Internet Performance Transparency

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Public Thesis Defense
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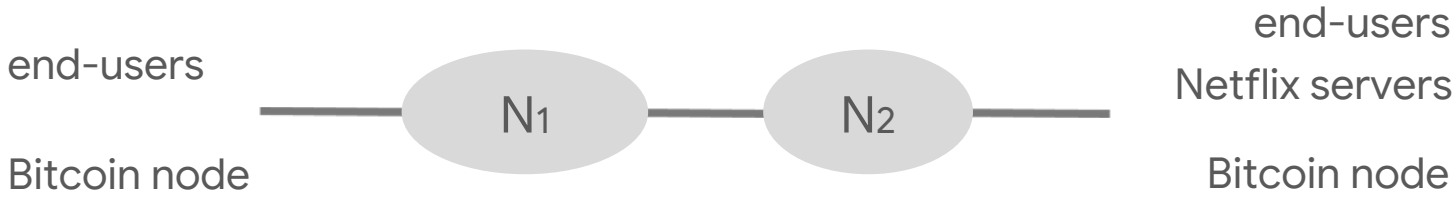
EPFL

Internet's goal: enable end-systems to communicate *w/ good performance*



- Users need to trace performance attacks [Apostolaki et al. 2017]
- Networks need to prove competitive performance
- Regulators need to verify SLAs and neutrality rules

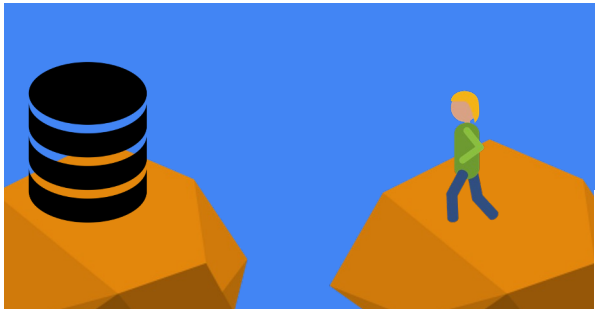
Users & regulators need to localize performance issues to networks

Why is localizing performance issues hard?

Networks

Generate performance measurements

Exaggerate network performance



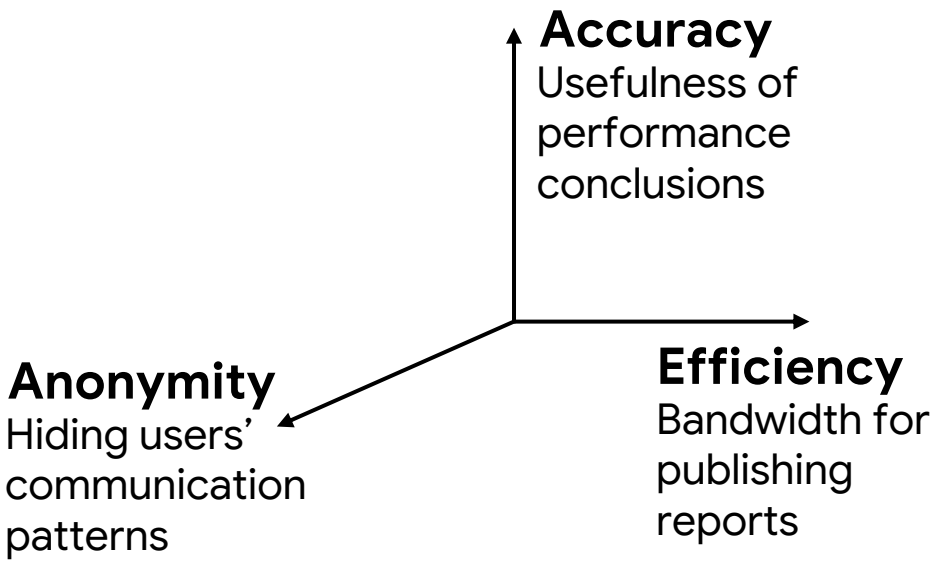
Users

Unreliable access to measurements

Reliably assess network performance

Bridge gap to enable network performance transparency

Transparency goals



No existing design with good balance

Existing designs rely on fine-grained reporting

- Networks report on individual packets
- Networks sample packet reports
- Networks accurately report fate of individual packets
  - Requires incentives for honestly reporting fate of individual packets
  - Reveals users' communication patterns

Inaccuracy because of unrealistic incentives & lower anonymity

Thesis

Accurate and efficient Internet performance transparency is possible
by adapting the incentive structure to the underlying honesty incentives
and combining incentives with mathematical tools;
adapting the report granularity eases the transparency-anonymity tussle.

Outline

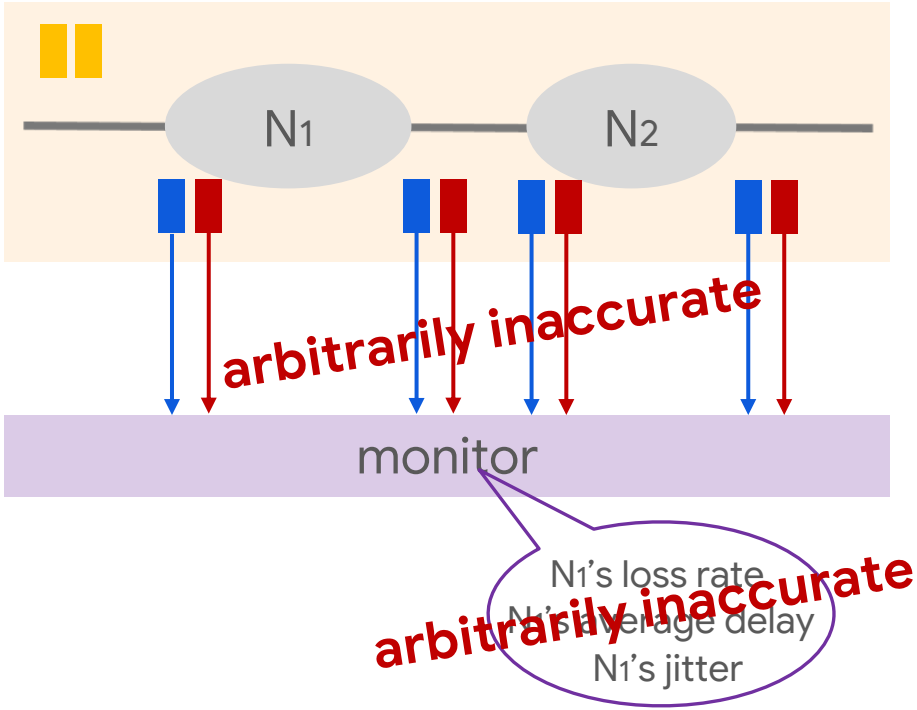
- **Accurate & efficient Internet performance transparency**
  - Split-responsibility for verifiable, user-based average metrics
  - Policy-based grouping of traffic for verifiable jitter

- Reconcile transparency with anonymity
  - Time granularity as noise
  - Adaptive reports for anonymity

Transparency protocols

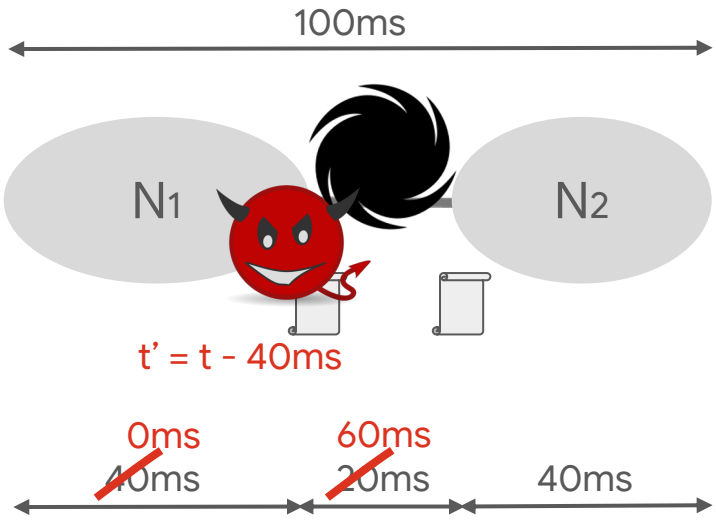
- **Data plane:** sampling packets
  - + consistent => same samples
  - + secure => representative samples

- **Control plane:** per-network performance estimation
  - loss rates & delay averages
  - jitter & neutrality



Need: accurate network statistics despite inaccurate packet reports

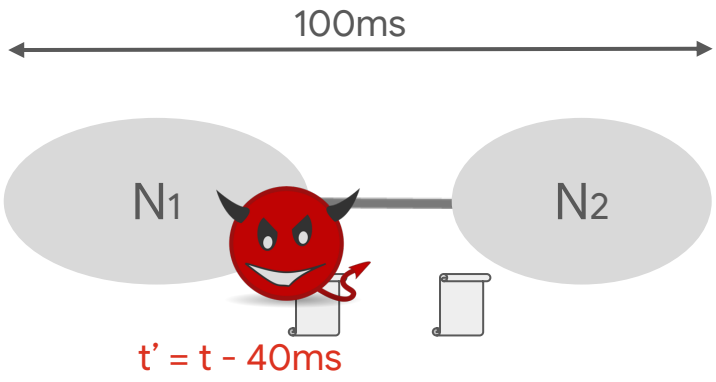
Packet delay



externalizability
someone has to take responsibility for orphan delay

Externalizability not enough for accuracy

Creating incentives for honesty through conflict

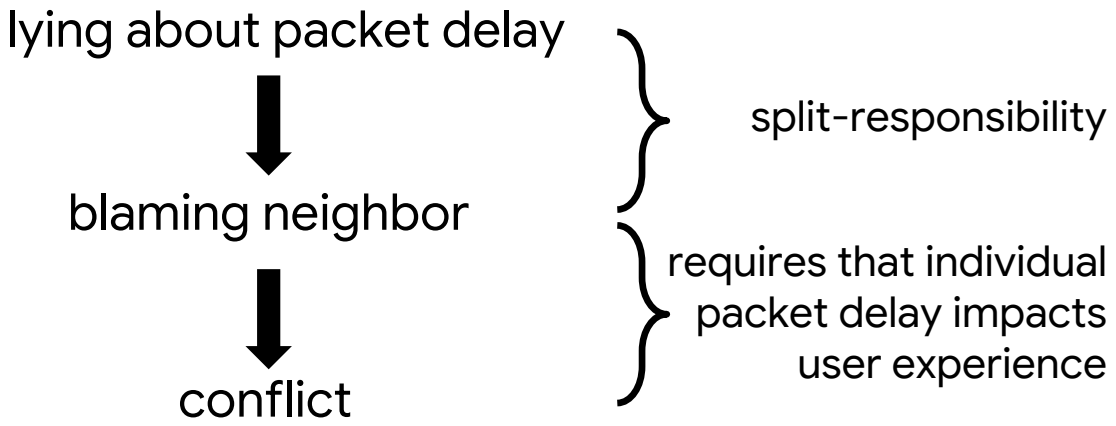


split-responsibility

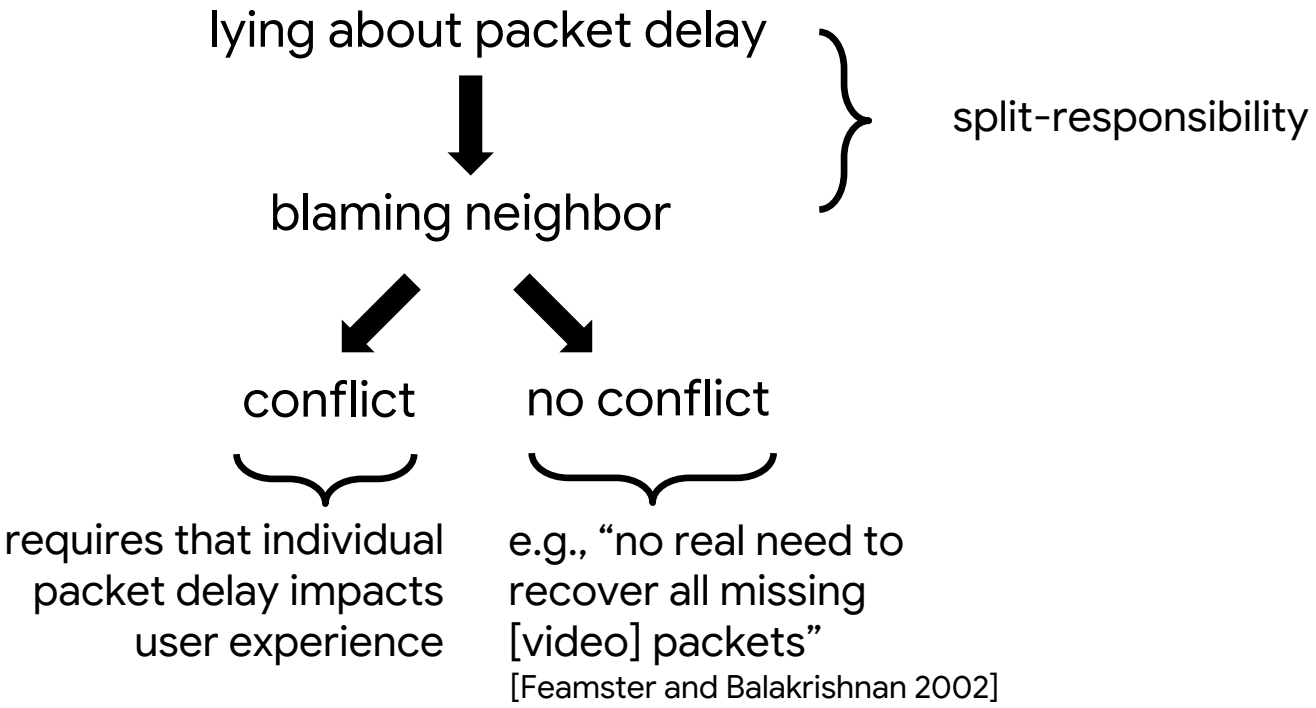
lying about pkt delay
=> blaming neighbor
=> conflict

Networks have an incentive to honestly report packet delay

The impact of lying about individual packets



The impact of lying about individual packets



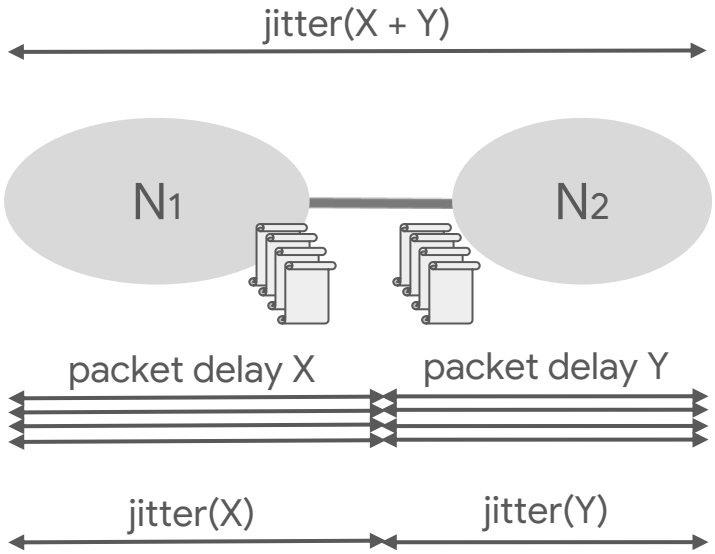
Lying does not always lead to conflict => inaccurate packet delays

Accurate metrics from inaccurate packet delays

Accurate delay averages by adapting to user interests

Jitter

- Conflicts on jitter?
  - BUT jitter not externalizable:
    jitter(X + Y) = jitter(X) + jitter(Y) **+ 2cov(X,Y)**



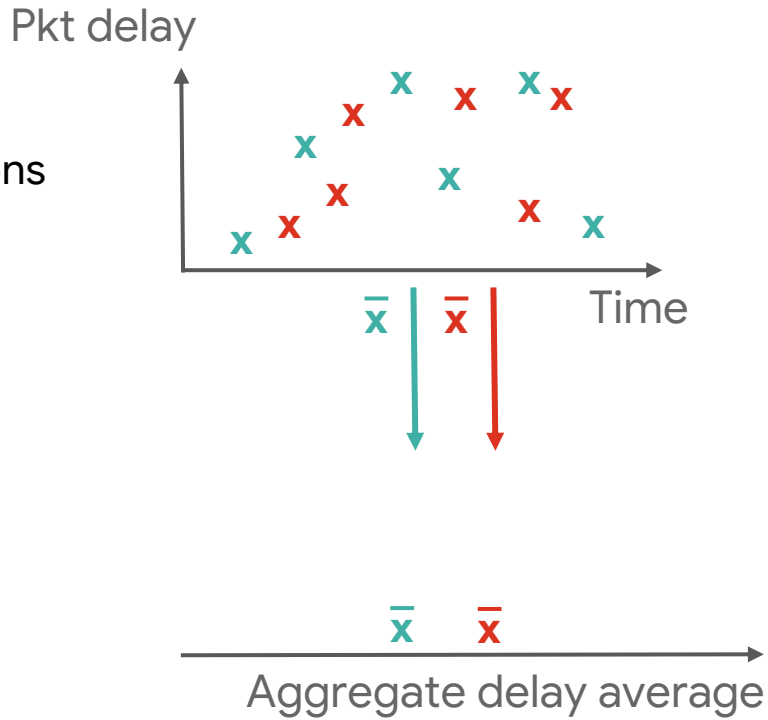
Jitter not externalizable => conflicts not enough

Accuracy for jitter: a unifying perspective

- **Similarly treated traffic** subject to **math constraints**
- Jitter reliably extracted from delay averages & math constraints

Neutrality

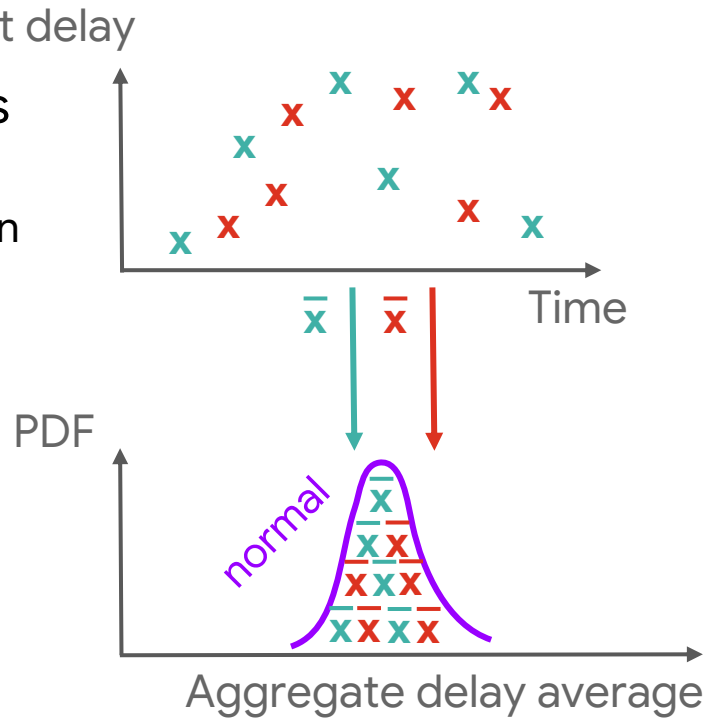
- Defining neutrality
  - exposing packets to same network conditions
  - ⇒ same packet delay distribution
- Measuring neutrality
  - “draw” distributions & check if similar
  - BUT cannot directly see distributions



Gap between metric of interest and incentivizable info

Neutrality imposes constraints

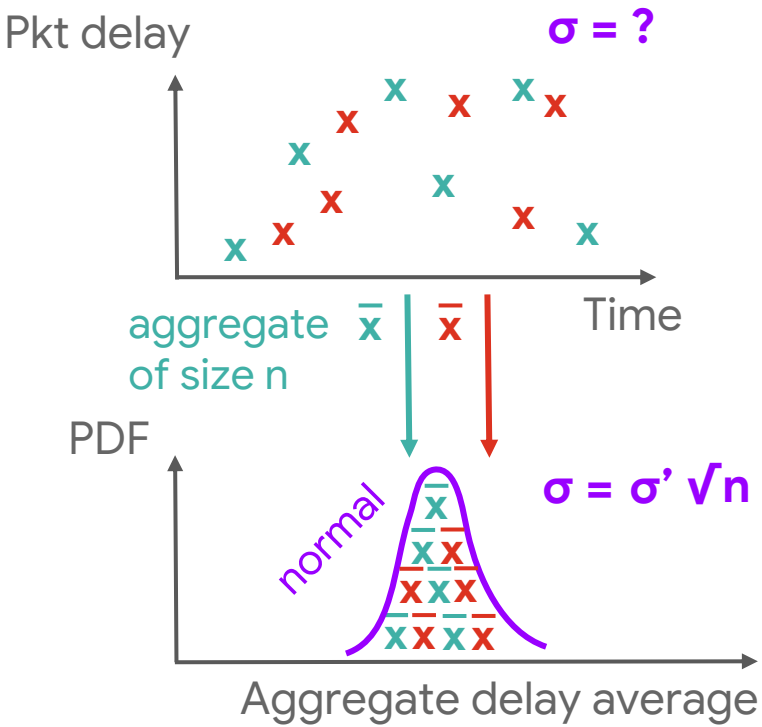
- CLT ties together aggregate delay averages
  - each average follows same normal distribution
  - take many averages to draw normal distribution



Reliably extract neutrality via normality check over delay averages

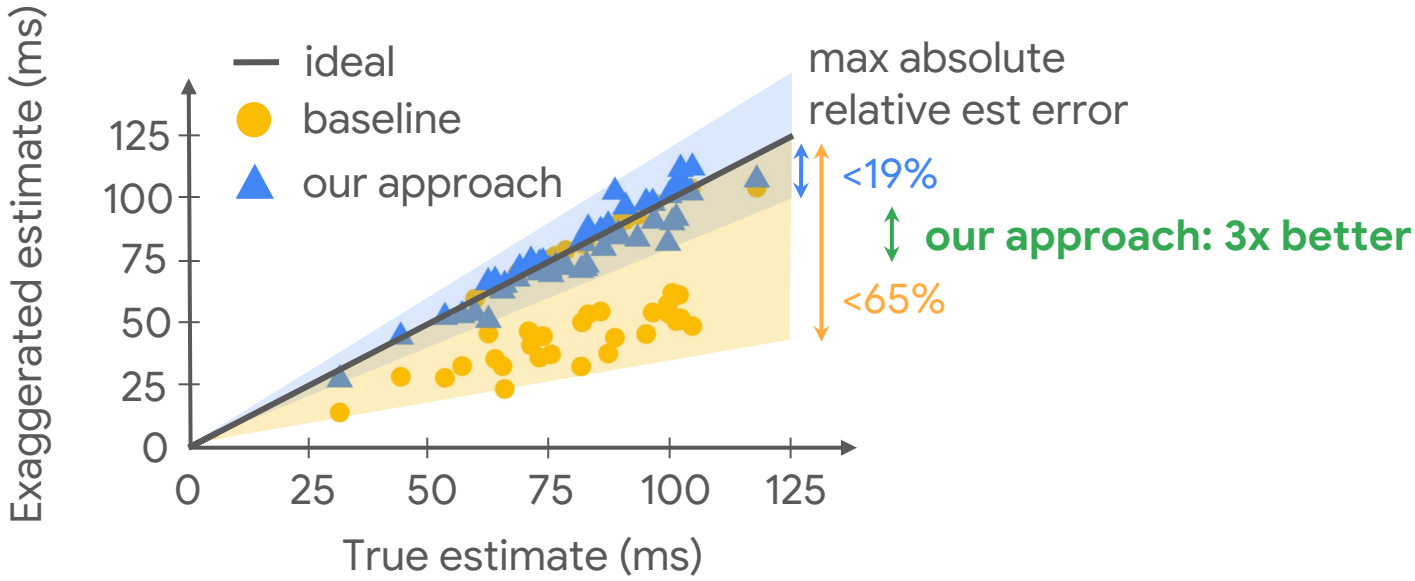
Jitter

- Estimate jitter using CLT
  - ⇒ jitter = known function of known quantities



Reliably extracted from delay averages

Glimpse of results



3x better accuracy by relying on incentivizable information

Transparency

SLAs & neutrality

Anonymity

Tor-like overlays

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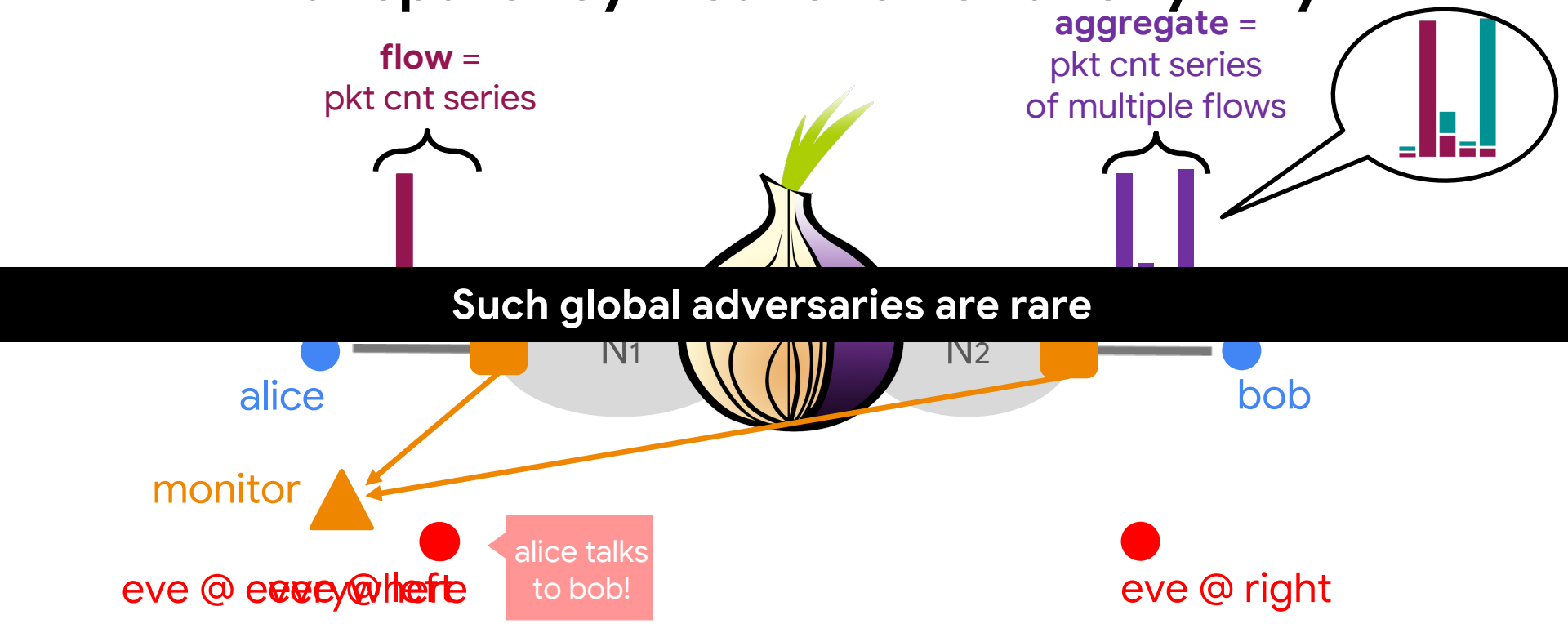
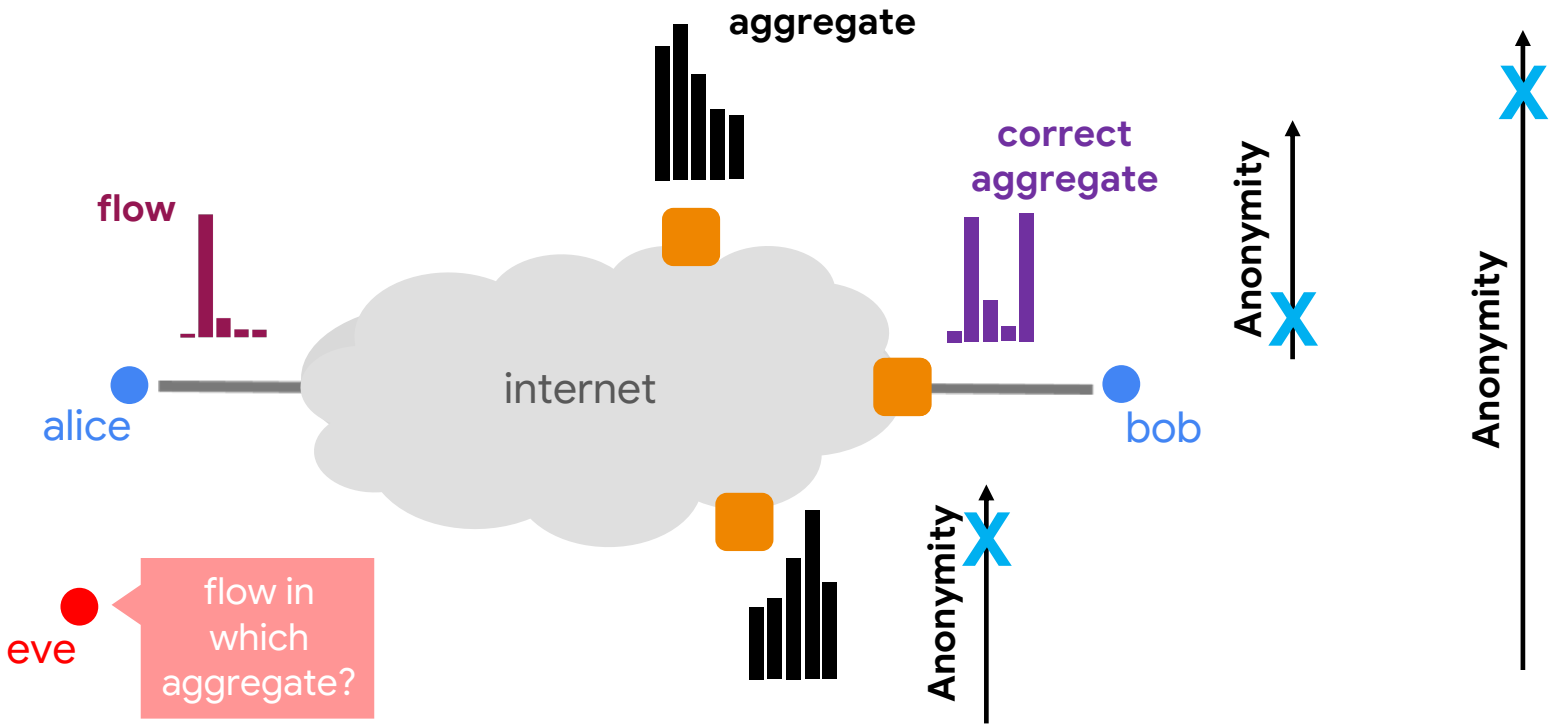
  - Time granularity as noise
  - Adaptive reports for anonymity

Transparency weakens Tor anonymity



Transparency introduces global adversary

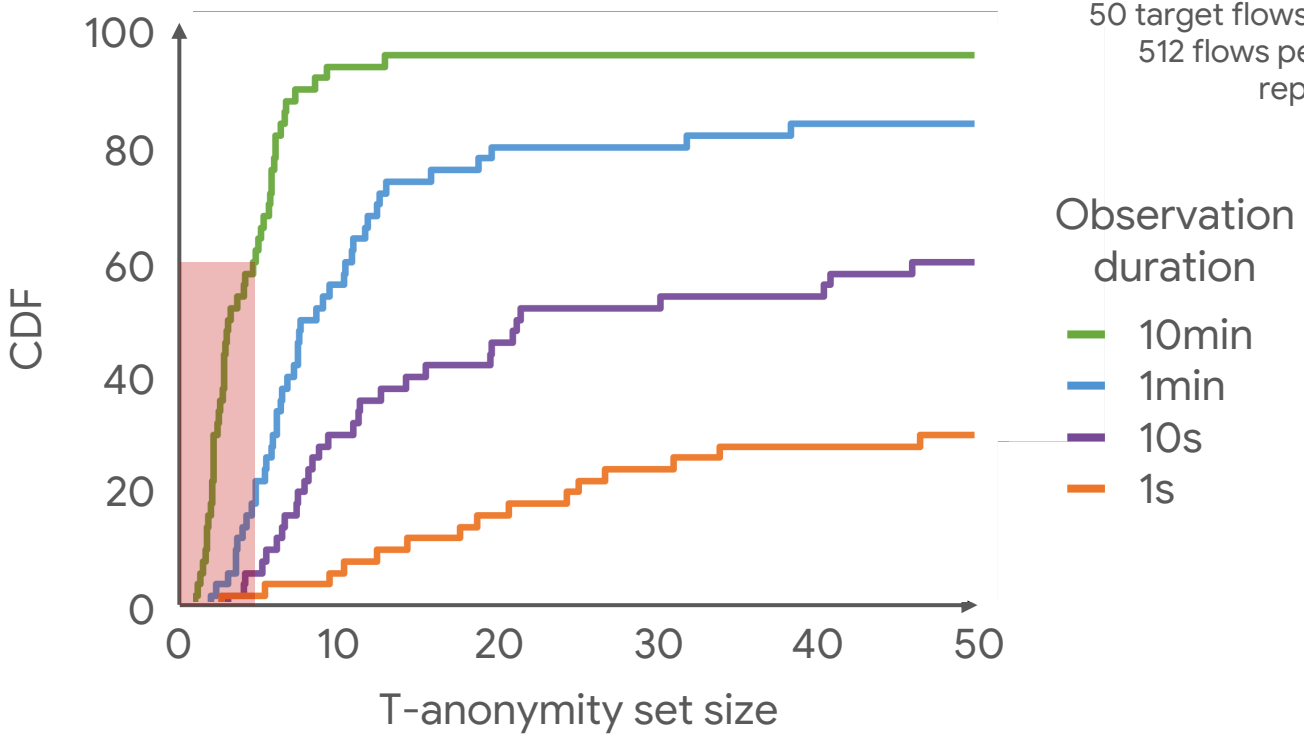
Quantifying anonymity



T-anonymity set size captures deviation from ground truth

Effect of transparency on anonymity

2018 CAIDA traces
50 target flows/aggregates
512 flows per aggregate
reports per 1ms



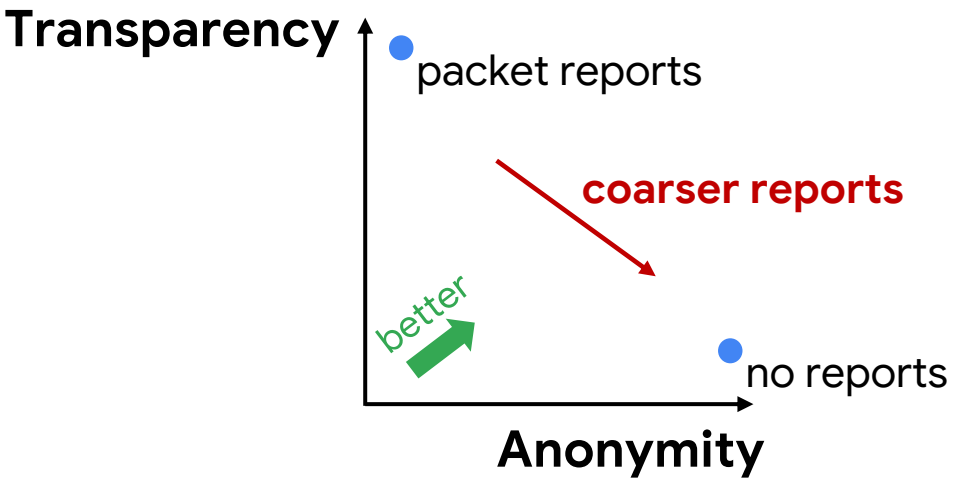
Given enough time, adversary deanonymizes ~60% of cases

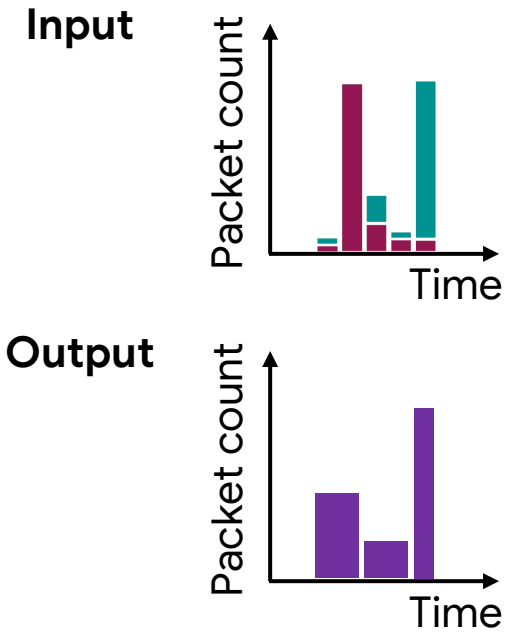
Constraints

- Any flow could be a target
- No network coordination

Improve anonymity for all flows with network-local decisions

Time granularity as noise

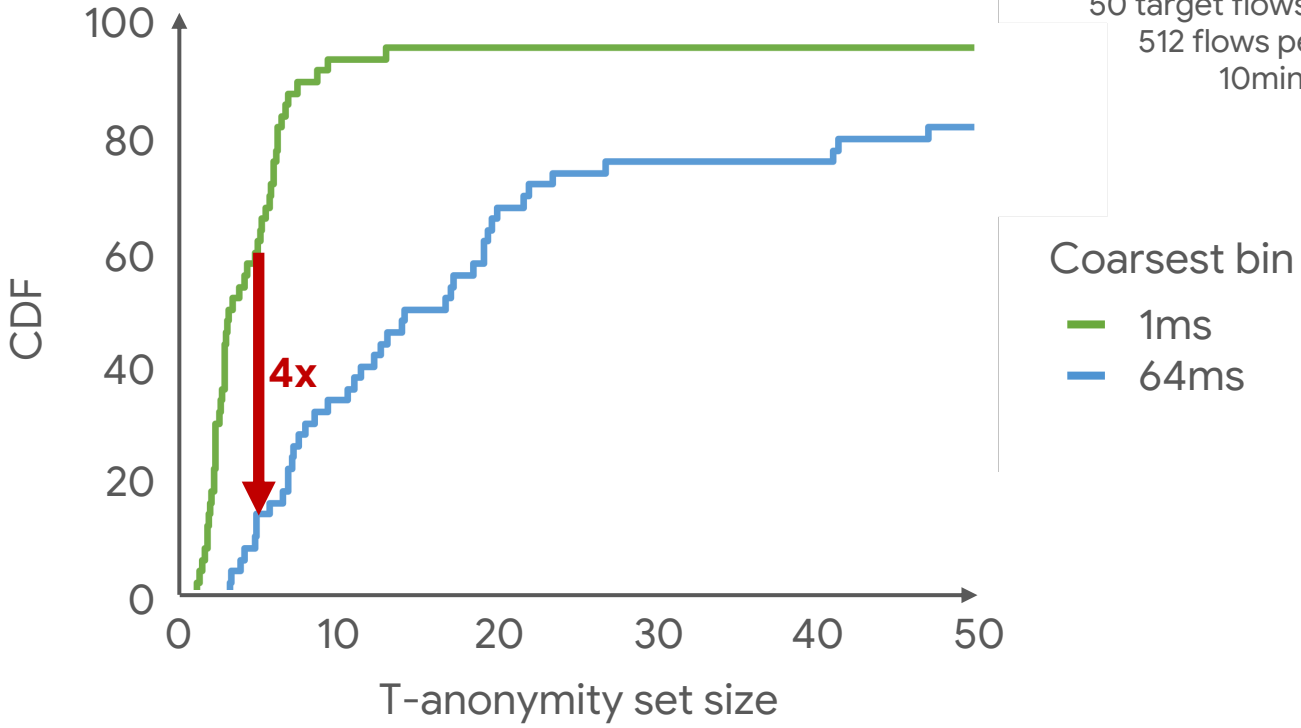




Hides sensitive flow patterns but impacts report utility

Effect of coarser reports on anonymity

2018 CAIDA traces
50 target flows/aggregates
512 flows per aggregate
10min observation



4x improvement at sub-second granularity

Accurate, efficient & anonymous transparency

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