Virtual Memory

A Project for CS854

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Simon Pratt
Krishna Vaidyanathan

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February 25, 2016

Abstract

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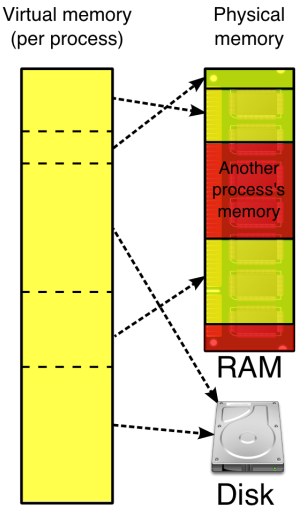
- We propose to study virtual memory!

Background: Virtual Memory



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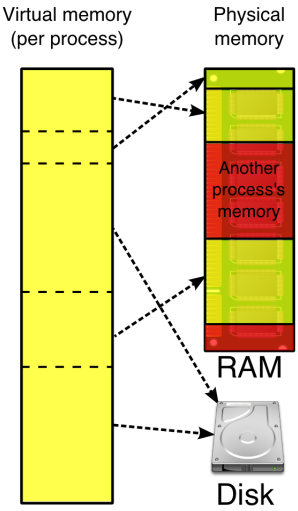

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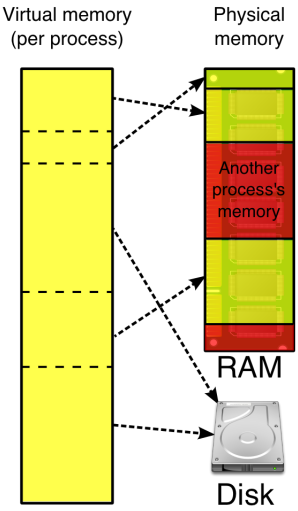

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- Data may be stored:
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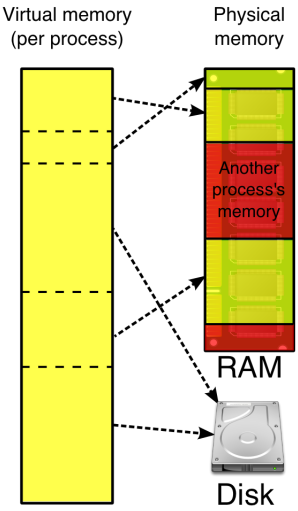

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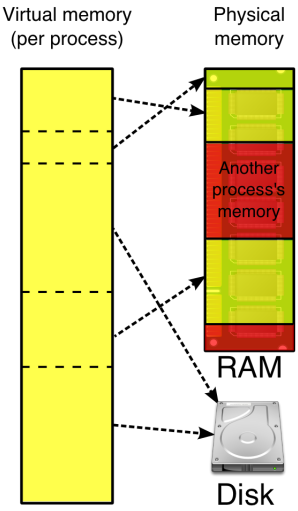

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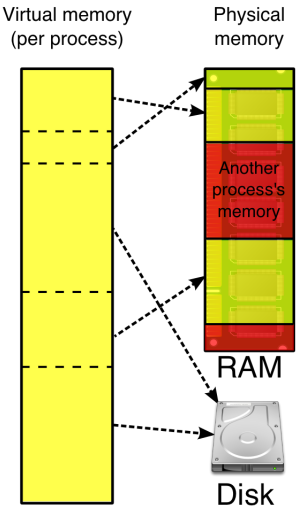

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- Data may be stored:
  - In physical memory
  - On disk
- Each process has a page table
  - Maps virtual $\rightarrow$ physical addresses

Proposal

Our proposal has 3 parts:

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1. Literature Review

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2. Experimental Design

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  - What happens when the kernel runs out of memory?
- Do they do anything special on Non-Uniform Memory Access (NUMA) architectures?

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High-level design

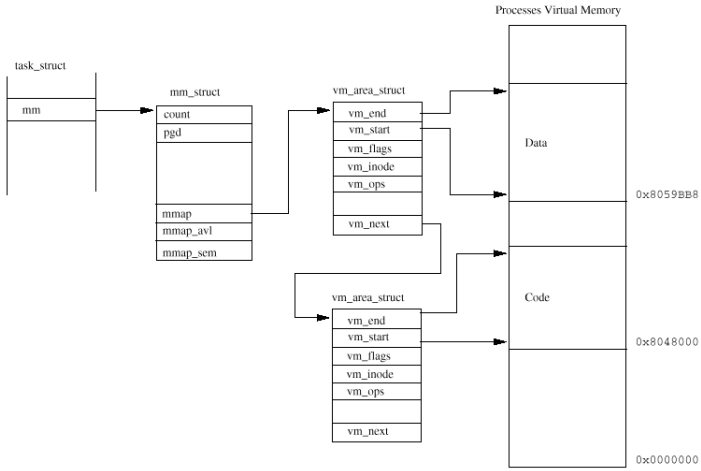
Now we'll summarize the VM design of:

- Linux
- NetBSD
- OpenIndiana

High-level: Linux

- vm_area_struct

```
44 struct vm_area_struct {
45     struct mm_struct * vm_mm;
46     unsigned long vm_start;
47     unsigned long vm_end;
48
49
50     /* linked list of VM areas per task, sorted by address */
51     struct vm_area_struct *vm_next;
52
53     pgprot_t vm_page_prot;
54     unsigned long vm_flags;
55
56     rb_node_t vm_rb;
57
63     struct vm_area_struct *vm_next_share;
64     struct vm_area_struct **vm_pprev_share;
65
66     /* Function pointers to deal with this struct. */
67     struct vm_operations_struct * vm_ops;
68
69     /* Information about our backing store: */
70     unsigned long vm_pgoff;
72     struct file * vm_file;
73     unsigned long vm_raend;
74     void * vm_private_data;
75 };
```



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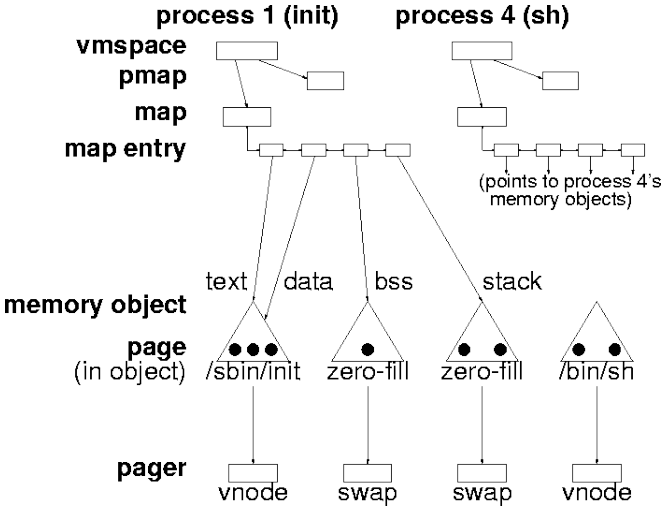

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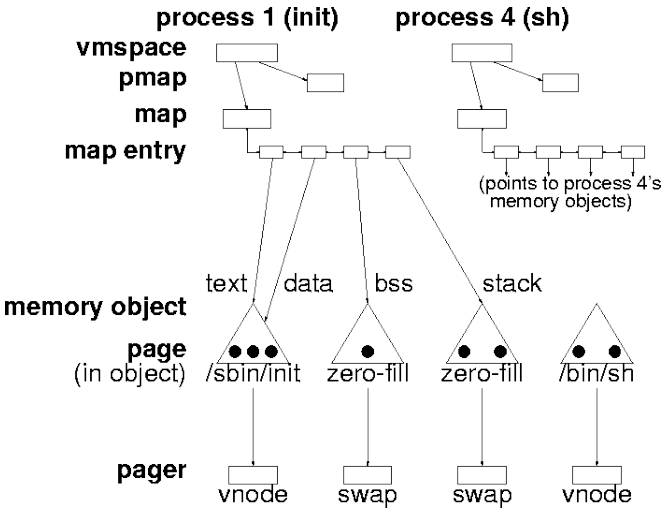

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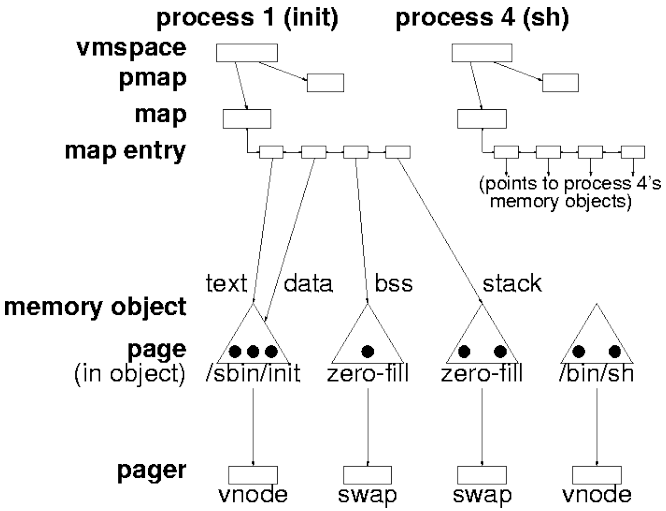

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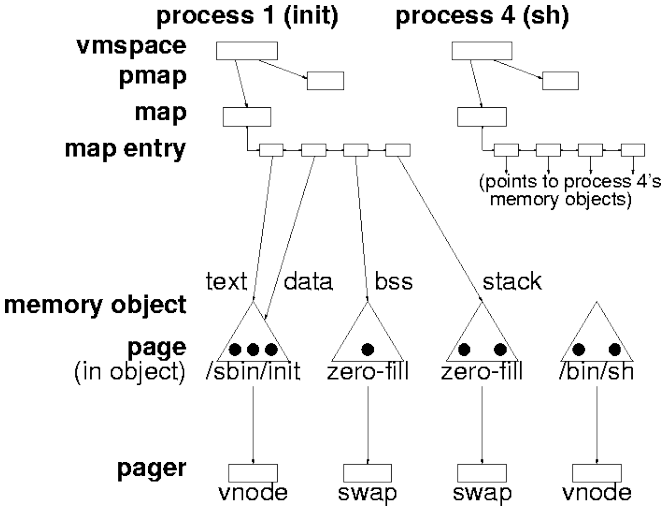

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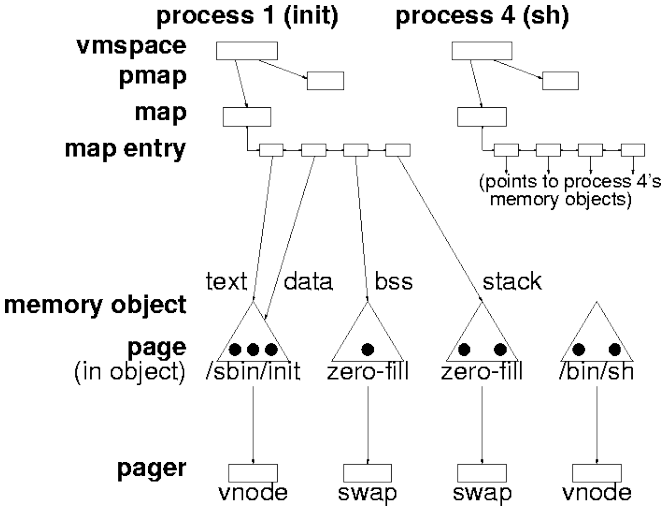

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2. Hardware MMU maps pages to physical memory using platform-specific translation tables
3. Memory management to manage pages is basically swapping and demand paging

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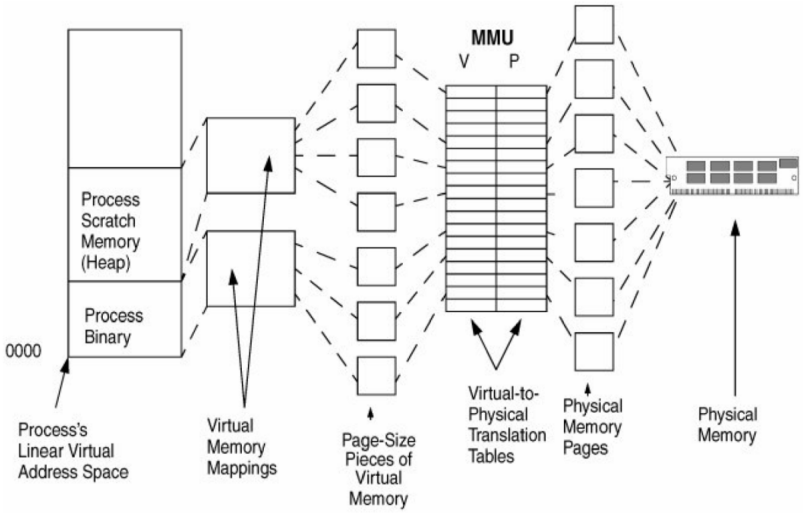

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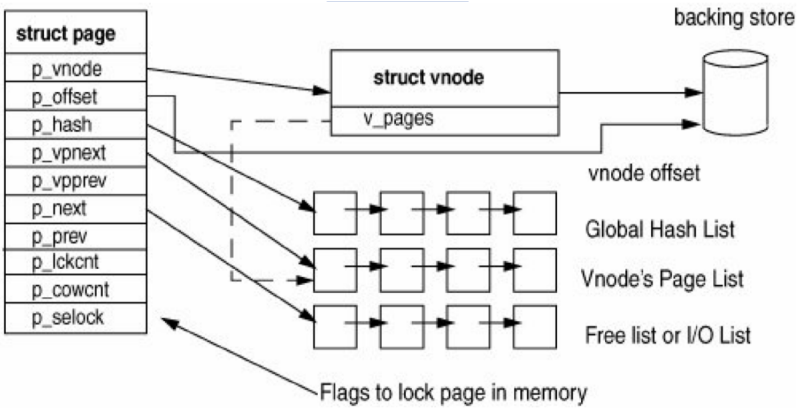

- Page table structure different from x86 hardware page table structure

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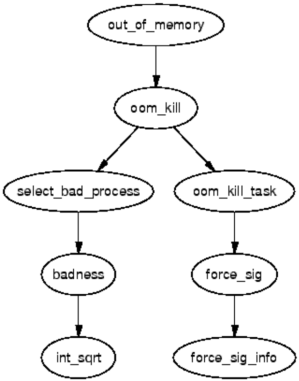
- What happens when the kernel runs out of memory?
- What are the copy-on-write mechanisms?

What happens when the kernel runs out of memory?

Linux:

- Start killing processes



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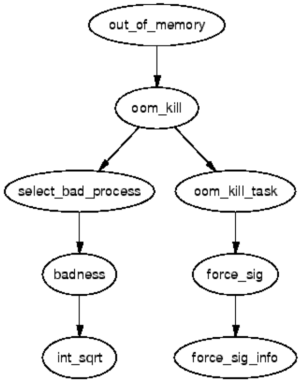

NetBSD:

- Panic!

What happens when the kernel runs out of memory?

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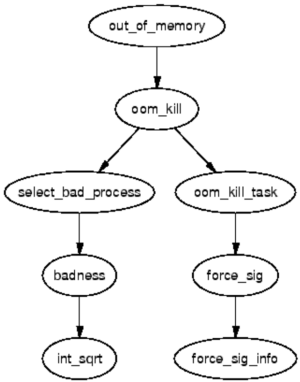

NetBSD:

- Panic!

OpenIndiana:

- Periodically checks kernel space, and "snaps" data to user space if kernel space is low
- If kernel runs out of memory, crashes as far as I can tell

What are the copy-on-write mechanisms?

Linux:

- Page-based copy

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OpenIndiana:

- Anonymous maps

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NetBSD:

- Copied SunOS/Solaris

Summary

1. Literature Review
   - High-level design
   - Differences
2. Experimental Design
3. Implementation

References

- UVM dissertation:
  `http://vorpal.math.drexel.edu/course/opsys2/uvm-project/uvm.pdf`
- UVM paper:
  `https://www.usenix.org/legacy/event/usenix99/full_papers/cranor/cranor.pdf`
- UBC paper:
  `https://www.usenix.org/legacy/publications/library/proceedings/usenix2000/freenix/silvers.html`
- *Understanding the Linux Virtual Memory Manager*
  `https://www.kernel.org/doc/gorman/html/understand/index.html`
- McDougall, Richard, and Jim Mauro. Solaris internals: Solaris 10 and OpenSolaris kernel architecture. Pearson Education, 2006.

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  http://usenix.org/legacy/publications/library/proceedings/usenix99/full_papers/cranor/cranor_html/index.html
- Linux vm_area_struct source from:
  ???
- Linux data structures diagram from:
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- Linux OOM diagram from:
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- Solaris VM diagram:
  McDougall, Richard, and Jim Mauro. Solaris internals: Solaris 10 and OpenSolaris kernel architecture. Pearson Education, 2006.

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