Reliable operating systems

Reliable operating systems

Can we make operating systems reliable and secure?

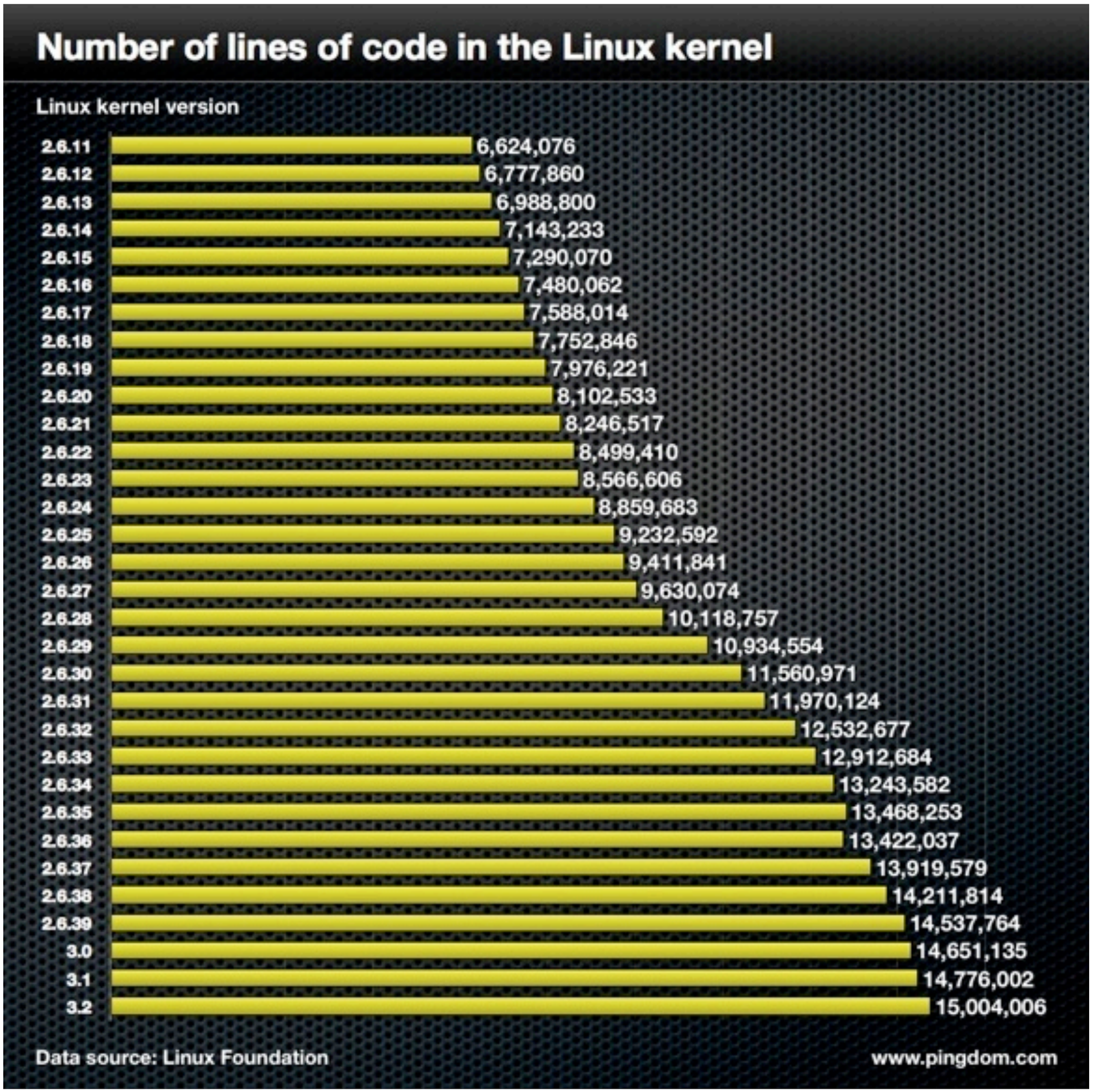
[Andy Tanenbaum, Jorrit Herder, Herbert Bos, 2006]

What makes operating systems unreliable?

- They are huge
- They have poor fault isolation

What makes operating systems unreliable?

- They are huge
  - millions of lines of code


Number of lines of code in the Linux kernel
Linux kernel version
2.6.11 6,624,076
2.6.12 6,777,860
2.6.13 6,988,800
2.6.14 7,143,233
2.6.15 7,290,070
2.6.16 7,480,062
2.6.17 7,588,014
2.6.18 7,752,846
2.6.19 7,976,221
2.6.20 8,102,533
2.6.21 8,246,517
2.6.22 8,499,410
2.6.23 8,566,606
2.6.24 8,859,683
2.6.25 9,232,592
2.6.26 9,411,841
2.6.27 9,630,074
2.6.28 10,118,757
2.6.29 10,934,554
2.6.30 11,560,971
2.6.31 11,970,124
2.6.32 12,532,677
2.6.33 12,912,684
2.6.34 13,243,582
2.6.35 13,468,253
2.6.36 13,422,037
2.6.37 13,919,579
2.6.38 14,211,814
2.6.39 14,537,764
3.0 14,651,135
3.1 14,776,002
3.2 15,004,006
Data source: Linux Foundation
www.pingdom.com

What makes operating systems unreliable?

- They are huge
  - millions of lines of code
  - between 6 and 16 bugs per 1000 lines of code

What makes operating systems unreliable?

- They have poor fault isolation
    - thousands of procedures linked together as a single binary program
    - can overwrite key kernel data-structures
    - if a virus infects even just one procedure, it ca spread quickly to the whole kernel

What can we do?

- Improve on legacy operating systems
  - device drivers are the core of the problem
    - isolate them [***Nooks,*** SOSP'03]
    - synthesize them [***Termite,*** SOSP'09]
- Re-design the OS
  - microkernel

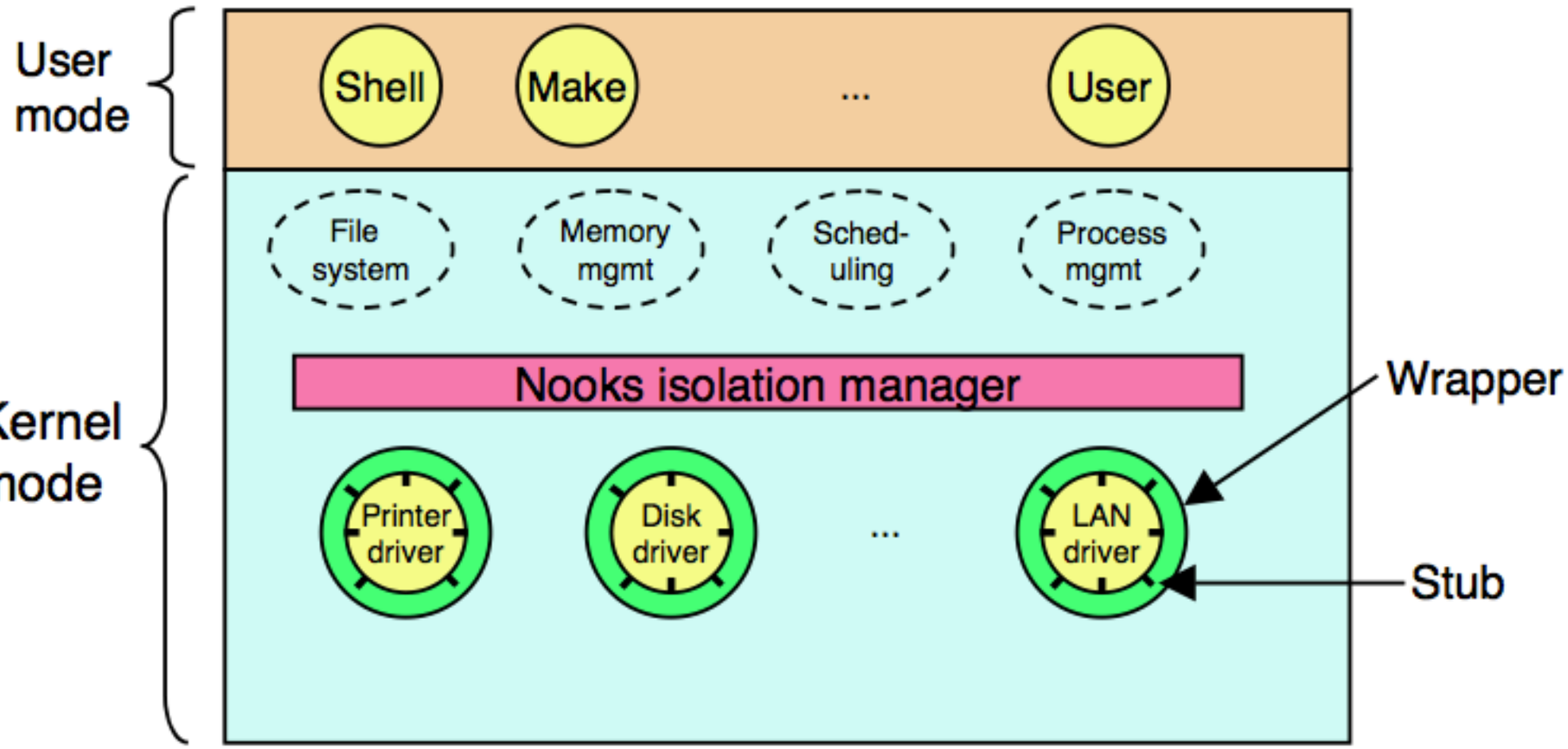
Nooks

- conservative approach, maintains monolithic kernel design
- protects the kernel from buggy device drivers

Nooks: An architecture for reliable device drivers

[Mike Swift, Hank Levy, et. all, SOSP'03]

Nooks architecture



Each driver is wrapped in a layer of protective software that monitors all interactions between the driver and the kernel

Nooks

- Goals:
  - protect the kernel against driver failures
  - recover automatically from driver failures
  - as few changes as possible to the drivers and kernel

Nooks techniques

- Isolation
- Interposition
- Recovery

Nooks techniques

- Isolation
  - *lightweight kernel protection domain* is a module that
    - executes in kernel mode
    - is logically part of the kernel
    - has read access to kernel structures
    - has *restricted* write access to kernel structures

Nooks techniques

- Interposition
  - each driver class exports an interface
  - wrappers for both exported and imported functions
    - some automatically generated
    - 455 wrappers: 329 for the functions exported by the kernel
- when a driver attempts to write a kernel object:
  - first, copy object to driver's protection domain

Nooks techniques

- Recovery
  - user-mode recovery agent (consults configuration database)
  - in many cases enough just to release the resources held and restart the driver
  - shadow drivers are used to allow applications to continue after the crash

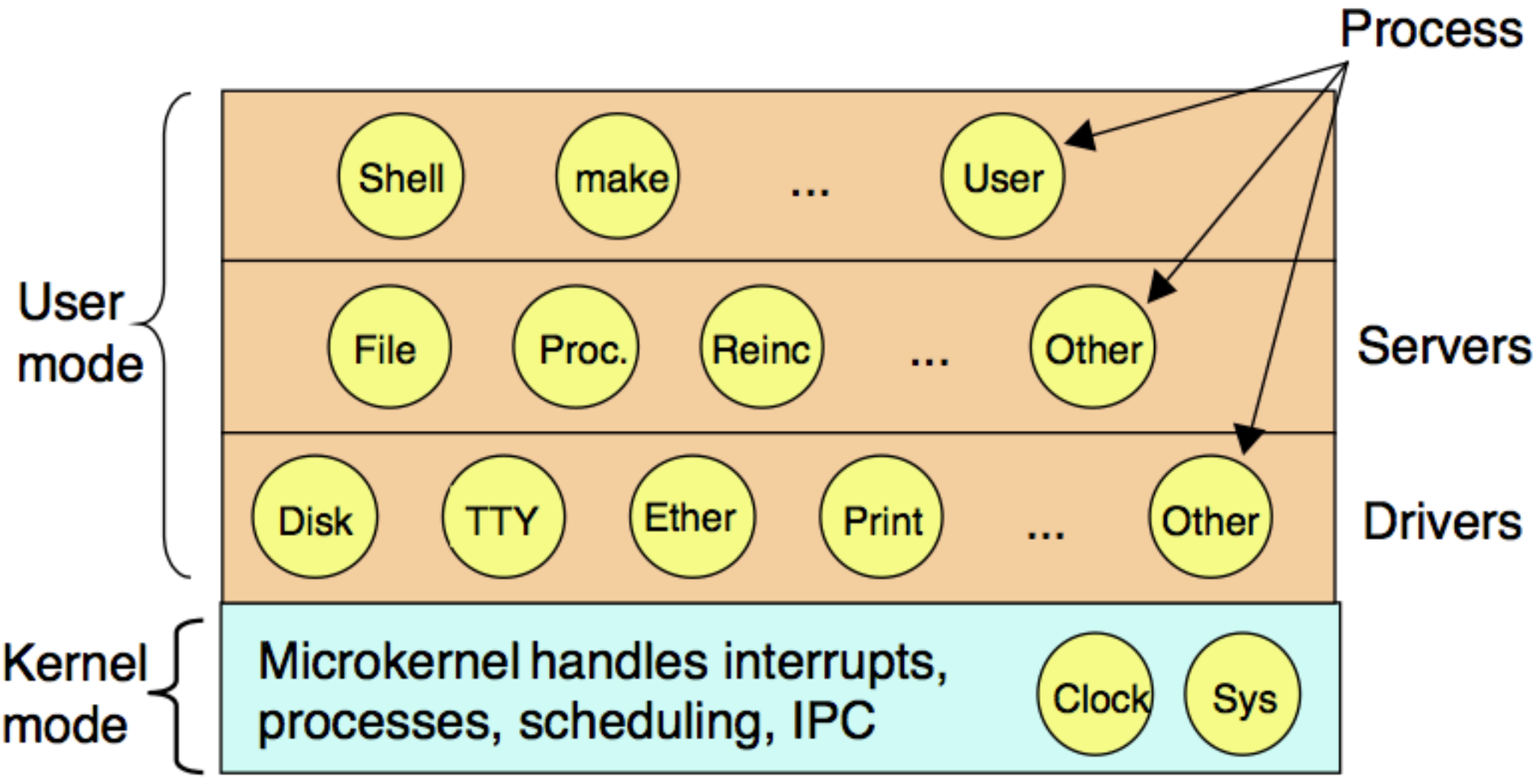
Nooks limitations

- can catch 99% of fatal driver errors and 55% of the non fatal ones
- drivers can execute privileged instructions
- wrappers themselves can contain bugs
- drivers can re-enable access to all memory

Microkernels

- directly attack the core of the problem: having the entire OS running as a huge binary in kernel mode

Minix architecture



A tiny kernel runs in kernel mode with the rest of the OS running as a collection of fully-isolated user-mode server and driver processes

Another conservative approach

- Termite-1, today's talk
- Termite-1 generates bug-free drivers
    - push-button synthesis
- Termite-2 [OSDI'14]
    - user-guided synthesis
    - "*the first tool to combine the power of automation with the flexibility of conventional development*" - what about SKETCH? [ASPLOS'06]