DREAM:
Dynamic Resource Allocation for Software-defined Measurement

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Google

Measurement is Crucial for Network Management

Tenant:

Netflix | Expedia | Reddit

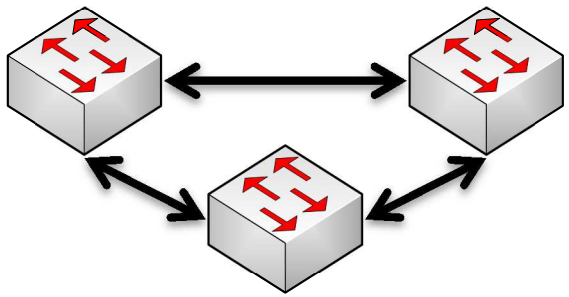
Management:

Accounting | Failure Detection | Traffic Engineering

Measurement:

Heavy Hitter detection | Change detection

Network:



High Level Contribution: Flexible Measurement

Management:

Users **dynamically instantiate** complex measurements on network state

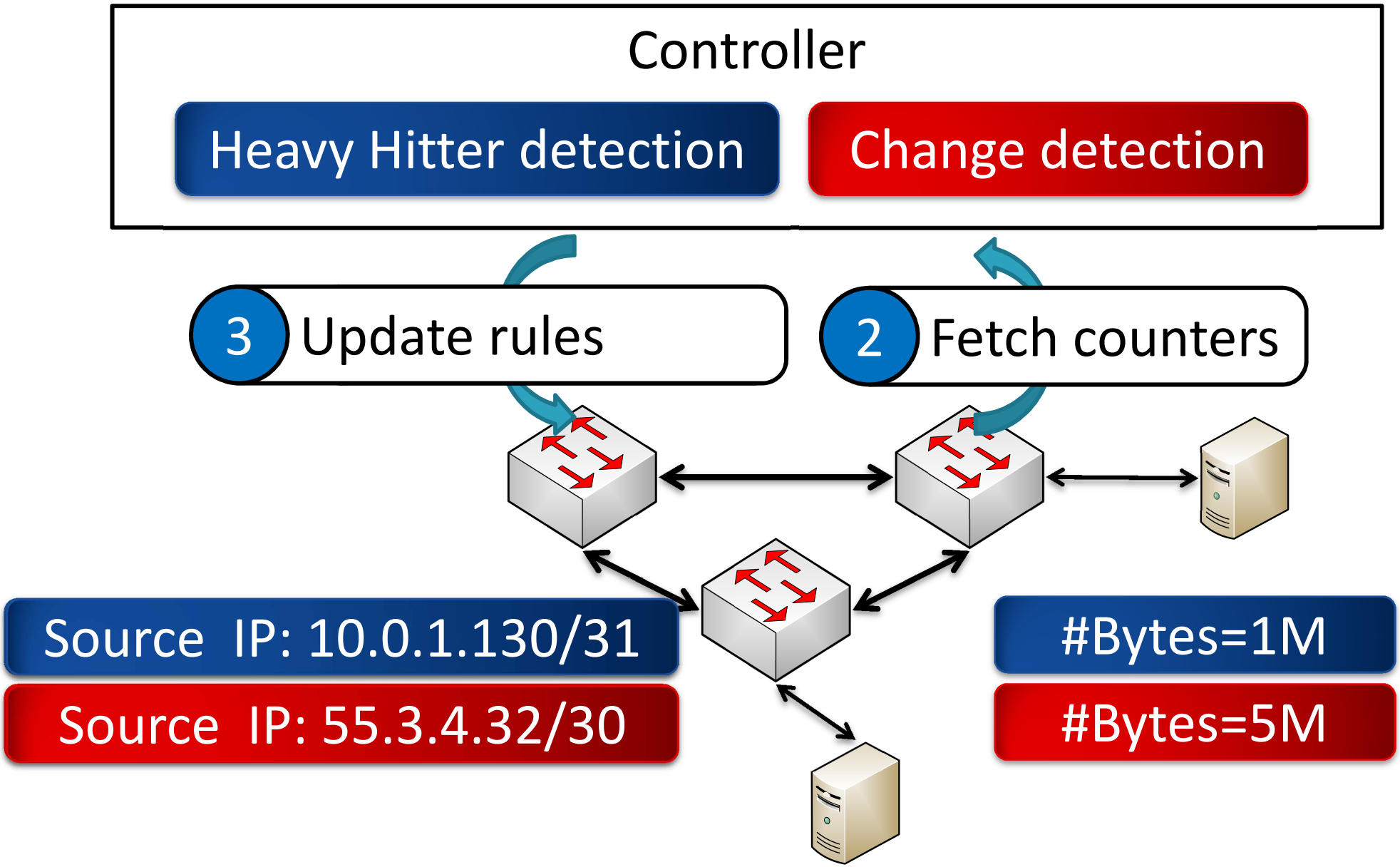
Measurement:

DREAM supports **the largest number** of measurement tasks while **maintaining measurement accuracy**, by dynamically leveraging tradeoffs between switch resource consumption and measurement accuracy

Network:

We leverage **unmodified hardware** and existing switch interfaces

Prior Work: Software Defined Measurement (SDM)



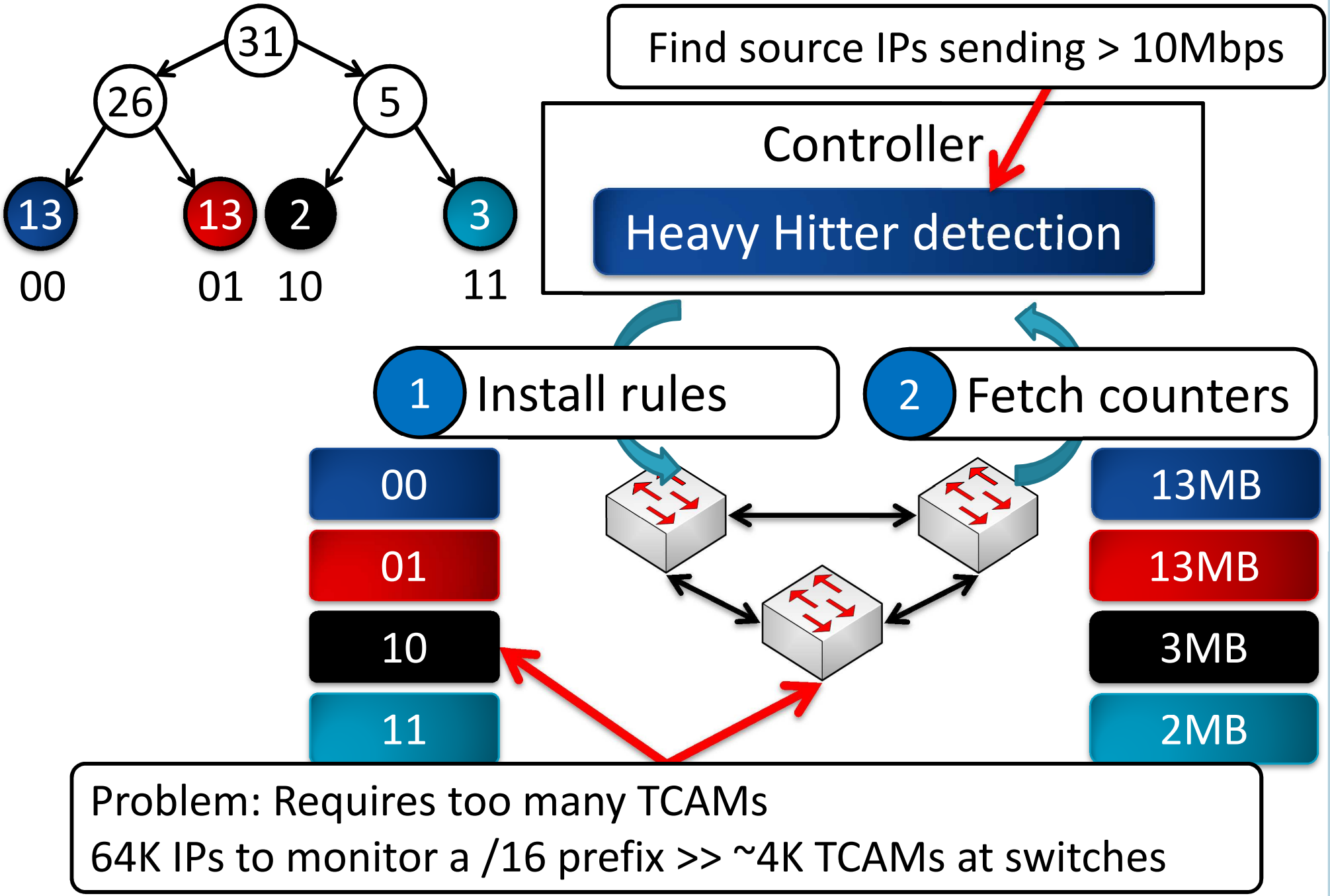
Our Focus: Measurement Using TCAMs

Existing OpenFlow switches use TCAMs which permit counting traffic for a prefix

Focus on TCAMs enables immediate deployability

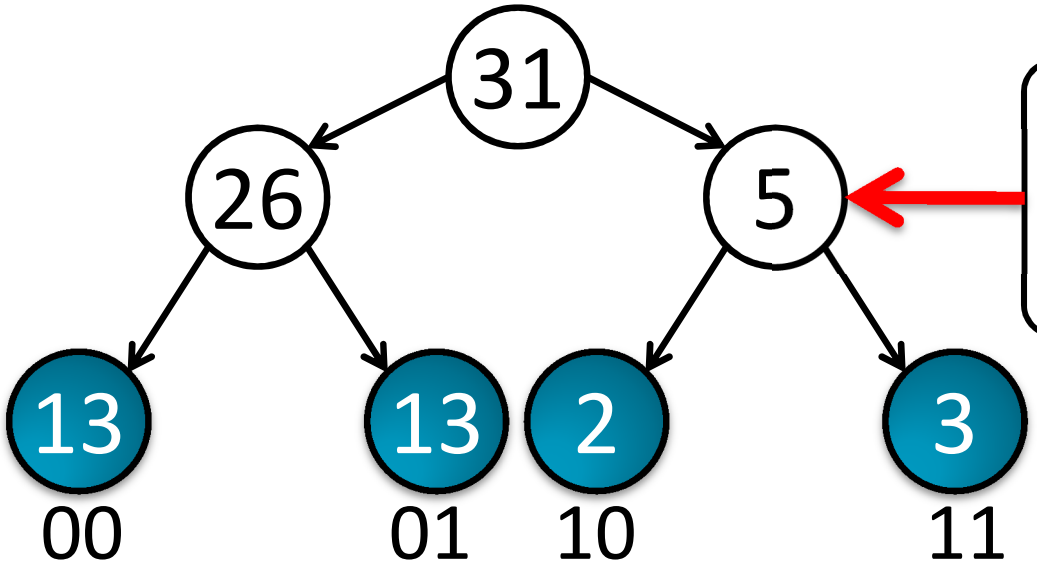
Prior work has explored other primitives such as hash-based counters

Challenge: Limited TCAM Memory

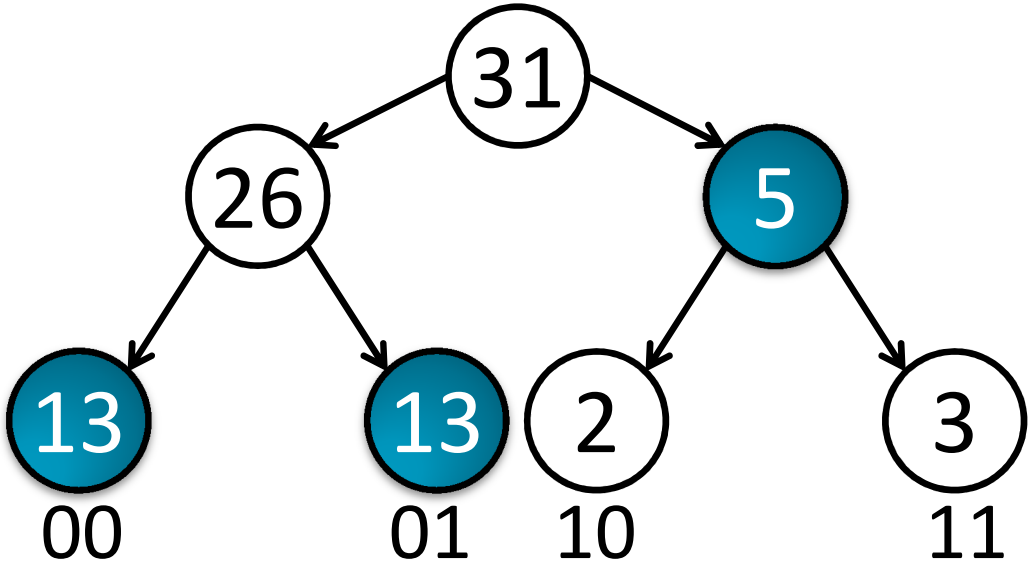


Reducing TCAM Usage

Monitor internal nodes to reduce TCAM usage

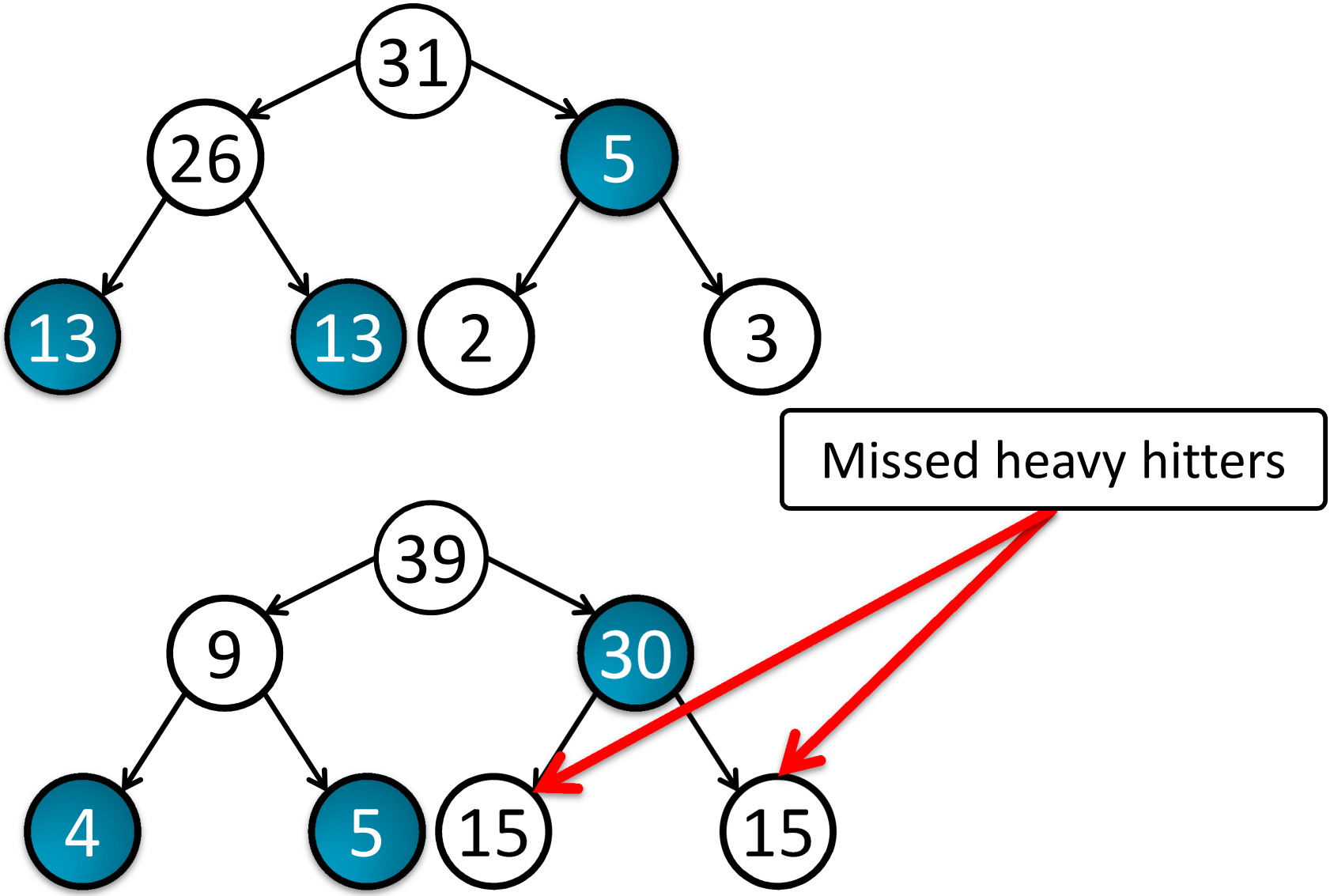


Monitoring 1* is enough because a node with size 5 cannot have leaves >10

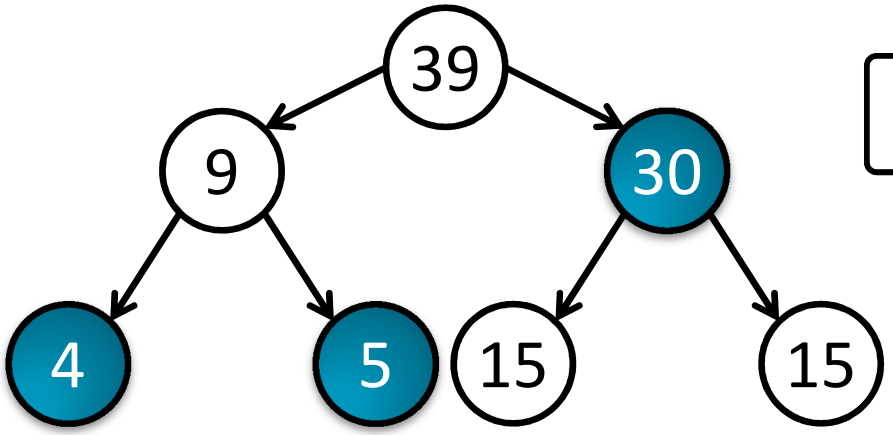


Challenge: Loss of Accuracy

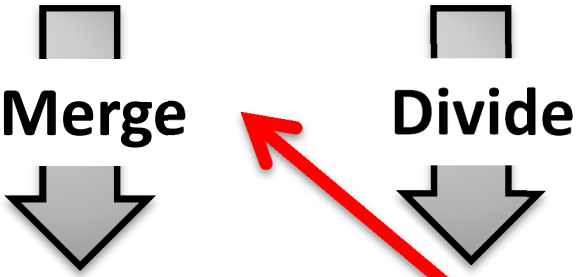
Fixed configuration misses heavy hitters as traffic changes



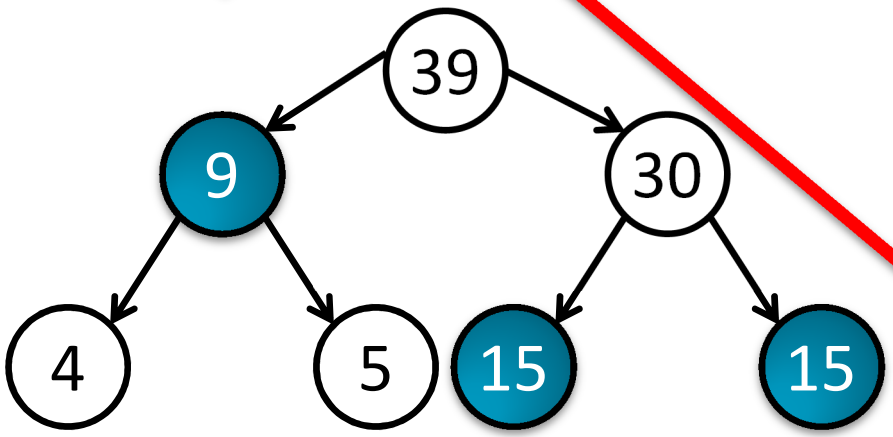
Dynamic Configuration to Avoid Loss of Accuracy



Find leaves >10Mbps using 3 TCAMs

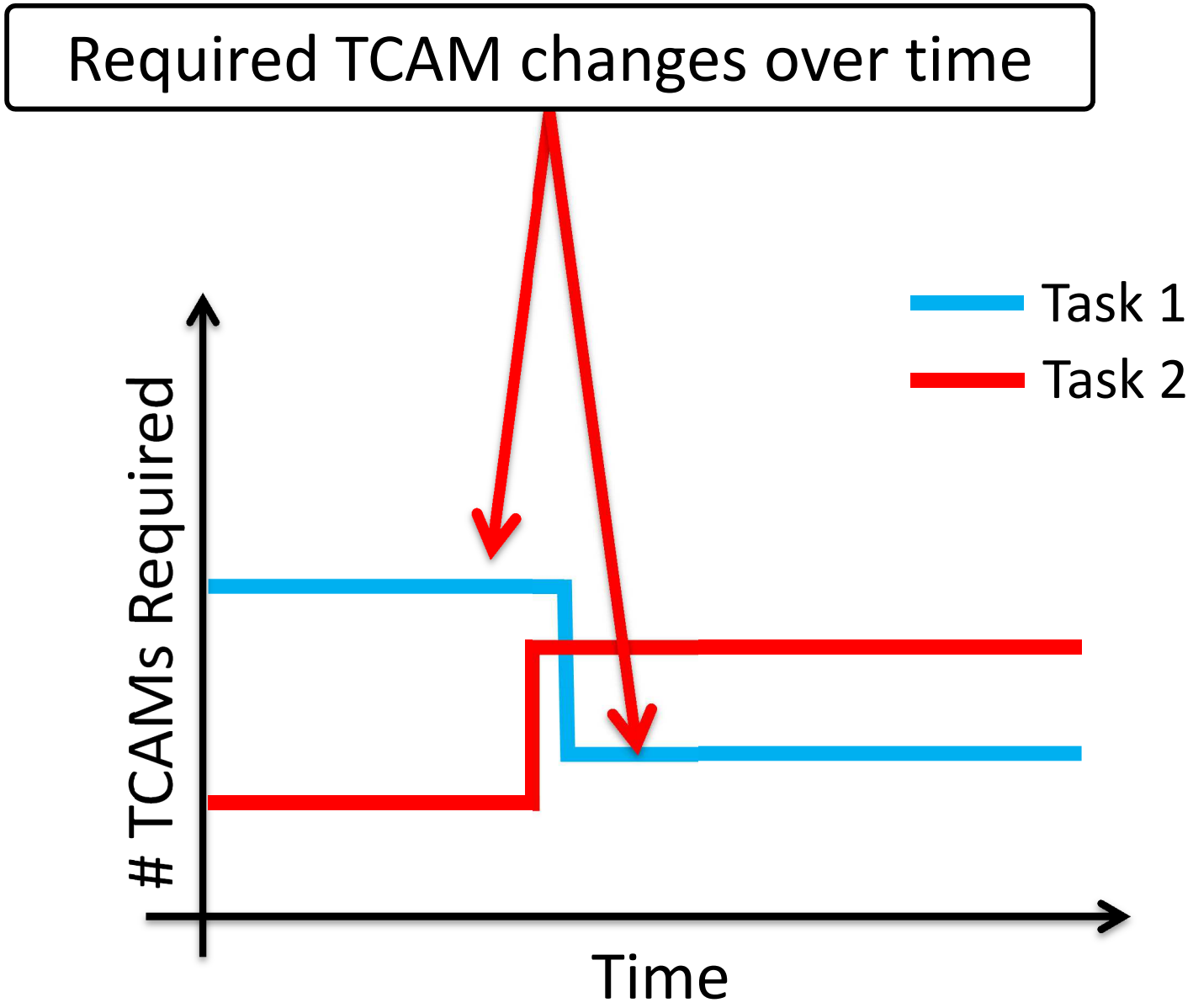


Monitor children to detect HHs but using 2 TCAMs

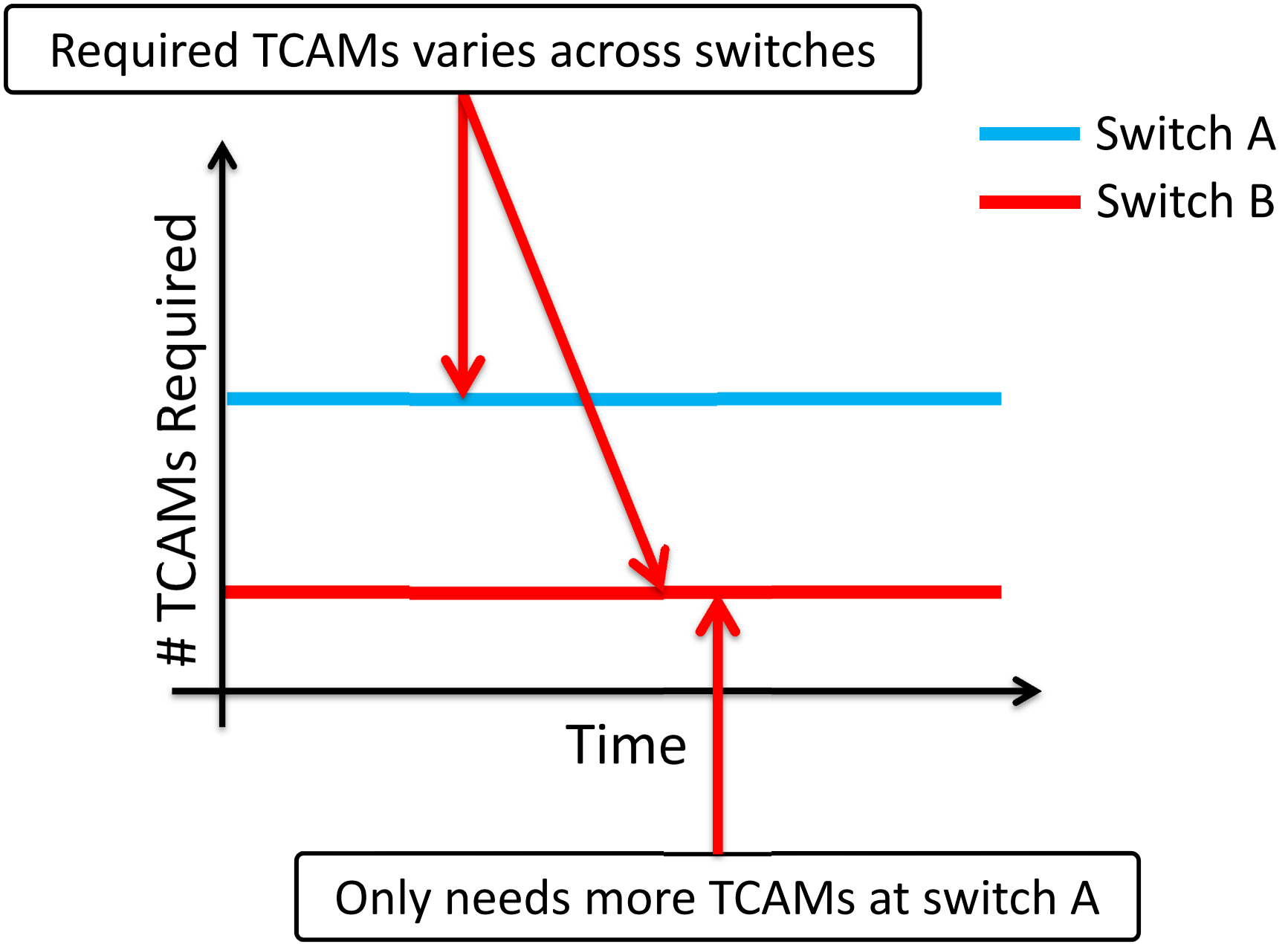


Monitor parent to save a TCAM

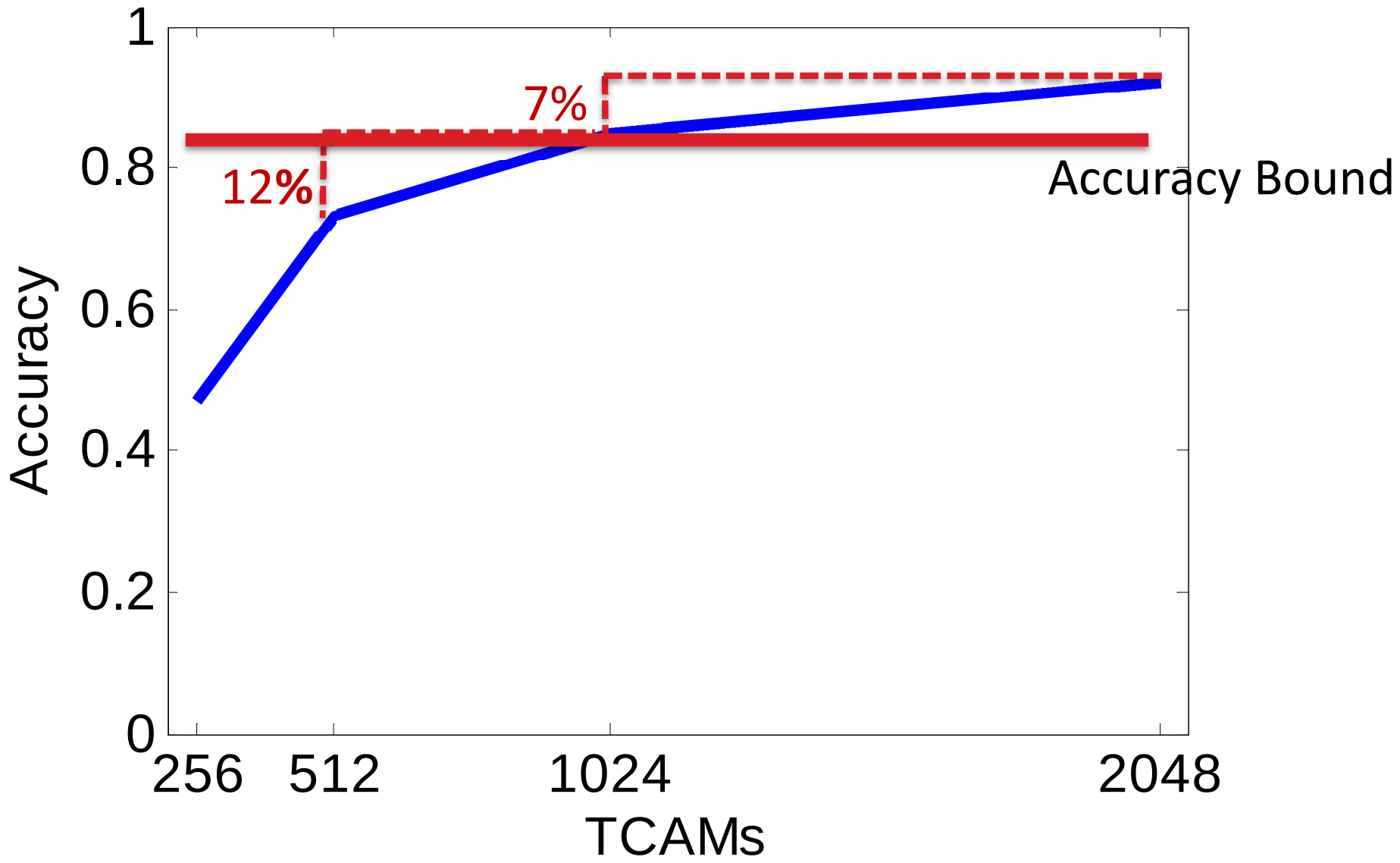
Reducing TCAM Usage: Temporal Multiplexing



Reducing TCAM Usage: Spatial Multiplexing



Reducing TCAM Usage: Diminishing Returns



Can accept an accuracy bound <100% to save TCAMs

Key Insight

Leverage **spatial and temporal multiplexing** and **diminishing returns**

to dynamically adapt the **configuration and allocation** of TCAM entries per task

to achieve **sufficient accuracy**

DREAM Contributions

System

Supports concurrent instances of three task types: Heavy Hitter, Hierarchical HH and Change Detection

Algorithm

Dynamically adapts tasks TCAM **allocations** and **configuration** over time and across **switches**, while maintaining **sufficient accuracy**

Evaluation

Significantly outperforms fixed allocation and scales well to larger networks

DREAM Tasks

Management

Anomaly detection

Traffic engineering

Network provisioning

Accounting

Network visualization

DDoS detection

Measurement

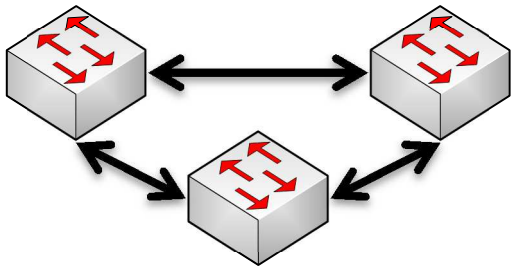
Heavy Hitter detection

Hierarchical HH detection

Change detection

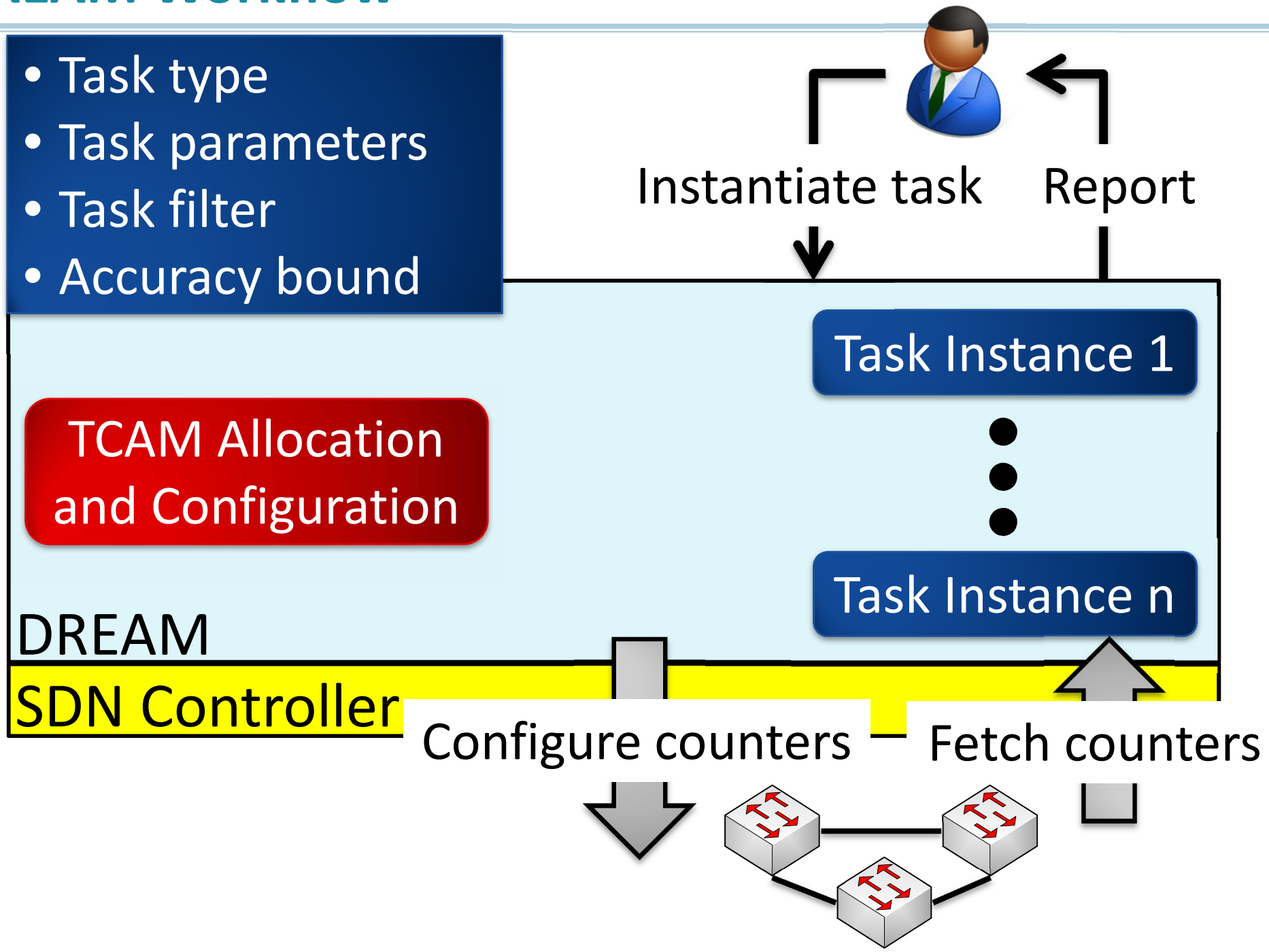
DREAM

Network



DREAM Workflow

- Task type
- Task parameters
- Task filter
- Accuracy bound



Algorithmic Challenges

Dynamically adapts tasks TCAM **allocations** and **configuration** over time and across **switches**, while maintaining **sufficient accuracy**

How to **allocate** TCAMs for **sufficient accuracy**?

Which **switches** to **allocate**?

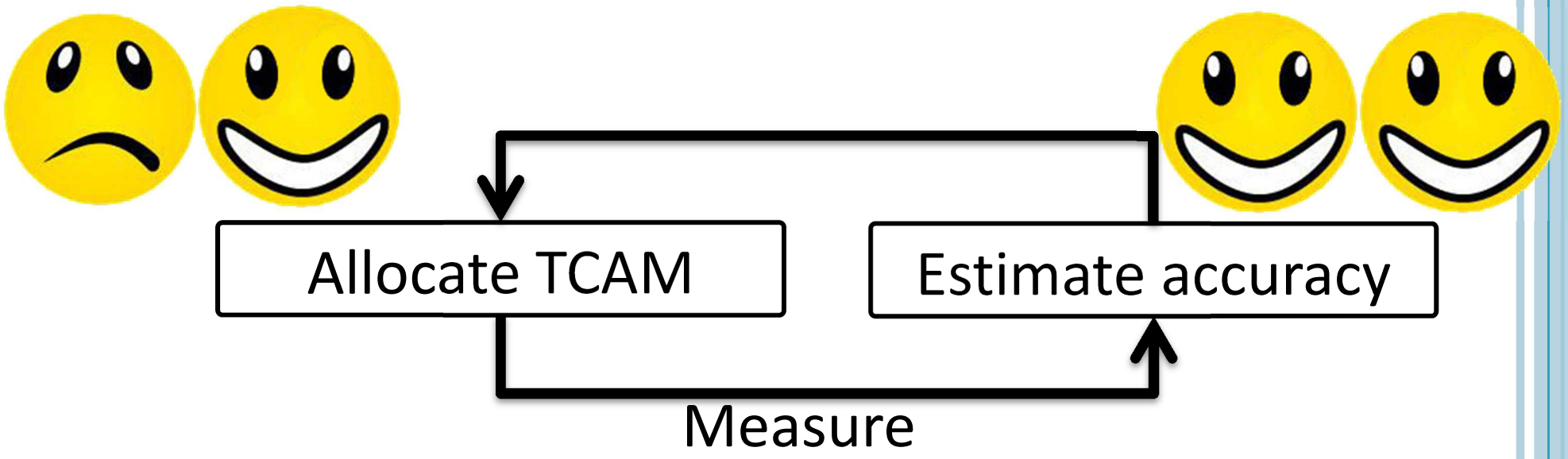
How to adapt TCAM **configuration** on multiple **switches**?

Diminishing Return

Temporal Multiplexing

Spatial Multiplexing

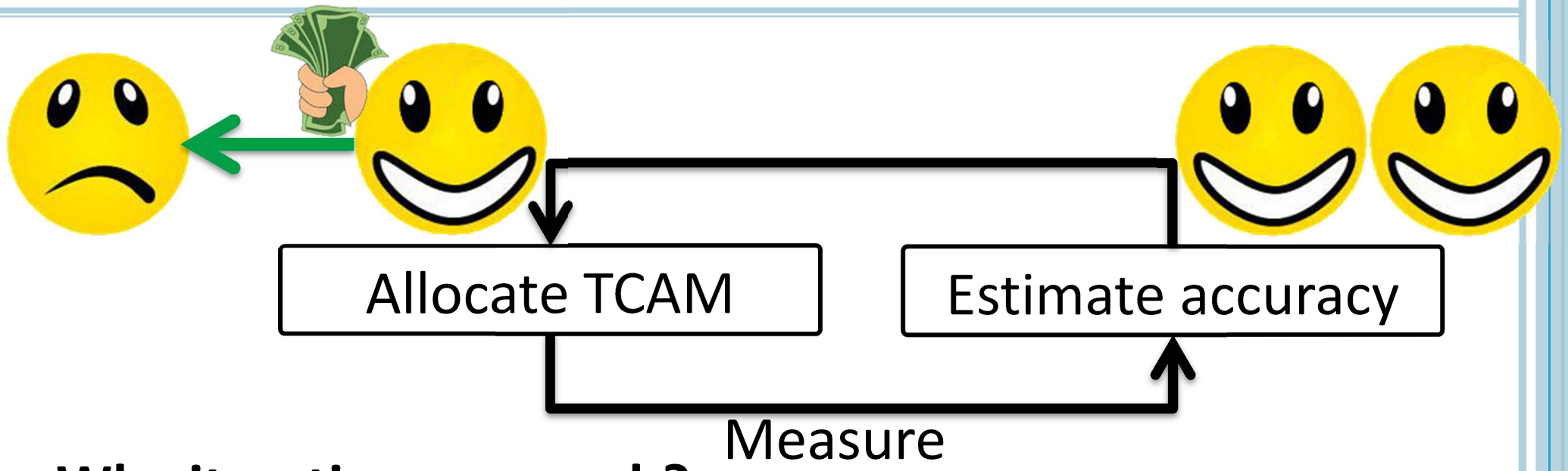
Dynamic TCAM Allocation



Enough TCAMs → High accuracy → Satisfied

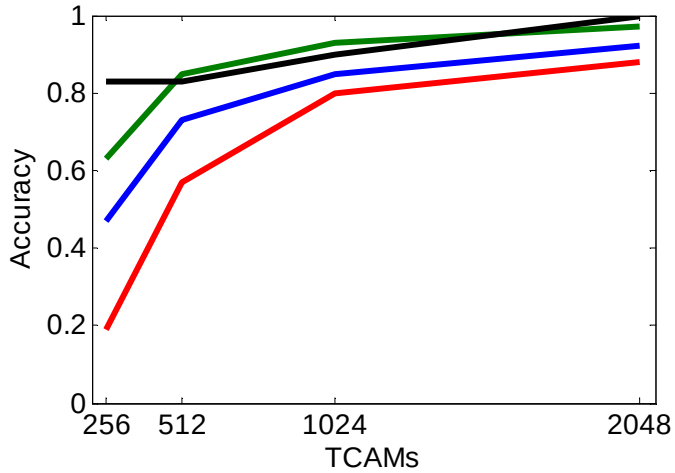
Not enough TCAMs → Low accuracy → Unsatisfied

Dynamic TCAM Allocation

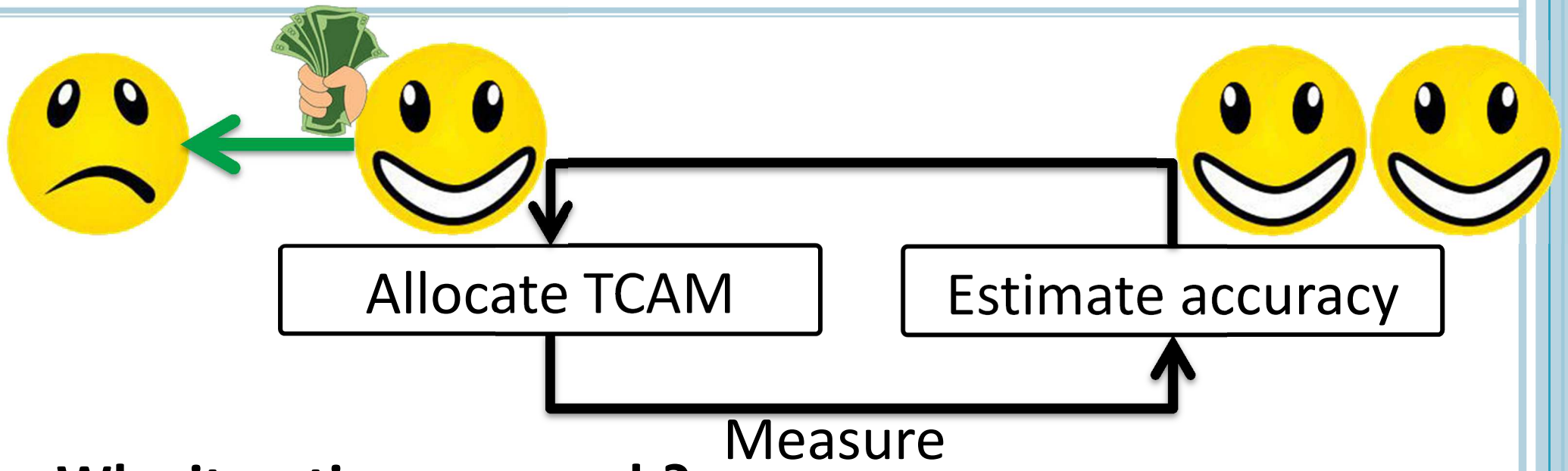


Why iterative approach?

We cannot know the curve for every traffic and task instance
Thus we cannot formulate a one-shot optimization



Dynamic TCAM Allocation



Why iterative approach?

We cannot know the curve for every traffic and task instance
Thus we cannot formulate a one-shot optimization

Why estimating accuracy?

We don't have ground-truth
Thus we must estimate accuracy

Estimate Accuracy: Heavy Hitter Detection

$$\text{Precision} = \frac{\text{True detected HH}}{\text{Detected HHs}}$$

Is 1 because any detected HH is a true HH

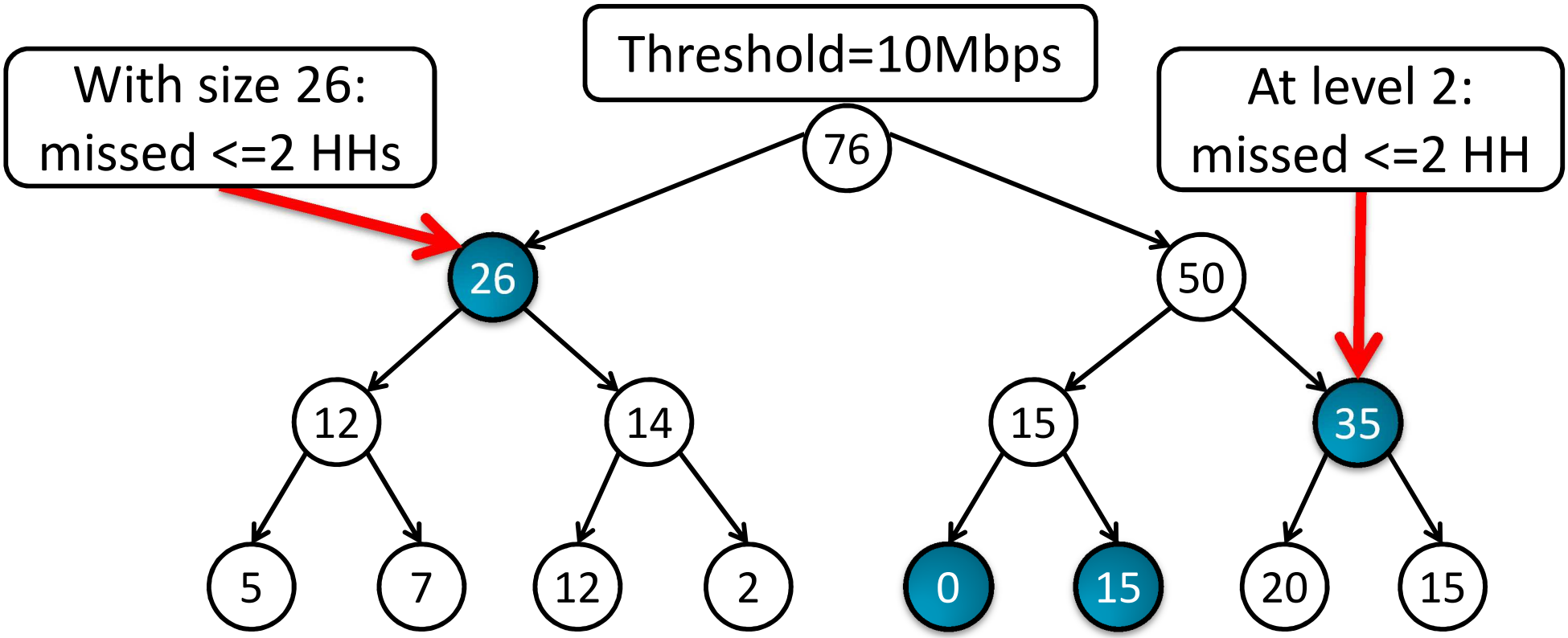
$$\text{Recall} = \frac{\text{True detected HH}}{\text{True detected + Missed HHs}}$$

Estimate missed HHs

Estimate Recall for Heavy Hitter Detection

$$\text{Recall} = \frac{\text{True detected HH}}{\text{True detected + Missed HHs}}$$

Find an upper bound of missed HHs using size and level of internal nodes



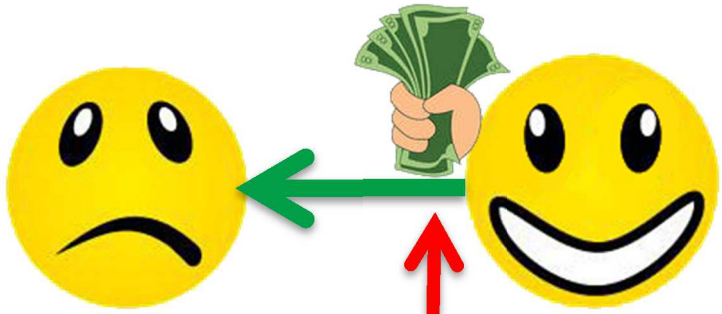
Allocate TCAM

Goal: maintain high task *satisfaction*

Fraction of task's lifetime with sufficient accuracy

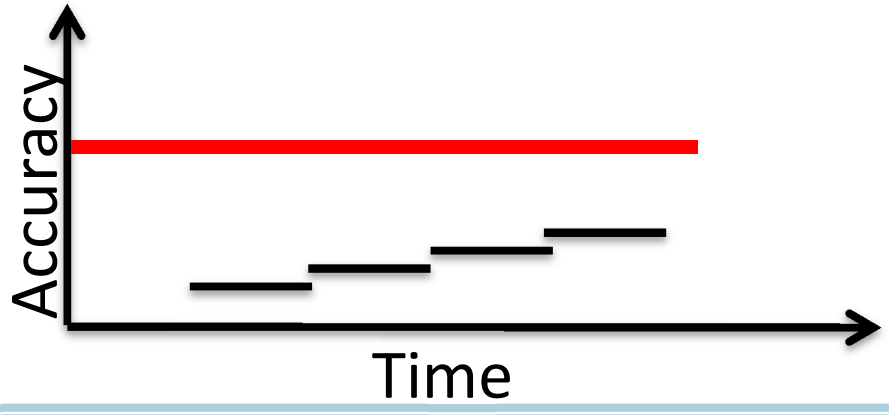
Allocate TCAM

Goal: maintain high task *satisfaction*

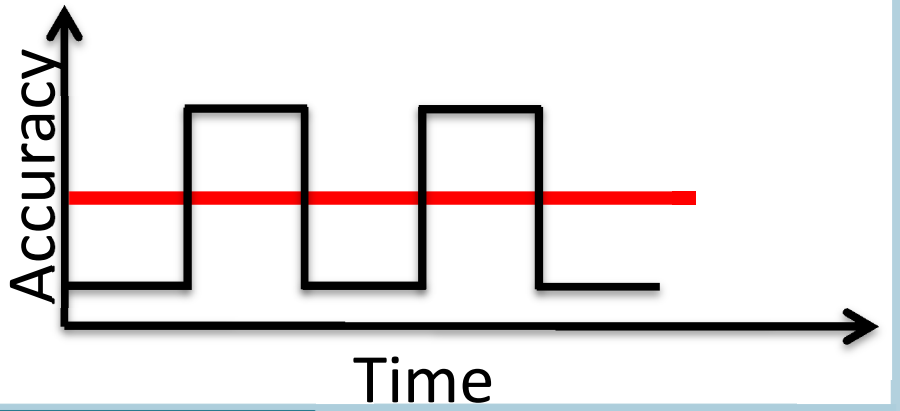


How many TCAMs to exchange?

Small → Slow convergence



Large → Oscillations



Avoid Overloading

Not enough TCAMs to satisfy all tasks

Solutions

Reject new tasks

Drop existing tasks

Algorithmic Challenges

Dynamically adapts tasks TCAM **allocations** and **configuration** over time and across **switches**, while maintaining **sufficient accuracy**

How to **allocate** TCAMs for **sufficient accuracy**?

Which **switches** to **allocate**?

How to adapt TCAM **configuration** on multiple **switches**?

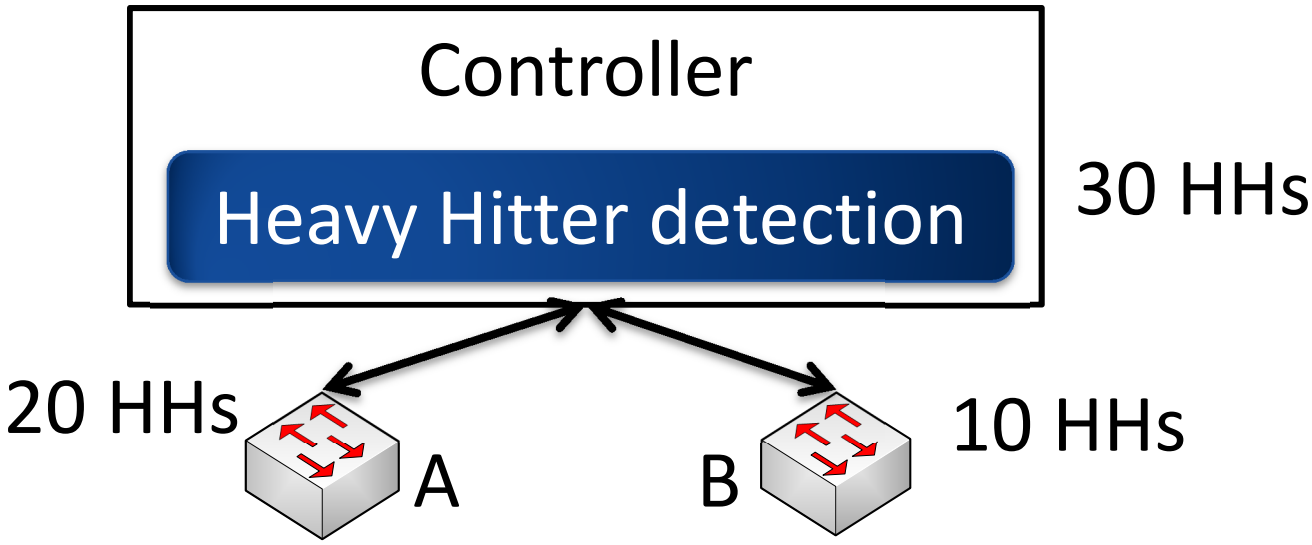
Diminishing Returns

Temporal Multiplexing

Spatial Multiplexing

Allocate TCAM: Multiple Switches

A task can have traffic from multiple switches



Allocate TCAM: Multiple Switches

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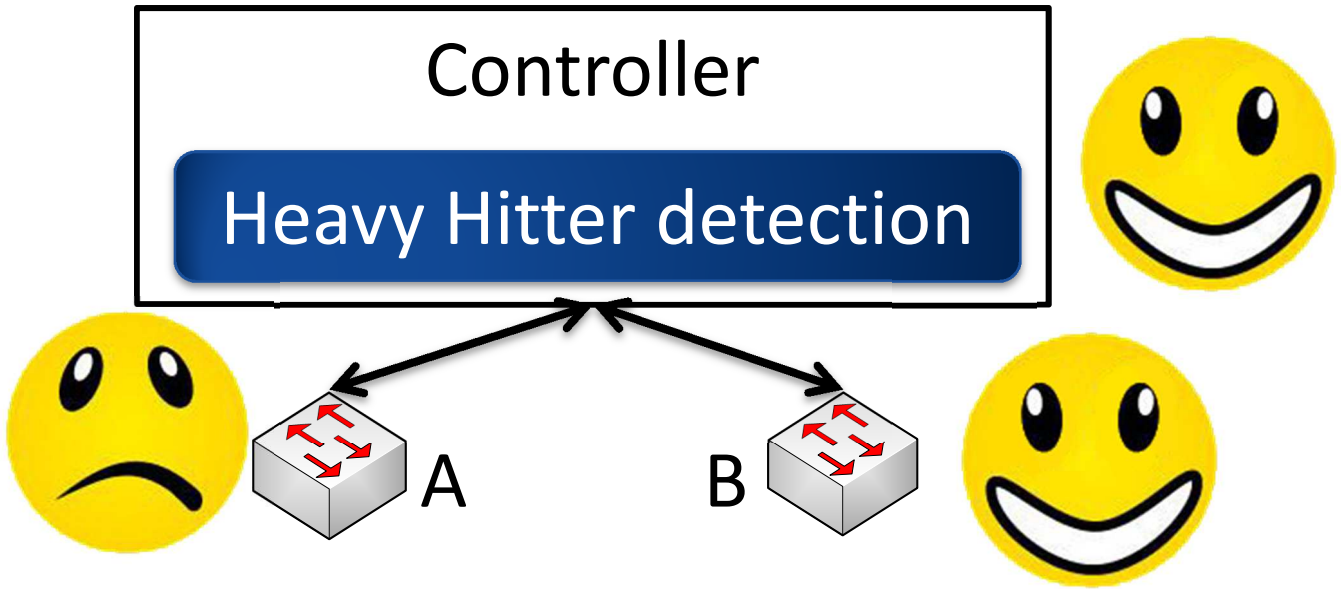
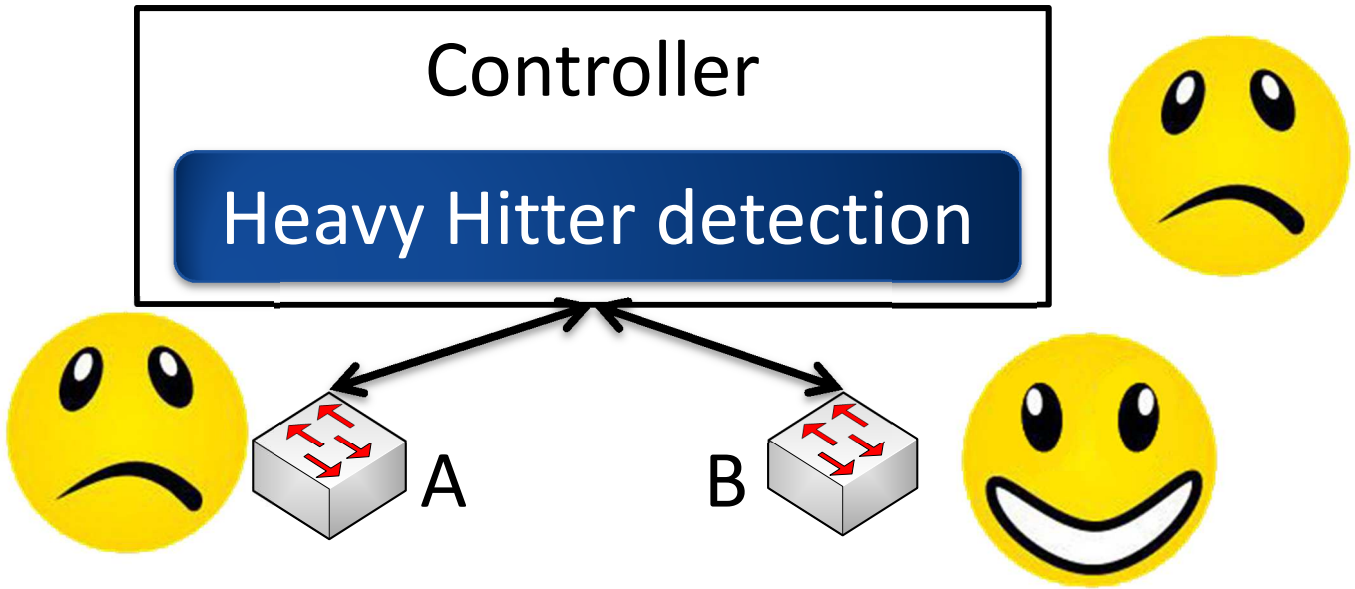


Global accuracy is important

If a task is globally satisfied, no need to increase A's TCAMs

Allocate TCAM: Multiple Switches

A task can have traffic from multiple switches

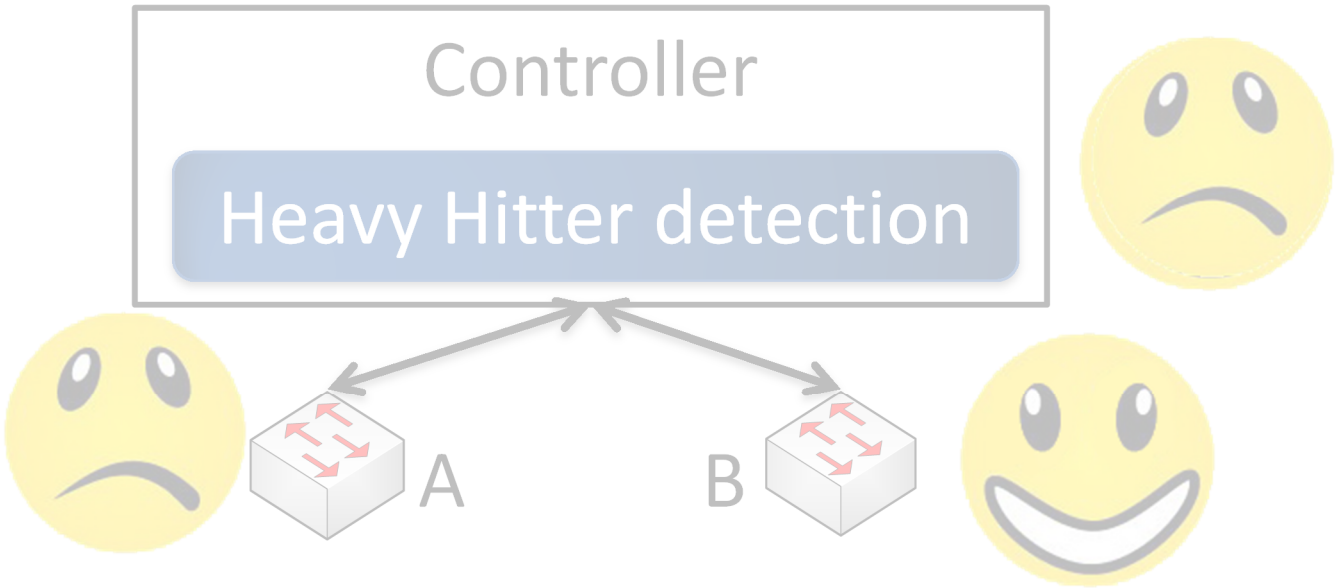


Local accuracy is important

If a task is globally unsatisfied, increasing B's TCAMs is expensive (diminishing returns)

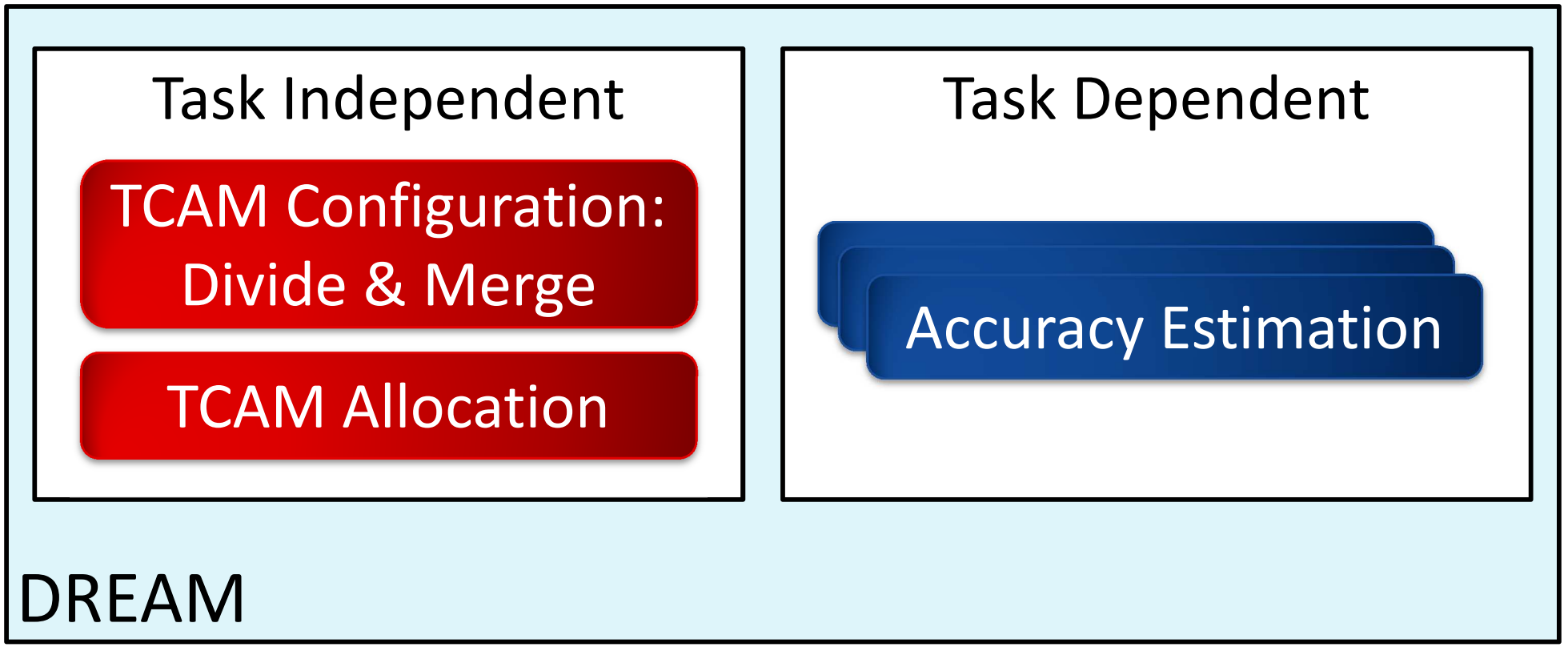
Allocate TCAM: Multiple Switches

A task can have traffic from multiple switches



Use both local and global accuracy

DREAM Modularity



Evaluation: Accuracy and Overhead

Accuracy

Satisfaction of a task: Fraction of task's lifetime with sufficient accuracy

% of rejected/dropped tasks

Overhead

How fast is the DREAM control loop?

Evaluation: Alternatives

Equal: divide TCAMs equally at each switch, no reject

Fixed: fixed fraction of TCAMs, reject extra tasks

Evaluation Setting

Prototype on 8 Open vSwitches

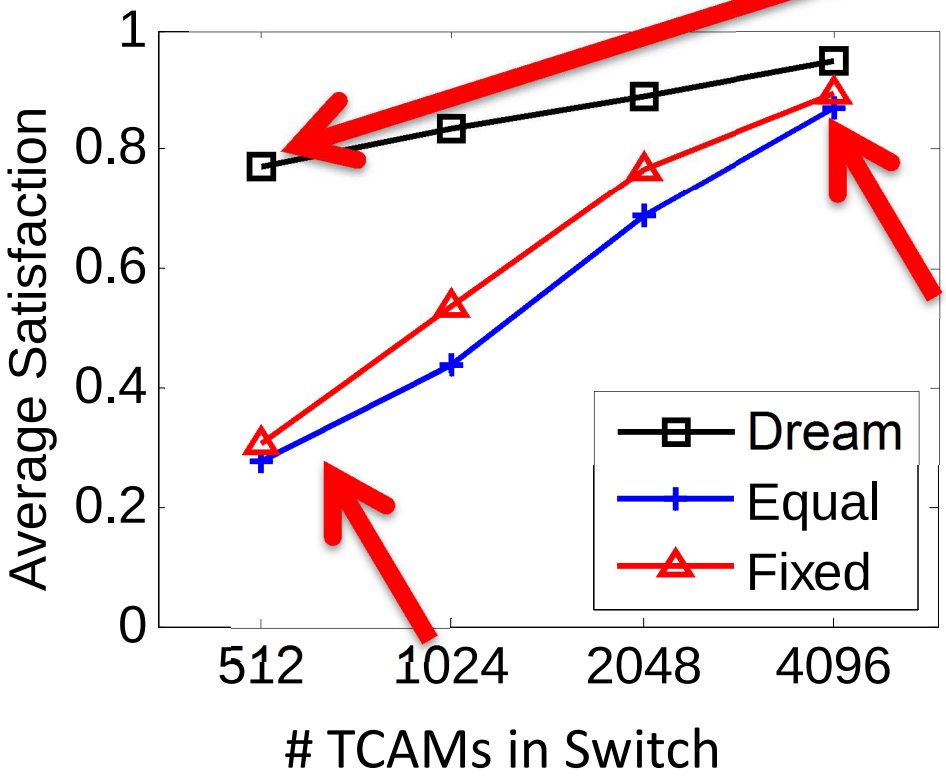
- 256 tasks (HH, HHH, CD, combination)
- 5 min tasks arriving in 20 mins
- Accuracy bound=80%
- 5 hours CAIDA trace
- Validate simulator using prototype

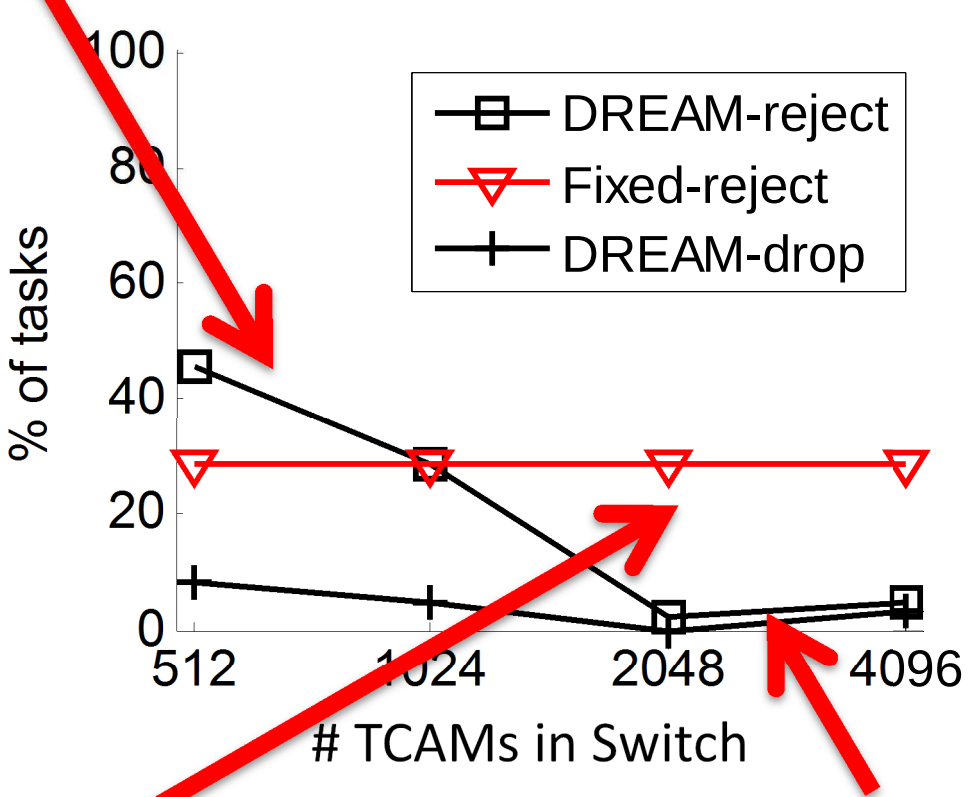
Large scale simulation (4096 tasks on 32 switches)

- accuracy bounds
- task loads (arrival rate, duration, switch size)
- tasks (task types, task parameters e.g., threshold)
- # switches per tasks

Prototype Results: Average Satisfaction

DREAM: High satisfaction of tasks
at the expense of more rejection for small switches

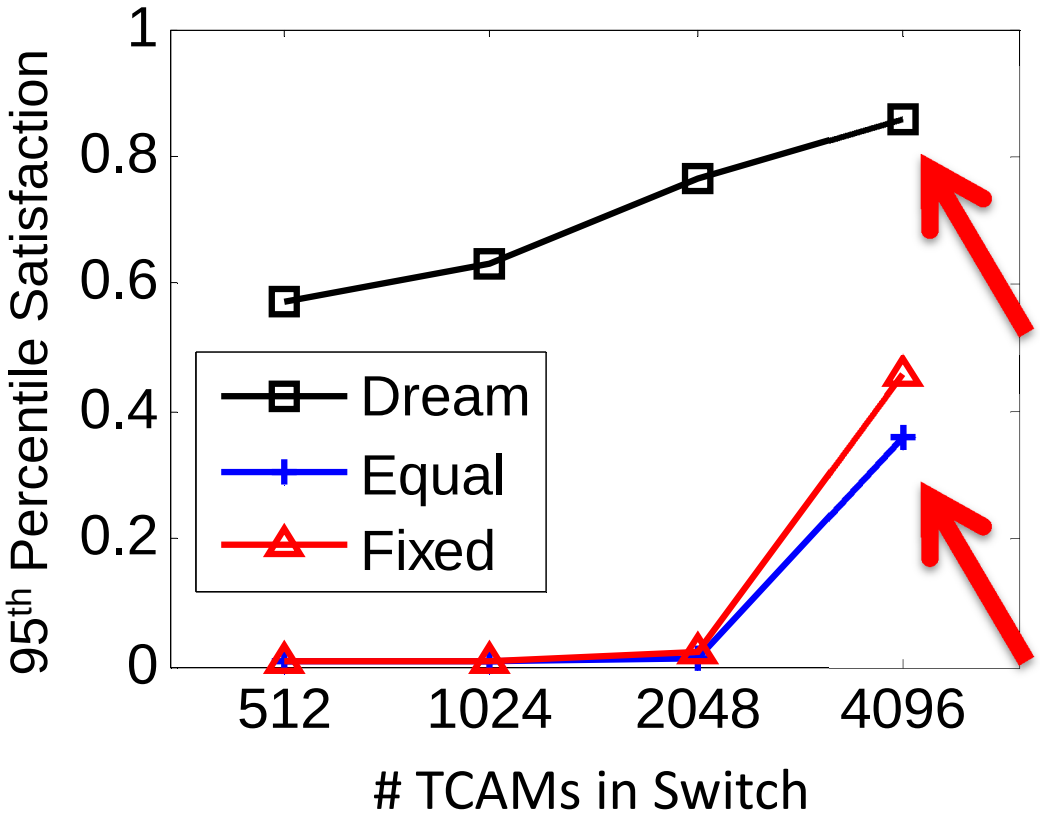




Fixed: High rejection as over-provisions for small tasks

Prototype Results: 95th Percentile Satisfaction

DREAM: High 95th percentile satisfaction



Equal and Fixed only keep small tasks satisfied

Conclusion

Measurement is crucial for SDN management in a resource-constrained environment

Dynamic TCAM allocation across measurement tasks

- Diminishing returns in accuracy
- Spatial and temporal multiplexing

Future work

- More TCAM-based measurement tasks (quintiles for load balancing, entropy detection)
- Hash-based measurements

DREAM is available at

github.com/USC-NSL/DREAM