ELEG 2310B: Principles of Communication Systems **2021-22 First Term**

Handout 1: Communication Systems Overview

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Suggested Reading: Chapter 1 of Simon Haykin and Michael Moher, *Communication Systems (5th Edition)*, Wily & Sons Ltd.

In engineering, the term "communication" usually refers to the process of transmitting information from one point to another—we will assume this to be *always* true in this course. There are numerous forms of communication. We have wired communication, wherein examples are telephone, broadband internet at home, local area networks at office, just to name a few. We also have wireless communication such as mobile, WiFi, Bluetooth, radio broadcast, TV broadcast, and many others. It seems that our lives could not function properly without communication (imagine that you cannot access WhatsApp, social media, and the like, in ELEG 2310B class).

1 A System View on Communication

Communication systems used to have a straightforward architecture, where we only mean to transmit an analog signal from one point to another. A very classical example is telephone, where voice signals are sent over copper wires. Analog radio and TV broadcasts are another two classical examples. However, communication systems today are much more complicated—this is mainly due to the involvement of networks (most notably, Internet), multimedia services, the need to serve many users in one physical transmission medium (e.g., mobile), and many other factors.

We try to give a simplified view on communication systems by using the diagram in Figure 1. Here, there is an information source. The task is to send the information of the source to the information sink, or destination, through a physical medium. There are several important components.

- *Information:* Examples for information are voice, music, data files, pictures and video. Information can take analog form, or digital form. Information in digital form is currently dominant in most communication systems, although we can still see analog information in existing systems such as FM broadcast.

- *Channel:* This term is used to represent the physical transmission medium. In real world, a channel can be a cable (e.g., copper wires in telephone and broadband internet at home), an optical fiber, or free space.

- *Transmitter and Receiver:* Transmitter refers to the process of converting information to a form suitable for transmission over a channel. FM, a frequently heard term in radio broadcast, is a transmitter in engineering terms—it is called frequency modulation. Simply speaking, receiver is the inverse of transmitter, where the signal transmitted over the channel is converted back to information. A receiver would also perform other tasks, such as combating undesirable effects introduced by the channel.

Note that we also have network and control layers. They are absent in classical systems such as FM broadcast, but are integral to most modern systems, particularly, internet and mobile networks.

Simply but roughly speaking, we can have a system consisting of more than one physical medium and/or many information sources and sinks. The network and control layers play the role of managing the information flow and how the physical medium (or media) is shared.

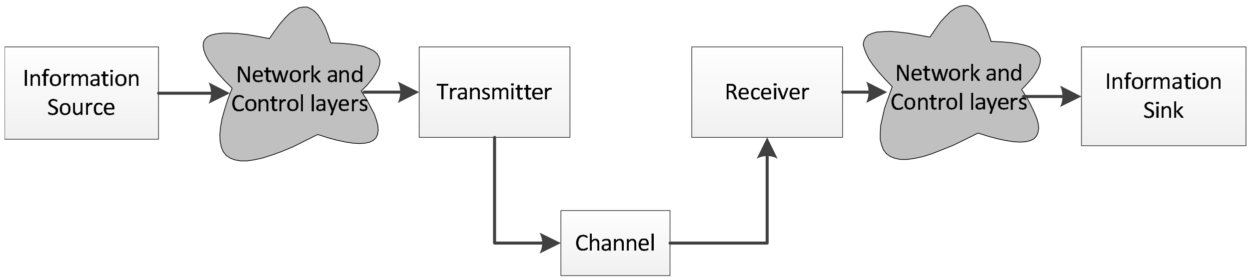


Figure 1: A block diagram for communication systems.

We should also mention the Open System Interconnect (OSI) model, illustrated in Figure 2. OSI is a well-known model in computer communications. The rationale behind OSI is to analyze a communication system via a layered approach, where each layer has defined functions to carry out. The upshot of doing so is that it permits independent development of each layer, thereby simplifying the design of communication systems. It is not important for you to understand the functions of each layer. What we would like you to recognize is that the *physical layer*, at the bottom of the OSI model, is the transmitter, channel and receiver in Figure 1. This course will focus on the physical layer.

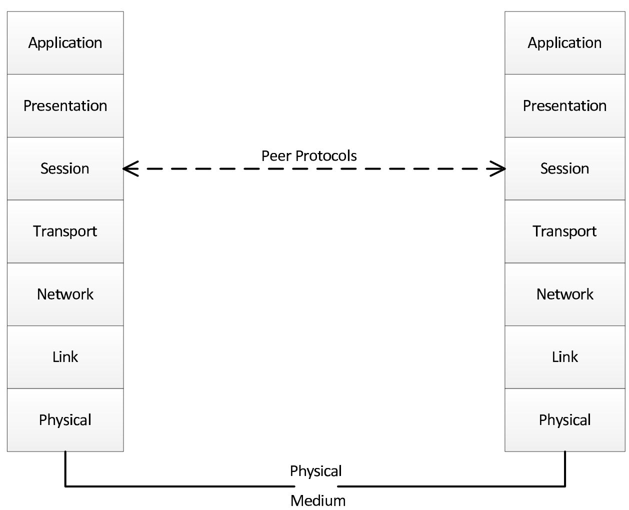
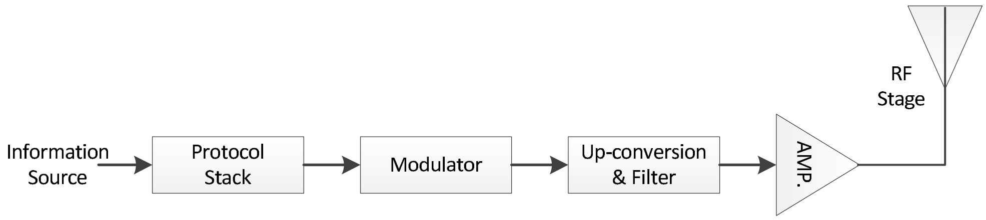


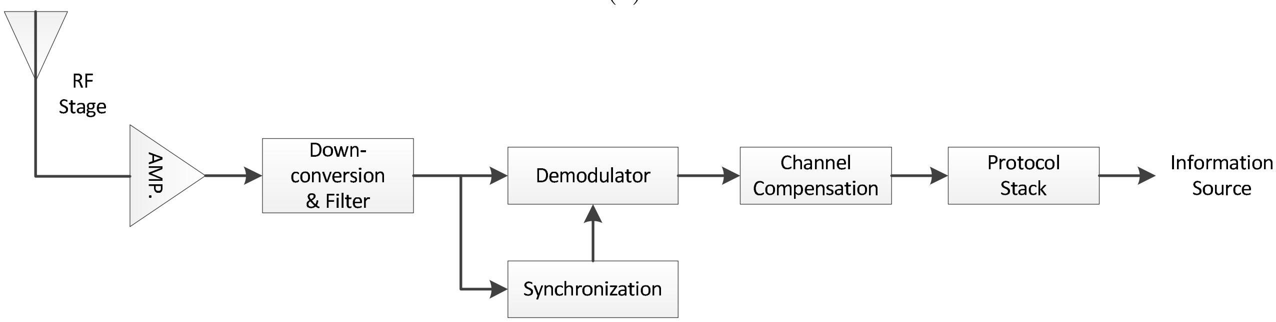
Figure 2: The seven-layer OSI model for computer communications.

2 Example: Wireless Communications

We use wireless communications as an example to explain how transmitters and receivers operate. In fact, wireless communications represents one of the very exciting developments in engineering—it has a long history with both beautiful and sad stories, and research is still very active today[1].



(a)



(b)

Figure 3: A block diagram for the physical layer of wireless communications. (a) Transmitter; (b) receiver.

Figure 3(a) shows a block diagram for a transmitter in wireless communications. The protocol stack is the stack of layers we saw in the OSI model in Figure 2. The other blocks are described as follows.

- *Modulator:* Information is converted to an analog signal with a carrier frequency.
- *Up-Conversion:* The modulated signal is converted to a final radio frequency (RF) for transmission. However, note that modern technology also allows us to modulate information directly to the final RF, that is, combine the modulator and up-conversion blocks into one.
- *RF Stage:* The signal is amplified and then emitted via an antenna. In essence, the process turns the electrical signal from the previous stage to an electromagnetic wave.

Physically, the up-conversion and RF stages are analog or RF circuits. As for the modulator, analog circuits were used in the old days. Nowadays, it is very common, if not always true, that we implement the modulator by digital signal processing (DSP) technology. By DSP, we may be using a digital signal processor, a field-programmable gate array (FPGA) or a specific integrated circuit. They all aim at one thing—generation and processing of signals in a convenient, flexible and powerful manner. Along this line it is worthwhile to mention *software defined radio*—it is a state-of-the-art technology that allows one to design a transmitter and receiver by just programming. Essentially, one can program the modulation technique desired.

[1]Part of the reason for the active research in wireless communications is the proliferation of mobile data service in recent years, which has drawn a great deal of wireless resources (think about everybody downloading video at the same time and the same place). Some speculators predicted that in the near future, mobile service providers would be faced with severe data traffic jams under the existing wireless technology.

Figure 3(b) shows a block diagram for the receiver. The RF stage picks up the electromagnetic wave at a desired RF band, and the amplifier boosts the signal to a level that can be processed by subsequent stages. Down-conversion and demodulation may simply be viewed as the inverses of up-conversion and modulation, respectively. There are additional stages in Figure 3(b), namely, synchronization and channel compensation. We will elaborate upon their functions in the future. Before we finish, we should note that perfect recovery of information at the receiver is not always possible—the channel, or free space in this wireless example, is rarely ideal in real world and it often introduces a number of damaging effects to the received signal (e.g., noise, interference and signal distortions). Generally speaking, the aim of channel compensation is to combat such damaging effects.