

# The Elusive Internet Flattening: 10 Years of IXP Growth

T. Böttger<sup>1</sup>, G. Antichi<sup>1</sup>, E.L. Fernandes<sup>1</sup>, R. Lallo<sup>2,3</sup>, M. Bruyere<sup>4</sup>, S. Uhlig<sup>1</sup>, **I. Castro<sup>1</sup>**

<sup>1</sup>QMUL

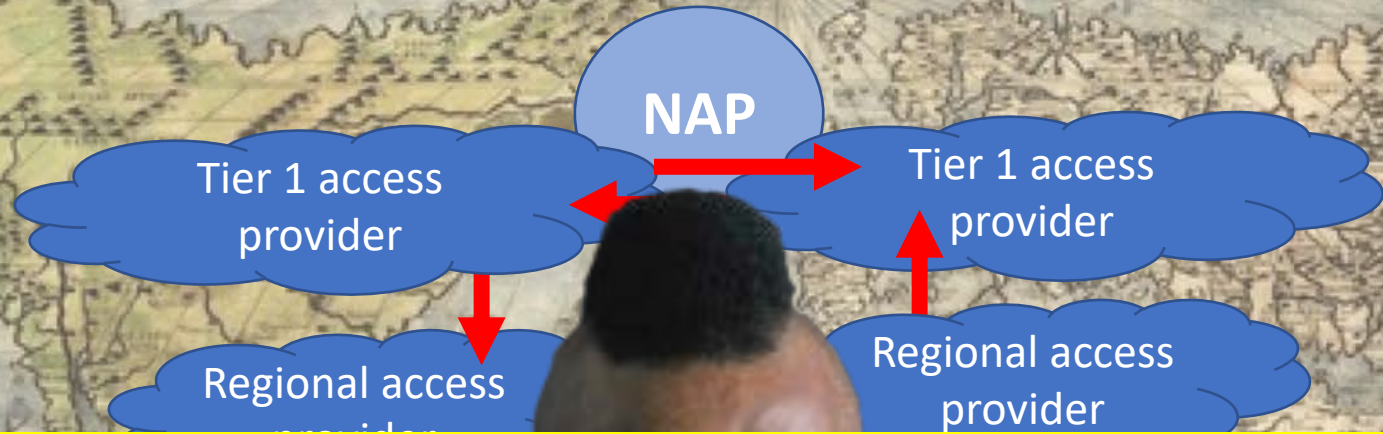
<sup>2</sup> Roma Tre University

<sup>3</sup>Consortium GARR

<sup>4</sup>University of Tokyo

# Spoiler

- IXP evolution:
  - Large growth: # IXPS and members tripled in 2008-2016
  - Reachability stagnation: % IPv4 addresses reachable through IXPS has stabilised around 80%
- Macroscopic impact?
  - Little path-shortening: not one-hop away
  - Hierarchical flattening: less transit dependence



# The early Internet



# Hierarchical early Internet

IXP



Donald J. Trump

@realDonaldTrump

Follow

Very few hops, **LESS HOPS** than ever, we will make no hops at all!!! Trust me!!!  
#Internetisflat #lesshops



Donald J. Trump

@realDonaldTrump

Follow

There is **LESS TRANSIT DEPENDENCE**, in fact the least transit dependence ever!!!  
#Internetisflat #lesstransit



# Are there that many IXPs to “flatten” Internet paths??

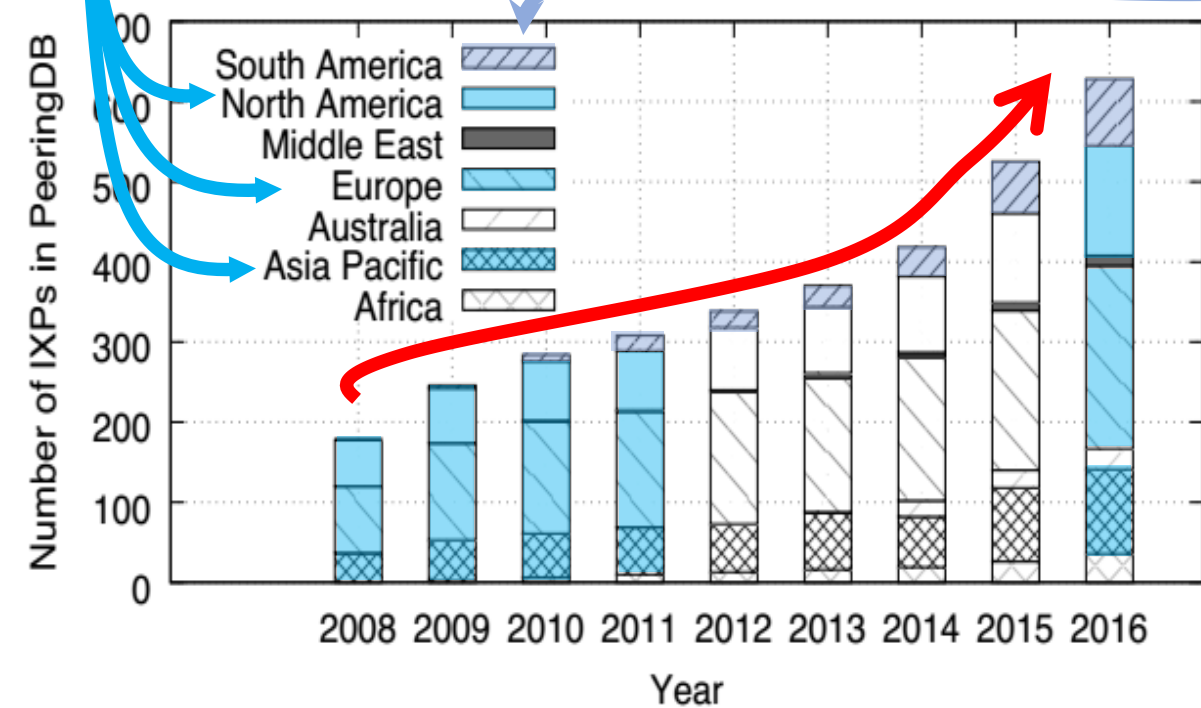
Historical growth of IXPs:

1. Number
2. Size
3. Reachability

# Big stay big

## Large IXP growth over time

## Rise of new regions



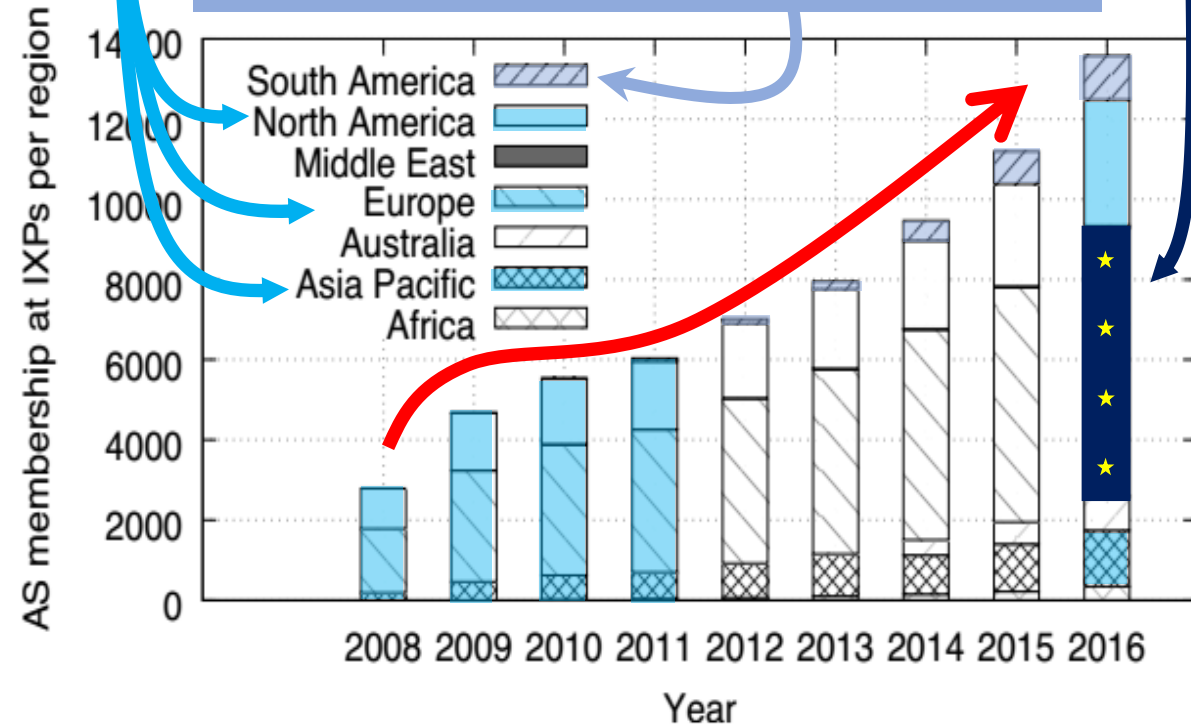
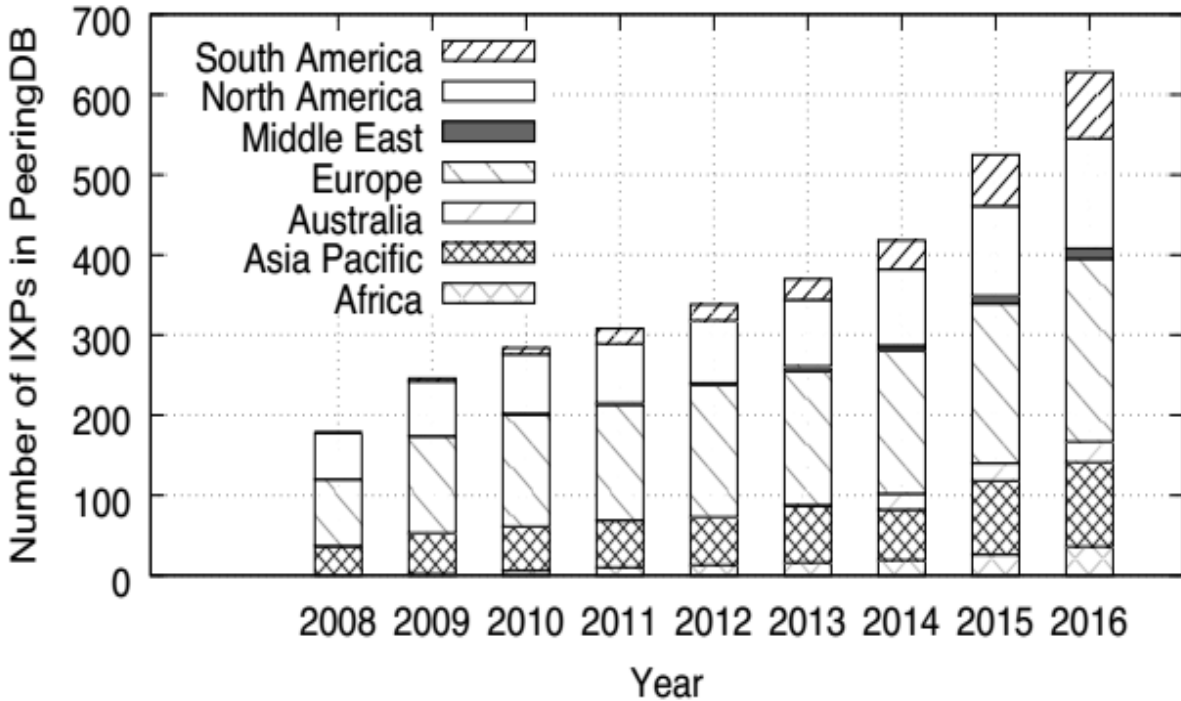
- In number of IXPs

**Big stay big**

**Europe tops growth**

Large IXP growth over time

**Rise of new regions**

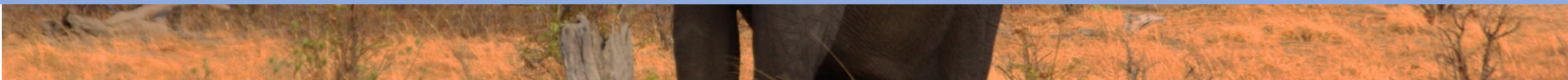


- In number of IXPs

- In number of ASes/members

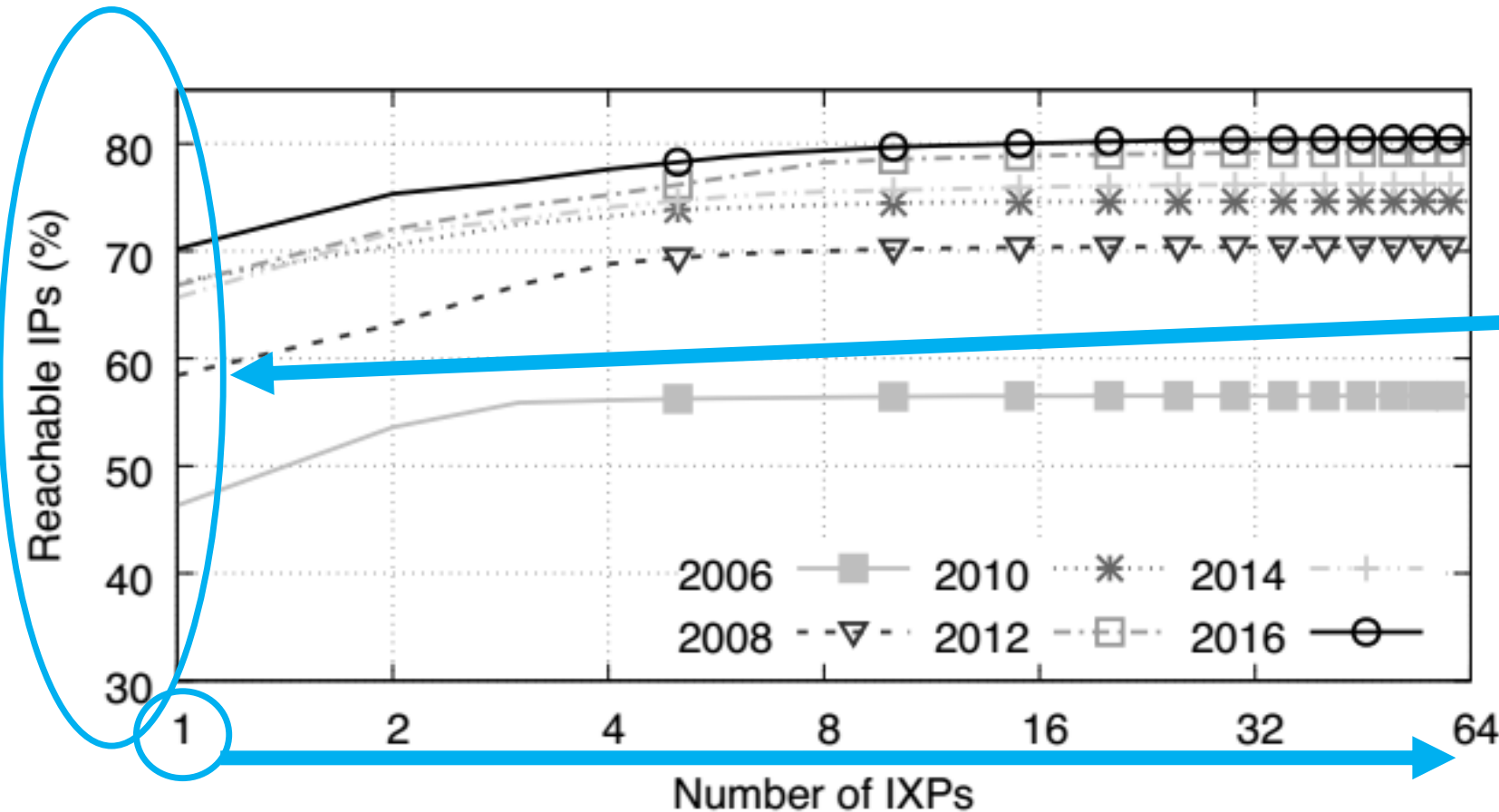


**What about reachability?**





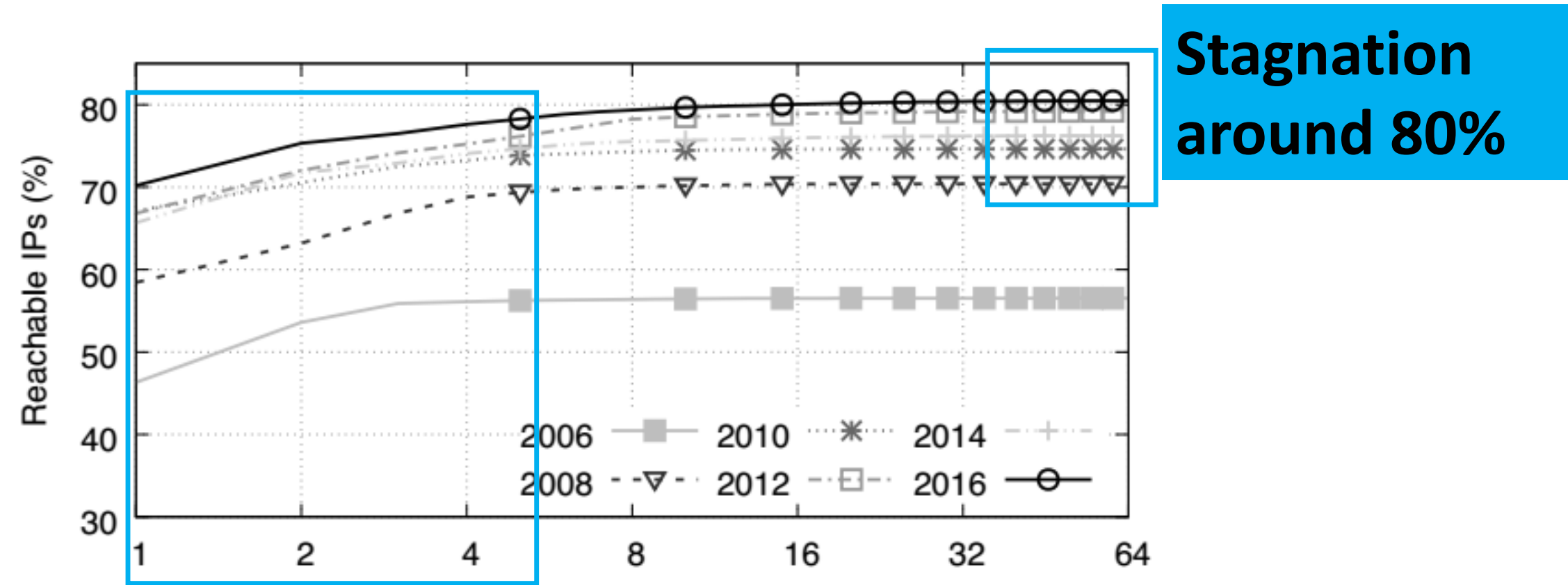
# ~80% of announced IP's are reachable via IXPs



- 100% IPs =  
IPs reachable through T1s  
(approx. 99% of the IP space)

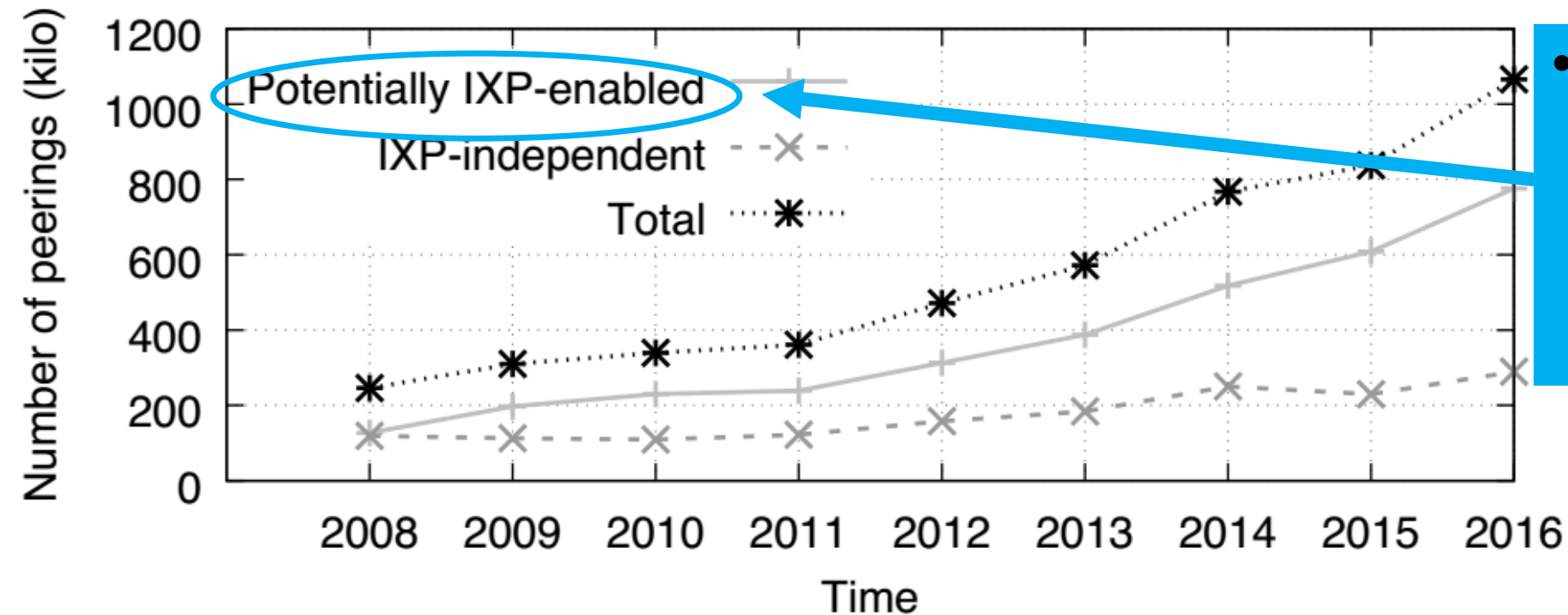
- IPv4 reachability =  
IPs that an AS could reach by  
collocating at an IXP and  
peering with all its members  
(T1s excluded)

~80% of announced IP's are reachable via IXPs



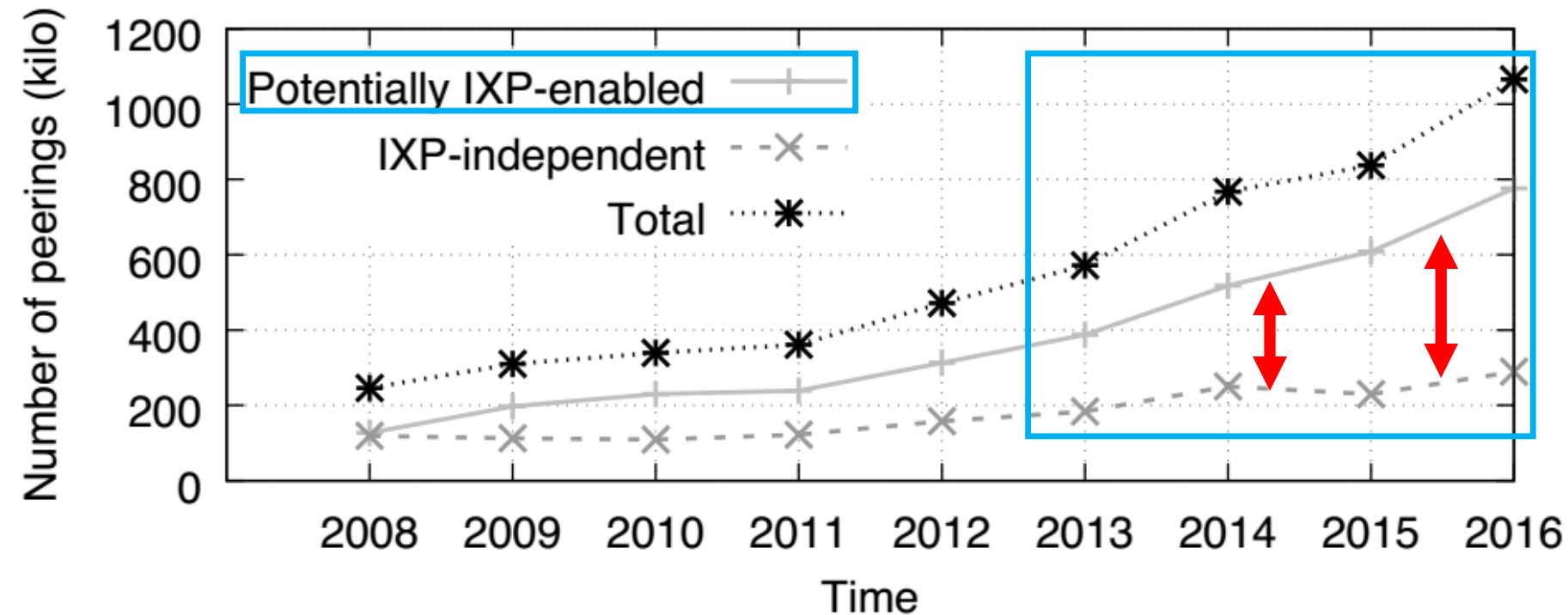
few IXPs are enough  
(for reachability )

# Large growth of potential peerings at IXPs



- Potential peering if 2 ASes are:
  - peering (CAIDA)
  - Colocated (PeeringDB)

# Large growth of potential peerings at IXPs



**Most peering growth is (potentially) IXP-enabled**

# How & how much do IXPs matter?

Historical impact of IXPs on Internet paths:

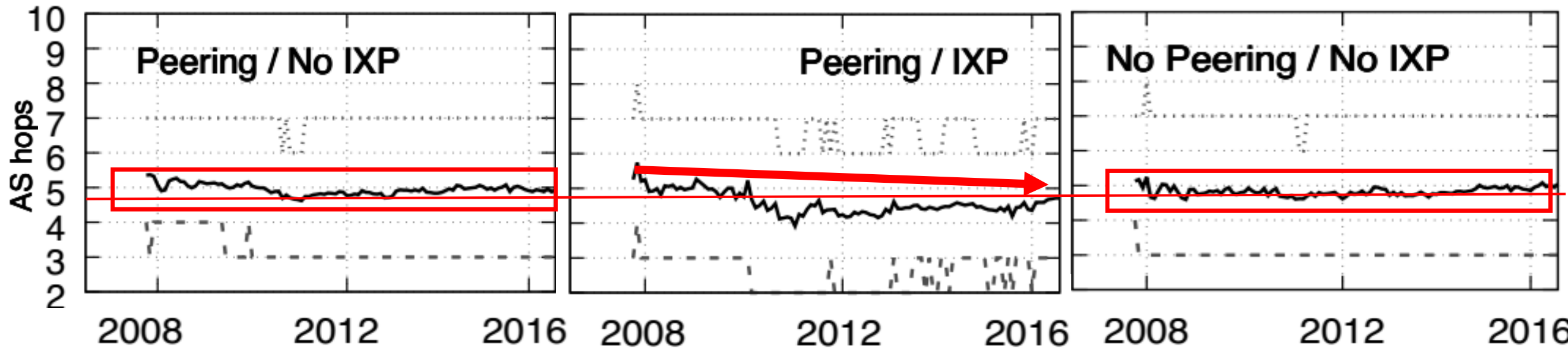
*how much have Internet paths “flattened”?*

- a) Reduction of path lengths?
- b) Reduced transit dependence?

# Data & Methodology

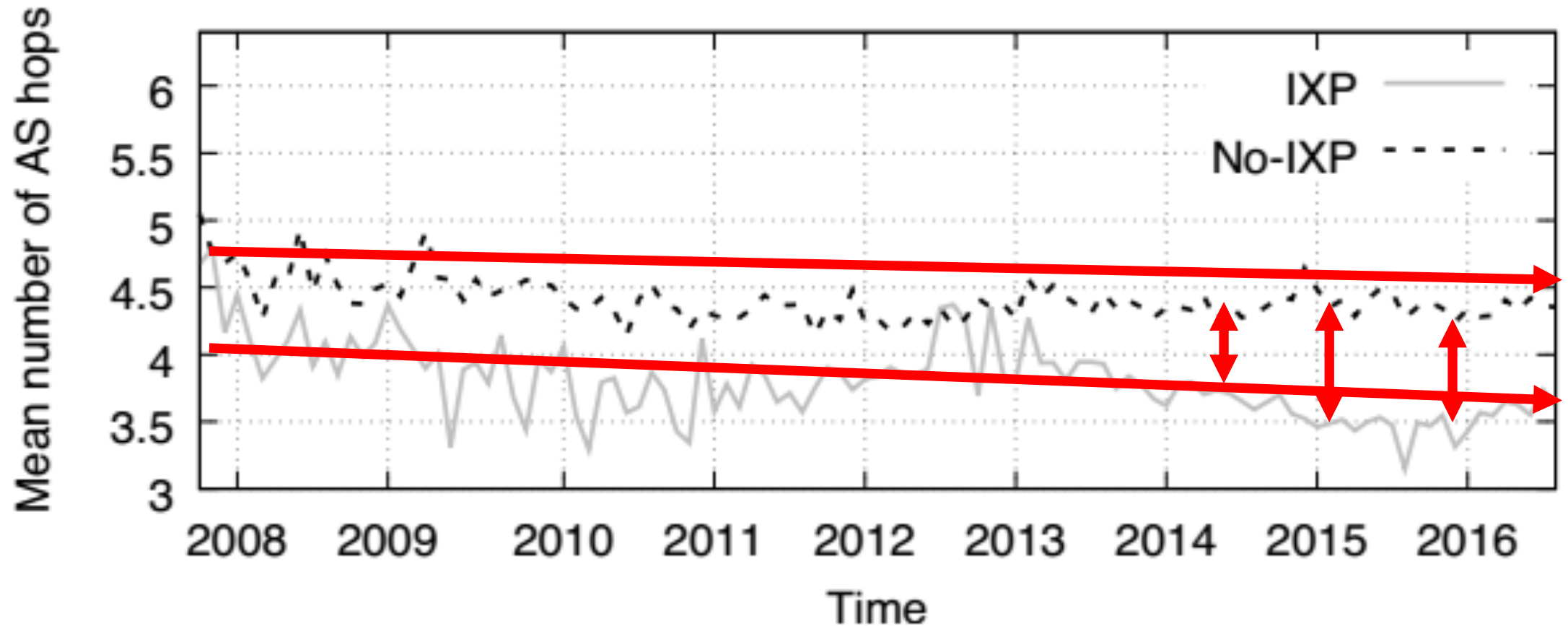
- **Traceroute data** (monthly snapshots)
  - a) iPlane (2006 -2016): from PlanetLab nodes, 2.3 billion traceroutes
  - b) CAIDA Ark (2007-present): from Ark monitors, 4.4 billion
- Sanitization of traceroutes (358M Ark, 1.1 billion iPlane)
  1. destination IP required
  2.  $\geq 1$  unresolved IP-hop
  3.  $\geq 1$  IXP
- **Identification of IXPs:**
  - G. Nomikos & X. Dimitropoulos. *“traIXroute: Detecting IXPs in traceroute paths”*. PAM 2016

# Path length stability



- Path-length is stable out of IXPs
- IXPs enjoy a small path-length reduction
- IXPs have slightly shorter path lengths

# Some path-shortening for very large networks

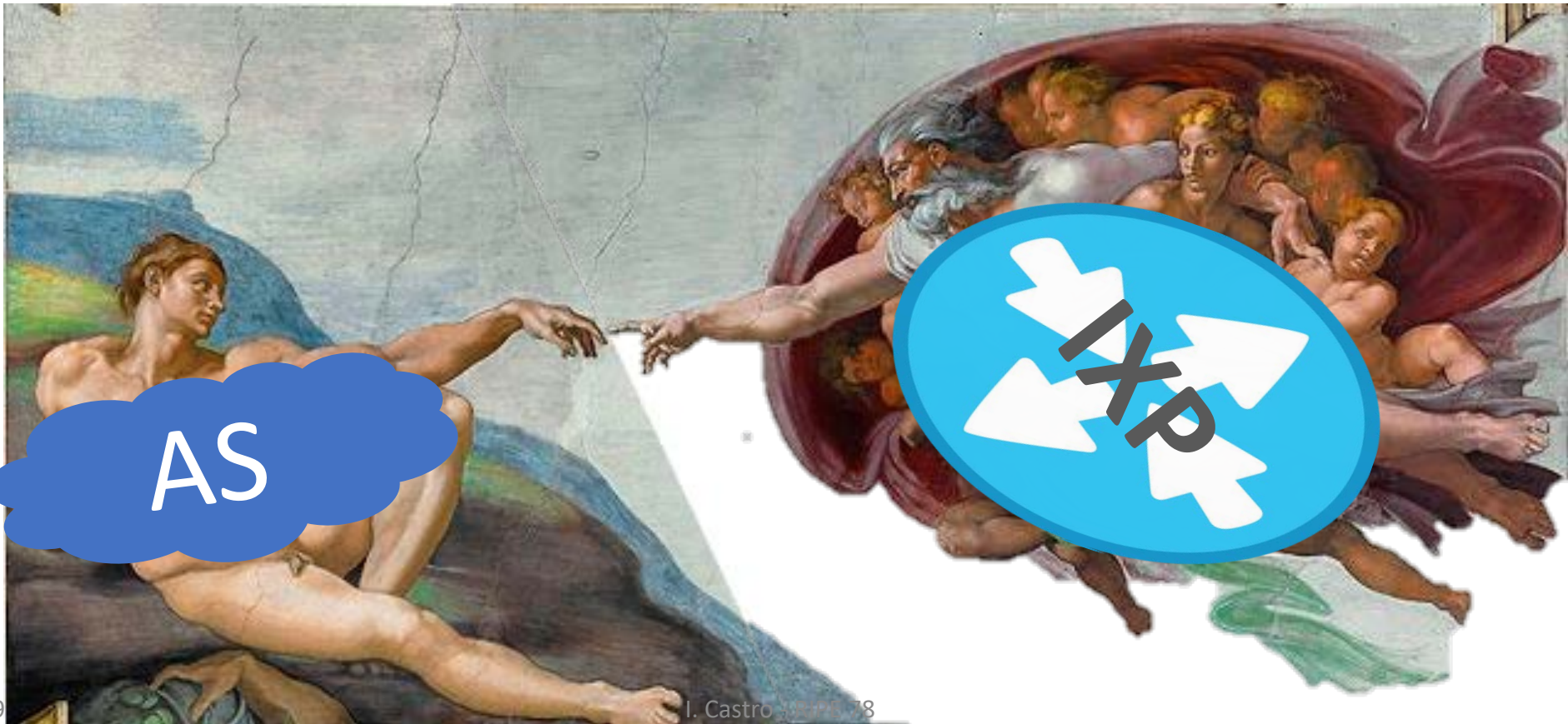


15 “Very large large networks”: T Boetger et al., “Looking for Hypergiants in PeeringDB”, ACM CCR 2018



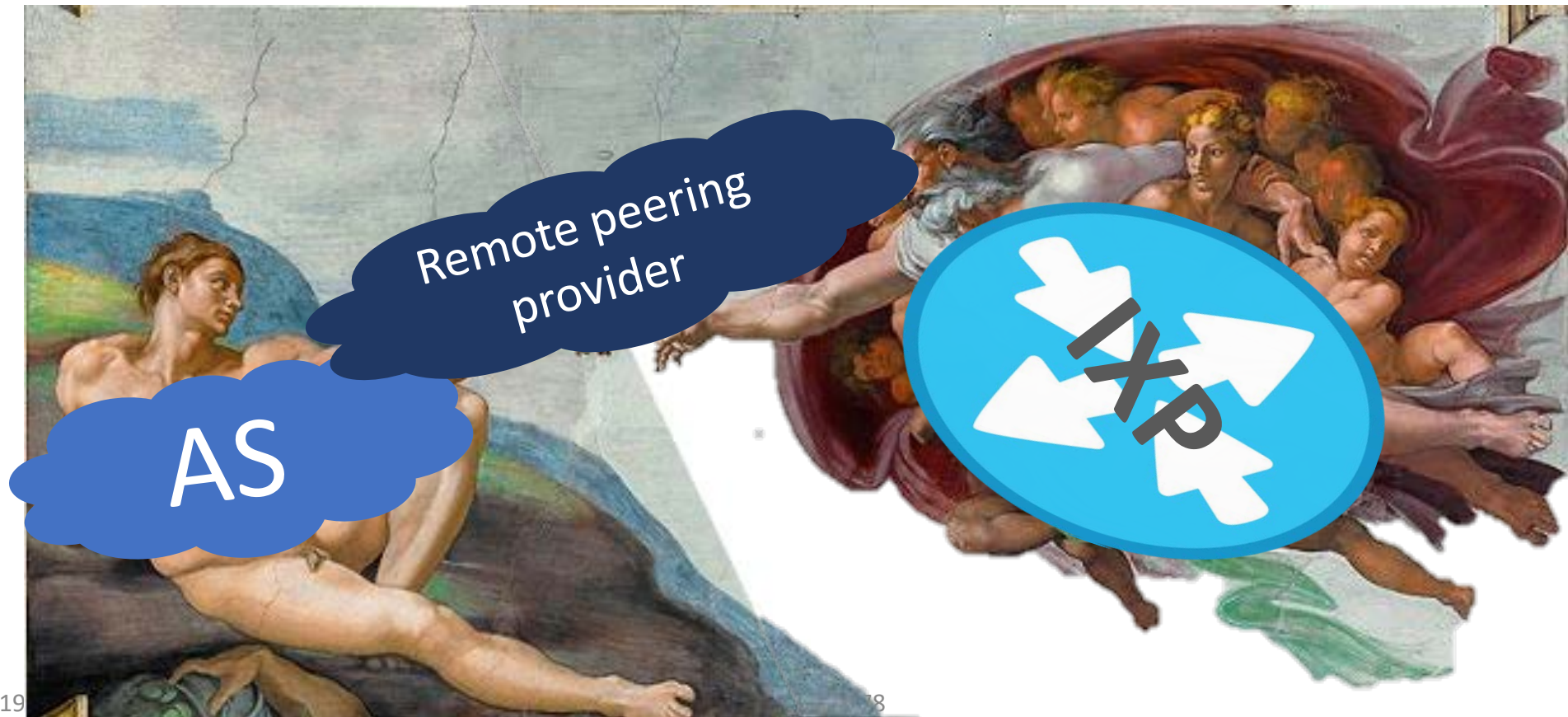
# How meaningful are path-lengths?

- Emergence of remote peering:



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- Emergence of remote peering:
  - Since (at least) 2014 most IXPs have remote peers (Castro et al, CoNEXT 2015)
  - On going trend (Nomikos et al, IMC 2018)
- CDN redirecting (e.g., Netflix, Castro et al. 2018)
- Path-length does not (necessarily) correlate with performance
- Impossible to know the traffic volumes corresponding to each route
- No vantage point in the Internet has full visibility

# How & how much do IXPs matter?

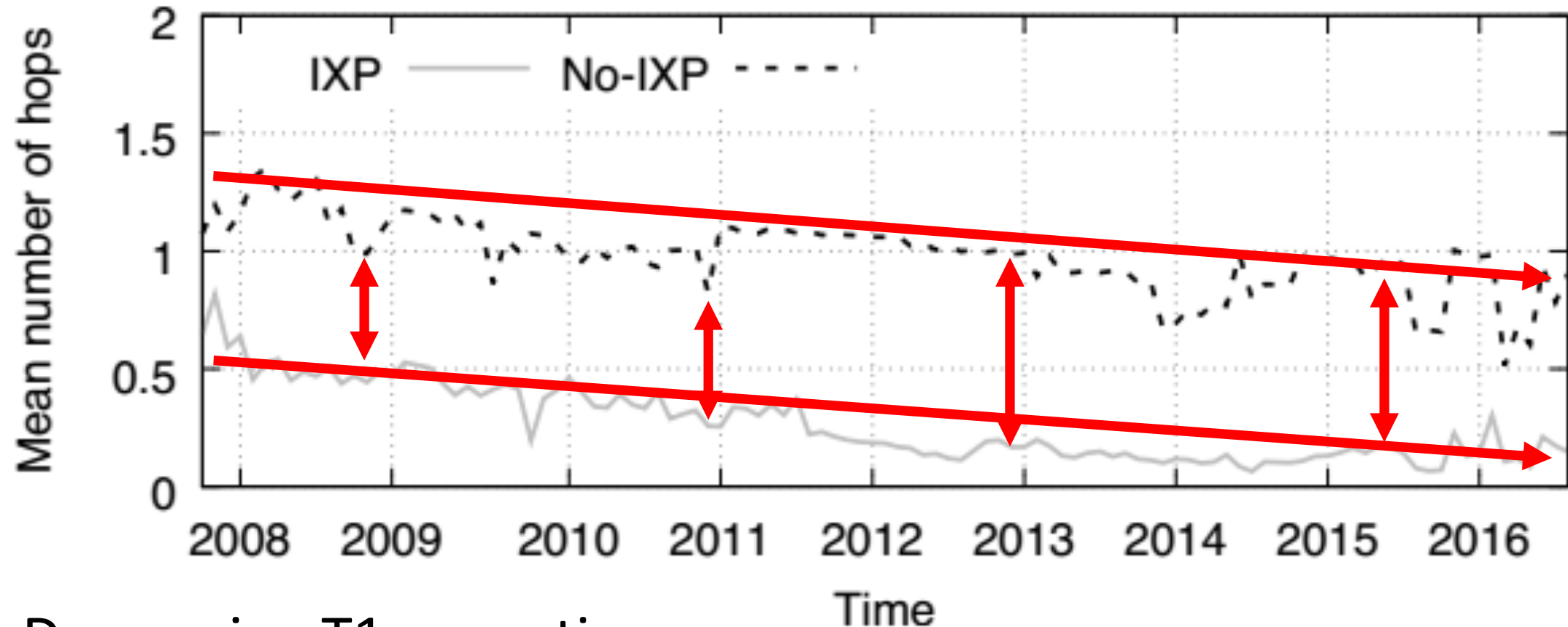
Historical impact of IXPs on Internet paths:

*how much have Internet paths “flattened”?*

a) Reduction of path lengths?

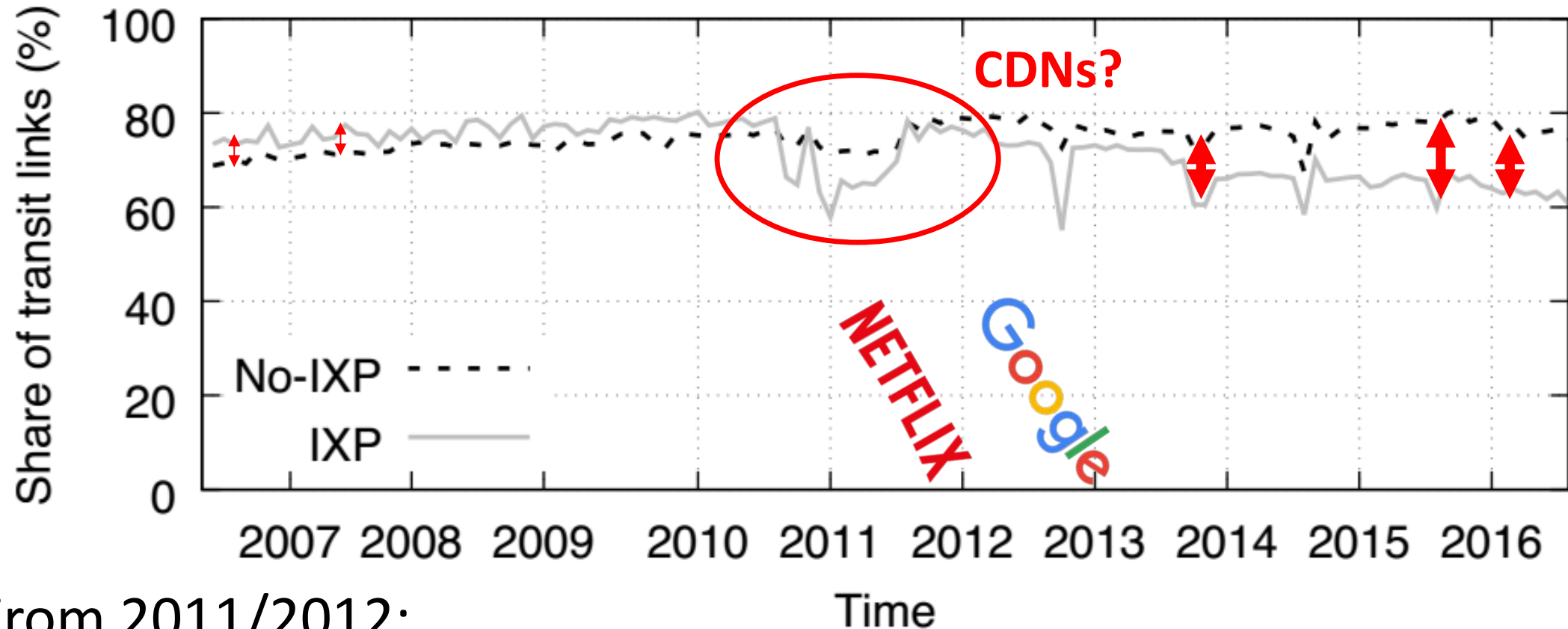
b) Reduced transit dependence?

# Hierarchical flattening: less T1s



- Decreasing T1s over time
- Less T1s in IXP paths

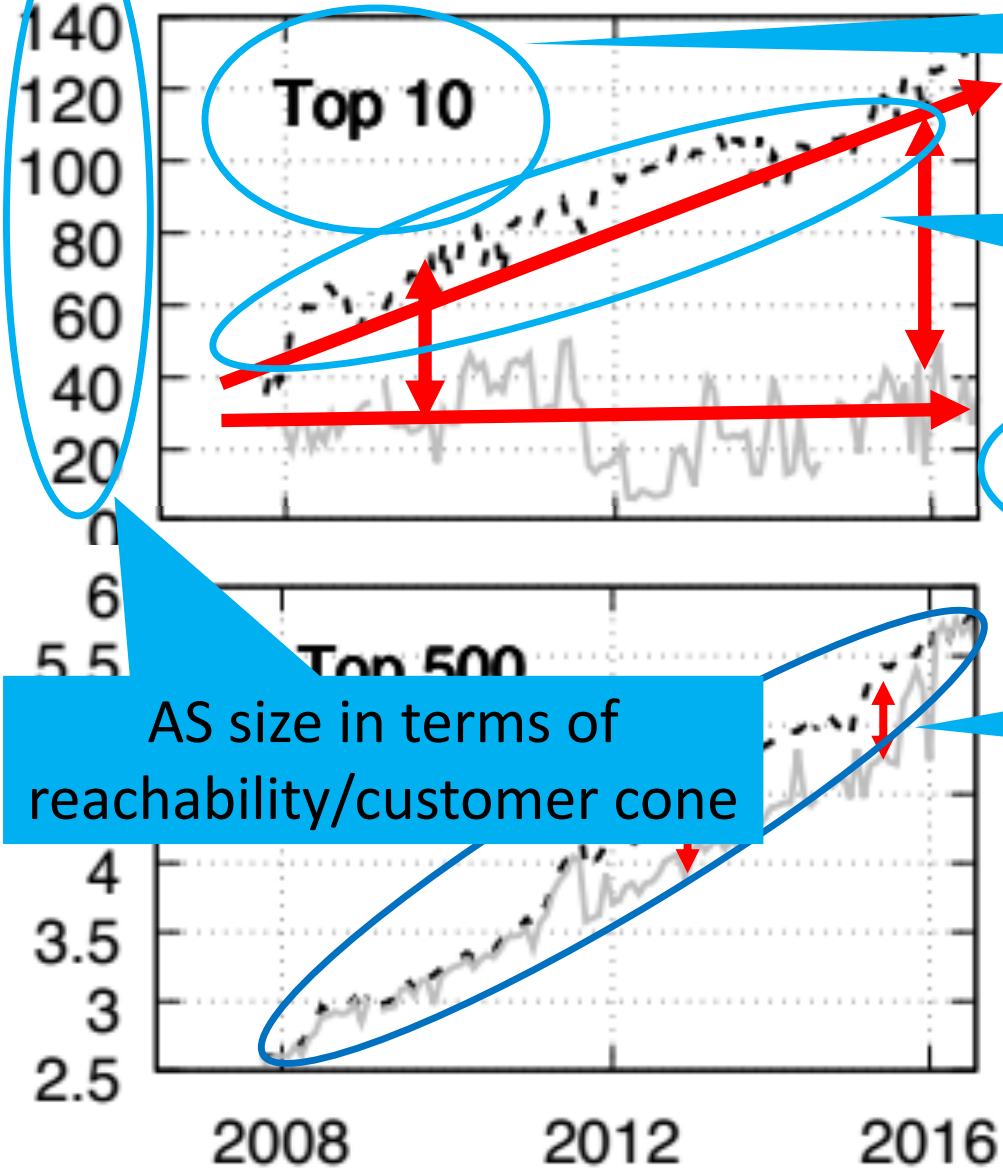
# Hierarchical flattening: less transit links



- From 2011/2012:
  - Decreasing % of transit links at IXPs
  - Less transit links in IXP paths

# A small number of ASes still play a central role

Avg. customer cone size (thousands of ASes)



Ranked in terms of traces traversing an AS

Most central ASes are large & NOW avoid IXPs

No-IXP - - - -  
IXP - - - -

Divergence in customer cone sizes over time

AS size in terms of reachability/customer cone

Least central ASes are small & "like" IXPs they traverse and IXP or not

Divergence vanishes for less central networks

# Next things to look at

- More data/data bias
- CDN emergence
- Specific impact of IXP emergence on reduced transit dependence:
  - Local benefit of creating an IXP (and its growth)
  - Local benefit of the creation of abroad IXPs
- Model/predict the emergence/growth of IXPs
- Current draft: <https://arxiv.org/abs/1810.10963>

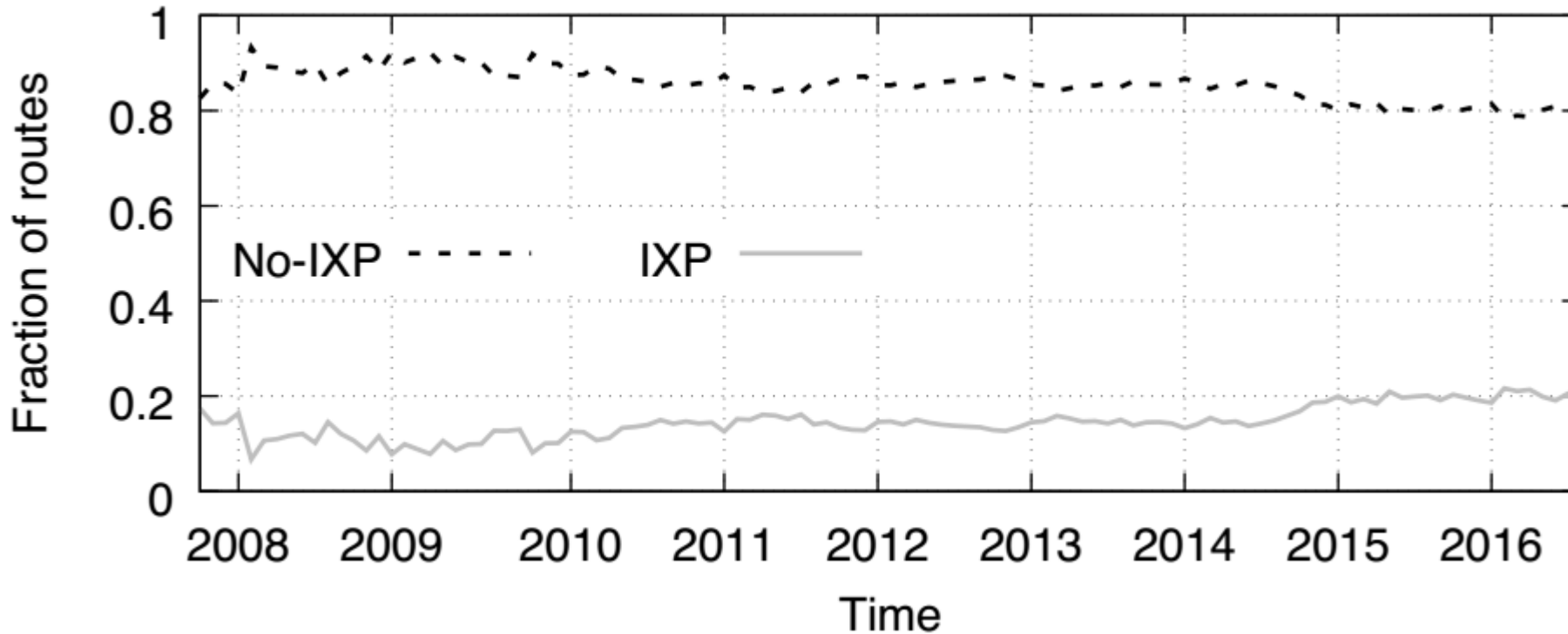


Questions?  
Thoughts?

...

[i.castro@qmul.ac.uk](mailto:i.castro@qmul.ac.uk)

# More traceroutes traverse IXPs



- About the double