Blocked Bloom Filters with Choices

Jens Zentgraf, Johanna Elena Schmitz and Sven Rahmann
Algorithmic Bioinformatics, Saarland University

Bloom Filter

- Probabilistic set membership data structure
- A set K of $n=|K|$ elements
- k hash functions
  - false positive rate of 2^{-k}
- Bit array of size m bits
  - $m = nk / \ln(2)$

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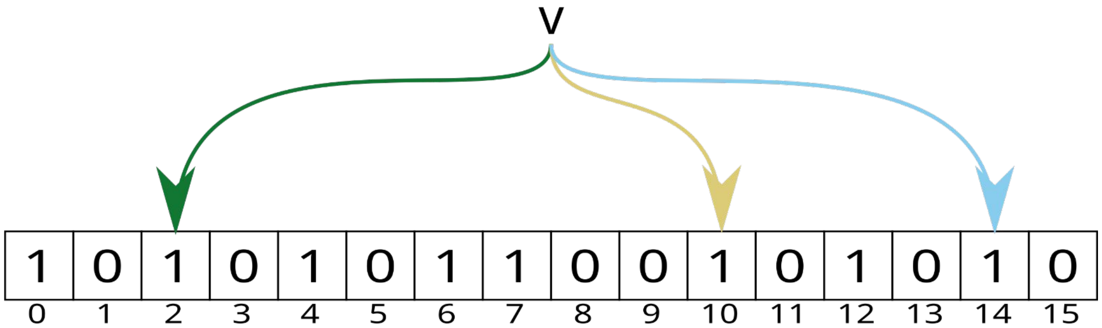

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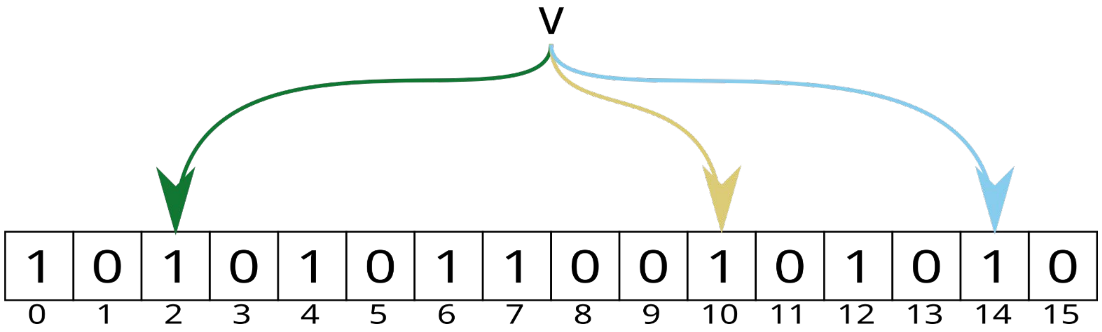
- Bit array of size m bits
  - ➢ $m = nk / \ln(2)$
- Insert:
  - ➢ Compute k positions
  - ➢ Set all positions to 1
- Lookup:
  - ➢ Compute k positions
  - ➢ All positions 1 ➡ contained



Bloom Filter

Advantages:

- Simple
- Adjustable FPR
  (number of hash functions)
- Online insertion

Disadvantages:

- High overhead (≈1.44)
- Slow
  - *k* cache misses

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- *M* is typically a cache line (512 bits)
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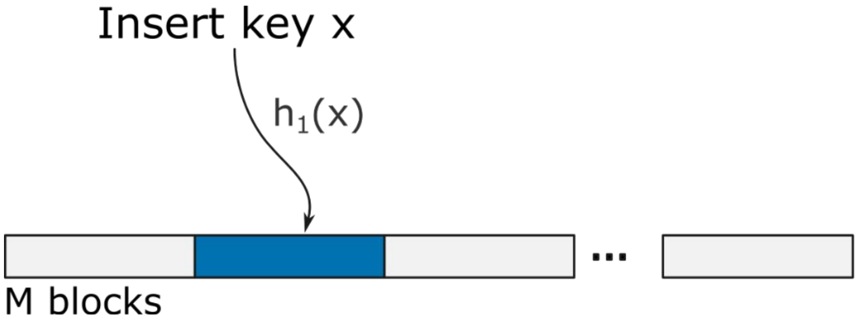

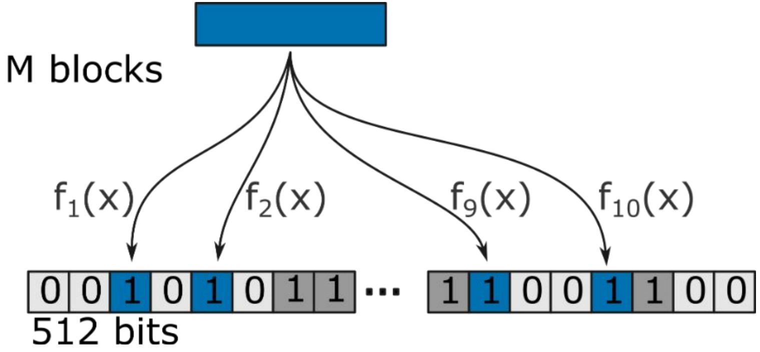

Blocked Bloom Filter

Advantages:

- One cache miss
- Faster than the normal Bloom filter

Disadvantages:

- One additional hash function to select a block
- Blocks are not filled evenly.
  - Some blocks are more filled, some are less
  - Higher FPR
- Increase size to counter increased FPR

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- **Goal**:
  - Reduce FPR and keep filter size
  - Reduce overhead and keep FPR

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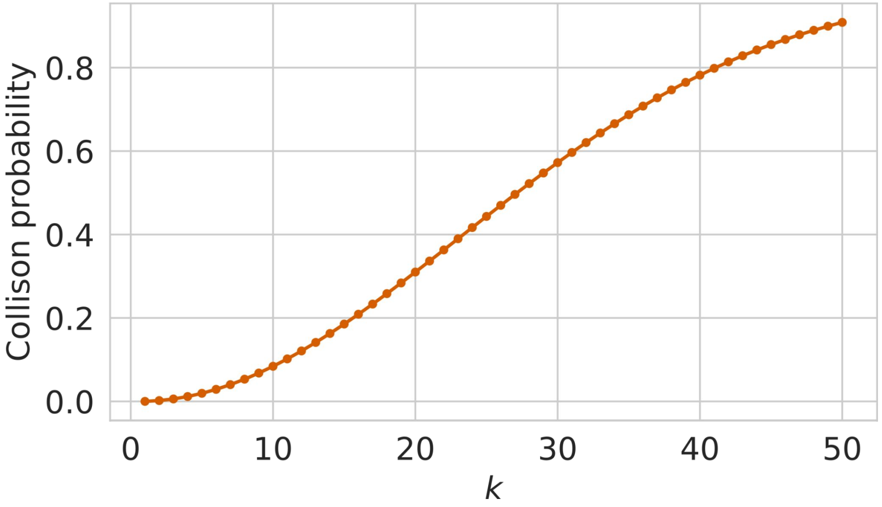
Random vs. Distinct hash positions

- One or multiple hash functions can point to the same bit positions
- We only get $k' \leq k$ different positions
- Reduces the FPR to $2^{-k'}$



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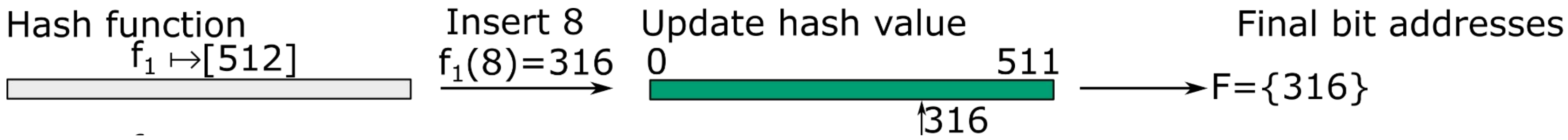

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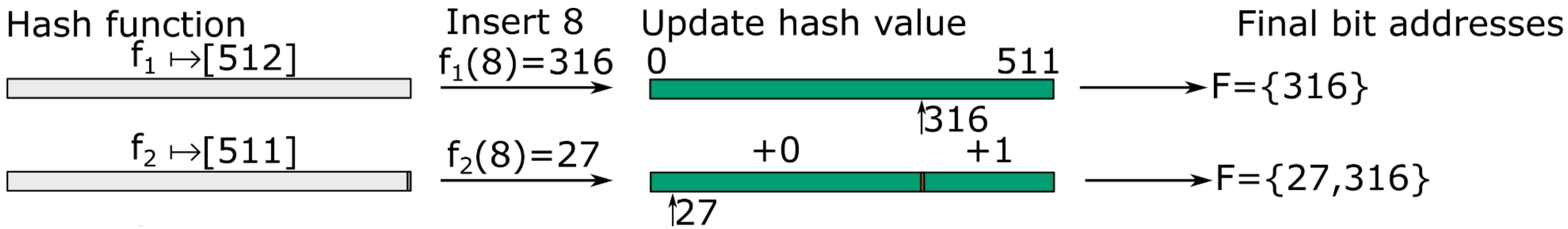

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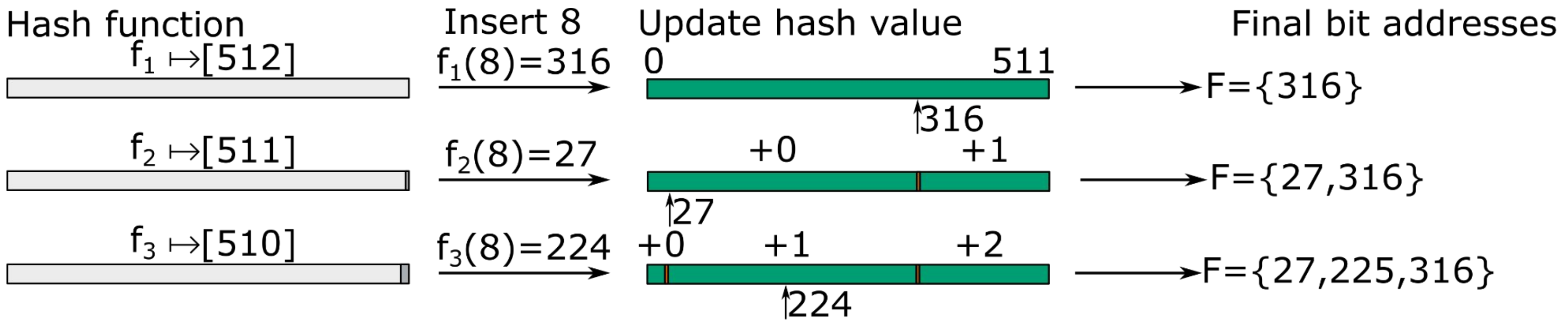

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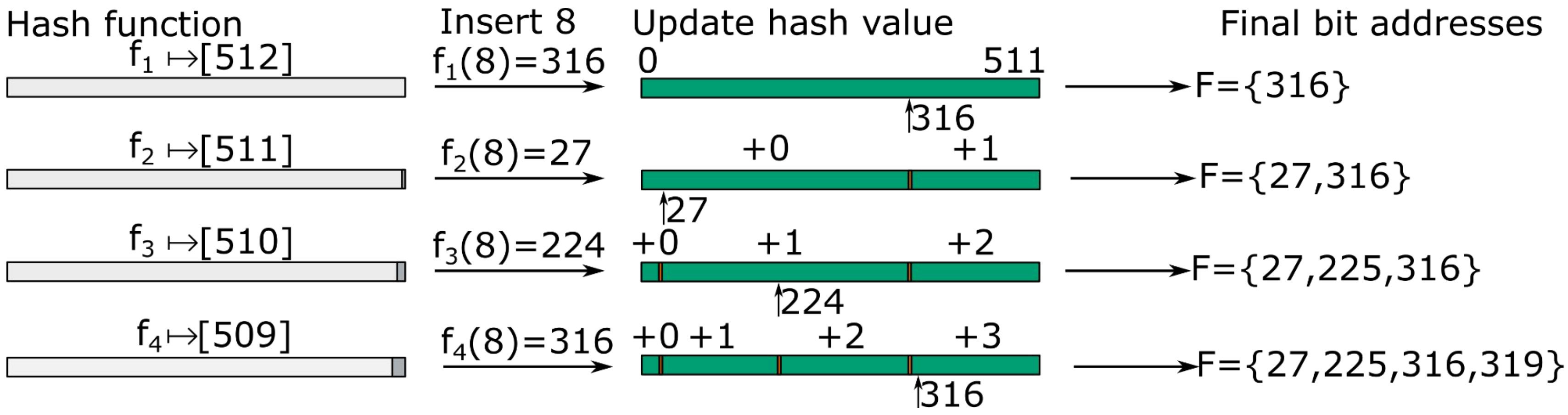

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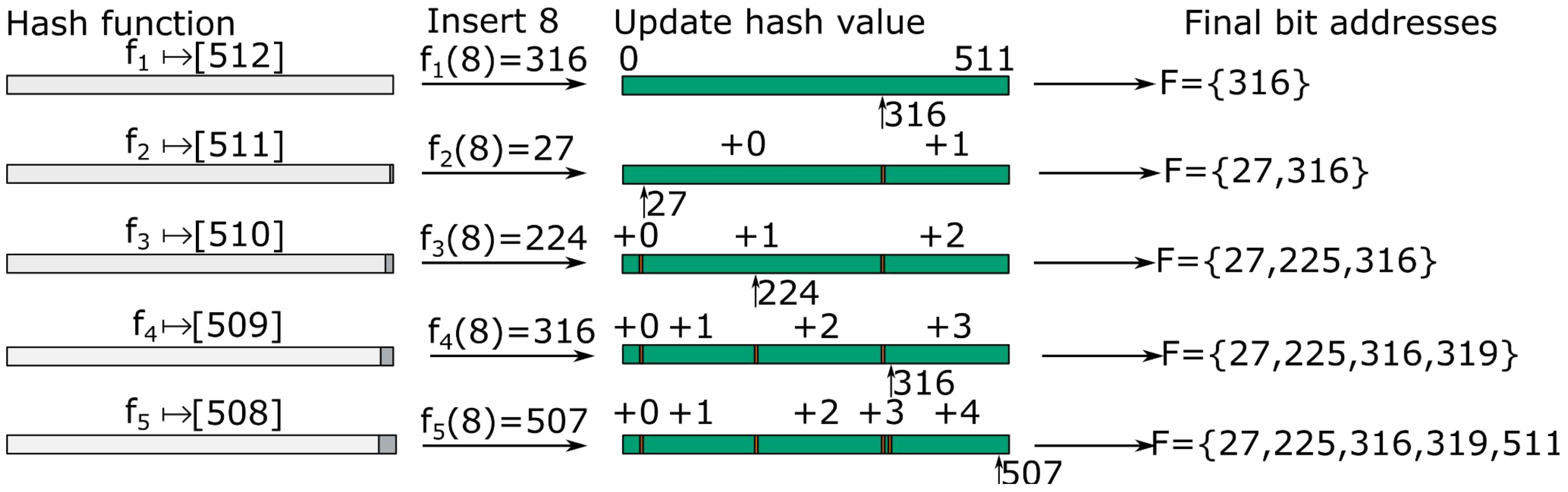

Blocked Bloom filters with choices

- Instead of computing one block, we can choose one block out of *c* possible blocks.

- Keep local FPR low in each block
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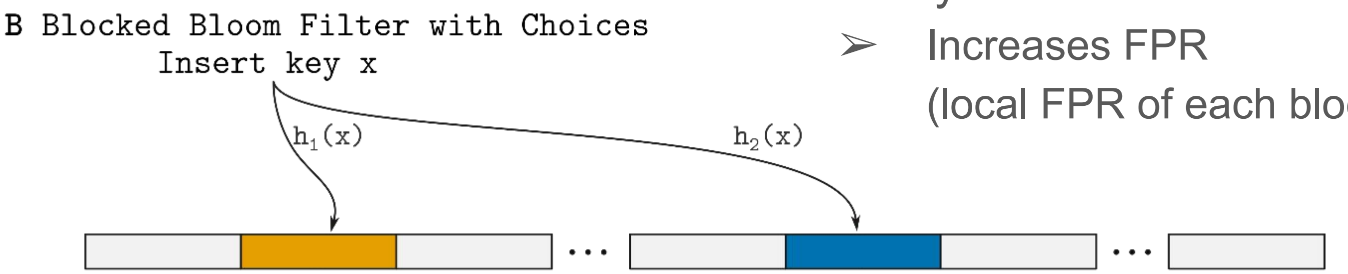

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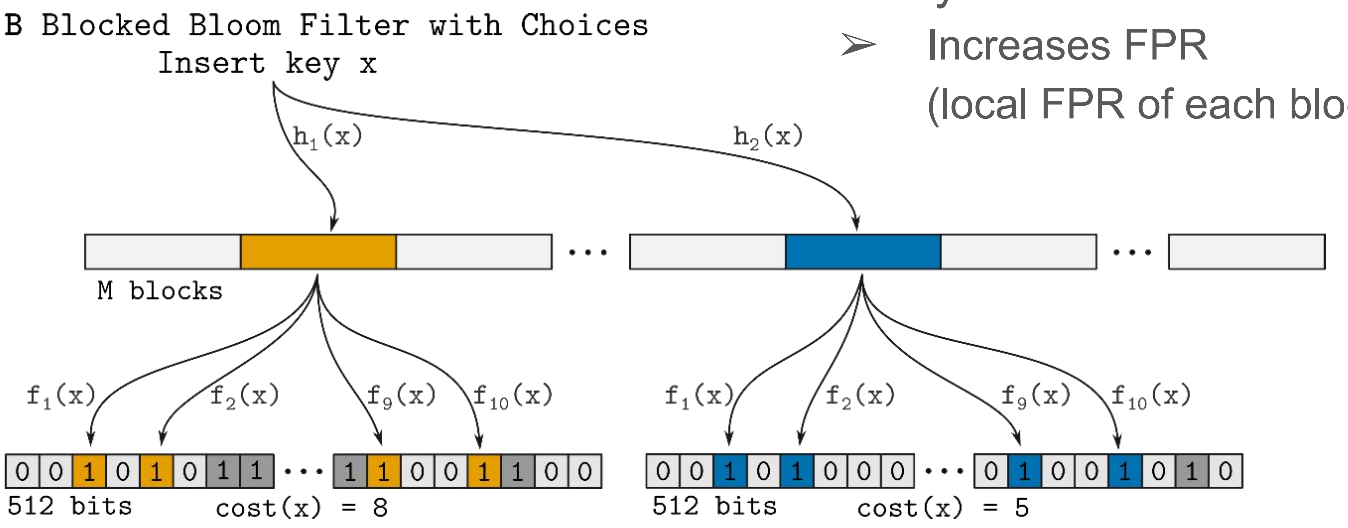

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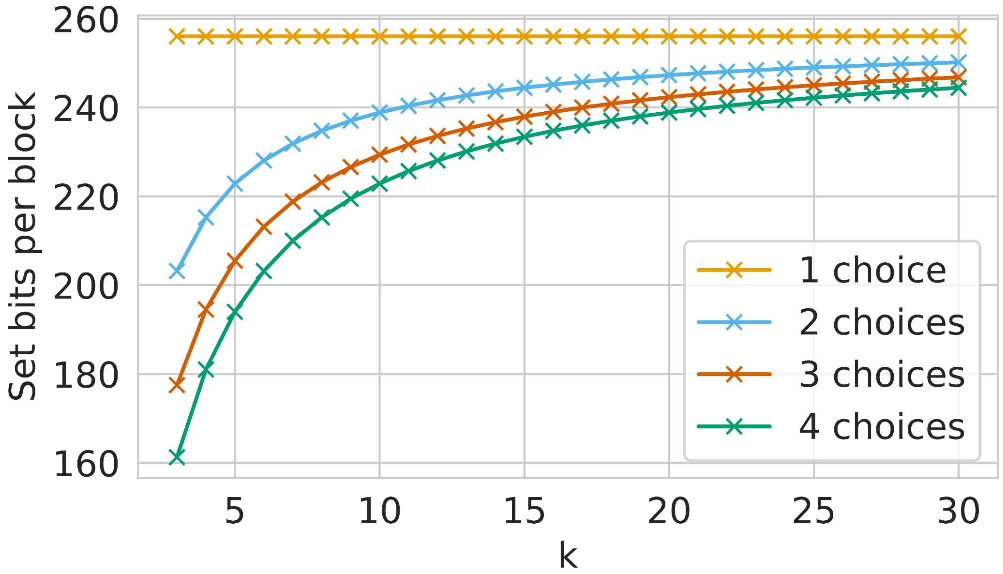

Cost functions

The cost functions are based on two parameters:

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- *a* number of new set bits after insertion

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- $k = 10$
- $2^{-k} = 2^{-10} \approx 0.0009765625$

k=10	random		distinct	
choices	set bits (j)	new bits (a)	set bits (j)	new bits (a)
2	0,001634	0,008066	0,001587	0,008201
3	0,001957	0,034652	0,001893	0,035655

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Three different cost functions:

- Mixed cost function
- Lookahead cost function
- Exponential cost function

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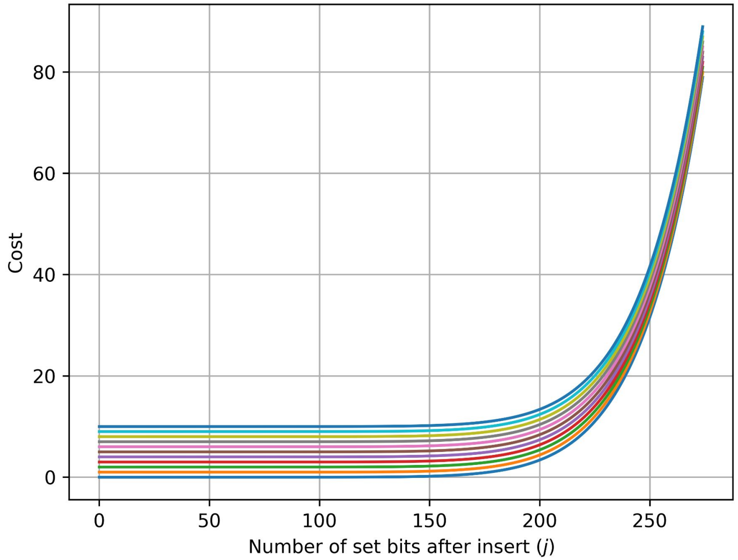

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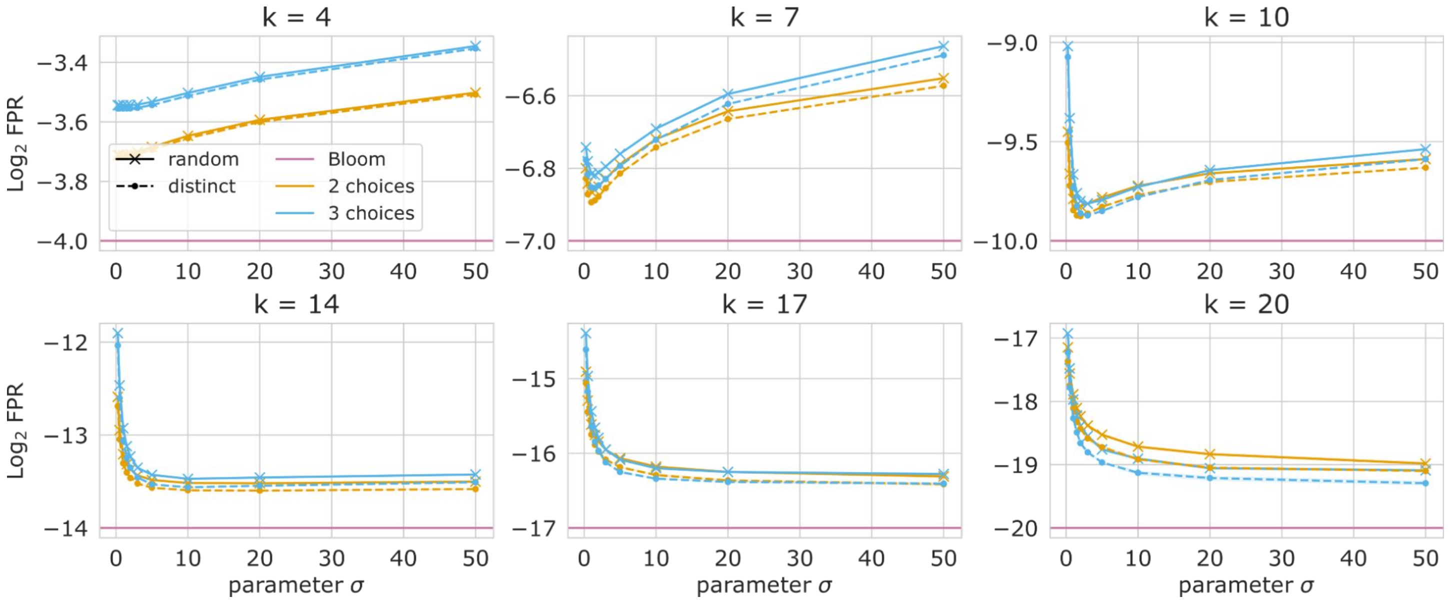

Lookahead Cost function

- Still a lot of overfull blocks
- Penalize already less full blocks stronger

$$\mathrm{cost}^{LA}_{\mu}(j, a) := \mathrm{cost}^{MIX}_{1}(j + \mu k, a)$$
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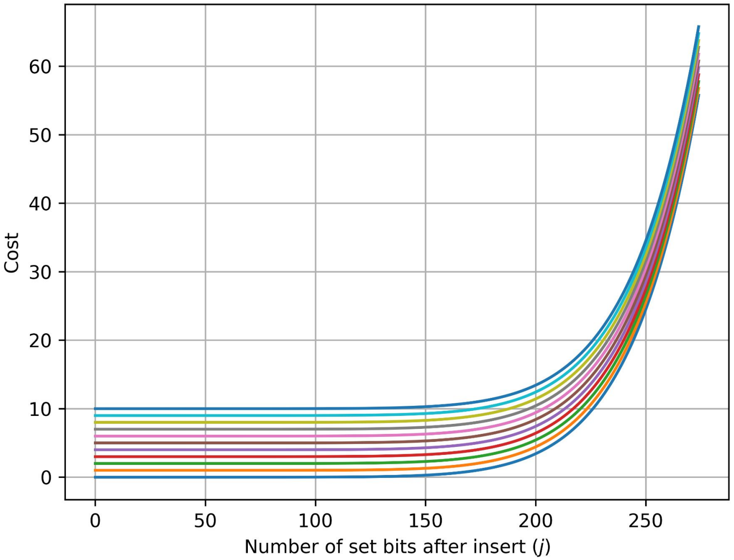

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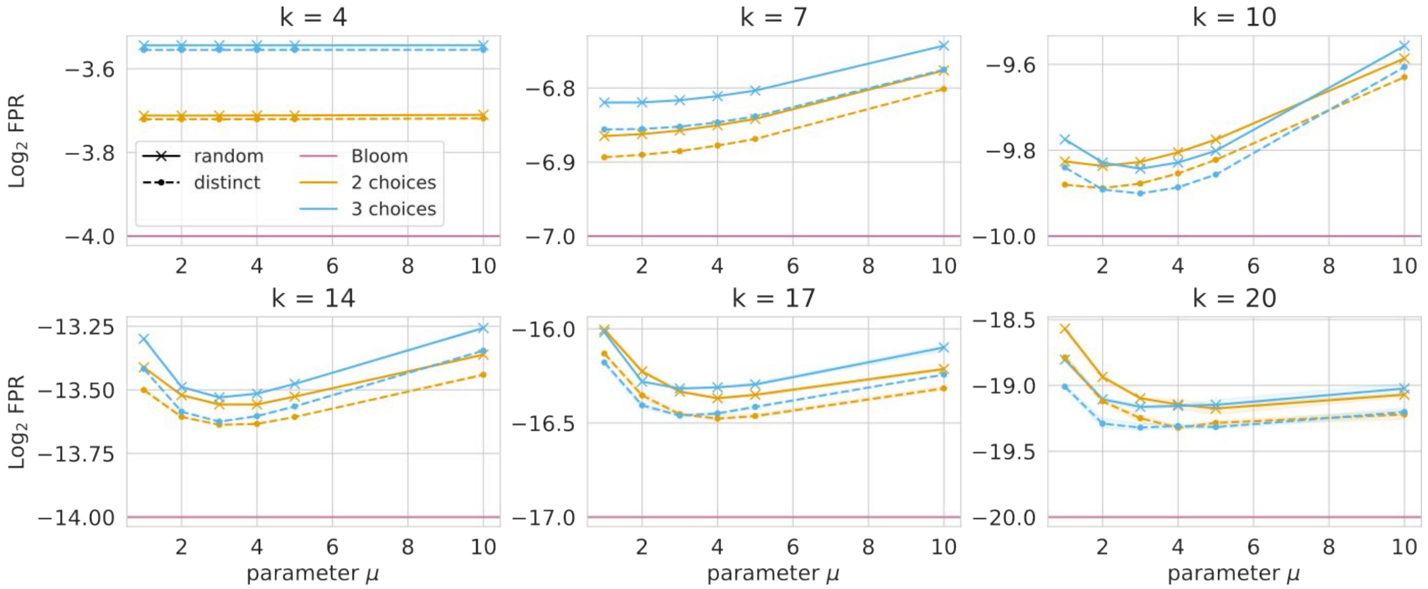

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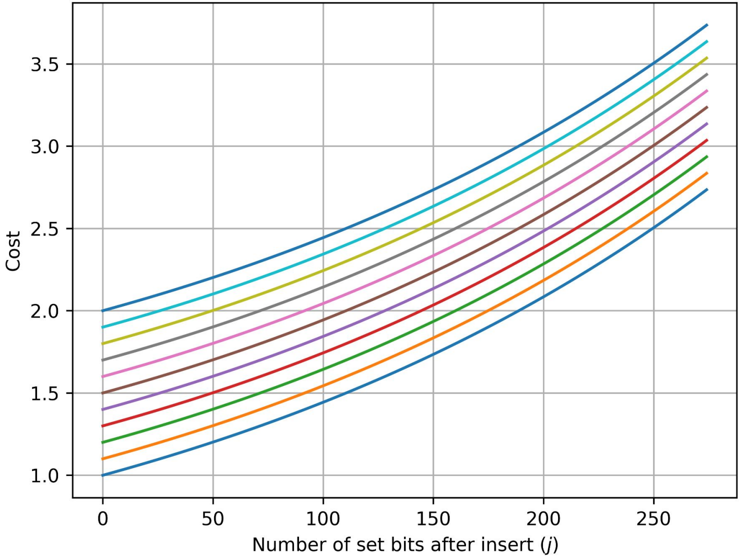

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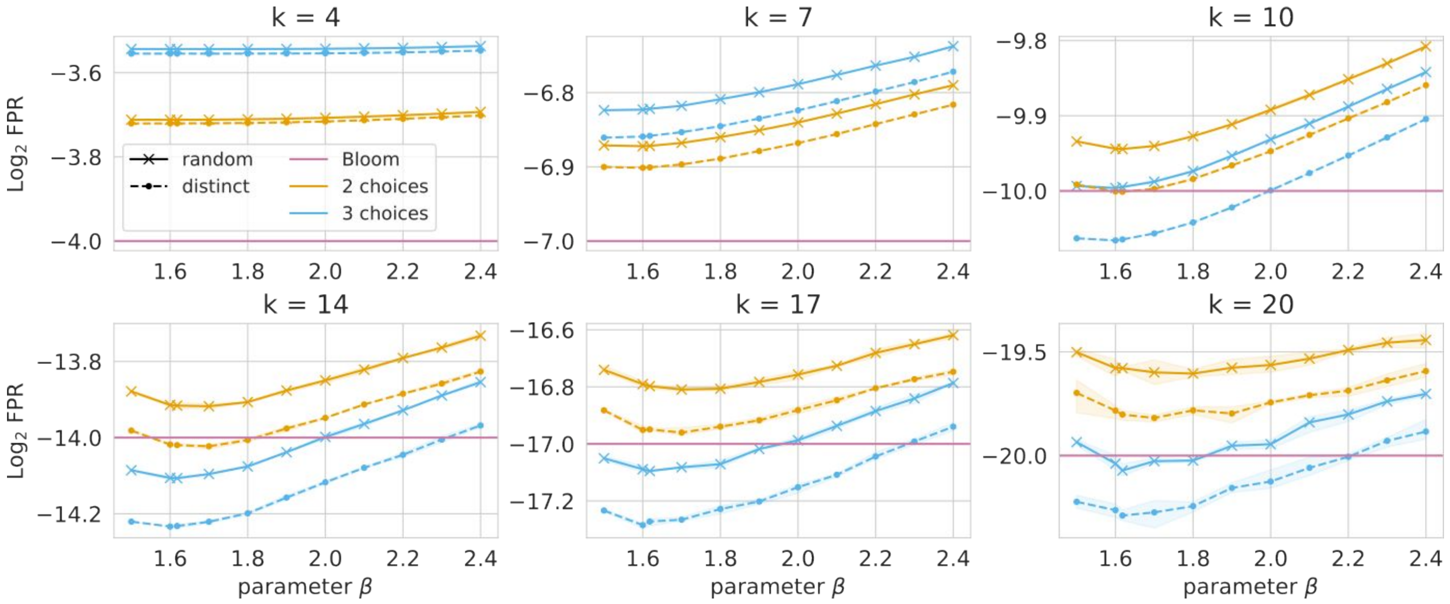

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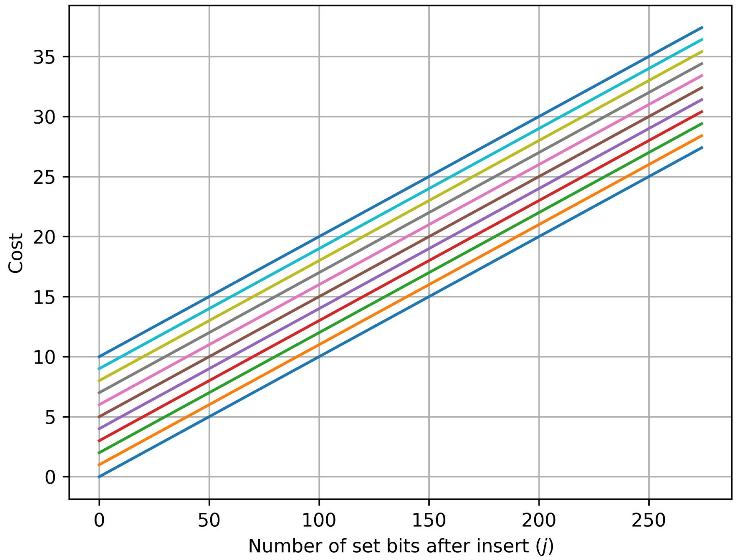

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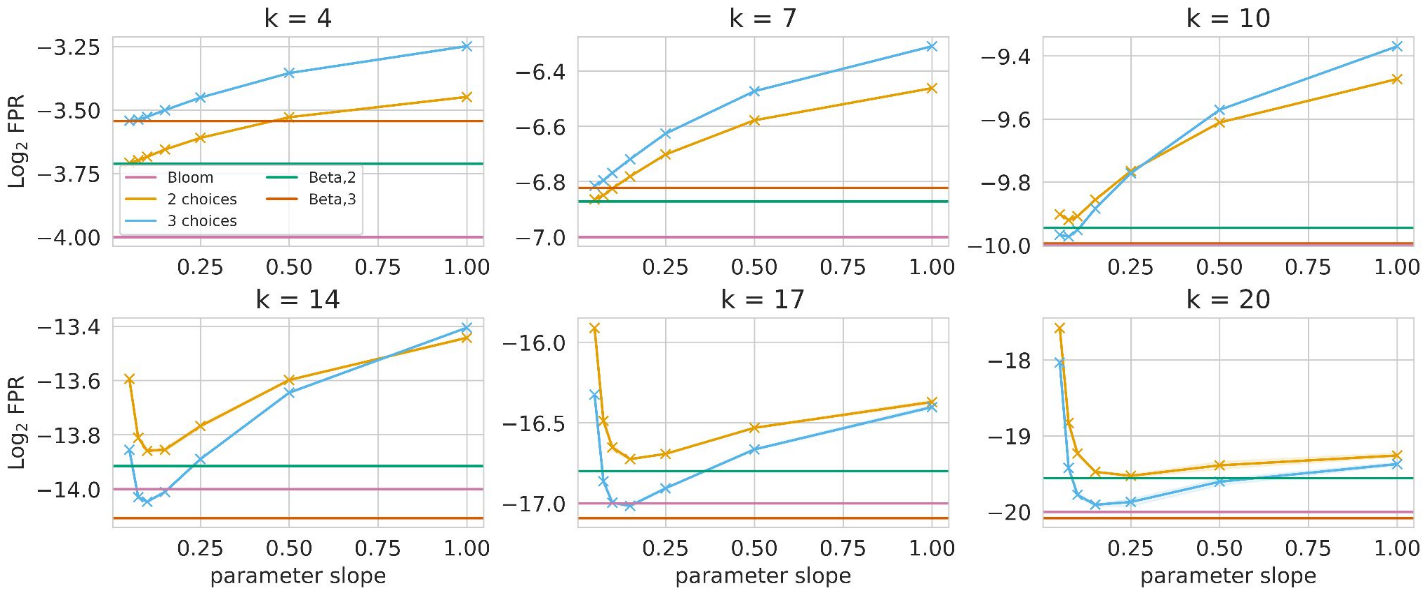
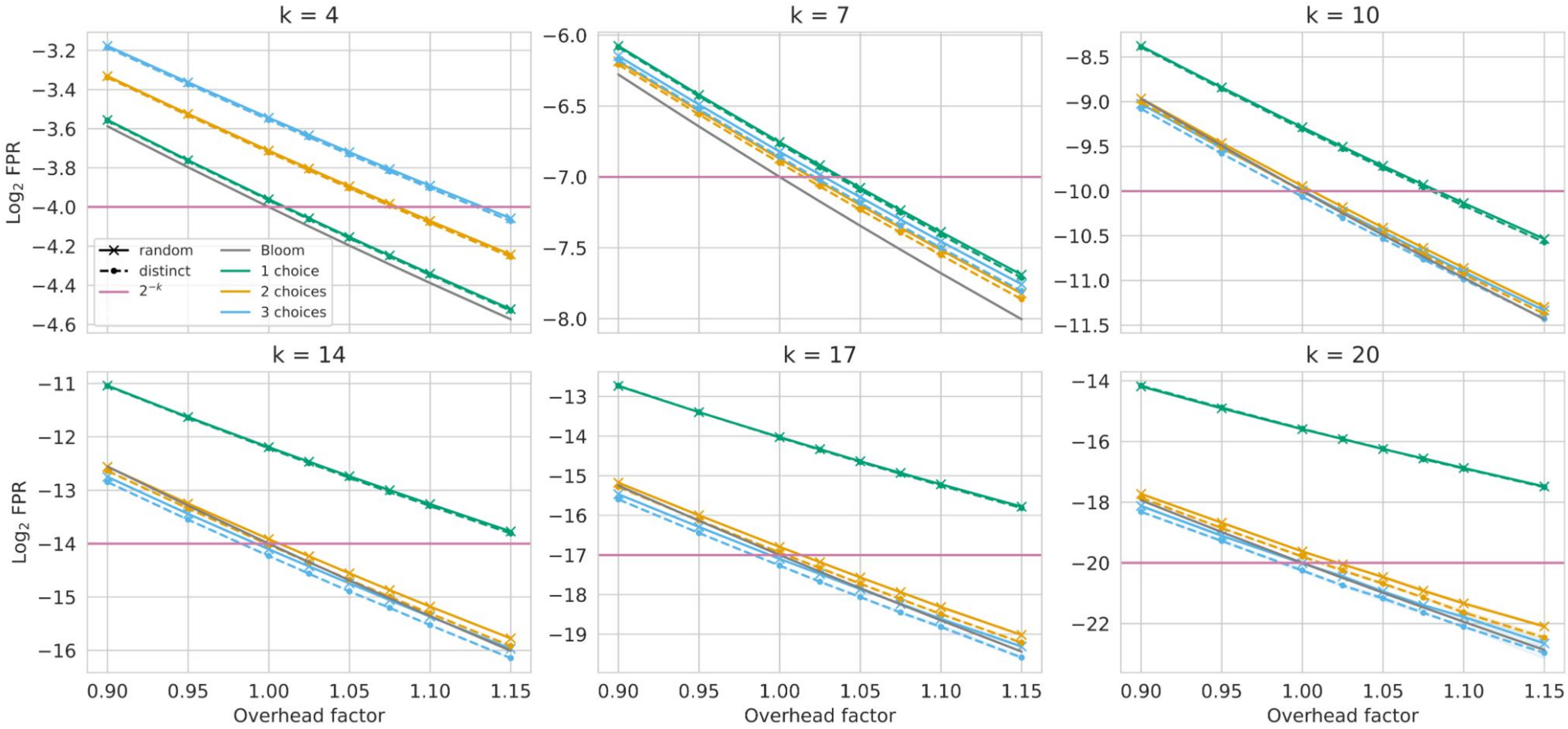
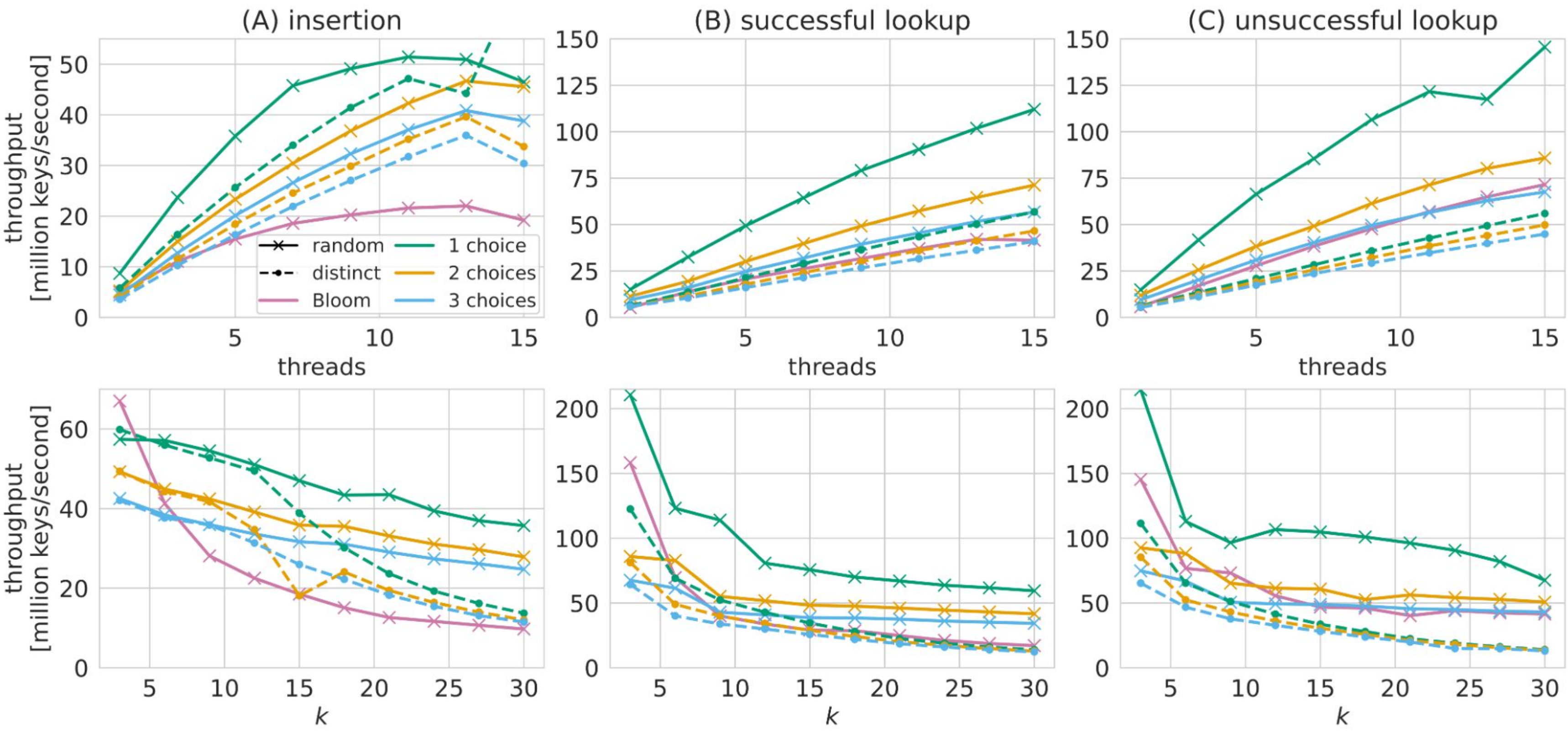


Overhead (Exp. Cost function)



Running times (Exp. Cost function)



Summary

Blocked Bloom filters with choices:

- Same space overhead as normal Bloom filters
- Better FPR than Blocked Bloom filters.
- Better FPR than normal Bloom filters using exponential cost function.