Embedded Linux Conference
Europe

Allocators for Compressed Pages

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Intro: Compressed memory allocator

- It’s an allocator, Cap.
  - allocates memory according to user’s demands
- It’s designed to store compressed data
  - chunks of arbitrary length
    - usually quite small, way less than a page
    - ordinary kernel allocator would be a waste of space
  - it doesn’t compress anything itself

Okay what purpose does all that serve?

Swapping

- using secondary storage to store and retrieve data
  - secondary storage is usually a HD or a flash dveice
  - saves memory by pushing rarely used pages out
- trade memory for performance?
  - reading and writing pages may be quite slow

Swapping optimization

- use RAM to cache swapped-out pages
  - but what's the gain then?
- compress swapped-out pages
- trade performance for memory?
  - bigger cache means better performance
  - now we can be more flexible

Swapping and compression

- zswap: compressed write-back cache
  - compresses swapped-out pages and moves them into a pool
  - when the pool is full enough, pushes the compressed pages to the secondary storage
  - pages are read back directly from the storage

Allocator for zswap?

- zbud: the first compressed data allocator
  - stores up to 2 objects per page
    - one bound to the beginning
    - one bound to the end
  - actual compression ratio may be quite low
    - imagine high amount of chunks sized 2K+Ɛ

zsmalloc

- came as an alternative to zbud
  - addresses the situation with 2k+ε sized objects
  - allocates objects contiguously within physically uncontiguous pages
    - objects may span across several pages
      - high compression ratio in the beginning
      - hard to mitigate in-page fragmentation over time as objects are allocated and released

Compressed allocator API

- 2 allocators used by zswap and doing the same thing differently
  - That calls for unification
- zpool: a common compressed allocator API
  - zswap is converted to use zpool
  - zbud and zswap both implement zpool API

Quite boring so far...
What happened next?

ZRAM: compressed RAM disk

- RAM block device with on-the-fly compression/decompression
  - uses zsmalloc directly via its API
- Alternative to zswap for embedded devices
  - no backing storage necessary
  - pages swapped to compressed RAM storage

Can’t do zram with zbud?!

	zbud	zsmalloc
zswap	🟩 ▯	🟩 ▯
zram	🟥 ▯	🟩 ▯

ZRAM over zpool API

- Pros
  - unification and versatility
- Cons
  - none
- Patches ready
- Several attempts to mainline the patches
  - blocked by the maintainer

ZRAM over zpool API: test with zbud

- No performance degrade over time
  - stable and sustainable operation
- Peak performance lower than with zsmalloc
  - spinlocks don’t scale well
- Low compression ratio
  - 1.5x - 1.7x in real life scenarios
  - not enough to justify ZRAM for embedded

So what if we modify zbud to hold up to 3 objects?

z3fold: new kid on the block

- spun off zbud
- 3 objects per page instead of 2
- can handle PAGE_SIZE allocations
- only implements zpool API
  - no custom API here
- work started after ELC 2016 in San Diego
  - in the mainline since 4.8

z3fold: good for both ZRAM and zswap

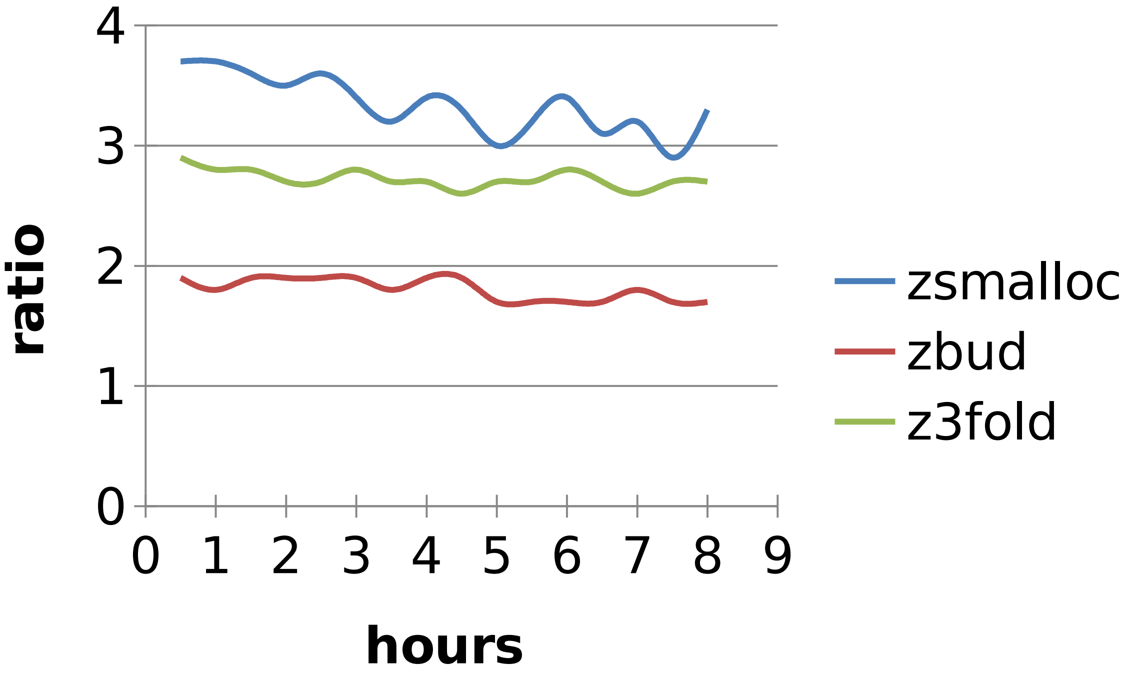
- for ZRAM
  - supports up to page size allocations
  - low latency operation
  - good compression ratio
- for zswap
  - supports eviction unlike zsmalloc
  - higher compression ratio than zbud

Ok let’s do the fun part. Comparisons!

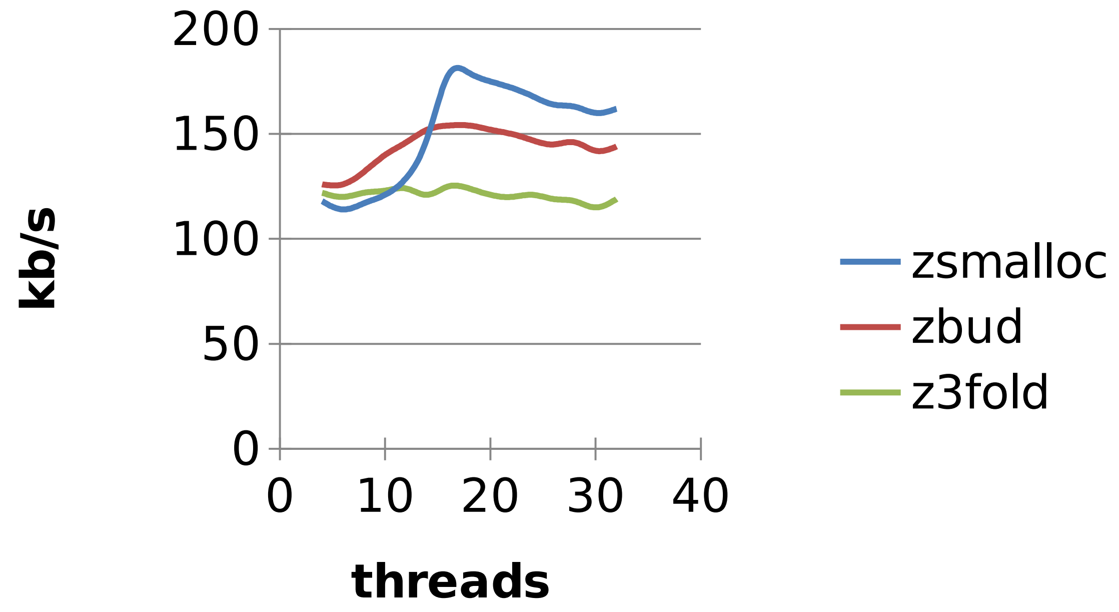
Currently allowed combinations

	zbud	zsmalloc	z3fold
zswap	🟩	🟩	🟩
zram	🟥	🟩	🟥

Compression under stress (4.8)



Random read/write(4.8)



Conclusions so far

- z3fold provides good compression ratio
- z3fold doesn't scale well to larger number of CPUs/threads
    - Third level
        - Fourth level
            - » Fifth level

z3fold: profiling

- using perf while running fio
  - identify bottlenecks under stress load
- using perf while Android LMK is triggered
  - how z3fold operation affects user experience

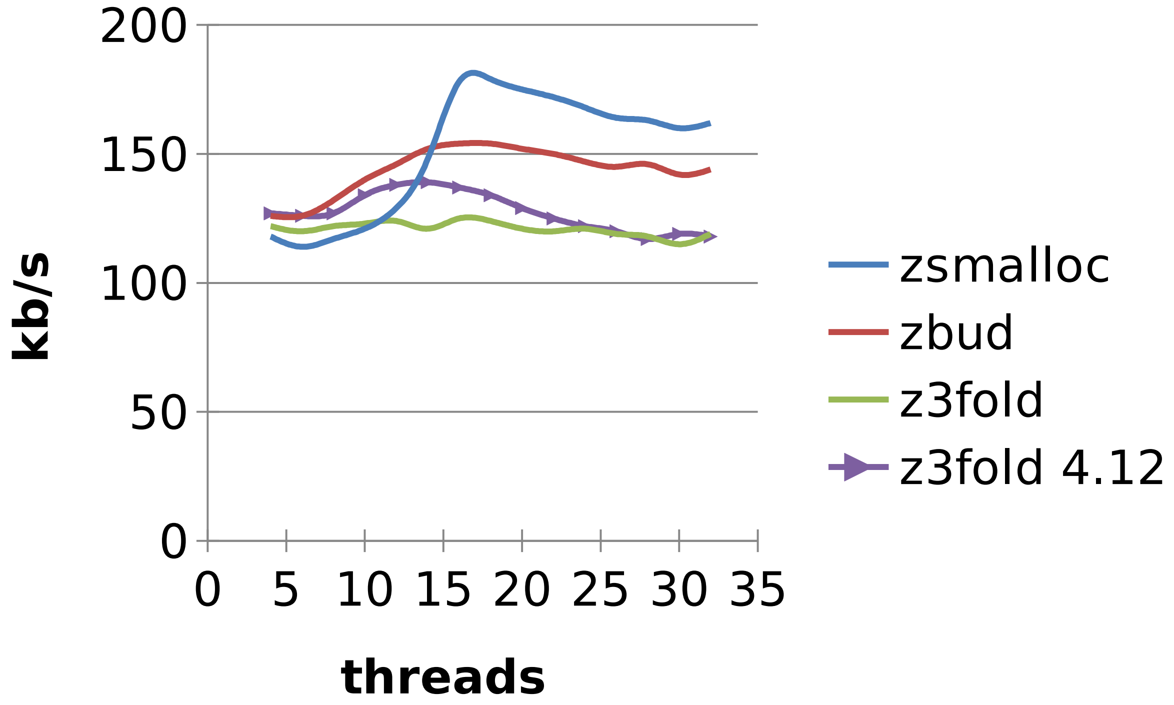
z3fold: profiling results

- spinlocks are the main obstacle to scalability
  - the “big” spinlock that protects “unbuddied” lists is the biggest one
- using perf while Android LMK is triggered
  - how z3fold operation affects user experience

z3fold: per-page locks

- Keep “big” spinlock for list operations
- Have “small” spinlocks to protect in-page operation
  - this goes well with async in-page layout optimization
- in mainline kernel since 4.11

Random read/write(4.12)



z3fold: lockless lists (llist)

- Idea: implement unbuddied lists using llist
  - Should improve scalability with less locking needed
- Unfortunately llist wasn't a fit
  - Can't do a llist_del
    - Complicates unbuddied lists manipulation up to the point where it makes no sense

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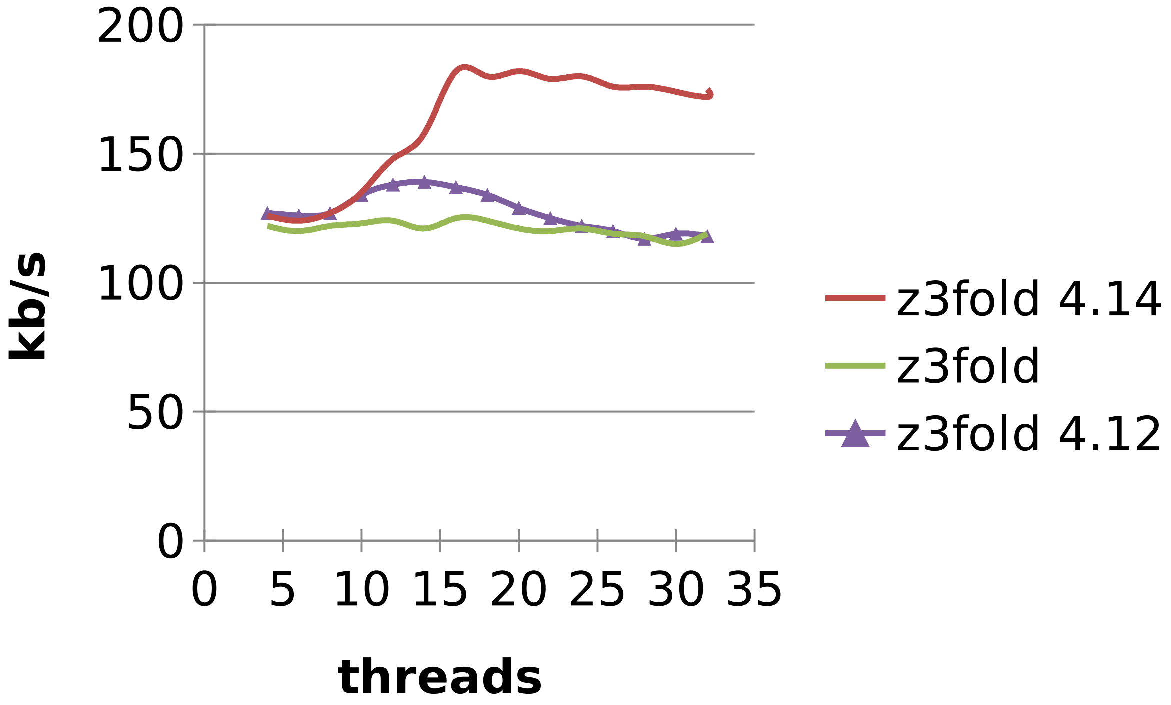
z3fold: per-CPU “unbuddied” lists

- z3fold can operate only on this CPU's list
  - Reduces contention on spin lock
  - Speeds up search
- That can have adverse effect on ratio
  - Z3fold header gets bigger
  - Worse selection
  - More memory for multiple lists
- Will get into 4.14

Random read/write(4.14-rc4)



z3fold: bit locks

- Z3fold header size better be 1 chunk
  - Now 2
- Bit locks may be used to mitigate bigger header
  - Slightly worse performance
  - Evaluation in progress

Conclusions

- Z3fold is still a young allocator
- Still z3fold already outperforms other allocators
- Z3fold is a good fit both for zswap and ZRAM
- We need to push ZRAM to use zpool

Questions welcome!

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