# United We Stand: Collaborative Detection and Mitigation of Amplification DDoS Attacks at Scale


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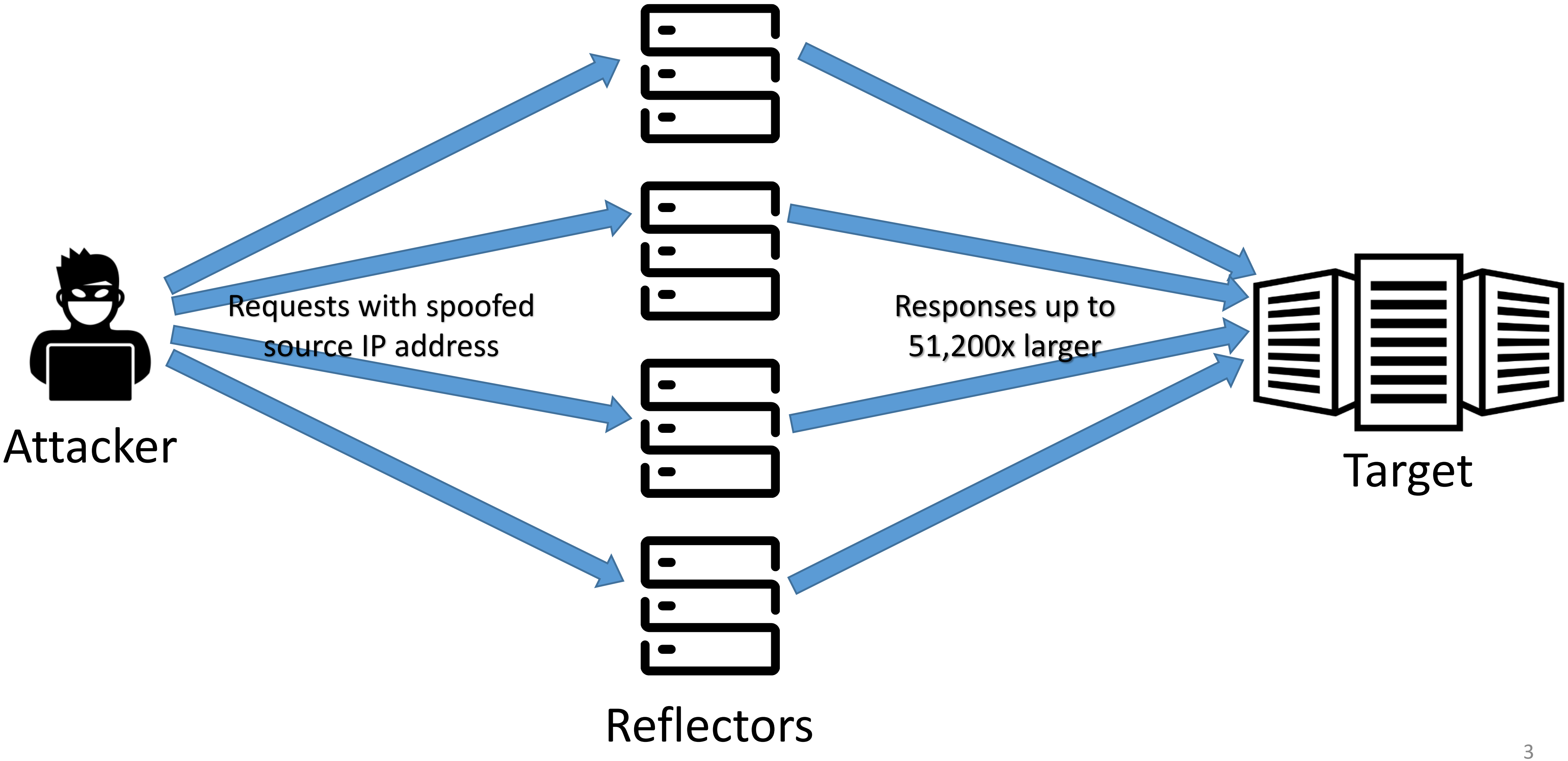
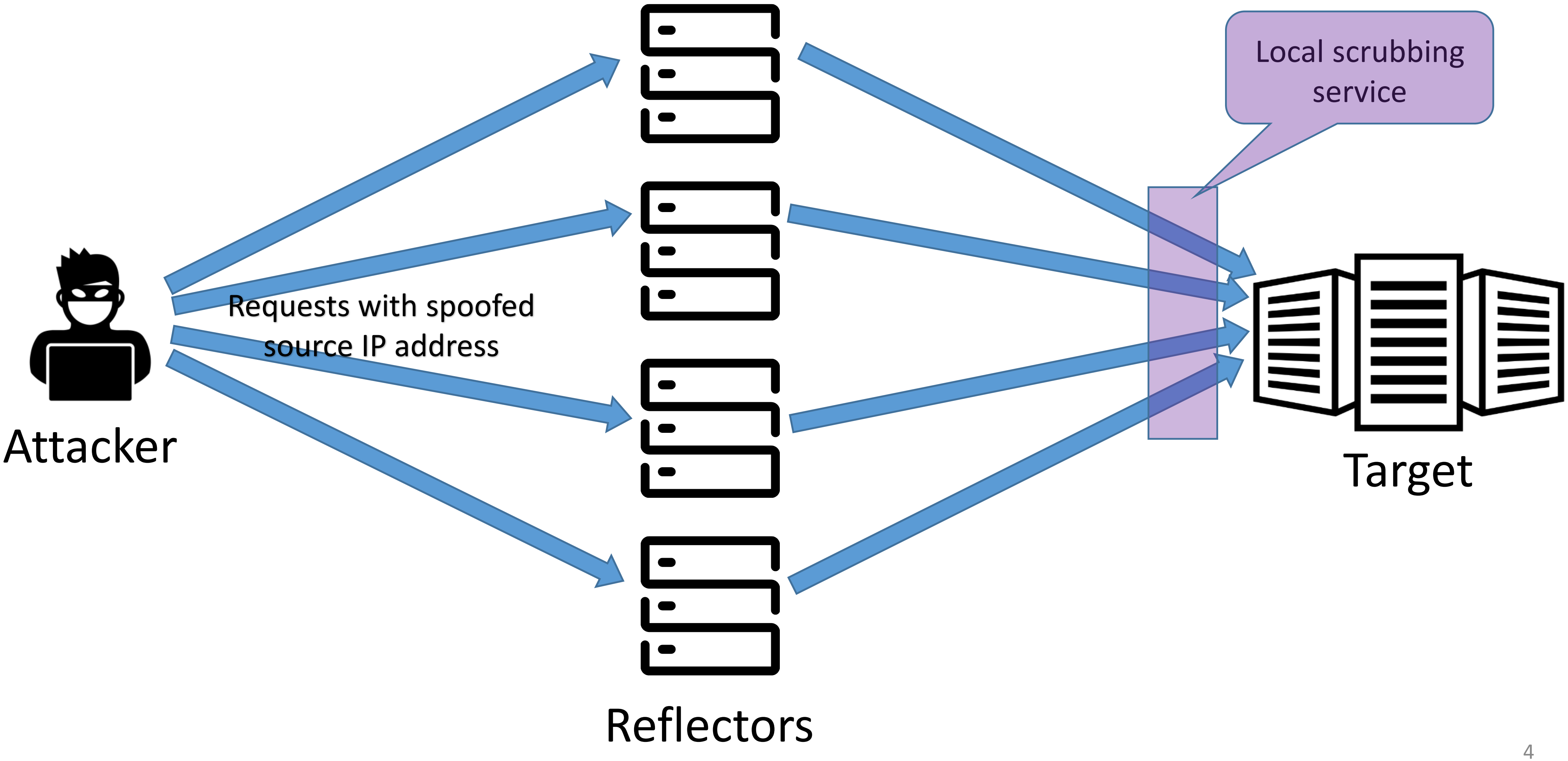
# Distributed Denial of Service (DDoS)

- Network attack causing service downtime
- Targets: Financial services, health sector, …

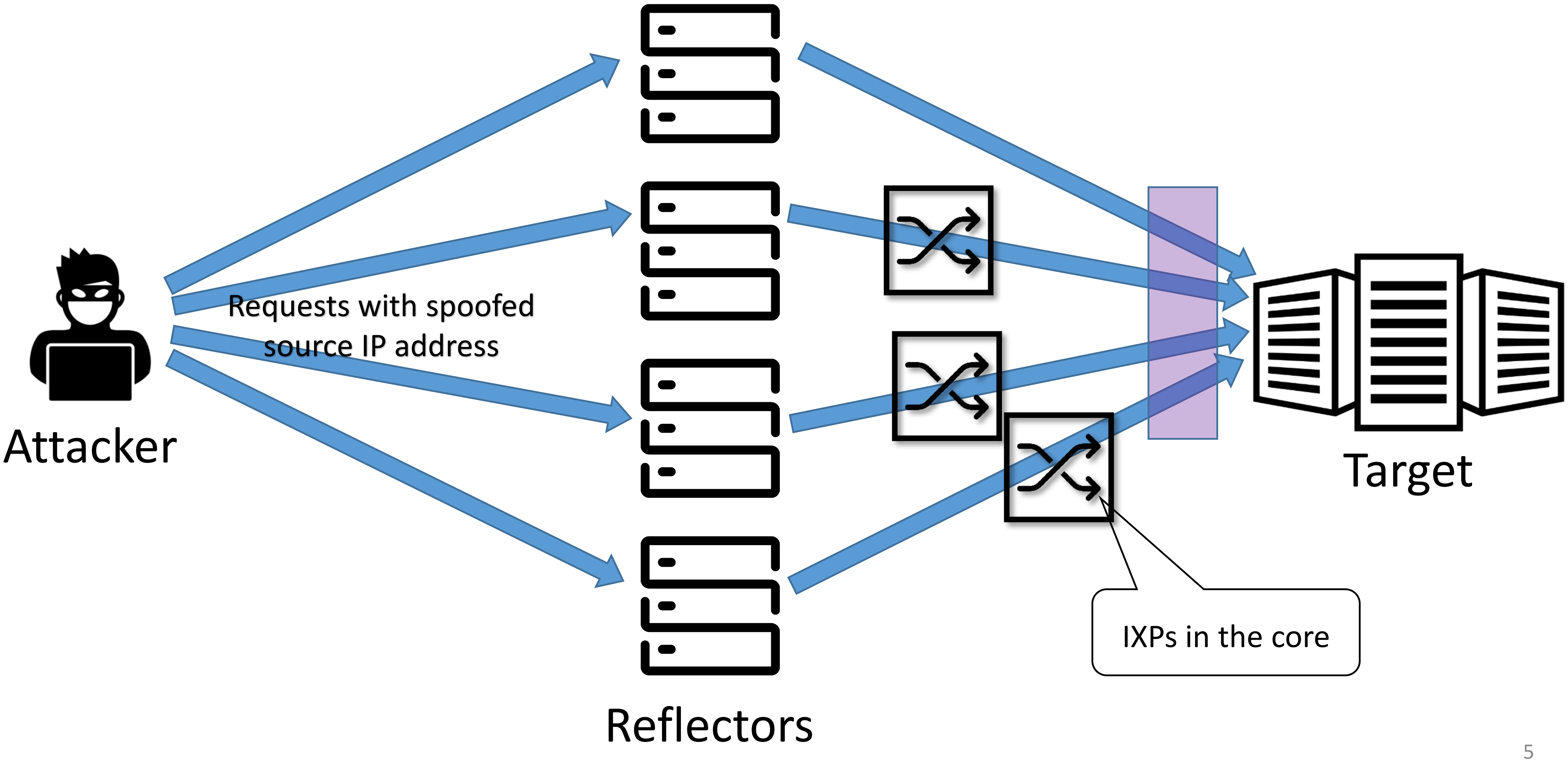
# Amplification DDoS Attacks



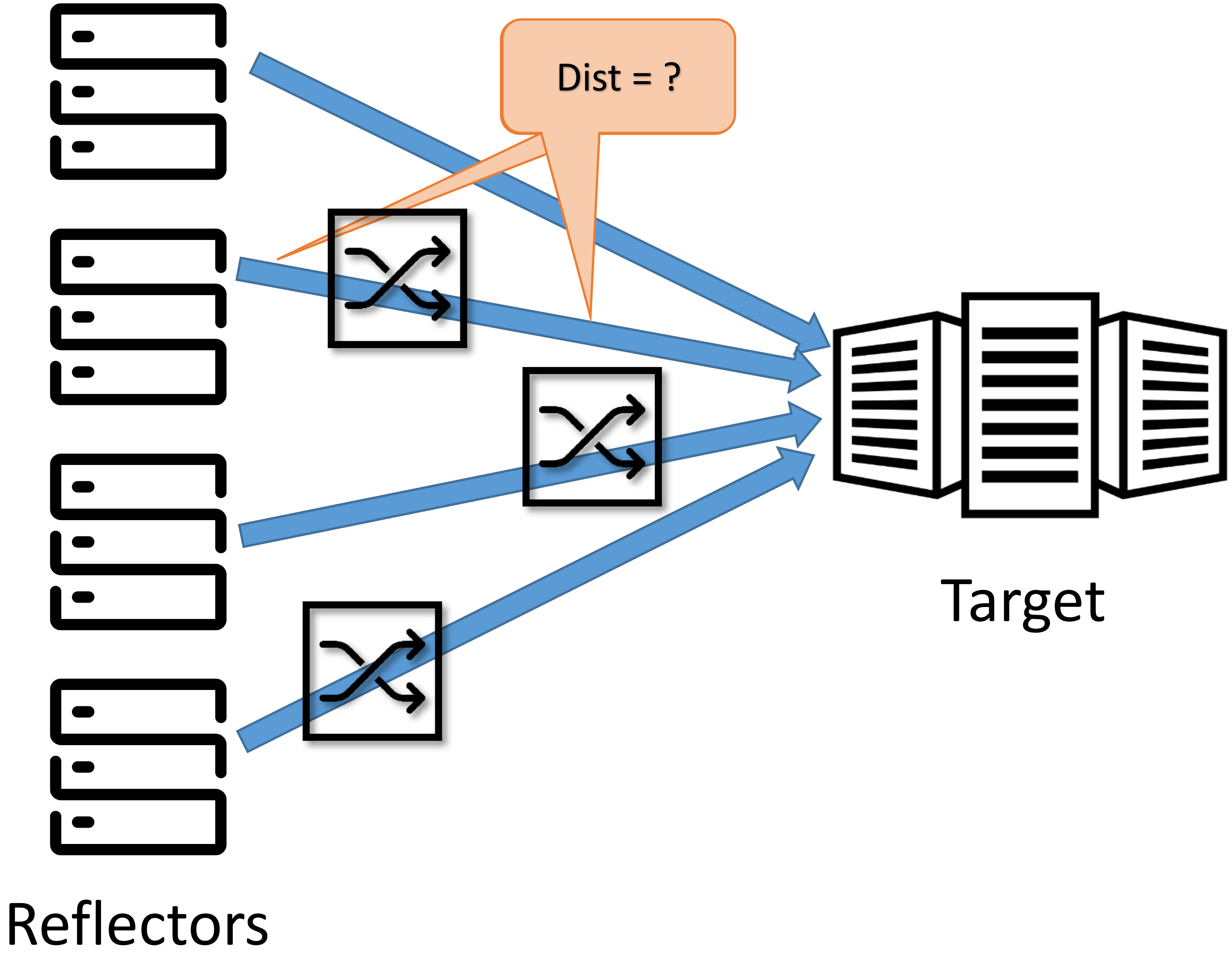
# Amplification DDoS Attacks



# Amplification DDoS Attacks

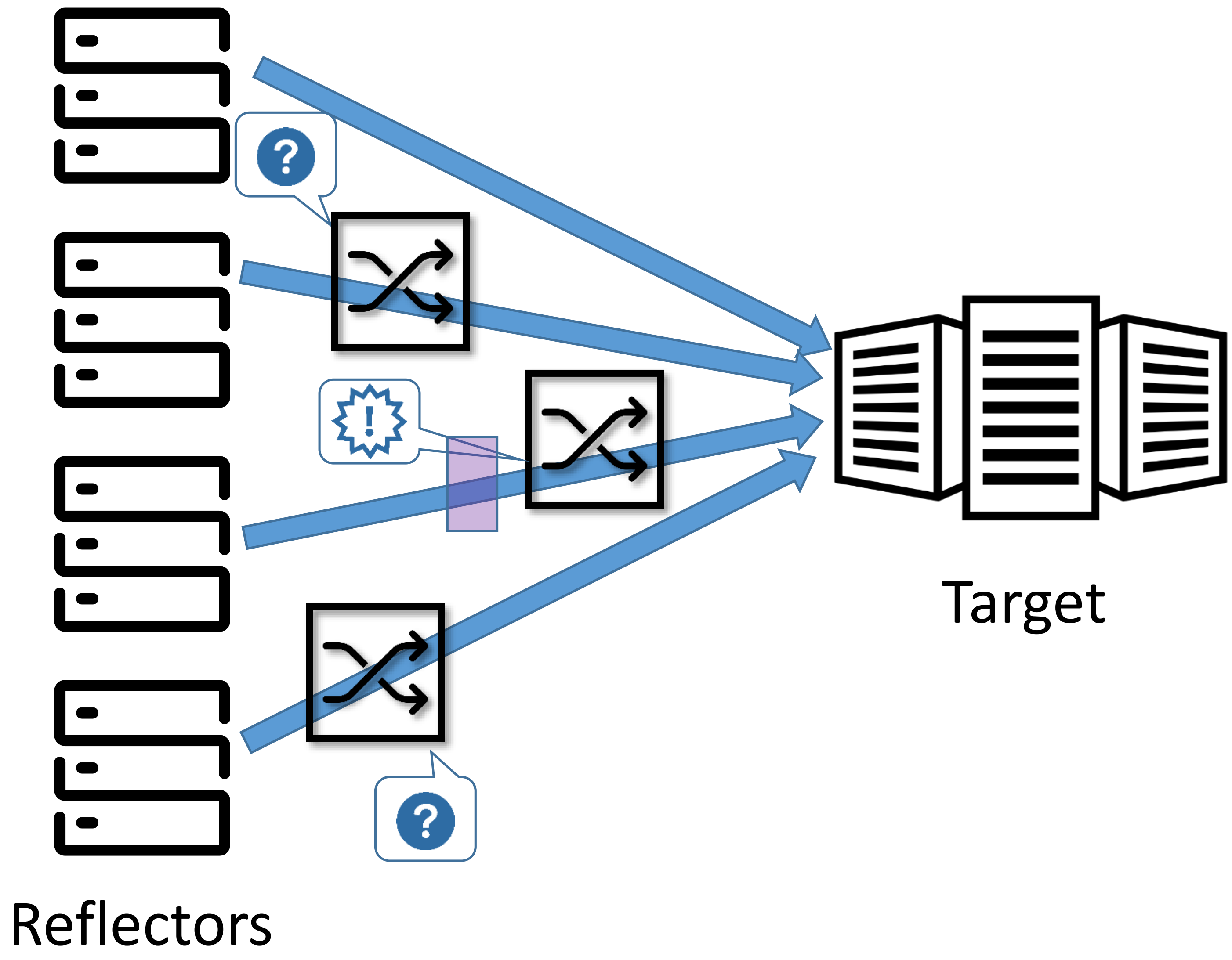


# Contributions (1/3)




- Distance analysis
  - #hops from refelctor?
  - #hops to target?

# Contributions (2/3)

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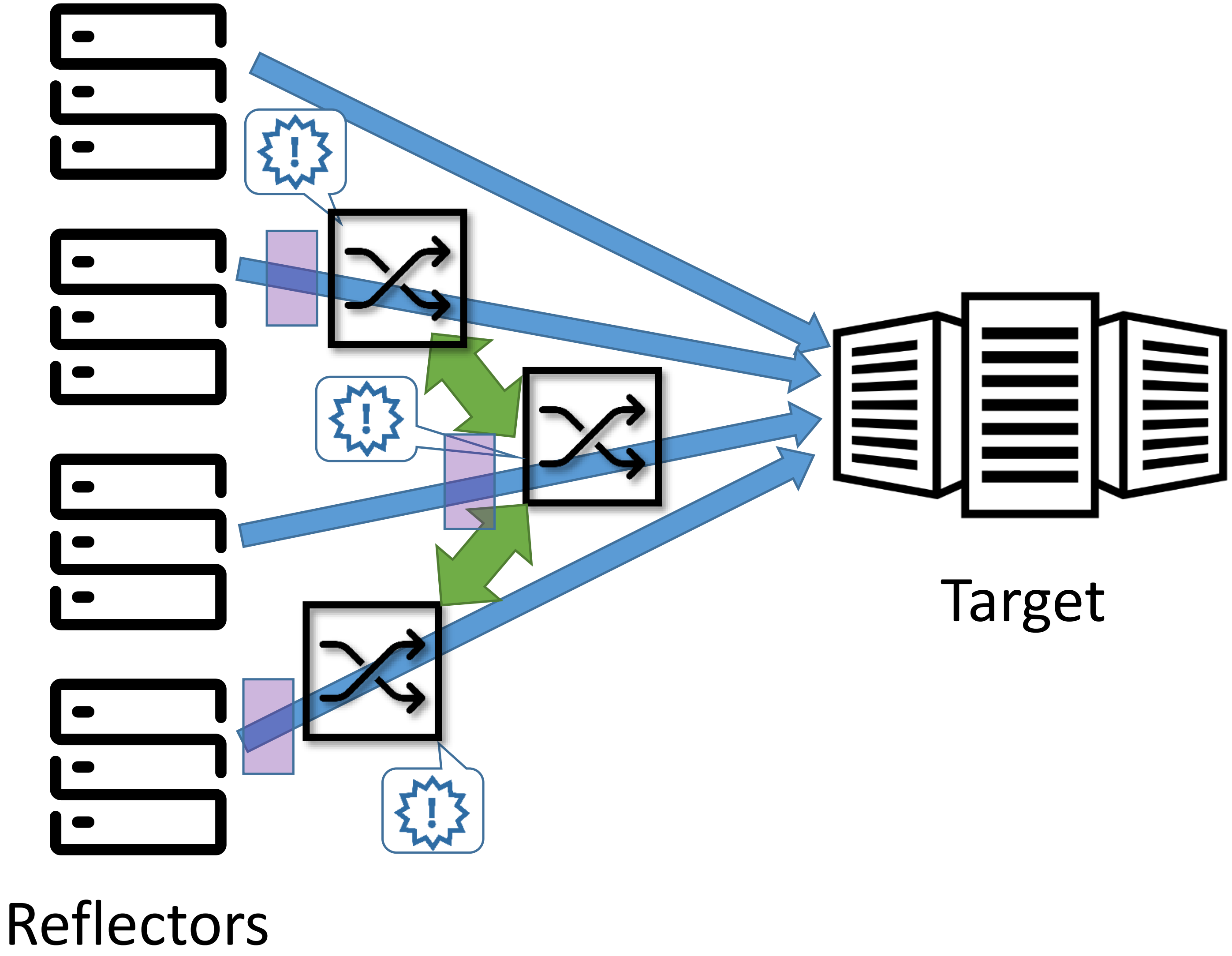


- Distance analysis
    - #hops from refelctor?
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- Collaboration benefit
- Information exchange platorm

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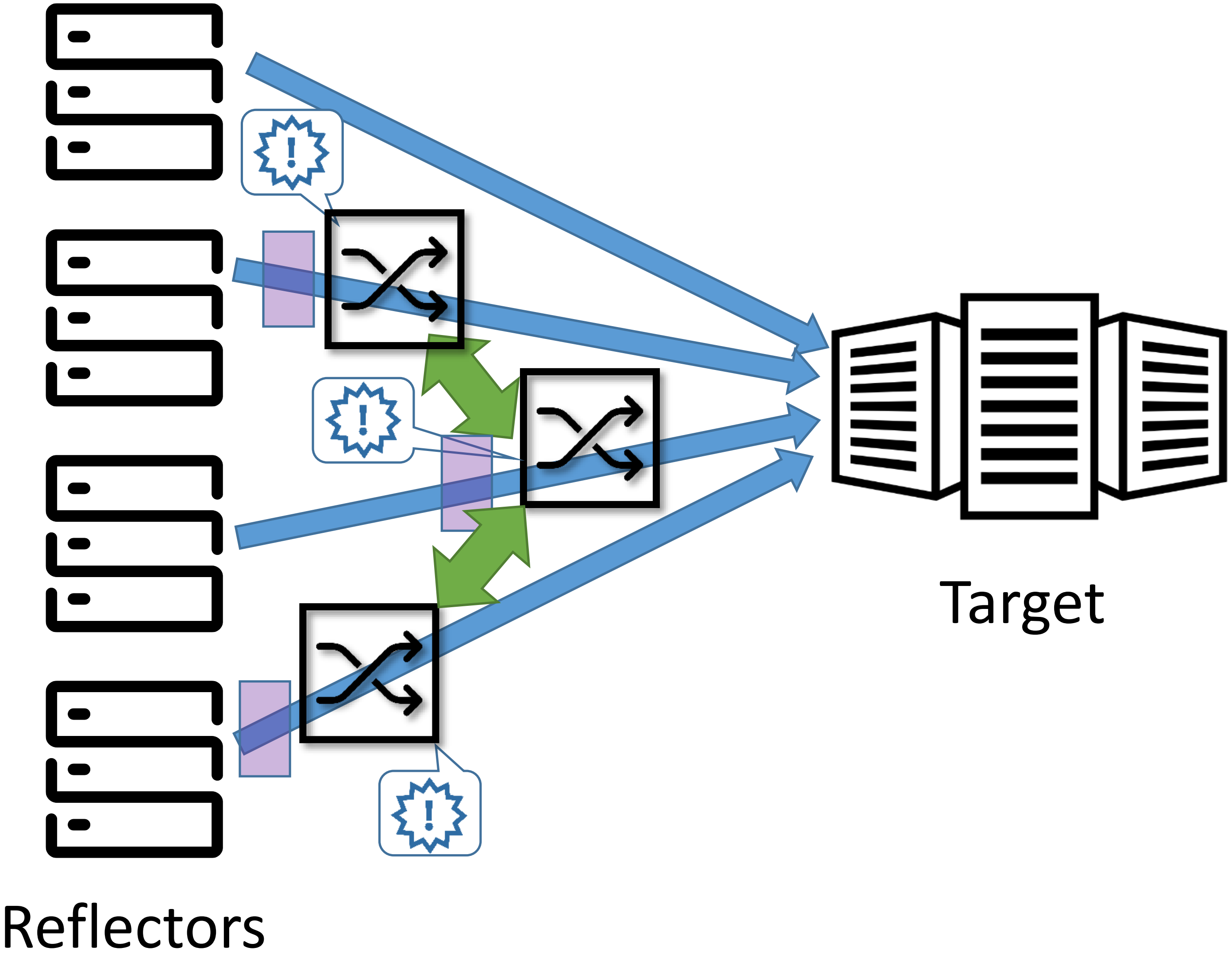



- Distance analysis
  - #hops from refelctor?
  - #hops to target?
- Collaboration benefit
- Information exchange platorm

- Let‘s leverage some data!

# Data Set

- Flow data from 11 IXPs, April 2020 – October 2020

| IXP Code | #Networks | Peak traffic | Region | #sampled Flows |
|---|---|---|---|---|
| CE1 | >900 | >9000 Gb/s | Central Europe | 1.08 Trillion |
| CE2 | >200 | >150 Gb/s | Central Europe | 9.9 Billion |
| CE3 | >200 | >150 Gb/s | Central Europe | 3.2 Billion |
| CE4 | >200 | >100 Gb/s | Central Europe | 3.6 Billion |
| NA1 | >200 | >800 Gb/s | North America | 78 Billion |
| NA2 | >75 | >150 Gb/s | North America | 16.7 Billion |
| SE1 | >175 | >400 Gb/s | South Europe | 30.5 Billion |
| SE2 | >75 | >100Gb/s | South Europe | 12.2 Billion |
| SE3 | >40 | >10 Gb/s | South Europe | 2.2 Billion |
| SE4 | >30 | >100 Gb/s | South Europe | 17.9 Billion |
| SE5 | >20 | >50 Gb/s | South Europe | 2 Billion |

# Traffic Filtering

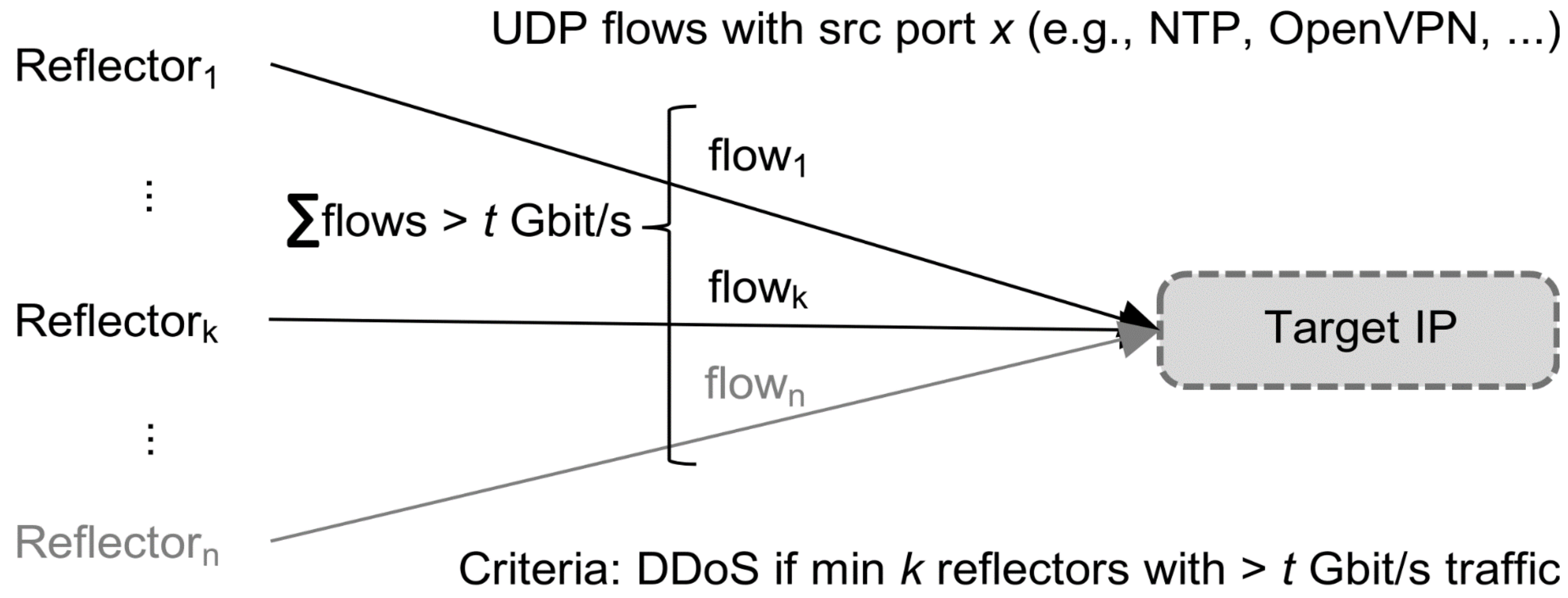
- UDP only
- Filtering for typical DDoS amplification protocols[2]
- Packet size[2]

| **Protocol** | Chargen | DNS | RPC | NTP | SNMP | CLDAP | OpenVPN | SSDP | ARMS | WS Discovery | Device Discovery | memcached |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Transport port** | 19 | 53 | 111 | 123 | 161 | 389 | 1194 | 1900 | 3283 | 3702 | 10001 | 11211 |

[2] "DDoS Never Dies? An IXP Perspective on Amplifcation DDoS Attacks", PAM 2020, D. Kopp et al.

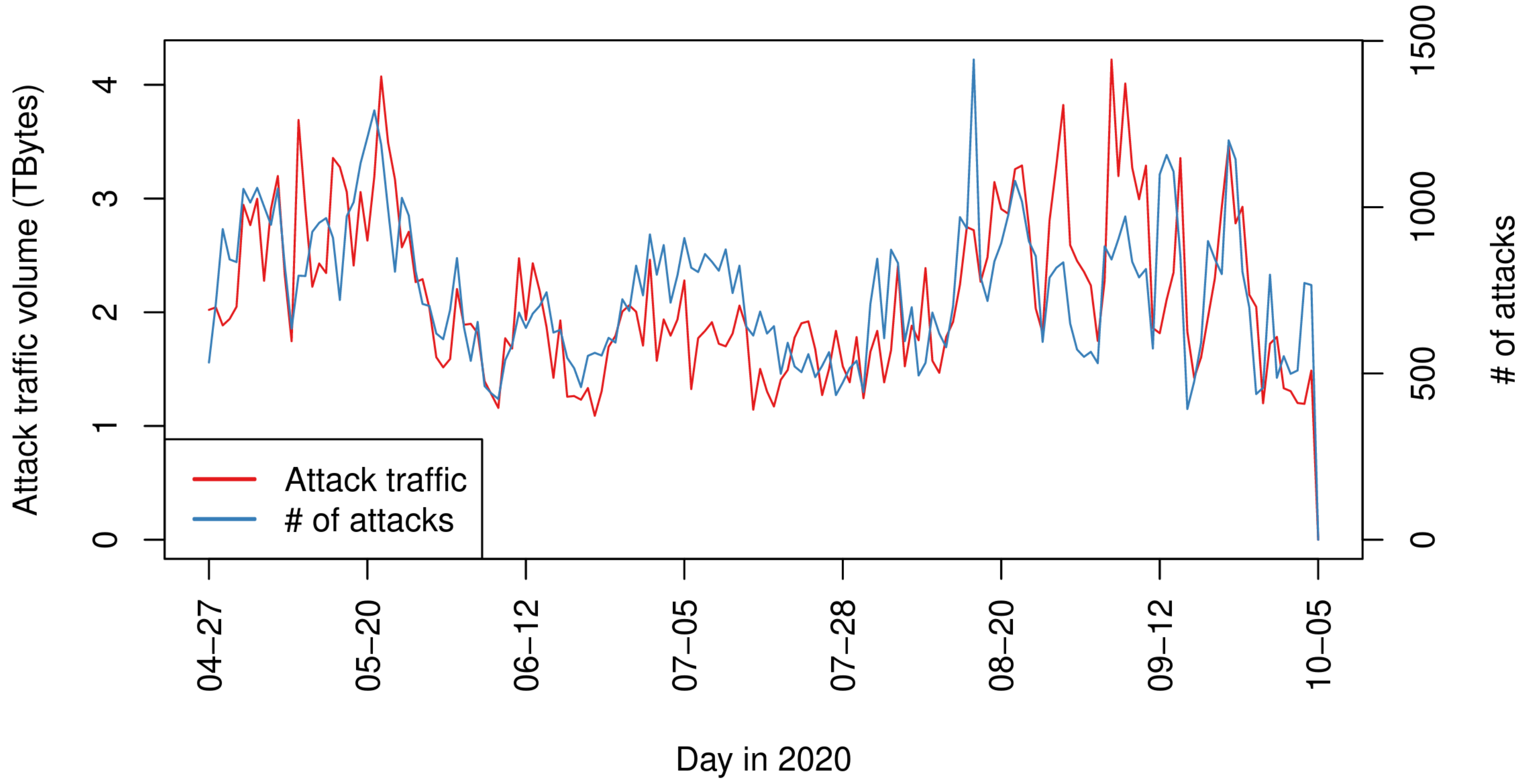
# Attack Detection

[2]



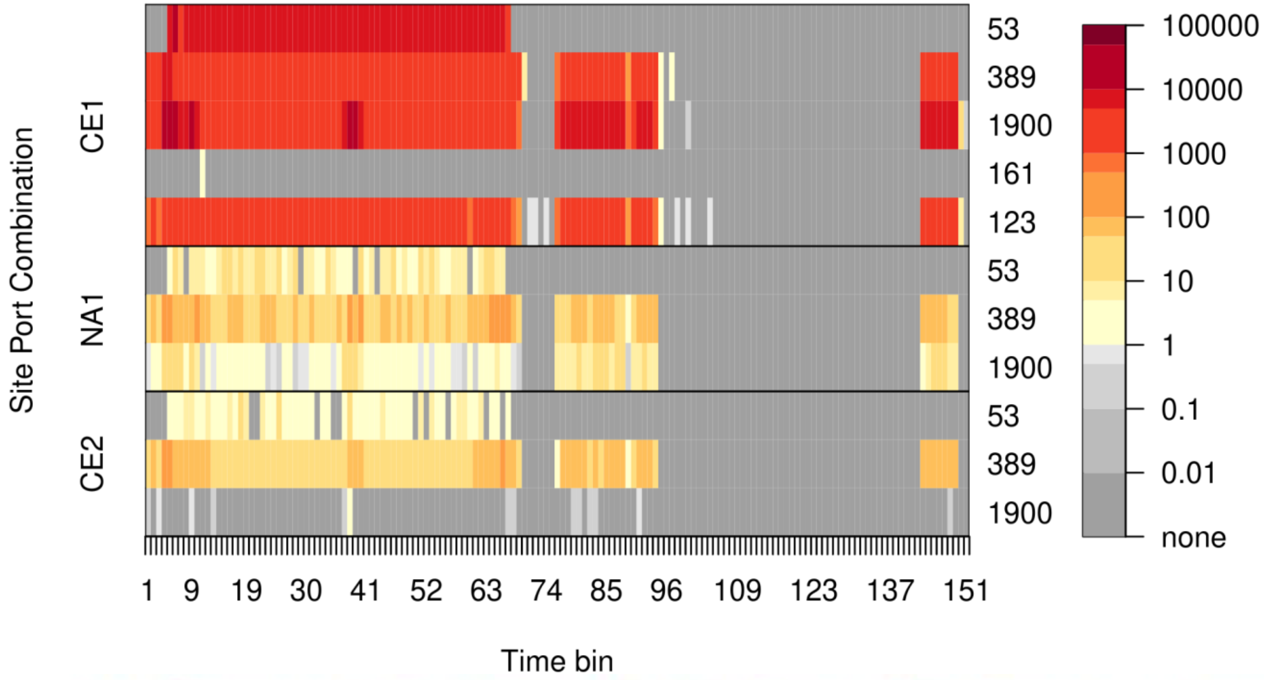

- Global attack traffic with n>=10 reflectors, t>1Gbps attack traffic
- We identified >120k DDoS attacks
- Including confirmed attacks

# Number of DDoS Attack Events per Day




- Thousands of attacks every day!

# Case study: Attack to Akamai



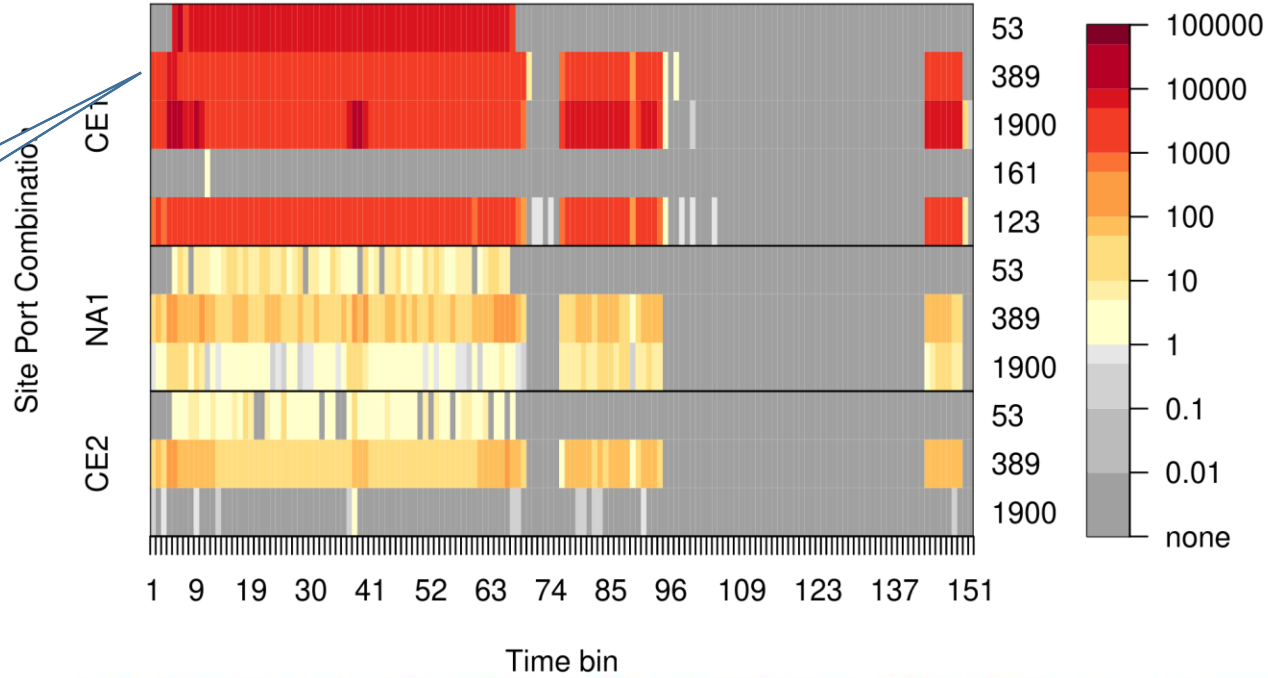


[1]

[1] “Akamai Mitigates Sophisticated 1.44 Tbps and 385 Mpps DDoS Attack”, Akamai.com

# Case study: Attack to Akamai

Local detection feasible

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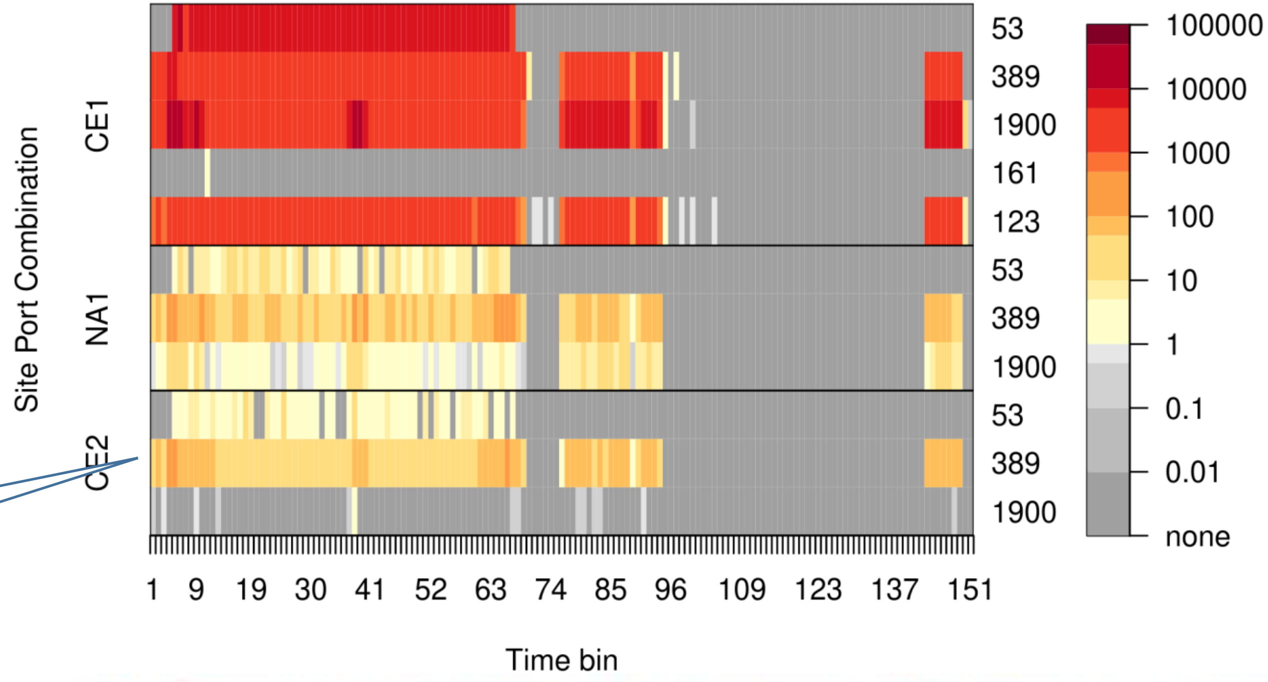
# Case study: Attack to Akamai




Local detection infeasible

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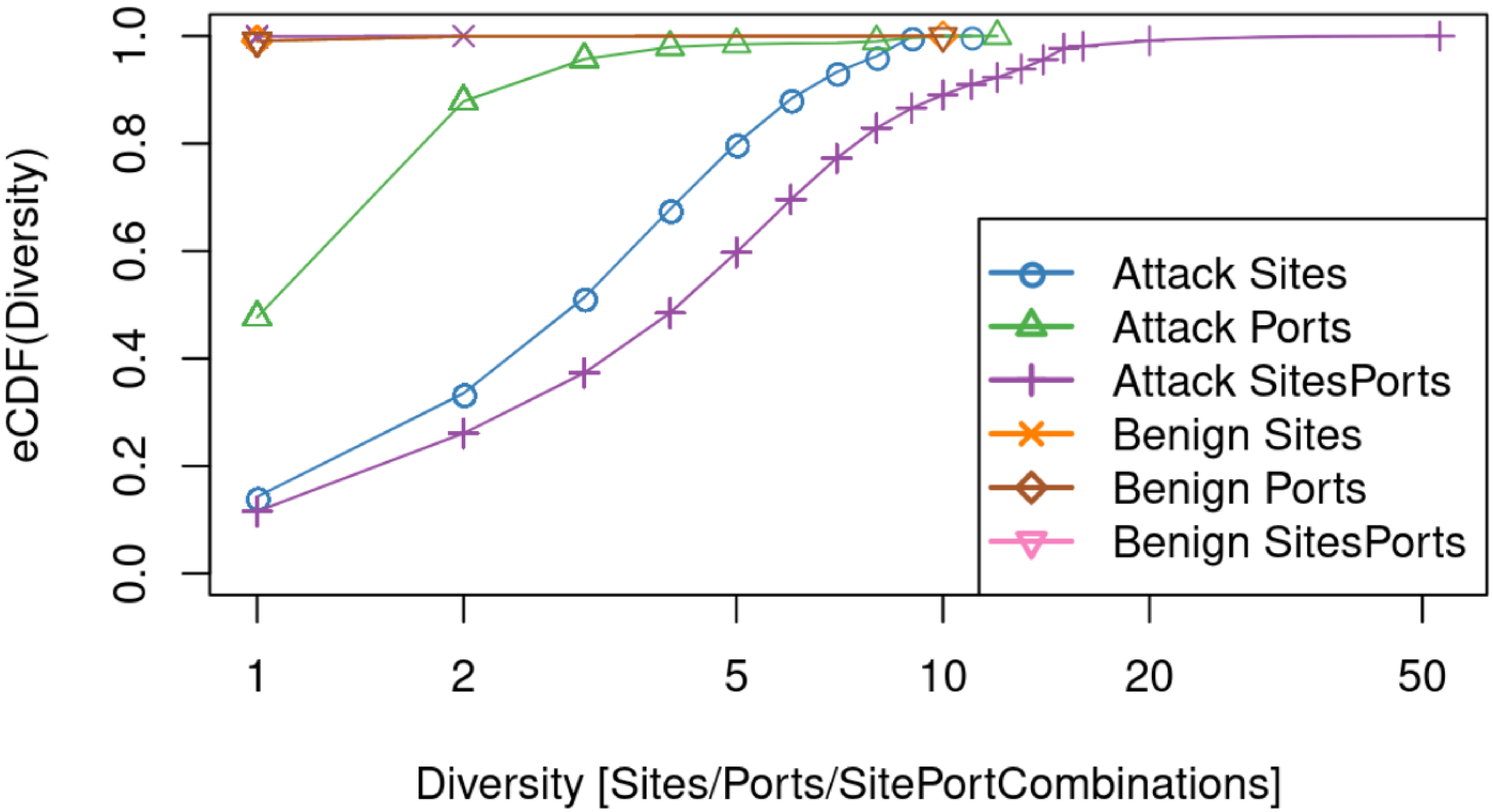
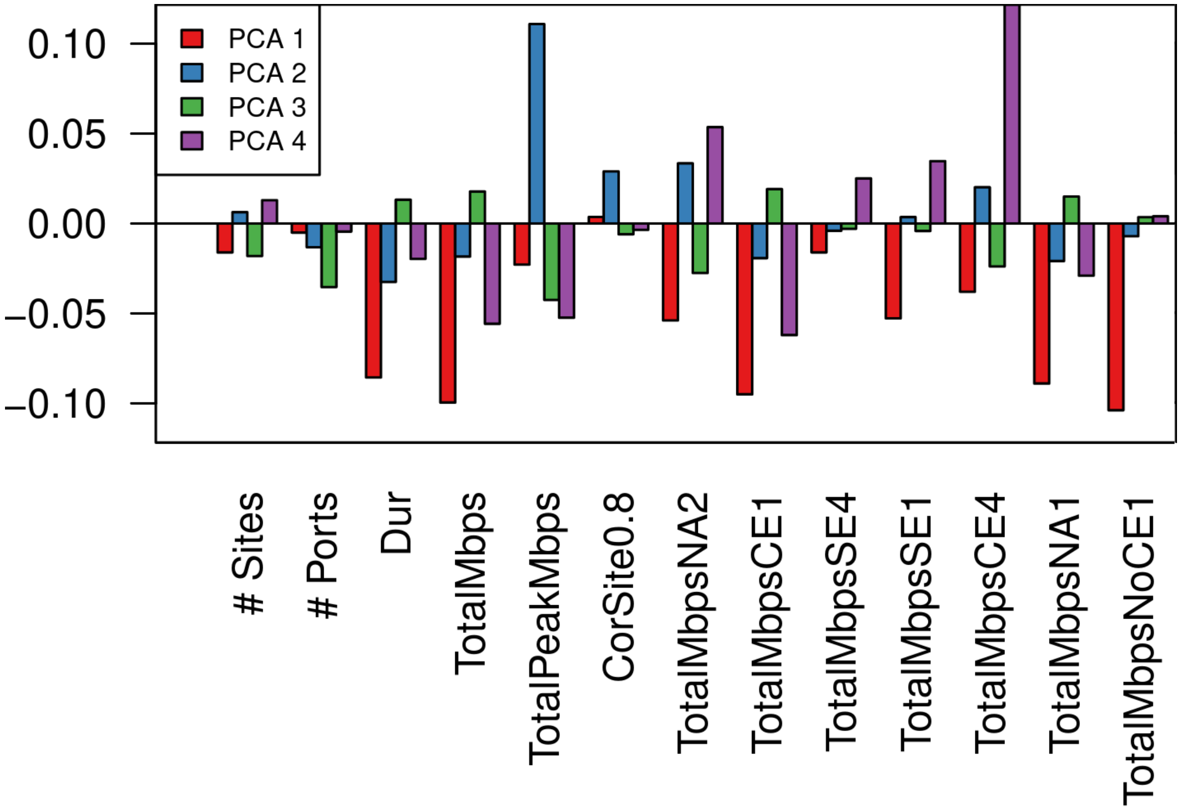
# How accurate are we? (1/2)

- Compare found events to bengin data
  - Traffic to IP addresses that was
    - Caught by the filter
    - Not caught by the detection mechansism
  - Compare traffic characteristics
  - Geographical distribution and port combinations

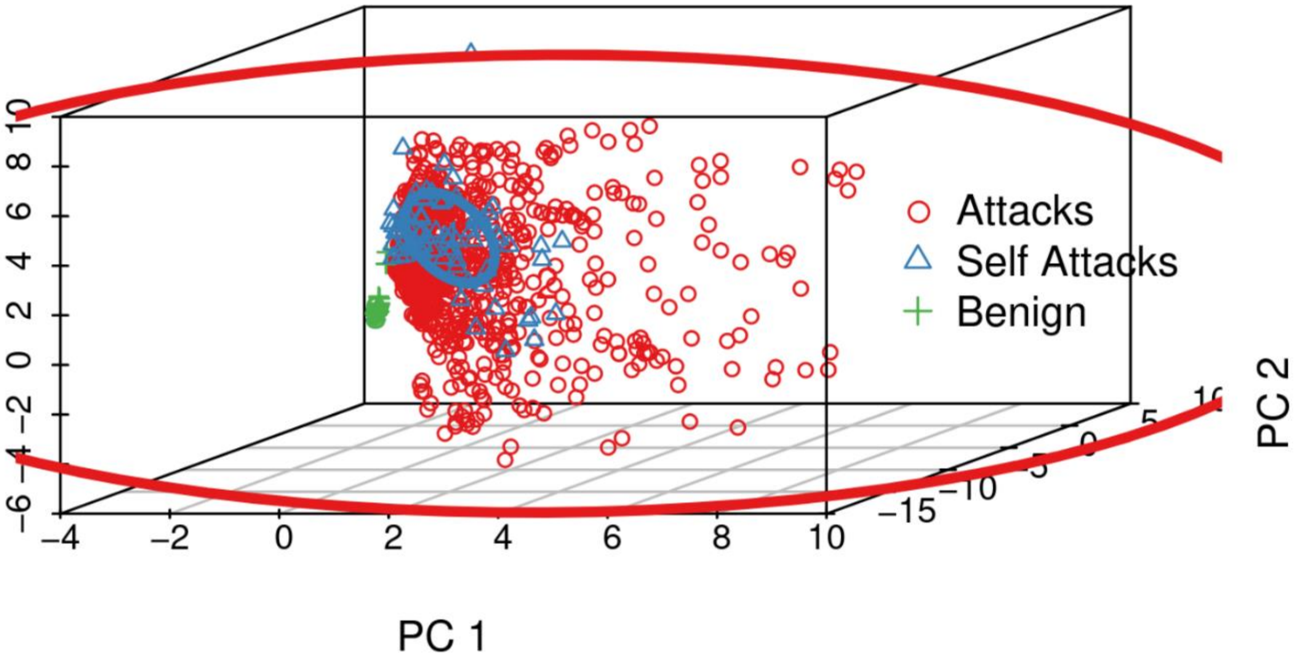
# Benign Traffic vs. Attacks: Sites / Ports



# Self-Attacks: Features and Clustering




Sample features to the rotation of the first 4 PCAs

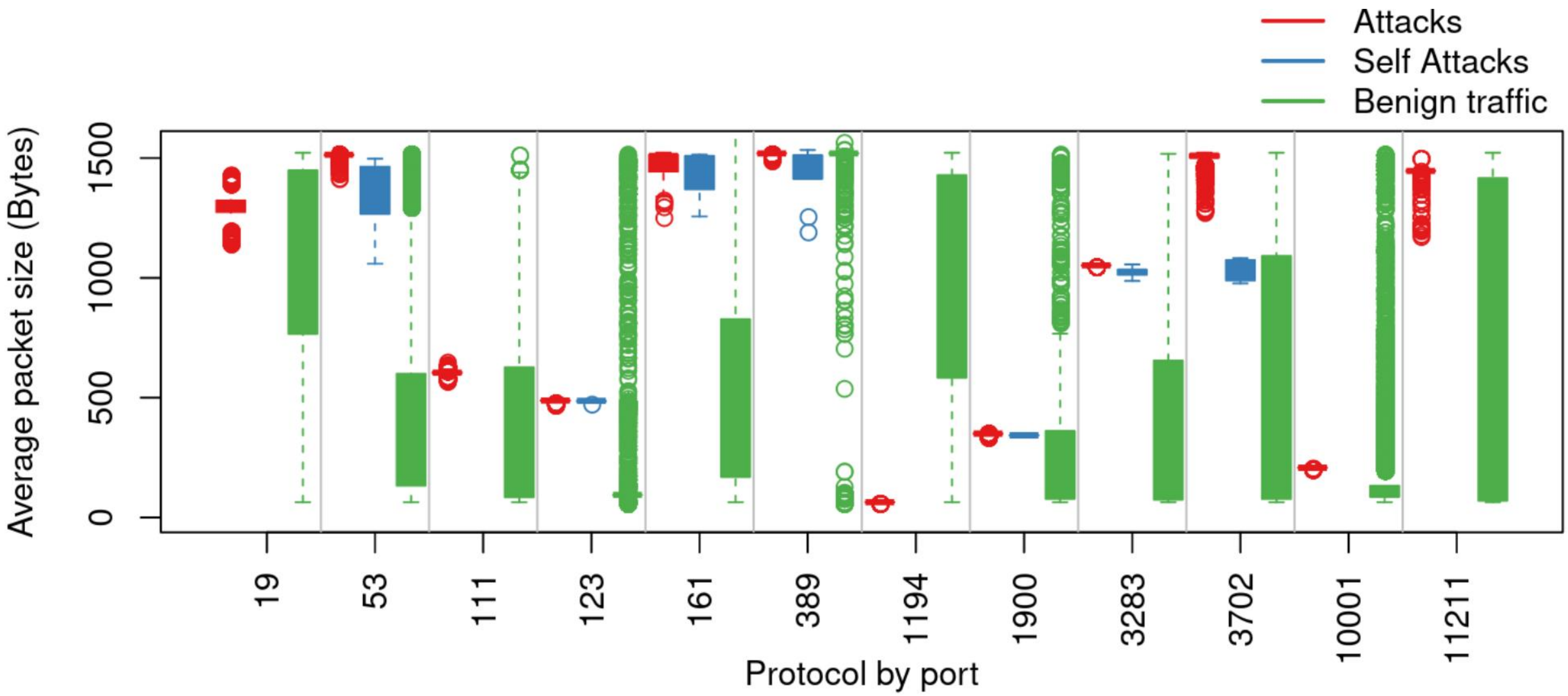



3 most explaining PCs (25% of the variance)

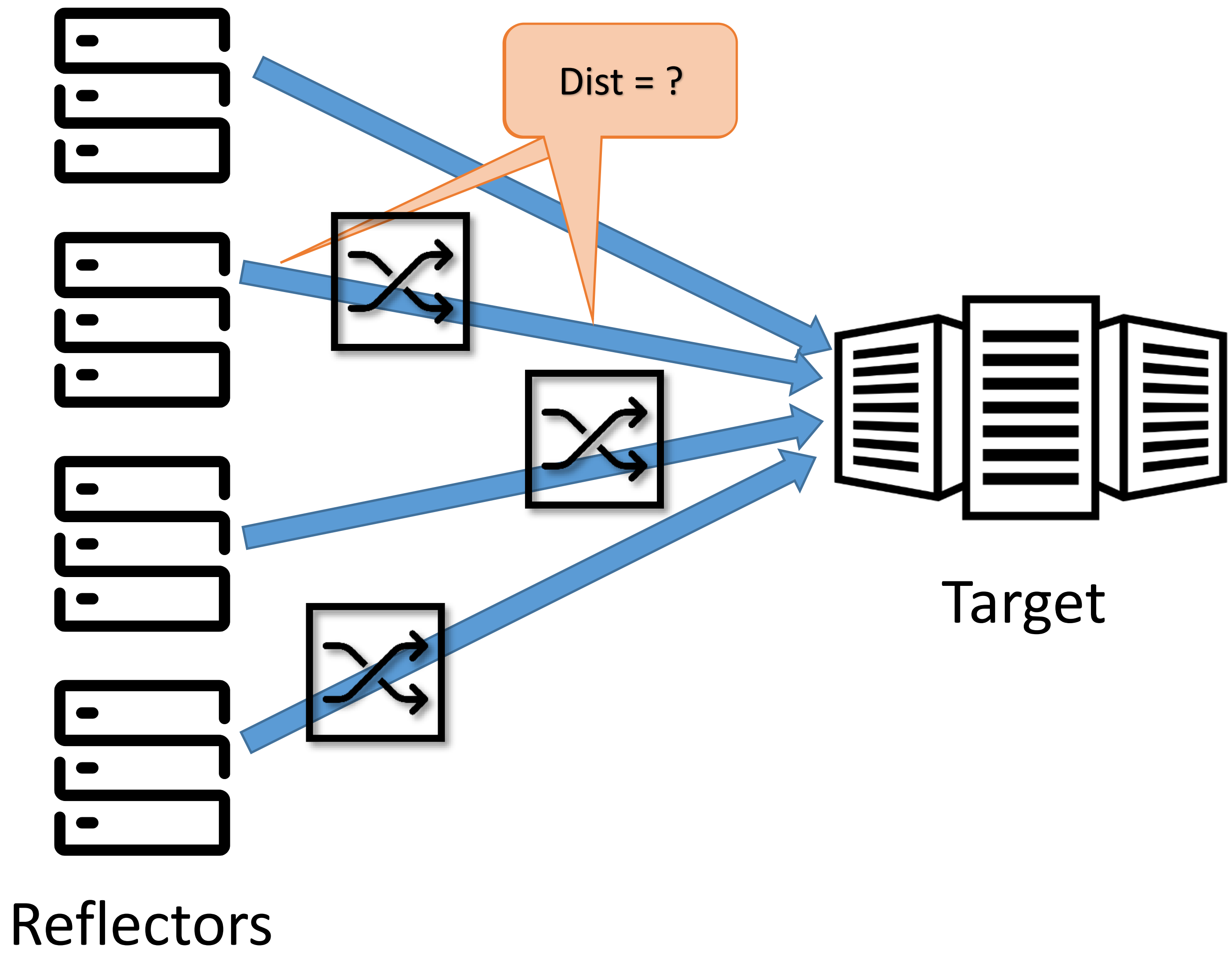
# How accurate are we? (2/2)

- Compare found events to bengin data
  - Traffic to IP addresses that was
    - Caught by the filter
    - Not caught by the detection mechansism
  - Compare traffic characteristics
  - Geographical distribution and port combinations
- Fire up self-attacks to get ground truth
  - Derive and compare features
  - Compare packet sizes

# Packet Sizes



# Contributions (1/3)




- Distance analysis
  - #hops from refelctor?
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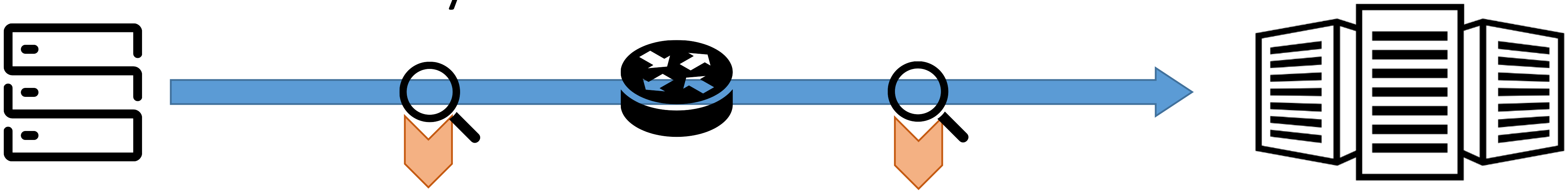
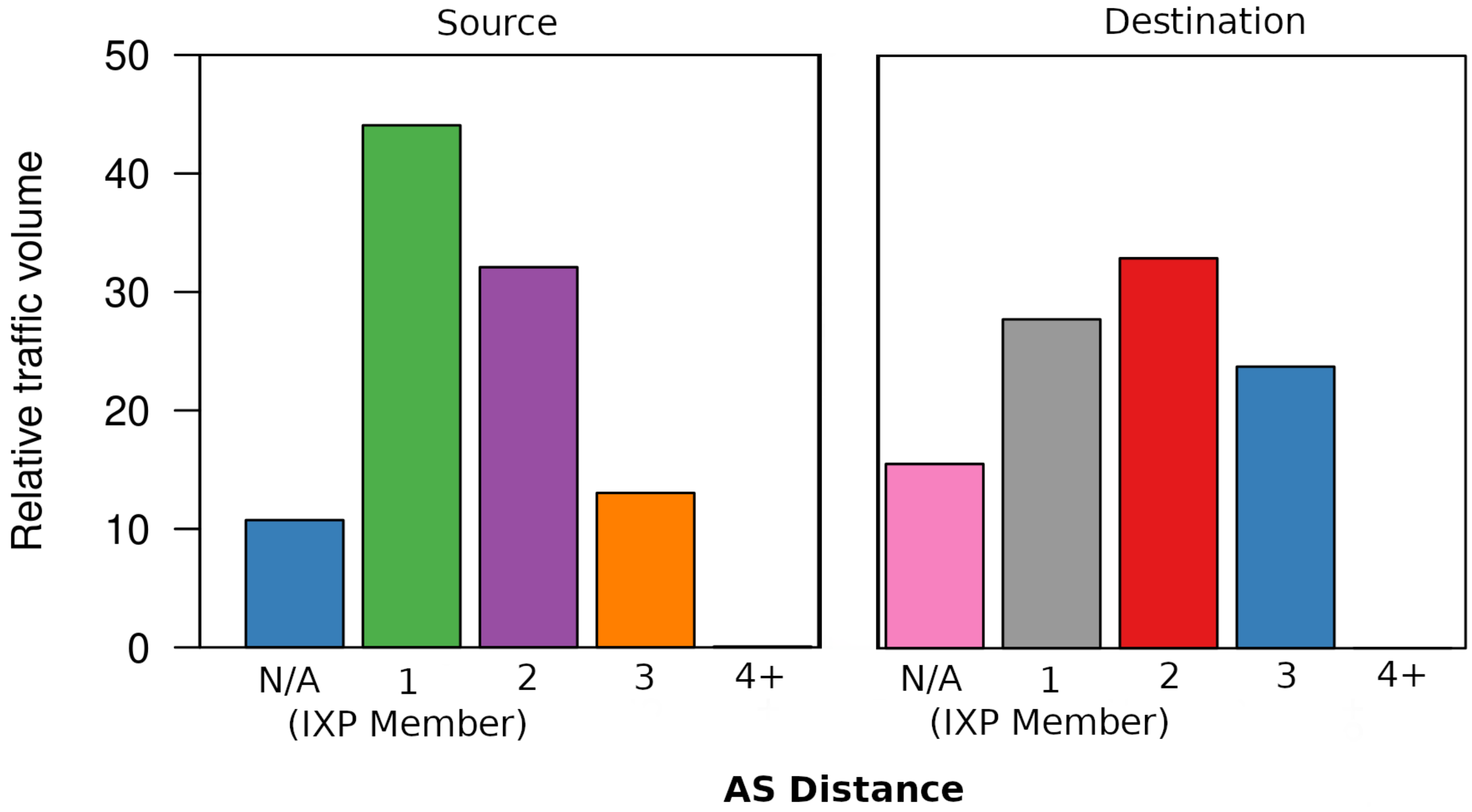
- Collaboration benefit
- Information exchange platorm

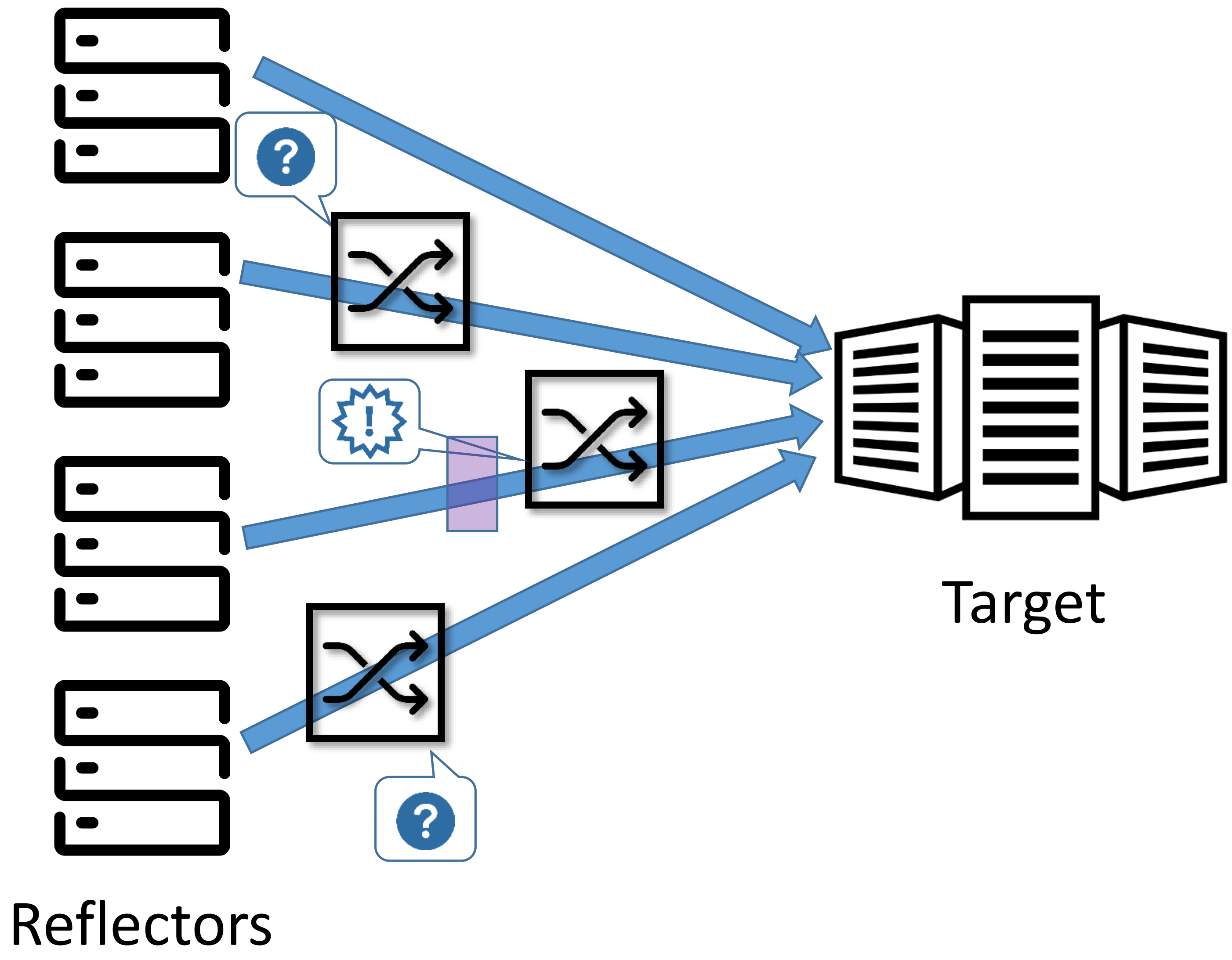
# Distance analysis






- Hops counted from IXP's RS
- About 45% of attack traffic originates from a direct neighbor
- About 70% of attack traffic's destination is just two hops away

# Contributions (2/3)

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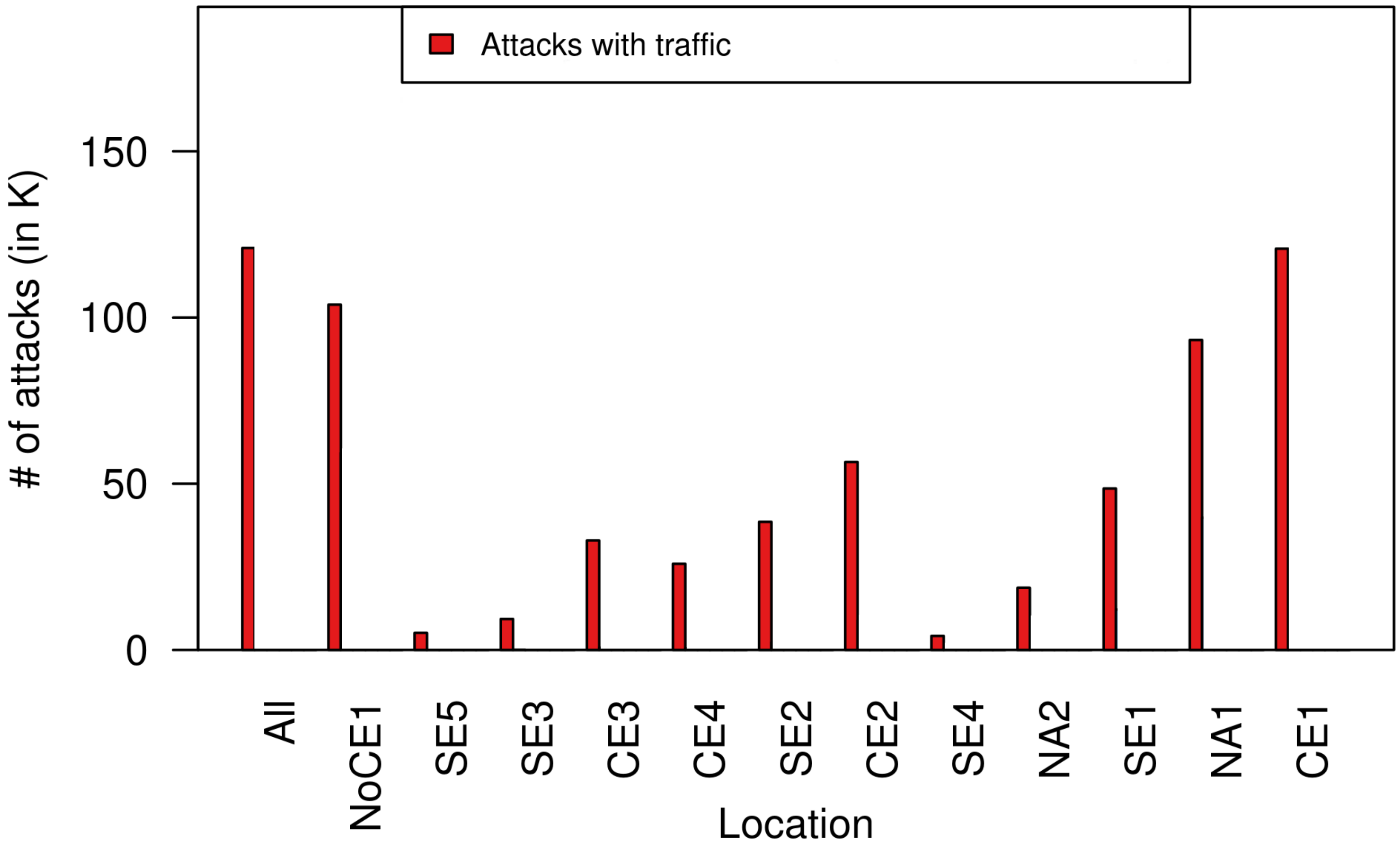
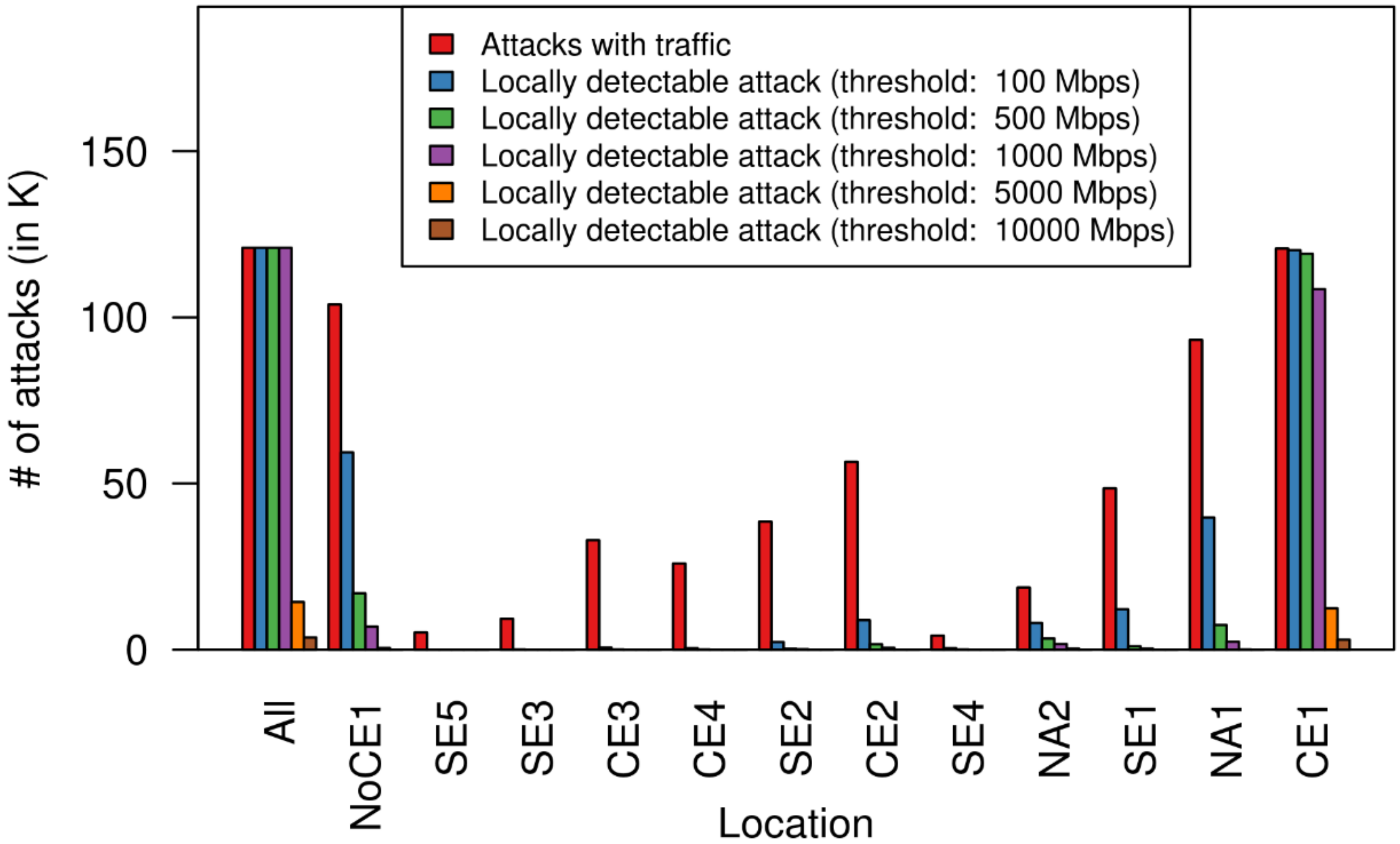
# Attack Events



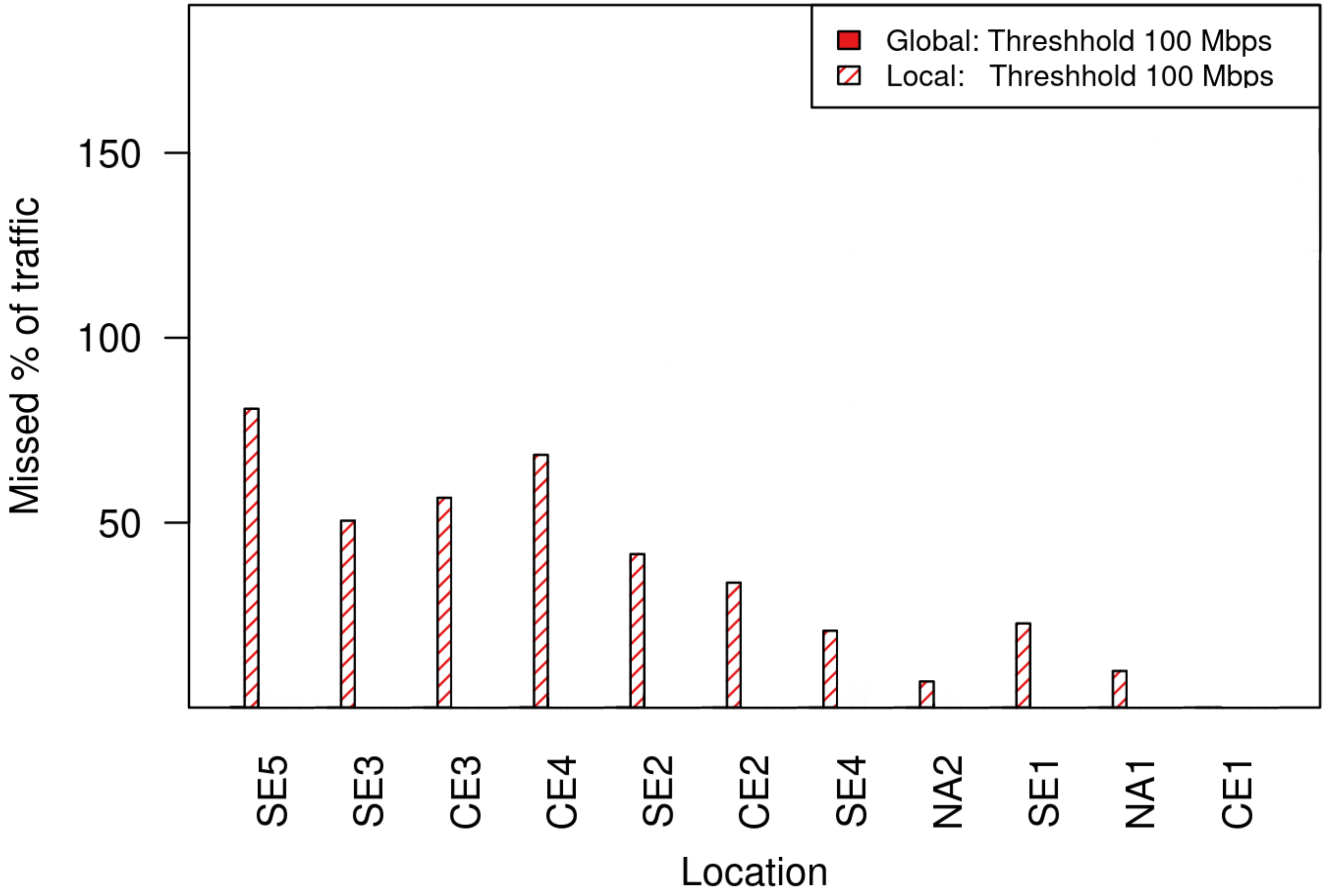

- Ground truth of combined data

# Attack Events




- Ground truth of combined data
- Versus local detectable attack traffic

# Collaboration benefit



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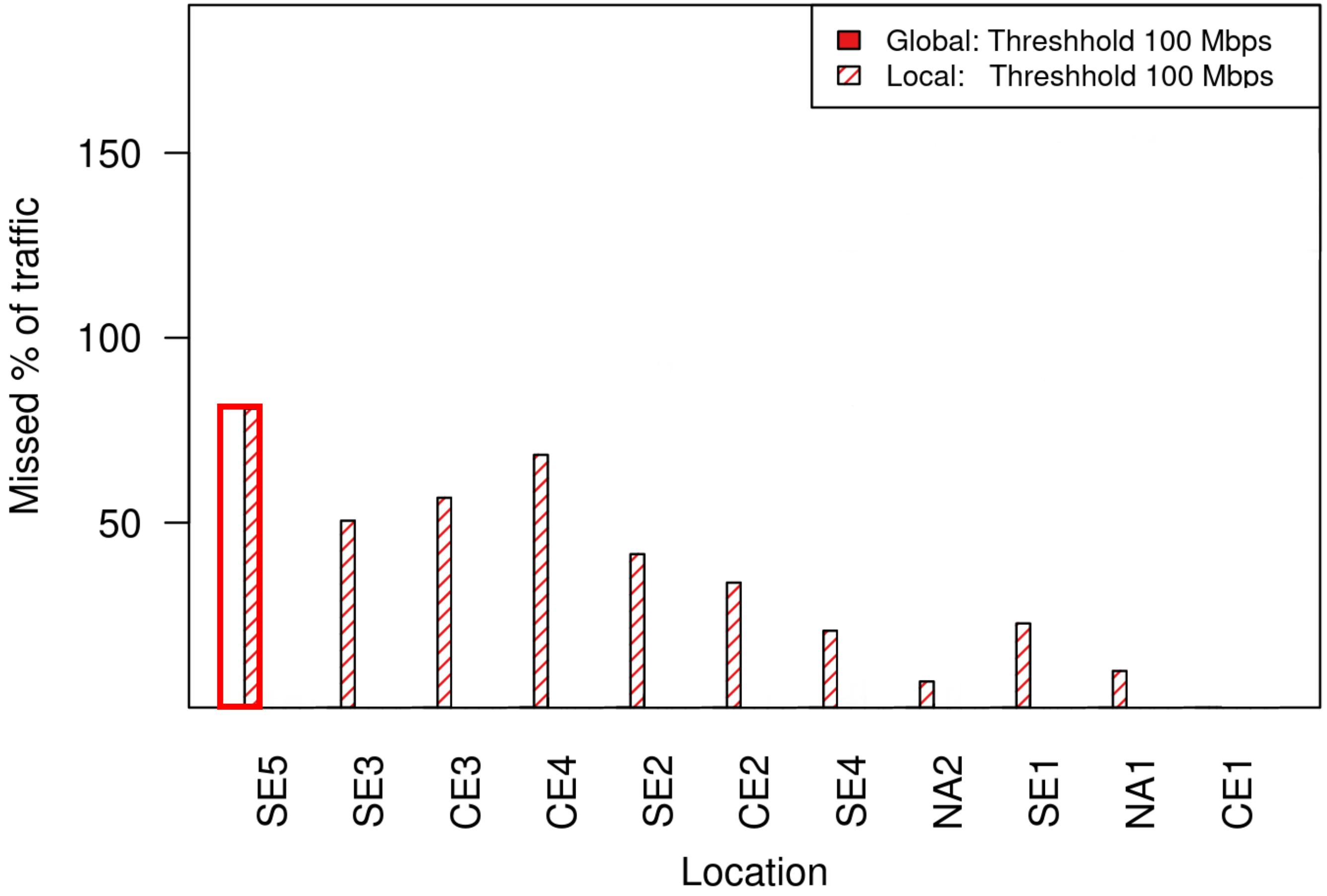
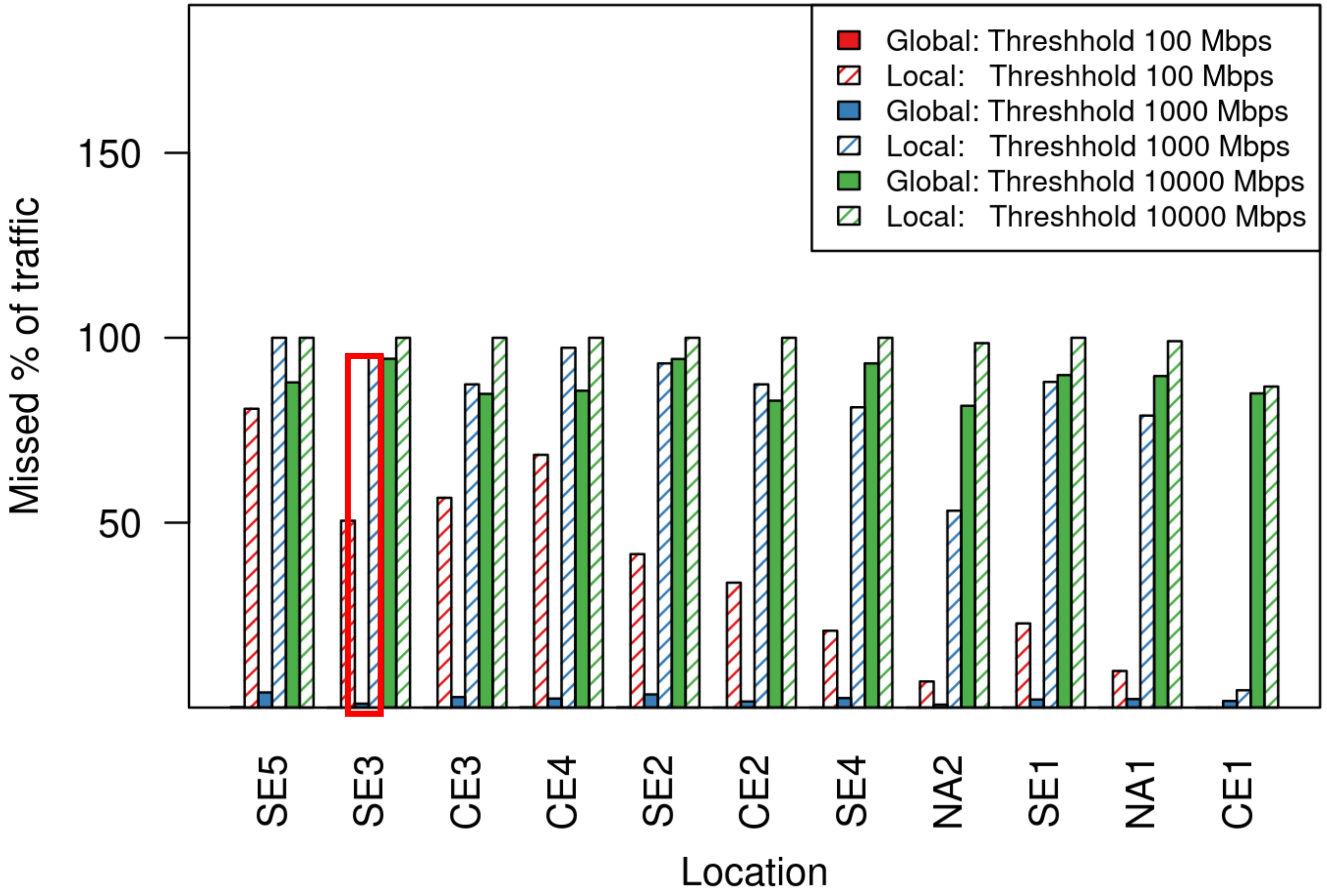


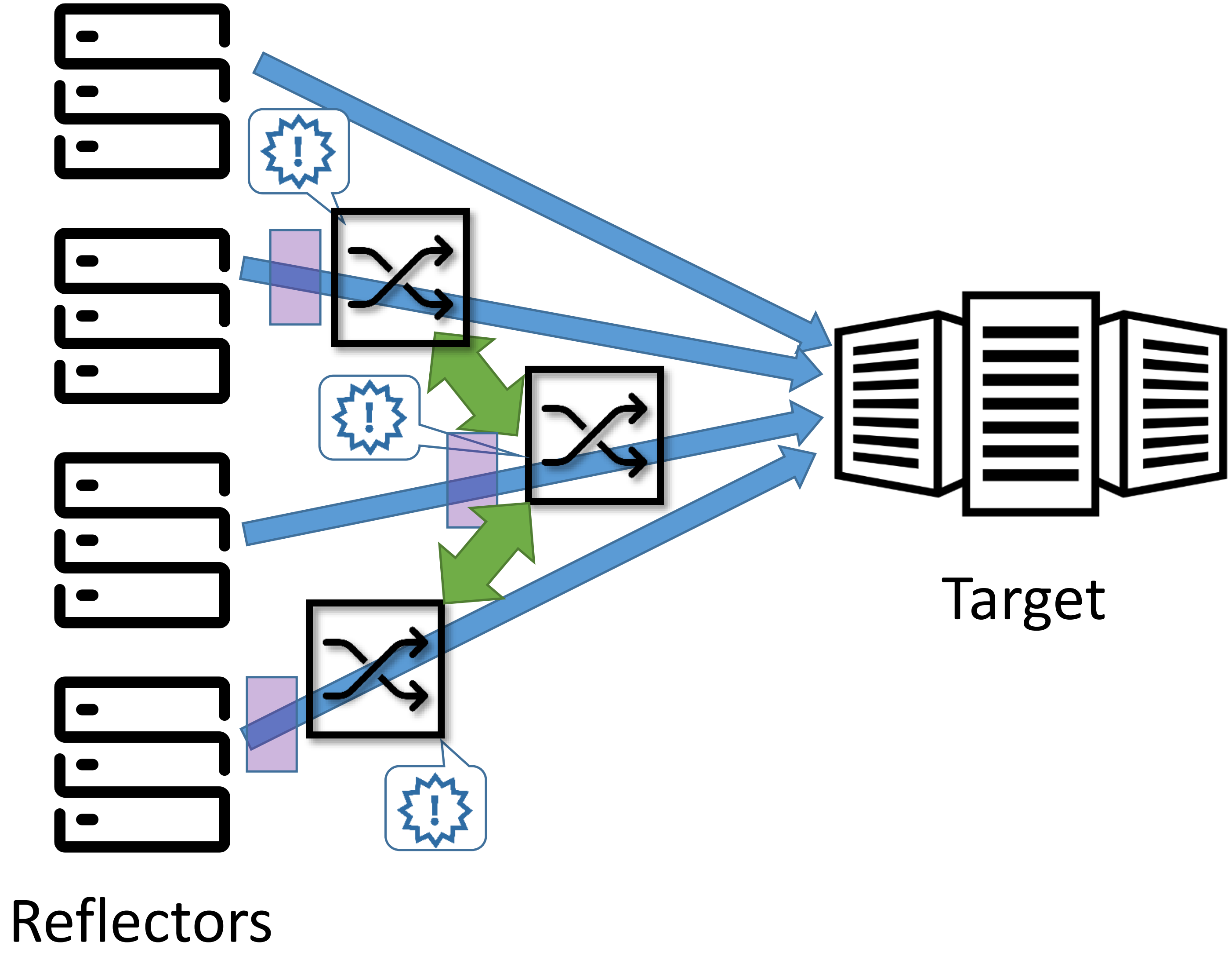

- Up to ~80% of attacks locally undetected („missed“)

# Collaboration benefit




- Up to ~80% of attacks locally missed (100mb/s)
- Up to ~90% of attacks locally missed (1Gb/s)

# Contributions (3/3)




- Distance analysis
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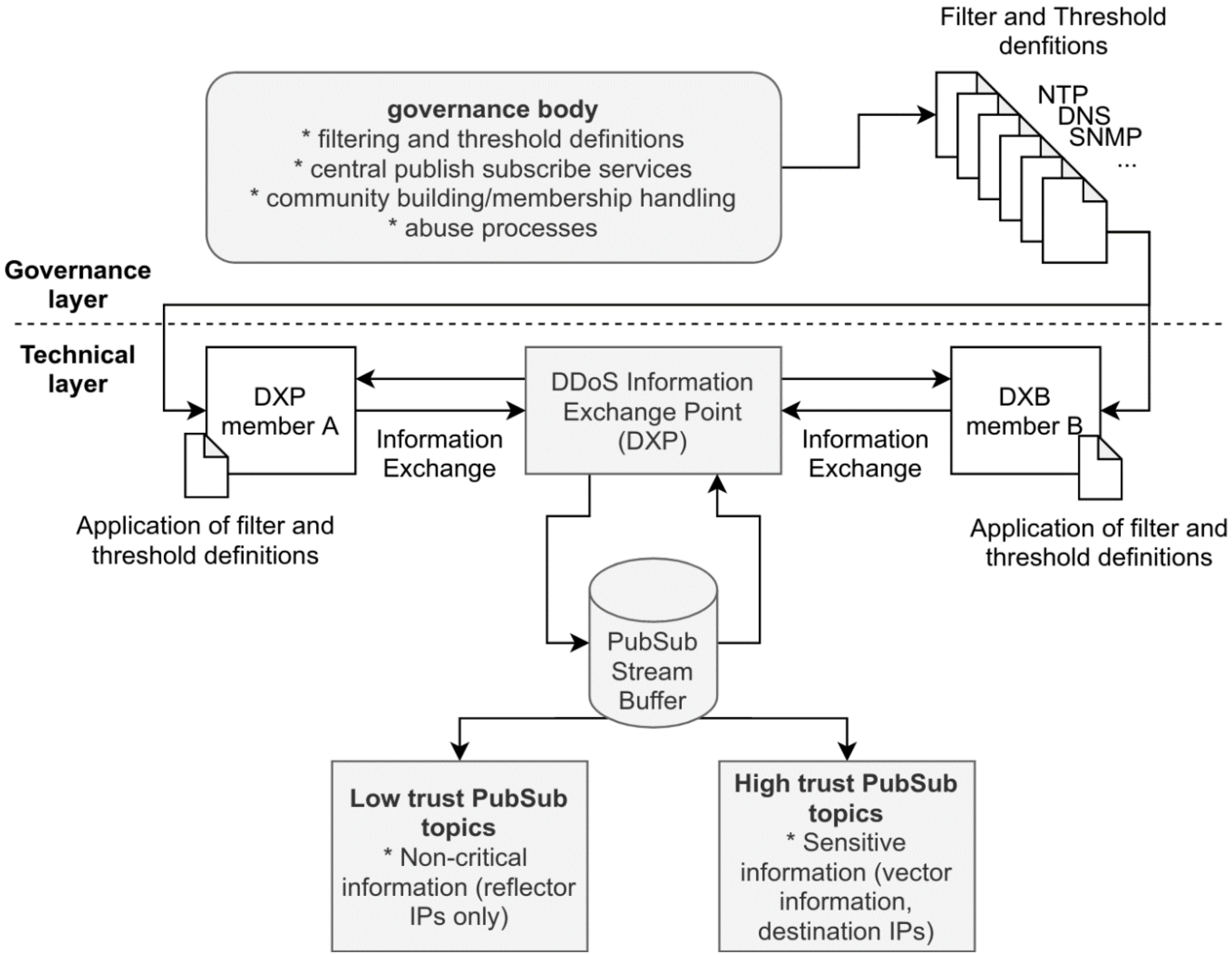
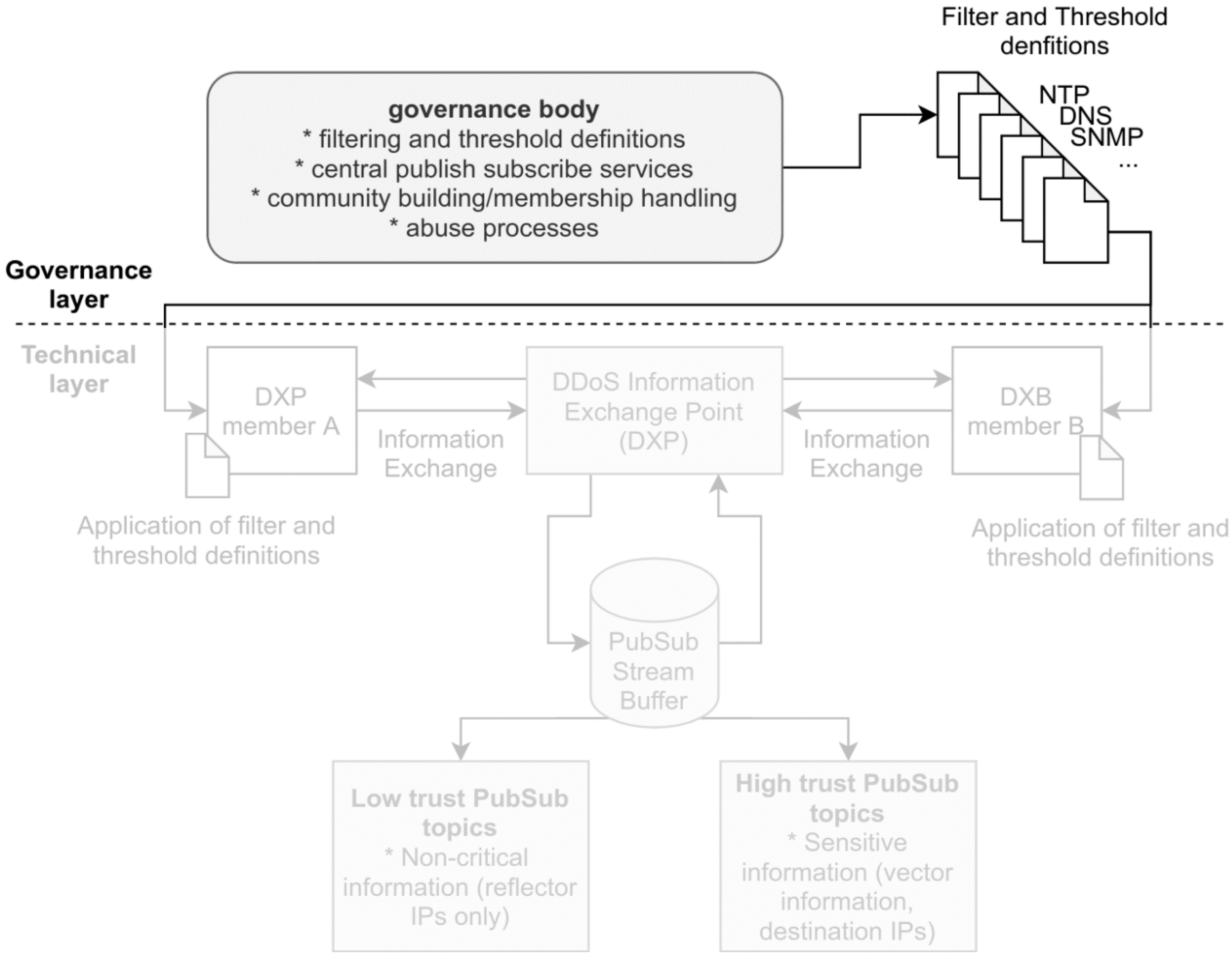
- Collaboration benefit
- Information exchange platform

# DDoS Information Exchange Point (DXP)



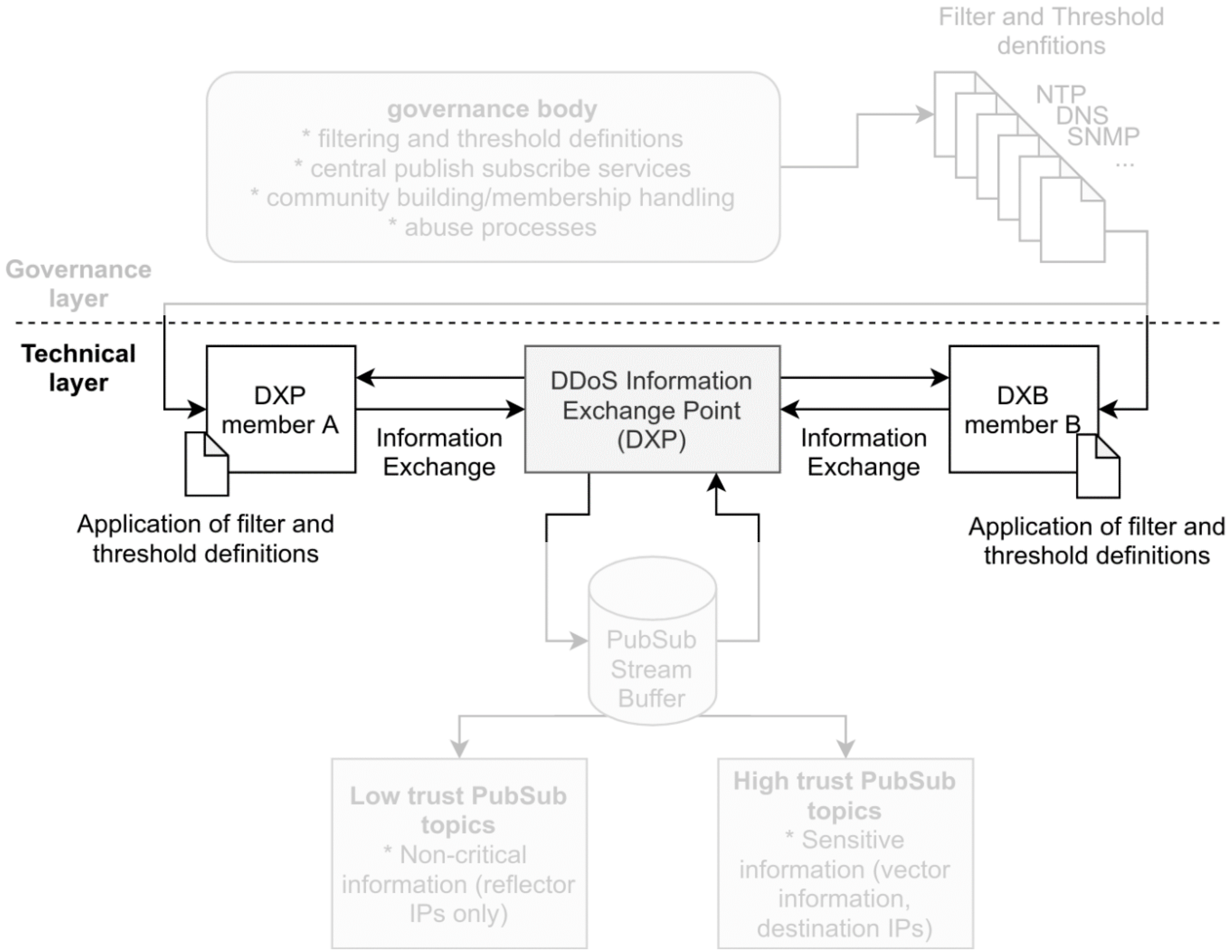
# DDoS Information Exchange Point (DXP)

- Governance body
- Defines filters and thresholds
- Builds community
- Handles SLAs
- Processes abuse cases



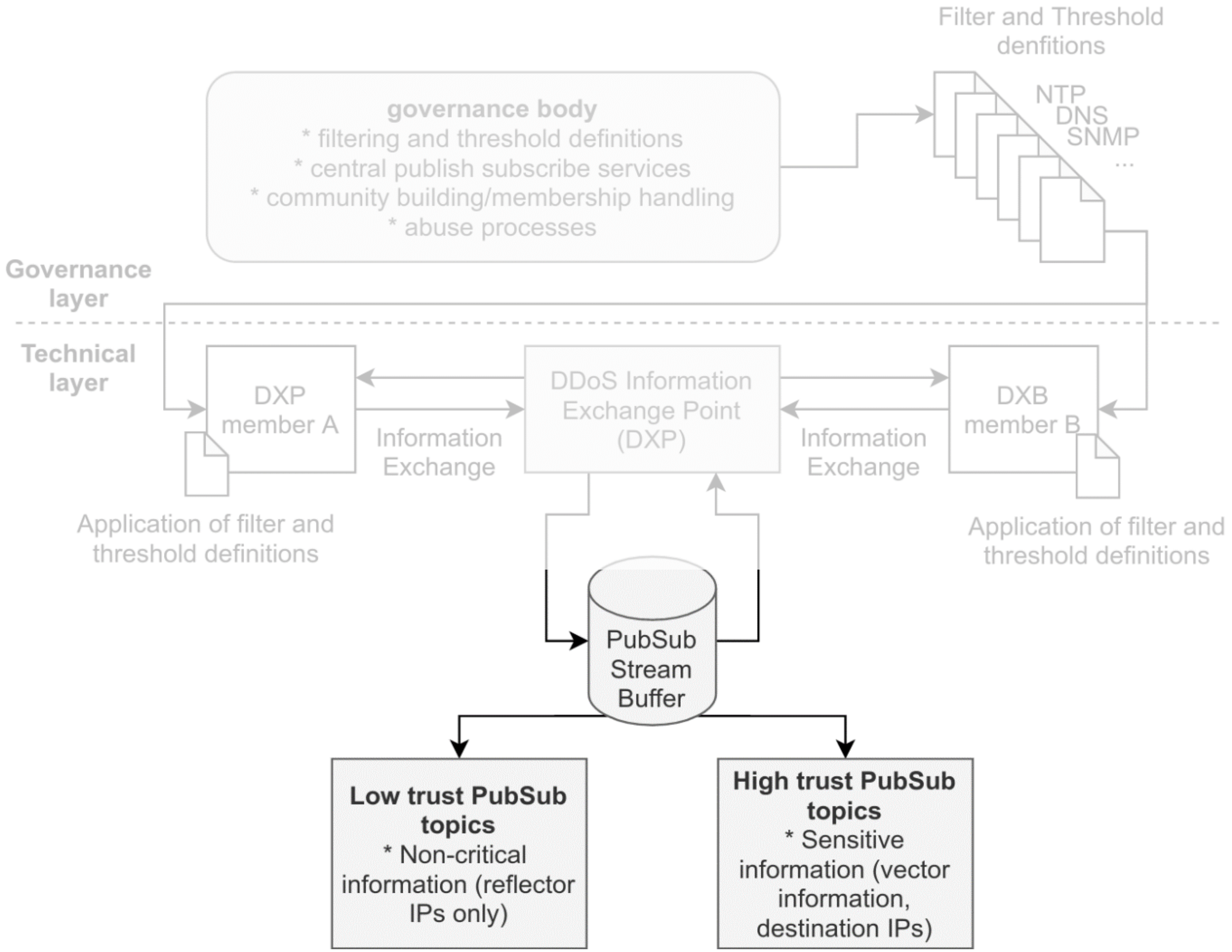
# DDoS Information Exchange Point (DXP)

- Members pull and push rules from / to the DXB
- Apply filters
- Choose a trust scenario

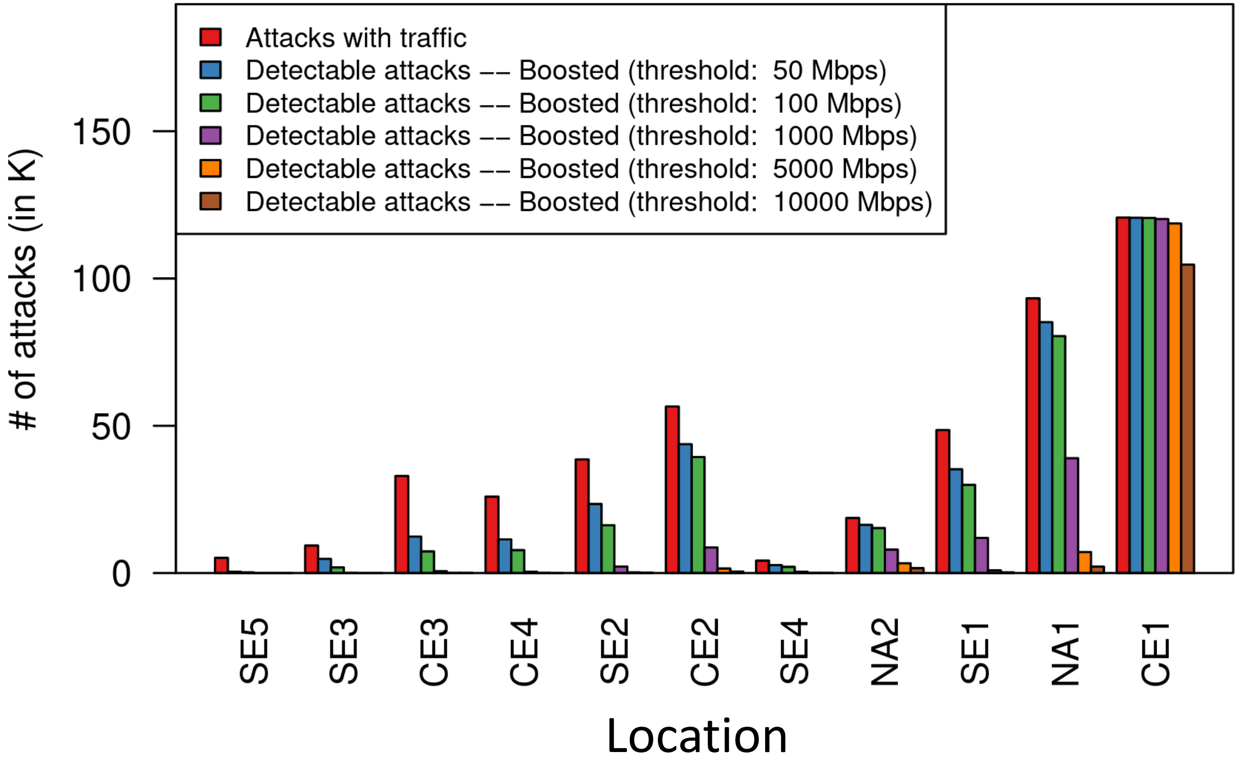


# DDoS Information Exchange Point (DXP)

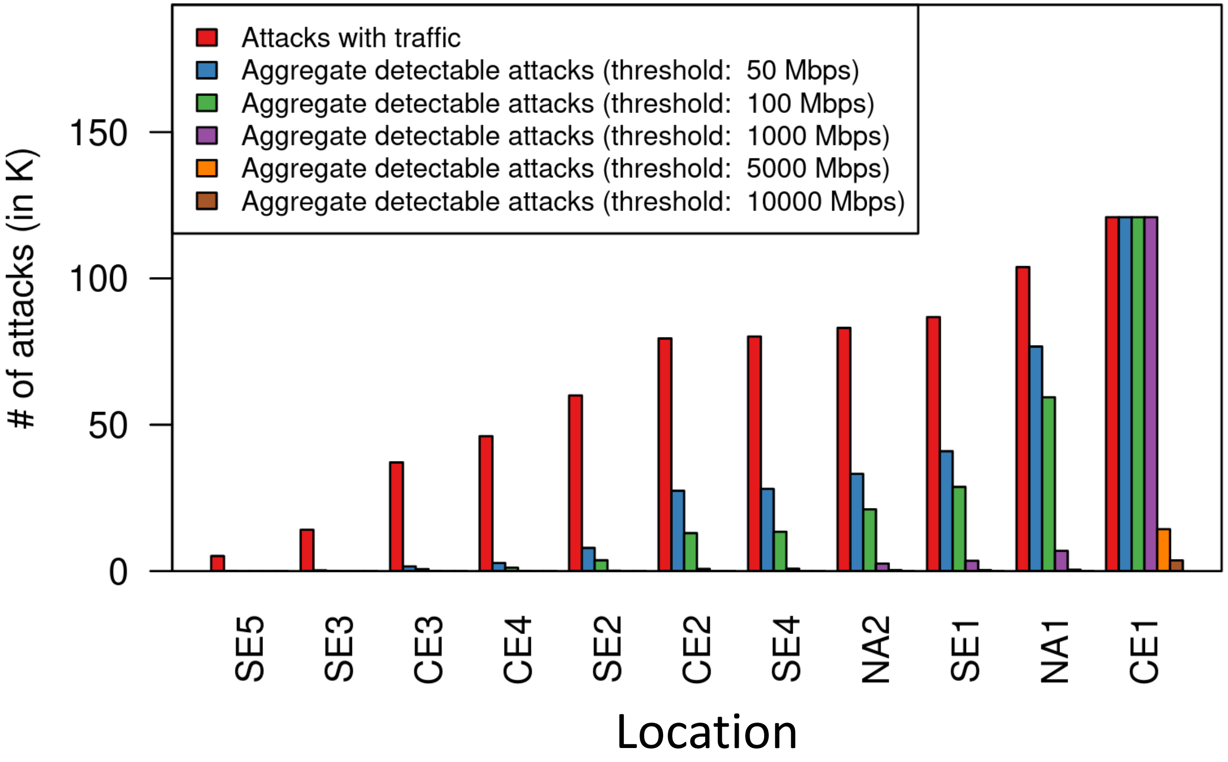
- Low trust:
  - Reflector‘s IP shared
  - Semi-sensitive
- High trust:
  - All information shared
    - Scr/dst IP & port
    - Traffic volume
    - Duration
    - ….



# DXP Evaluation: Low Trust - High Trust




Low trust




High trust

# Conclusion

- Quantification of DDoS origin distribution
  - About 50% of attacks in >=3 locations, about 25% in >=5 locations

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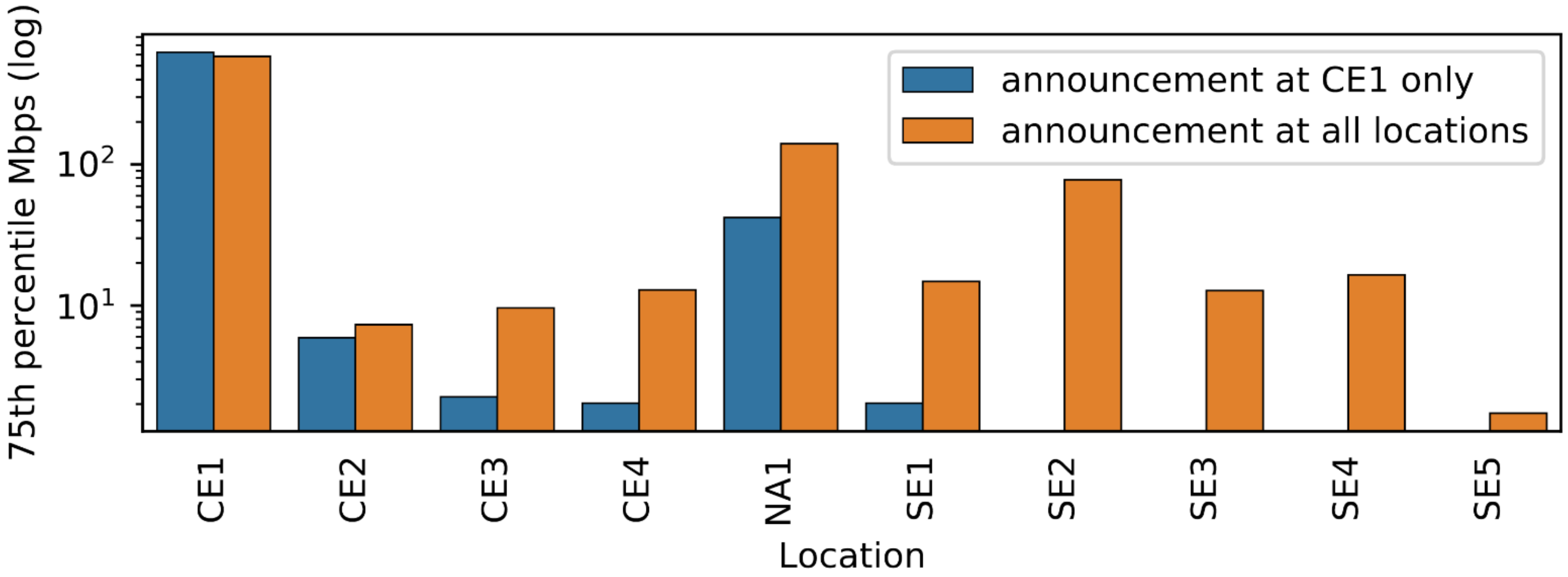
- Emphasis on IXP's critical role for DDoS mitigation
  - About 45% of the reflectors and about 30% of the targets are an IXP member
- Collaboration platform proposal and evaluation
  - DXP
  - Up to 90% more attack traffic detectable at a site due to collaboration

# (Backup Slides)

# Distance / geographical distribution analysis



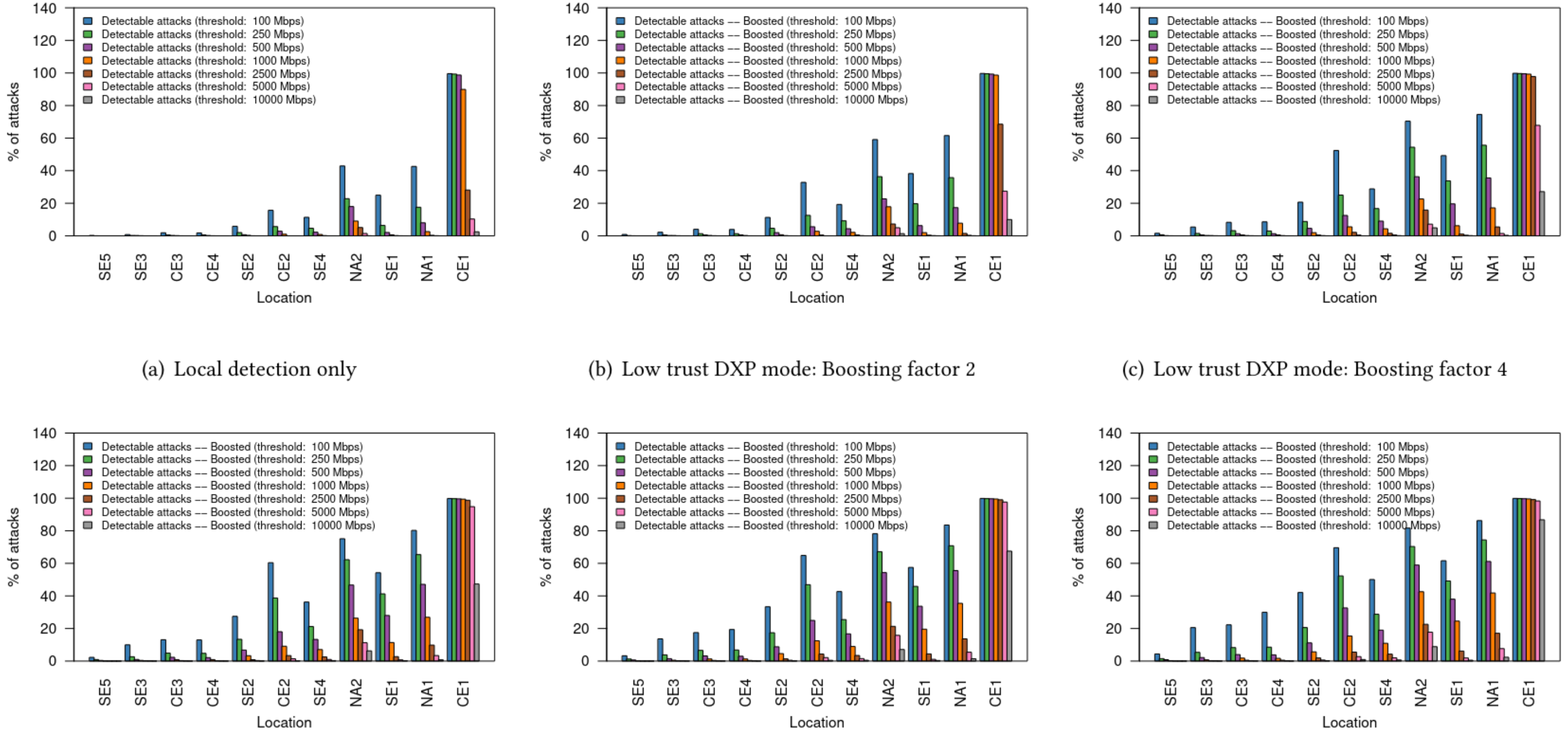
# Features

| Feature Class | Feature Count | Description |
|---|---|---|
| Sites | 1 | Number of sites involved in the attack |
| Ports | 1 | Number of source transport ports involved in the attack |
| SitesPorts | 1 | Sum of source transport ports seen at the sites, where the attack is visible |
| Dur | 1 | Total duration of the attack in minutes |
| DurAttack | 1 | Duration in minutes where the attack volume is greater than $t$ (In our study: 1 Gbps) |
| TotalMbps | 1 | Volume of the attack in Mbps, summed across all sites and all source transport ports |
| TotalMbpsAttack | 1 | Volume of the attack in Mbps, summed across all sites and all source transport ports, while the volume is greater than $t$ |
| TotalPeakMbps | 1 | Peak of the attack volume in Mbps, summed across all sites and all source transport ports |
| Peak Mbps | 1 | Peak of the attack volume in Mbps, single site, single source transport port |
| TotalMbpsCE1 | 1 | Sum of the attack traffic across all source transport ports in Mbps, seen at site CE1 |
| TotalMbpsAttackCE1 | 1 | Sum of the attack volume across all source transport ports in Mbps, seen at site CE1 while exceeding $t$ |
| TotalPeakMbpsCE1 | 1 | Peak attack volume across all source transport ports, seen at site CE1, in Mbps |
| PeakMbpsCE1 | 1 | Peak attack volume of a single source transport port, seen at site CE1, in Mbps |
| TotalMbpsNoCE1 | 1 | Volume of the attack in Mbps, seen at all sites but CE1, all source transport ports |
| TotalMbpsAttackNoCE1 | 1 | Volume of the attack in Mbps, seen at all sites but CE1, all source transport ports while exceeding $t$ |
| TotalPeakMbpsNoCE1 | 1 | Peak volume of the attack in Mbps, seen at all sites but CE1, across all source transport ports |
| PeakMbpsNoCE1 | 1 | Peak volume of the attack in Mbps, seen at all sites but CE1, across a single transport port |
| Cor[Site\|Port]{0.7,0.8,0.9} | 6 | Counter for correlation of the attack between sites and source transport ports, respectively, being greater than .7, .8, .9, respectively per minute. |
| TotalMbps[IXP*] | 11 | Volume of the attack in Mbps, as seen at the 11 sites, all source transport ports, respectively |
| TotalMbps[PORT*] | 12 | Volume of the attack in Mbps, summed across all sites, for each of the 12 source transport ports in our study |
| PeakMbps[IXP*] | 11 | Peak volume of the attack in Mbps, as seen at the 11 sites, respectively, single source transport port |
| PeakMbps[PORT*] | 12 | Peak volume of the attack in Mbps, summed across all sites, for each of the 12 source transport ports in our study |
| TotalMpps | 1 | Sum of packets transmitted for the attack across all sites, all source transport protocols, in Mpps |
| TotalMppsAttack | 1 | Sum of packets transmitted for the attack across all, all source transport ports, sites while exceeding $t$, in Mpps |
| TotalPeakMpps | 1 | Peak of packets transmitted for the attack, summed across all sites, all source transport ports, in Mpps |
| PeakMpps | 1 | Peak of packets transmitted for the attack at any site, single transport port, in Mpps |
| TotalMpps[IXP*] | 11 | Sum of packets transmitted across all source transport ports, at the 11 sites, respectively |
| TotalMpps[PORT*] | 12 | Sum of packets transmitted at all sites, for each of the 12 source transport protocols in our study |
| TotalMbpsNorm | 1 | Volume of the attack, summed across all source transport ports and all sites, normalized by their size |

# Features (cont.)

| Feature Class | Feature Count | Description |
|---|---|---|
| TotalMbpsAttackNorm | 1 | Volume of the attack in Mbps, summed across all source transport ports, all sites, normalized by their size, while exceeding *t* |
| TotalPeakMbpsNorm | 1 | Peak of the attack volume in Mbps, summed across all source transport ports, all sites, normalized by their size |
| PeakMbpsNorm | 1 | Peak of the attack volume in Mbps, single source transport port, at a single site, normalized by their size |
| TotalMbpsNormNoCE1 | 1 | Volume of the attack in Mbps, all source transport ports, seen at all sites but CE1, normalized by their size |
| TotalMbpsAttackNormNoCE1 | 1 | Volume of the attack in Mbps, all source transport ports, seen at all sites but CE1, normalized by their size, while exceeding *t* |
| TotalPeakMbpsNormNoCE1 | 1 | Peak volume of the attack, summed all source transport ports, seen at all sites but CE1, normalized by their size |
| PeakMbpsNormNoCE1 | 1 | Peak volume of the attack, single source transport ports, seen at all sites but CE1, normalized by their size |
| TotalMbpsNorm[IXP*] | 11 | Volume of the attack in Mbps, all source transport ports, as seen at the 11 sites, normalized by their size, respectively |
| PeakMbpsNorm[IXP*] | 11 | Peak volume of the attack in Mbps, single source transport port, as seen at the 11 sites, normalized by their size, respectively |
| Allthresh-Before-[THRESHHOLD*] | 7 | Volume of traffic across all source ports that belong to an attack, greatest volume of a single site, before the respective threshold was exceeded |
| Allthresh-Detect-[THRESHHOLD*] | 7 | Volume of traffic across all source ports that belong to an attack, greatest volume of a single site, while the respective threshold is exceeded |
| Allthresh-After-[THRESHHOLD*] | 7 | Volume of traffic across all single source transport ports that belong to an attack, greatest volume of a single site, after the respective threshold is no longer exceeded |
| Allthresh-Time-[THRESHHOLD*] | 7 | Amount of time bins for which the attack volume across all source transport ports, greatest of al single site, exceeded the respective threshold |
| Allthreshnorm-Before-[THRESHHOLD*] | 7 | Volume of traffic across all source ports that belong to an attack, greatest of a single site, normalized by its size, before the respective threshold was exceeded |
| Allthreshnorm-Detect-[THRESHHOLD*] | 7 | Volume of traffic across all source ports that belong to an attack, greatest of a single site, normalized by its size, while the respective threshold is exceeded |
| Allthreshnorm-After-[THRESHHOLD*] | 7 | Volume of traffic across all source transport ports that belong to an attack, greatest of a single site, normalized by its size, after the respective threshold is no longer exceeded |
| Allthreshnorm-Time-[THRESHHOLD*] | 7 | Amount of time bins for which the attack volume across all source transport ports, greatest of a single site, normalized by its size, exceeded the respective threshold |
| SiteThresh-[IXP*]-Before-[THRESHHOLD*] | 77 | Volume of the attack, for every site respectively, single source transport port, before exceeding the respective threshold |
| SiteThresh-[IXP*]-After-[THRESHHOLD*] | 77 | Volume of the attack, for every site respectively, single source transport port, after the respective threshold is no longer exceeded |
| SiteThresh-[IXP*]-Detect-[THRESHHOLD*] | 77 | Volume of the attack, for every site respectively, single source transport port, while exceeding the respective threshold |
| SiteThresh-[IXP*]-Time-[THRESHHOLD*] | 77 | Amount of time bins, for every site respectively, for every threshold, single source transport port, before exceeding the respective threshold |
| GlobalThresh-[IXP*]-Before-[THRESHHOLD*] | 77 | Volume of the attack, adding all site's volume to every site respectively, all source transport ports, before exceeding the respective threshold |
| GlobalThresh-[IXP*]-After-[THRESHHOLD*] | 77 | Volume of the attack, adding all site's volume to every site respectively, all source transport ports, after the respective threshold is no longer exceeded |
| GlobalThresh-[IXP*]-Detect-[THRESHHOLD*] | 77 | Volume of the attack, adding all site's volume to every site respectively, all source transport ports, while exceeding the respective threshold |
| GlobalThresh-[IXP*]-Time-[THRESHHOLD*] | 77 | Amount of time bins, when adding all site's volume to the respective site, for every threshold, all source transport ports, while exceeding the respective threshold |
| SiteThreshNorm-[IXP*]-Before-[THRESHHOLD*] | 77 | Volume of the attack, for every site, normalized by its size, single source transport port, before exceeding the respective threshold |
| SiteThreshNorm-[IXP*]-After-[THRESHHOLD*] | 77 | Volume of the attack, for every site respectively, normalized by its size, single source transport port, after the respective threshold is no longer exceeded |
| SiteThreshNorm-[IXP*]-Detect-[THRESHHOLD*] | 77 | Volume of the attack, for every site respectively, normalized by its size, single source transport port, while exceeding the respective threshold |
| SiteThreshNorm-[IXP*]-Time-[THRESHHOLD*] | 77 | Amount of time bins, for every site respectively, normalized by its size, for every threshold, single source transport port, before exceeding the respective threshold |
| Total | 1106 | |

# Boosting Factor evaluation (1)




(a) Local detection only

(b) Low trust DXP mode: Boosting factor 2

(c) Low trust DXP mode: Boosting factor 4

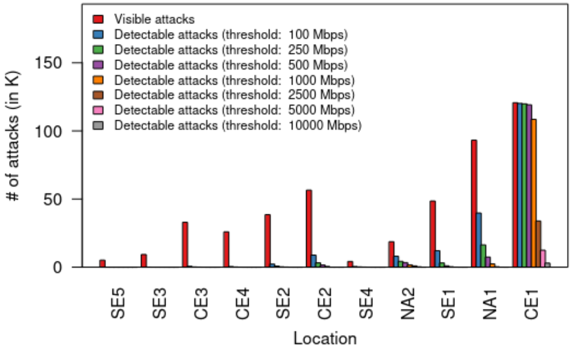
(d) Low trust DXP mode: Boosting factor 6

(e) Low trust DXP mode: Boosting factor 8

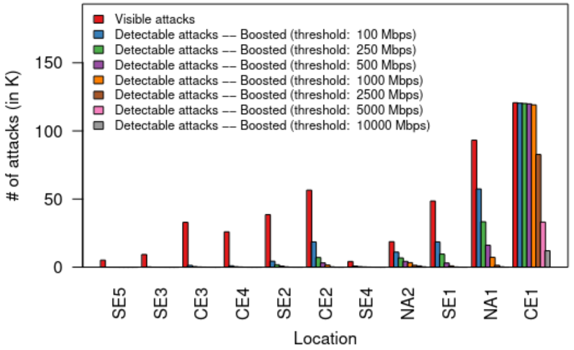
(f) Low trust DXP mode: Boosting factor 10

**Figure 21: Relative: Sensitivity of the detectable DDoS attacks in the low trust DXP setting for different boosting factors.**

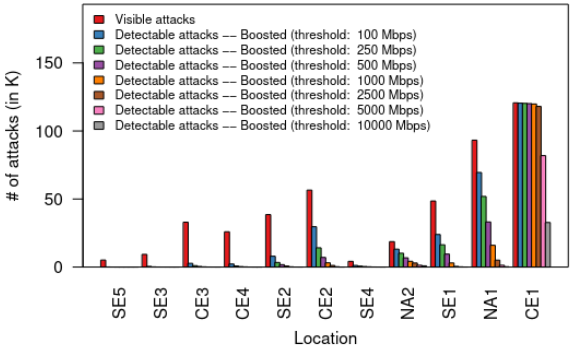
# Boosting Factor evaluation (2)



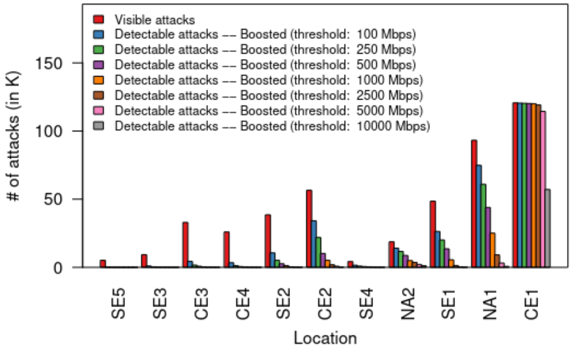

(a) Local detection only



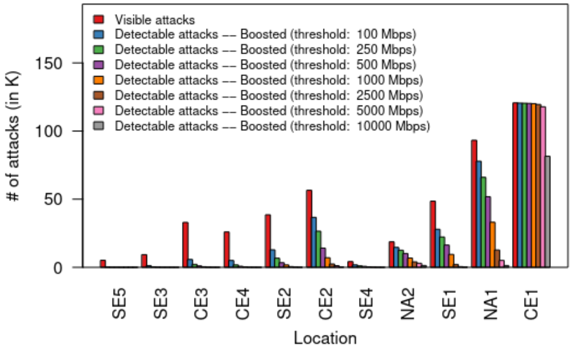

(b) Low trust DXP mode: Boosting factor 2



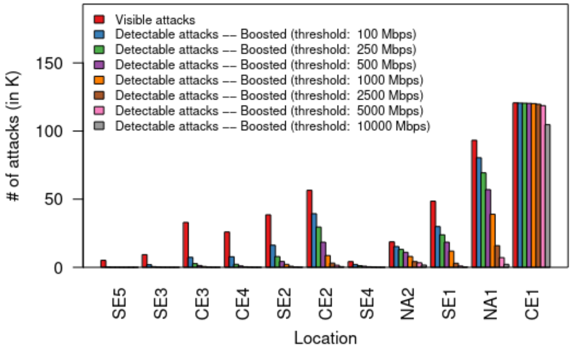

(c) Low trust DXP mode: Boosting factor 4




(d) Low trust DXP mode: Boosting factor 6



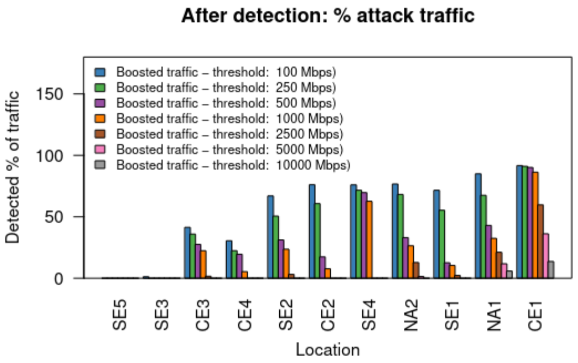

(e) Low trust DXP mode: Boosting factor 8



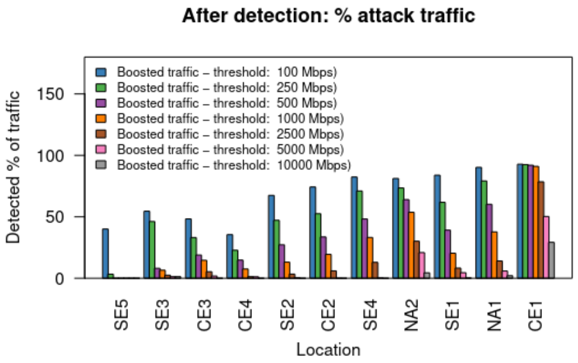

(f) High trust DXP mode: Boosting factor 10

**Figure 22: Absolute: Sensitivity of the detectable DDoS attacks in the low trust DXP setting for different boosting factors.**

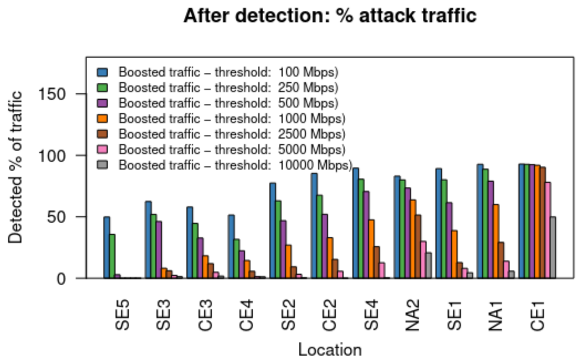
# Boosting Factor evaluation (3)



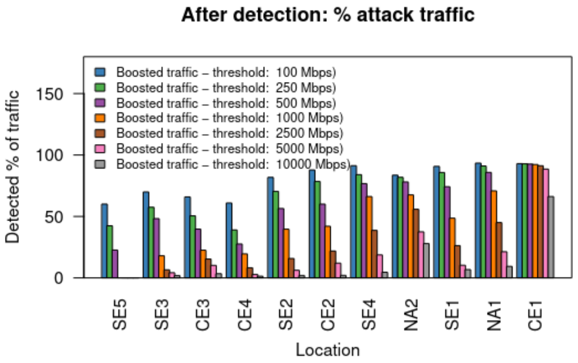

(a) Local detection only



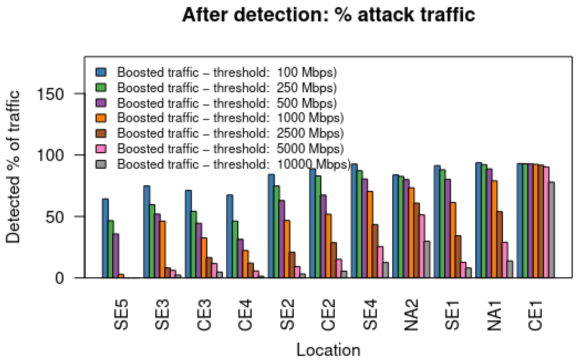

(b) Low trust DXP mode: Boosting factor 2



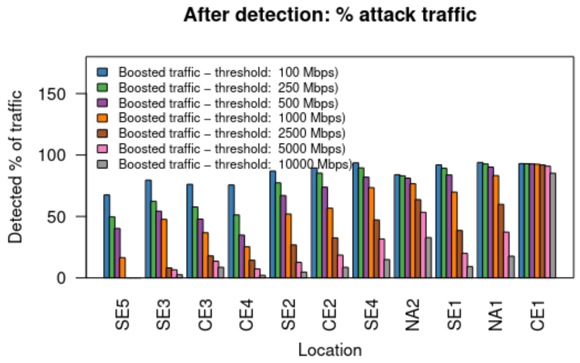

(c) Low trust DXP mode: Boosting factor 4




(d) Low trust DXP mode: Boosting factor 6




(e) Low trust DXP mode: Boosting factor 8




(f) Low trust DXP mode: Boosting factor 10

**Figure 23: Sensitivity of the share of the attack traffic detected in the low trust DXP setting for different boosting factors.**