CS 43: Computer Networks
Reliable Data Transfer

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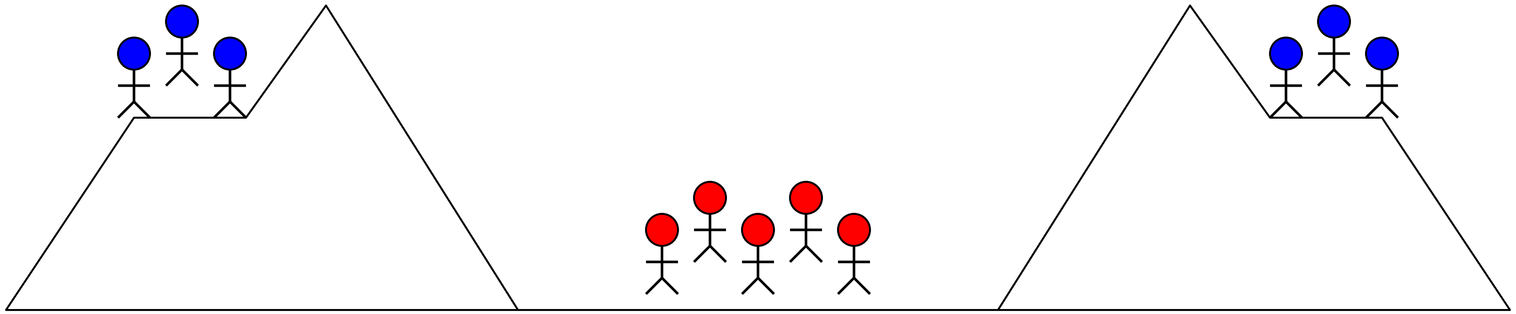
Agenda

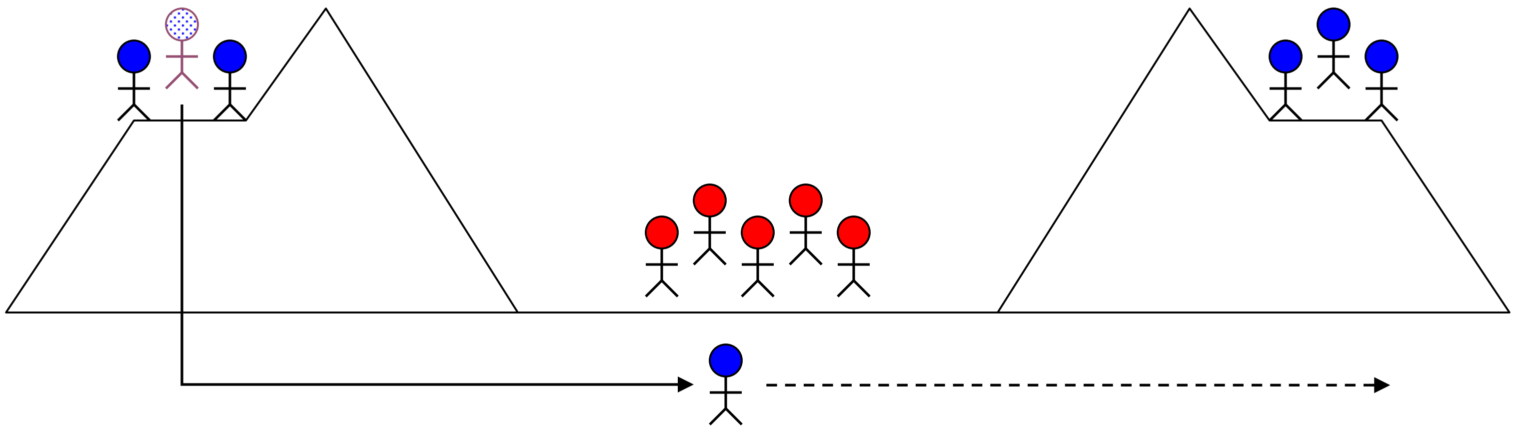
- Today: General principles of reliability
- Next time: details of one concrete, very popular protocol: TCP

The Two Generals Problem



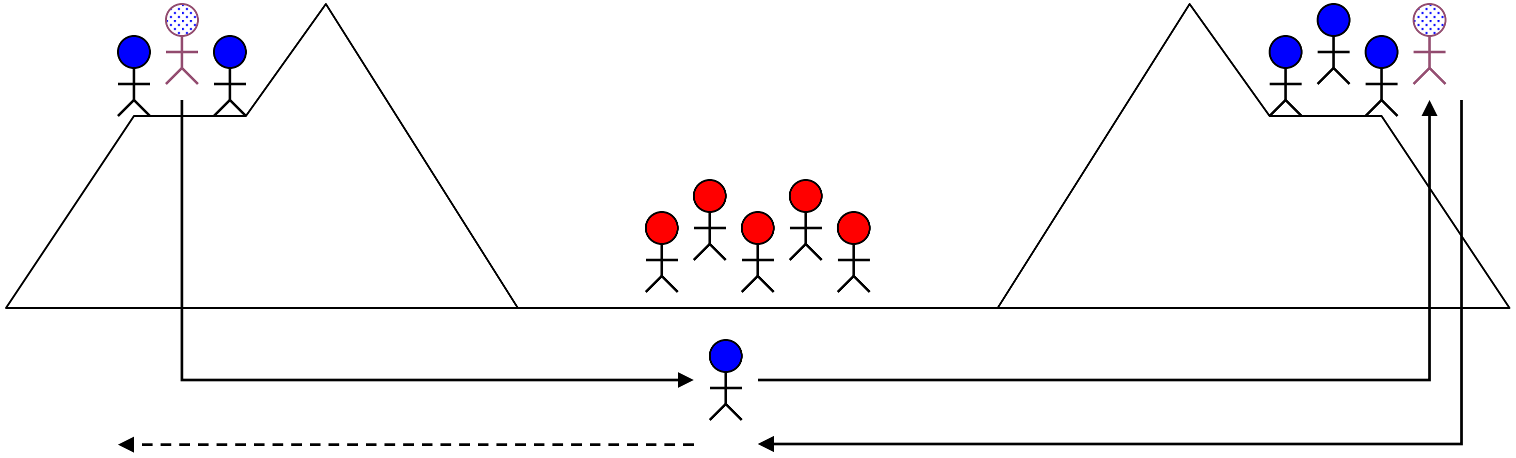
- Two army divisions (blue) surround enemy (red)
  - Each division led by a general
  - Both must agree when to simultaneously attack
  - If either side attacks alone, defeat
- Generals can only communicate via messengers
  - Messengers may get captured (unreliable channel)

The Two Generals Problem



- How to coordinate?
  - Send messenger: “Attack at dawn”
  - What if messenger doesn’t make it?

The Two Generals Problem

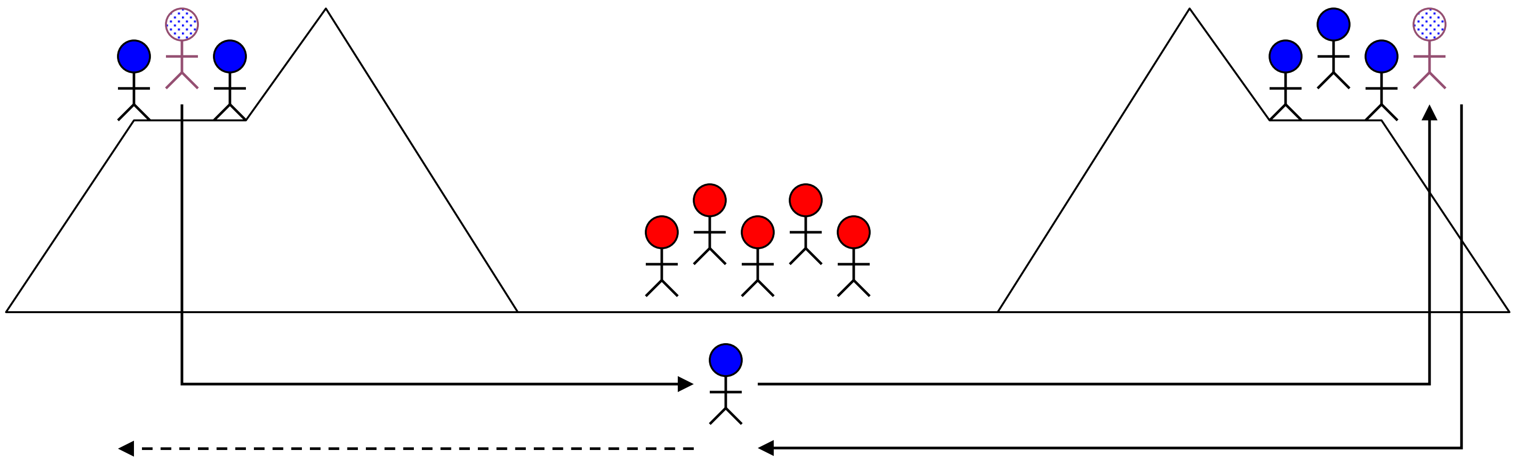


- How to be sure messenger made it?
  - Send acknowledgment: “I delivered message”

In the “two generals problem”, can the two armies reliably coordinate their attack?

- A. Yes (explain how)
- B. No (explain why not)

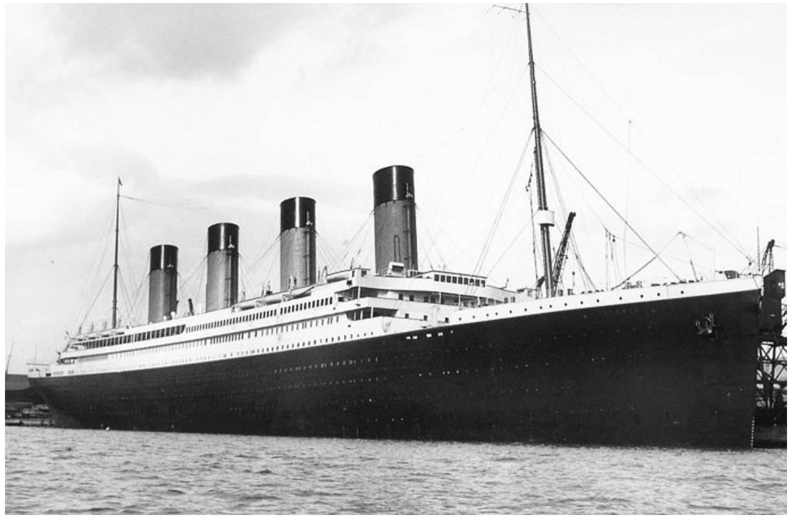
The Two Generals Problem



- Result
  - Can’t create perfect channel out of faulty one
  - Can only increase probability of success

Give up? No way!

- As humans, we like to face difficult problems.
  - We can’t control oceans, but we can build canals
  - We can’t fly, but we’ve landed on the moon
  - We just need engineering!



(Unsinkable)

Engineering

- Concerns
  - Message corruption
  - Message duplication
  - Message loss
  - Message reordering
  - Performance
- Our toolbox
  - Checksums
  - Timeouts
  - Acks & Nacks
  - Sequence numbering
  - Pipelining

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We use these to build Automatic Repeat Request (ARQ) protocols.

(We’ll briefly talk about alternatives at the end.)

Automatic Repeat Request (ARQ)

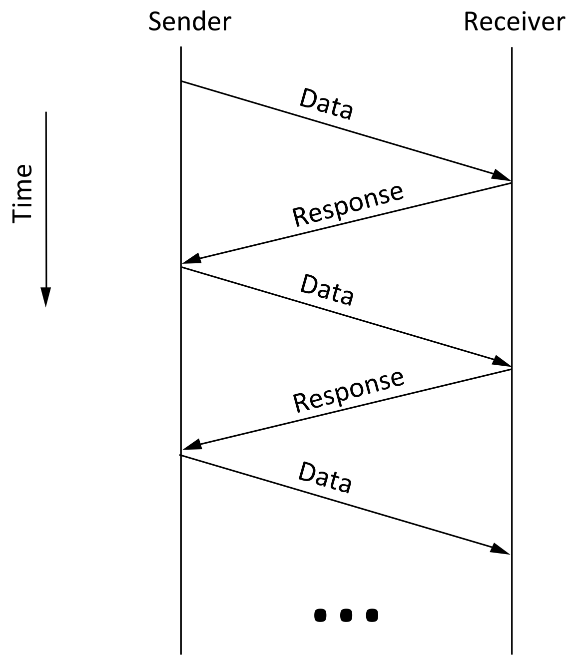
- Intuitively, ARQ protocols act like you would when using a cell phone with bad reception.
  - Message garbled? Ask to repeat.
  - Didn’t hear a response? Speak again.

- Refer to book for building state machines.
  - We’ll look at TCP’s states soon

ARQ Broad Classifications

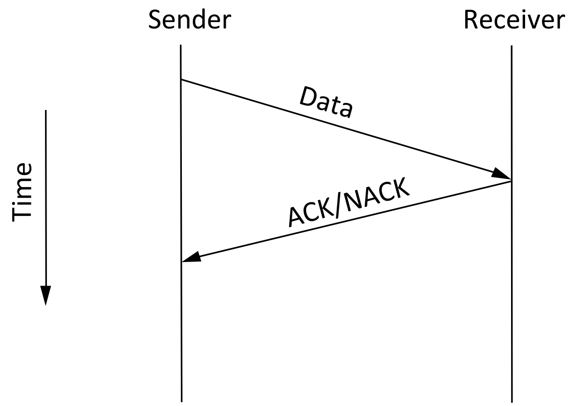
1. Stop-and-wait

Stop and Wait



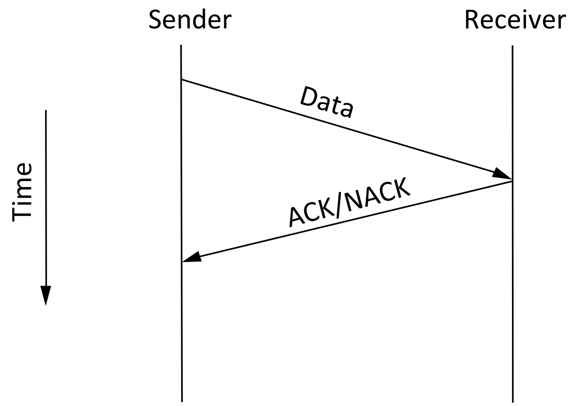
Up next: concrete problems and mechanisms to solve them. These mechanisms will build upon each other, so please stop me if you have Questions!

Corruption?



- Error detection mechanism: checksum
  - Data good – receiver sends back ACK
  - Data corrupt – receiver sends back NACK

Could we do this with just ACKs or just NACKs?



A. No, we need them both.

B. Yes, we could do without one of them, but we'd need some other mechanism.

C. Yes, we could get by without one of them.

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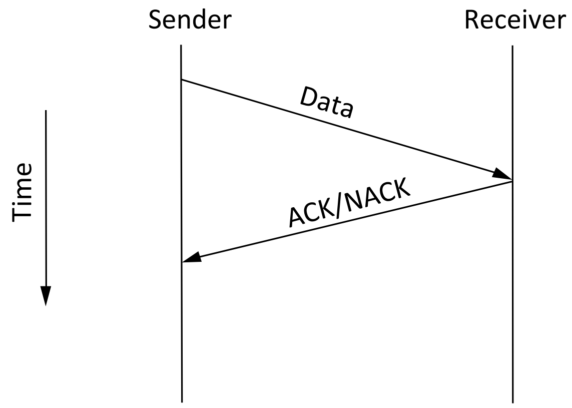


A. No, we need them both.

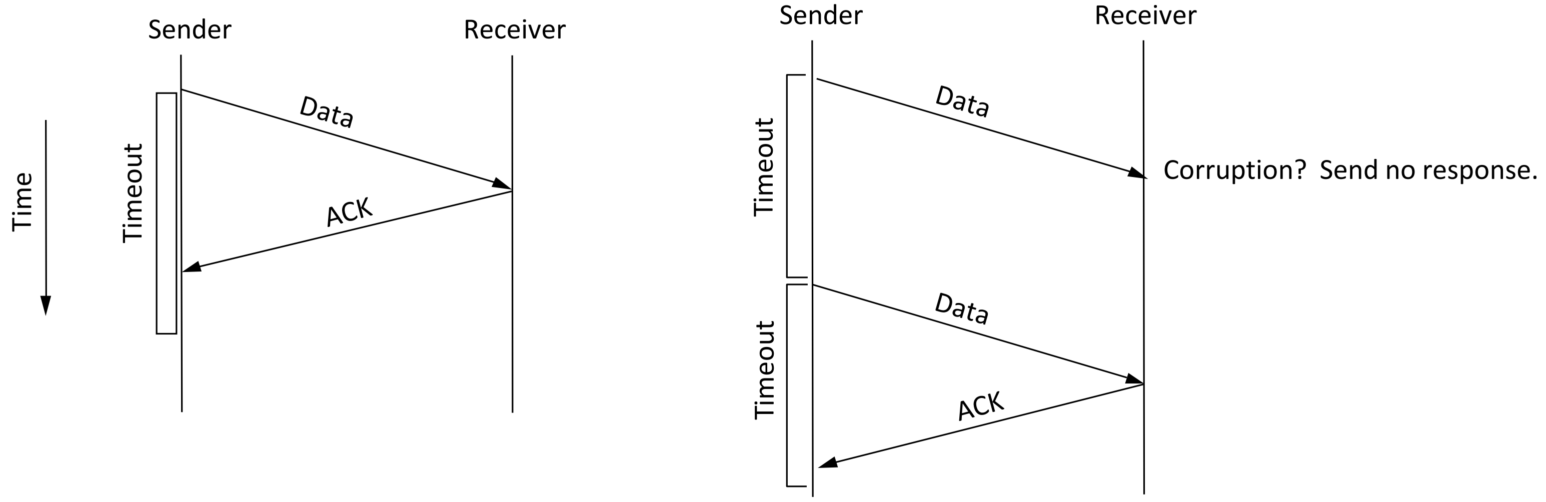
B. Yes, we could do without one of them, but we'd need some other mechanism.

C. Yes, we could get by without one of them.

With only **ACK**, we could get by with a timeout.

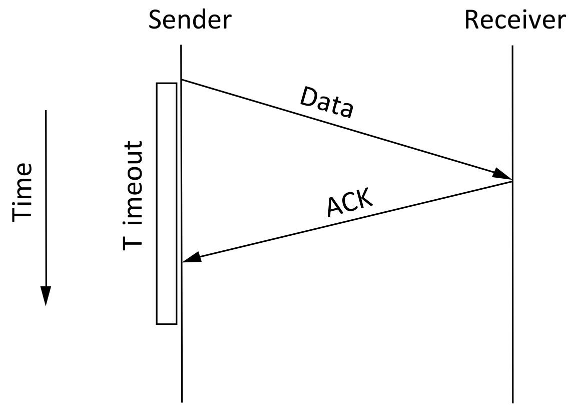
With only **NACK**, we couldn't advance (no good).

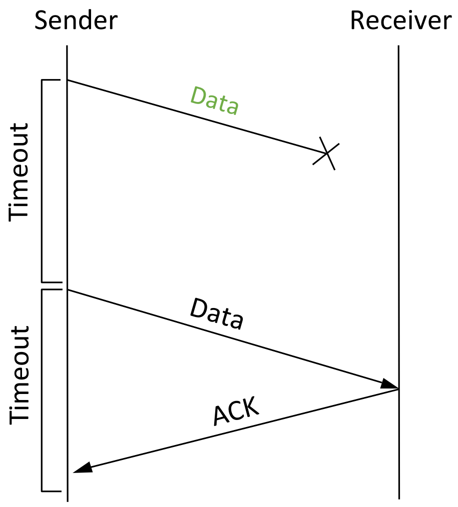
Timeouts



- Sender starts a clock. If no response, retry.
- Probably not a great idea for handling corruption, but it works.

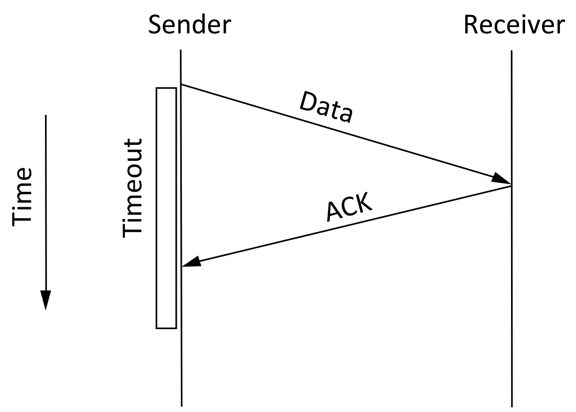
Timeouts and Losses

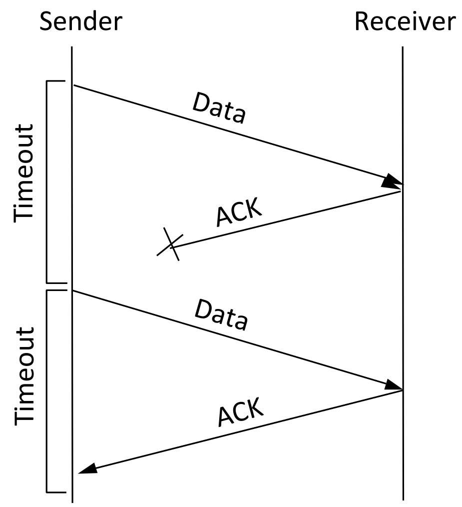




- Timeouts help us handle message losses too!

Adding timeouts might create new problems for us to worry about. How many? Examples?





A. No new problems (why not?)
B. One new problem (what is it?)
C. Two new problems (what are they?)
D. More than two new problems (what are they?)

Sequence Numbering

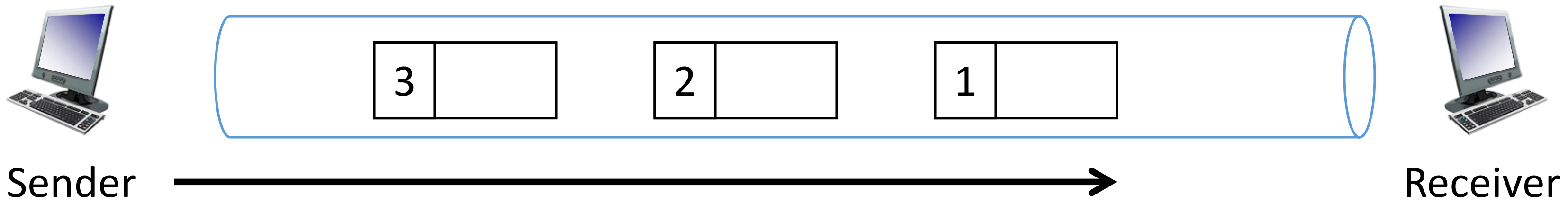
Sender

- Add a monotonically increasing label to each msg

Receiver

- Ignore messages with numbers we've seen before

- When pipelining (a few slides from now)
  - Detect gaps in the sequence (e.g., 1,2,4,5)



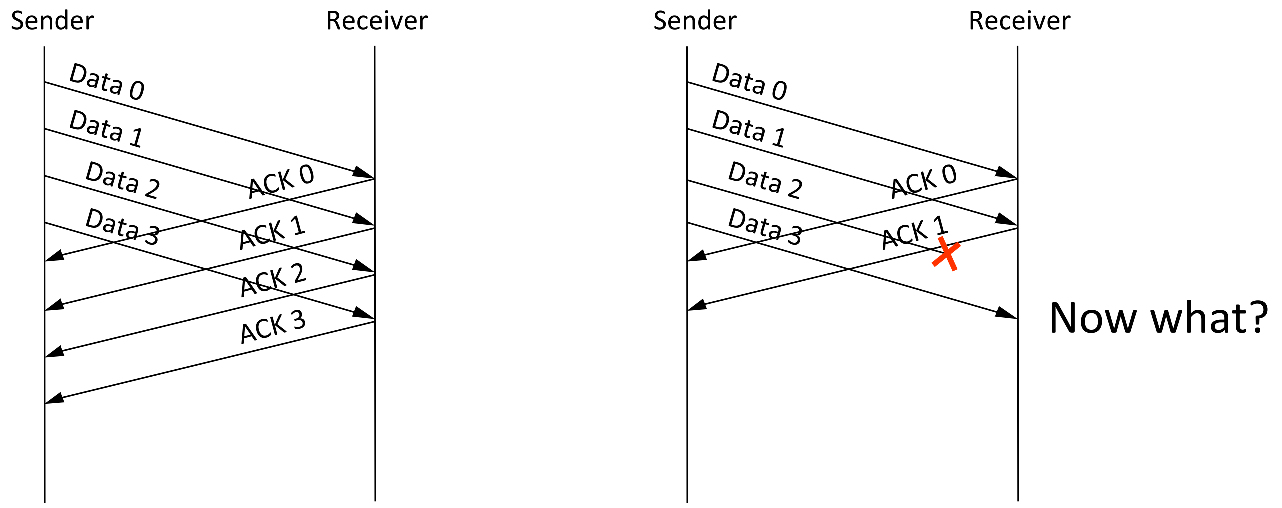
Suppose we had a modest 8 Mbps (one megabyte per second) link. Our RTT is 100 ms, and we send 1024-byte (1K) segments. What is our link utilization with a stop and wait protocol?

A. < 0.1 %
B. ≈ 0.1 %
C. ≈ 1 %
D. 1-10 %
E. > 10 %

Big Problem for stop and wait:

Performance is determined by RTT, not channel capacity!

Pipelined Transmission

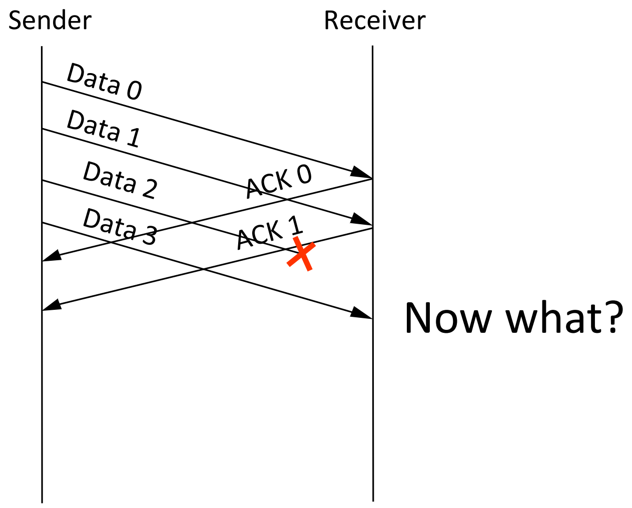


- Keep multiple segments "in flight"
  - Allows sender to make efficient use of the link
  - Sequence numbers ensure receiver can distinguish segments
  - We'll talk about "how many" next time (windowing).

What should the sender do here?

What information does the sender need to make that decision?

What is required by either party to keep track?



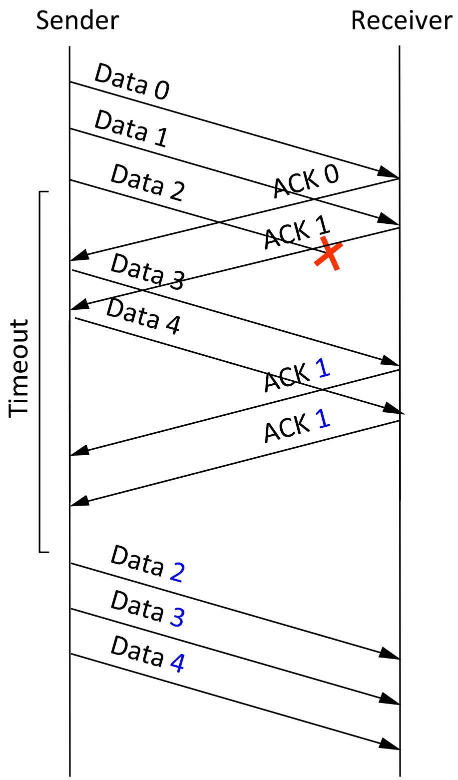
A. Start sending all data again from 0.
B. Start sending all data again from 2.
C. Resend just 2, then continue with 4 afterwards.

ARQ Broad Classifications

1. Stop-and-wait

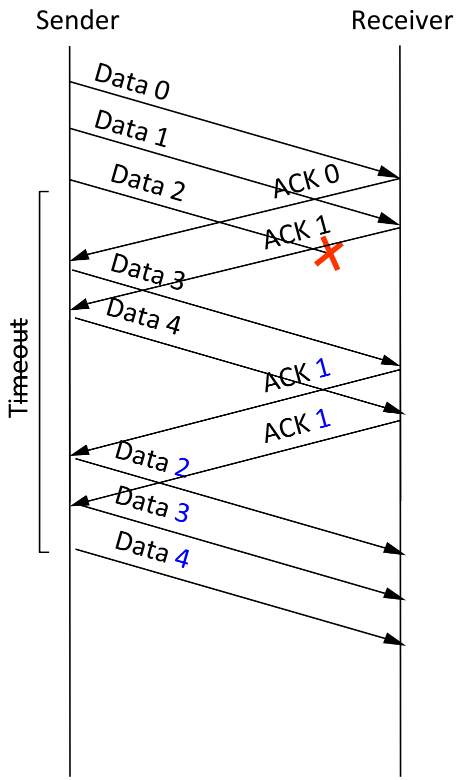
2. Go-back-N

Go-Back-N



- Retransmit from point of loss
  - Segments between loss event and retransmission are ignored
  - “Go-back-N” if a timeout event occurs

Go-Back-N



- Retransmit from point of loss
  - Segments between loss event and retransmission are ignored
  - "Go-back-N" if a timeout event occurs
- Fast retransmit
  - Don't wait for timeout if we get N duplicate ACKs

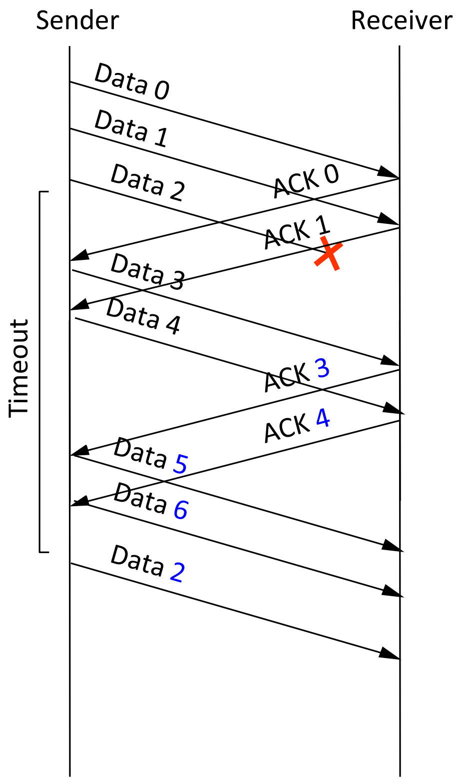
ARQ Broad Classifications

1. Stop-and-wait

2. Go-back-N

3. Selective repeat
    - a.k.a selective reject, selective acknowledgement

Selective Repeat



- Receiver ACKs each segment individually (not cumulative)
- Sender only resends those not ACKed
- Requires extra buffering and state on the receiver

ARQ Alternatives

- Can’t afford the RTT’s or timeouts?

- When?
  - Broadcasting, with lots of receivers
  - Very lossy or long-delay channels (e.g., space)

- Use redundancy – send more data
  - Simple form: send the same message N times
  - More efficient: use “erasure coding”
    - For example, encode your data in 10 pieces such that the receiver can piece it together with any subset of size 8.

Summary

- Guaranteeing reliability is impossible over a lossy channel
  - We can do a lot of things to maximize our chances
  - The things we can do are usually good enough in practice

- Tools available: acknowledgements, sequence numbers, timeouts, etc
  - They help solve problems
  - They often introduce other problems too, though – must be careful

- Several styles of ARQ protocols: trade-off throughput vs. complexity