Performance of μ-kernel-based OS

Härtig et al. implemented Linux on L4 ("L^{4}Linux") and conducted a performance analysis.

Their implementation

- made minimal changes to Linux
- replaced some 2,500 lines of architecture dependent code by 6,500 lines new code
- runs Linux as a single server
- is binary compatible with native Linux on ix86

Linux System Call Implementation: Trampoline

- Linux system calls in application code trigger *exception*
- Linux server has *syscall exception handler* to catch these and convert into IPC to server
- Linux server "replies" back to application thread
- full binary compatibility at some performance cost
- secure

Linux System Call Implementation: Libc

- modify `libc` to convert "system calls" into RPC to Linux server
- still fully binary compatible for dynamically linked applications
- requires re-linking for statically linked applications
- minimal overhead
- secure

Performance of L^{4}Linux: Microbenchmarks

`getpid` system call costs

System	**Time**	**Cycles**
Linux	1.68 μs	223
L^{4}Linux (library stubs)	3.95 μs	526
L^{4}Linux (trampoline)	5.66 μs	753
Mach/Linux in kernel	15.41 μs	2050
Mach/Linux user mode	110.60 μs	14710

"library stubs": `libc` convert Linux syscalls into RPC to server

"trampoline": Linux server exception handler catches kernel call traps

"in kernel": Linux server runs as part of Mach kernel

"user mode": Linux runs as user-level server

Performance of L⁴Linux: Macrobenchmarks

Linux server compilation times

System	Time	rel perf
Linux	476 s	100
L^4Linux (library stubs)	506 s	94
L^4Linux (trampoline)	509 s	93
Mach/Linux in kernel	555 s	86
Mach/Linux user mode	605 s	79

⇒ there is a measurable cost of the μ-kernel implementation

... but it's small on L4 (and the kernel matters)

- obviously performance could be improved by more extensive modifications to Linux source

Performance potential example: Pipes

More extensive rewrite of Linux can make better use of efficient L4 IPC and thus provide performance exceeding that of native Linux.

System	Latency	"Bandwidth"
Linux pipe	29 μs	41 MB/s
L^4Linux pipe	46 μs	40 MB/s
L^4Linux (trampoline) pipe	56 μs	38 MB/s
Mach/Linux (user) pipe	722 μs	10 MB/s
Mach/Linux (in-kernel) pipe	316 μs	13 MB/s
L4 pipe (IPC, bypasses Linux)	22 μs	48–70 MB/s
synchronous L4 RPC (strings)	5 μs	65–105 MB/s
synchronous L4 RPC (fpages)	12 μs	2470–2900 MB/s

L^4Linux Performance

For more details see:

[1] Herrmann Härtig, Michael Hohmuth, Jochen Liedtke, Sebastian Schönberg, and Jean Wolter. The performance of μ-kernel-based systems. In *Proc. 16th ACM Symp. OS Princip.*, pages 66–77, St. Malo, France, October 1997. ACM.