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

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Large Scale Network Tomography in the ETOMIC Testbed
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.
Large Scale Network Topology in the ETOMIC Testbed

Topology of routers

etomic stations

routers
Delay estimation for the Y-topology

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

\[
Y_1(k) = X_1(k) + X_2(k) \\
Y_2(k) = X_1(k) + X_3(k) \quad k \in \{1..N\}
\]

- **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 $q$

\[
X_i^d(k) = jq \quad \text{if } (j-1)q < X_i(k) \leq jq \quad i \in \{1,2,3\} \quad j \in \{1,2,..B\}
\]
\[ P_{i,j} = \frac{n_{i,j}}{\sum_{j=1}^{B} n_{i,j}} \]

\[ Y_1^d(k) = X_1^d(k) + X_2^d(k) \]

\[ Y_2^d(k) = X_1^d(k) + X_3^d(k) \]

\[ P(Y_1^d = lq, Y_2^d = mq) = P(l, m) = \sum_{s \in H} P_{1,s} P_{2,(l-s)} P_{3,(m-s)} \]

\[ H = \{ B \geq s \geq 1 \} \cap \{ B \geq (l-s) \geq 1 \} \cap \{ B \geq (m-s) \geq 1 \} \]

\[ L = \prod_{n=1}^{N} P(Y_1^d(n), Y_2^d(n)) \]
EM-algorithm

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

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

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

\[ P_i^0_{i,j} = \frac{n_{i,j}}{\sum_{j=1}^{B} n_{i,j}} \]

\[ n_{i,j} = \sum_{k=1}^{N} P(X_i^d (k) = jq \mid Y_1^d (k), Y_2^d (m)) \]
Large Scale Network Tomoraphy in the ETOMIC Testbed
Large Scale Network Tomoraphy in the ETOMIC Testbed
Daily change of mean queuing delays
Main results

Log-normal distribution of the delay

Variance and delay are proportional
Large Scale Network Tomography in the ETOMIC Testbed

Snapshot of queuing delays in Europe
Growing number of monitored links
Thanks!

IST Future and Emerging Technologies

Large Scale Network Tomoraphy in the ETOMIC Testbed