Towards Practical Private Internet Routing using MPC

Privacy-preserving interdomain routing at Internet scale (PETS'17)

SIXPACK: Securing Internet eXchange Points Against Curious onlooKers (CoNEXT'17)

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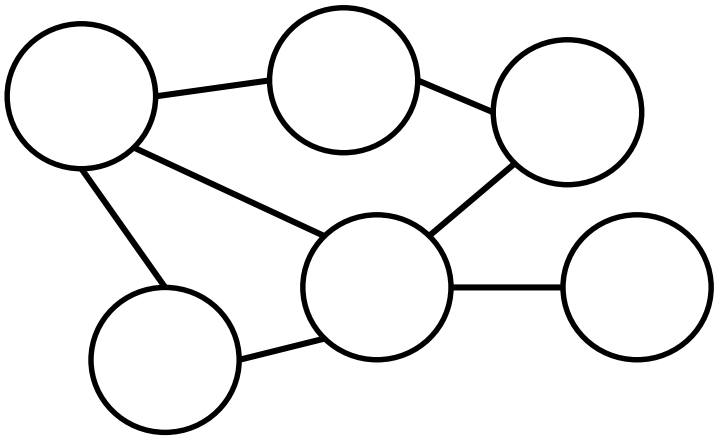
MOTIVATION:
BGP AND ROUTING ON THE INTERNET

Motivation

The Border Gateway Protocol (**BGP**) connects the Internet

- Route *computation* between ISPs
- Route *dispatch* at IXPs



Issues with BGP

- Slow convergence
- Privacy

We use MPC to approach these!

Privacy-Preserving Inter-Domain Routing

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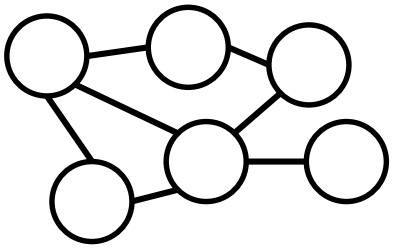
BGP for **computation** of inter-domain routes for the Internet



Original Idea [GSP+, Hotnets'12] – Only toy example, impractical runtime

Our Work [ADS+, PETS'17] – Real-world parameters:

>51.000 autonomous systems (domains) with >196.000 connections

Topology from the CAIDA AS relation dataset

We protect the **relations** between ASes

Customer / Provider or Peering

More generic: Allow routing based on private AS **preferences.**

Privacy-Preserving Inter-Domain Routing

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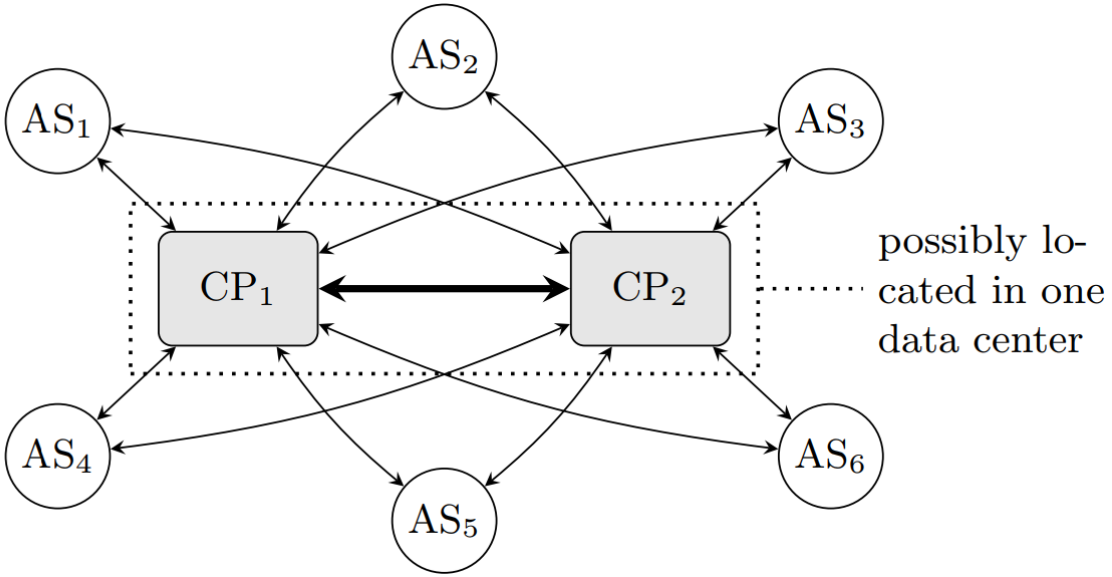
Centralized approach: faster & privacy issues solved by MPC

- 2 computational parties (CPs), running our protocol
- CPs are semi-honest and non-colluding
- Each AS secret-shares his relation info/preferences with the CPs

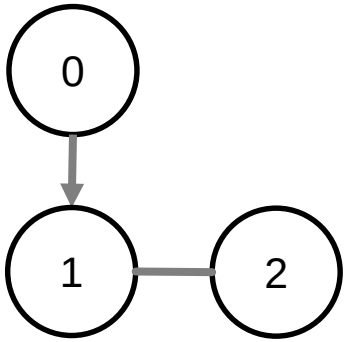


Privacy-Preserving Inter-Domain Routing

Routing based on **relationship** between nodes:

Customers pay *providers* to route traffic

Peers route traffic for free



"*Economically driven*" routing instead of shortest paths

<u>High-level Neighbor Relation Algorithm:</u>

Plaintext input: **Topology, Target AS** – Private input: EP-**Relations**

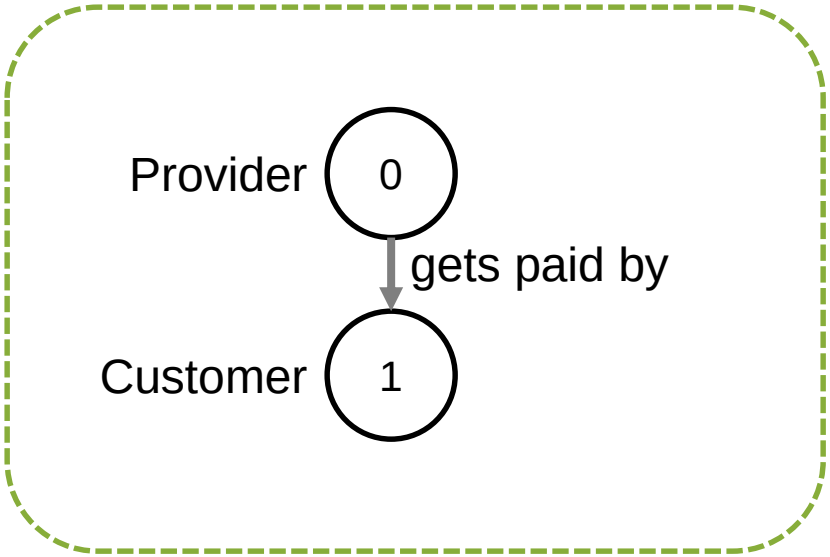
10 iterations for customer relation hops

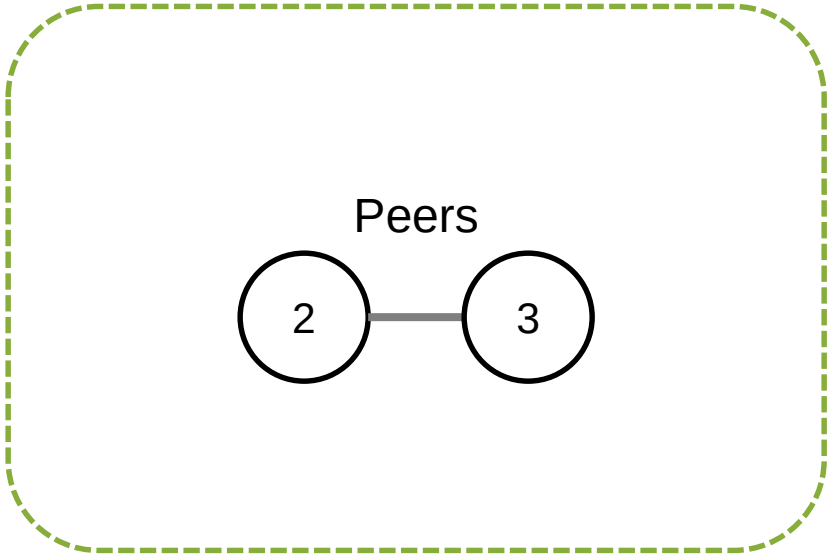
1 iteration for peer hops

10 iterations for provider hops

Private output: for every AS the next hop to target AS

BGP Example – Notation

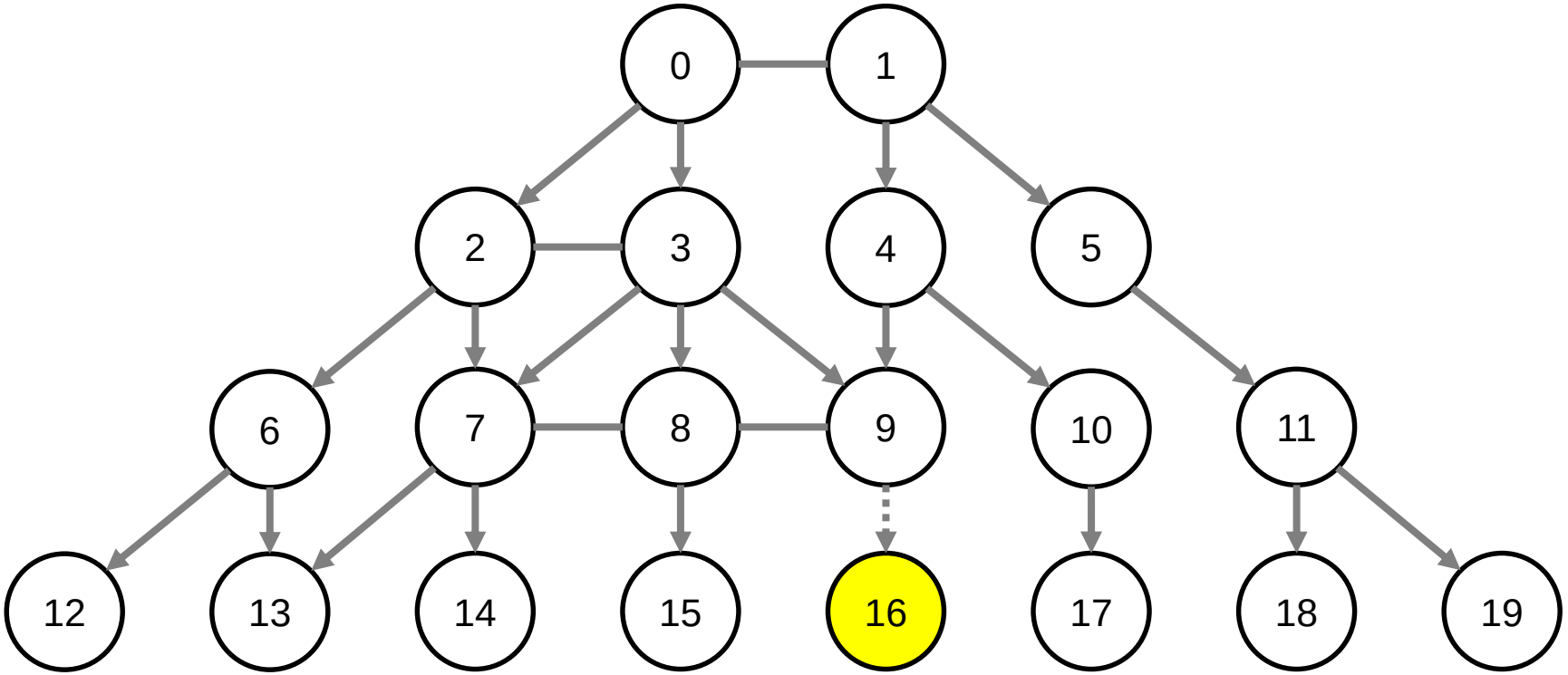




BGP Example

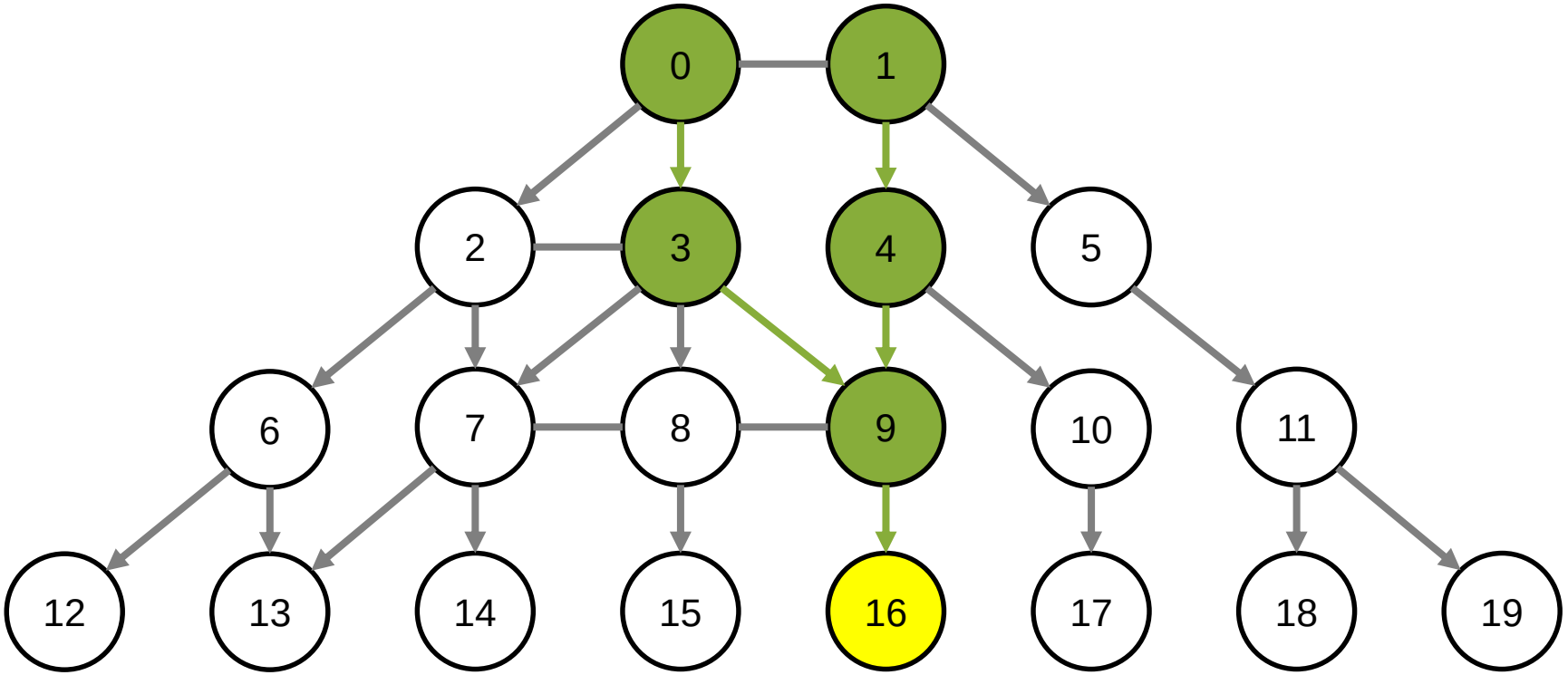
Public network topology

Node 16 is added



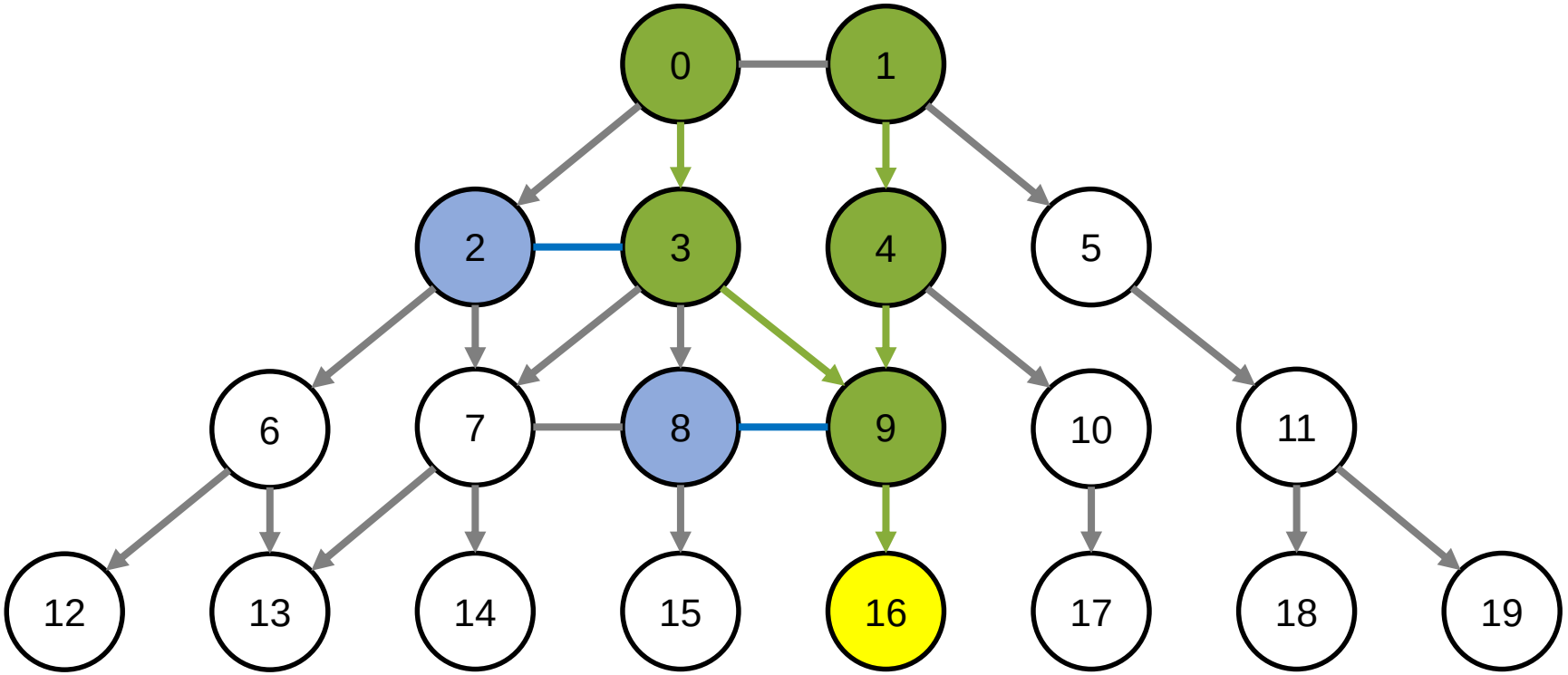
BGP Example

Routes through **customers** to 16



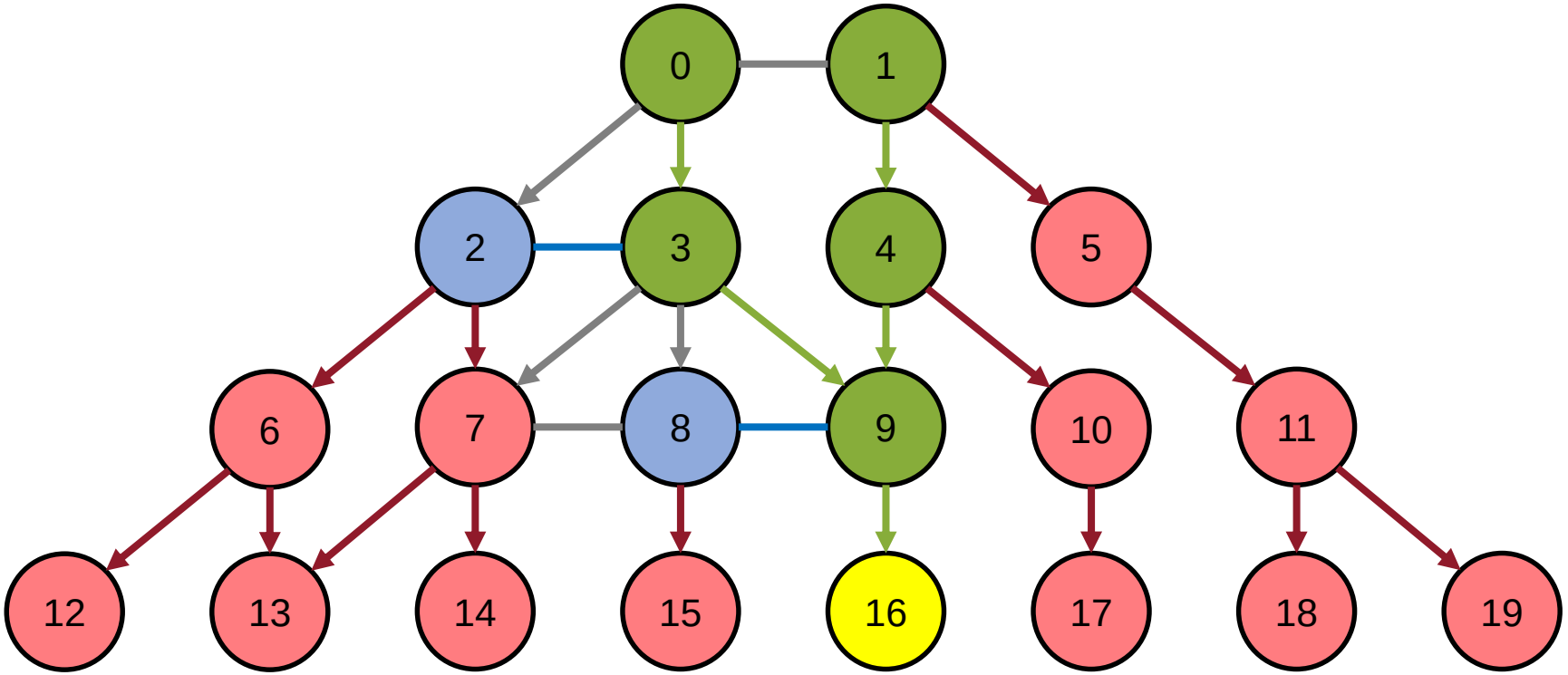
BGP Example

Routes through **peers** to 16



BGP Example

Routes through **providers** to 16



Preference-Based Routing

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Routing based on **export policy** and **preference** between nodes:

ASes decide which routes are *published (exported)*

ASes have *preferences* for their neighbors

<u>High-level Neighbor Preference Algorithm:</u>

Plaintext input: **Topology, Target AS** – Private input: **EP - Preferences**

21 Iterations:

for all ASes:

for all of the ASes neighbors:

find highest **preference** neighbor with **published** route to **target**

Private output: for every AS next hop to target AS

Privacy-Preserving BGP – Circuit

Algorithm implemented as Boolean circuit evaluated with GMW

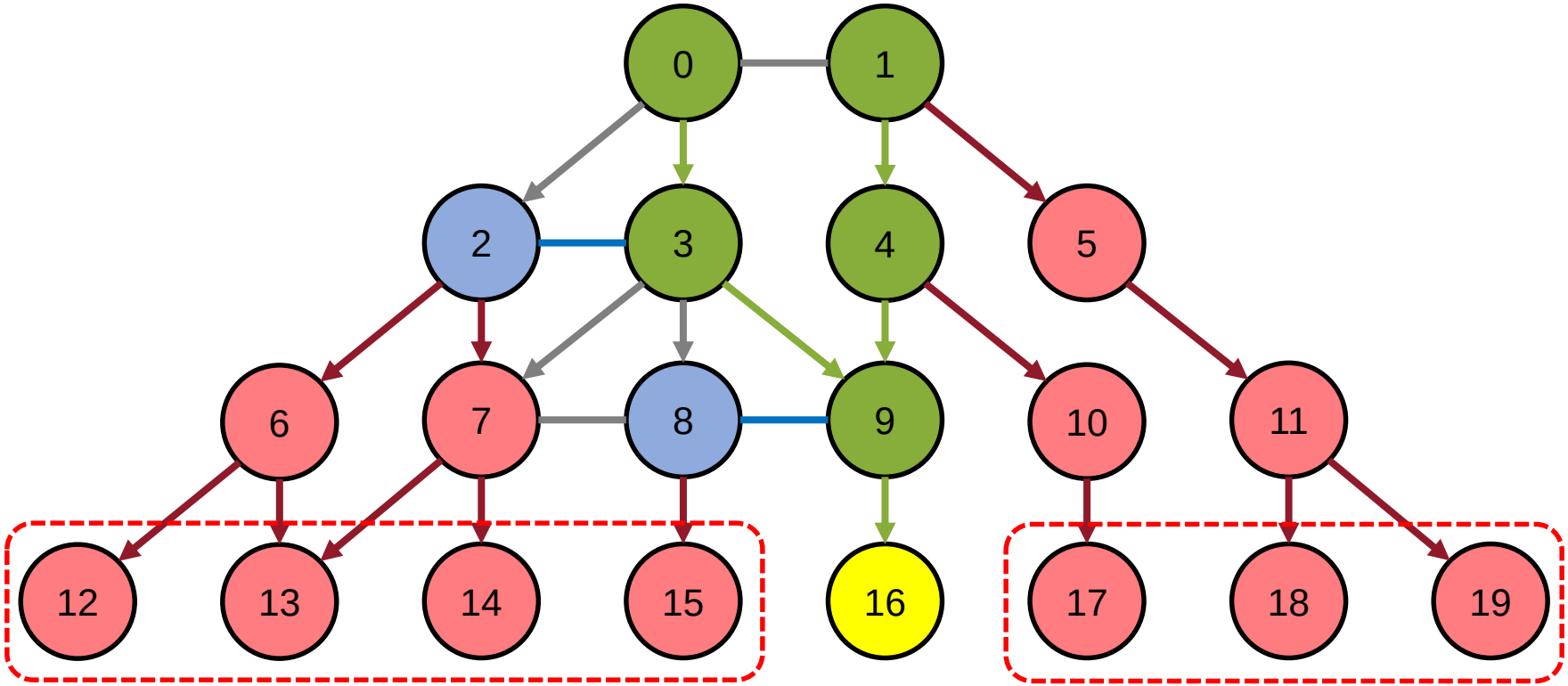
- SIMD operations
  - 1 Operation for multiple bits in parallel
  - Process all nodes in parallel
- Efficient MUX with vector ANDs in GMW
  - only 1 OT for n-bit values
- Tree structure for depth-efficient parallel evaluation
- ASes evaluated in groups of similar degree

Algorithmic optimization: Exclude stub nodes

BGP Stub Nodes

Stub nodes: Nodes that are *only* customers, not peers, not providers.

85% of all ASes!



CAIDA BGP Statistics 1998 – 2016

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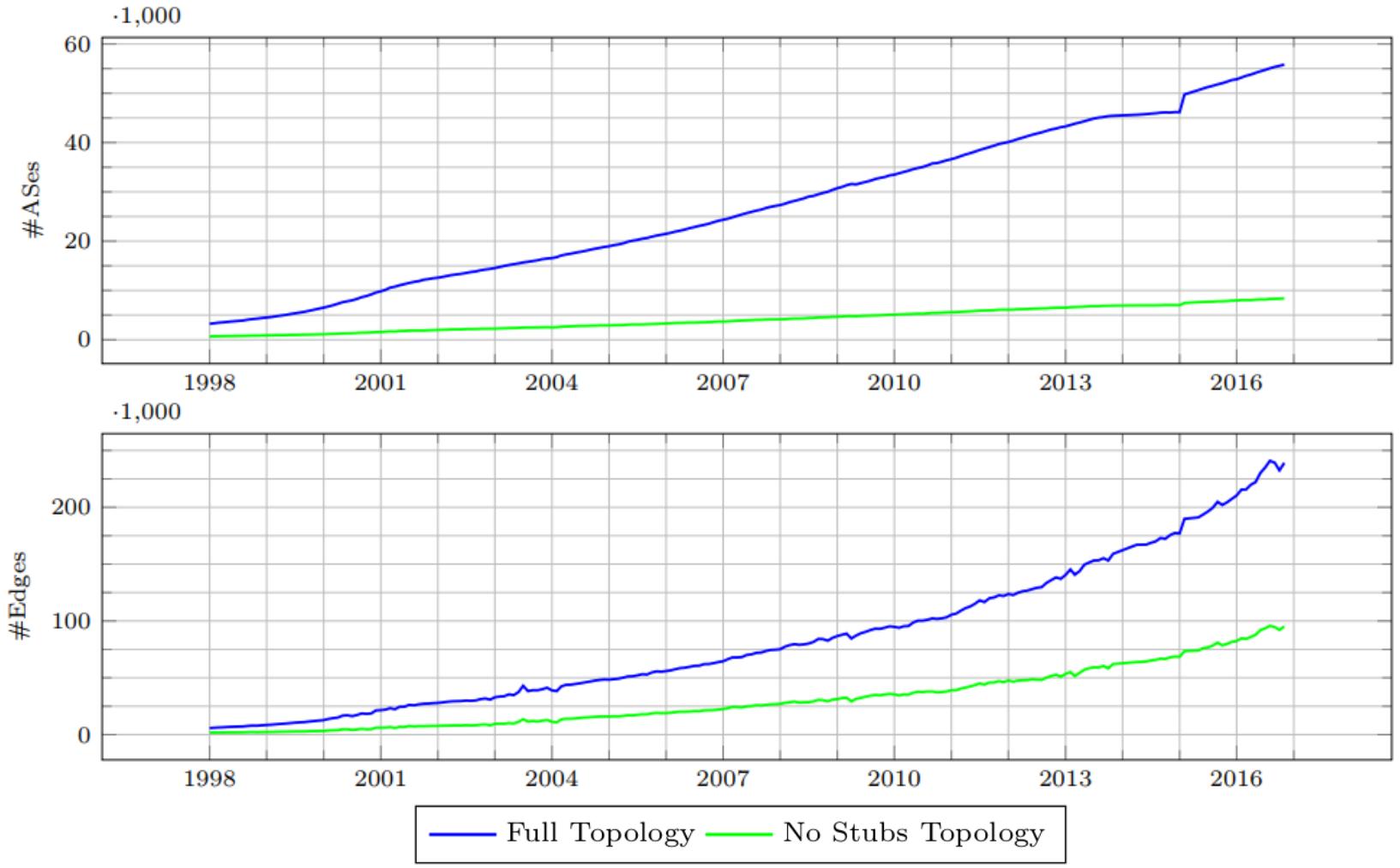

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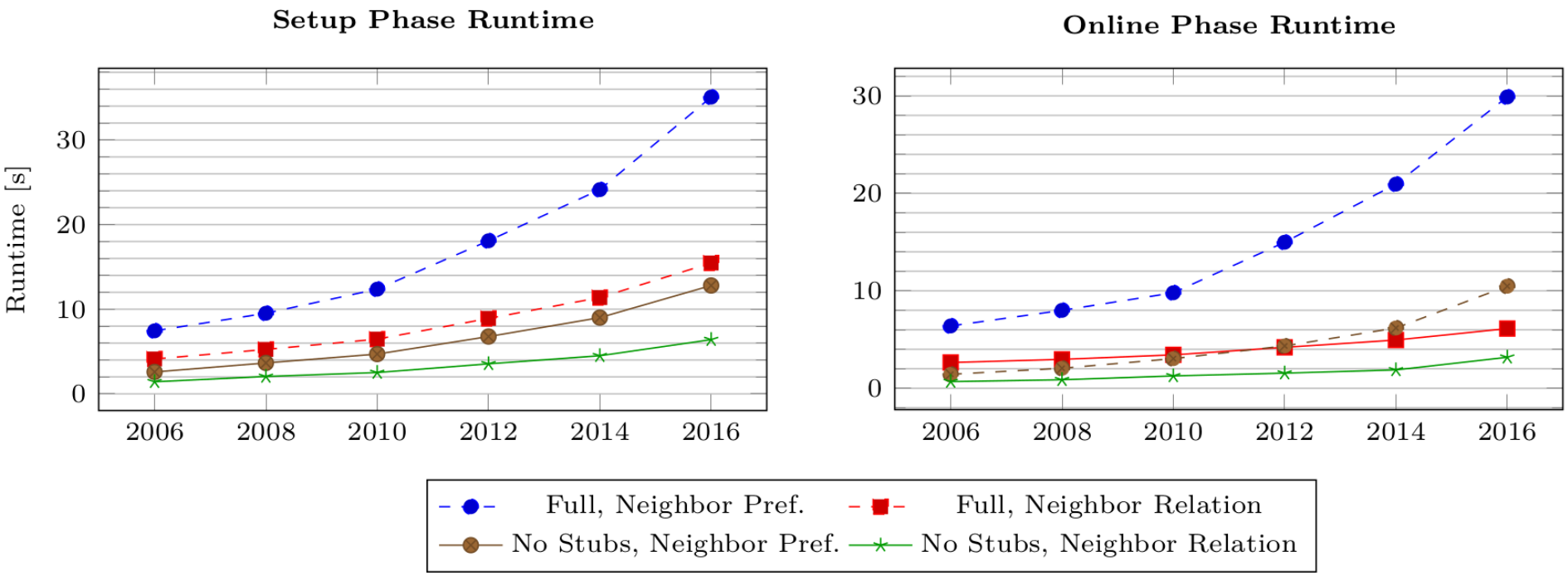
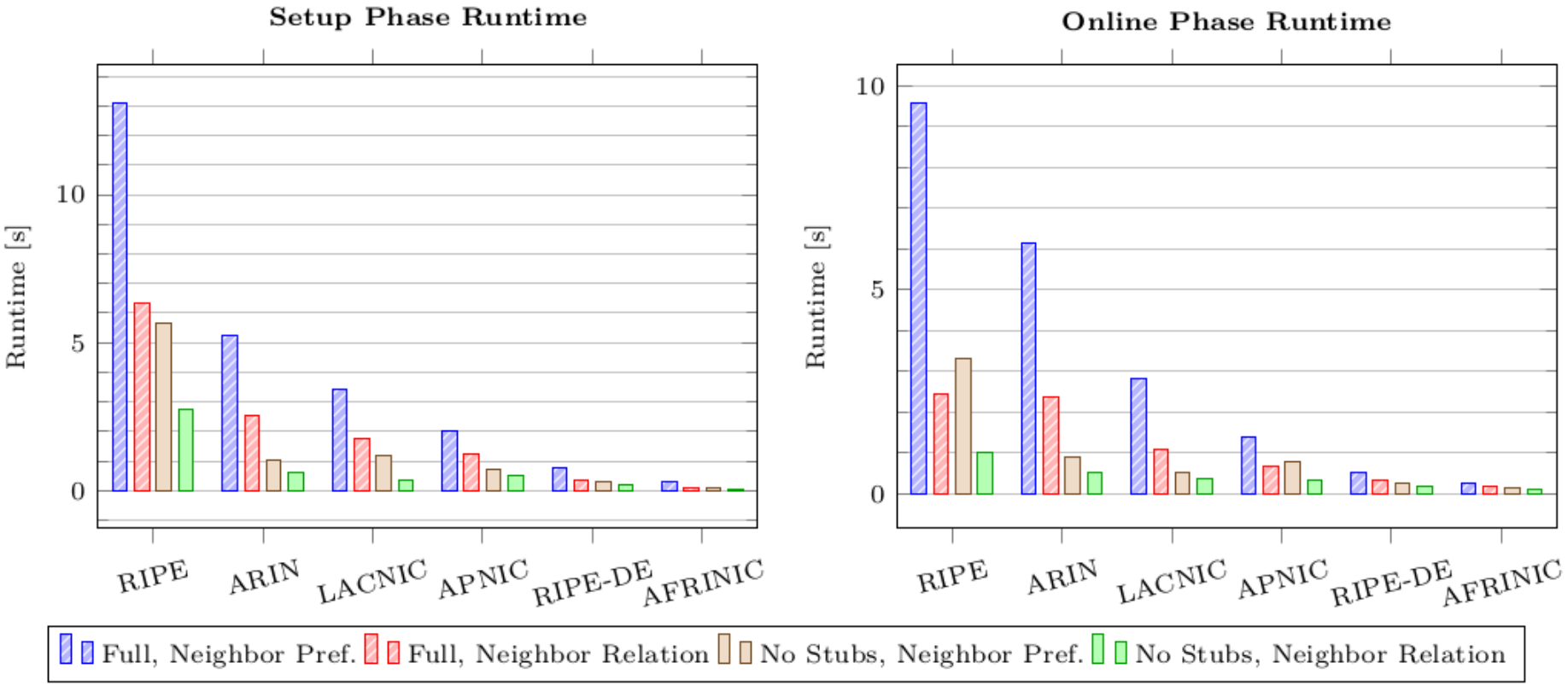
BGP MPC Benchmarks – Internet Topology



BGP MPC Benchmarks – RIR Topology



Possible Deployment

Instantiate one party with a somewhat trustworthy entity:

RIPE, DENIC, NANOG, etc. – often co-located at IXPs

Parallel Execution for fault tolerance / robustness

Software-Defined-Networking for deployment

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[C**D**CSS, CoNEXT'17]

SIXPACK – PRIVACY-PRESERVING ROUTE DISPATCHING AT IXPS

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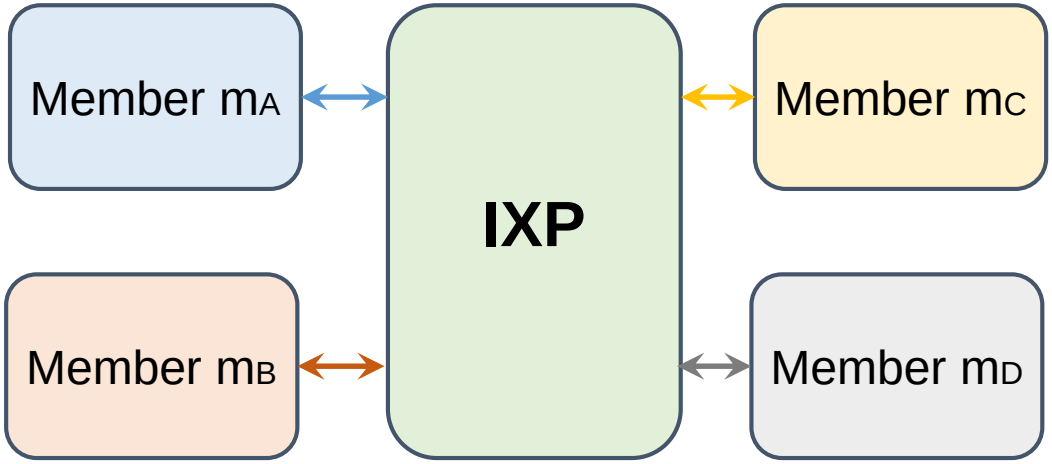
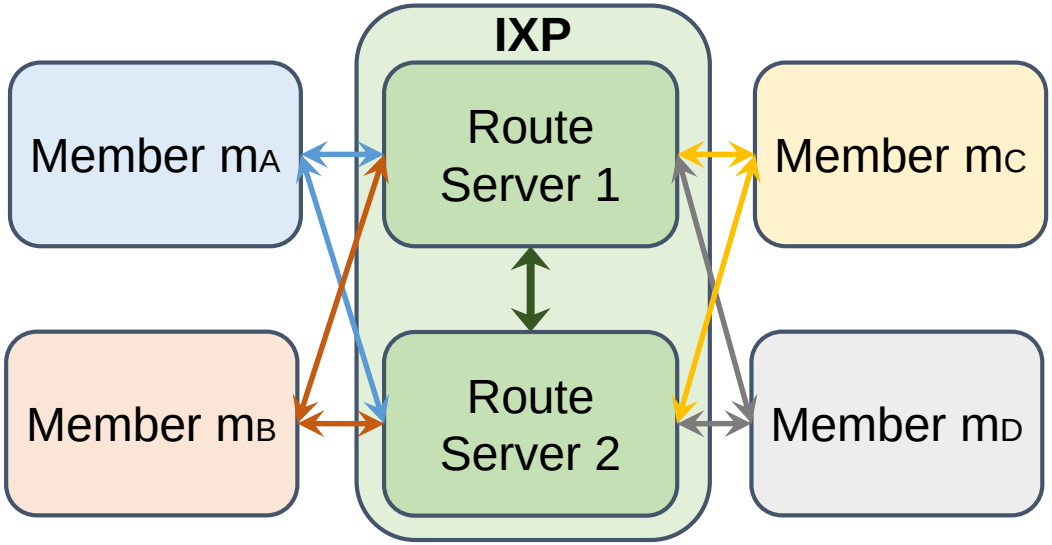
Internet Exchange Points (IXPs)



Members (ASes) connect to IXP to exchange routing information via BGP.
IXP dispatches routes based on export policies & auxiliary information.

Problem: Export policies & preferences are sensitive business information!
Survey with 119 network operators confirm privacy & control issues.

SIXPACK

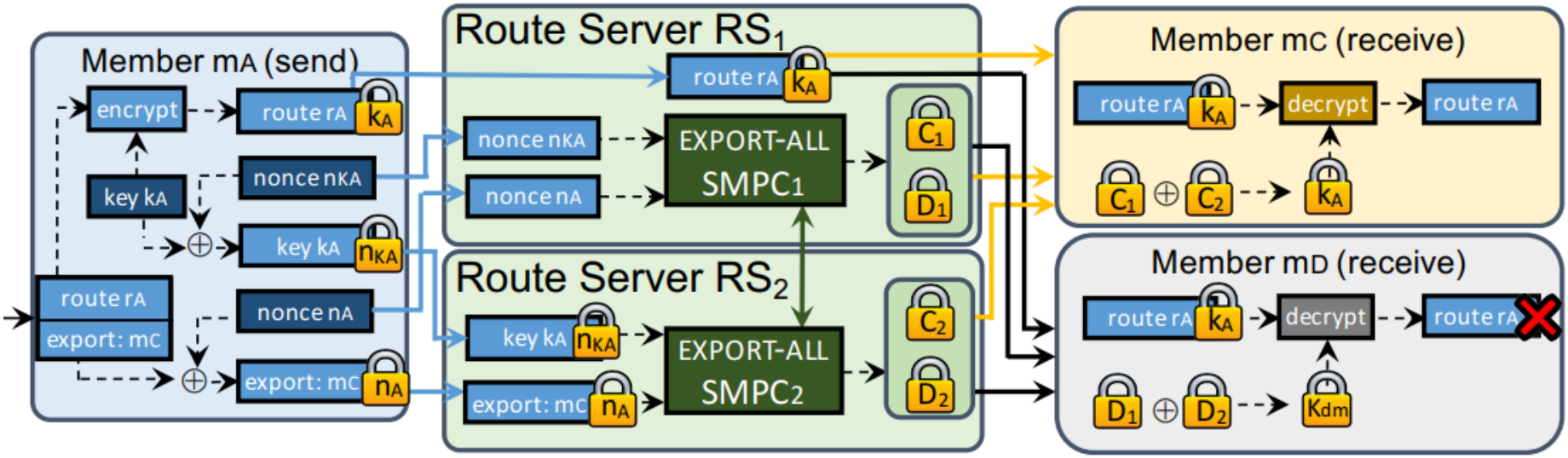


SIXPACK: **S**ecuring **I**nternet e**X**change **P**oints **A**gainst **C**urious onloo**K**ers.

We split the IXP into (at least) 2 computational parties than run SIXPACK.

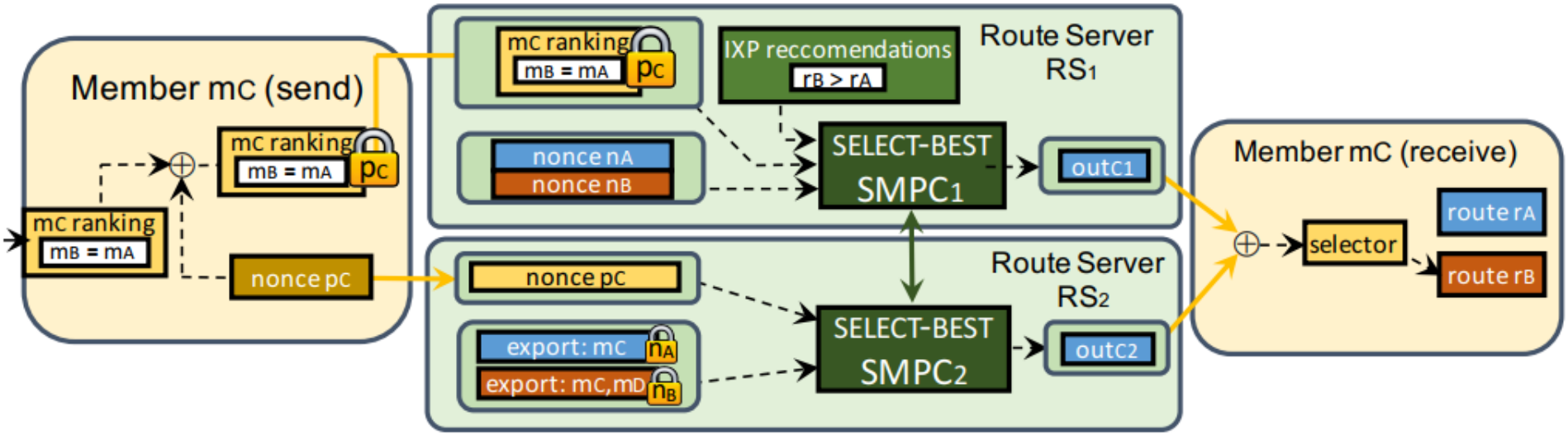
Route servers are semi-honest and non-colluding.

SIXPACK: EXPORT-ALL Approach



Dispatch all routes that are allowed by the export policy of Member mA

SIXPACK: SELECT-BEST Approach



Goal: Find a single *best route* for every member

Based on the private combination of

- Export Policy (as before)
- Local Preference of Members
- Congestion and other Quality of Service info from the IXP

SIXPACK: Implementation

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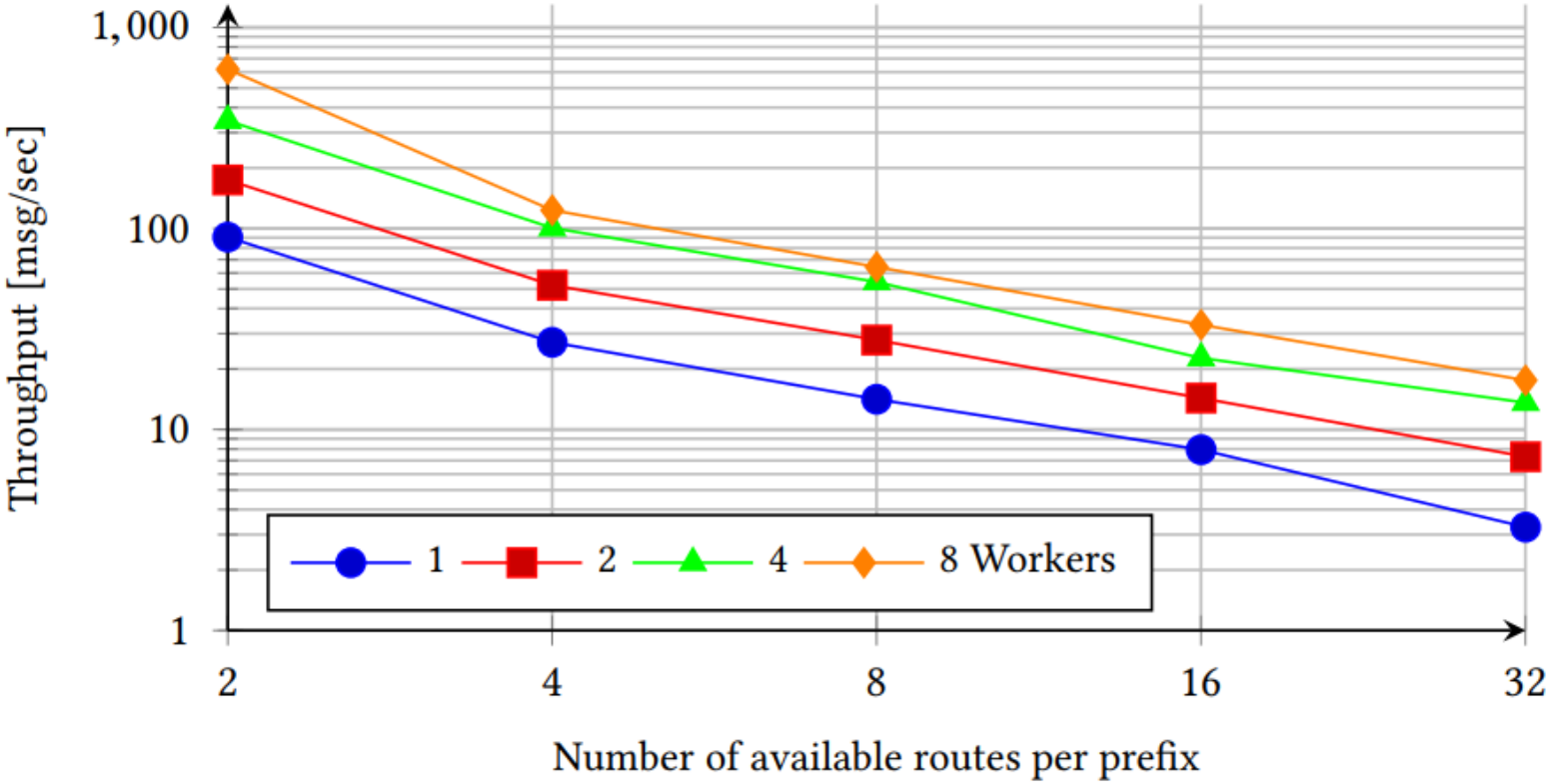
MPC Implementation using the GMW protocol in ABY

Demonstrator in Python that simulates network members and their route announcements and withdrawals

Simulation based on a network trace from one of the largest IXPs in the world (750 members, ~10 BGP updates / sec)

SIXPACK: Runtimes



MPC implementation ready for **real-time** application!

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[**D**SZ, NDSS'15]

ABY – A FRAMEWORK FOR IMPLEMENTING MPC PROTOCOLS

ABY – A Framework for Efficient Mixed-Protocol Secure Two-Party Computation

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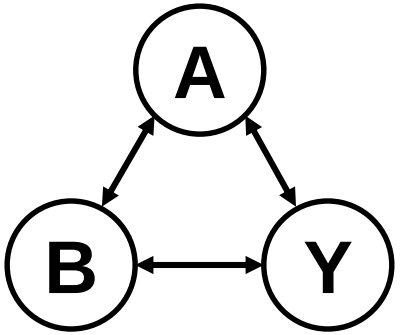
Framework for hybrid secure 2-party computation

Efficient Mixed-Protocol Secure Computation:

Arithmetic Sharing

Boolean Sharing (with the GMW protocol)

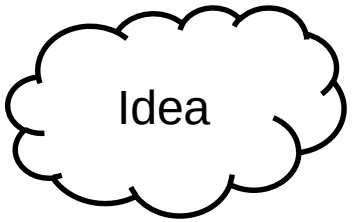
Yao‘s Garbled Circuits

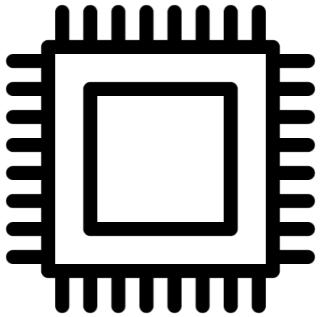


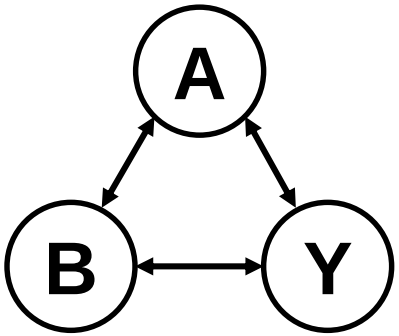
Separate Setup Phase (precomputable) and Online Phase

ABY – Development

Function ⇨ Circuit ⇨ Protocols ⇨ Optimizations







OT-Extension
Efficient Garbling
Fast Conversion
…

ABY – The Framework

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Open-source C/C++ framework:

encrypto.de/code/ABY

Many recent optimizations included

Abstracts from underlying circuit and protocol details

- Many building blocks already included: `ADD`, `MUX`, `MIN`, …

Efficient conversion between protocols, based on OT

Built-in performance analysis

Continuously improved and extended

Outlook

Security against malicious (active) Adversaries

Secure *Multi*-Party Computation (*n*>2 parties)

Summary

Privacy-Preserving **BGP Route Computation** at Internet-scale

Privacy-Preserving **Route Dispatching** at IXPs at real-world scale with practical performance

The **ABY framework** as a tool for implementing MPC protocols

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Thanks for your attention!

Questions?

Contact: encrypto.de

References

[ADS+17] – G. Asharov, D. Demmler, M. Schapira, T. Schneider, G. Segev, S. Shenker, and M. Zohner. **Privacy-preserving interdomain routing at Internet scale**. *Proceedings on Privacy Enhancing Technologies (PoPETs)*, 2017(3)

[CDC+17] M. Chiesa, D. Demmler, M. Canini, M. Schapira, and T. Schneider. **SIXPACK: Securing Internet eXchange Points Against Curious onlooKers.** In *13. International Conference on emerging Networking EXperiments and Technologies (CoNEXT'17)*

[DSZ15] – D. Demmler, T. Schneider, and M. Zohner. **ABY - a framework for efficient mixed-protocol secure two-party computation**. In *22. Annual Network and Distributed System Security Symposium (NDSS'15)*

[GSP+12] D. Gupta, A. Segal, A. Panda, G. Segev, M. Schapira, J. Feigenbaum, J. Rexford, and S. Shenker. **A new approach to interdomain routing based on secure multi-party computation.** In *ACM Workshop on Hot Topics in Networks (HotNets'12)*