Announcements
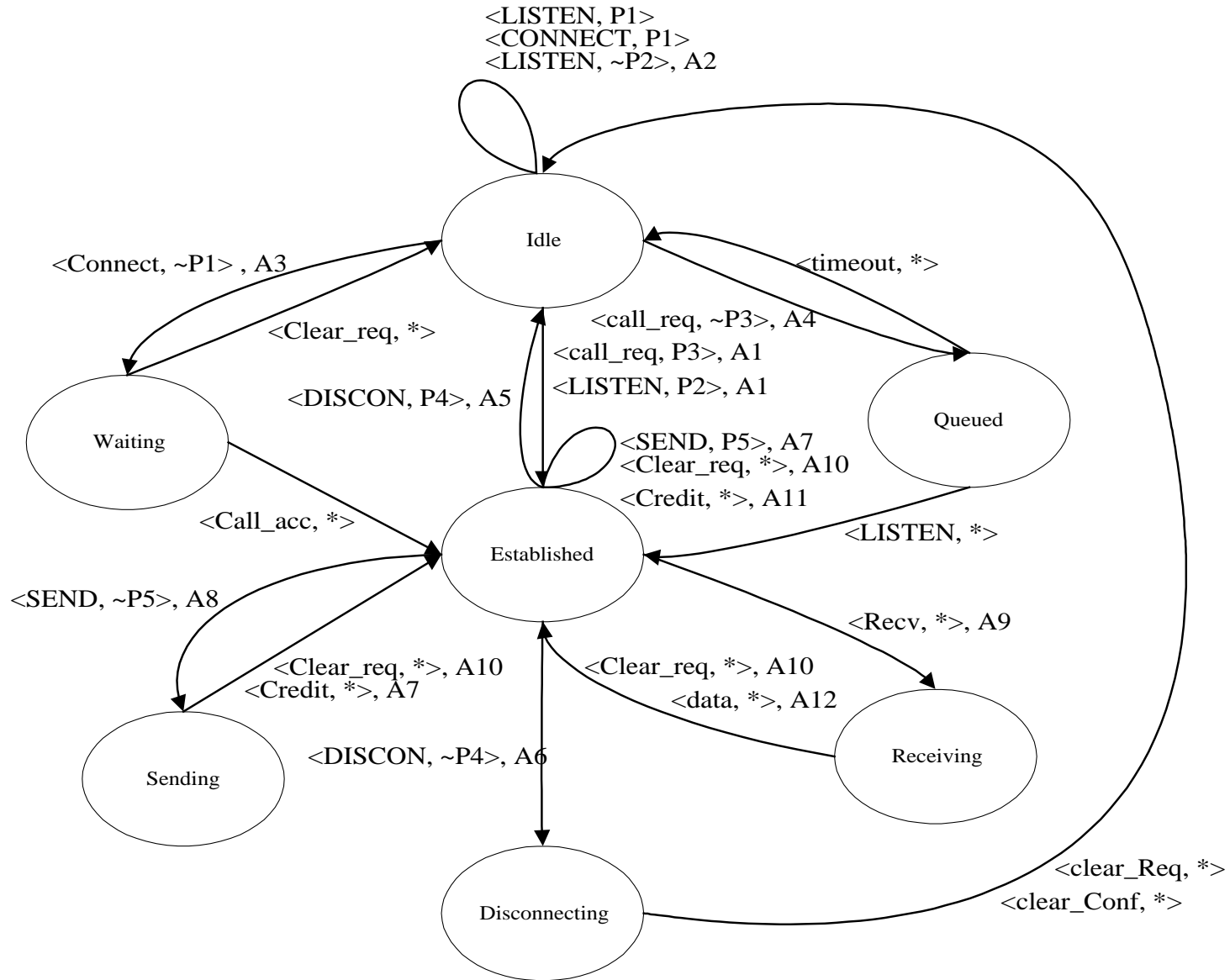
- Project Proposals were returned

- Reading
  - Today: 6.4
  - Tuesday: 3.1

Protocol State Machines

<LISTEN, P1>
<CONNECT, P1>
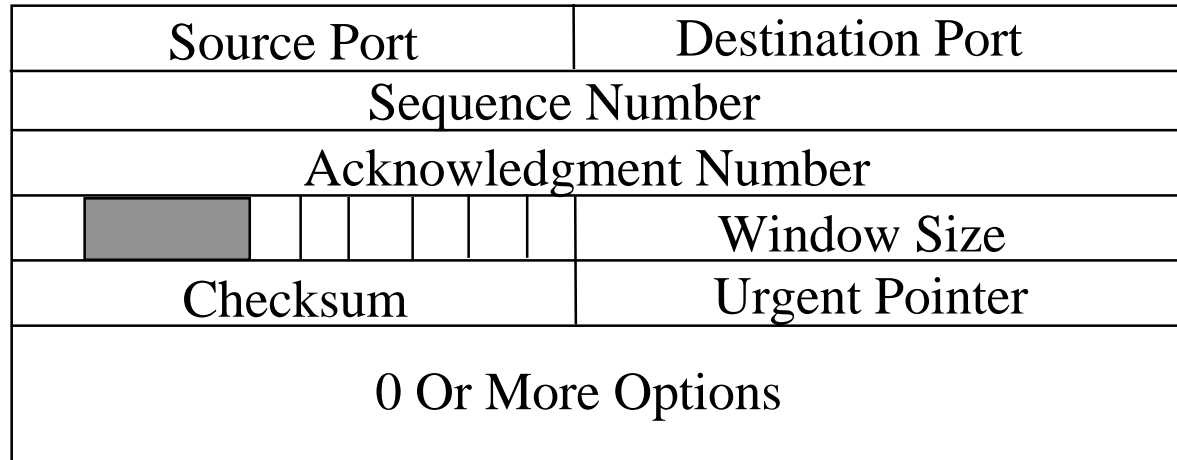<LISTEN, ~P2>, A2

Idle

<Connect, ~P1> , A3

<timeout, *>

<Clear_req, *>

<call_req, ~P3>, A4
<call_req, P3>, A1
<LISTEN, P2>, A1

<DISCON, P4>, A5

Waiting

Queued

<SEND, P5>, A7
<Clear_req, *>, A10
<Credit, *>, A11

<Call_acc, *>

Established

<LISTEN, *>

<SEND, ~P5>, A8

<Recv, *>, A9

<Clear_req, *>, A10
<Credit, *>, A7

<Clear_req, *>, A10
<data, *>, A12

Sending

<DISCON, ~P4>, A6

Receiving

Disconnecting

<clear_Req, *>
<clear_Conf, *>

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Predicates And State Transitions

Pred	Meaning
P1	Connection table full
P2	Call_req pending
P3	LISTEN Pending
P4	Clear_req Pending
P5	Credit Available

Act	Meaning
A1	Send Call_acc
A2	Wait for Call_req
A3	Send Call_req
A4	Start Timer
A5	Send Clear_conf
A6	Send Clear_req
A7	Send message
A8	Wait for credit
A9	Send Credit
A10	Set Clr_req_recv flag
A11	Record credit
A12	Accept message

TCP Protocol

- ## TSAPs
  - Use <host, port> combination
  - Well known ports provide services
    - first 256 ports
    - SMTP 25, Telnet 23, Ftp 21, HTTP 80

- ## Provides a **byte** stream
  - this is **not** a message stream
  - a message (single call to send) may be split, merged, etc.

- ## Urgent Data field
  - provides cut through delvery *within* a trasport connection
  - used to send breaks or other high priority info

TCP Packet Format

- **Permits ACKs to be piggy packed**
  - ACK is next byte expected
  - ACK is only valid if ACK bit is set
- **Sequence number**
  - first byte in packet
- **Also used for connection establishment**

Source Port	Destination Port
Sequence Number	
Acknowledgment Number	
	Window Size
Checksum	Urgent Pointer
0 Or More Options	

← 32 bits →

TCP Connection Management

- **Three-way Handshake**

- **Initial Sequence Numbers**
  - Use a 4 micro-second clock
  - hosts must wait T (120 seconds) before a reboot

- **Connection Closure**
  - Each side uses a FIN and FIN_ACK message
  - A FIN times out after 2 T (240 seconds)
  - Keep alives used to timeout half dead connections

TCP Flow Control

- **Use Variable Sized Sliding Window**
  - ACK indicates start of window
  - Window size indicates current size of window

- **Receiver can send a window of 0**
  - indicates that it want to pause connection
  - urgent data need not follow this request

- **Window size of 16 bits is too small**
  - 64K Bytes
  - only a small fraction of the in-flight bytes when
    - bandwidth is high
    - delay is high
  - solution: window shift option:
    - bit shift window up to 16 bits
    - permits up to 2^{32} byte windows
    - reduces window granularity

TCP Congestion Control

- **Detecting Congestion**
  - In general it is difficult
  - But, consider why a packet might be dropped
    - link error - but links are very reliable now
    - buffer overflow --> congestion
  - Use re-transmission timeouts as an estimate of congestion
- **Dealing with Congestion**
  - add a second window (congestion window)
    - limit transmissions to min(recv window, congestion window)
  - start with congestion window = max segment window
    - initial max segment is one kilo-byte
    - on a ACK without a timeout
      - if window < threshold, increment by one max segment
      - otherwise increment by initial max segment
  - on timeout
    - cut threshold in half
    - set window size to initial max segment

TCP Congestion Window
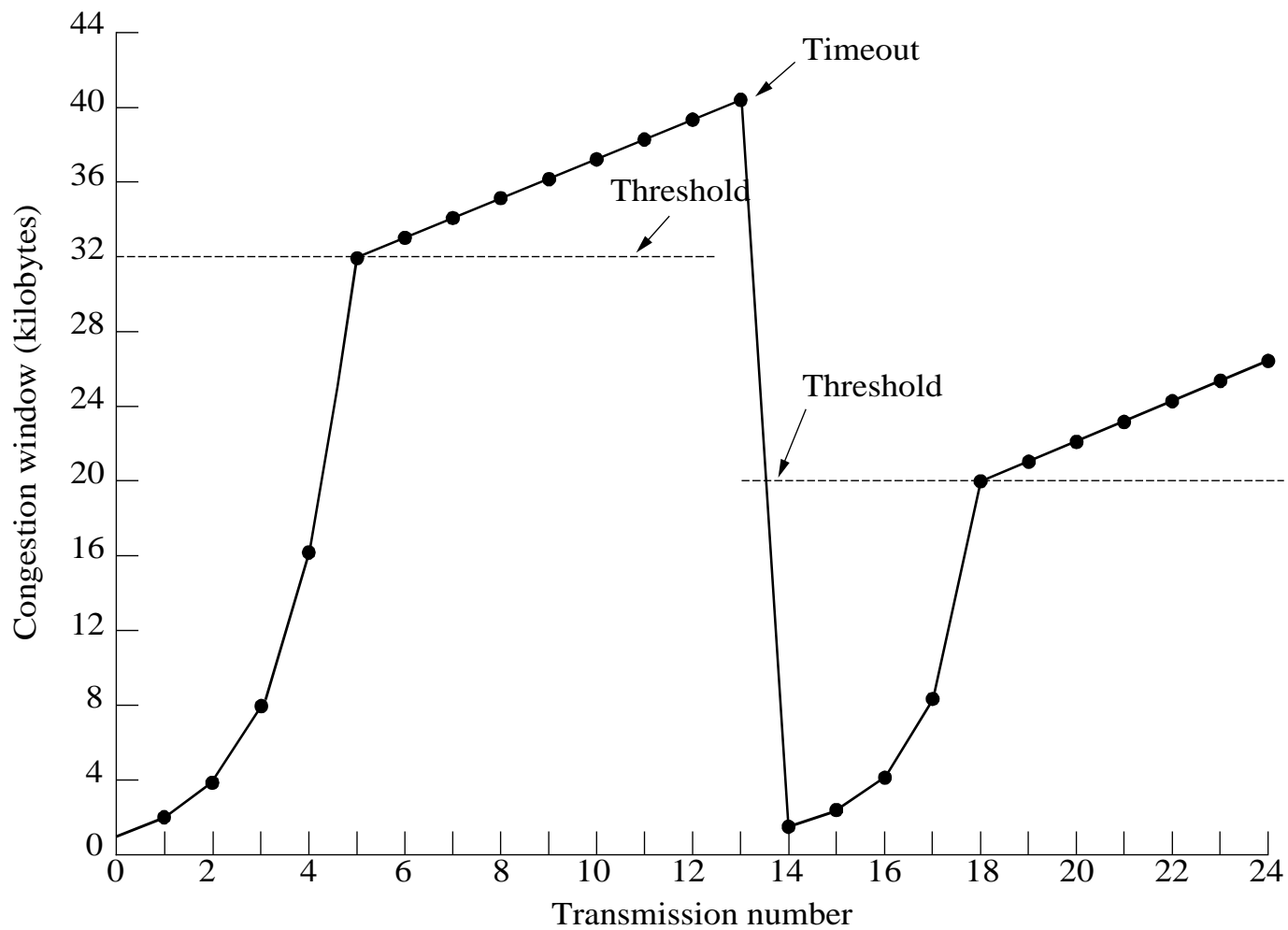
From: *Computer Networks*, 3rd Ed. by Andrew S. Tanenbaum, (c)1996 Prentice Hall.

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