NDSS SYMPOSIUM

San Diego, California
23-27 February 2026

STRATEGIC GAMES AND ZERO SHOT ATTACKS ON HEAVY-HITTER NETWORK FLOW MONITORING

FRANCESCO DA DALT (ETH ZÜRICH) (Presenter)

ADRIAN PERRIG (ETH ZÜRICH)

ETH zürich

CHALLENGE

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Configure complex systems

to be **optimally secure** against

PAST and FUTURE attack strategies

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Alice

Bob

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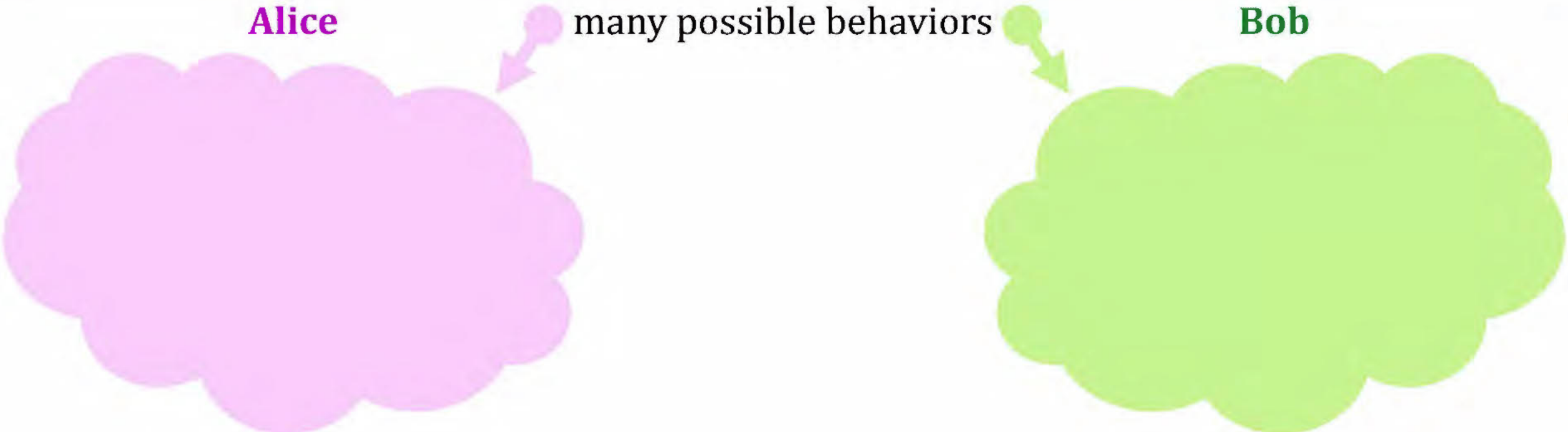
Alice many possible behaviors **Bob**



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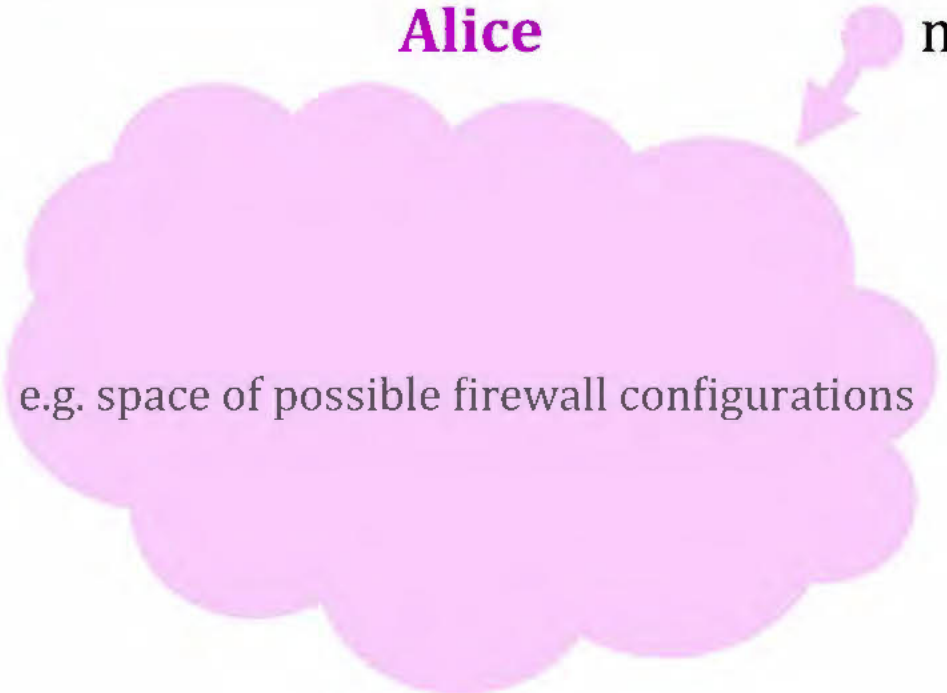

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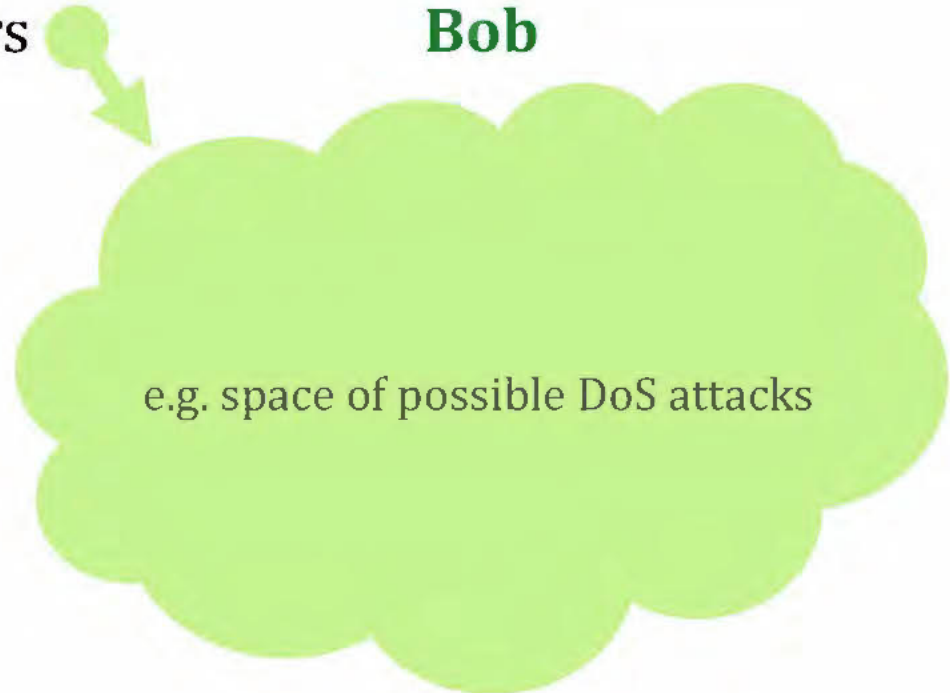

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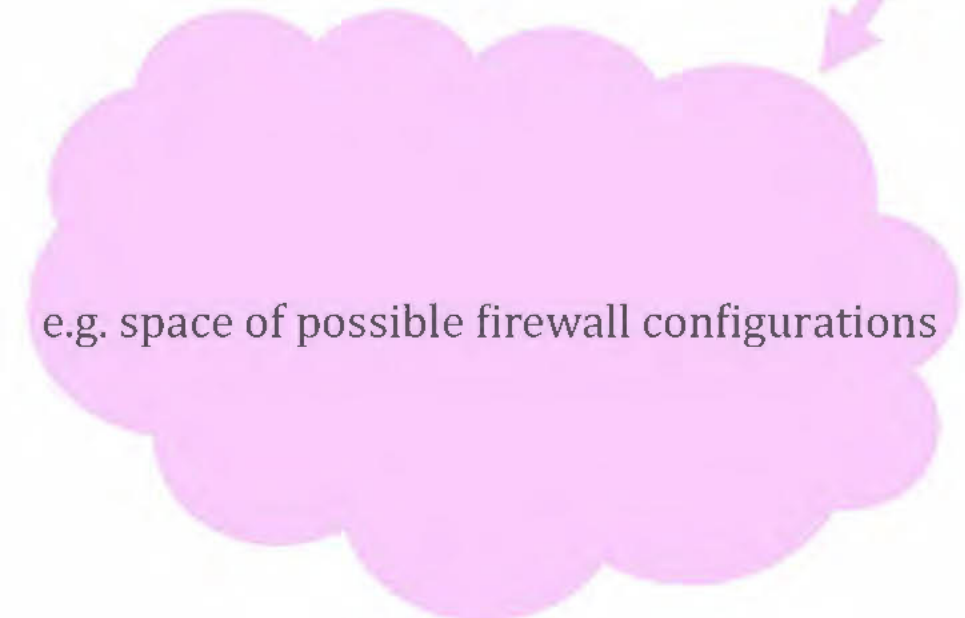
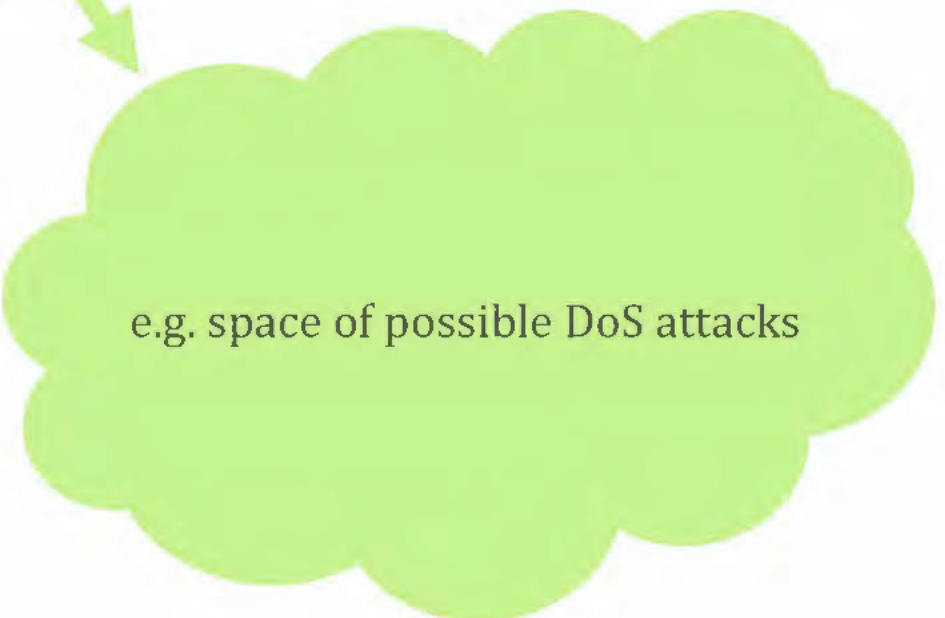


heuristic



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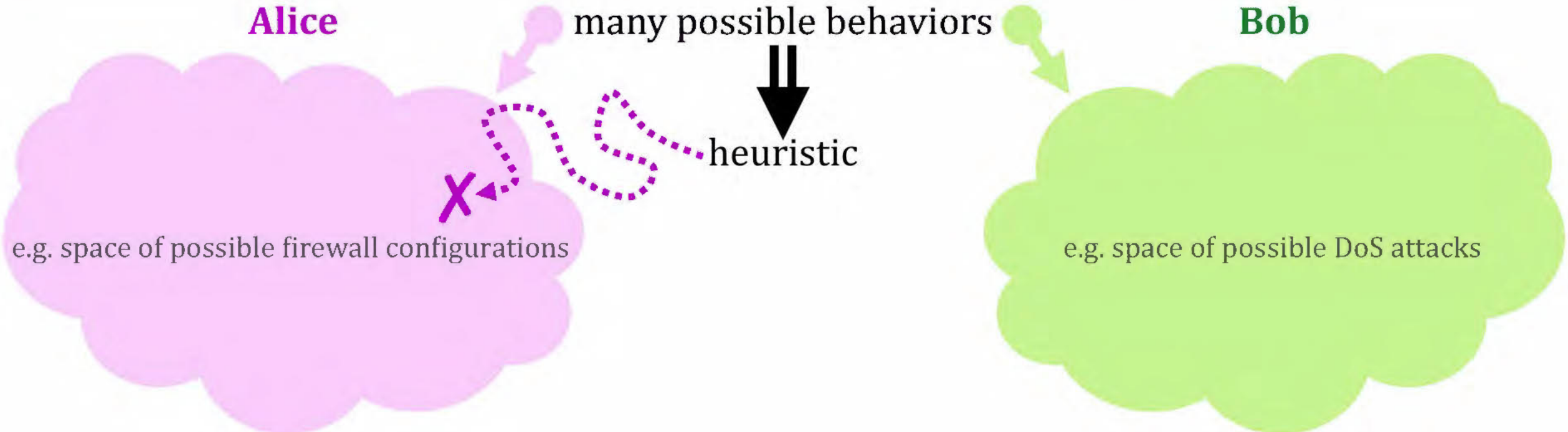

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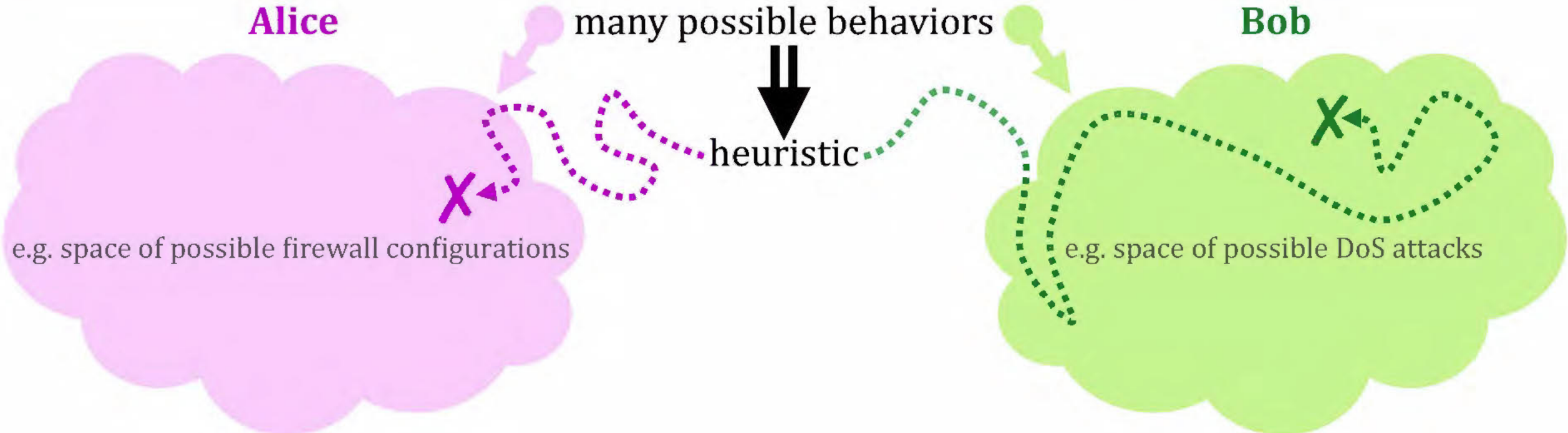

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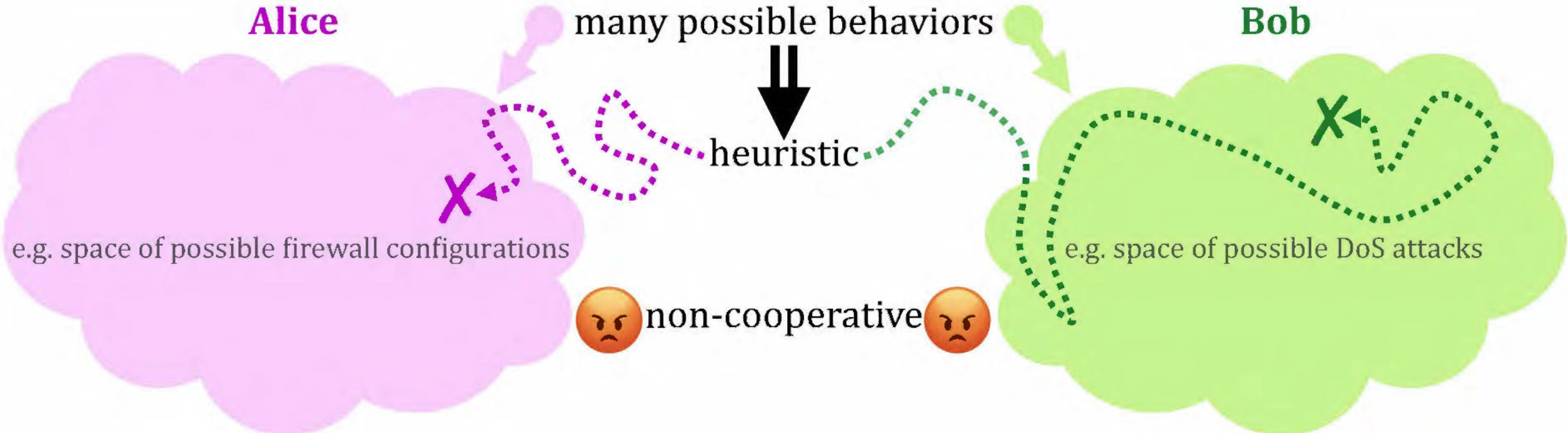

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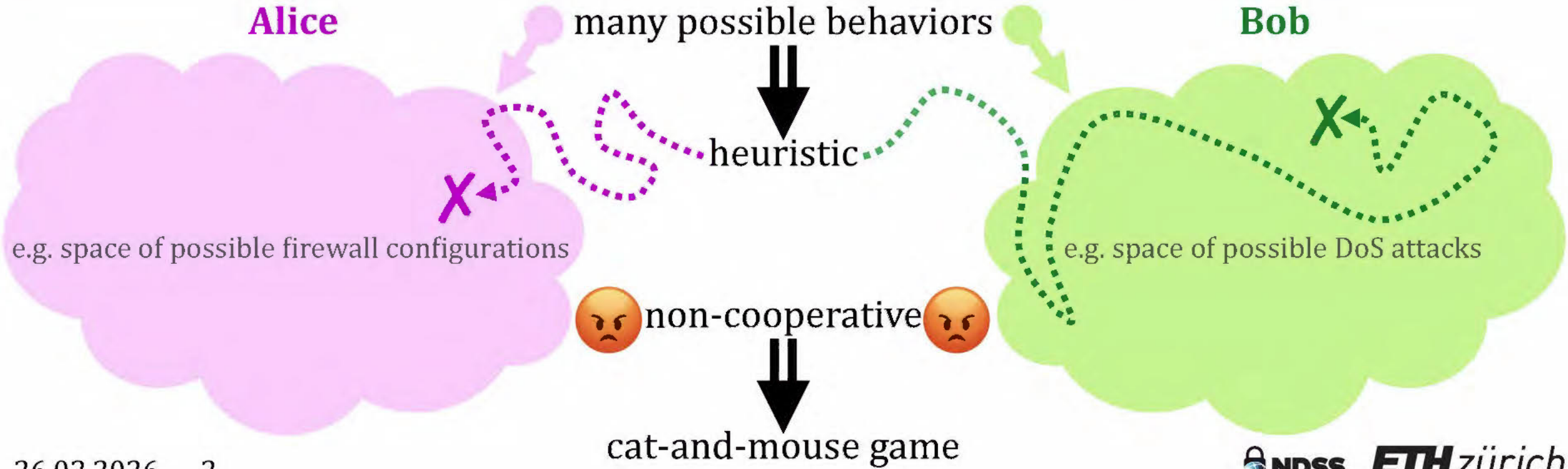

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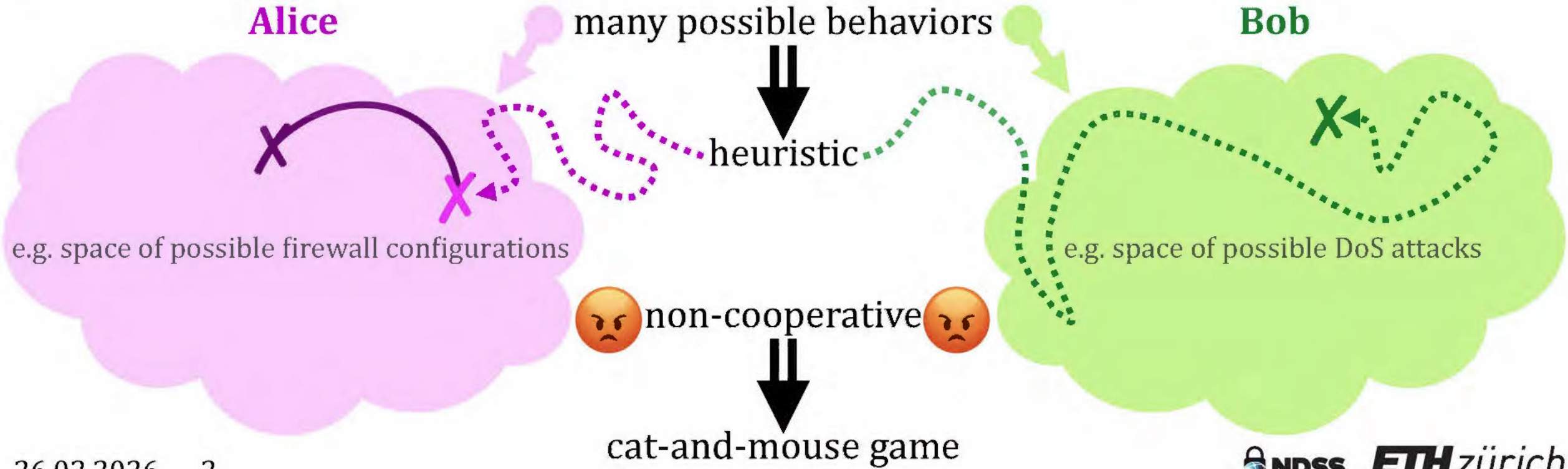

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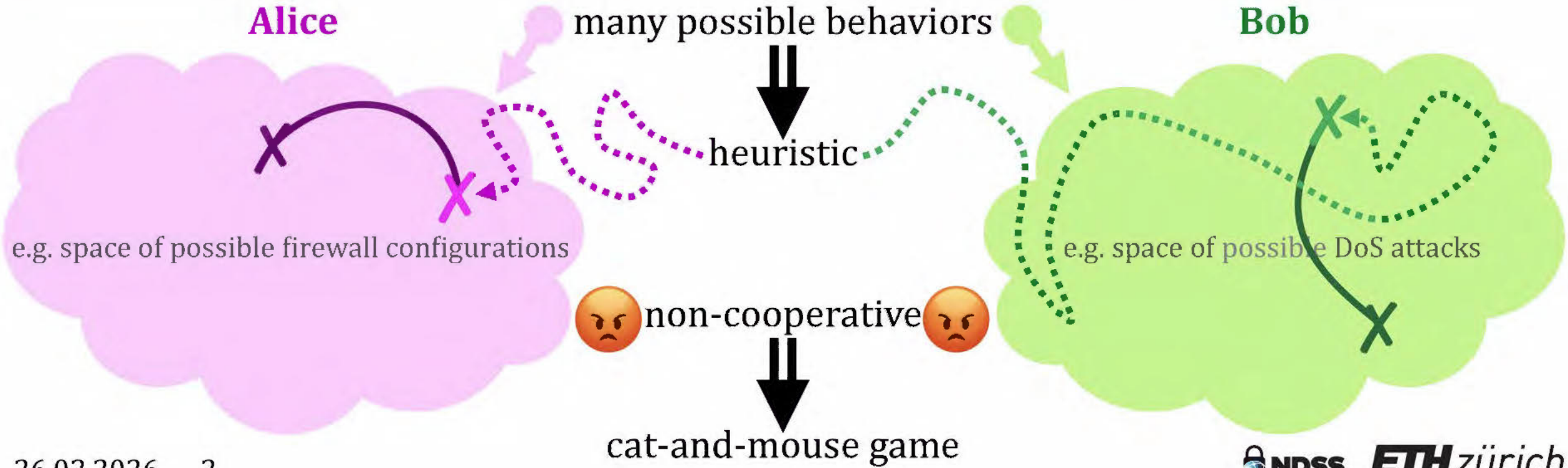

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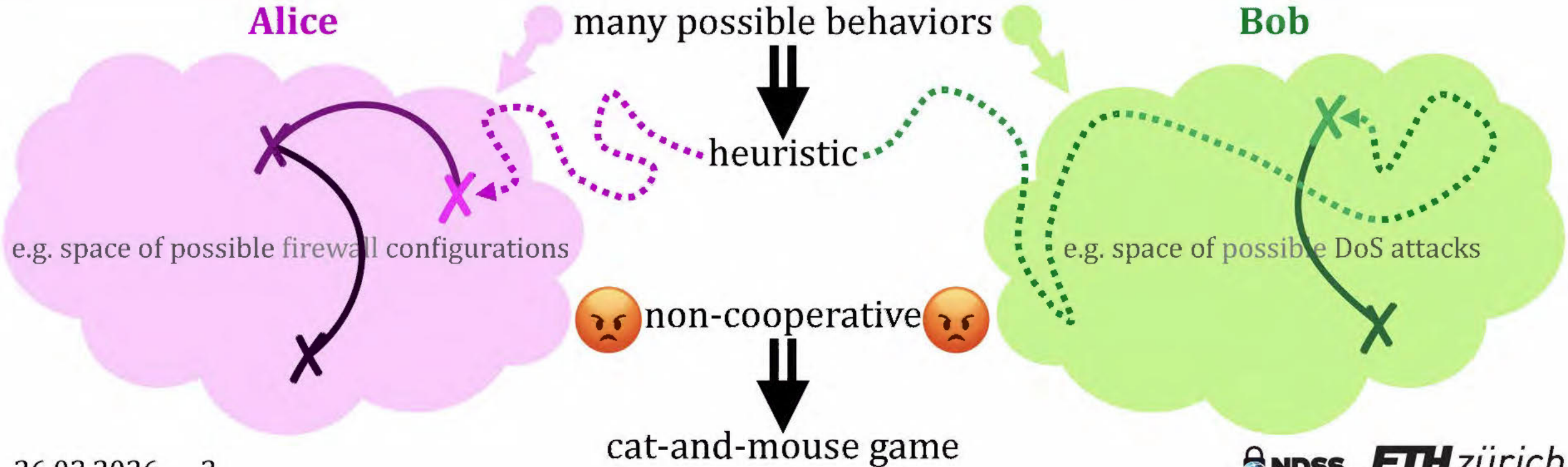

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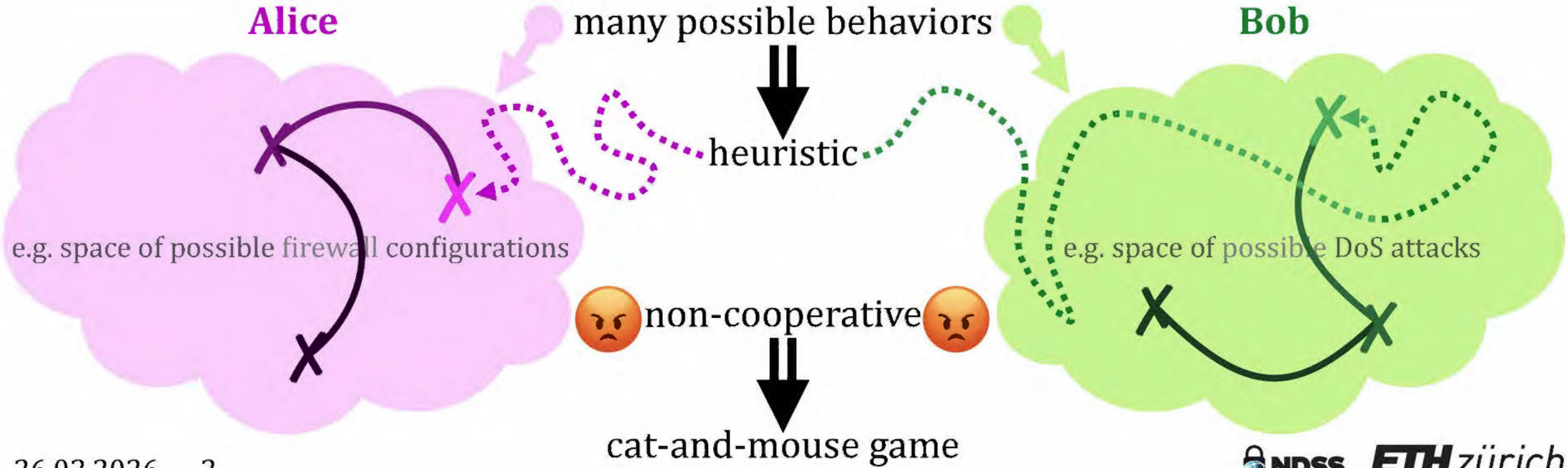

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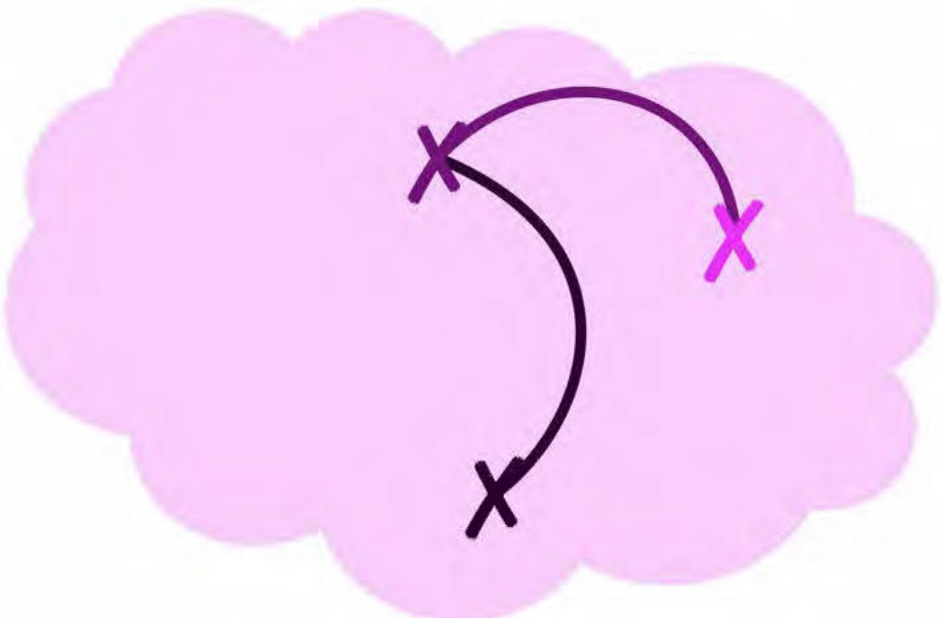
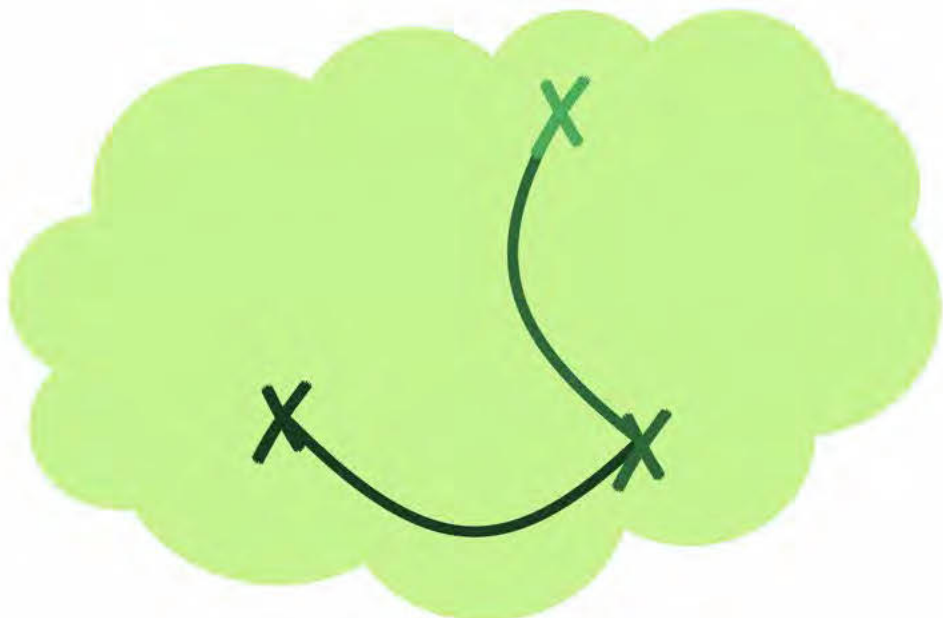


Bob



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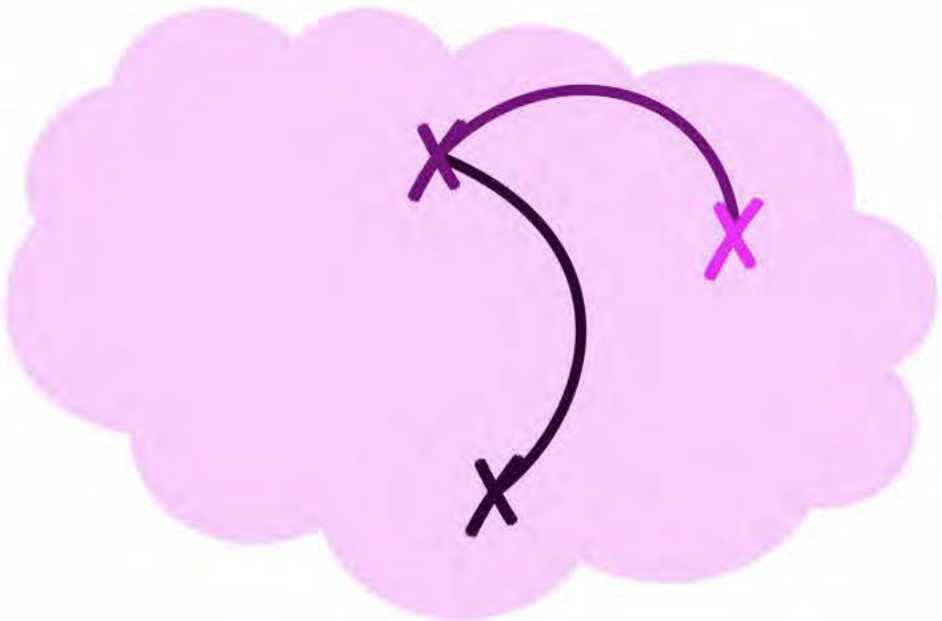
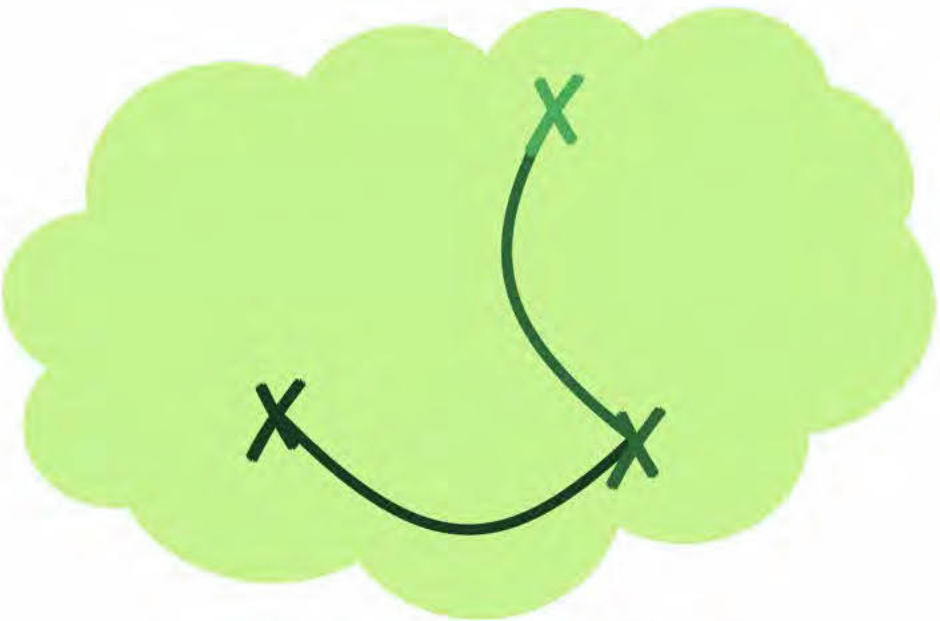
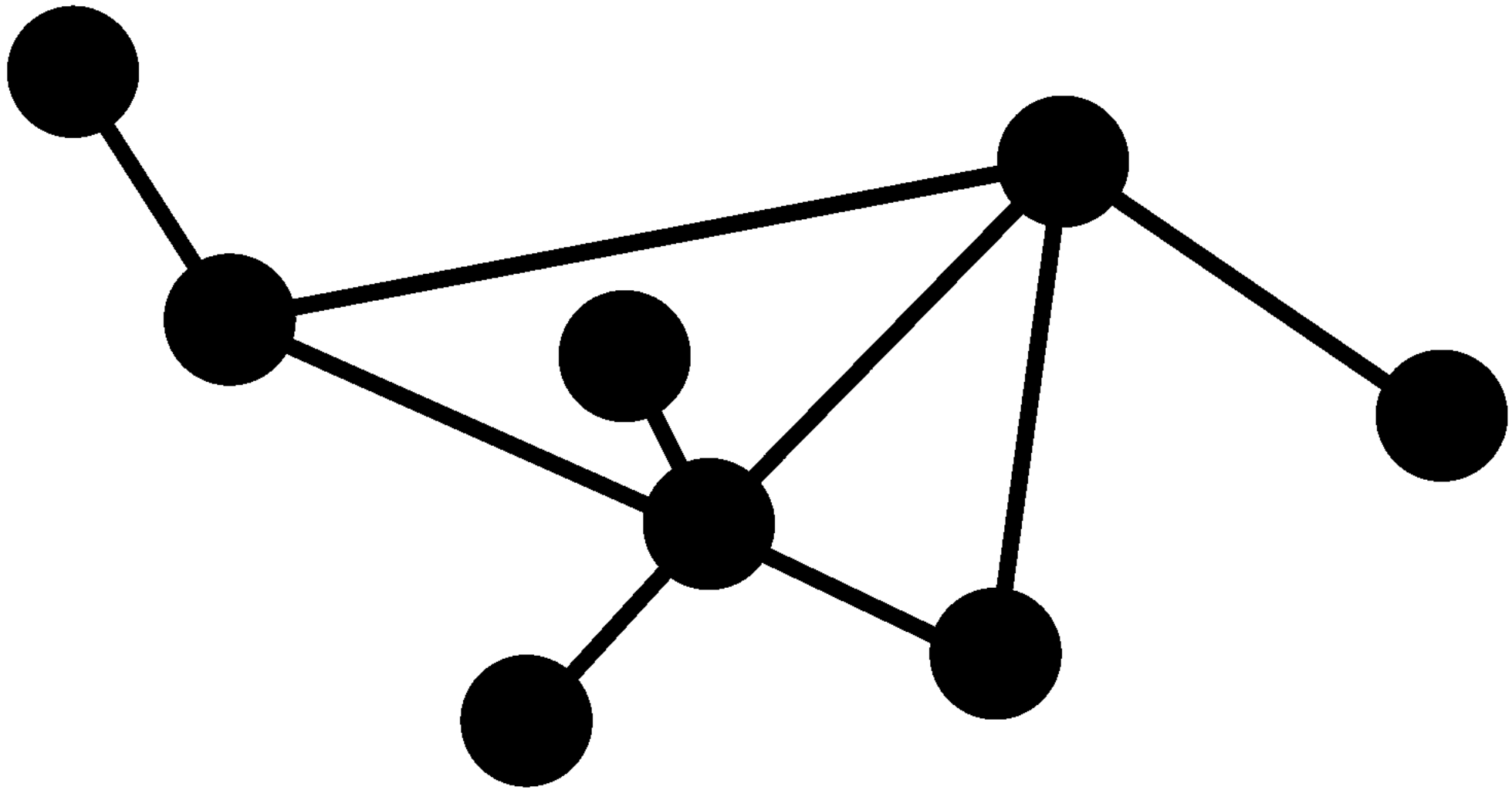


Do in Principled Way

Bob



FLOW MONITORING



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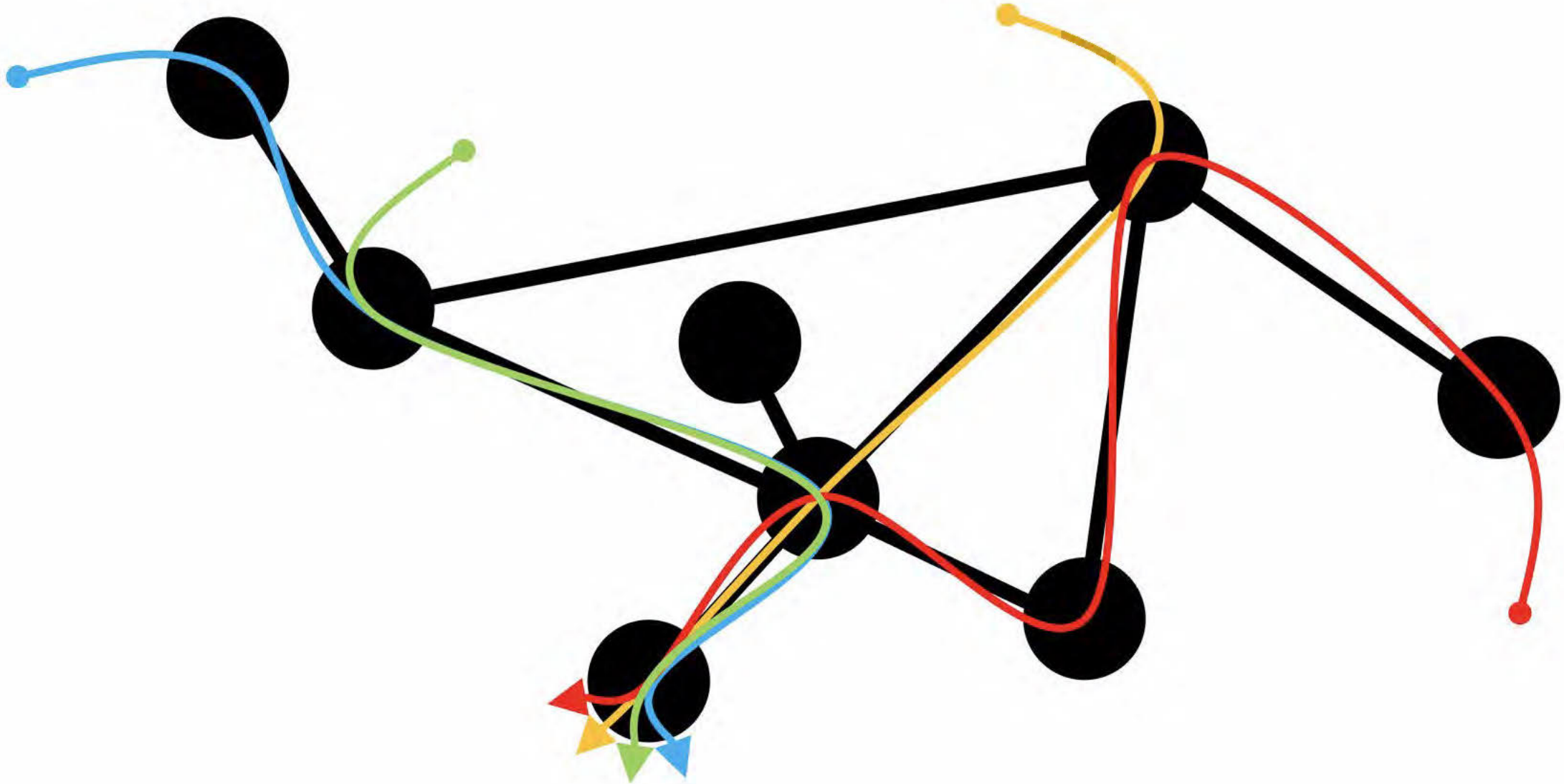

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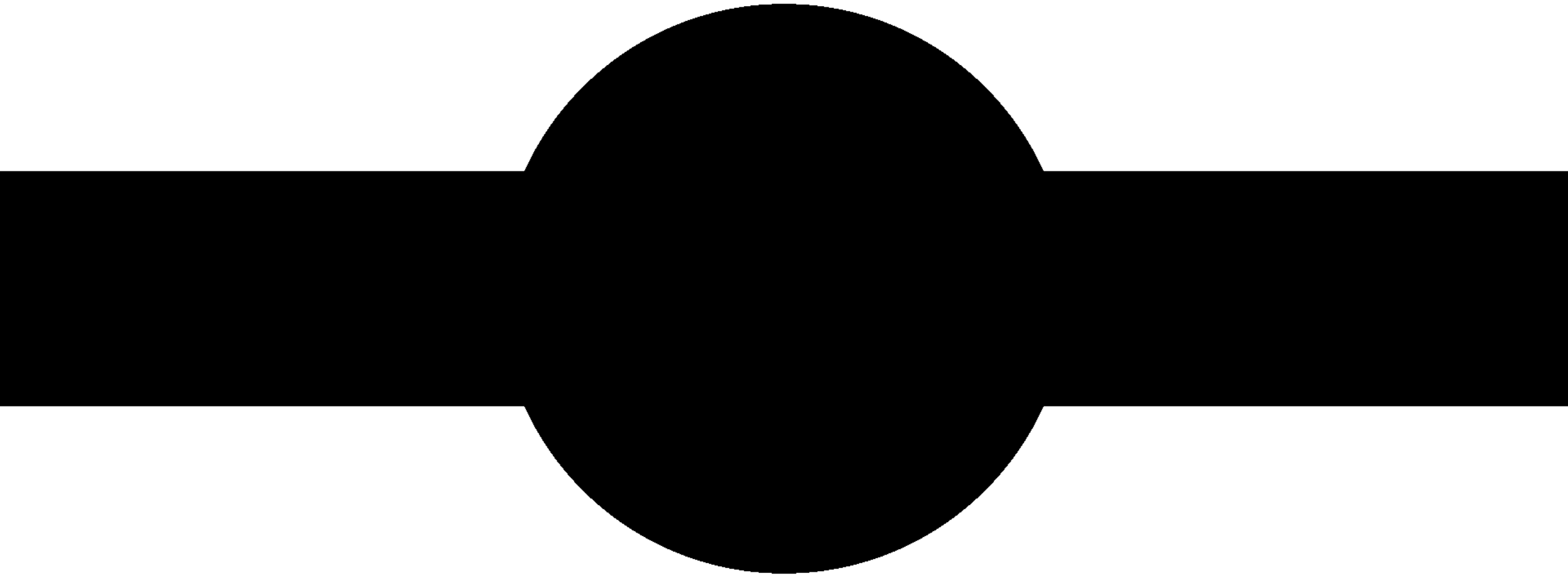

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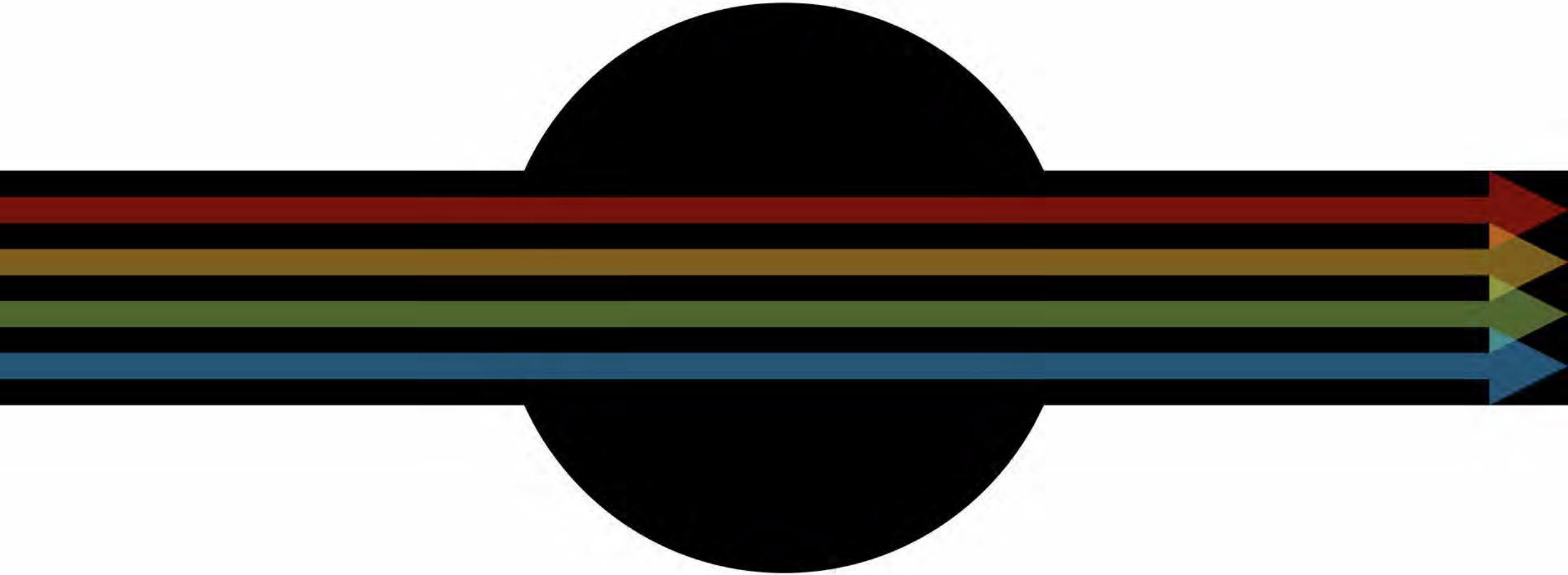

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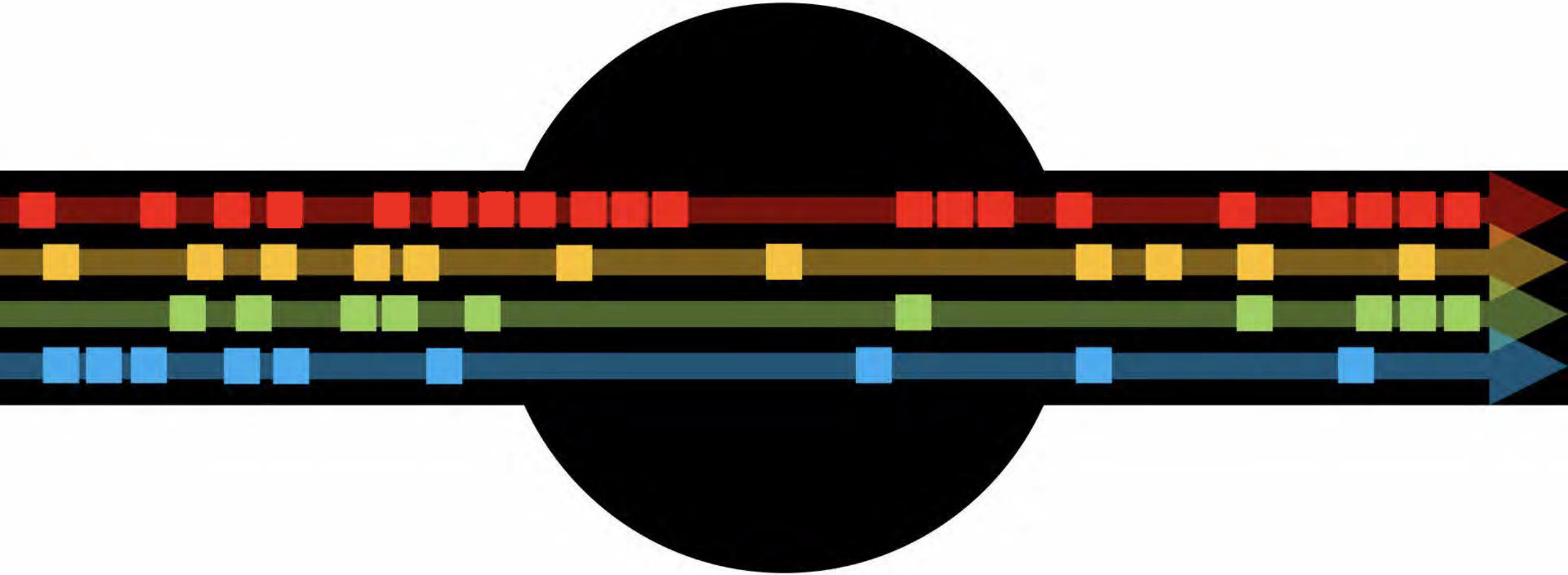

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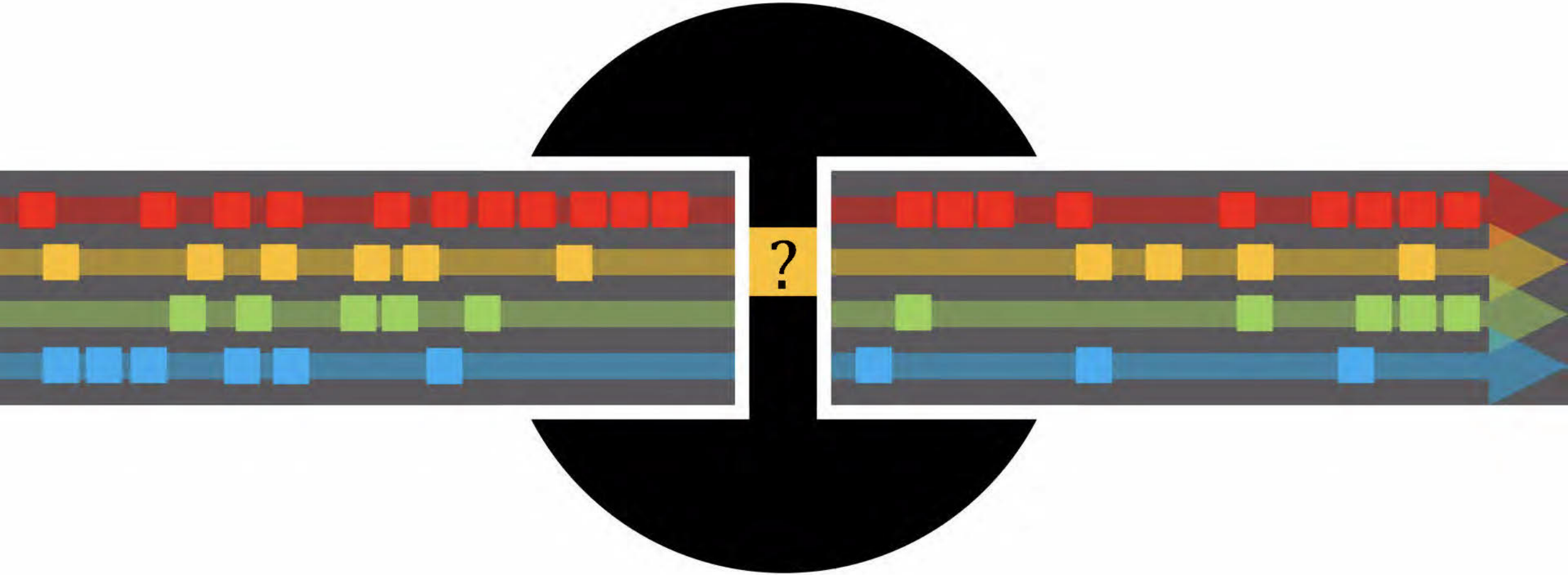

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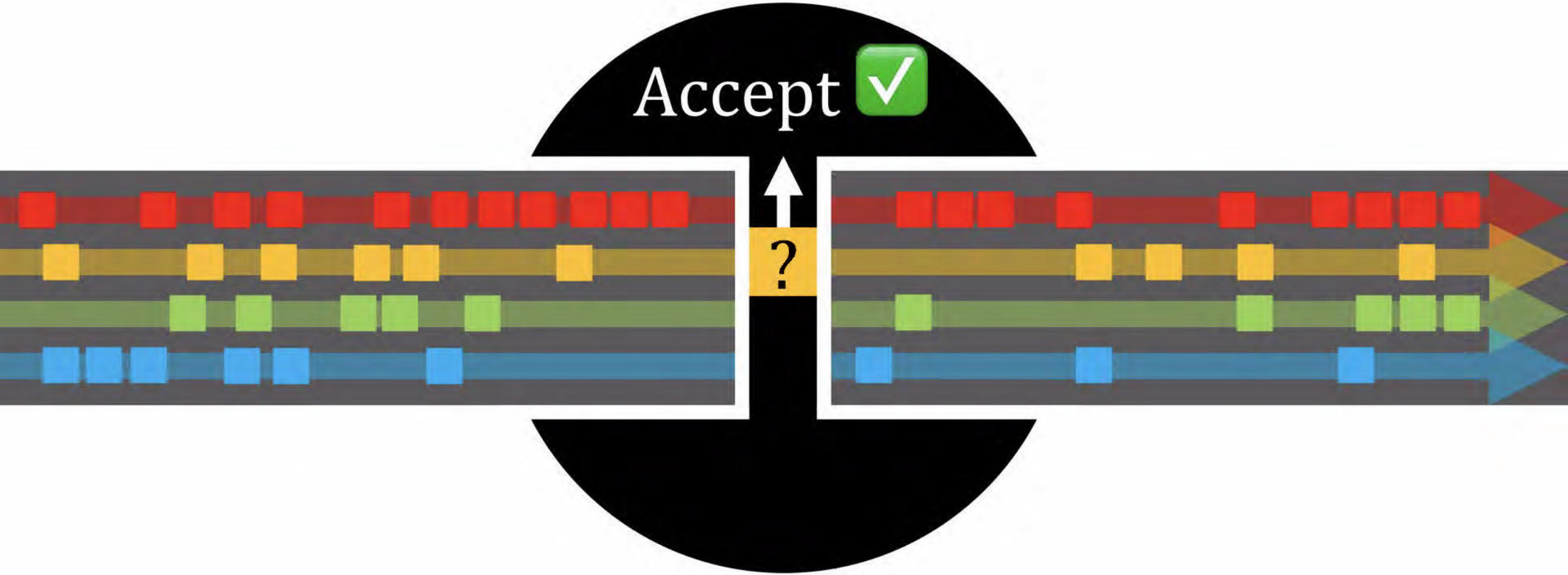

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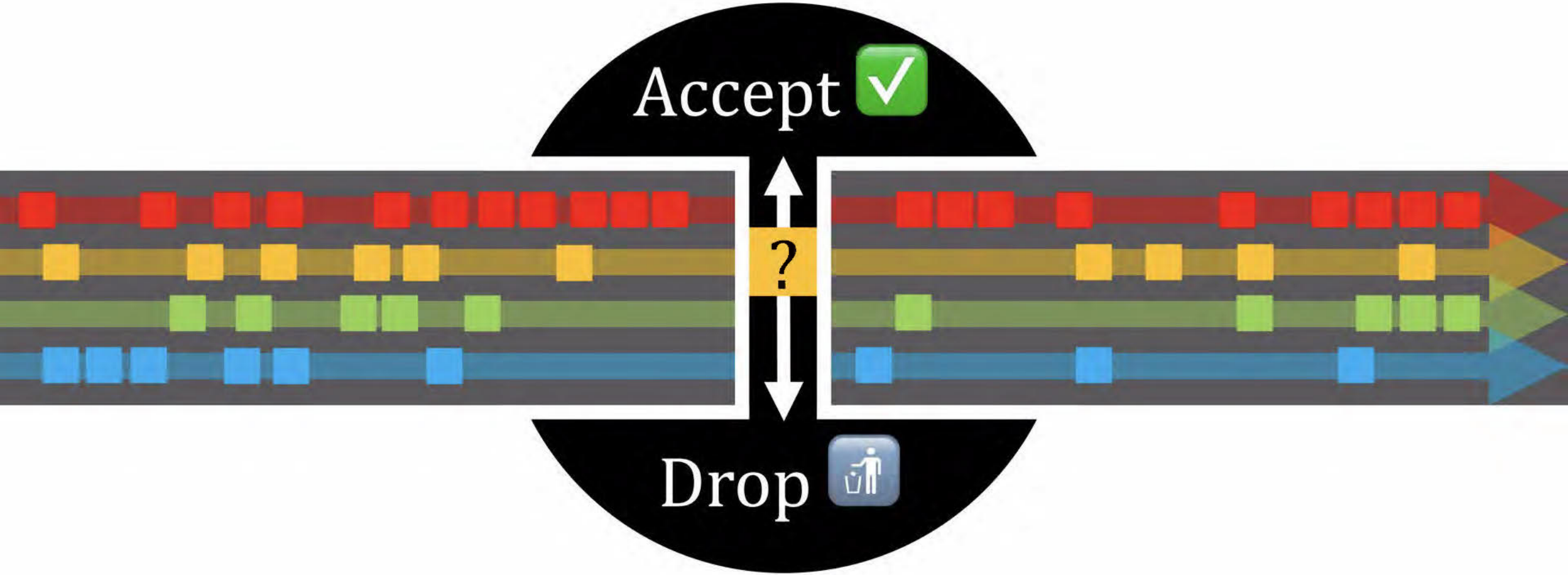
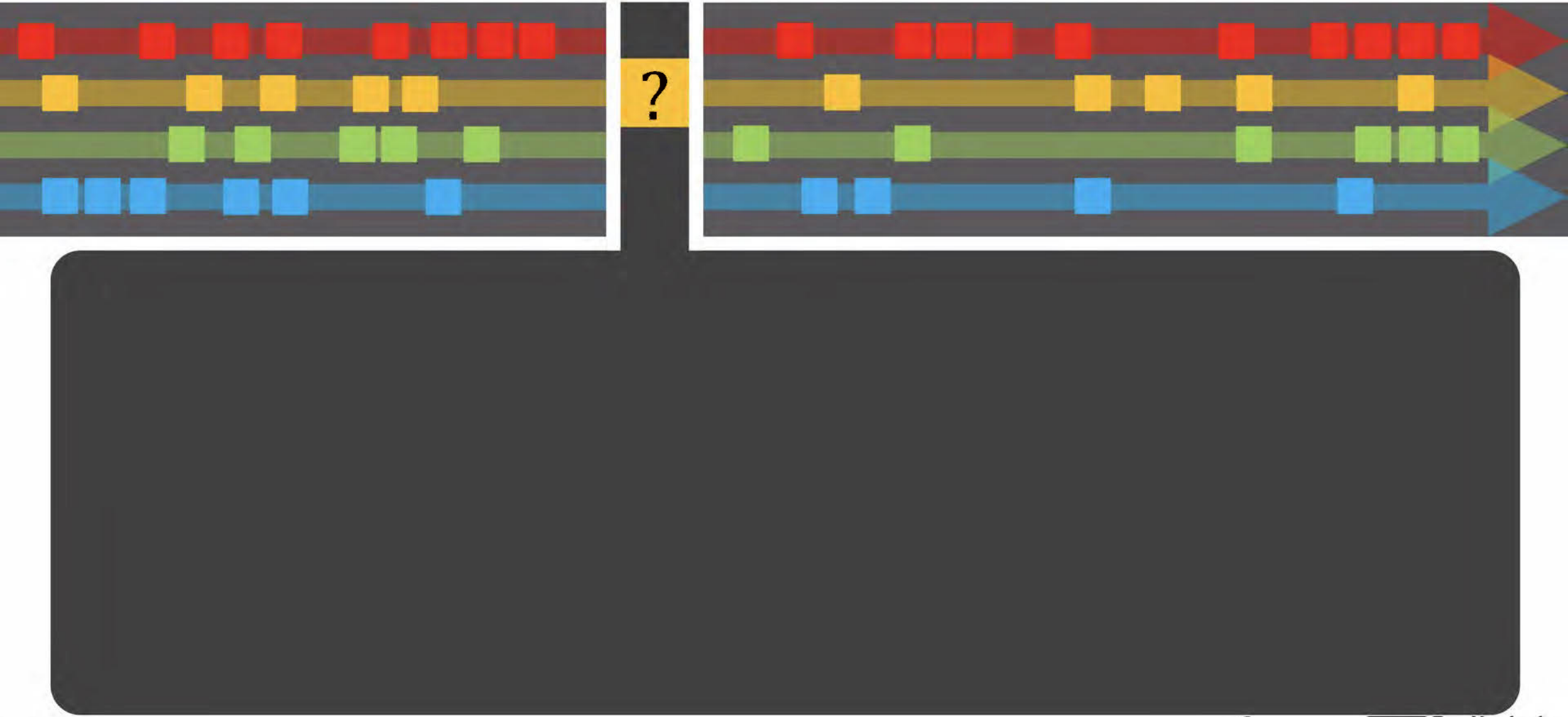


RATE MONITORING AND LIMITING



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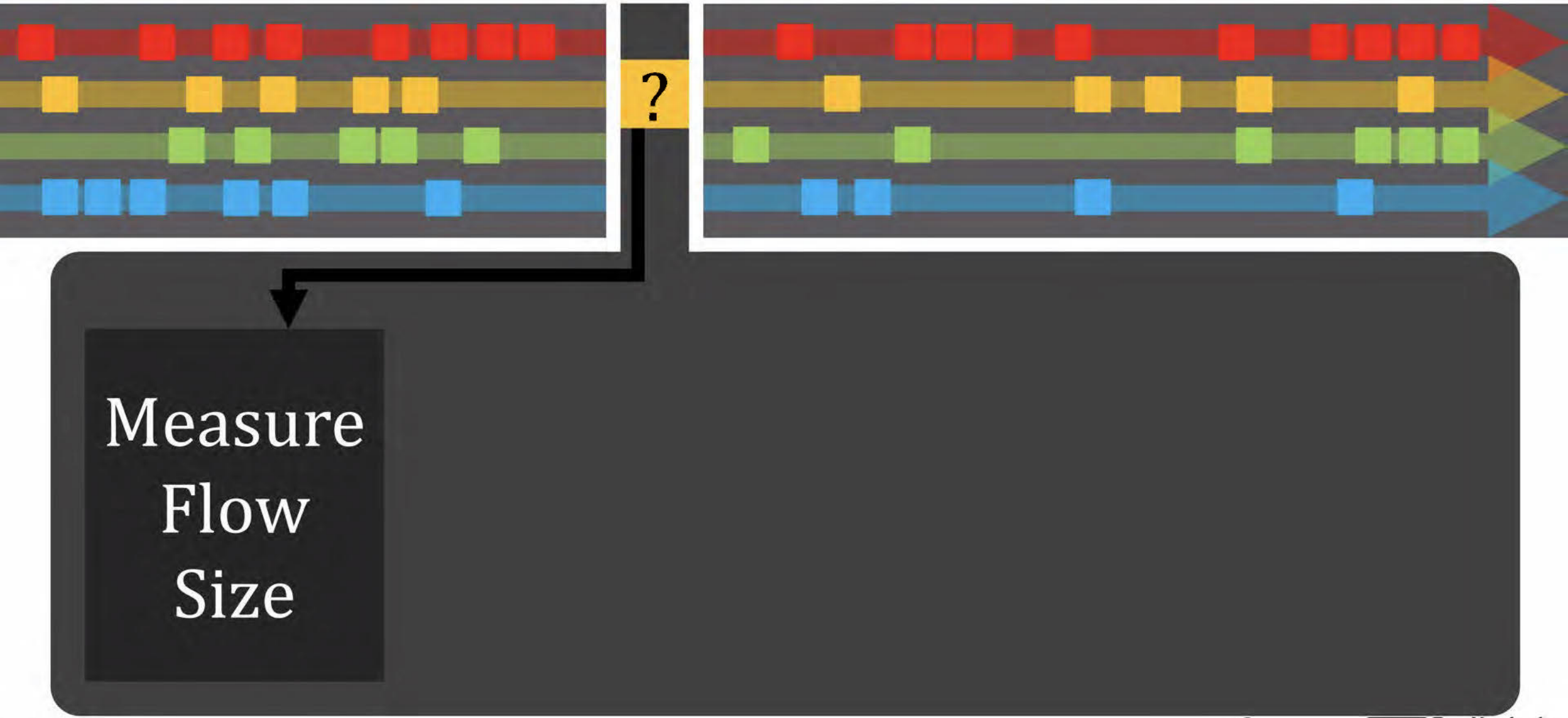

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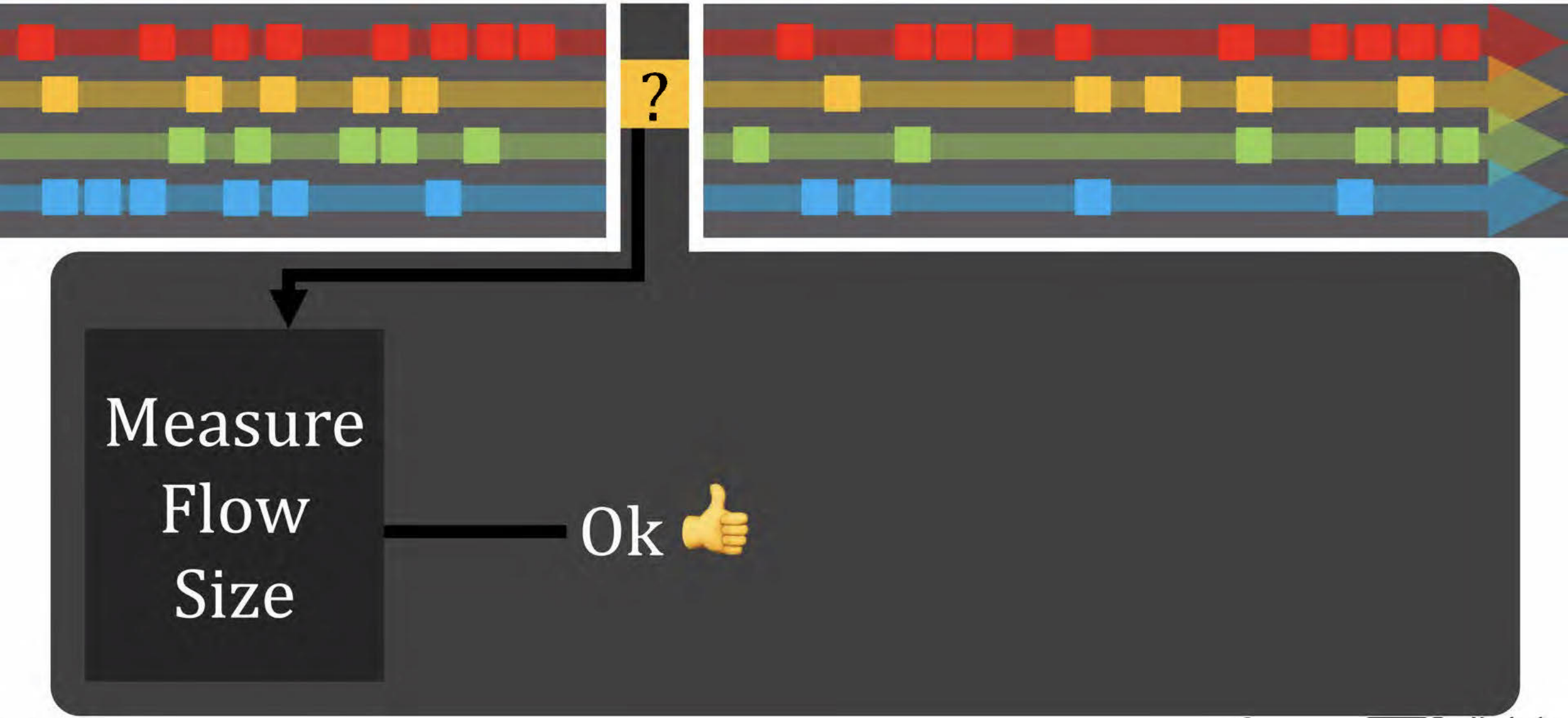

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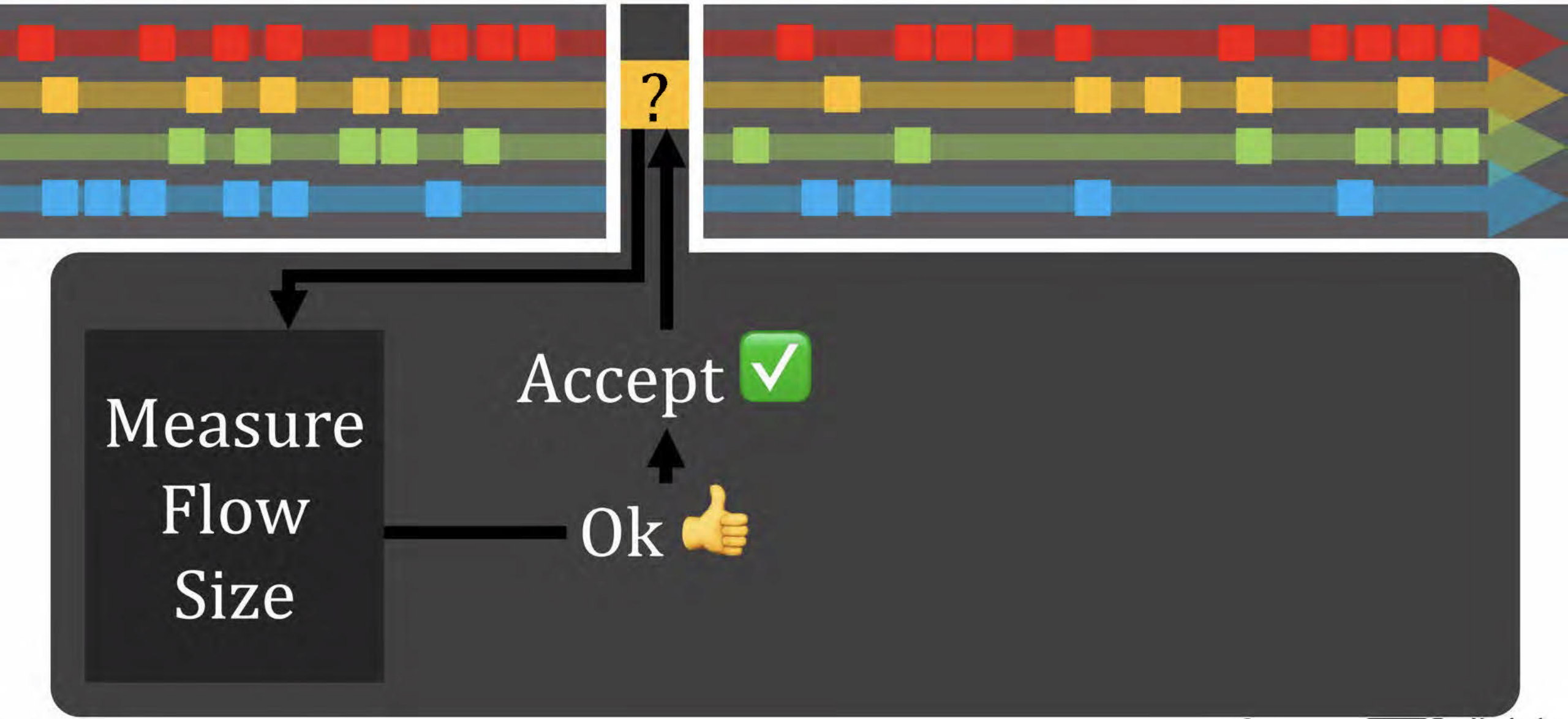

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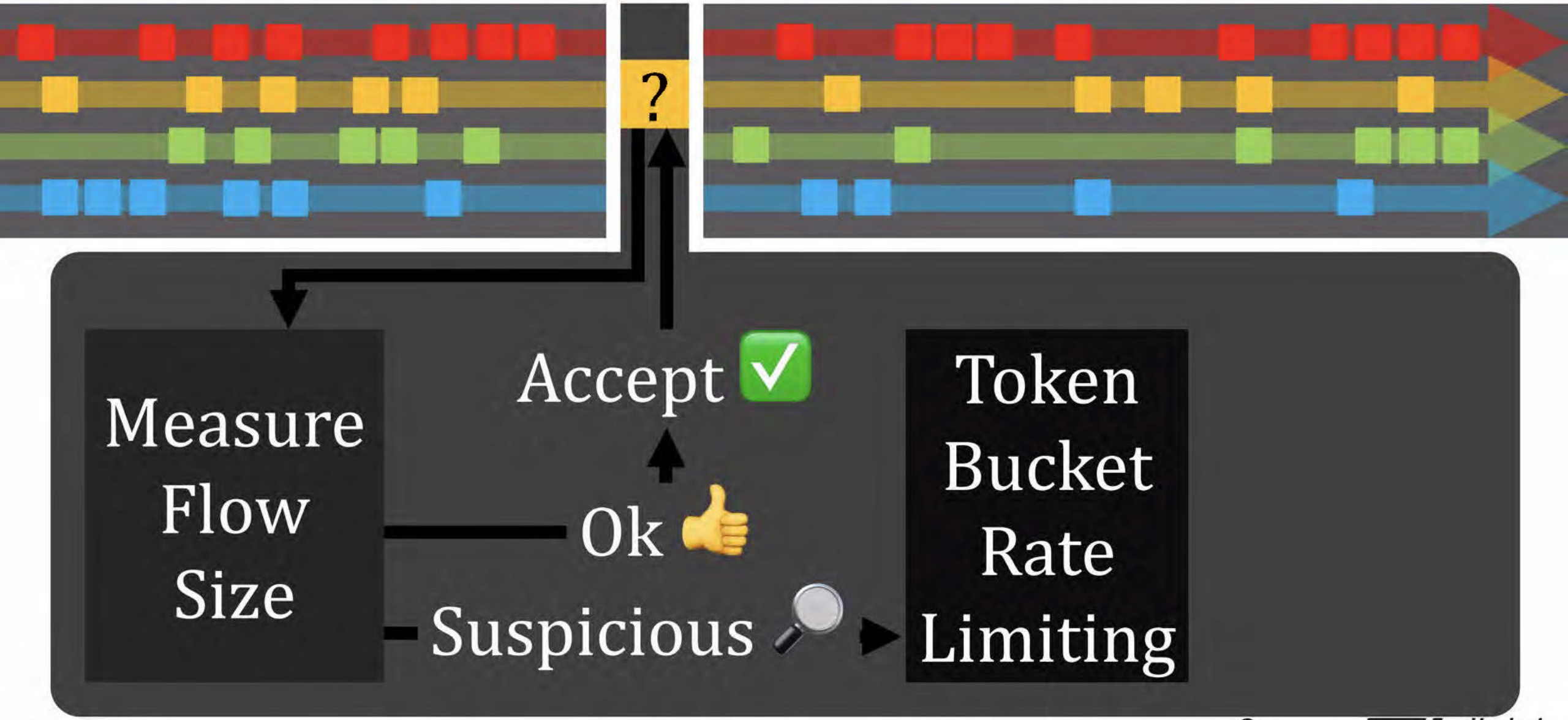

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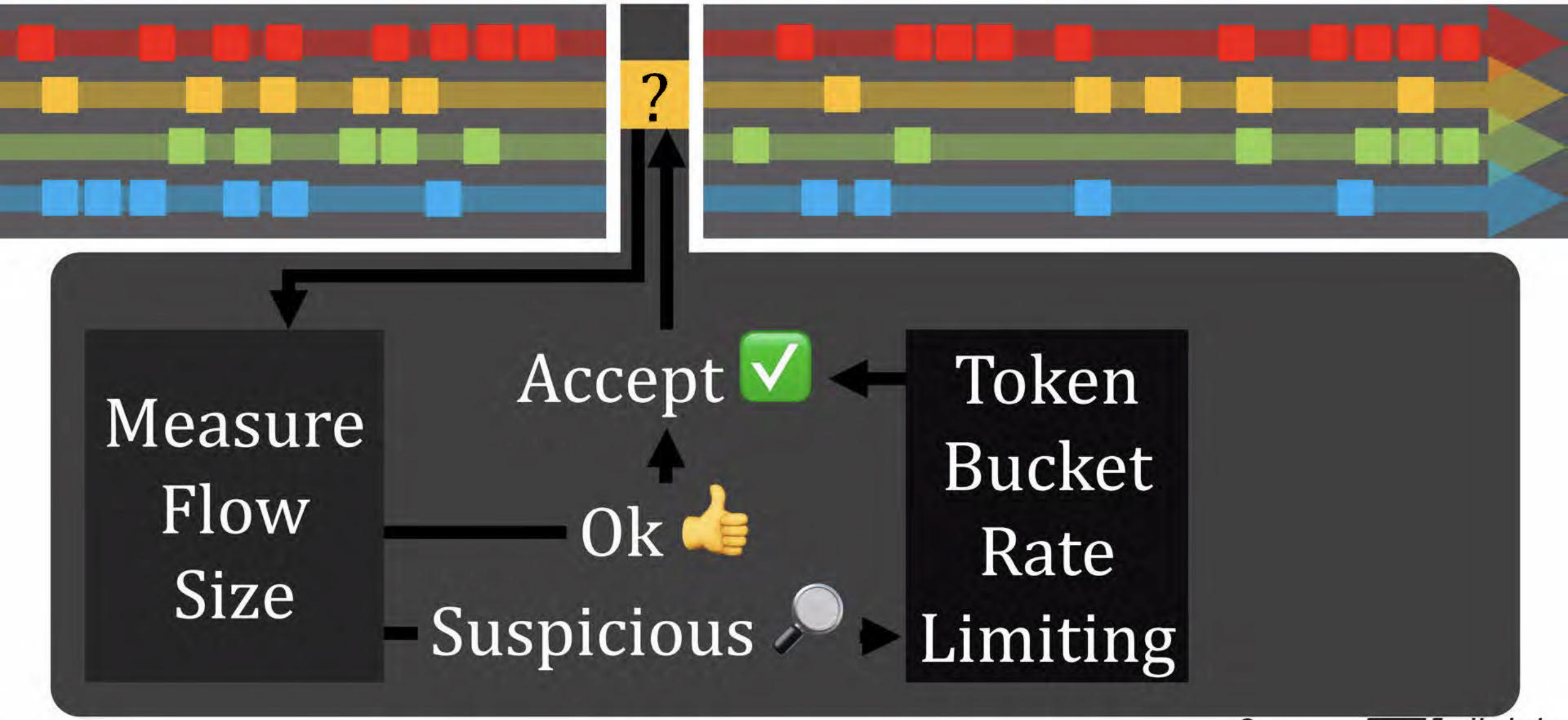

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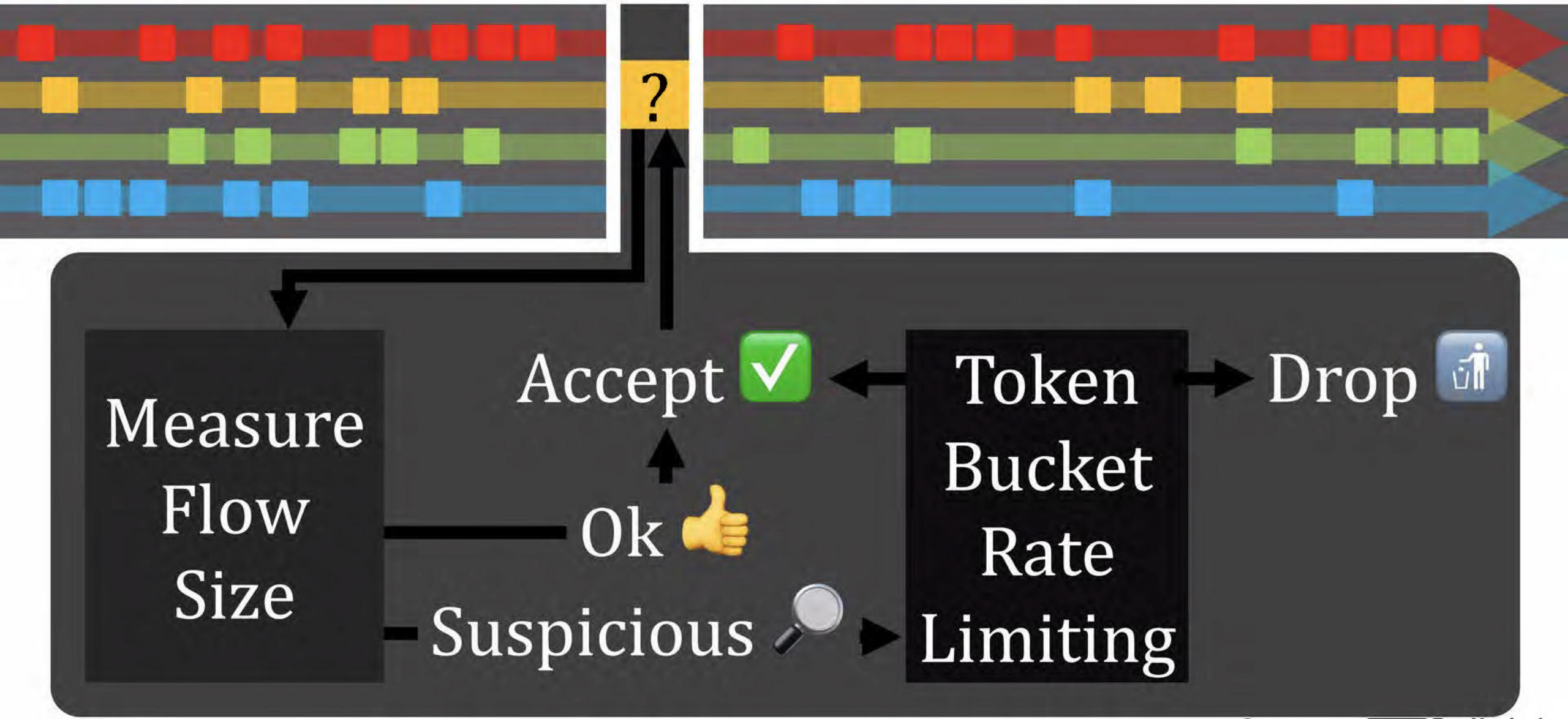

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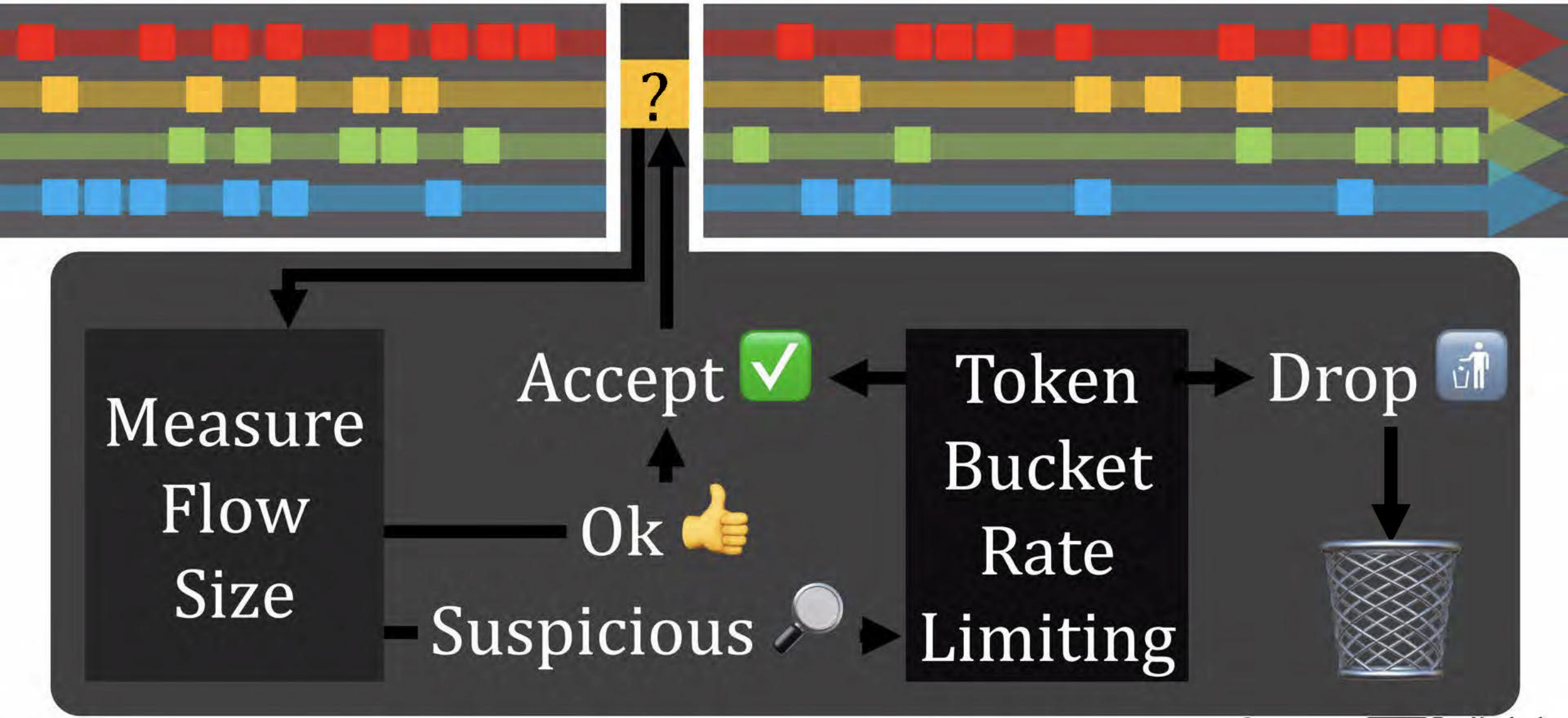

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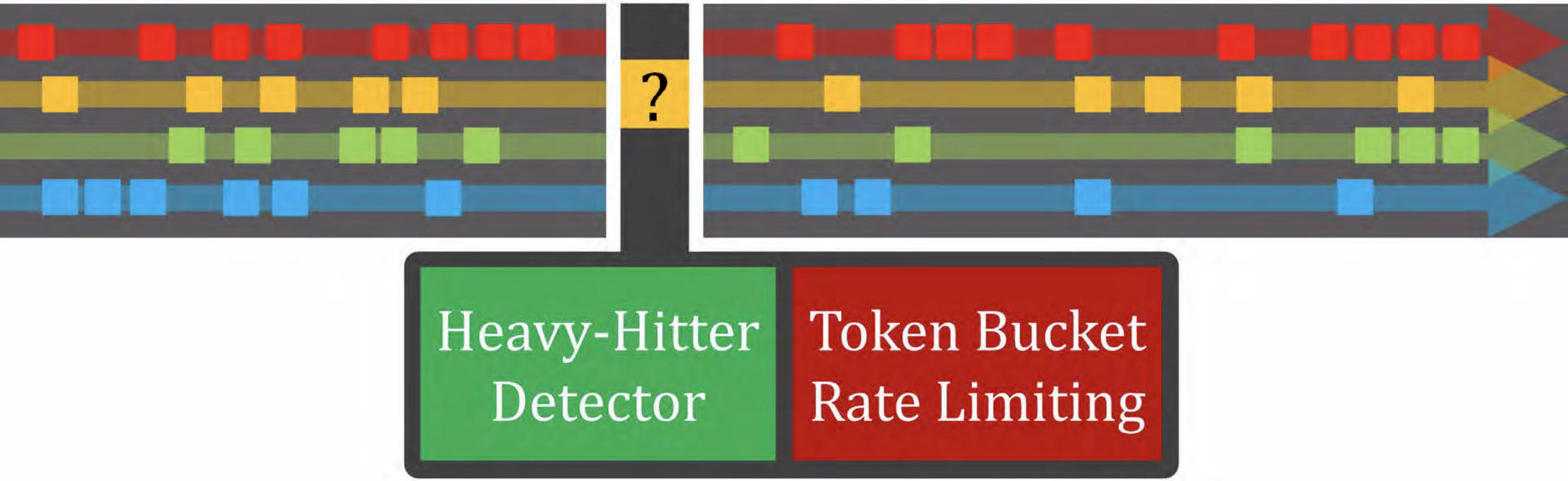

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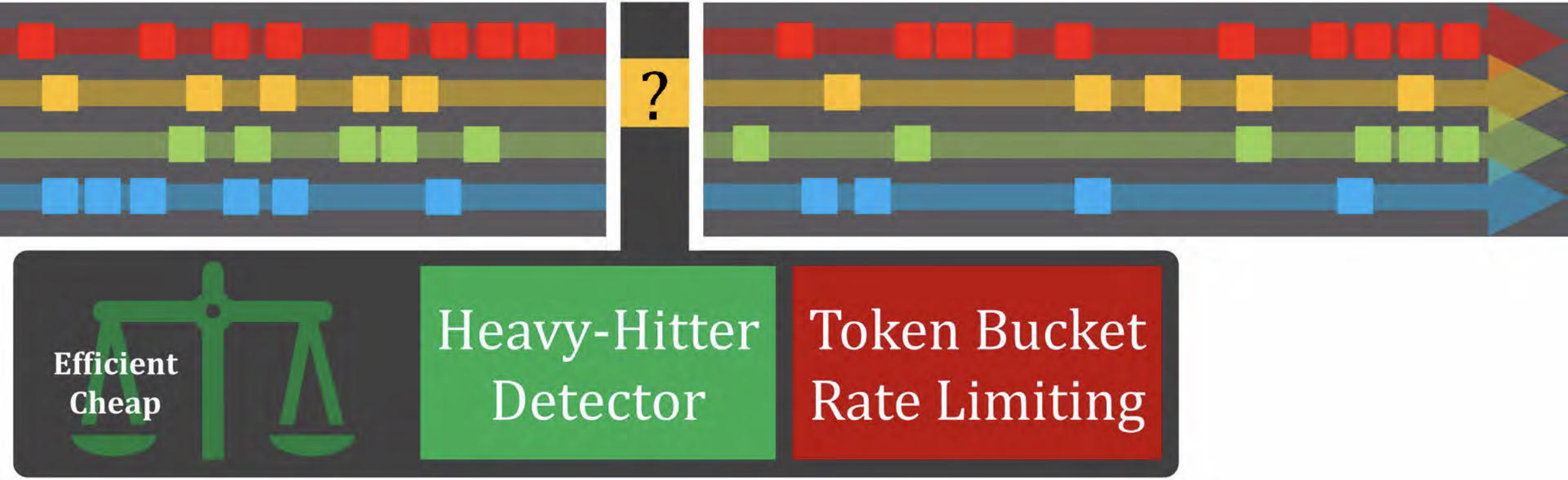

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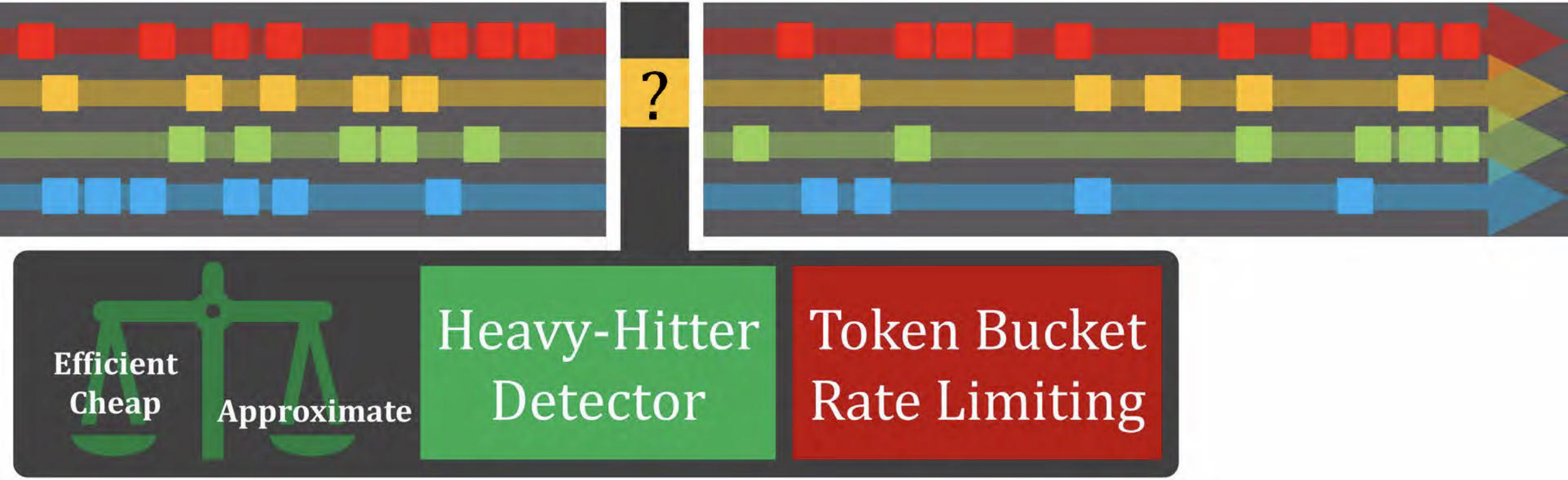

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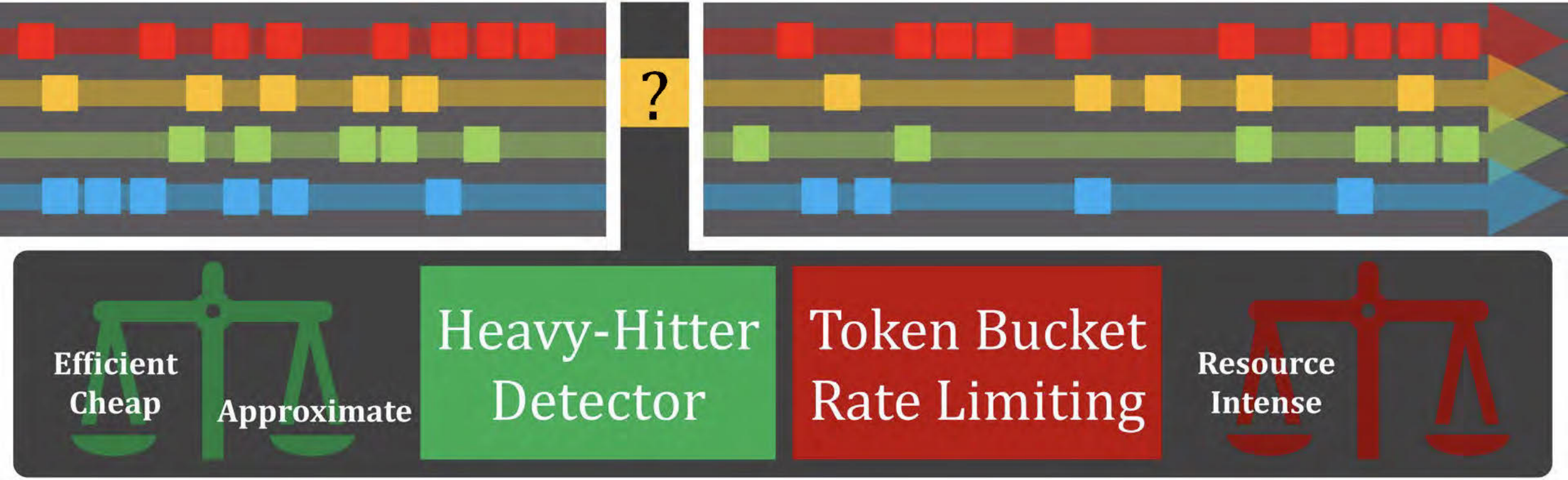

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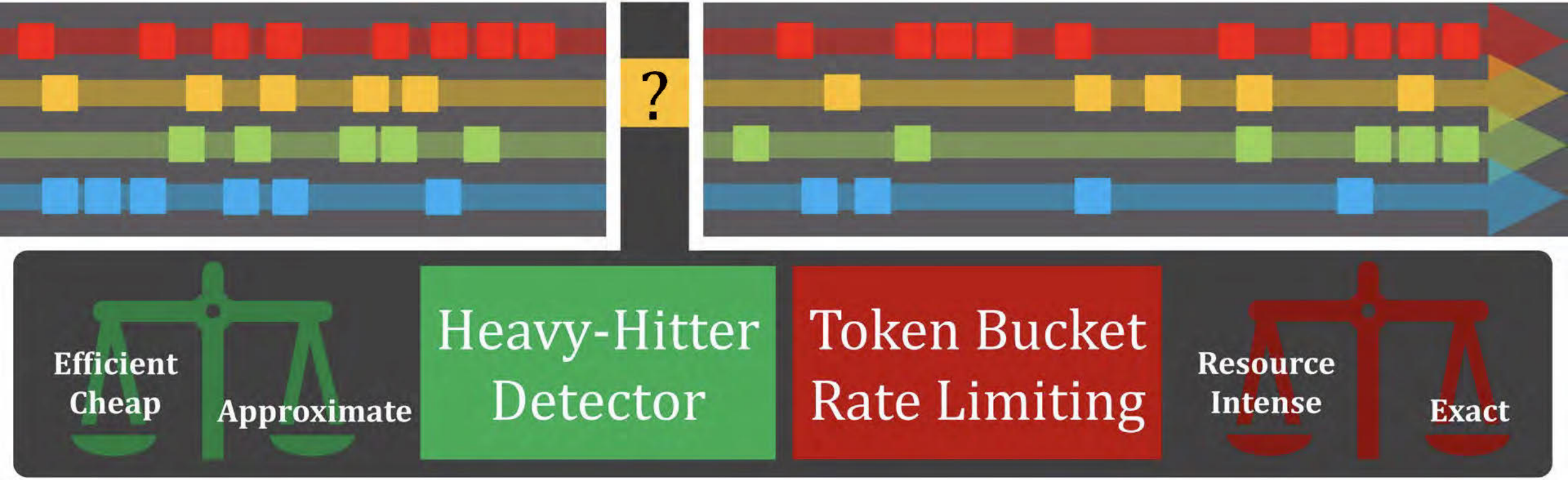

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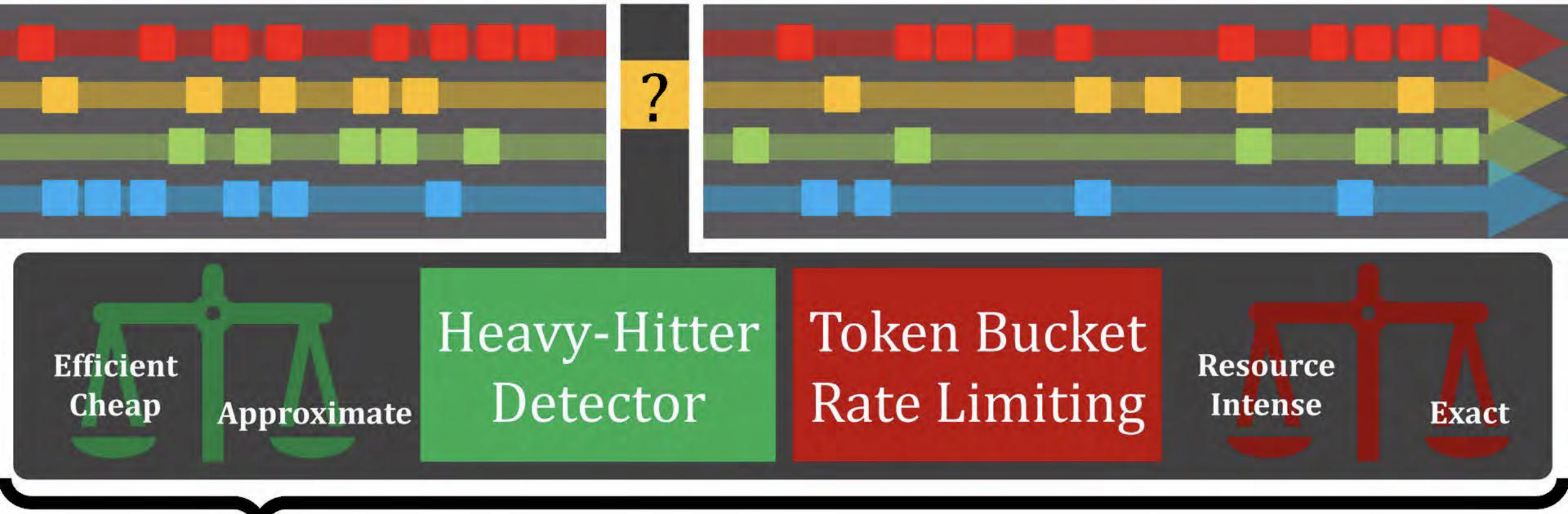
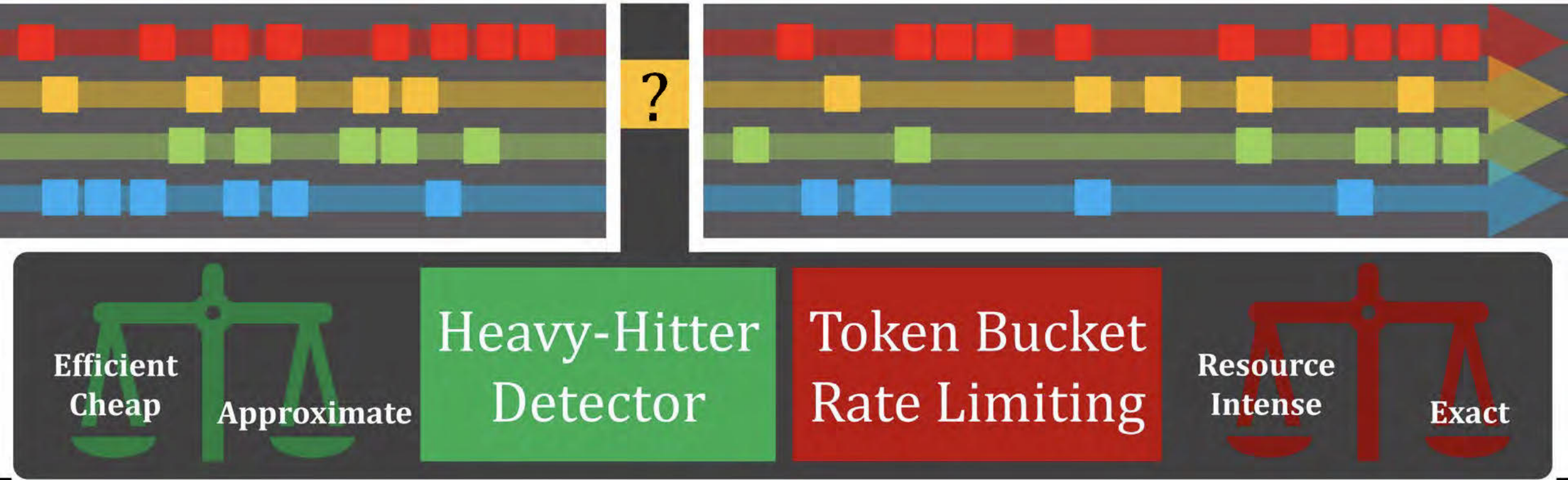


How to configure optimally ?

RATE MONITORING AND LIMITING



How to configure optimally ?

Depends on attack.

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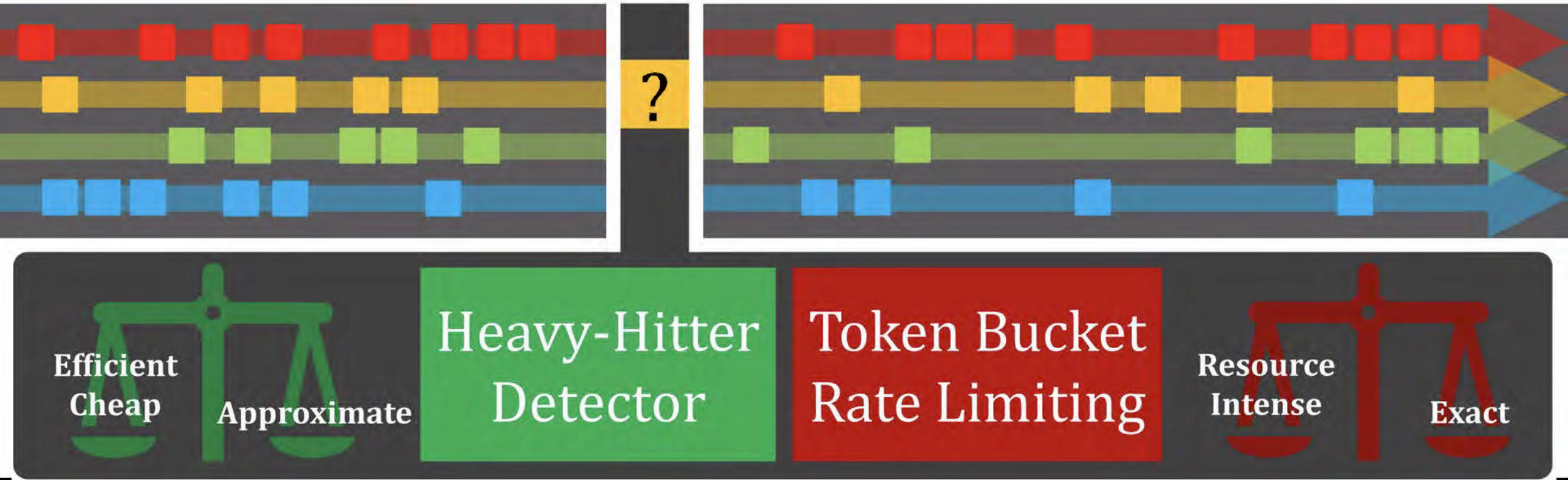

How to configure optimally ?

Depends on attack.

Whats the optimal attack?

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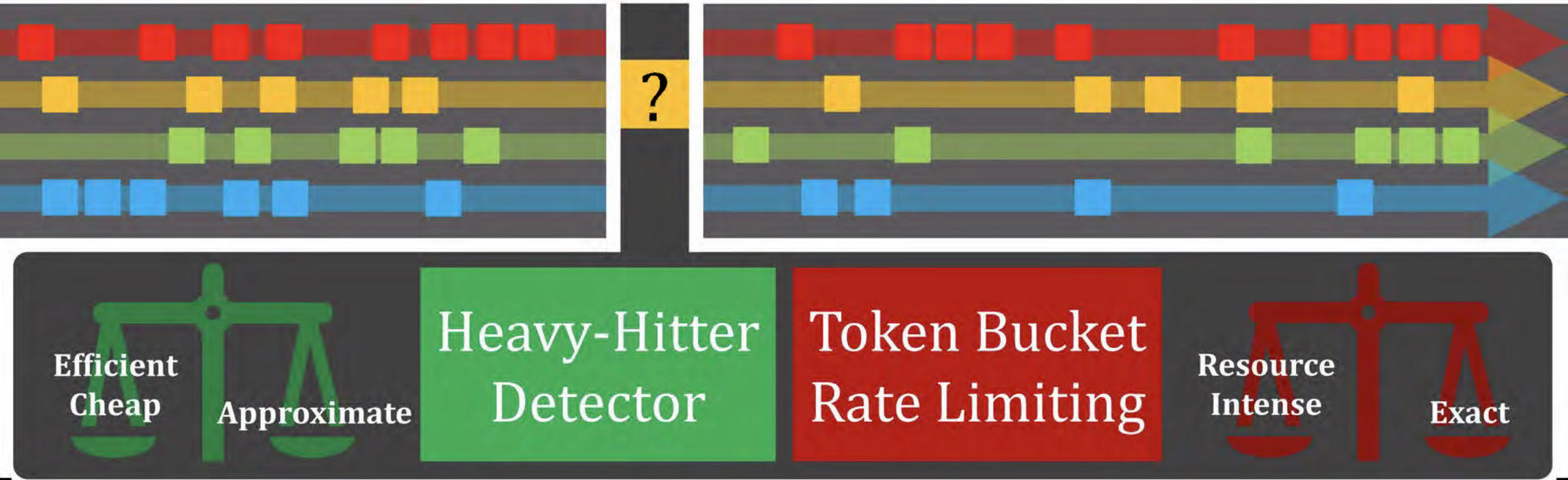

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Whats the optimal attack?

Depends on configuration.

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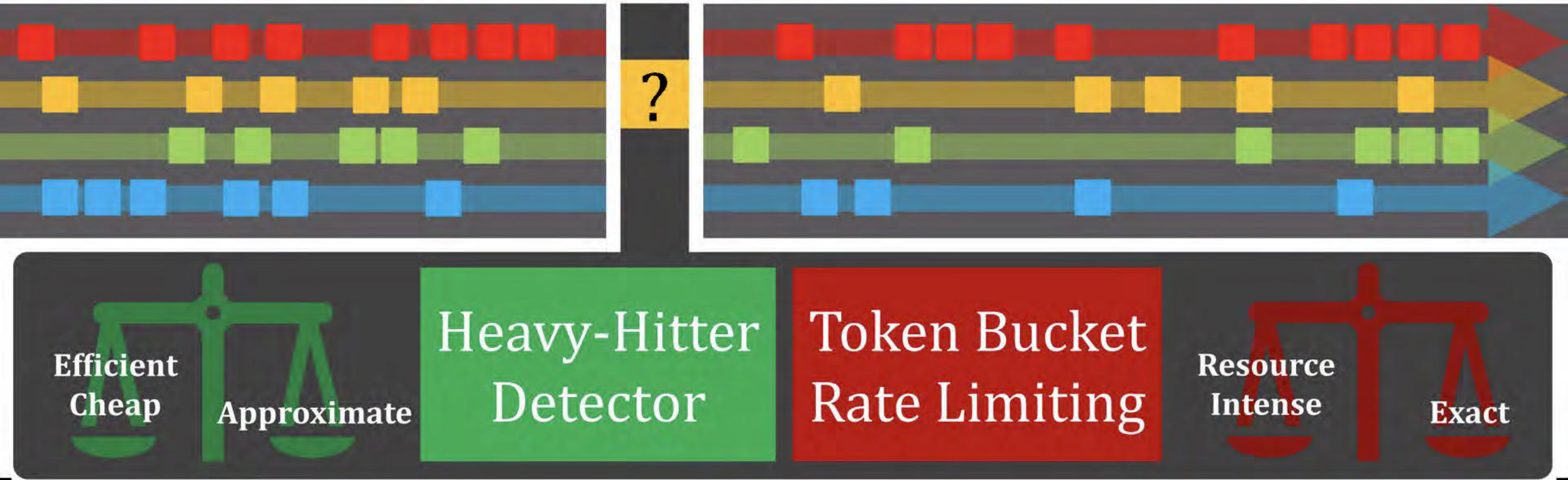

How to configure optimally ? → **Depends on attack.**

Whats the optimal attack? → **Depends on configuration.**

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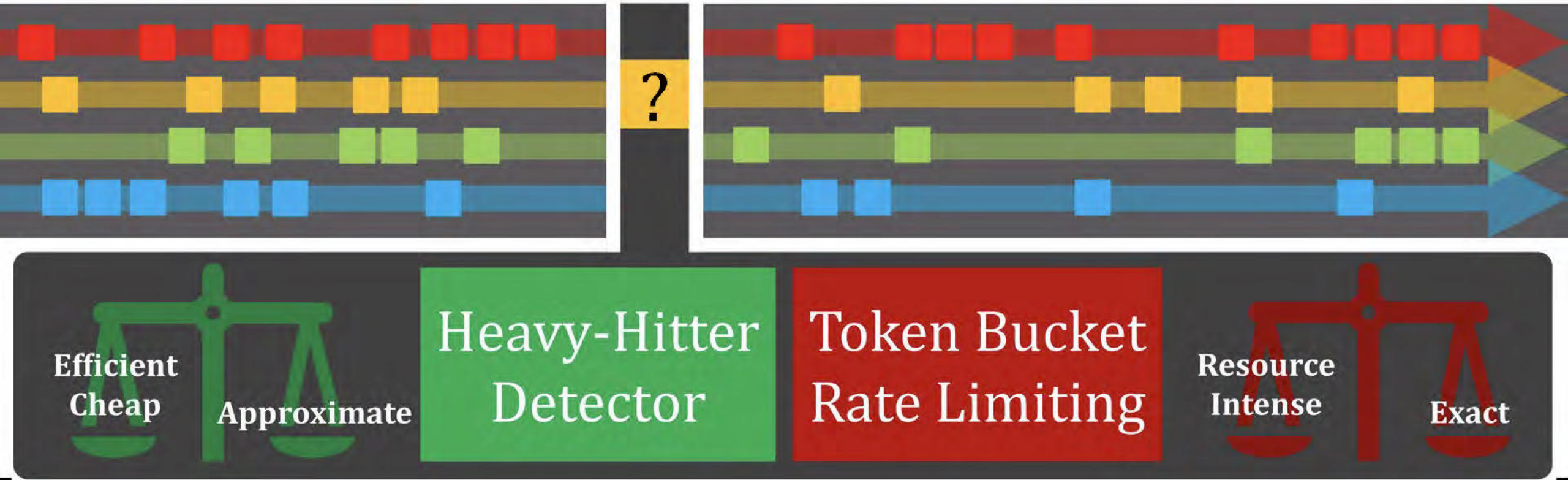
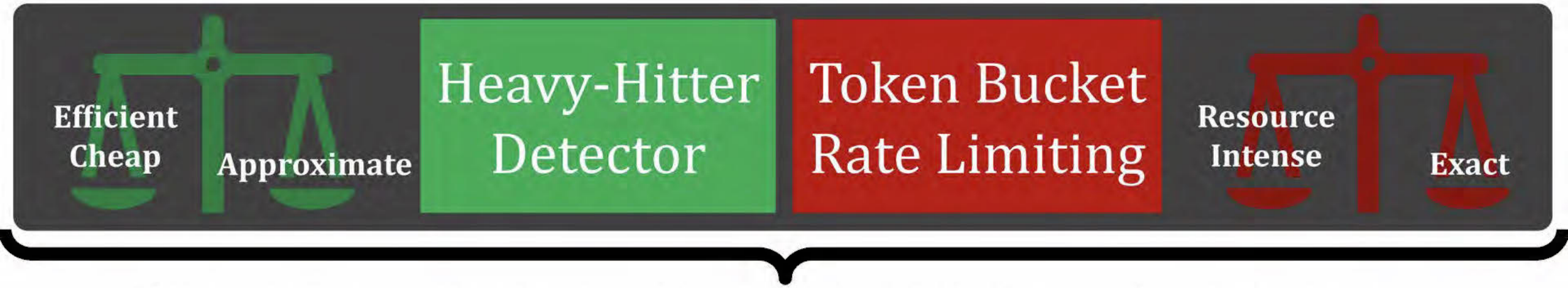


How to configure optimally ? → **Depends on attack.**

Whats the optimal attack? → **Depends on configuration.**

Nobody knows

RATE MONITORING AND LIMITING



How to configure optimally ? → **Depends on attack.**

Whats the optimal attack? → **Depends on configuration.**

RATE MONITORING AND LIMITING

How to configure optimally ?

Depends on attack.

Whats the optimal attack?

Depends on configuration.

RATE MONITORING AND LIMITING

How to configure optimally ? **Whats the optimal attack?**

Depends on attack. **Depends on configuration.**

Ignoring this dependency leaves one vulnerable to adaptive adversaries.

SYSTEM STRUCTURE AND DYNAMICS

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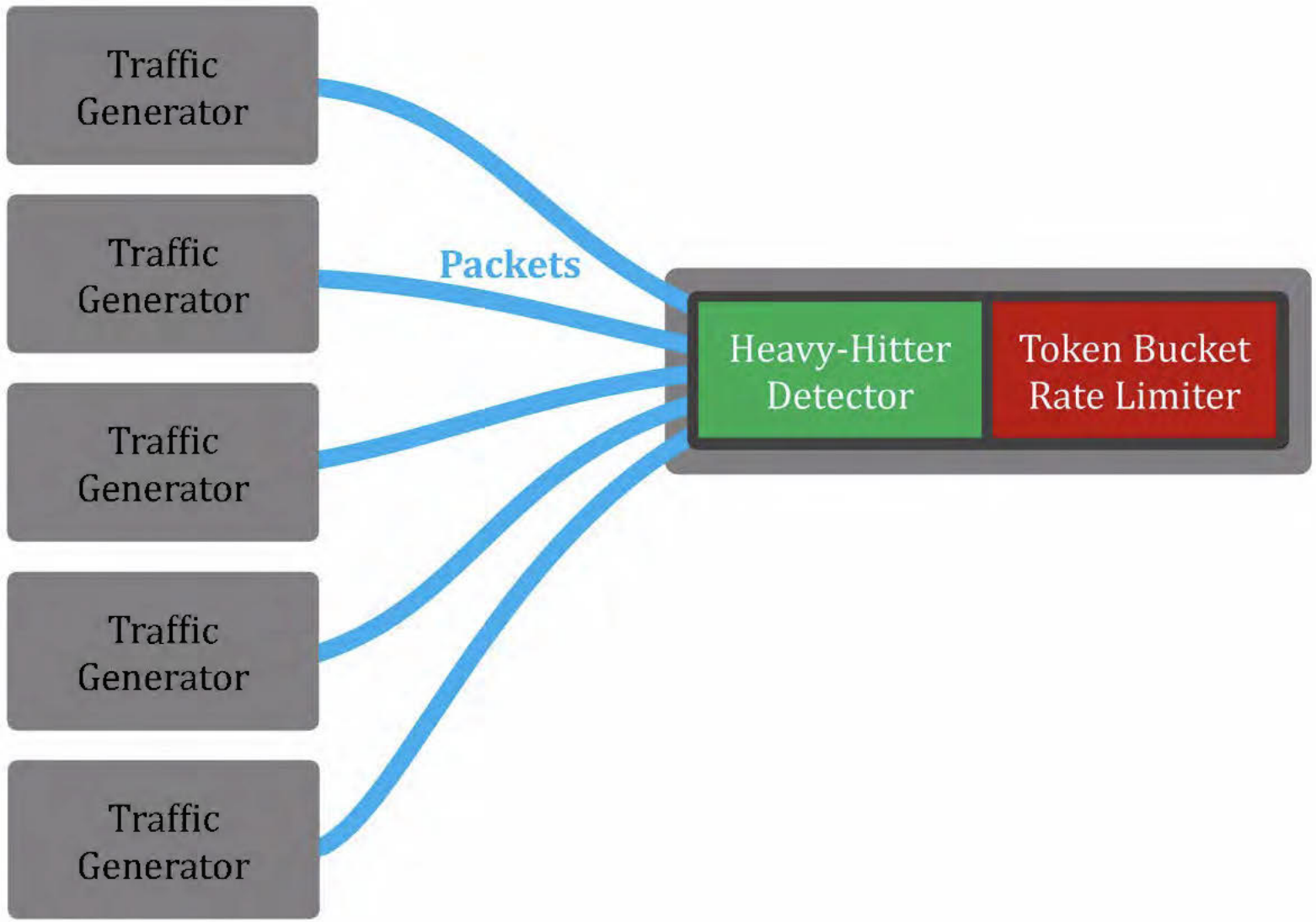
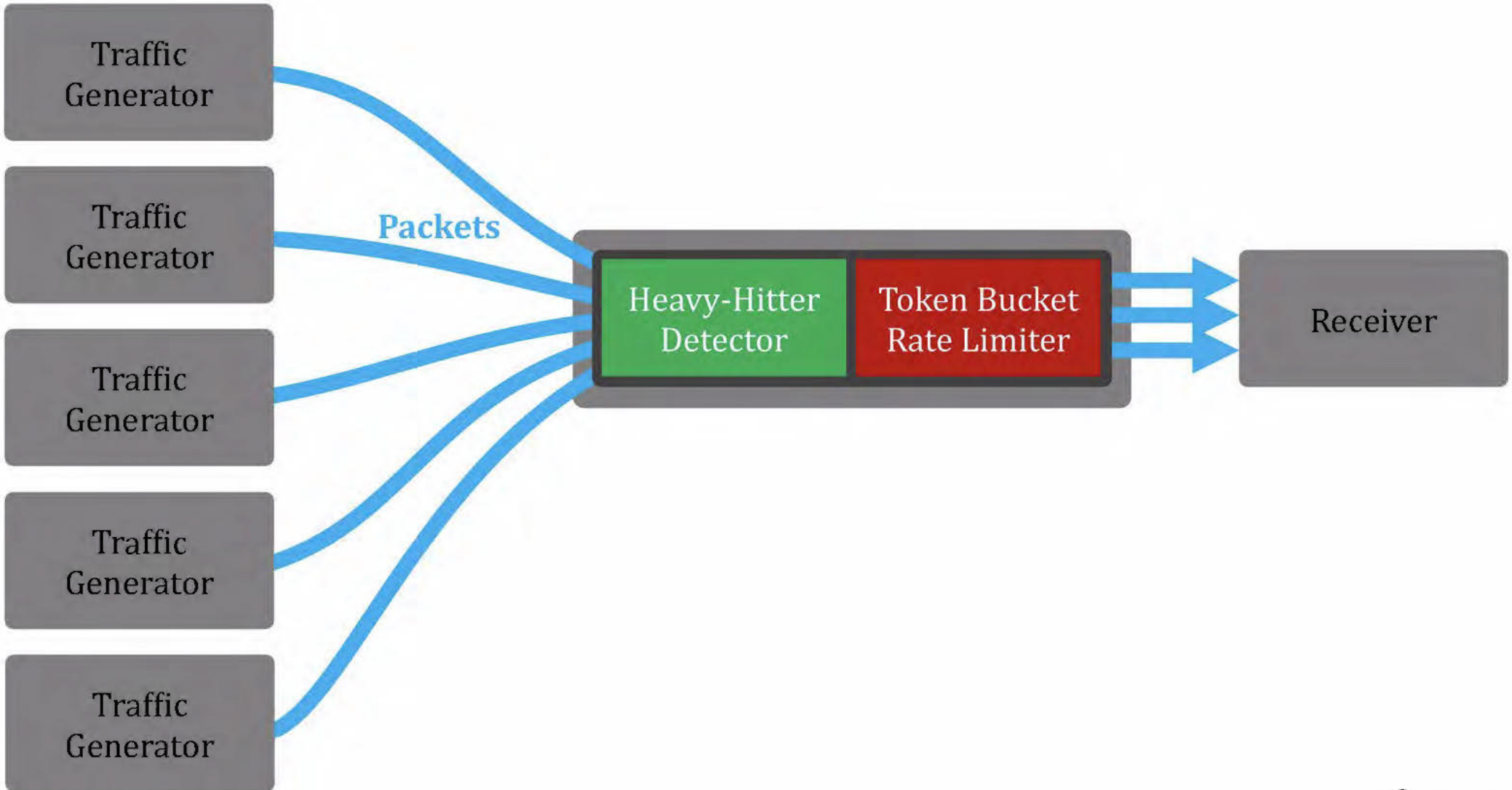


SYSTEM STRUCTURE AND DYNAMICS



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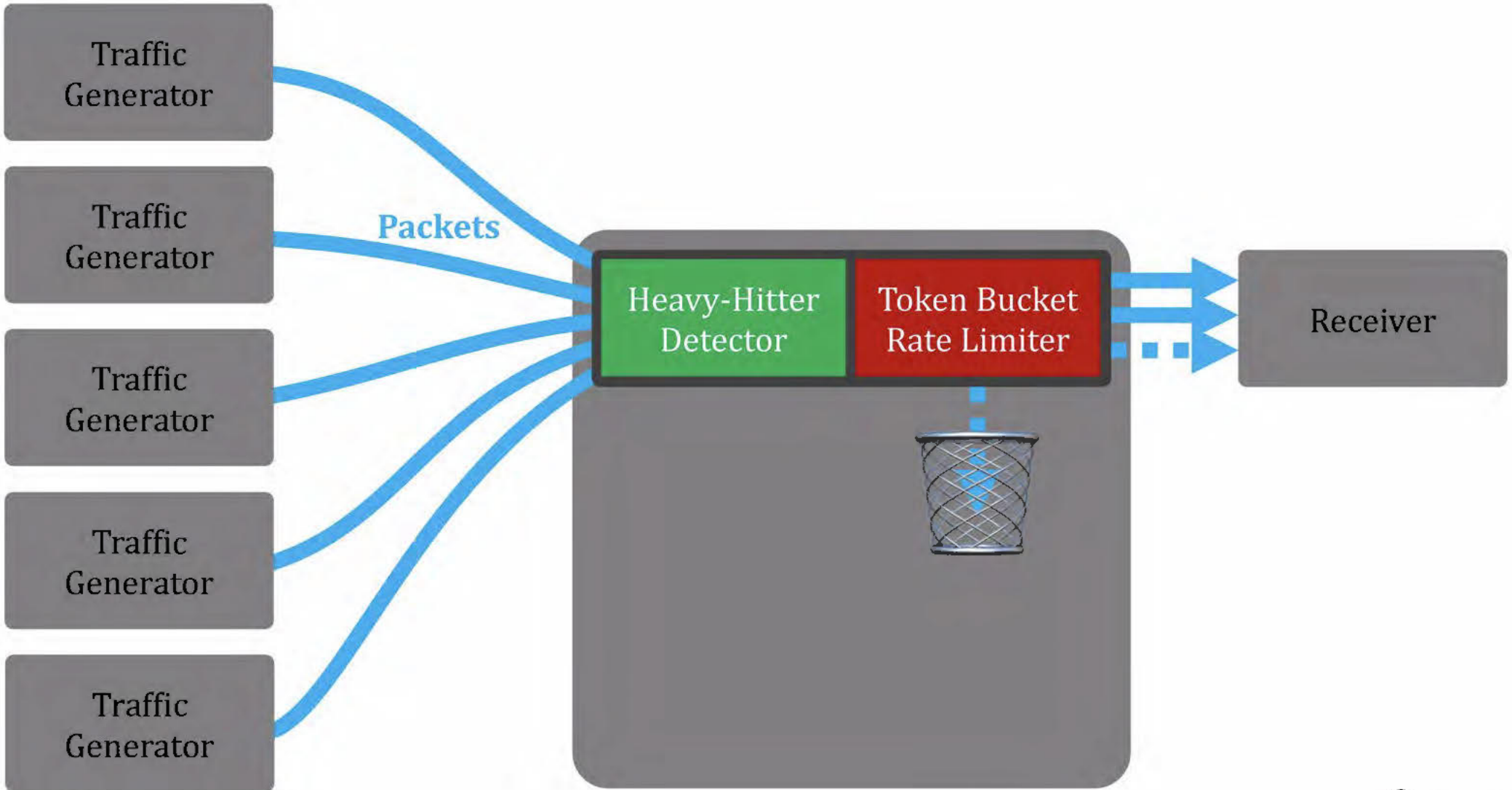

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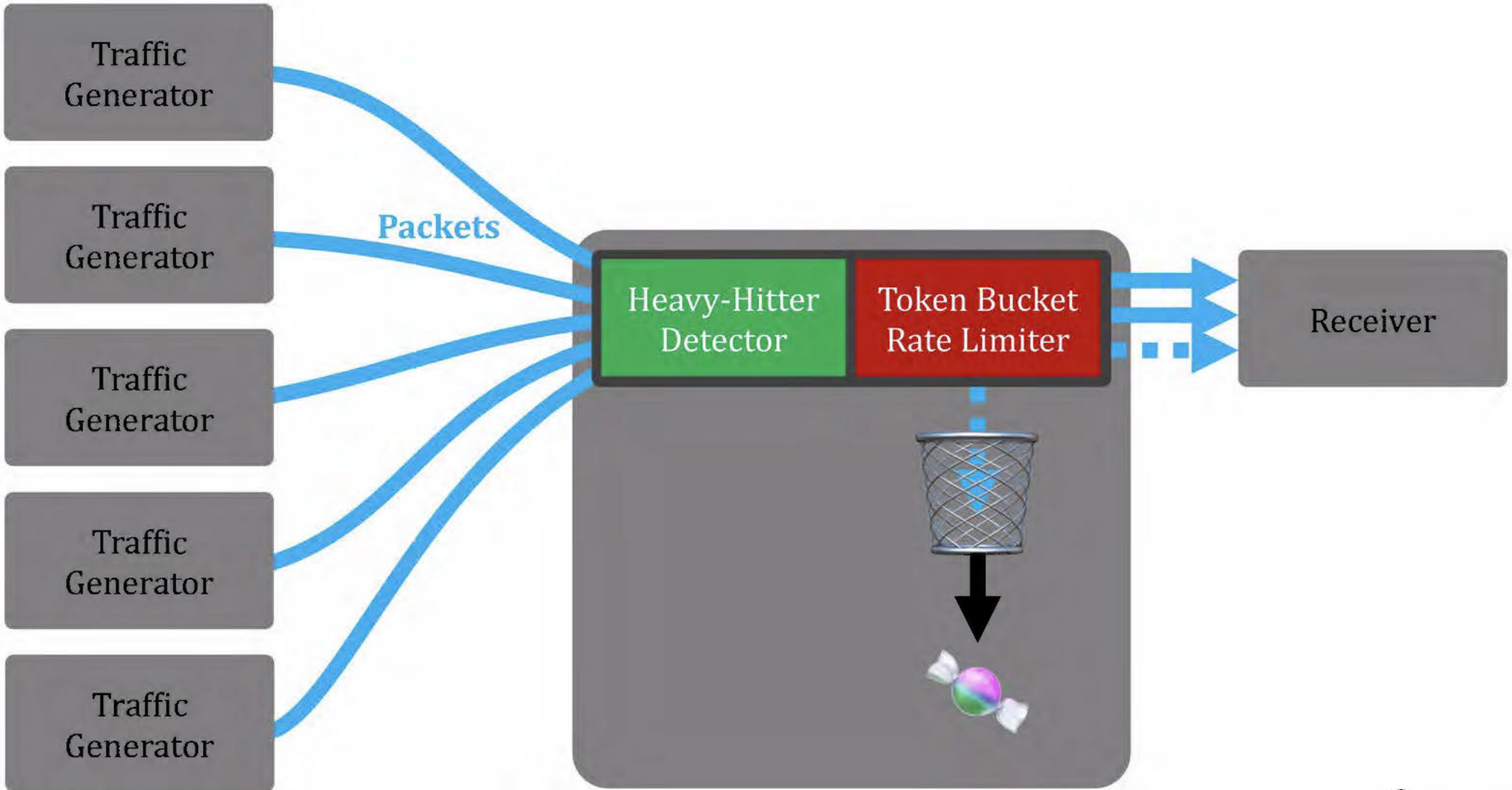

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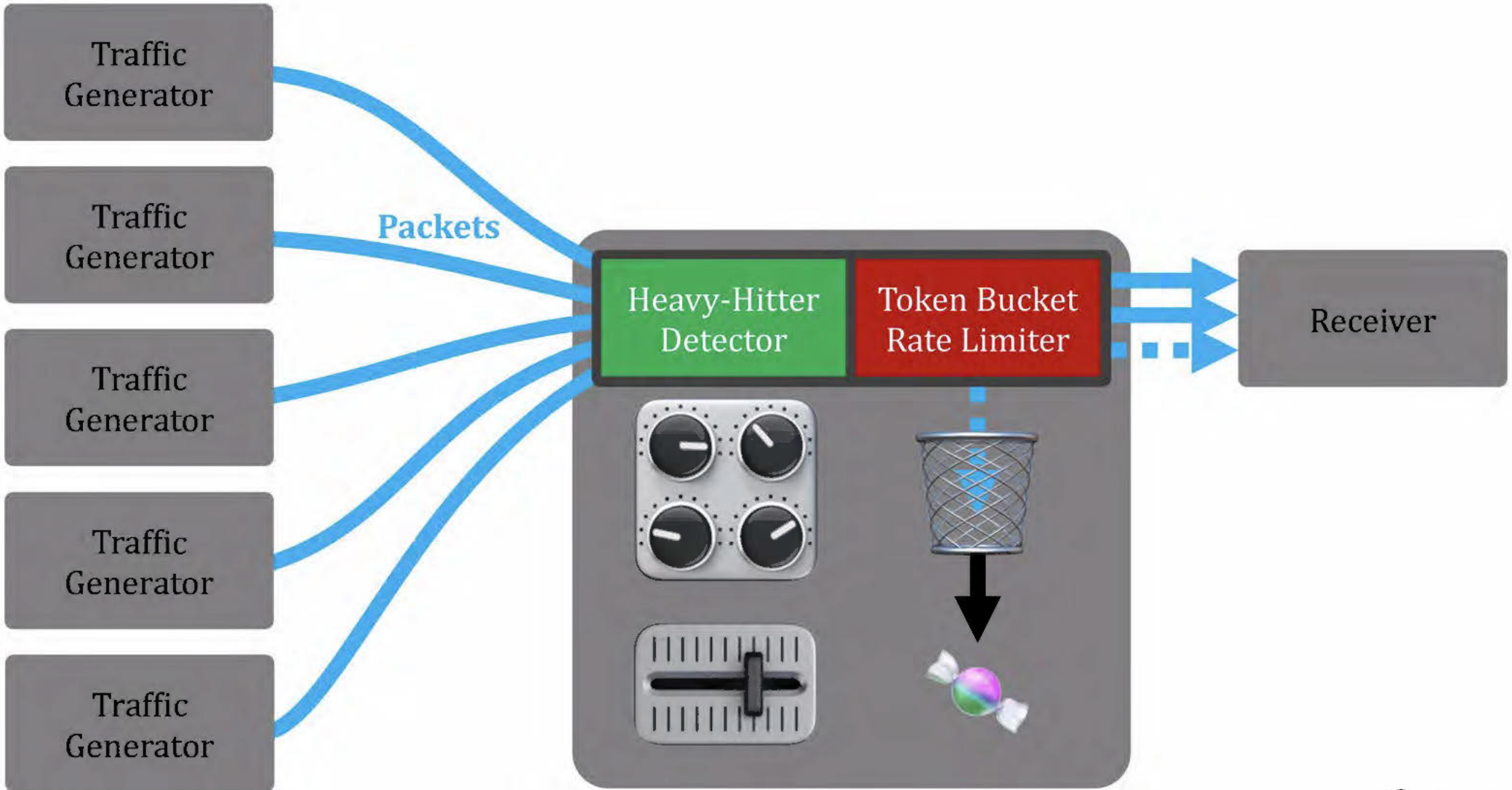

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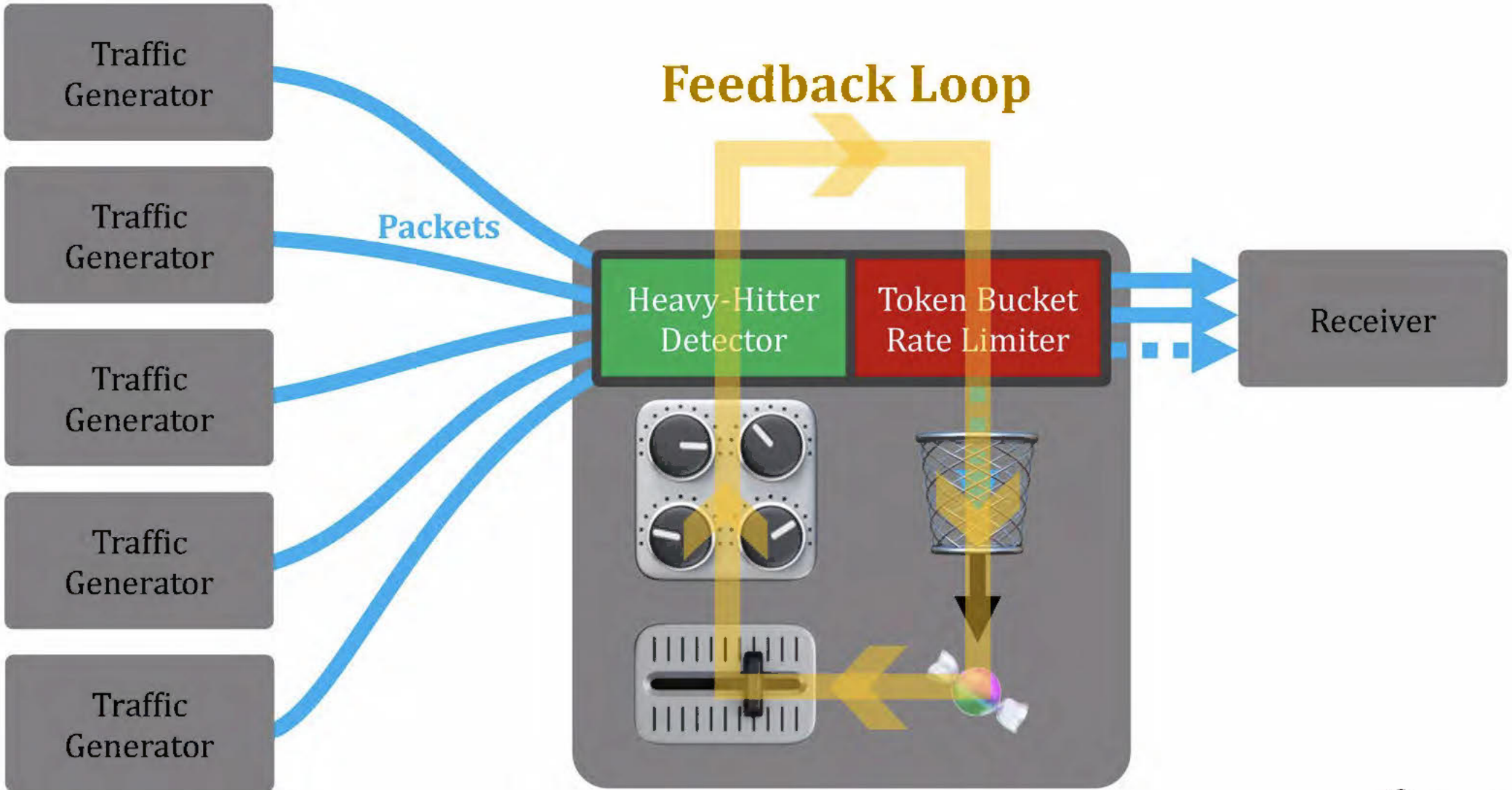
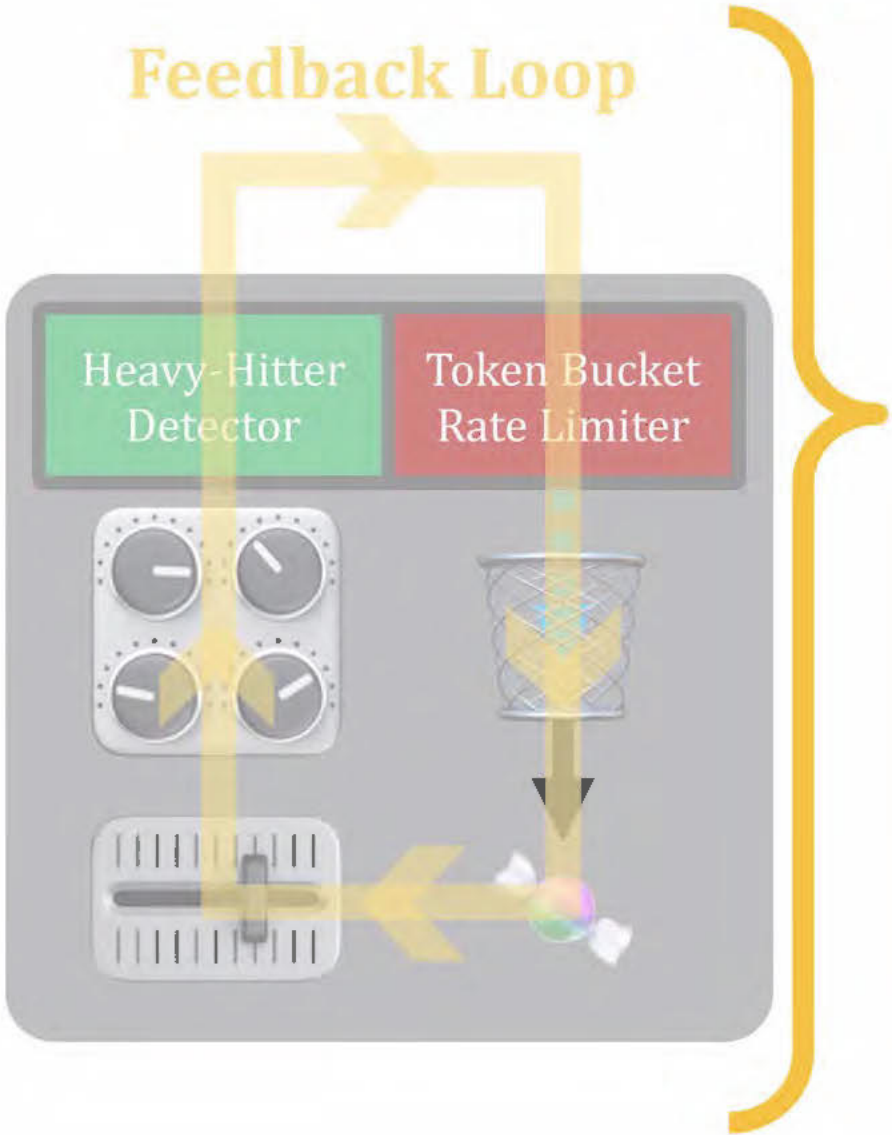


TUNING HHD PARAMETERS



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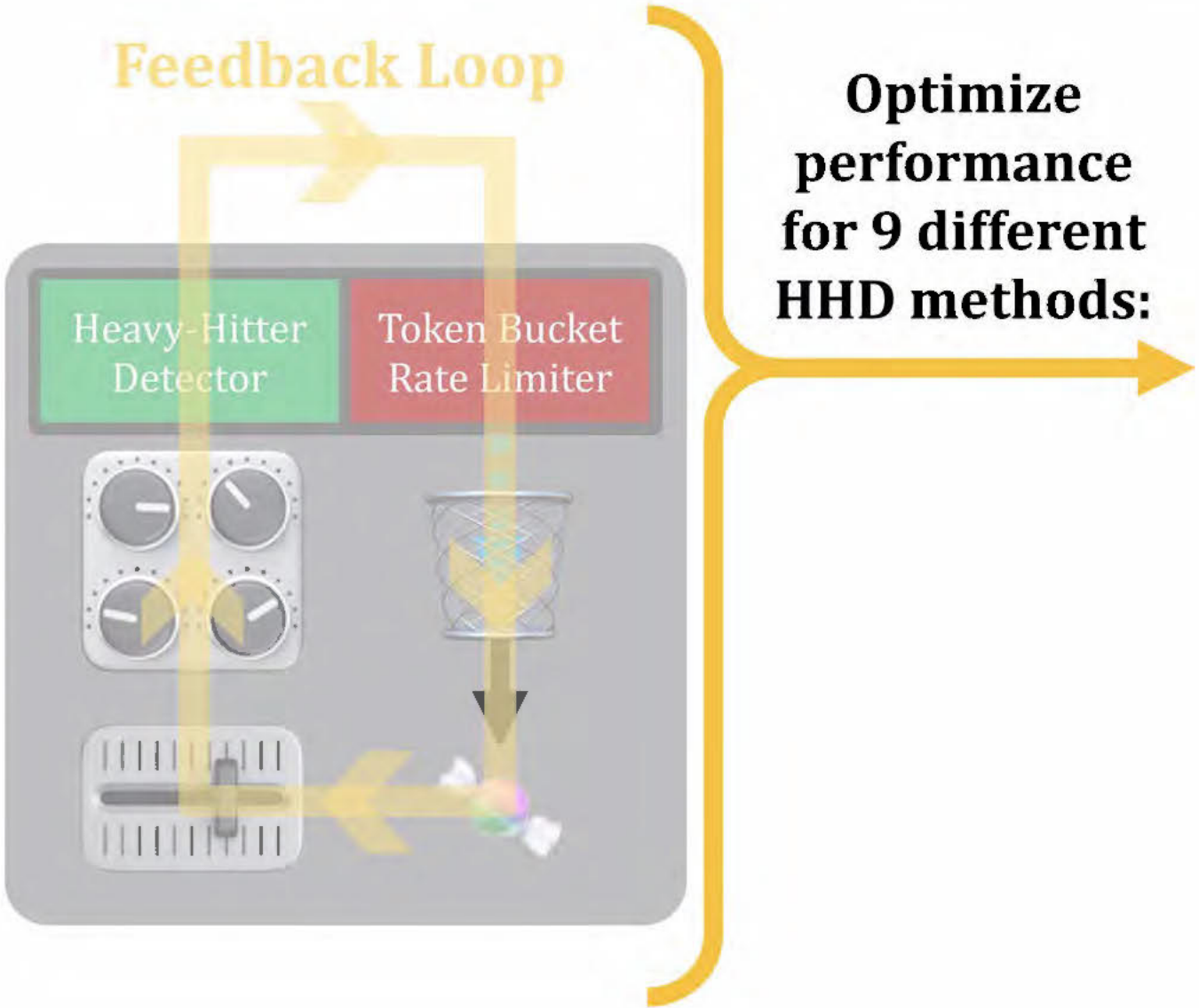
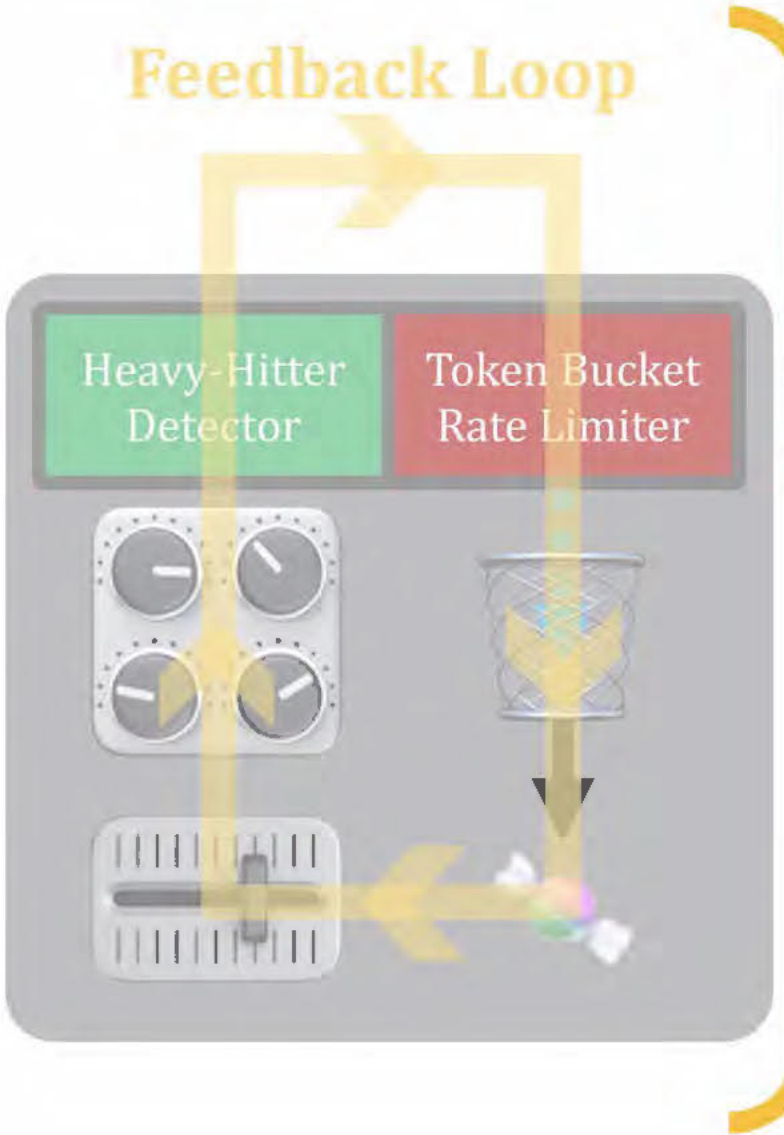


Optimize performance for 9 different HHD methods:

TUNING HHD PARAMETERS



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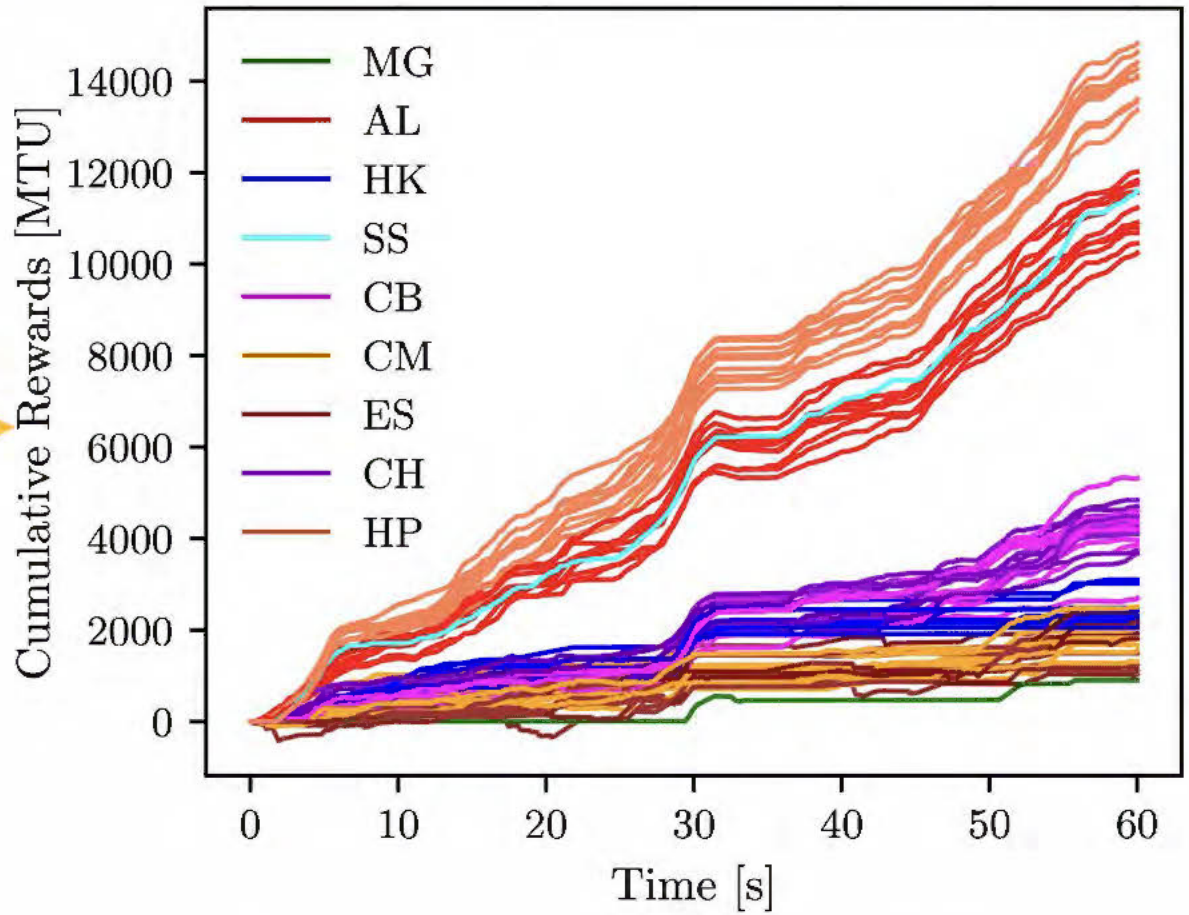
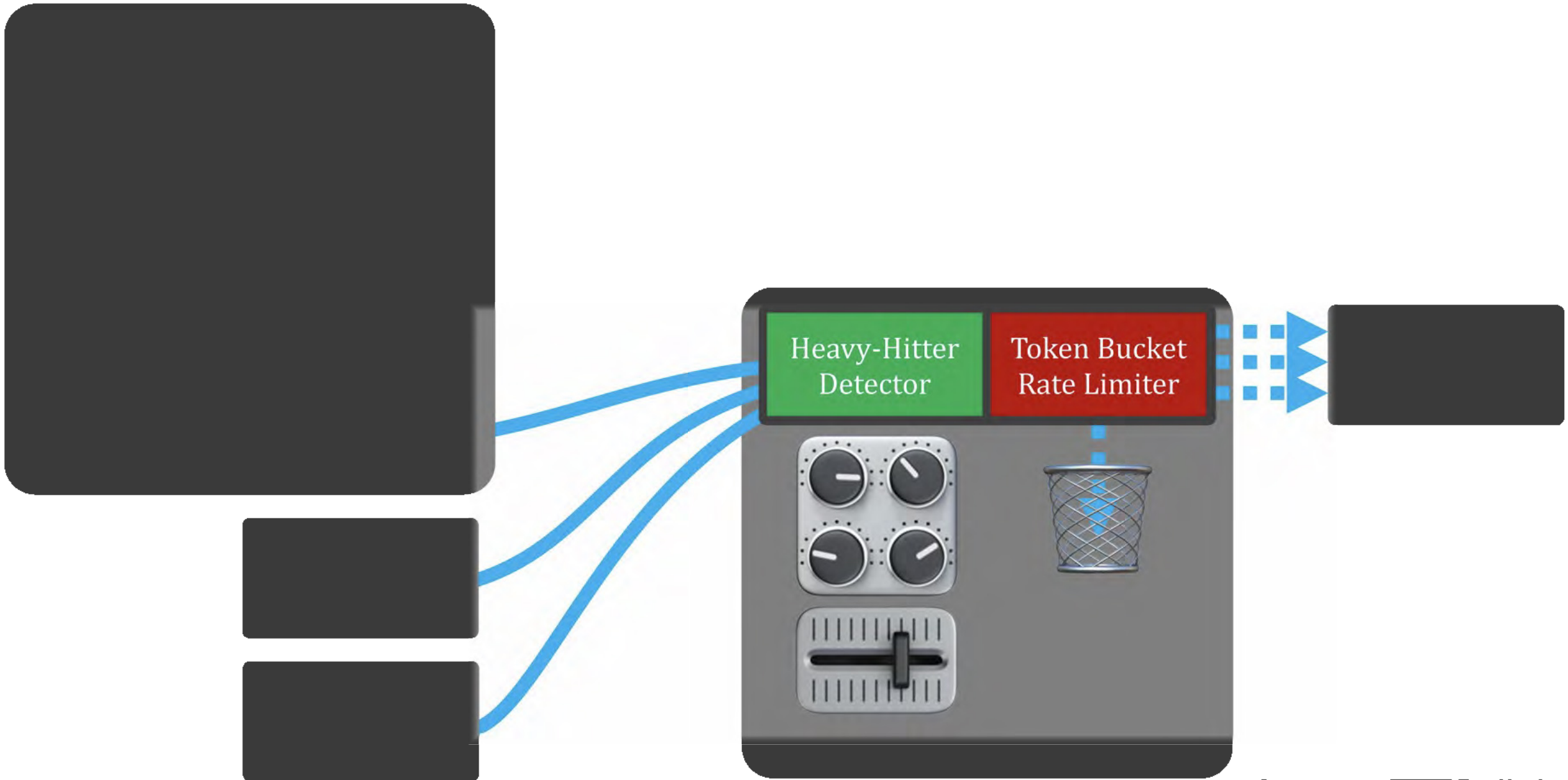


Rewards earned by the HHDs as a function of time

ADVERSARIAL BEHAVIOR



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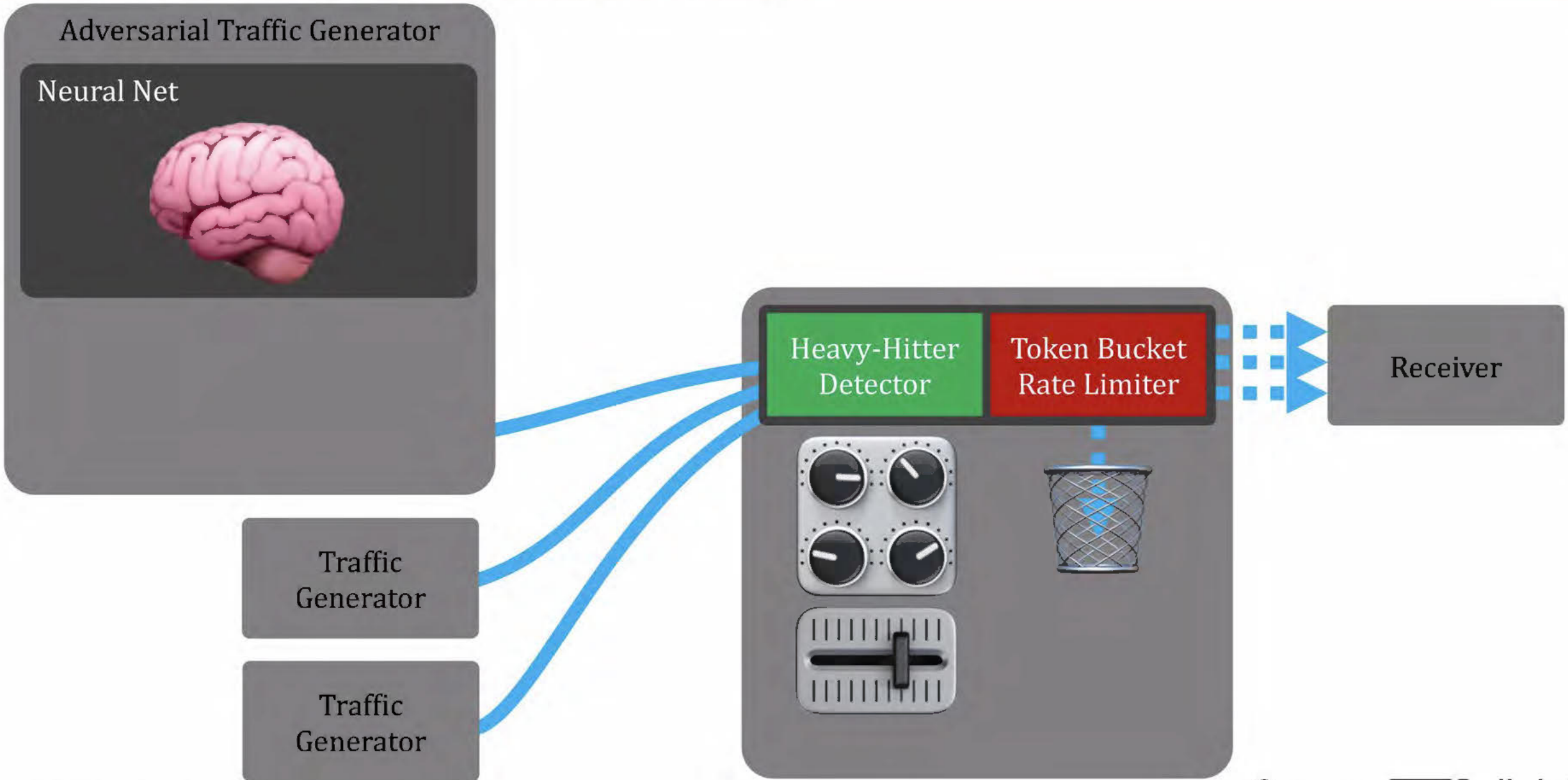

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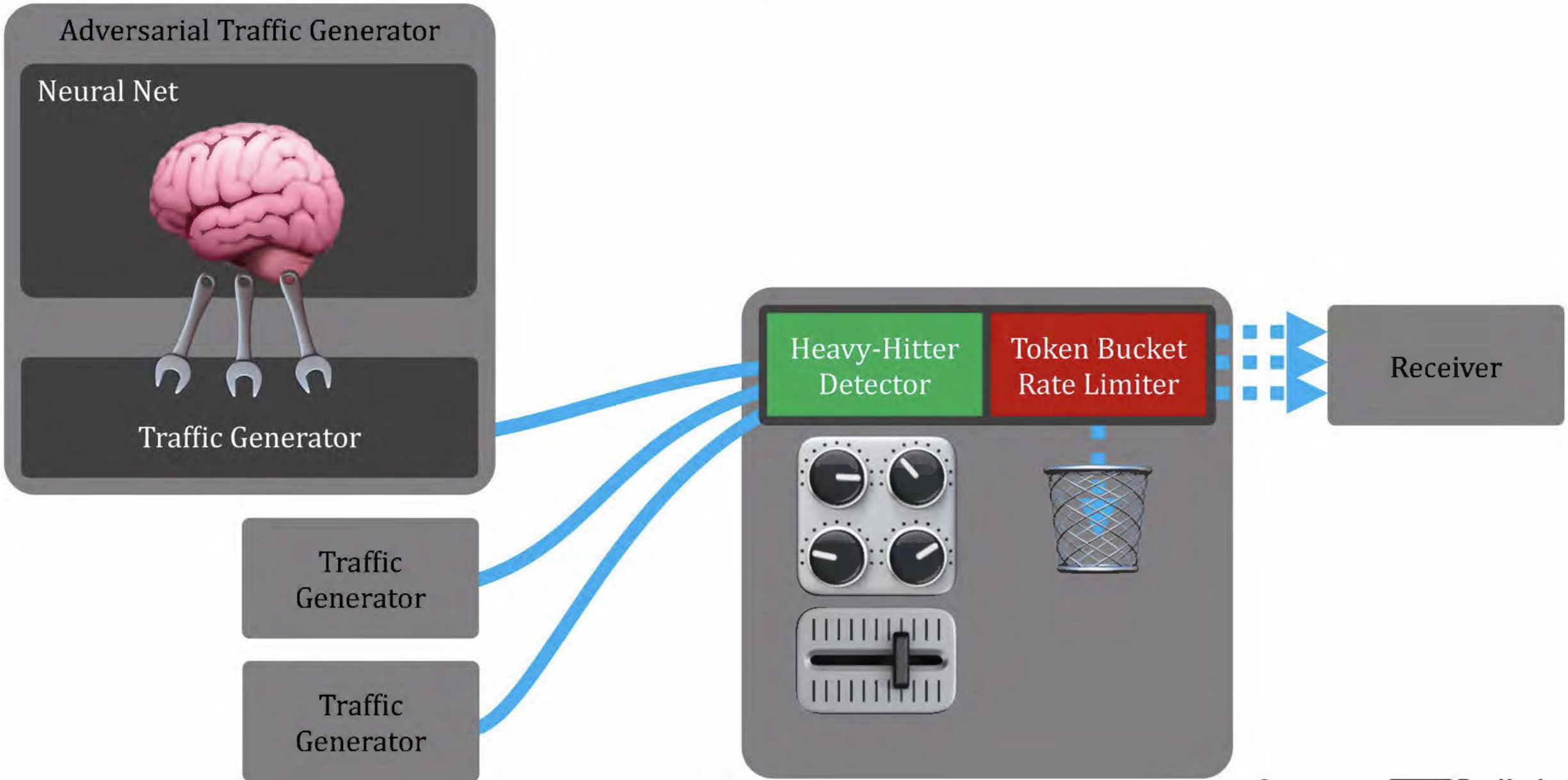

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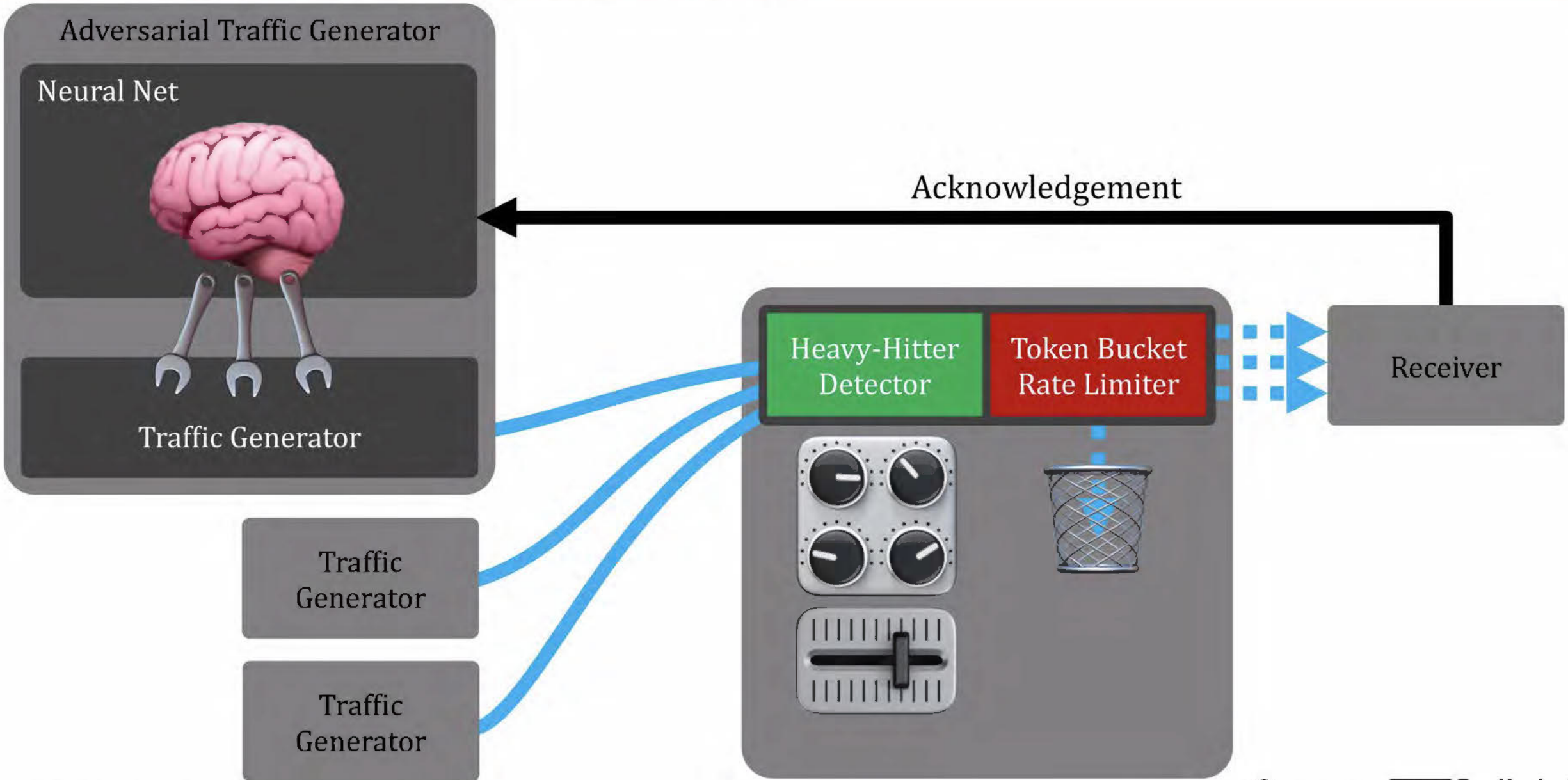

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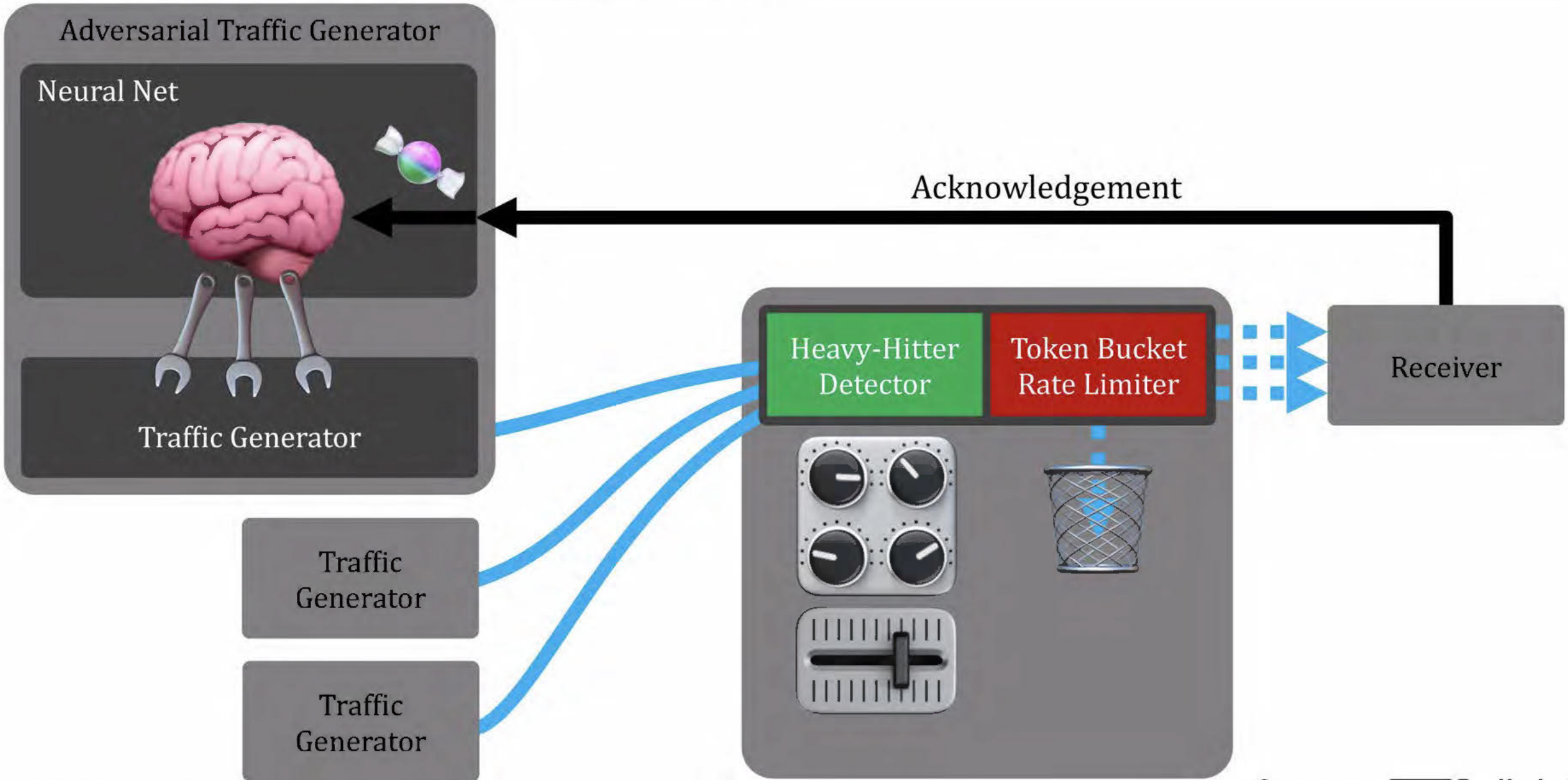

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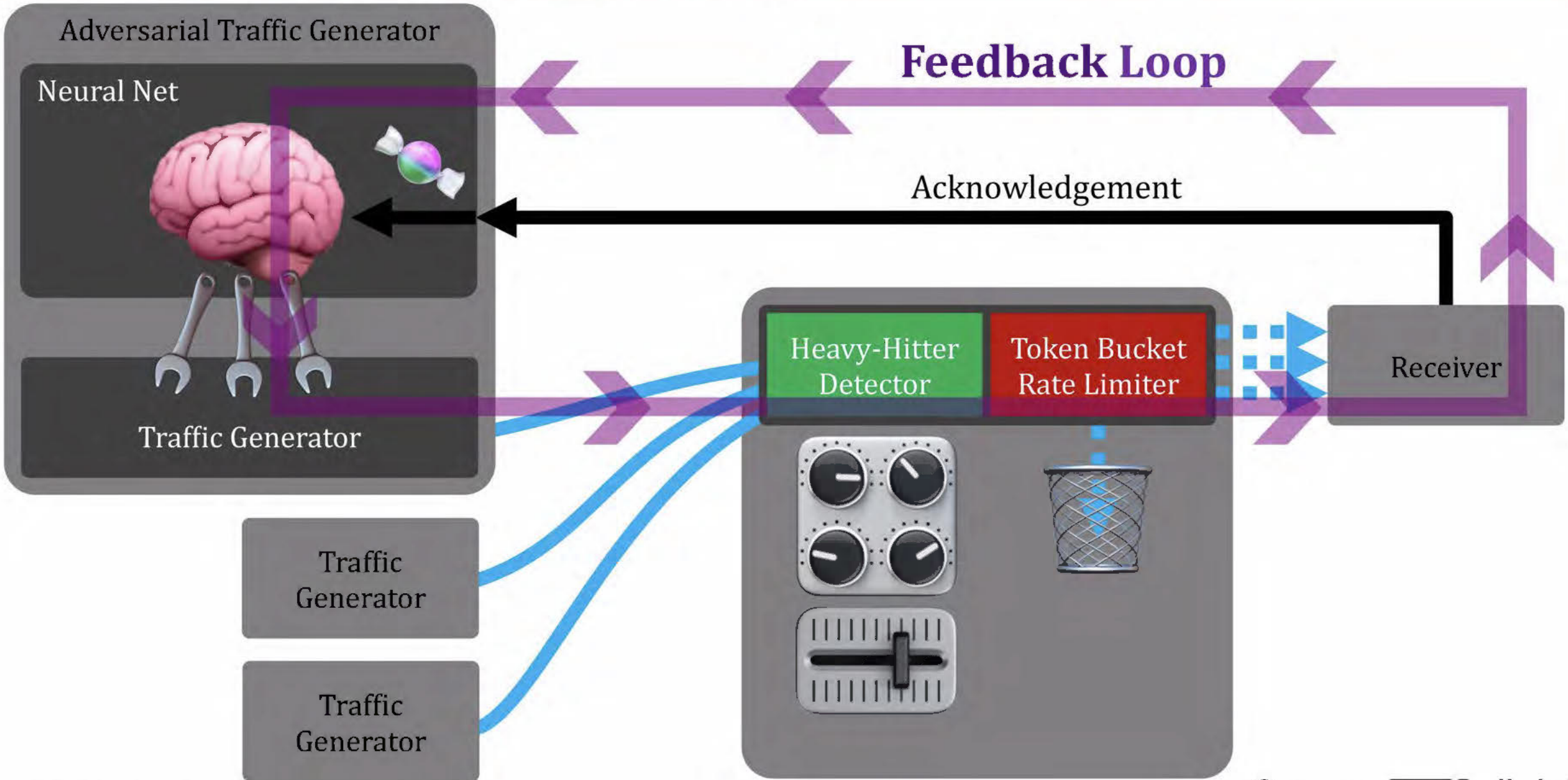

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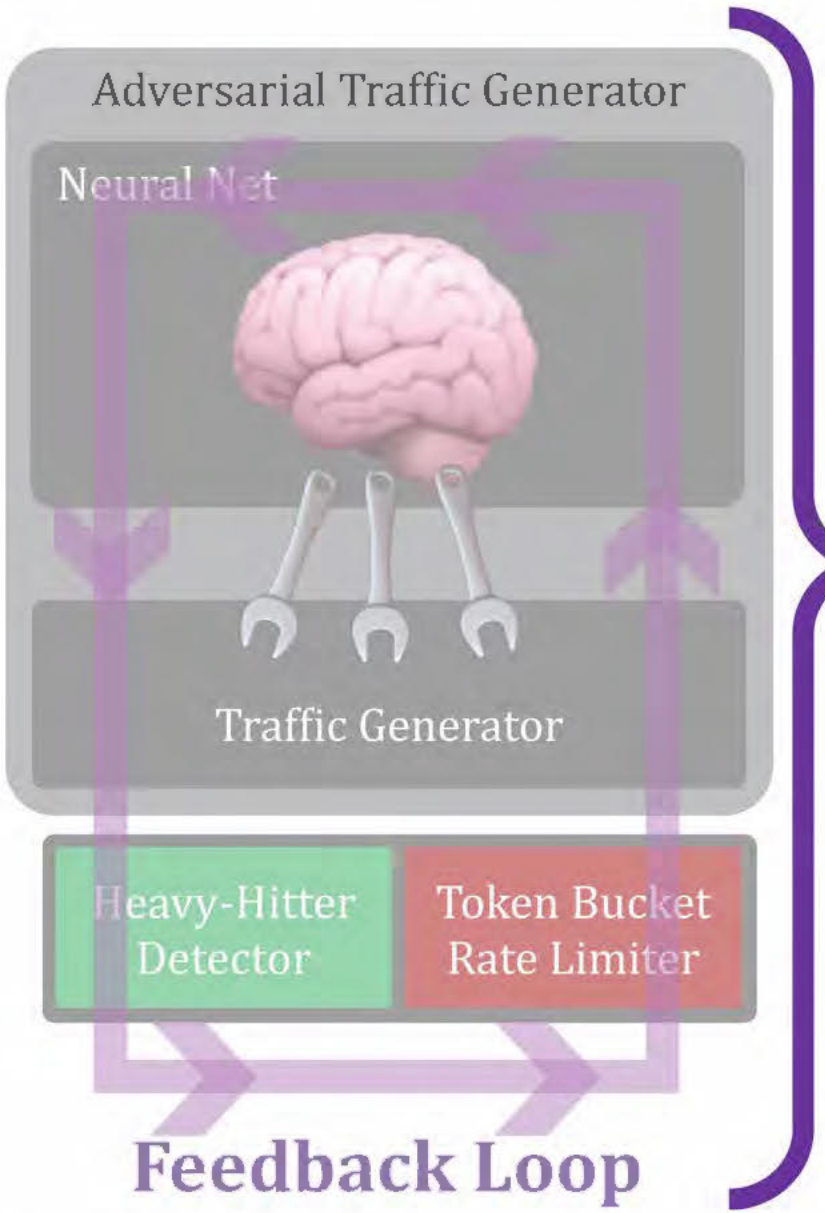
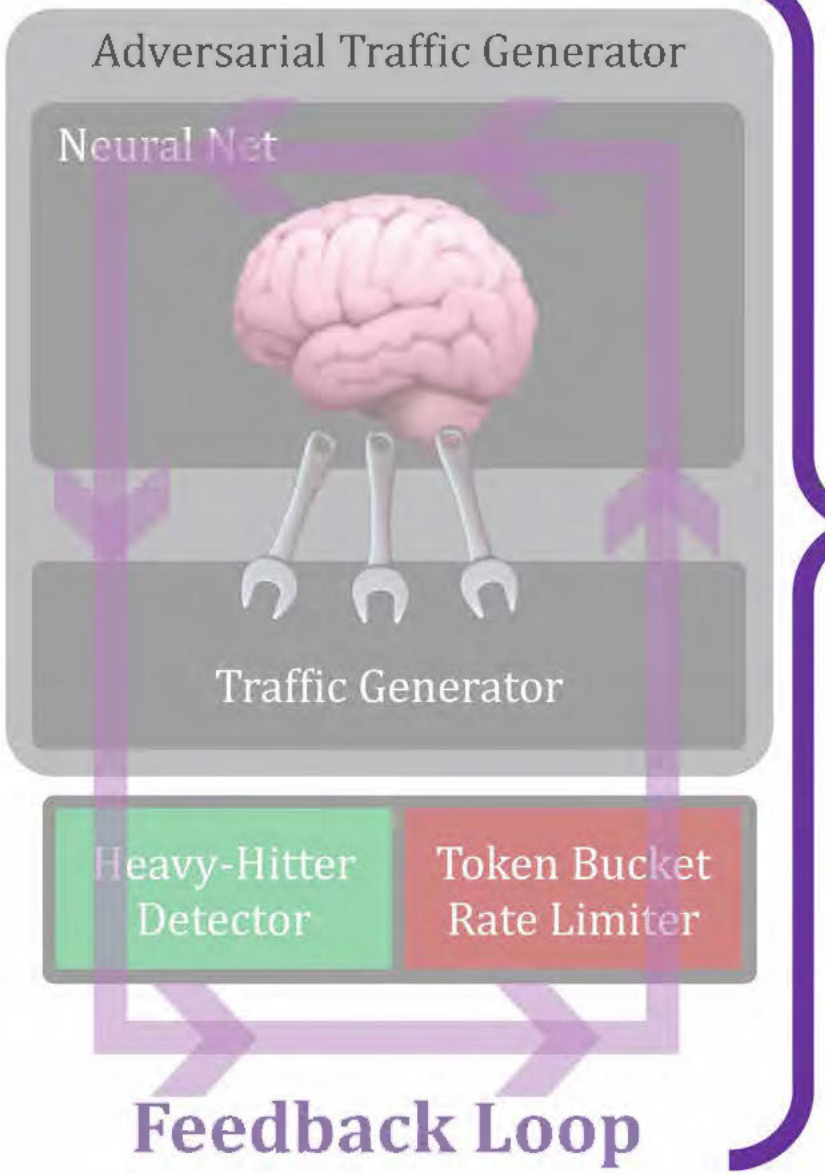


Generate adversarial traffic for each HHD method individually

ADVERSARIAL BEHAVIOR



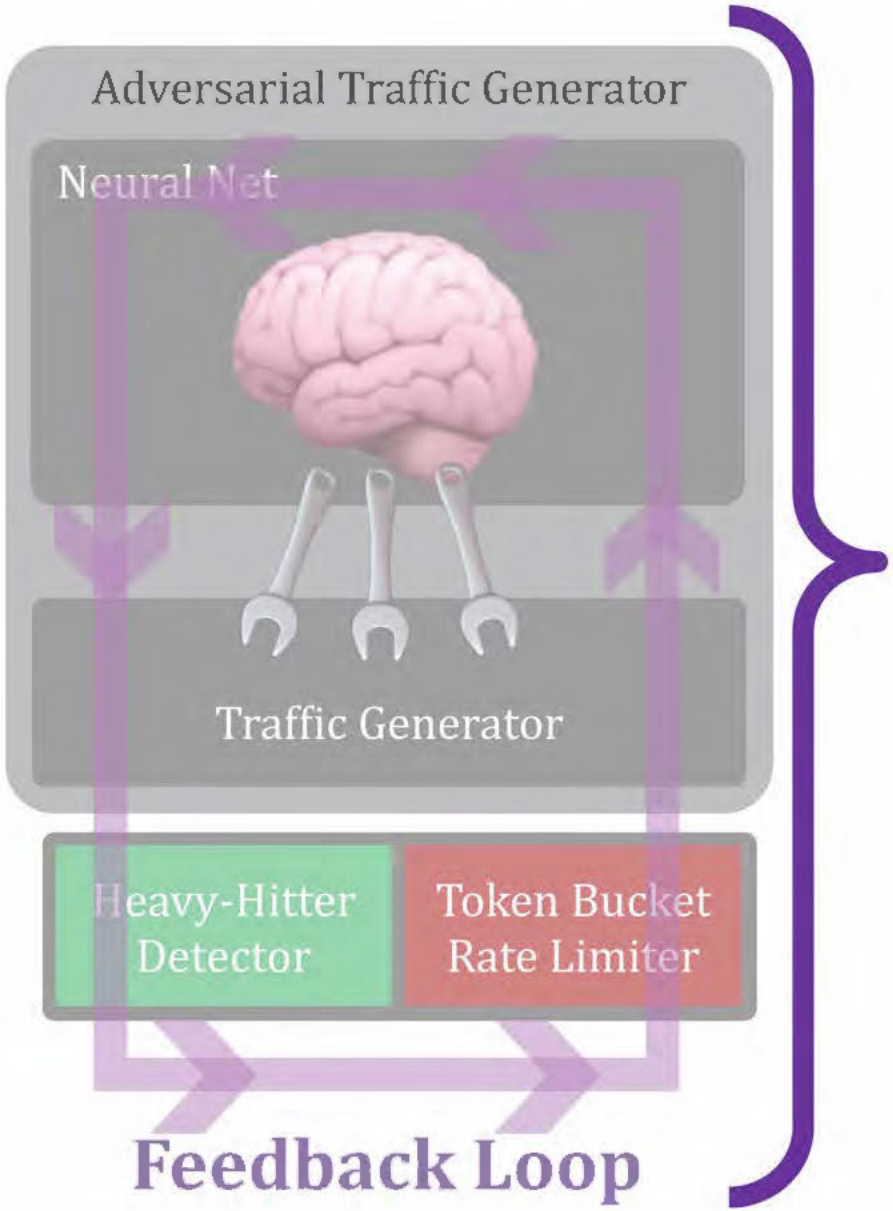
Generate adversarial traffic for each HHD method individually

Evaluated for 9 different heavy-hitter detectors

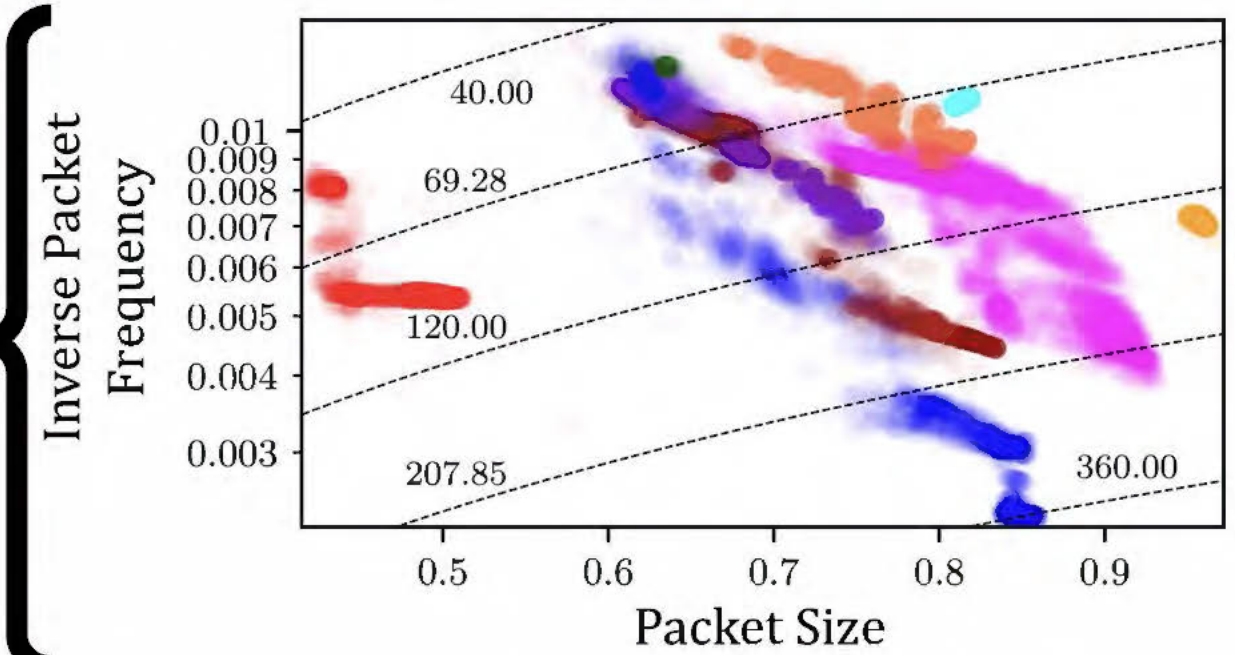
	AL	CB	CM	ES	HK	MG	SS	CH	HP
Synthetic traffic	85%	78%	138%	299%	10%	37%	68%	67%	54%
Captured traffic	90%	185%	326%	670%	-21%	78%	88%	161%	82%

Adversary Overuse

ADVERSARIAL BEHAVIOR



Phase-Space Diagram



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Adversary Overuse

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Problem: HHD algorithm not ready for adaptive adversary…

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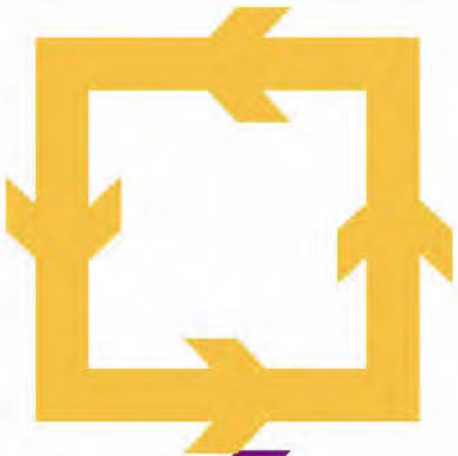
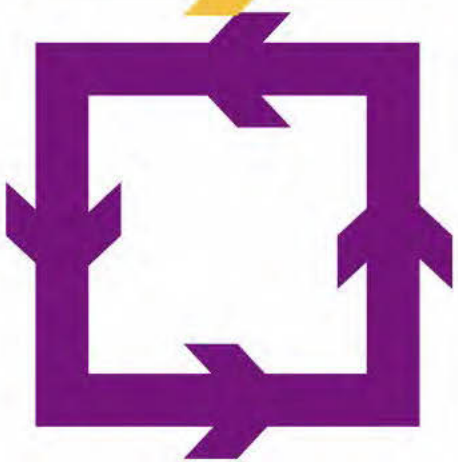


HHD Feedback Loop



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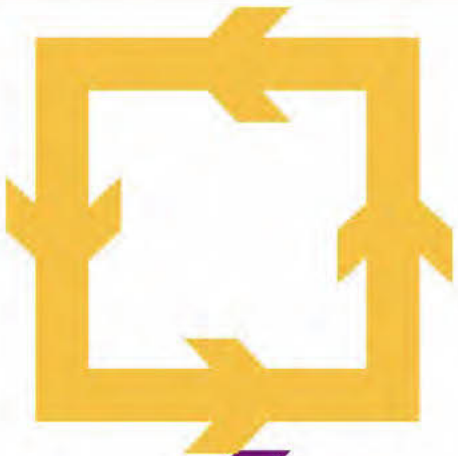

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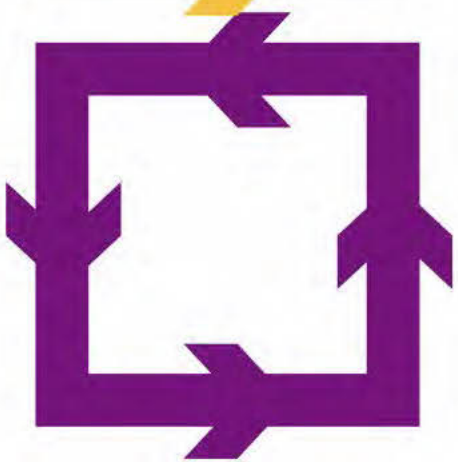

Adversary Feedback Loop

Co-train entities

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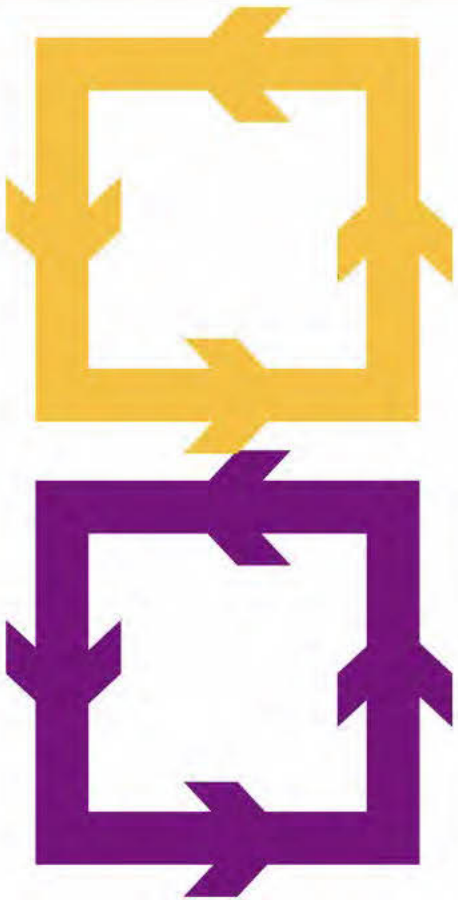

HHD Feedback Loop

Adversary Feedback Loop

Co-train entities

Each learns to exploit the other's weakness

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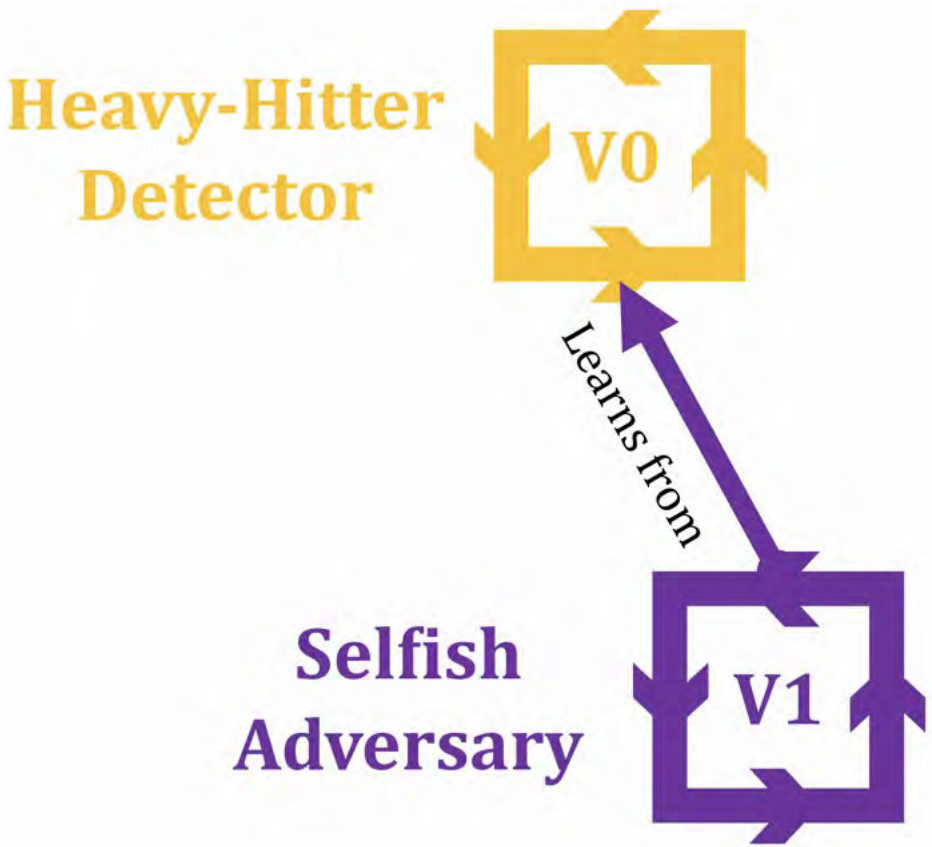

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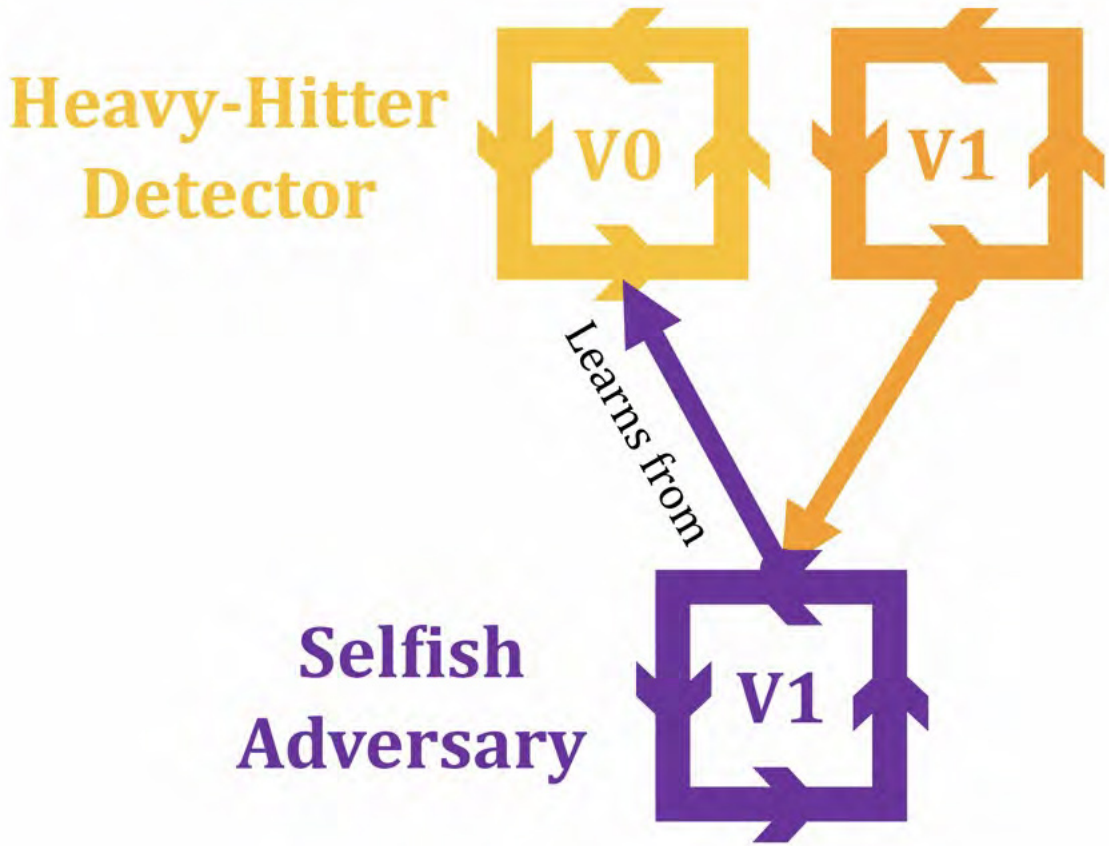

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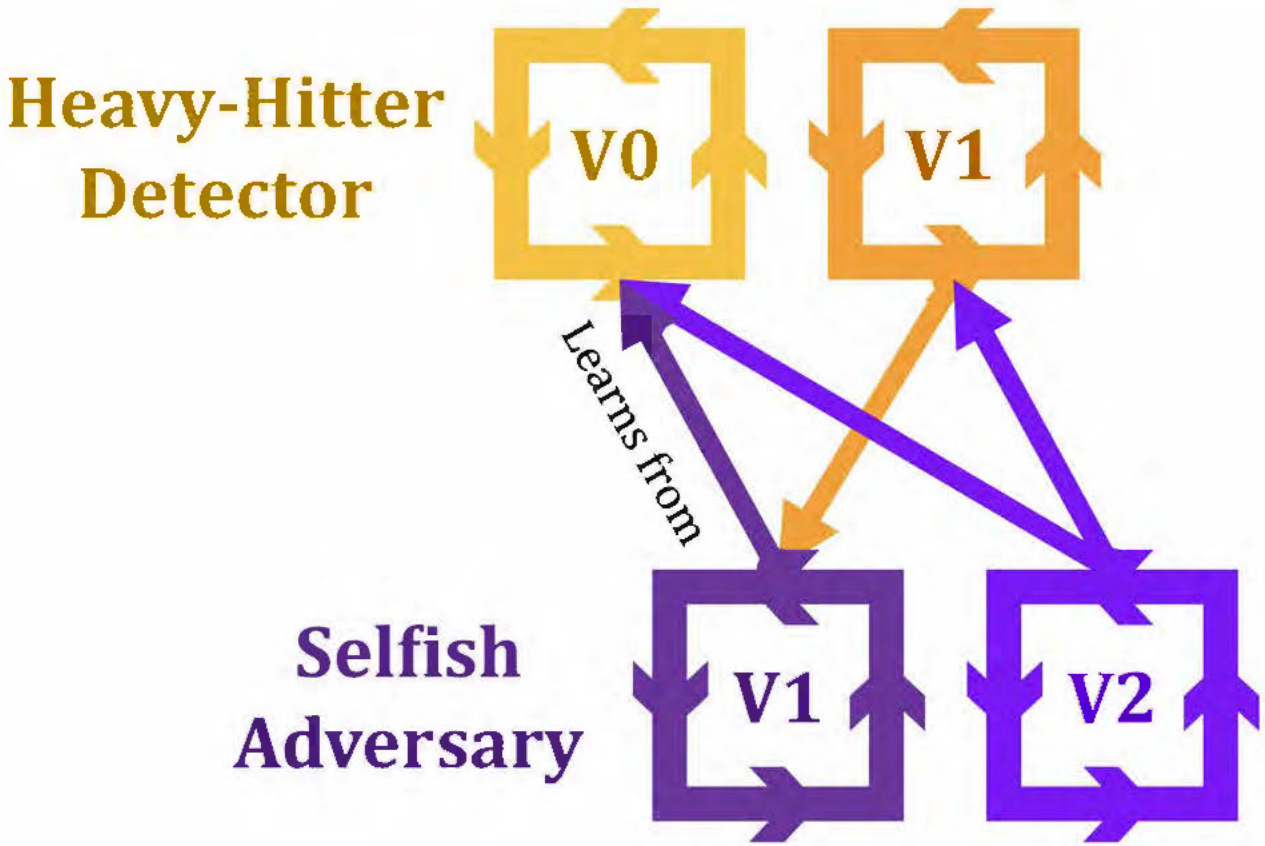

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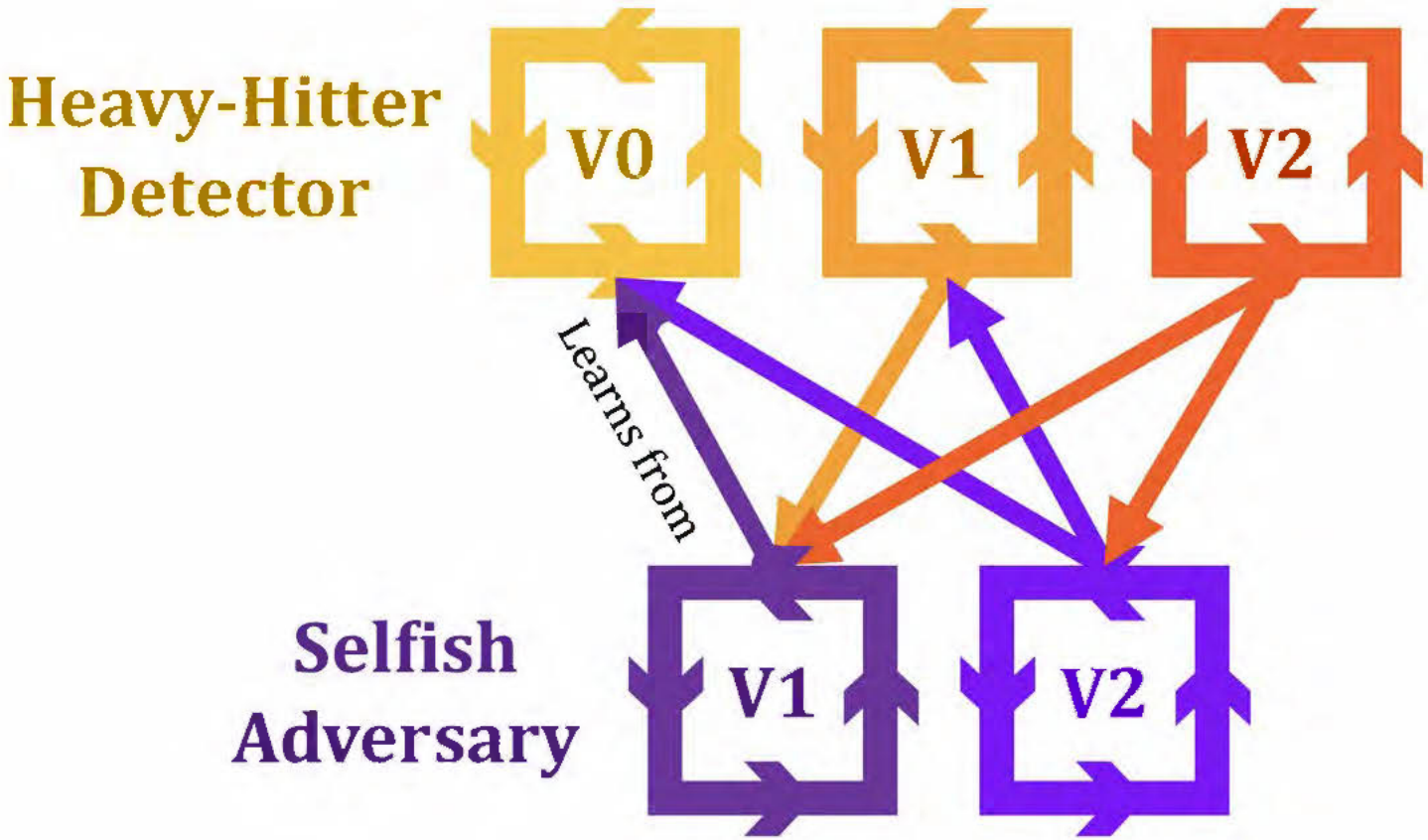

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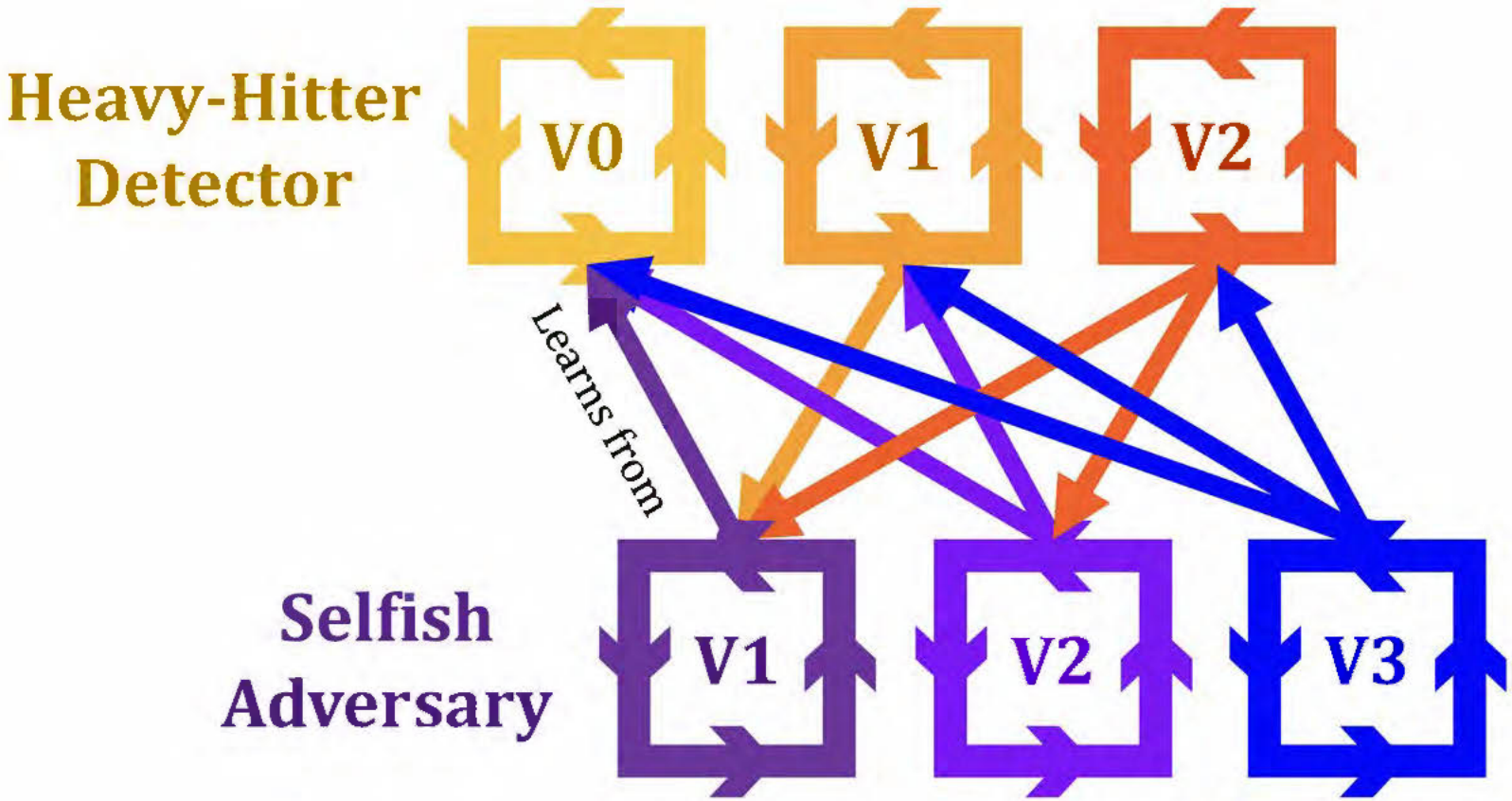

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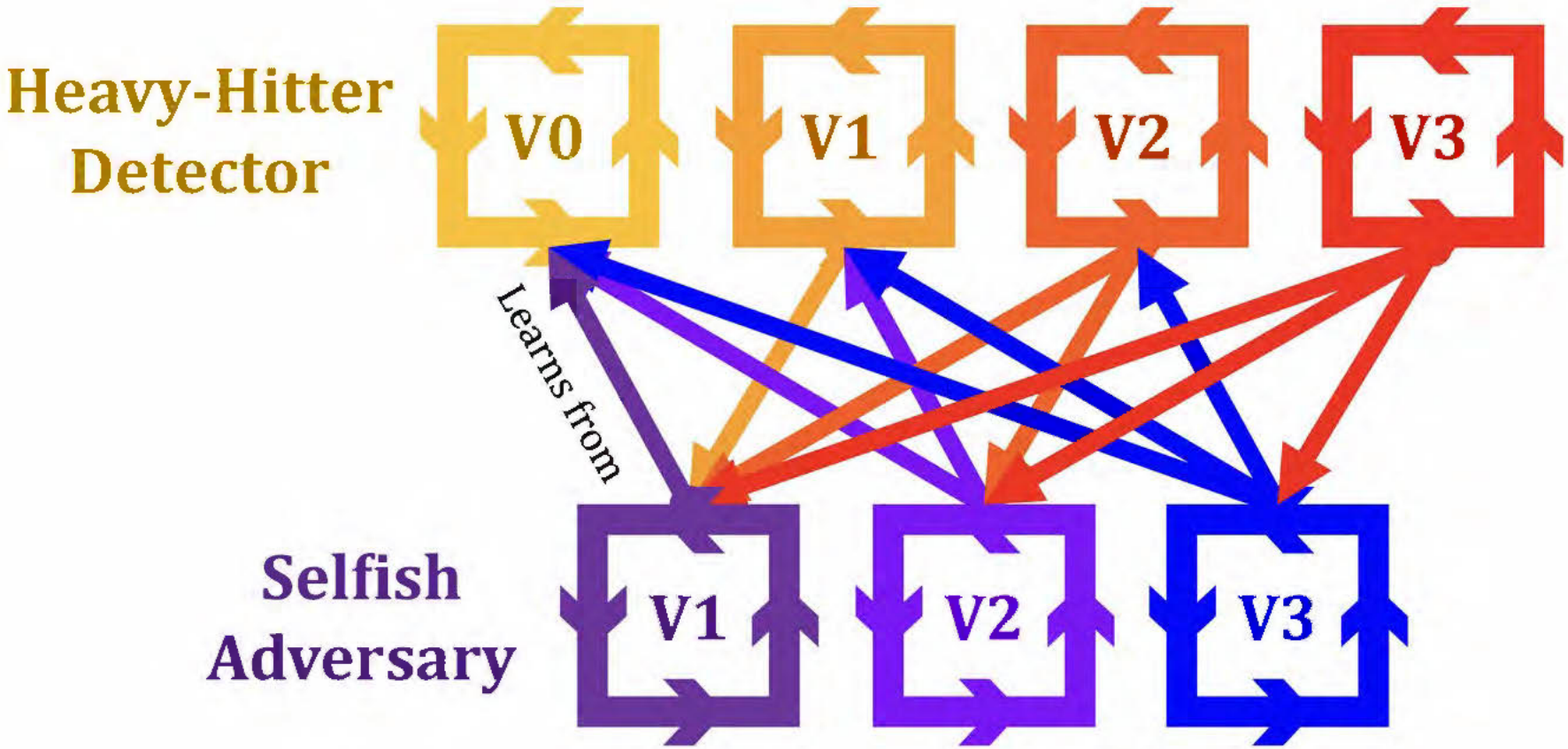

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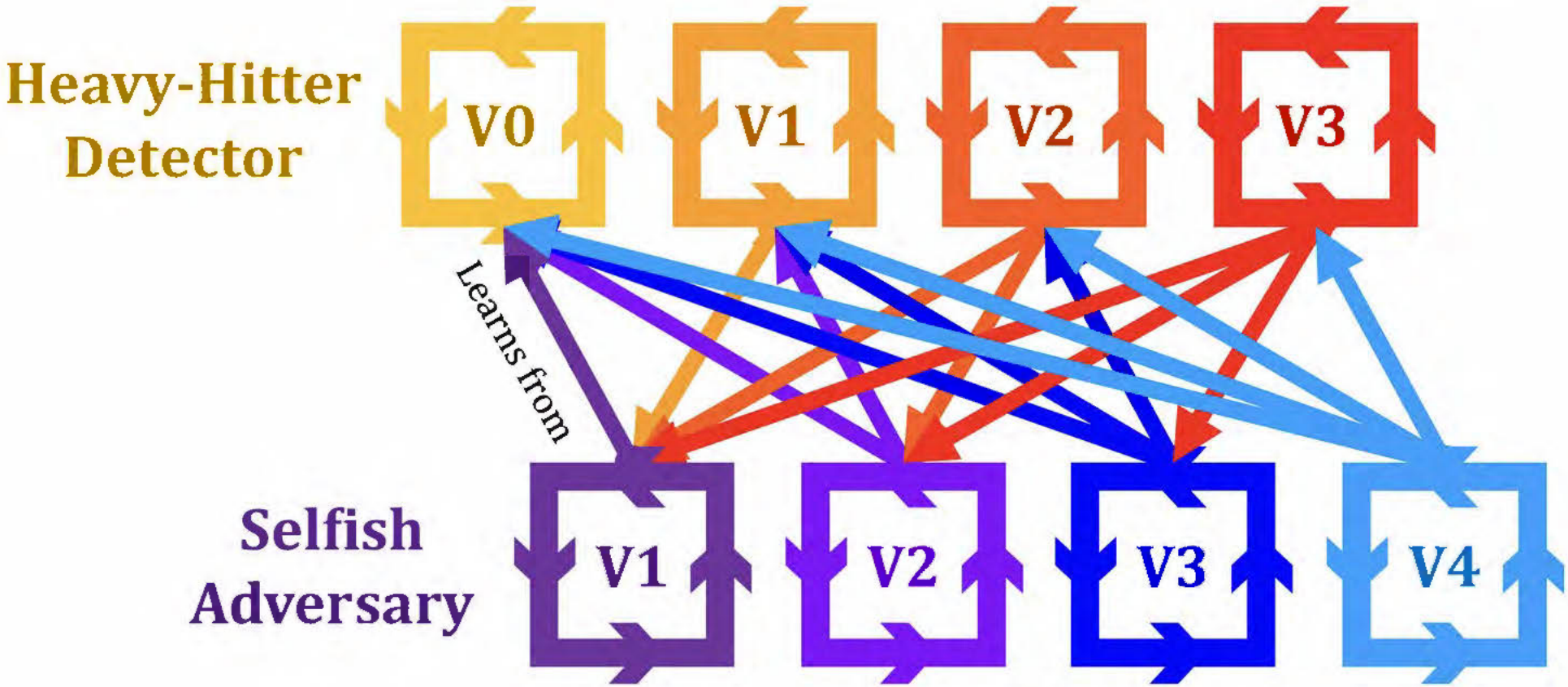

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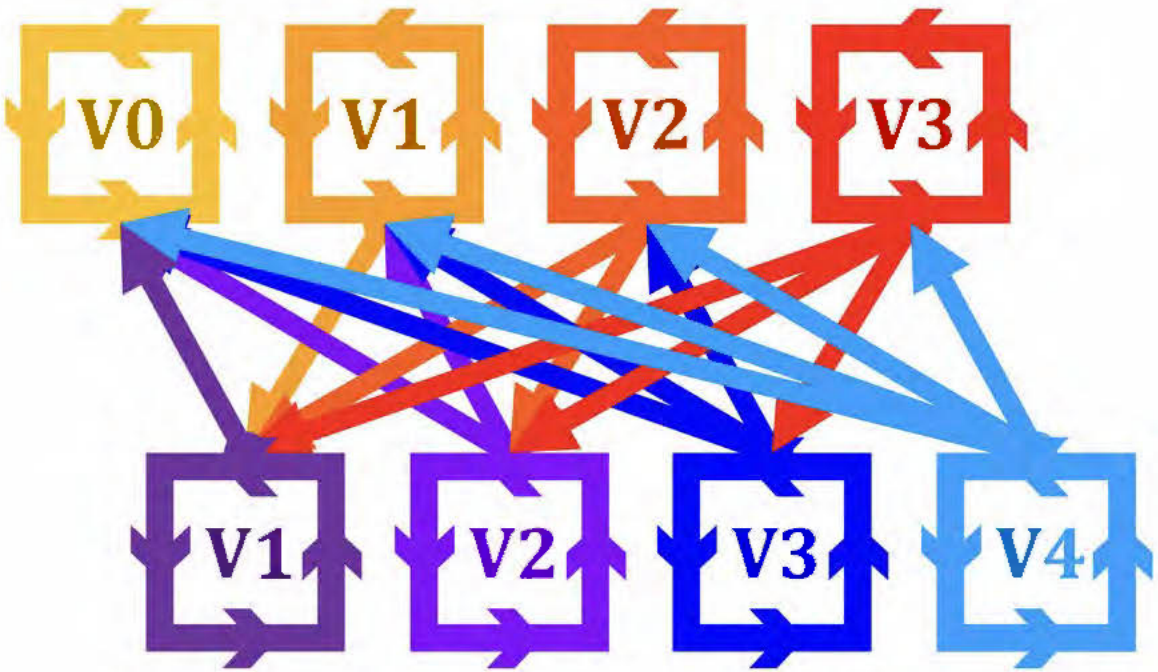

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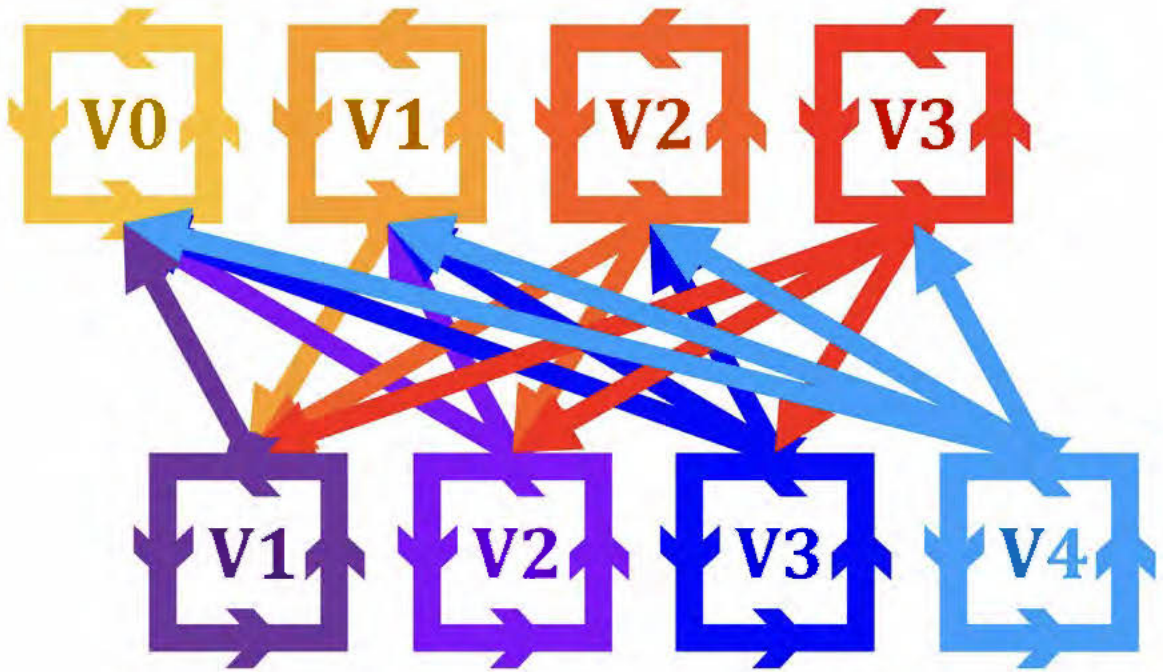

Example results (HHD = Elastic-Sketch):

Before co-training: 300% adversary overuse.

LEARN FROM AN ADAPTIVE ADVERSARY

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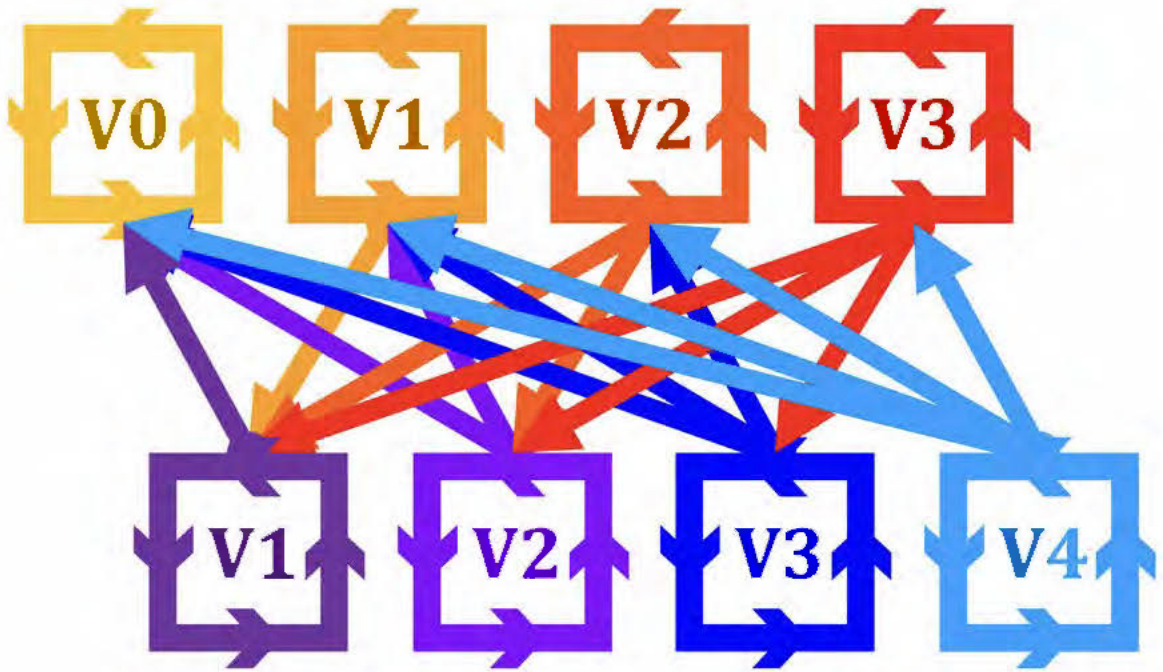

Example results (HHD = Elastic-Sketch):

Before co-training: 300% adversary overuse.

After co-training: 139% adversary overuse.

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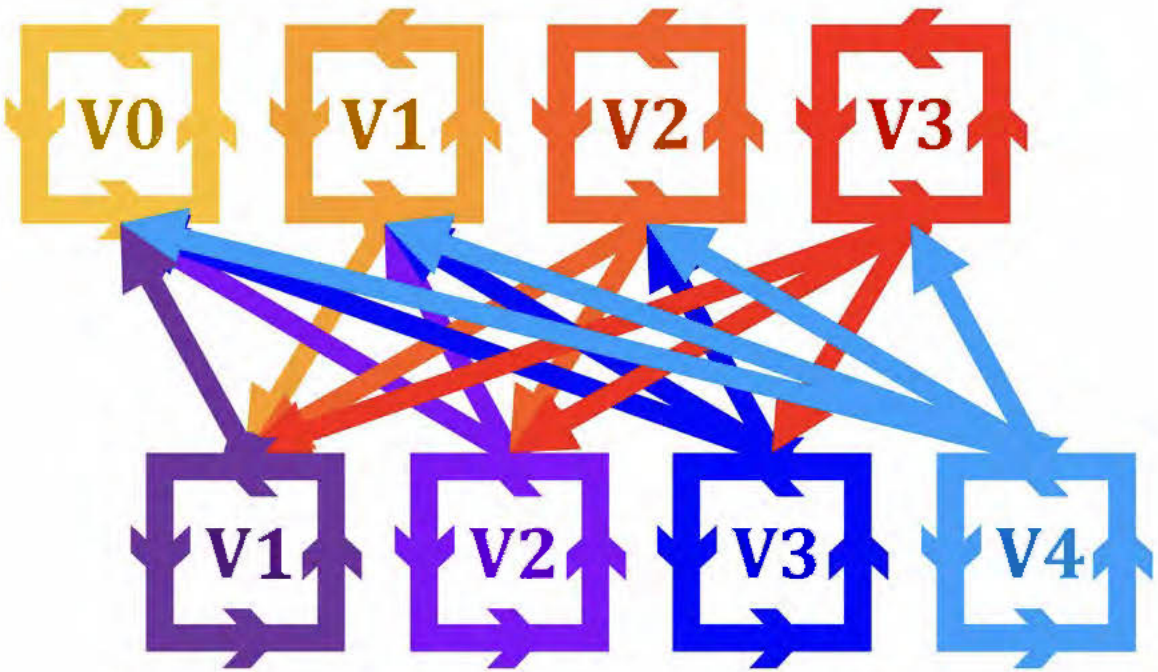

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Reduction by x2.2 “for free”.

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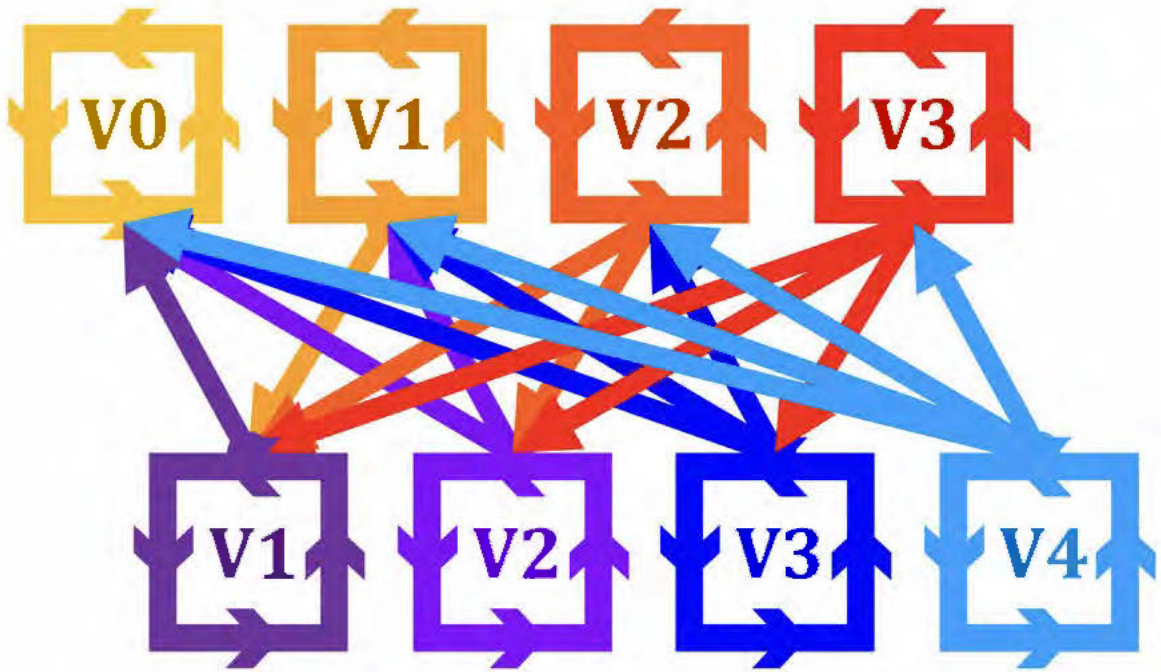

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HHD score increased by x1.6 “for free”.

WHERE WE STAND

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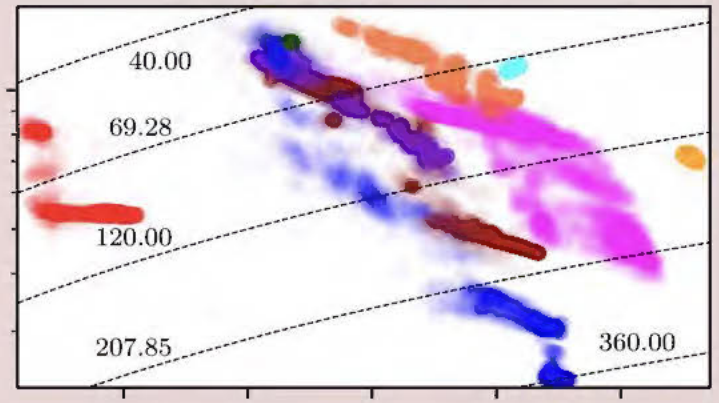
1) Shown that **adversaries can adapt** to monitoring systems.



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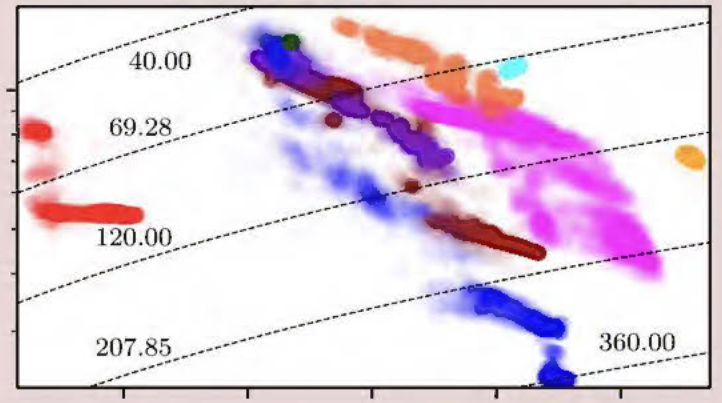
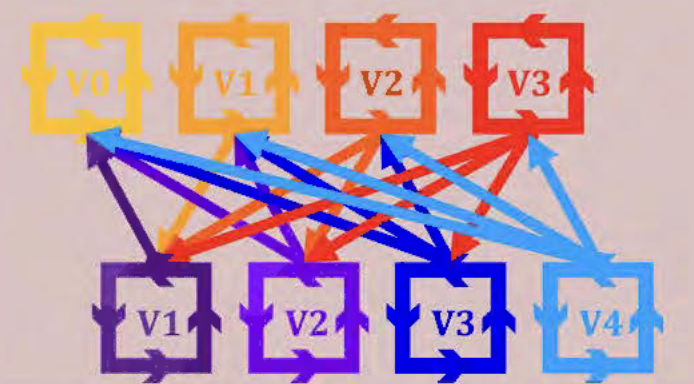


2) Shown that we can **prepare monitors** to **deal with any adversary**.



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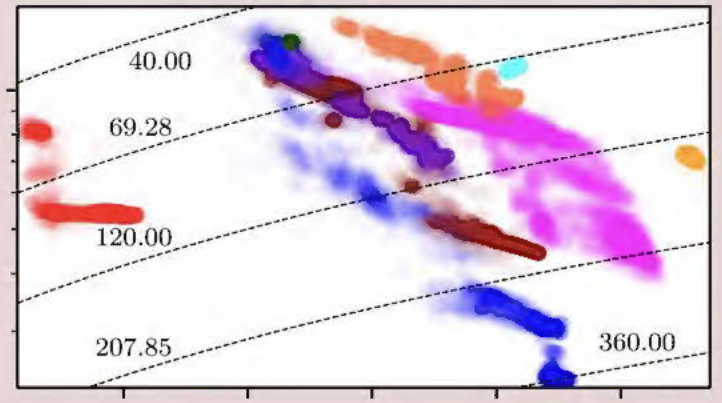

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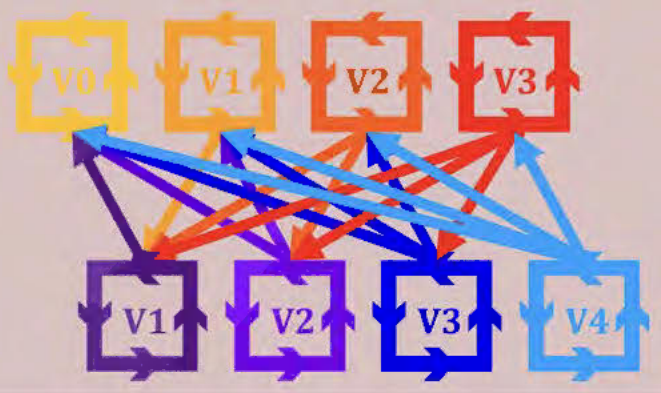
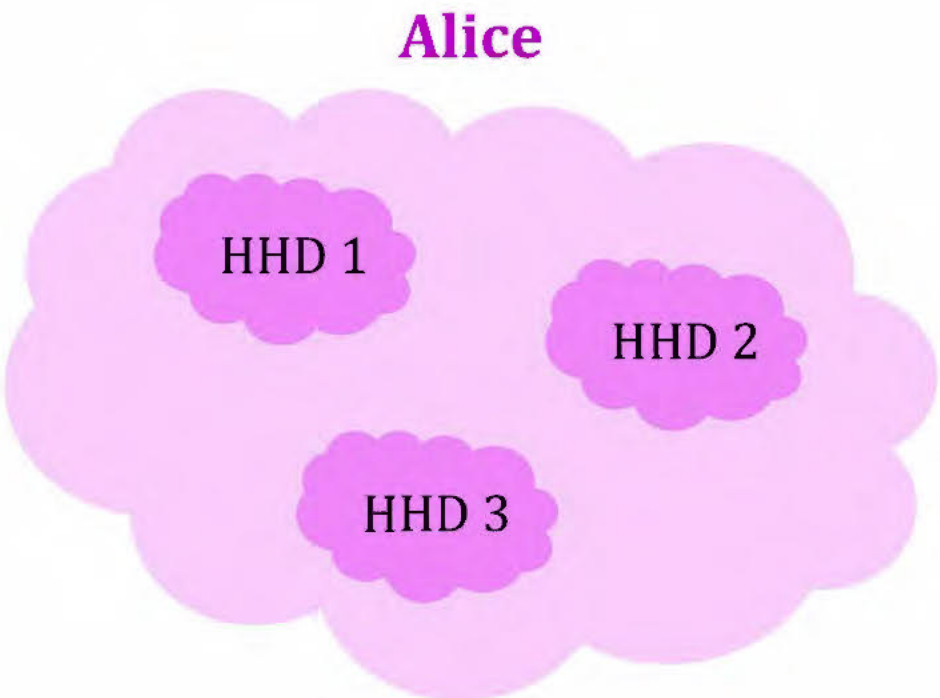


3) Can we also **create adversaries** that can **deal with any monitor?**

THE ROADBLOCK

THE ROADBLOCK



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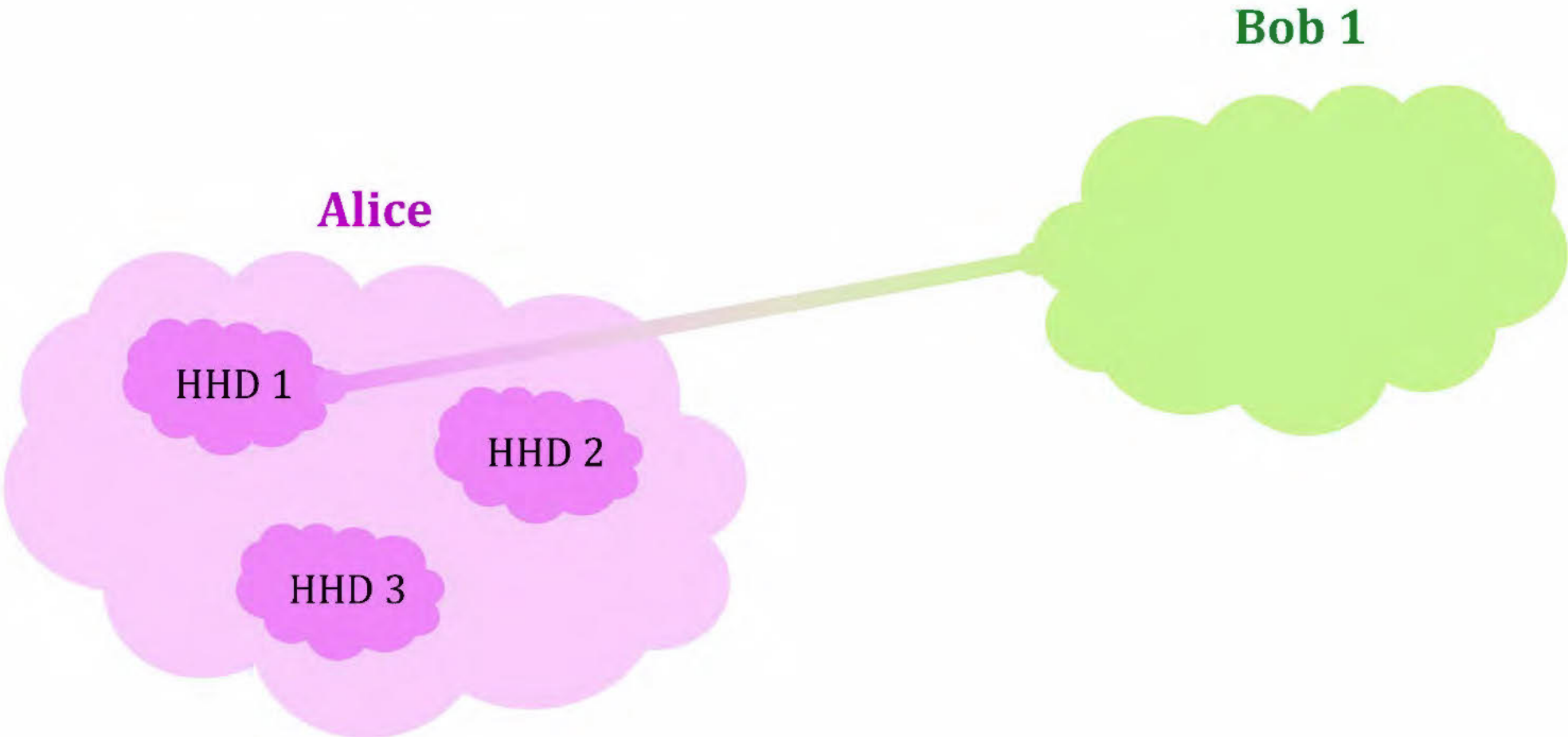

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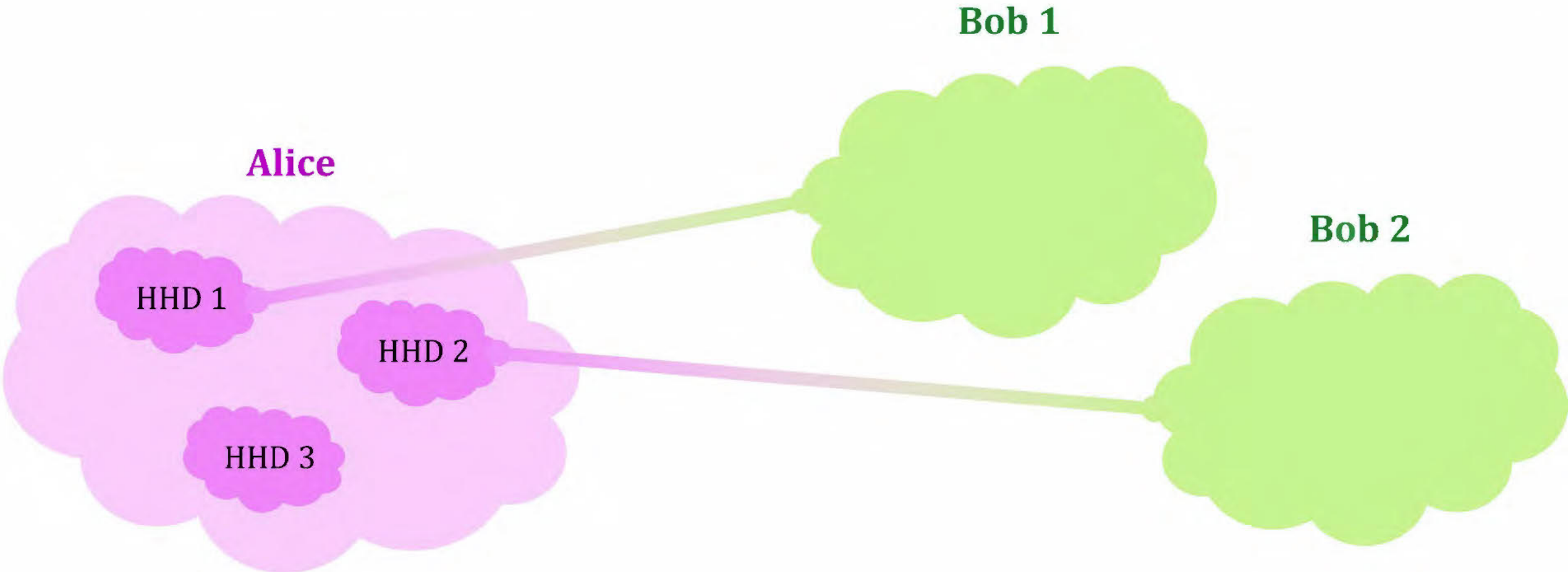

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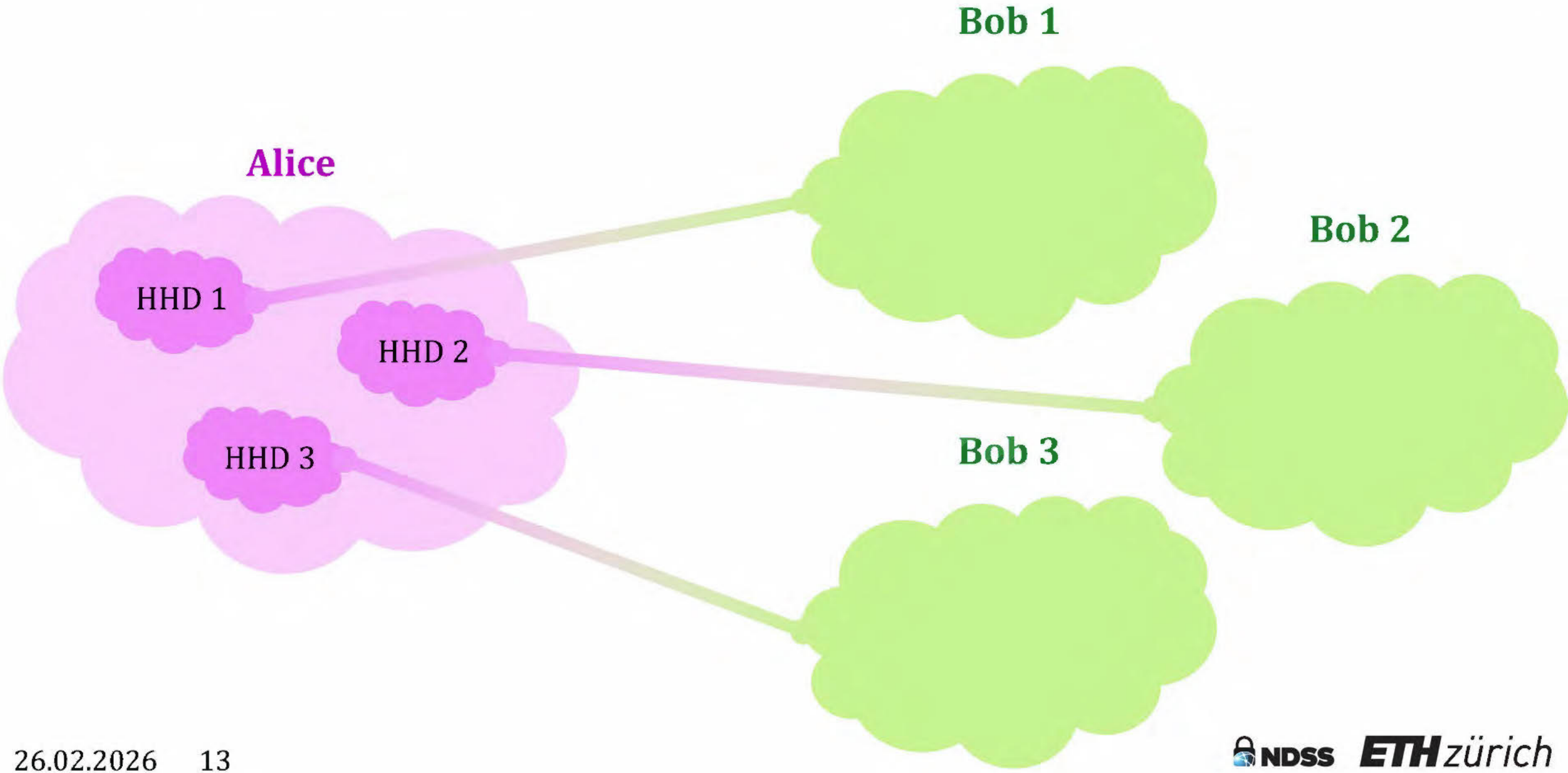

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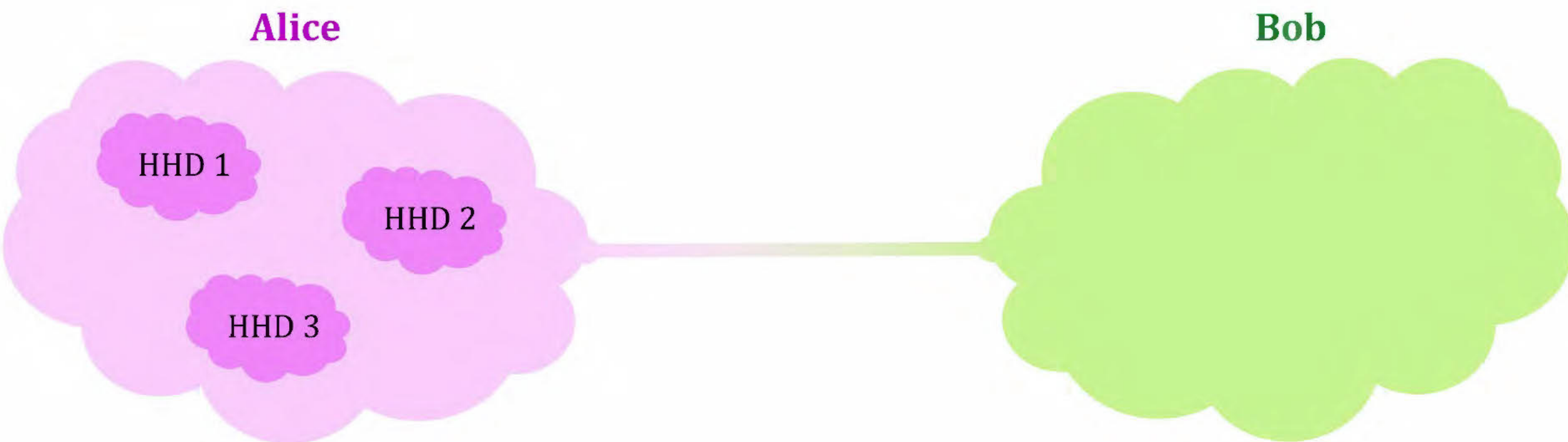
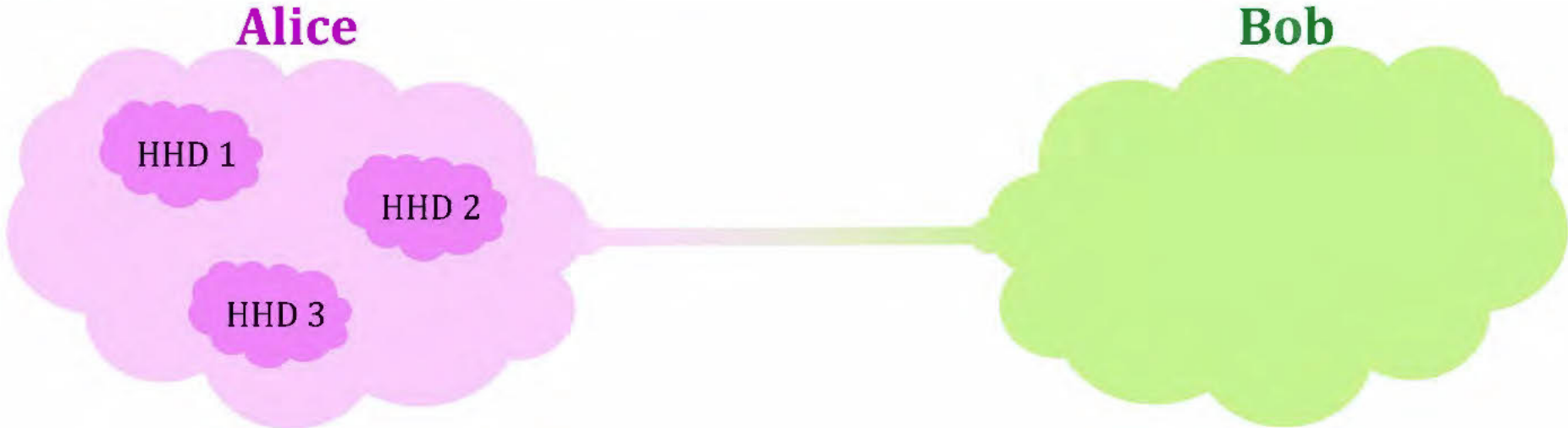


ZERO-SHOT ATTACKS



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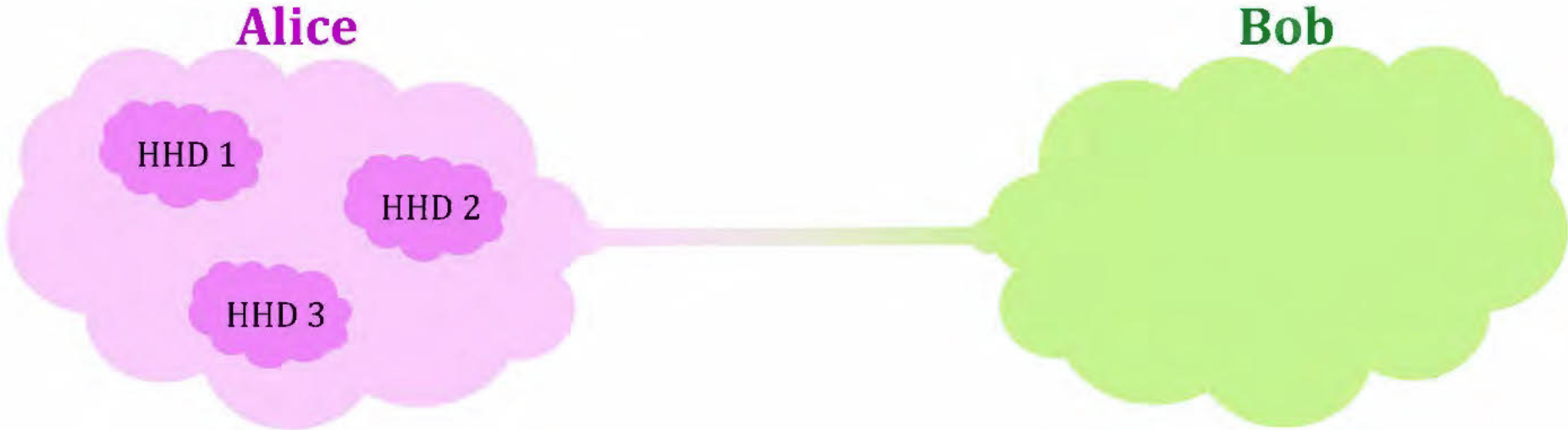

Step 1: More Flexibility

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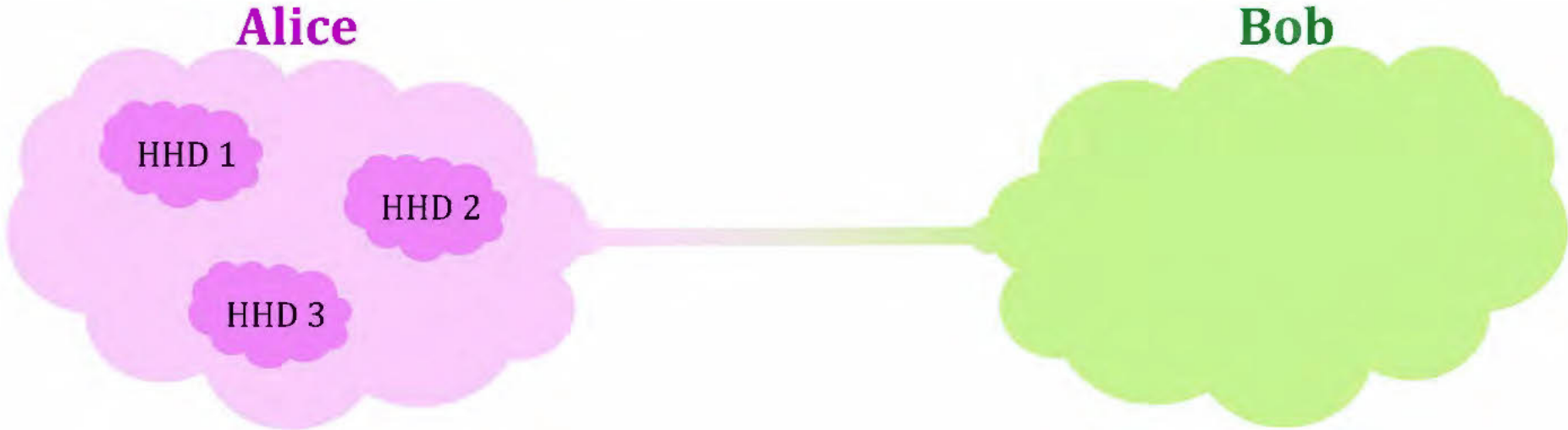

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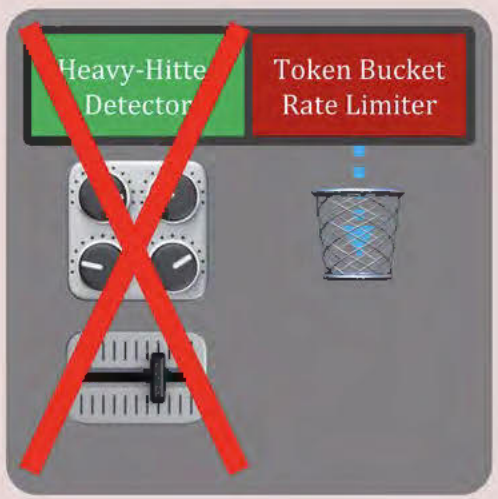

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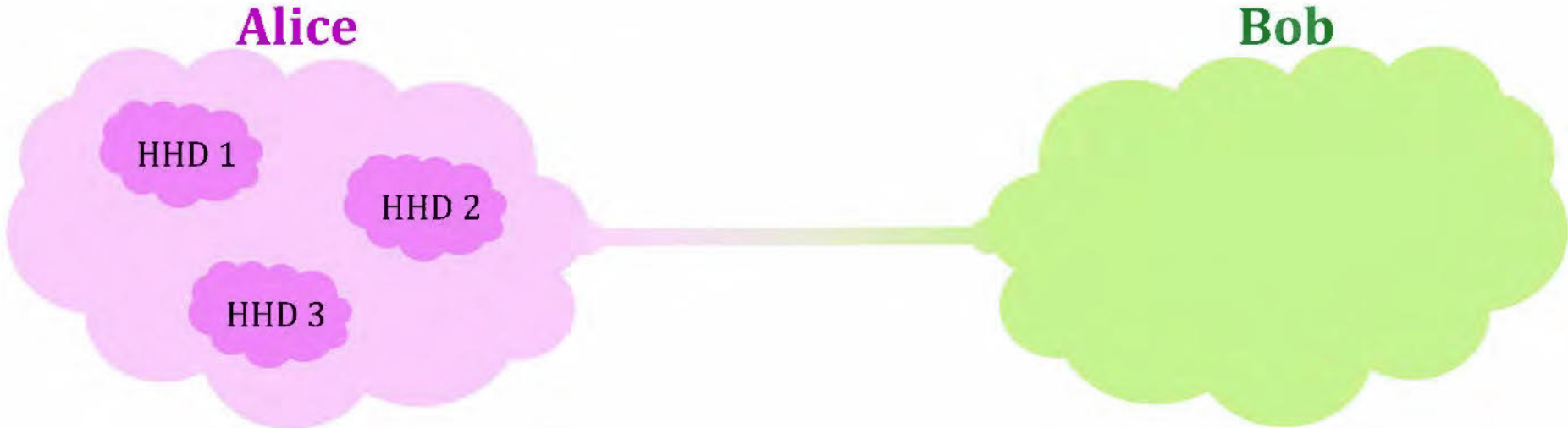

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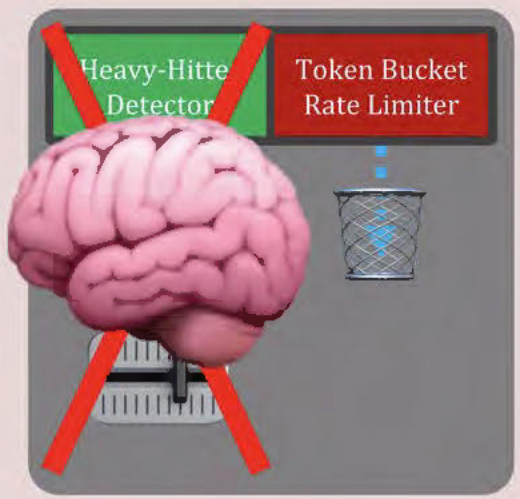

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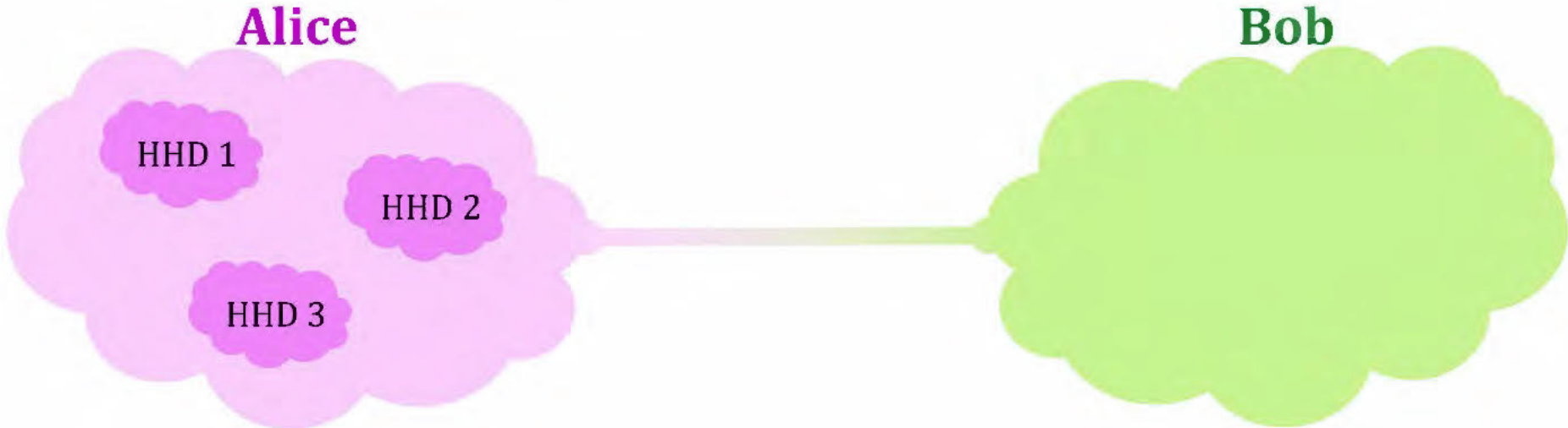
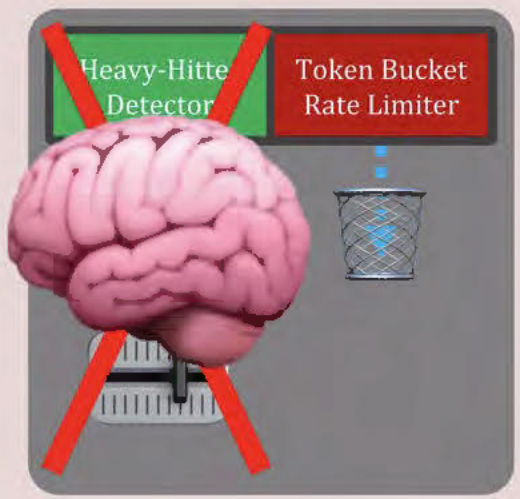
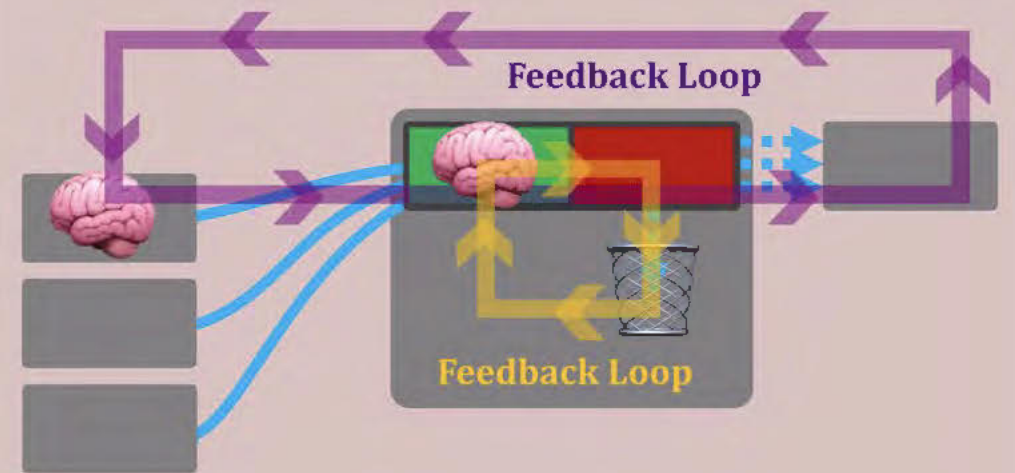


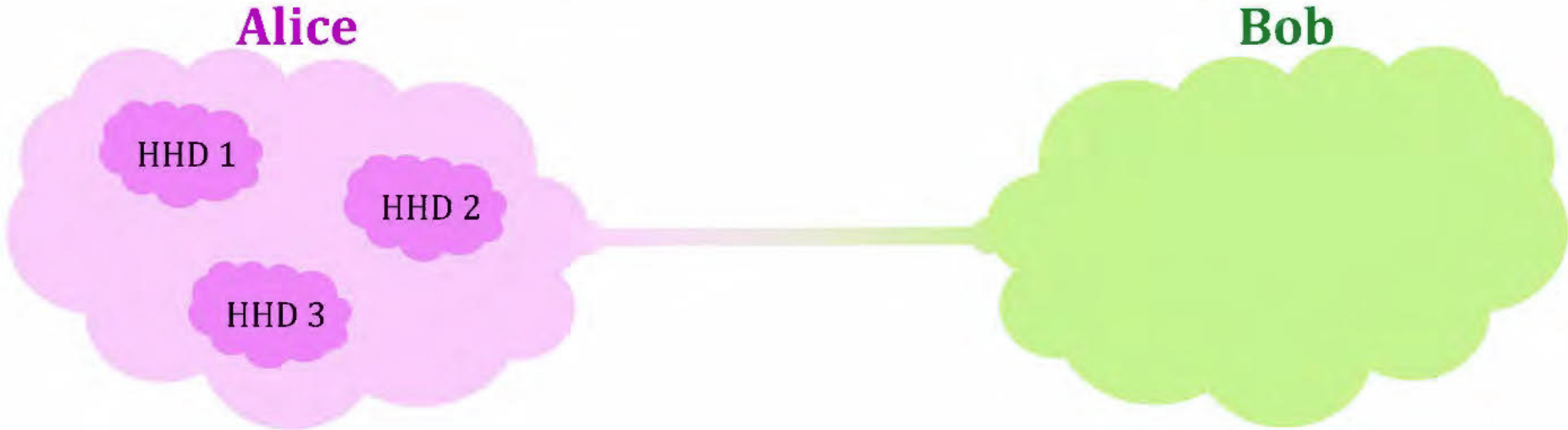
Step 1: More Flexibility



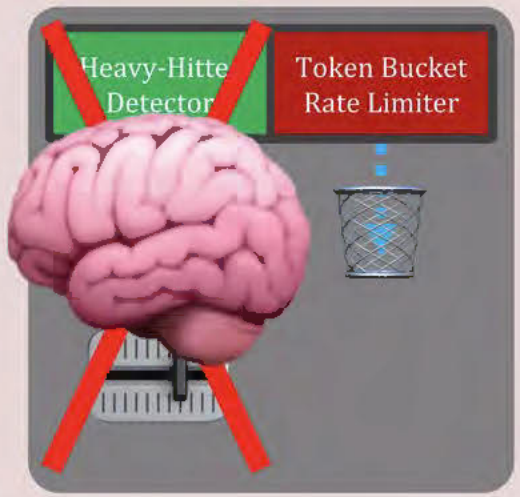
Step 2: Adversarial Co-Training



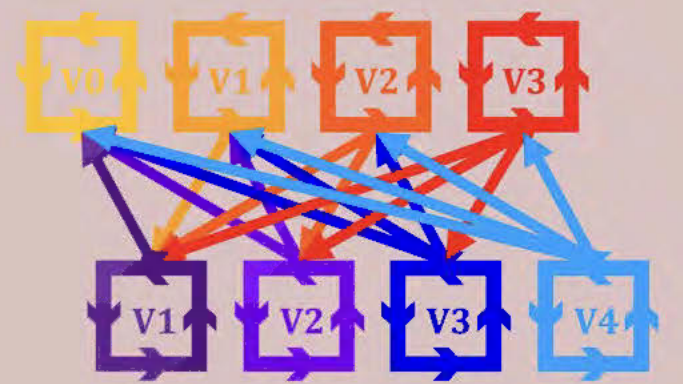
ZERO-SHOT ATTACKS



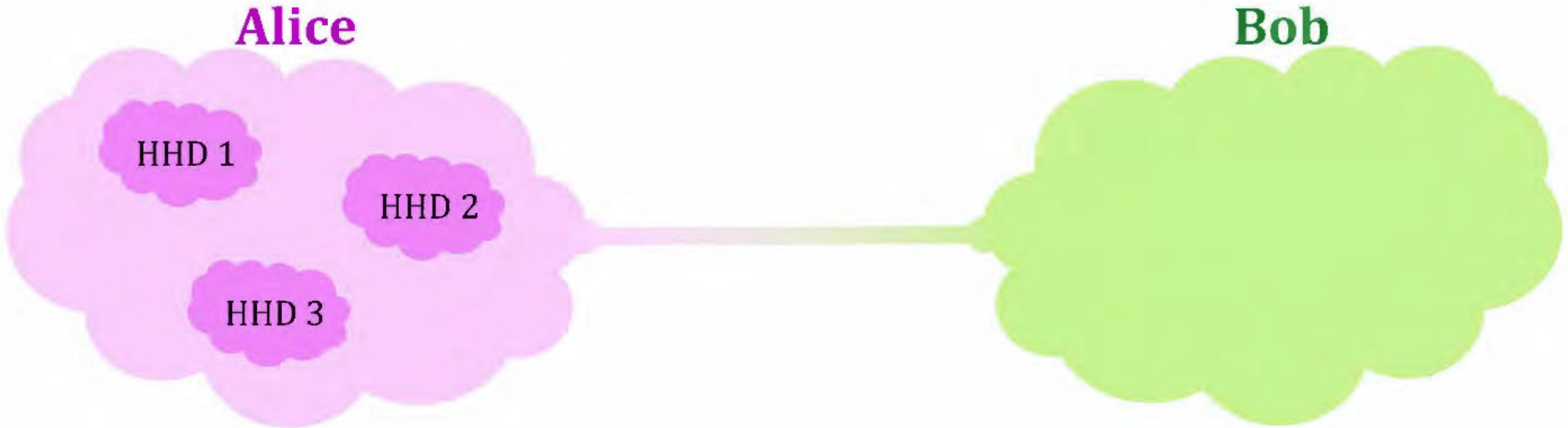
Step 1: More Flexibility



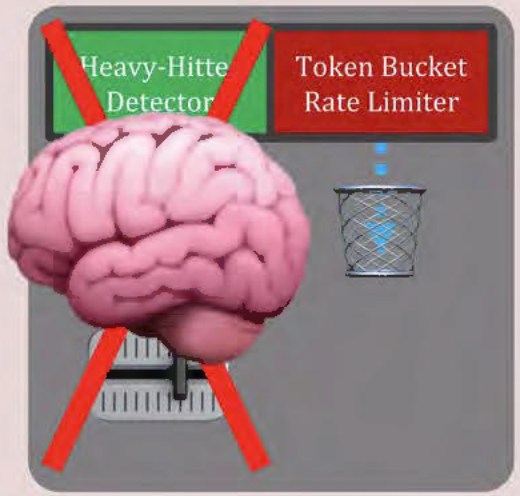
Step 2: Adversarial Co-Training



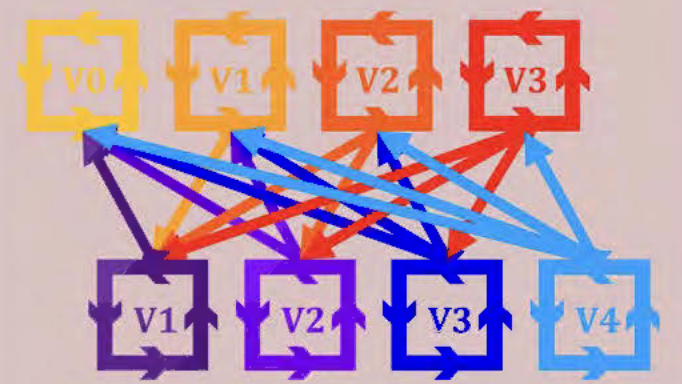
ZERO-SHOT ATTACKS



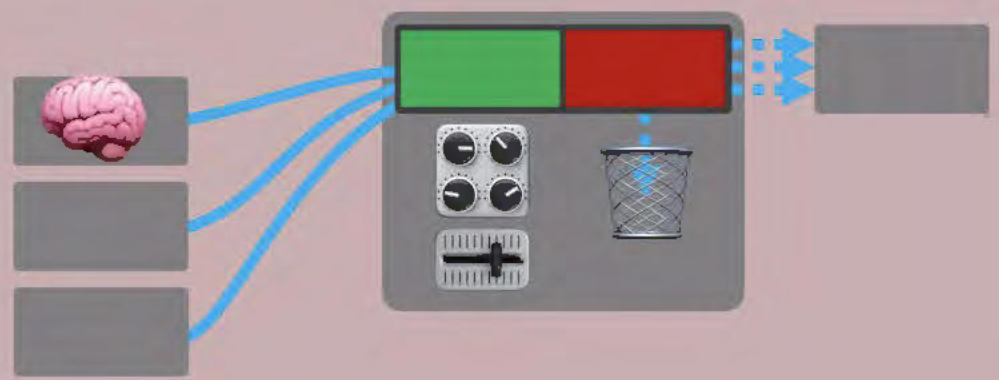
Step 1: More Flexibility



Step 2: Adversarial Co-Training

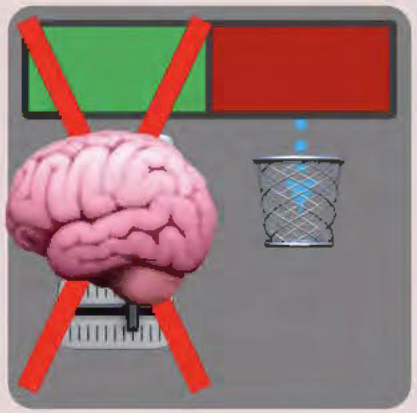


Step 3: Evaluate against HHDs

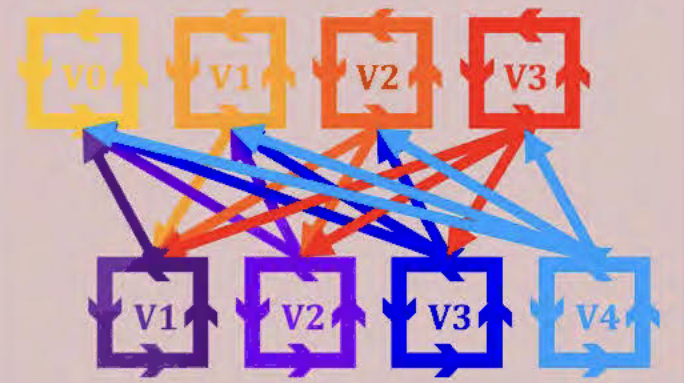


ZERO-SHOT ATTACKS

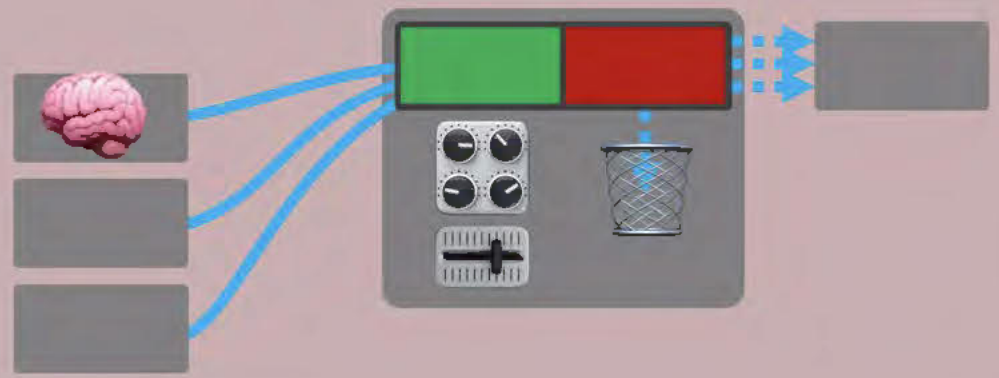
Step 1: More Flexibility



Step 2: Adversarial Co-Training

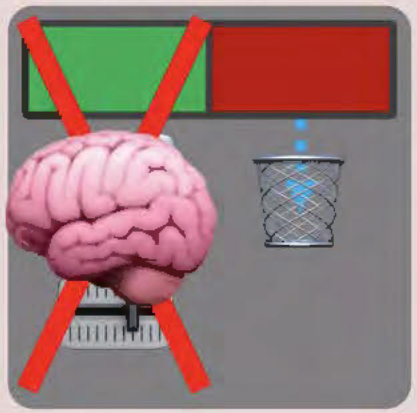


Step 3: Evaluate against HHDs

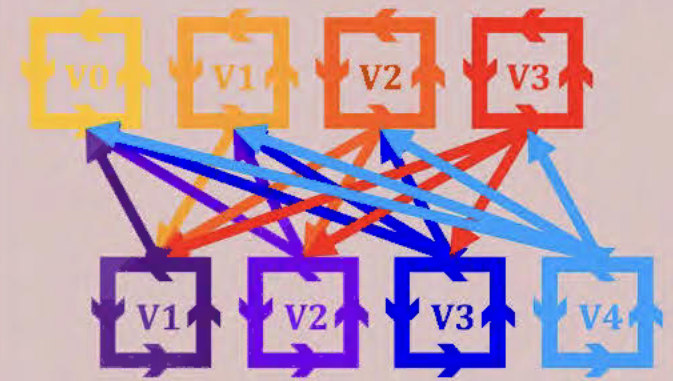


ZERO-SHOT ATTACKS

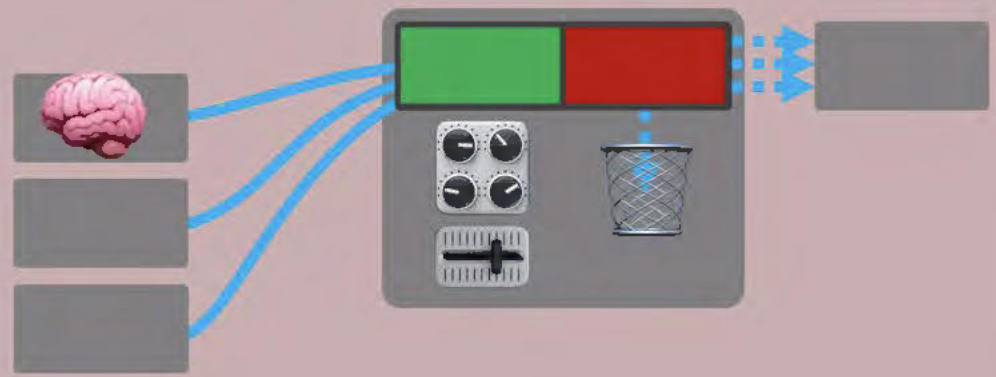
Step 1: More Flexibility



Step 2: Adversarial Co-Training



Step 3: Evaluate against HHDs



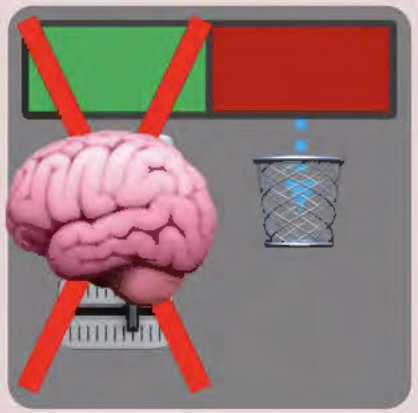
Evaluated for 9 different heavy-hitter detectors

	AL	CB	CM	ES	HK	MG	SS	CH	HP
Synthetic traffic	50%	82%	113%	117%	-20%	27%	58%	86%	38%
Captured traffic	103%	130%	125%	184%	162%	130%	148%	127%	119%

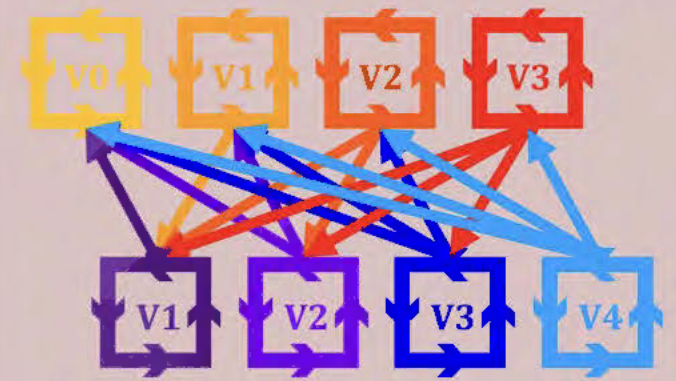
Adversary Overuse

ZERO-SHOT ATTACKS

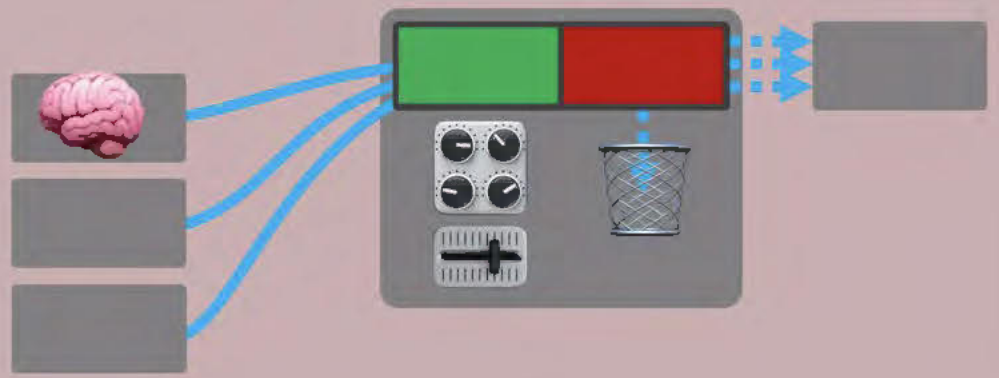
Step 1: More Flexibility



Step 2: Adversarial Co-Training



Step 3: Evaluate against HHDs

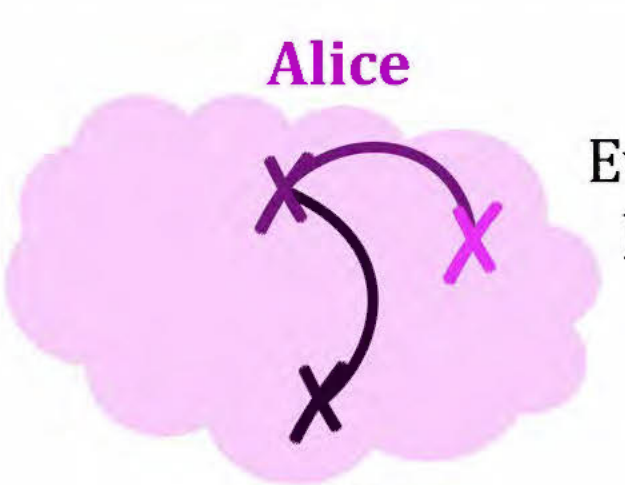


Evaluated for 9 different heavy-hitter detectors

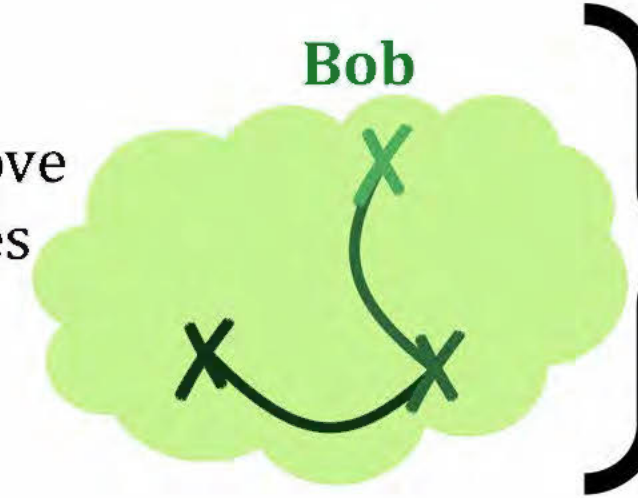
	AL	CB	CM	ES	HK	MG	SS	CH	HP	
Synthetic traffic	50%	82%	113%	117%	-20%	27%	58%	86%	38%	**8/9**
Captured traffic	103%	130%	125%	184%	162%	130%	148%	127%	119%	**9/9**

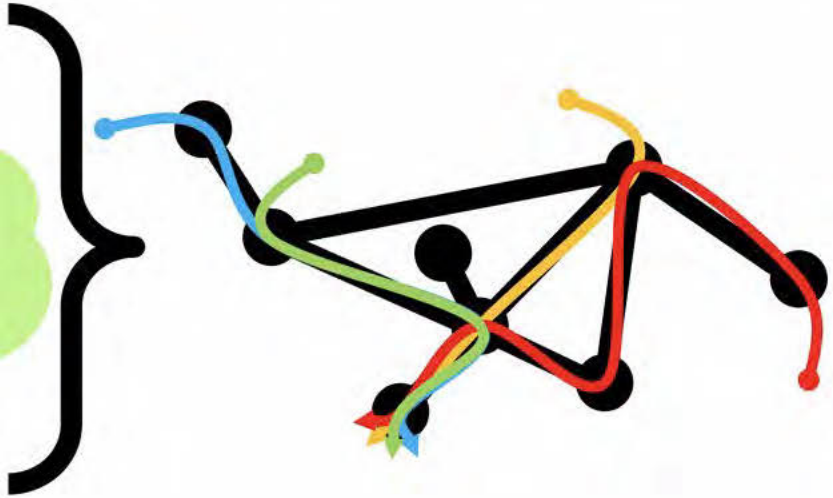
Adversary Overuse

CONCLUSIONS

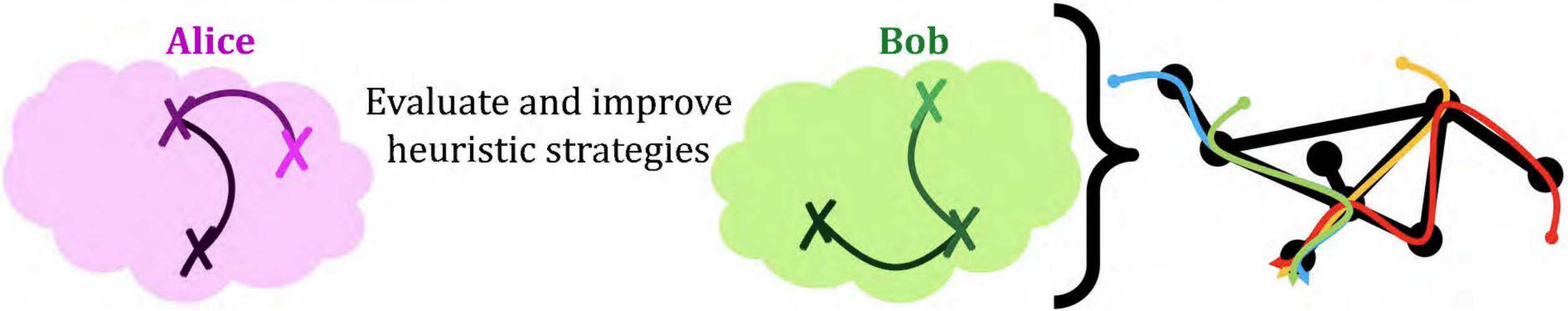


Evaluate and improve heuristic strategies



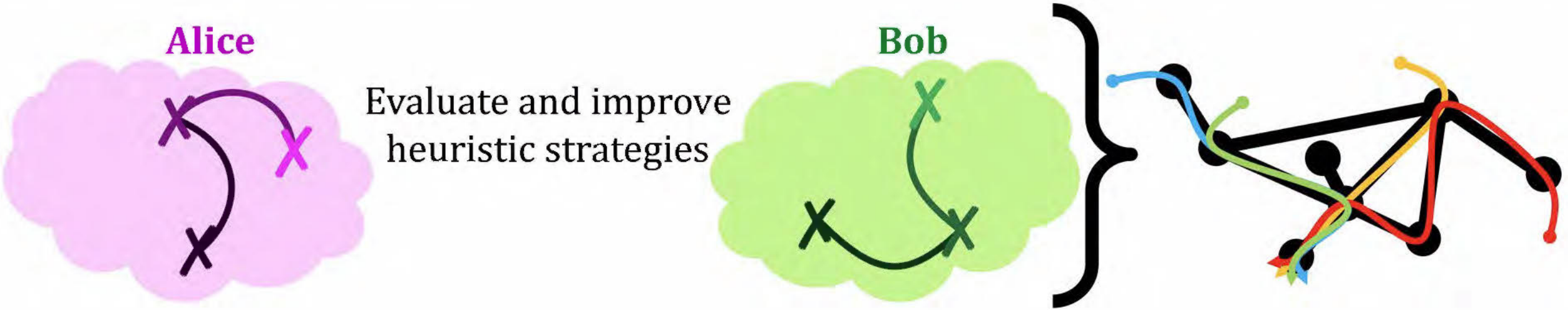


CONCLUSIONS



1) Works with label-free data or no data at all

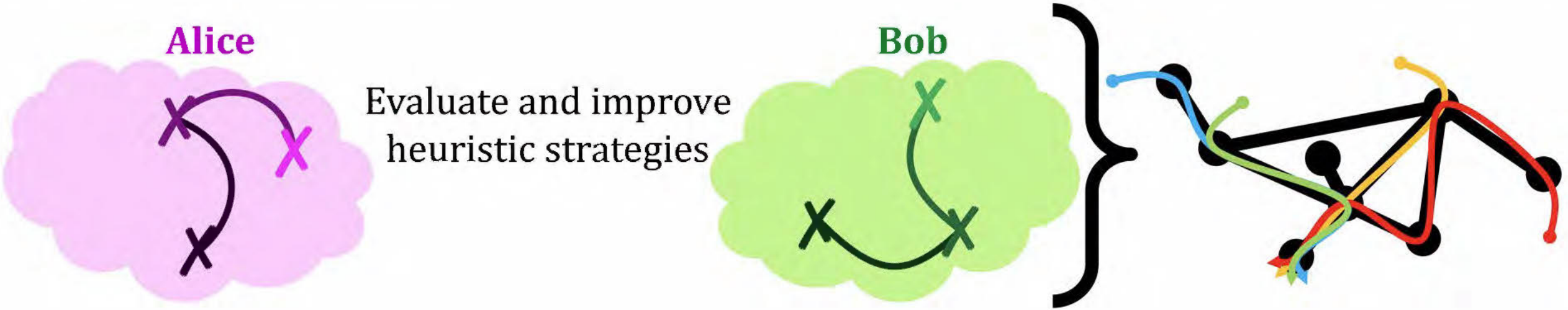
CONCLUSIONS



1) Works with label-free data or no data at all

2) Core ideas can be applied to other scenarios

CONCLUSIONS



1) Works with label-free data or no data at all

2) Core ideas can be applied to other scenarios

3) Code and framework is available online