Analog and Digital Communication

Part - 1

The transfer of data from one machine to another machine such that, the sender and the receiver both interpret the data correctly is known as **Data Communication**.

All communication between devices requires that the devices agree on the format of the data. The set of rules defining a format is known as a **protocol**. At the very least, a communications protocol must define the following:

- Transmission media used
- Rate of transmission (in baud or bps)
- Whether transmission is to be synchronous or asynchronous
- Whether data is to be transmitted in half-duplex or full-duplex mode.

Some basic concepts and terminologies related to data transmission are given below:

Data Communication Terminologies

Channel

In communications, the term channel refers to a path of communications between two computers or devices. A communication channel provides everything that is needed for the transfer of electronic information from one location to another. It refers to the physical medium, such as a co-axial cable, or to a specific career frequency (sub-channel) within a larger channel or a wireless medium.

The channel capacity of a transmission system is the maximum rate at which information can be transferred reliably over a given period of time.

Baud

Baud is the number of signaling elements that occur each second. The baud indicates the number of bits (signaling elements) transmitted per second. For example 300 bauds means, 300 bits are transmitted per second, which may also be referred to as 300 bps. Assuming asynchronous transmission, which requires 10 bits per character, this 300 bps or 300 bauds, translates into 30 characters per second (cps), which is being transmitted through the channel.

For slow rates (below 1,200 bauds), we can divide the baud by 10 to see how many number of characters are sent. But for higher speeds, it is possible to encode more than one bit in each electrical change. For example, 4800 baud may allow 9,600 bits to be sent each second. Therefore at high transfer speeds, data rates are usually expressed in bits per second (bps) rather than baud. For example, a 9,600 bps modem may operate at only 2,400 baud.

Bandwidth

The amount of data or signal that the transmission media can carry in a fixed amount of time is called bandwidth. The bandwidth of a channel depends upon length, media and signaling technique used. A high bandwidth allows increased throughput and better performance.

A bandwidth is calculated using the difference between the highest and the lowest frequencies that the medium can carry. For digital devices, the bandwidth is usually expressed in bits per second (bps) or bytes per second. For analog devices, the bandwidth is expressed in cycles per second or Hertz (Hz).

Frequency

Frequency is the number of cycles or periods a signal completes within one second. The unit of measuring frequency is cycles per second or Hertz. Higher units such as KHz or MHz may also be used, where one Hz is one cycle per second.

Modes of Data Transmission

Data can be transmitted from Source to Destination in a number of ways. The different modes of data transmission are follows:

- Parallel and Serial Communication
- Asynchronous, Synchronous and Isochronous Communication
- Simplex, Half-Duplex and Full-Duplex

Serial and Parallel Communication

There are mainly two options for transmitting data, commands and other control information from the sender to the receiver. These are:

- Serial Communication and
- Parallel Communication

In Serial data transmission, bits are transmitted serially, one after another. The least significant bit (LSB) is usually transmitted first. While sending data serially, characters or bytes have to be separated and sent bit by bit. Thus, some hardware is required to convert the data from parallel to serial. At the destination, all the bits are collected, measured and put together as bytes in the memory of the destination. This requires conversion from serial to parallel.

As compared to parallel transmission, serial transmission requires only one circuit interconnecting the two devices. Therefore, serial transmission is suitable for transmission over long distances.

In Parallel transmission, all the bits of the byte are transmitted simultaneously on separate wires. Hence multiple connections between the two devices are required. It is a very fast method of transmitting data from one place to another.

The disadvantage of parallel transmission is that it is very expensive, as it required several wires for both sending as well as receiving equipments. Secondly it demands extraordinary accuracy that cannot be guaranteed over long distances.

Asynchronous, Synchronous and Isochronous Communication

One of the major difficulties in data transmission is that of synchronizing the receiver with the sender. This is the main problem in serial communication, as the receiver must be able to detect the beginning of each new character in the bit stream to reform the bytes at its end correctly.

The three mechanisms used for synchronization are:

- Asynchronous Communication
- Synchronous Communication

- Isochronous Communication

Asynchronous communication sends individual characters one at a time, framed by a start bit and 1 or 2 stop bits. Each frame begins with a start bit that enables the receiving device to adjust to the timing of the transmitted signal. The message can begin at any time. Here the messages are kept as short as possible.

Asynchronous communication is most frequently used to transmit character data and is ideally suited for characters that are transmitted at irregular intervals, such as when users are typing character data from the keyboard.

A typical frame used to transmit a character data has four components:

- A Start Bit – Signals the starting of a frame, which enables the receiving device to synchronize itself with the message
- Data Bits – Consists of 7 or 8 bits when character data is being transmitted
- Parity Bits – Optionally used as a crude method for detecting transmission errors. It can detect one bit error only.
- A Stop Bit or Bits – Signals the end of data frame.

Asyn-chro-nous transmission is useful **for** transmitting small frames **at** irregular intervals. But **for** large amounts **of** data, it is not preferred, **as** it adds a high overhead (start bit, parity bit, stop bits) **with** each transmitted character.

In Synchronous Communication, the whole block of data bits is transferred at once, instead of one character at a time. The transmission begins at a predetermined regular time instant. A sync signal is used to tell the receiving station that a new frame is arriving and to synchronize the receiving station.

Sync signals, generally utilize a bit pattern that cannot occur anywhere in the message. As the sender and the receiver remain in synchronization for the duration of the transmission, frames can be of longer length.

As the frames are longer in length, parity checking is not suitable for error detection. Instead Synchronous transmission uses Cyclic Redundancy Check (CRC) technique for reporting errors. The transmitter uses an algorithm to calculate a CRC value, which is appended with the data frame. The receiver uses the same algorithm to recalculate the CRC and compare it with the data in the frame.

The end bit pattern is also distinct, similar to the sync signal, which can be recognized as the end of the frame at the receiving end.

Synchronous Communication is used for high-speed data transmission. It is more efficient because only 4 additional bytes are required to transmit up to 64 k bits.

Advantage of Synchronous Communication

- Synchronous Communication is more efficient and gives more throughputs compared to Asynchronous Communication. It can eliminate upto 20% of associated overheads inherent in Asynchronous Communication.
- Synchronous Communication is not really prone to distortion, as a result, it can be used at high-speed data communications.
- It is well suited to remote communication between a computer and such a device as buffered card readers, printers or another computer.

Disadvantage of Synchronous Communication

- Synchronous transmission is expensive as complex circuitry is required and it is difficult to implement.
- If an error occurs during transmission, rather than just a single character the whole block of data is lost.
- The sender cannot transmit characters simply, as they occur, but has to store them until it has built up a block. Thus this is not suitable where characters are generated at irregular intervals.

The efficiency of transmission is defined as the ratio of the number of message bits to the total number of transmitted bits.

$$\% \text{ efficiency} = \frac{\text{Data bits}}{\text{Total bits}} \times 100$$

Problem 1

Suppose on a transmission channel, 600 character message using ASCII 7 bit code is used. For Synchronous data stream, there are two SYN characters and a single error-detection character is added.
In Case of Asynchronous data transmission, there is one start bit and one stop bit and a single error-detection bit.
Calculate the efficiency of transmission in the above two transmission mode.

Solution

For Synchronous mode of transmission:

Total number of characters transmitted = 600 + 2 (SYN) + 1 (Error detection character) = 603 chars
= 603 x 7 = 4221 Bits

Total number of bits carrying actual message = 600 characters x 7 bits = 4200 bits.

Hence Efficiency = (4200/4221) x 100 = 99.5%

For Asynchronous mode of transmission:

For each character transmitted, there is a start bit, a stop bit and a error correction bit.

Total bits required for each characters transmission = 7 + 1 (start bit) + 1 (stop bit) + 1 (error bit)
Hence each frame size = 10 bits.
Since 600 such frames are transmitted, total number of bits transmitted = 600*10=6000 bits

Hence Efficiency = (4200/6000) x 100 = 70%

Isochronous Communication

This method combines the approaches of asynchronous and synchronous communication. As in the asynchronous method, each character has both the start and stop bits. But the idle period between the two characters is not random but an exact multiple of one character time interval.

If the time to transmit a character (including its parity, start and stop bits) is **t**, the time interval between characters cannot be random as in the asynchronous method. It is also not 0, as in the synchronous method. It has to be **t**, 2**t**, 3**t** …. n**t** etc.

Advantages of Isochronous communication are that:

- Isochronous transmission guarantees transmission rates, and it is almost deterministic.
- It has low overheads.
- It has high speeds, at least higher than asynchronous communication.

The main disadvantage is that in Isochronous transmission it is necessary to ensure that the clocking device is fault tolerant.

Simplex, Half Duplex and Full duplex Communication

This classification is based on the question of which communication can send data and at what point of time.

Simplex

This is the simplest signal flow technique, where one of the communicating devices can only send data, whereas the other can only receive it. Here, communication is only in one direction (unidirectional) where one party is the transmitter and the other is the receiver.

Examples of simplex communication are the simple radio and public broadcast television where, you can receive data from stations but can't transmit data back. This kind of channel design is easy and inexpensive to set up.

Half Duplex

Half-Duplex refers to two-way communication where, only one party can transmit data at a time. Unlike the Simplex mode here, both devices can transmit data though, not at the same time. In other words, Half-Duplex provides Simplex communication in both directions in a single channel, but not at the same time. Thus when one device is sending data, the other device must only receive it and vice versa.

This requires a definite turn-around time during which, the device changes from the receiving mode to the transmitting mode. Due to this delay, half duplex communication is slower than simplex communication. However it is more convenient, as both the devices can send and receive data.

For example, a walkie-talkie is a half-duplex device because only one party can talk at a time.

Full Duplex

Full duplex refers to the transmission of data in two directions simultaneously. Here both the devices are capable of sending as well as receiving data at the same time, as a result, this configuration requires full and independent transmitting and receiving capabilities at both ends of the communication channel.

Sharing the same channel and moving signals in both directions increases the channel throughput without increasing its bandwidth.

For example, a telephone is a full-duplex device because both parties can talk to each other simultaneously.

Analog and Digital Data Transmission

The two major types of signals are Analog and digital. The manner in which these two types of signals can be transmitted from source to destination are of the two types:

- Analog data transmission
- Digital data transmission

Analog Signal

Analog signals vary constantly in one or more values and these changes in values can be used to represent data. An analog signal is continuous and can be represented by using sine waves. Human voice, video and music are all examples of analog signals which vary in amplitude (volume) and frequency (pitch). Human voice generates an analog (continuously varying) signal containing multiple frequencies that is transmitted as an analog signal over the medium.

Analog signals suffer attenuation while transmission on the way and amplifiers are used to compensate this attenuation. But the main drawback is that amplifiers amplify noise along with the original signal and hence, if the signal gets distorted, it cannot be reconstructed and it becomes a permanent loss.

However, by converting analog signals to digital signals, the original audio or video data can be preserved indefinitely within the specified error bounds and can be copied over and over without deterioration.

Digital Signal

Digital data transmission describes any system based on discontinuous data or events. Computers are digital machines because at their most basic level, they can distinguish between just two values, 0 and 1, or just off and on. There is no simple way to represent all the values in between such as 0.25.

As the signal traverses through the medium, it gets distorted. A hardware device called Repeater is used to regenerate the digital signal and the 0s and 1s are reconstructed. Thus there is a minimum chance of the loss of original signal, which can be copied again and again without any loss.

Transmission Impairments

When data is transmitted from the sender to the receiver, there is a scope of transmission error, as because the transmission media is never perfect. In such cases, the received signal may not be the same as the transmitted signal. Transmission suffers from three major problems:

- Attenuation.
- Delay distortion.
- Noise.

Attenuation

Attenuation is the loss of energy, as the signal propagates outwards. On guided media (e.g. wires, optical fibers), the signal falls off logarithmically with the distance. The loss is expressed in decibels per kilometer (db/km). The amount of energy loss depends on the frequency, which is higher at higher frequencies.

In many cases, the attenuation properties of a medium are known, and amplifiers can be put in place to try to compensate for the frequency-dependent attenuation, although the original signal cannot be regenerated.

Delay Distortion

Delay distortion is caused by the fact that the signals of varying frequencies travel at different speeds along the medium. Any complex signal can be decomposed into different sinusoidal signals of different frequencies, resulting in a frequency bandwidth for every signal.

One property of signal propagation is that the speed of travel of the frequency is the highest at the centre of this bandwidth and lowest at both ends. Therefore, at the receiving end, signals with different frequencies in a given bandwidth will arrive at different times. If the signals received are measured at a specific time, they will not be exactly like the original signal resulting in its misinterpretation.

Noise

Noise is unwanted energy from sources other than the transmitter. Thermal noise is caused by the random motion of the electrons in a wire and is unavoidable. Cross talk is caused by inductive coupling between two wires that are close to each other.

Finally there is impulse noise, caused by spikes on the power line or other causes.