Information Technology Principles

Instructor : Dr. Moaath Shatnawi

Information Technology Principles

The overview definitions of Information technology principles

- Introduction
- Explain the meaning of Data, Information, Knowledge, etc.
- Types of information
- The definition of Computer, Computer Technology, Information representation, etc.

Information Technology Principles

1.1. Definitions

Data: are raw facts or elementary descriptions of things, events, activities and transactions that are captured, recorded, stored and classified, but not organized to convey any specific meaning.

Examples➔ scores, bank balances, and worked hours.

Information: is a collection of facts (data) organized in some manner so that they are meaningful to a recipient

Examples➔ if we include: student names with scores, customer names with bank balances, and employee wages with hours worked. We would have useful information. In other word, information comes from data that have been processed.

Knowledge: consists of information that has been organized and processed to convey understanding, experiences, accumulated learning and expertise as it applies to a current business problem or process.

Information should be accurate, complete, flexible, reliable, relevant, timely, verifiable, accessible and secure to be useful to managers and organizations. Info. That is not of high quality can lead to poor decisions, and costing a great deal of money

Information Technology Principles

- Data" means raw counts of things.
- Data can be useful or not useful.
- In and of itself, data has no meaning.(example: If I count the number of cars that stop at the stop sign on my block per hour for a week), that's data.
- It may be useful or not, depending on the context. It has no meaning until it is placed in a context.
- Data can be accurate or inaccurate. It can also be reliable or unreliable, valid or invalid.
- Data is only as good as the measurement device we use to collect it, and if I fall, I'm not a very good data collector!. (Schuler2004)

Information Technology Principles

Information ? A good short definition of information is a "collection of words, numbers or pictures which have meaning."

Information is data that has context.

For example -:
There are **42 files** in that Folder and each one of them has **4MB** free size.

My telephone number is 0794324553 Call me at 5 **pm** . This is information. It adds context and meaning to the Data This gives it meaning so that people can understand it.

Information Technology Principles

Information

When you put a whole lot of data together that is related to one subject, it can be collected to yield information. In other words, (sets of data) + (collection of related data sets) = information .(Schuler2004)

Information:

data that are processed to be useful; provides answers to "who", "what", "where", and "when" questions. (Bellinger 2004)

Information Technology Principles

1.1. Definitions

Technology (Greek: systematic treatment)
The branch of knowledge that deals with industrial art, applied science, engineering

Information Technology (IT):
The phrase IT refers to the creation, gathering, processing, storage, and delivery of information and the processes and devices that make all this possible. [Ref #2]

Information Systems (IS):
A system that collects, processes, stores, and analyzes data, and disseminates (distributes) information for a specific purpose. [Ref #1]

Information Technology Principles

What is system?

A system is a <u>collection</u> of <u>parts</u> which <u>interact</u> with each other to function as a <u>whole.</u>

Information Technology Principles

What IT can do?

IT can process raw data into useful information.

For example: The evaluation of a student in an IT course may include:

Quiz,	Exams,	Activities, etc.	
4, 0, 3	13, 11, 37	B+	← a whole range of scores over the semester

Each score represents one bit of **raw data.** To turn these to **useful info.** we need to convert them into a grade for the course. [Say accumulated to 74%].

➔ It becomes useful information because it's a measure for the student's overall performance in the course. The teacher can now decide if you pass or fail the course.

IT can recycle processed information and use it as data in another processing step. Already processed data can be combined with other information to increase its impact.

Information Technology Principles

What IT can do?

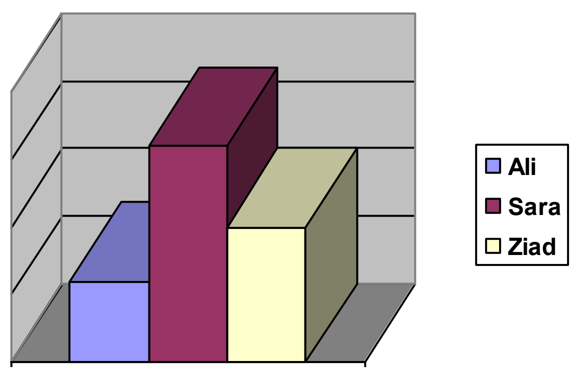
For example: the IT score [74%] can be combined with other scores of other courses taken by the same student to calculate his GPA (Grade Point Average) in that semester

IT	Calculus	Physics	etc.
74	70	69	

[say the GPA has been calculated to 71%].

IT can package information in a new form so it's easier to understand, and more attractive.

For example: All the GPAs for the classmates can be stored into descending order or placed on a chart so you can quickly see how you stand in relation to everyone else.



Information Technology Principles

Why You Need to Know about IT ?

"No one considering a career in business can afford to be ignorant of the powerful and revolutionary roles that IT plays in business and almost all areas of human endeavor.

IT enables great advancing in human work and makes enterprises perform at higher level, more intelligent and more efficiently. And that is necessary to survive and compete.

IT effect on the world is fascinating, so it is generally interesting."

Information Technology Principles

<u>How important IT to Organizations and Managers ?</u>

IT facilitate work in organizations:

- Change how we structure and manage our organization
- Change how we work, interact and transact (processes).
- Change the organizational strategy and business.
- Important to every manager and staff member to learn about IT from his/her standpoint.

Information Technology Principles

<u>How important IT to Organizations and Managers ?</u>

IT offers career opportunities:

- Although it eliminates some jobs, it creates many others.
- <u>Systems analysts</u>, <u>systems designers</u>, <u>programmers</u>, and <u>system administrators.</u>
- Well-paid opportunities appearing in emerging areas such as <u>Web page design</u> and operation, <u>e-commerce</u>, <u>system development</u>, <u>telecommunications, multimedia design</u>, <u>artificial intelligence</u> and document management.
- The US Dept. of Commerce says IT doubled the growth rate of the US economy over the last 5 years. IT makes up 8% of the economy, employing 7.5 million workers. IT workers average salary is $50,000 annually while non-IT workers average salary is $28000. Commerce says 1.5 million IT positions needing to be filled in the next 10 years.

Information Technology Principles

How important IT to Organizations and Managers ?

IT is used by all business departments:

In **finance** and accounting, managers use such systems to forecast (anticipate) revenues and business activity, determine the best sources & uses of funds, manage cash & other financial resources, analyze investment and audit reports and documents.

In **sales** and **marketing**, managers use IT to

* Develop new goods and services (product analysis),
* Determine best advertising and sales (promotion analysis)
* Set product prices to get the highest total revenues (price analysis).
* Marketing managers also use IT to manage the customer relationships.

In **manufacturing**, managers use IT to process customer orders, develop production schedules, control inventory levels and monitor product quality. In additions, they use IT to design product (CAD: computer-assisted-design), manufacturing items (CAM: computer-assisted-manufacturing) and integrate multiple machine or pieces of equipment (CIM : computer-integrated-manufacturing).

In **human resources**, managers use IT to screen job applicants, administer performance tests to employees, and monitor employee productivity.

Information Technology Principles

The Information Processing Cycle

Input

[Text, Numbers, Images or Sounds
via Keyboard, Scanner, Mouse,
Microphone, Video camera etc.]

Distribution

[Data can be printed, or distributed
from one computer to another
via attachment, web-site, or ftp.]

Processing

[Compare, Sort, Sum
numbers, Format text, or
let you edit Images and
Sounds.]

Storage

[Programs and data that are not
currently being used are normally
Stored on disks or tape of some kind.]

Output

[See or hear what the
computer has processed.
Output to Screen, Printer,
Or may be transferred to
Another device for further
Processing.]

< → This process cycle is put at work in many different ways

Information Technology Timeline

Egyptian Book of the Dead

Telegraph Key Circa 1840

Flat Disk Gramophone 1887

75,000 B.C. Rock Carvings

<4000 B.C. Hieroglyphics

2200 B.C. Papyrus

1500 B.C. Alphabetic Writing

1450 A.D. Printing Press

1835 Photography

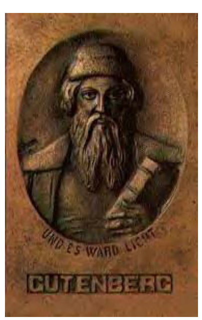
1840 Telegraph

1876 Telephone

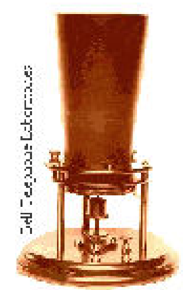
1876 Phonograph

1894 Wireless Telegraph

1895 Silent Movies



Johannes Gutenberg



Bell's Telephone 1876

Information Technology Timeline (cont.)

Sputnik
1957

IBM PC
1981

AOL has 200K Subscribers
1992

1922 Radio Broadcasts

1954 Transistor Radio

1970s VCR

1977 Apple II Home Computers

1983 CDs

1993 World Wide Web

TODAY

1940 Black and White TV

1965 Local Cable TV

1973 Fax Machines

1980s Cell Phones

1990 Digital Photography

1998 MP-3 (Compressed Sound Files)

Fiber Optics
1977

Apple Mac
1984

Information Technology Principles

Computers:

Are information processing machines used in different department and organizations, they can be connected, all over the world. There fore, more productivity and good quality with less cost

They perform three main operations:

- Receive inputs (data, raw facts)
- Process it according to predefined instructions
- Produce output (information which is meaningful data)

Information Technology Principles

The components of a computer system are :

- **Hardware**: physical components like screen, cables, keyboard, system box and printer
- **Software**: a set of instructions that tells the computer what to do and how to do it such as word processing, computer games and graphics programs.
- **Users** : are people who use the software on the computer to do some tasks

Information Technology Principles

COMPUTER TECHNOLOGY:

the activity of designing and constructing and programming computers using:

- HARDWARE
- SOFTWARE
- STORAGE
- COMMUNICATIONS
- NETWORKS

Information Technology Principles

What is the difference between Computer Technology and Information Technology?

- Computer Technology deals more with hardware usage and building/repairing PC's, networks, etc,
- While Information Technology deals with using computers to acquire knowledge as applied in the business world.
- For example: A person with a Computer Technology degree may find themselves working for a repair company building pcs or upgrading the current computing infrastructure.
- A person with an Information Technology degree may find themselves working as a programmer or building database queries to ferret out information for a company to make decisions based upon that data.

Information Technology Principles

Information Representation

There are two ways to represent information:

Analog information: Information that is continuous, that is, any piece of information that can take on any of an infinite set of values.

- For example, the time, the temperature, the speed of your car--all of these have a continuous range of values. While you say, for example, that it is 55 degrees outside, it could really be 55.12492 degrees, or any value between that and 56.

Information Technology Principles

Information Representation

Digital information: restricted to a finite set of values.

- For example, a traffic light is (normally) red, yellow or green; not "yellow-green" or orange.
- Computers use a form of digital information called *binary information*. Here, the information is restricted to only two values: one or zero.

Information Technology Principles

Computers use binary information for several reasons:

- **Simplicity:** It is the simplest, most compact and least ambiguous way to express information about something: for example, zero=off and one=on could be used to represent the status of a regular light bulb.

- **Expandability:** It is easy to build on and expand: you can use two binary values together to represent the status of two light bulbs.

Information Technology Principles

Computers use binary information for several reasons (Cont.):

- **Clarity:** Errors are reduced when a value can only be one or zero; the computer knows there are no values in between, which is useful when electrical signals become "dirty". If a 0.95 value shows up on your modem line, the computer knows it is probably really a 1, since 0.95 isn't a valid value. It will interpret the 0.95 as a 1, and no data will be lost as a result.

- **Speed:** Computers make millions of decisions a second, and these decisions are easier to make when the number of values is small.

Information Technology Principles

Why do people need information?

- **Individuals:** Entertainments and explanation.
- **Business:** Decision making, problem solving and controls.

Information Technology Principles

References:

- Kenneth c. laoudon and Jane laoudon , Management information systems ,8 edition, 2004.
- Turban, Wetherbe, Information Technology for management, second edition,1999.
- Luftaman, Management Information Technology Resource,2004.

Information Technology Principles

Instructor : Dr. Moaath Shatnawi

Information Technology Principles

Why Binary?

- Early computer design was decimal
  - Mark I and ENIAC
- John von Neumann proposed binary data processing (1945)
  - Simplified computer design
  - Used for both instructions and data
- Natural relationship between on/off switches and calculation using Boolean logic

	
On	Off
True	False
Yes	No
1	0

Information Technology Principles

http://en.wikipedia.org/wiki/Computer_technology

Defining characteristics of five early digital computers

Computer	First operation	Place	Decimal/Binary	Electronic	Programmable	Turing complete
Zuse Z3	May 1941	Germany	binary	No	By punched film stock	Yes (1998)
Atanasoff–Berry Computer	Summer 1941	USA	binary	Yes	No	No
Colossus	December 1943 / January 1944	UK	binary	Yes	Partially, by rewiring	No
Harvard Mark I – IBM ASCC	1944	USA	decimal	No	By punched paper tape	Yes (1998)
ENIAC	1944	USA	decimal	Yes	Partially, by rewiring	Yes
	1948	USA	decimal	Yes	By Function Table ROM	Yes

Information Technology Principles

Harvard Mark I

- *Howard Aiken*
- Born in 1901 in New Jersey, USA
- A physics graduate program in 1931 at Harvard University
- it's was not greatly recognized, Mark I was not electronic it was electromagnetical
- Mark I in size, measuring 8 feet high, 51 feet long And three feet deep. It weighed 5 tons, used 530 miles of wire And 730,000 separate parts

Harvard Mark I

Information Technology Principles

Harvard Mark I

- 2200 counter wheels and 3300 relay components
- A table with time for various operations

Operation	Seconds	Cycles
Addition	0.3	1
Subtraction	0.3	1
Multiplication	6.0	20
Division	11.4	38
Logarithm	68.4	228
sin(x)	60.0	199

Harvard Mark I

Information Technology Principles

Binary Conventions (Base 2)

- Most Significant Bit (MSB) and Least Significant Bit (LSB)
  - Decimal Example: 64
    - 6 is the Most Significant Digit;
    - 4 is the Least Significant Digit
  - Binary Example: 1000000
    - 1 is the MSB;
    - 0 on the right is the LSB
- What does 1000000_2 represent in decimal?
- How do I represent 13_{10} in binary?

Information Technology Principles

Thinking Binary

- When dealing with binary, think in powers of 2
- Binary Computer conventions (need to know!)
  - 1 bit can represent two (2^1) symbols: either a 0 or a 1
  - 8 bits is a byte: one byte can represent 256 (2^8) symbols
  - 1 kilobyte = 2^{10} bytes = 1024 bytes = 8192 bits
  - 1 Megabyte = 2^{20} bytes = 1,048,576 bytes

Information Technology Principles

Binary Multipliers

- Kilo (K) $2^{10} = 1{,}024$
- Mega (M) $2^{20} = 1{,}048{,}576$
- Giga (G) $2^{30} = 1{,}073{,}741{,}824$
- Tera (T) $2^{40} = 1{,}099{,}511{,}627{,}776$

- Note: You use these factors with base 2 numbers, **not** base 10 numbers!

Information Technology Principles

Something to Remember

- "**Bits**" are often used in terms of a data rate, or speed of information flow:
  - 56 Kilo***bit*** per second modem (56 Kbps)
  - A T-1 line is 1.544 Mega***bits*** per second (1.544 Mbps or 1544 Kbps)

- "**Bytes**" are often used to describe storage capacity or file size--computer memories are organized in terms of 8 bits
  - 256 Mega***byte*** (MB) RAM
  - 40 Giga***byte*** (GB) Hard disk

Information Technology Principles

Practical Use

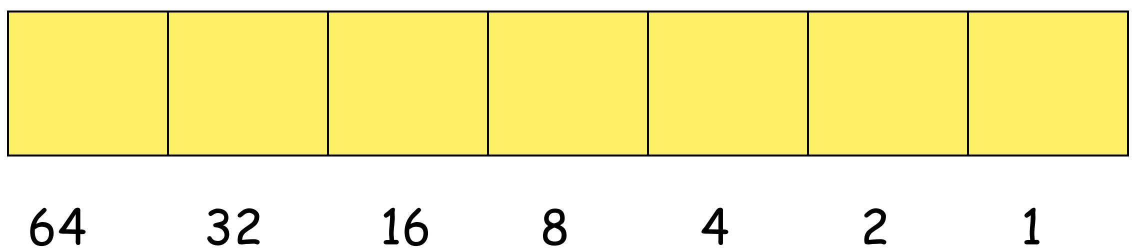
- Everyday stuff that uses 2^X:
  - 32-bit sound card
  - 64-bit Video Accelerator card
  - 128-bit encryption in your browser

- Is 64-bit twice as good as 32-bit?
  - 32 bit = 2^{32} = 4,294,967,296 bits = 4.29×10^8 bits
  - 64 bit = 2^{64} = 1.8×10^{19} bits
  - 128 bit = 2^{128} = 3.4×10^{38} bits

Information Technology Principles

Convert Decimal to Binary

- Consider a byte, consisting of 7 bits and a parity bit (not shown):
  - Each bit can take on a value of 1 or zero
  - If a bit is 1, it's "contribution" to the byte value is dependent upon it place in the byte:



- The total value the byte can represent (the sum of all the contributions) is 1+2+4+8+16+32+64=127
- Thus, any byte can equal a value between 0-127

Information Technology Principles

Convert Decimal to Binary

Convert Decimal 49 to Binary

49 / 2 = 24	remainder: 1	(49 - 2*24 = 49 - 48 = 1)
24 / 2 = 12	remainder: 0	(24 - 2*12 = 24 - 24 = 0)
12 / 2 = 6	remainder: 0	(12 - 2* 6 = 12 - 12 = 0)
6 / 2 = 3	remainder: 0	(6 - 2* 3 = 6 - 6 = 0)
3 / 2 = 1	remainder: 1	(3 - 2* 1 = 3 - 2 = 1)
1 / 2 = 0	remainder: 1	(1 - 2* 0 = 1 - 0 = 1)

Proof: 110001 = 32+16+0+0+0+0+1 = 49_{10}

Information Technology Principles

Convert Binary to Decimal

01001001 =	0×2^7	->	0×128	= 0
	1×2^6	->	1×64	= 64
	0×2^5	->	0×32	= 0
	0×2^4	->	0×16	= 0
	1×2^3	->	1×8	= 8
	0×2^2	->	0×4	= 0
	0×2^1	->	0×2	= 0
	1×2^0	->	1×1	= 1
				73

- The largest number which can be represented by a byte is 255 or 128 + 64 + 32 + 16 + 8 + 4 + 2 + 1 = 255 or the bit pattern: 1111 1111
- The smallest number is 0 represented by the bit pattern: 0000 0000
- 0 to 255 gives 256 possible values

Information Technology Principles

Rules for Binary Addition

- 0 + 0 = 0
- 0 + 1 = 1
- 1 + 0 = 1
- 1 + 1 = 0, and carry 1 to the next more significant bit

For example,

00011010 + 00001100 = 00100110

			1	*1*						*carries*
	0	0	0	1	1	0	1	0	=	$26_{(\text{base } 10)}$
+	0	0	0	0	1	1	0	0	=	$12_{(\text{base } 10)}$
	0	0	1	0	0	1	1	0	=	$38_{(\text{base } 10)}$

00010011 + 00111110 = 01010001

		1	*1*	*1*	*1*	*1*				*carries*
	0	0	0	1	0	0	1	1	=	$19_{(\text{base } 10)}$
+	0	0	1	1	1	1	1	0	=	$62_{(\text{base } 10)}$
	0	1	0	1	0	0	0	1	=	$81_{(\text{base } 10)}$

Information Technology Principles

More Examples (Excludes parity bit)

- Convert 12_{10} to binary
  - 0001100
- Convert 1010101 to decimal
  - 1+4+16+64=85
- Convert 255_{10} to binary
  - 11111111
- Convert 1110001110 to decimal
  - 2+4+8+128+256+512=

Information Technology Principles

Representing Positive and negative Numbers in Binary

When a number of bits is used to store values, the most significant bit is used to store the sign (positive or negative) of the number.

The remaining bits hold the actual value.

If the number is negative, the sign is 1, and for positive numbers, the sign is 0.

For example -7 is represented as:

10000111

Information Technology Principles

Representing Positive and negative Numbers in Binary

Because of problems doing addition and subtraction, negative numbers are usually stored in a different format to positive numbers as shown below

Ones Complement

<u>1's complement</u>

is a method of storing negative values. It simply inverts all 0's to 1's and all 1's to 0's.

Original Number	Binary value	1's Complement value
7	00000111	11111000

Information Technology Principles

Representing Positive and negative Numbers in Binary

Twos Complement

2's complement is another method of storing negative values. It is obtained by adding 1 to the 1's complement value.

Original Number	Binary value	1's Complement value	2's Complement
7	00000111	11111000	11111001

Another way of generating a 2's complement number is to start at the least significant bit, and copy down all the 0's till the first 1 is reached. Copy down the first 1, then invert all the remaining bits

Information Technology Principles

Rules for Binary Subtraction

- 0 – 0 = 0
- 0 – 1 = 1, and borrow 1 from the next more significant bit
- 1 – 0 = 1
- 1 – 1 = 0

For example,

00100101 – 00010001 = 00010100

$$
\begin{array}{rcccccccccl}
 & & & 0 & & & & & & & \textit{borrows} \\
 & 0 & 0 & \cancel{1} & {}^{1}0 & 0 & 1 & 0 & 1 & = & 37_{(\text{base } 10)} \\
- & 0 & 0 & 0 & 1 & 0 & 0 & 0 & 1 & = & 17_{(\text{base } 10)} \\
\hline
 & 0 & 0 & 0 & 1 & 0 & 1 & 0 & 0 & = & 20_{(\text{base } 10)}
\end{array}
$$

00110011 – 00010110 = 00011101

$$
\begin{array}{rcccccccccl}
 & & & 0 & {}^{1}0 & 1 & & & & & \textit{borrows} \\
 & 0 & 0 & \cancel{1} & \cancel{1} & \cancel{0} & {}^{1}0 & 1 & 1 & = & 51_{(\text{base } 10)} \\
- & 0 & 0 & 0 & 1 & 0 & 1 & 1 & 0 & = & 22_{(\text{base } 10)} \\
\hline
 & 0 & 0 & 0 & 1 & 1 & 1 & 0 & 1 & = & 29_{(\text{base } 10)}
\end{array}
$$

Information Technology Principles

Binary Subtraction using the Complement

1101011001 - 0010111010 (note the leading zeros)

Complement the second row and add:

```
1101011001 +
1101000101
------------
(1)1010011110
```

Now you notice that there is an embarrassing (1) at the left of the row.

The rule now is to take this 1 across to the first column on the right and add it there, as shown below:

```
1010011110
         1
-----------
1010011111
```

That completes the subtraction. With practice, the method of subtraction by adding the complement is quicker and less error

Information Technology Principles

Rules for Binary Multiplication

- like one in base ten, the larger number above the smaller.
- for each digit on the bottom that you go to the left, you move that answer one digit to the left.
- For multiplication you just have to remember that 1 times a number is that number and 0 times a number is 0.
- Once you have all of the little multiplications done, you add up the products.

Information Technology Principles

Rules for Binary Multiplication

Example: 101 (5) and 10 (2):

```
101
x
10
----
     0 0 0
  1  0 1
-----------
  1  0  1  0
```

Which is in base 10 is 10, and correct.

Information Technology Principles

Rules for Binary Division

- First you take the first digit of the number you are dividing and see whether the number you are dividing into it goes in.
- If it does, you make subtraction and continue with the rest.
- if it doesn't go in, see whether the number goes into the next digits.
- Keep going on like this until it does go in.

Information Technology Principles

Rules for Binary Division

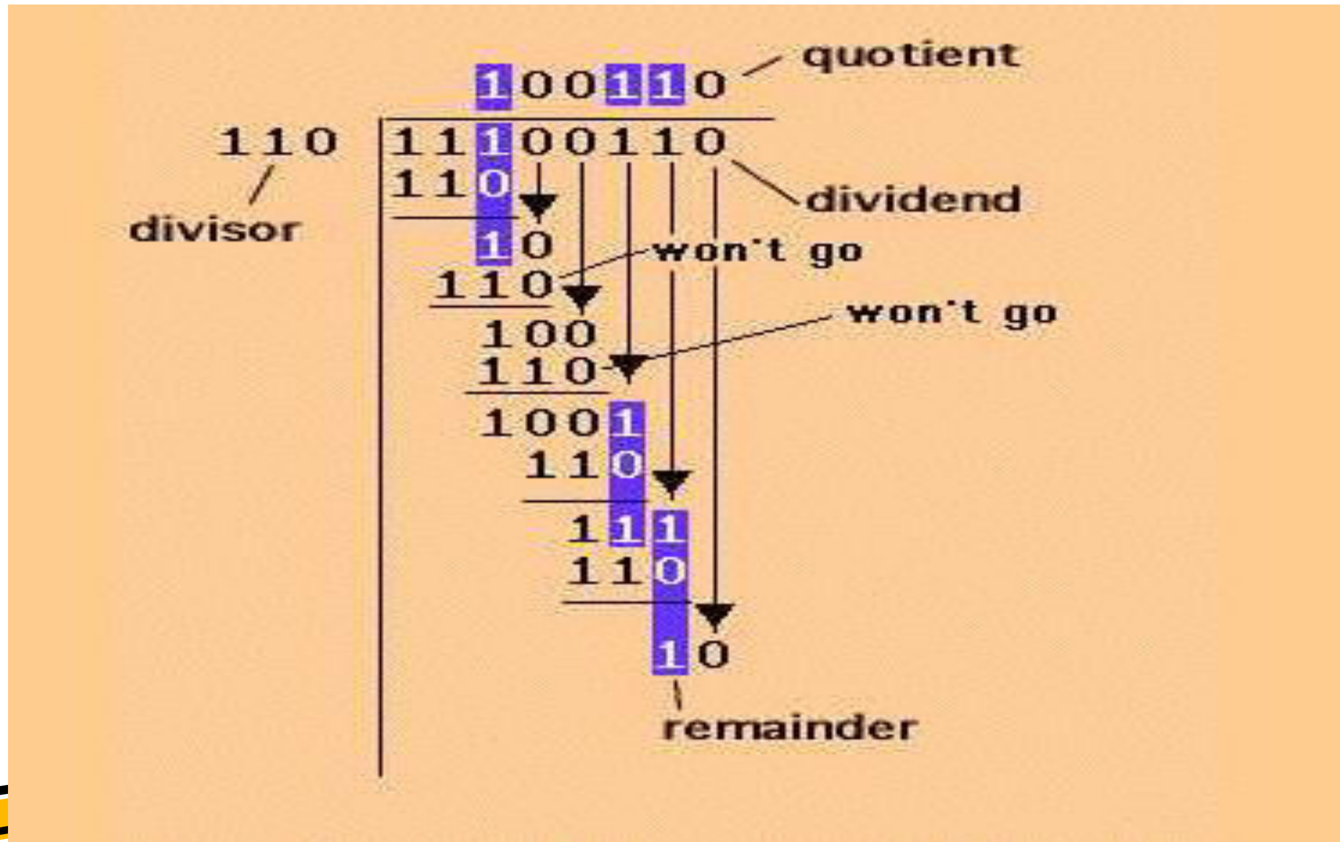
Example: divide 10110 (22) by 111 (7).

- 111 does not goes into the first digit, 1.
- 111 doesn't go into 10 or 101, but it does go into 1011 once,
- so the first digit of the answer is 1.
-
- Now you subtract 111 from the 1011, this leave 100, and we start over
- Does 111 go into 100?" Since it doesn't, we bring down the 0
- Now 1000 which 111 does go into.
- Subtracting 111 from 1000, we get 1 with 1 left over.
- 111 does not go into 1 so that is our remainder,
- the final answer is 11 remainder 1,
- which is 3 remainder 1, which is correct.

You could also continue this process indefinitely after the decimal point, because 1/7 is a repeating decimal so you will always have a remainder.

Information Technology Principles

Rules for Binary Division



Information Technology Principles

Rules for Binary Division

Binary division can be made by Multiply, Shift and Subtract.

- **Set** quotient to 0
- Align leftmost digits in dividend and divisor
- **Repeat**
  - **If** that portion of the dividend above the divisor is greater than or equal to the divisor
    - **Then** subtract divisor from that portion of the dividend and
    - Concatentate 1 to the right hand end of the quotient
    - **Else** concatentate 0 to the right hand end of the quotient
  - Shift the divisor one place right
- **Until** dividend is less than the divisor
- quotient is correct, dividend is remainder
- **STOP**

Information Technology Principles

Other Ways to Count

- **Octal**--base 8
  - 0, 1, 2, 3, 4, 5, 6, 7
  - $8_{10} = 10_8$
  - **Represents 3 bit code.**

- **Hexadecimal**--base 16
  - 0, 1, 2, 3, 4, 5, 6, 7, 8, 9, A, B, C, D, E, F
  - **Represents 4 bit code.**

- Compresses notation: $15_{10} = 1111_2 = 17_8 = F_{16}$
  - Note that 7-bits are being converted into hex often a leading 0 is inserted into each group of 7 bits to make a byte
  - Notice that if you break each byte into a 4 bit "word" you can easily convert binary into hex

Information Technology Principles

Decimal – Hex – Binary Conversion Table

Dec	Octal	Hex	Bin
0	0	0	00000000
1	1	1	00000001
2	2	2	00000010
3	3	3	00000011
4	4	4	00000100
5	5	5	00000101
6	6	6	00000110
7	7	7	00000111
8	10	8	00001000
9	11	9	00001001
10	12	A	00001010
11	13	B	00001011
12	14	C	00001100
13	15	D	00001101
14	16	E	00001110
15	17	F	00001111

Information Technology Principles

Decimal to Octal Conversion

Repeated Division By 8

- For this method, divide the decimal number by 8, and write the remainder on the side as the least significant digit. This process is continued by dividing he quotient by 8 and writing the remainder until the quotient is 0. When performing the division, the remainders which will represent the octal equivalent of the decimal number are written beginning at the least significant digit (right) and each new digit is written to the next more significant digit (the left) of the previous digit. Consider the number 44978_{10}.

$$44978_{10} = 127662_8$$

Division	Quotient	Remainder	Octal Number
44978 / 8	5622	2	2
5622 / 8	702	6	62
702 / 8	87	6	662
87 / 8	10	7	7662
10 / 8	1	2	27662
1 / 8	0	1	127662

Octal to Decimal Conversion

- To convert from Octal to Decimal, multiply the value in each position by its Octal weight and add each value. Using the value from the previous example, 127662, we would expect to obtain the decimal value 44978.

1*8^5	2*8^4	7*8^3	6*8^2	6*8^1	2*8^0
1*32768	2*4096	7*512	6*64	6*8	2*1
32768	8192	3584	384	48	2

➔ 44978 = 2 + 48 + 384 + 3584 + 8192 + 32768

Information Technology Principles

Decimal ←→ Hex Conversion

Convert 4823 to Hex:

4823 / 16 = 301	remainder: 7	(4823 - 16*301 = 4823 - 4816 = 7)
301 / 16 = 18	remainder: 13	(301 - 16* 18 = 301 - 288 = 13)
18 / 16 = 1	remainder: 2	(18 - 16* 1 = 18 - 16 = 2)
1 / 16 = 0	remainder: 1	(1 - 16* 0 = 1 - 0 = 1)

→ Hex value: 0x12D7

Convert 0x12D7 to Decimal:

$$0x12D7_{16} = 7*16^0 + 13*16^1 + 2*16^2 + 1*16^3 = 4823_{10}$$

Information Technology Principles

Octal to Binary Conversion

- It is also easy to convert from an integer octal number to binary. This is accomplished by:
    1. Convert the decimal number to its 3-bit binary equivalent.
    2. Combine the 3-bit sections by removing the spaces.
- For example, the octal value 127662 will be written:

1	2	7	6	6	2
001	010	111	110	110	010

- This yields the binary number 001010111110110010 or 00 1010 1111 1011 0010 in our more readable format.

Information Technology Principles

Binary to Octal Conversion

- It is easy to convert from an integer binary number to octal. This is accomplished by:

  1. Break the binary number into 3-bit sections from the LSB to the MSB.
  2. Convert the 3-bit binary number to its octal equivalent.

- For example, the binary value 001010111110110010 will be written:

001	010	111	110	110	010
1	2	7	6	6	2

Information Technology Principles

Binary ←→ Hex Conversion

- One hexadecimal digit corresponds to a four-digit binary number
  $2^3+2^2+2^1+2^0 = 8 + 4 + 2 + 1 = 15$

- This makes it easy to convert a number from binary to hex (just replace the binary pattern with the hex digits) or from hex to binary (replace the hex digit with the binary pattern)

Binary: 0000 1111 -> Hex: 0x0F
Binary: 1011 0011 0000 0010 -> Hex: 0xB302

Hex: 0xA0FF -> Binary: 1010 0000 1111 1111
Hex: 0xF075 -> Binary: 1111 0000 0111 0101

Decimal	Hex	Binary	Decimal	Hex	Binary
0	0	0000	8	8	1000
1	1	0001	9	9	1001
2	2	0010	10	A	1010
3	3	0011	11	B	1011
4	4	0100	12	C	1100
5	5	0101	13	D	1101
6	6	0110	14	E	1110
7	7	0111	15	F	1111

Information Technology Principles

How to represent numerals (1-9) in computing and electronic systems?

→ **binary-coded decimal** (**BCD**) is an encoding for decimal numbers in which each digit is represented by its own binary sequence.

Numeral	BCD
– 0	0000
– 1	0001
– 2	0010
– 3	0011
– 8	1000
– 9	1001

Drawback: inefficient, but it is still used!

Information Technology Principles

Fixed Length Codes

- **Fixed length codes** represent information in a format someone has agreed to
- ***American Standard Code for Information Exchange*** (ASCII)--
  - Structure is a 7 bit code (plus a parity bit or an “extended” bit in some implementations)
  - ASCII can represent 128 symbols (2^7 symbols)
  - INFT 101 is: 73 78 70 84 32 49 48 49 (decimal) or
    49 4E 46 54 20 31 30 31 (hex)
  - 1001001 1001110 1000110 1010100 0100000 0110001 0110000 0110001

Information Technology Principles

Extended ASCII Chart

- You can easily convert hex to binary
- Upper case D is 44_{16}
- 4_{16} is 0100_2
- Upper case D is then 0100 0100 in binary
- Note 8 bits used

Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
0	00	Null	32	20	Space	64	40	@	96	60	`
1	01	Start of heading	33	21	!	65	41	A	97	61	a
2	02	Start of text	34	22	"	66	42	B	98	62	b
3	03	End of text	35	23	#	67	43	C	99	63	c
4	04	End of transmit	36	24	$	68	44	D	100	64	d
5	05	Enquiry	37	25	%	69	45	E	101	65	e
6	06	Acknowledge	38	26	&	70	46	F	102	66	f
7	07	Audible bell	39	27	'	71	47	G	103	67	g
8	08	Backspace	40	28	(	72	48	H	104	68	h
9	09	Horizontal tab	41	29	)	73	49	I	105	69	i
10	0A	Line feed	42	2A	*	74	4A	J	106	6A	j
11	0B	Vertical tab	43	2B	+	75	4B	K	107	6B	k
12	0C	Form feed	44	2C	,	76	4C	L	108	6C	l
13	0D	Carriage return	45	2D	-	77	4D	M	109	6D	m
14	0E	Shift out	46	2E	.	78	4E	N	110	6E	n
15	0F	Shift in	47	2F	/	79	4F	O	111	6F	o
16	10	Data link escape	48	30	0	80	50	P	112	70	p
17	11	Device control 1	49	31	1	81	51	Q	113	71	q
18	12	Device control 2	50	32	2	82	52	R	114	72	r
19	13	Device control 3	51	33	3	83	53	S	115	73	s
20	14	Device control 4	52	34	4	84	54	T	116	74	t
21	15	Neg. acknowledge	53	35	5	85	55	U	117	75	u
22	16	Synchronous idle	54	36	6	86	56	V	118	76	v
23	17	End trans. block	55	37	7	87	57	W	119	77	w
24	18	Cancel	56	38	8	88	58	X	120	78	x
25	19	End of medium	57	39	9	89	59	Y	121	79	y
26	1A	Substitution	58	3A	:	90	5A	Z	122	7A	z
27	1B	Escape	59	3B	;	91	5B	[	123	7B	{
28	1C	File separator	60	3C	<	92	5C	\	124	7C	|
29	1D	Group separator	61	3D	=	93	5D	]	125	7D	}
30	1E	Record separator	62	3E	>	94	5E	^	126	7E	~
31	1F	Unit separator	63	3F	?	95	5F	_	127	7F	□

Information Technology Principles

Extended ASCII Continued

- Another example: You want to represent the Yen sign (¥)
- You see it is 9D
- $9_{16} = 9_{10} = 1001_2$
- $D_{16} = 13_{10} = 1101_2$
- The ¥ sign in binary is: 1001 1101

Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char	Dec	Hex	Char
128	80	Ç	160	A0	á	192	C0	└	224	E0	α
129	81	ü	161	A1	í	193	C1	┴	225	E1	ß
130	82	é	162	A2	ó	194	C2	┬	226	E2	Γ
131	83	â	163	A3	ú	195	C3	├	227	E3	π
132	84	ä	164	A4	ñ	196	C4	─	228	E4	Σ
133	85	à	165	A5	Ñ	197	C5	┼	229	E5	σ
134	86	å	166	A6	ª	198	C6	╞	230	E6	µ
135	87	ç	167	A7	º	199	C7	╟	231	E7	τ
136	88	ê	168	A8	¿	200	C8	╚	232	E8	Φ
137	89	ë	169	A9	⌐	201	C9	╔	233	E9	Θ
138	8A	è	170	AA	¬	202	CA	╩	234	EA	Ω
139	8B	ï	171	AB	½	203	CB	╦	235	EB	δ
140	8C	î	172	AC	¼	204	CC	╠	236	EC	∞
141	8D	ì	173	AD	¡	205	CD	═	237	ED	φ
142	8E	Ä	174	AE	«	206	CE	╬	238	EE	ε
143	8F	Å	175	AF	»	207	CF	╧	239	EF	∩
144	90	É	176	B0	░	208	D0	╨	240	F0	≡
145	91	æ	177	B1	▒	209	D1	╤	241	F1	±
146	92	Æ	178	B2	▓	210	D2	╥	242	F2	≥
147	93	ô	179	B3	│	211	D3	╙	243	F3	≤
148	94	ö	180	B4	┤	212	D4	╘	244	F4	⌠
149	95	ò	181	B5	╡	213	D5	╒	245	F5	⌡
150	96	û	182	B6	╢	214	D6	╓	246	F6	÷
151	97	ù	183	B7	╖	215	D7	╫	247	F7	≈
152	98	ÿ	184	B8	╕	216	D8	╪	248	F8	°
153	99	Ö	185	B9	╣	217	D9	┘	249	F9	∙
154	9A	Ü	186	BA	║	218	DA	┌	250	FA	·
155	9B	¢	187	BB	╗	219	DB	█	251	FB	√
156	9C	£	188	BC	╝	220	DC	▄	252	FC	ⁿ
157	9D	¥	189	BD	╜	221	DD	▌	253	FD	²
158	9E	₧	190	BE	╛	222	DE	▐	254	FE	■
159	9F	ƒ	191	BF	┐	223	DF	▀	255	FF	□

Information Technology Principles

Other Text Codes

- Extended Binary Coded Decimal Interchange Code **(EBCDIC)** used by IBM—
  8 bit (2^8 bits) 256 symbols

- Unicode is 16 bit (2^{16}) 65,536 symbols
  - World Wide Web supports many languages
  - Unicode supports Latin, Russian, Cherokee, other alphabet representation
  - www.unicode.org

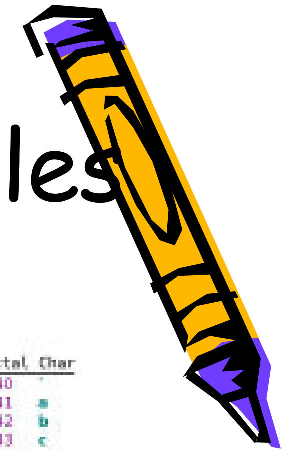
ASCII/8859-1 Text

A	0100 0001
S	0101 0011
C	0100 0011
I	0100 1001
I	0100 1001
/	0010 1111
8	0011 1000
8	0011 1000
5	0011 0101
9	0011 1001
-	0010 1101
1	0011 0001
	0010 0000
t	0111 0100
e	0110 0101
x	0111 1000
t	0111 0100

Unicode Text

A	0000 0000 0100 0001
S	0000 0000 0101 0011
C	0000 0000 0100 0011
I	0000 0000 0100 1001
I	0000 0000 0100 1001
	0000 0000 0010 0000
天	0101 1001 0010 1001
地	0101 0111 0011 0000
	0000 0000 0010 0000
س	0000 0110 0011 0011
ل	0000 0110 0100 0100
ا	0000 0110 0010 0111
م	0000 0110 0100 0101
	0000 0000 0010 0000
α	0000 0011 1011 0001
≤	0010 0010 0111 0000
γ	0000 0011 1011 0011

Information Technology Principles

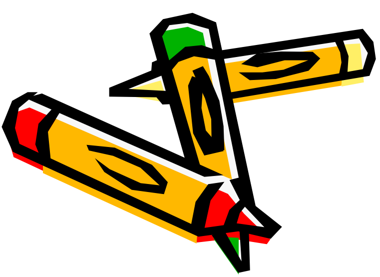


ASCII TABLE

Decimal	Hexadecimal	Binary	Octal	Char
0	0	0	0	[NULL]
1	1	1	1	[START OF HEADING]
2	2	10	2	[START OF TEXT]
3	3	11	3	[END OF TEXT]
4	4	100	4	[END OF TRANSMISSION]
5	5	101	5	[ENQUIRY]
6	6	110	6	[ACKNOWLEDGE]
7	7	111	7	[BELL]
8	8	1000	10	[BACKSPACE]
9	9	1001	11	[HORIZONTAL TAB]
10	A	1010	12	[LINE FEED]
11	B	1011	13	[VERTICAL TAB]
12	C	1100	14	[FORM FEED]
13	D	1101	15	[CARRIAGE RETURN]
14	E	1110	16	[SHIFT OUT]
15	F	1111	17	[SHIFT IN]
16	10	10000	20	[DATA LINK ESCAPE]
17	11	10001	21	[DEVICE CONTROL 1]
18	12	10010	22	[DEVICE CONTROL 2]
19	13	10011	23	[DEVICE CONTROL 3]
20	14	10100	24	[DEVICE CONTROL 4]
21	15	10101	25	[NEGATIVE ACKNOWLEDGE]
22	16	10110	26	[SYNCHRONOUS IDLE]
23	17	10111	27	[ENG OF TRANS. BLOCK]
24	18	11000	30	[CANCEL]
25	19	11001	31	[END OF MEDIUM]
26	1A	11010	32	[SUBSTITUTE]
27	1B	11011	33	[ESCAPE]
28	1C	11100	34	[FILE SEPARATOR]
29	1D	11101	35	[GROUP SEPARATOR]
30	1E	11110	36	[RECORD SEPARATOR]
31	1F	11111	37	[UNIT SEPARATOR]
32	20	100000	40	[SPACE]
33	21	100001	41	!
34	22	100010	42	"
35	23	100011	43	#
36	24	100100	44	$
37	25	100101	45	%
38	26	100110	46	&
39	27	100111	47	'
40	28	101000	50	(
41	29	101001	51	)
42	2A	101010	52	*
43	2B	101011	53	+
44	2C	101100	54	,
45	2D	101101	55	-
46	2E	101110	56	.
47	2F	101111	57	/

Decimal	Hexadecimal	Binary	Octal	Char
48	30	110000	60	0
49	31	110001	61	1
50	32	110010	62	2
51	33	110011	63	3
52	34	110100	64	4
53	35	110101	65	5
54	36	110110	66	6
55	37	110111	67	7
56	38	111000	70	8
57	39	111001	71	9
58	3A	111010	72	:
59	3B	111011	73	;
60	3C	111100	74	<
61	3D	111101	75	=
62	3E	111110	76	>
63	3F	111111	77	?
64	40	1000000	100	@
65	41	1000001	101	A
66	42	1000010	102	B
67	43	1000011	103	C
68	44	1000100	104	D
69	45	1000101	105	E
70	46	1000110	106	F
71	47	1000111	107	G
72	48	1001000	110	H
73	49	1001001	111	I
74	4A	1001010	112	J
75	4B	1001011	113	K
76	4C	1001100	114	L
77	4D	1001101	115	M
78	4E	1001110	116	N
79	4F	1001111	117	O
80	50	1010000	120	P
81	51	1010001	121	Q
82	52	1010010	122	R
83	53	1010011	123	S
84	54	1010100	124	T
85	55	1010101	125	U
86	56	1010110	126	V
87	57	1010111	127	W
88	58	1011000	130	X
89	59	1011001	131	Y
90	5A	1011010	132	Z
91	5B	1011011	133	[
92	5C	1011100	134	\
93	5D	1011101	135	]
94	5E	1011110	136	^
95	5F	1011111	137	_

Decimal	Hexadecimal	Binary	Octal	Char
96	60	1100000	140	`
97	61	1100001	141	a
98	62	1100010	142	b
99	63	1100011	143	c
100	64	1100100	144	d
101	65	1100101	145	e
102	66	1100110	146	f
103	67	1100111	147	g
104	68	1101000	150	h
105	69	1101001	151	i
106	6A	1101010	152	j
107	6B	1101011	153	k
108	6C	1101100	154	l
109	6D	1101101	155	m
110	6E	1101110	156	n
111	6F	1101111	157	o
112	70	1110000	160	p
113	71	1110001	161	q
114	72	1110010	162	r
115	73	1110011	163	s
116	74	1110100	164	t
117	75	1110101	165	u
118	76	1110110	166	v
119	77	1110111	167	w
120	78	1111000	170	x
121	79	1111001	171	y
122	7A	1111010	172	z
123	7B	1111011	173	{
124	7C	1111100	174	|
125	7D	1111101	175	}
126	7E	1111110	176	~
127	7F	1111111	177	[DEL]



Information Technology Principles

Instructor: Dr. Moaath Shatnawi

Information Technology Principles

Error Detection and Correction

- Binary codes are used to represent different forms of information's
- When binary information is sent across physical channel (wires, coaxial cable, optical fiber, airwaves, etc.) some bits may change due to interference.
- One important function of coding is to enable the detection (and often correction) of errors.
- A fundamental aspect of error control coding is **redundancy**

Information Technology Principles

Parity Bit

- An extra bit is appended to the code
- **Even parity:** an even parity bit is set to 1 if the number of ones in a given set of bits is odd (making the total number of ones even)
- **Odd parity:** an odd parity bit is set to 1 if the number of ones in a given set of bits is even (making the total number of ones odd)

7 bits of data	byte with parity bit	
	even	odd
0000000	00000000	10000000
1010001	11010001	01010001
1101001	01101001	11101001
1111111	11111111	01111111

Information Technology Principles

Error Detection and Correction

Transmitted Character	Transmitted Information	Transmitted Parity	Received Information	Received Parity	Do We Detect an Error?
H	1001000	0	1000000	0	Yes
e	1100101	0	1100101	0	No
l	1101100	0	1101100	0	No
p	1110000	1	1110000	1	No

TABLE 3.1 Even Parity Example

- Parity can detect errors, but cannot correct them
- We were able to detect a one bit error, but there is no indication as to which bit was in error.
- If the information includes a parity bit, the receiver can detect errors and you can request a retransmission.

Information Technology Principles

Repetition

- Coding techniques rely on fundamental idea of adding structured redundancy to information before it is stored (CD, DVD ..) or transmitted.
- The repetition of the data allow the receiver to detect errors
- If an error is detected, the receiver can either request that the data be retransmitted, or can possibly even correct the data itself.
- Repetition is the provision of extra bits to ensure the information is received correctly.
- The more error resistant we want our system to be, <u>the more redundancy we should add.</u>

Information Technology Principles

Repetition

- Original data: 1 0 0 1
- Transmitted: 111 000 000 111
- Received: 011 000 001 111
  - Errors in the first and third bits detected
  - Errors in the first and third bits can be corrected
  - Note: Not 100% reliable

Information Technology Principles

Hamming (7,4) Code

- Around 1947 Richard W. Hamming developed technique for detecting and correcting single bit errors in transmitted data.

- His technique requires that three parity bits (or check bits) be transmitted with every four data bits.

- The algorithm is called a (7, 4) code, because it requires seven bits to encoded four bits of data.

- The goal of Hamming codes is to create a set of parity bits that overlap such that a single-bit error (the bit is logically flipped in value) in a data bit *or* a parity bit can be detected *and* corrected.

Information Technology Principles

Hamming (7,4) Code

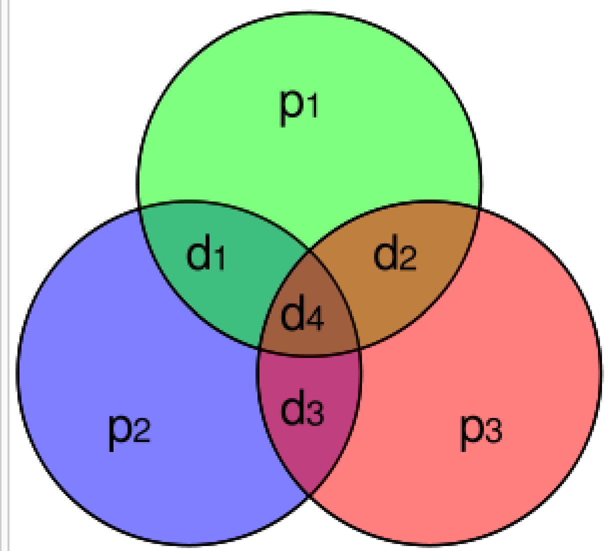
Bit #	1	2	3	4	5	6	7
Transmitted bit	p_1	p_2	d_1	p_3	d_2	d_3	d_4
p_1	Yes	No	Yes	No	Yes	No	Yes
p_2	No	Yes	Yes	No	No	Yes	Yes
p_3	No	No	No	Yes	Yes	Yes	Yes

$$\mathrm{H} := \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix}.$$

This table describes which parity bits cover which transmitted bits in the encoded word. For example, p_2 covers bits 2, 3, 6, & 7.

It also details which transmitted by which parity bit by reading the column.

Venn Diagramm



Graphical depiction of the 4 data bits and 3 parity bits and which parity bits apply to which data bits

For example, d_1 is covered by p_1 and p_2 but not p_3. This table will have a striking resemblance to the **parity-check matrix (H)**

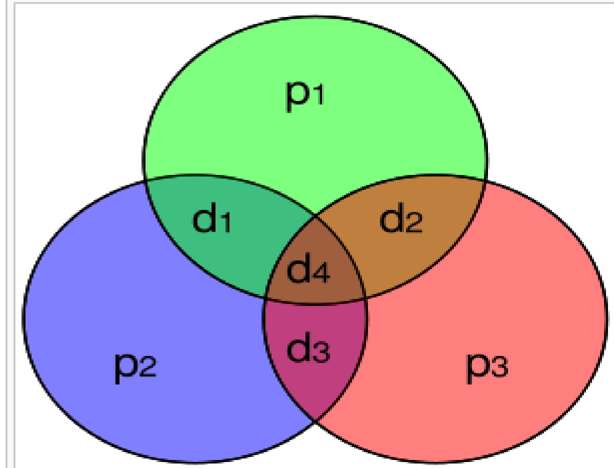
Information Technology Principles

Hamming (7,4) Code

Furthermore, if the parity columns in the above table were removed

	d_1	d_2	d_3	d_4
p_1	Yes	Yes	No	Yes
p_2	Yes	No	Yes	Yes
p_3	No	Yes	Yes	Yes

$$\mathbf{G} := \begin{pmatrix} 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix}$$



Graphical depiction of the 4 data bits and 3 parity bits and which parity bits apply to which data bits

then resemblance to rows 1, 2, & 4 of the code generator matrix (*G*)

In coding theory, a **generator matrix** is a matrix whose rows generate all elements of a linear code. If the matrix is *G* and the linear code is *C*, $w = \mathbf{c}\ G$

where *w* is a unique codeword of the linear code *C*, **c** is a unique row vector, and a bijection exists between *w* and **c**

Information Technology Principles

Hamming (7,4) Code

Channel coding

Suppose we want to transmit this data

$$\mathbf{p} = \begin{pmatrix} d_1 \\ d_2 \\ d_3 \\ d_4 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

(1011) over a noisy communication channel.

first we take the product of ***G*** and **p**, with entries modulo 2, to determine the transmitted codeword **x**:

$$\mathbf{x} = \mathbf{G}\mathbf{p} = \begin{pmatrix} 1 & 1 & 0 & 1 \\ 1 & 0 & 1 & 1 \\ 1 & 0 & 0 & 0 \\ 0 & 1 & 1 & 1 \\ 0 & 1 & 0 & 0 \\ 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 1 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 2\%2 \\ 3\%2 \\ 1\%2 \\ 2\%2 \\ 0\%2 \\ 1\%2 \\ 1\%2 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

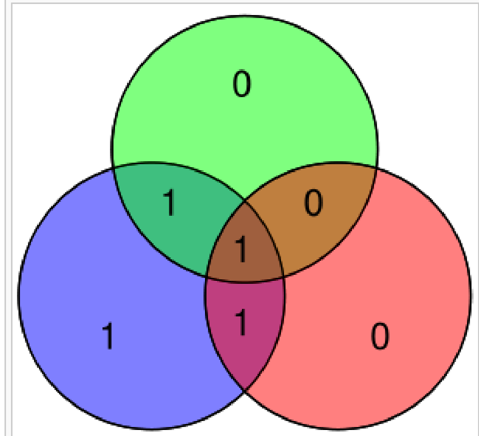
This means that 0110011 would be transmitted instead of transmitting 1011.

Information Technology Principles

Hamming (7,4) Code

Channel coding

In the diagram to the right, the 7 bits of the encoded word are inserted into their respective locations; from inspection it is clear that the parity of the red, green, and blue circles are even:



Mapping in the example x. The parity of the red, green, and blue circles are even.

- red circle has 2 1's
- green circle has 2 1's
- blue circle has 4 1's

- if, during transmission, a bit is flipped then the parity of 2 or all 3 circles will be incorrect and the errored bit can be determined (even if one of the parity bits) by knowing that the parity of all three of these circles should be even.

Hamming (7,4) Code

Parity check (error detection)

- If no error occurs during transmission, then the received codeword *r* is identical to the transmitted codeword *x*.
- The receiver multiplies *H* and *r* to obtain the **syndrome** vector , which indicates whether an error has occurred, and if so, for which codeword bit.
- Performing this multiplication (again, entries modulo 2):

$$\mathbf{z} = \mathbf{H}\mathbf{r} = \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 2\%2 \\ 4\%2 \\ 2\%2 \end{pmatrix} = \begin{pmatrix} 0 \\ 0 \\ 0 \end{pmatrix}$$

- Since the syndrome *z* is the null vector, the receiver can conclude that no error has occurred.

Information Technology Principles

Hamming (7,4) Code

Error correction

For example, suppose we have introduced a bit error on bit #5

$$\mathbf{r} = (\mathbf{x} + \mathbf{e}_5)\,\%2 = \left(\begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix} + \begin{pmatrix} 0 \\ 0 \\ 0 \\ 0 \\ 1 \\ 0 \\ 0 \end{pmatrix} \right) \%2 = \begin{pmatrix} 0\%2 \\ 1\%2 \\ 1\%2 \\ 0\%2 \\ 1\%2 \\ 1\%2 \\ 1\%2 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 1 \\ 1 \\ 1 \end{pmatrix}$$

Now,

$$\mathbf{z} = \mathbf{H}\mathbf{r} = \begin{pmatrix} 1 & 0 & 1 & 0 & 1 & 0 & 1 \\ 0 & 1 & 1 & 0 & 0 & 1 & 1 \\ 0 & 0 & 0 & 1 & 1 & 1 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 1 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 3\%2 \\ 4\%2 \\ 3\%2 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 1 \end{pmatrix}$$

Hamming (7,4) Code

Error correction

which corresponds to the fifth column of H .

According to the general algorithm bit set 101 corresponds to the binary value of 5, which also indicates the fifth bit was corrupted.

Thus, an error has been detected in bit 5, and can be corrected (simply flip or negate its value):

$$\mathbf{r}_{corrected} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ \overline{1} \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

This corrected received value indeed, now, matches the transmitted value from above.

Information Technology Principles

Hamming (7,4) Code

Decoding

- Once the received vector has been determined to be error-free or corrected if an error occurred (assuming only zero or one bit errors are possible) then the received data needs to be decoded back into the original 4 bits.

- First, define a matrix :

$$\mathbf{R} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix}$$

- Then the received value, p_r is:

$$\mathbf{p_r} = \mathbf{R}\mathbf{r}$$

and using the running example from above

$$\mathbf{p_r} = \begin{pmatrix} 0 & 0 & 1 & 0 & 0 & 0 & 0 \\ 0 & 0 & 0 & 0 & 1 & 0 & 0 \\ 0 & 0 & 0 & 0 & 0 & 1 & 0 \\ 0 & 0 & 0 & 0 & 0 & 0 & 1 \end{pmatrix} \begin{pmatrix} 0 \\ 1 \\ 1 \\ 0 \\ 0 \\ 1 \\ 1 \end{pmatrix} = \begin{pmatrix} 1 \\ 0 \\ 1 \\ 1 \end{pmatrix}$$

Hamming (7,4) Code

Multiple bit errors

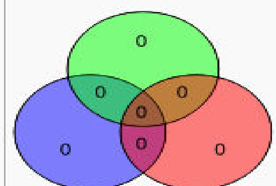
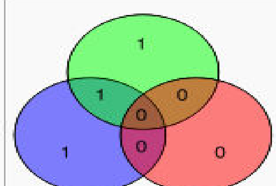
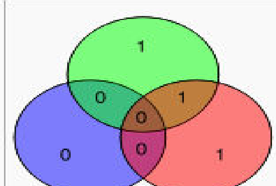
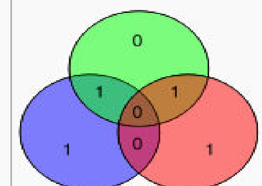
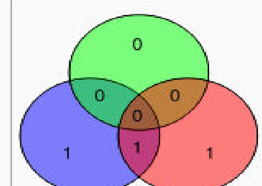
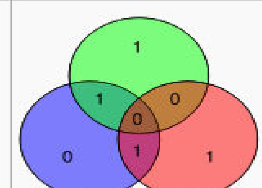
- It can show that only single bit errors can be corrected using this scheme.
- In a (7,4) Hamming Error Correcting Code with 7 bits it is possible to detect and correct a <u>single bit error</u> in every 4-bit group
- Alternatively, Hamming codes can be used to detect single and double bit errors, by merely noting that the product of **H** is nonzero whenever errors have occurred.
- If two bits were flipped. This yield to invalid parity and the errors are not recoverable.
- However, the Hamming (7,4) and similar Hamming codes cannot distinguish between single-bit errors and two-bit errors

Information Technology Principles

Hamming (7,4) Code

All codes

Since the source is only 4 bits then there are only 16 possible transmitted words.

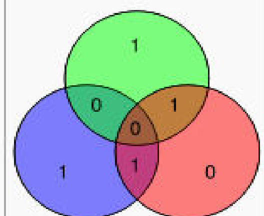
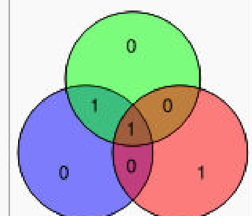
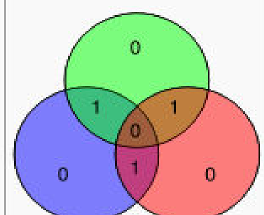
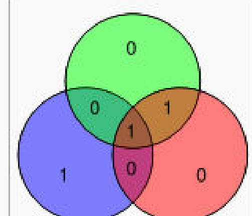
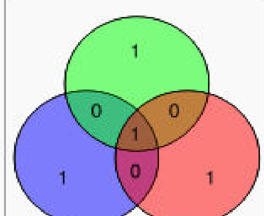
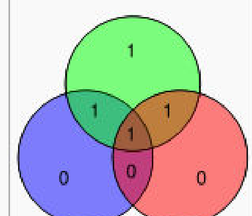
Data (d_1, d_2, d_3, d_4)	Hamming(7,4)	
	Transmitted $(p_1, p_2, d_1, p_3, d_2, d_3, d_4)$	Diagram
0000	0000000	
1000	1110000	
0100	1001100	
1100	0111100	
0010	0101010	
1010	1011010	

Information Technology Principles

Hamming (7,4) Code

All codes

Since the source is only 4 bits then there are only 16 possible transmitted words.

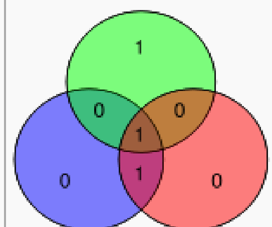
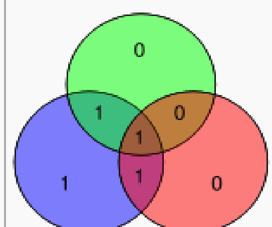
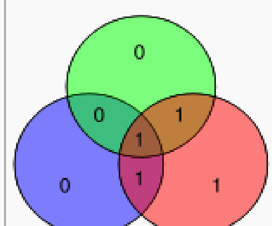
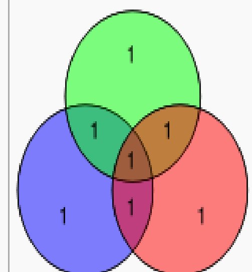
0110	1100110		1001	0011001	
1110	0010110		0101	0100101	
0001	1101001		1101	1010101	

Information Technology Principles

Hamming (7,4) Code

All codes

Since the source is only 4 bits then there are only 16 possible transmitted words.

0011	1000011	
1011	0110011	
0111	0001111	
1111	1111111	

Information Technology Principles

Hamming (7,4) Code

Example (2):

- Consider the 7-bit data word "1011". To demonstrate how Hamming codes are calculated and used to detect an error, see the tables below.

	p1	**p2**	**d1**	**p3**	**d2**	**d3**	**d4**
Data (without parity)			1		0	1	1
P1	0		1		0		1
P2		1	1			1	1
P3				0	0	1	1
Data (with parity)	0	1	1	0	0	1	1

Hamming (7,4) Code

Example (2):

- The new data word (with parity bits) is now "0110011".
- If we now assume the third bit gets corrupted and turned from 1 to 0. Our new data word is "0100011";
- This time when we analyze how the Hamming codes were created we flag each parity bit as 1 when the even parity check fails.

	p1	p2	d1	p3	d2	d3	d4	Parity check	Parity bit
Received data word	0	1	0	0	0	1	1		
P1	0		0		0		1	Fail	1
P2		1	0			1	1	Fail	1
P3				0	0	1	1	pass	0

Information Technology Principles

Hamming (7,4) Code

Example (2):

- The final step is to evaluate the value of the parity bits (remembering the bit with lowest index is the least significant bit, i.e., it goes furthest to the right).

- The integer value of the parity bits is 3, signifying that the 3th bit in the data word (including parity bits) is wrong and needs to be flipped.

	p3	p2	p1	
Binary	0	1	1	
Decimal		2	1	= 3

- Flipping the 3th bit gives changes 0100011 back into 0110011. Removing the Hamming codes gives the original data word of 1011.

Information Technology Principles

Hamming code

Example (3): using the (11,7) Hamming code

Char.	ASCII	Check bits
H	1001000	00110010000
a	1100001	10111001001
m	1101101	11101010101
m	1101101	11101010101
i	1101001	01101011001
n	1101110	01101010110
g	1100111	01111001111
	0100000	10011000000
c	1100011	11111000011
o	1101111	10101011111
d	1100100	11111001100
e	1100101	00111000101

Order of bit transmission

Information Technology Principles

Hamming code

Example (3): using the (11,7) Hamming code

- Consider the 7-bit data word "0110101". To demonstrate how Hamming codes are calculated and used to detect an error, see the tables below.

	p_1	p_2	d_1	p_3	d_2	d_3	d_4	p_4	d_5	d_6	d_7
Data word (without parity):			**0**		**1**	**1**	**0**		**1**	**0**	**1**
p_1	1		0		1		0		1		1
p_2		0	0			1	0			0	1
p_3				0	1	1	0				
p_4								0	1	0	1
Data word (with parity):	1	0	0	0	1	1	0	0	1	0	1

Calculation of Hamming code parity bits

- They use d to signify data bits and p to signify parity bits.

- Firstly the data bits are inserted into their appropriate positions and the parity bits calculated in each case <u>using even parity</u>.

Information Technology Principles

Hamming code

Example (3): using the (11,7) Hamming code

- The new data word (with parity bits) is now "100’001100101".
- If we now assume the final bit gets corrupted and turned from 1 to 0. Our new data word is "10001100100";
- This time when we analyze how the Hamming codes were created we flag each parity bit as 1 when the even parity check fails.

	p_1	p_2	d_1	p_3	d_2	d_3	d_4	p_4	d_5	d_6	d_7	Parity check	Parity bit
Received data word:	**1**	**0**	**0**	**0**	**1**	**1**	**0**	**0**	**1**	**0**	**0**		
p_1	1		0		1		0		1		0	Fail	1
p_2		0	0			1	0			0	0	Fail	1
p_3				0	1	1	0					Pass	0
p_4								0	1	0	0	Fail	1

Checking of parity bits (switched bit highlighted)

Hamming code

Example (3): using the (11,7) Hamming code

- The final step is to evaluate the value of the parity bits (remembering the bit with lowest index is the least significant bit, i.e., it goes furthest to the right).

- The integer value of the parity bits is 11, signifying that the 11^{th} bit in the data word (including parity bits) is wrong and needs to be flipped.

	P_4	P_3	P_2	P_1	
Binary	1	0	1	1	
Decimal	8		2	1	= 11

- Flipping the 11th bit gives changes 10001100100 back into 10001100101. Removing the Hamming codes gives the original data word of 0110101.

- Note that as parity bits do not check each other, if a single parity bit check fails and all others succeed, then it is the parity bit in question that is wrong and not any bit it checks.

Information Technology Principles

Hamming code

- The fundamental principal embraced by Hamming codes is parity.
- Hamming codes, are capable of correcting one error or detecting two errors but not capable of doing both simultaneously.
- You may choose to use Hamming codes as an error detection mechanism to catch both single and double bit errors or to correct single bit error.
- This is accomplished by using more than one parity bit, each computed on different combination of bits in the data.
- The position of error are called syndrome
- There are two useful proprieties of the syndrome. If the syndrome is all zeros, the encoded data is error free. If the syndrome has a non-zero value, flipping the encoded bit that is in the position of the column matching the syndrome will result in a valid code word.

Information Technology Principles

Hamming code

- The number of parity or error check bits required is given by the Hamming rule, and is a function of the number of bits of information transmitted.

- The Hamming rule is expressed by the following inequality:

$$d + p + 1 <= 2^{(p)}$$

Where d is the number of data bits and p is the number of parity bits.

- The result of appending the computed parity bits to the data bits is called the Hamming code word.

- The size of the code word c is obviously d+p, and a Hamming code word is described by the ordered set (c , d).

Information Technology Principles

Hamming code

- The case of p=3 is used to develop a (7,4) code using even parity, but larger code words are typically used in applications.
- The most common convention is that a parity value of 1 indicates that there is an odd number of ones in the data, and a parity value of 0 indicates that there is an even number of ones in the data. In other words: The data and the parity bit together should contain an even.
- Hamming also noticed the problems with flipping two or more bits, and described this as the "distance" (it is now called the Hamming distance, after him).
- In information theory, the **Hamming distance H(s1,s2)** between two strings s1,s2 of equal length is the number of positions for which the corresponding symbols are different

Example: The Hamming distance between:

1011101 and **1001001** is 2.

2143896 and **2233796** is 3.

"**toned**" and "**roses**" is 3.

Information Technology Principles

Instructor: Dr. Moaath Shatnawi

Information Technology Principles

IT Infrastructure

There are three components that make up the Infrastructure of IT:

- **Hardware**: is applied to any of the physical equipment in a system. Not only the computer and devices such as screens and printers but also all the elements used to tie information systems together.

  Including: - Input/output/memory/storage/processing units.
  - Peripheral devices.

  Telephone wires, antennas and network cables.

  Any other electronic components.

  Any other communication devices.

- **Software**: the instructions that guide the hardware in the performance of its duties.

- **Communications and networking.**

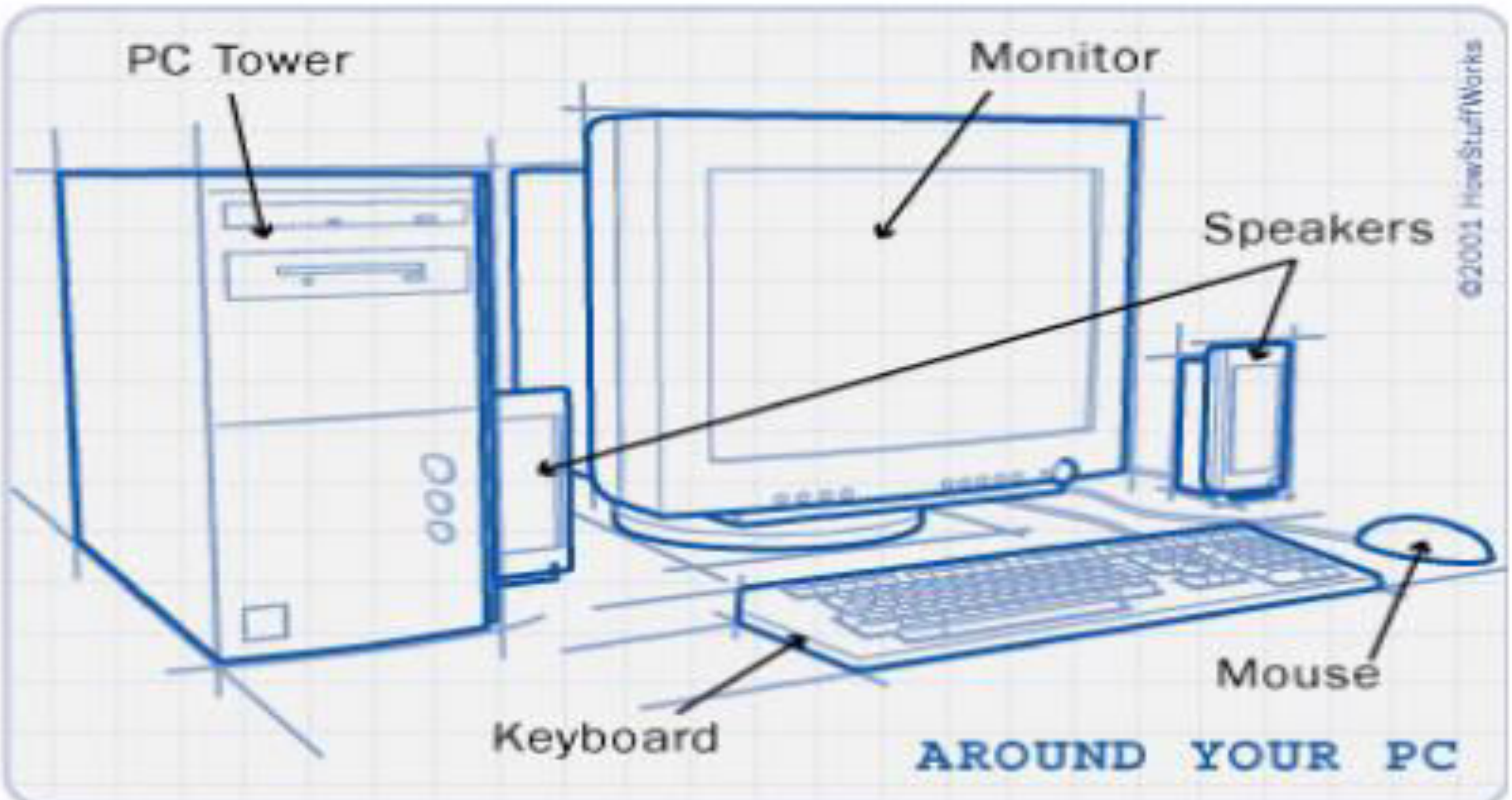
Information Technology Principles

Introduction to Computer Architectures and Software

- The IT world is based on Computers
- Students should have a basic understanding of how the computer works and about the software that drives it.
- Basics about computer Hardware components
- The purpose of each computer hardware component
- The overall structure of the computer hardware
- The technology behind the computer hardware
- etc.

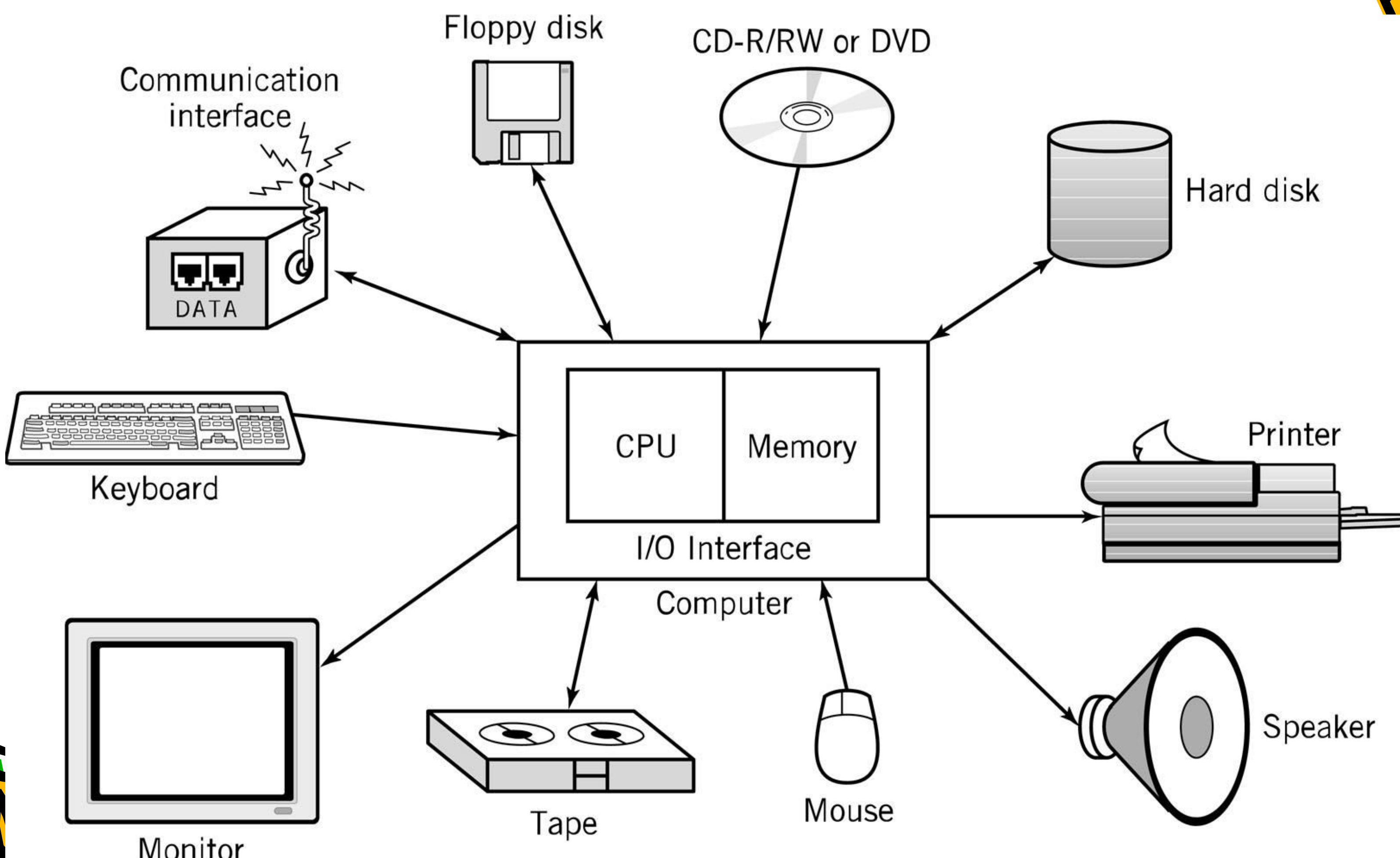
Information Technology Principles

Introduction to Computer Architectures and Software



Information Technology Principles

Introduction to Computer Architectures and Software

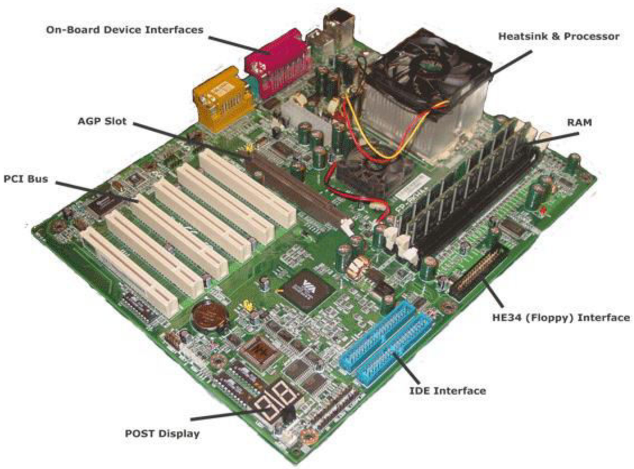


Information Technology Principles

Introduction to Computer Architectures and Software

Motherboard

- This is the main circuit board that all of the other internal components connect to.
- The CPU and memory are usually on the motherboard.
- Other systems may be found directly on the motherboard or connected to it through a secondary connection.

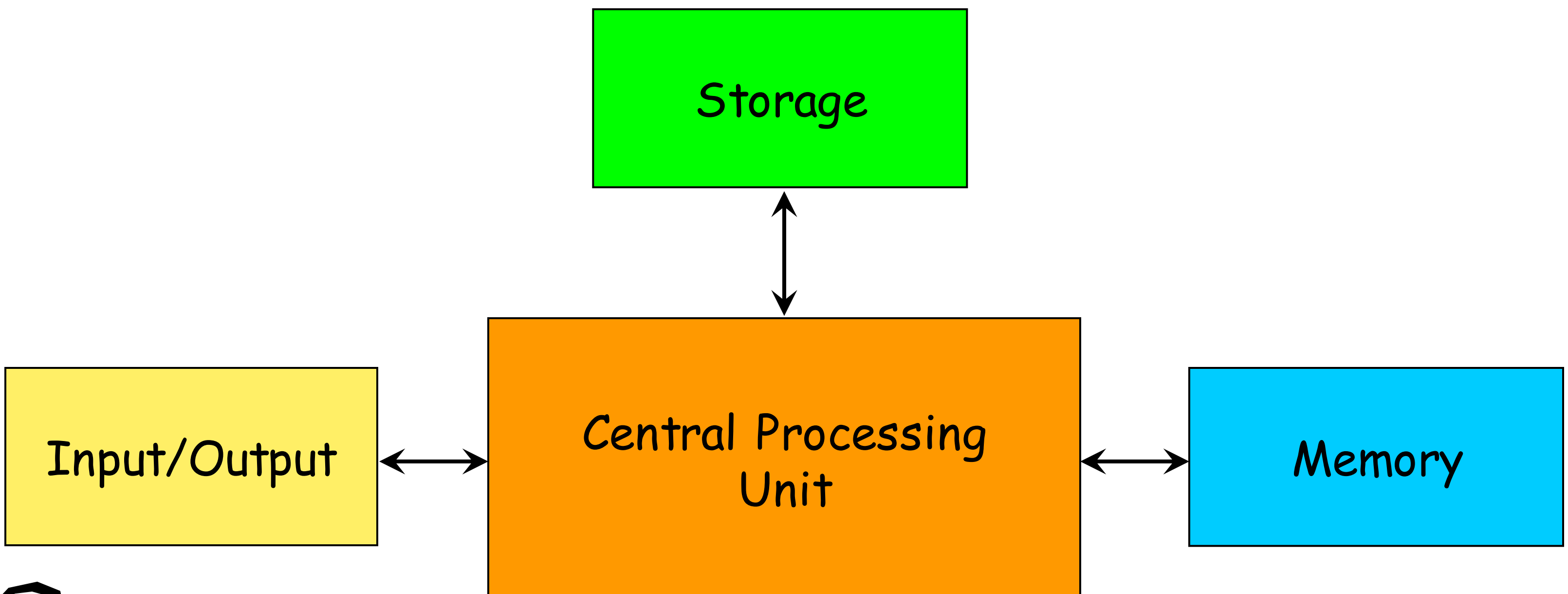


For example, a Sound Card can be built into the motherboard or connected through PCI.

Information Technology Principles

Introduction to Computer Architectures and Software

The Desktop PC

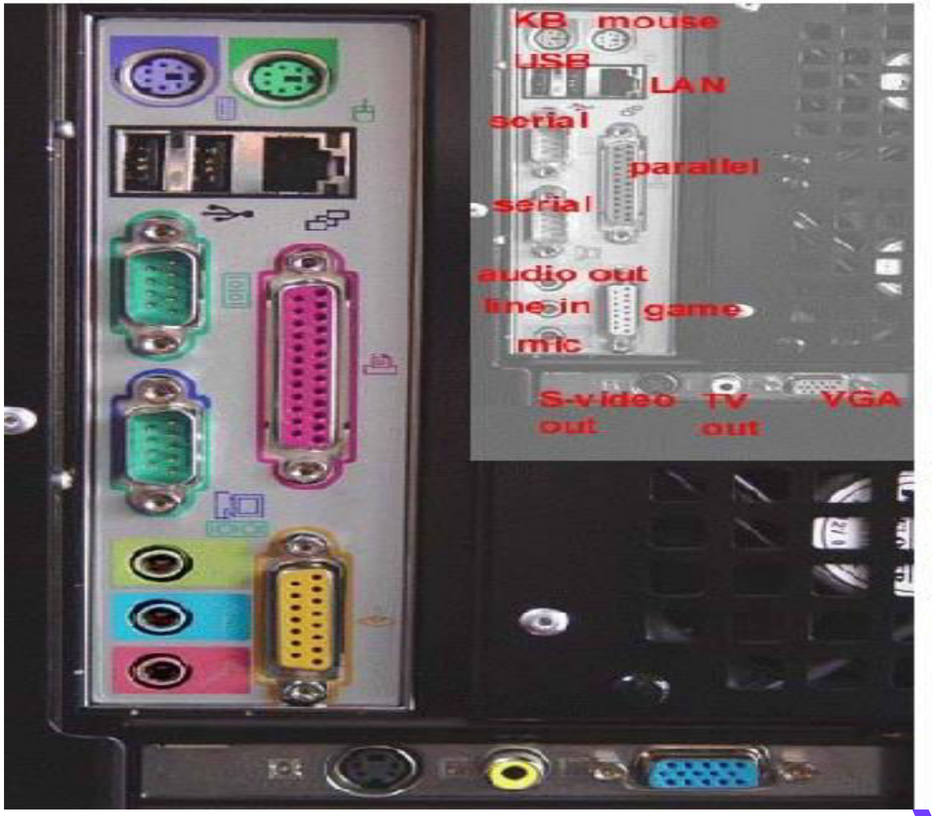


Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

- Two ways to think of I/O:
  - #1 At the board/chip level (Physical Connections)
  - #2 What is connected to the board (User I/O's)



Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

- The board:
  - Parallel, serial, network, game, digital ports

- What is connected to the board
  - Printer, scanner, keyboard, joystick, modem, speaker, monitor, network card

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Standard Keyboard (considered as the Standard-Input-Unit)

Most common device, the primary requirement is typing.

* Slow process.

* Intensive use may cause problems: "Repetitive Stress Injuries" (Carpal Tunnel Syndrome).

<u>Solution #1:</u> Split keyboards. Hands and writ take proper placement while typing.

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Solution #2: DataHand keyboards (by DataHand Systems, Phoenix, Arizona). Two unattached pads. The device has touch-sensitive finger-wells for the fingers and thumbs. Each finger-well allows 5 different commands (4 sides plus the bottom).

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Solution #3: **Ergonomic keyboards** (the scientific analysis of man-machine interactions is called ergonomics) Different structures of keyboards have been designed to reduce physical stress injuries (eg. Split and unattached two pieces on an arm-chair).

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

- **Virtual Keyboards**
- **Soft or Touch-screen keyboards** (tapping screen with your finger).
    - Light Pen (Stylus) (tapping screen with alight pen)

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

- **Pointing Devices** used to move a pointer around on the screen to execute commands or to manipulate the data that has already been entered. Pointing devices include:
- **Mouse** (Point a cursor and click). **Cordless mouse** also exist.
- **Trackball** (Up-side-down pregnant mouse).
- **Track Stick** (Suitable for portable compact/note book PCs)
- **Joy Stick** (Used for graphics and games).
- **Touch Pad** are flat rectangular pad sense the movement and pressure of your fingertip to control the mouse pointer.
- **Graphics Tablet (Digitizer).** You use a pencil-like stylus to execute commands and create drawings according to hand movement on the top of the pad.

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Scanners

- Use Optical-Character-Recognition (OCR) software
- Like reversing the process of printing .
- Scanning converts text from a printed form back to an electronic form that you can edit and manipulate.

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Scanner

The operation goes through several **steps**:

(i). Scanned page converted to a picture called a bit-mapped-image.

(ii). OCR software analyze the light and dark areas on the page, making a guess at how the page is laid out.

(iii). OCR looks up for each character (template) in its library for matching a character on the page.

(iv). OCR uses a process called "Feature Extraction" to analyze chars.

(v). Unclear characters appears in special symbols.

(vi). After conversion is complete, the page of text can be edited, modified, and then saved.

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Bar codes and bar code scanner

Bar code scanners are commonly found in retail stores. They scan the black and white bar code lines typicallly printed on labels on merchandise. In addition, they are very popular for tracking inventory items (eg. Library books)

Information Technology Principles

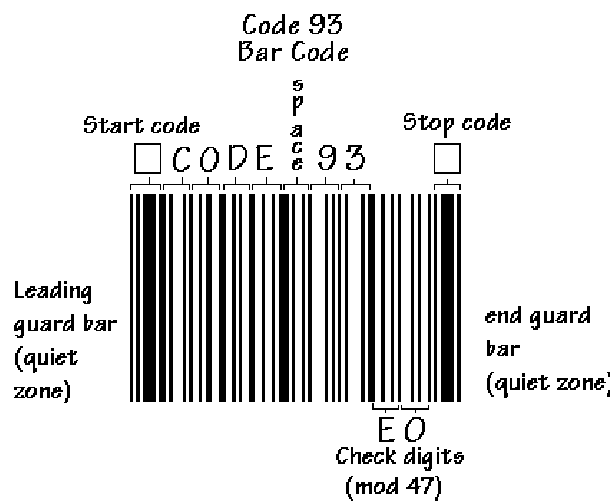
Introduction to Computer Architectures and Software

Input / Output

➔ About the Bar code:-

Made up of bars of different width and spacing that convey alphabetic and numeric information (usually about products or addresses)

Universal Product Code (UPC) consists of 11-digits {known as EAN outside the US and Canada}.



Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

POSTNET (developed by the US Postal Service).

➔ **Point -of-Sale (POS) Terminals,** are computerized cash registers incorporate bar cod scanners to input product code for pricing and other numerous data.

•

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Optical Mark Reader

Is a special scanner for detecting the presence of pencil marks on a predetermind grid, such as multiple-choice test answer sheets.

(eg. Marking the TOEFL exam papers in the past before they become on-line examinations).

Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Magnetic Ink Character Reader (MICR)

Mostly, is used in the banking industry. Information is printed on checks in magnetic ink that can be read by the MICR technology. When characters magnetized they release signal that identify the characters.

In banks, since a long time, checks are fed through Reader/Sorter Machines that can read, sort and route checks with speed of 2,400 checks per minute.

➔ Greatly increase the efficiency of handling checks.

•

Information Technology Principles

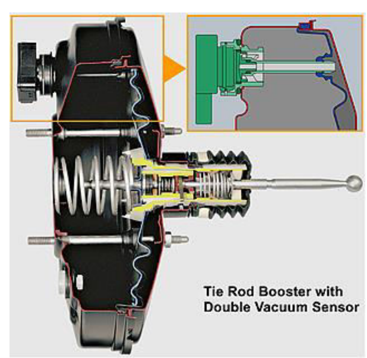
Introduction to Computer Architectures and Software

Input / Output

Sensors

Sensors, usually embedded in other technologies, collects data directly from the environment and inputs them into a computer.

Examples:
= Car air bag activation sensor.
= Fuel mixture/pollution control sensor (eg. Emetion test).
= Countless numbers/types of sensors built into a modern aircraft.



Information Technology Principles

Introduction to Computer Architectures and Software

Cameras

Digital Camera can capture images using the receptors called <u>Charge-Coupled-Devices</u> (CCD) instead of film. The images are stored on memory in the camera for later transfer to a computer, and then used in a document or printed.

Digital Video Camera can be hooked up to a computer to feed images to the screen and to the hard disk.

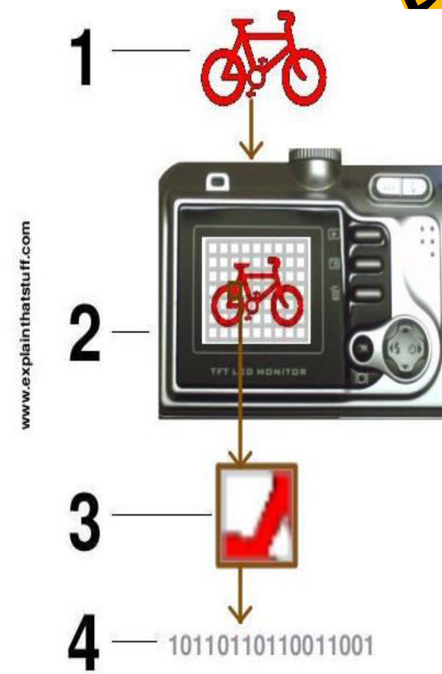
Film scanner/Recorder is used to digitize slide film & negatives.

➔ **Application:**

= **Virtual Reality** gives you the feeling that you are experiencing a different space than the one you actually occupy.[hear,see & feel]

Eg. Flight simulator used to train pilots.

= **Hologram** (provides a realistic 3-D vision) you may view a car model from different angles.



Information Technology Principles

Introduction to Computer Architectures and Software

Input / Output

Speech Recognition Devices/Voice Recognition Devices.

- Used in conjunction with microphones to input speech in to computers. Voice Recognition software (VRS) attempts to identify spoken words and translates them in to digital text.
- VRS requires training to become accustomed to the users voice and accent (the way you pronounce each word).
- Most commonly, voice systems work only for a single person, they are speaker – dependent.
- You first train the computer to become familiar with your accent to pronounce each word

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

- Used by the computer to store programs, information, data **(Write)**
- Used by the computer to access information and programs when necessary **(Read)**
- Some storage can do both read and write, some only one
- Some storage can randomly access information, some can only sequentially access
- Magnetic
  - Hard disk, floppy disk, ZIP disk, tape
- Optical
  - CD, DVD
- Solid State
  - Flash cards, PCMCIA cards

Introduction to Computer Architectures and Software

Storage

Memory and Storage in Computers

Definition: Memory is the functional unit of a computer that stores and retrieves information.

➔ The amount and type of memory in a computer affect:

i. The type of program we can run, and type of work to do.
ii. The speed (to store/write and to retrieve/read information).
iii. The cost of the computer and the cost of processing data.

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

There are two basic categories of memory:

(i). Primary/Main memory.

(ii). Secondary/Auxiliary storage.

Main	Vs Auxiliary
- Instant storage.	- Permanent storage.
- Small amount of info. Stored	- Much larger amount of info.
- Fast and closer to CPU	**- Relatively slower & away from CPU.**
-Used to store 3 types of info. Data being processed by CPU Instructions for CPU to process data. 3- Operating sys. Instructions to manage processing.	**- Used to store data, files** & applications that are not currently under processing.

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

<u>Memory Size and Measurements</u>

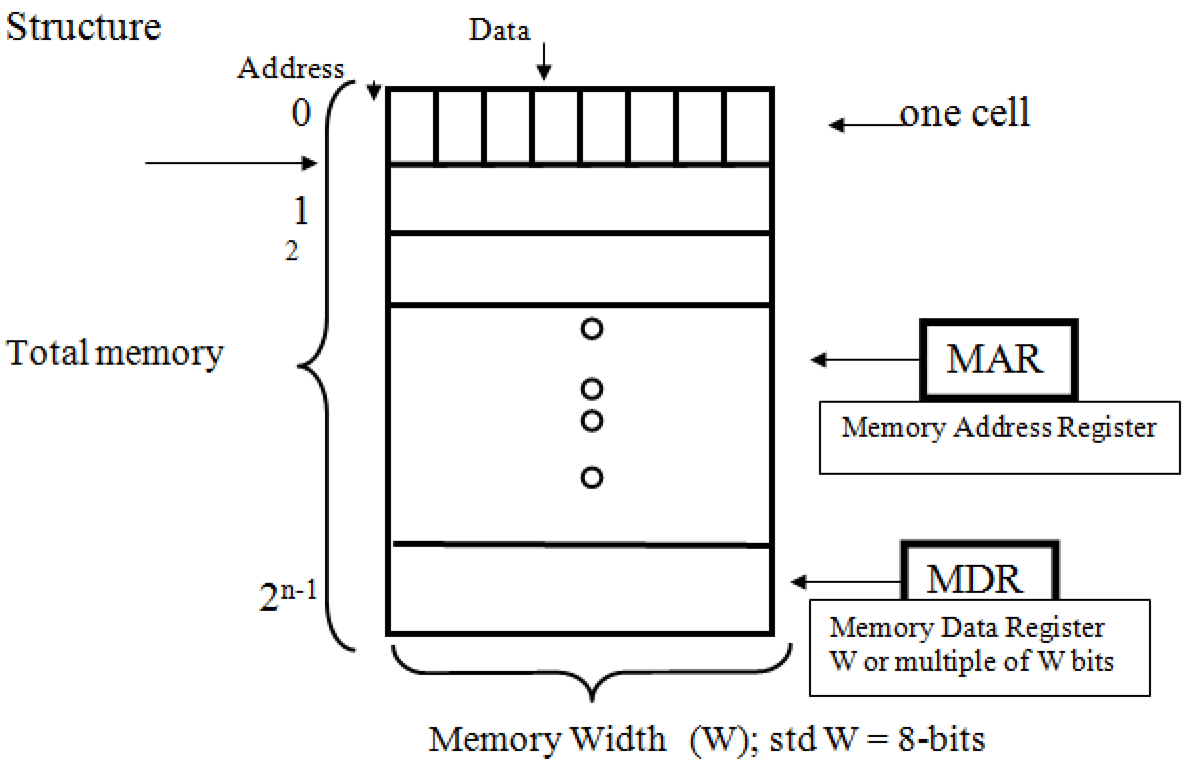
8-binary bits	=	1 byte	10^0 bytes	One character.
(exact 1024 byte)		1 Kilobyte	10^3 bytes	One page.
		1 Megabyte	10^6 bytes	Three novels.
		1 Gigabyte	10^9 bytes	Large personal library.
		1 Terabyte	10^{12} bytes	Research Library in Uni.
		1 Petabyte	10^{15} bytes	All printed materials in- all lib.s in North America.
		1 Exabyte	10^{18} bytes	All words ever printed- through out human history.
		1 Zettabyte	10^{21} bytes	

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

<u>RAM: Random Access Memory (Read/write)</u>



<u>Remark:</u> *MAR & MDR used to implement Fetch and Store operations*

Information Technology Principles

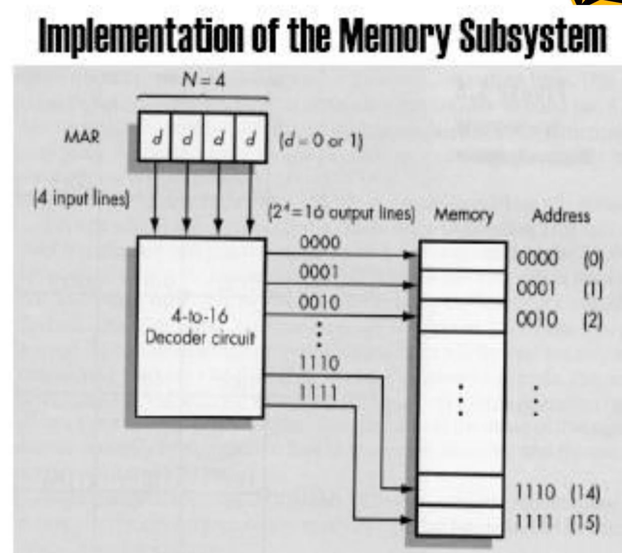
Introduction to Computer Architectures and Software

Storage

Illustration on how Fetch & Store work?

Fetch (address)
Load the address into MAR.
Decode the address into MAR.
Copy the contents of that memory location into MDR.

Store (address, value)
Load the address into MAR.
Load the value into MDR.
Decode the address in MAR.
Store the contents of MDR into that Memory location.

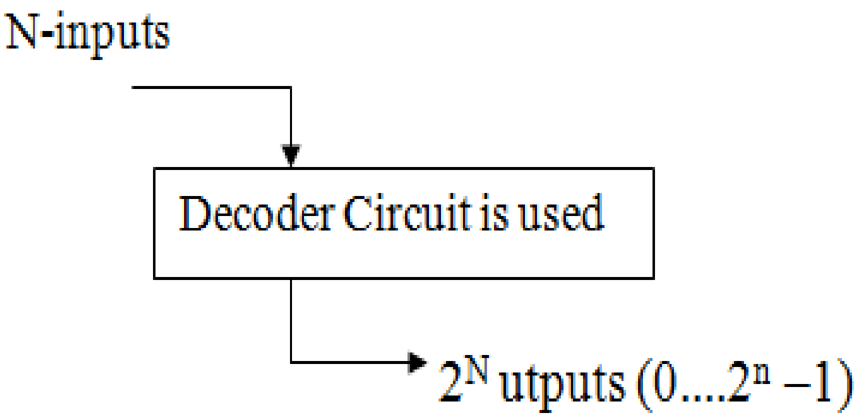


Information Technology Principles

Introduction to Computer Architectures and Software

Storage

Decode: Means that the memory unit must translate the N-bit address stored in MAR into the set of signals needed to access that one specific memory cell.



Information Technology Principles

Introduction to Computer Architectures and Software

Storage

<u>Four Types of Primary-Memory:</u>

(i). Registers

Part of the CPU.

Extremely limited capacity.

Store data & instruction during processing only.

(ii). Cache Memory

Closer to CPU & faster than RAM.

Used to store information (blocks of info) that used most often in the running application.

Those used less often remain in RAM until they are transferred to cache,

those used infrequently stay stored in secondary storage.

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

<u>Four Types of Primary-Memory:</u>

(iii). Random Access Memory (RAM)

- Farther away from the CPU, when you start a program its loaded into the RAM, as you use the program small parts of instructions and data are sent into the registers and then processed by the CPU.

(iv) Read only Memory (ROM)

- Unlike all above, it is non-volatile

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

<u>Four Types of Primary-Memory:</u>

(iv) Read only Memory (ROM)

- Unlike all above, it is nonvolatile

Used to store critical instructions, eg. those needed to "boot" the computer. (safe-guarded info.)

- ROM: computer only Read from them & user can't change them.

But, there are other types of ROM:

(a). PROM: Programmable ROM, user can program it on.

(b). EPROM: Erasable PROM, can reprogrammed, can be Reprogramed, (erased first) using special tools.

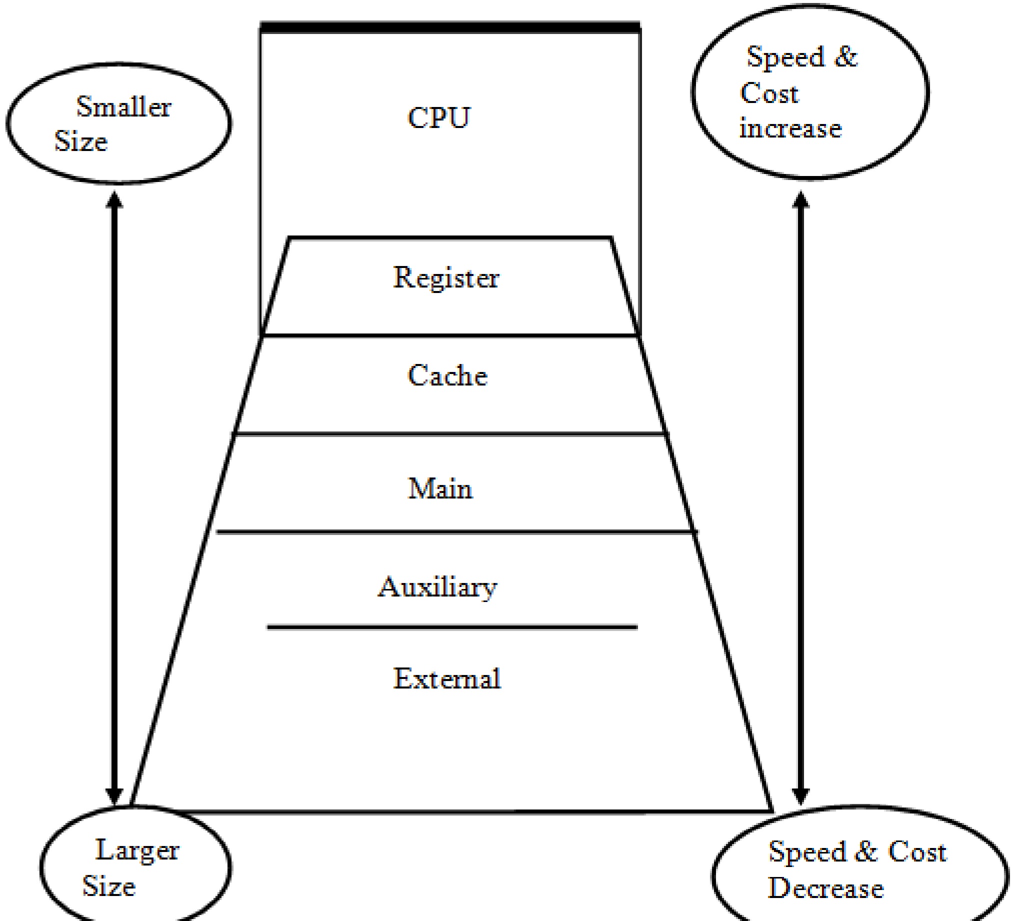
(c). **<u>Flash Memory</u>** (Rewritable from of ROM) can be built-in into a system mother-board or installed on a card (Flash-Card).

Information Technology Principles

Introduction to Computer Architectures and Software

Storage

Hierarchy of Memory/Storage Levels in the Computer System



Information Technology Principles

Introduction to Computer Architectures and Software

Auxiliary/Secondary/External/ or Mass-storage

{A computer RAM is never large enough to store all applications, documents and other system generated files that you work on}

NOTICE the difference between:

Storage-device: Floppy-Disk-Drive	Medium: singular
Storage-Medium: Magnetic-Disk	Media: plural

Two-Operations:

(1). Writing: copies data from RAM to Hard Drive.

(2). Reading: copies data from Hard Drive to RAM.

………….Read/Write Heads used to store and extract data…………………….

Information Technology Principles

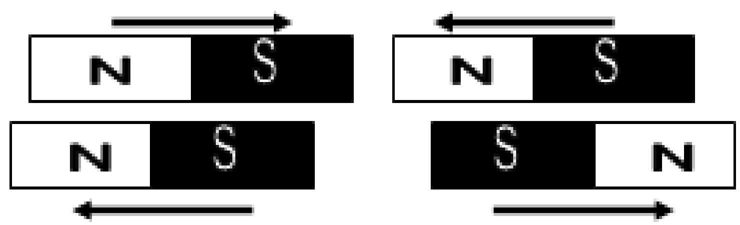
Introduction to Computer Architectures and Software

<u>Three Types of Secondary Storage</u>

1. Magnetic (floppies, hard disks and tapes).
2. Optical (CDs).
3. Solid state (flash/ solid-state memory).

1- <u>Magnetic</u>

- Polarity:



It is Known that:

- Opposite polarities attract each other.
- Identical polarities repel each other.

Information Technology Principles

Introduction to Computer Architectures and Software

These Two magnetic states are used to record data on a disk:

WRITING

"while the disk spins, electrical signals on the R/W head change the polarity of tiny magnetic particles on the surface of the surface of the disk to record 0s and 1s."

READING

"When you open a file, the process is reversed. The polarties of the medium immediately under the R/W head induce an electrical current in the R/W head that is transmitted back to the computer in the Gorm of 0s and 1s."

Information Technology Principles

Storage

2- **Optical**:

Optical storage devices use a laser to burn small, dark pits, into the surface of a disk.

Pits Dark

Lands Shiny & Smooth

"While the disc spins in the drive, a narrow laser-beam is focused on the disk's surface. The amount of light that is reflected back is determined by whether the beam is focused on a Pit or a **Land**. Pits reflect less light.

A device called photo-detector measures the light and a circuit converts its reading into a 0 or 1."

Information Technology Principles

Storage

- **CD-Discs**

* CD-ROM, may store up to 660 MB of data
They are rated by their access-time & transfer-rate (performance).
The faster they spin the better their performance.
Spin-Rate 2x, 4x, 6x, 16x etc. [16x times faster than the original CD-Drive]
Read only. It is an advantage for documents/software copy rights.

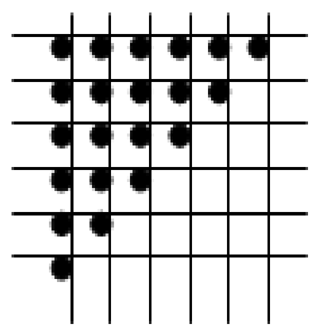
* CD-R (Recordable) Writ-Once-Read-Many
CD-R disc, can be written on, once only.
Have thin layer of gold with another of green dye.
To Record data the laser forms bumps in the dye-larger.
[1: represented by a bump (نتوء). 0: represented by absence.]

Information Technology Principles

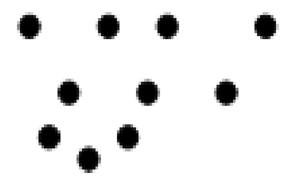
Storage

- **CD-Discs**

  * CD-RW (Rewriteable)
    - Can be recorded, erased, and reused just like disks.
    - They record data by changing a material from a well-structured crystalline state to Less-ordered amorphous state.



Well-Structured



Less-Ordered

Information Technology Principles

Storage

<u>DVD Discs</u>

Latest generation of optical discs.

DVD: Digital Video Disk.

Digital Versatile Disk. متعدد الجوانب/متقلب

- This Technology is about to replace: Music-CDs , Videotapes and CD-ROMs

Its physical size same as CD-ROM.

DVD-Discs may store up to 4.7 GB on a single-sided, single-layer disc.

Double-sided may stores 9.4 GB

- Double-sided & double-layer may stores 17 GB

  (that is 30 times the capacity of today's CD-ROM discs)

Information Technology Principles

Storage

Magneto-Optical storage (MO)

-Offer longevity, removability, high storage capacity and random access.

-To record data, the laser **heats** the optical surface then the particles can be changed to indicate 0s & 1s thru. R/W heads, when the surface cools down the data then hard to erase ➔ More secure than others.

Available in two format:

-Rewritable.

-Write-Once and Read-Many (WORM).

Information Technology Principles

Storage

<u>**Solid State Storage**</u>

-Known as Flash Memory, one of the latest memory technology.

-Uses solid-state chips, nonvolatile.

-They have no moving parts ➔ much faster than mechanically operated disks and tapes.

-One form is PC-Card, can be plugged into slots in the side of notebook and take the place of a hard disk drive.

-They use less energy.

-They are Removable -Pop one out when its full and pop in another.

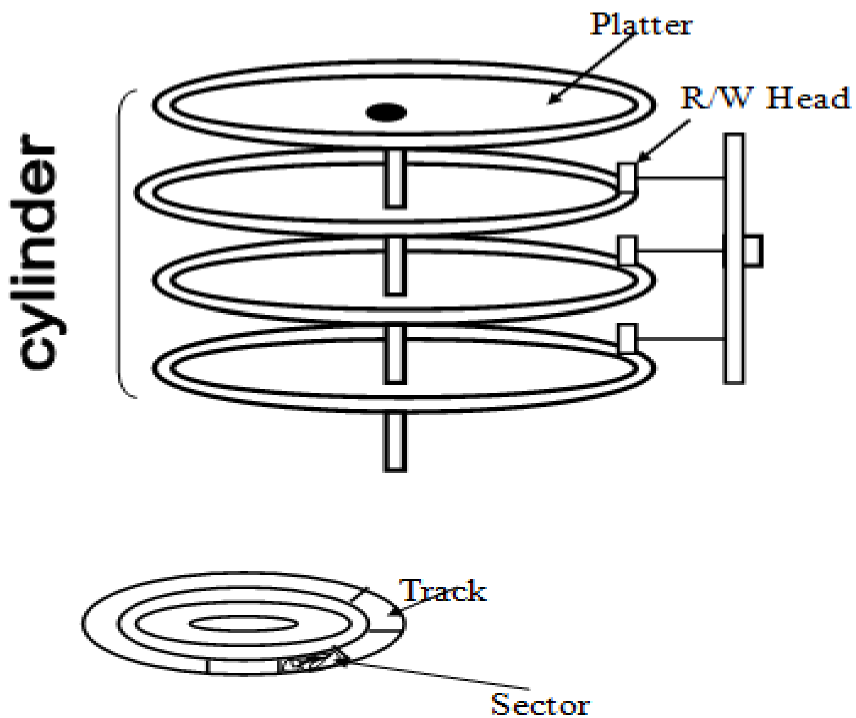
-Used with PDAs (Private Digital Assistants), organizers, digital camera, mobiles, and other hand held devices.

{Characteristics of flash-memory: compact, portable, require little energy.}

Information Technology Principles

Storage

- **Structure of A Hard Disk**



Information Technology Principles

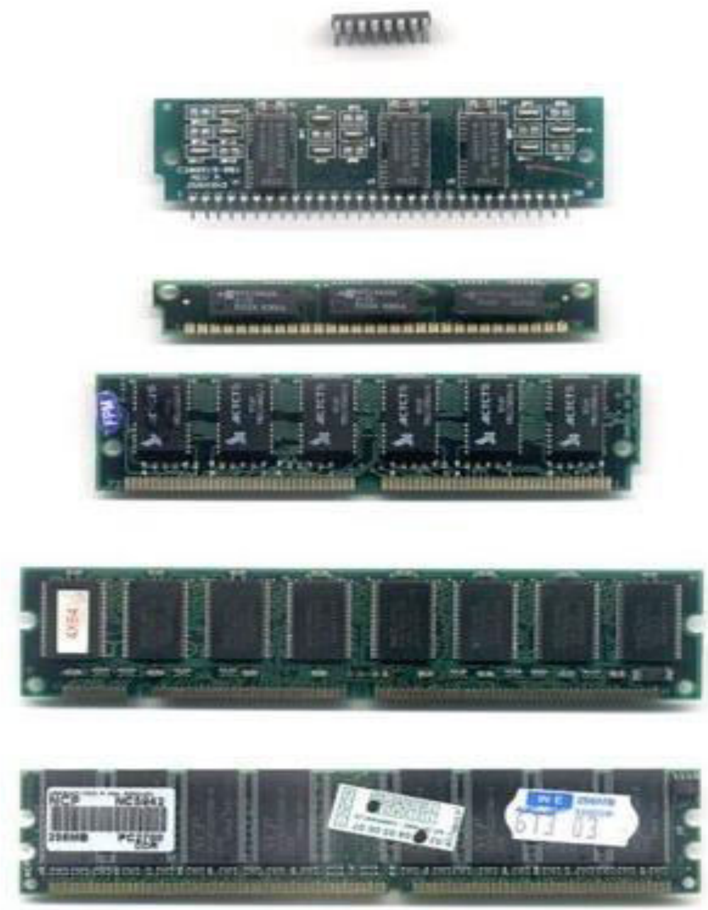
Introduction to Computer Architectures and Software

Memory

- Memory helps computers operate faster and more efficiently

- Random Access Memory (RAM)
  - Memory chips in a PC
  - Virtual Memory
  - Cache Memory (on the CPU)

- Read-Only Memory (ROM)
  - CD-ROM
  - DVD-ROM

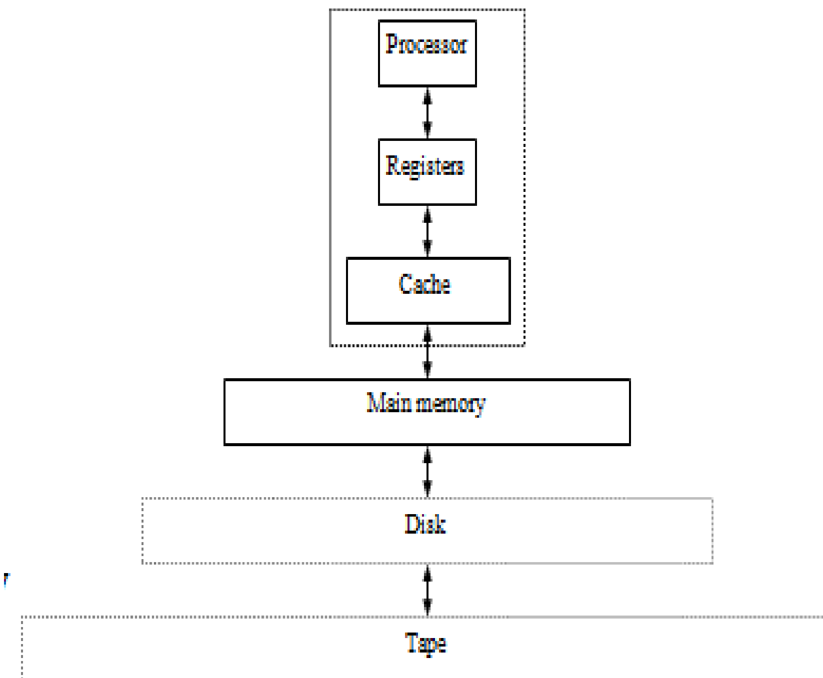


Information Technology Principles

Introduction to Computer Architectures and Software

Memory hierarchy

- Want inexpensive, fast memory
- Main memory
  - Large, inexpensive, slow memory stores entire program and data
- Cache
  - Small, expensive, fast memory stores copy of likely accessed parts of larger memory
  - Can be multiple levels of cache



Information Technology Principles

Introduction to Computer Architectures and Software

Storage permanence

- Range of storage permanence
  - High end
    - essentially never loses bits
    - e.g., mask-programmed ROM
  - Middle range
    - holds bits days, months, or years after memory's power source turned off
    - e.g., NVRAM
  - Lower range
    - holds bits as long as power supplied to memory
    - e.g., SRAM
  - Low end
    - begins to lose bits almost immediately after written
    - e.g., DRAM

Information Technology Principles

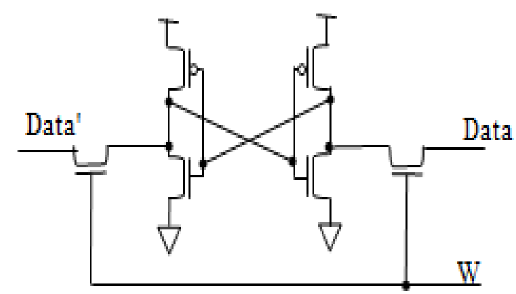
Introduction to Computer Architectures and Software

Basic types of RAM

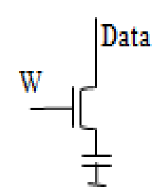
- SRAM: Static RAM
  - Memory cell uses flip-flop to store bit
  - Requires 6 transistors (used as memory cache)
  - Holds data as long as power supplied
  - Frequently small amount used in *cache memory* for high-speed access (more expensive than DRAM)
- DRAM: Dynamic RAM
  - Memory cell uses MOS transistor and capacitor to store bit
  - More compact than SRAM
  - "Refresh" required due to capacitor leak
    - word's cells refreshed when read
  - Typical refresh rate 15.625 microsec.
  - Slower to access than SRAM

memory cell internals

SRAM



DRAM



Information Technology Principles

Introduction to Computer Architectures and Software

ROM: "Read-Only" Memory

- Non-volatile memory:
  - Holds bits after power is no longer supplied
  - High end and middle range of storage permanence

- Can be read from but not written to, by a processor in an embedded system
- Traditionally written to, "programmed", before inserting to embedded system
- Uses
  - Store software program for general-purpose processor
    - program instructions can be one or more ROM words
  - Store constant data needed by system

Information Technology Principles

Introduction to Computer Architectures and Software

ROM: "Read-Only" Memory

- Memory to hold software that is not expected to change over the life of the system
- Magnetic core memory
- EEPROM
  - Electrically Erasable Programmable ROM
  - Slower and less flexible than Flash ROM
  - EEPROM write/erase one byte but Flash ROM W/E in blocks
- Flash ROM
  - Faster than disks but more expensive
  - Uses
    - BIOS: initial boot instructions and diagnostics
    - Digital cameras

Information Technology Principles

Introduction to Computer Architectures and Software

Hierarchy of Computer Systems

1. Supercomputers

Most **powerful** computers available (4-10 times faster than mainframes).

First used in **Military**, now used in **scientific**, **technical** and **business**.

Especially valuable for large simulation models of real-world phenomena, where complex mathematical representations & calculations are required.

Cray is the leading supercomputer manufacturer, while **Intel** also manufactured supercomputers. A recent Intel supercomputer can:

- Execute over 1 trillion operations per second.
- It has over 7,000 processors, thus supports parallel processing.
- Thus, it can calculate in 1 second what it would take the people of the US 125 years to calculate manually.

Used to generate extremely realistic scene in many movie special effects.

Size of RAM, Fixed Drive, Registers Size, Max. Integer and number of operations are also very powerful and higher scale than all other computers.

Information Technology Principles

Weather Forecasting – The National Oceanic and Atmospheric Administration (NOAA) in the US use Cray supercomputer to model weather for better prediction of weather. Providing early warnings of hurricanes, floods and storms.

(ii). Automotive Design - Japanese Nissan used Cray supercomputer in 1986 to:

a. Improve quality of car models

b. Reducing costs.

c. Shortening development time

(iii). Aircraft Design - The Boeing 777 design was modeled using a supercomputer, for more efficient and less costly production. A typical supercomputer calculation result can be displayed as graphic represents "air flow over an automobile, or aircraft. One color to indicate high pressure build-up, another color to indicate low pressure

Information Technology Principles

Introduction to Computer Architectures and Software

(iv). Movies – <u>Jurassic Park and Star War</u> movies, their graphics design produced by supercomputers. Supercomputers can make many sequences in motion pictures

<u>Specifications</u>:

- 60 billion to 3 trillion MIPs
- 8,000 MB (or more) of RAM.
- US$ 2 - 4 million.
- A size of a car

Information Technology Principles

Introduction to Computer Architectures and Software

2. Mainframes

Also called **servers**, and **time-sharing** systems. Less powerful and less expensive than supercomputers. Used in large corporations **to centralize data** processing and maintain large/shared databases.

Occupy an **entire room** and must be maintained and operated by highly trained staff or **specialists**.

Provide system administrators with **better control, security, management and maintenance** on data, information and applications.

IBM, **HP** and **Sun** are manufacturers of mainframes.

Application examples:

- Airline Reservation System
- Inventory Control System
- Payroll System
- Students Grade Calculation and Reporting System.

Information Technology Principles

Introduction to Computer Architectures and Software

<u>Specifications</u>:

- 40 - 4,500 MIPs
- 256 - 1,024 MB of RAM.
- US$ 1/4 - 2 million (or more).
- A size of refrigerator
- High capacity of magnetic/optical storage media [In TB (Tera Byte)].
- Several hundreds/thousands of on-line computers/terminals can be linked with mainframes.
- Today's mainframes can handle up to one-billion transaction per day.

Information Technology Principles

Introduction to Computer Architectures and Software

3. Minicomputers

Also called, **Midrange**, are similar to mainframes in supporting multi-user and multitasking environment but in a smaller scale.

Used in **scientific research**, and **engineering** applications.

Distributing data processing with minicomputers provides flexibility to large companies, instead of centralized computing in one location.

Inexpensive compared to mainframes. IBM is the market leader of minicomputers with its AS/400 series.

Specifications:

- 25 - 100 MIPs
- 32 - 512MB of RAM.
- US$ 20,000 – 100,000 (or more).
- A size of file cabinet

Information Technology Principles

Introduction to Computer Architectures and Software

<u>4. Workstations</u>

Desktop engineering workstation (workstation for short).

Provide very **<u>high-speed</u>** calculations and **<u>high-resolution graphics</u>**. Also support multitasking capabilities. Usually come with large displays.

Widespread acceptance in **<u>scientific community</u>** and , more recently, within the business community.

Originally more powerful than PCs, but now one of the latest PC may have computing power similar or more than a recent workstation.

Examples: **<u>IBM's RISC</u>** Systems/6000 and **<u>Sun</u>** Workstations

<u>Specifications</u>:

- 50 - 100 MIPs
- 32 - 256 MB of RAM.
- US$ 4,000 – 20,000 (or more).
- Fits on desktop.

Information Technology Principles

Introduction to Computer Architectures and Software

5. Microcomputers

Also called **Personal Computers** (PCs) are the smallest and least expensive category of general-purpose computers.

First introduced by **Apple**, then other vendors like **IBM** followed.

A group of PCs usually hooked together to form a **network** (eg. LAN) and act as a sort of mainframe like system.

They can be classified into three types, based on their sizes:

- **Desktops** (most common ones every boy use them)
- **Laptops** and **Notebooks** (small, portable and easy transportable)
- **Palmtops** (hand held, but limited in no. of ways for I/O . For example, a Personal Digital Assistant (PDA) is a hand held, palmtop computer uses a pen rather keyboard for inputs. PDAs support hand-writing, and voice-recognition).

Specifications:

- 5 - 20 MIPs
- 16 - 128 MB of RAM (or more).
- US$ 1,000 – 2,500
- Fits on desktop

Information Technology Principles

Introduction to Computer Architectures and Software

6. Network computers (NCs)

Also known as **"thin clients"** because they store little data and few applications and do not have full functionality like desktops.

Less expensive than standard PCs, and need less maintenance.

Used to **access networks**, they act more like terminals, temporarily, receiving/using data and applications stored some where else.

They work best in the following situations:

- Users who work with a limited set of programs (secretaries and top-level executives –For email, word-processing etc.).
- Shared Desktops (contractors, consultants, part-time employees etc.)
- Remote users who are difficult to support (less to go wrong and less to fix in such computers).
- Whenever security is critical.

Specifications:

- 5 MIPs
- 4 - 16 MB of RAM.
- US$ 500 – 1,500
- Fits on desktop.

Information Technology Principles

Introduction to Computer Architectures and Software

The Central Processing Unit (CPU)

- The “brains” of the computer
- Performs calculations and completes instructions
- Performance based on clock speed--how many instructions can it accomplish in a cycle
  - Pentium 4 --- 2.0 GHz chip operates at 2 billion cycles per second…can do one instruction per cycle per pipeline (“20 stage depth pipeline” says the information Intel provides on their website: www.intel.com)

Information Technology Principles

Introduction to Computer Architectures and Software

The Central Processing Unit (CPU)

Central Processing Unit (CPU) –Processor

It performs the computations or "**number crunching**" inside any computer.

The CPU is made up of millions of microscopic **transistors** embedded in a circuit on a silicon chip, that's why it is called a **chip**.

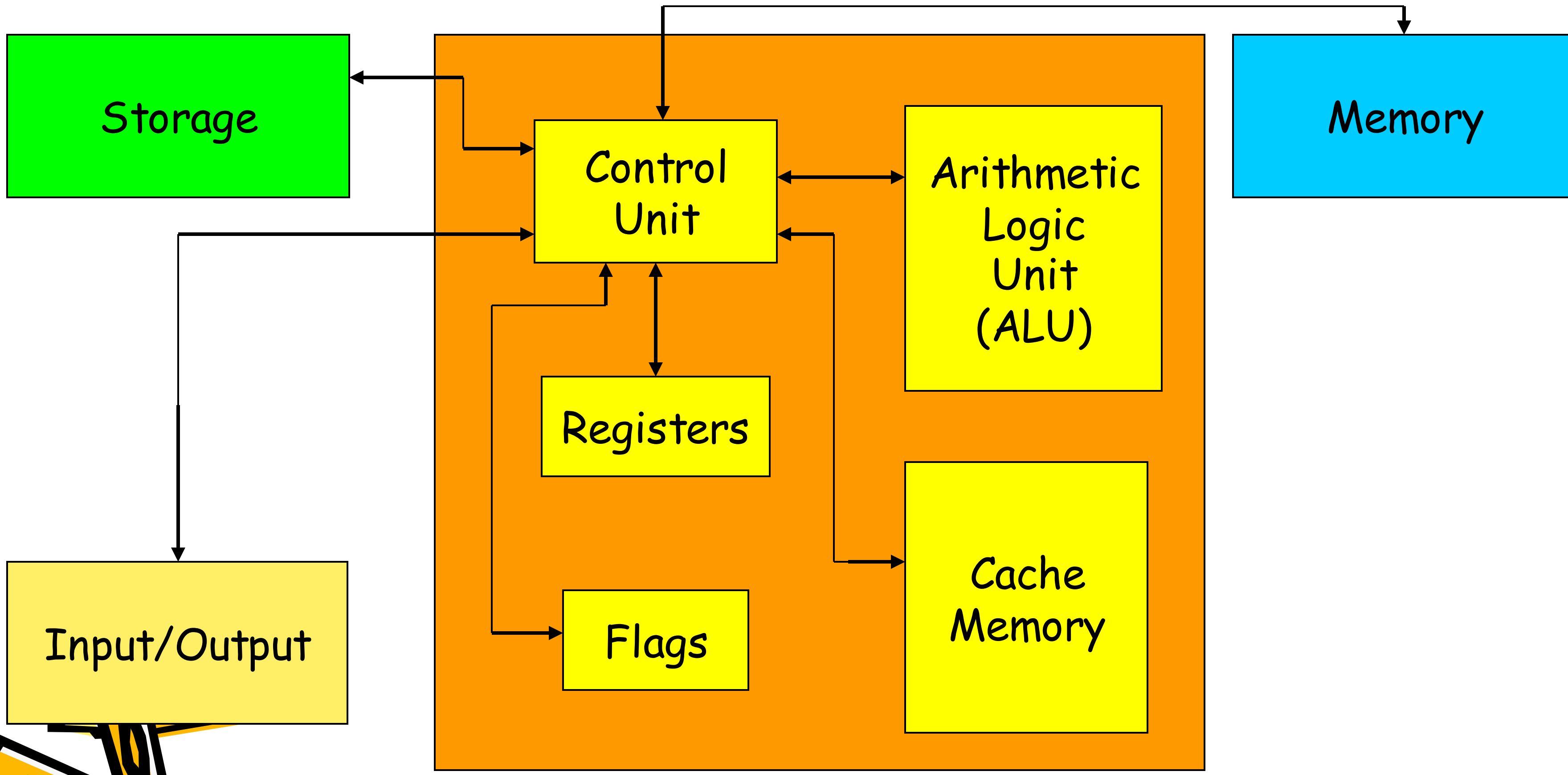
The CPU has different portions:

- **Control-Unit (CU)**, controls the flow of information between the computer system components.
- **Arithmetic-Logic-Unit (ALU)**, performs the arithmetic and logic operations
- **Registers**, store very small amount of information (data & instructions) for short period of time.

Information Technology Principles

Introduction to Computer Architectures and Software

The CPU

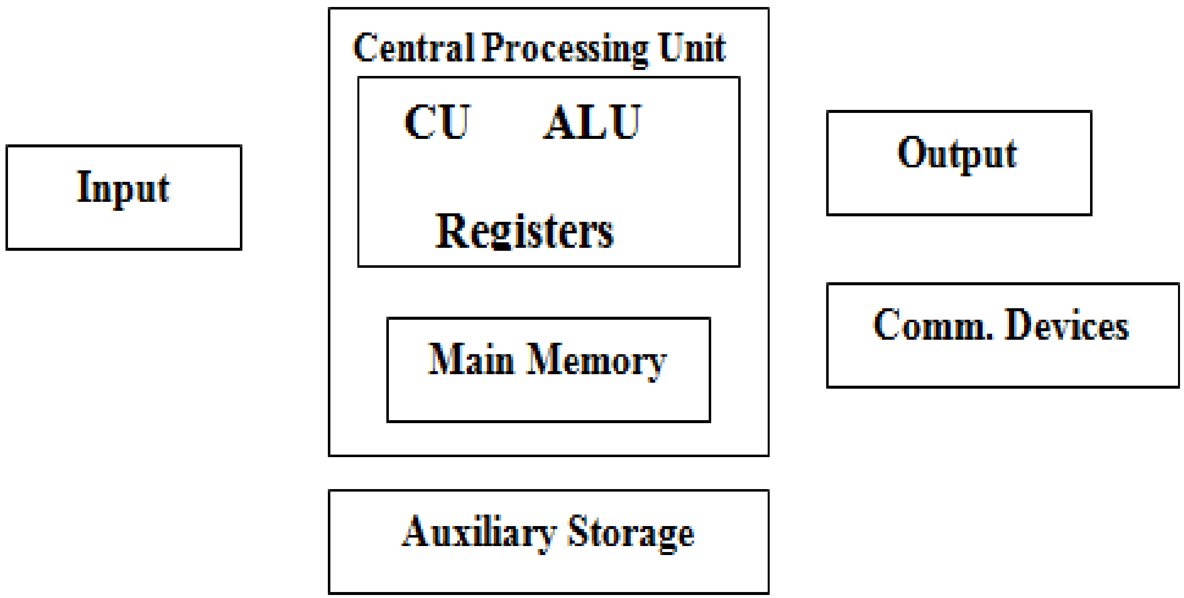


63

Information Technology Principles

Introduction to Computer Architectures and Software

The Central Processing Unit (CPU)



The Central Processing Unit (CPU)

How the CPU works?

{Think of it as a tiny factory!}

Steps:

- **Inputs** (data & instructions) come from software programs. Data may be entered from the keyboards, or read from a data file.
- Inputs are stored in **registers** until they are sent to the next step.
- The ALU receives the data and instructions from the registers and makes the desired **computation**.
- The **transformed** data **stored** temporarily into another register and then **out** of the CPU (monitor, or file).

Information Technology Principles

Introduction to Computer Architectures and Software

The Central Processing Unit (CPU)

How the CPU works?

Notes:

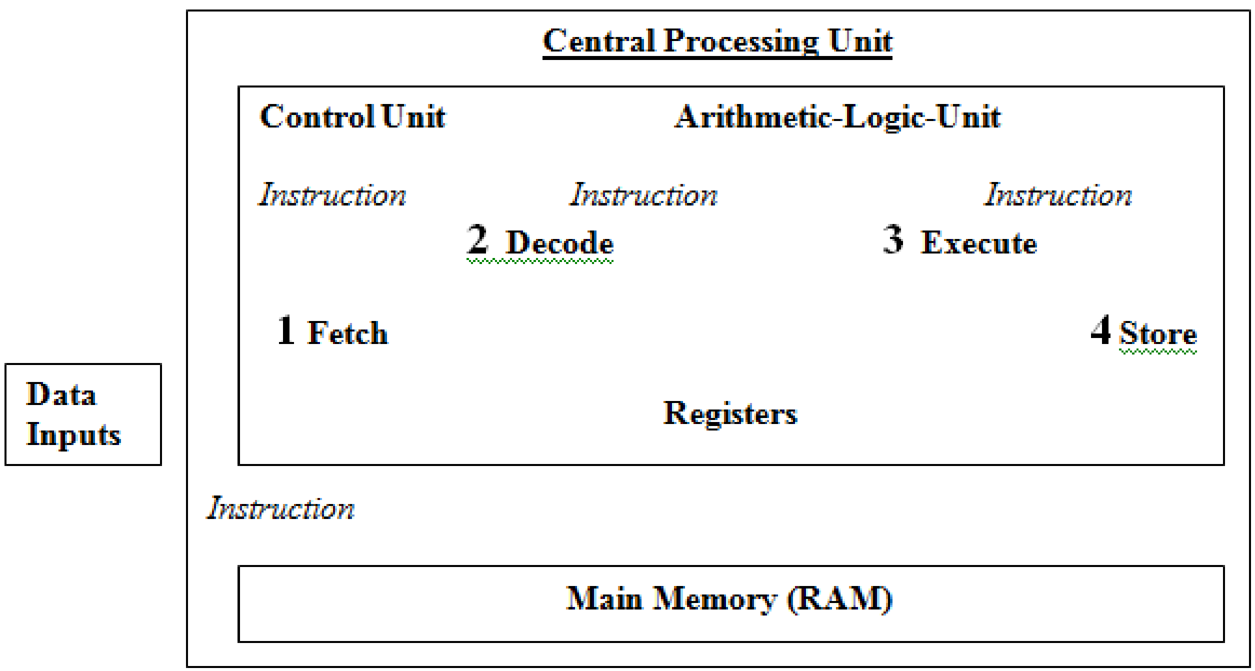
- CPU can only process binary data, so data & instructions are translated into binary form.
- CU directs the flow of data and instructions within the chip.
- Data and instructions travel within electrical pathways called buses.

Information Technology Principles

Introduction to Computer Architectures and Software

The Central Processing Unit (CPU)

How the CPU works?



Information Technology Principles

Introduction to Computer Architectures and Software

How the CPU works?

This cycle of processing known as "**machine instruction cycle**" occurs millions of times per seconds. The speed is commonly measured by the number of instructions the chip processes per second - **machine instruction cycles per second (MIPS).**

➔ The speed depends on the following **factors:**

The preset speed of the clock that times all chip activities, measured in megahertz (MHz). The faster the **clock speed**, the faster the chip.

- **Word-length**, the no. of bits that can be processed at one time (8, 16 or 32-bit)

Bus-Width, the physical avenues down which the data travel as electrical impulses. The wider the bus the faster data can be moved. Buses measured in microns (1000,000,000 microns = 1 meter).

The **physical design** of the chip, the more compact and efficiently laid out, the faster the processing. The more transistors the faster the chip.

[factory & material Vs chip & data/instructions]

Information Technology Principles

Introduction to Computer Architectures and Software

How the CPU works?

- ***Advancing the chip design:***
- Increase **miniaturization** of transistors.
- Decreasing **line-width** (distance between transistors).
- Components layout design Vs efficiency.
- Using better **conductive** materials (for better flow of electricity)
  - Silicon
  - Gallium Arsenide}____Faster
  - Silicon **G**ermanium}
- Amount of basic instructions programmed into the chip:
  - Complex Instruction Set Computing (**CISC**), very comprehensive.
  - Reduced Instruction Set Computing (**RISC**), rely on software to provide special instructions

Information Technology Principles

		Von Neumann (CISC) Architecture Processors				Harvard (RISC) Architecture Processors			
		(Macs)		(PCs)		(PCs)			(Macs)
External Bus	Internal Bus	Motorola CPU	Cache	Intel CPU	Approx Year	AMD CPU	Berkeley Fujitsu CPU	Stanford MIPS CPU	Motorola/IBM CPU
8-bit		6500, 6502	-	8080	1975	-	-	-	-
		6800	-		1976	-	-	-	-
8	16		-	8088	1977	-	-	-	-
			-	8086 (1)	1980	-	-	-	-
16-bit			-	80186	1981	-	-	-	-
			-	80286	1982	-	-	-	-
16	32	68000	-	80286 (2)	1982	-	-	-	-
		68020	256	-	1985	-	-	R2000	-
32-bit		68030 (mmu)	8K	80386 (3)	1987	29000	-	R3000	-
		68040 (mmu)	8K	80486 (4)	1990	-	SPARC	-	-
			-	-	1991	-	-	R4000	-
			-	Pentium (5)	1993	-	-	R4400	PPC 601
32	64		-	-	1994	5x86	SPARC II	R4600	PPC 603
64-bit			256K	Pentium Pro (6)	1995	-	USPARC I	-	PPC 620
			512K	Pentium II	1996	K5	SPARC 2	R5000	-
			-	Pent MMX	1997	K6	USPARC II	R6000	-
			128K	Celeron	1998	-	-	R12000	-
			256K	Pentium 3	1999	Athlon	-	-	G3
64	128		512K	Pentium 4 (7)	2000	K7	Ultra	-	-
			-	Celeron II		-	SPARC 3	-	G4
			-	Duron		-	-	-	-
128-bit			-	-	2001	-	USPARC III	R14000	-
			-	-	2002	-	-	R16000	-
128	256		-	-	2003	-	-	-	-
256-bit			-	-	2004	-	-	R16000A	G5
			-	-	2005	-	-	-	-
			-	Intel Core (8)	2006	-	-	-	-
		(von neumann bottleneck) (1 bus system)				Separate address and data space (2 bus system)			

Information Technology Principles

Introduction to Computer Architectures and Software

The Lineage of Intel Microprocessor (1974-1999):

April 1974	8080 Chip	Clock Speed 2 MHz MIPS: 0.64 **Transistors: 6,000** Internal Bus: 8-bit
June 1978	8086 Chip	Clock Speed 5 MHz MIPS: 0.33 **Transistors: 29,000** Internal Bus: 16-bit
June 1979	8088 Chip	Clock Speed 5 MHz MIPS: 0.33 **Transistors: 29,000** Internal Bus: 16-bit

Information Technology Principles

Introduction to Computer Architectures and Software

<u>The Lineage of Intel Microprocessor (1974-1999):</u>

[~ ~ ~ 1981	IBM PC]	
February 1982	286 Chip	Clock Speed 8 MHz
	{80286}	MIPS: 1.2
		Transistors: 134,000
		Internal Bus: 16-bit
[~ ~ ~ 1984	IBM PC AT]	
October 1985	386DX Chip	Clock Speed 16 MHz
		MIPS: 6
		Transistors: 275,000
		Internal Bus: 32-bit

Information Technology Principles

Introduction to Computer Architectures and Software

The Lineage of Intel Microprocessor (1974-1999):

- [~ ~ ~ 1986 Compaq Desktop 386]
-
- June 1988 386SX Chip Clock Speed 16 MHz
- MIPS: 2.5
- **Transistors: 275,000**
- Internal Bus: 32-bit

- April 1989 486DX Chip Clock Speed 25 MHz
- MIPS: 20
- **Transistors: 1.2 million**
- Internal Bus: 32-bit
-
- [~ ~ ~ 1989 ALR PowerCache 4]

Information Technology Principles

Introduction to Computer Architectures and Software

The Lineage of Intel Microprocessor (1974-1999):

April 1991	486SX Chip	Clock Speed 20 MHz
		MIPS: 16.5
		Transistors: 1.185 million
		Internal Bus: 32-bit
March 1992	486DX2 Chip	Clock Speed 50 MHz
		MIPS: 40
		Transistors: 1.2 million
		Internal Bus: 32-bit
May 1993	Pentium Chip	Clock Speed 66 MHz
		MIPS: 112
		Transistors: 3.1 million
		Internal Bus: 64-bit

Information Technology Principles

Introduction to Computer Architectures and Software

The Lineage of Intel Microprocessor (1974-1999):

Fall	1995	Pentium Pro Chip	Clock Speed 150-200 MHz MIPS: ? ? ? **Transistors: 5.5 million**
May	1997	Pentium II Chip	Clock Speed 350-400 MHz MIPS: ? ? ? **Transistors: 7.5 million**
January	1999	Pentium III Chip	Clock Speed 450-550 MHz MIPS: ? ? ? **Transistors: 9.5 million**

Information Technology Principles

Introduction to Computer Architectures and Software

Central processing Units (CPU's) History:

Intel Processor Generations Summary

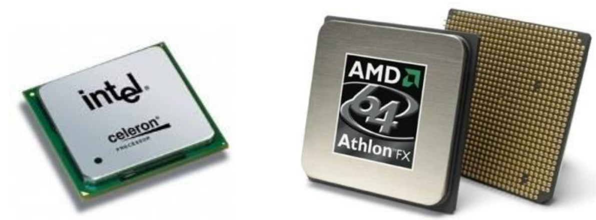
Generation	Intel CPU	Approx. Year
1st Generation	8086 (1)	**1980**
	80186	1981
	80286	1982
2nd Generation	80286 (2)	**1982**
3rd Generation	80386 (3)	**1987**
4th Generation	80486 (4)	**1990**
5th Generation	Pentium (5)	**1993**
6th Generation	Pentium Pro (6)	**1995**
	Pentium II	1996
	Pent. MMX	1997
	Celeron	1998
	Pentium 3	1999
7th Generation	Pentium 4 (7)	**2000**
	Celeron II	2000
	Duron	2000
8th Generation	Intel Core (8)	**2006**
	DX= w/ math copro. SX= without SLC= low power	

CPU processor development chronology
History of Computer Processor Evolution
List of CPU microprocessors
Central Processor Unit Summary
CPU Upgrade Path

Information Technology Principles

Introduction to Computer Architectures and Software

Central processing Units (CPU's) Manufacturers:



1. Intel (www.intel.com)

2. AMD (www.amd.com)

3. Motorola (www.motorola.com)

4. Cyrix (beg. in 1988, and in Nov. 1997 merged with National Semiconductor)

4. VIA Technologies (www.viatechnology.com)

5. Transmeta Corporation (www.transmeta.com, Founded in 1995,)

Information Technology Principles

Introduction to Computer Architectures and Software

COPROCESSORS

- Additional chips which could be purchased with 386 and older chips.
- An option to help reduce the cost of computers.
- Coprocessors allow the hardware for floating-point math.
- Math coprocessors will speed your computer's operation

Processor	Coprocessor
8086	8087
8088	8087
80286	80287
80386SX	80387SX
80386SL	80387SX
80386SLC	80387SX
80486SLC	80387SX
80486SLC2	80387SX
80386DX	80387DX
80486SX	80487SX, DX2/Overdrive
80487SX	Included FPU
80486SX2	DX2/Overdrive
80486DX	Included FPU
80486DX2	Included FPU
80486DX4	Included FPU
Pentium/Pentium-MMX	Included FPU
Pentium Pro	Included FPU
Pentium II	Included FPU
Pentium III	Included FPU

- Computers now no longer require the extra purchase of the math compressor.

Information Technology Principles

Introduction to Computer Architectures and Software

COMPATIBLE INTEL PROCESSORS

- Several companies such as AMD and Cyrix are also developing processors
- Such which are completely compatible with Intel processors.
- This means that they are capable of emulating every processor instruction in the Intel chips.

Parallel Processing - Method of evenly <u>distributing computer processes</u> Between two or more computer processors. This requires a computer with two or more processors installed and enabled, an Operating System capable of Supporting two or more processors, and software programs capable of evenly Distributing processes between the computer processors.

Information Technology Principles

Introduction to Computer Architectures and Software

Clock Speed:

Also could be called Clock Rate, clock speed is the speed at which the microprocessor executes each instruction. The CPU requires a fixed number of clock ticks, or cycles, to execute each instruction. The faster the clocks rate, the faster the CPU, or the faster it can execute instructions. Clock Speeds are usually determined in MHz, 1 MHz representing 1 million cycles per second, or in GHz, 1 GHz representing 1 thousand million cycles per second.

Information Technology Principles

Introduction to Computer Architectures and Software

Dual Processors - Computer that has two separate processors that work together.

Dual processors are commonly used for intensive processing demands and improves the computer's overall processing efficiency. It is important to note that not all operating systems and software programs support dual processors. Often this is true with older operating systems such as Microsoft Windows 98; however, newer operating systems such as Microsoft Windows XP do support dual processors.

MIPS - Short for **Milli Instructions Per Second**, **MIPS** is the approximate number of commands carried out in one second. MIPS is a measurement of speed for a processor or program.

Information Technology Principles

Introduction to Computer Architectures and Software

Overclocking: The term overclocking is thrown around a lot, for better or worse.

The idea is simple enough; make the computer's processor run faster than its
Stock speed to gain more performance without paying for it.

Overclocking a computer's processor or memory causes it to go faster than its factory rated speed

Overclocking a computer's processor or memory causes it to go faster than its factory rated speed. A processor rated at 2.4GHz might be overclocked to 2.5GHz or 2.6GHz, while memory rated at 200MHz might be pushed to 220MHz or higher.

The extra speed results in more work being done by the processor and/or memory in a given time period, increasing the overall computing performance of the PC.

Information Technology Principles

Introduction to Computer Architectures and Software

Bus System

- The physical connection that makes it possible to transfer data from one location in the computer system to another

- Group of electrical conductors for carrying signals from one location to another
  - *Line*: each conductor in the bus

- 4 kinds of signals
  1. Data (alphanumeric, numerical, instructions)
  2. Addresses
  3. Control signals
  4. Power (sometimes)

Information Technology Principles

Introduction to Computer Architectures and Software

Bus System

- Connect CPU and Memory

- I/O peripherals: on same bus as CPU/memory or separate bus

- Physical packaging commonly called *backplane*
  - Also called *system bus* or *external bus*
  - Example of *broadcast bus*
  - Part of printed circuit board called *motherboard* that holds CPU and related components

Information Technology Principles

Introduction to Computer Architectures and Software

Bus System

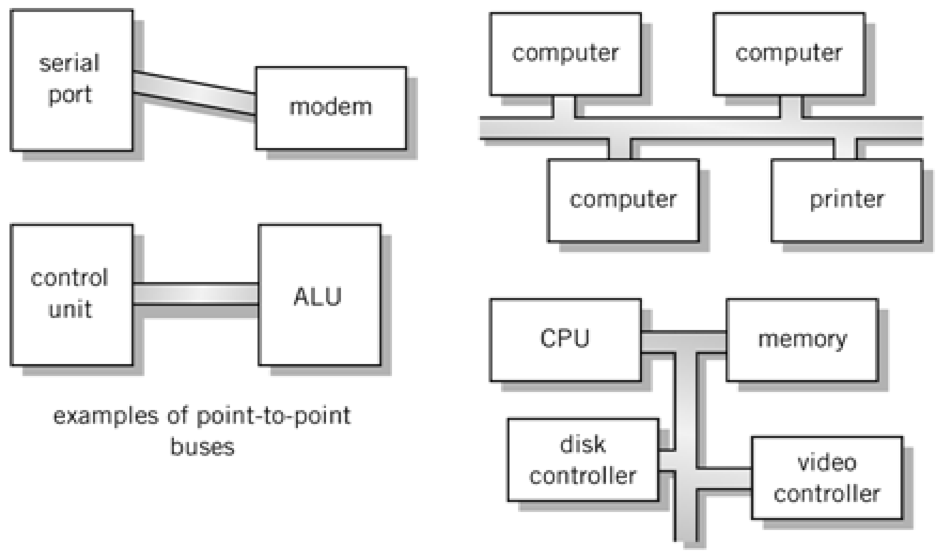
- **Protocol**
  - Documented agreement for communication
  - Specification that spells out the meaning of each line and each signal on each line
- **Throughput**, i.e., data transfer rate in bits per second
- **Data width** in bits carried simultaneously

Information Technology Principles

Introduction to Computer Architectures and Software

Bus system (Point-to-point vs. Multipoint)

Plug-in device



examples of point-to-point buses

examples of multipoint buses

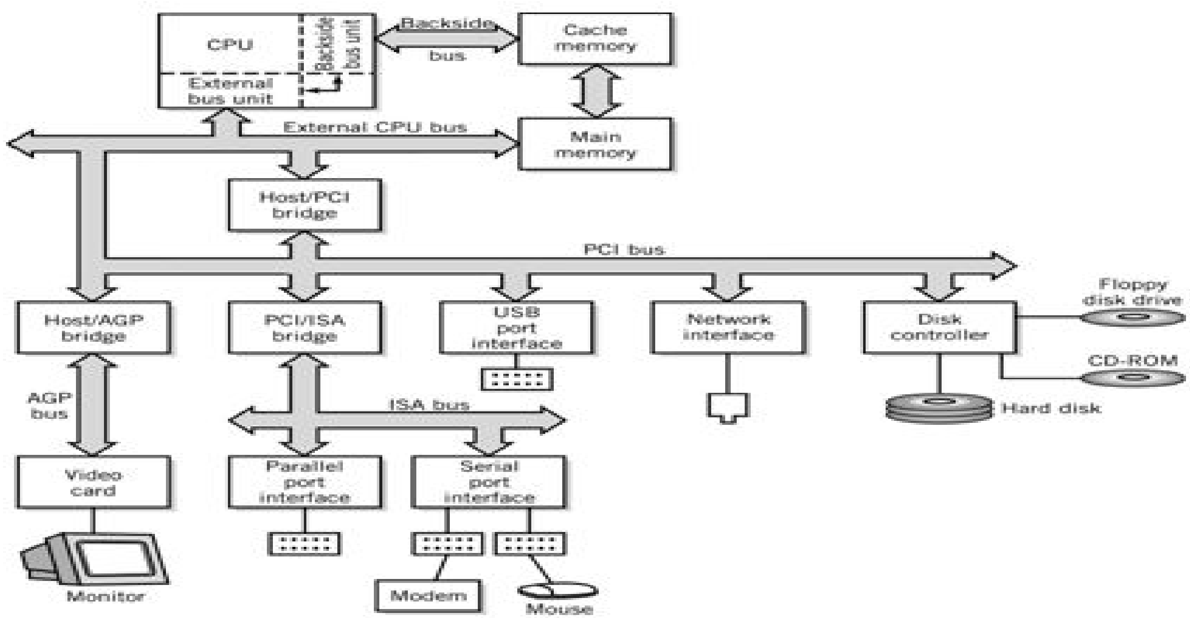
Broadcast bus Example: Ethernet

Shared among multiple devices

Information Technology Principles

Introduction to Computer Architectures and Software

Bus system (Typical PC Interconnections)



Bus interface bridges connect different bus types

Information Technology Principles

Introduction to Computer Architectures and Software

Bus system (Typical PC Interconnections)

PCI bus: Short for *Peripheral **C**omponent **I**nterconnect*, a local bus standard

Developed by Intel Corporation

- PCI is also used on newer versions of the Macintosh computer.
- PCI is a **64-bit bus**, though it is usually implemented as a **32-bit** **bus**.
- It can run at clock speeds of **33 or 66** **MHz**.
- At 32 bits and 33 MHz, it yields a
- **throughput rate of 133 MBps.**
- Although it was developed by Intel, PCI is not tied to any particular family of microprocessors.
- Using PCI, a computer can support both new PCI cards while continuing to support Industry Standard Architecture (ISA) expansion cards, an older standard
- PCI is now installed on most new desktop computers, not only those based on Intel's Pentium processor but also those based on the PowerPC

Information Technology Principles

Introduction to Computer Architectures and Software

Bus system (Typical PC Interconnections)

- **Industry Standard Architecture** (in practice almost always shortened to **ISA**) was a computer bus standard for IBM compatible computers.
- ISA originated as **an 8-bit system in the IBM PC in 1981**,
- and was extended in 1983 as the XT bus architecture.
- The newer 16-bit standard was introduced in 1984. Designed to connect peripheral cards to the motherboard,
- The 8-bit bus ran at 4.77 MHz, while the 16-bit bus operated at 6 or 8 MHz. In reference to the XT bus, it is sometimes referred to as the AT bus architecture

Information Technology Principles

Introduction to Computer Architectures and Software

Bus system (Typical PC Interconnections)

- AGP bus: Short for ***Accelerated Graphics Port***, an interface specification developed by Intel Corporation. AGP is based on PCI, but is
- **Designed especially for the throughput demands** of 3-D graphics. Rather than using the PCI bus for graphics data,
- AGP introduces a dedicated **point-to-point channel** so that the graphics controller can directly access main memory.
- **The AGP channel is 32 bits** wide and
- **runs at 66 MHz**. This translates into a
- total **bandwidth of 266 MBps**, as opposed to the PCI bandwidth of 133 MBps. AGP also supports two optional **faster modes, with throughputs of 533 MBps and 1.07 GBps**.

Introduction to Computer Architectures and Software

Instructions

- Instruction
  - Direction given to a computer
  - Causes electrical signals to be sent through specific circuits for processing
- Instruction set
  - Design defines <u>functions performed by the processor</u>
  - Differentiates computer architecture by the
    - Number of instructions
    - Complexity of operations performed by individual instructions
    - Data types supported
    - Format (layout, fixed vs. variable length)
    - Use of registers
    - Addressing (size, modes)

Information Technology Principles

Introduction to Computer Architectures and Software

Instructions Elements

- OPCODE: task
- Source OPERAND(s)
- Result OPERAND
  - Location of data (register, memory)
    - Explicit: included in instruction
    - Implicit: default assumed

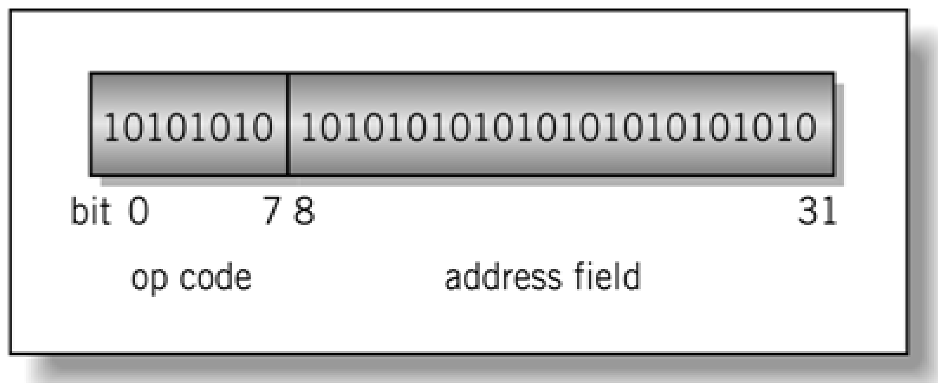
OPCODE	Source OPERAND	Result OPERAND

Introduction to Computer Architectures and Software

Instruction Format

- *Machine-specific* template that specifies
  - Length of the op code
  - Number of operands
  - Length of operands

Simple 32-bit Instruction Format



Information Technology Principles

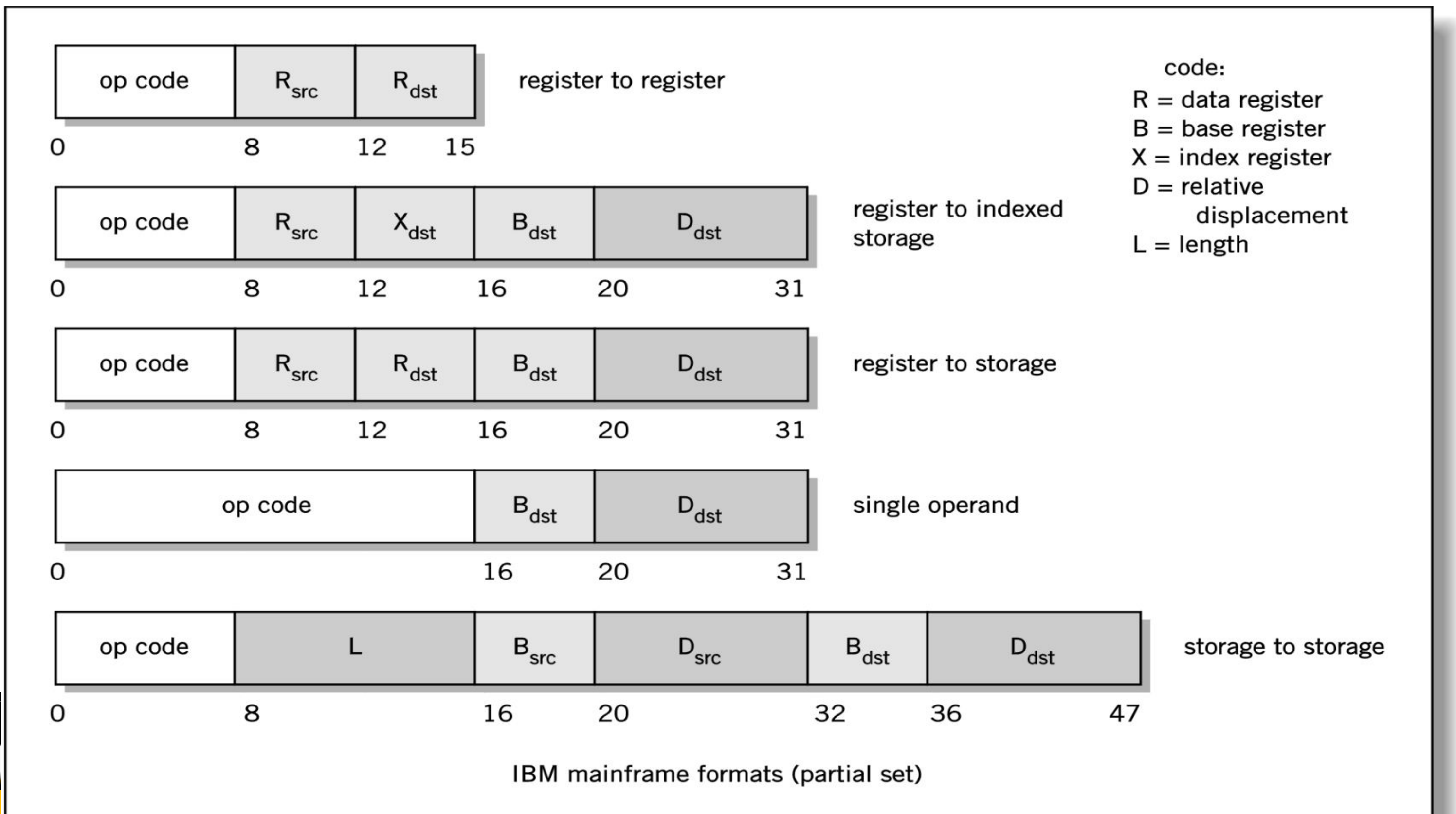
Introduction to Computer Architectures and Software

Instruction Format

Information Technology Principles

Introduction to Computer Architectures and Software

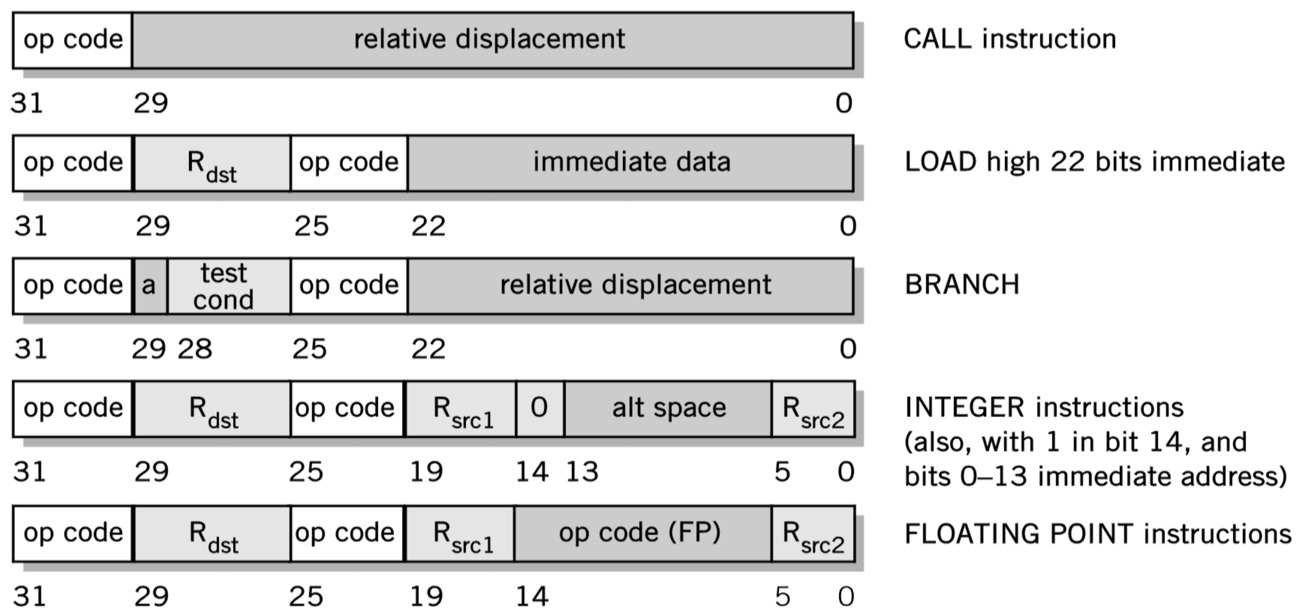
Instruction Formats: CISC



Information Technology Principles

Introduction to Computer Architectures and Software

Instruction Formats: RISC



SPARC RISC formats (complete set)

Information Technology Principles

Introduction to Computer Architectures and Software

Instruction Formats: RISC example1

Statements in H	Statements in Assembly for A-1 computer
1.A = 20; 2.B = Cube(A);	1.Move [A, 20] 2.Mult [A, A] 3.Mult [A, A] 4.Move [B, A]

Information Technology Principles

Introduction to Computer Architectures and Software

Instruction Formats: CISC example1

Statements in H	Statements in Assembly for A-2 computer
1.A = 20; 2.B = Cube(A);	1.Move [A, 20] 2.Cube[B, A]

Information Technology Principles

Introduction to Computer Architectures and Software

Instruction Formats: RISC example2

RISC processors only use simple instructions that can be executed within one clock cycle. Thus, the "MULT" command described above could be divided into three separate commands: "LOAD," which moves data from the memory bank to a register, "PROD," which finds the product of two operands located within the registers, and "STORE," which moves data from a register to the memory banks. In order to perform the exact series of steps described in the CISC approach, a programmer would need to code four lines of assembly:

```
LOAD A, 2:3
LOAD B, 5:2
PROD A, B
STORE 2:3, A
```

Information Technology Principles

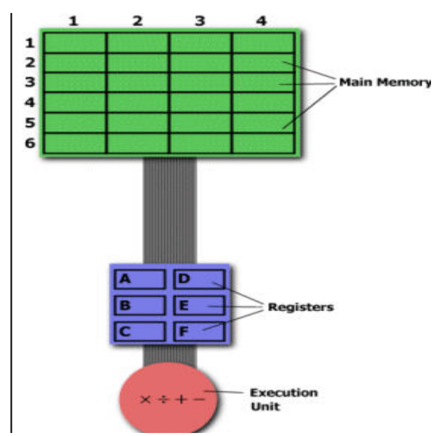
Introduction to Computer Architectures and Software

Instruction Formats: CISC example2

- **The CISC Approach**
  The primary goal of CISC architecture is to complete a task in as few lines of assembly as possible. This is achieved by building processor hardware that is capable of understanding and executing a series of operations. For this particular task, a CISC processor would come prepared with a specific instruction (we'll call it "MULT"). When executed, this instruction loads the two values into separate registers, multiplies the operands in the execution unit, and then stores the product in the appropriate register. Thus, the entire task of multiplying two numbers can be completed with one instruction:

MULT 2:3, 5:2

MULT is what is known as a "complex instruction."



Information Technology Principles

Introduction Computer Architectures and Software

Chip Types

- Complex Instruction Set Computer (CISC)
  - Many forms of instructions (some special purpose, but chip must support them all)
  - x86, Pentium
- Reduced Instruction Set Computer (RISC)
  - Specific list of supported instructions (Want to do something else? Find a combination of instructions to accomplish the task)
  - Power PC (Motorola), Alpha, IBM RISC System/6000, Sun SPARC, MIPS
- Difference is speed of execution: RISC is faster, but may require longer instruction combinations to accomplish the same task as a CISC

Information Technology Principles

Introduction Computer Architectures and Software

CISC Architecture

Characteristics

- Few general purpose registers
- Many addressing modes
- Large number of specialized, complex instructions
- Instructions are of varying sizes

Information Technology Principles

Introduction Computer Architectures and Software

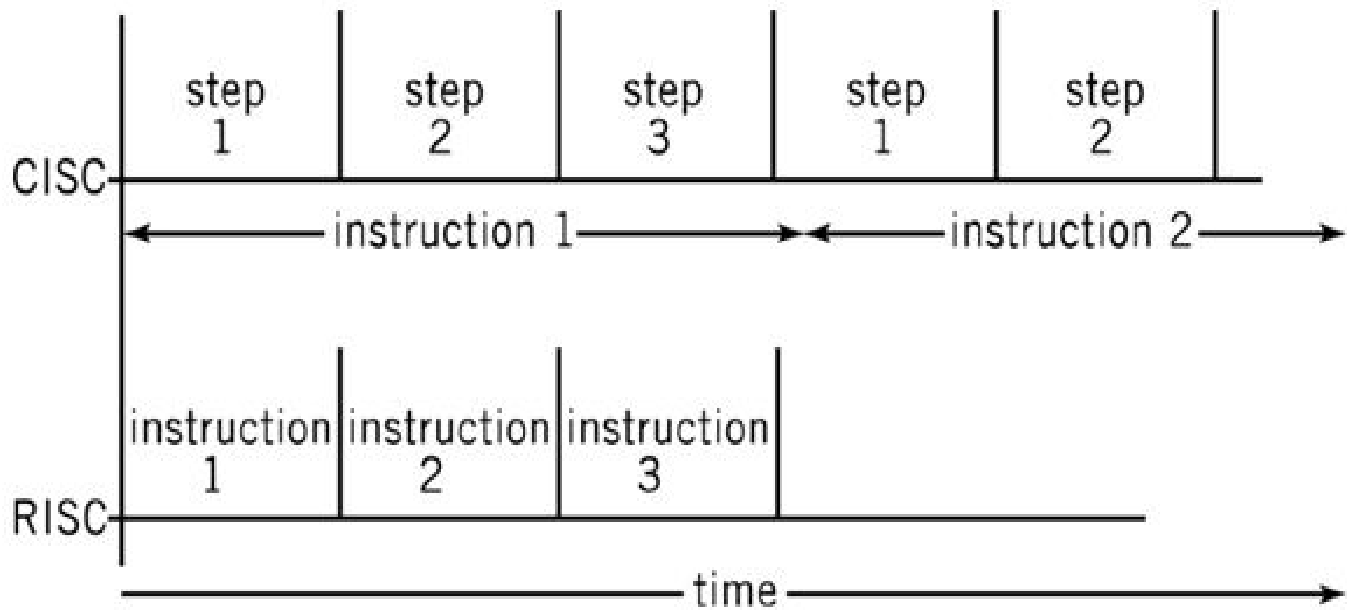
RISC Features

- Limited and simple instruction set
- Fixed length, fixed format instruction words
  - Enable pipelining, parallel fetches and executions
- Limited addressing modes
  - Reduce complicated hardware
- Register-oriented instruction set
  - Reduce memory accesses
- Large bank of registers
  - Reduce memory accesses
  - Efficient procedure calls

Information Technology Principles

Introduction to Computer Architectures and Software

CISC vs. RISC Processing



Information Technology Principles

Introduction to Computer Architectures and Software

Instruction Types

- Data Transfer (load, store)
  - Most common, greatest flexibility
  - Involve memory and registers
- Arithmetic
  - Operators **+ - / * ^**
  - Integers and floating point
- Logical or Boolean
  - Relational operators: **> < =**
  - Boolean operators **AND, OR, XOR, NOR,** and **NOT**
- Single operand manipulation instructions
  - Negating, decrementing, incrementing

Information Technology Principles

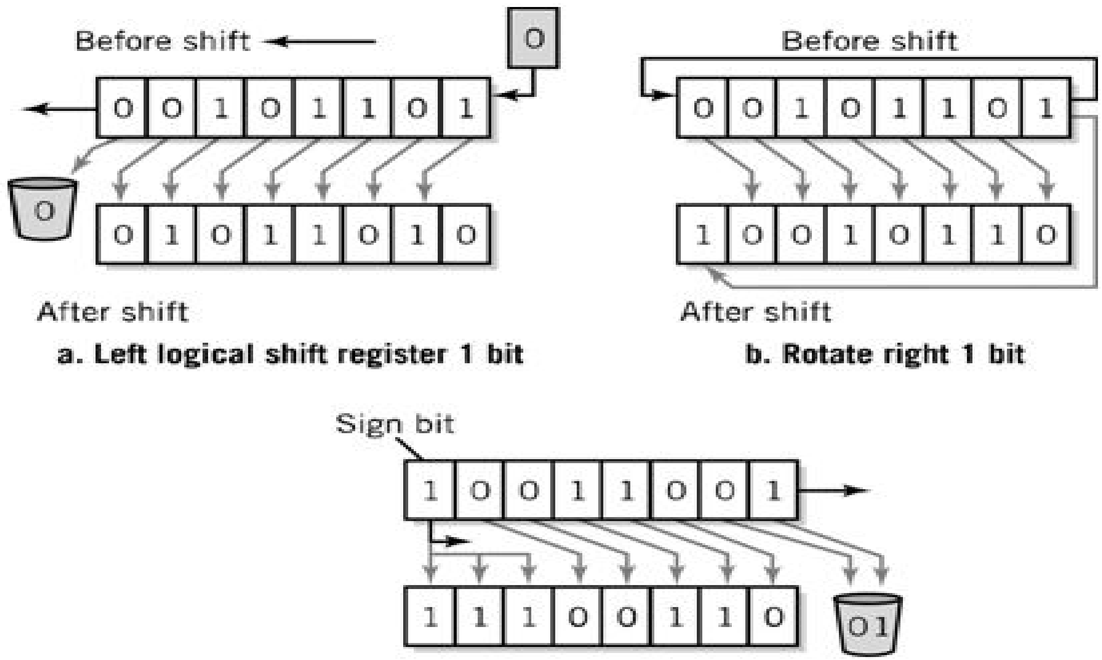
Introduction to Computer Architectures and Software

More Instruction Types

- Bit manipulation instructions
  - Flags to test for conditions
- Shift and rotate
- Program control
- Stack instructions
- Multiple data instructions
- I/O and machine control

Introduction to Computer Architectures and Software

Register Shifts and Rotates



a. Left logical shift register 1 bit

b. Rotate right 1 bit

c. Right arithmetic shift 2 bits

Information Technology Principles

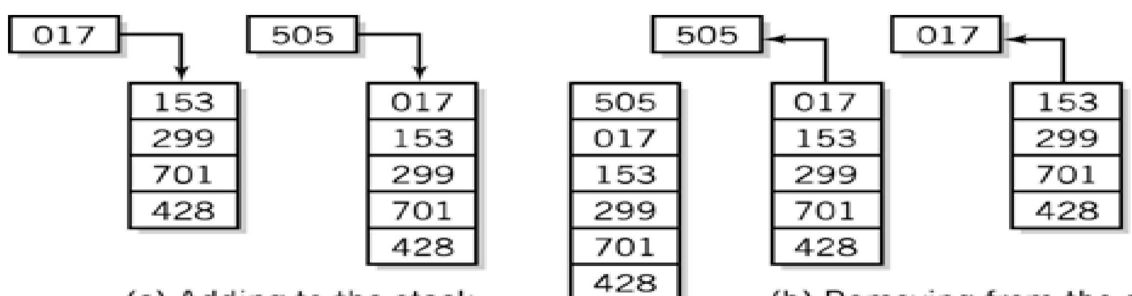
Introduction to Computer Architectures and Software

Stack Instructions

The stack is a place where data is temporarily stored

POP and PUSH are the most basic ones. PUSH can "push" a value on the stack and POP can retrieve that value from the stack

- Stack instructions
  - LIFO method for organizing information
  - Items removed in the reverse order from that in which they are added



(a) Adding to the stack (b) Removing from the stack

Push Pop

Information Technology Principles

Introduction to Computer Architectures and Software

Stack Instructions (PUSH, POP example 1)

```
MOV   AX,1234H
PUSH  AX
MOV   AH,09
INT   21H
POP   AX
```

The final value of AX will be 1234h. First we load 1234h into AX, then we push that value to the stack. We now store 9 in AH, so AX will be 0934h and execute an INT. Then we pop the AX register. We retreive the pushed value from the stack. So AX contains 1234h again. Another example:

Stack Instructions (PUSH, POP example 2)

The values: AX=5678h BX=1234h First the value 1234h was pushed after that the value 5678h was pushed to the stack. Acording to LIFO 5678h comes of first, so AX will pop that value and BX will pop the next

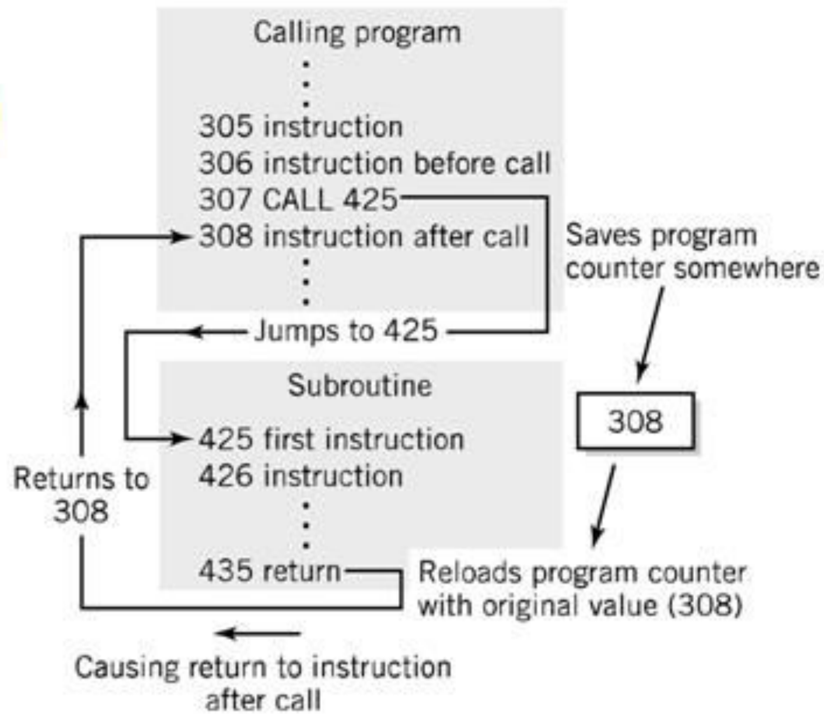
```
MOV   AX,1234H
MOV   BX,5678H
PUSH  AX
PUSH  BX
POP   AX
POP   BX
```

Information Technology Principles

Introduction to Computer Architectures and Software

Program Control Instructions

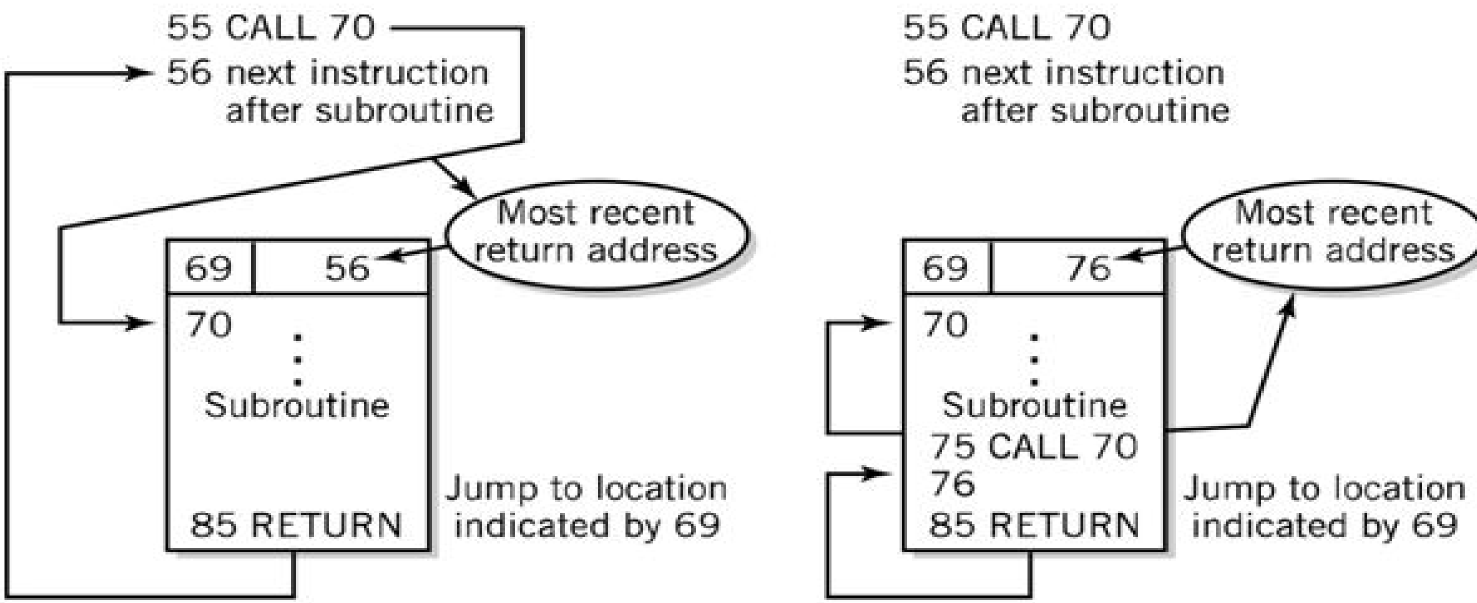
- Program control
  - Jump and branch
  - Subroutine call and return



Information Technology Principles

Introduction to Computer Architectures and Software

Fixed Location Subroutine Return Address Storage



a. Subroutine called from loc.55

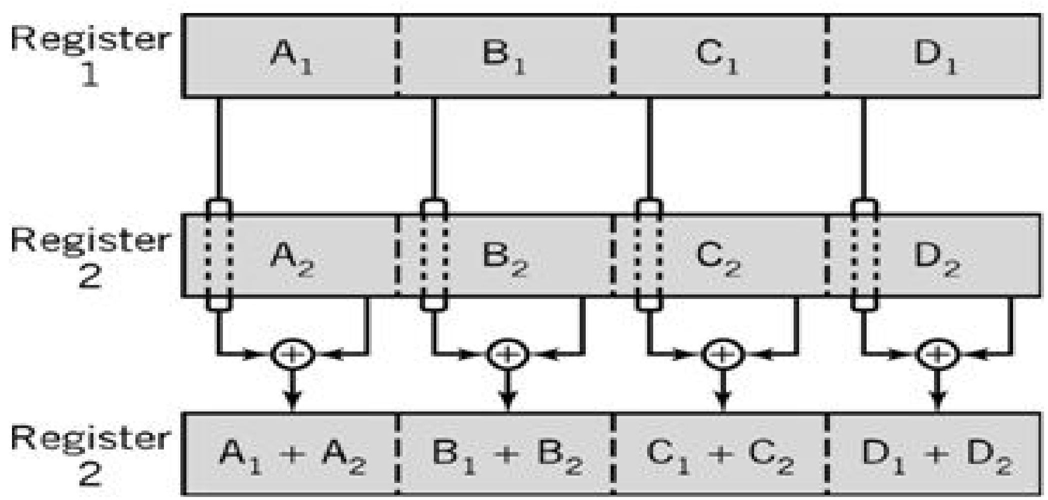
b. Subroutine re-called from 75, within the subroutine

Information Technology Principles

Introduction to Computer Architectures and Software

Multiple Data Instructions

- Perform a single operation on multiple pieces of data simultaneously
  - SIMD: Single Instruction, Multiple Data
  - Intel MMX™: 57 multimedia instruction
  - Commonly used in *vector* and array processing applications



Information Technology Principles

Introduction Computer Architectures and Software

Simple Instruction

- You want your computer to add 1 + 2 + 4
- MOV 1, R0 (Move the number 1 into Register 0)
- MOV 2, R1 (Move the number 2 into Register 1)
- ADD R0, R1 (Add R0 to R1 and put the result in R1)
- MOV 4, R0 (Move the number 4 into Register 1)
- ADD R0, R1 (Add R0 to R1 and put the result into R1)

- Move, Add are examples of "instruction sets"
- "Real" computers have many more Registers

Information Technology Principles

Instructor: Dr. Moaath Shatnawi

Information Technology Principles

Introduction Computer Architectures and Software

What is software?

Computers cannot operate without instructions (step by step procedures that tell computers what to do and when to do it). These instructions, called programs or software, are written by specialists called programmers.

History:

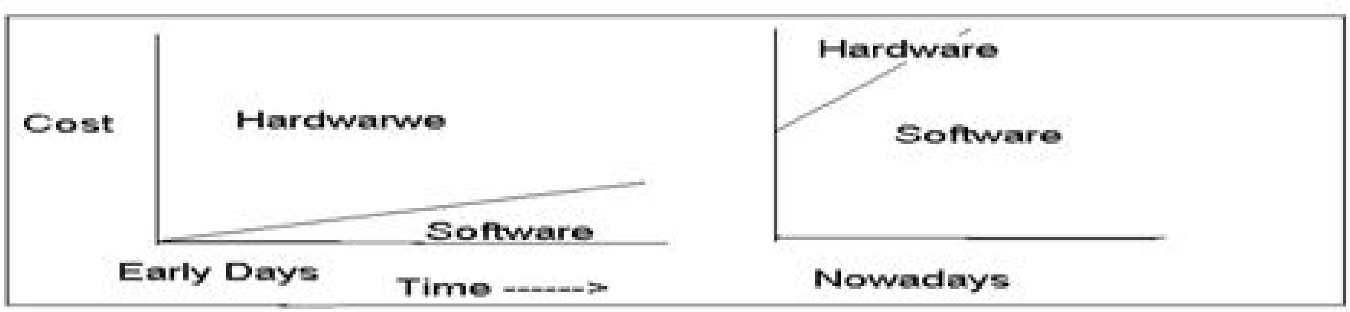
The first applications of computers in business were in the early 1950s. Software was less important and less costly.

Information Technology Principles

Introduction Computer Architectures and Software

Today’s software comprises a much larger percentage of the cost of modern computer systems than it did in the 1950s due to the following facts:

- Price of hardware has dramatically decreased while the performance has increased exponentially.
- Software has become increasingly complex, and its price has increased.
- Building applications remains as much as an art as a science. The software development process is usually slow, complex, error prone and expensive. So the high salaries for developers increased demand for their skills.



Information Technology Principles

Introduction Computer Architectures and Software

Software Crisis:

1* Organizations are unable to develop new software applications fast enough to keep up with rapidly changing business conditions and rapidly evolving technologies (Think of e-commerce on the Internet)

2* Hardware designed/manufactured on automatic assembly lines, so it turned out quickly. On the other hand, software must be engineered manually. Thus software is several generations behind hardware. As a result ➔ Organizations are unable to make full use of hardware due to a lack of software to effectively exploit the hardware.

3* The increasing complexity of software naturally leads to the increased potential for errors or bugs in the software. Large applications today may contain millions of LOC (line of code) written by hundreds of people over several years, clearly the potential of errors is huge and testing and debugging software is expensive and time consuming process.

Information Technology Principles

Introduction Computer Architectures and Software

Hierarchy of Software
(Above the Abstraction Level [i.e. 0's and 1's])

Application

↑

Computer Language
(High Level Language)

↑

Operating System

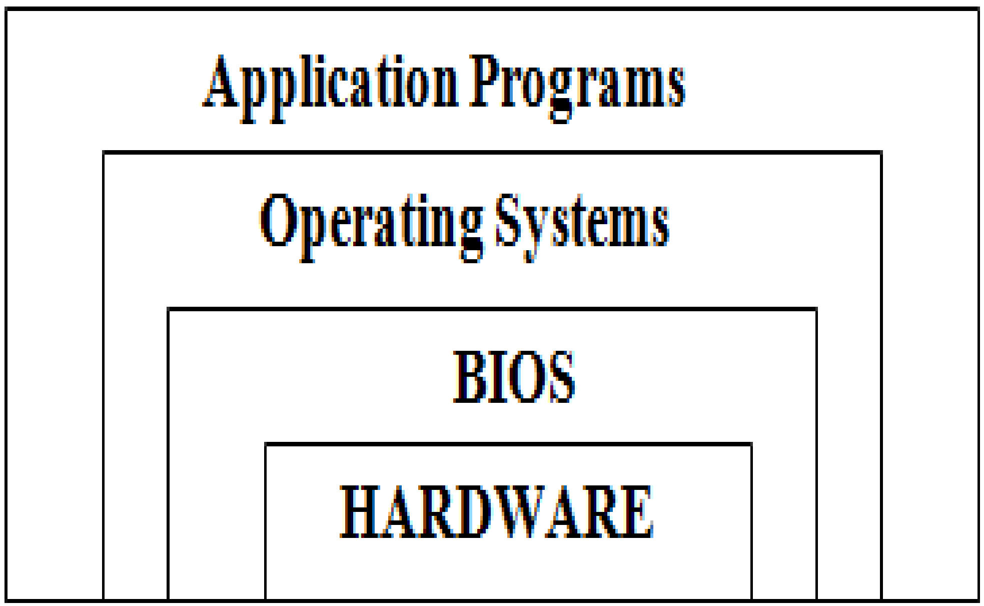
↑

Assembly Code

Information Technology Principles

Introduction Computer Architectures and Software

➔ *The following Figure shows the abstract-levels of applications, operating and BIOS system with regard to the hardware:-*



Information Technology Principles

Introduction Computer Architectures and Software

Assembly Code

- Assembly Code: Most basic of abstraction
  - ADD R1, R2
  - MOV ADDR, R1
  - Different computer systems (RISC v. CISC) use different languages
  - Breaks down instructions to their most basic--at the level of implementation of the chip (or what instructions a particular chip will understand)

Information Technology Principles

Introduction Computer Architectures and Software

Operating System

- OS provides for common system tasks
  - Display information on a monitor
  - Print services
  - User interface
    - Text based
    - Graphical User Interface (GUI)
- Examples:
  - MS/DOS, Windows 3.0, Windows 95/98/2000/Me/XP
  - Microsoft NT/2000 Professional/Server/XP Professional
  - Mac OS X (and other earlier)
  - Linux
  - HP Unix
  - Sun Solaris
  - IBM OS/2

Key note: *OS can run on different chips--difference is in what language the OS speaks to the chip (Assembly Language)*

Information Technology Principles

Introduction Computer Architectures and Software

Basic Input/Output System (**BIOS**) Also known as Freeware

BIOS is a small program permanently stored on a ROM-chip (i.e. small software embedded on a chip). The purpose of this system is to give software a link to the hardware. Thus, it isolate the software from the hardware (it is in between that's why it is called firmware).

BIOS Important Functions:

- Test the system and finds the drives and devices attached to it during Boot-time.
- Interprets keystrokes.
- Displays characters on screen.
- Handles communications through computer ports.

➔ For example; when you ask an app program to print a document, the request is first passed to the BIOS and then sent on to the printer (hardware device).

Information Technology Principles

Introduction Computer Architectures and Software

Drivers, are small programs that translate the program's generic instructions into instructions for a specific piece of hardware (Modem, Scanner, Tape drive etc.)

When a new piece of hardware comes on the market, the programmers of the O.S. just write a driver for it; they don't have to revise the O.S. program itself.

O.S.s generally have a library of device drivers, one for each specific piece of hardware. If you have a piece of hardware that the O.S. does not include a driver for, you won't be able to use it. For example using a printer without the correct driver can give totally unexpected results

Information Technology Principles

Introduction Computer Architectures and Software

<u>Utility Programs (Classified as System Support Programs)</u>,

Closely related to the O.S., for example:-

- Compress utilities used to compress your files on a disk.
- Antivirus utilities to protect your system from viruses.
- Diagnostic utilities help you locate errors an d fix them on your sys.
- Uninstall utilities to remove applications and files you no longer need.
- Performance enhancement utilities to speed up your system and increase storage space.

Information Technology Principles

Introduction Computer Architectures and Software

- **<u>Interface Programs,</u>** they come in different ways:-

- <u>Graphical-User-Interface (</u>GUI –pronounced "gooee")

  [Developed, at a company called **Xerox,** in the 70s and introduced to the market in 1980. **Apple** company made it more popular on the **Apple-MacIntosh** computers. Then **Microsoft** soon introduced its **Windows-GUI.**

  GUIs display overlapping windows on the screen. Each window can contain an application program or a document. You operate them by pointing and clicking on a digital " desktop"]
- <u>Pen-based interface</u>, if you want a computer fits in your pocket, a different O.S. and User-Interface is needed. You use a stylus to write on the screen, which will sense the position of the stylus and execute the associated command.]
- <u>Touch-screen interface</u>, you find them in airports, museums and other public places. Touching the screen by fingers executes commands.]
- <u>Conversational interface</u>, respond to spoken commands.

Information Technology Principles

Introduction Computer Architectures and Software

Computer Language (High Level Language)

- Used to program instructions for computer use
  - Eases programming, since the “Compiler” translates almost human syntax into lower level code
- Examples:
  - Java
  - Fortran
  - C++
  - Visual Basic
  - Pascal
  - Ada
  - HTML

Information Technology Principles

Introduction Computer Architectures and Software

Application Program:

- There are thousands of application programs that you can use on your computer. In order to make it easy to study we may classify them as follows:

Horizontal Market Applications,

[These are used to perform basic and general tasks, they can be used almost by everyone regardless of the job or situation].

Examples:- Word-Processing and Spreadsheet App.s. allow users to work with text and numbers.

This type of application sometimes sold as a group of programs bundled together in what's called suite and may be sold at a discounted price. For example MS-Office App.s by Microsoft.

Information Technology Principles

Introduction Computer Architectures and Software

Application Software

- This is how we usually interface with the computer
  - MS Word
  - MS PowerPoint
  - Lotus Notes
  - Quicken TurboTax
  - AOL Instant Messenger
  - Etc., etc., etc…..

Information Technology Principles

Introduction Computer Architectures and Software

Application Software

Vertical Market Applications,

- An application of this category is usually specific to a single industry or a single task. Examples:-
  - Ticket Reservation & Selling…………Airline Industry
  - Estimating Building Cost………………Construction Industry.
  - ATM Stations………………………….Banking Industry
  - Admission & Registration……………Universities

Custom Applications,

- [It is known that Horizontal & Vertical App.s are "One-Size-Fits-All" approach.]
- However; some companies may need particular type of processing so the application that is needed to do the job should be more customized to their special needs. Such companies decide to write (code) its own app.s and it is usually cost a lot.

Information Technology Principles

Introduction Computer Architectures and Software

Application Software

- Custom Applications,

  [It is known that Horizontal & Vertical App.s are "One-Size-Fits-All" approach.]

  However; some companies may need particular type of processing so the application that is needed to do the job should be more customized to their special needs. Such companies decide to write (code) its own app.s and it is usually cost a lot.

Shareware (*or Freeware*) and Public-Domain Software,

Shareware are programs developed by companies or individuals then distributed to be used by users for free or by little registration-fee.

This is a form or marketing because such companies hope people will try their programs and continue to using them.

Information Technology Principles

Introduction Computer Architectures and Software

Application Software

- **Freeware**: Software to which the author or developer still retains copyright (unlike public domain) but carries no charge (unlike shareware or commercial software). See also Open Source

- **Public Domain** - In few cases, developers (companies) go past giving their software away, they also give away their rights to it. The programs then move into the public-domain. There are no restrictions on what you can do with such public-domain programs (you may use, change or modify them etc.)

Information Technology Principles

Introduction Computer Architectures and Software

Application Software

Open source means that the source code is available to all potential users, and they are free to use, modify, and re-distribute the source code. (For more details, see the Open Source Definition.) Legally, the "free" of open source refers exclusively to the source code, and it is possible to have support, services, documentation, and even binary versions which are not monetarily free. (Although some licenses, notably the GPL, requires that the source code always be freely available in such cases.)

In practice, open source usually means that the application is free to users as well as developers. Furthermore, most open source software have communities that support each other and collaborate on development. Therefore, unlike freeware, there are future enhancements, and, unlike shareware, users are not dependent on a single organization.

Information Technology Principles

Instructor: Dr. Moaath Shatnawi

Information Technology Principles

Introduction to LAN/WAN/Ethernet

- Computers are powerful.
  - Networking is a "force multiplier"
- When Xerox developed the first viable networking scheme for small PC-like computers, a revolution was begun
- This small-computer, networked architecture was a HUGE paradigm shift from the days of the mainframe

Information Technology Principles

The Local Area Network (LAN)

- The LAN has many variations:
  - Wired (or fiber) or Wireless
  - Operate at speeds from 1 Mbps to 1 Gbps (+++)
  - Support Desktops, Laptops, Personal Devices
  - Allow access to many resources
    - Print
    - File Server
    - Internet
    - Mainframe
    - Etc….

Information Technology Principles

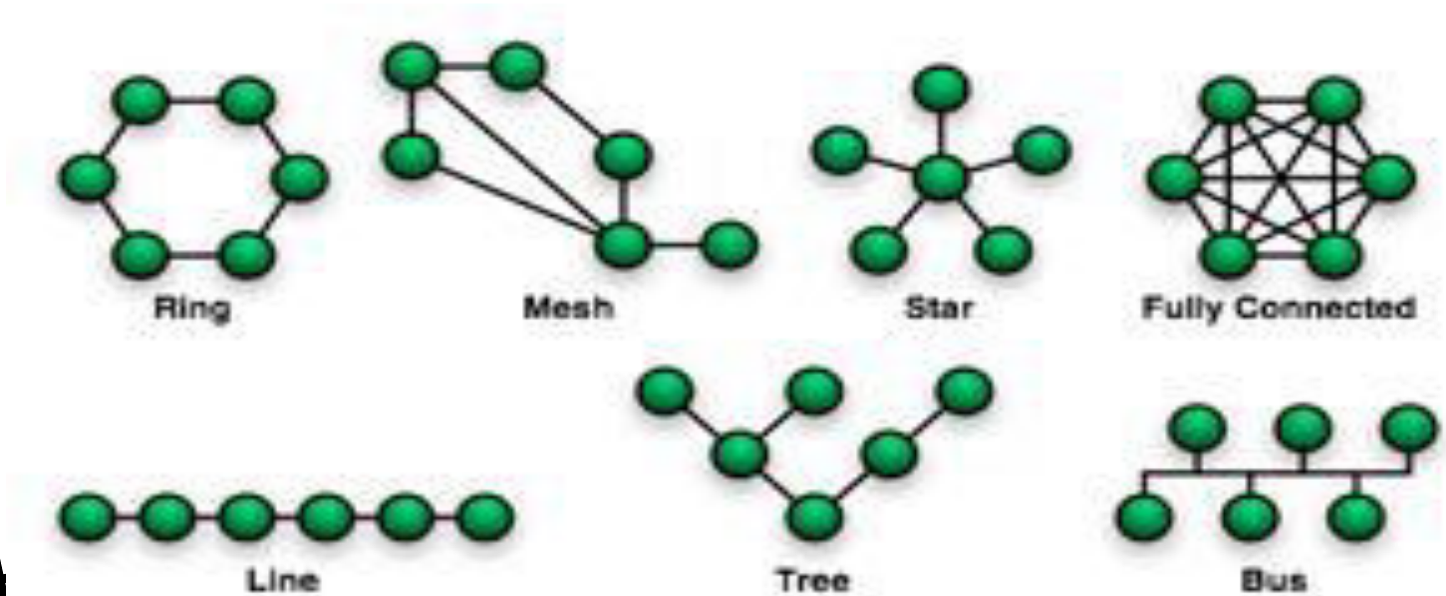
LAN Characteristics

- Typically serves a limited area
- Typically serves a single organization
- Varies from serving a few users to thousands
- Provides access to shared services
  - Through a Network Operating System (NOS)
    - Examples: Windows NT, Novell, HP Unix
- Uses some form of access control
- High speed network connection

Information Technology Principles

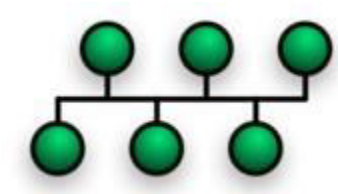
LAN Topologies

- LAN Topology describes how the network is constructed and gives insight into its strengths and limitations



Information Technology Principles

Bus Topology



In local area networks where bus technology is used, each machine is connected to a single cable.

Each computer or server is connected to the single bus cable through some kind of connector.

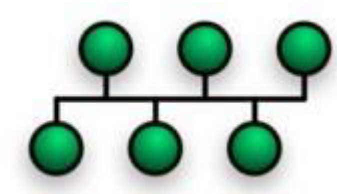
A terminator is required at each end of the bus cable to prevent the signal from bouncing back and forth on the bus cable.

A signal from the source travels in both directions to all machines connected on the bus cable until it finds the MAC address or IP address on the network that is the intended recipient.

If the machine address does not match the intended address for the data, the machine ignores the data.

Information Technology Principles

Bus Topology



Alternatively, if the data does match the machine address, the data is accepted.

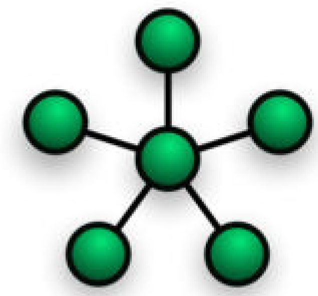
Since the bus topology consists of only one wire, it is rather inexpensive to implement when compared to other topologies.

However, the low cost of implementing the technology is offset by the high cost of managing the network.

Additionally, since only one cable is utilized, it can be the single point of failure. If the network cable breaks, the entire network will be down

Information Technology Principles

Star Topology



In local area networks where the star topology is used, each machine is connected to a central hub.

In contrast to the bus topology, the star topology allows each machine on the network to have a point to point connection to the central hub.

All of the traffic which transverses the network passes through the central hub.

The hub acts as a signal booster or repeater which in turn allows the signal to travel greater distances.

As a result of each machine connecting directly to the hub, the star topology is considered the easiest topology to design and implement.

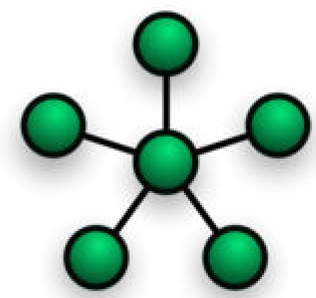
Information Technology Principles

Star Topology

An advantage of the star topology is the simplicity of adding other machines.

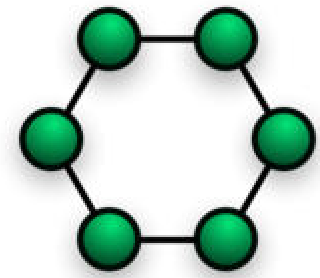
The primary disadvantage of the star topology is the hub is a single point of failure.

If the hub were to fail the entire network would fail as a result of the hub being connected to every machine on the network.



Information Technology Principles

Ring Topology



In local area networks where the ring topology is used, each computer is connected to the network in a closed loop or ring.

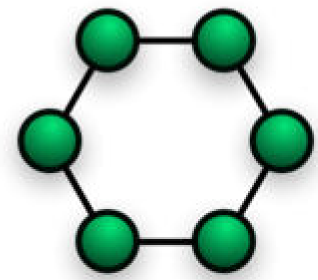
Each machine or computer has a unique address that is used for identification purposes.

The signal passes through each machine or computer connected to the ring in one direction.

Ring topologies typically utilize a token passing scheme, used to control access to the network.

Information Technology Principles

Ring Topology



By utilizing this scheme, only one machine can transmit on the network at a time.

The machines or computers connected to the ring act as signal boosters or repeaters which strengthen the signals that transverse the network.

The primary disadvantage of ring topology is the failure of one machine will cause the entire network to fail.

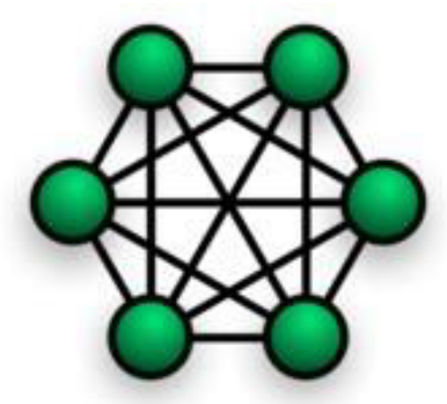
Information Technology Principles

Mesh Topology

The value of fully meshed networks is proportional to the exponent of the number of subscribers, assuming that communicating groups of any two endpoints, up to and including all the endpoints

Fully connected

The physical fully connected mesh topology is generally too costly and complex for practical networks, although the topology is used when there are only a small number of nodes to be interconnected.



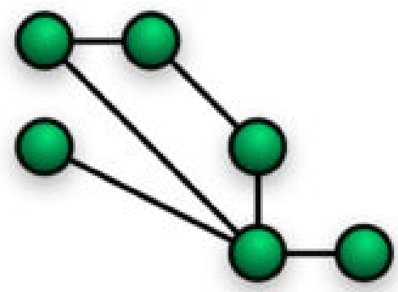
Information Technology Principles

Mesh Topology

Partially connected

The type of network topology in which some of the nodes of the network are connected to more than one other node in the network with a point-to-point link –

this makes it possible to take advantage of some of the redundancy that is provided by a physical fully connected mesh topology without the expense and complexity required for a connection between every node in the network.



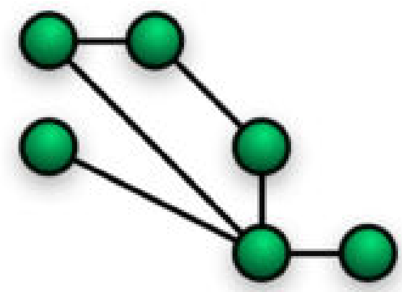
Information Technology Principles

Mesh Topology

Partially connected

The type of network topology in which some of the nodes of the network are connected to more than one other node in the network with a point-to-point link –

this makes it possible to take advantage of some of the redundancy that is provided by a physical fully connected mesh topology without the expense and complexity required for a connection between every node in the network.



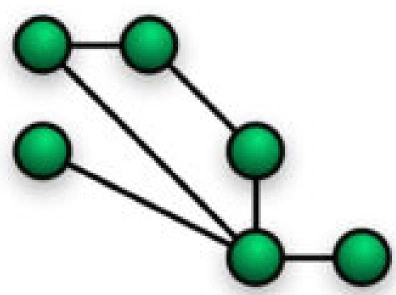
Information Technology Principles

Mesh Topology

Partially connected

In most practical networks that are based upon the physical partially connected mesh topology, all of the data that is transmitted between nodes in the network takes the shortest path (or an approximation of the shortest path) between nodes, except in the case of a failure or break in one of the links,

in which case the data takes an alternative path to the destination. This requires that the nodes of the network possess some type of logical 'routing' algorithm to determine the correct path to use at any particular time

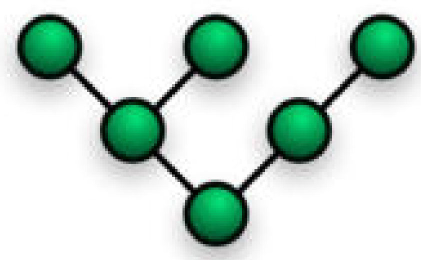


Information Technology Principles

Tree/Hierarchical Network Topology

The type of network topology in which a central 'root' node (the top level of the hierarchy) is connected to one or more other nodes that are one level lower in the hierarchy (i.e., the second level) with a point-to-point link between each of the second level nodes and the top level central 'root' node, while each of the second level nodes that are connected to the top level central 'root' node will also have one or more other nodes that are one level lower in the hierarchy (i.e., the third level) connected to it, also with a point-to-point link, the top level central 'root' node being the only node that has no other node above it in the hierarchy (The hierarchy of the tree is symmetrical.)

Each node in the network having a specific fixed number, of nodes connected to it at the next lower level in the hierarchy, the number, being referred to as the 'branching factor' of the hierarchical tree.



Information Technology Principles

Access Control

- Like a noisy classroom--difficult to communicate if every terminal is going at the same time
- Two forms we'll discuss
  - **Non-Contention** Access:
    - Token
  - **Contention** Access:
    - Carrier Sense Multiple Access with Collision Detection (CSMA/CD)

Information Technology Principles

Token

- Used in Bus and Ring topologies
  - Token Ring for instance
- A token is placed on the network and passed to each member of the network
- When someone has something to say, they "grab" the token and then transmit their information
- The message is sent to all other members of the network
- The member the message is addressed to "hears" the message and all others ignore the message
- Once the message is delivered, the token is freed for someone else to use

Information Technology Principles

Token Issues

- The system has very good control, but is complex in implementation
- If token is lost or mutilated, a member of the network must replace the token
  - Usually automatic after some specified wait time
- System is deterministic
  - That means that if a station has higher priority traffic to send, the system can deal with that, either by preemption or allocation

Information Technology Principles

CSMA/CD

- Carrier Sense, Multiple Access with Collision Detection is a Contention Access system
- Any stations can send whenever it has data to be sent
- First, a station listens to the network, if idle (that is, no one is talking), data is sent
- But, it is possible for two stations to send, thinking that the channel is clear
- When this happens, a collision occurs

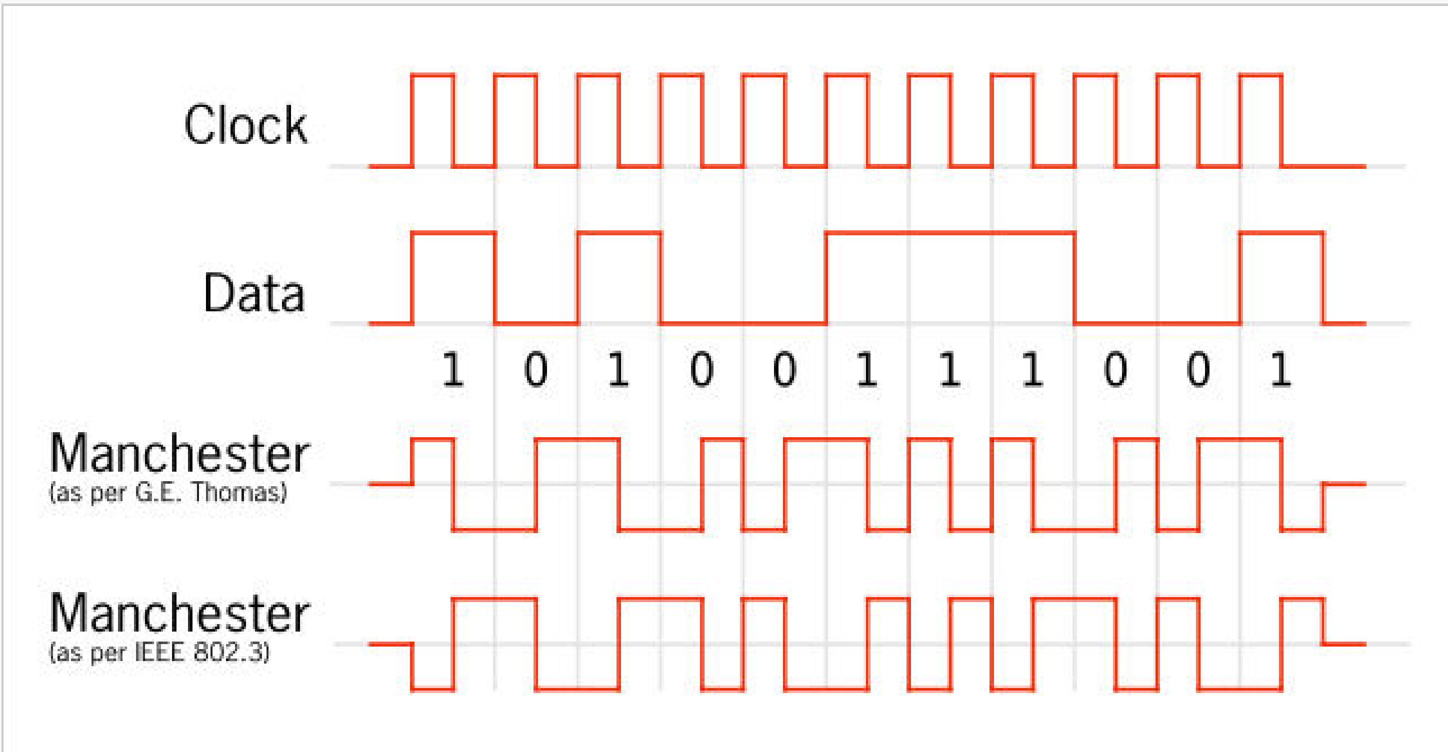
Information Technology Principles

CSMA/CD Continued

- The first station to detect a collision sends a special signal
- The stations in contention then wait a random time to again attempt transmission
- Used in Ethernet
- Simple to implement
- Not much in the way of control
- Performance goes down as traffic on network goes up

Information Technology Principles

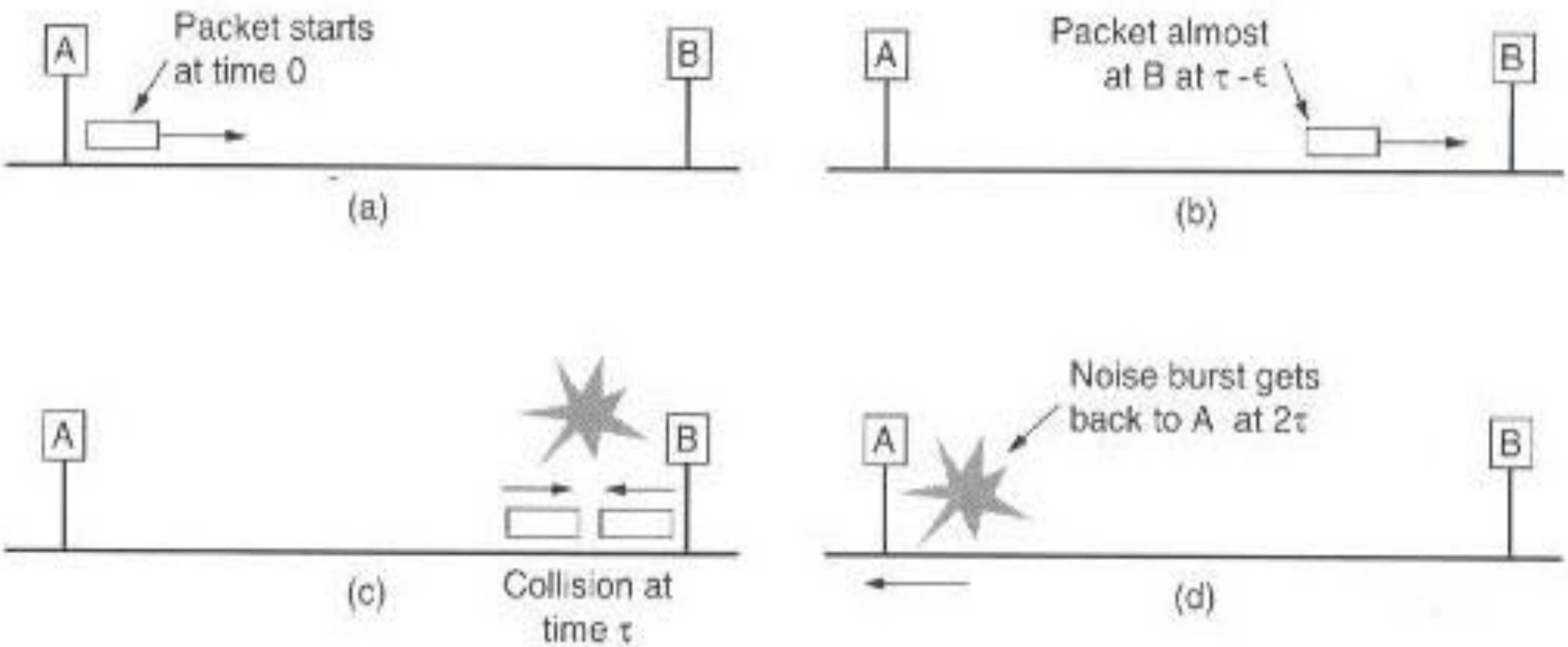
Manchester Encoding



An example of Manchester encoding showing both conventions

Information Technology Principles

Collision Detection



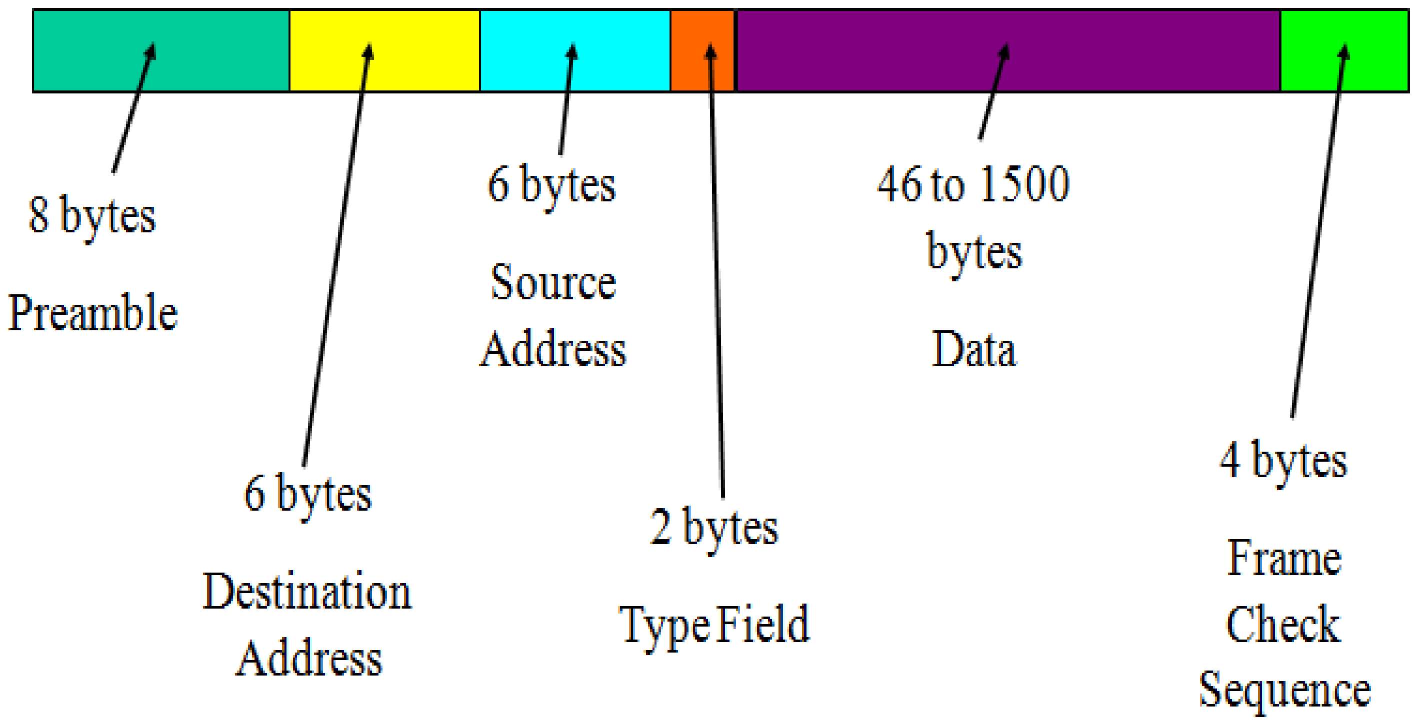
Information Technology Principles

Ethernet

- Developed by Xerox in 1976
- Eventually became an IEEE standard (IEEE 802.3)
  - Has been modified for wireless applications (IEEE 802.11)
  - And for higher speeds (IEEE 802.3ae for 10 Gigabit Ethernet)
- Ethernet is based on the <u>Datagram</u>

Information Technology Principles

Ethernet Datagram Structure



Information Technology Principles

Ethernet Datagram Structure

- **Preamble**: Repeating Flag that ID's the sequence as an Ethernet diagram (10101010 7 times followed by 10101011)
- **Destination Address**: Unique identifier found nowhere else but on the Network Interface Card -- to whom the datagram is being sent
- **Source Address**: Who originated the datagram
- **Type Field**: Tells the recipient what kind of datagram is being received (IP, UDP, etc)
- **Data**: What it is that you are trying to send (text, JEPG, MP3, etc)
- **Frame Check Sequence**: Detects and corrects errors

Information Technology Principles

Ethernet Tidbits

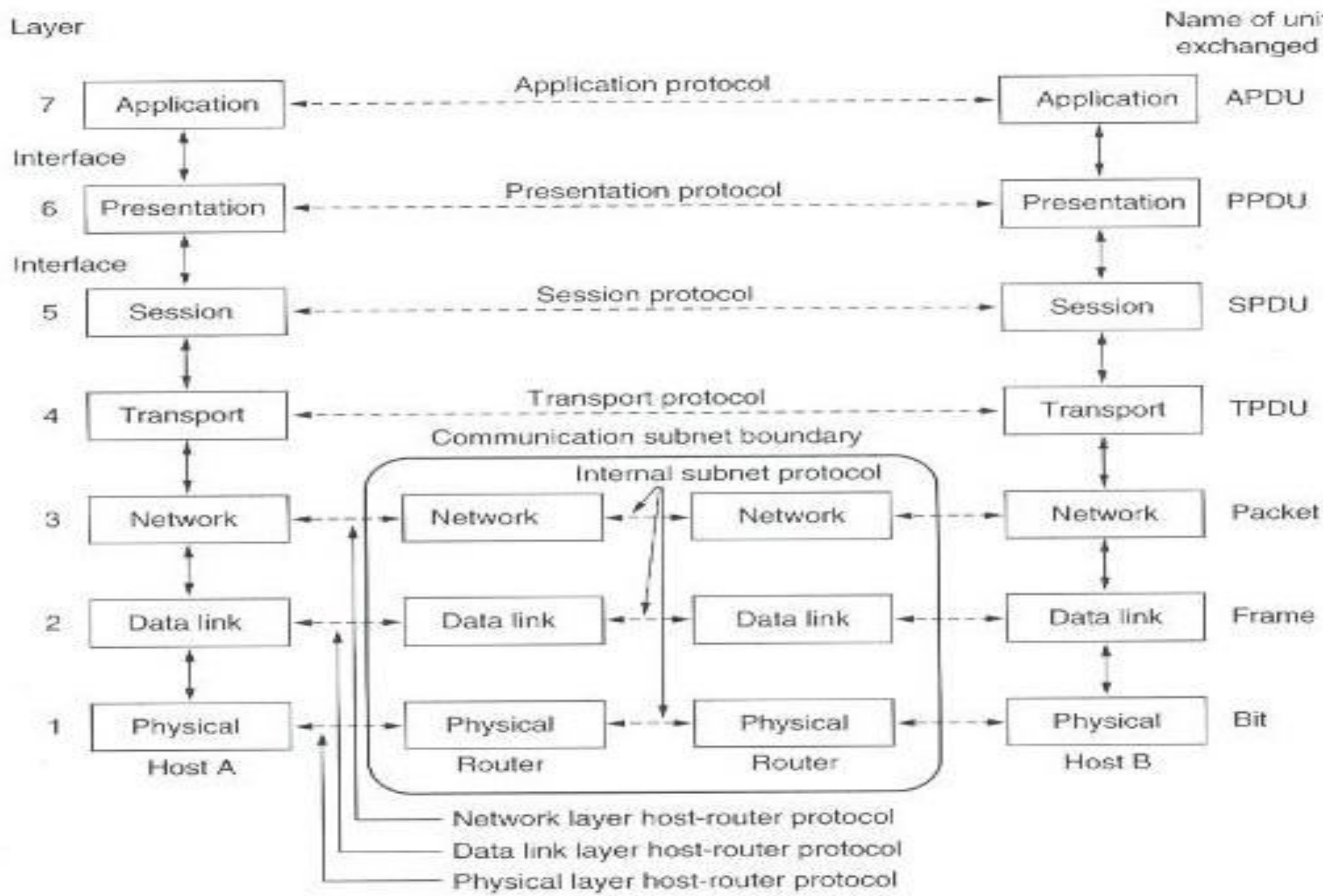
- If a message has less than 46 bytes of data, “padding” is added

- Ethernet is often referred to as 100 Base T
  - First digit is the speed of the system in Mbps
  - Base refers to a cable or wire system
  - T refers to the system is UTP: Unshielded Twisted Pair
  - What is: 10 Base 5? 10 Mbps on a cable that can go 500 m

- Bytes that aren’t the data we are interested in sending is called “overhead”
  - Ethernet has 26 bytes of overhead
  - If you had 100 bytes of data to send, you’d have to send 126 bytes of data--ratio of overhead to data is 26%

Information Technology Principles

OSI Reference Model



Information Technology Principles

WANs and the Internet

- The power of the computer is nothing compared to the power of networking (I've already heard that!)
- LAN's connect "small", "local" groups of users
- WAN's connect LANs
- The Internet provides a "super" WAN--if you touch it, you can connect to someone else if they touch it

Information Technology Principles

WAN's

- Wide Area Networks have evolved, just as LAN's have
  - Once they were called Metropolitan Area Networks (MAN's)
  - Now they are usually described as an "Enterprise Network" if they support one large organization
  - Sometimes an organization describes its network as an organization's Intranet
- WAN's can support global organizations

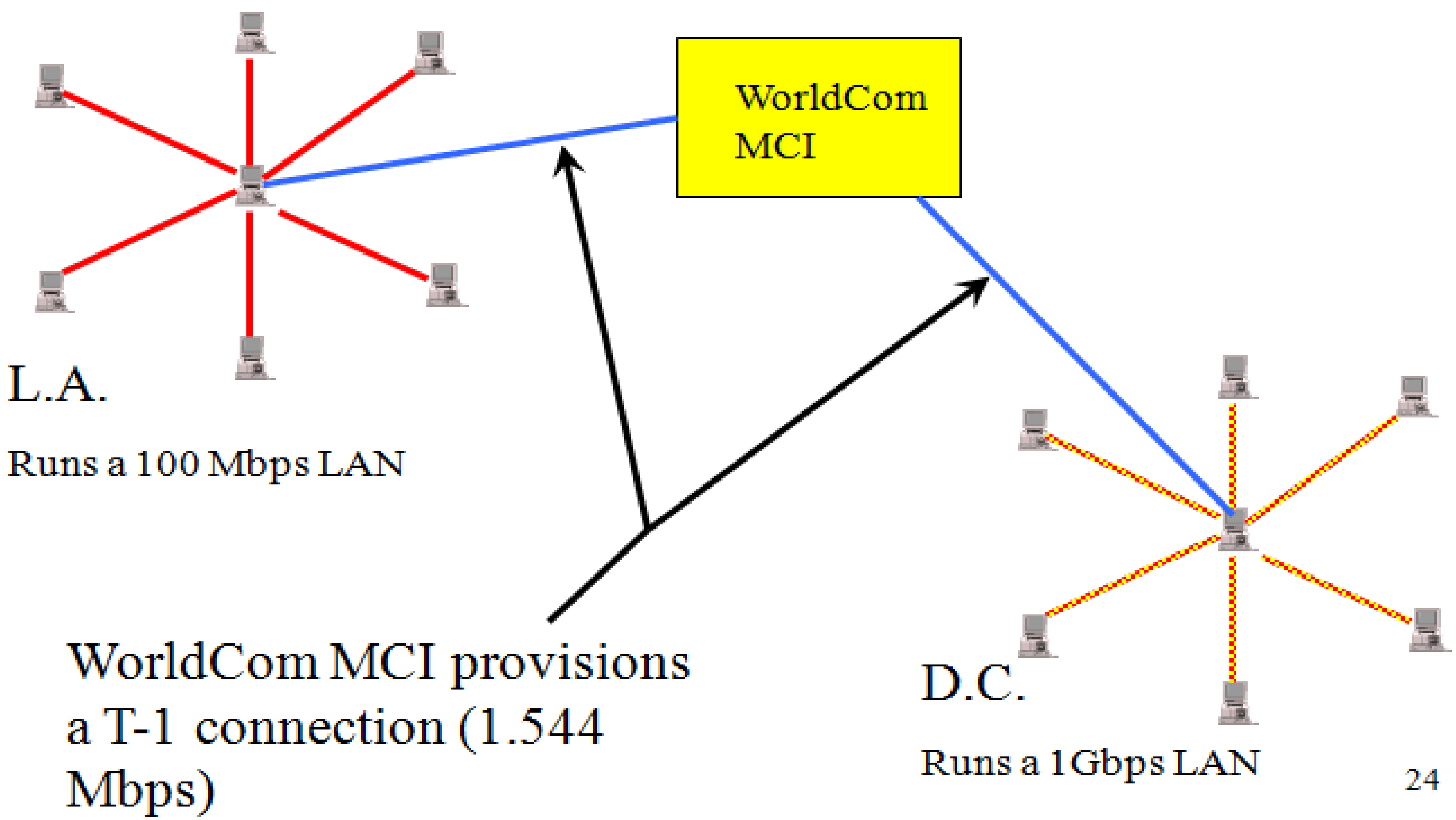
Information Technology Principles

WAN Characteristics

- WAN's connect widely separated LAN's and other services into a single network
- LAN's are owned by the local organization
- WAN infrastructure (or connectivity) is often provided by a common carrier (AT&T, Sprint, MCI, etc)
- WAN line speeds are usually much slower than that found on LAN's

Information Technology Principles

Example



Information Technology Principles

Enterprise Networks or Intranets

- Enterprise Networks not only connect LAN's separated by great distance, but also provide additional services that are central to the business--Mainframes, Oracle Databases, Automated business process software, etc
- Intranets can do the same as Enterprise Networks, but are based on a World Wide Web model--access all through the browser
  - Goal is to distribute information within the organization

Information Technology Principles

WAN Notes

- You should see that implementing a WAN might cause you to have to go outside your organization to accomplish
  - Reason: Even large companies can't afford to lay in high capacity circuits everywhere in the world
  - Companies lease service
    - Fiber Optic, Satellite, cable, microwave carries the service
    - At capacities needed: T1, T2 (6.176 Mbps), T3 (44.736 Mbps), OC1 (51.84 Mbps), OC192 (9,953.28 Mbps)
    - From and to locations desired to implement the WAN

Information Technology Principles

The Internet

- The Internet began as a Department of Defense experiment
  - (Defense) Advanced Research Projects Agency (D)(ARPA) established the ARPANet in 1968 by hooking together a few mainframe computers
- DoD got out of the business in 1986
- Today, it is a collection of millions of computers connected together by the standards that were developed while DoD operated the network

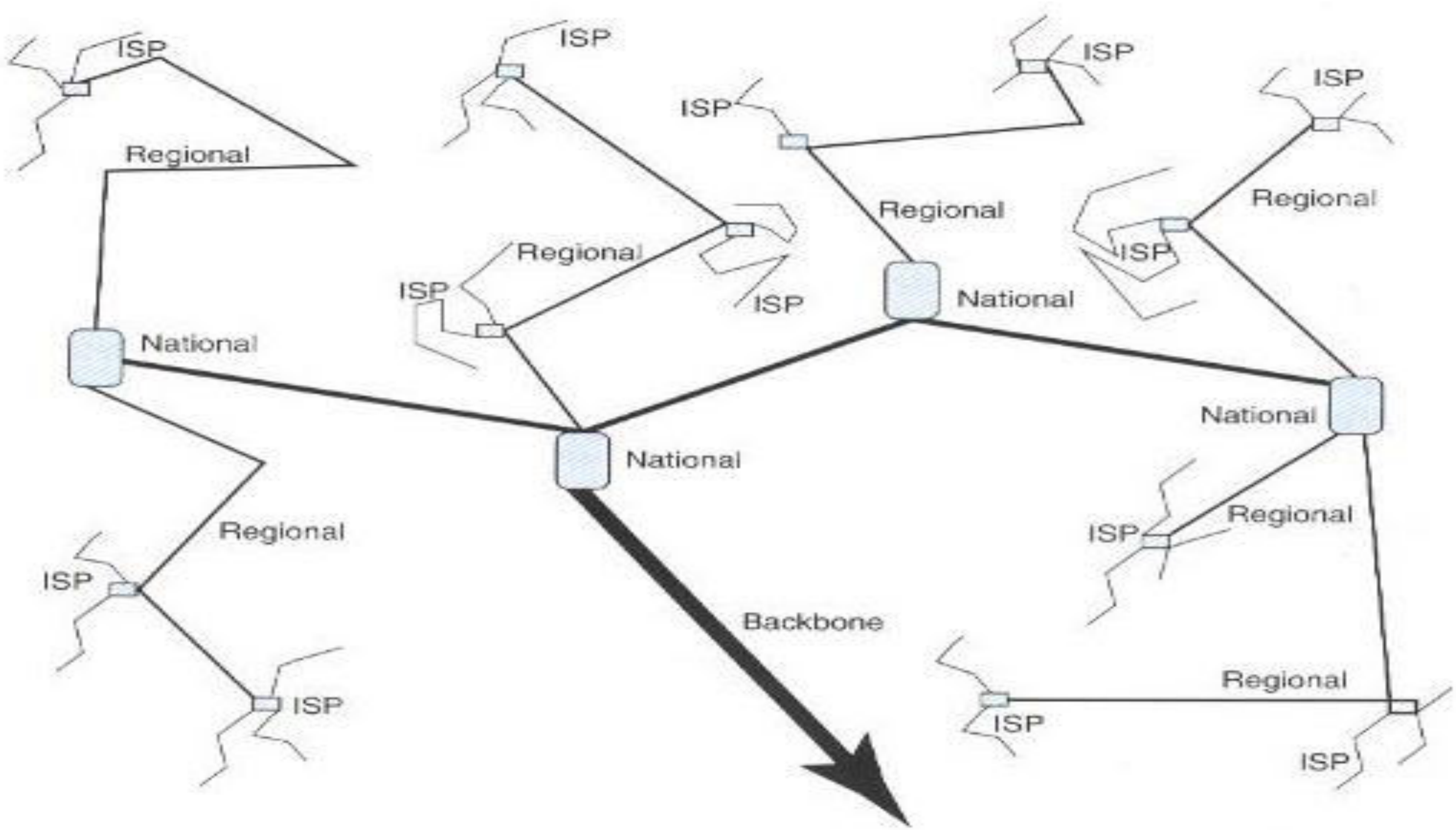
Information Technology Principles

The Internet, Con't

- In many ways, the Internet can be viewed as a "backbone" system--that is, many individuals rely on it to establish networks
- The Internet is owned by no one individual--parts of it are owned, parts are publicly managed
- Chaotic environment
- But…it works!

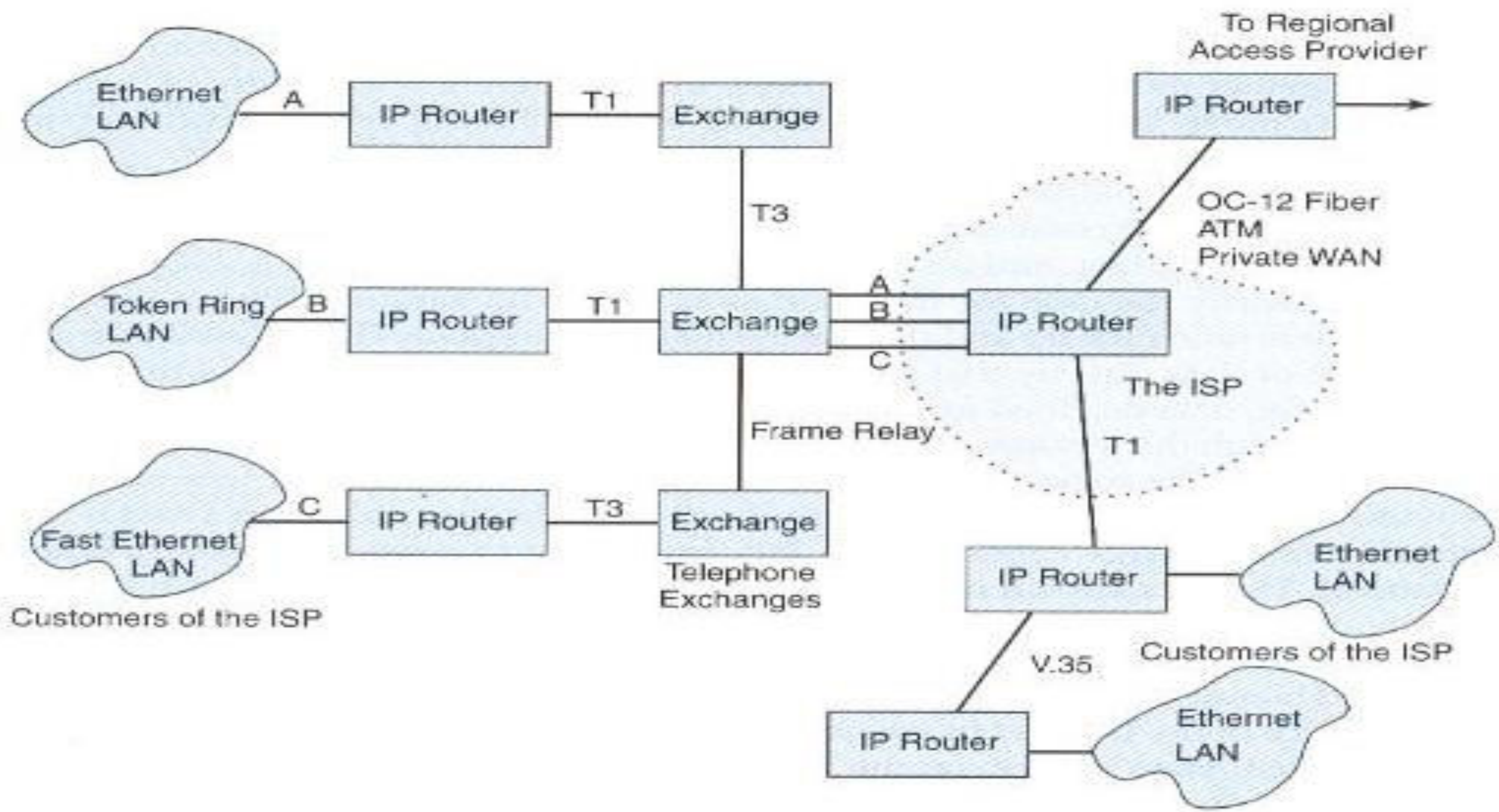
Information Technology Principles

The Internet (Hierarchical Access Providers)



Information Technology Principles

The Internet (Diverse Telecom Technologies Integrated by a Common Protocol)



Information Technology Principles

TCP/IP (One of many reasons why the Internet works)

- So you are connected to the Internet and you want to send something to someone…how do you do that?
- In 1975, the Transmission Control Protocol/ Internet Protocol (TCP/IP) began to be implemented on the ARPANET
- Manufacturers of data systems began to use TCP/IP because---it was FREE!
  - And non-proprietary!

Information Technology Principles

TCP/IP

- TCP/IP consists of two different protocols
  - IP is a connectionless protocol that provides addressing services to a datagram flowing across the network (IP operates at the Network layer [Layer 3])
    - In other words, IP just puts an address and sends the datagram off into the darkness and doesn't care if it gets there or not
  - TCP is a connection oriented protocol that provides transmission services over a session (TCP operates at the Transport layer [Layer 4])
    - In other words, TCP ensures that datagram's get where they are supposed to go and makes sure duplicates and out of order problems are solved

Information Technology Principles

IP

- IP is the way things are addressed on the Internet
- Based on a 32-bit (4 octet) address, like:

  129.174.1.8

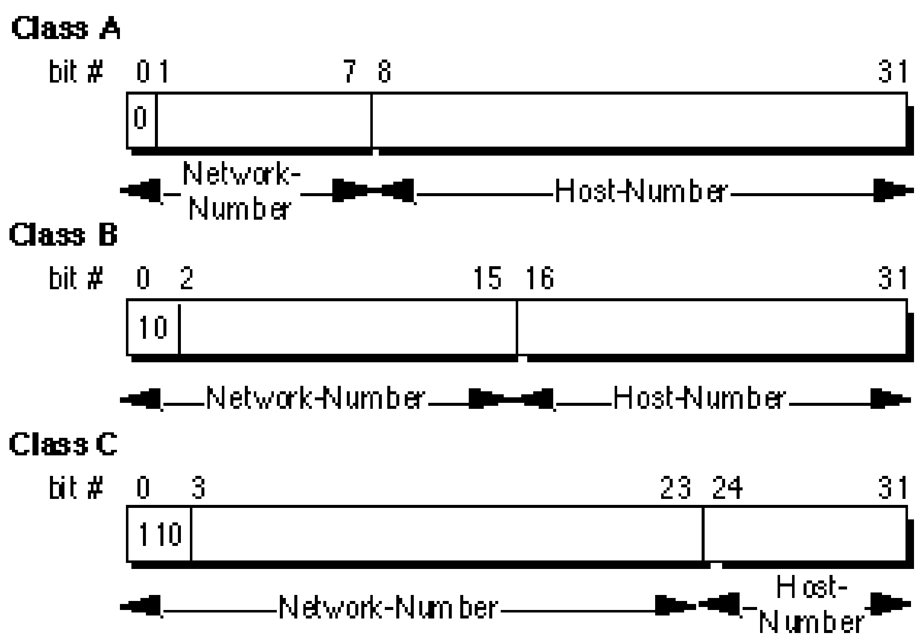
- There are 4 classes of address (you can tell by the first octet):

Address Class	Dotted-Decimal Notation Ranges
A (/8 prefixes)	1.xxx.xxx.xxx through 126.xxx.xxx.xxx
B (/16 prefixes)	128.0.xxx.xxx through 191.255.xxx.xxx
C (/24 prefixes)	192.0.0.xxx through 223.255.255.xxx

Information Technology Principles

IP Con't

- The fourth class is D--reserved for multicast
- An IP address has two parts--network and host
  - For example, a Class A network could support 126 networks, each with 16,777,216 hosts



Information Technology Principles

IP Structure

<table>
<tr><td>4</td><td>8</td><td>16</td><td></td><td>32 bits</td></tr>
<tr><td>Ver.</td><td>IHL</td><td>Type of service</td><td colspan="2">Total length</td></tr>
<tr><td colspan="3">Identification</td><td>Flags</td><td>Fragment offset</td></tr>
<tr><td colspan="2">Time to live</td><td>Protocol</td><td colspan="2">Header checksum</td></tr>
<tr><td colspan="5">Source address</td></tr>
<tr><td colspan="5">Destination address</td></tr>
<tr><td colspan="5">Option + Padding</td></tr>
<tr><td colspan="5">Data</td></tr>
</table>

IP header structure

The data field can contain other information (like the TCP header) as well as data…its maximum size (total, including header bytes) can be 65,535 bytes, but most systems can't handle that large a datagram…all systems must be able to handle 576 bytes, minimum

Information Technology Principles

IP Problems

- Believe it or not, the number of IP addresses provided for by a 32 bit code are running short
  - IPv6 is going to increase the address space to 128 bits
  - There are other techniques as well:
    - Classless Addressing (allows for more efficient use of addresses)
    - Sub-net masking (stretches the number of assignable hosts)
- Numbers aren't easy to remember
- # 1 problem--IP doesn't guarantee delivery

Information Technology Principles

TCP

- TCP is the way you guarantee that your datagram gets to the other end
- It provides additional data in a header that requires acknowledgement of data as it is received
  - Will retransmit a packet if an acknowledgement is not received
  - Discards duplicates, if they occur
- TCP uses a "sliding window" scheme where only a certain amount of data can be accepted without acknowledgement
  - Prevents buffer overflows
  - Causes problems with some transmission systems

Information Technology Principles

The TCP Header

<table>
<tr><th>4</th><th>10</th><th colspan="6">16</th><th>32 bits</th></tr>
<tr><td colspan="8">Source port</td><td>Destination port</td></tr>
<tr><td colspan="9">Sequence number</td></tr>
<tr><td colspan="9">Acknowledgement number</td></tr>
<tr><td>Offset</td><td>Resrvd</td><td>U</td><td>A</td><td>P</td><td>R</td><td>S</td><td>F</td><td>Window</td></tr>
<tr><td colspan="8">Checksum</td><td>Urgent pointer</td></tr>
<tr><td colspan="9">Option + Padding</td></tr>
<tr><td colspan="9">Data</td></tr>
</table>

TCP header structure

The TCP Header costs you at least 24 bytes…more if the header implements any data (normally done in the IP datagram)--but it ensures you get the message through you sent using IP

Information Technology Principles

Addressing Schemes

TCP/IP allows for addressing and delivery, but IP isn't the only addressing game in town

- Three addressing schemes are used in sending information across the Internet
  - Organizationally-Unique Identifier (OUI)
    - This is the 48-bit address stamped on Network Interface Cards… no two devices have the same address
  - IP Address
    - The 32-bit address used to identify an "attachment" to the Internet (port, NIC, logical address, etc.)
  - Domain Name System
    - Hierarchical, alphanumeric addressing scheme that is a "synonym" of an IP address

Information Technology Principles

DNS Example

- The machine that hosts the IT 101 website has an IP address…that's how computers and browsers can find it
- A DNS address is: www.yahoo.com, www.hotmail.com, …
- The DNS can reflect the machine, organization, type of organization, country of an address
- Another DNS example: www.ammanu.edu.jo

Information Technology Principles

"Standard" DNS Components

- You may see:
  - .edu--Educational
  - .com--Commercial
  - .gov--Government (US)
  - .org--Non-profit organization
  - .net--Internet organization
  - .mil--Military domain
  - .uk--United Kingdom
  - .ja--Japan

Note: The rules used to be pretty strict, but have loosened up…especially as the pool of easily remembered or catchy names have been used up!

Information Technology Principles

The World Wide Web

- The WWW was the brainchild of a guy who wanted to help nuclear physicists share information

- The Internet existed before the WWW…the Web only really started in the early 1990's
  - Remember the Internet was born in 1968

- The WWW concept established a method to both ask for and get the address for a particular document: The Universal Resource Locator (URL)

Information Technology Principles

The URL

- The URL is both an address and a set of directions
  - DNS is closely coupled to the URL…though the URL gives much more detail:
  - http://www.yahoo/start/index.html
  - This URL describes exactly where the homepage is with information for visitors to the yahoo website
  - On the yahoo server, in the subdirectory start, there is an html file called “index”--the document can be obtained using the Hypertext Transfer Protocol (HTTP)

Information Technology Principles

URL Con't

- The URL has certain advantages
  - Data can change, yet the directions stay the same
  - Users don't have to know how to get to a file…they only need the URL
  - URL's can support documents or software (like a search engine or other service)
  - Other services are supported by the URL--FTP (file transfer protocol), Gopher, Telnet (old technologies work fine!)
  - **There is no centralized organization needed to administer the WWW…the URL takes care of publishing problem (anyone can publish to the Web)**

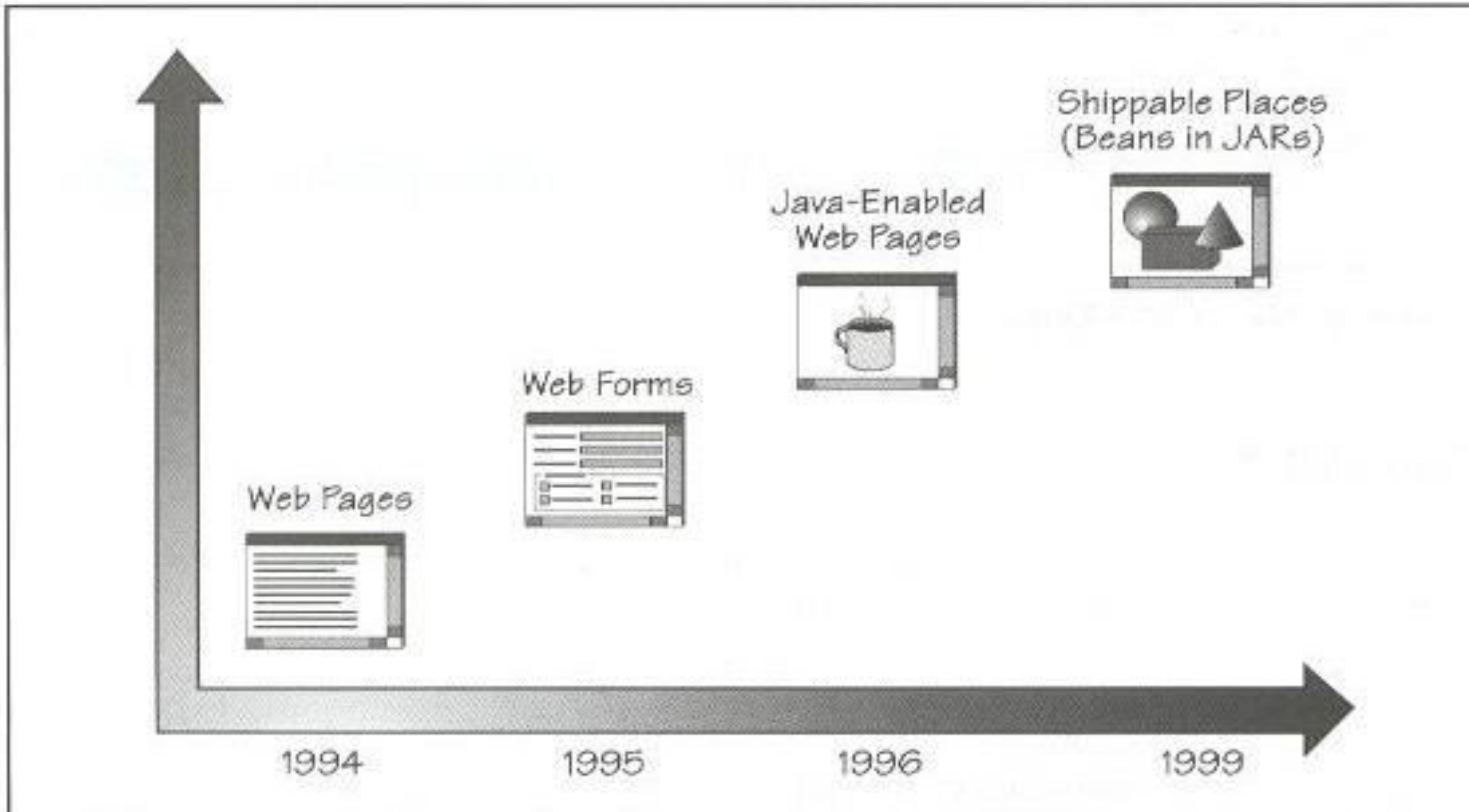
Information Technology Principles

Interacting with the Web

- The Web requires something called a "browser"
- A browser provides an interface for a user to make requests of the web
- The Web Browser is a "killer app"
  - The browser greatly simplified the interface for the user, improved performance, became cheap and was universally accepted
- The Browser has become a place where different systems can commonly interact

Information Technology Principles

From Web Pages to Shippable Places



Information Technology Principles

Interacting with the Web

- Hypertext Markup Language (HTML) became a method to embed things other than text in a document and be able to commonly share the document, regardless of system capabilities
- Other protocols provide this ability, but HTML has become the most widely used
  - Many e-mail programs today send mail as HTML--MIME (Multi-purpose Internet Mail Extensions) was the first way to embed this information in e-mail, but now is not used as much

Information Technology Principles

Basic Components of the Web Client/Server Architecture

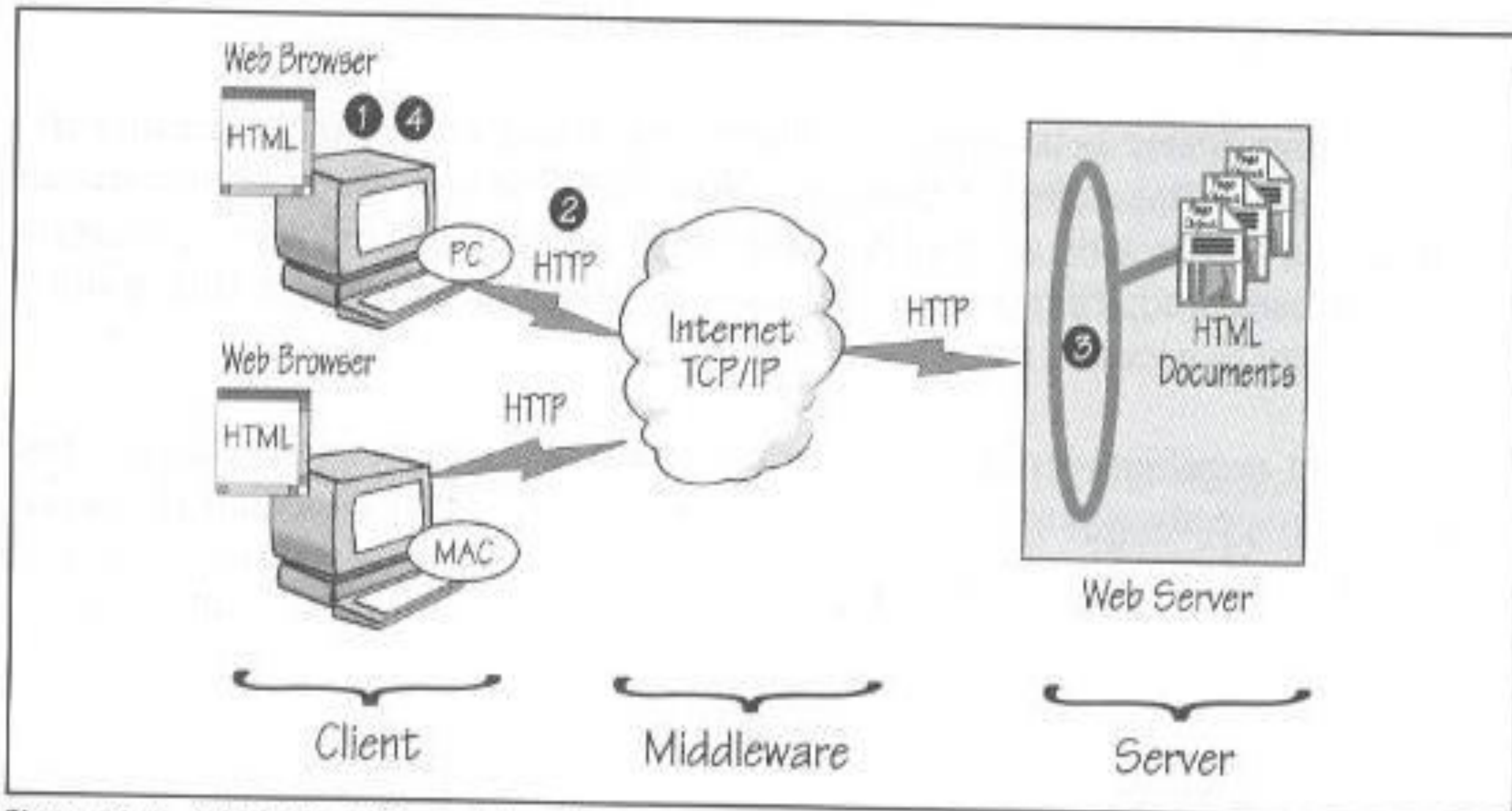


Figure 26-2. A Web Client/Server Interaction.

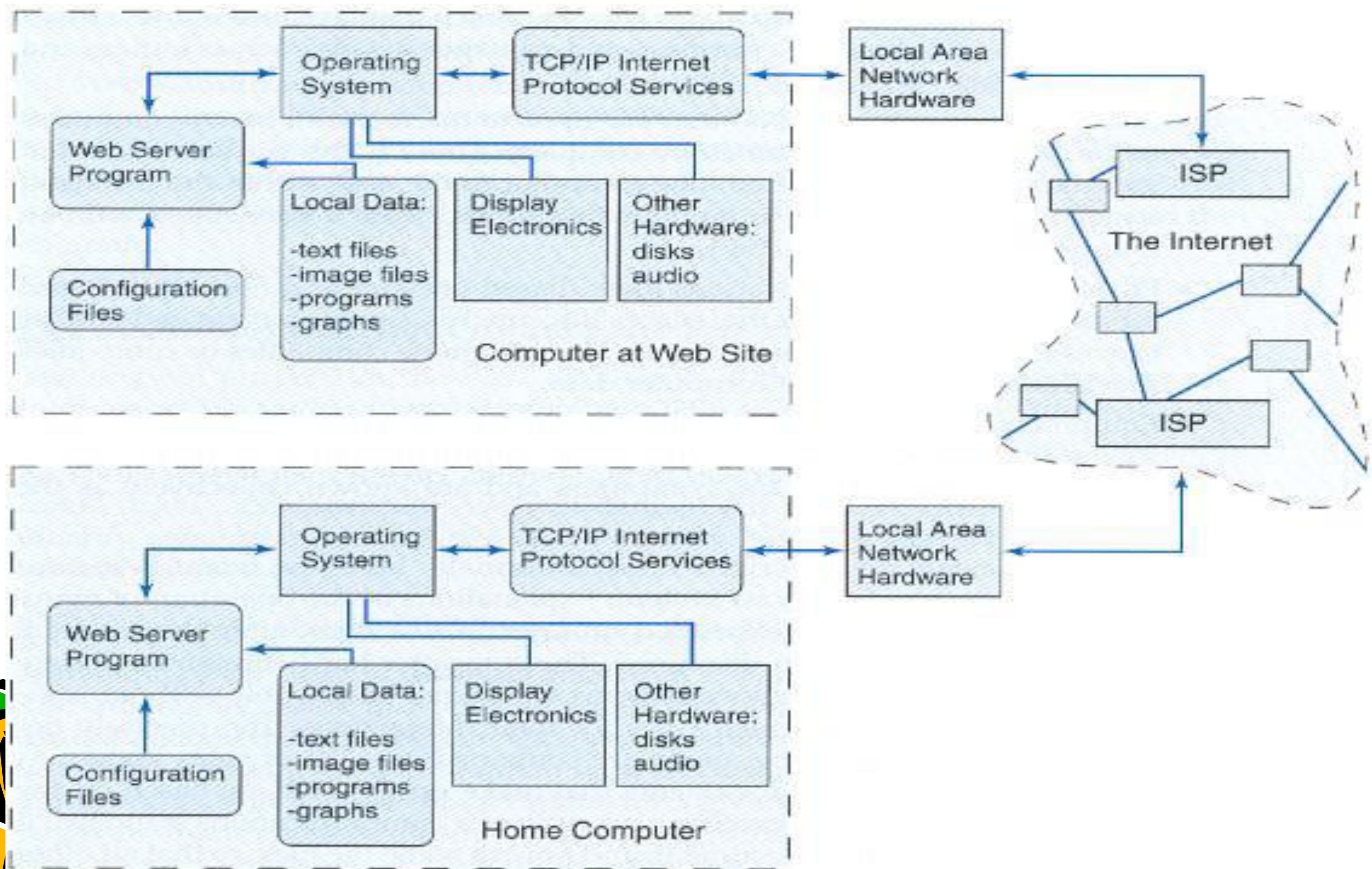
Information Technology Principles

The Web Today

- The Web is not the Internet…it is just one application of the Internet--and perhaps the dominant one
- New technologies add functionality and features to the Web (Java, ActiveX, scripts, etc) and can be supported by “Plug-ins” that provide support for these new services
- The power of the Web is the ease that one can become a provider of information or a seeker
  - That is--the browser, URL, HTTP, and all the other technologies work together to make the Web searchable, despite the chaotic nature of its design

Information Technology Principles

The key is that the Web is a system of systems, all working together



Information Technology Principles

3-Tier Client/Server Architecture

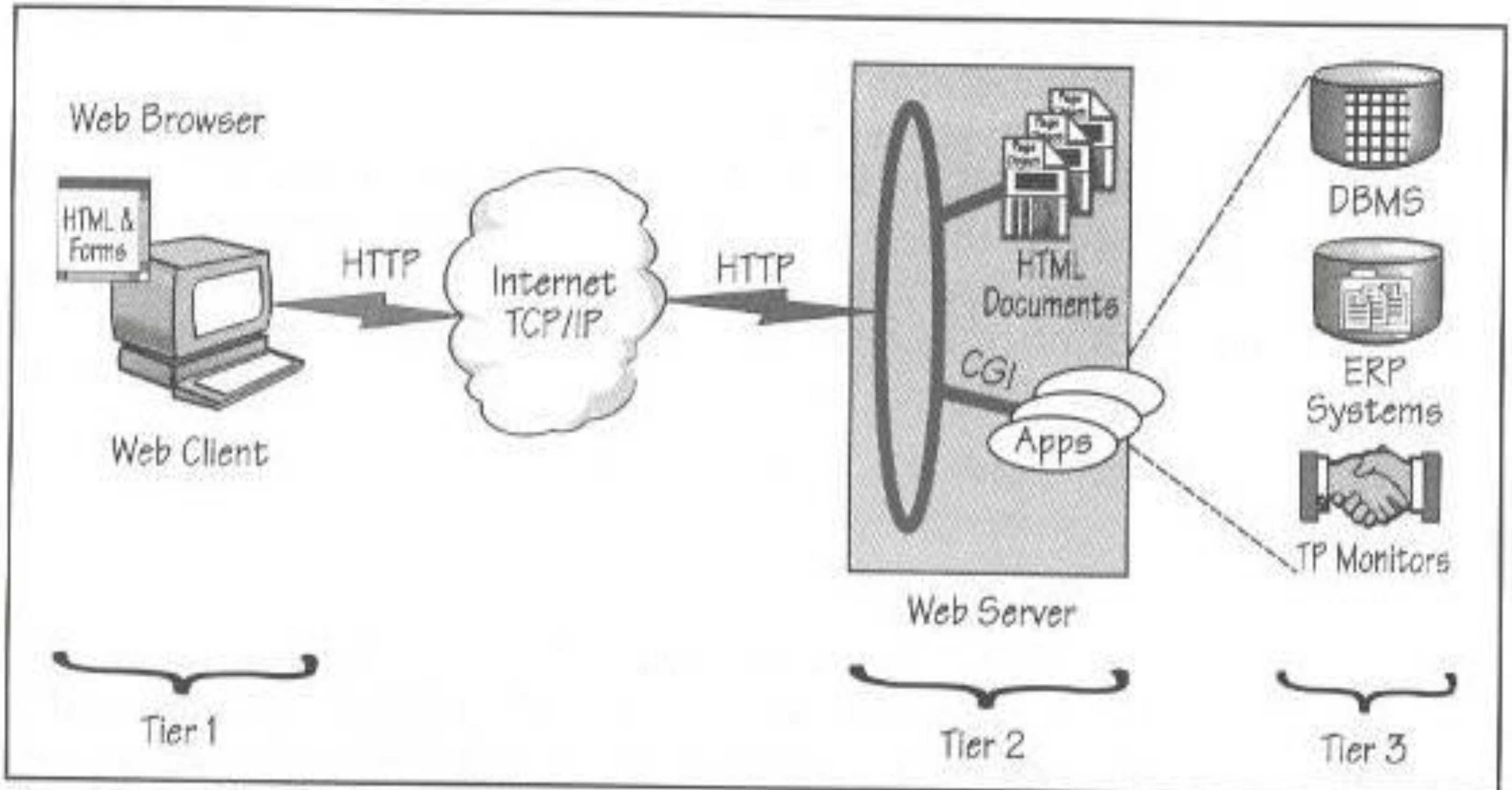


Figure 27-1. 3-Tier Client/Server, Web-Style.

Information Technology Principles

Structured Wire and Fiber Optic Systems

- To this point, we've learned about all sorts of things, but we haven't yet described the systems that bring IT to you

- Wire and Fiber Optic Systems carry the bulk of all information around the world--other systems don't even come close

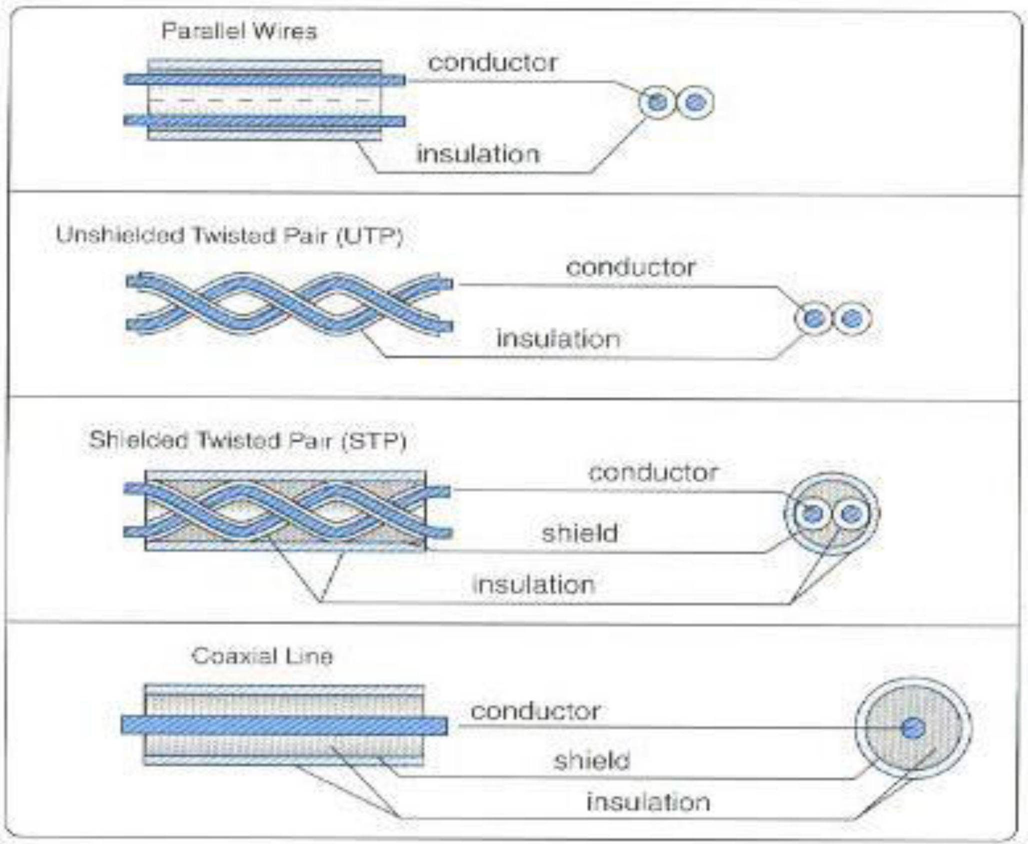
Information Technology Principles

Structured Wire Systems

- Structured Wire Systems are based on standards that were developed in the early 1990's
  - Problem: Rapidly developing networks resulted in incompatible wiring
  - The standards that rule today's wiring systems were developed by the Electronic Industries Association (EIA) and the Telecommunications Industries Association (TIA)
- What forced the standardization? Data (binary) systems are not as forgiving as voice (analog)

Information Technology Principles

Types of Wire

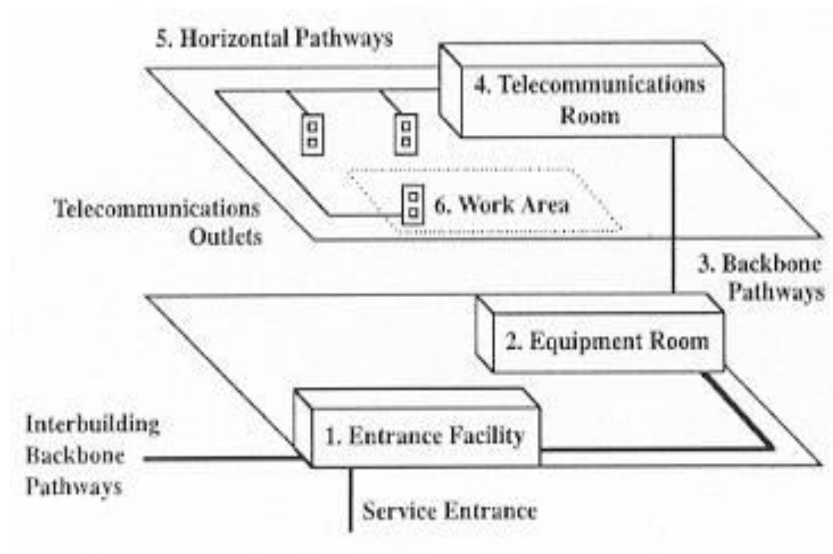


- Parallel Wires--a few of you might remember when this was how cable TV was first installed
- Unshielded Twisted Pair--used for many applications today
- Shielded Twisted Pair--special purpose wire situations
- Coaxial--is shielded…used for cable TV/Internet today

Information Technology Principles

EIA/TIA Structured Wire Systems

- Standards are based not only on wire itself, but also how parts will be connected
- Defines Equipment Rooms (ER), Telecommunications Closets (TC), Backbone Wiring, Work Areas (WA), Telecommunications Outlets (TO), Horizontal Wiring, Entrance Facility (EF)
- Defines certain wire standards,
- or categories



Scope of ANSI/TIA/EIA-569-A

Information Technology Principles

EIA/TIA Wire Categories (EIA/TIA 568)

- **dB** - The unit for measuring the relative strength of a signal.
- **dB** - decibel, logarithmic representation of a ratio often used to express gain or loss
- **dB** - A decibel is a unit used to measure the relative intensity of sound.
- **dB** - Sound level in decibels as a logarithmic ratio. Sound intensity described in decibels. ie: Breathing 5 dB, office activity 50 dB, Jet Aircraft during takeoff at 300' distance 130 dB.
- **dB** - The decibel (**dB**) is used to measure sound level, but it is also widely used in electronics, signals and communication. The dB is a logarithmic unit used to describe a ratio. The ratio may be power, sound pressure, voltage or intensity or several other things.
- **POTS** - Plain Old Telephone Service. Conventional analog telephone lines using twisted-pair copper wire. This is used to provide residential service

Information Technology Principles

EIA/TIA Wire Categories (EIA/TIA 568)

- **POTS** - Meaning of POTS - "Plain Old Telephone Service". Traditional telephone service found in most homes and businesses that remains the most basic form of telephone service everywhere in the world. POTS was first invented when Alexander Graham Bell connected New York to San Francisco in January 25, 1915 - 39 years after the first ever telephone call. This historic telephone call used 15,000 technicians spread across the nation, 14,000 miles of copper wire, and 130,000 telephone poles. POTS features minimally by directional or full-duplex communications within the v300-3400Hz frequency range, dial tone, pulse or rotary dialing, ring signal, and operator services such as directory, long distance, and emergency assistance. With the advent of electronic telephone switching in 1970s came additional services such as tone dialing, caller ID, voice mail, call waiting, and other optional services. POTS is what innovations like Voice over Internet Protocol (VoIP) try to emulate in terms of level of service, quality, and redundancy. POTS was only designed to support voice, however the advent of modems enabled up to 56 kbs of data to be carried over these lines.

Information Technology Principles

EIA/TIA Wire Categories (EIA/TIA 568)

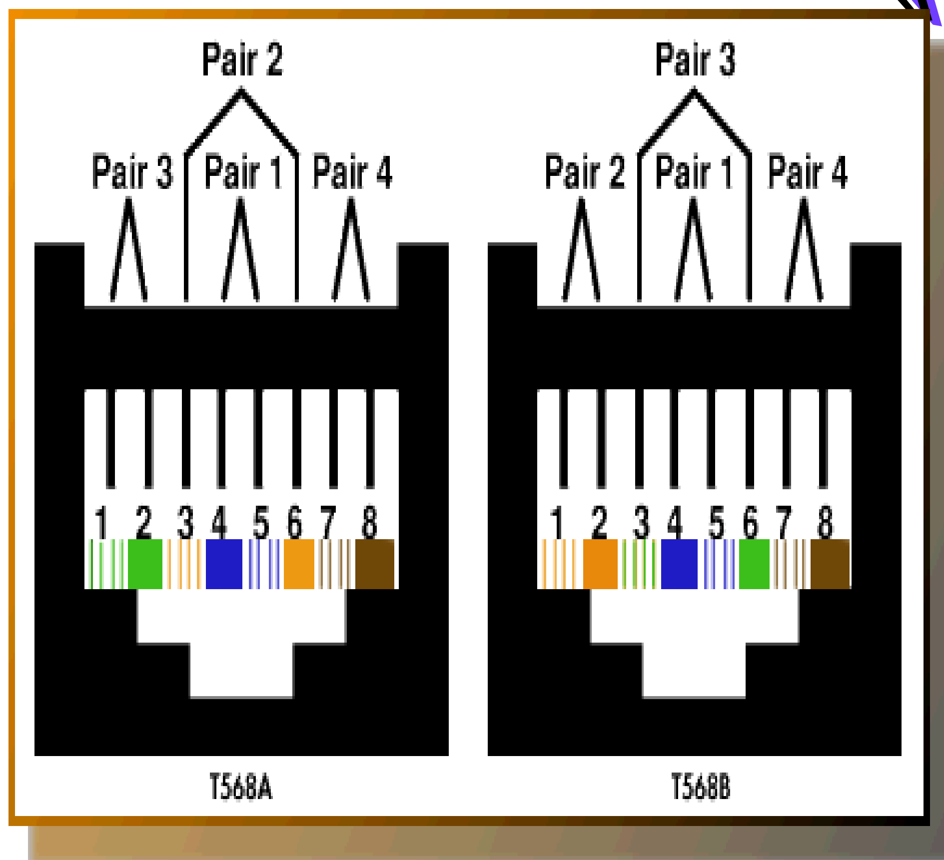
- Category 1--Plain Old Telephone System (POTS) --really a UL standard "Level 1"
- Category 2-- IBM cabling standard--UL "Level 2"
- Category 3 (and up are for UTP, and are specified)--supports low grade data (10 MHz) 10 Mbps max, @ 10 MHz 30 dB attenuation/1000 ft, @ 16 MHz 40 dB attenuation/1000 ft
- Category 4--supports 16 MHz Token Ring LAN
- Category 5--supports 100 MHz LAN (current Data service wire standard) 100 Mbps max, @ 10 MHz 32 dB attenuation/1000 ft, @ 100 MHz 67 dB attenuation/1000 ft

Defines distances that each cable can run--100 meters total for Cat 5

Information Technology Principles

EIA/TIA 568 Specifics

- This standard refers to a 4 pair wire system
- You must know how to connect each of these pairs
- Most systems only use 2 pair
- A is used for "straight through"
- B is used for "crossover"



Information Technology Principles

New Standards

- Category 5e
  - Enhanced Cat 5
  - Same bandwidth, less noise…more speed

- Category 6 aka ISO Class E
  - Souped up Cat 5
  - More than twice the bandwidth (250 MHz)
  - Less noise…even more speed

- Category 7 (proposed) aka ISO Class F
  - Four pair system that supports wide range of applications
  - 600 MHz of bandwidth

Information Technology Principles

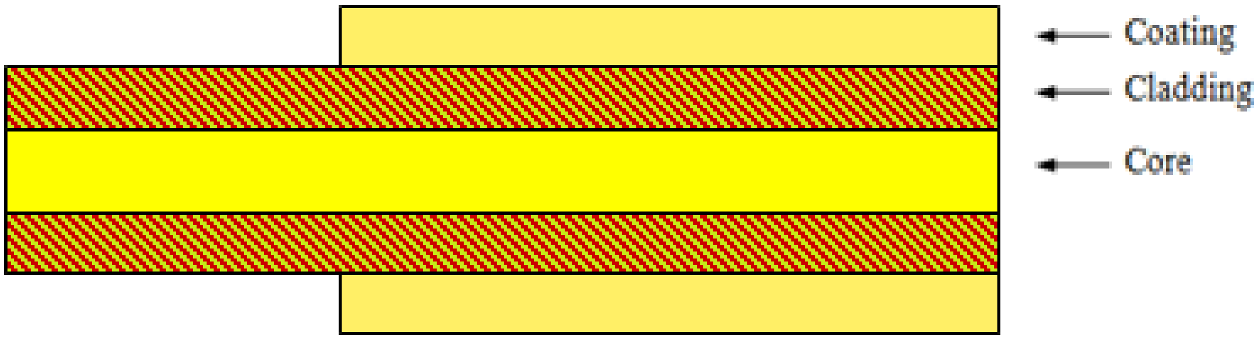
Fiber Optic Systems

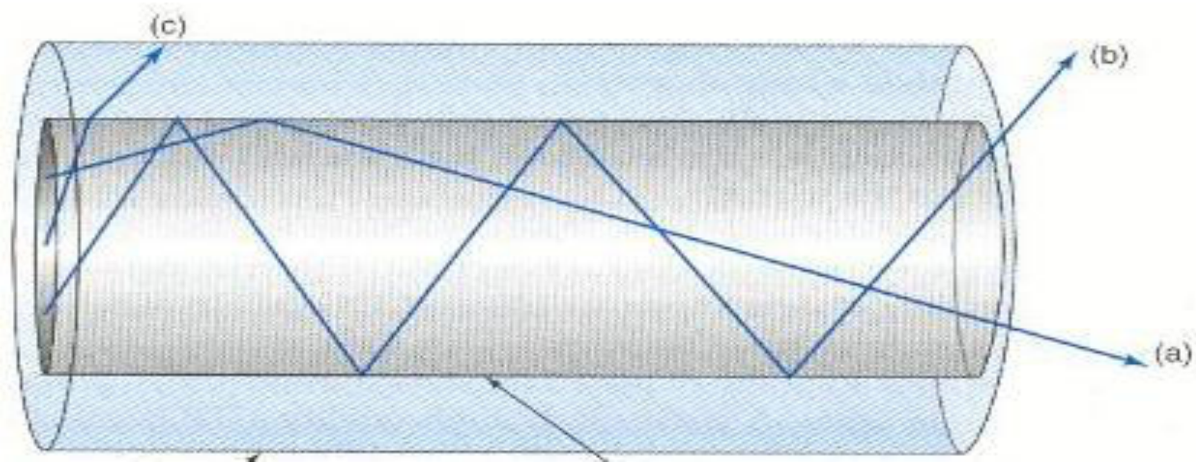
- Fiber Optic Cable systems take advantage of something you should be familiar with
  - Light refracts when it encounters materials of different density
  - In other words, light bends

- Fiber optic cables are made of three components
  - Core (glass or plastic with low refractive index)
  - Cladding (same, with higher refractive index)
  - Protective cover

Information Technology Principles

Fiber Optic Cable





Information Technology Principles

Types of Fiber Optic Cable/Systems

- Multimode Systems
  - Core size is 62.5 µm (microns)
  - Cladding size is 125 µm (microns)
  - Light source is often an LED
- Single Mode Systems
  - Core size is 9 µm (microns)
  - Cladding size is 125 µm (microns)
  - Light source is a laser

Information Technology Principles

Fiber Optic Systems

- Multimode is cheaper than Single Mode Fiber

- Single Mode can support much higher data rates than Multimode
  - Single Mode is into the Terabit per second range
  - Multimode is in the multi-megabit per second range

- Single mode is for long haul networks
  - Attenuation is as low as 0.03 dB/1000 ft

- Multimode is for local networks
  - Attenuation is 2.5 dB/1000 ft

Information Technology Principles

Problem

You have a Single Mode Fiber Optic System, with an attenuation of 0.03 dB per 1000 ft. You are required to run this system 3000 miles. If your engineers tell you that you must have a repeater set up when the signal loses 50 dB, how many repeaters do you need?

Information Technology Principles

Radio Spectrum, Radio and Satellite Systems

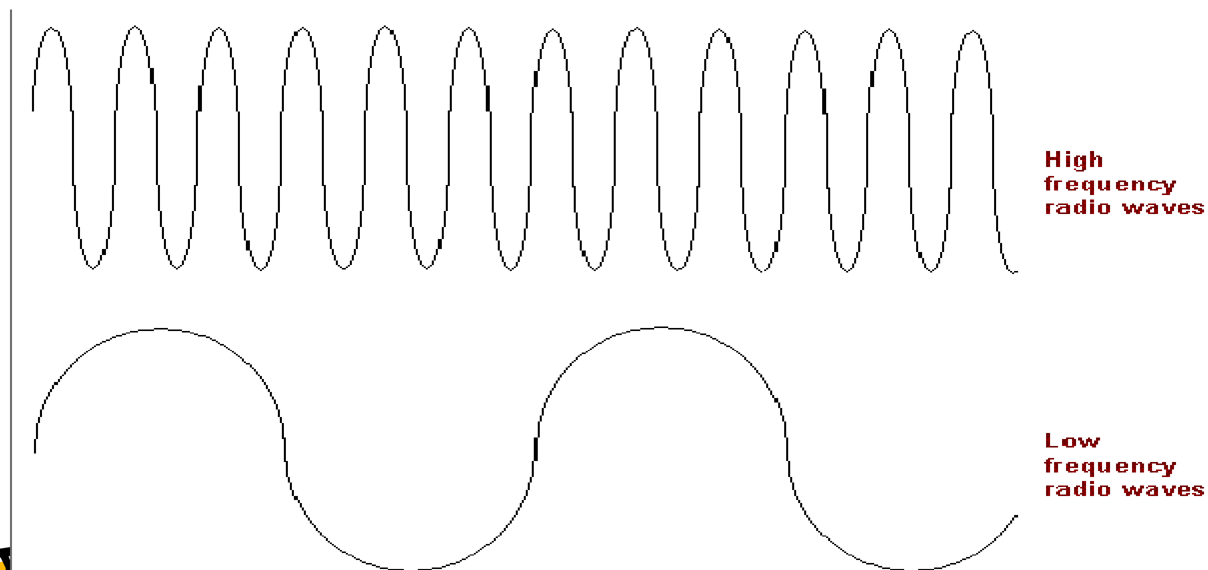
- We've covered wired and cabled systems
- "Wireless" systems are all kinds--narrowband, wideband and provide an important part of the IT infrastructure--provides service to those not wired and those whose mobility require it
- Radio spectrum is divided into groups (bands) and is tightly controlled by governments and international authority
- In the United States, the Federal Communications Commission (FCC) and National Telecommunications and Information Administration (NTIA) are the controlling authorities

Information Technology Principles

Radio Spectrum

What is frequency?

Frequency describes the number of waves that pass a fixed place in a given amount of time. So if the time it takes for a wave to pass is 1/2 second, the frequency is 2 per second. If it takes 1/100 of an hour, the frequency is 100 per hour.

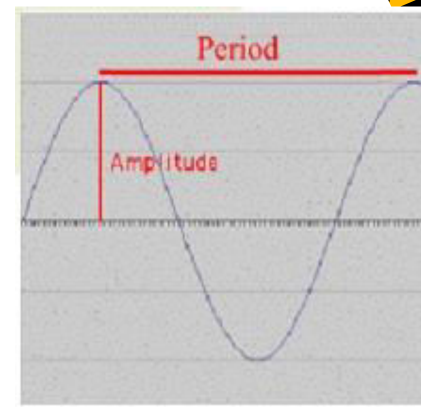


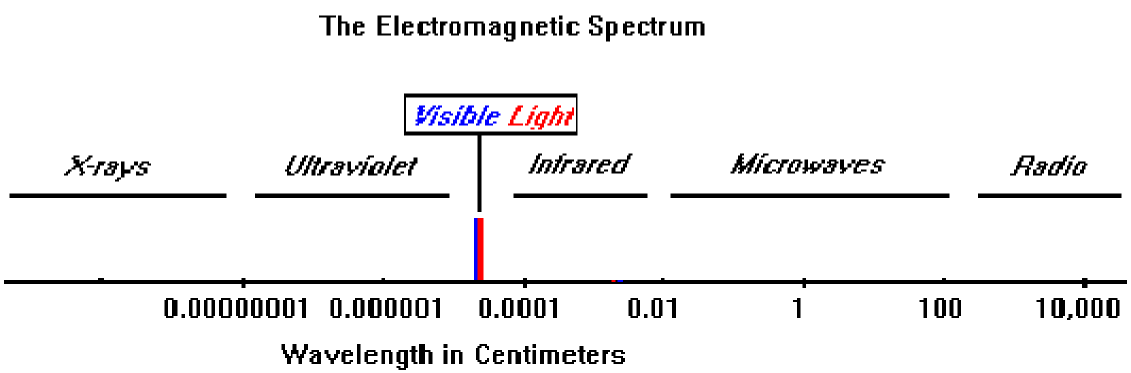
Information Technology Principles

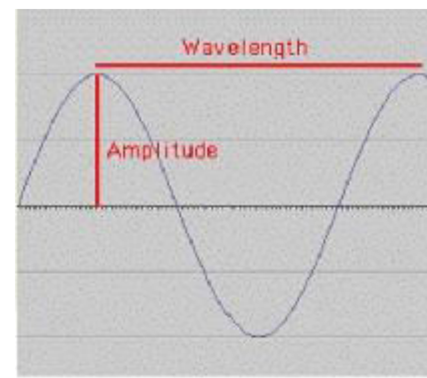
Radio Spectrum

Amplitude, Wavelength?

Since frequency and period are exact inverses of each other, there is a very basic formula you can use to calculate one from the other: $f = 1 / T$ or $T = 1 / f$







Information Technology Principles

Radio Frequency Bonus (**wavelength**)

- RF is often described as "wavelength" in the place of frequency
  - Relationship: $1/f \times C$ = wavelength (λ)
  - C is a constant--the speed of light (300,000,000 m/sec)
  - 101.1 MHz (DC 101) wavelength is

1/101.1 MHz x 300,000,000 m/sec = 2.967 m

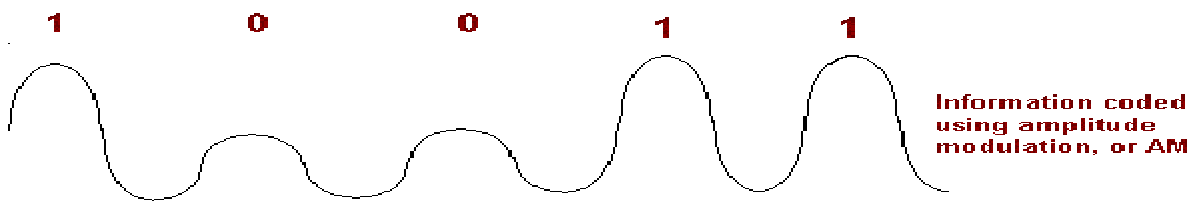
Remember--101.1 MHz is 101,100,000 Hz!

Information Technology Principles

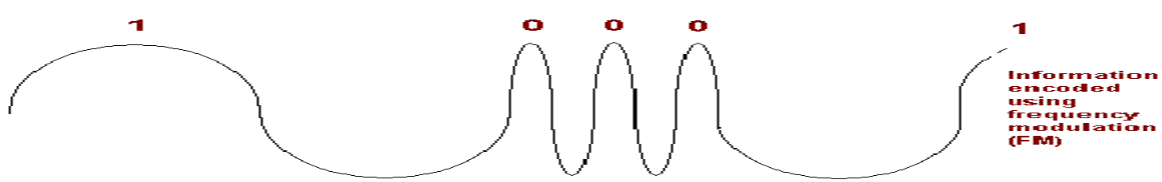
Radio Spectrum

How is data put on radio waves?

A.M. stands for amplitude modulation. In this method, the information is put into a radio wave by varying the amplitude. For example, if all we wanted to do was send 1's and 0's, we could have just two different levels of amplitude that correspond to these numbers--1 being high, 0 being low.

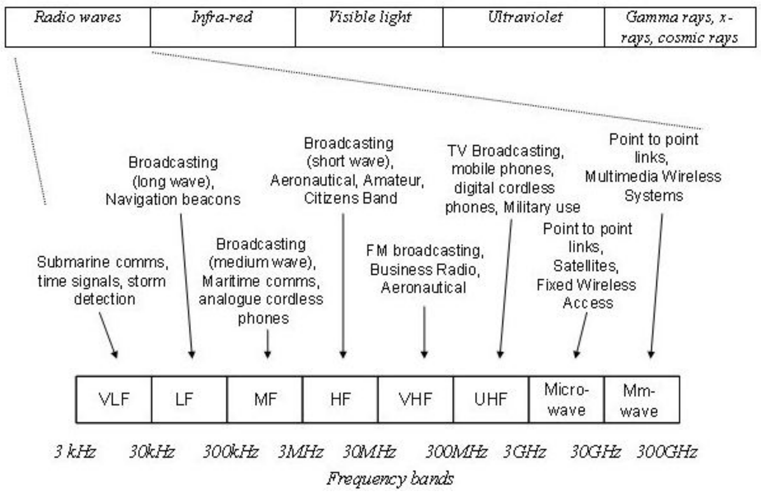


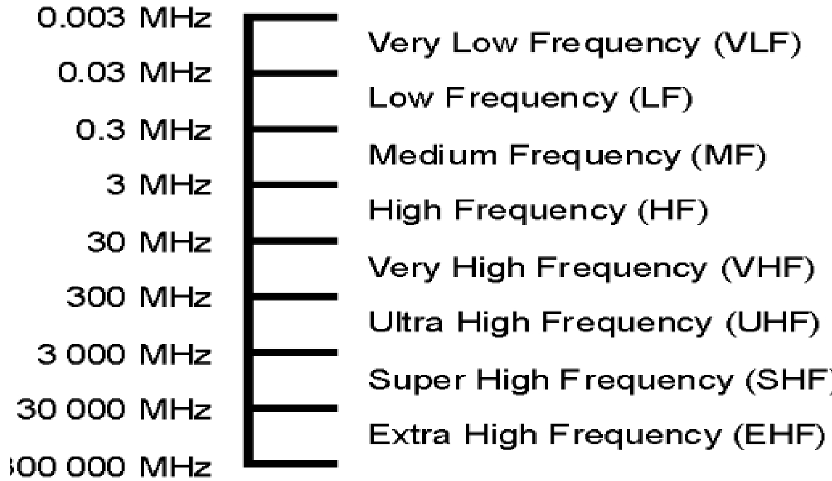
F.M. stands for frequency modulation. This time the amplitude is kept constant, it is the frequency that is varied..

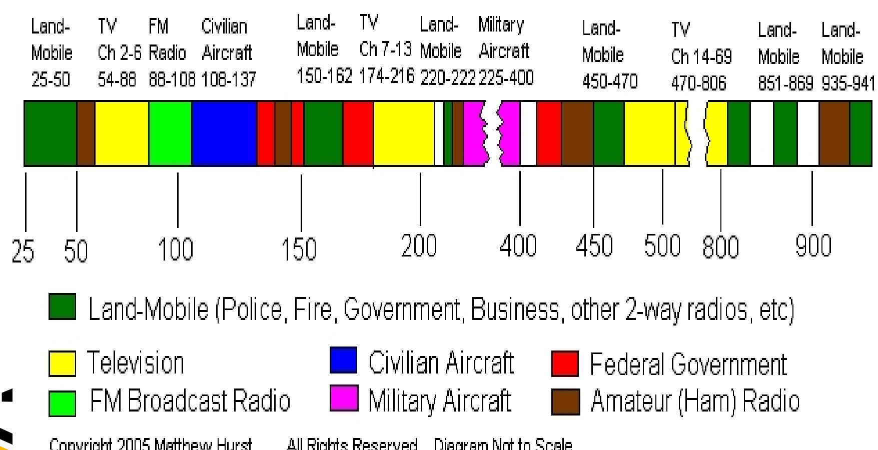


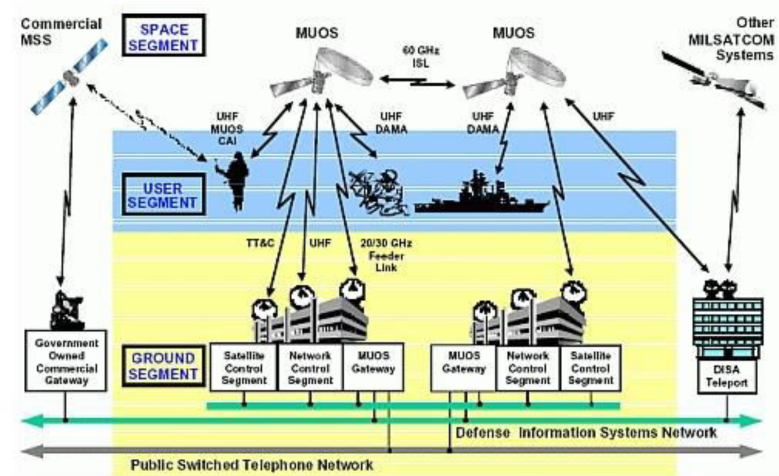
Information Technology Principles

Radio Spectrum









Information Technology Principles

RF Spectrum

- Bands of interest
  - Medium Frequency (MF) (300 kHz - 3 MHz) Commercial AM radio
  - High Frequency (HF) (3 MHz - 30 MHz) “Shortwave”
  - Very High Frequency (VHF) (30 - 300 MHz) Commercial FM radio and TV Ch 2-13, Land Mobile Radio
  - Ultra High Frequency (UHF) (300 MHz - 3 GHz) TV Ch 14 - 69, Cellular, PCS, Land Mobile Radio, Global Positioning Service (GPS)

Information Technology Principles

RF Spectrum

- Bands of interest (Con't)
  - Super High Frequency (SHF) (3 - 30 GHz) Satellite systems
  - Extremely High Frequency (EHF) (30 - 300 GHz) Satellite systems
- Note: Higher the frequency, more the bandwidth

Information Technology Principles

Characteristics of Radio Systems

- The band a system operates in describes to a large degree what the system does
- Low frequencies are “low” energy--they bend in the atmosphere and are low data rate
- High frequencies are “high” energy--they don’t bend…if they run into something, they bounce (buildings, etc) and are high data rate (they have more bandwidth)

Information Technology Principles

Components of a Radio System

- Transmitter: Takes a modulated signal and puts it on a circuit to an antenna. Power is a prime consideration, but depends on the system.

- Receiver: Takes a signal captured by an antenna (very weak usually), amplifies the signal and demodulates it.

- Antenna: The apparatus that either puts the signal out of the transmitter and/or captures the signal for the receiver. How “good” an antenna is often is measured in “gain” expressed in dB or dBi (dB compared to an isotropic antenna)

Information Technology Principles

Radio Design Considerations

- Desired transmission distance
- Transmitter Frequency
- Transmitter Power
- Receiver Sensitivity--more sensitive, less power needed at the transmitter
- Limitations on antenna size
  - A reasonably effective "whip" antenna is a 1/4 wavelength--related to the frequency of the transmitter

Information Technology Principles

Satellite Systems

- A satellite system is just a special purpose radio system
  - The satellite is a radio that is in view of a large area of the Earth

- A little orbital mechanics (that would be physics)
  - What is a satellite doing in orbit?
    - It is falling--at a rate that is not as great as its forward velocity.

Information Technology Principles

Satellite Orbits

- For communications systems, there are four classes of orbit
  - Geosynchonous Earth Orbit (GEO) 22,500 miles up
    - Geostationary Earth Orbit is a special case
  - Medium Earth Orbit (MEO) 6,000 - 12,000 miles
  - Low Earth Orbit (LEO) 100 - 300 miles
  - Highly Inclined Orbit (HIO) perigee of 100 miles, apogee of 30,000 miles or more

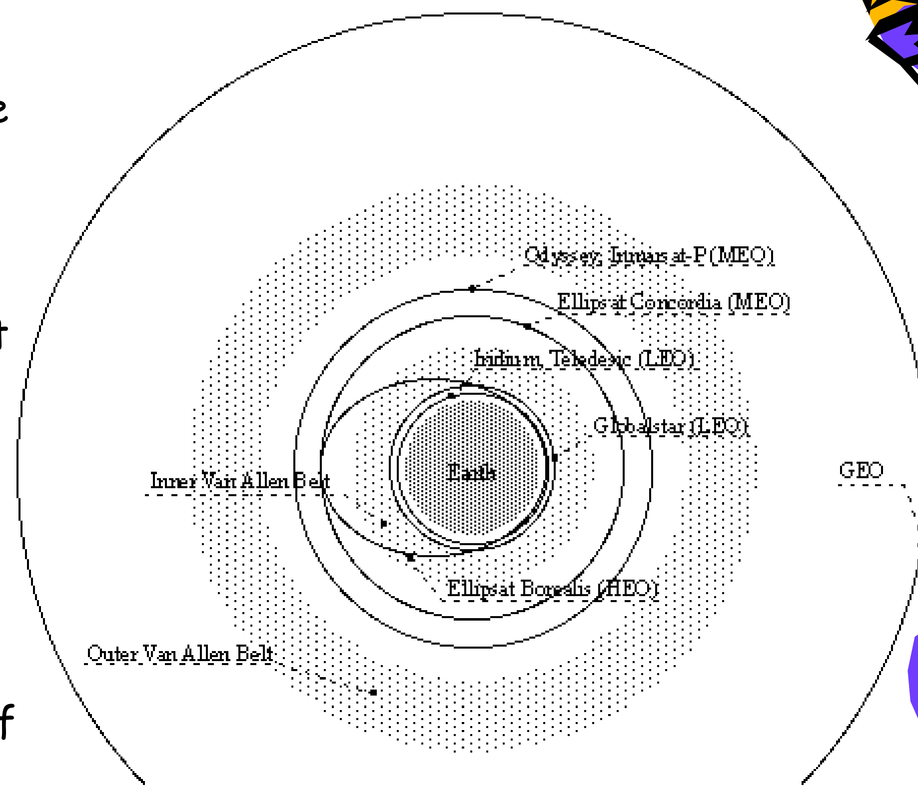


Figure 1.1 Orbital altitudes for Big LEOs and GEO. © Tor E. Wisløff¶

Figure is to scale (except for the ellipse shape of the Ellipsat Borealis orbit). The Van Allen belts are shown stylised in light grey.

Information Technology Principles

Satellite Coverage

- Three GEO satellites can provide world-wide (versus global) coverage
  - Satellites don't move much relative to a spot on the Earth (Orbital period is 24 hours)

- GPS is a MEO system that requires about 20 satellites to provide global coverage
  - Satellites are visible for a few hours (Orbital period is about 6 hours)

- Iridium is a LEO system that uses 65 satellites to provide global coverage
  - Satellites are visible for about 20 minutes (Orbital period is about 90 minutes)

Information Technology Principles

Satellite Advantages

- Signal is broadcast, not point-to-point (that means you can connect a large number of folks together without having to run a bunch of wire)
- Works well in areas with sparse infrastructure
- Supports mobile users
- Cost of service is independent of distance service is carried

Information Technology Principles

Current Satellite Issues

- In areas where infrastructure is built up, satellite service can't compete with terrestrial systems
  - Iridium found this out the hard way
- It is expensive to get on orbit
- Hard to fix something on orbit
- But…satellite service provides advantages
  - Local news can go global
  - Digital TV can be supported (no reliance on the analog terrestrial network)
  - If you need to be wireless, satellites provide truly ubiquitous service (ever looked at your cellular coverage area map closely?)