An Approximation Algorithm for QoS Routing with Two Additive Constraints

Ronghui Hou, King-Shan Lui, Ka-Cheong Leung

Dept. of Electrical and Electronic Engineering

University of Hong Kong, Hong Kong

Fred Baker

Cisco Research Center

Outline

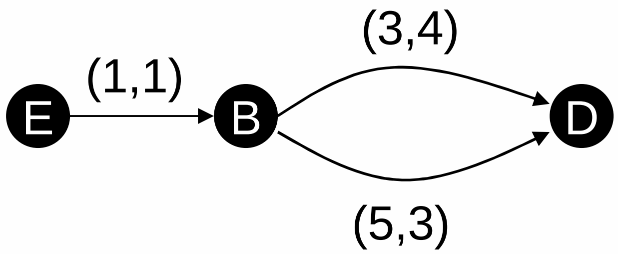
- Introduction
  - Precomputing the supported QoS
  - Sampling approximation method
- The approximation error produced by the sampling approximation method.
- Two-dimensional sampling mechanism.
- Simulation and Conclusion

Our focus

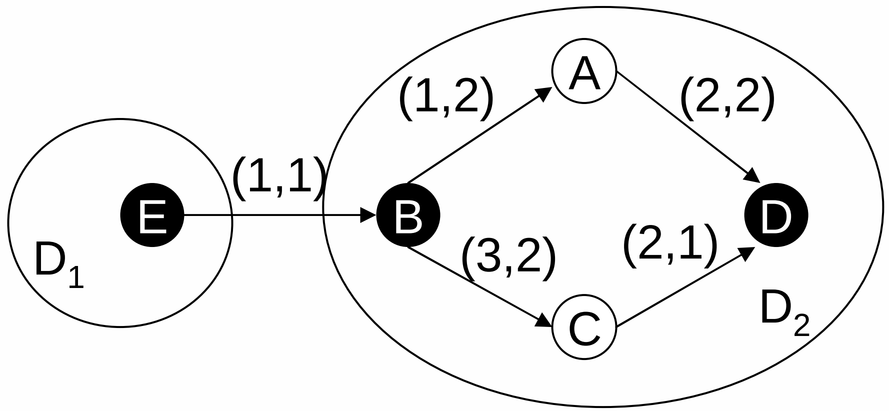
- Each link is associated with two additive metrics.
- Precomputing the supported QoS between two nodes.
- Different than the most current works
  - Given a request, finding a feasible path for this request.
  - Cannot support QoS in the Internet.

Routing with two constraints

- Finding a feasible path from E to D.
- Cannot find the best path from B to D.
  - (3,4); (5,3)



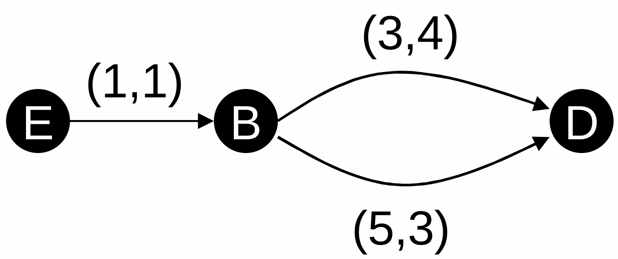
The aggregated topology



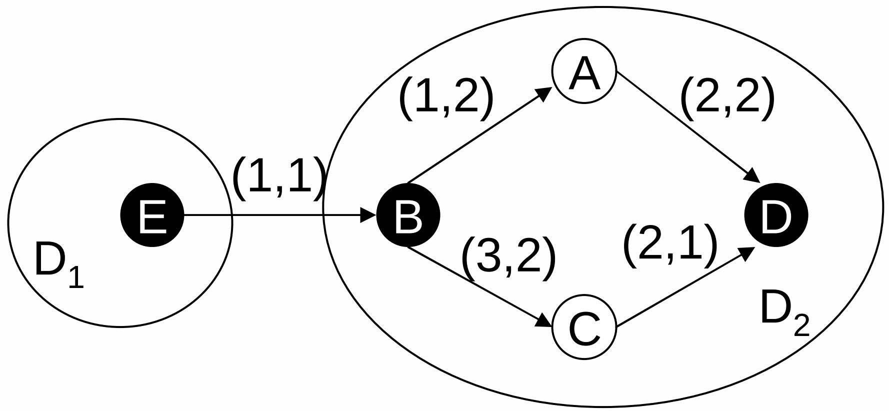
The original topology

Challenge !

- Precomputing the supported QoS between any two border nodes in a domain.



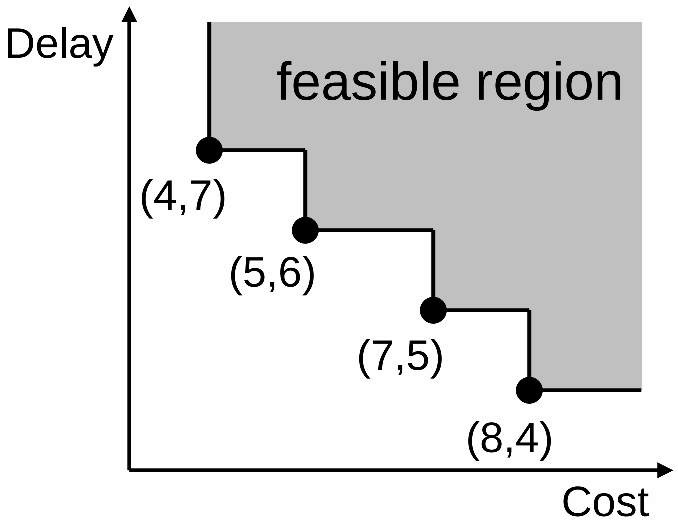
The aggregated topology

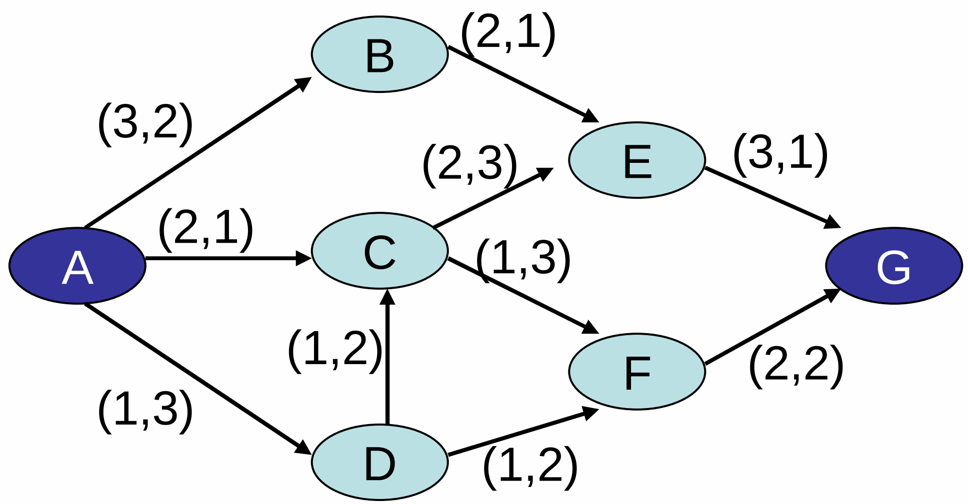


The original topology

Non-dominated paths

- Six paths: (4,7), (5,6), (5,10), (7,5), (7,9), (8,4)
- Non-dominated paths: (4,7), (5,6), (7,5), (8,4)
- Representative points.



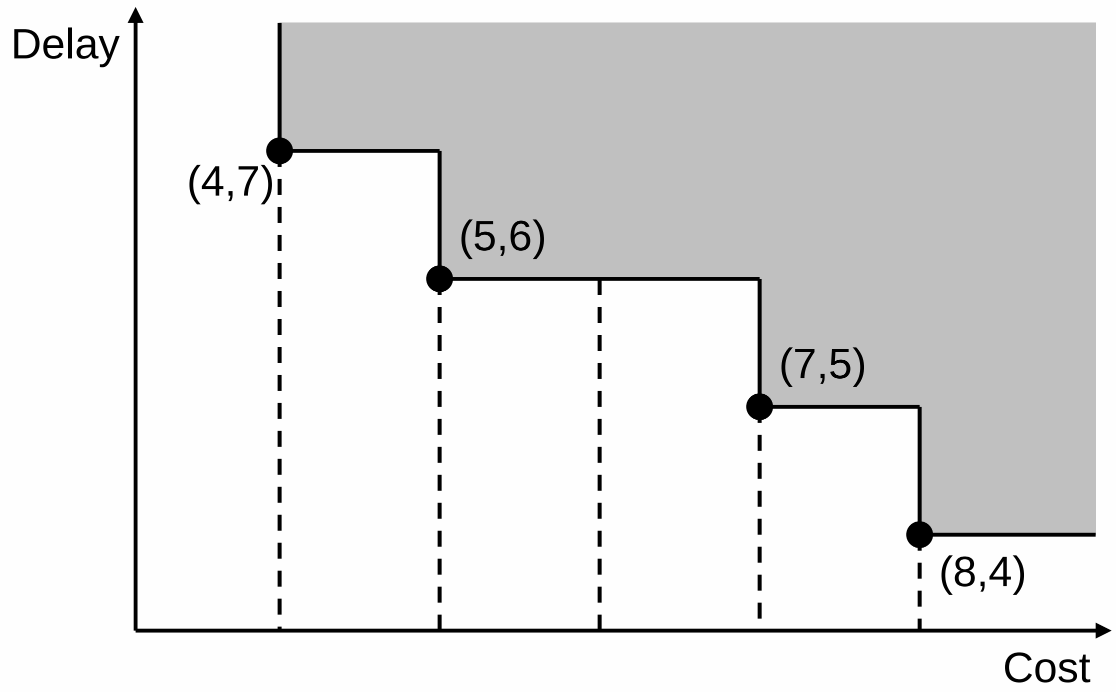


Our contributions

- NP-complete problem.
- **Propose** a new approximation method, two-dimensional sampling mechanism.
- **First study** to analyze the approximation error.
- **Formally prove** that our mechanism produces **smaller** approximation error than the existing algorithms.

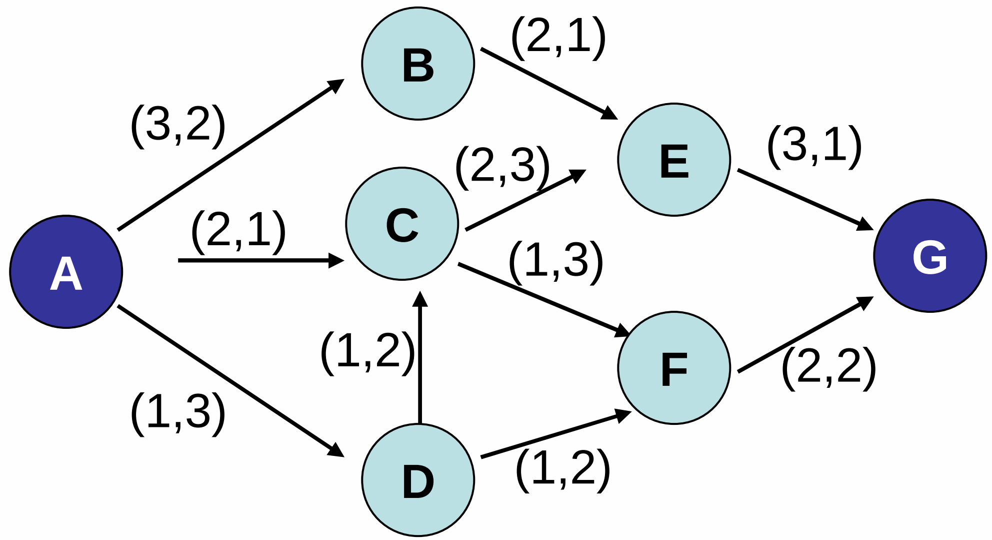
QoS with integral constraints

The minimum delay with a cost constraint



Procedure for computing the supported QoS

- Hop-by-hop
- Polynomial-time
  - Depends on the metric of link

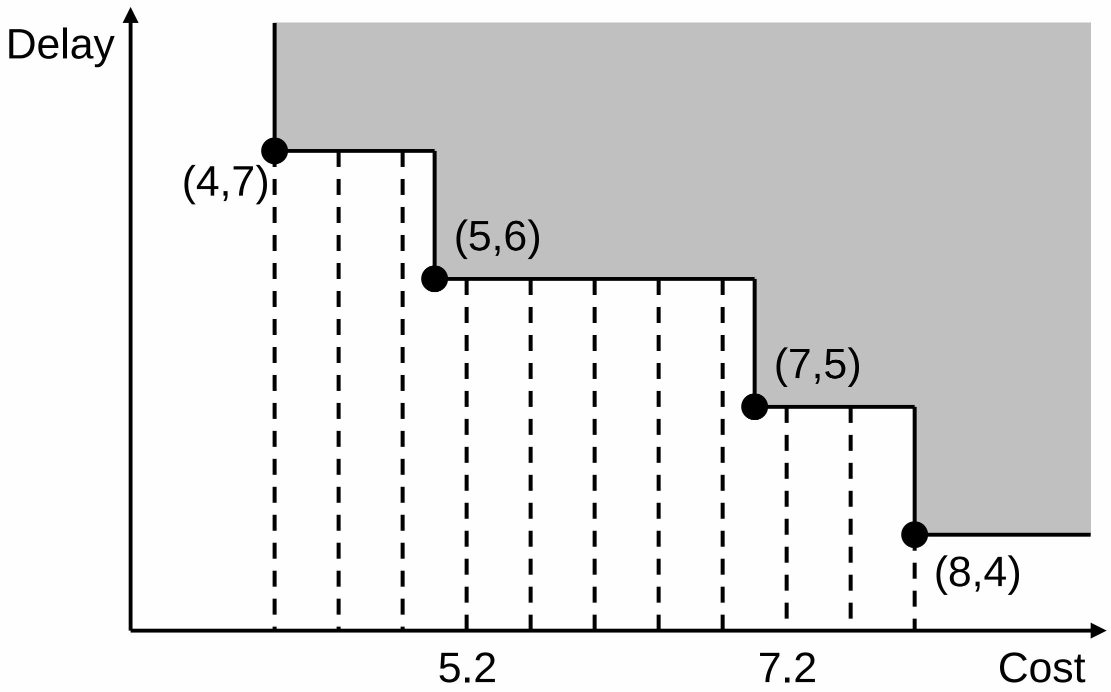


Sampling approximation method with real-number metrics

Uniform: δ, 2δ, 3δ, … *(Xin TON 2002)*

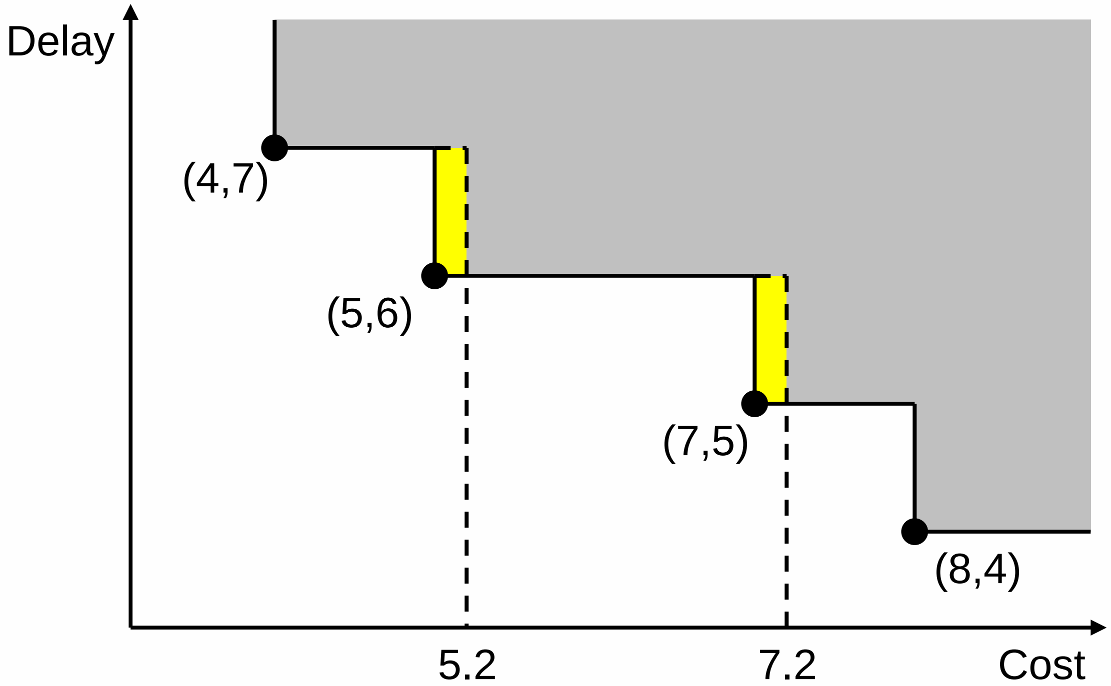
Logarithmic: 1, 1+δ, $(1+δ)^2$ … *(Orda TON 2003)*

Uniform:
δ=0.4



Sampling approximation method

Approximation error ?



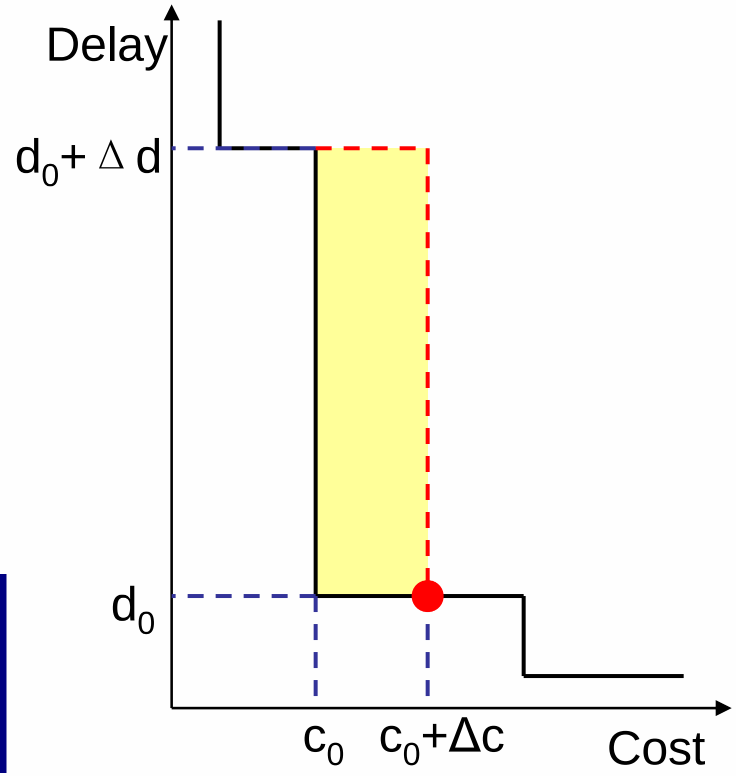
Cost-deviation

- Cost-deviation: $\Delta c = c - c_0$

Uniform: $\Delta c \leq h\delta$

Logarithmic:
$\Delta c \leq ((1+\delta)^h - 1)c_0$

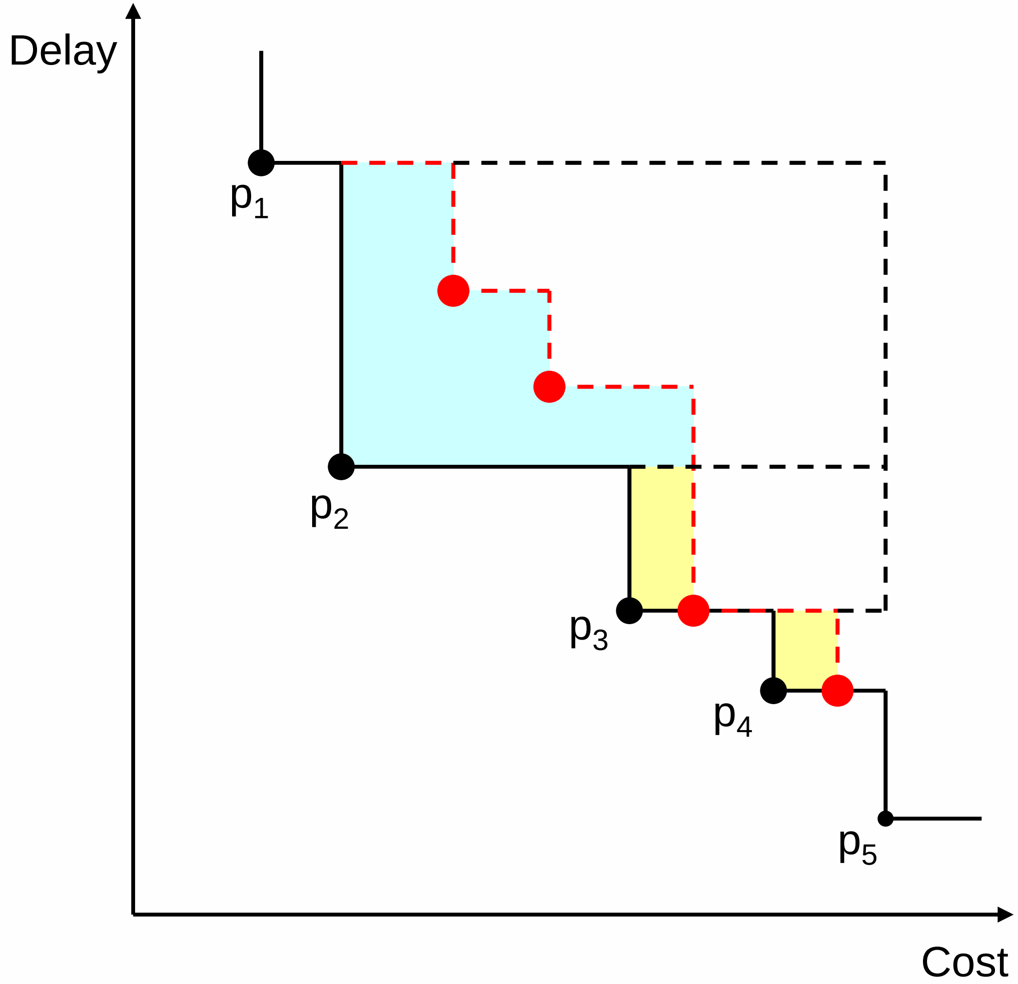
Property: accumulated with h
Technique: induction



Setting the sampling parameter

- *Lemma*: Given a predefined ε, when $\delta \leq \varepsilon/2N$, where N is the number of nodes, the cost deviation of c_0 is less than εc_0.

Computing the error



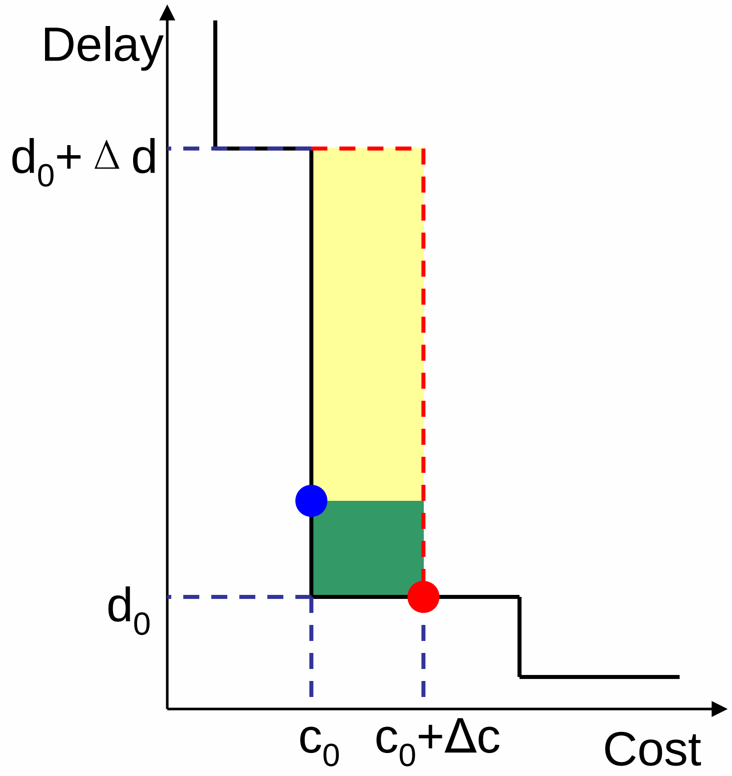
The approximation error

- Approximation error
  - Uniform sampling ε*UB
  - Logarithmic sampling ε*(UB)^2
- Computational overhead
  - Uniform sampling O(N*UB/ε).
  - Logarithmic sampling O(N*log(UB)/ε).

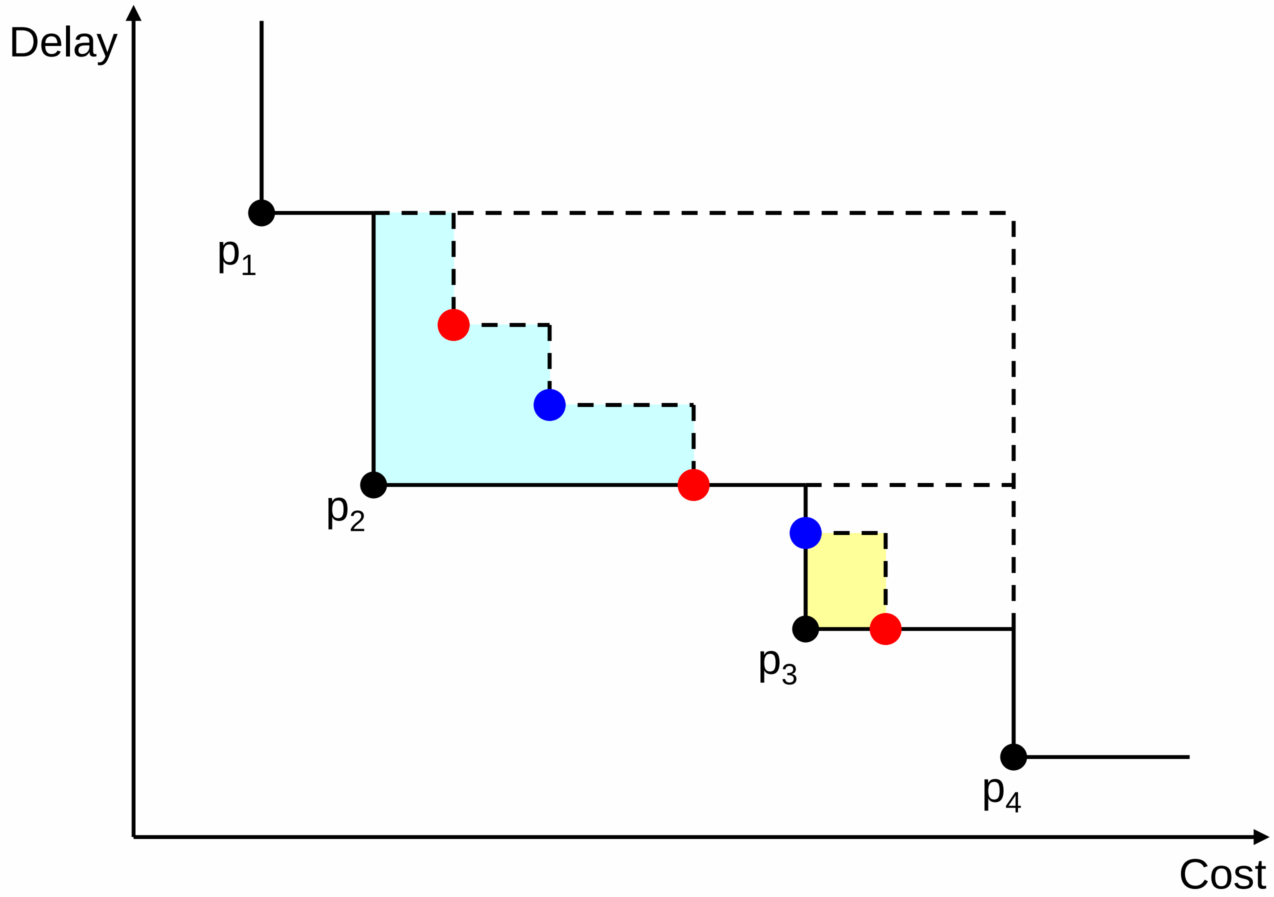
The approximation error depends on UB

Two-dimensional sampling

- The main philosophy:
  – Bound both the cost-deviation and delay-deviation.
- Technique: sample both cost and delay



Computing the approximation error of our approach



Comparing errors

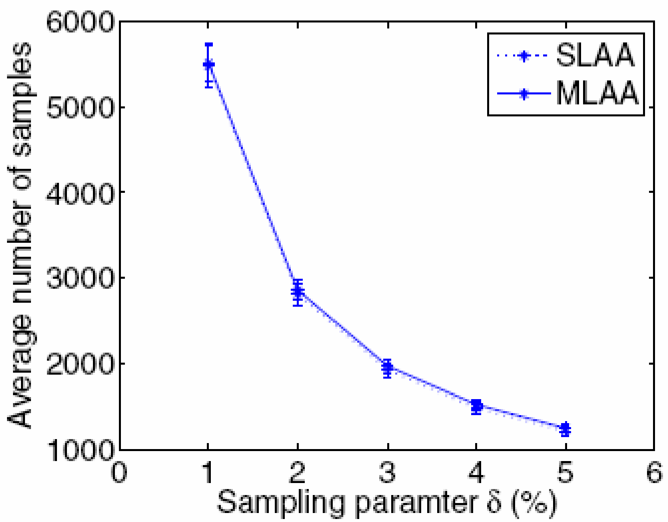
- Uniform sampling
  - $N\varepsilon^2$ (two-dimensional)
  - $\varepsilon*N*B$ (cost-sampling)
- Logarithmic sampling
  - $N\varepsilon^2*UB^2$ (two-dimensional)
  - $\varepsilon*UB^2$ (cost-sampling)
  - $N\varepsilon$ should be less than 1.

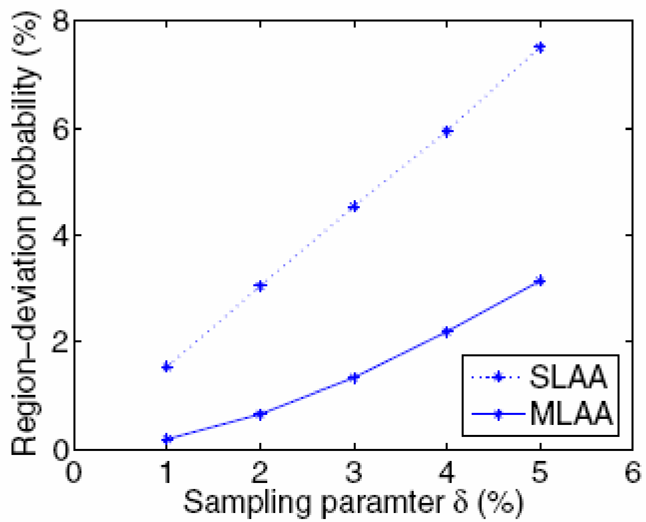
Simulation Experiments

- Waxman-model based network topology.
  - 100 domains
  - 50-node or 100-node domains
- Two evaluation metrics
  - Region-deviation probability
    - The ratio of the approximation error to the actual feasible region.
  - The computational overhead
    - The average number of samples.

Simulation results

- Logarithmic sampling
  - 100-node domain





Conclusion and Future works

- Studied the problem of computing the supported QoS with two additive constraints.
- Extend to more than two additive constraints.
- Study the impact of the number of constraints on the performance of approximation algorithms.

Thank you!