**Number of TCP connections established is 3**

1.a)

Sequence Number is the first byte of data in the TCP packet.

Acknowledgment Number is the sequence number of the next byte the sender/receiver expects.

Window Size is the Receive window buffer size (for flow control), both the sender and the receiver will send this size. Has to be scaled, as the window size in header is only assigned 16 bits, so maximum can be 2^16. So, in order to increase this, a scale bit is included in the header, which helps to scale the window size obtained from 16 bits.

First TCP Connection

```
The Number of TCP connections established: 3
Flow btw ports 43498 and 80
First Transaction after Handshake
 Sender Sequence number: 705669103
 Sender Acknowledgment number: 1921750144
 Sender Receive window size: 3*16384
 Receiver Sequence number: 1921750144
 Receiver Acknowledgment number: 705669127
 Receiver Receive window size: 3*16384
Second Transaction after Handshake
 Sender Sequence number: 705669127
 Sender Acknowledgment number: 1921750144
 Sender Receive window size: 3*16384
 Receiver Sequence number: 1921750144
 Receiver Acknowledgment number: 705670575
 Receiver Receive window size: 3*16384
```

Second TCP Connection

```
Flow btw ports 43500 and 80
First Transaction after Handshake
 Sender Sequence number: 3636173852
 Sender Acknowledgment number: 2335809728
 Sender Receive window size: 3*16384
 Receiver Sequence number: 2335809728
 Receiver Acknowledgment number: 3636173876
 Receiver Receive window size: 3*16384
Second Transaction after Handshake
 Sender Sequence number: 3636173876
 Sender Acknowledgment number: 2335809728
 Sender Receive window size: 3*16384
 Receiver Sequence number: 2335809728
 Receiver Acknowledgment number: 3636175324
 Receiver Receive window size: 3*16384
```

Third TCP Connection

```
Flow btw ports 43502 and 80
First Transaction after Handshake
 Sender Sequence number: 2558634630
 Sender Acknowledgment number: 3429921723
 Sender Receive window size: 3*16384
 Receiver Sequence number: 3429921723
 Receiver Acknowledgment number: 2558634654
 Receiver Receive window size: 3*16384
Second Transaction after Handshake
 Sender Sequence number: 2558634654
 Sender Acknowledgment number: 3429921723
 Sender Receive window size: 3*16384
 Receiver Sequence number: 3429921723
 Receiver Acknowledgment number: 2558636102
 Receiver Receive window size: 3*16384
```

1b)

Throughput is calculated by considering the packets sent from the source, it is calculated as total number of bits send in a specific timeframe (time-stamp difference between the first and the last packet

```
Flow btw ports 43498 and 80
Throughput = 42.01112890330047
Flow btw ports 43500 and 80
Throughput = 10.283365814606448
Flow btw ports 43502 and 80
Throughput = 11.852051078605756
```

1c)

Loss packets are the packets which are retransmitted.

Loss rate is calculated at source (from sender to receiver) as number of packets lost per total number of packets sent.

```
Flow btw ports 43498 and 80
packets sent: 6977
packets lost: 3
Loss Rate: 0.0004299842339114232
Flow btw ports 43500 and 80
packets sent: 7068
packets lost: 94
Loss Rate: 0.013299377475947935
Flow btw ports 43502 and 80
packets sent: 729
packets lost: 0
Loss Rate: 0.0
```

1d)

For calculating RTT we should not include the retransmitted packets. It is calculated as the total time for all transactions divided by the total number of transactions

```
Flow btw ports 43498 and 80
Average RTT: 0.07352114802099784
Theoretical Throughput: 9.383177385152338
Flow btw ports 43500 and 80
Average RTT: 0.08857328554621063
Theoretical Throughput: 1.4004579110034154
Flow btw ports 43502 and 80
Average RTT: 0.0731122042113989
Theoretical Throughput is Infinite as loss rate is zero
```

In the last case theoretical throughput is zero as the number of loss packets are zero.

In the above examples the Empirical throughput is greater than theoretical throughput in all the cases. I guess one of the reasons is that number of packets should be large for the theoretical throughput and empirical throughput to converge. As the number of packets keep increasing the empirical throughput will also increase as there is a more chance that it might encounter network delays.