Cloud Provider Connectivity in the Flat Internet

Todd Arnold†, Jia He†, Weifan Jiang†, Matt Calder‡†, Italo Cunha§†, Vasileios Giotsas#, Ethan Katz-Bassett†
Evolving Internet Topology

- Traditional: Hierarchical
  - Tier-1 ISPs are global networks, and all other networks fall under at least one
  - Tier-2 ISPs are larger, regional networks
  - Tier-3 ISPs interconnect edge networks
  - Edge networks at the bottom
  - Networks pay higher tiers to transport their data (a.k.a. transit)
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Motivation and Goals

- Majority of Internet traffic now occurs over direct connections
- Impact of flattening is not captured by traditional approaches
  - Invisible to traditional vantage points
  - Existing metrics of importance (e.g., customer cone)
    - Do not reflect the rich peering interconnectivity of the flat Internet
    - Focus on how much transit an AS could provide rather than how much it does provide
- To understand this gap and capture the progress of Internet flattening
  - Uncover the missing links
  - Understand to what degree they enable the major cloud providers (Amazon, Google, IBM, and Microsoft) to bypass the traditional hierarchy
Methodology

AS topology graph from two sources

- CAIDA’s AS relationship dataset
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- Traceroutes from inside clouds
  - Used to identify directly connected neighbors to add to the topology
  - Map IP-to-ASN
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Validation

- Iterative process with feedback from both Microsoft and Google
- Worked with Microsoft while we refined our methodology
- Google’s feedback validated our refinements
- Microsoft: 11% FDR, 21% FNR, 3,565 neighbors
- Google: 15% FDR, similar FNR, 7,554 neighbors
- Amazon: 1,188 neighbors
- IBM: 2,747
Calculating Hierarchy-free Reachability

- Calculate reachability propagating announcements through customers and peers, but not
  - Cloud’s providers
  - Tier-1 ISPs
  - Tier-2 ISPs

- Reachability
  - If AS B receives a prefix announcement from the cloud, AS B is reachable by the cloud
  - Announcing AS called the *origin*
  - Uses augmented topology
  - Enforces common routing policies

- **Hierarchy-free Reachability**
  - Count of reachable ASes when using peer links and not the hierarchical Internet

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Legend

- **Transit**
- **Peer**
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Hierarchy-free Reachability Results

Takeaway
- Cloud providers have higher reachability than most networks, including the Tier 1 and Tier 2 ISPs.
- They are able to reach the majority of networks even when bypassing their transit providers, Tier 1 ISPs, and Tier 2 ISPs.
- Thousands of networks benefit from flattening.

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## Table: Reachability (%) by Network

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Conclusions

● Emulated connectivity using an AS-level topology graph constructed from:
  ○ BGP data
  ○ Traceroutes
  ○ Validated cloud neighbor lists

● Hierarchy-free Reachability quantifies the extent of Internet flattening and how little networks rely on the Internet hierarchy.

● Show that thousands of networks benefit from flattening:
  ○ Other metrics do not capture these insights
  ○ The cloud providers rely less on the hierarchy than most other networks