Practical Verifiable In-network Filtering for DDoS Defense

Deli Gong, **<u>Muoi Tran</u>**, Shweta Shinde,

Hao Jin, Vyas Sekar, Prateek Saxena, Min Suk Kang

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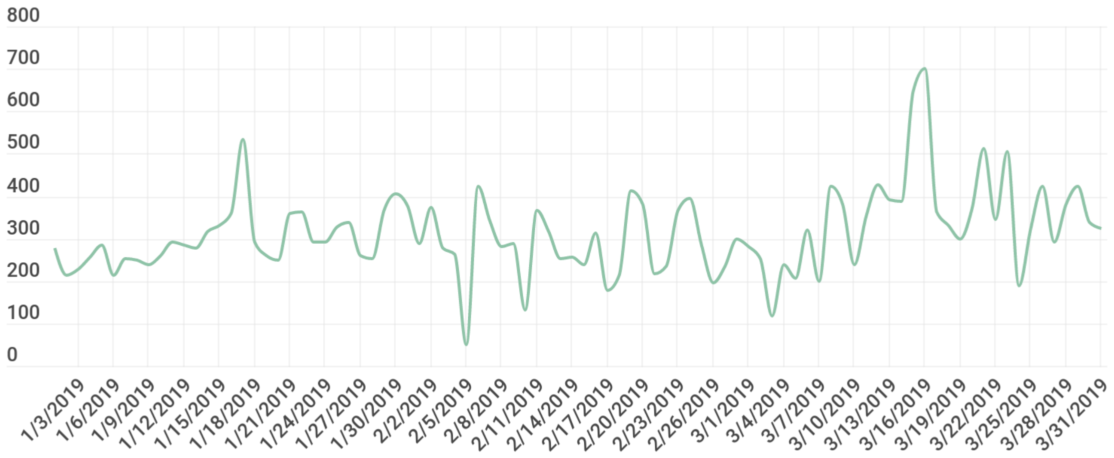
NUS National University of Singapore
Berkeley UNIVERSITY OF CALIFORNIA
TEXAS A&M UNIVERSITY
Carnegie Mellon University

Large-scale volumetric DDoS attacks are common

(distributed denial of service)

- ***Hundreds*** DDoS attacks occur ***daily****
- Volume of DDoS traffic is ***escalating***
- New attack vectors (e.g., amplification) and attack source (e.g., botnets)



* According to Kaspersky Lab's report on DDoS attacks in Q1 2019

(2013)

COMPUTERWORLD

SECURITY IS SEXY

By Darlene Storm | Follow

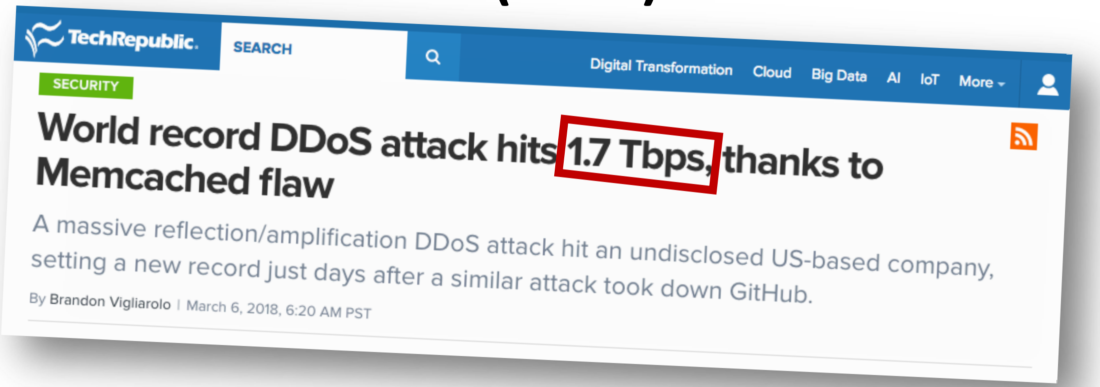
About

Most security news is about insecurity, hacking and cyber threats, bordering on scary. But when security is done right, it's a beautiful thing...sexy even. Security IS sexy.

OPINION

Biggest DDoS attack in history slows Internet, breaks record at 300 Gbps

(2018)



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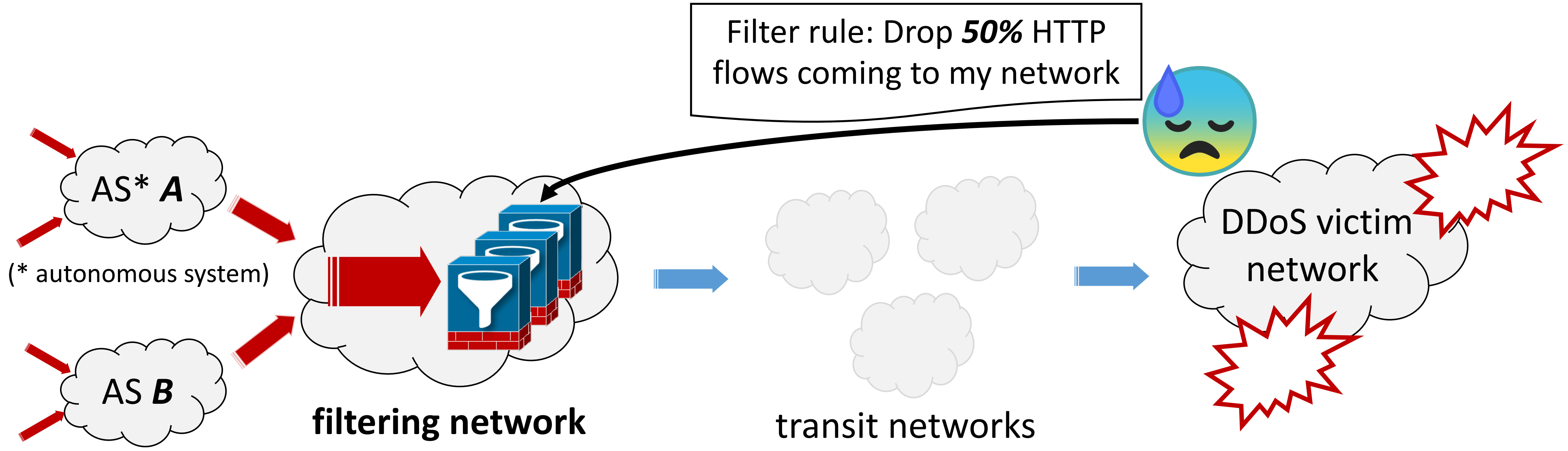
SECURITY

World record DDoS attack hits 1.7 Tbps, thanks to Memcached flaw

A massive reflection/amplification DDoS attack hit an undisclosed US-based company, setting a new record just days after a similar attack took down GitHub.

By Brandon Vigliarolo | March 6, 2018, 6:20 AM PST

In-network filtering: a promising DDoS mitigation

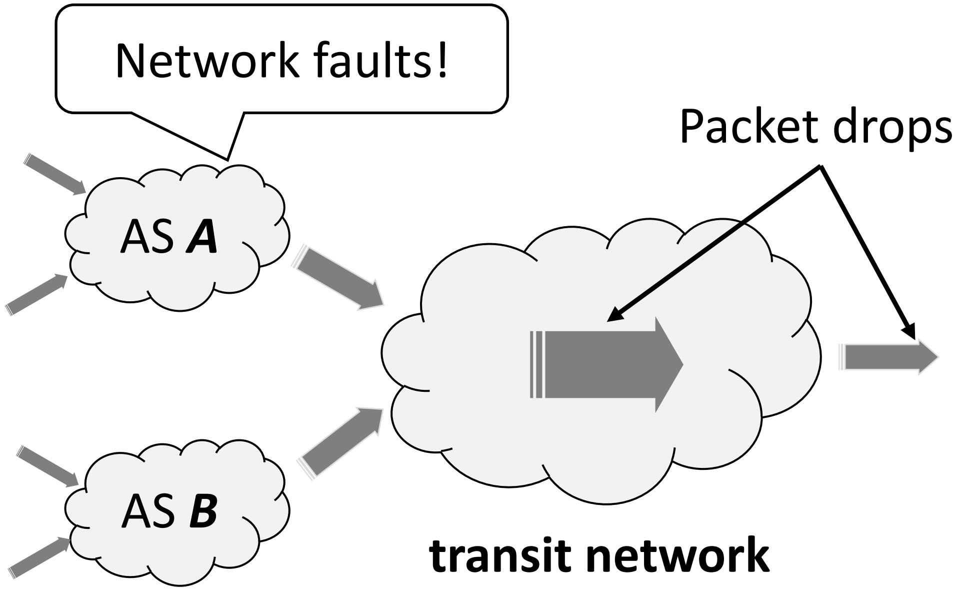


- In-network filtering
  - ✓ allows the DDoS victim to install traffic filters nearer to attack source
  - ✓ not a new idea:

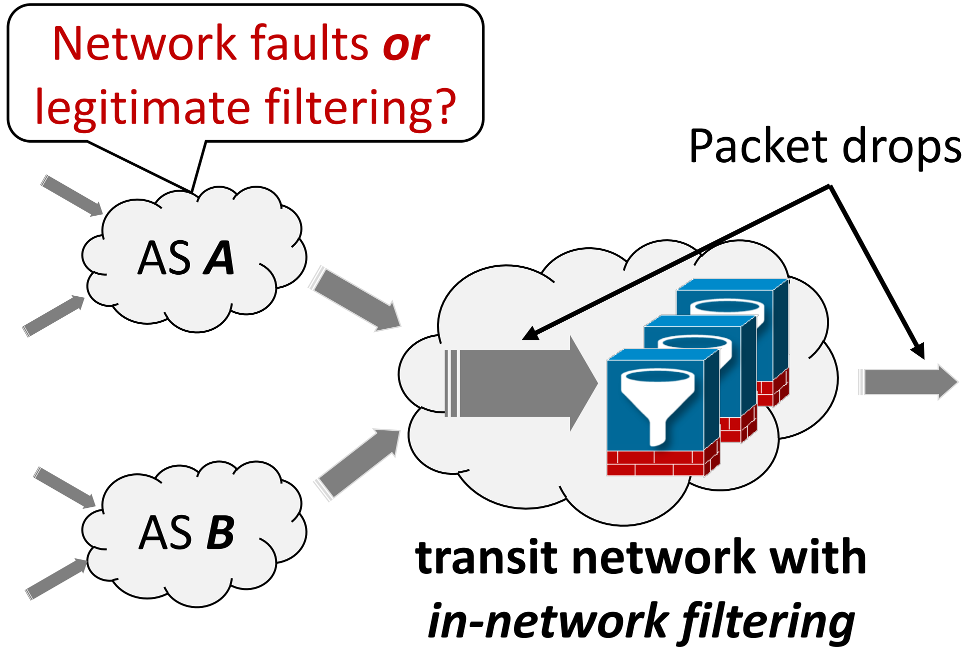
    e.g., *Pushback* [SIGCOMM'02], *D-WARD* [ICNP'02], *AITF* [USENIX ATC'05], *StopIt* [SIGCOMM'08]
  - ✓ installs at ***1% of ISPs*** can mitigate ***90% of DDoS attacks*** (*SENSS* [ACSAC'18])

One ***ignored*** problem: In-network filtering creates ***ambiguity*** about packet drops

Without in-network filtering

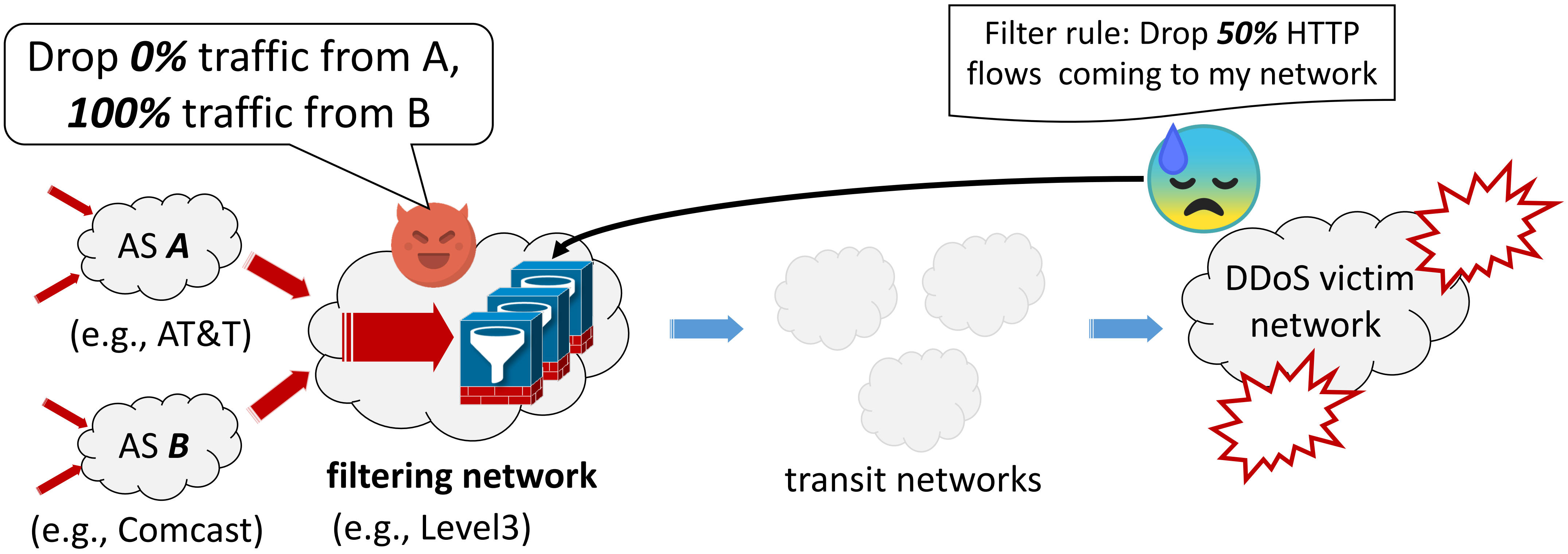


With in-network filtering

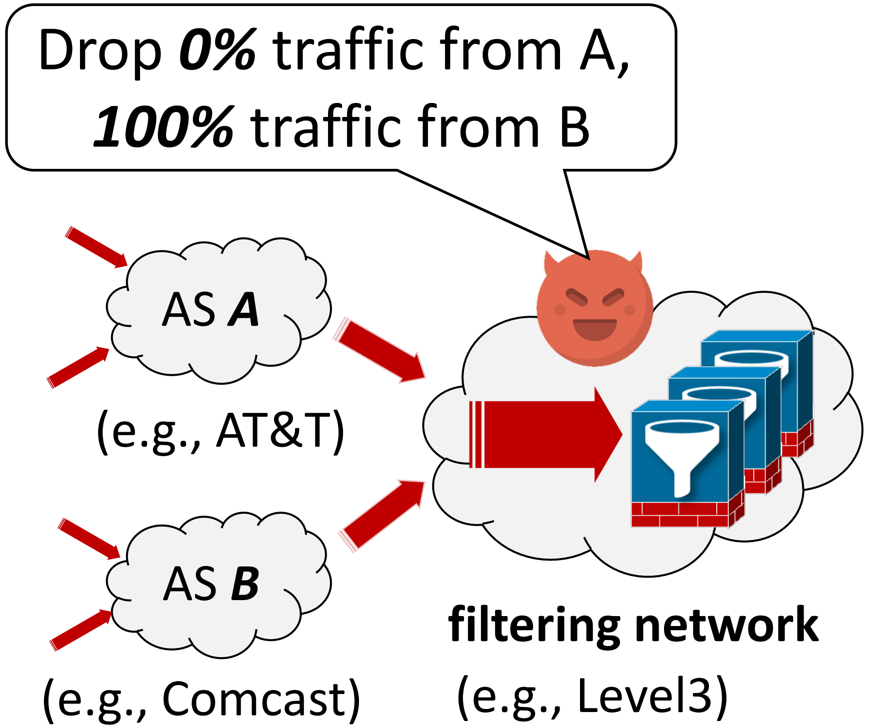


What can go wrong because of this ambiguity?

Filtering can be used as an ***excuse*** for ***discriminating*** neighboring ASes



Filtering can be used as an ***excuse*** for ***discriminating*** neighboring ASes



(2013)

FierceTelecom

AI TELECOM TECH PLATFORMS

Telecom

Verizon blames Cogent for unbalanced peering in Netflix dispute

by Sue Marek | Jun 20, 2013 11:13am

(2014)

INTERNET

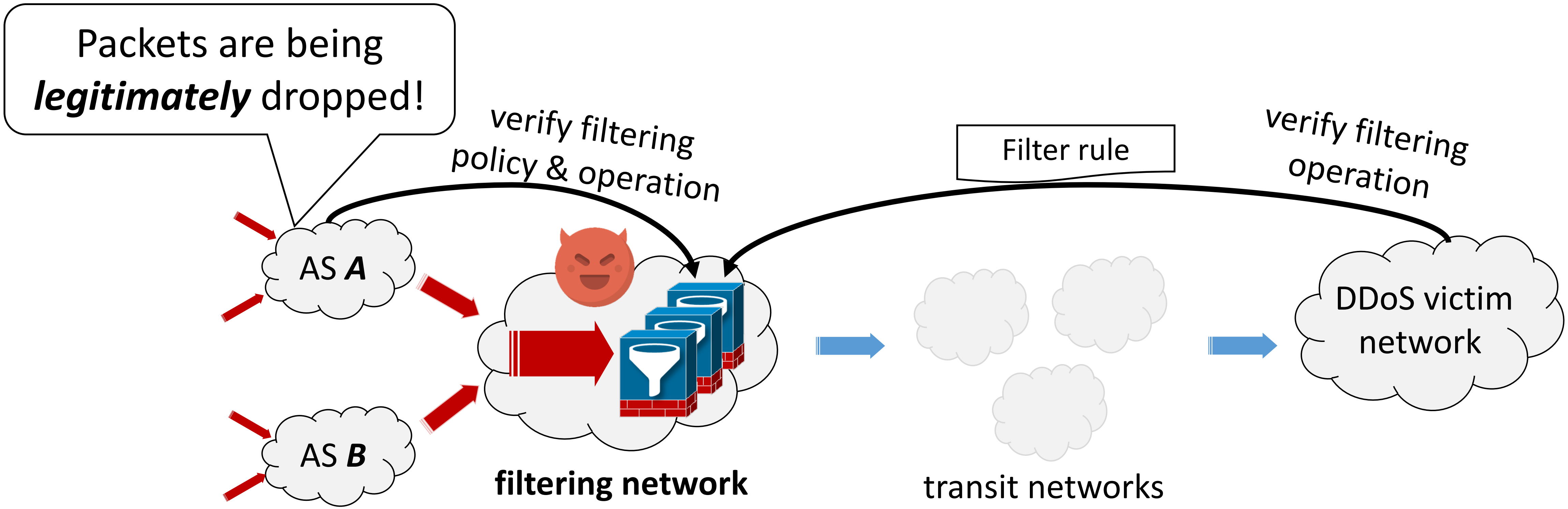
Level 3 accuses six broadband providers of degrading network traffic

Level 3 says the providers are slowing down Internet traffic to extract payment from it. But a deeper dive into the specifics reveals there may be another side to the story.

Several disputes ***already exist*** between transit networks

How to remove such an ambiguity?

Verifiability of filtering distinguishes legitimate DDoS mitigation from network faults



How to make the operations of in-network filtering ***verifiable***?

Our contributions

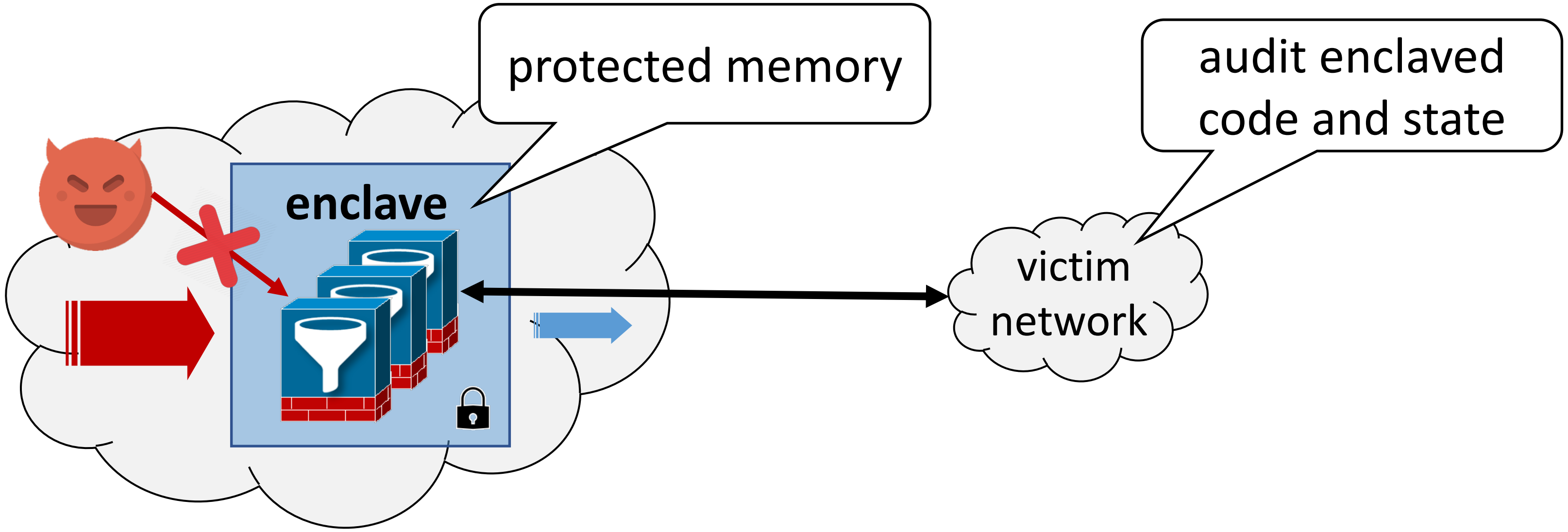
- We propose ***V*erifiable *I*n-network *F*iltering (VIF):**
  - ✓ Software networking functions with Trusted Execution Environments (e.g., Intel SGX) as root of trust.

Auditable **filter**
- ✓ uses TEEs
- ✓ is stateless
- ✓ detects bypass

Scalable **design**
- ✓ multiple filters run in parallel

Practical deployment
- ✓ at Internet Exchange Points (IXPs)

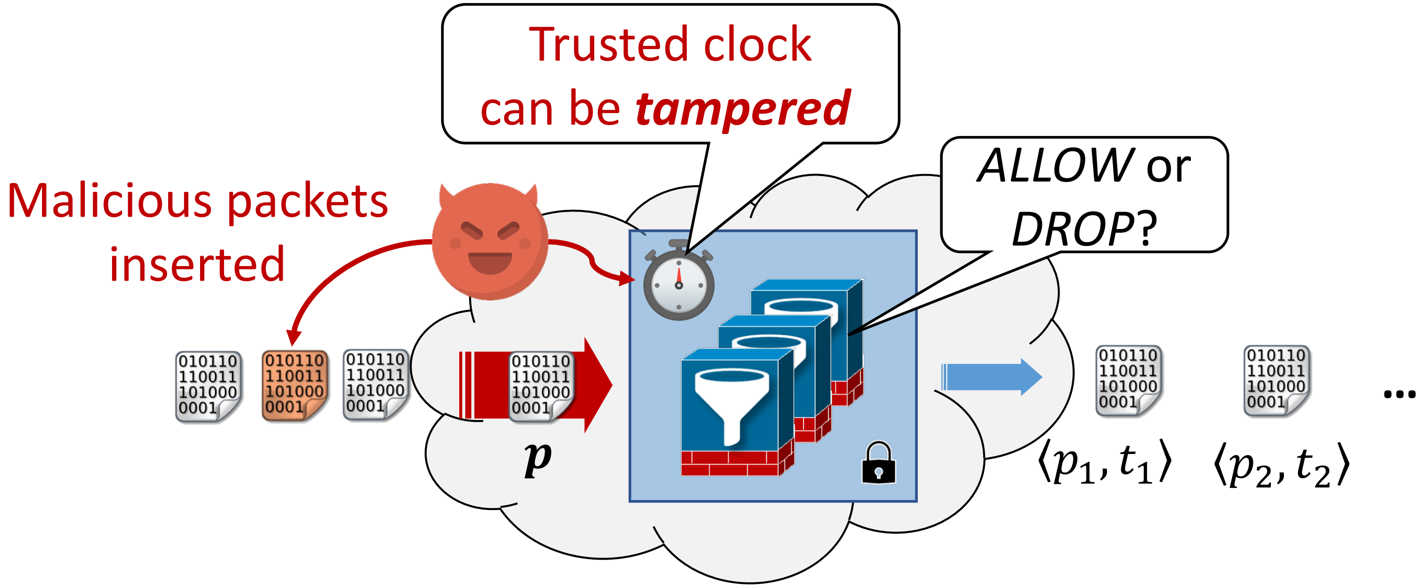
VIF design: ***auditable*** filter with TEEs



- Filtering within Trusted Execution Environments (TEEs) (e.g., Intel SGX)
  - ✓ Isolated execution
  - ✓ Remote attestation

TEEs alone is ***insufficient***
for auditable filter design!

Challenge 1: Influence from ***malicious inputs***



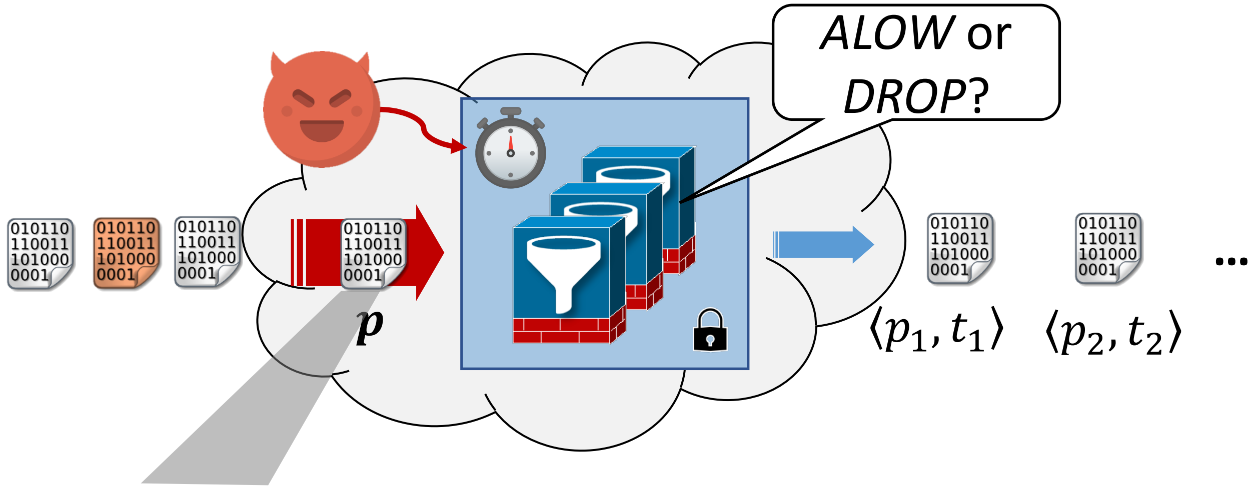
- ***Abstract model*** of the filtering function for packet $\boldsymbol{p}$*:*

$$\{ALLOW, DROP\} \leftarrow f(\langle p, t \rangle, (\langle p_1, t_1 \rangle, \langle p_2, t_2 \rangle, \langle p_3, t_3 \rangle, \dots))$$

Arrival time

Previous packets/
packet order

Solution: ***Stateless*** filter design

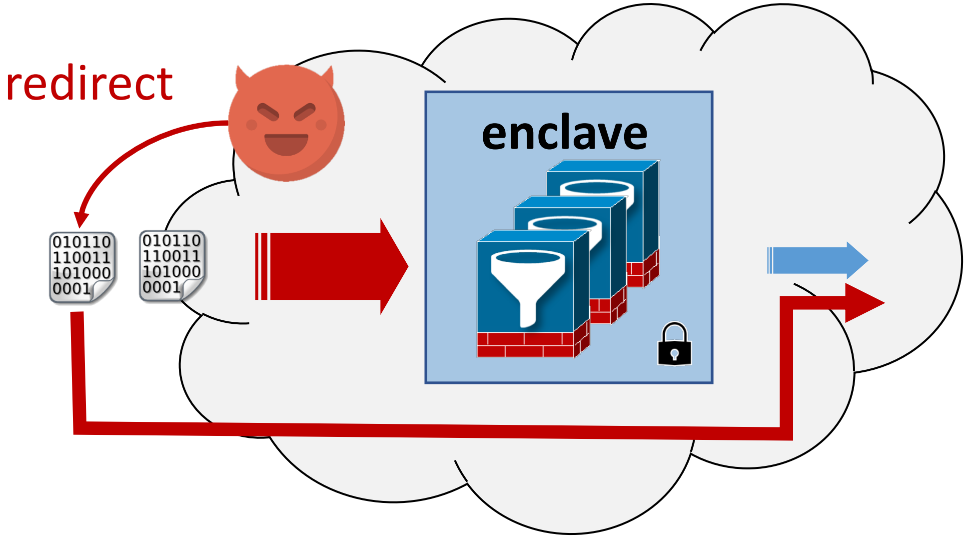


5-tuple (`srcIP, srcPort, dstIP, dstPort, protocol`)

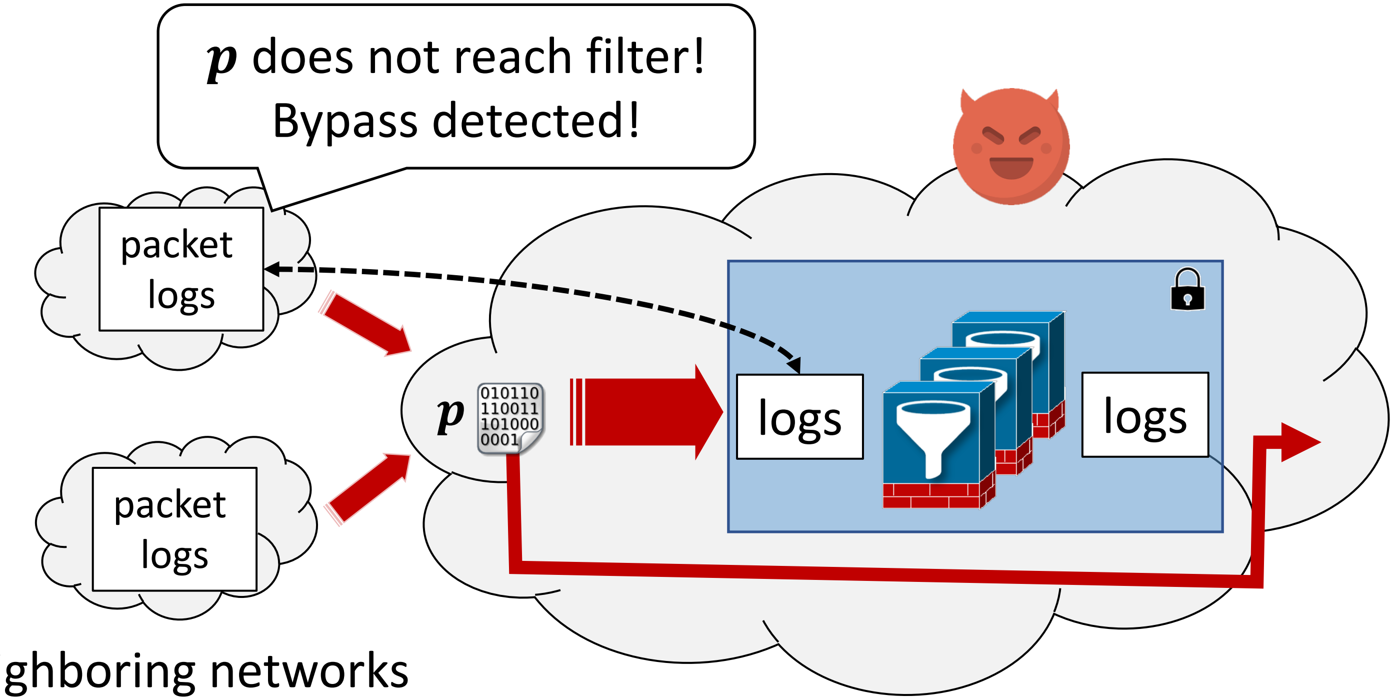
- No reliance on packet arrival time and packet order

$$\{ALLOW, DROP\} \leftarrow f(\langle p \rangle)$$

Challenge 2: Traffic may be redirected to bypass filter



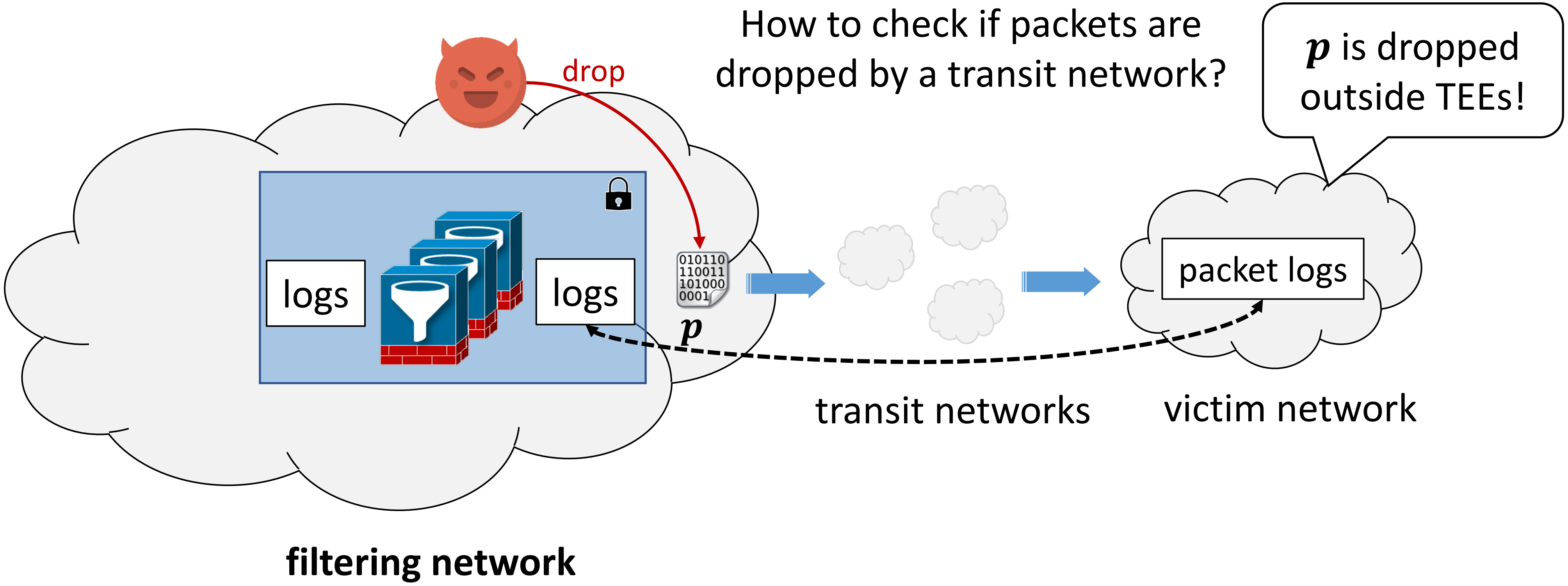
Solution to filter bypass:
Accountable logs for bypass detection



filtering network

- Accountable packet logging before and after filtering
  - ✓ Compare logs to detect bypass

Solution to filter bypass:
Accountable logs for bypass detection



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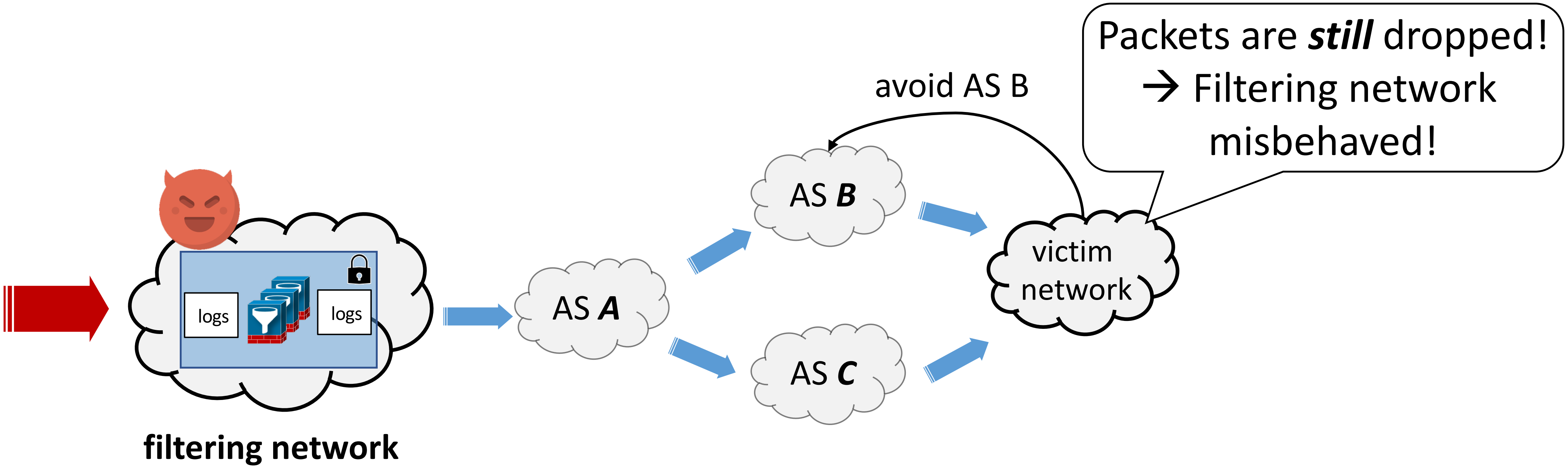
How does victim know ***who*** is dropping packets?



- Victim network ***tests*** individual intermediate ASes
  - ✓ Rerouting inbound traffic using ***BGP poisoning*** (LIFEGUARD[SIGCOMM’12])
  - ✓ Detour takes place in a ***few minutes*** and ***no*** collaboration needed (Nyx [S&P’18])

Our contributions

Auditable **filter**
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Practical deployment
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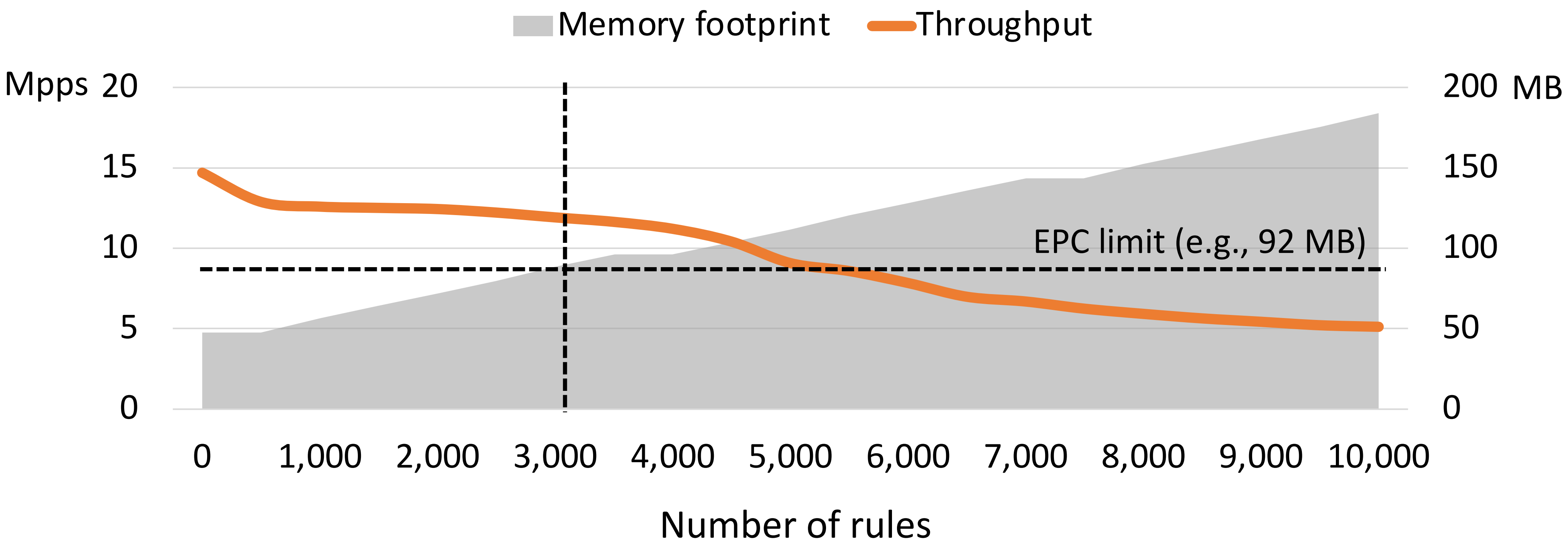
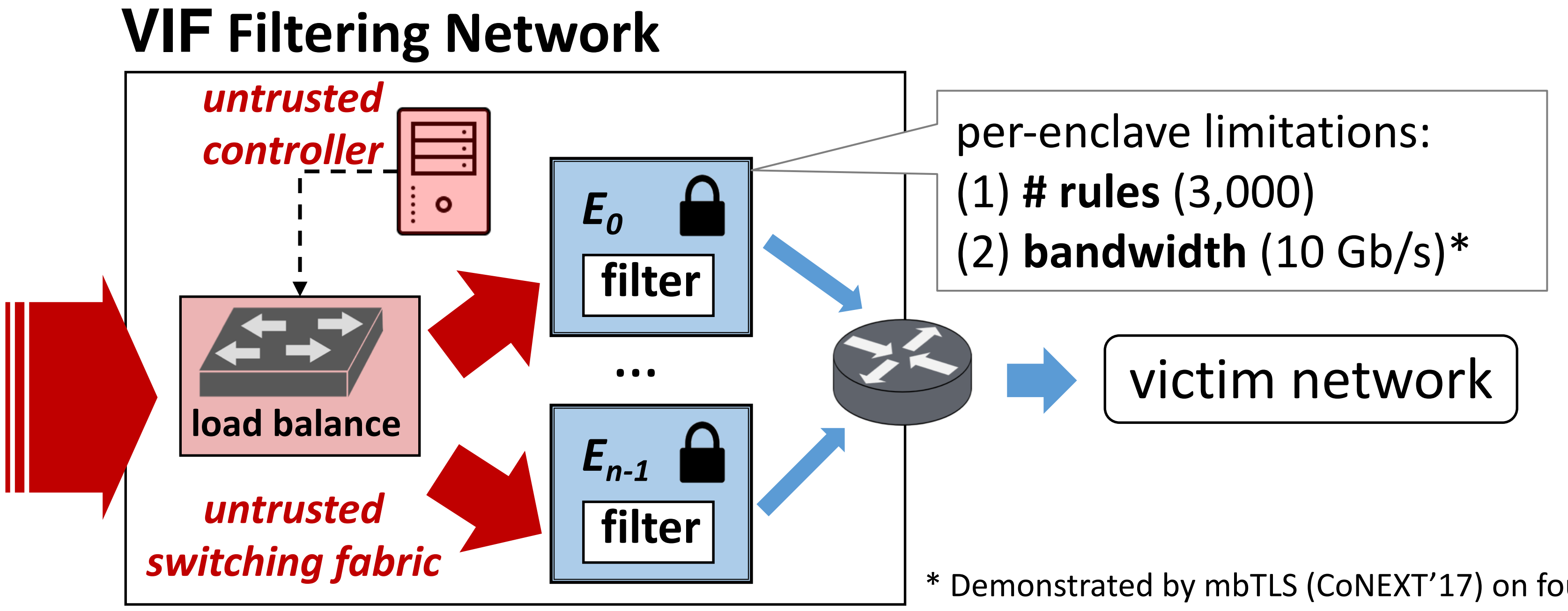
Deployment issue: Scalability



- ***Performance issues*** when filtering within a ***single*** enclave:
  - ✓ Memory footprint grows ***linearly*** with number of rules
  - ✓ Throughput ***degrades*** when number of rules exceeds ~***3,000***

Solution to scalability issue: multiple SGX filters



* Demonstrated by mbTLS (CoNEXT'17) on four SGX-core machines.

- **More in our paper:**
  - ✓ How trusted filters detect misbehaviors from untrusted components
  - ✓ A greedy solution to calculate filter rules among filters
  - ✓ Filter rules redistribution

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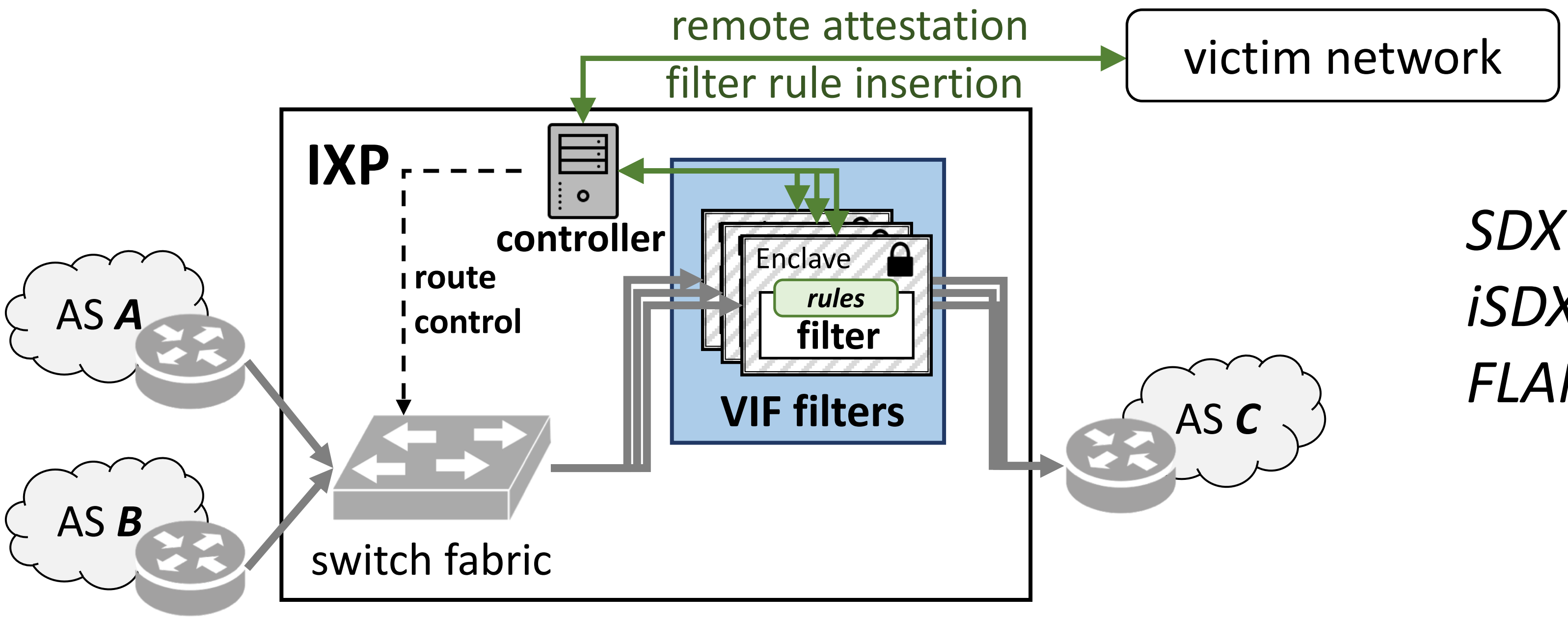
Deployment example



SDX [SIGCOMM'15]
iSDX [NSDI'16]
FLANC [SOSR'16]

- Internet Exchange Points (IXPs) :
  - ✓ have peering relationship with ***hundreds*** ISPs
  - ✓ have flexible software-defined architecture

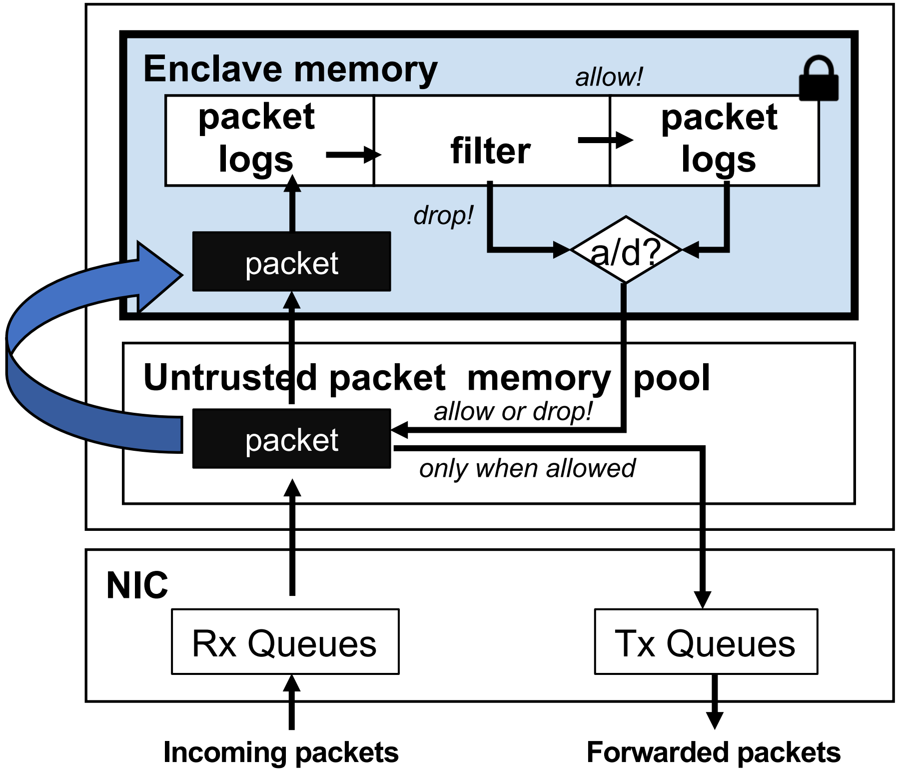
Implementation

- Overview
  - ✓ Intel SGX SDK for Linux 2.1
  - ✓ Data Plane Development Kit (DPDK) 17.05.2
- Trusted computing base:
  - ✓ modification of DPDK `ip_pipeline` (1,044 SLoC)
  - ✓ packet logging and optimizations (162 SLoC)

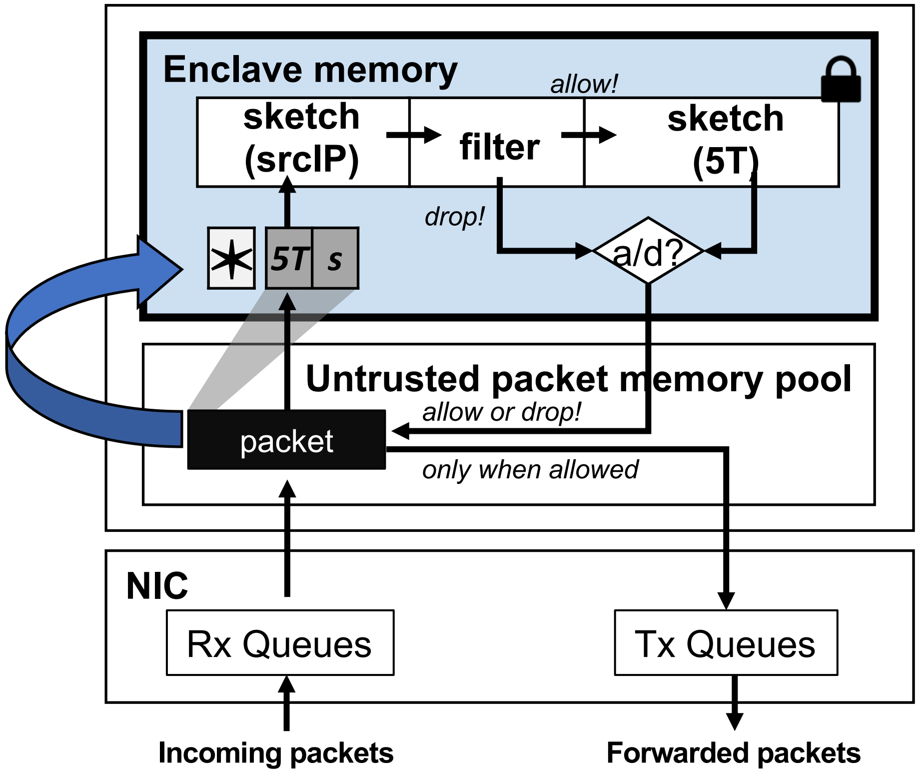
  } **1,206** SLoC
- Two optimizations:
  - ✓ Reducing context switches (more in our paper)
  - ✓ Near-zero copy approach

Optimization: ***near-zero*** copy

Full packet copy



Near-zero copy

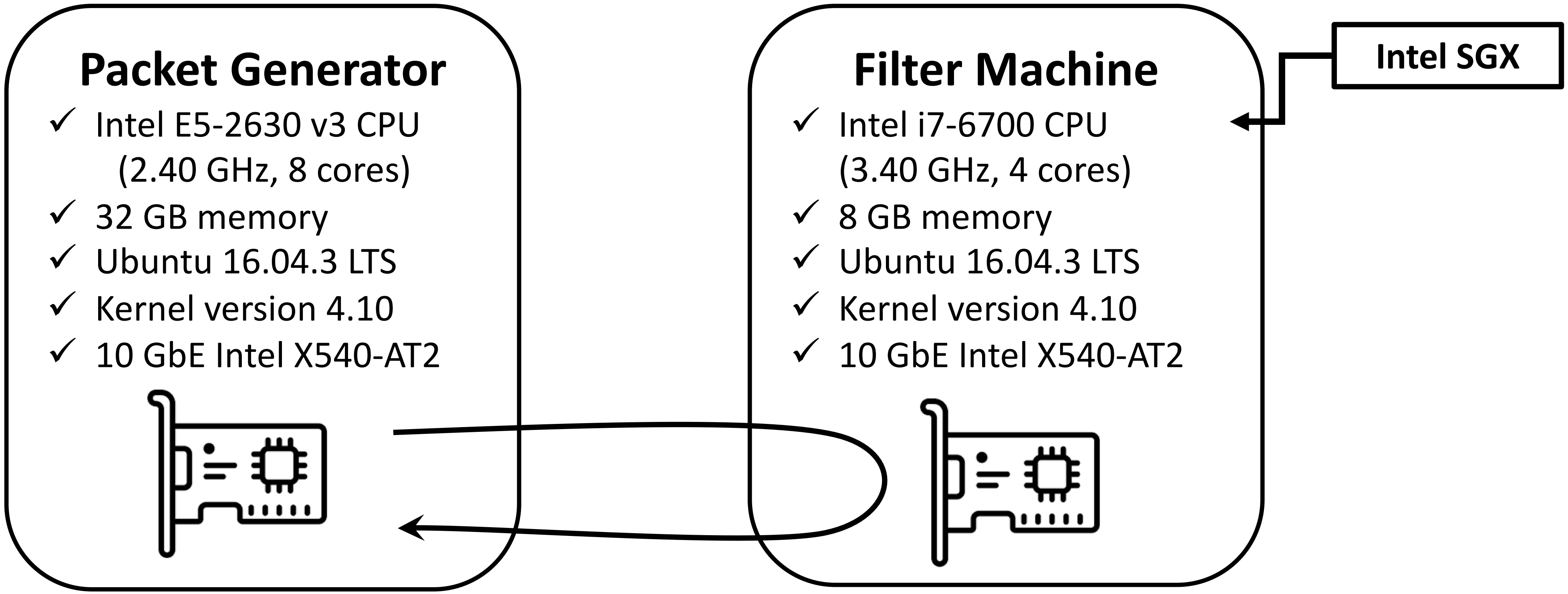


✓ low memory usage

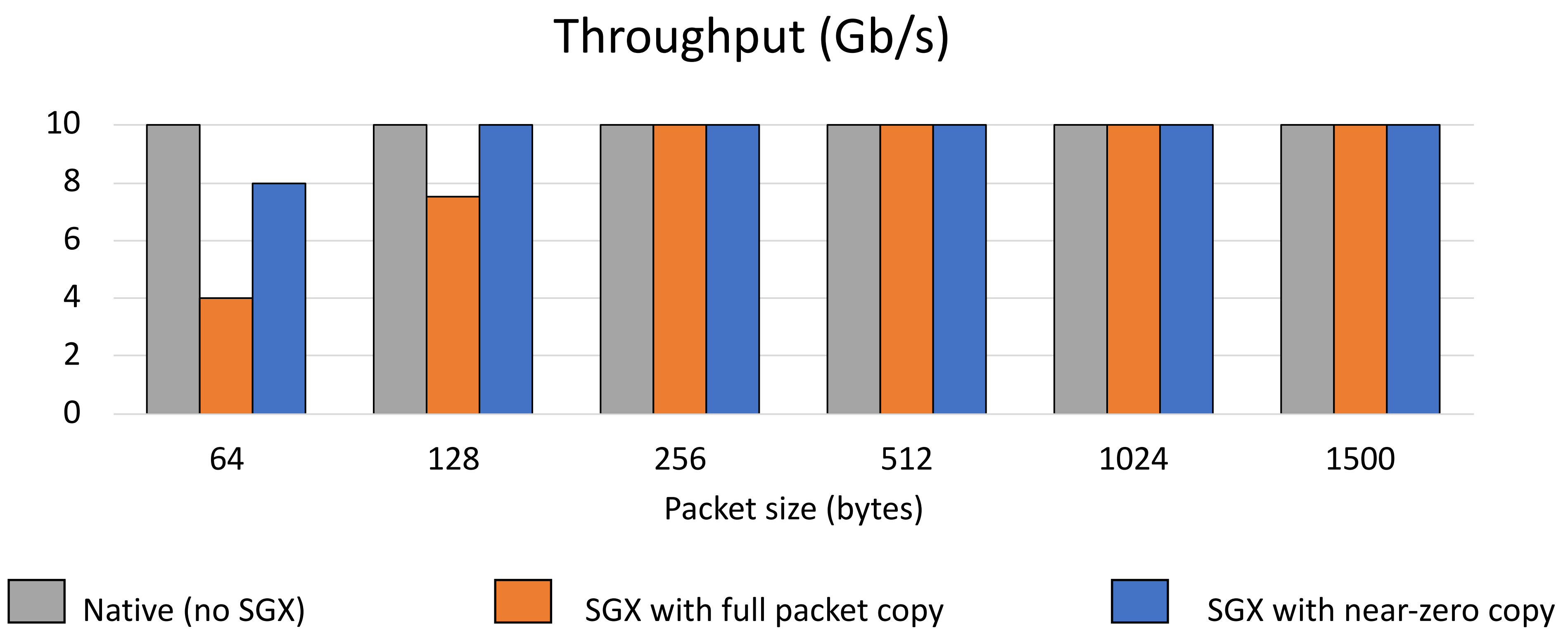
✓ low packet-logging overhead

Data-plane implementation

- **Testbed**
  - ✓ Packet generator ⟷ Filter machine
  - ✓ Measurement is done at packet generator
- **Synthetic data**
  - ✓ 3,000 random filter rules
  - ✓ 10 Gb/s traffic



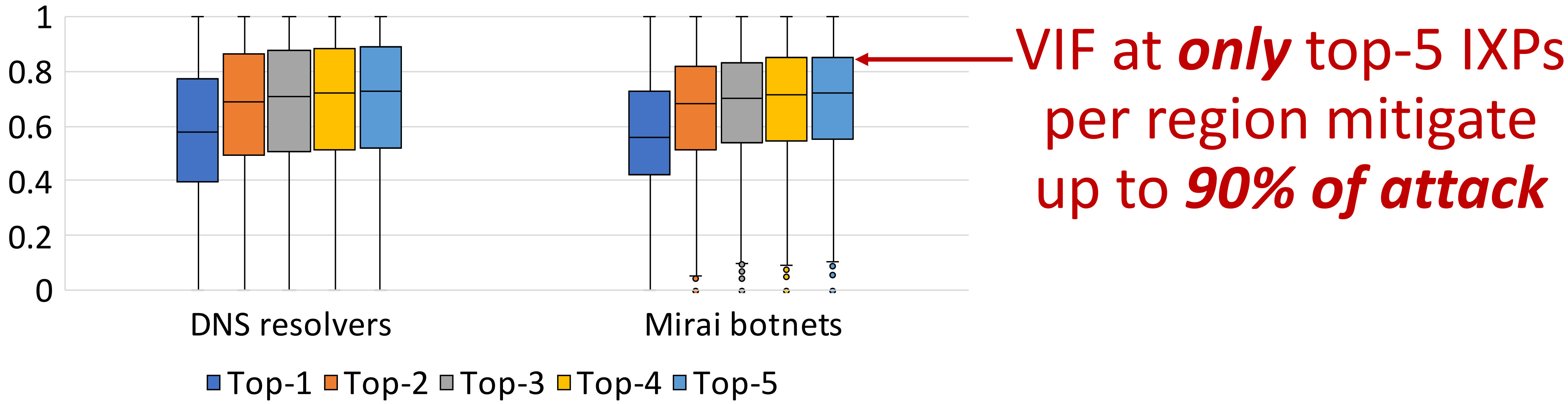
Evaluation: Data-plane performance



- **Throughput of near-zero copy:**
  - ✓ 8 Gb/s throughput even with smallest packet size (64 bytes)

Evaluation: VIF deployment at IXPs

Ratio of attack source IPs handled by top-***n*** IXPs per region



- Simulation setup:
  - ✓ Two real attack source data: ***3 millions*** DNS resolvers and ***250K*** Mirai botnets
  - ✓ CAIDA AS relationship and IXP peering for building inter-domain topology

Conclusion

- VIF addresses the ***core issue*** of in-network filtering
  - ✓ Lack of filtering verifiability → ***ambiguity*** in handling packet drops which can be exploited by malicious ISPs
- VIF: the first ***auditable*** and ***scalable*** DDoS traffic filter
- VIF takes advantages of:
  - ✓ ***Trusted execution environments*** as the root of trust
  - ✓ Software-defined, ***line-rate packet processing***
  - ✓ ***IXPs*** for practical deployment

Question?

Muoi Tran
muoitran@comp.nus.edu.sg

NUS
National University of Singapore