L41 - Lecture 3: The Process Model (1)

Dr Robert N. M. Watson

2 November 2015

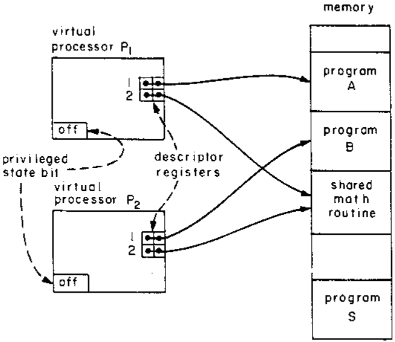
Reminder: last time

1. DTrace
2. The probe effect
3. The kernel source
4. A little on kernel dynamics

This time: the process model

1. The process model and its evolution
2. Brutal (re,pre)-introduction to virtual memory
3. Where do programs come from?
4. Traps and system calls
5. Reading for next time

The process model: 1970s foundations



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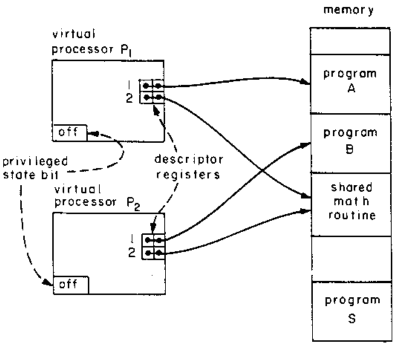

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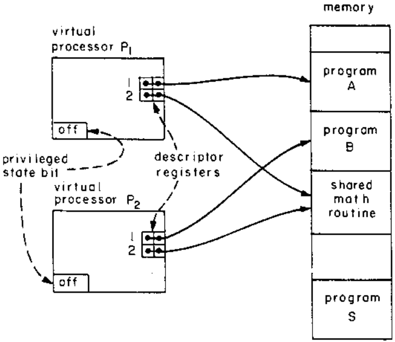

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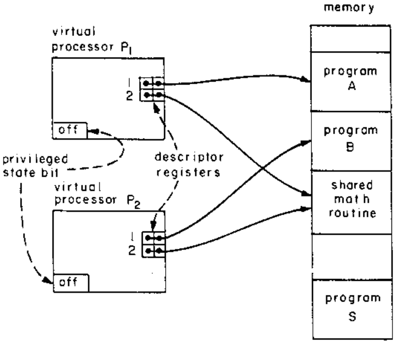

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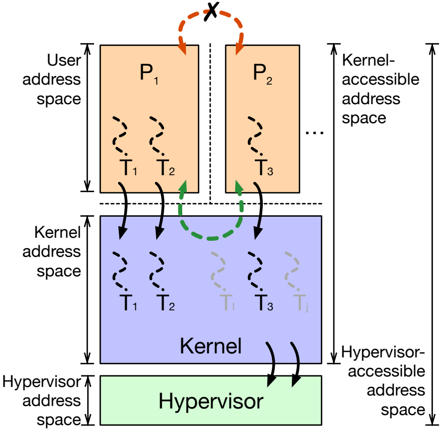

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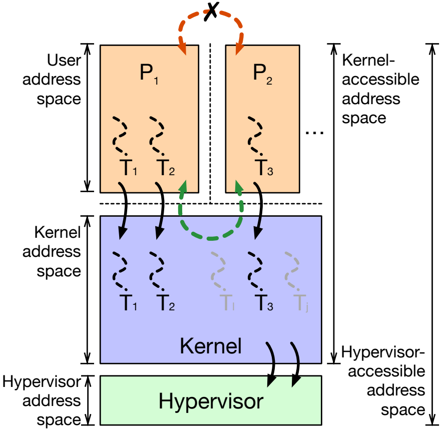

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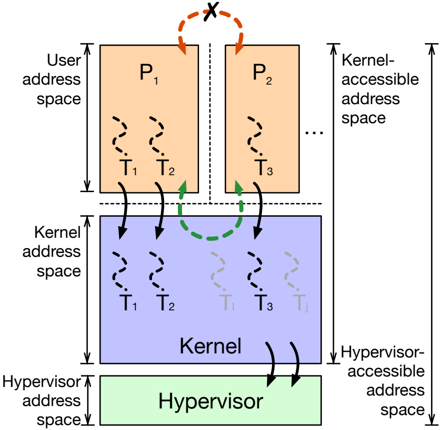

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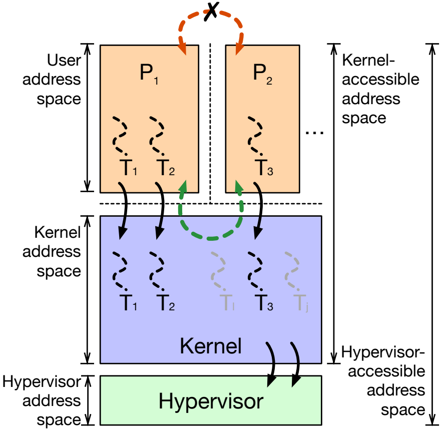

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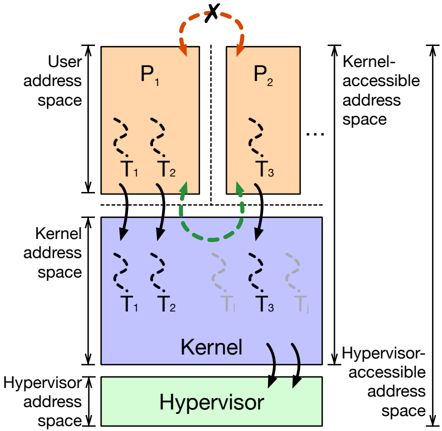

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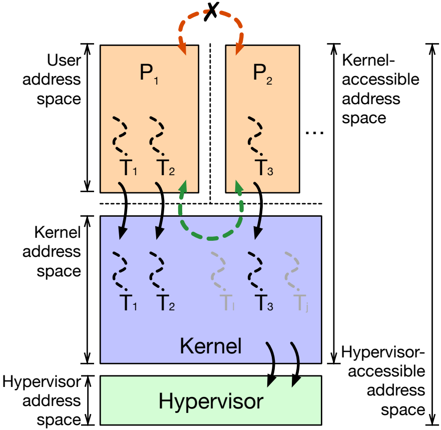

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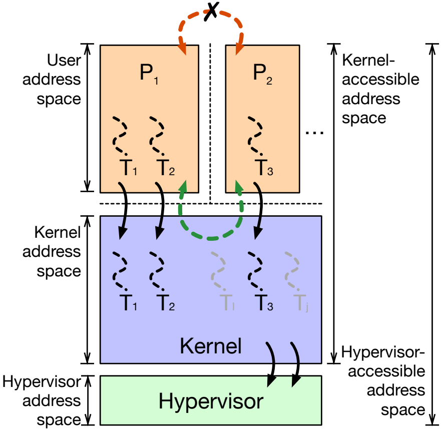

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- Recently: OS-App trust model inverted: Trustzone, SGX

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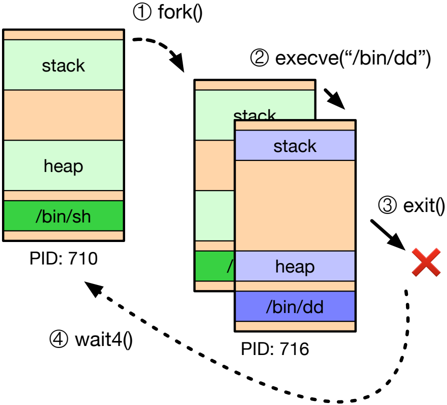

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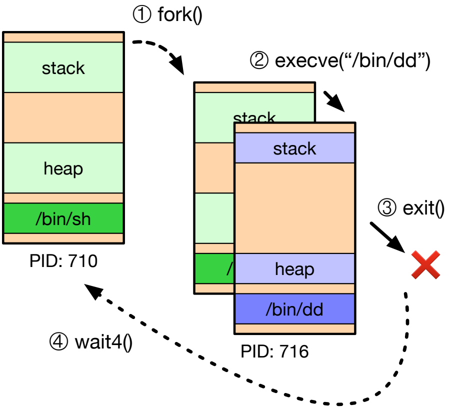

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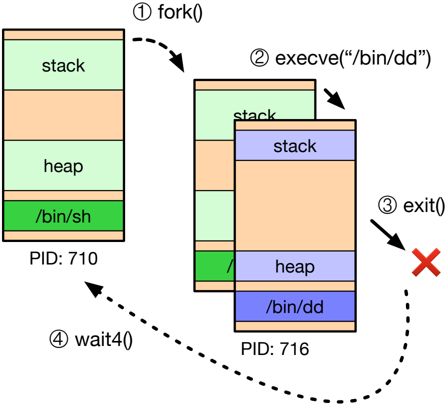

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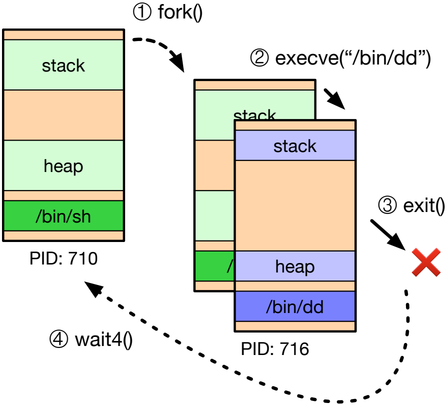

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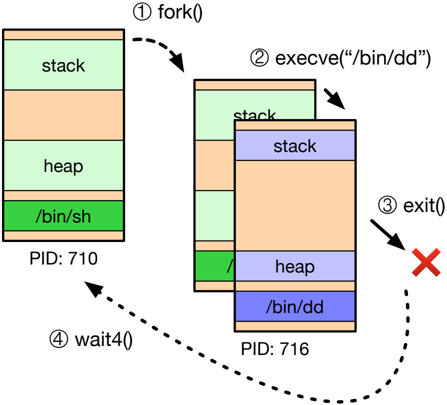

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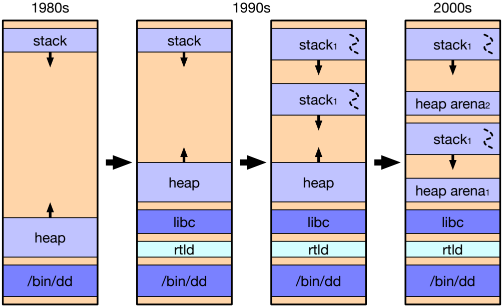
- `wait4` (et al)
  - Parent can await exit status

Process model evolution



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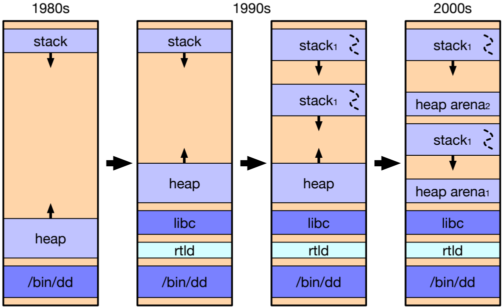

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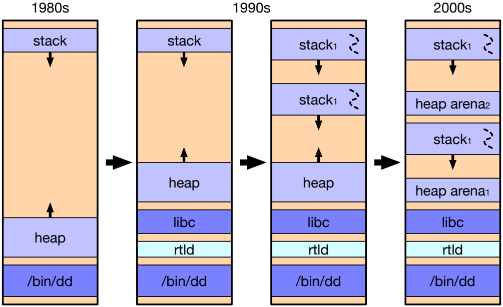

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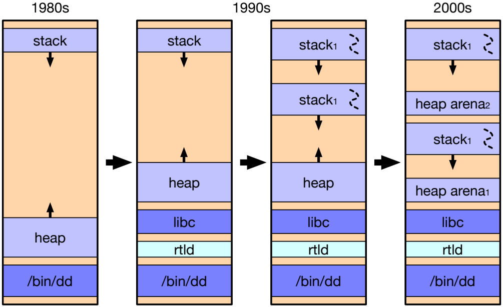

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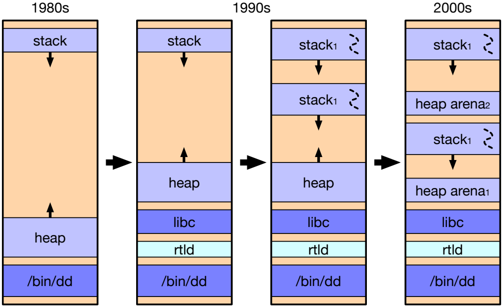

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- Coevolution with virtual memory research (Acetta, et al: *Mach* microkernel (1986); Navarro, et al *Superpages* (2002))

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  734    0x14000    0x16000 rw-    2    2   1   0 ---- df
  734 0x20014000 0x20031000 r-x   29   32  31  14 CN-- vn /libexec/ld-elf.
  734 0x20038000 0x20039000 rw-    1    0   1   0 C--- vn /libexec/ld-elf.
  734 0x20039000 0x20052000 rw-   16   16   1   0 ---- df
  734 0x20100000 0x2025f000 r-x  351  360  31  14 CN-- vn /lib/libc.so.7
  734 0x2025f000 0x20266000 ---    0    0   1   0 ---- df
  734 0x20266000 0x2026e000 rw-    8    0   1   0 C--- vn /lib/libc.so.7
  734 0x2026e000 0x20285000 rw-    7  533   2   0 ---- df
  734 0x20400000 0x20c00000 rw-  526  533   2   0 --S- df
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r: read
w: write
x: execute

C: Copy-on-write
D: Downward growth
S: Superpage

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Program Header:
0x70000001 off    0x0000469c vaddr 0x0000c69c paddr 0x0000c69c align 2**2
         filesz 0x00000158 memsz 0x00000158 flags r--
    PHDR off    0x00000034 vaddr 0x00008034 paddr 0x00008034 align 2**2
         filesz 0x000000e0 memsz 0x000000e0 flags r-x
  INTERP off    0x00000114 vaddr 0x00008114 paddr 0x00008114 align 2**0
         filesz 0x00000015 memsz 0x00000015 flags r--
    LOAD off    0x00000000 vaddr 0x00008000 paddr 0x00008000 align 2**15
         filesz 0x000047f8 memsz 0x000047f8 flags r-x
    LOAD off    0x000047f8 vaddr 0x000147f8 paddr 0x000147f8 align 2**15
         filesz 0x000001b8 memsz 0x00001020 flags rw-
 DYNAMIC off    0x00004804 vaddr 0x00014804 paddr 0x00014804 align 2**2
         filesz 0x000000f0 memsz 0x000000f0 flags rw-
    NOTE off    0x0000012c vaddr 0x0000812c paddr 0x0000812c align 2**2
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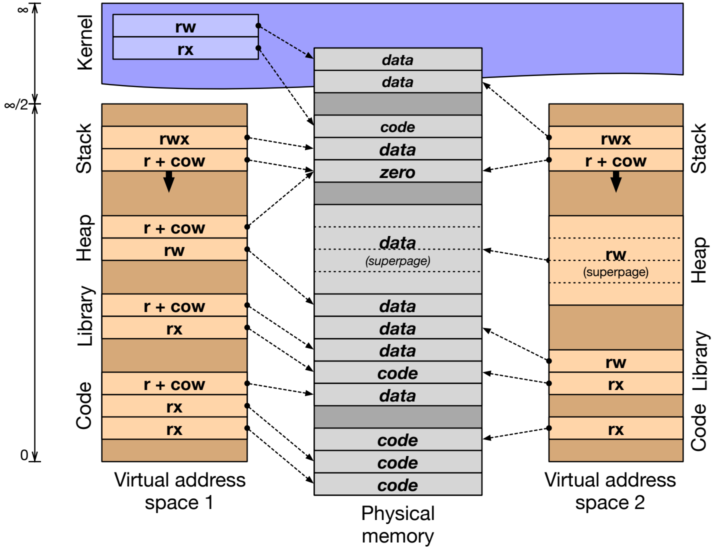
Virtual memory (quick but painful primer)



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- Hypervisors and *I/O MMUs*: I/O sources as ‘processes’

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  - Also used for plug-ins via `dlopen()`, `dlsym()`
- Three separate but related activities:
  - *Loading*: Load ELF segments at suitable virtual addresses
  - *Relocating*: Rewrite position-dependent code to load address
  - *Symbol resolution*: Rewrite inline addresses to other loaded code

Role of the run-time linker (`rtld`) (cont)

```
root@beaglebone:~ # ldd /bin/dd
/bin/dd:
        libc.so.7 => /lib/libc.so.7 (0x20100000)
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- When the `execve` system call starts the new program:
  - ELF binaries name their *interpreter* in ELF metadata
  - Kernel maps `rtld` and the application binary into memory
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- Optimisations:
  - *Lazy binding*: don't resolve all function symbols at load time
  - *Prelinking*: relocate, link in advance of execution

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  716 dd               AT_PHENT            32
  716 dd               AT_PHNUM            7
  716 dd               AT_PAGESZ           4096
  716 dd               AT_FLAGS            0
  716 dd               AT_ENTRY            0x8cc8
  716 dd               AT_BASE             0x20014000
  716 dd               AT_EXECPATH         0xbfffffc4
  716 dd               AT_OSRELDATE        1100062
  716 dd               AT_NCPUS            1
  716 dd               AT_PAGESIZES        0xbfffff9c
  716 dd               AT_PAGESIZESLEN     8
...
```

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- Key challenge: kernel must gain control safely, reliably, securely

RISC $pc saved, $epc installed, control coprocessor (MMU, ...) made available, kernel memory access enabled, reserved exception registers in ABI. Software must save other state (e.g., registers)

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- NB: User context switch = trap to kernel, restore a different context

For next time

- We will continue with system calls and traps
- Then more on virtual memory
- Threading models: the great debate

- McKusick, et al: Chapter 6 (*Memory Management*)
- Optional: Anderson, et al, on *Scheduler Activations*