# TCP Exercises

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## 1. Basic problems

1. Let the TCP connection configured with a $MTU = 1320$ Bytes, running over a 20Mbps link with a propagation time of 5ms. Calculate the RTT (Round Trip Time).

2. Unless instructed otherwise in the problem you can assume that **Every segment is individually acknowledged** (simplifies calculations) abd that **the sender always sends data if there are data to be sent** (whenever there is enough window and data pending to be sent). Reason about differences in cases when you assume this and when not.

3. If the sender sends the whole window during an RTT, how much will the window grow depending on the TCP mode (slow start or congestion avoidance)? How can it be simplified (provide a simplification for congestion avoidance)?

## 2. Problems

4. In a TCP connection, after exchanging several segments, we have an effective window of 16 segments $V_{ef} = 16$. The slow start threshold has the default TCP value (65535). If $MSS = 1024 bytes$ and the advertised window in both cases is $WIN = 200$

segments. Answer the following:

(a) What is the MTU provided by the link layer?

(b) What is the value of *cwnd*?

(c) How long would it take for the congestion window (*cwnd*) to reach 120 segments?

(d) How many ACKs would need to be received to reach that window of 120?

5. Hosts A and B establish a TCP connection. They both announced $WIN = 4KB$ and $MSS = 256B$ in their respective SYN segments.

   (a) How was the connection affected by a timeout event of the first segment?

   (b) Fill in the following table with the corresponding values of the variables: data sent, cwnd and ssthresh. Indicate which algorithm was applied by TCP in each case.

| Data | Sender Segment | Receiver ACK | Algorithm and cwnd | ssthresh |
|---|---|---|---|---|
| | SYN | | ..................... | ....... |
| TIMEOUT | | | | |
| | SYN | | | |
| | | SYN,ACK | ..................... | ....... |
| | ACK | | | |
| D | ............... | | | |
| | | ACK 257 | ..................... | ....... |
| D | ............... | | | |
| D | ............... | | | |
| | | ACK 513 | ..................... | ....... |
| D | ............... | | | |
| D | ............... | | | |
| | | ACK 769 | ..................... | ....... |
| D | ............... | | | |
| | | ACK 1025 | ..................... | ....... |
| D | ............... | | | |
| | | ACK 1281 | ..................... | ....... |

Figura 1: Table for problem 5 part c

   (c) The connection of the previous example remained active and it reached a situation where the last ACK received was waiting for data byte 6401, being the cwnd=2426 bytes and ssthresh=512 bytes. Fill in the following table with data of the cwnd and ssthresh and indicate the algorithms used by the sender.

| Data | Sender Segment | Receiver ACK | Algorithm and cwnd | ssthresh |
|---|---|---|---|---|
| | | ACK 6401 | | |
| | | ACK 6657 | 2426 | 512 |
| D | 8705:8960 | | | |
| | | ACK 6657 | ..................... | ....... |
| | | ACK 6657 | ..................... | ....... |
| | | ACK 6657 | ..................... | ....... |
| D | 6657:6912 | | | |
| | | ACK 6657 | ..................... | ....... |
| | | ACK 6657 | ..................... | ....... |
| | | ACK 6657 | ..................... | ....... |
| D | 8961:9216 | | | |
| | | ACK 6657 | ..................... | ....... |
| D | 9217:9472 | | | |
| | | ACK 6657 | ..................... | ....... |
| D | 9473:9728 | | | |
| | | ACK 8961 | ..................... | ....... |

Figura 2: Table for problem 5 part b

6. A company's backup system over TCP follows this protocol:

```
C > S: header (40 Bytes)
S > C: header (40 Bytes)
S > C: path and name of the file in the server (les or equal to 1024 Bytes)
C > S: data
S > C: md5sum(data)
```

The backup is carried over a full duplex of 56kbps with MTU=700 bytes (at IP level) and 50 ms propagation delay, the server announces a win=32KB and the length of the backup archive sent by the client is 10MB. Answer the following questions:

(a) Draw the timing diagram of the whole connection. regarding data transmission, limit the diagram data exchange to the first 8 segments and the last one.

(b) From the point where the client starts sending backup data, how many server ACKs have to be received to be able to send the two first data segments?

(c) What is the maximum value of the effective window reached at the client? How many ACKs have to be received since the client started sending data?

(d) If after the first segments the line experiments a 100ms problem affecting only the traffic client to server. When will happen the retransmission of the lost segment? What would be the value of the cwnd when the acknowledgemnt to that segment is received? How many ACKs would be needed to reach the maximum effective value of the sender window? Illustrate your answer with a timing diagram.

(e) If the link is done as indicated in the figure,

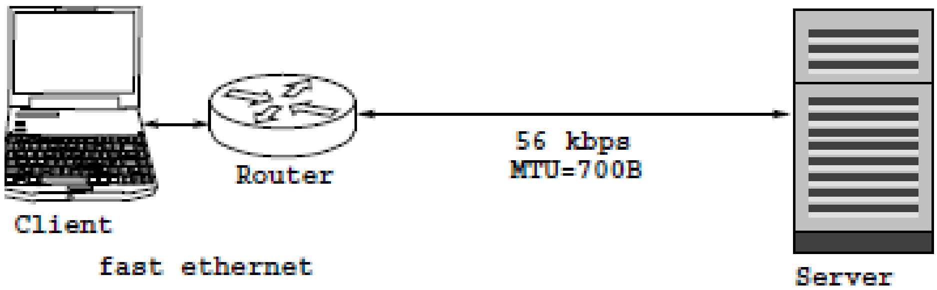


Figura 3: Table for problem 6 part e

How would this affect the cwnd? what buffer size would be needed at the router to allow the continuous sending in the client backup?

7. A company with five regional offices uses a TCP application to backup and send data to its Data Center (DC). The backup application is run every night in the regional offices and in the DC. The application is run in the DC as a server with the TCP socket configured to initially offer a window of 10MB. The protocol of the backup application consists of the client sending the data, and once it is finished, the server sends the md5 sum of the received data in return. Every office has a PPP link (1Gbps,

MTU of 1500B, and propagation delay of 2ms). Night traffic in the PPP links is only due to the backup application. The servers running the backup application (both in the regional offices and in the DC) are connected to their respective routers at 2Gbps.

(a) If only one regional office is active (i.e. only one sending backup data):

1. What window size value (We) allows continuous sending in the PPP link?
2. If $W_e$ is reached by the sender and a timeout occurs, how much time is required to reach $W_e$ again?

(b) If all the offices are active (i.e. sending traffic) to the DC server:

1. Can they reach the value We as computed in previous questions?
2. Is the link to the server of the DC fairly shared?
3. Tuning any TCP parameter can provide a better performance? Explain your answer.

# 3. Advanced problems

8. An online gaming company is willing to release its latest game called "cephalopods game" in Spain that will work over TCP. The game requires large networking resources so the company is making a profile of the average connection in Spain to test if the game can be correctly played by average internet users. The average network model of Spanish clients is shown in figure 4 (for any question, you can suppose WIN does not limit and that sstrhesh is 65535 bytes).

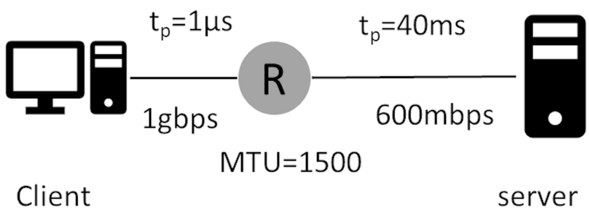


Figura 4: Average connection

(a) Calculate the window that allows for continuous sending

(b) Calculate the exact (bandwidth at application level (in Mbps) once the continuous sending window has been reached. Can be the game played considering it requires more than 500Mbps at application level? (1p)

(c) How long would it take (in both RTTs and seconds) to reach the continuous sending window since the beginning of the connection? Indicate always the algorithm used to calculate the window and the value of cwnd at any time, especially when the algorithm changes (1p)

9. (Continues the previous problem points) The developers of the game consider the time it takes to reach the window is very long and can be frustrating to the most impatient players. So, they decide to play a video whereas the client downloads updates, new content and new multimedia from the server to improve the game. In this way the game gets updated whereas the window increases to the appropriate value and the player is happy watching game related videos.

To achieve this, they propose two different protocols at application level.

**Protocol A**: the client uses the `Sol(N)` message to request $N$ segments to be sent by the server while the `Sol(N)` confirms the reception of the previous $N-1$ segments. The server does not send any segment until the `Sol(N)` message is received; the client does not send `Sol(N)` until $N-1$ previous segments are received. Since the purpose is to increase the window, $N$ will be always the effective window value. Fig 5 shows the protocol for `cwnd>sstresh`.

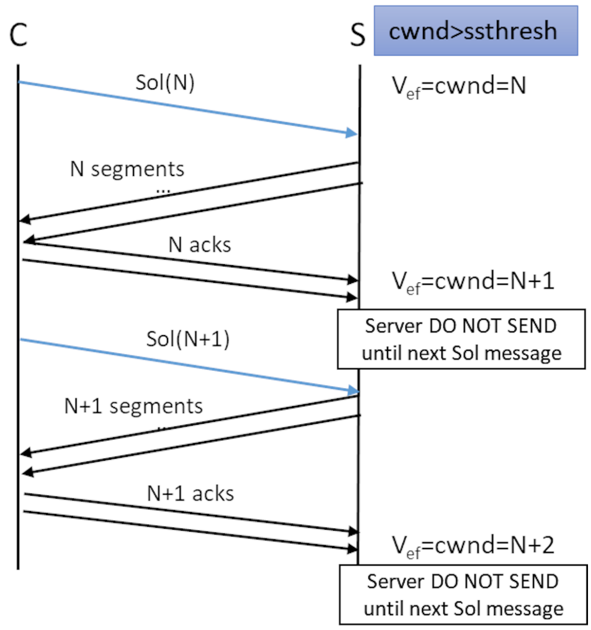


Figura 5: Prococol A

**Protocol B**: the client uses the `Sol(N)` message to confirm the reception of the $N-1$ previous segments. The server can always send if there is available window it does not need to wait for the next `Sol` message, but the client does not send `Sol(N)` until $N-1$ previous segments are received. Since the purpose is to increase the window, $N$ will be always the effective window value. Fig 6 shows the protocol for `cwnd>sstresh`.

(a) The developers perform some tests and discover that several Internet providers have a defect that the last segment sent by the server get lost when the effective window is exactly 1024. Considering that defect, how long (in RTT) will it take to reach the continuous sending window from the beginning in the case of the protocol A? (calculate the cwnd and indicate the algorithm at any change)

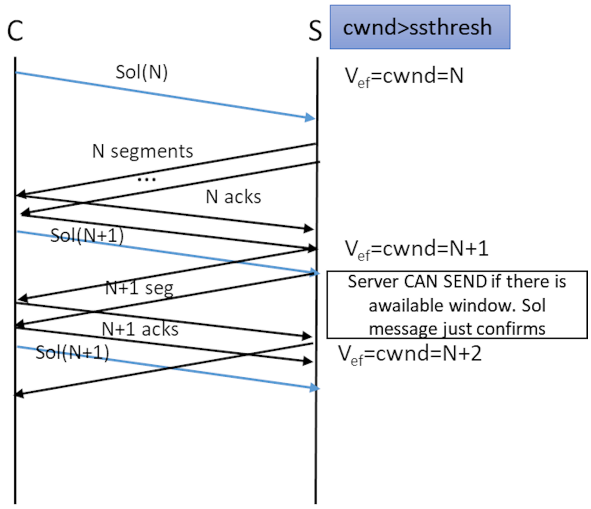


Figura 6: Prococol B

(b) Considering the same defect as in the previous question, how long (in RTT) will it take to reach the continuous sending window from the beginning in the case of the protocol B? (calculate the cwnd and indicate the algorithm at any change)

10. You have been asked to advise a group of scientists on the data link between a rover and a base station for a Mars mission.

    Several scenarios are considered to determine the best solution. The application at the rover (app_1) works in periods in which it performs the following: collects data, opens a connection, sends a data set, closes the connection, and starts again.

**Scenario one** There is a single rover that collects samples and sends data. The antenna is omidirectional, so it can receive data regardless of the location of the rover. The MTU is 1040Bytes

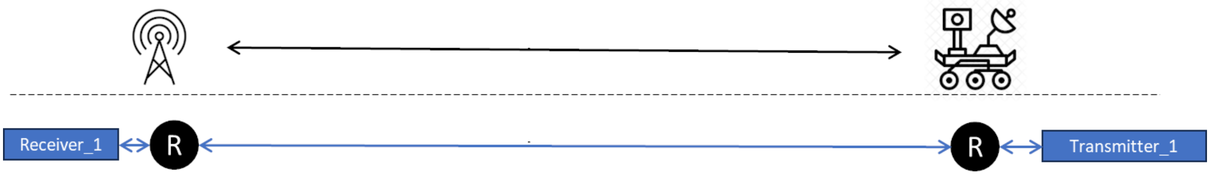


Figura 7: scenario 1 problem 10

(a) Considering the $sstresh$ = 63000 Bytes and that $WIN$ = 64 segments, if the rover sends a data set of 1MB at a time,

 I. how many RTTs will it take to send it?

 II. The scientific team tested the application under Martian conditions and it did not work. Not finding the problem, they consult you stating that the link between the base station and the rover is 1Mbps and the propagation time is 5ms.

III. How long, **in RTTs**, does the rover take to send the data set in this case?

(b) After making some changes to the link, the scientific team gets the application to work. After the change, the application can send, at most, using the link the best it cans, 64 segments each RTT ($V_{cs}$). As an additional design decision, they force the sender (rover) and receiver (base station) to use an announced window of 64.

They also add a monitoring application to the rover that sends 6 segments every RTT with the status of the hardware.

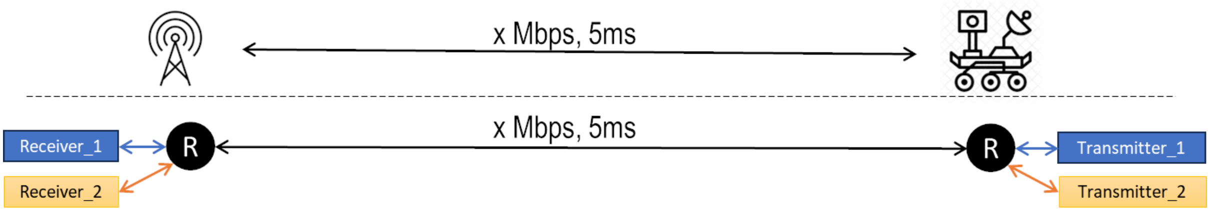


Figura 8: Scenario 1 - 3)

I. What changes has the scientific team made to the link to allow sending that number of segments each RTT? Calculate the new link settings [2].

[2] you can discard the transmission time of the ACK

ii. The application (app_1) begins sending data continuously **until the congestion window reaches 8**. Then, it sends the corresponding 8 segments, but, **after sending the 8 segments, it waits until the transmission and acknowledgment of all segments is completed before continuing to send data**. Unfortunately, the new application (app_2) affects the first one (app_1) in such a way that segment $D_9$ is lost. Use as many rows as needed from the following tables (as seen from the rover sending the data), filling in all fields to indicate what happens (alg must clearly contain the algorithm used at each moment - if there are changes - and the calculation) [3]

[3] In the column segment, indicate the name, $D_n$ for data, $ACK_n$ for ACKs. If the segment is received, put an X in the Rx column, if it is sent, in the Tx column. Reflect in *cwnd* the value of the congestion window, in $V_{ef}$ the value of the effective window, and in $V_{ef}u$ the usable window (considering the pending ACK segments). sst is used for the slow start threshold.

| Segmento | Rx | Tx | cwnd | $V_{ef}$ | $V_{ef}u$ | sst | alg |
|---|---|---|---|---|---|---|---|
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |
| | | | | | | | |

**Scenario two** There is more than one rover. All vehicles collect samples and send data. The antenna is directional and rotates, so it can only receive data when the rover is aligned with it. Only one rover transmits at a time. The MTU is 1040Bytes.

In this scenario, each rover sends a data set including images, which occupies a total of 20MBytes. There is no limitation on flow control. The ssthresh parameter has a value of 63.

Since the antenna rotates, each rover has a limited time to transmit all the information. The scientific team is trying to figure out how much time each rover needs to transmit all the data to determine the rotation speed.

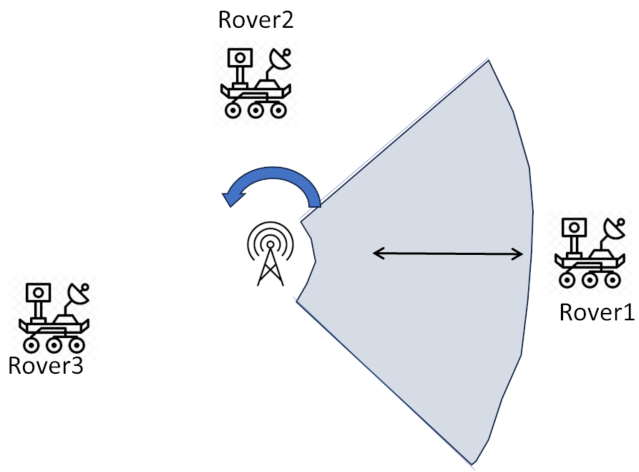


Figura 9: Scenario 2 problem 10

(c) How many RTTs will the vehicle need to transmit the complete data set in this scenario (20 MB)?[4]

—- Drawing for the solution —-

```
segments  <----63-----> <----------------19937------------------>
cwnd      1...     ...64   65     66    ..      ..  (an -2)  (an-1)
cwnd      1...     ...64 (64+1) (64+2) ..     ...(64+n-2) (64+n-1)
succesion                   1      2                n-2      n-1
alg       <--s.start--> <---  congestion avoidance ------------->
```

[4]It might be helpful to consider the following questions: How many segments will need to be transmitted in total? How many RTTs will it take for cwnd to reach the value of 63? After that, how many RTTs will it take to transmit the remaining segments?
Based on the window size, which algorithm will be used, and how will the window grow each RTT?

It may also be useful to know
1) The sum of monotonic sequences $(a_0 + a_1 + \ldots + a_n)$ where $a_1 = a_0 + 1$, $a_2 = a_1 + 1$, $\ldots$, can be calculated as $S = \frac{n\cdot(a_0+an)}{2}$
2) The solution to a quadratic equation $ax^2 + bx + c = 0$ is $x = \frac{-b\pm\sqrt{b^2-4ac}}{2a}$.

Page 22