New Measurement Abstractions for Data Centers

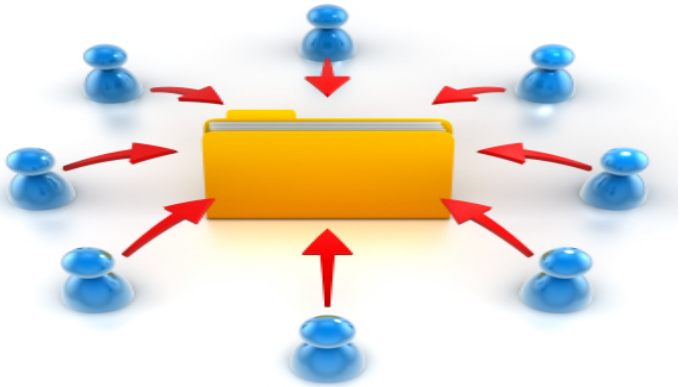
Minlan Yu

University of Southern California

Key Challenges in Data Centers

- Service level agreements
  - Good, predictable performance

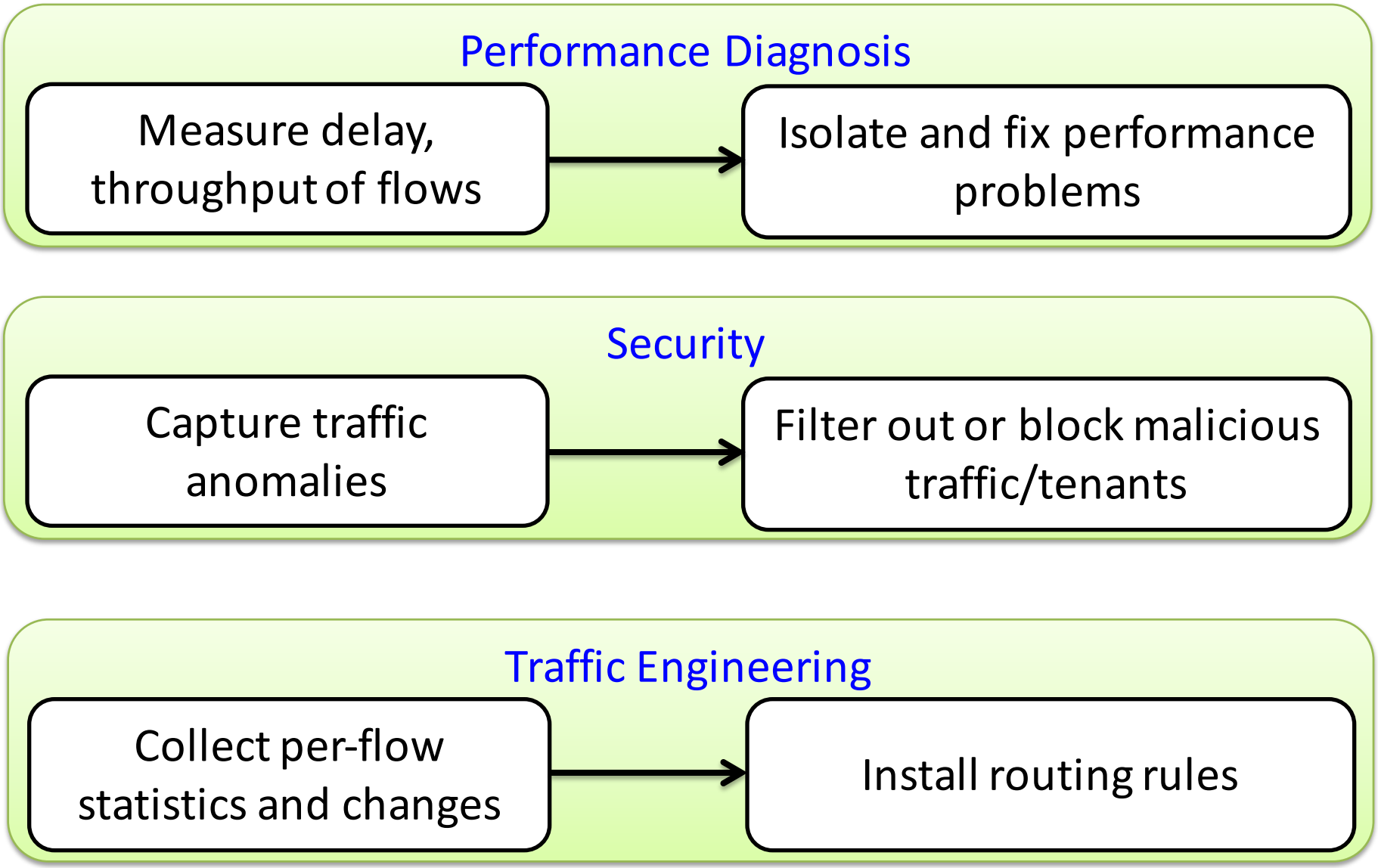
- Multi-tenancy
  - Resource isolation across tenants



- Cost reduction
  - Drive the network to high utilization

All require fine-grained network management

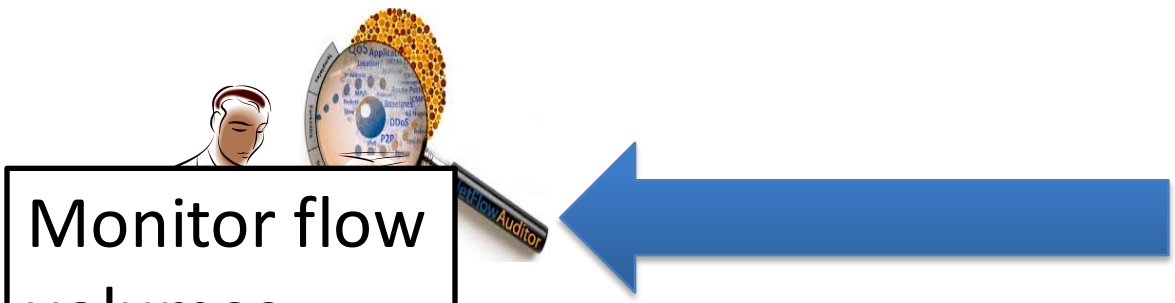
Management = *Measurement* + Control

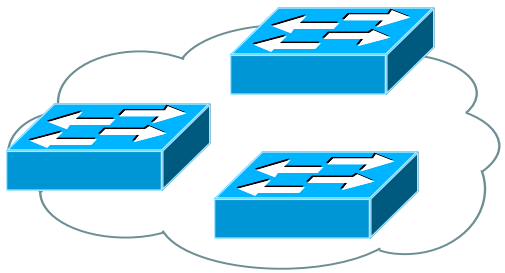


The state of today's Datacenter measurement

The need for new measurement abstractions

Many Measurement Programs





Monitor flow volumes

Performance diagnosis

Anomaly detection

Query independence:
Specify many measurement queries
with simple, programmable abstractions

Many Data Collection Primitives

- Passively collect different sources of data

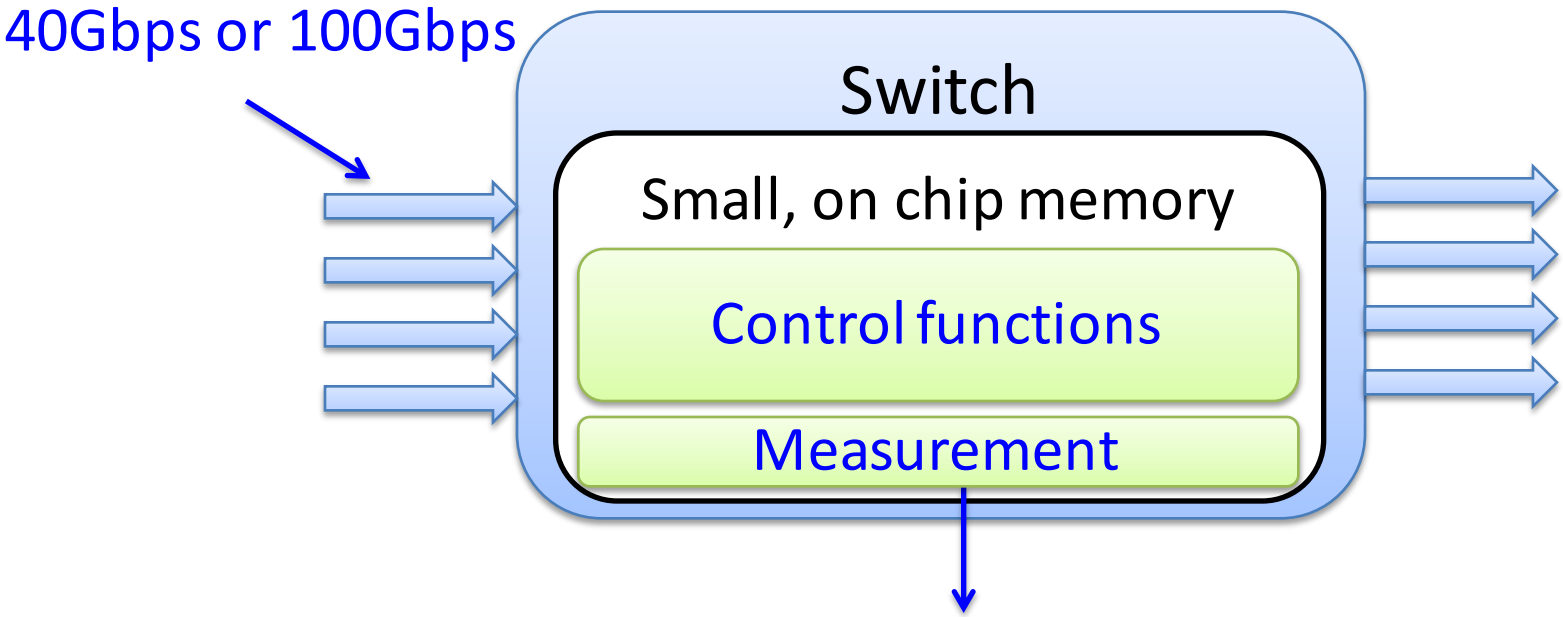
→Little control on what (not) to measure

Target independence:

Specify which data to collect

independent of where and how it is collected

Limited Measurement Resources



- Low sampling rates
- Miss many important information

Reconfigurable:
Dynamically change the way resources are used for different measurement queries and traffic

A New Abstraction for Measurement

Specify measurement queries

Measurement Framework

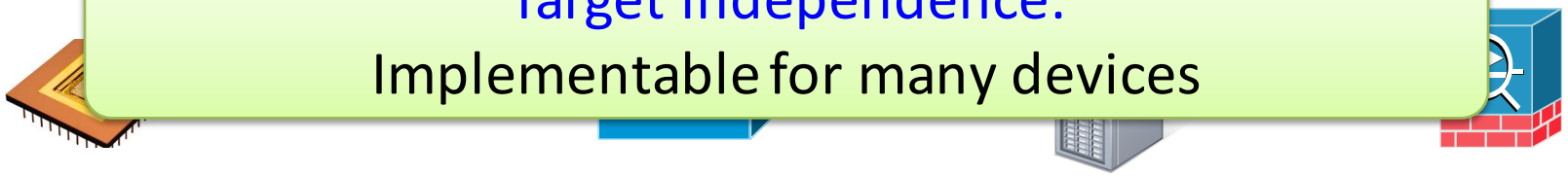
Query independence:
Expressive Abstractions for many queries

Reconfigurable: Efficient Runtime

Dynamically configure devices & manage resources

Automatically collect the right data

Target independence:
Implementable for many devices



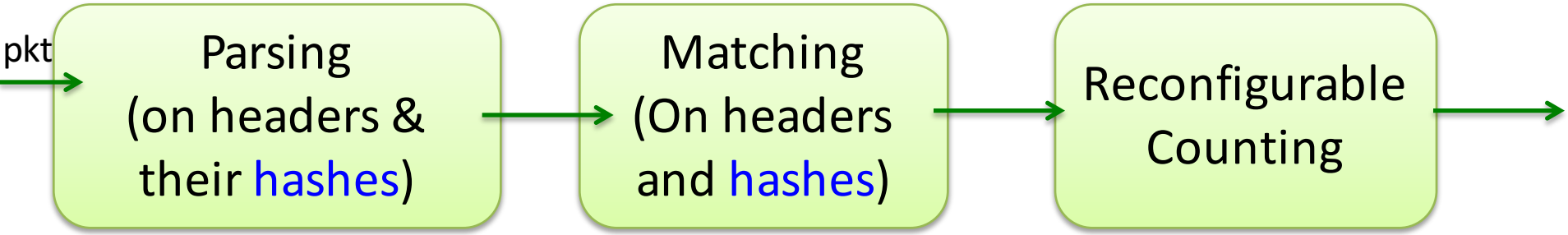
Expressive Abstractions (OpenSketch)

Picking the packets to measure

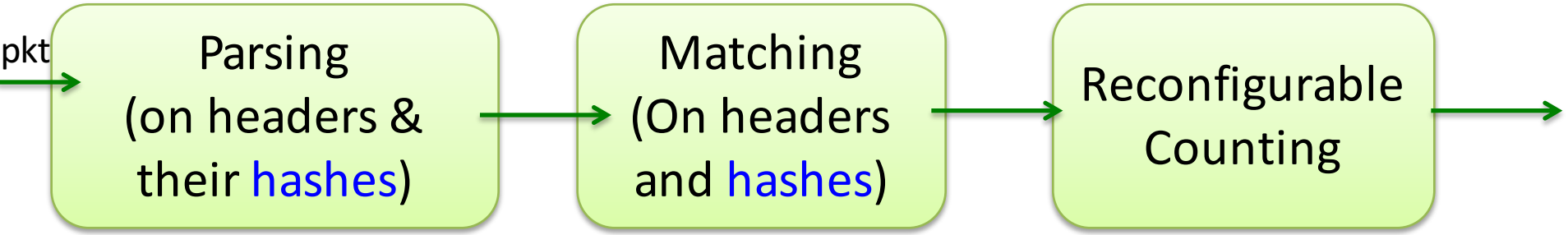
Storing & exporting data

Filter traffic aggregates
(e.g., to host A)
Classify a set of flows
(e.g., a set of malicious source IPs)

Dynamically flows to counters
(e.g., more counters for elephant flows)

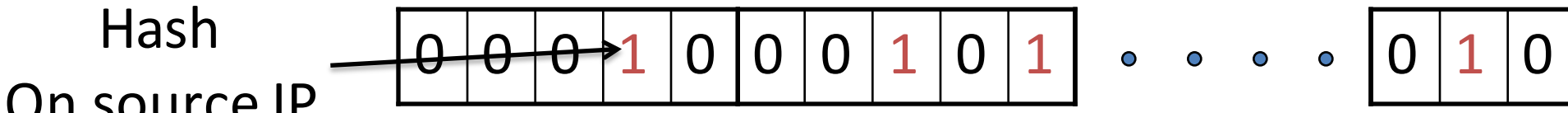


Support Many Queries



How many unique IPs send traffic to host A?

Bitmap



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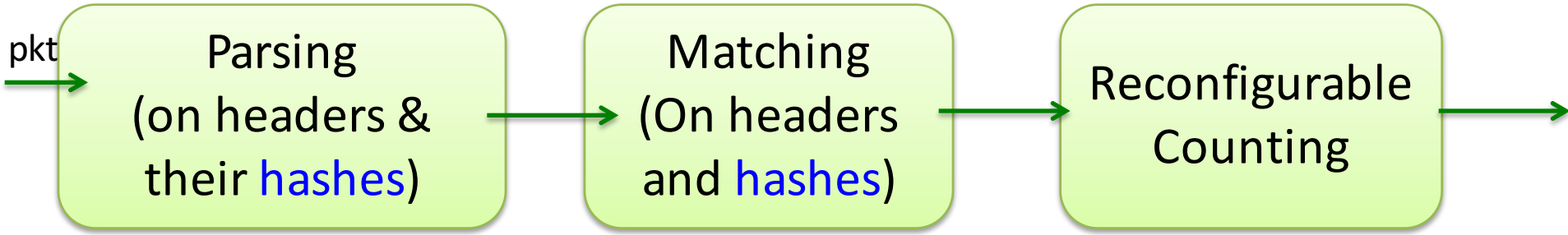
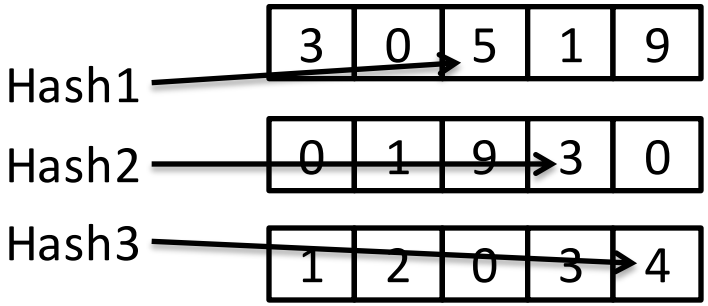


Who's sending a lot to host A?

Count-Min Sketch

Dst = host A
3 hashes on source IP



Multiple Tables

- Multiple tables for one query
  - Who's sending a lot to host A?
  - *count-min sketch* to count volume of flows
  - *reversible sketch* to identify flows with heavy counts in the count-min sketch

- Multiple tables for many queries
  - Bitmap for counting unique source IPs
  - CountMin sketch for counting traffic for each source IP

Support NetFlow

- NetFlow
  - Store flows and their counters in a hash table
  - Accounting network utilization, capacity planning, troubleshooting, and attack detection
  - It is challenging to implement NetFlow in hardware

SrcIPadd	DstIPadd	Protocol	SrcPort	DstPort	Pkts	Bytes/Pkt
173.100.21.2	10.0.227.12	11	00A2	00A2	11000	1528
173.100.3.2	10.0.227.12	6	15	15	2491	740
173.100.20.2	10.0.227.12	11	00A1	00A1	10000	1428
173.100.6.2	10.0.227.12	6	19	19	2210	1040
173.100.7.2	10.0.227.12	1	41	41	3456	1140
173.100.4.2	10.0.227.12	11	16	16	1929	840
173.100.2.2	10.0.227.12	6	0	0	2228	628
173.100.5.2	10.0.227.12	11	17	17	1325	940

A Better NetFlow

- How to handle hash collisions
  - A larger hash table to reduce collisions

  →Too much memory usage
  - A linked list of buckets, or send to the control plane

  →Too much delay per packet
- Our idea: Embrace hash collisions
  - Encode all the collided (flow, counter) pairs in one bin
  - Network-wide decode in the controller
  - Simple fixed per packet processing
  - Memory usage similar to perfect hashing and actually smaller

A Better Netflow

- Encode Hash a flow into multiple bins

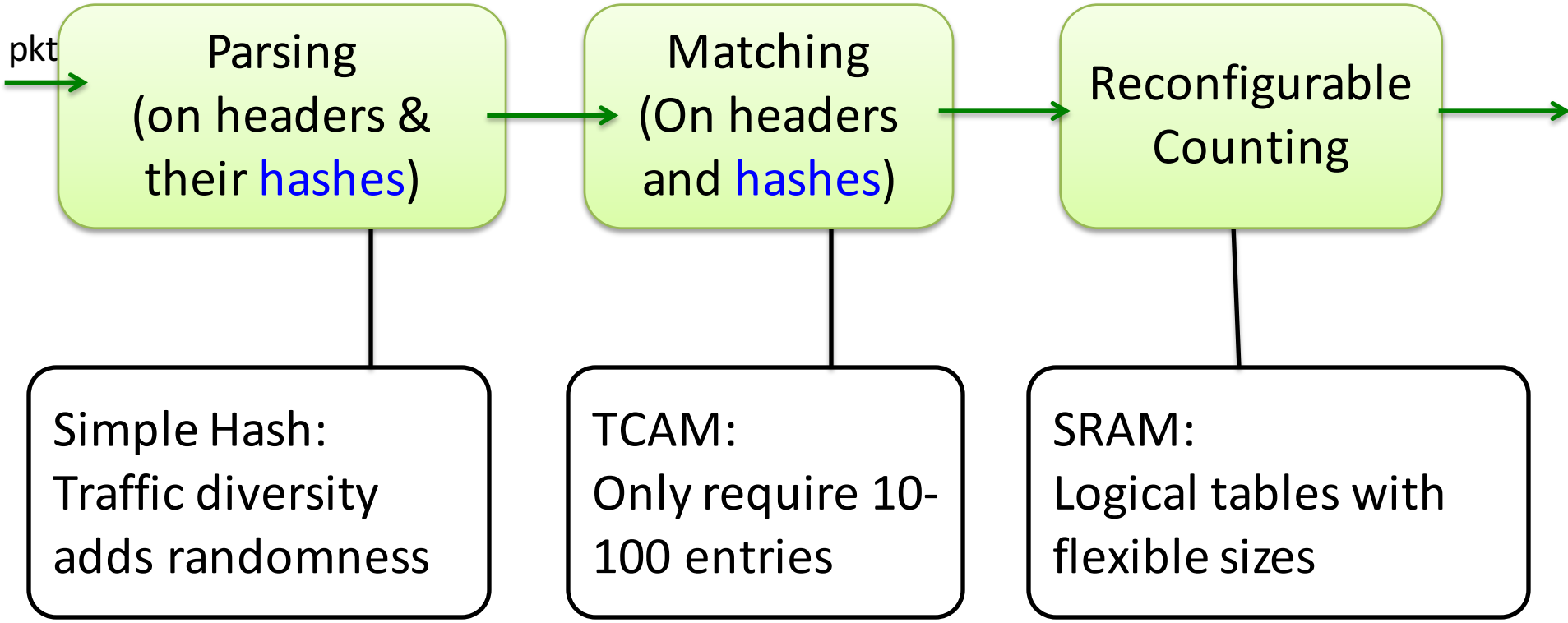
FlowXOR	a	a⊕b	b⊕c	…
FlowCounter	1	2	2	
PacketCounter	C_a	C_a+C_b	C_b+C_c	

- Decode
  - Identify bins with a single flow
  - Remove these flows, and then iterate
- Extensions
  - Identify more bins with a single flow
  - Leverage flow information from other hops

Even More Queries…

Measurement Programs	**Reconfigurable, hash-based counting table**
Loss Detection	Inversible Bloom Filter
Superspreaders	Count-min sketch; Bitmap; Reversible sketch
Traffic change detection	Count-min sketch; Reversible sketch
Traffic entropy on port field	Multi-resolution classifier; Count-min sketch
Flow size distribution	multi-resolution classifier; hash table

Build on P4-compatible Switches



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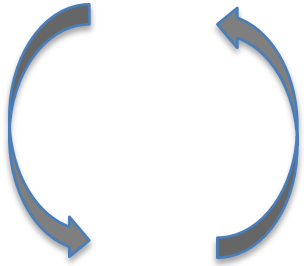

Automatically collect the right data

Target independence:
Implementable for many devices