L41: Lab 4
The TCP State Machine

Lecturelet 4

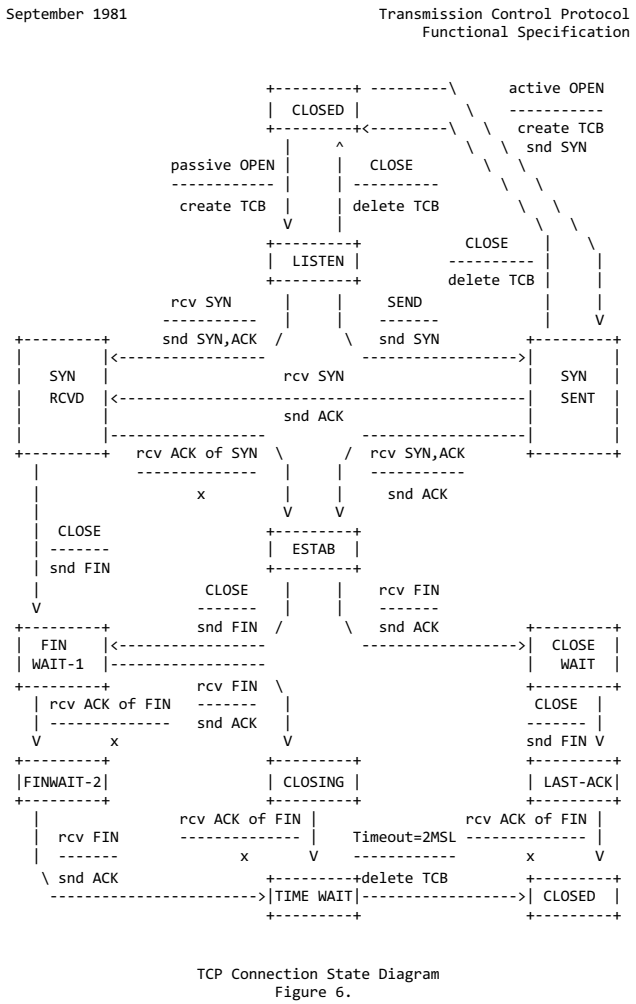
Dr Robert Watson / Dr Graeme Jenkinson

2019-2020

L41: Lab 4 – The TCP State Machine

- The TCP state machine.
- Setting the MTU, IPFW, and DUMMYNET.
- TCP mode for the IPC benchmark.
- DTrace probes of interest.
- Plotting the state machine with Graphviz.
- Experimental questions.

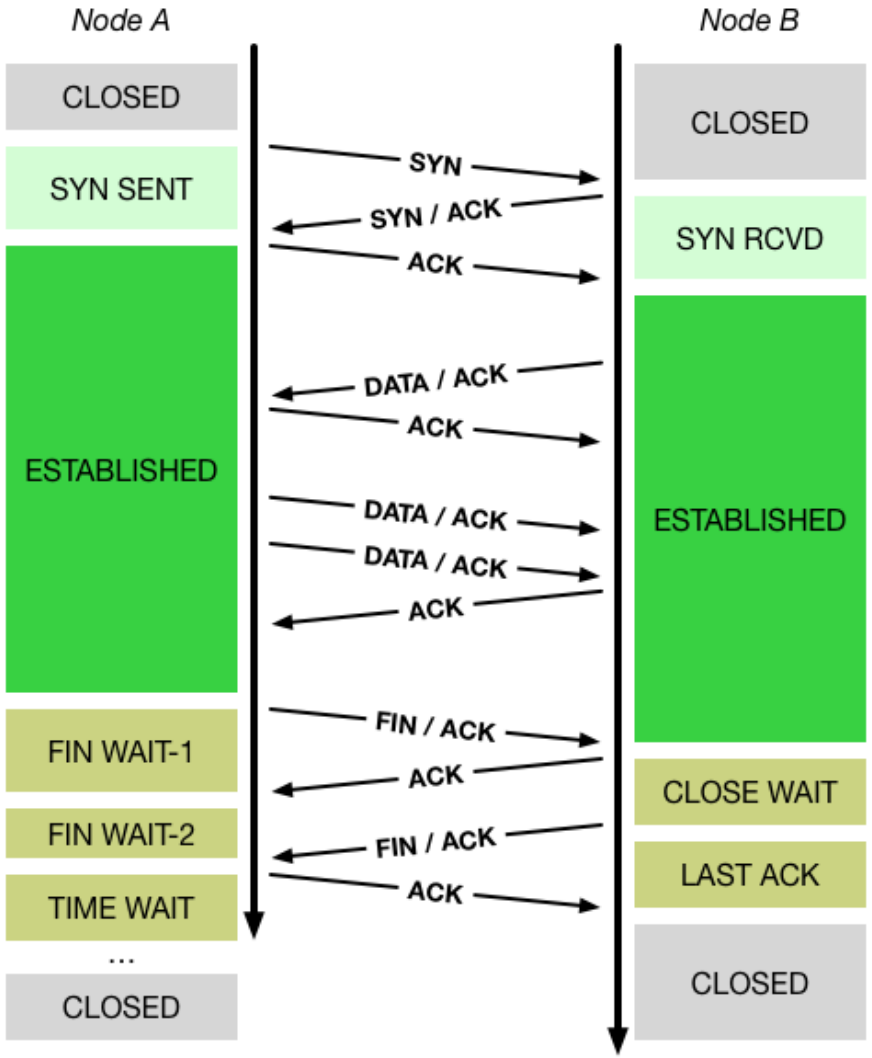
Lecture 6: The Transmission Control Protocol (TCP)



TCP Connection State Diagram
Figure 6.

- V. Cerf, K. Dalal, and C. Sunshine, *Transmission Control Protocol (version1)*, INWG General Note#72, December 1974.
- In practice: Jon Postel, Ed, *Transmission Control Protocol: Protocol Specification*, RFC 793, September, 1981.

Lecture 6: TCP principles and properties



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

Loopback interface, IPFW, and DUMMYNET

- Network-stack features to configure **once per-boot**
- Loopback interface
  - Simulated local network interface: packets “loop back”
  - Interface name `lo0`
  - Assigned IPv4 address `127.0.0.1`
- 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 `10141`
- Configure (and reconfigure) **for each experiment**
- DUMMYNET – link simulation tool by Rizzo, et al.
  - Widely used in network research
  - Impose simulated network conditions – delay, bandwidth, loss, ...

TCP in the IPC benchmark

```
root@beaglebone:/data/ipc # ./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)
```

- `tcp` IPC type
- `-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 someday .. but not today.

pygraphviz (1/2)

Graphviz is open source graph visualization software for drawing graphs specified in DOT language scripts. This language describes three kinds of objects: graphs, nodes, and edges.

Graph `graph` or `digraph` undirected or directed graph

Node `syn-sent;`

Edge `"closed" ->"syn-sent";`

Nodes and Edges can be assigned attributes changing, for example, their colour or shape:

Node syn-sent [color=blue];

Edge "closed" ->"syn-sent" [label="Active open", color=green];

Pygraphviz (2/2)

Programmatic interface for creating visualizations with Graphviz.

```
>>> import pygraphviz as pgv
>>> G = pgv.AGraph(strict=False, directed=True)
>>> G.add_node('a')
>>> G.add_edge('b','c')
>>> print(G)
digraph {
    a;
    b ->c;}
```

pygraphviz graphs can be viewed directly in a Juyter Notebook (see laboratory template).

Experimental questions for the lab report

- Plot an effective (measured) TCP state-transition diagram for both directions of a flow
- Label the state-transition diagram with causes – TCP headers, system calls, etc.
- Compare the diagram with RFC 793
- What observations can we make about state-machine transitions as latency increases?
- Describe any apparent simulation or probe effects.

In the next lab, we will start a causal analysis of why latency affects bandwidth

This lab session

- Setup IPFW, DUMMYNET, and loopback MTU (see notes).
- Start with the analysis of the TCP state machine.
- Do ask us if you have any questions or need help.
- Remember to use data from both Lab 4 and Lab 5 to write the second assessed lab report.