Exploration: IP Datagram Fragmentation

Introduction

The modern internet has many legacy components and technologies. Datagrams must be routed through all of these systems. Given that some datagrams may be too large to traverse legacy networks, what can be done?

In this exploration we will examine:

- Frame Encapsulation
- Maximum Transmission Unit (MTU)
- IP Datagram Fragmentation

Frame Encapsulation

Whenever a datagram transits a physical network, it is encapsulated in a frame appropriate to that network. Each router in the path from the source to the destination will un-encapsulate the incoming datagram from the frame, and process the datagram to determine the next hop. It will then re-encapsulate the datagram in an outgoing frame appropriate for the next-hop network. That network may be a legacy system.

Every hardware technology specification includes the definition of the maximum size of the frame data. This is known as the maximum transmission unit (MTU). Any datagram encapsulated in a hardware frame must be smaller than the MTU for that hardware. As mentioned , the Internet has a variety of network technologies with different MTUs. What can be done to pass datagrams through these networks? There are two choices:

1. Choose to limit all datagrams to the smallest MTU available anywhere (inefficient)
2. Fragment datagrams into smaller datagrams and reassemble them later

Datagram Fragmentation

IPv4 will fragment datagrams. How is this done?

A router will detect if an inbound datagram is larger than the outbound network MTU. In this case, it is necessary to split the datagram into fragments that can traverse the outgoing link. Each fragment must be smaller than the MTU of the outbound network.

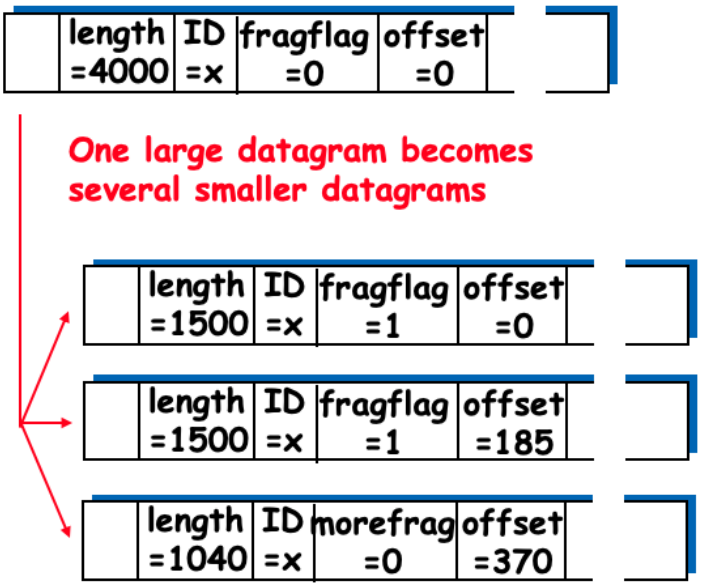
What do these fragments look like? Each fragment is itself an independent datagram. Each includes all the usual IP header fields which include:

- All fragments have the IDENTIFIER of the original datagram
- A 3-bit FLAGS field may indicate if datagram is a fragment (“more fragments” flag)
- 13-bit FRAGMENT OFFSET gives order of fragment in the original datagram
- If either “more fragments” flag is set, or if the offset is non-zero, then the datagram is a fragment.

Example

In our example, we have the following:

- 4000-byte datagram with minimum header size (20 bytes)
- MTU = 1500 bytes



One large datagram becomes three smaller ones, each with the same id and with a reassembly offset.

Step 1: Calculate the number of fragments

Because our original datagram has a header of 20 bytes, we need to subtract 20 from the total size to get the size of the payload. Thus the payload data of the original datagram is 3980 bytes.

Because each fragment has its own 20 byte header, we need to subtract 20 from the MTU of 1500 bytes. This gives us the payload data of each fragment: 1480 bytes.

Now we divide the size of the original payload by the fragment payload and take the ceiling (not round):

$$3980/1480 = 2.69$$
$$Ceiling\,(2.69) = 3\ fragments$$

Step 2: Calculate the amount of payload in each fragment

The first two fragments will each carry 1480 bytes. The last fragment will carry the remainder of 1020 bytes:

$$1480 + 1480 + 1020 = 3980$$

Step 3: Re-encapsulate and send

We now have all the information needed to create the headers, copy the payload data, and pass the three datagrams down to the Link-Layer.

Datagram Reassembly

Our three datagrams are enroute to the destination. Where should they be reassembled?

1. The next link
2. The next link with large enough MTU
3. The destination host

If you answered #3, you are correct. IPv4 datagrams are always reassembled at the destination host. There are several related reasons for this:

- The MTU's over the entire route may vary, which could cause fragmentation again.
- It is more efficient to keep the data fragmented until it reaches its destination.
- Routers already do a lot without adding the burden of reassembly.

For more on datagram fragmentation, be sure to watch the video lecture, then test your knowledge with the Self-Check exercises below.

Video Lecture

IP Fragmentation

(PDF (https://oregonstate.instructure.com/courses/1798856/files/83165050/download?wrap=1) (https://oregonstate.instructure.com/courses/1798856/files/83165050/download?wrap=1) |PPT (https://oregonstate.instructure.com/courses/1798856/files/83165060/download?wrap=1) (https://oregonstate.instructure.com/courses/1798856/files/83165060/download?wrap=1))

Self-Check Exercises

If a TCP segment has been fragmented (with header length = 20 bytes), where does the TCP header go?

- ○ It is duplicated in the payload of every fragment.
- ○ It is the header of the first fragmented IP datagram.
- ○ In the first 20 bytes of payload in the first fragmented IP datagram.

What is an MTU? What is a path MTU?

Turn

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