Jaqen: A High-Performance Switch-Native Approach for Detecting and Mitigating Volumetric DDoS Attacks with Programmable Switches

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DDoS attacks are getting worse

- Increasing in *volume*
- Increasing in *diversity*
- Increasing in *cost to defend the attacks*

Surge in DDoS attacks targeting education and academic sector

9/15/2020 Infosecurity

CISA Warns of Increased DDoS Attacks

Security Experts Say Remote Workforce, Online Learning Create Opportunities

9/10/2020 U.S. CISA

DDoS Attacks Increase by 151% in First Half of 2020

9/16/2020 Neustar

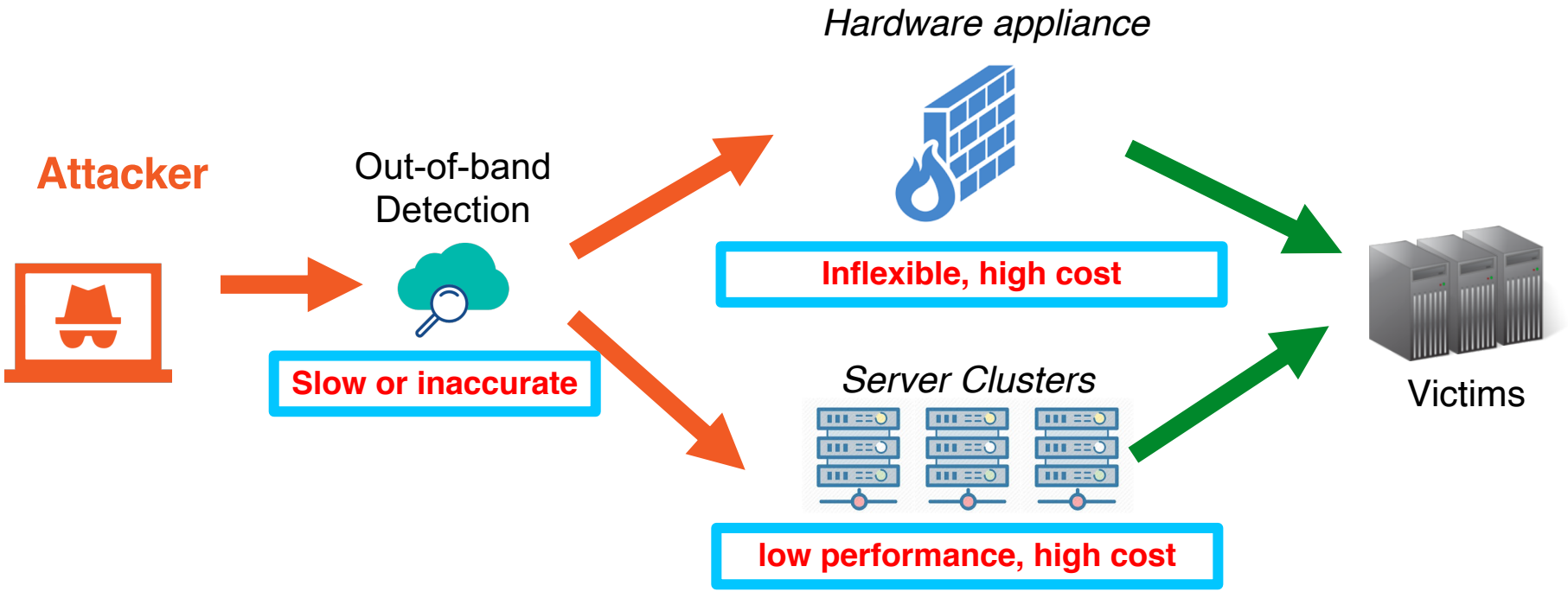
European ISPs report mysterious wave of DDoS attacks

9/3/2020 ZDNet

Requirements for DDoS Defense

- Performance:
  handle *large volumes* with *low latency*
- Flexibility:
  handle *diverse attack vectors*
- Cost-effectiveness:
  handle attacks with *low capital and operational costs*

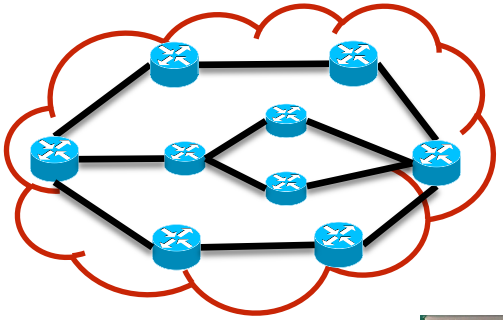
Current DDoS Solutions: Middleboxes



E.g., 100 servers for 1000Gbps mitigation. [Security'15]

Can we do better?

Trend: Network devices are more programmable



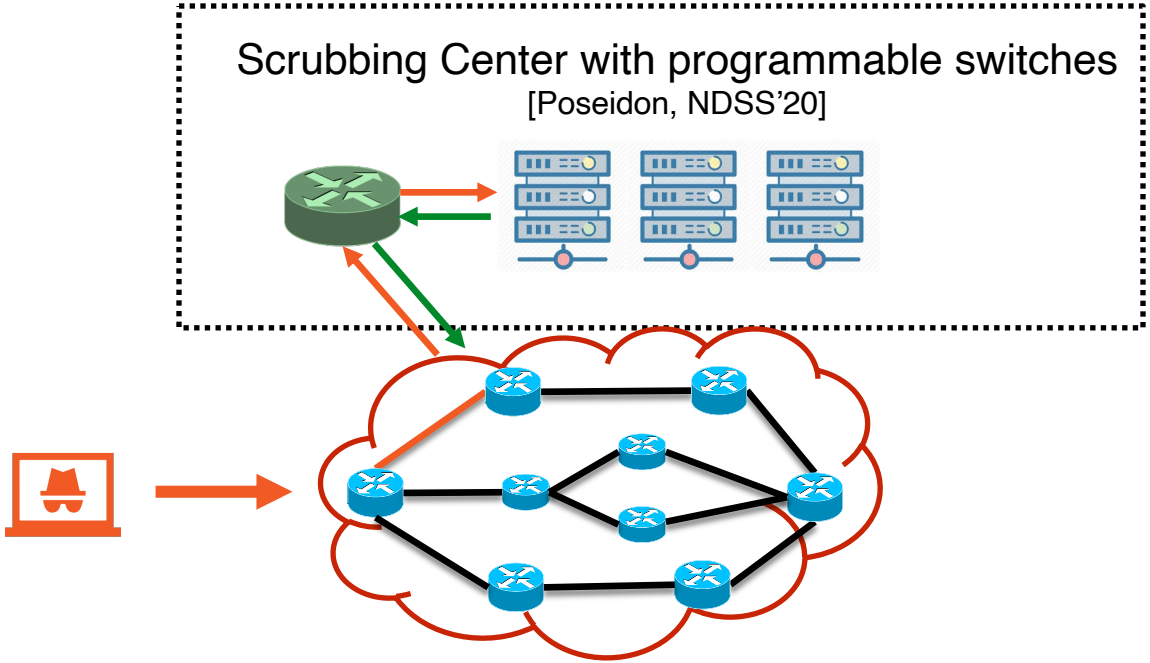
Increasing in-network *programmability* in ISP networks

Programmable Switch

Switch ASICs

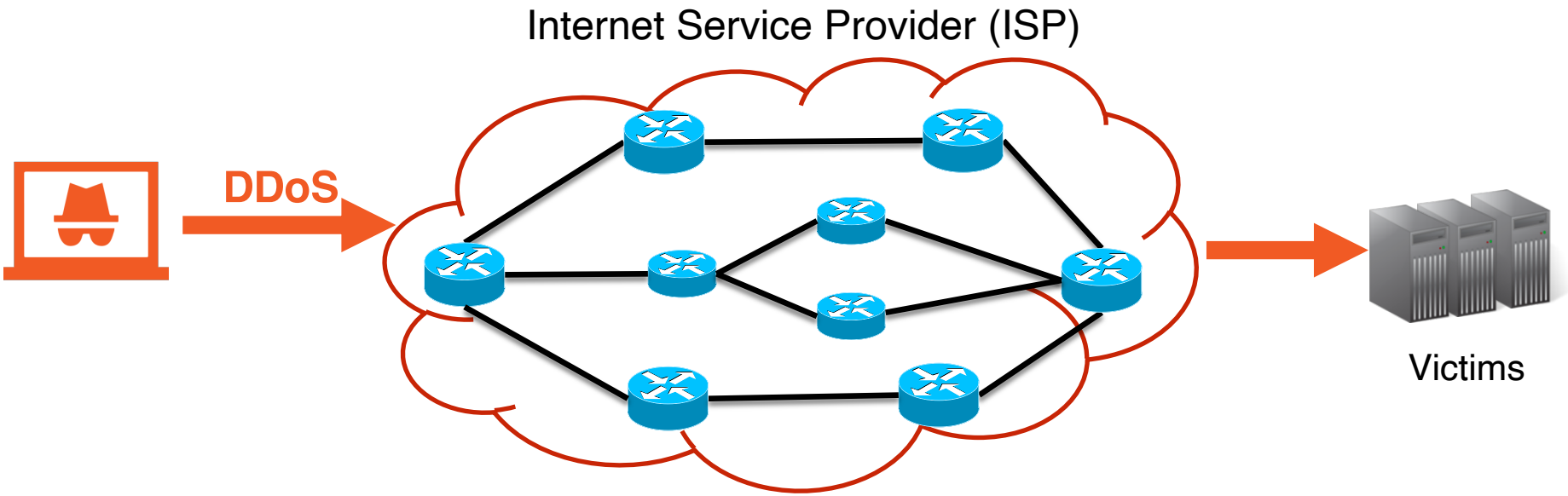
- High line-rate performance (e.g., Tbps)
- High programmability using high-level language (e.g., P4)
- Cost effective with similar cost as traditional switches

Current DDoS Solutions: Switches for Scrabbing



- Still need out-of-band detection.
- Scrubbing approach adds large latency.
- Unscalable mitigation functions (e.g., Server-like SYN Proxy)

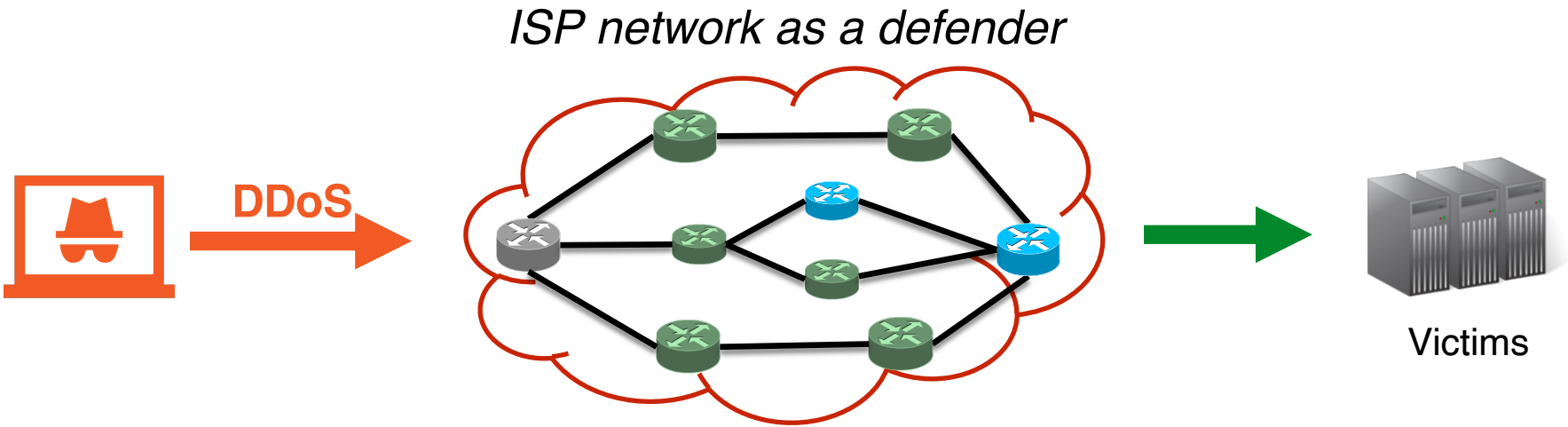
Opportunity: Programmable ISP Networks for DDoS Defense



- Near the source or victim of the attacks
- Provide defense-as-a-service to the clients

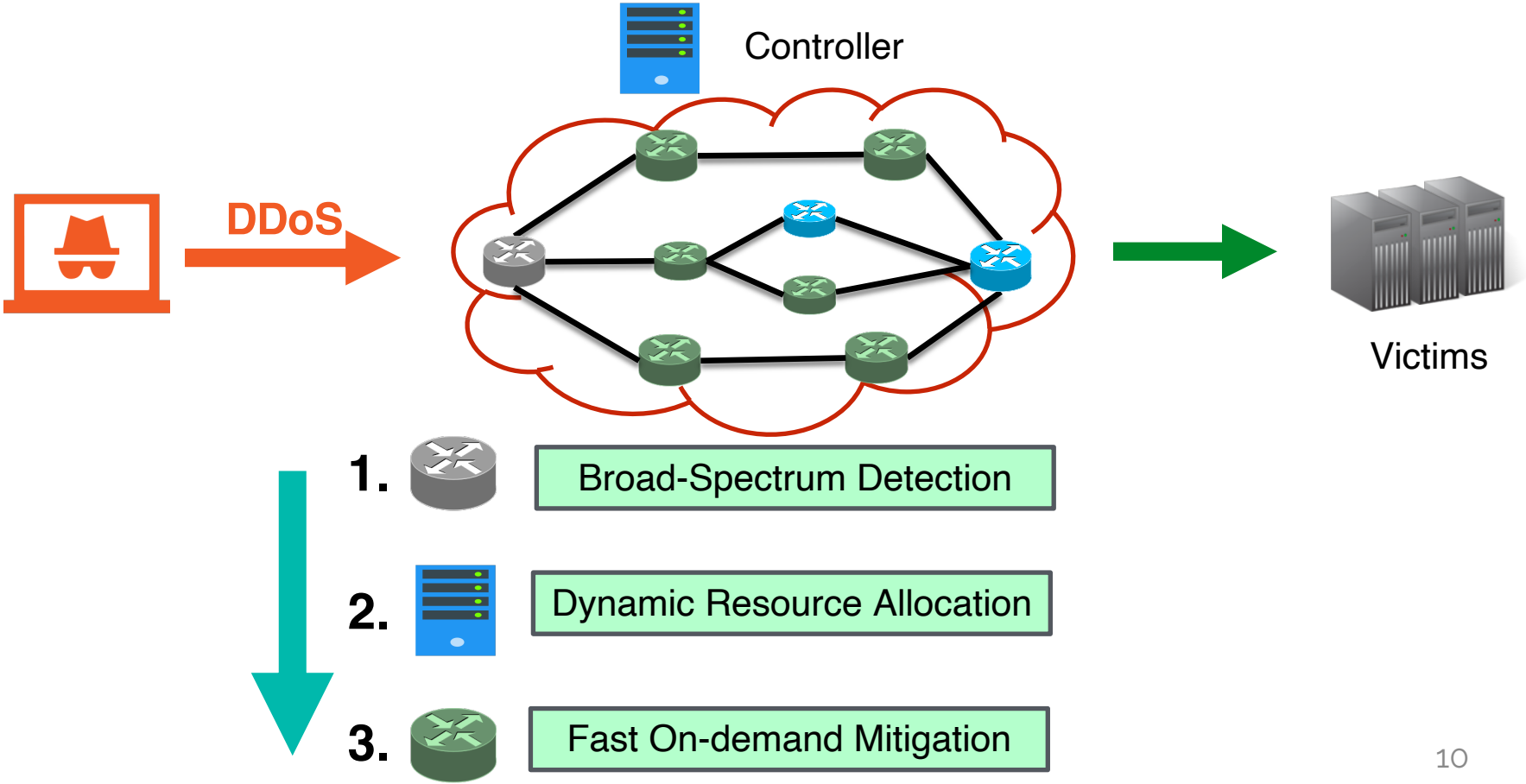
Can we design ISP-based DDoS defense that fully leverages programmable switches?

Jaqen: Switch-Native DDoS Defense for ISP

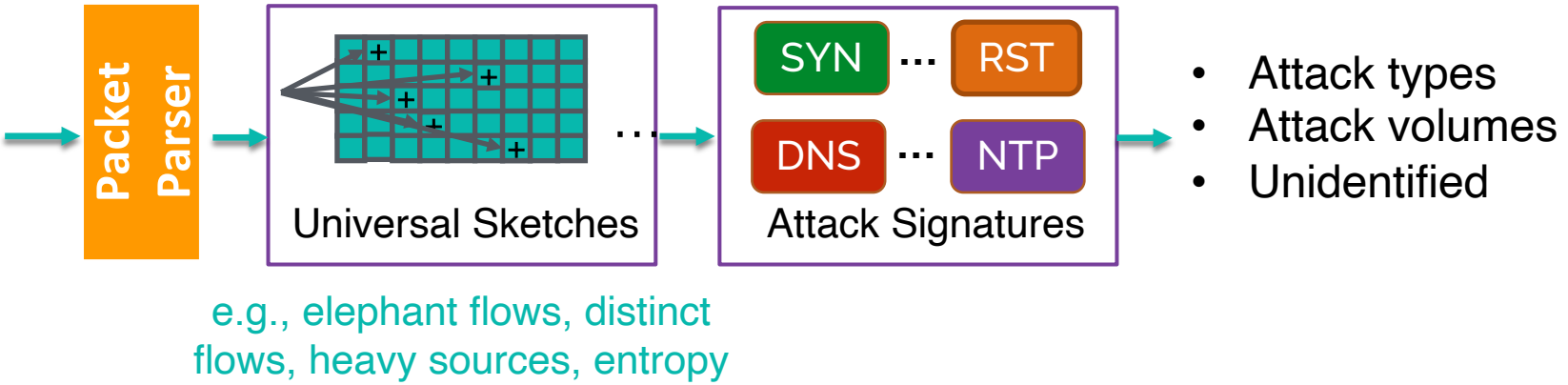


- Detection + Mitigation integrated “switch-native” solution.
- Designed for ISP networks where there are a LOT of switches.

Jaqen's Full Stack Design

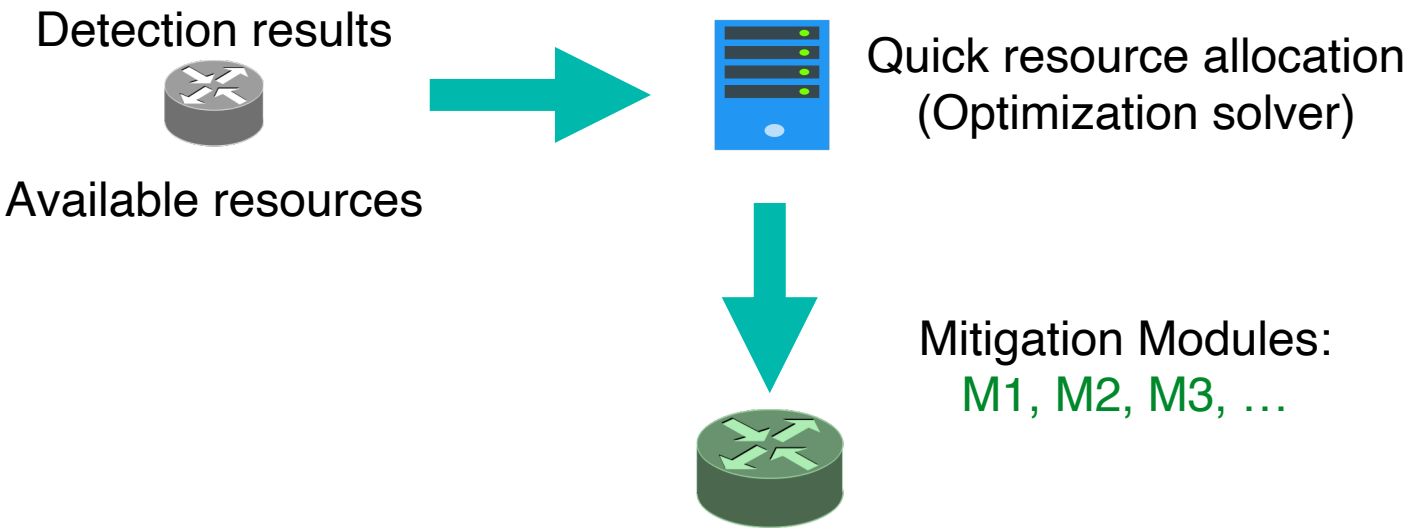


Broad-Spectrum and Always-On Detection



- A wide-spectrum detection of volumetric attacks.
- Compact design with future-proof universal sketches.
- Detection metric API: Query (proto, func, mode, freq)

Fast On-Demand Mitigation



- Cannot afford preloading all possible mitigation modules.

Switch-Optimized Mitigation Library

SYN Cookie/proxy
[BSDC'02, RFC4987]
Block-List [WDFIA'07]
Allow-List [WDFIA'07]
ICMP block
DNS filter
…

Sketches
Bloom filters
Counting bloom filters
SYN Proxy with filters
Exact-match table
Rater limiter
…

Mitigation API
RateLimit(identity,rate)
ExactBlockList(identity,size)
ExactAllowList(identity,size)
ApproxBlockList(identity,config)
ApproxAllowList(identity,config)
ActionAndTest(action,List(predicate))
HeaderHashAndTest(identity,action)
UnmatchAndAction(action,List(predicate))
KVStore(key,value,size)
ReportCtr(identity,type)
Recirculate(identity,type)

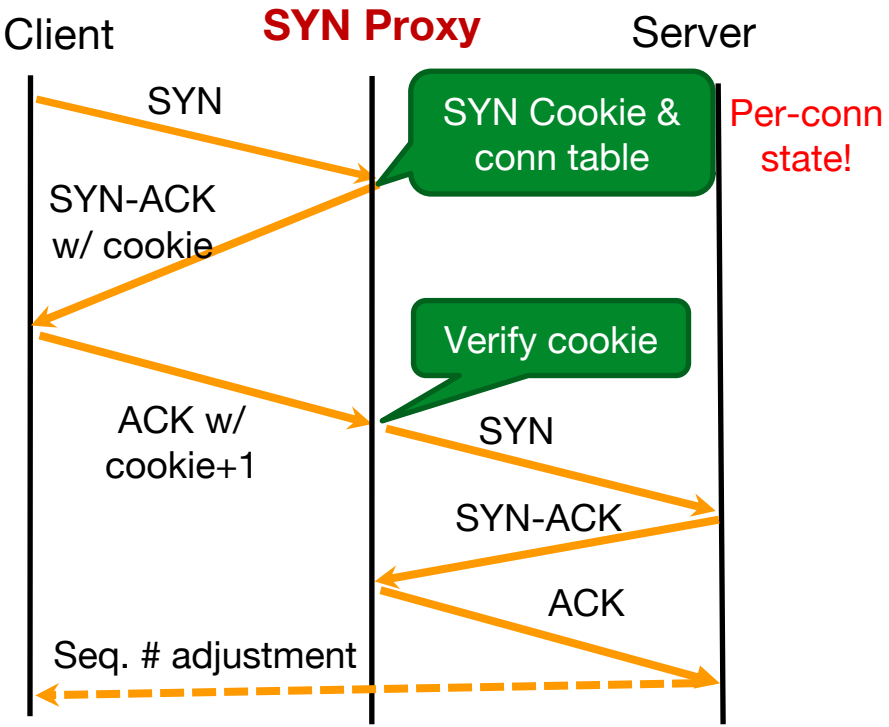
Best-practice mitigation

Switch-optimized library

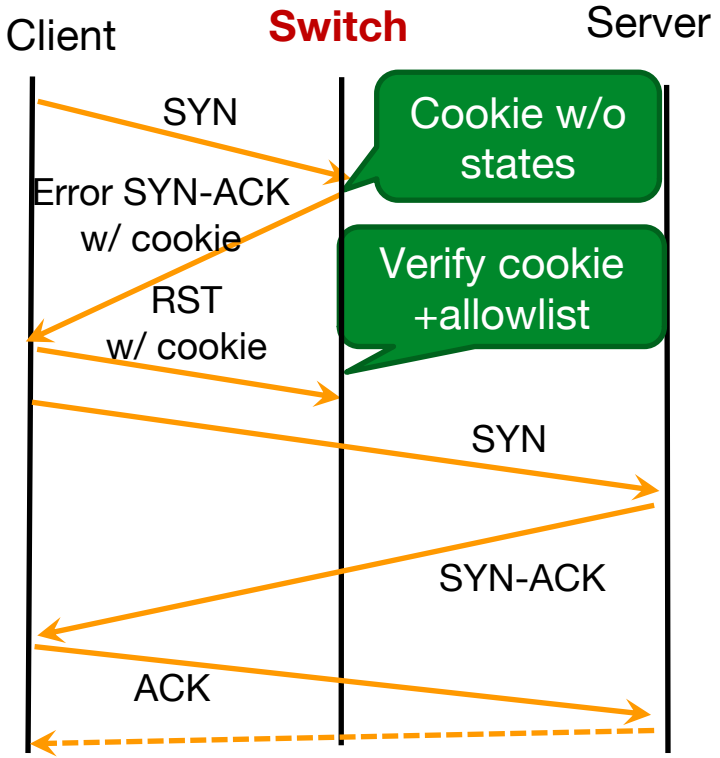
Mitigation API

- Preserve O(10 Million) legitimate connections with O(10 MB) on-switch memory.
- Support mitigation strategies on 21 attacks.

Switch-Native SYN Proxy



SYN Proxy [NDSS'20]



Jaqen SYN Proxy

Evaluation – Single Attack

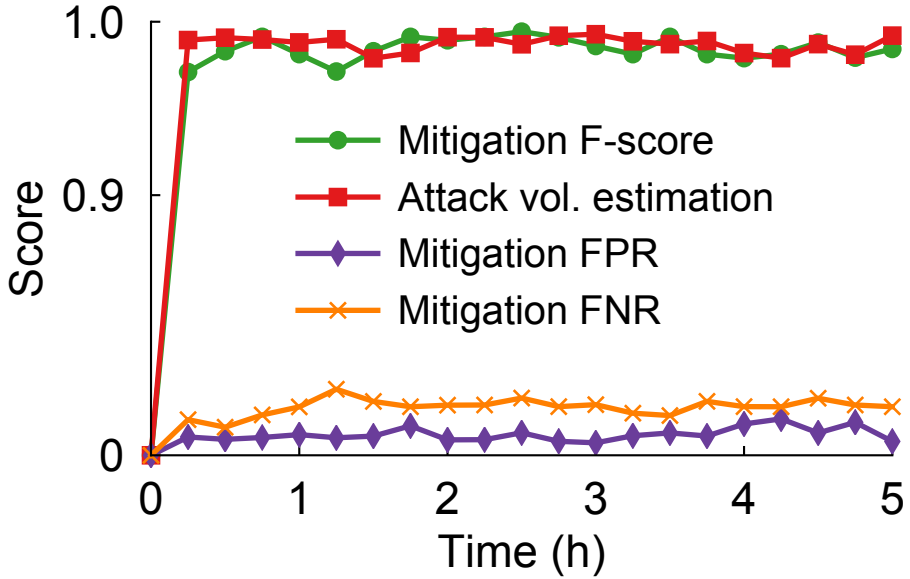
- Comparison with Poseidon [NDSS'20].
- Single Intel Tofino switch.
- 40Gbps attack traffic with 2M legitimate TCP connections.

Defense (40G)	Poseidon (FPR / FNR)	Jaqen (FPR / FNR)
SYN proxy	2M, 25.2% / 1.3%	2M, 0.0% / 1.3%
DNS/NTP defense	2M, 1.2% / 3.7%	2M, 0.7% / 3.1%

- Mitigation with probabilistic data structures is more scalable.

Evaluation – Dynamic Attacks

- 6 volumetric attacks (SYN, ICMP, UDP, DNS, NTP, Memcached)
- 380Gbps total volume, 3.2 Tbps Intel Tofino switch



High detection accuracy and high mitigation effectiveness

Conclusions

- ISP DDoS defense compromises performance, flexibility and cost-effectiveness.

- Appealing programmable network devices (e.g., programmable switches)
  * High line-rate packet processing
  * Full packet programmability with low cost

- Jaqen: Switch-native DDoS defense for ISP networks
  * Broad-spectrum detection integrated with on-demand mitigation
  * Network-wide resource management
  * Switch-optimized library for best practice mitigation

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