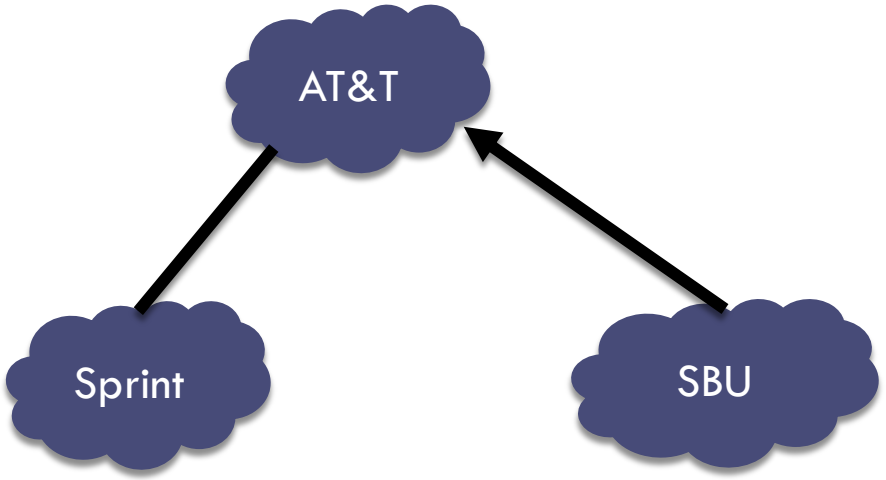
TDTS21: Advanced Networking

Lecture 7: Internet topology

Based on slides from P. Gill and D. Choffnes
Revised 2015 by N. Carlsson

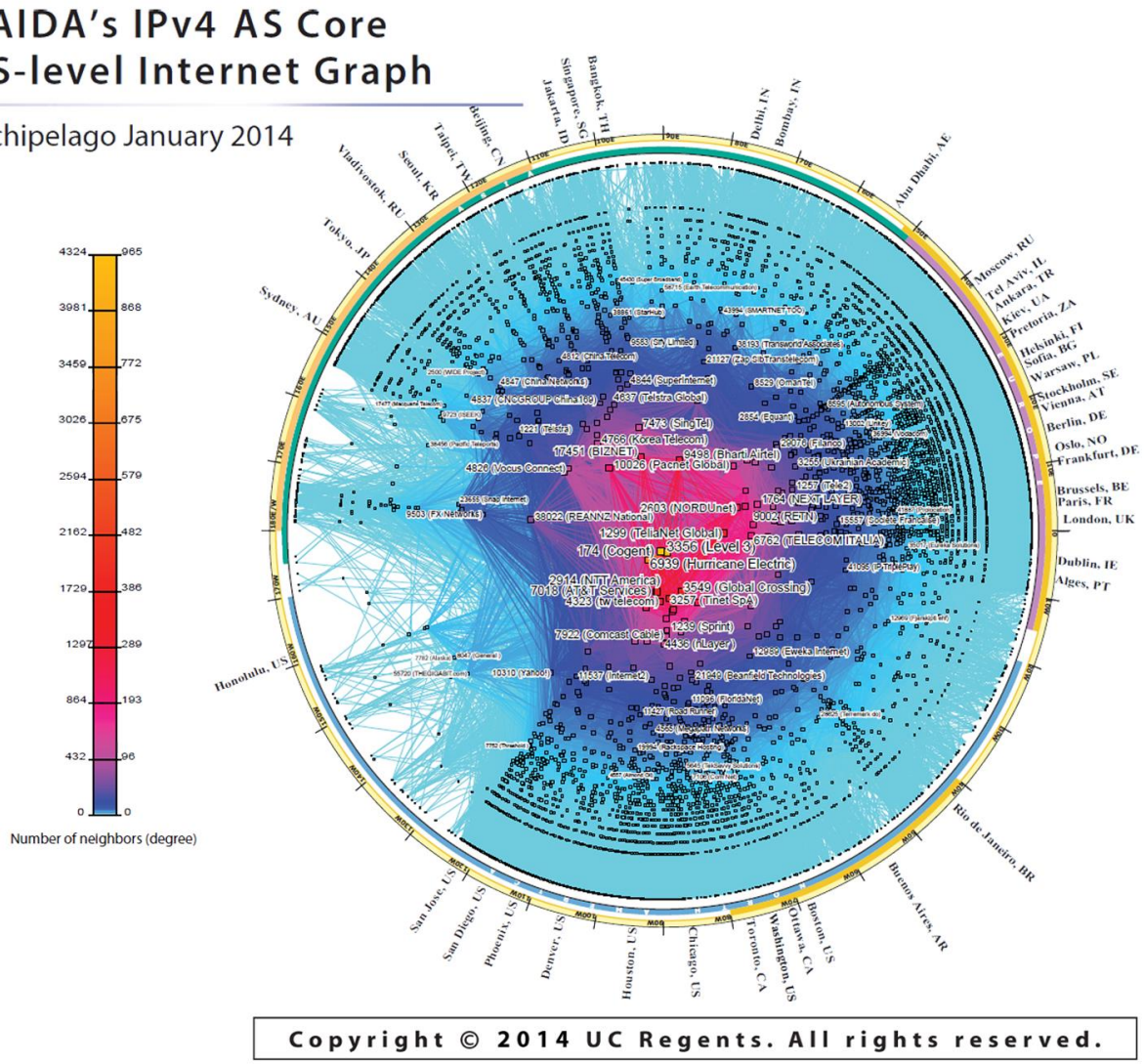
Measuring the Internet's topology

- What do we mean by topology?
  - Internet as graph
  - Edges? Nodes?
  - Node = Autonomous System (AS); edge = connection.
- Edges labeled with business relationship
- Customer → Provider
- Peer -- Peer



The outputs ….

15412 12041 p2c
15412 12486 p2c
15412 12880 p2c
15412 13810 p2c
15412 15802 p2c
15412 17408 p2c
15412 17554 p2c
15412 17709 p2c
15412 18101 p2c
15412 19806 p2c
15412 19809 p2c
15413…

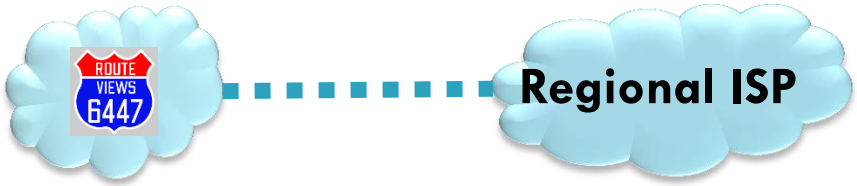


So how do we measure this graph?

- Passive approach: BGP route monitors
  - Coverage of the topology
  - Amount of visibility provided by each neighbor
- Active approach: Traceroute
  - From where?
  - Traceroute gives series of IP addresses not ASes
- Active approach: TransitPortal
  - Much more control over what we see
  - …scalability/coverage?

Passive approach: BGP Route Monitors

- Receive BGP announcements from participating ASes at multiple vantage points



www.routeviews.org

"originally motivated by interest on the part of operators in determining how the global routing system viewed their prefixes and/or AS space"

www.routeviews.org

Going from BGP Updates to a Topology

- Example update:
- TIME: 03/22/11 12:10:45
- FROM: 12.0.1.63 AS7018
- TO: 128.223.51.102 AS6447
- ASPATH: 7018 4134 9318 32934 32934 32934
- 69.171.224.0/20

AT&T (AS7018) it telling Routeviews (AS 6447) about this route.

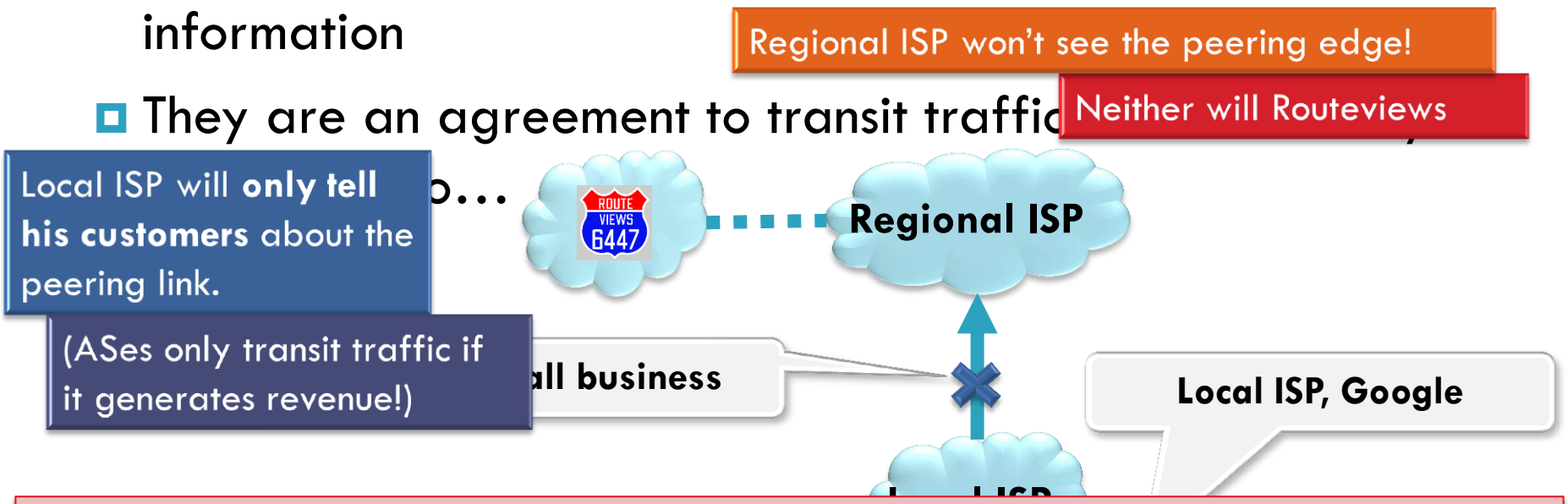
This /20 prefix can be reached via the above path

Going from BGP Updates to a Topology

- Key idea
  - The business relationships determine the routing policies
  - The routing policies determine the paths that are chosen
  - So, look at the chosen paths and infer the policies
- Example: AS path "7018 4134 9318" implies
  - AS 4134 allows AS 7018 to reach AS 9318
  - China Telecom allows AT&T to reach Hanaro Telecom
  - Each "triple" tells something about transit service

Why are peering links hard to see?

- **The challenge:**
  - BGP announcements ***do not reflect complete connectivity*** information
  - They are an agreement to transit traffic…

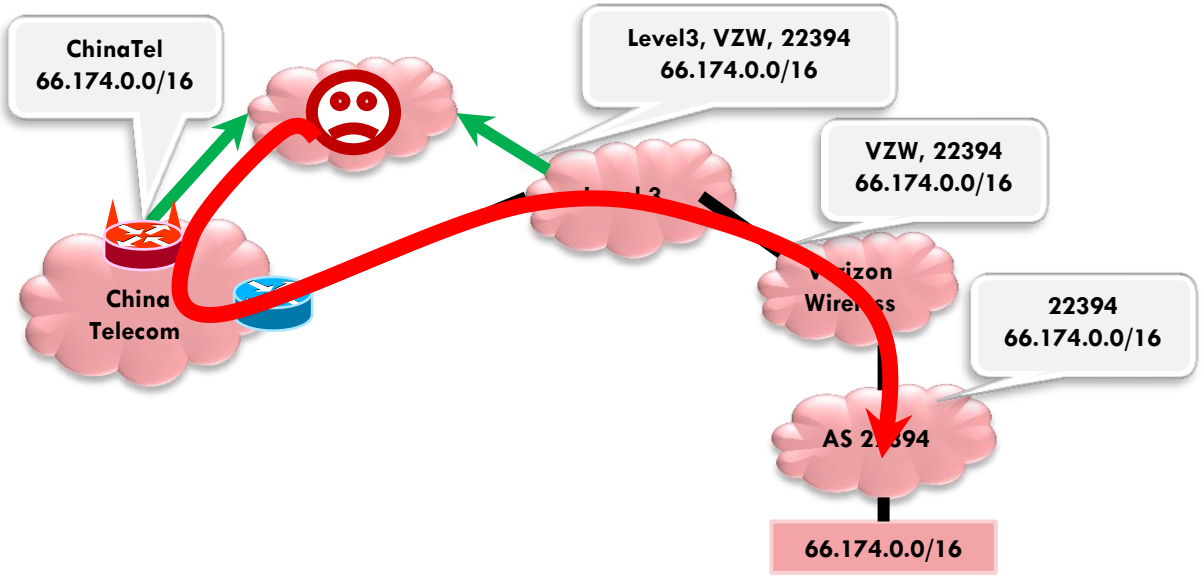


Combination of ***no valley routing policy*** and a ***lack of monitors in stub ASes*** mean missing **up to 90%** of peering links of content providers! (Oliveria et al. 2008)

Active approach: Traceroute

- Issu[illegible]ute
  - H[illegible]
- http[illegible]
  - C[illegible]
  - H[illegible]rsities)
- RIPI[illegible]
  - D[illegible]
  - C[illegible]
- Das[illegible]
  - Bittorrent plug in that does measurements
  - O(200) ASes with Dasu clients

Traceroute vs Announced Path



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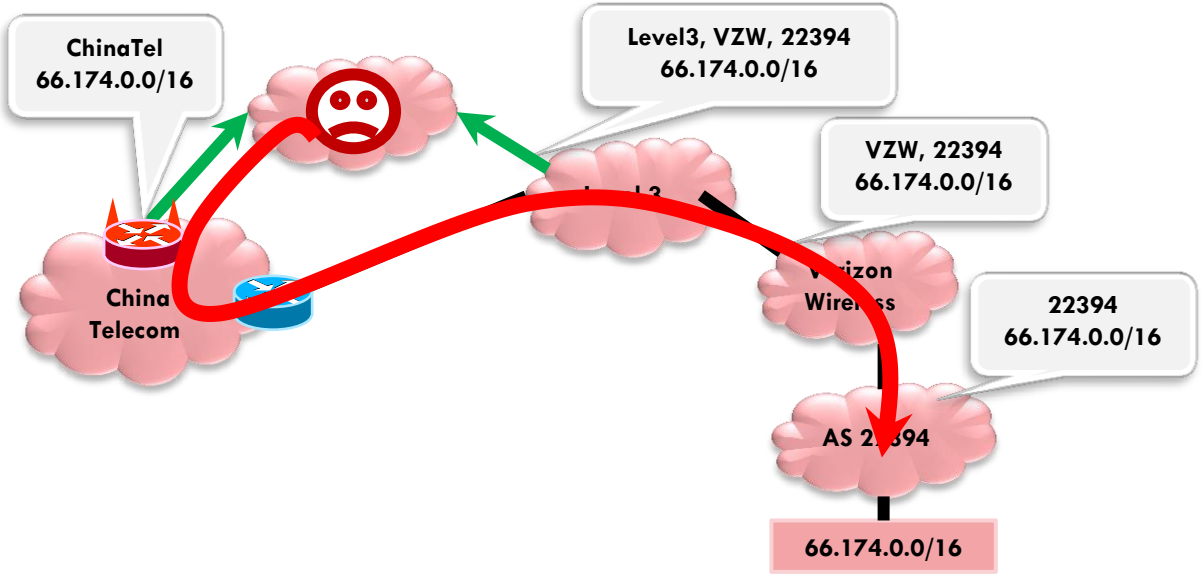
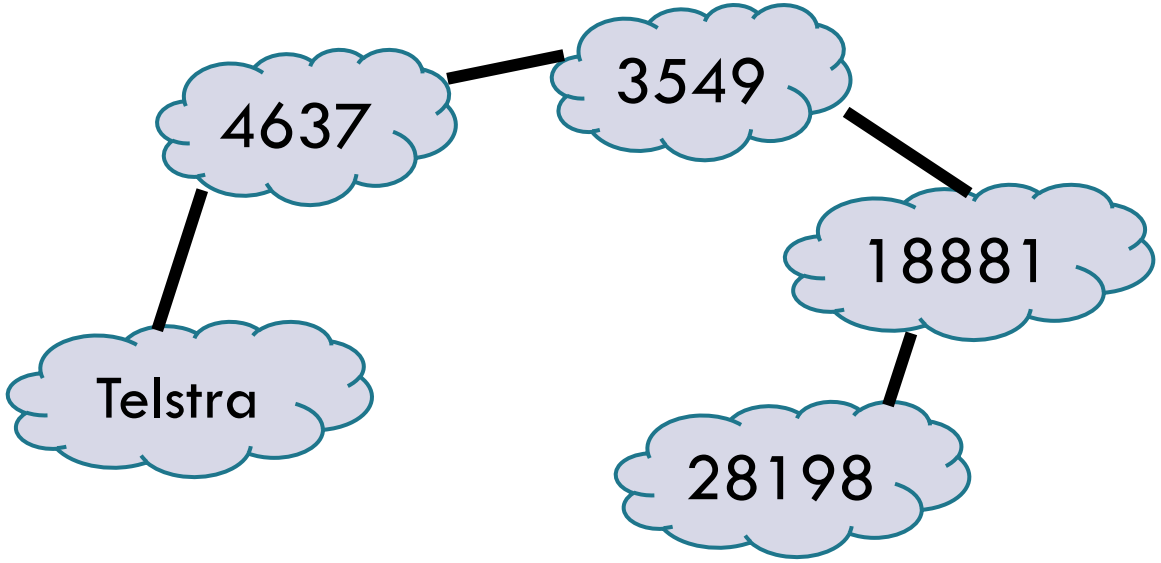


Interception typically results in differences between

- Announced AS-PATH
- Data path (traffic)

Policy checks if legit reason(s)

Traceroute vs Announced Path

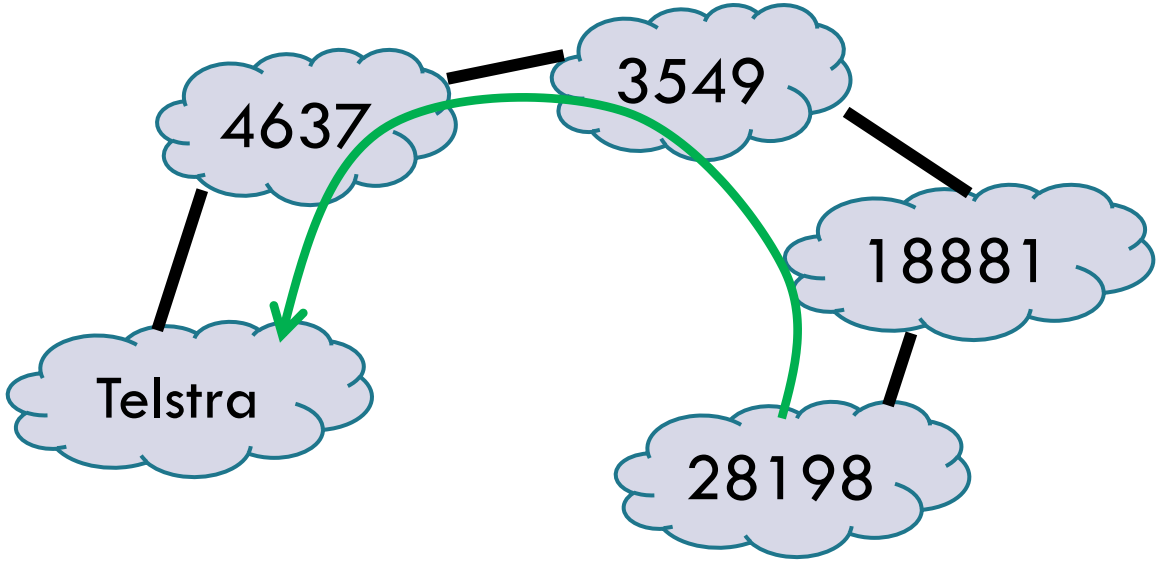


Sometimes differences

- Announced AS-PATH
- Data path (traffic)

Many legit reason(s)

Traceroute vs Announced Path



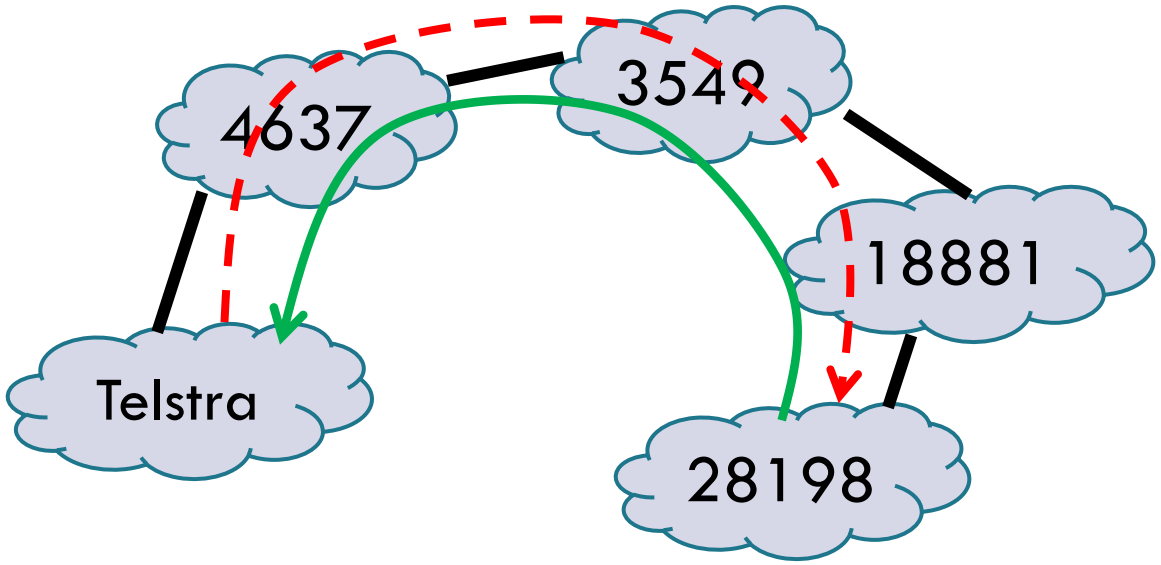
Sometimes differences

- Announced AS-PATH
- Data path (traffic)

Many legit reason(s)

AS-PATH: 177.52.48.0/21 | 1221 4637 3549 18881 28198

Traceroute vs Announced Path



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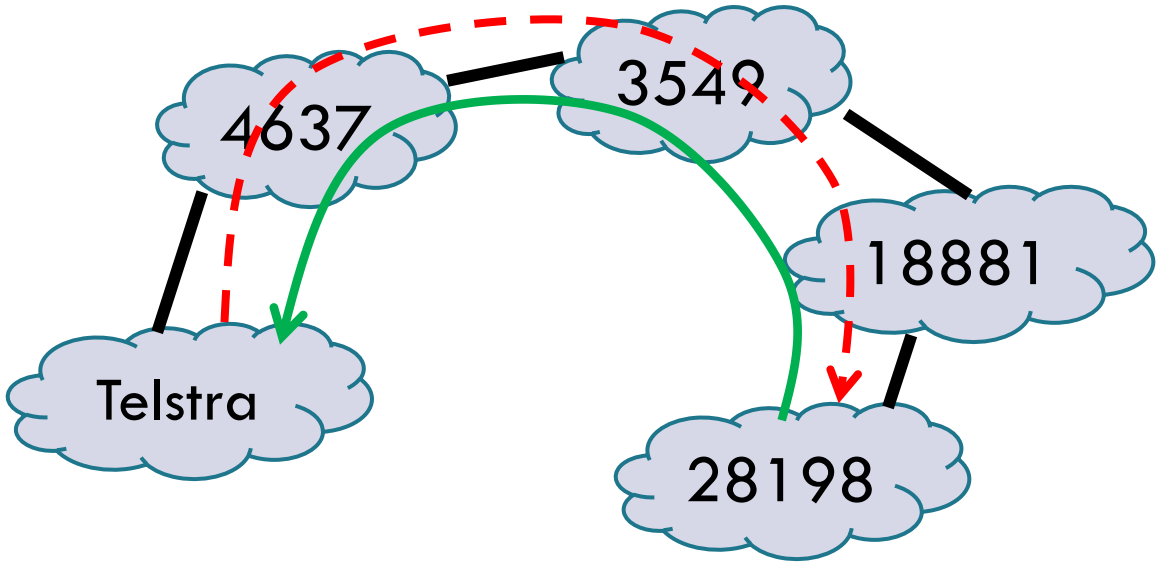

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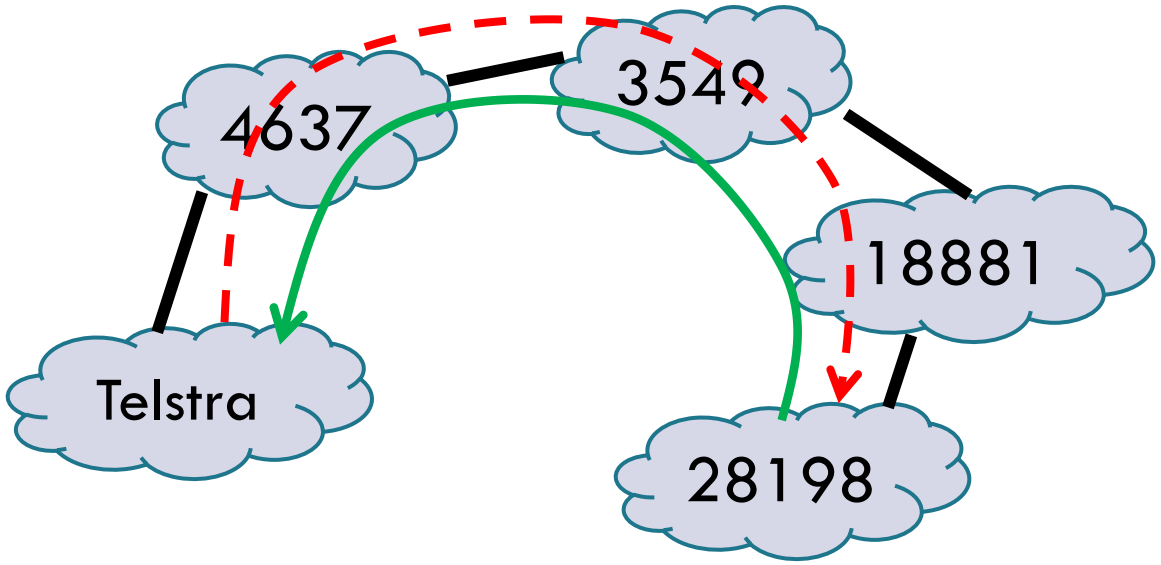
Traceroute:

```
... (initial hops)
9.  telstraglobal.net (134.159.63.202)  164.905 ms
10  impsat.net.br (189.125.6.194)  337.434 ms
11  spo.gvt.net.br (187.115.214.217)  332.926 ms
12  spo.gvt.net.br (189.59.248.109)  373.021 ms
13  host.gvt.net.br (189.59.249.245)  343.685 ms
```

Traceroute vs Announced Path



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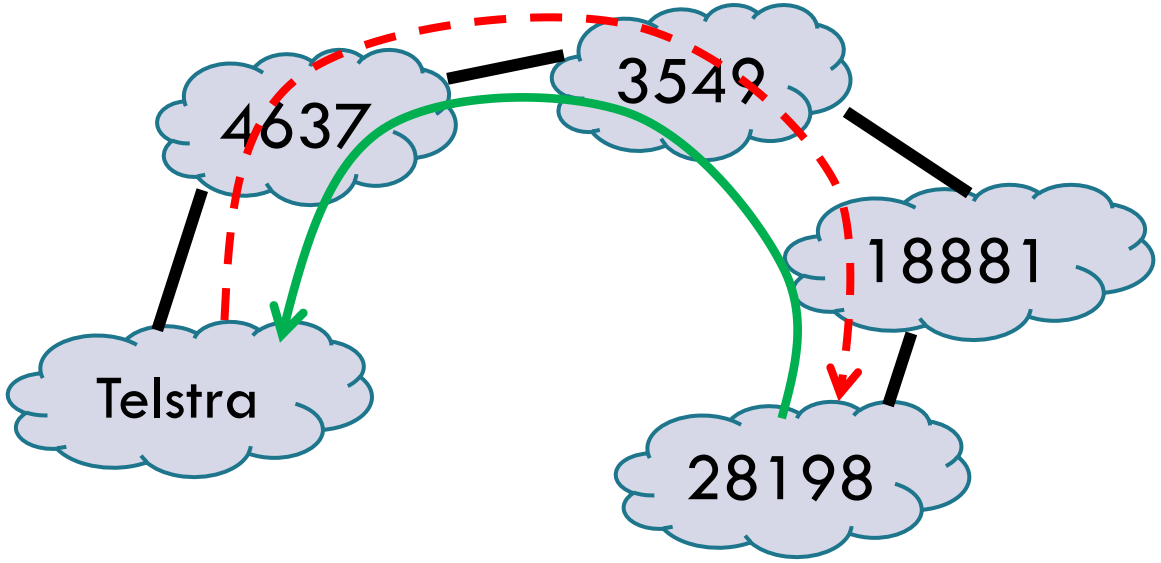
Traceroute vs Announced Path



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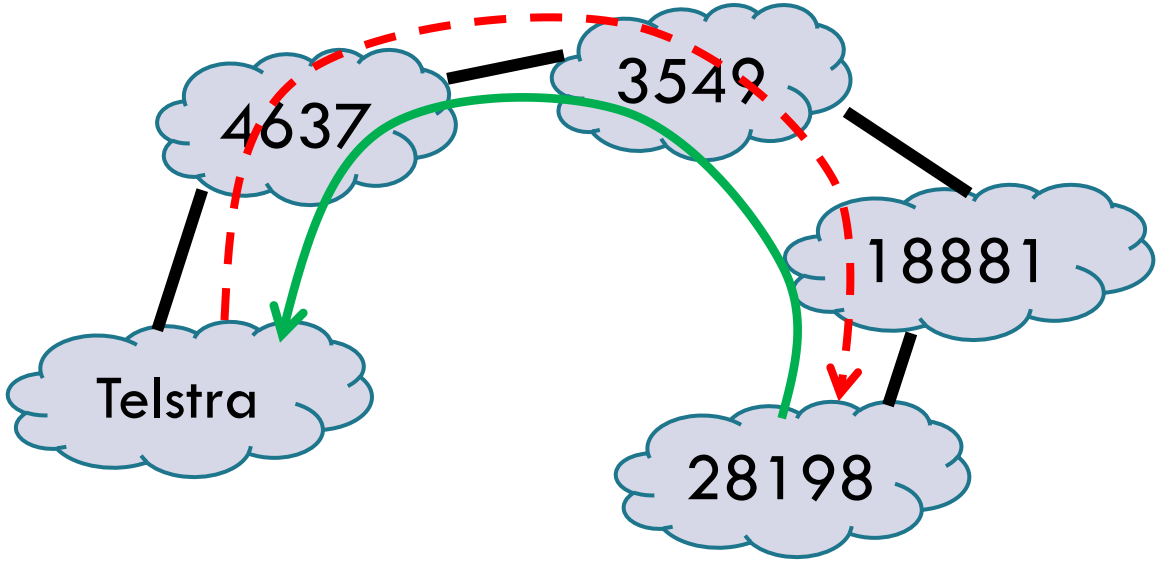
Traceroute-PATH: 1221 4637 3549 18881 28198

Traceroute vs Announced Path



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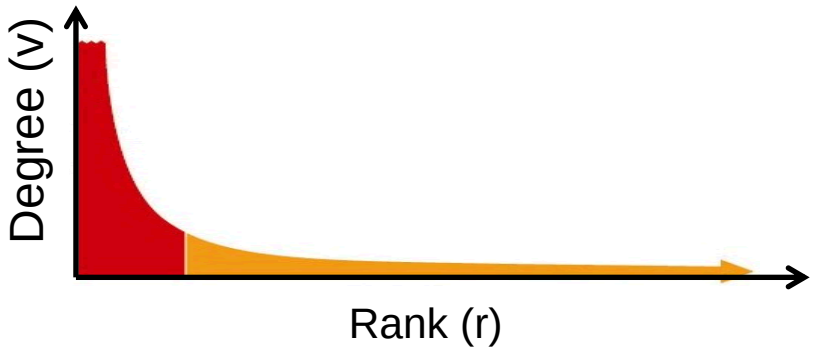
Traceroute-PATH: 1221 4637 3549 18881 28198

Zipf popularity...

... and long tails



$$v_r \propto r^{-\alpha}$$

Zipf popularity...

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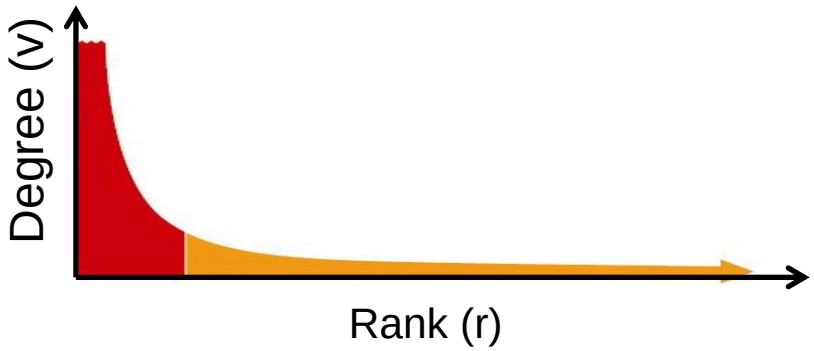

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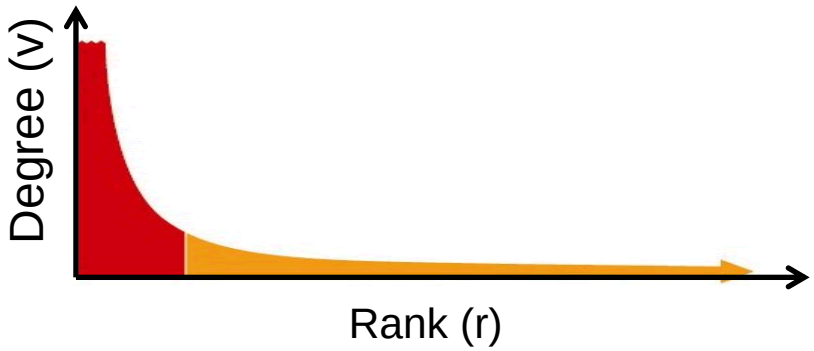

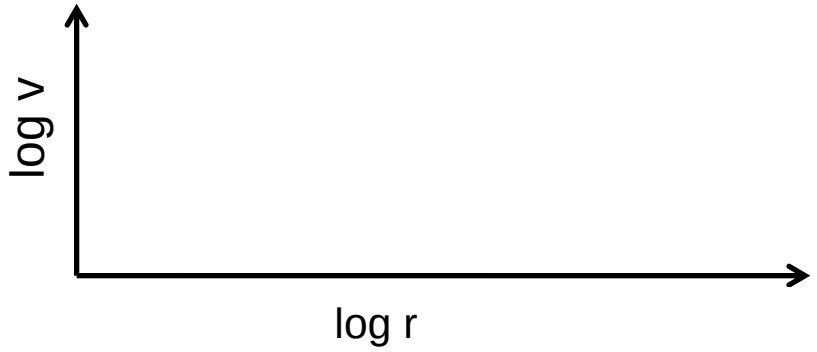

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$$\log v_r = \log v_1 - \alpha \log r$$

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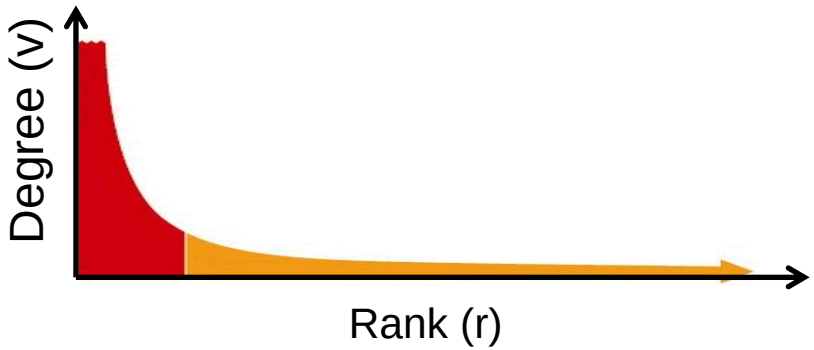

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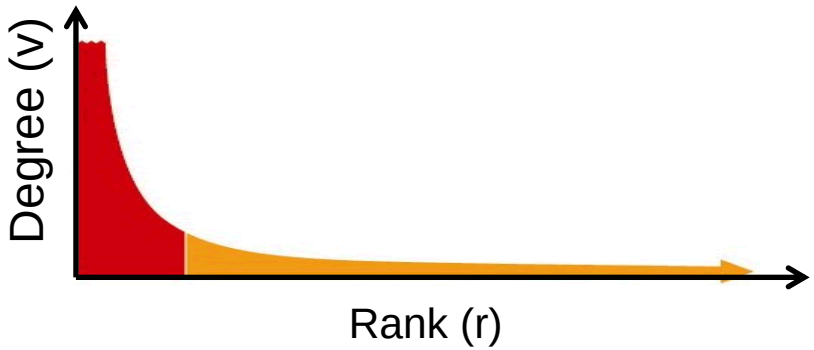

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y(x) = x_0 -- α x

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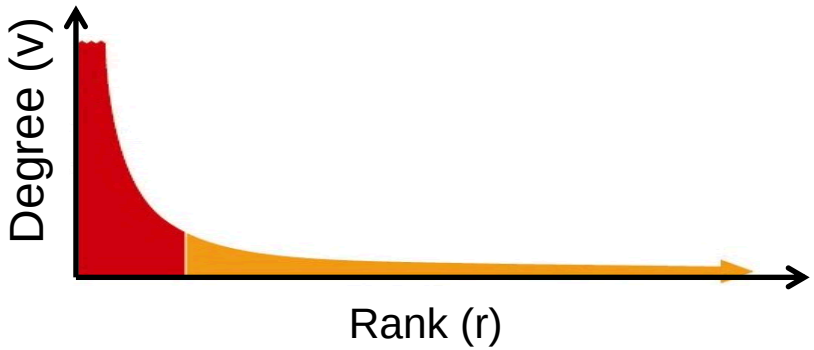

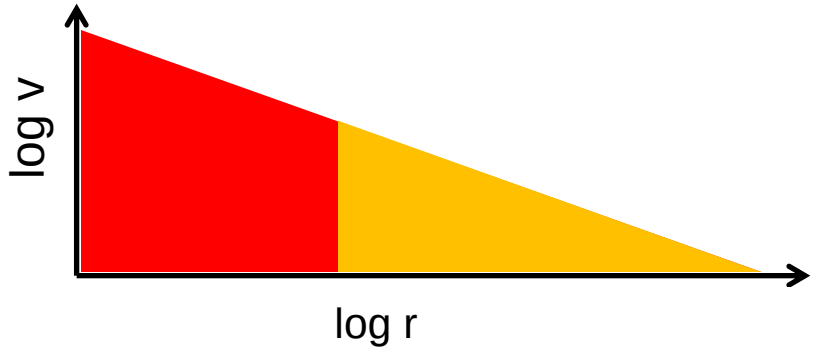

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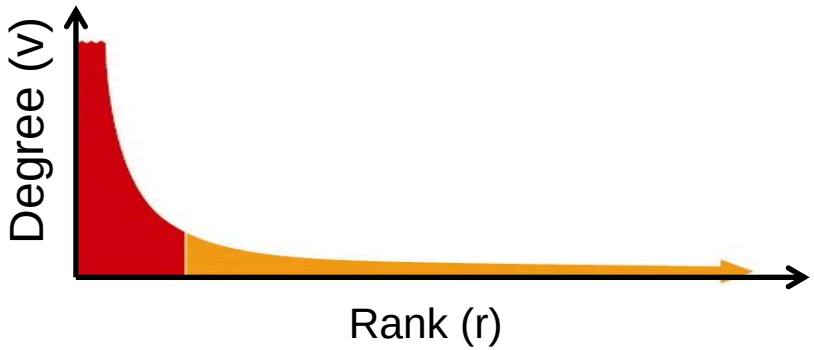

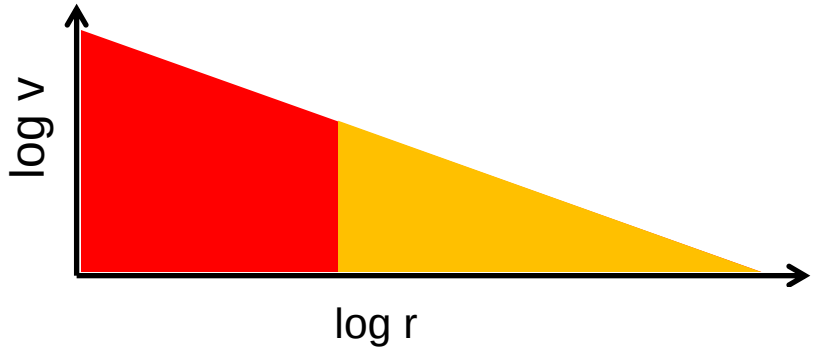

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Power law, Pareto, and Zipf

- Power-law, Pareto, Zipf (in some sense the same)
  - Power-law: $f(x) \sim x^{-\eta}$ (probability of value x)
  - Pareto: $F(x) = P[X > x] = \int f(x)\, dx \propto x^{-\kappa}$ (cumulative prob.)
  - Zipf: $v_r \propto r^{-\alpha}$ (discrete representation; frequency v_r of rank r)
  - Parameters related as: $\kappa = \eta - 1 = 1/\alpha$
    - E.g., paper and references therein: "A Tale of the Tails: Power-laws in Internet Measurements", IEEE Network, Mahanti et al., 2013

Heavy-tail distributions …

- "A probability distribution is said to have a heavy tail if the tail is not exponentially bounded"
- … and then there are many many other "heavy tail" distributions, variations and generalizations, including distributions such as log-normal, various generalized Zipf/Pareto distributions, etc.