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Large Scale Network Tomography in Practice: Queuing Delay Distribution Inference in the ETOMIC Testbed

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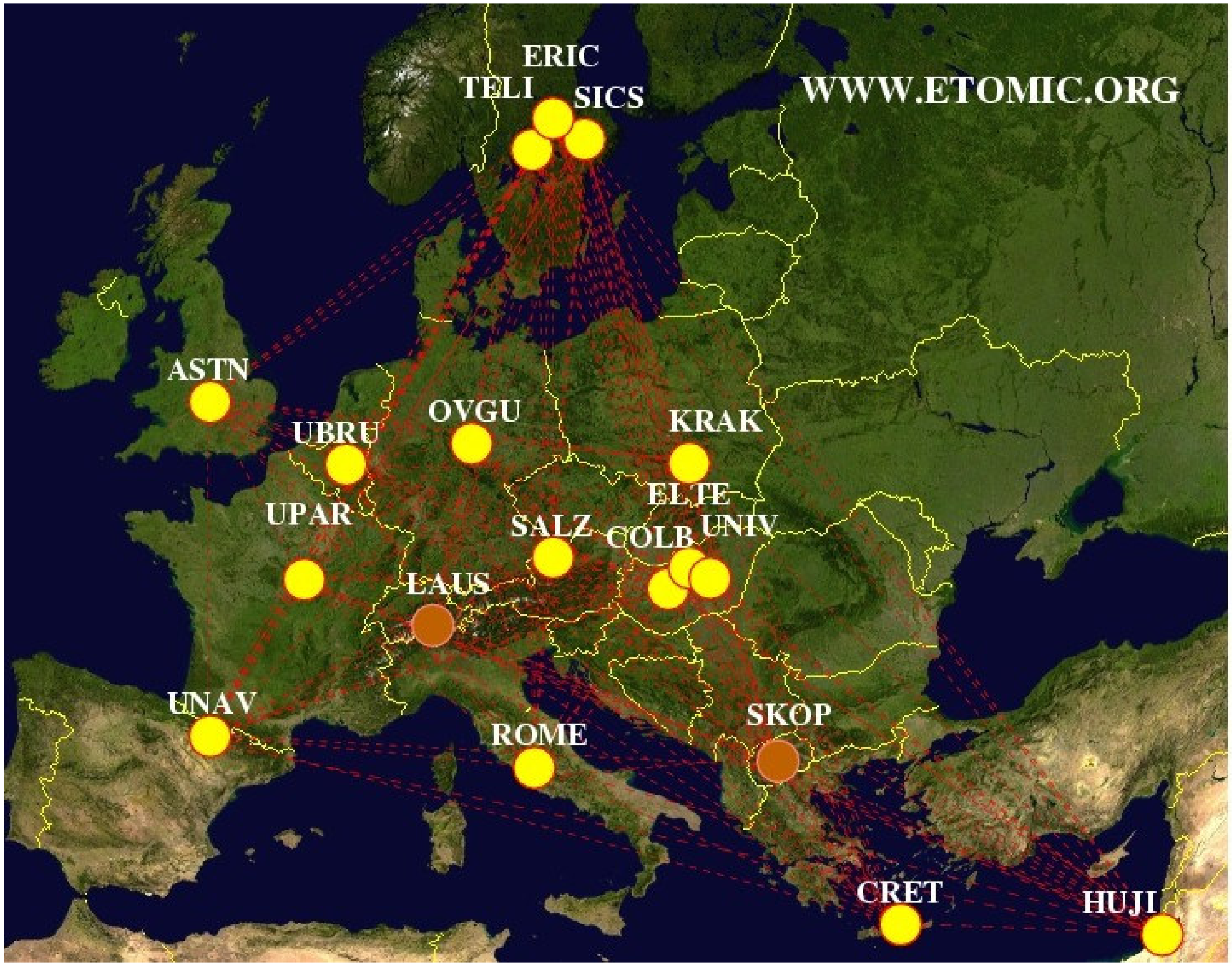
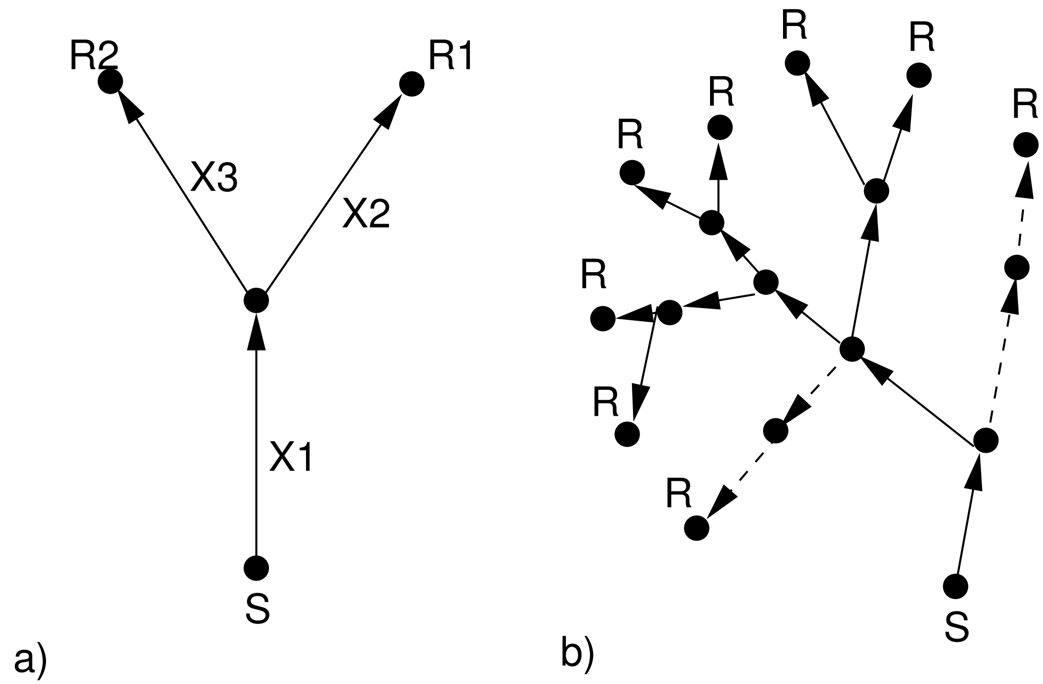


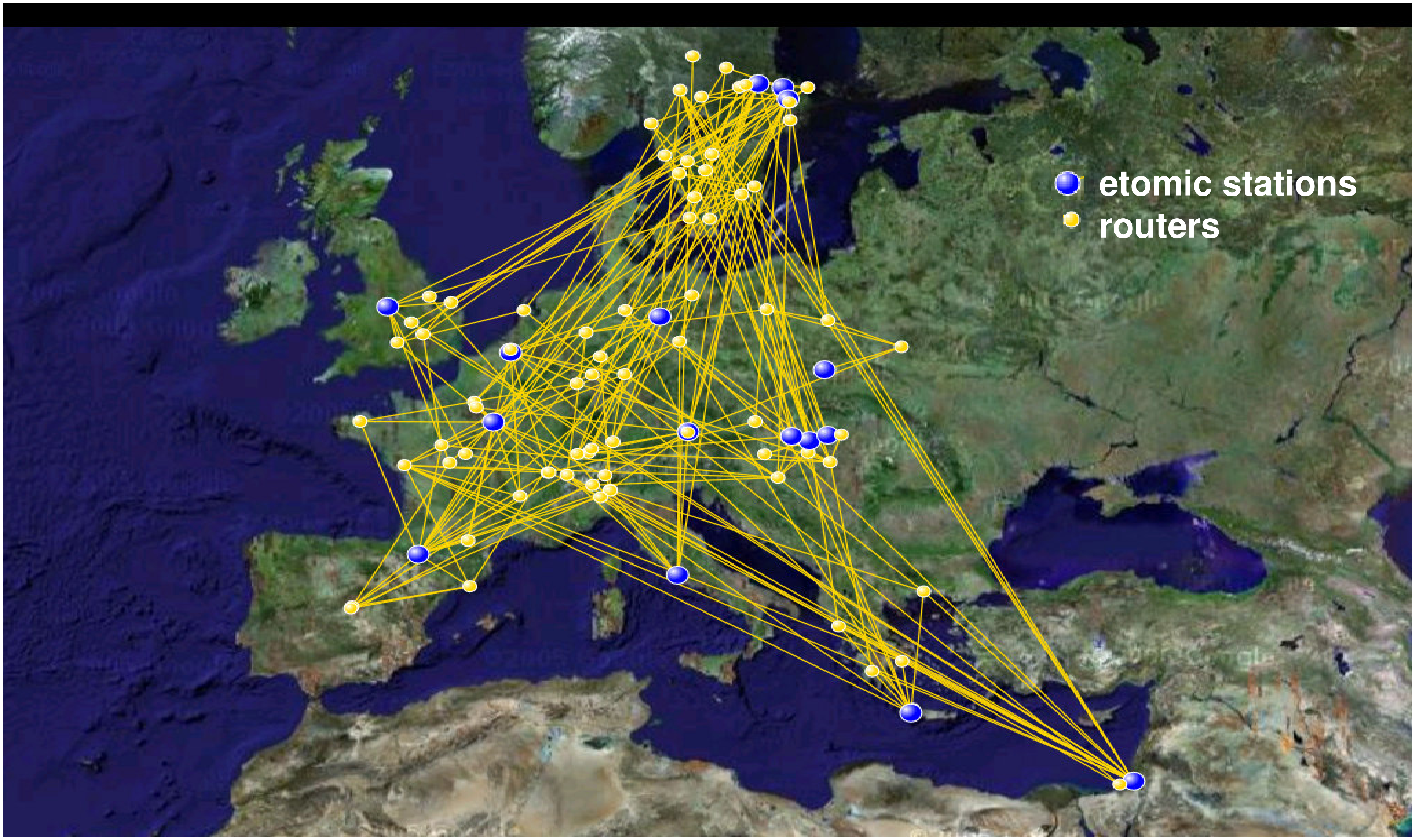
Network Tomography

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



Shoot back-to-back packet pairs …
and measure their delay at arrival with very high precision

Topology of routers



Delay estimation for the Y-topology

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Definitions:

- N - number of successful pairs, where none of the probes is lost.
- $Y_1(k)$ and $Y_2(k)$, the end-to-end delay experienced by the probes of the k-th pair

$$\boxed{Y_1(k) = X_1(k) + X_2(k)} \qquad \boxed{Y_2(k) = X_1(k) + X_3(k)} \qquad k \in \{1..N\}$$

- **Goal:** Estimate the distribution of $X_1(k)$, $X_2(k)$ and $X_3(k)$ from the end-to-end delays.

- Quantization of the delay into *B* bins of uniform size *q*

$$X_i^d(k) = jq \quad \text{if} \quad (j-1)q < X_i(k) \le jq \ , \quad i \in \{1,2,3\} \qquad j \in \{1,2,..B\}$$

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$$P_{i,j} = \frac{n_{i,j}}{\sum_{j=1}^{B} n_{i,j}}$$

$$Y_1^d(k) = X_1^d(k) + X_2^d(k)$$

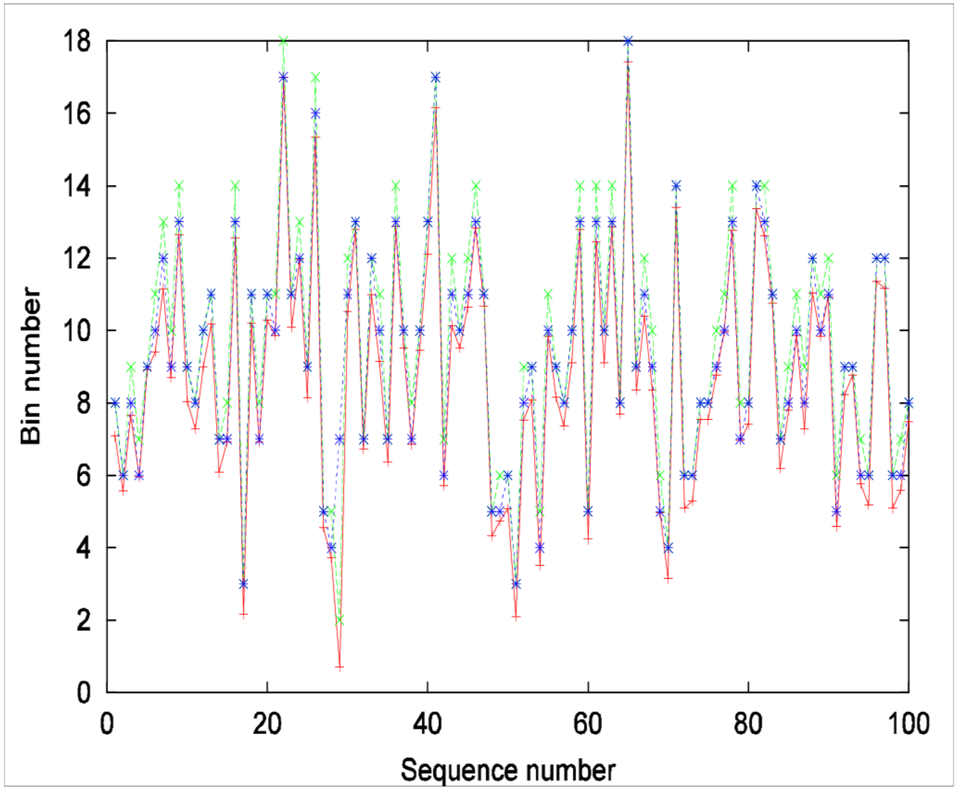
$$Y_2^d(k) = X_1^d(k) + X_3^d(k)$$

$$P(Y_1^d = lq, Y_2^d = mq) \equiv$$

$$P(l,m) = \sum_{s \in H} P_{1,s} P_{2,(l-s)} P_{3,(m-s)}$$

$$H \equiv \{ B \geq s \geq 1 \} \cap \{ B \geq (l-s) \geq 1 \} \cap \{ B \geq (m-s) \geq 1 \}$$

$$L = \prod_{n=1}^{N} P(Y_1^d(n), Y_2^d(n))$$



EM-algorithm

$$P(X_1^d = jq \mid lq, mq) = \frac{P_{1,j} P_{2,(l-j)} P_{3,(m-j)}}{P(l,m)}$$

$$P(X_2^d = jq \mid lq, mq) = \frac{P_{1,(l-j)} P_{2,j} P_{3,(m-l+j)}}{P(l,m)}$$

$$P(X_3^d = jq \mid lq, mq) = \frac{P_{1,(m-j)} P_{2,(l-m+j)} P_{3,j}}{P(l,m)}$$

$$P_{i,j}^0$$

$$n_{i,j} = \sum_{k=1}^{N} P(X_i^d(k) = jq \mid Y_1^d(k), Y_2^d(m))$$

$$P_{i,j} = \frac{n_{i,j}}{\sum_{j=1}^{B} n_{i,j}}$$

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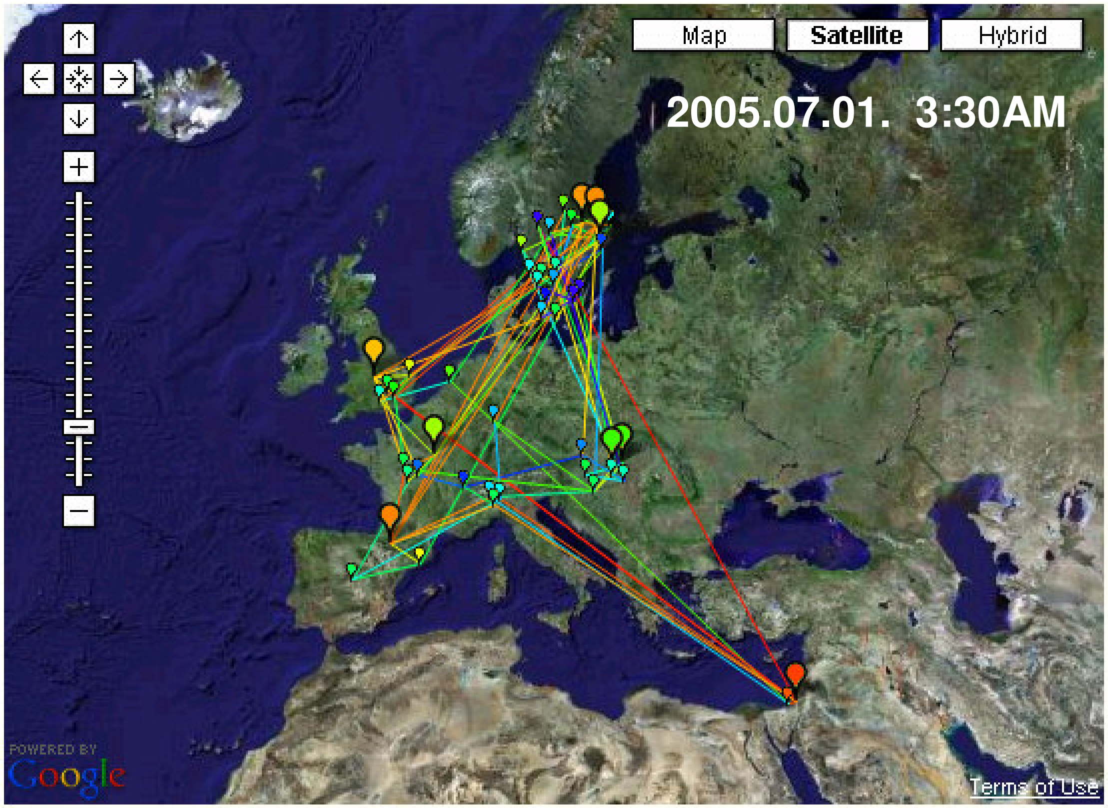
Visualization



ETOMIC node

Visualization

DATA TYPE	(•) Mean ( ) Standard Deviation
TOPOLOGY	( ) End to End (•) Resolved

Info

SOURCE NODE	
DESTINATION NODE	
MEAN	
STANDARD DEVIATION	

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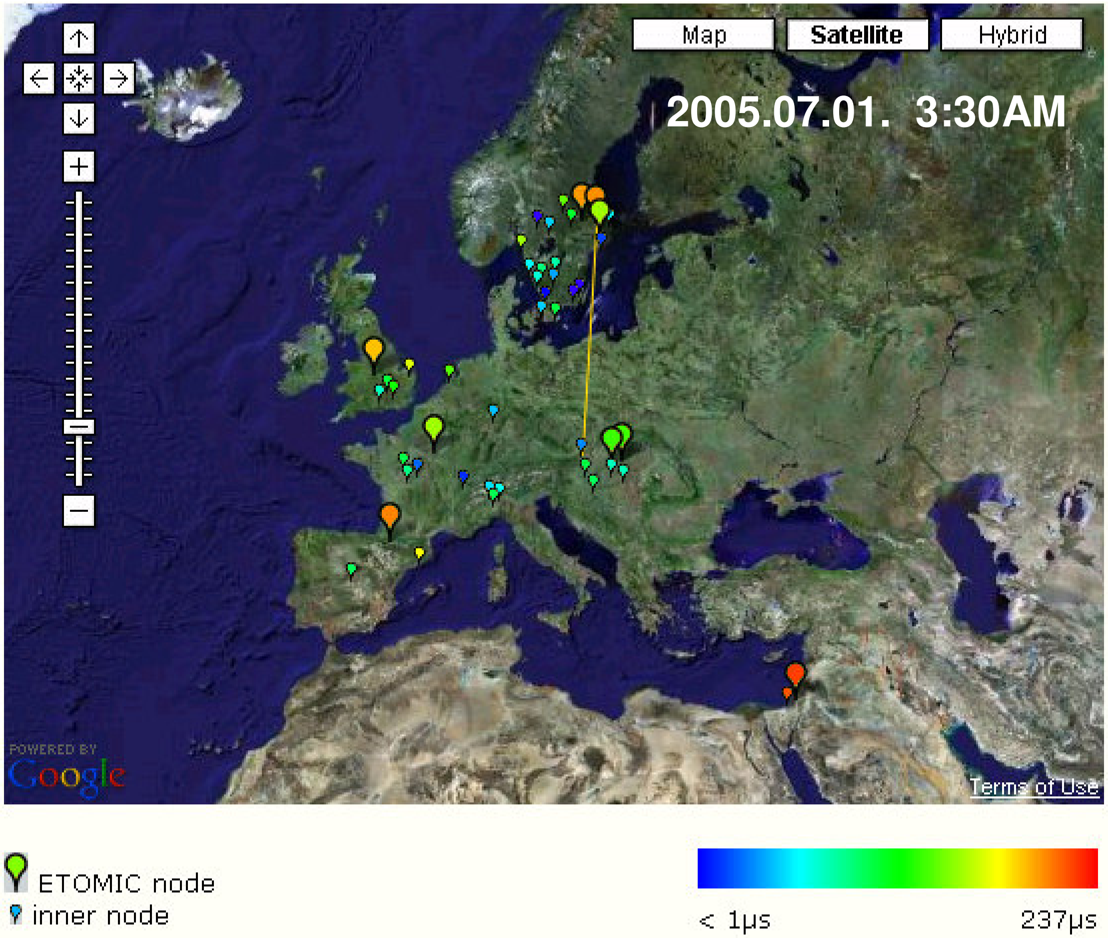
Visualization

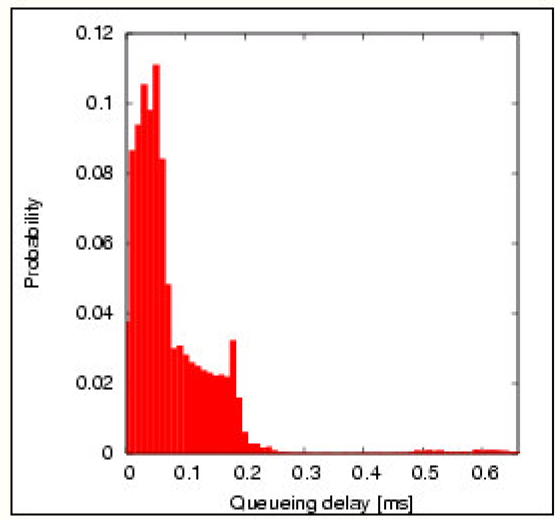


Visualization

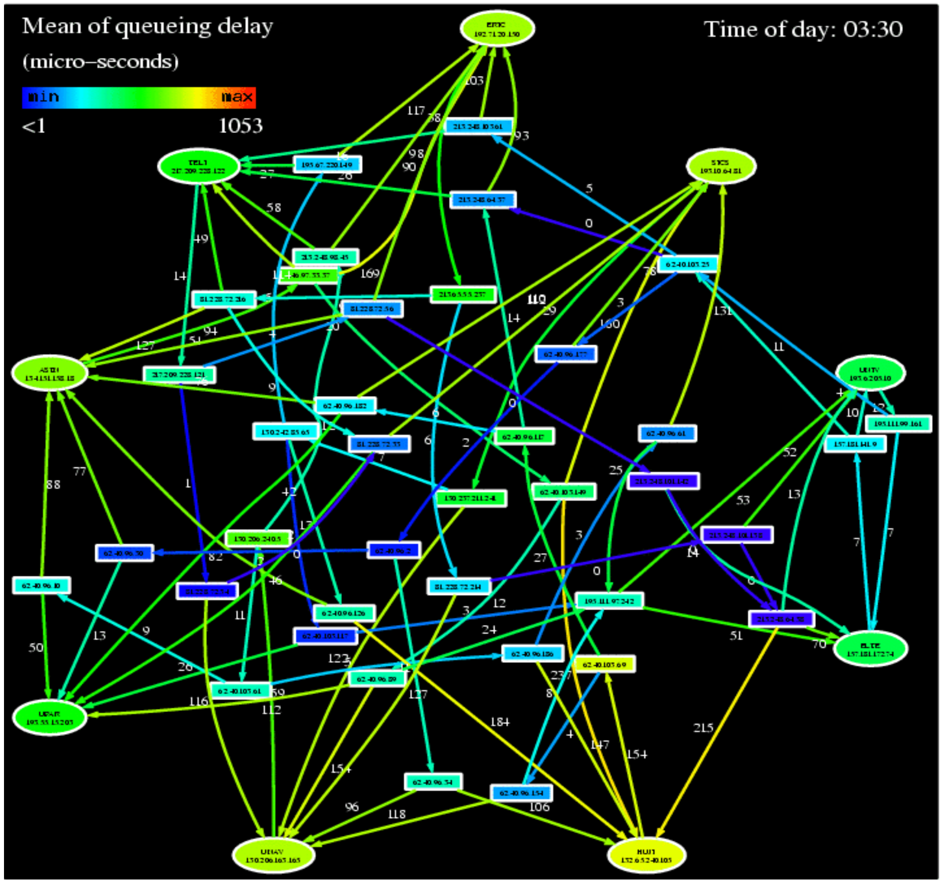
DATA TYPE	◉ Mean ○ Standard Deviation
TOPOLOGY	○ End to End ◉ Resolved

Info

SOURCE NODE	62.40.96.177
DESTINATION NODE	193.10.64.81
MEAN	78μs
STANDARD DEVIATION	97μs



Daily change of mean queuing delays



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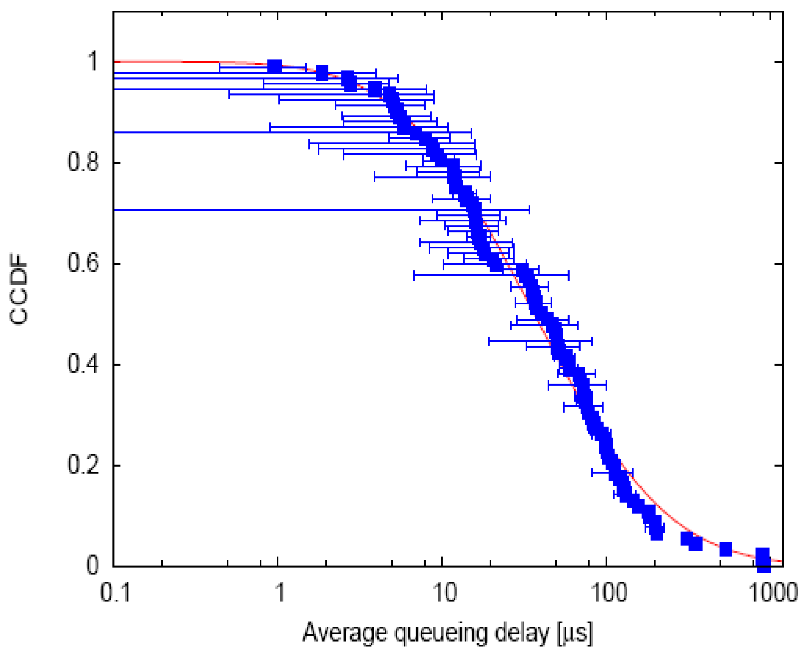
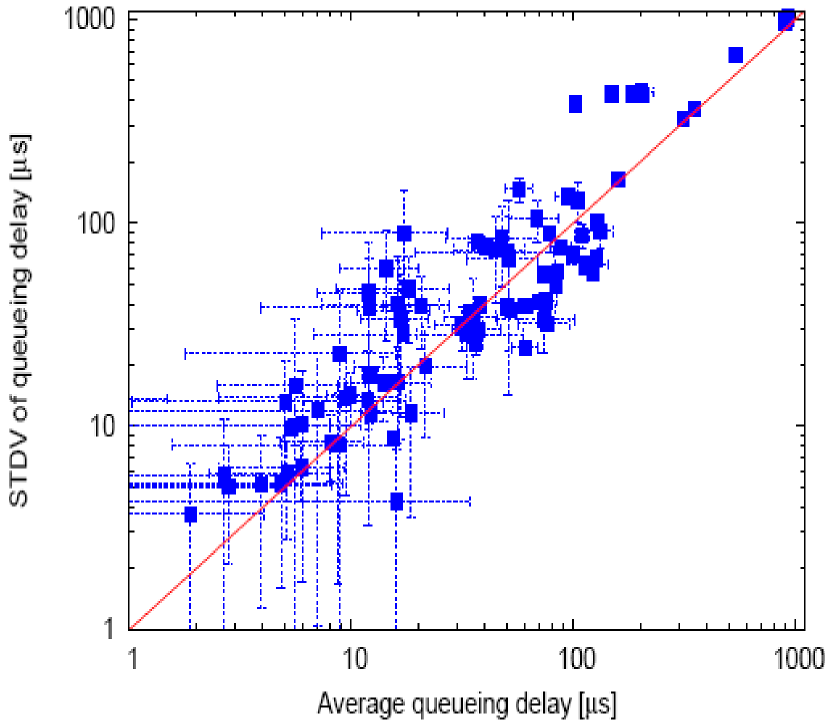
Main results

Log-normal distribution of the delay



Variance and delay are proportional



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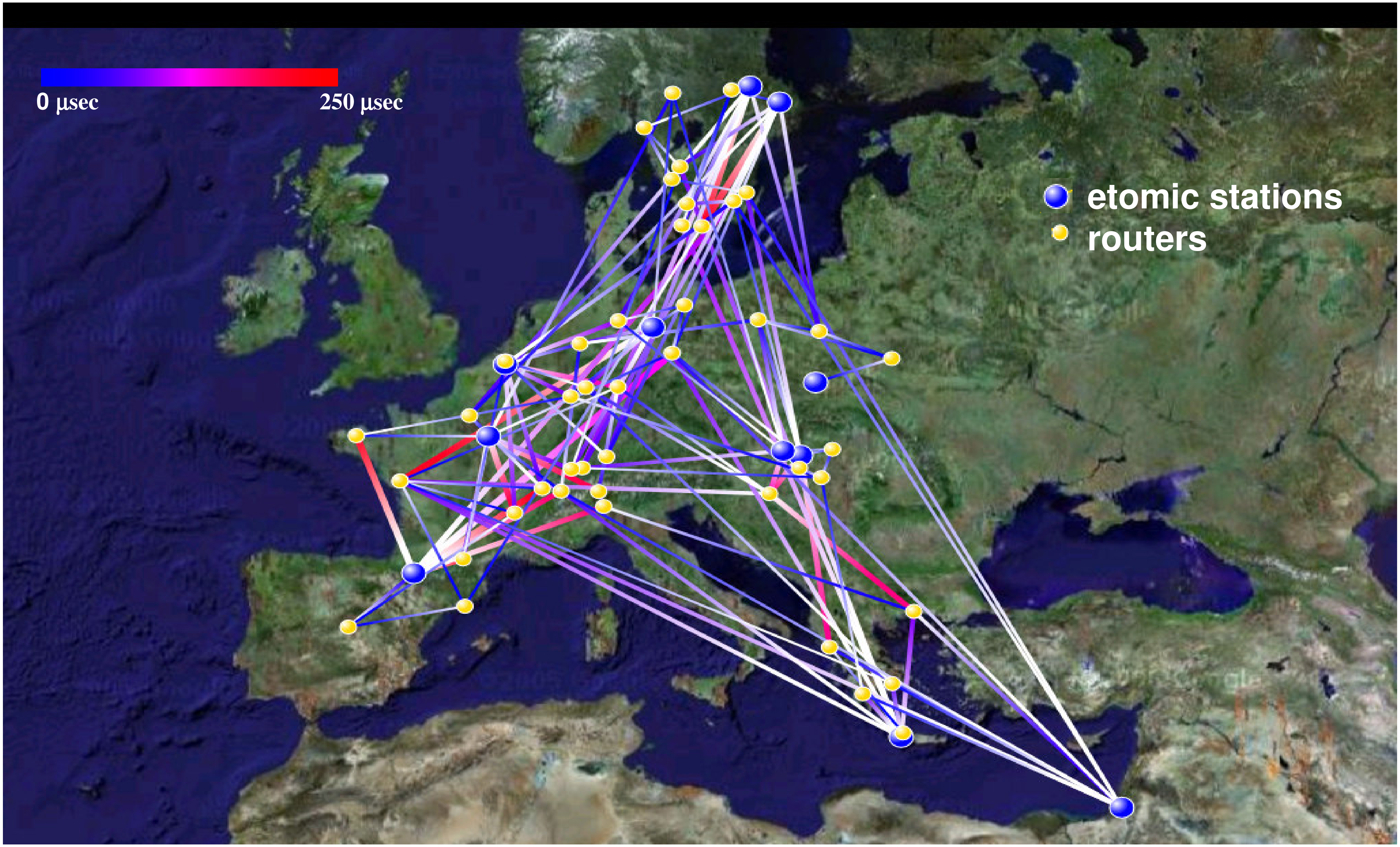
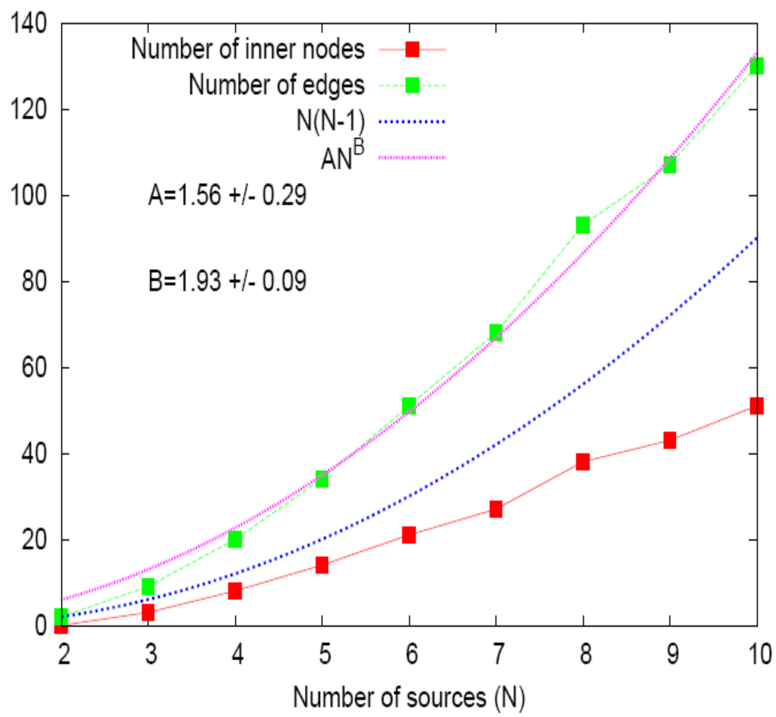
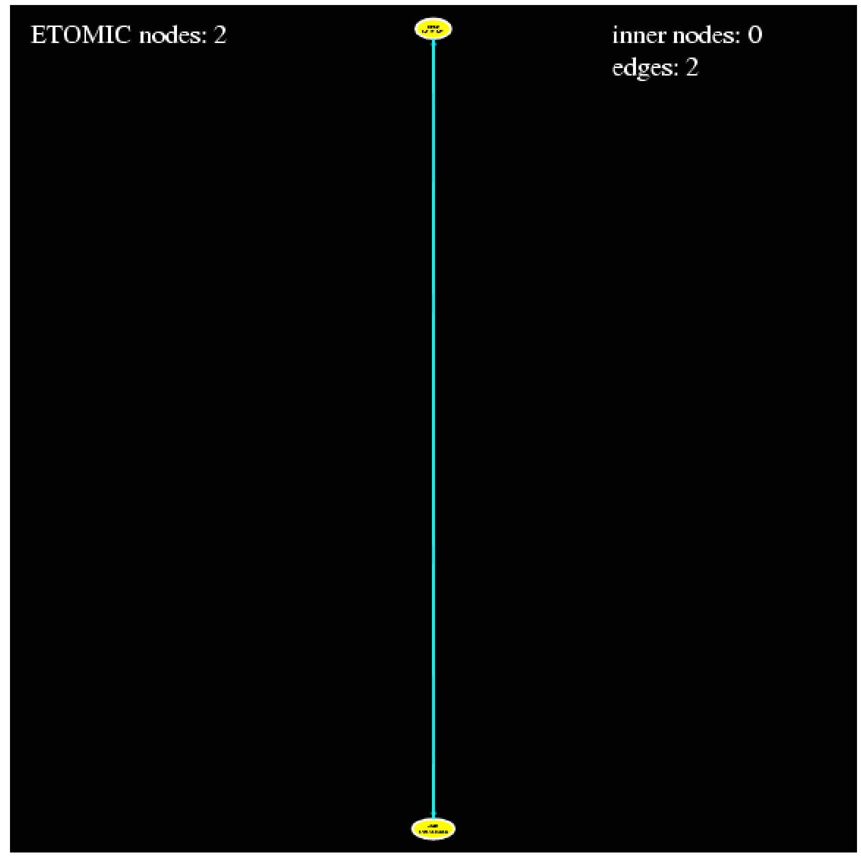
Snapshot of queuing delays in Europe



Growing number of monitored links





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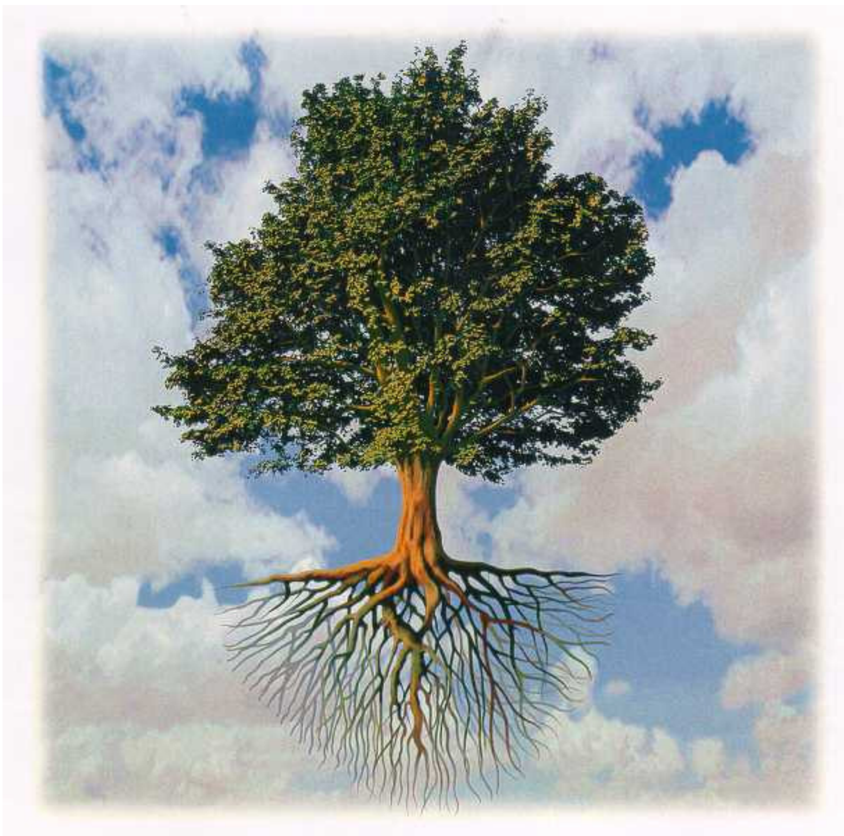

IST Future and Emerging Technologies

Thanks!

NKTH
Nemzeti Kutatási és Technológiai Hivatal