# Large Scale Internet Queueing Delay Tomography

Y. Shavitt, E. Shir, J. Stéger,
G. Simon, G. Vattay, I. Csabai

History

- Distributed measurements and simulation (Dimes) and the European Traffic Observatory Measurement InfrastruCture (Etomic) are two efforts in the framework of EU funded project Evergrow.
- In Etomic an EU wide hardware based, precise GPS synchronized, active measurement infrastructure was built in 2004-2005
- In Dimes thousands of software based agents were distributed to volunteers to let Internet measure itself in a SETI@home fashion
- The Etomic infrastructure can take tomographic snapshots of queuing delay over the European part of the Internet.
- The two systems together can produce the world's largest Internet tomography project, where thousands of Dimes agents can send and Etomic stations can receive packets with high precision.
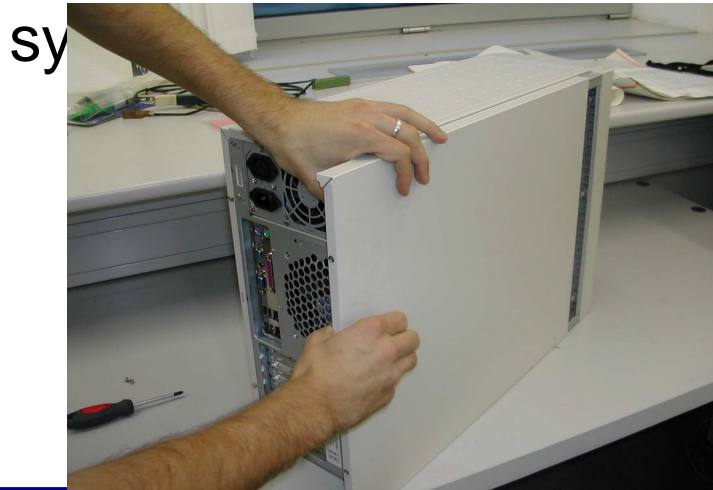
Snapshot of queuing delays in Europe

Dimes

0 μsec — 250 μsec

Etomic stations
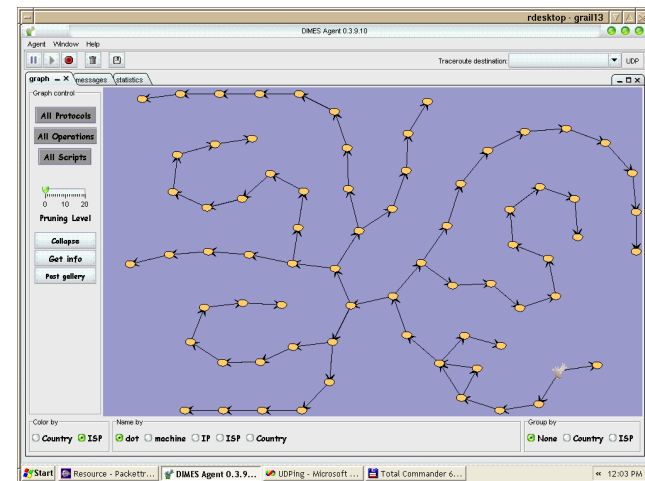**Branching routers**

Architecture
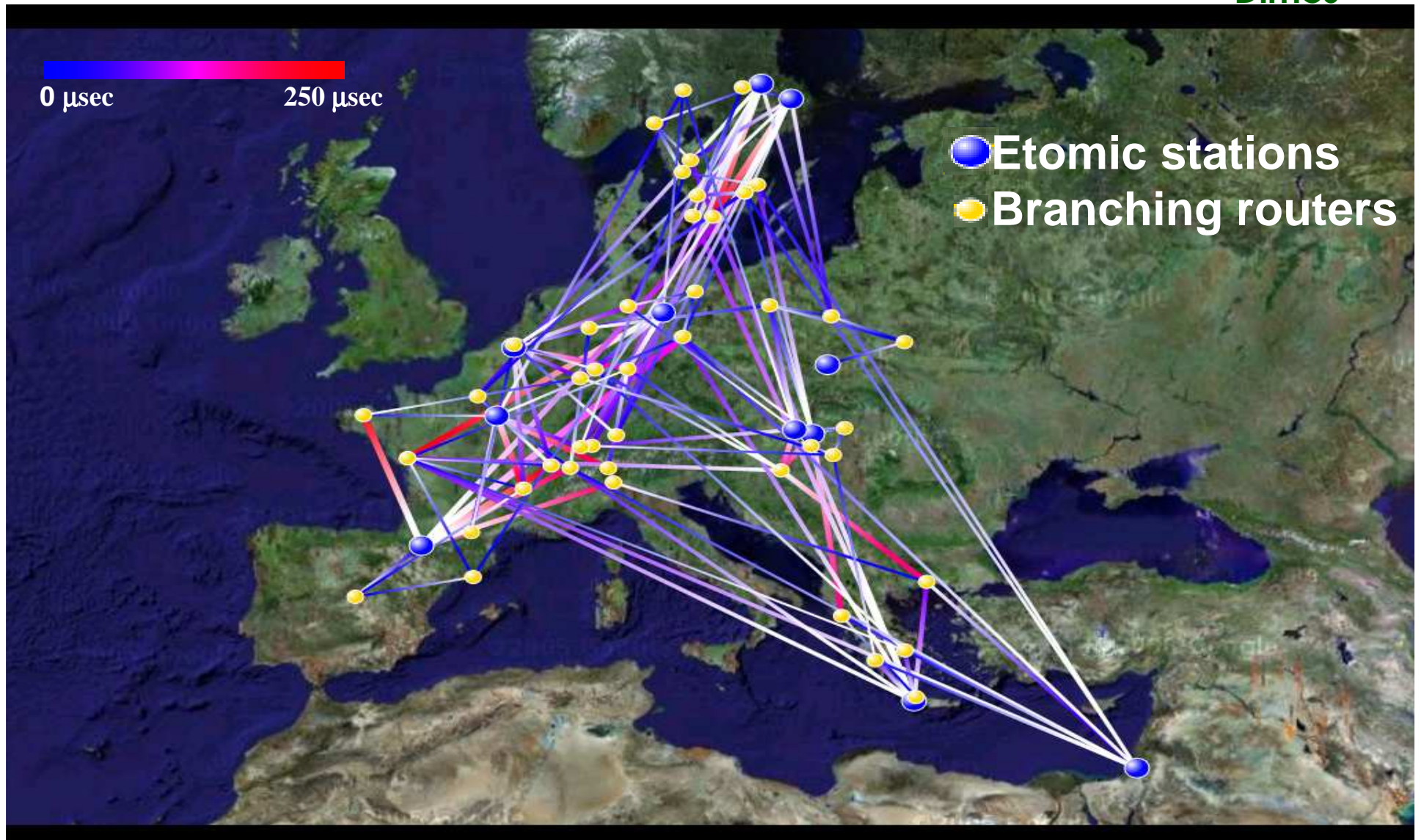
Dimes

Etomic measurement stations

- Standard server PC
- DAG 3.6 GE card
- GPS antenna (Garmin 35HVS) for time sy

Dimes measurement agents

- Userspace GUI application
- Windows OS, Linux OS
- Experiments: ping, traceroute, packettrain

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Web interfaces 1.

etomic
European Traffic Observatory Measurement Infrastructure

Dimes

www.etomic.org

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Web interfaces 2.

Dimes

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Network Tomography

Dimes

Getting delay statistics from the interior of the network, where we don't have monitoring stations

a)

b)
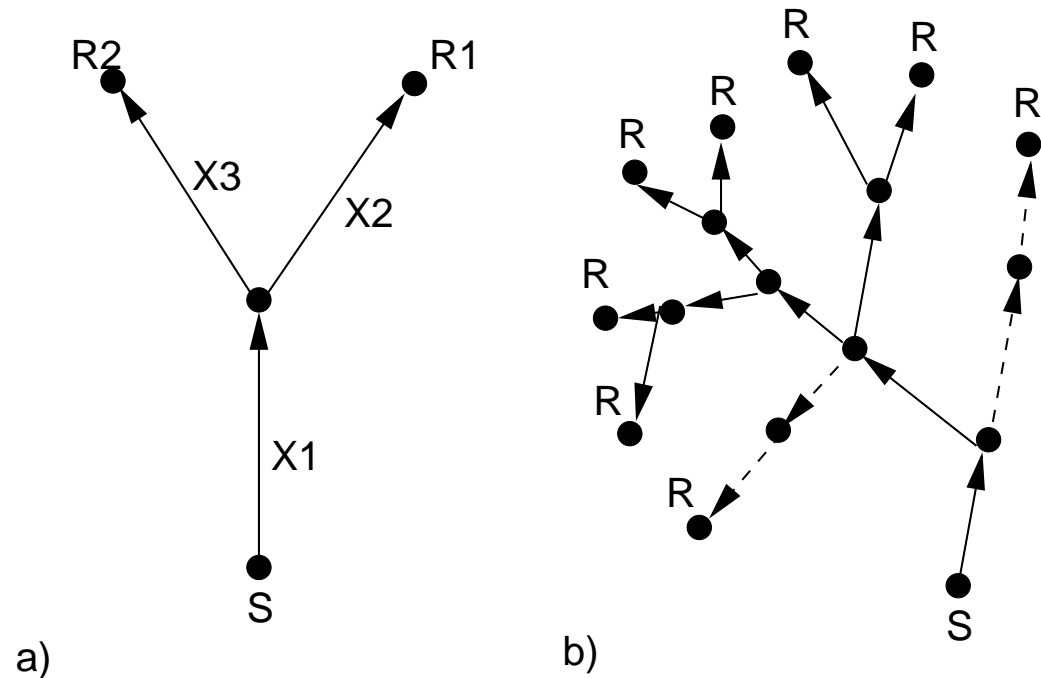
**Shoot back-to-back packet patterns …
and measure their delay at arrival with very high precision**

Measurement scheme

Dimes

Researcher

ETOMIC CMS

DIMES Server

DIMES Agent

ETOM

WAN

ISP

DIMES Agent

ETOM

ISP

DIMES Agent

ETOM

DIMES Agent

DIMES Agent

ISP
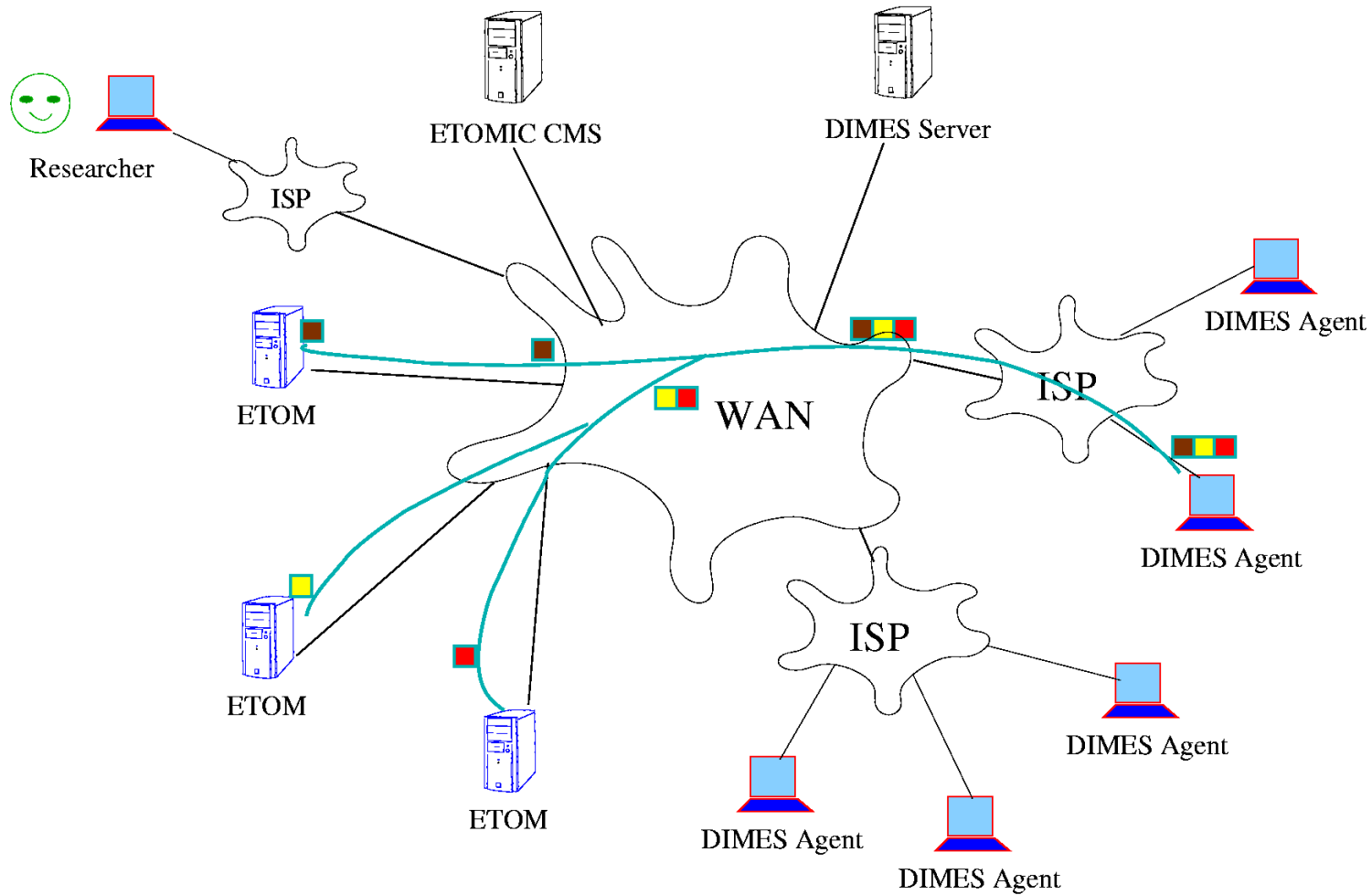
Dimes

Topology discovery (2006 January)

Question	Answer
When?	23th January, 12[46] -- 1st February, 21[49]
N[o] Etoms?	5 Etomic measurement stations targetted
N[o] Dimes?	257 Dimes agents: traceroute exp.
Measurements?	3913/9509 ≈ 41.2 % translatable routes
New nodes?	2898 unique IP addresses found
New edges?	5359 unique links found
Branching?	826 branching routers 2839 internal segments

Expectations 2.

Traceroute between 257 Dimes agents and 15 Etomic nodes

Newly discovered internal segments

Newly discovered branching routers

Number of discovered segments/branching routers

Number of Dimes agents

New module
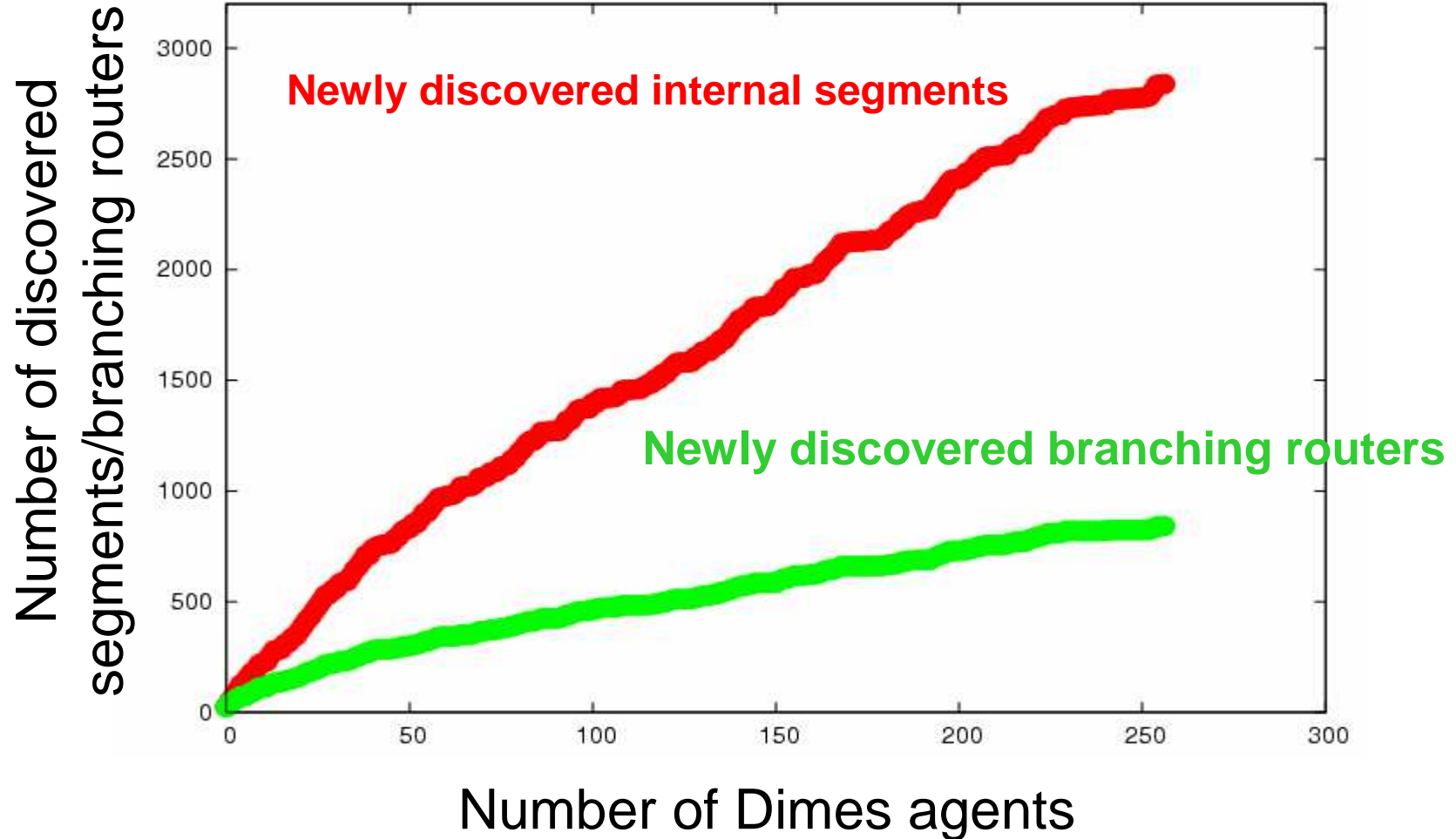
Dimes

PACKETTRAIN <no robins> <delay> <packetlength> <packettype> <destination port> <IP list>

Dimes application

Java/C interface

packettrain.dll

UDP header

Local timestamp

Packet id: #robin

Packet id: #sequence

Robin 1

| 0 | 1 | 2 | 3 |

Robin 2

| 0 | 1 | 2 | 3 |

Robin 3

| 0 | 1 | 2 | 3 |

Network

Measurement sites
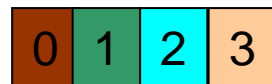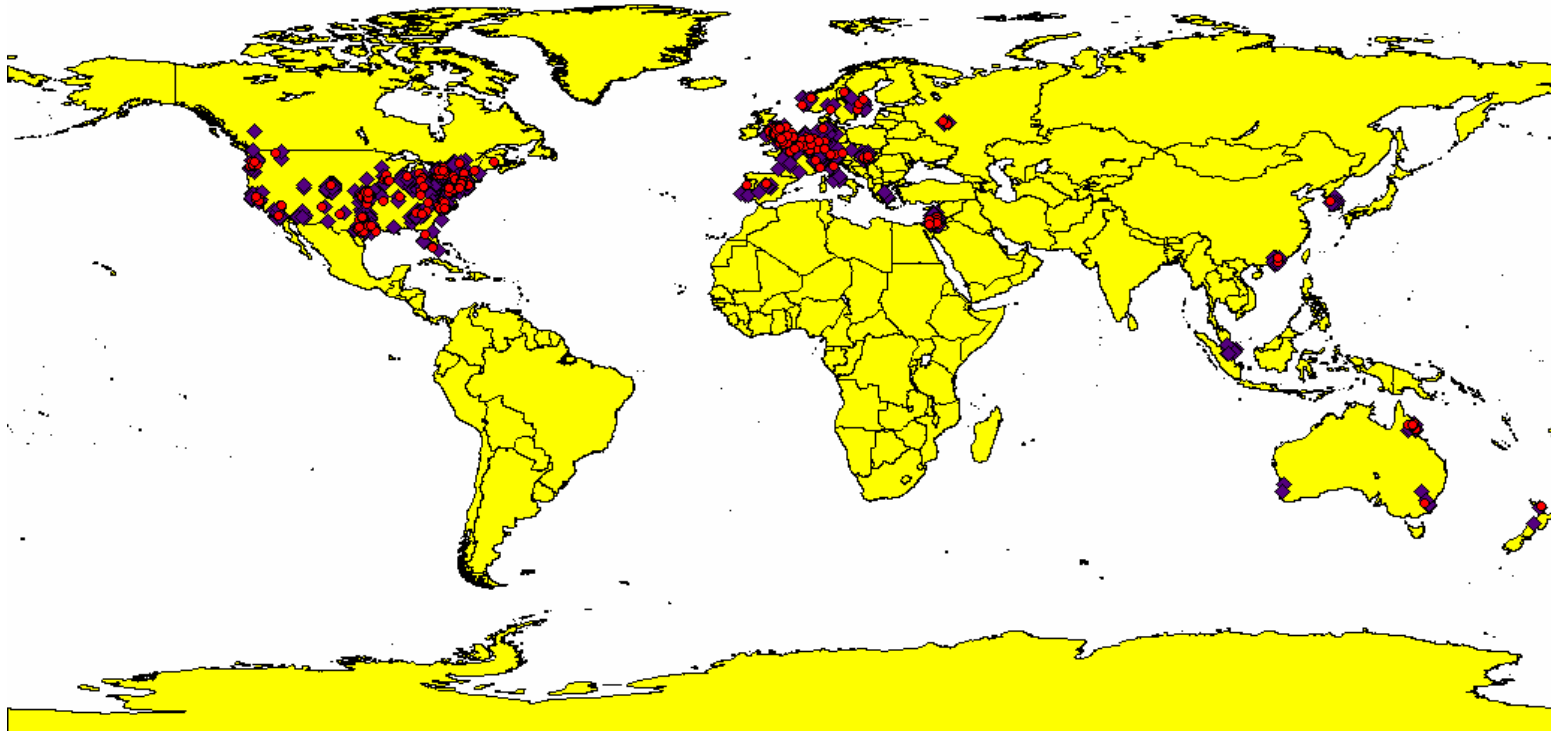
Dimes

Properly located Dimes agents (red)
Branching routers (blue)

An example 1.

Dimes

Test experiment
- 12th July 2005
- a dimes agent: Budapest (ELTE)
- Etomic nodes: Budapest (UNIV); Stockholm (ERIC); Birmingham (ASTN); Pamplona (UNAV); Paris (UPAR) and Jerusalem (HUJI).
- Topology revealed using traceroute.
- Probes: 10^4 six packet pattern sent, spaced: 0,1s.

ELTE -> HUJI

1. Step
- Oneway delay constructed
- Clock skew removed
- Outlayer data (1%) removed
- Constant offset removed

Queueing delay

Time

An example 2.

Dimes
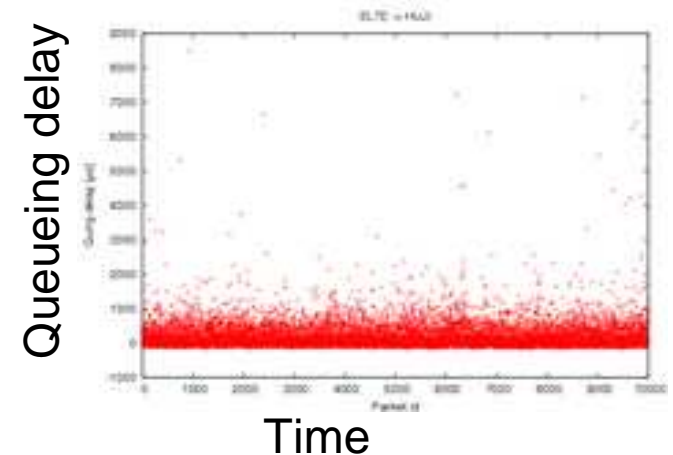
2. Step
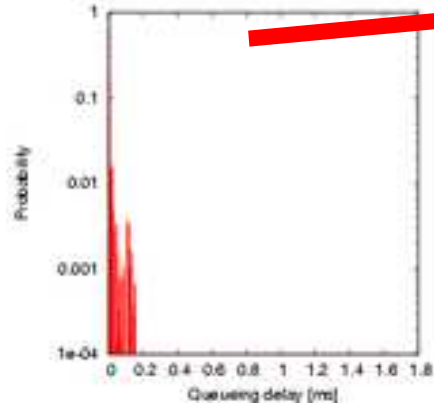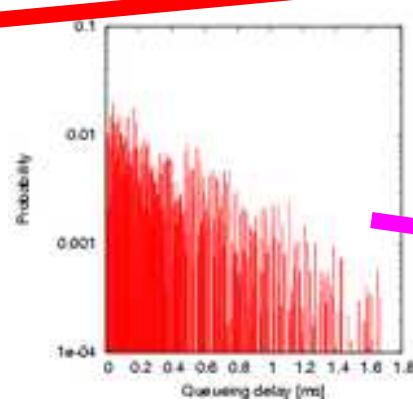- Topology reconstructed
- Branching routers determined

3. Step
- Revealing queueing delay distributions using EM algorithm for all internal segments

Dimes agent
Branching routers
Etomic stations

Backbone link   Access link
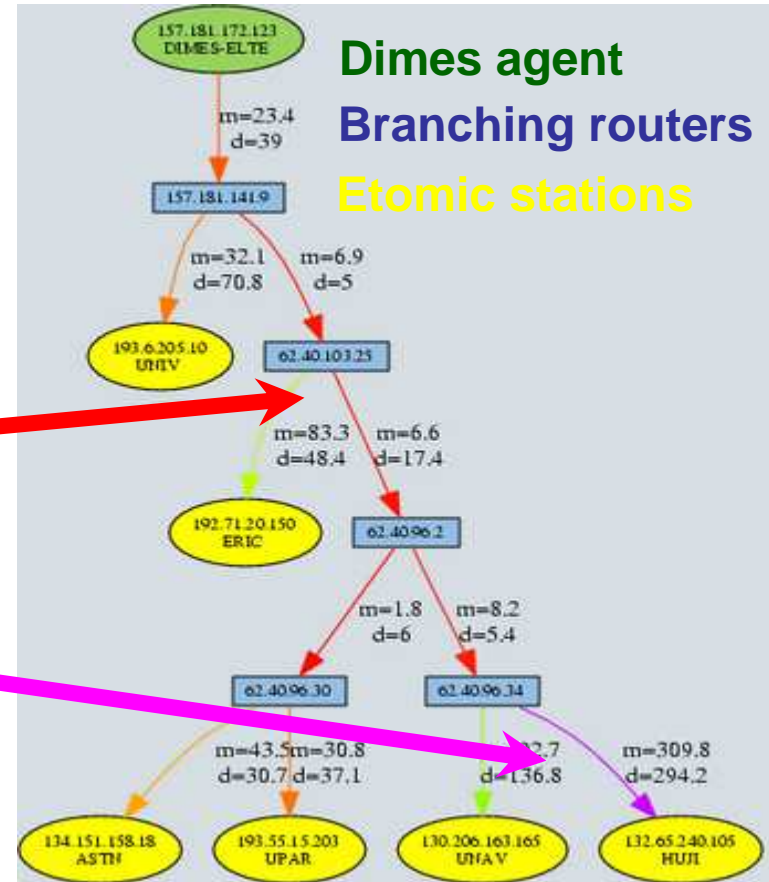
An example 3.

Link	Avg. q.d.(µs)	Error	Std dev. (µs)	Error
1	23.446	2.738	35.044	4.652
2	6.976	3.883	3.883	2.048
3	32.196	2.779	70.856	2.678
4	6.693	4.016	17.467	10.557
5	83.373	5.730	48.426	1.373
6	1.802	0.707	6.059	4.215
7	8.273	1.452	5.441	0.981
8	43.575		30.752	
9	30.866		37.188	
10	309.853		294.230	
11	92.723		136.885	

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Timeseries 1.

Source: 132.66.50.208

elte (l=4)
ericsson (l=8)
paris (l=14)
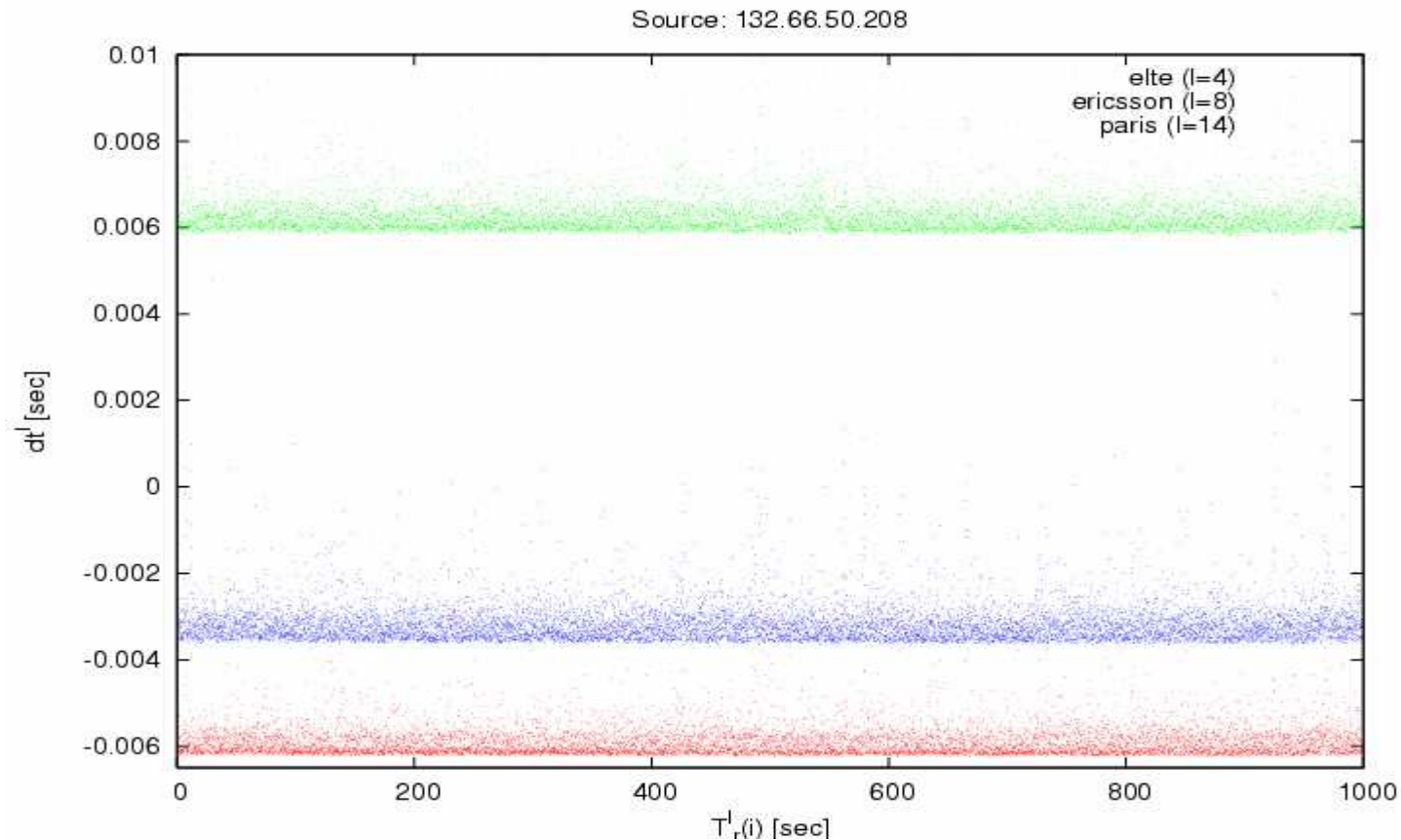
Dimes agent probably connected to a high bandwith access link
similar oneway delay series experienced like within internal Etomic measurements

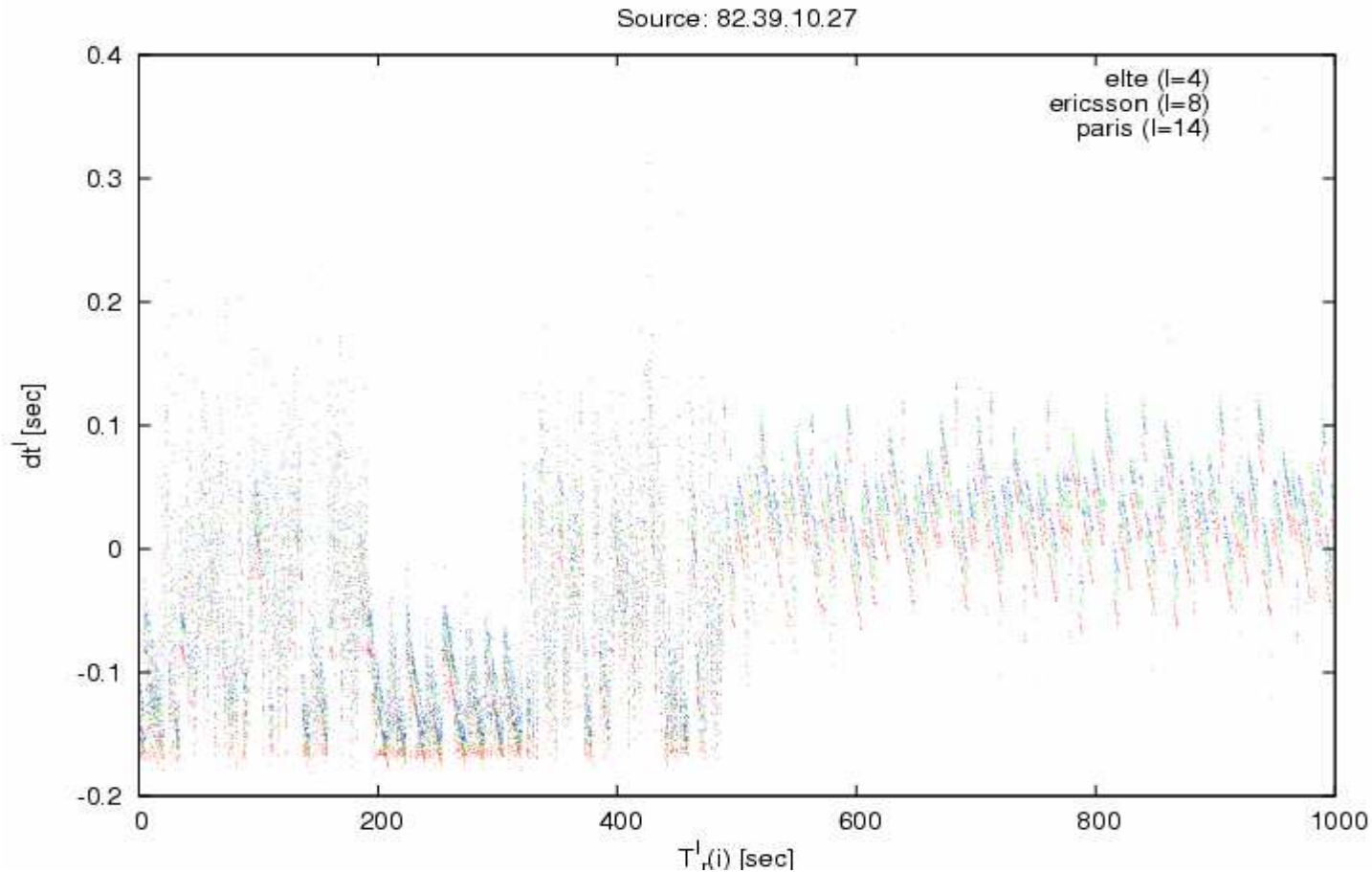Large Scale Internet Queuing Delay Tomography

Timeseries 2.
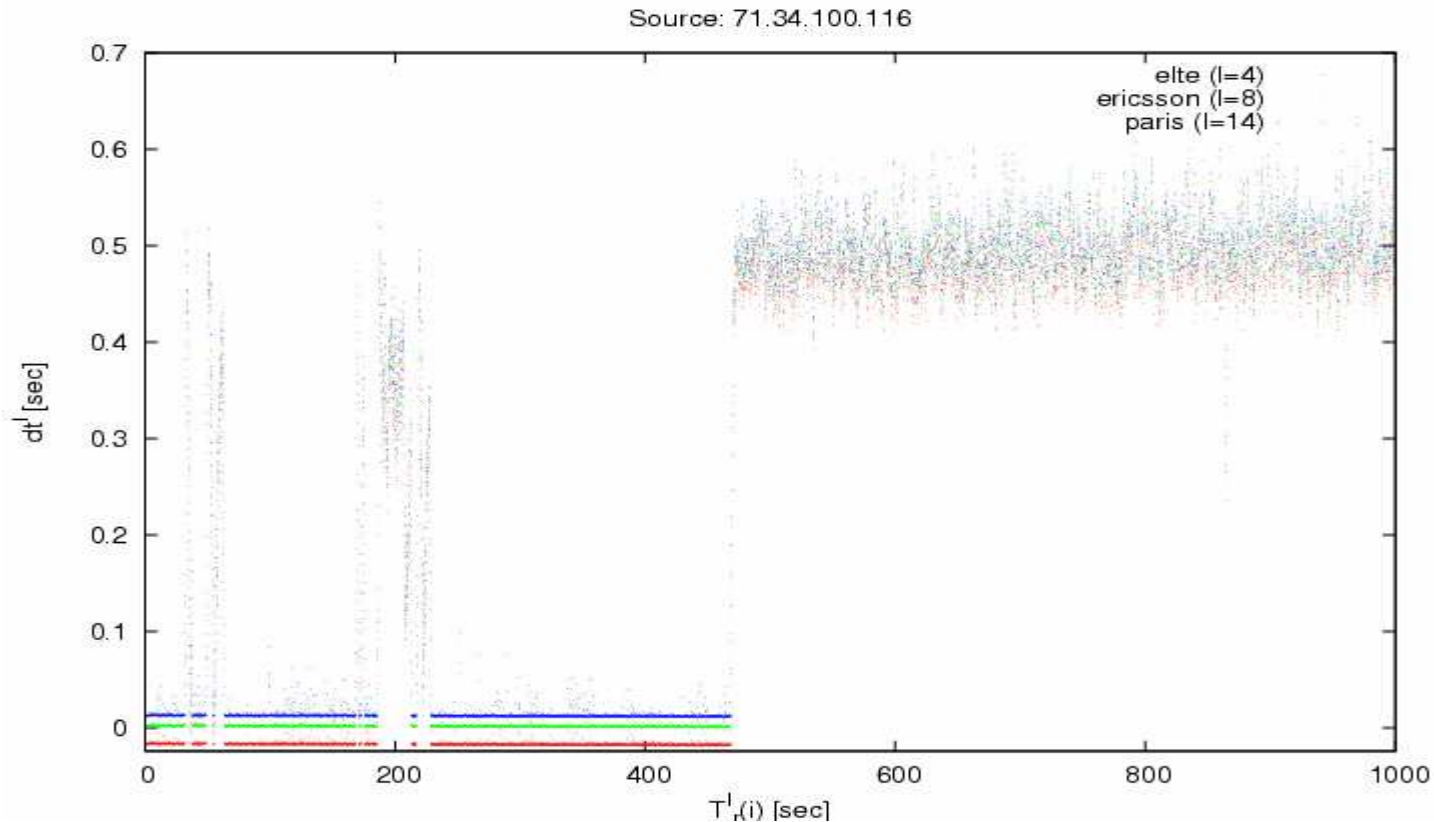
Dimes

Dimes agent probably connected to a high bandwith access link
first similar delay series experienced like within internal Etomic measurements,
then drastic step in delay series: probably dimes ran on in the background

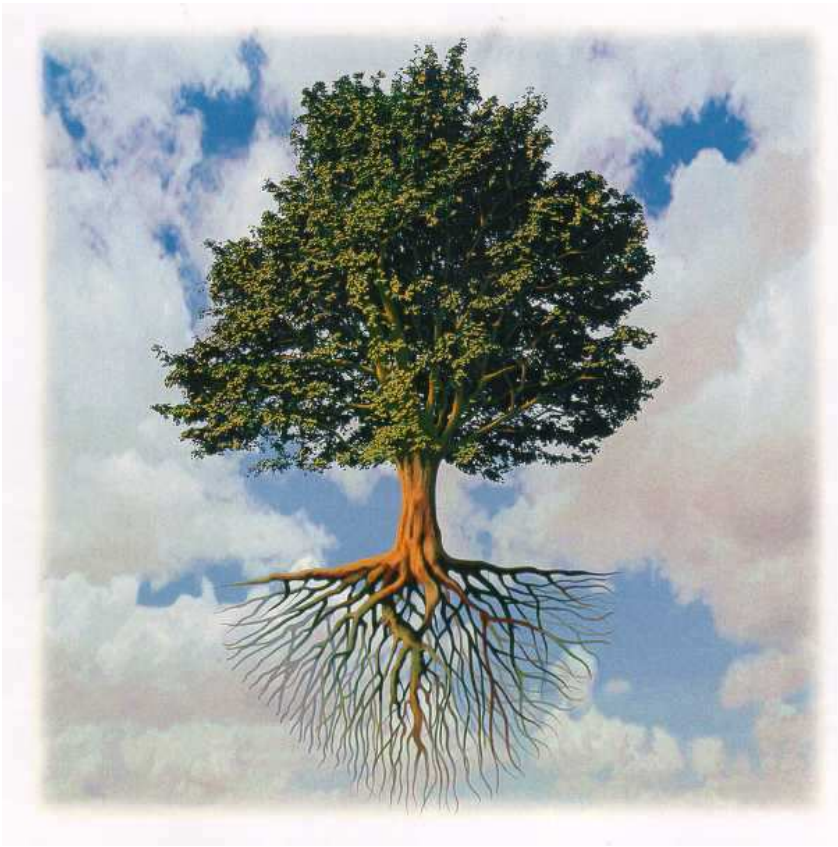# Timeseries 3.

Dimes

Source: 82.39.10.27

elte (I=4)
ericsson (I=8)
paris (I=14)

Dimes agent probably connected to a low bandwith access link
heavy cross traffic causes large fluctuations in queueing delay

The future

Dimes

The two systems, **Dimes** agents and **Etomic** infrastructure, together can produce the world's largest Internet tomography project.

Precise **Etomic** stations cooperating with thousands of **Dimes** agents can discover and measure numerous segments of the Internet across the world.

Defining and implementing new measurement modules for the two systems may open new dimensions in designing and conducting experiments, for example bandwidth tomography or packet loss tomography.

Thanks!

IST Future and Emerging Technologies

Dimes

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