

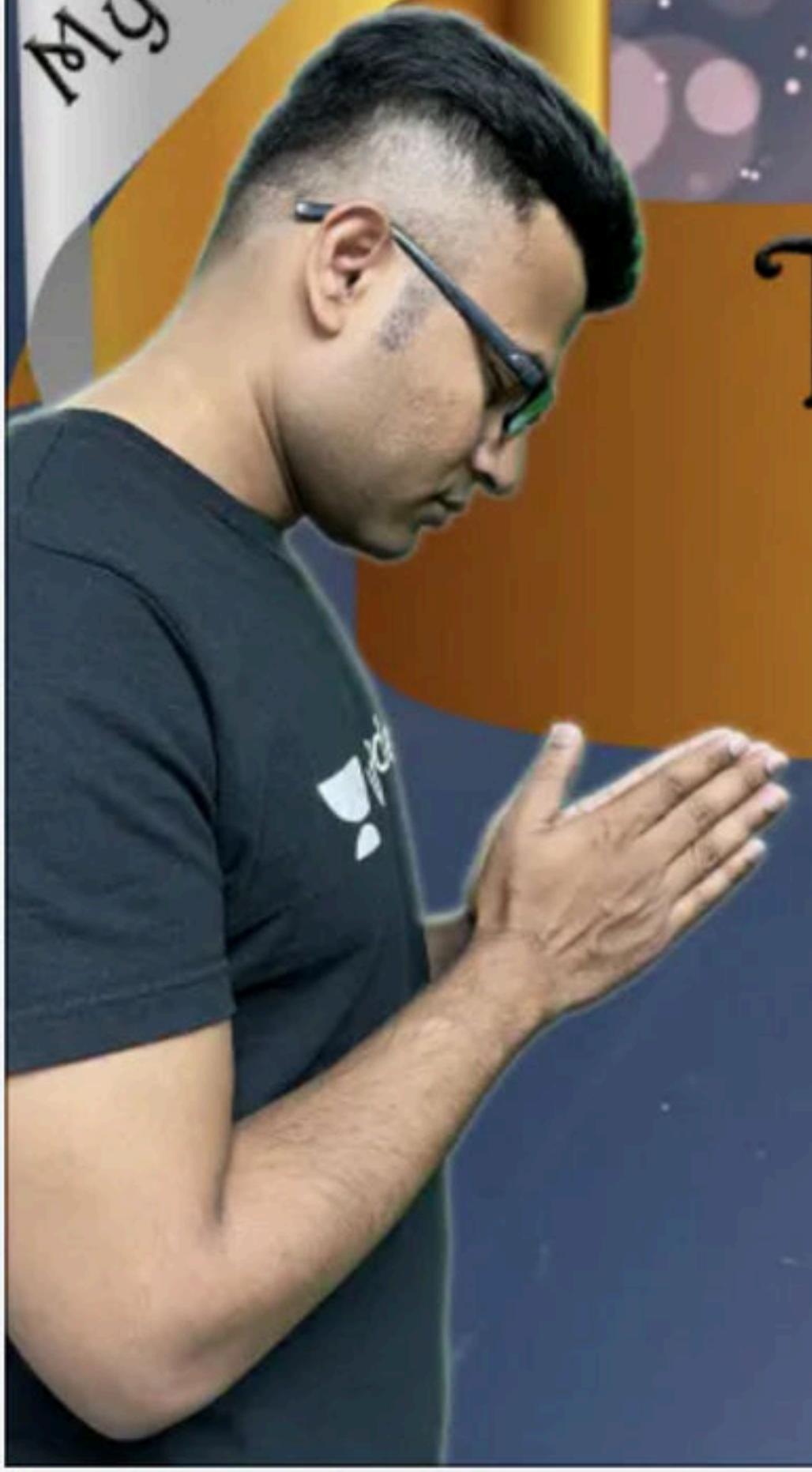
# TCP Header - Part II

Complete Course on Computer Networks - Part III

Ravindrababu Ravula • Lesson 15 • Apr 10, 2021

My philosophy

TEACHING IS WORSHIP  
STUDENTS ARE GODS



*Thank you  
for  
trusting me*

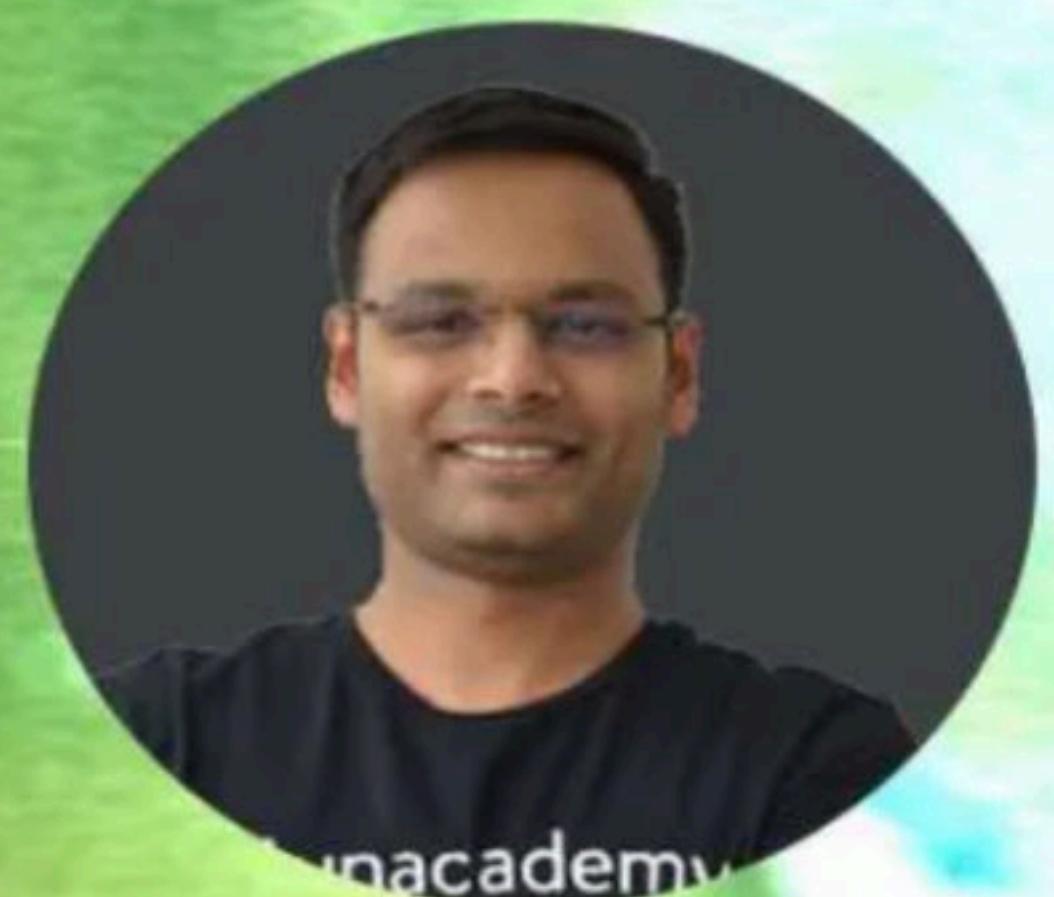




## 10-04-2021 Full Day Schedule of RBR



Lecture Name	Time
Introduction to Relational Algebra, Selection Operation, Projection Operation & GATE Questions   DBMS	06:00 AM - 07:00 AM
Normalization GATE Practice Questions   DBMS	08:05 AM - 09:05 AM
TCP Header Part-II   CN	09:15 AM - 10:15 AM
Complete Revision of Algorithms & Data Structures   Revision of Classes Happened From 04 Apr-09 Apr	05:00 PM-06:00PM
Complete Revision of Java   Revision of Classes Happened From (4/4/21) to (9/4/21)	06:00 PM - 07:00 PM
Complete Revision of Linux   Revision of Classes Happened From (4/4/21) to (9/4/21)	07:00 PM - 08:00 PM
Complete Revision of Git Hub/Web Tech   Revision of Classes Happened From (4/4/21) to (9/4/21)	08:00 PM - 09:00 PM



**LEARN FROM TOP EDUCATORS**

How many shortest-length paths are there to get from your house to the doughnut shop?



$$C_n^k = \frac{n!}{(n-k)!k!}$$

$$e^{i\pi} + 1 = 0$$

101

101  
B,

101000101

1 5 10 10 5 1

One-to-One

25 = 349 + 349 + 349 + 349 + ... + 349

2S<sub>n</sub> = 349 + 68

S<sub>n</sub> =  $\frac{349 + 68}{2}$

S<sub>4</sub> = 31866

Original:

$\exists x \forall y (x \geq 2y \rightarrow x > y + 1)$

Converse:

$\exists x \forall y (x > y + 1 \rightarrow x \geq 2y)$

Negation:

$\neg [\exists x \forall y (\neg(x \geq 2y) \vee x > y + 1)]$

$\forall x \exists y (x \geq 2y \wedge x \leq y + 1)$

Contrapositive:

$\exists x \forall y (x \leq y + 1 \rightarrow x < 2y)$

# Discrete Mathematics

## Set Theory & Algebra

Ravindrababu Ravula

Jay Bansal

unacademy.com/@jay.bansal

(A ∪ B ∪ C) ∩ (A ∩ B ∩ C)



$$v - e + f = 2$$

P.I.E. Example:

$$61 - \left[ \binom{6}{1} 51 - \binom{6}{2} 41 + \binom{6}{3} 31 - \binom{6}{4} 21 + \binom{6}{5} 11 - \binom{6}{6} 01 \right]$$

7, 11, 15, 19, 23...

$$K_s - D_s = 4$$

$$D_s - K_s = 4$$

$$K_s - D_s = 4$$

$$\vdots \quad \vdots \quad \vdots$$

$$+ D_s - K_s = 4$$

$$D_s - D_s = 4n$$

$$D_s = D_s + 4n$$

$$K_{3,3}$$



How many shortest-length paths are there to get from your house to the doughnut shop?



$$\binom{n}{k} = \frac{n!}{(n-k)!k!}$$

# Discrete Mathematics for GATE CSE

- Set Theory & Algebra
- Combinatorics & Propositional Logic
- Graph Theory

There are six dogs to give 13 tacos.  
use a "stars and bars" diagram to illustrate the first  
and sixth dog get 3 tacos, the second dog gets none,  
the third dog gets 5 and the fourth dog gets one.

★ ★ ★ || ★ ★ ★ ★ | ★ | ★ ★ ★ |

$$A = \{2, 4, 10, \text{apple}\}$$

$$(A \cup B \cup C) \cap (A \cap B \cap C)$$



$$v - e + f = 2$$

P.I.E. Example:

$$6! = \left[ \binom{6}{1} 5! - \binom{6}{2} 4! + \binom{6}{3} 3! - \binom{6}{4} 2! + \binom{6}{5} 1! \right]$$

7, 11, 15, 19, 23...

$$K_2 - K_0 = 4$$

$$K_3 - K_1 = 4$$

$$K_4 - K_2 = 4$$

$$\vdots \quad \vdots \quad \vdots$$

$$+ K_n - K_{n-2} = 4$$

$$a_n - a_0 = 4n$$

$$a_n = a_0 + 4n$$

$$K_{3,3}$$



original:

$$\exists x \forall y (x \geq 2y \rightarrow x > y + 1)$$

Converse:

$$\exists x \forall y (x > y + 1 \rightarrow x \geq 2y)$$

Negation:

$$\neg [\exists x \forall y (\neg(x \geq 2y) \vee x > y + 1)]$$

$$\forall x \exists y (x \geq 2y \wedge x \leq y + 1)$$

contrapositive:

$$\exists x \forall y (x \leq y + 1 \rightarrow x < 2y)$$

# Set Theory & Algebra

Apr 7 2021 - Apr 27 2021

**(20 Days Course)**

(Everyday except Fridays &  
Sundays)

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How many shortest-length paths are there to get from your house to the donut shop?

# Schedule

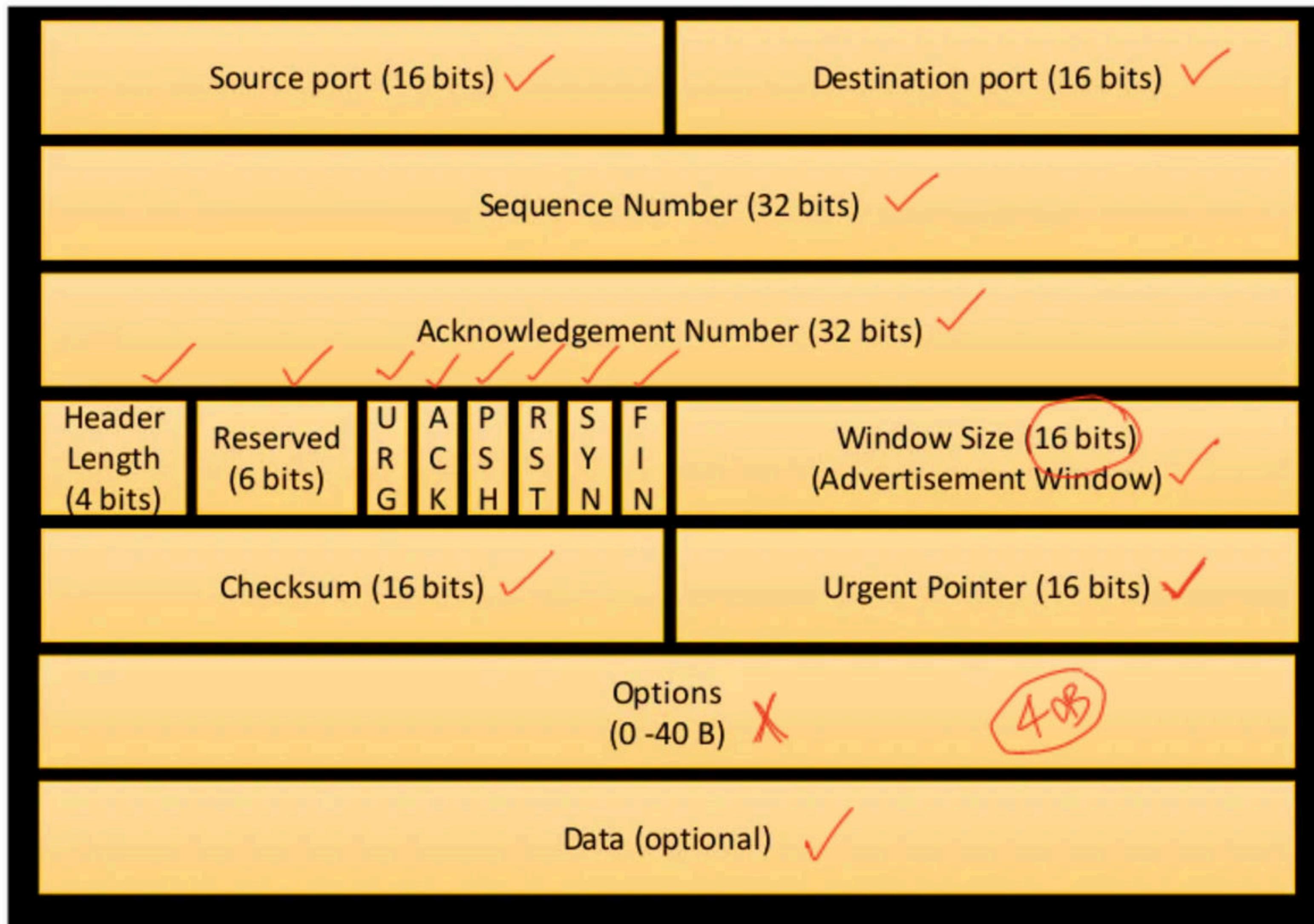
1	Sets, Power set, Laws of sets			Apr 7	Wed	Plus 08:00-09:00
2	Introduction to Relations			Apr 8	Thu	Plus 08:00-09:00
3	Reflexive, Symmetric Relations			Apr 10	Sat	Plus 08:00-09:00
4	Transitive, Equivalence Relations			Apr 12	Mon	Plus 08:00-09:00
5	Partially & Totally Ordered Sets			Apr 13	Tue	Plus 08:00-09:00
6	Least Upper Bound, Greatest Lower Bound, Lattices			Apr 14	Wed	Plus 08:00-09:00
7	Lattices: Properties & Types			Apr 15	Thu	Plus 08:00-09:00
8	Bounded, Complemented Lattice, Boolean Algebra			Apr 17	Sat	Plus 08:00-09:00
9	Practice Questions on Sets & Lattice			Apr 19	Mon	Plus 08:00-09:00
10	Algebraic Structures, Semigroup, Monoid, Group			Apr 20	Tue	Plus 08:00-09:00
11	Groups, Abelian Groups, Finite Group			Apr 21	Wed	Plus 18:00-19:00
12	Subgroup, Cyclic groups, Order of Group			Apr 22	Thu	Plus 18:00-19:00
13	Functions, One-one, Onto functions			Apr 24	Sat	Plus 18:00-19:00
14	Bijections, Inverse Functions			Apr 26	Mon	Plus 18:00-19:00
15	Practice Questions on Set Theory & Algebra			Apr 27	Tue	Plus 18:00-19:00

# Computer Networks

## TCP Header

Source Port, Destination Port,  
Sequence Number, Acknowledgment Number

## TCP HEADER

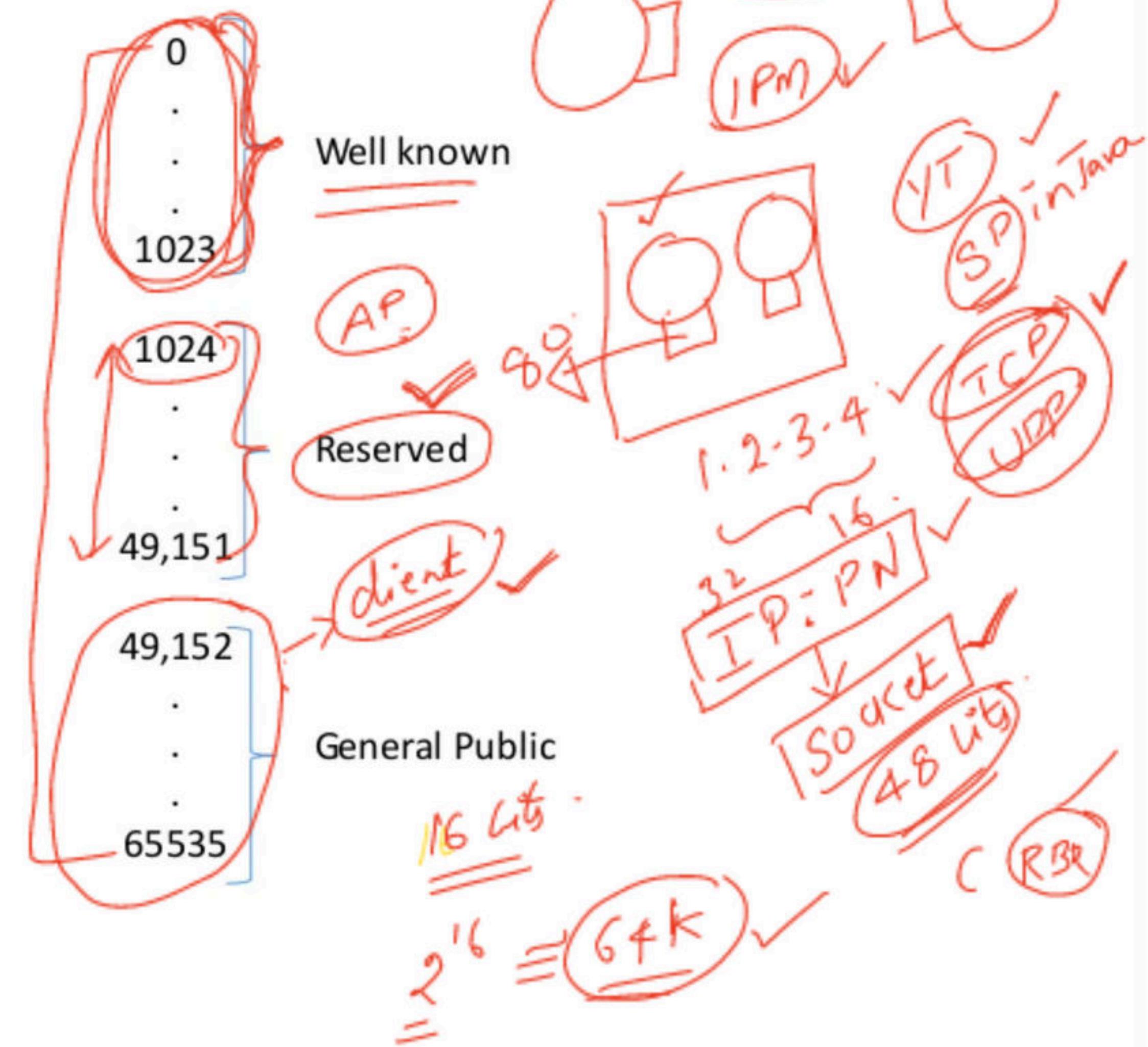


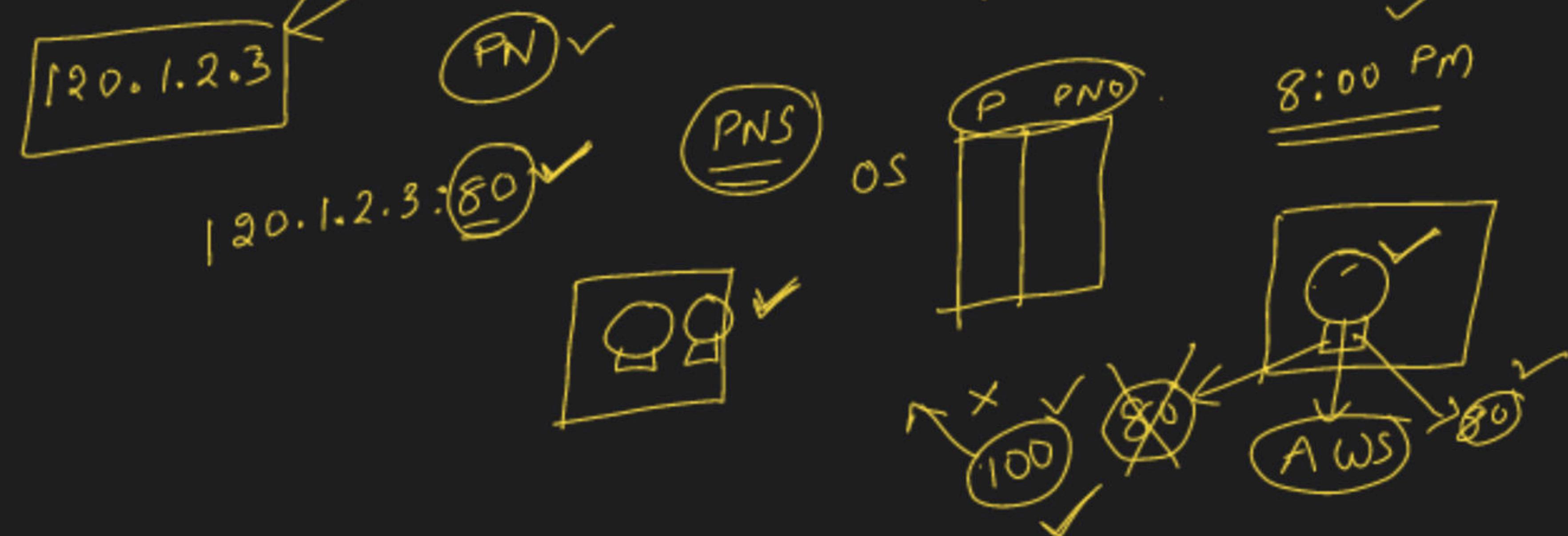
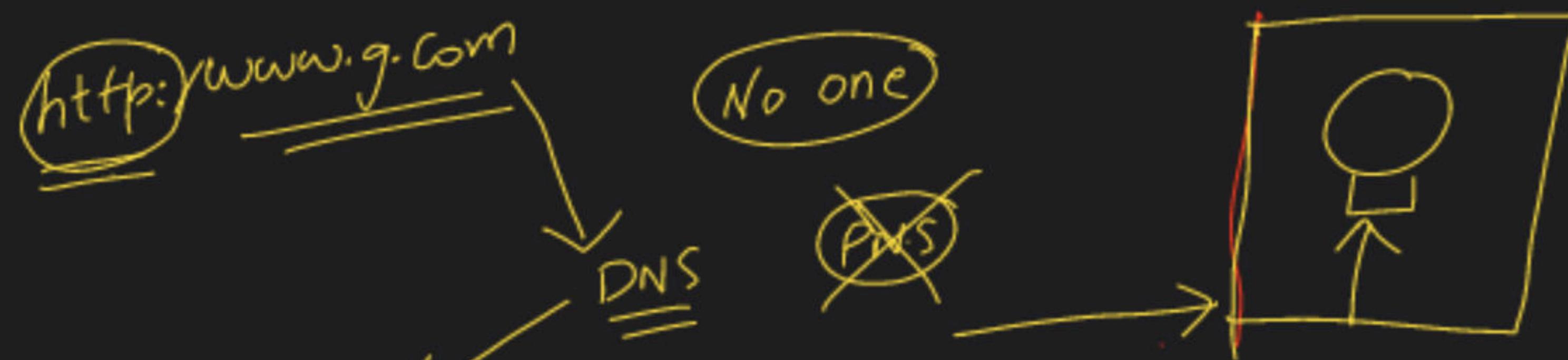
## TCP and Port Numbers

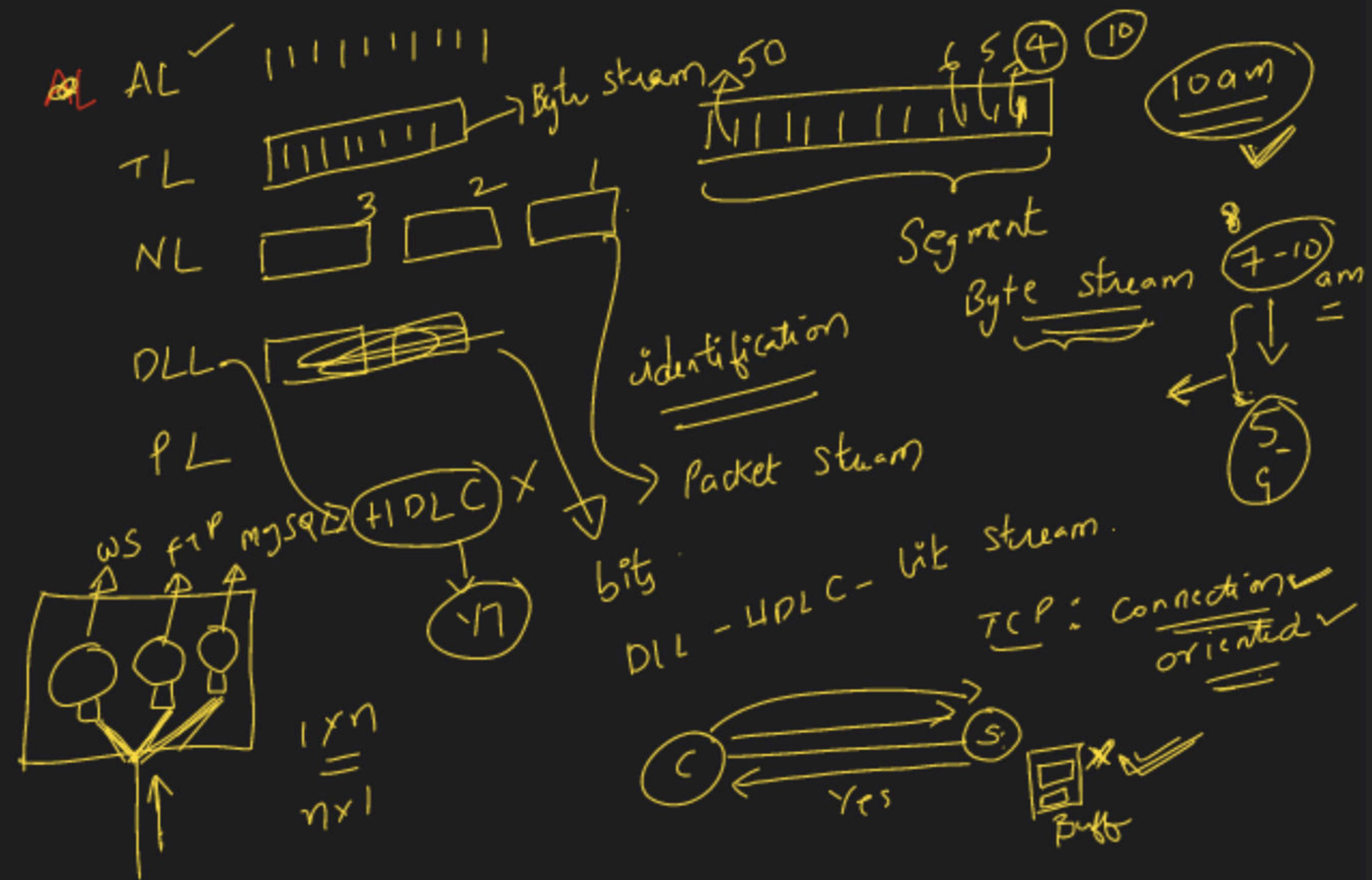
- End to End Protocol. It is byte stream protocol ✓
- Multiplexing and Demultiplexing ✓
- TCP is a connection oriented protocol.

Port Number	Usage
20 ✓	File Transfer Protocol (FTP) Data Transfer
21 ✓	File Transfer Protocol (FTP) Command Control
22	Secure Shell (SSH)
23	Telnet - Remote login service, unencrypted text messages
25	Simple Mail Transfer Protocol (SMTP) E-mail Routing
53	Domain Name System (DNS) service
80	Hypertext Transfer Protocol (HTTP) used in World Wide Web
110	Post Office Protocol (POP3) used by e-mail clients to retrieve e-mail from a server
119	Network News Transfer Protocol (NNTP)
123	Network Time Protocol (NTP)
143	Internet Message Access Protocol (IMAP) Management of Digital Mail
161	Simple Network Management Protocol (SNMP)
194	Internet Relay Chat (IRC)
443	HTTP Secure (HTTPS) HTTP over TLS/SSL

Range ( $0, 2^{16-1}$ )









## 1. Source Port-

- Source Port is a 16 bit field. ✓
- It identifies the port of the sending application.

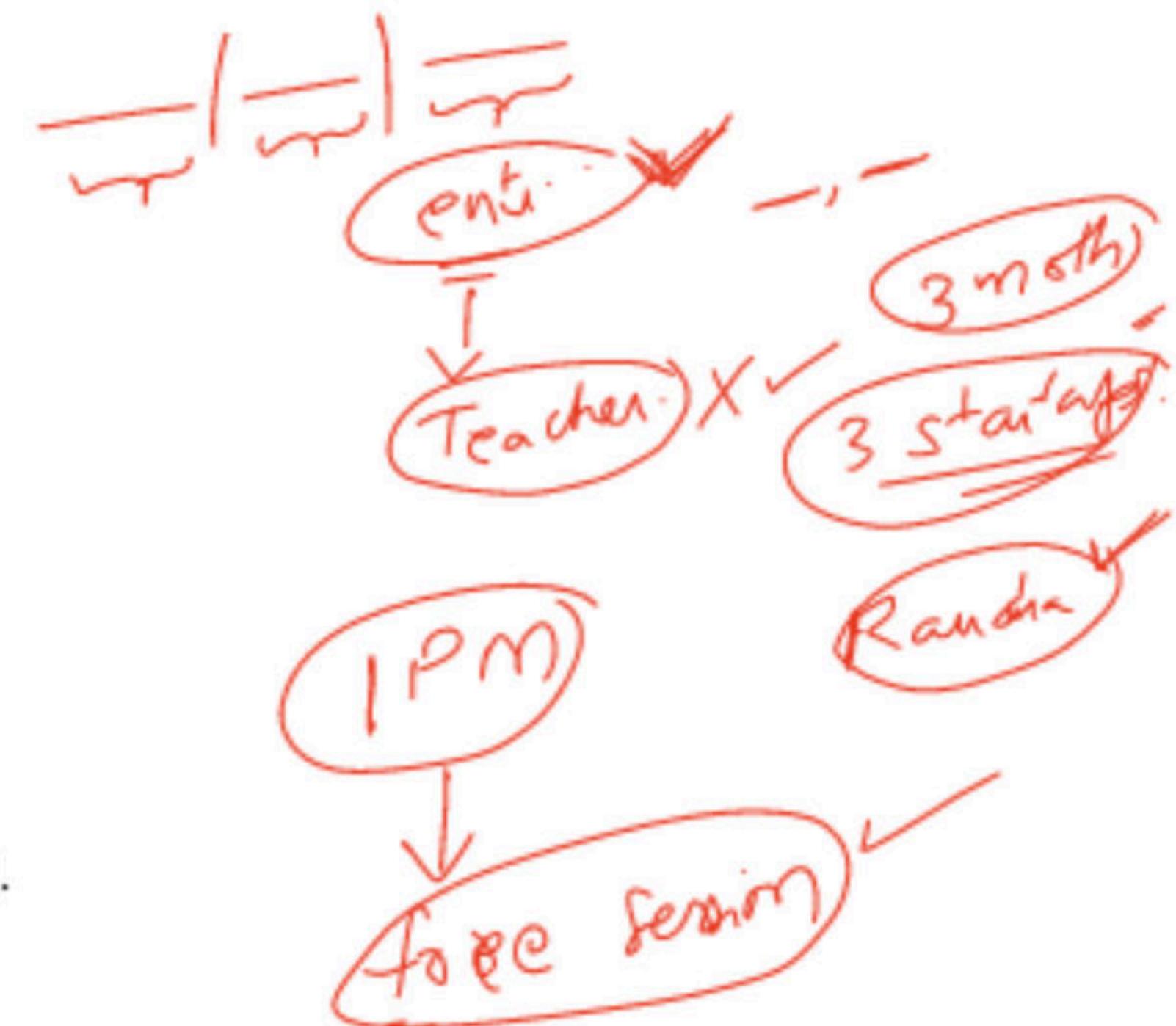


## 2. Destination Port-

- Destination Port is a 16 bit field.
- It identifies the port of the receiving application.

It is important to note-

- A TCP connection is uniquely identified by using-  
Combination of port numbers and IP Addresses of sender and receiver
- IP Addresses indicate which systems are communicating.
- Port numbers indicate which end to end sockets are communicating.

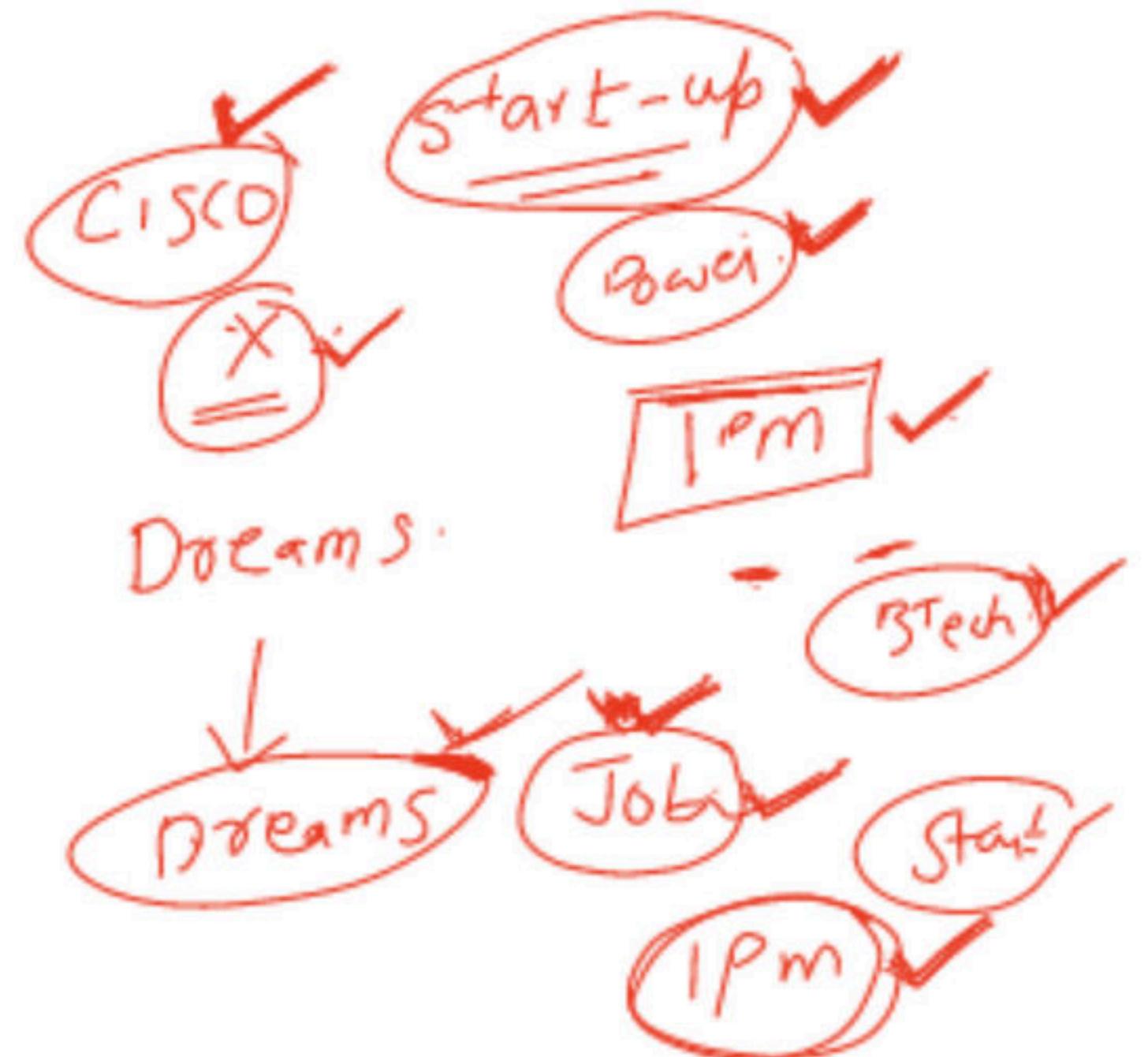


### 3. Sequence Number-

- Sequence number is a 32 bit field.
- TCP assigns a unique sequence number to each byte of data contained in the TCP segment.
- This field contains the sequence number of the first data byte.

### 4. Acknowledgement Number-

- Acknowledgment number is a 32 bit field.
- It contains sequence number of the data byte that receiver expects to receive next from the sender.
- It is always sequence number of the last received data byte incremented by 1.

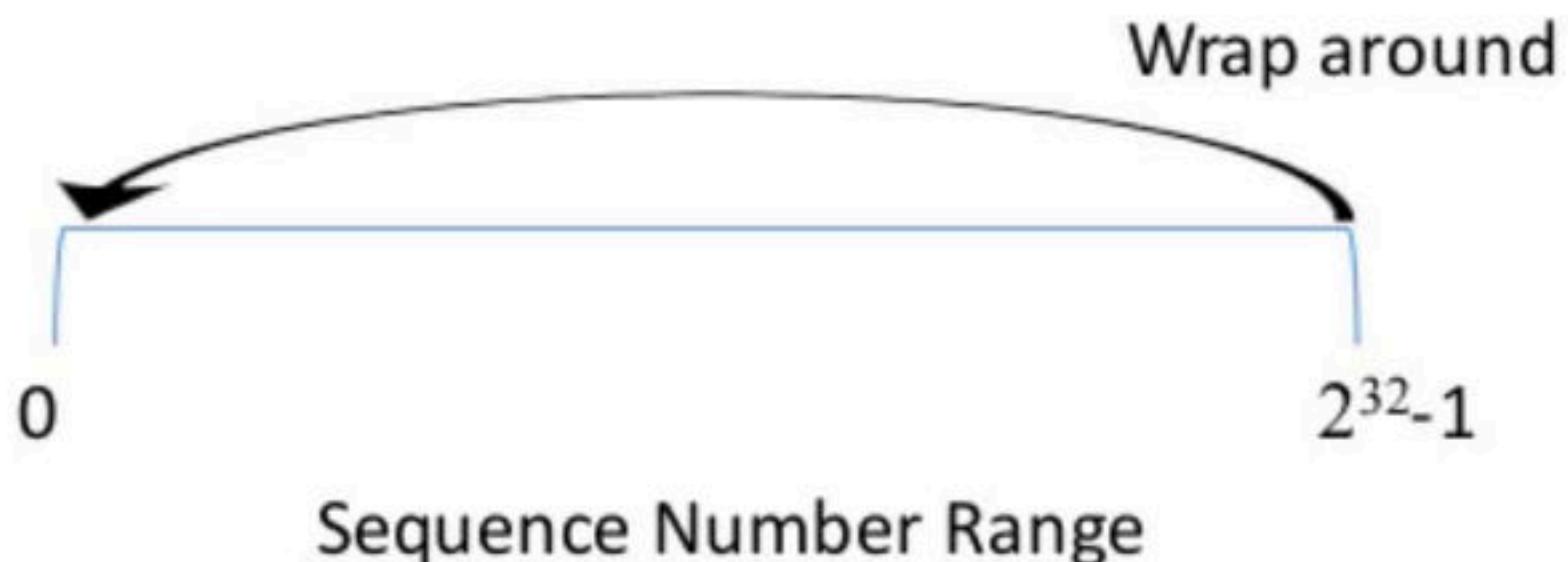


# Computer Networks

**TCP Header Part 2**

**Wrap around time**

### Wrap Around Time



After all the  $2^{32}$  sequence numbers are used up and more data is to be sent, the sequence numbers can be wrapped around and used again from the starting.

In general,

- If the initial sequence number chosen is X.
- Then sequence numbers are used from X to  $2^{32} - 1$  and then from 0 to X-1.
- Then, sequence numbers are wrapped around to send more data.

## Example-

- Consider the initial sequence number used is 0.
- Then after sending 4 GB data, all the sequence numbers would get used up.
- To send more data, sequence numbers are reused from the starting.
- Wrapping around can be done again and again to send more and more data.

## Wrap Around Time-

- Time taken to use up all the  $2^{32}$  sequence numbers is called as **wrap around time**.
- It depends on the bandwidth of the network i.e. the rate at which the bytes go out.
- More the bandwidth, lesser the wrap around time and vice versa.

$$\text{Wrap Around Time} \propto 1 / \text{Bandwidth}$$

## Formula-

If bandwidth of the network =  $x$  bytes/sec, then

$$\text{Wrap Around Time} = \frac{2^{32}}{x} \text{ sec}$$

## Life Time Of TCP Segment-

In modern computers,

- Life time of a TCP segment is 180 seconds or 3 minutes.
- It means after sending a TCP segment, it might reach the receiver taking 3 minutes in the worst case.

## How Wrap Around Is Possible?

It is possible to wrap around the sequence numbers because-

- The life time of a TCP segment is just 180 seconds.
- Wrap around time is much greater than life time of a TCP segment.
- So, by the time the sequence numbers wrap around, there is no probability of existing any segment having the same sequence number.
- Thus, even after wrapping around, the sequence number of all the bytes will be unique at any given time.

## Reducing Wrap Around Time-

Wrap around time can be reduced to the life time of a TCP segment.

To reduce the wrap around time to the life time of segment,

- There must exist as many sequence numbers as there are number of data bytes sent in time equal to life time of segment.

Number of bits required in the sequence number field  
so that wrap around time becomes equal to lifetime of  
TCP segment

$$= \log_2 (\text{lifetime of TCP segment} \times \text{Bandwidth})$$

- The number of bits will be greater than 32 bits.
- The extra bits are appended in the Options field of TCP header.

# Computer Networks

TCP header Part 3

Header Length and TCP Connection establishment

## 5. Header Length-

- Header length is a 4 bit field.
- It contains the length of TCP header.
- It helps in knowing from where the actual data begins.

## Minimum and Maximum Header length-

The length of TCP header always lies in the range-

[20 bytes , 60 bytes]

- The initial 5 rows of the TCP header are always used.
- So, minimum length of TCP header =  $5 \times 4$  bytes = 20 bytes.
- The size of the 6th row representing the Options field vary.
- The size of Options field can go up to 40 bytes.
- So, maximum length of TCP header = 20 bytes + 40 bytes = 60 bytes.

## Concept of Scaling Factor-

- Header length is a 4 bit field.
- So, the range of decimal values that can be represented is [0, 15].
- But the range of header length is [20, 60].
- So, to represent the header length, we use a scaling factor of 4.

In general,

$$\text{Header length} = \text{Header length field value} \times 4 \text{ bytes}$$

## Examples-

- If header length field contains decimal value 5 (represented as 0101), then-

$$\text{Header length} = 5 \times 4 = 20 \text{ bytes}$$

- If header length field contains decimal value 10 (represented as 1010), then-

$$\text{Header length} = 10 \times 4 = 40 \text{ bytes}$$

- If header length field contains decimal value 15 (represented as 1111), then-

$$\text{Header length} = 15 \times 4 = 60 \text{ bytes}$$

## NOTES

It is important to note-

- Header length and Header length field value are two different things.
- The range of header length field value is always [5, 15].
- The range of header length is always [20, 60].

While solving questions-

- If the given value lies in the range [5, 15] then it must be the header length field value.
- This is because the range of header length is always [20, 60].

**We will check out the other fields and flags of the TCP header along with TCP phases**

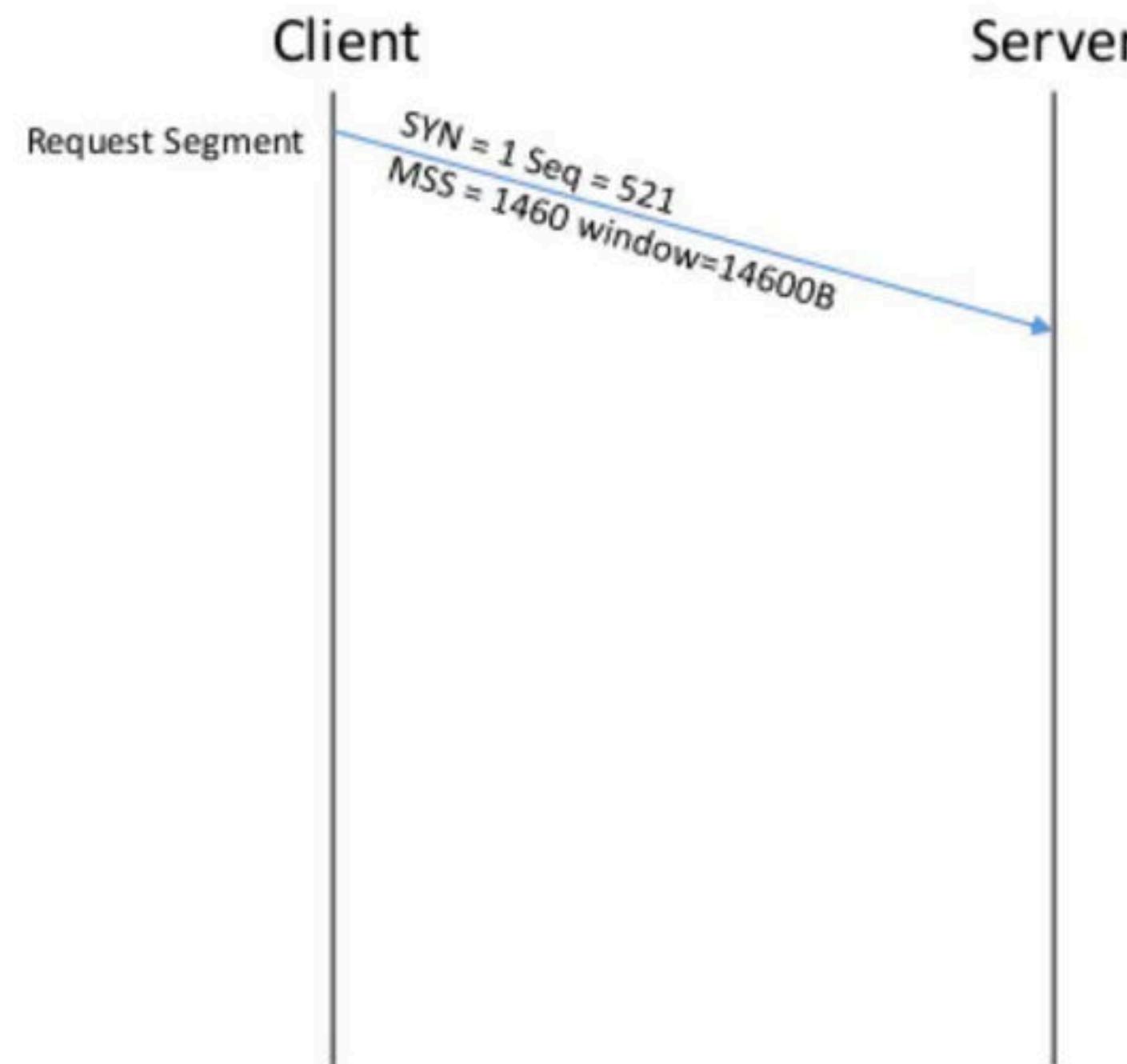
## TCP PHASES

CONNECTION ESTABLISHMENT

DATA TRANSMISSION

CONNECTION TERMINATION

**Three Way Handshake** is a process used for establishing a TCP connection.



### **Step-01: SYN-**

For establishing a connection,

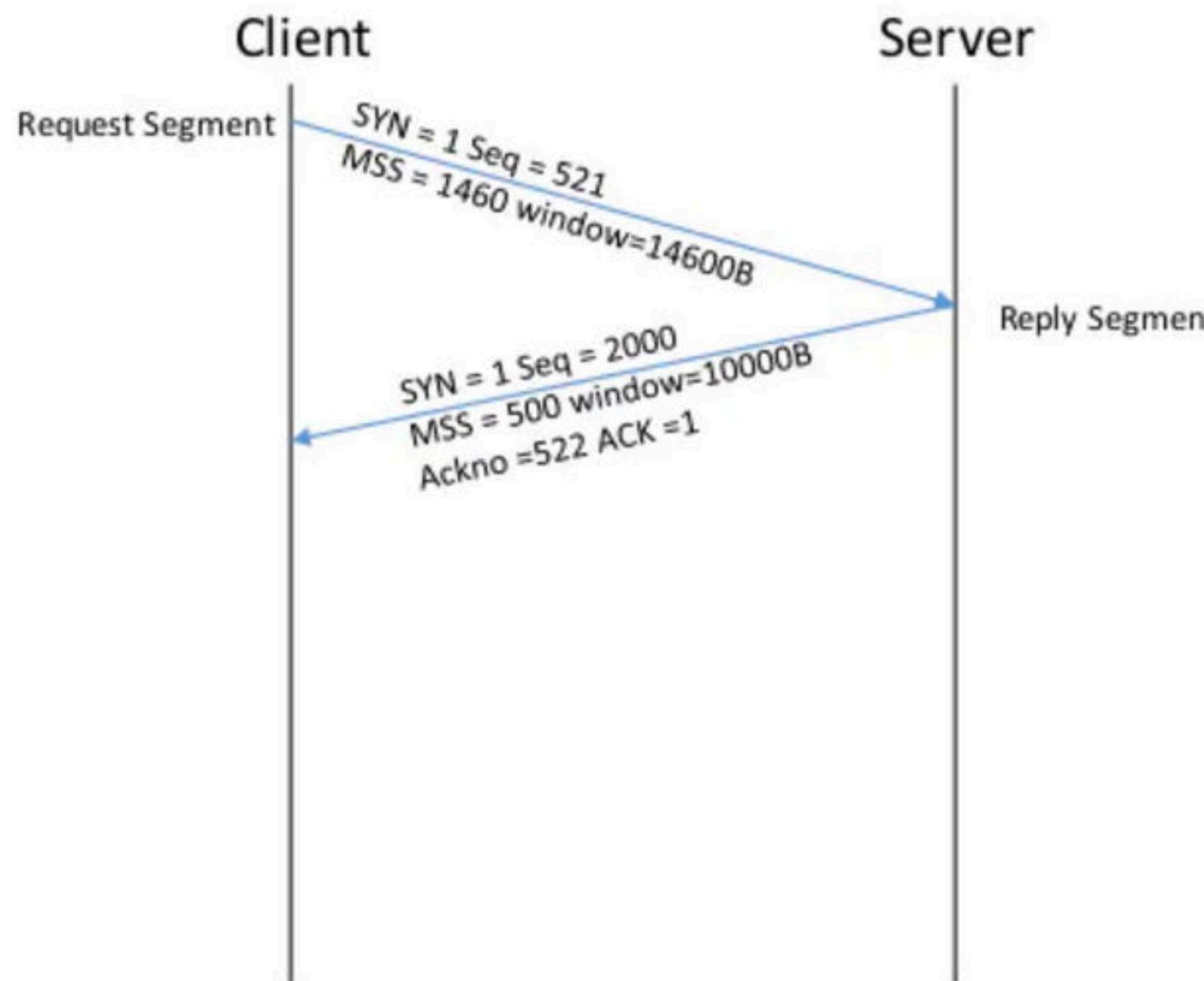
- Client sends a request segment to the server.
- Request segment consists only of TCP Header with an empty payload.
- Then, it waits for a reply segment from the server.

Request segment contains the following information in TCP header-

1. Initial sequence number
2. SYN bit set to 1
3. Maximum segment size
4. Receiving window size

Imagine this scenario for connection  
Establishment

**Three Way Handshake** is a process used for establishing a TCP connection.



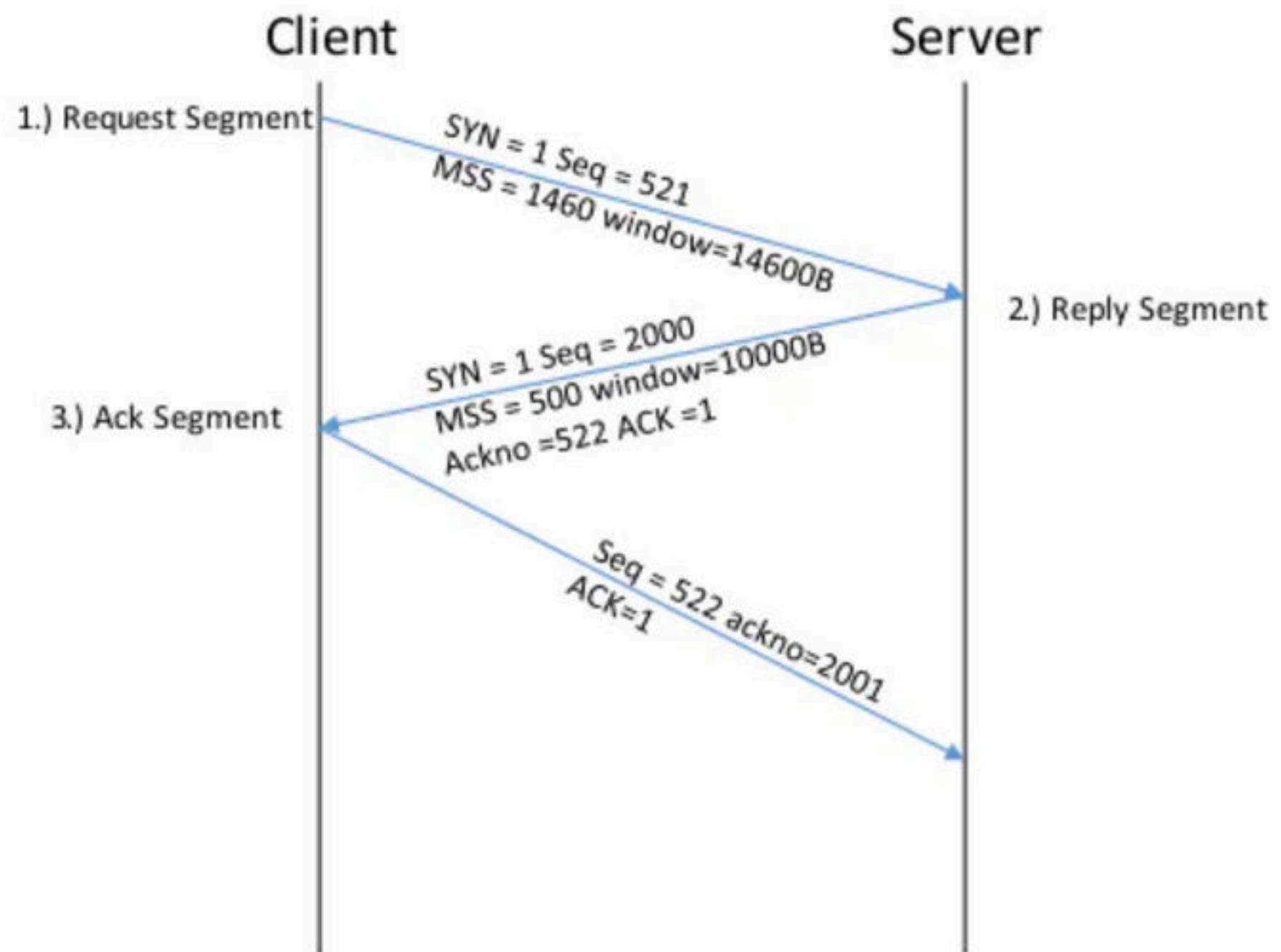
### Step-02: SYN + ACK-

After receiving the request segment,

- Server responds to the client by sending the reply segment.
- It informs the client of the parameters at the server side. Reply segment contains the following information in TCP header-
  1. Initial sequence number
  2. SYN bit set to 1
  3. Maximum segment size
  4. Receiving window size
  5. Acknowledgment number
  6. ACK bit set to 1

Imagine this scenario for connection  
Establishment

**Three Way Handshake** is a process used for establishing a TCP connection.



### Step-03: ACK-

After receiving the reply segment,

- Client acknowledges the response of server.
- It acknowledges the server by sending a pure acknowledgement.

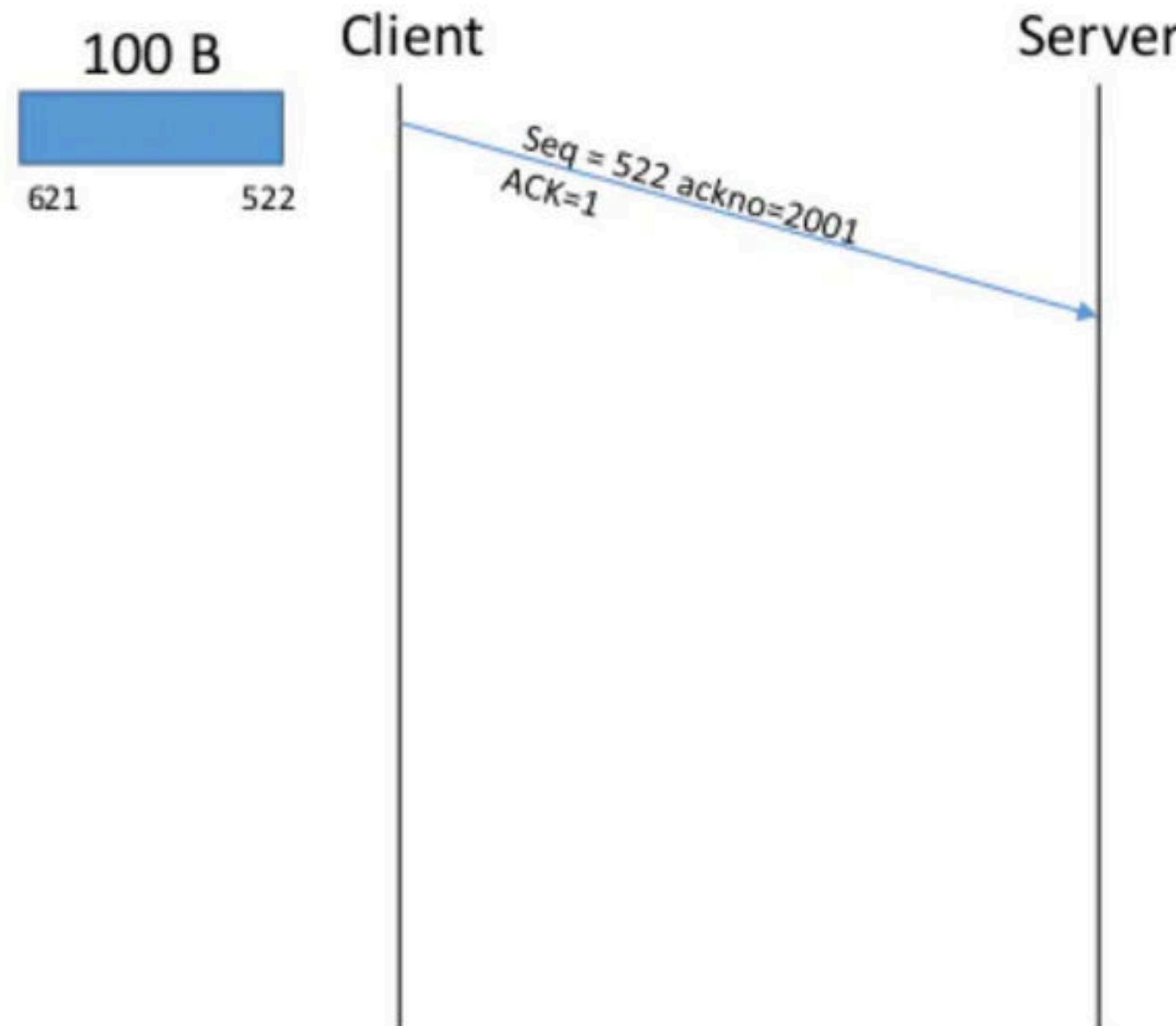
Imagine this scenario for connection  
Establishment

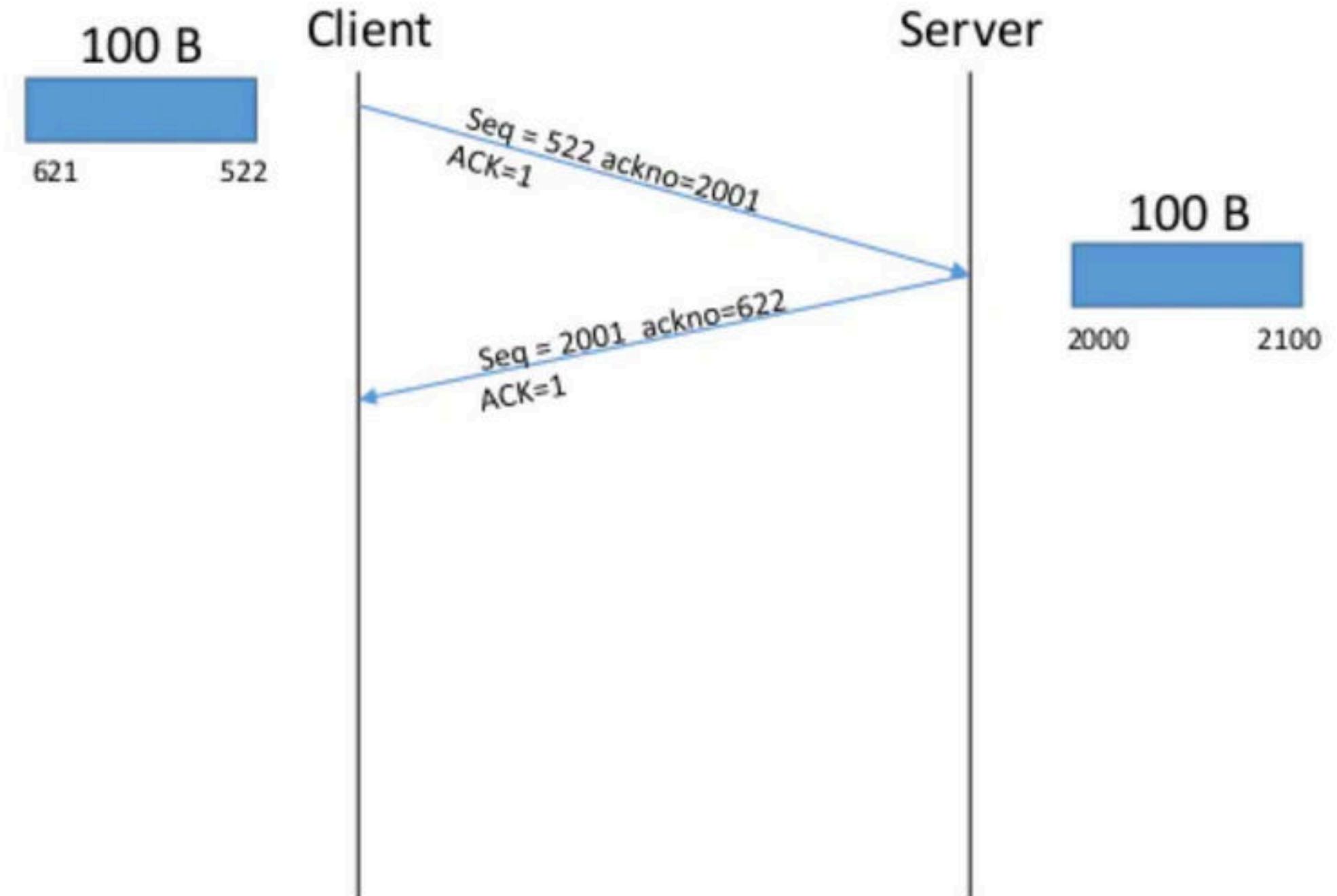
In any TCP segment,

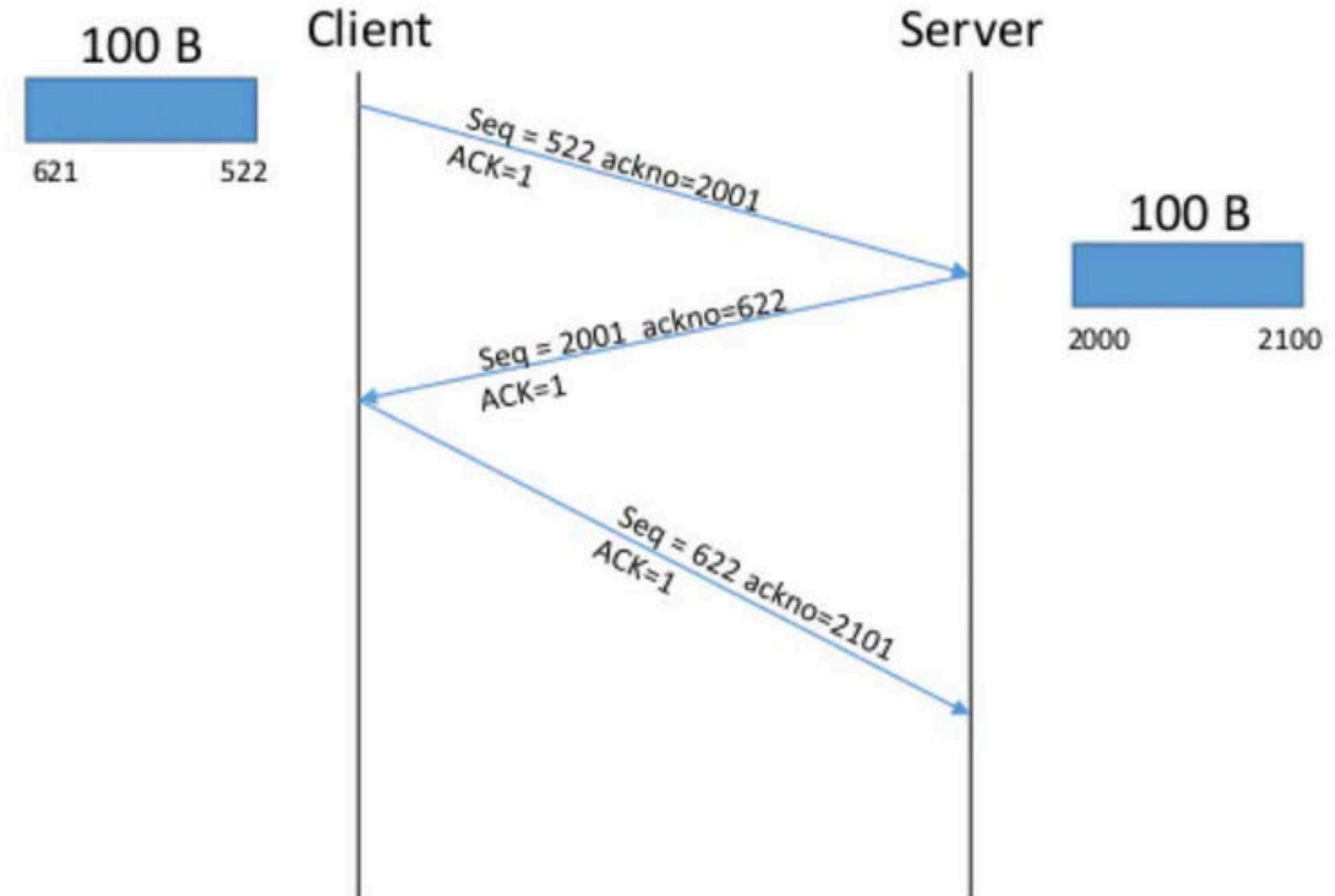
1. If SYN bit = 1 and ACK bit = 0, then it must be the request segment.
2. If SYN bit = 1 and ACK bit = 1, then it must be the reply segment.
3. If SYN bit = 0 and ACK bit = 1, then it can be the pure ACK or segment meant for data transfer.
4. If SYN bit = 0 and ACK bit = 0, then this combination is not possible.

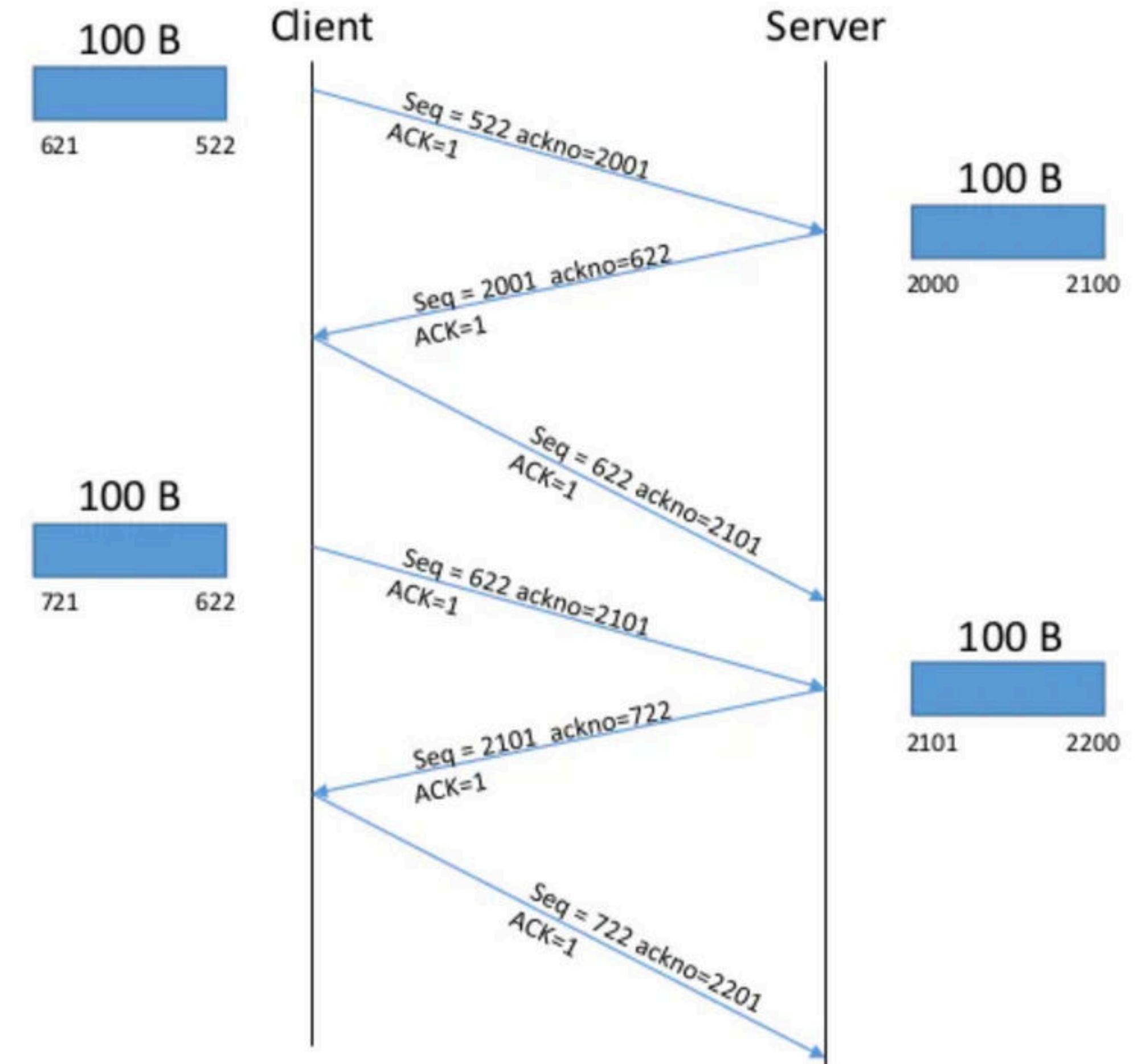


## DATA TRANSMISSION







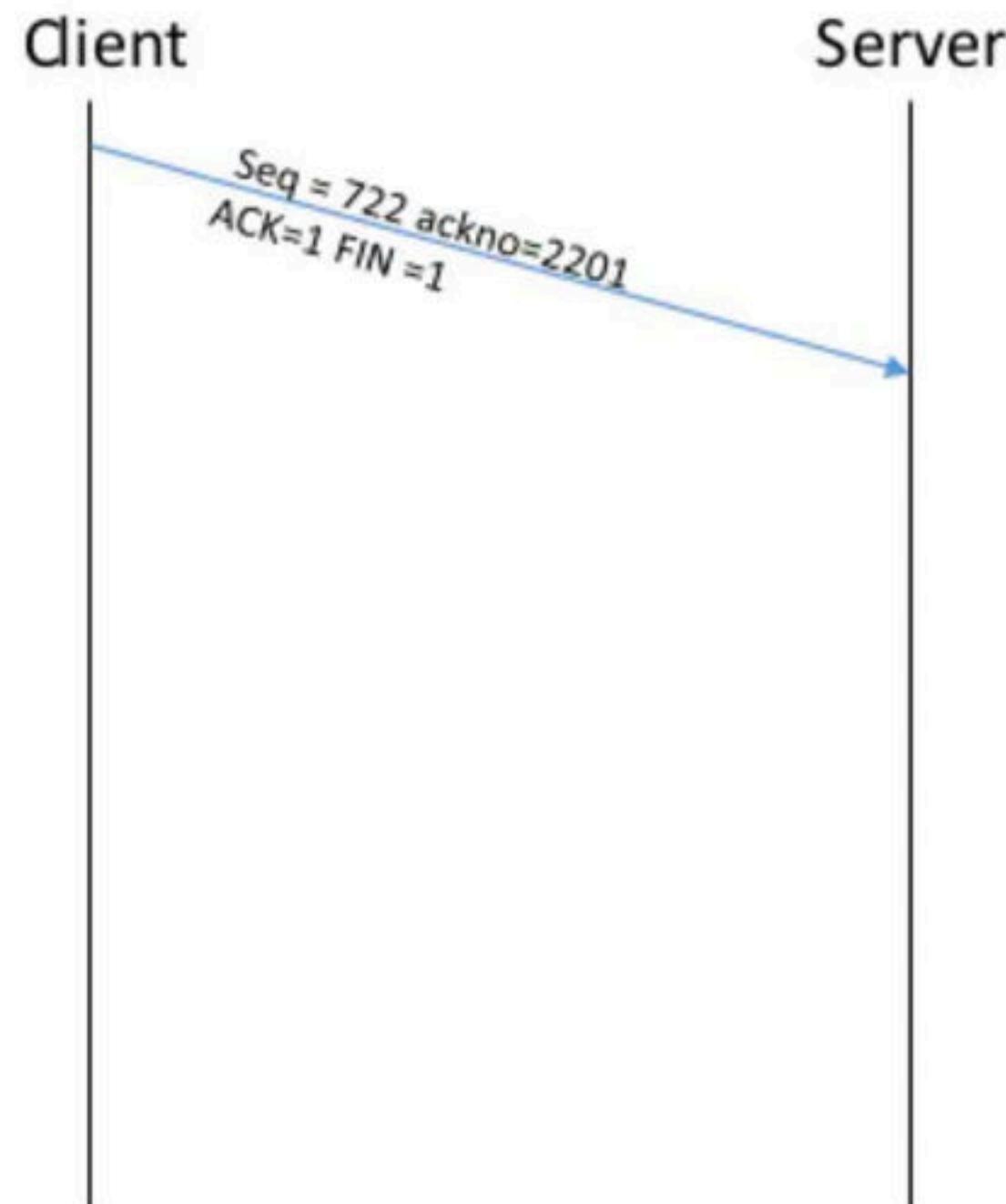


## CONNECTION TERMINATION

Consider-

There is a well established TCP connection between the client and server.

Client wants to terminate the connection.



### Step-01:

For terminating the connection,

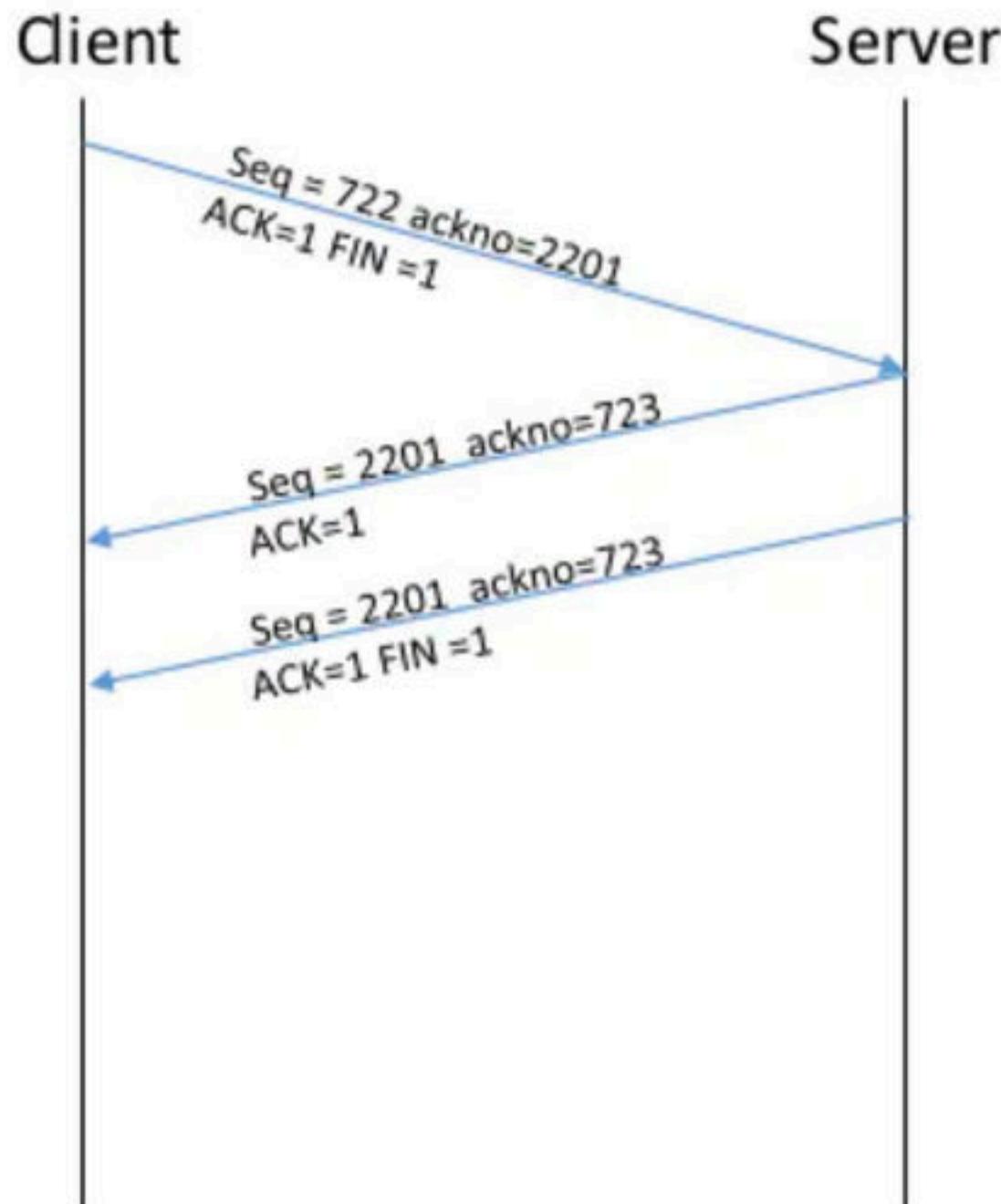
- Client sends a FIN segment to the server with FIN bit set to 1.
- Client enters the **FIN\_WAIT\_1 state**.
- Client waits for an acknowledgement from the server.

## CONNECTION TERMINATION

### Step-02:

After receiving the FIN segment,

- Server frees up its buffers.
- Server sends an acknowledgement to the client.
- Server enters the CLOSE\_WAIT state.



### Step-03:

After receiving the acknowledgement, client enters the FIN\_WAIT\_2 state.

For terminating the connection,

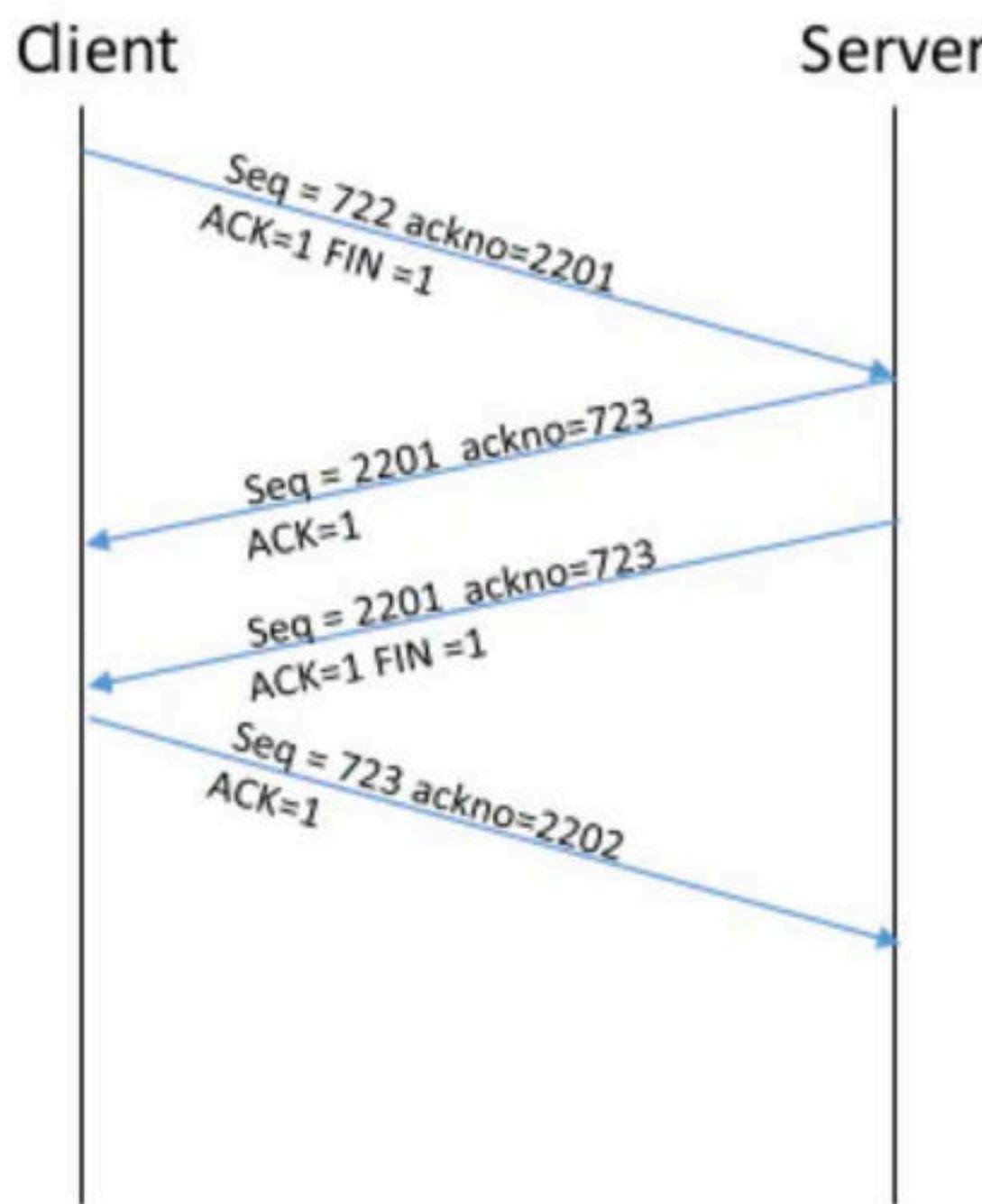
- Server sends a FIN segment to the client with FIN bit set to 1.
- Server waits for an acknowledgement from the client.

## CONNECTION TERMINATION

### Step-04:

After receiving the FIN segment,

- Client frees up its buffers.
- Client sends an acknowledgement to the server (not mandatory).
- Client enters the TIME\_WAIT state.



# Computer Networks

TCP header Part 4

## PSH Bit-

PSH bit is used to push the entire buffer immediately to the receiving application.

When PSH bit is set to 1,

- All the segments in the buffer are immediately pushed to the receiving application.
- No wait is done for filling the entire buffer.
- This makes the entire buffer to free up immediately.

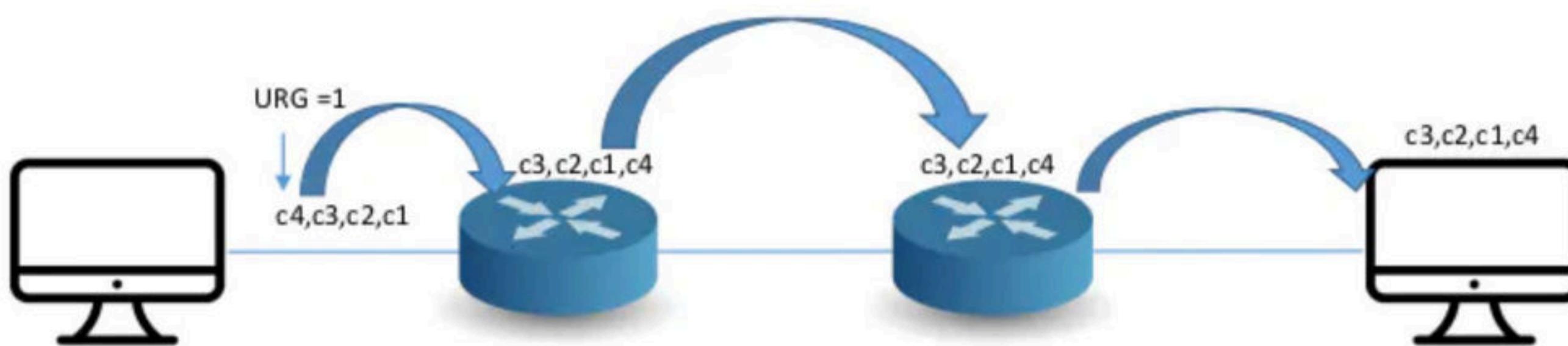
Useful in case of chat applications

## URG Bit-

URG bit is used to treat certain data on an urgent basis.

When URG bit is set to 1,

It indicates the receiver that certain amount of data within the current segment is urgent.



## Urgent Pointer-

- Urgent pointer is a 16 bit field.
- It indicates how much data in the current segment counting from the first data byte is urgent.
- Urgent pointer added to the sequence number indicates the end of urgent data byte.
- This field is considered valid and evaluated only if the URG bit is set to 1.

Number of urgent bytes = Urgent pointer + 1

End of urgent byte  
= Sequence number of the first byte in the segment + Urgent pointer

## **RST Bit-**

RST bit is used to reset the TCP connection.

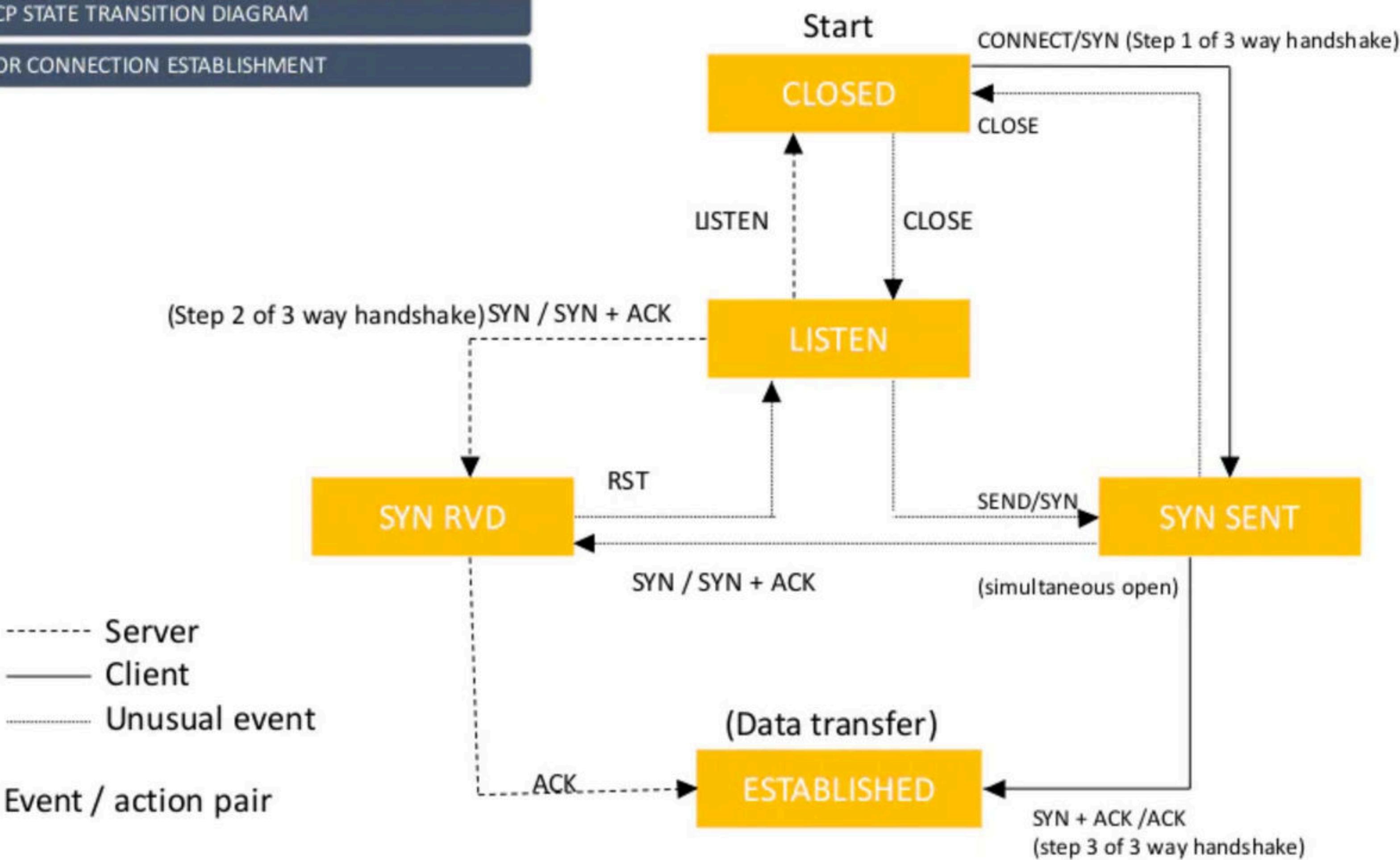
When RST bit is set to 1,

- It indicates the receiver to terminate the connection immediately.
- It causes both the sides to release the connection and all its resources abnormally.
- The transfer of data ceases in both the directions.
- It may result in the loss of data that is in transit.

This is used only when-

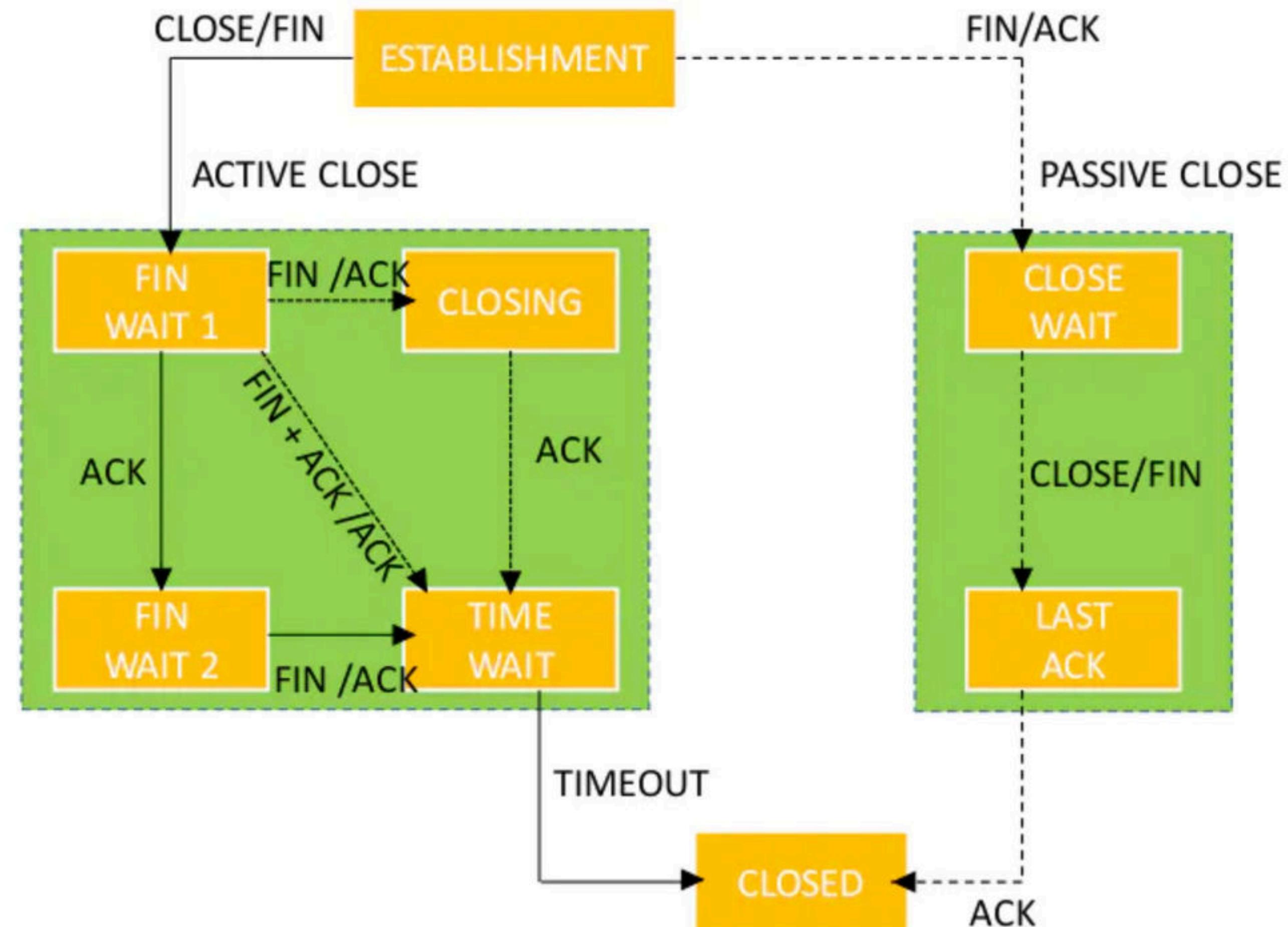
- There are unrecoverable errors.
- There is no chance of terminating the TCP connection normally.

TCP STATE TRANSITION DIAGRAM  
FOR CONNECTION ESTABLISHMENT



## TCP STATE TRANSITION DIAGRAM

## FOR CONNECTION TERMINATION

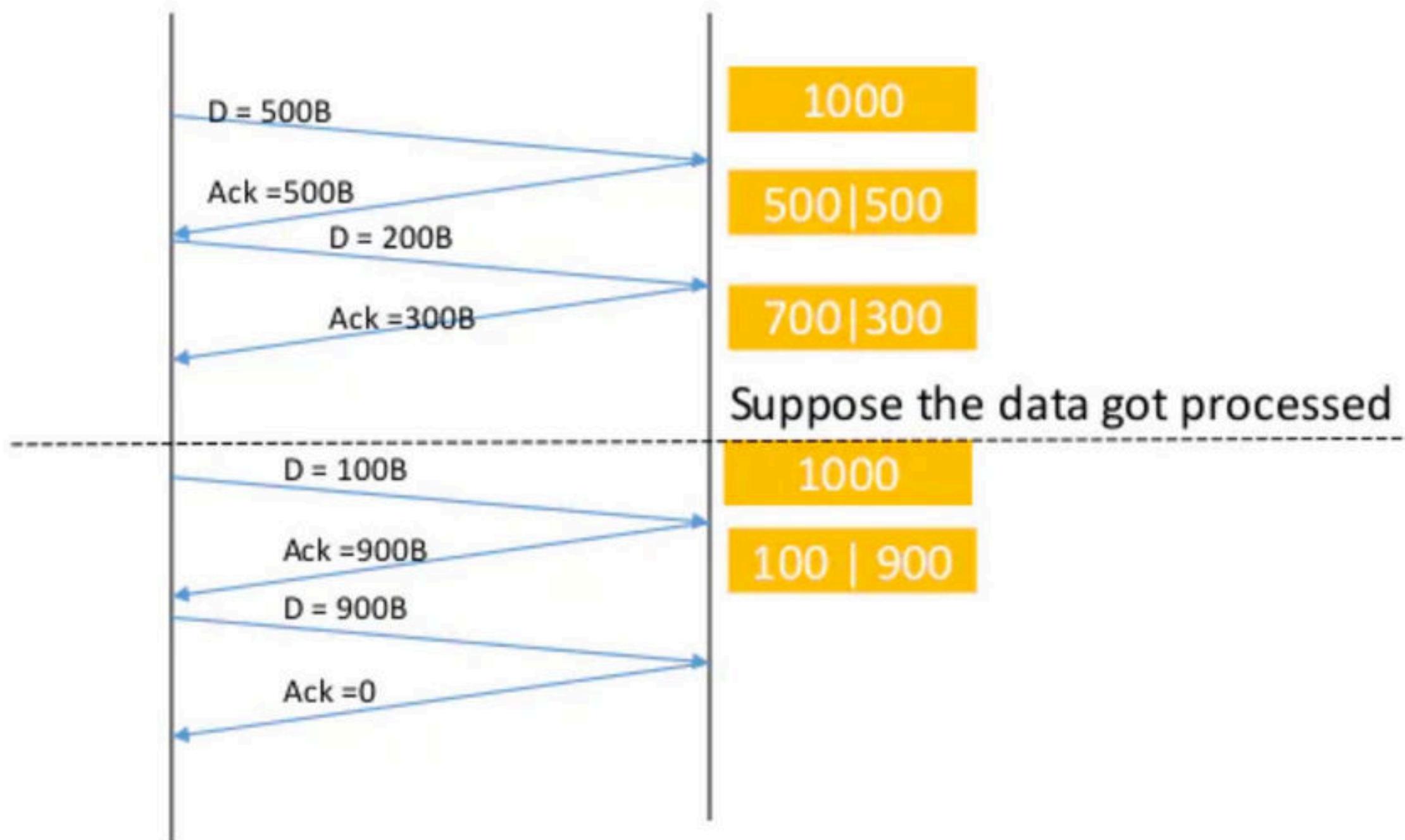


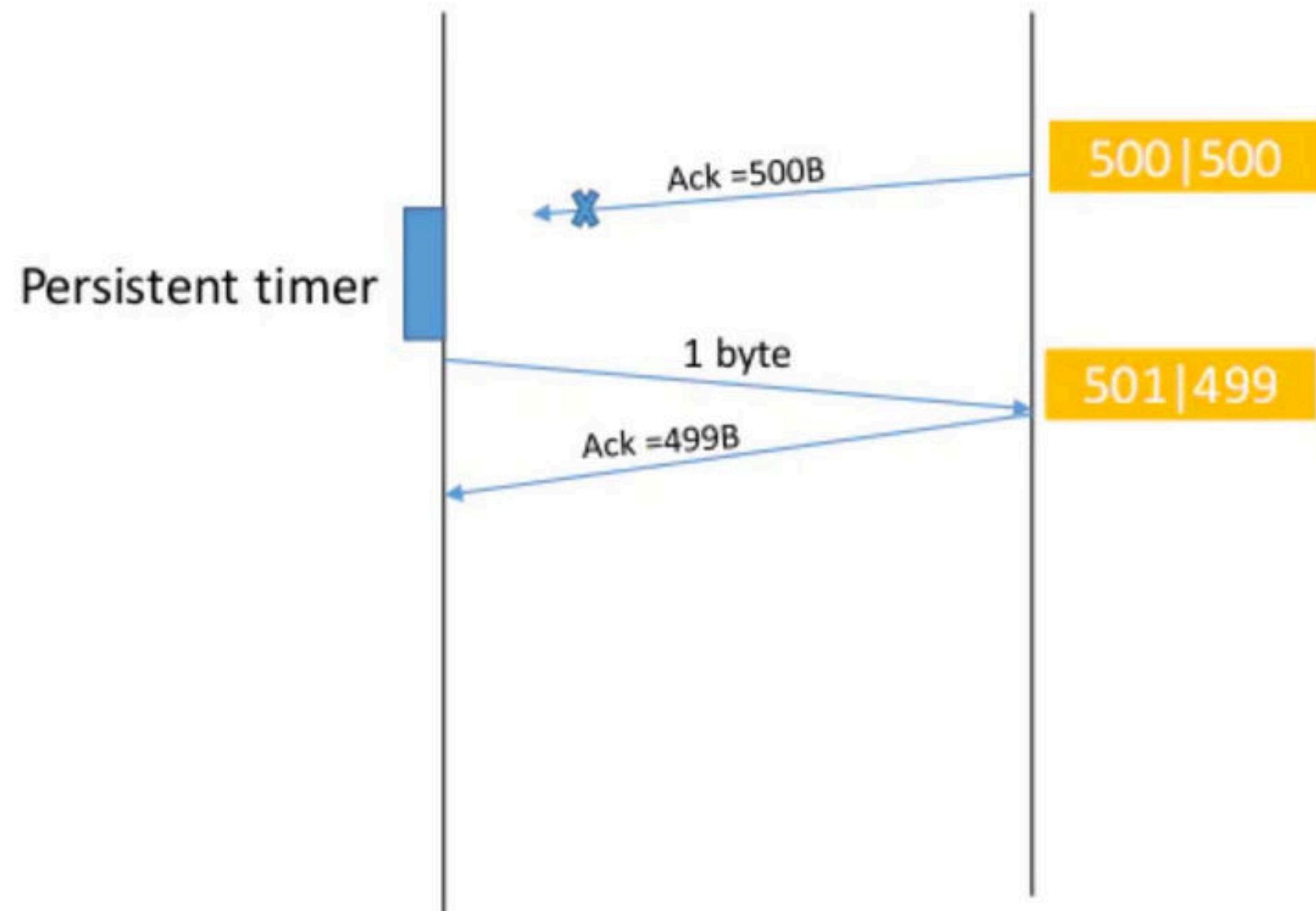
# Computer Networks

TCP header part 5

## Window Size

- Window size is a 16 bit field.
- It contains the size of the receiving window of the sender.
- It advertises how much data (in bytes) the sender can receive without acknowledgement.
- Thus, window size is used for **Flow Control**.





Consider the following situation-  
Sender receives an acknowledgment from the receiver with zero window size.  
This indicates the sender to wait.  
Later, receiver updates the window size to 500B and sends the segment with the update to the sender.  
This segment gets lost.  
Now, both sender and receiver keeps waiting for each other to do something.  
To deal with such a situation, TCP uses a persistent timer.

## Checksum

Checksum is a 16 bit field used for error control.

It verifies the integrity of data in the TCP payload.

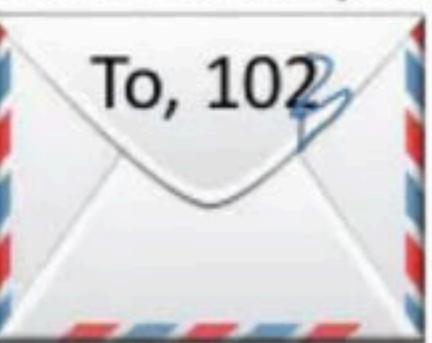
Sender adds CRC checksum to the checksum field before sending the data.

Receiver rejects the data that fails the CRC check.

Understanding with an example



Got damaged  
While transporting



Letter delivered to wrong house

## Checksum

Checksum is a 16 bit field used for error control.

It verifies the integrity of data in the TCP payload.

Sender adds CRC checksum to the checksum field before sending the data.

Receiver rejects the data that fails the CRC check.



Writing the delivery address  
Inside the letter too



## Options

Options field is used for several purposes.

The size of options field vary from 0 bytes to 40 bytes.

Options field is generally used for the following purposes-

1. Time stamp
2. Window size extension
3. Parameter negotiation
4. Padding

## **Time Stamp**

When wrap around time is less than life time of a segment,

Multiple segments having the same sequence number may appear at the receiver side.

This makes it difficult for the receiver to identify the correct segment.

If time stamp is used, it marks the age of TCP segments.

Based on the time stamp, receiver can identify the correct segment

## **Window Size Extension**

Options field may be used to represent a window size greater than 16 bits.

Using window size field of TCP header, window size of only 16 bits can be represented.

If the receiver wants to receive more data, it can advertise its greater window size using this field.

The extra bits are then appended in Options field.

## **Parameter Negotiation**

Options field is used for parameters negotiation.

Example- During connection establishment,

Both sender and receiver have to specify their maximum segment size.

To specify maximum segment size, there is no special field.

So, they specify their maximum segment size using this field and negotiates.

## **Padding**

Addition of dummy data to fill up unused space in the transmission unit and make it conform to the standard size is called as padding.

Options field is used for padding.

My philosophy

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STUDENTS ARE GODS

