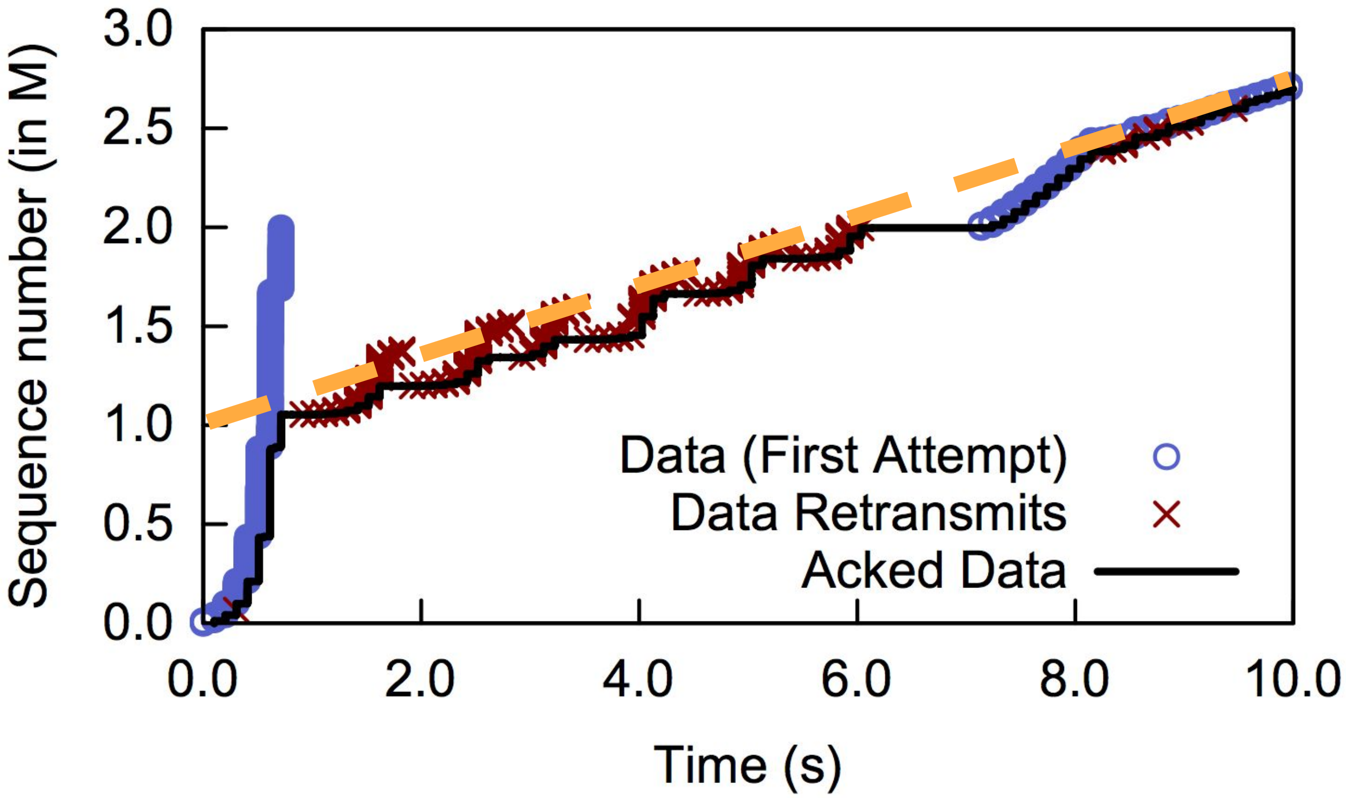
Traffic Policing in the Internet

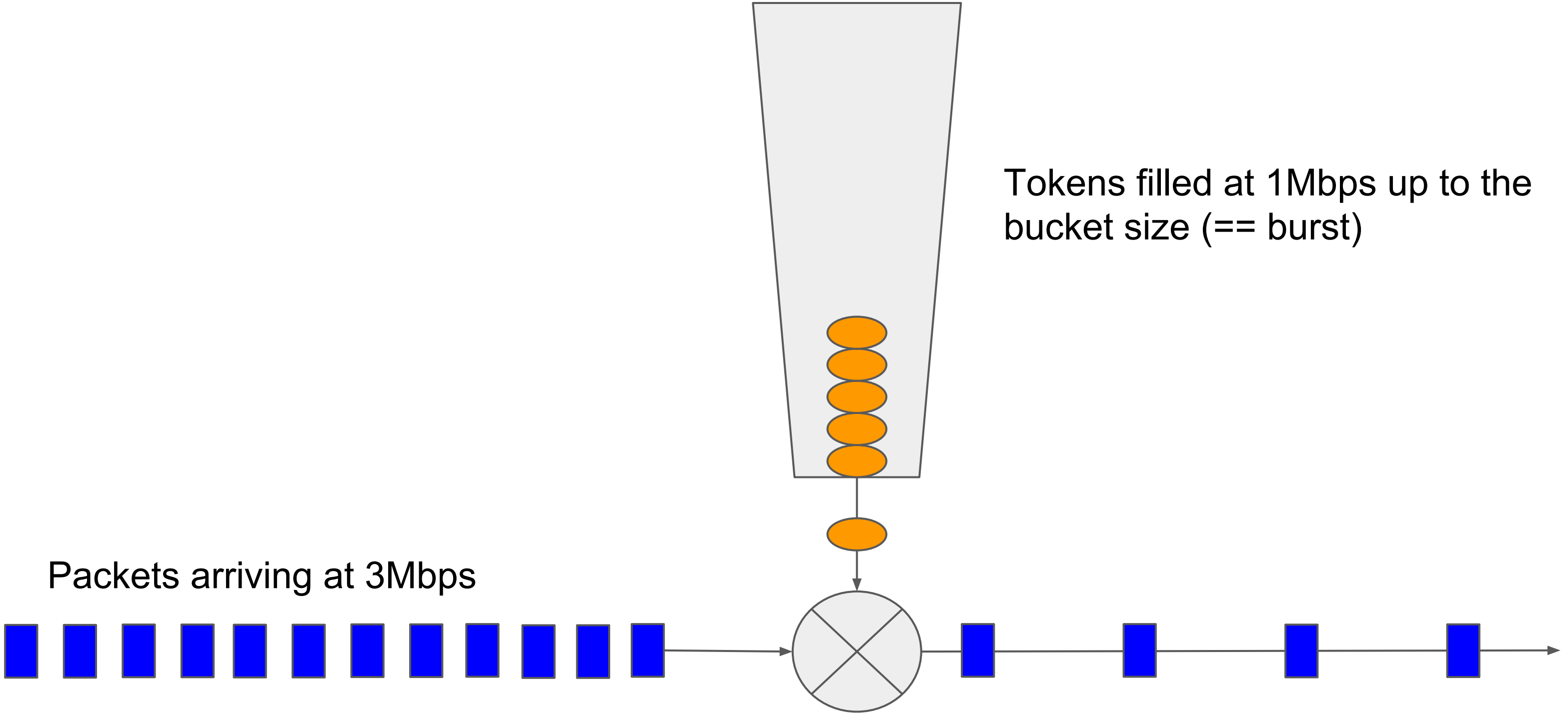
Yuchung Cheng, Neal Cardwell

Google

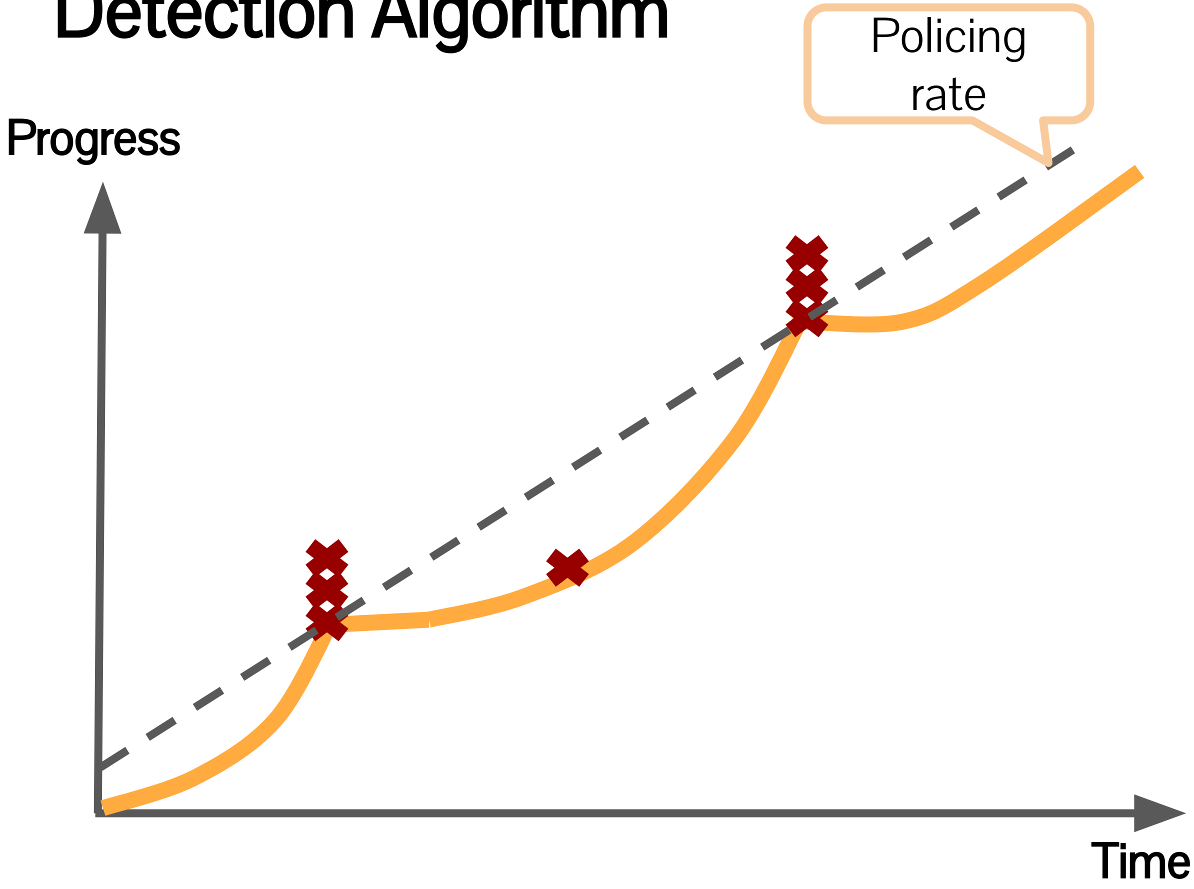
Policing on YouTube videos



Token bucket traffic policer



Detection Algorithm



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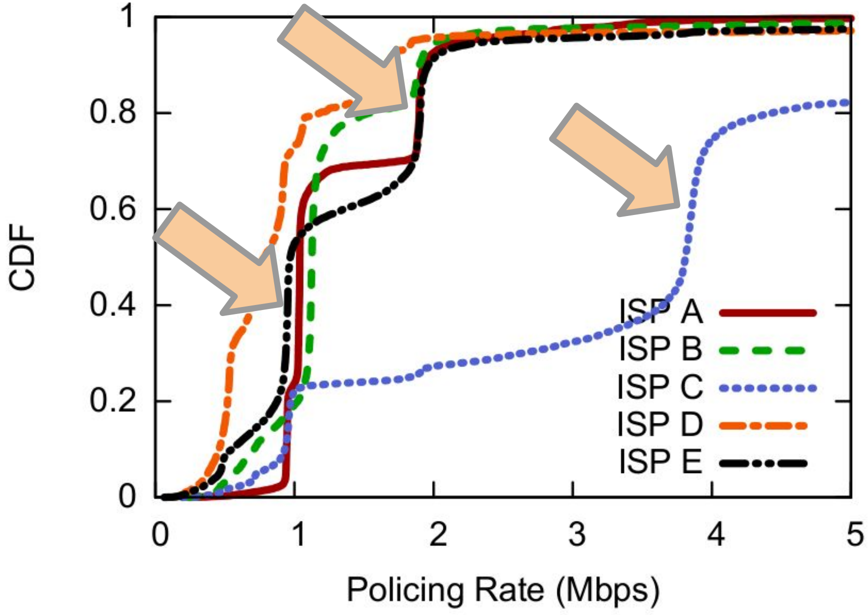
- Use measured throughput between an early and late loss as estimate

2 Match performance to expected policing behavior

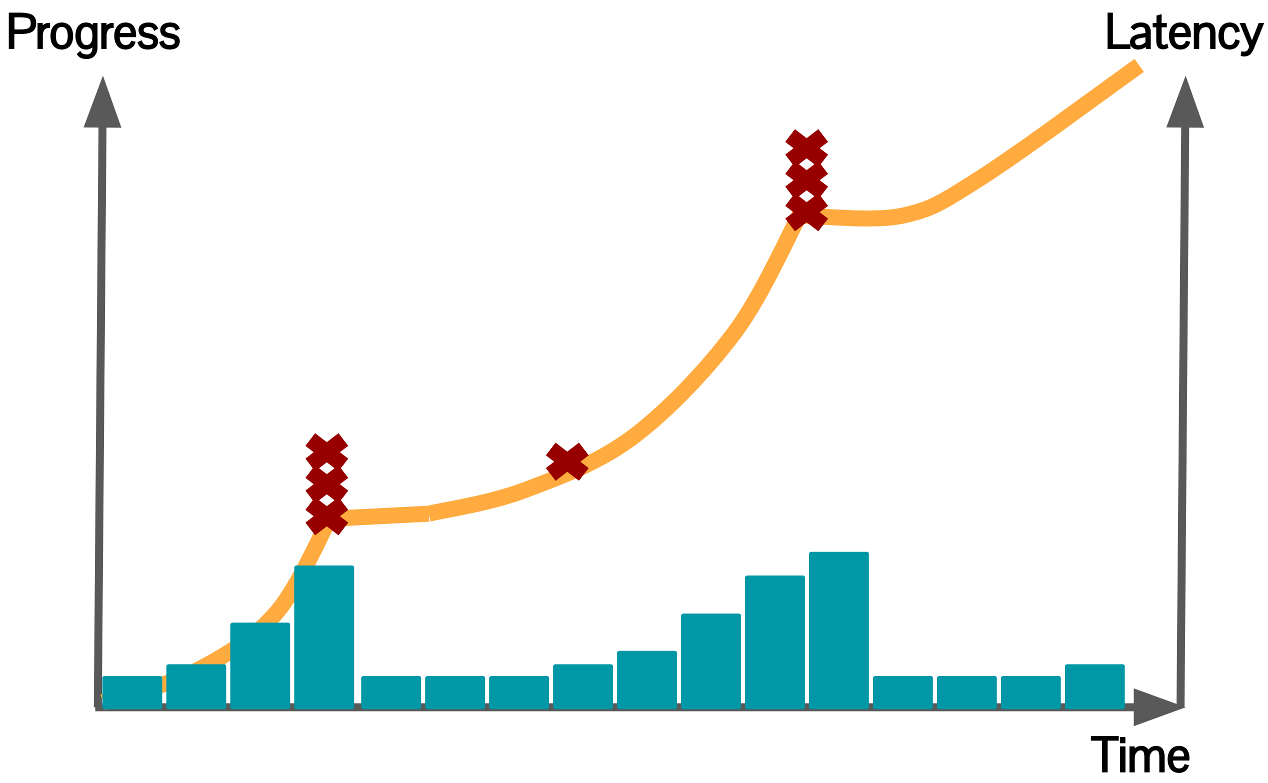
- Everything above the policing rate gets dropped
- (Almost) nothing below the policing rate gets dropped

Validation 2: Live Traffic



- Observed only few policing rates in ISP deep dives
  - ISPs enforce a limited set of data plans
- Confirmed that per ISP policing rates cluster around a few values across the whole dataset
- And: Observed no consistency across flows without policing

Congestion Looks Similar to Policing!



Packets are usually dropped when a router's buffer is already full

Buffer fills → queuing delay increases

Use inflated latency as signal that loss is not caused by a policer

Analysis of Traffic Policing on YouTube

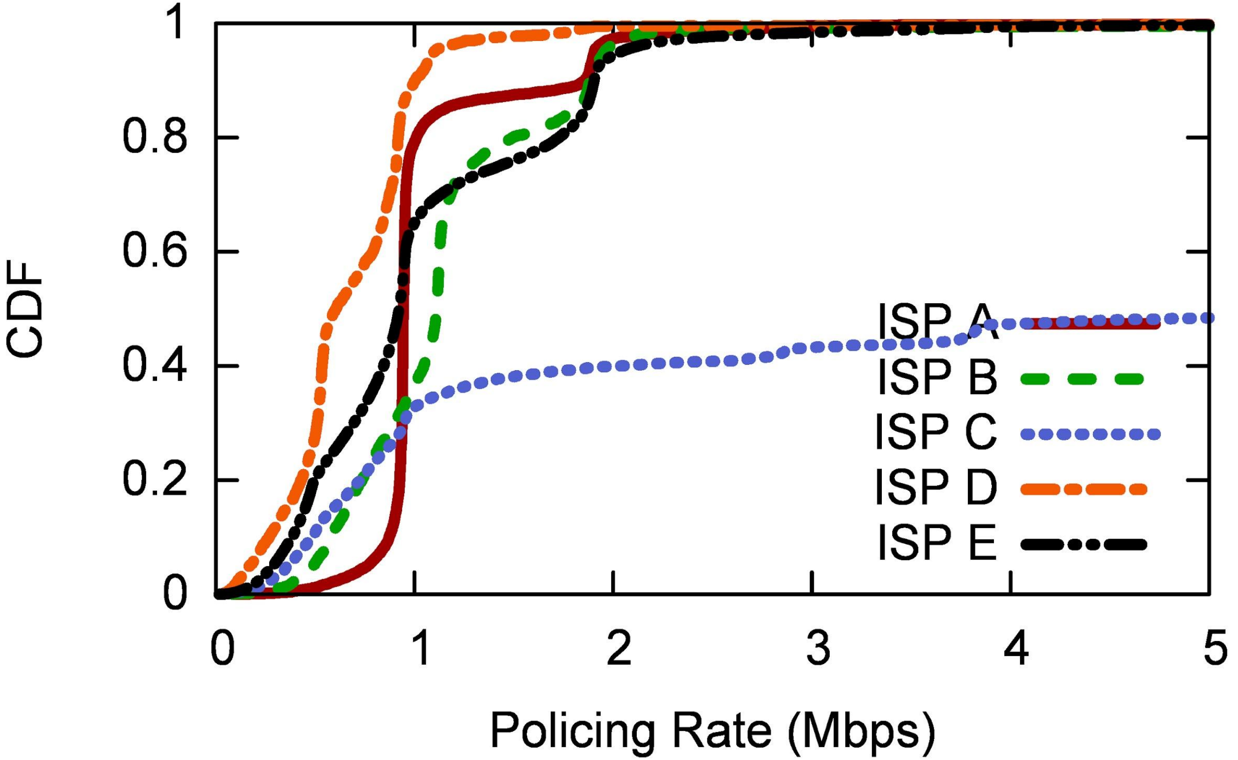
- 1 week in September 2015
- 0.8B HTTP queries
- Over 28K ASes
- Servers running Linux TCP, Cubic, PRR, RACK, fq/pacing
- New algorithm to detect policed connections using packet traces

An Internet-Wide Analysis of Traffic Policing

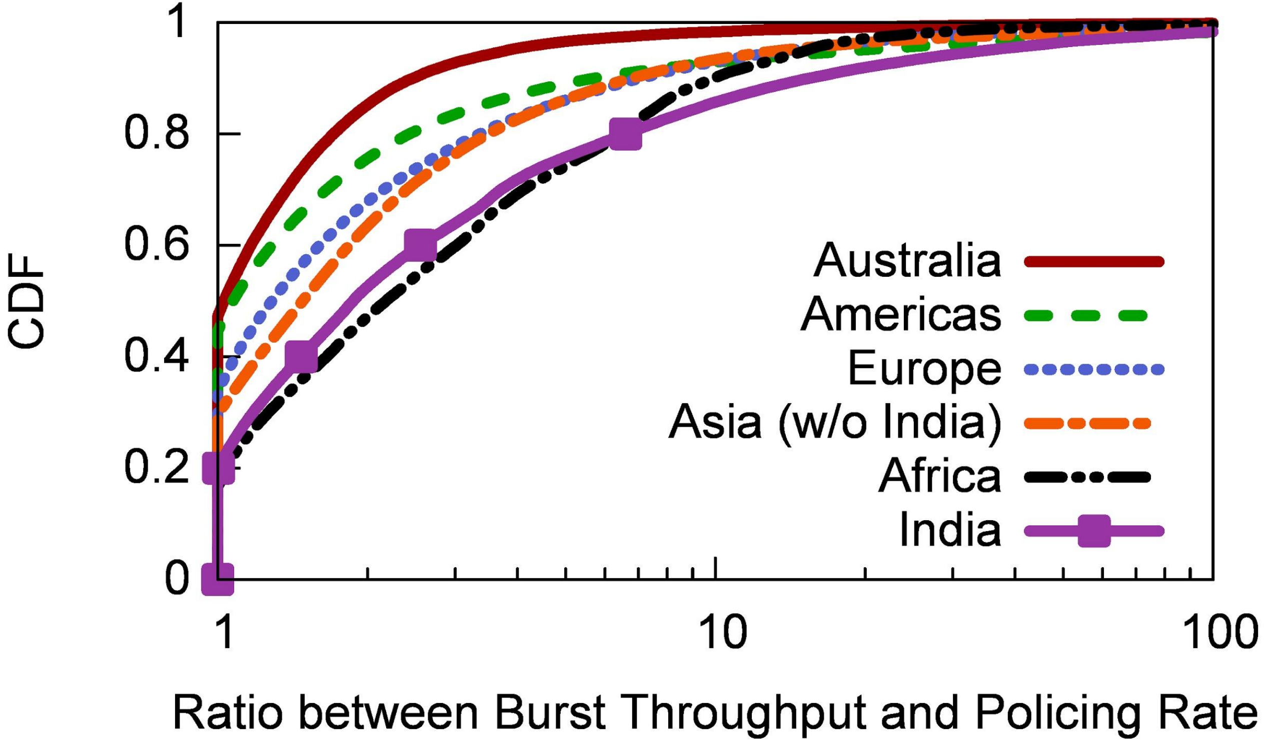
Flach , Papageorge , Terzis , Pedrosa , Cheng , Karim , Katz-Bassett ,

Govindan. SIGCOMM (2016)

Policed rates are often static



Policing rate is often less than half of burst rate



Policing causes heavy losses

Region	Policed segments (overall)	Policed (lossy conns)	Loss Rate (policed)	Loss (non-policed)
Africa	**1.3%**	6.2%	**27.5%**	**4.1%**
Asia	**1.3%**	**6.6%**	24.9%	2.9%
Europe	0.7%	5.0%	20.4%	1.3%
N. America	0.2%	2.6%	22.5%	1.0%
S. America	0.7%	4.1%	22.8%	2.3%

BBR congestion control

Bottleneck **B**andwidth and **R**ound-trip propagation time

Seeks high throughput with small queues by probing BW and RTT *sequentially*

Explicit model of the bottleneck

- Track max BW and min RTT on each ACK using windowed max-min filters
- Pace near BW (`+-25%`) to keep tput high but queue low
- On loss: reduce to current delivery rate but reprobe quickly

[1] BBR: congestion-based congestion control. Cardwell, Cheng, Gunn, Hassas Yeganeh, Jacobson, ACM Queue, Oct 2016

How BBR models policers

BBR explicitly models the presence and throughput of policers

Long-term sampling intervals (4 - 16 round trips)

Starting and ending with packet loss (to try to measure empty token buckets)

Record average throughput and packet loss rates over each interval

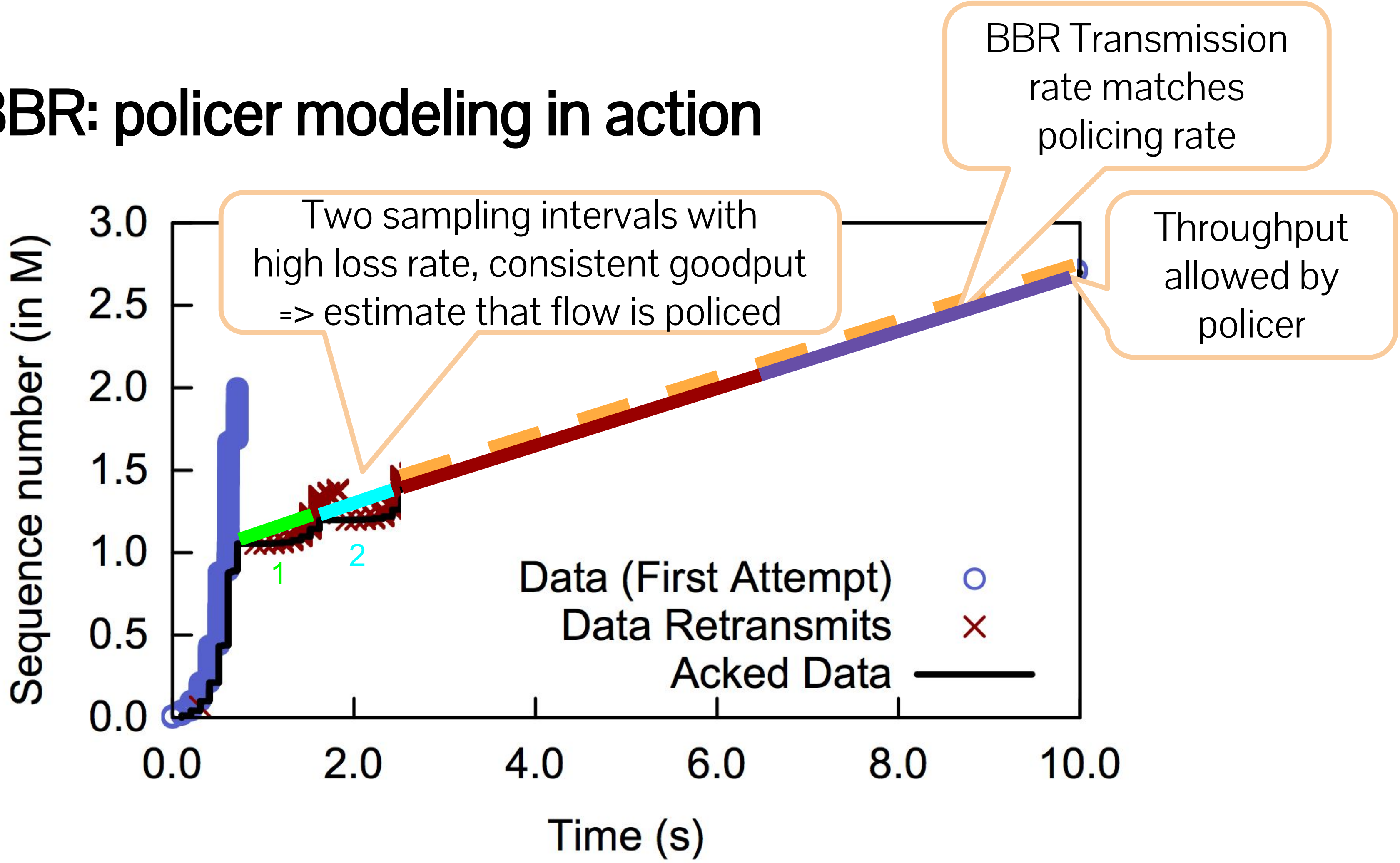
If two consecutive intervals with

loss rates >= 20% && throughputs within 12.5% or 4 Kbps of each other) Then:

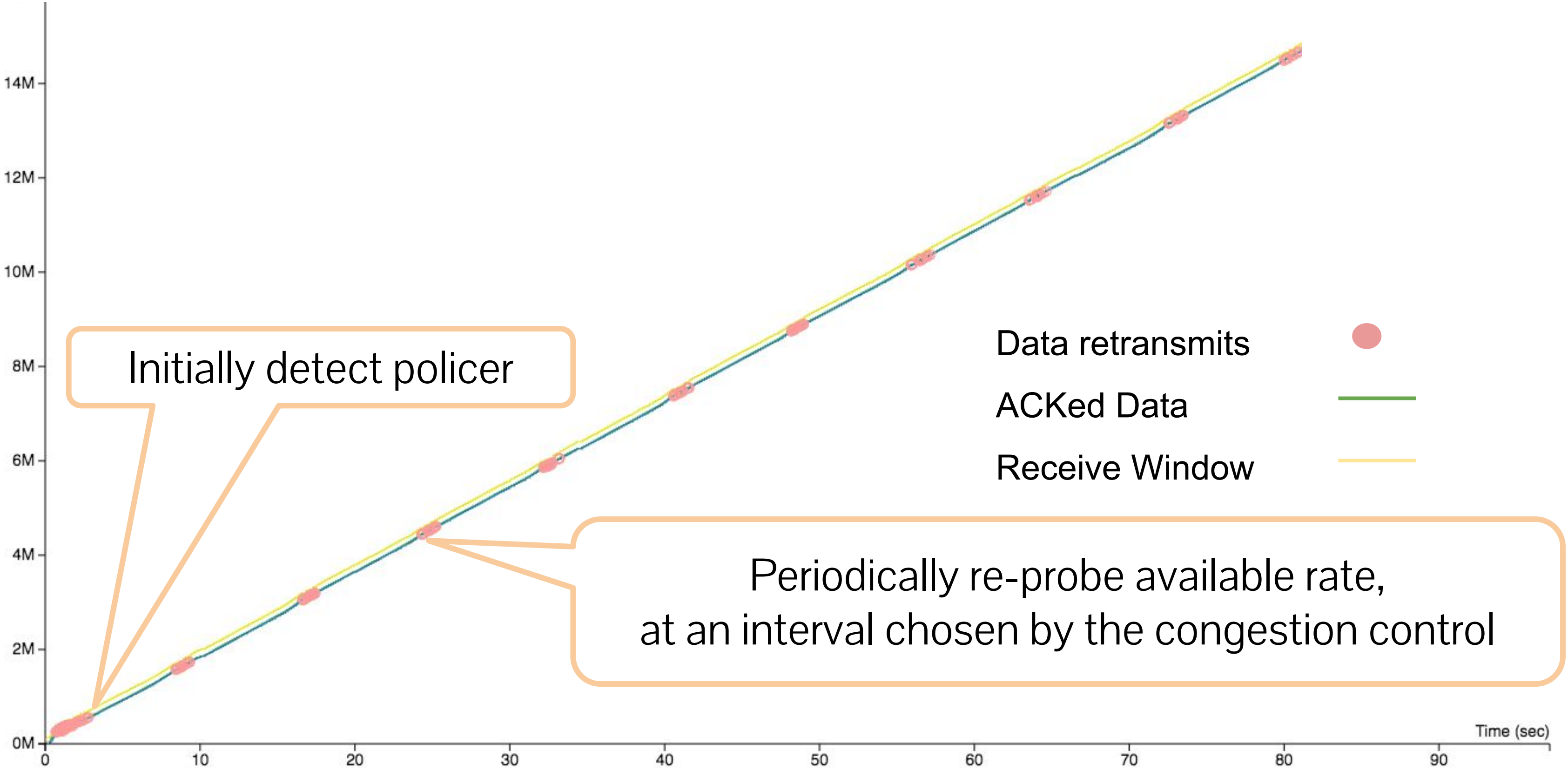
Estimated policed rate is **average** of the rates from each interval

Send at <= estimated policed rate for 48 round trips

BBR: policer modeling in action



BBR: a policed YouTube trace (major US cellular ISP)



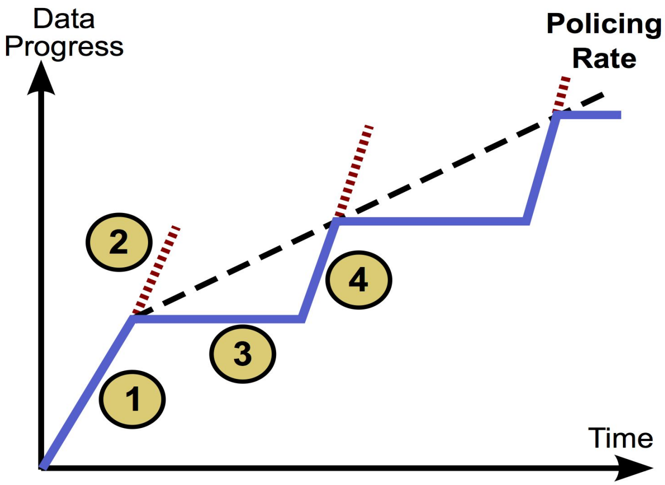
Conclusion

- YouTube analysis indicates prevalent traffic policing
  - Often uses deep token bucket
  - More common in developing regions deploys more
  - TCP bursts initially then suffers severe losses
  - Interact badly with video chunking delivery and rate adaptation

- Promising protocol changes under testing
  - BBR congestion control detects and models policer
  - RACK loss recovery to detect lost retransmit quickly

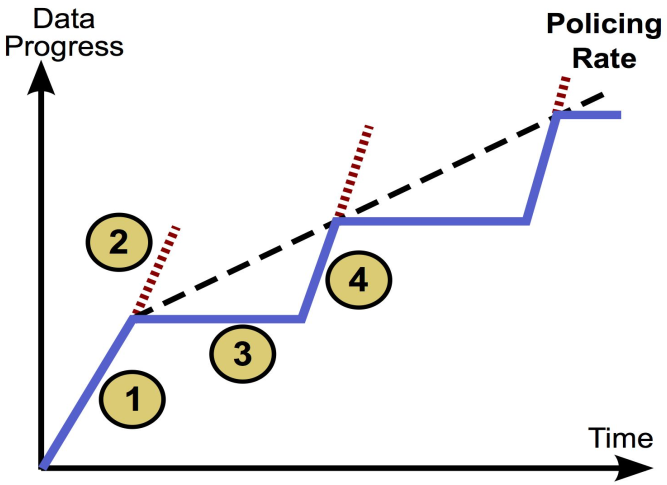
Backup Slides

Interaction with TCP Congestion Control



(1) Bucket filled
→ unbounded throughput
(2) Bucket empty → bursty loss
(3) Waiting for timeout
(4) Repeats from (1)

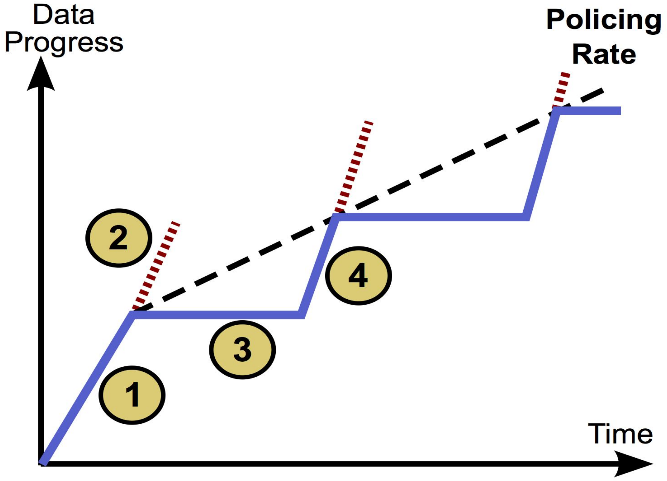
Interaction with TCP Congestion Control

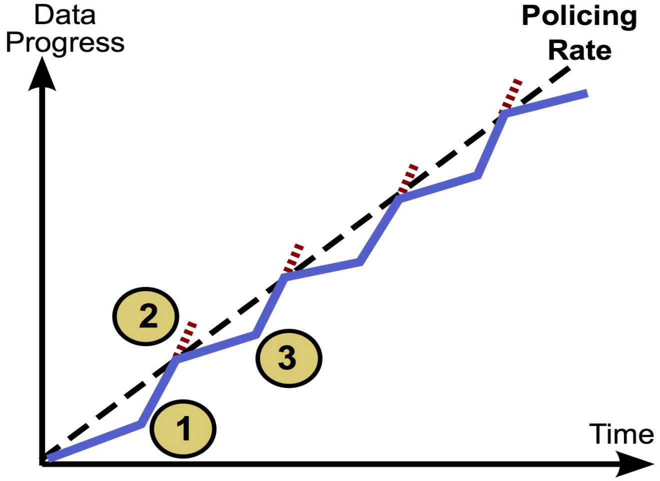


Staircase pattern

High goodputs followed by heavy losses and long timeouts

Interaction with TCP Congestion Control



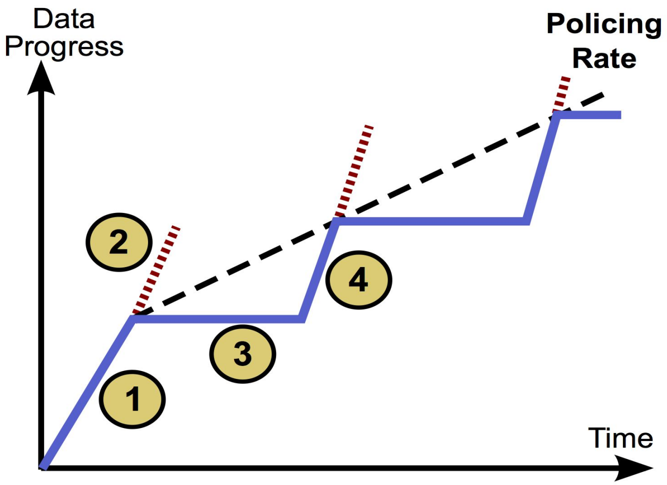


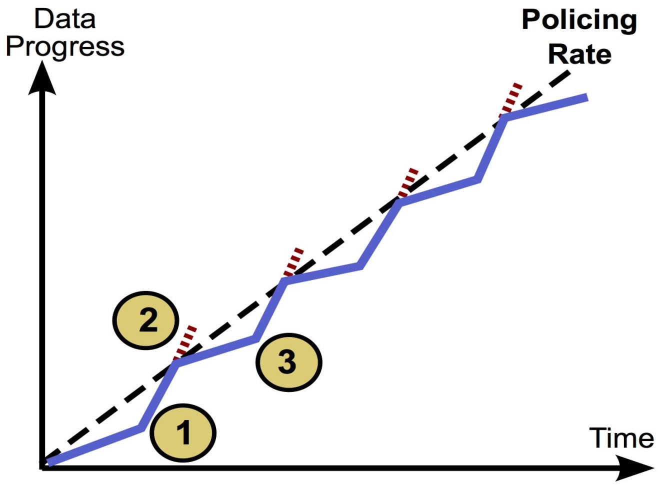
Staircase pattern

High goodputs followed by heavy losses and long timeouts

(1) Throughput with cwnd = 1 stays below policing rate
(2) Throughput with cwnd = 2 exceeds policing rate
(3) Repeats from (1)

Interaction with TCP Congestion Control





Staircase pattern

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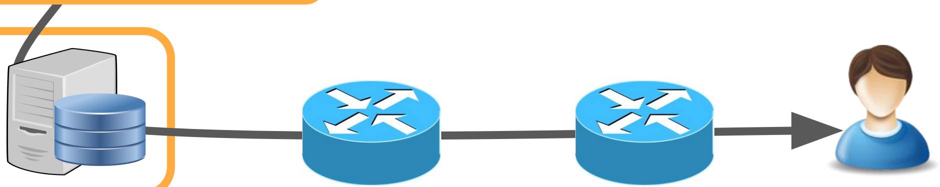
Doubling window pattern

Flipping between rates since connection cannot align with policing rate

Understanding Policing

HTTP Response

Collect packet traces



Forward samples to analysis backend

Handles over 30 billion packets daily

Derive basic features

e.g. retransmissions, latency, HTTP chunks, ...

Apply policing detection heuristic

Store & query aggregate results

Validation

- Accuracy of heuristic (lab validation)
  - Generated test traces covering common reasons for dropped packets
    - Policing (using carrier-grade networking device that can do policing)
    - Congestion (bottleneck link with tail queuing and different AQM flavors)
    - Random loss
    - Shaping (also using third-party traces)
  - TODO: Result summary

- Consistency of policing rates (in the wild)
  - Validated that policing rates cluster around a few values (per AS)
  - No clustering in ASes without policing
    - And: false positives in lab did not observe clustering either

Common Mechanisms to Enforce ISP Policies

Policing

Enforces rate by **dropping** excess packets immediately

- − Can result in high loss rates
- + Does not require memory buffer
- + No RTT inflation

Shaping

Enforces rate by **queuing** excess packets

- + Only drops packets when buffer is full
- − Requires memory to buffer packets
- − Can inflate RTTs due to high queuing delay

Policing can have negative side effects for all parties

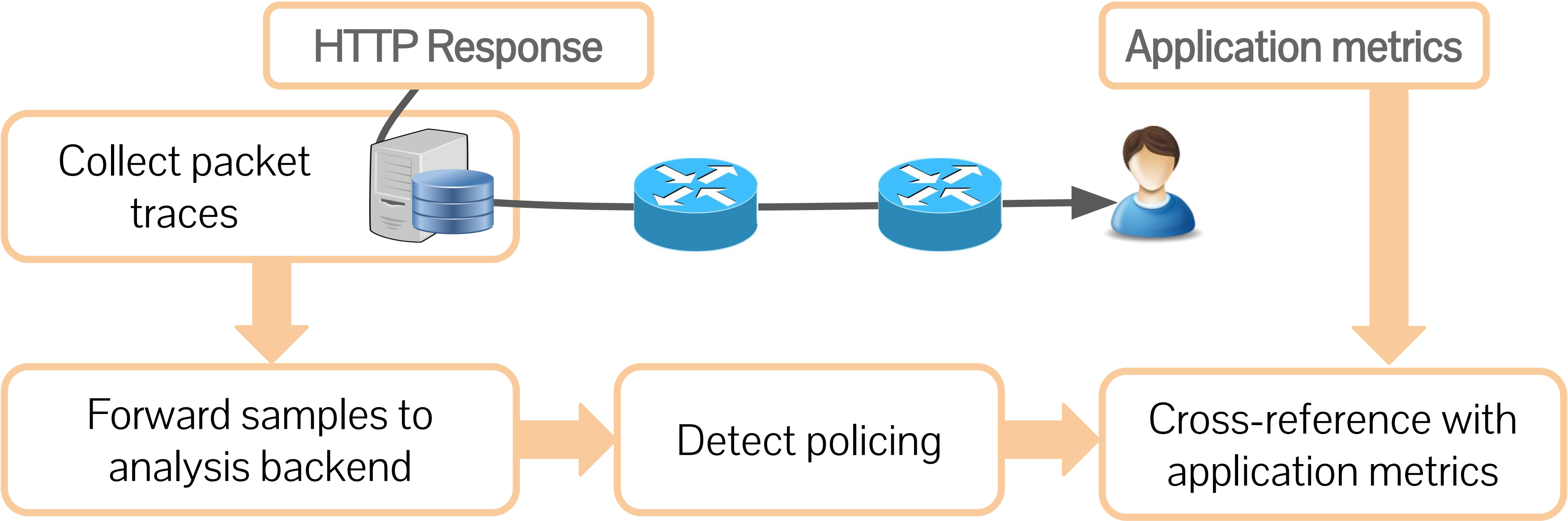
- Content providers
  - Excess load on servers forced to retransmit dropped packets

    (global average: 20% retransmissions vs. 2% when not policed)

- ISPs
  - Transport traffic across the Internet only for it to be dropped by the policer
  - Incurs avoidable transit costs

- Users
  - Can interact badly with TCP-based applications
  - We measured degraded video quality of experience (QoE) → user dissatisfaction

Analysis Pipeline



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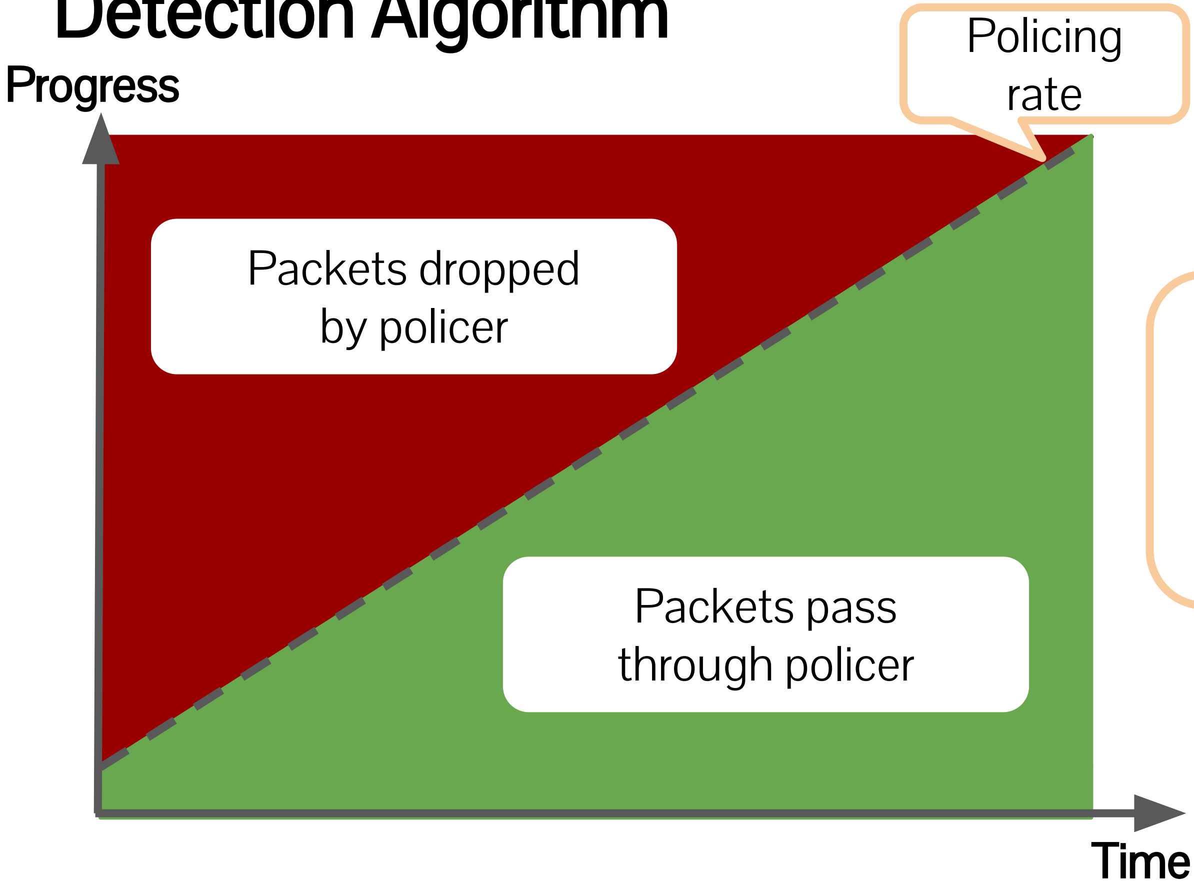

Packets are always dropped when crossing the "policing rate" line

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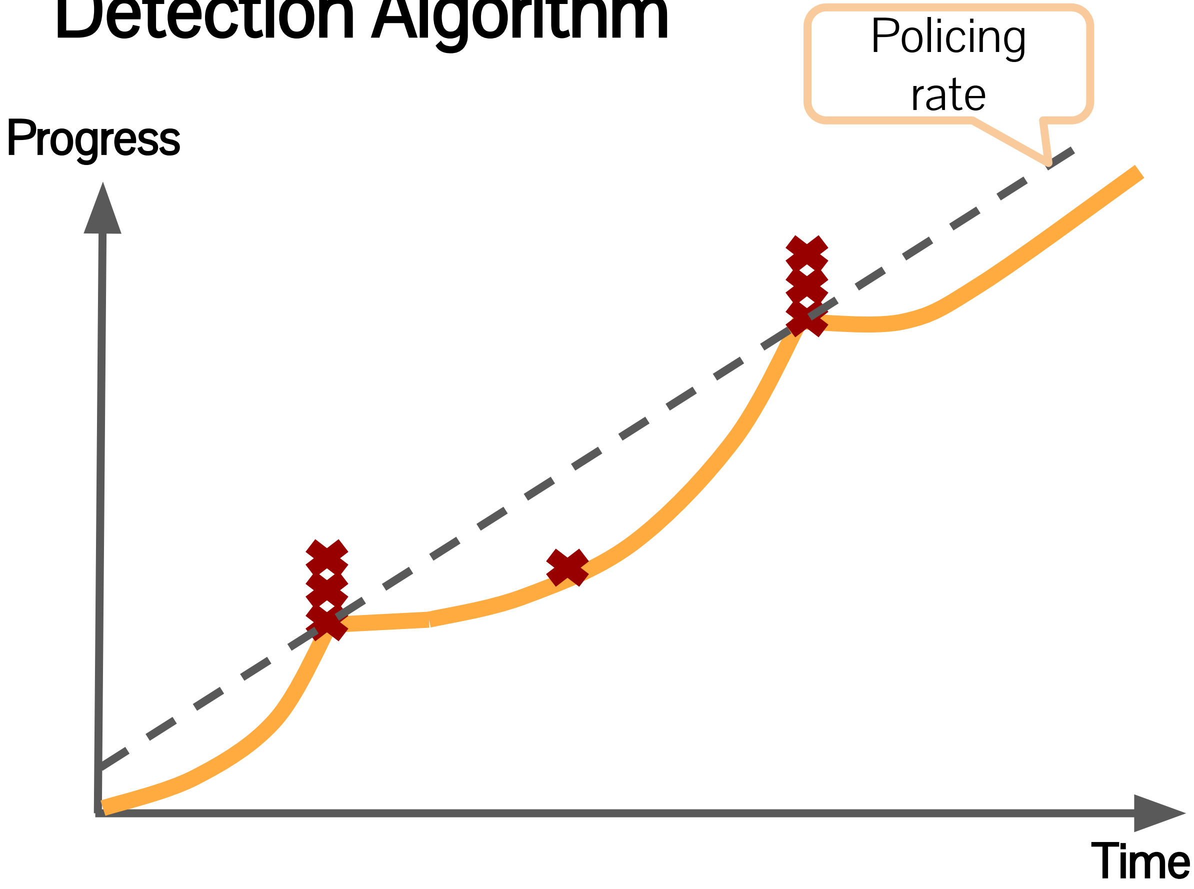

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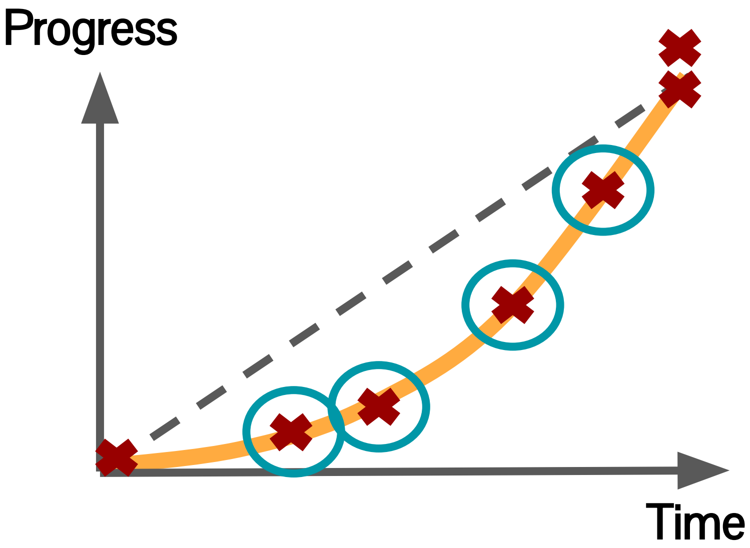
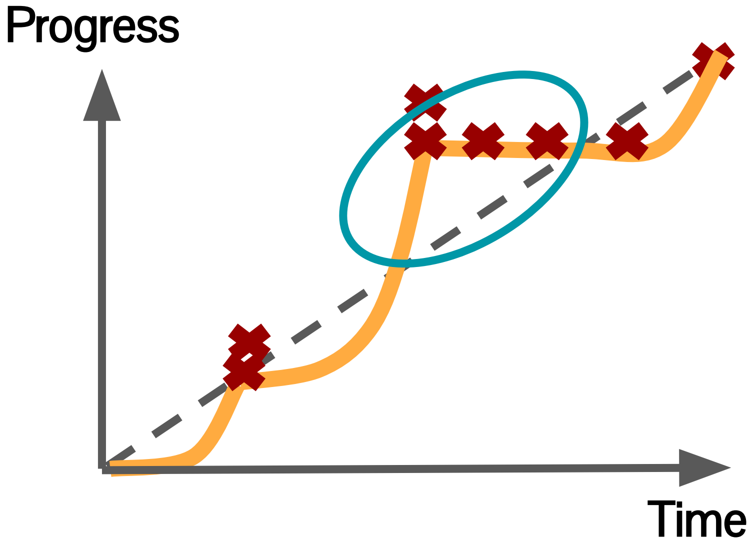
Avoiding Falsely Labeling Loss as Policing



But: Traffic below policing rate should go through



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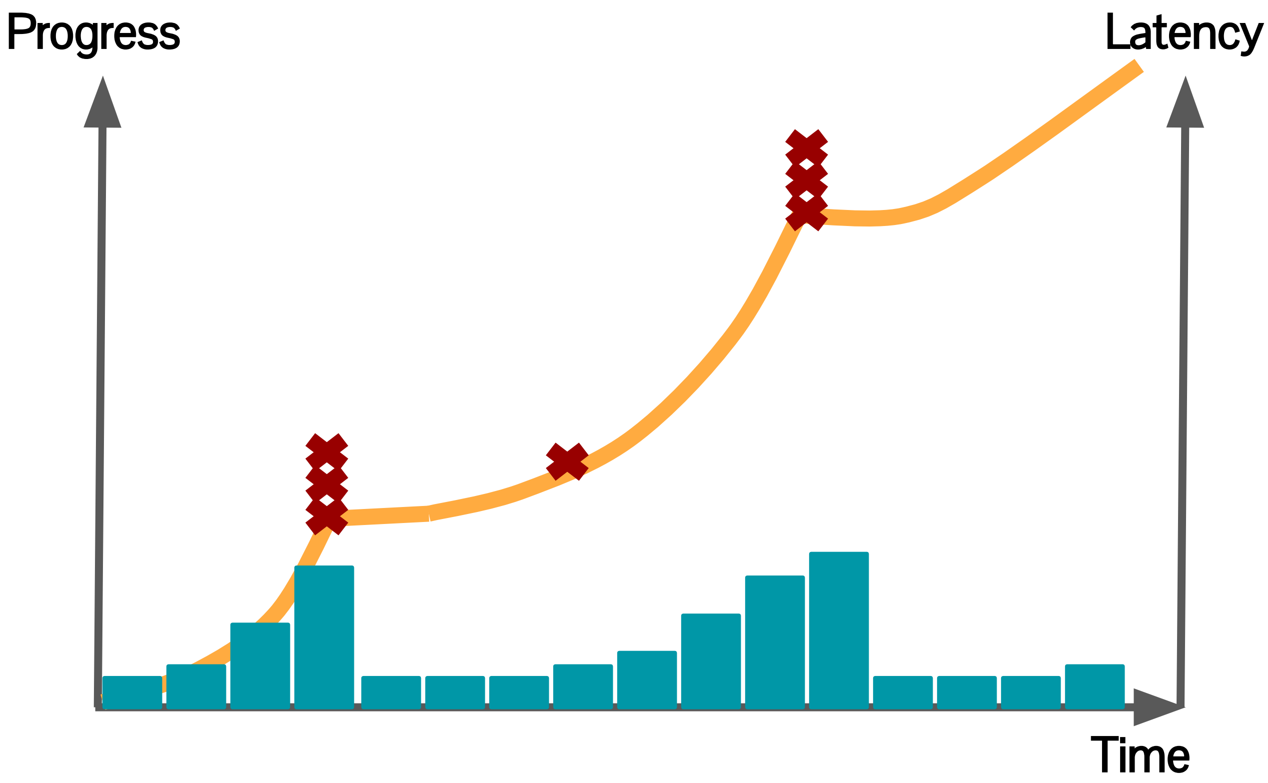

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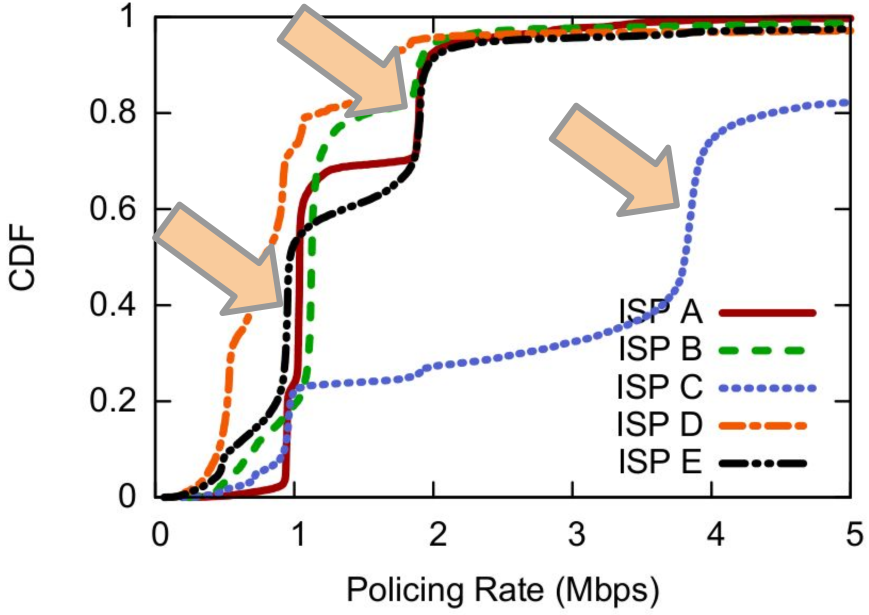

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