Computer Networks

Lecture on

Packet Transmission Issues

Plan of This Lecture

- How to achieve communication reliability?
- Network congestion problem
- Packet delay

Communication Reliability

Problems

- Corrupted message
  - Noise at transmission medium
- Lost message
  - Noise at transmission medium
  - Buffer overload in network switches or in the terminal device
- Duplicated messages
  - Due to retransmissions or bad configuration of communication protocols
- Modified message order
  - Due to multipath propagation in switched networks

Solutions

- Corrupted message
    - Bit error detection
    - Bit error correction – using an error correcting code, e.g. Hamming code
- Lost message
    - Flow control mechanisms
    - Message numbering
    - Positive or negative acknowledgments (ACKs or NACKs)
    - Retransmission timers
- Duplicated messages
    - Message numbering How long the number should be?
- Modified message order
    - Message numbering

Bit Error Detection

- Bit parity check for every byte sent – used in asynchronous lines
- Cyclic Redundancy Check codes – used in synchronous lines
- Check sum of all bytes of a message
  - supplementary check on network & transport layers

Longer frame

- Higher probability of bit errors
- Better efficiency, i.e. $\left(\frac{\text{payload bits}}{\text{transmitted bits}}\right)$ rate

Shorter frame

- Lower probability of bit errors
- Lower efficiency

Radio links – higher probability of serial bit errors

- Parallel transmission of several frames can change a serial error to several single-bit errors

b0	b1	b2	...	bN	CRC_B
c0	c1	c2	...	cN	CRC_C
...	...	...	...	...	...
x0	x1	x2	...	xN	CRC_X

Transmission order: b0, c0, ..., b1, c1, ..., b2, c2, ...

Message Repetition

- Each message is sent two or three times or with error-correcting code – in very noisy networks
- Using positive acknowledgement ACK
  - Sender sets a timer for each message sent
  - Arriving ACK cancels the respective timer
  - When a timer fires the message is retransmitted and the timer is set
  - Number of retransmissions is limited

How to set the timer?

- Using negative acknowledgement NACK
  - Recipient sends NACK when it gets a message out of sequence
  - Recipient sets a timer for each sent NACK
  - Sender retransmit the message pointed by NACK

How long to store the message?

ACKs

- Needlessly take bandwidth in reliable links
- Slower retransmission
- Recommended for unreliable links

NACKs

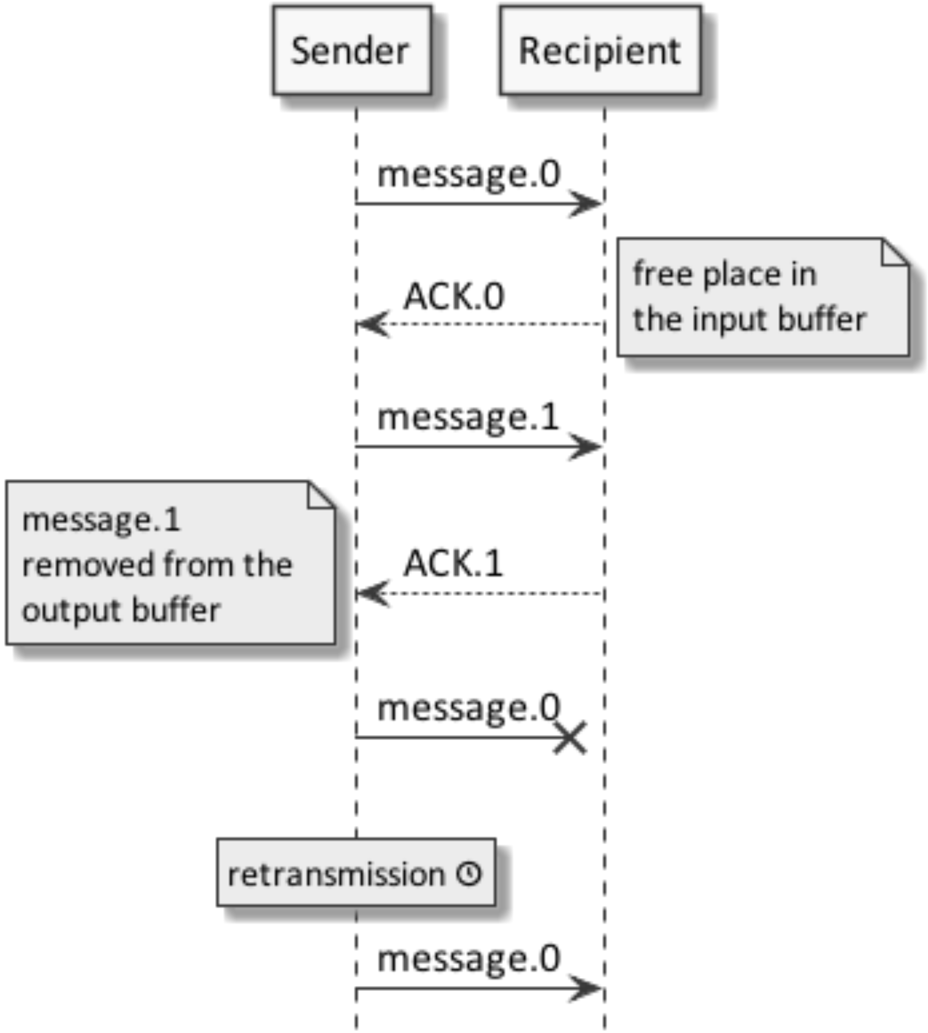
- Can be frequent in unreliable links
- Faster retransmission
- Recommended for reliable links
- Periodic ACKs help to free buffers

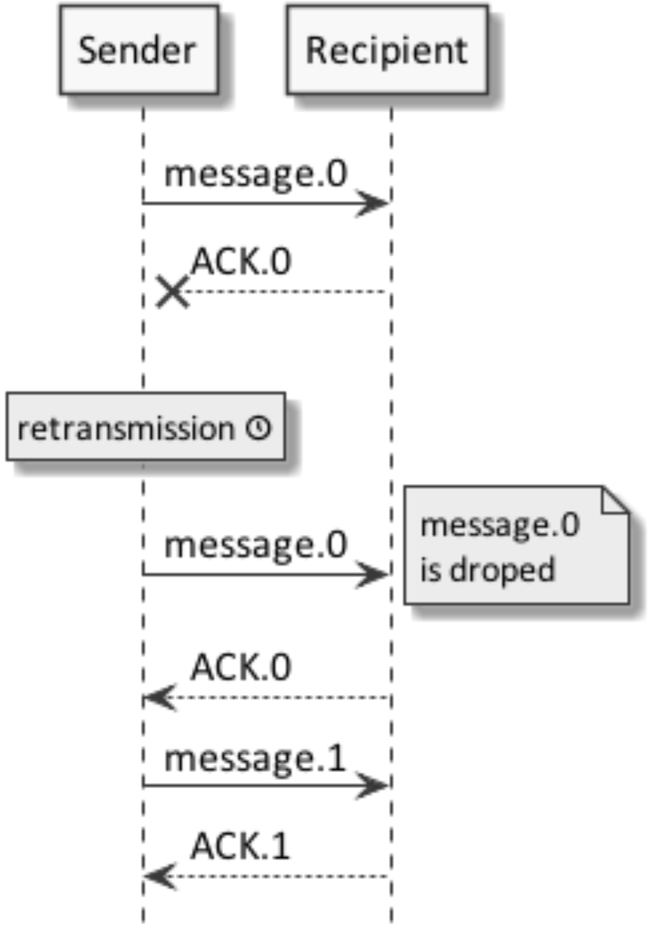
A retransmission can be too late – if long delay

- then forward error correction or even multiple-transmission of the same packet

Flow control – Send and Wait (Bit Alternate Protocol)

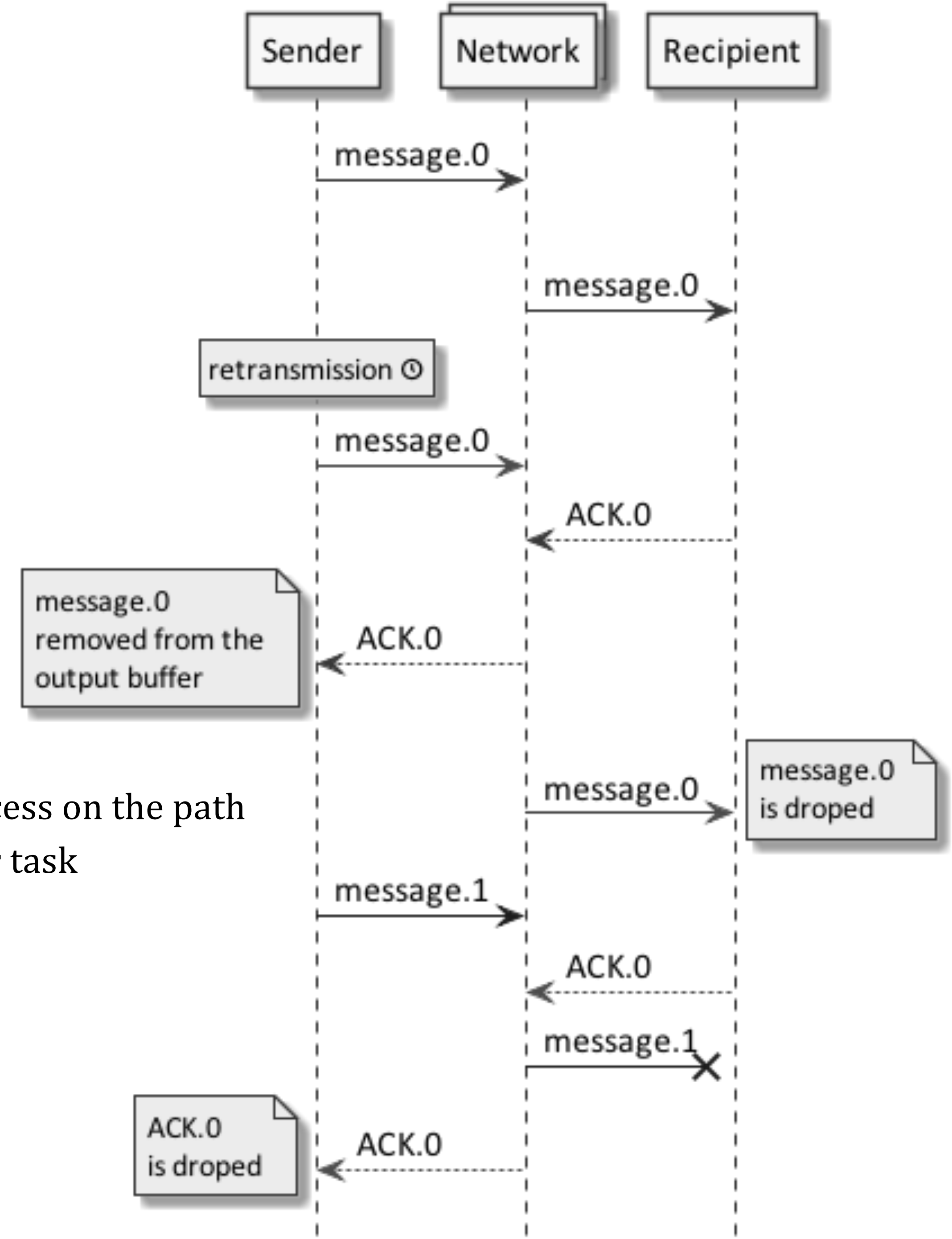
There is 1 output and 1 input buffer





This is why messages must be numbered

This is why
ACKs must be numbered



Reasons for ACK delay:

- Transmission time
- Signal propagation time
- Buffering time by every process on the path
- Recipient processed another task

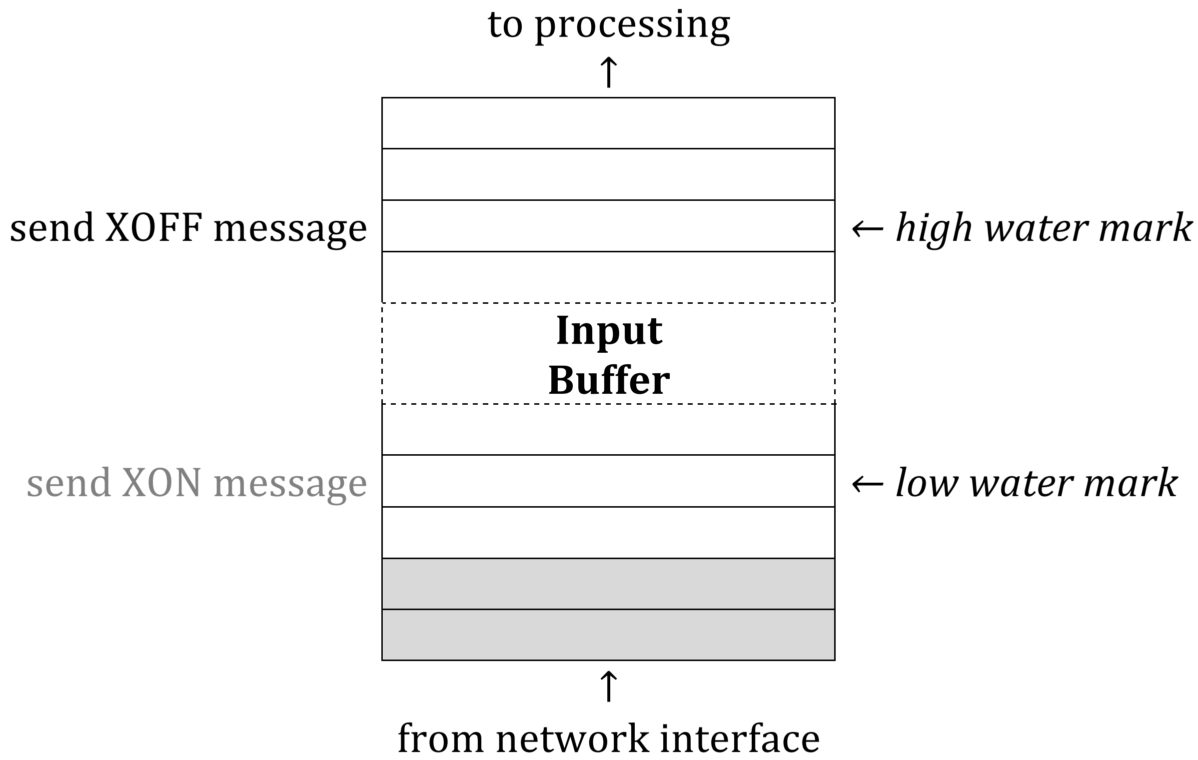
Messages are buffered by:

- operating systems
- communication hardware

Flow control – XON/XOFF Protocol

- Is efficient – while processing a message, the next are transmitted
- Do not guarantee message delivery (by itself)

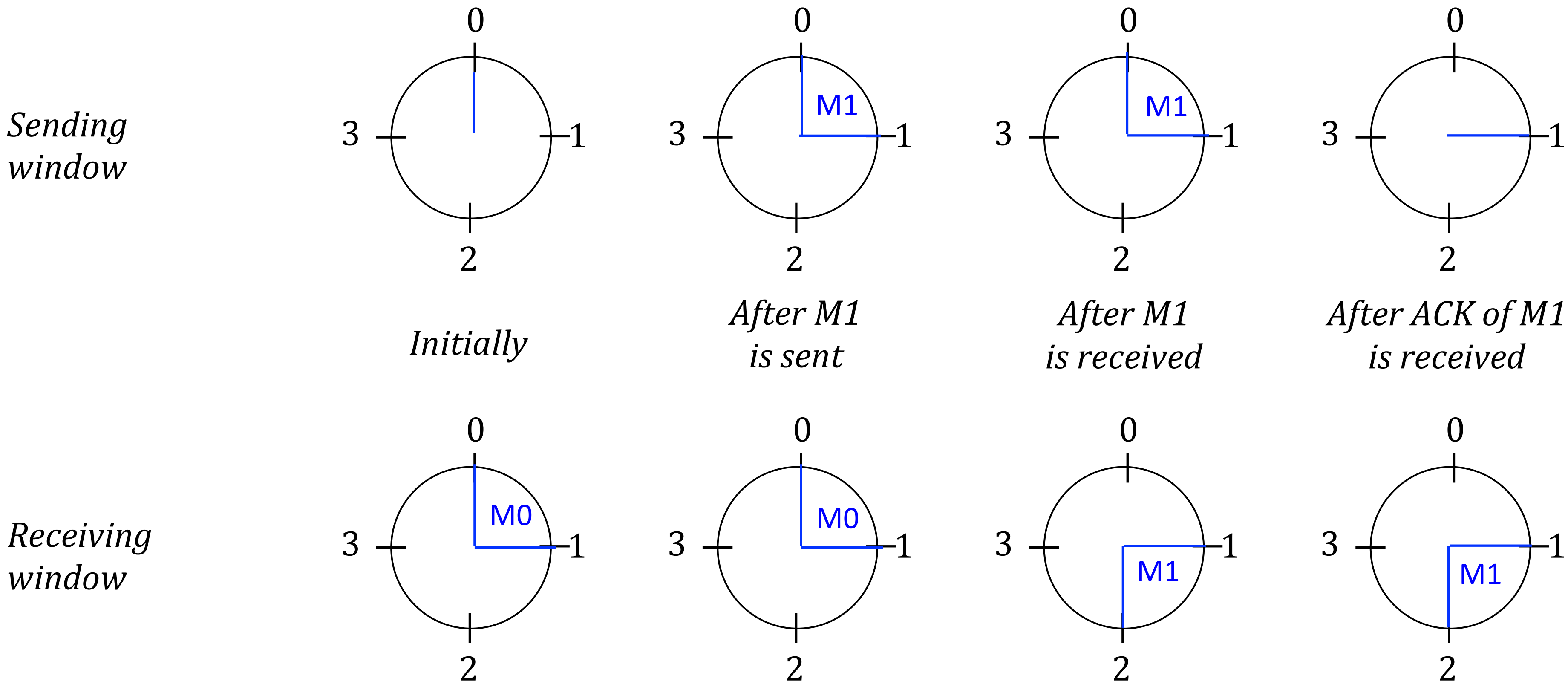
Input buffer can store N messages



A message size can be 1 byte

Flow control – Sliding Window Mechanism

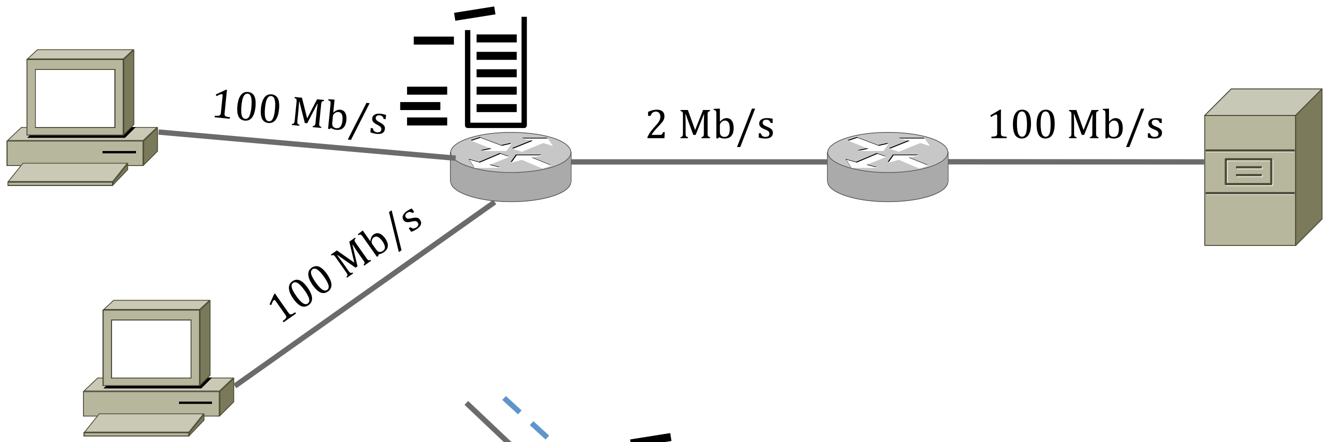
- Is efficient – while processing a message, the next are transmitted
- Guarantee message delivery

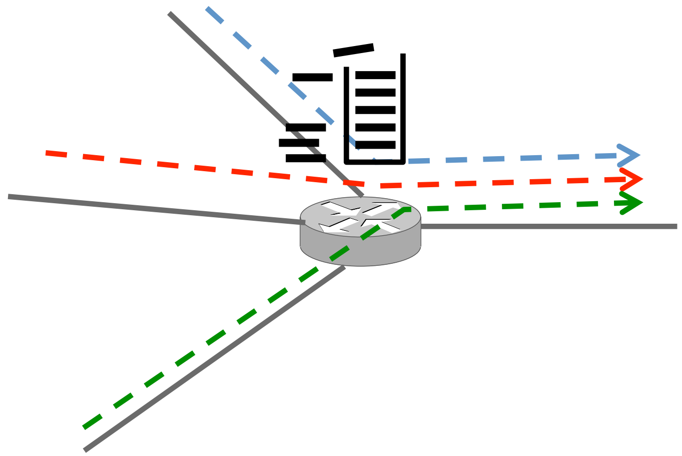


Parameters to be set: window size and number of messages to be sent without ACK

Network Congestion

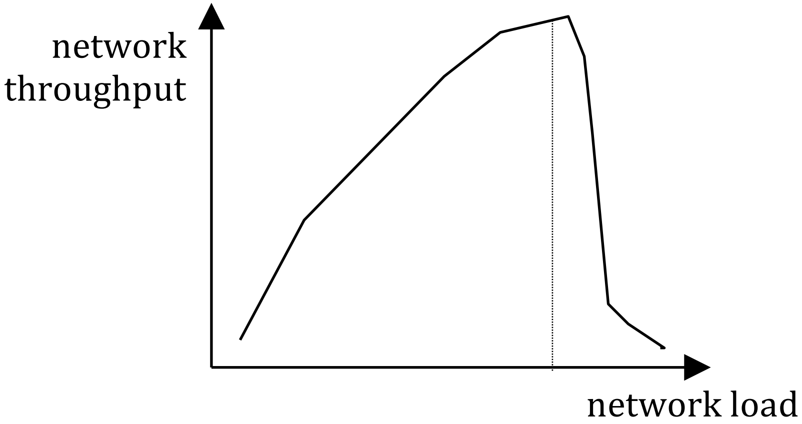
Source of the problem:

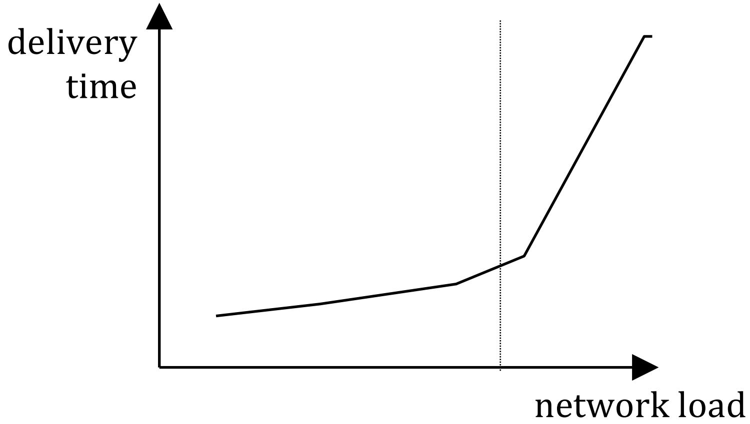


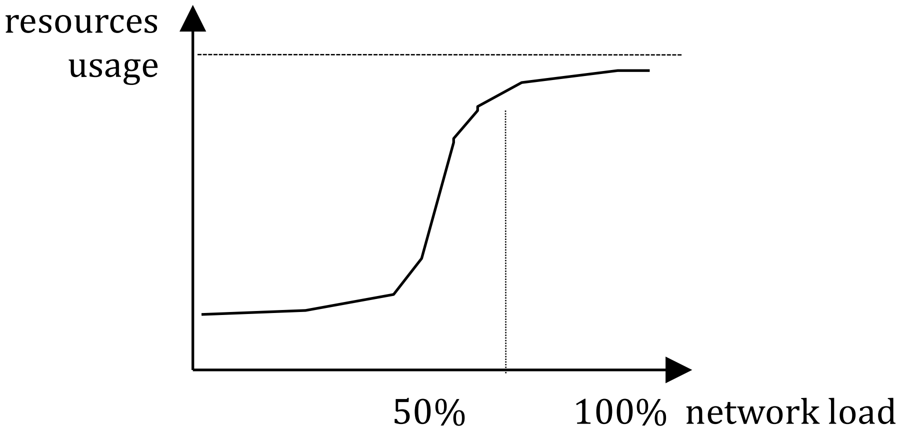


Retransmissions of dropped packets can lead to the *congestion collapse*

Effects of the Congestion Collapse







Communication suffers from
- queueing delay
- packet loss
- blocking of new connections

Techniques Used to Avoid the Collapse

- Congestion control – reactive
  helps the network to recover from the congestion state
  - exponential backoff
    - as in CSMA/CD Ethernet & Wi-Fi
  - transmission window reduction in TCP
  - explicit notifications
  - some queuing & scheduling mechanisms with active queue management

- Congestion avoidance – proactive
  allows a network to operate in the region of low delay and high throughput
  - admission control
  - some queuing & scheduling mechanisms

Packet Delay

Delay	Where	Example
Bandwidth	per-transmitter	Sending 1 Mb at 10 Mb/s will take 100 ms
Propagation	per-link	At twisted pair wire, coax, fibre: $\simeq 2/3$ of the light speed, thus $\simeq 200$ km/ms
Store-and-forward	per-switch	Transmission time of the frame
Queuing	per-switch	Generally less than 10 ms and often is less than 1 ms; at bad moments this can exceed 1 s
Total packet from sender to receiver	per-path	Sum of the above for each switch and link

Store-and-forward

– A switch receives entire packet, checks its CRC, and then decides to retransmit it

Fast-forward

– A switch receives header with addresses, and then decides to retransmit the packet

Summary

- Reliability problems & solutions
  - Bit error detection
  - Message repetition
  - Flow control mechanisms
    - Send and wait
    - Xon/Xoff
    - Sliding window
- Network congestion
  - Effects of the congestion collapse
  - Techniques used to avoid the collapse
- Packet delay

Questions

1. What are the causes of communication reliability problems?
2. What are the mechanisms used to make communication reliable?
3. Which frames are better long or short and why?
4. What size of frames is more efficient in transmission over noisy radio channels?
5. What size of frames is more efficient in transmission over reliable fibre cables?
6. What are pros & cons of positive and negative acknowledgements?
7. Under which conditions error-correcting codes or repeated frames should be used?
8. Why Bit Alternate Protocol is inefficient?
9. What is the aim of XON/XOFF protocol?
10. What for we define low and high water marks for data buffers?
11. Explain sliding window mechanism.
12. Why do we need congestion control and avoidance mechanisms?
13. Why the ring network topology is congestion resistant?
14. What techniques are used to avoid the congestion collapse?
15. What are the elements of total packet delay?
16. Explain the fast-forward technique.