Chapter 1

Problem 1.5 Solution
a. Total execution time = 128/2 = 64 unit time, which is the longest time.
b. Processor utilization rate = (32+64+64/3+32)/(64*4) = 58.33%

Problem 1.7 Solution
According to formula of speedup,
\[ S = \frac{T_1}{T_n} = \frac{cN^3}{n} + \frac{dN^2}{n^{0.5}} = \frac{cN}{n} + \frac{d}{n^{0.5}} \]
If \( n = 64, c = 0.8, d = 0.1, N = 15000 \), then \( S = 63.99 \)
The efficiency of cluster can be calculated by
\[ E = \frac{S}{n} \]
The E = 99.98% since sequential bottleneck \( \alpha = 0 \).
If \( N \) is enlarged to 60000, then \( S \) and \( E \) are the same, since \( \alpha = 0 \).

Comment: If the workload is fully parallel, the speedup of Amdahl’s law and Gustafson’s Law are the same.

Problem 1.11 Solution
a. Single-threaded superscalar. Only instructions from the same threaded are executed in the superscalar pipeline. Superscalar means there are multiple datapath in parallel. It is simple without parallelism.
b. Fine-grain multi-threading. It schedules the instructions from the same thread to execute in only one cycle.
c. Coarse-grain multi-threading. It schedules the instructions from the same thread to execute in a few cycles before switching to another thread.
d. Simultaneous multi-threading. It permits scheduling the instructions from different thread in the same cycle. It has the highest utilization efficiency of datapath, but the scheduler is complicated.
e. Chip multi-processor. It executes threads completely in different cores. Each core supports one thread. Intel Xeon and AMD Opteron have 4, 6, 8, or10 cores. The isolation of thread is good, but it is hard to do thread synchronization.
Problem 1.14 Solution

a. Application cloud service indicates browser based application over millions of cloud users. This service is offered by SaaS provider such as Salesforce.com

b. Platform cloud service indicates a service which enables developer to deploy customized applications on a cloud platform. This platform includes OS, middleware, database, and API to support cloud application development. The service is offered by PaaS provider such as Google App Engine platform.

c. Compute and storage service indicates service to provide infrastructure of computing such as servers, storage, and networking. The service is provided by IaaS provider such as AWS.

d. Collocation cloud service is a service to house, power, and secure all the physical hardware and network resources.

e. Network cloud service is a service connecting all hardware components. Definition is referenced from P235 in the textbook.

Problem 1.16 Solution

a. Power consumption of data center is critical because it has direct impact on cost and performance of data center. That is, significant cost of money for data center operation is attributed to energy consumption. In addition, the performance of data center will degrade without efficient cooling system.

b. Dynamic voltage-frequency scaling (DVFS) is a popular method in decreasing power consumption of processor when it is idle. It constitutes scaling down both voltage and frequency of processor when there is no workload.

c. No time to do green IT research.

Chapter 2

Problem 2.5 Solution

a1. UMA (uniform memory access) is a shared memory architecture used in parallel computer. All processor in the UMA share the physical memory uniformly. Access time to a memory location is independent of which processor make the request or where the data locate in memory.

a2. NUMA (non-uniform memory access) is a memory access model which is contrast to UMA. The memory access time depends on the memory location relative to the requesting processor. That is, accessing on local memory is faster than non-local memory.

a3. COMA (cache only memory architecture) is memory model that use local memory such as DRAM at each node as cache. In contrast, NUMA use local memory as main memory.

a4. DSM (distributed shared memory) is a memory model that physical separate memory of each node in a cluster can be logically shared by all processing nodes.

a5. NORMA (no remote memory access).
c. The fundamental difference between computer cluster and networked computers is computer cluster has single-system image (SSI), which means all computing nodes in cluster has the same access to resource pool such as single memory space, storage space, and IO space. Computing nodes also need to collaborate to finish one job through scheduling. Moreover, cluster also need to have high availability, fault tolerance, and load-balancing.

d. Conventional SMP has disadvantage of single-point failure. For instance, shared bus and memory space are single failure point in the SMP system. In contrast, computer cluster use redundancy to eliminate single-point failure. Therefore, the availability of cluster is higher than traditional SMP system.

Problem 2.8 Solution

a. Since each array A, B, and C is 120 MB, the size of data segment is 120*3 = 360 MB. The code segment is 16 MB, then the total size of process is 360 + 16 = 376 MB. Since the disk bandwidth is 1 MB/second, the time to load the program from disk to main memory is 376 seconds. The time to execute one loop takes 30min*60s = 1800s. There is 1000 iterations, thus the total execution time is 1800*1000+376 = 1800376 seconds. If the computer fail once, the worst case should at the almost end of program execution. Without checkpointing, the program has to be reloaded and re-executed, the execution time is 3600752 seconds.

b. With regular checkpointing in the OS kernel, the execution of program can continue at where the failure happens. The time to write data segment back to disk take 360 seconds. If there are N number of checkpointing, the total to execute the program is 1800752 + N*360 seconds.

c. Fork checkpointing is beneficial, since the code can continue execution while checkpointing is done by separate threads simultaneously.

d. If code is modified to

```c
Do 1000 iterations
    A = foo(C);
    Checkpoint();
    B = goo(A);
    Checkpoint();
    C = hoo(B);
    Checkpoint();
End do
```

The total execution time of worst case is 1800752 + 360*3*1000 = 2880752 seconds.

e. If fork() checkpointing is used, the time to store the data back to disk is saved. The total time is 1800752 seconds.
Problem 2.10

a1. Tianhe-1A use 14,336 Intel six-core Xeon E5540/E5450 CPU running at 2.93 GHz with 7168 Nvidia Tesla M2050 GPU. Each node has two CPU plus one GPU with 32GB memory. The theoretical peak is 4.7 Pflops/second. The key benefit comes from using GPU to accelerate computing and save power consumption. Tianhe-1A use fat-tree infiniband in its topology with bidirectional bandwidth of 160 Gbps.

a2. Cray XT5 Jaguar use more than 37,360 AMD six-core Opteron CPU with peak performance of 1.76 Pflops/second. The supercomputer use commercial component, but the system consume a lot of power. Cray use custom designed 3D Torus interconnect suing SeaStar2+ router chips. The peak bidirectional bandwidth of each link is 9.6GB/s.

a3. IBM roadrunner has 12,960 IBM 3.2GHz PowerXcell 8i CPU with 6480 AMD 1.8GHz Opteron 2210 CPU. The system use hybrid CPU and IBM Cell processor for acceleration. The peak performance is 1.456 Pflops/second. Roadrunner use infiniband switch cluster.