IEEE INFOCOM

Towards the Fairness of Traffic Policer

Danfeng Shan[1], Peng Zhang[1], Wanchun Jiang[2], Hao Li[1], Fengyuan Ren[3]

[1]Xi'an Jiaotong University, [2]Central South University, [3]Tsinghua University

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中南大學 CENTRAL SOUTH UNIVERSITY

清華大學 Tsinghua University

Background

Background

YouTube

NETFLIX

Google

Content Providers

Background

YouTube

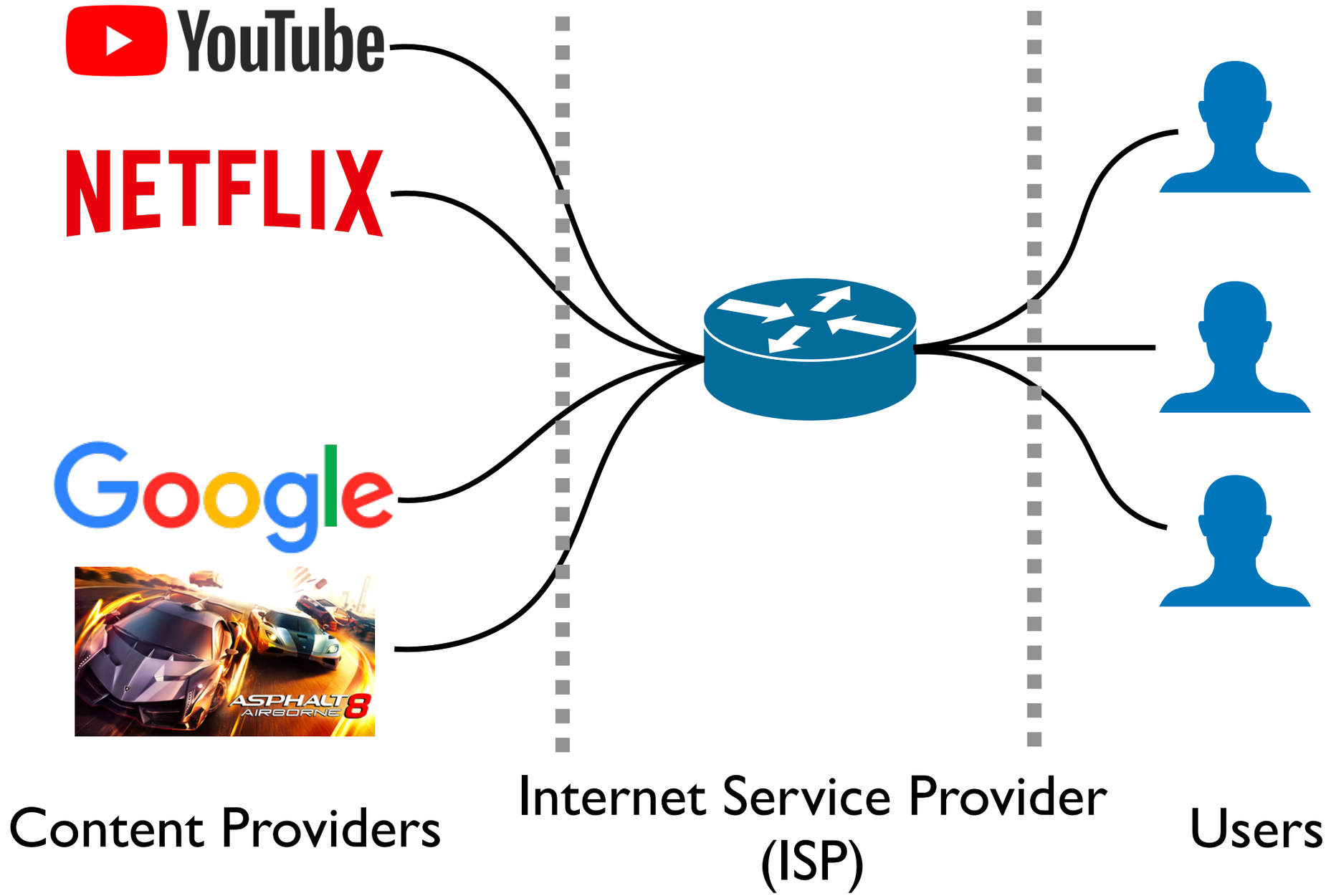
NETFLIX

Google

Content Providers

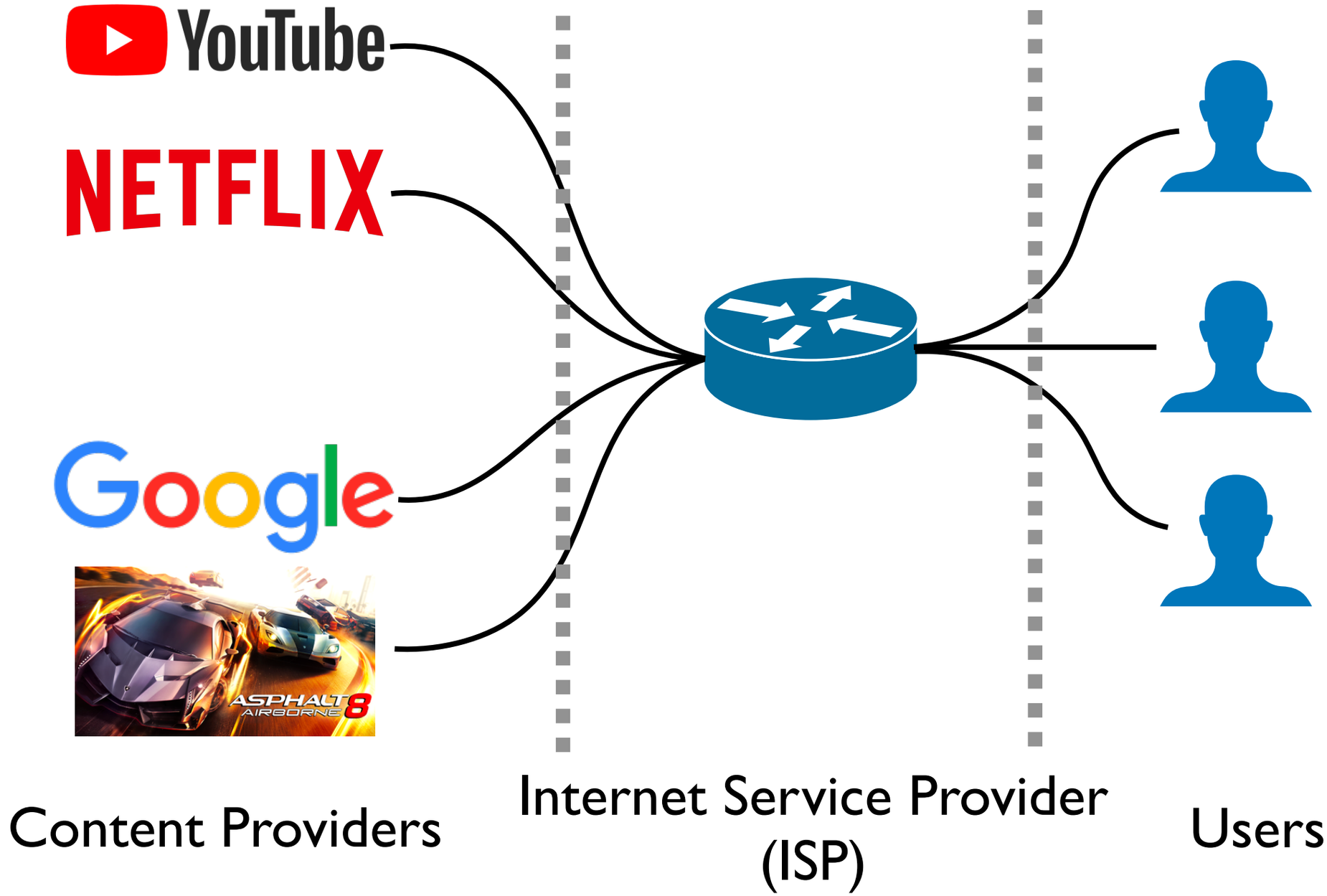
Users

Background


YouTube
NETFLIX
Google
ASPHALT 8 AIRBORNE
Content Providers
Internet Service Provider (ISP)
Users

Background

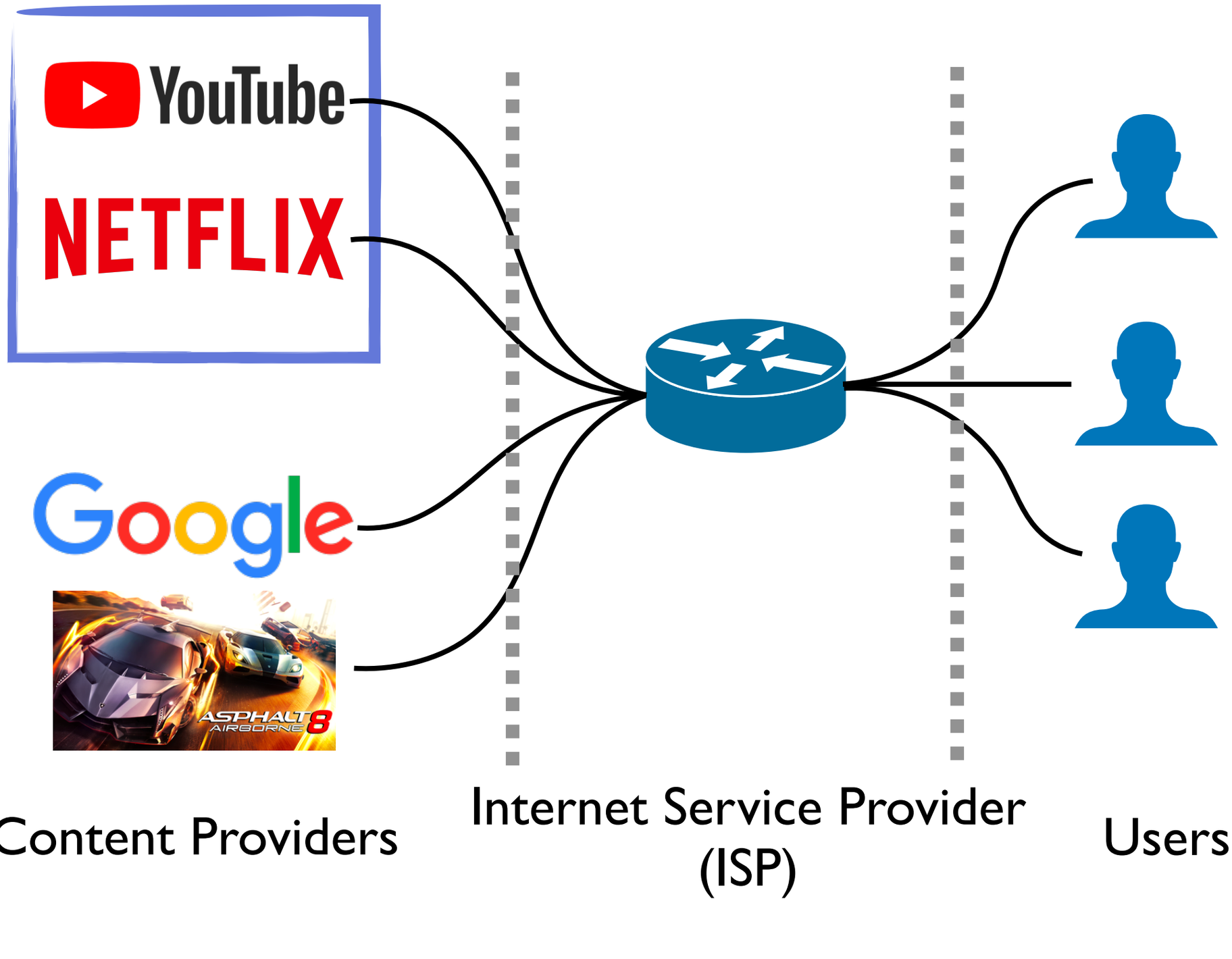
Application Requirements



Background

Application Requirements

Throughput Intensive



Content Providers

Internet Service Provider (ISP)

Users

Background

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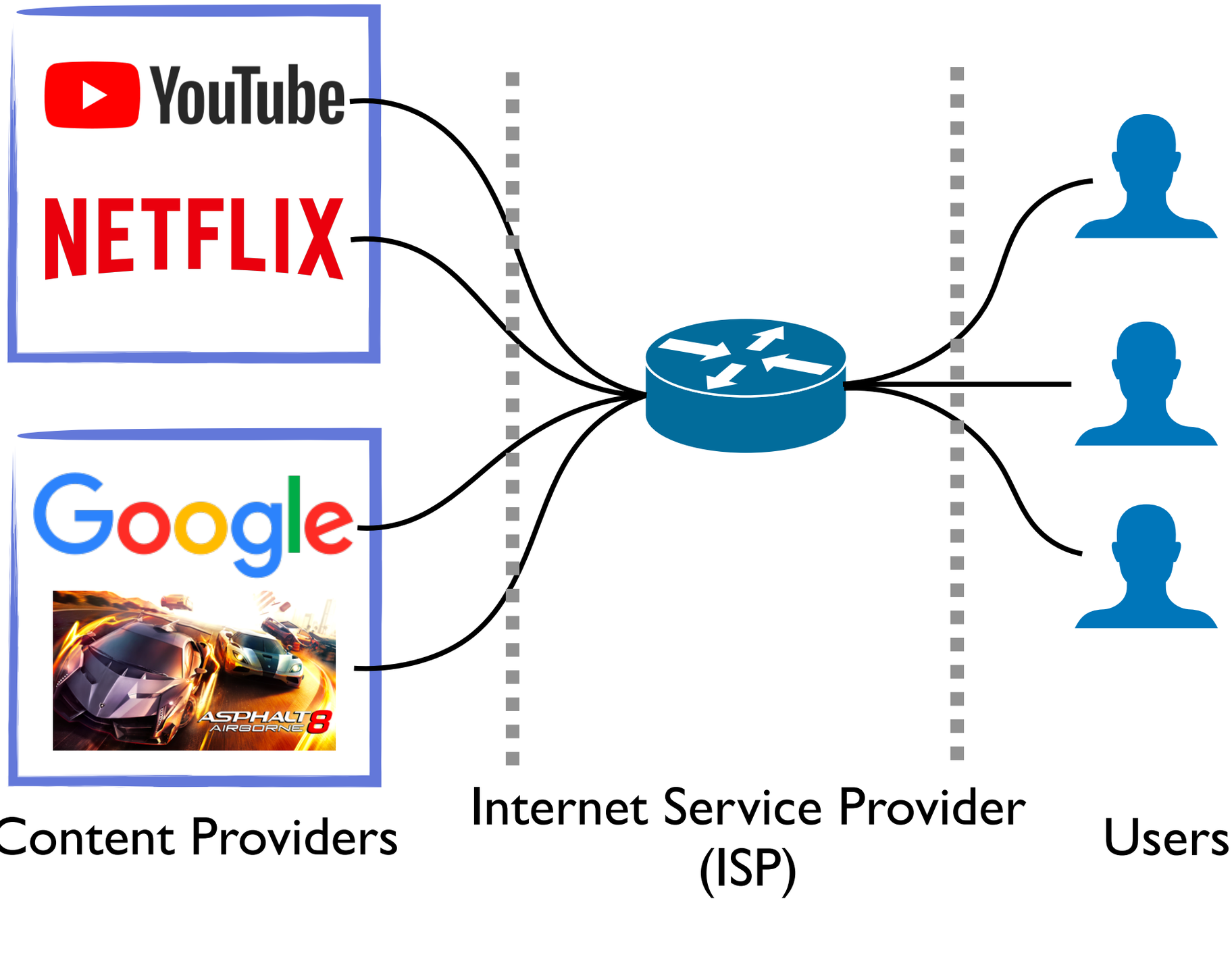
Throughput Intensive

Latency Sensitive



Content Providers

Internet Service Provider (ISP)

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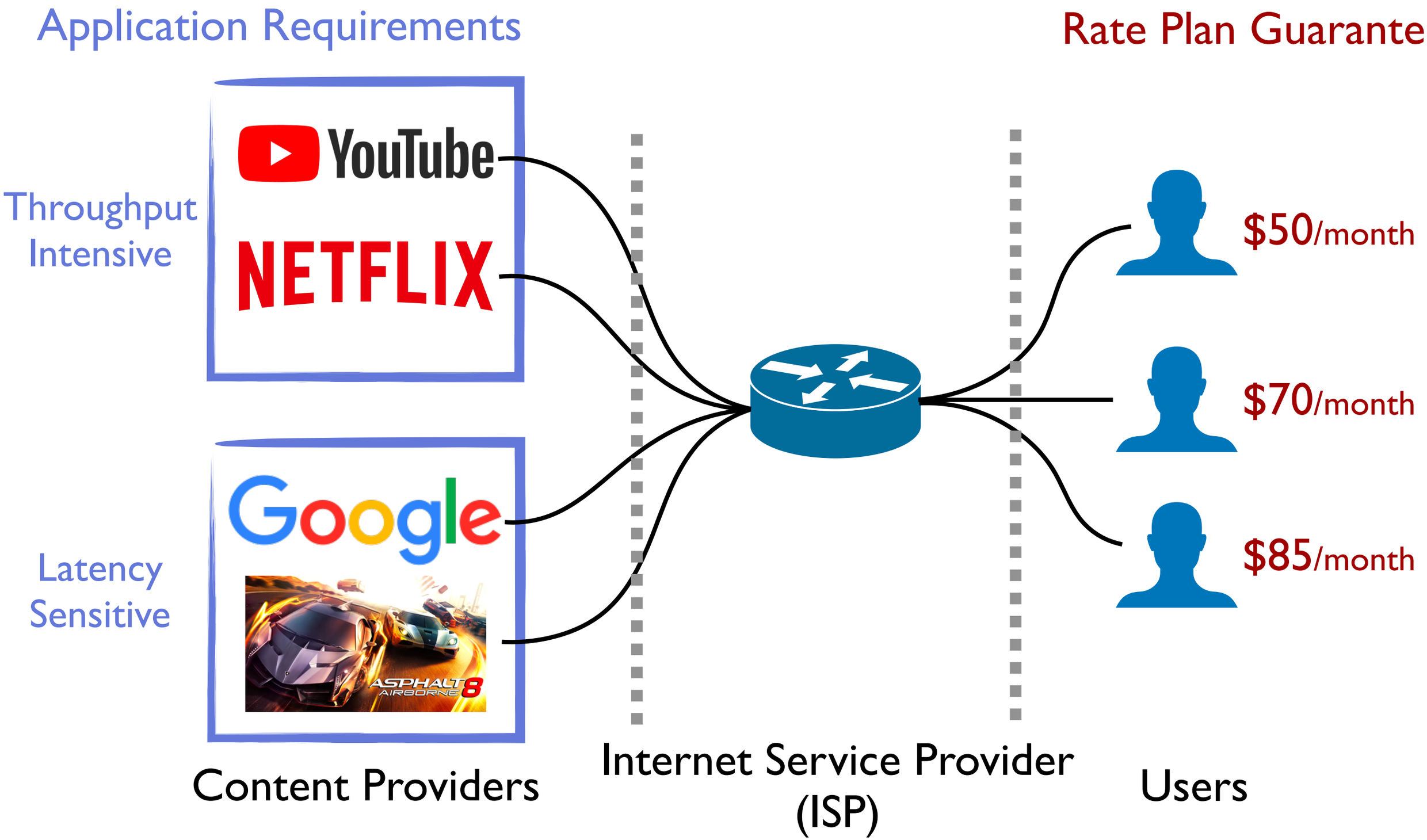
Application Requirements
Rate Plan Guarantee
Throughput Intensive
YouTube
NETFLIX
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Google
ASPHALT 8 AIRBORNE
$50/month
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$85/month
Content Providers
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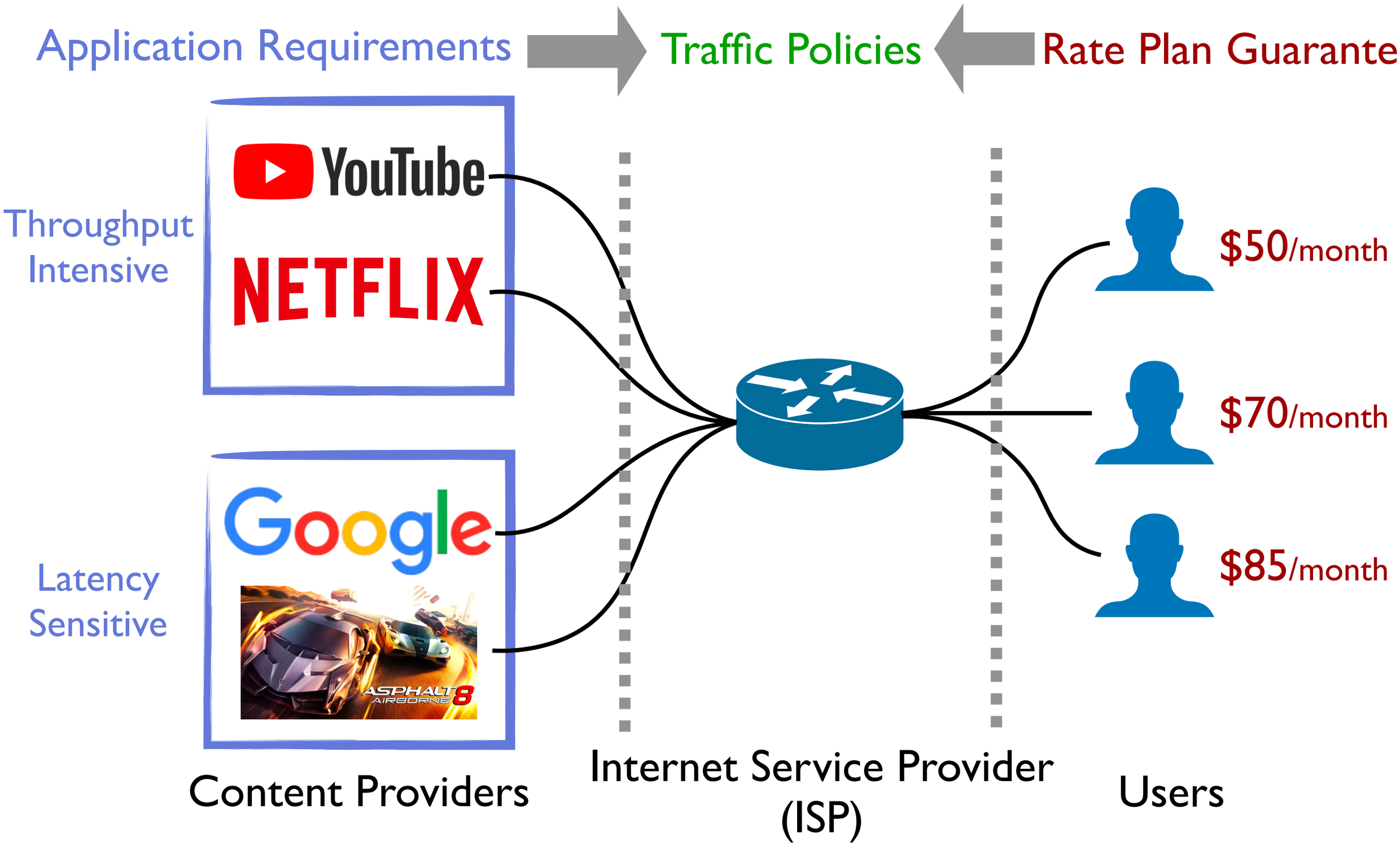
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Traffic Policies
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Enforce Traffic Policies
(Throttle Traffic Rate)

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Traffic Policing

Drop packets once reaching the limit

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Traffic Policing

Drop packets once reaching the limit

Traffic Shaping

Buffer packets after reaching the limit

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Enforce Traffic Policies
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Traffic Policing

Drop packets once reaching the limit

- ✓ No RTT inflation
- ✓ Lower cost
- x Higher loss rate

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Buffer packets after reaching the limit

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Buffer packets after reaching the limit

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Drop packets once reaching the limit

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Buffer packets after reaching the limit

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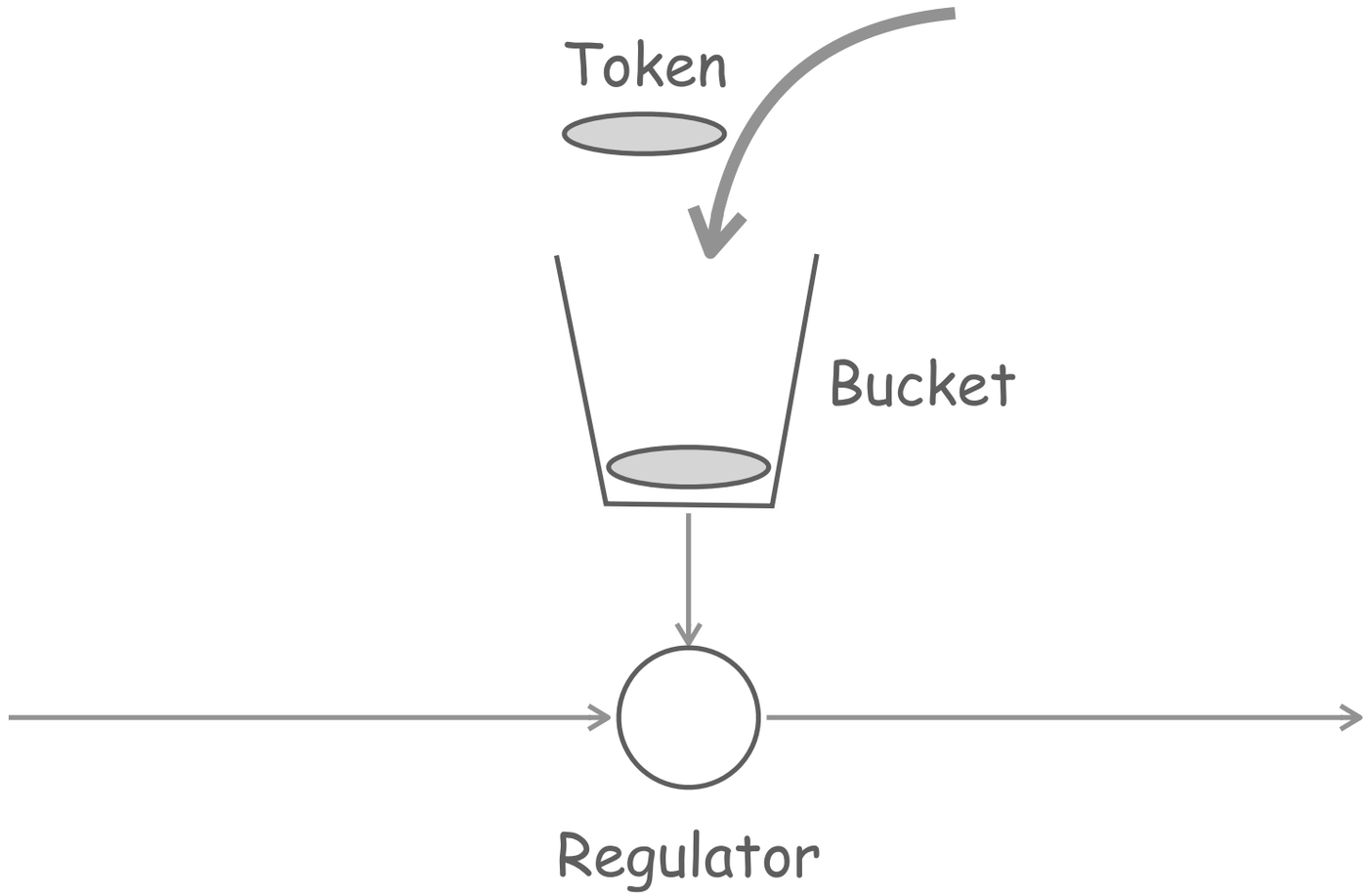
Our Focus

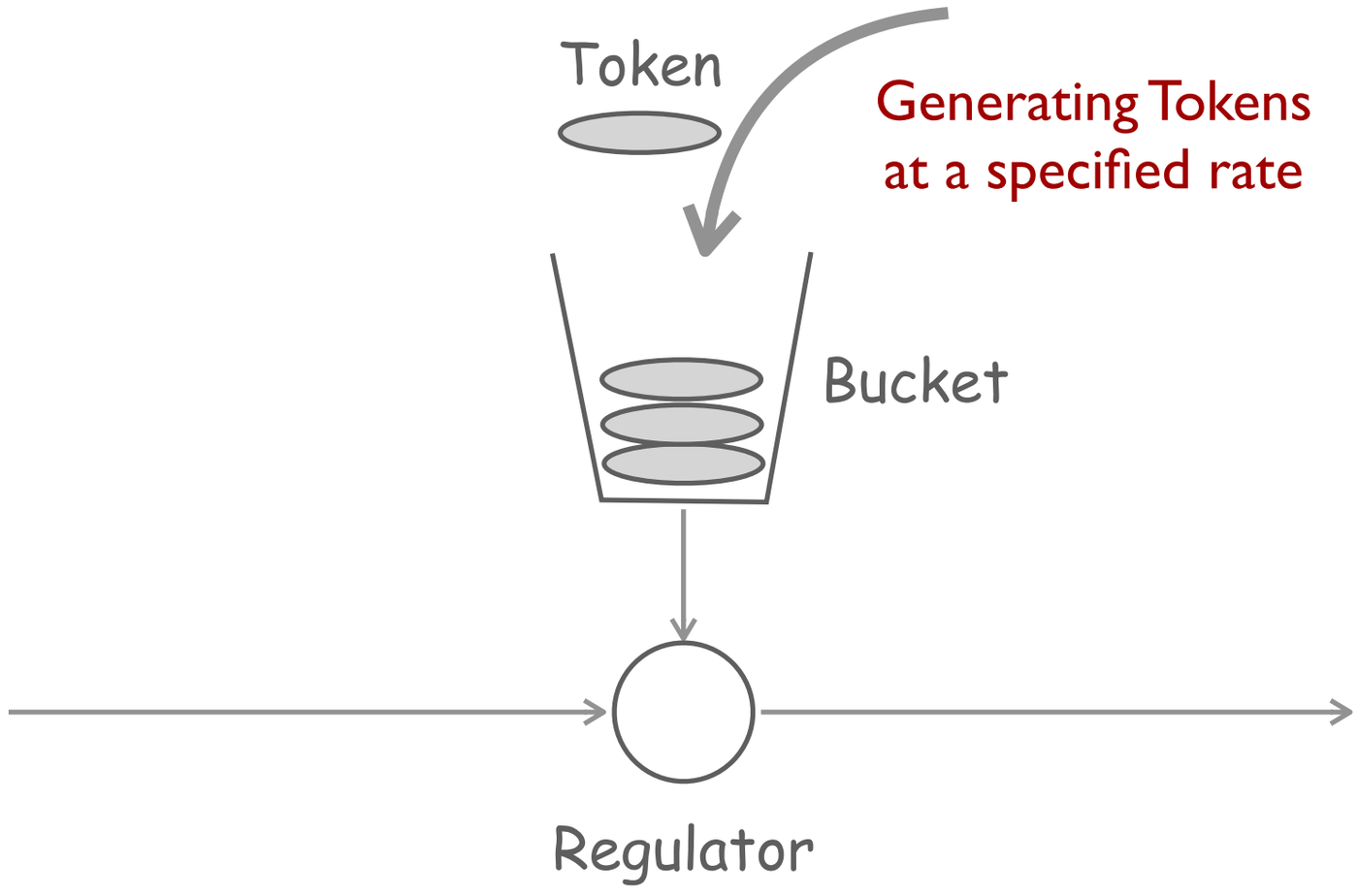
How Traffic Policer Works

Token Bucket Algorithm



How Traffic Policer Works

Token Bucket Algorithm



How Traffic Policer Works

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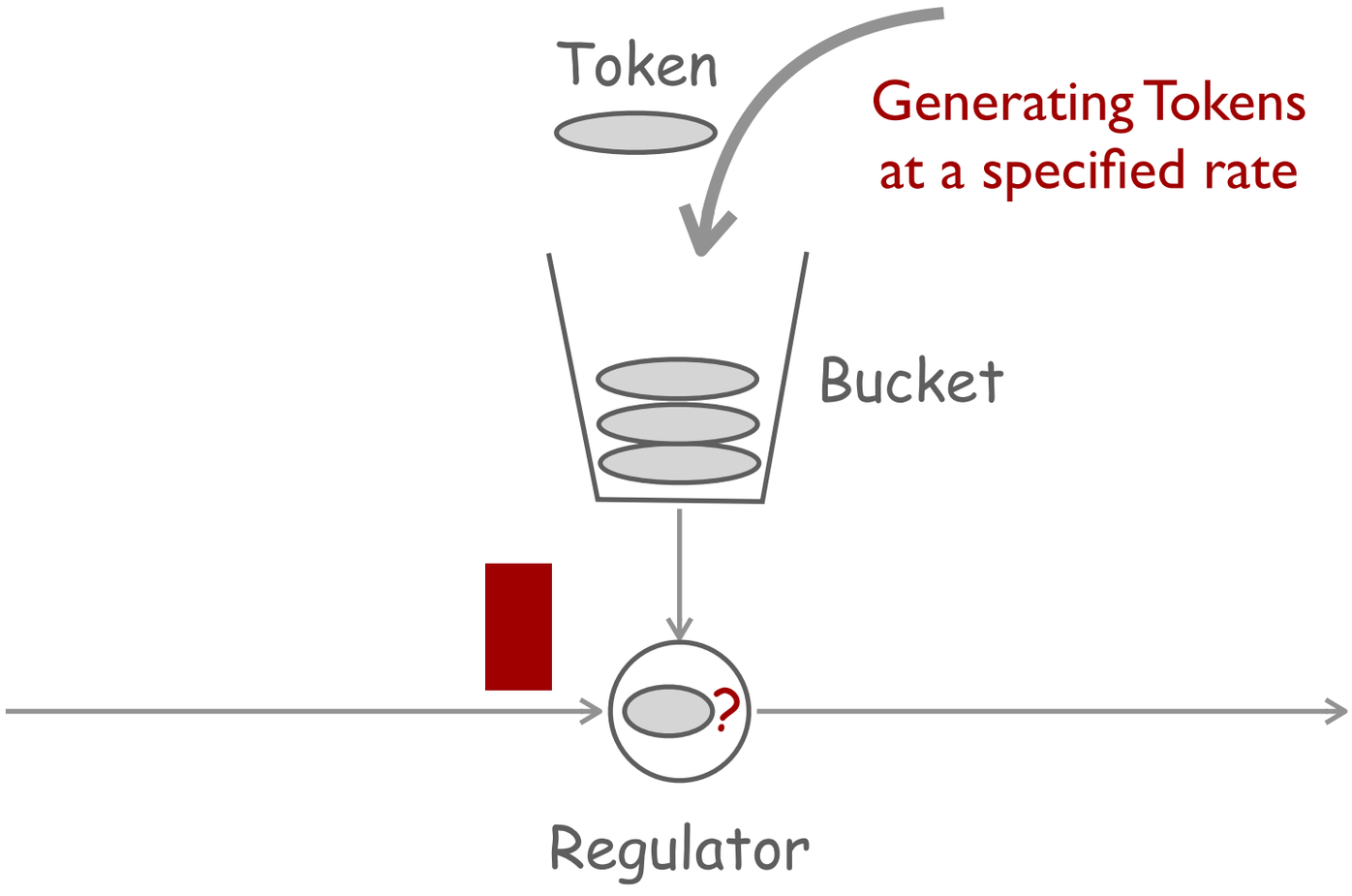
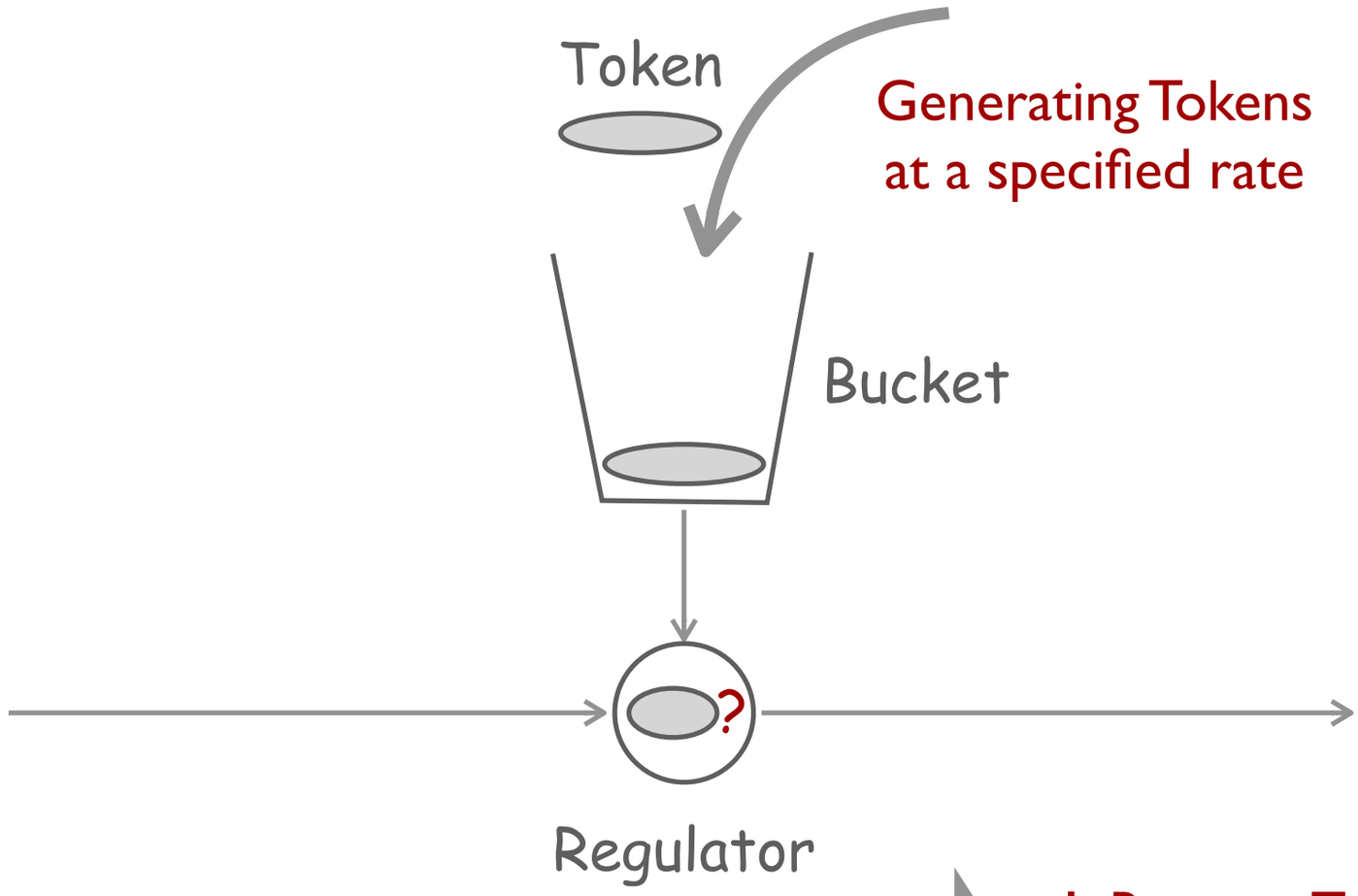


Token Num >= Packet Length

How Traffic Policer Works

Token Bucket Algorithm

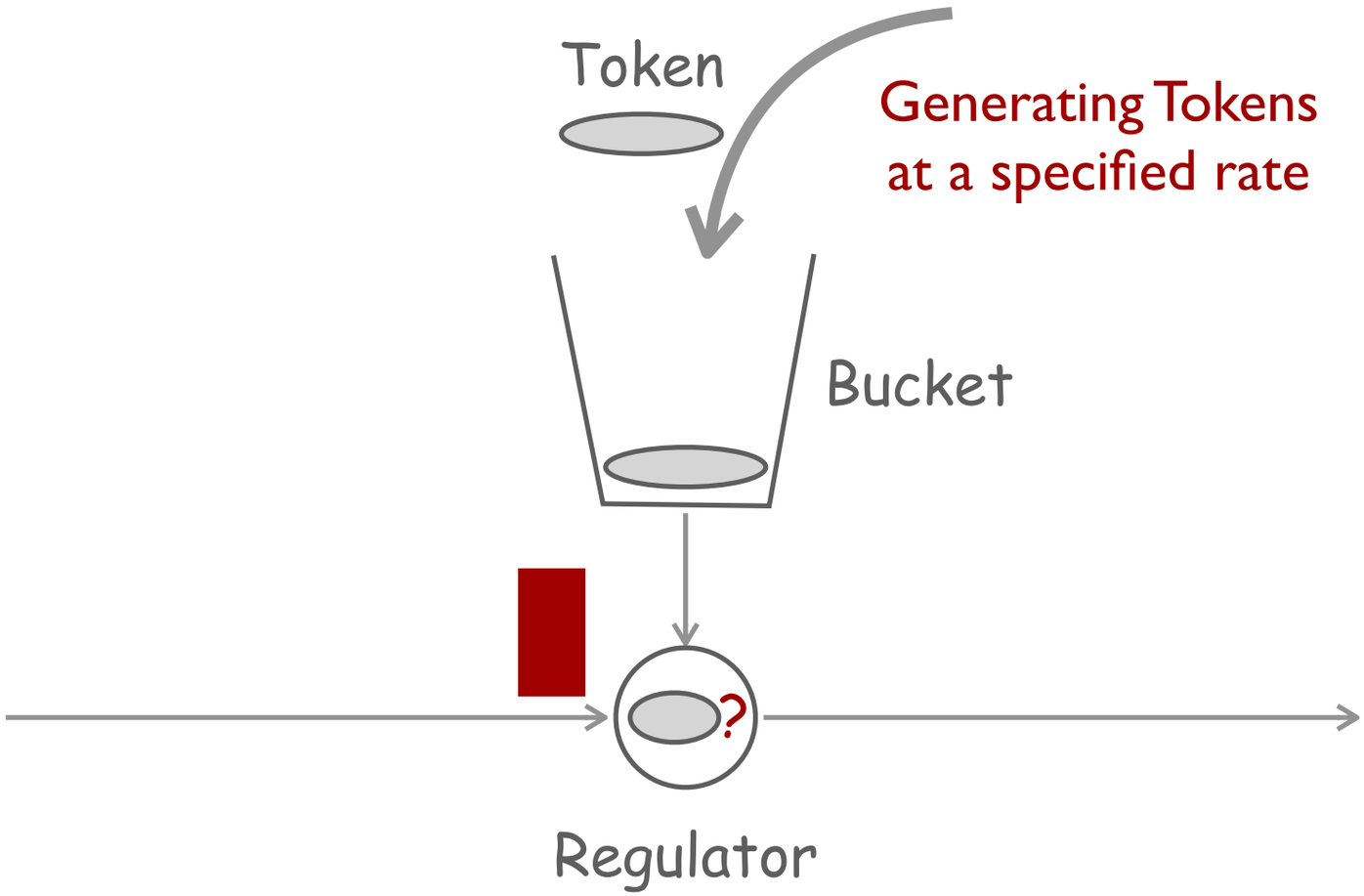


Token Num >= Packet Length

1. Remove Tokens from Bucket
2. Transmit Packet

How Traffic Policer Works

Token Bucket Algorithm



Token Num < Packet Length

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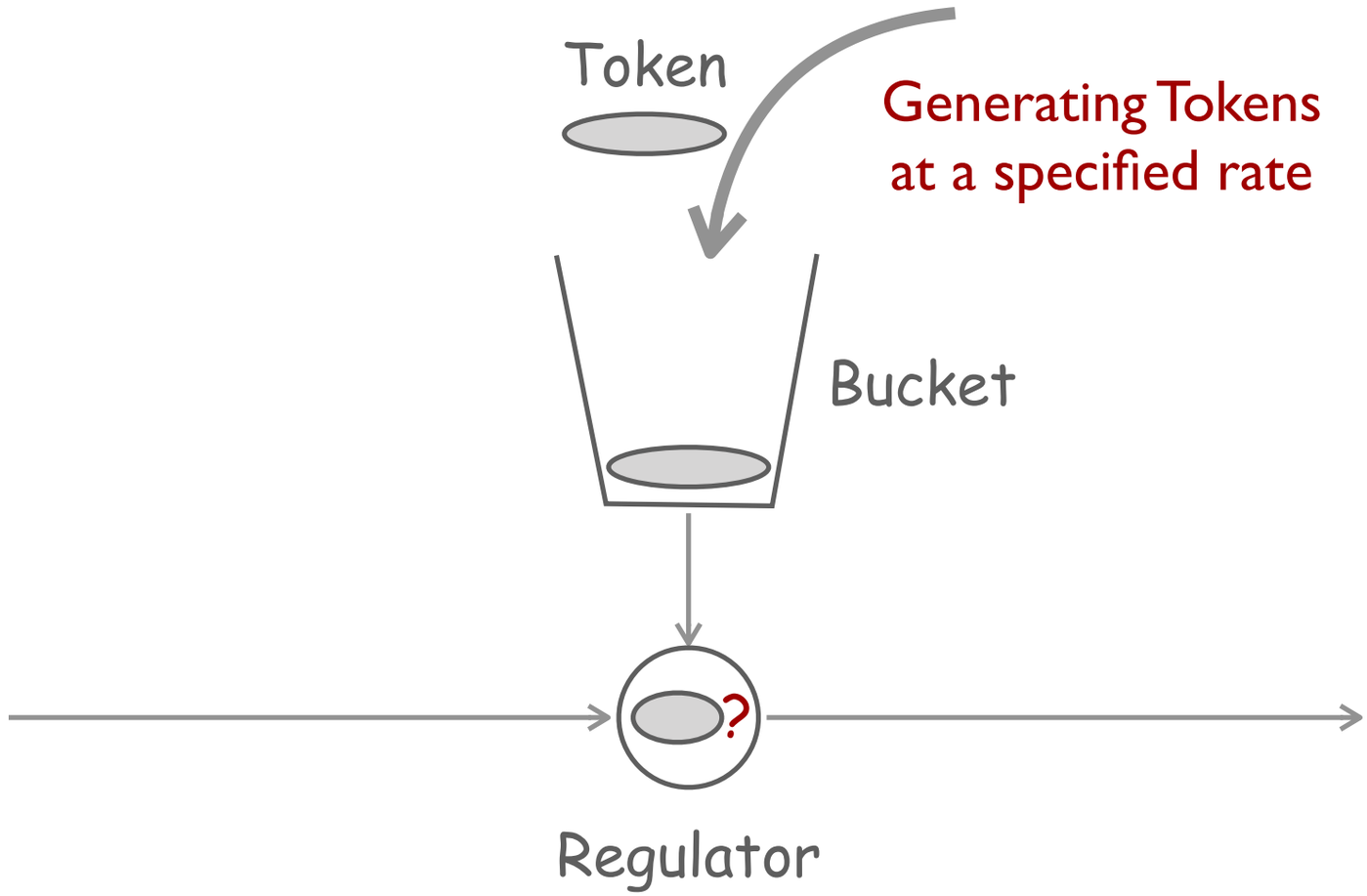
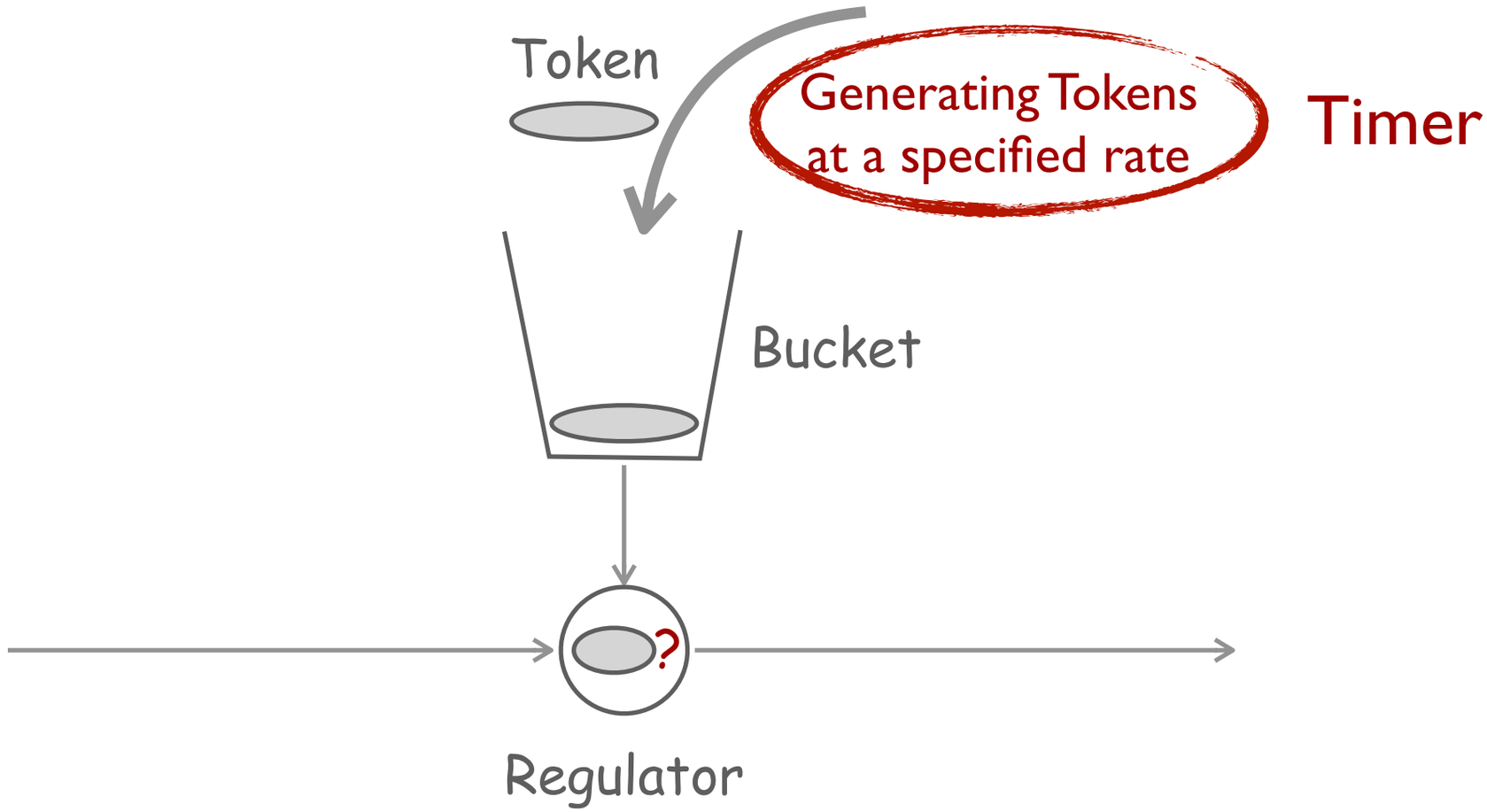


Token Num < Packet Length → Drop Packet

How Traffic Policer Works

Token Bucket Algorithm



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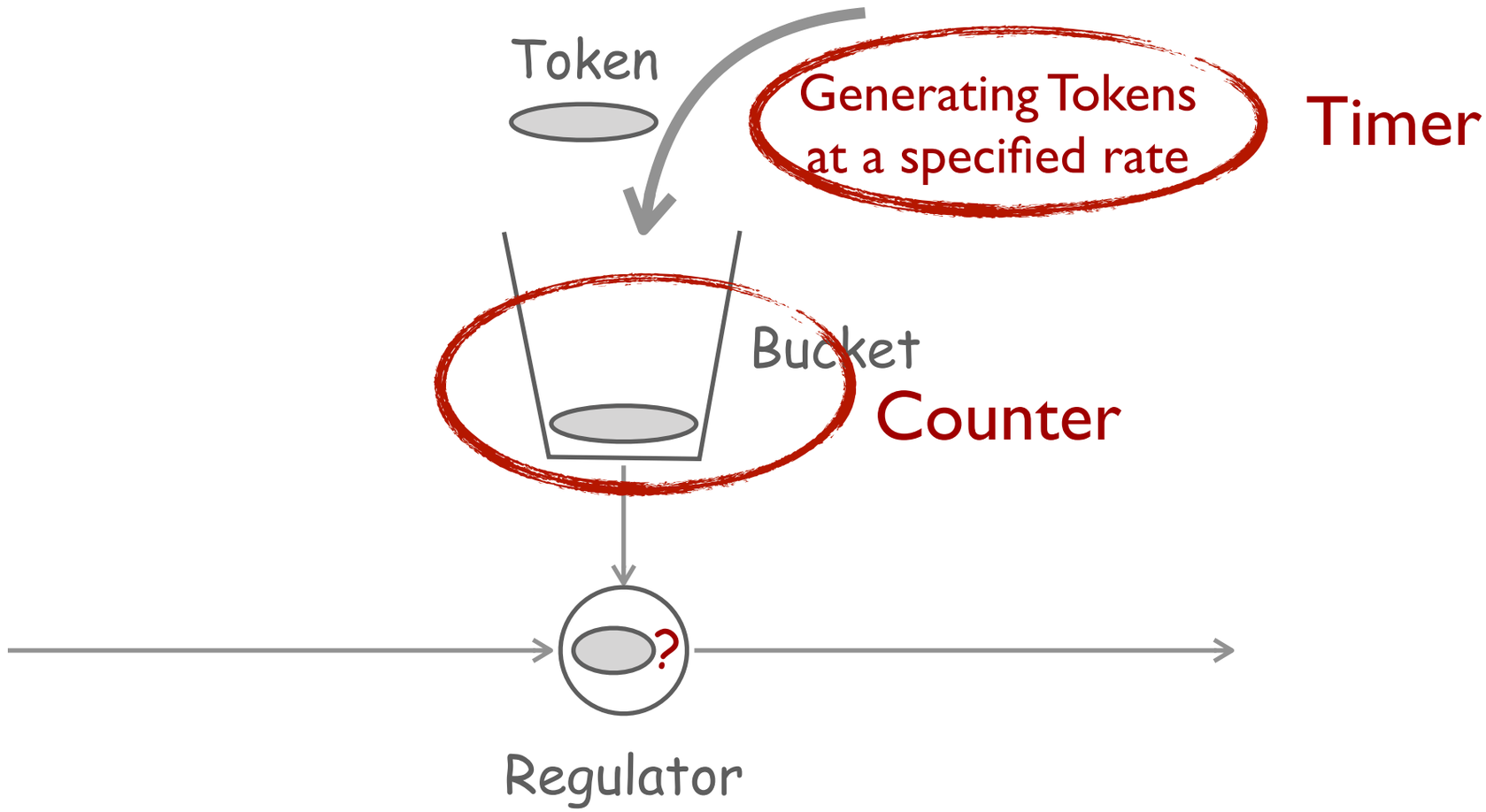

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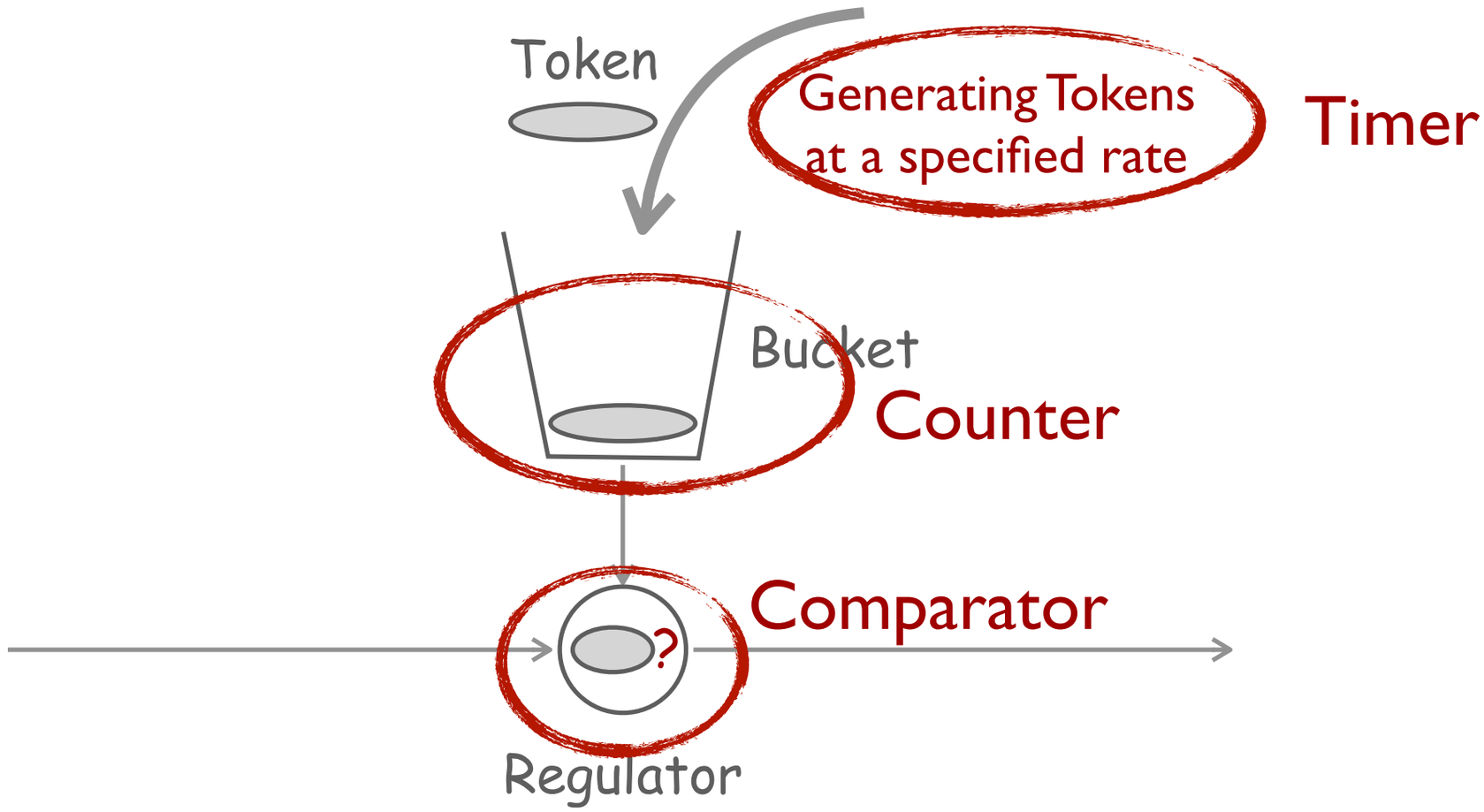

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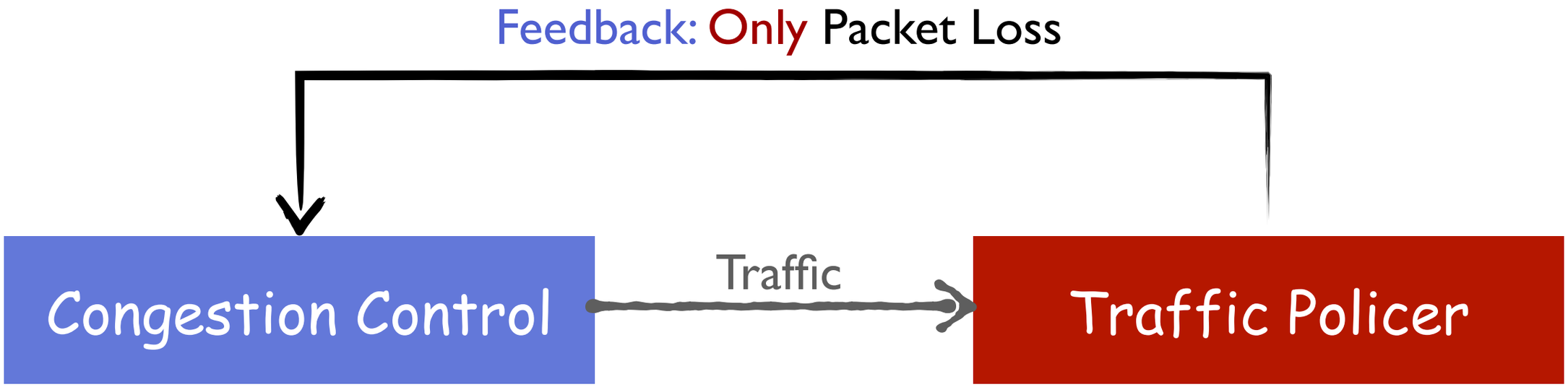
Congestion Control (CC) Interaction with Traffic Policer



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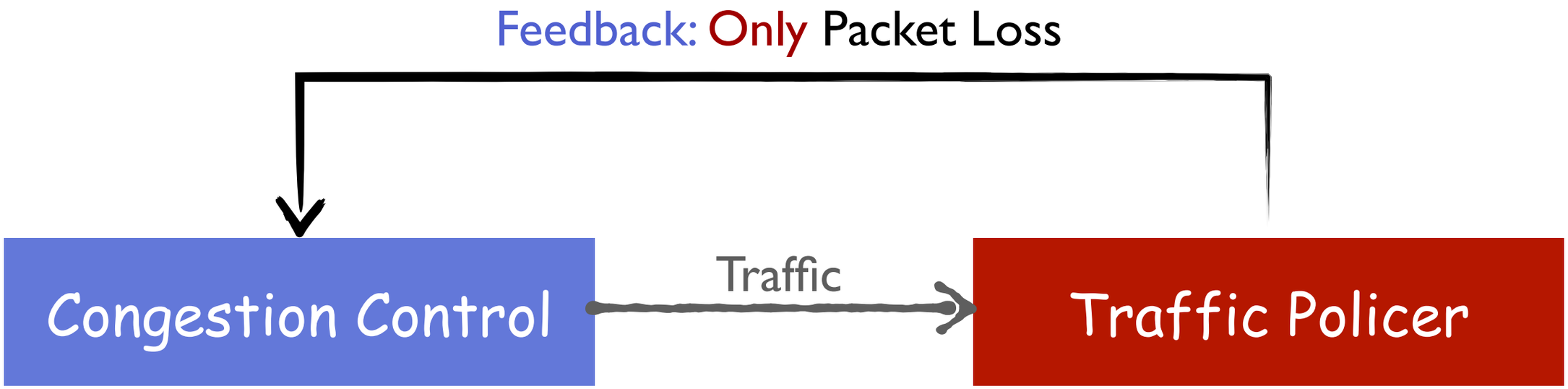
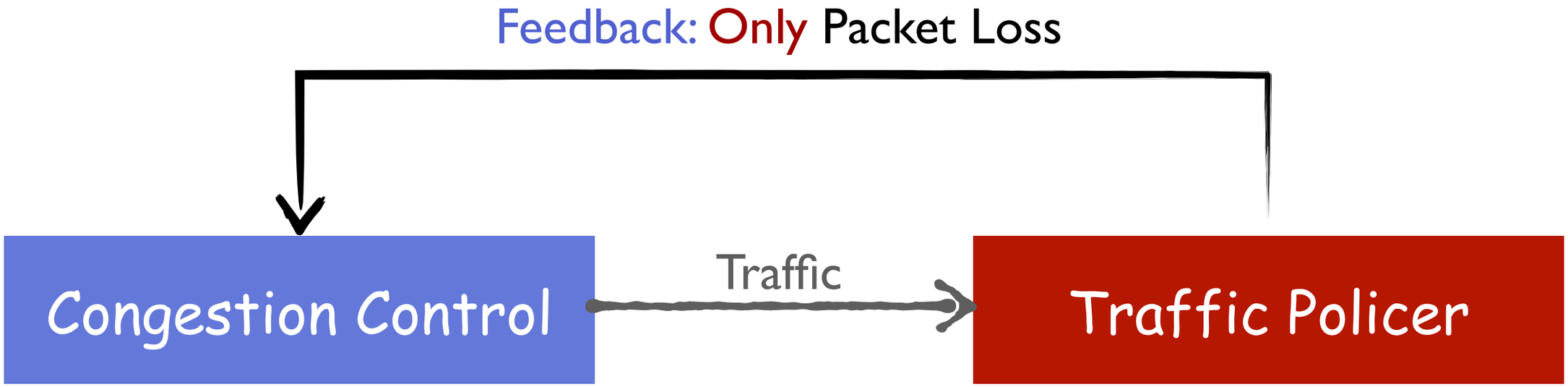


Traditional CC (CUBIC)

Loss-sensitive

Congestion Control (CC) Interaction with Traffic Policer



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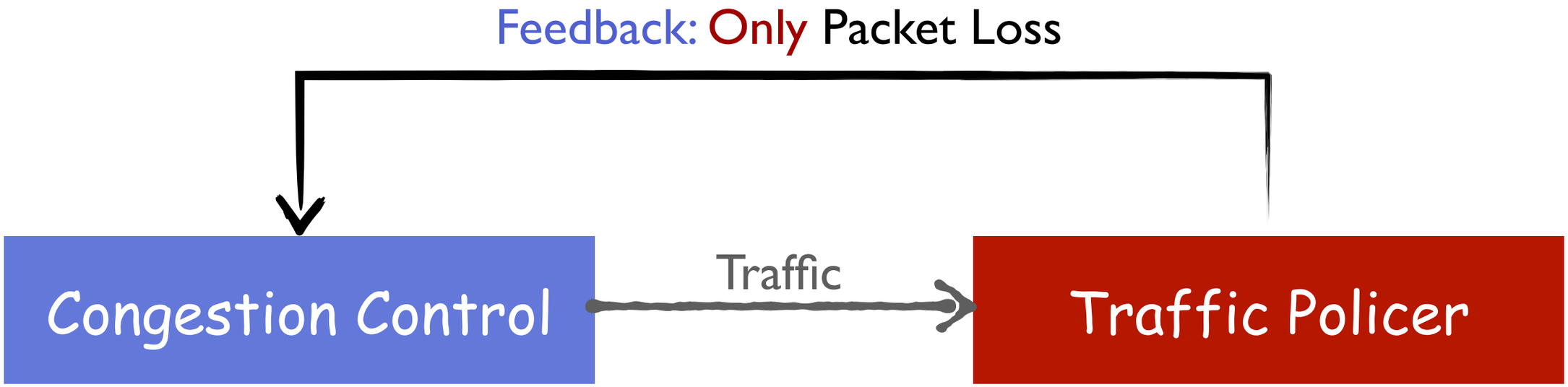
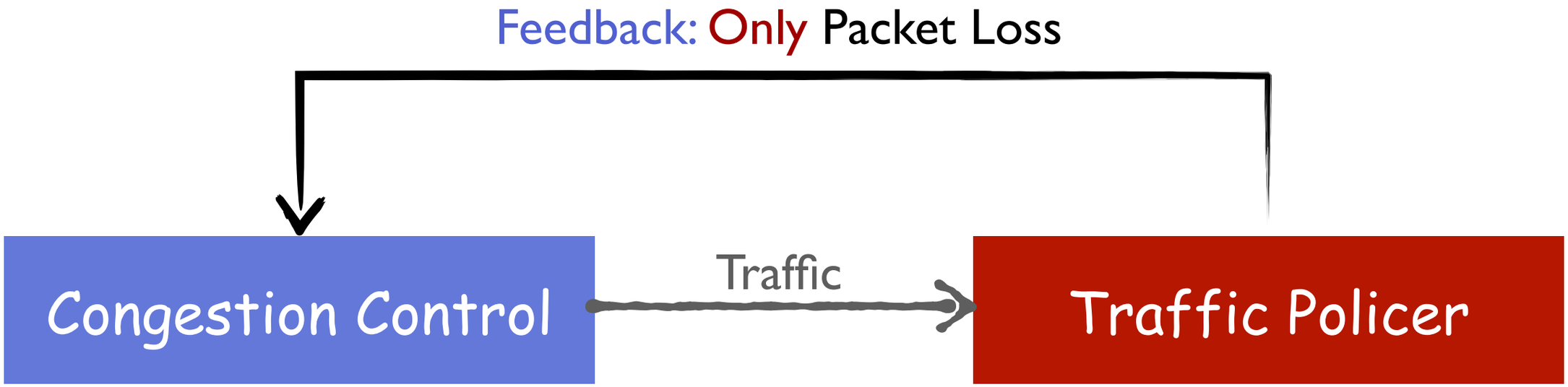


Traditional CC (CUBIC)
Loss-sensitive

New CC (BBR, PCC)
Loss-resilient

Congestion Control (CC) Interaction with Traffic Policer



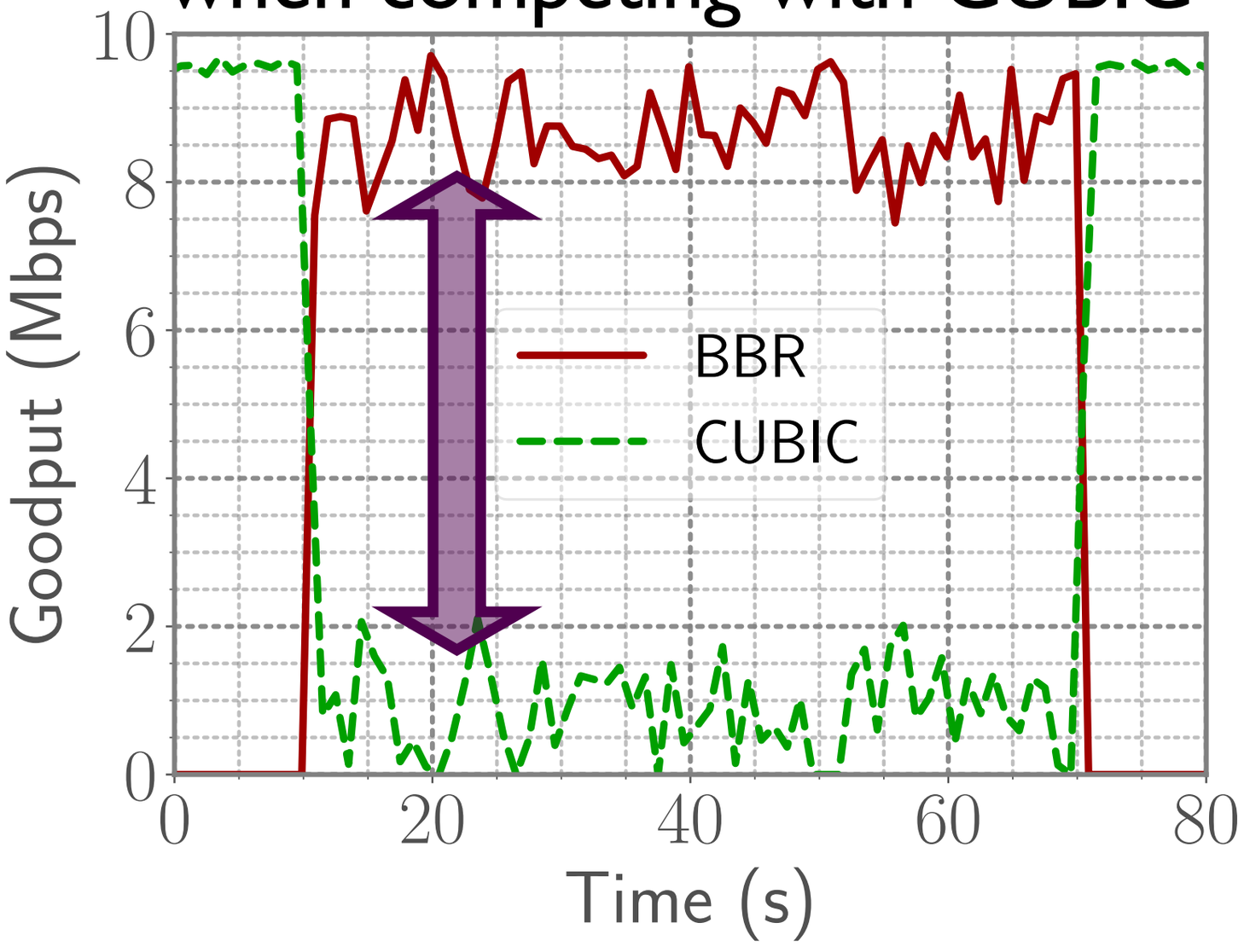
Traditional CC (CUBIC)
Loss-sensitive

New CC (BBR, PCC)
Loss-resilient

Traditional CC vs. new CC ⟶ Unfairness

The Unfairness Problem

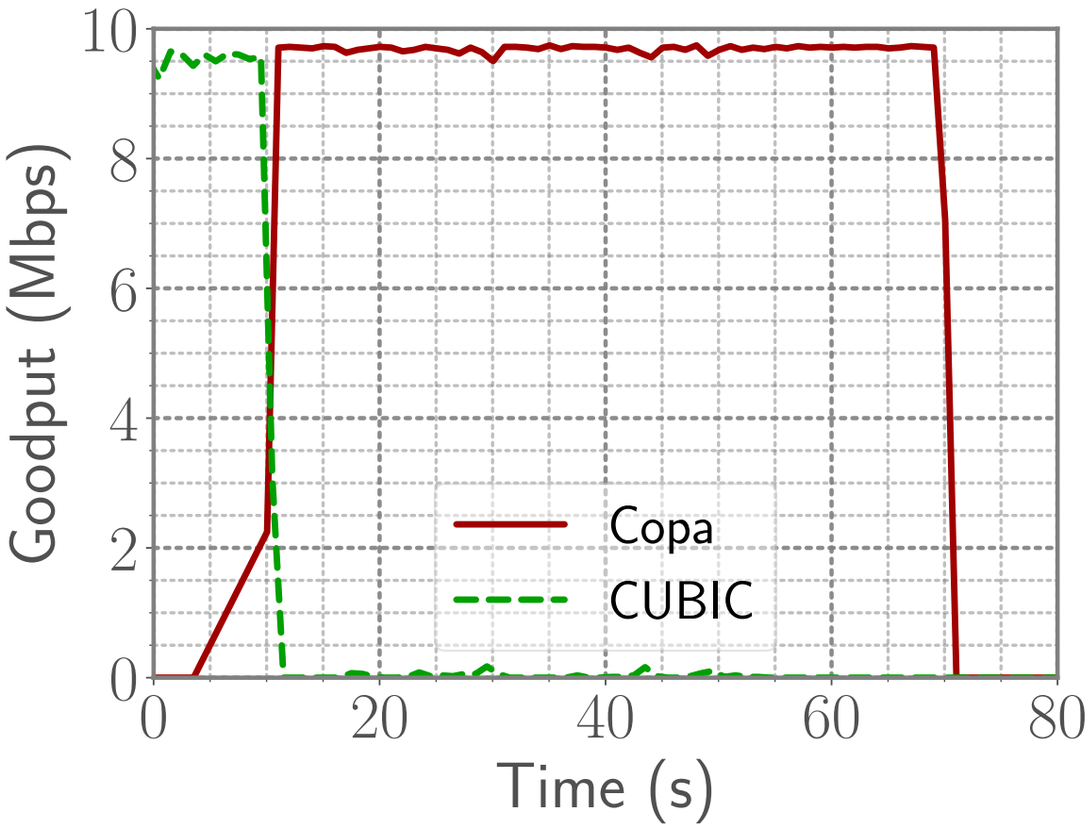
BBR occupies 90.6% bandwidth
when competing with CUBIC



1 CUBIC vs. 1 BBR

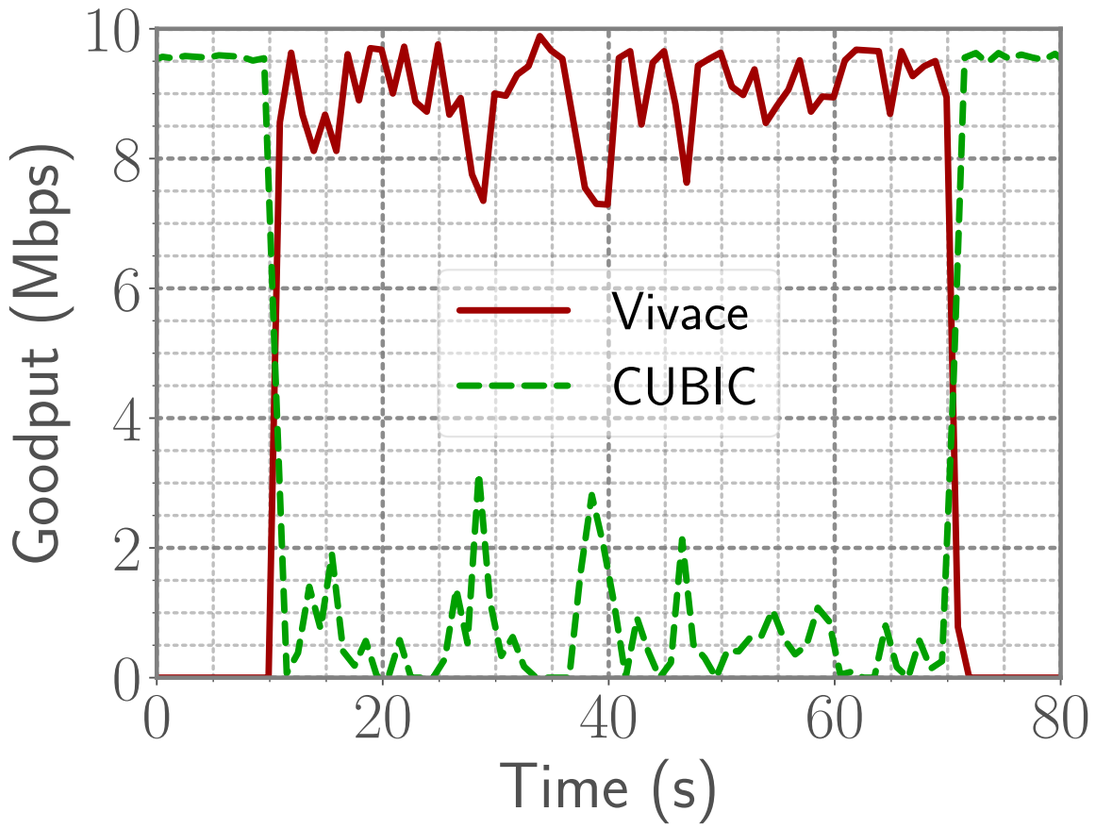
The Unfairness Problem

Copa occupies 99.8% bandwidth



1 CUBIC vs. 1 Copa

PCC Vivace occupies 93.8% bandwidth



1 CUBIC vs. 1 PCC Vivace

More in Paper: How new CC occupies the majority of bandwidth

How to Tackle the Unfairness Problem?

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Improve Congestion Control

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Not Practicable:
Content Providers want higher bandwidth

How to Tackle the Unfairness Problem?

Improve Congestion Control

Use Traffic Shaping

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Use Traffic Shaping

Inflate RTT
Increase Overhead

How to Tackle the Unfairness Problem?

Our Approach

Improve Congestion Control

Not Practicable:
Content Providers want higher bandwidth

Use Traffic Shaping

Inflate RTT
Increase Overhead

FairPolicer: Enforce Fairness in the Policer

Design of FairPolicer

Observation

Bandwidth is allocated in the unit of Tokens

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↓

Goal

Fairly allocate tokens to flows

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Basic Idea

Per-flow Token Buckets

Design of FairPolicer

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Bandwidth is allocated in the unit of Tokens

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Fairly allocate tokens to flows

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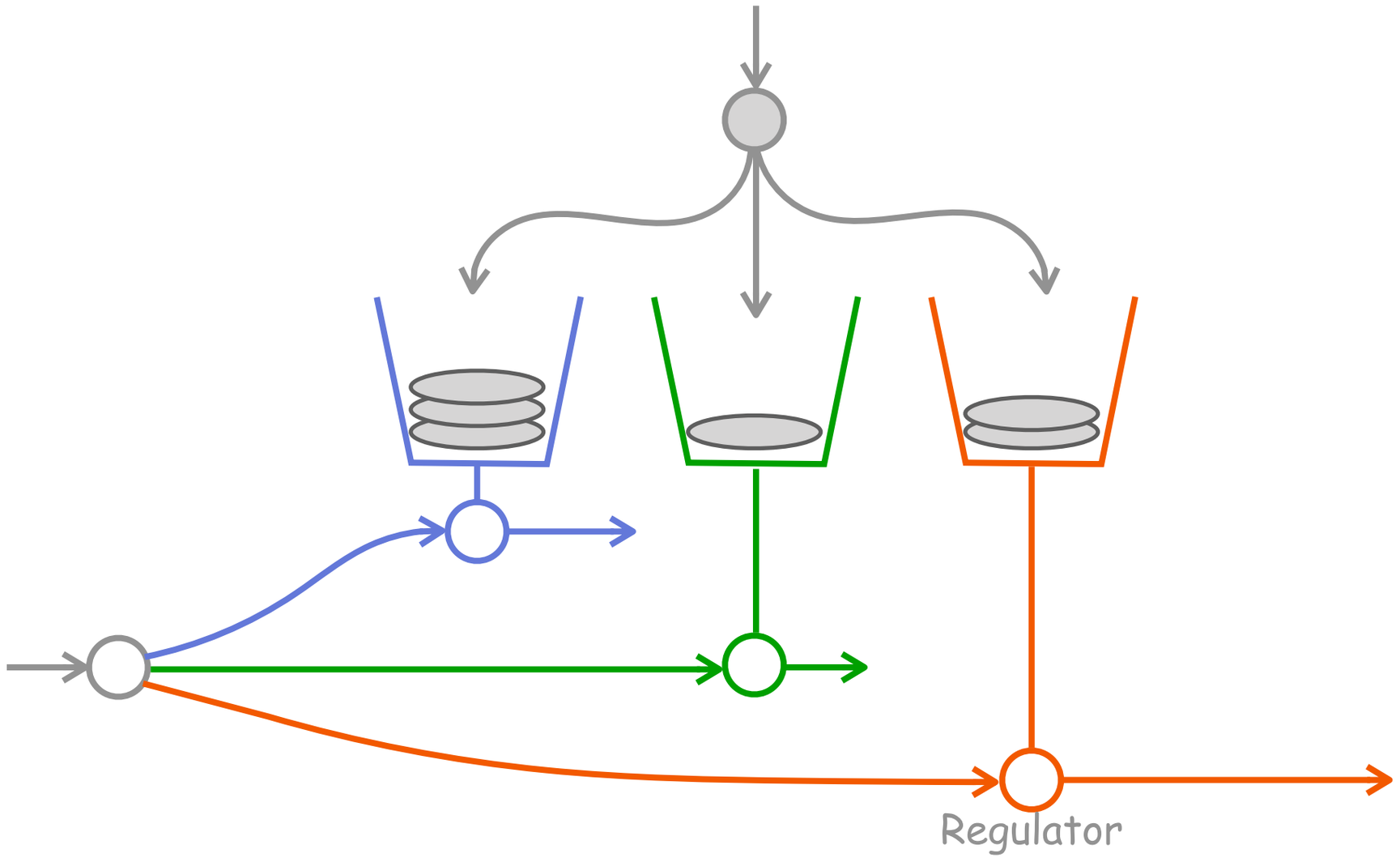
Basic Idea

Per-flow Token Buckets

↑

Token bucket is a very simple structure
(Counter)

Design of FairPolicer



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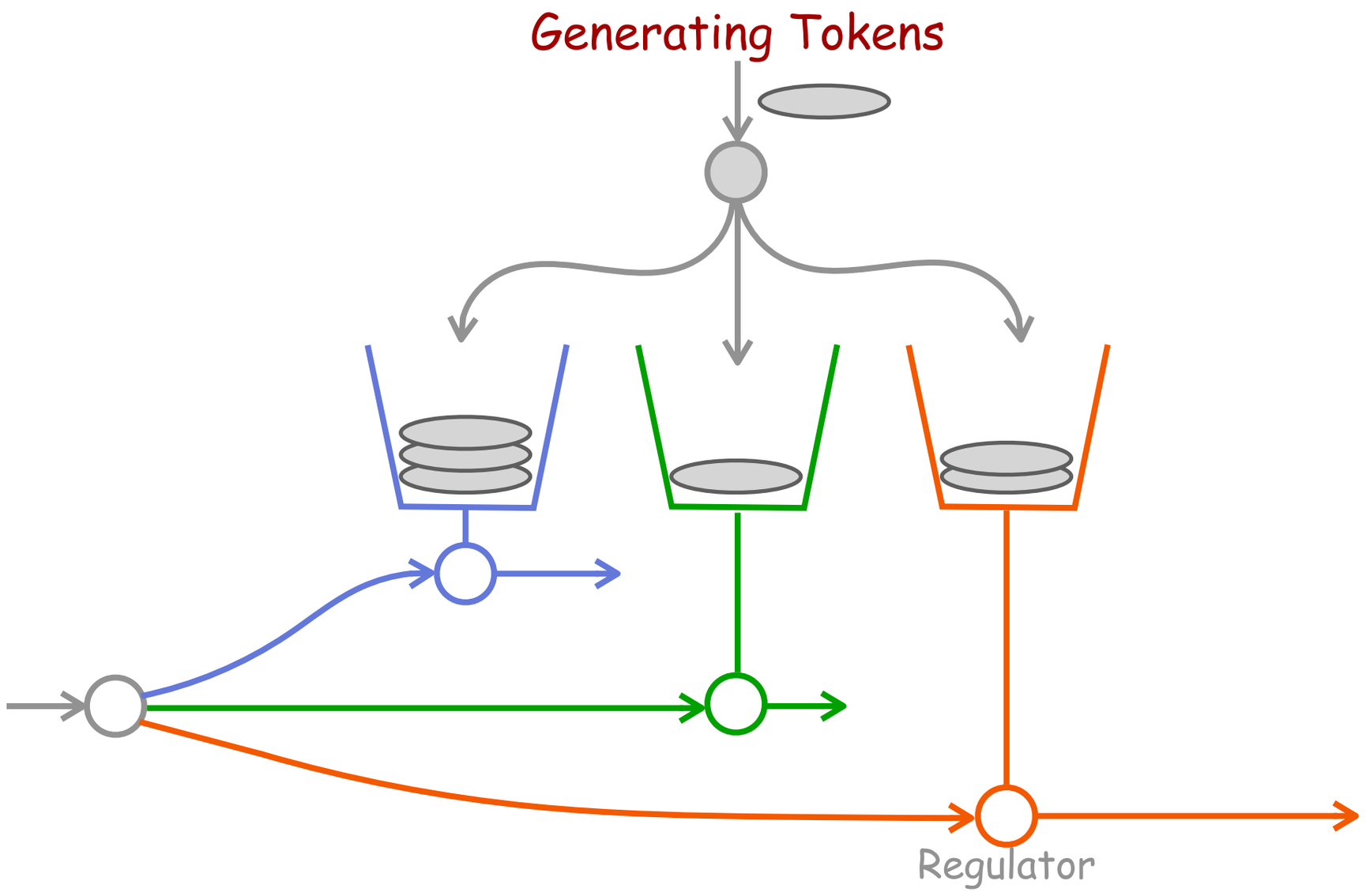

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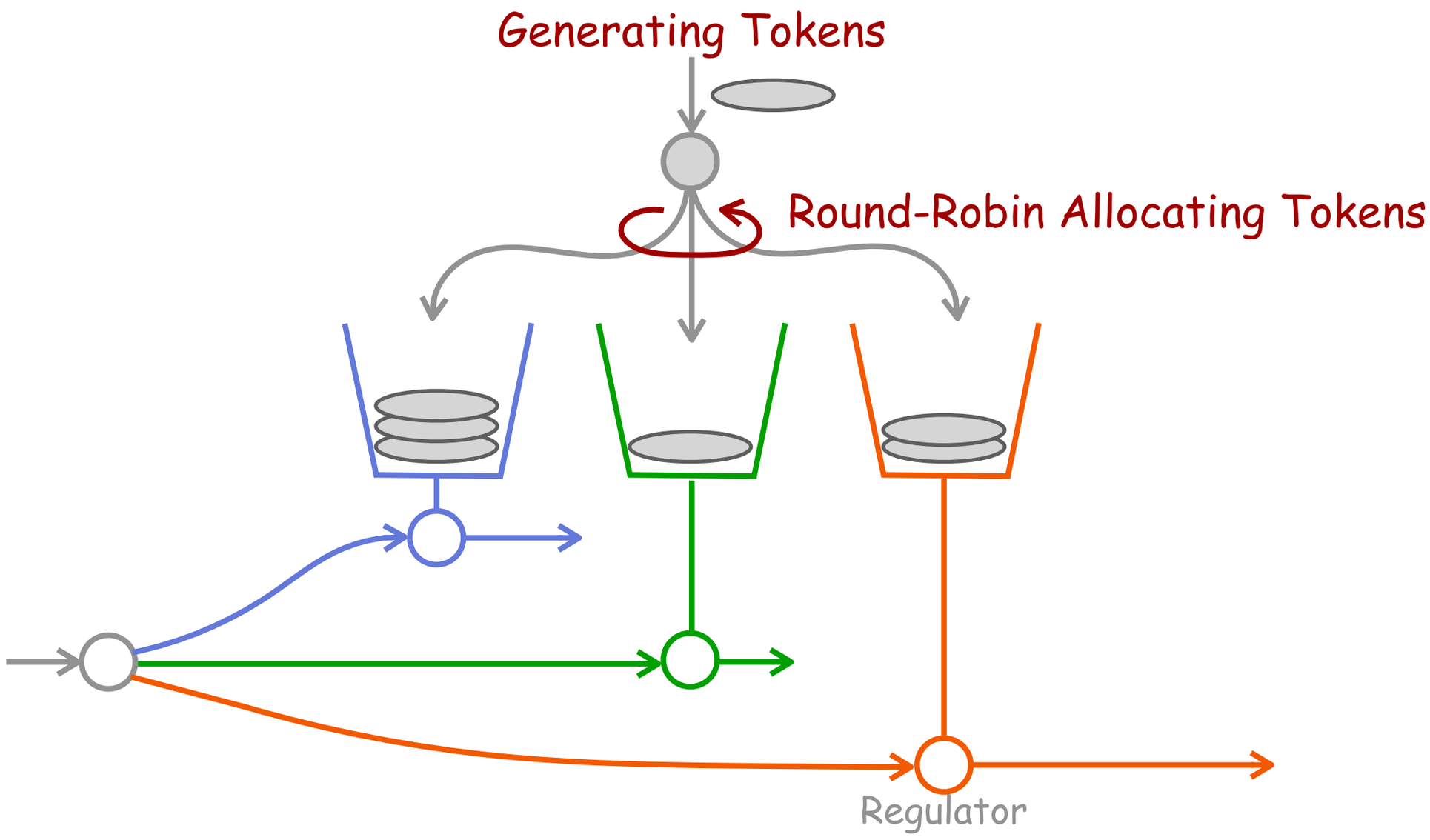

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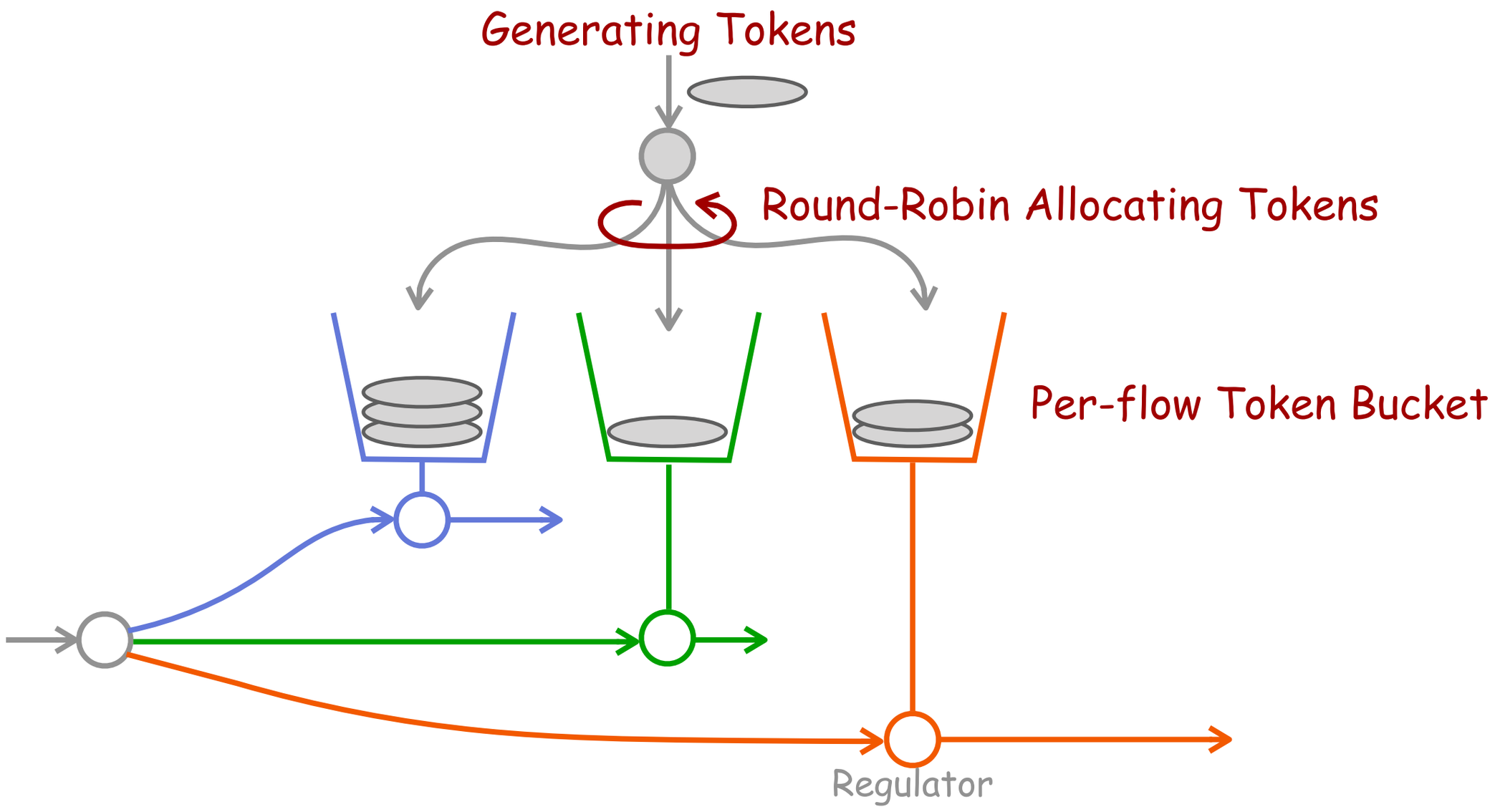

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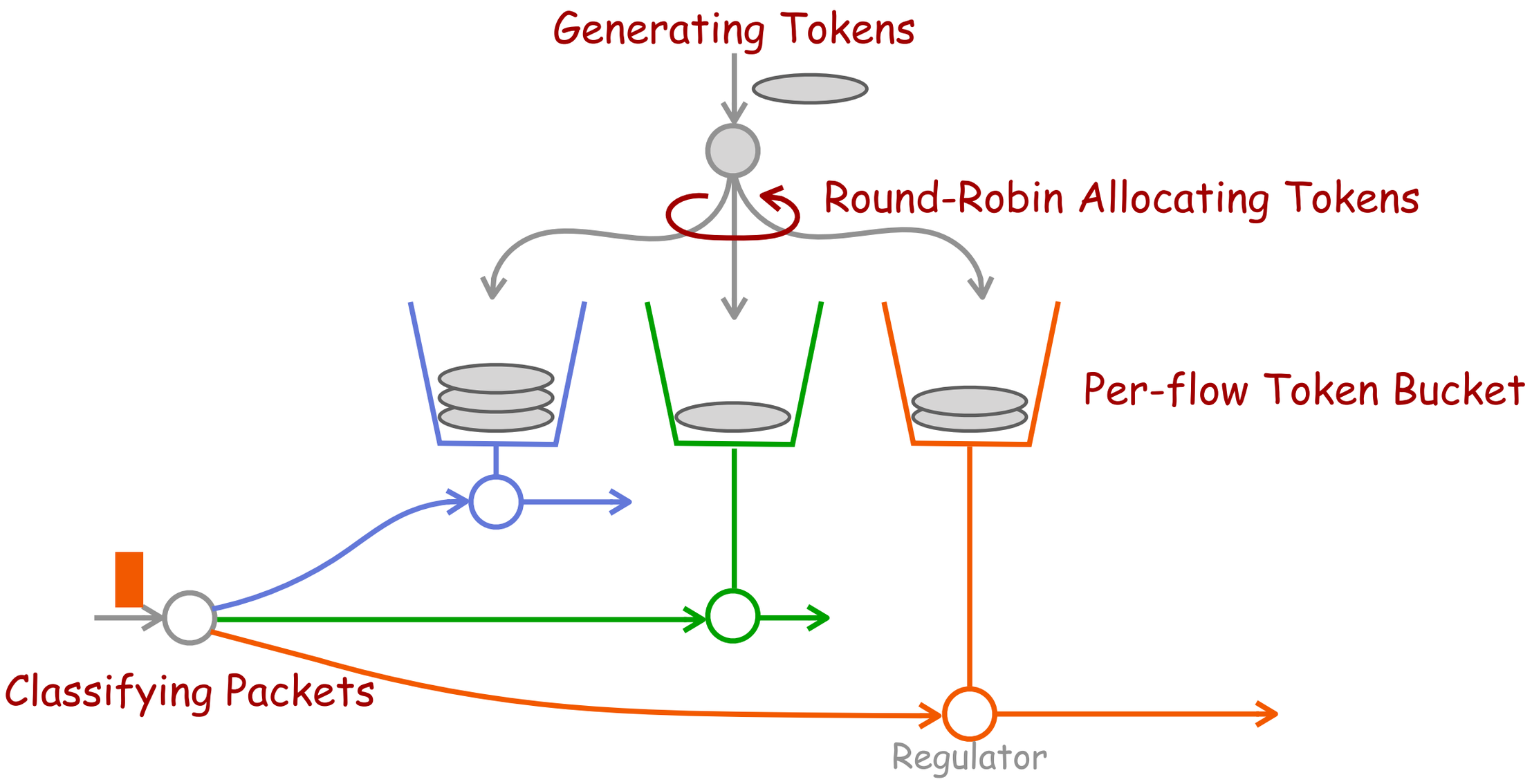

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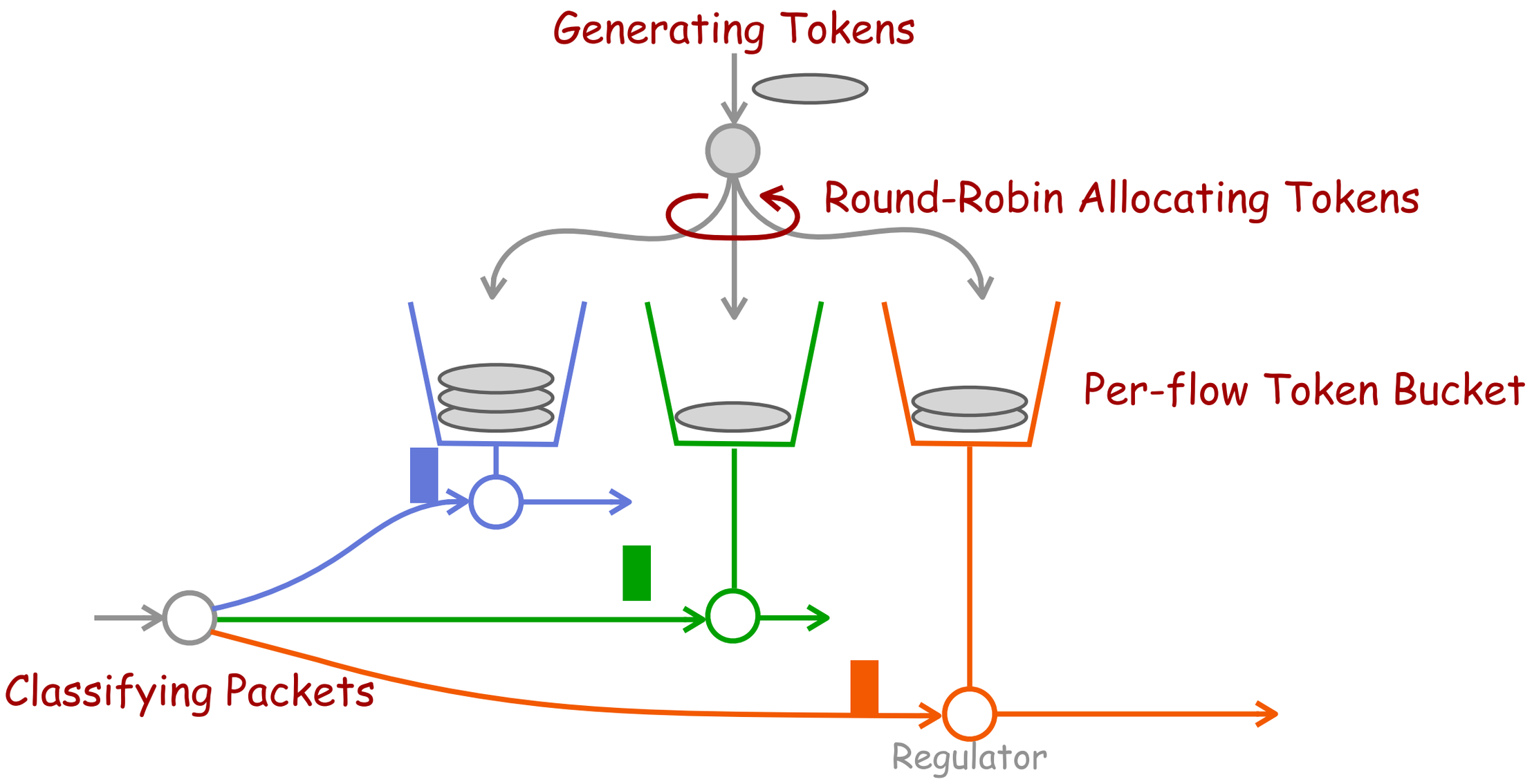
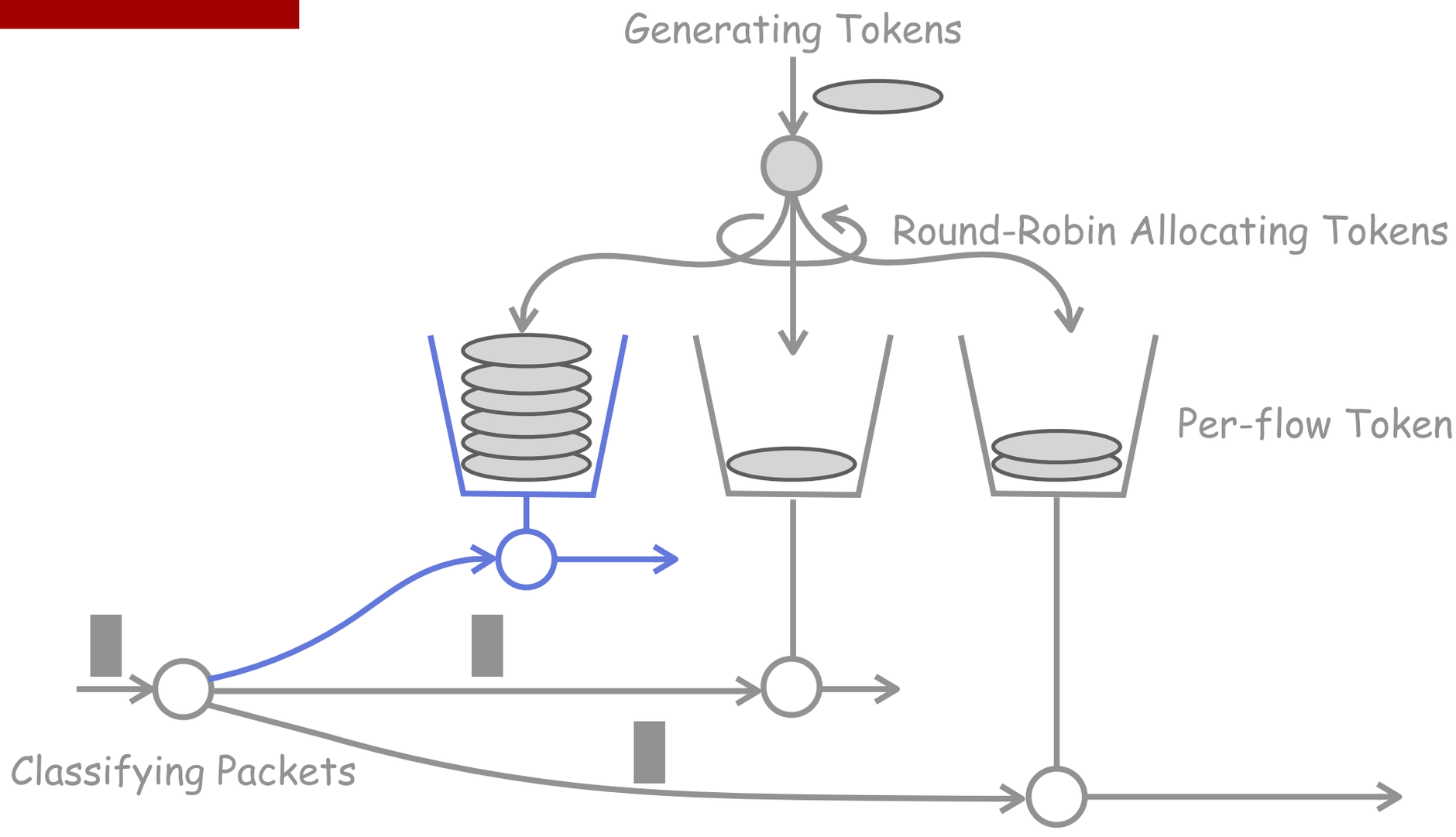


Basic Idea

Design of FairPolicer

Challenges #1: Flows Come and Go

Flow becomes inactive

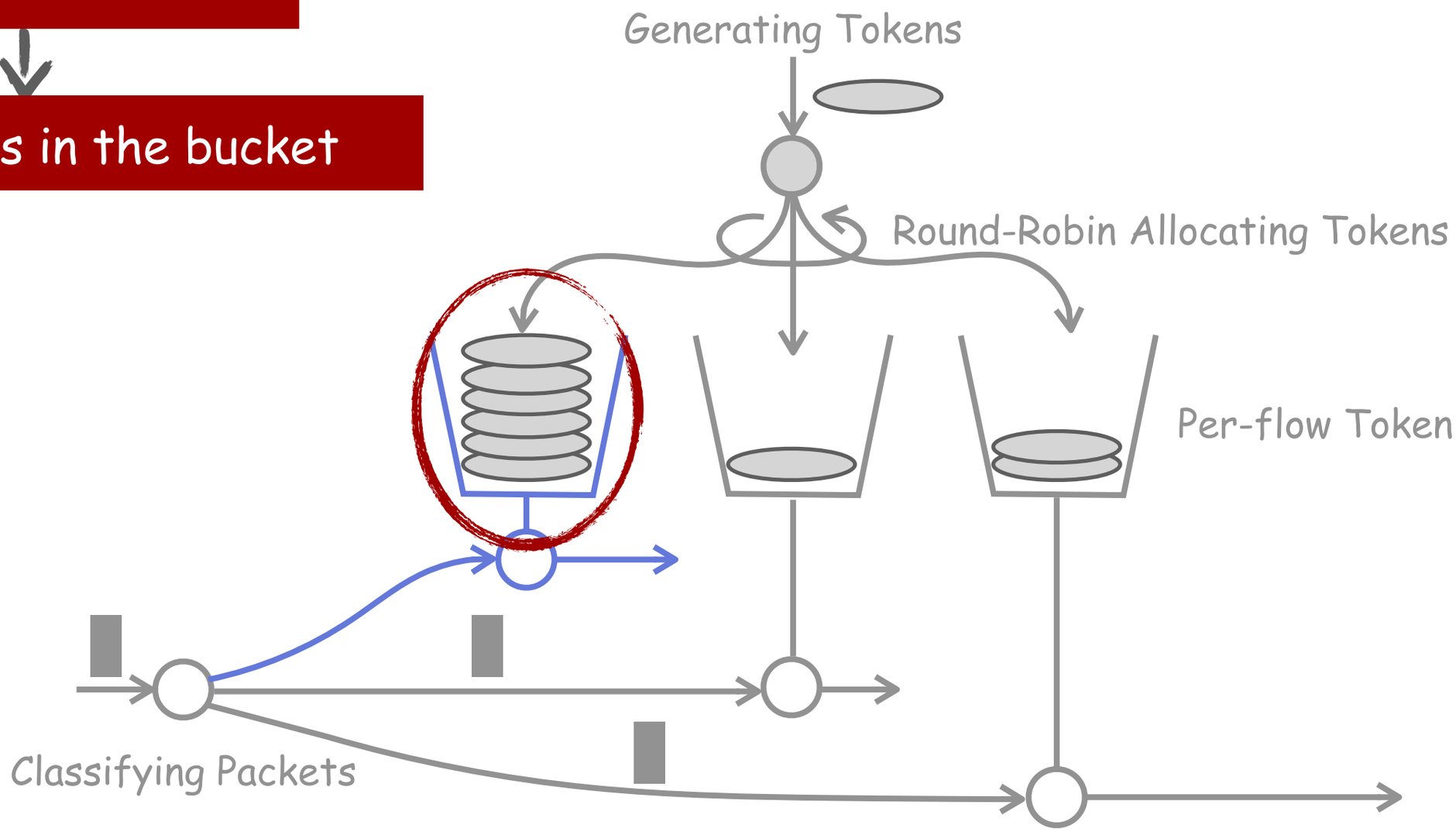


Design of FairPolicer

Challenges #1: Flows Come and Go

Flow becomes inactive

Full of tokens in the bucket



Design of FairPolicer

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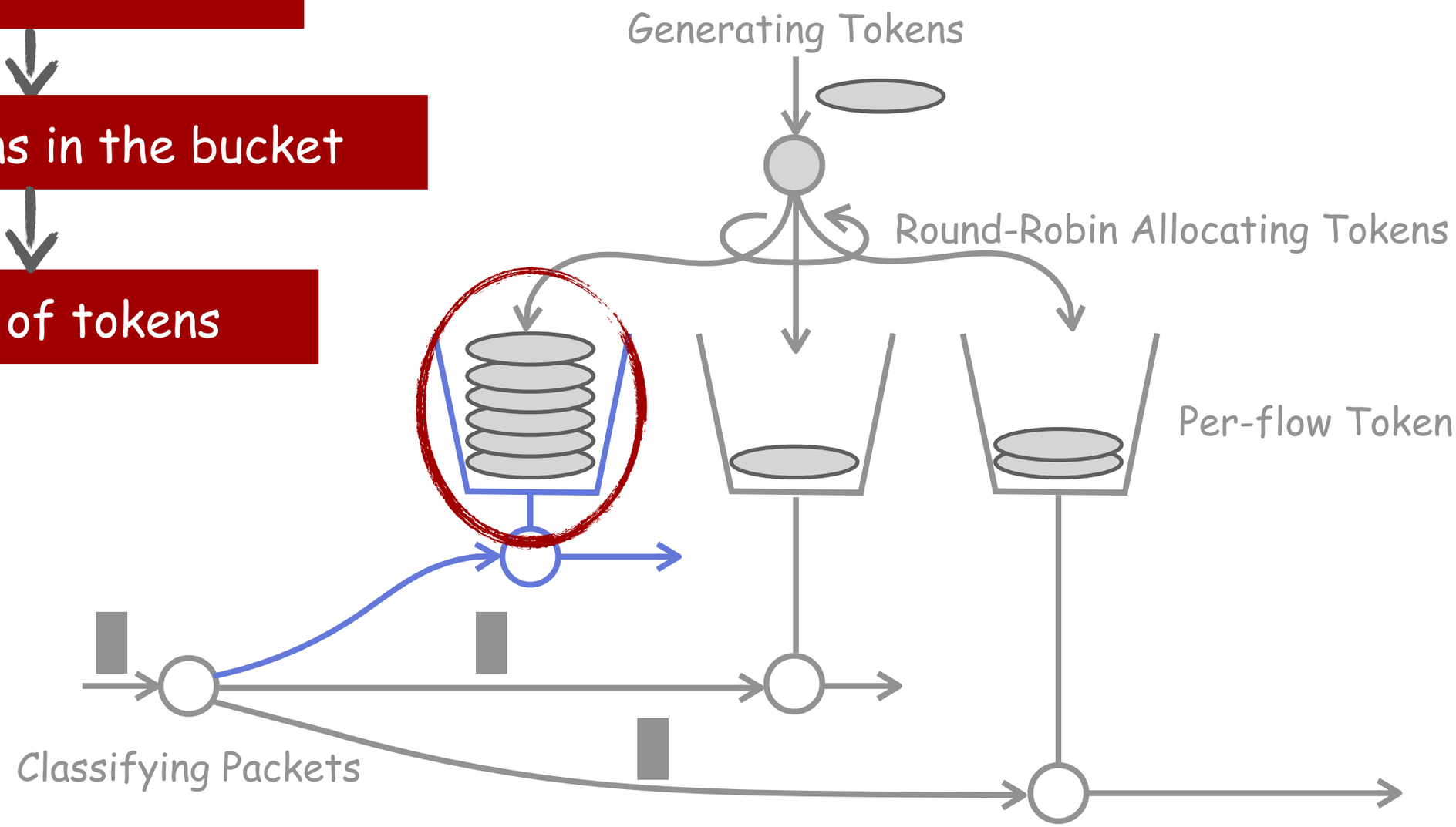
Full of tokens in the bucket

Waste of tokens



Design of FairPolicer

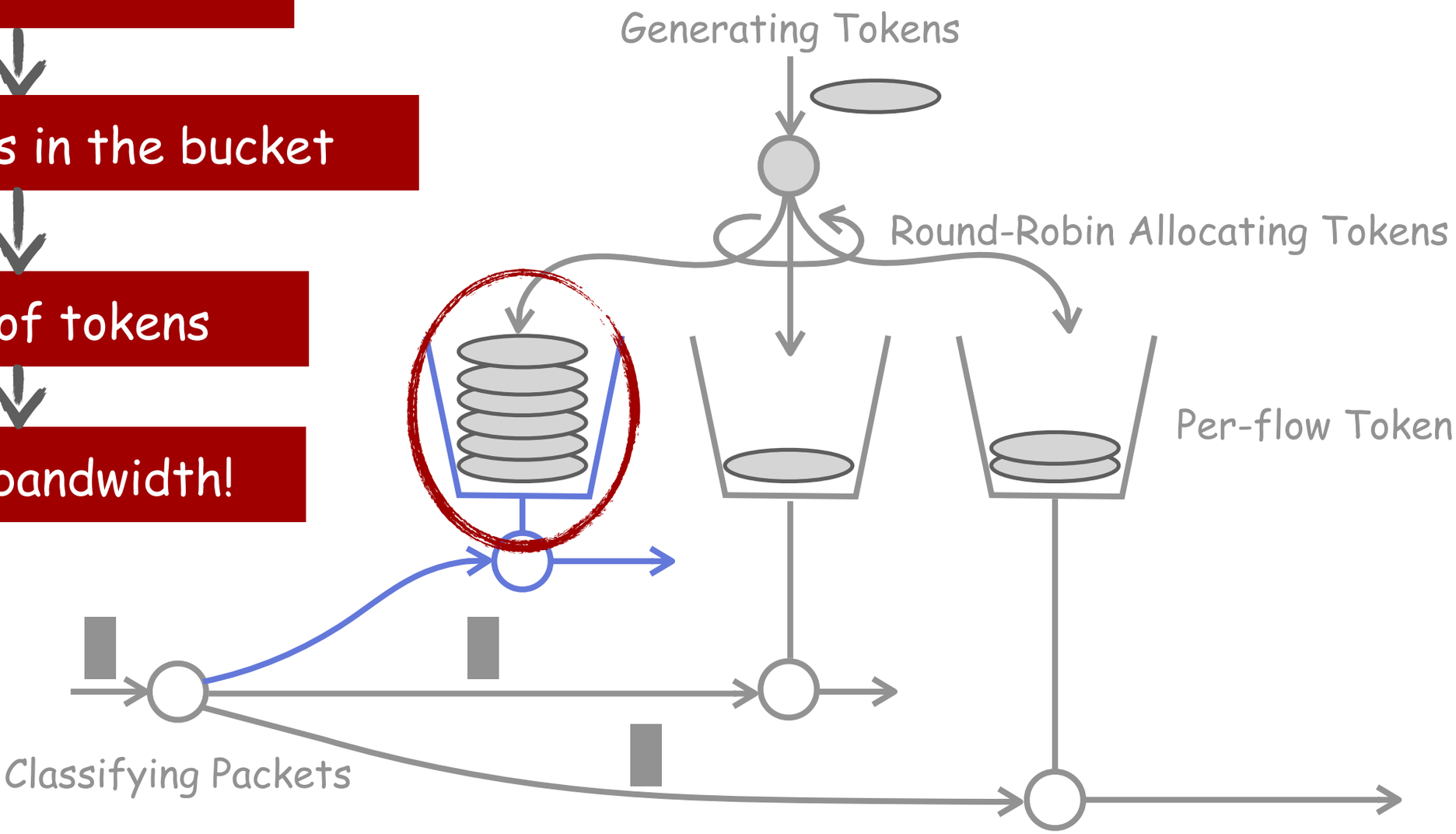
Challenges #1: Flows Come and Go

Flow becomes inactive

Full of tokens in the bucket

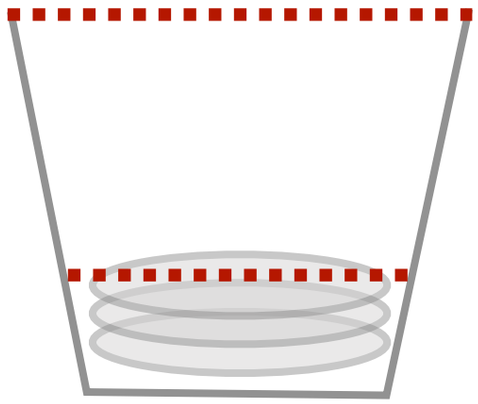
Waste of tokens

Waste of bandwidth!



Design of FairPolicer

Address Challenges #1



Token Bucket

Design of FairPolicer

Address Challenges #1

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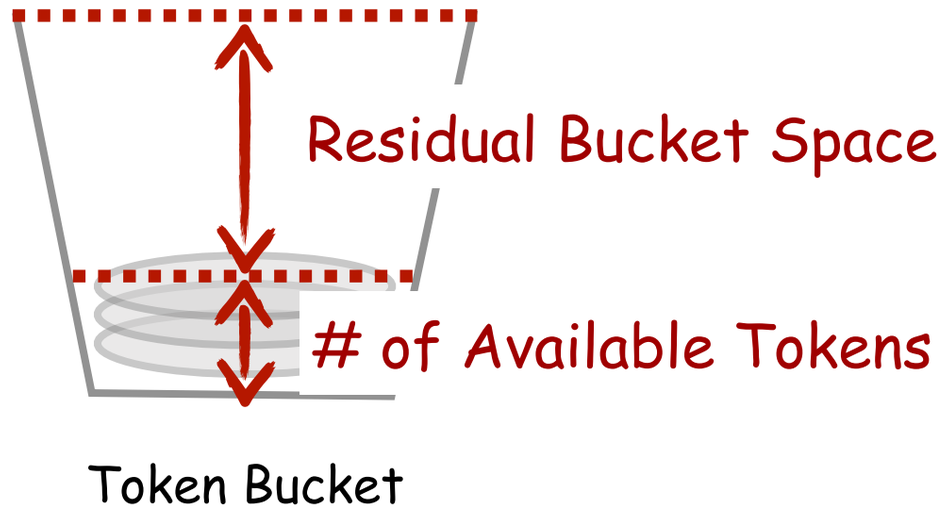


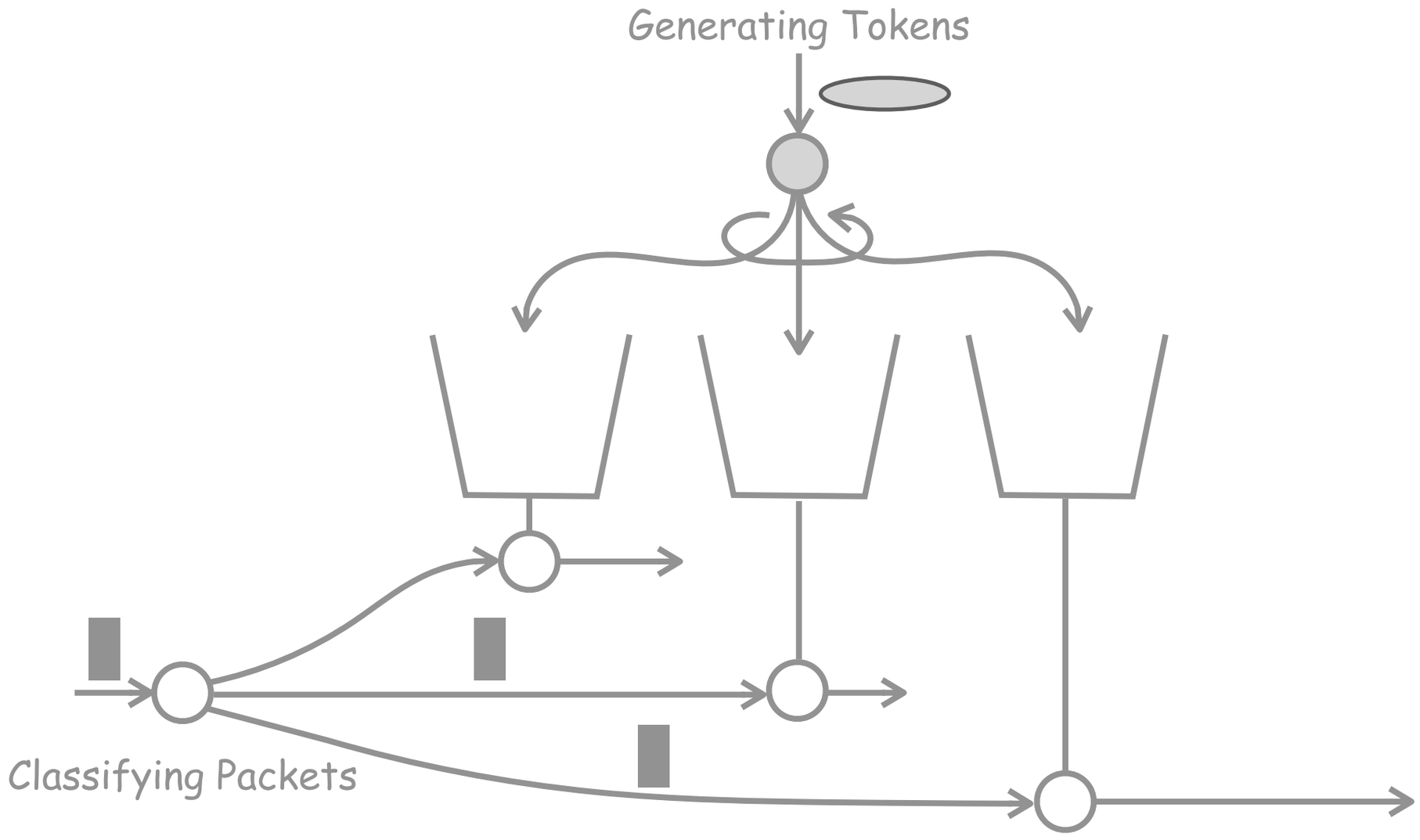
Token Bucket

Token Bucket Full ⟷ Residual Bucket Space = 0

Residual bucket space instead of # of available tokens

Design of FairPolicer

Address Challenges #1



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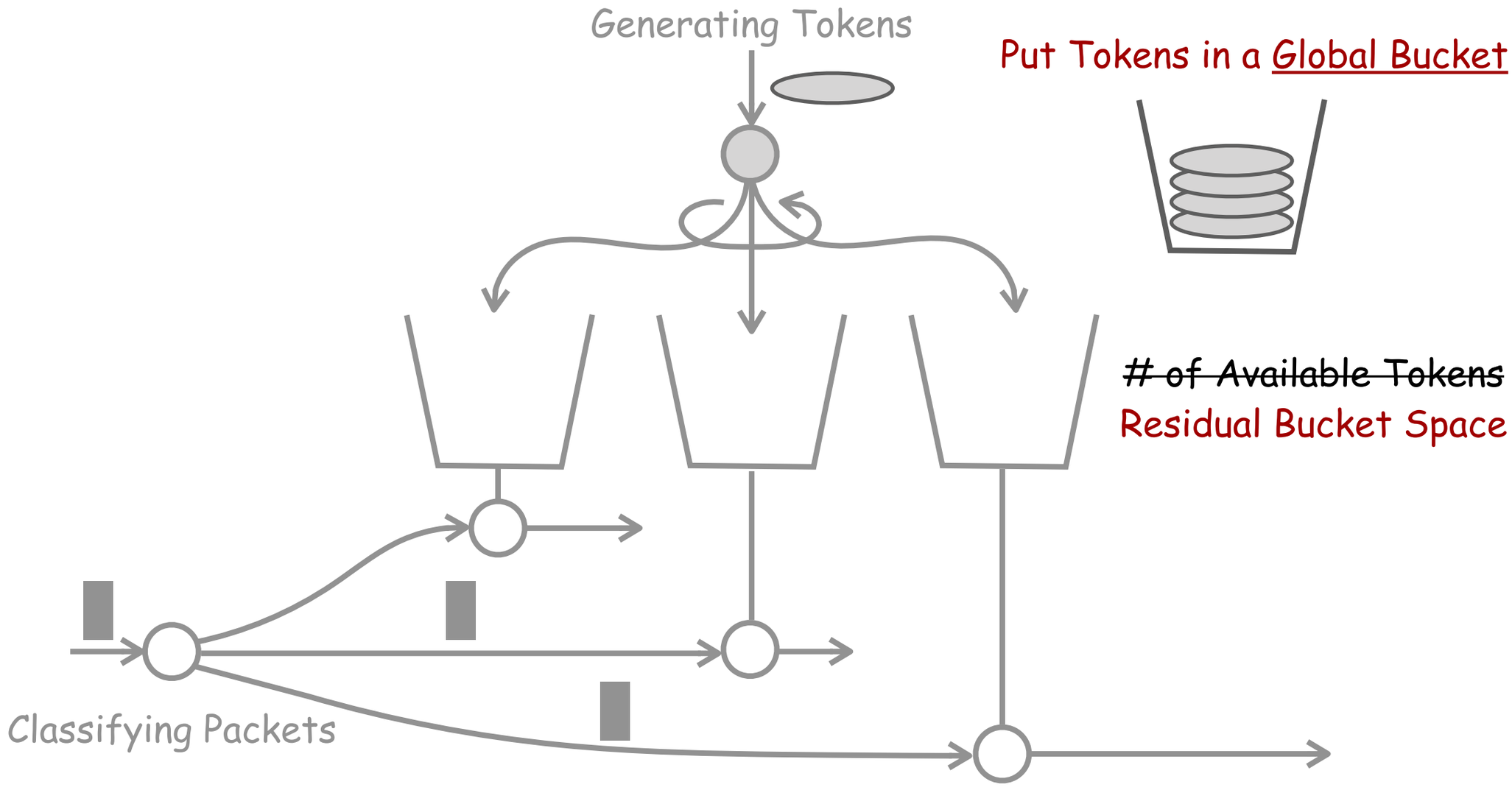

Design of FairPolicer

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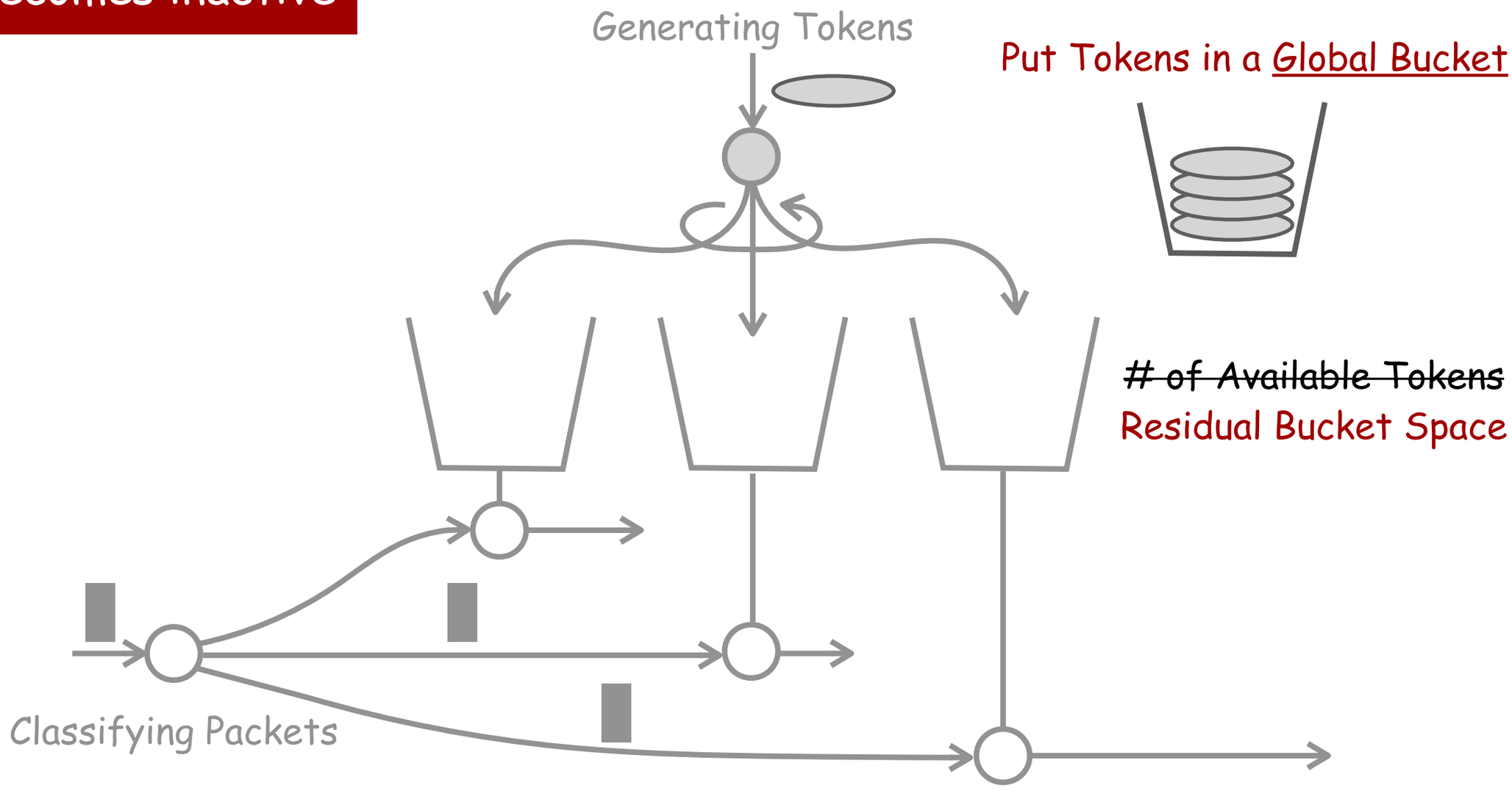
Flow becomes inactive



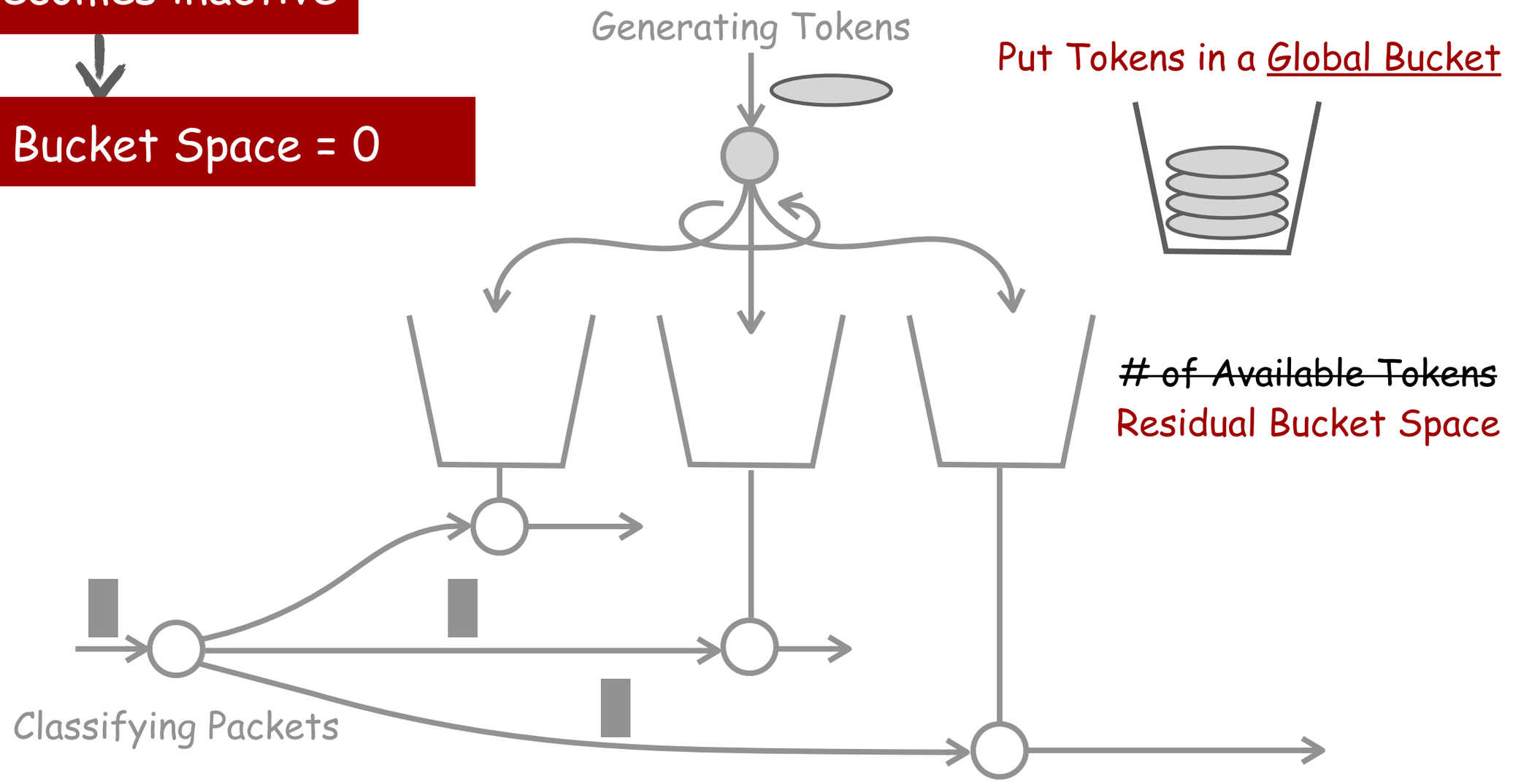
Design of FairPolicer

Address Challenges #1

Flow becomes inactive

↓

Residual Bucket Space = 0



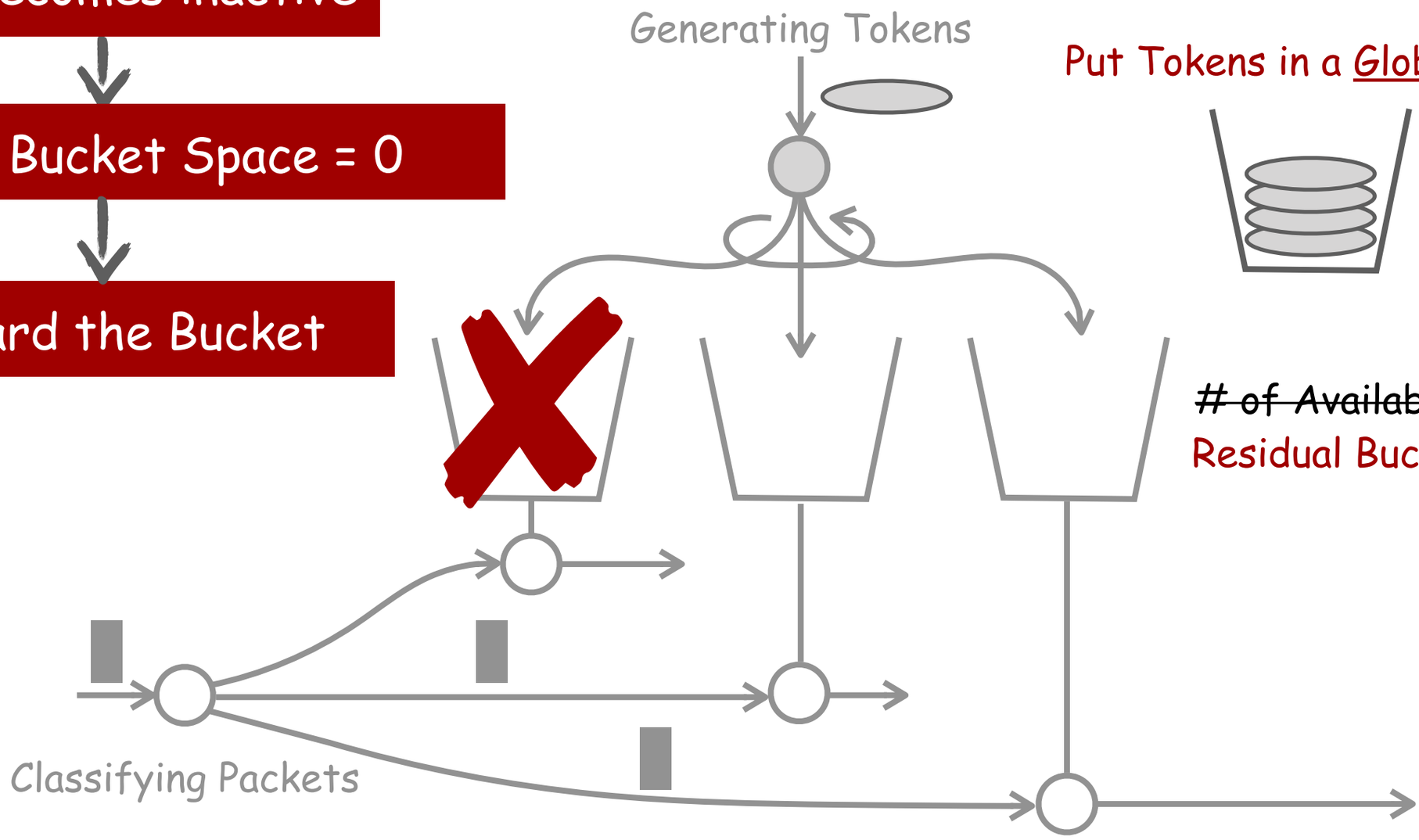
Design of FairPolicer

Address Challenges #1

Flow becomes inactive

Residual Bucket Space = 0

Discard the Bucket



Put Tokens in a Global Bucket

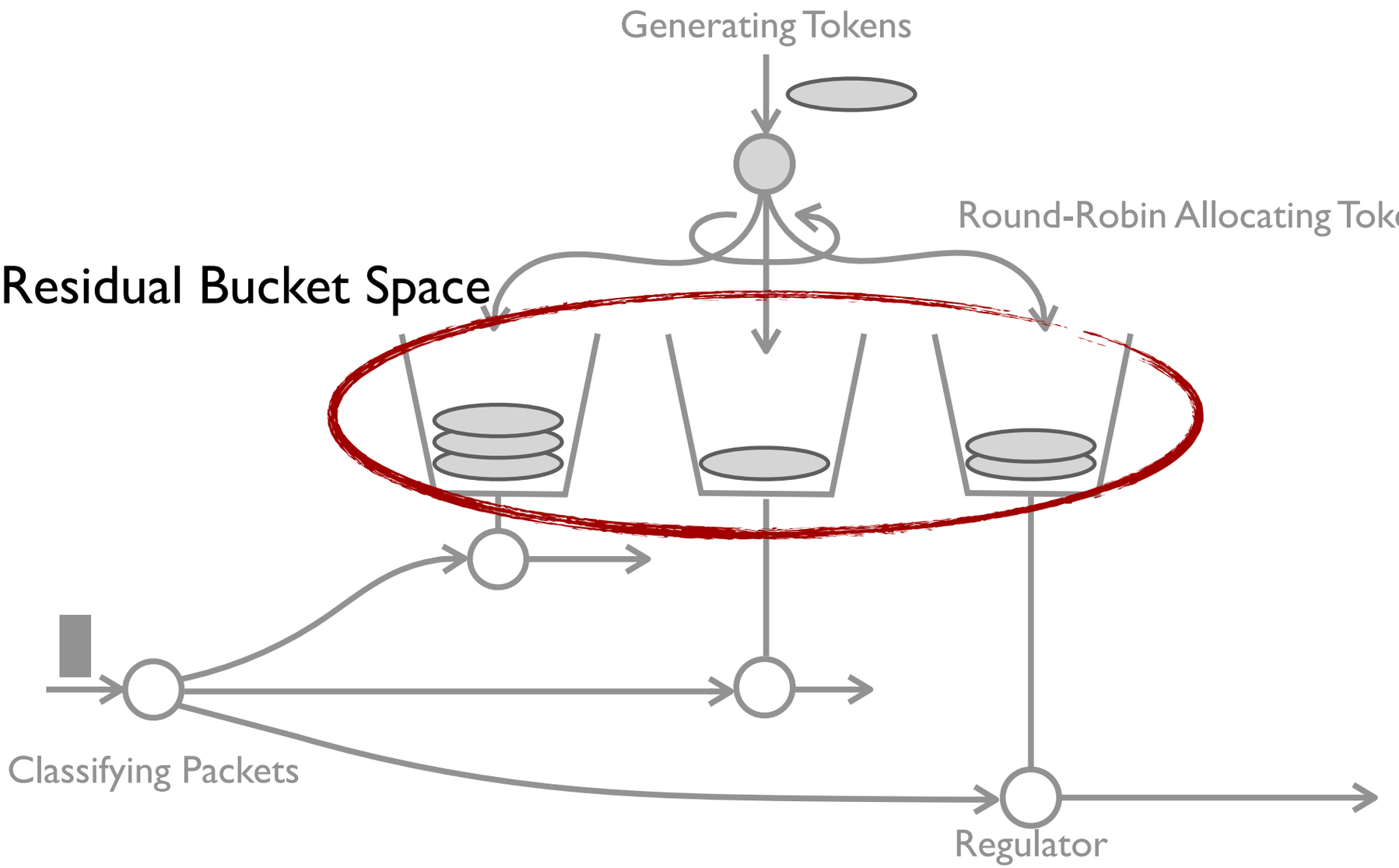
~~# of Available Tokens~~

Residual Bucket Space

Design of FairPolicer

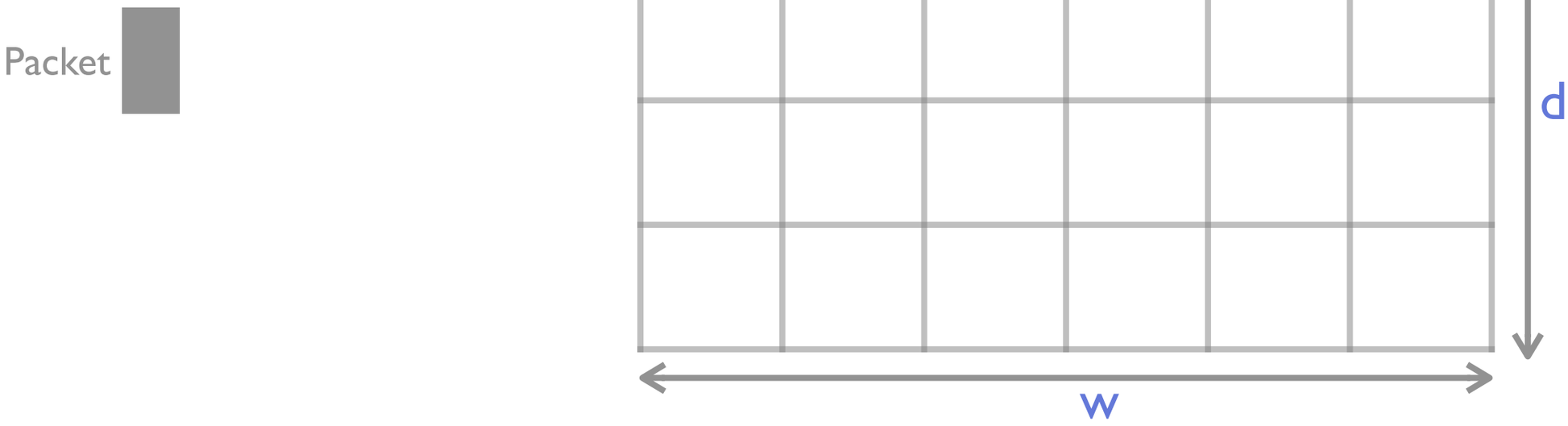
Challenges #2: Maintain Per-flow Data

Per-flow Residual Bucket Space



Design of FairPolicer

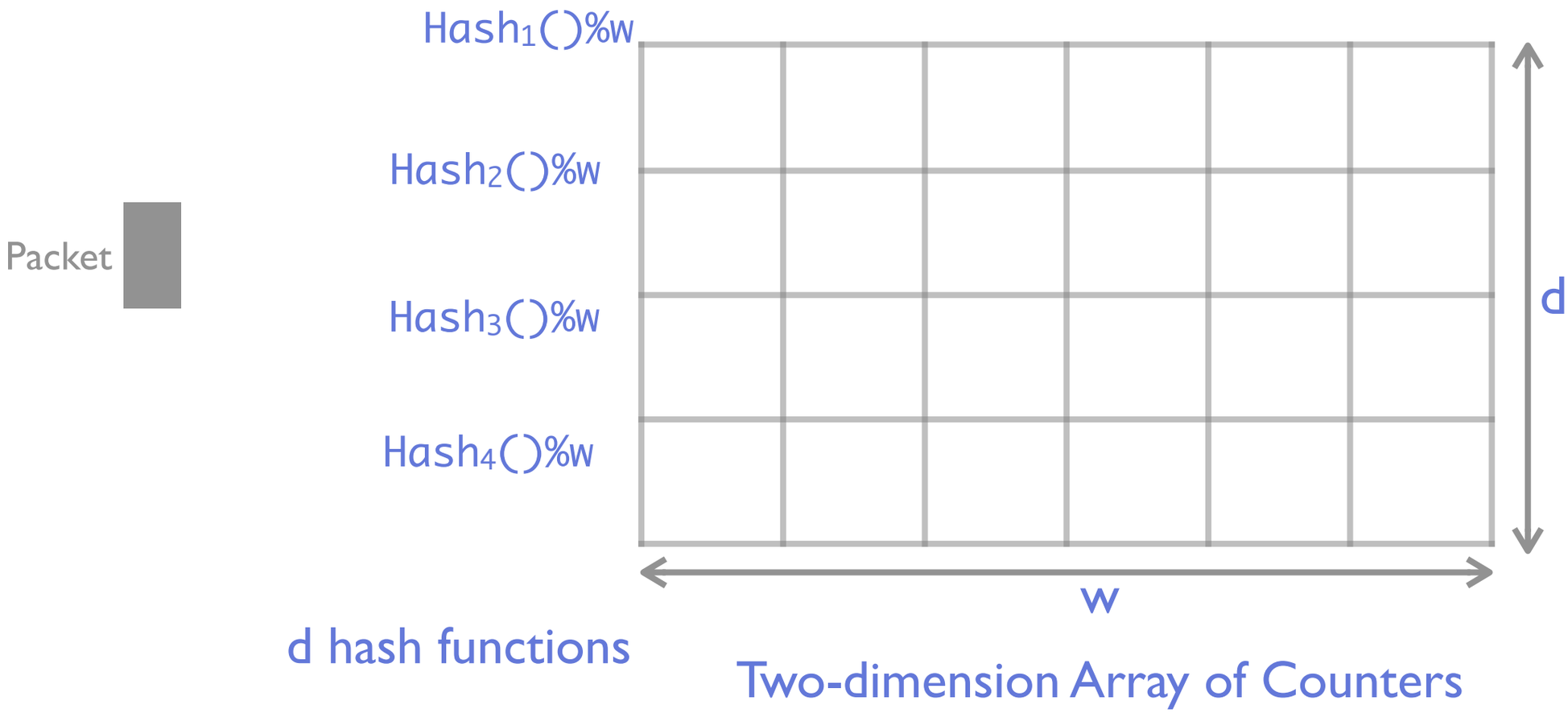
Address Challenges #2: Count-min Sketch



Two-dimension Array of Counters

Design of FairPolicer

Address Challenges #2: Count-min Sketch



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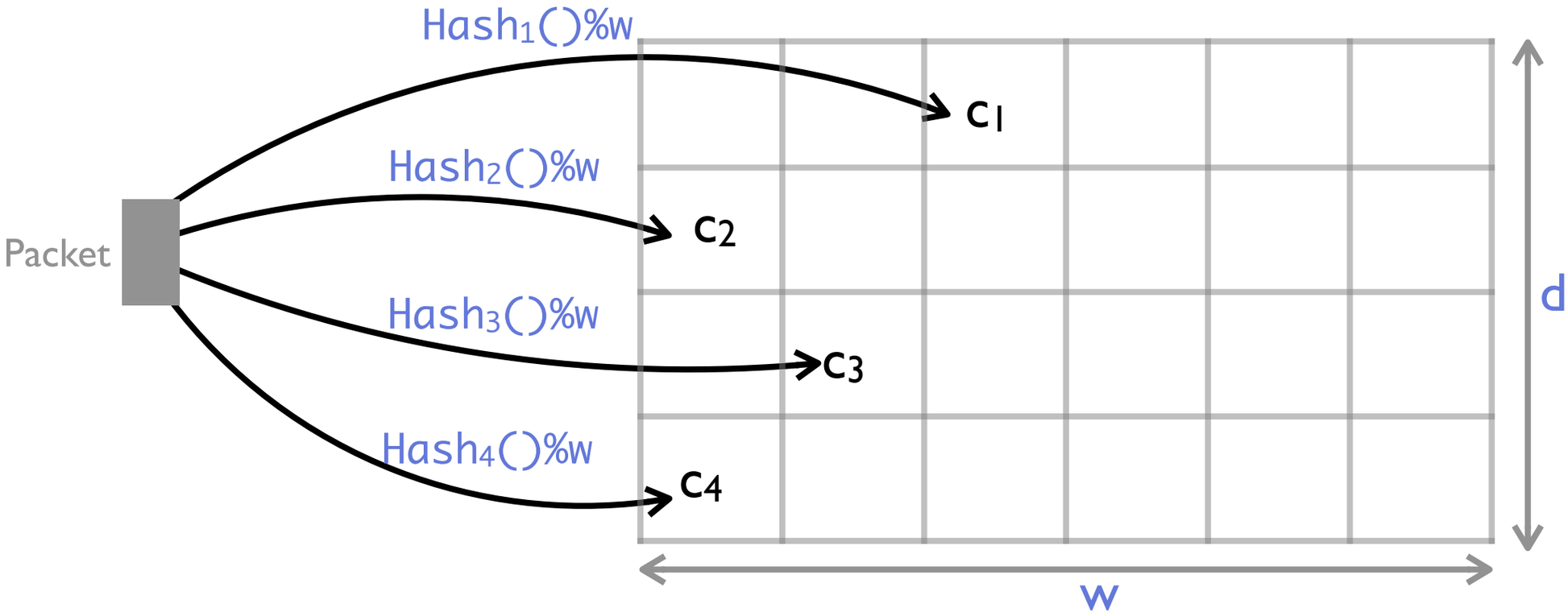
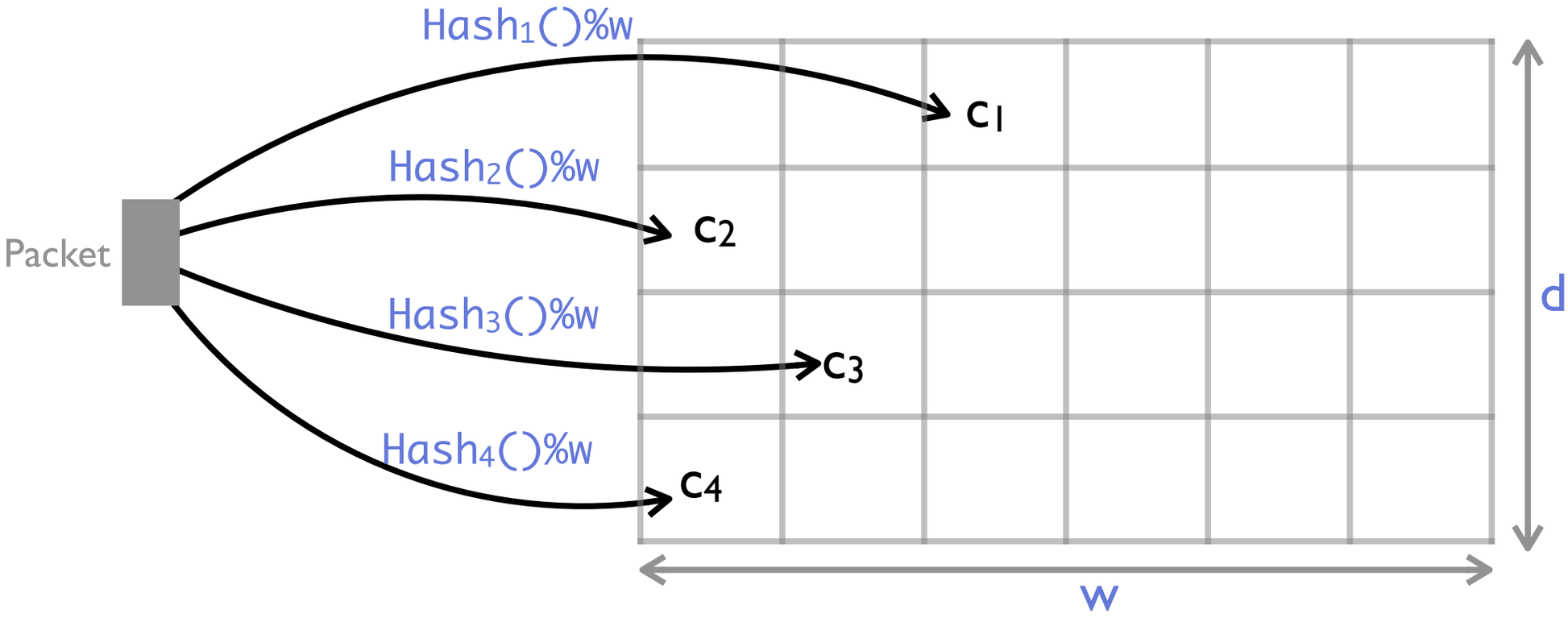


Design of FairPolicer

Address Challenges #2: Count-min Sketch

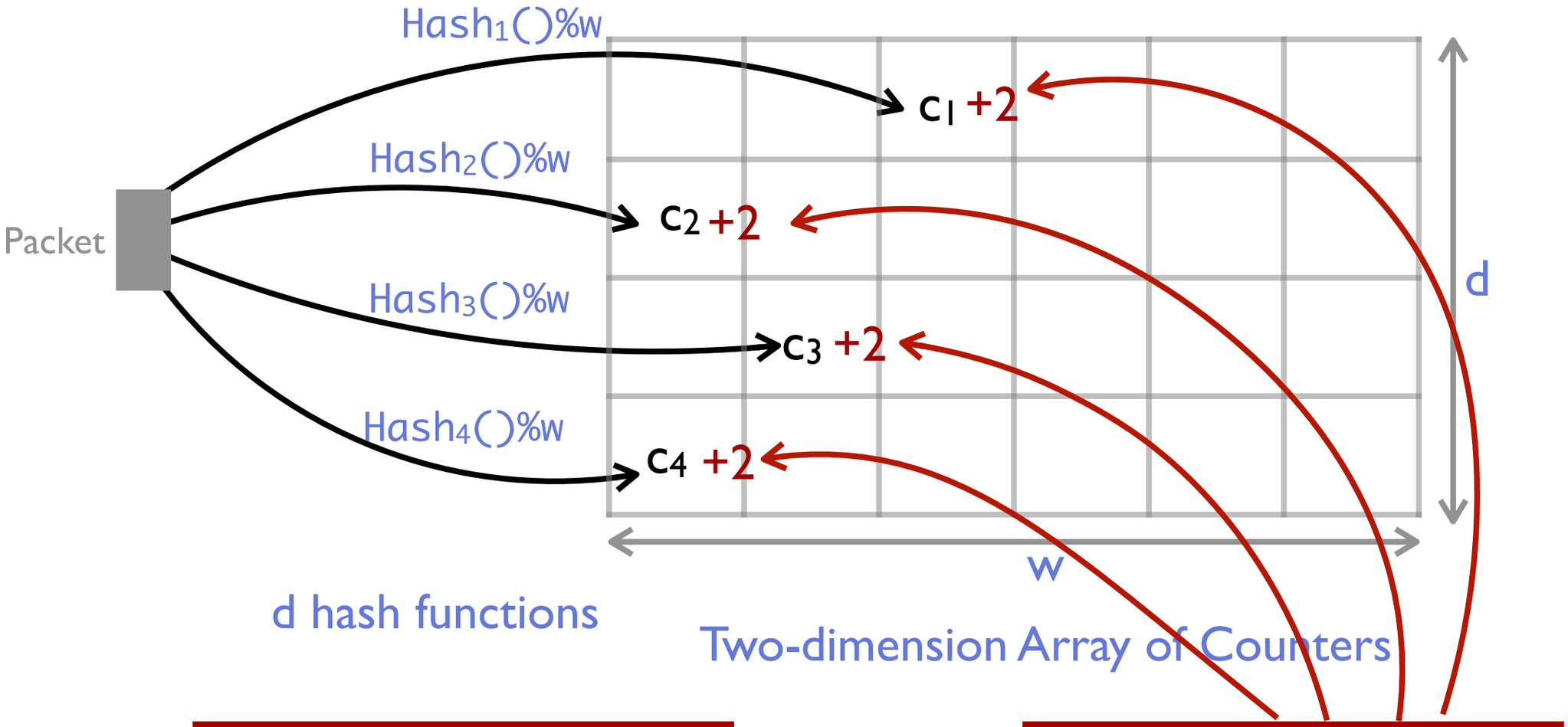


Update Per-flow Data

Query Per-flow Data

Design of FairPolicer

Address Challenges #2: Count-min Sketch

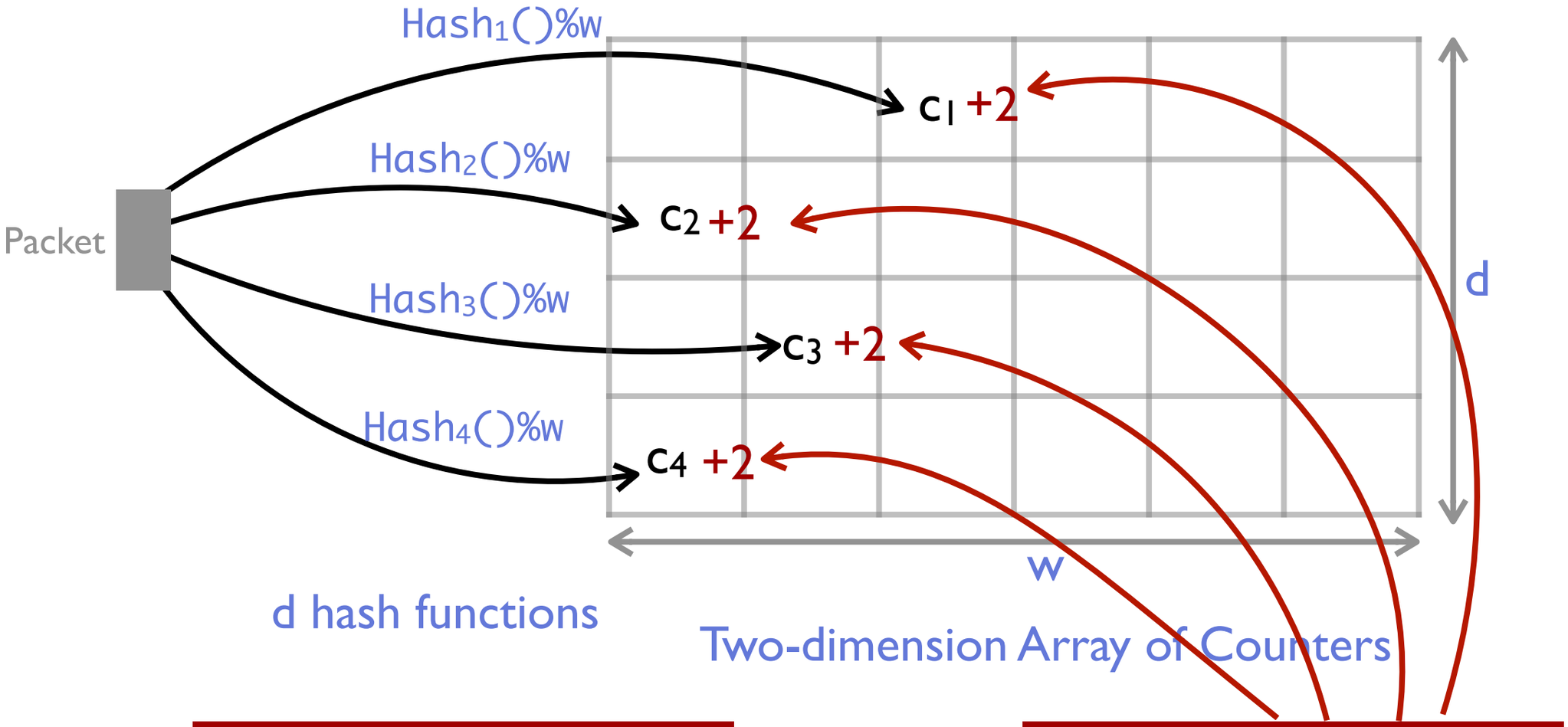


Update Per-flow Data → Update All Counters

Query Per-flow Data

Design of FairPolicer

Address Challenges #2: Count-min Sketch

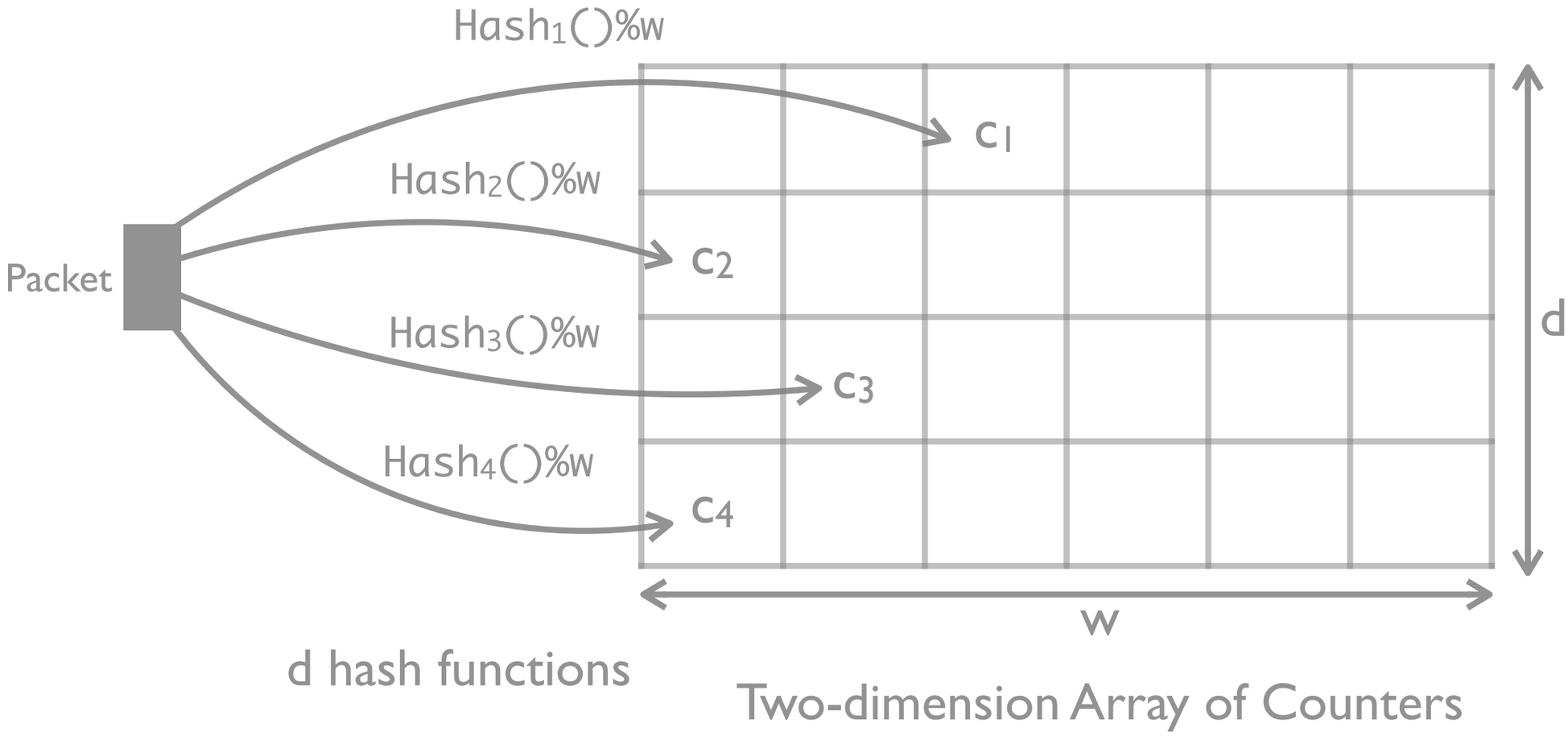


Update Per-flow Data → Update All Counters

Query Per-flow Data → Return the Minimum

Design of FairPolicer

Address Challenges #2: Count-min Sketch



Accuracy of Count-min Sketch with lots of flows?

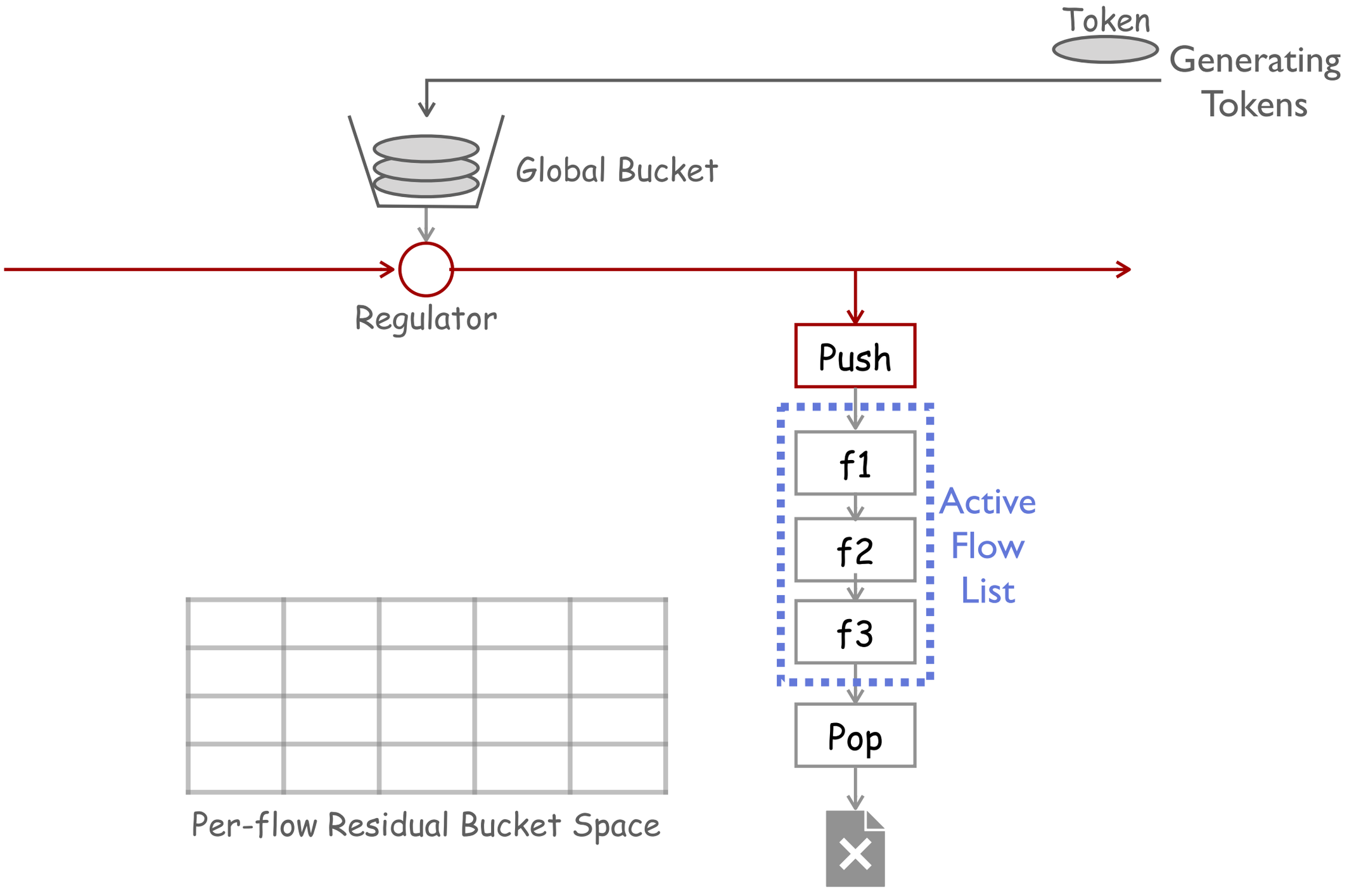
Accuracy of Count-Min Sketch

- The estimation error is bounded

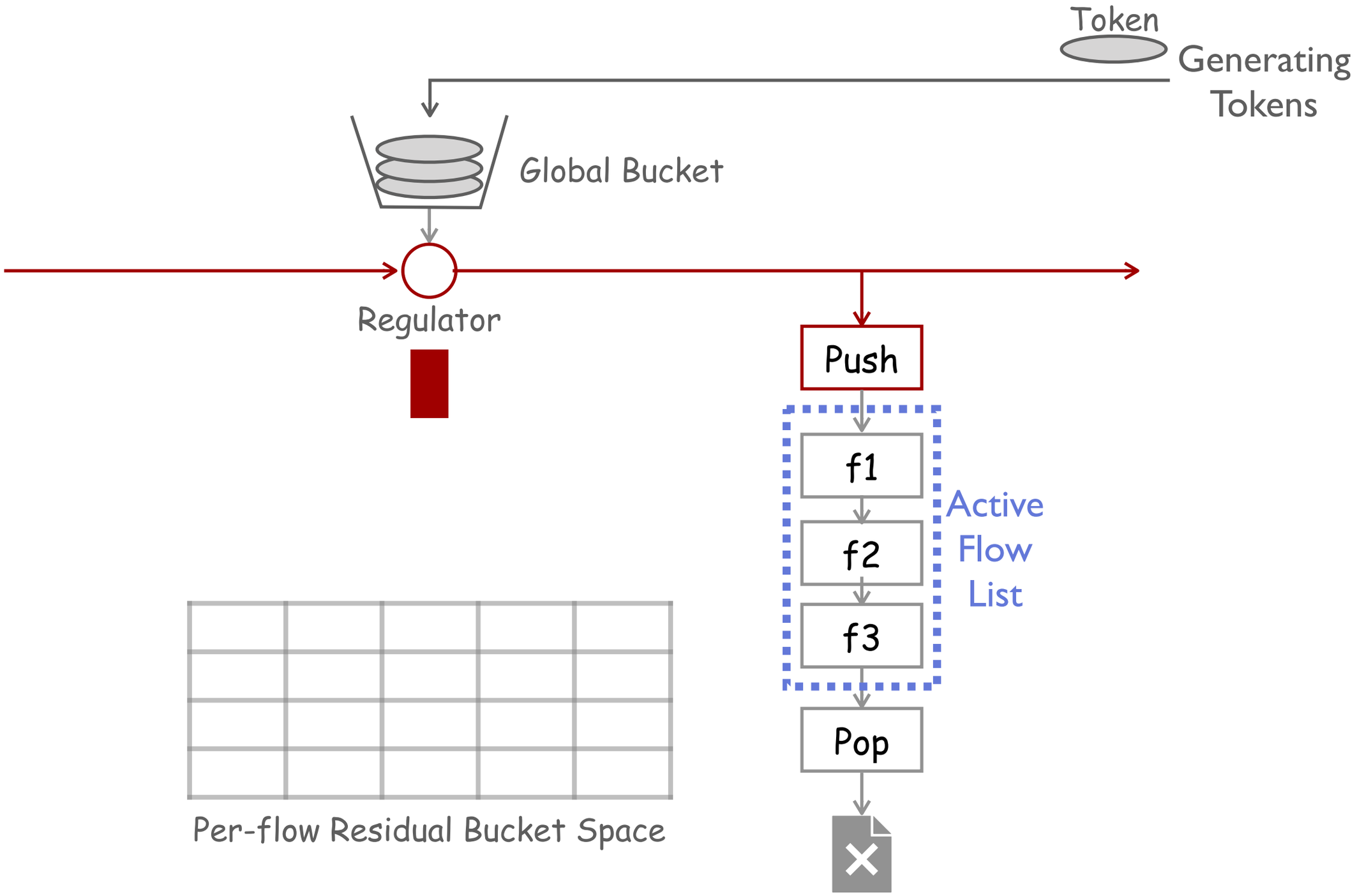
Theorem 1. *The estimation error is within ϵB with a probability of $1-\delta$, where $\epsilon = e/w$ and $\delta = 1/e^d$.*

- Employing a large Count-Min Sketch is not exorbitant
  - A counter is no larger than B (bucket size)
  - A counter only needs $\Theta(log_2 B)$ bits
  - E.g., 100KB bucket, 4×4096 sketch
    - 2B memory for a counter (40B granularity)
    - 32KB memory for the total sketch
    - Commercial switching chip: MBs memory

FairPolicer: On Packet Arrival



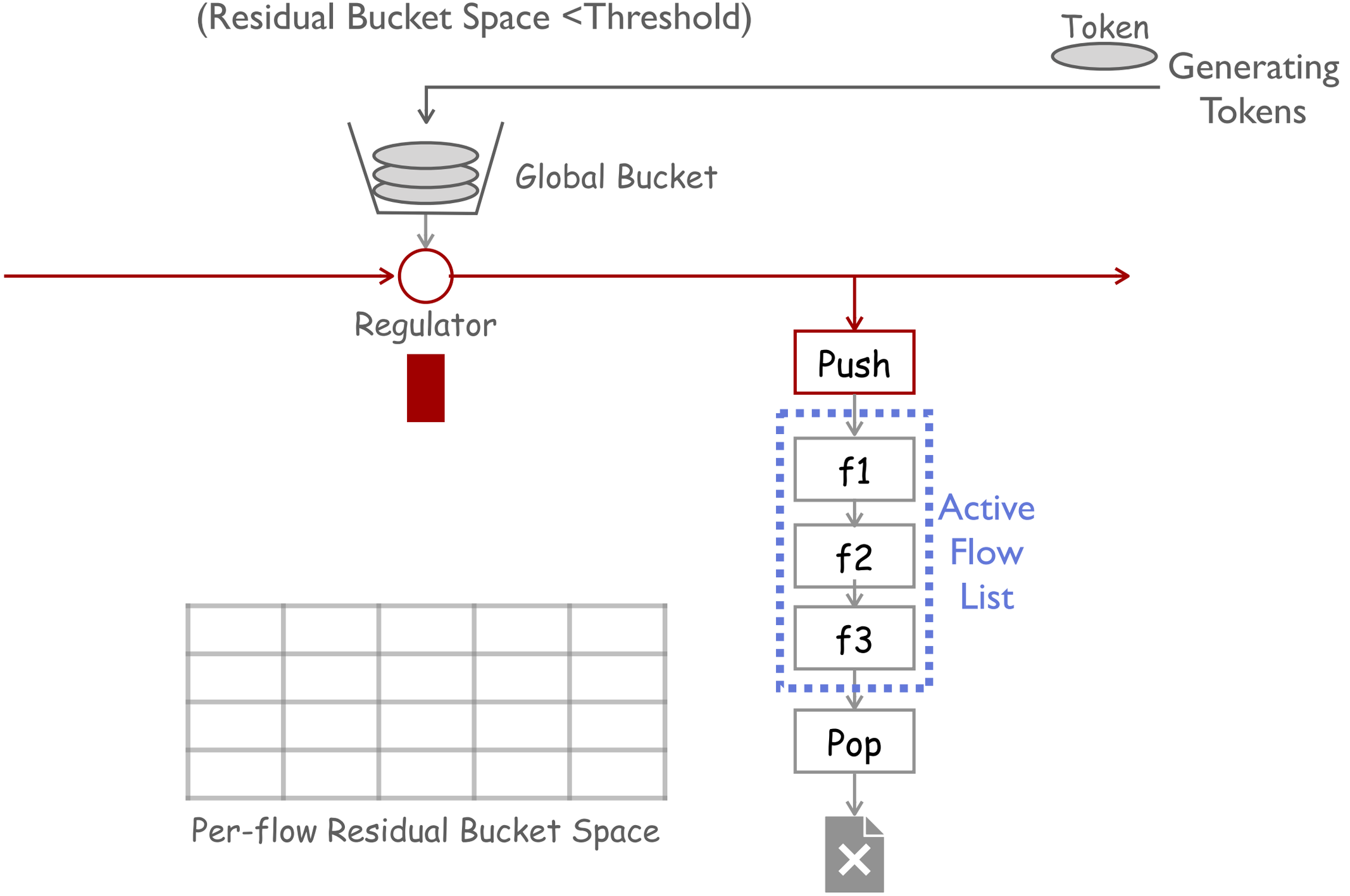
FairPolicer: On Packet Arrival



FairPolicer: On Packet Arrival

Case 1: Enough Tokens in the Bucket

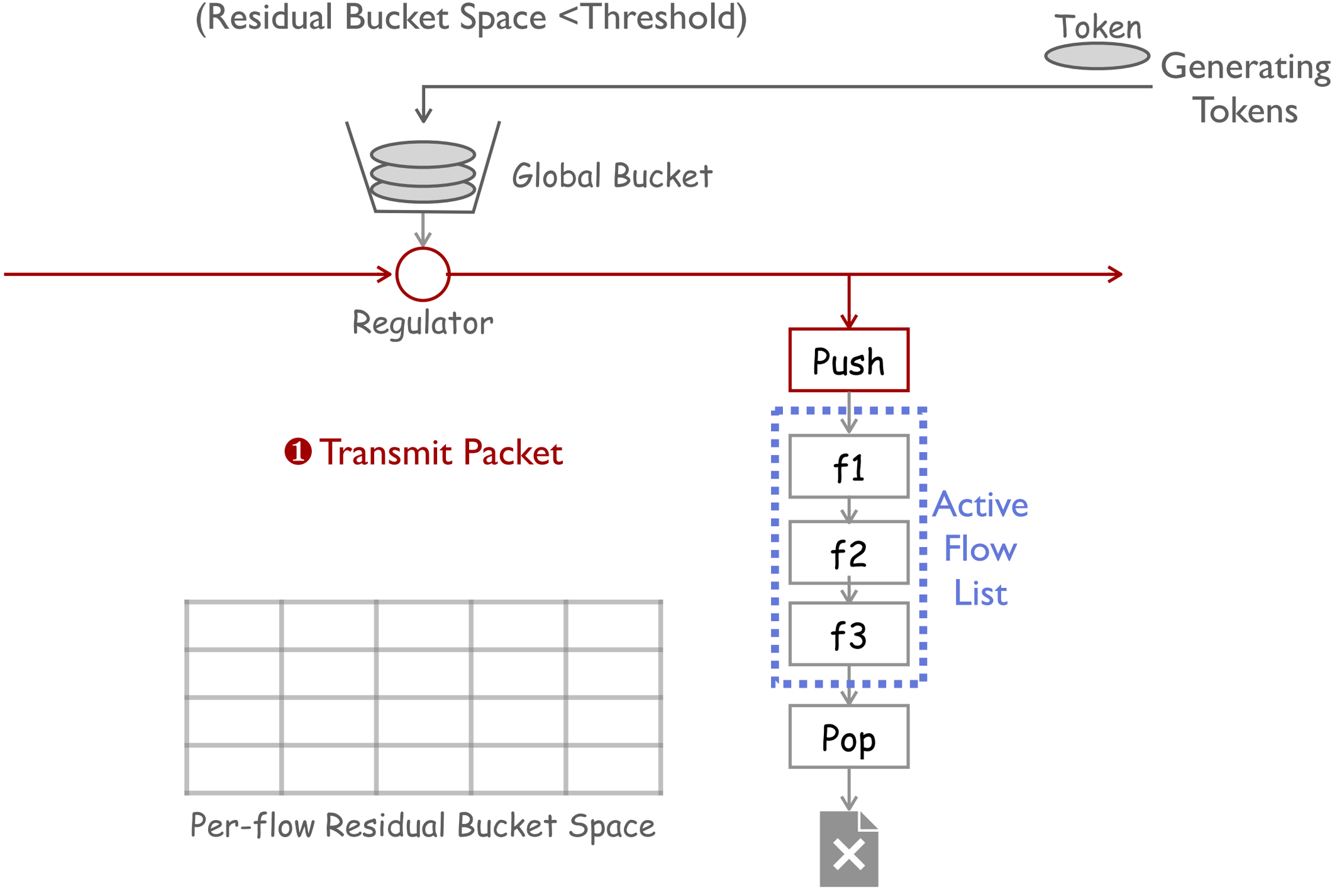
(Residual Bucket Space <Threshold)



FairPolicer: On Packet Arrival

Case 1: Enough Tokens in the Bucket

(Residual Bucket Space <Threshold)

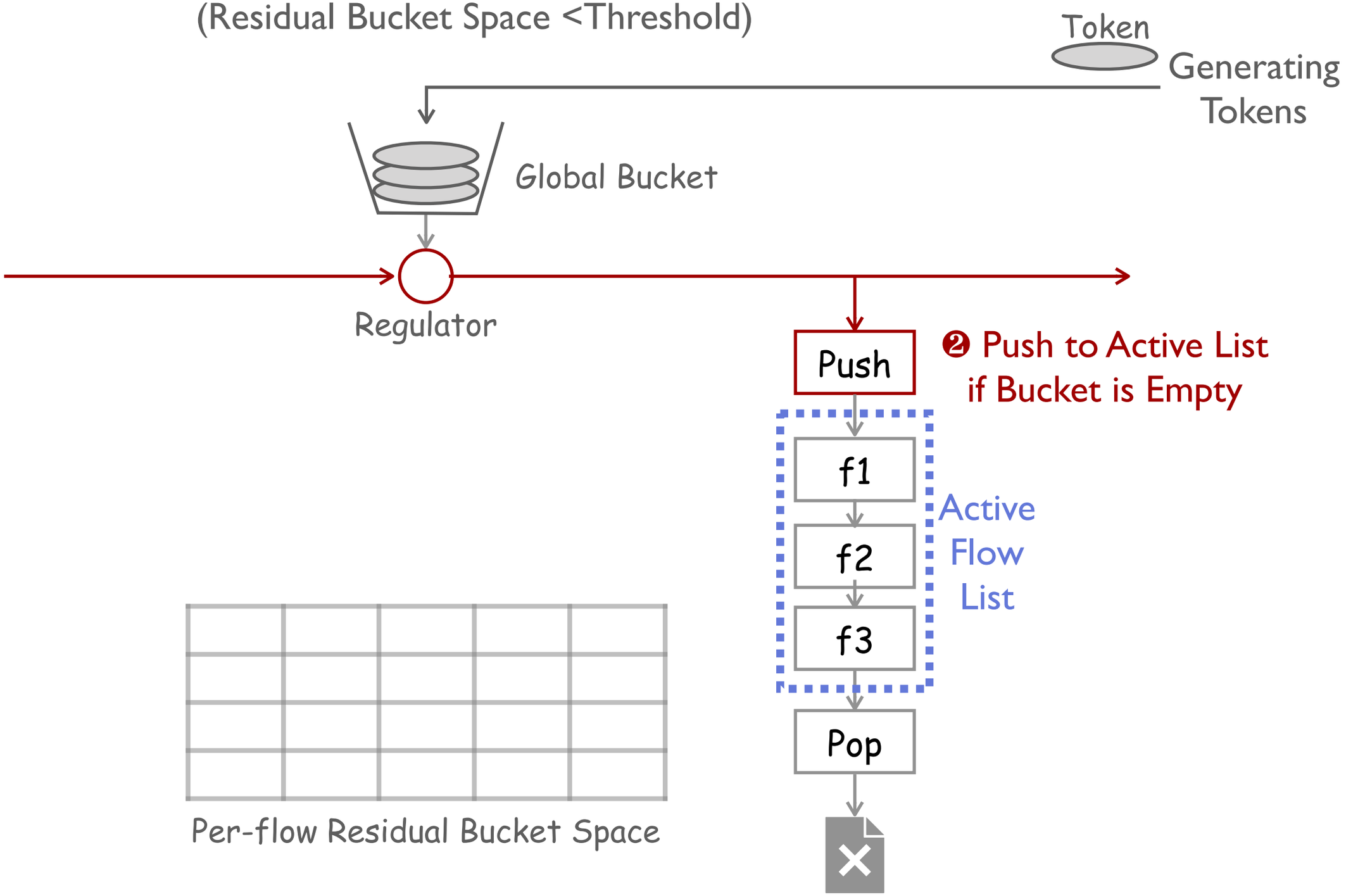


❶ Transmit Packet

FairPolicer: On Packet Arrival

Case 1: Enough Tokens in the Bucket

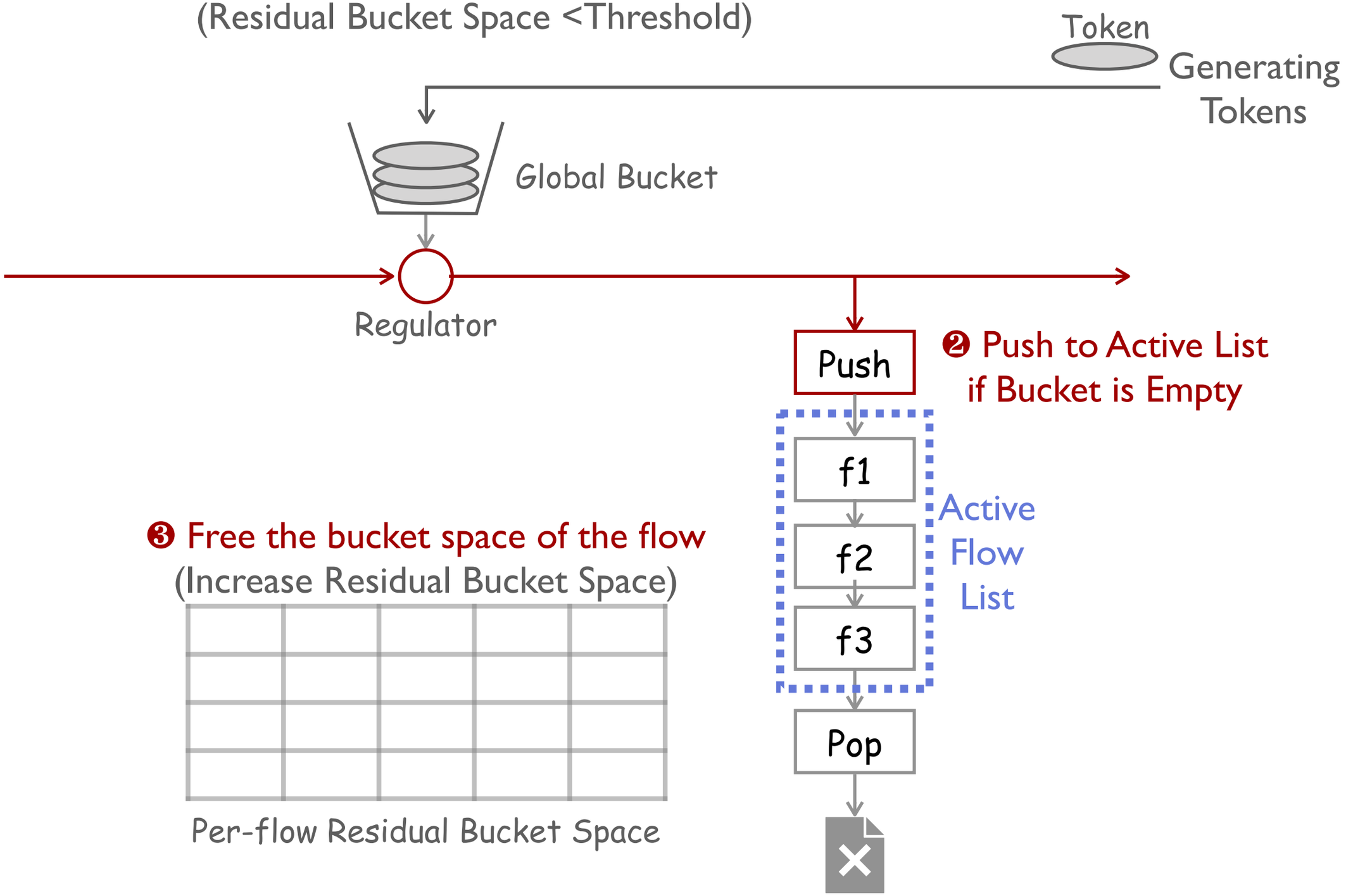
(Residual Bucket Space <Threshold)



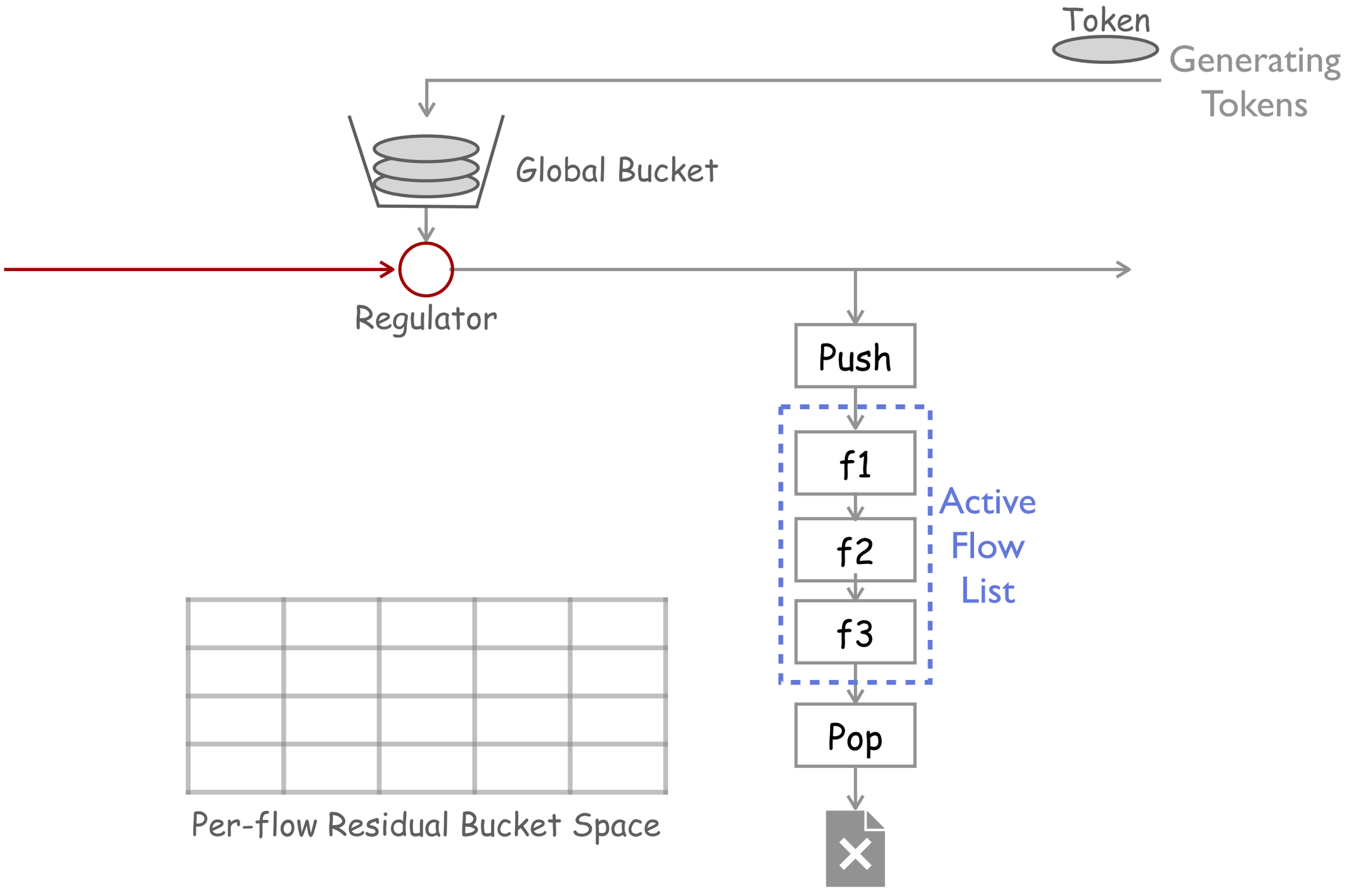
FairPolicer: On Packet Arrival

Case 1: Enough Tokens in the Bucket

(Residual Bucket Space <Threshold)



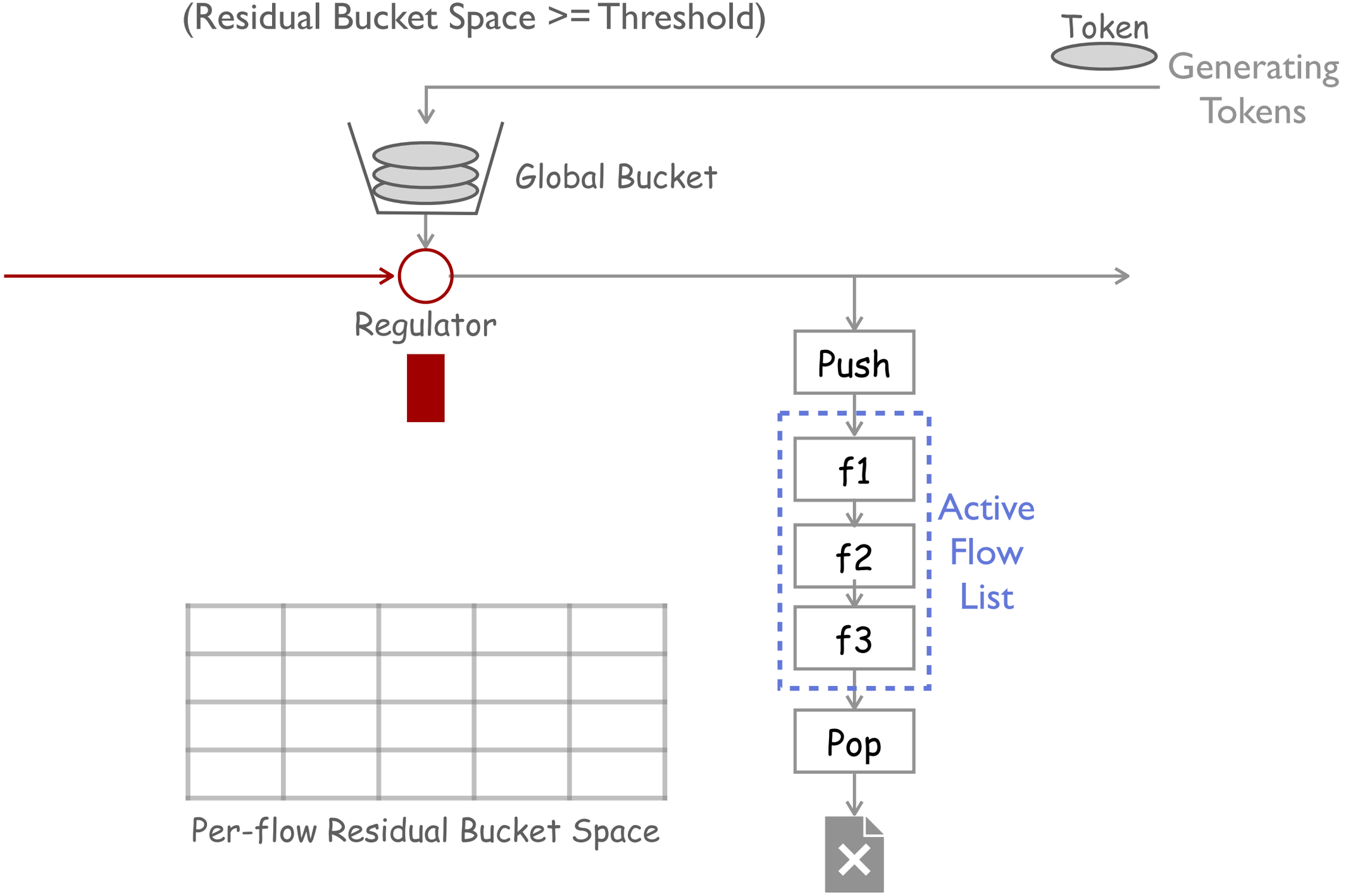
FairPolicer: On Packet Arrival



FairPolicer: On Packet Arrival

Case 2: Not Enough Tokens in the Bucket

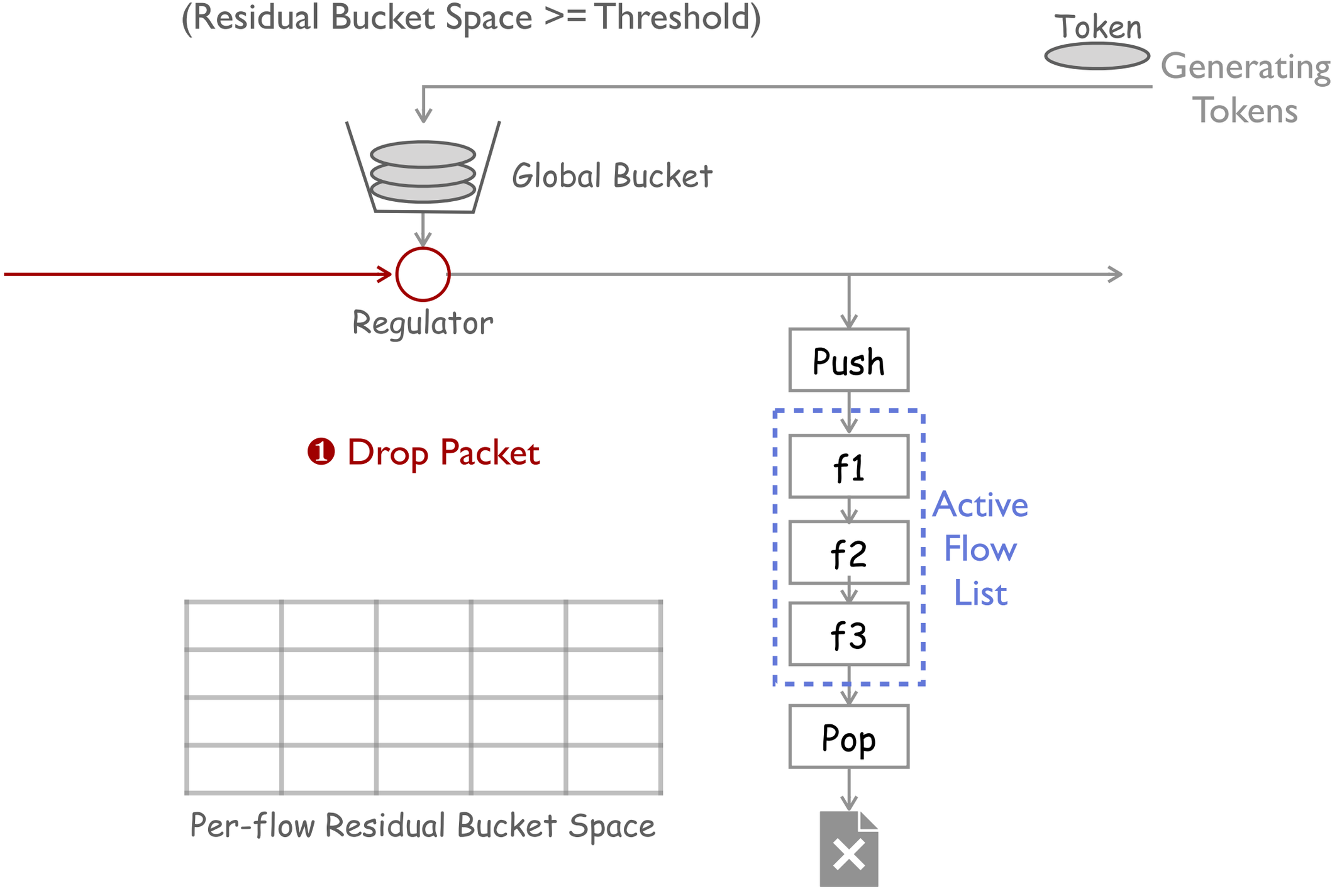
(Residual Bucket Space >= Threshold)



FairPolicer: On Packet Arrival

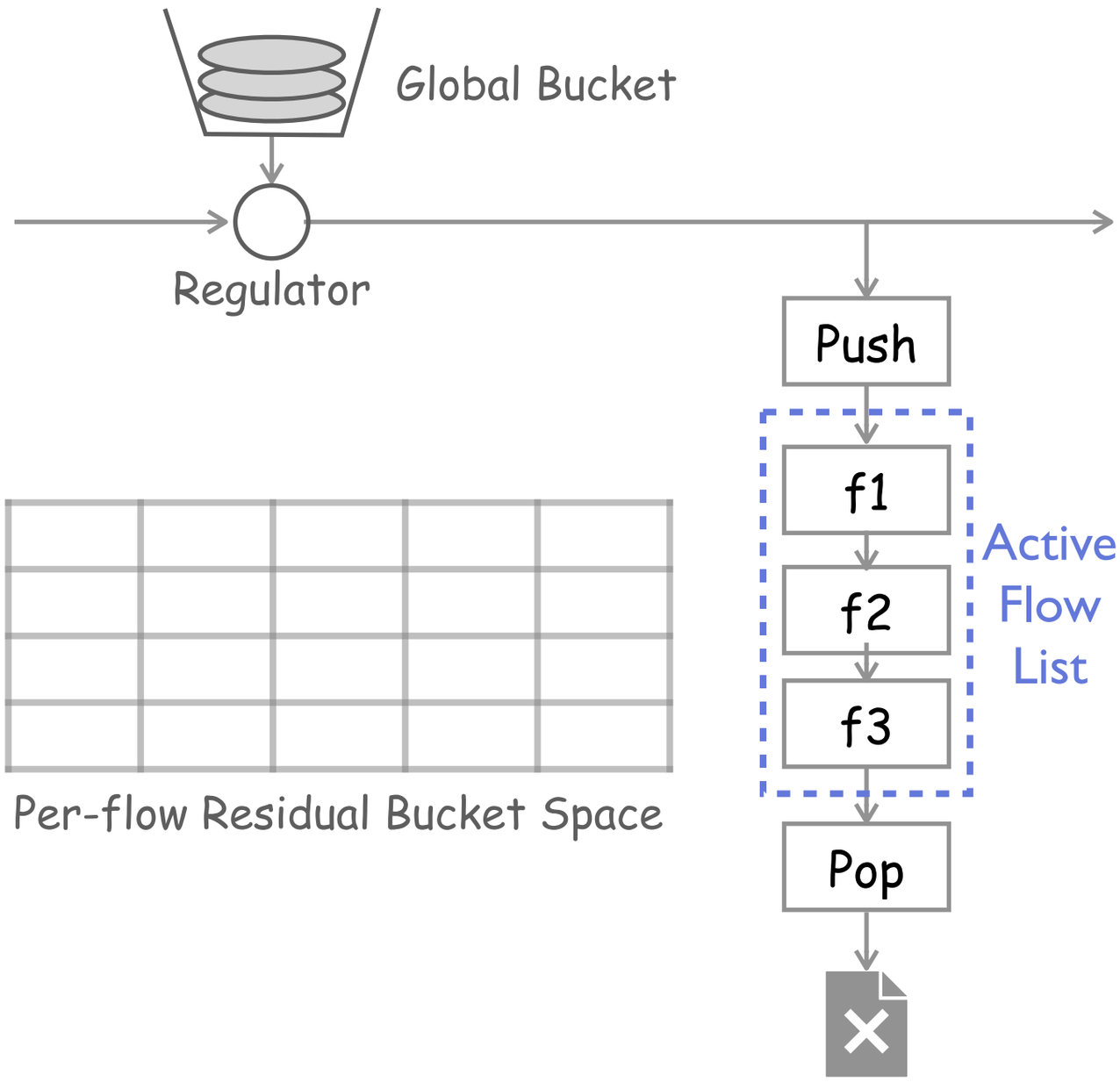
Case 2: Not Enough Tokens in the Bucket

(Residual Bucket Space >= Threshold)

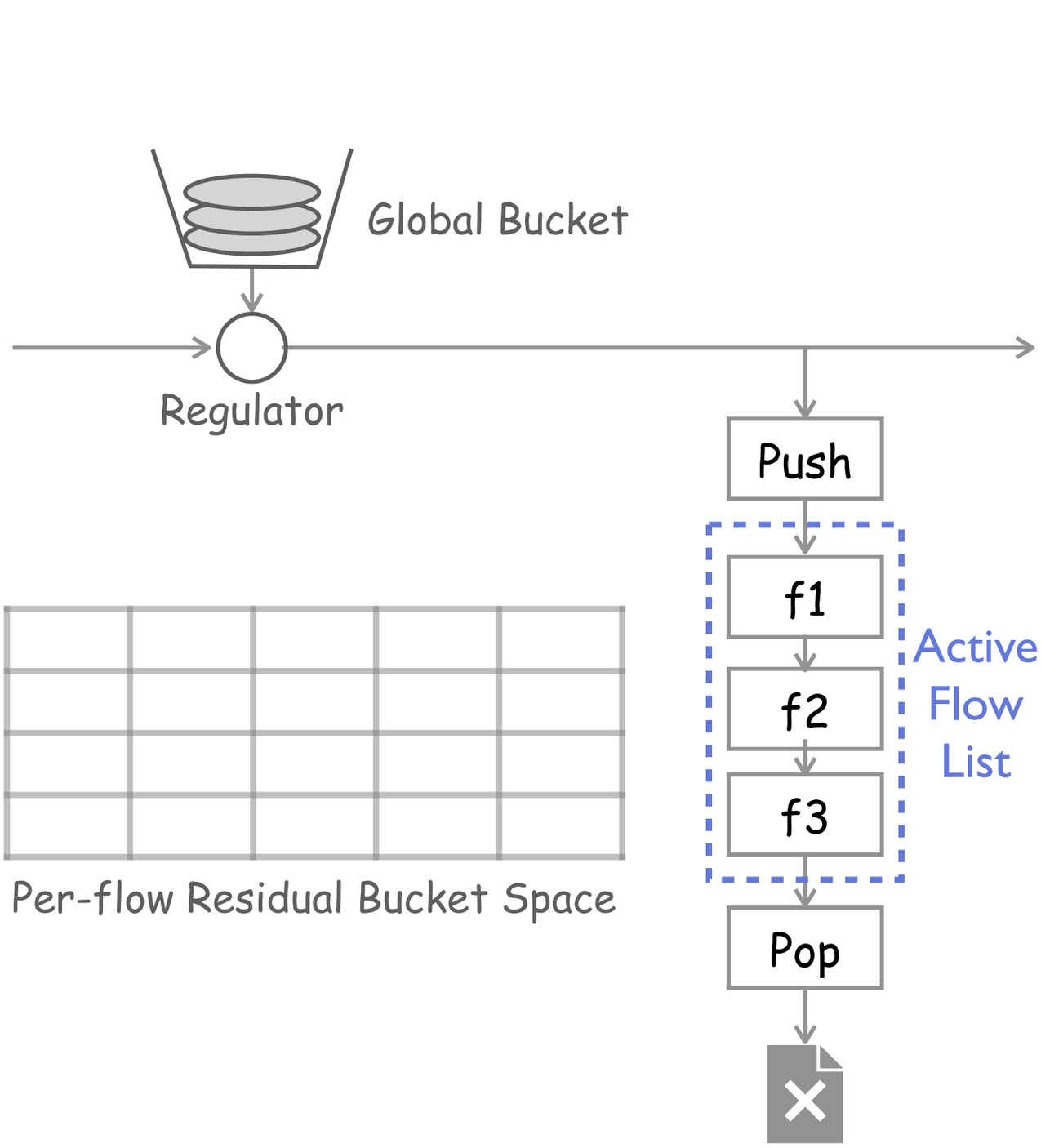


❶ Drop Packet

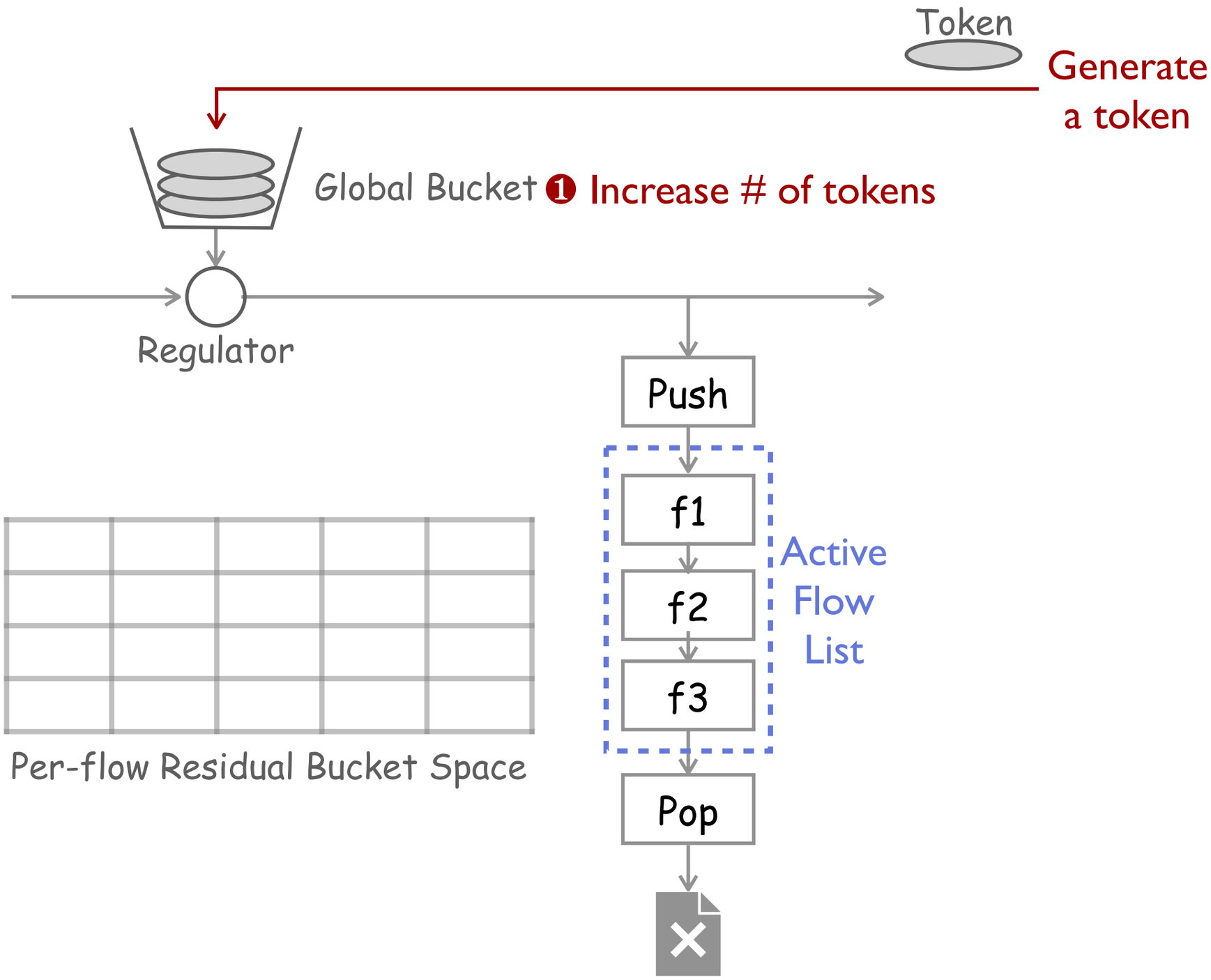
FairPolicer: On Token Generation



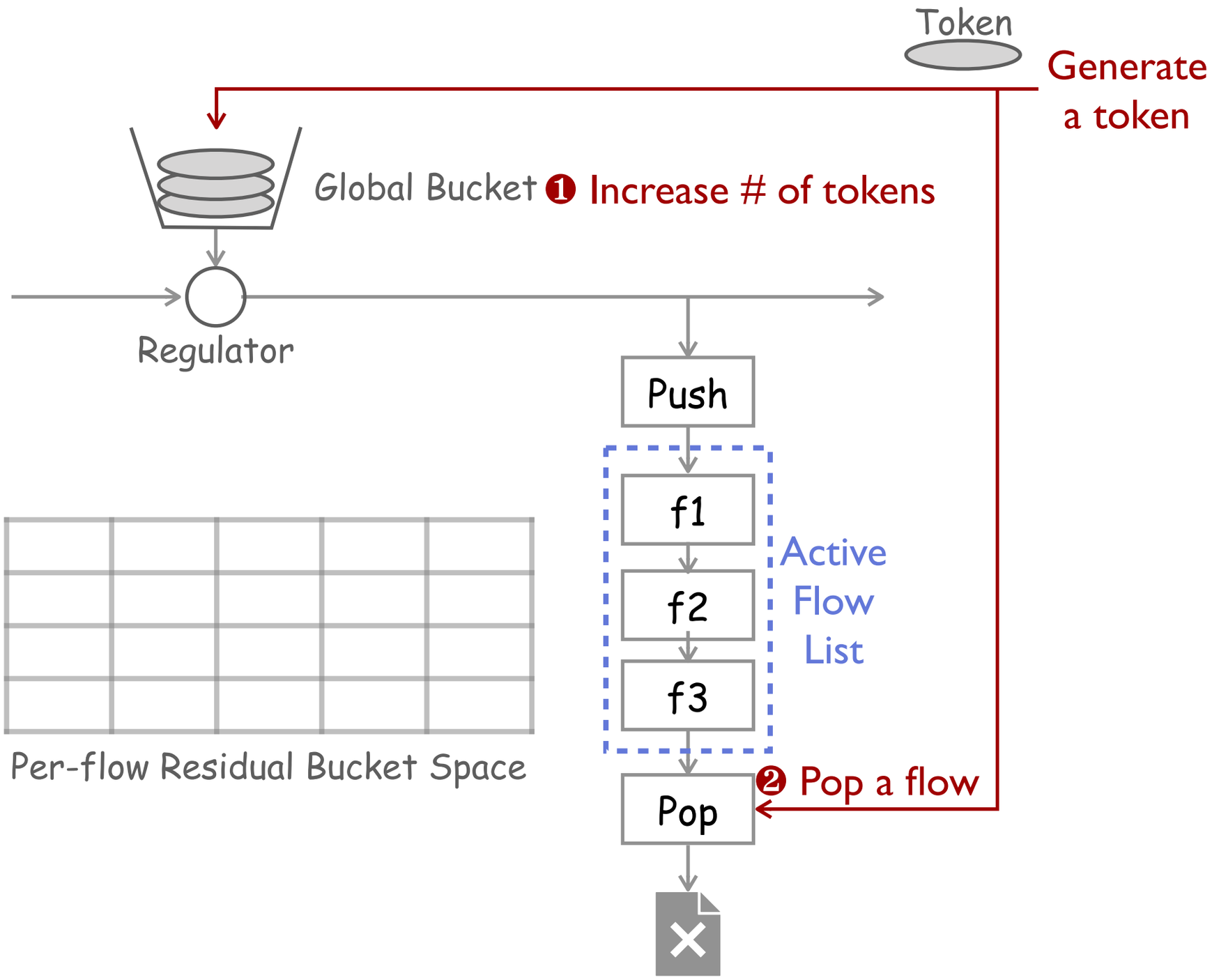
FairPolicer: On Token Generation



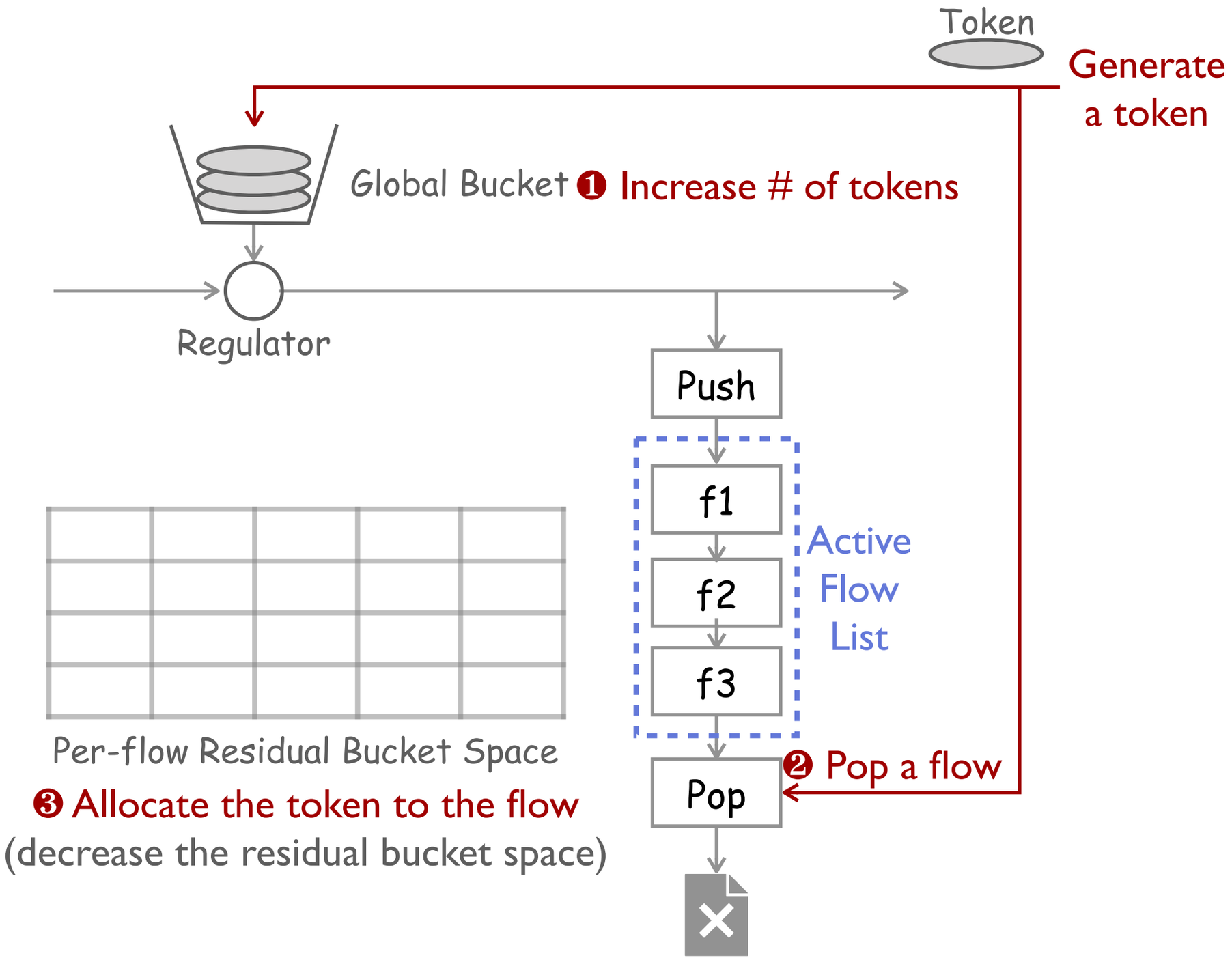
FairPolicer: On Token Generation



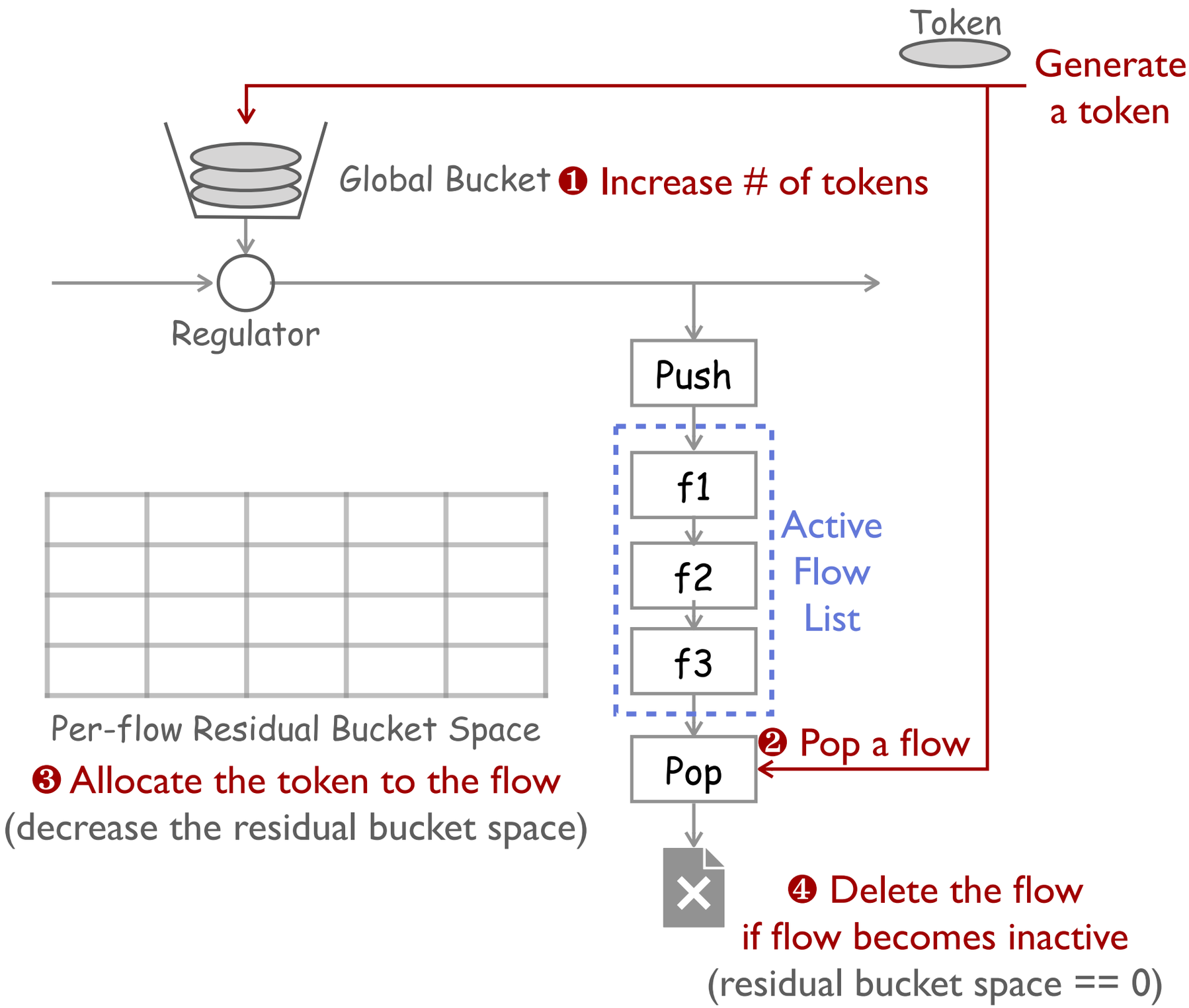
FairPolicer: On Token Generation



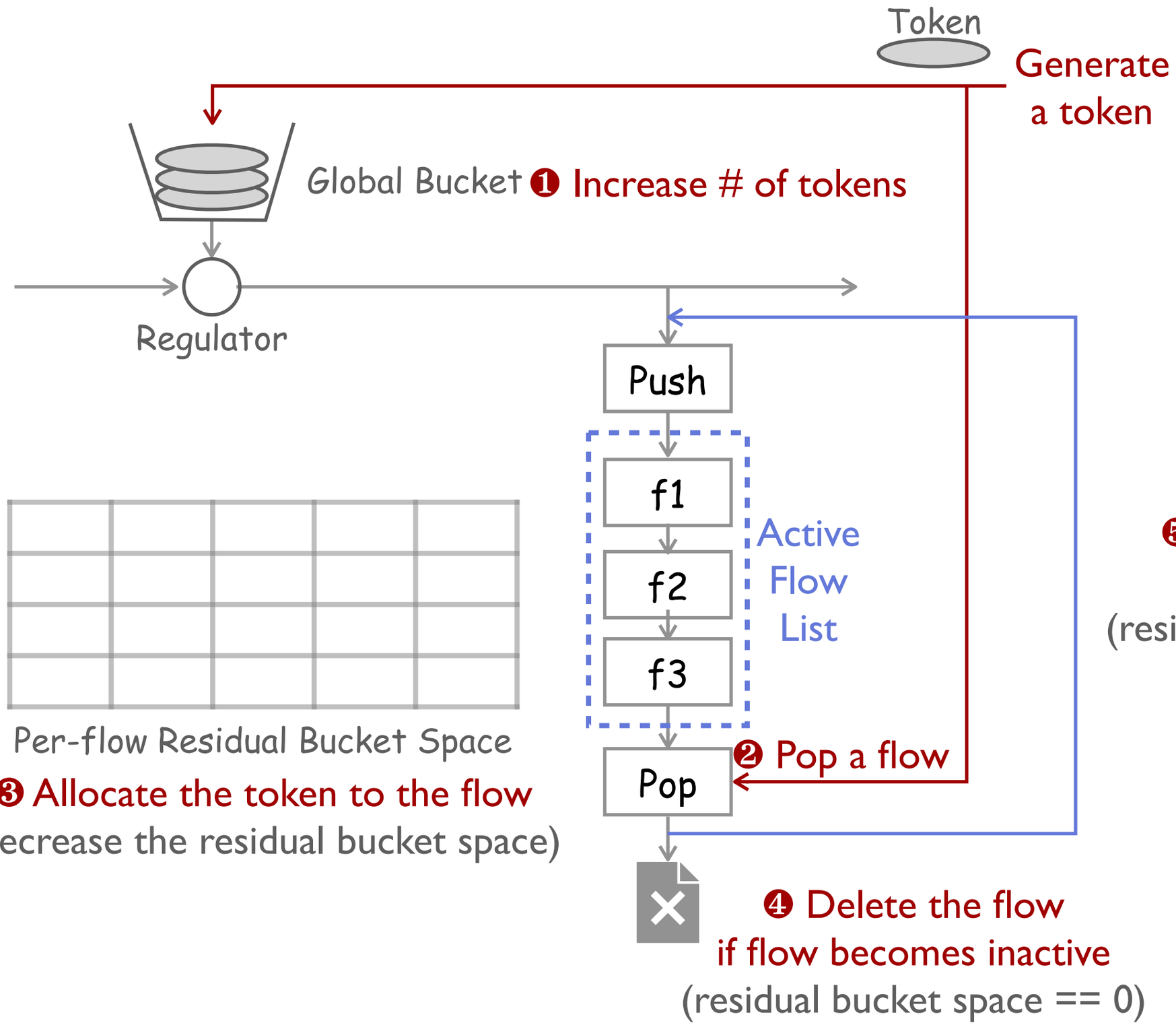
FairPolicer: On Token Generation



FairPolicer: On Token Generation



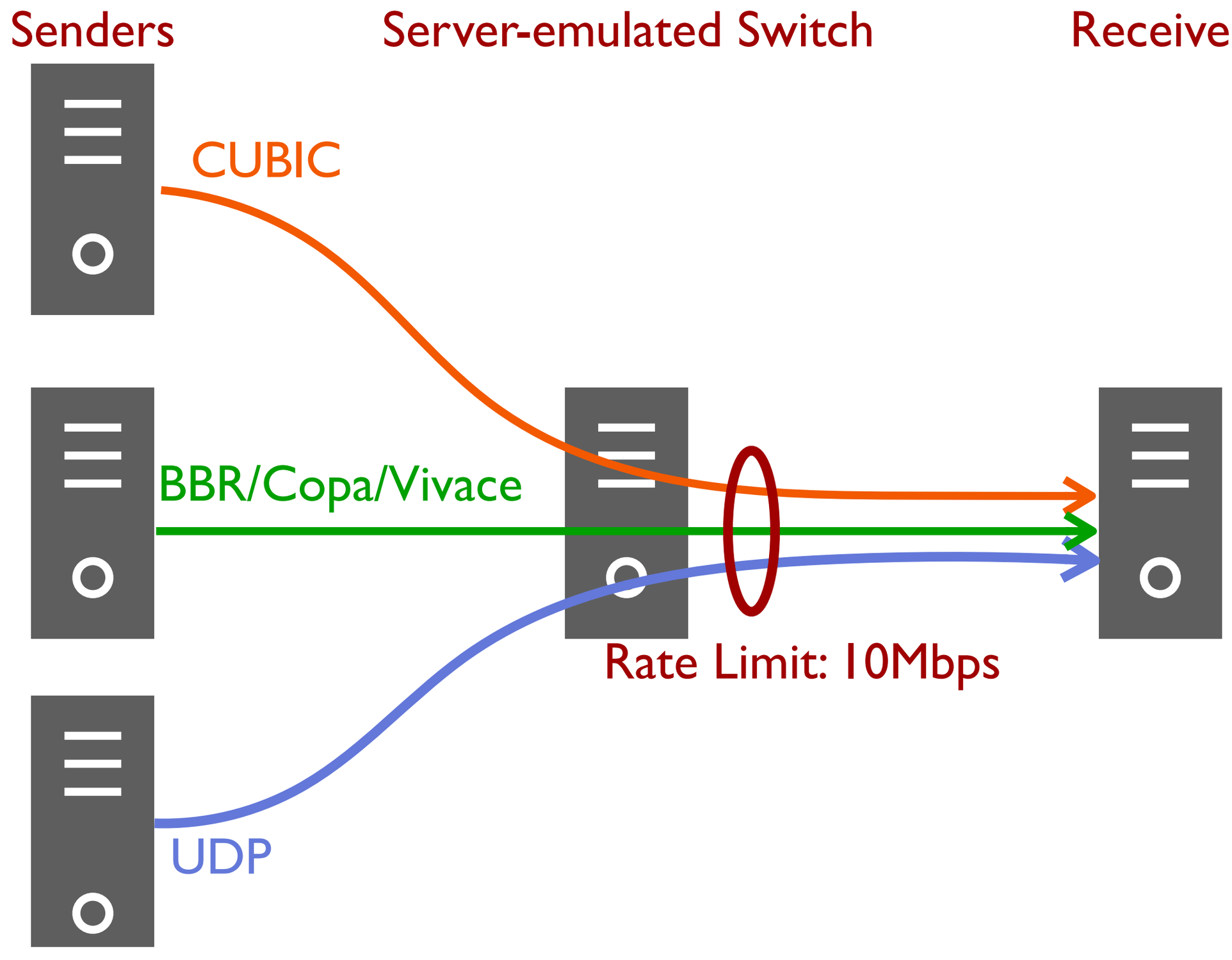
FairPolicer: On Token Generation



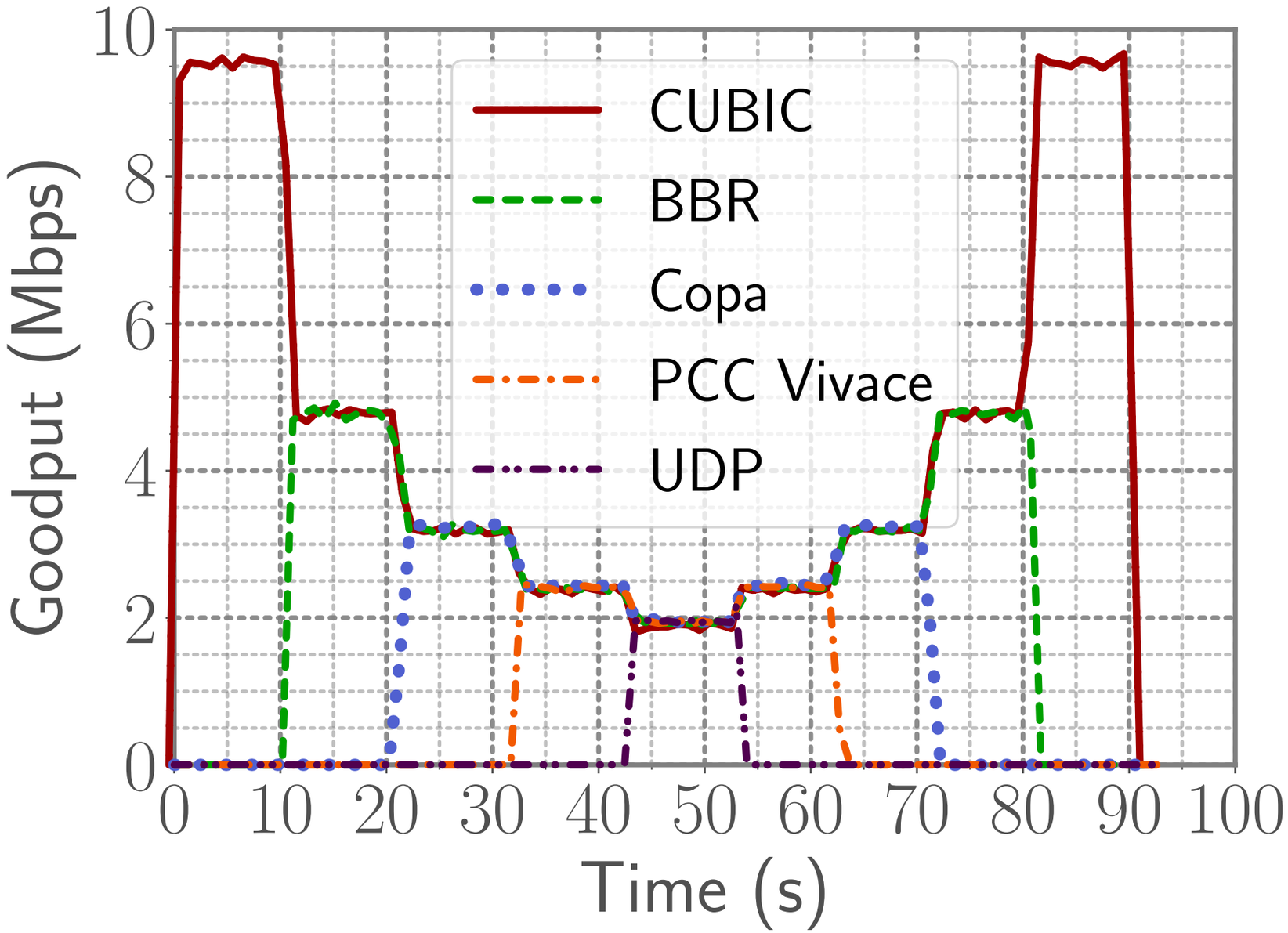
Design of FairPolicer

- More details in the paper
  - Dynamically adjust the per-flow bucket space
  - Parameter settings

Evaluation — Testbed Setup



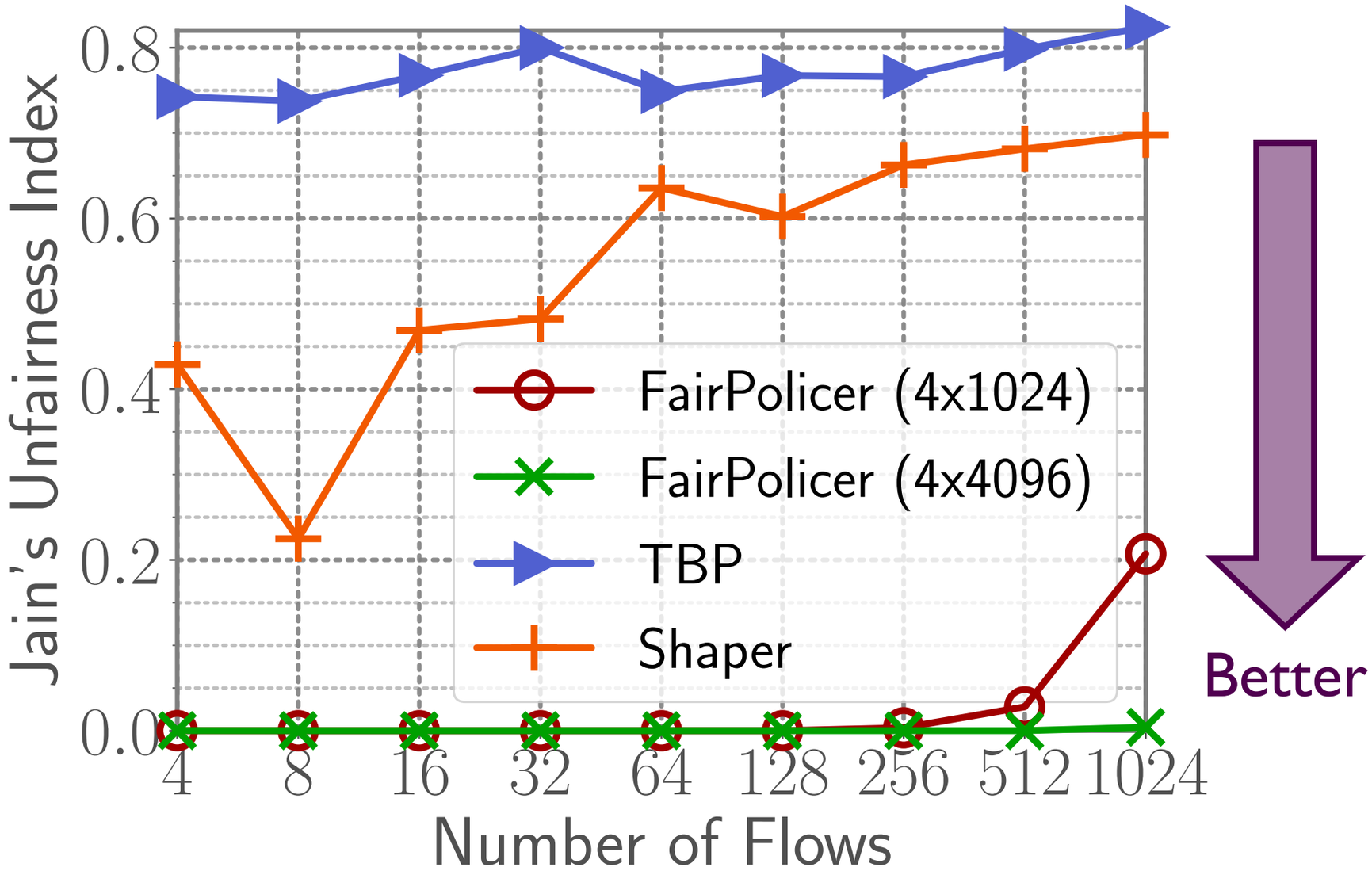
Evaluation — Fairness



Fairness and Convergence

Ensure fairness regardless of CC algorithms

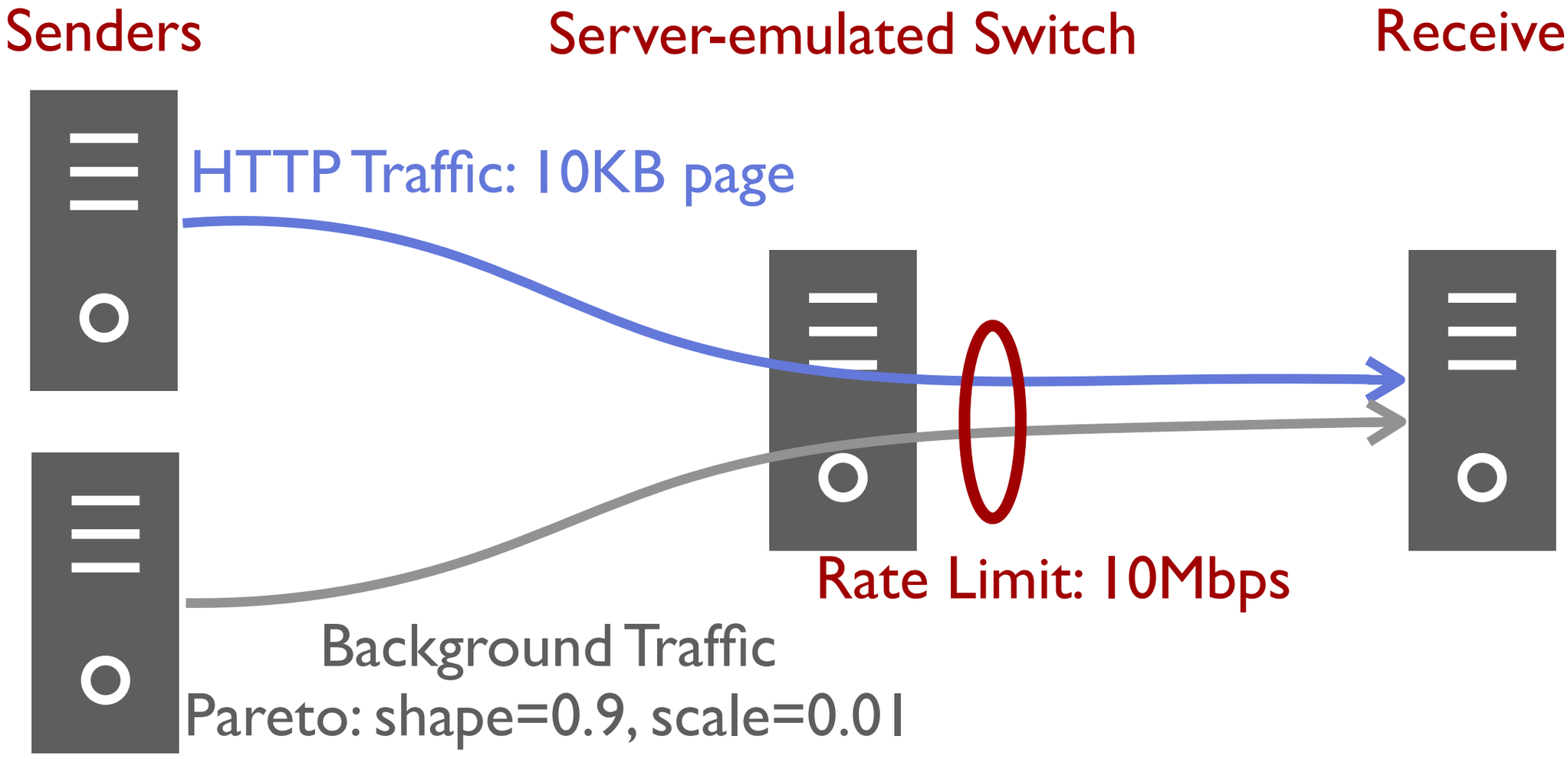
Evaluation — Fairness



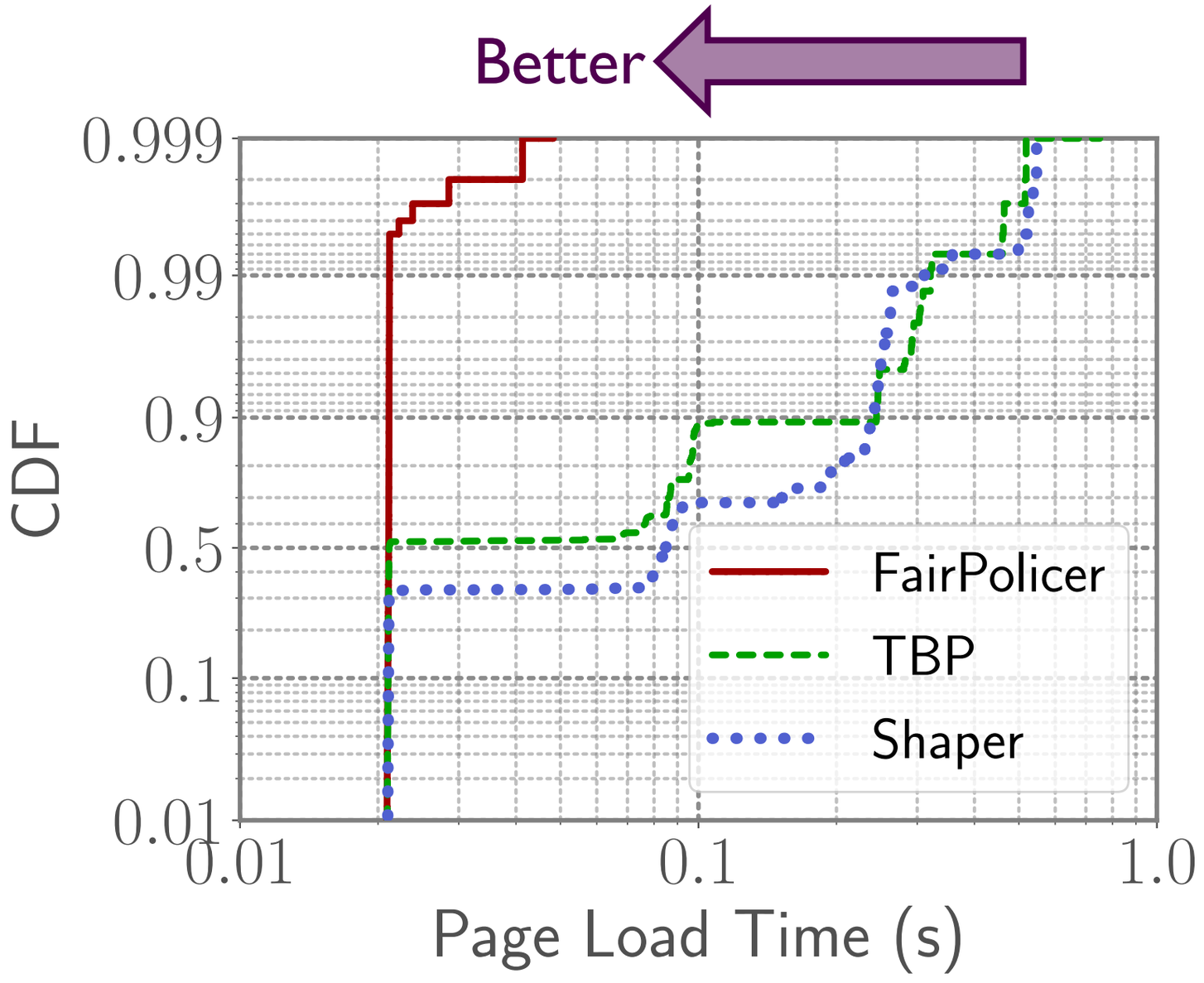
Unfairness Index

Unfairness Index is within 0.004 with 4x4096 sketch size (32KB memory)

Evaluation — Latency



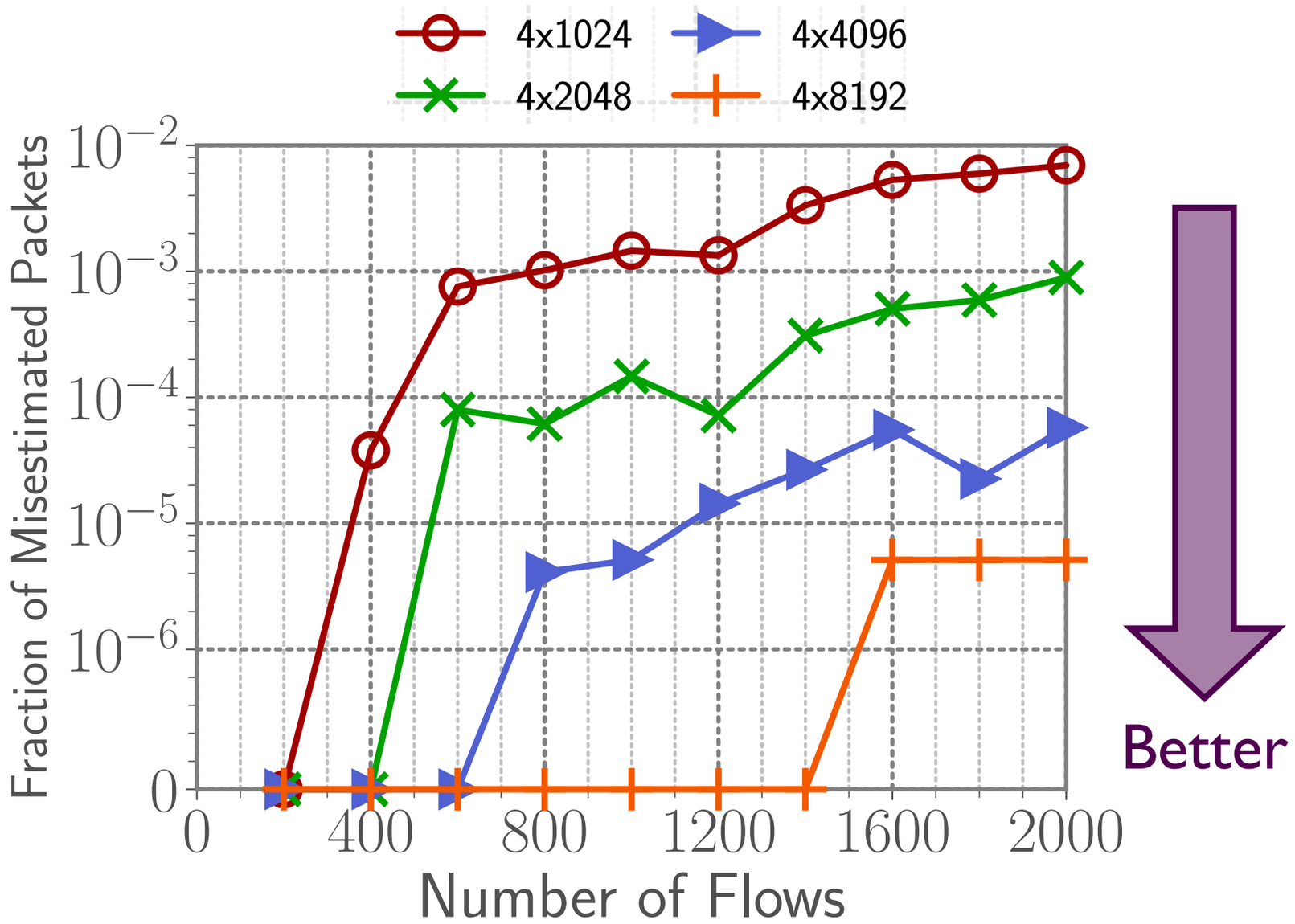
Evaluation — Latency



Web Page Load Time

Reduce the avg. page load time by 14.0x

Evaluation — Accuracy of Count-min Sketch



Accuracy

Scale to 2K flows with a sketch size of 4x4096 (32KB memory)

Conclusion

- Discover and validate the unfairness problem
- Propose FairPolicer that can fairly allocate bandwidth regardless of CC algorithms
- Prototype and evaluate FairPolicer in a testbed

Thank you!

Q&A

Source code: https://github.com/ants-xjtu/fairpolicer