Inter-domain DDoS mitigations: potentials, challenges, and solutions

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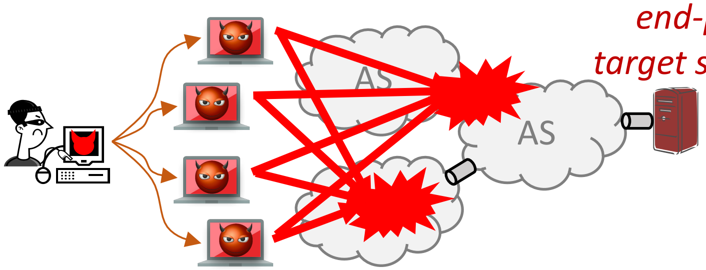
Large-scale ***volumetric*** attacks are common and often congest ***more than one*** networks

- Escalation in ***volume*** of DDoS attack traffic; e.g., 300 Gbps in 2013 – 1.2 Tbps in 2016.
- Volumetric attacks often flood ***upstream*** autonomous systems (ASes) [WISR'16]
- Advanced *link-flooding* attacks ***congest multiple*** ASes concurrently

"*link-flooding*" attacks (e.g., Coremelt, Crossfire)



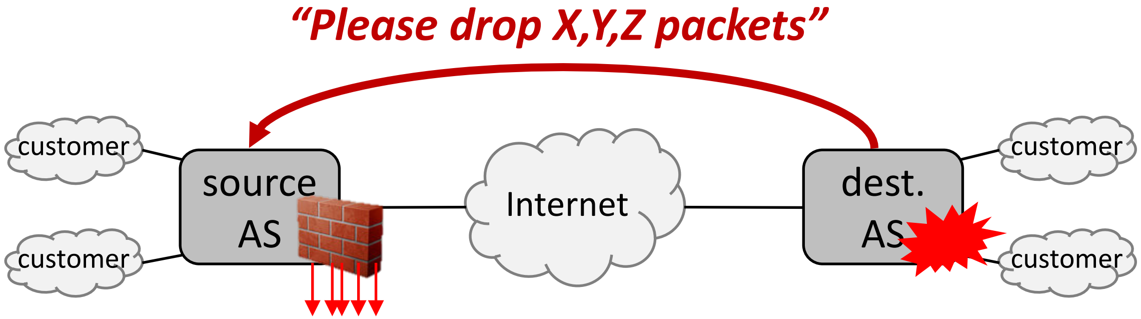
[WISR'16] Arbor Networks, "Worldwide Infrastructure Security Report: Volume XI," Arbor Special Report, 2016.

Inter-domain DDoS mitigation becomes ***necessary*** for large-scale volumetric attacks

- ***Inter-domain packet filtering*** is often necessary:
  - e.g., inter-AS links are flooded, large portion of AS is flooded
- ***Packet-filtering outsourcing***: an AS asks another AS for packet filtering
- State-of-the-art:
  - **AT&T and CenturyLink***: ***automated*** packet-filtering outsourcing between two ASes for DDoS mitigation
  - **IETF DOTS**: standardization effort for common channels for inter-domain coordination

(*) N. Levy, D. Smith, and J. Schiel, "Operationalizing ISP cooperation during DDoS attacks," in NANOG 71, Oct 3, 2017.

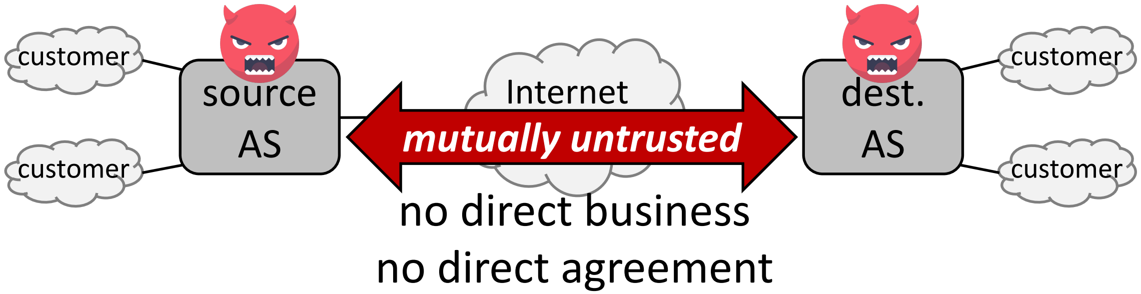
Holy grail of inter-domain mitigation: ***source-end filtering***



- ***Ideal*** DDoS mitigation: ***stops*** attacks ***earlier*** by outsourcing filtering to source AS (e.g., D-WARD, StopIt)

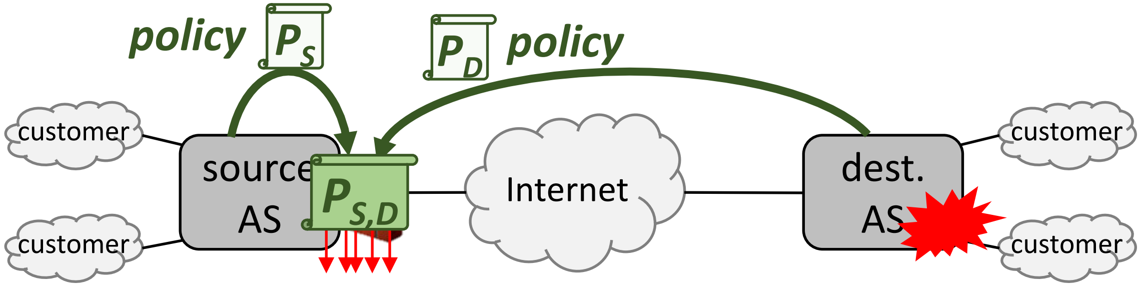
- Advantages
  - ***Reduction of bandwidth*** waste (thus ***cost*** saving)
  - ***Resource-demanding filtering*** operations
  - ***Local contexts*** may be utilized (e.g., list of usual suspects)

Yet, source-end filtering has ***not*** been deployed due to the ***lack of trust*** between ASes



- ***Mutually untrusted*** ASes may launch attacks
  - Source AS can ***modify*** or ***leak*** the requested policy
- ***No strong incentives*** for source AS
  - Filtering incurs ***non-negligible cost***.
- ***Risk*** of dropping packets
  - Source AS may be ***blamed*** for dropping its own customer packets

From ***outsourcing*** to ***collaboration***: source and destination ***collaboratively*** determine filtering policy

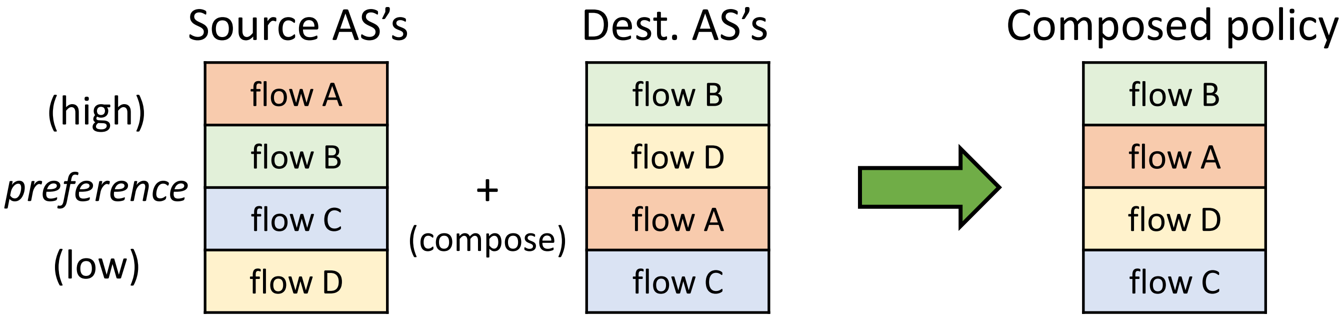


- ***Source*** AS can also ***express its own policy*** for its customers (e.g., preference, black/white lists)
- Security concerns:
  1) *how to **guarantee fair policy** composition?*
  2) *how to protect the **sensitive filtering policies**?*
  3) *what if source AS **bypasses** the packet filtering?*

Desired property 1)

Fair composition must be ***verified by both*** source and destination ASes

- ***Collaboration*** platform requires ***fair*** policy composition and enforcement
- ***Fair***: we find a ***middle ground*** of two policies, favoring neither of the policies
    - Example: ASes express flow preferences



preference	Source AS's	+ (compose)	Dest. AS's		Composed policy
(high)	flow A		flow B		flow B
	flow B		flow D		flow A
	flow C		flow A		flow D
(low)	flow D		flow C		flow C

- Two ASes should be able to ***verify*** the fair composition and enforcement of their policies

Desired property 2)

Filtering policy of each AS must be ***protected*** from each other with privacy guarantees

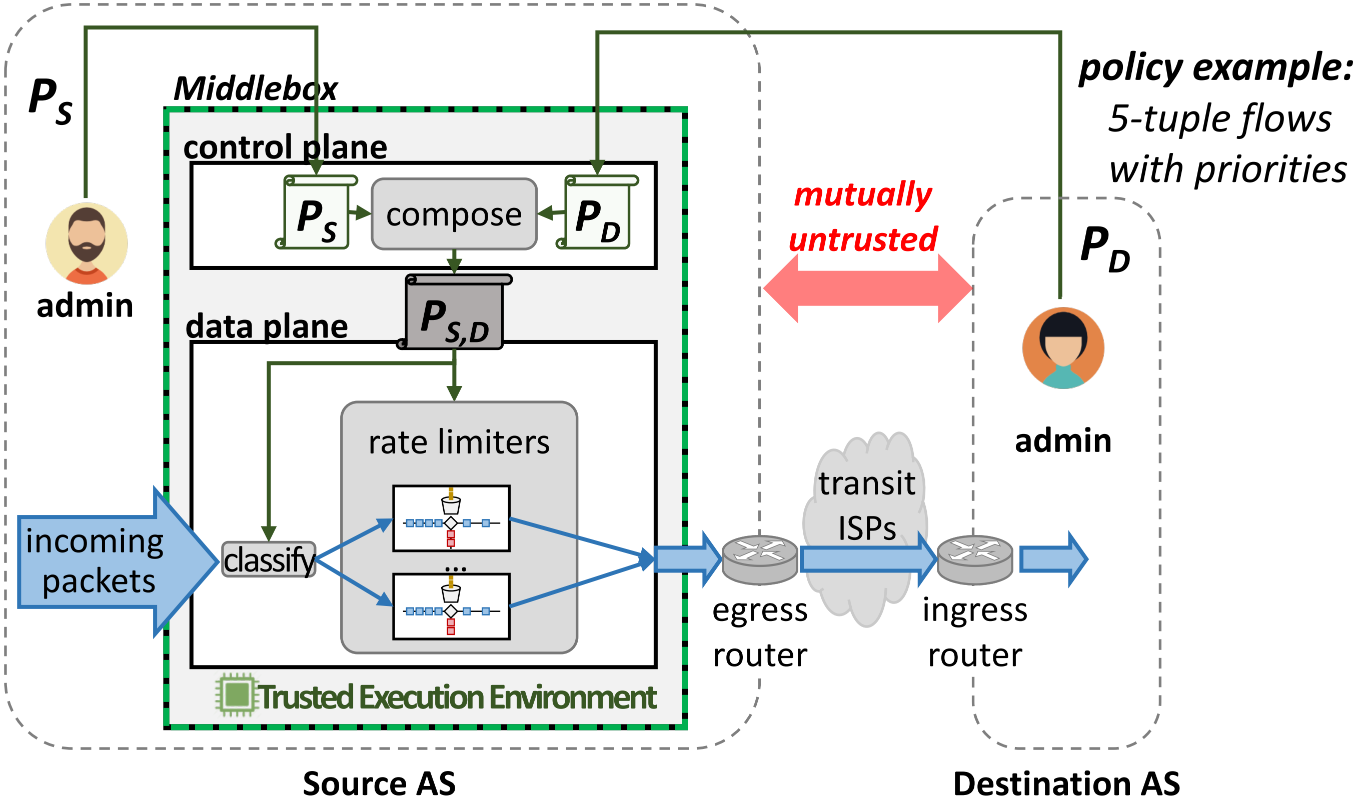
- Filtering policies are inherently ***sensitive***; e.g.,
  - Preference due to ***private contracts, proprietary algorithms***
  - ***Attack*** information, ***vulnerable points*** of the network
  - Internal ***white/black policies***
- Two ASes should be able to ***<u>negotiate</u>*** and determine the ***<u>guaranteed</u> degree of <u>privacy</u>***

Desired property 3)

Filtering operations must ***not*** be ***bypassed*** for ***any packet*** from source to destination

- Source AS ***can evade*** the filtering when it wishes to ignore the composed filtering policy
- ***<u>Non-bypassability</u>***: filtering operation ***must be invoked*** for ***all*** packets from source AS to destination AS

Middlebox-based filtering: a practical design choice for ***rapid*** and ***widespread*** deployment

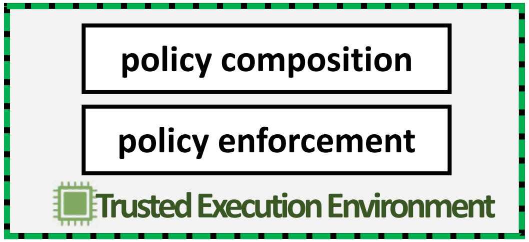


- ***Commodity*** hardware for ***multi-Giga-bps throughput***
- ***Trusted execution environment (TEE)*** capabilities (e.g., memory isolation, remote attestation) from commodity CPUs

  => ***verifiable control-/data-plane operations***

TEE-based ***middlebox*** can satisfy three desired ***security properties***

- ***Policy composition*** and ***enforcement*** are ***isolated*** and ***verifiable*** via remote attestation
  - ***fair packet filtering is guaranteed***

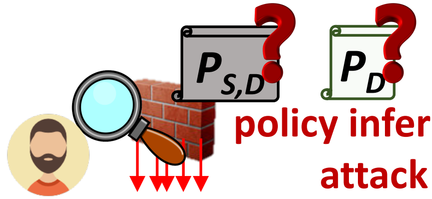


policy composition

policy enforcement

Trusted Execution Environment

- Two ASes can ***negotiate*** the desired level of ***privacy*** and policy ***fairness***
  - ***policy inference attack***: ~$O(\log(N))$
  - ***tradeoff***: degree of anonymity vs. fairness

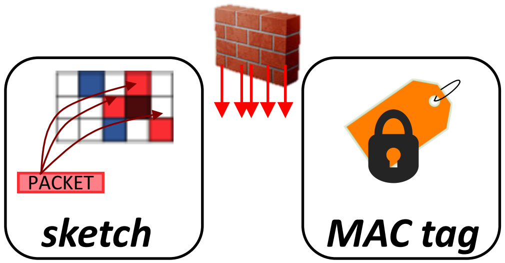


Source AS

policy inference attack

=> ***tradeoff analysis***

- ***Bypass*** is ***immediately detected*** by ***efficient sketch*** and ***MAC*** operations
  - ***only 5-tuple*** information copied to ***TEE*** => ***multi-Giga-bps*** performance



efficient per-packet TEE operations

Preliminary results: ***multi-Giga-bps*** filtering with ***Intel SGX*** platform

- Filtering up to ~***1.8 Gbps*** with ***3 Intel SGX*** cores
  - CPU: Intel® Core™ i5-6400
  - Memory: 8 GB (128 MB reserved for EPC)
  - NIC: Intel® 10-Gigabit X540-AT2
- ***TCB*** – 1,369 SLoC, 1.9 MB binary.
- SGX-integration of ***DPDK***
  - libraries ported to SGX: mempool, mbuf, ring, sched
- Plan: ***scale out*** with load balanced parallel middleboxes for ***10 Gbps*** or higher throughput

Conclusion

Collaborative source-end packet filtering

Potentials:

Collaborative source-end filtering is an ideal defense for ever-increasing volumetric attacks

Challenges:

Lack of trust between ASes makes existing solutions impractical

Solutions:

TEE-based middlebox solution can offer ***three security properties*** (i.e., verifiable fairness, privacy, non-bypassability) necessary for secure and practical collaborative DDoS solution

We are open for ***feedback*** and ***collaboration***

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