11/7 Eviction

Limited Memory

→ Physical memory is full, what do we do?

① Out of memory killer
- → disruptive in desktop setting
- → more common in mobile OSes

② Reuse physical frames
- → storage devices (disk, SSD, larger in size)
- → eviction: select a frame to evict, write its content to storage, give the frame to another page

1 million times slower → 1000x slower

Why? Bc it might be accessed later!

✱ Do we always need to write the frame out to disk?
- → code & clean data page (already in Elf file on disk)
- → memory mapped files

iOS developers trying to figure out memory budget to avoid their apps from being killed ^^

device: (crash amount/total amount/percentage of total)

- iPhone X: 1392/2785/50% (iOS 11.2.1)
- iPhone XS: 2040/3754/54% (iOS 12.1)
- iPhone XS Max: 2039/3735/55% (iOS 12.1)
- iPhone XR: 1792/2813/63% (iOS 12.1)
- iPhone 11: 2068/3844/54% (iOS 13.1.3)
- iPhone 11 Pro Max: 2067/3740/55% (iOS 13.2.3)
- iPhone 12 Pro: 3054/5703/54% (iOS 16.1)

3 iPhone 5 crashes at ±645 MB. – asp_net Dec 15, 2013 at 21:03

iPhone 5S crashes at ±646 MB pretty reliably here. – eAi Oct 3, 2014 at 13:30

iPhone 4S crashes at ±286MB (286MB/512MB/56%). – Xaree Lee May 29, 2015 at 21:50

iPhone 4S doesn't crash until it reaches ±363 MB for me. (iOS 5.1.1) – Soeholm Jun 3, 2015 at 16:53

2 Awesome that this list has been created and maintained. In my experience, I've had to keep memory much lower to be safe, maybe 20% of what's shown here. Device-to-device differences are also highly variable. – user1021430 Aug 10, 2015 at 19:24

1 Just ran this on a 12.9 iPad Pro. Memory warning at 2451MB, crash at 3064MB, total 3981MB. – lock Jul 15, 2016 at 13:22

iPhone 6s+: 1392MB/2048MB/ 68% (iOS 10.2.1); iPhone 7+: 2040MB/3072MB/66% (iOS 10.2.1) – Slyv Feb 13, 2017 at 15:39

Eviction Mechanisms

→ Where do we write the evicted page to?

- Swap partition (or file)
  - ↳ section of sectors or blocks
- Swap allocation (track which sectors/blocks are free, bitmap)
- update bookkeeping structures so we can serve page fault for the evicted page

→ How to reflect the eviction

- remove the old mapping (TLB shootdown) ← vspaceinstall (lcr3 instr) flushes TLB
- zero out the frame (prevent info leaking)
- install the new mapping

Can multiple pages be mapped to a single frame?

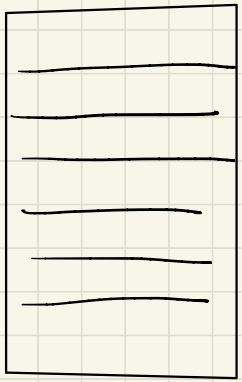
→ shared memory

→ cow fork

~~&~~ needs to track refcount "core_map_entry" tracks info about each frame

Eviction Policies

→ What frames to choose from?



physical memory

→ global page replacement (eviction) policy
  → can evict any frame in physical memory
  → a process can affect other processes' performance by evicting their pages out

→ local page replacement policy
  → only evict frames occupied by the current process, doesn't affect other processes
  → need to decide on how many frames each process can have

Policies

★ goal: select page to evict that will result in less page faults in the future

→ LRU: least recently used, if not used recently, less likely to be used in the future, so good candidate for eviction

→ How to implement this?

→ SW: queue, easy to do

→ HW: timestamp??

} much cheaper to approximate LRU in HW instead

→ What access patterns might be bad for LRU?

→ N frames, N+1 pages (iterate through every page a couple of times)

frame # 0 1 2 3 .... N

page # ~~0~~ ~~1~~ ~~2~~ ~~3~~ .... N

N+1 0 1 2

→ Clock (Approximate LRU)

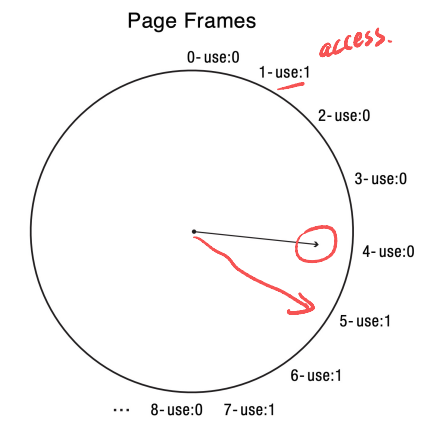
→ clock hand: starting frame for eviction

→ check frame's page's page table entry

→ pte stores permission & access info (bits = access bit) ← set by the hw when it caches the translation

→ access bit == 0 : select frame to evict, advance clock hand

→ access bit == 1 : clear bit and move on (keep looking)



☆ Clock only considers timing info, but recall that some frames might not need to get written back to disk, picking those frames could make eviction much faster