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Computer Networking and IT Security (INHN0012)

Tutorial 6

Problem 1 ARP and IP fragmentation

Figure 1.1 shows an arrangement of network components with their IP and MAC addresses. The two computers PC1 and PC2 use the respective local router as default gateway. PC1 sends an IP packet with 1000 B payload data to PC2. The MTU on the WAN link between R1 and R2 is 580 B. Within the local networks the usual Ethernet MTU of 1500 B applies.

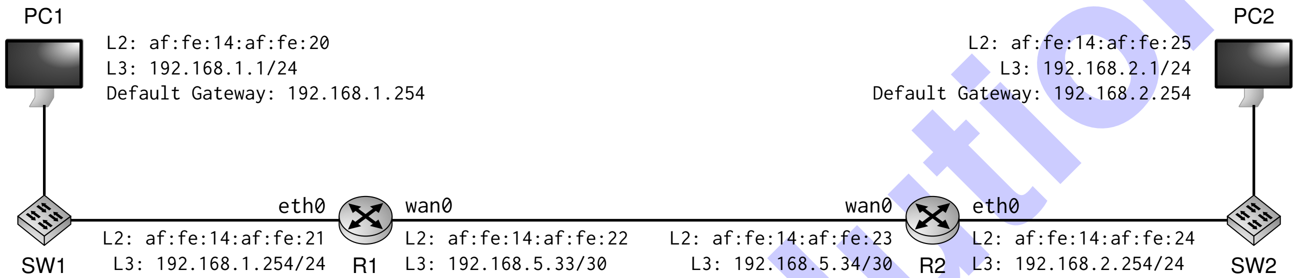


Figure 1.1: Network topology

In the following, the transfer of the packet with all necessary intermediate steps shall be traced. Assume initially that the ARP caches of all network components involved have been flushed.

a)* To what extent do the two switches SW1 and SW2 have an effect in this example?

The switches have no influence on the exchanged messages.Switches are usually transparent to the connected hosts.In particular, switches do not change the sender or recipient address.

b)* Into how many fragments must R1 break down the packet from PC1?

The MTU (Maximum Transmission Unit) is the maximum size of a packet on layer 3 incl. header. It is therefore exactly the same as the maximum size of the payload on layer 2. Knowing that an IP header is 20 B long (exception when using options), we get:

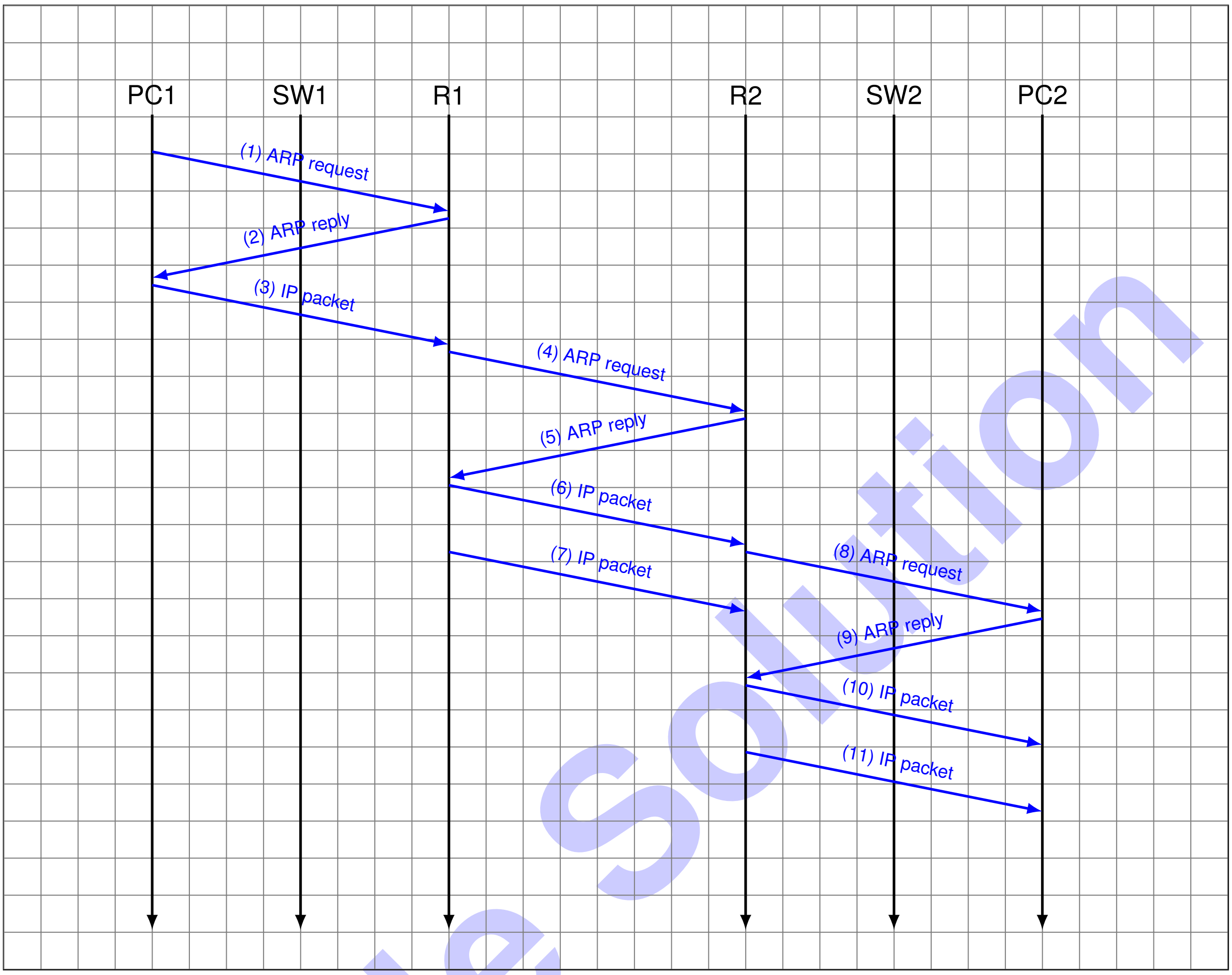
$$N = \left\lceil \frac{1000\,\mathrm{B}}{580\,\mathrm{B} - 20\,\mathrm{B}} \right\rceil = 2$$

c)* At what point in the network are the fragments reassembled?

Only the receiver, here PC2, reassembles the fragments.In fact, no other node can perform the reassembly, since the fragments represent individual and independent packets.
In particular, this means that they are routed independently and may therefore take different paths to the destination – of course, this is not seen from the simple example in Figure 1.1, where there is only one path between PC1 and PC2.

Sample Solution

d) Sketch a simple path-time diagram that considers **all frames** that need to be transferred on each link. **Name the type of frames replaced and number the frames (1,2,3,...).** (The diagram does not need to be to scale. Serialization times and propagation delays are to be ignored.)



At the end of this exercise sheet you will find preprinted forms for Ethernet header, ARP packets (header and payload) and IP header (more than needed). It is not necessary to fill in the header in binary. Just be sure to clearly mark the number base, e.g., `0x10` for hexadecimal or $63_{(10)}$ for decimal.

e) For each of the first three frames from subtask d), fill in an Ethernet header and the appropriate payload (ARP packet or IP header with indicated payload). Label the dashed box next to each header/packet with the frame number assigned in subtask d).

f) Fill in an Ethernet and IP header for each of the remaining frames that transport an IP payload. Label the dashed box next to each header with the frame number assigned in subtask d).

g)* Assume that PC1 and PC2 communicate via IPv6:

1. What impact would this have on switches SW1 and SW2?
2. In this case, would routers R1 and R2 also have to be IPv6-capable?
3. Where would the fragmentation of packets take place?

1. In the given case, none at all: switches work only with MAC addresses, which would not change (except for multicast, if applicable).
2. Yes, at least on the local interfaces `eth0`, because IPv6 and IPv4 are not compatible. Transporting IPv6 over IPv4 using GRE (General Routing Encapsulation) is theoretically possible, but not very useful or generally possible due to the non-injective mapping of IPv4 to IPv6.
3. Fragmentation would now take place directly at PC1, since IPv6 routers do not fragment at all.

Sample Solution

Problem 2 Packet Pair Probing

Packet Pair Probing is a method to determine the bandwidth of a link section by cleverly exploiting serialization and delay times. We will demonstrate this using the example network shown in Figure 2.1.
Nodes PC1 and PC4 are each connected to their routers via Ethernet with a data rate of 1 Gbit/s. However, the connection between routers R2 and R3 is significantly slower. This transmission rate r_{23} is to be determined by PC1 and PC4 by generating as little load as possible on the already slow connection.

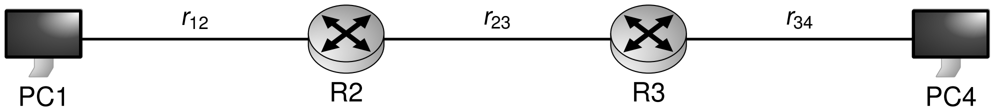


Figure 2.1: Network topology

In this task, we first derive a general procedure by means of which nodes PC1 and PC4 can determine the required transmission rate. We then evaluate the procedure for given numerical values and discuss possible problems that will occur in practice.

a)* Specify the serialization time $t_s(i, j)$ between two neighboring nodes i and j as a function of packet size p and transmission rate r_{ij}.

$$t_s(i, j) = \frac{p}{r_{ij}}$$

b)* Give the propagation delay $t_p(i, j)$ between two adjacent nodes i and j as a function of distance d_{ij}.

With the relative propagation velocity ν (which depends on the medium) and the speed of light c_0 we get:

$$t_p(i, j) = \frac{d_{ij}}{\nu c_0}$$

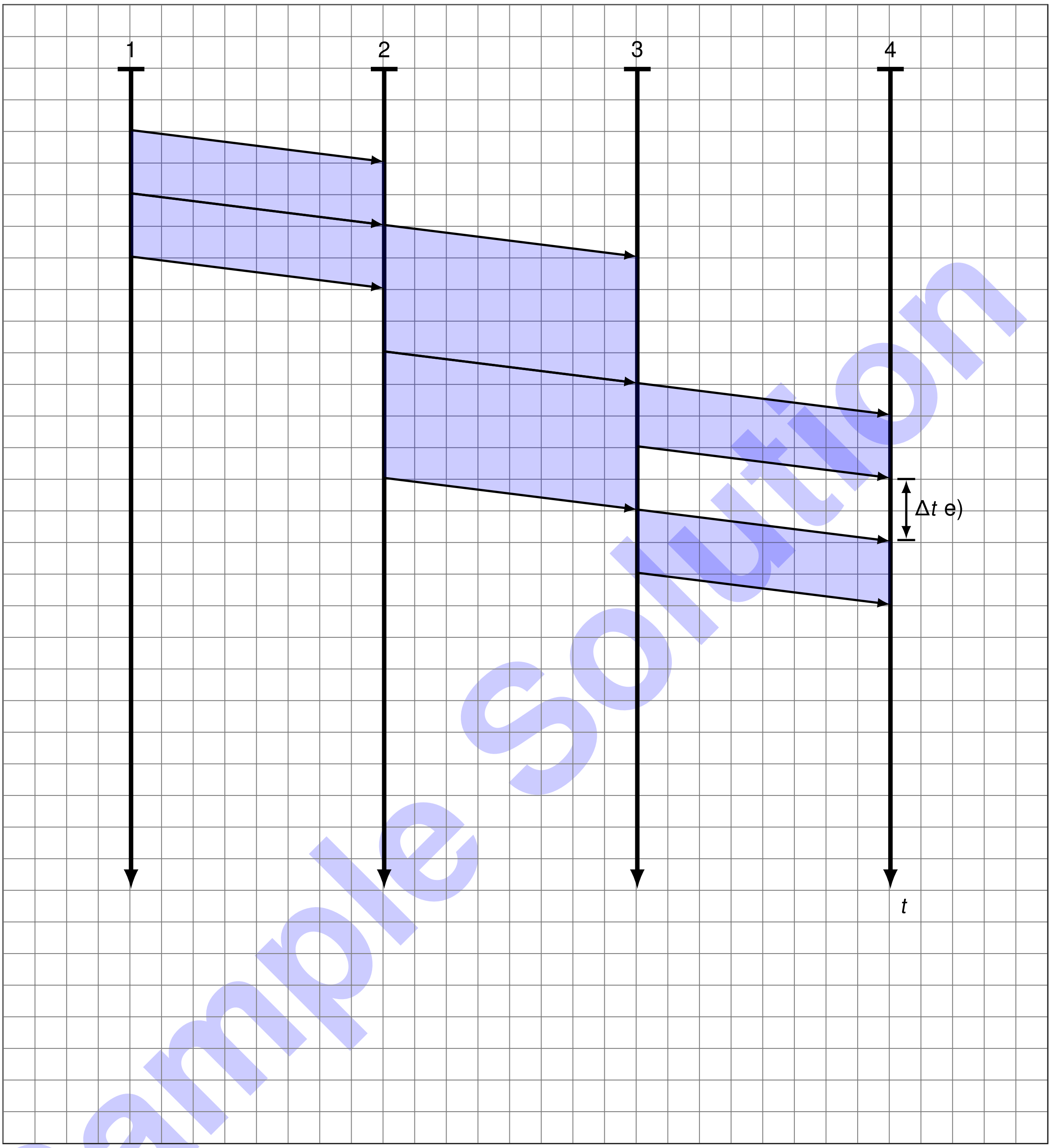
c)* Briefly explain how PC1 can determine the maximum MTU on the path to PC4 when using IPv4.

PC1 sends a packet with the MTU_{12} of the local segment and sets the DF bit (do not fragment) in the IP header. If MTU_{12} is greater than MTU_{23}, R2 will drop the packet and return a corresponding ICMP message type 3 code 4 (Destination Unreachable Fragmentation Needed, DF set to 1). This message contains the maximum MTU_{23} for the section from R2 to R3.

PC1 now sends two packets of length p to PC4 in immediate succession. You can assume that no other traffic will affect the transmission. Let the length p be such that no fragmentation is necessary. You can neglect any processing times at the nodes.

Sample Solution

d) Draw a path-time diagram that correctly represents the transmission of the two packets qualitatively. In particular, consider $r_{23} < r_{12} = r_{34}$ as mentioned at the beginning.



Sample Solution

Due to the low transmission rate between R2 and R3, a transmission pause Δt occurs at node R3 between the two forwarded packets. This can be measured by PC4 and used to determine the transmission rate between R2 and R3.

e) Mark Δt in your solution of subtask d). On which factors does Δt depend?

Only of r_{23}, r_{34} and p, but not of the propagation delays.

f) Specify an expression for Δt. Simplify the expression as much as possible.

$$\Delta t = t_s(2,3) - t_s(3,4) = \frac{p}{r_{23}} - \frac{p}{r_{34}} \tag{2.1}$$

g) Give an expression for the data rate r_{23} you are looking for. Simplify the expression as much as possible.

Resolving (2.1) to r_{23} gives:

$$r_{23} = \frac{p}{\Delta t + \frac{p}{r_{34}}} \tag{2.2}$$

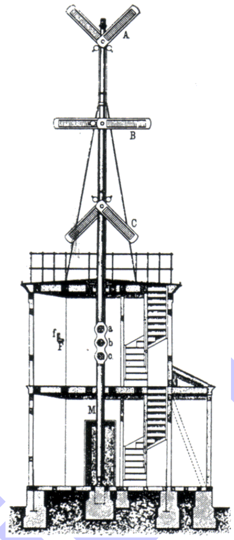
Repeated measurements on PC4 give an average value of $\overline{\Delta t} = 1.2\,\text{ms}$ for a packet size of $p = 1500\,\text{B}$.

h) Determine r_{23} as a numerical value in Mbit/s.

$$r_{23} = \frac{p}{\overline{\Delta t} + \frac{p}{r_{34}}} = 9.90\,\text{Mbit/s} \tag{2.3}$$

Sample Solution

Problem 3 Homework: Optical Telegraph



In this task we consider optical telegraphs. The distance between two neighboring telegraph stations is 15 km. The mast of such a station (see adjacent figure) has three wings (indicators) on the left and right, each of which can take up four different positions (|, ╲, — and ╱).
A *symbol* is the configuration of all indicators.
To set a symbol, 10 s is required. The reading at the receiver takes place in parallel and therefore requires no additional time.

a)* How many bits can be transferred with each symbol?

Symbols: $4^6 = 4096$, Bits: $N = \log_2 4096 = 12$

b) Determine the data rate achieved in B/s.

$$r = \frac{N}{8 \cdot 10}\,\mathrm{B/s} = 0.15\,\mathrm{B/s}$$

c)* The available (gross) data rate is usually not fully used for user data. Name two other useful tasks that take up part of the data rate in common systems.

- Control Characters (Start of Frame, End of Frame)
- 4B5B Code: Clock recovery
- Error detection (checksum) / error correction
- Header information (addressing)
- Padding

A message of length 72 B should now be transmitted.

d) Calculate the serialization time required for this message.

$$t_s = \frac{72\,\mathrm{B}}{r} = \frac{72\,\mathrm{B}}{0.15\,\mathrm{B/s}} = 480\,\mathrm{s}$$

Sample Solution

e)* Calculate the propagation delay of this message between two stations. The reduction in the speed of light due to the air can be neglected here.

$$t_p = \frac{d}{\nu c} = \frac{15\,000\,\text{m}}{300\,000\,000\,\text{m/s}} = 0.05\,\text{ms}$$

We now consider a chain of a total of 4 telegraph stations, which are each 15 km apart. This message of length 72 B is now to be transmitted using packet switching. The protocol used on layer 2 can only transfer frames up to a size of 36 B.

f)* How many packets must the message be divided into if a header of 4 B must be added to each packet?

$$p_{max} = 36\,\text{B} - 4\,\text{B} = 32\,\text{B}$$

$$N = \left\lceil \frac{L}{p_{max}} \right\rceil = \left\lceil \frac{72\,\text{B}}{32\,\text{B}} \right\rceil = 3$$

g) Calculate the duration of a completely packet-based transmission of the message over the entire telegraph chain. Assume that the transmissions are always successful and therefore no confirmations are required.

$$T_{PV} = \frac{1}{r}\left(\left\lceil \frac{L}{p_{\max}} \right\rceil \cdot L_h + L\right) + \frac{d}{\nu c} + n \cdot \frac{L_h + p_{\max}}{r}$$

$$|\text{Number of intermediate stations}| = n = 2$$

$$T_{PV} = \frac{1}{0.15\,\text{B/s}}(3 \cdot 4 + 72) + \frac{45\,\text{km}}{c} + 2 \cdot \frac{4 + 32}{0.15\,\text{B/s}}$$

$$= 560\,\text{s} + 0.15\,\text{ms} + 480\,\text{s} \approx 1040\,\text{s}$$

h) How much does the duration deviate with continuous message switching? Assume that no header is used for message transfer.

Each station must receive the message in full before the message can be forwarded.

Total distance $d = 3 \cdot 15\,\text{km} = 45\,\text{km}$

$$T_{NV} = (n+1) \cdot t_s + t_{p,gesamt}$$

$$= (2+1) \cdot 480\,\text{s} + 0.15\,\text{ms} = 1440\,\text{s}$$

A message switching would be approx. $1440\,\text{s} - 1040\,\text{s} = 400\,\text{s}$ slower.

Sample Solution

Preprints for protocol headers:

Ethernet frames

1	ff:ff:ff:ff:ff:ff	af:fe:14:af:fe:20	0x0806	Payload	FCS
2	af:fe:14:af:fe:20	af:fe:14:af:fe:21	0x0806	Payload	FCS
3	af:fe:14:af:fe:21	af:fe:14:af:fe:20	0x0800	Payload	FCS
6	af:fe:14:af:fe:23	af:fe:14:af:fe:22	0x0800	Payload	FCS
7	af:fe:14:af:fe:23	af:fe:14:af:fe:22	0x0800	Payload	FCS
10	af:fe:14:af:fe:25	af:fe:14:af:fe:24	0x0800	Payload	FCS
11	af:fe:14:af:fe:25	af:fe:14:af:fe:24	0x0800	Payload	FCS
				Payload	FCS

ARP packets

1

Bits 0–7	Bits 8–15	Bits 16–31
0x0001		0x0800
0x06	0x04	0x0001
0xaffe14af		
0xfe20		$192_{(10)}$ $168_{(10)}$
$1_{(10)}$ $1_{(10)}$		0x0000
0x00000000		
$192_{(10)}$ $168_{(10)}$ $1_{(10)}$ $254_{(10)}$		

2

Bits 0–7	Bits 8–15	Bits 16–31
0x0001		0x0800
0x06	0x04	0x0002
0xaffe14af		
0xfe21		$192_{(10)}$ $168_{(10)}$
$1_{(10)}$ $254_{(10)}$		0xaffe
0x14affe20		
$192_{(10)}$ $168_{(10)}$ $1_{(10)}$ $1_{(10)}$		

Sample Solution

0–3	4–7	8–15	16	17	18	19–31

IP packets

3

0–3	4–7	8–15	16	17	18	19–31
0x4	0x5		$1020_{(10)}$			
$32913_{(10)}$			0	0	0	$0_{(10)}$
$64_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $1_{(10)}$ $1_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $2_{(10)}$ $1_{(10)}$						
Payload						

6

0–3	4–7	8–15	16	17	18	19–31
0x4	0x5		$580_{(10)}$			
$32913_{(10)}$			0	0	1	$0_{(10)}$
$63_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $1_{(10)}$ $1_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $2_{(10)}$ $1_{(10)}$						
Payload						

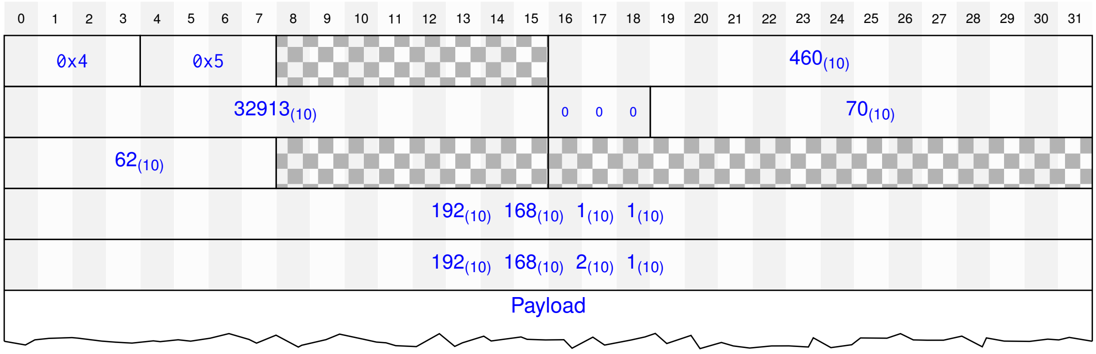
7

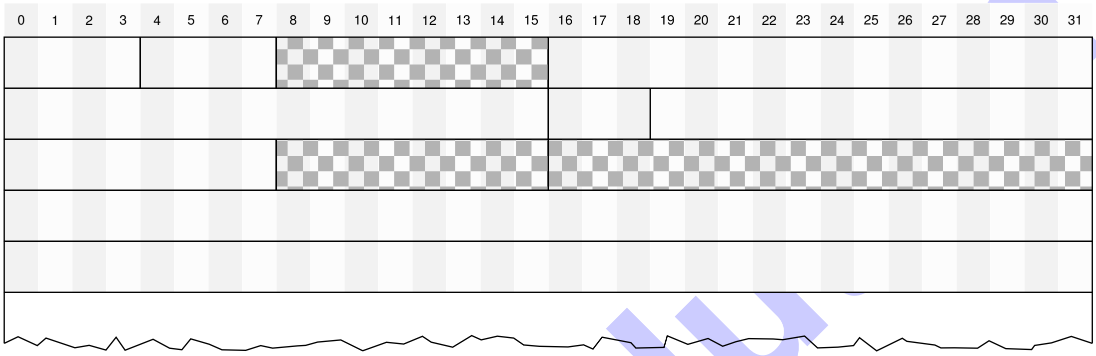
0–3	4–7	8–15	16	17	18	19–31
0x4	0x5		$460_{(10)}$			
$32913_{(10)}$			0	0	0	$70_{(10)}$
$63_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $1_{(10)}$ $1_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $2_{(10)}$ $1_{(10)}$						
Payload						

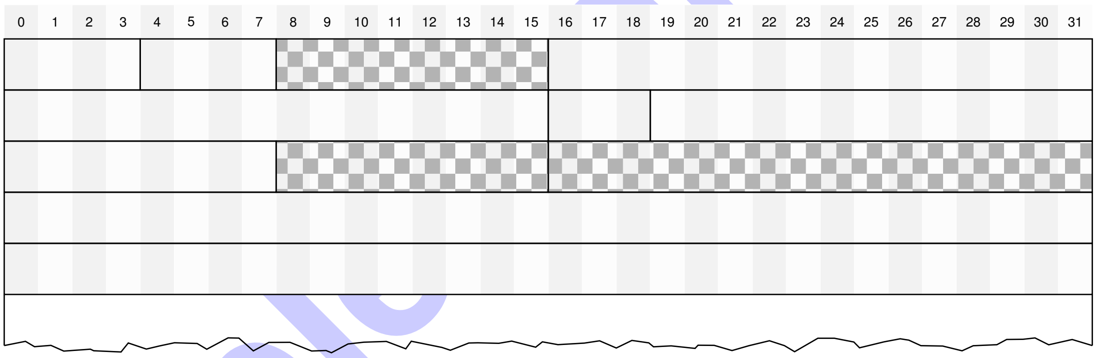
10

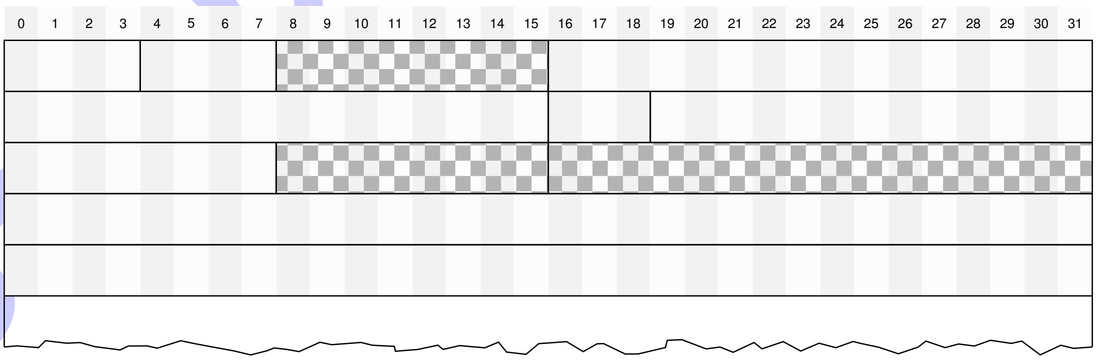
0–3	4–7	8–15	16	17	18	19–31
0x4	0x5		$580_{(10)}$			
$32913_{(10)}$			0	0	1	$0_{(10)}$
$62_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $1_{(10)}$ $1_{(10)}$						
$192_{(10)}$ $168_{(10)}$ $2_{(10)}$ $1_{(10)}$						
Payload						

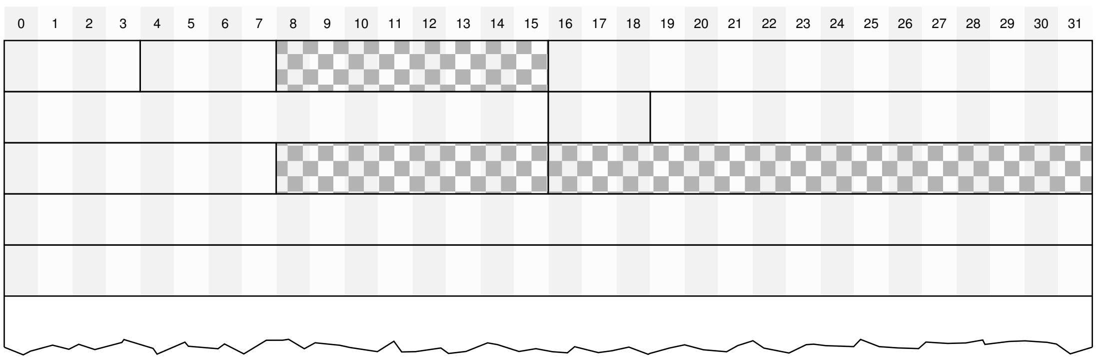
11

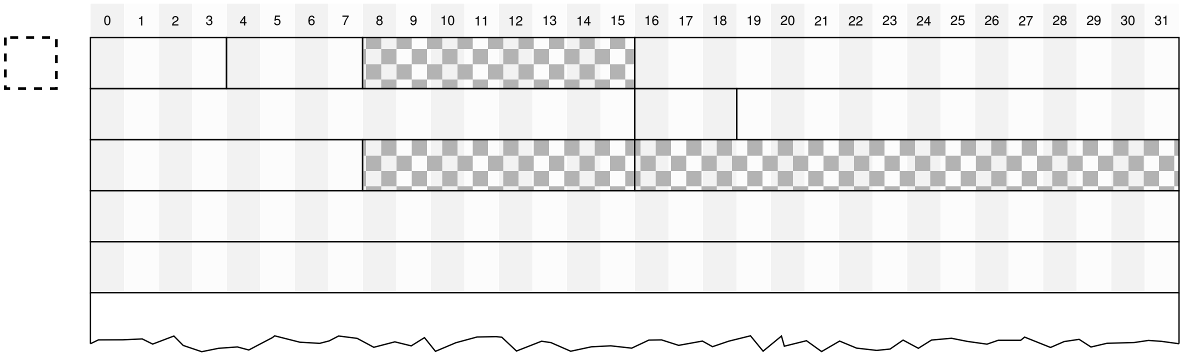

0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31
0x4
0x5
460(10)
32913(10)
0 0 0
70(10)
62(10)
192(10) 168(10) 1(10) 1(10)
192(10) 168(10) 2(10) 1(10)
Payload


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31


0 1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31



Sample Solution

Sample Solution