SSDAlloc: Hybrid SSD/RAM Memory Management Made Easy

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Memory in Networked Systems

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  - Memcache like tools
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- As an index to reduce pressure on the disk
  - Indexes for proxy caches, WAN accelerators and inline data-deduplicators
  - Help avoid false positives and use the disk effectively

Problem: Memory Density

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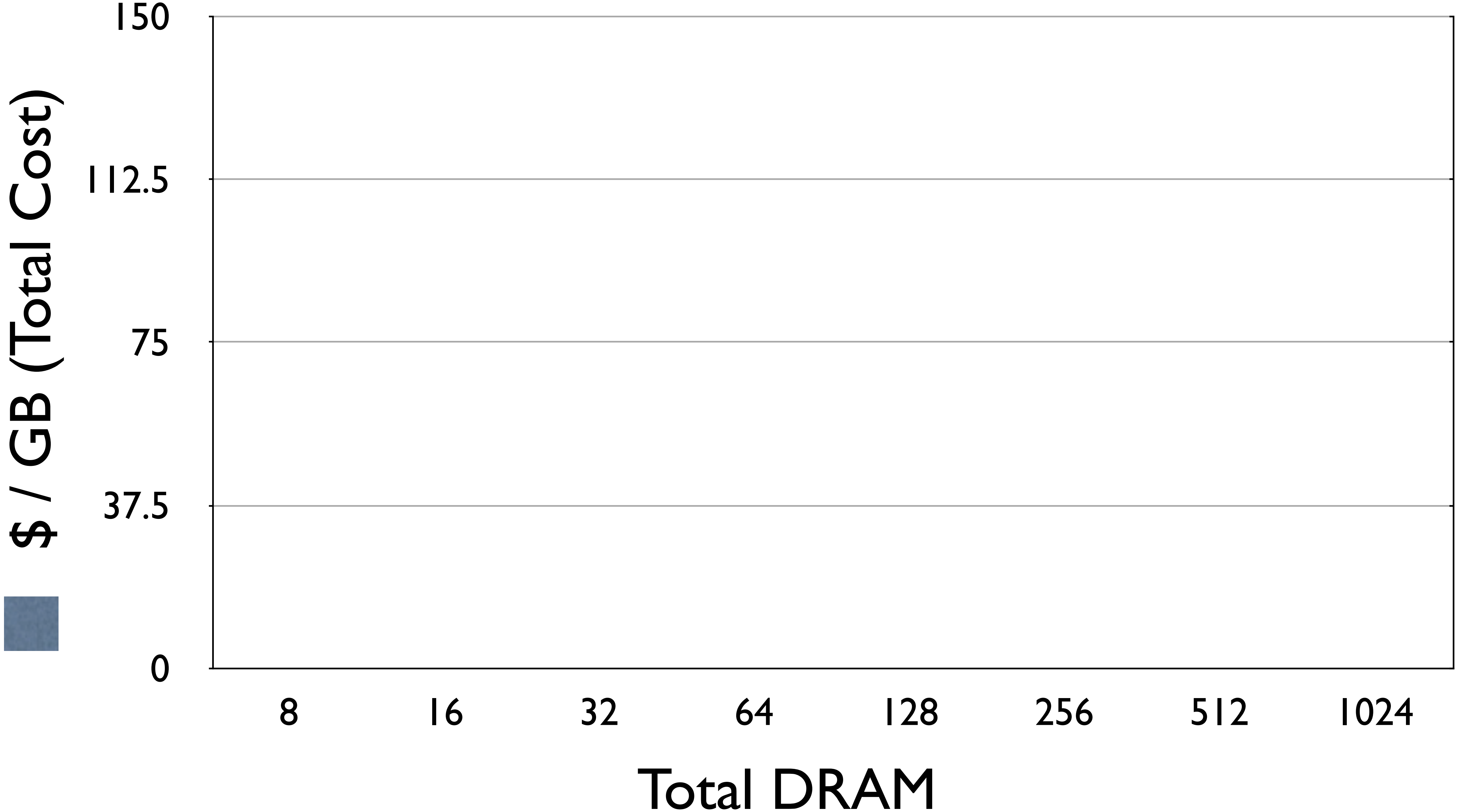

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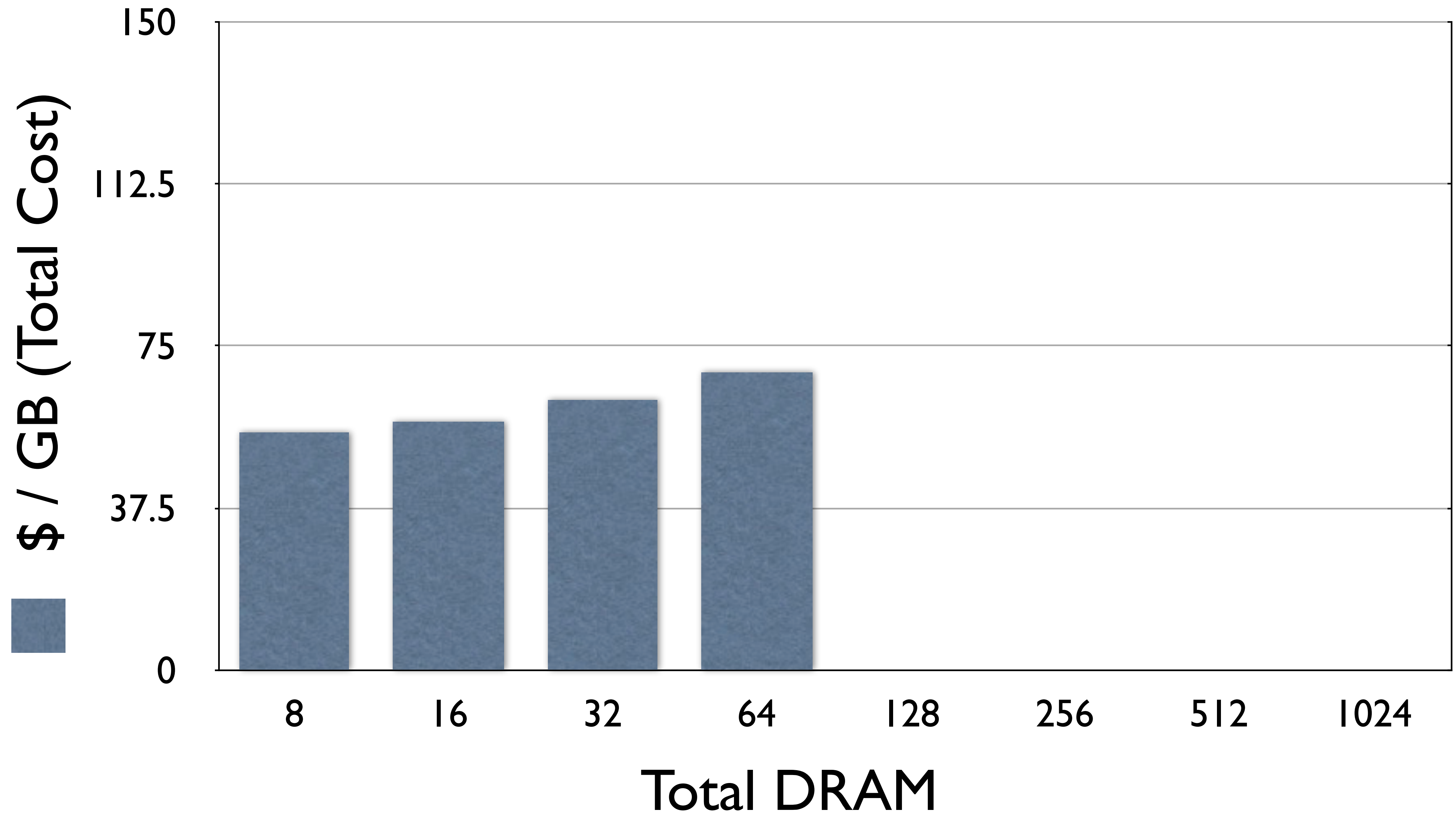

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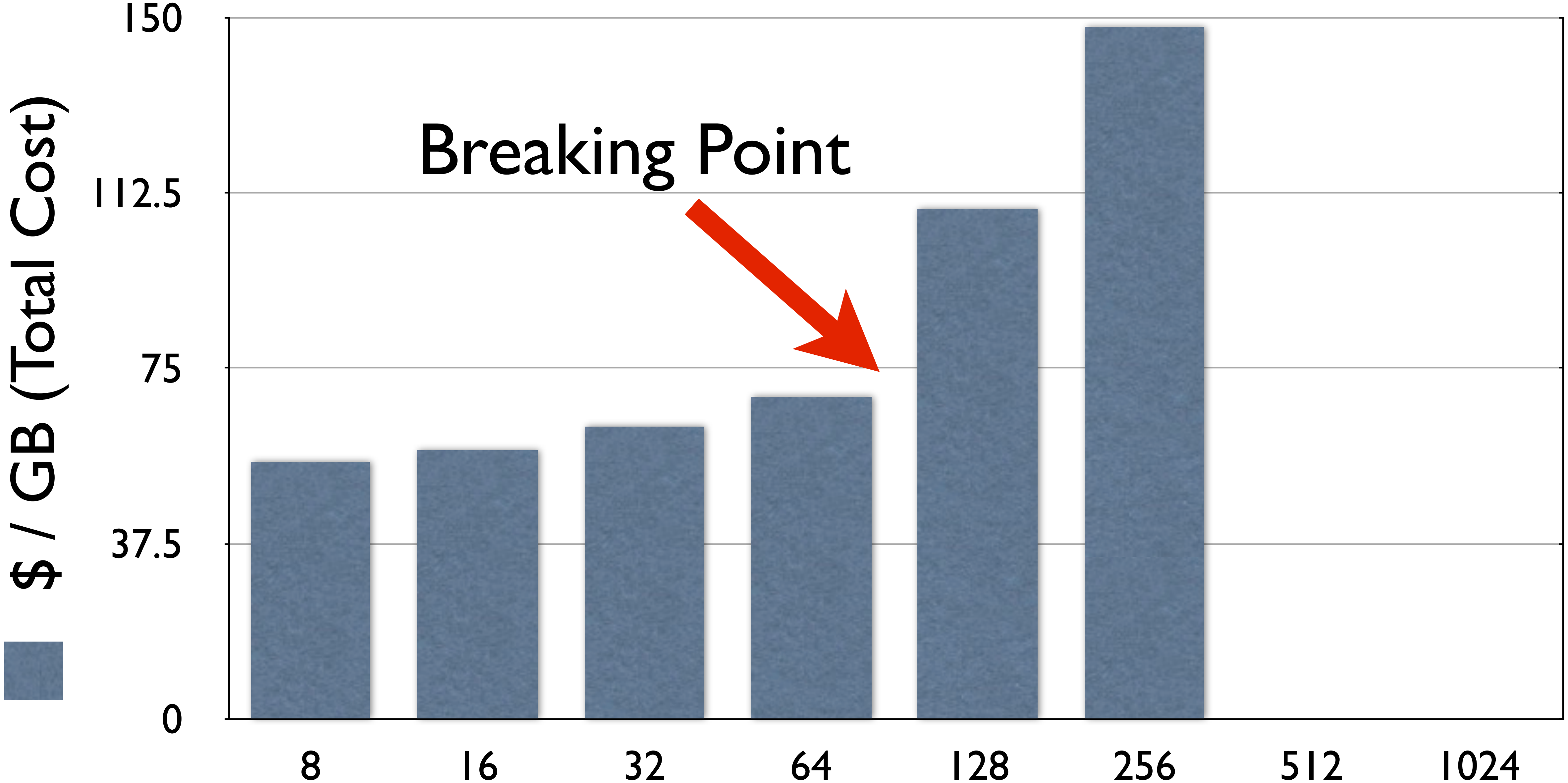

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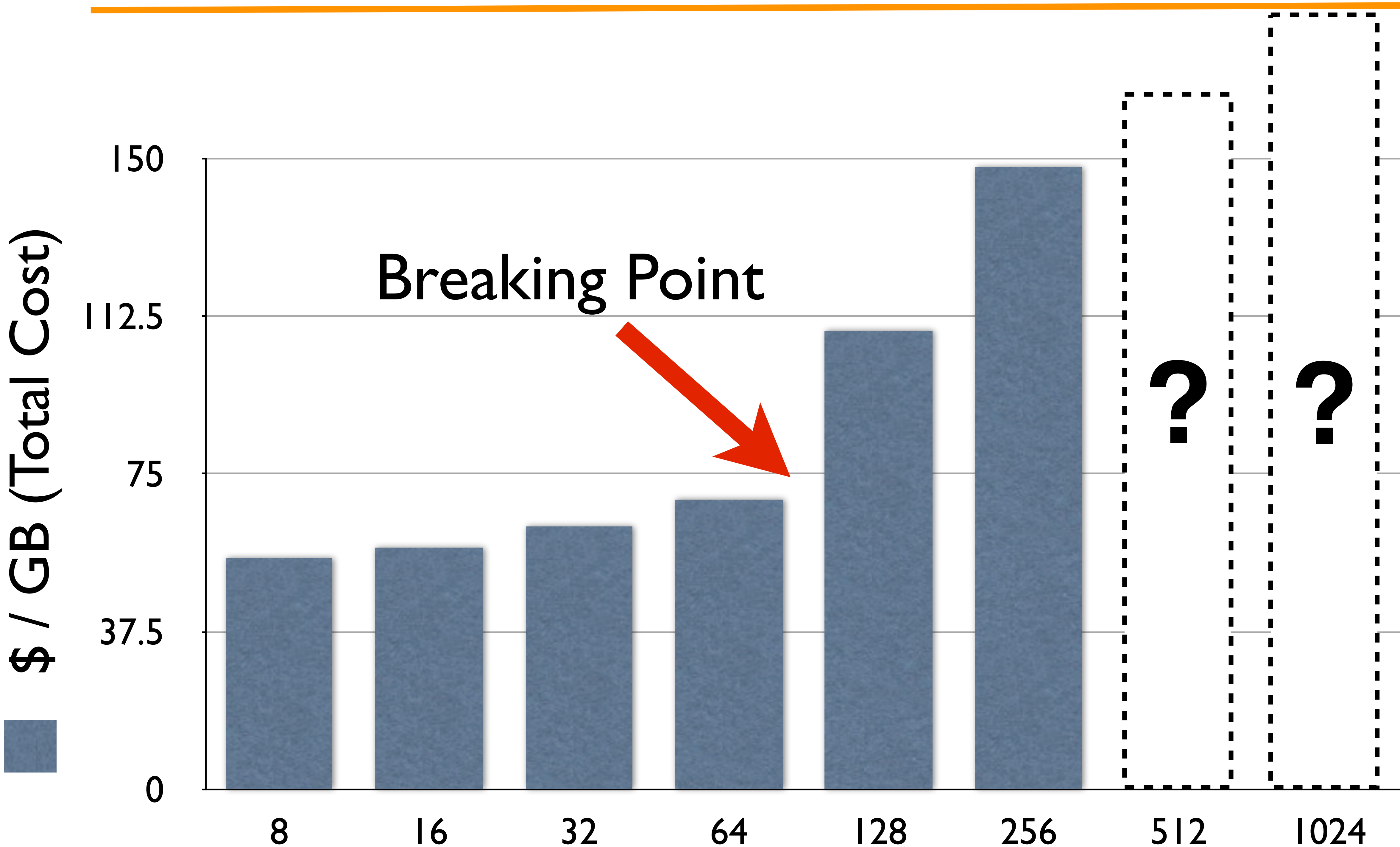

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- High speed disk arrays: many smaller capacity drives
  - Total cost about 10X more compared to similar capacity 7200 rpm drives
  - Use more rack space per byte

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- **How to ease application development with flash memory?**

Flash Memory Primer

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- Fast random reads (upto 1M IOPS per drive)
- Writes happen after an erase
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- No seek latency (only read/write latency)
- Large capacity (single 2.5" disk ~ 512GB)
    - PCIe 10.2 TB - Fusion-io io-octal drive

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Memory	**Disk**

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Byte Addressable	Block Addressable

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  - Native pager delivers only 10% of the SSD's performance
  - Flash aware pager delivers only 30% of the SSD's performance
  - OS pager optimized for seek limited disks and was designed as a "dead page storage"

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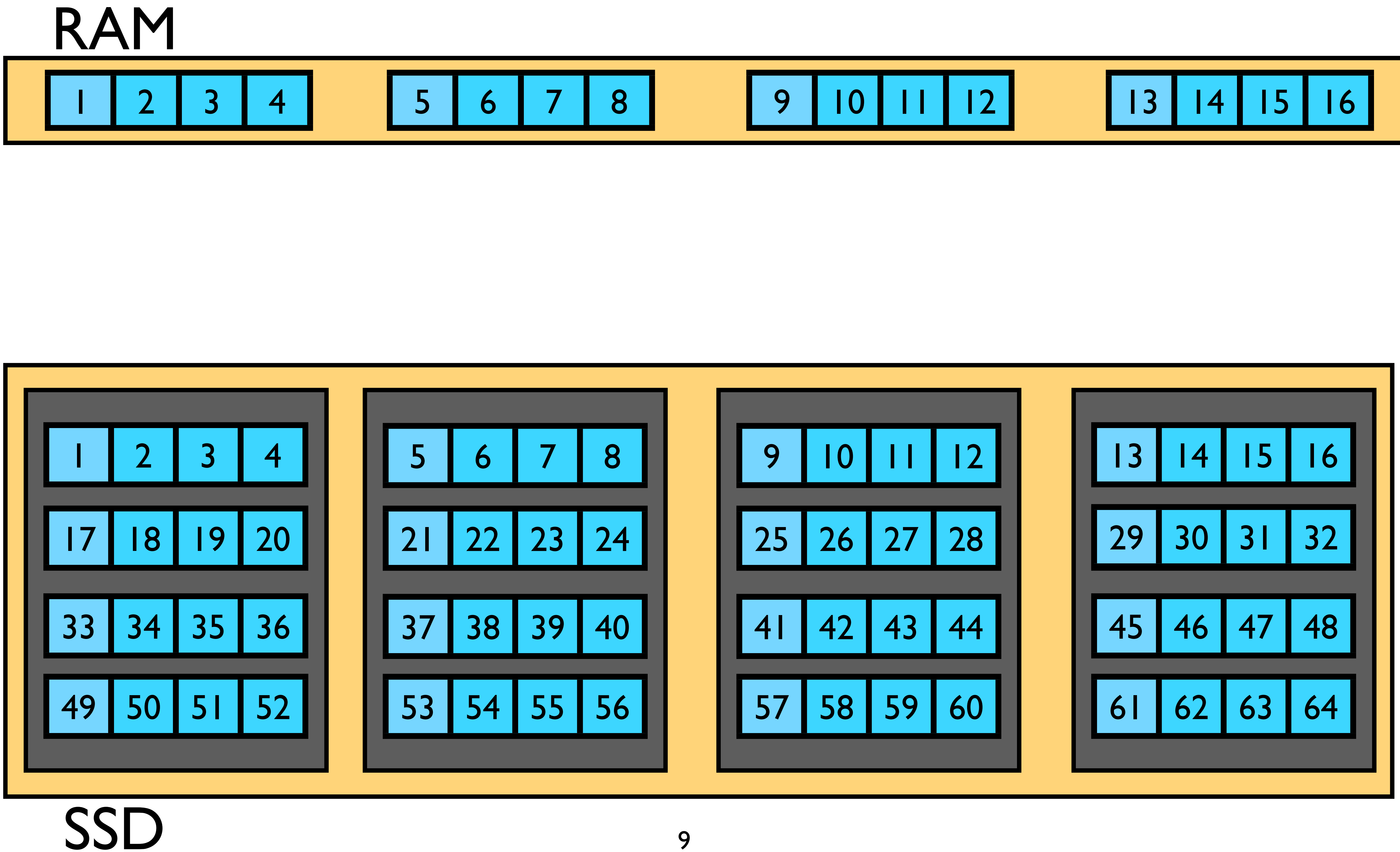

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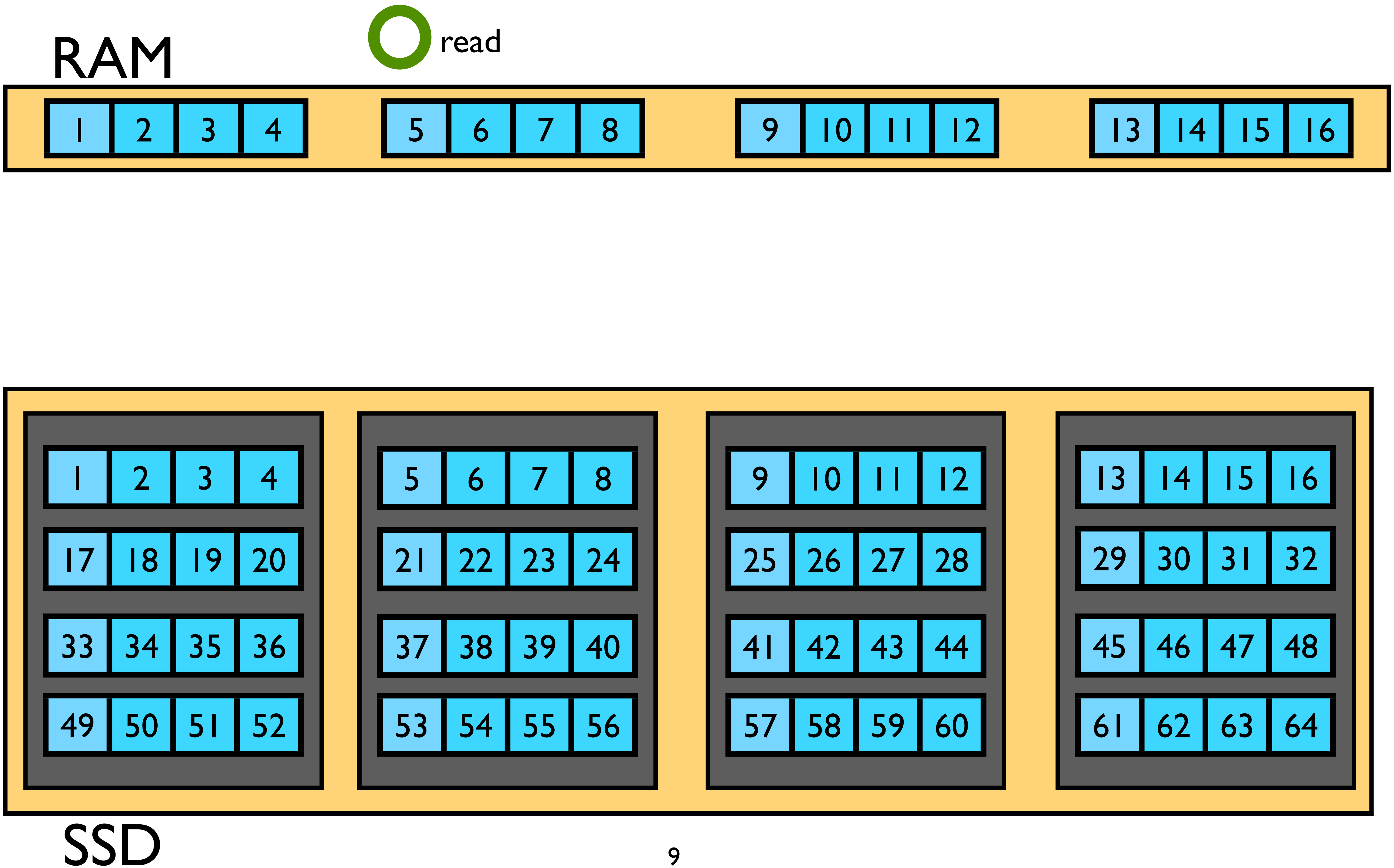

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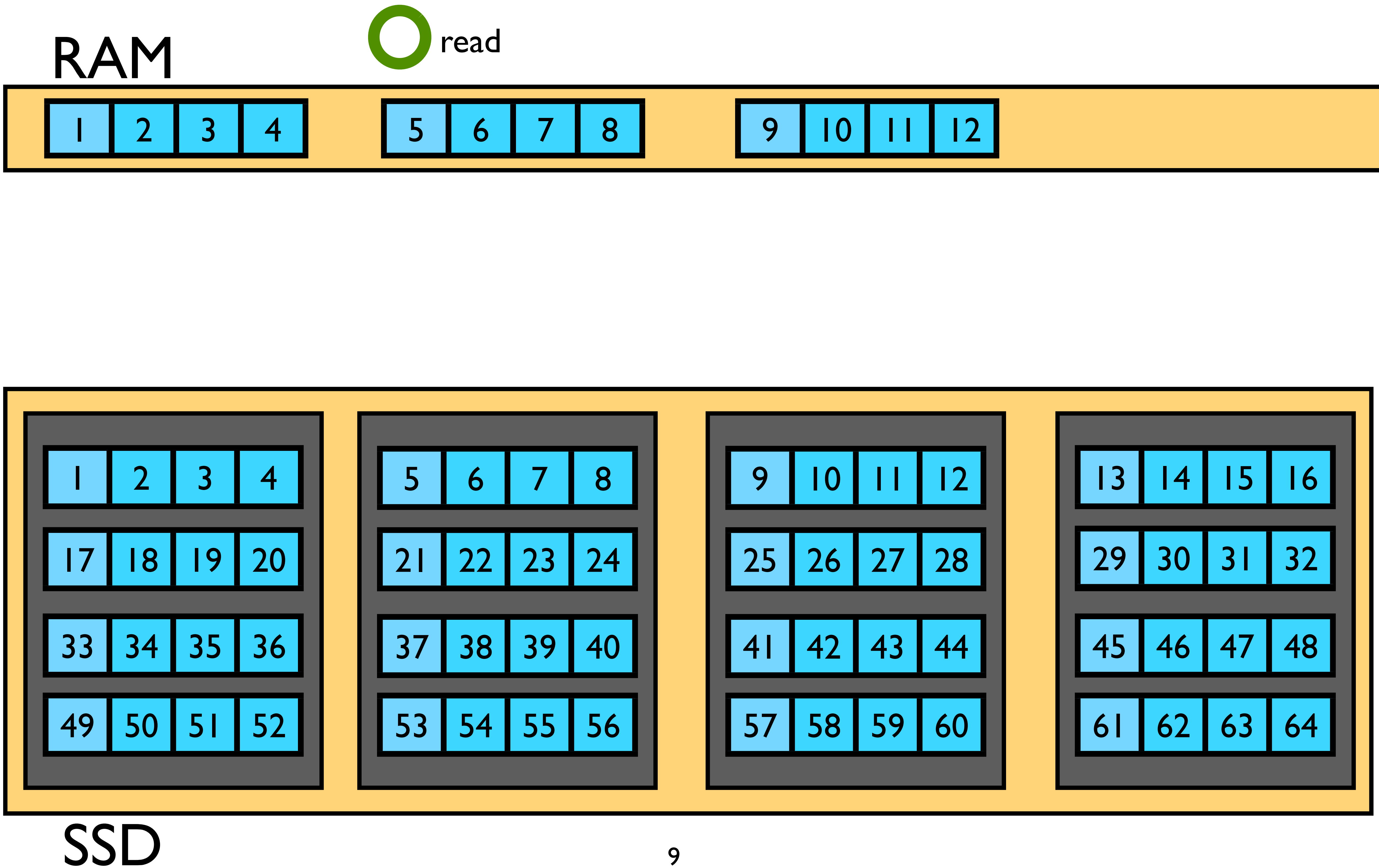

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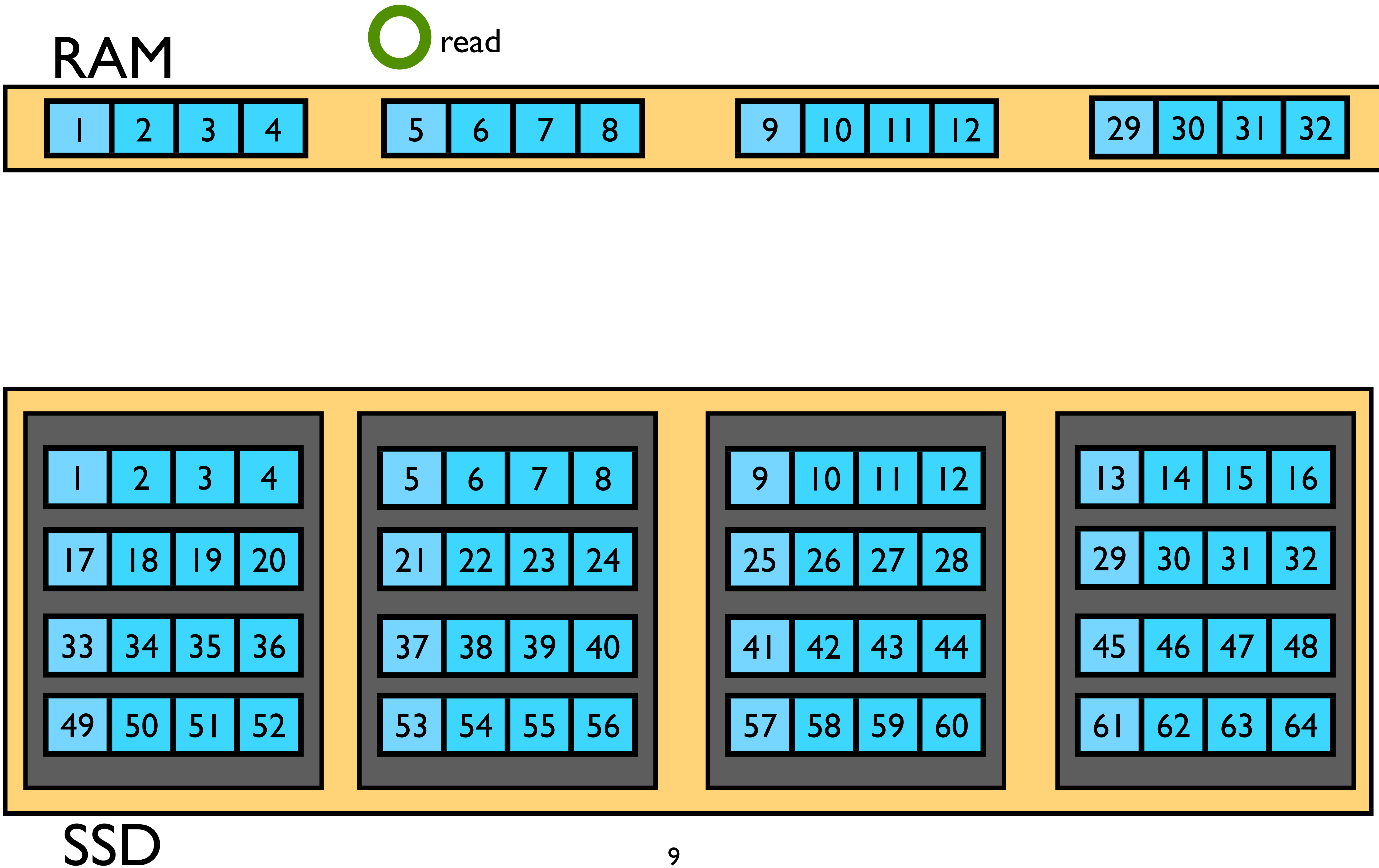

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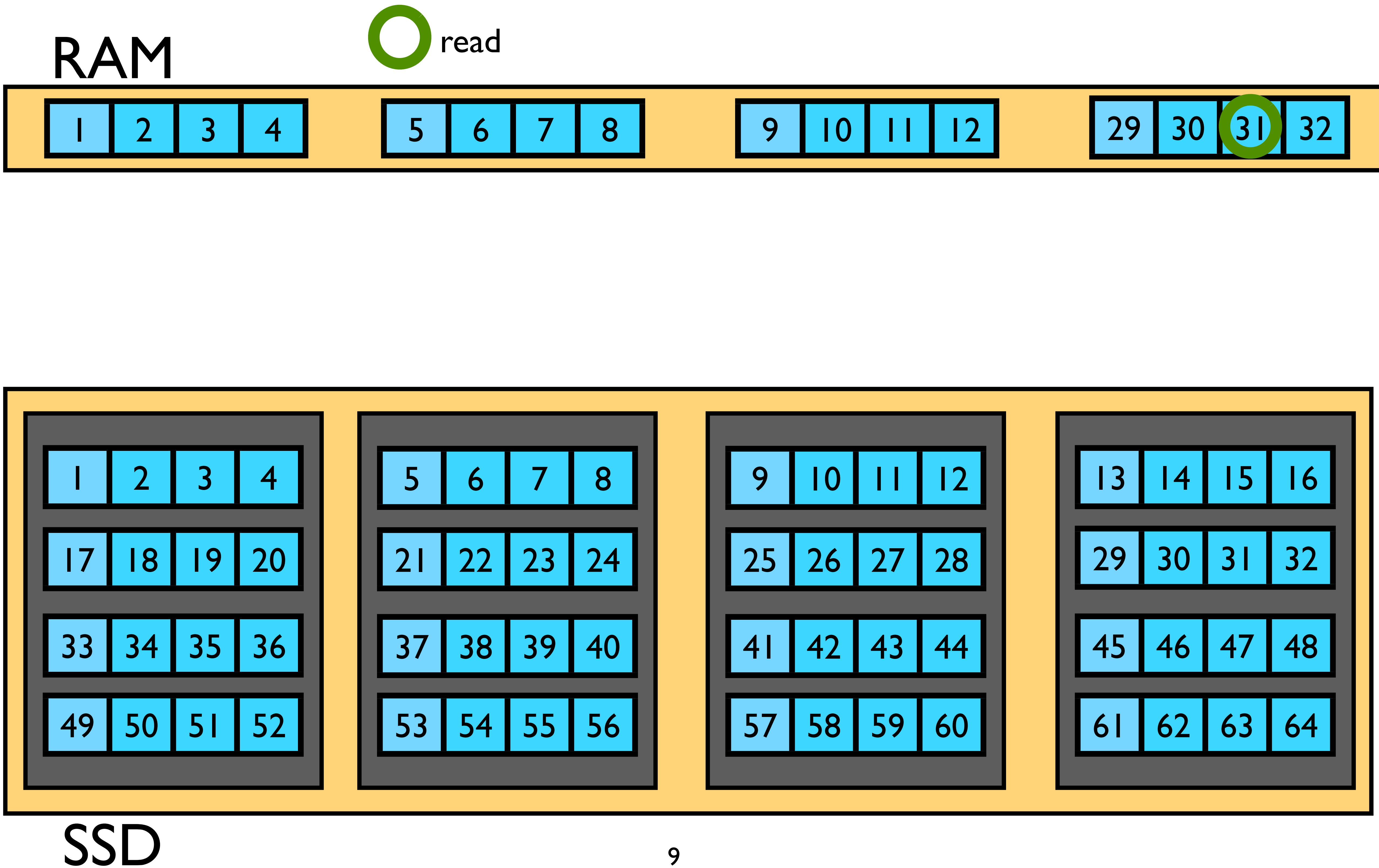

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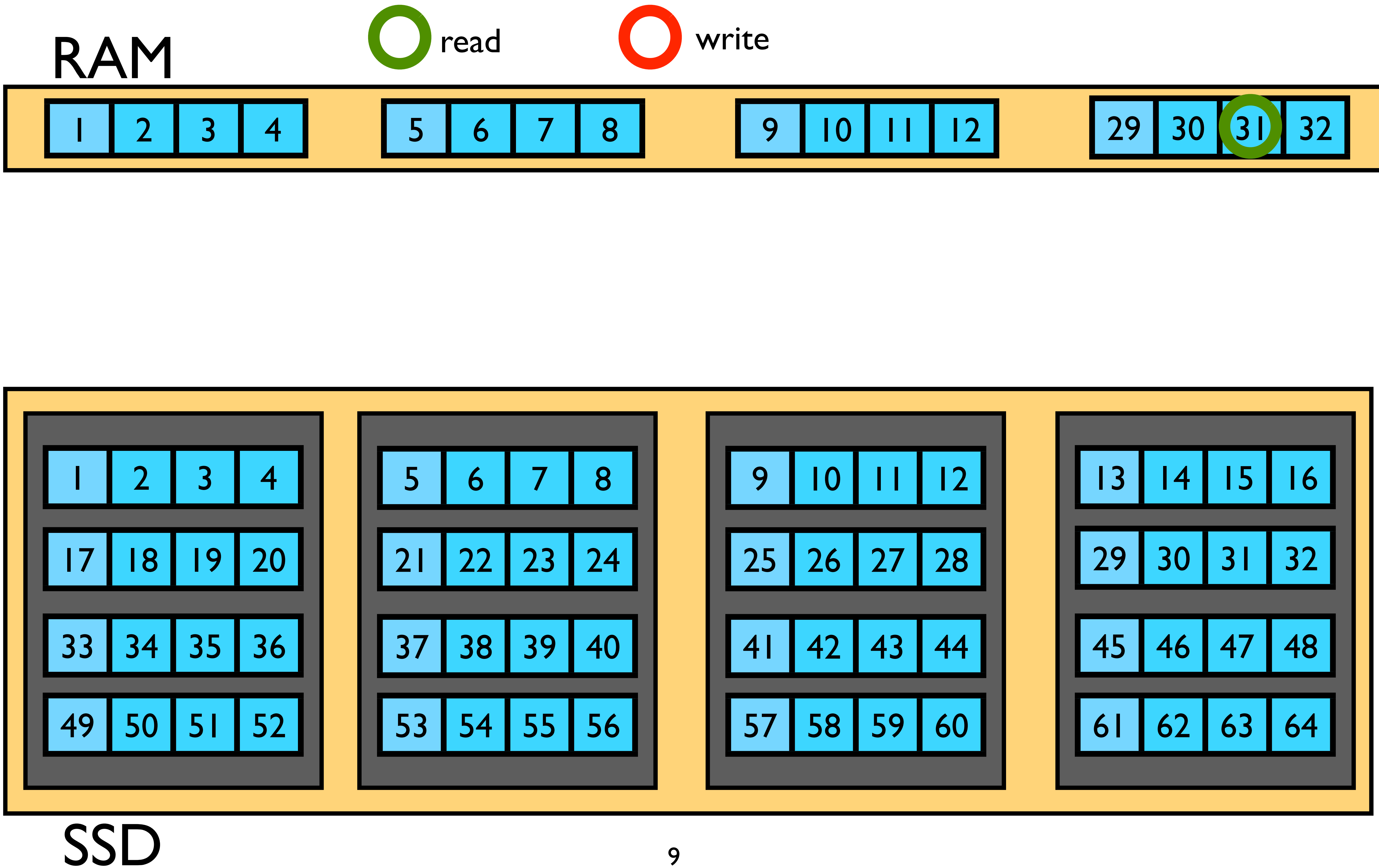

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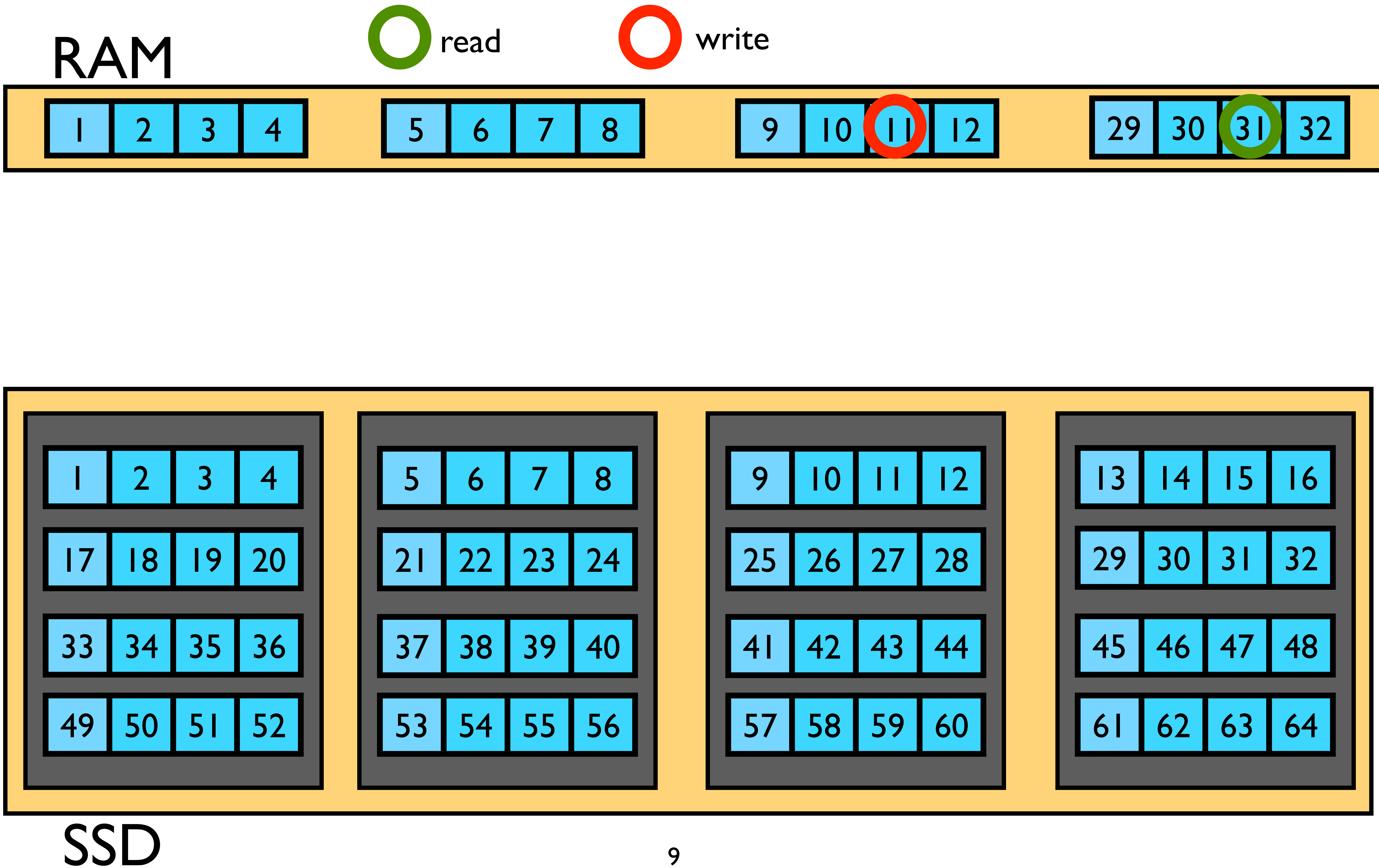

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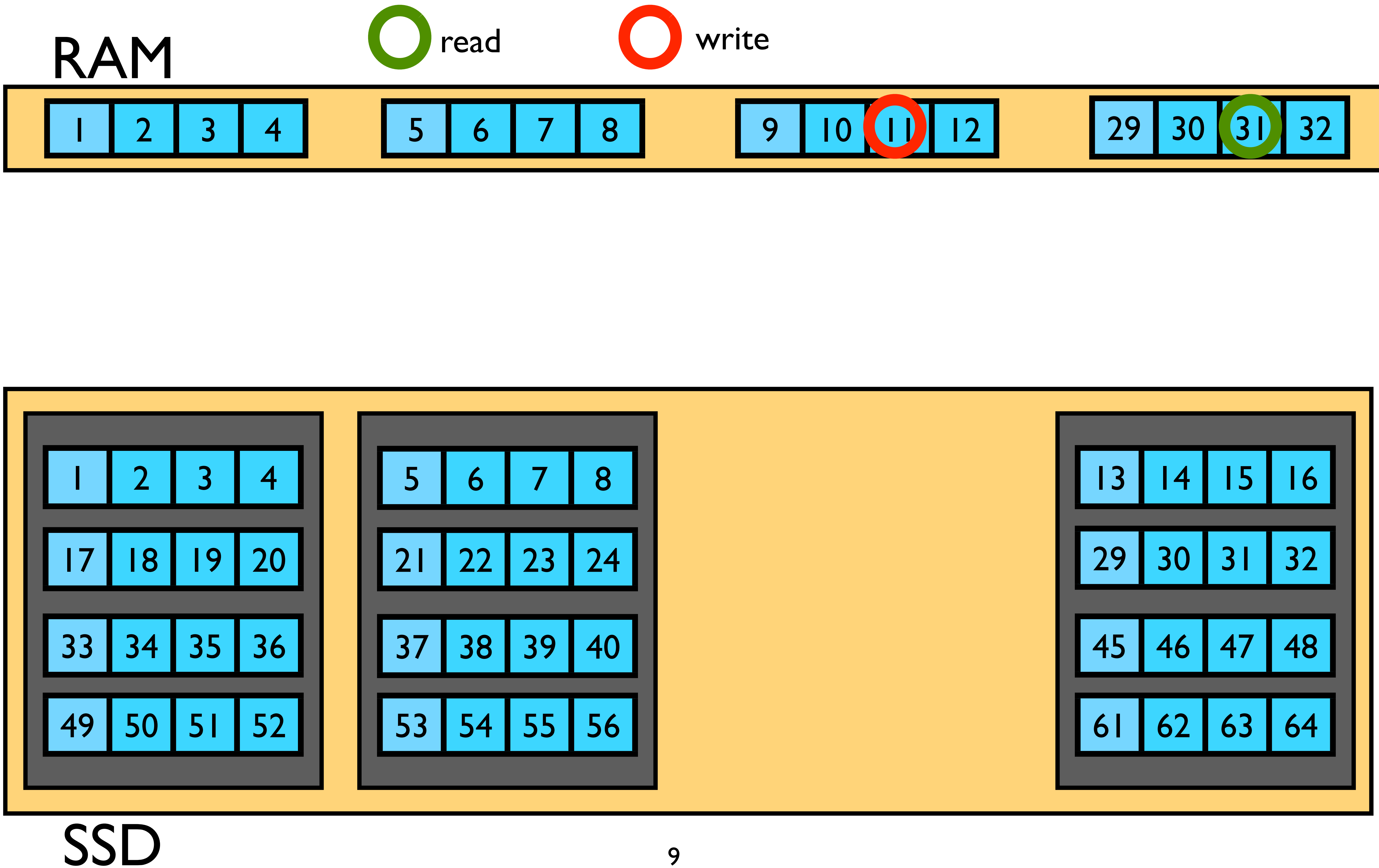

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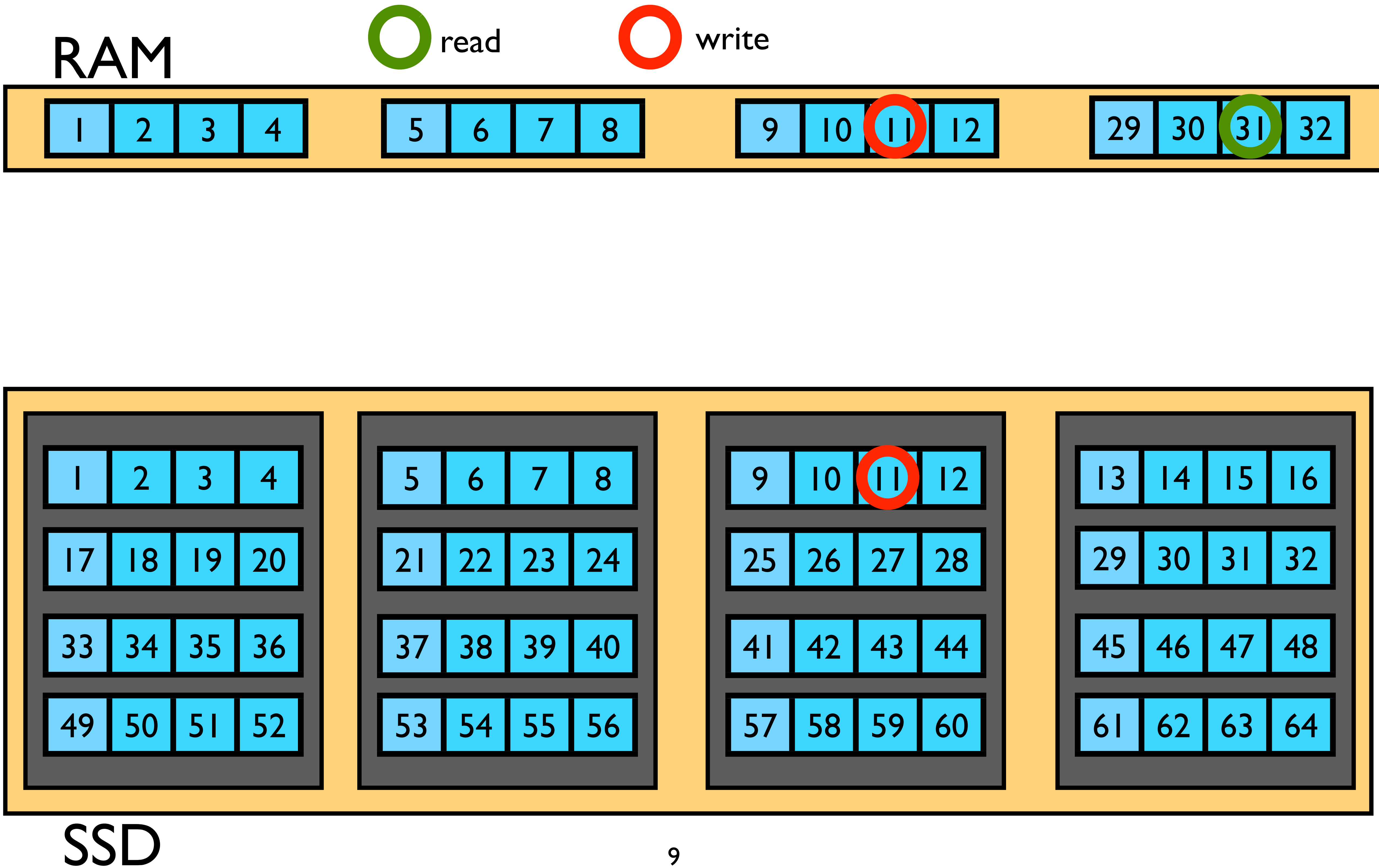

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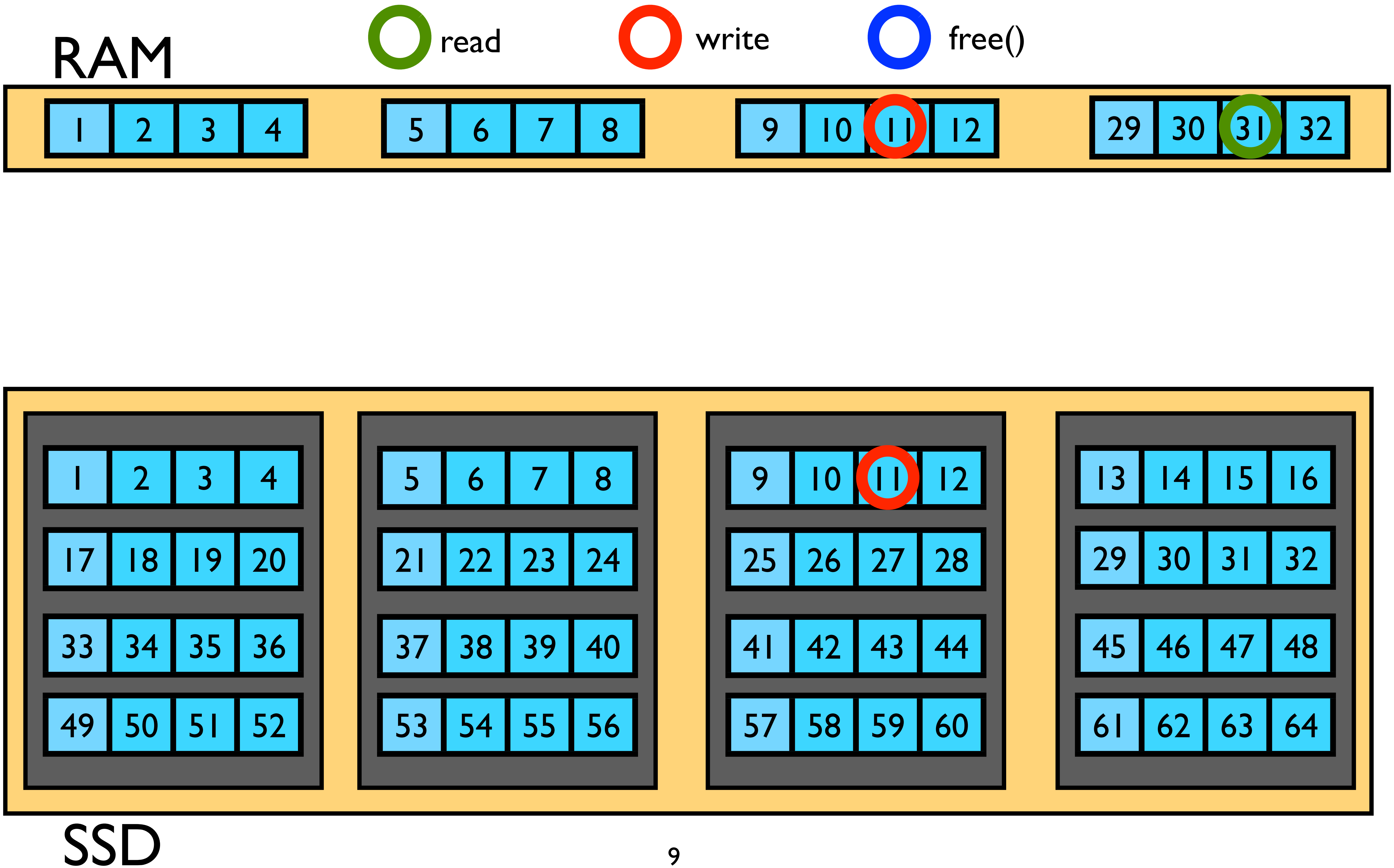

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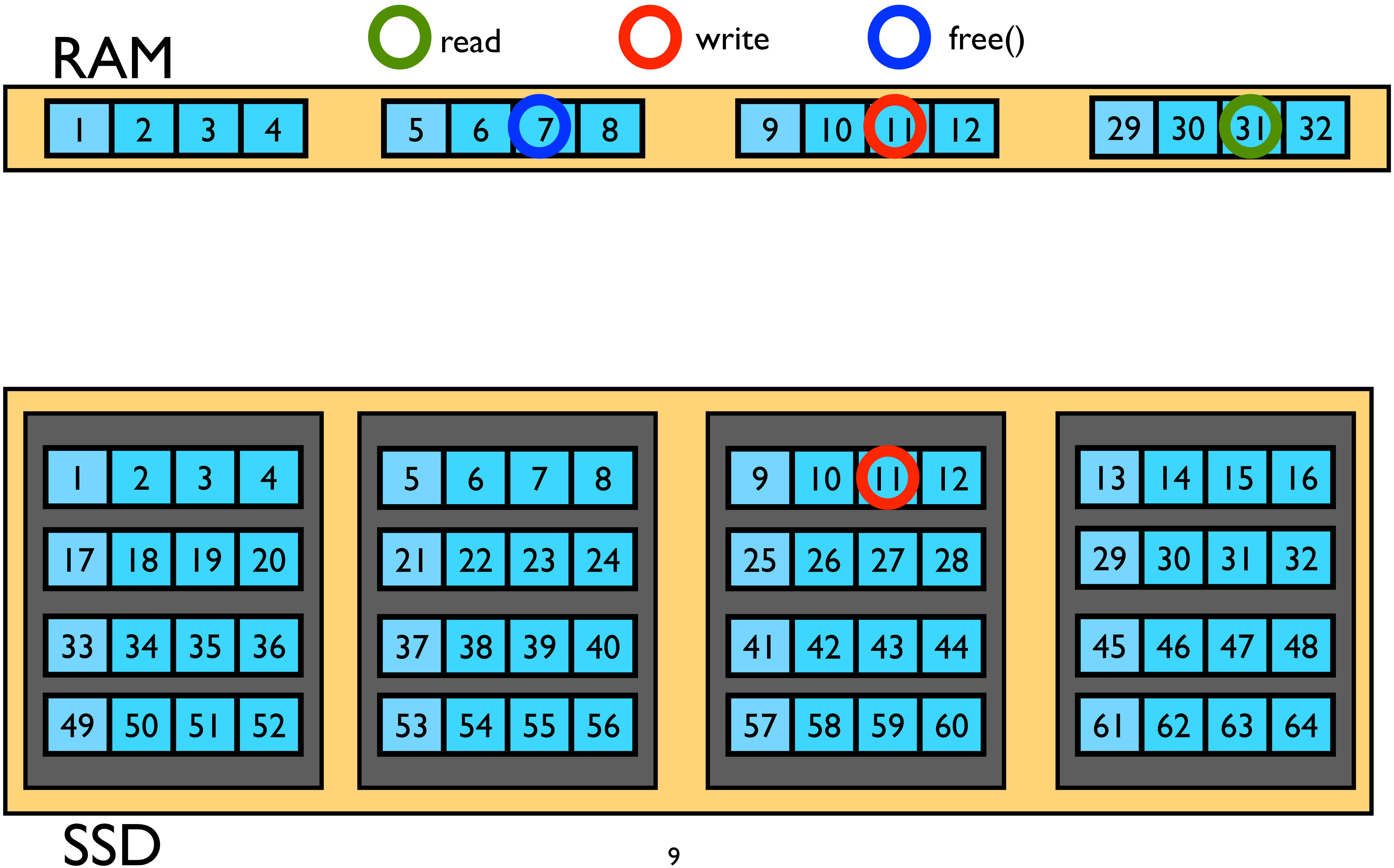

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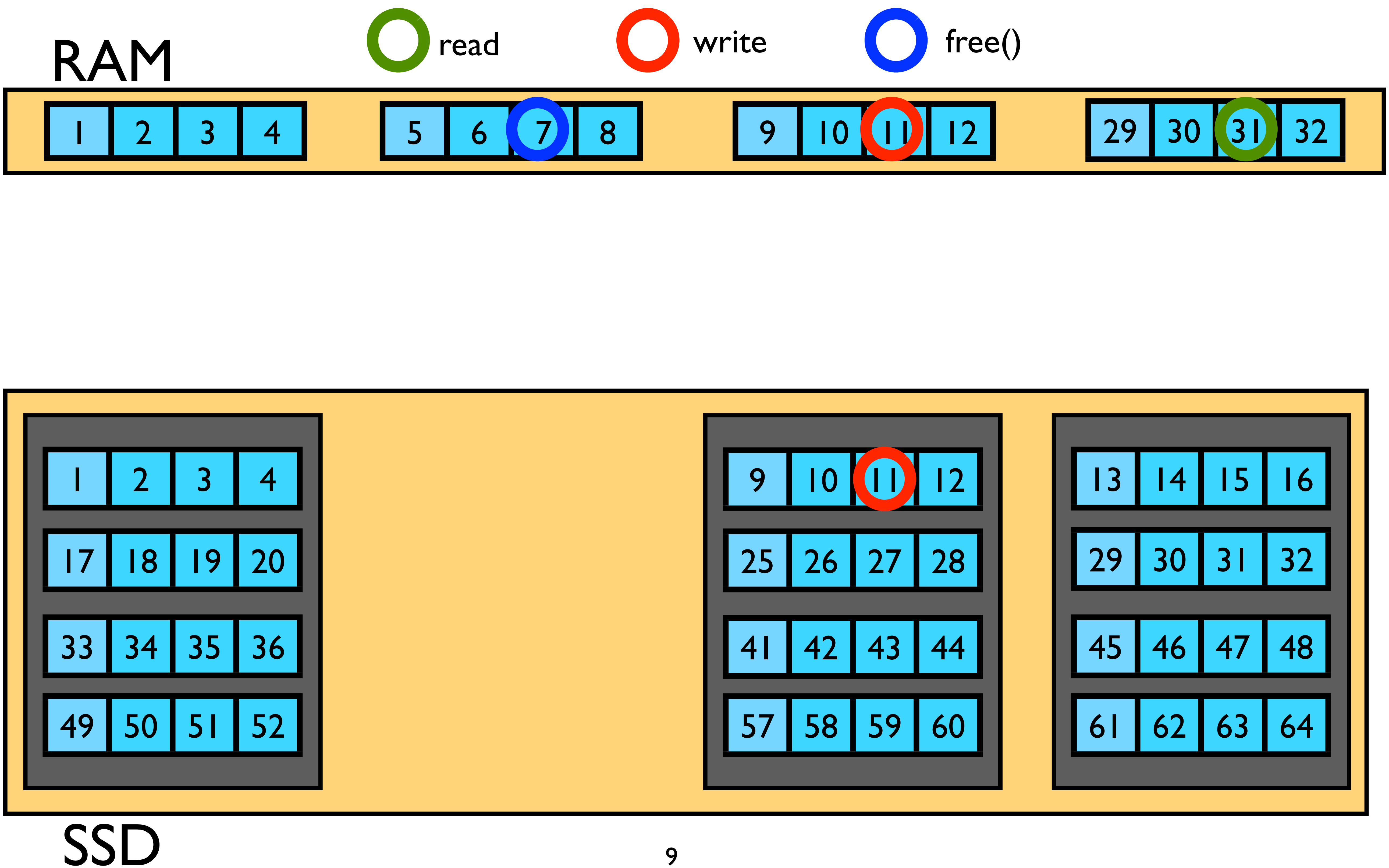

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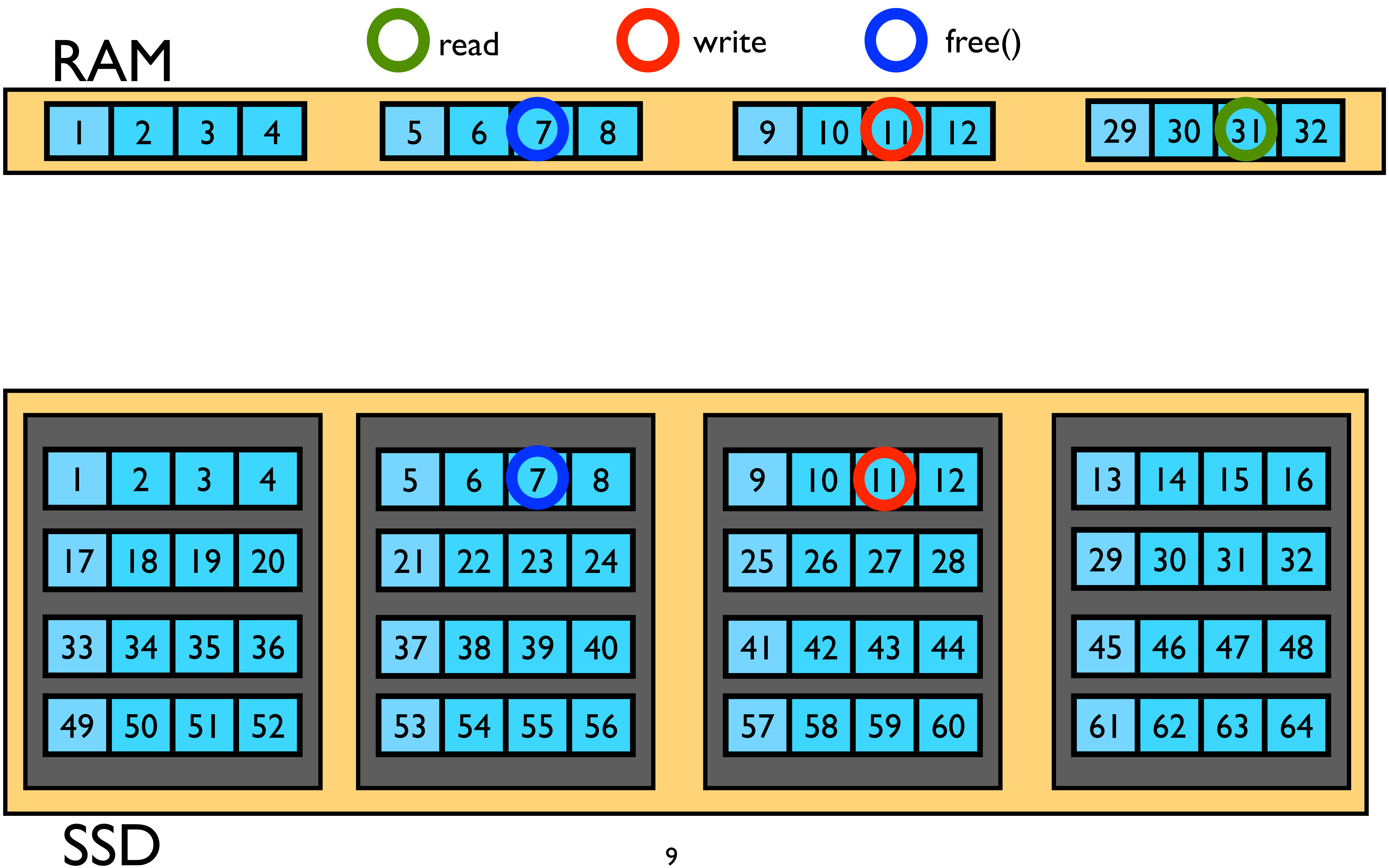

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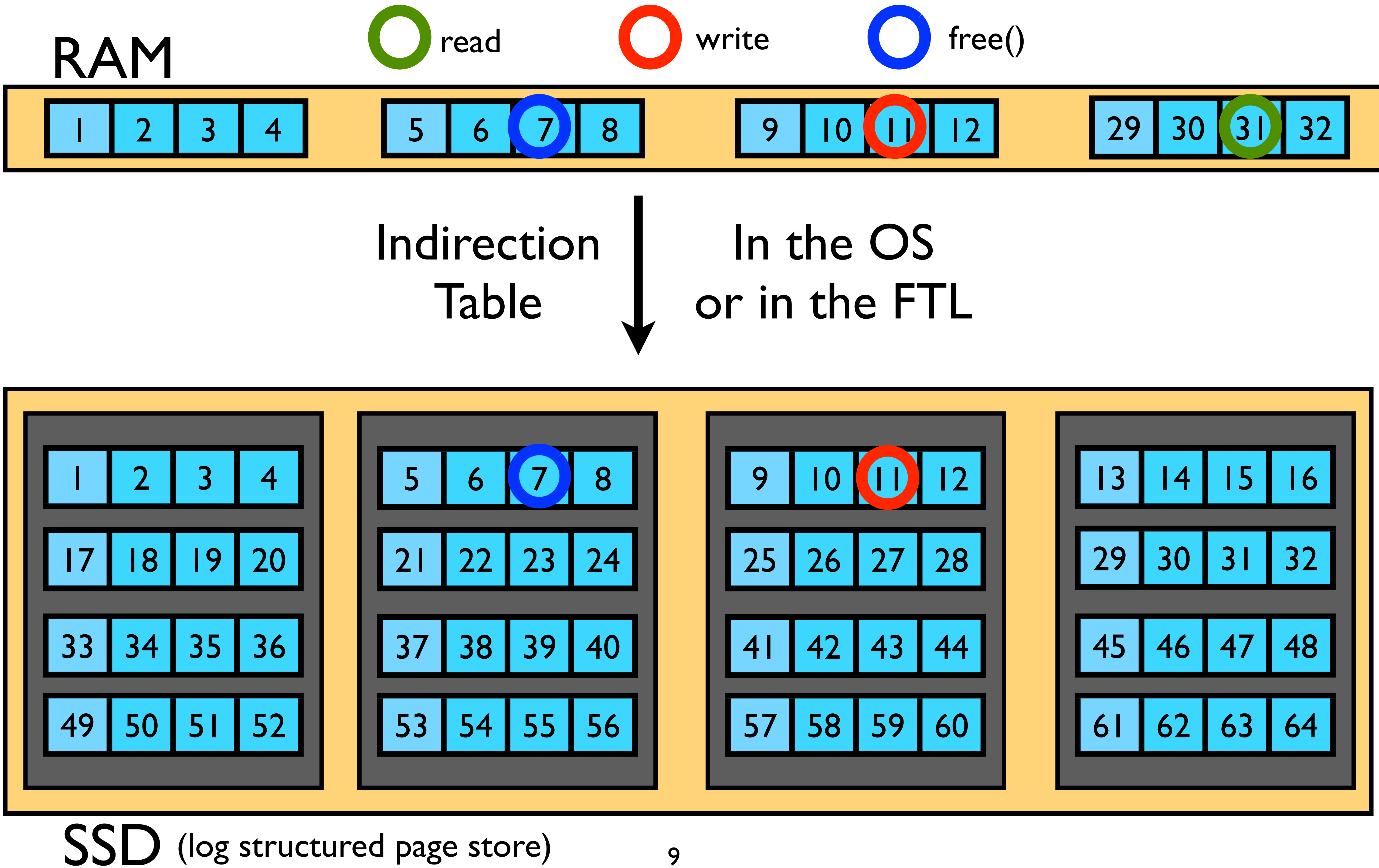

Non-Transparent Tiering

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- Redesign application to be flash aware
  - Custom object store with custom pointers
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  - Intrusive modifications needed
  - Expertise with flash memory needed

Non-Transparent Tiering

malloc
+
SSD-swap

```
MyObject* obj = malloc( sizeof( MyObject ) );

obj->x = 0;
obj->y = 1;
obj->z = 2;
free( obj );
```

Application Rewrite

```
MyObjectID oid = createObject( sizeof( MyObject ) );
MyObject* obj = malloc( sizeof( MyObject ) );

readObject( oid, obj );
obj->x = 0;
obj->y = 1;
obj->z = 2;
writeObject( oid, obj );
free( obj );
```

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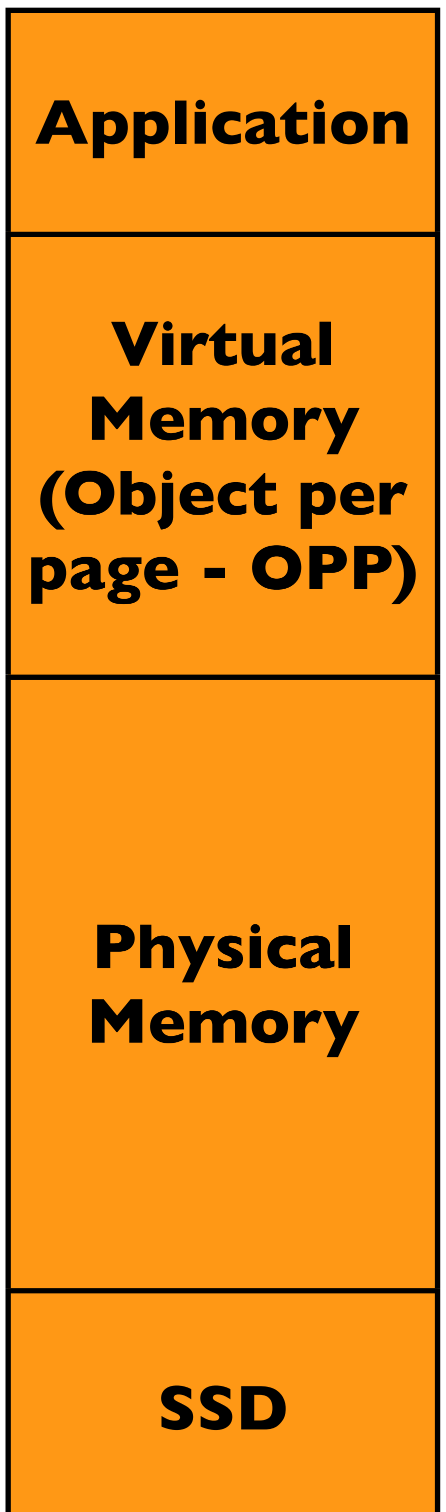
- Reorganize virtual memory allocation to discern object information

SSDAlloc Overview



SSDAlloc Overview

Application

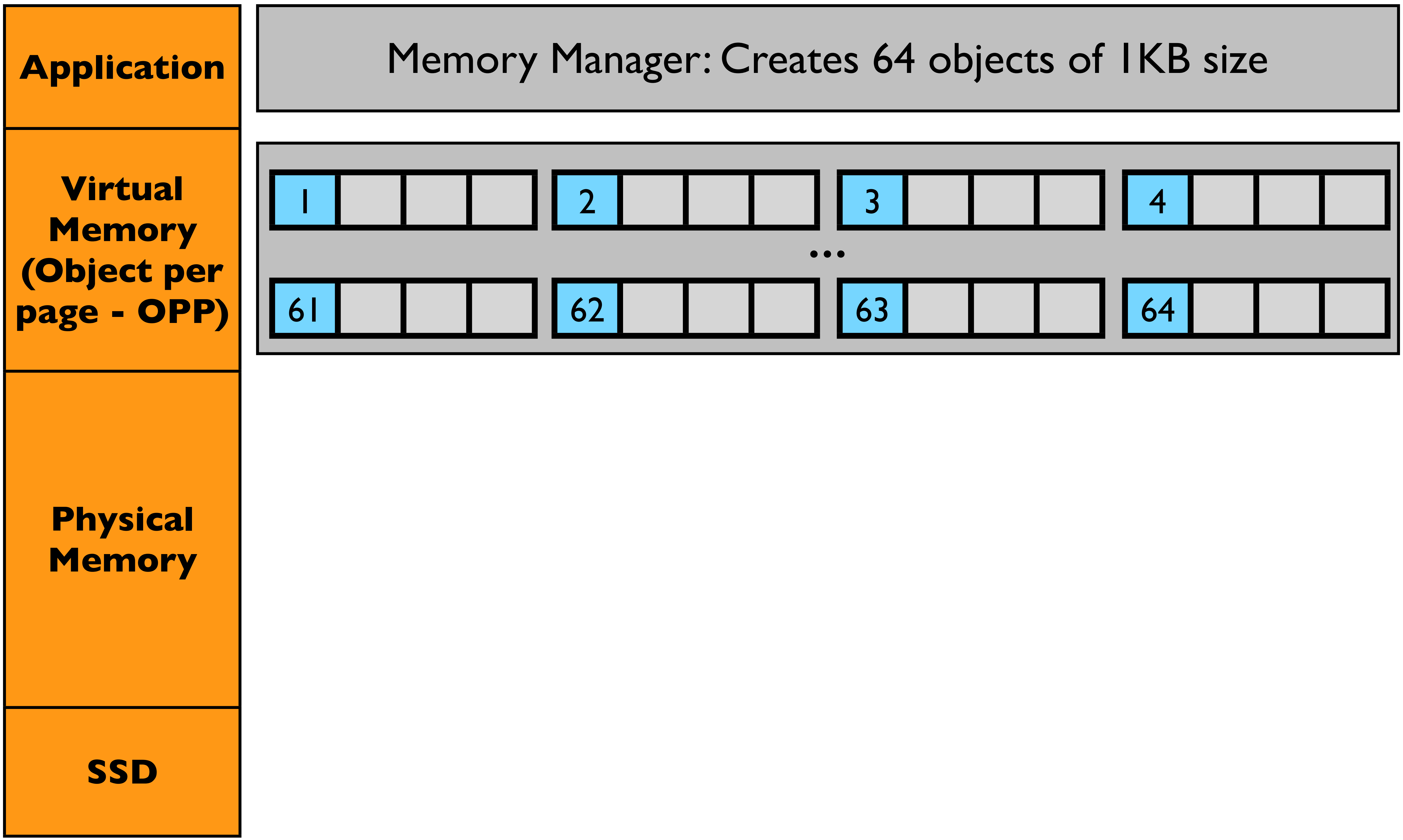
Virtual Memory (Object per page - OPP)

Physical Memory

SSD

Memory Manager: Creates 64 objects of 1KB size

SSDAlloc Overview



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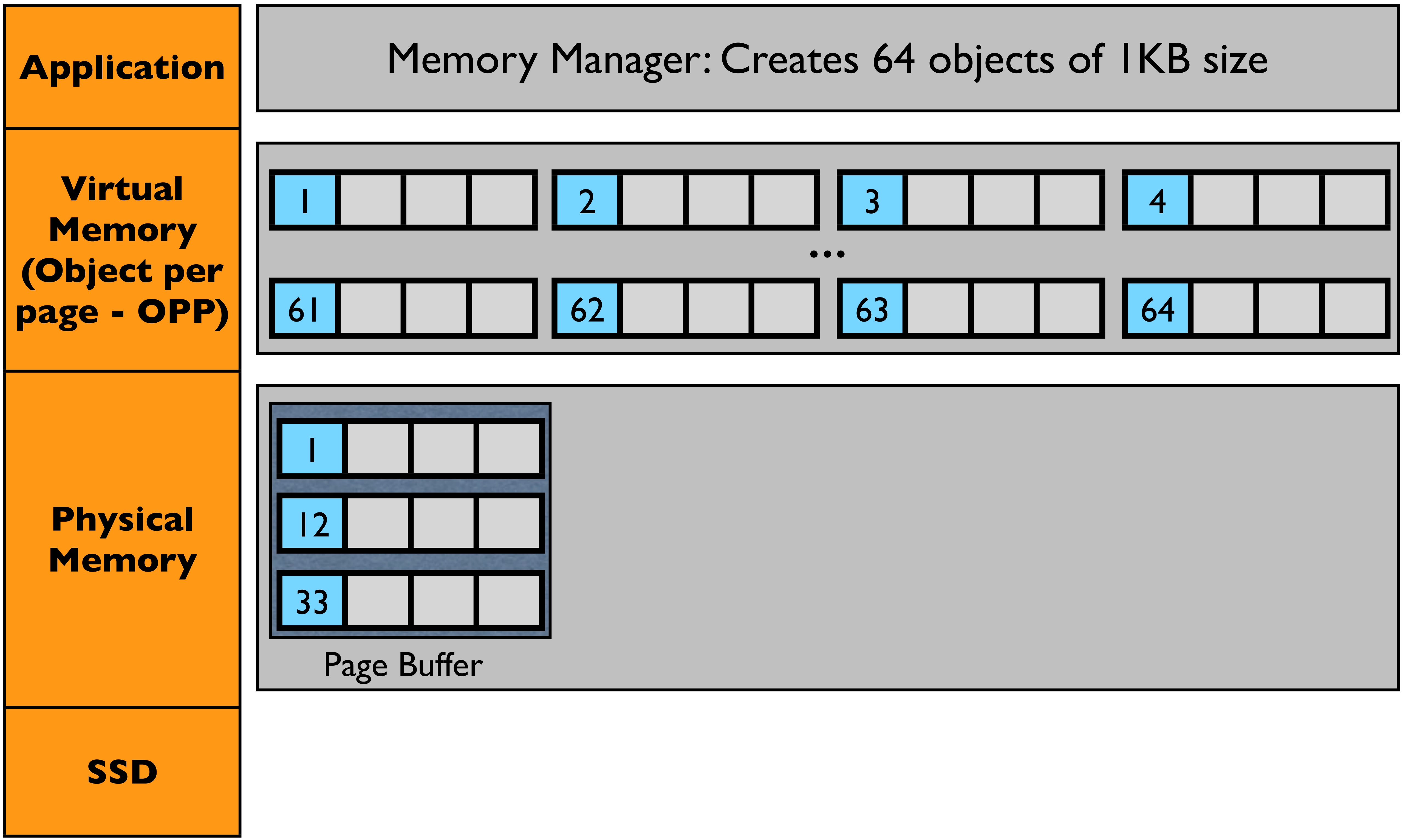

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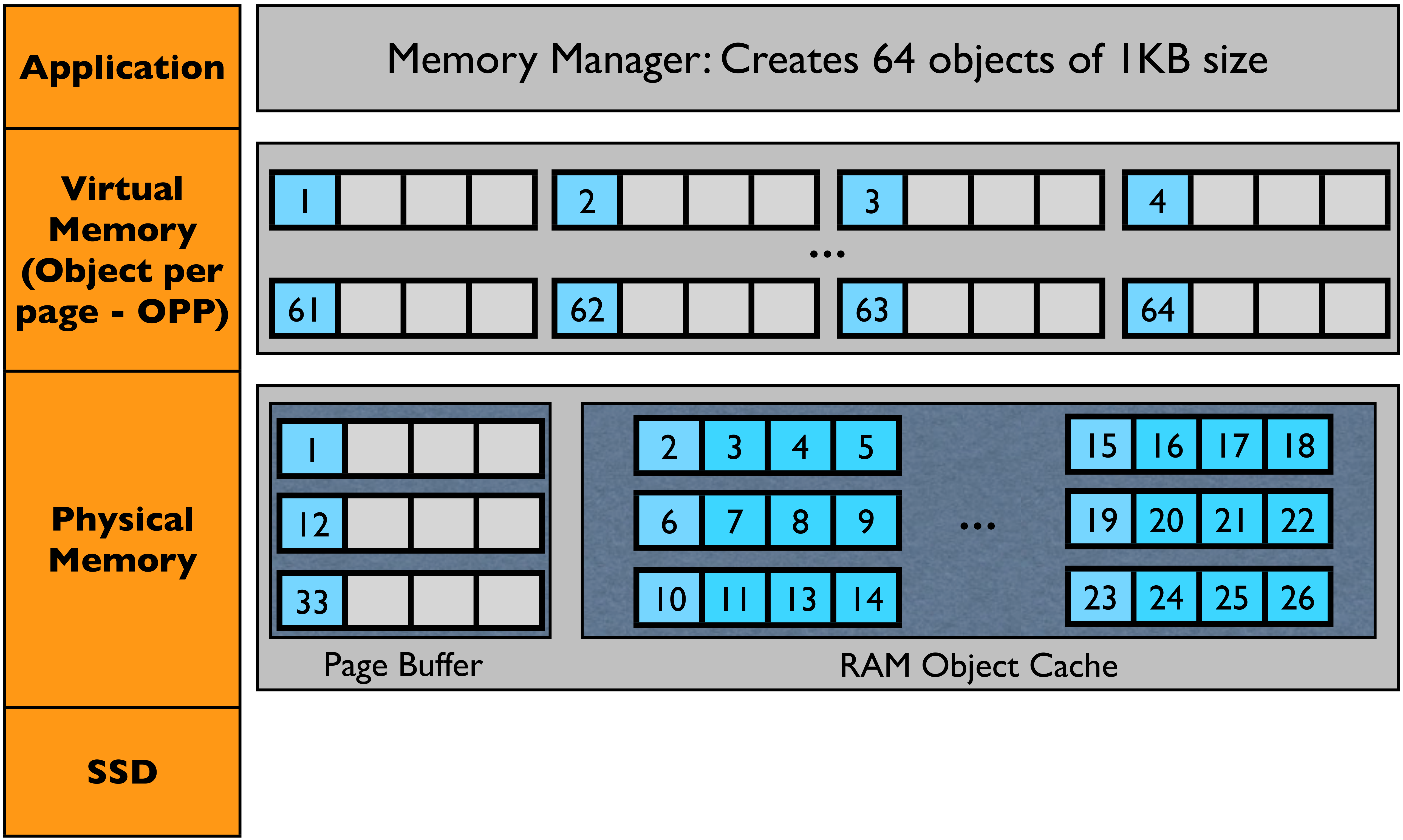

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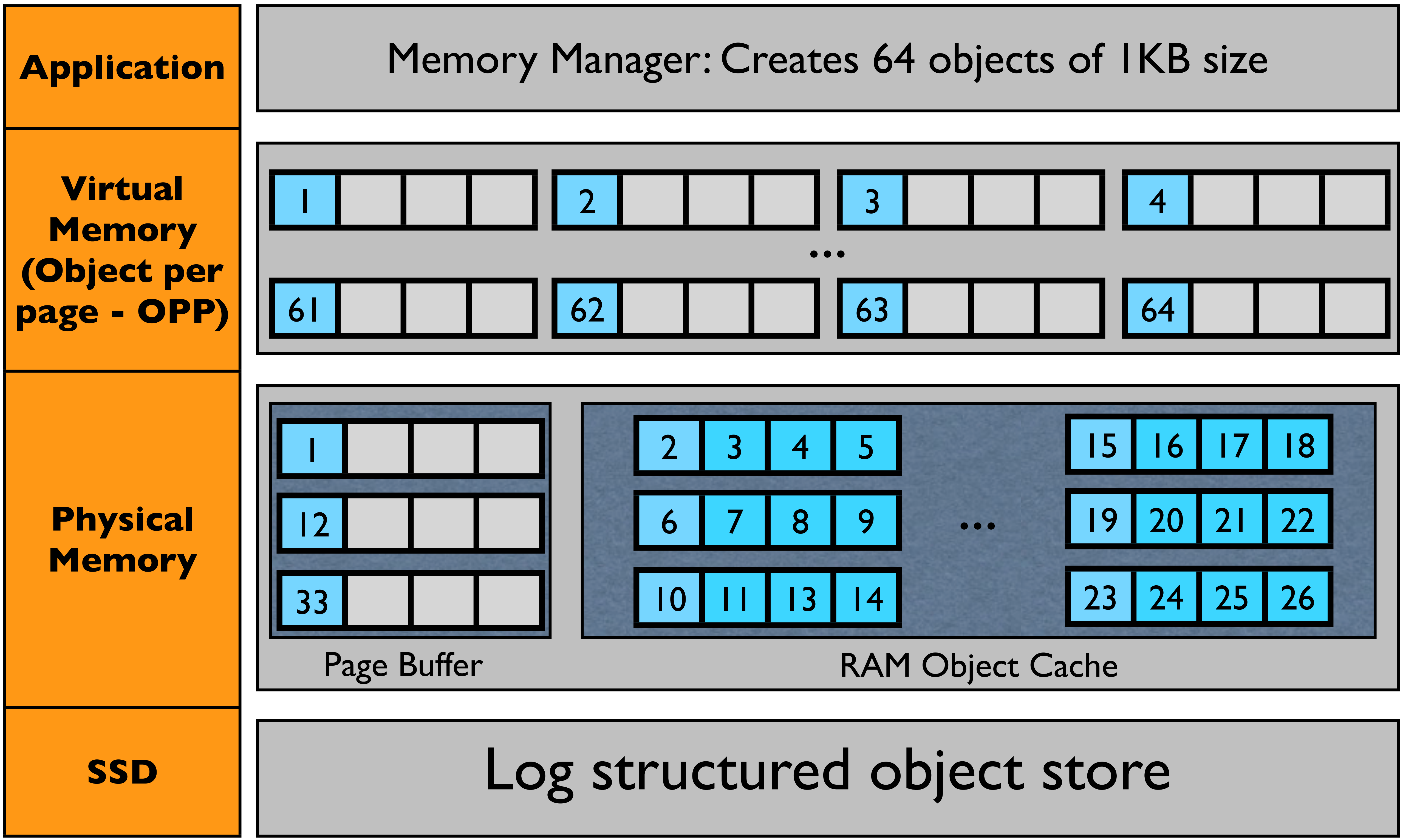

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	Object Per Page (OPP)	Memory Page (MP)
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Code Changes	Minimal changes restricted to memory allocation	No changes needed

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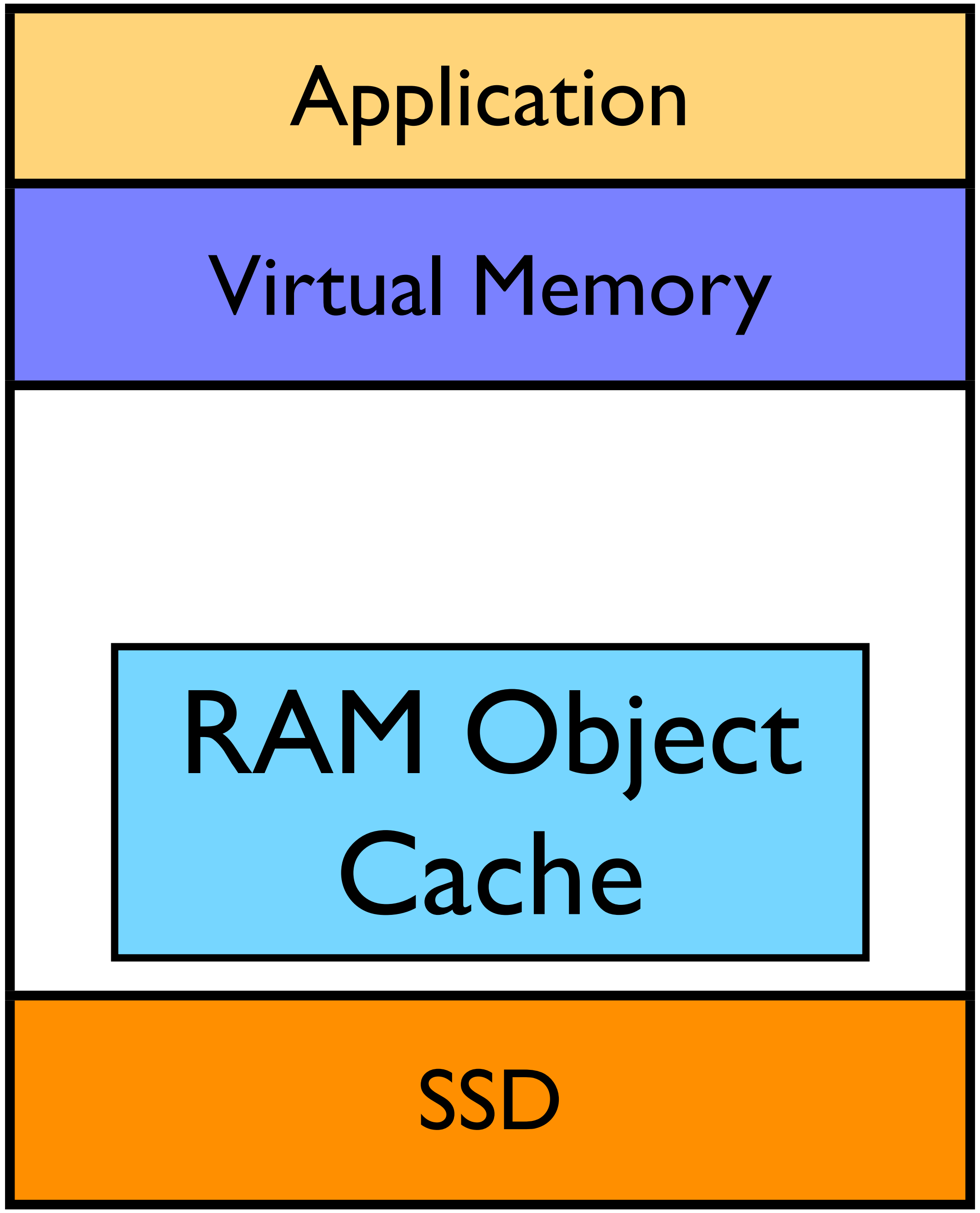

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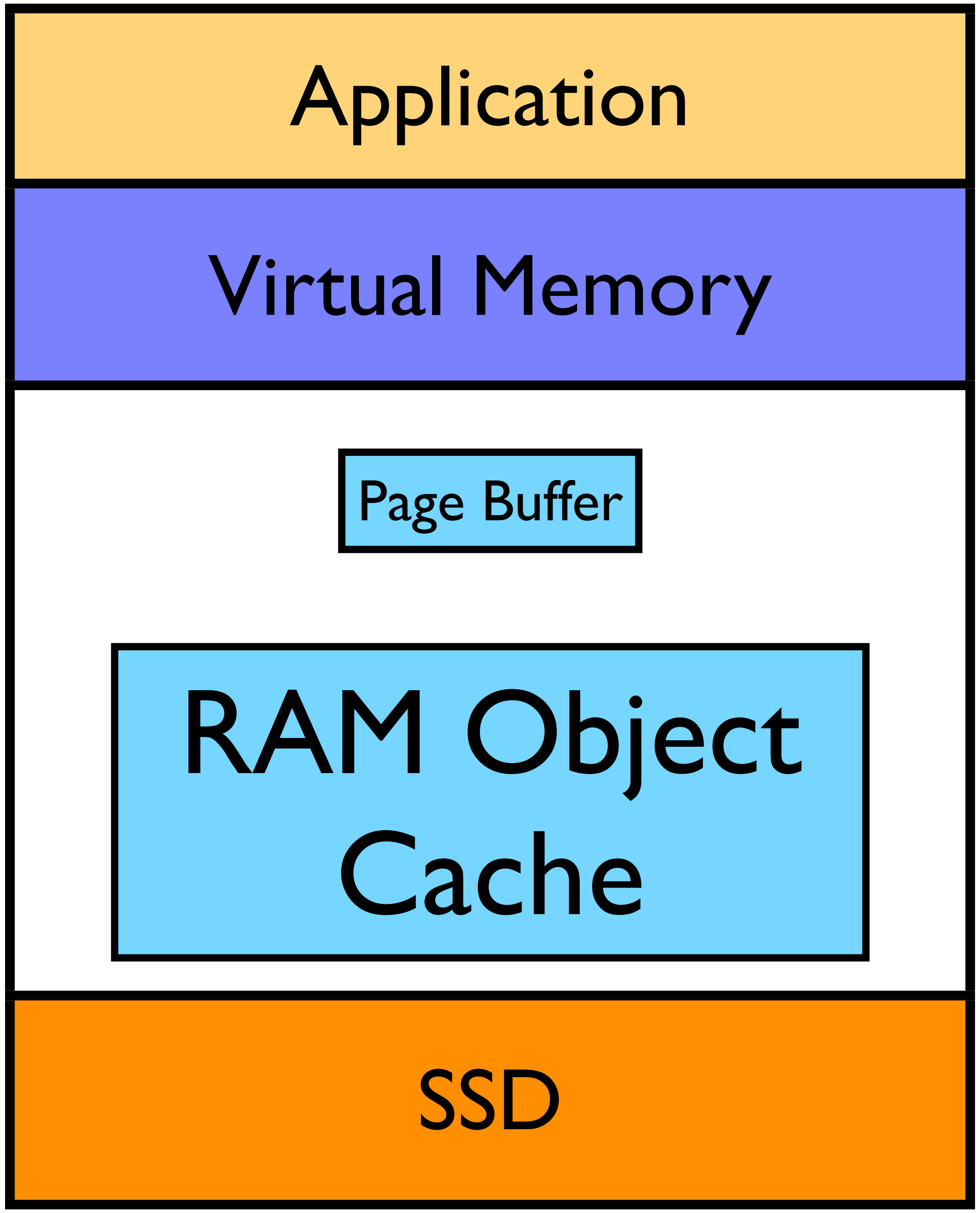

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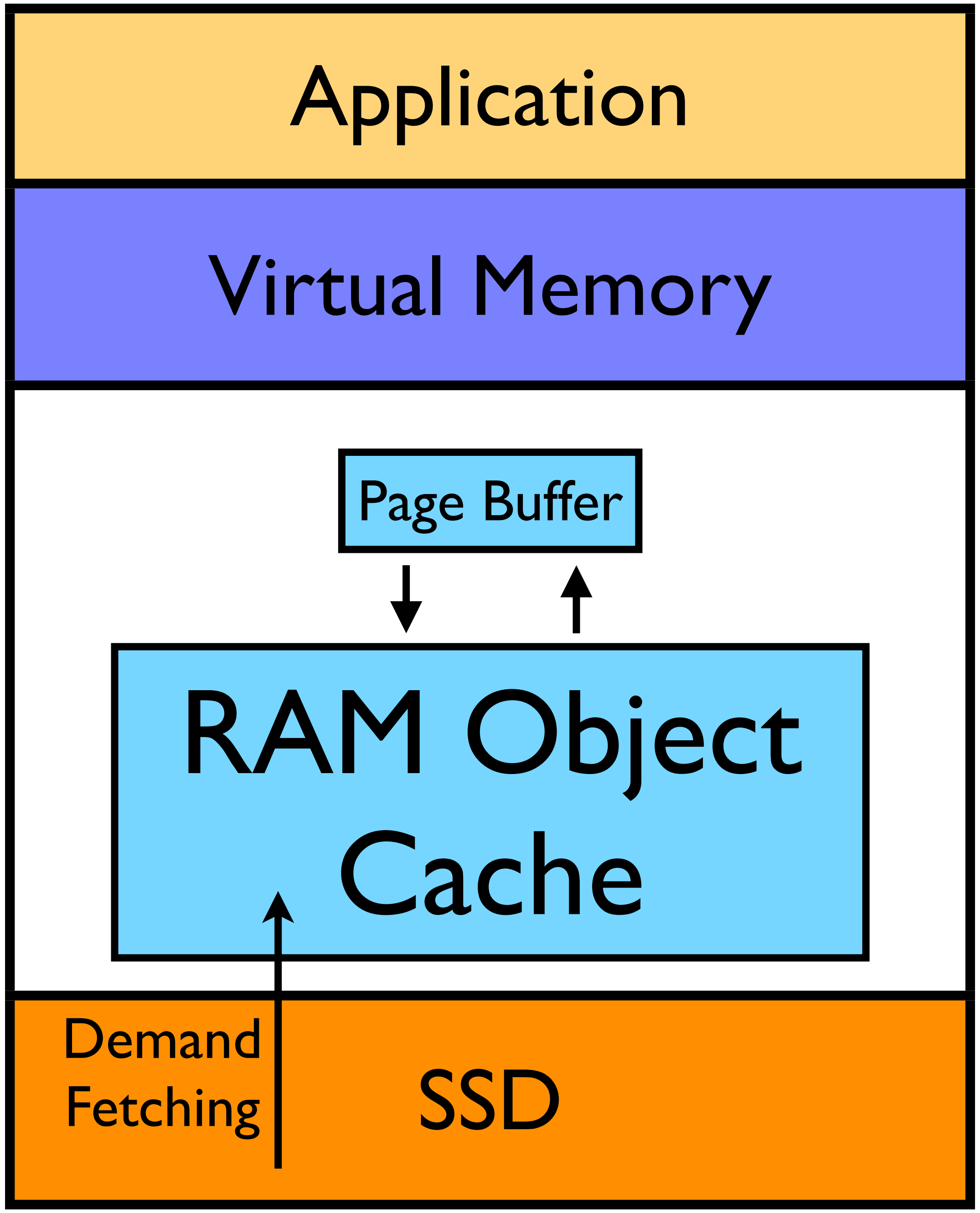

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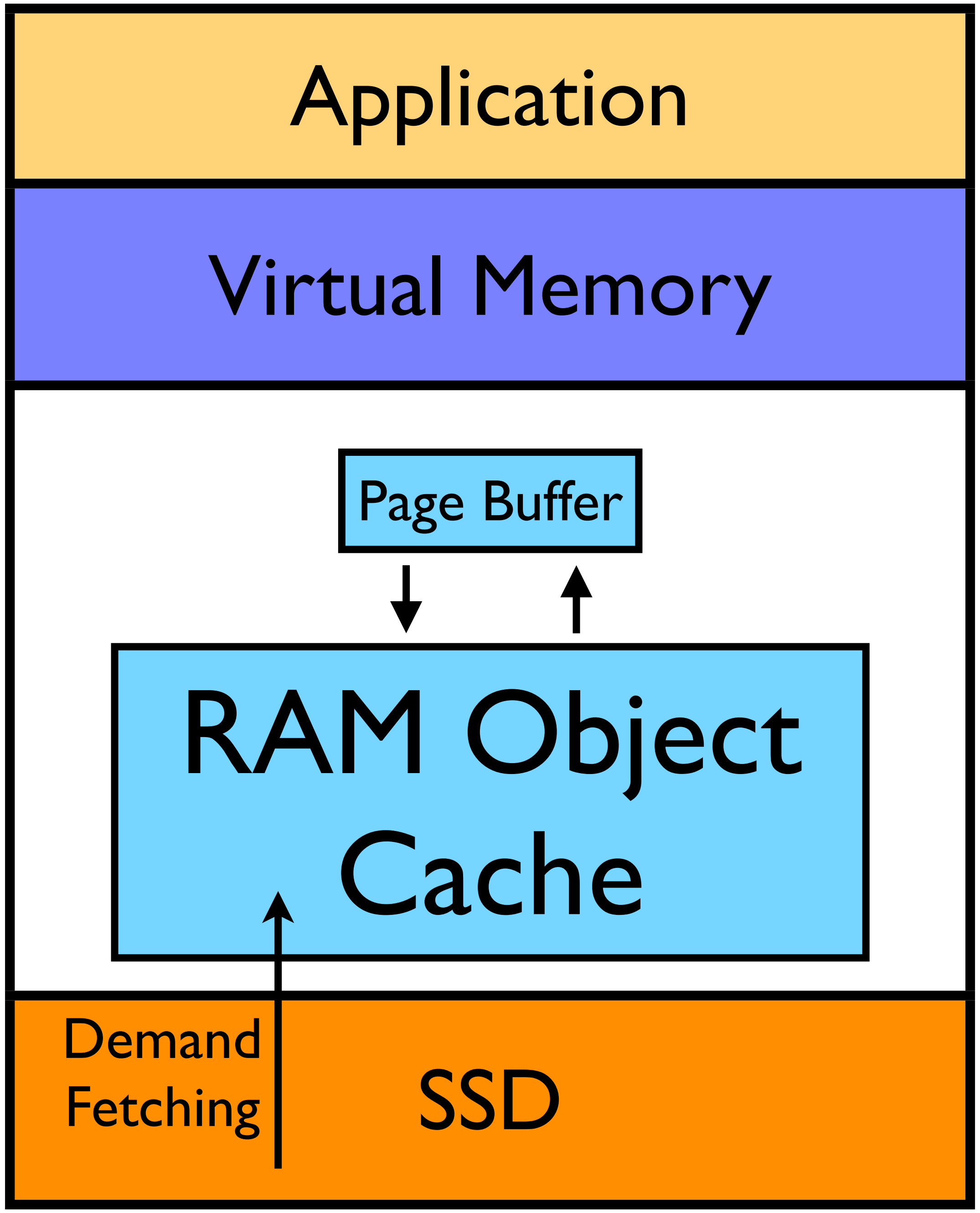

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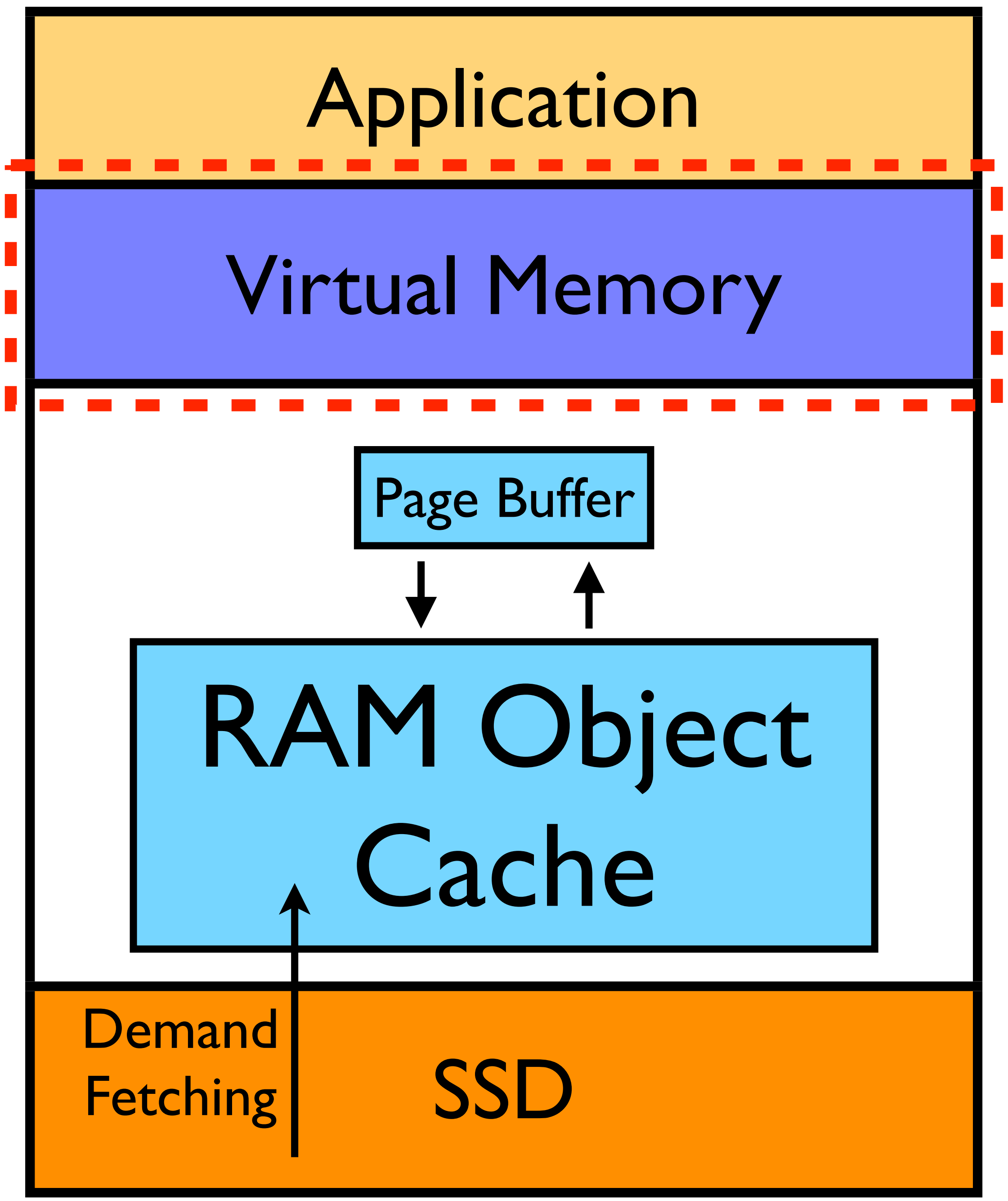

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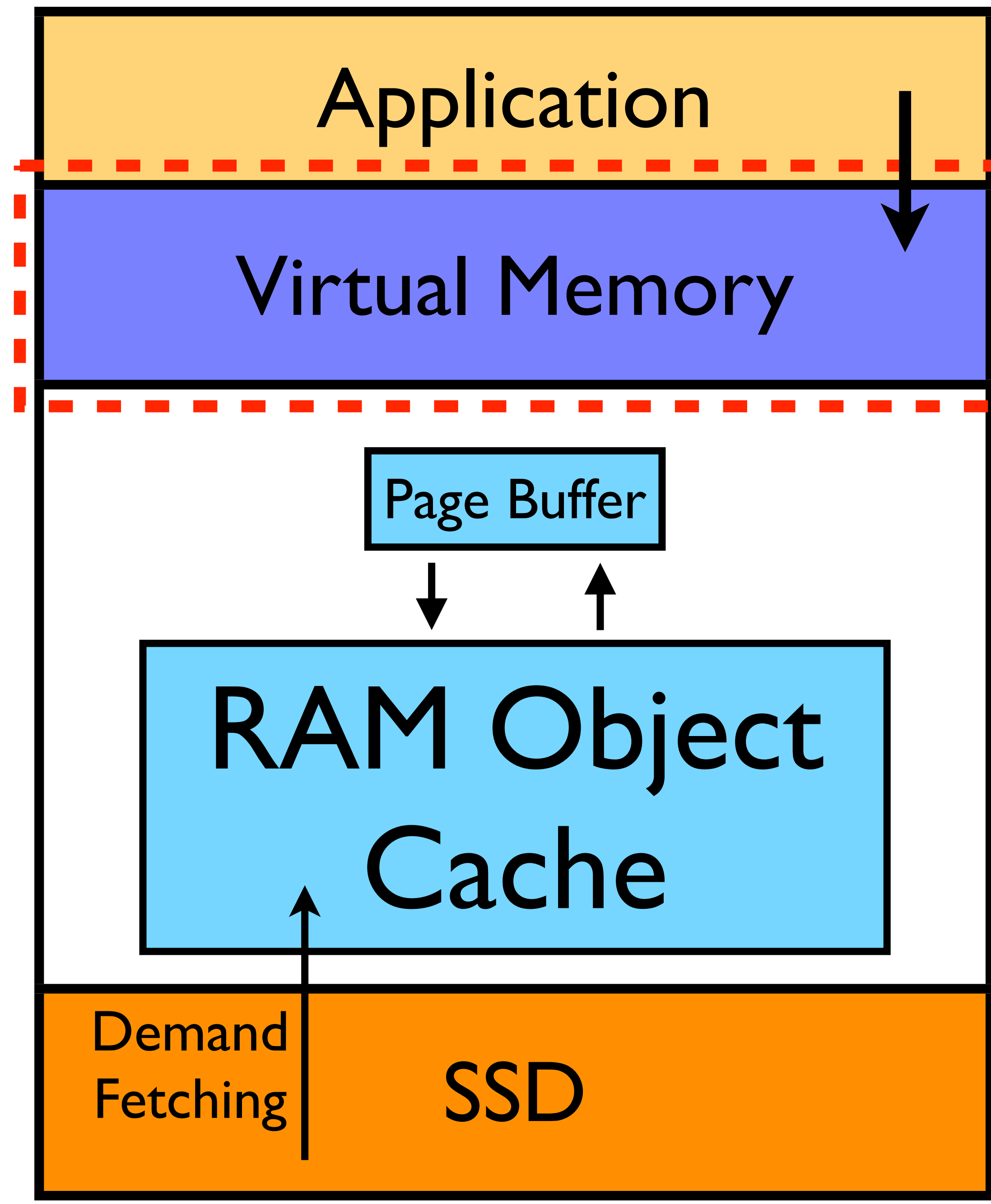

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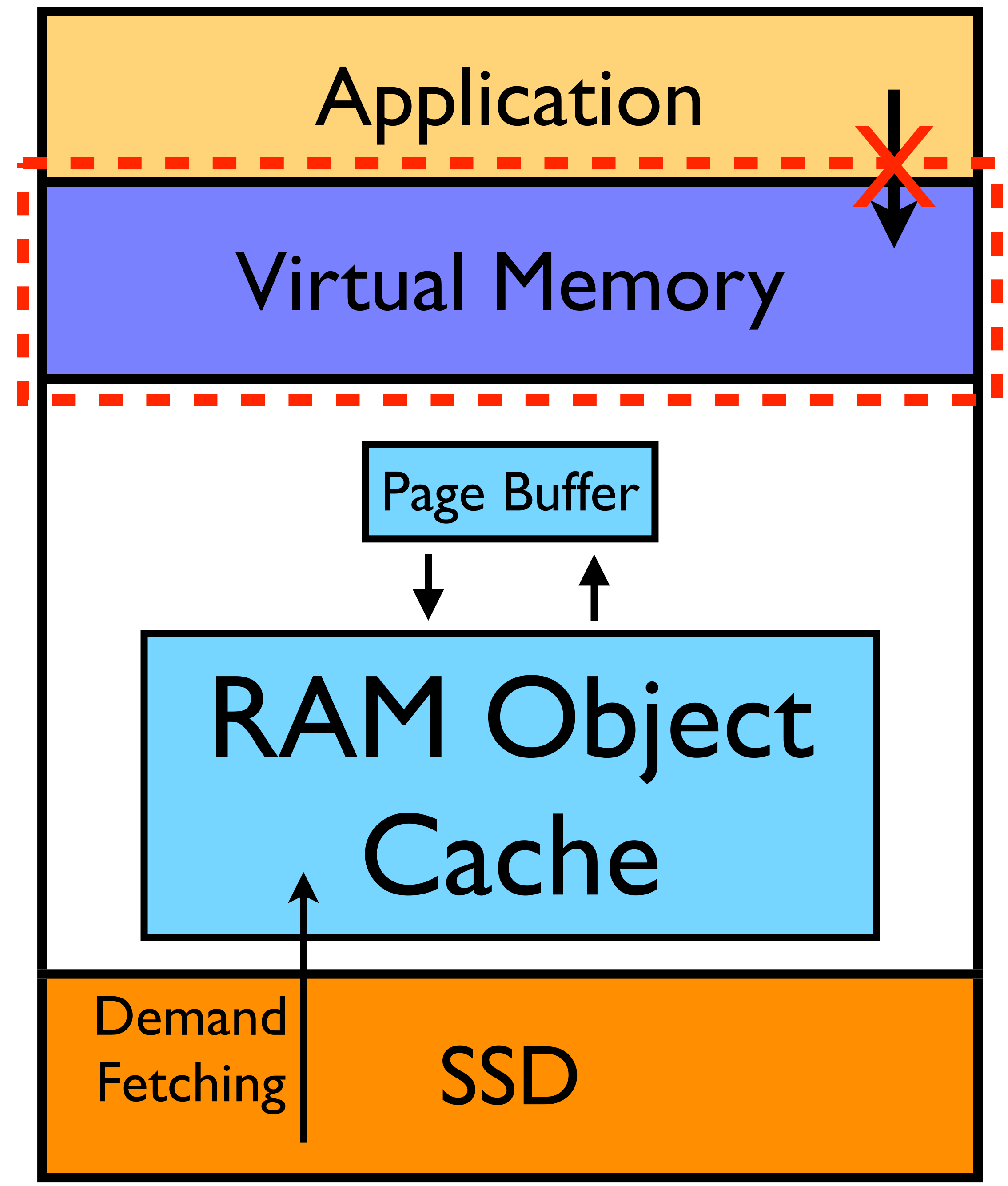

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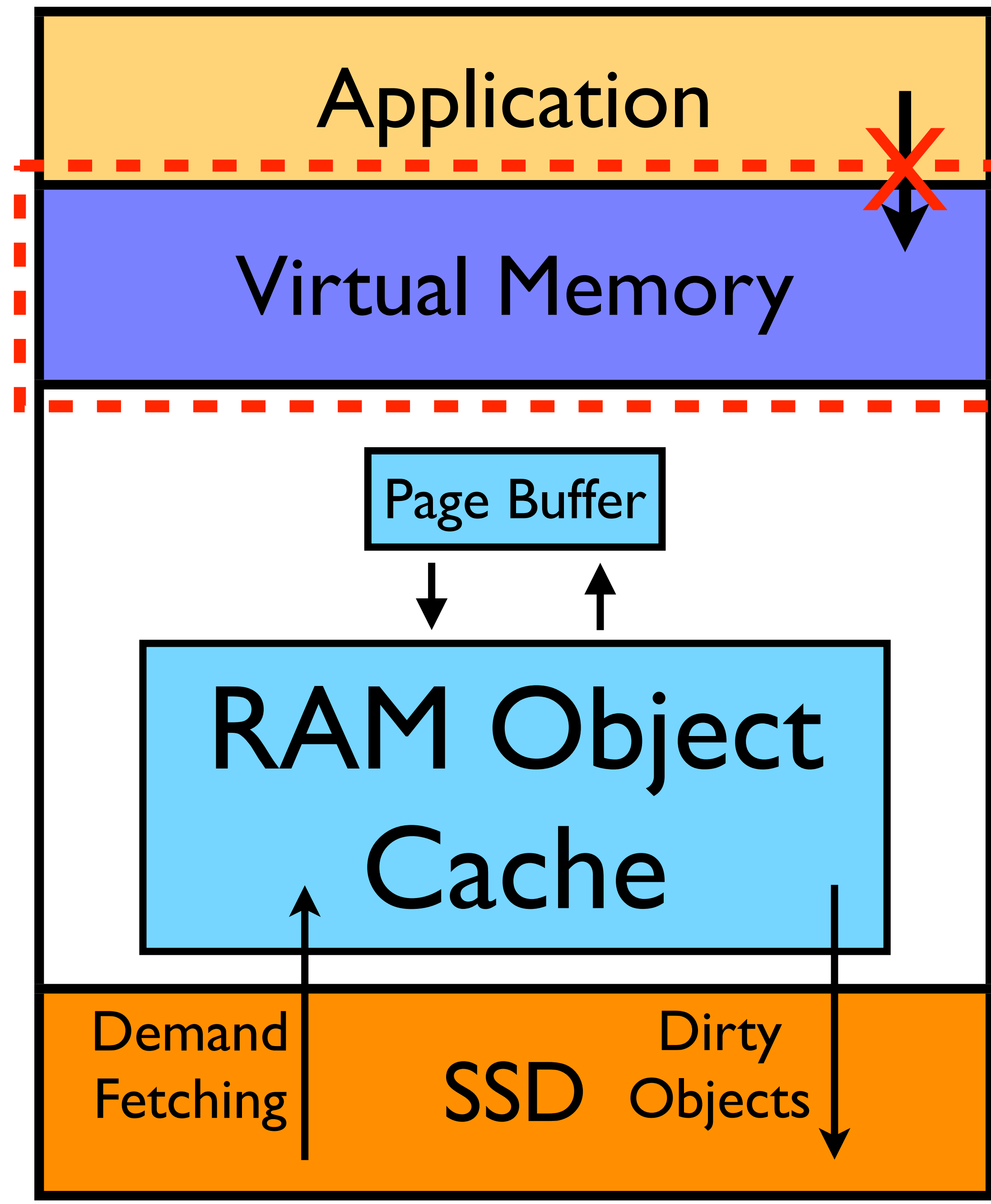
- RAM Object Cache continuously flushes dirty objects to the SSD in LRU order



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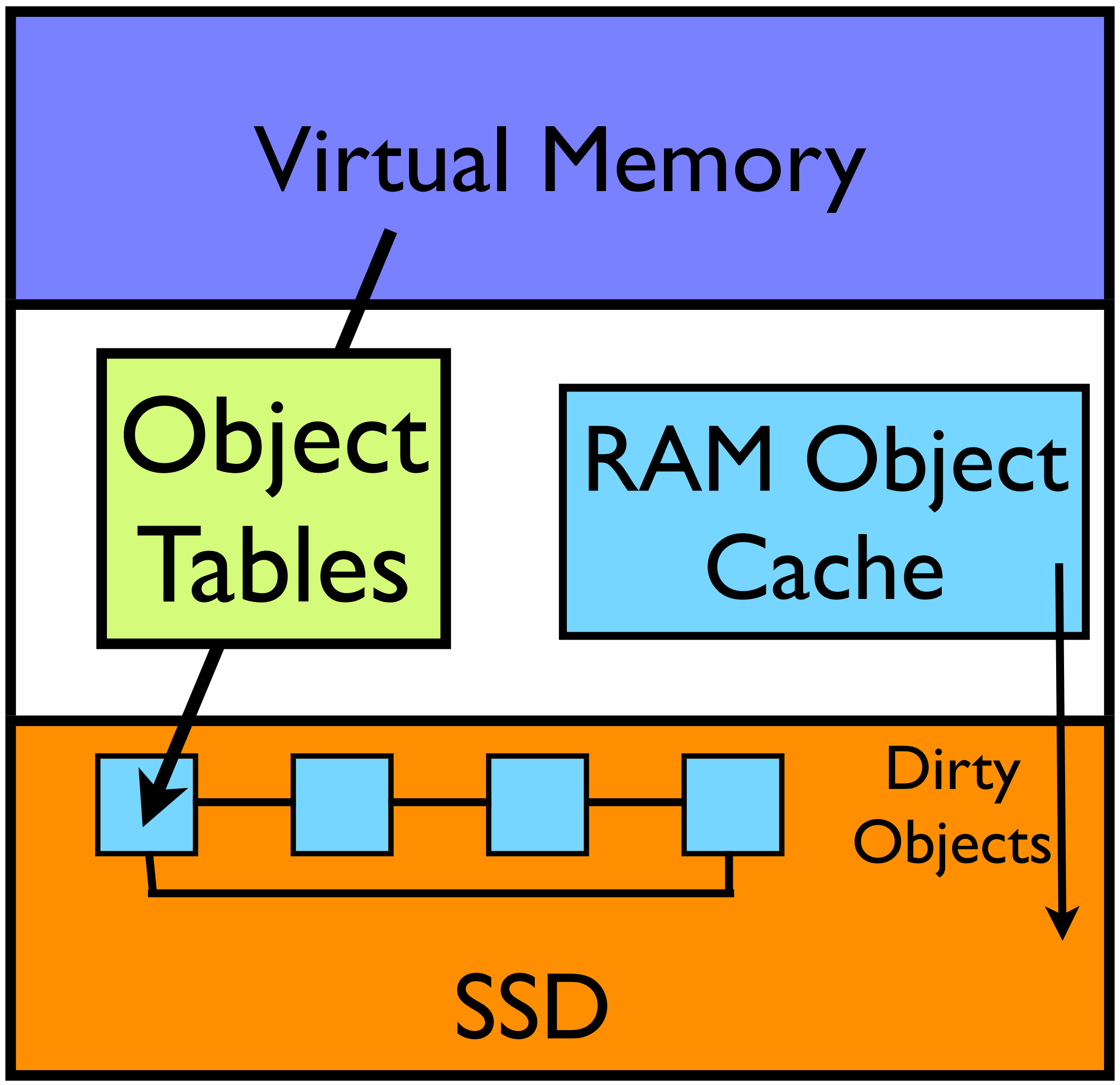

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- Garbage is disposed
  - Objects written elsewhere are garbage
  - OPP object which is "free" is garbage

Implementation

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- 11,000 lines of C++ code (runtime library)
  - Implemented using *mprotect, mmap, and madvise*
  - *SSDAlloc-OPP* pool and array allocator
  - *SSDAlloc-MP* coalescing allocator (array allocations)
  - *SSDFree* frees the allocated data
  - Can coexist with malloc pointers

SSD Usage Techniques

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Technique	Write Logging	Access < 4KB	Finegrained GC	Avoid DRAM Pollution	High Performance	Programming Ease
SSD Swap						✔
SSD Swap (Write Logged)	✔					✔
Application Rewrite	✔	✔	✔	✔	✔	

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SSDAlloc	✔	✔	✔	✔	✔	✔

SSDAlloc Runtime Overhead

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- Overhead for SSDAlloc runtime intervention

Overhead Source	Max Latency
TLB Miss (DRAM Read)	0.014 µSec
Object Table Lookup	0.046 µSec
Page Materialization	0.138 µSec
Page Dematerialization	0.172 µSec
Signal Handling	0.666 µSec
Combined Overhead	0.833 µSec

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- NAND Flash latency ~ 30-50 µSec
- Can reach 1 Million IOPS

Experiments

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- Comparing three allocation methods
  - *malloc* **replaced with** *SSDAlloc-OPP*
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  - *Swap*

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- 2.4Ghz Quadcore CPU with 16GB RAM
  - RiData, Kingston, Intel X25-E, Intel X25-V and Intel X25-M

Results Overview

Application	Original LOC	Modified LOC	SSDAlloc-OPP's gain vs	
			Swap	SSDAlloc-MP
Memcached	11,193	21	5.5 - 17.4x	1.4 - 3.5x
B+Tree Index	477	15	4.3 - 12.7x	1.4 - 3.2x
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- SSDAlloc applications write up to 32 times less data to the SSD than when compared to the traditional VM style applications

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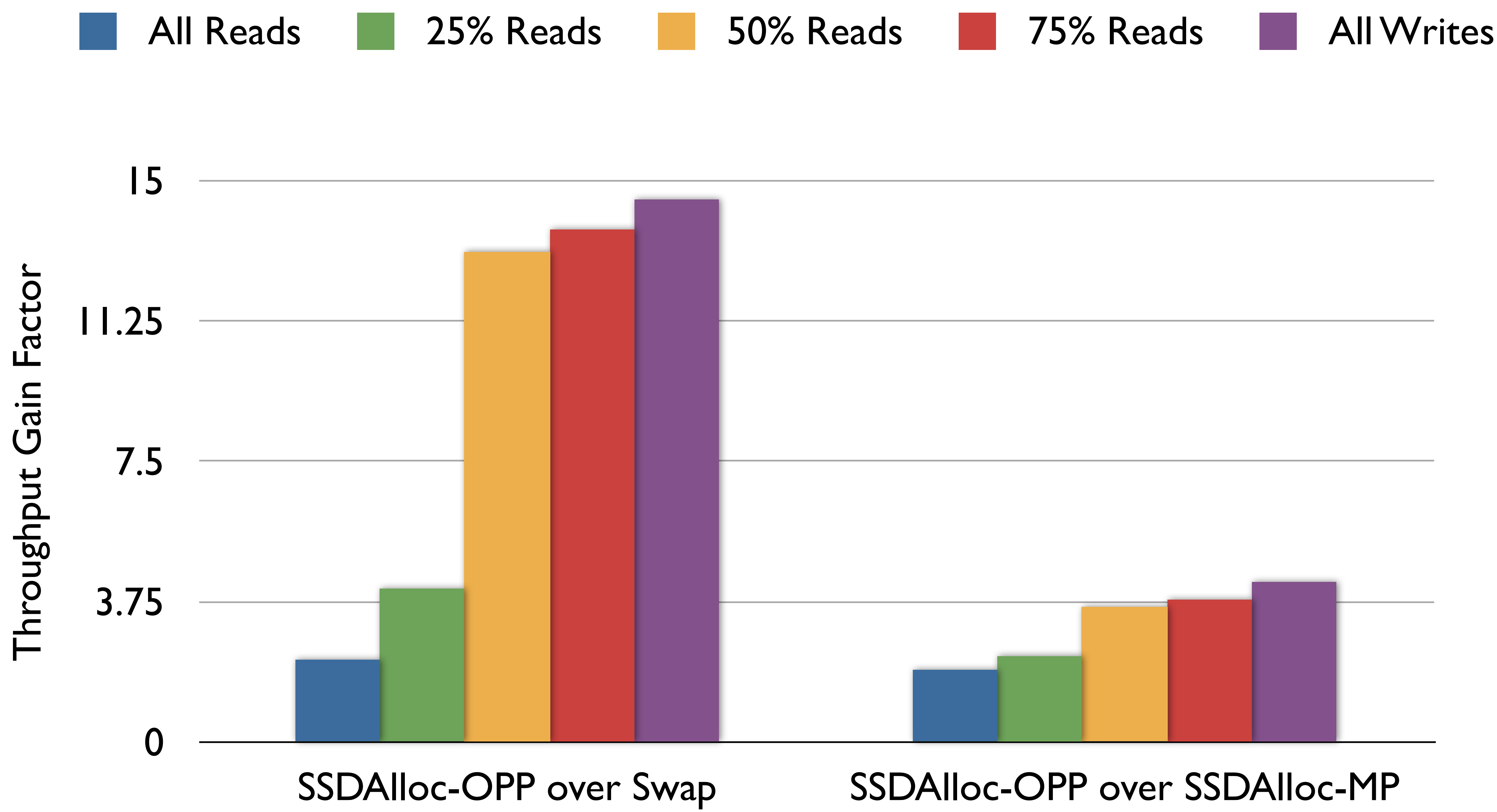

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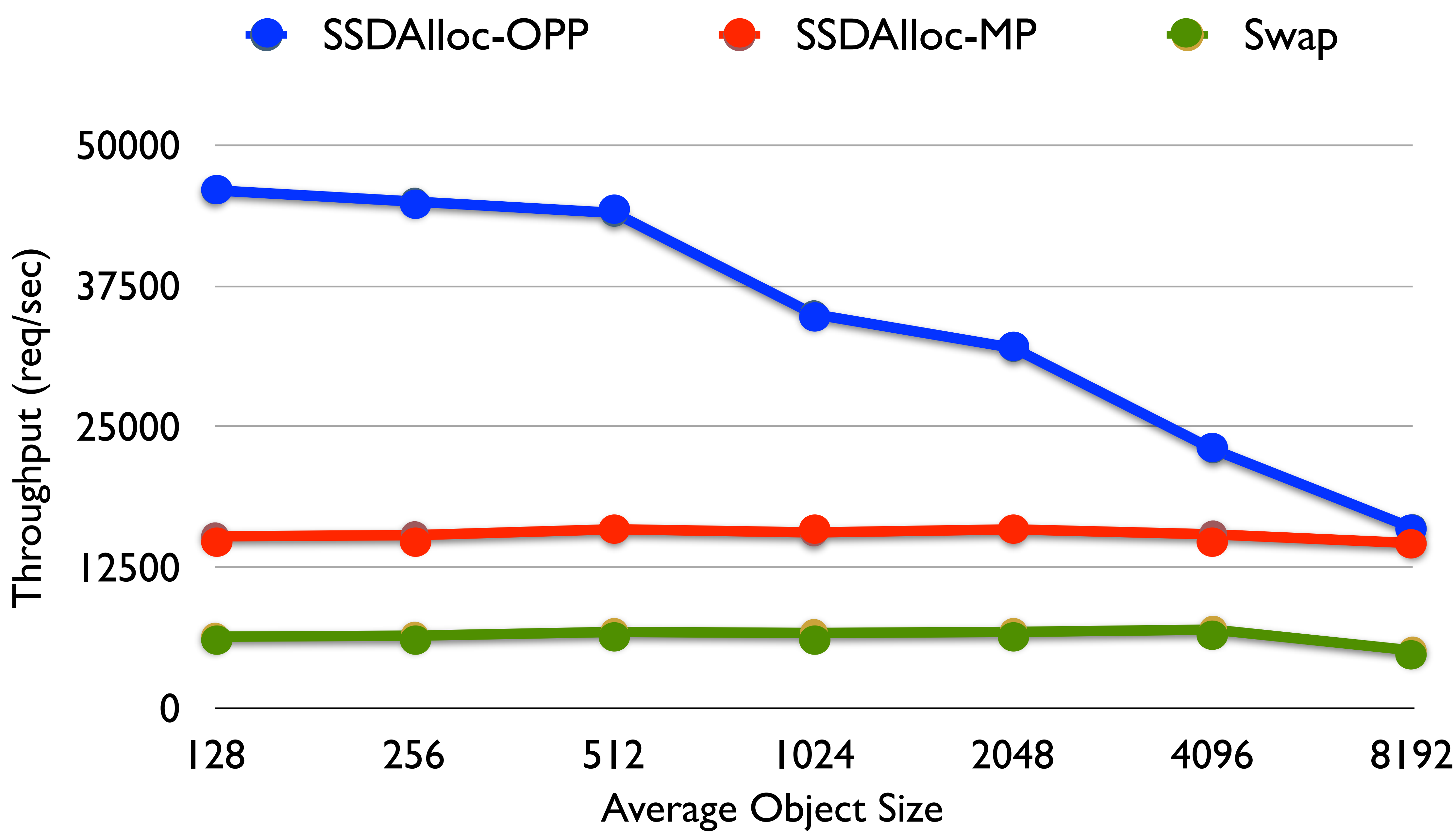

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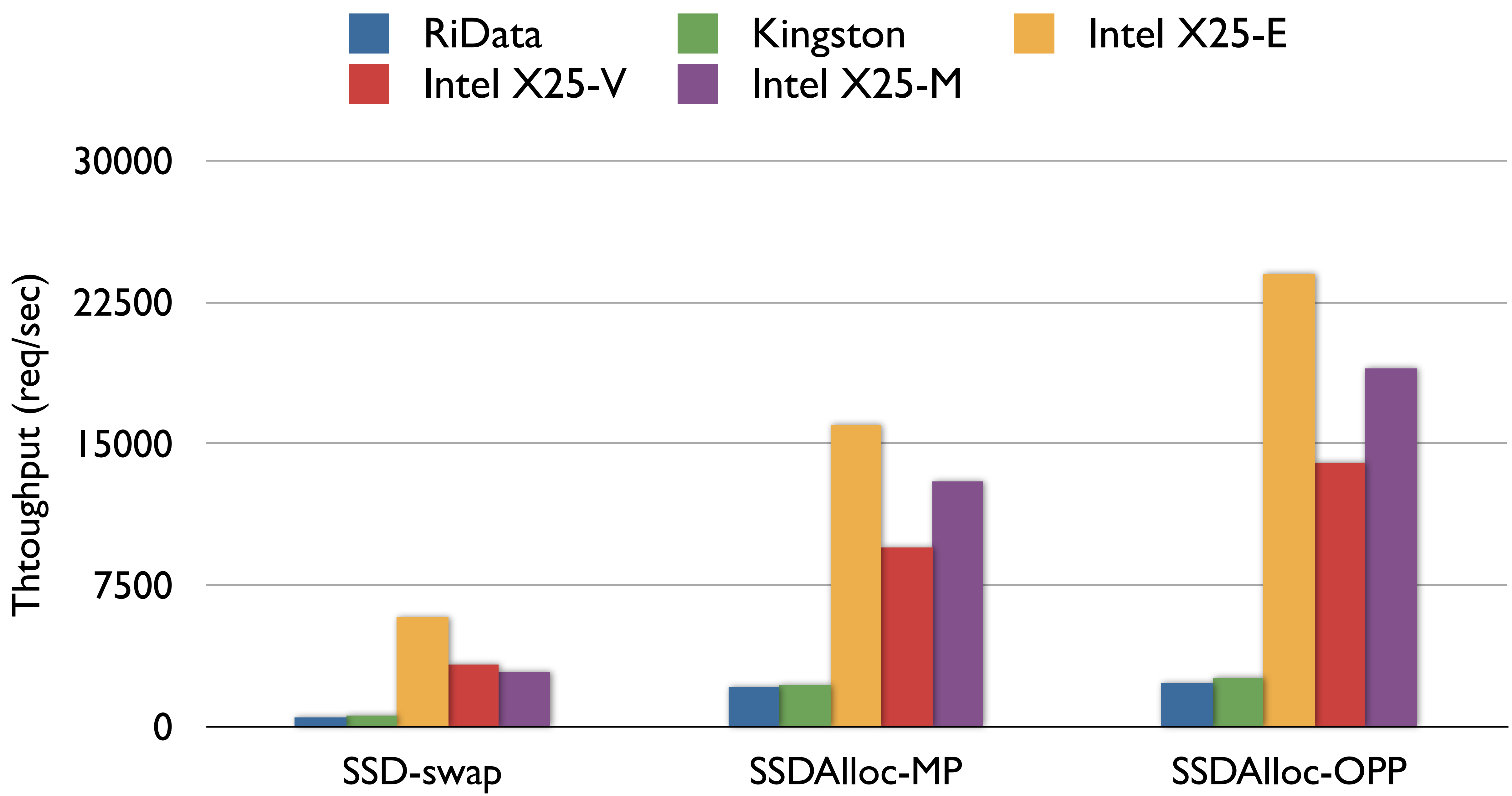
Memcached Benchmarks

- Performance for 50% reads and 50% writes



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- SSDAlloc migrates SSD naturally into VM system
  - RAM as a compact object cache
  - Virtual memory addresses are used
  - Only memory allocation code changes (9 to 36 LOC)
  - Other approaches need intrusive modifications

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  - Other approaches need intrusive modifications
- SSD as log-structured object store
  - Can obtain 90% raw SSD random read performance
  - Other transparent approaches deliver only 10--30%
  - Reduce write traffic by up to 32 times

Thanks

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http://tinyurl.com/ssdalloc