NVAll

A Crash-Resistant and Kernel-Compatible Memory Allocator for NVRAM

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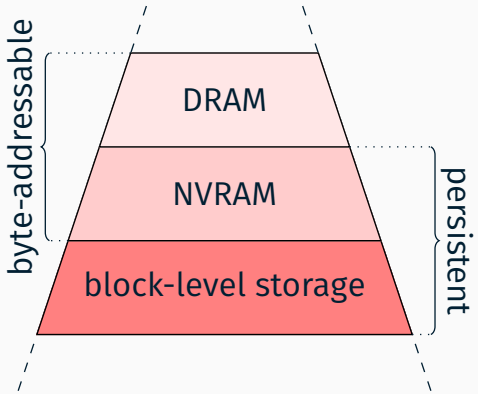
Persistent Memory

Characteristics of Intel® Optane™ Persistent Memory

- byte-addressable
- persistent, no refresh required
- available in TiB
- faster than Flash, slower than DRAM
- better price/capacity ratio than DRAM



Non-Volatile Memory Challenges

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enqueue(queue_t *this, chain_t *item)
{

    item->next=NULL;
    this->tail->next=item;

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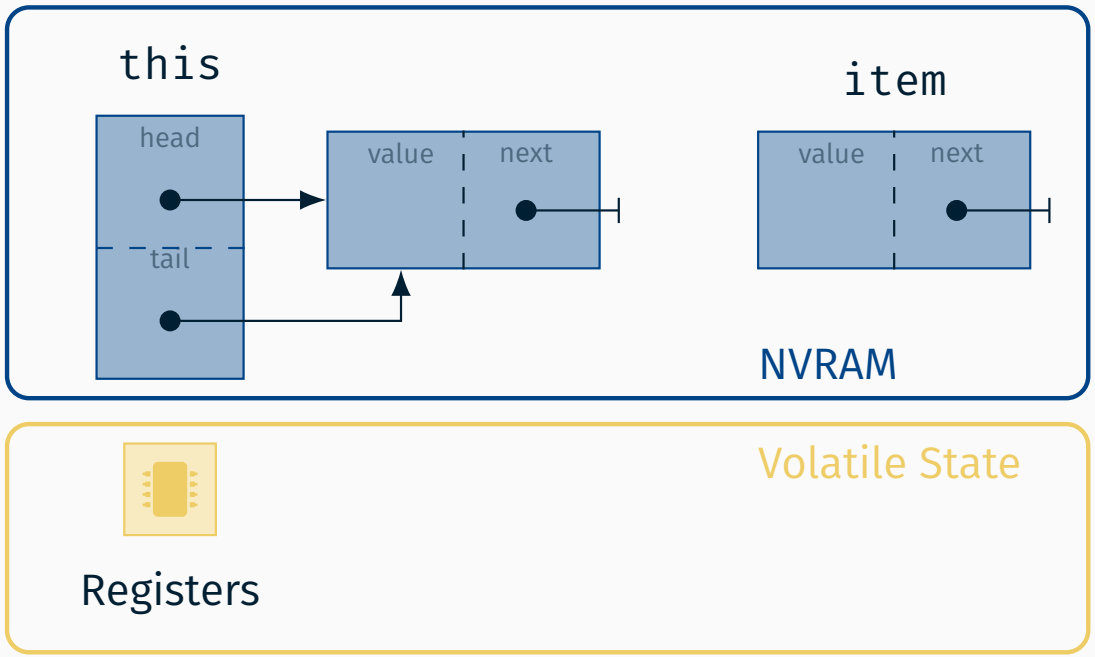

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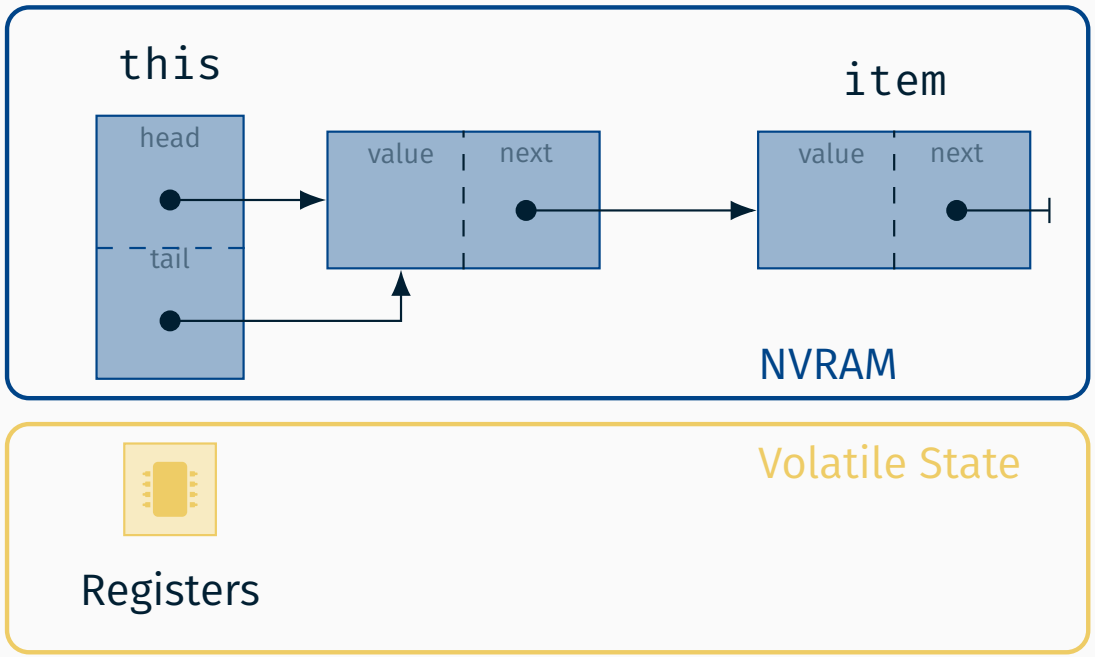

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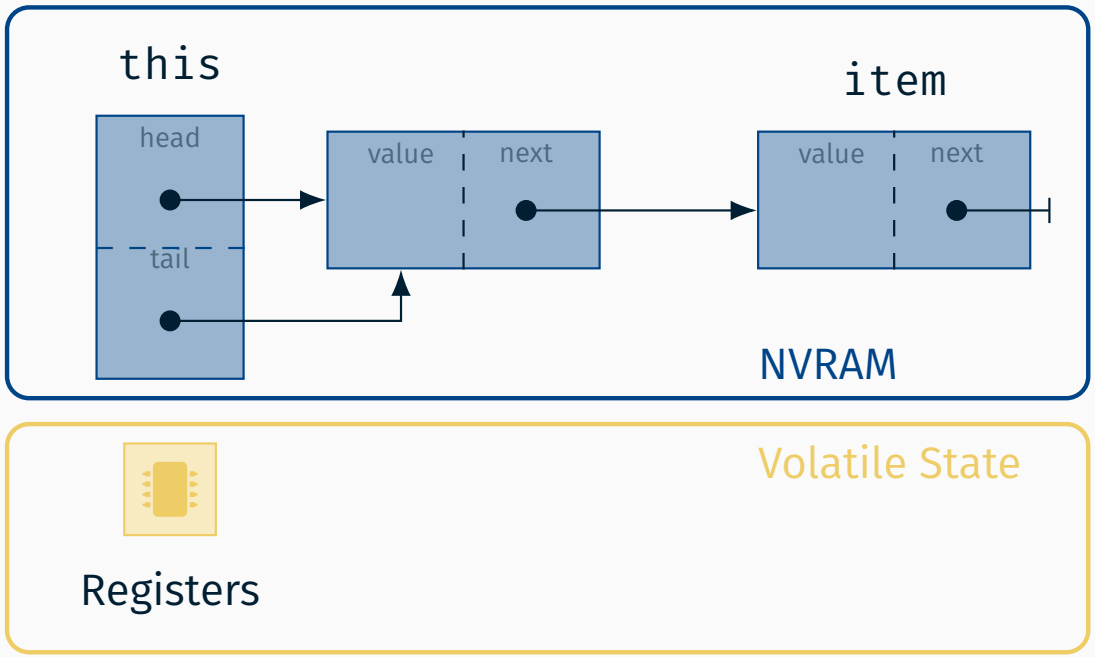

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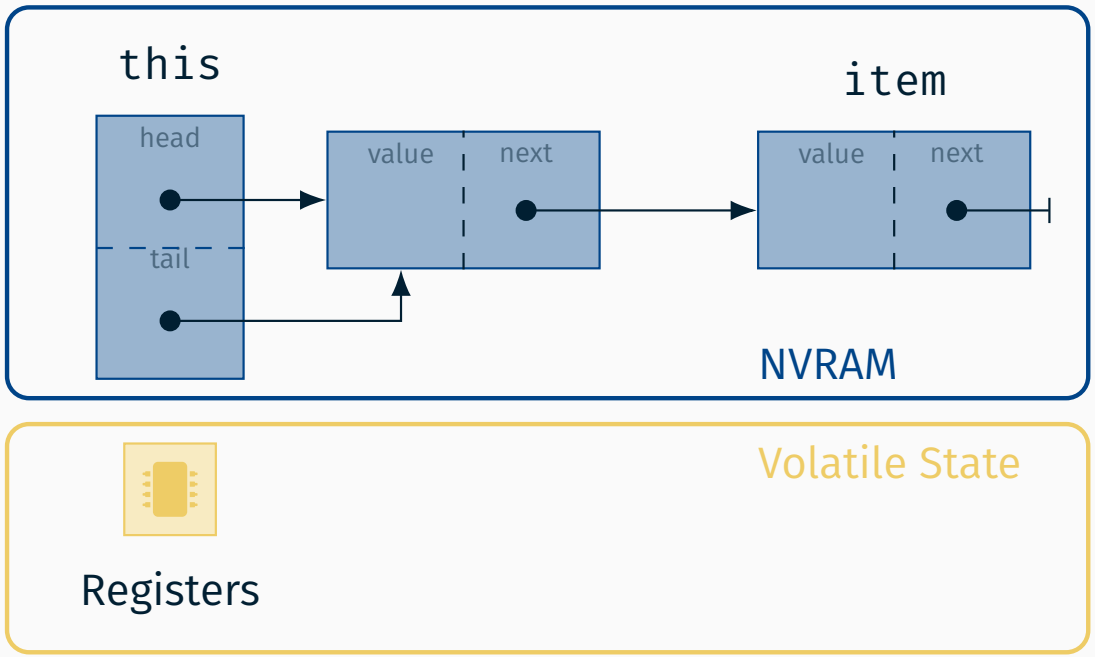

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Broken Time Machine

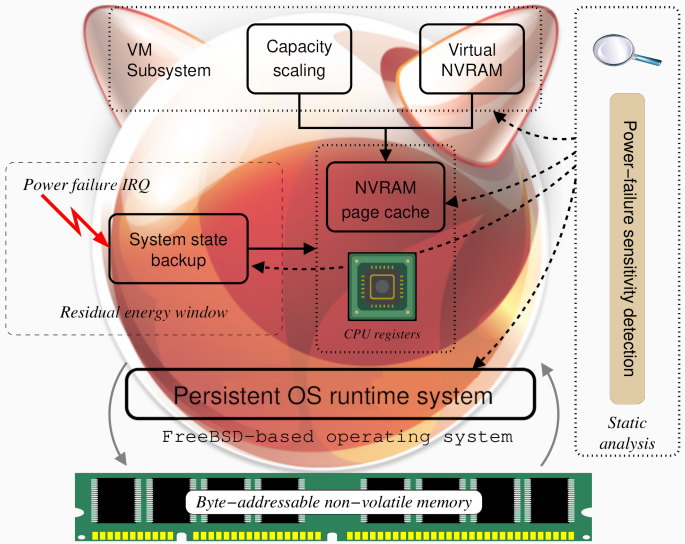
- inconsistent `tail`-pointer
- mutexes are not sufficient

Access Behaviour

- write amplification
- complex multi-threaded performance
- not all data required persistent

NVRAM in the *PAVE* project

- integrate NVRAM into the VM-subsystem
  - utilize NVRAM capacity
  - balance between DRAM and NVRAM
- tolerate sudden blackouts
  - write back volatile state
  - create restauration point
  - resume computation on boot



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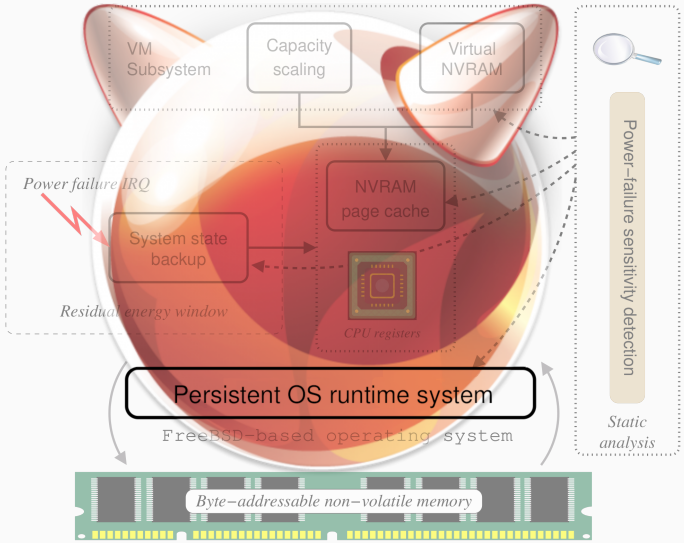
→ recover state from NVRAM



Requirements for an allocator

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- provide multiple page granularities
- minimal dependencies
- durability during power outage
- retrieval of data (by *key*)
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- ✗ awareness of physical memory characteristics
- ✗ NVRAM capable locks
- ✗ minimal data structures
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→ new transactional allocator required

Interface

```
int example(void) {
    int err, flags = NVA_FLAG_ALIGN | NVA_FLAG_ZERO;
    struct example {
        nv_ptr next;
        unsigned value;
    } *ptr;
    nv_ptr parent;

    nv_store_resolve("example", &parent);
    if (*parent == 0)
        err = nva_alloc(parent, 2, NVA_SIZE_4K, flags);
    ptr = *(struct example **)parent;

    if (ptr->next == 0)
        nva_alloc(&ptr->next, 1, NVA_SIZE_4K, flags);

    ptr->value++;
    struct memory_range_nv r = {ptr, ptr+1};
    nv_persist_range(&r);
    return ptr->value;
}
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- recovery of previous allocation

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- recovery of previous allocation
- new allocation to volatile root obj
- new allocation to persistent obj
- enforce write to NVDIMM

Transactions

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// ar: Allocated Range
// container: nv_ptr
ar->range.end = free_range.end;
ar->range.start = free_range.start;
nv_persist_range(ar);
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ar->parent = container;
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*container = range->start;
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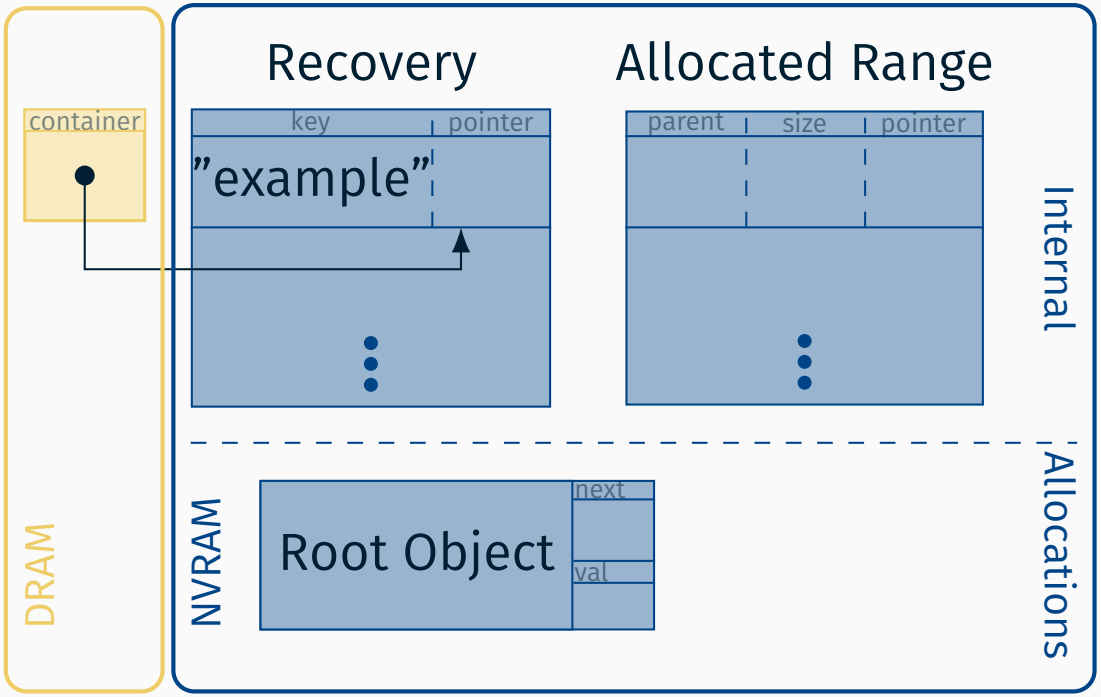

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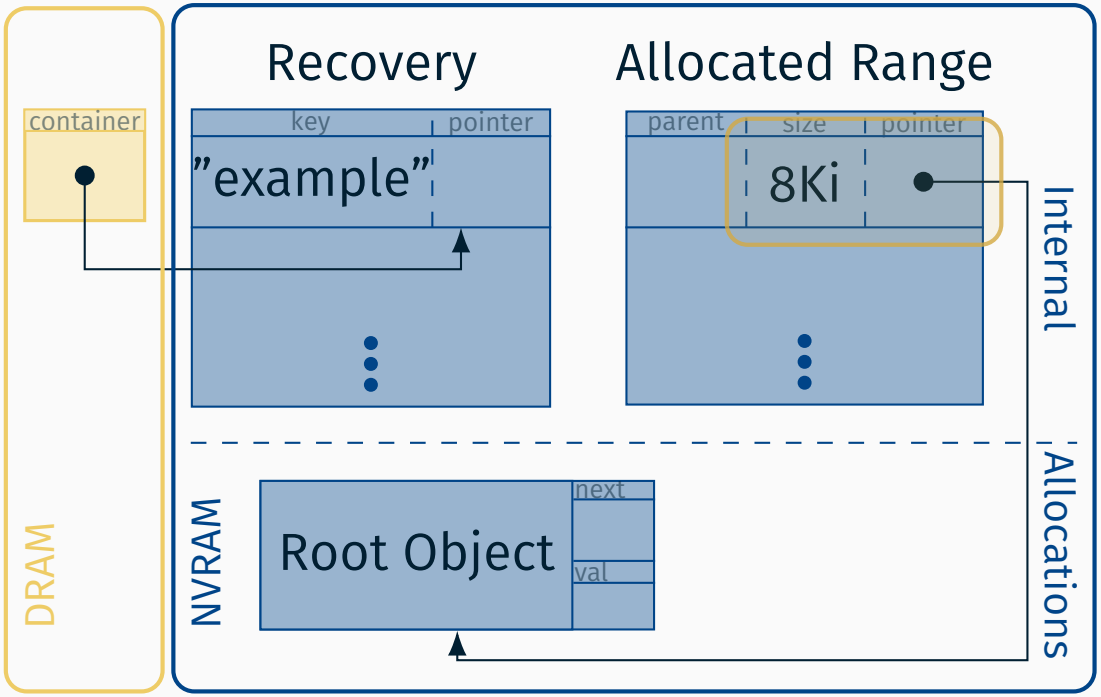

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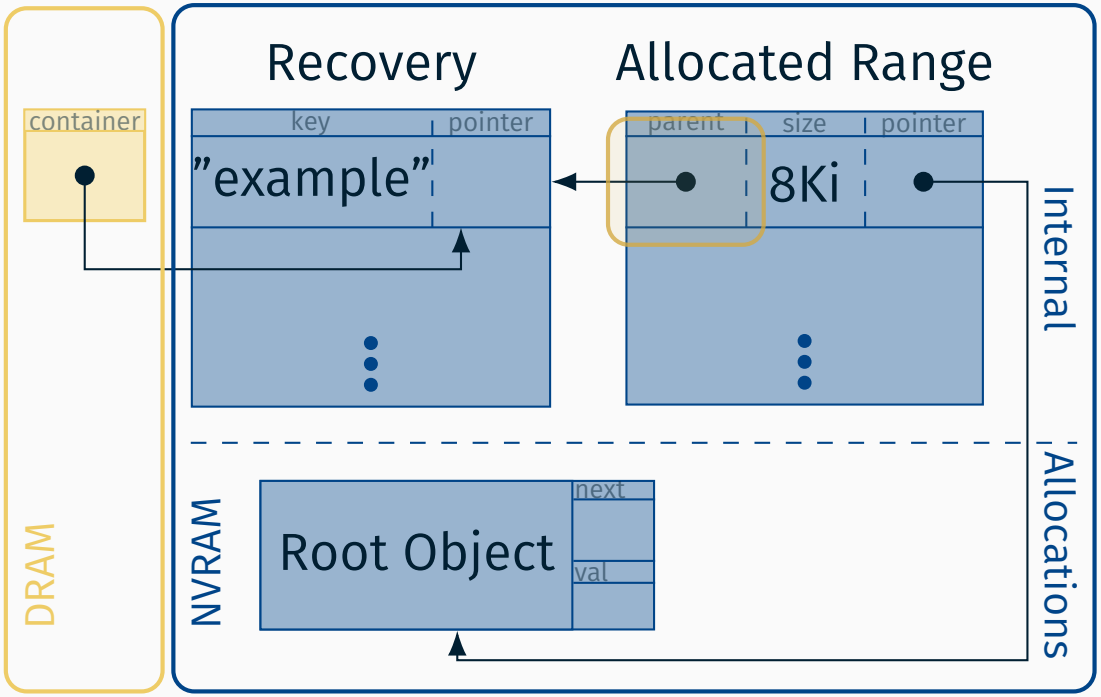

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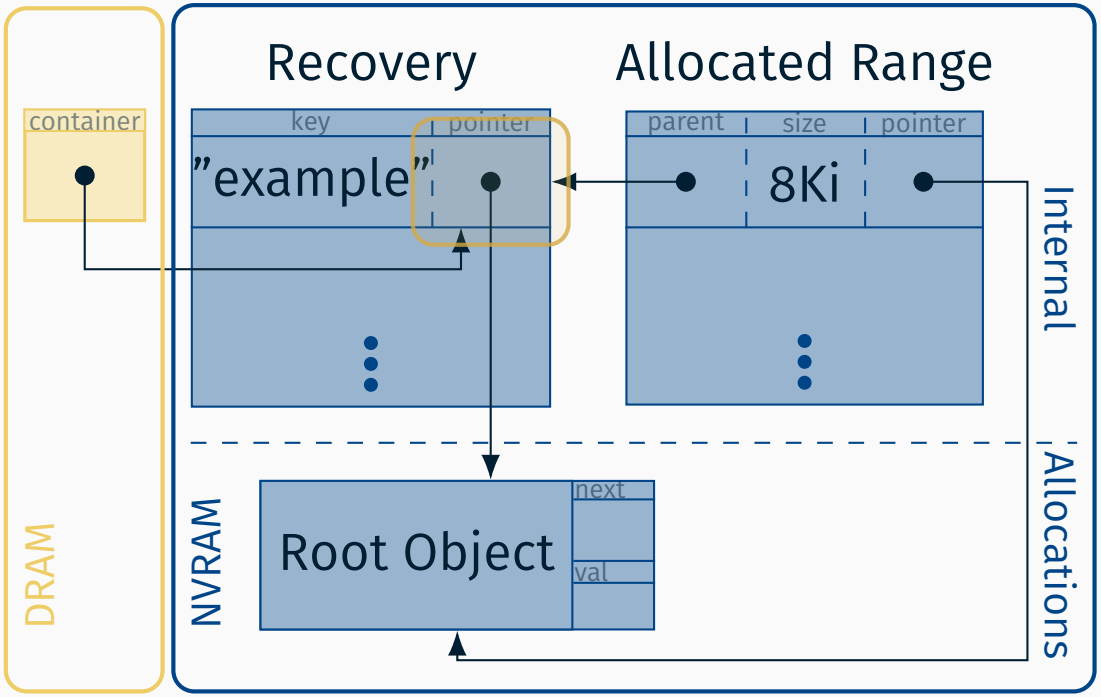

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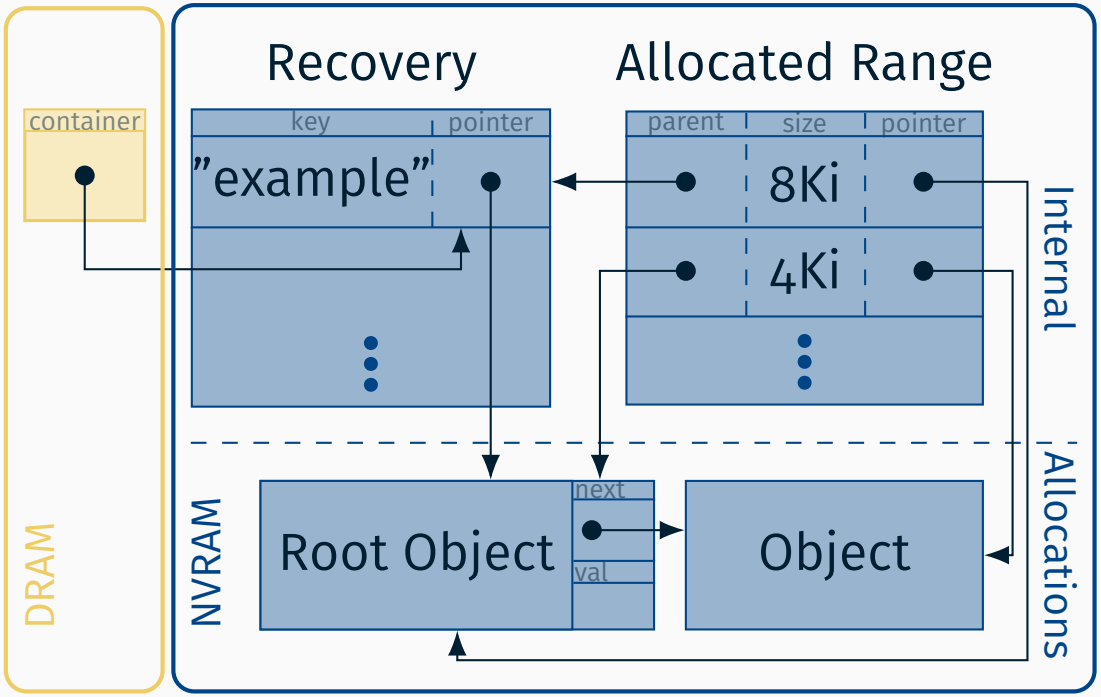


Conclusion

With *NVall* we have

- ✓ very few dependencies
- ✓ support for varying granularity
- ✓ durability in case of crash
- ✓ retrieval of previous state

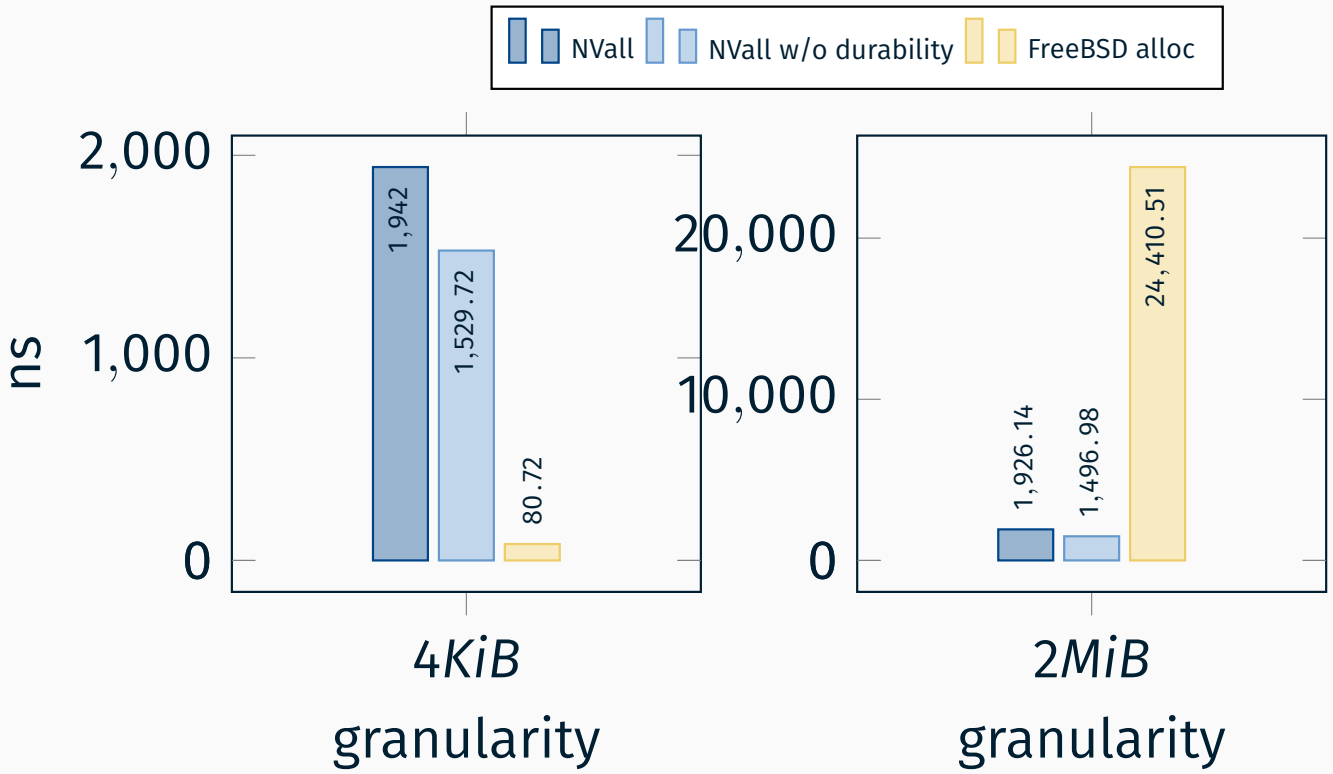
We can build

- → suspend/resume with NVRAM
- → statistic logging of early boot/shutdown

Source code available at:
https://doi.org/10.5281/zenodo.8364439

Appendix

Eval


NVall
NVall w/o durability
FreeBSD alloc
ns
2,000
1,000
0
1,942
1,529.72
80.72
4KiB
granularity
20,000
10,000
0
1,926.14
1,496.98
24,410.51
2MiB
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