Computer Networks
Handout—Class 1

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1 Class Overview

- Basic definitions. Describing the layers in the network architecture. Motivation for the course.
- How data travels in a medium? Describing electromagnetic (EM) signals conceptually and mathematically.
- Briefly describing a digital signal and identifying the difference between EM signal and digital signal.

2 Course Introduction

In this course, we will try to build our foundation of computer networks from the ground up. We will not just study protocols and systems in use today, but also those that were discarded for their demerits. Learning the guiding principles will help us build an understanding of what is important in a computer network, how to build networks from the ground up, and how to improve networks. The fundamental principles that we will learn in this course were valid in the past, are valid today and are likely to remain valid in the future. Some definitions:

Computer Network A network is a group of entities connected together. So, a computer network is a group of computers connected together. Internet is the largest computer network.

Network Layers Network engineers find it convenient to arrange all the operations that make up a network into layers. Each layer has a different responsibility and builds on top of the layer below it.

2.1 How network layers work

- When an application has data to send, it hands the data to transport layer

- The Transport layer hence has the job of delivering the data reliably to the other end.
- Transport layer in turn hands data to network layer.
- The Network layer has the job of breaking the data into packets.
- Network layers hands packets to the link layer.
- The Link layer has the responsibility of delivering the packet from one hop to the next along the path.
- The data makes it way hop by hop until it reaches destination.
- There the data is passed up the layers until it reaches the application.

Application Layer
Transport Layer
Network Layer
Link Layer
Physical Layer

3 Sending Data

3.1 The basic idea

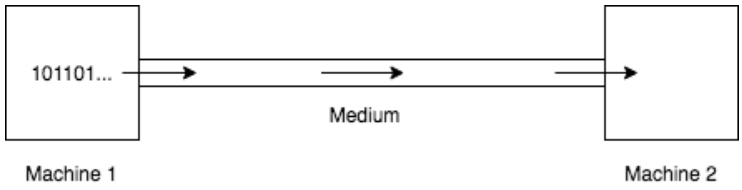

Figure 1: The basic idea of sending data in a network

1. Find a way to encode binary data into electromagnetic signals that can be transferred over a physical medium.
2. Decode the electromagnetic signals back to binary data at the receiver's end.

3.2 Electromagnetic Signals

Signal A signal is a function $s : \mathbb{R} \to \mathbb{R}$.

3.2.1 Periodic Signal

A signal is called periodic if $\exists T \in \mathbb{R}$ such that $\forall t \in \mathbb{R}$:

$$s(t+T) = s(t)$$

3.2.2 Sinusoid

One of the most fundamental periodic signals is a sinusoid. A sinusoid is a function $s : \mathbb{R} \to \mathbb{R}$ that is defined as follows:

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

In this equation:

- A = amplitude of the EM wave
- A periodic function repeats a pattern of y-values at regular intervals. One complete repetition of such a pattern is called a **cycle**.
- The **frequency** f of the sinusoid is the number of cycles completed by the function in one second. It is measured in Hertz (Hz).
- The **period** of the sinusoid function is the horizontal length of one such cycle.
- ϕ = phase of the wave (in radians)

Period of a sinusoid The period of a sinusoid signal is $T = \frac{1}{f}$ where f is its frequency. We can verify this in the following manner:

$$\begin{aligned} s\left(t + \frac{1}{f}\right) &= A \cdot \sin\left(2\pi f \cdot \left(t + \frac{1}{f}\right) + \phi\right) \\ &= A \cdot \sin\left(2\pi f t + 2\pi + \phi\right) \\ &= A \cdot \sin\left(2\pi f t + \phi\right) && \text{(sin has a period of } 2\pi\text{)} \\ &= s(t) \end{aligned}$$

Example For $A = 1$, $f = \frac{1}{2\pi}$, and $\phi = 0$, $s(t) = \sin(t)$. This function is plotted in figure 2. The figure shows that the period of the sine function is $T = 2\pi = \frac{1}{f}$.

3.2.3 Electromagnetic Signals

Based on the Fourier theory, all electromagnetic signals can be decomposed into a linear combination of sinusoids. So, sinusoids can be considered as certain types of building blocks for EM signals, and hence our discussion about sinusoids above.

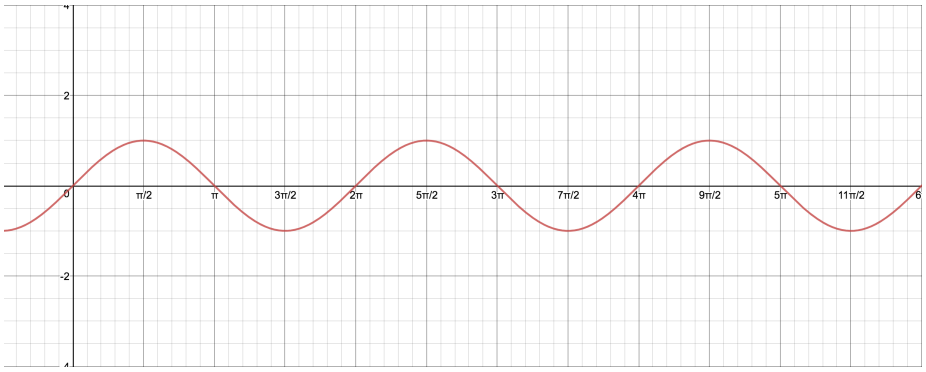

Figure 2: The sine curve

3.3 Digital Signals

A digital signal is a function $s : \mathbb{R} \to \{A, -A\}$. Unlike EM signals, digital signals are discrete functions. Consider this data: 01011010. The digital representation of this data can be seen in figure 3.

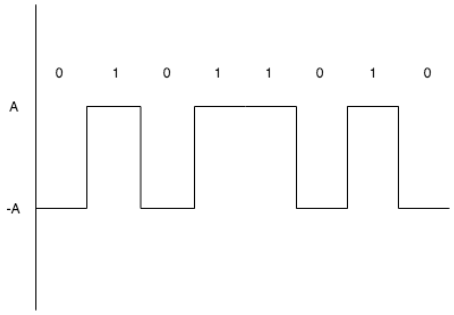

Figure 3: A digital signal