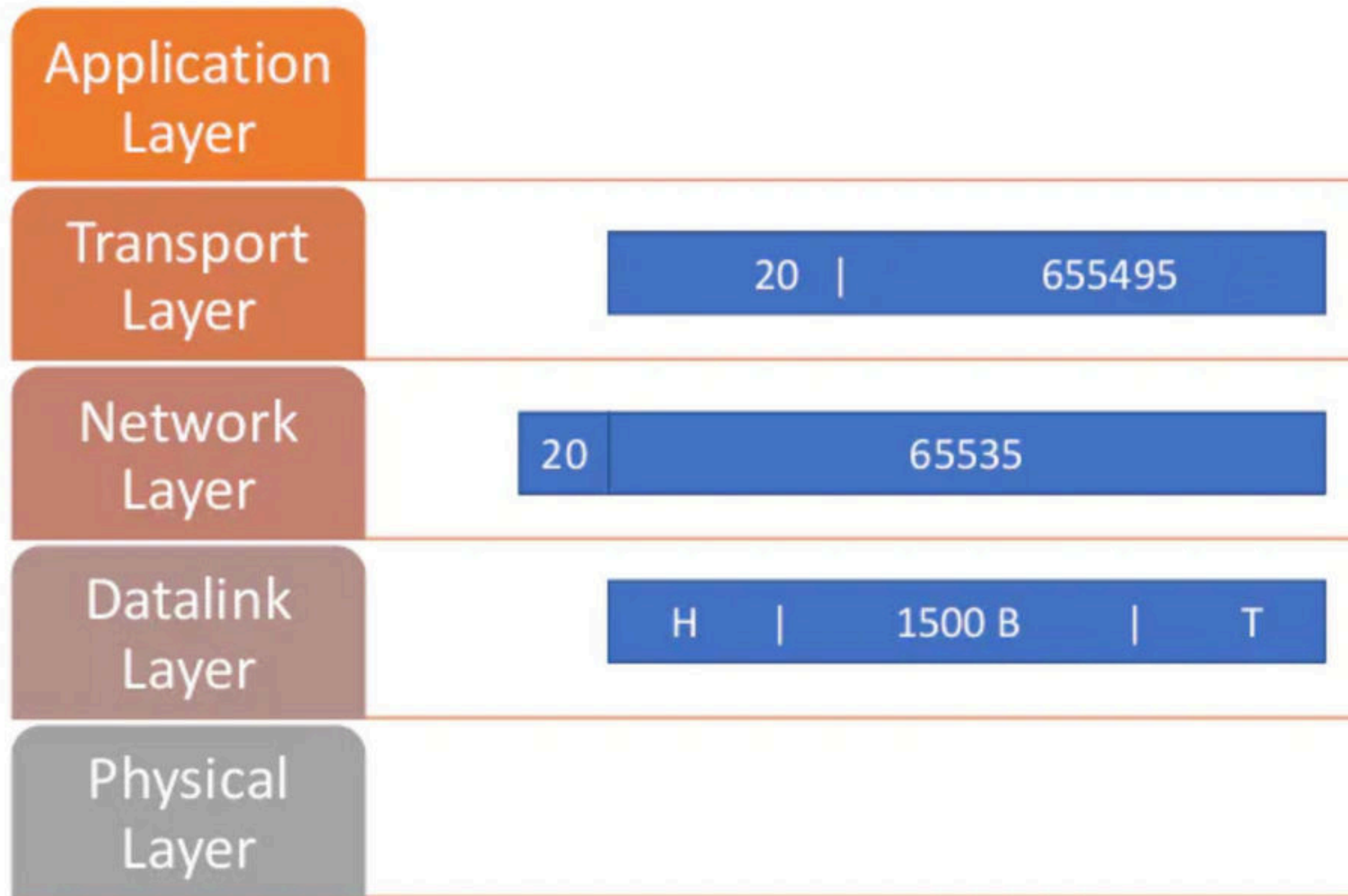|	
Application Layer	Message
Transport Layer	Segment - Segmentation
Network Layer	Packet - Fragmentation
Datalink Layer	Frame - Framing
Physical Layer	Single PDU

Example: Segmentation and Fragmentation

SEGMENTATION AND FRAGMENTATION

This occurs during the original creation of the packets when a set of data doesn't fit within the "Maximum Segment Size (MSS)".
The data is then divided into multiple segments referred as "Protocol Data Unit". This process is known as **Segmentation.**

In order to avoid Fragmentation (which we will see further) , note that
(Number of bytes in the data segment + the header) < MTU

Fragmentation occurs during the original creation of frames where the network layer must send packets down to the Data Link Layer for transmission. Some Data Link Layer technologies have limits on the length of the data that can be sent. In short some links have smaller MTU (Maximum Transmission Unit).
If the packet that is to be sent is larger than the MTU then it is divided into pieces.
This process is known as fragmentation.
These pieces are reassembled once they arrive at the network layer of the destination.
As mentioned earlier Fragmentation can be avoided if,
(Number of bytes in the data segment + the header) < MTU

Computer Networks

Reassembly Algorithm

Reassembly Algorithm

Receiver applies the following steps for reassembly of all the fragments-
1. It identifies whether datagram is fragmented or not using MF bit and Fragment offset field.

2. It identifies all the fragments belonging to the same datagram using identification field.

3. It identifies the first fragment. Fragment with offset field value = 0 is the first fragment.

4. It identifies the subsequent fragments using total length, header length and fragment offset.

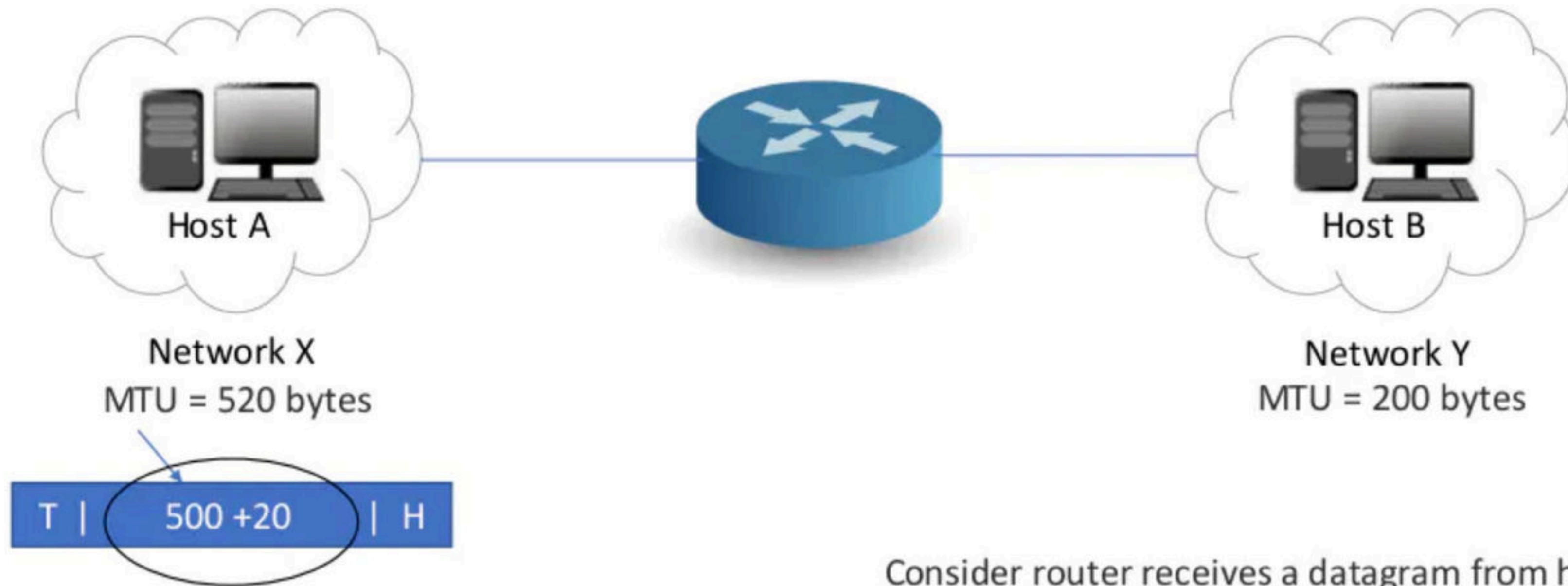5. It repeats step-04 until MF bit = 0.

Computer Networks

Fragmentation

Lets us discuss some examples of IP fragmentation to understand how the fragmentation is actually carried out.

EXAMPLE 1

Host A wants to send a message to host B

Network X
MTU = 520 bytes

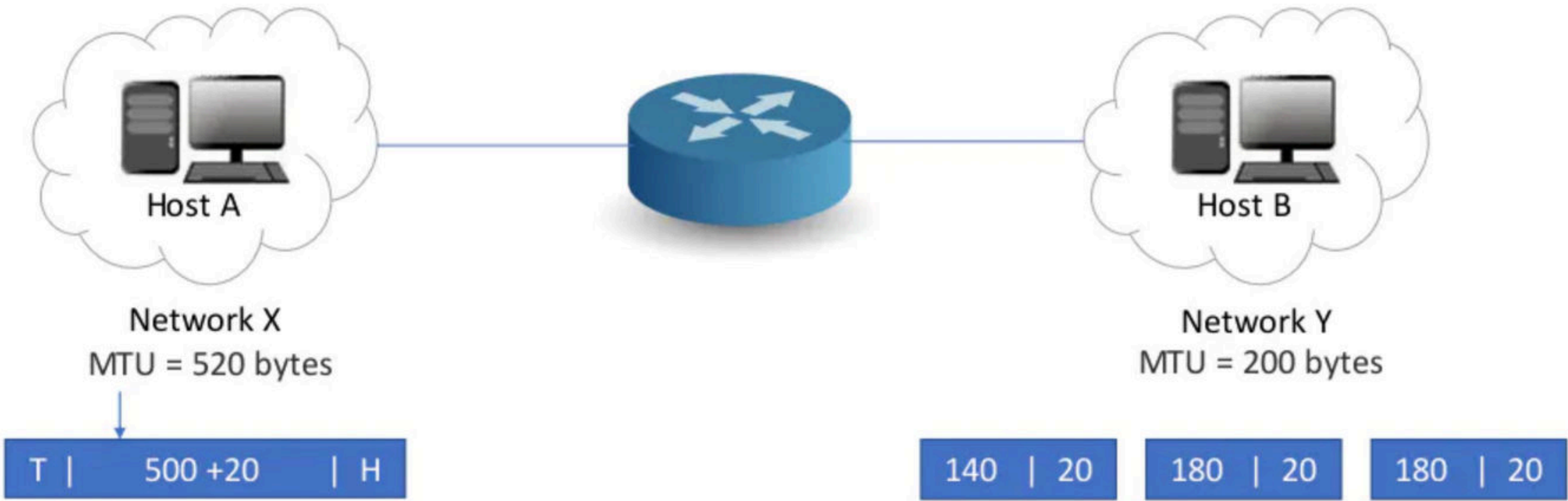Network Y
MTU = 200 bytes

T | 500 +20 | H

Consider router receives a datagram from host A having-
Header length = 20 bytes
Payload length = 500 bytes
Total length = 520 bytes

Lets us discuss some examples of IP fragmentation to understand how the fragmentation is actually carried out.

EXAMPLE 1

Host A wants to send a message to host B

Host A

Network X
MTU = 520 bytes

| T | 500 +20 | H |

Host B

Network Y
MTU = 200 bytes

| 140 | 20 | 180 | 20 | 180 | 20 |

Router decides the amount of data that it should transmit in each fragment.

•It is not compulsory for the last fragment to contain the amount of data that is a multiple of 8.
•This is because it does not have to decide the fragment offset value for any other fragment.

Host A

Host B

Network X
MTU = 520 bytes
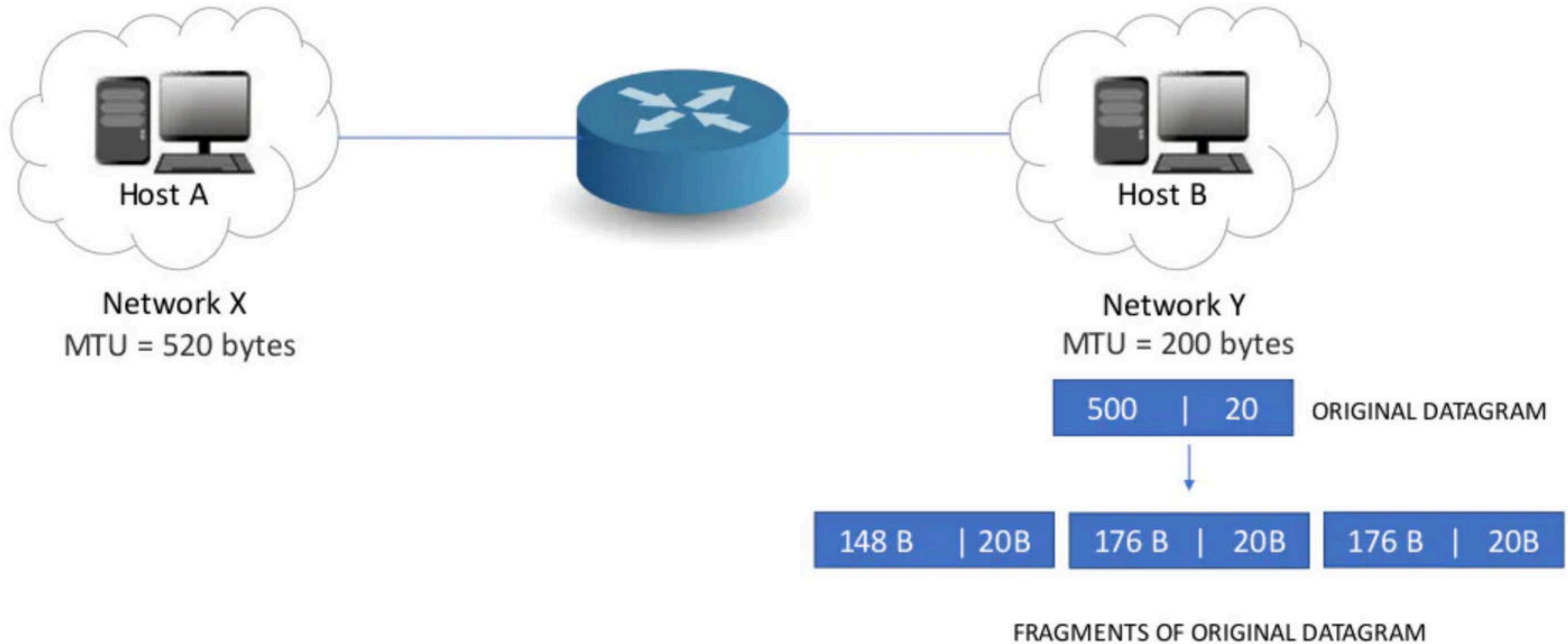
Network Y
MTU = 200 bytes

500 +20
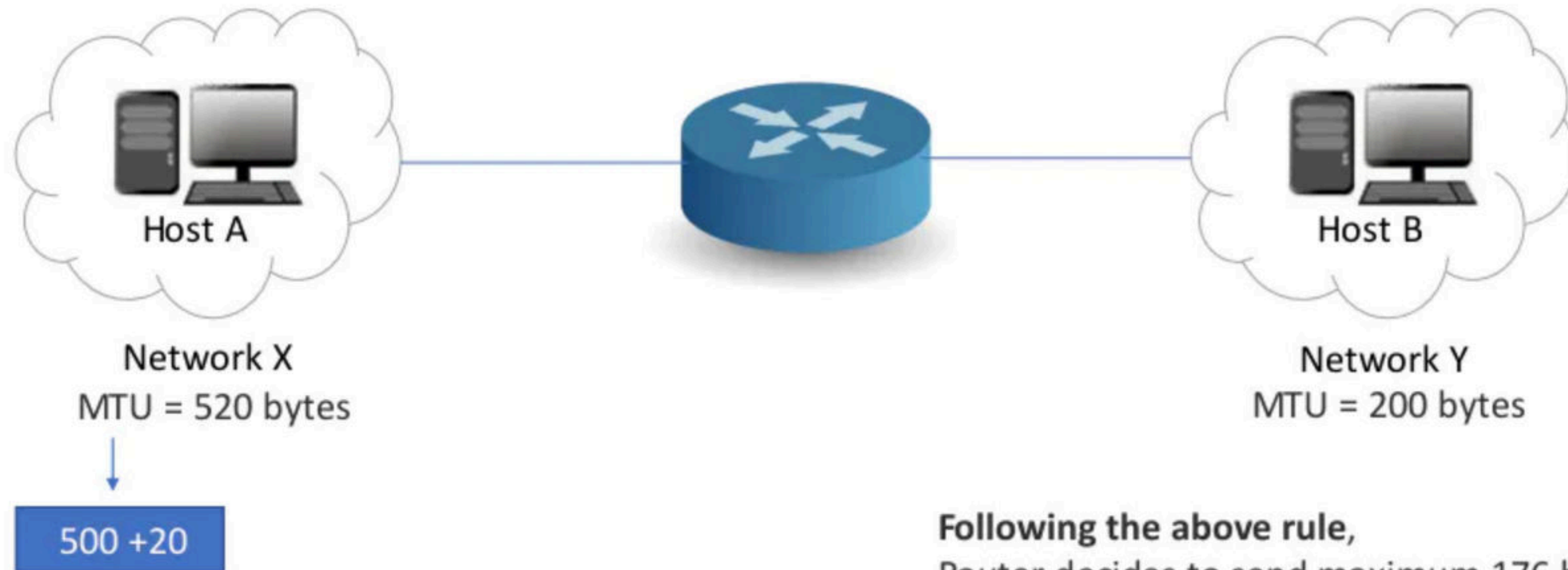
Following the above rule,
Router decides to send maximum 176 bytes of data in one fragment.
This is because it is the greatest value that is a multiple of 8 and less than MTU.

Router creates three fragments of the original datagram where-

First fragment contains the data = 176 bytes

Second fragment contains the data = 176 byes

Third fragment contains the data = 148 bytes

Host A

Network X
MTU = 520 bytes

Host B

Network Y
MTU = 200 bytes

| 500 | 20 | ORIGINAL DATAGRAM |

| 148 B | 20B | 176 B | 20B | 176 B | 20B |

FRAGMENTS OF ORIGINAL DATAGRAM

The information contained in the IP header of each fragment is-

Header Information Of 1st Fragment-

• Header length field value = 20 / 4 = 5
• Total length field value = 176 + 20 = 196
• MF bit = 1
• Fragment offset field value = 0
• Header checksum is recalculated.
• Identification number is same as that of original datagram.

Header Information Of 2nd Fragment-

• Header length field value = 20 / 4 = 5
• Total length field value = 176 + 20 = 196
• MF bit = 1
• Fragment offset field value = 176 / 8 = 22
• Header checksum is recalculated.
• Identification number is same as that of original datagram.

Header Informtion Of 3rd Fragment-

• Header length field value = 20 / 4 = 5
• Total length field value = 148 + 20 = 168
• MF bit = 0
• Fragment offset field value = (176 + 176) / 8 = 44
• Header checksum is recalculated.
• Identification number is same as that of original datagram.
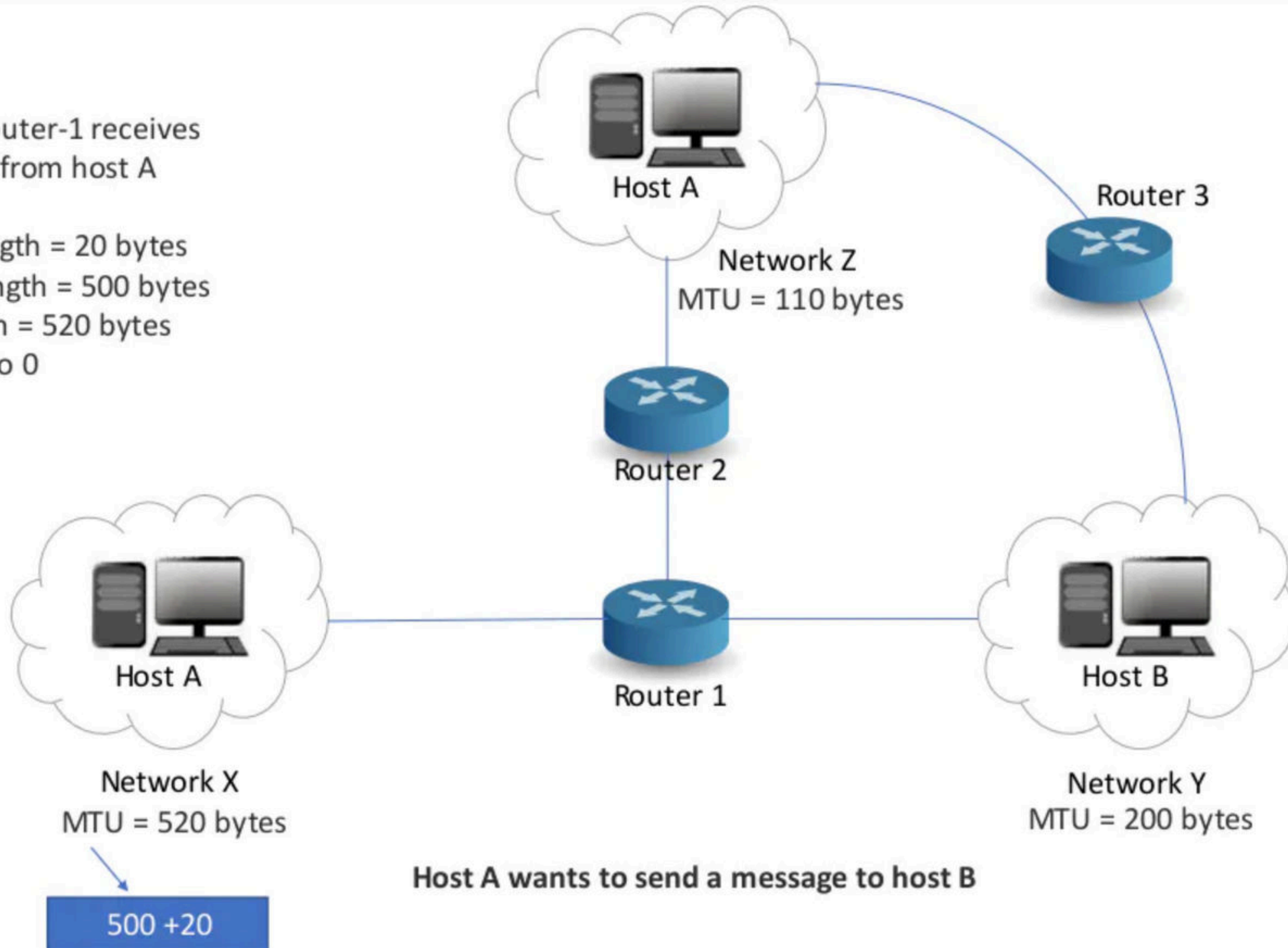
Router transmits all the fragments.

At destination side,
• Receiver receives 3 fragments of the datagram.
• Reassembly algorithm is applied to combine all the fragments to obtain the original datagram.

EXAMPLE 2

Consider Router-1 receives
a datagram from host A
having-
• Header length = 20 bytes
• Payload length = 500 bytes
• Total length = 520 bytes
• DF bit set to 0

Host A

Network Z
MTU = 110 bytes

Router 3

Router 2

Host A

Router 1

Host B

Network X
MTU = 520 bytes

Network Y
MTU = 200 bytes

500 +20

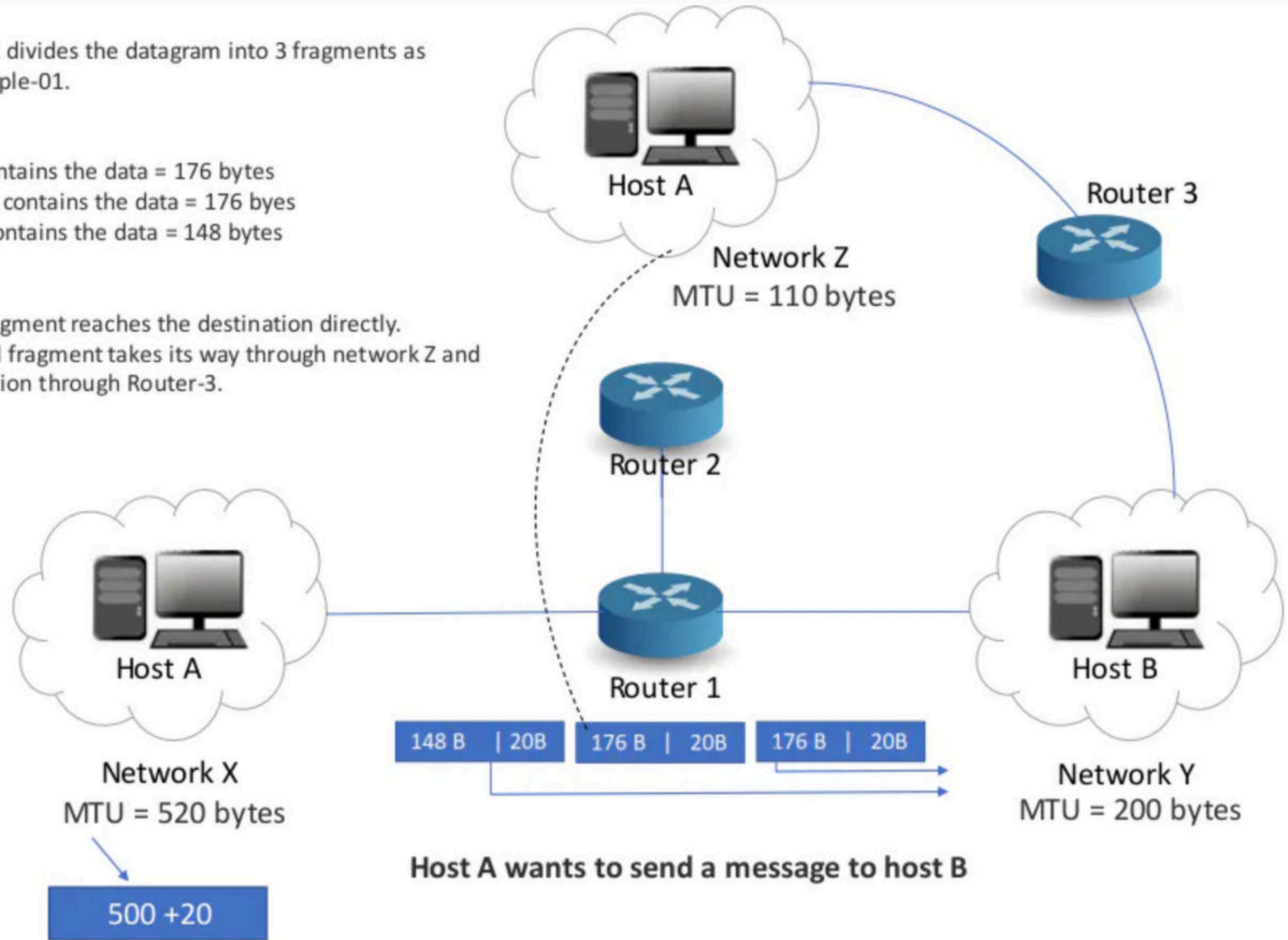**Host A wants to send a message to host B**

Consider Router-1 divides the datagram into 3 fragments as discussed in Example-01.

Then,
• First fragment contains the data = 176 bytes
• Second fragment contains the data = 176 byes
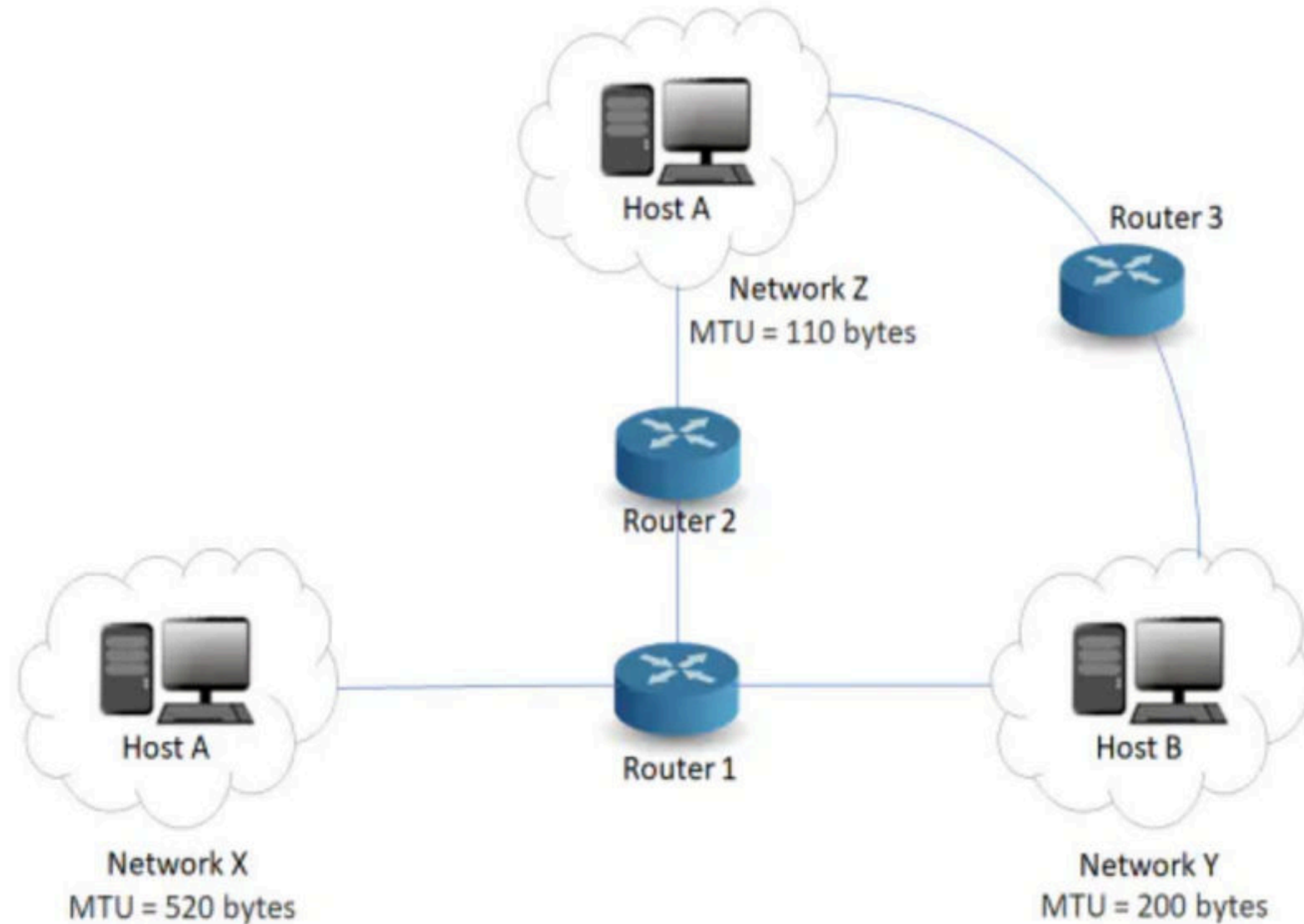• Third fragment contains the data = 148 bytes

Now, consider-
• First and third fragment reaches the destination directly.
• However, second fragment takes its way through network Z and reach the destination through Router-3.

Host A

Network Z
MTU = 110 bytes

Router 3

Router 2

Router 1

Host A

Host B

Network X
MTU = 520 bytes

| 148 B | 20B | | 176 B | 20B | | 176 B | 20B |

Network Y
MTU = 200 bytes

500 +20

Host A wants to send a message to host B

Now, let us discuss the journey of fragment-2 and how it finally reaches the destination.

Router-2 receives a datagram (second fragment of original datagram) where-
- Header length = 20 bytes
- Payload length = 176 bytes
- Total length = 196 bytes
- DF bit set to 0

Host A

Router 3

Network Z
MTU = 110 bytes

Router 2

Router 1

Host A

Host B

Network X
MTU = 520 bytes

Network Y
MTU = 200 bytes

Step-01:

Router-2 examines the datagram and finds-
- Size of the datagram = 196 bytes
- Destination is network Z having MTU = 110 bytes
- DF bit is set to 0

Router-2 concludes-
- Size of the datagram is greater than MTU.
- So, it will have to divide the datagram into fragments.
- DF bit is set to 0.
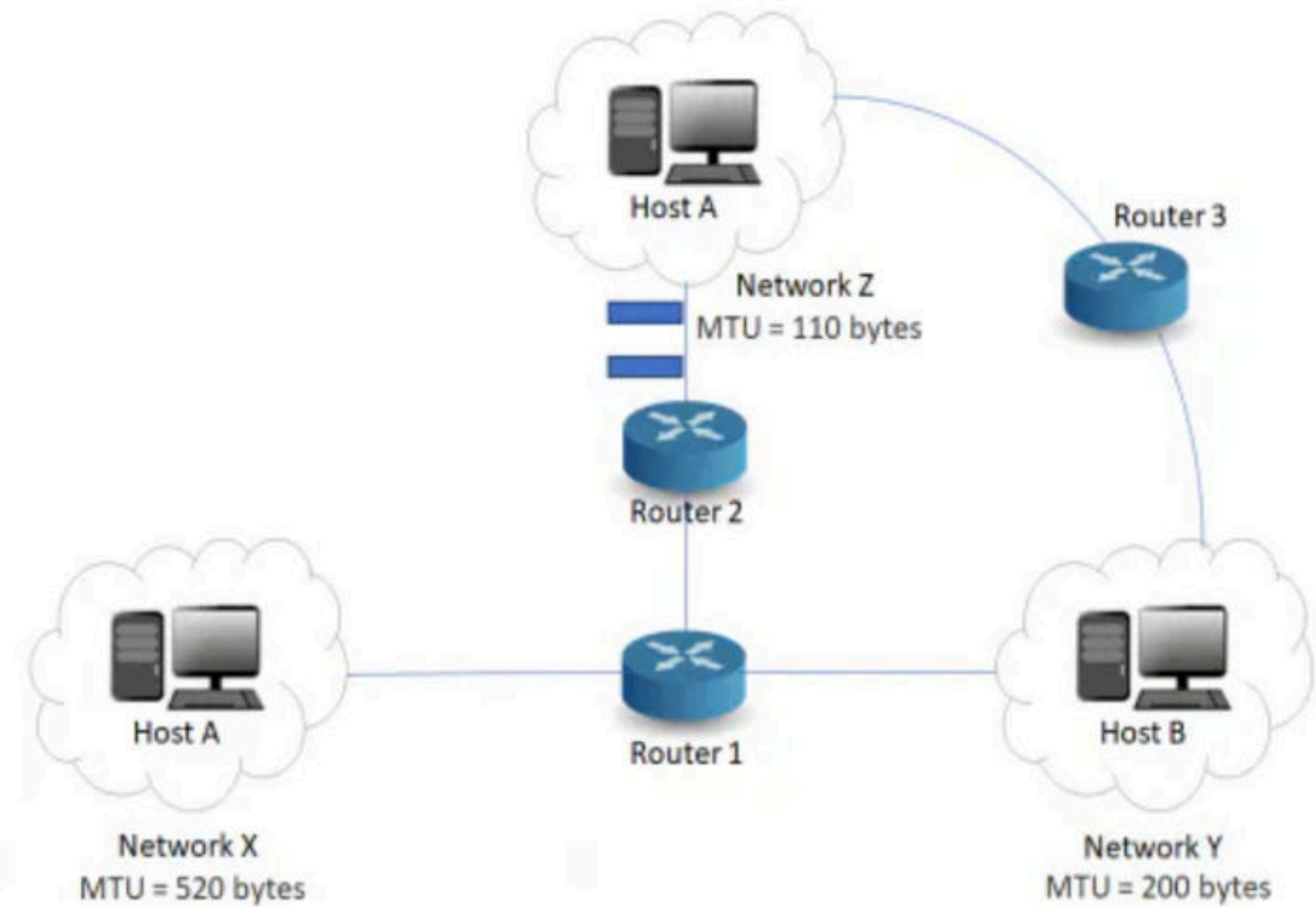- So, it is allowed to create fragments of the datagram.

Step-02:

Router-2 decides the amount of data that it should transmit in each fragment.
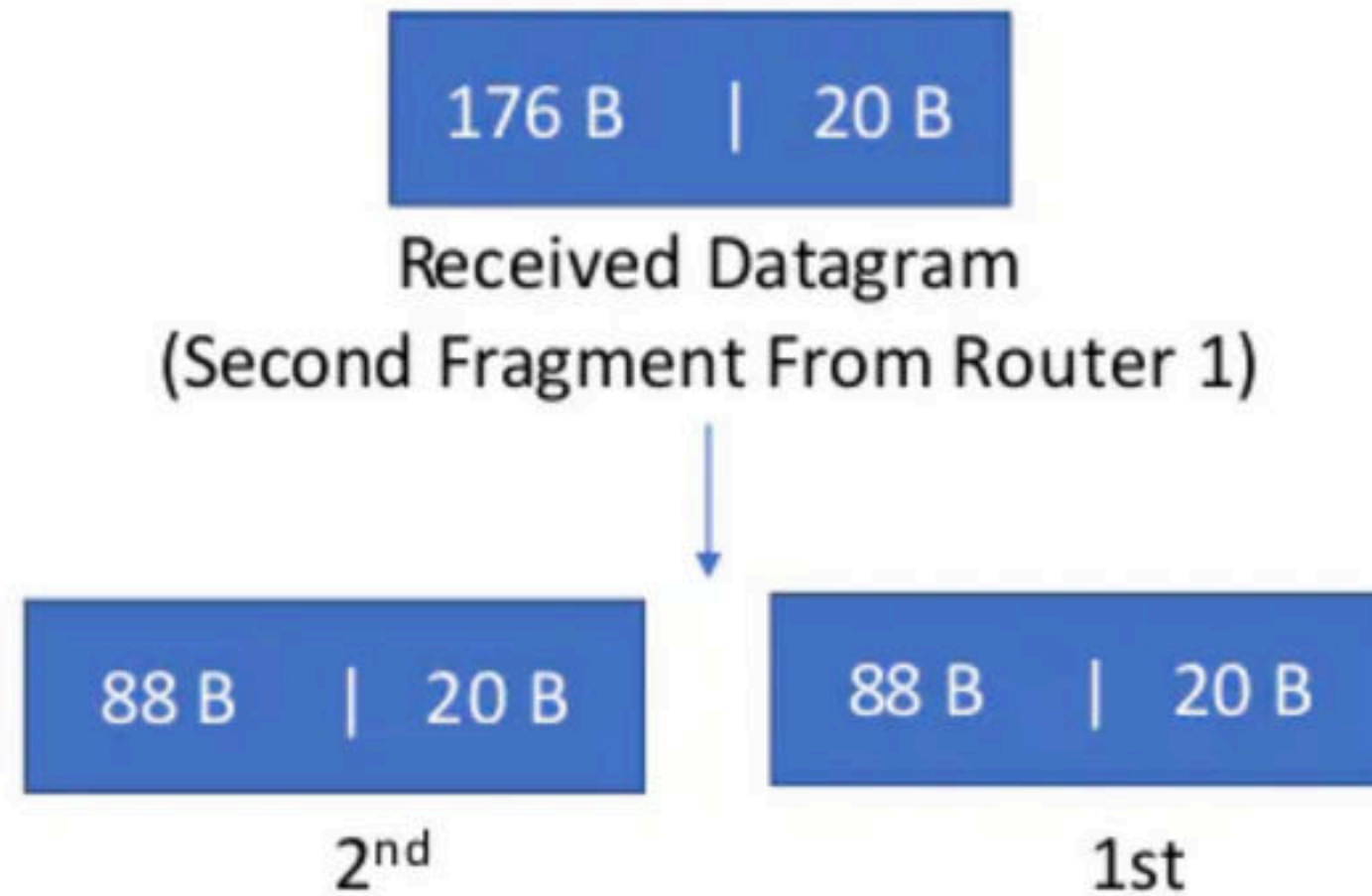
Router-2 knows-
- MTU of the destination network = 110 bytes.
- So, maximum total length of any fragment can be only 110 bytes.
- Out of 110 bytes, 20 bytes will be taken by the header.
- So, maximum amount of data that can be sent in any fragment = 90 bytes.

Following the rule,
- Router-2 decides to send maximum 88 bytes of data in one fragment.
- This is because it is the greatest value that is a multiple of 8 and less than MTU.

Host A

Router 3

Network Z
MTU = 110 bytes

Router 2

Host A

Router 1

Host B

Network X
MTU = 520 bytes

Network Y
MTU = 200 bytes

Router-2 creates two fragments of the received datagram where-

Received Datagram
(Second Fragment From Router 1)

2nd

1st

The information contained in the IP header of each fragment is-

Header Information Of 1st Fragment-

- Header length field value = 20 / 4 = 5
- Total length field value = 88 + 20 = 108
- MF bit = 1
- Fragment offset field value = 176 / 8 = 22
- Header checksum is recalculated.
- Identification number is same as that of original datagram.

<u>NOTE-</u>

- This fragment is **NOT** the first fragment of the original datagram.
- It is the first fragment of the datagram received by Router-2.
- The datagram received by Router-2 is the second fragment of the original datagram.
- This datagram will serve as the second fragment of the original datagram.
- Therefore, fragment offset field is set according to the first fragment of the original datagram.
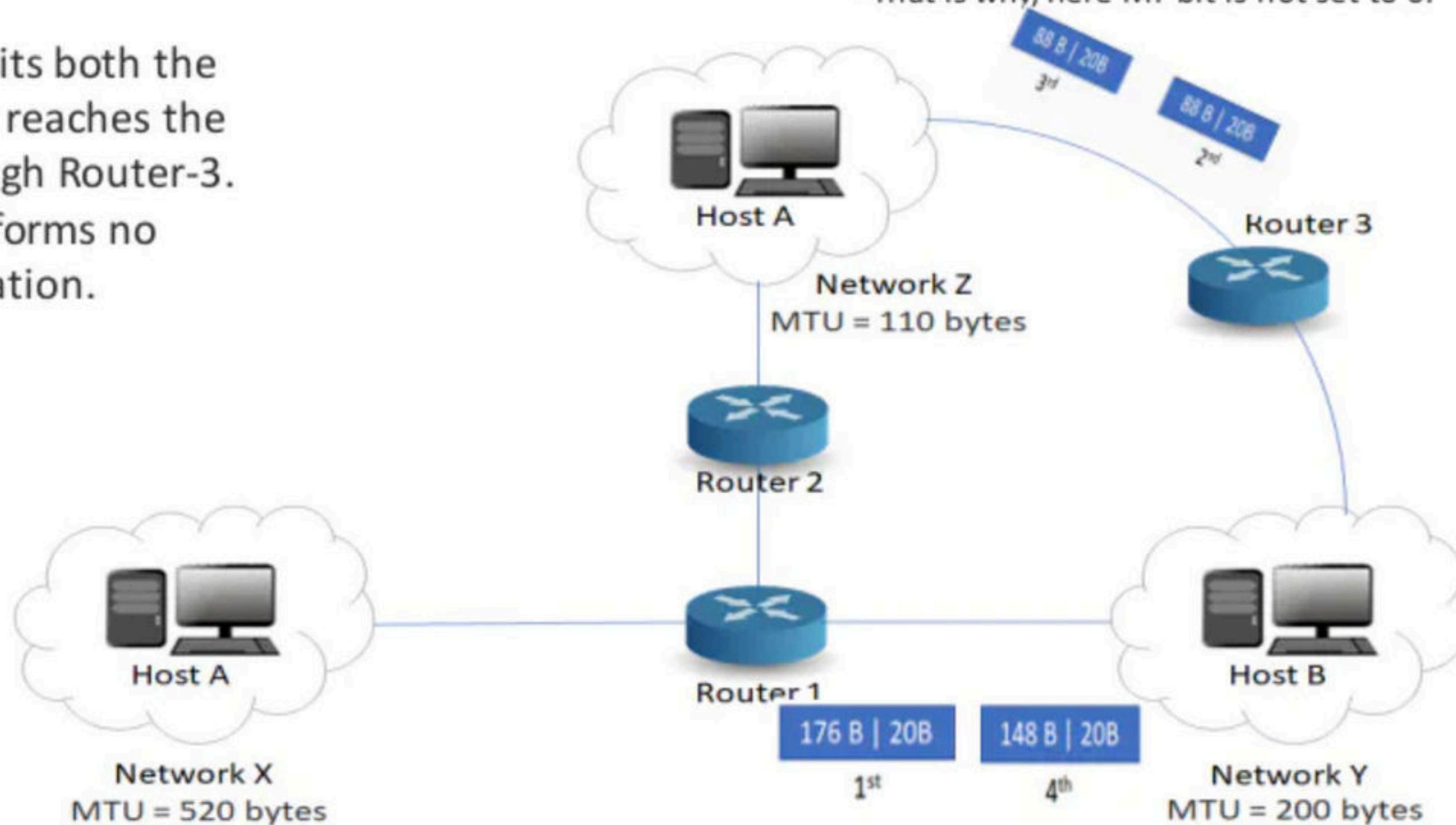
Header Information Of 2nd Fragment-

- Header length field value = 20 / 4 = 5
- Total length field value = 88 + 20 = 108
- MF bit = 1
- Fragment offset field value = (176 + 88) / 8 = 33
- Header checksum is recalculated.
- Identification number is same as that of original datagram.

Router-2 transmits both the fragments which reaches the destination through Router-3. Router-3 performs no fragmentation.

NOTE-

- This fragment is **NOT** the last fragment of the original datagram.
- It is the last fragment of the datagram received by Router-2.
- The datagram received by Router-2 is the second fragment of the original datagram.
- This datagram will serve as the third fragment of the original datagram.
- There is another fragment of the original datagram that follows it.
- That is why, here MF bit is not set to 0.

Host A

Network Z
MTU = 110 bytes

Router 2

Router 3

88 B | 20B
3rd

88 B | 20B
2nd

Host A

Network X
MTU = 520 bytes

Router 1

176 B | 20B
1st

148 B | 20B
4th

Host B

Network Y
MTU = 200 bytes

At destination side,

•Receiver receives 4 fragments of the datagram.

•Reassembly algorithm is applied to combine all the fragments to obtain the original datagram.

148 B | 20B	88 B | 20B	88 B | 20B	176 B | 20B
4th	3rd	2nd	1st
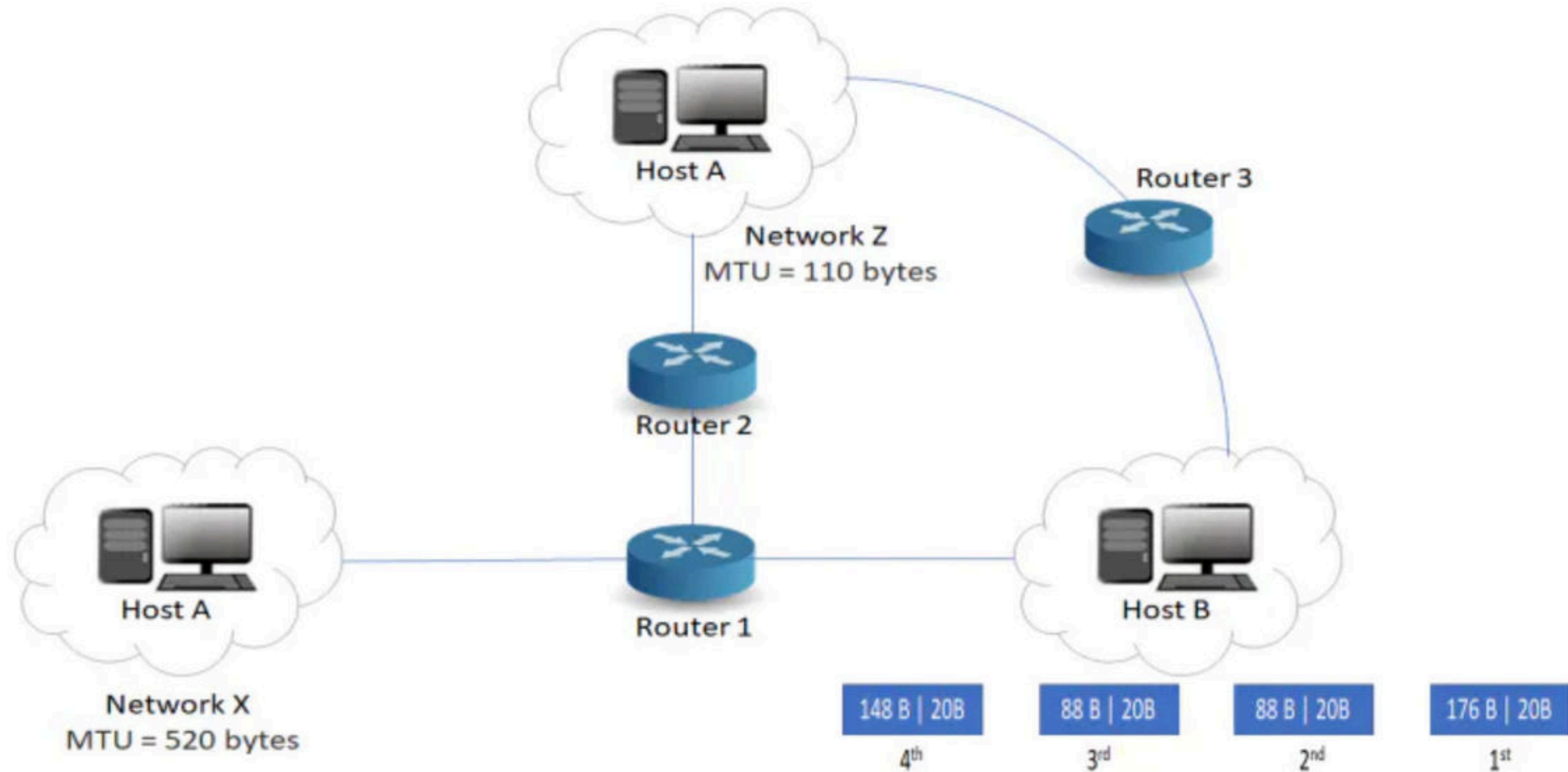
Fragment Offset field value for the next subsequent fragment
= (Payload length of the current fragment / 8) + Offset field value of the current fragment
= (Total length – Header length / 8) + Offset field value of the current fragment

Fragmentation Overhead

• Fragmentation of datagram increases the overhead.

• This is because after fragmentation, IP header has to be attached with each fragment.

Total Overhead
= (Total number of fragmented datagrams − 1) x size of IP header

Efficiency = Useful bytes transferred / Total bytes transferred

OR

Efficiency = Data without header / Data with header

Bandwidth Utilization or Throughput = Efficiency x Bandwidth

NOTE:

MF bit	Offset value	Represents
1	0	1st Fragment
1	!=0	Intermediate Fragment
0	!=0	Last Fragment
0	0	No Fragmentation

Reassembly is not done at the routers because-

All the fragments may not meet at the router.

Fragmented datagrams may reach the destination through independent paths.

There may be a need for further fragmentation.