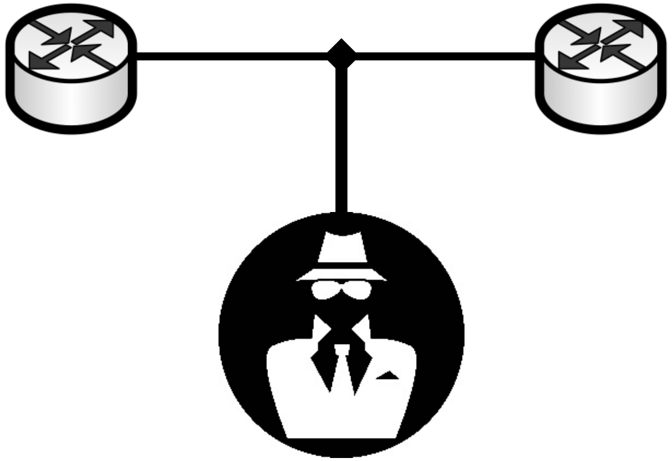
iTAP: In-network Traffic Analysis Prevention using Software-Defined Networks

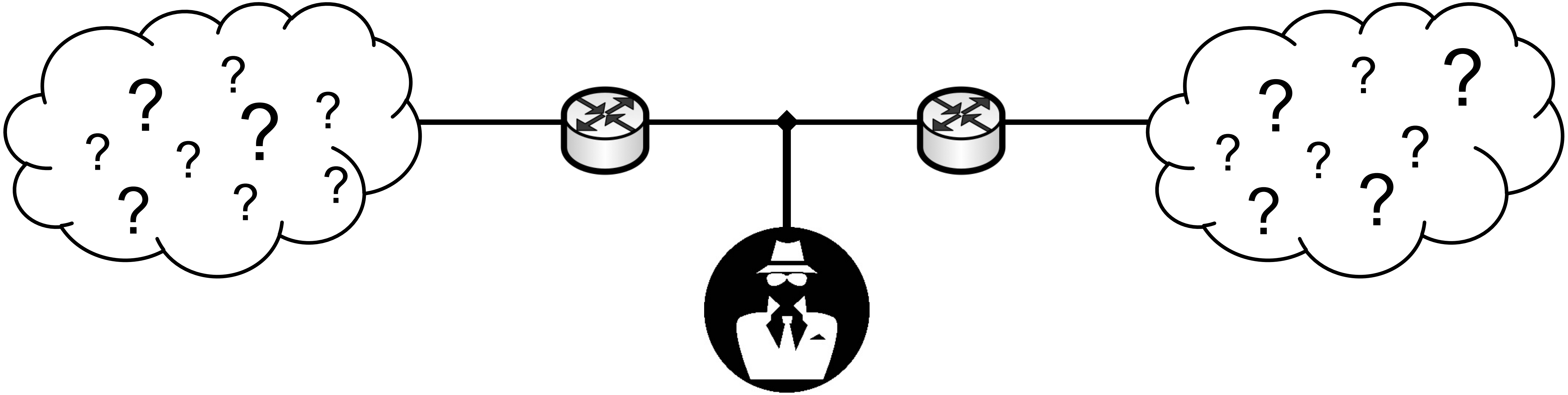
Roland Meier, David Gugelmann, Laurent Vanbever

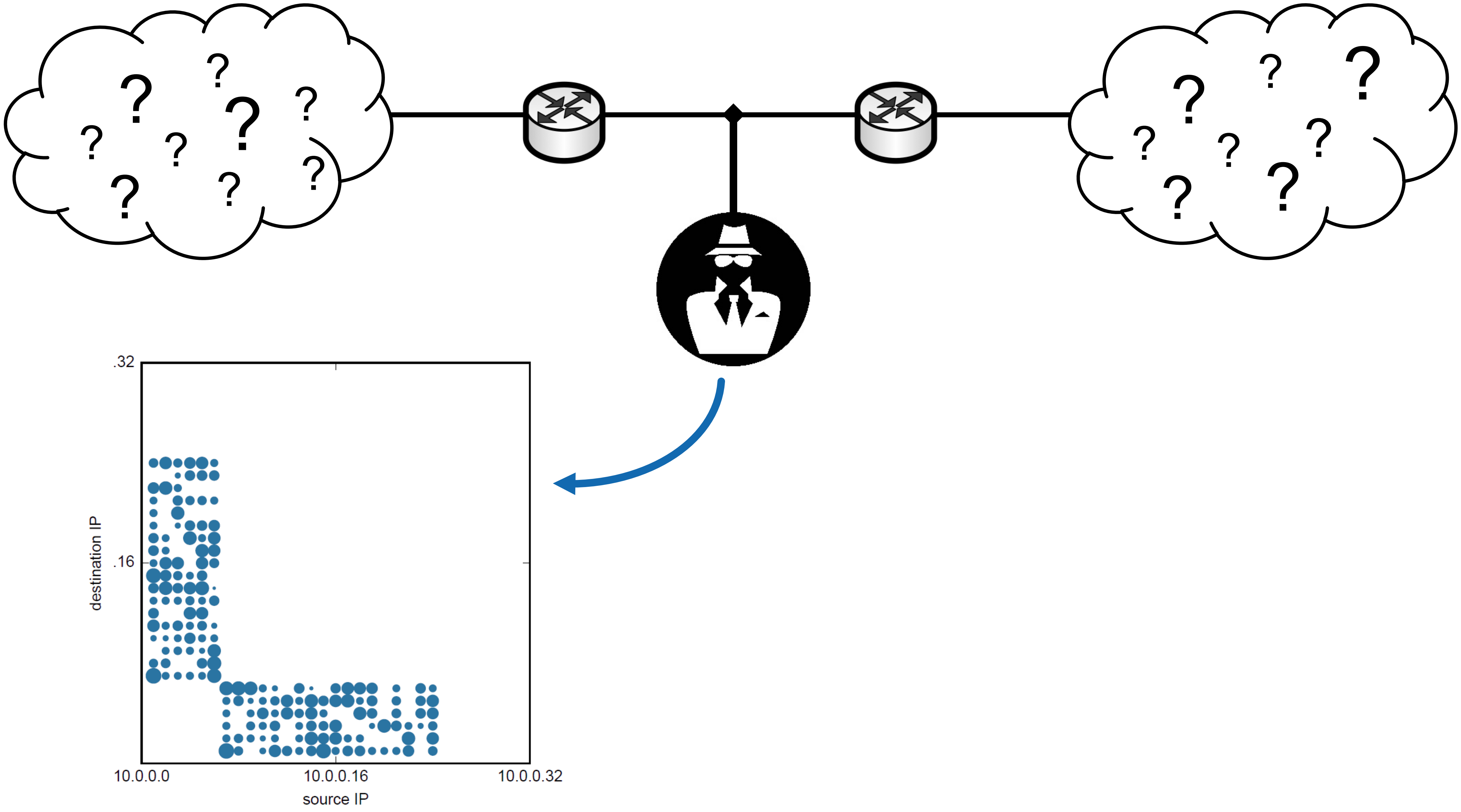
https://itap.ethz.ch

SDN Switzerland, 8th SDN Workshop.
Zürich, CH (June 2017).

ETH zürich



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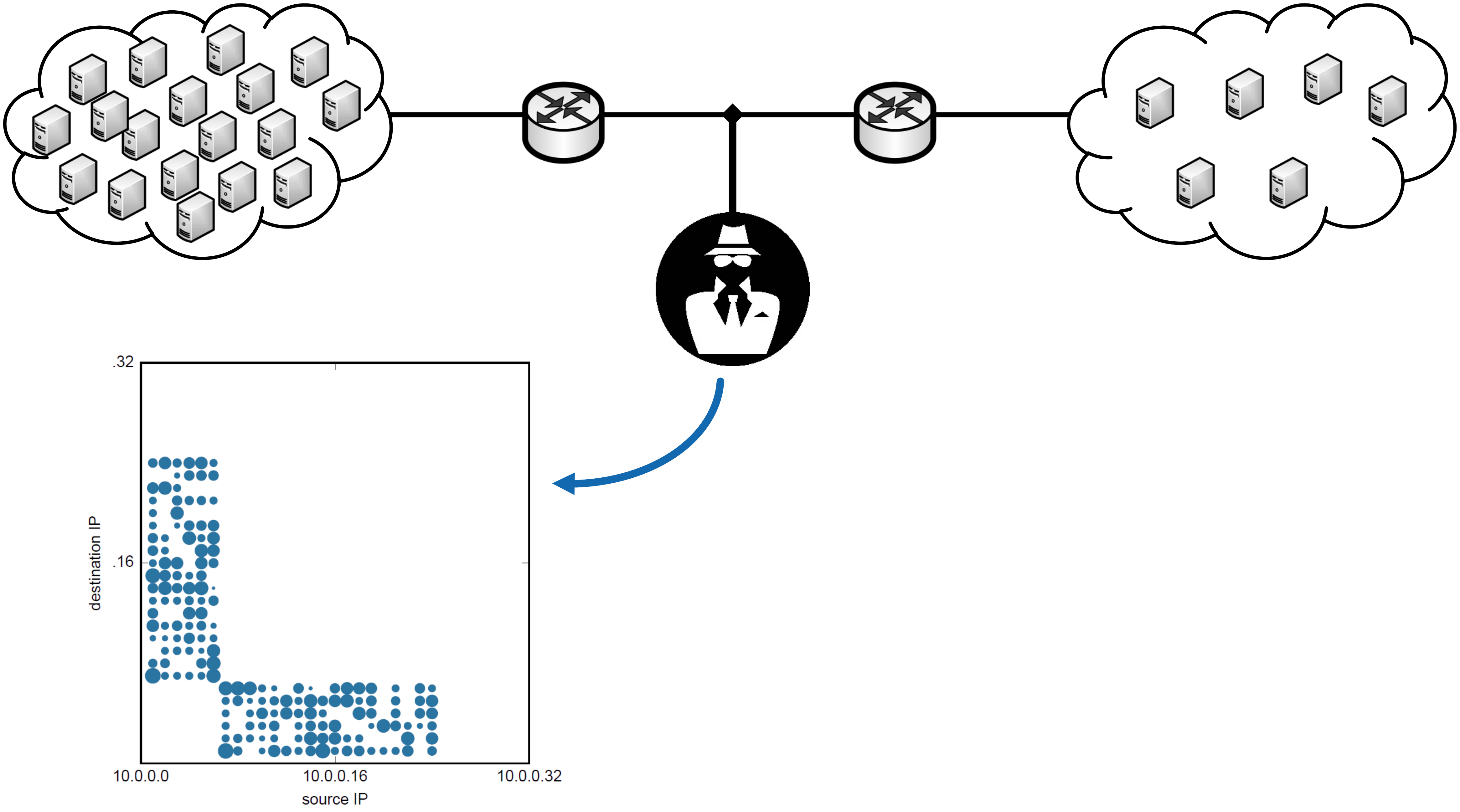
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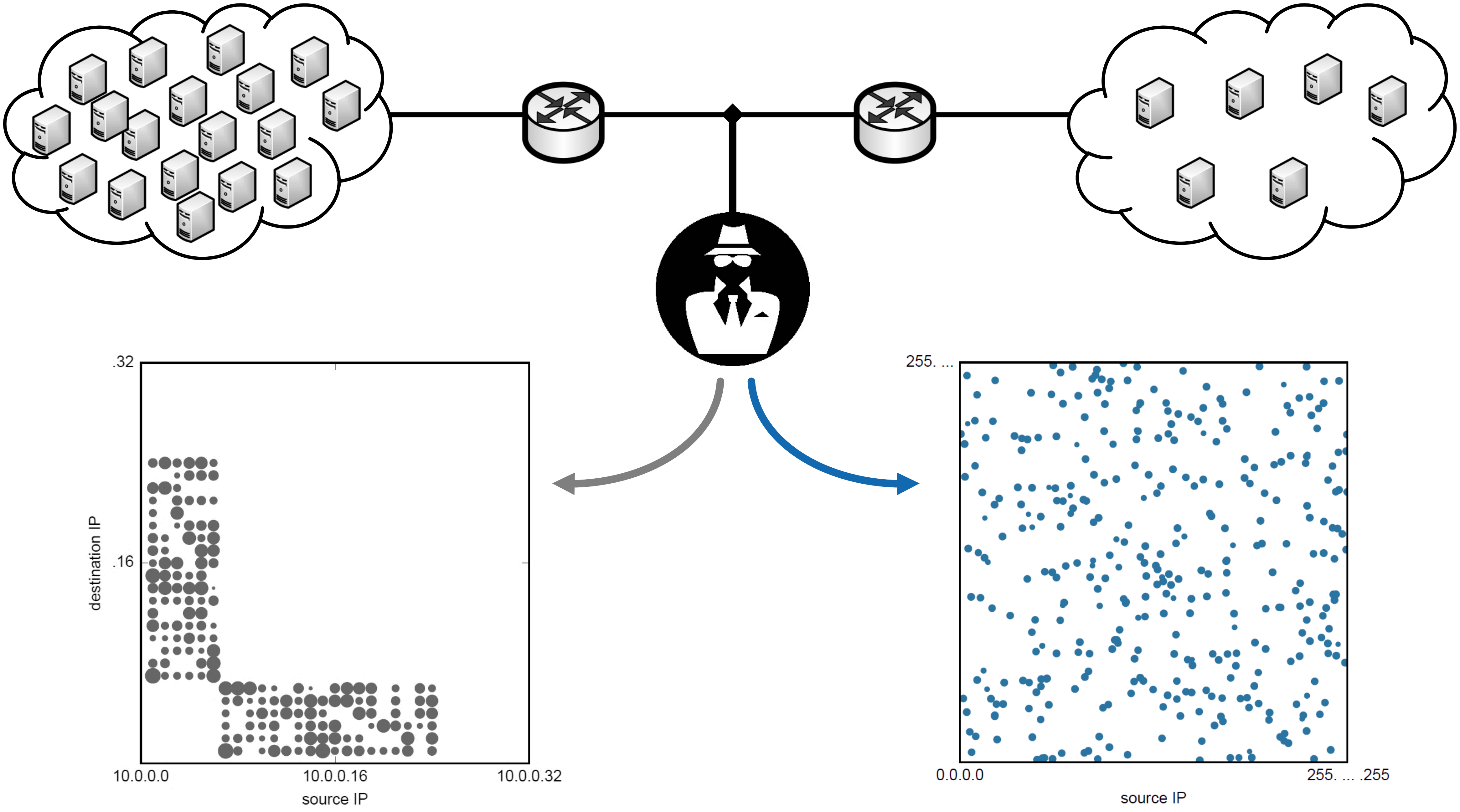
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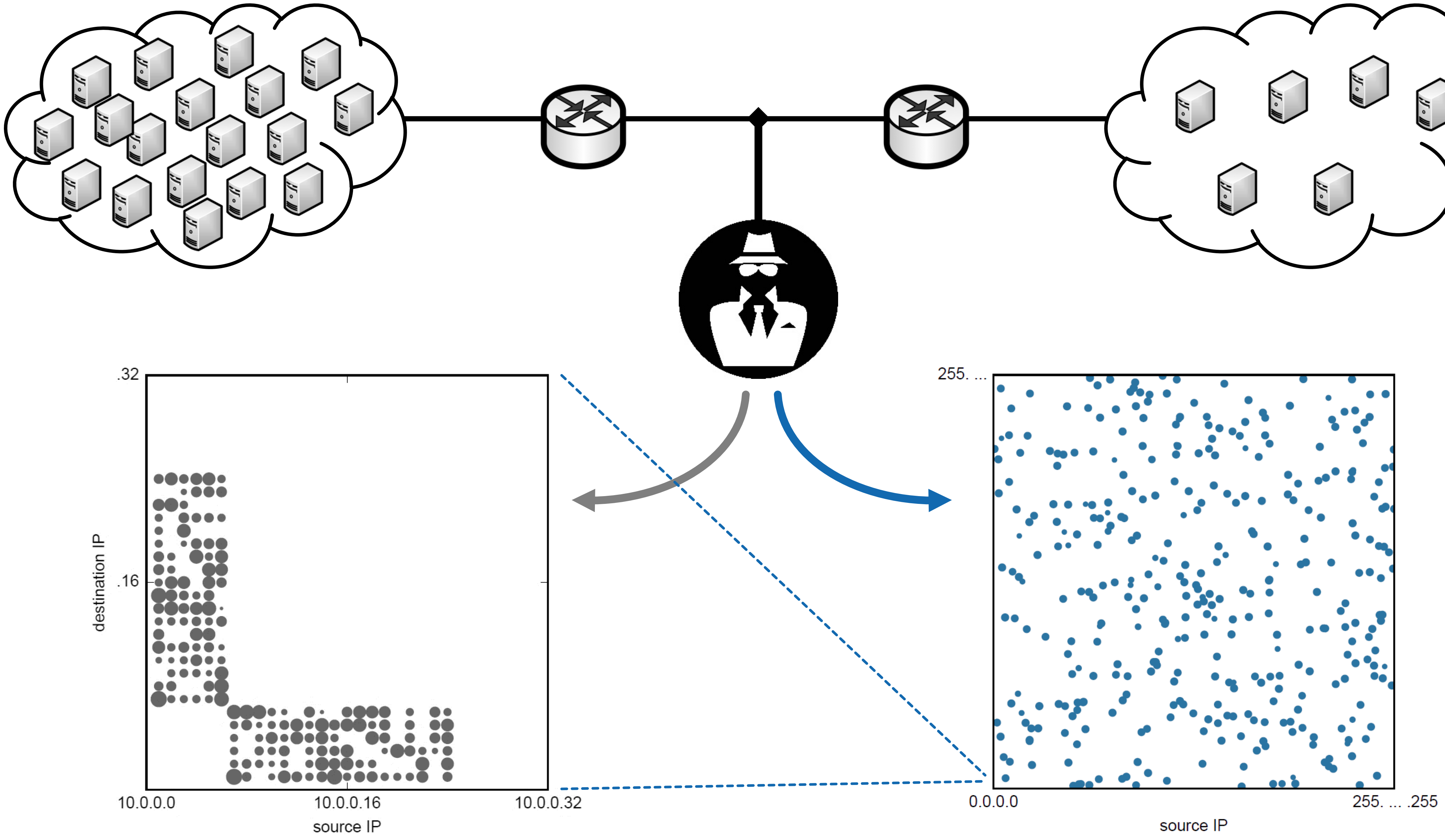
source IP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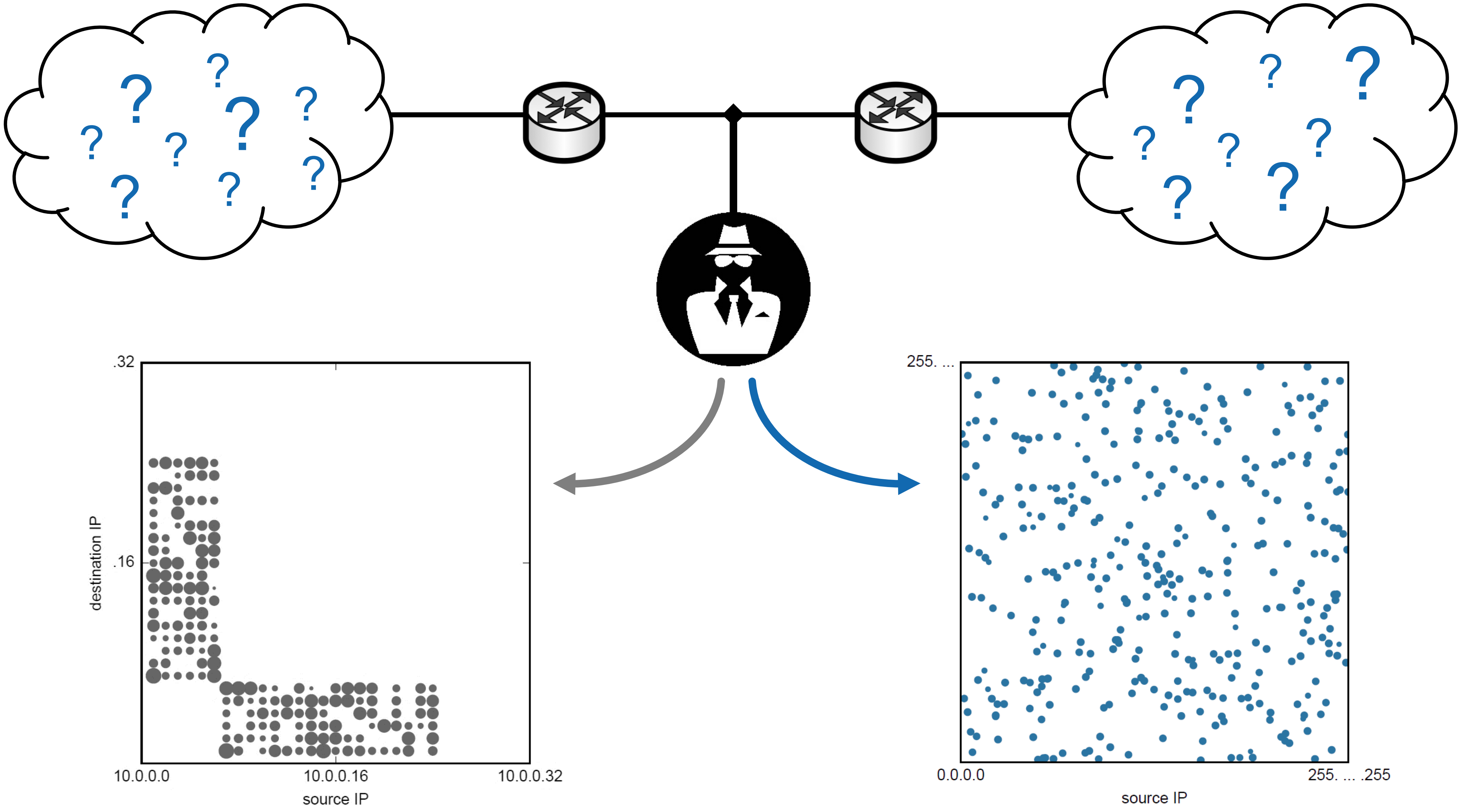
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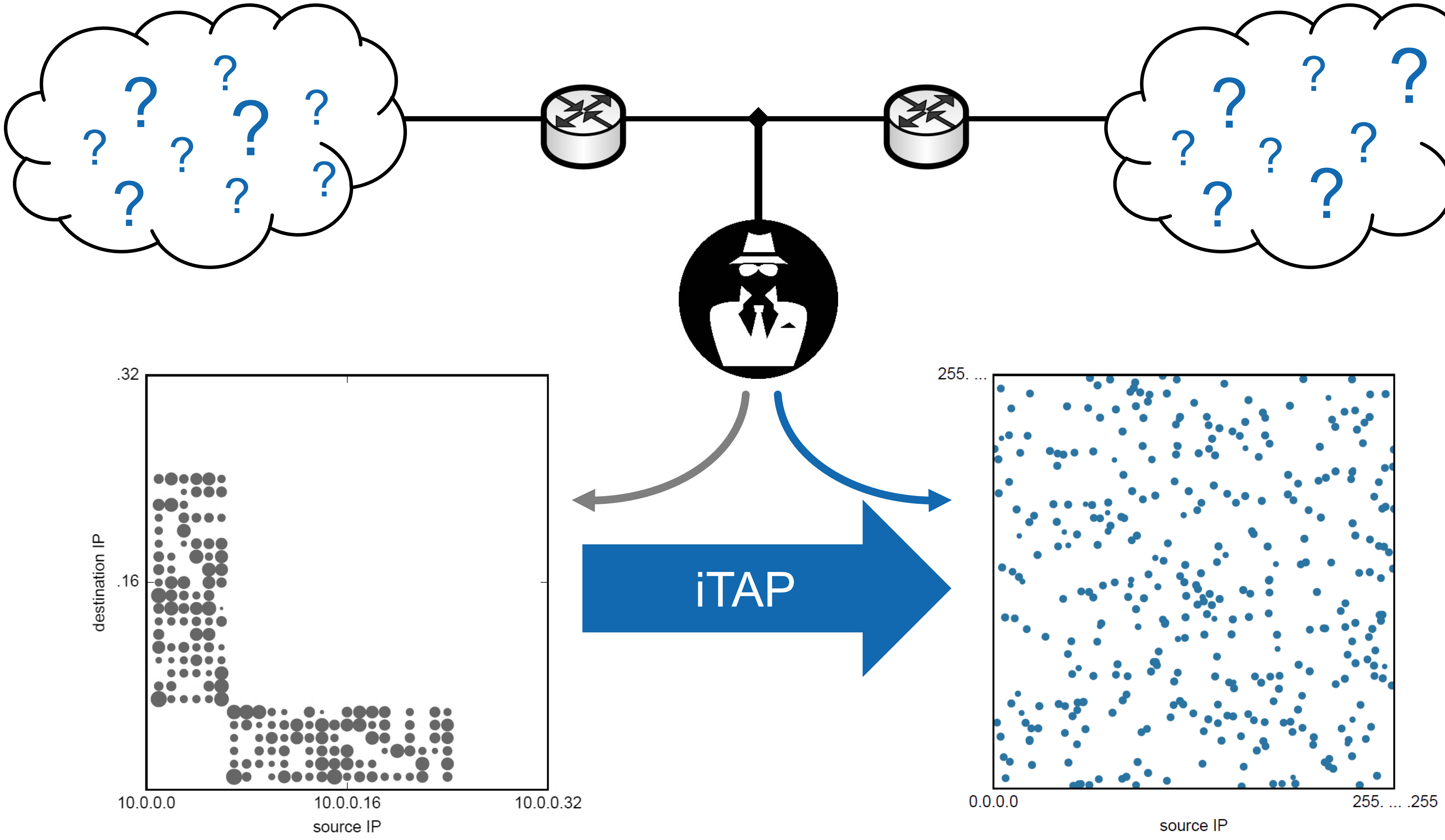
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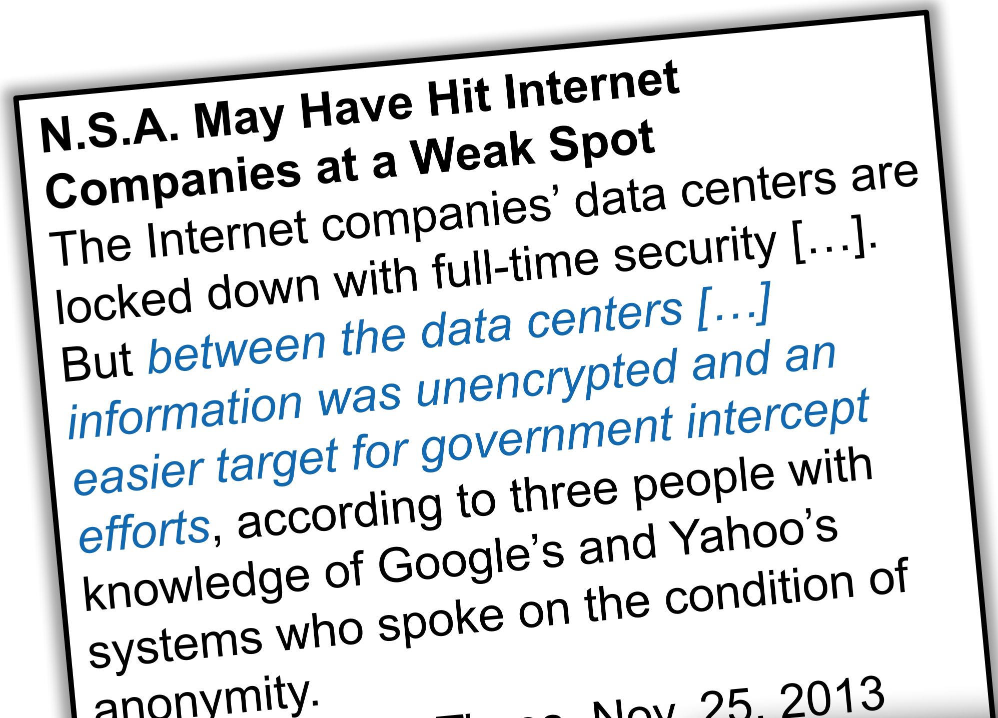
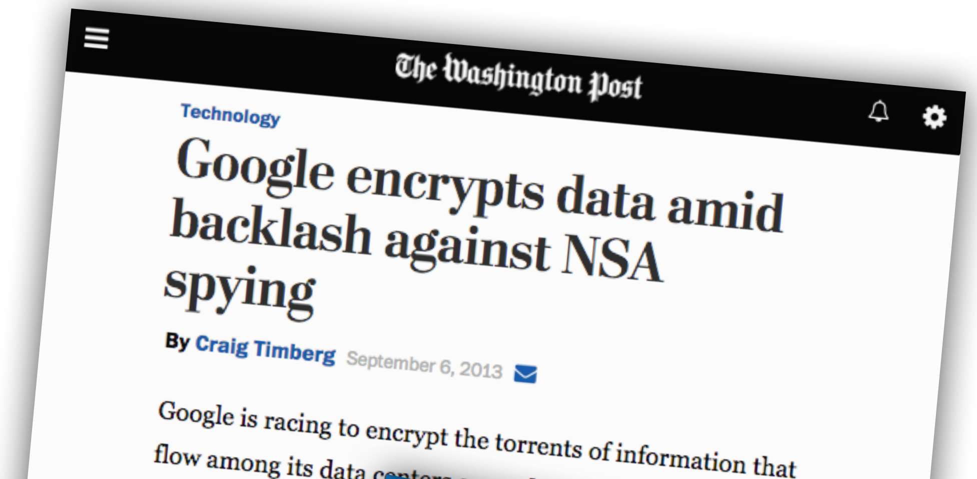
iTAP



N.S.A. May Have Hit Internet Companies at a Weak Spot

The Internet companies' data centers are locked down with full-time security […]. But *between the data centers […] information was unencrypted and an easier target for government intercept efforts*, according to three people with knowledge of Google's and Yahoo's systems who spoke on the condition of anonymity.

- The New York Times, Nov. 25, 2013



Technology

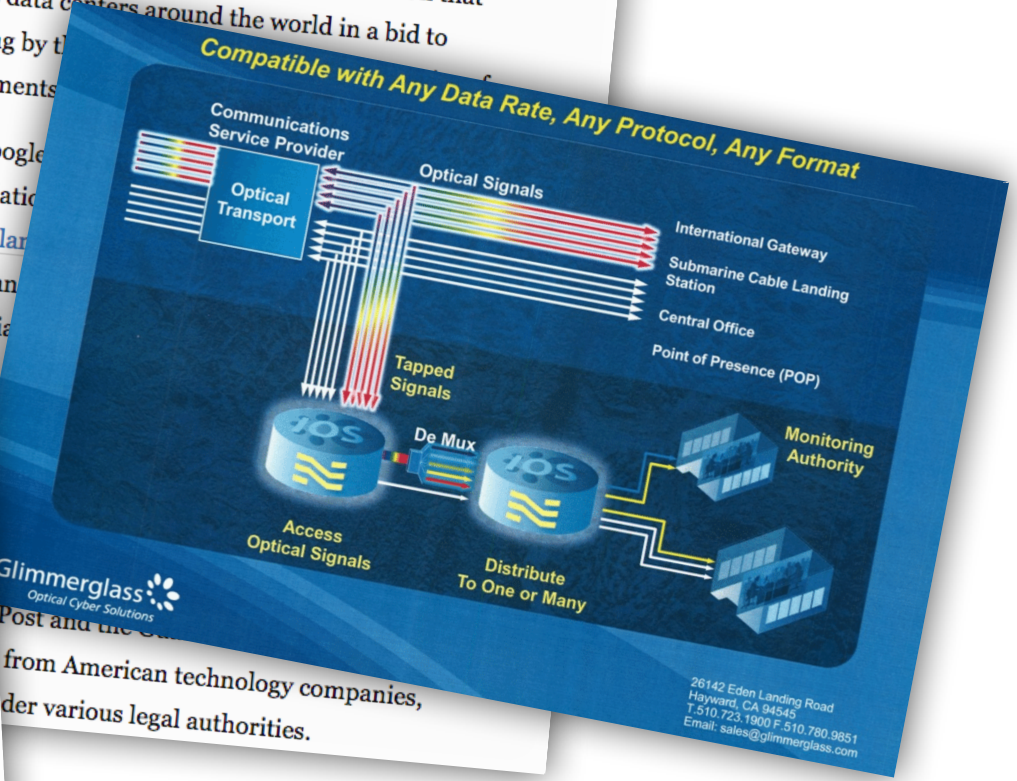
Google encrypts data amid backlash against NSA spying

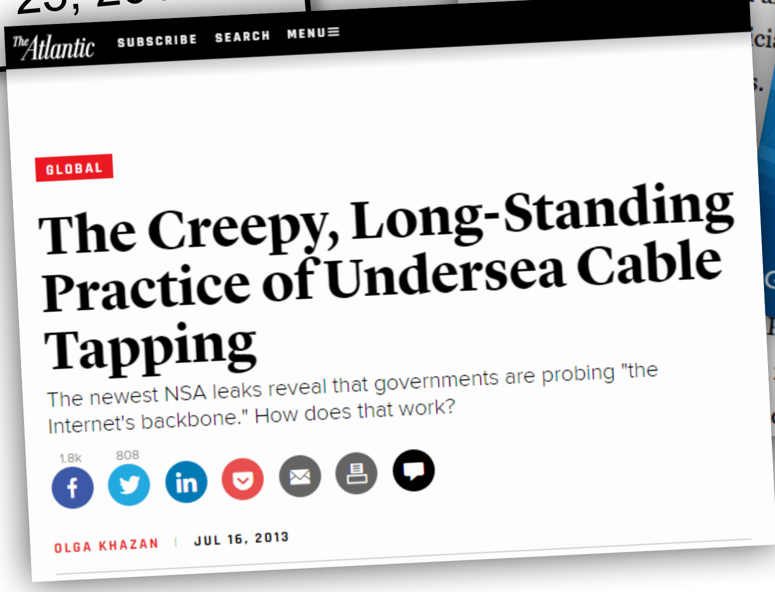
By Craig Timberg September 6, 2013

Google is racing to encrypt the torrents of information that flow among its data centers around the world in a bid to thwart snooping by t
foreign governments

The move by Google
that recent revelatio
sweeping surveillan
backlash within an
cia

Post and the G
from American technology companies,
der various legal authorities.



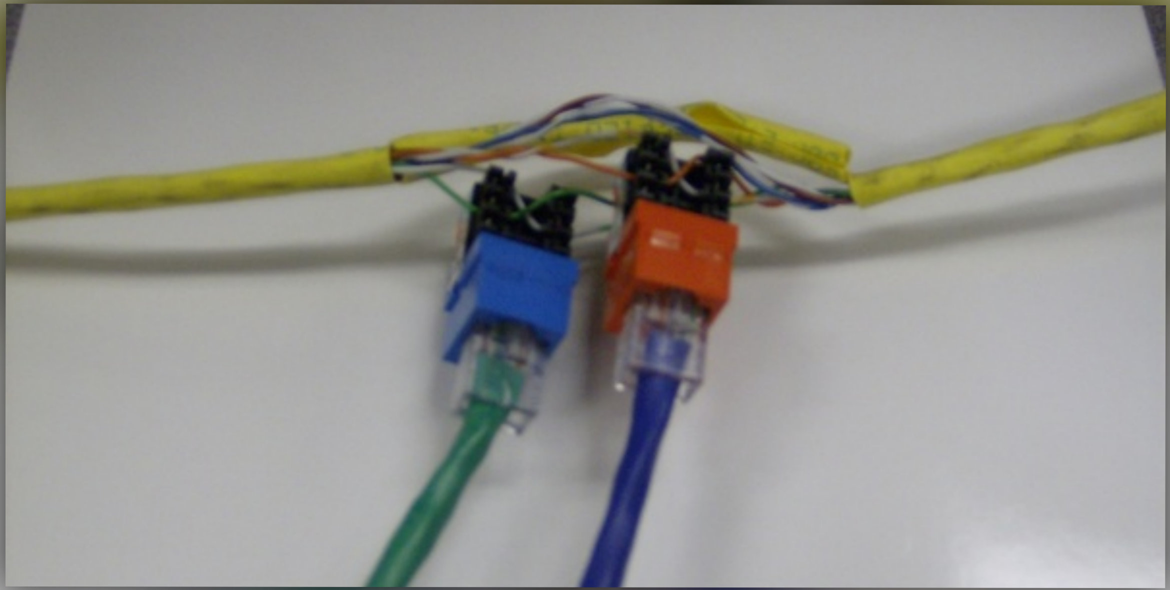


GLOBAL

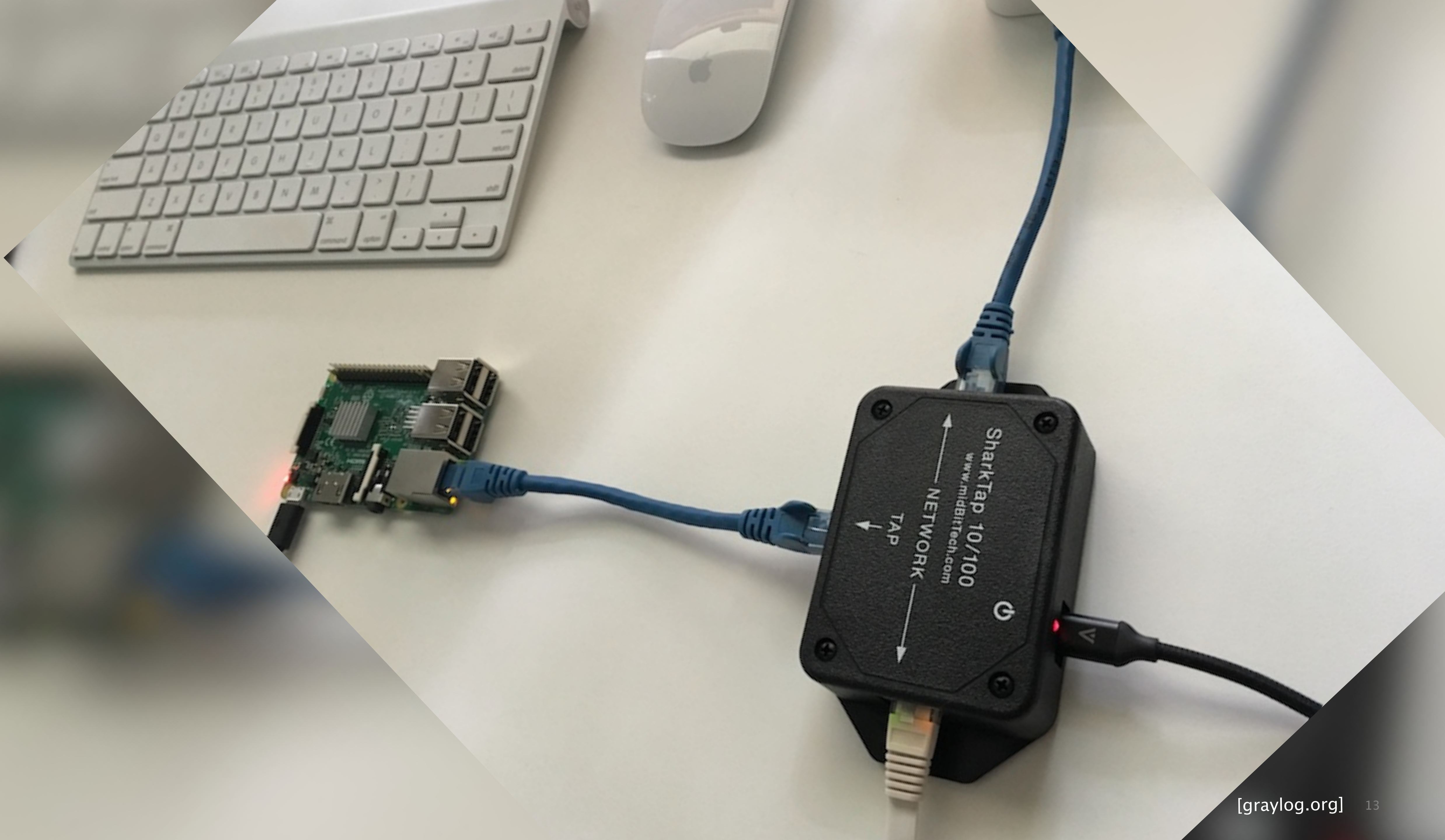
The Creepy, Long-Standing Practice of Undersea Cable Tapping

The newest NSA leaks reveal that governments are probing "the Internet's backbone." How does that work?

OLGA KHAZAN | JUL 16, 2013



[janitha.com]


SharkTap 10/100
www.midBitTech.com
NETWORK
TAP

Existing solutions

Do not protect communicating parties
[SSL/TLS, IPsec Transport, MACsec]

Require modifications at end-hosts or additional middleboxes
[APOD, CONTRA]

Do not support partial deployment or have scalability problems
[MACsec, PHEAR]

More references provided in the paper

iTAP

In-network Traffic Analysis Prevention using Software-Defined Networks

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iTAP

In-network Traffic Analysis Prevention
using Software-Defined Networks

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- Communication anonymity
  who is communicating with whom?

iTAP

In-network Traffic Analysis Prevention
using Software-Defined Networks

- Communication anonymity
  who is communicating with whom?
- Volume anonymity
  how much traffic flows between X and Y?

iTAP

In-network Traffic Analysis Prevention
using Software-Defined Networks

- Communication anonymity
  who is communicating with whom?
- Volume anonymity
  how much traffic flows between X and Y?
- Topology anonymity
  how many hosts are in the network?

iTAP

In-network Traffic Analysis Prevention using Software-Defined Networks

- No modifications at end-hosts

iTAP

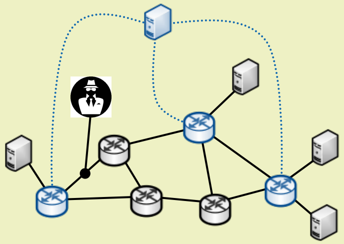
In-network Traffic Analysis Prevention
using Software-Defined Networks

- Central controller
- Rewriting capabilities of switches

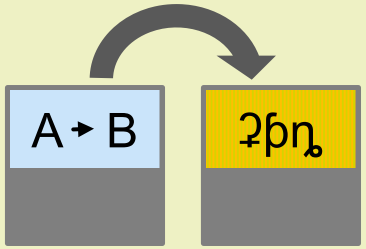
iTAP

Overview

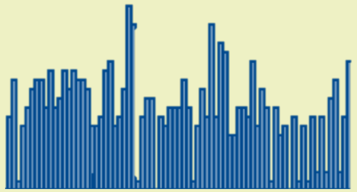
Architecture



Header rewriting



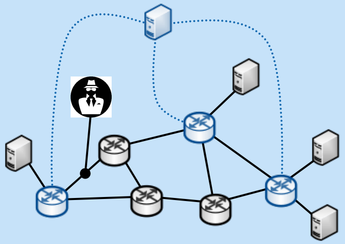
Evaluation



iTAP

Overview

Architecture



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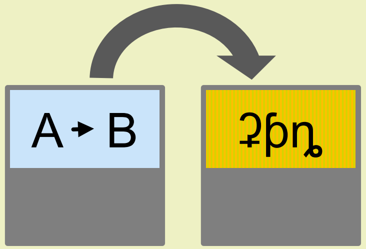

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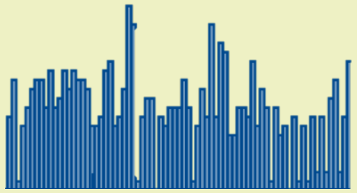
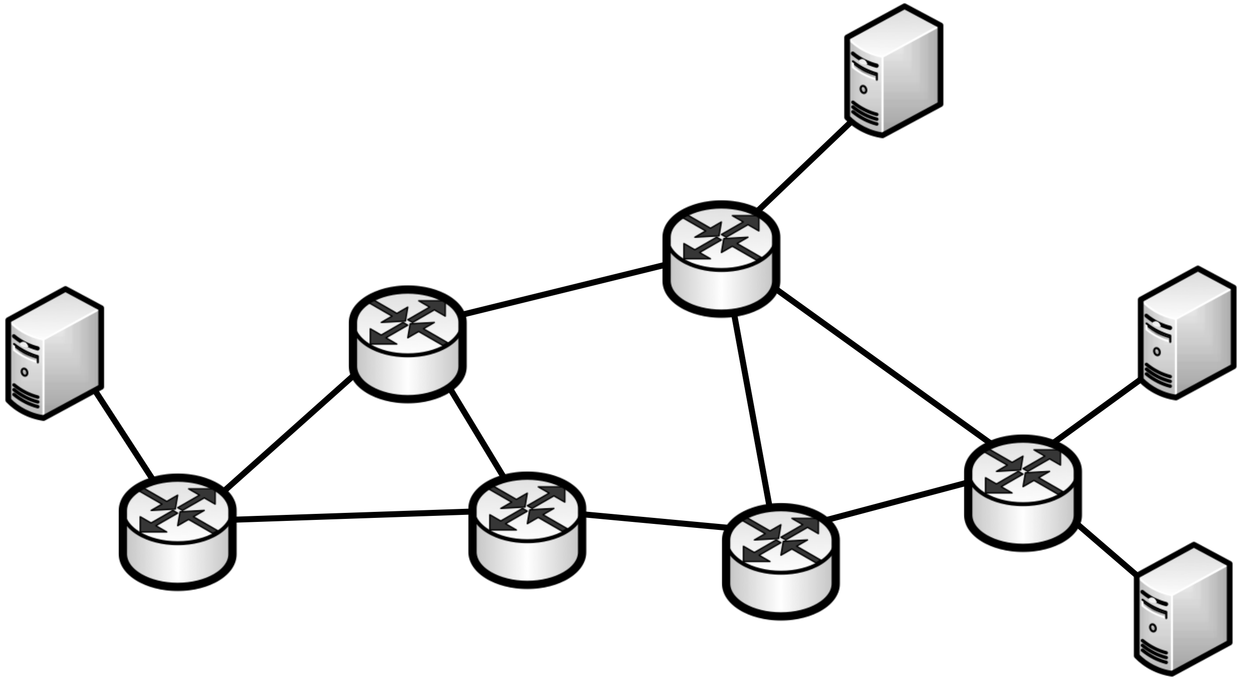


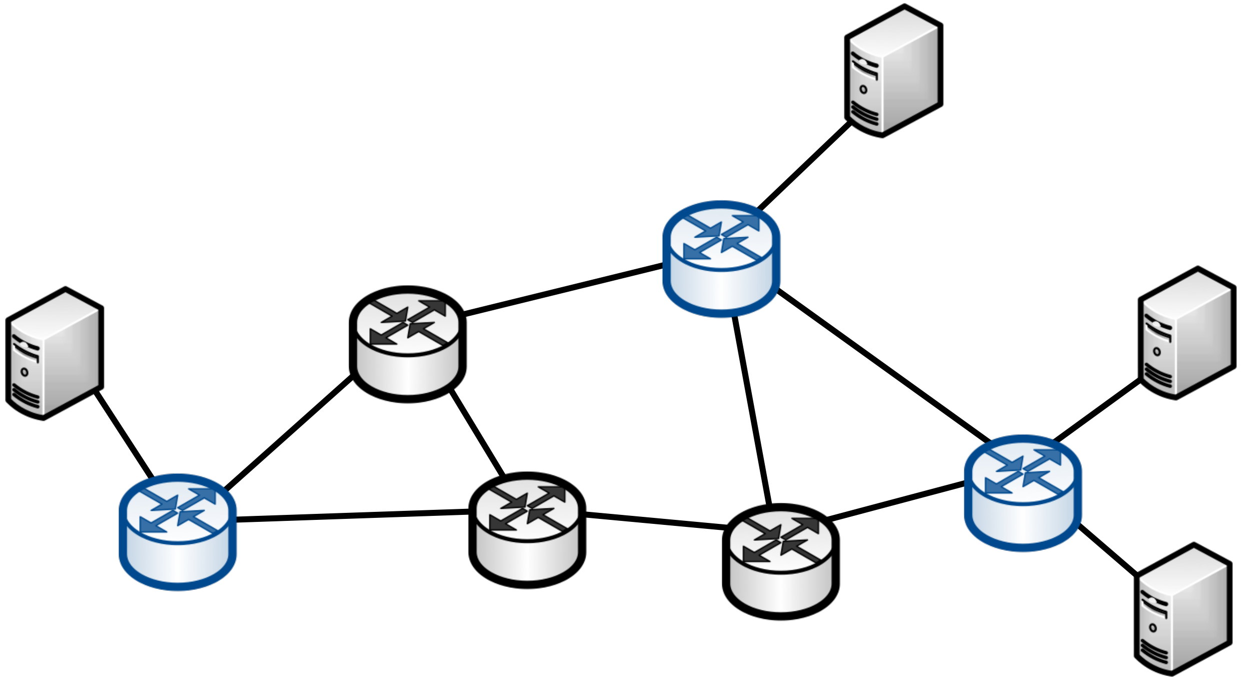
An iTAP-protected network

An iTAP-protected network



Layer 2 network

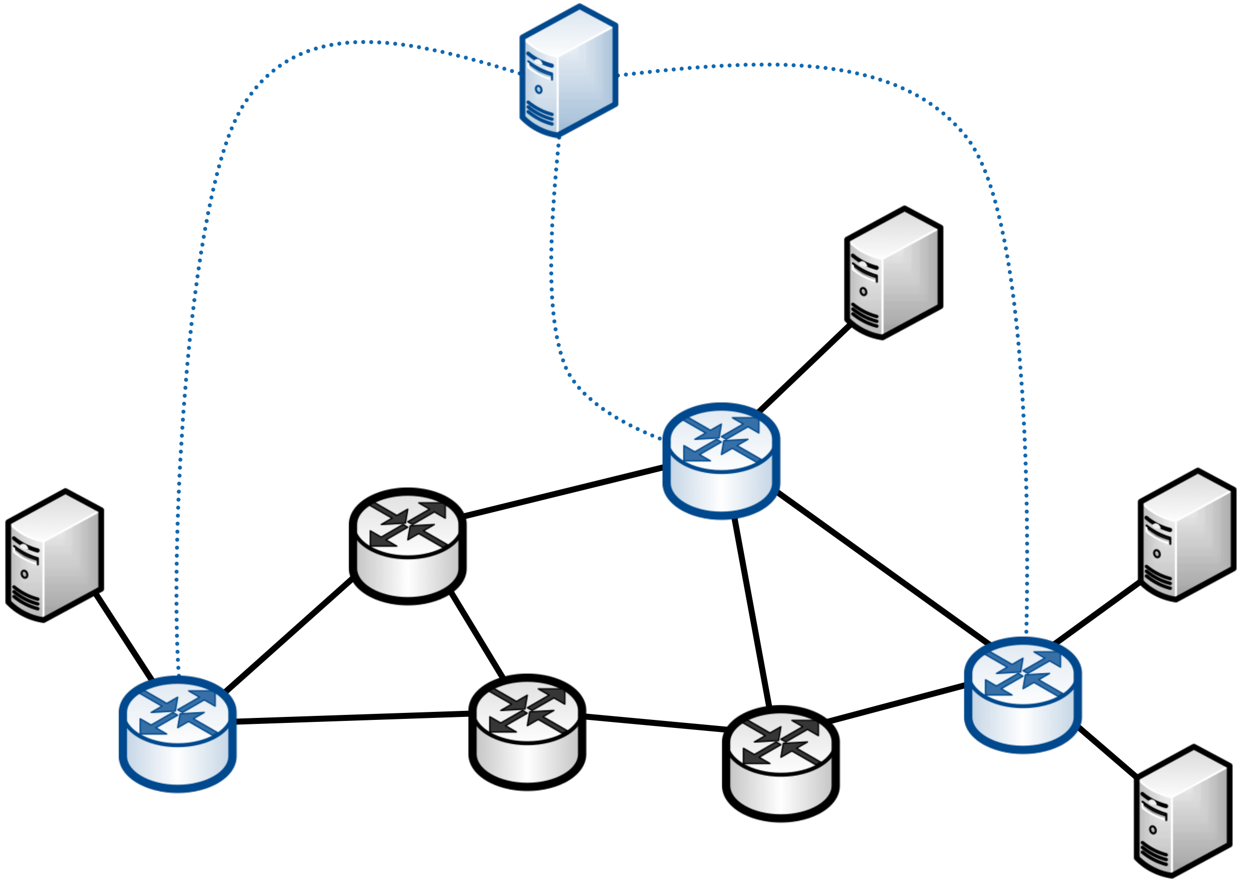
An iTAP-protected network



Layer 2 network

With some SDN switches

An iTAP-protected network

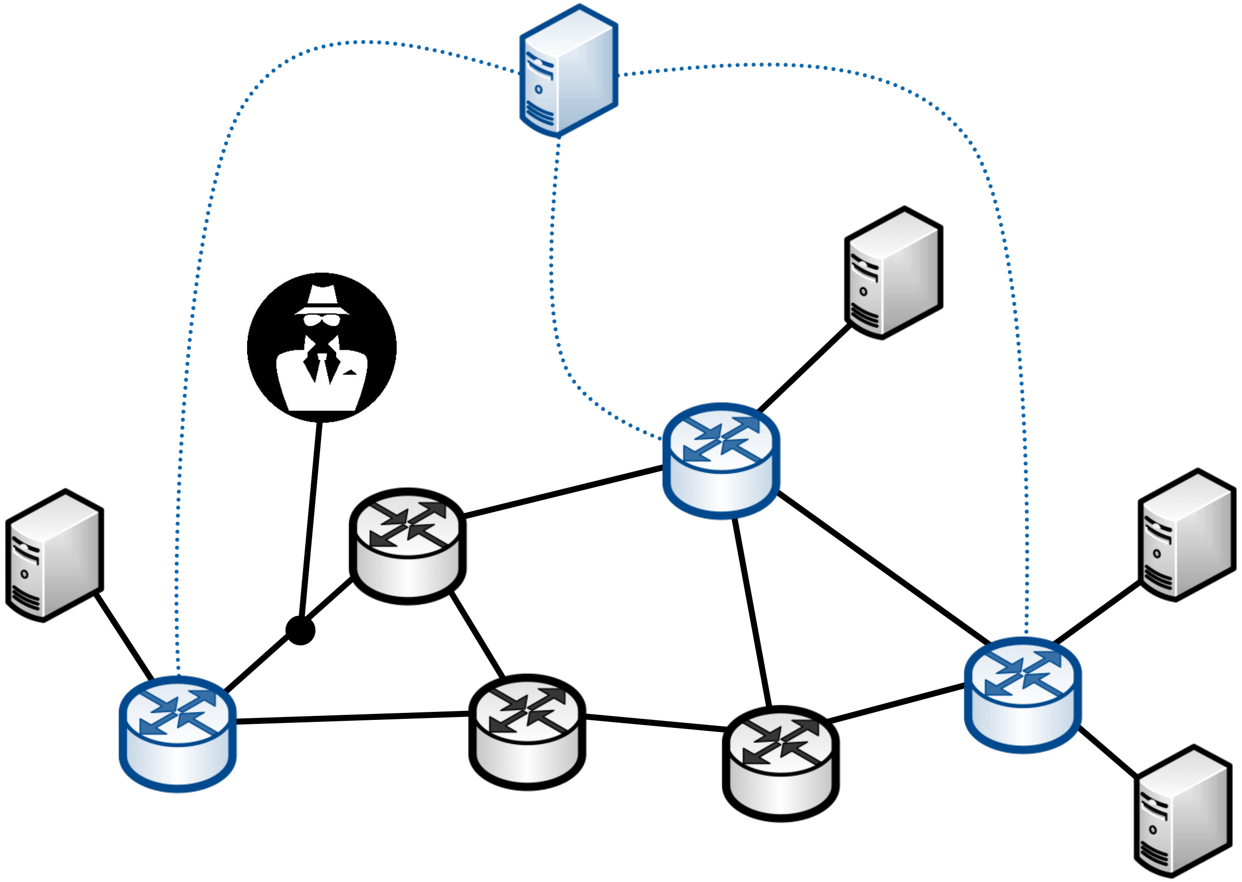


Layer 2 network

With some SDN switches

And a central controller

An iTAP-protected network



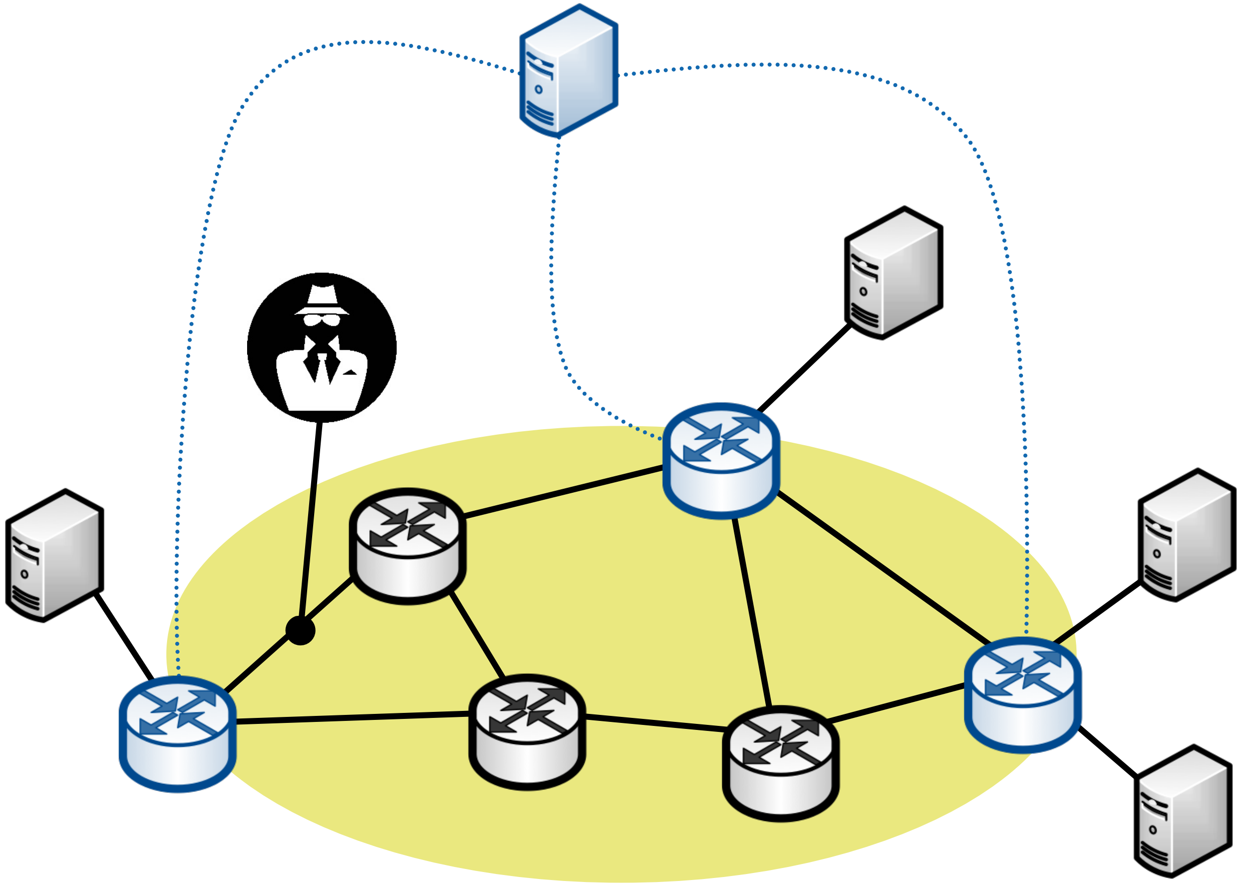
Layer 2 network

With some SDN switches

And a central controller

Attacked by an eavesdropper

An iTAP-protected network



Layer 2 network

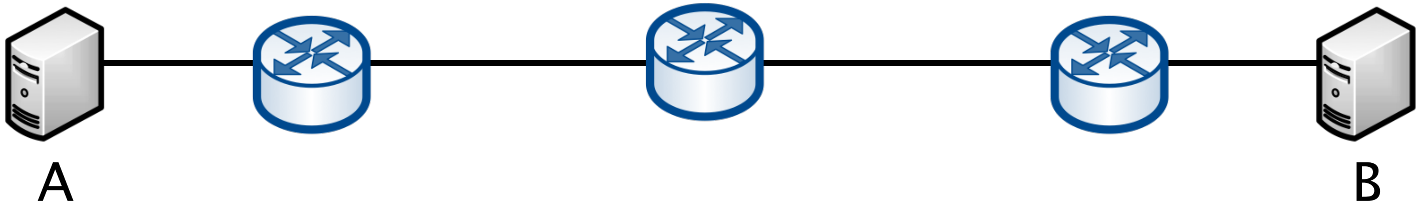
With some SDN switches

And a central controller

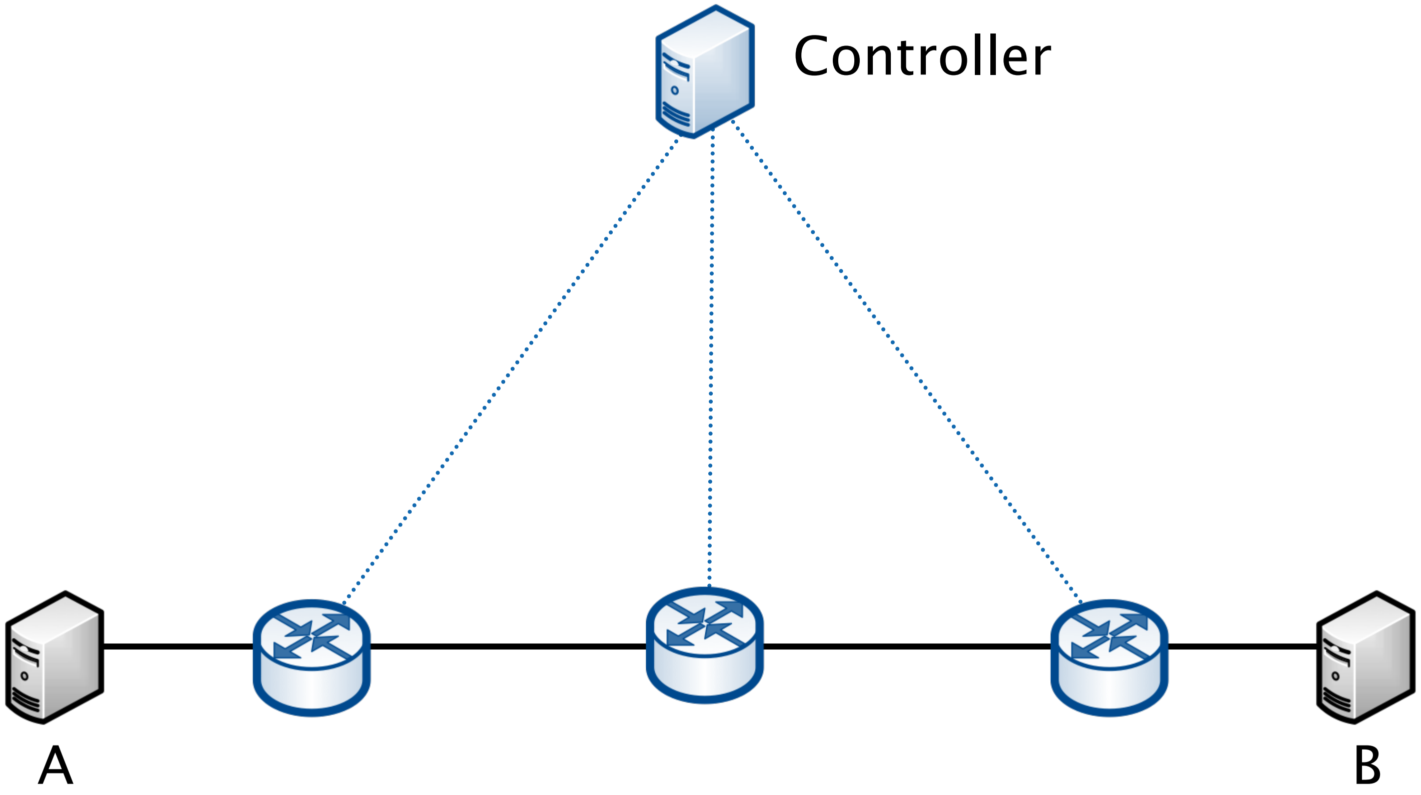
Attacked by an eavesdropper

Protected by iTAP

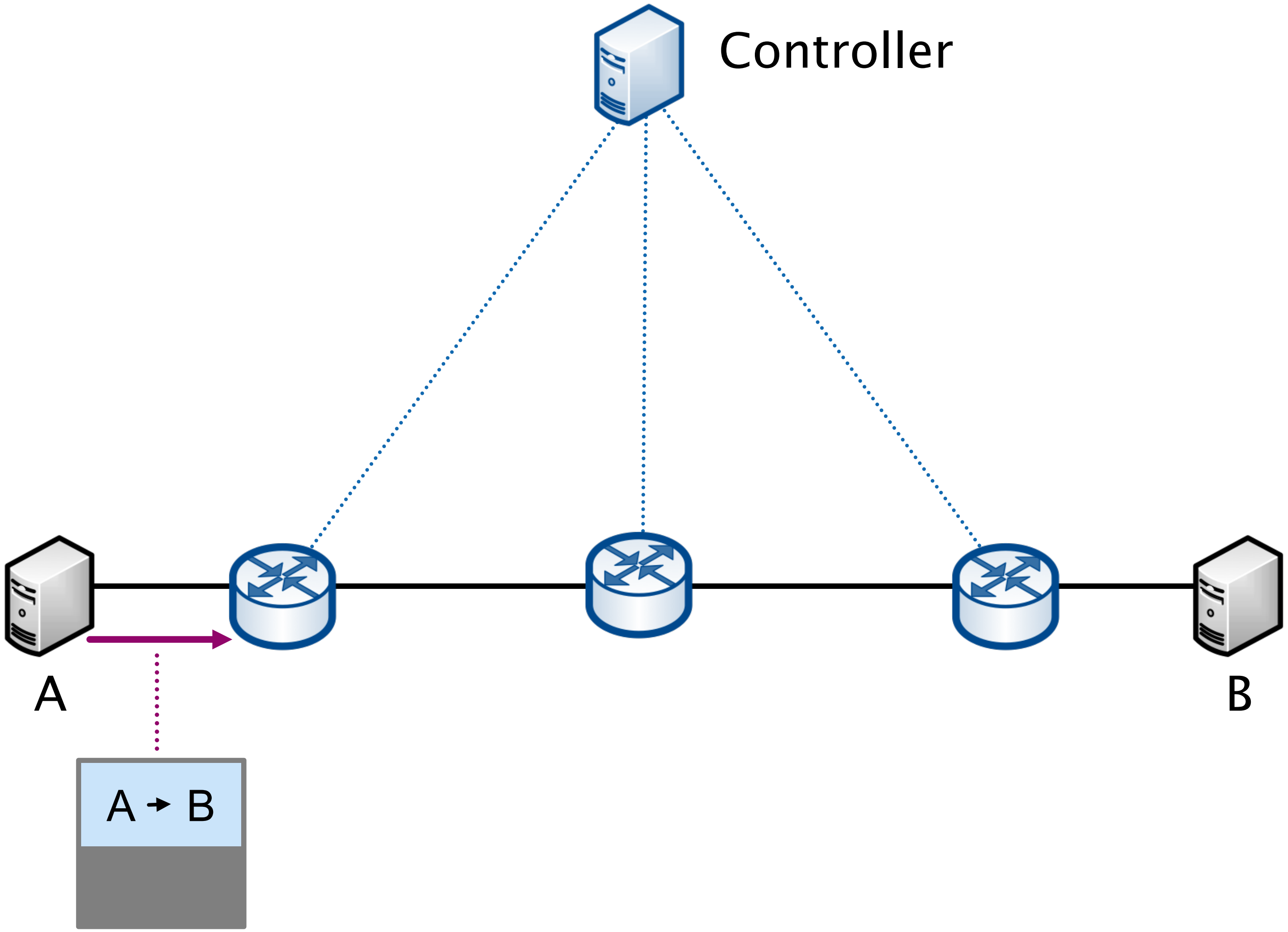
Example



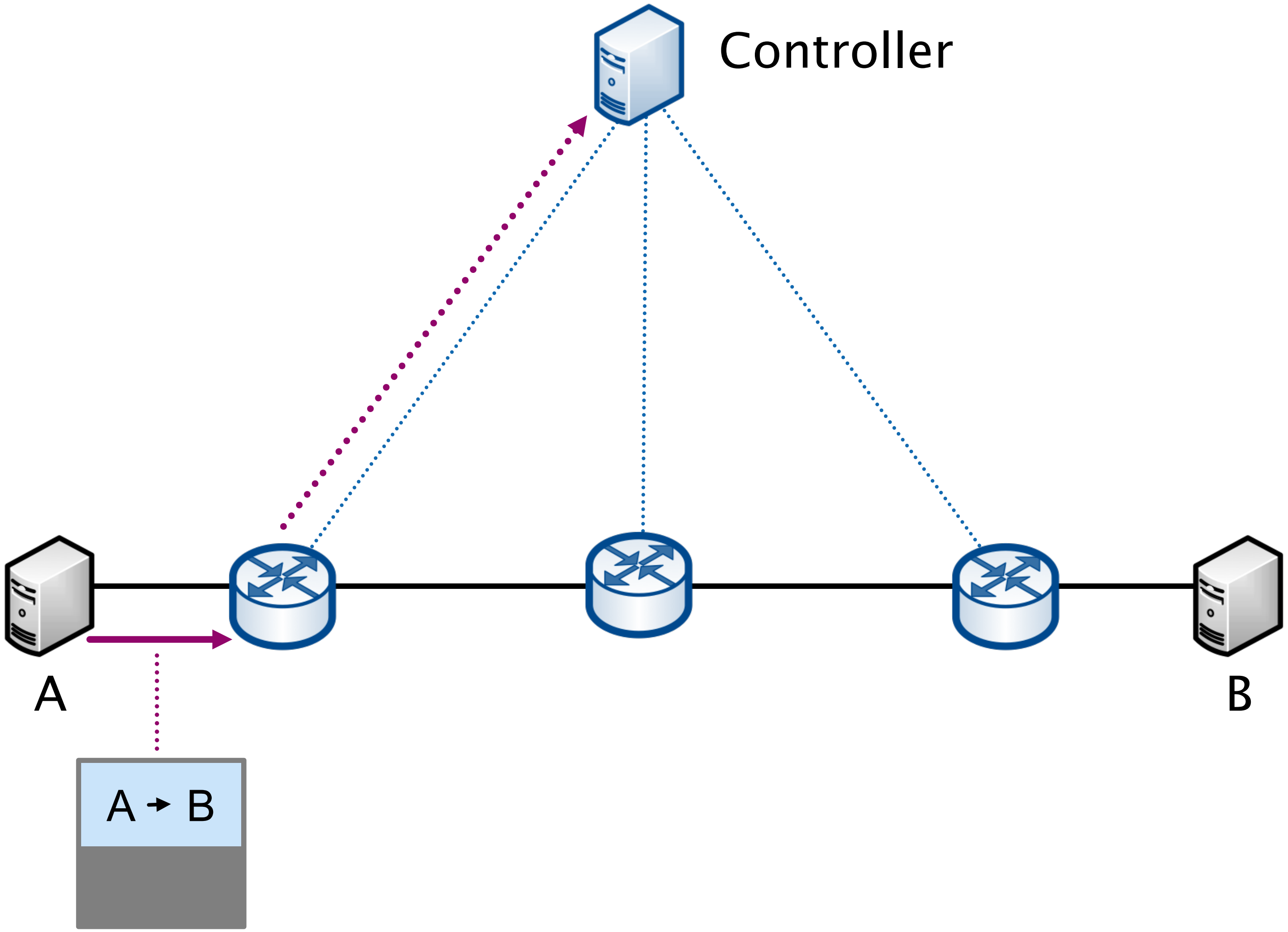
Example



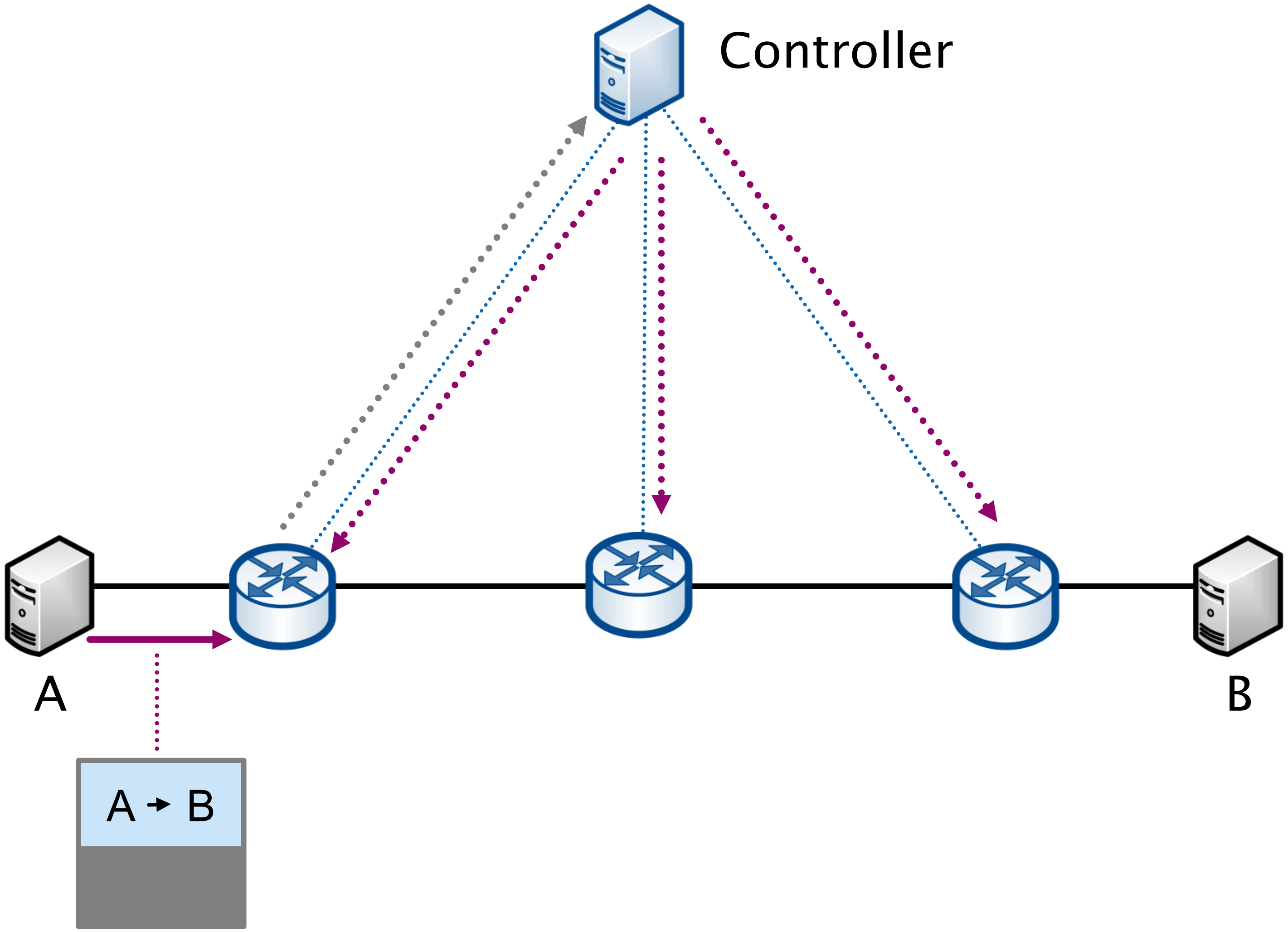
Packet from A to B enters the network



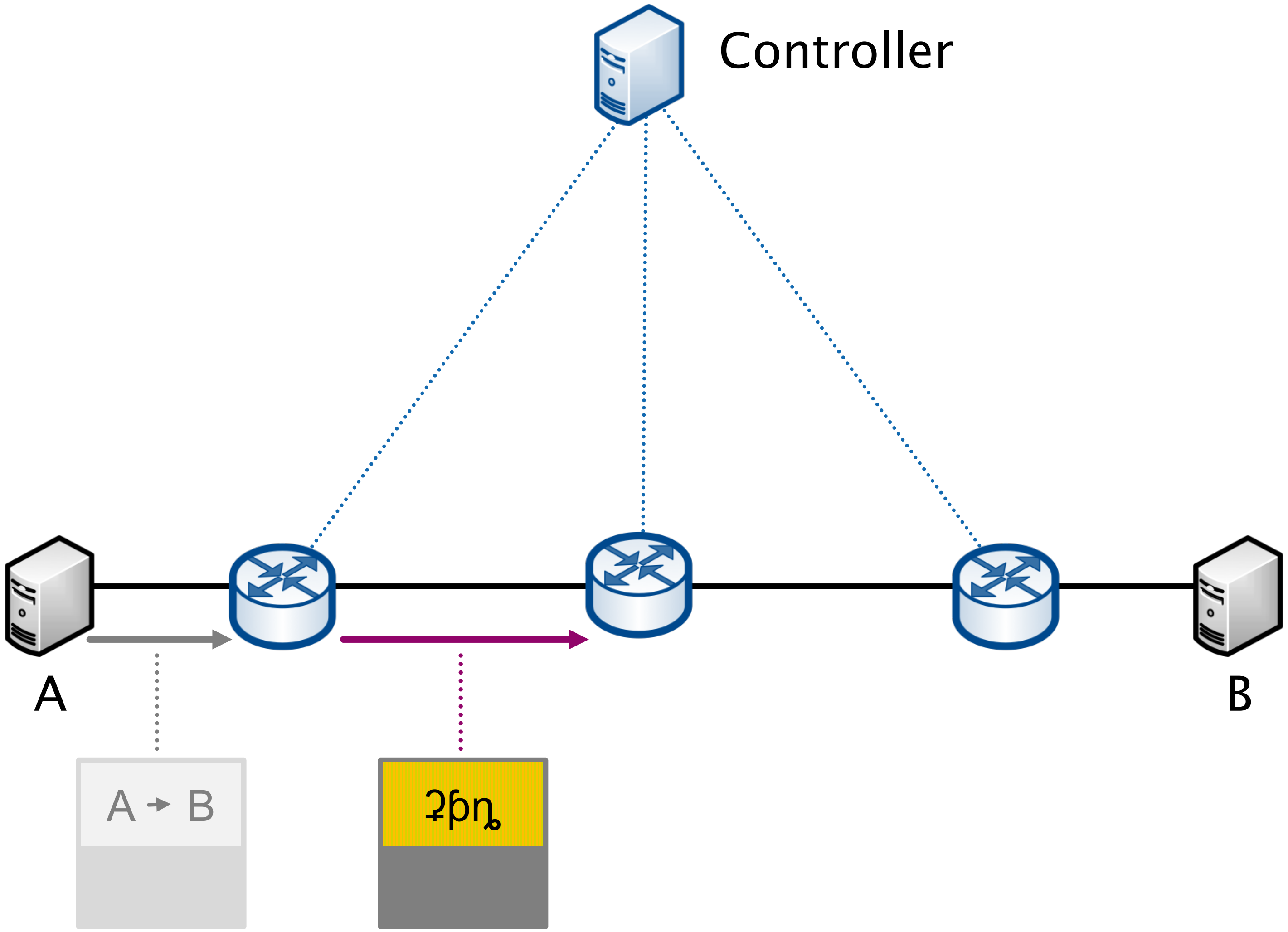
Ingress switch notifies controller



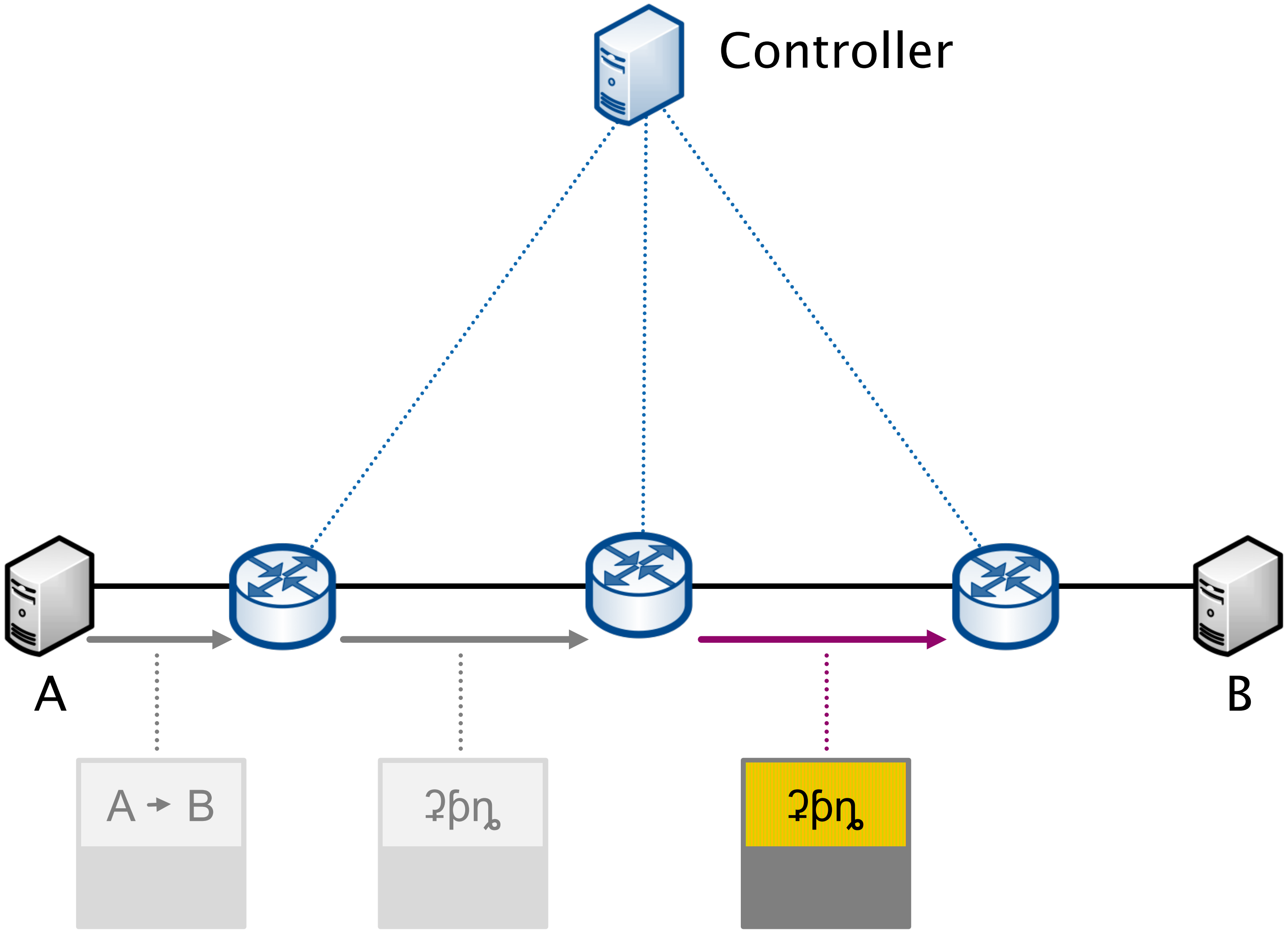
Controller computes & installs flow rules



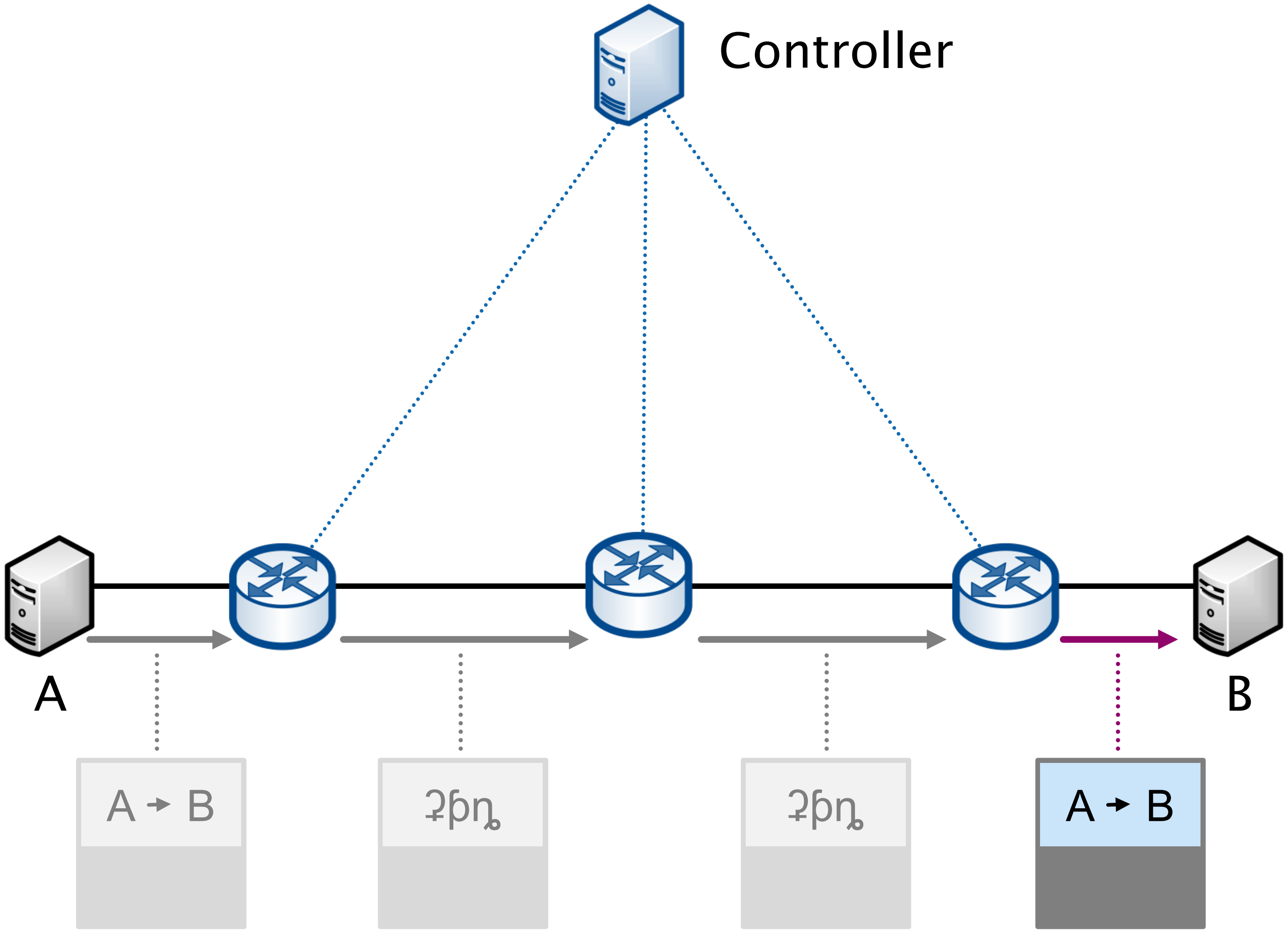
Ingress switch obfuscates source and destination



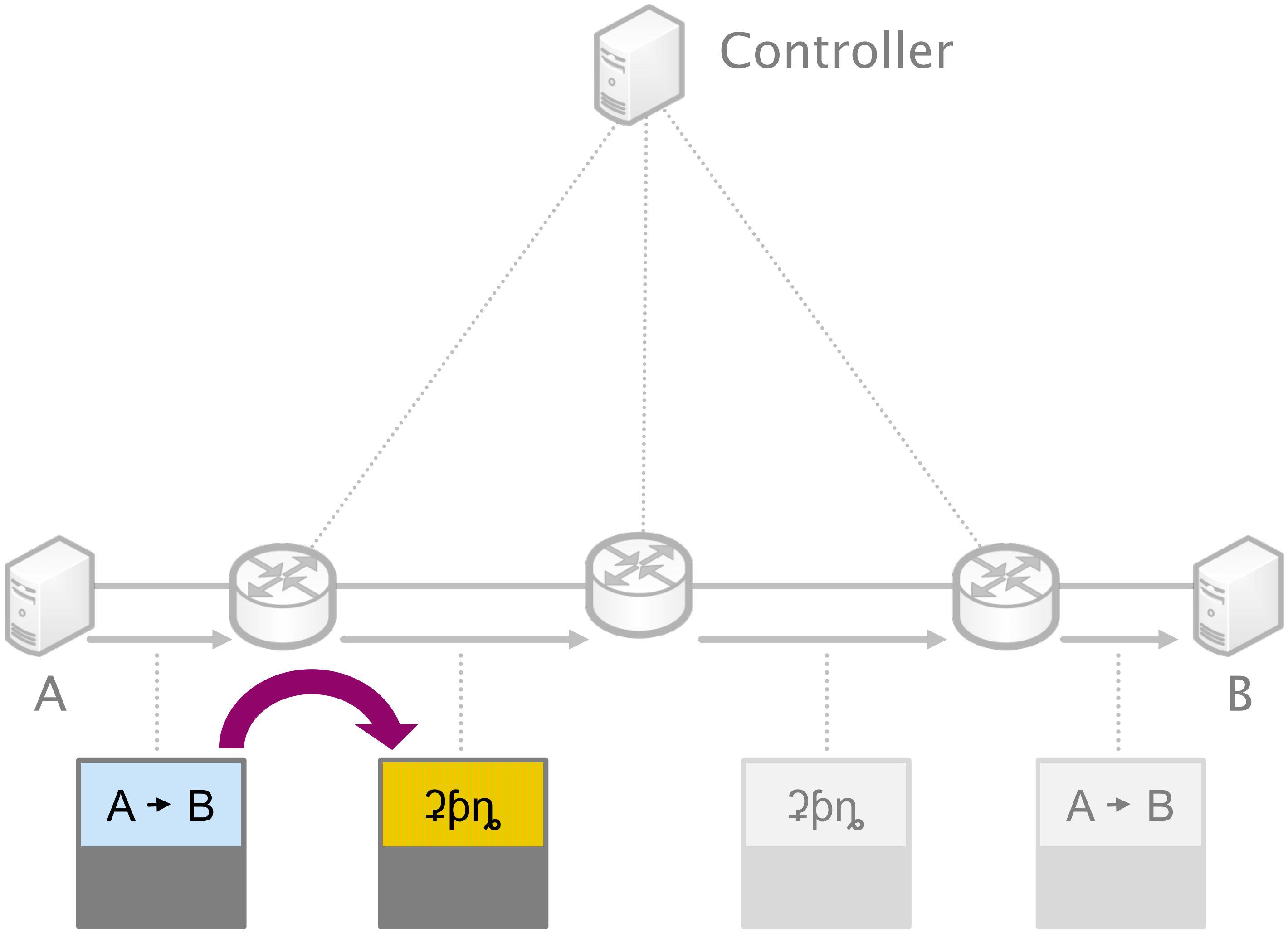
Core switch forwards obfuscated packet



Egress switch de-obfuscates source and destination



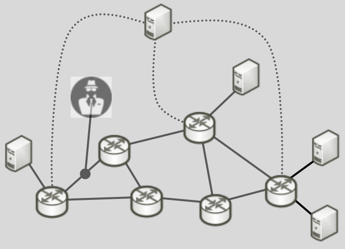
How does the rewriting work?



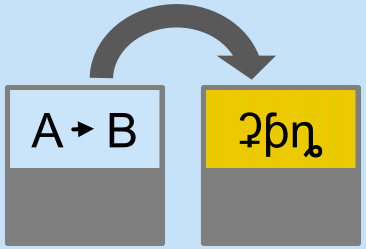
iTAP

Overview

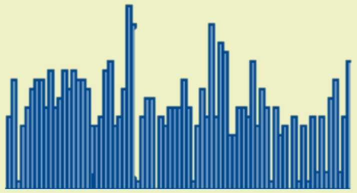
Architecture



Header rewriting



Evaluation



Rewriting packet headers

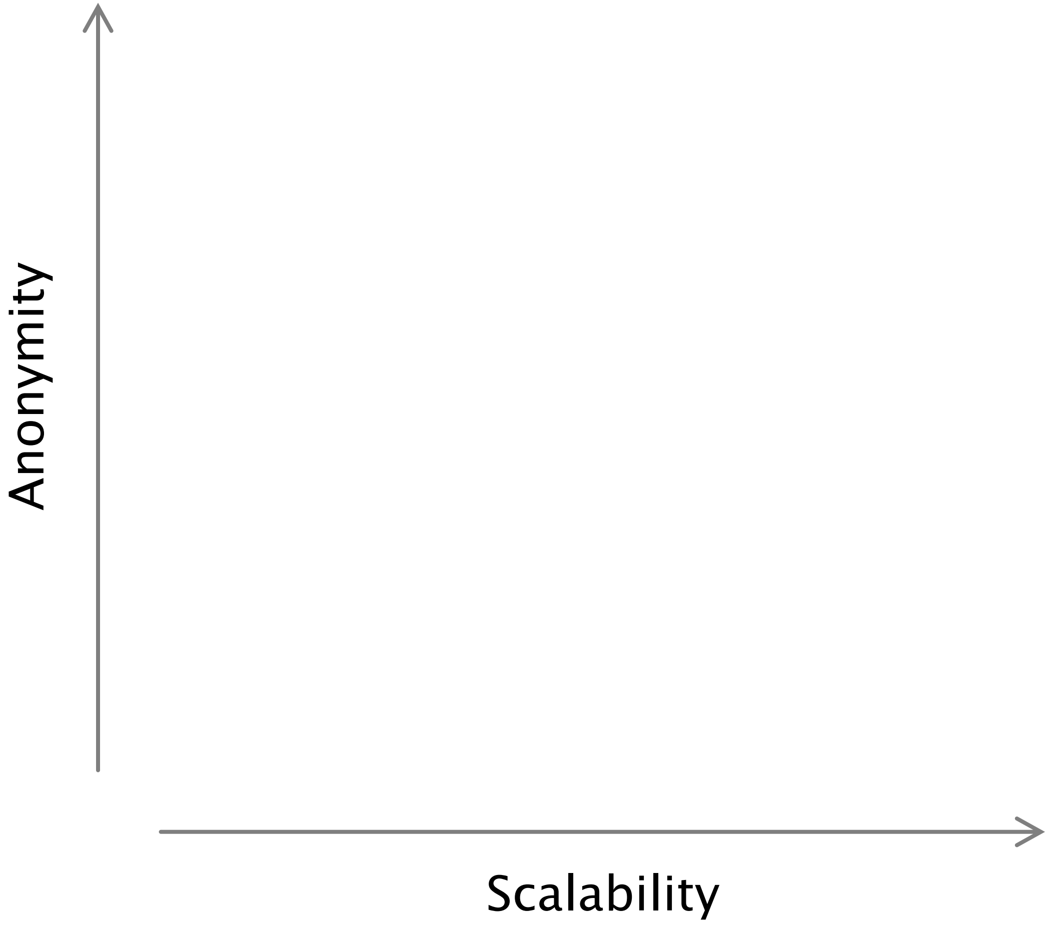
Trade-off between anonymity and scalability

iTAP approach: Mixing per-host IDs and random bits

Measure information leakage & counteract attacker

Solution for potential scalability-issues at Internet-facing edge

Rewriting packet headers as a trade-off between anonymity and scalability



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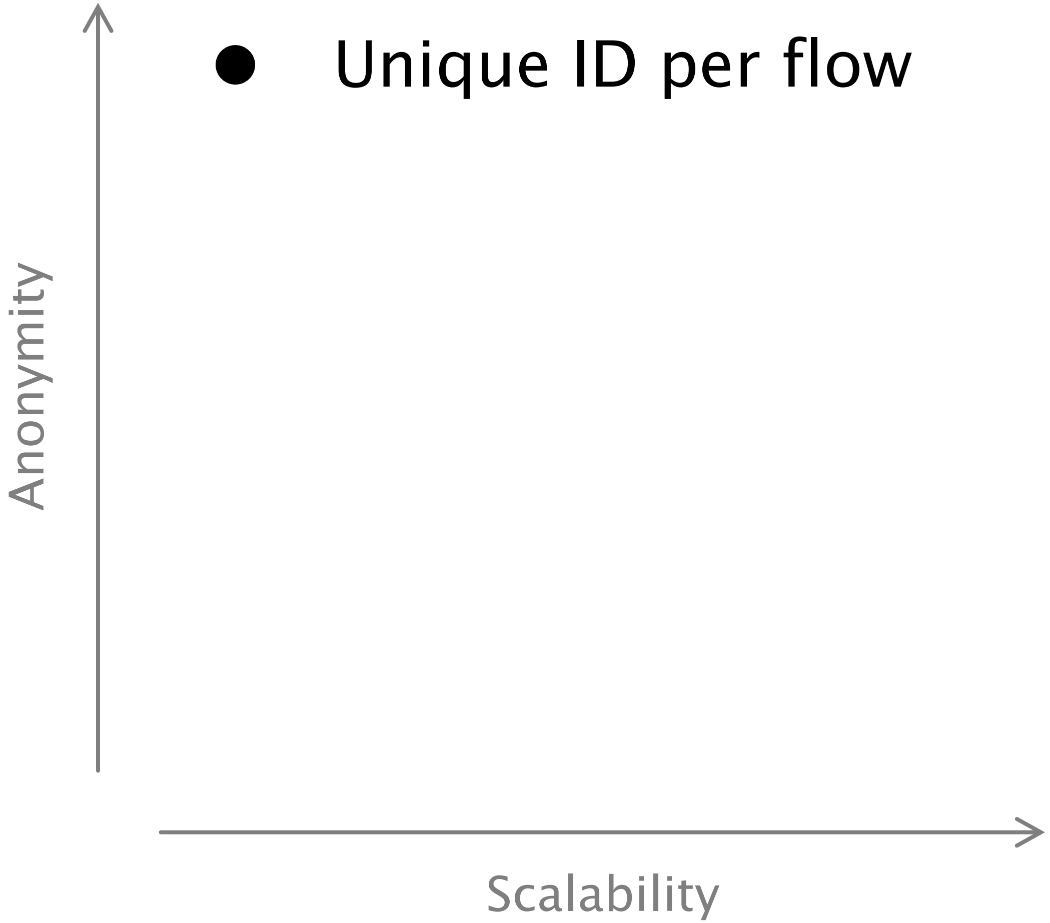

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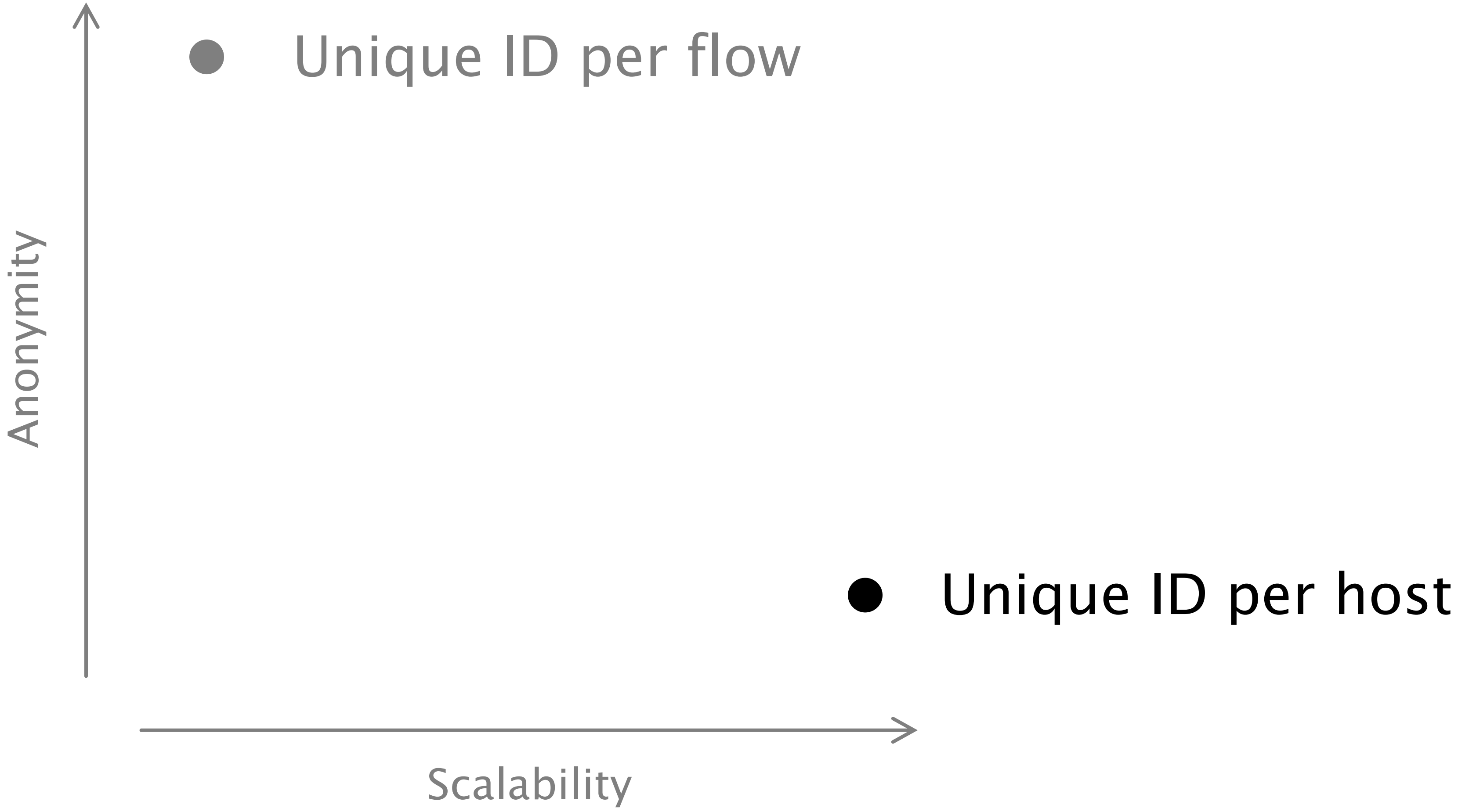

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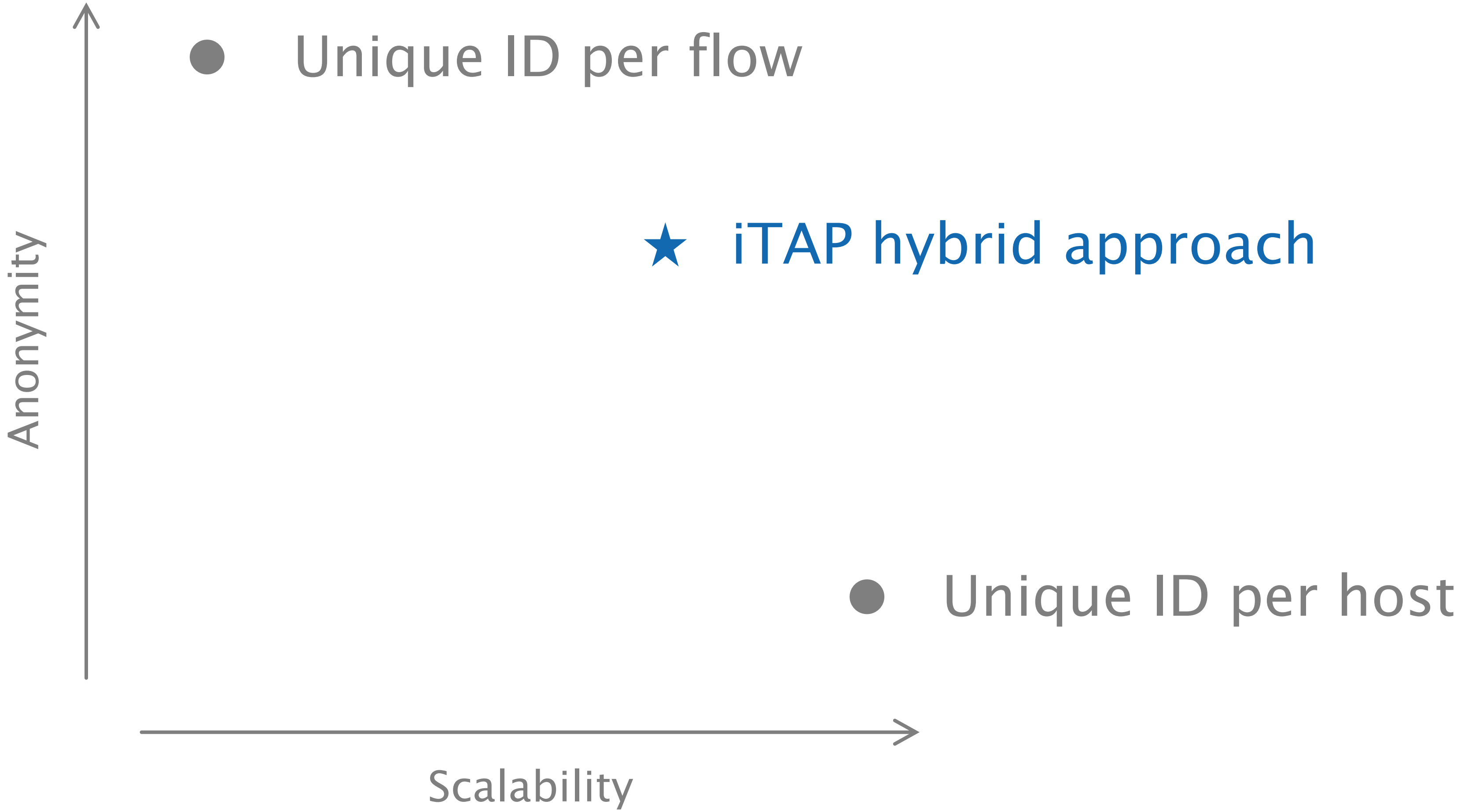

iTAP hybrid obfuscation scheme

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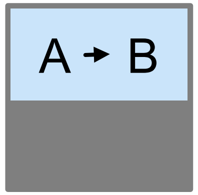
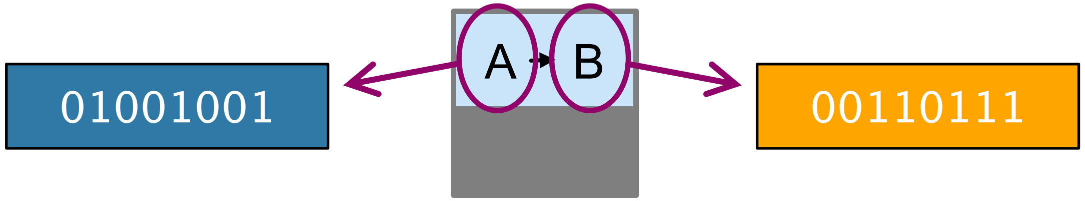


A → B

iTAP hybrid obfuscation scheme

Map source and destination to IDs



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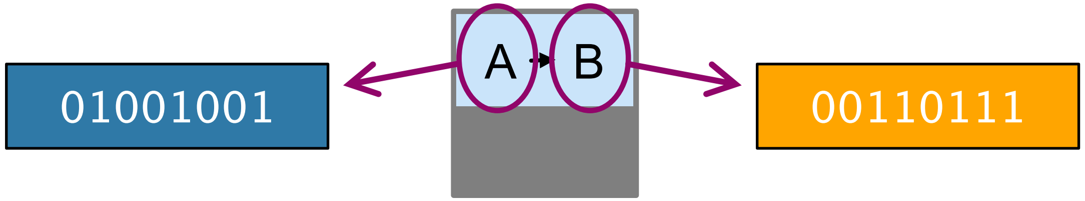


Match-fields with arbitrary bitmasks

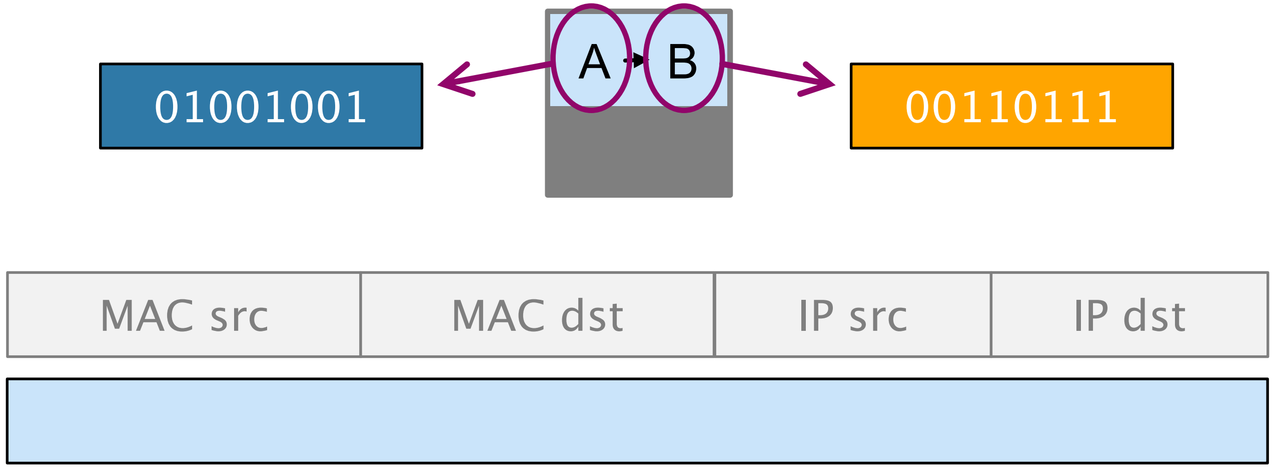
MAC src	MAC dst	IP src	IP dst

iTAP hybrid obfuscation scheme

Map source and destination to IDs

Match-fields with arbitrary bitmasks

Interpret as bit-string of 160 bits



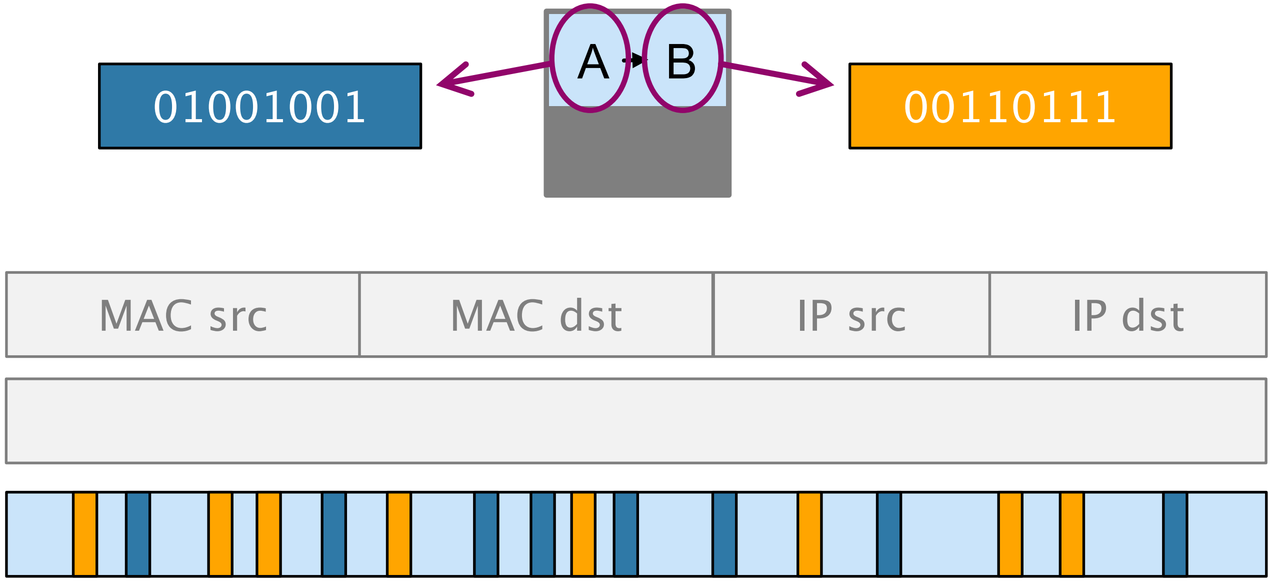
iTAP hybrid obfuscation scheme

Map source and destination to IDs

Match-fields with arbitrary bitmasks

Interpret as bit-string of 160 bits

Randomly select bits that are used for source and destination ID



iTAP hybrid obfuscation scheme

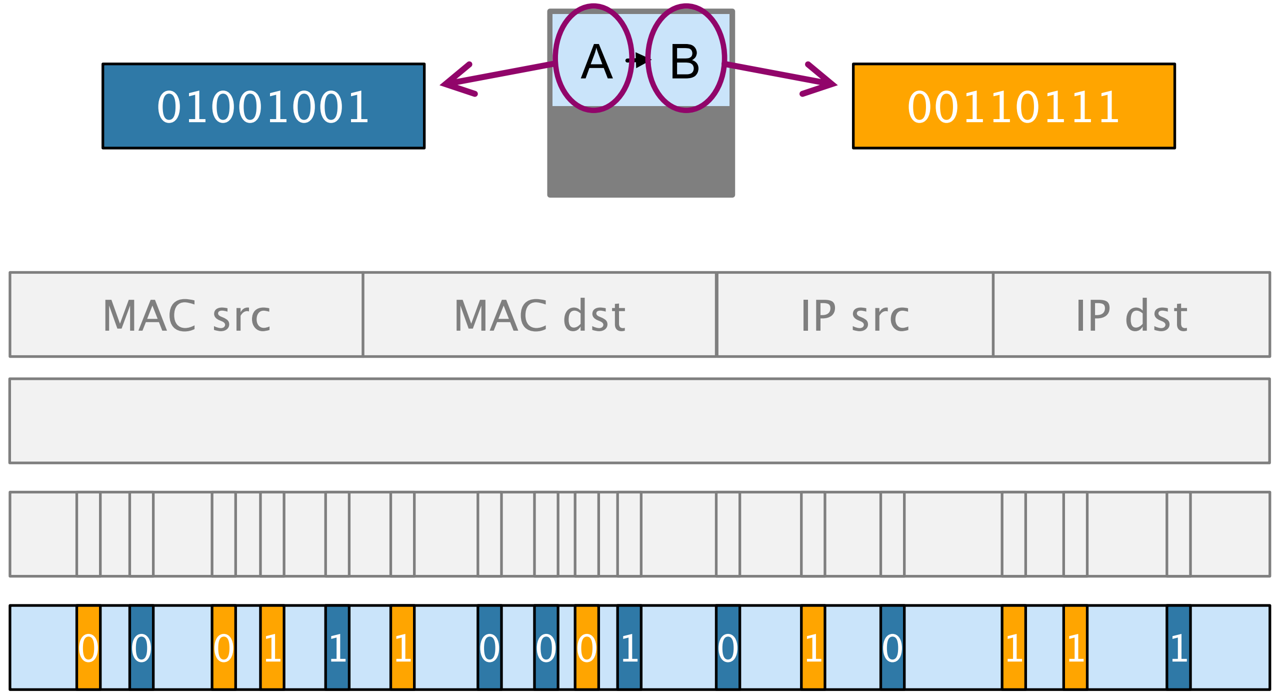
Map source and destination to IDs

Match-fields with arbitrary bitmasks

Interpret as bit-string of 160 bits

Randomly select bits that are used for source and destination ID

Add source and destination ID



iTAP hybrid obfuscation scheme

Map source and destination to IDs

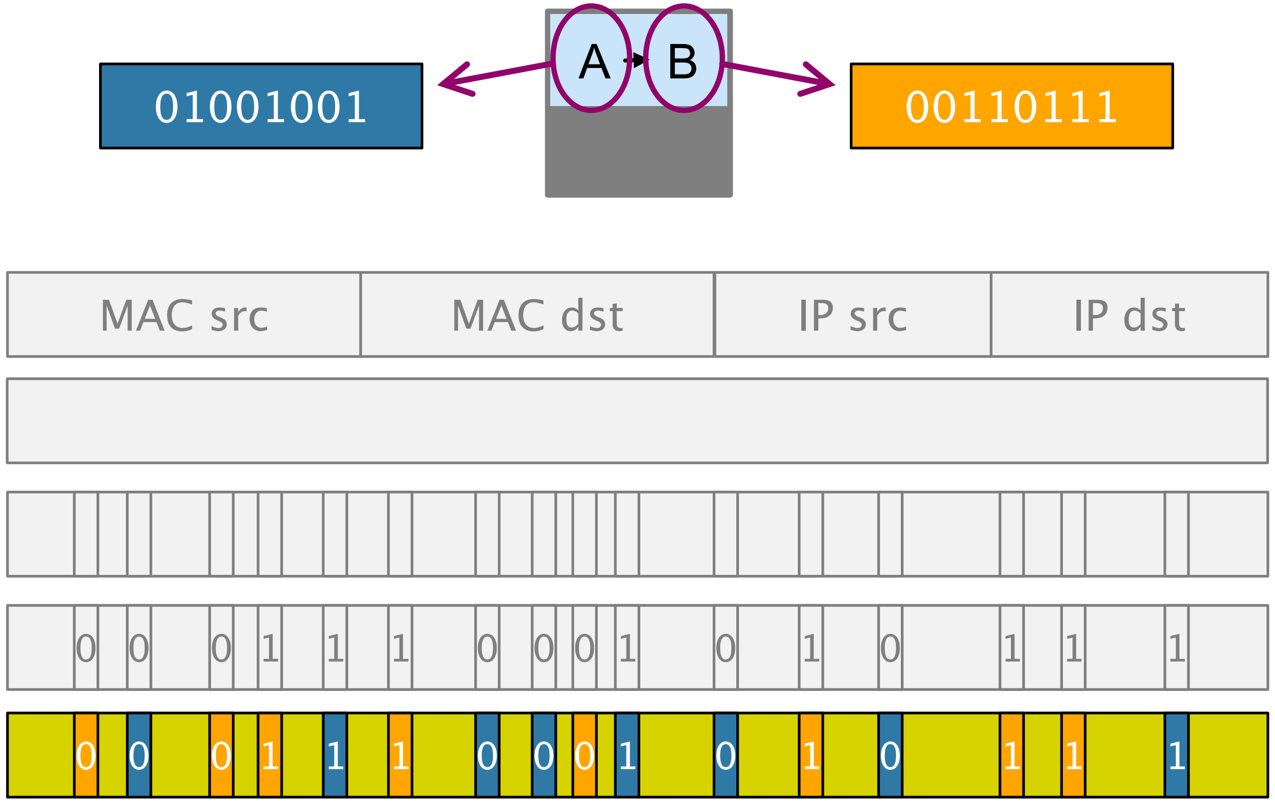
Match-fields with arbitrary bitmasks

Interpret as bit-string of 160 bits

Randomly select bits that are used for source and destination ID

Add source and destination ID

Set other bits to random values



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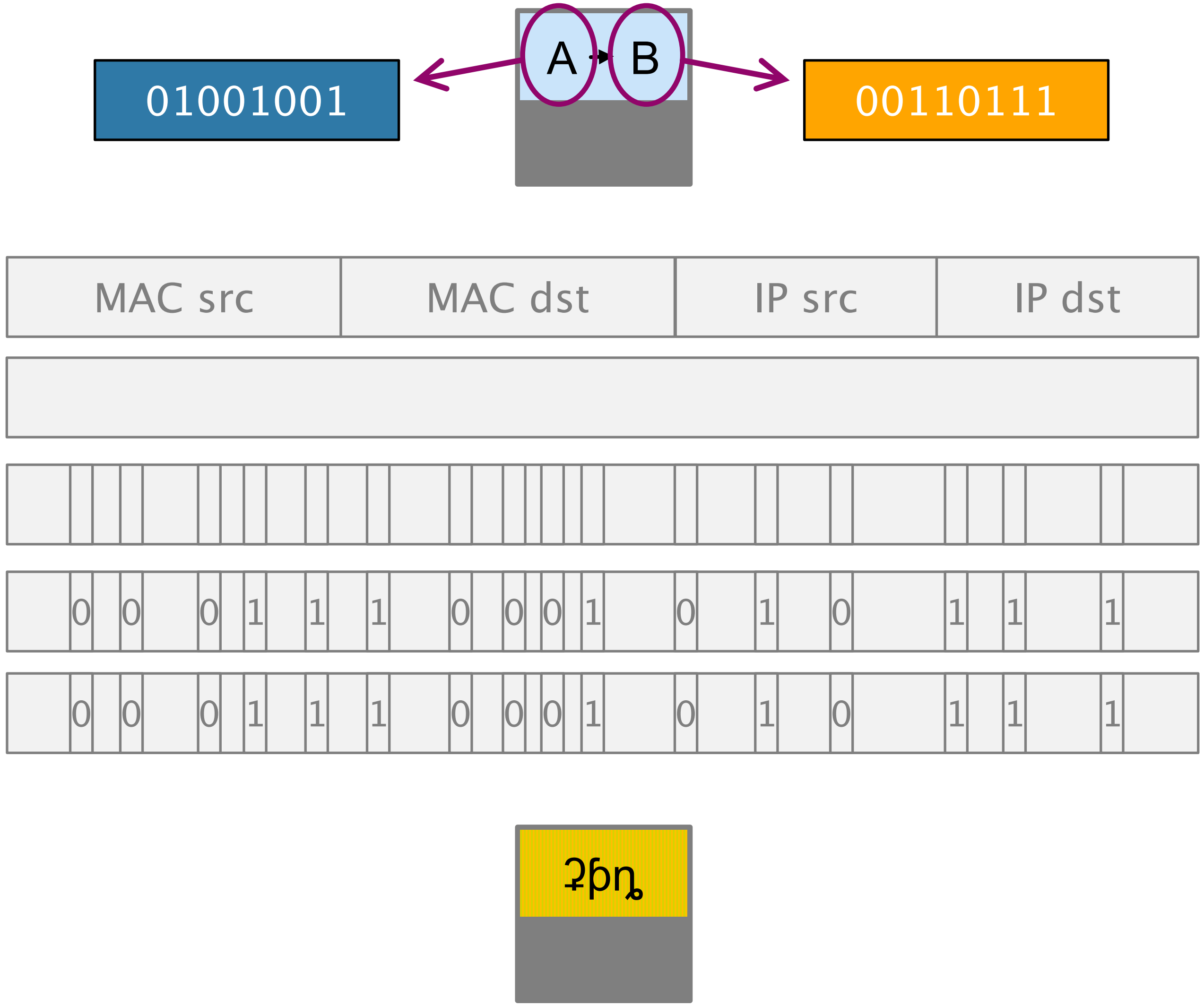
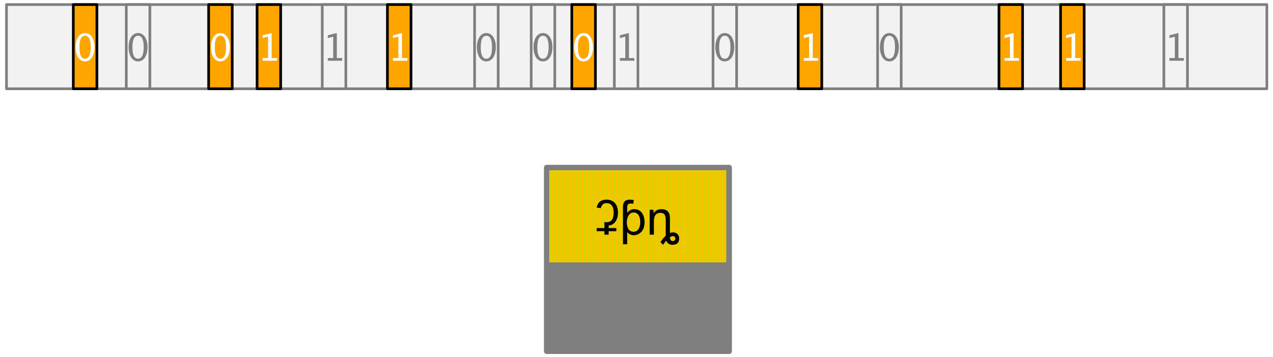


iTAP hybrid obfuscation scheme

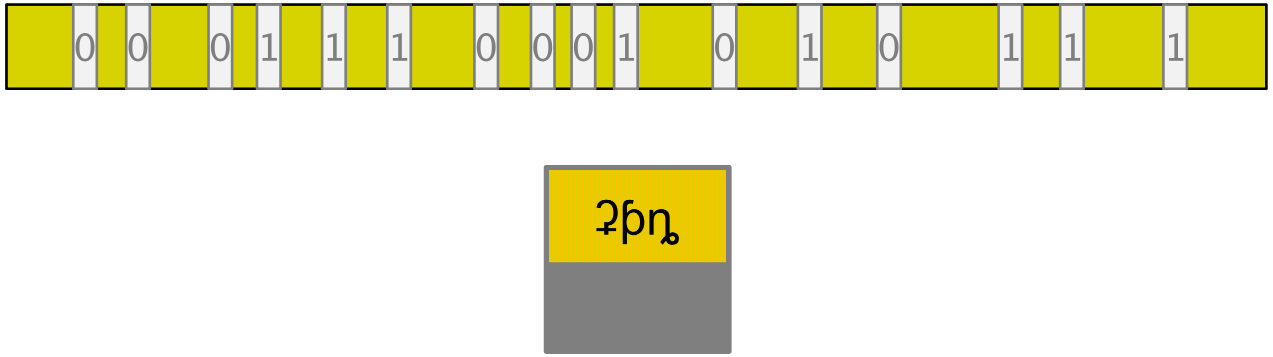
Forwarding based on the destination ID
→ good scalability



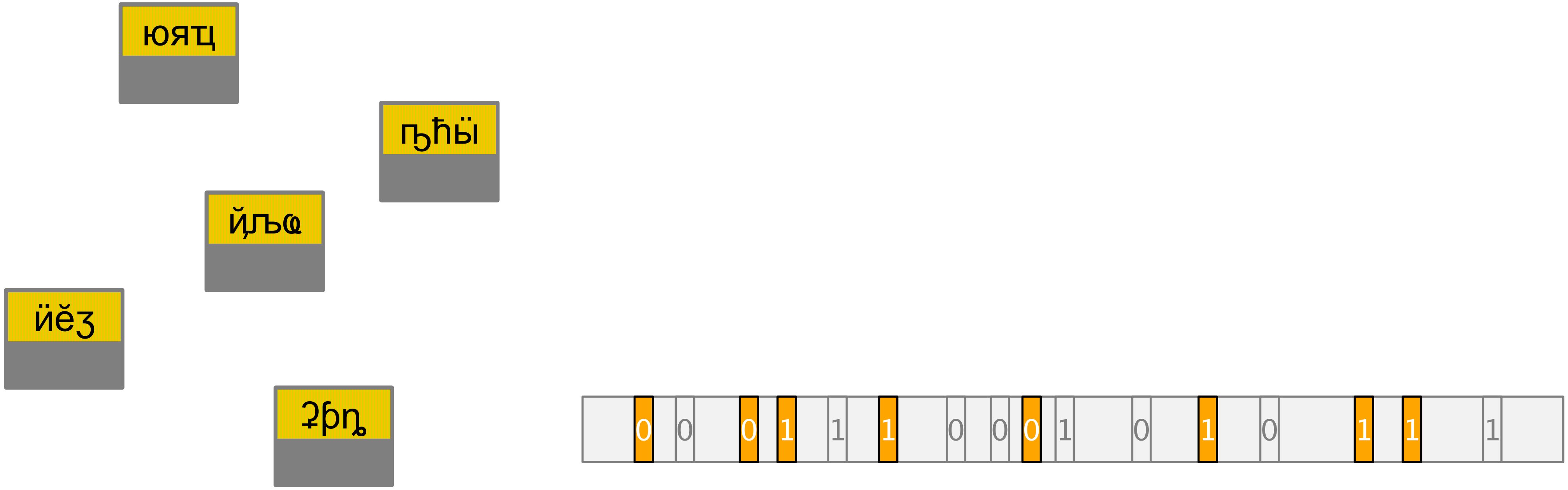
iTAP hybrid obfuscation scheme

Eavesdropper cannot distinguish between random and non-random bits

→ good anonymity



What if an attacker analyzes multiple flows?



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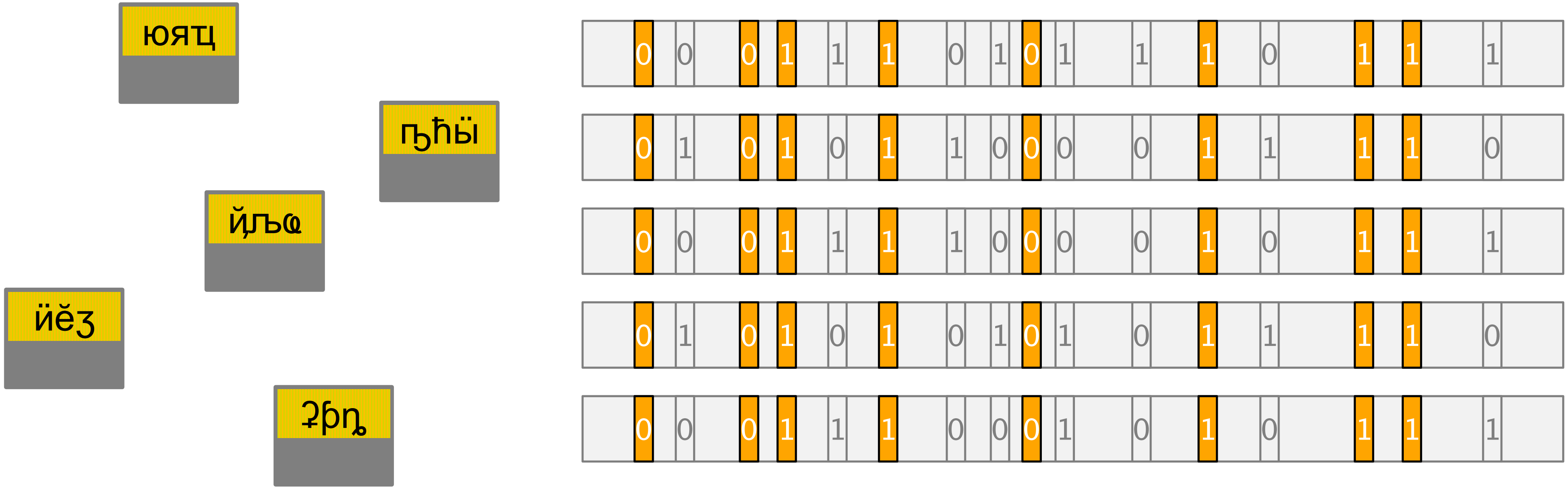

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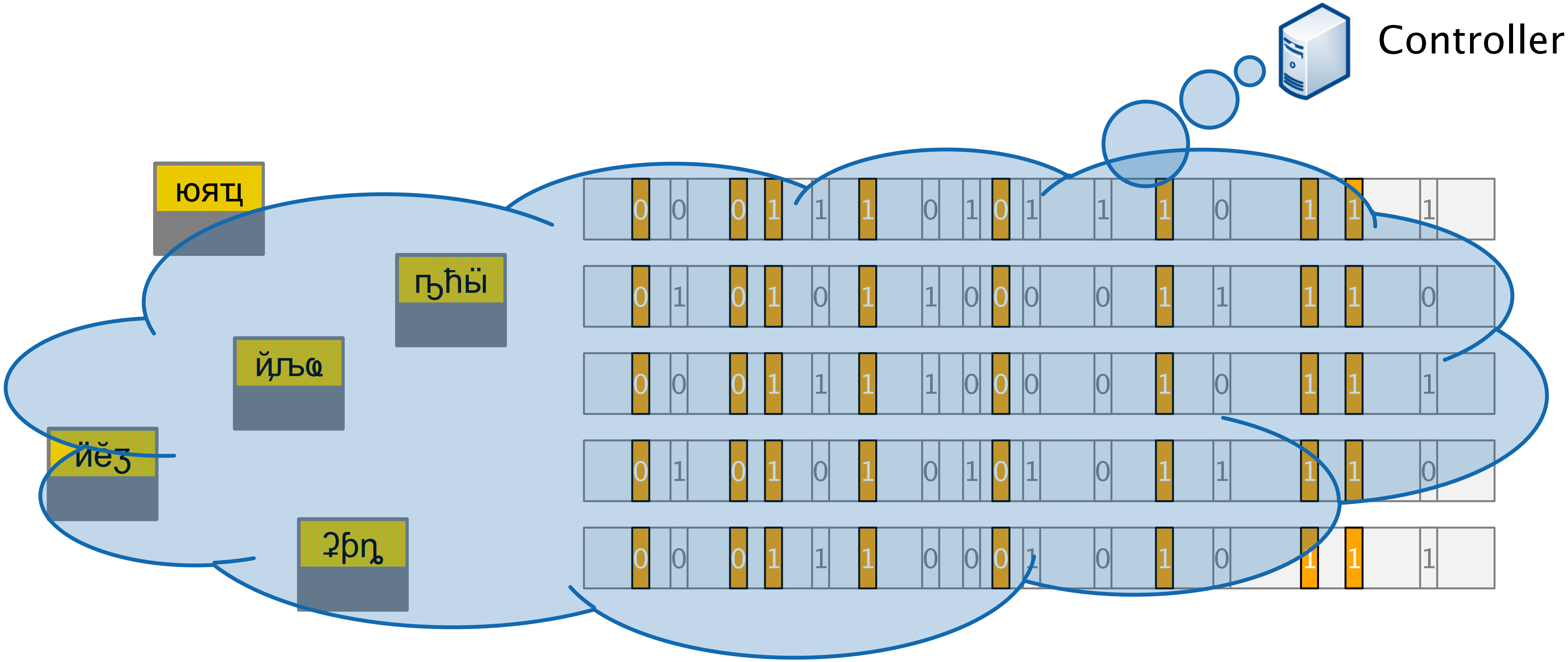
0 1 0 1 0 1 1 0 0 0 0 1 1 1 1 0

0 0 0 1 1 1 1 0 0 0 0 1 0 1 1 1

0 1 0 1 0 1 0 1 0 1 0 1 1 1 1 0

0 0 0 1 1 1 0 0 0 1 0 1 0 1 1 1

What if an attacker analyzes multiple flows?

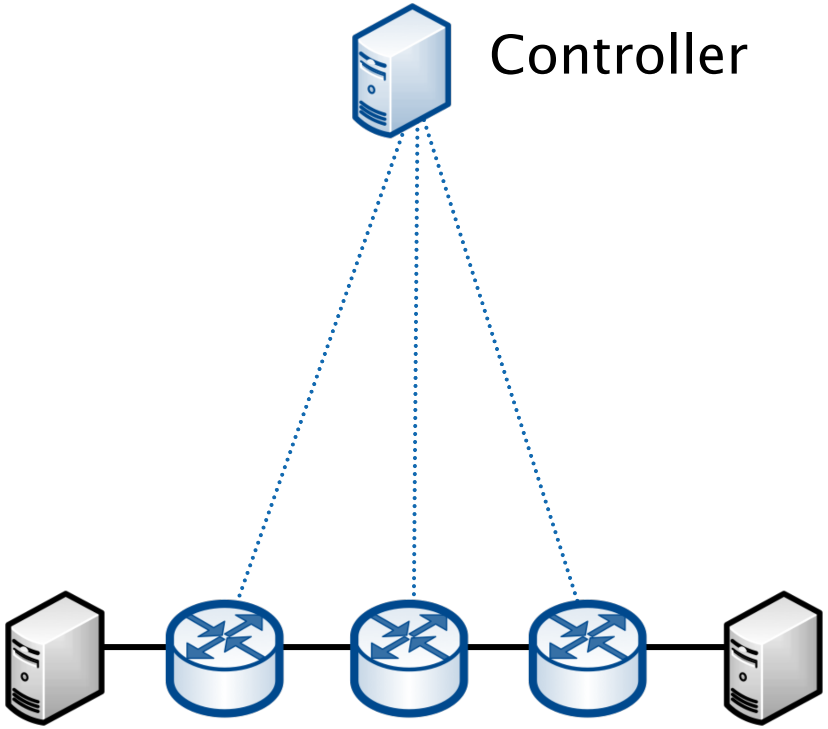


0	0	0	1	1	1	0	1	0	1	1	1	0	1	1	1
0	1	0	1	0	1	1	0	0	0	0	1	1	1	1	0
0	0	0	1	1	1	1	0	0	0	0	1	0	1	1	1
0	1	0	1	0	1	0	1	0	1	0	1	1	1	1	0
0	0	0	1	1	1	0	0	0	1	0	1	0	1	1	1

iTAP controls information leakage and proactively adapts the encoding

The controller monitors the observed entropy for each link…

… and changes the encoding before an eavesdropper is able to break it.

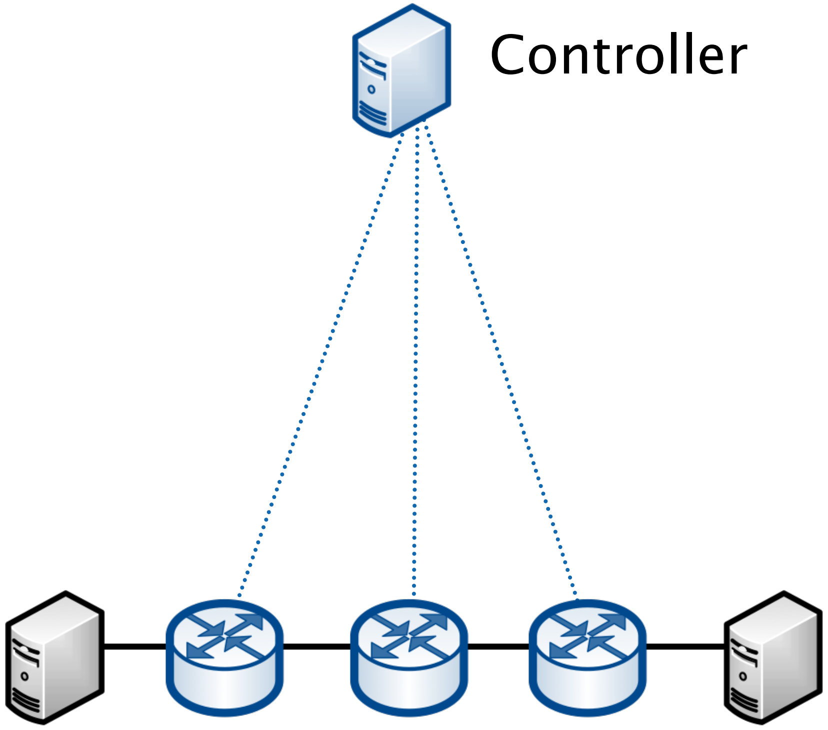


iTAP controls information leakage and proactively adapts the encoding

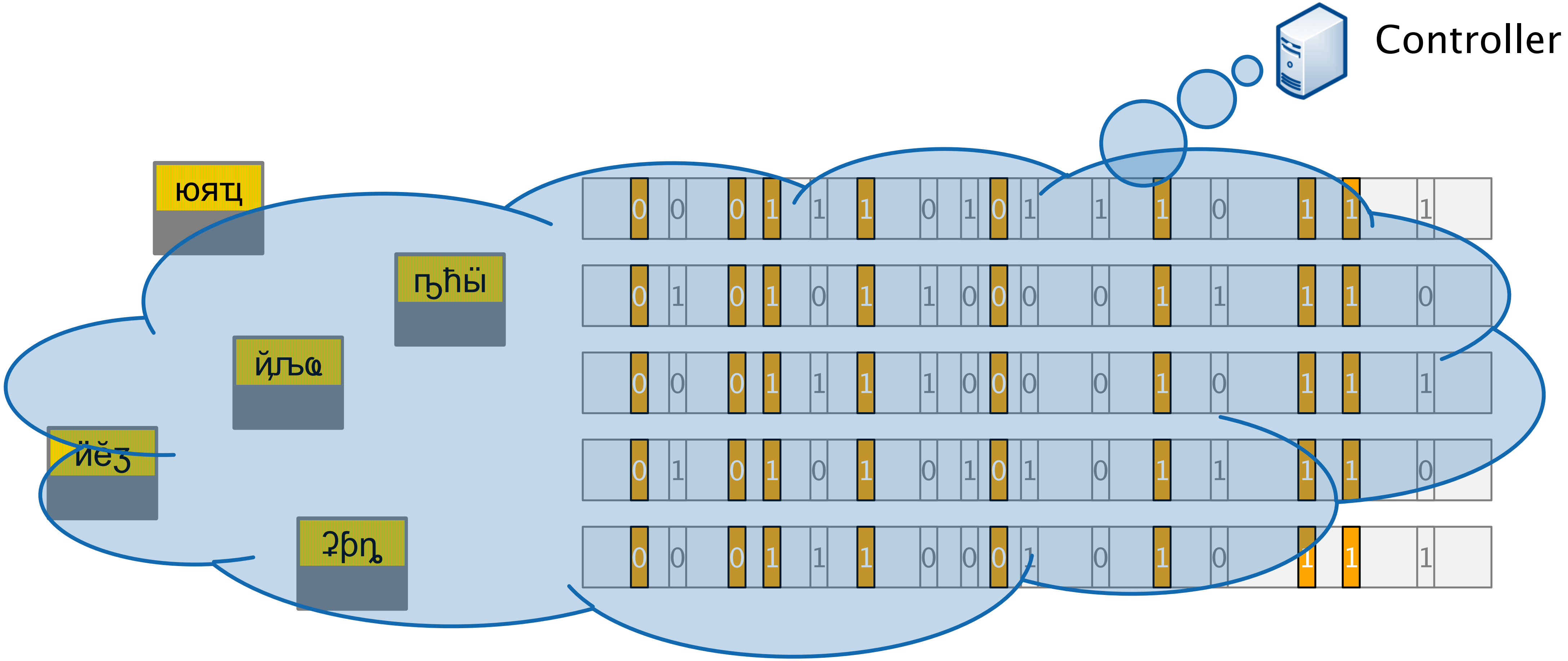
The controller monitors the observed entropy for each link…

… and changes the encoding before an eavesdropper is able to break it.*

* According to the Unicity Distance



iTAP controls information leakage and proactively adapts the encoding



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0 1 0 1 0 1 1 0 0 0 0 1 1 1 1 0
0 0 0 1 1 1 1 0 0 0 0 1 0 1 1 1
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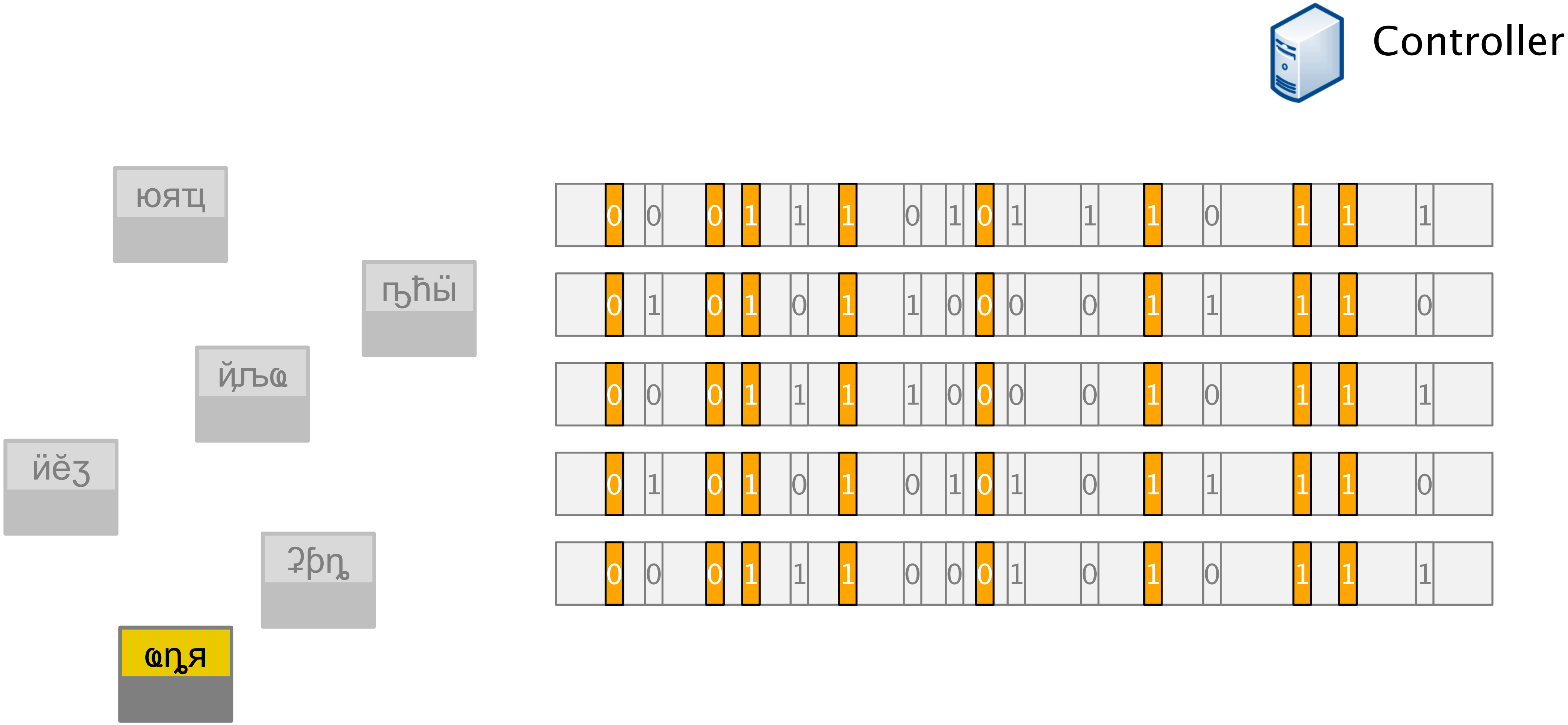
0 0 0 1 1 1 0 0 0 1 0 1 0 1 1 1

iTAP controls information leakage and proactively adapts the encoding



0 0 0 1 1 1 0 1 0 1 1 1 0 1 1 1

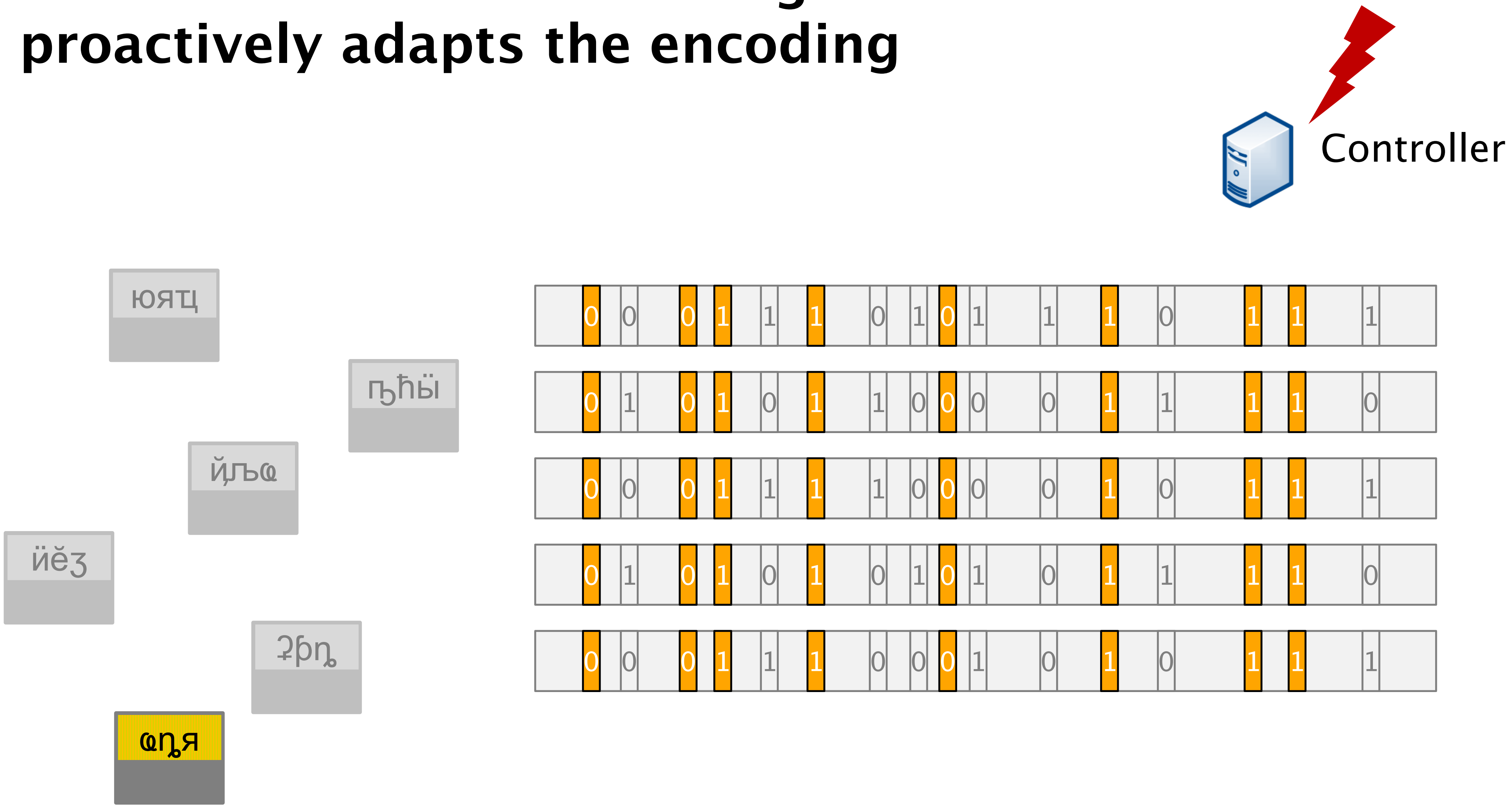
0 1 0 1 0 1 1 0 0 0 0 1 1 1 1 0

0 0 0 1 1 1 1 0 0 0 0 1 0 1 1 1

0 1 0 1 0 1 0 1 0 1 0 1 1 1 1 0

0 0 0 1 1 1 0 0 0 1 0 1 0 1 1 1

iTAP controls information leakage and proactively adapts the encoding



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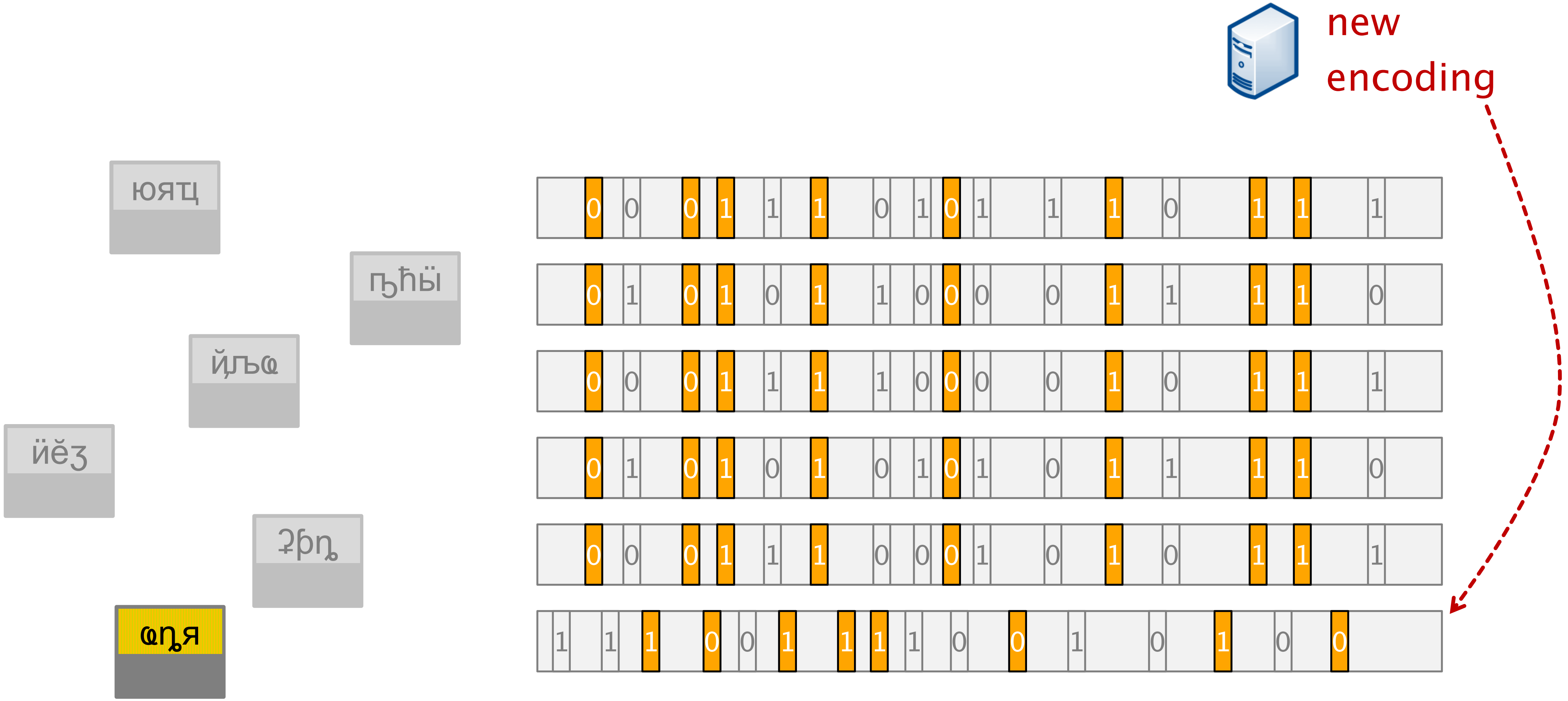
0 1 0 1 0 1 1 0 0 0 0 1 1 1 1 0
0 0 0 1 1 1 1 0 0 0 0 1 0 1 1 1
0 1 0 1 0 1 0 1 0 1 0 1 1 1 1 0
0 0 0 1 1 1 0 0 0 1 0 1 0 1 1 1
```

iTAP controls information leakage and proactively adapts the encoding



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0 0 0 1 1 1 1 0 0 0 0 1 0 1 1 1

0 1 0 1 0 1 0 1 0 1 0 1 1 1 1 0

0 0 0 1 1 1 0 0 0 1 0 1 0 1 1 1

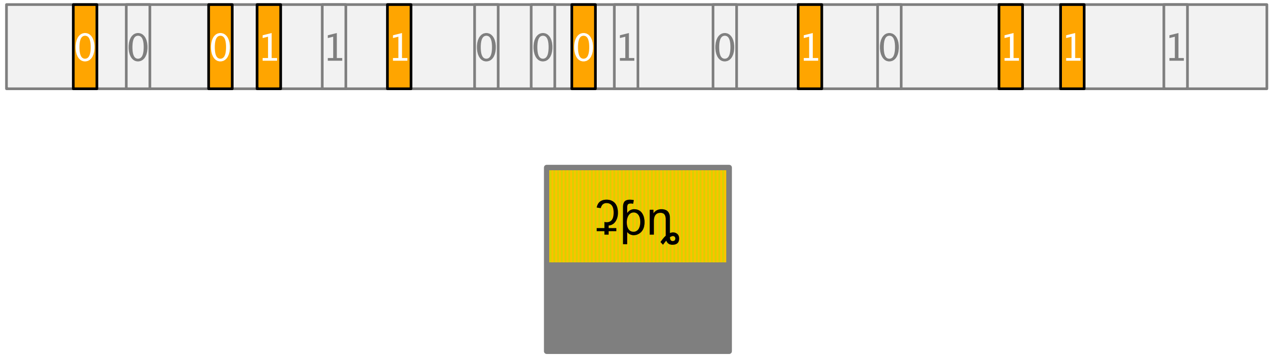
1 1 1 0 0 1 1 1 1 0 0 1 0 1 0 0

new encoding

iTAP hybrid obfuscation scheme

Forwarding based on the destination ID

→ good scalability

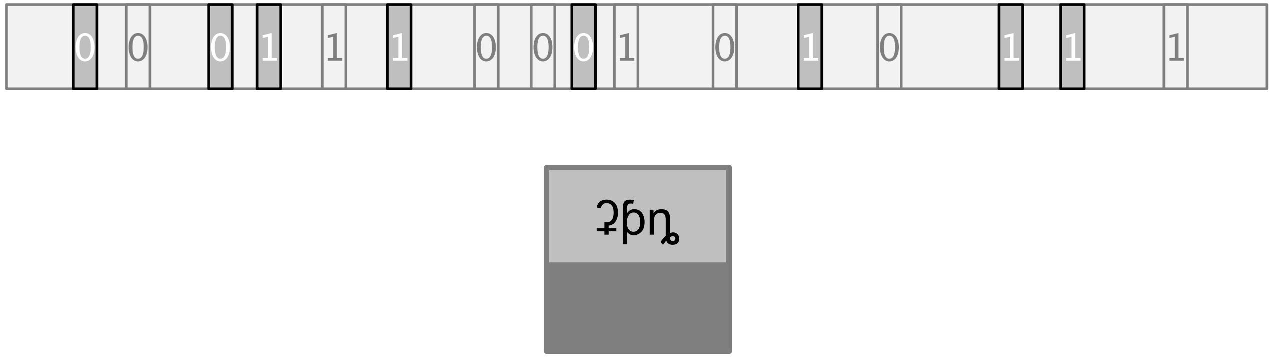


iTAP hybrid obfuscation scheme

Forwarding based on the destination ID

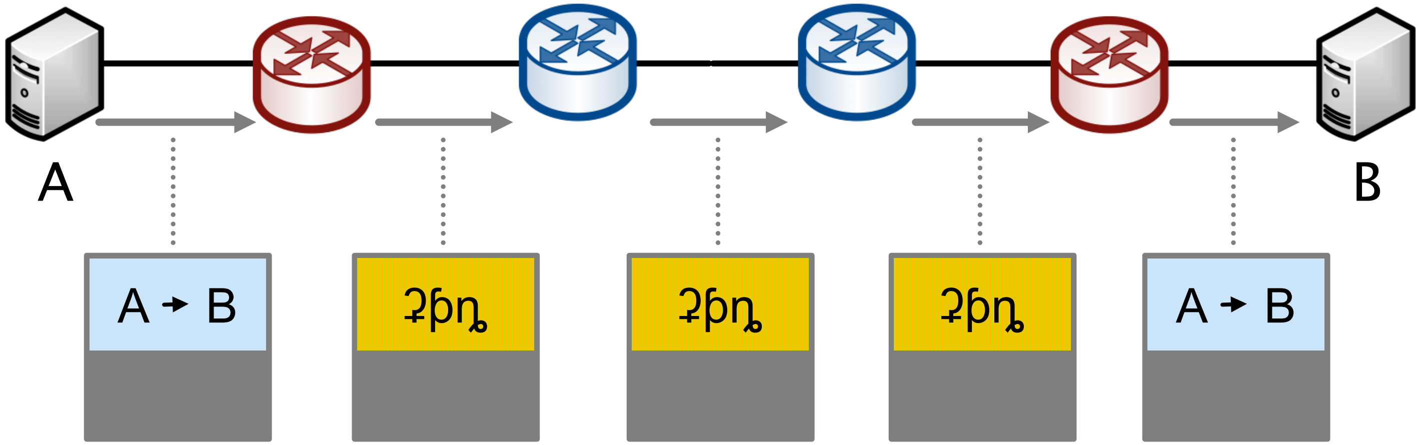
→ good scalability

→ but what about the edge switches?



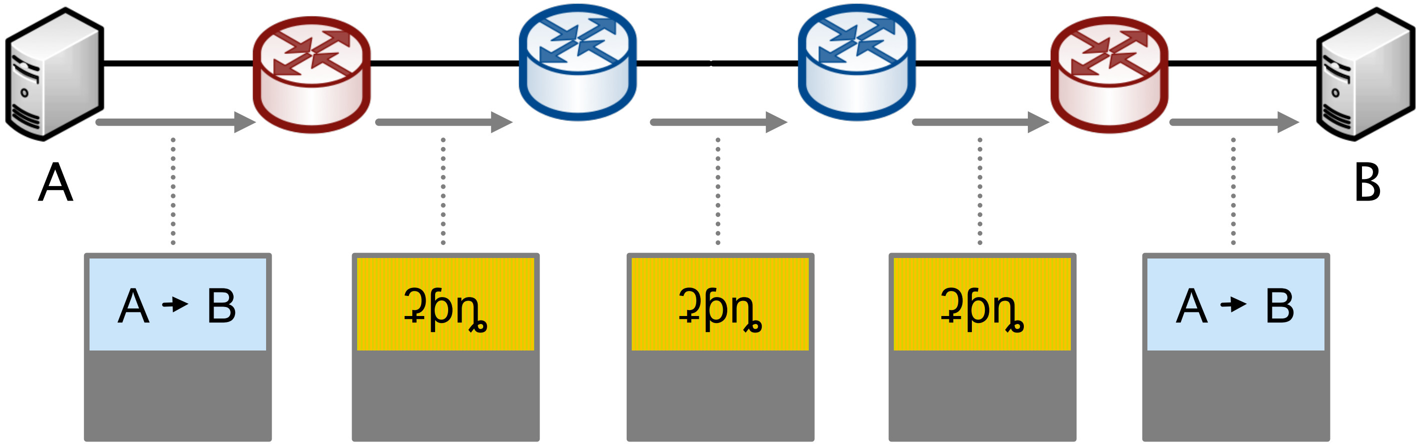
Distributed rewriting for better scalability at the network edge

●	Forwarding	core switches
●	Rewriting	edge switches



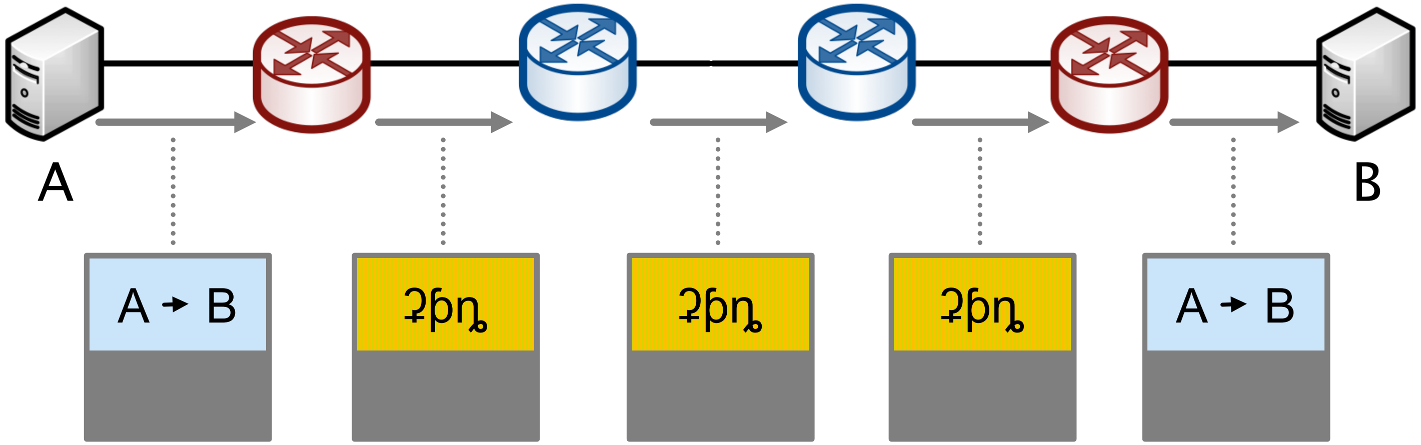
Distributed rewriting for better scalability at the network edge

🔵	Forwarding	core switches	1 rule / destination (ID)
🔴	Rewriting	edge switches	



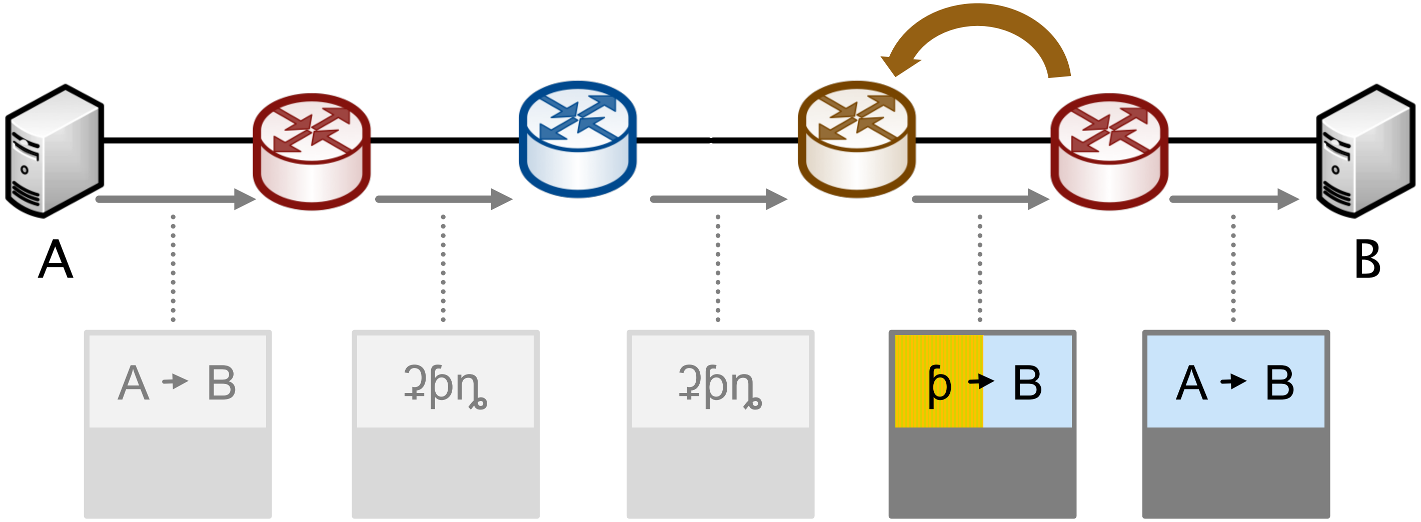
Distributed rewriting for better scalability at the network edge

Forwarding	core switches	1 rule / destination (ID)
Rewriting	edge switches	1 rule / flow



Distributed rewriting for better scalability at the network edge

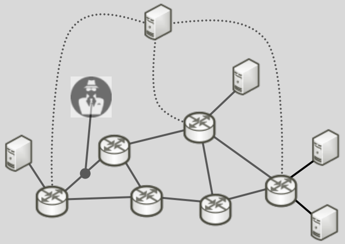
Forwarding	core switches	1 rule / destination (ID)
Rewriting	edge switches / core switches	1 rule / flow



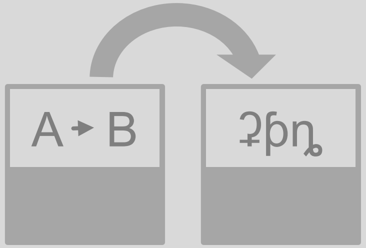
iTAP

Overview

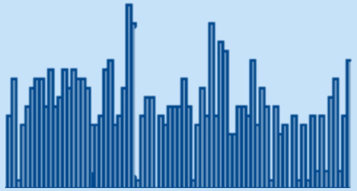
Architecture



Header rewriting



Evaluation



iTAP evaluation based on real network traffic

iTAP evaluation based on

7 days	of network traffic
400	hosts
128 M	flows

iTAP evaluation based on real network traffic

7 days of network traffic   400 hosts   128 M flows

Indicators: controller actions / s

flow table updates / s

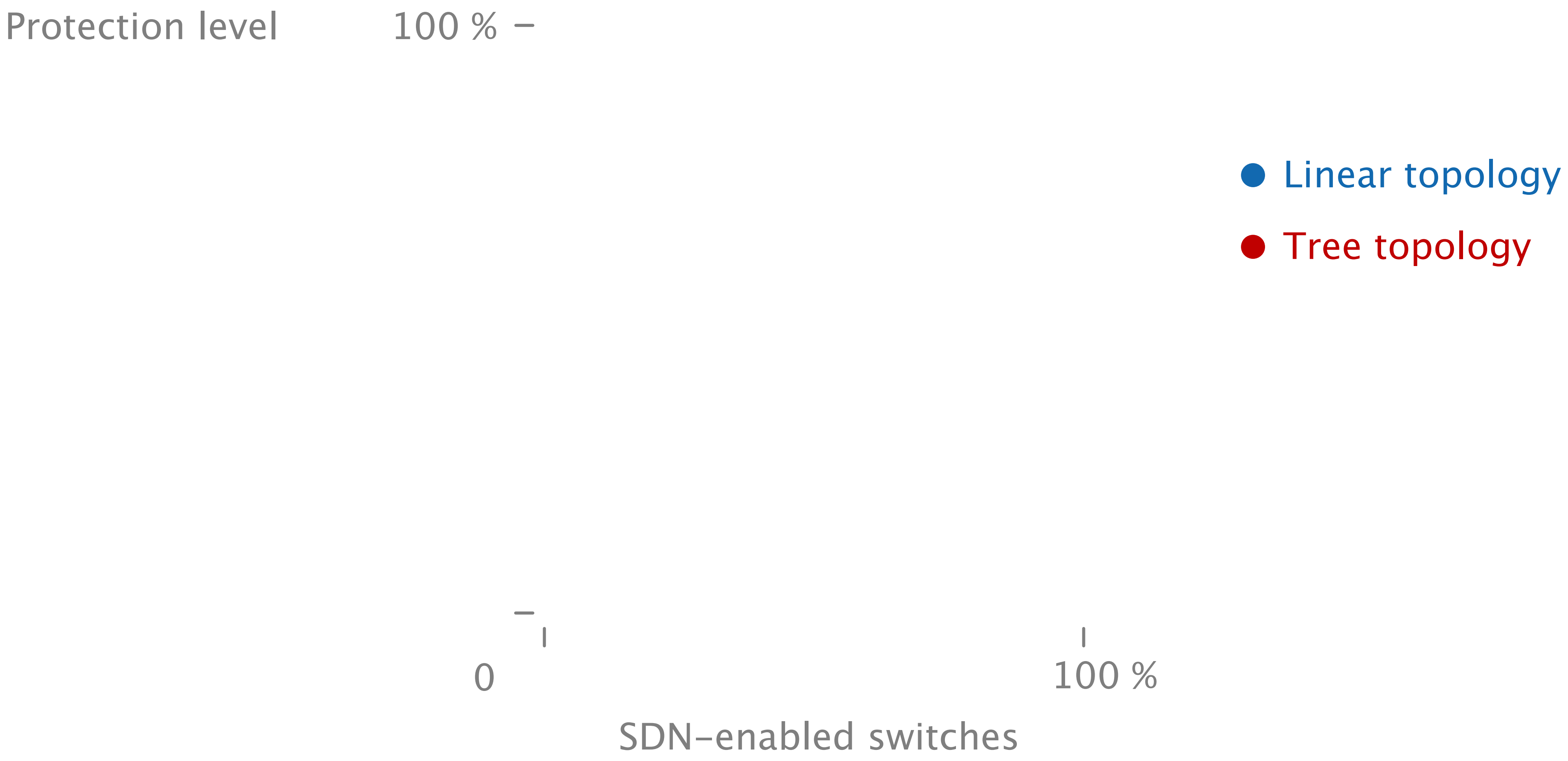
forwarding rules

iTAP works in practice

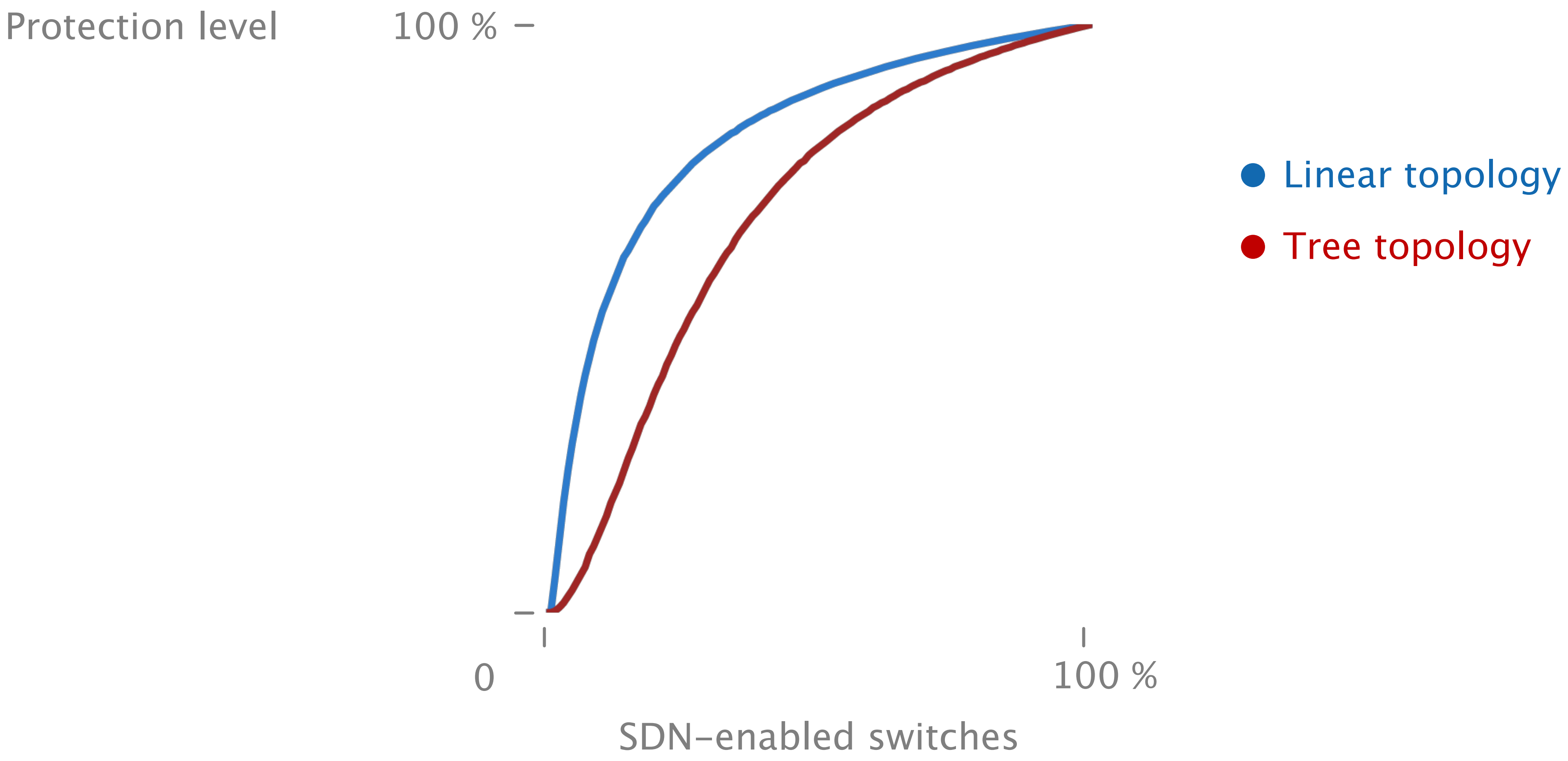
7 days of network traffic   400 hosts   128 M flows

avg	max	
200	700	controller actions / s
50	250	flow table updates / s
600	2.5 k	forwarding rules

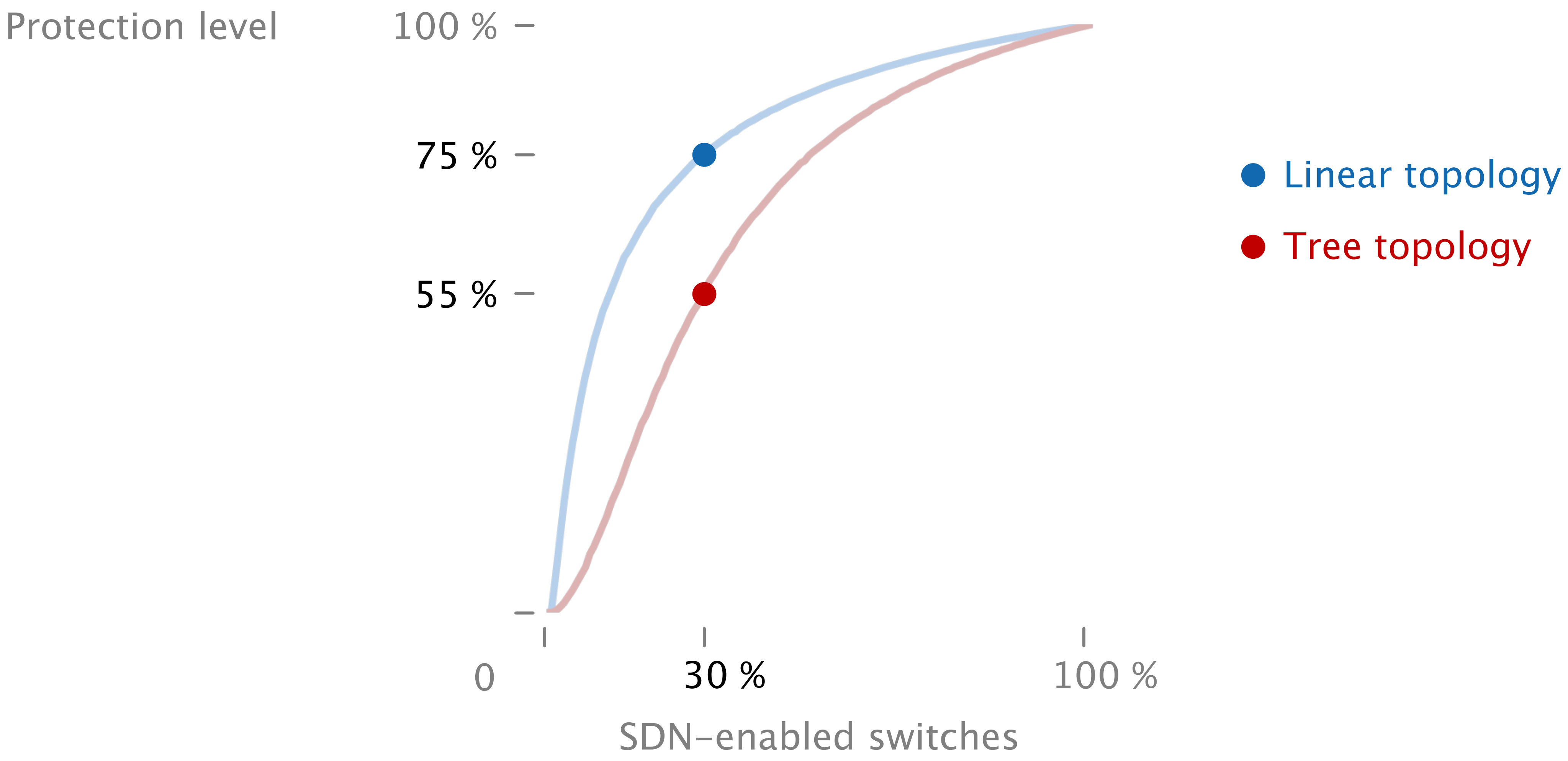
Only a small share of SDN switches is sufficient to protect a large share of the network traffic



Only a small share of SDN switches is sufficient to protect a large share of the network traffic



Only a small share of SDN switches is sufficient to protect a large share of the network traffic

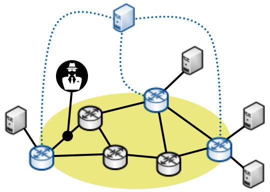


Outlook
Improving network security through programmability

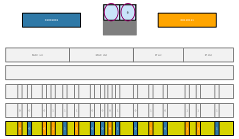
- Anonymity & privacy
- Detecting & locating attackers
- Deception techniques

Contributions

https://itap.ethz.ch

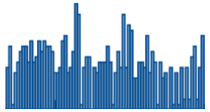


iTAP design



Scalable & anonymity-providing header rewriting scheme

iTAP prototype implementation



Evaluation based on real user traffic