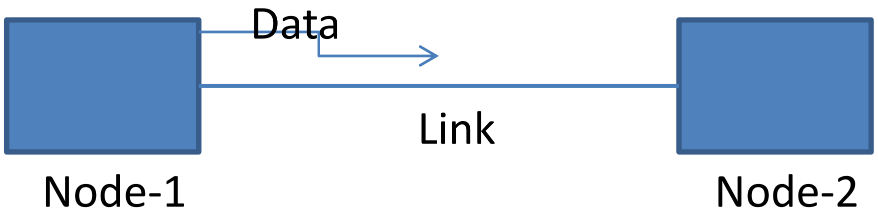
Line Codes

Kameswari Chebrolu

Recap

- Nodes generate data (bits: 1’s and 0’s)
- Links carry signals in the form of electromagnetic waves
- Task on hand: Convert data into signals
  - Process termed: Encoding/Modulation

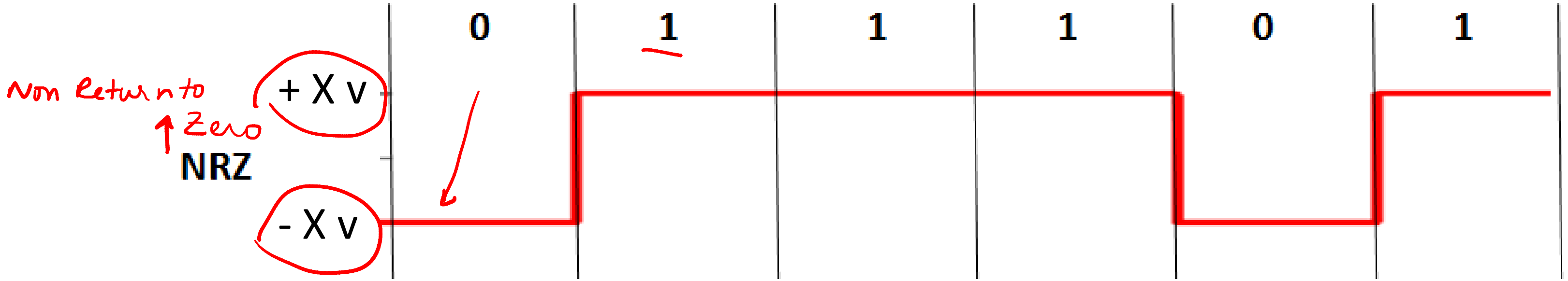


Simple Encoding

- Data: 101111011

~~I will follow the wire, reach other end and convey the data in person~~

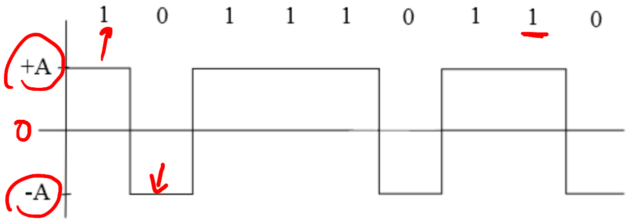
- How would you send the data over the wires?



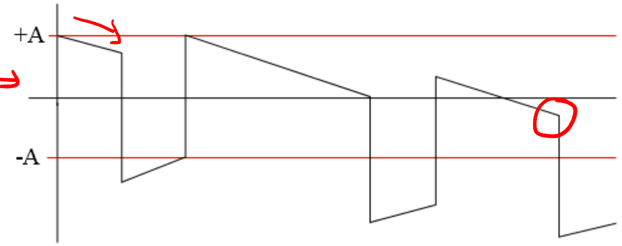
Decoding

Attenuation, noise

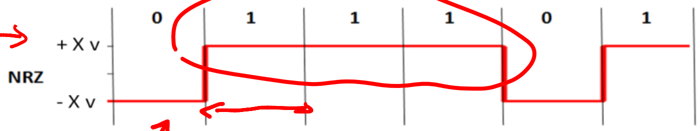
- How does a receiver decode the data i.e determine bits from waveform?
- Compare with a threshold RC
  - Receiver maintains average of the signal, uses average to distinguish between low and high signals
- Clock to determine bit durations
  - Receiver's clock need to be perfectly synchronized with the sender, otherwise it results in errors
  - Clock should preferably be derived from the received signal itself
    - Transitions in received signal help recover the clock



Rx



6 1's

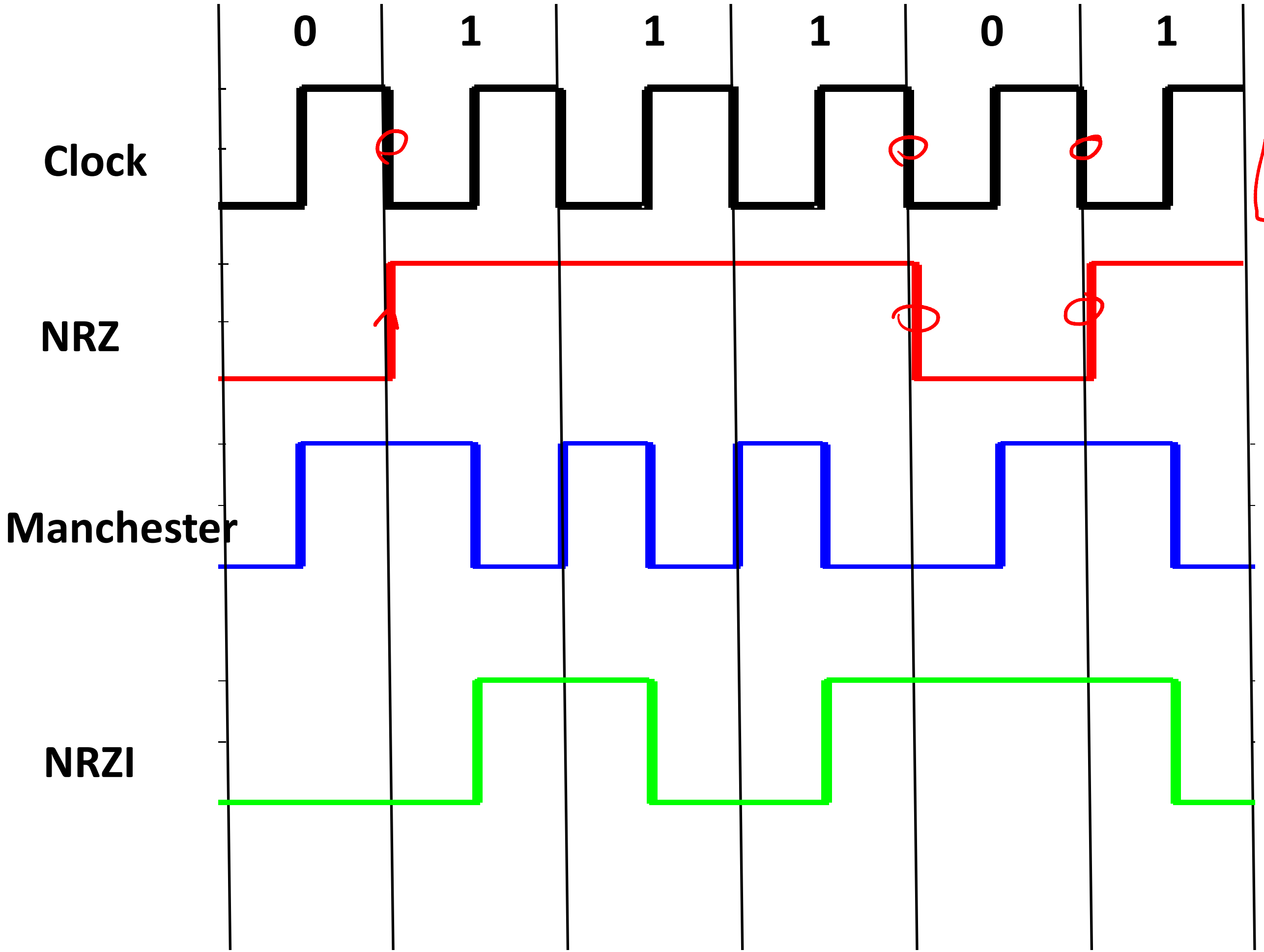


3 1's and not 5 1's or 8 1's

signal

clock

cost



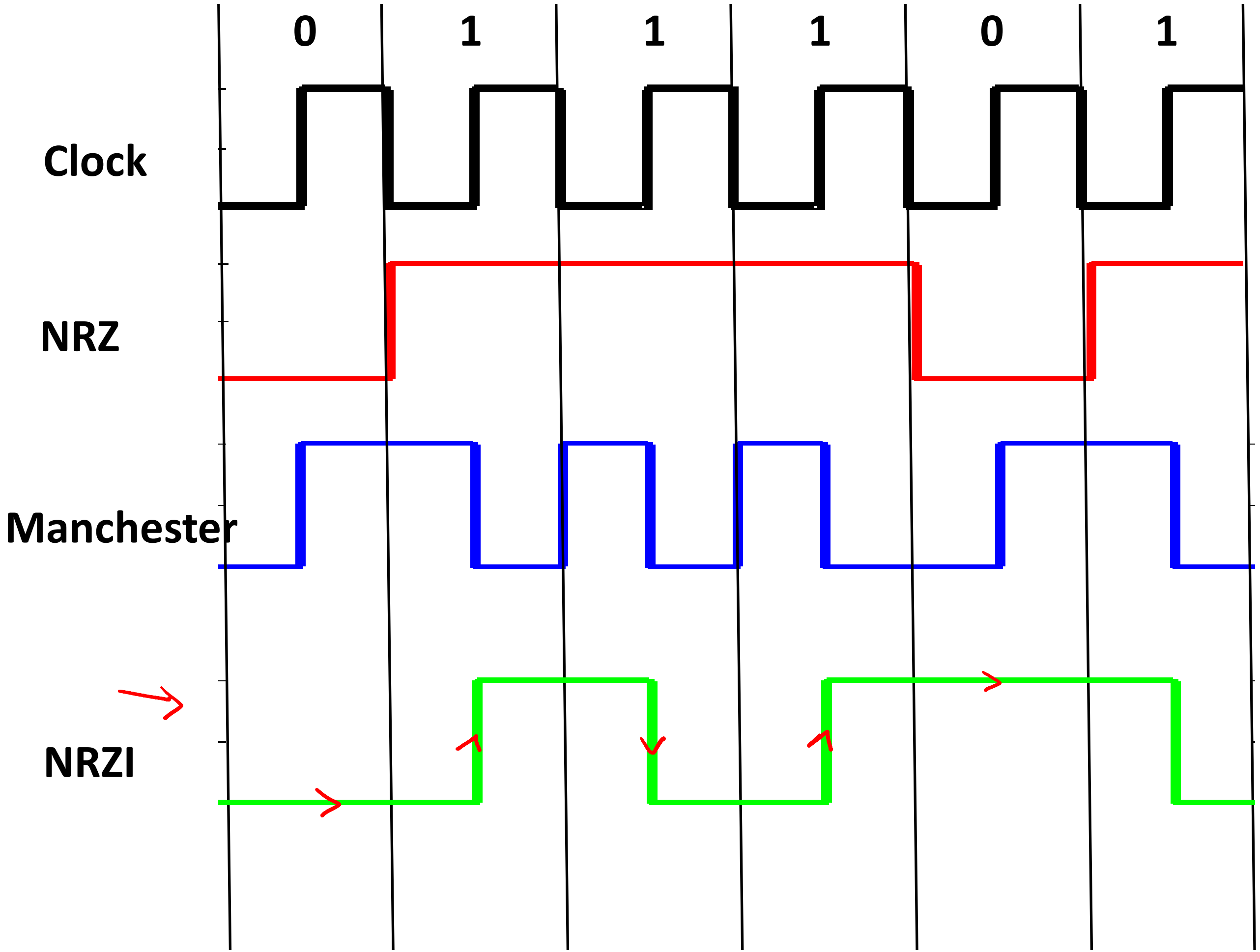
- threshold based detection
- transitions for clock recovery

Problems with NRZ

- Consecutive 1s or 0s
  - Changes the average leading to errors (*baseline wander)*
  - Lesser number of transitions leads to clock drift between sender and receiver
- Goal of Line Encoding: Provide enough number of transitions in the signal (over a specified interval)

NRZ-Inverted (NRZI)

- Form of differential encoding
  - To encode a 1, make a transition
  - To encode a 0, stay at the current signal
- Used in USB

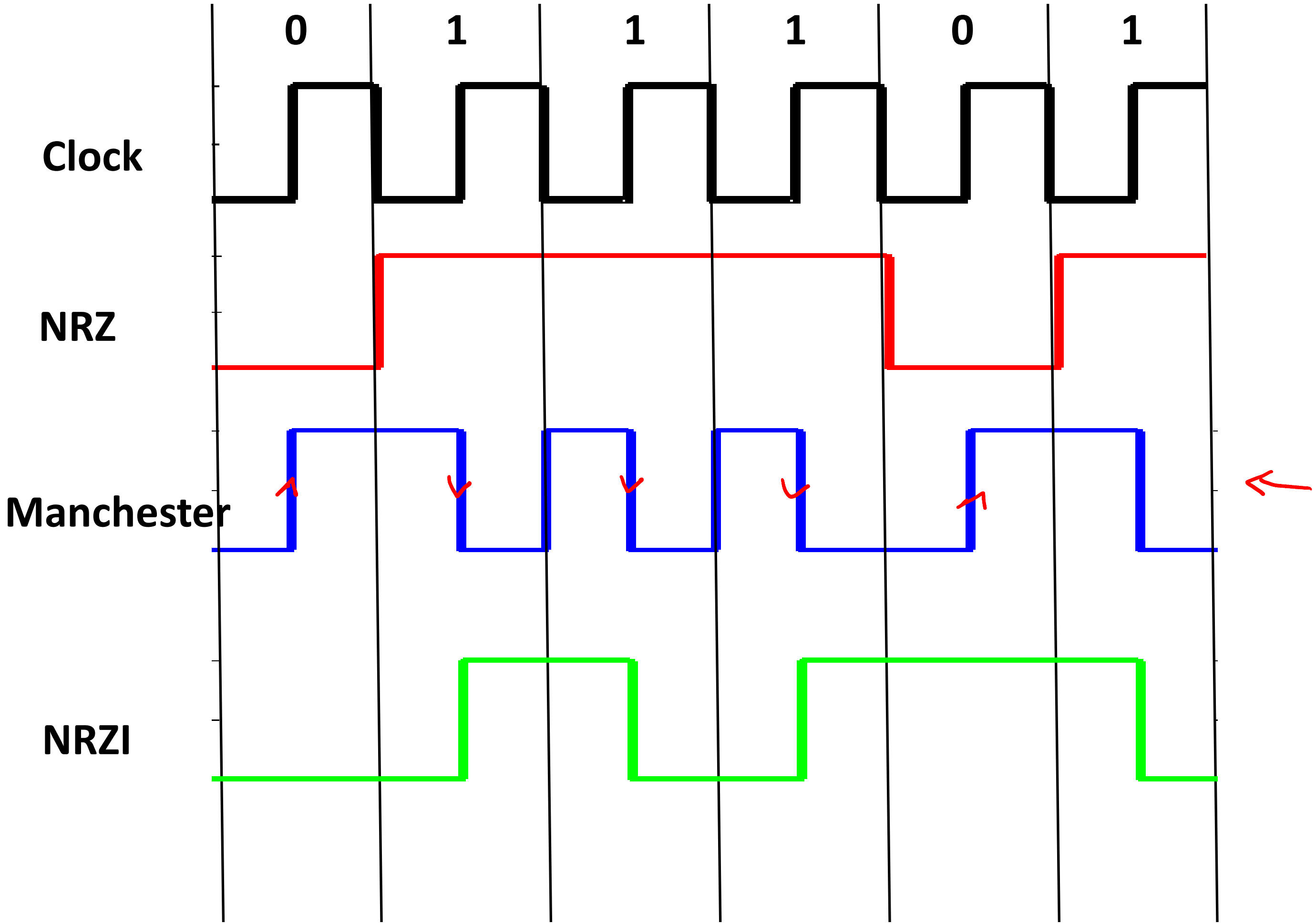

0
1
1
1
0
1
Clock
NRZ
Manchester
NRZI

NRZ-Inverted (NRZI)

- Advantages:
  - Works well in presence of noise (detecting transitions easier than comparison with threshold)
  - Eliminated baseline wander
  - Accidental inversion of leads from device to twisted pair has no effect
- Solves problem of consecutive 1's but not 0's
  - Clock recovery is difficult in presence of consecutive 0’s
  - Signal can have a dc component

Manchester Encoding

- Transmits XOR of the NRZ encoded data and the clock
  - 0 is encoded as low-to-high transition
  - 1 as high-to-low transition
- Used in Ethernet (10Mbps)


0
1
1
1
0
1
Clock
NRZ
Manchester
NRZI

Manchester Encoding

- Advantages:
  - Eliminates both baseline wander
  - Easy synchronization (self-clocking)
  - No DC component
- Disadvantage: Only 50% efficient
  - Maximum encoding rate is twice that of NRZ (more number of transitions) → Require more bandwidth
  - One could send twice as many bits in the same time period with NRZ, NRZI

4B/5B Encoding

- Used in Ethernet (100Mbps), FDDI
- Every 4 bit of actual data is encoded into a 5 bit code
- The 5 bit code words have
  - No more than one leading 0
  - No more than two trailing 0s
- Solves consecutive 0s problem
- The 5 bit codes are sent using NRZI (solves consecutive 1's problem)
- Achieves 80% efficiency

0	0	0000	11110
1	1	0001	01001
2	2	0010	10100
3	3	0011	10101
4	4	0100	01010
5	5	0101	01011
6	6	0110	01110
7	7	0111	01111
8	8	1000	10010
9	9	1001	10011
10	A	1010	10110
11	B	1011	10111
12	C	1100	11010
13	D	1101	11011
14	E	1110	11100
15	F	1111	11101

Summary: Encoding

- Encoding transforms string of bits to voltage levels
- Goal of many encoding techniques
  - Provide enough transitions for clock recovery
  - Achieve above while minimizing bandwidth
- Looked at a variety of line codes: NRZ, NRZI, Manchester, 4B/5B
  - Each has certain advantages and disadvantages

Summary: Physical Layer

- Goal of physical layer is to transfer bits on a link
- Hardware components: Node, Links
- Theory behind data-rates, error rates and delays experienced on links
- Data Transformation: Line codes and Passband modulation
- Looked at encoding techniques (line codes) used in popular wired links