COMP0023

Bit Errors

* Reliable packet delivery.
* Rowarding & Rowting.

Reliable Delivery

1. No packets are corrupted.
2. All packets are delivered.
3. In order

Bit Error Rates.

BER. - independent, random errors
- bursty., unpredictable.
- corrupt contiguous bits. during burst.
- greater bit rate.

10^{-6} / 10^{-7} / 10^{-8} BER rate

FER. $p = 10^{-6}$. L → length.

$P_{correct} = (1-p)^L$

$P_{FER} = 1 - (1-p)^L$. BER = 10^{-6}, L = 12,000 bits.
FER = 1.19%

reduce L shorter frames → more headers / overhead.

reduce p → error control encoding

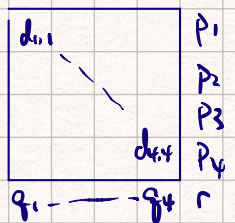
Strategy.

1. detect error / checksum.
2. respond. to error
   - error correction code.
   - re-send.
   - discard

Error Detection & Correction Code ECC.

PHY. Parity Bit, even number of bits

Two-Dimension Parity



9/25
16/25. error checking
data. bits

Hamming (7,4) Code.

$D_1 D_2 D_3 D_4$ $P_1 P_2 P_3$

L2.

CRC quickly filters corrupted frames

- detects single bit errors — g(x) two non-zero terms
- burst error $\leq g-1$. — g(x) start with x^{g-1} ends 1.
- Any odd number of errors — g(x) even number of coefficients

L2 detects most errors before applications

L2 with CRC most errors, especially across links

L3 IP checksum.

only check header. — check in a multiple host env. right packet, right machine.

Transport checksum.

end-to-end at L4. — right packet right destination

E2E communication

from sender to receiver

Why? Intermediate device in the Internet

introduce errors, L2, L3 headers can be replaced. / introduce errors

Less frequent, additional checksums

Space efficient: 16-bit all the way.

recomputing fast: $C' = \sim(\sim C + \sim m + m')$.

guarantee: single-bit error detectable.

FEC. Error correction / very expensive to archive low Frame Loss Rate.

Some Errors are too severe. (bursts)

CRC32 + IP + TCP checksums.

Practical, enough FEC to put Loss Rate under 10^{-3}.

Reliable Transmission.

- corrupt packets.
- Can lose packets
- delays / reorder packets

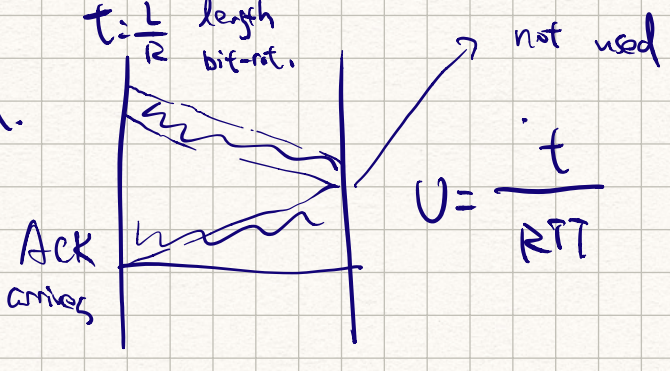
Design: Stop and wait protocol.

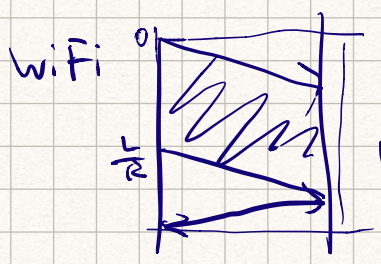
- Send a packet — Re-transmission
- wait until ACK or RTX expires

sequence number should be large.

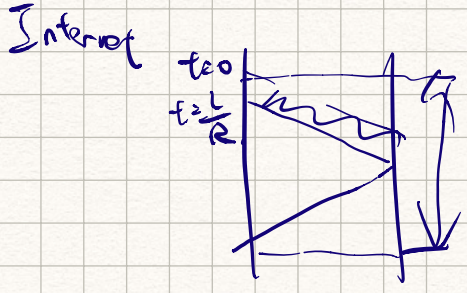
32-bit for TCP.

Stop-Wait Protocol.



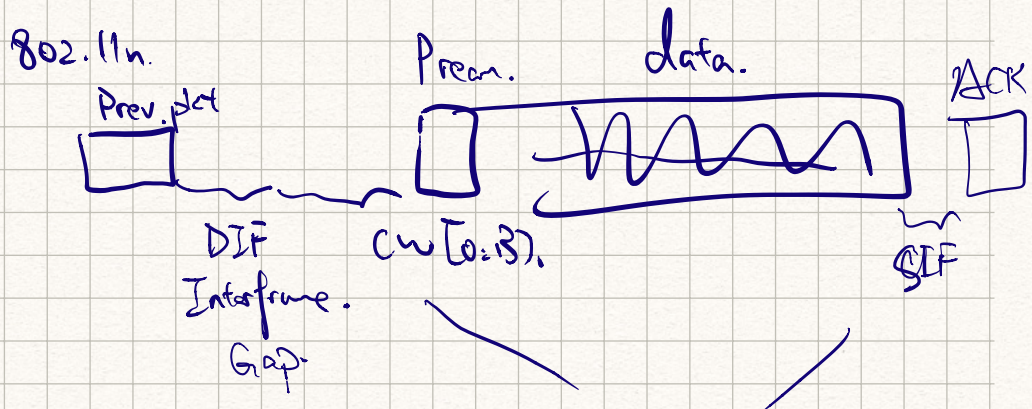


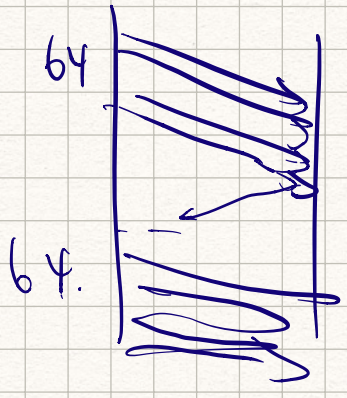
99.3%



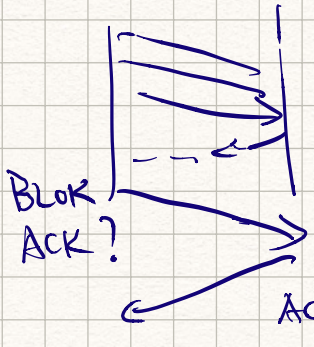
2.1%

Aggregate Packet on WiFi





expensive to do full resend.



Reliability + Efficient across Internet.

Pipeling: Sender sends multiple packets at a time.

Go Back N.

Cumulative ACK, resend from the lost ACK

- not great to discard all new packets

Pipeling with Selective ACK