Improving Restore Speed for Backup Systems that Use Inline Chunk-Based Deduplication

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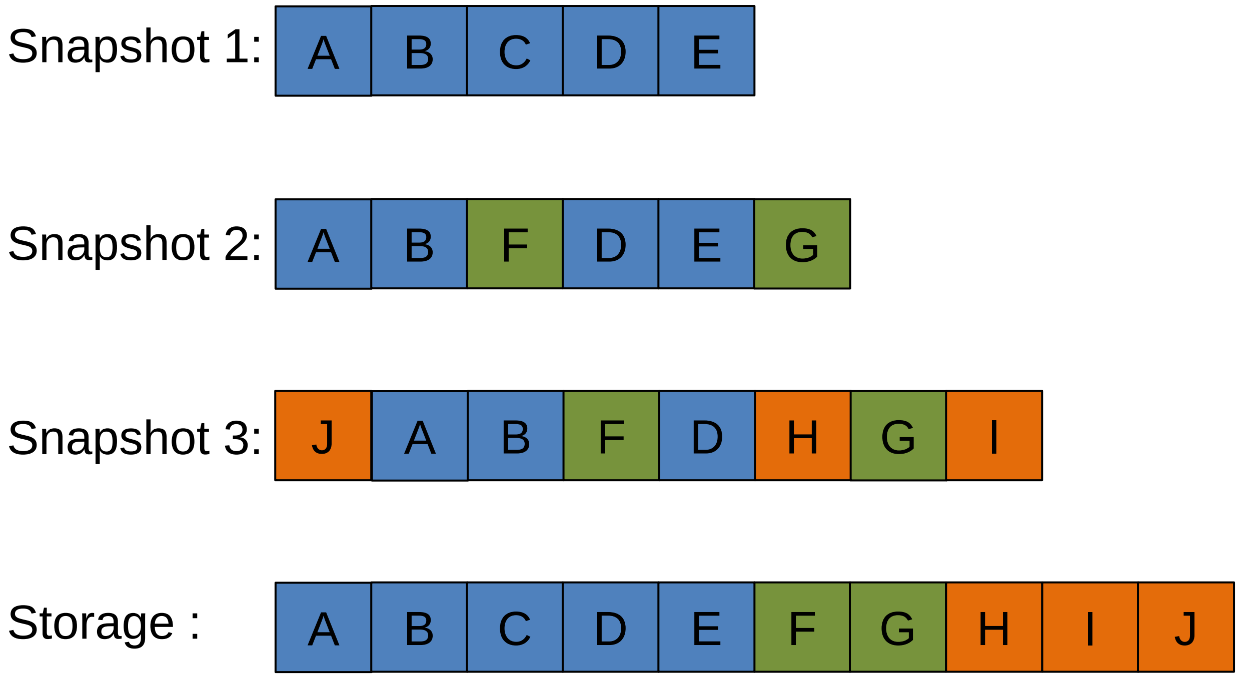
FAST 13

The Problem

- Slow restore performance due to chunk fragmentation
  - Store chunks according to the order of appearance of unique chunks
  - Restore the newer snapshot, the more random reads, the lower the performance



The Problem

- Solve the problem via defragment data periodically?
- No layout makes most backups restore fast
  - Backups disagree about optimal order of chunks (MFDedup[FAST'21])
  - Could focus on last week's backups (RevDedup[APSYS'13])
- Rearranging chunks is expensive
  - Example: keep last snapshot's chunks in order
- This work: improve speed without rearranging data

Measuring Fragmentation & Restore Speed

- Deduplication storage unit: containers
  - Standard size: 4 MB
  - Observation: reading containers is dominant restore cost (over 80%)
- Measure method: Container read per MB restored
  - Total # of container reads that occur / restored backup size
  - Depends on caching used
  - Uncaptured restore-time variance:
    - Container size is difference
    - File system fragmentation, seek time variance, etc.

Simulating Restoration

- Baseline algorithm:

  For chunk c in backup B:

  Read in c's container C

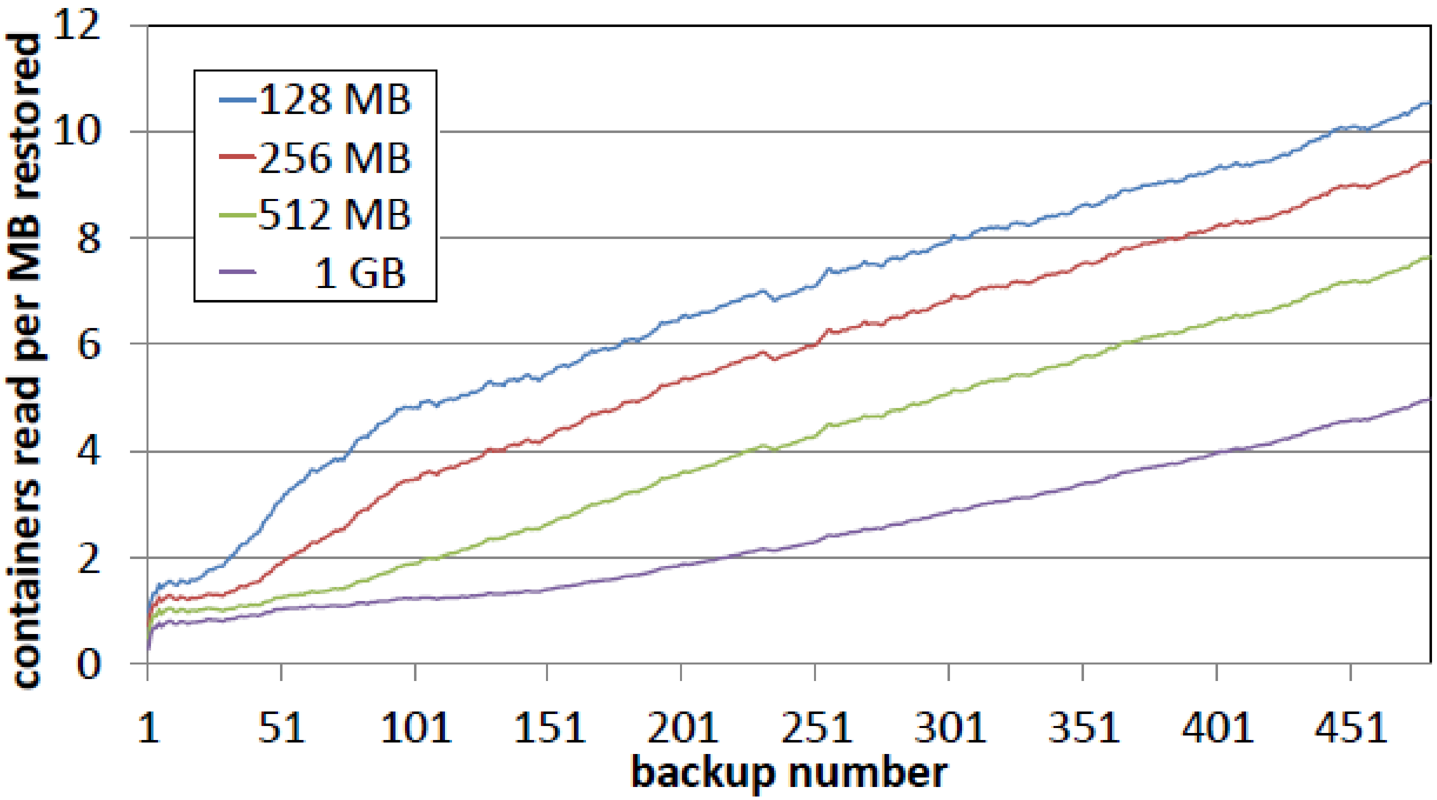
  Extract c's content from C via offset and size

  Send out c's data

- Subtleties:
  - LRU caching (Impact of cache size)
  - Read entire containers: Read speed >> Seek time

Fragmentation Over Time

- The curves are different LRU cache sizes

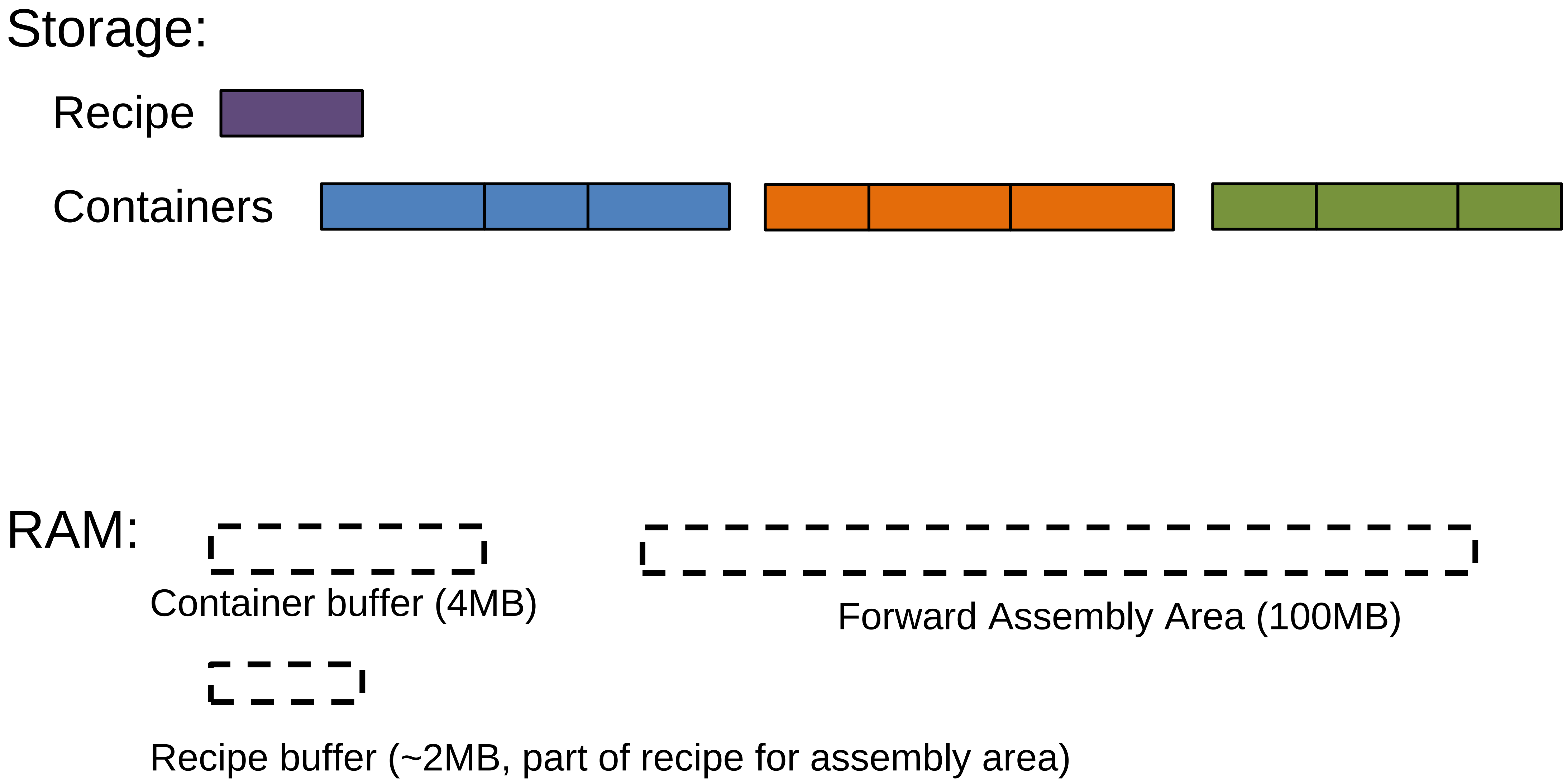


Large caches smooth out small-scale fragmentation

Improving Restore-time Caching

- A new caching method:
  - The forward assembly area method
- Exploits:
  - Perfect knowledge of future accesses
    - Courtesy of the recipe
  - Keeps only needed chunks
- Designed to minimize memory overhead
  - Lots of small variable-sized objects
  - Reduce memory copies

Forward Assembly Area Method



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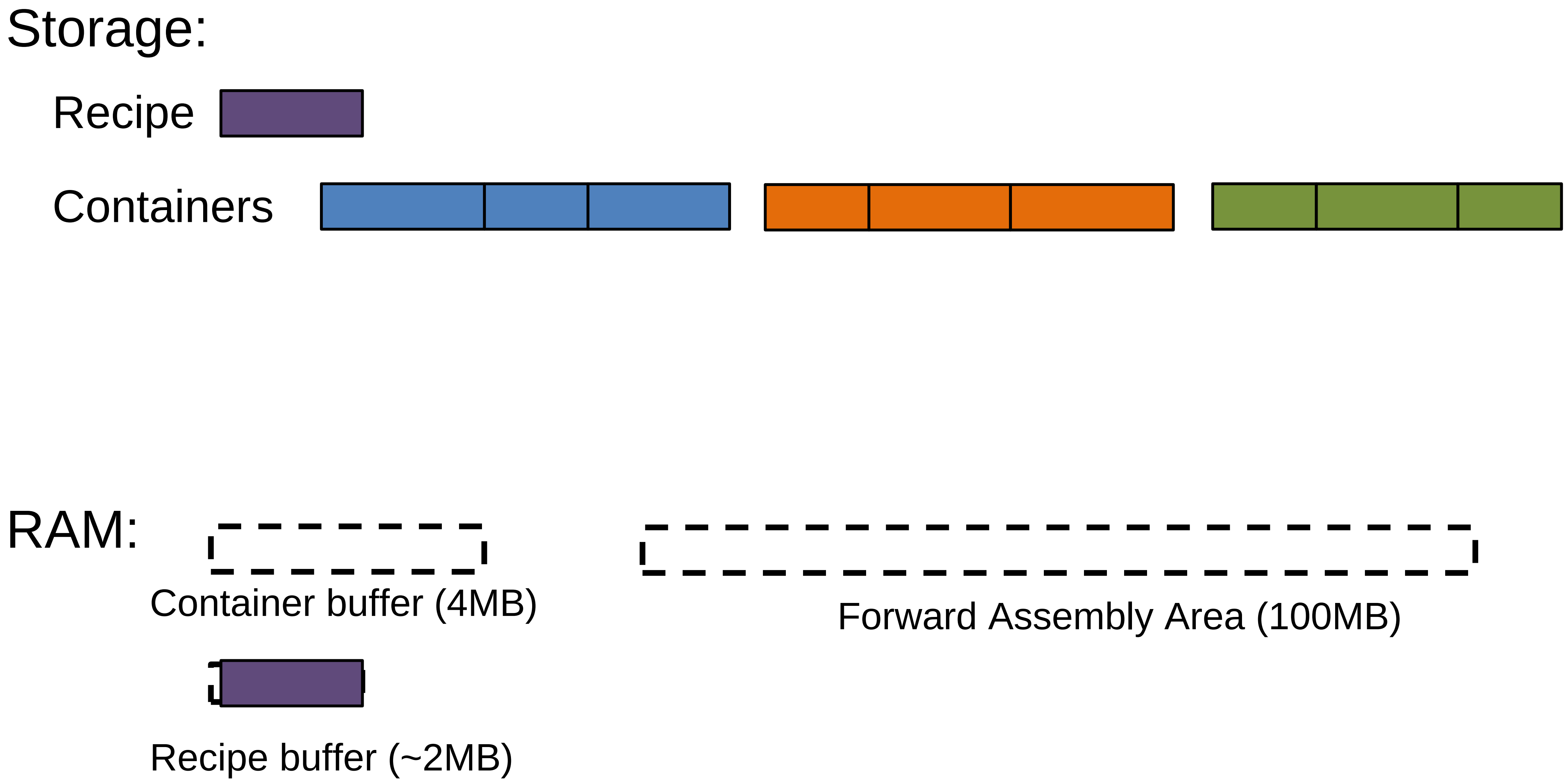

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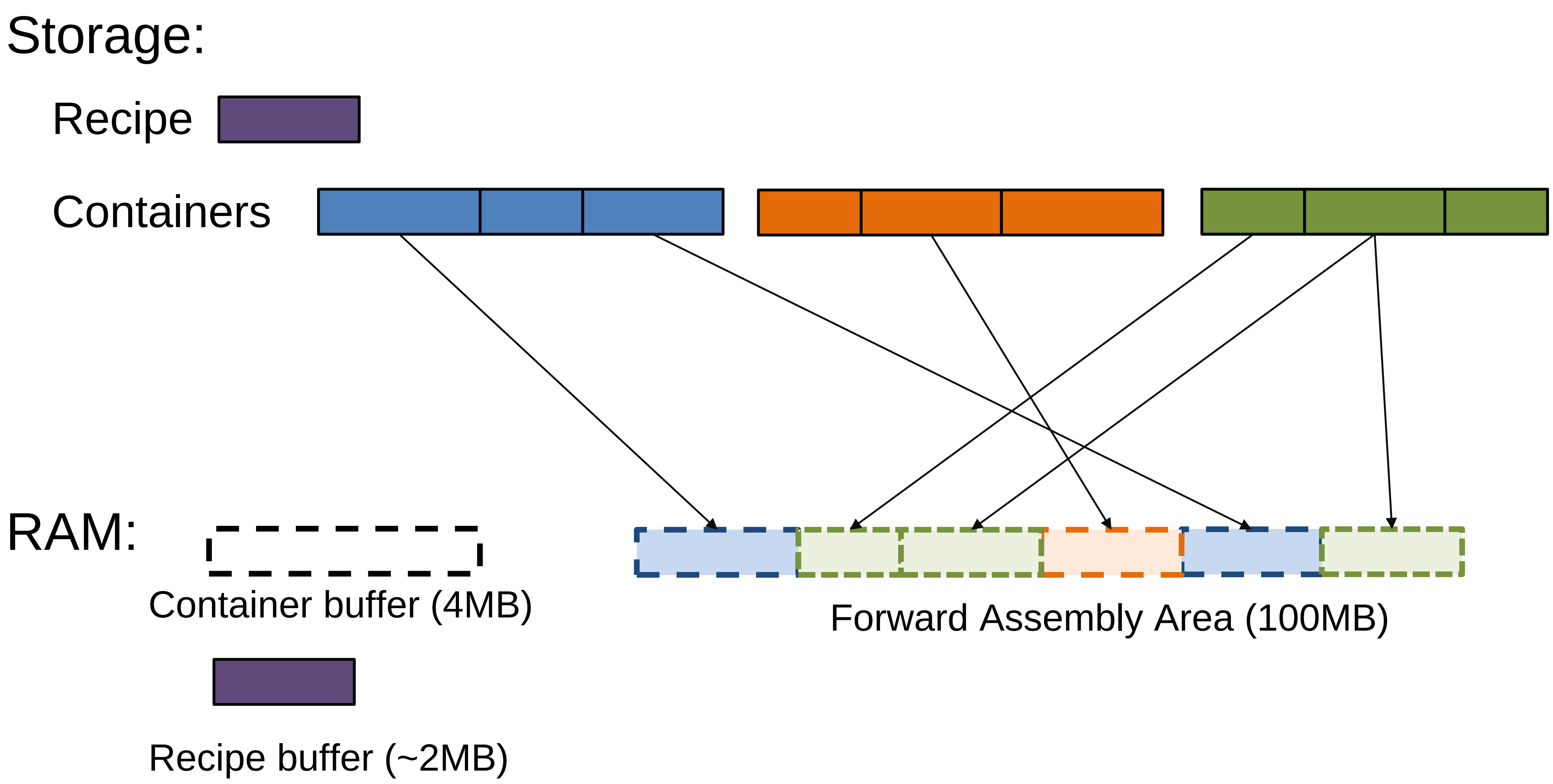

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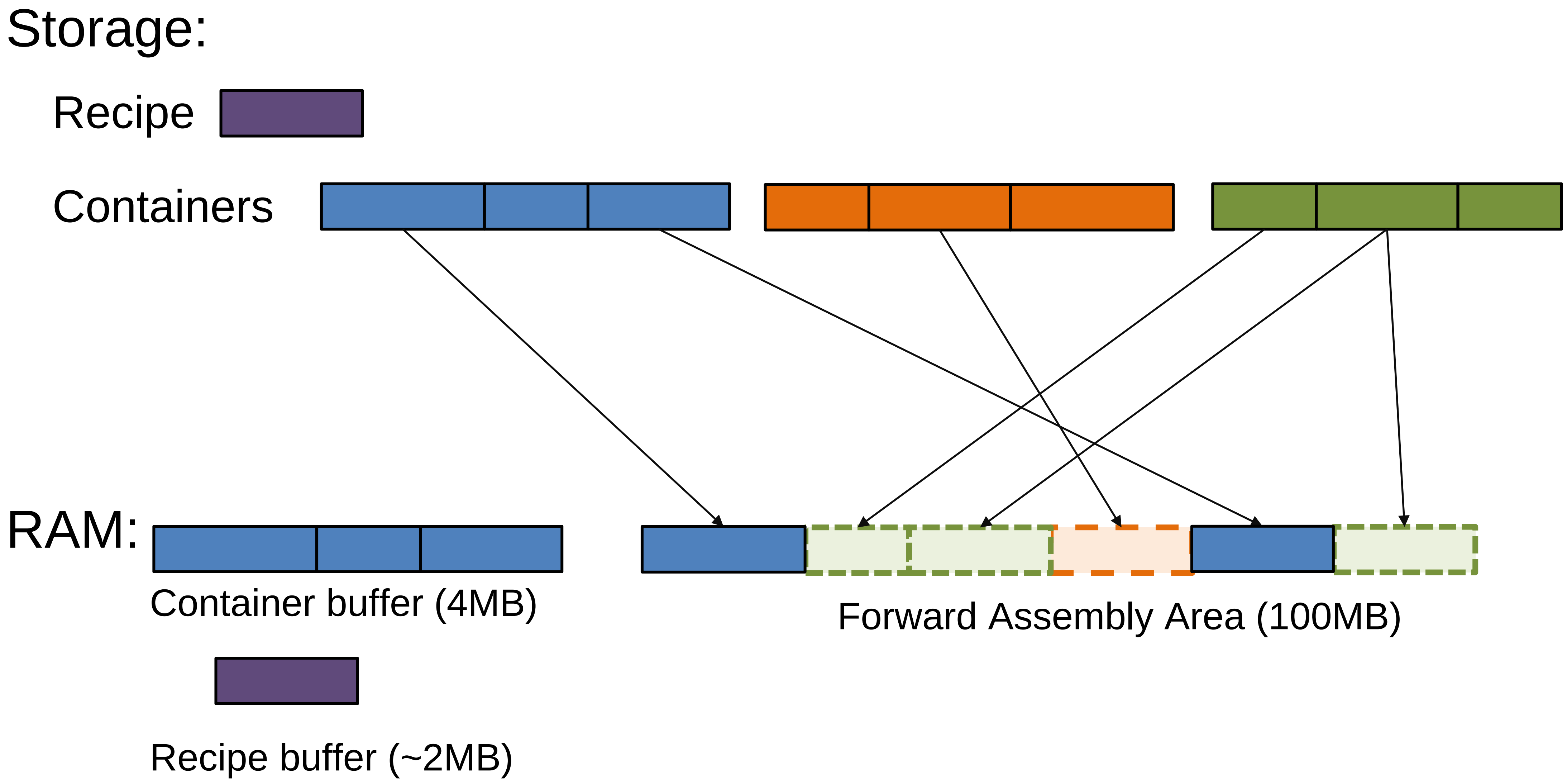

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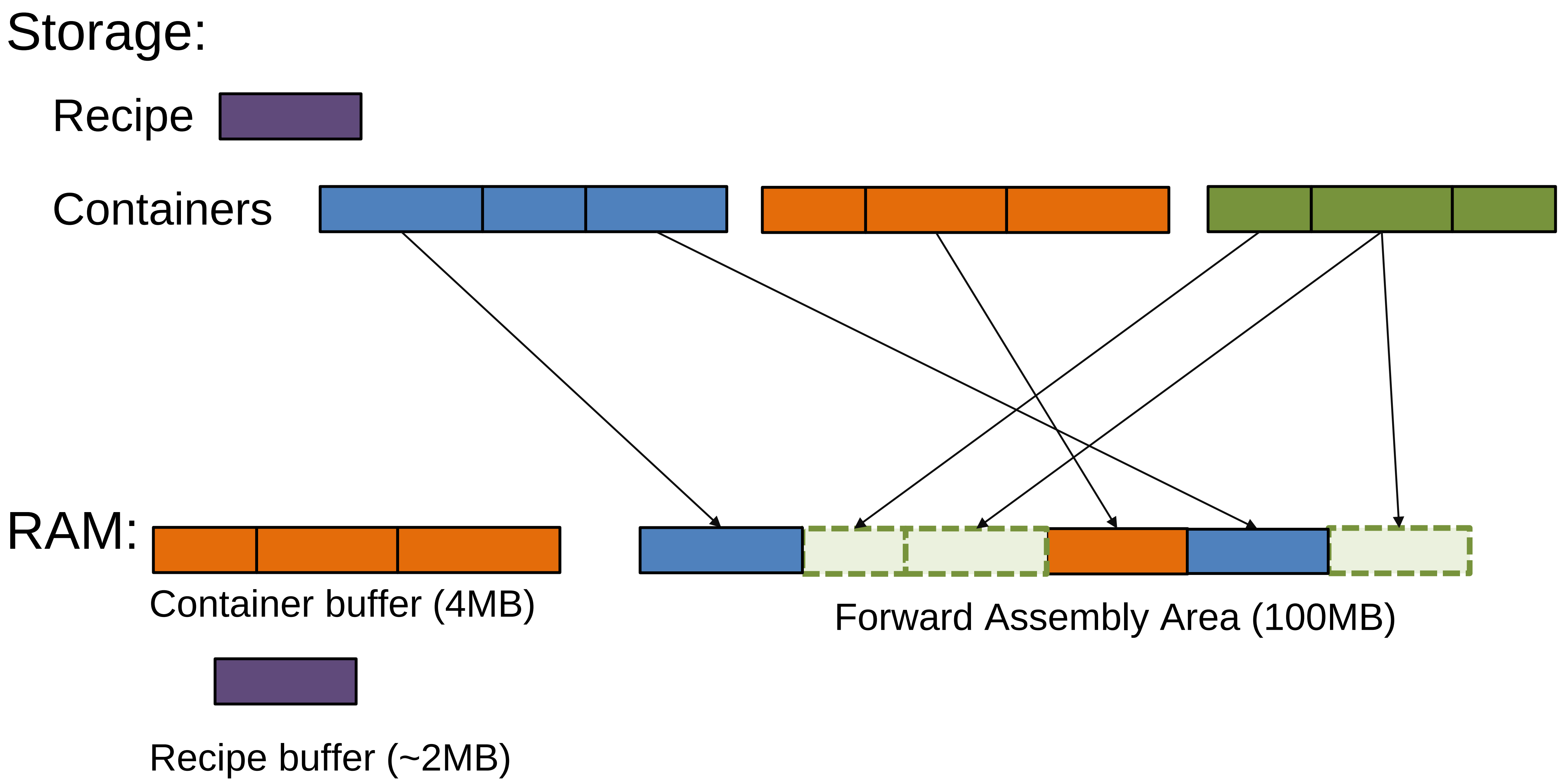

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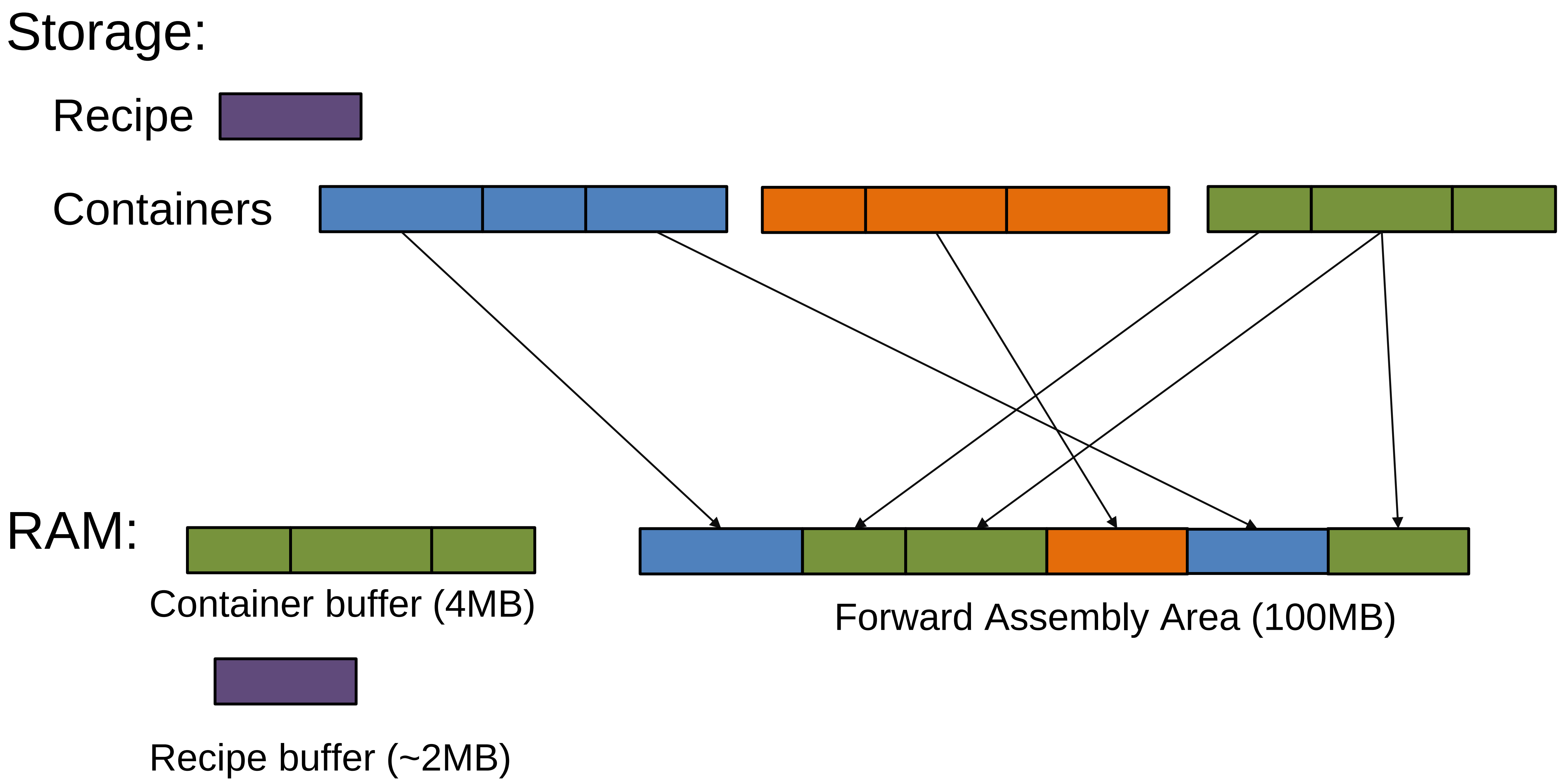
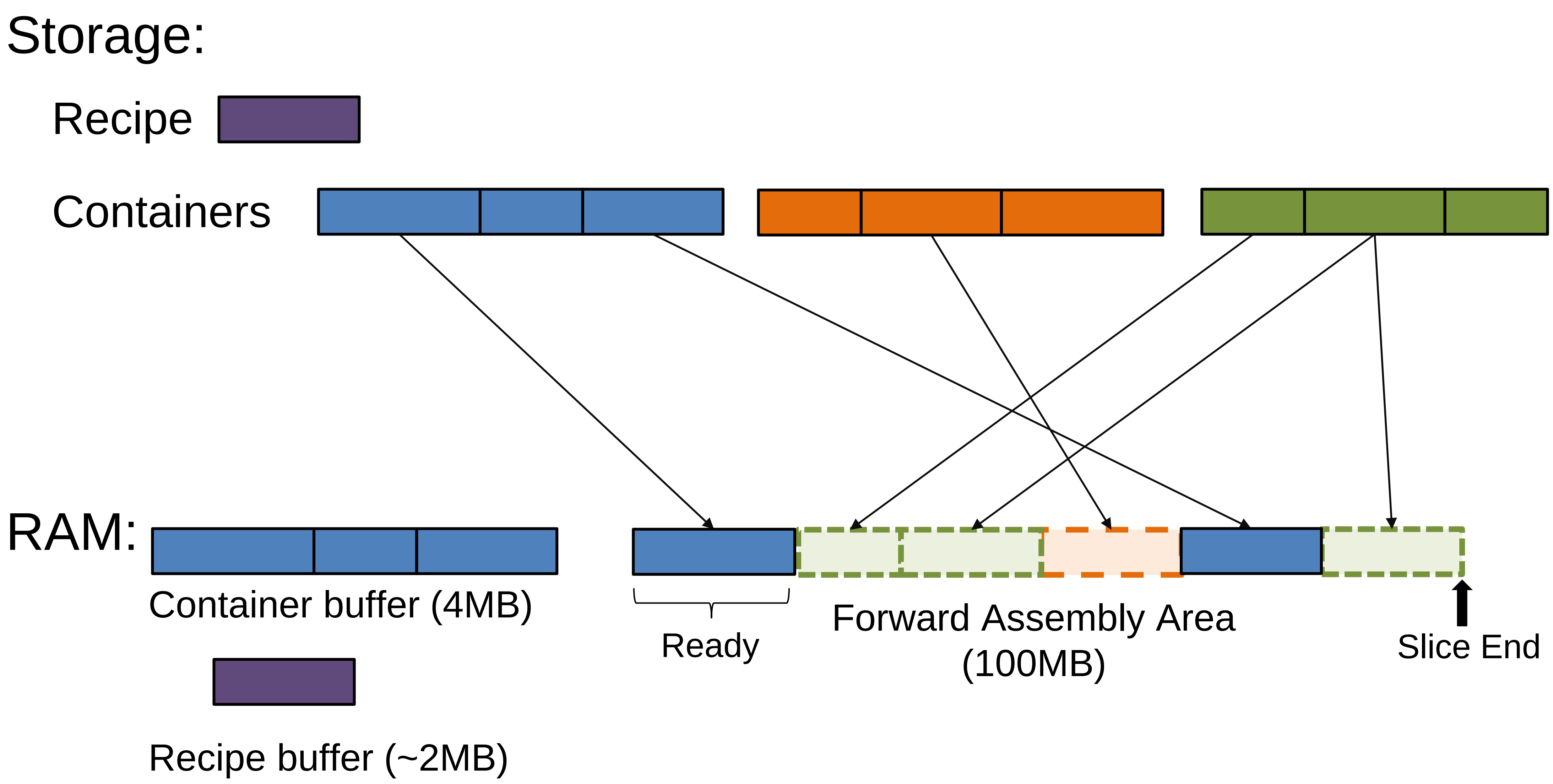


Forward Assembly Area Method

- Cache only needed chunks
  - Load each container once per slice (100 MB)
  - Uses memory more efficiently
- Moves chunks directly into position
  - No intermediate storage or extra copies
- Better rolling approach
  - A ring-buffer based approach,
  - Send out the continuous filled-in part at the (logical) start of the forward assembly area and then rotate the ring buffer.
  - Not need to reloads around slice boundaries

Forward Assembly Area Rolling Method



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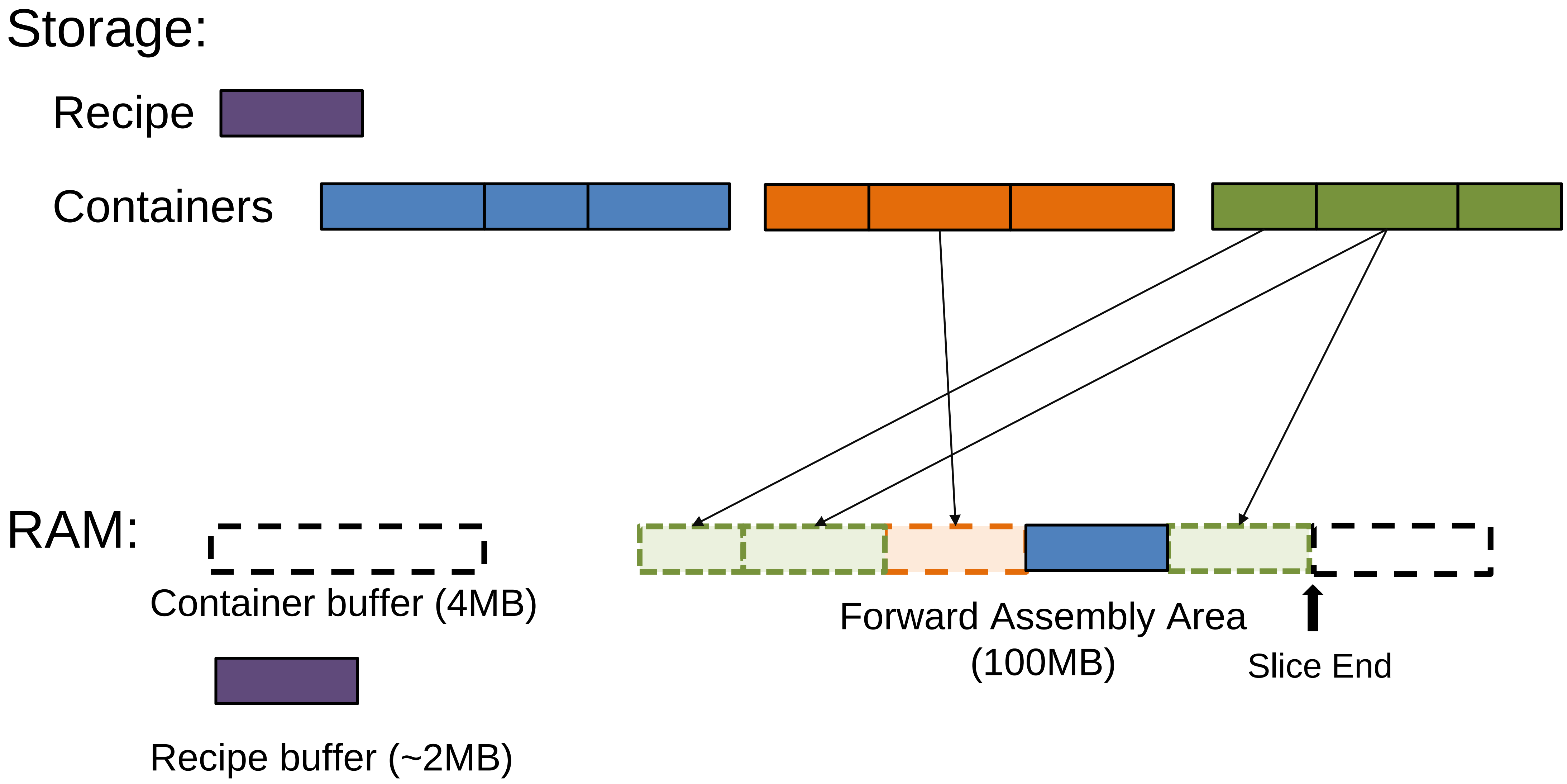

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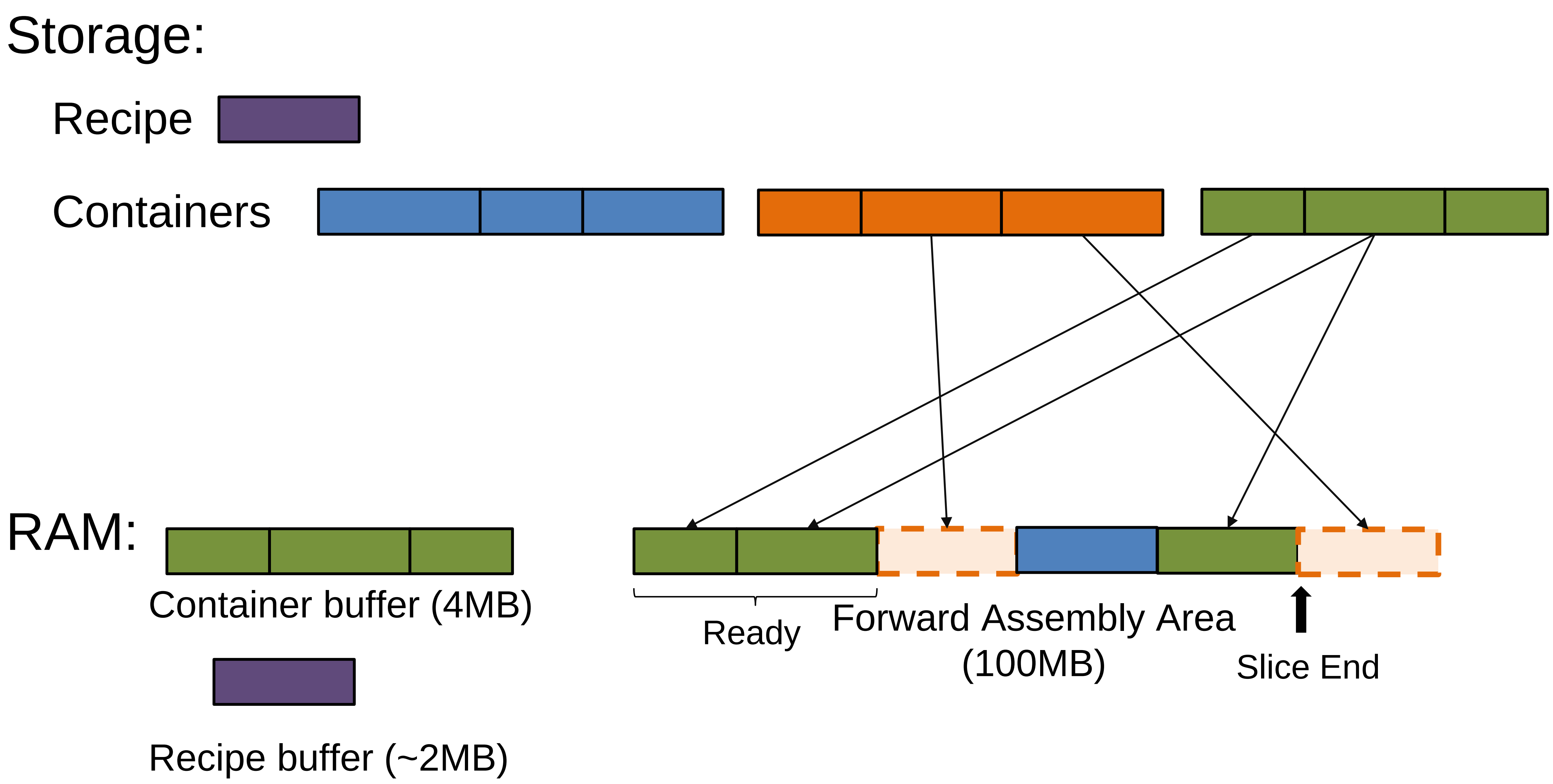

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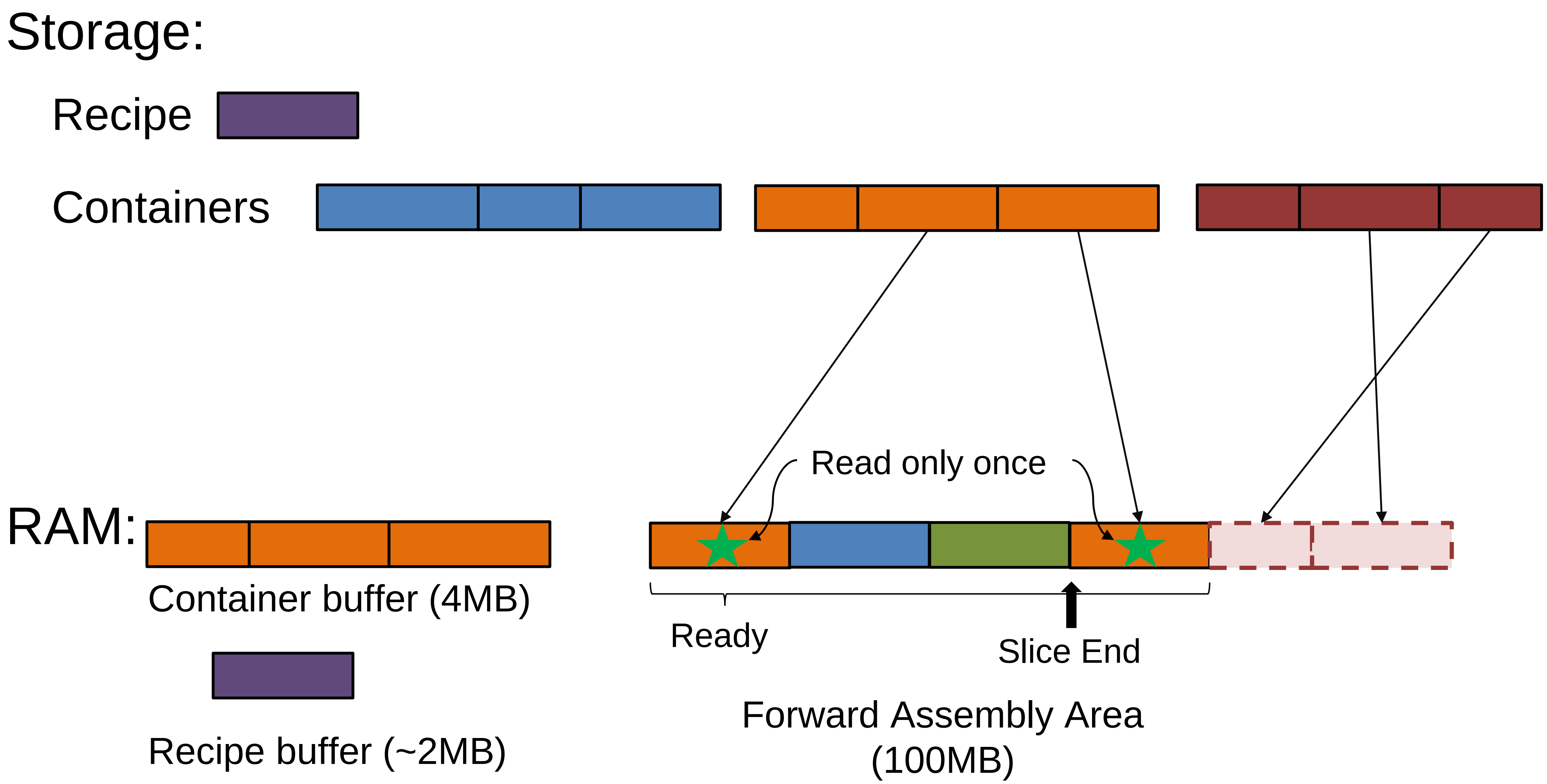
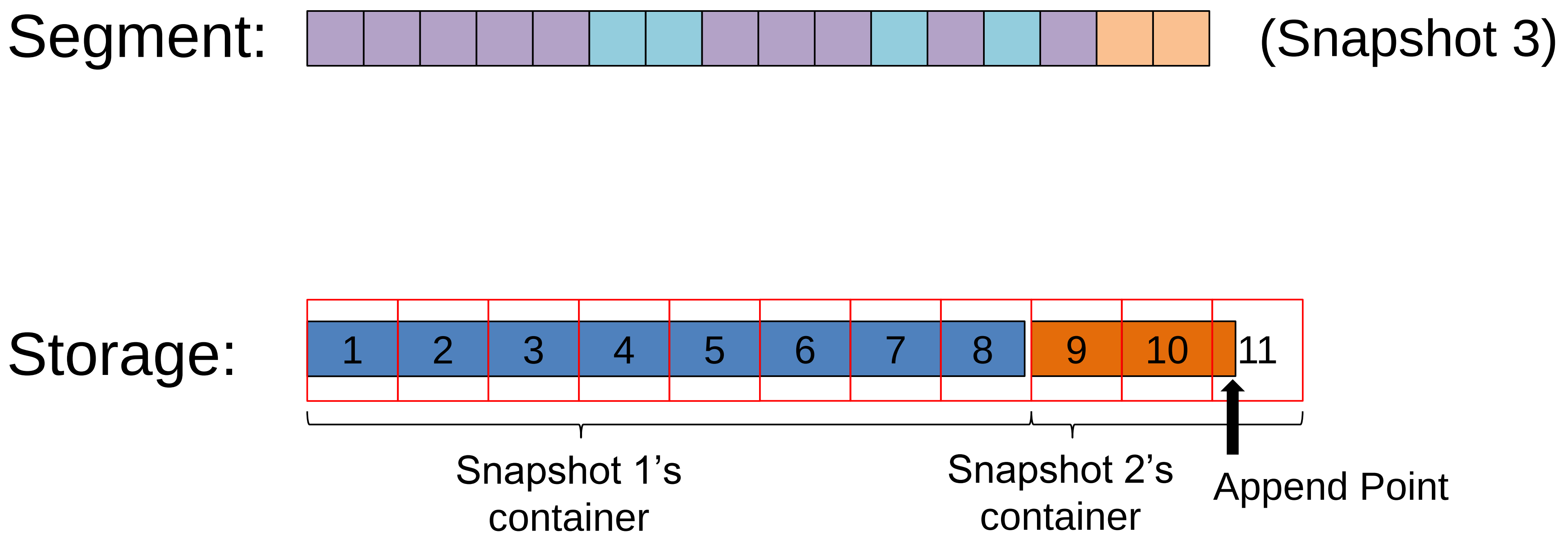


Limiting Fragmentation by Reducing Deduplication

- Goal: bound containers read per MB ingested
  - Guarantees minimal restore speed
- The capping method
  - Break input into 20 MB segments
  - Deduplicate segment against at most T containers
  - Limits fragmentation to (T+5)/20MB
    - Here we use 4 MB container, 5 = 20 MB/4MB (That is, the effective T=0 situation)
  - Minimize chunks duplicating by using best T containers
    - Select T according to the number of duplicate chunks contained in each container

Container Capping



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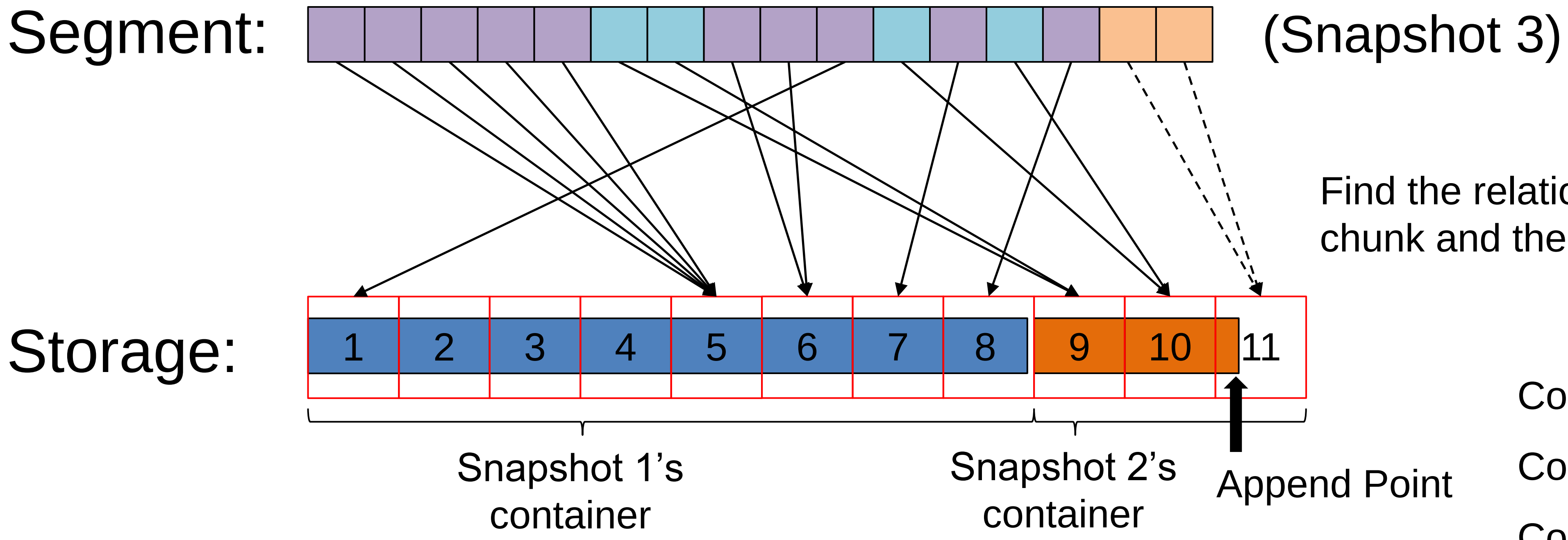


Find the relationship between each chunk and the stored containers

Container ID : Number

Container 5: 5

Container 6: 2

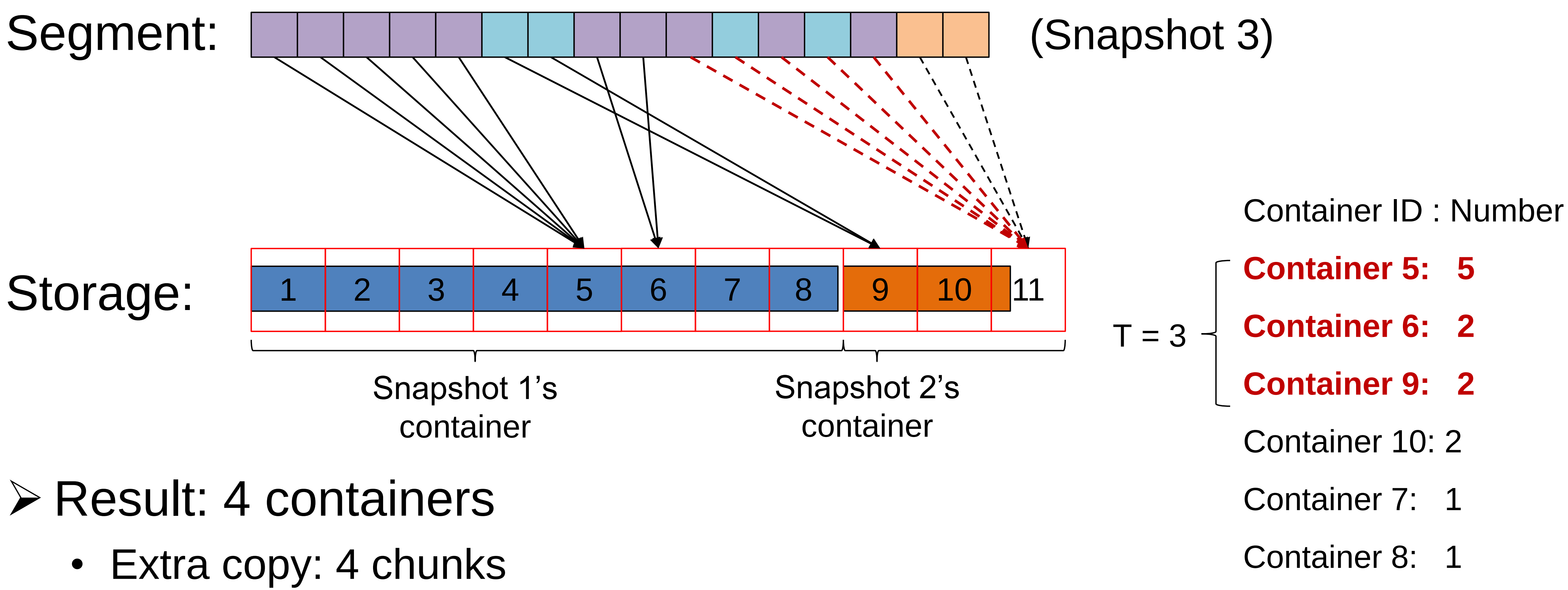
Container 9: 2

Container 10: 2

Container 7: 1

Container 8: 1

Container Capping



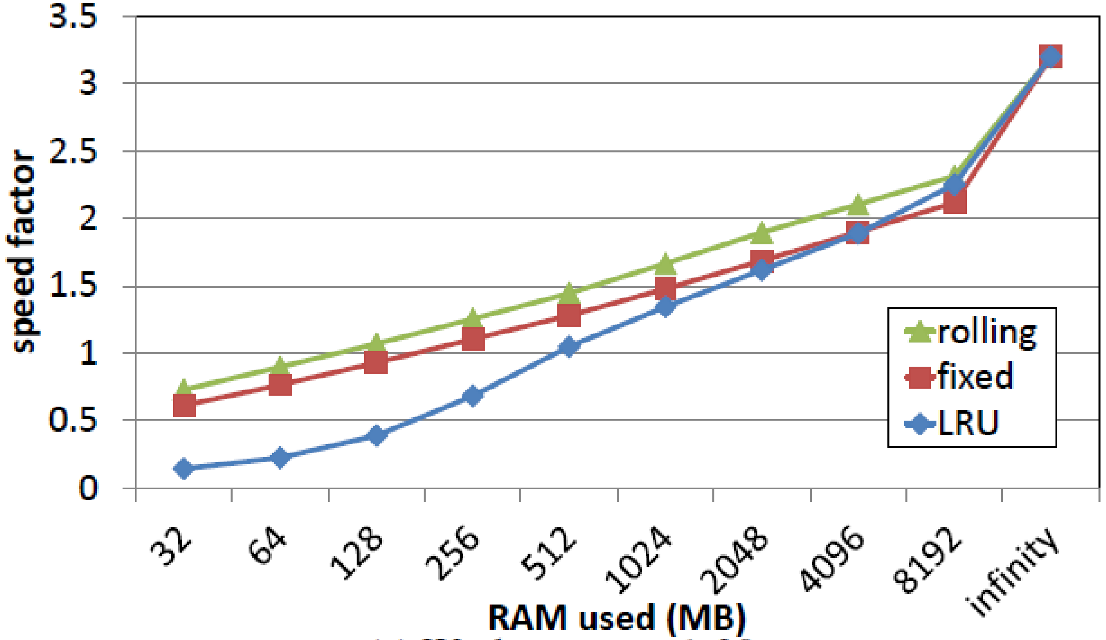
- Result: 4 containers
  - Extra copy: 4 chunks
  - No capping: restore need to access 8 containers

Evaluation

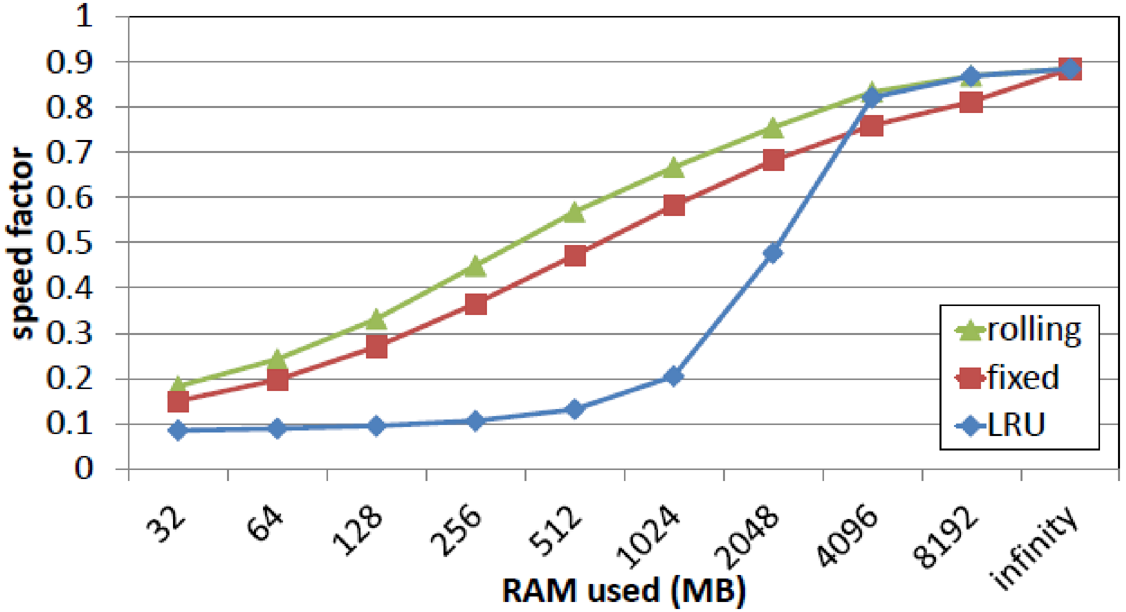
- Glossary:
  - Speed factor: 1/ container read per MB
  - Deduplication factor: logic size / stored size
- Dataset:
  - 2year 212 TB
    - Created based on HP customer data (10 GB snapshot), modify 2% of files by overwriting 10%, and add 200 MB data for each day.
    - 1 full + 4 incrementals per week for 2 years (480 backups)
    - ~4KB mean-size chunks
  - Workgroup 3.8 TB
    - Backups of 20 desktop PCs for 91 days.

Evaluation

- Assembly vs. LRU
  - The bigger the speed factor, the better



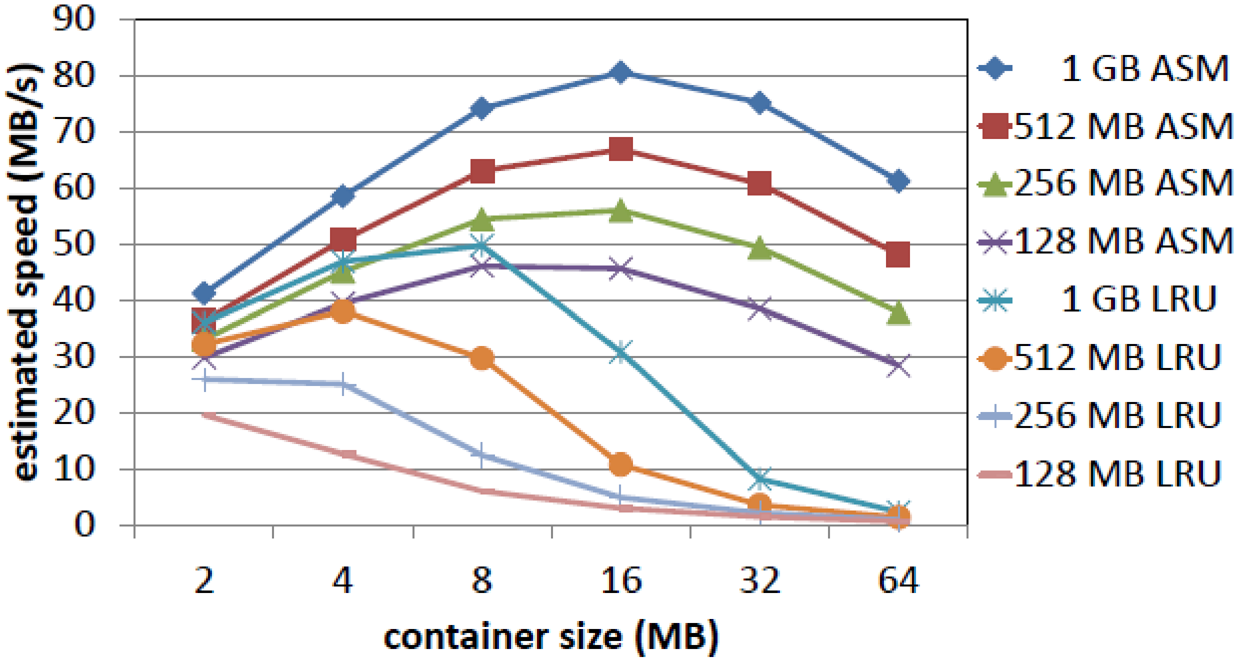
(a) Workgroup-cycle30



(b) 2year-cycle30

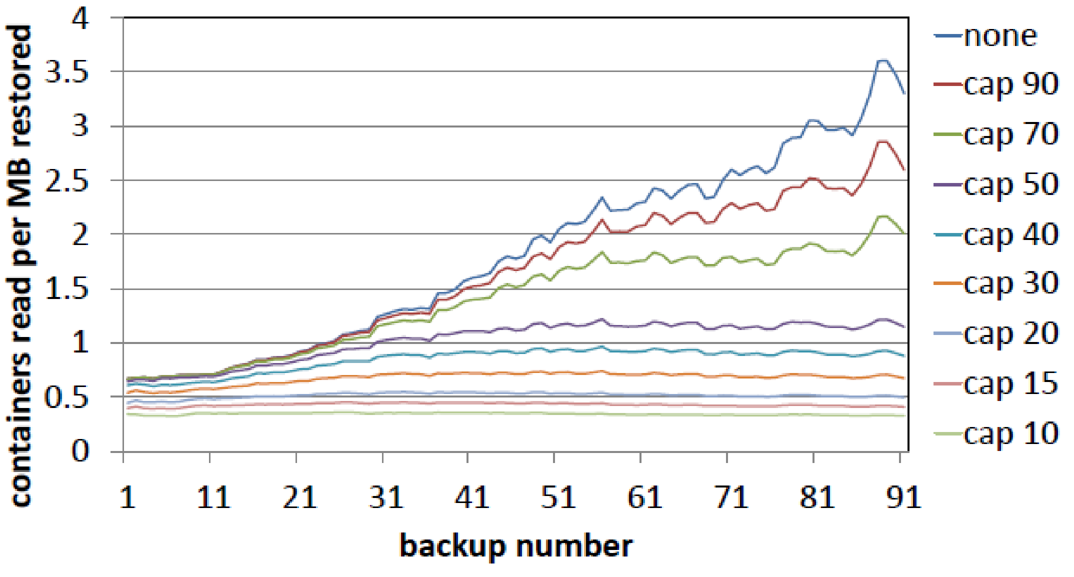
Evaluation

- Estimated speed for a sample system as container size is varied
  - Workgroup-cycle30
  - 4 cache sizes and assembly (rolling) and caching
  - Assume system reads at 1000 MB/s and opens a container in 20 ms
  - All containers were assumed to be full.
  - LRU collapses as container size grows



Evaluation

- Effect of varying capping level on fragmentation



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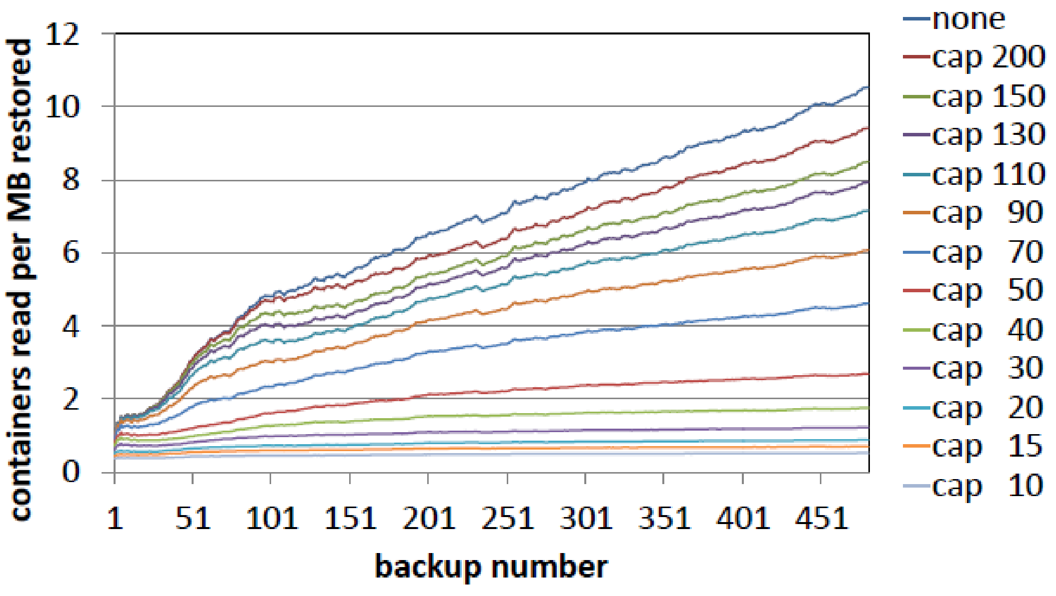
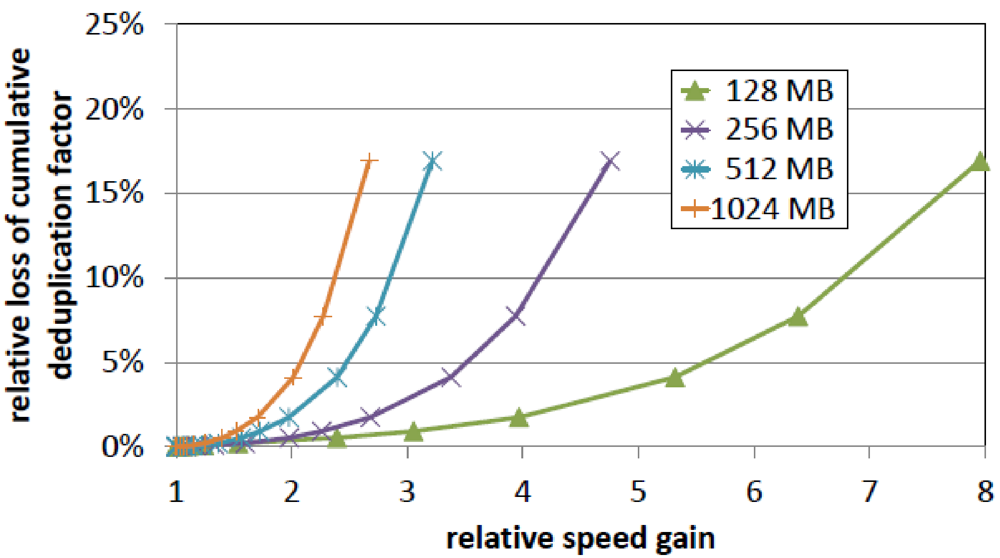


(b) 2year-cycle30

Evaluation

- Relative deduplication loss versus relative speed gain as a result of capping
  - T = 10, 15, 20, 30, 40, 50, 70, 90, 110, 130, 150, 200, 250, none



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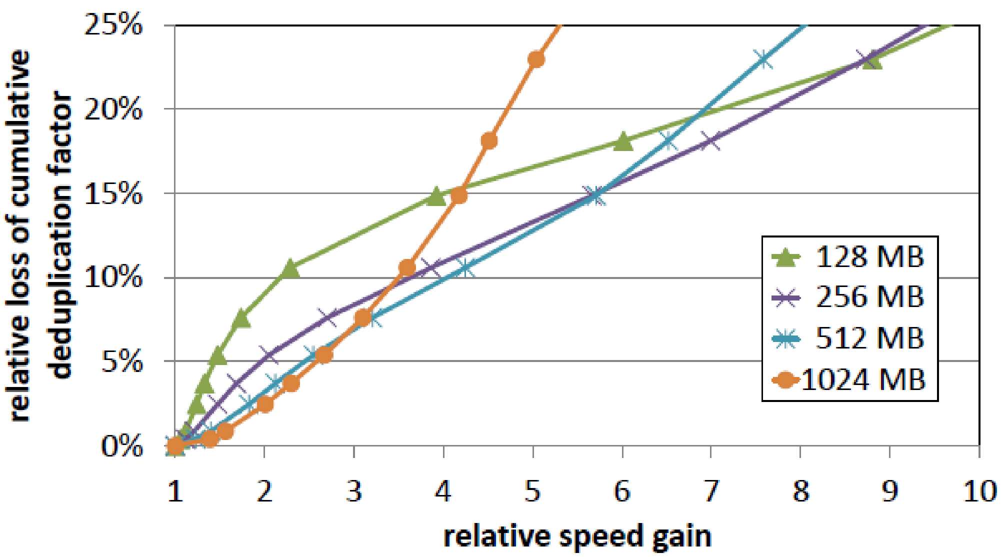
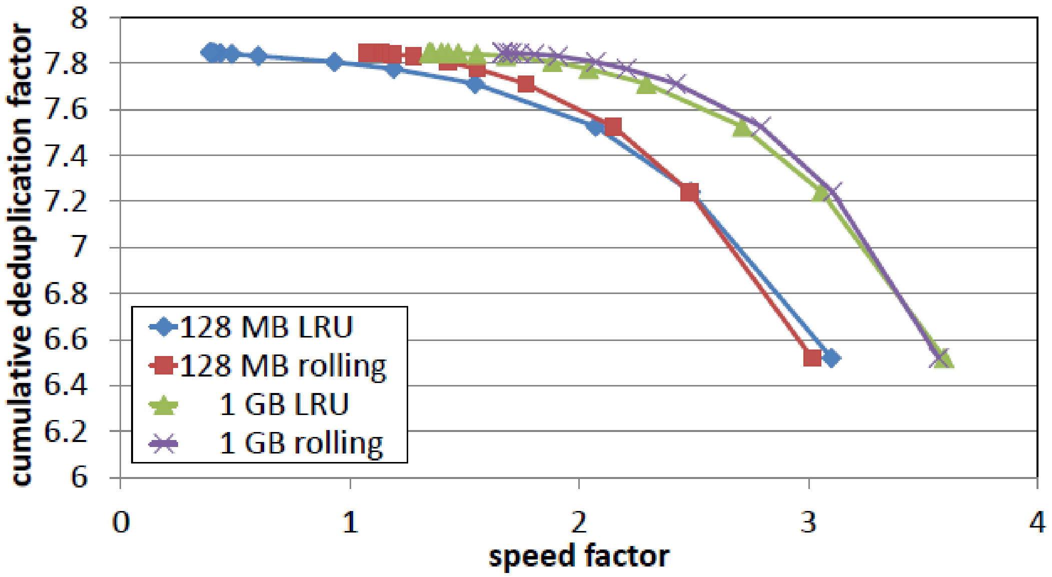


(b) 2year-cycle30

Evaluation

- Comparing deduplication and speed as capping level varies between LRU and assembly
  - T = 10, 15, 20, 30, 40, 50, 70, 90, 110, 130, 150, 200, 250, none



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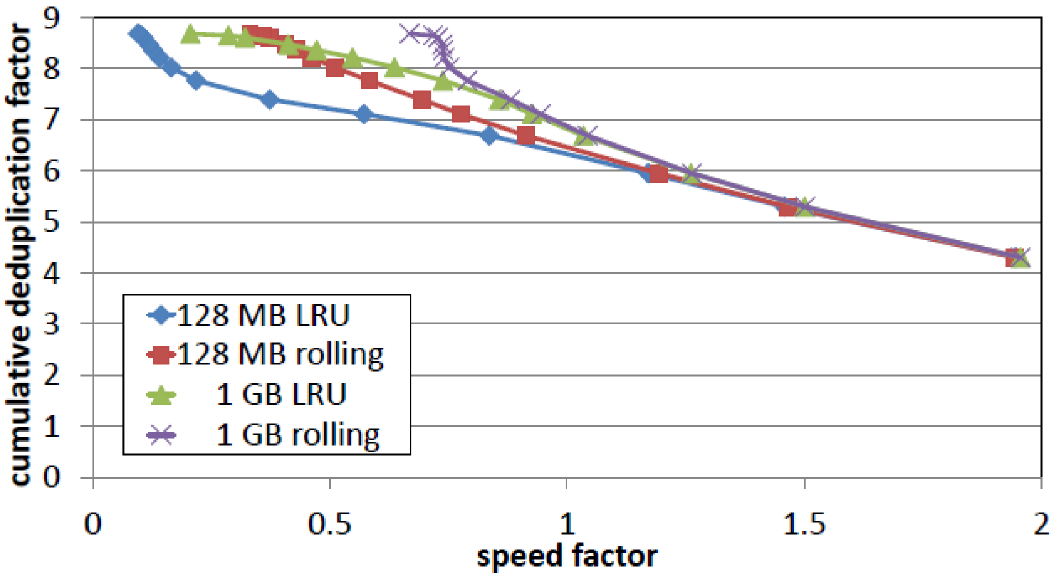

(b) 2year-cycle30

Conclusion

- Fragment analysis:
  - Reading containers is dominant restore cost
  - Measure fragment by container read per MB
- Caching: Reduce seeks through better caching
  - Forward assembly area
  - Load each container once per slice (100 MB)
- Capping: Limiting fragmentation by reducing deduplication
  - Deduplicate segment against at most T containers
  - Bound containers read per MB ingested