A Performance Comparison of UNIX Operating Systems on the Pentium

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Why PC?

Mainframe → Minicomputer → Workstation → PC

Market trend:

Increase in PC hardware performance/price ratio

100 MHZ Pentium, 32MB, 2GB disk, 17” monitor
10Mb/sec. Ethernet

~ 100 SpecInt92/$5000 (June 1995)

Desirable *Research* Operating System Features:

performance,
reliability,
kernel source code,
technical support,
driver support,
application software,
large user base

Which Brand?

- Homemade OS
- Commercial UNIX
- Free UNIX

    A Toy?

1995 Platform

How we went shopping for an OS:

- Runs on our hardware:

  100 MHZ Pentium, 32MB, NCR 53c810 SCSI controller,
  2GB internal disk, 2GB external disk, 17” monitor
  10Mb/sec. Ethernet

- Easily installable
- Easily available

Operating Systems Tested

Non-development release version of the OS in June 1995: (Bug fixes until October 1995)

OS	Version
Linux	1.2.8
FreeBSD	2.0.5R
Solaris x86	2.4

Methodology

Benchmarking vs. Other Techniques (e.g. kernel counters)

Advantages:

- Portable
- Most Important Metric = Wall Clock Time
- Comparable results

How we benchmarked:

- Black box
- No optimizations

Benchmarks

- Microbenchmarks
  System Call
  Context Switch
  File System
  Networking
- Application Benchmark
  Modified Andrew Benchmark

System Call

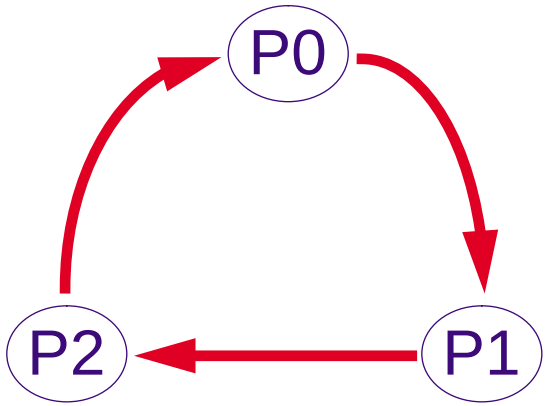
OS	Time (μseconds)	Normalized to best
Linux	2.31	1.00
FreeBSD	2.62	0.88
Solaris	3.52	0.66

Table 1. Results averaged over 1000 iterations of calling `getpid()` in a loop

Linux: Slightly more optimized kernel entry assembly

Solaris: Multi-threaded, fully preemptive kernel

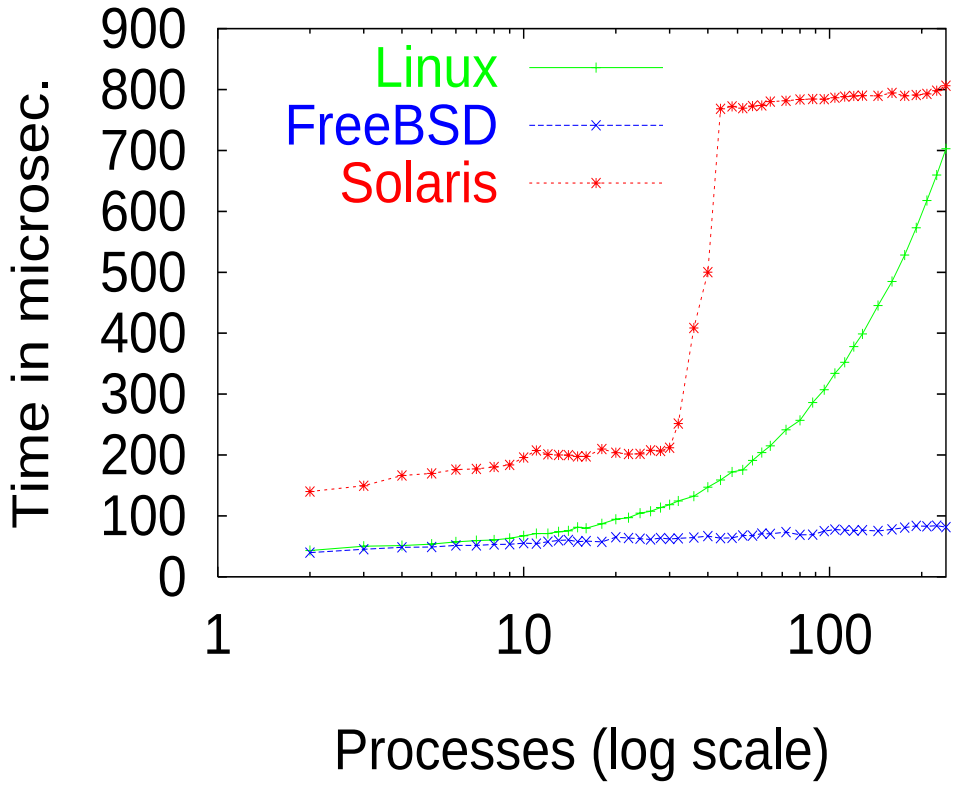
Context Switch Benchmark Design



What is measured:

- Pipe latency
- Scheduling
- Context switching

Context Switch (mostly)

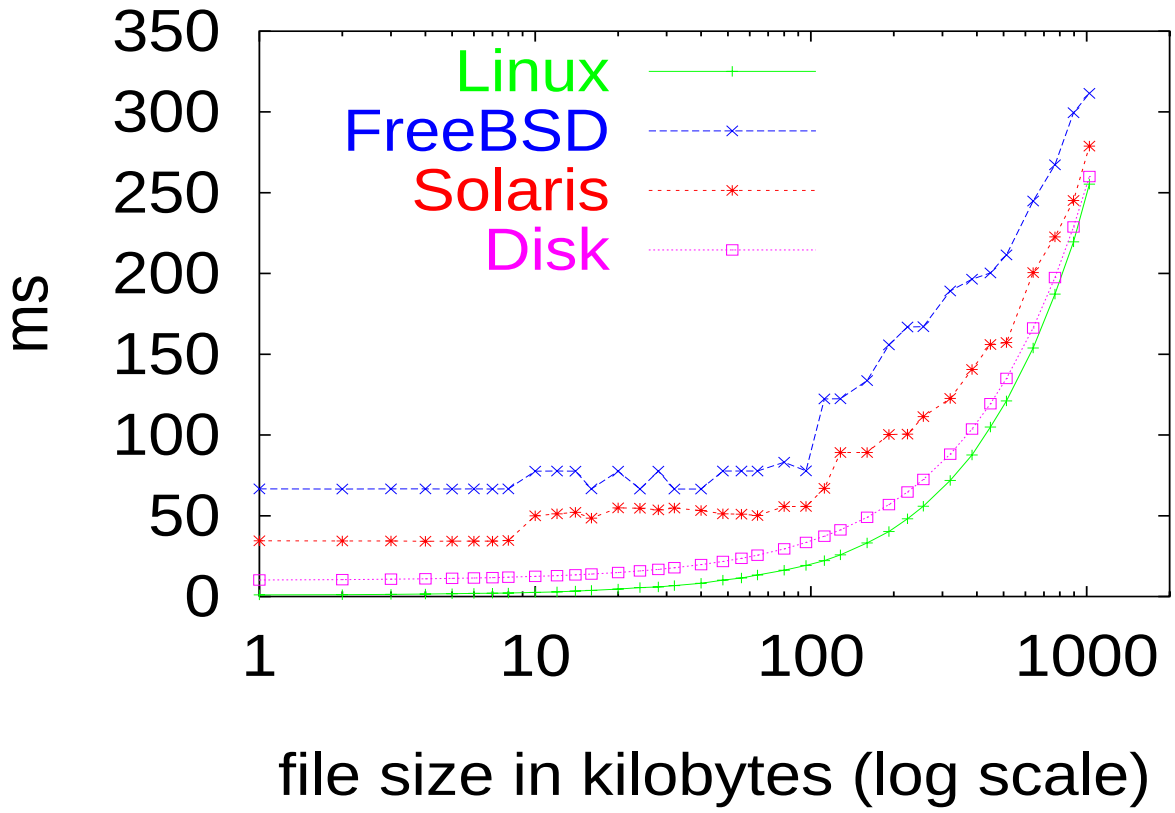


Linux: Searching long linked list during context switch

Solaris: Multi-threaded kernel has complex scheduler

Small File Performance

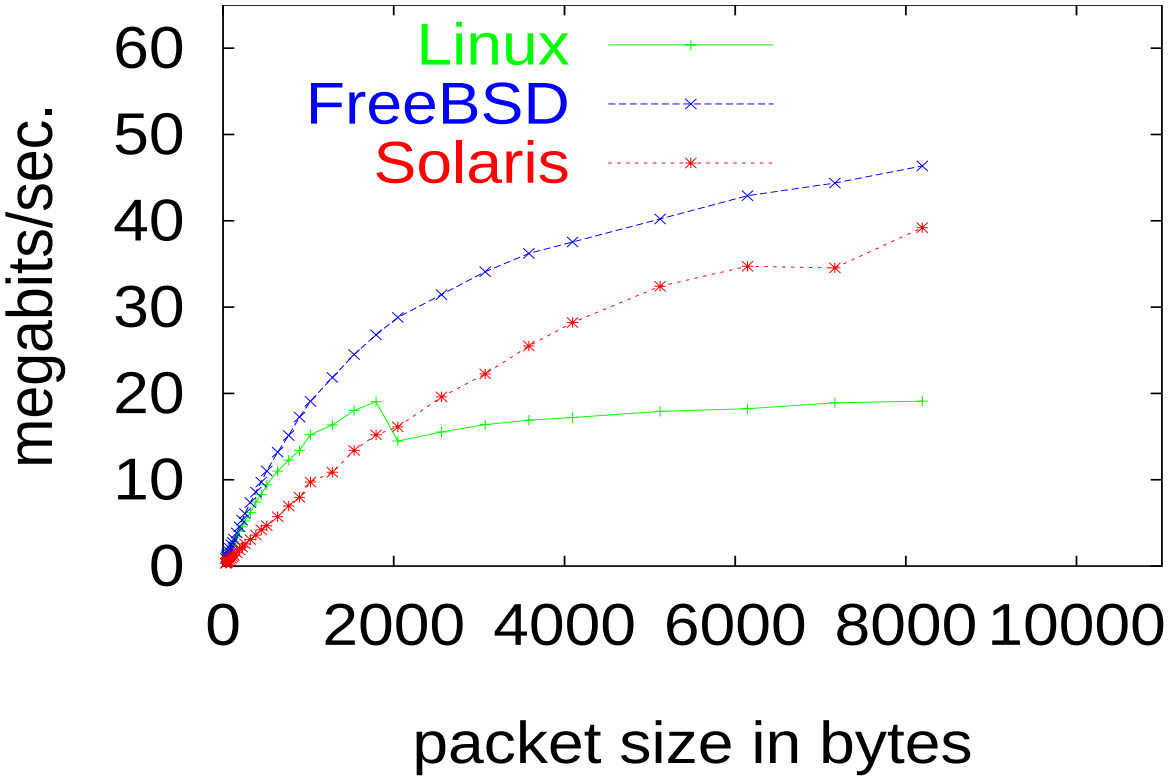
- Create file
- Write n bytes
- Read n bytes
- Delete file



Linux: Uses asynchronous writes of file metadata.

FreeBSD: Performance worse than Solaris on similar FS.

Networking Performance (UDP)



Linux: Does too many memory copies

Networking Performance (TCP)

OS	Bandwidth (megabits/ second)	Normalized to best
FreeBSD	65.95	1.00
Solaris	60.11	0.91
Linux	25.03	0.38

Linux: Does too many memory copies,
TCP window of 1 packet.

Modified Andrew Benchmark

On the local disk:

OS	Time (seconds)	Normalized to best
Linux	43.12	1.00
FreeBSD	47.45	0.91
Solaris	54.31	0.80

Linux: Uses asynchronous file metadata write.

Modified Andrew Benchmark

Across NFS to a SunOS server:

OS	Time (seconds)	NFS overhead	Normalized to best
FreeBSD	53.24	+12.20%	1.00
Linux	57.73	+33.20%	0.92
Solaris	58.38	+7.49%	0.91

Linux: Poor networking performance, untuned.

Results

Linux:	fast:	system call, small file performance
	slow:	networking
FreeBSD:	fast:	networking
	slow:	small file performance
Solaris:	fast:	some other benchmark?
	slow:	system call, context switching

Conclusion

Performance (generally) doesn't matter!

Qualitative factors make the difference:

Linux, FreeBSD:	Freely distributable kernel source
Linux:	Vast user community
Solaris:	Support for multiprocessing

What's Happening Now

Linux 1.3.53:

- Extremely fast context switch
  (<50 μseconds, independent of number of processes)
- Much better TCP performance (50% higher BW)

FreeBSD 2.1R

- Ordered asynchronous file metadata writes (unverified)

Solaris 2.5

- Faster context switching (unverified)
- Faster networking