OctoSketch: Enabling Real-Time, Continuous Network Monitoring over Multiple Cores

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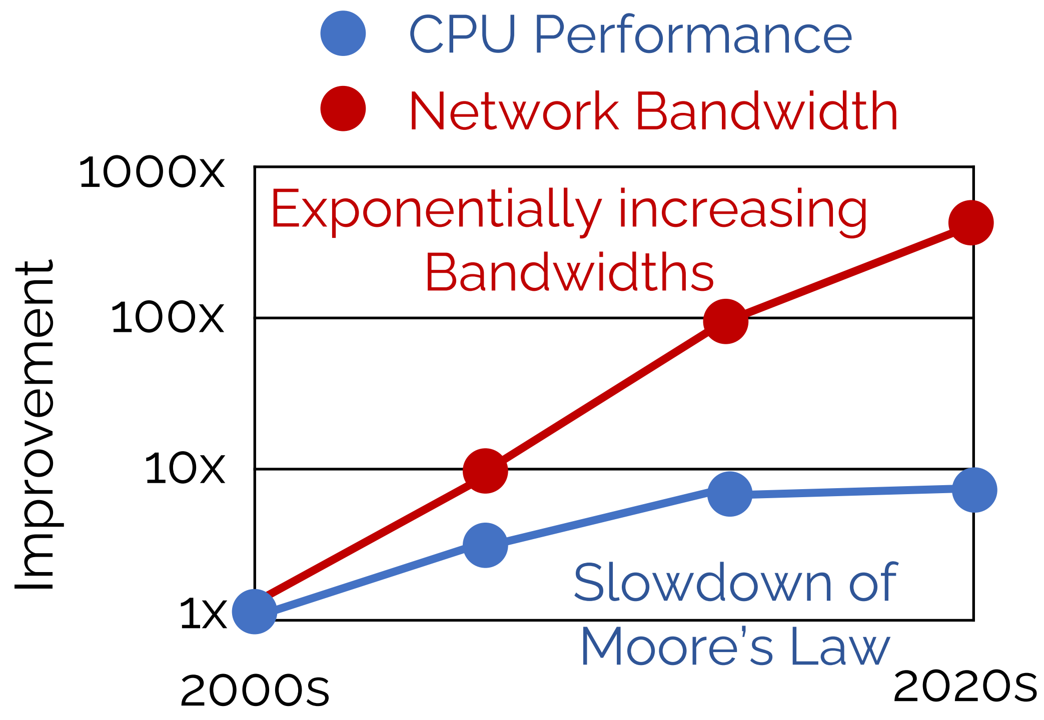
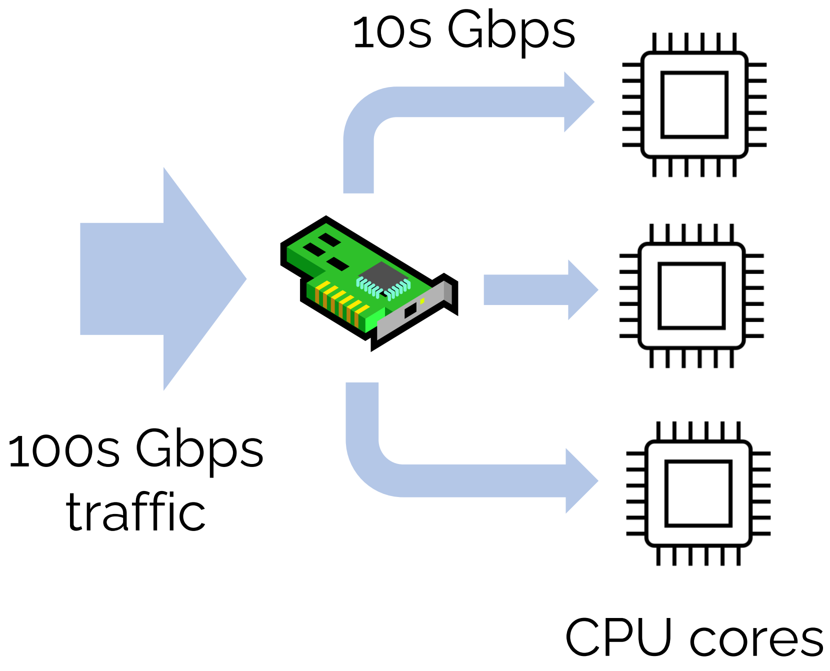
Packet processing needs multiple CPU cores

OvS Open vSwitch

fd.io The Universal Dataplane

BESS





Need for network telemetry over multiple cores

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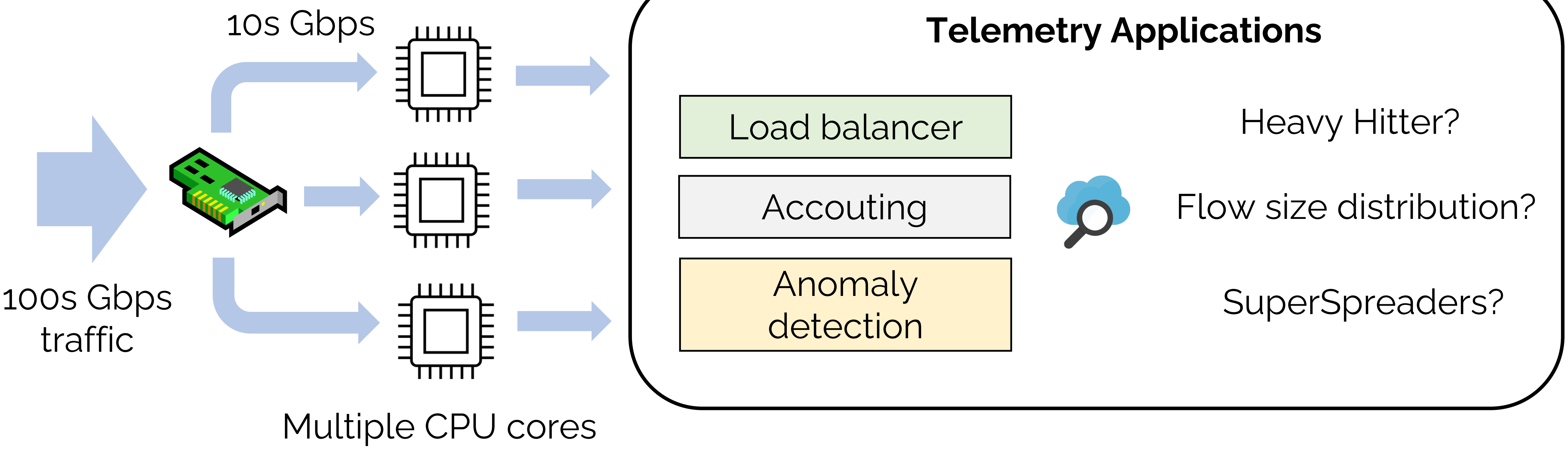
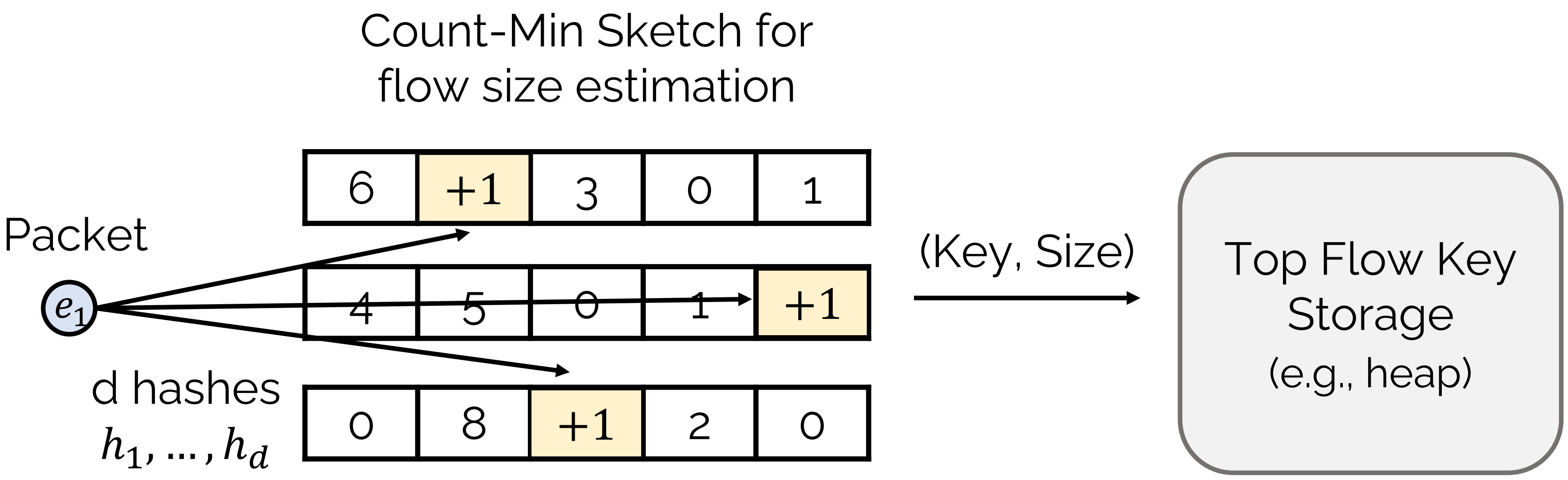


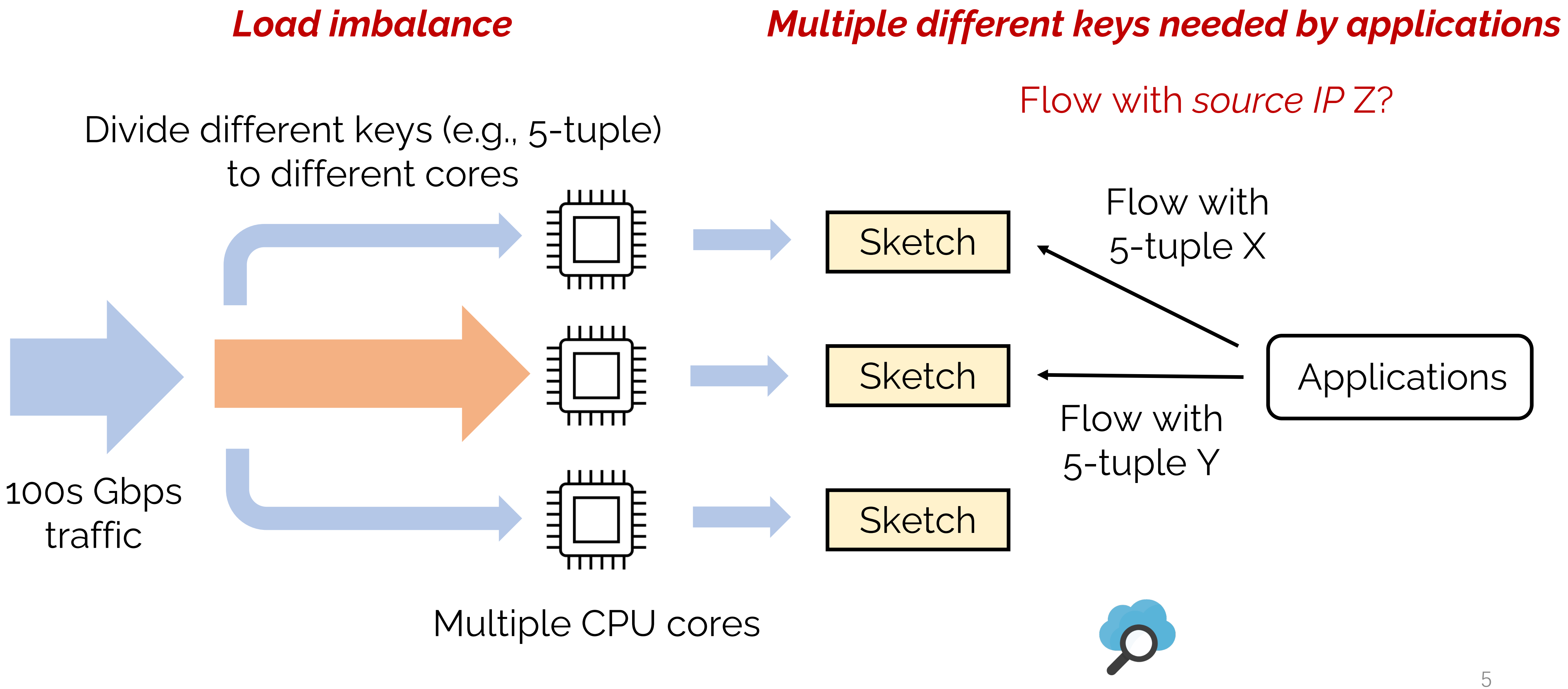
Sketches: promising solutions for *single-core telemetry*

(UnivMon [SIGCOMM'16], NitroSketch [SIGCOMM'19], CocoSketch [SIGCOMM'21])



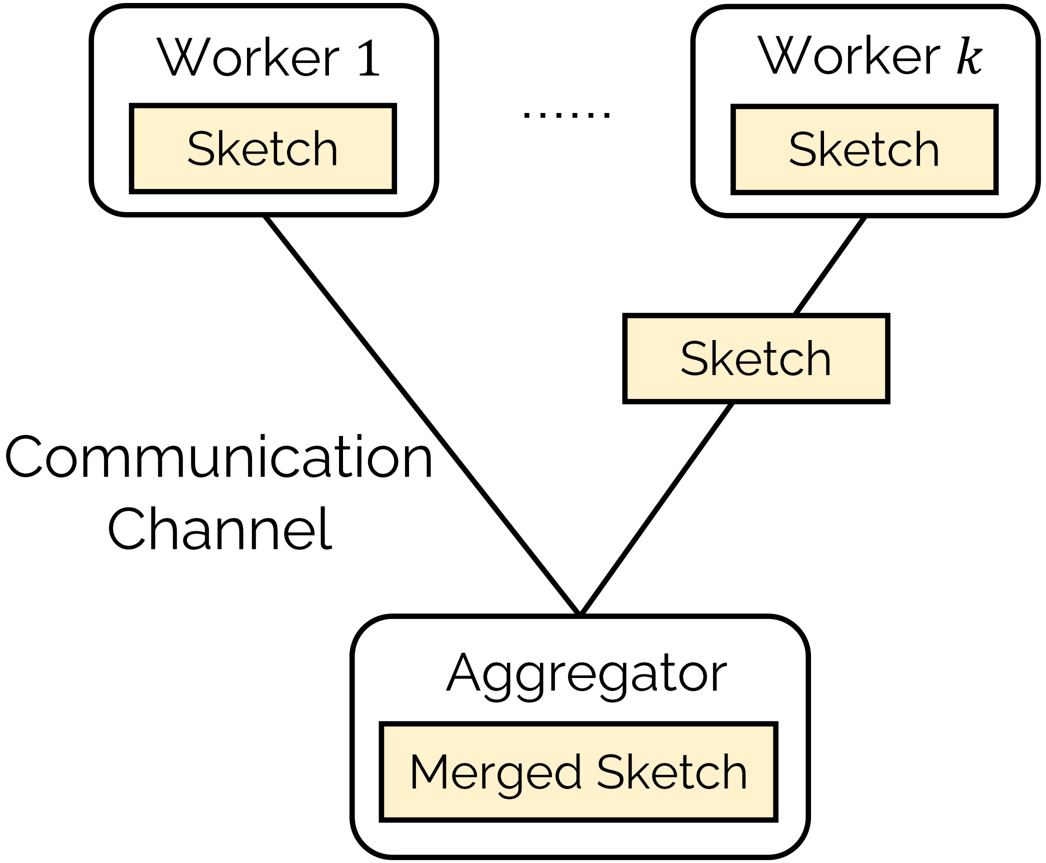
(1) **high** throughput (2) **small** memory usage (3) **bounded** error rates

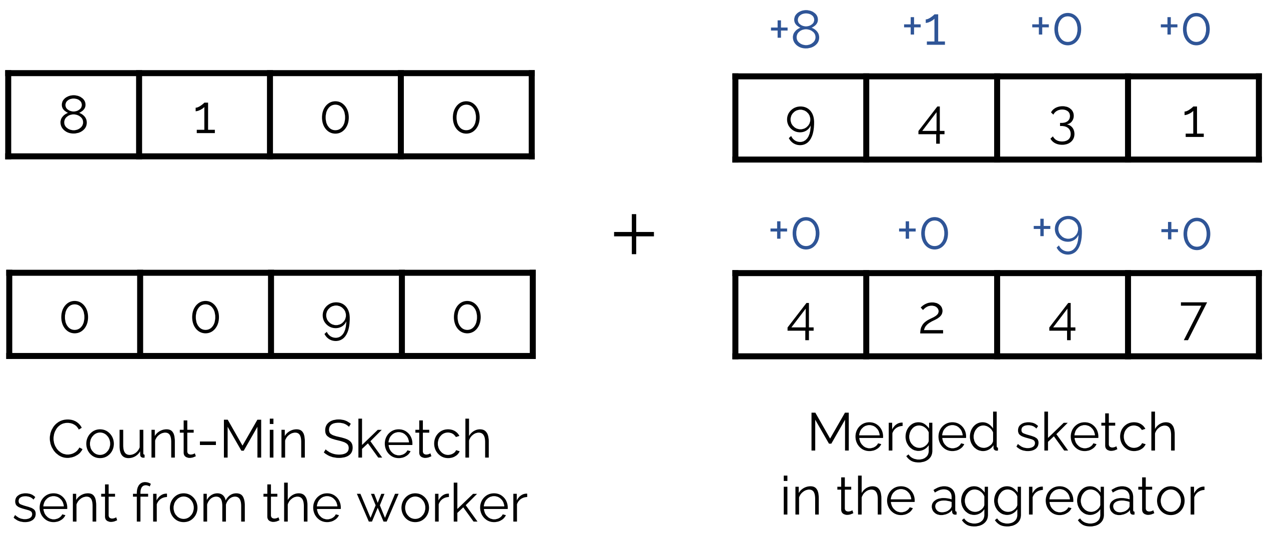
Strawman solution for *multi-core telemetry*: *Key-based Partition*



Existing solution for *multi-core telemetry*: *Entire-sketch-merge*

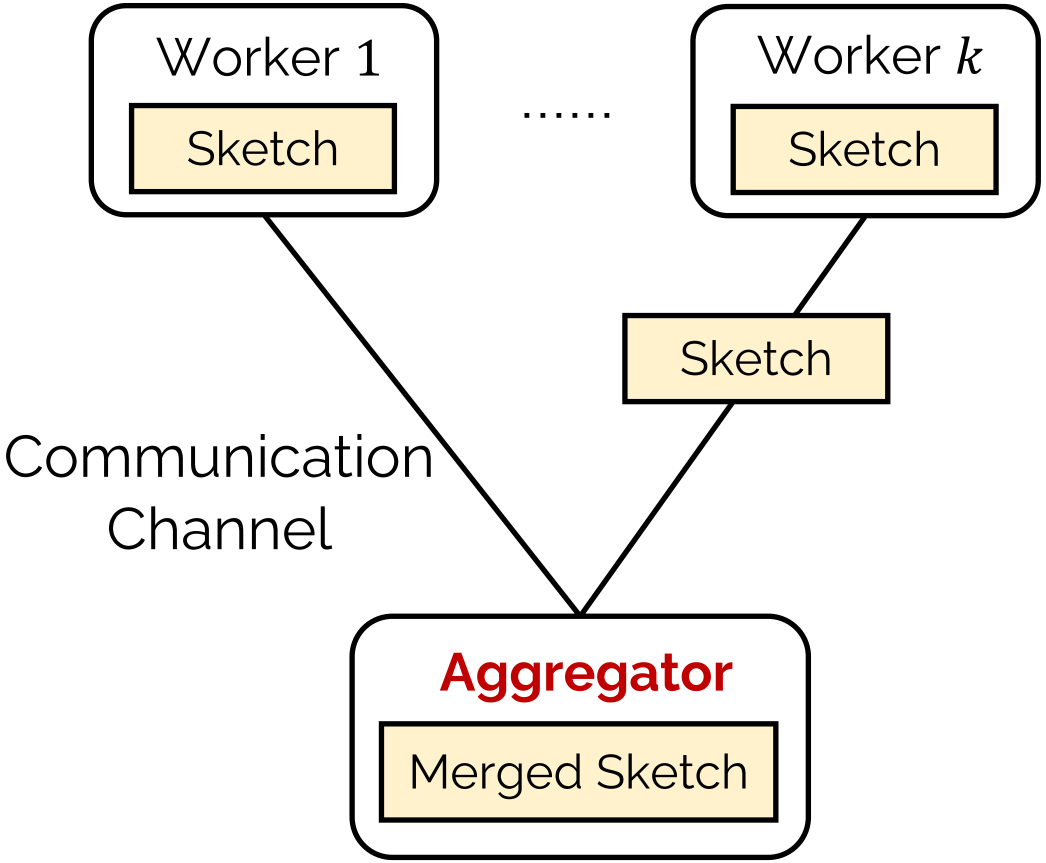
(UnivMon [SIGCOMM'16], Elastic Sketch [SIGCOMM'18], HeteroSketch [NSDI'22])



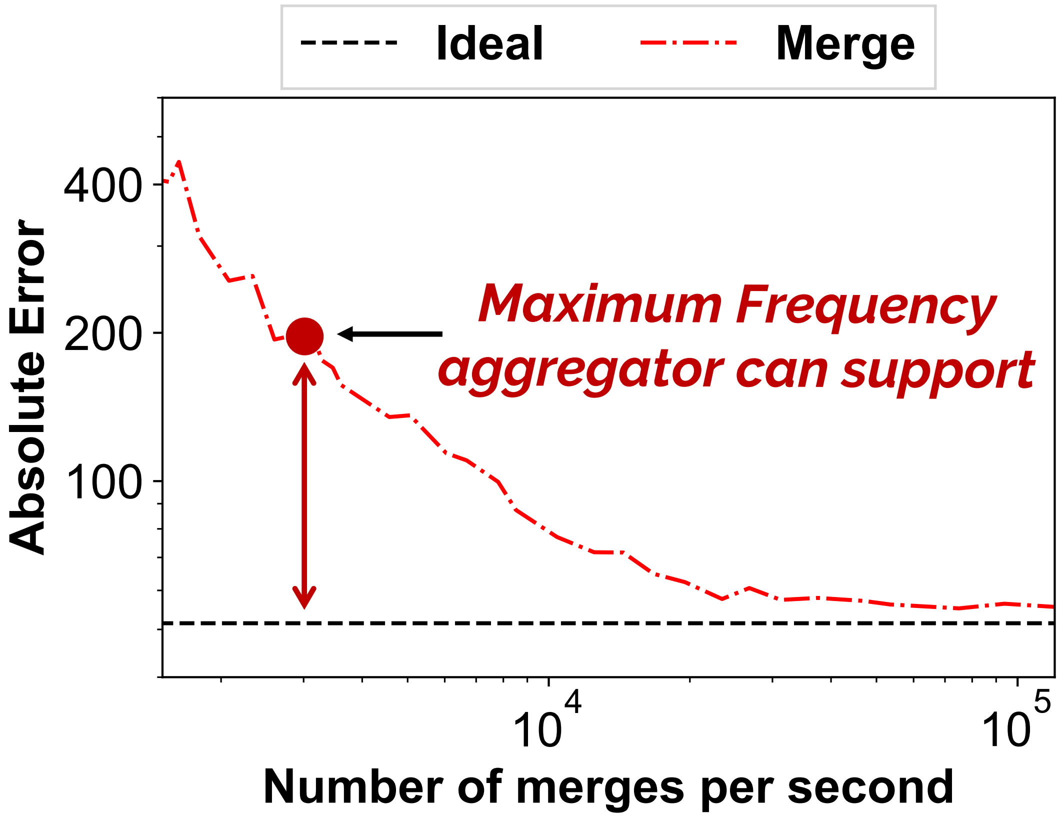


Merge process

Bottleneck In the aggregator



Ideal accuracy: the accuracy of sketch that works in a single core and measures the whole traffic



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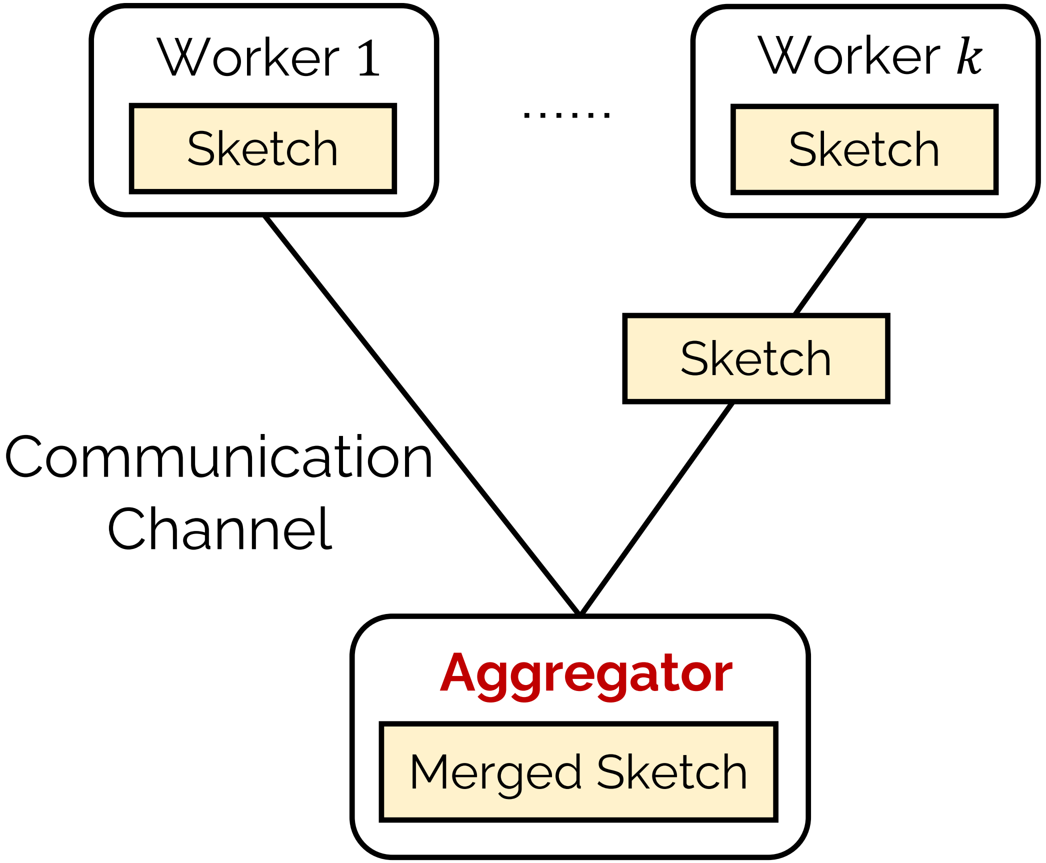
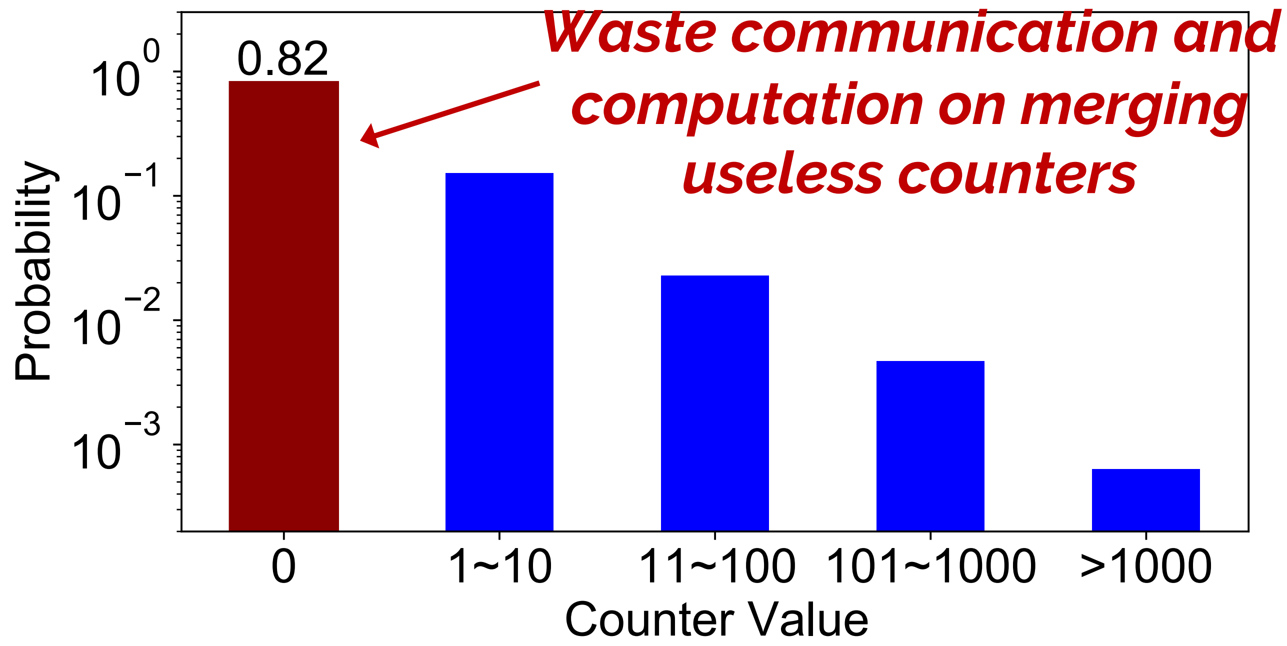


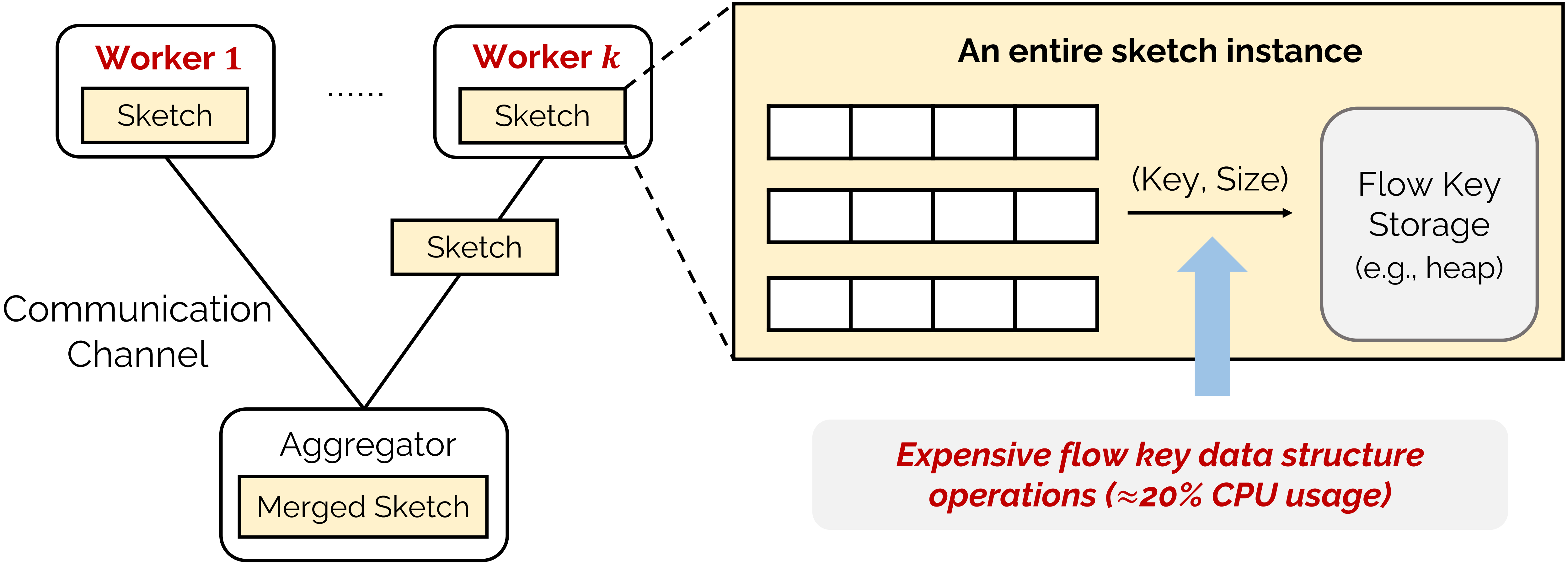
Counter value distribution when sketch-merge



Heavy-tailed network traffic leads to **heavy-tailed counter values** in the sketch

Bottleneck in the workers

(Elastic Sketch [SIGCOMM'18], NitroSketch [SIGCOMM'19], CocoSketch [SIGCOMM'21])



Expensive flow key data structure operations (≈20% CPU usage)

OctoSketch: Real-Time multi-core monitoring

A sketching framework for multicore monitoring that simultaneously has:

- **Online accuracy**: accuracy guarantees at any query time
  - Idea 1: Only send “sufficiently changed” counters
- **Adaptive**: adaptive to packet arrival rate and system objectives
  - Idea 2: Dynamic resource allocation based on queue length
- **Performance**: line-rate (e.g., 100G) with minimal CPU and memory
  - Idea 3: Remove redundant data structures

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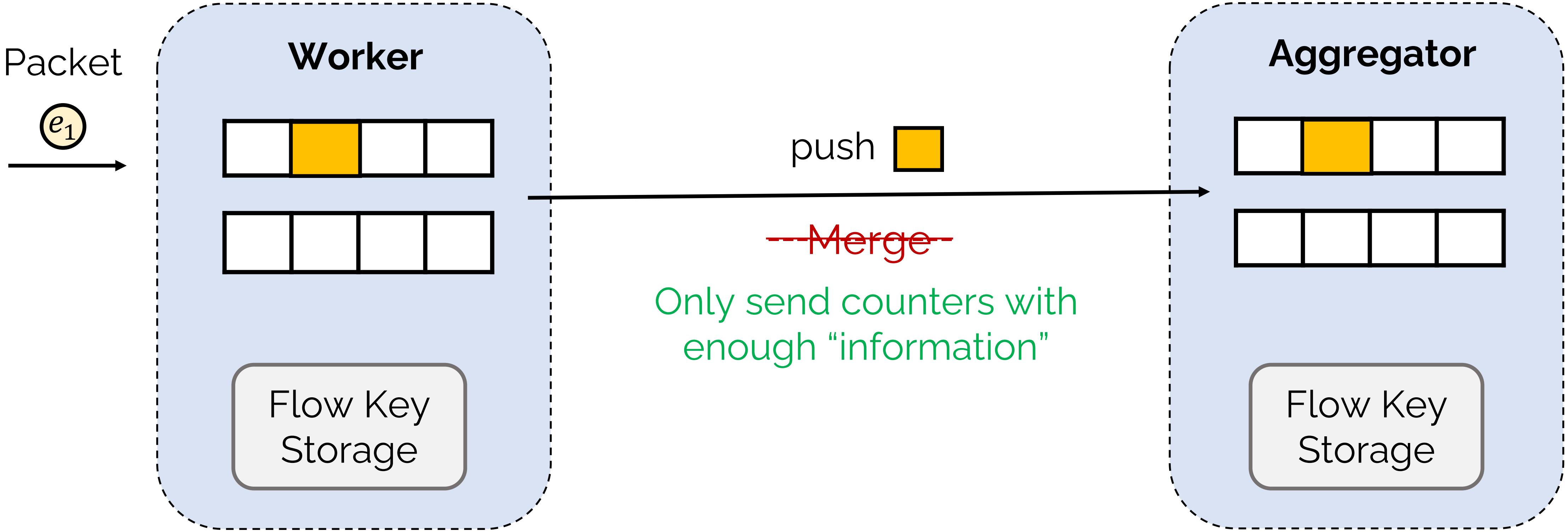
Key Idea: Only send “sufficiently changed” counters

~~A large sketch merging operation~~

A series of small counter change notification



General to different sketches

- **Applied to 9 representative sketches over 6 different tasks**
- Cardinality-related sketches
  - e.g., HyperLogLog
- Counters with flow keys
  - e.g., CocoSketch
- Negative counter values
  - e.g., UnivMon

Check out our paper for more details!

Benefit of the continuous, change-based mechanism

- Retains the **same asymptotic error bounds as in the ideal case** in which traffic is not distributed **at any query time**.
- Offers accuracy guarantees for a variety of measurement tasks.
  - e.g., finding heavy hitters, estimating cardinality

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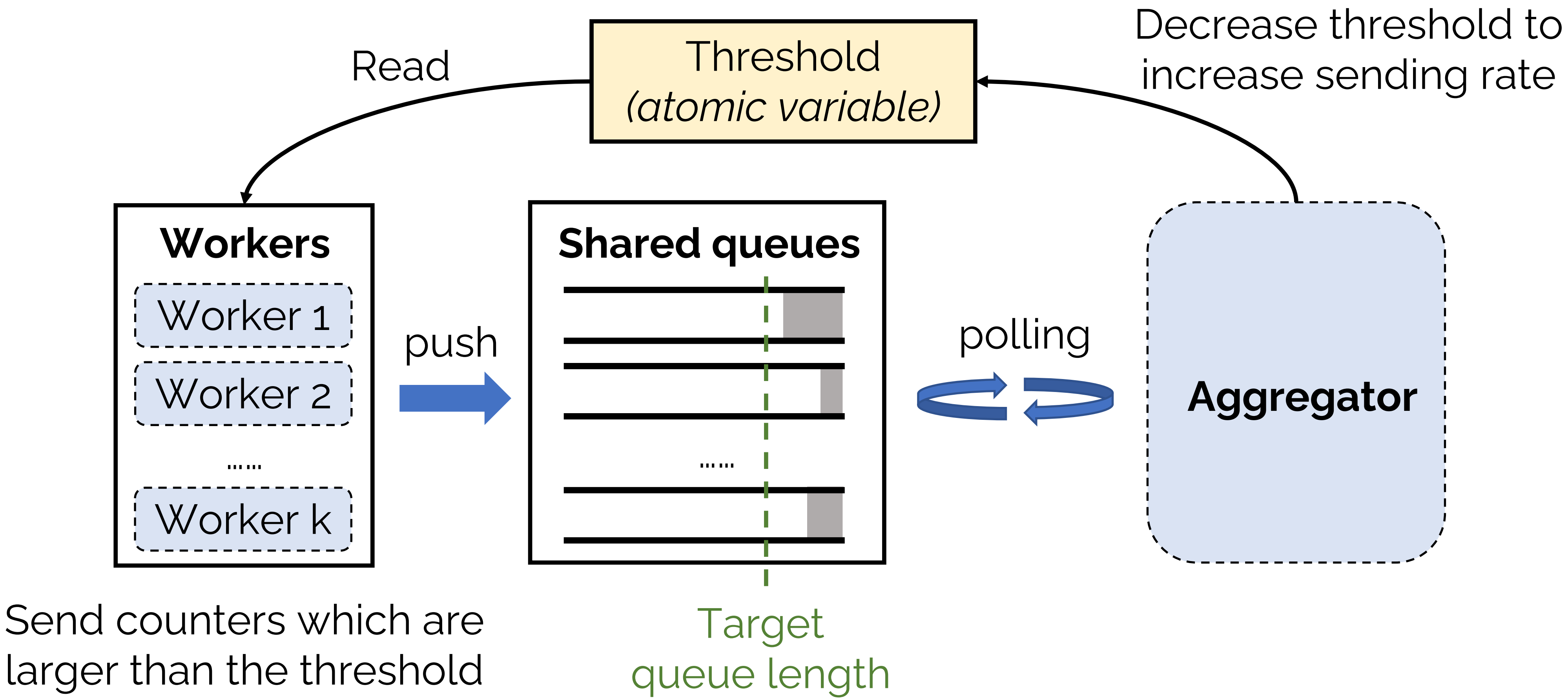
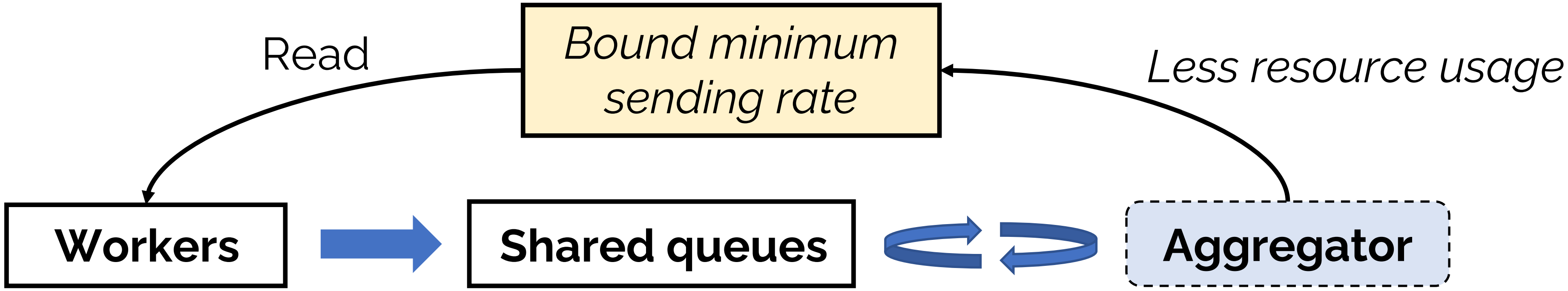
Idea 2: Adaptive sending rate

- Packet rate is low ⇒ Send changes frequently (high online accuracy)



Policies to meet various objectives

- Scenario 1: Given resource budget, achieve best possible online accuracy
  - Given *70% CPU usage* for the aggregator, modify the threshold to *optimize the online accuracy*
- Scenario 2: Given accuracy target, achieve minimum resource usage
  - Given a *99% accuracy target*, bound the minimum sending rate to *free up extra computation resources*



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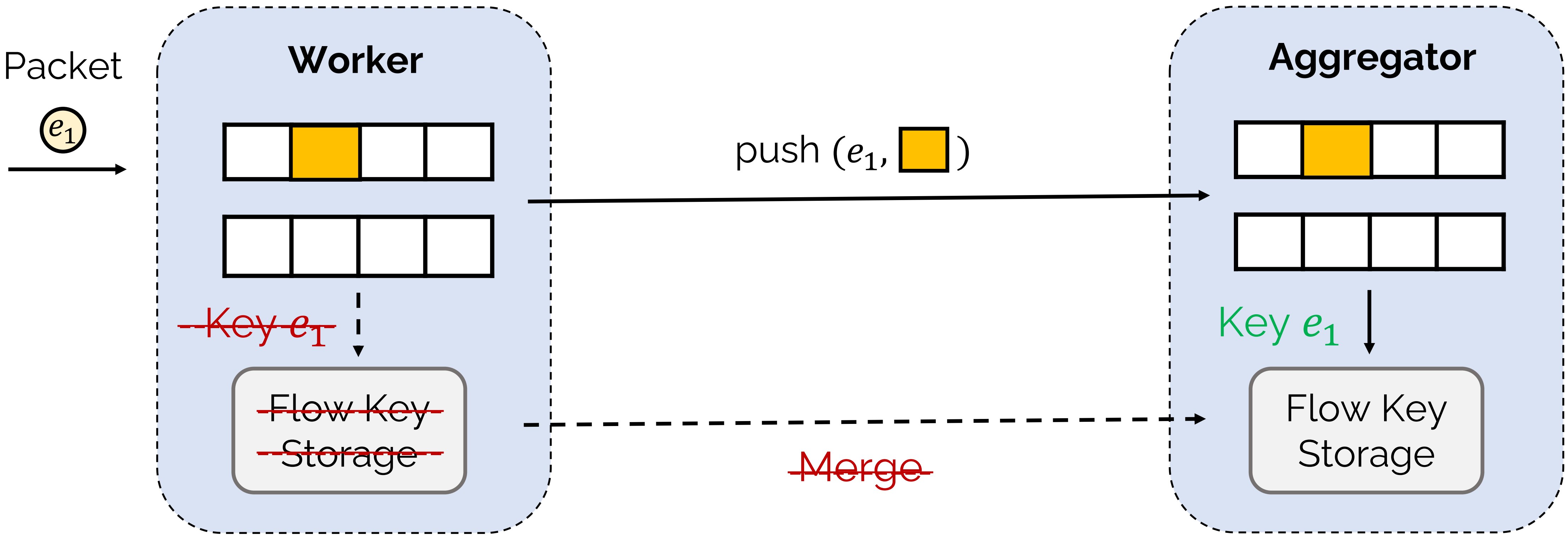
Idea 3: Remove redundant data structures

~~Expensive flow key data structure operations~~

Remove flow key storage in workers

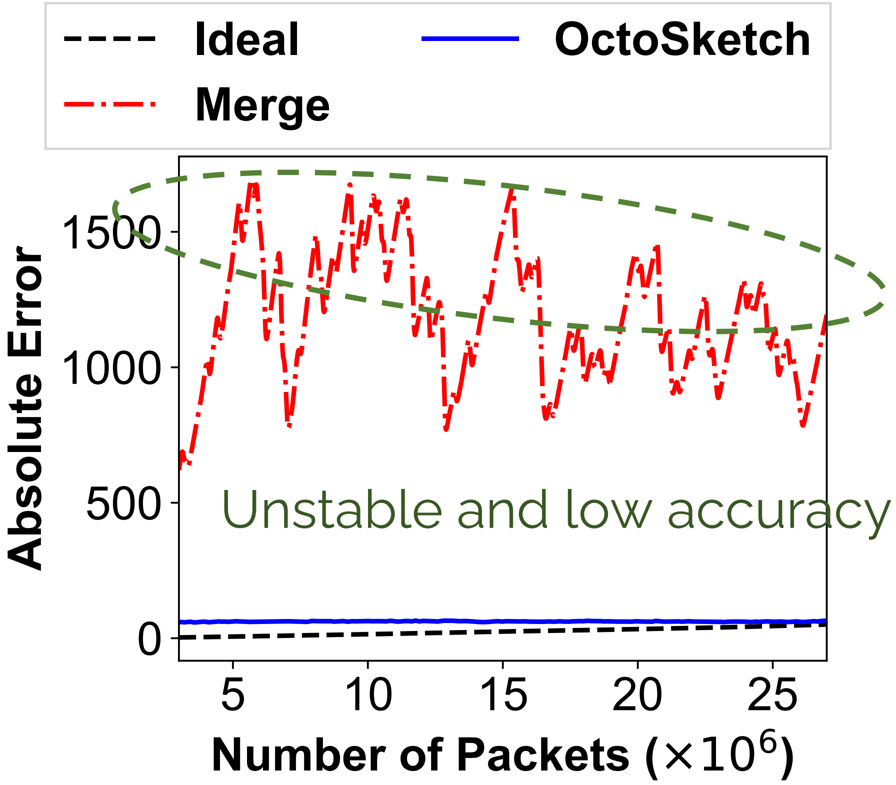


Evaluation setup

- **Use cases:** load balancer, key-value cache
- **Platforms:** CPU, DPDK, eBPF XDP
  - 2-16 workers' CPU + 1 aggregator CPU
- **Baselines**
  - **Entire-sketch-merge:** operating at maximum frequency for merging
  - **Ideal accuracy:** the accuracy of the sketch that works in a single core and measures the whole traffic

OctoSketch can achieve high online accuracy

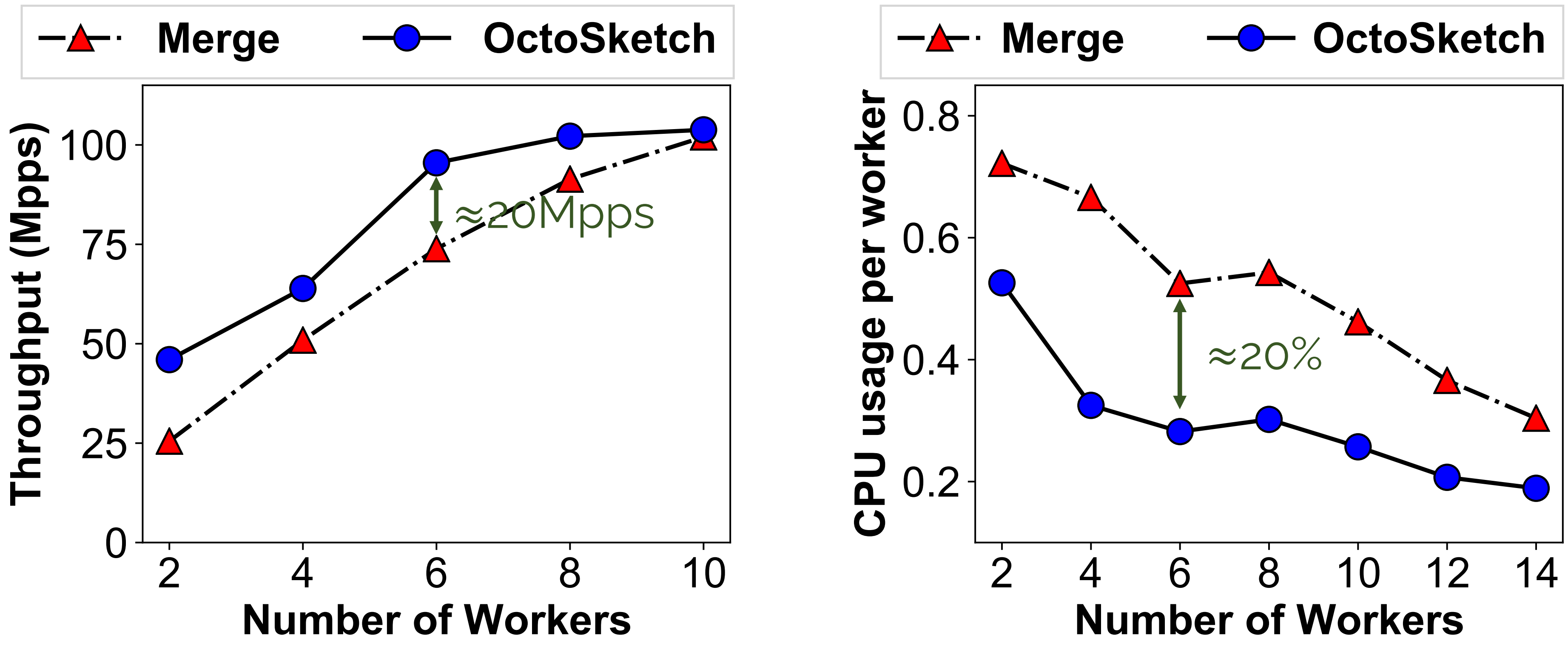
OctoSketch for the Count-Min sketch (Finding heavy hitters)



OctoSketch's *continuous mechanism* helps it maintain **accuracy close to the ideal one**

OctoSketch can achieve good CPU performance

OctoSketch for the Count-Min sketch in DPDK



Removing redundant data structures helps OctoSketch achieve both **high throughput** and **low CPU usage on workers**

OctoSketch is general to different sketches

Query Type	Sketch	Accuracy	Throughput
Flow Size	Count-Min	**9.32x**	**3.85x**
	Count Sketch	**9.04x**	**3.22x**
Cardinality	LogLog	**54.93x**	**1.29x**
	HyperLogLog	**38.97x**	**1.29x**
Super-Spreader	Locher Sketch	**4.06x**	**4.51x**
Quantile	DDSketch	**4.29x**	0.92x
Multi-Key	CocoSketch	**37.25x**	**1.01x**
Genreal	UnivMon	**13.55x**	**2.63x**
	ElasticSketch	**14.03x**	0.93x

Conclusions

- Multicore monitoring is needed
- Sketch-merge over multiple cores is impractical
- OctoSketch key ideas:
  - Continuous, change-based mechanism
  - Adaptive resource allocation
  - Remove redundant data structures
- OctoSketch achieves about 15.6x higher online accuracy and up to 4.5x higher throughput while retaining the generality

Source code: https://github.com/Froot-NetSys/OctoSketch