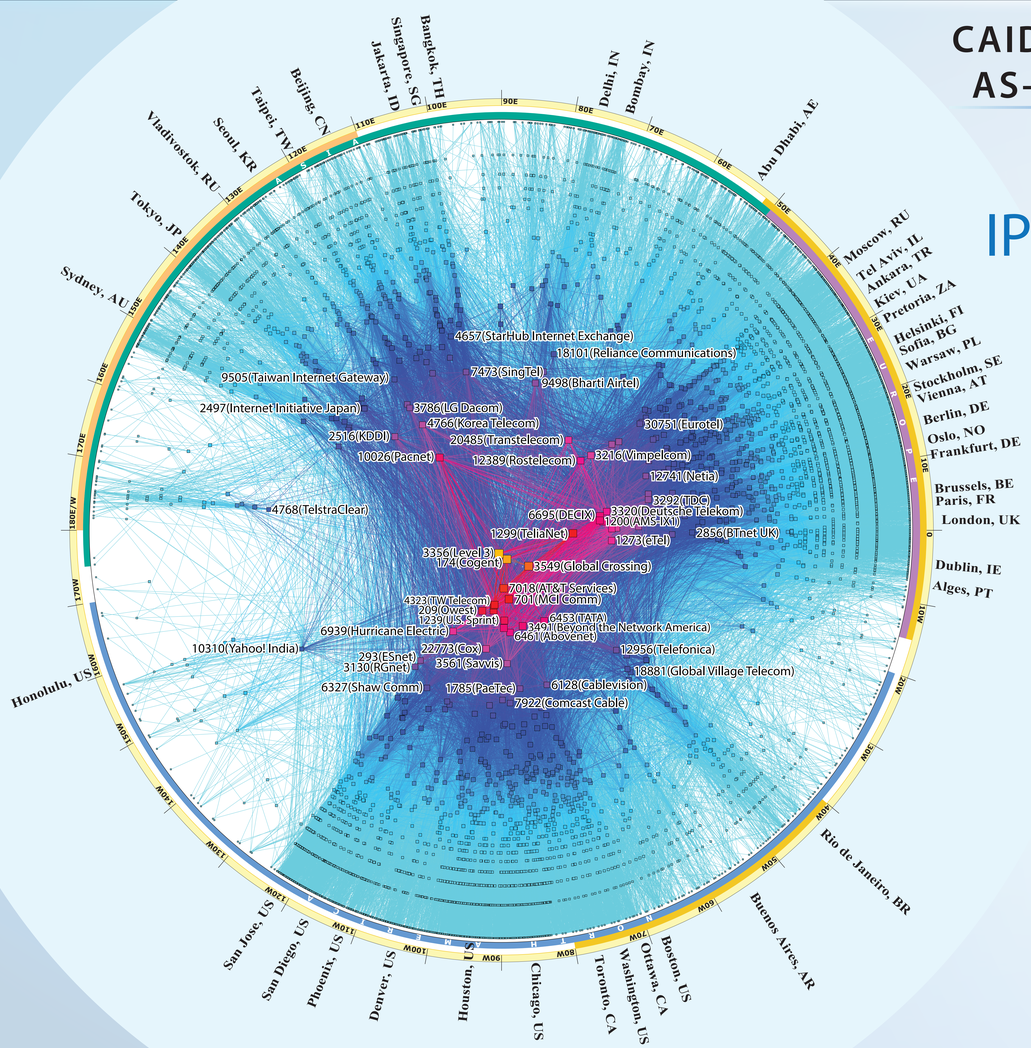
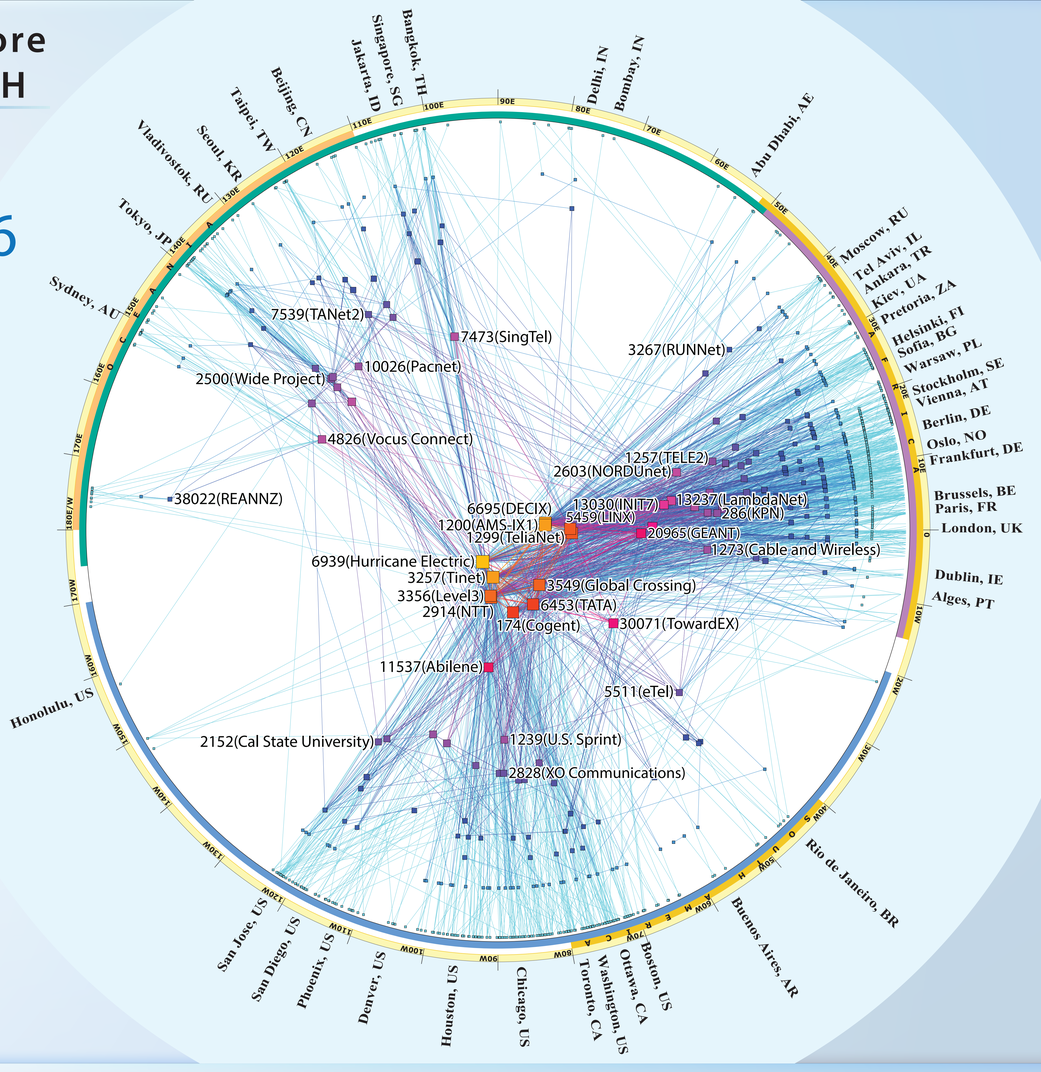
# CAIDA'S IPv4 & IPv6 AS Core AS-level INTERNET GRAPH

## Archipelago April 2011




Peering OutDegree:

| | |
|---|---|
| 3208 | 184 |
| 2887 | 165 |
| 2566 | 147 |
| 2245 | 128 |
| 1924 | 110 |
| 1604 | 92 |
| 1283 | 73 |
| 962 | 55 |
| 641 | 36 |
| 320 | 18 |
| 0 | 0 |




This visualization represents macroscopic snapshots of IPv4 and IPv6 Internet topology samples captured in 2011. The plotting method illustrates both the extensive geographical scope as well as rich interconnectivity of nodes participating in the global Internet routing system.

For the IPv4 map, CAIDA collected data from 54 monitors located in 29 countries on 6 continents. Coordinated by our active measurement infrastructure, Archipelago (Ark[1]), the monitors probed paths toward 207 million /24 networks that cover 93.3% of the routable prefixes seen in the Route Views[2] Border Gateway Protocol (BGP) routing tables on 1 April 2011.

For the IPv6 map, CAIDA collected data from 16 IPv6-connected Ark monitors located in 12 countries on 4 continents. This subset of monitors probed paths toward 307,000 IPv6 prefixes which represent 71.9% of the globally routed IPv6 prefixes seen in Route Views BGP tables on 1 April 2011.

We aggregate this IP-level data to construct IPv4 and IPv6 Internet connectivity graphs at the Autonomous System (AS) level. Each AS approximately corresponds to an Internet Service Provider (ISP). We map each observed IP address to the AS responsible for routing traffic to it, i.e., to the origin (end-of-path) AS for the IP prefix representing the best match for this address in BGP routing tables collected from Route Views.

[1]Ark: http://www.caida.org/projects/ark/
[2]Route Views: http://www.routeviews.org/

The position of each AS node is plotted in polar coordinates (radius, angle) calculated as follows:

$$\text{radius} = 1 - \log\left(\frac{\text{outdegree(AS)} + 1}{\text{maximum.outdegree} + 1}\right)$$

$$\text{angle} = \left(\text{longitude of the AS's BGP prefixes in netacq}\right)$$

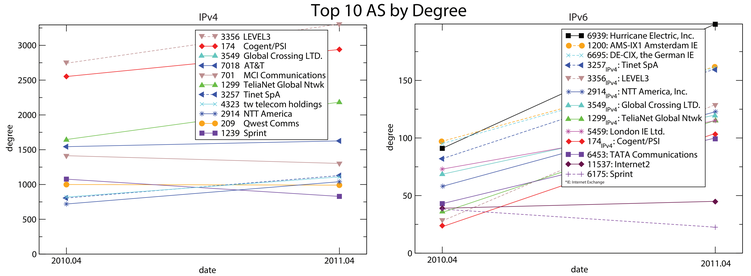
Our IPv6 graph grew from 677 AS nodes in January 2010 to 1,183 nodes in April 2011 (74% growth). Over the same period, the number of ASes in our IPv4 graph grew 14.0% from 28,175 to 29,315.

Most ASes grew their observed peering degree in both our IPv4 and IPv6 graphs, although at different rates, which alters their relative degree-based rank over time. In the IPv4 graph Level 3 (AS 3356) remained dominant with the largest observed degree in both 2010 and 2011. The ASes with the second, third, and fourth largest degrees (Cogent's AS 174, Global Crossing's AS 3549, and AT&T's AS 7018) also maintained their previously observed degree rank. While most ASes increased their degree over this period, the fifth most highly connected AS, Sprint's AS 1239, had its degree decline, dropping its rank to tenth. Note that we rank each AS independently; some network providers have topology spread across multiple ASes. A more accurate topology-based ranking of providers would require a validated list of AS ownership by organization, a data set we are still working to compile.

The observed IPv6 AS ranking experienced greater change. Hurricane's AS 6939 moved up from third place in 2010 to first place in 2011, not surprising given Hurricane's aggressive peering policy. AS 1200 (Amsterdam IX, an exchange point) dropped from first to second place. Internet's AS 11537 and Sprint's AS 6175 fell out of the top ten, and Sprint's AS 1299 and Cogent's AS 174 have moved into the top ten. In the case of the two Sprint ASes, 57% of AS 6175's dropped neighbors were never seen as neighbors of AS 1299, while 64% of AS 1299's new neighbors were never seen as neighbors of AS 6175. The prominence of a European exchange point and a U.S. research network in the observable IPv6 topology is a symptom of the immaturity of the IPv6 infrastructure. As IPv6 deployment progresses we expect increasing congruity between IPv4 and IPv6 topologies, a trend reflected in the increasing presence of the same top-ranked ASes (by degree) in the two peering graphs. This trend also implies increasing congruity in the North America, as the top-ranked ASes in the IPv4 graph increased their connectivity in the IPv6 graph.

In 2010, the top-ranked ASes in the IPv6 graph were mostly divided across North American and European ASes, but in our 2011 topology measurements the balance has shifted toward

### Top 10 AS by Degree





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| | Number of IP addresses | Number of IP links | Number of ASes | Number of AS links |
|---|---|---|---|---|
| IPv4 | 23,037,154 | 20,187,579 | 29,316 | 77,610 |
| IPv6 | 14,683 | 33,927 | 1,183 | 2,738 |


ARK HOSTS AARNet, Acreo, AMS-IX, APAN, ARIN, ASTI, CAIDA, Canarie, CENIC, CNRST, Colorado State Univ., DePaul Univ., Evolva Telecom, FORTH, FunkFeuer, HEANet, Hurricane Electric, Indonesian IPv6 Task Force, Internet Systems Consortium, Iowa State Univ., Kantonsschule, KREONet2, Level 3 Communications, Men and Mice, National Research Council Canada, NCAR, NIC Chile, NIC Mexico, NORDUnet, Northeastern Univ., Public Univ. of Navarra, Purdue Univ., Registro.br, RNP, Simula Research Laboratory, SURFnet, TKK, TWAREN, UCAD, Univ. Leipzig, Univ. Politècnica de Catalunya, Univ. of Cambridge, Univ. of Hawaii, Univ. Melbourne, Univ. of Napoli, Univ. of Nevada at Reno, Univ. of Oregon, Univ. of Waikato, Univ. of Washington, Univ. of Zurich, US Army Research Lab

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