Verification of Accuracy Improvement for CoMPACT Monitor Due to Suboptimal Inter-probe Time

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Background (1)

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Change of recent Internet

- The Internet plays an important role as infrastructure
- Various applications provide new services
- The Internet is used not only as a private tool but also a business tool

Internet service providers (ISP) need a measurement technology to produce per-flow QoS information. (e.g. one-way delay for each flow)

Background (2)

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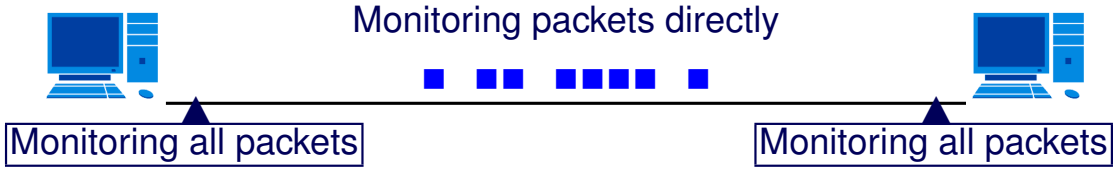
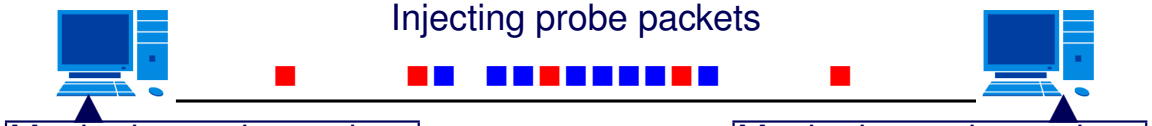
- Conventional means of measuring one-way delay can be classified into passive and active measurements

Passive measurement



- It monitors the target user packet directly by capturing the packets
- It can get accurate one-way delay for each flow
- One-point monitoring to measure volume of traffic can be conducted very easily
- Two-point monitoring to measure one-way delay lacks scalability

Active measurement



Background (3)

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Traditional method

- Passive measurement has scalability problem
- Active measurement can not measure per-flow one-way delay

In large-scale network, we can not get per-flow one-way delay by using traditional method.

The ovjective (1)

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We have proposed change-of-measure-based passive/active monitoring (CoMPACT monitor) that achieves scalable measurement of one-way delay distribution for each flow.

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Study of F.Baccelli

- Study about inter-probe time for active measurement
- Suboptimal probing in terms of accuracy was proposed

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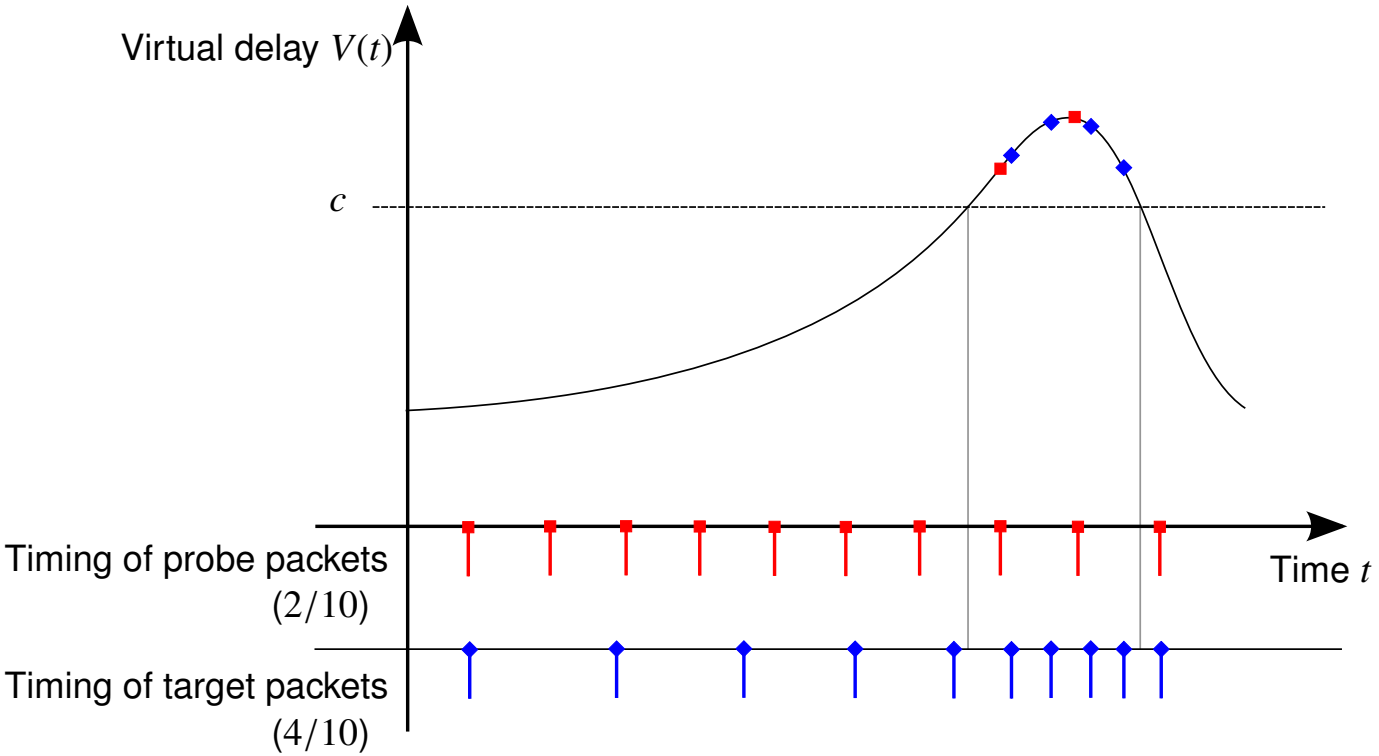
In this study, we have applied this suboptimal probing to CoMPACT monitor and tried to improve CoMPACT monitor in accuracy.

CoMPACT monitor (1)

- If arrival timing is different, packet delay is different



- In probe packets, 2 packets of 10 packets arrive in congestion
- In target packets, 4 packets of 10 packets arrive in congestion
- CoMPACT monitor transfer probe packets delay into target packets delay according to dencity of target packets

CoMPACT monitor (2)

- Estimator of one-way delay distribution by CoMPACT monitor
- It estimate the probability for target packet delay to exceed c

m : Number of probe packets
T_n : Arrival time of nth probe packet
$V(t)$: Virtual one-way delay
$a(t)$: Volume of traffic of target flow

$$\underbrace{\frac{1}{m}\sum_{n=1}^{m} 1_{\{V(T_n)>c\}}}_{\text{Delay of probe packet (Active)}} \underbrace{\frac{a(T_n)}{\sum_{l=1}^{m} a(T_l)/m}}_{\text{Translation (Passive)}}$$

- Passive measurement to measure traffic has not scalability problem

Suboptimal probing (1)

- Intervals with an exponential distribution have been widely used as probe packets arrivals
  (Probing method according to PASTA property)
- This is the only appropriate method if we can not ignore the effect of probe packets

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Assumption

- We can ignore the effect of probe packets

- PASTA-based probing is not the only method
- Some other probing method can estimate true value
  (e.g. Intervals with a uniform or Gamma distribution etc.)

Suboptimal probing (2)

Assumption

- The autocovariance function of the target process is convex

- Periodic-probing achieves minimum variance of the estimator
- A lower variance is connected with accuracy
- If the autocovariance function is convex, periodic-probing is optimal in accuracy

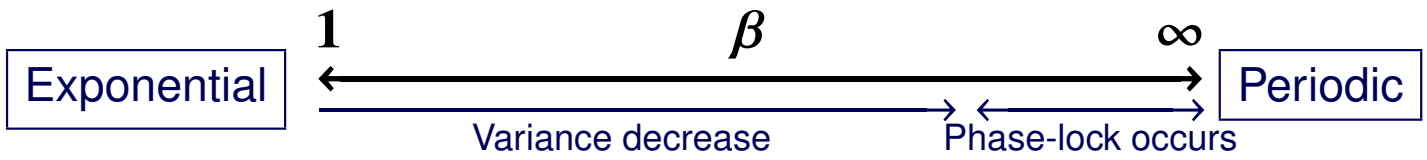
when the cycle of the target process corresponds to the cycle of the probe packet, a phase-lock phenomenon occurs and the estimator may converge on a false value.

Suboptimal probing (3)

- To solve the tradeoff, intervals with the parameterized Gamma distribution is proposed
- When $\beta = 1$, it corresponds to exponential distribution
- When $\beta \to \infty$, it converges on determinate value

Property of this Gamma-probing

This Gamma-probing links PASTA-based probing with periodic-probing continuously.



- Variance decreases with increase of β
- Phase-lock occurs when β is so large
- We can get a suboptimal probing if we tune appropriate β

Simulation (1)

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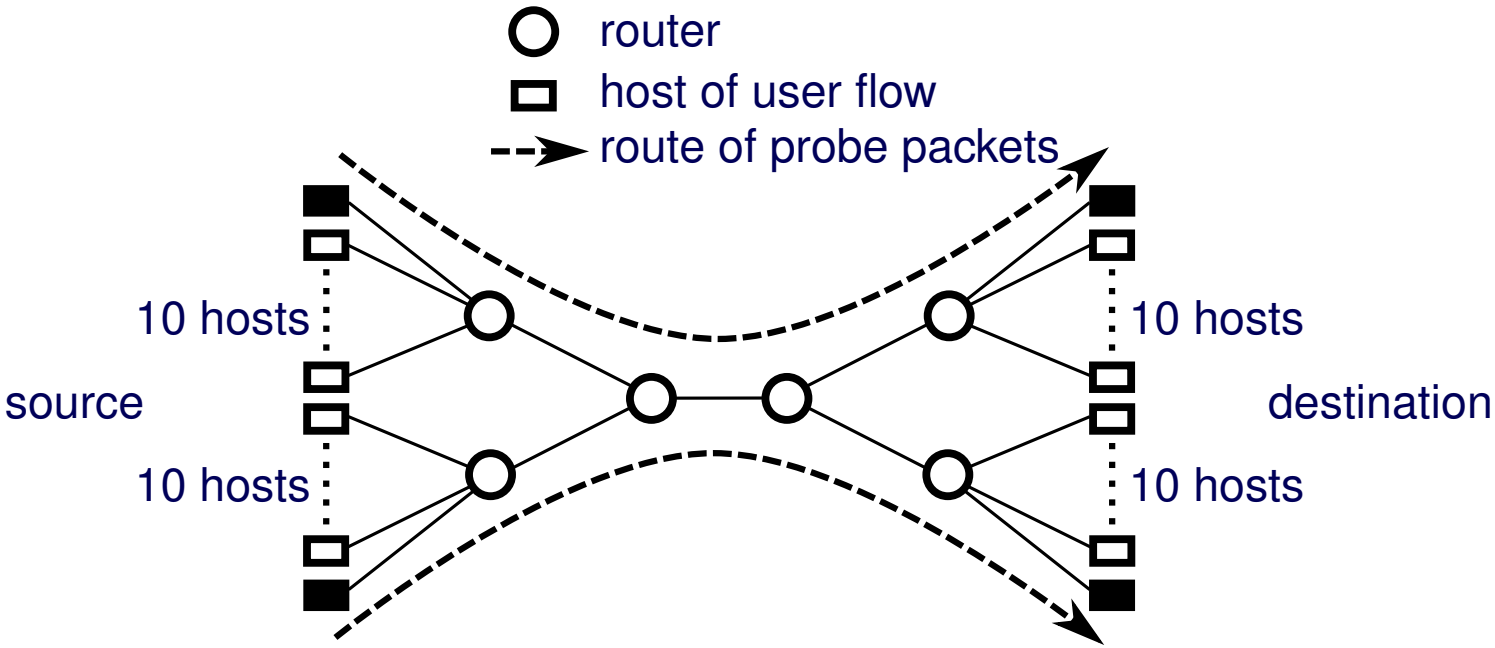
- We investigated the effectiveness of Gamma-probing for CoMPACT monitor through simulations
- Each end host on the left side transfers packets by UDP to the corresponding destination end host on the right side



Simulation (2)

- User flows are given as ON/OFF processes and categorized into the 4 types
- Probe packet trains are categorized into the 5 types listed in the following table

Distribution of probe intervals	Parameter of Gamma distribution	Mean probe intervals
Exponential	$(\beta = 1)$	0.5 s
Gamma	$\beta = 5$	0.5 s
Gamma	$\beta = 25$	0.5 s
Gamma	$\beta = 125$	0.5 s
Periodic	$(\beta \to \infty)$	0.5 s

- Parameters of Exponential and Periodic are parameters of the Gamma distribution corresponding to each probing

Simulation (3)

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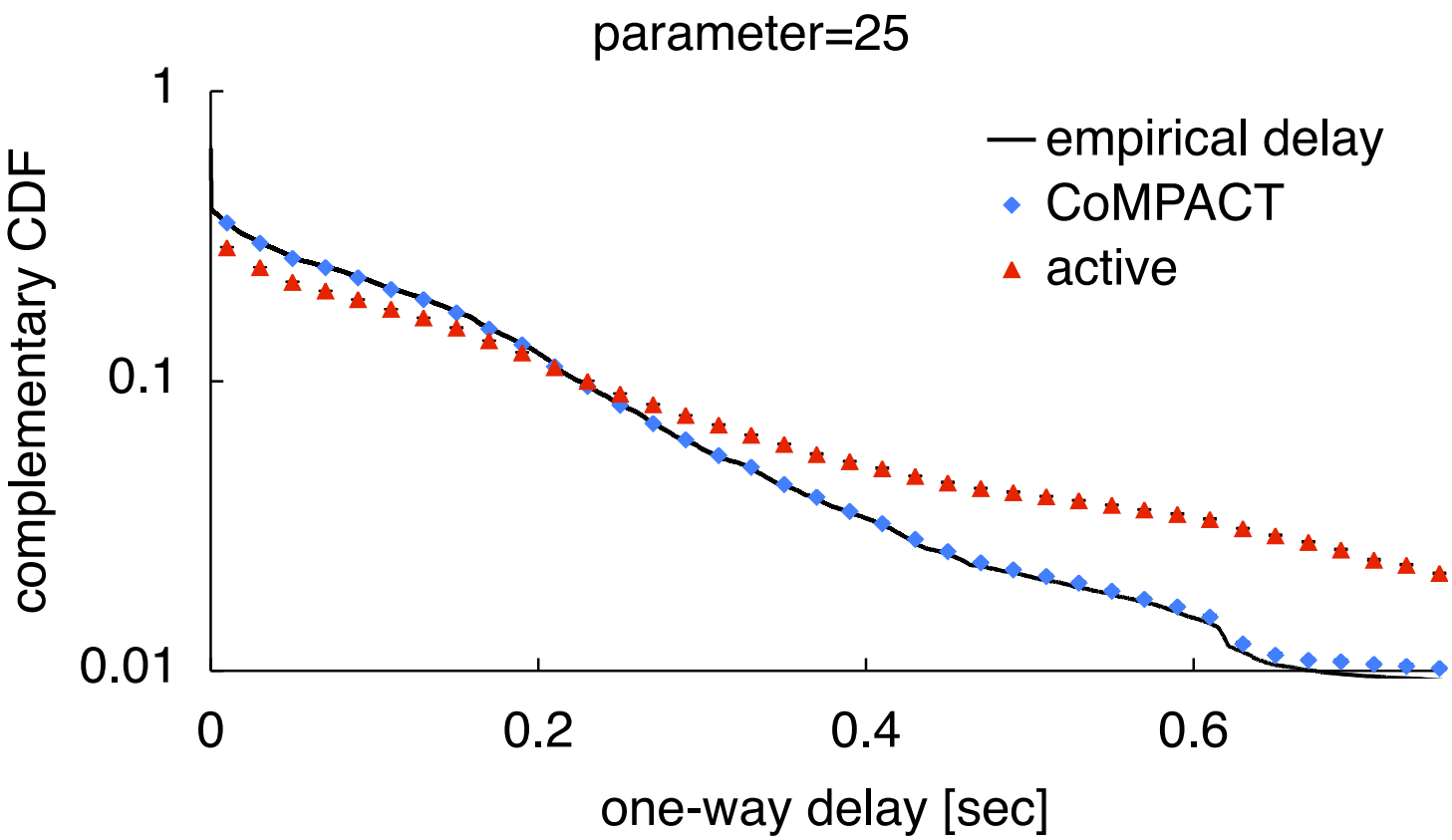
- The result of estimation by CoMPACT monitor with Gamma-probing
- Parameter β of Gamma-probing is 25



Simulation (4)

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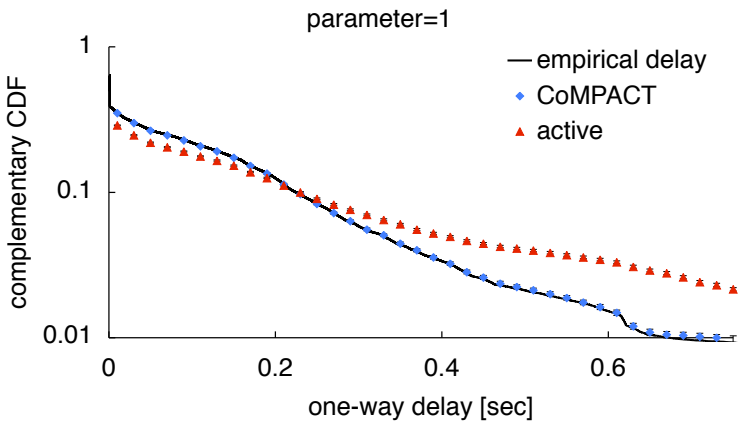
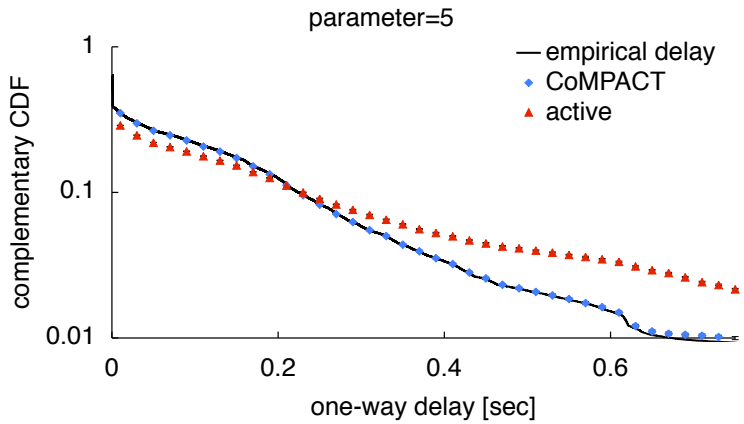
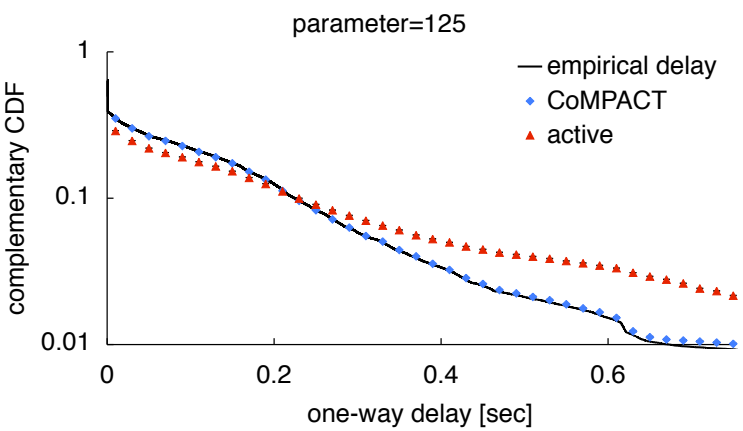
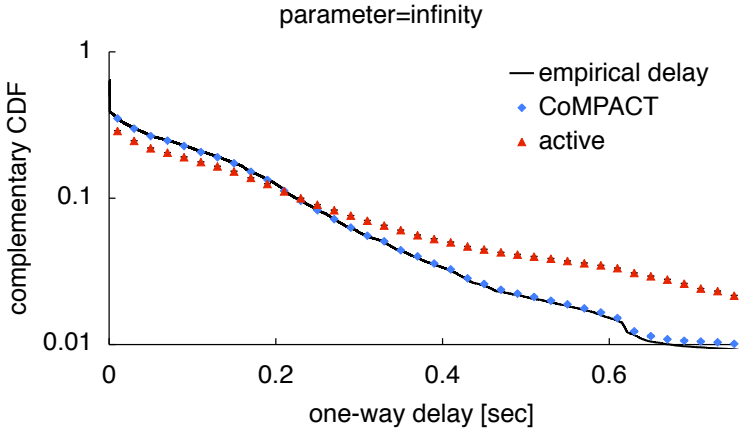
- We have plotted for other parameters and gotten similar results









Simulation (5)

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- We were able to confirm that the CoMPACT monitor with Gamma-probing gives good estimates
- We cannot judge the superiority or inferiority of any parameter
- To judge the superiority or inferiority, we should investigate variance of estimator

Simulation (6)

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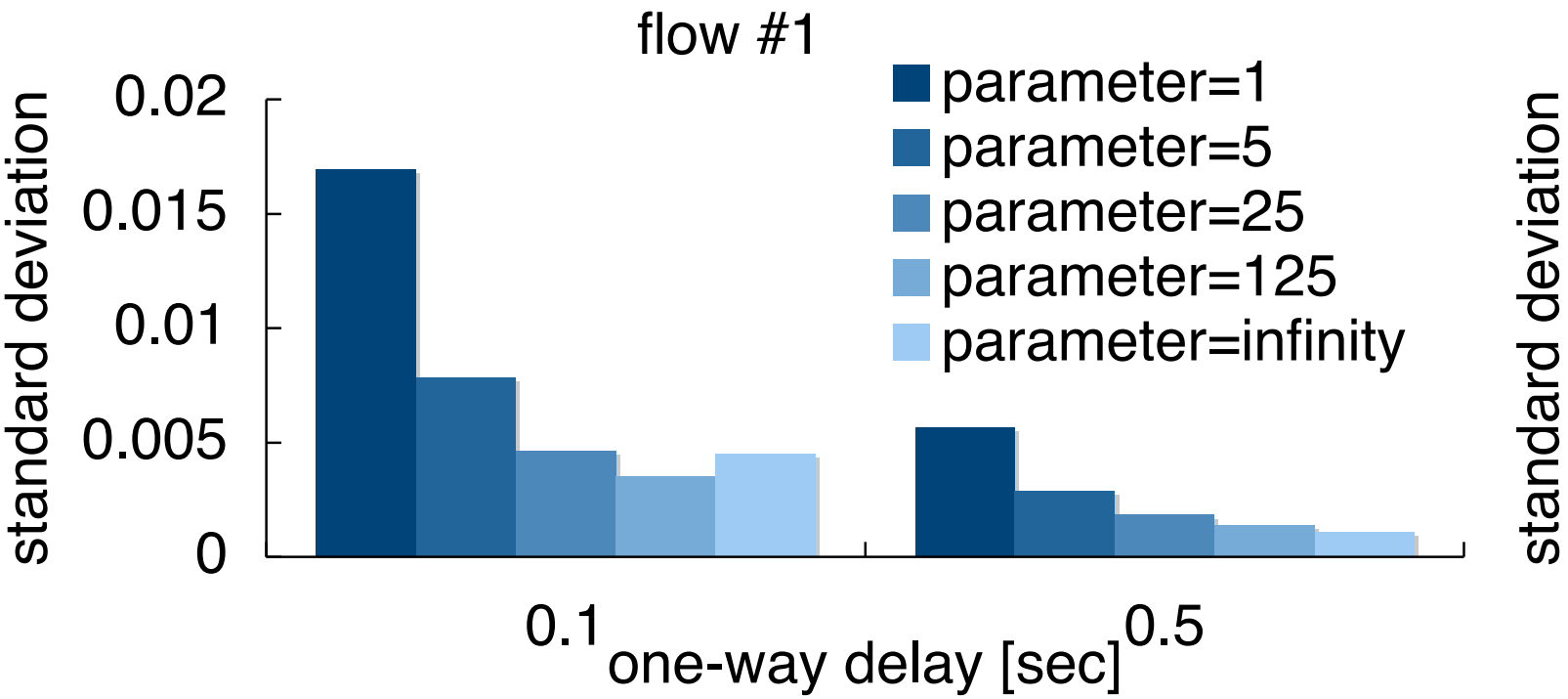
- We show the standard deviation of estimator
- A case of flow #1
- A case of flow #11



Simulation (7)

- The standard deviation clearly decreases as β increases from $\beta = 1$ to $\beta = 125$
- In result of flow #1, the standard deviation of periodic-probing is larger than that for $\beta = 125$
- This reversal may be a sign of incorrectness due to the phase-lock
- If we tune appropriate parameter β, we can get more accurate estimation than traditional PASTA-based probing

Conclusion

It was confirmed that Gamma-probing is effective when the complementary CDF of one-way delay was estimated by CoMPACT monitor.

- the convexity of the autocovariance function of the target process requires special attention

Residual issues

- We should present the method to determine appropriate parameter
- Application should be verified about not only one-way delay but also packet loss

Thank you very much for your kind attention