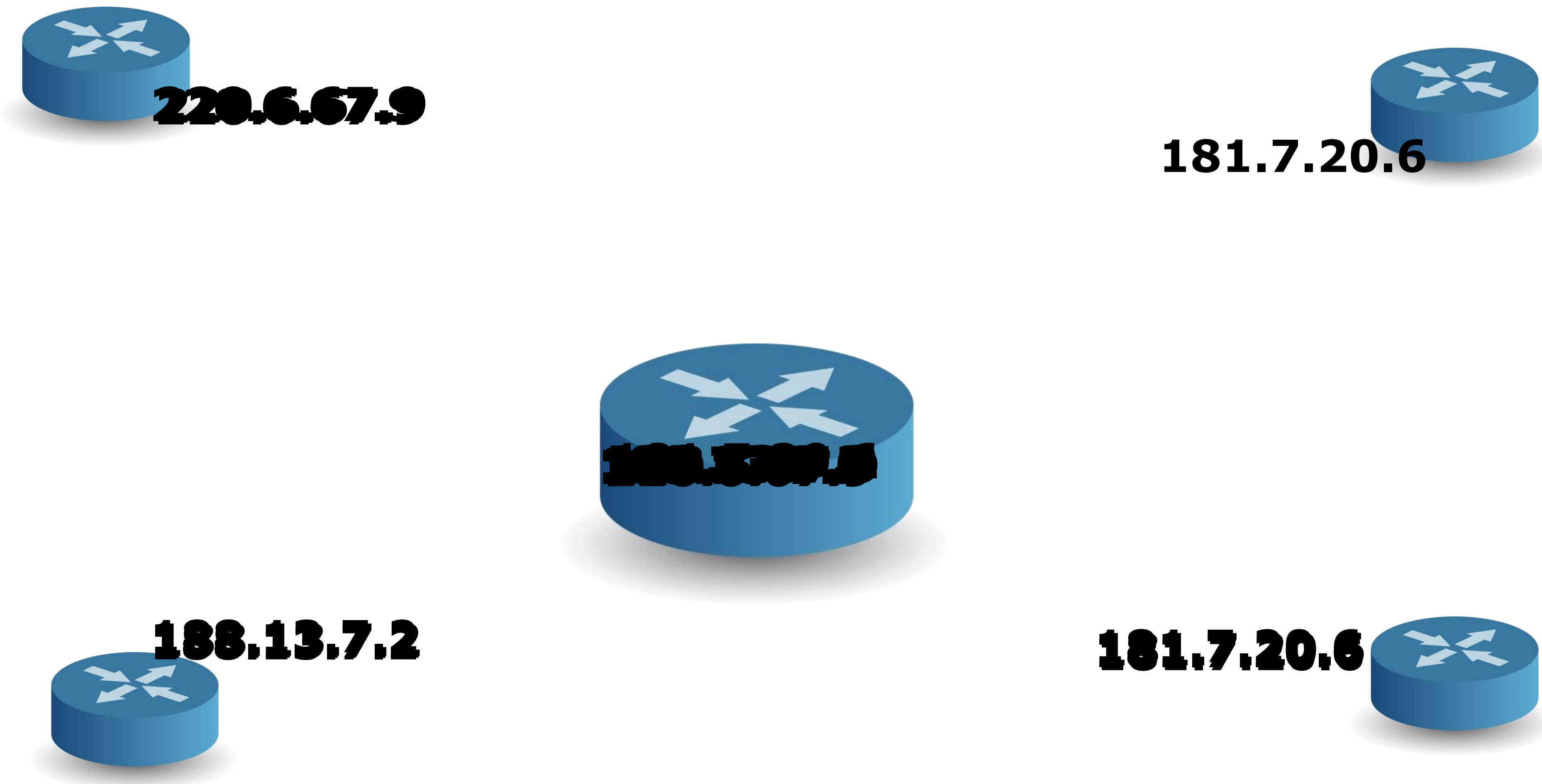
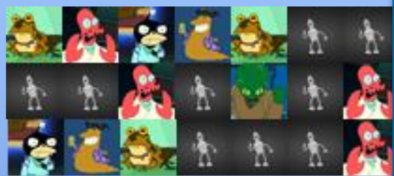



Network Measurements



Network Measurements



Elephant Flov

Load Balancing
Traffic Engineer
C

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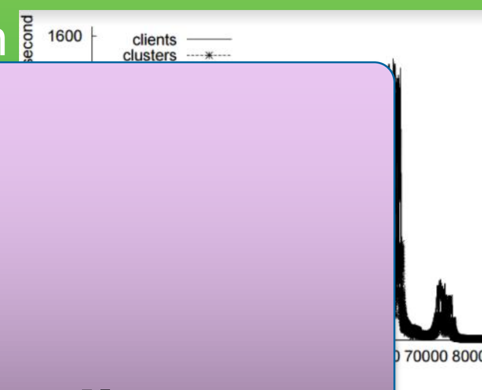
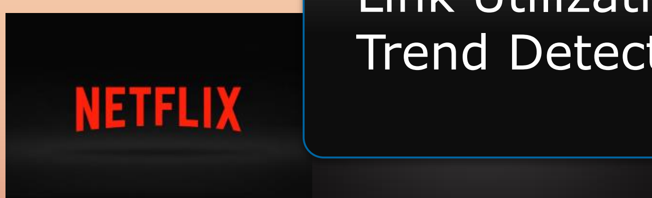
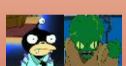


Averaging over Sliding Windows

Link Utilization
Trend Detection



Estimating the fraction of rare flows

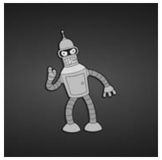


Customer Satisfaction
DDoS Detection

Computing Quantiles

Data Log Analysis
Network Health Monitoring

Frequency Estimation

- How many packets has  sent?

Classic Setting:

Can’t allocate a counter for each flow!

In software:

Memory is cheap (to an extent)

Speed is the new bottleneck

Agenda

- **Classical Frequency Estimation Algorithms.**
- Accelerating space-oriented algorithms.
- Hierarchical Heavy Hitters.

Count Min Sketch (Cormode and Muthukrishnan)

$$\frac{2}{\epsilon}\ counters$$

0	0	0	0	0	0	0	0	0	0	0	1	1
0	0	0	0	1	0	0	0	1	0	0	0	0
0	0	0	0	0	0	0	0	0	0	0	2	0
0	0	0	0	0	1	0	0	0	0	1	0	0
0	1	0	0	0	0	1	0	0	0	0	0	0

$\log \delta^{-1}\ Rows$

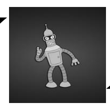
$E[Noise] \leq N\epsilon/2$

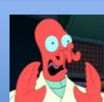
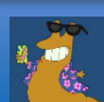
$\Pr[Noise > N\epsilon] \leq 1/2$

Query()= 2

Overall $\Pr[Noise > N\epsilon] \leq \delta$

Space Saving (Metwally et al.)

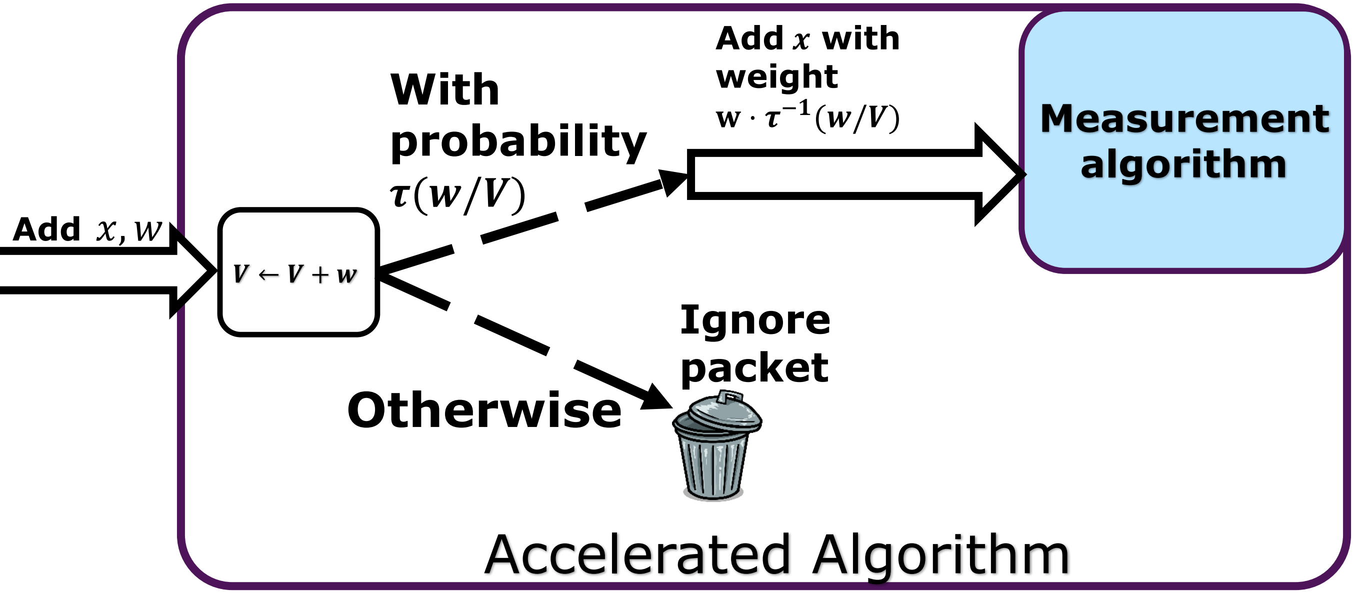
- For a N-sized stream, when allocated with *m* counters, Space Saving guarantees:
  - $Query($$)$ returns 3
  - $f_x \le Query(x) \le f_x + \frac{N}{m}$
  - $Query\ ($$)$ returns 2
- For achieving an $N\epsilon$ approximation, $\lceil 1/\epsilon \rceil$ counters are needed.

ID	Value
	[illegible]
	[illegible]

Agenda

- Classical Frequency Estimation Algorithms.
- **Accelerating space-oriented algorithms.**
- Hierarchical Heavy Hitters.

Accelerating Measurements Algorithms

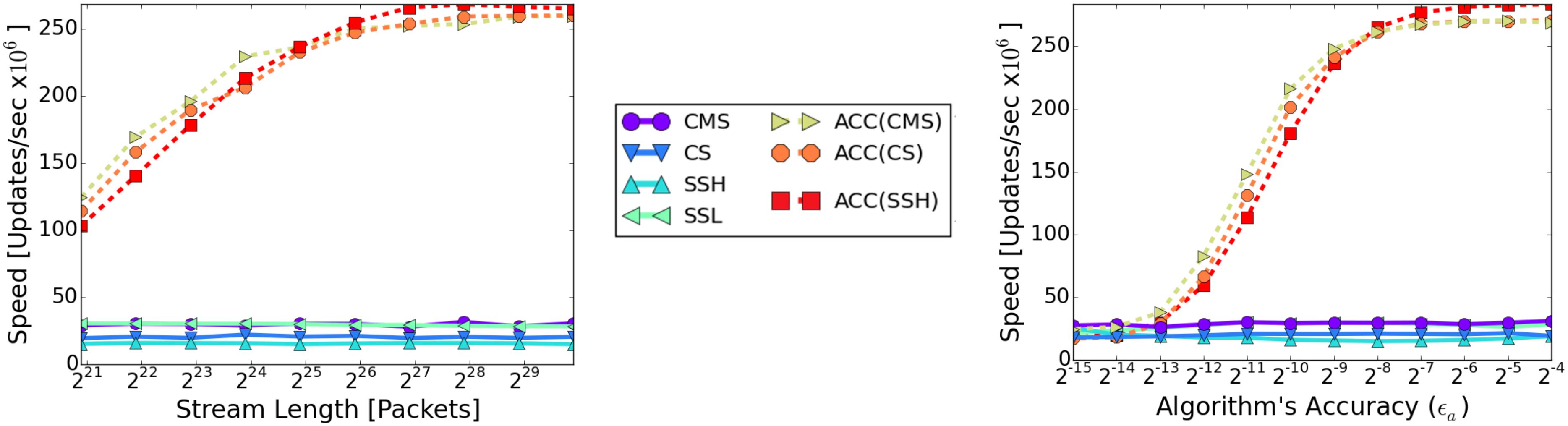


Start with a N sized stream and a (ϵ, δ) measurement algorithm.

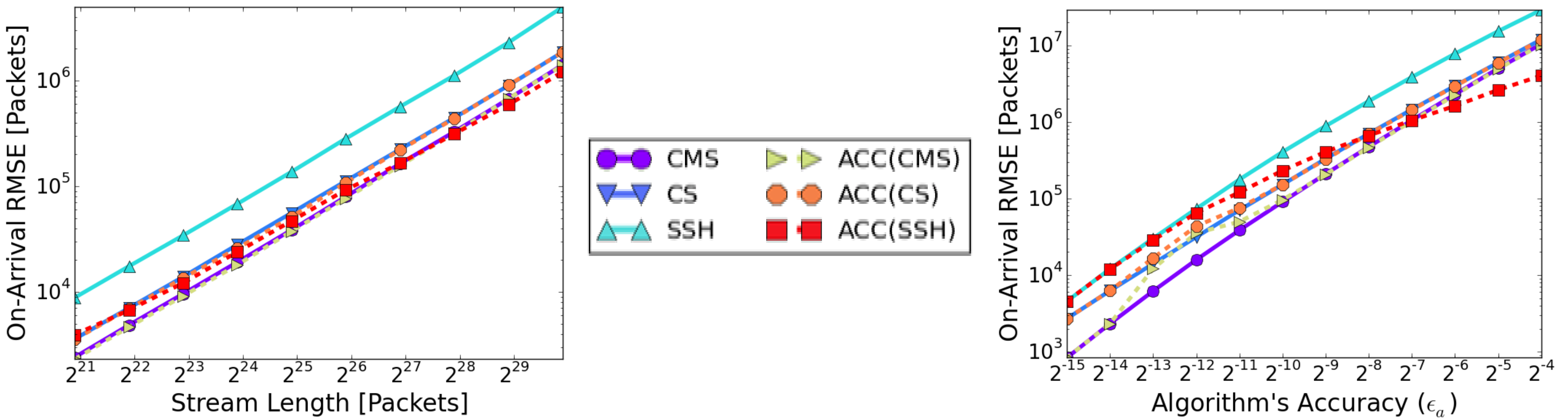
Get an $O(\log N \cdot \epsilon^{-2} \log \delta)$ sized stream and a $(2\epsilon, 3\delta)$ measurement algorithm.

- We can iteratively accelerate ourselves!

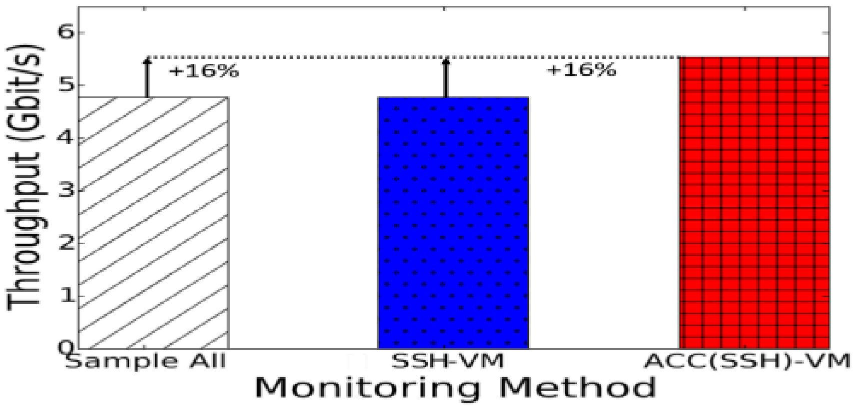
Empirical Evaluation



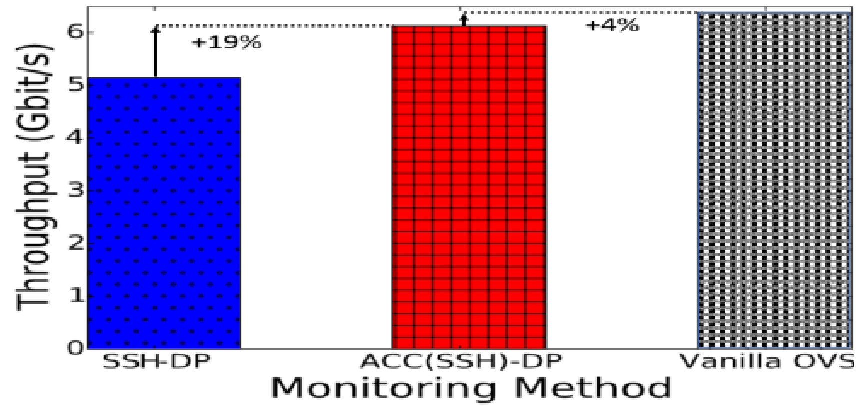
Empirical Evaluation



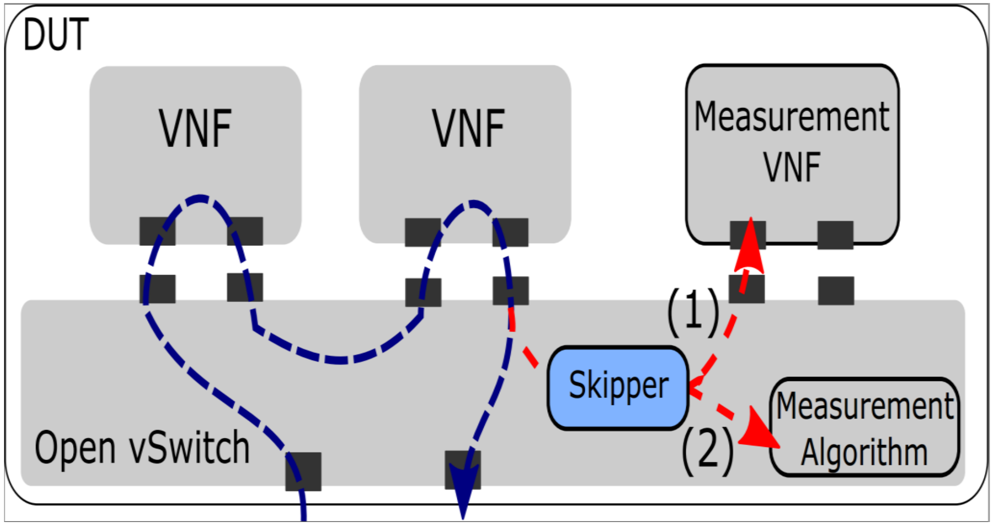
Distributed SDN Implementation



(a) VM implementation



(b) Dataplane implementation



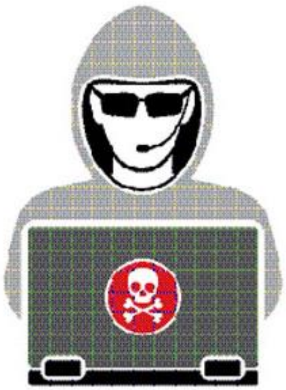
Agenda

- Classical Frequency Estimation Algorithms.

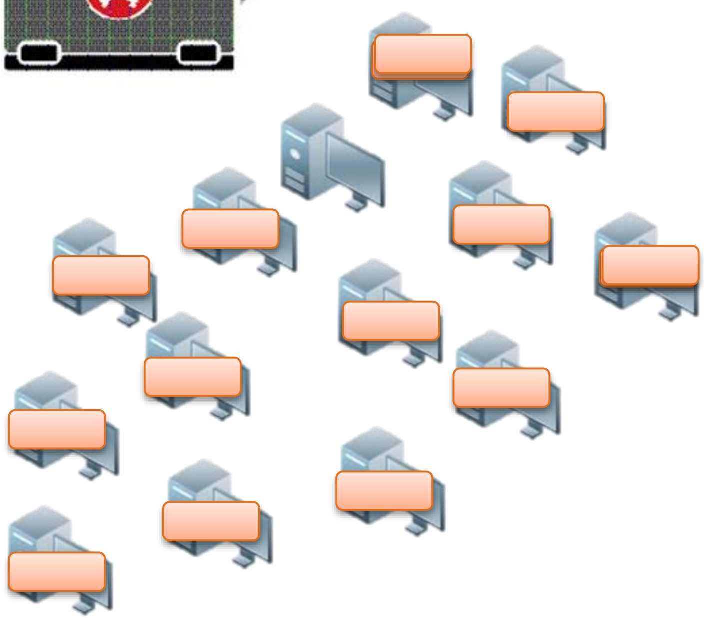
- Accelerating space-oriented algorithms.

- **Hierarchical Heavy Hitters.**

Hierarchical Heavy Hitters



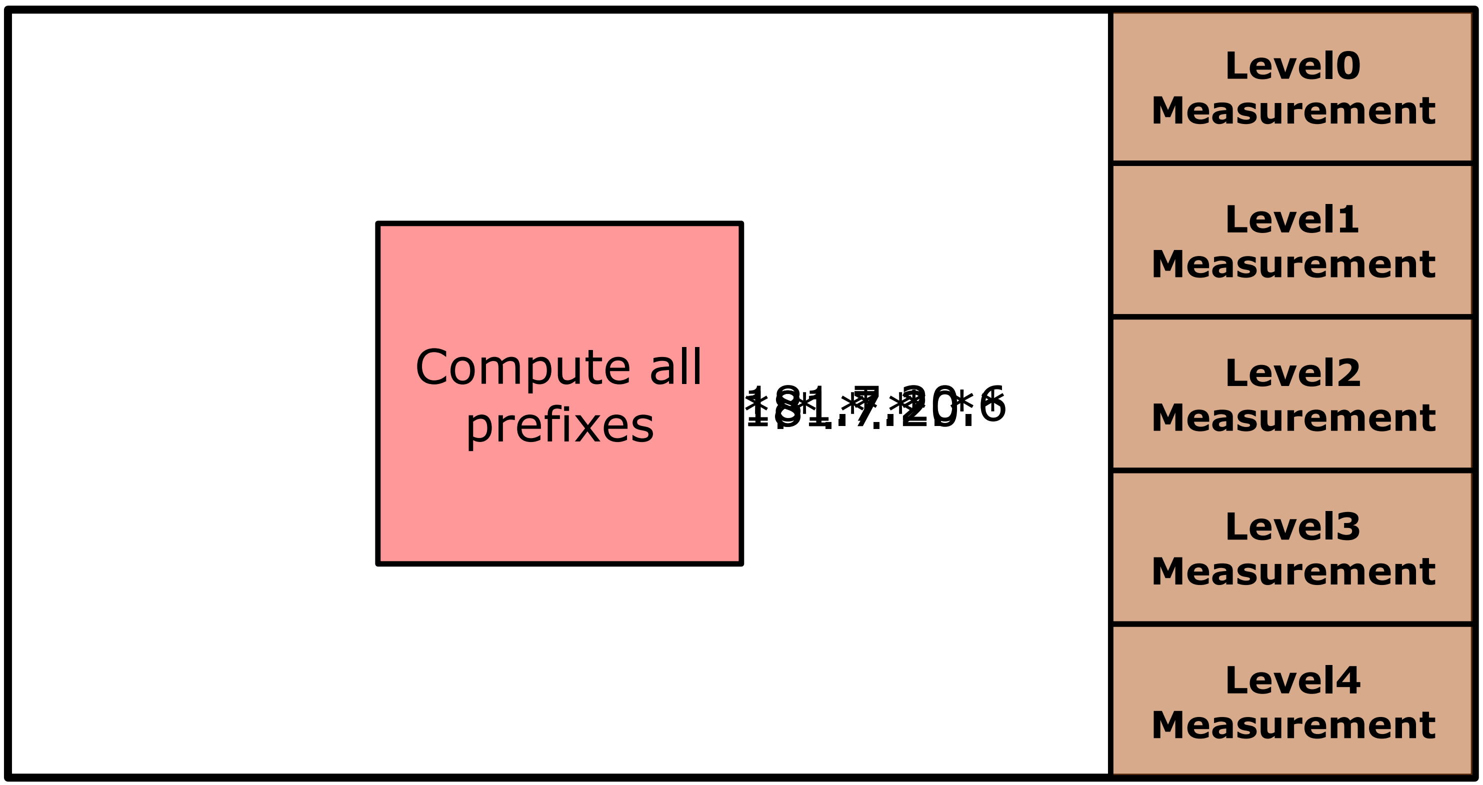
181.7.20.1
181.7.20.2
…
181.7.21.1
181.7.21.2
…



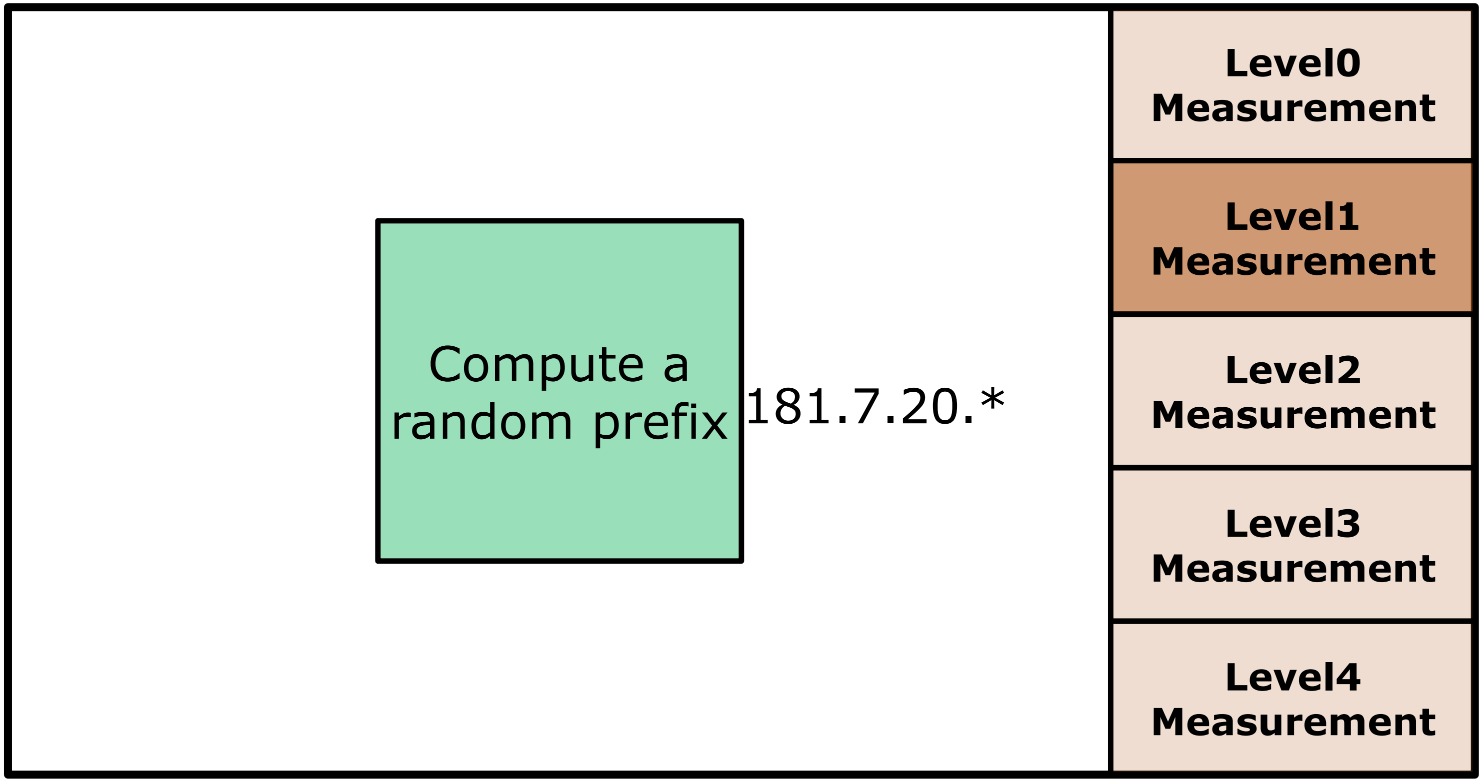
Can we block only the attacking devices?

Multi-Dimensional Hierarchies

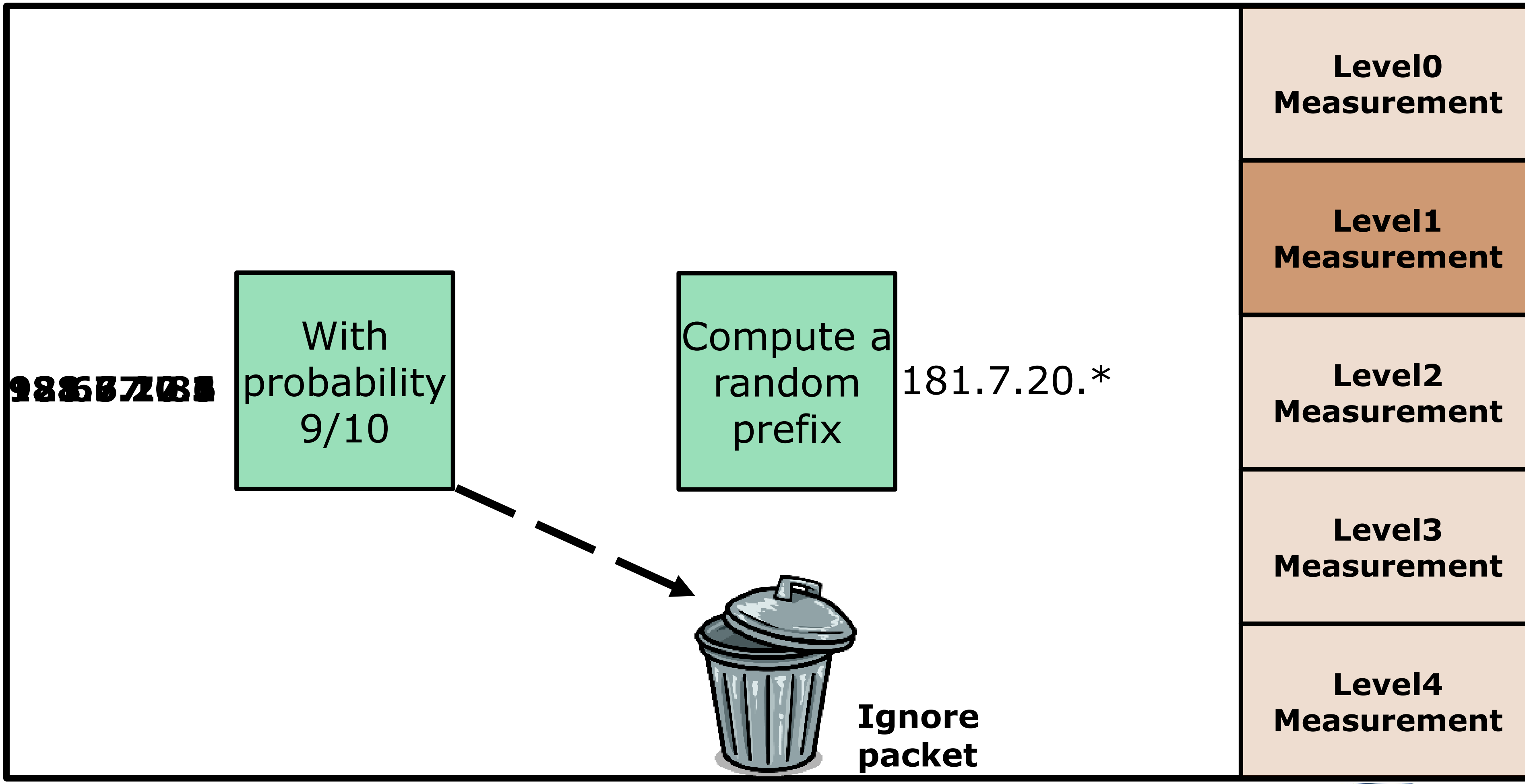
Hierarchical Heavy Hitters using Space Saving (Mitzenmacher et al.)



Constant Time Hierarchical Heavy Hitters (SIGCOMM2017)



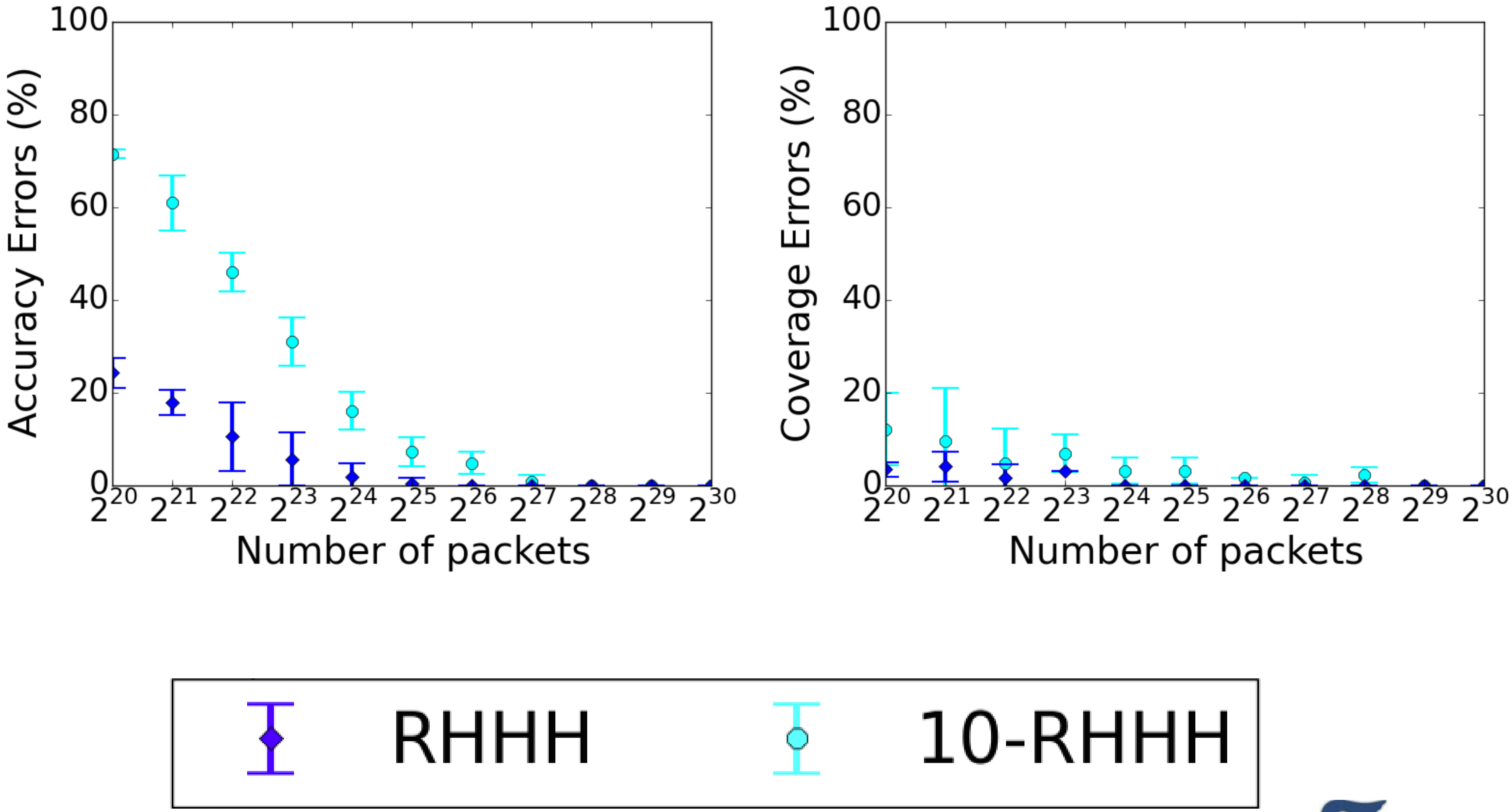
Constant Time Hierarchical Heavy Hitters (SIGCOMM2017)



Constant Time Hierarchical Heavy Hitters (SIGCOMM2017)

- How to detect the minimal prefix networks?
- How long it takes to converge?

Constant Time Hierarchical Heavy Hitters (SIGCOMM2017)



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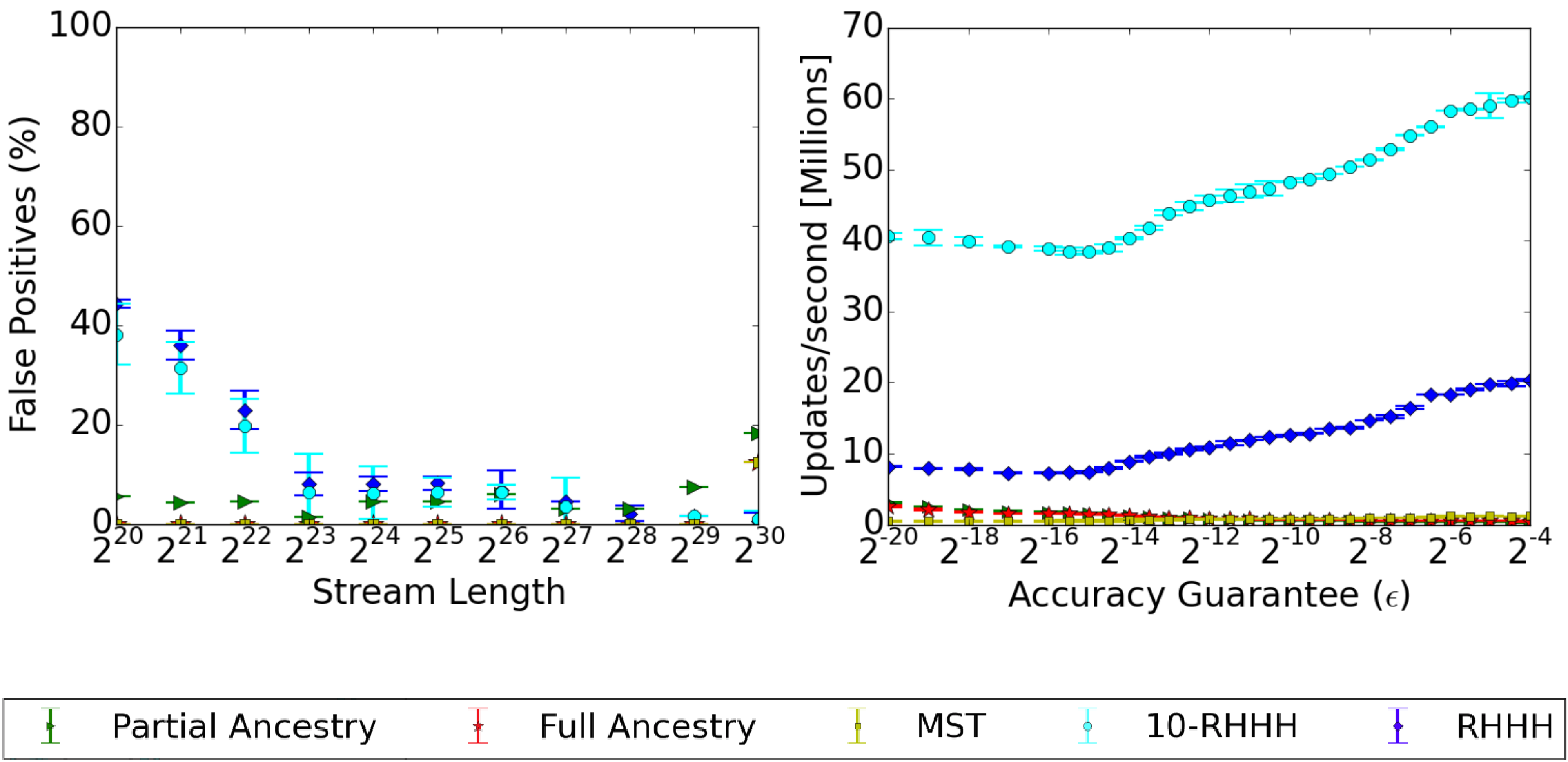

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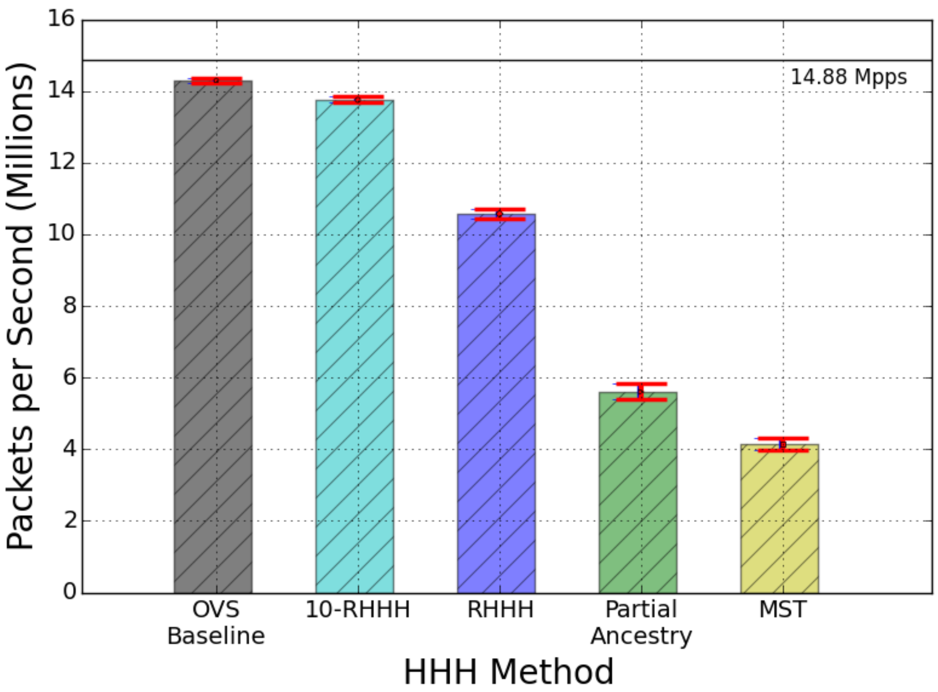

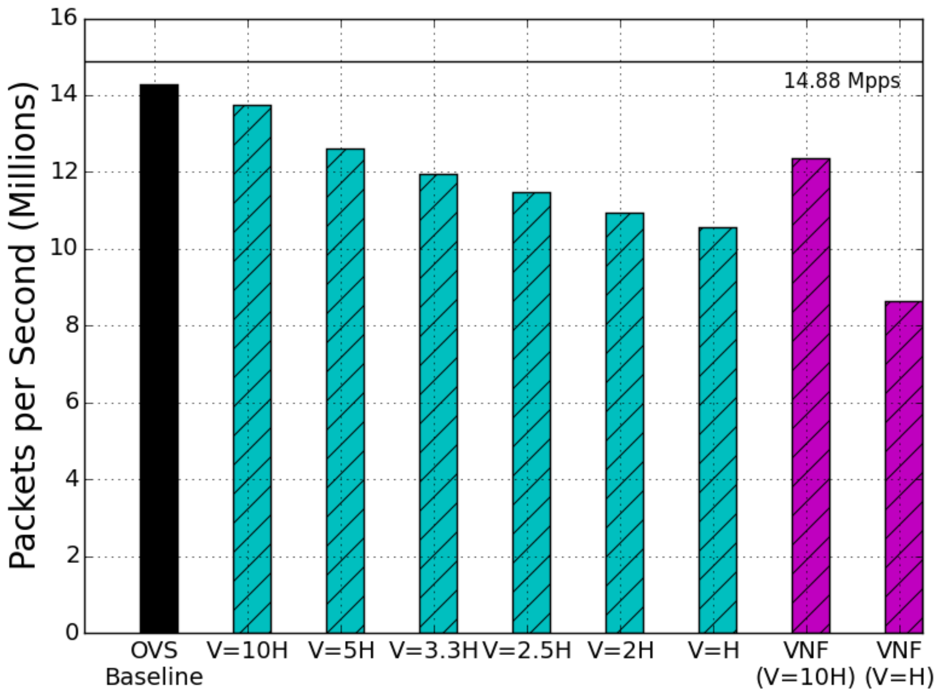

Any Questions