

C7005 Final Assignment

Mat Siwoski

Shane Spoor

Installation:

To install the application, ensure that python 3.15 is installed on the machine

```
dnf install python3
```

Afterwards, move to the emu folder in the terminal.

To run as host or receiver:

```
python3 -m emu.host <config.json> <sender|receiver> <list of files>
```

To run as sender:

```
python3 -m emu.host hostconfig.json sender <list of files>
```

To run as receiver:

```
python3 -m emu.host hostconfig.json receiver <list of files>
```

To run the emulator:

```
python3 -m emu.emulator hostconfig.json <BER| Delay | Both | None>
```

To run the emulator with Delay:

```
python3 -m emu.emulator hostconfig.json Delay
```

To run the emulator with bit error rate:

```
python3 -m emu.emulator hostconfig.json BER
```

To run the emulator with both restrictions (delay and Bit Error Rate):

```
python3 -m emu.emulator hostconfig.json Both
```

To run the emulator with no restrictions:

```
python3 -m emu.emulator hostconfig.json None
```

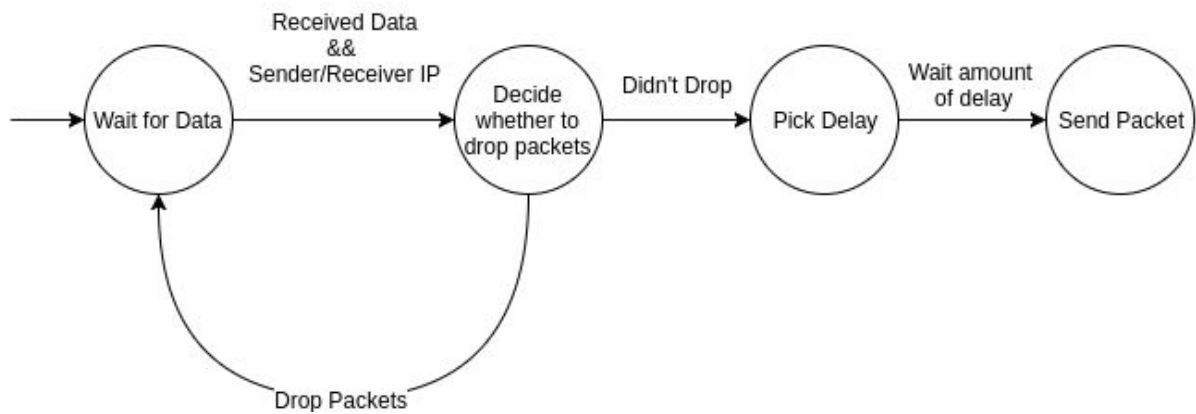
Settings are configured in hostconfig.json

"host0": "192.168.0.8",	#host0 IP (typically the sender)
"host1": "192.168.0.10",	#host1 IP (typically the receiver)
"emulator": "192.168.0.9",	#emulator ip
"timeout": 0.3,	#seconds
"port": 25500,	#port for all three
"window_size": 10,	#window size
"delay": 1.0,	#seconds
"BER":50	#percentage between 0 and 100

State Diagrams:

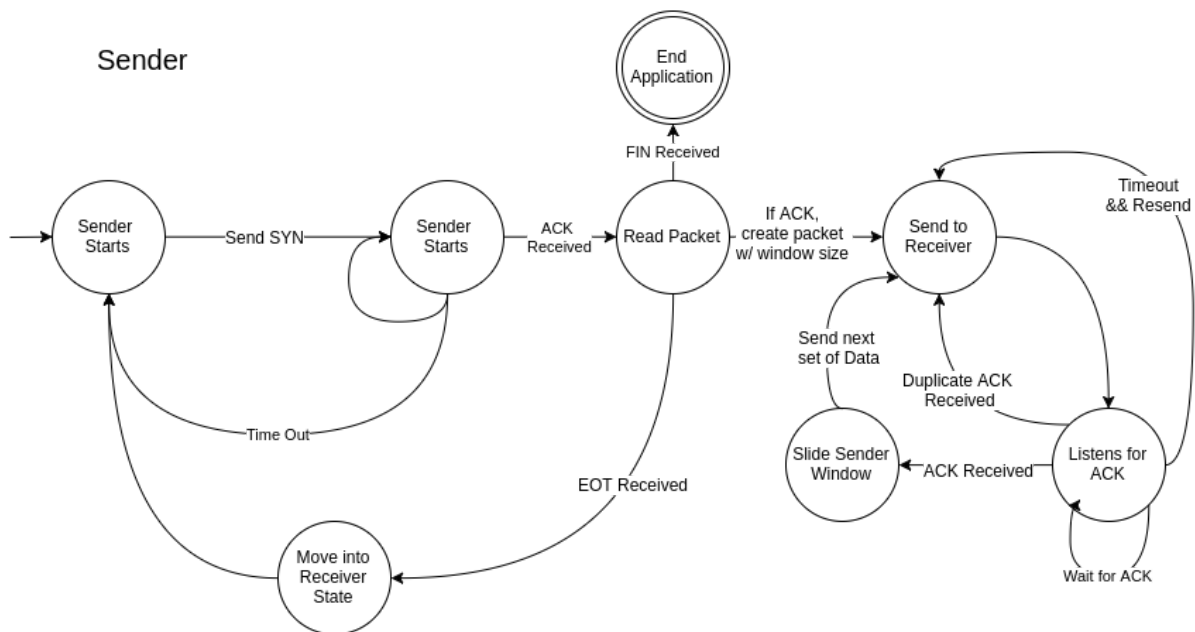
Network emulator

Network Emulator

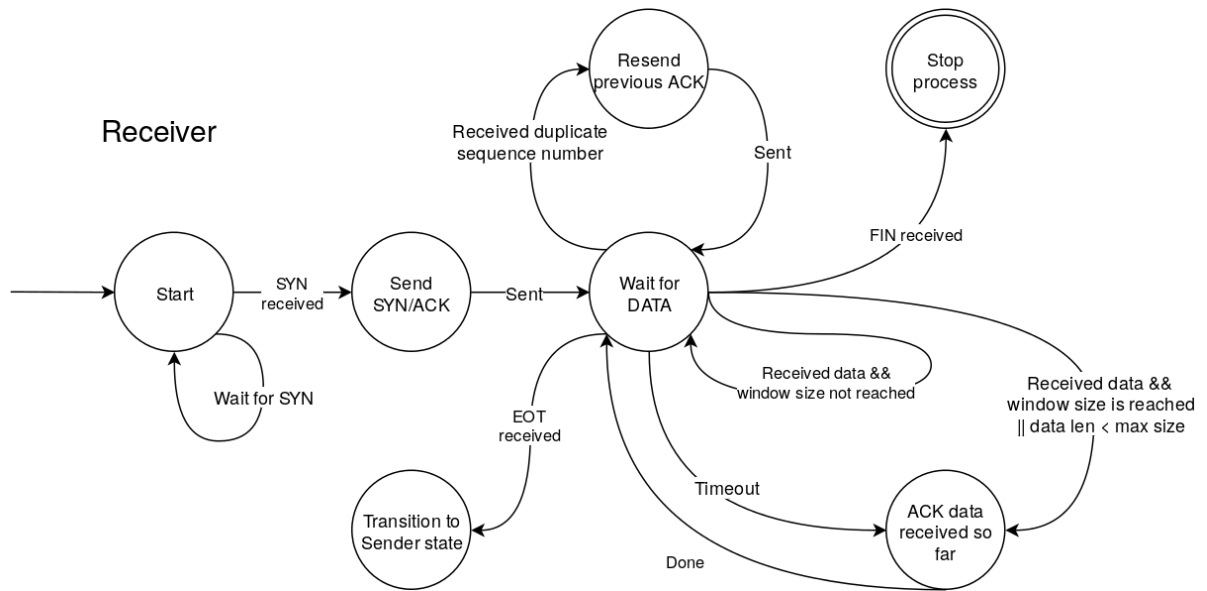


Sender

Sender



Receiver



Tests

No Restrictions (Bit Error Rate and Delay of 0):

Emulator

```
root@datacomm  
File Edit View Search Terminal Help  
[root@datacomm emu]# python3 -m emu.emulator hostconfig.json None  
Welcome to the goodput emulator  
  
Shane Spoor and Mat Siwoski  
  
started emulator with host 0 192.168.0.8 and host 1 192.168.0.10 on port 25500  
user has select None for the emulator function  
received packet with flags SYN, seq num 0, ack_num 0  
send all the packets  
received packet with flags ACK|SYN, seq num 0, ack_num 1  
send all the packets  
received packet with flags DATA, seq num 1, ack_num 0  
send all the packets  
received packet with flags DATA, seq num 1462, ack_num 0  
send all the packets  
received packet with flags DATA, seq num 2923, ack_num 0  
send all the packets  
received packet with flags DATA, seq num 4384, ack_num 0  
send all the packets  
received packet with flags ACK, seq num 0, ack_num 5645  
send all the packets  
received packet with flags EOT, seq num 0, ack_num 0  
send all the packets  
received packet with flags ACK|EOT, seq num 0, ack_num 0  
send all the packets  
received packet with flags ACK, seq num 0, ack_num 0  
send all the packets  
received packet with flags FIN, seq num 0, ack_num 0  
send all the packets  
█
```

In this mode, the emulator just forwards all packets without interference.

Host:

```
root@datacomm:~/emu
File Edit View Search Terminal Help
[root@datacomm emu]# python3 -m emu.host hostconfig.json receiver
waiting for SYN packet...
received SYN packet; responding with SYN/ACK
entering main receiver loop
waiting for next packet...
received packet with sequence number 1; received 1461 bytes this window, current
ack number is 1462
waiting for next packet...
received packet with sequence number 1462; received 2922 bytes this window, curr
ent ack number is 2923
waiting for next packet...
received packet with sequence number 2923; received 4383 bytes this window, curr
ent ack number is 4384
waiting for next packet...
packet had length 1261; acking now
received packet with sequence number 4384; received 5644 bytes this window, curr
ent ack number is 5645
sending ack 5645
waiting for next packet...
received EOT packet, responding with EOT/ACK
waiting for next packet...
received ACK for EOT/ACK, switching modes
finished running, returning status SWITCH
[root@datacomm emu]#
```

The receiver gets all of the sender's packets and ACKs immediately on detecting that the sender is almost out of data (packet length is < max length). On receiving an EOT, it switches to sender mode, determines that it has no data to send, and quits.

Sender:

```
root@datacomm:~/emu
File Edit View Search Terminal Help
[root@datacomm emu]# python3 -m emu.host hostconfig.json sender small.txt
starting the connection
waiting for SYN ACK packet...
received SYN ACK packet: responding with ACK
sent DATA packet with seq 1 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 1462 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 2923 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 4384 and data len 1261 to 192.168.0.9 on port 25500
entering main sender loop
received ACK with ack num 5645 from host 192.168.0.9
received EOT/ACK; responding with ACK and switch to receiver mode
finished running, returning status SWITCH
waiting for SYN packet...
received FIN packet, finishing up
finished running, returning status DONE
[root@datacomm emu]#
```

The sender begins with the syn packet, waits for syn_ack, then responds with an ack, the initial window of DATA is sent, at which the main sender loop is entered. Here, the remaining data is sent and then the EOT/FIN is enacted. The file was sent successfully from host to receiver. There was no drops in packets nor were there any delays.

Bit Error Rate of 50% (0 delay)

Emulator:

```
File Edit View Search Terminal Help
Welcome to the goodput emulator

Shane Spoor and Mat Siwoski

started emulator with host 0 192.168.0.8 and host 1 192.168.0.10 on port 8080
user has select BER for the emulator function
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 4
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 5
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 84
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK|SYN, seq num 0, ack_num 1
the bit error rate is 84
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags DATA, seq num 1, ack_num 0
the bit error rate is 29
packet has been dropped
received packet with flags DATA, seq num 1462, ack_num 0
the bit error rate is 29
packet has been dropped
received packet with flags DATA, seq num 2923, ack_num 0
the bit error rate is 27
packet has been dropped
received packet with flags DATA, seq num 4384, ack_num 0
the bit error rate is 87
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 5845, ack_num 0
the bit error rate is 45
packet has been dropped
received packet with flags DATA, seq num 7306, ack_num 0
the bit error rate is 69
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 8767, ack_num 0
the bit error rate is 85
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 10228, ack_num 0
the bit error rate is 47
packet has been dropped
received packet with flags DATA, seq num 11689, ack_num 0
the bit error rate is 96
received packet from 192.168.0.8, forwarding to 192.168.0.10
```

File Edit View Search Terminal Help

```
the bit error rate is 37
packet has been dropped
received packet with flags DATA, seq num 1, ack_num 0
the bit error rate is 35
packet has been dropped
received packet with flags DATA, seq num 1462, ack_num 0
the bit error rate is 77
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 2923, ack_num 0
the bit error rate is 12
packet has been dropped
received packet with flags DATA, seq num 4384, ack_num 0
the bit error rate is 16
packet has been dropped
received packet with flags ACK|SYN, seq num 0, ack_num 1
the bit error rate is 7
packet has been dropped
received packet with flags DATA, seq num 5845, ack_num 0
the bit error rate is 35
packet has been dropped
received packet with flags DATA, seq num 7306, ack_num 0
the bit error rate is 26
packet has been dropped
received packet with flags DATA, seq num 8767, ack_num 0
the bit error rate is 76
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 10228, ack_num 0
the bit error rate is 41
packet has been dropped
received packet with flags DATA, seq num 11689, ack_num 0
the bit error rate is 2
packet has been dropped
received packet with flags DATA, seq num 13150, ack_num 0
the bit error rate is 85
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 1, ack_num 0
the bit error rate is 53
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 1462, ack_num 0
the bit error rate is 65
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 2923, ack_num 0
the bit error rate is 98
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 4384, ack_num 0
```


File Edit View Search Terminal Help

```
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 4384, ack_num 0
the bit error rate is 75
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 5845, ack_num 0
the bit error rate is 4
packet has been dropped
received packet with flags DATA, seq num 7306, ack_num 0
the bit error rate is 50
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 8767, ack_num 0
the bit error rate is 46
packet has been dropped
received packet with flags DATA, seq num 10228, ack_num 0
the bit error rate is 17
packet has been dropped
received packet with flags ACK|SYN, seq num 0, ack_num 1
the bit error rate is 86
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags DATA, seq num 11689, ack_num 0
the bit error rate is 20
packet has been dropped
received packet with flags DATA, seq num 13150, ack_num 0
the bit error rate is 18
packet has been dropped
received packet with flags DATA, seq num 1, ack_num 0
the bit error rate is 19
packet has been dropped
received packet with flags DATA, seq num 1462, ack_num 0
the bit error rate is 31
packet has been dropped
received packet with flags DATA, seq num 2923, ack_num 0
the bit error rate is 72
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 4384, ack_num 0
the bit error rate is 4
packet has been dropped
received packet with flags DATA, seq num 5845, ack_num 0
the bit error rate is 50
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 7306, ack_num 0
the bit error rate is 1
packet has been dropped
received packet with flags DATA, seq num 8767, ack_num 0
the bit error rate is 33
```

“The bit error rate is x” in the logs shows the random number that selected by the emulator. If this number is \geq the percentage of packets that should be dropped, the packet is sent.

```
root@datacomm:~/emu
File Edit View Search Terminal Help
packet has been dropped
received packet with flags DATA, seq num 10228, ack_num 0
the bit error rate is 47
packet has been dropped
received packet with flags DATA, seq num 11689, ack_num 0
the bit error rate is 63
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 13150, ack_num 0
the bit error rate is 56
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 5845
the bit error rate is 96
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags DATA, seq num 5845, ack_num 0
the bit error rate is 74
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 7306, ack_num 0
the bit error rate is 6
packet has been dropped
received packet with flags DATA, seq num 8767, ack_num 0
the bit error rate is 44
packet has been dropped
received packet with flags DATA, seq num 10228, ack_num 0
the bit error rate is 38
packet has been dropped
received packet with flags DATA, seq num 11689, ack_num 0
the bit error rate is 14
packet has been dropped
received packet with flags DATA, seq num 13150, ack_num 0
the bit error rate is 78
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 14611, ack_num 0
the bit error rate is 70
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 16072, ack_num 0
the bit error rate is 82
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 5845, ack_num 0
the bit error rate is 79
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 7306, ack_num 0
the bit error rate is 85
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 7306
the bit error rate is 21
```

50% error of the packets, showing on avg. 50% error rate

Receiver:

```

root@datacomm:~/emu
File Edit View Search Terminal Help
timed out while waiting for packet; retransmitting ack with ack number 1
waiting for next packet...
received packet with sequence number 1; received 1461 bytes this window, current ack number is 1462
waiting for next packet...
received packet with sequence number 1462; received 2922 bytes this window, current ack number is 2923
waiting for next packet...
received packet with sequence number 2923; received 4383 bytes this window, current ack number is 4384
waiting for next packet...
received packet with sequence number 4384; received 5844 bytes this window, current ack number is 5845
waiting for next packet...
received packet with sequence number 7306, packet with sequence number 5845 was dropped
waiting for next packet...
spurious retransmission with sequence number 2923
retransmitting ACK in response to spurious retransmission
waiting for next packet...
received packet with sequence number 5845; received 7305 bytes this window, current ack number is 7306
waiting for next packet...
received packet with sequence number 11689, packet with sequence number 7306 was dropped
waiting for next packet...
received packet with sequence number 13150, packet with sequence number 7306 was dropped
waiting for next packet...
spurious retransmission with sequence number 5845

```

Spurious retransmission of sequence 2923. Receiver has already received this packet, so it sends an ACK for the packet it's expecting (5485). The receiver will only retransmit one ACK per window (which it detects by checking the sequence number of the current packet against the number for which it last retransmitted an ACK).

Sender:

```

root@datacomm:~/emu
File Edit View Search Terminal Help
received ACK with ack_num 1 from host 192.168.0.9
sent DATA packet with seq 1 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 1462 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 2923 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 4384 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 5845 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 7306 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 8767 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 10228 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 11689 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 13150 and data len 1461 to 192.168.0.9 on port 25500
received ACK with ack_num 5845 from host 192.168.0.9
sent DATA packet with seq 5845 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 7306 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 8767 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 10228 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 11689 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 13150 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 14611 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 16072 and data len 861 to 192.168.0.9 on port 25500

```

This window is showing the requests for retransmissions of packets that the receiver has not received. When the sender receives an ACK with a sequence number part-way through its window, it slides the window up and reads starting at that offset.

Bit Error Rate of 100%:

Emulator:

```
root@datacomm:~/emu
File Edit View Search Terminal Help
^C
Caught keyboard interrupt, exiting
[root@datacomm emu]# clear

[root@datacomm emu]# python3 -m emu.emulator hostconfig.json BER
Welcome to the goodput emulator

Shane Spoor and Mat Siwoski

started emulator with host 0 192.168.0.8 and host 1 192.168.0.10 on port 25500
user has select BER for the emulator function
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 24
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 65
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 61
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 25
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 56
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 15
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 94
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 94
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 81
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 31
packet has been dropped
received packet with flags SYN, seq num 0, ack_num 0
the bit error rate is 13
packet has been dropped
received packet with flags SYN, seq num 0, ack num 0
```

All the packets received are dropped, causing both sides to wait indefinitely.

Receiver:

```
root@datacomm:~/emu
File Edit View Search Terminal Help

[root@datacomm emu]# python3 -m emu.host hostconfig.json receiver
waiting for SYN packet...
^C
caught keyboard interrupt, sending FIN
finished running, returning status DONE
[root@datacomm emu]#
```

Receiver never receives a response from the host

Sender:

```
root@datacomm:~/emu
File Edit View Search Terminal Help

starting the connection
waiting for SYN_ACK packet...
^CTraceback (most recent call last):
  File "/usr/lib64/python3.5/runpy.py", line 170, in _run_module_as_main
    "__main__", mod_spec)
  File "/usr/lib64/python3.5/runpy.py", line 85, in _run_code
    exec(code, run_globals)
  File "/root/emu/emu/host.py", line 264, in <module>
    h.run()
  File "/root/emu/emu/host.py", line 229, in run
    result = sender.run()
  File "/root/emu/emu/sender.py", line 119, in run
    self.wait_for_syn_ack()
  File "/root/emu/emu/sender.py", line 56, in wait_for_syn_ack
    pkt = self.wait_for_packet(True)
  File "/root/emu/emu/sender.py", line 44, in wait_for_packet
    pkt, addr = self.sock.recvfrom(packet.MAX_PACKET_LENGTH)
KeyboardInterrupt
[root@datacomm emu]#
```

Like the receiver, the sender is stuck waiting for a SYN_ACK.

Delay Less Than or Equal to Host/Receiver Timeout:

Emulator:

```
File Edit View Search Terminal Help
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 16072, ack_num 0
delay for this packet is 0.20390958490568034 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 16933
delay for this packet is 0.3653068720406299 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags ACK, seq num 0, ack_num 16933
delay for this packet is 0.43925203679064284 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags DATA, seq num 14611, ack_num 0
delay for this packet is 0.2155889618395812 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags DATA, seq num 16072, ack_num 0
delay for this packet is 0.383678493387396 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 16933
delay for this packet is 0.151089398239802 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.38467460088855754 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.361832262022609 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 16933
delay for this packet is 0.4402584162003911 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.34007765337554063 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK|EOT, seq num 0, ack_num 0
delay for this packet is 0.44039899719803277 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.40775590536908735 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 0
delay for this packet is 0.15627692786772363 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags FIN, seq num 0, ack_num 0
delay for this packet is 0.31286399673135334 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
```

Delay is less than or equal to the host and receiver. As you can see, the delays are random but avg. out to 0.3 seconds.

Receiver:

```
root@datacomm:~/emu
File Edit View Search Terminal Help
waiting for next packet...
spurious retransmission with sequence number 5845
waiting for next packet...
spurious retransmission with sequence number 7306
waiting for next packet...
spurious retransmission with sequence number 8767
waiting for next packet...
spurious retransmission with sequence number 10228
waiting for next packet...
spurious retransmission with sequence number 11689
waiting for next packet...
spurious retransmission with sequence number 13150
waiting for next packet...
received packet with sequence number 14611; received 1461 bytes this window, current ack number is 16072
waiting for next packet...
packet had length 861; acking now
received packet with sequence number 16072; received 2322 bytes this window, current ack number is 16933
sending ack 16933
waiting for next packet...
spurious retransmission with sequence number 14611
retransmitting ACK in response to spurious retransmission
waiting for next packet...
spurious retransmission with sequence number 16072
waiting for next packet...
spurious retransmission with sequence number 14611
retransmitting ACK in response to spurious retransmission
waiting for next packet...
spurious retransmission with sequence number 16072
waiting for next packet...
spurious retransmission with sequence number 14611
retransmitting ACK in response to spurious retransmission
waiting for next packet...
spurious retransmission with sequence number 16072
waiting for next packet...
received EOT packet, responding with EOT/ACK
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
received ACK for EOT/ACK, switching modes
finished running, returning status SWITCH
[root@datacomm emu]#
```

The host receives packets from the emulator. As the packets get delayed, the receiver occasionally receives multiple spurious retransmissions, because if even a single ACK times out, the sender retransmits its entire window.

Sender:

```
root@datacomm:~/emu
File Edit View Search Terminal Help
received ACK with ack_num 14611 from host 192.168.0.9
sent DATA packet with seq 14611 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 16072 and data len 861 to 192.168.0.9 on port 25500
received ACK with ack_num 14611 from host 192.168.0.9
sent DATA packet with seq 14611 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 16072 and data len 861 to 192.168.0.9 on port 25500
timed out while waiting for ACK
sent DATA packet with seq 14611 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 16072 and data len 861 to 192.168.0.9 on port 25500
received ACK with ack_num 14611 from host 192.168.0.9
sent DATA packet with seq 14611 and data len 1461 to 192.168.0.9 on port 25500
sent DATA packet with seq 16072 and data len 861 to 192.168.0.9 on port 25500
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received EOT/ACK; responding with ACK and switch to receiver mode
finished running, returning status SWITCH
waiting for SYN packet...
received FIN packet, finishing up
finished running, returning status DONE
[root@datacomm emu]#
```

With the delay set to be at most equal to the host/receiver timeout value, most packets get through without unnecessary retransmissions. At the end of the transmission there were several larger delays, causing multiple spurious retransmissions before both sides could correctly finish.

Delay Greater Than Host/Receiver Timeout:

Emulator:

File Edit View Search Terminal Help

```
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.2903482245319509 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.7952379710946779 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.1721316838880793 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.5267048149670867 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.5053384583696298 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.070992805818794 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.4419154021360918 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.3408980554079868 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.2290481386973795 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 1.0399879216816337 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags EOT, seq num 0, ack_num 0
delay for this packet is 0.771377832733474 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 0
delay for this packet is 0.8450146823289073 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags ACK, seq num 0, ack_num 0
delay for this packet is 1.3553494027028181 seconds
received packet from 192.168.0.8, forwarding to 192.168.0.10
received packet with flags FIN, seq num 0, ack_num 0
delay for this packet is 0.8235445118591371 seconds
received packet from 192.168.0.10, forwarding to 192.168.0.8
```

Emulator delays the packets with values that are greater than the timeouts of the host and receiver. Although this is happening, eventually the file passed through

Receiver:

```
File Edit View Search Terminal Help
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
waiting for next packet...
received ACK for EOT/ACK, switching modes
finished running, returning status SWITCH
[root@datacomm emu]#
```

Although the delay was greater than the host/receiver, the file was still able to be sent to the host.

Sender:

```
root@datacomm:~/emu
File Edit View Search Terminal Help
timed out while waiting for ACK
received ACK with ack_num 16933 from host 192.168.0.9
timed out while waiting for ACK
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
timed out while waiting for ACK
received ACK with ack_num 16933 from host 192.168.0.9
timed out while waiting for ACK
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received ACK with ack_num 16933 from host 192.168.0.9
received EOT/ACK; responding with ACK and switch to receiver mode
finished running, returning status SWITCH
waiting for SYN packet...
received EOT/ACK packet while waiting for SYN; remote side didn't receive final ACK, retransmitting
received FIN packet, finishing up
finished running, returning status DONE
[root@datacomm emu]#
```

The large timeouts cause huge numbers of spurious retransmissions as both sides constantly time out and infer that the other host didn't receive their packets. Eventually, the queued packets with the up-to-date information are processed by both hosts, which moves them (slowly) forward.