L8: Virtual machines

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Kernel complexity

• 1975: Unix v6

10,500 total lines of kernel code

• 2012: Linux 3.2

300,000 lines: header files (data structures, APIs)

490,000 lines: networking

530,000 lines: sound

700,000 lines: support for 60+ file systems

1,880,000 lines: support for 25+ CPU architectures

5,620,000 lines: drivers

9,930,000 total lines of code

Linux (2002-2009): avg of 2+ bugs fixed every day

Status Counts for -All-5000.000 CODE FIX 4000.000 3000.000 Counts **2000.000** 1000.000 03/19/03 12/08/03 08/28/04 05/19/05 02/07/06 10/29/06 07/20/07 04/09/08 12/29/08 09/19/09

11/07/02 07/29/03 04/18/04 01/07/05 09/28/05 06/19/06 03/10/07 11/29/07 08/19/08 05/10/09

Dates

```
set ptp(guest pt):
  for gva in 0...2^{20}:
     if guest pt[gva] & PTE P:
       gpa = guest pt[gva] >> 12
       hpa = host pt[gpa] >> 12
       shadow pt[gva] = (hpa << 12) | PTE P
     else:
       shadow pt[gva] = 0
  PTP = shadow pt
```

```
set_ptp_exception(guest_pt):
    acquire(t_lock)
    id = cpus[CPU].thread
    if threads[id].vm_k:
        set_ptp(guest_pt)
    else:
        ## deliver exception to guest VM
    release(t_lock)
```

Physical-Page Base Address

AVL

G

AVL

G

AVL

G

A

D

A

C

W

/ / / P

D

T

S

W

```
set ptp(guest pt, kmode):
  for gva in 0...2^{20}:
     if guest pt[gva] & PTE P and
       (kmode or guest pt[gva] & PTE U):
        gpa = guest pt[gva] >> 12
        hpa = host pt[gpa] >> 12
        shadow pt[gva] = (hpa << 12) | PTE P | PTE U
     else:
        shadow pt[gva] = 0
  PTP = shadow pt
```

Summary

Monolithic OS kernels are complex, error-prone

- Microkernels
 - Enforce OS modularity with client/server (designing modular OS services is hard work)

- Virtual machines
 - Multiplex hardware between multiple OSes (does not enforce modularity within kernel)