Advanced Computer Architecture

Lecture No. 43

Reading Material

Vincent P. Heuring & Harry F. Jordan
Computer Systems Design and Architecture

Patterson, D.A. and Hennessy, J.L. Chapter 8
Computer Architecture - A Quantitative Approach

Summary

- Introduction to computer network
- Difference between distributed computing and computer networks
- Classification of networks
- Interconnectivity in WAN
- Performance Issues
- Effective bandwidth versus Message size
- Physical Media

Introduction to Computer Networks

A computer architect should know about computer networks because of the two main reasons:

1. Connectivity

Connection of components with in a single computer follows the same principles used for the connection of different computers. It is important for the computer architect to know about connectivity for better sharing of bandwidth

Sharing of resources

Consider a lab with 50 computers and 2 printers using a network, all these 50 computers can share these 2 printers.

Protocol

A set of rules followed by different components in a network. These rules may be defined for hardware and software.

Host

It is a computer with a modem, LAN card and other network interfaces. Hosts are also called nodes or end points. Each node is a combination of hardware and software and all nodes are interconnected by means of some physical media.

Difference between Distributed Computing and Computer Networks

In distributed computing, all elements which are interconnected operate under one operating system. To a user, it appears as a virtual uni-processor system.
In a computer network, the user has to specify and log in on a specific machine. Each machine on the network has a specific address. Different machines communicate by using the network which exists among them.

Classification of Networks
We can classify a network based on the following two parameters:

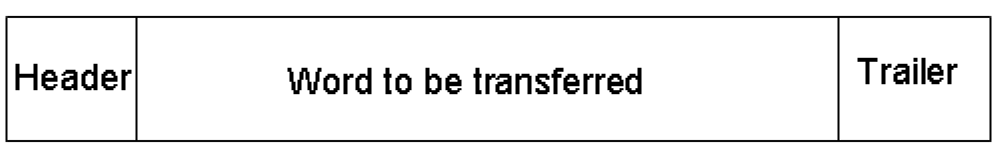
- The number and type of machines to be interconnected
- The distance between these machines

Based on these two parameters, we have the following type of networks:
SAN (System/Storage Area Network)
It refers to a cluster of machines where large disk arrays are present. Typical distances could be tens of meters.
LAN (Local Area Network)
It refers to the interconnection of machines in a building or a campus. Distances could be in Kilometers.
WAN (Wide Area Network)
It refers to the interconnection between LANs.

Interconnectivity in WAN

Two methods are used to interconnect WANs:

1. **Circuit switching**
   It is normally used in a telephone exchange. It is not an efficient way.
2. **Packet switching**
   A block (an appropriate number of bits) of data is called a packet. Transfer of data in the form packets through different paths in a network is called packet switching. Additional bits are usually associated with each packet. These bits contain information about the packet. These additional bits are of two types: header and trailer. As an example, a packet may have the form shown below:



If we use a 1- bit header, we may have the following protocol:
Header = 0, it means it is a request
Header = 0, Reply
By reading these header bits, a machine becomes able to receive data or supply data.
To transfer data by using packets through hardware is very difficult. So all the transfer is done by using software. By using more number of bits, in a header, we can send more messages. For example if n bits are used as header then 2^n is the number of messages that can be transmitted over a network by using a single header.
For a 2 bit header: we may have 4 types of messages:

00= Request
01= Reply
10= Acknowledge request
11= Acknowledge reply

Error detection

The trailer can be used for error detection. In the above example, a 4 bit checksum can be used to detect any error in the packet. The errors in the message could be due to the long distance transmission. If the error is found in some message, then this message will be repeated. For a reliable data transmission, bit error rate should be minimum.

Software steps for sending a message:

- Copy data to the operating system buffer.
- Calculate the checksum, include in trailer and star timer.
- Send data to the hardware for transmission.

Software steps for message reception:

- Copy data to the operating system buffer.
- Calculate the checksum; if same, send acknowledge and copy data to the user area otherwise discard the message.

Response of the sender to acknowledgment:

- If acknowledgment arrives, release copy of message from the system buffer.
- When timer expires, resend data and restart the time.

Performance Issues

1. **Bandwidth**
   It is the maximum rate at which data could be transmitted through networks. It is measured in bits/sec.
2. **Latency**
   In a LAN, latency (or delay) is very low, but in a WAN, it is significant and this is due to the switches, routers and other components in the network
3. **Time of flight**
   It is the time for first bit of the message to arrive at the receiver including delays. Time of the flight increases as the distance between the two machines increases.
4. **Transmission time**
   The time for the message to pass through the network, not including the time of flight.
5. **Transport latency**
   Transport latency= time of flight + transmission time
6. **Sender overhead**

It is the time for the processor to inject message in to the network.

7. **Receiver overhead**
   It is the time for the processor to pull the message from the network.
8. **Total latency**
   Total latency = Sender overhead + Time of flight + Message size/Bandwidth + Receiver overhead
9. **Effective bandwidth**
   Effective bandwidth = Message size/Actual Bandwidth
   Actual bandwidth may be larger than the effective bandwidth.

Example#1

Assume a network with a bandwidth of 1500Mbits/sec. It has a sending overhead of 100µsec and a receiving overhead of 120µsec. Assume two machines connected together. It is required to send a 15,000 byte message from one machine to the other (including header), and the message format allows 15, 00 bytes in a single message. Calculate the total latency to send the message from one machine to another assuming they are 20m apart (as in a SAN). Next, perform the same calculation but assume the machines are 700m apart (as in a LAN). Finally, assume they are 1000Km apart (as in a WAN). Assume that signals propagate at 66% of the speed of light in a conductor, and that the speed of light is 300,000Km/sec.

Solution

By using the assumption, we get:

$$\text{Time of flight} = \frac{\text{Distance between two machines in Km}}{2/3 \times 300{,}000\text{Km/sec}}$$

Total Latency = Sender overhead + Time of flight + Message size/bandwidth + Receiver overhead

For SAN:

Total latency = 100µsec
+ (0.020Km/(2/3 x 300,000Km/sec))
+ 15,000bytes/ 1500Mbits/sec
+ 120µsec
= 100µsec + 0.1µsec + 80µsec + 120µsec
= 300.1µsec

For LAN

Total latency = 100µsec
+ (0.7Km/(2/3 x 300,000Km/sec))
+ 15,000bytes/ 1500Mbits/sec + 120µsec
= 100µsec + 3.5µsec + 80µsec + 120µsec

= 303.1µsec

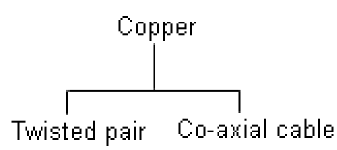
For WAN

Total latency = 100µsec
+ (1000Km/(2/3 x 300,000Km/sec))
+ 15,000bytes/ 1500Mbits/sec
+ 120µsec
= 100µsec + 5000µsec + 80µsec + 120µsec
= 5300µsec

Effective bandwidth versus Message size

Effective bandwidth is always less than the raw bandwidth. If the effective bandwidth is closer to the raw bandwidth, the size of the message will be larger. If the message size is larger then network will be more effective.
If large number of the messages are present then a queue will be formed, and the user has to face delay. To minimize the delay, it is better to use packets of small size.

Physical Media



Twisted pair does not provide good quality of transmission and has less bandwidth. To get high performance and larger bandwidth, we use co-axial cable. For increased performance, better performance, we use fiber optic cables, which are usually made of glass. Data transmits through the fiber in the form of light pulses. Photo diodes and sensors are used to produce and receive electronic pulses.