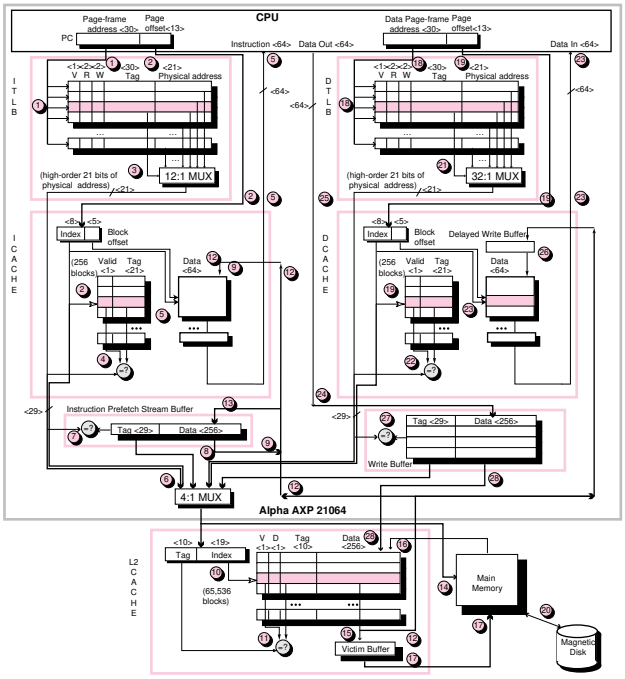
Alpha 21064

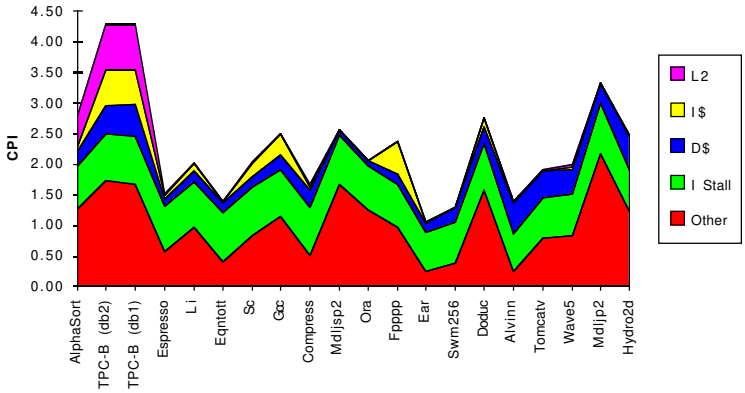
- Separate Instr & Data TLB & Caches
- TLBs fully associative
- Caches 8KB direct mapped
- Critical 8 bytes first
- Prefetch instr. stream buffer
- 2 MB L2 cache, direct mapped
- 256 bit path to main memory, 4 64-bit modules



© Patterson 1994

Alpha CPI components

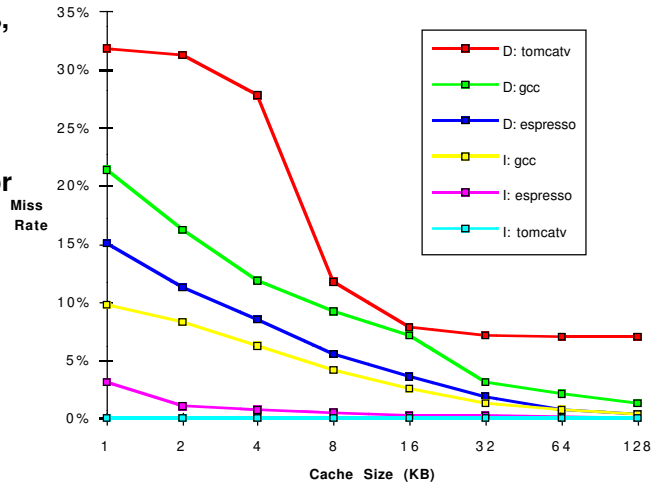
- Instr stall: branch mispredict;
  Other: compute + reg conflicts, structural conflicts



© Patterson 1994

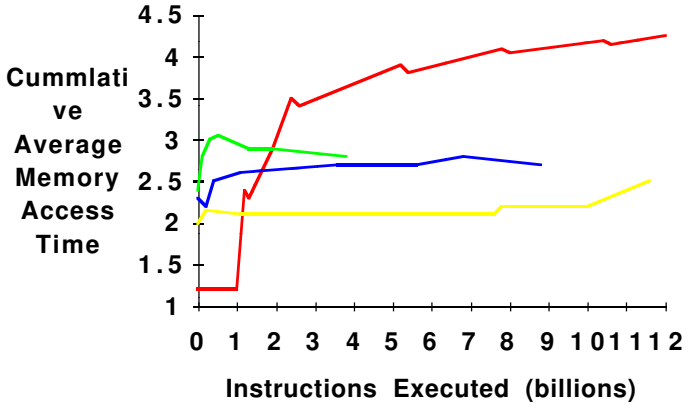
Pitfall: Predicting Cache Performance from Different Program (ISA, compiler, ...)

- 4KB Data cache miss rate 8%,12%, or 28%?
- 1KB Instr cache miss rate 0%,3%, or 10%?
- Alpha vs. MIPS for 8KB Data: 17% vs. 10%



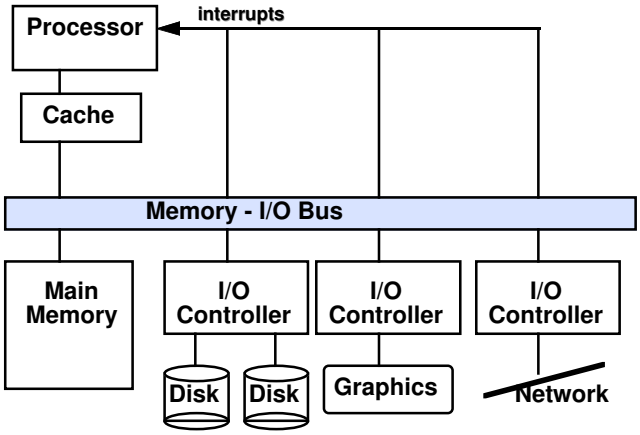
© Patterson 1994

Pitfall: Simulating Too Small an Address Trace

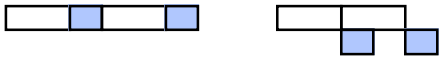


© Patterson 1994

I/O Systems



Time(workload) = Time(CPU) + Time(I/O) - Time(Overlap)



© Patterson 1994

Storage System Issues

- Historical Context of Storage I/O
- Storage I/O Performance Measures
- A Little Queuing Theory
- Secondary and Teriary Storage Devices
- Processor Interface Issues
- I/O Buses
- Redundant Arrarys of Inexpensive Disks (RAID)
- ABCs of UNIX File Systems
- I/O Benchmarks
- Comparing UNIX File System Performance

© Patterson 1994

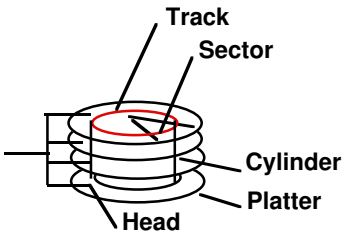
Motivation: Who cares about I/O?

- CPU Performance: 50% to 100% per year
- Multiprocessor supercomputers 150% per year
- I/O system performance limited by *mechanical* delays
  < 5% per year (IO per sec or MB per sec)
- Amdahl's Law: system speed-up limited by the slowest part!
  10% IO & 10x CPU => 5x Performance (lose 50%)
  10% IO & 100x CPU => 10x Performance (lose 90%)
- I/O bottleneck:
  => Diminishing fraction of time in CPU
  => Diminishing value of faster CPUs

© Patterson 1994

Devices: Magnetic Disks

- Purpose:
  - Long-term, nonvolatile storage
  - Large, inexpensive, slow level in the storage hierarchy
- Characteristics:
- Seek Time (~20 ms avg, 1M cyc at 50MHz)
  - positional latency
  - rotational latency
- Transfer rate
  - about a sector per ms (1-10 MB/s)
  - blocks
- Capacity
  - Gigabytes
  - quadruples every 3 years (areodynamics)



3600 RPM = 60 RPS => 16 ms per rev
ave rot. latency = 8 ms
32 sectors per track => 0.5 ms per sector
1 KB per sector => 2 MB / s
32 KB per track
20 tracks per cyl => 640 KB per cyl
2000 cyl => 1.2 GB

Response time
= Queue + Controller + Seek + Transfer

Service time

© Patterson 1994

Tape vs. Disk

- Longitudinal tape uses same technology as hard disk; will track density improvements.
- Inherent cost-performance based on geometries:
  fixed rotating platters with gaps
  (random access, limited area, 1 media / reader)
  vs.
  removable long strips wound on spool
  (sequential access, "unlimited" length, multiple / reader)
- New technology trend:
  Helical Scan (VCR, Camcoder, DAT)
  spins head at angle to tape to improve density

© Patterson 1994

Alternative Data Storage Technologies

Technology	Cap (MB)	BPI	TPI	BPI*TPI (Million)	Data Xfer (KByte/s)	Access Time
Conventional Tape:						
Cartridge (.25")	150	12000	104	1.2	92	minutes
IBM 3490 (.5")	800	22860	38	0.9	3000	seconds
Helical Scan Tape:						
Video (8mm)	4600	43200	1638	71	492	45 secs
DAT (4mm)	1300	61000	1870	114	183	20 secs
D-3 (1/2")	20,000					15 secs?
Magnetic & Optical Disk:						
Hard Disk (5.25")	1200	33528	1880	63	3000	18 ms
IBM 3390 (10.5")	3800	27940	2235	62	4250	20 ms
Sony MO (5.25")	640	24130	18796	454	88	100 ms

© Patterson 1994

Optical Disk vs. Tape

	Optical Disk	Helical Scan Tape
Type	5.25"	8mm
Capacity	0.75 GB	5 GB
Media Cost	$90 - $175	$8
Drive Cost	$3,000	$3,000
Access	Write Once	Read/Write
Robot Time	10 - 20 s	10 - 20 s

Media cost ratio optical disk vs. helical tape = 75 : 1 to 150 : 1

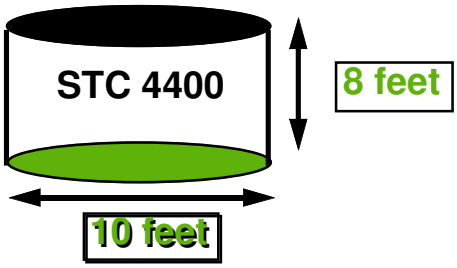
© Patterson 1994

Current Drawbacks to Tape

- Tape wear out: Helical 100s of passes to 1000s for longitudinal
- Head wear out: 2000 hours for helical
- Both must be accounted for in economic / reliability model
- Long rewind, eject, load, spin-up times; not inherent, just no need in marketplace (so far)

© Patterson 1994

Automated Cartridge System



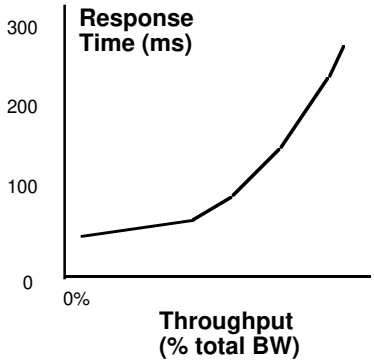
6000 x 0.8 GB 3490 tapes = 5 TBytes in 1992
$500,000 O.E.M. Price

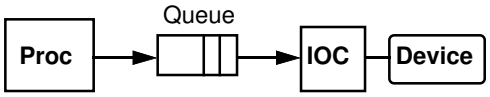
6000 x 20 GB D3 tapes = 120 TBytes in 1994
1 Petabyte (1024 TBytes) in 2000

© Patterson 1994

Disk I/O Performance

Metrics: Response Time and Throughput



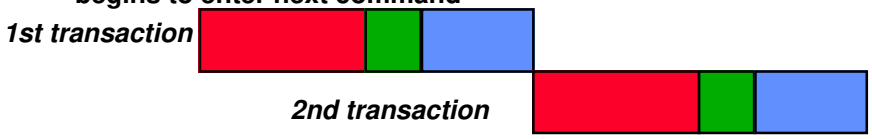


Response time = Queue + Device Service time

© Patterson 1994

Response Time vs. Productivity

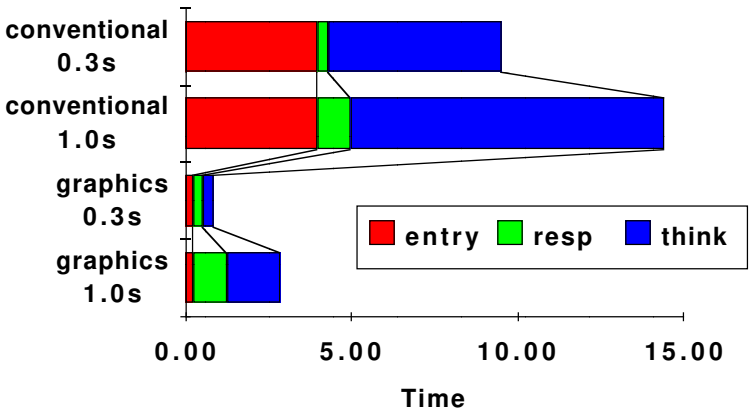
- Interactive environments. Each interaction or *transaction* has 3 parts:
  - *Entry Time*: time for user to enter command
  - *System Response Time*: time between user entry & system replies
  - *Think Time*: Time from respention of response unilt user begins to enter next command



- What happens to transaction time as shrink system response time from 1.0 sec to 0.3 sec?
  - Before Graphics: 0.25 sec entry, 1.6 sec think time
  - Before Keyboard: 4.0 sec entry, 9.4 sec think time

© Patterson 1994

Response Time & Productivity?



- 0.7sec off response saves 4.9 sec (34%) and 2.0 sec (70%) total time per transaction => greater productivity
- Another study: everyone gets more done with faster response, but novice with fast response = expert with slow

© Patterson 1994