IFC6501 - Wireless Data Communications

Session 1: Course Overview

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Department of Electrical Engineering
Faculty of Engineering
Universitas Sam Ratulangi

Outline

Acknowledgement

When not specifically cited, the contents of this presentation are adapted from [1].

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The Rules of the Game

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7. You are college students, please behave with the appropriate attitude.

Outline

Topics

- Fundamental aspects in wireless communications.

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- Wireless networks

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- Simulation

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- *See attachment for more details*

Outline

Scoring Components

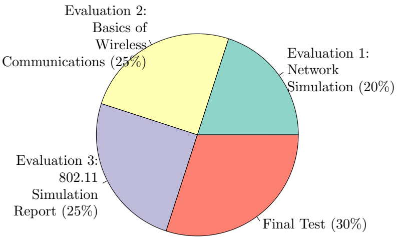
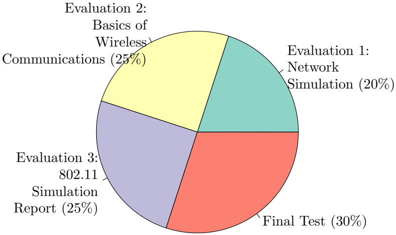


Figure 1 : Scoring components

- 3 Evaluations 70%

Scoring Components



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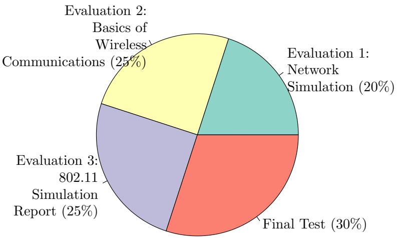

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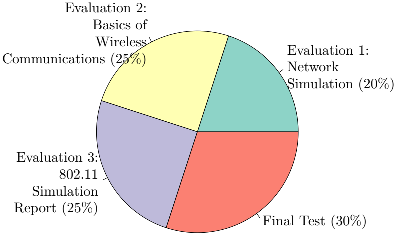

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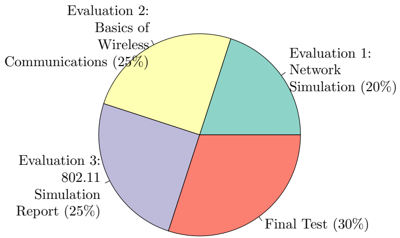

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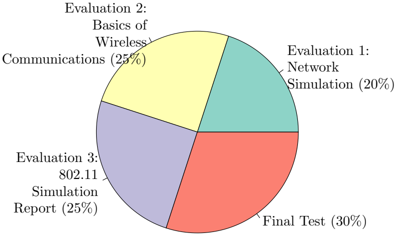

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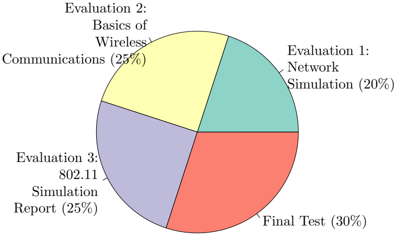

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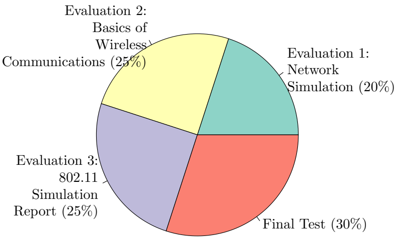

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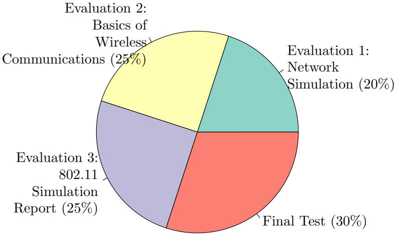

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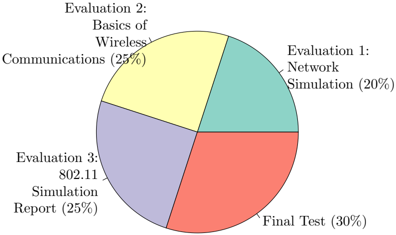

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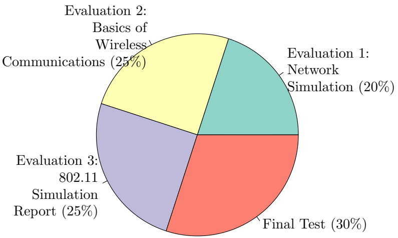

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- Statistical processing: GNU R

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Data Communication

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- Data communications also introduces e-Learning and distance learning in the education field, that makes education contents available even for the people in the remote area.

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Data Communications

Fundamental Characteristics

- Delivery

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- Delivery
- Accuracy

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- Delivery
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  - **Connecting device** such as router, switch, and bridge.

Networks

Criteria

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- Oftenly evaluated in **throughput** and **delay**.

Networks

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Networks

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- Measured by:
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  - Required time for recovery from a failure
  - Robustness during a catastrophe

Networks

Criteria: Security

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- Protecting data from unauthorized access
- Implementing policies and procedures for recovery from breaches and data losses

- Type of Connection

Networks

Physical Structures

- Type of Connection
- Physical Topology

Networks

Physical Structures: Type of Connection - Point-to-Point

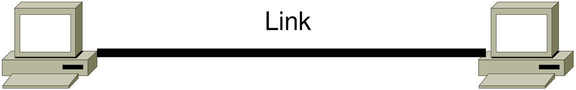

Figure 2 : Point-to-Point connection.

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Networks

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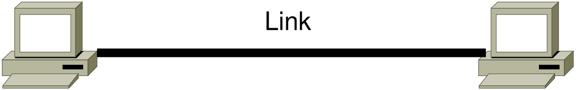

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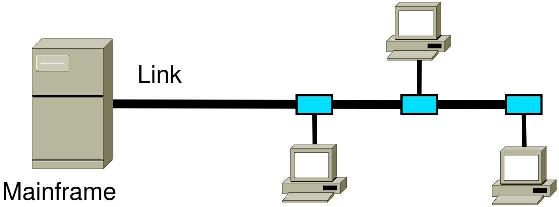
- Entire link capacity is reserved for transmission between those devices.

Networks

Physical Structures: Type of Connection - Multipoint



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Networks

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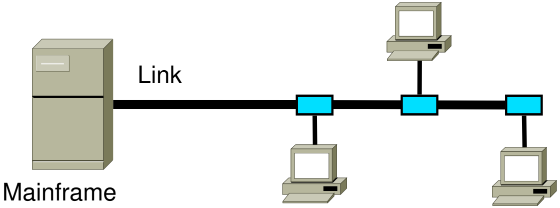

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- Multipoint connection¡+-¿also known as multidrop connection. shares a single link to be used by multiple devices.
- The link capacity is shared, either spatially or temporally.

Networks

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Networks

Physical Structures: Physical Topology - Bus

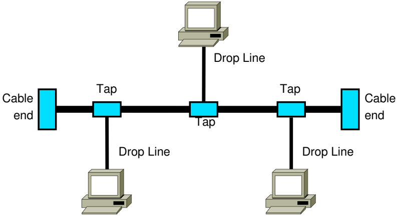

Figure 4 : Bus topology with three stations

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Networks

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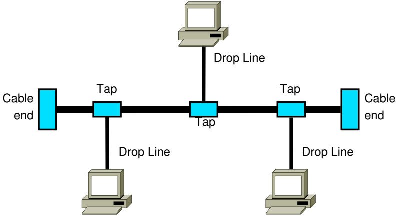

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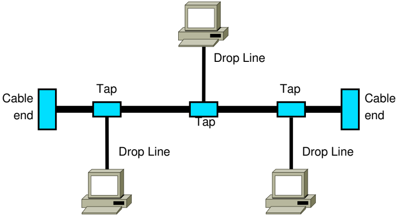

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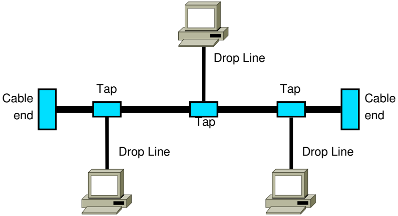

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- The number of supported taps, and distances between taps are limited.

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  - A single fault stops all transmission.

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Physical Structures: Physical Topology - Ring

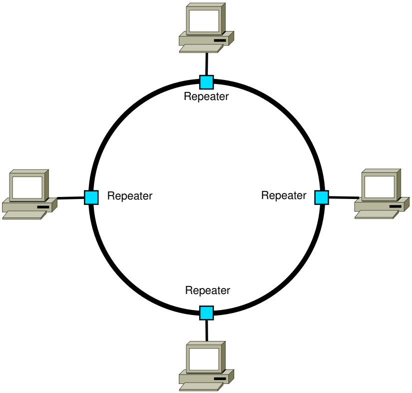

Figure 5 : Ring topology with four stations

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Physical Structures: Physical Topology - Ring

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  - Fault isolation is simplified.
- Disadvantage:
  - Unidirectional traffic can be a disadvantage.A break in can disable entire network.

Networks

Physical Structures: Physical Topology - Star

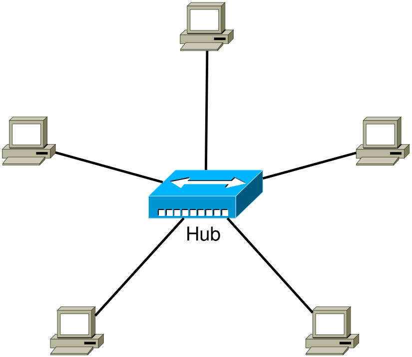

Figure 6 : Star topology with five stations

Networks

Physical Structures: Physical Topology - Star

- Each device has a dedicated point-to-point connection only to a central controller.

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- Disadvantage:
  - If the hub down, whole network is dead.

Networks

Physical Structures: Physical Topology - Mesh

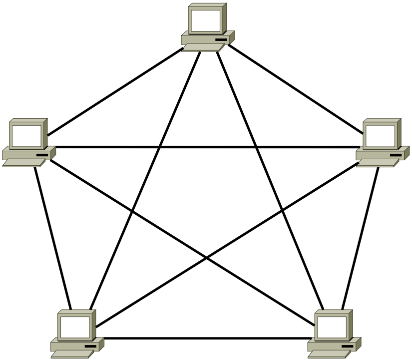

Figure 7 : Mesh topology with five stations

Networks

Physical Structures: Physical Topology - Mesh

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  - Privacy and security
  - Easy fault identification and isolation
- Disadvantage:
  - Requires $n(n-1)/2$ duplex mode links and in each device $n-1$ I/O ports. n represents the number of nodes.

Network Types

- Local Area Network (LAN)

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- Wide Area Network

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  - Switched WAN

Network Types

- Local Area Network (LAN)
- Wide Area Network
  - Point-to-point WAN
  - Switched WAN
- Internetwork (network of networks)

Network Types

Switching

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Network Types

The Internet

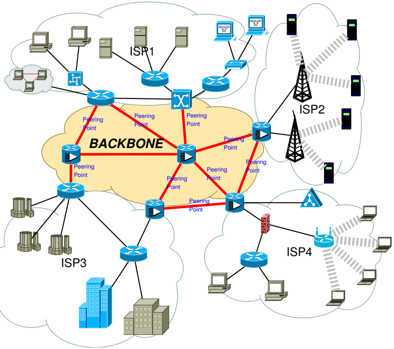

Figure 8 : A simplified model of the Internet.

Network Types

The Internet

- The **Internet** is the most notable internet.

Network Types

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- To gain access to the Internet, the LANs should have a connection to the service provider network.
- Later, the networks of the service providers are connected to the **Backbone Network**.

Network Types

Accessing The Internet

- Using telephone networks

Network Types

Accessing The Internet

- Using telephone networks
  - Dial-up service

Network Types

Accessing The Internet

- Using telephone networks
  - Dial-up service
  - DSL Service

Network Types

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- Using telephone networks
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  - DSL Service
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  - DSL Service
- Using cable networks
- Using wireless networks

Network Types

Accessing The Internet

- Using telephone networks
  - Dial-up service
  - DSL Service
- Using cable networks
- Using wireless networks
- Direct connection to the Internet

Outline

TCP/IP Protocol Suite

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- Hierarchical means an *upper layer* protocol is supported by the services provided by one or more *lower level* protocols.
- Originally TCP/IP suite was defined as four software layers built upon the hardware, but in present condition it is considered as five-layer model.

TCP/IP Protocol Suite

Layers

- The layers[4] in the TCP/IP Protocol Suite are:

TCP/IP Protocol Suite

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TCP/IP Protocol Suite

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TCP/IP Protocol Suite

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  2. Data link
  3. Network
  4. Transport
  5. Application

[4] In the present consideration

TCP/IP Protocol Suite

Object in Each Layer

Table 1 : Objects in the TCP/IP Protocol Suite

Layer	**Object**
Physical	Bits
Data link	Frames
Networks	Datagrams
Transport	Segments or User Datagrams
Application	Messages

TCP/IP Protocol Suite

Physical Layer

- Responsible for carrying individual bits in a frame across the link.

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- Although physical layer is the lowest layer in the suite, there is still another layer: the transmission medium.
- Devices are physically connected by the transmission medium, but it carries signals not bits.
- Physical layer handles the bits-to-signals and signals-to-bit transformation.

TCP/IP Protocol Suite

Data link Layer

- Data link handles data communication within the same link.

TCP/IP Protocol Suite

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- Data link takes the datagram from network layer and moving it across the link.
- No specific protocol defined for this layer, so it supports all standard and proprietary protocols.
- Several protocols provide complete error detection and correction, some only provide error correction.

TCP/IP Protocol Suite

Network Layer

- Network layer is responsible for creating a host-to-host connection between source and destination.

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- Network layer is responsible for creating a host-to-host connection between source and destination.
- The source and destination may located in different networks.
- Routers work in this layer, and responsible to choose the best route for each packet.
- Network layer includes the main main protocol: Internet Protocol (IP).

TCP/IP Protocol Suite

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- In other words the transport layer is responsible for giving services to the application layer: to get a message from an application running at the source host and deliver it to the corresponding application program on the destination host.

TCP/IP Protocol Suite

Application Layer

- Two application layers exchange messages between each other as though there were a bridge between the two layers[5].

[5] Keep in mind that the communication goes through all layers.

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Application Layer

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- The communication is between two *processes* (programs) running at this layer.
- To communicate , a process sends a request to the process at the other host and receives a response.

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Layered Architecture Operation

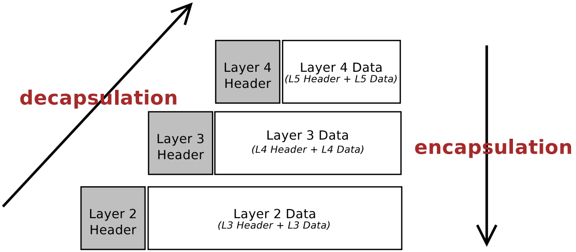

Figure 9 : Encapsulation and decapsulation concept

Layered Architecture Operation

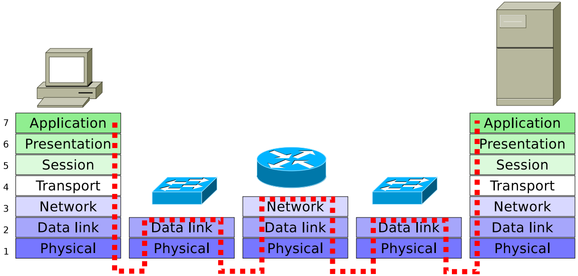

Figure 10 : Data communication in layered architecture.

Outline

Physical Layer

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- Physical layer is responsible to move data in form of electronic signals across transmission medium.

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- First, let us discuss the medium.

Outline

Transmission Medium [2]

- In data communication, nodes are always connected by physical path.

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- Electromagnetic wave is the element that being transmitted between connected parties.

Transmission Medium [2]

Forms of Transmission Medium

- **Guided Media:** electromagnetic waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, or optical fiber.

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Forms of Transmission Medium

- **Guided Media:** electromagnetic waves are guided along a solid medium, such as copper twisted pair, copper coaxial cable, or optical fiber.
- **Unguided Media:** the transmission occurs through the atmosphere, outer space, or water.

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- The form of the signals could be analog or digital.

Outline

Analog and Digital Data

- Analog Data: continuous information.

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- Example:the data stored in computer memory in binary form.

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- An analog signal has infinitely many levels of intensity over a period of time.
- On the contrary, a digital signal can only has a limited number of defined values.
- Figure 11 shows an example of analog signal plotted on a pair of perpendicular axes. Figure 12 shows the plot of digital signal.

Analog and Digital Signals

Example of Analog Signal

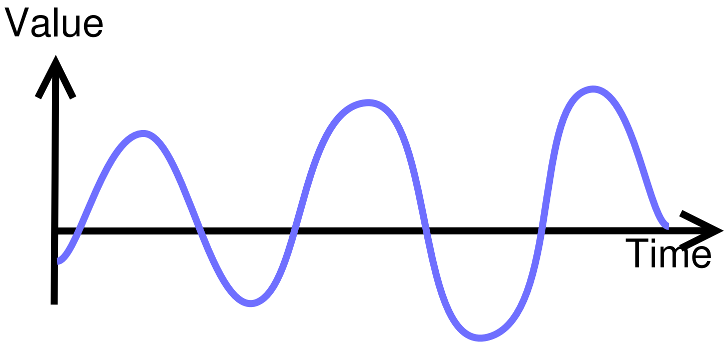

Figure 11 : Analog signal

Analog and Digital Signals

Example of Digital Signal

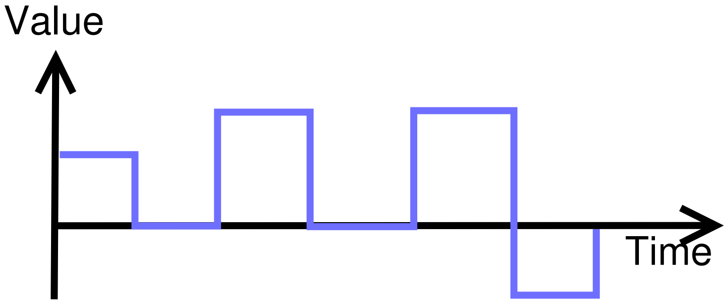

Figure 12 : Digital signal

Outline

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- In data communication we commonly use **periodic analog signals** and **nonperiodic digital signals**.

Outline

Periodic Analog Signals

- Periodic signals can be classified as simple or composite.

Periodic Analog Signals

- Periodic signals can be classified as simple or composite.
- A composite signal is composed of multiple simple signals.

Outline

Sine Wave

- A sine wave has three parameters:

Sine Wave

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  - Peak amplitude (A)

Sine Wave

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- Figure 13 shows two signals with the same phase and frequency, but different amplitudes.

Sine Wave

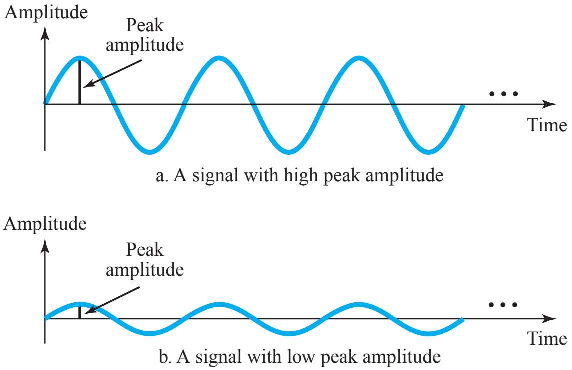

Figure 13 : Two sine waves, with different amplitude.

Sine Wave

Parameters [2]

- Frequency (f) is the rate at which the signal repeats. It is measured as cycle(s) per second, or Hertz (Hz).

Sine Wave

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- Phase (ϕ) is a measure of relative position in time within a single period of signal.
- Peak amplitude (A) is the maximum value or strength of the signal over time. Typically measured in volts.

Sine Wave

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Sine Wave

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$$s(t) = A \cdot sin(2\pi ft + \phi) \quad (2)$$

Sine Wave

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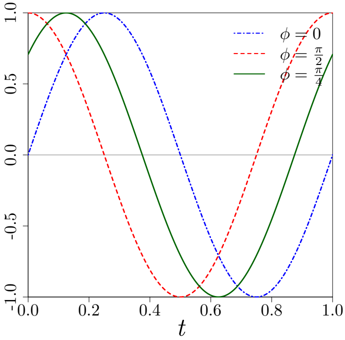

Figure 14 : Plot of sine waves with $f = 1$, $A = 1$, and various values of ϕ.

Sine Wave

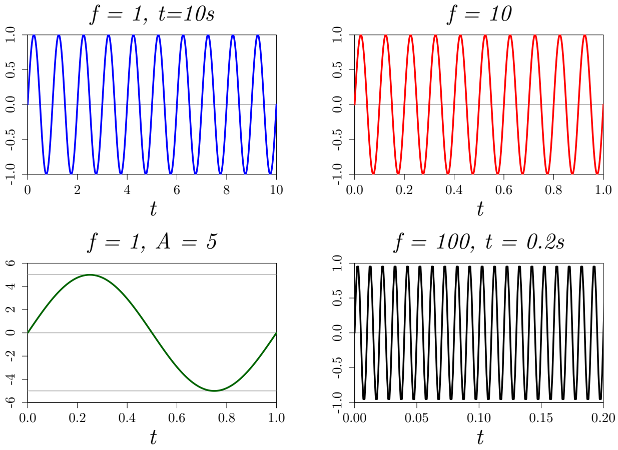

Figure 15 : Sine waves of various frequencies and amplitudes.

Sine Wave

Wavelength

- Wavelength (λ) binds the period (T) or the frequency (f) of a sine wave to the propagation speed of the medium.

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$$\lambda = v \times T \tag{3}$$

Sine Wave
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- with $c \approx 3 \times 10^8 \ m/s$, which is known as the speed of light in vacuum.

Outline

Composite Signals

- Simple sine waves have many applications in daily life (e.g. in electricity).

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- However, in data communications, a single sine wave carries no information.
- To communicate data, we need a composite signals.
- According to Fourier analysis, any composite signal is a combination of simple sine waves with different frequencies, amplitudes, and phases.

Composite Signals

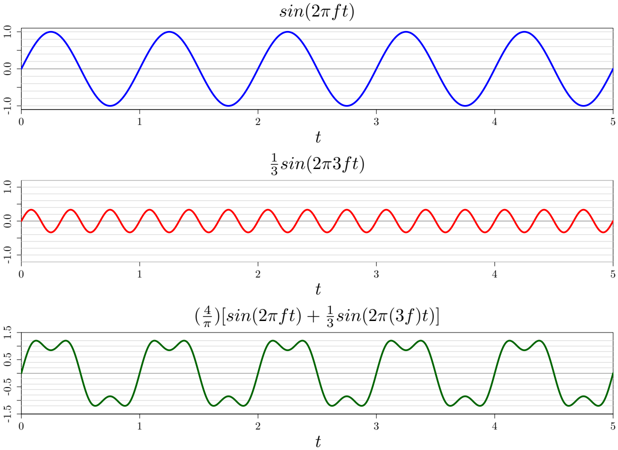

Figure 16 : Simple sine waves and a composite signal.

Outline

Bandwidth

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[6] Forouzan uses f_h and f_l for the highest and the lowest frequencies, respectively.

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  - The second signal (b) has four levels, 2 bits per level.

Digital Signal

Levels

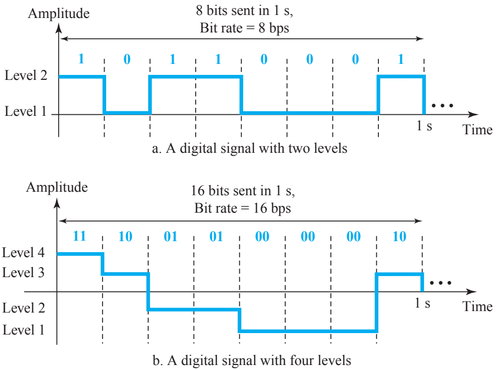

Figure 17 : Two digital signals with different levels.

Digital Signal

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where L is the number of levels of a signal.

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- Bit rate is the number of bits sent in a second, hence the unit is <u>bits per second</u> (bps).
- In Figure 17, the bit rate of the first signal is 8 bps while the second signal has 16 bps.

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$$\text{Bit length} = \text{propagation speed} \times \text{bit duration} \tag{7}$$

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- Due to the requirements, bandpass channel is more available than the low-pass channel.

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- The cause is the signal suffers transmission impairments.
- In analog signal, the quality may be deteriorated.
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- The causes of impairment are attenuation, distortion, and noise.

Outline

Attenuation

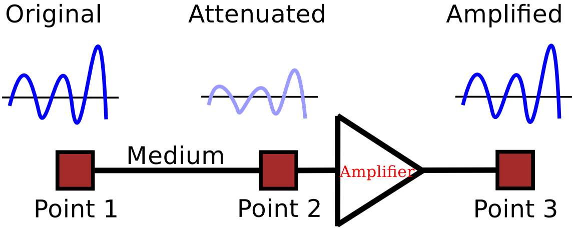

Figure 18 : Illustration of attenuation.

- Attenuation means a loss of energy.

Attenuation

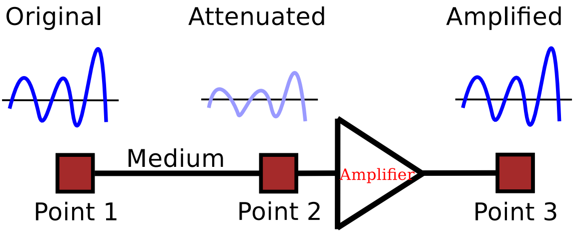

Figure 18 : Illustration of attenuation.

- Attenuation means a loss of energy.
- To show whether the signal has gain or loss strength, engineers use the unit of **decibel**.

Attenuation

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- P_1 and P_2 are the **powers** of a signal at locations 1 and 2, respectively.

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- Different propagation speeds cause variance of delay. It means each component arrived at different time.
- In other words, the received signal has different phases from the transmitted signal.

Distortion

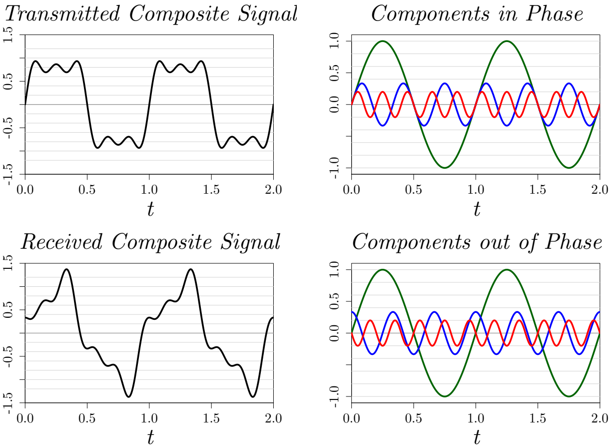

Figure 19 : Distortion affecting the received signals.

Outline

Noise

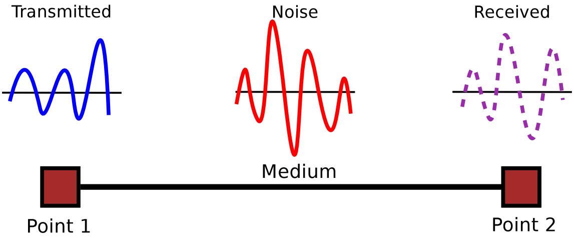

Figure 20 : Noise effect.

- Thermal noise

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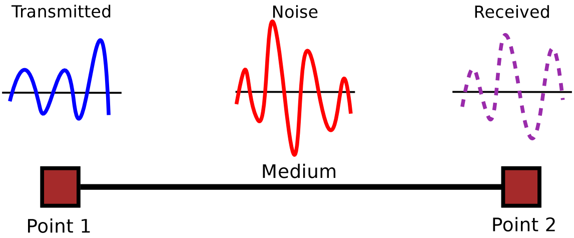

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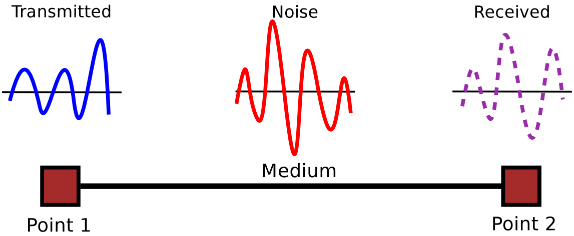

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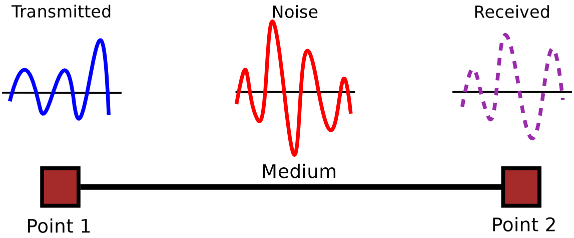

Figure 20 : Noise effect.

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- Data rate is depend on:
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  - Channel quality (level of noise)
- There are two theoretical formulas to calculate the data rate: Nyquist formula and Shannon formula.

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- Although more signal levels means higher data rate, unfortunately it also means more burden to the system.

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- The capacity of the channel according to Shannon formula is 6 Mbps.

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4 \times 10^6 &= 2 \times 10^6 \times \log_2 L \\
4 \times \cancel{10^6} &= 2 \times \cancel{10^6} \times \log_2 L \\
4 &= 2 \times \log_2 L \\
\cancel{4} &= \cancel{2} \times \log_2 L \\
2 &= \log_2 L \\
\sqrt{L} &= 2 \\
L &= 4
\end{aligned}$$

- The number of signal levels is 4.

Outline

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Bandwidth

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- Although they have different context, both types of bandwidth are related.

Outline

- Course Details
- Review: Data Communications and Networking
- Review: Physical Layer
  - Transmission Medium
  - Data and Signals
  - Periodic Analog Signals
  - Digital Signals
  - Transmission Impairments
  - Data Rate Limits
  - Performance
    - Bandwidth
    - Throughput
    - Latency
    - Bandwidth-Delay Product
    - Jitter
- Exercise

Throughput

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- Throughput is affected by network congestion, bottleneck, etc.

Outline

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$$\begin{aligned}\text{Latency} = {} & \text{propagation time} + \text{transmission time} \\ & + \text{queuing time} + \text{processing delay}\end{aligned} \tag{13}$$

Latency

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$$\text{Propagation Time} = \frac{\text{distance}}{\text{propagation speed}} \tag{14}$$

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Transmission Time

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$$\text{Transmission time} = \frac{(\text{Message Size})}{\text{bandwidth}} \tag{15}$$

Latency

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- Processing delay is the amount of time needed by an device to process a message.
- For example, a router – when it receives a packet – should determine whether to self-process the packet or forward it, then if the packet should be forwarded, the packet should determine where to forward it.

Outline

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Review: Data Communications and Networking

Review: Physical Layer

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  Case 1: A link with 1 bps bandwidth and 1 s delay, see Figure 21.

  Case 2: A link with 5 bps bandwidth and 5 s delay, see Figure 22.

Bandwidth-Delay Product

Case 1

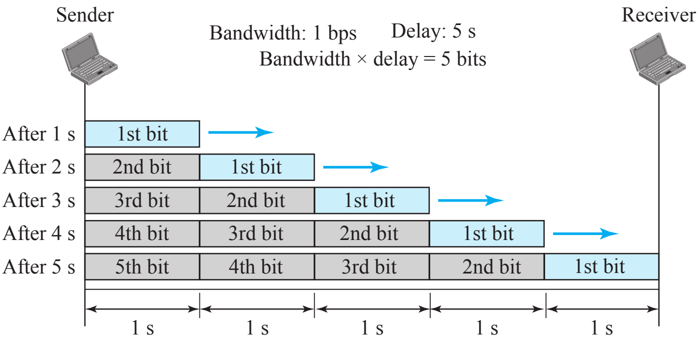

Figure 21 : Bandwidth-link product, case 1.

Bandwidth-Delay Product

Case 2

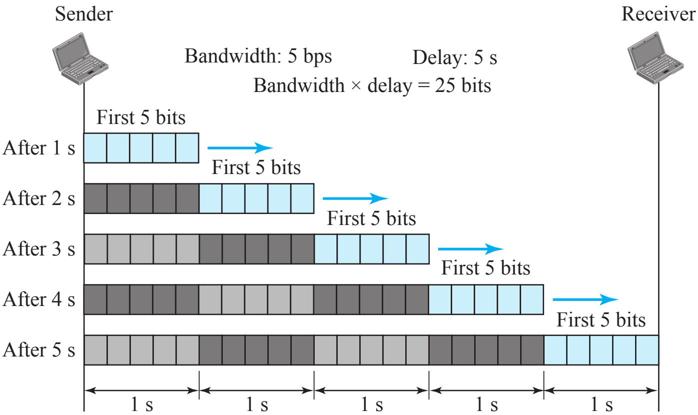

Figure 22 : Bandwidth-link product, case 2.

Outline

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- Jitter becomes a problem when the application is time-sensitive, (e.g. audio and video data).

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4. The wavelength of a signal is 0.125 m. Suppose it is propagating in vacuum, then what is its frequency?
5. The frequency of a signal is 900 MHz and the wavelength is 0.25 m. What is the propagation speed of the medium?

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8. A signal propagates through a noiseless channel. What is the $\mathrm{SNR}_{\mathrm{dB}}$ of such channel for signal power S?

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- Both Equations (8) and (16) are used to calculate attenuation. If we ignore other wireless link budget parameters, give the mathematical correlation between both equations!

Exercise

10. A Wireless Service provider is going to cover the customers at a new area. You are acting as the consultant for this WISP and the managers are requesting your consideration about their going-to-be-deployed wireless backbone.
    If the sensitivity threshold is -67 dBm, calculate the minimum transmit power by using the mathematical correlation between Equations (8) and (16) you found in the previous question!
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    The following information are available to you:
    - The sites are located at the coordinates shown in Figure 23.
    - These sites will form a ring topology, so a site is connected to the other two.
    - This WISP uses 802.11n technology, and the frequency in-use follows the regulation issued by the Indonesian government.

Exercise

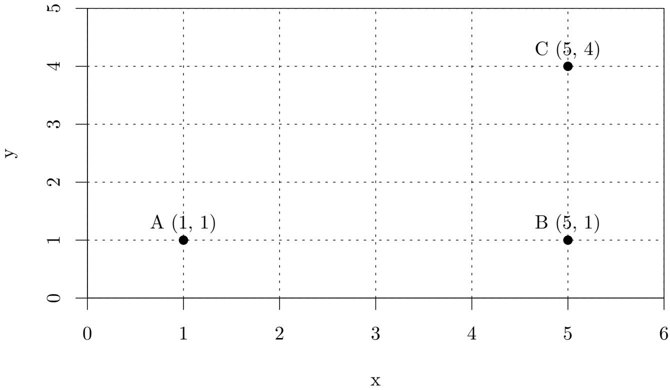

Figure 23 : Locations of the backbone sites.

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13. How many bits can fit on a link with a 2 ms delay if the bandwidth of the link is 1 Mbps?
14. What is the total delay for a frame of size 5 million bits that is being sent on a link with 10 routers, each having a queuing time of $2\mu\mathrm{s}$ and processing time of $1\mu\mathrm{s}$ the length of the link is 2000 Km. The propagation speed is $2 \times 10^8 \mathrm{m/s}$ The link has a bandwidth of 5 Mbps. Which component of the total delay is dominant? Which one is negligible?

Next session..

- OMNeT++
- Finish TicToc Tutorial before class!
- Have OMNeT++, R (and optionally RStudio) installed in your notebooks. Each student who has notebook is highly advised to bring his/her own notebook.

Outline

Course Details

Review: Data Communications and Networking

Review: Physical Layer

Exercise

References

References I

[1] B. Forouzan, Data Communications and Networking, 5th ed. New York: McGraw-Hill Education, 2013.

[2] W. Stallings, Data and Computer Communications, 8th ed. NJ: Pearson/Prentice Hall, 2007.