On Accurate Packet Loss Estimation for Networks without Traffic Models

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Introduction

- It is important to accurately model network traffic when we evaluate Quality of Service (QoS) of networks through simulations.
  - It is difficult to select an appropriate traffic model and tune its parameters.
  - Even if the accurate traffic modeling is achieved, it is also difficult to accurately estimate QoS regarding rare events.

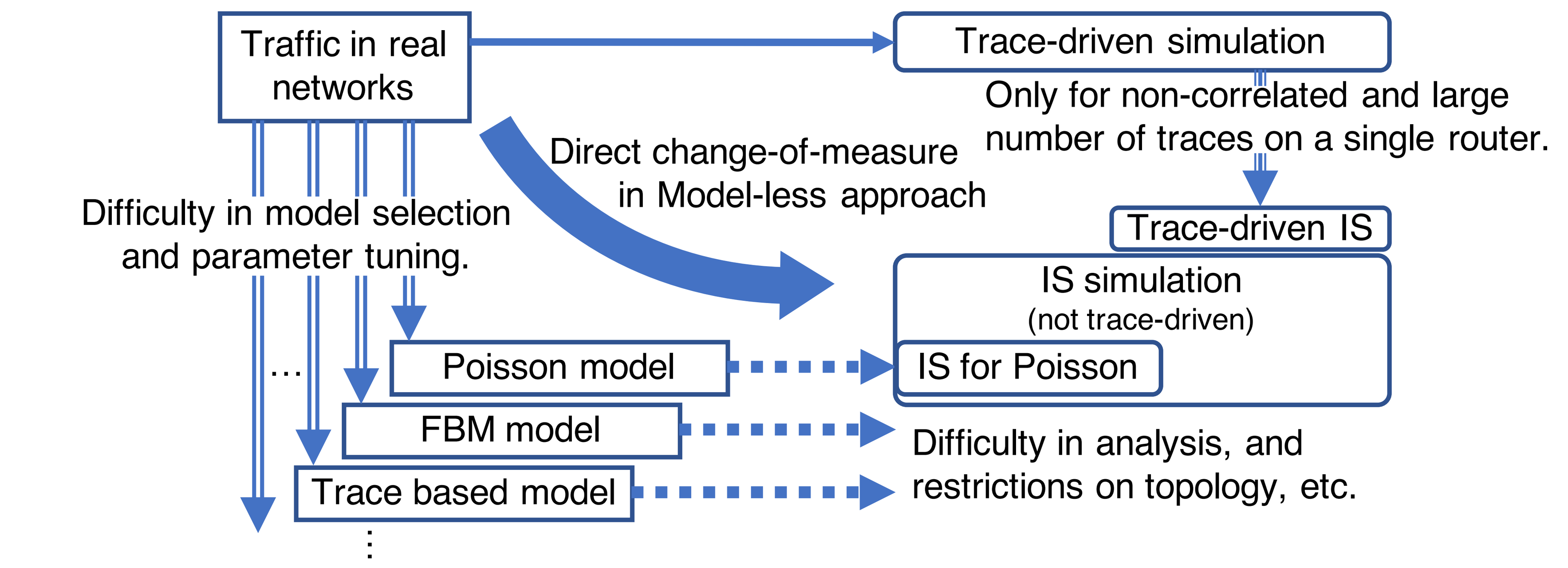

Figure 1: The model-less approach and the conventional simulations.

- Importance Sampling (IS) for accurate estimations of rare events [2]
  - The events occur more frequently in IS simulation.
  - The estimator is obtained by the change-of-measure.
  - The applicable traffic models, topology etc. are extremely limited.
- Trace-driven IS without traffic models [3]
  - It cannot be applied for single flow traffic.
  - It is not applicable for traffic with correlated flows.

Goal of our study

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

Model Based IS

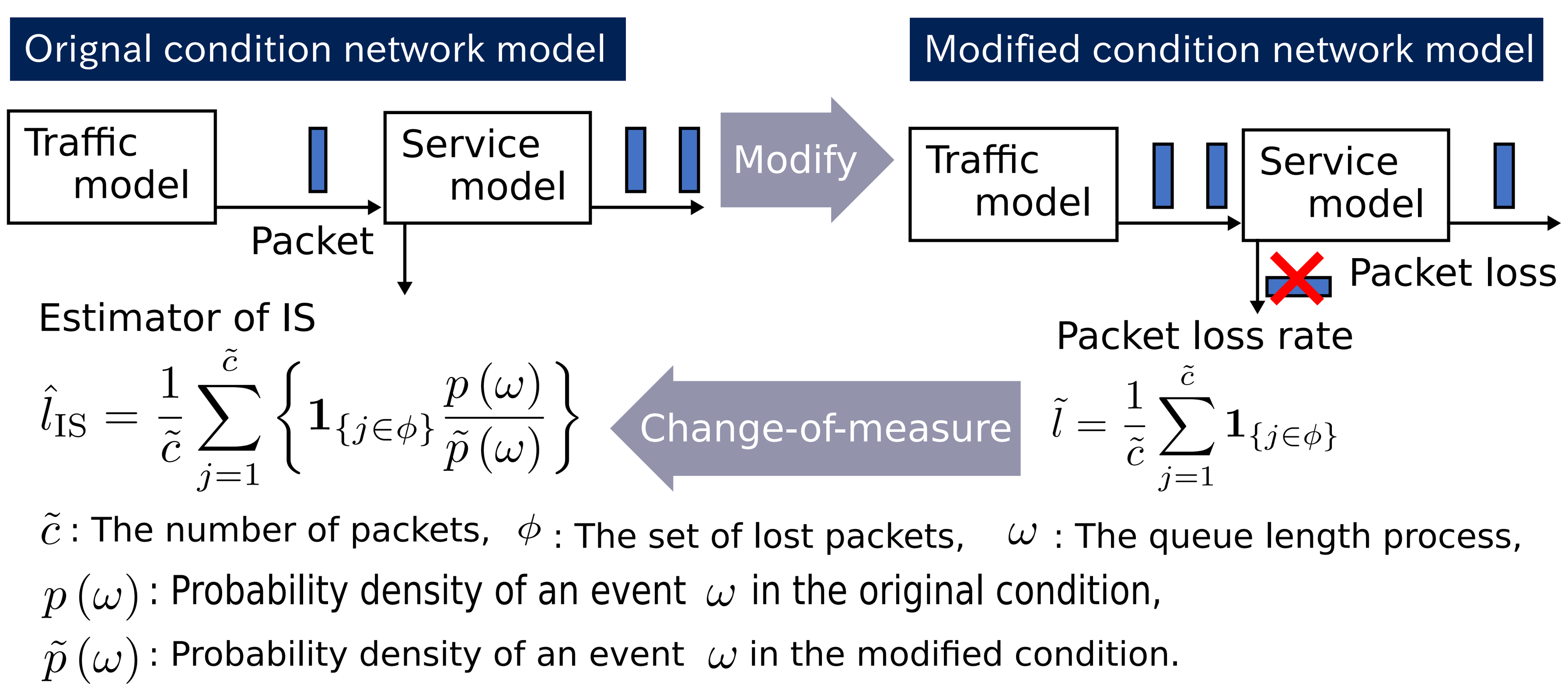

Figure 2: Outline of model base IS

- When IS estimates a loss rate on a single router into which a single flow streams, the change-of-measure is performed based on probability density of a path ω of the queue length process [2].
- The change-of-measure $p(\omega)/\tilde{p}(\omega)$ is analytically derived from a traffic model in model-based IS.

Model-less Approach

- Our goal is to accurately estimate a packet loss rate through a simulation in a real network without assuming any traffic model.

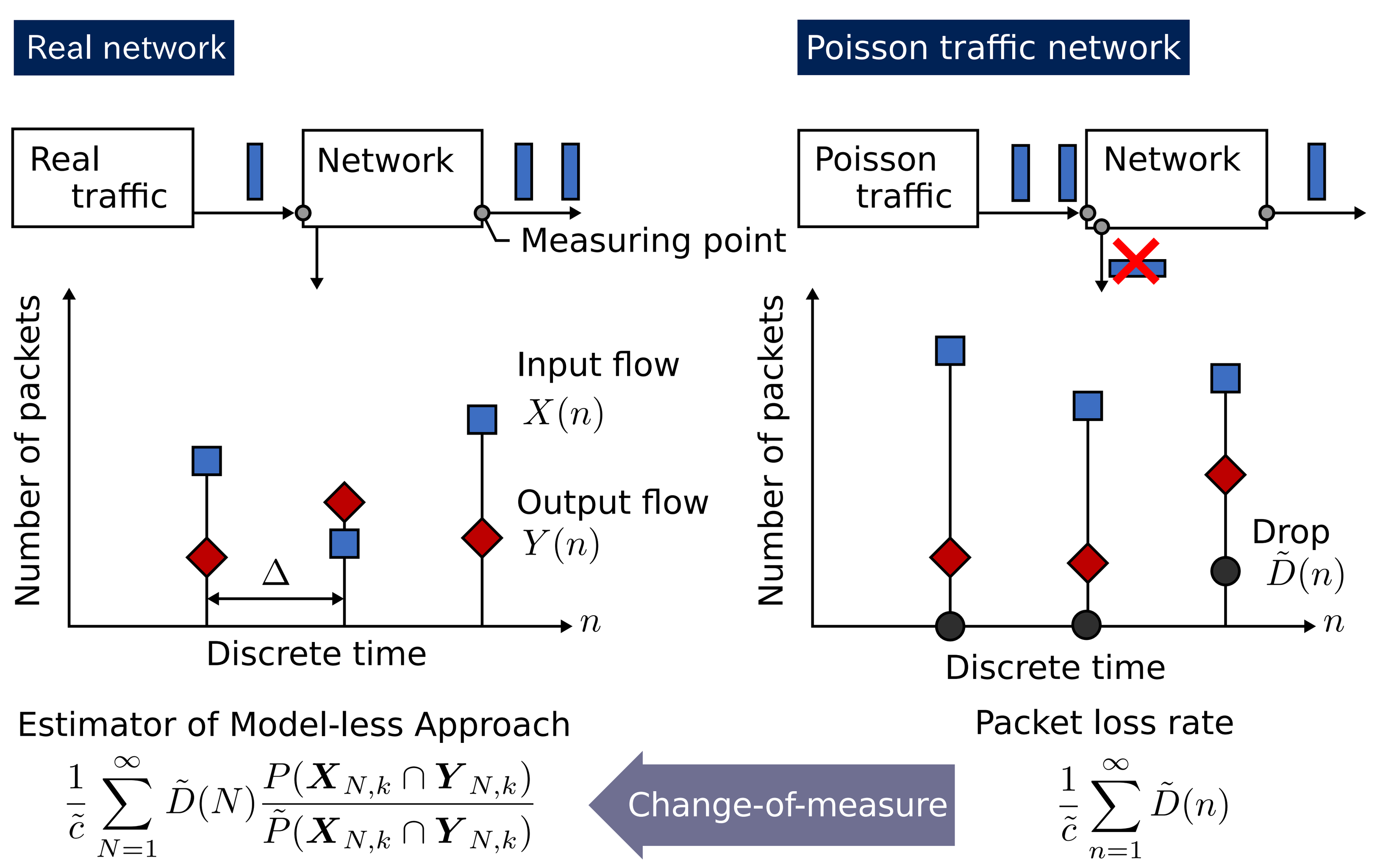

Figure 3: Outline of model-less approach

- The model-less approach follows the procedure below.
  - A simulation with Poisson traffic model is performed.
  - Input traffic, output traffic and loss processes are discretized with Δ.
  - Change-of-measure is based on frequency of discretized traffic pattern.
- Our estimator is

$$\hat{l} = \frac{1}{\tilde{c}} \sum_{N=1}^{\infty} \tilde{D}(N) \frac{P(\boldsymbol{X}_{N,k} \cap \boldsymbol{Y}_{N,k})}{\tilde{P}(\boldsymbol{X}_{N,k} \cap \boldsymbol{Y}_{N,k})}, \quad (1)$$

where

$\boldsymbol{X}_{N,k} = \{X(n)\}_{N-k<n\leqq N}$: Discretized input flow traffic in past k periods.
$\boldsymbol{Y}_{N,k} = \{Y(n)\}_{N-k<n\leqq N}$: Discretized output flow traffic in past k periods.
$\hat{D}(n)$: Discretized packet loss process.

- When we assume a single router and a single flow, in the limit as $\Delta \to 0$ and $k \to N$, our estimator converges to that of model based IS.
- By expressing the estimator by input and output traffic instead of a queue length process, (1) is applicable for multiple flows on a network with complicated topology.

Experiments

- As a first step in the development, we investigate the case when the packet loss rate of an MMPP/M/1/K system is estimated from an M/M/1/K simulation.
- The simulation time is 2000 [s], simulation sets is 30, $\Delta = 0.025$ [s], and $k = 2$.
- In these systems, since the packet arrivals and a service time are independent.
- Therefore, the change-of-measure can be expressed as $P(X_{1,N,k} \cap Y_{1,N,k})/\tilde{P}(X_{1,N,k} \cap Y_{1,N,k}) = P(X_{1,N,k})/\tilde{P}(X_{1,N,k})$.

Table 1: Target network parameters

Arrive Rate at State 1 [packet/s]	100
Arrive Rate at State 2 [packet/s]	339
Transition Rate of Each State [times/s]	1.00
Mean Service Time [s/packet]	0.001
Queue Size K [packet]	10
Packet Loss Rate [-]	10^{-5}

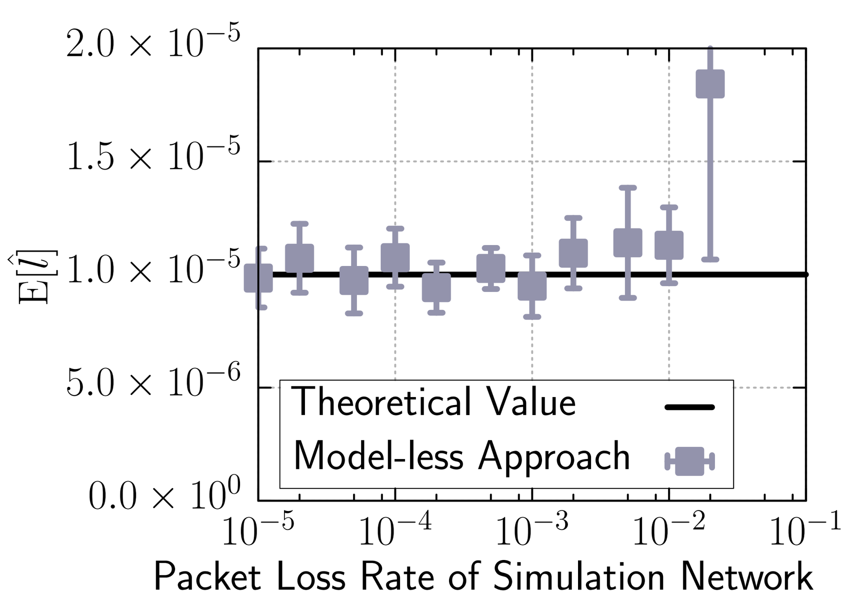

Figure 4: Result of mean

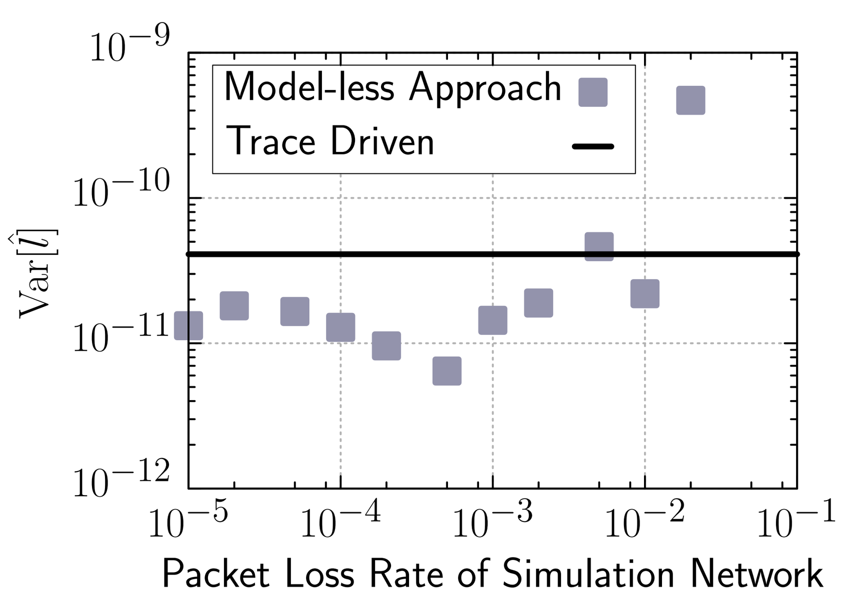

Figure 5: Result of variance

- According to the figures, we can find the region in which the model-less approach can estimate the packet loss rate of the original system.
- Additionally, we can confirm that the variances of the estimators are about 1/3 in the region, compared with the estimator by the trace-driven simulation.

Conclusions and Future Directions

- We proposed the model-less approach to accurately estimate a packet loss rate through simulation with traffic trace without traffic models.
- We will verify the applicability of our approach to the various trace on various networks in our future works.

References

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[3] I. C. Paschalidis *et al.*, "Importance Sampling for the Estimation of Buffer Overflow Probabilities via Trace-driven Simulations," *IEEE/ACM Transactions on Networking*, vol. 12, no. 5, 2004.

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