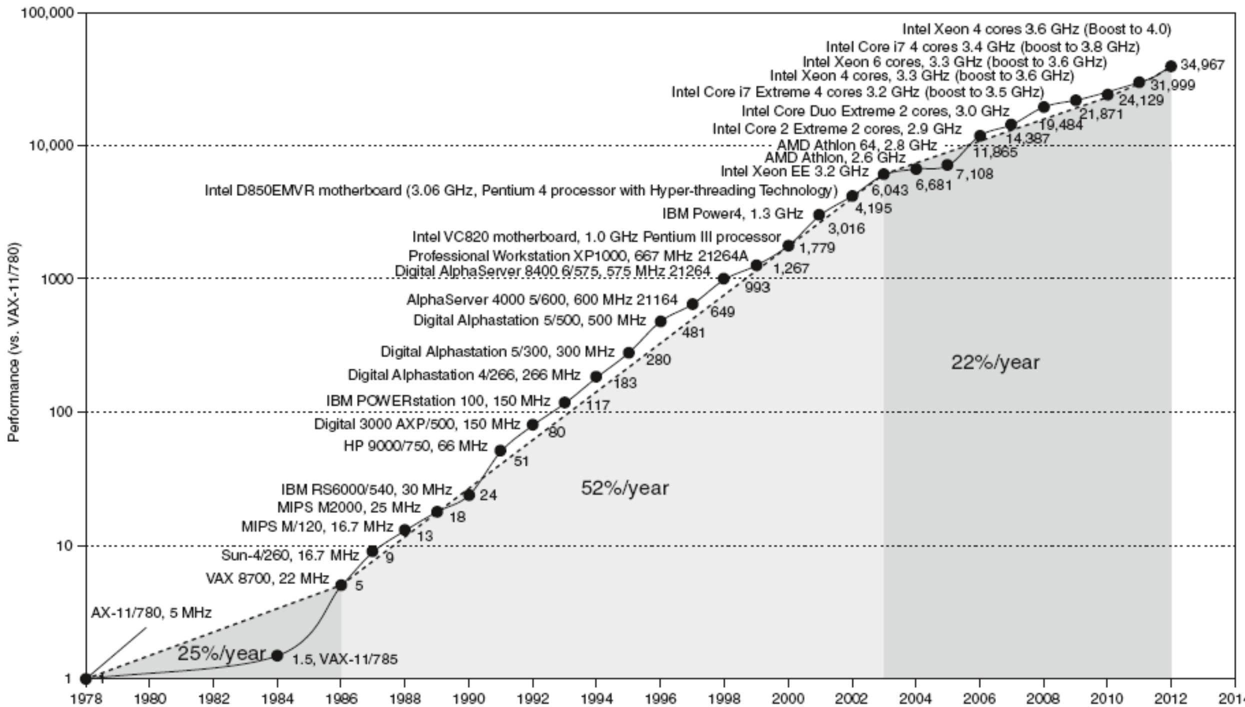
Chapter 1

Computer Abstractions and Technology

Growth in Processor Performance



- Rather than continuing to decrease the response time of a single program running on the single processor, as of 2006 companies are shipping microprocessors with multiple processors per chip, where the benefit is often more on throughput than on response time

Multiprocessors

- Multicore microprocessors
  - More than one processor (core) per chip
- Parallel programming is required to get significant improvement in response time
- Parallel programming increases the difficulty of programming ; the program must be correct and fast
- Programmer must divide an app, so that **each processor has roughly same amount to do at the same time**; Challenges: scheduling, load balancing, time for synchronization, and overhead for communication
- **Pipeline is an example of instruction level parallelism**
  - Hardware executes multiple instructions at once
  - Parallel nature of the hardware is hidden from the programmer

SPEC CPU Benchmark

- **Programs used to measure performance**
  - Supposedly typical of actual workload
- System Performance Evaluation Cooperative (SPEC)
  - Develops benchmarks for CPU, I/O, Web, …
- SPEC CPU2006 (consists of 12 integer benchmarks (CINT2006) and 17 floating points benchmarks (CFP2006))

SPEC integer benchmarks and their execution time on Intel Core i7

Description	Name	Instruction Count x 10^9	CPI	Clock cycle time (seconds x 10^{-9})	Execution Time (seconds)	Reference Time (seconds)	SPECratio
Interpreted string processing	perl	2252	0.60	0.376	508	9770	19.2
Block-sorting compression	bzip2	2390	0.70	0.376	629	9650	15.4
GNU C compiler	gcc	794	1.20	0.376	358	8050	22.5
Combinatorial optimization	mcf	221	2.66	0.376	221	9120	41.2
Go game (AI)	go	1274	1.10	0.376	527	10490	19.9
Search gene sequence	hmmer	2616	0.60	0.376	590	9330	15.8
Chess game (AI)	sjeng	1948	0.80	0.376	586	12100	20.7
Quantum computer simulation	libquantum	659	0.44	0.376	109	20720	190.0
Video compression	h264avc	3793	0.50	0.376	713	22130	31.0
Discrete event simulation library	omnetpp	367	2.10	0.376	290	6250	21.5
Games/path finding	astar	1250	1.00	0.376	470	7020	14.9
XML parsing	xalancbmk	1045	0.70	0.376	275	6900	25.1
Geometric mean	–	–	–	–	–	–	25.7

- **SPECratio: Dividing execution time of the reference computer to execution time of the measured computer**
- To summarize all 12 integer benchmarks, a single number quoted as SPECINTC2006 **(geometric mean of the SPECratio)** . The formula for geometric mean is :

$$\sqrt[n]{\prod_{i=1}^{n} \text{Execution time ratio}_i}$$

SPEC Power Benchmark
SPECpower ssj2008 for Xeon X5650

Target Load %	Performance (ssj_ops)	Average Power (Watts)
100%	865,618	258
90%	786,688	242
80%	698,051	224
70%	607,826	204
60%	521,391	185
50%	436,757	170
40%	345,919	157
30%	262,071	146
20%	176,061	135
10%	86,784	121
0%	0	80
Overall Sum	4,787,166	1,922
Σssj_ops/Σpower =		2,490

- **Given the increasing importance of energy and power, SPEC added a benchmark to measure power.**
- **It reports <u>power consumption of servers at different workload levels</u>, divided into 10% increments, over a period of time**
- **<u>Performance is measured in throughput</u>, and the units are business operations per second**
- **To simplify, SPEC boils these numbers down to a single number, called "overall ssj_ops per watt." The formula for this number is**

$$\text{Overall ssj\_ops per Watt} = \left(\sum_{i=0}^{10} \text{ssj\_ops}_i\right) \Big/ \left(\sum_{i=0}^{10} \text{power}_i\right)$$

Reading assignment

Read 1.8, 1.9, and 1.10 of the text book