MinCounter: An Efficient Cuckoo Hashing Scheme for Cloud Storage Systems

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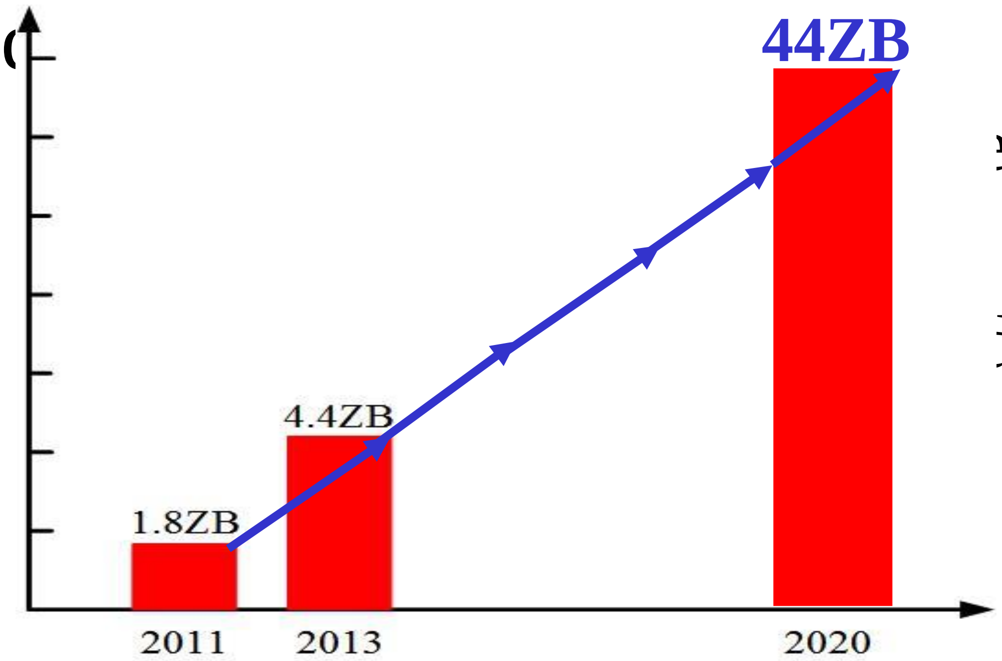
Outline

- Motivations and Backgrounds
- Design and Implementations
- Performance Evaluation
- Conclusion

Index for Big Data

- Large amounts of data (IDC)
  - 1.8ZB in 2011, 4.4ZB in 2013
  - 44ZB , 5.2TB for each user in 2020
- Inc
  - es
  -
  - l storage

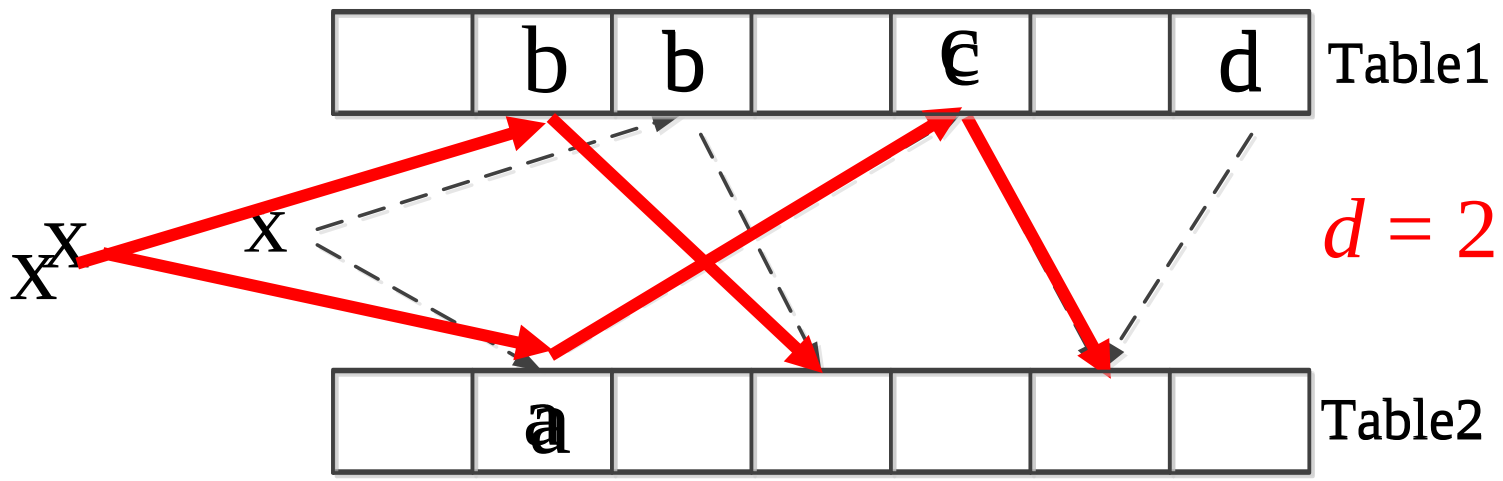


Hashing-based Index Structures

- Hashing-based data structures have been widely used in constructing the index.
- Advantages
  - Constant-scale addressing complexity
  - Fast query response
- Weaknesses
  - Low space utilization
  - High-latency risk of handling hashing collisions
- Cuckoo hashing

Cuckoo Hashing Scheme

- Uses *d* hash tables and *d* hash functions
- Random selection
- "Kicking-out" operation

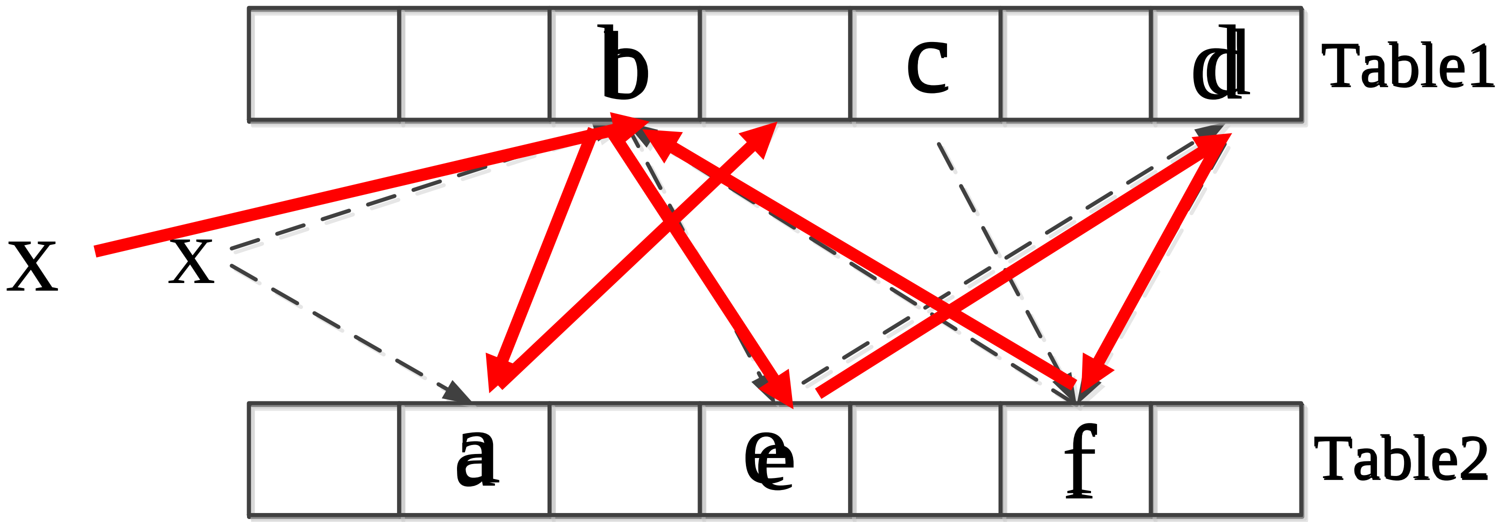


Advantages in Cuckoo Hashing

- Handle hash collisions
  - Moving the items among hash tables
- Ensure a more even distribution
  - *d* hash tables and *d* hash functions
- Constant-scale query time complexity
  - O(1)
- Improve space utilization

Challenges in Cuckoo Hashing

- Intensive migration operations
- Endless loops
  - Reconstruct hash tables

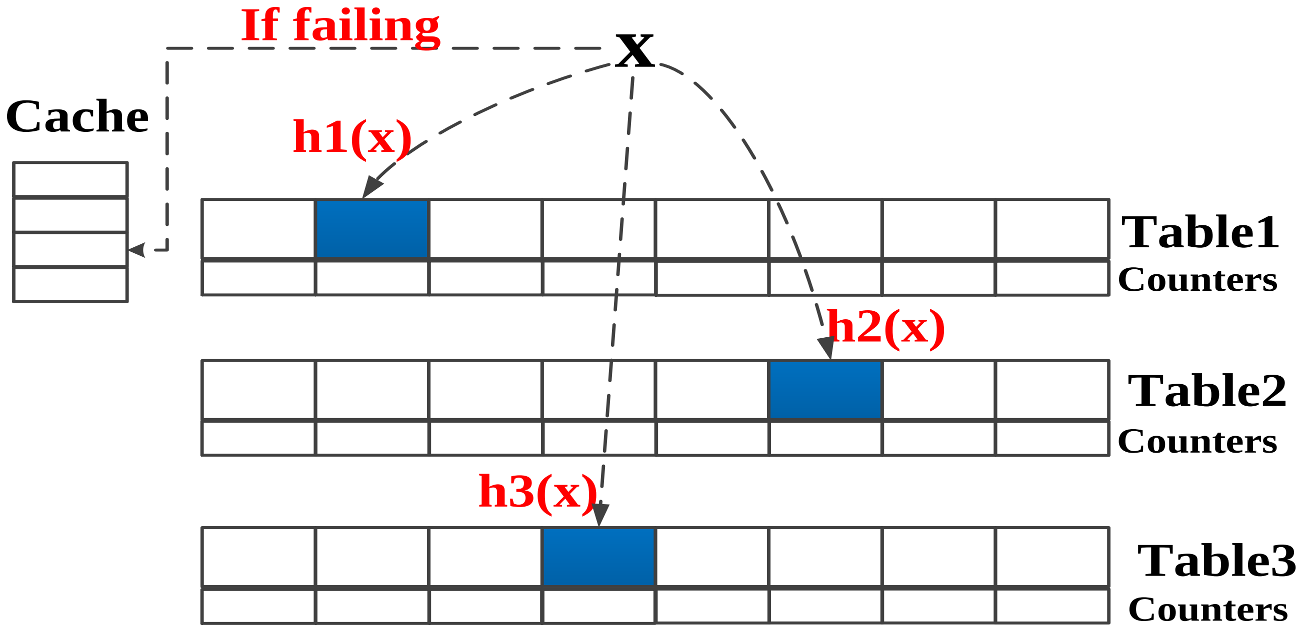


MinCounter

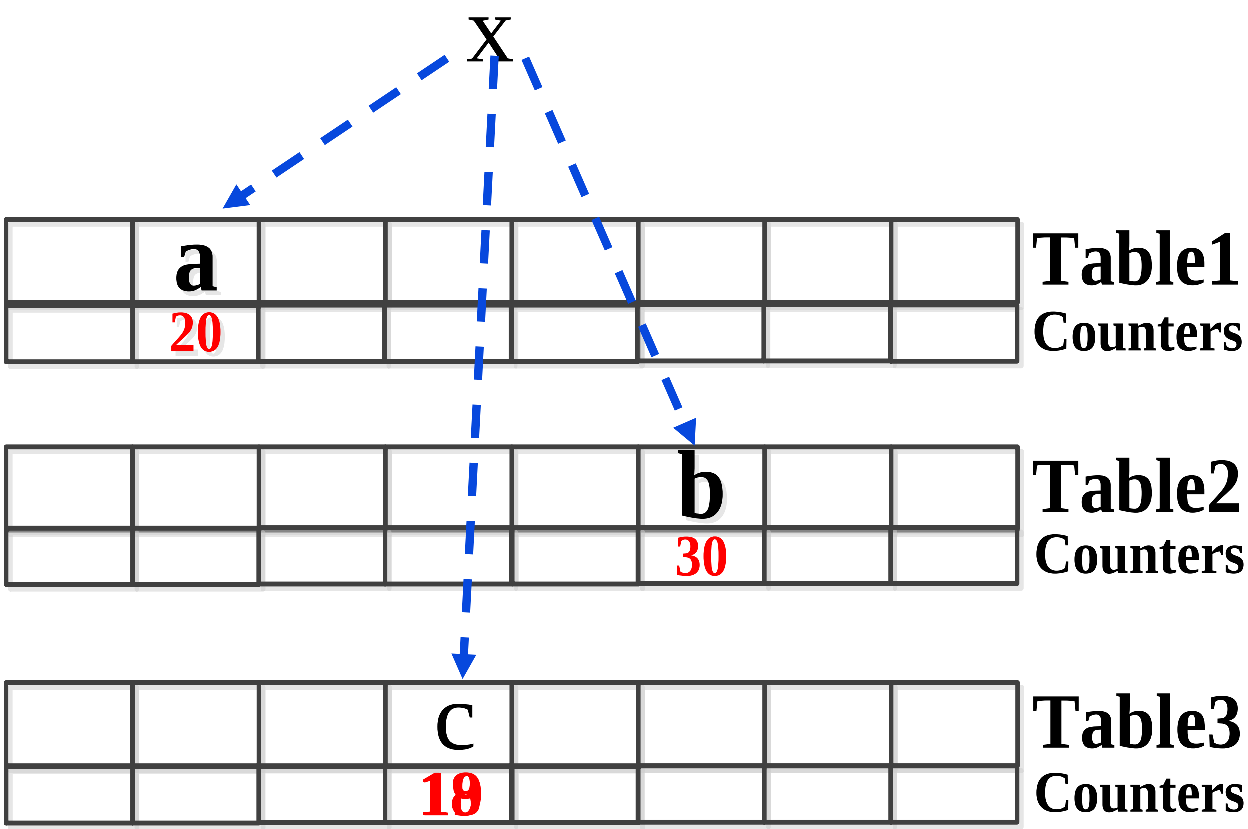
- Allocating a counter for each bucket to record kicking-out times
- Selecting the bucket with the minimum counter to kick out
- Avoiding busy routes and selecting the "cold" buckets
  - Infrequently accessed
  - Alleviate the occurrence of endless loops in data insertion process

Data Structure

- Focus on the cases of $d \geq 3$
- Insertion failure: kicking-out times is more than a threshold



An Example



x
a
20
Table1
Counters
b
30
Table2
Counters
c
10
Table3
Counters

Evaluation dataset

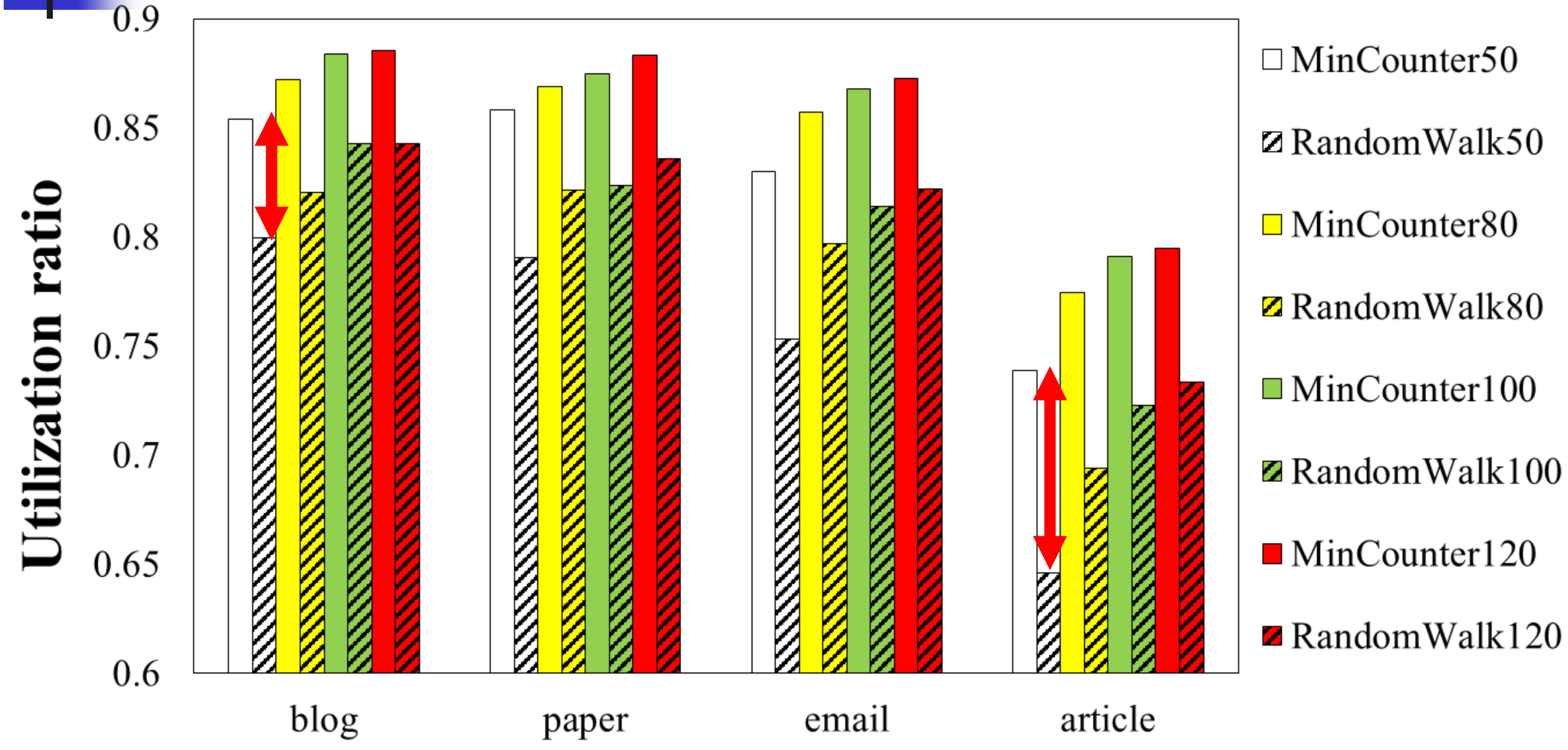
- Bag of Words
  - Four text collections in the form of bags-of-words
  - About 10 million items in total
  - Taking advantage of the union of docID and wordID as keys of items
  - http://archive.ics.uci.edu/ml/datasets/Bag+of+Words

Text collectons	Doc	Word	Total _W(Million)
KOS blog entries	3,430	6,906	0.4
NIFS full papers	1,500	12,419	0.8
Enron emails	39,861	28,102	3.8
NYTimes news articles	300,000	102,660	5.0

Evaluation Metrics

- Utilization ratio of hash tables
  - Occupied buckets / all buckets
  - Space efficiency
- Total kicking-out times during insertion operations
  - Insertion latency
- The kicking-out thresholds: 50, 80, 100 and 120
- The initial rate of hash tables: size of hash table / size of dataset
  - Initial rate 1.1: high collision rate
  - Initial rate 2.04: low collision rate

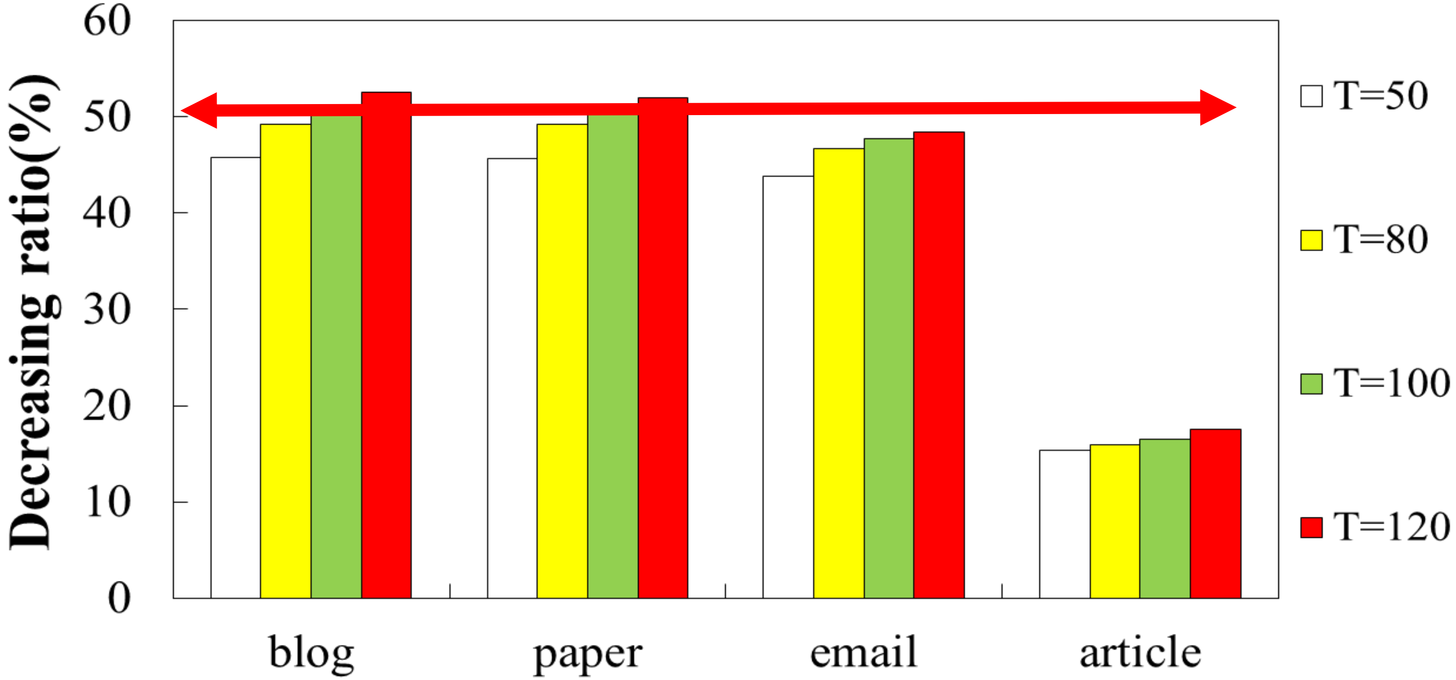
Utilization ratio of hash tables



- MinCounter obtains 5%-10% utilization improvement, compared with RandomWalk scheme.

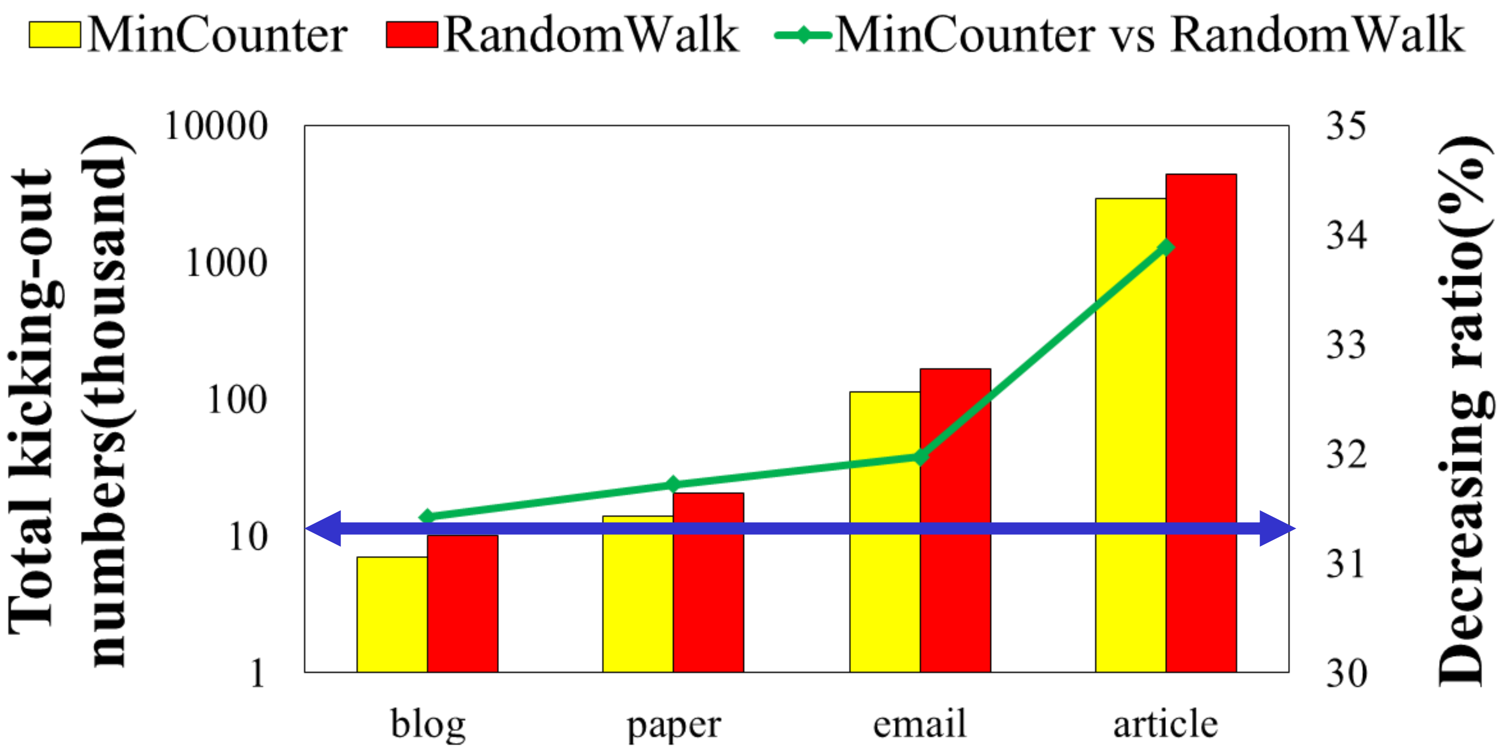
Total kicking-out times(Rate = 1.1)

$$DR = \frac{N\_RandomWalk - N\_MinCounter}{N\_RandomWalk}$$



- MinCounter reduces almost 50% total kicking-out times (R=1.1).

Total kicking-out times(Rate = 2.04)



- MinCounter reduces more than 31% total kicking-out nunbers (R=2.04).

Conclusion

- Endless loops and high insertion latency
- MinCounter selects the “cold” buckets to kick out
  - Alleviate hash collisions
  - Decrease insertion latency
- Substantially decreases the total kicking-out times and improves the utilization ratio of hash tables.
- We release the source code of MinCounter in GitHub.

  https://github.com/syy804123097/MinCounter

Thanks & Questions

Challenges in Cuckoo Hashing

- Intensive kicking out when inserting items
- Endless loops
  - Reconstruct hash tables