Measurement Based Geolocation in the ETOMIC Infrastructure

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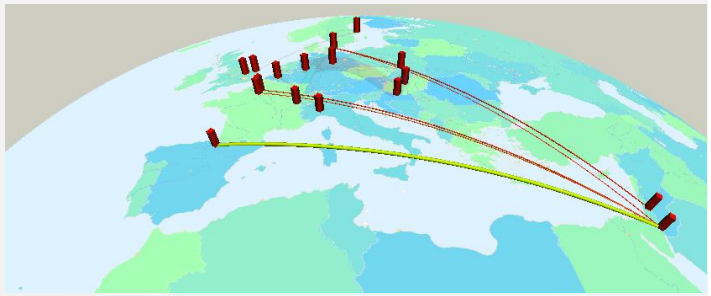
Agenda

- **Introduction**
- Path-latency Model
- Velocity of Signal Propagation in Network
- Geographic Constraints
- Data Collection
- Performance Analysis
- A „Case Study"
- Summary

Motivation

- **Location information can be useful to both private and corporete users**
  - Targeted advertising on the web
  - Restricted content delivery
  - Location-based security check
  - Web statistics
- **Scientific applications**
  - **<u>Measurement visualization</u>**
  - **Network diagnostics**



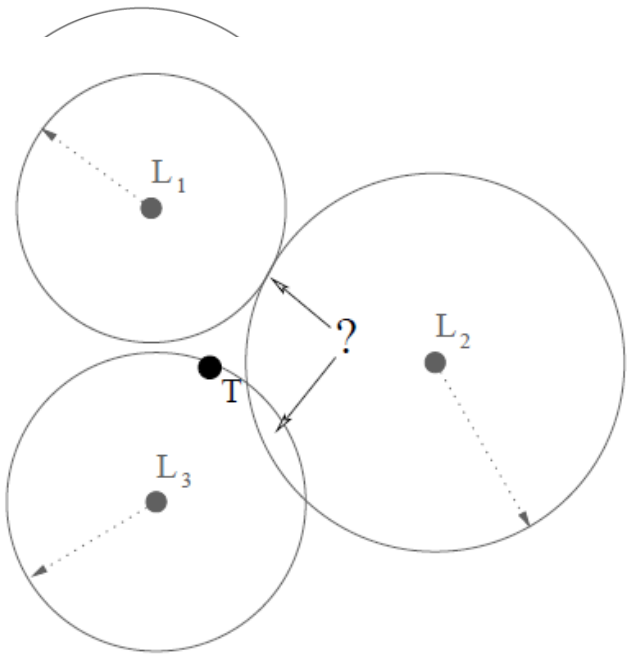
Geolocation in General

- **Passive geolocation**
  - Extracting location information from domain names
  - DNS and WhoIS databases
  - Commercial databases
    - MaxMind, IPligence, Hexasoft
  - Large and geographically dispersed IP blocks can be allocated to a single entity

- **Active geolocation**
  - Active probing
  - Measurement nodes with **known locations (landmarks)**
  - GPS-like multilateration (CBG)

Measurement Based Geolocation

- Active measurements
  - **Network Delays**
    - ***Delays can be transformed to geographic distance***
      - Round Trip Time (ping)
      - One-way delay
    - Effects of over and underestimation



  - **Topology**
    - Network-path discovery
      - Traceroute with fixed port pairs
    - Interface clustering
      - Mercator, etc.

Presentation Outline

- Introduction
- **<u>Path-latency Model</u>**
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Why do we need a latency model?

- The basis of active methods is to **transform delays to geographic distance**

- The model aims to **decompose the overall packet delay to linkwise components**

- Approximating propagation delays along a network path leads to more precise distance estimations...

Modelling Packet Delays

- A packet delay (d) can be divided into…
  - Queuing delay (D_q)
  - Processing delay (D_{pc})
  - Transmission delay (D_{tr})
  - Propagation delay (D_{pg})

Only the propagation component has role in the geolocation

- A given path: $\mathbf{n_0} \rightarrow \mathbf{n_1} \rightarrow \mathbf{n_2} \rightarrow \ldots \rightarrow \mathbf{n_H}$

- **The overall packet delay** for a network path ($\mathbf{s}=\mathbf{n_0}$ and $\mathbf{d}=\mathbf{n_H}$):

$$d(\mathbf{s},\mathbf{d}) = \sum_{i=1}^{H} (D_{pc}^{i} + D_{q}^{i} + D_{tr}^{i} + D_{pg}(\mathbf{n_{i-1}}, \mathbf{n_i}))$$

How to Estimate Propagation Delays

- Assumptions in the model
  - **No queuing** (D_q = 0)
  - The per-hop processing and transmission delays can be **approximated by a global constant** (d_h)
    - $d_h = D_{pc} + D_{tr}$
  - Based on the literature and our observations:
    - » $\boldsymbol{d_h}$ **= 100μs**

The one-way propagation delay along a given path:

$$D_{pg}(\mathbf{s}, \mathbf{d}) = d(\mathbf{s}, \mathbf{d}) - H \cdot d_h$$

An Extra Cost - ICMP Generation Time

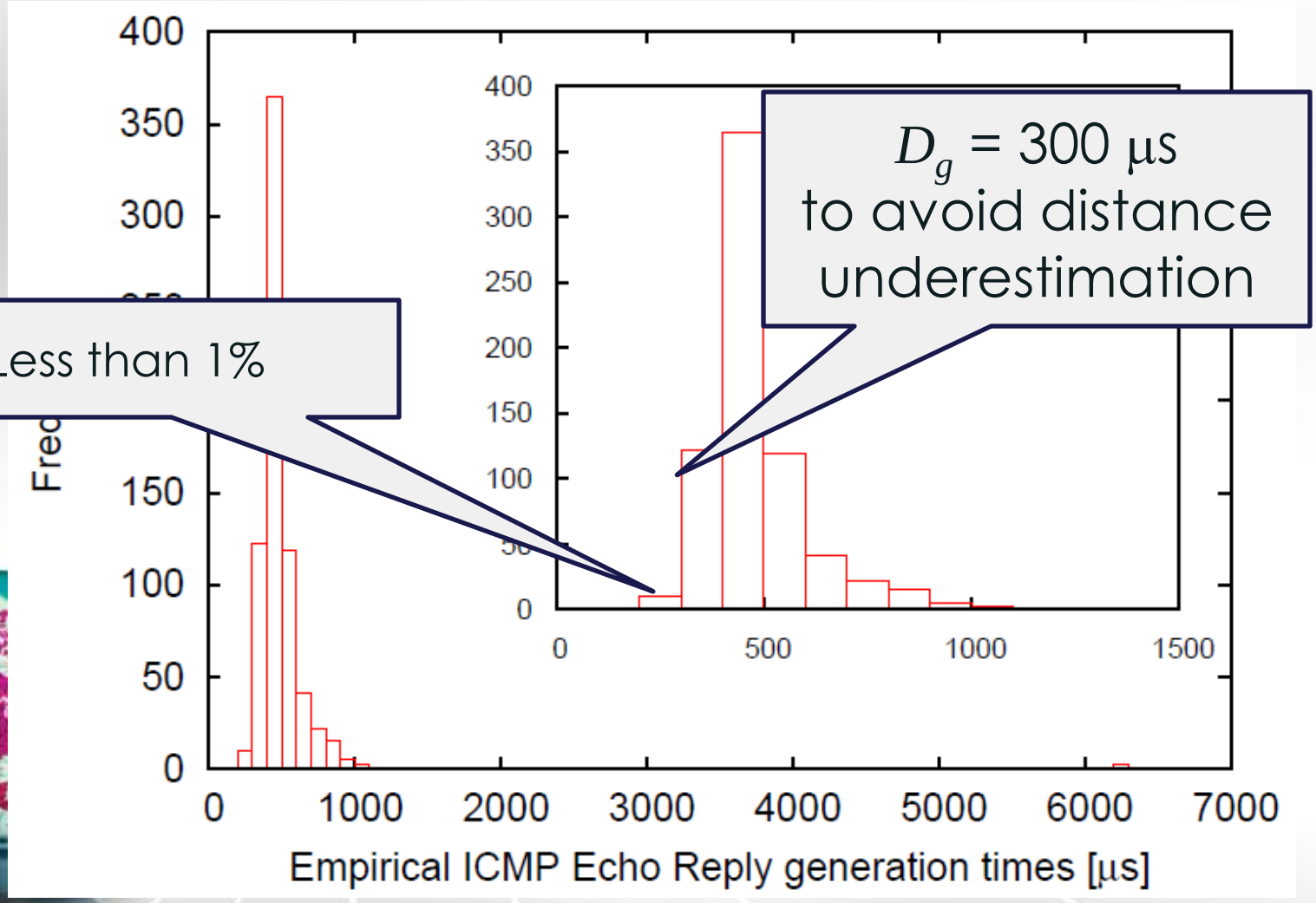
- In case of ICMP based RTT measurements **an extra delay appears** at the target node
  - **ICMP Echo Reply Generation Time (D_g)**
- The overall Round Trip Delay:

$$d(\mathbf{s}, \mathbf{d}, \mathbf{s}) = d_{\mathrm{fw}} + D_g + d_{\mathrm{bw}}$$

Is it possible to measure this D_g delay component?

Yes, there's a way…

ICMP Generation Times



Less than 1%

D_g = 300 µs
to avoid distance
underestimation

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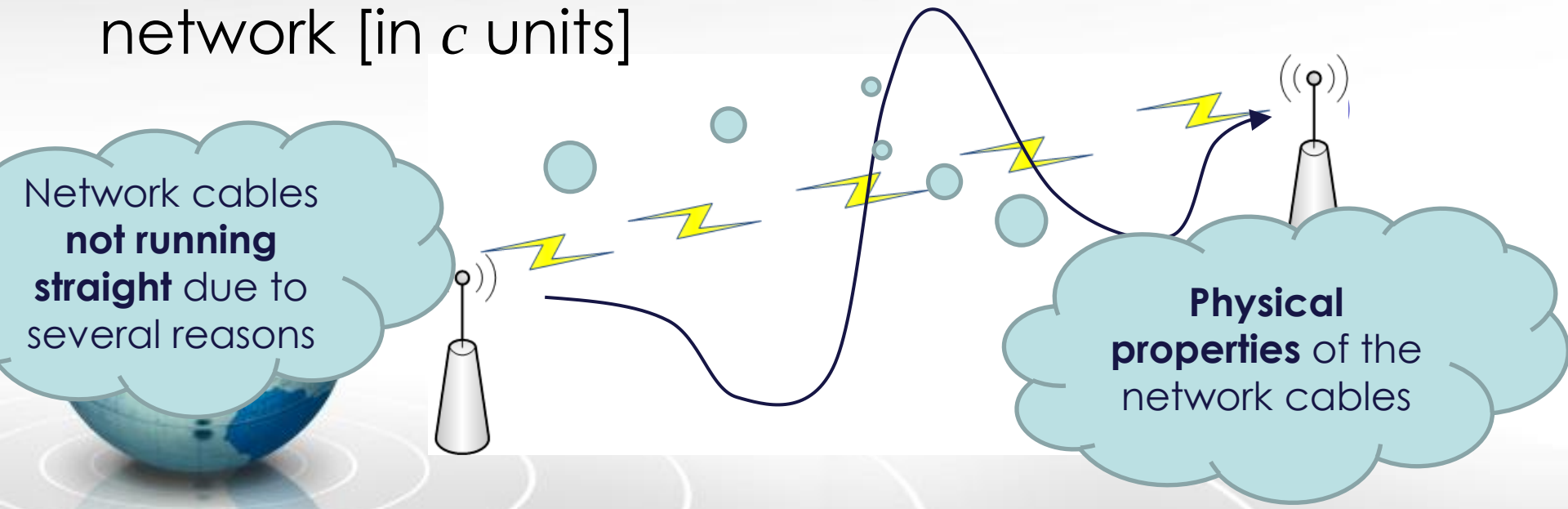
Distance Approximation

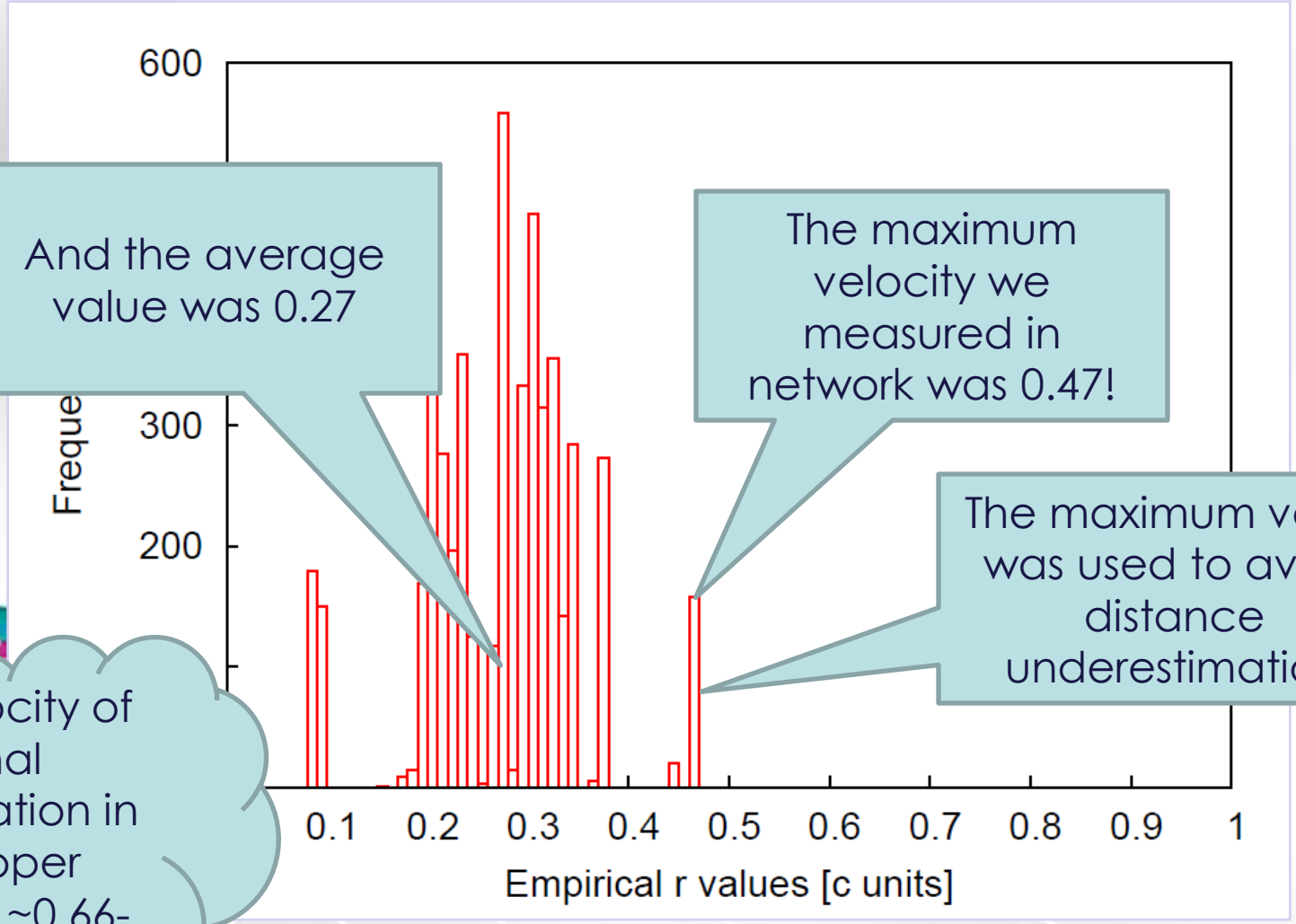
- An upper approximation of geographical distance from source **s** to destination **d**:

$$s(\mathbf{s},\mathbf{d}) \le s^* = c \cdot r \cdot \sum_{i=1}^{H} D_{pg}(\mathbf{n_{i-1}},\mathbf{n_i}) = c \cdot r \cdot D_{pg}(\mathbf{s},\mathbf{d})$$

- where r is the velocity of signal propagation in network [in c units]



Signal Propagation in Network



And the average value was 0.27

The maximum velocity we measured in network was 0.47!

The maximum value was used to avoid distance underestimation

The velocity of signal propagation in a copper cable is ~0.66-0.7!

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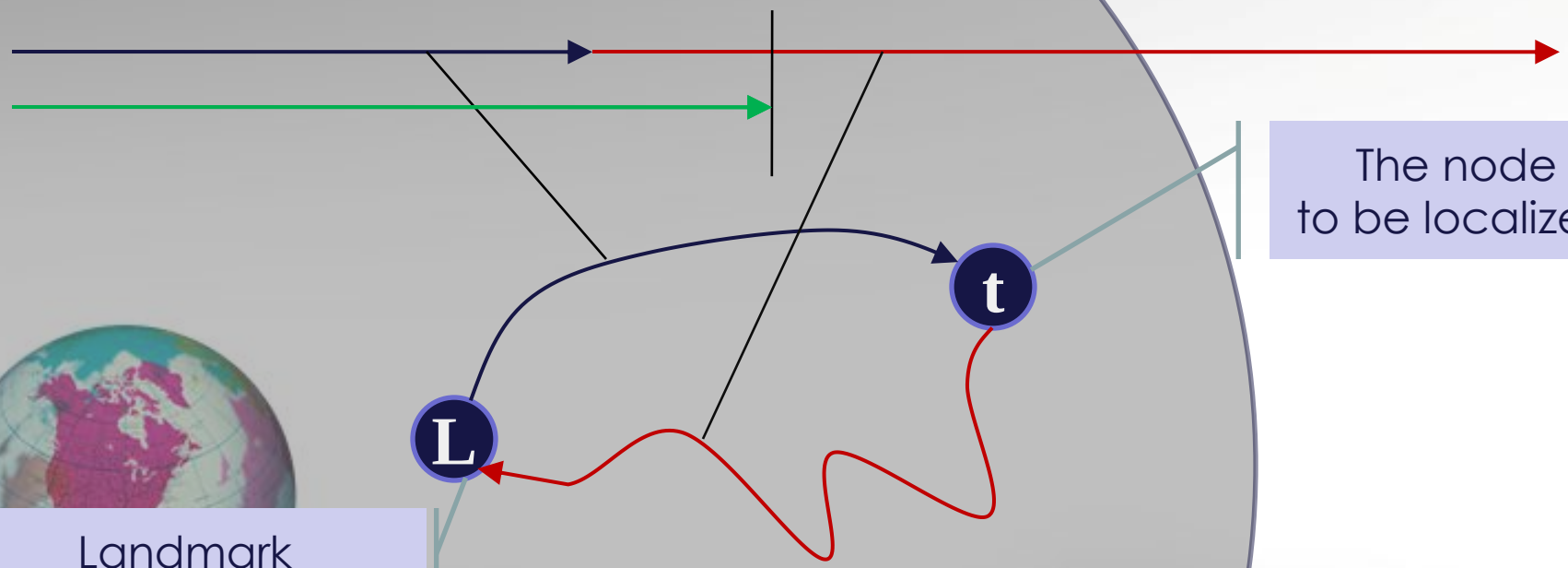
Solving Geolocation

- Defining geographic constraints
- We are looking for a location set where **all the constrains come true**
- Defining the **overall tension in the system**
  - A cost function
- **By minimizing this function** the problem can be solved
  - » Non-convex optimization problem
    - » **Well known solutions in sensor networks**

Round-Trip Time Constraint

- Using path-latency model
  - Round-trip propagation delay from a landmark
    - Upper approximation of one-way propagation delay



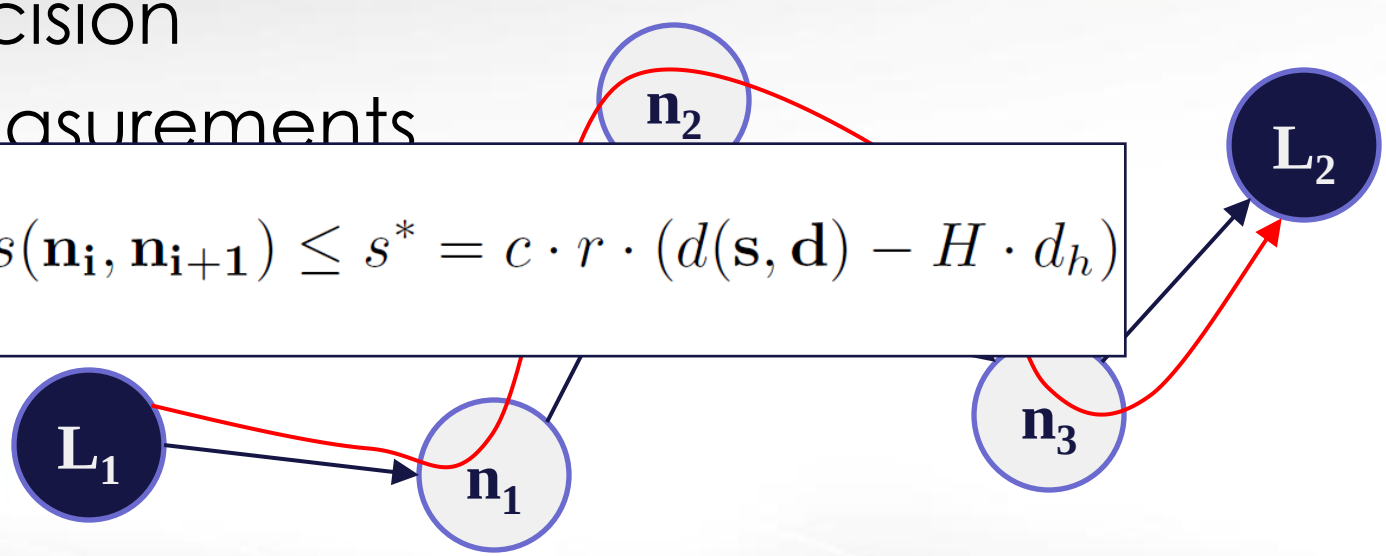
The node
to be localized

Landmark
with known location

One-way Delay Constraint

- A novel constraint for a network path between two landmarks
  - Limiting the geographic length of a given network path
- High-precision OWD measurements

$$\sum_{i=1}^{H-1} s(\mathbf{n_i}, \mathbf{n_{i+1}}) \leq s^* = c \cdot r \cdot (d(\mathbf{s}, \mathbf{d}) - H \cdot d_h)$$



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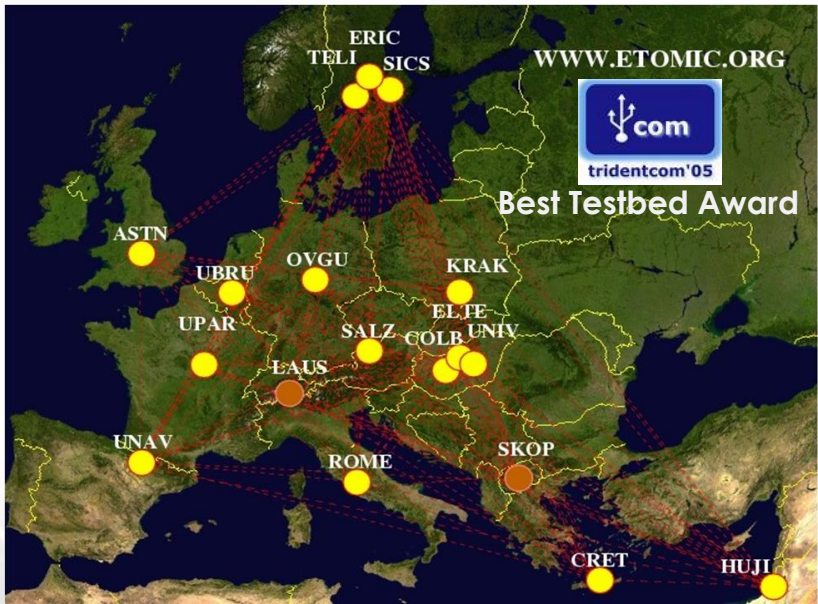
An Award-winning Testbed

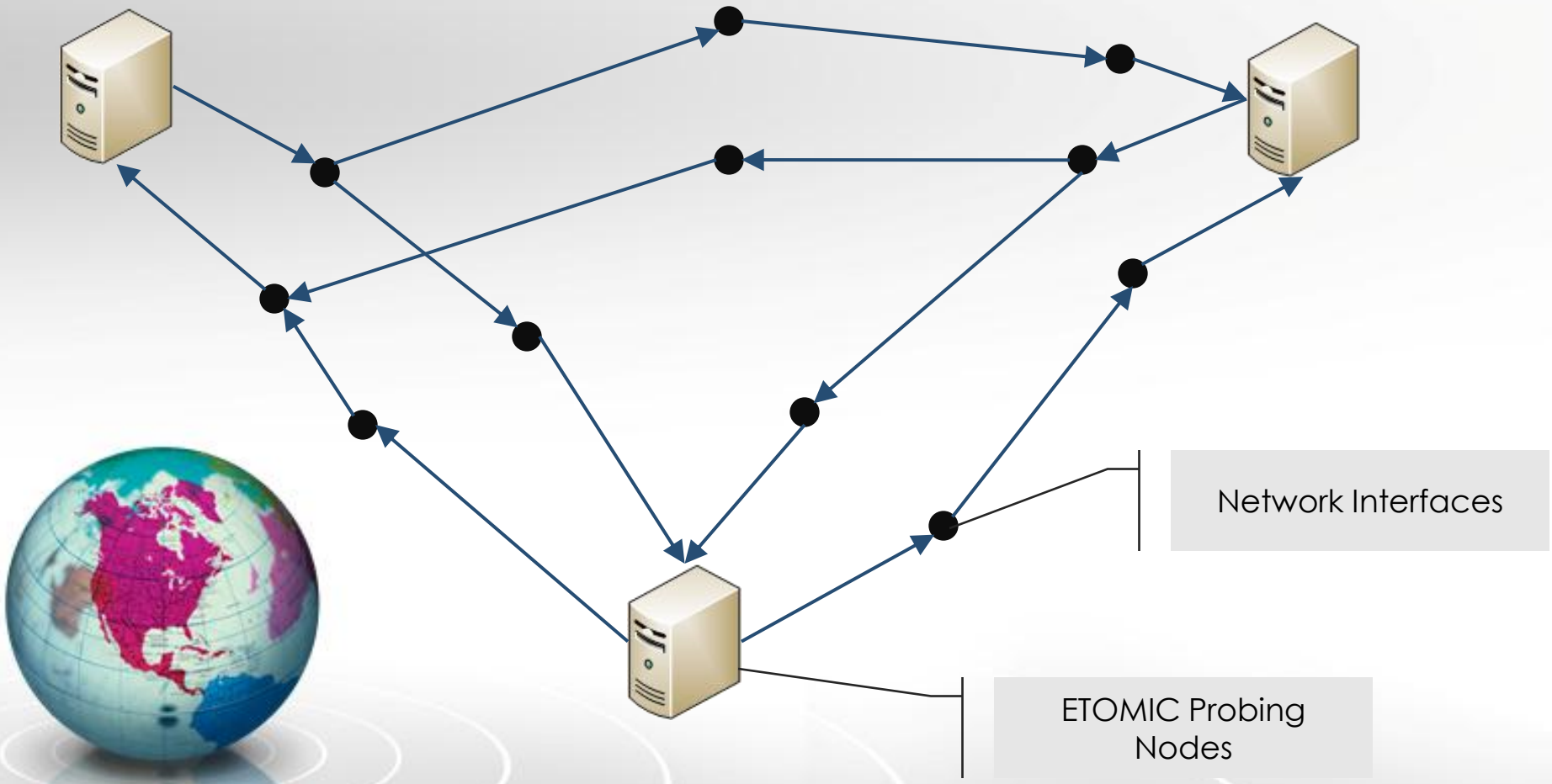
- **E**uropean **T**raffic **O**bservatory **M**easurement **I**nfrastru**C**ture (etomic) was created in 2004-05 within the **Evergrow** Integrated Project.
    - **Open** and **public** testbed for researchers experimenting the Internet
    - 18 GPS synchronized active probing nodes
    - Equiped with Endace DAG cards
        - **High-precision end-to-end measurements**
- Scheduled experiments
    - **NO SLICES**
        - » **You own the resources** during the experimentation



www.etomic.org

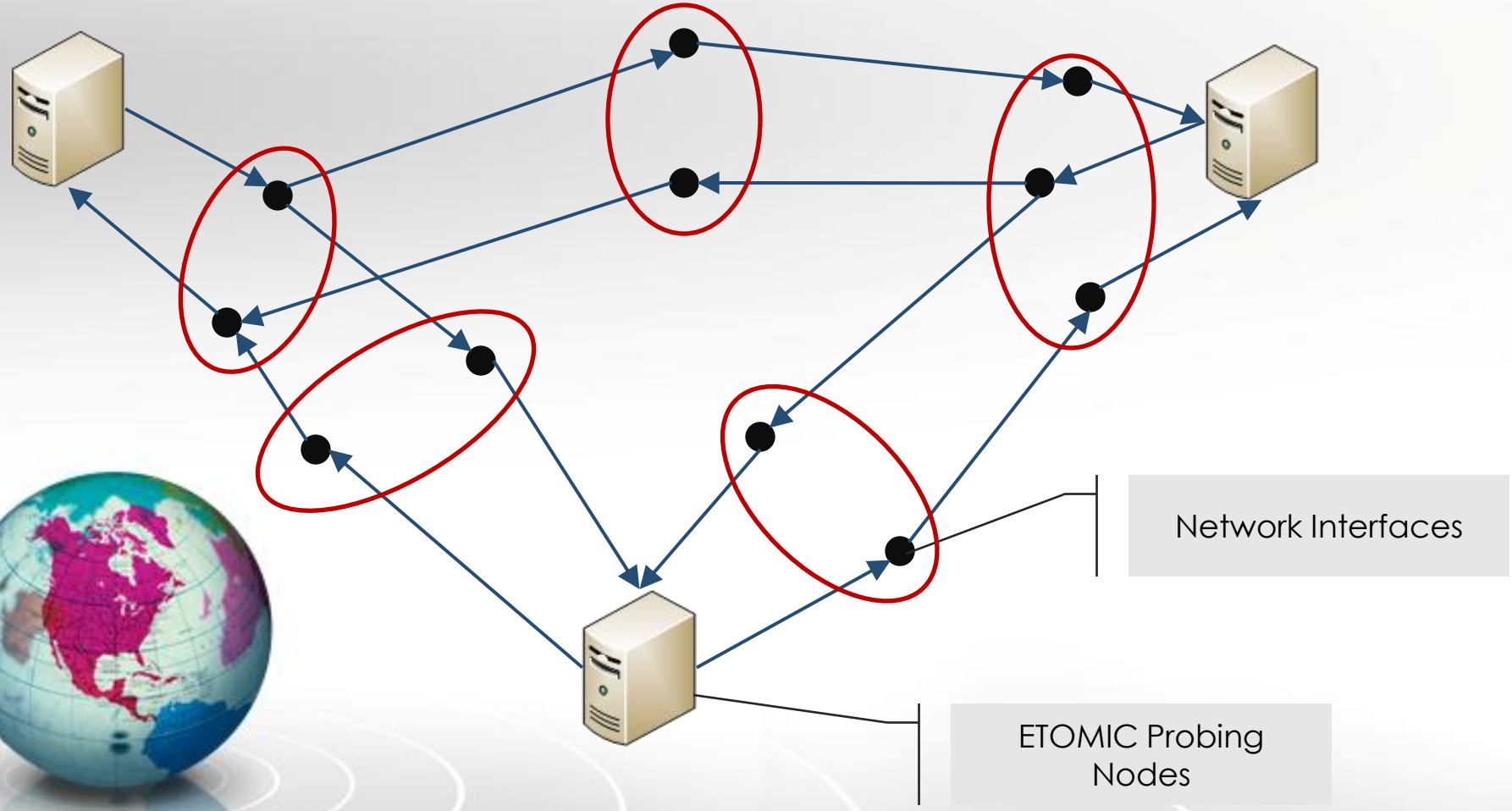
Data Collection and Evaluation
STEP 1 – Traceroute topology

- Goal: **Localizing inter-ETOMIC routers**



Data Collection and Evaluation
STEP 2 – Interface Clustering

- Goal: **Localizing inter-ETOMIC routers**



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STEP 2 – Interface Clustering

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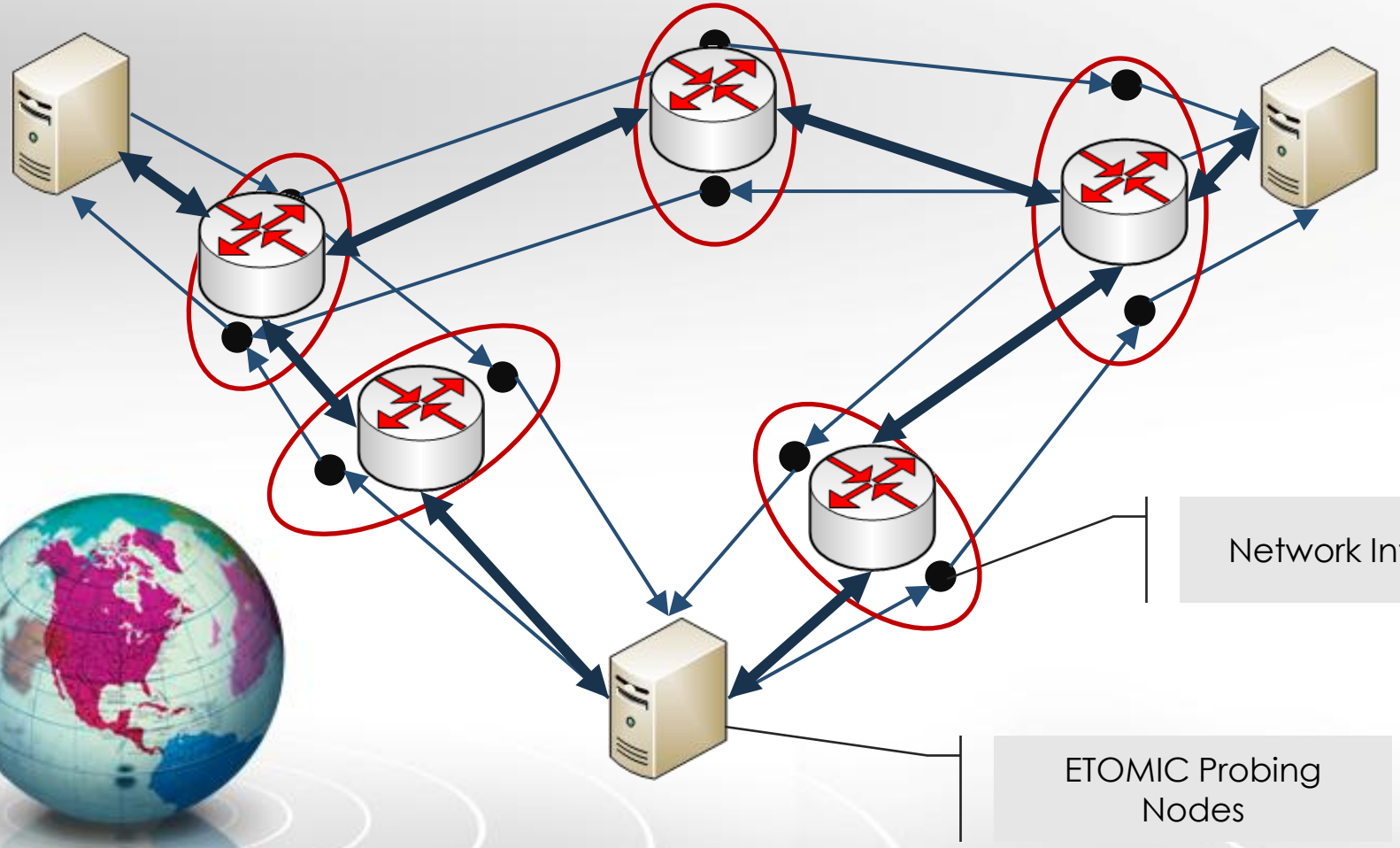
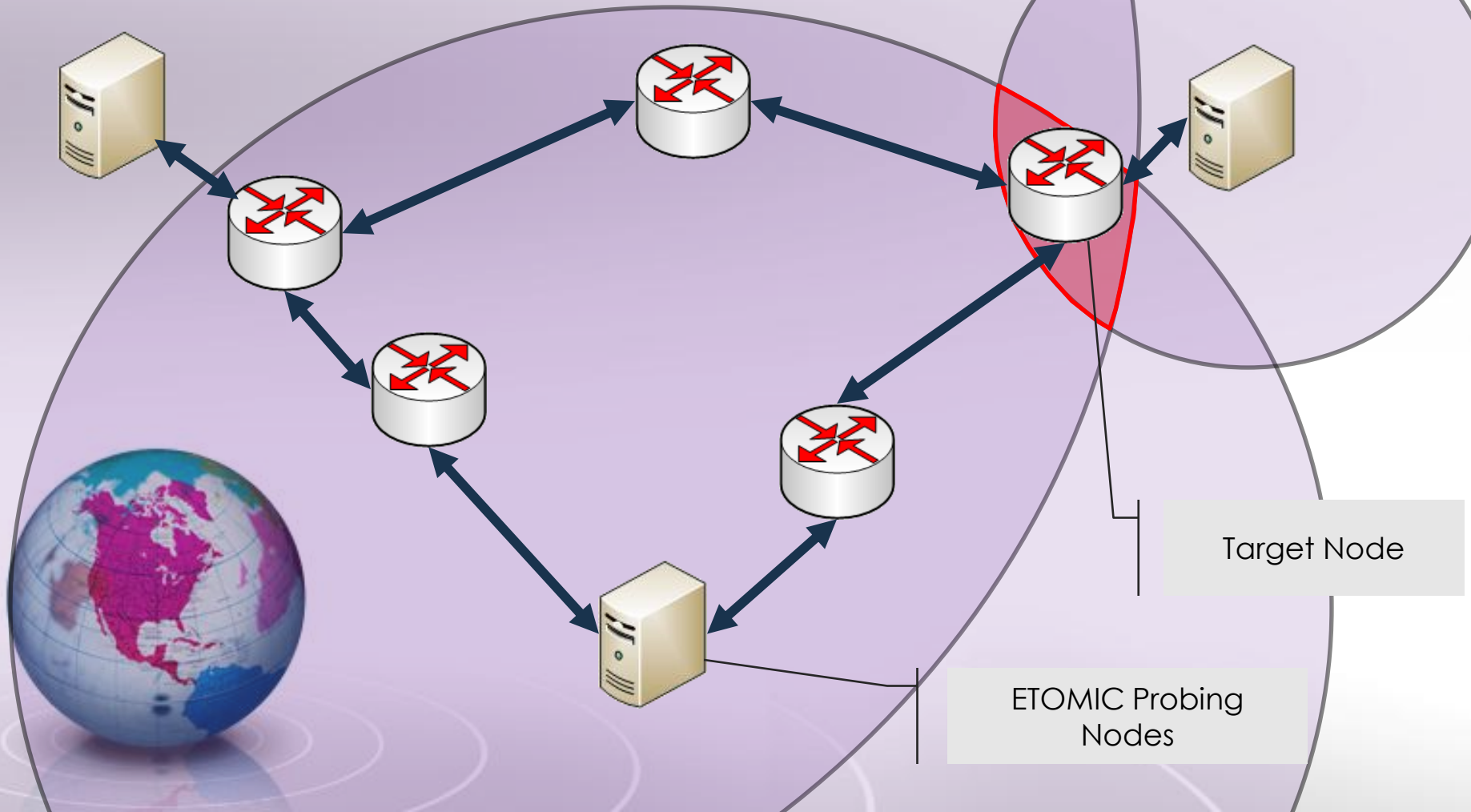


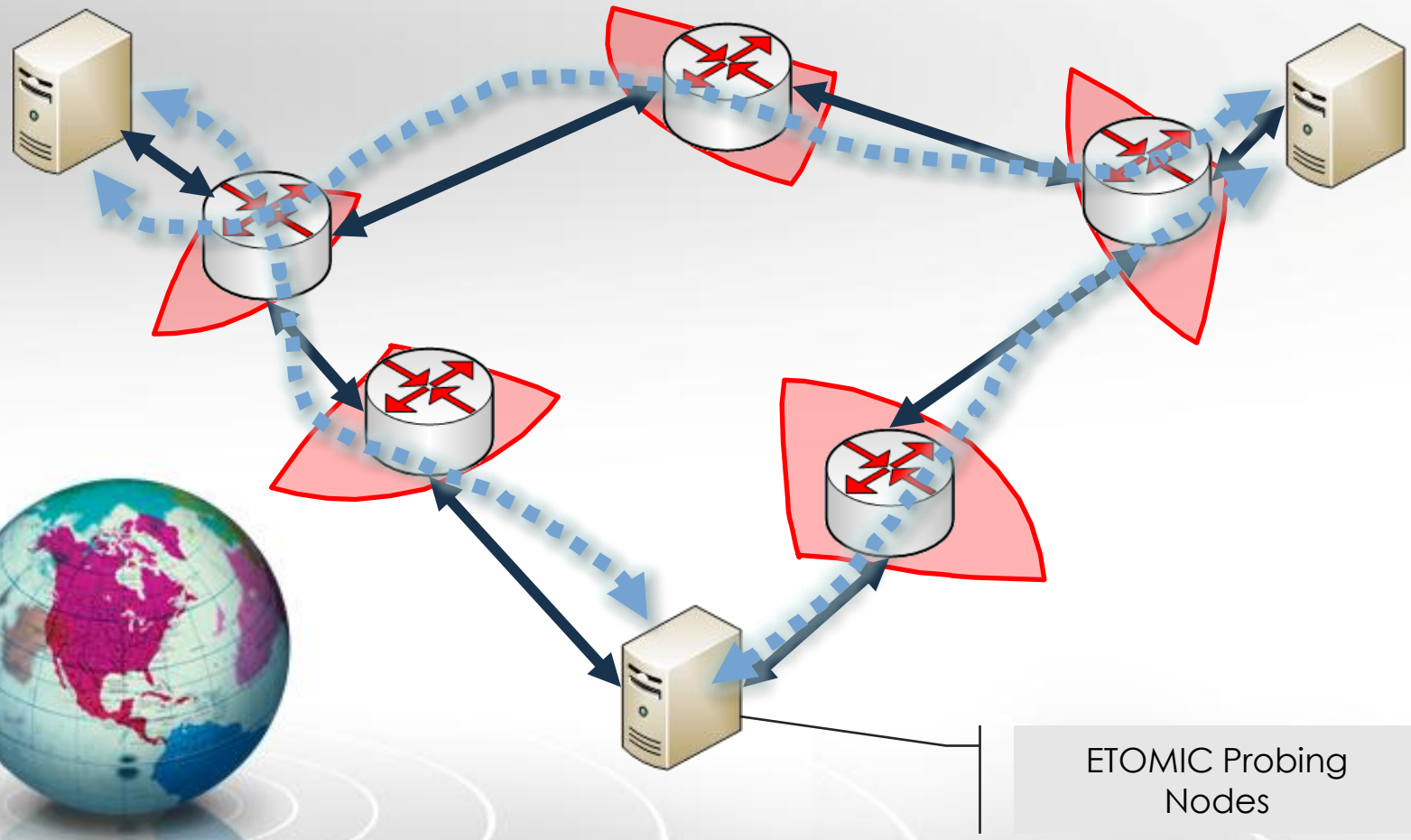
Data Collection and Evaluation
STEP 3 – RTT Measurements

- Goal: **Localizing inter-ETOMIC routers**



Data Collection and Evaluation
STEP 4 – OWD Measurement

- Goal: **Localizing inter-ETOMIC routers**



OneLab2 - The Next Generation of ETOMIC

OneLab2 sites:

- **≥2 PlanetLab nodes**
  - New features
    - Dummybox
    - WiFi access
    - UMTS, WiMax…
- **1 ETOMIC2-COMO integrated node**
  - High precision e2e measurements
  - ARGOS meas. card
  - available via ETOMIC's CMS
- **1 APE box**
  - A lightweight measurement tool

ETOMIC

www.etomic.org

OneLab2

www.onelab.eu

www.etomic.org

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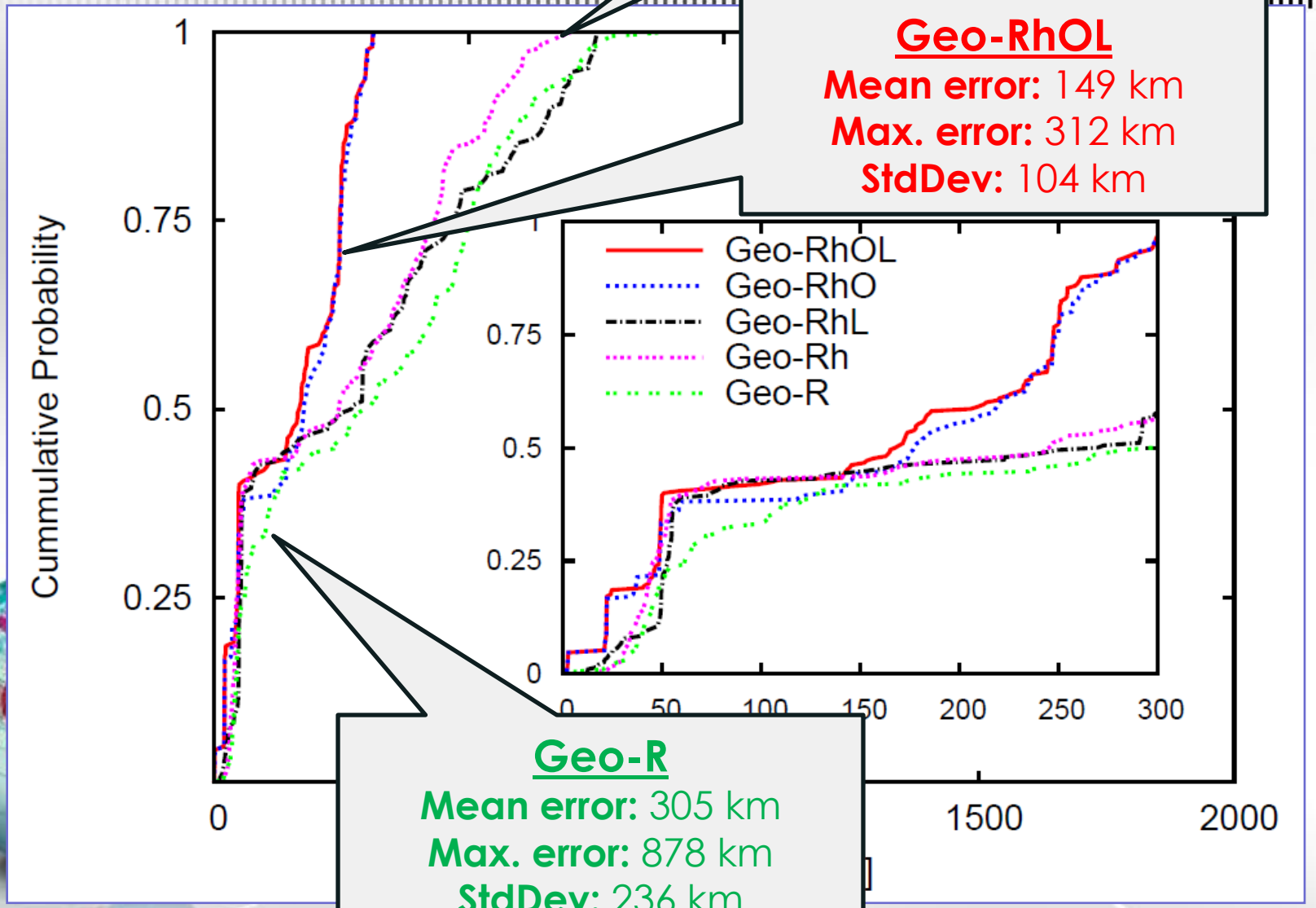
Performance Analysis

Geo-Rh
Mean error: 251 km
Max. error: 699 km
StdDev: 205 km

Geo-RhOL
Mean error: 149 km
Max. error: 312 km
StdDev: 104 km

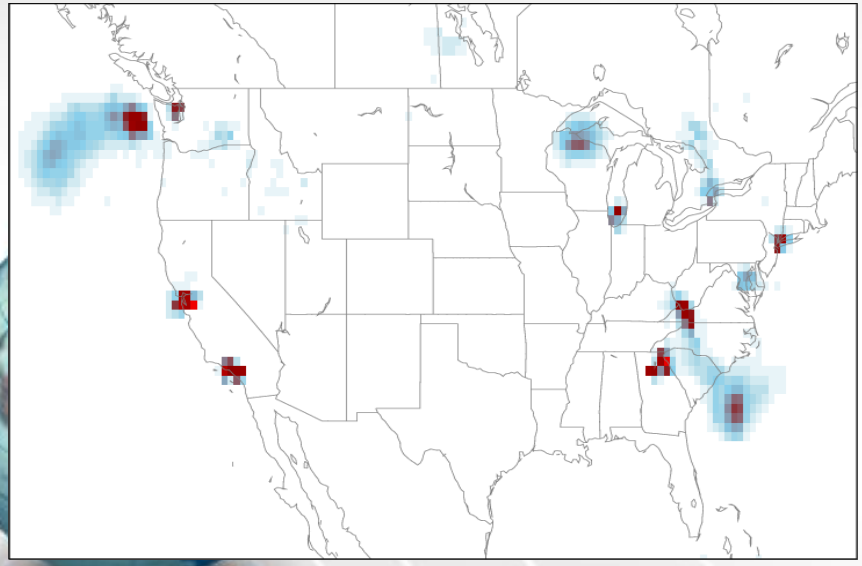


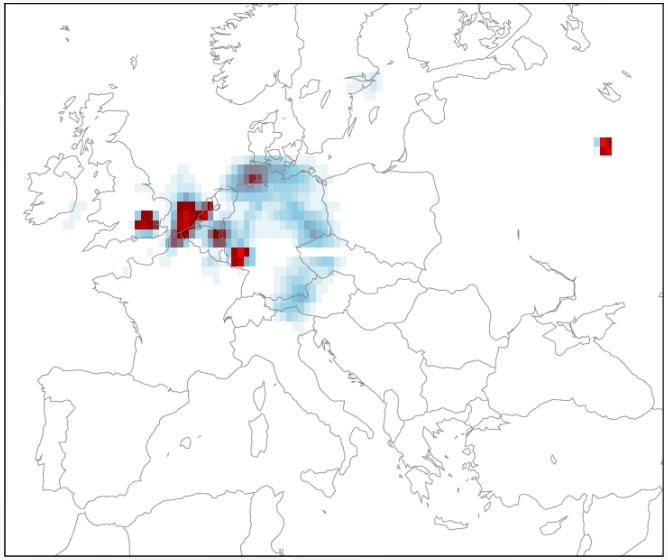
Geo-R
Mean error: 305 km
Max. error: 878 km
StdDev: 236 km

A case study –
Where are your YouTube videos?

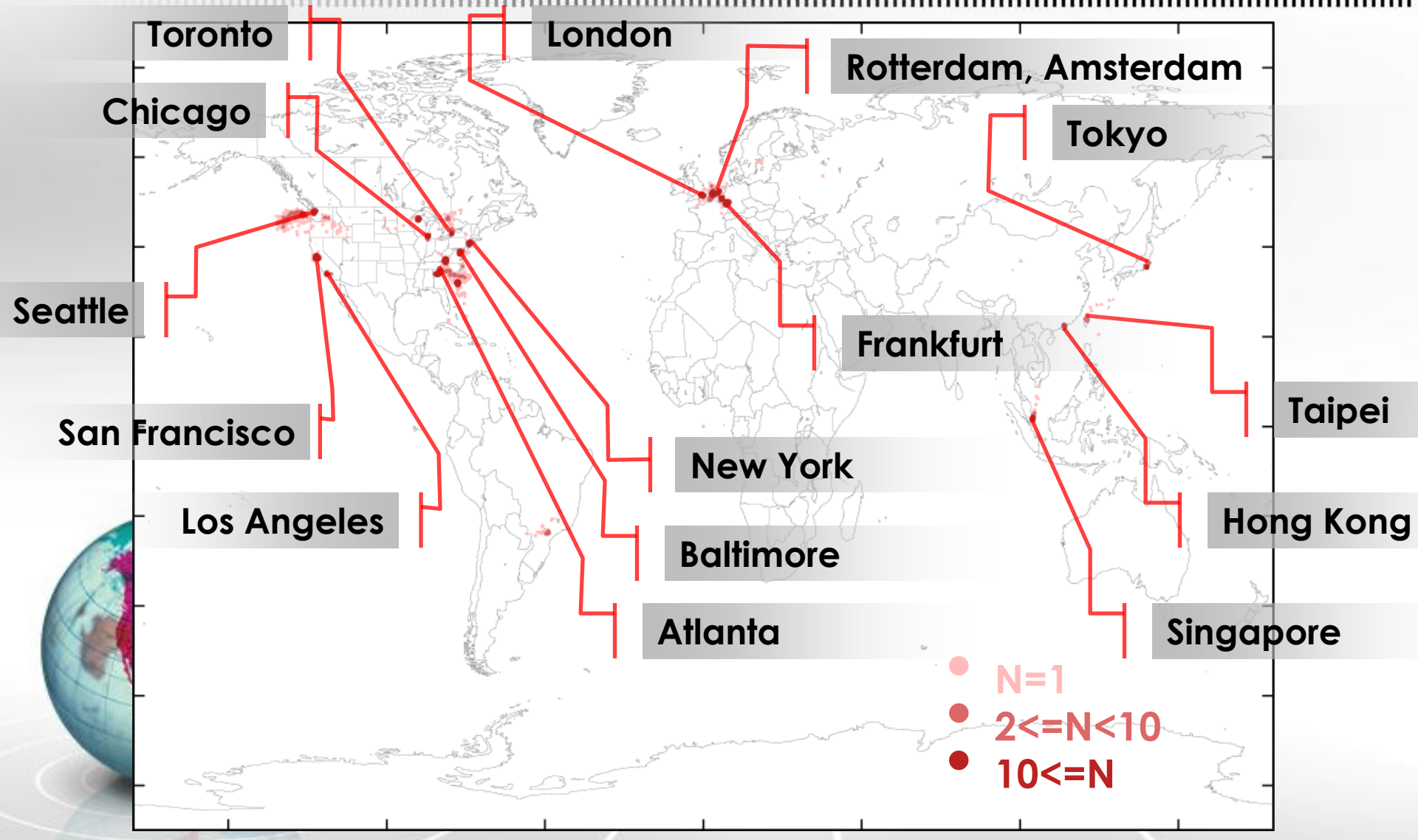
A case study – Where are your YouTube videos?

- Where are YouTube's content delivery servers?
  - The IP range: **74.125.0.0/16**
  - 8127 globally accessible IP addresses
  - 8127 nodes to be localized
- Using PlanetLab nodes as landmarks





A case study – Where are „YouTube" servers?



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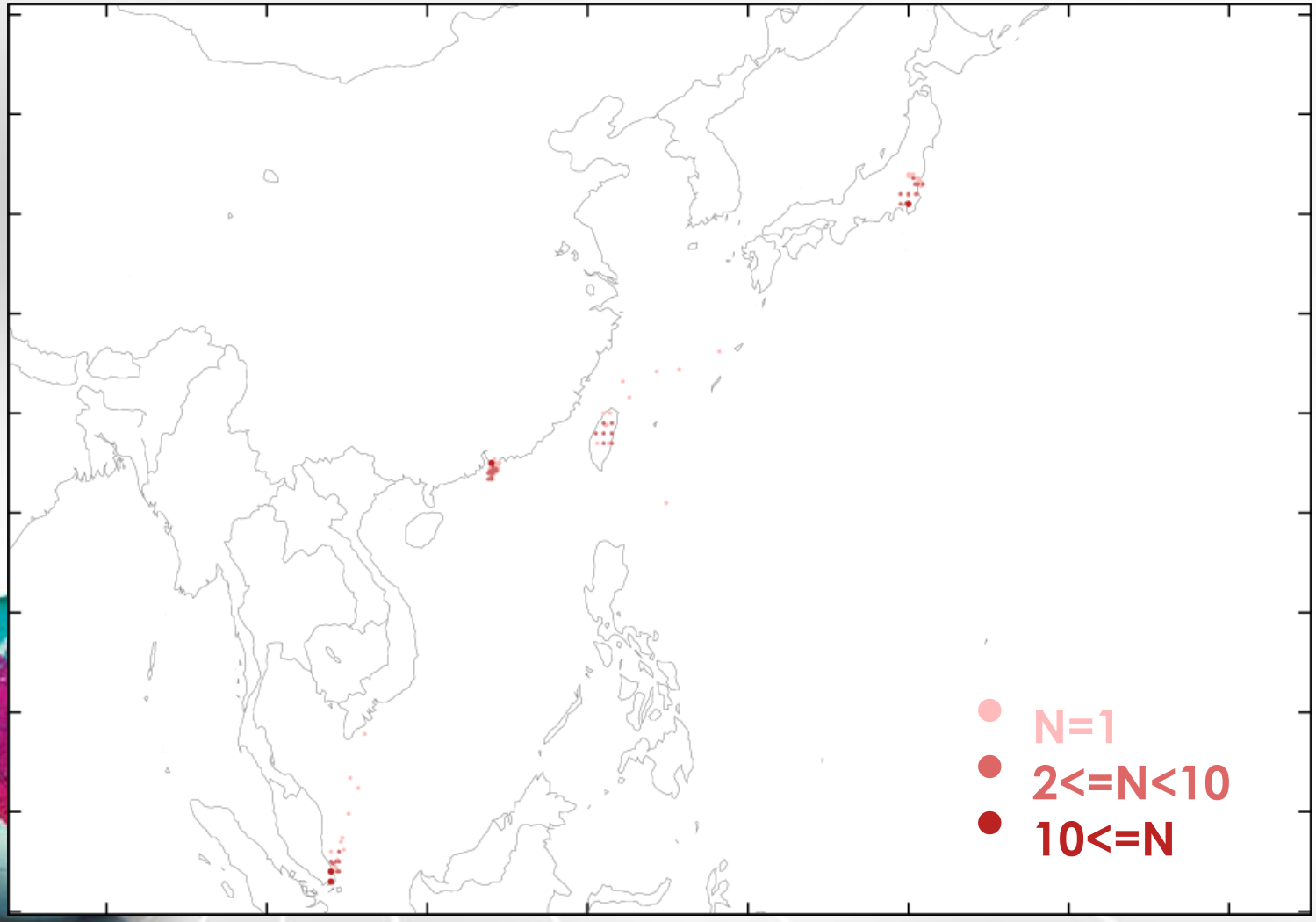

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Summary

- Estimating propagation delays more precisely
  - **Separation of propagation and per-hop delays** in the overall packet latency
- Velocity of **signal propagation in network** is much smaller than we assumed before due to curvatures
- The **novel one-way delay constraints** improve the accuracy of router geolocation significantly
- A „real life" study

- Plans for future extensions
  - The method can be **combined with passive techniques**
  - **Improving latency model**
  - **Real-time Geolocation Service using Web Services (details in the poster session)**

Thank you for your attention!

Contact: laki@complex.elte.hu

More details:

S. Laki, P. Mátray, P. Hága, P. Csabai and G. Vattay:
A Detailed Path-latency Model for Router Geolocation
Proceedings of Tridencom 2009 Conference, April 6-9 2009, Washington DC

http://cnl.elte.hu