CPE348: Introduction to Computer Networks

Lecture #4: Chapter 2.1

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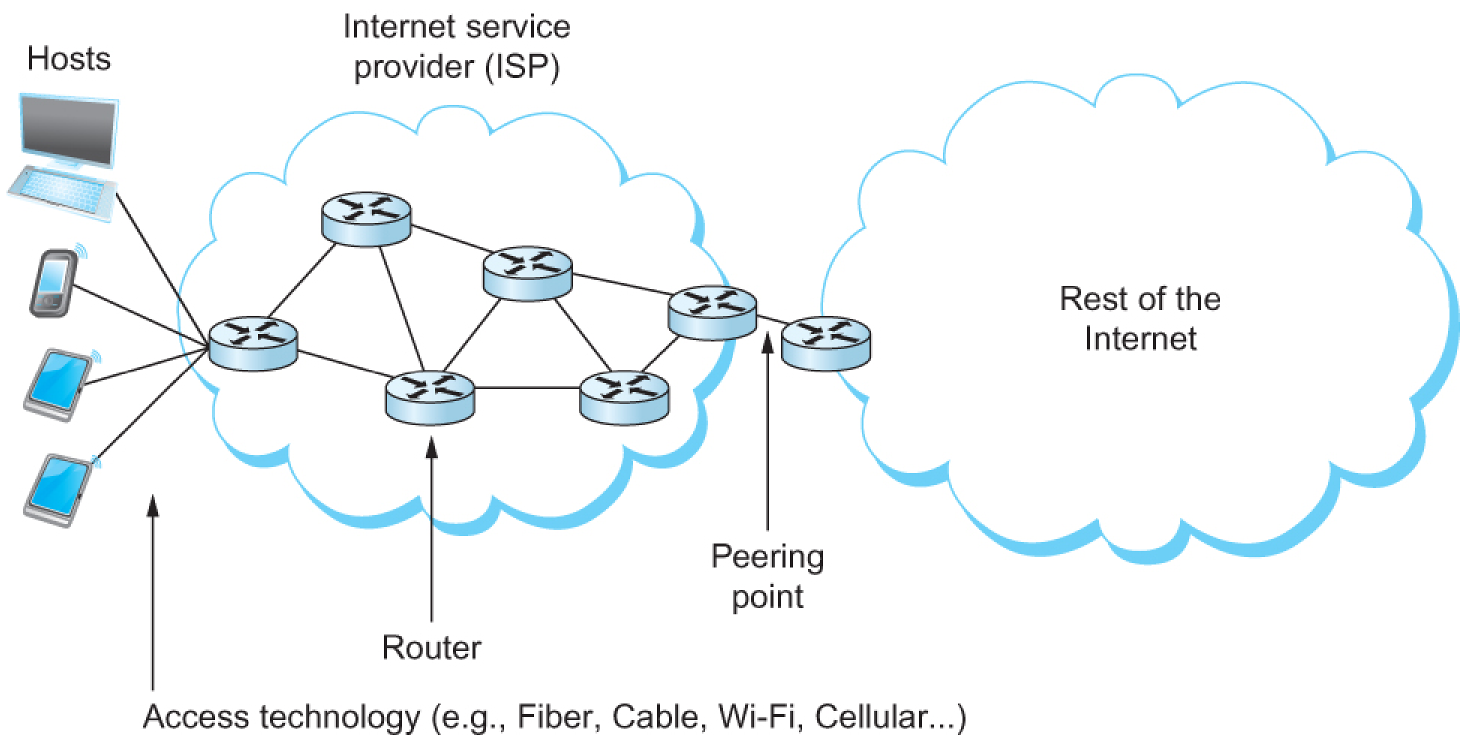
Chapter Outline

- Perspectives on Connecting nodes
- Encoding
- Framing
- Error Detection
- Reliable Transmission
- Ethernet and Multiple Access Networks
- Wireless Networks

Chapter Goal

- Exploring different communication medium
- Understanding the issue of encoding bits
- Discussing techniques to detect transmission errors
- Discussing how to make links reliable
- Introducing Media Access Control Problem
- Introducing Wireless Networks

Perspectives on Connecting



- “Last-mile” connection: access technology
- Backbone connection: Internet technology

What are communication medium?

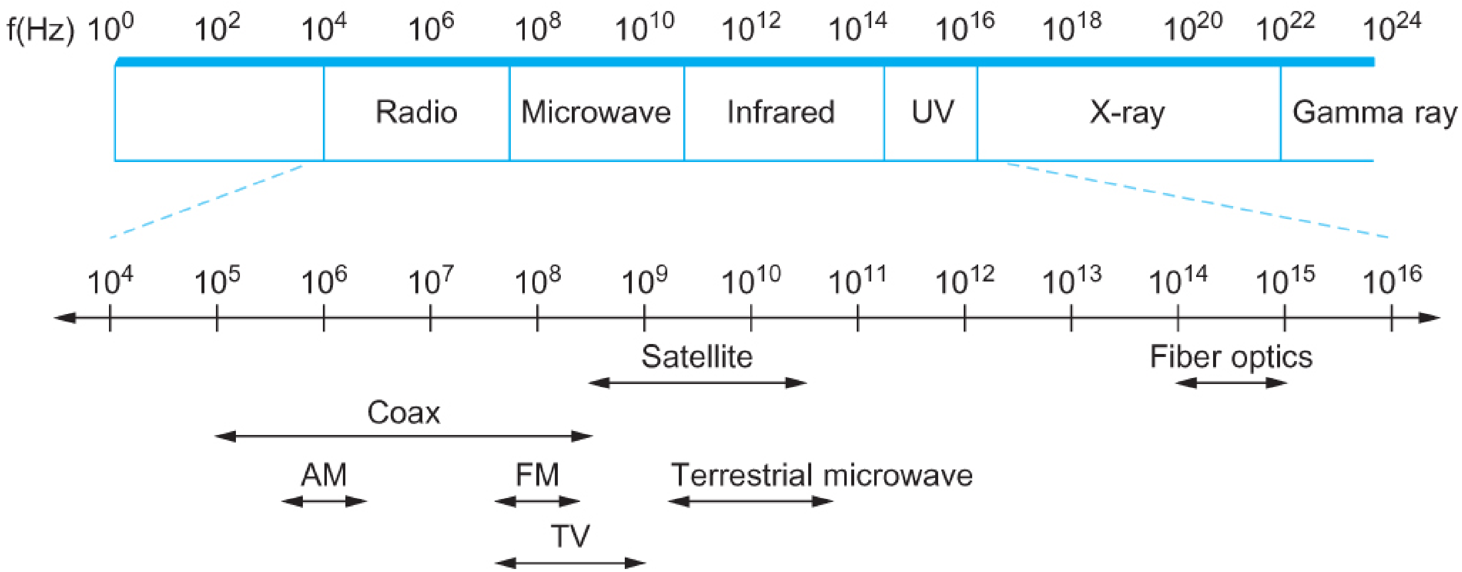
- All links rely on electromagnetic radiation propagating through a medium.

- Links can be classified by the medium they use
  - Coaxial cable (e.g., TV)
  - Optical fiber (e.g., Internet)
  - Air/free space (e.g., Bluetooth)
  - Visible light (e.g., barcode scanner)

How to characterize a link

- Frequency (in Hz)
  - WiFi/Bluetooth/Microwave Oven: 2.4 GHz
  - 4G/LTE: 2.5 GHz – 2.7 GHz
- Speed of light (in m/s)
  - How fast the light is travelled.
- Wavelength (in meter)
  - Speed of light divided by frequency gives the wavelength.

Radio frequency of a link



Electromagnetic spectrum

Performance metrics for a link

- How to evaluate the performance of a link?
- Channel capacity/throughput: Shannon-Hartley Theorem
- $C = B*\log_2(1+S/N)$
  - Where B = 3000Hz is the bandwidth
  - S is the signal power at the receiver
  - N the noise power at the receiver
- It is an upper bound of the data rate over that communication medium.
- How can we get 56kbps? Example

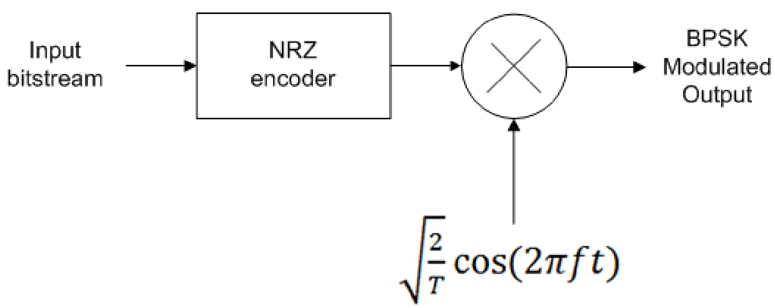
Some Examples

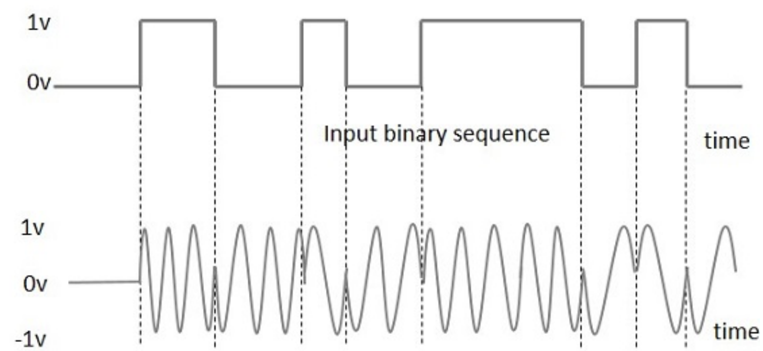
Service	Bandwidth (typical)
Dial-up	28–56 kbps
ISDN	64–128 kbps
DSL	128 kbps–100 Mbps
CATV (cable TV)	1–40 Mbps
FTTH (fibre to the home)	50 Mbps–1 Gbps

Common services available to connect your home

Encoding & Modulation

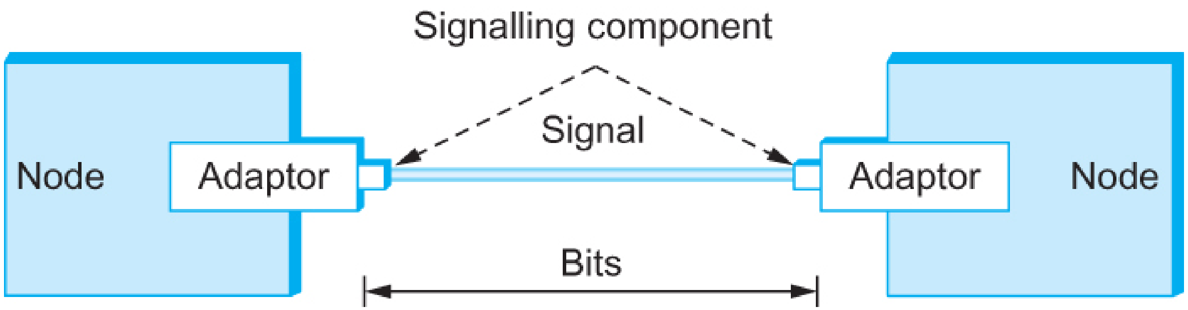
- Converting a stream of binary data to a stream of pulse signal is called *encoding*.
- Modifying (frequency, amplitude, and phase) the base-band signals to the carrier frequency is called *modulation*.



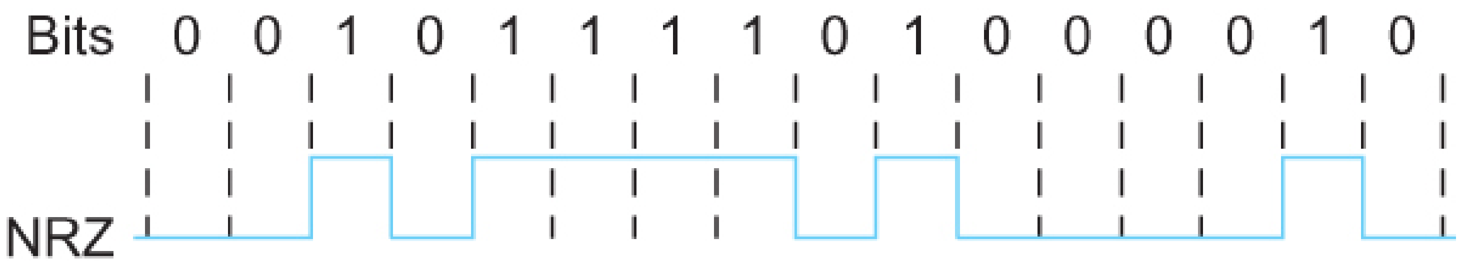


BPSK Modulated output wave

Encoding



Signals travel between signaling components; bits flow between adaptors



NRZ encoding of a bit stream

Encoding

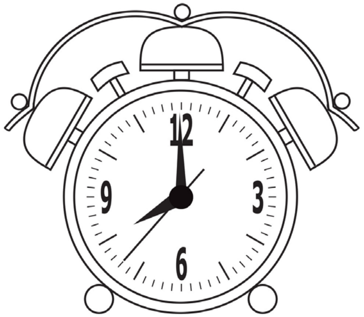
- Problem with NRZ - Baseline wander
  - The receiver keeps an average of the signals it has seen so far to distinguish between low and high signal
  - When a signal is significantly lower than the average, it is 0, else it is 1
  - Too many consecutive 0's and 1's cause this average to change, making it difficult to detect

Problem of consecutive 0's or 1's

Encoding

- Problem with NRZ - Clock recovery
  - Both the sending and decoding process is driven by a clock
  - Frequent transition from high to low or vice versa are necessary to enable clock recovery
  - The sender and receiver have to be precisely synchronized

Problem of consecutive 0's or 1's

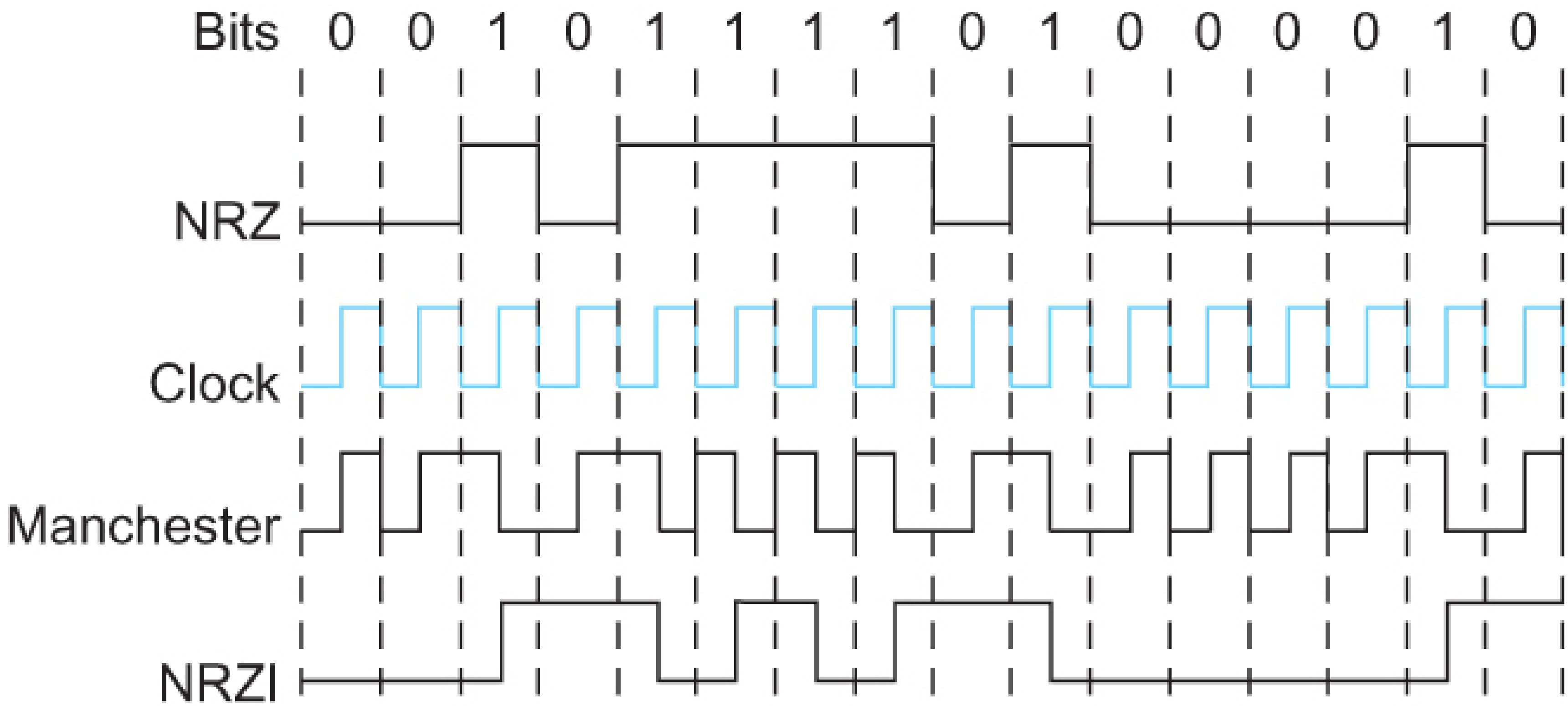


Encoding

- NRZI - Non Return to Zero Inverted
  - Sender makes a transition from the current signal to encode 1 and stay at the current signal to encode 0
  - Transition occurs on rising clock edge

- Solve for consecutive 1's, but does not solve problem with consecutive 0's

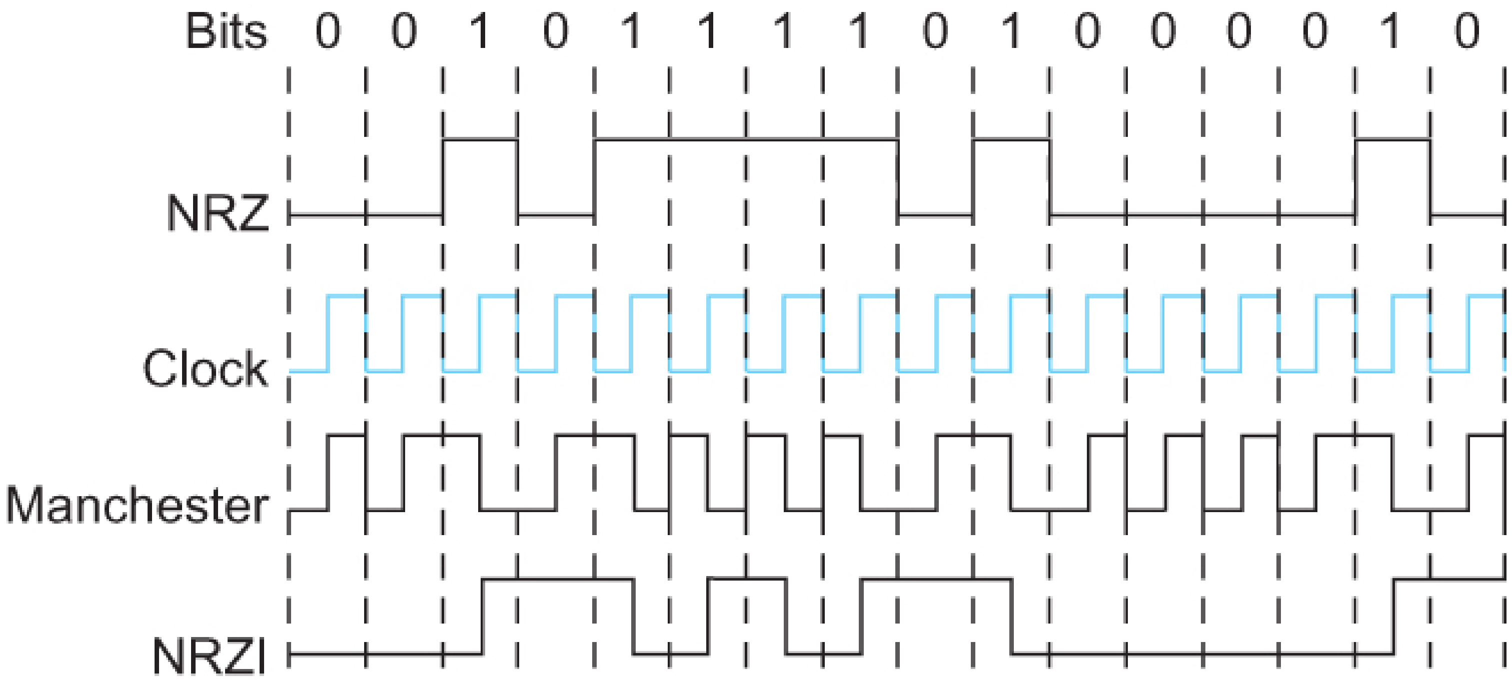
NRZI Waveform



Encoding

- Manchester encoding
  - Merging the clock with signal by transmitting Ex-OR of the NRZ encoded data and the clock
  - In Manchester encoding
    - 0: low→ high transition
    - 1: high→ low transition

Encoding



Different encoding strategies

Encoding

- Pros & Cons with Manchester encoding
  - Solves consecutive 1's and 0's problem
  - But, doubles the rate
    - Which means the receiver has half of the time to detect each pulse of the signal
    - In other words, consuming more bandwidth

Encoding

- 4B/5B encoding
  - Insert extra bits into bit stream so as to break up the long sequence of 0’s and 1’s
  - Every 4-bits of actual data are encoded in a 5- bit code that is transmitted to the receiver
  - Then, transmitted using NRZI
  - 80% efficient

Encoding

- 4B/5B encoding mapping

Data	**Transmit**	**Other 5B codes**
0000 →	11110	16 left (16 used for data)
0001 →	01001	11111 – when the line is idle
0010 →	10100	00000 – when the line is dead
..		00100 – to mean halt
..		
1111 →	11101	13 left : 7 invalid, 6 for various control signals

Encoding

- 4B/5B encoding

4-bit Data	5-bit code	4-bit Data	5-bit code
0000	11110	1000	10010
0001	01001	1001	10011
0010	10100	1010	10110
0011	10101	1011	10111
0100	01010	1100	11010
0101	01011	1101	11011
0110	01110	1110	11100
0111	01111	1111	11101