Adaptors Communicating

- Link layer implemented in "adaptor" (aka NIC)
  - Ethernet card, PCMCI card, 802.11 card

- Sending side:
  - Encapsulates datagram in a frame
  - Adds error checking bits, rdt, flow control, etc.

- Receiving side:
  - Looks for errors, rdt, flow control, etc
  - Extracts datagram, passes to rcving node

- Adapter is semi-autonomous

- Link & physical layers
Reliability at link layer

TCP connection

Your laptop

Link layer interface (NIC)

2 reasons why packets fail

Transmission Error

Congestion

Interference from noise

- Environments / cosmic interference
- Hardware/thermal noise (AWGN)

Risk of moving the sample to the wrong side of the decision boundary:

- Bit flips.

Noise ~ N(0, \sigma^2)

\sigma^2 variance
0 - mean.

Additive Gaussian Noise (AWGN)
Link Layer

- 5.1 Introduction and services
- 5.2 Error detection and correction
- 5.3 Multiple access protocols
- 5.4 Link-Layer Addressing
- 5.5 Ethernet
- 5.6 Hubs and switches
- 5.7 PPP
- 5.8 Link Virtualization: ATM
Error Detection

EDC= Error Detection and Correction bits (redundancy)
D = Data protected by error checking, may include header fields

• Error detection not 100% reliable!
  • protocol may miss some errors, but rarely
  • larger EDC field yields better detection and correction
Parity Checking

Error Detection

Single Bit Parity:
Detect single bit errors

Parity Checking

Two Dimensional Bit Parity:
Detect and correct single bit errors

Error correcting codes (Ecc)

Single Bit Parity:
Detect single bit errors

Parity bit

d data bits

0111000110101011

Parity bit

Parity bit

Two Dimensional Bit Parity:
Detect and correct single bit errors

Row parity

d1,1 \ldots d1,j

d2,1 \ldots d2,j

\ldots \ldots \ldots \ldots \ldots

di,1 \ldots di,j

di+1,1 \ldots di+1,j

Column parity

Row parity

Diagnosis:

0111000101011

Row parity

Diagnosis:

1010011

111100

011101

001010

No errors

Correctable single bit error

011100

011101

001010
Internet checksum

**Goal:** detect “errors” (e.g., flipped bits) in transmitted segment (note: used at transport layer only)

**Sender:**
- treat segment contents as sequence of 16-bit integers
- checksum: addition (1's complement sum) of segment contents
- sender puts checksum value into UDP checksum field

**Receiver:**
- compute checksum of received segment
- check if computed checksum equals checksum field value:
  - NO - error detected
  - YES - no error detected. But maybe errors nonetheless? More later ....
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Bob receives (Red Signal + Blue signal)

\[
SNR = \frac{\text{Signal power}}{\text{Noise power}}
\]

called a collision

point to point

5: DataLink Layer
Bob's SIRN = Signal to interference + noise ratio

\[
= \frac{\text{Red signal power}}{\text{Blue signal + Bob's HW noise power}}
\]

MAC protocols' task is to schedule transmissions such that collisions don't happen \(\Rightarrow\) maximize efficiency or channel utilization under constraints of fairness.

Arbitration / Centralized protocols.
Decentralized / Distributed MAC protocol

- Shared resource

[Diagram of a shared resource with arrows pointing towards it]