Model-less Approach for an Accurate Packet Loss Simulation

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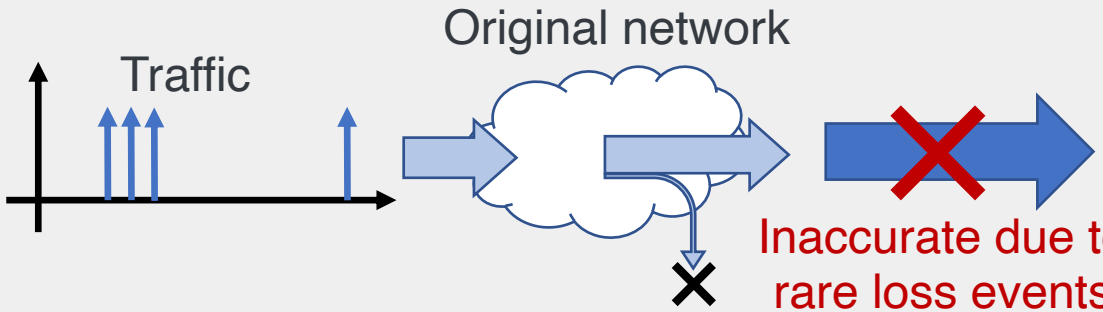
Introduction

- Accurate network simulation is a fundamental technique to evaluate Quality of Service (QoS).
- Importance Sampling (IS) has been used for accurate estimations of rare events.
  - In IS simulation, a simulation of a network where the events occur more frequently is performed.
  - Conventional IS simulation require the traffic model of the target network.
- IS simulations are inapplicable for real network traffic due to difficulty of traffic modelling.

- Objectives
  - We propose a model-less approach to accurately estimate a packet loss rate of real traffic through a simulation without directly modeling traffic.

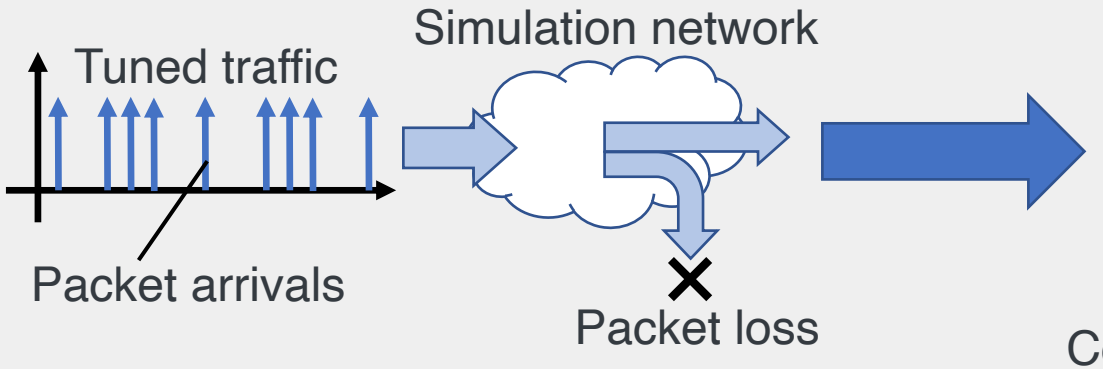
Model-based IS

- A simulation of a network where packet loss occur more frequently than the original network is performed.
- The result of the simulation is converted to the result of the original network.



Normal estimator

$$\hat{l}_{\mathrm{MC}} = \frac{1}{c}\sum_{j=1}^{c} \mathbf{1}_{\{j\in\phi\}}$$



IS estimator for original network

$$\hat{l}_{\mathrm{IS}} = \frac{1}{\tilde{c}}\sum_{j=1}^{\tilde{c}} \mathbf{1}_{\{j\in\phi\}} \frac{p(\tilde{\omega}_j)}{\tilde{p}(\tilde{\omega}_j)}$$

Conversion by change-of-measure with traffic model

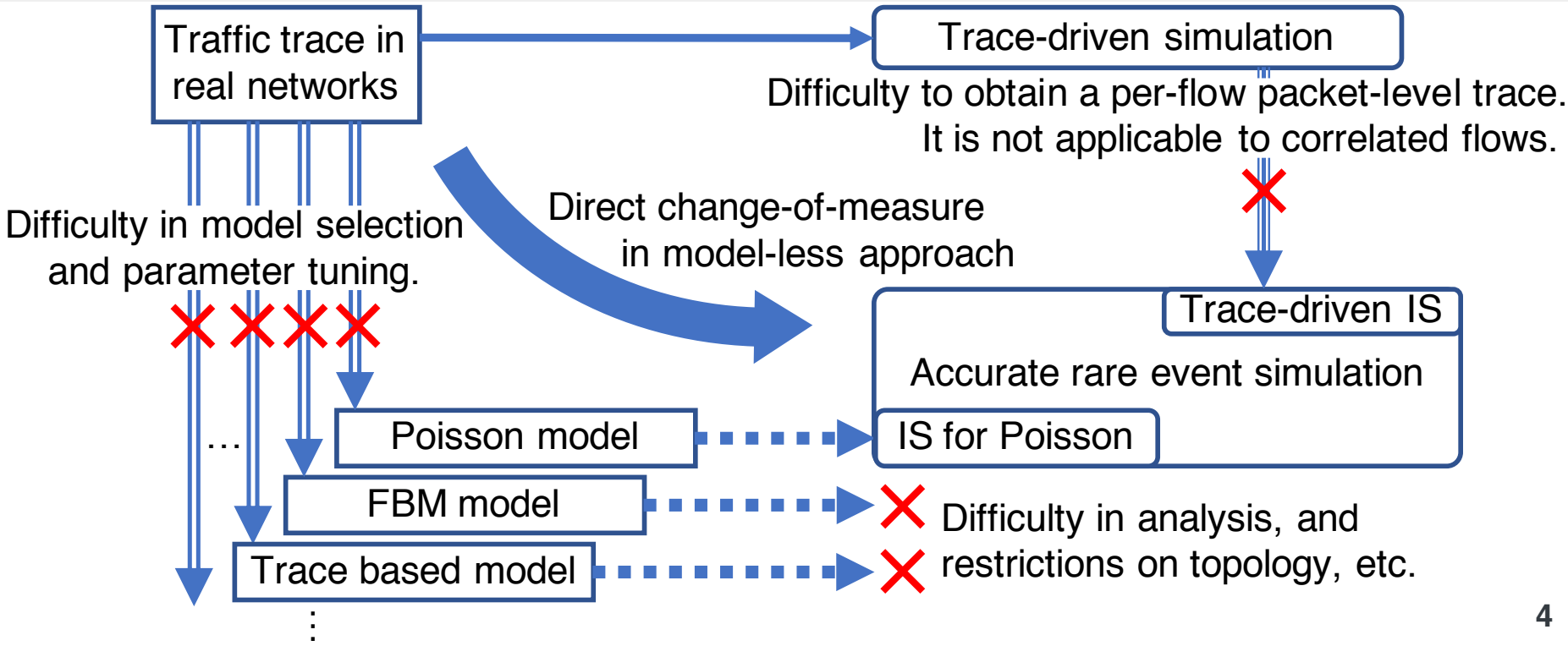
ϕ : A set of ID of loss packets

c and $\tilde{c}$: The number of arrival packets in original/simulation networks

$p(\tilde{\omega}_j)$ and $\tilde{p}(\tilde{\omega}_j)$: Probability density of queue length process before packet j arrival in original/simulation networks.

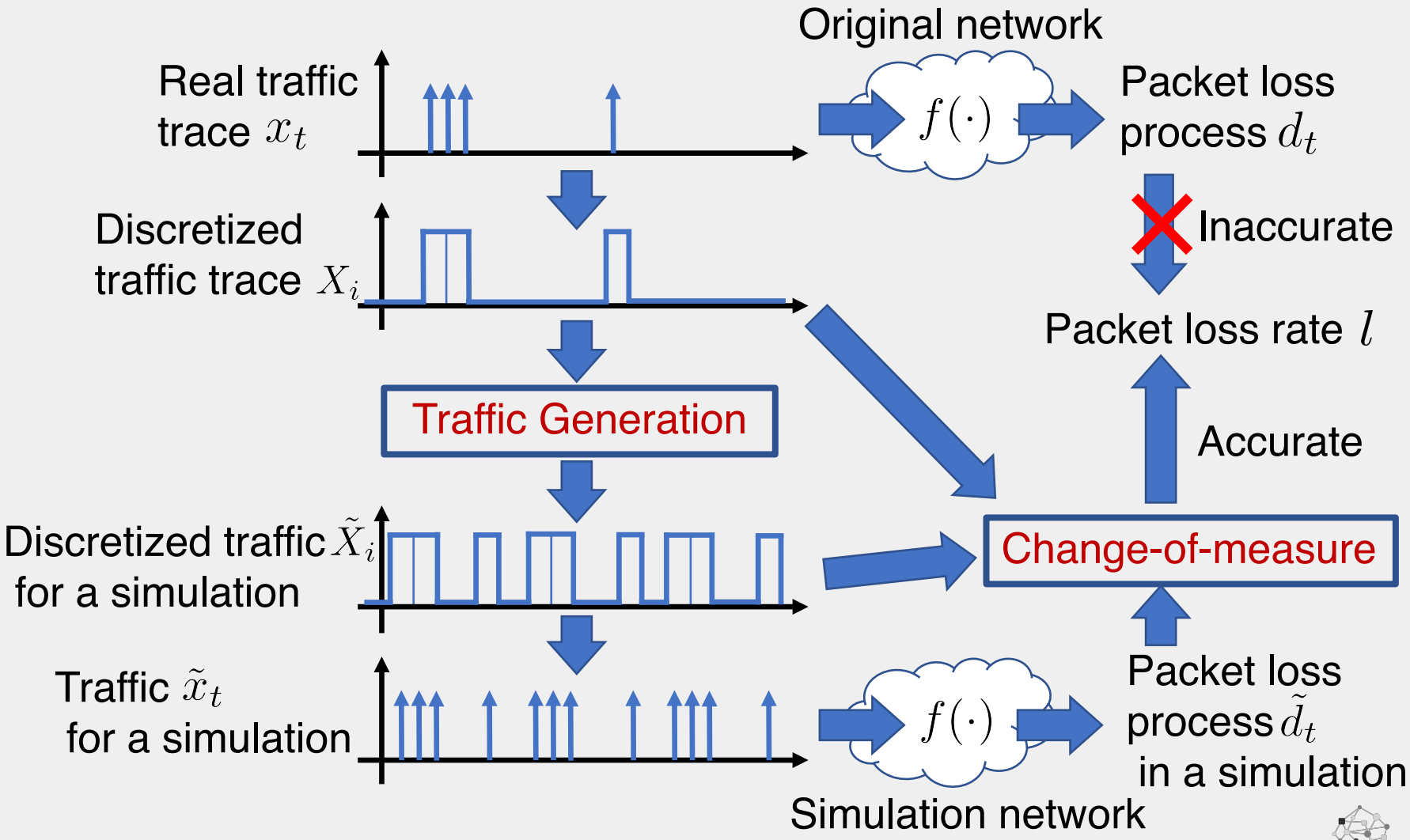
IS Simulations for Real Networks

- In conventional approach, real traffic is modeled and IS simulation with its model are performed.
- There are a few works regarding IS in trace-driven simulation without traffic models.
- These approaches have the following problems, and our approach overcome them.



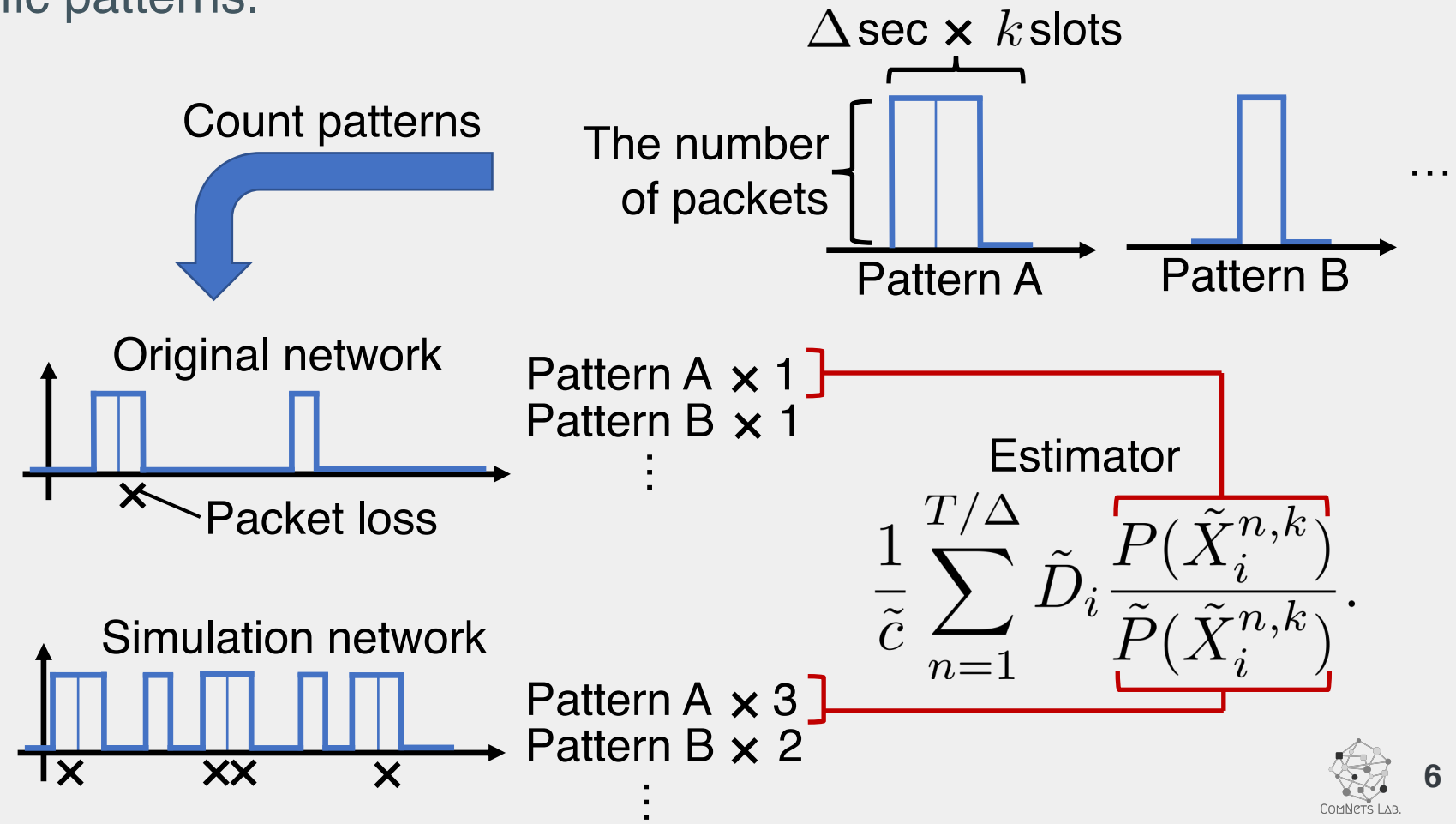
Model-less Approach

- Overview of the proposed method is as follows.



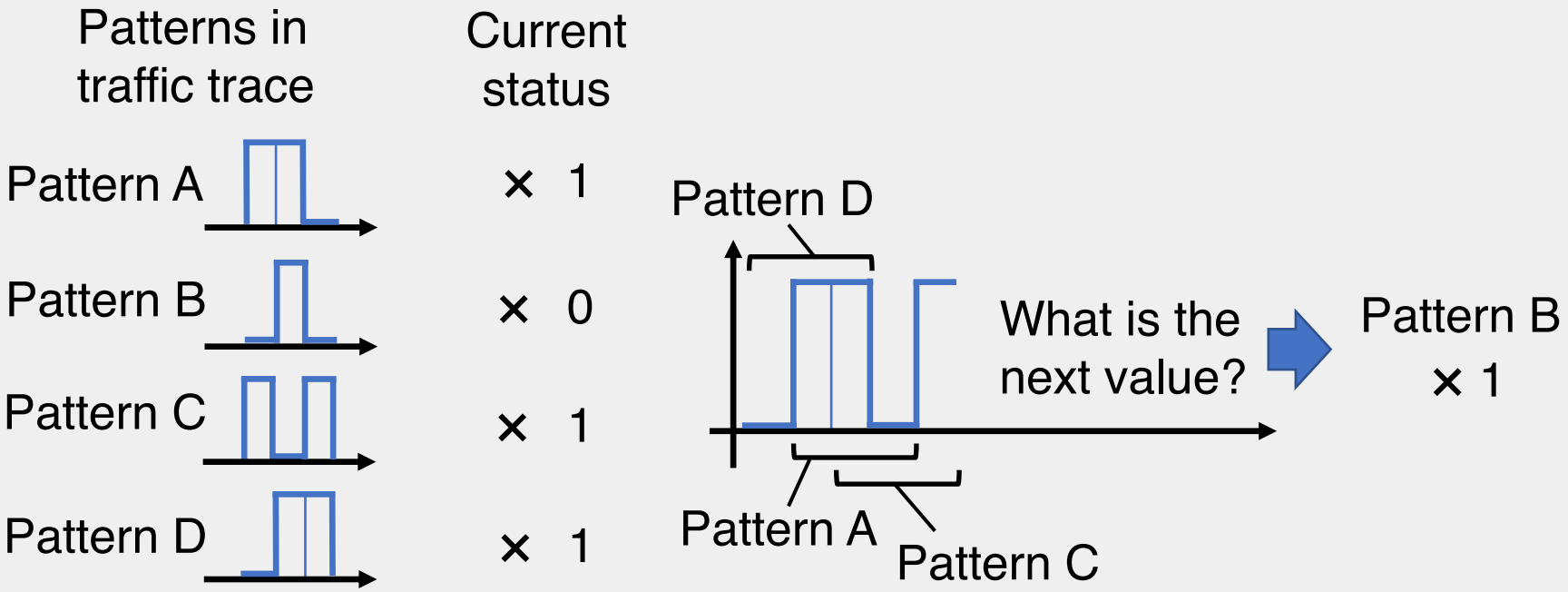
Change-of-measure Technique

- The model-less approach enable an empirical derivation of change-of-measure from a traffic trace.
- Change-of-measure is calculated from a frequency distribution of traffic patterns.



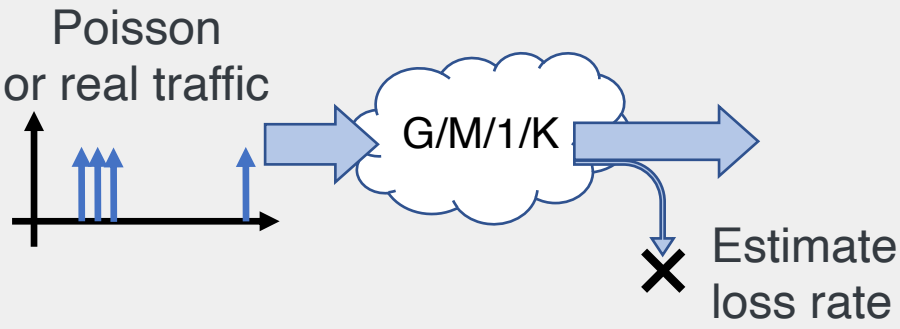
Traffic Generation in Simulations

- Traffic patterns that are observed in a traffic trace of an original network are listed, and input traffic is generated for a simulation so that the frequency of all patterns are the same.



Evaluations

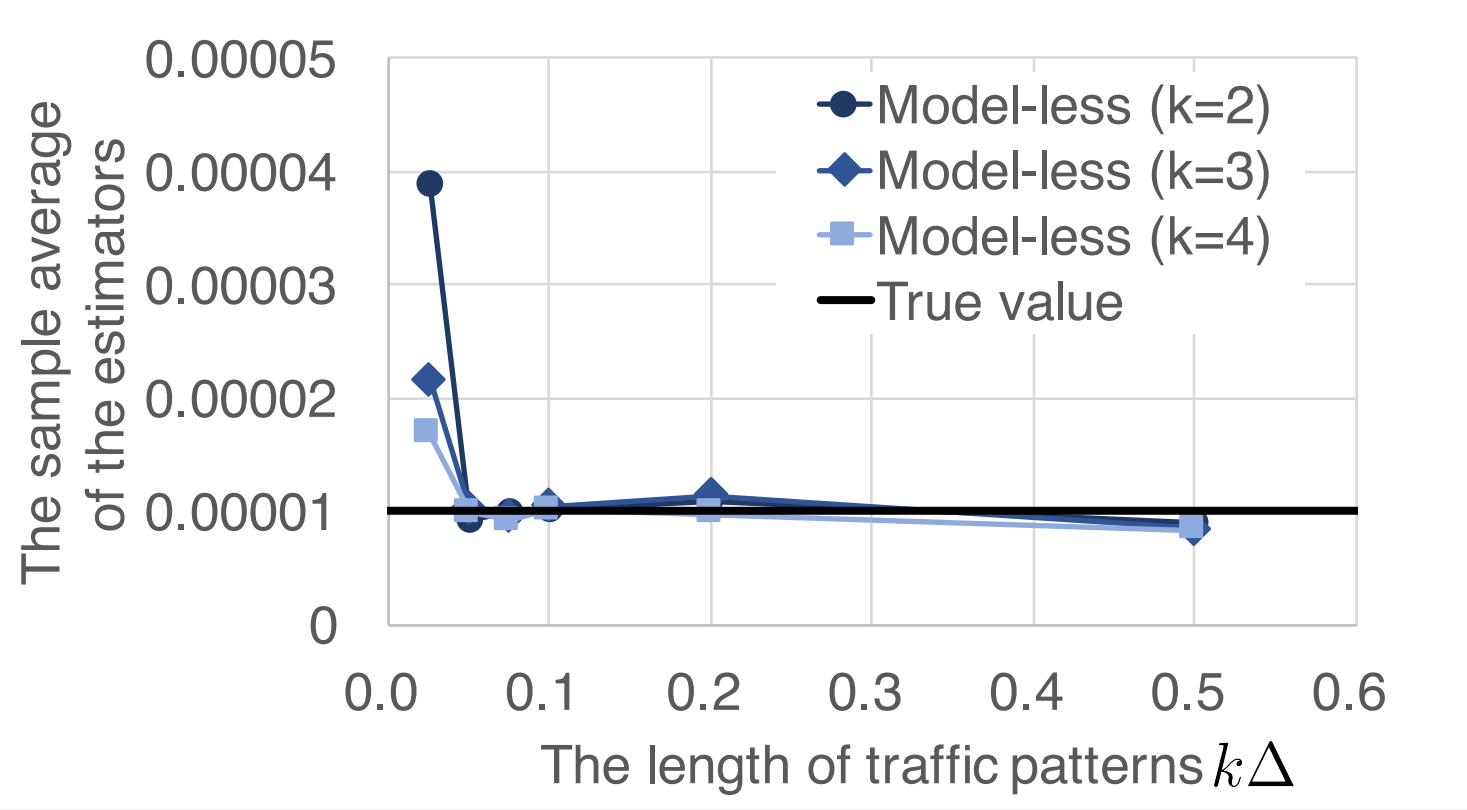
- In order to evaluate the effectiveness of the model-less approach, a packet loss rate is estimated in a simple queueing model by the model-less approach and trace-driven MC simulations.
- Traffic traces
  - Poisson traffic trace
  - A traffic trace of a real network (WIDE project)
- Evaluated network system
  - G/M/1/K



- Parameters
  - Arrival rate: 329.1 [packet/s]
  - Service rate:
    - 1000 [packet/s] (Poisson)
    - 10000 [packet/s] (Real trace)
  - The queue length K: 10 [packet]
- Simulation time:
  - 1000 [s] (Poisson)
  - 100 [s] (Real trace)
- Iteration:
  - 30 times (Poisson)
  - 10 times (Real trace)

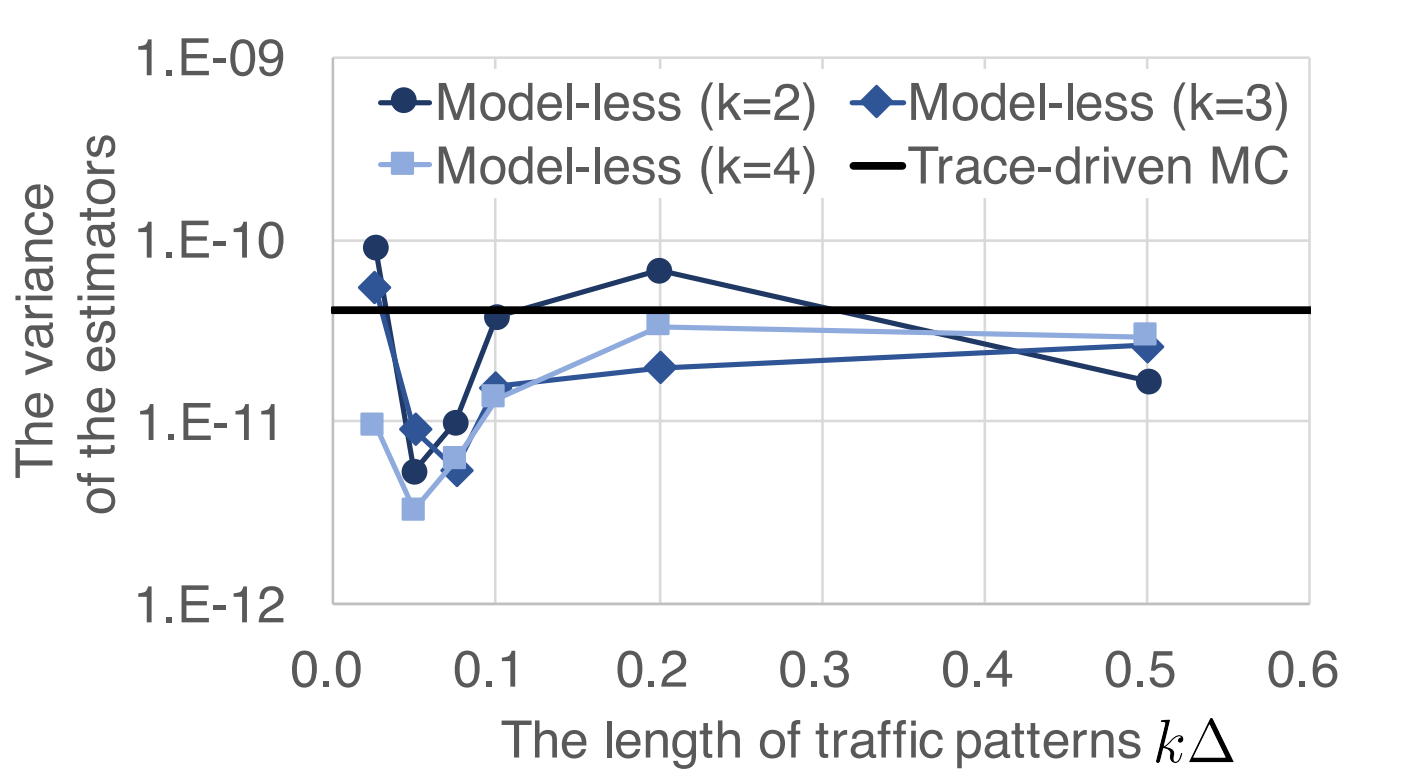
Poisson Traffic Trace - Bias

- The average of the estimators of the packet loss rate are calculated.
- We can confirm that the model-less approach estimates the packet loss rate without bias when $k\Delta \geq 5 \times 10^{-2}$.



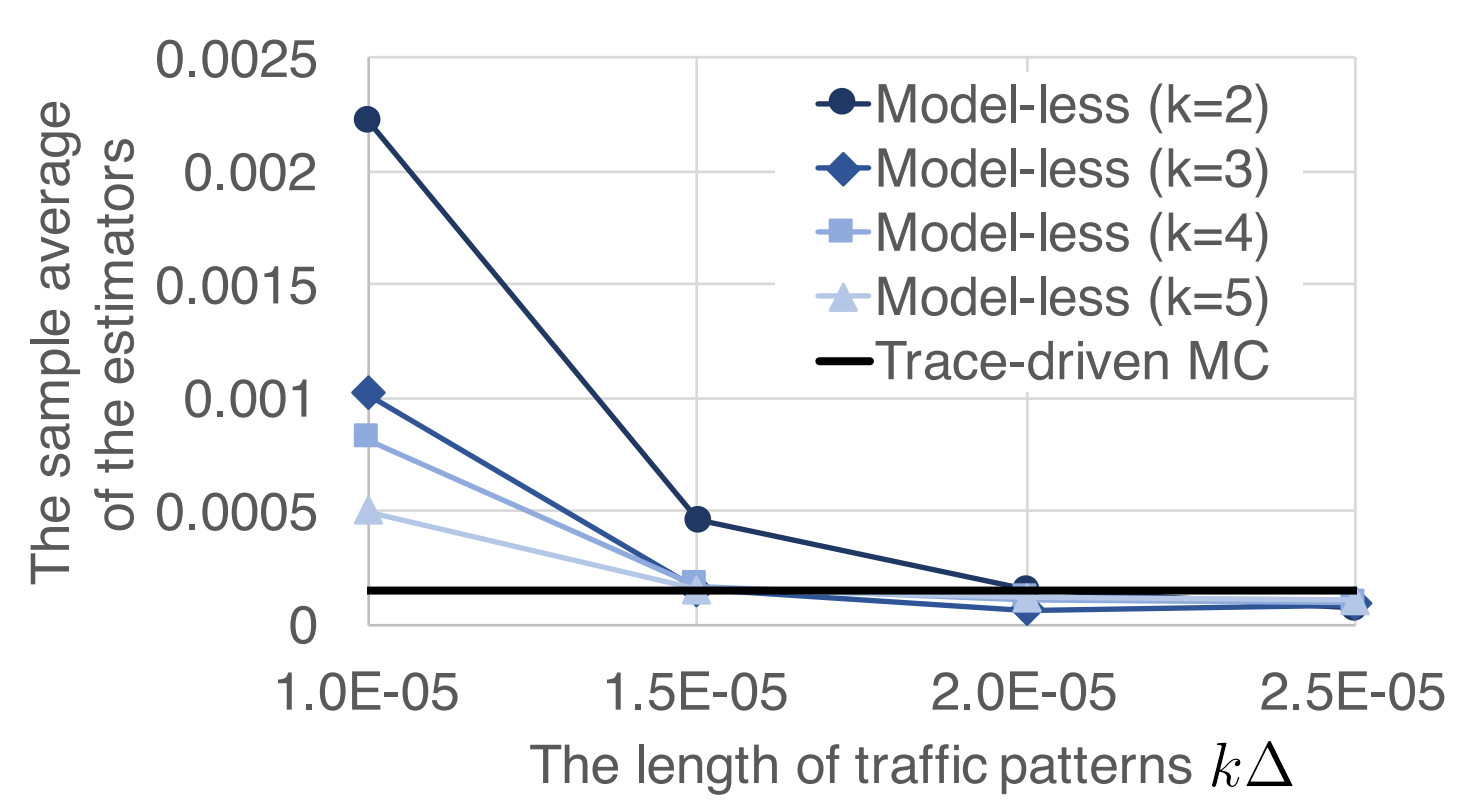
Poisson Traffic Trace - Variance

- The variance of the estimators of the model-less approach and the trace-driven MC simulation is calculated.
- Most of the results of the model-less approach is lower than that of the trace-driven MC simulation when $k\Delta \geq 5 \times 10^{-2}$.
- The lowest variance of the model-less approach is about 1/12.



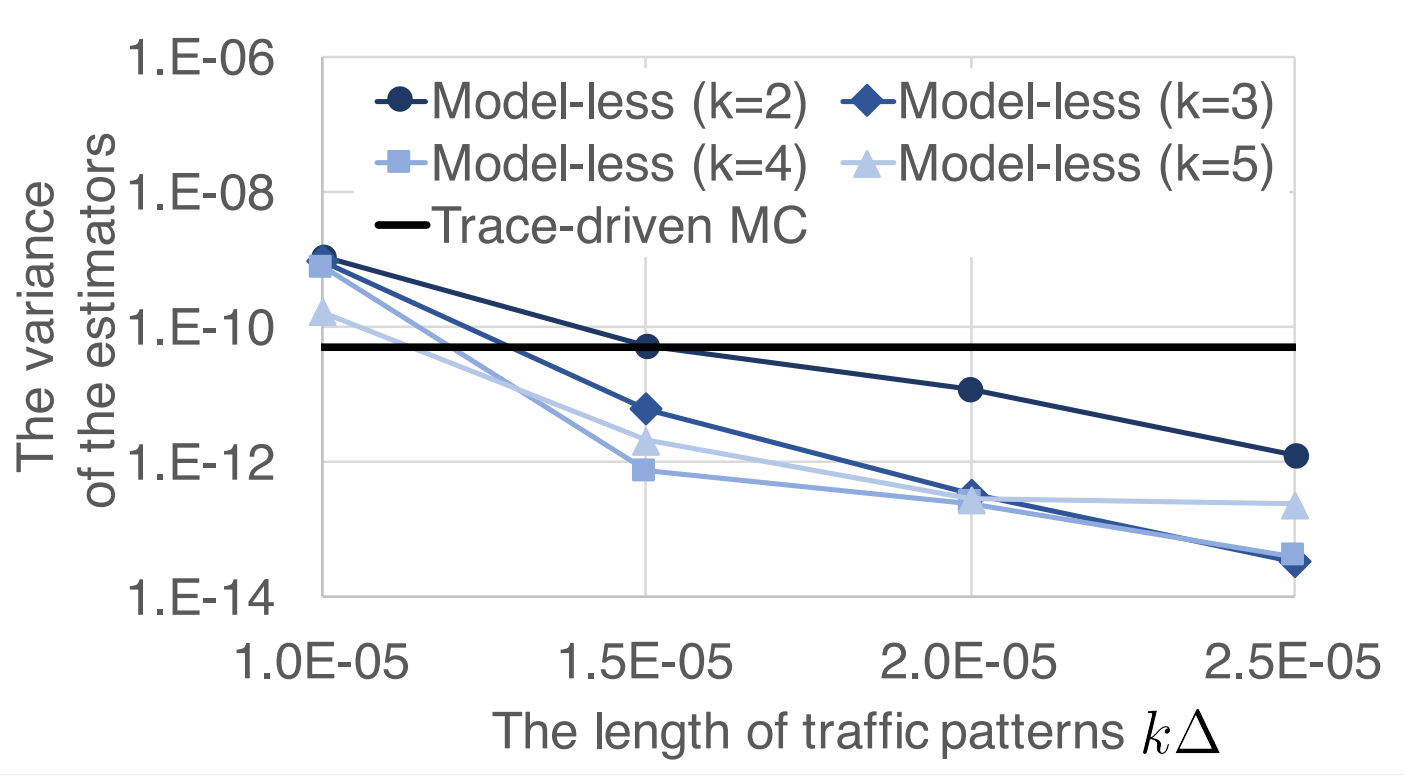
Traffic Trace of a Real Network - Bias

- The average of the estimators of the packet loss rate are calculated.
- We can confirm that an unbiased estimation is achieved if k and $k\Delta$ are sufficiently large.



Traffic Trace of a Real Network - Variance

- The variance of the estimators of the model-less approach and the trace-driven MC simulation is calculated.
- We can confirm that an accurate estimation is achieved for unbiased estimator.
- The lowest variance of the model-less approach is about 1/145.



Conclusions and Future Works

- Conclusion
  - In this paper, we proposed the model-less approach to accurately estimate a packet loss rate through a simulation without directly modeling traffic.
  - The model-less approach provides a change-of-measure technique based on model-based IS with a frequency distribution of discretized traffic patterns.
  - In the most effective cases in the evaluation, the accuracy of the model-less approach is 145 times accurate than that of the normal trace-driven MC simulation.
- Future works
  - The optimization problem of the parameters.
  - Evaluations in complex topology.

- Thank you for your kind attention.