Measuring foreign ASes and off-nets in Greece

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What is an off-net?

- Content providers ("Hypergiants"):
    - delivering the vast majority of Internet traffic
    - deploy servers (off-nets) inside end-user networks to:
        - reduce response time
        - improve the experience of end users
- We refer to these servers as off-nets because they are outside (off) the HG's own network

Methodology

1. Identify Greek ASes and Foreign ASes present in Greece
2. Correlate with off-net data from "*Seven Years in the Life of Hypergiants'] Off-Nets.*"[1] :
   a. Studies 30 largest hypergiants globally
   b. Covers 2013 - 2021
   c. Received Best Paper Award
3. Analyze the evolution of ASes and off-nets in Greece

[1] Petros Gigis, Matt Calder, Lefteris Manassakis, George Nomikos, Vasileios Kotronis, Xenofontas Dimitropoulos, Ethan Katz-Bassett, and Georgios Smaragdakis. 2021. Seven years in the life of Hypergiants' off-nets. In Proceedings of the 2021 ACM SIGCOMM 2021 Conference (SIGCOMM '21). Association for Computing Machinery, New York, NY, USA, 516–533. https://doi.org/10.1145/3452296.3472928

Dataset

- The ACM SIGCOMM 2021 Conference paper:
  - each HG lists the ASes that host its off-net
- CAIDA AS to Organization Mapping Dataset:
  - for each AS the ASN, the country registry and the organization name
- CAIDA Internet eXchange Points (IXPs) Dataset:
  - information about IXPs and their geographic locations, facilities, prefixes, and member ASes
  - derived by combining (union) information from PeeringDB, Hurricane Electric, PCH, and GeoNames
- The above datasets cover 3-month slots within 2013-2021 period

4

Detecting Greek ASes

- "Greek" ASes characterization based on AS to Organization Mapping Dataset
  - Exploits WHOIS databases from RIRs (ARIN, LACNIC, RIPE NCC, AFRINIC, and APNIC) and NIRs (KRNIC and JPNIC)
  - CAIDA infers the country from:
    - WHOIS that provides this field as an individual field
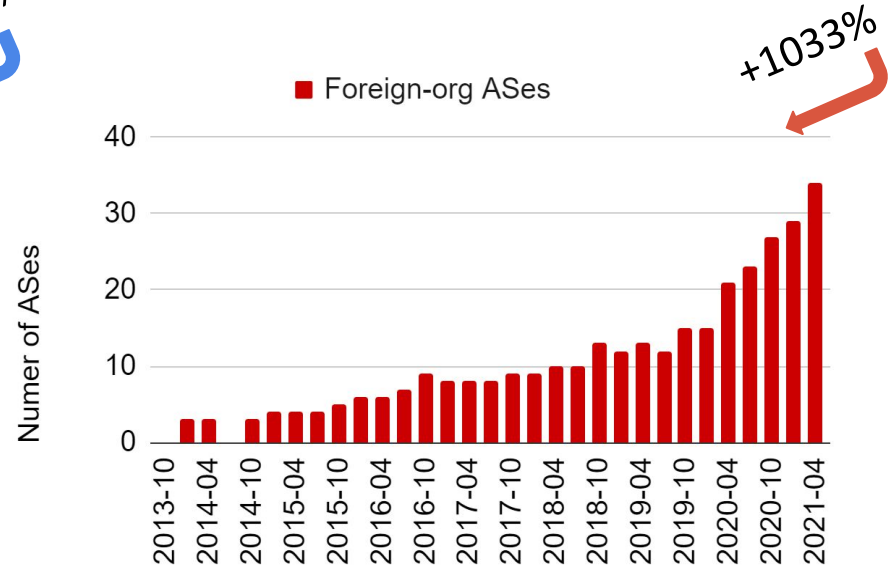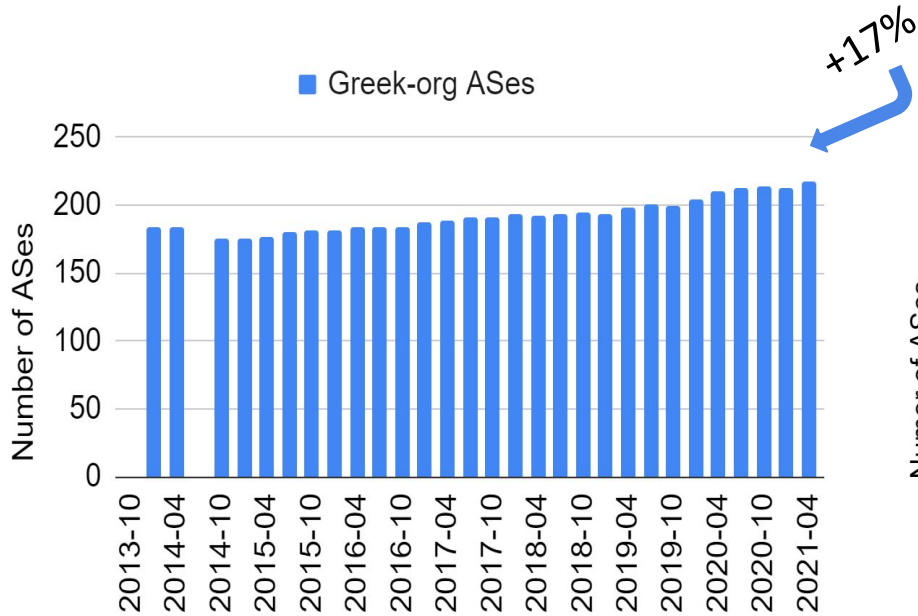   - the location addresses reported by administrators

```
{
"asn": "6799",
"changed": "20000101",
"asn_name": "OTENET-GR",
"org_id":"ORG-OSTO1-RIPE",
"source": "RIPE",
"org_name": "Ote SA",
"country": "GR"
}
```

Detecting Foreign ASes

- ASes in Greek IXPs and colocation facilities
- "Foreign" ASes with Organization's headquarters in other country
  - Exploits WHOIS databases from RIRs (ARIN, LACNIC, RIPE NCC, AFRINIC, and APNIC) and NIRs (KRNIC and JPNIC)
- CAIDA infers the country from:
  - WHOIS that provides this field as an individual field
  - the location addresses reported by administrators
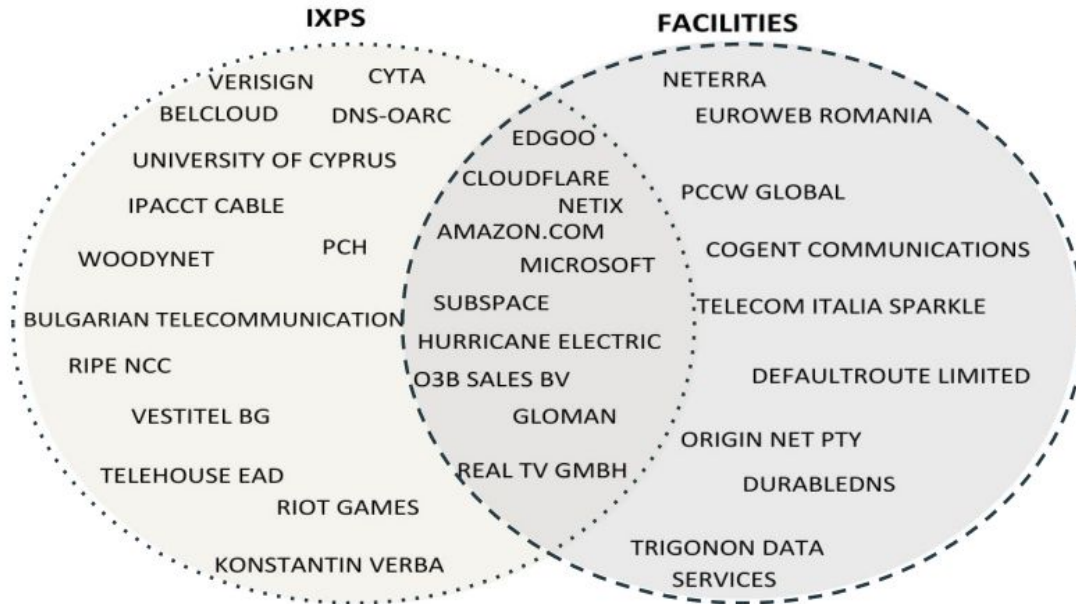
```
{
    "asn": 6939,
    "changed": "20031104",
    "asn_name": "HURRICANE",
    "org_id": "HURC-ARIN",
    "source": "ARIN",
    "org_name": "Hurricane
Electric LLC",
    "country": "US"
}
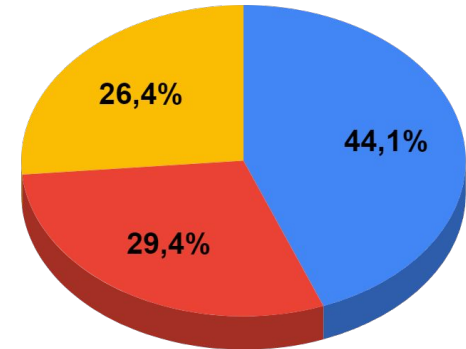```

# Greek and Foreign ASes over time
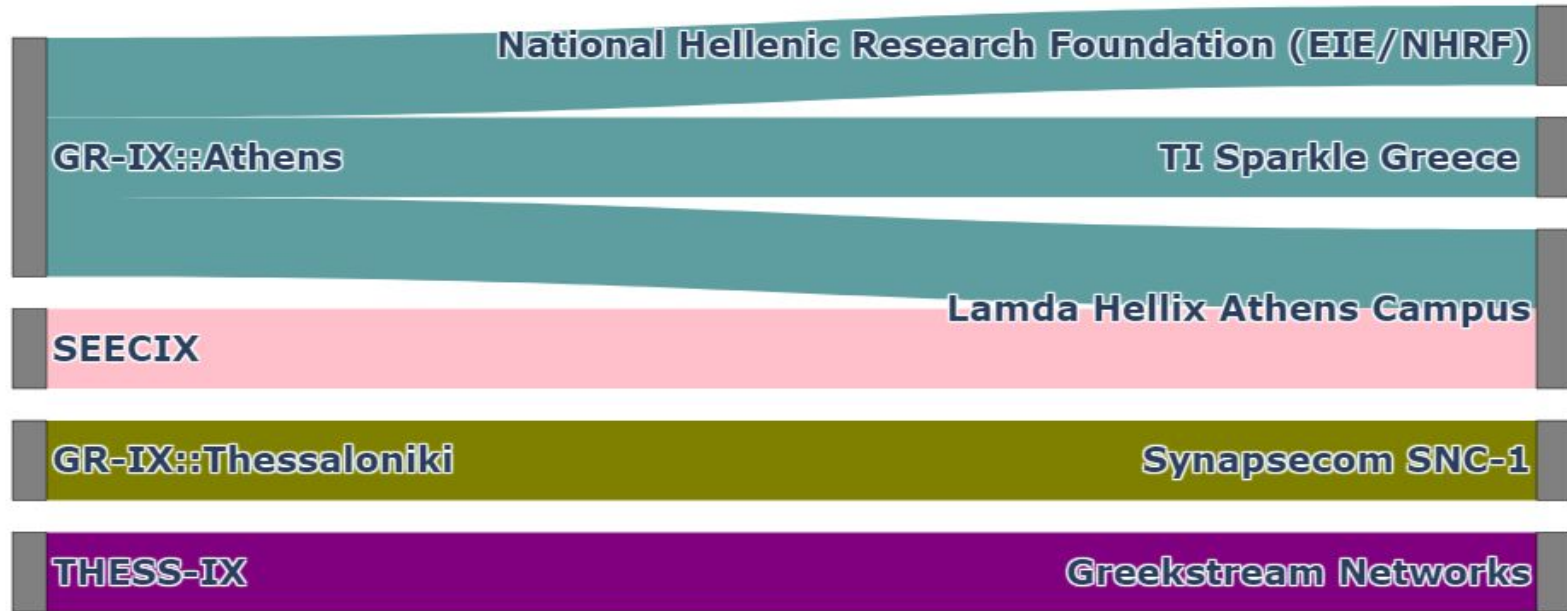
# Foreign ASes in Greek IXPs or Facilities

- Time period: April 2021



**IXPS**

VERISIGN  
CYTA  
BELCLOUD  
DNS-OARC  
UNIVERSITY OF CYPRUS  
IPACCT CABLE  
WOODYNET  
PCH  
BULGARIAN TELECOMMUNICATION  
RIPE NCC  
VESTITEL BG  
TELEHOUSE EAD  
RIOT GAMES  
KONSTANTIN VERBA

EDGOO  
CLOUDFLARE  
NETIX  
AMAZON.COM  
MICROSOFT  
SUBSPACE  
HURRICANE ELECTRIC  
O3B SALES BV  
GLOMAN  
REAL TV GMBH

**FACILITIES**

NETERRA  
EUROWEB ROMANIA  
PCCW GLOBAL  
COGENT COMMUNICATIONS  
TELECOM ITALIA SPARKLE  
DEFAULTROUTE LIMITED  
ORIGIN NET PTY  
DURABLEDNS  
TRIGONON DATA SERVICES

IXPs ● Facilities and IXPs ● Facilities

44,1%  
29,4%  
26,4%

8

# Present Greek IXPs in Greek Facilities



National Hellenic Research Foundation (EIE/NHRF)

GR-IX::Athens

TI Sparkle Greece

Lamda Hellix Athens Campus

SEECIX

GR-IX::Thessaloniki

Synapsecom SNC-1

THESS-IX

Greekstream Networks
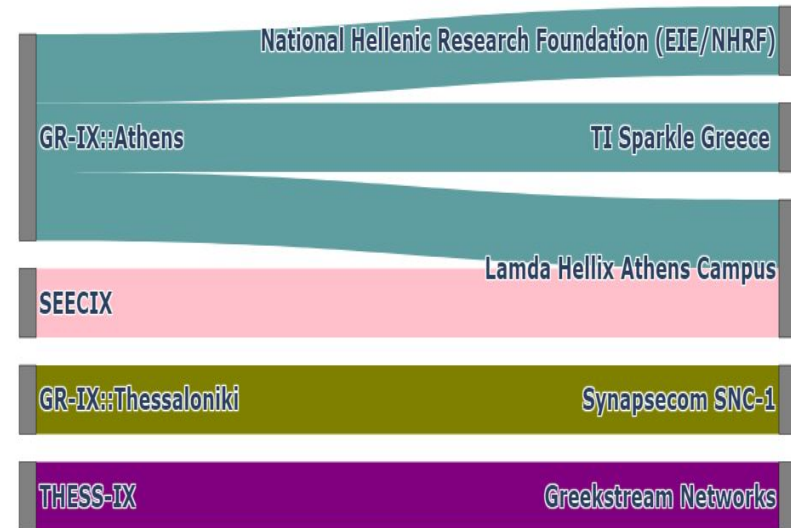
# Difficulty in characterizing "Foreign ASes"(1/2)

- IXPs Dataset
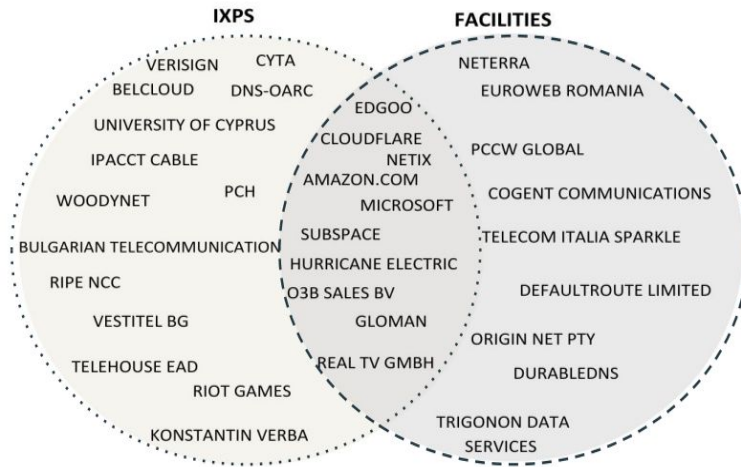
- IXP to facility mapping

# Difficulty in characterizing "Foreign ASes"(2/2)

- ASes may have different routing policies within an IXP compared to when they are present in a colocation facility
- Some ASes might only peer within the IXP and not establish direct connections within the colocation facility
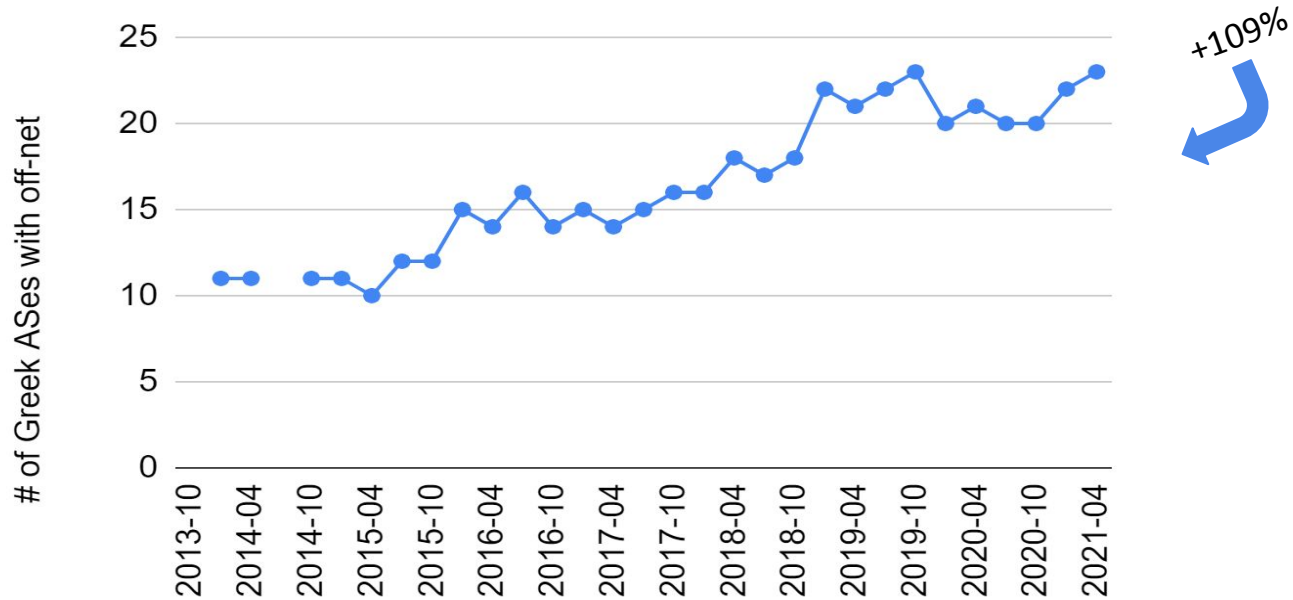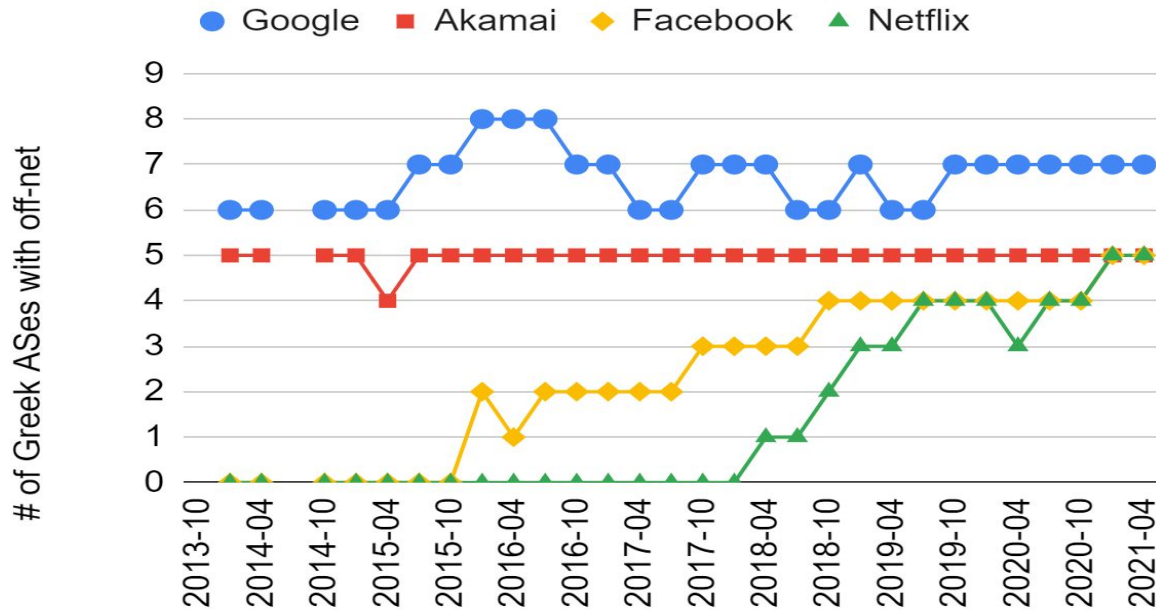
# Hypergiants with offnets in Greece
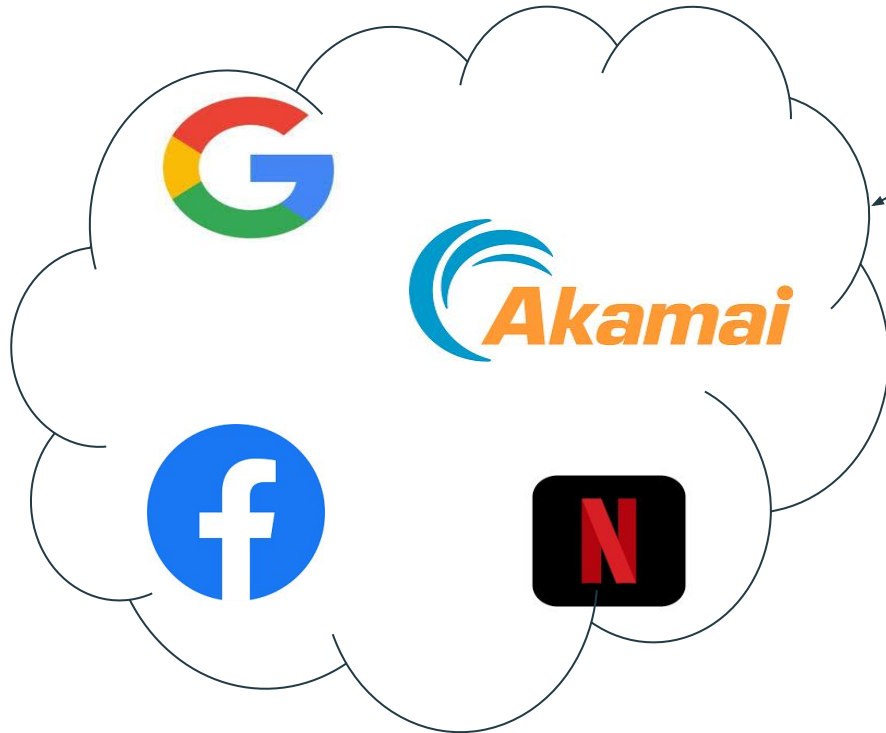
Responsible for 95% of off-nets in Greece

# Number of Greek ASes with an off-net over time



+109%

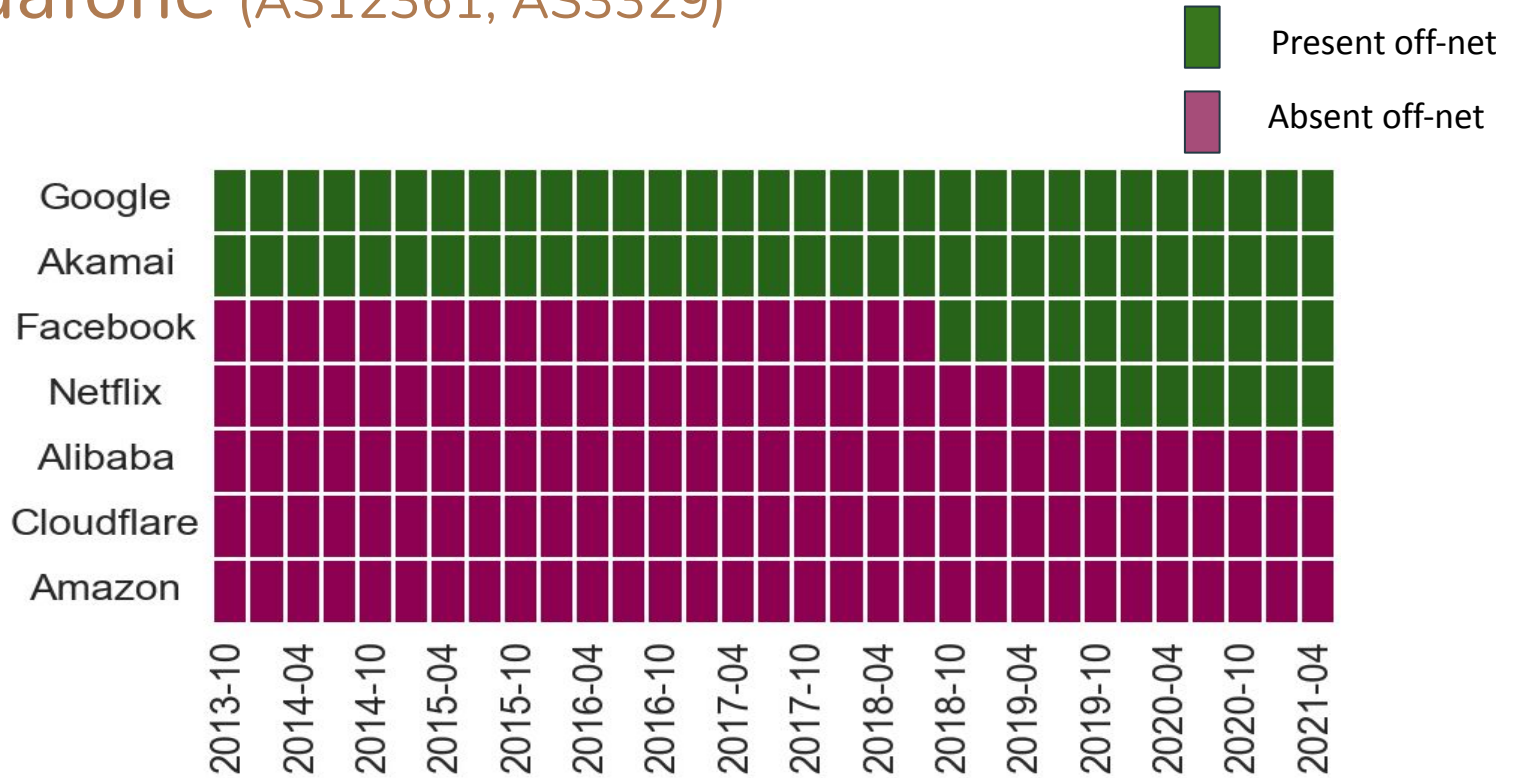# Number of Top-4 HG Off-nets' in Greek ASes over time

# Large Greek ISPs with Off-nets

| | | |
|---|---|---|
| **OTE** | Founded in 1949 | • offering fixed-line, mobile, and internet services |
| **Vodafone** | Founded in 1949 | • communications, introducing cutting-edge technologies and services, and contributing to the country's digital connectivity |
| **Wind** | Established in 1992 | • mobile, fixed-line, and internet service |
| **Forthnet** | Founded in 1995 | • Greece's broadband and pay-TV markets<br>• In 2020, Vodafone acquired Forthnet |
| **GRNET** | Founded in 1995 | • a non-profit organization<br>• providing high-speed network services<br>• advancing Greece's research infrastructure, supporting collaboration, and facilitating access to global research networks. |

# OTE (AS6799, AS12713, AS20962)
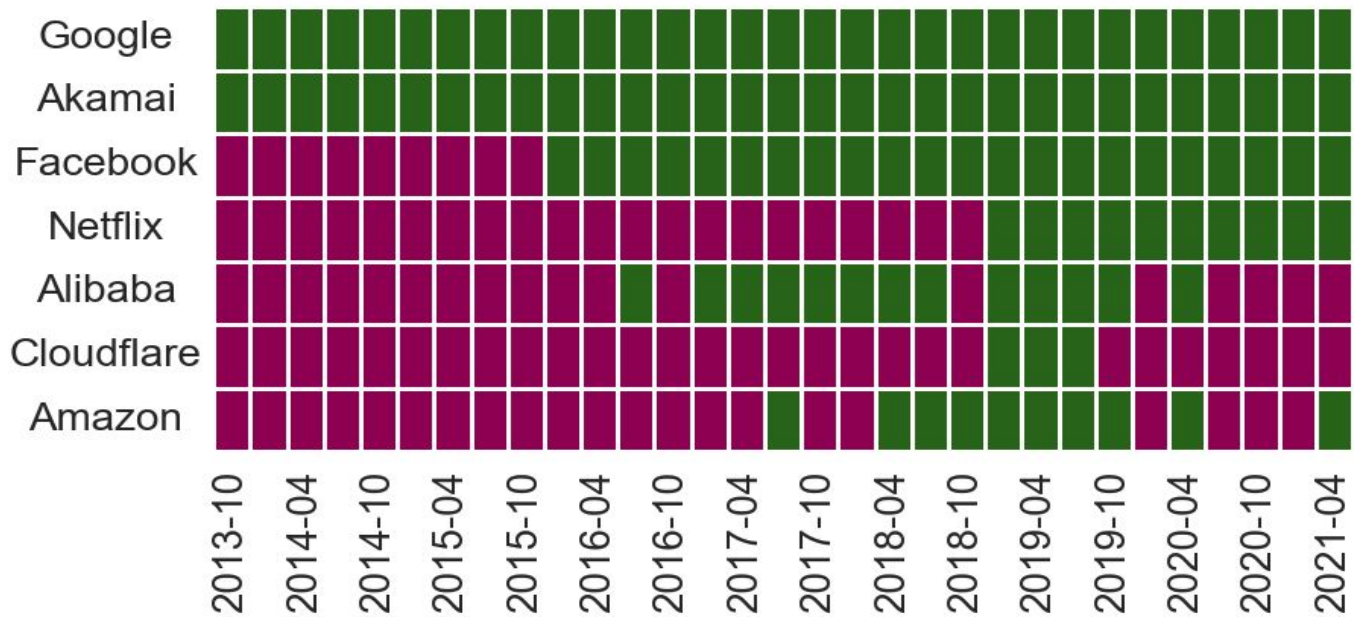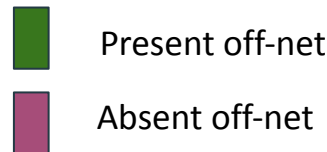
# Vodafone (AS12361, AS3329)

# WIND (AS15617, AS25472, AS24897)

# Forthnet (AS1241, AS8951)



Present off-net

Absent off-net
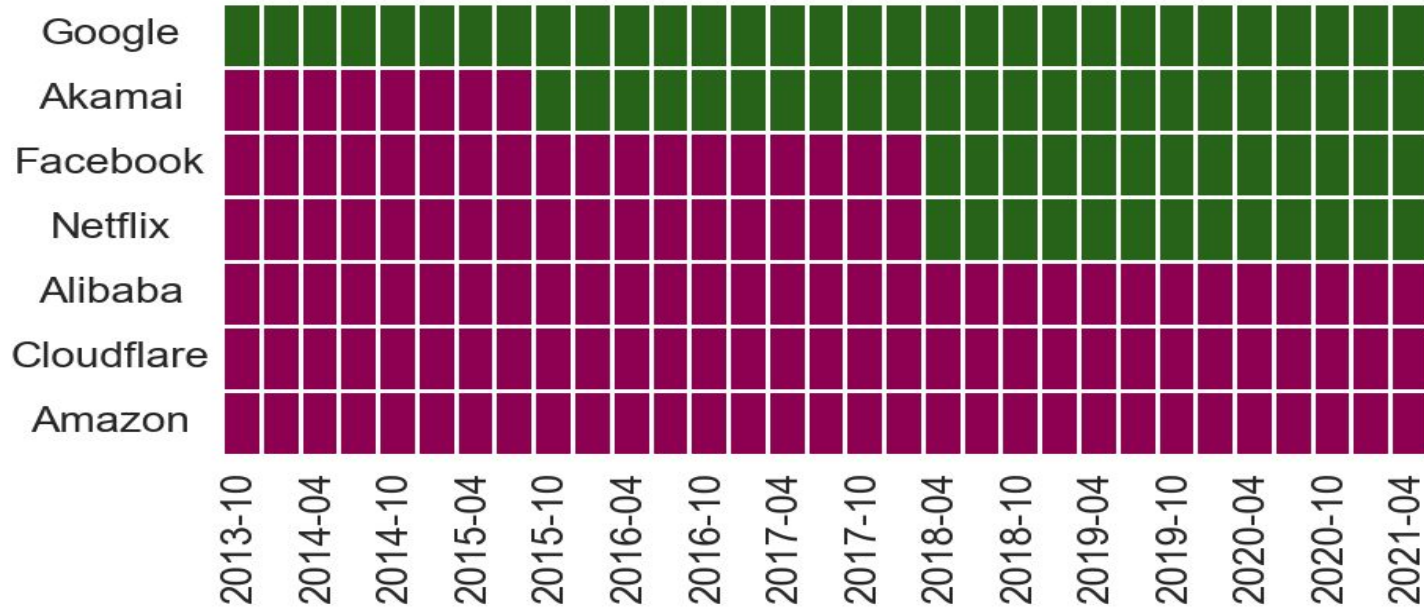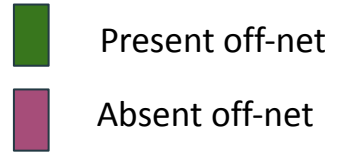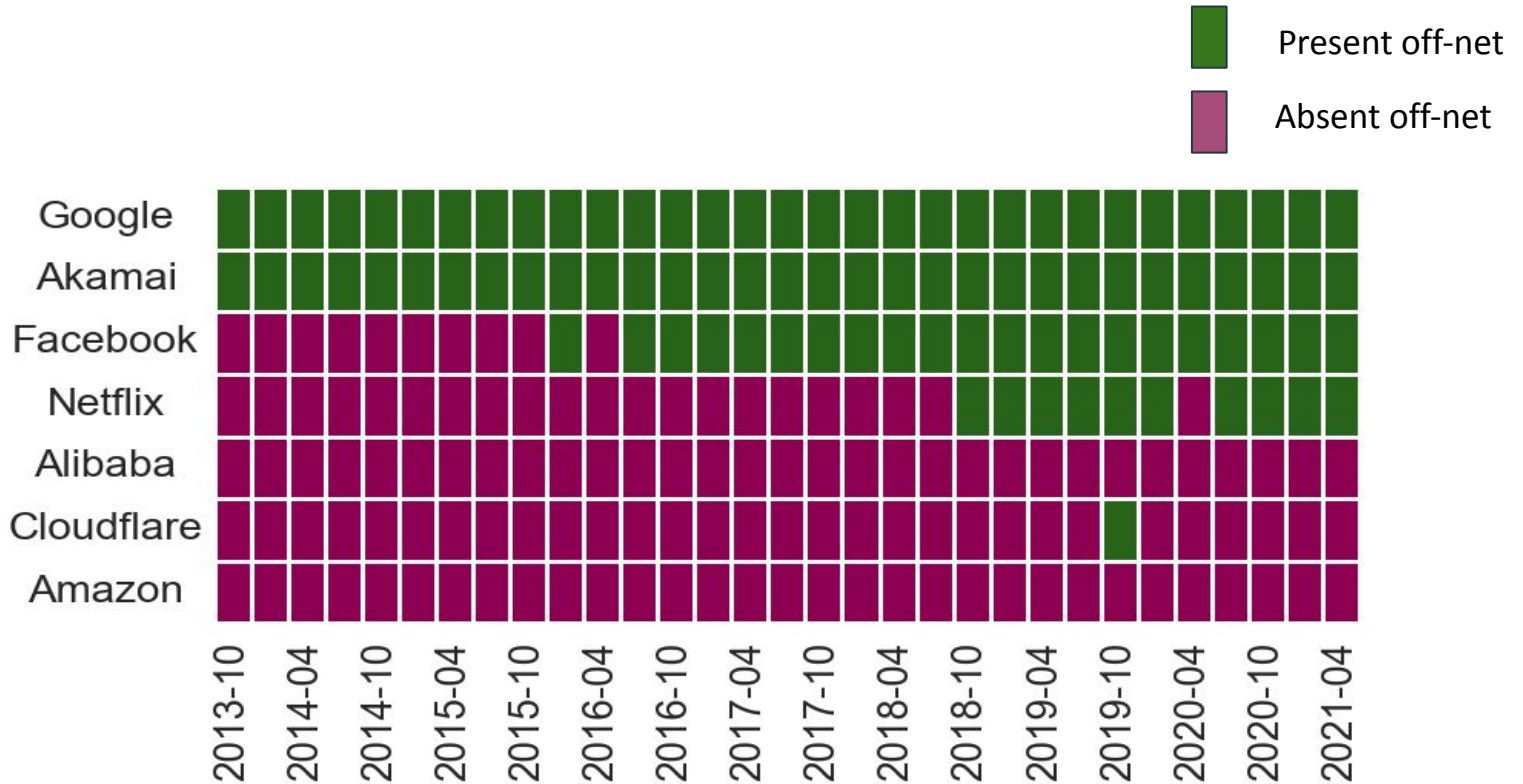
# GRNET (AS5408)
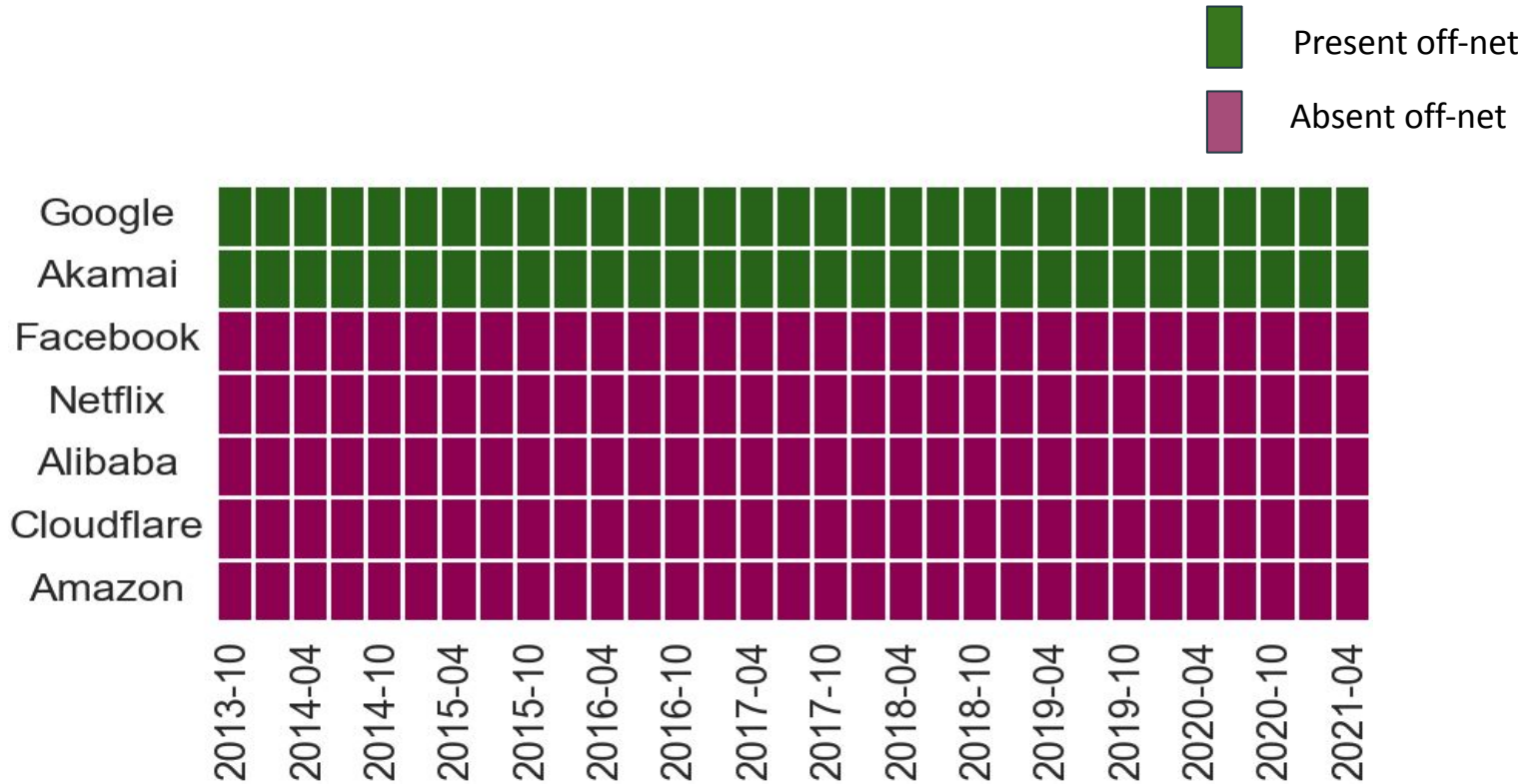
# Conclusions

- The number of the foreign ASes in Greece increased much faster than that of the Greek ones
- The top-4 HGs are responsible for 95% of the off-nets in Greek ASes
  - Google and Akamai had the most off-nets in Greek ASes
  - Facebook and Netflix entered the Greek Internet around 2018
- They did not host all the ASes of the organizations we are considering for HGs

# Future Work

- Extend the work timescale until 2023
- Investigate the partial presence of the HGs in Greek ISPs
- Cross validation of the CAIDA datasets with other databases

# Thank you!

# Methodology of the paper

1. Learn HG's TLS fingerprints by scanning its on-nets
2. Search for the TLS fingerprint in scans of off-net IP addresses to identify candidates
   - ○ Indicates ownership of the service rather than the underlying hardware
3. Learn the HG's HTTP(S) header fingerprint by scanning on-nets
4. Confirm the off-net candidates by scanning them for the HTTP(S) header fingerprints