Lab 5: BGP - Internet Topology Discovery

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December 5, 2025

1 Exercise 1: Internet Topology Discovery

1.1 Selected Autonomous Systems

For this exercise, we selected a target Autonomous System (AS) and three additional geographically dispersed ASes to analyze the internet topology. We ensured all chosen ASes provided accessible Looking Glass services.

Table 1: Selected Networks for Analysis

Role	**Network Name**	**AS Number**	**Location**
Target	Hurricane Electric	AS6939	Global / USA
Source 1	Cogent	AS174	USA (Los Angeles)
Source 2	Arelion (Telia)	AS1299	Europe (Berlin)
Source 3	NTT	AS2914	Asia (Hong Kong)
Local	Bouygues Telecom	AS5410	France

1.2 Traceroute Measurements

We performed traceroute measurements in both directions: the forward path from the source ASes to the target AS, and the reverse path from the target back to the sources.

1.2.1 Forward Path (Source → Target)

```
traceroute to 216.218.186.2 (216.218.186.2), 30 hops max, 60 byte packets
 1  C7.mshome.net (172.18.144.1)  1.392 ms  1.070 ms  1.047 ms
 2  bbox.lan (192.168.1.254)  4.639 ms  4.605 ms  4.583 ms
 3  176.187.168.2 (176.187.168.2)  7.703 ms  7.623 ms  7.519 ms
 4  * * *
 5  212.194.170.100 (212.194.170.100)  11.138 ms  11.080 ms  11.051 ms
 6  212.194.170.71 (212.194.170.71)  11.044 ms  7.936 ms  7.898 ms
 7  * * *
 8  he.par.franceix.net (37.49.236.10)  9.729 ms * *
 9  port-channel21.core3.nyc4.he.net (184.105.213.138)  80.319 ms * *
10  * * *
11  * * *
12  100ge0-79.core1.fmt1.he.net (184.104.188.48)  138.401 ms  138.379 ms  138.326 ms
13  mail.he.net (216.218.186.2)  137.630 ms  137.246 ms  137.214 ms
```

Figure 1: Trace from Local (Bouygues) to Hurricane Electric. Shows direct peering at FranceIX.

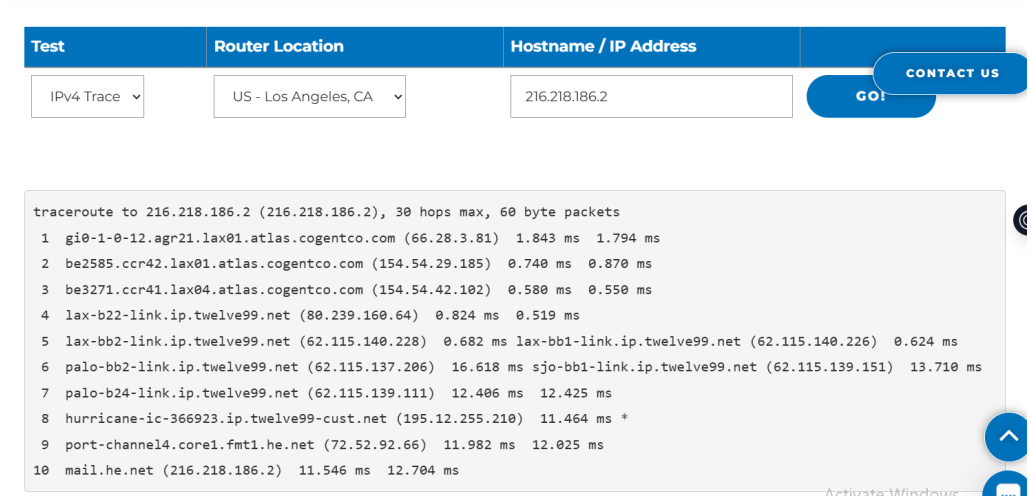


Figure 2: Trace from Cogent (AS174) to HE. Traffic routes via Arelion (AS1299).

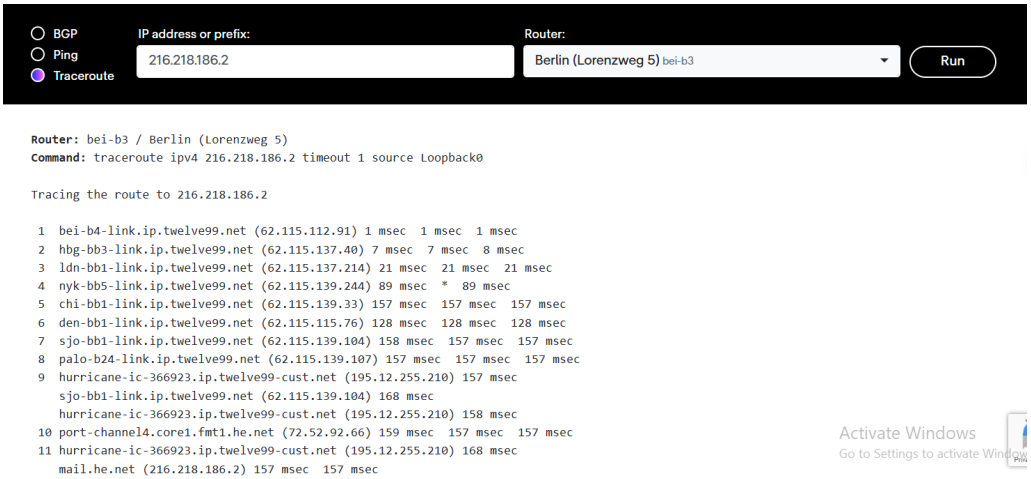


Figure 3: Trace from Arelion (AS1299) to HE. Direct connection.

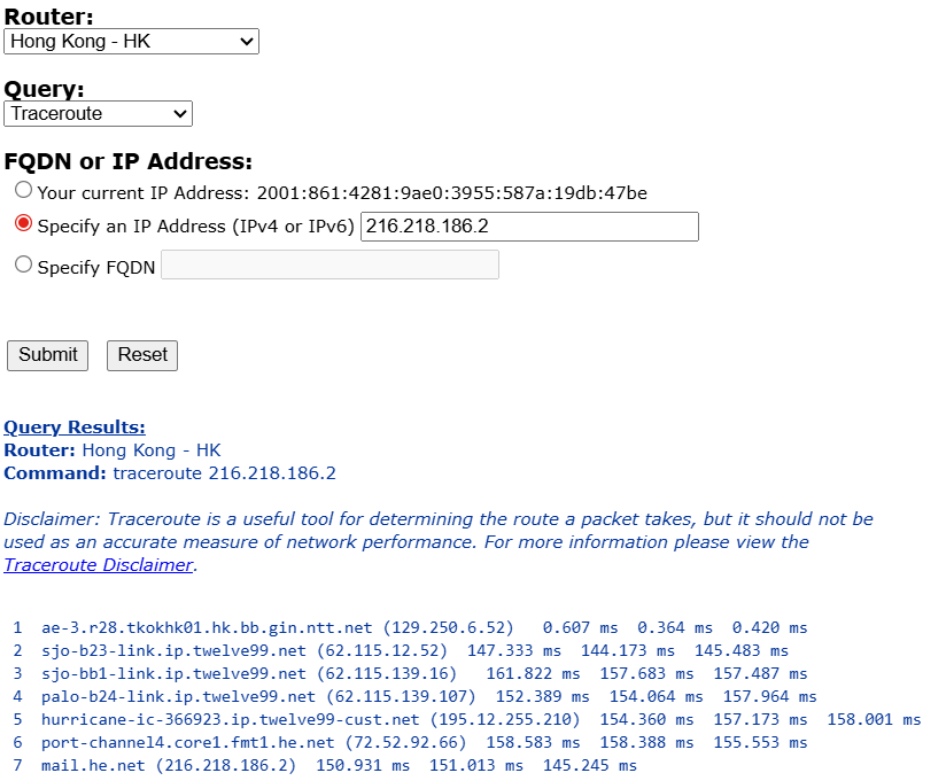


Figure 4: Trace from NTT (AS2914) to HE. Traffic immediately hands off to Arelion (AS1299).

1.2.2 Reverse Path (Target → Source)

We used the Hurricane Electric Looking Glass (Router: `core1.fmt1.he.net`) to trace back to the source IPs.

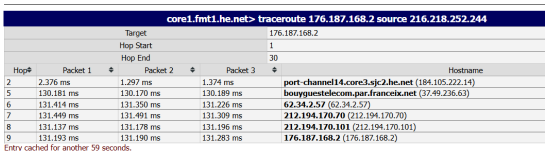


Figure 5: Reverse path to Local Network.

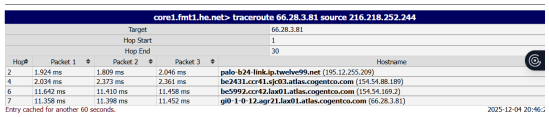
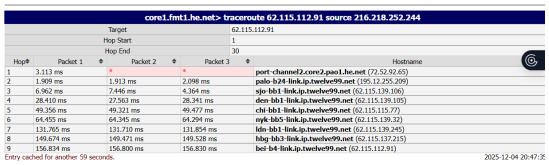


Figure 6: Reverse path to Cogent.



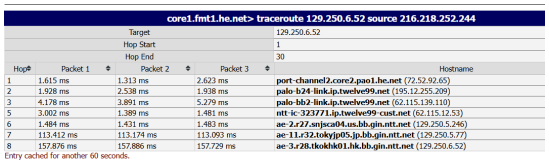
core1.fmt1.he.net> traceroute 62.115.112.91 source 216.218.252.244

Target	62.115.112.91
Hop Start	1
Hop End	30

Hop	Packet 1	Packet 2	Packet 3	Hostname
1	3.113 ms	*	*	port-channel2.core2.pao1.he.net (72.52.92.65)
2	1.909 ms	1.913 ms	2.098 ms	palo-b24-link.ip.twelve99.net (195.12.255.209)
3	6.962 ms	7.446 ms	4.364 ms	sjo-bb1-link.ip.twelve99.net (62.115.139.106)
4	28.410 ms	27.563 ms	28.341 ms	den-bb1-link.ip.twelve99.net (62.115.139.105)
5	49.356 ms	49.321 ms	49.477 ms	chi-bb1-link.ip.twelve99.net (62.115.115.77)
6	64.455 ms	64.345 ms	64.294 ms	nyk-bb5-link.ip.twelve99.net (62.115.139.32)
7	131.765 ms	131.710 ms	131.854 ms	ldn-bb1-link.ip.twelve99.net (62.115.139.245)
8	149.674 ms	149.471 ms	149.528 ms	hbg-bb3-link.ip.twelve99.net (62.115.137.215)
9	156.834 ms	156.800 ms	156.830 ms	bei-b4-link.ip.twelve99.net (62.115.112.91)

Entry cached for another 59 seconds.

Figure 7: Reverse path to Arelion.



core1.fmt1.he.net> traceroute 129.250.6.52 source 216.218.252.244

Target	129.250.6.52
Hop Start	1
Hop End	30

Hop	Packet 1	Packet 2	Packet 3	Hostname
1	1.615 ms	1.313 ms	2.623 ms	port-channel2.core2.pao1.he.net (72.52.92.65)
2	1.928 ms	2.538 ms	1.938 ms	palo-b24-link.ip.twelve99.net (195.12.255.209)
3	4.178 ms	3.891 ms	5.279 ms	palo-bb2-link.ip.twelve99.net (62.115.139.110)
5	3.002 ms	1.389 ms	1.481 ms	ntt-ic-323771.ip.twelve99-cust.net (62.115.12.53)
6	1.484 ms	1.431 ms	1.483 ms	ae-2.r27.snjsca04.us.bb.gin.ntt.net (129.250.5.246)
7	113.412 ms	113.174 ms	113.093 ms	ae-11.r32.tokyjp05.jp.bb.gin.ntt.net (129.250.5.77)
8	157.876 ms	157.886 ms	157.729 ms	ae-3.r28.tkokhk01.hk.bb.gin.ntt.net (129.250.6.52)

Entry cached for another 60 seconds.

Figure 8: Reverse path to NTT.

1.3 AS-Level Topology Diagram

Based on the traceroutes, we constructed the AS-level topology centered on the target AS. We identified that **Arelion (AS1299)** acts as a major transit provider for the other international carriers in this specific route.

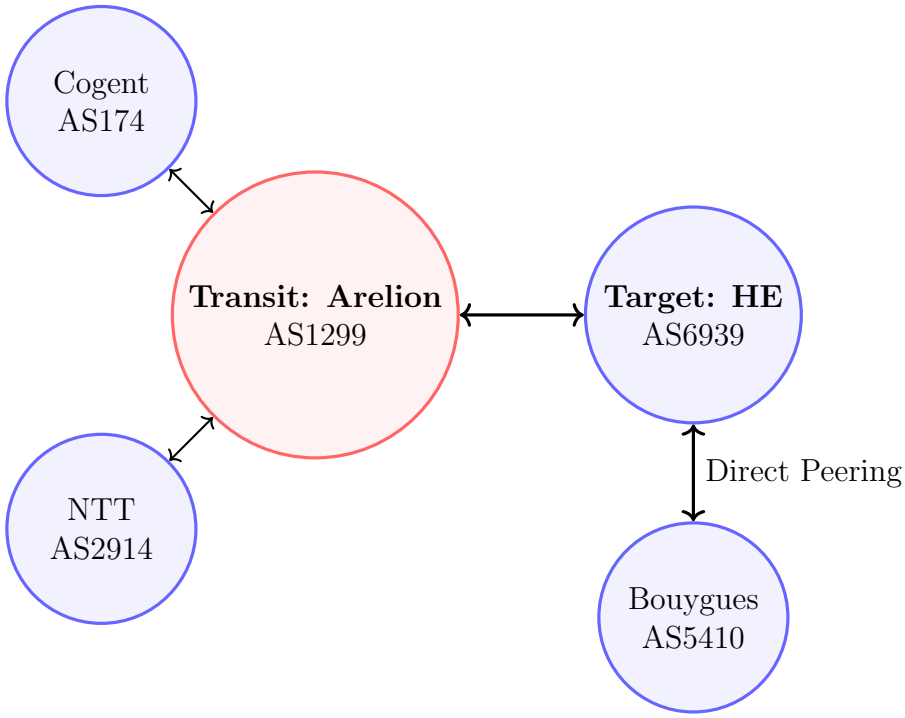


Figure 9: Constructed AS-Level Topology. Arrows indicate bidirectional connectivity observed in forward and reverse traces.

2 Exercise 2: Measuring Internet Distance

2.1 Methodology

To estimate the distance between nodes, we utilized the Round Trip Time (RTT) measurements from our traceroutes. As per lab instructions, we used the smallest measured RTT value for each hop and assumed a propagation speed of light in fiber equal to $300,000$ km/s.

The formula used for the calculation is:

$$\text{Distance} = \frac{\text{RTT}_{\text{link}}}{2} \times 300,000 \text{ km/s} \tag{1}$$

Where RTT_{link} is the time difference between the entering node and the exiting node.

2.2 Link Calculations

Based on our topology, we calculated the distances for the four distinct inter-AS links.

Link 1: Bouygues (AS5410) ↔ Hurricane Electric (AS6939)

Type: Trans-Atlantic (France to USA)

- **Hop A:** `he.par.franceix.net` (9.729 ms)
- **Hop B:** `core3.nyc4.he.net` (80.319 ms)
- **RTT:** 70.59 ms = 0.07059 s
- **Calculation:**

$$\frac{0.07059}{2} \times 300,000 = \mathbf{10,588} \text{ km}$$

Link 2: NTT (AS2914) ↔ Arelion (AS1299)

Type: Trans-Pacific (Hong Kong to USA)

- **Hop A:** `tkokhk01...` (0.364 ms)
- **Hop B:** `sjo-b23...` (144.173 ms)
- **RTT:** 143.809 ms = 0.1438 s
- **Calculation:**

$$\frac{0.1438}{2} \times 300,000 = \mathbf{21,570} \text{ km}$$

Link 3: Cogent (AS174) ↔ Arelion (AS1299)

Type: Local Interconnection (Los Angeles)

- **Hop A:** `...lax04...` (0.580 ms)
- **Hop B:** `lax-b22...` (0.824 ms)
- **RTT:** 0.244 ms = 0.000244 s
- **Calculation:**

$$\frac{0.000244}{2} \times 300,000 = \mathbf{36.6} \text{ km}$$

Link 4: Arelion (AS1299) ↔ Hurricane Electric (AS6939)

Type: Local Interconnection (California)

- **Hop A:** `hurricane-ic...` (157 ms)
- **Hop B:** `core1.fmt1...` (159 ms)
- **RTT:** 2.0 ms = 0.002 s
- **Calculation:**

$$\frac{0.002}{2} \times 300,000 = \mathbf{300} \text{ km}$$

2.3 Analysis of Delay

Analyse: Our calculated distances (e.g., 10,588 km for the Paris-NY link) are significantly higher than the actual geographic distance (5,800 km). This is because the calculation assumes delay is caused solely by straight-line propagation. In reality, other factors significantly increase delay:

- **Indirect Routing:** Cables follow coastlines and ocean floors, not straight lines.
- **Processing & Queuing:** Routers introduce delay while inspecting headers and buffering packets during congestion.
- **Refractive Index:** The speed of light in fiber is closer to 200,000 km/s, meaning the lab's assumption of 300,000 km/s inherently inflates the distance calculation.

3 Exercise 3: Interconnecting the ASes

3.1 3.1 Common Node Identification

Analyzing the paths from our different source ASes reveals that they do not all connect directly to the target. We identified a single node that appears in multiple paths:

- **Arelion (AS1299)** appears in the path originating from **Cogent (AS174)**.
- **Arelion (AS1299)** also appears in the path originating from **NTT (AS2914)**.

This indicates that Arelion acts as a central hub or "Transit AS" for these connections, effectively bridging the source networks to our target.

3.2 3.2 Interconnection Map

Based on the traceroute data, we have mapped the neighbors as follows:

Focus AS	Identified Neighbor	Relationship Type
Cogent (AS174)	Arelion (AS1299)	Transit to Target
NTT (AS2914)	Arelion (AS1299)	Transit to Target
Bouygues (AS5410)	Hurricane Electric (AS6939)	Direct Peering
Arelion (AS1299)	Hurricane Electric (AS6939)	Direct Connection

Table 2: Neighbor relationships identified from trace paths.

Conclusion: The topology relies heavily on AS1299 (Arelion) to interconnect geographically diverse networks (Asia and North America) with the target, while the local network (Bouygues) bypasses this transit node via a direct peering link at an Internet Exchange Point (FranceIX).

4 Exercise 4: Possible Paths

4.1 4.1 Analysis of Path Diversity

In our experiment, we observed stable paths primarily utilizing Arelion (AS1299). However, if we were to view the full BGP routing table (Looking Glass "show ip bgp" command), we would likely see multiple potential paths to the target.

Conclusion: The path visible in a traceroute is merely the "Best Path" currently selected by the router. The existence of multiple potential paths ensures **redundancy**. If the primary link to Arelion were to fail, BGP would automatically withdraw that route and install a backup path from the routing table, ensuring the target remains reachable without manual intervention.

4.2 4.2 Factors Influencing Path Selection

The lab asks what factors typically influence the selection of one path over others. Unlike protocols that select based on speed (latency), BGP selects paths based on **Policy**. The decision process generally follows this hierarchy:

1. **Business Relationships (Money):**
   - *Customer > Peer > Provider.*
   - ASes prefer routes that generate revenue (Customers) over routes that cost money (Providers).
2. **Local Preference:** Administrators can manually assign a high `Local_Pref` value to a specific route to force outbound traffic over a preferred link (e.g., a high-bandwidth fiber link) regardless of other factors.
3. **AS Path Length:** If policies are equal, BGP defaults to the "Shortest Path" rule, preferring the route with the fewest number of AS hops to reach the destination.
4. **Hot-Potato Routing:** When multiple exit points to the same destination exist, an AS will often choose the exit point physically closest to the source router (lowest IGP metric) to offload traffic from its internal network as quickly as possible.