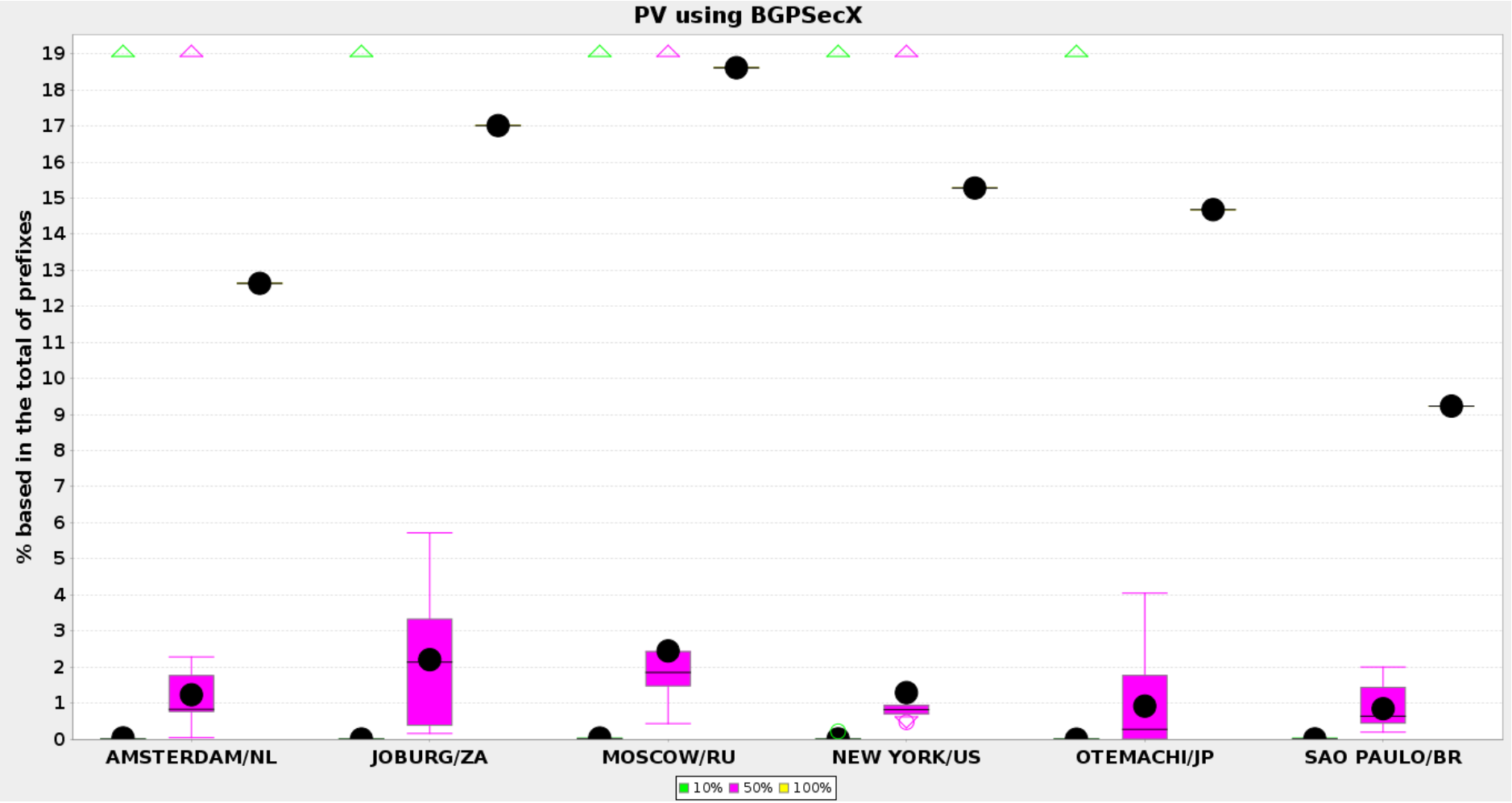
Verification results of **PV/BGPSECx** from NL, ZA, RU, JP and BR



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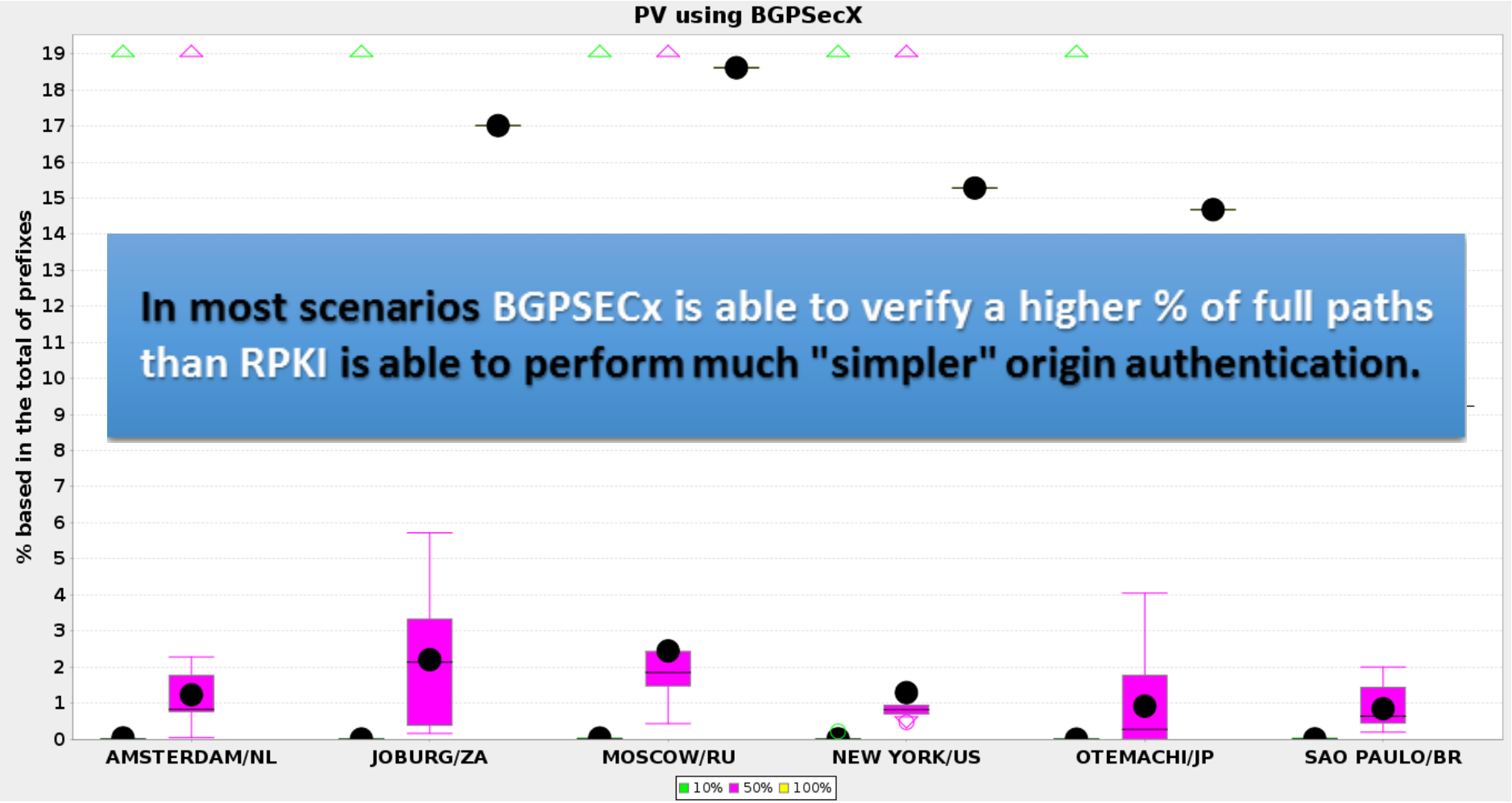

In most scenarios BGPSECx is able to verify a higher % of full paths than RPKI is able to perform much "simpler" origin authentication.

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  (1) They require **changes to BGP**.
  (2) They are **computationally expensive** for routers, and/or;
  (3) They do not give operators **incentives** for deployment.

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  - Solving problem (4) by collaborating and of privacy-preserving smart contracts on top of a blockchain (next step to research).

Thank you!