北京大学
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Finding Simplex Items in Data Streams

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Outline

PART 01 Background

PART 02 Problem Statement

PART 03 X-Sketch Design

PART 04 Experimental Results

PART 05 X-Sketch for ML

PART 06 Conclusion

01

PART ONE

Background

01/ Background

Frequency estimation is important

Finding frequent items in data streams have been well studied by the community .

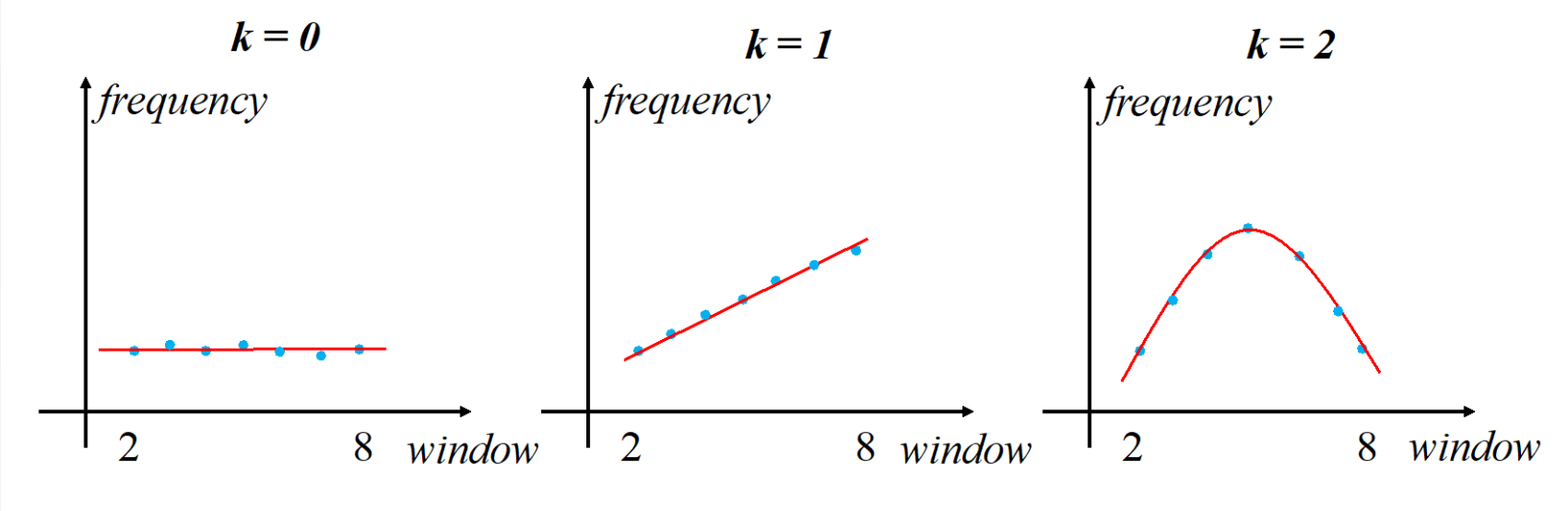
Best solution: Sketch

1) Memory efficient and time efficient
2) Small errors

01/ Background

Patterns in which item frequencies present in a certain number of **consecutive** windows are also worth exploring.

Such patterns in p consecutive windows may be fitted by k-degree polynomials.

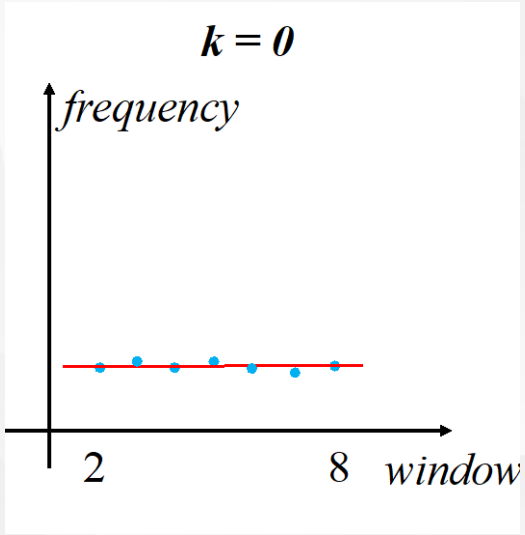


01/ Background

k=0:

1) stable cache lines

2) stable flows in network management

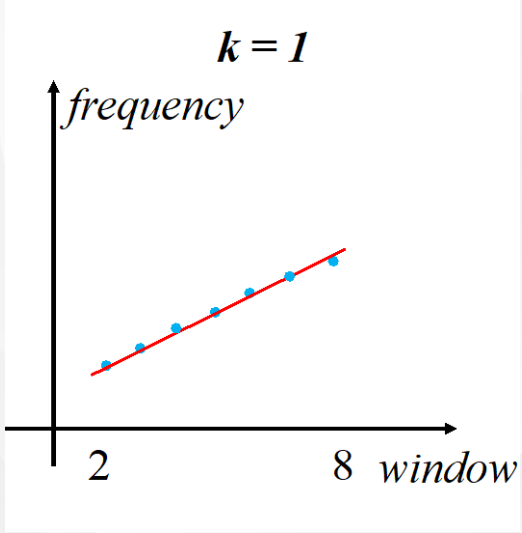


01/ Background

k=1:

1) speed up machine learning models

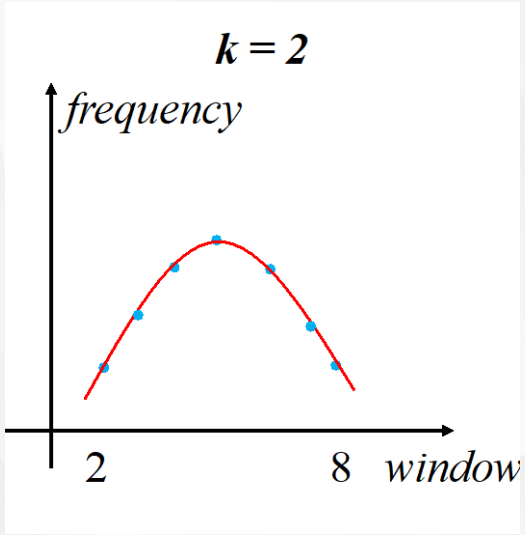
2) detect DDoS attacks



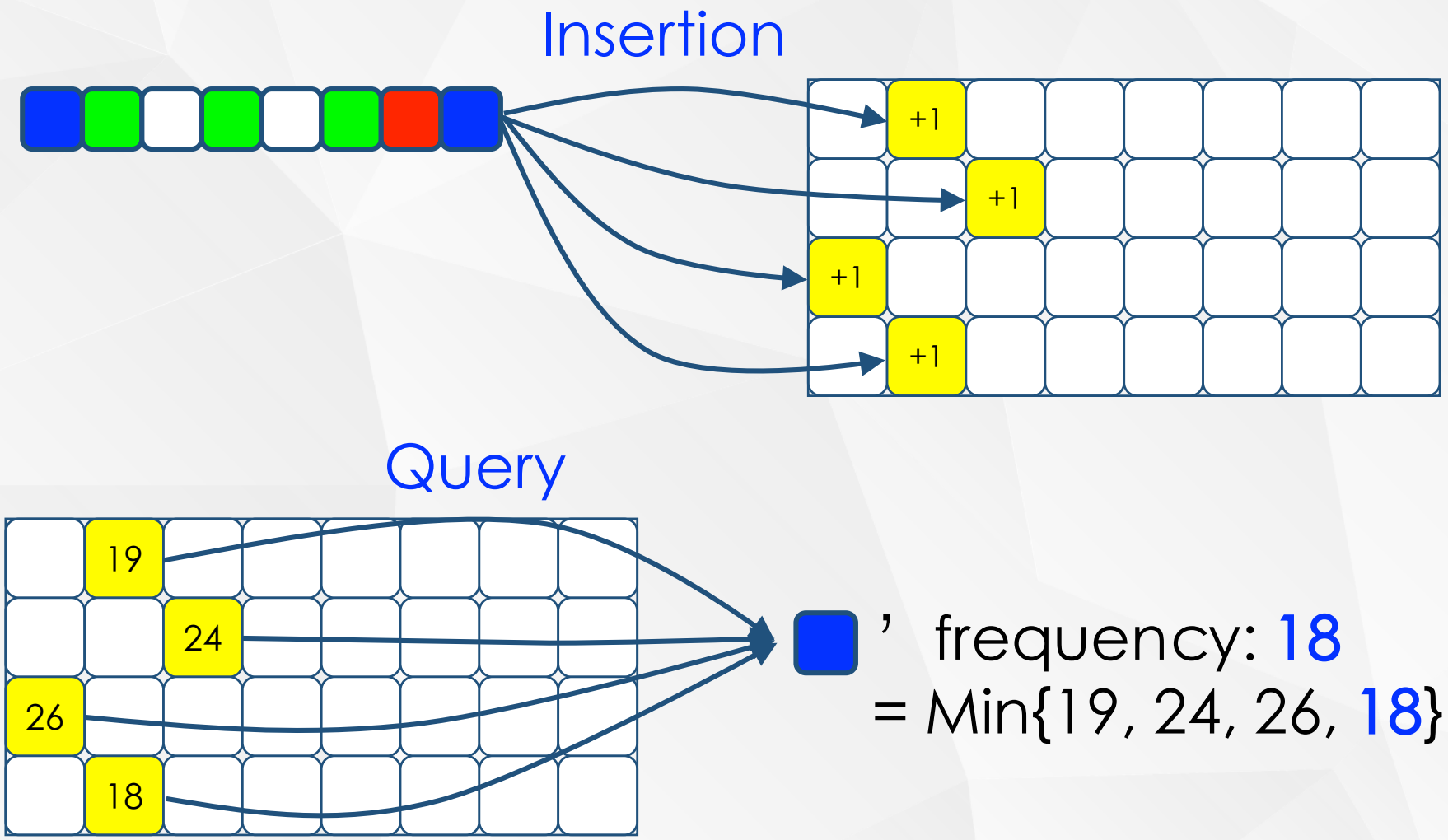
01/ Background

k=2:

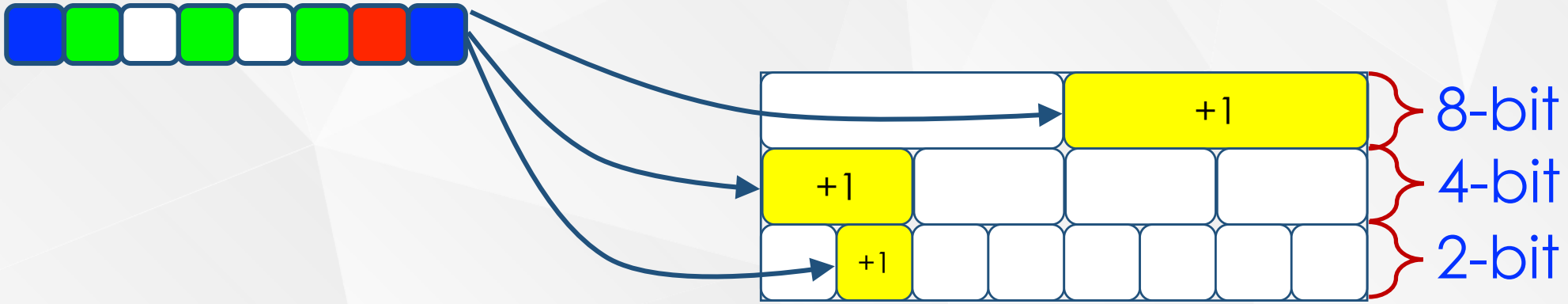
1) monitor traffic in wireless networks



01/ Background- CMSketch



01/ Background- TowerSketch



02

PART TWO

Problem Statement

02 Problem Statement

k-simplex items

An item e is called k-simplex item from window w if and only if its frequencies in p consecutive windows $f_w, f_{w+1}, \cdots, f_{w+p-1}$ satisfy:

(1) $f_{w+i} > 0, \forall i = 0, 1, \cdots, p-1$;

(2) There exists a k^{th}-degree polynomial

$$f(n) = a_0 + a_1 n + a_2 n^2 + \cdots + a_k n^k = \sum_{j=0}^{k} a_j n^j,$$

such that the mean squared error (MSE) ε satisfies

$$\varepsilon = \frac{1}{p} \sum_{i=0}^{p-1} (f(i) - f_{w+i})^2 \leq T;$$

where T is a predefined threshold.

02 Problem Statement

simplex items and persistent items

1) number of windows items appear
2) frequency is important
3) consecutive windows

03

PART THREE

X-Sketch

X-Sketch

01 Baseline Solution

02 An Optimization

03 Data Structure

03 X-Sketch - Baseline Solution

Part 1:

Record frequencies for last p windows using CMSketch

Part 2:

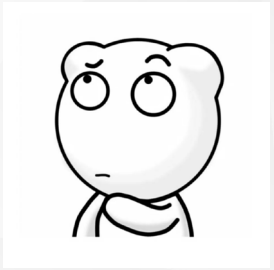
Record lasting time of simplex items using a set and a hash table.

03 X-Sketch - Optimization

The fitting error will not increase if we simply increase k.

Distinguish k-simplex items from (k-1)-simplex items:

Threshold for $|a_k|$



03 X-Sketch - Data Structure

Stage 1:

Record frequencies for last s windows using TowerSketch.

Stage 2:

Record potential simplex items and their lasting time using a hash table.

03 X-Sketch - Data Structure

Stage 1:

1) Short-Term Filtering: quickly filter non-simplex items

2) Potential: measure the probability of becoming simplex items

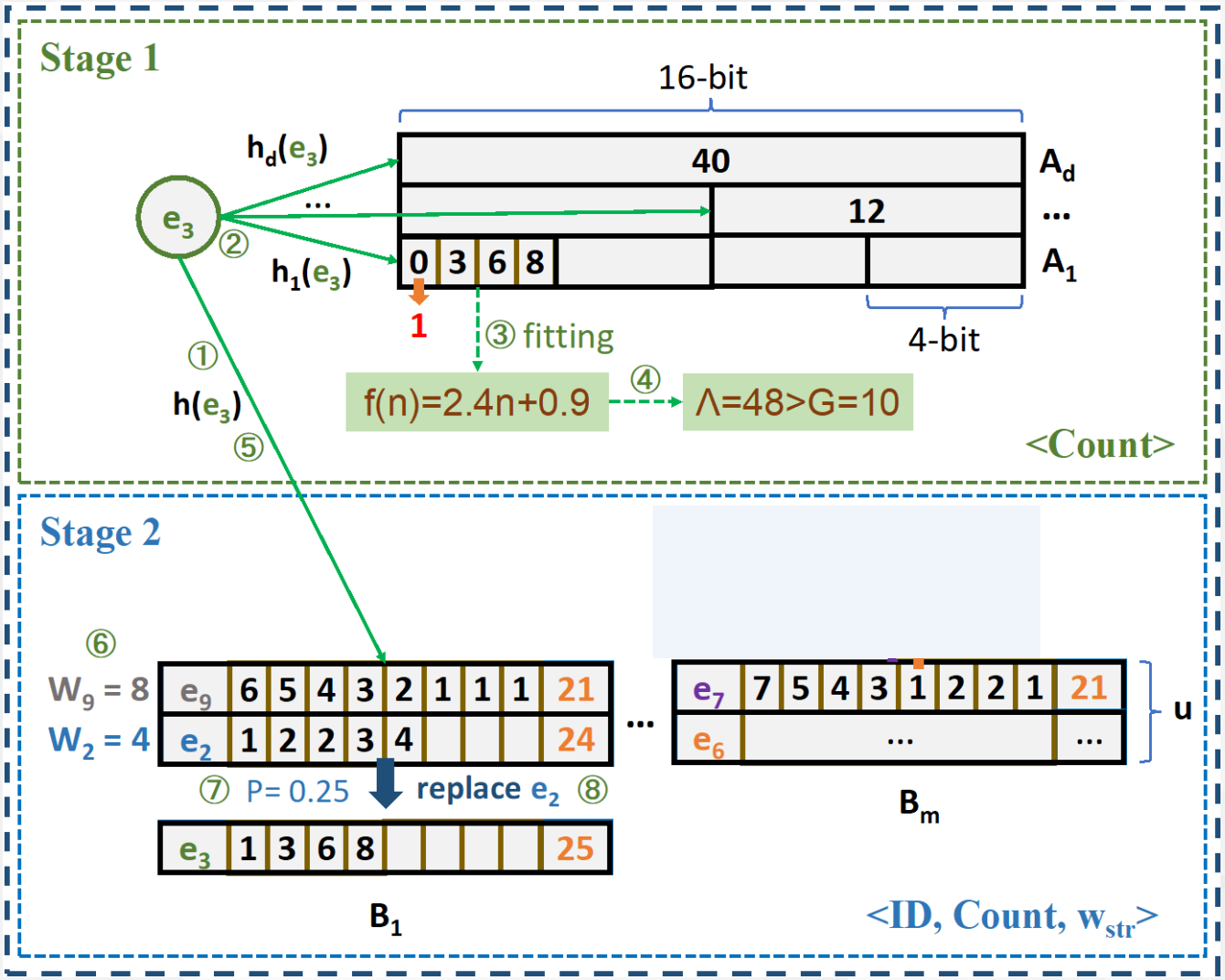
$$\Lambda = \frac{|a_k|}{\varepsilon + \Delta}$$

03 X-Sketch - Data Structure

Stage 2:

Weight Election: a reasonable replacement strategy

03 X-Sketch - Data Structure



04

PART FOUR

Experimental Results

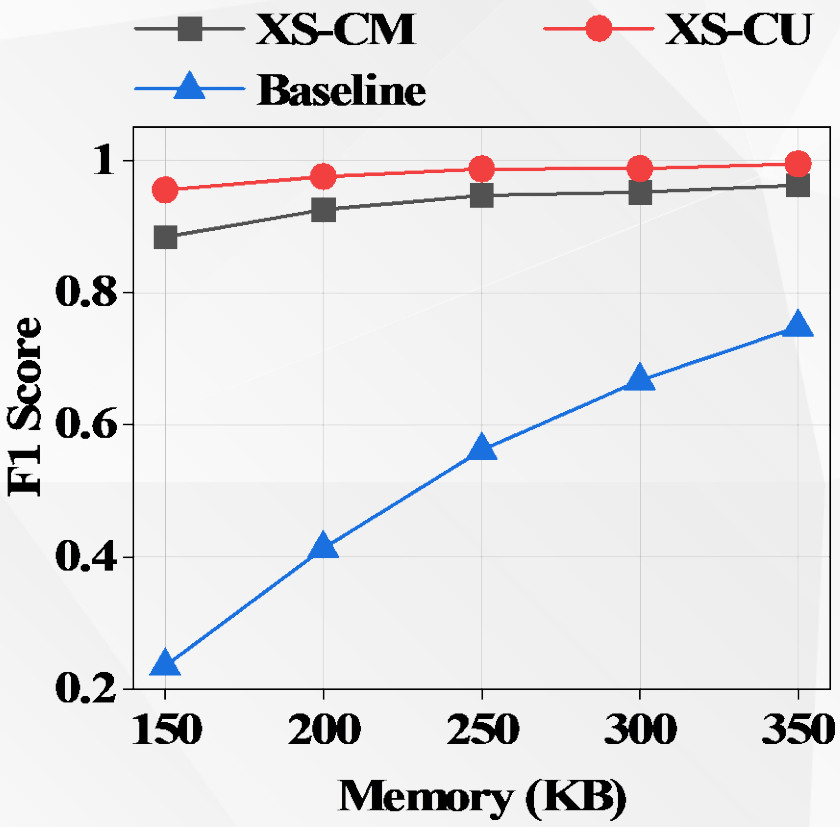
04 Experiments (Setup)

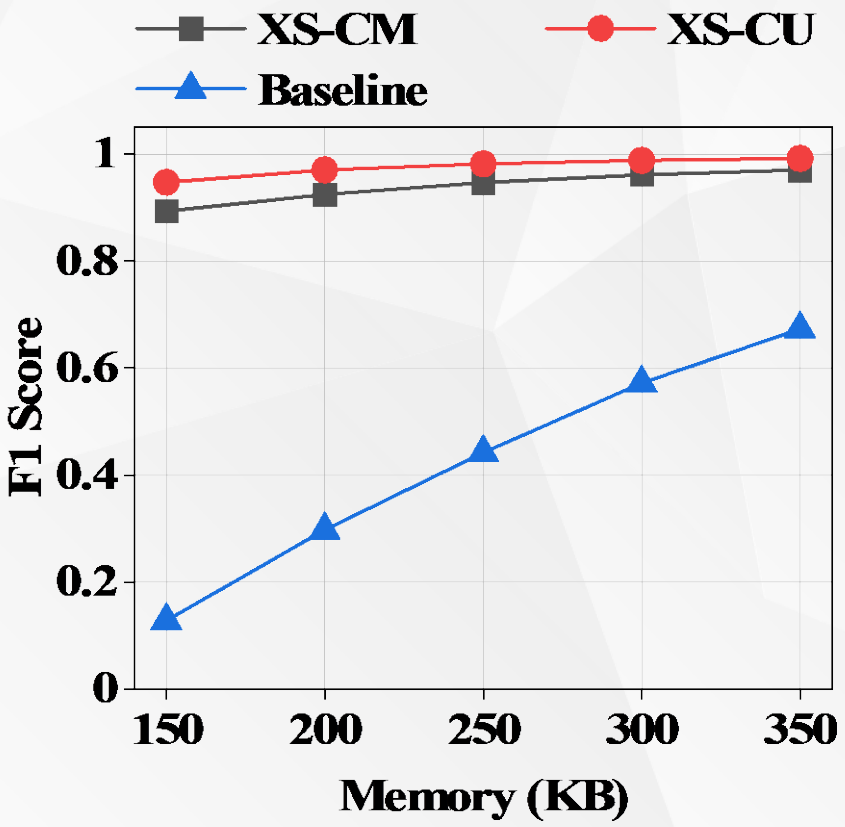
Datasets: CAIDA, MAWI, Data Center, Synthetic.

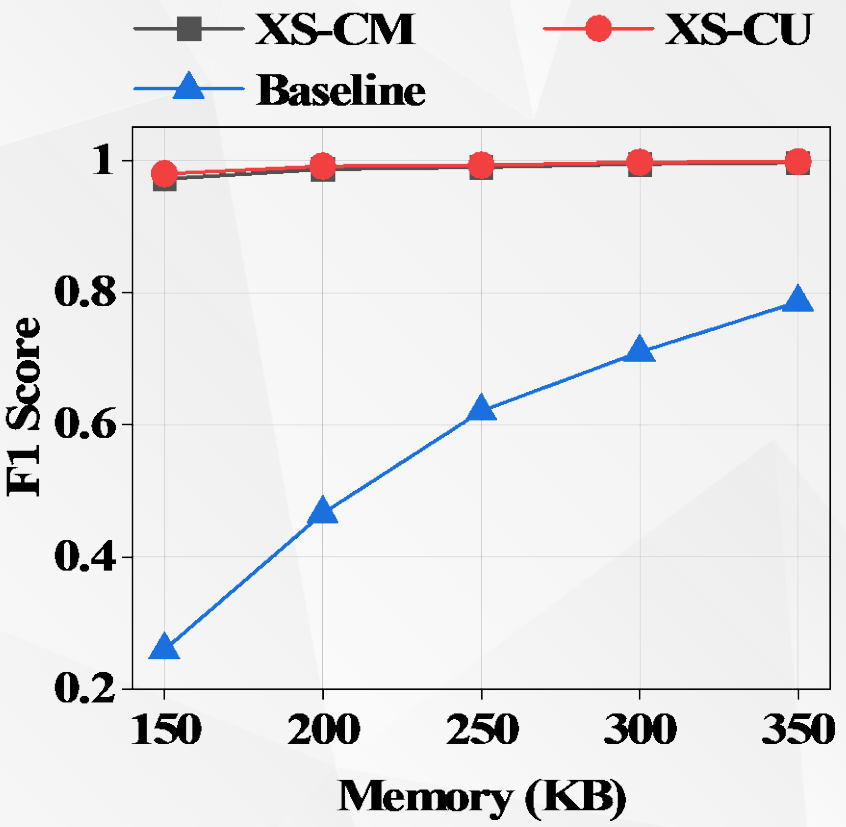
Metrics:

PR, RR, F1 Score, ARE, Throughput

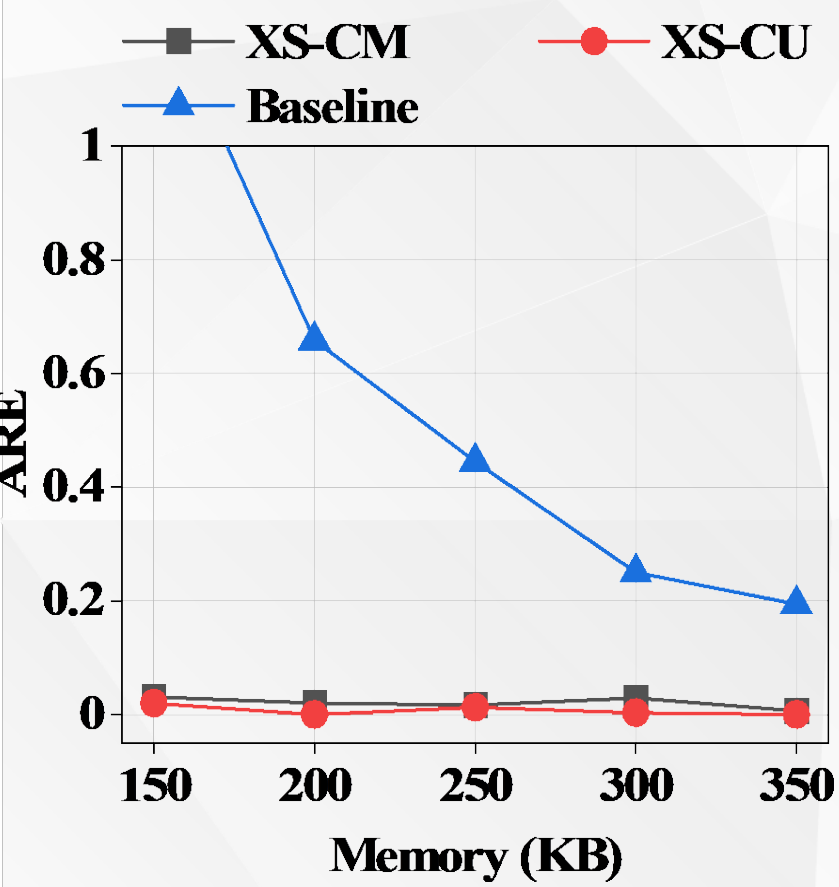
04 Experiments (F1 Score)

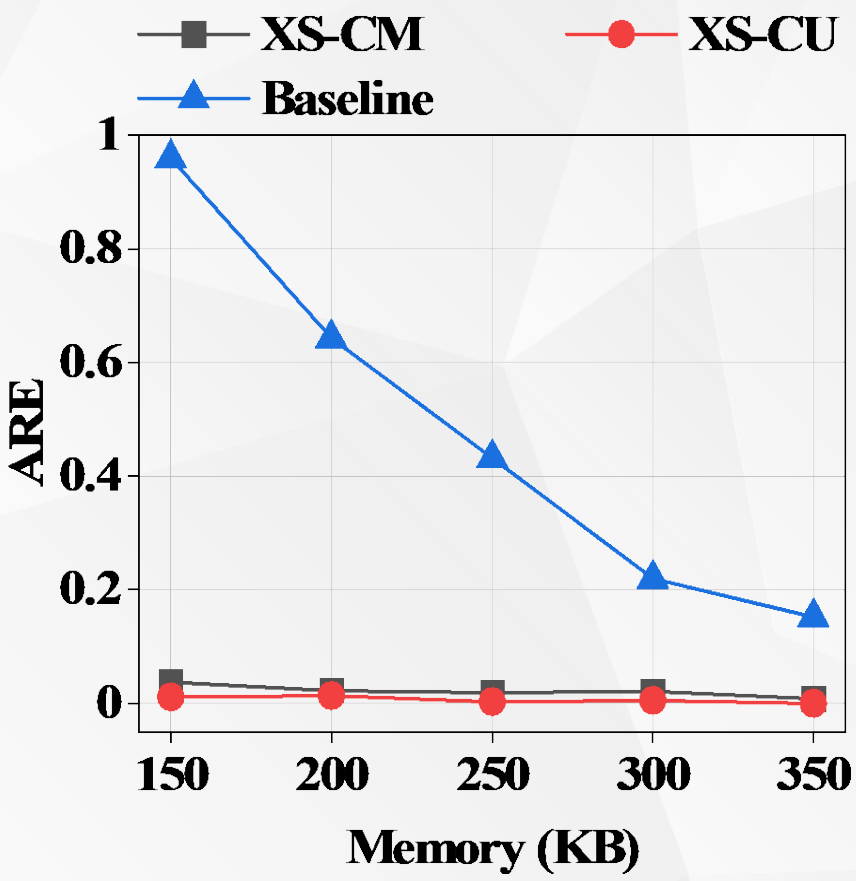


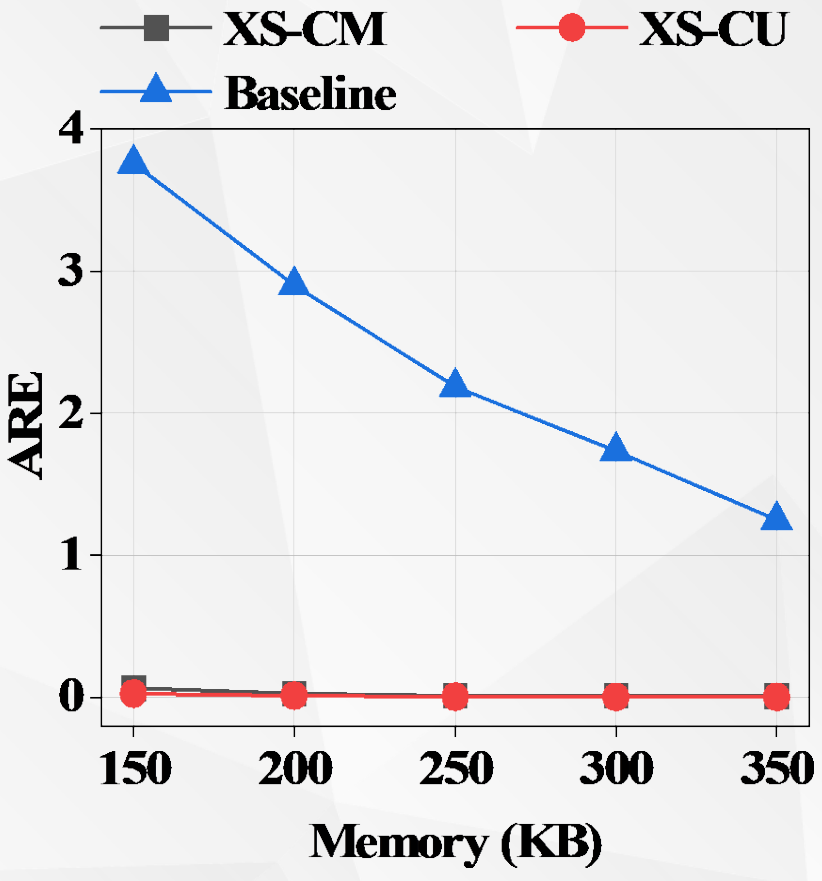




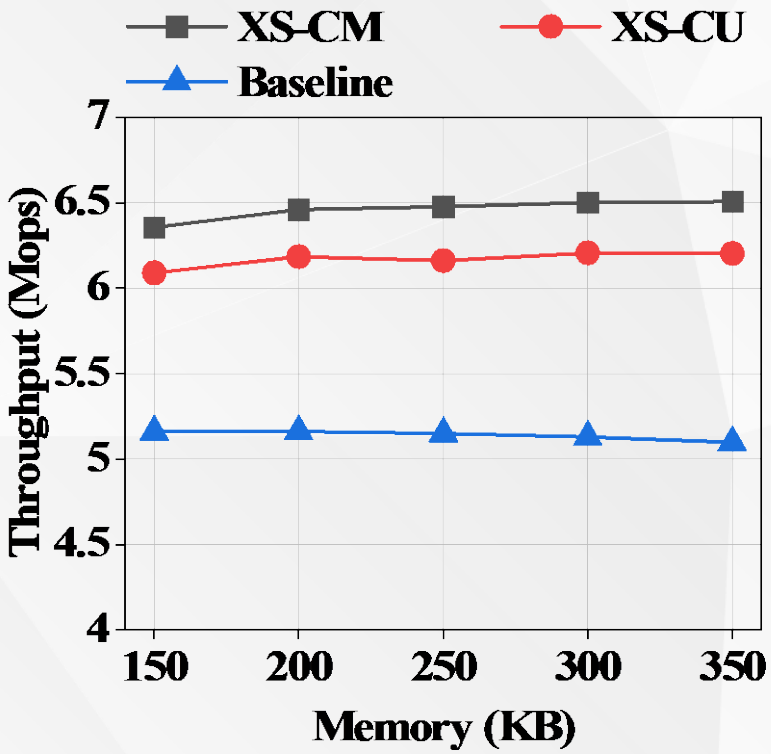
04 Experiments (ARE)

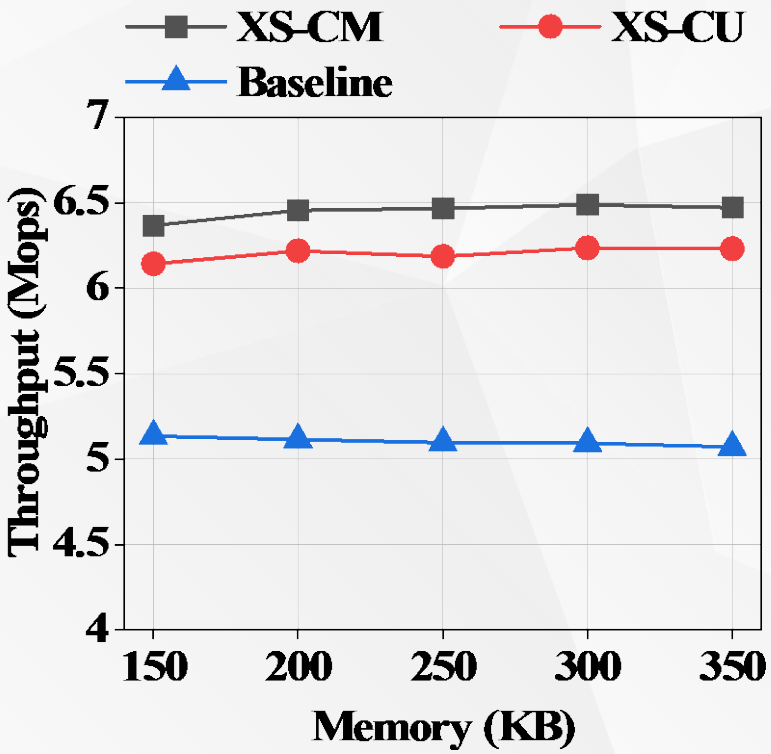


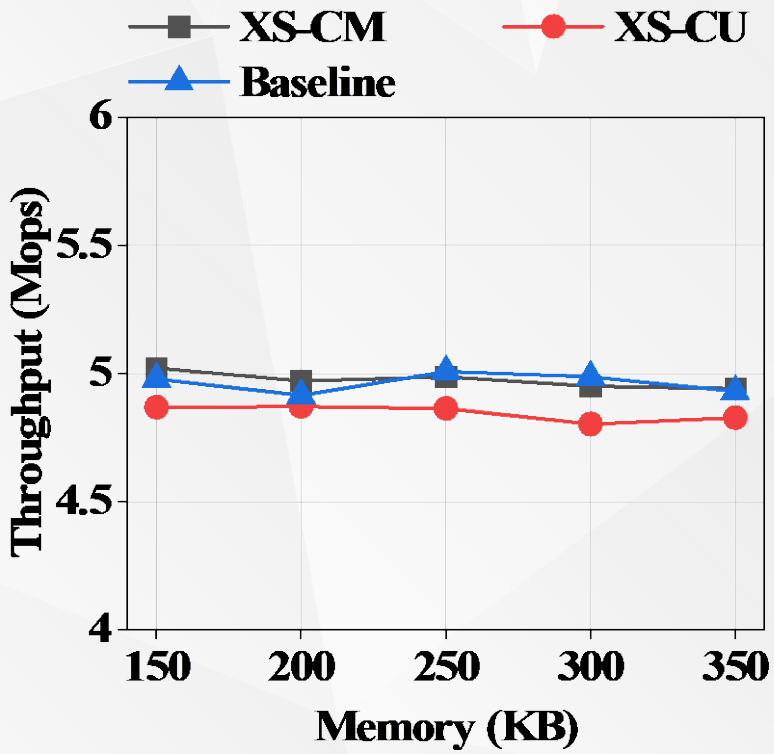




04 Experiments (Throughput)







05

PART Five

X-Sketch for ML

05 X-Sketch for ML

ML for predicting frequency:

1) massive training datasets
2) loops of training epochs
3) not all items are predictable

Solution: X-Sketch + ML

ML

X-Sketch+ML

05 X-Sketch for ML

TABLE III: Experiments on the Transactional Dataset.

	Model	Accuracy (%)	Running Time (s)
$k = 0$	X-Sketch (C++ / py)	98.49	0.014 / 0.225
	Linear Regression	98.38	2.14
	Time Series	98.47	71
$k = 1$	X-Sketch (C++ / py)	90.71	0.013 / 0.222
	Linear Regression	91.67	2.11
	Time Series	93.67	37.6
$k = 2$	X-Sketch (C++ / py)	85.31	0.015 / 0.228
	Linear Regression	85.67	2.13
	Time Series	95.36	71.8

06

PART SIX

Conclusion

06 Conclusion

1. k-simplex items
2. X-Sketch

   Key technique: Short-Term Filtering & Weight Election
3. Theoretical & experimental results
4. Accelerating machine learning

THANKS

Source code: https://github.com/SimpleX-Sketch/X-Sketch

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