# L41: Lab 4 - The TCP State Machine

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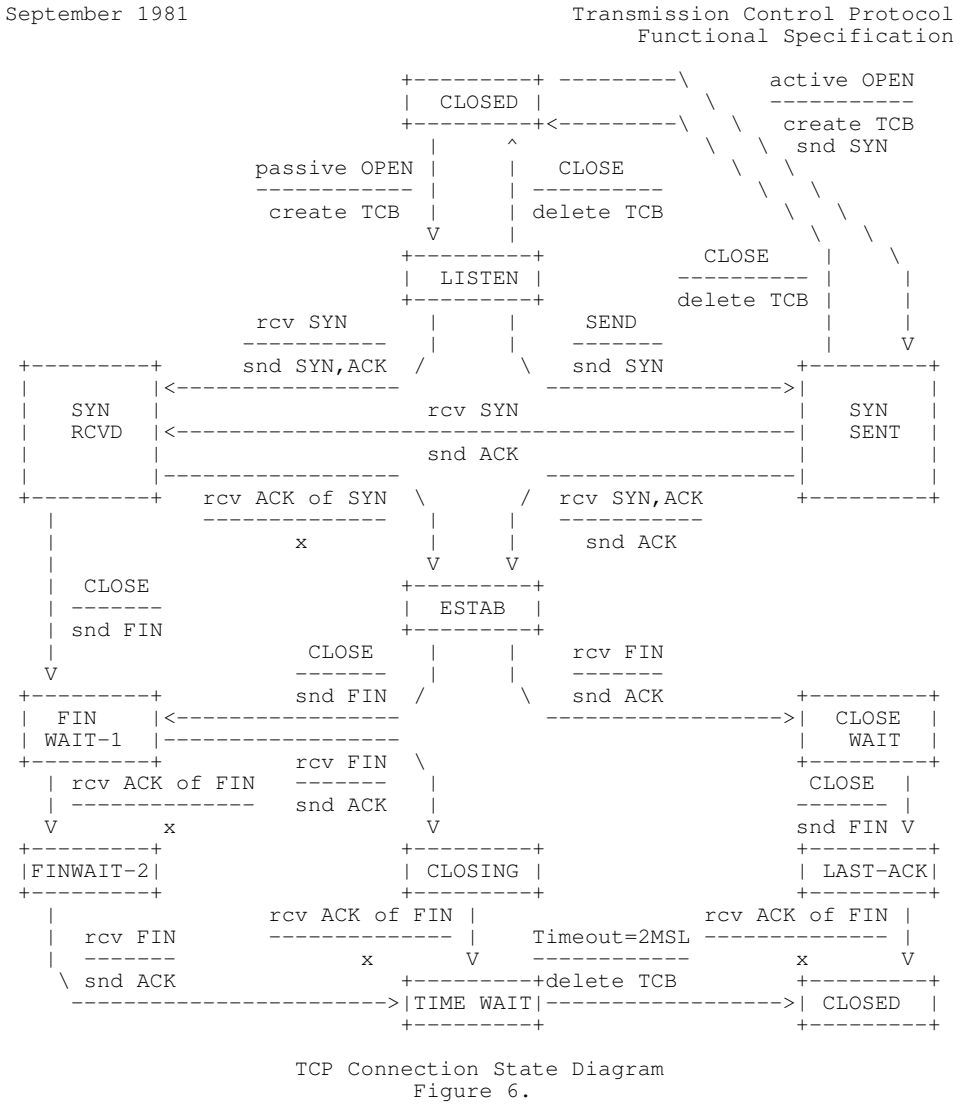
- The TCP state machine
- New IPC benchmark mode
- New DTrace probes of interest

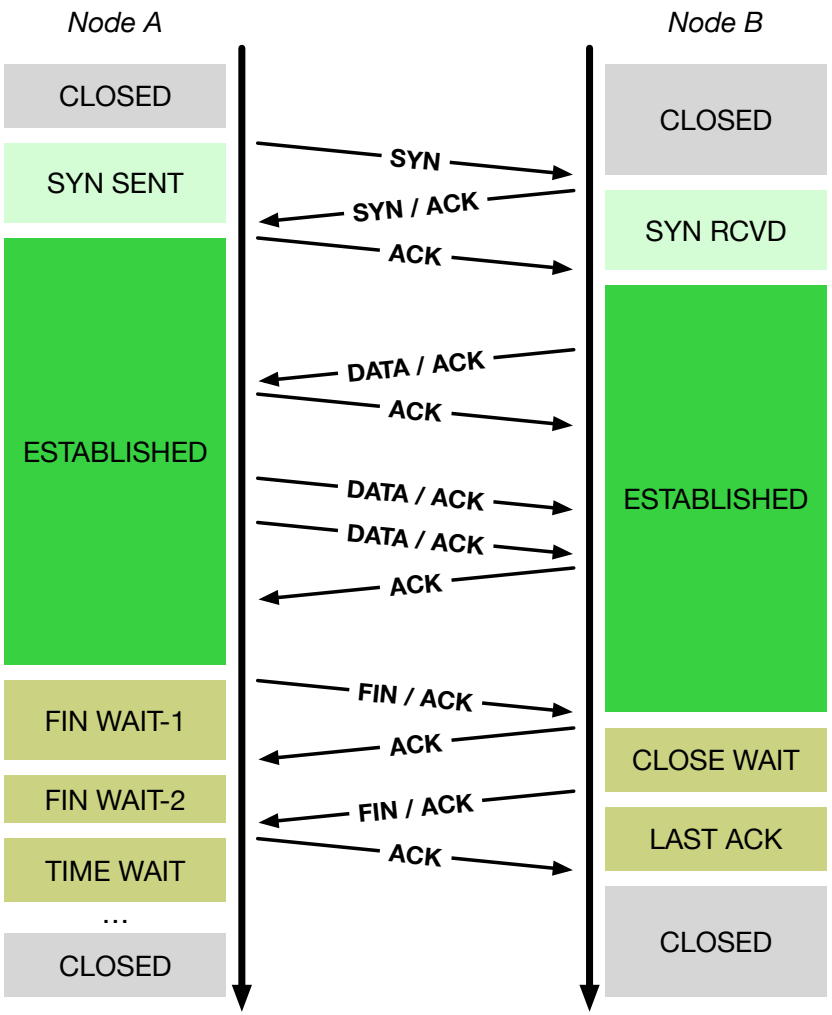
# Lect 6: The Transmission Control Protocol (TCP)




TCP Connection State Diagram
Figure 6.

- V. Cerf, K. Dalal, and C. Sunshine, *Transmission Control Protocol (version 1)*, INWG General Note #72, December 1974.
- In practice: Jon Postel, Ed, *Transmission Control Protocol: Protocol Specification*, RFC 793, September, 1981.

# Lect 6: TCP goals and properties




- Reliable, ordered, byte-stream transport protocol over IP
- Three-way handshake: SYN / SYN-ACK / ACK (mostly!)
- Flow control via advertised window size in ACKs
- Congestion control via packet loss and ECN ('fairness')
- Network may delay, (reorder), drop, corrupt packets
- Sequence numbers ACK'd; data retransmitted on loss
- Round-Trip Time (RTT) measured to time out loss

# Loopback interface, IPFW, and DUMMYNET

- Loopback interface
  - Simulated local network interface: packets “loop back”
  - Interface name `lo0`
  - Assigned IPv4 address 127.0.0.1
  - Configure the loopback MTU once per boot.
- IPFW - IP firewall by Rizzo, et al.
  - Numbered rules classify packets and perform actions
  - Actions include accept, reject, inject into DUMMYNET ...
  - We will match lab flows using the TCP port number 10,141
  - Configure **once per boot** (and with care!)
- DUMMYNET - link simulation tool by Rizzo, et al.
  - Widely used in network research
  - Impose simulated network conditions – delay, bandwidth, loss, ...
  - Configure and reconfigure as needed for experiments
- Instructions in lab assignment

# TCP in the IPC benchmark

```
root@beaglebone:/data/lab4 # ./ipc-static
ipc-static [-Bqsv] [-b buffersize] [-i pipe|local|tcp] [-p tcp_port]
        [-P l1d|l1i|l2|mem|tlb|axi] [-t totalsize] mode

Modes (pick one - default 1thread):
    1thread                 IPC within a single thread
    2thread                 IPC between two threads in one process
    2proc                   IPC between two threads in two different processes

Optional flags:
    -B                      Run in bare mode: no preparatory activities
    -i pipe|local|tcp       Select pipe, local sockets, or TCP (default: pipe)
    -p tcp_port             Set TCP port number (default: 10141)
    -P l1d|l1i|l2|mem|tlb|axi  Enable hardware performance counters
    -q                      Just run the benchmark, don't print stuff out
    -s                      Set send/receive socket-buffer sizes to buffersize
    -v                      Provide a verbose benchmark description
    -b buffersize           Specify a buffer size (default: 131072)
    -t totalsize            Specify total I/O size (default: 16777216)
```

- New `tcp` IPC type
- New `-p` argument to set the port number

# DTrace probes

Described in more detail in the lab assignment:

fbt::syncache_add:entry TCP segment installs new SYN-cache entry

fbt::syncache_expand:entry TCP segment converts SYN-cache entry to full connection

fbt::tcp_do_segment:entry TCP segment received post-SYN cache

fbt::tcp_state_change:entry TCP state transition

We are using implementation-specific probes (FBT) rather than portable TCP probes due to a bug in the FreeBSD/armv7 implementation of DTrace – the last (and most critical!) argument goes missing: the TCP header! We will fix this .. but not today.

# Exploratory questions

- Trace state transitions occurring in test TCP connections
- Identify causes of transitions – packets, system calls (etc)
- Varying one-way latency, explore performance of the benchmark with TCP

# Experimental questions for lab report

- Plot a TCP state-transition diagram for both directions of a flow
- Label the state-transition diagram with causes
- Compare the diagram with RFC 793
- Begin performance analysis of TCP latency vs. throughput

In the next lab, we will start a causal analysis of why latency affects bandwidth in the way that it does

# This lab session

- Upgrade your SD Card image (again)
- Ensure that you can build and run the TCP benchmark
- Set up IPFW, DUMMYNET, and loopback MTU (see notes)
- Ask us if you have any questions or need help
- Start with the TCP state machine analysis