

## Basic Concepts in Telecommunications Systems

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### Background

Wikipedia defines a telecommunication system in the following terms: “Telecommunication occurs when the exchange of information between two entities (communication) includes the use of technology [1]. Communication technology uses channels to transmit information (as electrical signals), either over a physical medium (such as signal cables), or in the form of electromagnetic waves”. Poor’s definition of a telecommunication system brings out very clearly its intimate relationship to statistics: “Signal detection and estimation is the area of study that deals with the processing of information-bearing signals for the purpose of extracting information from there. Applications of the theory of signal detection and estimation are found in many areas, such as communications and automatic control”. Signal detection is commonly called hypothesis testing in statistics and, it, hand-in-hand with estimation, forms the central core of statistics. Thus the importance of statistics for telecommunication systems is inherent in the very definition of these systems [2].

### Historical Perspective

Systems for communication over long distances existed long before the twentieth century technologies stated in the definition was invented. Smoke signals and beacons are two examples of older communications techniques. The famous phrase “One, if by land, and two, if by sea” is ascribed to the American poet, Henry W Longfellow in his poem, Paul Revere’s Ride, and referred to the secret signal chosen by Revere during his historic ride from Boston to Concord at the onset of the American Revolutionary War. Carrier pigeons, stagecoach and Pony Express riders were used to deliver messages and letters [3]. The technology of telegraph allowed people to communicate over long distances in the 1800s [4]. The earliest example of a telecommunication system was the telephone, the brainchild of Alexander Graham Bell, a Scottish scientist and inventor [5]. A Western Union internal memo in 1876 typifies the initial reactions to the telephone – “This ‘telephone’ has too many shortcomings to be seriously considered as a means of communication,—Western Union Internal Memo, 1876 [6]. Starting as of 1910, the telecommunications industry was regulated by the federal government until AT and T’s monopoly came to an end in 1984, which was also the year in which AT and T spun off the 22 Bell operating companies into seven regional holding companies [7]. Sweeping transformations of the industry are likely to be the norm in the future because the industry is monitored by Congress, the FCC, state regulators and the courts [8].

### Principles of Communication

It would be impossible to give more than a brief overview of the principles here and there is no claim to completeness. This article touch upon only the most basic concepts involved in communication. A communications channel is needed to carry the signal from one point to another. Traditionally, in the USA, the channel has been provided by pairs of copper wires—through land-based microwave, satellite microwave, fiber-optic cable and radio signals. These media differ in terms of their bandwidth which is the range of frequencies they can transmit [8]. The larger the bandwidth of a medium, the greater the amount of information it can carry. Waveguides are hollow tubes designed to confine and guide the radio waves between two locations. The transmitter has two choices of waveforms available to send

information over the network—analog and digital. An analog signal is an electrical waveform that takes values ranging over a continuum of amplitudes. A digital signal is an electrical waveform that can have only a finite set of discrete values at any given time. Digital signals constitute a series of on-off pulses called bits. Digital transmission speeds are typically measured in bits per second or bps [9]. Digital transmission requires conversion of the analog signal into bits, and the most frequently used technique for accomplishing this is pulse-code modulation (PCM) [8]. The receiver uses a modem to modulate the digitally coded pulses back into the analog wave, thus reconstructing the original signal.

The scientific knowledge of electricity and magnetism that is required to enable telecommunications began with the investigations of Michael Faraday, often considered the greatest experimentalist of his time. Faraday was not skilled in mathematics but his friend James Clerk Maxwell was. It was Maxwell who unified the disparate discoveries about the properties of electricity and magnetism, and their intimate inter-relationship and enshrined them in the four beautiful vector equations that are known as the Maxwell equations of electromagnetism. Furthermore, Maxwell mathematically represented Faraday’s intuitive concept of the electric and magnetic fields. All modern physical theories are field theories and enjoy the attractive advantage of banishing “action at a distance” concepts from science. From the mathematics of Maxwell’s equations, he was able to explicitly calculate the speed of light from the measurement of two electrical constants and demonstrate that electromagnetic effects travel through space at the speed of light. In his analysis, Maxwell introduced the famous concept of the displacement current by showing that without it, the rest of his equations would be inconsistent with the conservation of electric charge [10]. John Poynting showed that wherever electric and magnetic fields are present, there is a flow of energy at that point. It is this energy that permits transmission of messages through space.

### Conclusions and Projections

These are exciting times for telecommunications as evidenced by the volume of published work describing new discoveries and inventions in this field. An international team of scientists recently achieved the remarkable breakthrough of transmitting a thought from one brain to another brain located thousands of miles away. Such breakthroughs will become increasingly refined and sophisticated, and we may anticipate many such fundamental discoveries and inventions in the future [11].

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