Protocols and the TCP/IP Suite

Chapter 4

Key Features of a Protocol

- Syntax
  - Concerns the format of the data blocks
- Semantics
  - Includes control information for coordination and error handling
- Timing
  - Includes speed matching and sequencing

Agents Involved in Communication

- Applications
  - Exchange data between computers (e.g., electronic mail)
- Computers
  - Connected to networks
- Networks
  - Transfers data from one computer to another

TCP/IP Layers

- Physical layer
- Network access layer
- Internet layer
- Host-to-host, or transport layer
- Application layer

TCP/IP Physical Layer

- Covers the physical interface between a data transmission device and a transmission medium or network
- Physical layer specifies:
  - Characteristics of the transmission medium
  - The nature of the signals
  - The data rate
  - Other related matters

TCP/IP Network Access Layer

- Concerned with the exchange of data between an end system and the network to which it's attached
- Software used depends on type of network
  - Circuit switching
  - Packet switching (e.g., X.25)
  - LANs (e.g., Ethernet)
  - Others

T:TCP/IP Internet Layer

- Uses internet protocol (IP)
- Provides routing functions to allow data to traverse multiple interconnected networks
- Implemented in end systems *and* routers

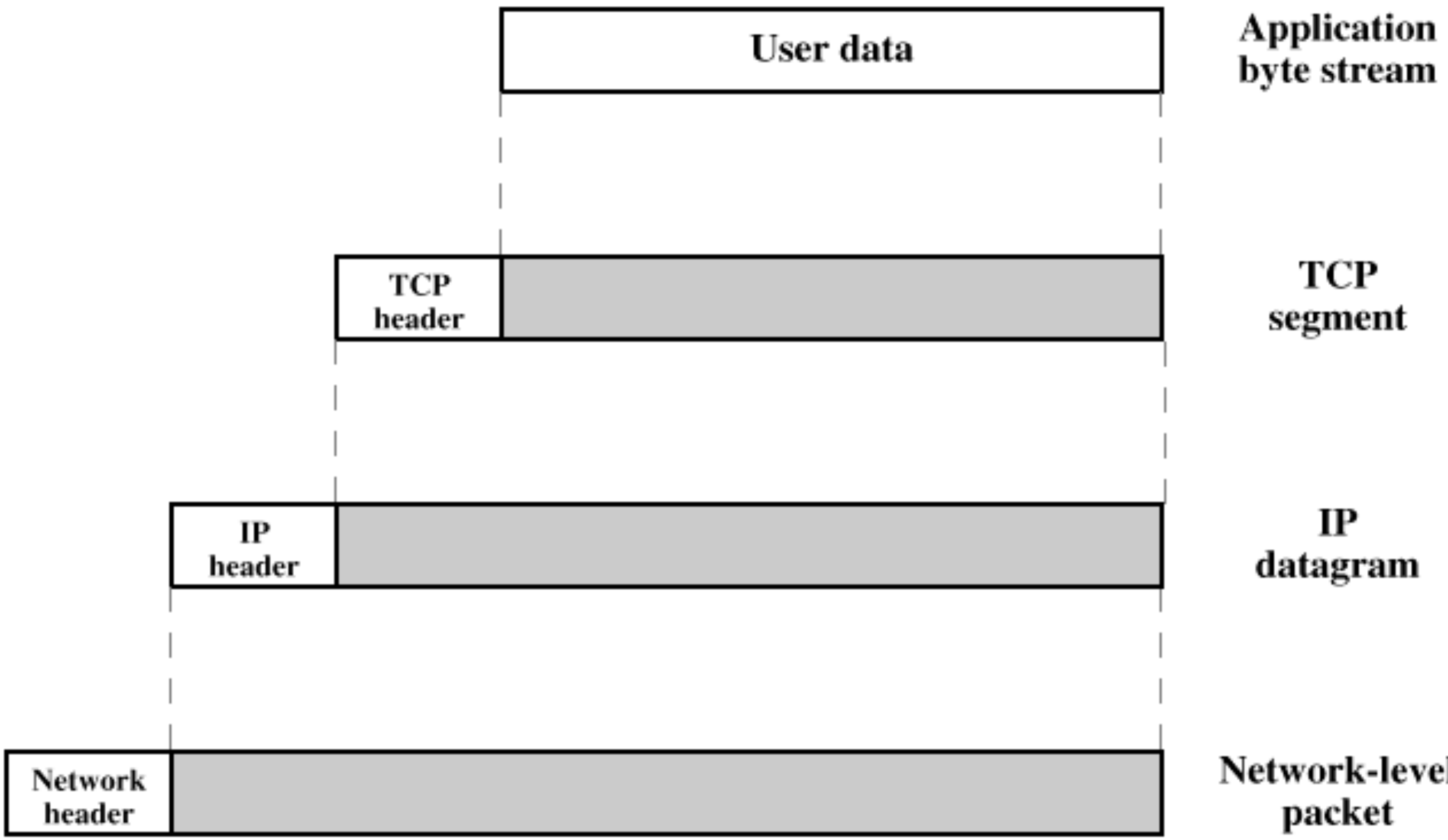
TCP/IP Host-to-Host, or Transport Layer

- Commonly uses transmission control protocol (tcp)
- Provides reliability during data exchange
  - Completeness
  - Order

TCP/IP Application Layer

- Logic supports user applications
- Uses separate modules that are peculiar to each different type of application

Protocol Data Units (PDUs)



Layers of the OSI Model

- Application
- Presentation
- Session
- Transport
- Network
- Data link
- Physical

OSI Application Layer

- Provides access to the OSI environment for users
- Provides distributed information services

OSI Presentation Layer

- Provides independence to the application processes from differences in data representation (syntax)

OSI Session Layer

- Provides the control structure for communication between applications
- Establishes, manages, and terminates connections (sessions) between cooperating applications

OSI Transport Layer

- Provides reliable, transparent transfer of data between end points
- Provides end-to-end error recovery and flow control

OSI Network Layer

- Provides upper layers with independence from the data transmission and switching technologies used to connect systems
- Responsible for establishing, maintaining, and terminating connections

OSI Data link Layer

- Provides for the reliable transfer of information across the physical link
- Sends blocks (frames) with the necessary synchronization, error control, and flow control

OSI Physical Layer

- Concerned with transmission of unstructured bit stream over physical medium
- Deals with accessing the physical medium
  - Mechanical characteristics
  - Electrical characteristics
  - Functional characteristics
  - Procedural characteristics

Antennas and Propagation

Chapter 5

Introduction

- An antenna is an electrical conductor or system of conductors
  - Transmission - radiates electromagnetic energy into space
  - Reception - collects electromagnetic energy from space
- In two-way communication, the same antenna can be used for transmission and reception

Radiation Patterns

- Radiation pattern
  - Graphical representation of radiation properties of an antenna
  - Depicted as two-dimensional cross section
- Beam width (or half-power beam width)
  - Measure of directivity of antenna
- Reception pattern
  - Receiving antenna's equivalent to radiation pattern

Types of Antennas

- Isotropic antenna (idealized)
  - Radiates power equally in all directions
- Dipole antennas
  - Half-wave dipole antenna (or Hertz antenna)
  - Quarter-wave vertical antenna (or Marconi antenna)
- Parabolic Reflective Antenna

Antenna Gain

- Antenna gain
  - Power output, in a particular direction, compared to that produced in any direction by a perfect omnidirectional antenna (isotropic antenna)
- Effective area
  - Related to physical size and shape of antenna

Antenna Gain

- Relationship between antenna gain and effective area

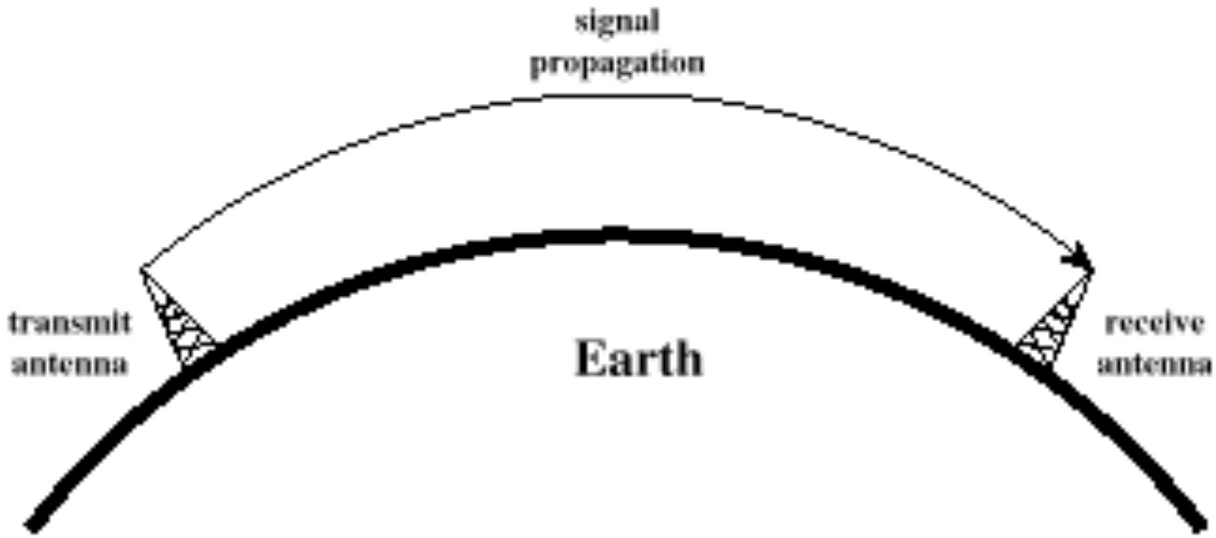
$$G = \frac{4\pi A_e}{\lambda^2} = \frac{4\pi f^2 A_e}{c^2}$$

  - G = antenna gain
  - A_e = effective area
  - f = carrier frequency
  - c = speed of light (3×10^8 m/s)
  - λ = carrier wavelength

Propagation Modes

- Ground-wave propagation
- Sky-wave propagation
- Line-of-sight propagation

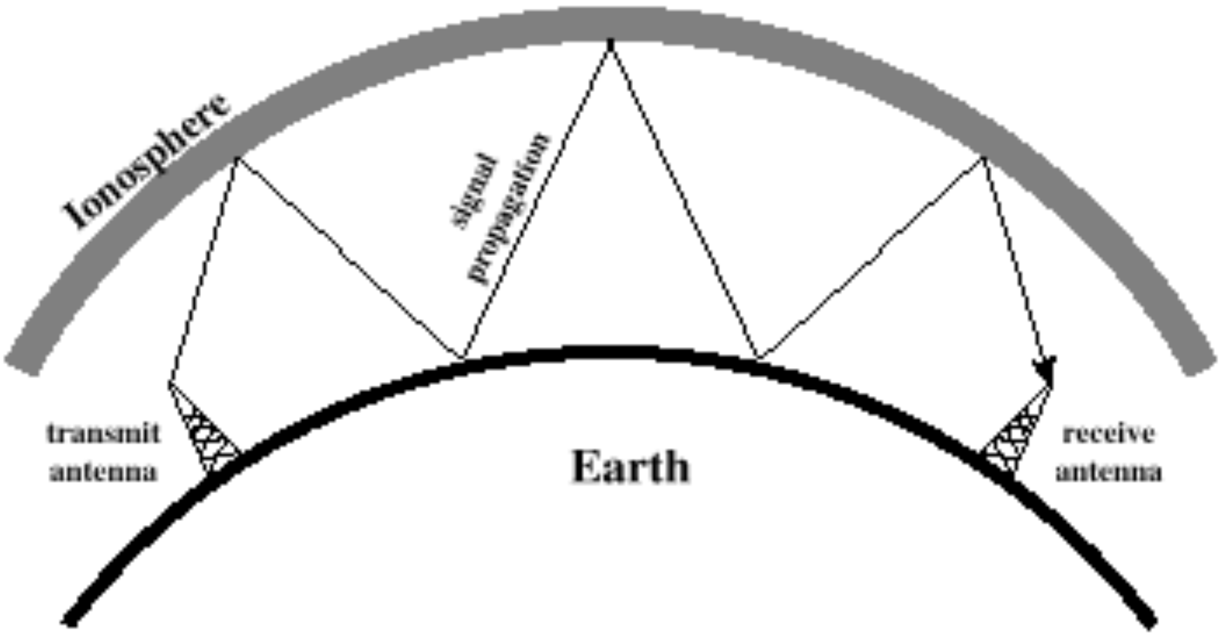
Ground Wave Propagation



Ground Wave Propagation

- Follows contour of the earth
- Can Propagate considerable distances
- Frequencies up to 2 MHz
- Example
  - AM radio

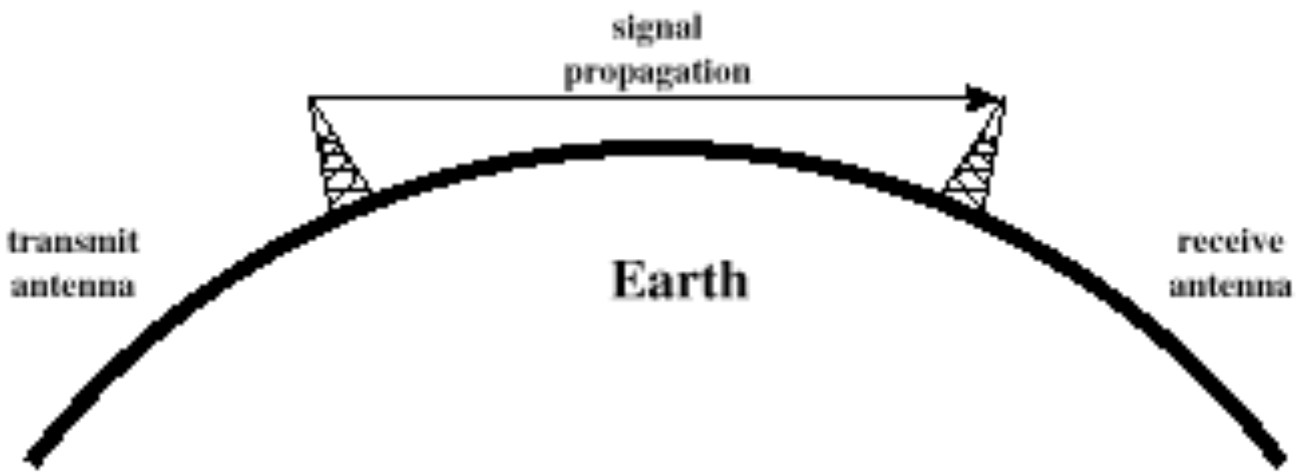
Sky Wave Propagation



Sky Wave Propagation

- Signal reflected from ionized layer of atmosphere back down to earth
- Signal can travel a number of hops, back and forth between ionosphere and earth's surface
- Reflection effect caused by refraction
- Examples
  - Amateur radio

Line-of-Sight Propagation



Line-of-Sight Propagation

- Transmitting and receiving antennas must be within line of sight
  - Satellite communication – signal above 30 MHz not reflected by ionosphere
  - Ground communication – antennas within *effective* line of site due to refraction
- Refraction – bending of microwaves by the atmosphere
  - Velocity of electromagnetic wave is a function of the density of the medium
  - When wave changes medium, speed changes
  - Wave bends at the boundary between mediums

Line-of-Sight Equations

- Optical line of sight

$$d = 3.57\sqrt{h}$$

- Effective, or radio, line of sight

$$d = 3.57\sqrt{\mathrm{K}h}$$

  - d = distance between antenna and horizon (km)
  - h = antenna height (m)
  - K = adjustment factor to account for refraction, rule of thumb K = 4/3

Line-of-Sight Equations

- Maximum distance between two antennas for LOS propagation:

$$3.57\left(\sqrt{\mathrm{K}h_1}+\sqrt{\mathrm{K}h_2}\right)$$

  - h_1 = height of antenna one
  - h_2 = height of antenna two

LOS Wireless Transmission Impairments

- Attenuation and attenuation distortion
- Free space loss
- Noise
- Atmospheric absorption
- Multipath
- Refraction
- Thermal noise

Attenuation

- Strength of signal falls off with distance over transmission medium
- Attenuation factors for unguided media:
  - Received signal must have sufficient strength so that circuitry in the receiver can interpret the signal
  - Signal must maintain a level sufficiently higher than noise to be received without error
  - Attenuation is greater at higher frequencies, causing distortion

Free Space Loss

- Free space loss, ideal isotropic antenna

$$\frac{P_t}{P_r} = \frac{(4\pi d)^2}{\lambda^2} = \frac{(4\pi f d)^2}{c^2}$$

  - P_t = signal power at transmitting antenna
  - P_r = signal power at receiving antenna
  - λ = carrier wavelength
  - d = propagation distance between antennas
  - c = speed of light (3×10^8 m/s)

  where d and λ are in the same units (e.g., meters)

Free Space Loss

- Free space loss equation can be recast:

$$L_{dB} = 10\log\frac{P_t}{P_r} = 20\log\left(\frac{4\pi d}{\lambda}\right)$$

$$= -20\log(\lambda) + 20\log(d) + 21.98\ \mathrm{dB}$$

$$= 20\log\left(\frac{4\pi f d}{c}\right) = 20\log(f) + 20\log(d) - 147.56\ \mathrm{dB}$$

Free Space Loss

- Free space loss accounting for gain of other antennas

$$\frac{P_t}{P_r} = \frac{(4\pi)^2 (d)^2}{G_r G_t \lambda^2} = \frac{(\lambda d)^2}{A_r A_t} = \frac{(cd)^2}{f^2 A_r A_t}$$

  - G_t = gain of transmitting antenna
  - G_r = gain of receiving antenna
  - A_t = effective area of transmitting antenna
  - A_r = effective area of receiving antenna

Free Space Loss

- Free space loss accounting for gain of other antennas can be recast as

$$L_{dB} = 20\log(\lambda) + 20\log(d) - 10\log(A_t A_r)$$

$$= -20\log(f) + 20\log(d) - 10\log(A_t A_r) + 169.54\text{dB}$$

Categories of Noise

- Thermal Noise
- Intermodulation noise
- Crosstalk
- Impulse Noise

Thermal Noise

- Thermal noise due to agitation of electrons
- Present in all electronic devices and transmission media
- Cannot be eliminated
- Function of temperature
- Particularly significant for satellite communication

Thermal Noise

- Amount of thermal noise to be found in a bandwidth of 1Hz in any device or conductor is:

$$N_0 = \mathrm{k}T\left(\mathrm{W/Hz}\right)$$

  - N_0 = noise power density in watts per 1 Hz of bandwidth
  - k = Boltzmann's constant = 1.3803×10^{-23} J/K
  - T = temperature, in kelvins (absolute temperature)

Thermal Noise

- Noise is assumed to be independent of frequency
- Thermal noise present in a bandwidth of B Hertz (in watts):

$$N = \mathrm{k}TB$$

or, in decibel-watts

$$N = 10\log \mathrm{k} + 10\log T + 10\log B$$
$$= -228.6\,\mathrm{dBW} + 10\log T + 10\log B$$

Noise Terminology

- Intermodulation noise – occurs if signals with different frequencies share the same medium
  - Interference caused by a signal produced at a frequency that is the sum or difference of original frequencies
- Crosstalk – unwanted coupling between signal paths
- Impulse noise – irregular pulses or noise spikes
  - Short duration and of relatively high amplitude
  - Caused by external electromagnetic disturbances, or faults and flaws in the communications system

Expression E_b/N_0

- Ratio of signal energy per bit to noise power density per Hertz

$$\frac{E_b}{N_0} = \frac{S/R}{N_0} = \frac{S}{\mathrm{k}TR}$$

- The bit error rate for digital data is a function of E_b/N_0
  - Given a value for E_b/N_0 to achieve a desired error rate, parameters of this formula can be selected
  - As bit rate R increases, transmitted signal power must increase to maintain required E_b/N_0

Other Impairments

- Atmospheric absorption – water vapor and oxygen contribute to attenuation
- Multipath – obstacles reflect signals so that multiple copies with varying delays are received
- Refraction – bending of radio waves as they propagate through the atmosphere

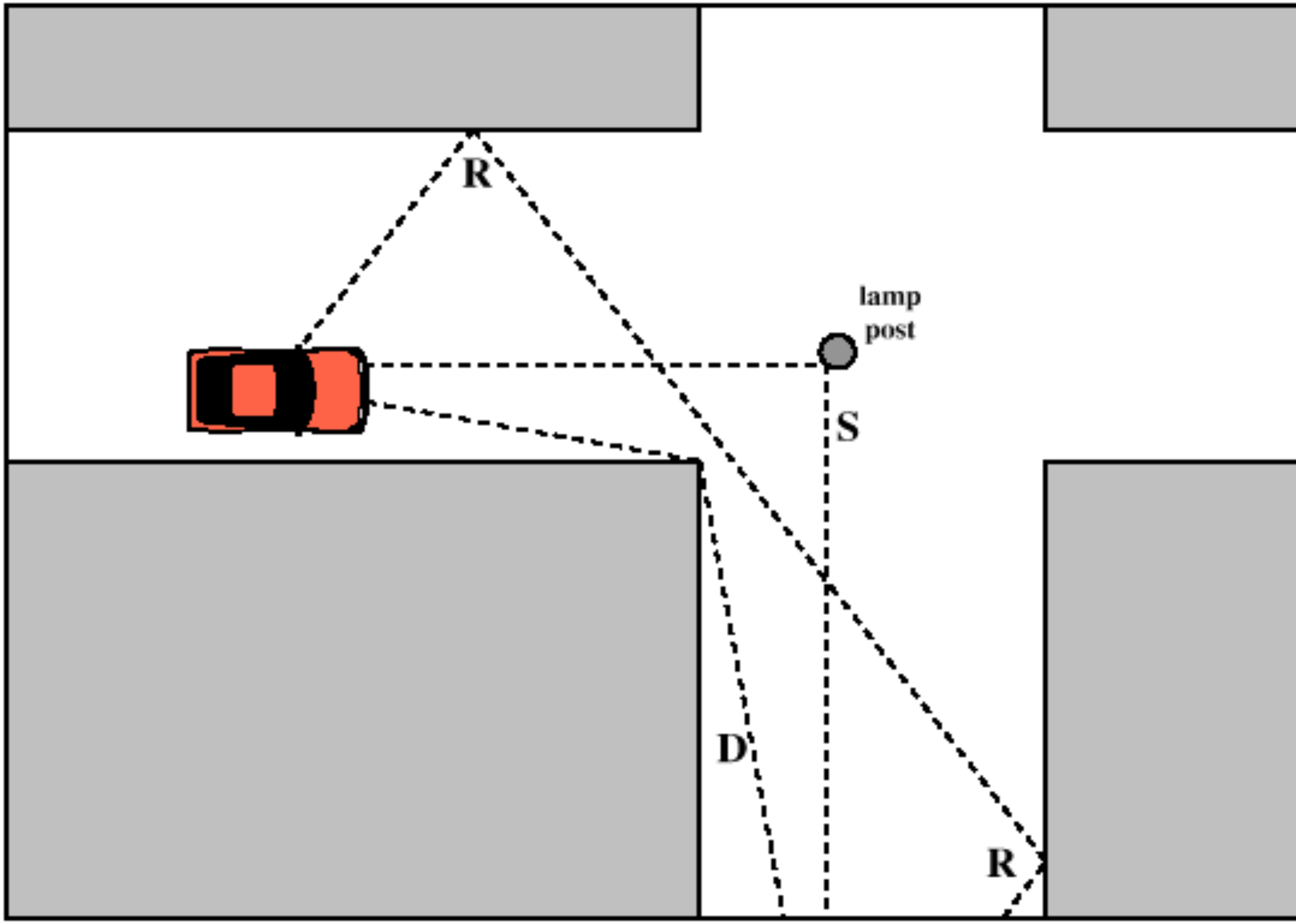


Figure 5.10 Sketch of Three Important Propagation Mechanisms: Reflection (R), Scattering (S), Diffraction (D) [ANDE95]

Multipath Propagation

- Reflection - occurs when signal encounters a surface that is large relative to the wavelength of the signal
- Diffraction - occurs at the edge of an impenetrable body that is large compared to wavelength of radio wave
- Scattering – occurs when incoming signal hits an object whose size in the order of the wavelength of the signal or less

The Effects of Multipath Propagation

- Multiple copies of a signal may arrive at different phases
  - If phases add destructively, the signal level relative to noise declines, making detection more difficult
- Intersymbol interference (ISI)
  - One or more delayed copies of a pulse may arrive at the same time as the primary pulse for a subsequent bit