AS-level traffic characteristics and their implications on traffic engineering

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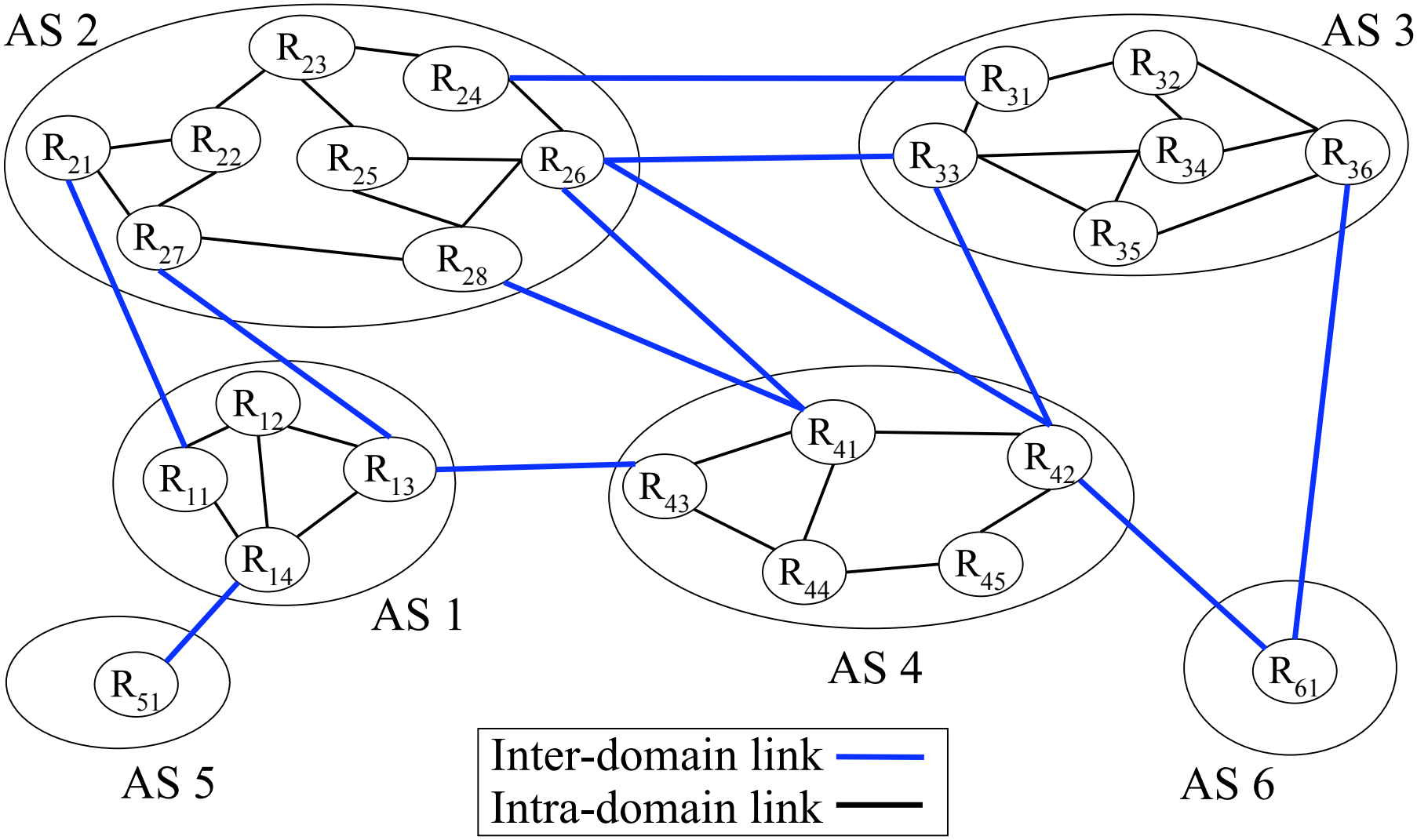
Agenda

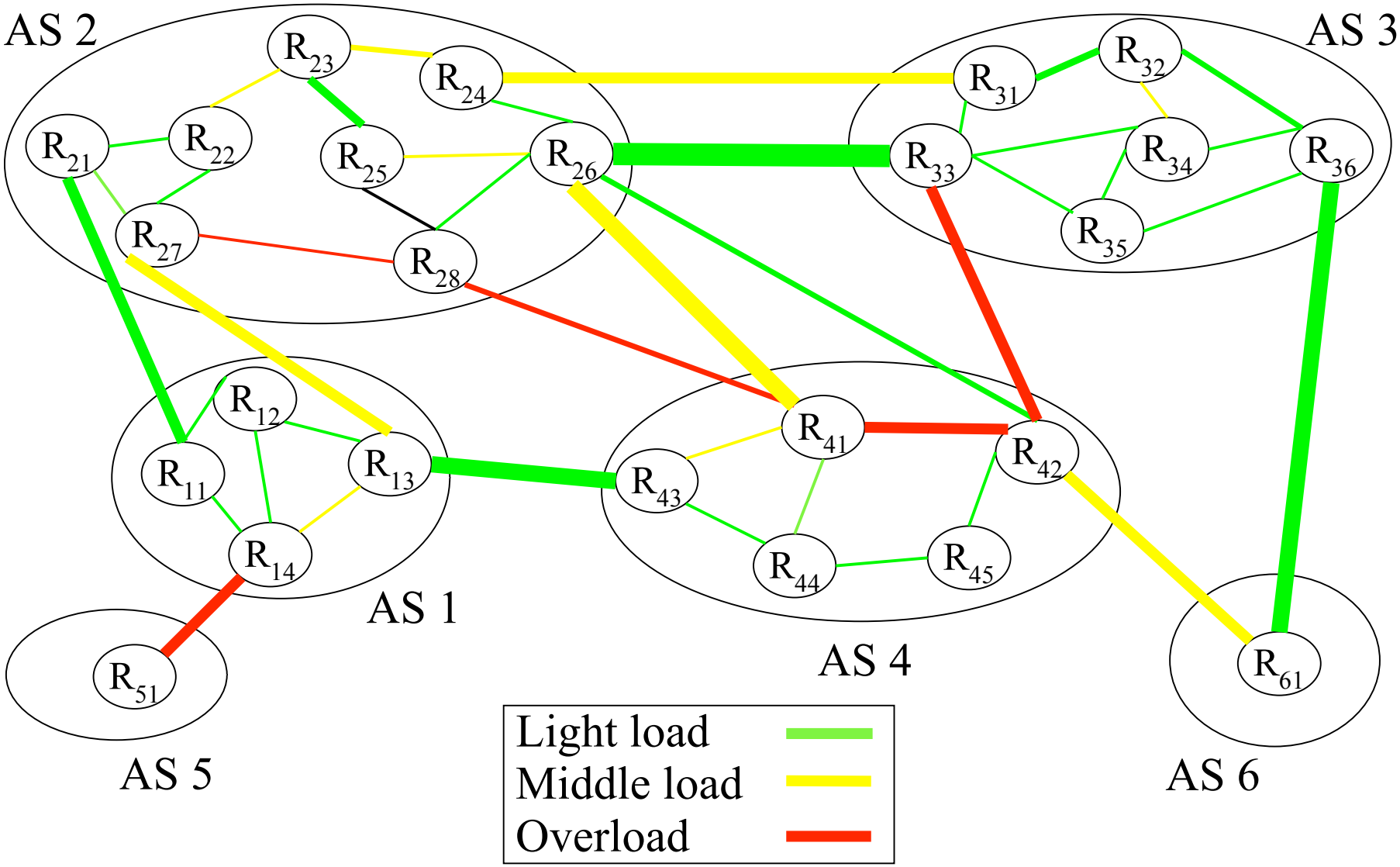
- AS-level topology
- Topological traffic distribution
- Topological traffic dynamics
- Towards Internet-wide topological traffic distribution
- Further work

AS-level topology

Routing viewpoint



Traffic viewpoint



AS-level topology

Some numbers :

- **20,000 ASs**
- **180,000 reachable networks**
- **86 % are stubs, 14 % transit ASs**
- **Hierarchical structure of the Internet :**
  - **core : 20 large transit ISPs**
  - **outer core : 3,000 smaller transit ISPs**
  - **edge : 17,000 stubs**

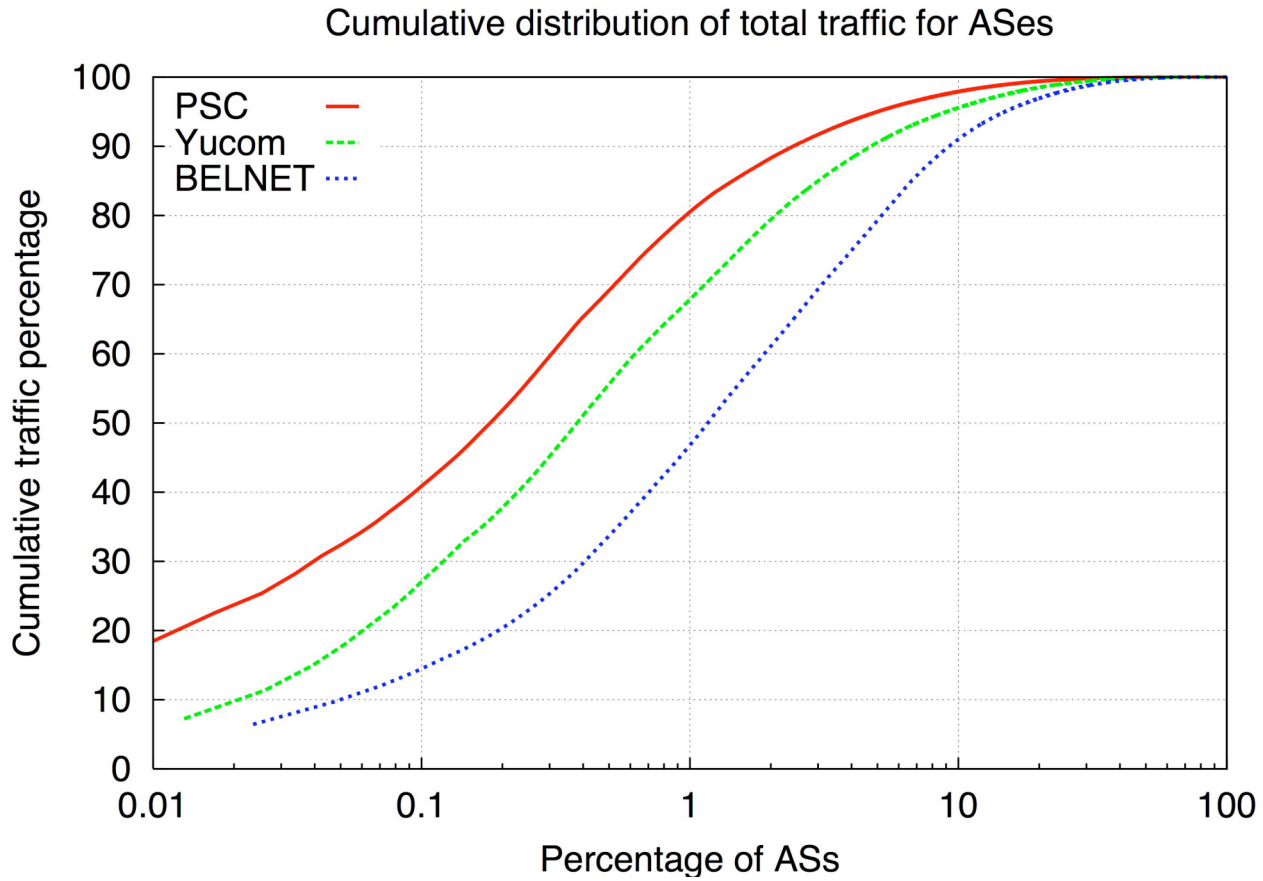
Topological traffic distribution

Topological traffic distribution

- With how many ASs does some AS exchange traffic ?
- How far away are ASs with whom most traffic is exchanged ?
- How much traffic aggregation is there on the interdomain topology ?

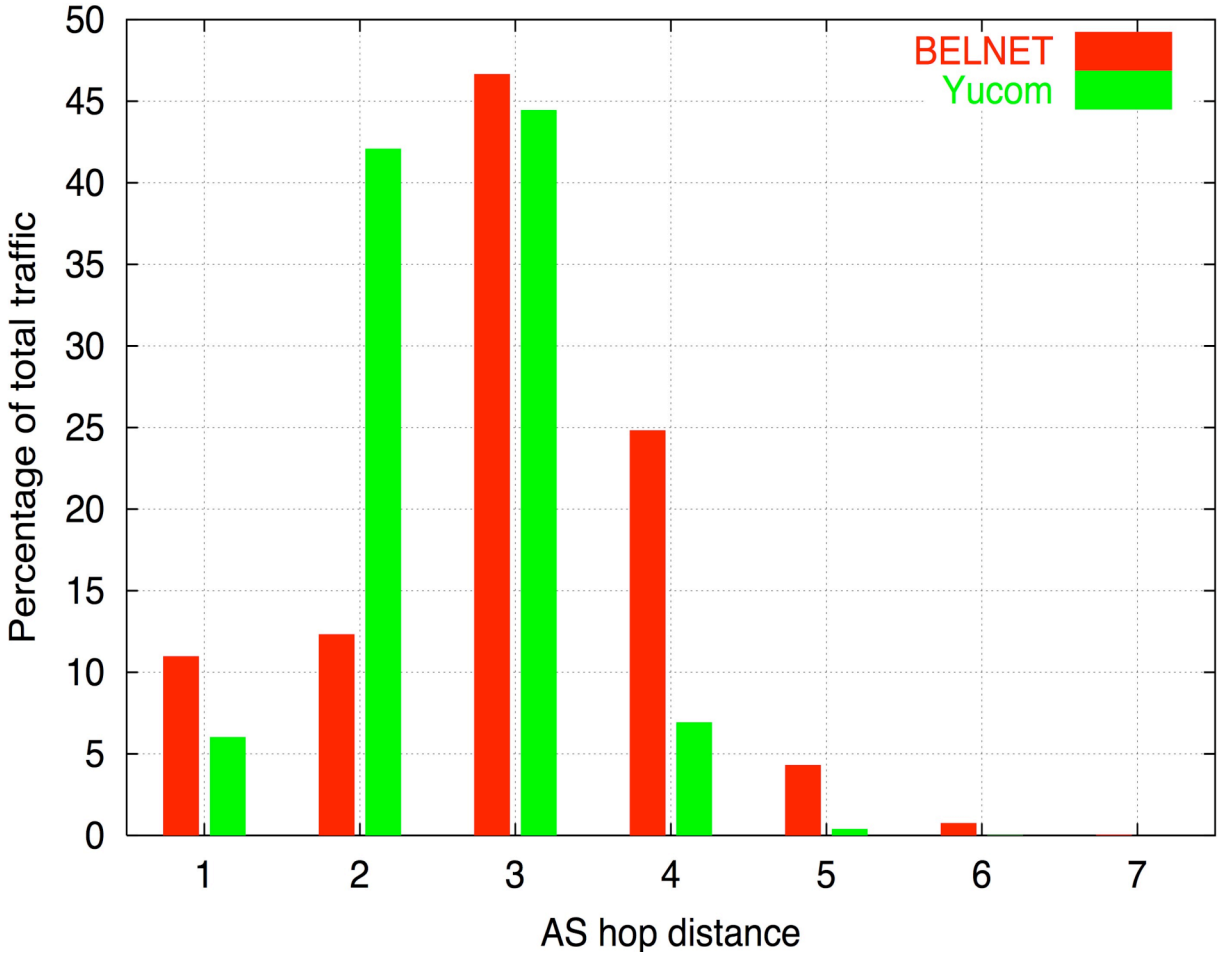
Topological traffic distribution

A limited fraction of ASs exchange traffic with a typical stub :



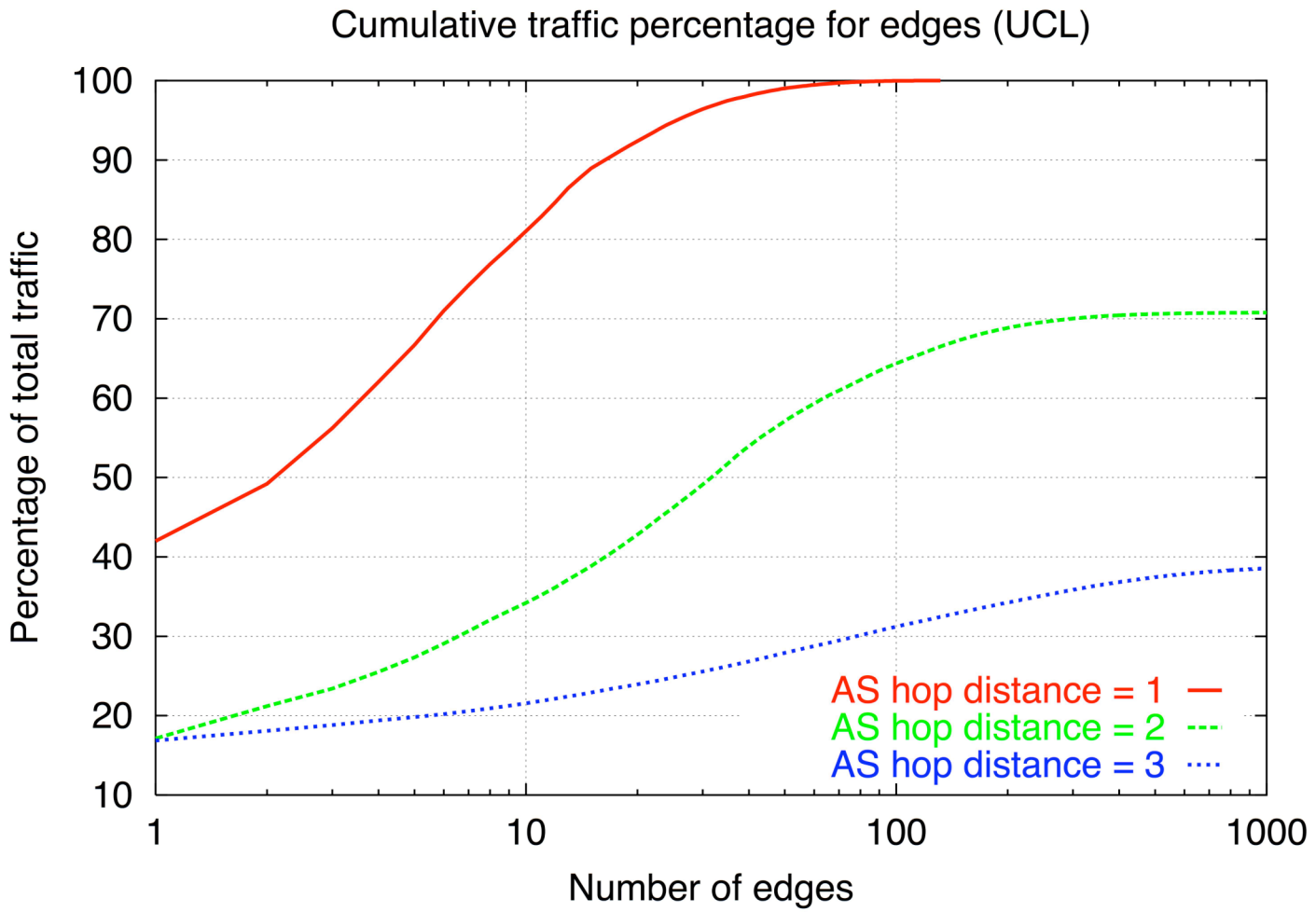
Topological traffic distribution

AS hop distance for traffic :



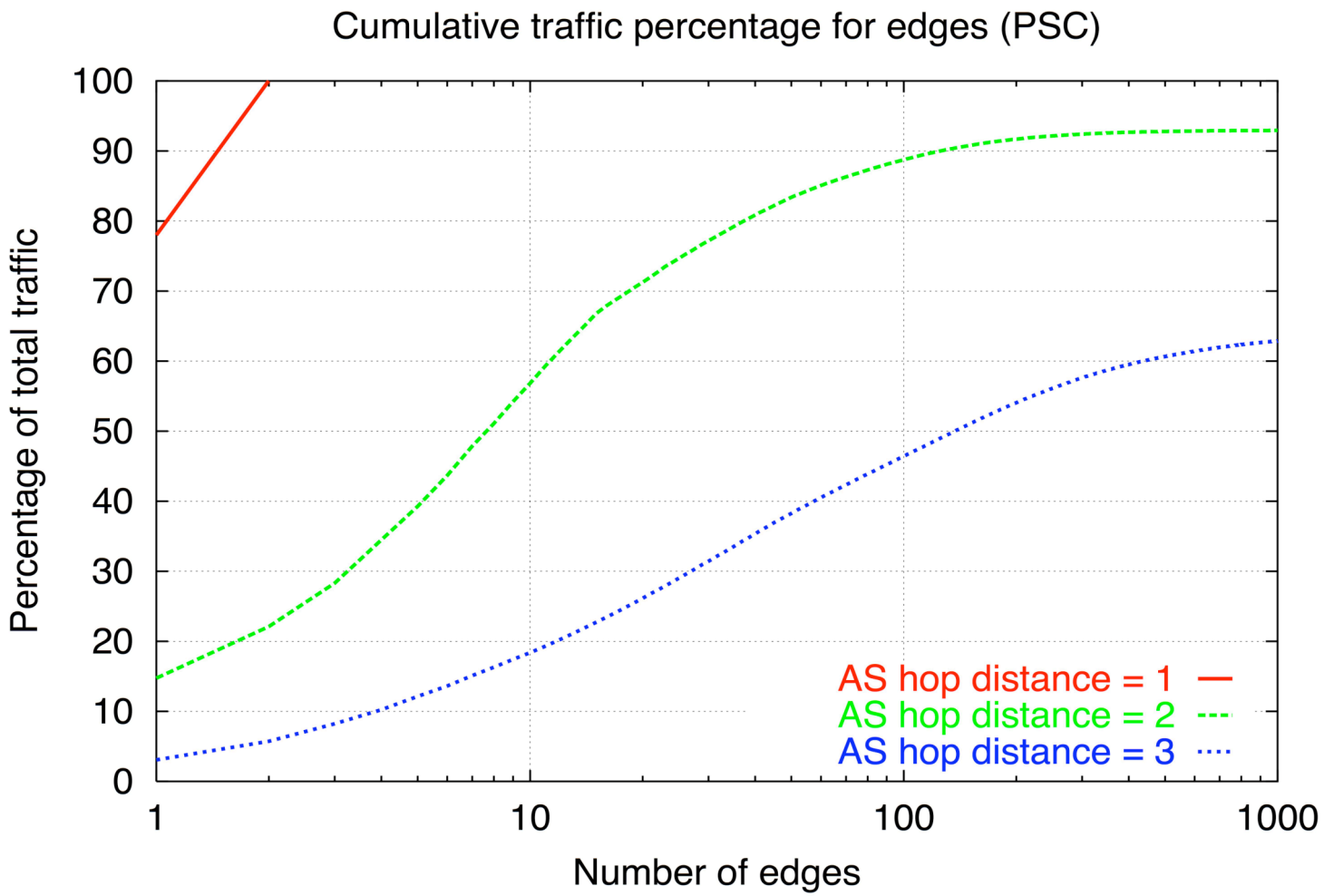
Topological traffic distribution

Lack of aggregation beyond peers :



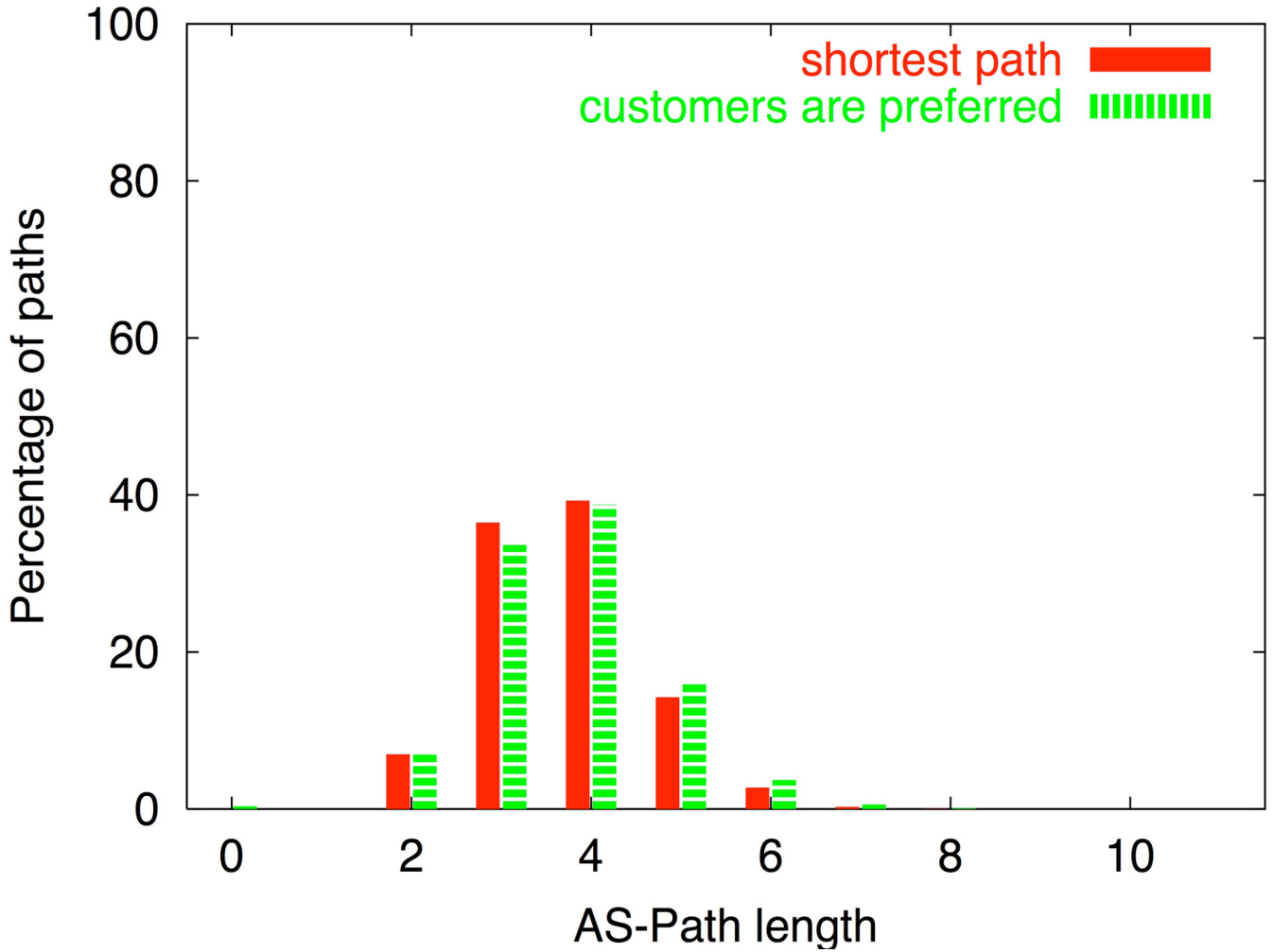
Topological traffic distribution

Aggregation depends on who you are :



Topological Traffic distribution

The Internet is shallow :



Topological traffic distribution

- A limited percentage of the AS-level topology sends/receives most of the traffic
- Most of the traffic exchanged with ASs located within a few AS hops
- Lack of traffic aggregation beyond peers
- Topological traffic distribution is a consequence of hierarchical structure of interdomain topology and business relationships : it won't change soon

Topological traffic distribution

Implications on traffic engineering:

- **A small percentage of traffic objects capture most of the traffic ⇒ no need to care about all the reachable sources/destinations**
- **Lack of aggregation ⇒ control is possible on direct peers only**
- **Shallowness of Internet ⇒ possible bypass of intermediate transits for popular destination (tunnels or physical peerings)**

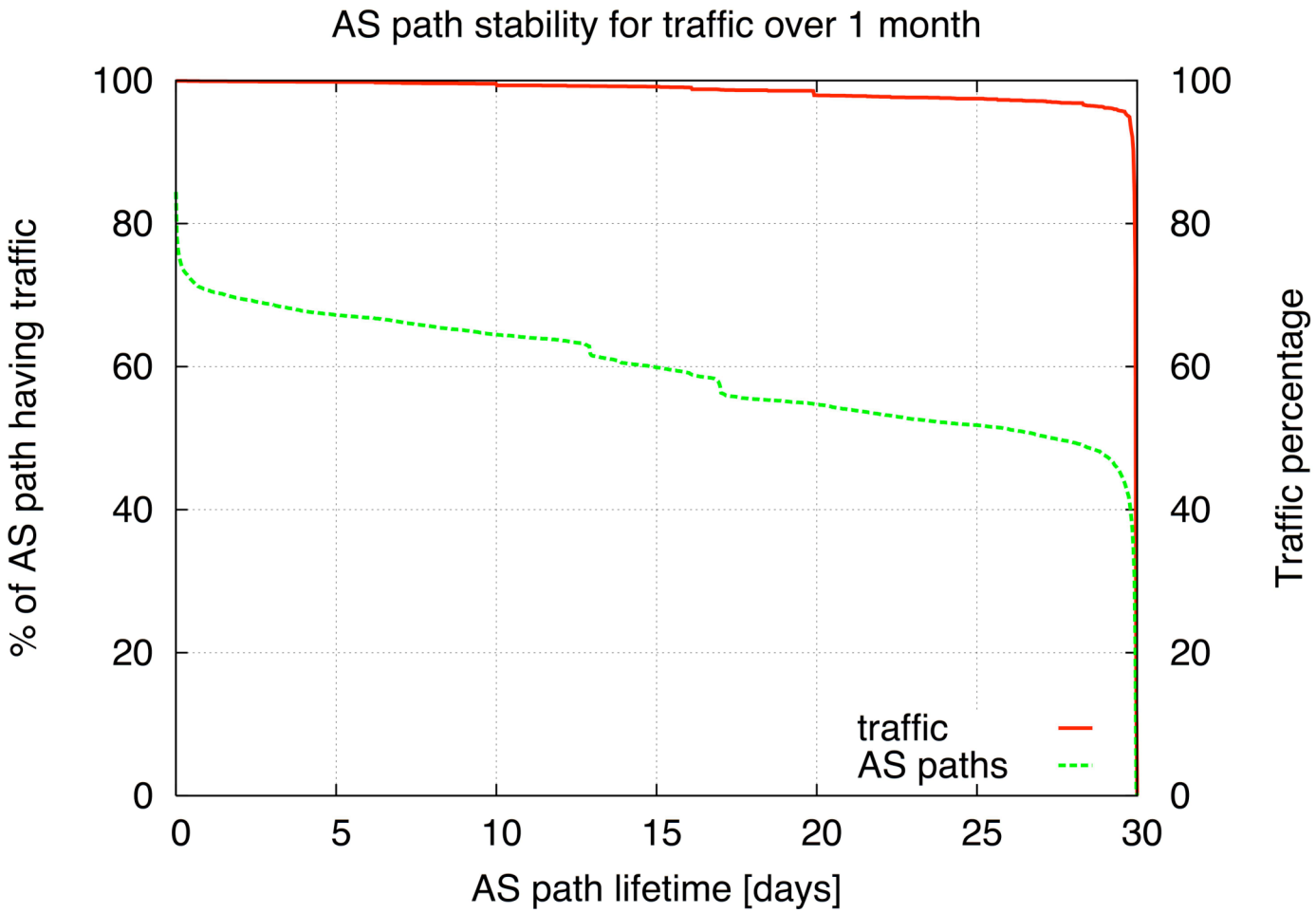
Topological traffic dynamics

Topological traffic dynamics

- **Previous results indicate that a small fraction of the ASs matter**
- **Is this static view representative of what happens over time?**

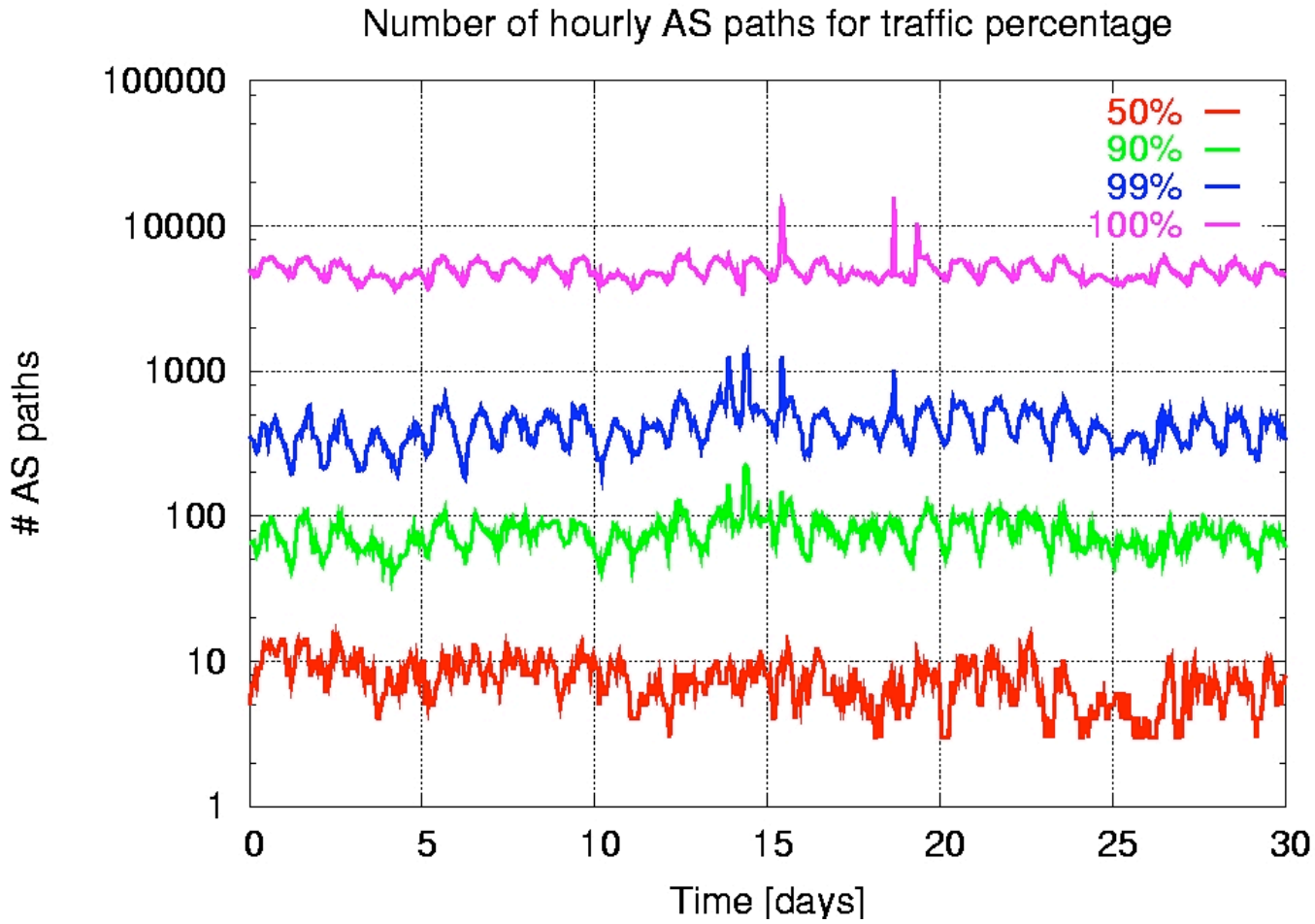
Topological traffic dynamics

Largest paths in traffic are stable :



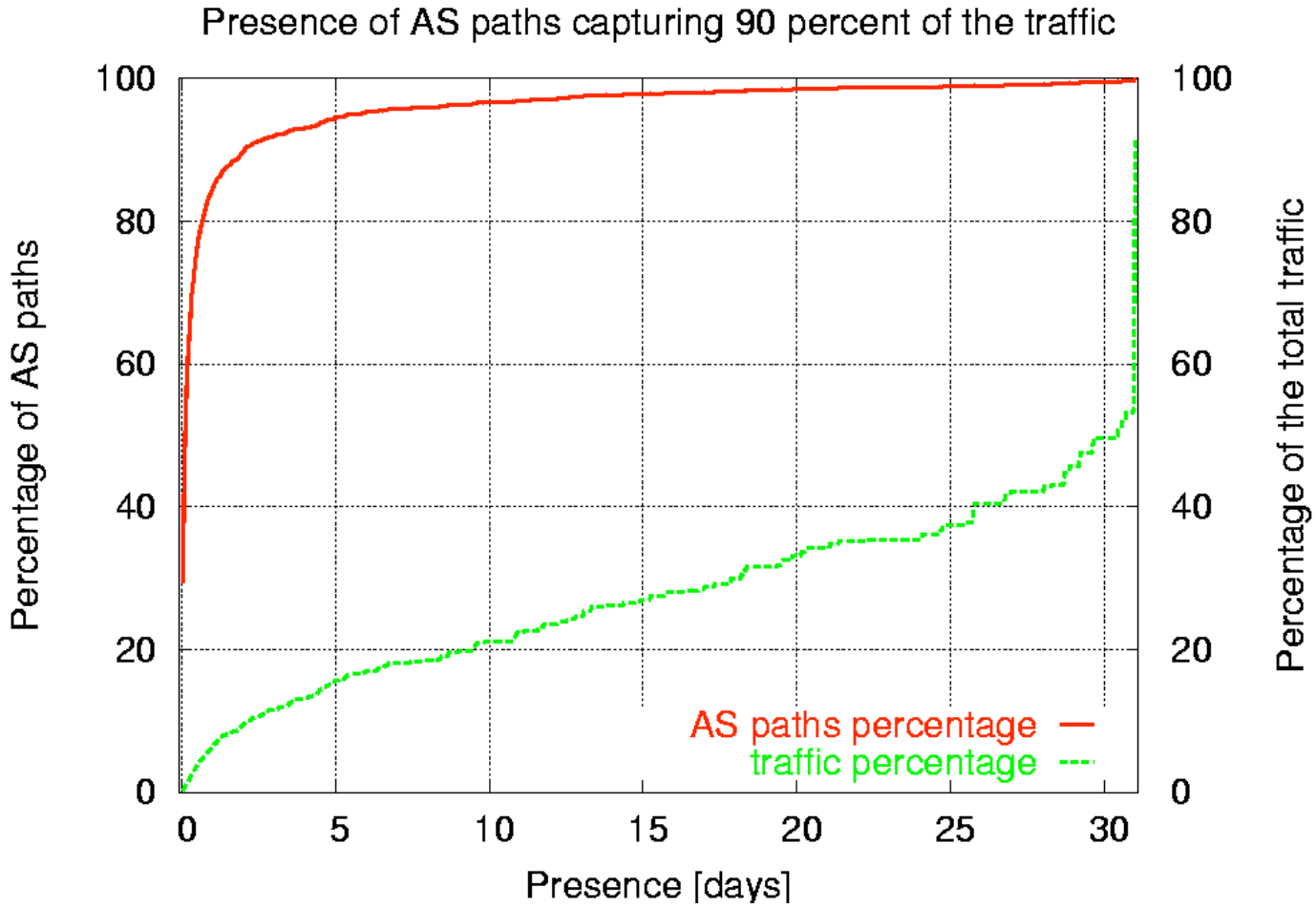
Topological traffic dynamics

Evolution of largest hourly paths :



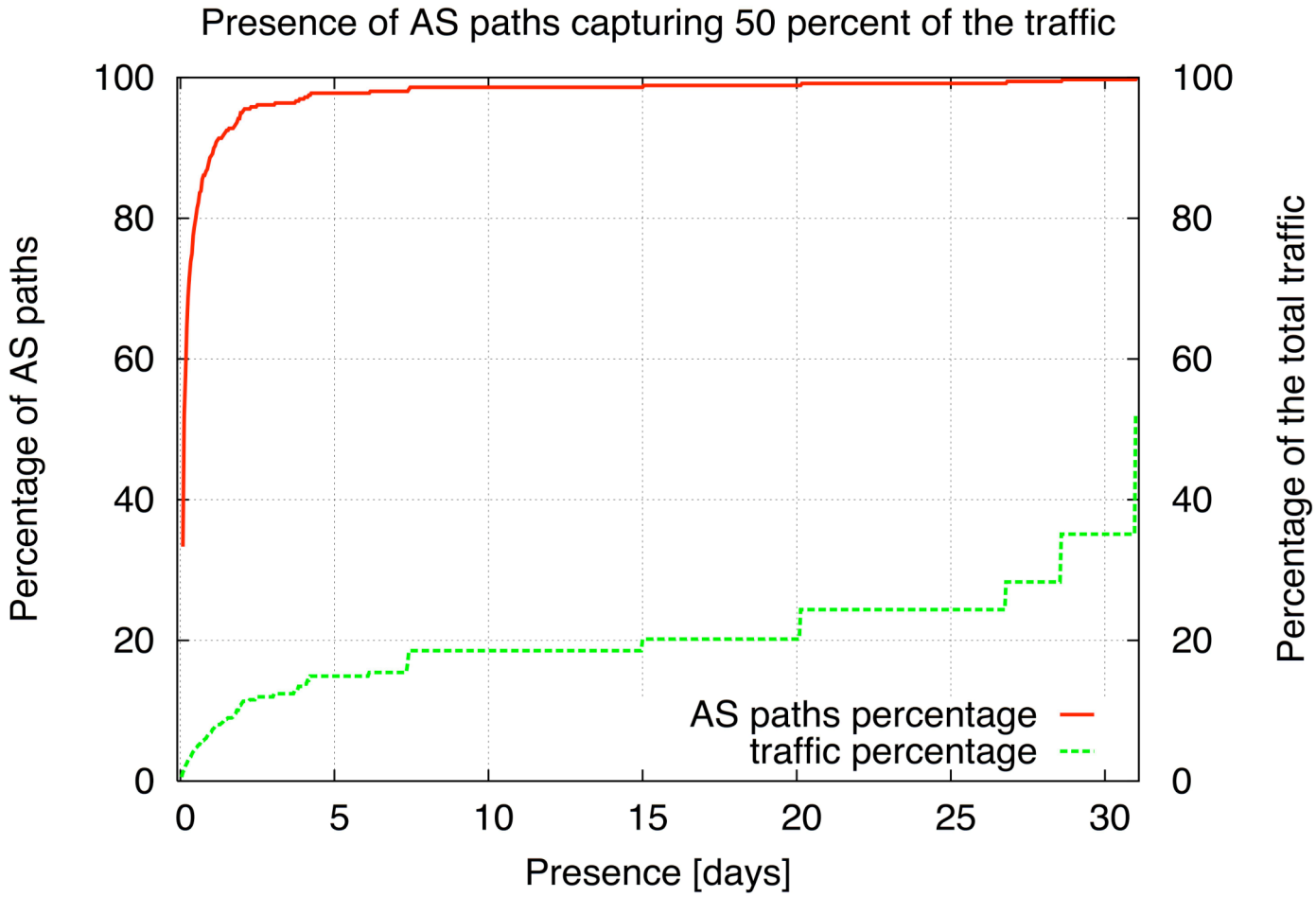
Topological traffic dynamics

Stability of top 90% paths :



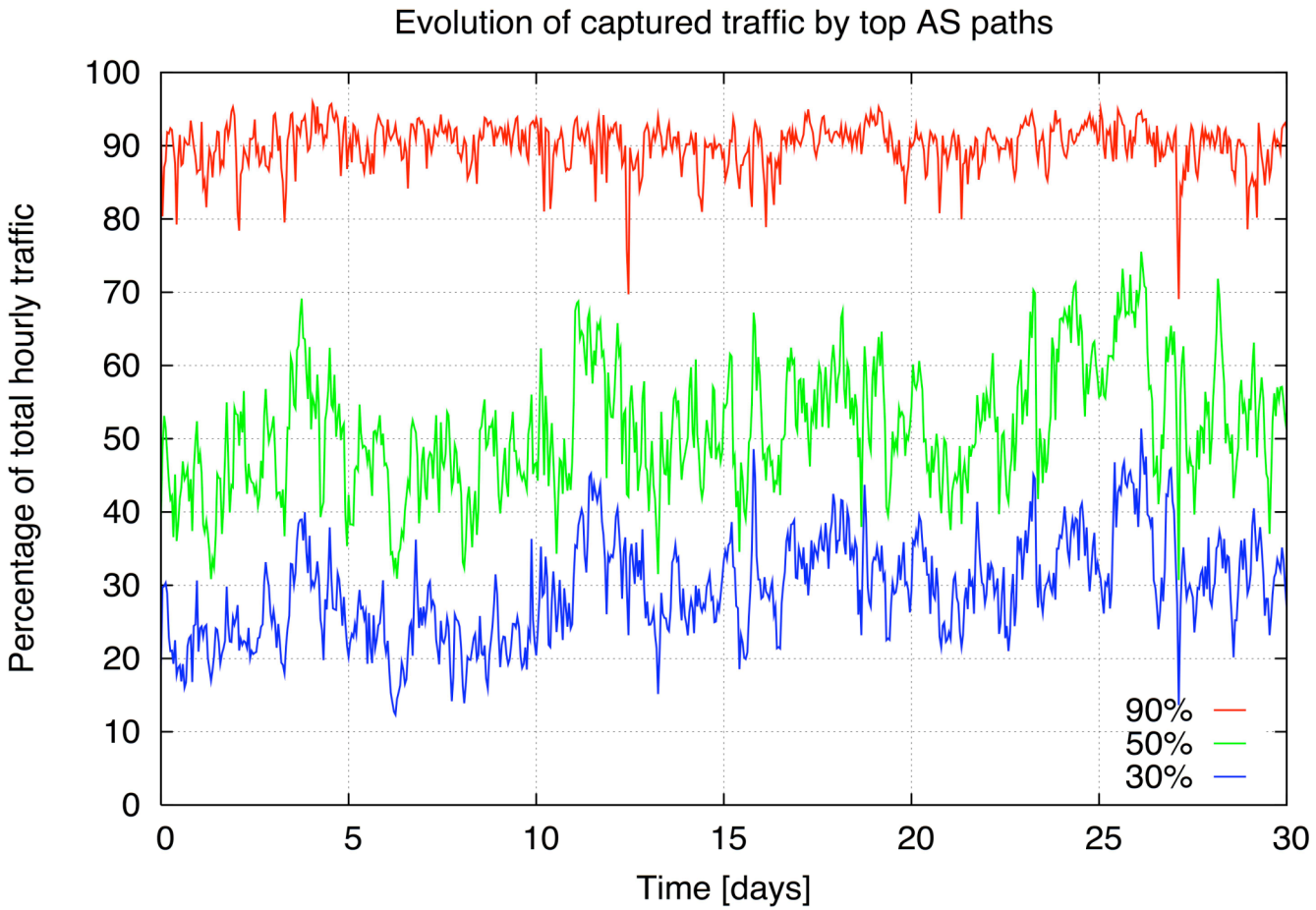
Topological traffic dynamics

Stability of top 50% paths :



Topological traffic dynamics

Hourly traffic captured by top paths :



Topological traffic dynamics

- *"A few <source, destination> pairs generate most of the traffic"* **is misleading because**
  - **still a** *large number of traffic objects* **at any given time**
  - **non-negligible fraction of traffic objects** *are not stable*

⇒ Interdomain traffic distribution *is not static*

Topological traffic dynamics

Implications on traffic engineering:

- ***Large number of traffic objects*** **at any given time ⇒ controlling a significant percentage of the total traffic is difficult**
- **Non-negligible fraction of unstable traffic objects ⇒** ***some traffic is inherently impossible to control !***

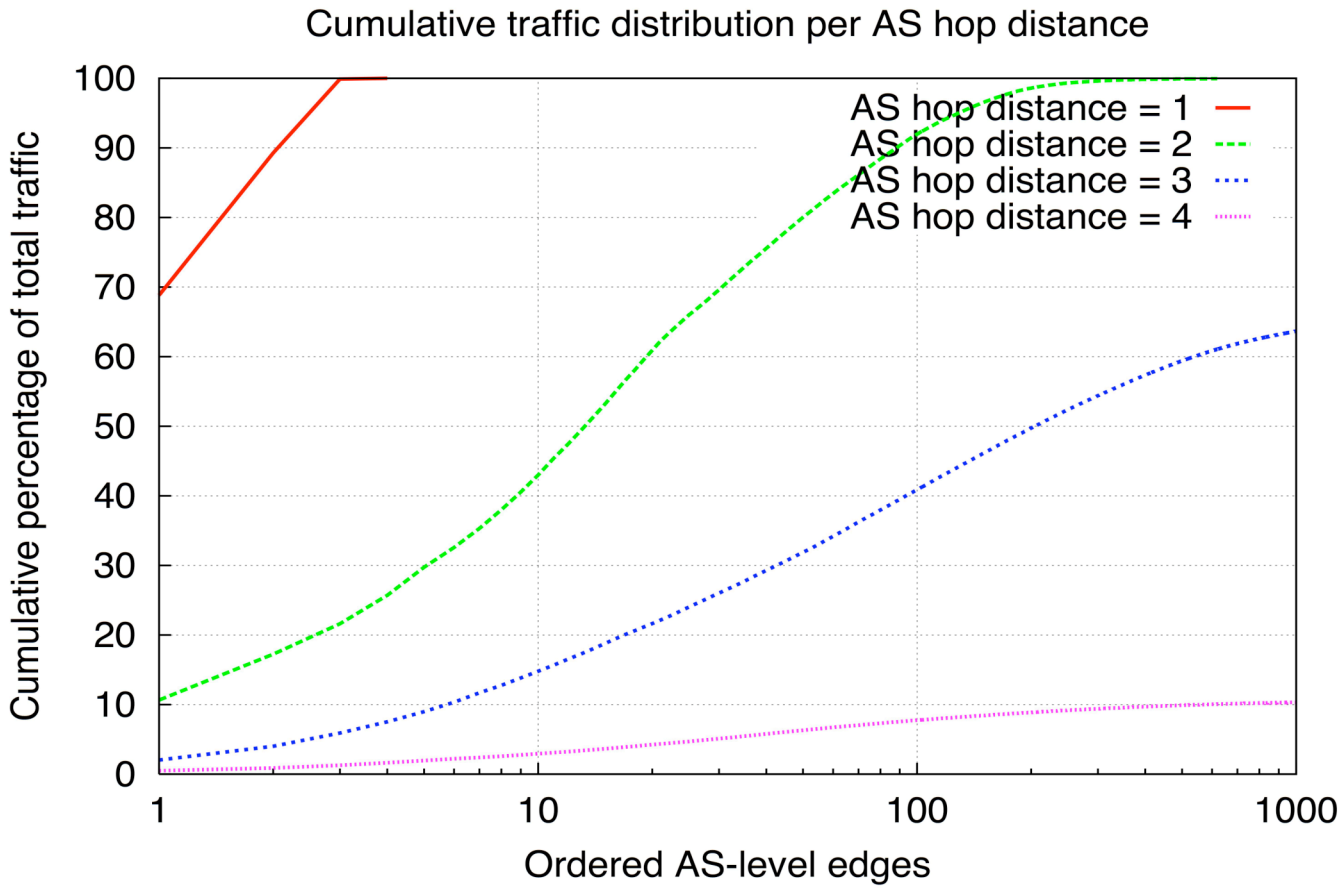
Towards Internet-wide traffic characterization

Towards Internet-wide traffic characterization

- How representative are observations taken from stub ASs ?
- Would the topological traffic distribution seen by a transit differ from a stub ?
- Can we approach Internet-wide characterization of Internet traffic ?

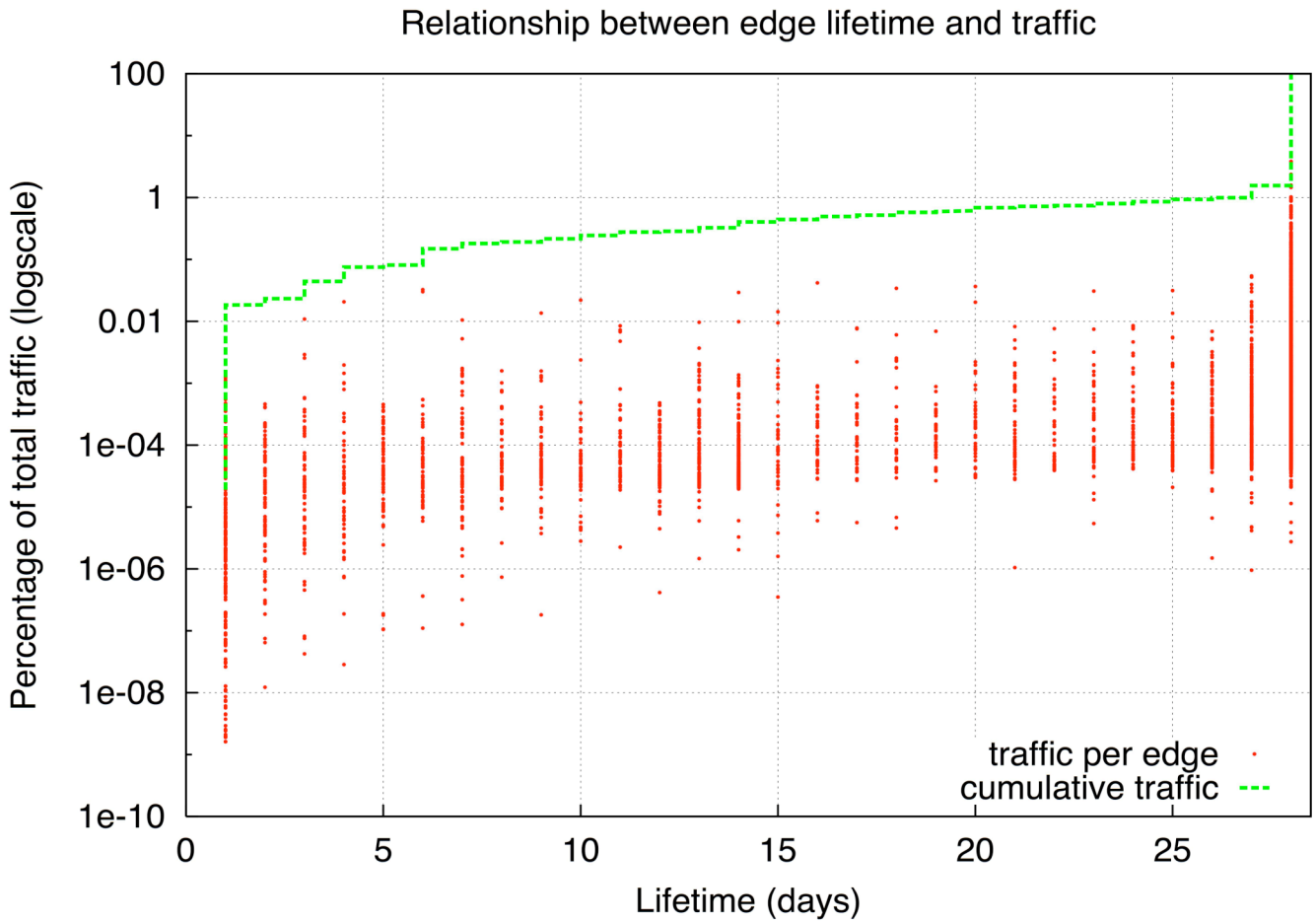
Towards Internet-wide traffic characterization

Topological traffic distribution seen by GEANT:



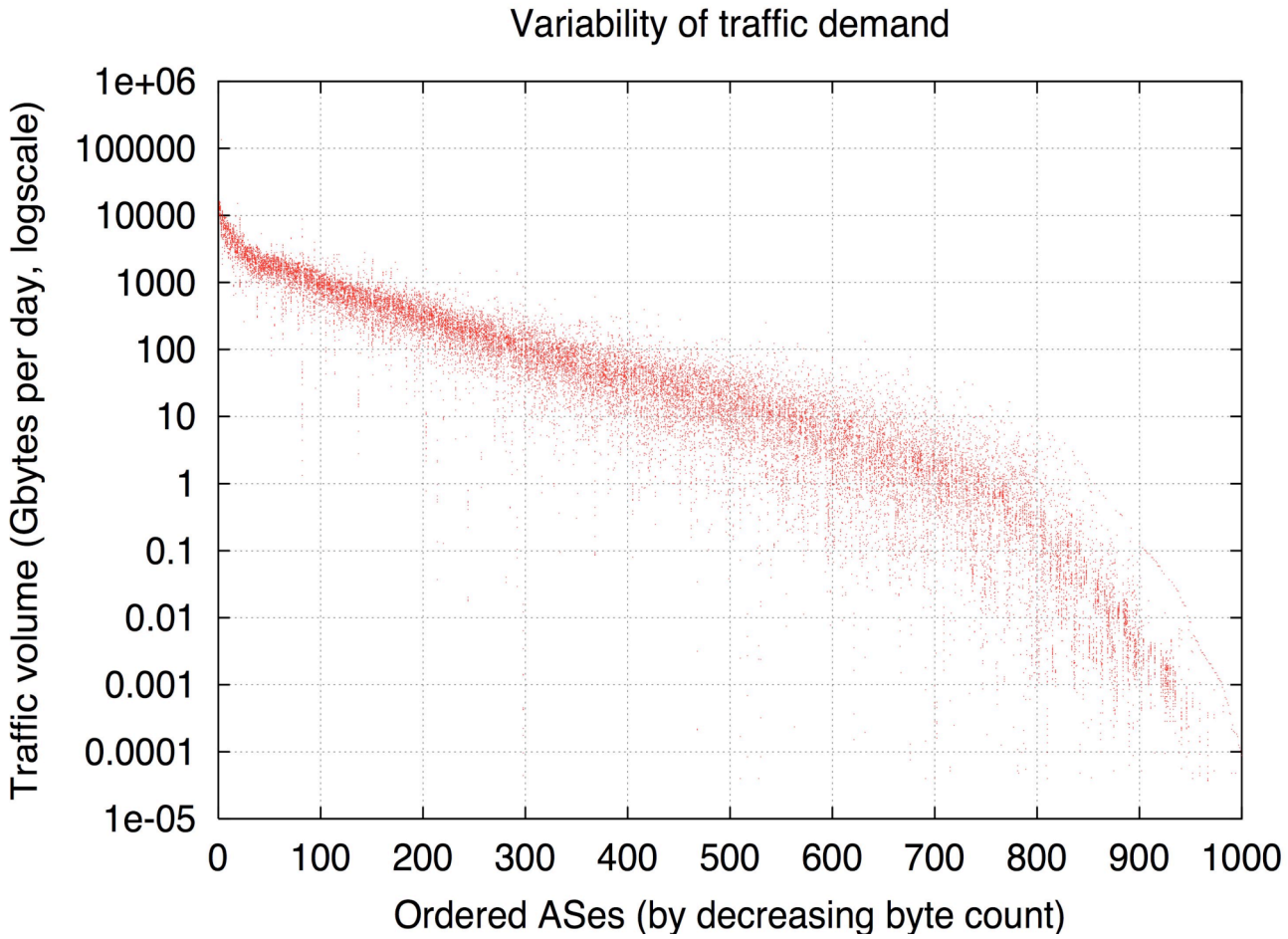
Towards Internet-wide traffic characterization

Lifetime of inter-AS edges seen by GEANT:



Towards Internet-wide traffic characterization

Variability of traffic demand on Abilene:



Towards Internet-wide traffic characterization

- Topological traffic distribution seen by a transit AS looks similar to those of stubs
- More aggregation on important AS-level edges for transit
- Large AS-level edges have traffic all the time
- Modeling topological traffic dynamics of a transit AS = modelling dynamics of the traffic on its important edges
- Significant traffic variations on destination prefixes over time

Towards Internet-wide traffic characterization

Implications on traffic engineering:

- **More aggregation on important AS-level edges ⇒ easier traffic control ?**
- **Large AS-level edges have traffic all the time ⇒ underlying graph to be controlled is static**
- **Predicting dynamics of traffic over time is the key to traffic control in transit ASs !**

Further work

Further work

- **Reproducing topological traffic distribution:**
  1. Reproduce the AS-level topology
  2. Reproduce set of destinations of each AS
  3. Correlation among sources/destinations
  4. Choose paths followed by traffic
- **Tricky aspects:**
  - Correlation among destinations (popularity)
  - Impact of routing on actual paths followed by traffic (does routing matter at all?)

Further work

- **Evaluating impact of global traffic engineering on the topological traffic distribution:**
  1. **Reproduce topological traffic distribution**
  2. **Simulate traffic engineering by each AS**
  3. **Look at what changed**
- **Tricky aspects:**
  - **Link capacities are important in practice**
  - **Relying on AS-level topology is very questionable**

Further work

- **Topological traffic dynamics:**
  - **Depends very much on whether a single AS is considered or the whole Internet**
  - **Considered timescales (cf. traffic properties)**
  - **Not enough measurements today**
- **Tricky aspects:**
  - **Even with enough measurements, how would you characterize a graph changing over time ?**

Selected readings

- L. Kleinrock and W. Naylor. ***On measured behavior of the ARPA network.*** Proc. of AFIS National Computer Conference, 1974.
- W. Fang and L. Peterson. ***Inter-AS traffic patterns and their implications.*** Proc. of IEEE Global Internet Symposium, December 1999.
- S. Uhlig and O. Bonaventure. ***Implications of Interdomain Traffic Characteristics on Traffic Engineering.*** European Transactions on Telecommunications, January 2002.
- J. Rexford, J.Wang, Z. Xiao and Y. Zhang. ***BGP Routing Stability of Popular Destinations.*** Proc. of the 2nd ACM SIGCOMM Internet Measurement Workshop, November 2002.
- S. Uhlig, V. Magnin, O. Bonaventure, C. Rapier and L. Deri. ***Implications of the Topological Properties of Internet Traffic on Traffic Engineering.*** Proc. of the 19th ACM Symposium on Applied Computing, March 2004.