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LAB 3: Principles of Reliable Data Transfer

Q1) In the simulation, the receiver successfully receives packet 0 without corruption. However, issues arise with packets (1, 2, and 3), which encounter corruption during transmission. Packet 4 is sent and received without corruption, but the receiver, expecting packet 1, and receives packet 4 instead, triggering an error. The halting simulation, addressing the sequence misalignment issue for a successful simulation.

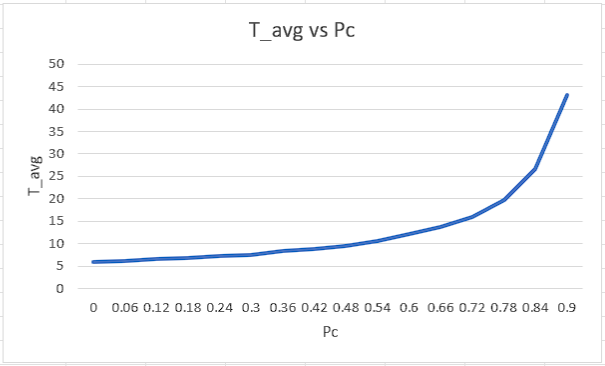
```
PS D:\Academic\CS212\LAB4> python -u "d:\Academic\CS212\LAB4\Testbench.py"
TIME: 3 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=0, corrupted=False)
TIME: 3 SENDING APP: sent data 0
TIME: 5 RECEIVING APP: received data 0
TIME: 8 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=1, corrupted=False)
TIME: 8 SENDING APP: sent data 1
TIME: 8 DATA_CHANNEL : Packet(seq_num=1, payload=$H!T, corrupted=True) was corrupted!
TIME: 10 DATA_CHANNEL : udt_send called for Packet(seq_num=2, payload=2, corrupted=False)
TIME: 10 SENDING APP: sent data 2
TIME: 10 DATA_CHANNEL : Packet(seq_num=2, payload=$H!T, corrupted=True) was corrupted!
TIME: 15 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 15 SENDING APP: sent data 3
TIME: 15 DATA_CHANNEL : Packet(seq_num=3, payload=$H!T, corrupted=True) was corrupted!
TIME: 17 DATA_CHANNEL : udt_send called for Packet(seq_num=4, payload=4, corrupted=False)
TIME: 17 SENDING APP: sent data 4
TIME: 19 RECEIVING APP: received data 4
ERROR!! RECEIVING APP: received wrong data: 4 ,expected: 1
Halting simulation...
PS D:\Academic\CS212\LAB4>
```

Q2) For Pc>0 for data channel, it indeed work.

```
PS D:\Academic\CS212\LAB4> python -u "d:\Academic\CS212\LAB4\Testbench.py"
TIME: 5 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=0, corrupted=False)
TIME: 5 SENDING APP: sent data 0
TIME: 7 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 7 RECEIVING APP: received data 0
TIME: 10 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=1, corrupted=False)
TIME: 10 SENDING APP: sent data 1
TIME: 12 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 12 RECEIVING APP: received data 1
TIME: 18 DATA_CHANNEL : udt_send called for Packet(seq_num=2, payload=2, corrupted=False)
TIME: 18 SENDING APP: sent data 2
TIME: 20 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 20 RECEIVING APP: received data 2
TIME: 22 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 22 SENDING APP: sent data 3
TIME: 22 DATA_CHANNEL : Packet(seq_num=3, payload=$H!T, corrupted=True) was corrupted!
TIME: 24 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 26 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 26 DATA_CHANNEL : Packet(seq_num=3, payload=$H!T, corrupted=True) was corrupted!
TIME: 28 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 30 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 30 DATA_CHANNEL : Packet(seq_num=3, payload=$H!T, corrupted=True) was corrupted!
TIME: 32 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 34 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 34 DATA_CHANNEL : Packet(seq_num=3, payload=$H!T, corrupted=True) was corrupted!
TIME: 36 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 38 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 38 DATA_CHANNEL : Packet(seq_num=3, payload=$H!T, corrupted=True) was corrupted!
TIME: 40 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 42 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 44 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 44 RECEIVING APP: received data 3
TIME: 47 DATA_CHANNEL : udt_send called for Packet(seq_num=4, payload=4, corrupted=False)
TIME: 47 SENDING APP: sent data 4
TIME: 49 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 49 RECEIVING APP: received data 4
TIME: 52 DATA_CHANNEL : udt_send called for Packet(seq_num=5, payload=5, corrupted=False)
TIME: 52 SENDING APP: sent data 5
TIME: 52 DATA_CHANNEL : Packet(seq_num=5, payload=$H!T, corrupted=True) was corrupted!
TIME: 54 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 56 DATA_CHANNEL : udt_send called for Packet(seq_num=5, payload=5, corrupted=False)
TIME: 58 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 58 RECEIVING APP: received data 5
TIME: 62 DATA_CHANNEL : udt_send called for Packet(seq_num=6, payload=6, corrupted=False)
TIME: 62 SENDING APP: sent data 6
TIME: 64 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 64 RECEIVING APP: received data 6
TIME: 66 DATA_CHANNEL : udt_send called for Packet(seq_num=7, payload=7, corrupted=False)
TIME: 66 SENDING APP: sent data 7
TIME: 68 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 68 RECEIVING APP: received data 7
TIME: 73 DATA_CHANNEL : udt_send called for Packet(seq_num=8, payload=8, corrupted=False)
TIME: 73 SENDING APP: sent data 8
TIME: 73 DATA_CHANNEL : Packet(seq_num=8, payload=$H!T, corrupted=True) was corrupted!
TIME: 75 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 77 DATA_CHANNEL : udt_send called for Packet(seq_num=8, payload=8, corrupted=False)
TIME: 77 DATA_CHANNEL : Packet(seq_num=8, payload=$H!T, corrupted=True) was corrupted!
TIME: 79 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 81 DATA_CHANNEL : udt_send called for Packet(seq_num=8, payload=8, corrupted=False)
TIME: 81 DATA_CHANNEL : Packet(seq_num=8, payload=$H!T, corrupted=True) was corrupted!
TIME: 83 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 85 DATA_CHANNEL : udt_send called for Packet(seq_num=8, payload=8, corrupted=False)
TIME: 85 DATA_CHANNEL : Packet(seq_num=8, payload=$H!T, corrupted=True) was corrupted!
TIME: 87 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
TIME: 89 DATA_CHANNEL : udt_send called for Packet(seq_num=8, payload=8, corrupted=False)
TIME: 91 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 91 RECEIVING APP: received data 8
TIME: 96 DATA_CHANNEL : udt_send called for Packet(seq_num=9, payload=9, corrupted=False)
TIME: 96 SENDING APP: sent data 9
TIME: 96 DATA_CHANNEL : Packet(seq_num=9, payload=$H!T, corrupted=True) was corrupted!
TIME: 98 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=NAK, corrupted=False)
```

Q3)

Pc	T_avg
0	5.998
0.06	6.181
0.12	6.469
0.18	6.847
0.24	7.183
0.3	7.57
0.36	8.269
0.42	8.731
0.48	9.424
0.54	10.669
0.6	12.139
0.66	13.615
0.72	16.054
0.78	19.696
0.84	26.737
0.9	43.075



T_avg vs Pc graph is increasing exponentially. As Pc increases, more packets are being corrupted during transmission, leading to a higher retransmissions and delays.

Q4)

```
PS C:\Users\vaibhav> & C:/Users/vaibhav/AppData/Local/Programs/Python/Python311/python.exe c:/Users/vaibhav/Downloads/Testbench.py
TIME: 1 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=0, corrupted=False)
TIME: 1 SENDING APP: sent data 0
TIME: 3 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 3 RECEIVING APP: received data 0
TIME: 5 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=1, corrupted=False)
TIME: 5 SENDING APP: sent data 1
TIME: 7 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 7 RECEIVING APP: received data 1
TIME: 12 DATA_CHANNEL : udt_send called for Packet(seq_num=2, payload=2, corrupted=False)
TIME: 12 SENDING APP: sent data 2
TIME: 14 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 14 RECEIVING APP: received data 2
TIME: 17 DATA_CHANNEL : udt_send called for Packet(seq_num=3, payload=3, corrupted=False)
TIME: 17 SENDING APP: sent data 3
TIME: 19 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 19 RECEIVING APP: received data 3
TIME: 19 ACK_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
ERROR! rdt_rcv() was expecting an ACK or a NAK. Received a corrupted packet.
Halting simulation...
PS C:\Users\vaibhav>
```

```
def rdt_rcv(self,packt):
    # This function is called by the lower-layer
    # when an ACK/NAK packet arrives
    assert(self.state==WAIT_FOR_ACK_OR_NAK)
    if(packt.payload=="ACK"):
        # Received an ACK. Everything's fine.
        self.state=WAITING_FOR_CALL_FROM_ABOVE
    elif(packt.payload=="NAK"):
        # Received a NAK. Need to resend packet.
        self.channel.udt_send(self.packet_to_be_sent)
    else:
        print("ERROR! rdt_rcv() was expecting an ACK or a NAK. Received a corrupted packet.")
        print("Halting simulation...")
        sys.exit(0)
```

The ACK_CHANNEL sends an ACK for the received data (3) to the rdt_Sender. In the code above the code flow goes to else part instead of going to ACK or NAK since the packet is corrupted ($H!T). Therefore, it gives the simulation halts due to the error in rdt_Sender.

Q5)

```
TIME: 947 RECEIVING APP: received data 95
TIME: 951 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=96, corrupted=False)
TIME: 951 SENDING APP: 96  data sent...
TIME: 953 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK0, corrupted=False)
TIME: 953 RECEIVING APP: received data 96
TIME: 957 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=97, corrupted=False)
TIME: 957 SENDING APP: 97  data sent...
TIME: 959 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK1, corrupted=False)
TIME: 959 RECEIVING APP: received data 97
TIME: 963 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=98, corrupted=False)
TIME: 963 SENDING APP: 98  data sent...
TIME: 963 DATA_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 965 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK1, corrupted=False)
TIME: 965 ACK_CHANNEL : Packet(seq_num=1, payload=$H!T, corrupted=True) was corrupted!
TIME: 967 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=98, corrupted=False)
TIME: 969 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK0, corrupted=False)
TIME: 969 RECEIVING APP: received data 98
TIME: 969 ACK_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 971 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=98, corrupted=False)
TIME: 971 DATA_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 973 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK0, corrupted=False)
TIME: 973 ACK_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 975 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=98, corrupted=False)
TIME: 975 DATA_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 977 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK0, corrupted=False)
TIME: 981 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
TIME: 981 SENDING APP: 99  data sent...
TIME: 983 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK1, corrupted=False)
TIME: 983 RECEIVING APP: received data 99
TIME: 983 ACK_CHANNEL : Packet(seq_num=1, payload=$H!T, corrupted=True) was corrupted!
TIME: 985 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
TIME: 985 DATA_CHANNEL : Packet(seq_num=1, payload=$H!T, corrupted=True) was corrupted!
TIME: 987 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK1, corrupted=False)
PS D:\Academic\CS212\LAB4>
```

Q6)

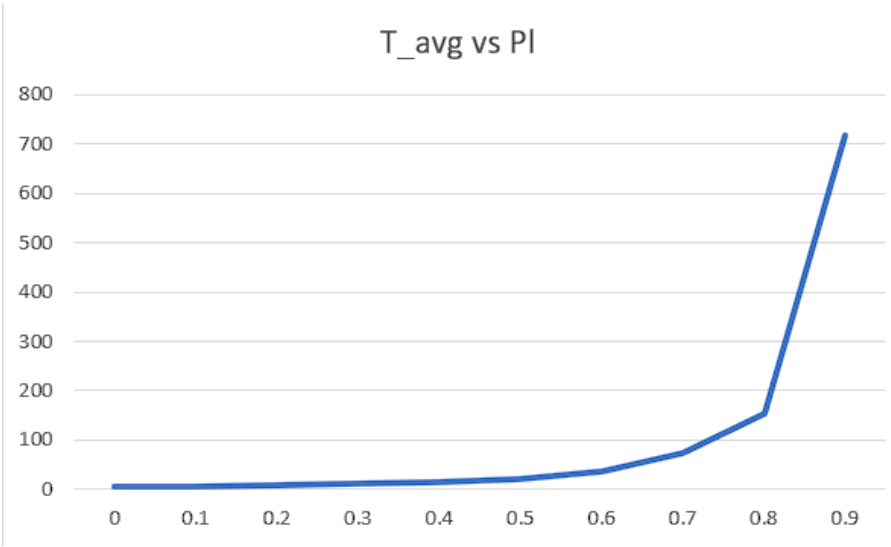
a)Once the packet is lost, the sender gets in the state of waiting for ACK1 or ACK0, and doesn't send the next packet. We can clearly say that protocol_rdt22.py doesn't work when packets gets lost

```
PS D:\Academic\CS212\LAB4> python -u "d:\Academic\CS212\LAB4\q5_Testbench.py"
TIME: 3 SENDING APP: 0  data trying to send...
TIME: 3 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=0, corrupted=False)
TIME: 3 DATA_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 5 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK1, corrupted=False)
TIME: 6 SENDING APP: 1  data trying to send...
TIME: 7 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=0, corrupted=False)
TIME: 7 DATA_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 9 SENDING APP: 1  data trying to send...
TIME: 9 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK1, corrupted=False)
TIME: 11 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=0, corrupted=False)
TIME: 11 DATA_CHANNEL : Packet(seq_num=0, payload=0, corrupted=False) was lost!
TIME: 12 SENDING APP: 1  data trying to send...
TIME: 15 SENDING APP: 1  data trying to send...
TIME: 18 SENDING APP: 1  data trying to send...
TIME: 21 SENDING APP: 1  data trying to send...
TIME: 24 SENDING APP: 1  data trying to send...
TIME: 27 SENDING APP: 1  data trying to send...
TIME: 30 SENDING APP: 1  data trying to send...
```

b)

```
TIME: 1491 SENDING APP: 99  data trying to send...
TIME: 1491 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
TIME: 1491 DATA_CHANNEL : Packet(seq_num=1, payload=99, corrupted=False) was lost!
TIME: 1497 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
Time:  1497  Timeout! Sending again ...
TIME: 1497 DATA_CHANNEL : Packet(seq_num=1, payload=99, corrupted=False) was lost!
TIME: 1503 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
Time:  1503  Timeout! Sending again ...
TIME: 1503 DATA_CHANNEL : Packet(seq_num=1, payload=99, corrupted=False) was lost!
TIME: 1509 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
Time:  1509  Timeout! Sending again ...
TIME: 1509 DATA_CHANNEL : Packet(seq_num=1, payload=$H!T, corrupted=True) was corrupted!
TIME: 1511 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 1511 ACK_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 1515 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=99, corrupted=False)
Time:  1515  Timeout! Sending again ...
TIME: 1517 RECEIVING APP: received data 99
TIME: 1517 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK, corrupted=False)
```

c) Graph is increasing exponentially.



d)

(d) ∵ Packet loss can happen both in Data & Ack channel.

∴ RTT = (1-Pe)*Delay + (Pe (Timeout) → Data channel
+ (1-Pe)(2*Delay) + Pe(timeout) → Ack channel

→ Data channel has ∑P part because with Pe Probability, 1st packet transmission fails, Pe^2 2nd fails, Pe^3 3rd fails & so on.

where timeout = 3*Delay

$RTT = 2(1-Pe)(2*Delay) + Pe(timeout) + timeout*(Pe + Pe^2 + Pe^3 + \dots)$.

$= 2(1-Pe)(2*Delay) + [Pe\,timeout)(1 + \frac{1}{1-Pe})$

$= 2((1-Pe)*Delay) + (Pe\,timeout)*(\frac{2-Pe}{1-Pe})$.

Reverting in y-x notation.

$*[y = C_1(1-x) + C_2x(\frac{2-x}{1-x})]*$

This is a Hyperbola equation.
(Verified by graphing using desmos.com).

e) If delay is set to random value, there will be a case of reordering of packets, therefore the protocol fails.

```
else:
    # Is this packet corrupted?
    if random.random()<self.Pc:
        packt.corrupt()
        print("TIME:",self.env.now,self.name,":",packt,"was corrupted!")
    # Now wait for "delay" amount of time
    delay= random.randint(0,3*self.delay)
    yield self.env.timeout(delay)
    # deliver the packet by calling the rdt_rcv()
    # function on the receiver side.
    self.receiver.rdt_rcv(packt)
```

```
TIME: 535 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 535 ACK_CHANNEL : Packet(seq_num=0, payload=$H!T, corrupted=True) was corrupted!
TIME: 539 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=38, corrupted=False)
Time:  539  Timeout! Sending again ...
TIME: 544 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 546 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=39, corrupted=False)
TIME: 546 SENDING APP: 39  data sent...
TIME: 551 RECEIVING APP: received data 39
TIME: 551 ACK_CHANNEL : udt_send called for Packet(seq_num=1, payload=ACK, corrupted=False)
TIME: 556 DATA_CHANNEL : udt_send called for Packet(seq_num=1, payload=39, corrupted=False)
Time:  556  Timeout! Sending again ...
TIME: 558 DATA_CHANNEL : udt_send called for Packet(seq_num=0, payload=40, corrupted=False)
TIME: 558 SENDING APP: 40  data sent...
TIME: 559 RECEIVING APP: received data 40
TIME: 559 ACK_CHANNEL : udt_send called for Packet(seq_num=0, payload=ACK, corrupted=False)
TIME: 560 RECEIVING APP: received data 39
ERROR!! RECEIVING APP: received wrong data: 39 ,expected: 41
Halting simulation...
```