Detecting Peering Infrastructure Outages in the Wild

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Peering Infrastructures are critical part of the interconnection ecosystem

Internet Exchange Points (IXPs) provide a shared switching fabric for layer-2 bilateral and multilateral peering.

- Largest IXPs support > 100 K of peerings, > 5 Tbps peak traffic
- Typical SLA 99.99% (~52 min. downtime/year)[1]

Carrier-neutral **co-location facilities** (CFs) provide infrastructure for physical co-location and cross-connect interconnections.

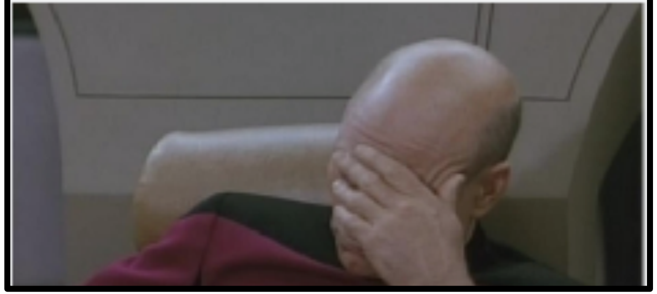
- Largest facilities support > 170 K of interconnections
- Typical SLA 99.999% (~5 min. downtime/year)[2]

[1] https://ams-ix.net/services-pricing/service-level-agreement [2] http://www.telehouse.net/london-colocation/

Outages in peering infrastructures can severely disrupt critical services and applications

BT, other ISPs hit by second major Internet outage—power failure blamed

After Telecity power outage, it seems Telehouse has had problems of its own.



BT broadband users hit by second UK-wide outage in two days

Power supply issues at Docklands datac… behind loss of internet access for more … broadband users

Equinix cooling outage leads to flight delays in Australia

Equinix Outage Means Downtime for Zoho

A power outage Friday morning in an Equinix data center in California caused problems for a number of customers, most notably Zoho, which experienced hours of downtime for several of its web based office applications. Equinix acknowledged the incident, but did not provide details on the cause of the outage at its SV4 facility in Silicon Valley.

OUTAGE AT AMSTERDAM INTERNET HUB AFFECTS MUCH OF NETHERLANDS

With additional reporting by Zack Newmark.

The Register

Biting the hand that feeds IT

SECURITY TRANSFORMATION DEVOPS BUSINESS PERSONAL TECH

Telecity London data centre outage borks VoIP, websites, AWS...

LINX reports sudden sharp traffic drop, Amazon Direct Connect goes TITSUP

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Outage detection crucial to improve **situational awareness**, **risk assessment** and **transparency**.

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OUTAGE AT AMSTERDAM INTERNET HUB AFFECTS MUCH OF NETHERLANDS

Telecity London data centre outage borks VoIP, websites, AWS...

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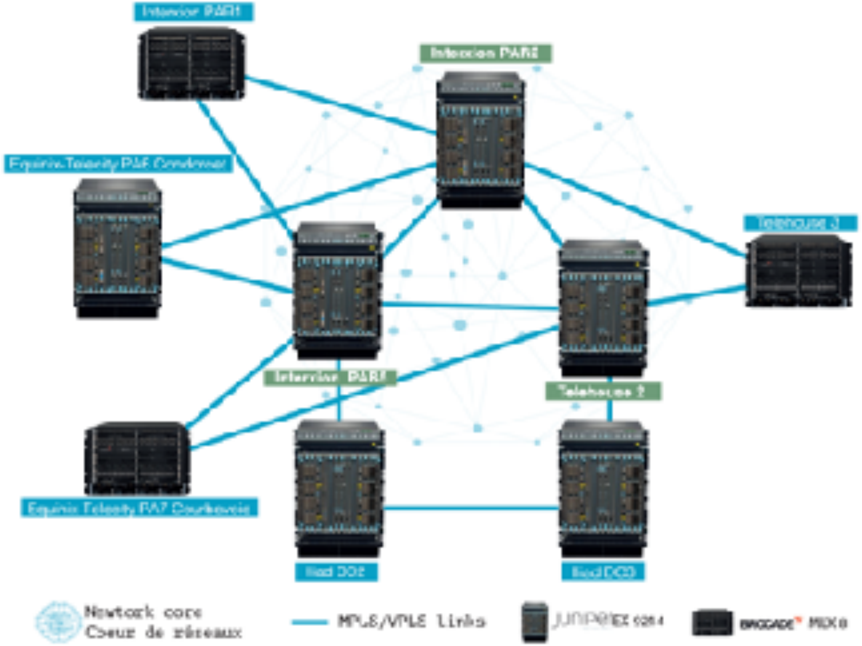
Current practice: “Is anyone else having issues?”

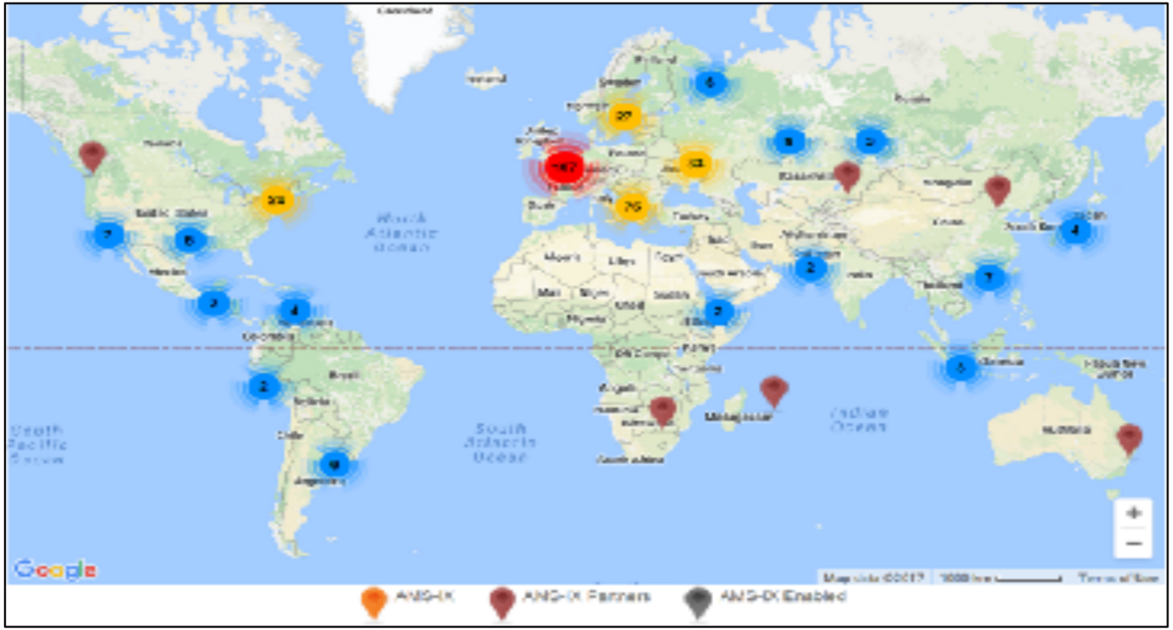
- ASes try to crowd-source the detection and localization of outages.
- Inadequate transparency/responsiveness from infrastructure operators.

Symbiotic and interdependent infrastructures



https://www.franceix.net/en/technical/infrastructure/

Remote peering extends the reach of IXPs and CFs beyond their local market



Global footprint of AMS-IX

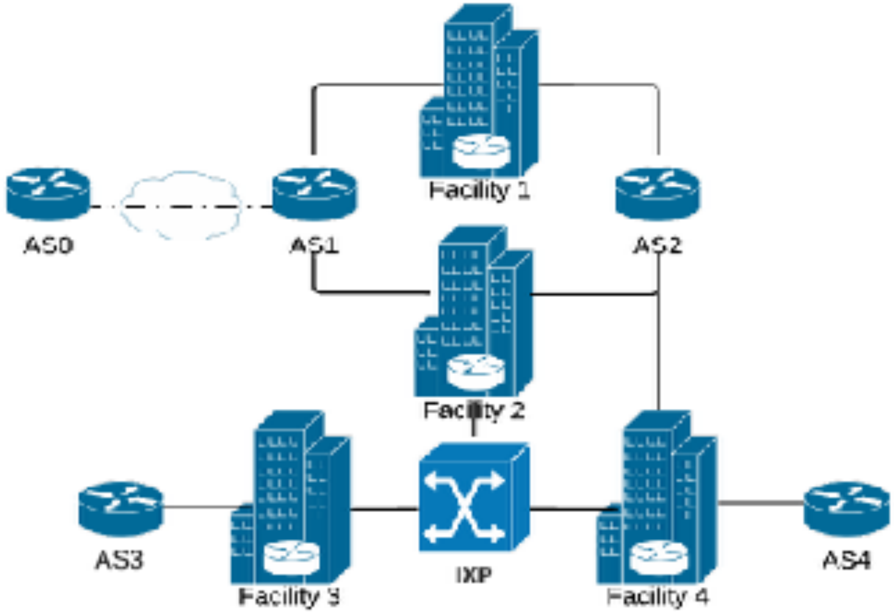
https://ams-ix.net/connect-to-ams-ix/peering-around-the-globe

Our Research Goals

1. Outage detection:
    - *Timely*, at the *finest granularity* possible
2. Outage localization:
    - Distinguish *cascading effects* from outage *source*
3. Outage tracking:
    - Determine duration, shifts in routing paths, geographic spread

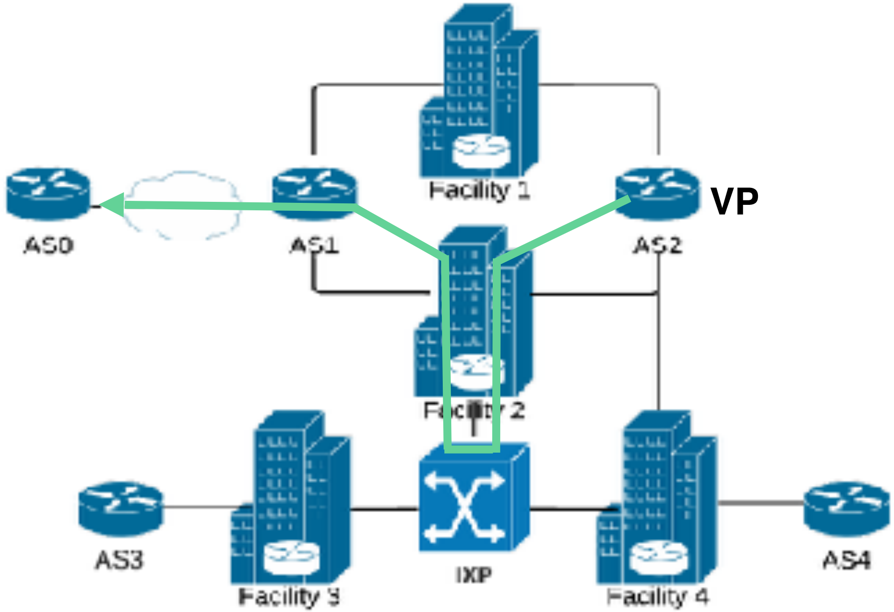
Challenges in detecting infrastructure outages

Actual incident



Challenges in detecting infrastructure outages

Actual incident

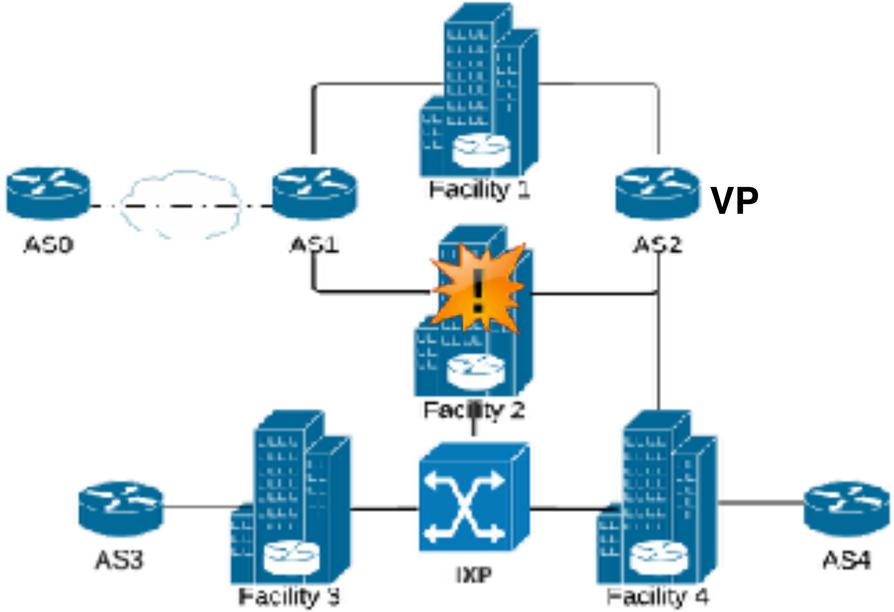


Observed paths

Before outage

Challenges in detecting infrastructure outages

Actual incident



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Challenges in detecting infrastructure outages

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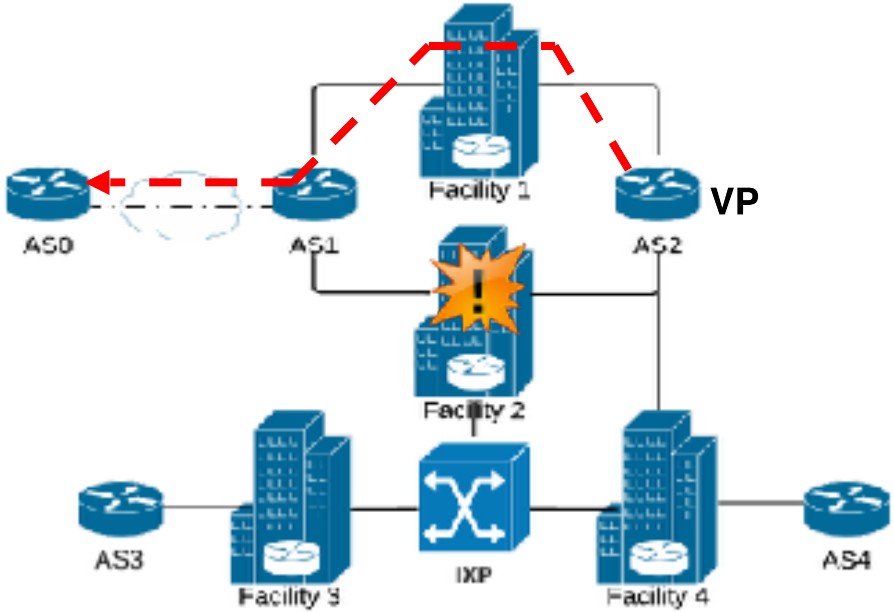

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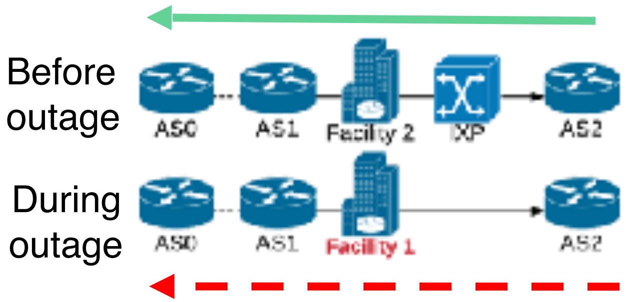
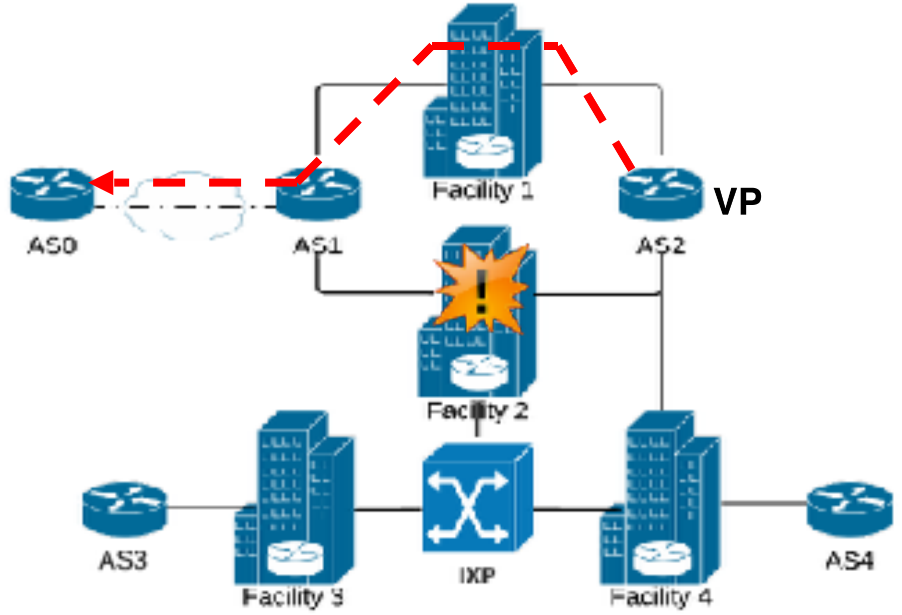


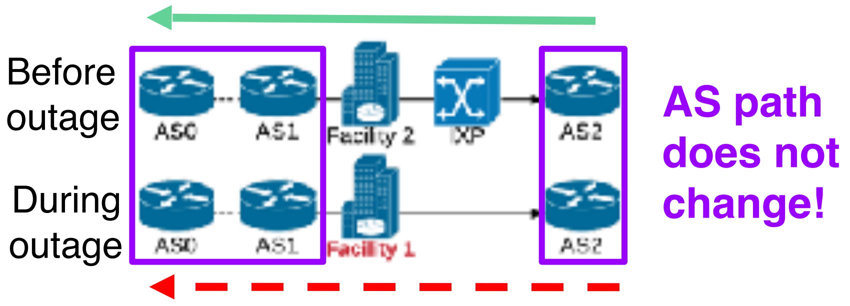
Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes

Actual incident



Observed paths



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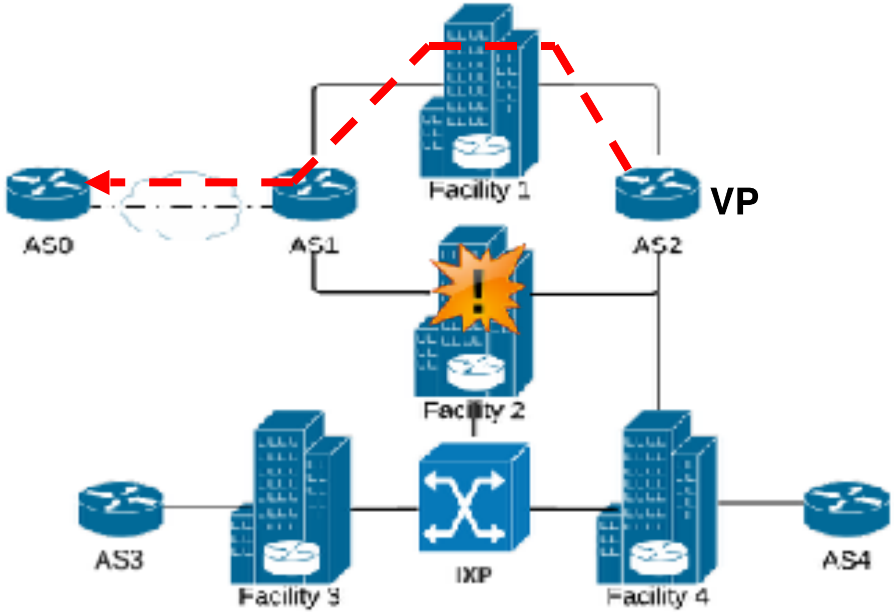
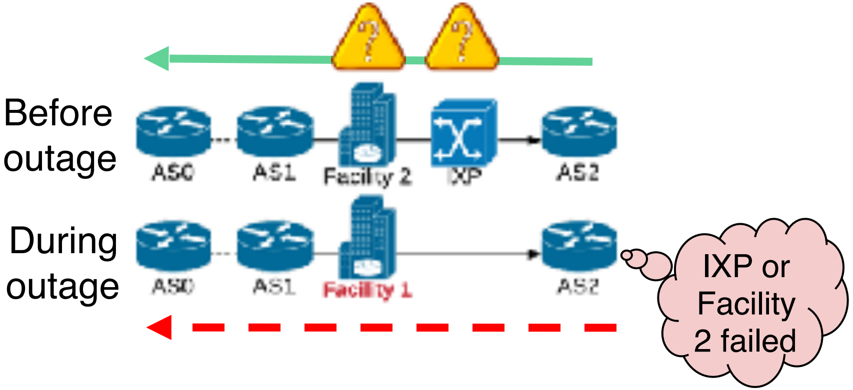


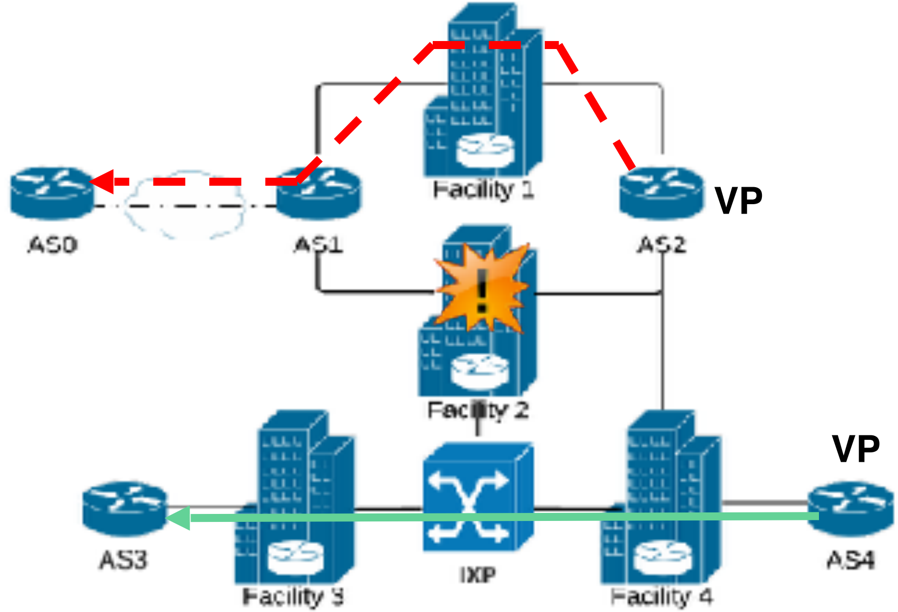
Observed paths



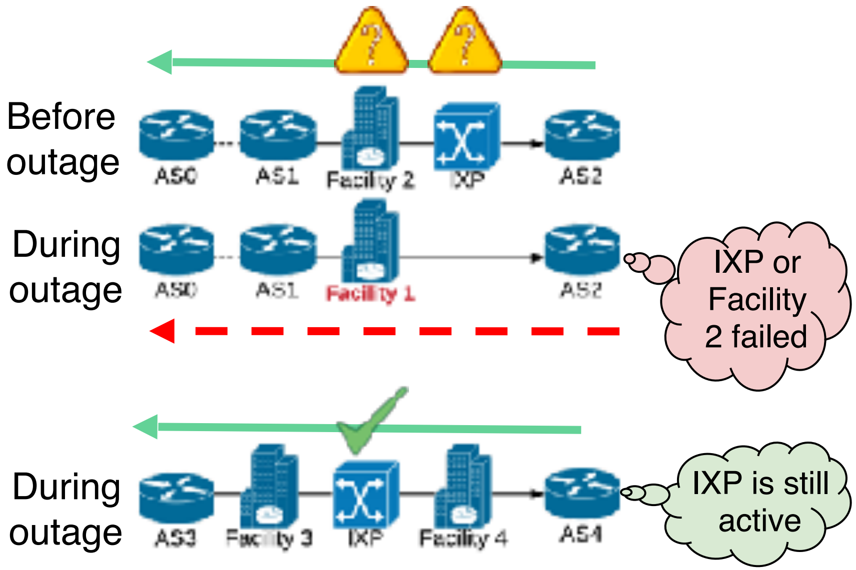
Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes
2. Correlating the paths from multiple vantage points

Actual incident



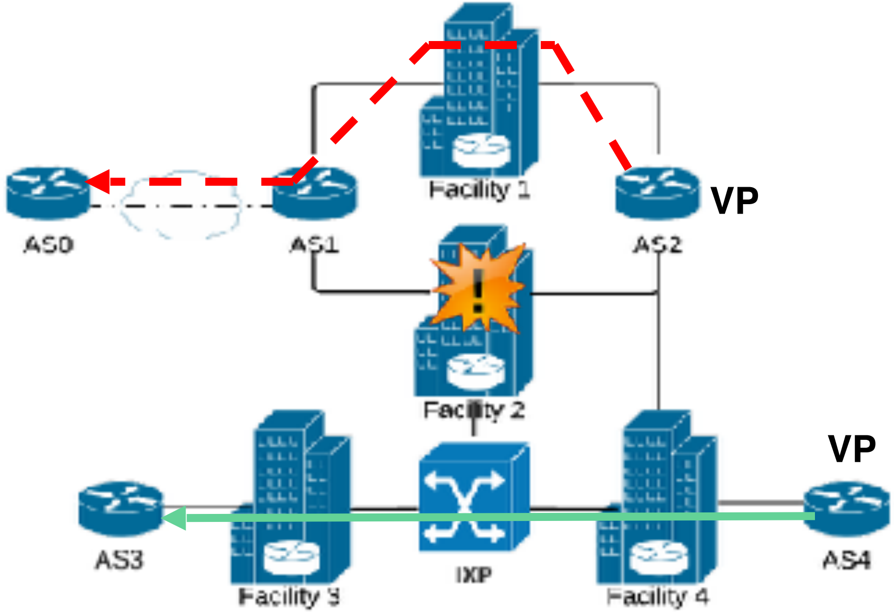
Observed paths



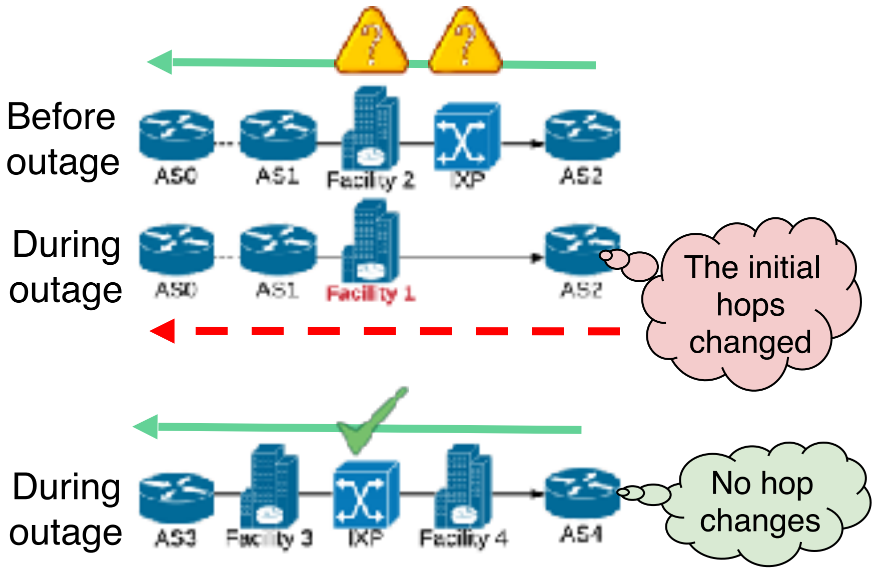
Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes
2. Correlating the paths from multiple vantage points
3. Continuous monitoring of the routing system

Actual incident



Observed paths



Challenges in detecting infrastructure outages

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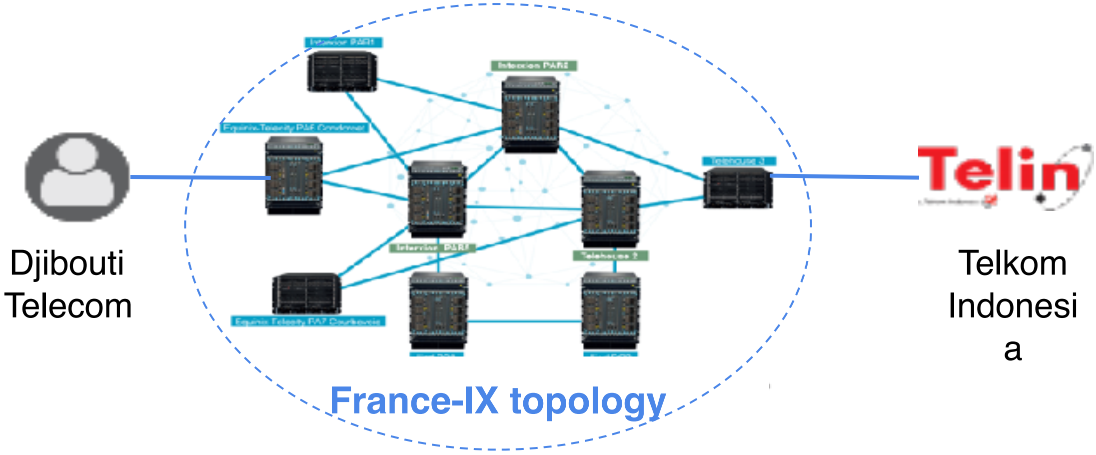
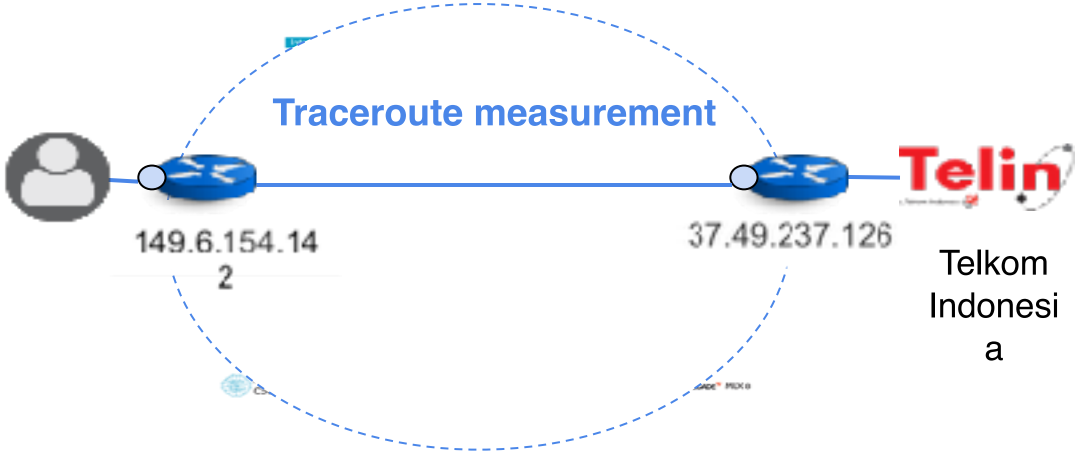


Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes — BGP
2. Correlating the paths from multiple vantage points — BGP
3. Continuous monitoring of the routing system — BGP

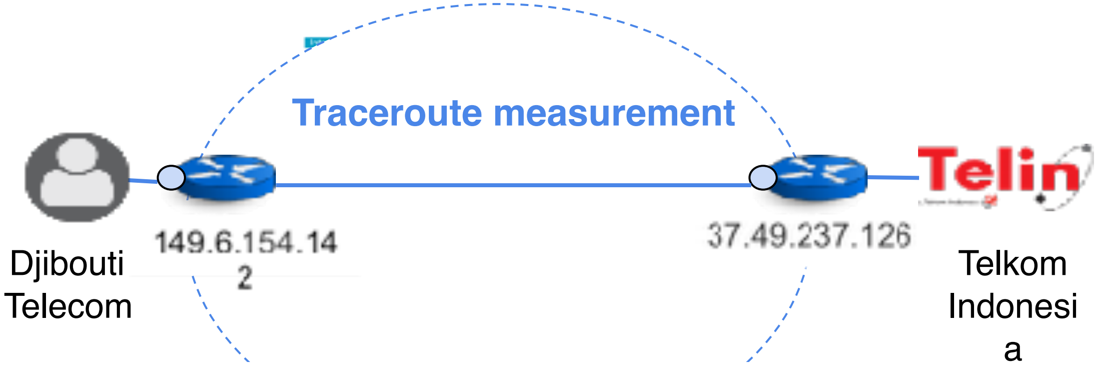
Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes ✗ **BGP**
2. Correlating the paths from multiple vantage points ✓ **BGP**
3. Continuous monitoring of the routing system ✓ **BGP**



Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes	✗ BGP	✓ Traceroute
2. Correlating the paths from multiple vantage points	✓ BGP	✗ Traceroute
3. Continuous monitoring of the routing system	✓ BGP	✗ Traceroute



IP-to-Facility[3,4] and IP-to-IXP[5] mapping **possible** but **expensive**!

[3] Giotsas, Vasileios, et al. "Mapping peering interconnections to a facility", CoNEXT 2015
[4] Motamedi, Reza, et al. "On the Geography of X-Connects", Technical Report CIS-TR-2014-02. University of Oregon, 2014
[5] Nomikos, George, et al. "traIXroute: Detecting IXPs in traceroute paths.". PAM 2016

Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes
2. Correlating the paths from multiple vantage points
3. Continuous monitoring of the routing system

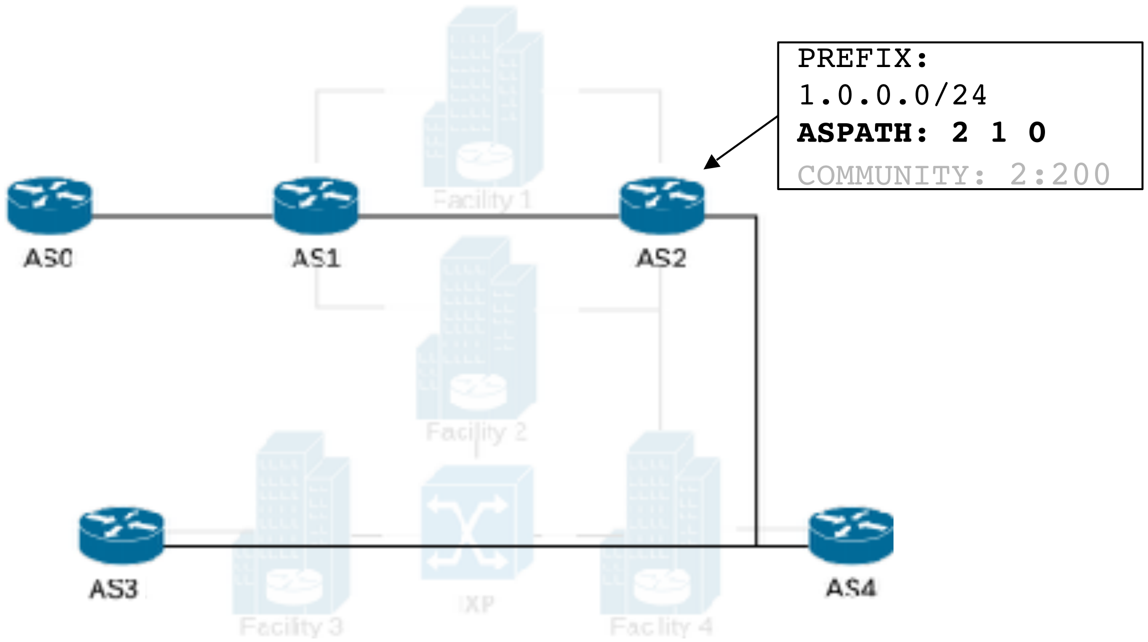
✗ BGP	✓ Traceroute
✓ BGP	✗ Traceroute
✓ BGP	✗ Traceroute

Can we combine **continuous passive** measurements with **fine-grained** topology discover?

Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes	✗ **BGP**	✓ **Traceroute**
2. Correlating the paths from multiple vantage points	✓ **BGP**	✗ **Traceroute**
3. Continuous monitoring of the routing system	✓ **BGP**	✗ **Traceroute**

Deciphering location metadata in BGP



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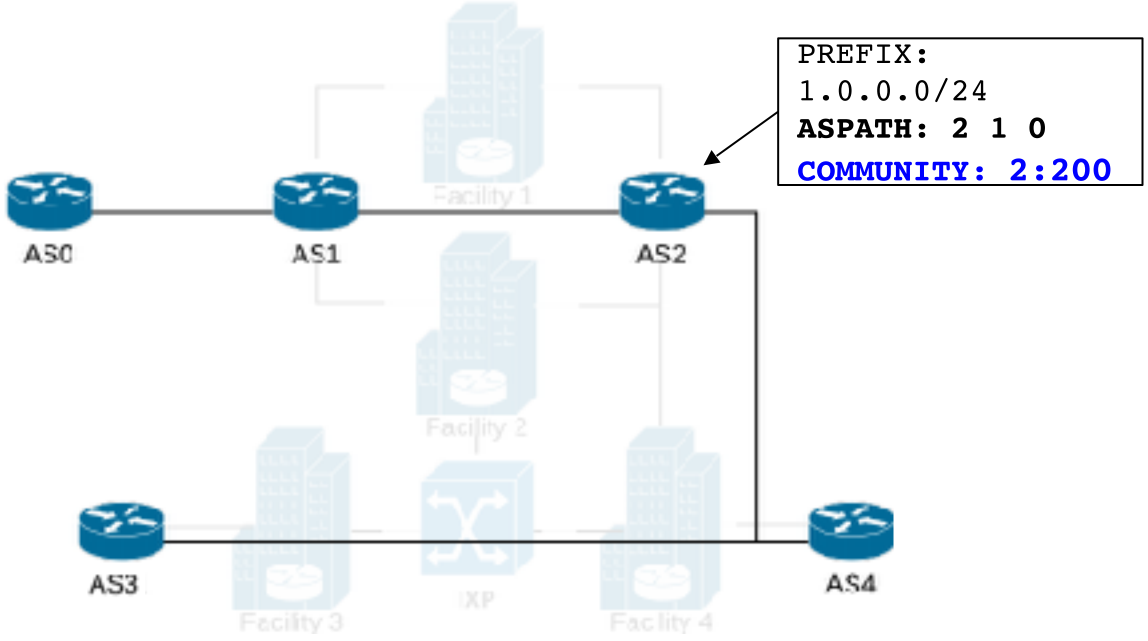
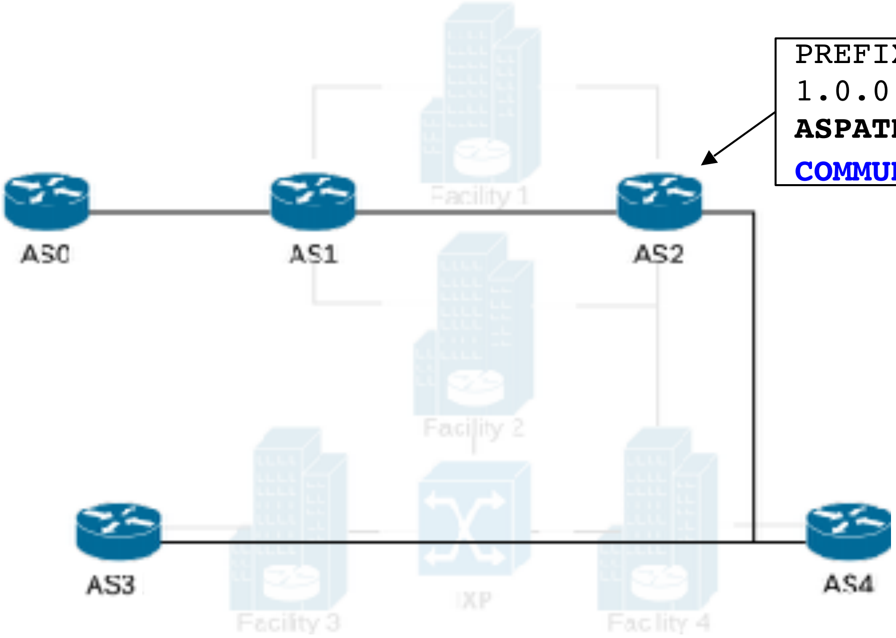


BGP Communities:

- Optional attribute
- 32-bit numerical values
- Encodes **arbitrary** metadata

Deciphering location metadata in BGP

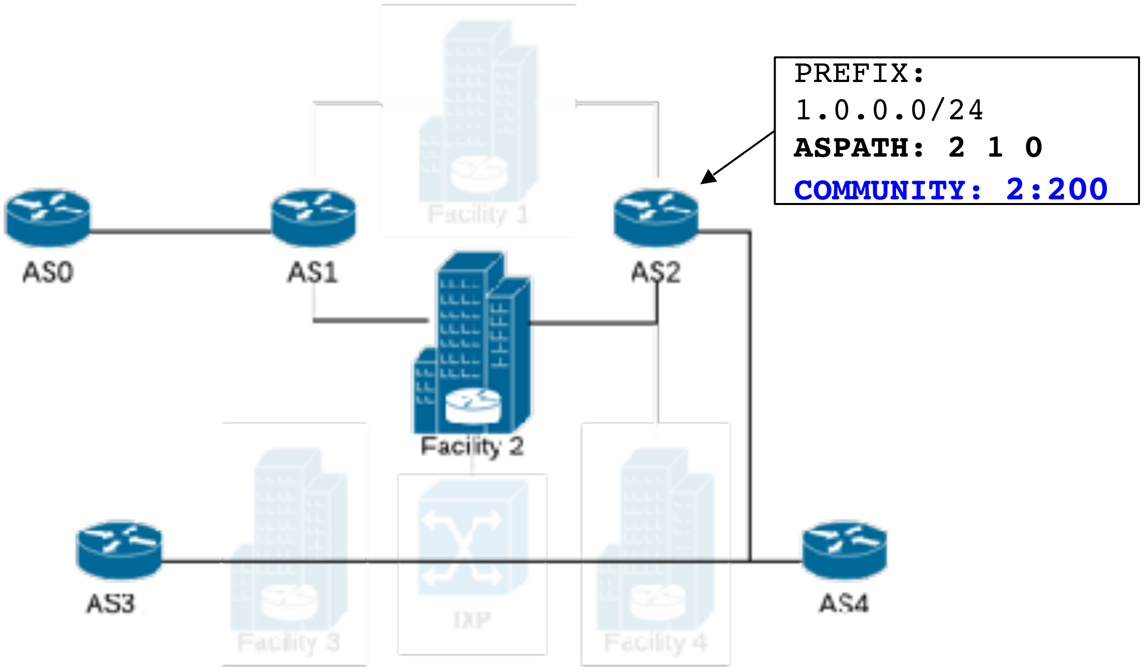



```
PREFIX:
1.0.0.0/24
ASPATH: 2 1 0
COMMUNITY: 2:200
```

Top 16 bits:
ASN that sets the community.

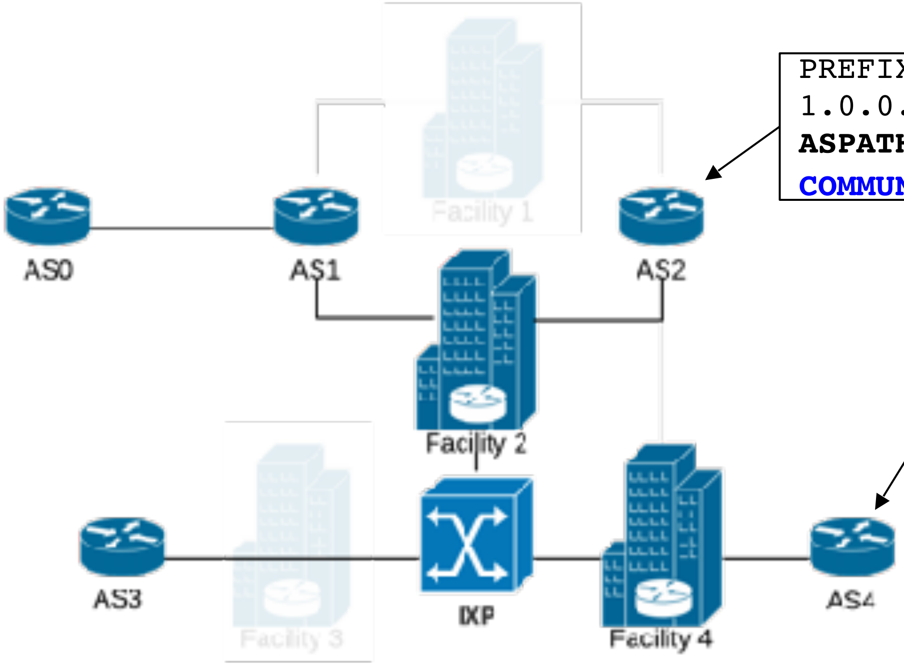
Bottom 16 bits: Numerical value that encodes the actual meaning.

Deciphering location metadata in BGP



The BGP Community 2:200 is used to tag routes received at Facility 2

Deciphering location metadata in BGP

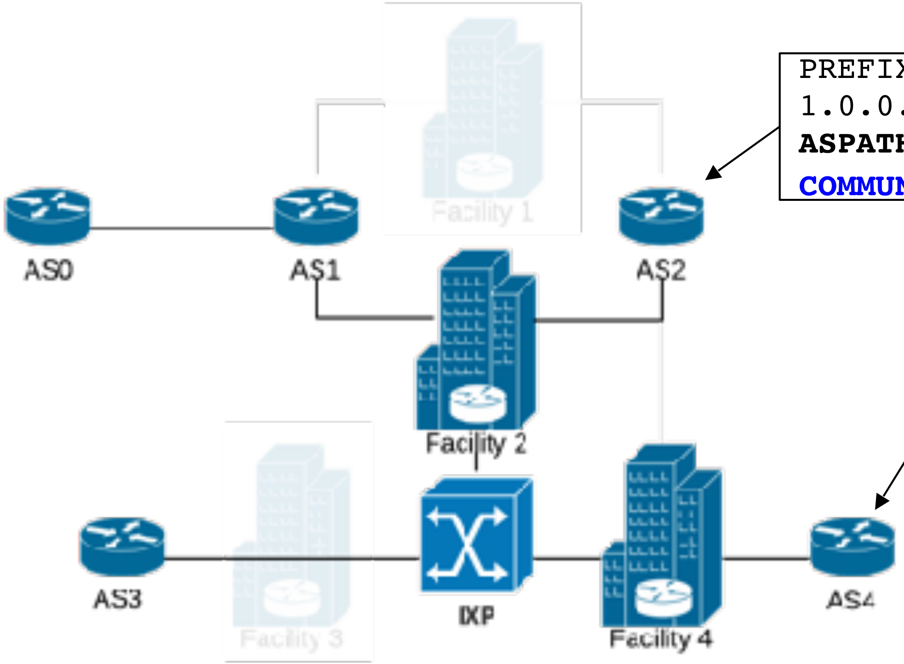


PREFIX:
1.0.0.0/24
ASPATH: 2 1 0
COMMUNITY: 2:200

PREFIX: 3.3.3.3/24
ASPATH: 4 3
COMMUNITY: 4:8714
4:400

PREFIX: 2.2.2.2/24
ASPATH: 4 2
COMMUNITY: 4:8714
4:400

Deciphering location metadata in BGP



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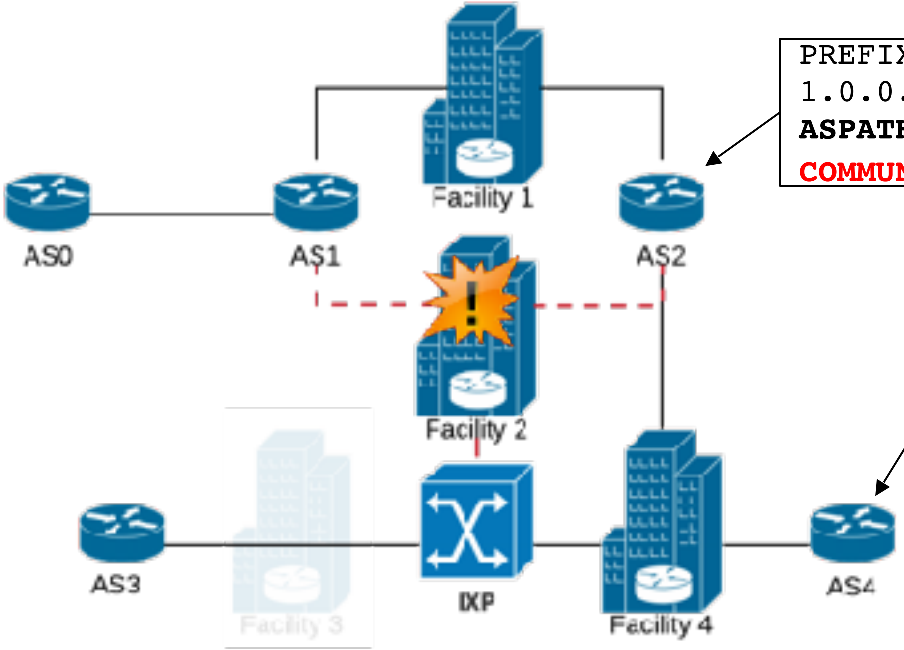
4:400

PREFIX: 2.2.2.2/24
ASPATH: 4 2
COMMUNITY: 4:8714
4:400

Multiple communities can tag different types of ingress points.

Deciphering location metadata in BGP



PREFIX: 1.0.0.0/24
ASPATH: 2 1 0
COMMUNITY: 2:100

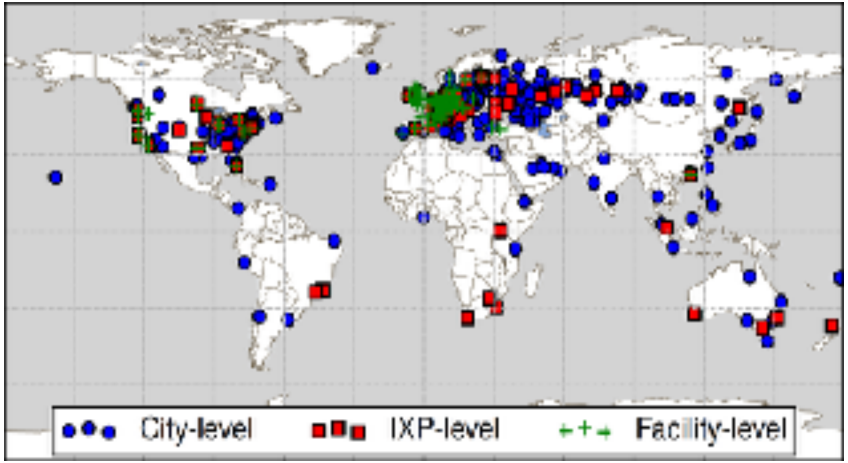
~~PREFIX: 3.3.3.3/24~~
ASPATH: 4 3
COMMUNITY: 4:400

PREFIX: 2.2.2.2/24
ASPATH: 4 2
COMMUNITY: 4:8714
~~**4:400**~~

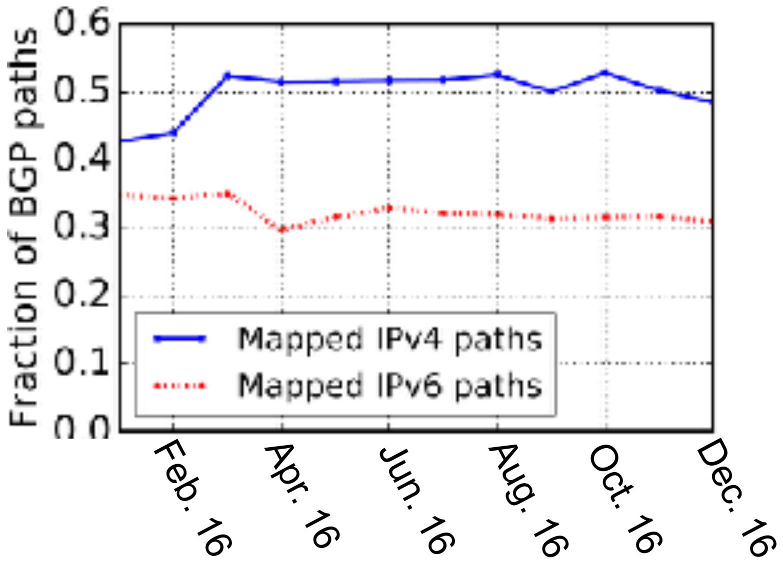
When a route changes ingress point, the community values will be update to reflect the change.

Interpreting BGP Communities

- Community values not standardized.
- Documentation in public data sources:
    - WHOIS, NOCs websites
- 3,049 communities by 468 ASes

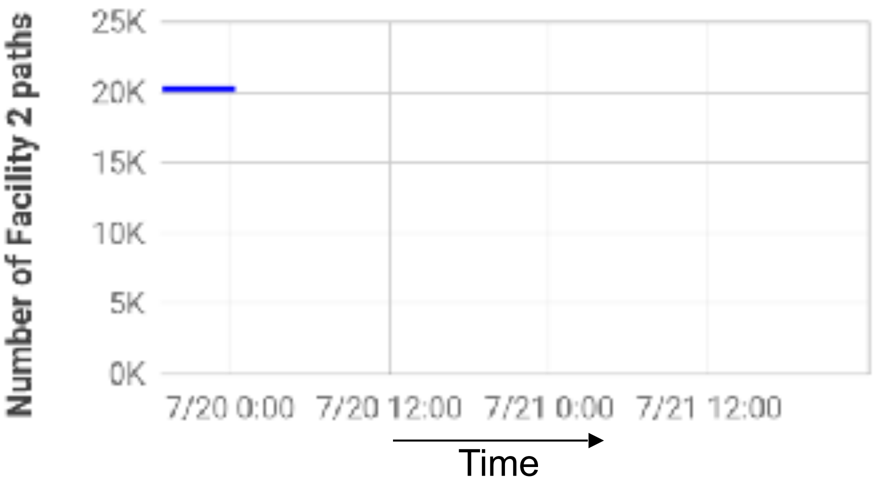


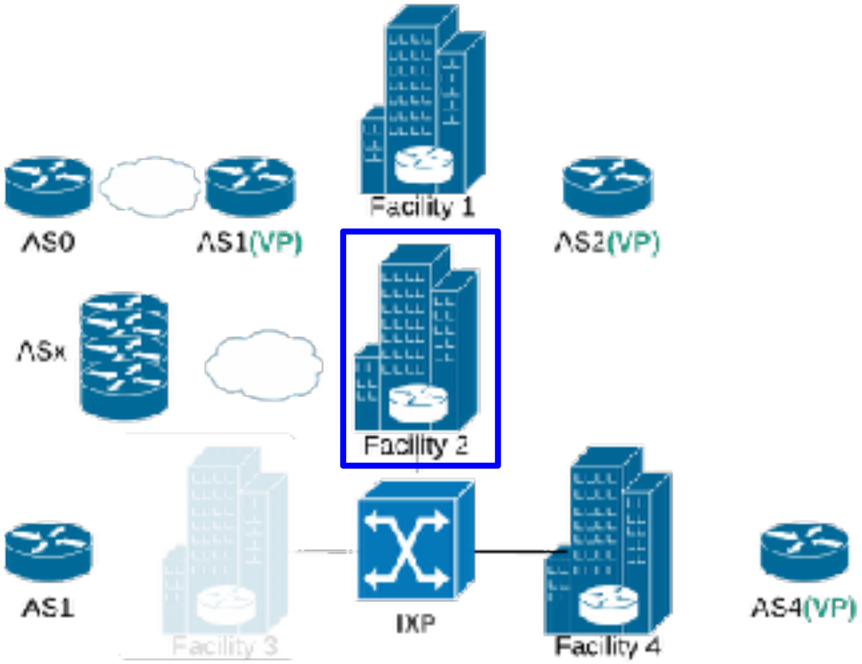
Topological coverage



- **~50%** of IPv4 and **~30%** of IPv6 paths annotated with at least one Community in our dictionary.
- **24%** of the facilities in PeeringDB, **98%** of the facilities with at least 20 members.

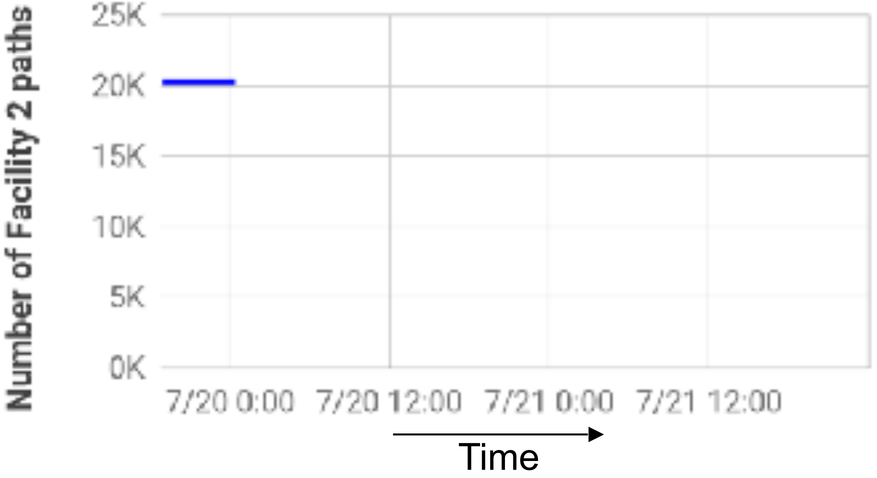
Passive outage detection: Initialization

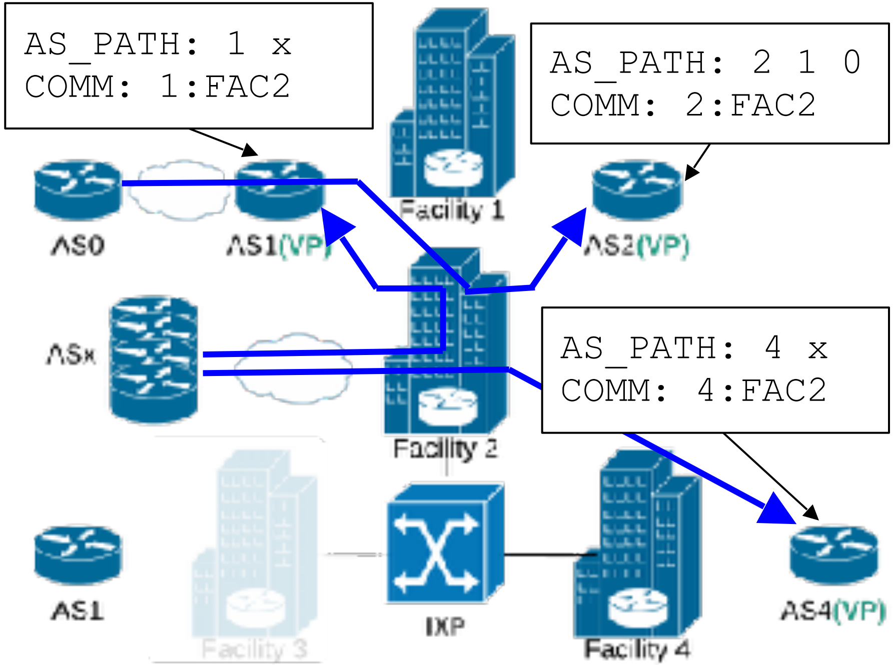




For each vantage point **(VP)** collect all the **stable** BGP routes tagged with the communities of the target facility (Facility 2)

Passive outage detection: Initialization





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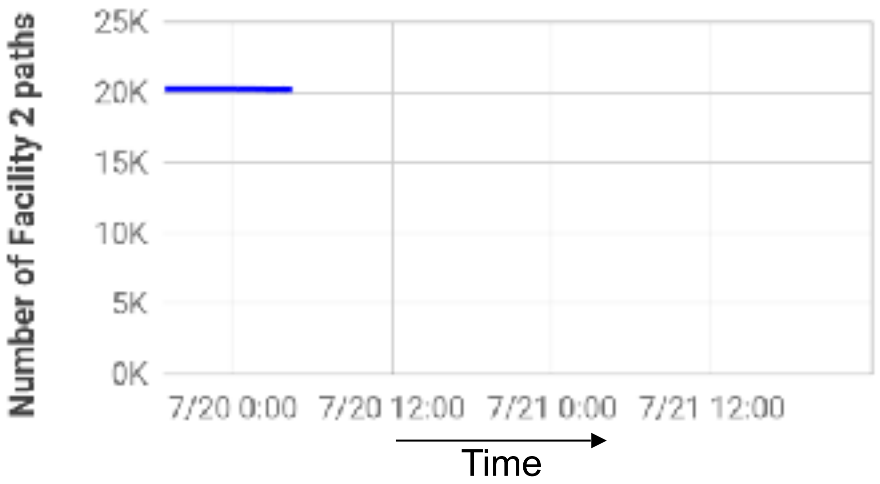
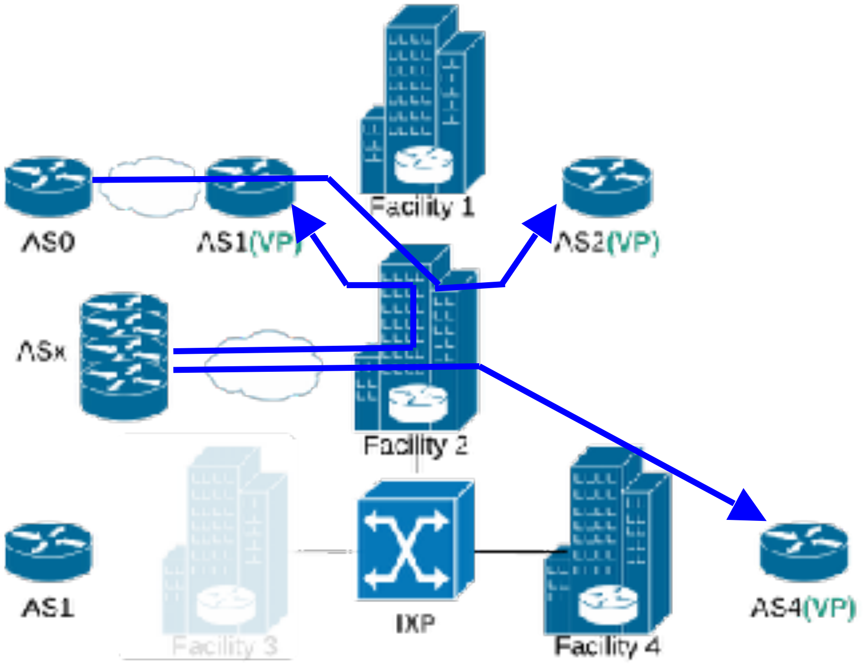
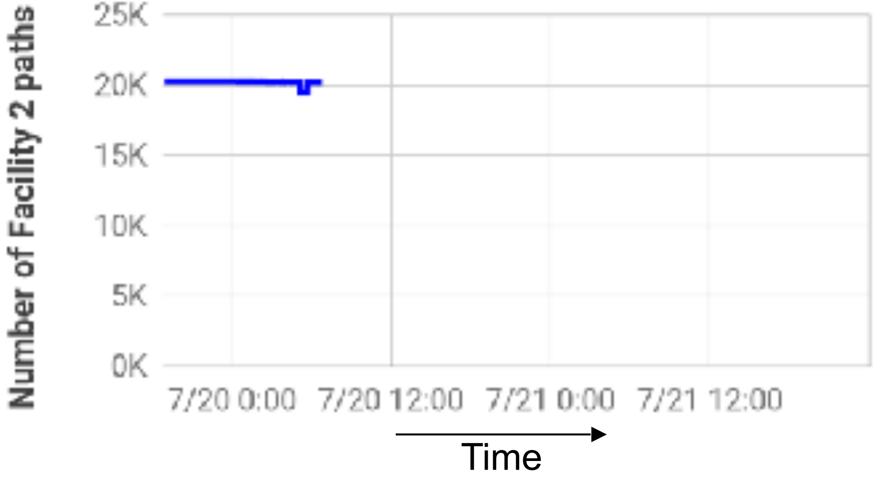
Passive outage detection: Monitoring

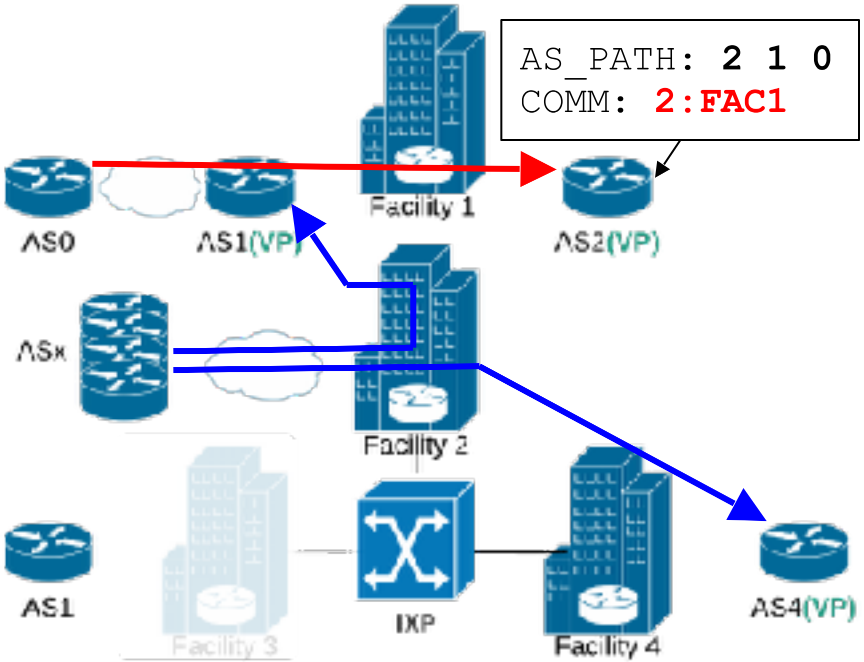




Track the BGP updates of the stable paths for changes in the communities values that indicate ingress point change.

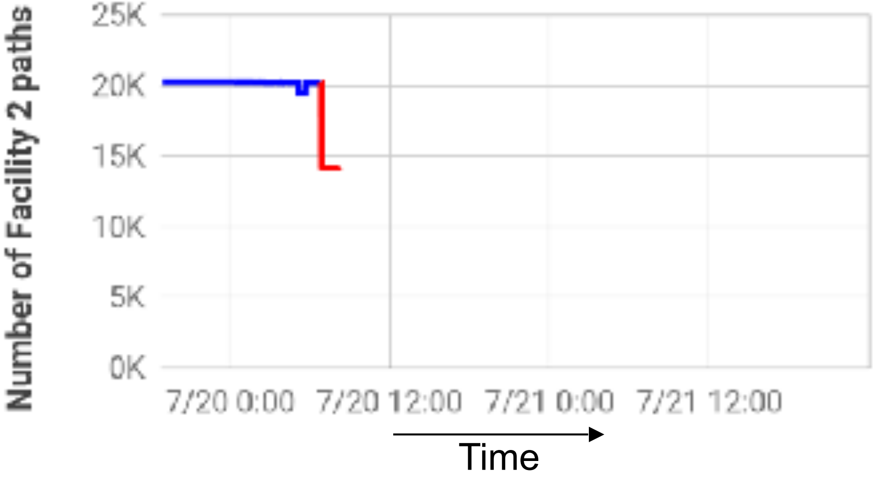
Passive outage detection: Monitoring

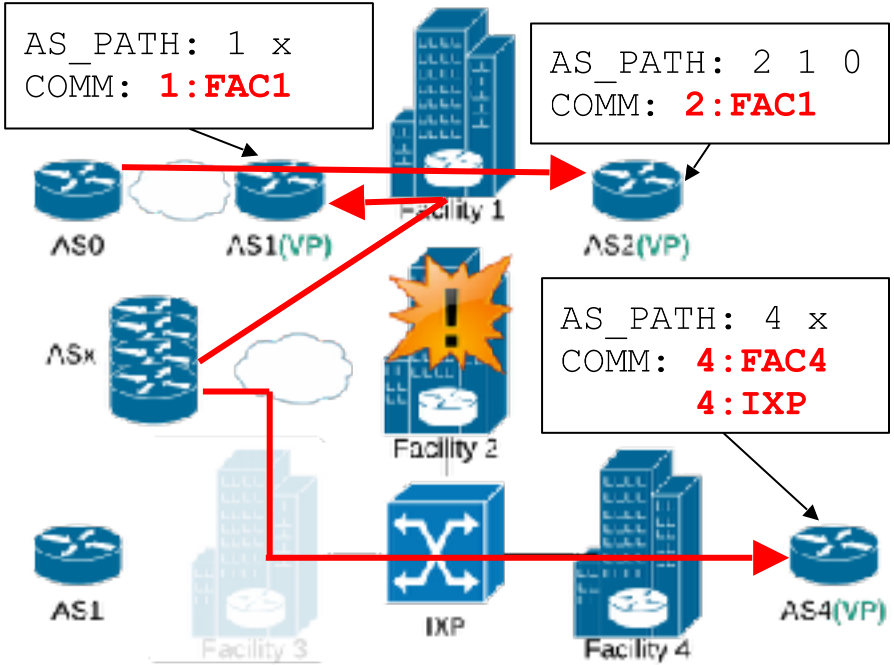




We don't care about AS-level path changes if the ingress-tagging communities remain the same.

Passive outage detection: Outage signal





- Concurrent changes of communities values for the same facility.
- **Indication** of outage but not final inference yet!

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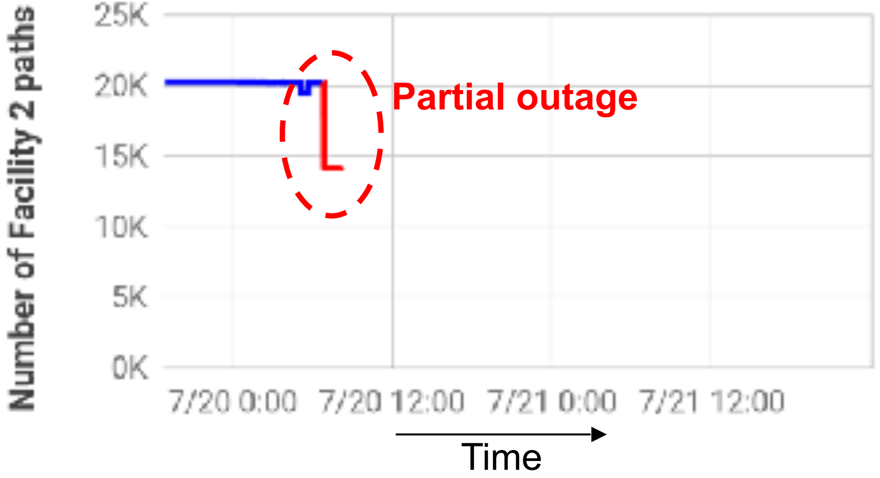

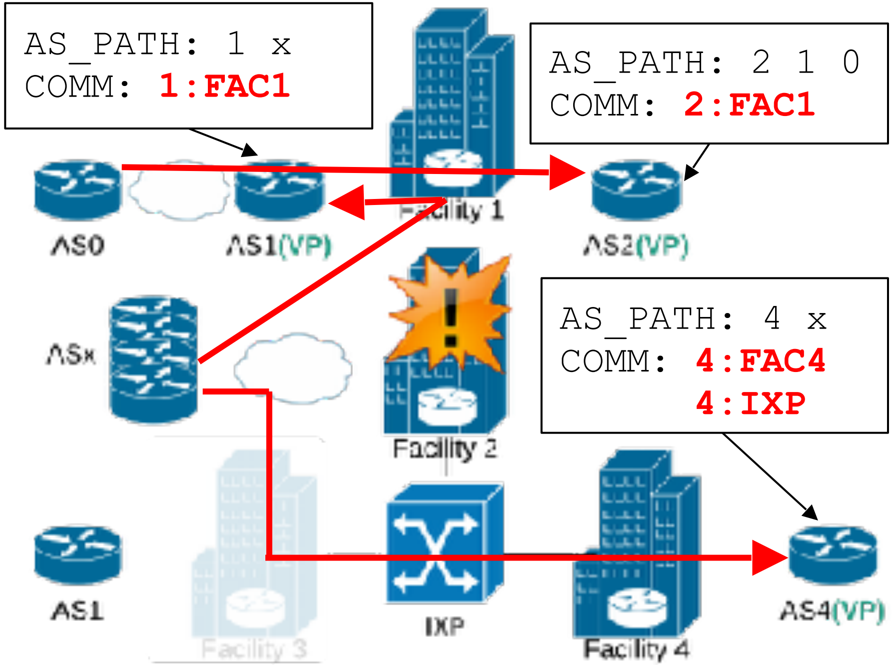

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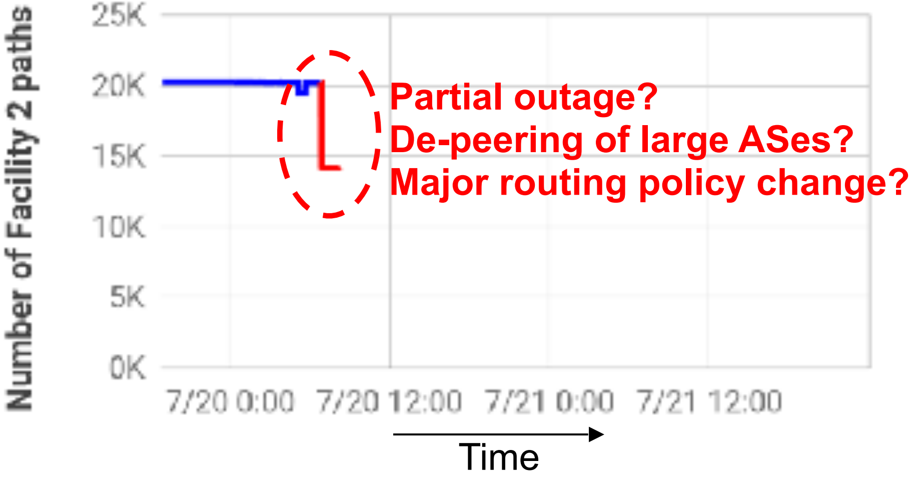

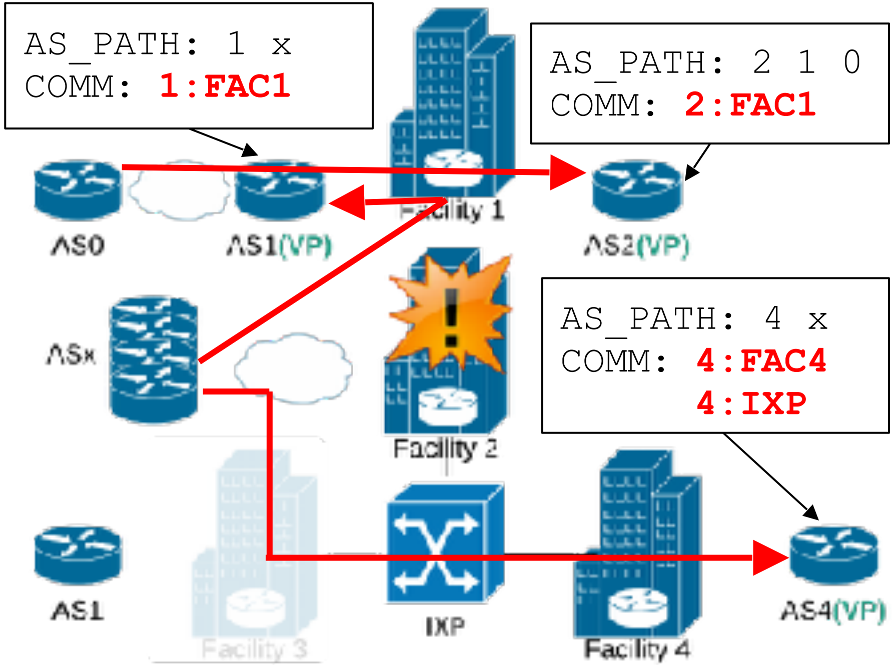

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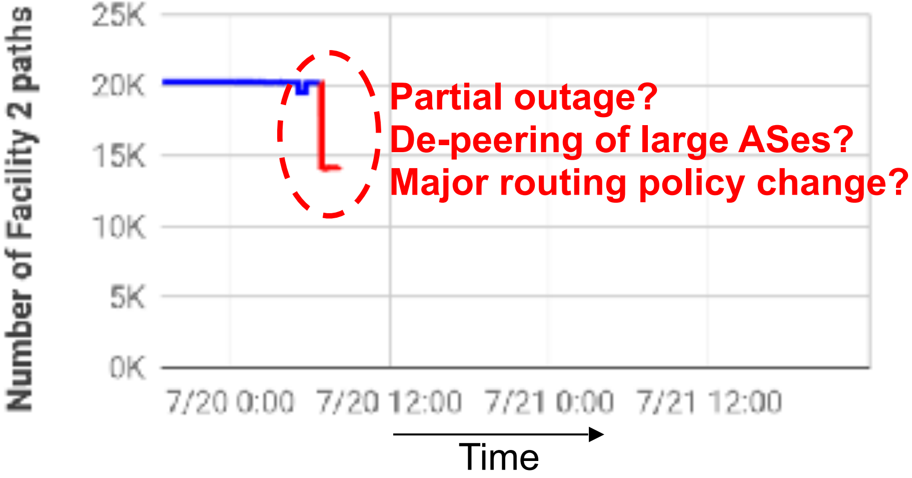
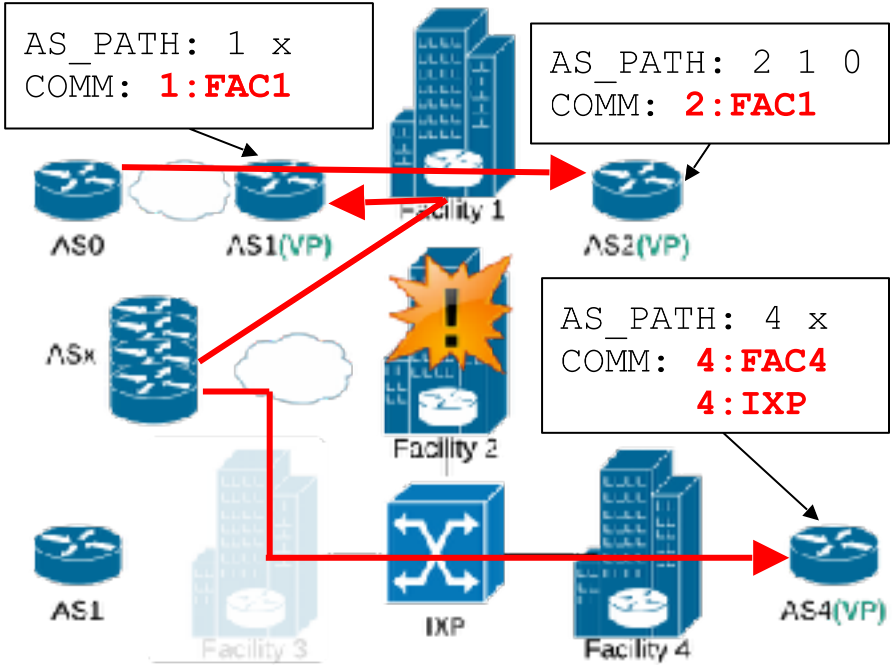
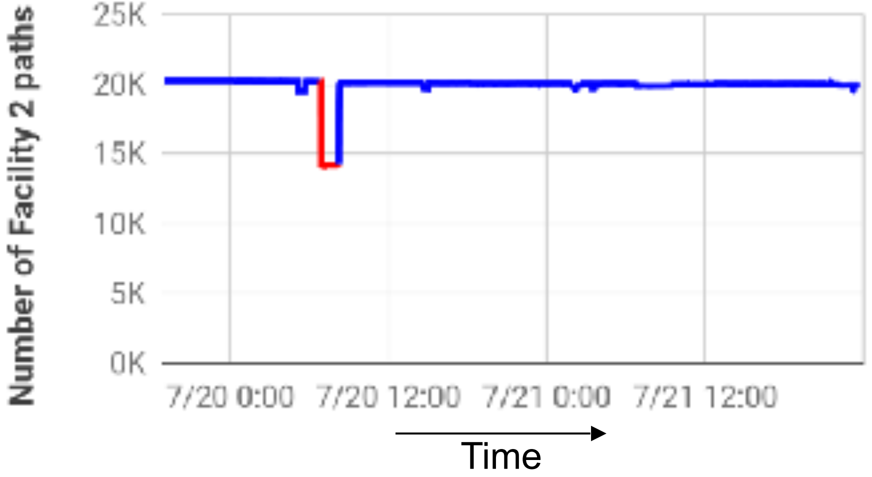


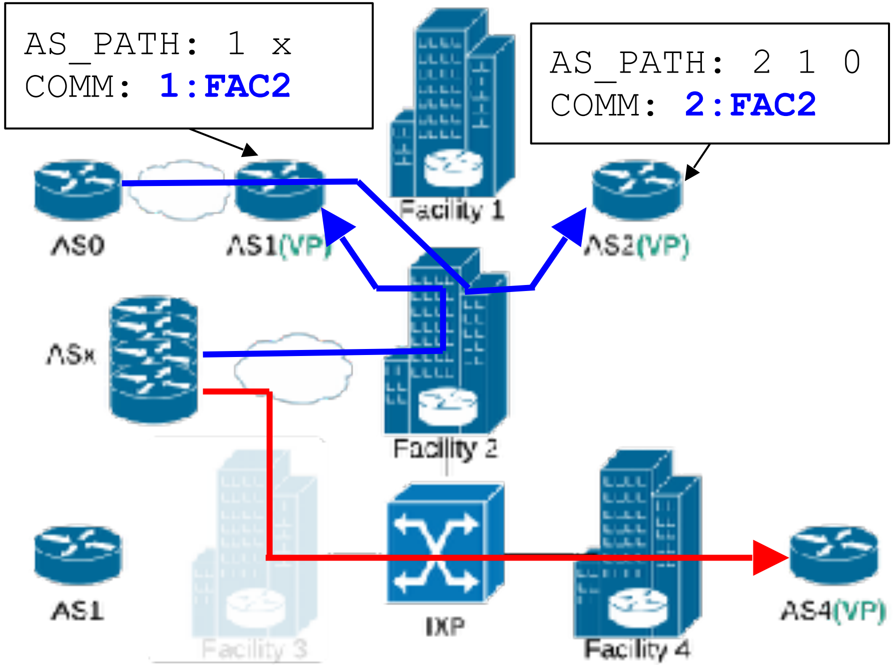


Signal investigation:

- Targeted active measurements.
- How disjoint are the affected paths?
- How many ASes and links have been affected?

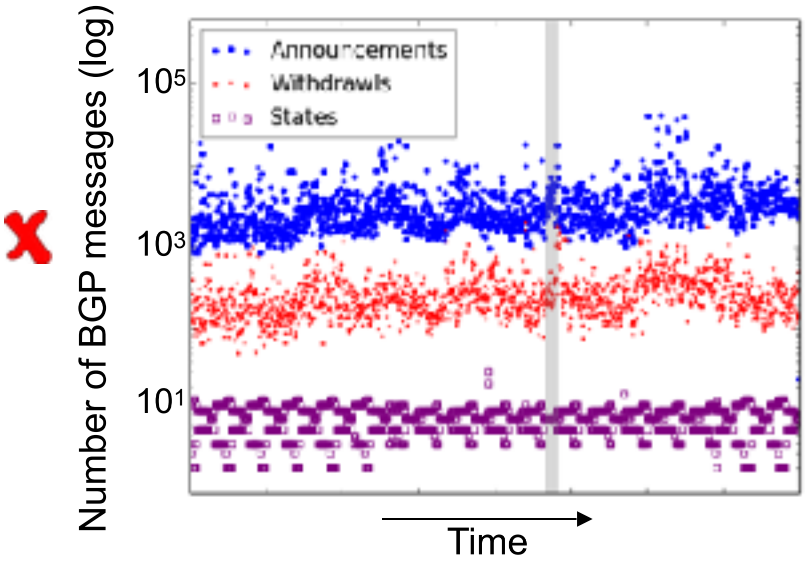
Passive outage detection: Outage tracking





End of outage inferred when the majority of paths return to the original facility.

De-noising of BGP routing activity



The aggregated activity of BGP messages (updates, withdrawals, states) provides no outage indication.

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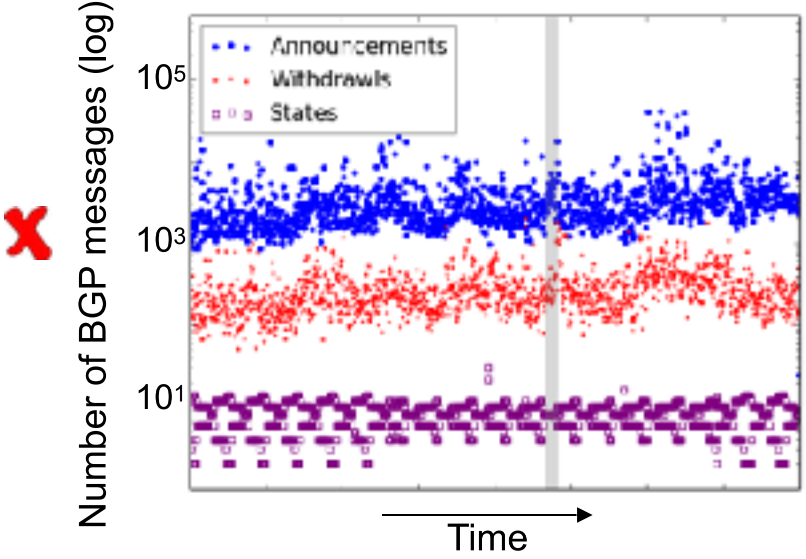
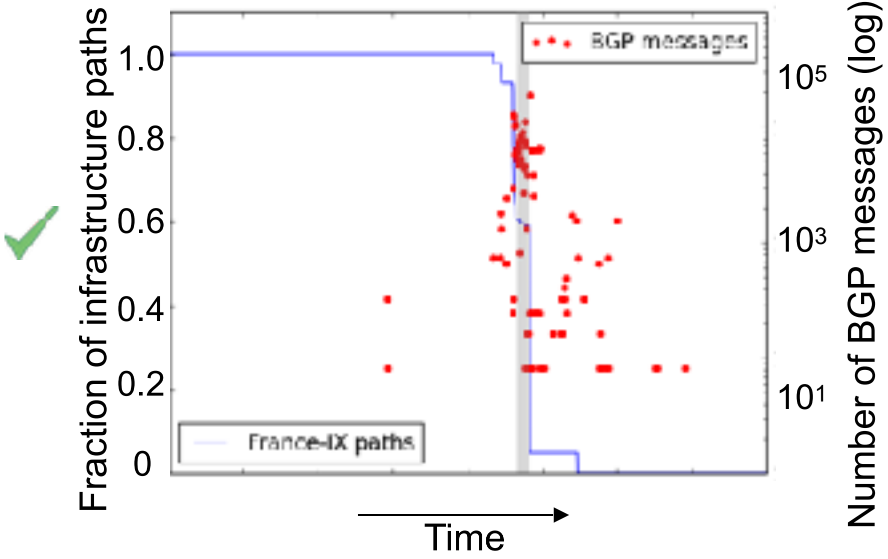




The aggregated activity of BGP messages (updates, withdrawals, states) provides no outage indication.

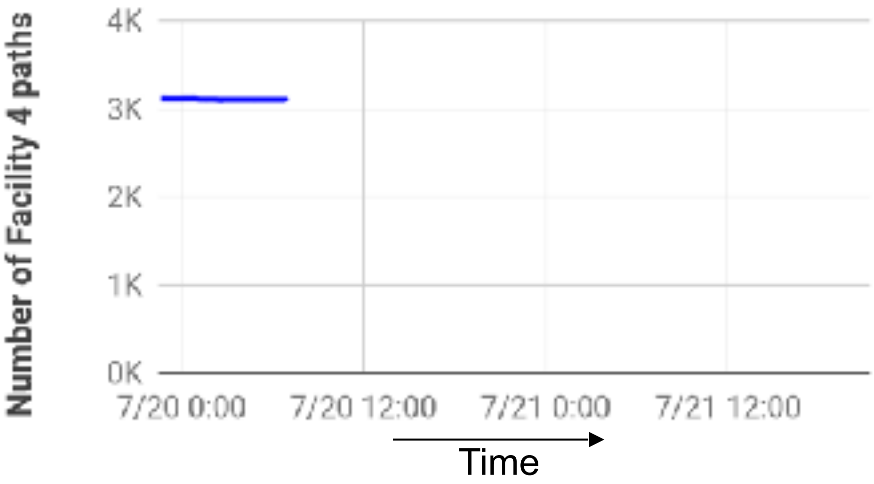
The BGP activity filtered using communities provides **strong outage signal**.

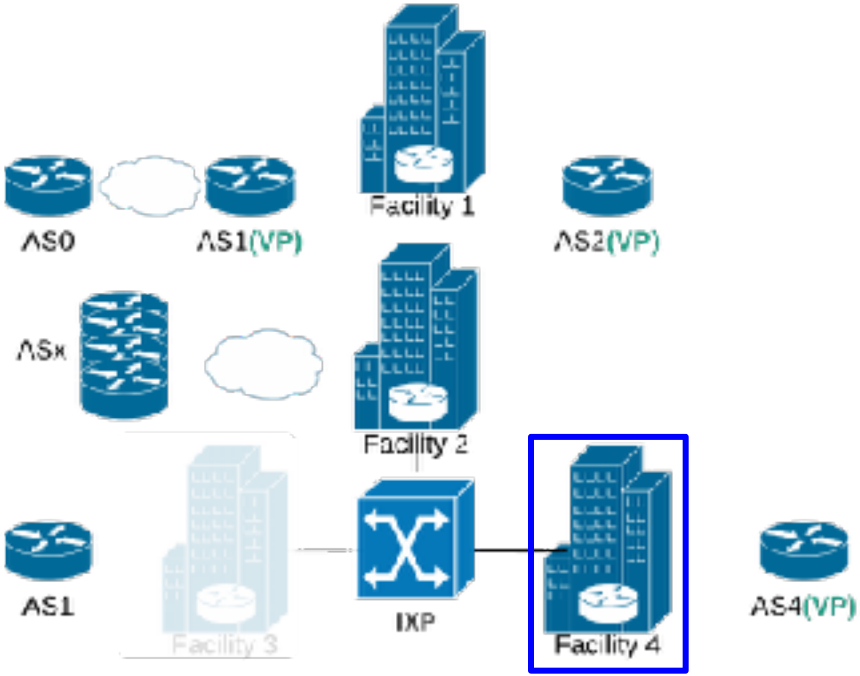
Outage localization is more complicated!

- The location of community values that trigger outage signals may <u>not</u> be the outage source!

- Communities encode the ingress point closest to our VPs (near-end infrastructure)
    - ASes may be interconnected over multiple intermediate infrastructures
    - Failures in intermediate infrastructures may affect the near-end infrastructure paths

Outage localization is more complicated!





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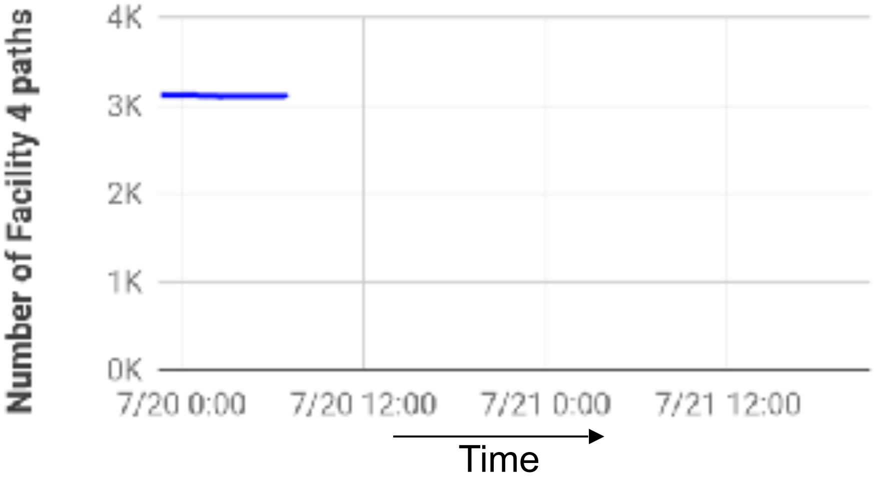

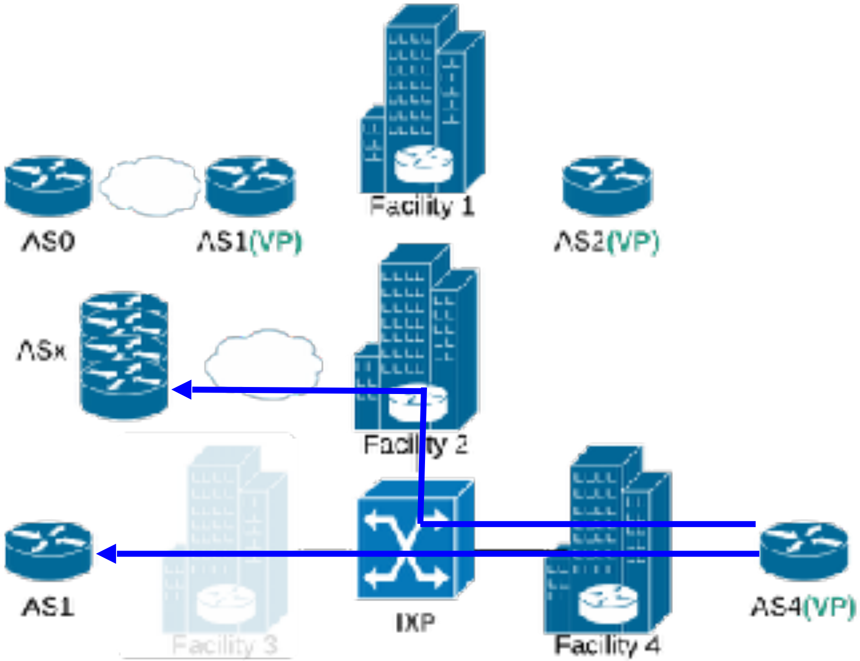

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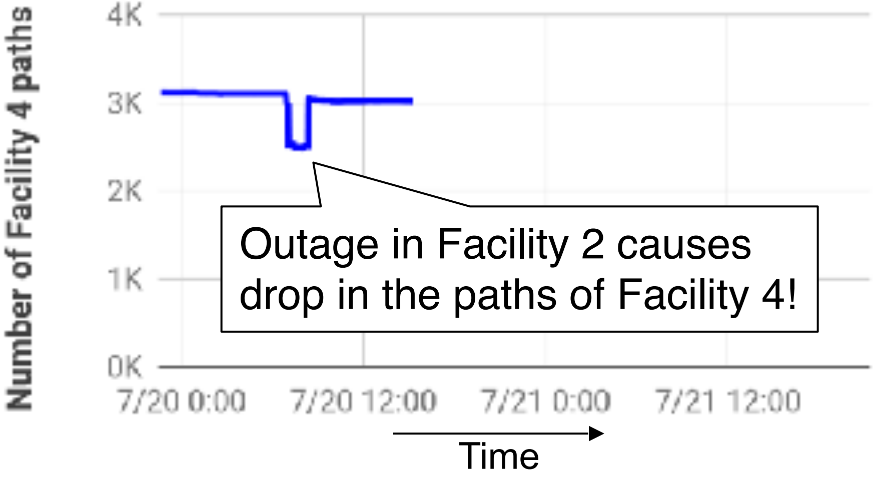

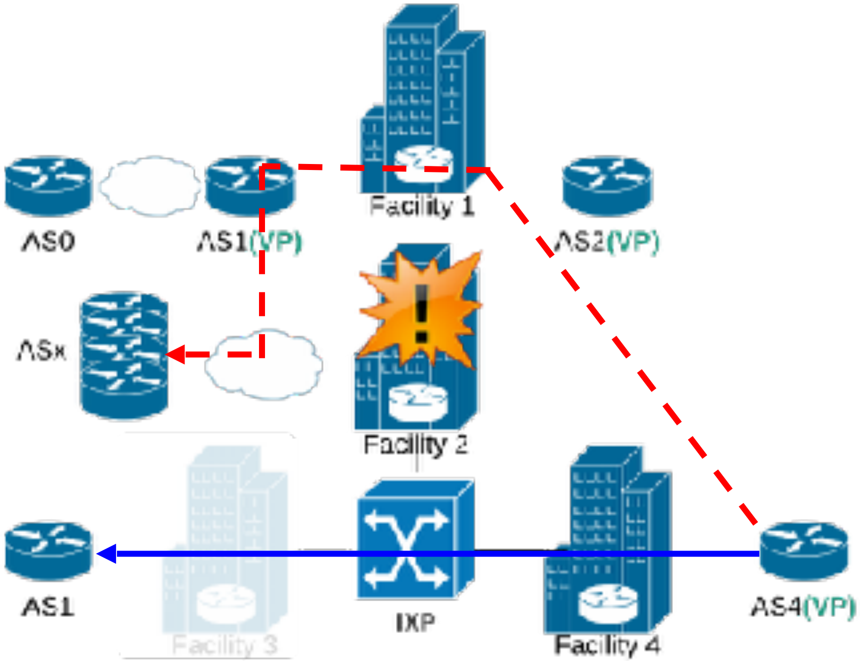

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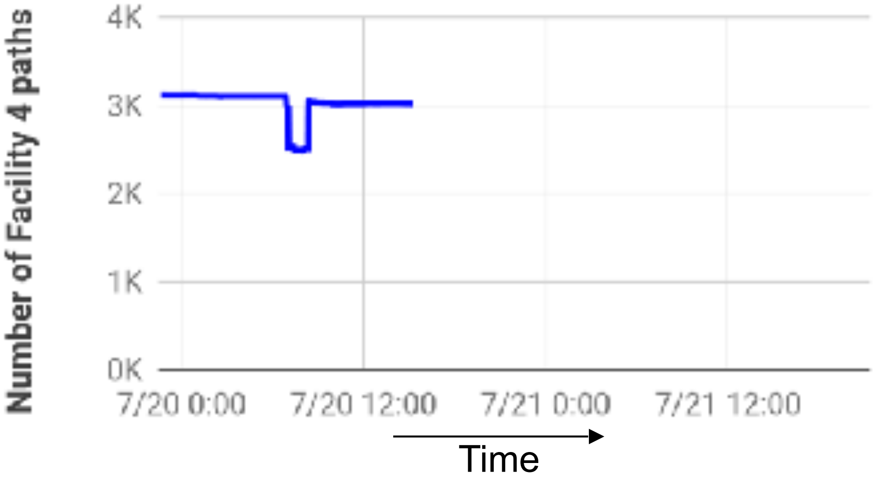

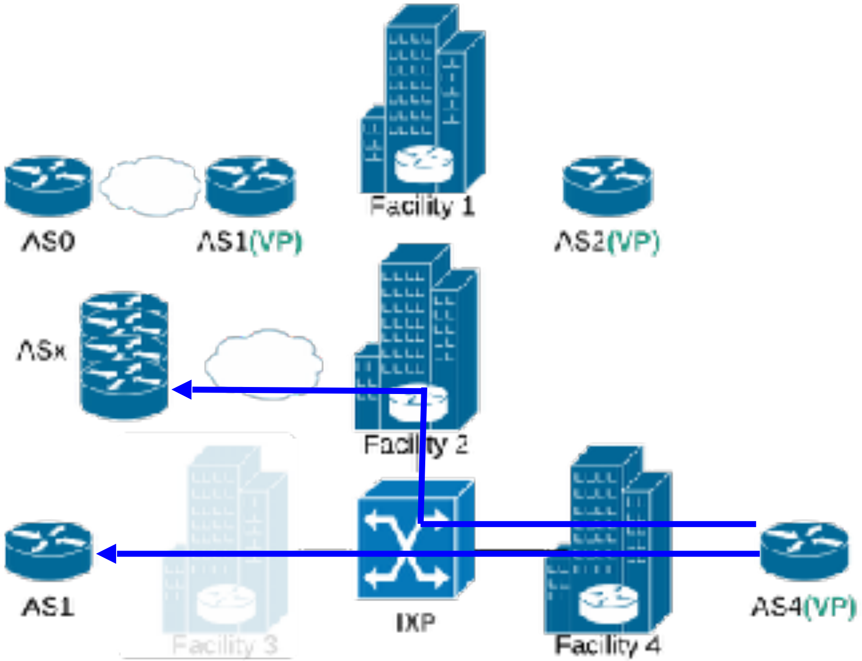

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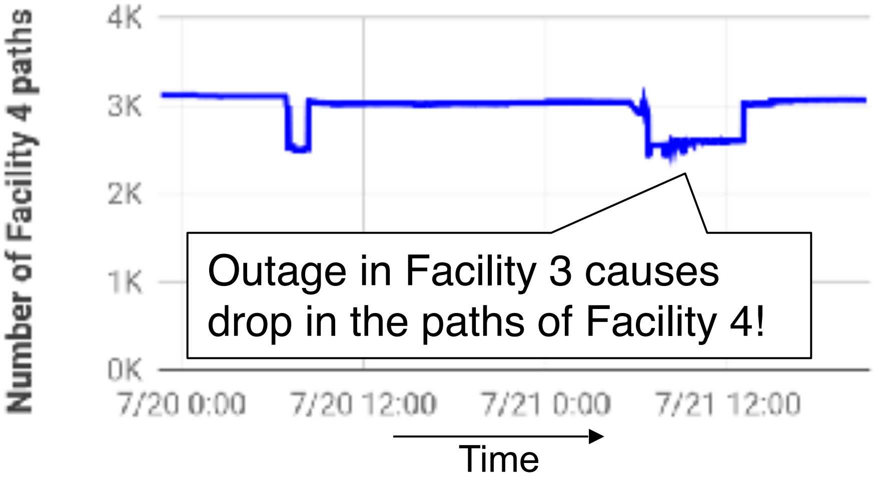
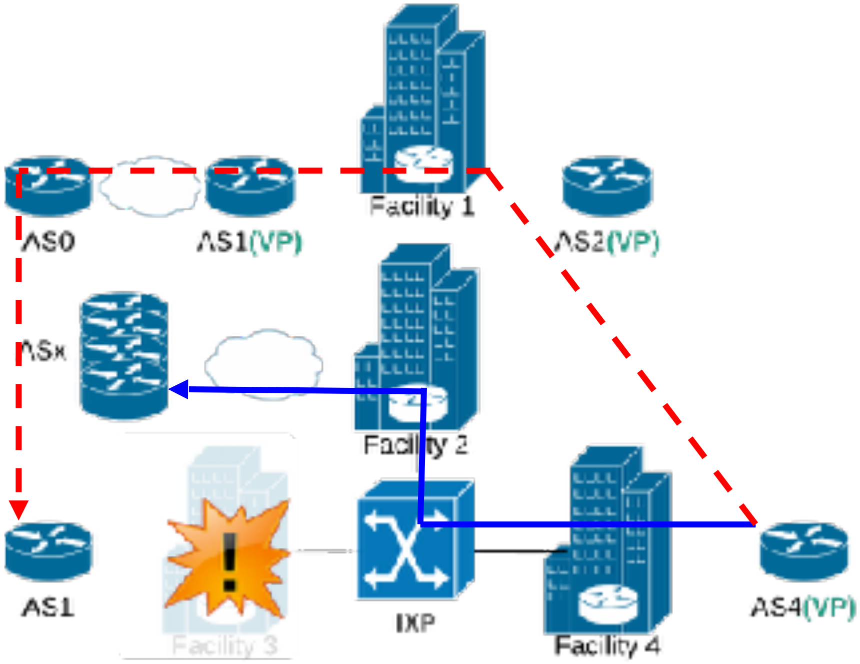
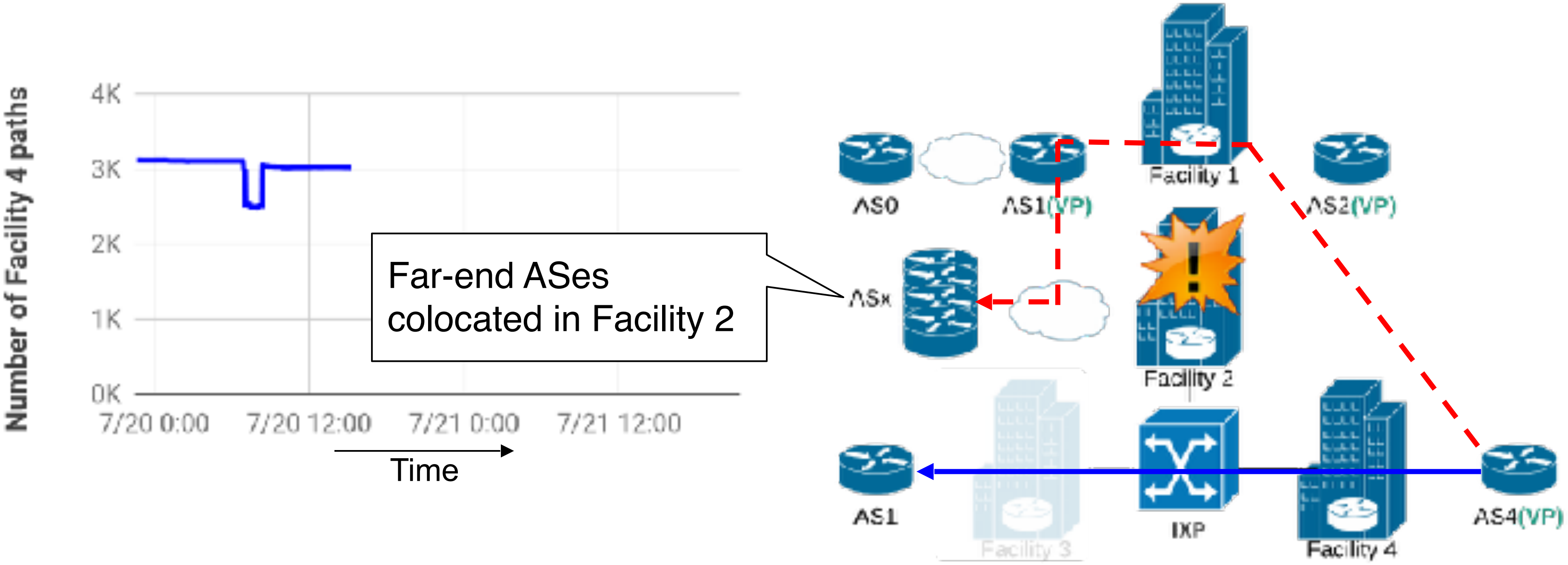




Outage source disambiguation and localization

- Create **high-resolution co-location maps**:
  - AS to Facilities, AS to IXPs, IXPs to Facilities
  - Sources: PeeringDB, DataCenterMap, operator websites
- Decorrelate the behaviour of affected ASes based on their infrastructure colocation.

Outage localization is more complicated!



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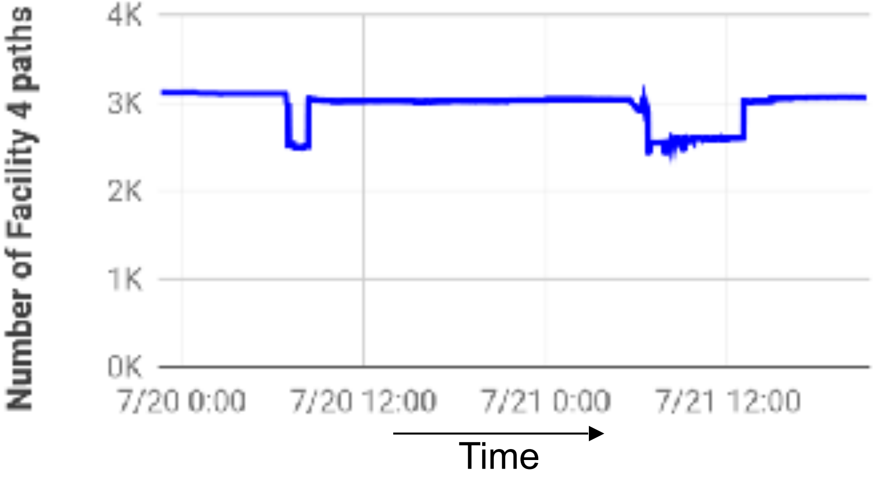
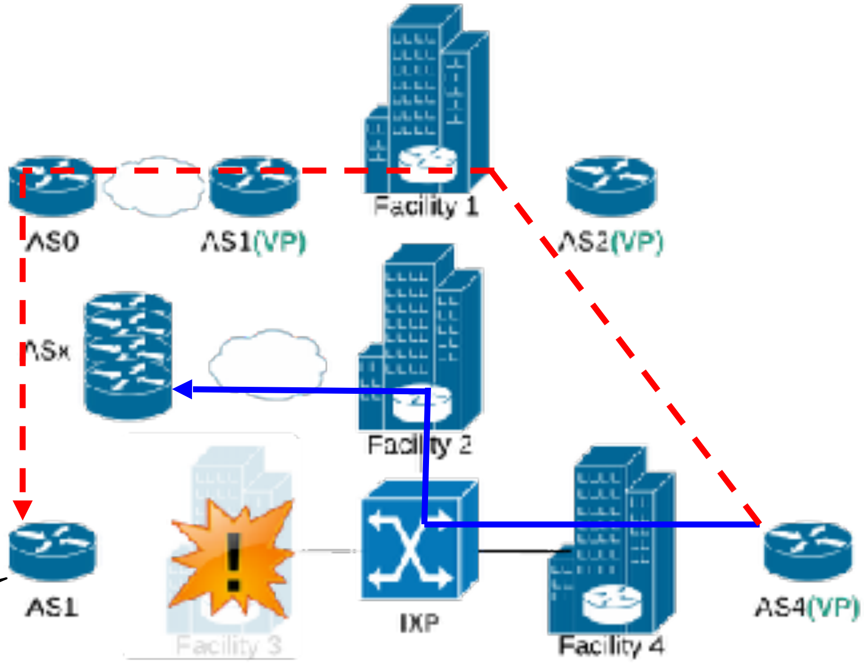
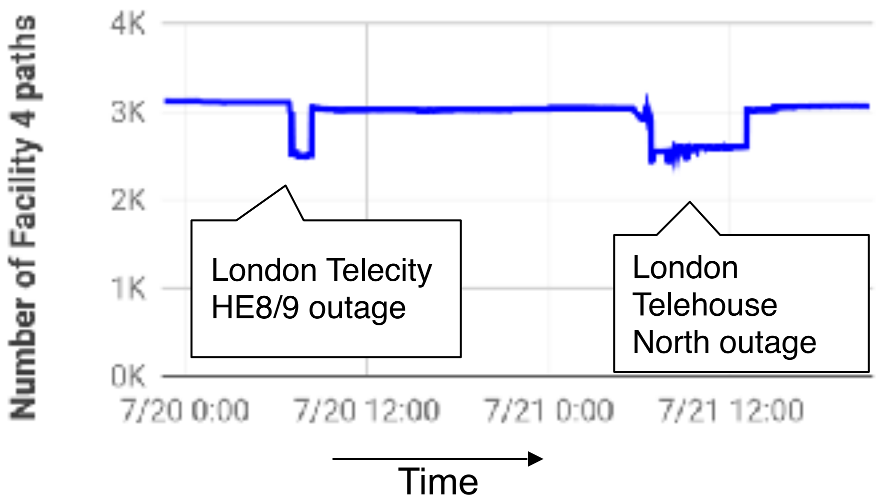
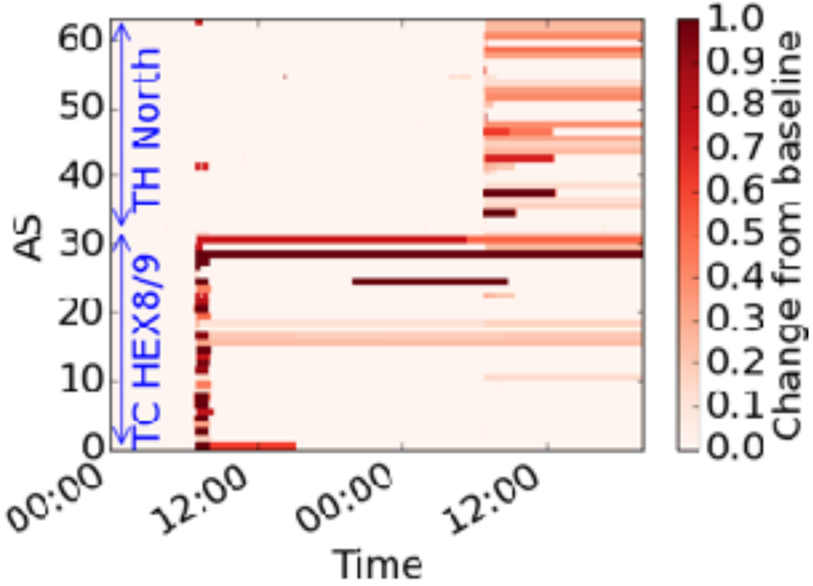




Far-end ASes
colocated in Facility 3

Paths not investigated in aggregated manner, but at the granularity of separate (AS, Facility) co-locations.





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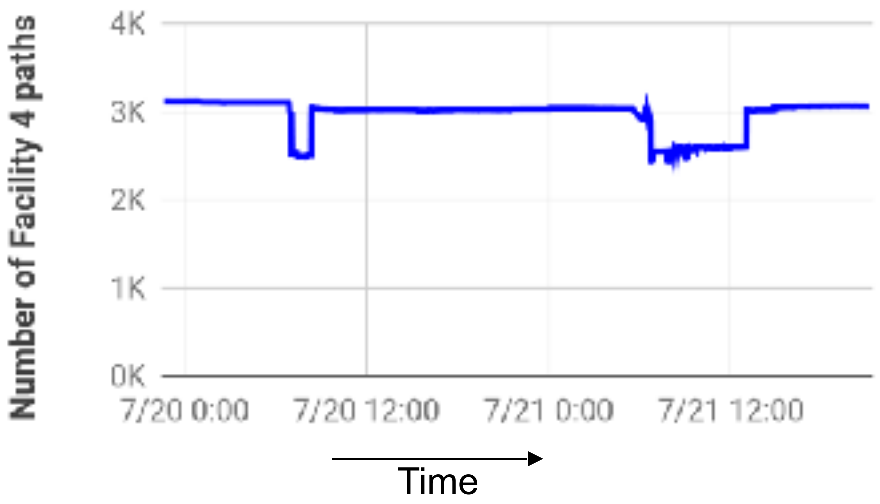
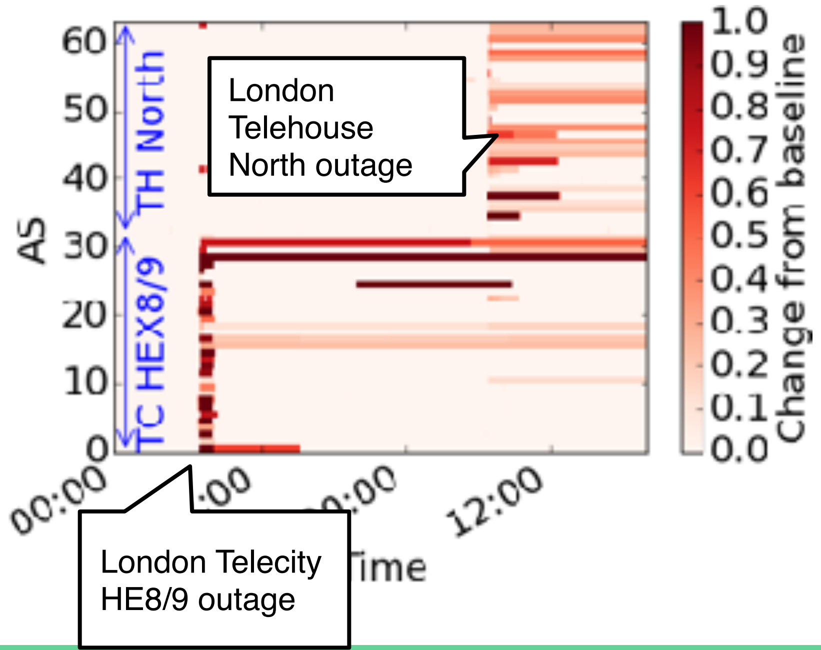
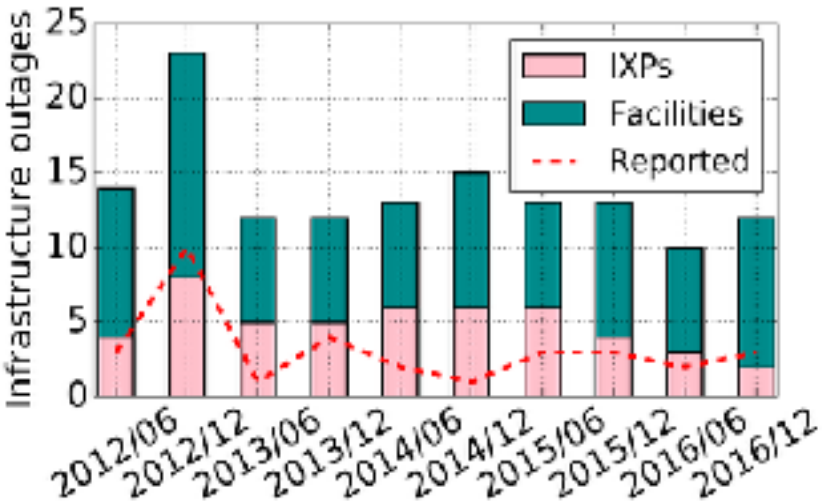


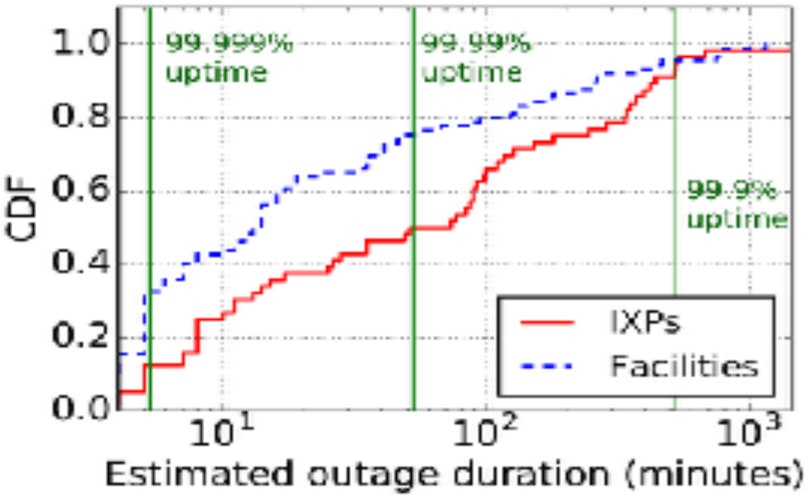


Detecting peering infrastructure outages in the wild



- **159** outages in 5 years of BGP data
  - **76%** of the outages not reported in popular mailing lists/websites
- Validation through status reports, direct feedback, social media
  - **90%** accuracy, **93%** precision (for trackable PoPs)

Effect of outages on Service Level Agreements

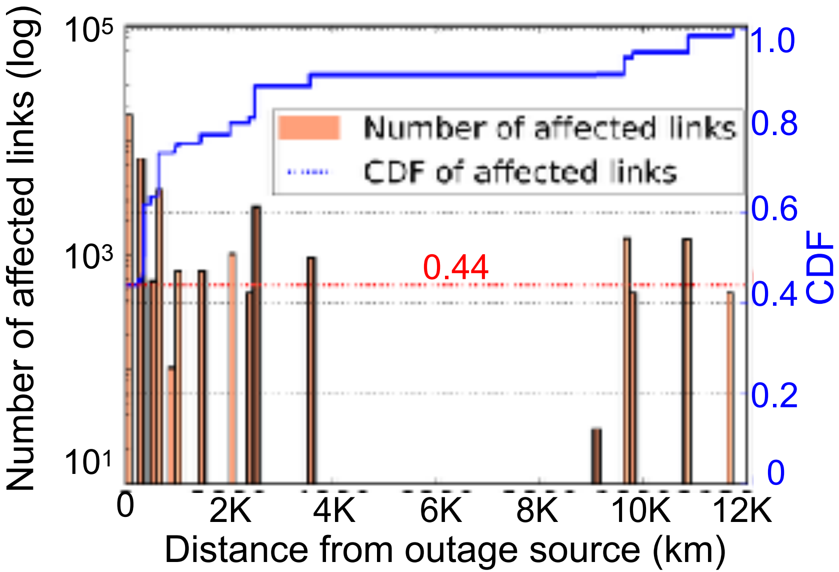


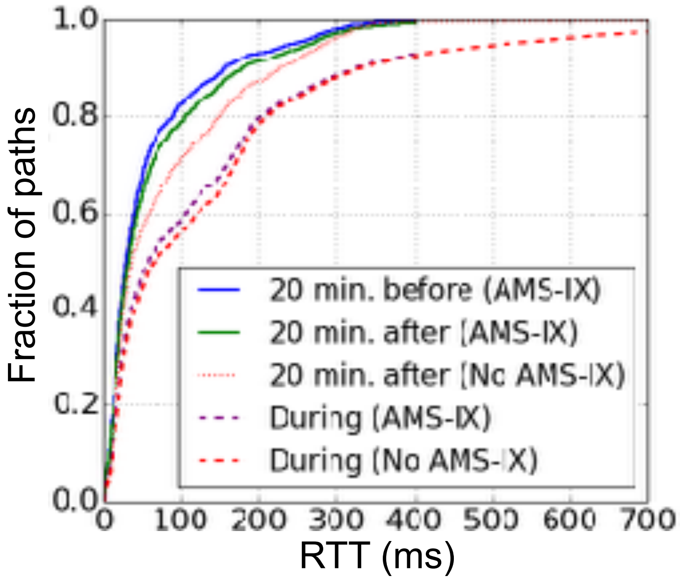
~70% of failed facilities below 99.999% uptime

~50% of failed IXPs below 99.99% uptime

5% of failed infrastructures below 99.9% uptime!

Measuring the impact of outages





> 56 % of the affected links in different country, **> 20%** in different continent!

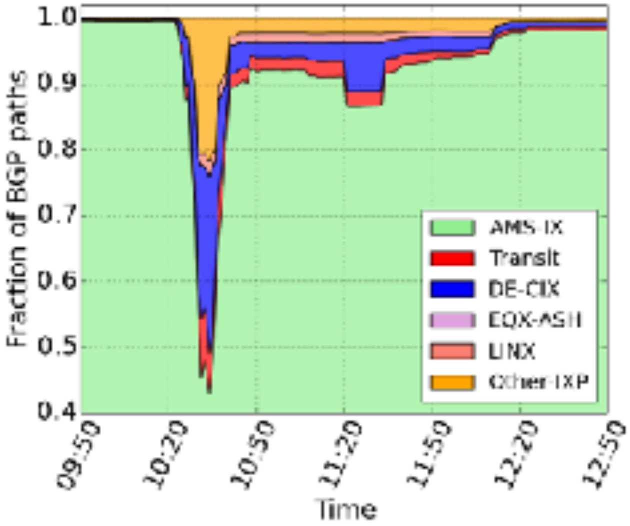
Median RTT rises by **> 100 ms** for rerouted paths during AMS-IX outage.

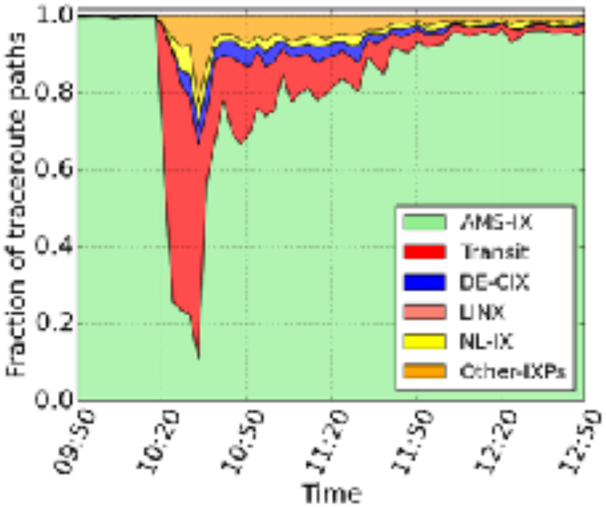
Conclusions

- **Timely** and **accurate** infrastructure-level outage detection through **passive** BGP monitoring
- Majority of outages not (widely) reported
- Remote peering and infrastructure interdependencies **amplify** the impact of local incidents
- **Hard evidence** on outages can improve accountability, transparency and resilience strategies

Thank you!

Tracking the progress of outages





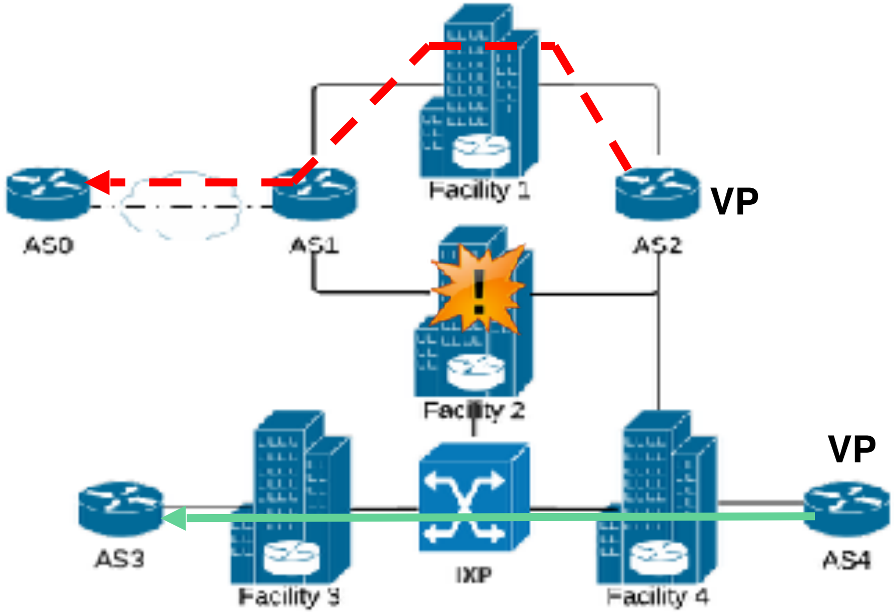
<u>Passive tracking</u>:
Monitor how location-tagging BGP Communities change during the outage.

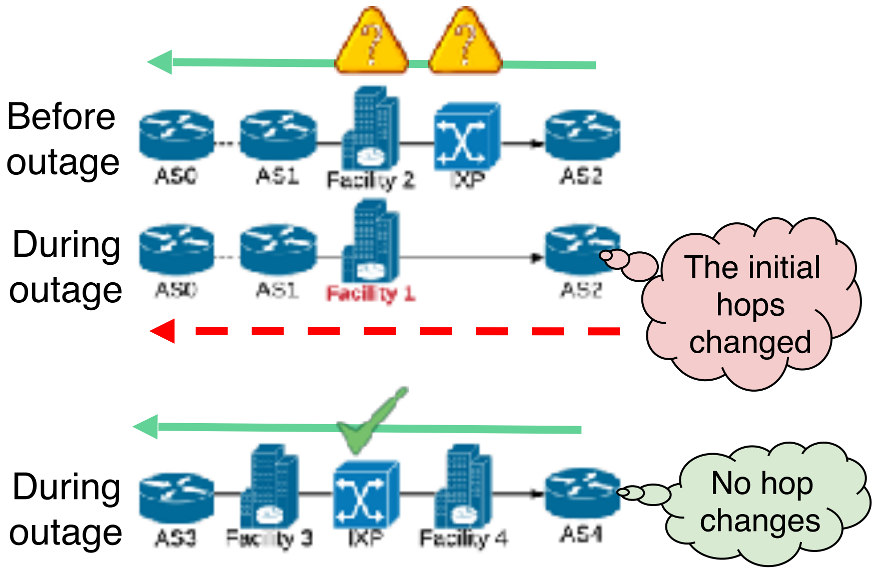
<u>Active tracking</u>:
Execute **targeted traceroutes** based on the hints of the BGP signals.

Challenges in detecting infrastructure outages

1. Capturing the infrastructure-level hops between ASes
2. Correlating the paths from multiple vantage points
3. Continuous monitoring of the routing system

→ Passive BGP monitoring

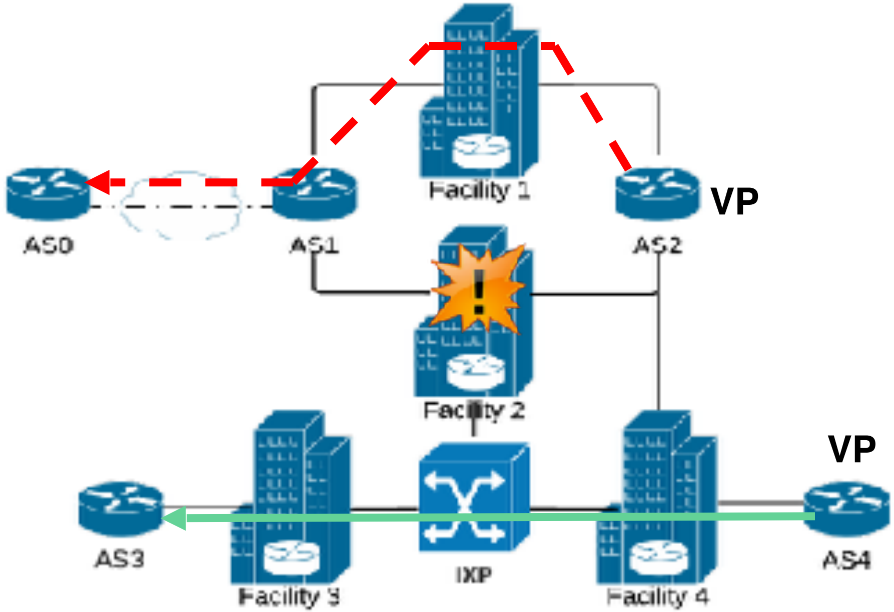


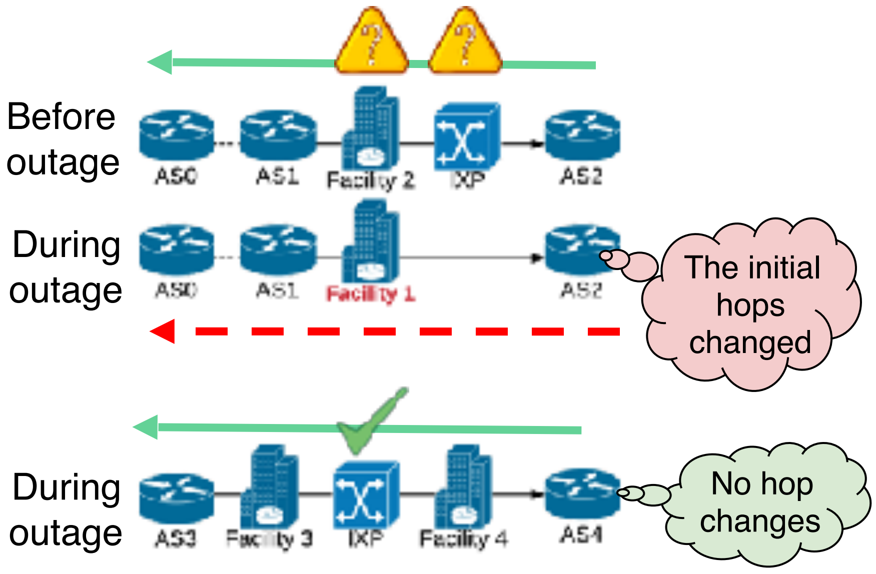


Challenges in detecting infrastructure outages

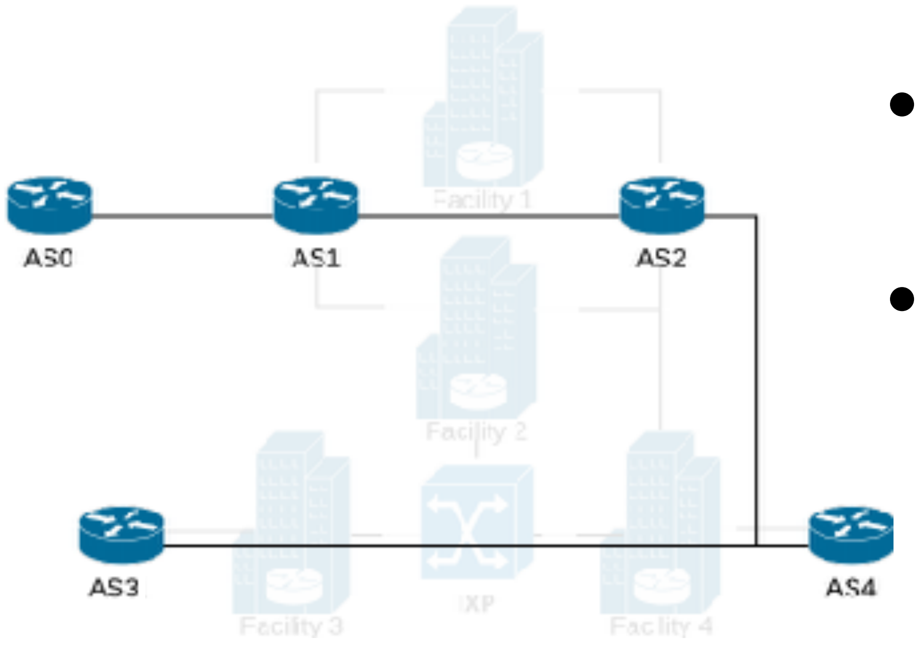
1. Capturing the infrastructure-level hops between ASes → BGP encodes AS paths
2. Correlating the paths from multiple vantage points
3. Continuous monitoring of the routing system

→ Passive BGP monitoring





Deciphering location-metadata in BGP



- BGP not entirely information-hiding!
- **Communities BGP attribute:**
  - Optional, tags BGP routes with arbitrary metadata
  - Often encodes the **ingress location** of prefixes