Proposal of Live Dump

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LinuxCon Japan '12

Agenda

1. What is Live Dump?
2. Implementation
3. Future work

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2. Implementation
3. Future work

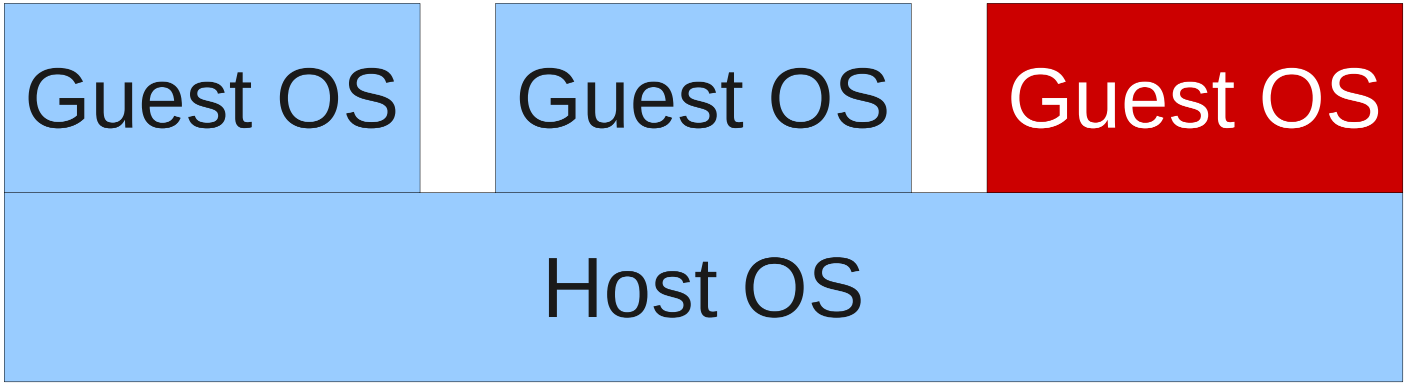
Motivation

- Server consolidation for very important systems

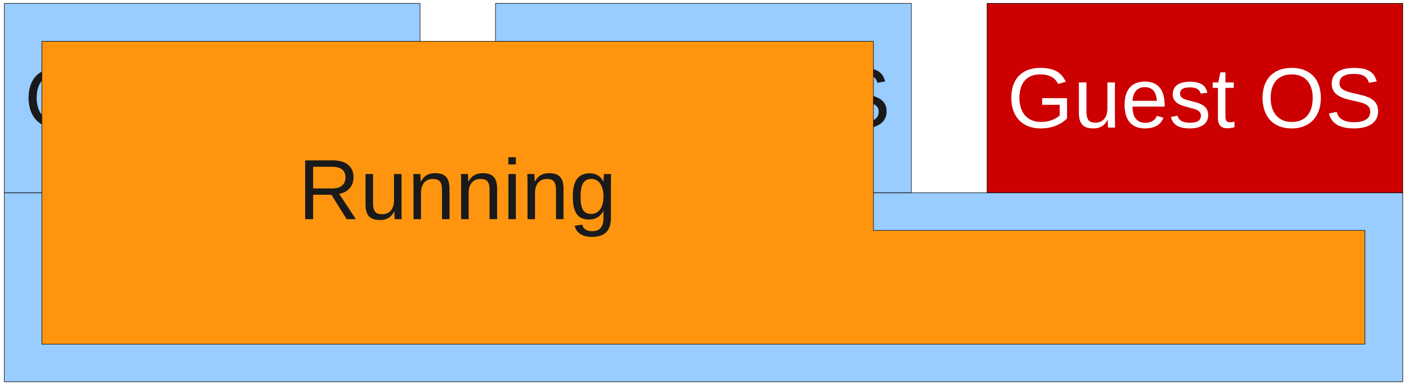
- Problem：Availability vs Serviceability
  - Availability
    - We have to keep a host OS running even after some of guests crash.
  - Serviceability
    - We have to obtain memory dump of both guests and a host to make sure to identify cause of the crash.

Goal

- Assume one guest crashed but others are still running normally.



Goal



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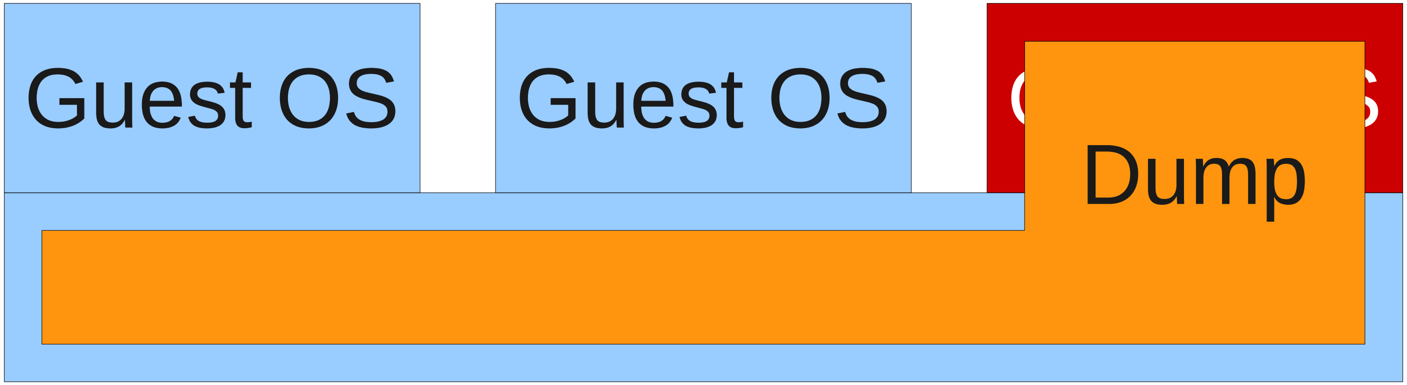
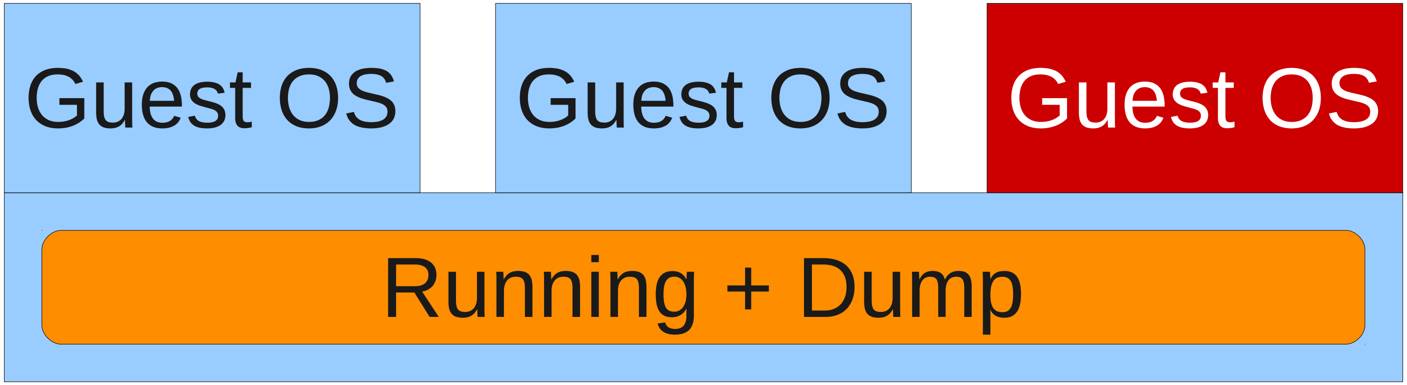


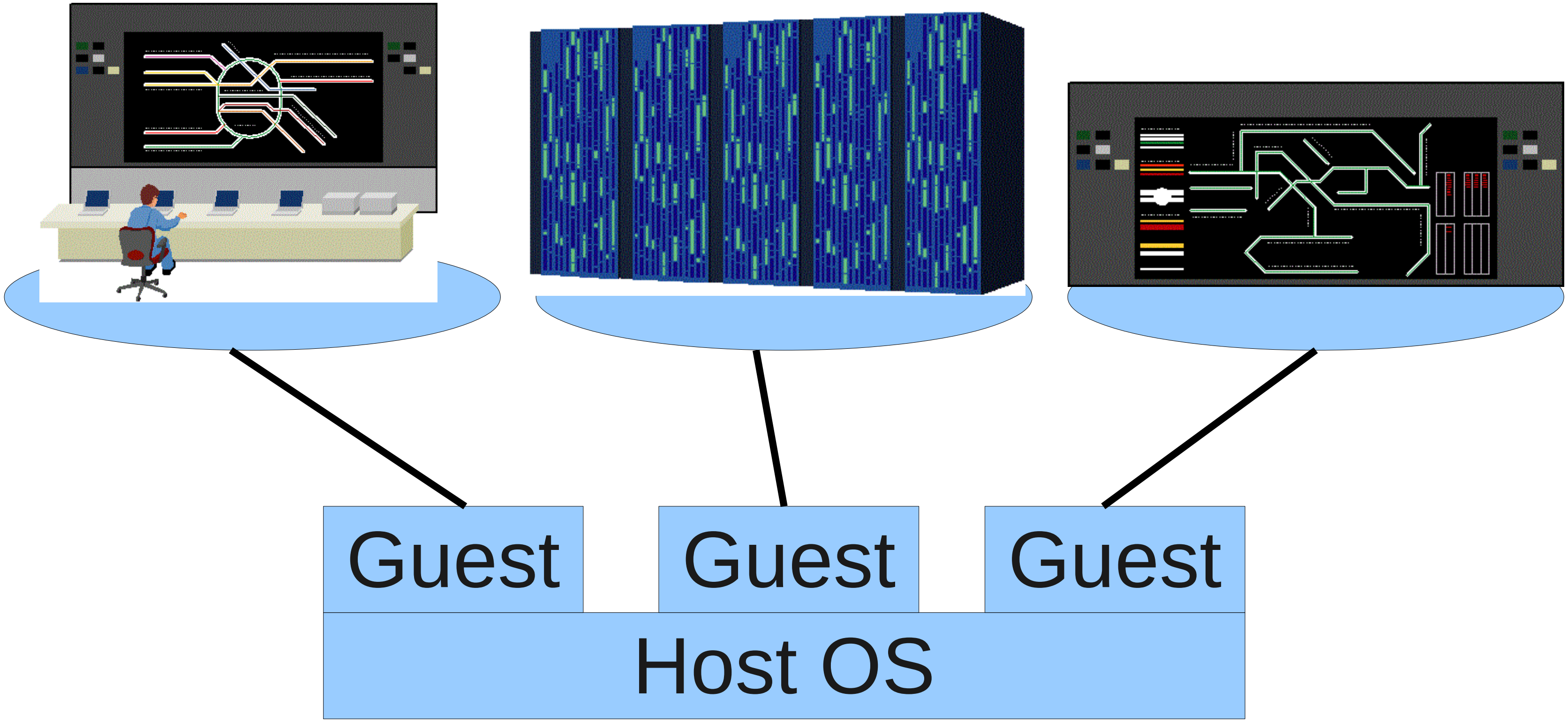
Goal

- Dump consistent memory snapshot of OS,
- without stopping the OS.



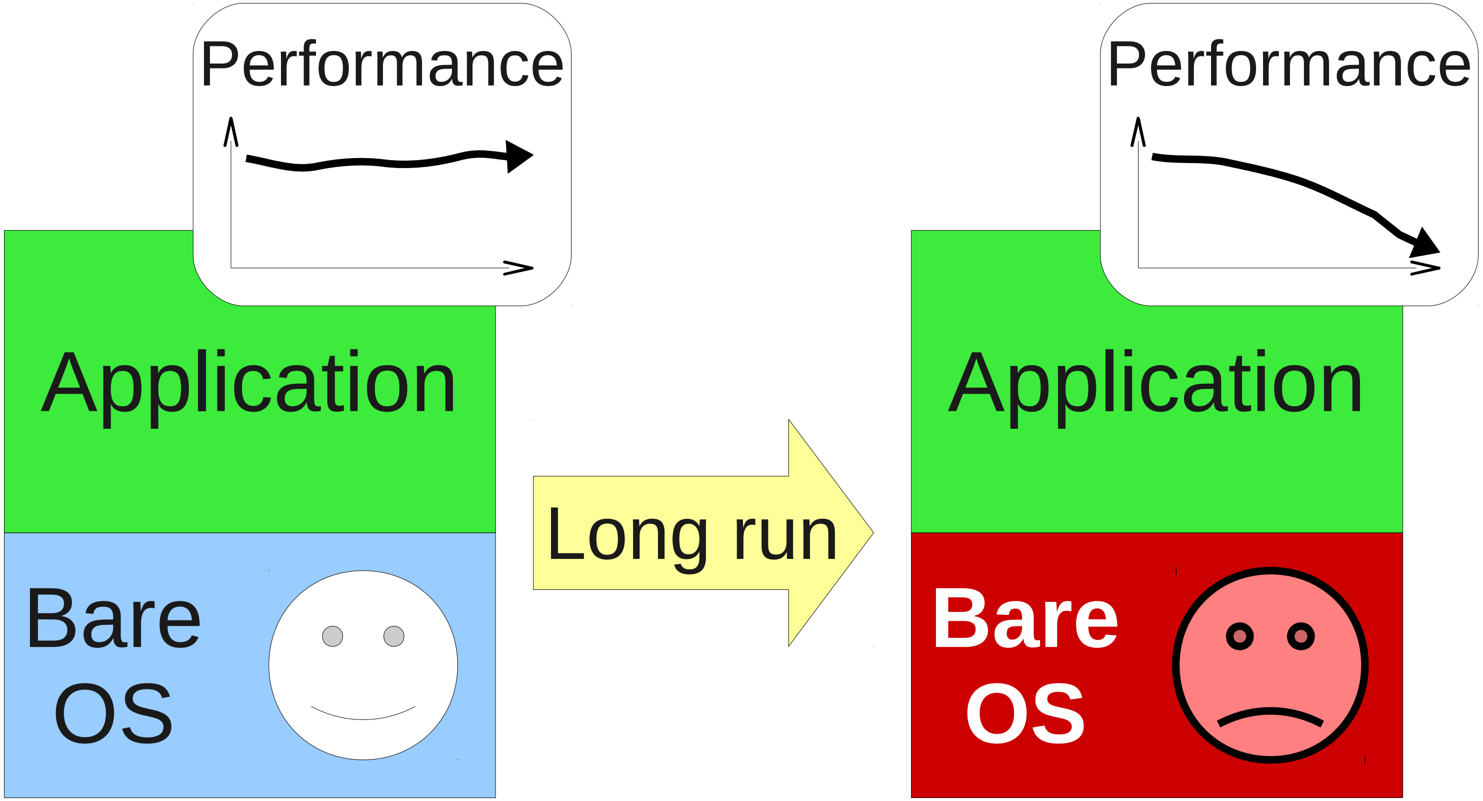
Use case

- Consolidation for very important systems



Use case

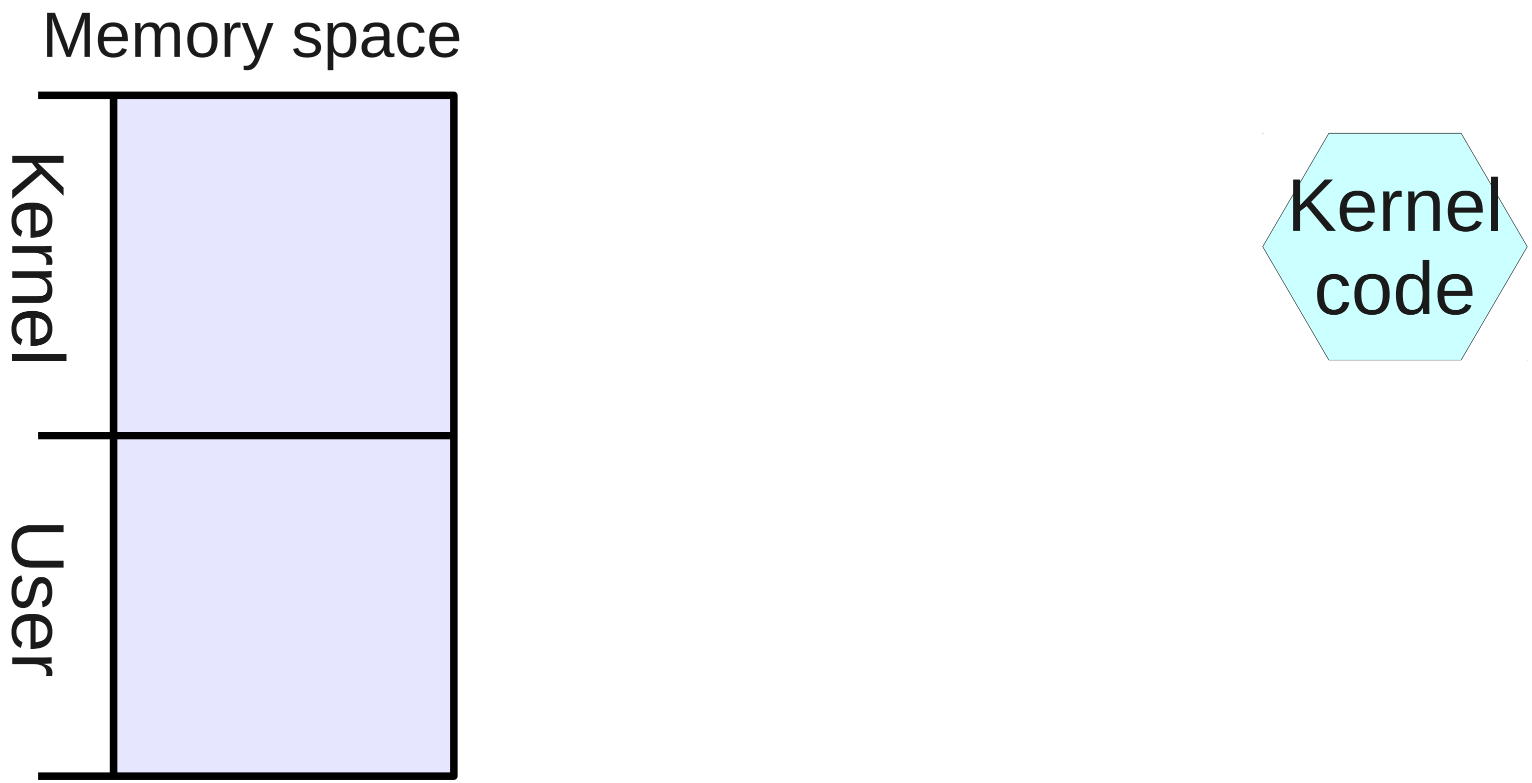
- Non-virtualization case
  - Performance degradation analysis



1. What is Live Dump?
2. Implementation
3. Future work

Core idea

- Copy on write



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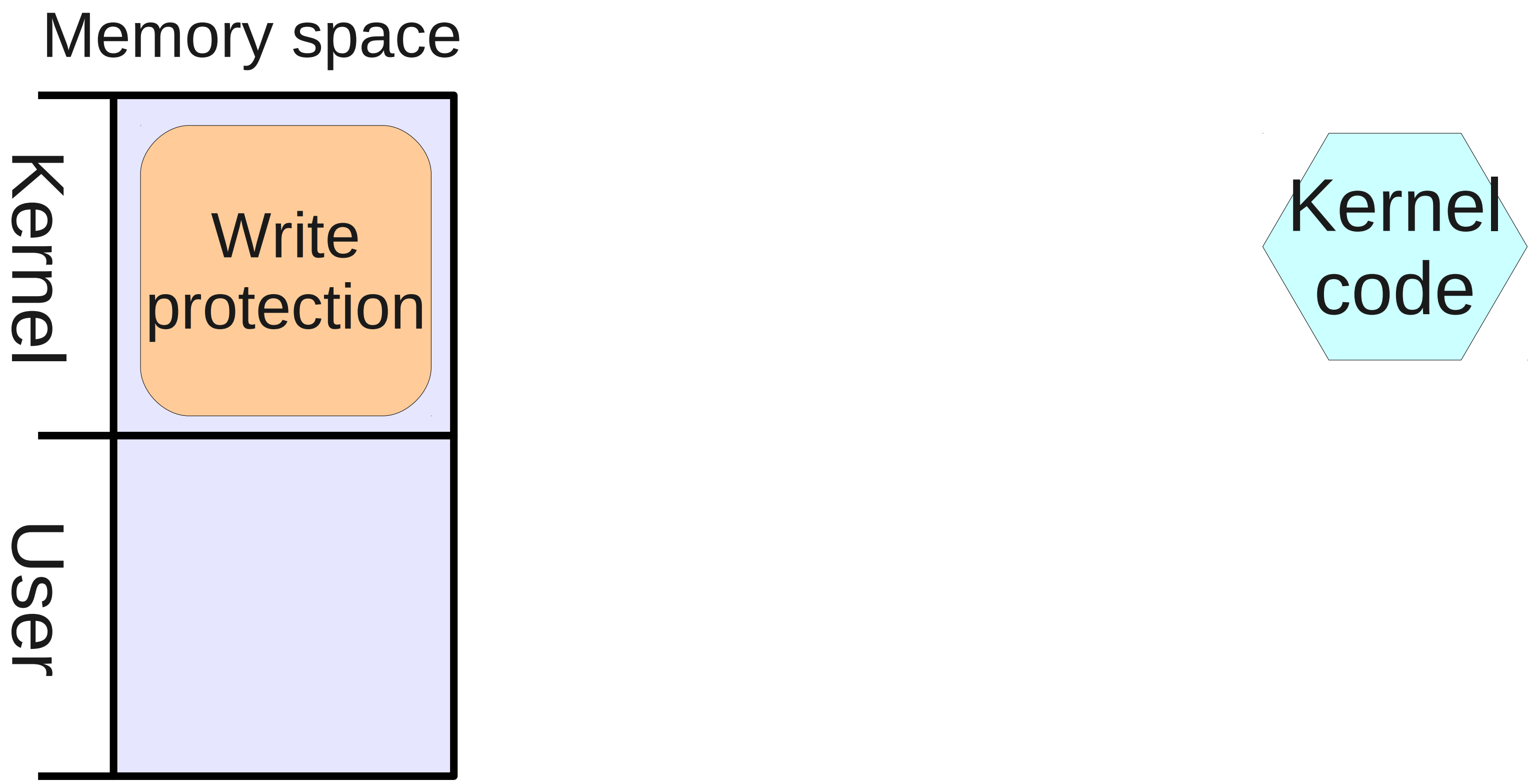

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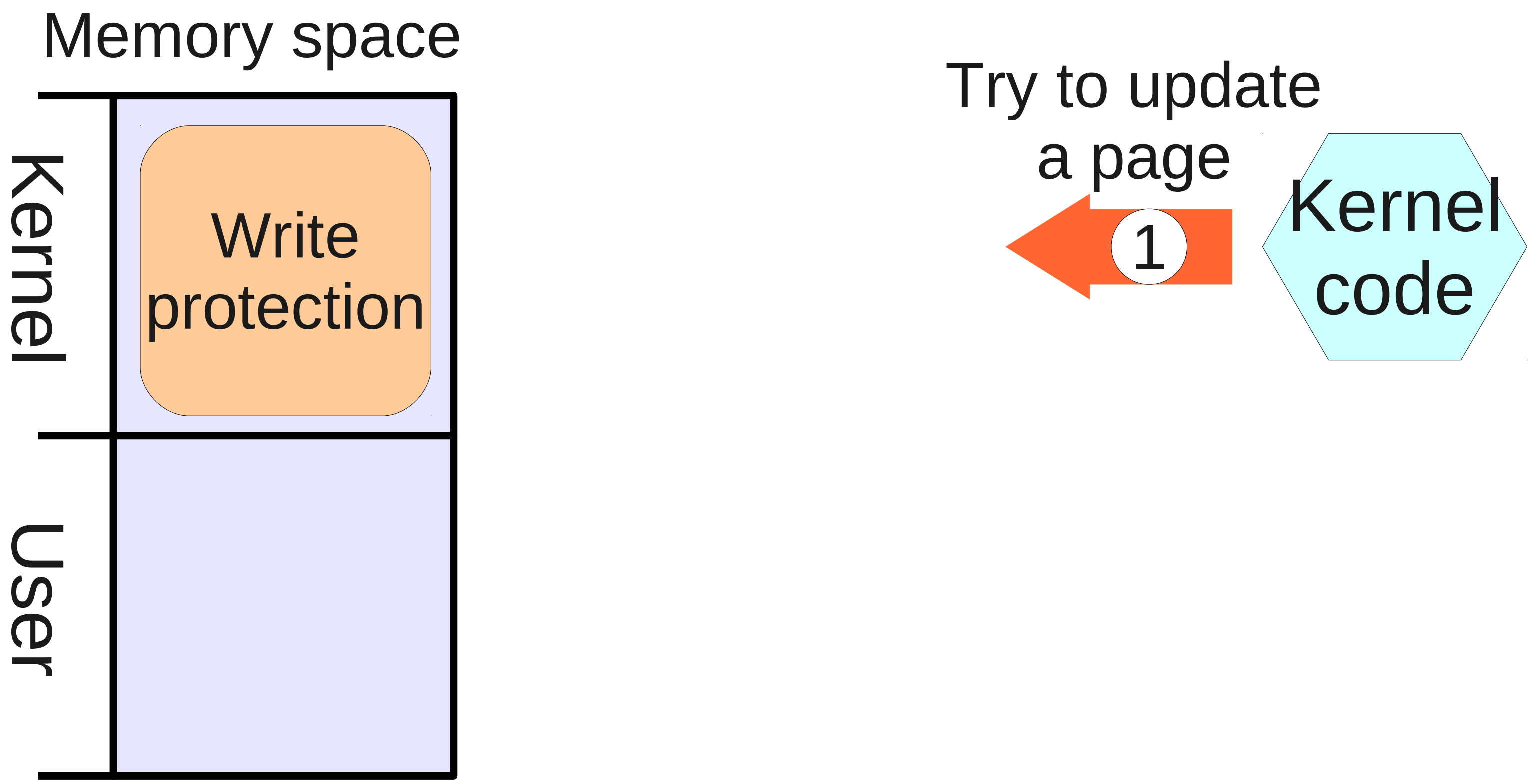

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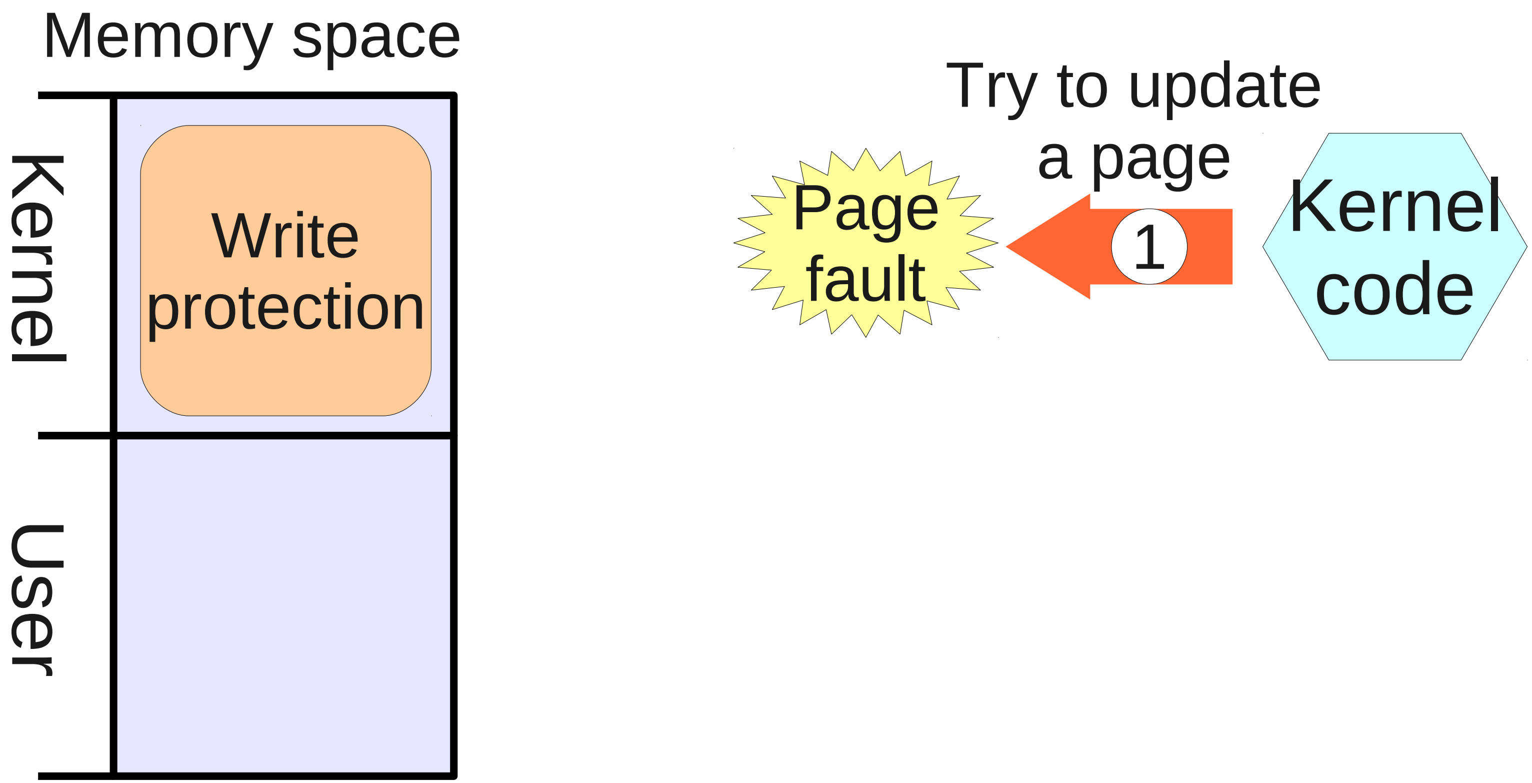

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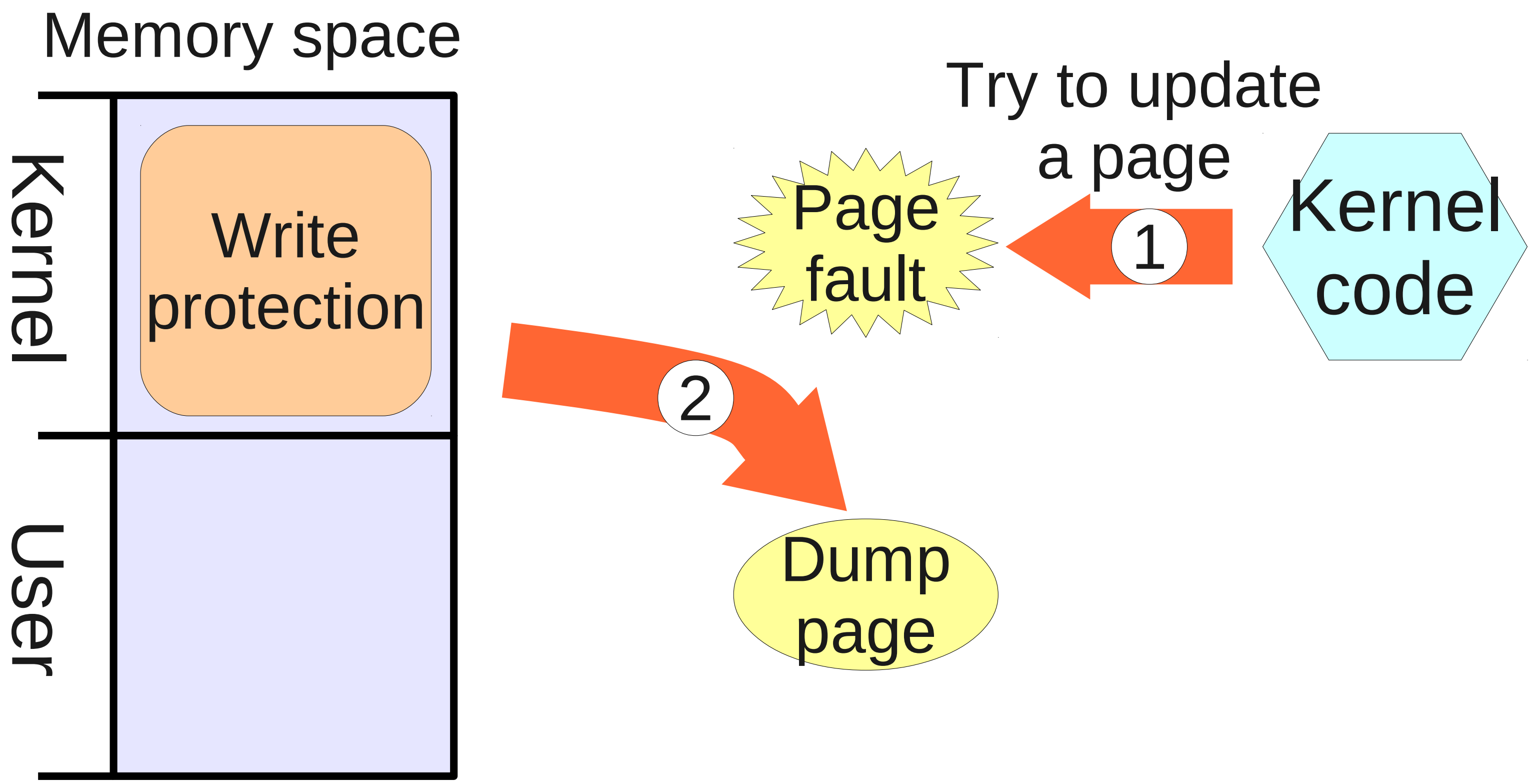

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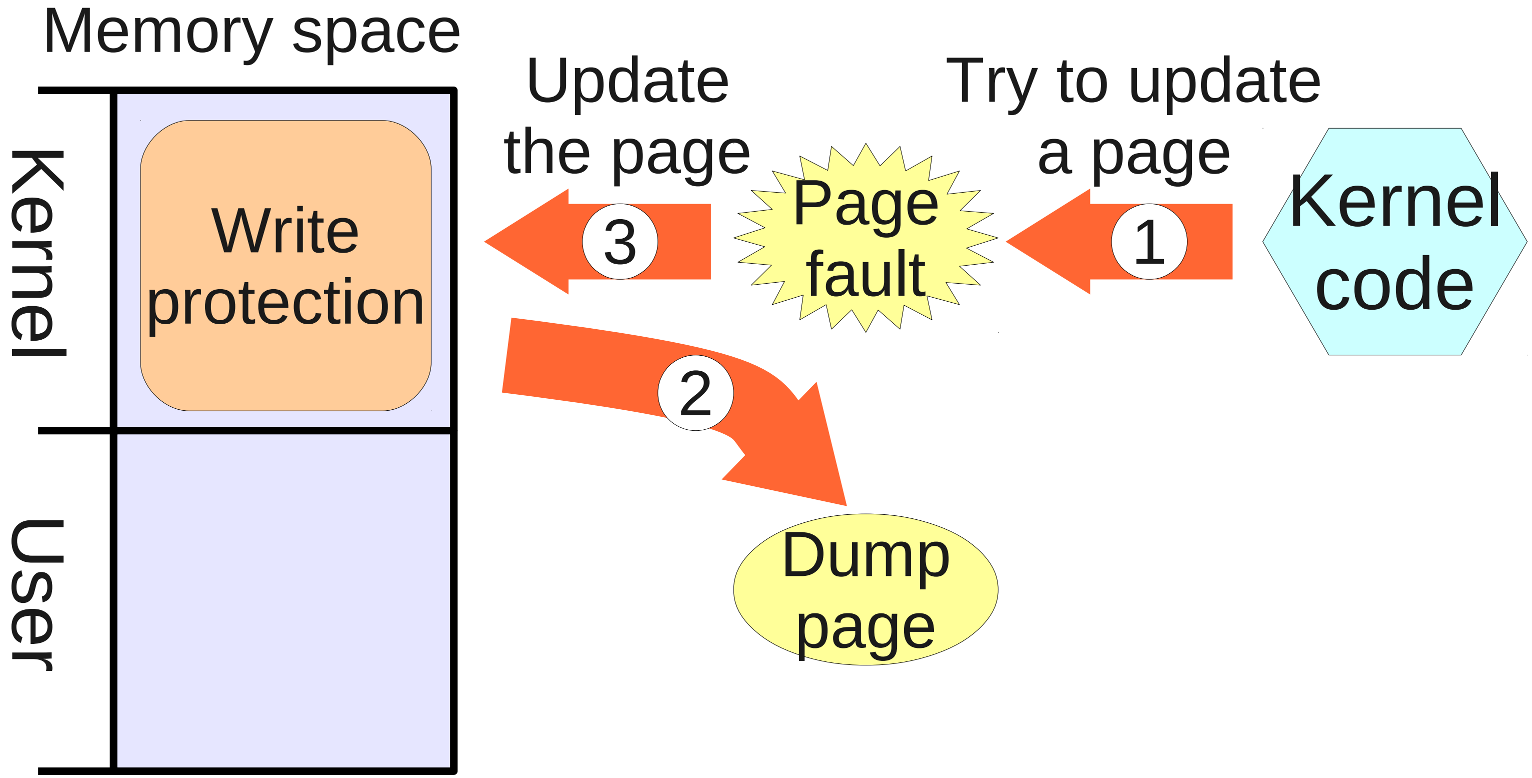


Core idea

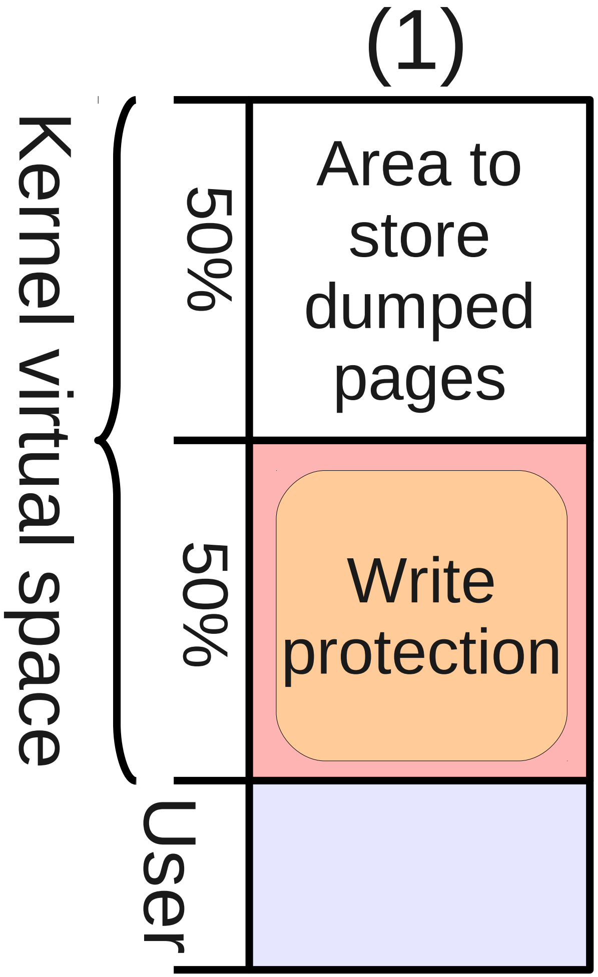
- Copy on write

Limitation

▪Only kernel space is dumped consistently.

– All phys pages are dumped,
  but those of user space aren't consistent.

Flow of processing



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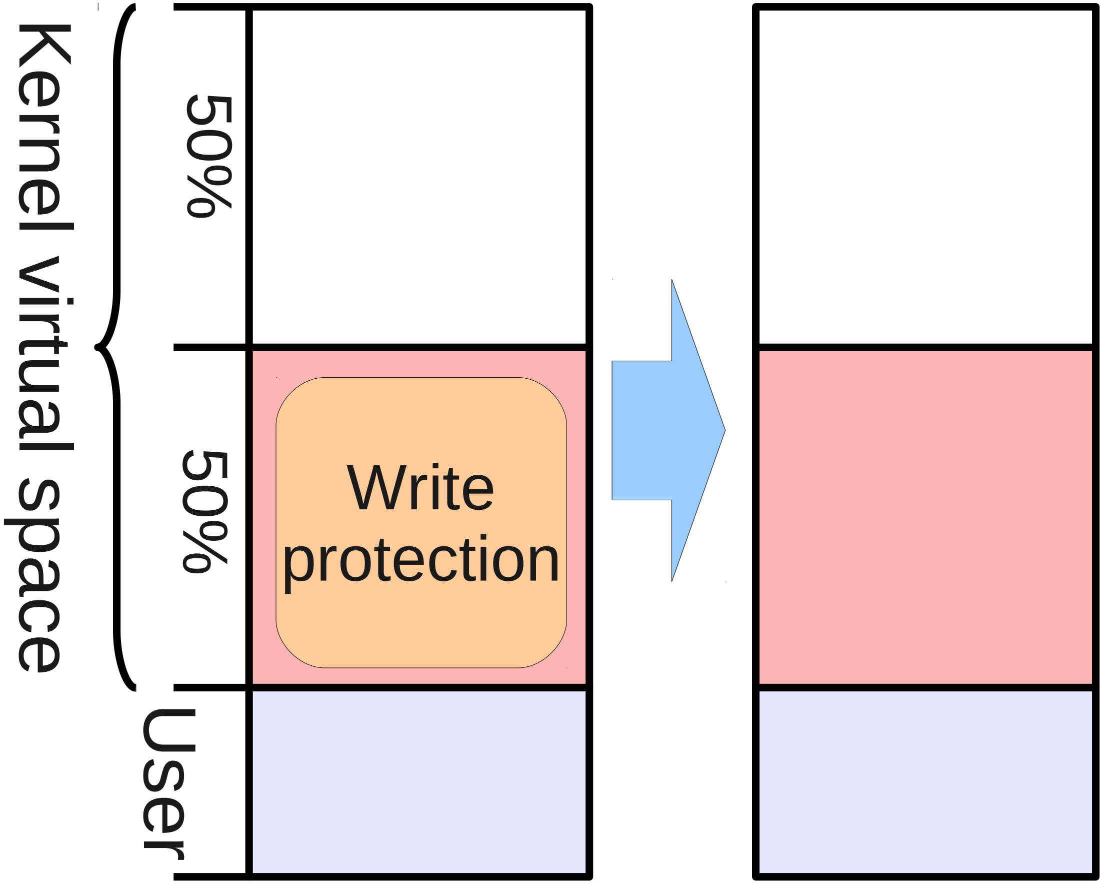
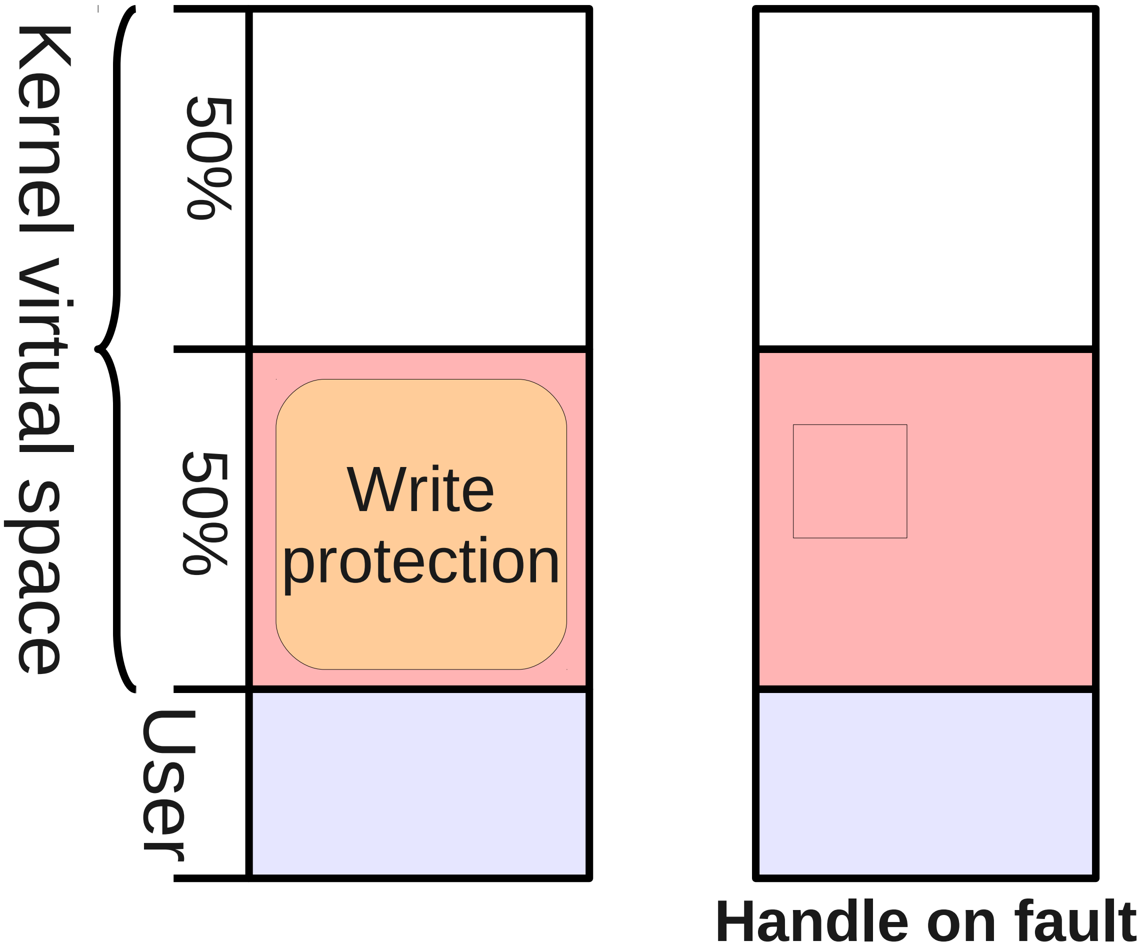
Flow of processing (2)



Handle on fault

Flow of processing (2)



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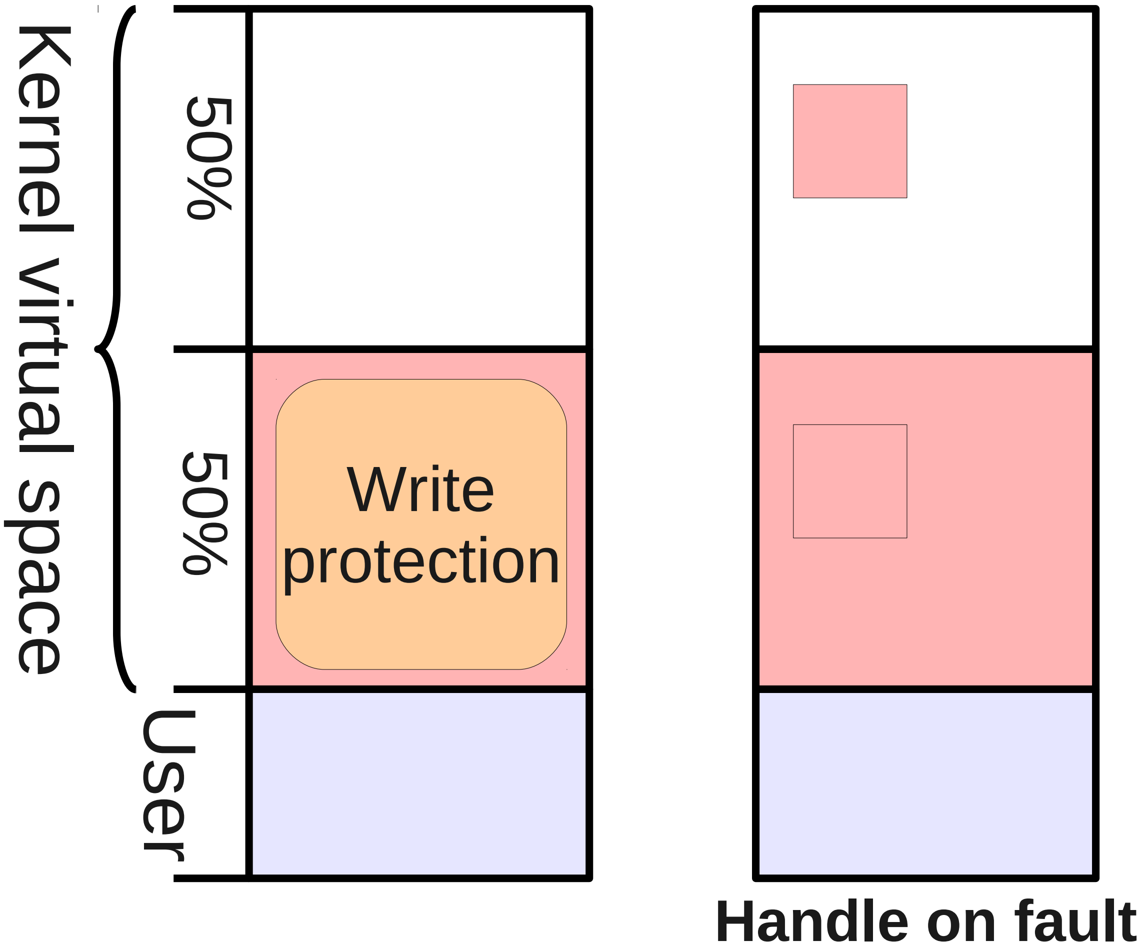

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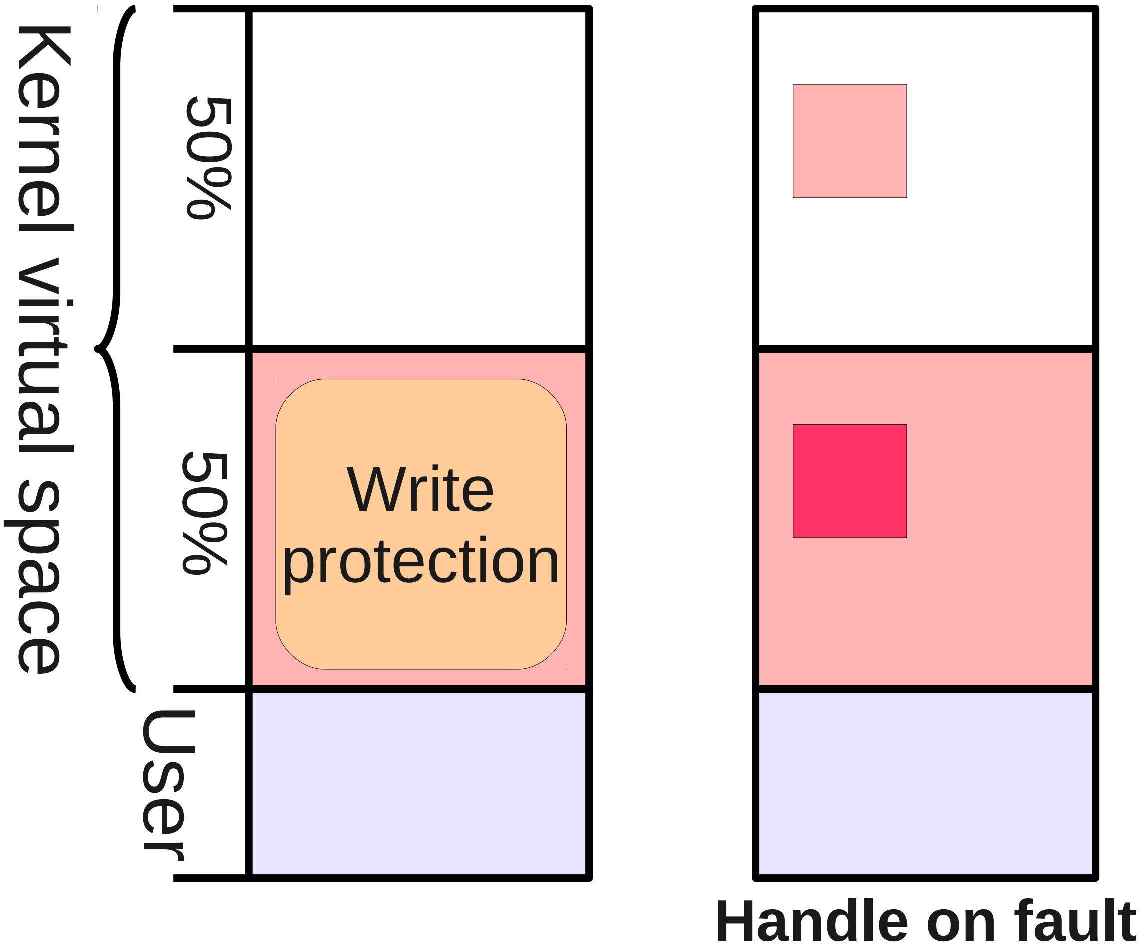

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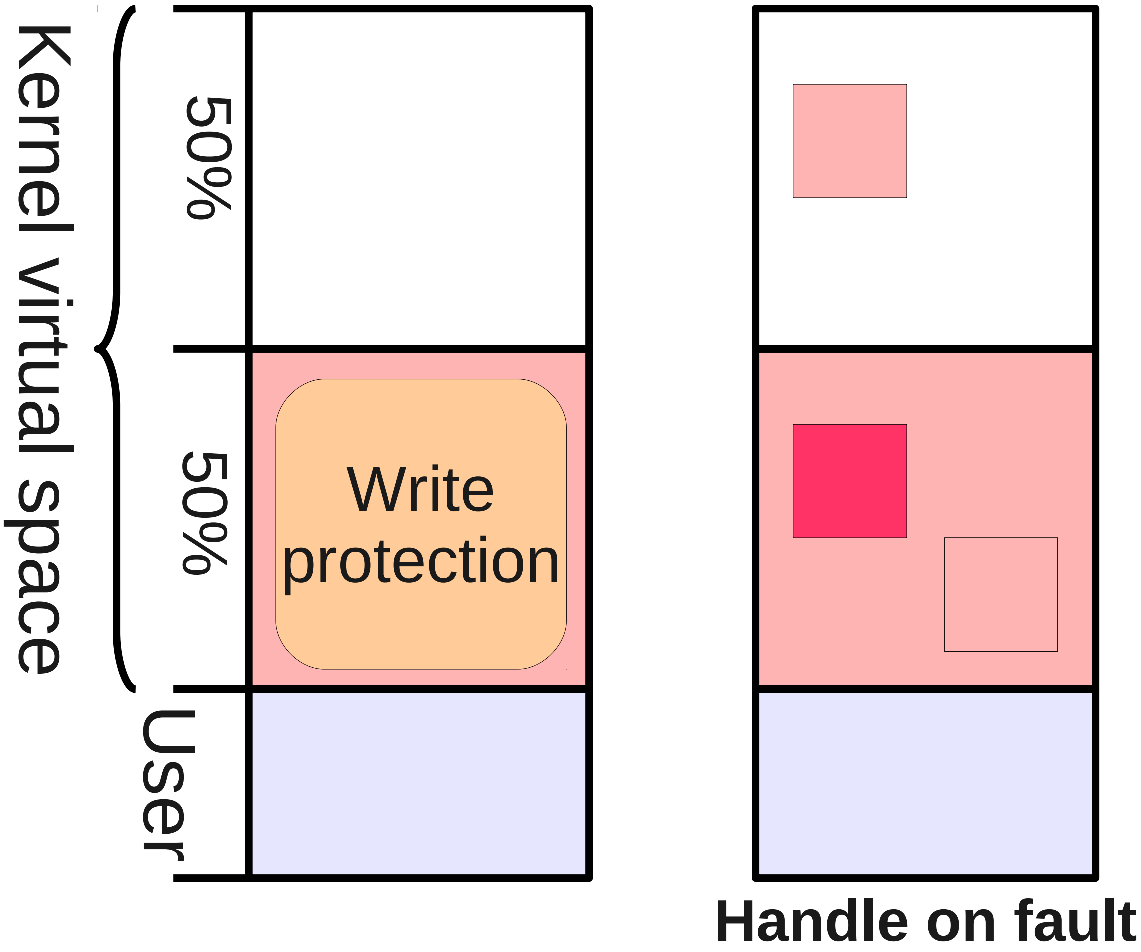

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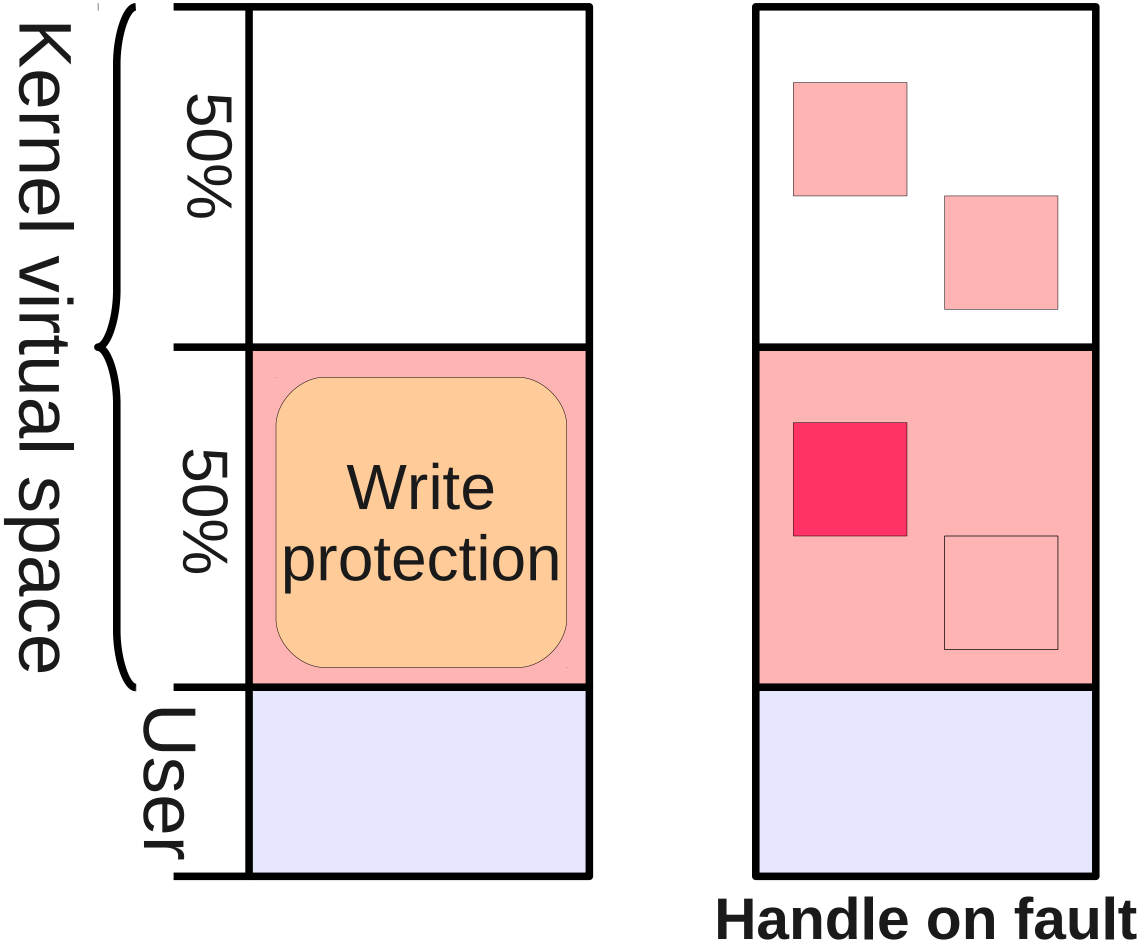

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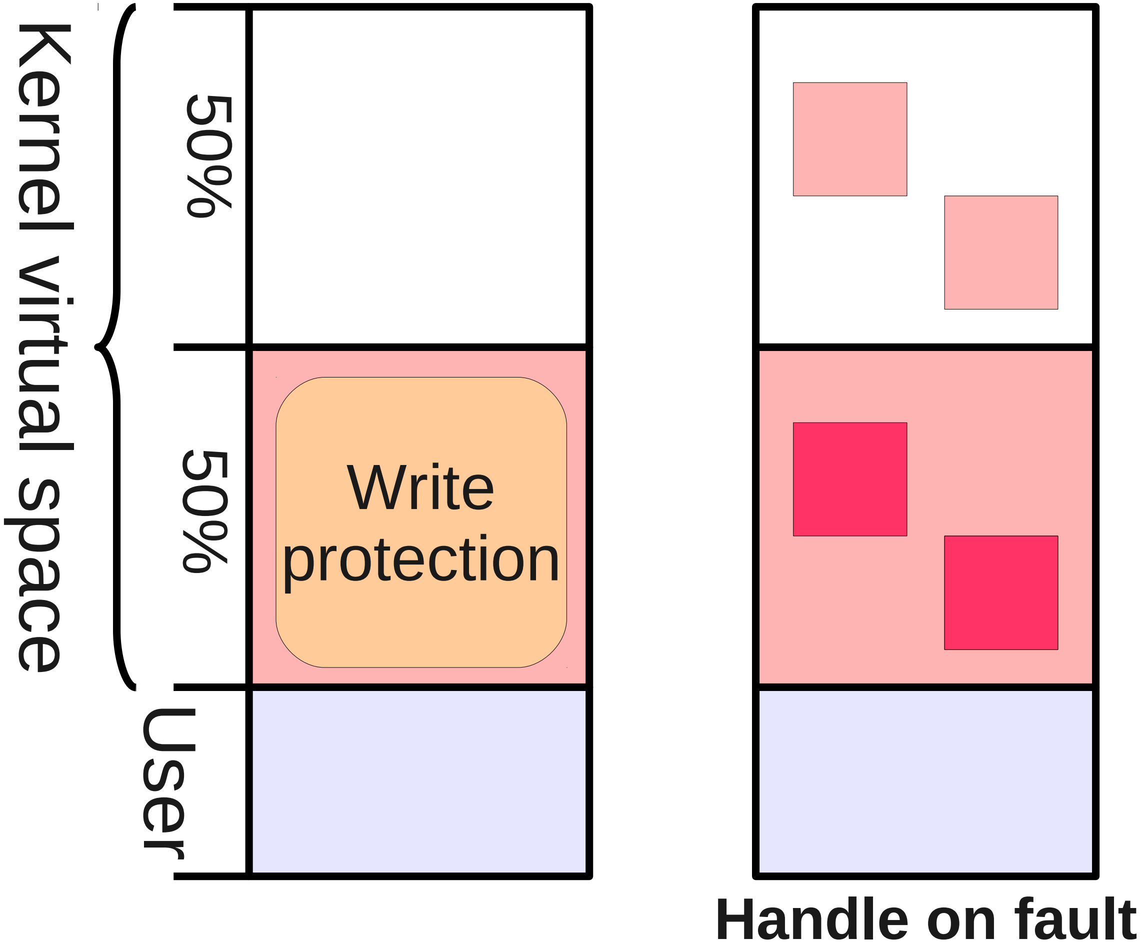

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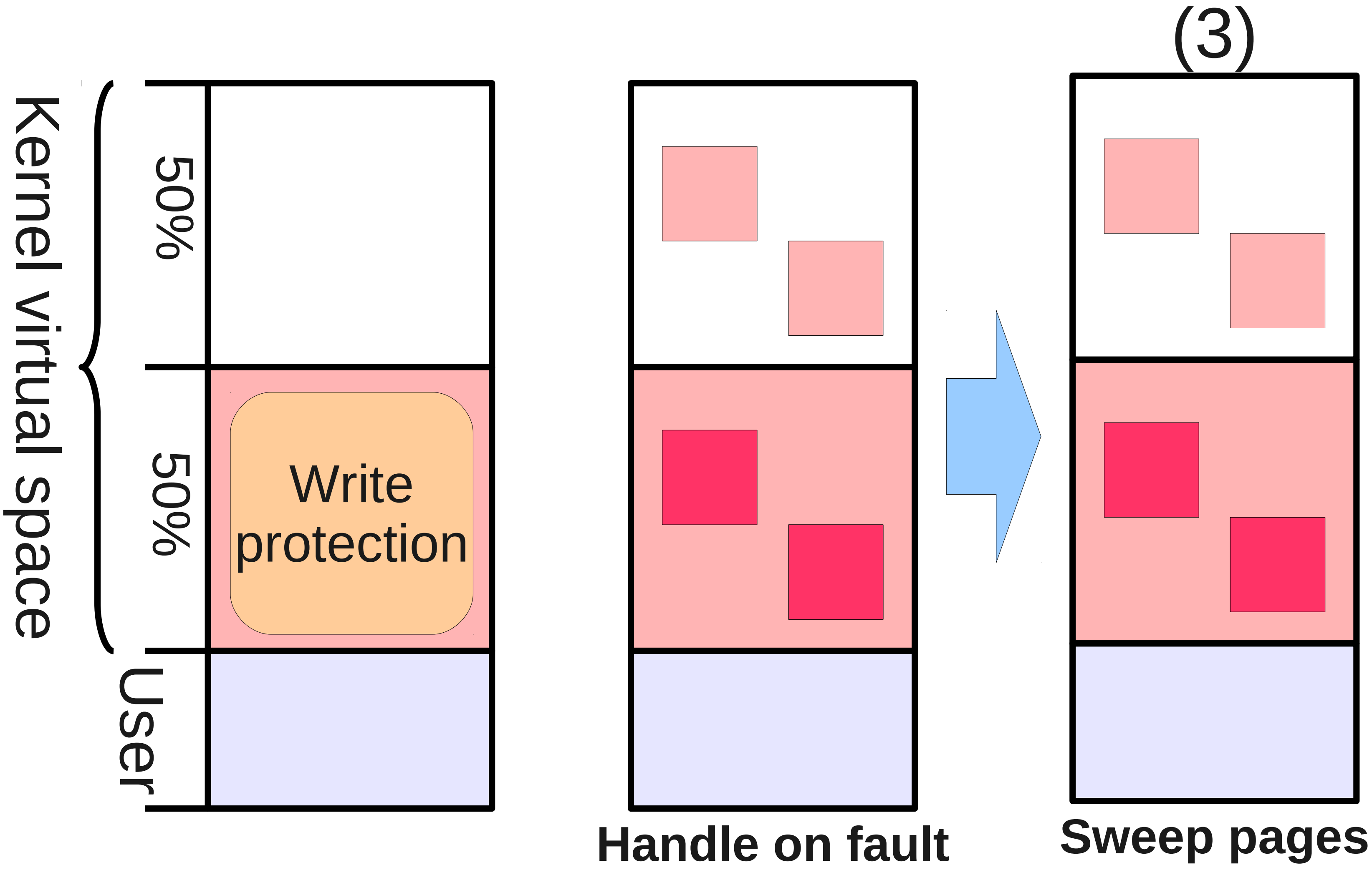

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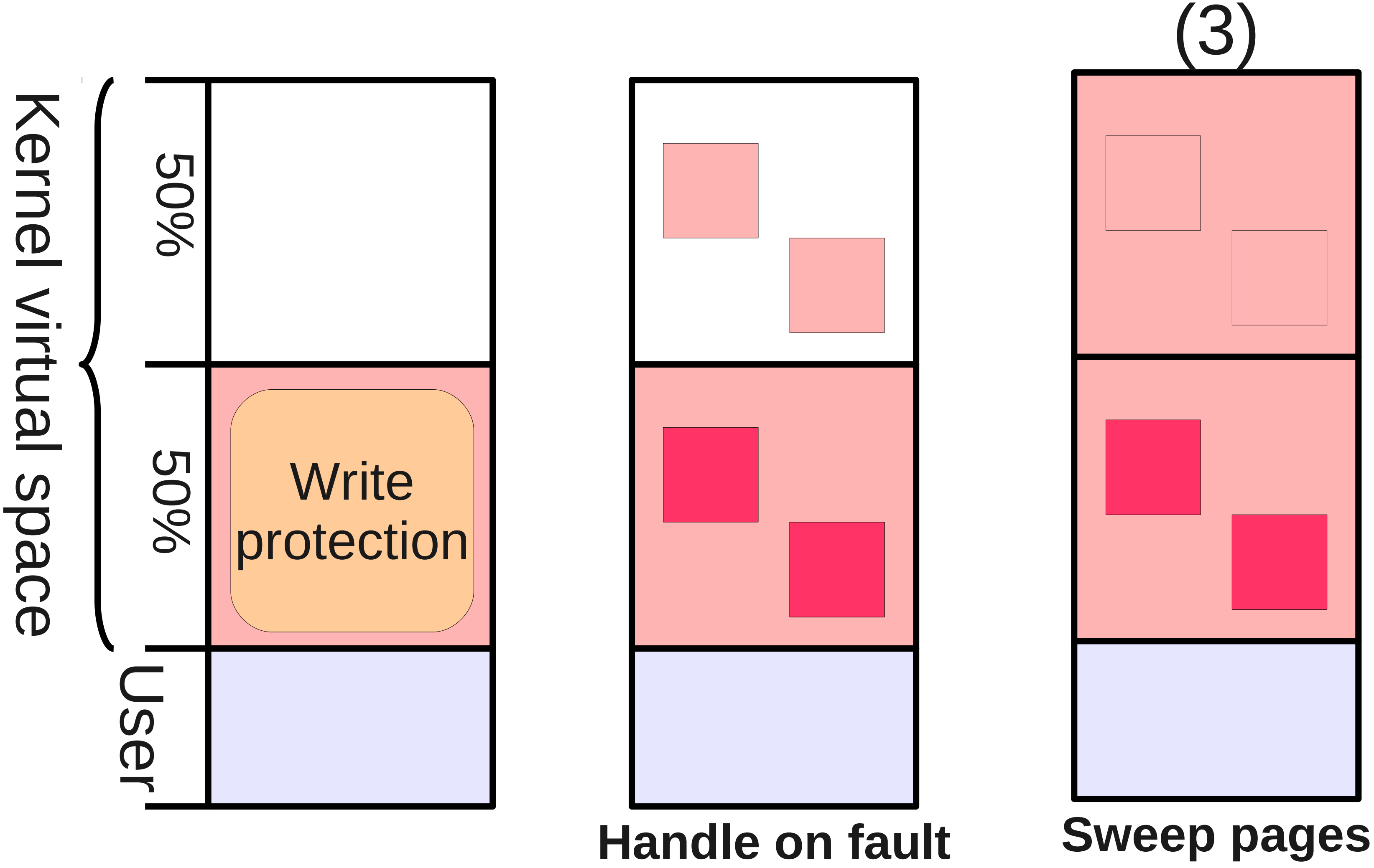
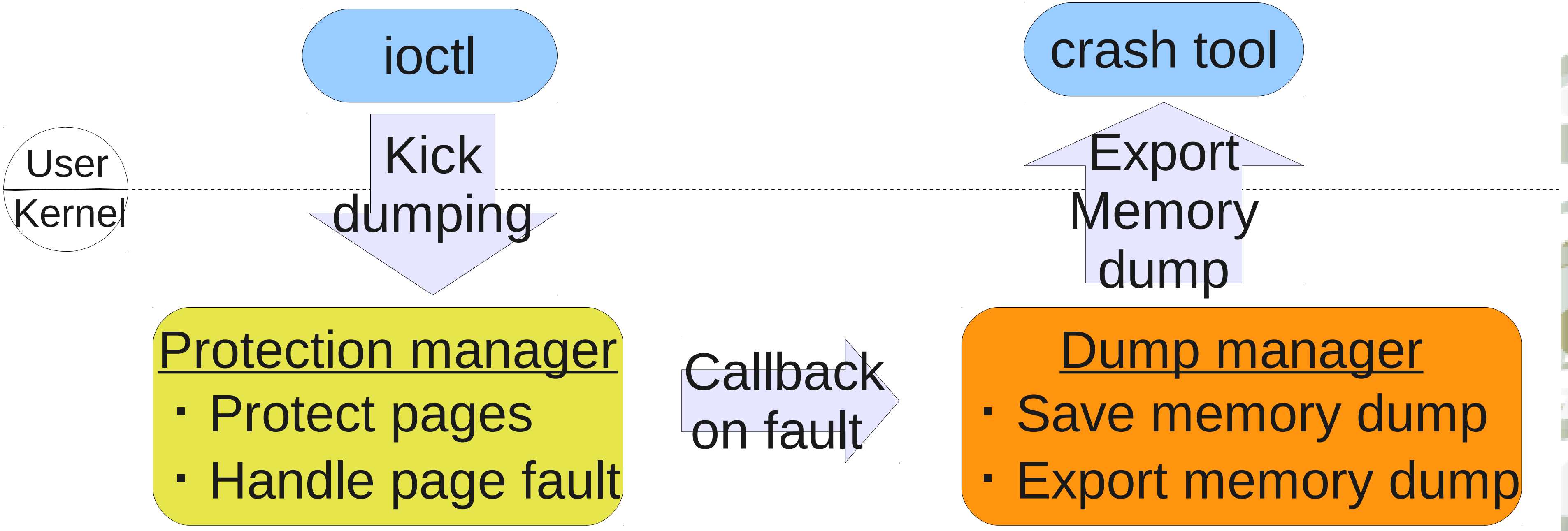


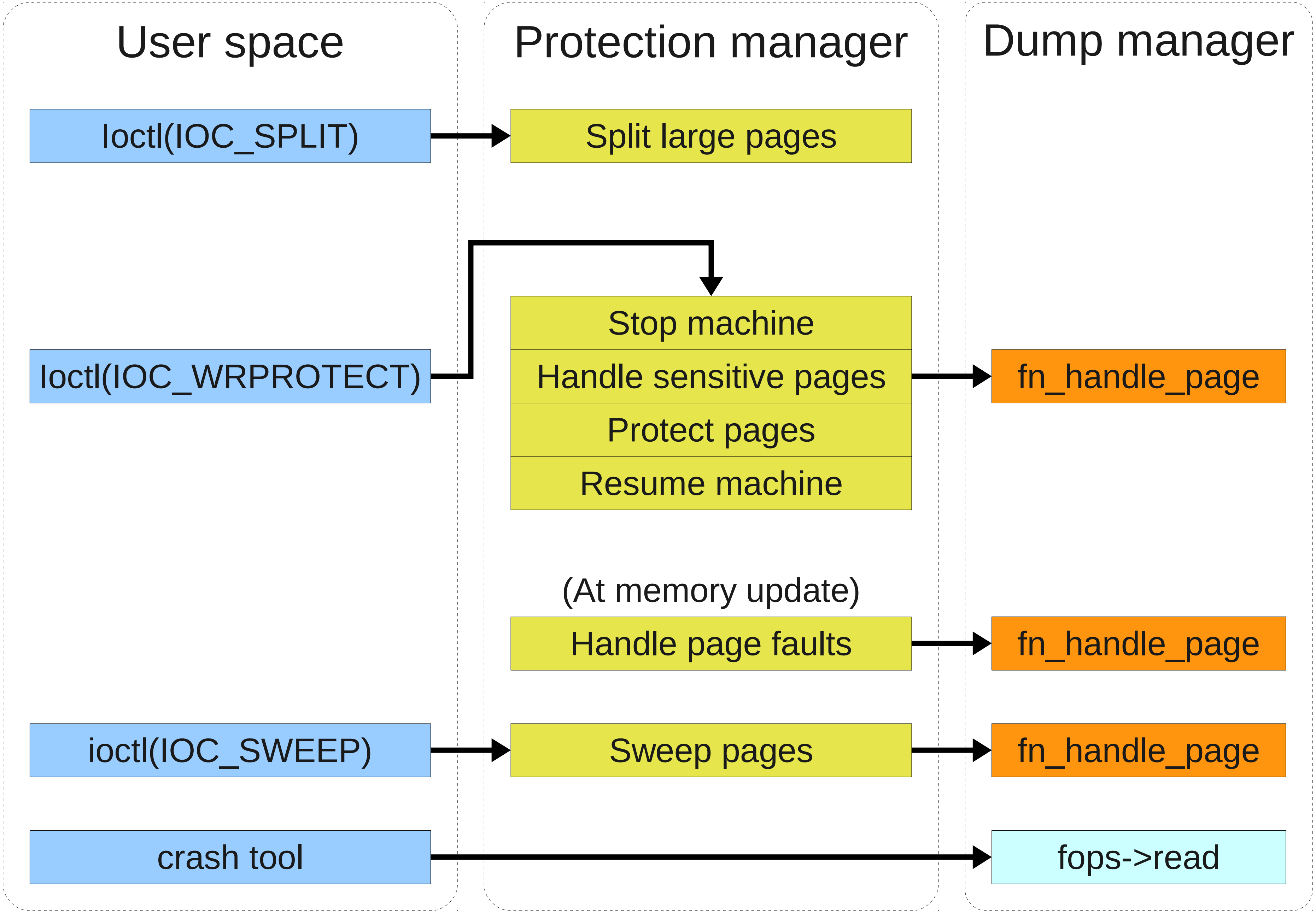
Overview of “livedump”

- 2 parts
  - Protection manager
  - Dump manager



Status of development

- 1150-line prototype with many limitations
- Limitation of Protection manager
    - Only supports protection of kernel space
    - Only supports x86-64 architecture
    - Only supports 4K pages
        - Need to split large pages into 4K ones in advance.
- Limitation of Dump manager
    - Need to allocate 50% of RAM to store dump.



User space

Protection manager

Dump manager

Ioctl(IOC_SPLIT)

Split large pages

Ioctl(IOC_WRPROTECT)

Stop machine

Handle sensitive pages

Protect pages

Resume machine

fn_handle_page

(At memory update)

Handle page faults

fn_handle_page

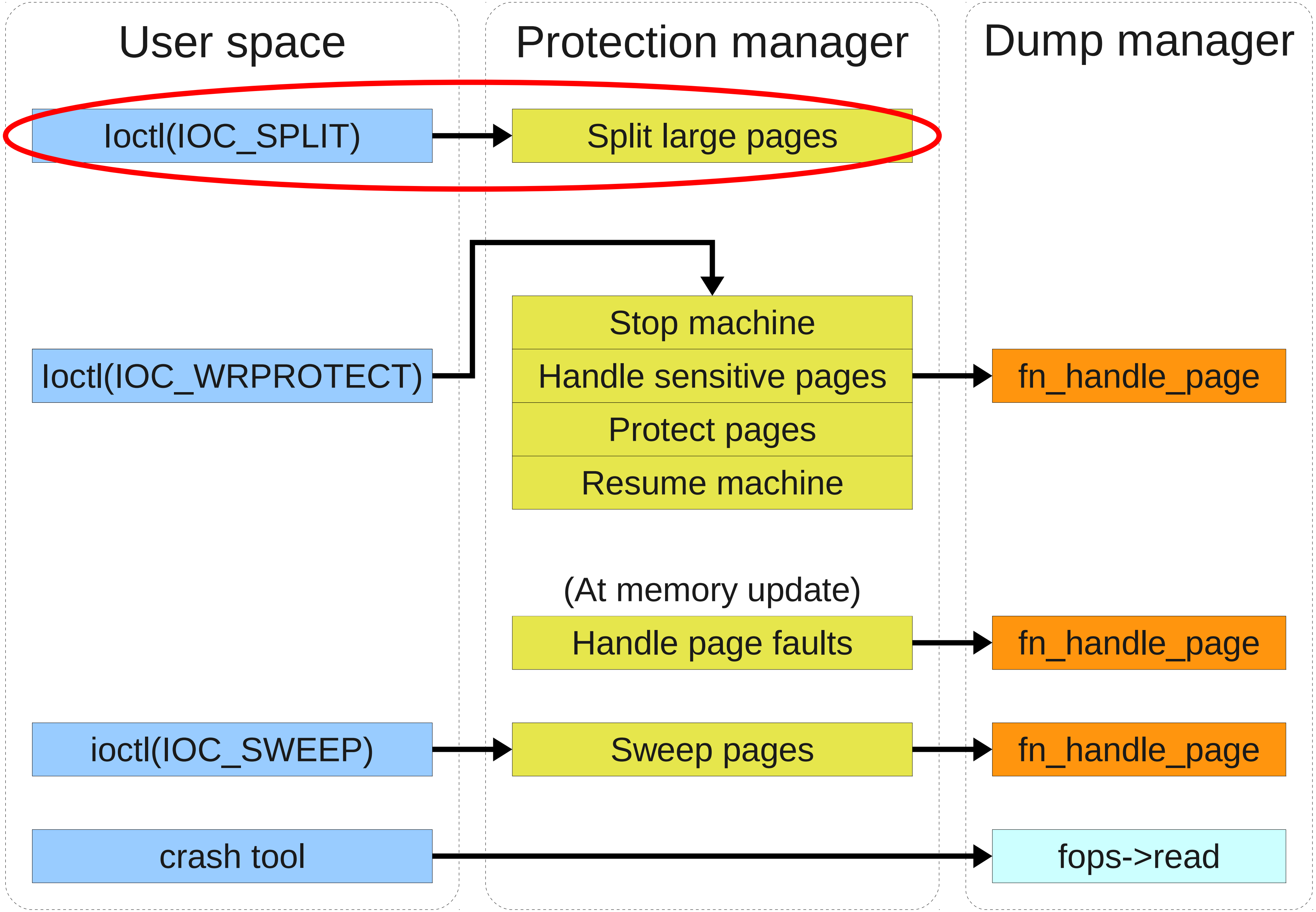
ioctl(IOC_SWEEP)

Sweep pages

fn_handle_page

crash tool

fops->read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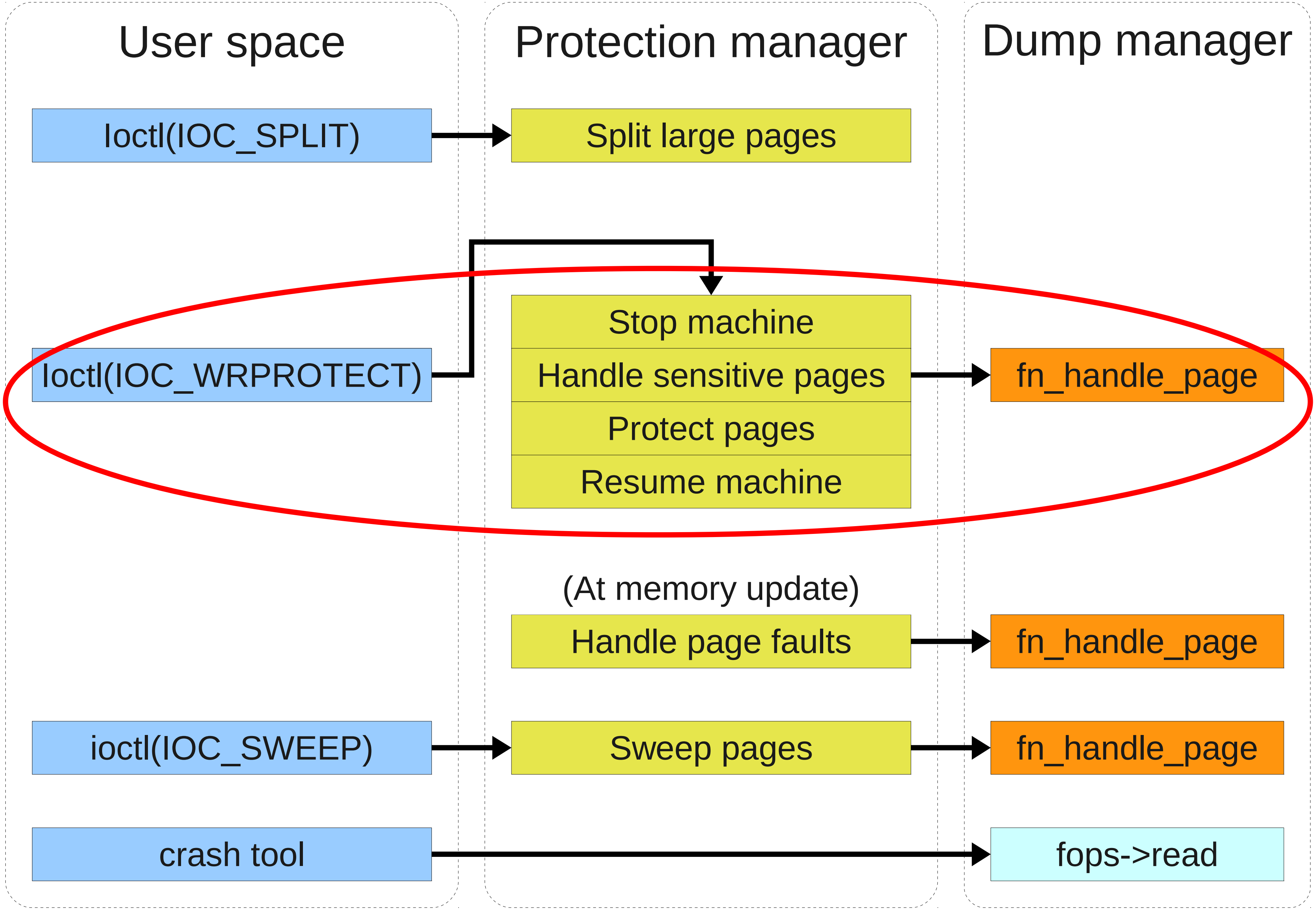
Split large pages

- Livedump can only protect 4K pages.
  - Splitting a large (2M or 1G) page during page fault handling is under development.
- At the moment, all large pages need to be split into 4K pages by set_memory_4k() in advance.
- This step will be unnecessary in the future.



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Write protection

- Sequence
  1. Stop machine
  2. Handle sensitive pages
  3. Protect pages
  4. Resume machine

Stop machine

- We need a consistent memory snapshot, and so must protect all pages while processing is suspended.
- Livedump simply uses stop_machine() for this purpose.
- SMP in stop machine
  - Leader CPU: Protect pages
  - All CPUs: Wait for leader's job, and then flush TLBs

Handle sensitive pages

- Sensitive pages
  - Following pages cannot be protected.
    - Pages that can be updated in PF handling (This leads to Infinite loop of PF)
    - Pages that can be updated in NMI handling (This leads to nested NMI handling => panic)
  - Such pages are:
    - Kernel/Exception/Interrupt stacks
    - Page table structure
    - task_struct
    - .data section of kernel
    - per_cpu areas

Handle sensitive pages (Cont'd)

- Livedump dumps sensitive pages in stop machine.
- Via callback
  - `int fn_handle_page(unsigned long pfn);`
- `fn_handle_page(pfn)`
  - Defined by Dump manager.
  - Saves content of page.

Protect pages

- Manipulation of PTEs(Page Table Entries)

1. Copy _PAGE_RW flag to _PAGE_ORG_RW flag
   - `#define _PAGE_ORG_RW _PAGE_UNUSED1`
   - Both flags are in each PTE.
   - This is needed because there can be originally read-only pages.
2. Clear _PAGE_RW flag
   - Make a page read-only.

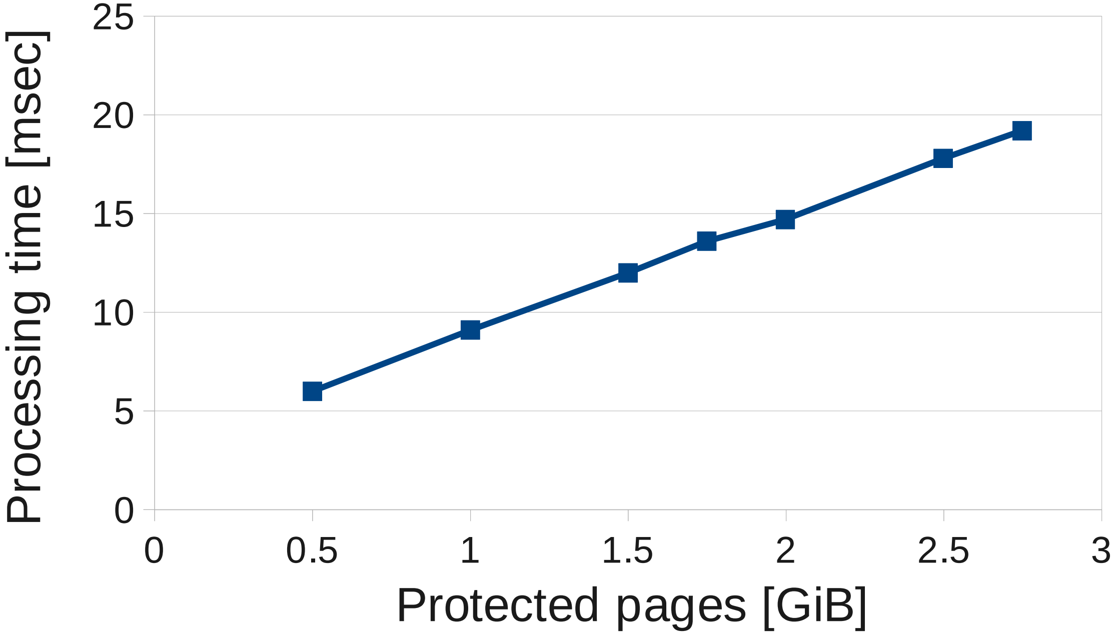
How long does it take?

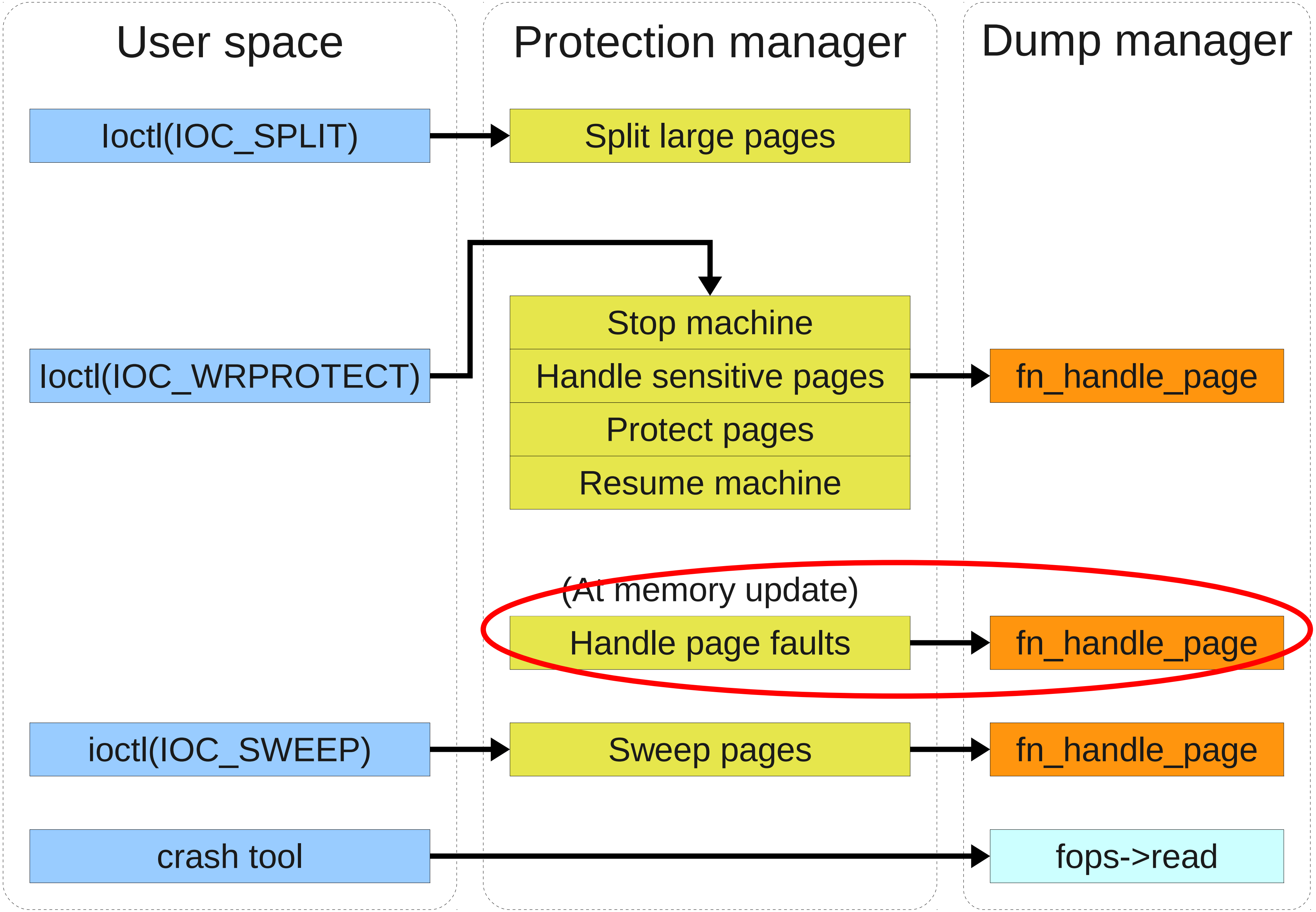
- Processing of write protection
  1. Stop machine
  2. Handle sensitive pages
  3. Protect pages
  4. Resume machine

Down time
(Stop machine)

How long does it take? (Cont'd)

- Down time
  - Is measured with Xeon W3520 @ 2.67 Ghz
  - Increases by 6 msec/GiB





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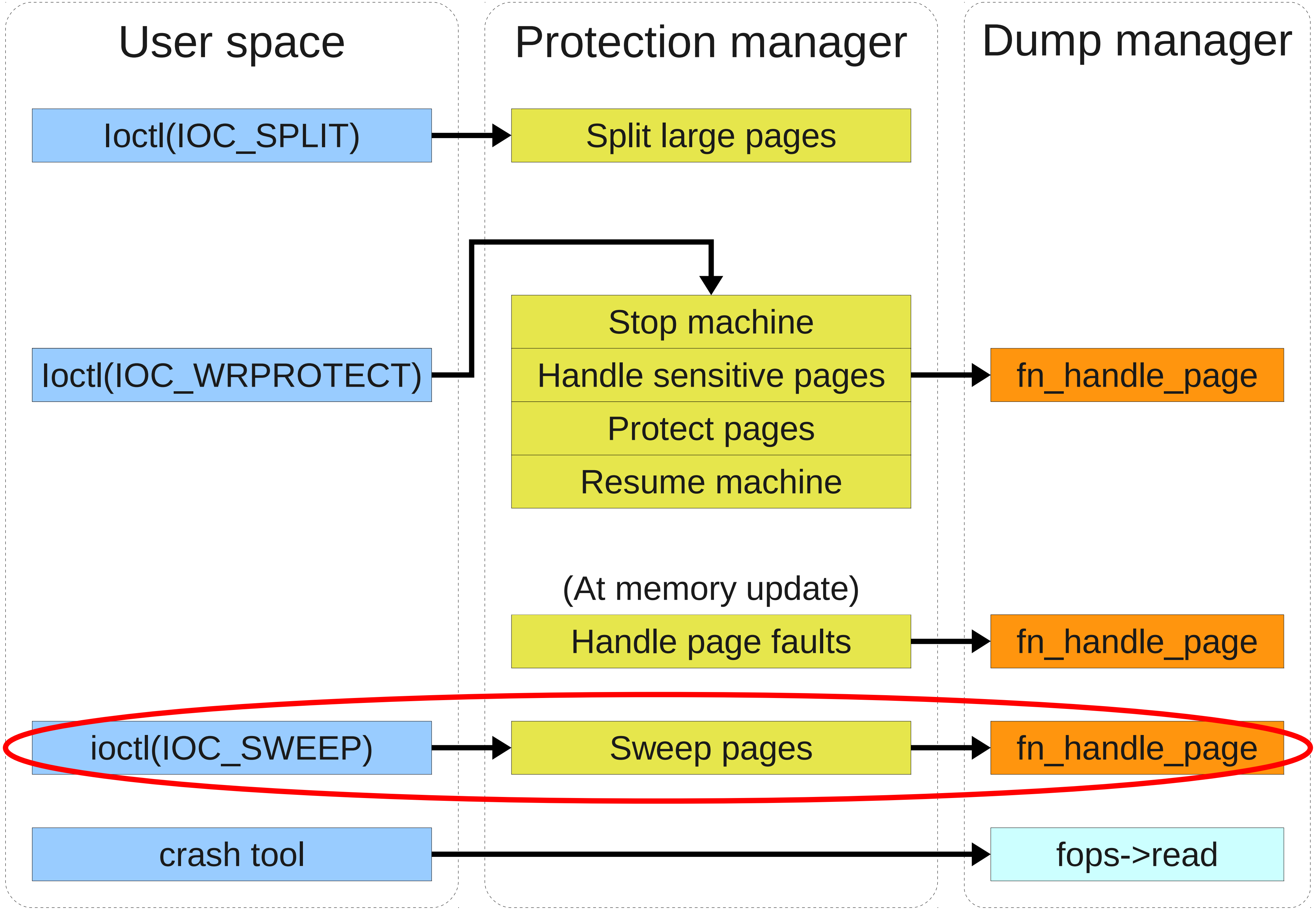
Handle page faults

- Livedump's notifier-call-chain in do_page_fault
  - Check cause of fault
    - Test _PAGE_ORG_RW flag
  - Exclusion control
    - test_and_clear_bit(pfn, pgbmp)
  - Dump the page
    - fn_handle_page(pfn)
  - Unprotect the page
    - Copy back _PAGE_ORG_RW flag to _PAGE_RW flag
    - Clear _PAGE_ORG_RW flag



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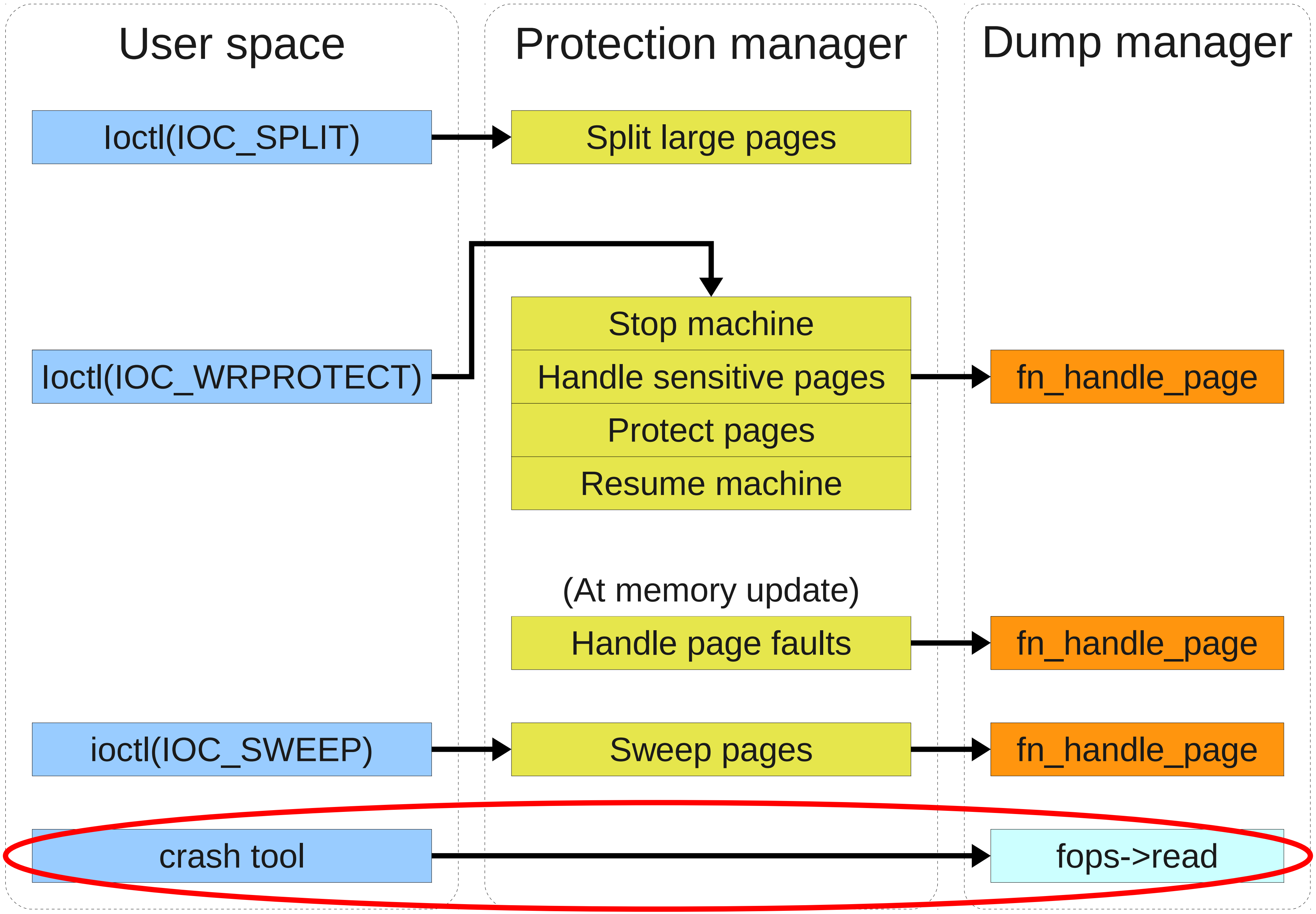
Sweep pages

- Batch dumping of all pages not dumped yet.
  - via `fn_handle_page()` in turn



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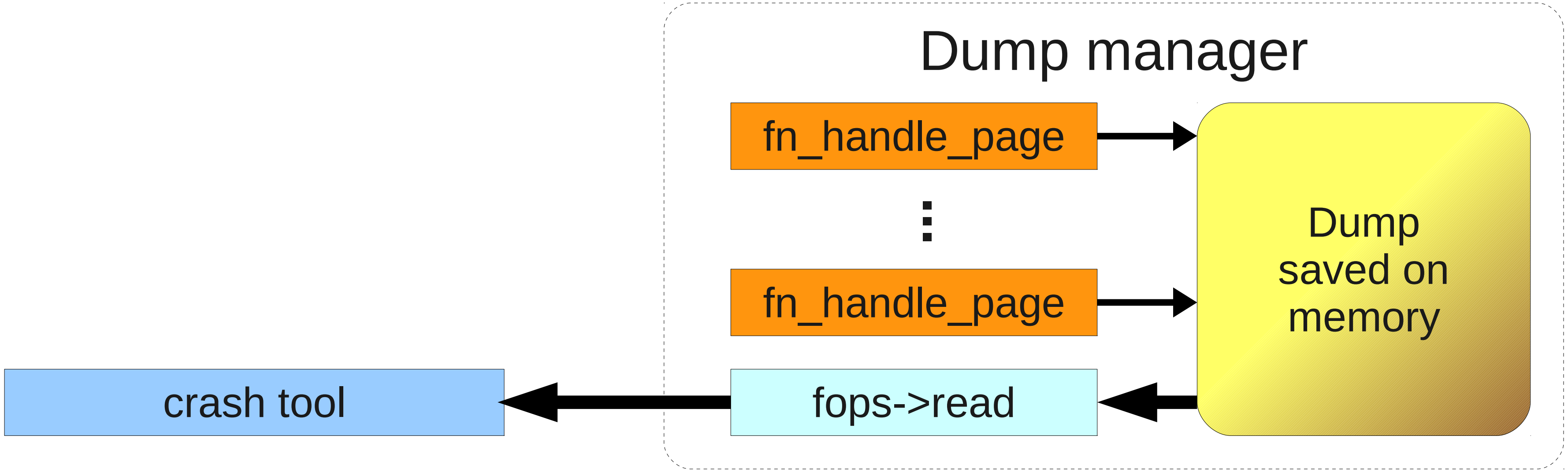
Dump analysis via crash

- Dumped pages are exported as a character device.
  - `fops->read()`
  - `fops->llseek()`
- You can use crash with the character device.



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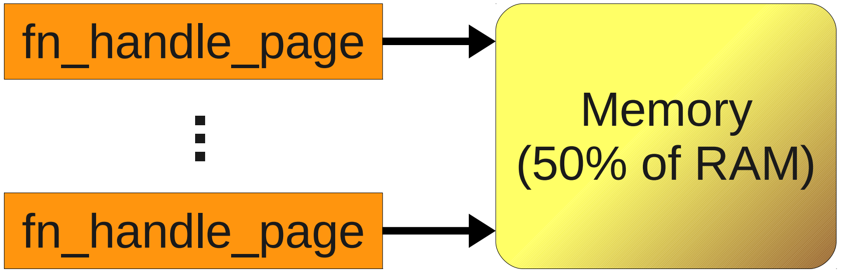
Large page support

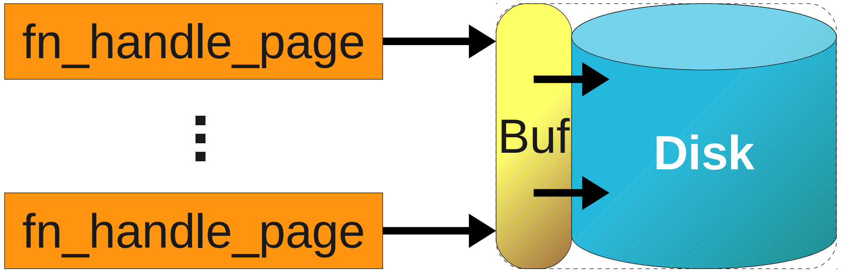
- Support write-protection of 2M pages
    - To reduce TLB consumption
- Fix splitting phase
    - Only 1G pages are split to 2M x 512 pages.
    - 2M pages remain 2MB.
- Fix page fault handling
    - 2MB data are copied on page fault.
        - Copy cost = 200usec (on my Xeon machine)

On-the-fly dumping to disk

- At the moment



- On-the-fly version



Conclusion

- I developed the prototype of Live Dump
  - Memory dump with a running OS
  - Technique based on CoW
- Performance (down time)
  - 15 ms with 2GB and increases by 6 ms / GB.
- Limitation
  - It has many many limitations...

RFC patchset

- RFC patchset of livedump has been submitted.
  - On May 25

- Please give me feedback!

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Thank you!