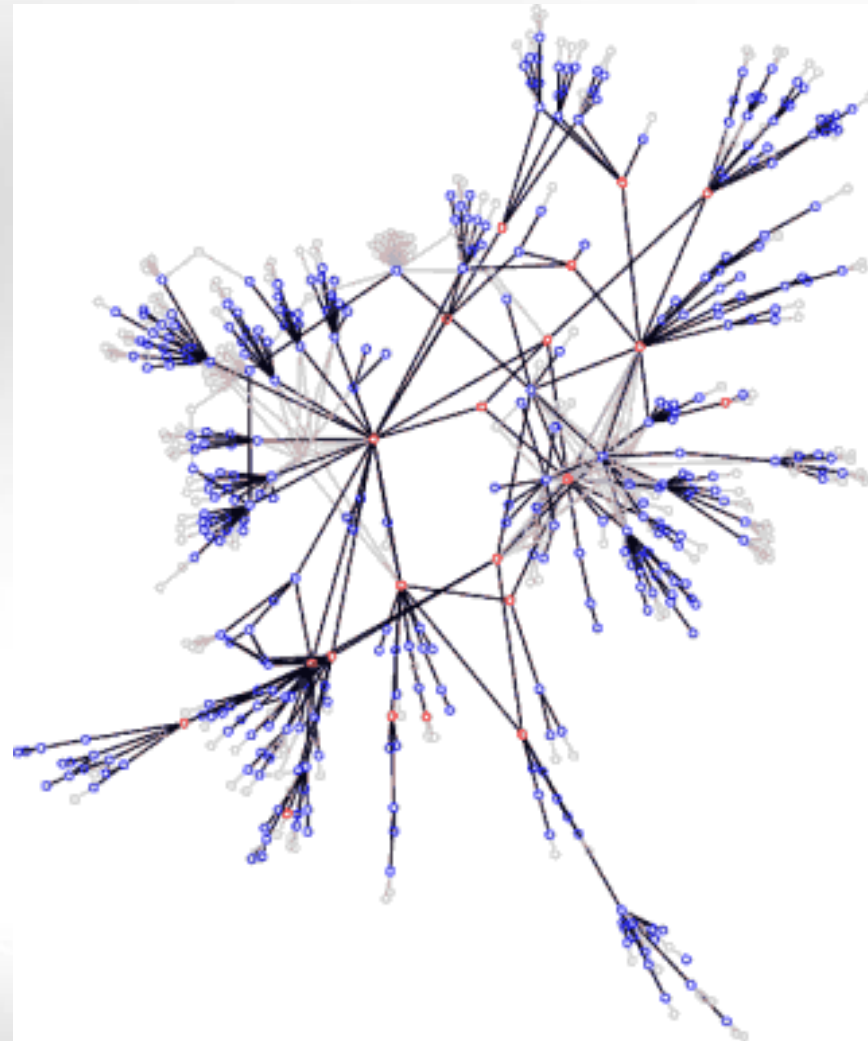


Internet Geography

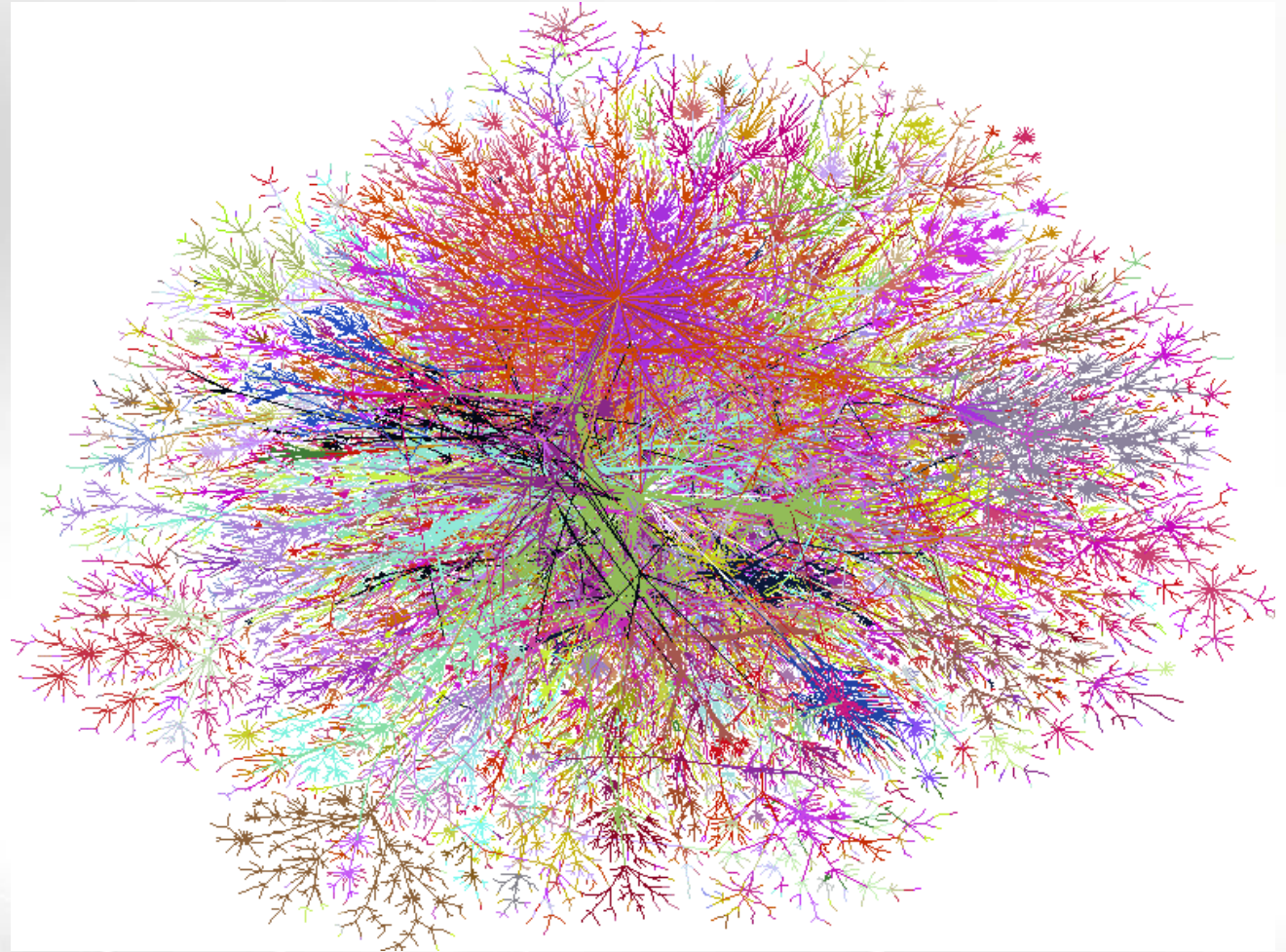


Gábor Vattay
Eötvös University, Budapest

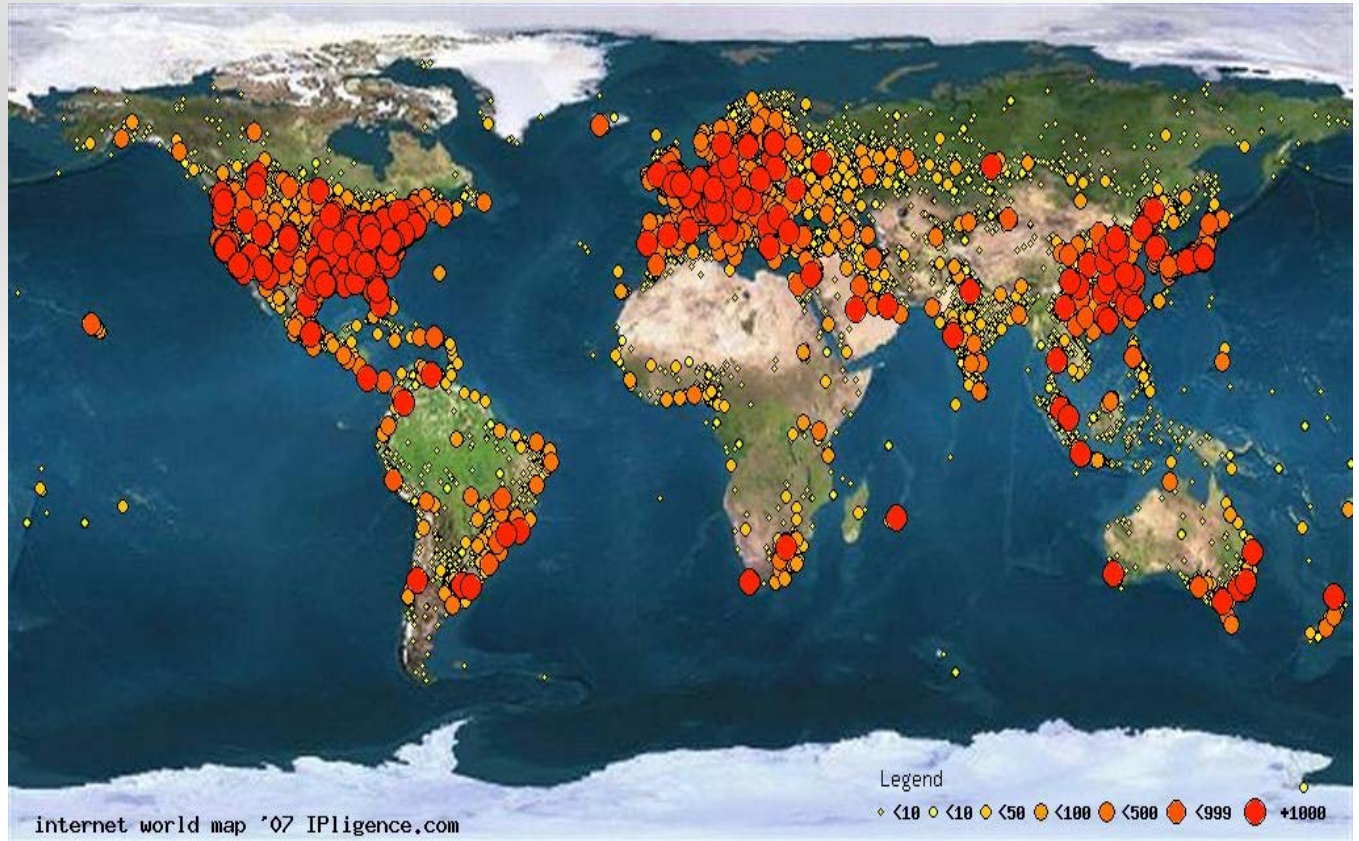
Network of an Internet service provider



Internet as a collection of ISPs



Internet on the map ?



We can ask questions like:

- Where are the spammers/hackers?
- Where are the visitors of my homepage?
- Where are the You Tube servers?
- Where are the routers of the Internet?
- Where are the Hungarian language webpages?



Homebrew measurement of routes

„tracert” command

www.ucsd.edu San Diego, California

```
C:\ Parancssor
1    10 ms    3 ms    3 ms    192.168.200.1
2    2 ms    1 ms    2 ms    leo.komplex.elte.hu [157.181.172.126]
3    5 ms    3 ms    2 ms    sup720.hbone-elte.elte.hu [157.181.141.9]
4    4 ms    2 ms    2 ms    c6509-tengbeth1-2.vh.hbone.hu [195.111.97.181]
5    3 ms    3 ms    3 ms    c6513-tengbeth13-1.vh.hbone.hu [195.111.96.73]
6    2 ms    2 ms    3 ms    gsr16-gbeth10-0.vh.hbone.hu [195.111.97.241]
7    4 ms    5 ms    2 ms    hungarnet.rt1.bud.hu.geant2.net [62.40.124.101]

8    11 ms   11 ms   11 ms   so-4-0-0.rt1.pra.cz.geant2.net [62.40.112.41]
9    19 ms   21 ms   21 ms   so-6-3-0.rt1.fra.de.geant2.net [62.40.112.38]
10   124 ms   125 ms  124 ms   abilene-wash-gw.rt1.fra.de.geant2.net [62.40.125
.18]
11   141 ms   140 ms  140 ms   atlang-washng.abilene.ucaid.edu [198.32.8.65]
12   162 ms   161 ms  167 ms   hstnng-atlang.abilene.ucaid.edu [198.32.8.33]
13   189 ms   189 ms  197 ms   losang-hstnng.abilene.ucaid.edu [198.32.8.21]
14   189 ms   190 ms  189 ms   hpr-lax-gsr1--abilene-LA-10ge.cenic.net [137.164
.25.2]
15   194 ms   197 ms  192 ms   hpr-ucsd-10ge--lax-hpr.cenic.net [137.164.27.165]
16   233 ms   193 ms  193 ms   nodeb-msfc--ucsd-gw-t320-ge.ucsd.edu [132.239.25
5.37]
17   206 ms   196 ms  195 ms   node-j-4506-nodeb-6509.ucsd.edu [132.239.255.245]
18   194 ms   200 ms  196 ms   adcom-720--nodej-4506-ge.ucsd.edu [132.239.255.1
0]
19   195 ms   195 ms  196 ms   cw-portal.ucsd.edu [132.239.180.101]

Az útvonalkövetés elkészült.
C:\Documents and Settings\Uattay Gábor>
```



Speed of thoughts ...



Homebrew measurement of speed

With the „ping“ command

We send a packet to another machine, which sends back an acknowledgement.

Time between sending the packet and receiving the ack the round trip time (RTT).



ping www.tuwien.ac.at

```
Parancssor
C:\Documents and Settings\Vattay Gábor>
C:\Documents and Settings\Vattay Gábor>
C:\Documents and Settings\Vattay Gábor>ping www.tuwien.ac.at

info.zv.tuwien.ac.at [128.130.102.130] pingelésé 32 bájt méretű adatokkal:

Válasz 128.130.102.130: bájt=32 idő=7 ms TTL=241
Válasz 128.130.102.130: bájt=32 idő=22 ms TTL=241
Válasz 128.130.102.130: bájt=32 idő=7 ms TTL=241
Válasz 128.130.102.130: bájt=32 idő=24 ms TTL=241

128.130.102.130 ping-statisztikája:
    Csomagok: küldött = 4, fogadott = 4, elveszett = 0 (0% veszteség),
    Oda-vissza út ideje közelítőlegesen, milliszekundumban:
    minimum = 7ms, maximum = 24ms, átlag = 15ms
C:\Documents and Settings\Vattay Gábor>
```

Budapest-Wien-Budapest 434 km



ping www.u-psud.fr

```
Parancssor
Csomagok: küldött = 10, fogadott = 10, elveszett = 0 (0% veszteség),
Oda-vissza út ideje közelítőlegesen, milliszekundumban:
  minimum = 39ms, maximum = 67ms, átlag = 54ms

C:\Documents and Settings\Uattay Gábor>ping -n 10 www.u-psud.fr

manon.notes.u-psud.fr [129.175.34.50] pingelése 32 bájt méretű adatokkal:

Válasz 129.175.34.50: bájt=32 idő=51 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=51 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=105 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=44 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=62 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=62 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=61 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=38 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=58 ms TTL=111
Válasz 129.175.34.50: bájt=32 idő=65 ms TTL=111

129.175.34.50 ping-statisztikája:
  Csomagok: küldött = 10, fogadott = 10, elveszett = 0 (0% veszteség),
  Oda-vissza út ideje közelítőlegesen, milliszekundumban:
    minimum = 38ms, maximum = 105ms, átlag = 59ms

C:\Documents and Settings\Uattay Gábor>
```

Budapest-Paris-Budapest 2496 km

ping www.columbia.edu

```
Parancssor
Csomagok: küldött = 10, fogadott = 9, elveszett = 1 (10% veszteség),
Oda-vissza út ideje közelítőlegesen, milliszekundumban:
  minimum = 131ms, maximum = 225ms, átlag = 168ms

C:\Documents and Settings\Uattay Gábor>ping -n 10 www.columbia.edu

www.columbia.akadns.net [128.59.48.24] pingelése 32 bájt méretű adatokkal:

Uálasz 128.59.48.24: bájt=32 idő=130 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=143 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=160 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=184 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=206 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=229 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=135 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=172 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=194 ms TTL=112
Uálasz 128.59.48.24: bájt=32 idő=130 ms TTL=112

128.59.48.24 ping-statisztikája:
  Csomagok: küldött = 10, fogadott = 10, elveszett = 0 (0% veszteség),
  Oda-vissza út ideje közelítőlegesen, milliszekundumban:
    minimum = 130ms, maximum = 229ms, átlag = 168ms

C:\Documents and Settings\Uattay Gábor>
```

Budapest-New York-Budapest 14024 km

www.ucsd.edu

Parancssor

```
Csomagok: küldött = 10, fogadott = 10, elveszett = 0 (0% veszteség),  
Oda-vissza út ideje közelítőlegesen, milliszekundumban:  
minimum = 2ms, maximum = 12ms, átlag = 3ms
```

```
C:\Documents and Settings\Vattay Gábor>ping -n 10 www.ucsd.edu
```

```
www.ucsd.edu [132.239.180.101] pingelése 32 bájt méretű adatokkal:
```

```
Uálasz 132.239.180.101: bájt=32 idő=194 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104  
Uálasz 132.239.180.101: bájt=32 idő=193 ms TTL=104
```

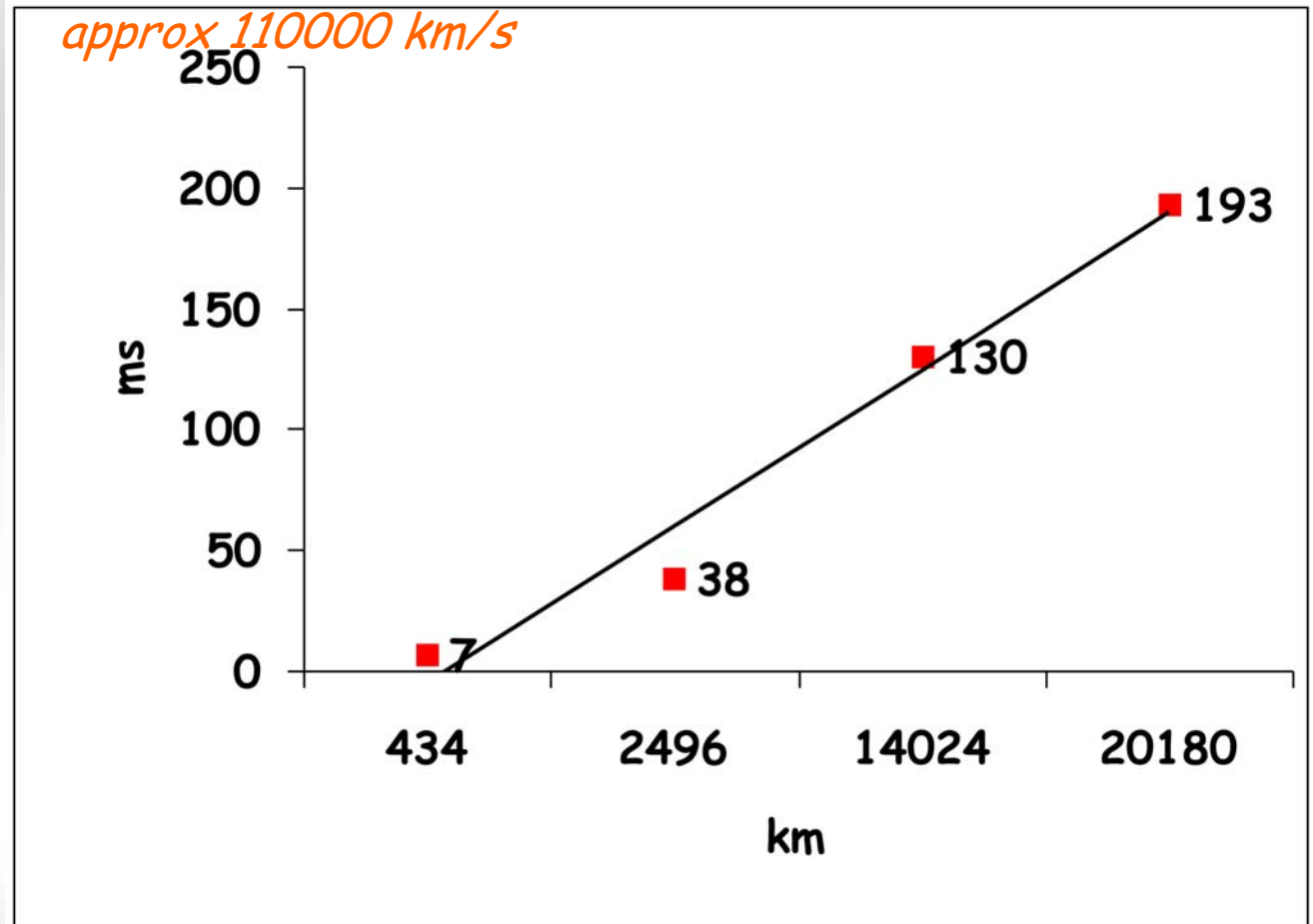
```
132.239.180.101 ping-statisztikája:
```

```
Csomagok: küldött = 10, fogadott = 10, elveszett = 0 (0% veszteség),  
Oda-vissza út ideje közelítőlegesen, milliszekundumban:  
minimum = 193ms maximum = 194ms, átlag = 193ms
```

```
C:\Documents and Settings\Vattay Gábor>
```

Budapest-San Diego-Budapest 20180 km

Speed of IP packets in wire

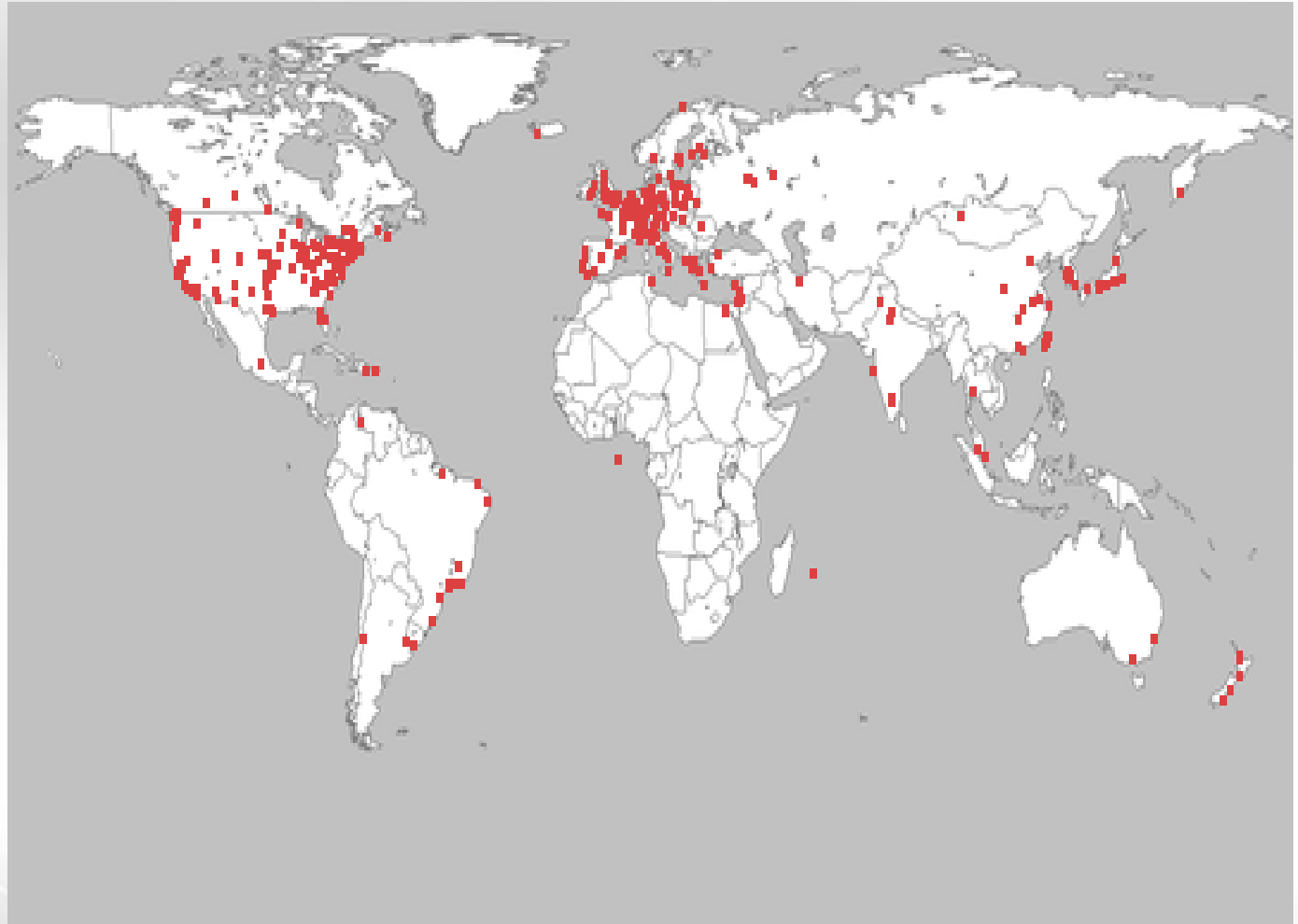


INTERNET MEASUREMENTS

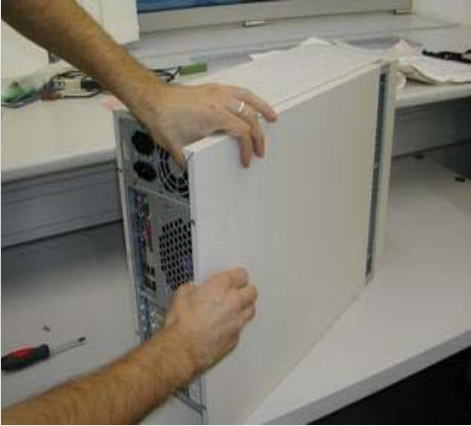


PlanetLab: experimental testbed

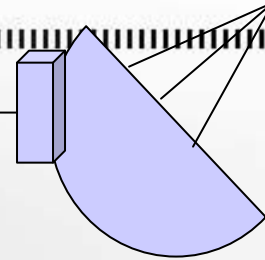
“Experimental Computer Science”



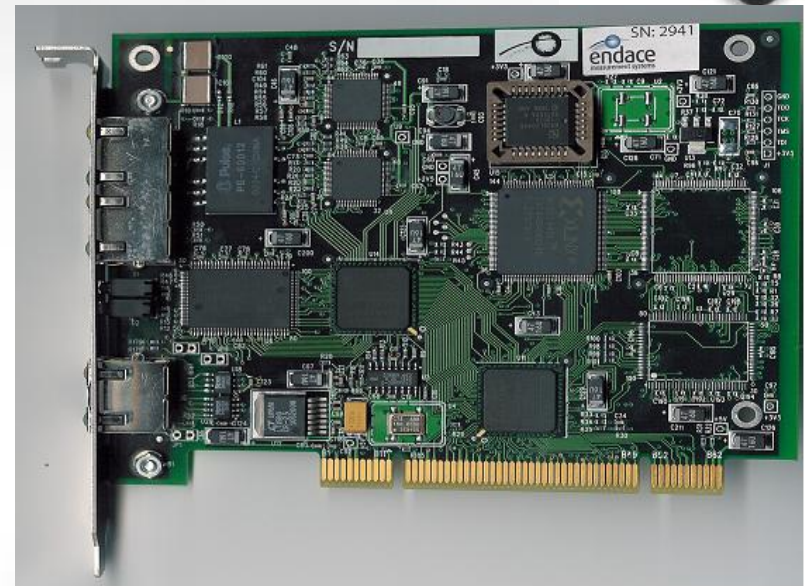
Precise measurement infrastructure



PC + special measurement cards

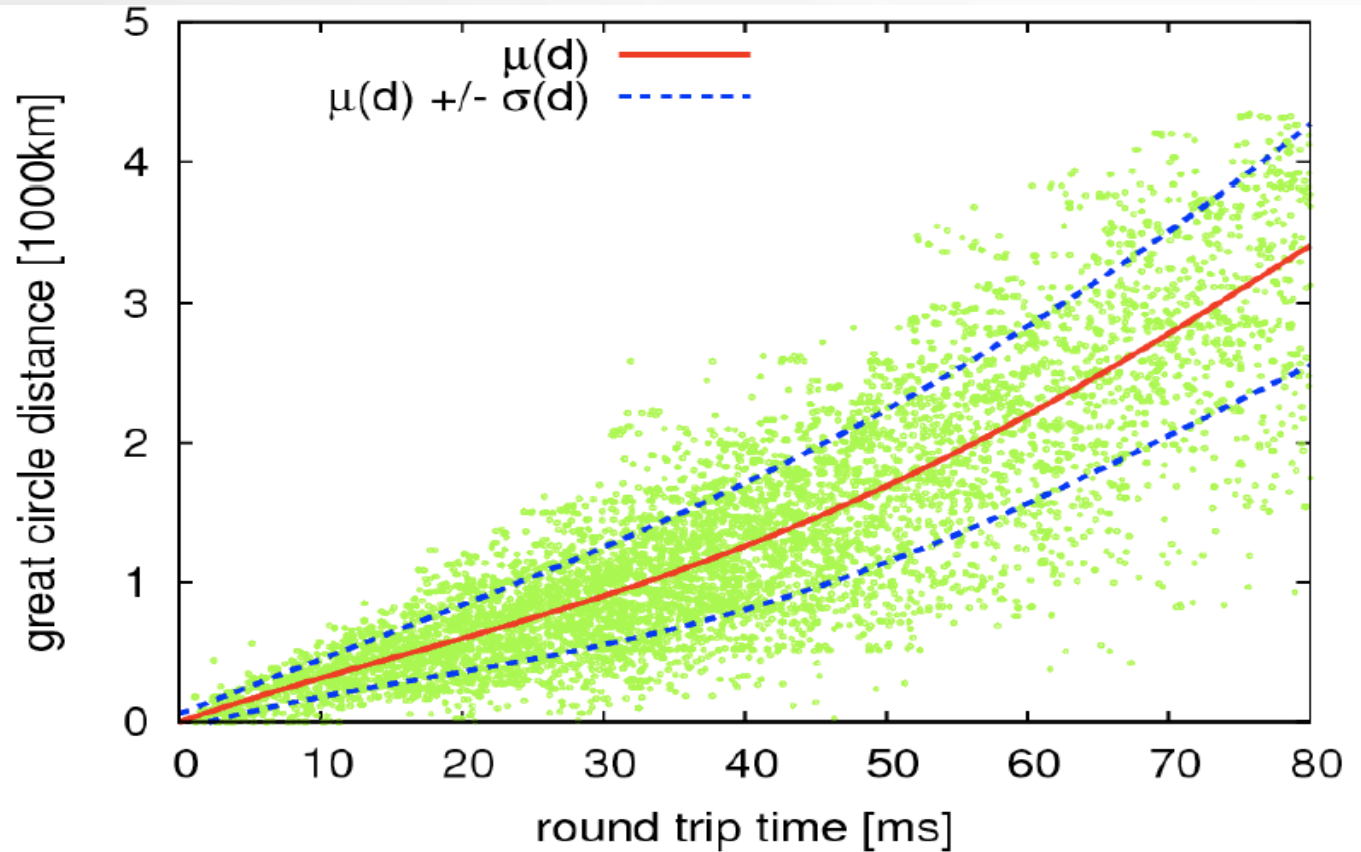


GPS receiver

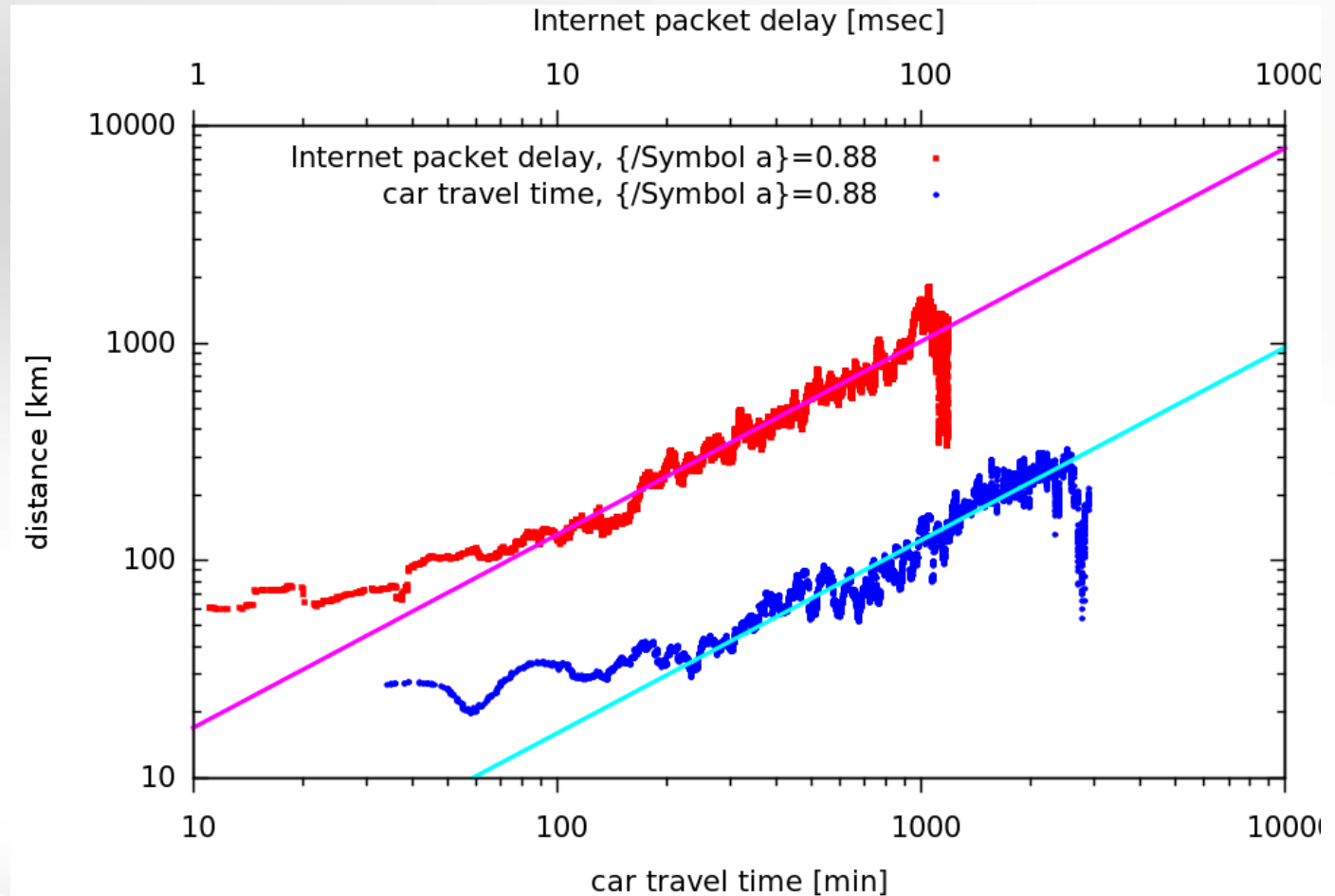


Precision: 10 ns in absolute time

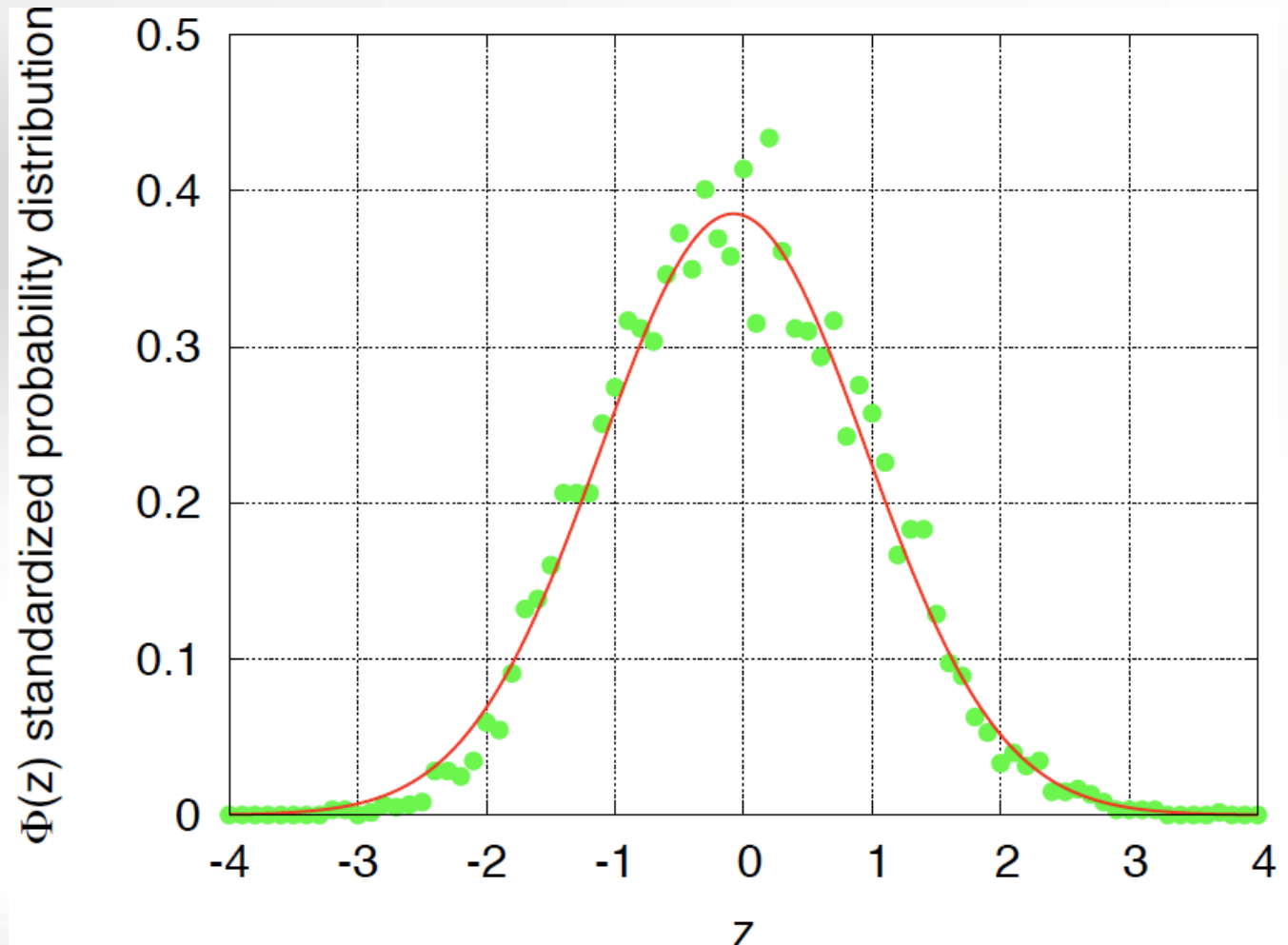
Collection of time-distance information



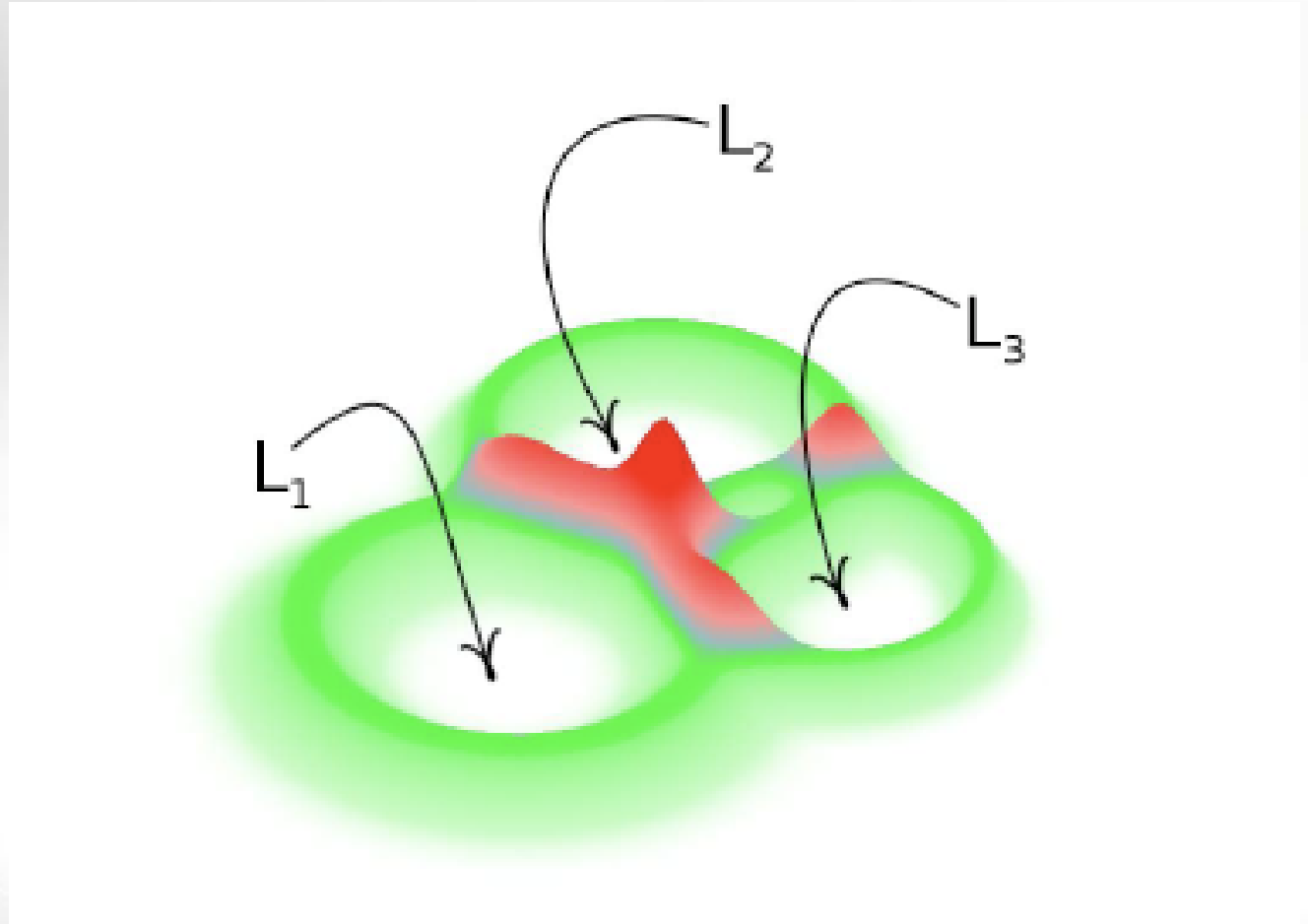
Standard deviation from average: universal curve for Internet and road traffic



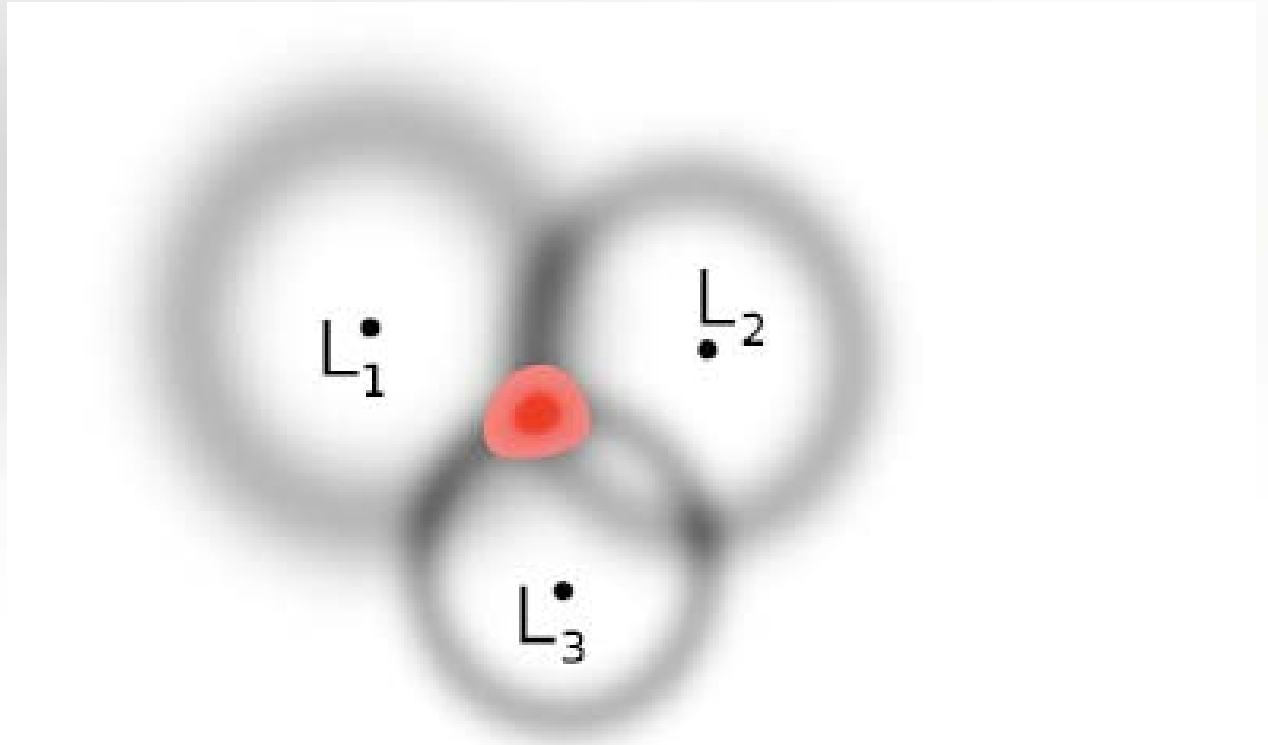
Standardized deviation from average



Location of a node from three RTT measurements



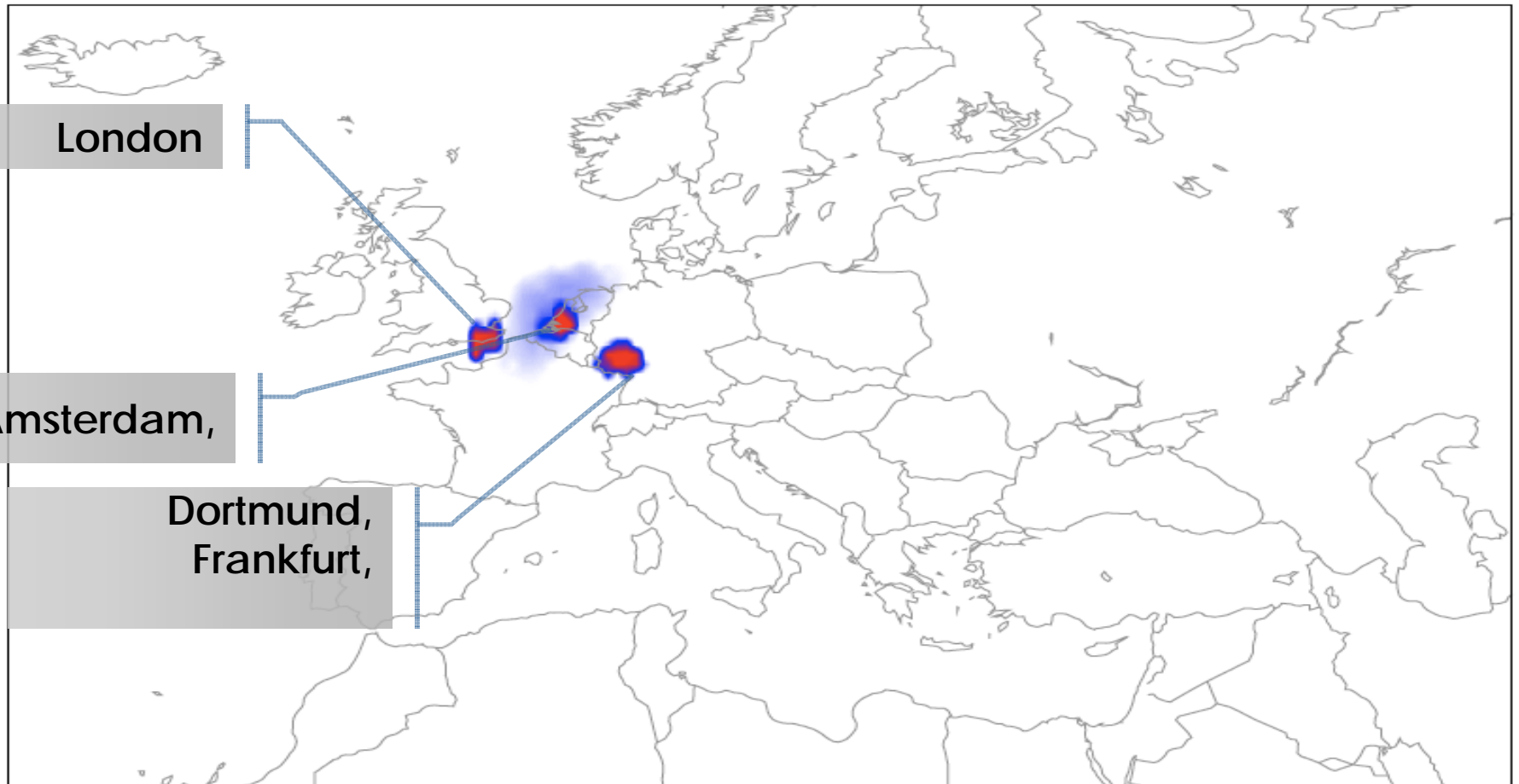
Likelihood distribution



Where are the YouTube servers?

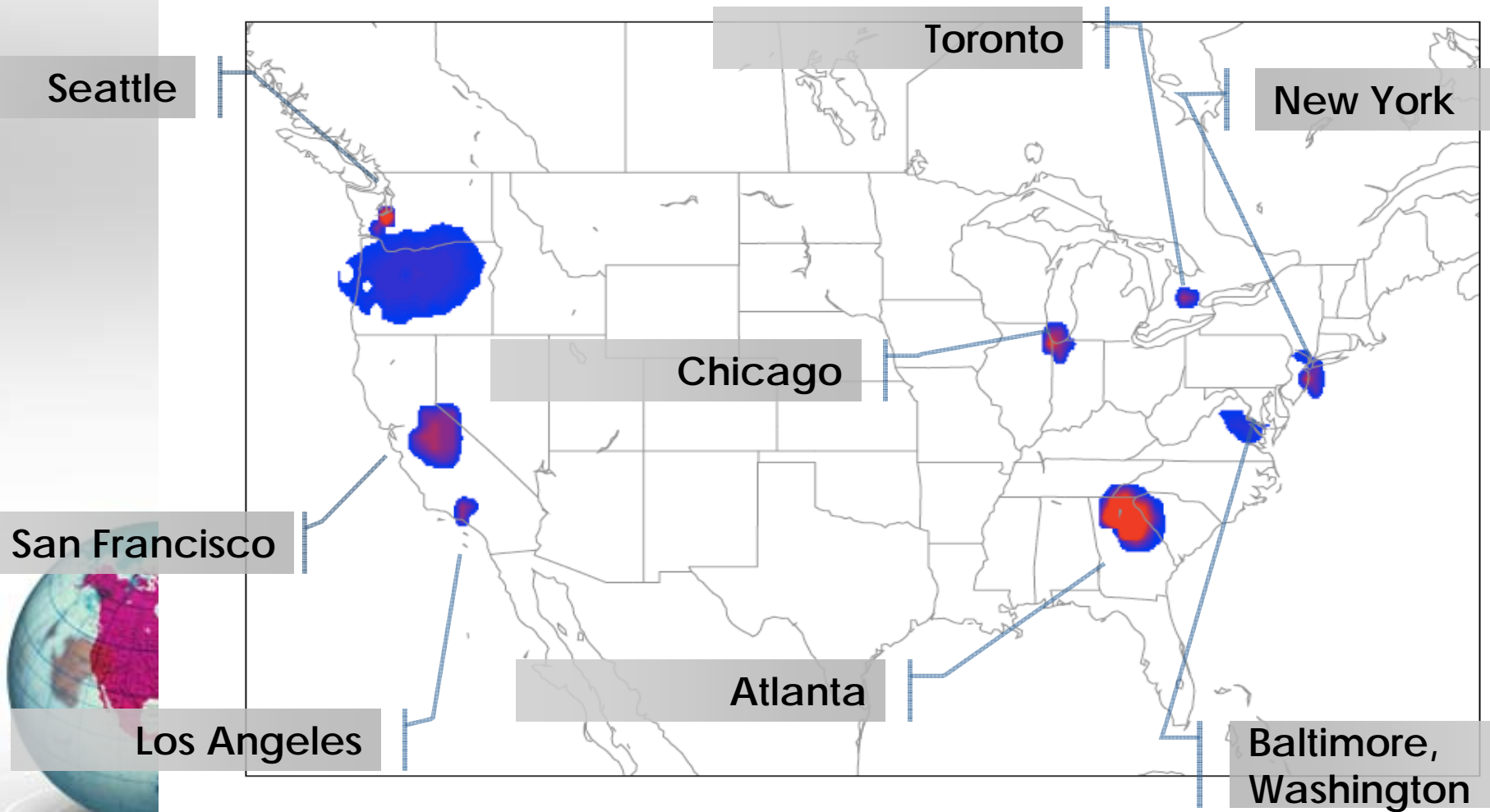


You Tube in Europe



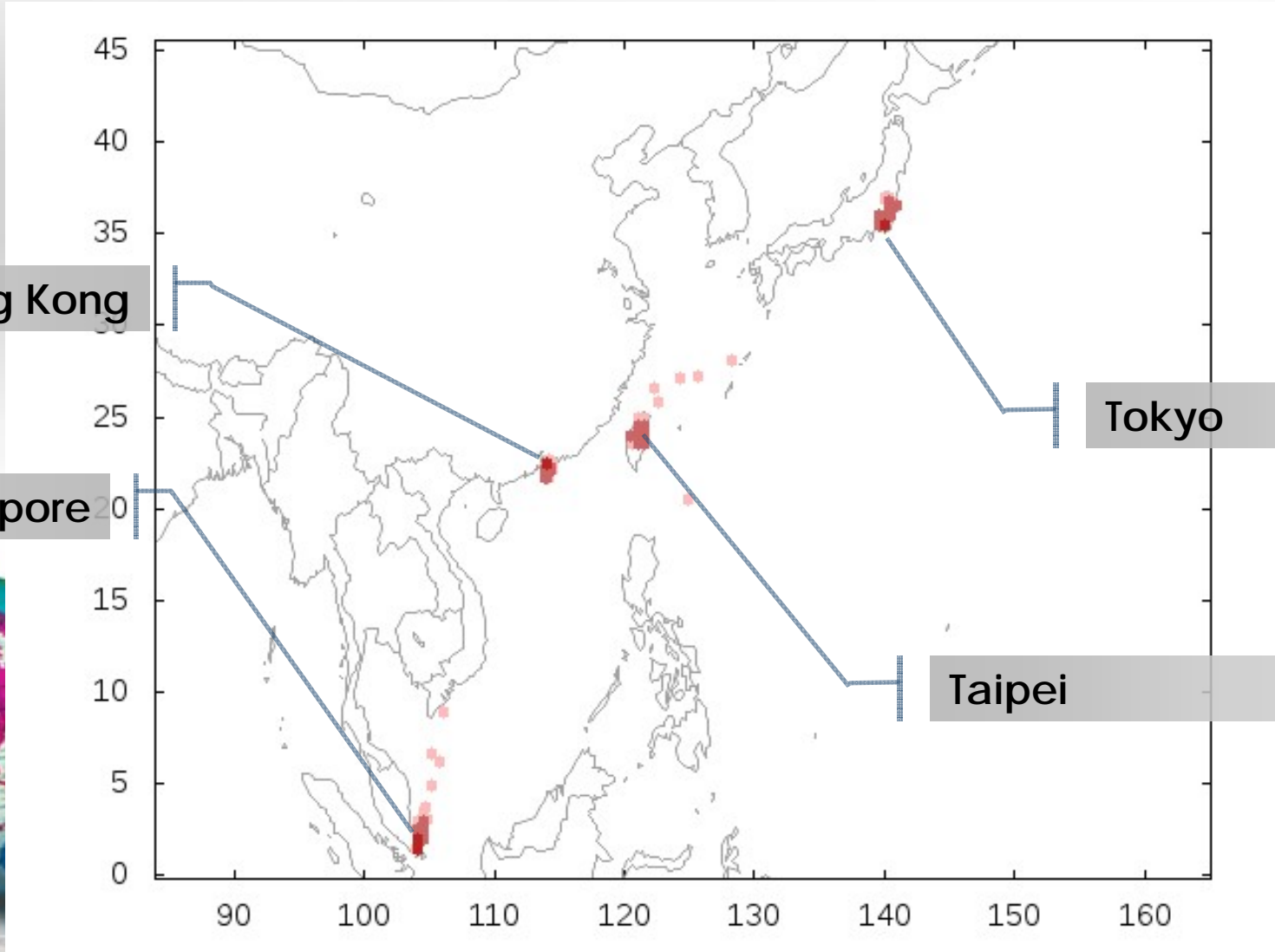
(b) YouTube sites in Europe

You Tube in North America



(a) YouTube sites in North America

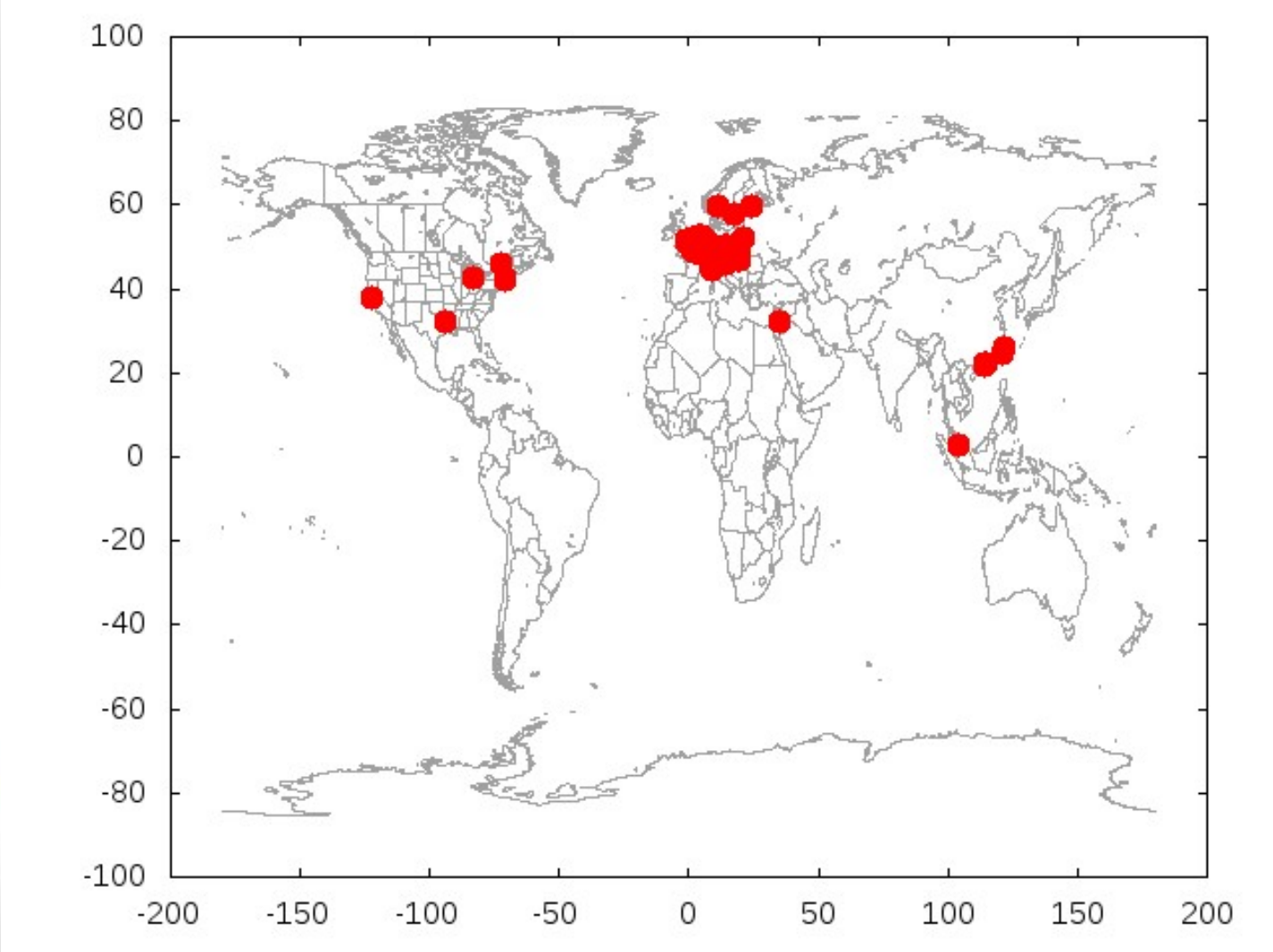
You Tube in Asia



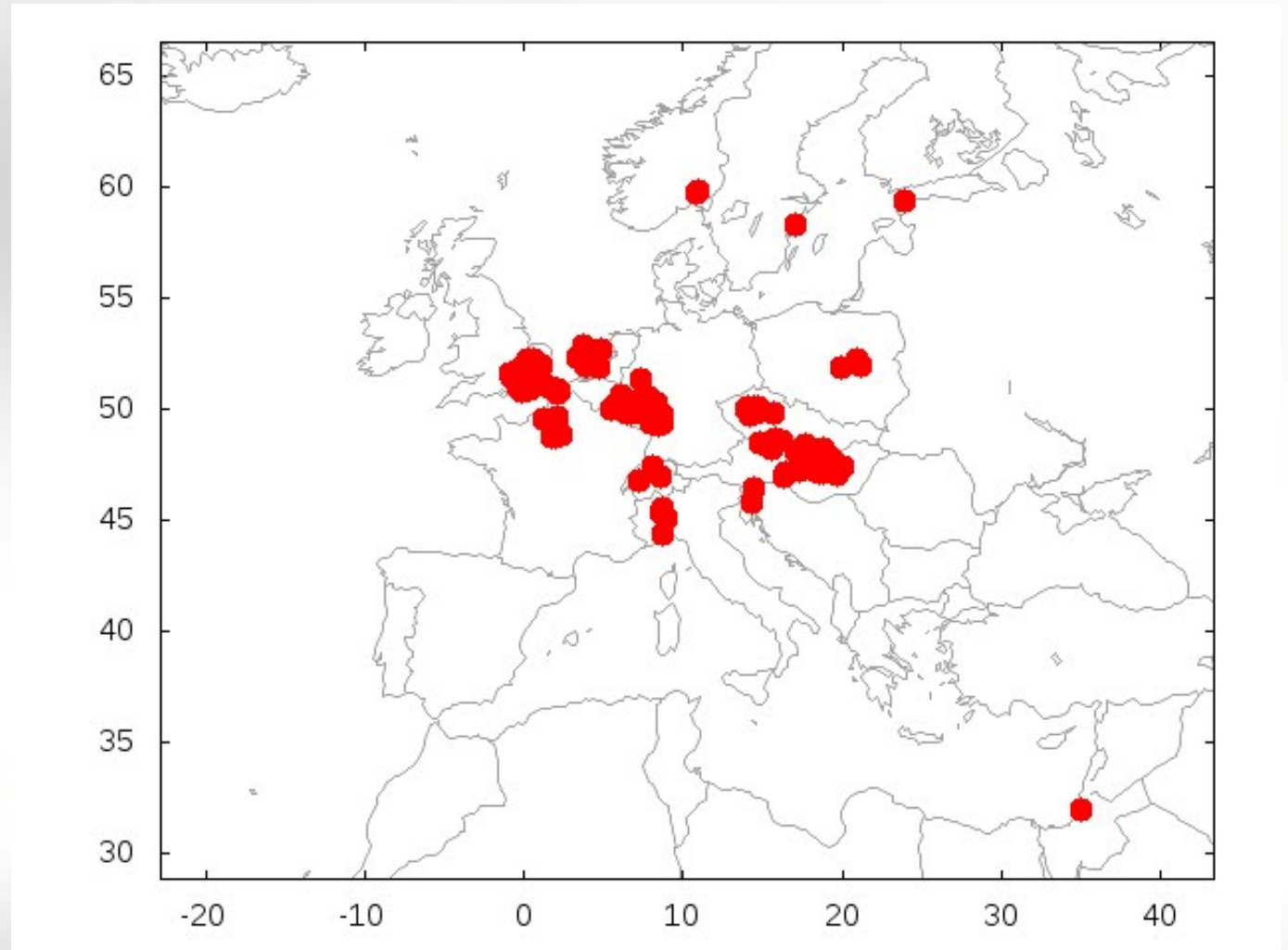
Where are the Hungarian pages?



Worldwide distribution of Hungarian content



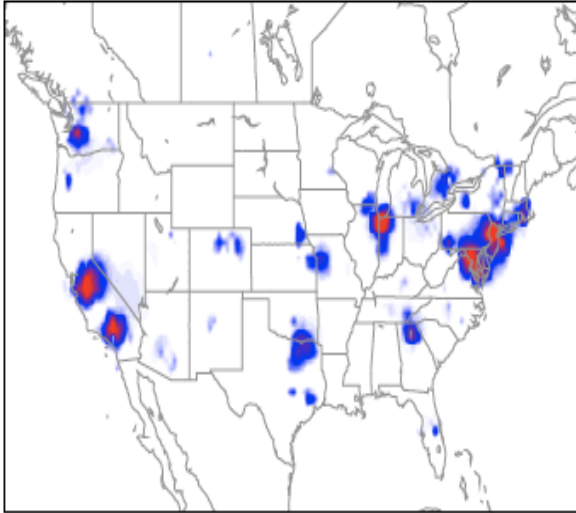
Hungarian content in Europe



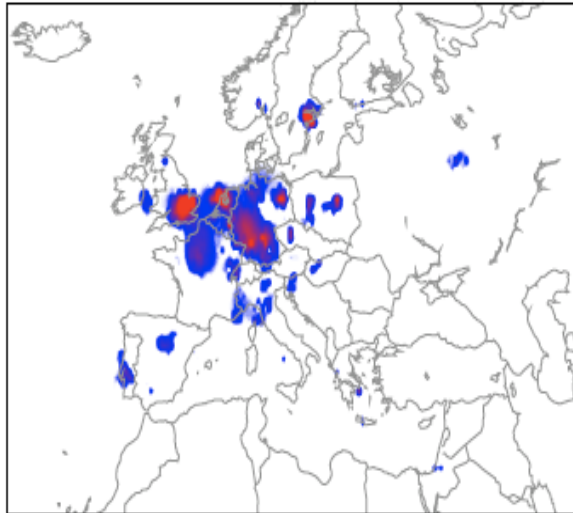
ROUTERS AND NETWORK PATHS



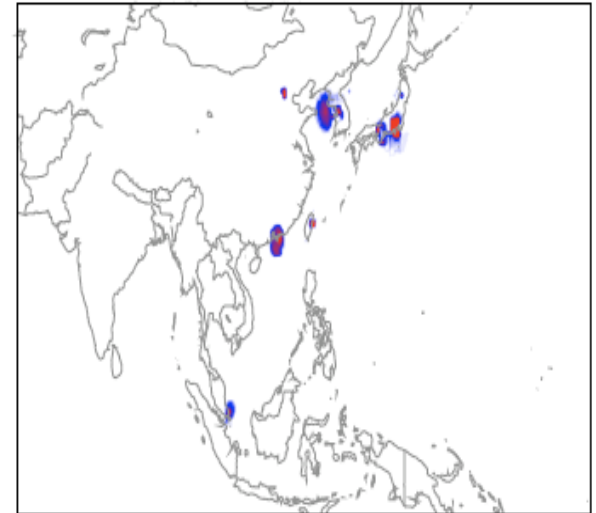
Distribution of inter-PlanetLab routers



(d) Inter-PlanetLab routers in North America



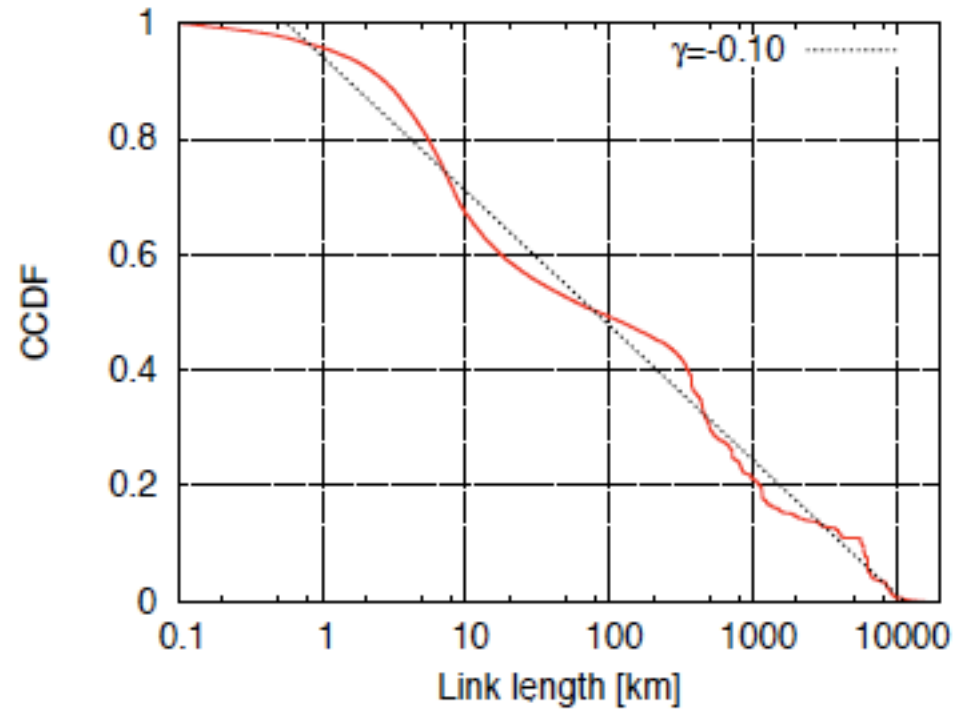
(e) Inter-PlanetLab routers in Europe



(f) Inter-PlanetLab routers in Asia



Router-distance distribution



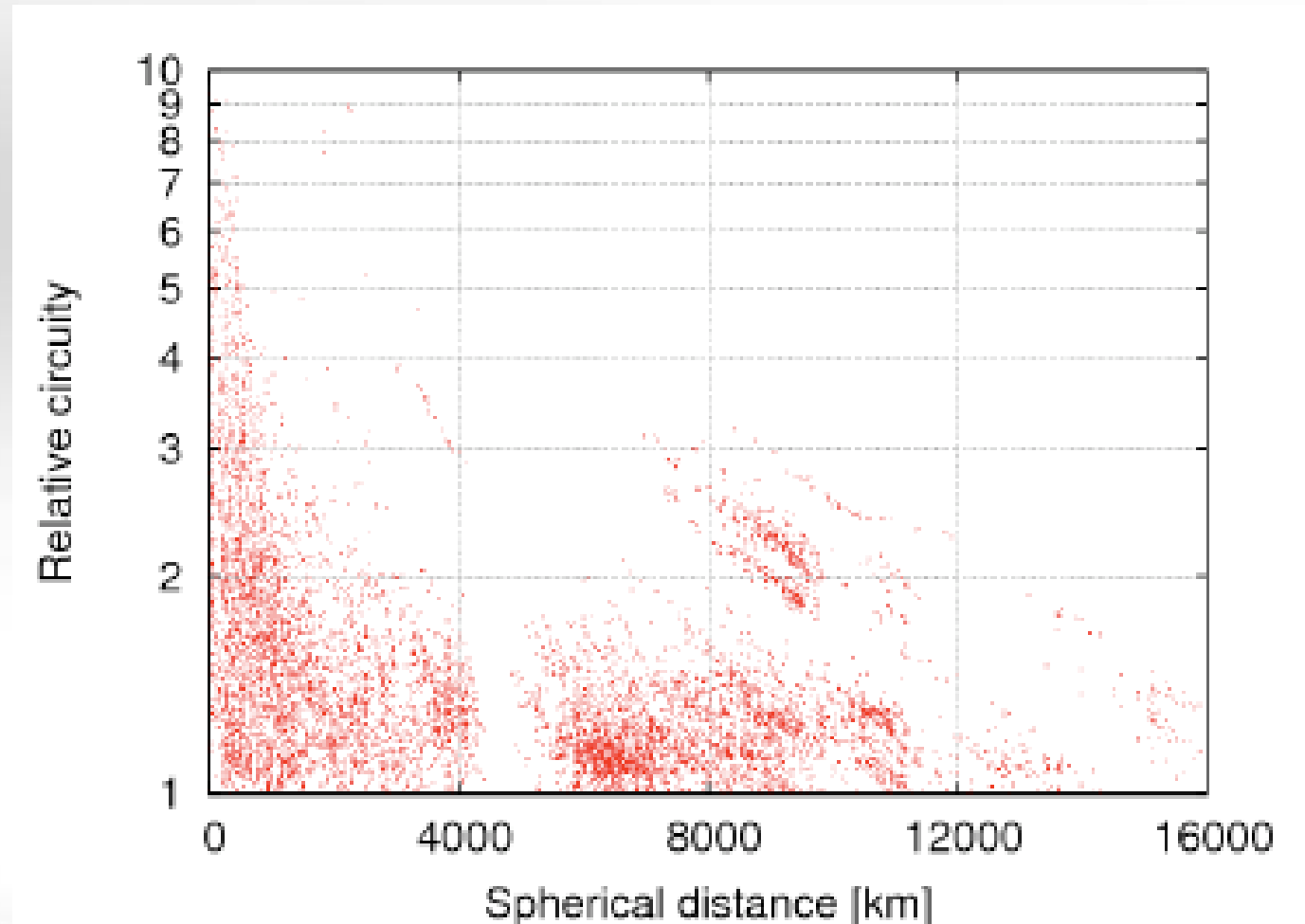
(c) CCDF of link distances. The plot indicates logarithmic relationship with fitted exponent of -0.1 .



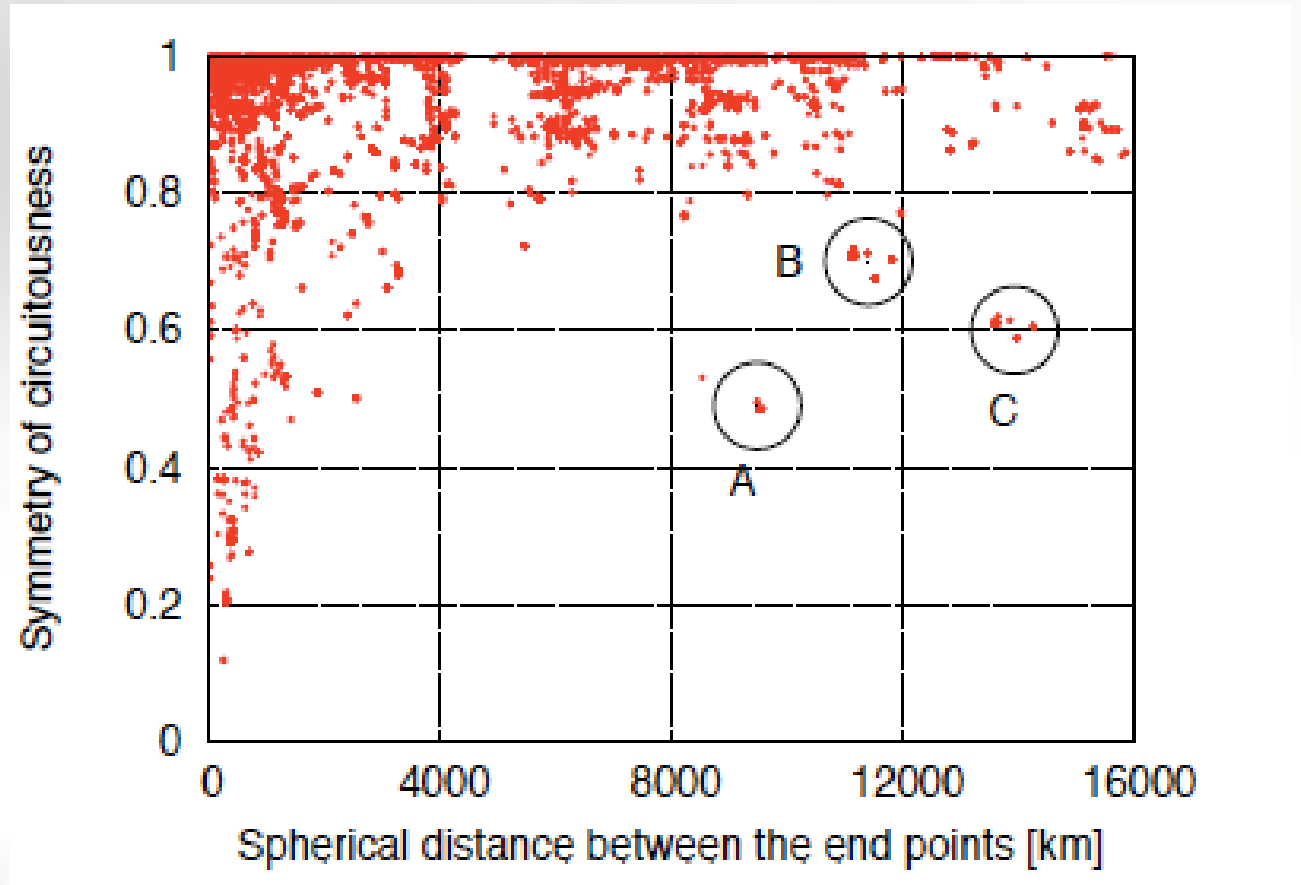
Relative circuitousness= $L(P)/G(P)$



Distribution of rcn



Distribution of the symmetry = $L(P)/L(P')$



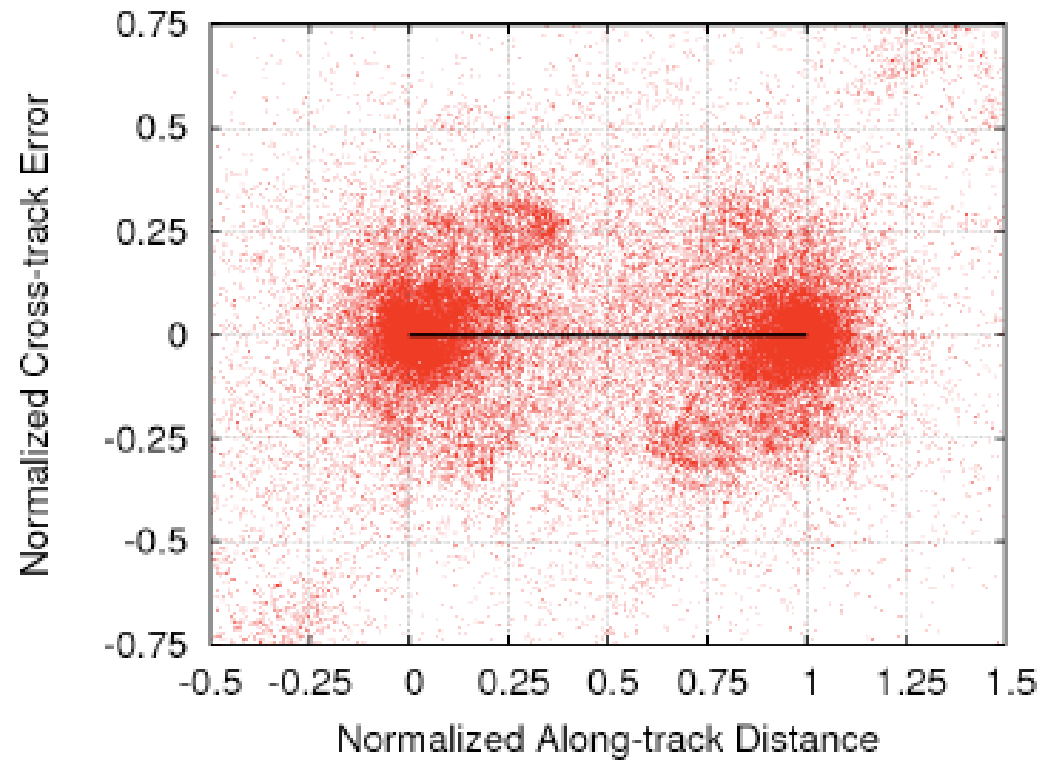
Outliers in Asia

J. Verne, "Around the World in Eighty Days", 1873.



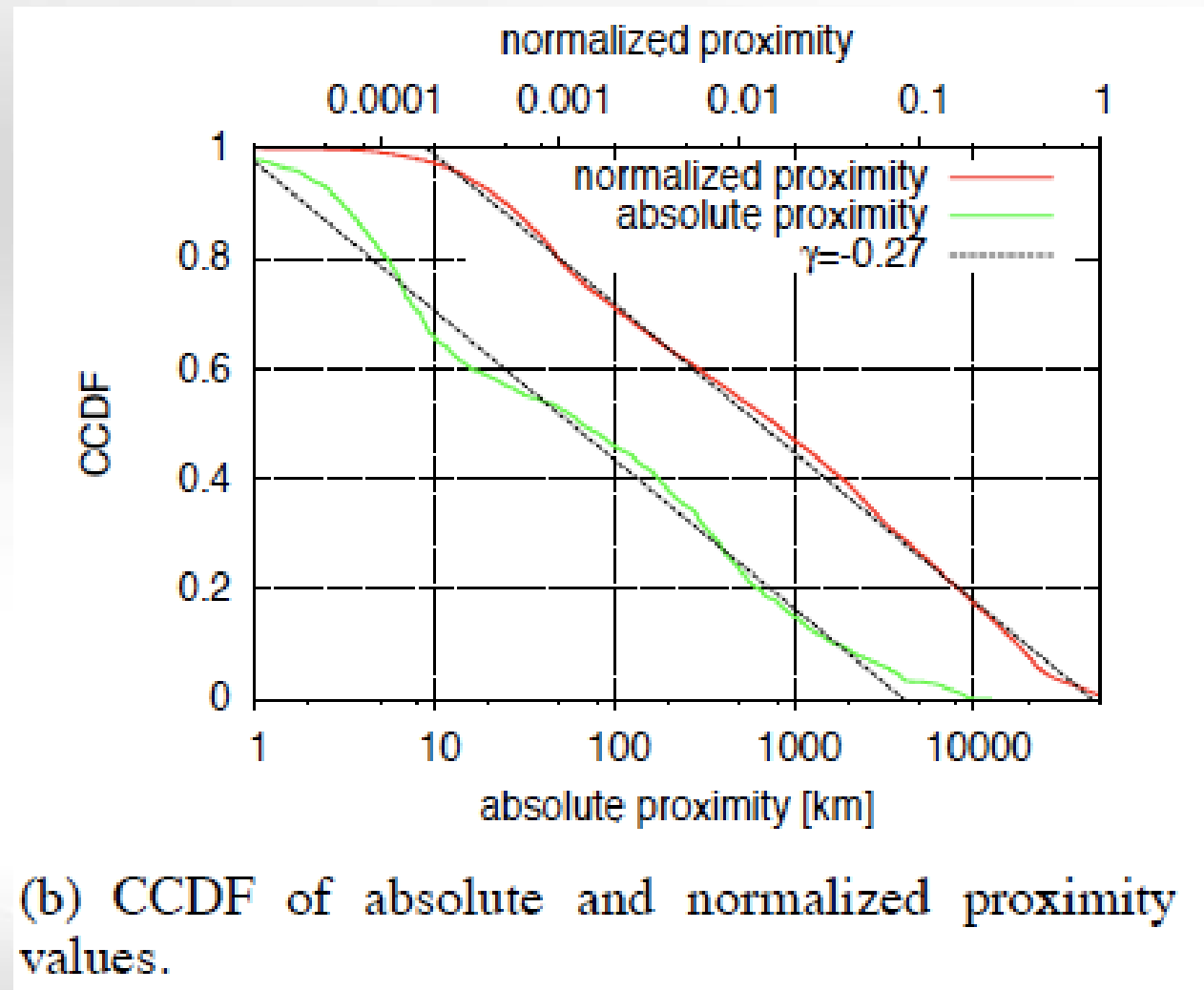
UK-Hong Kong vs. Hong Kong – UK routes

Diffusion of network paths

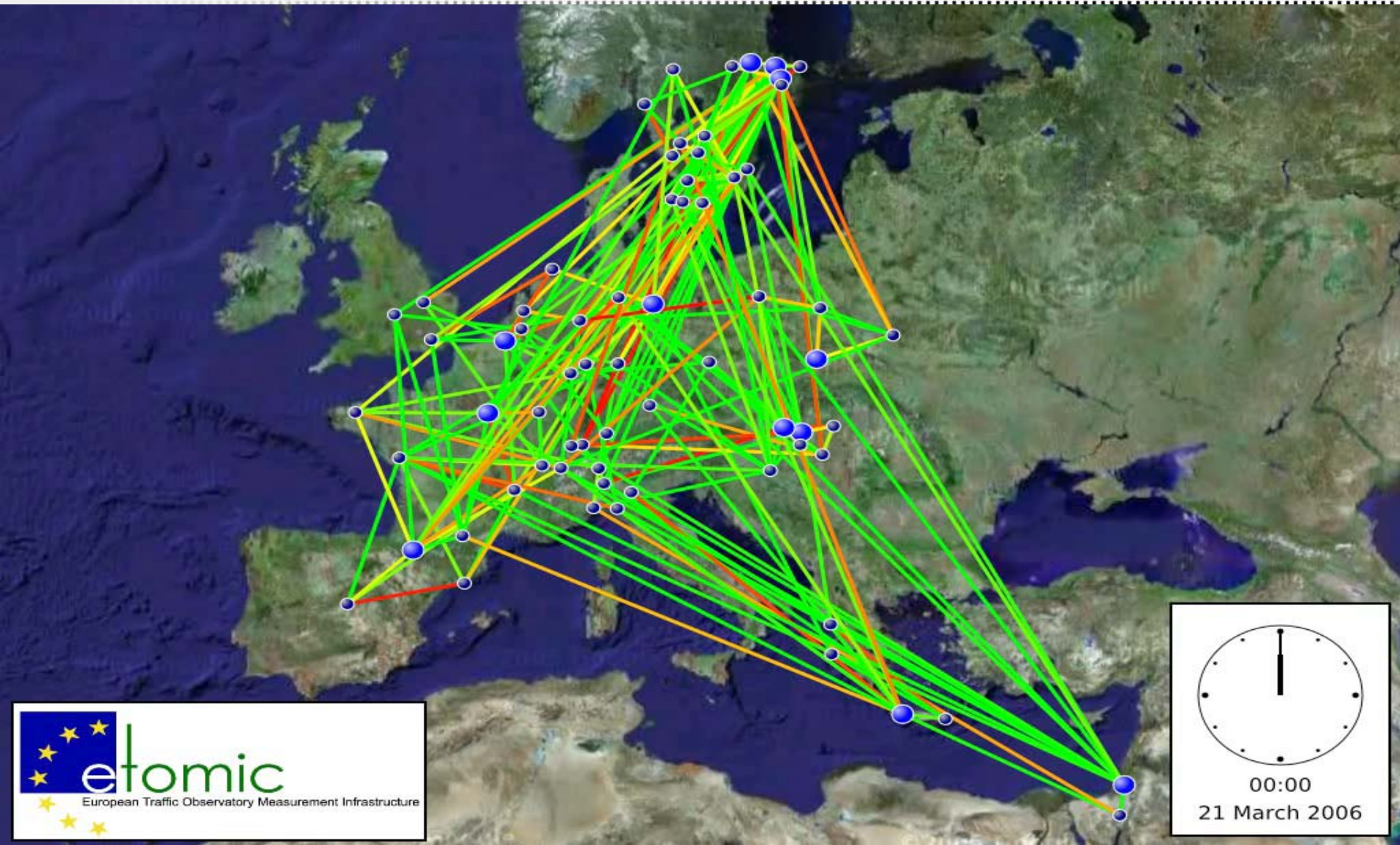


(a) Normalized spatial distribution of routers.

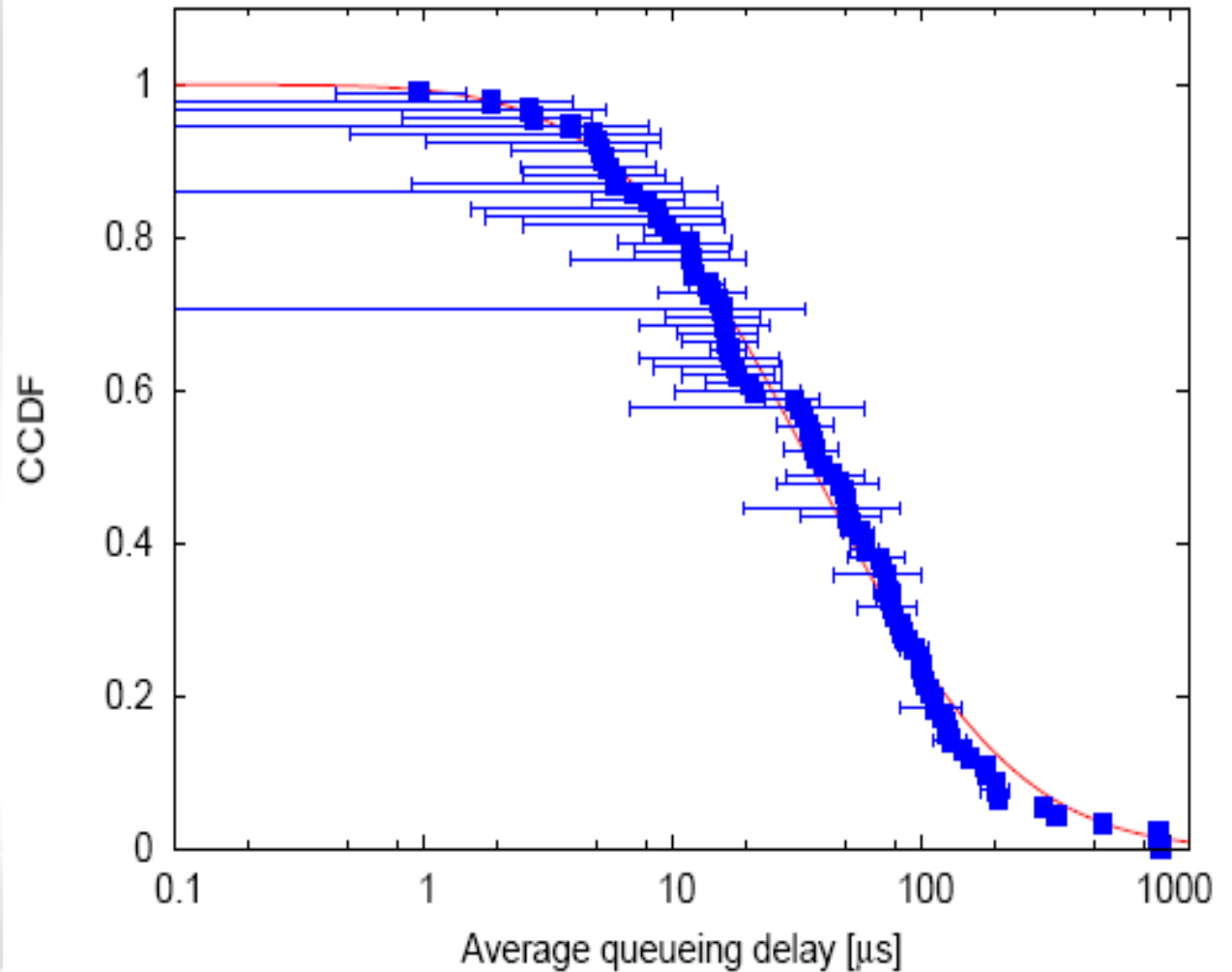
Endpoint proximity



Waiting time



Waiting time distribution



Thank you!



vattay@elte.hu

