Brunel University London

College of Engineering, Design and Physical Science
Electronic and Computer Engineering

Assignment
Java Testing and Measuring

Distributed Computing Systems Engineering Msc

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Contents

1 Introduction

The following report refers to the Computer network assignment and is structured into three parts. The first part's topic is an analysis of the network protocols ICMP and IP (both v4), while the second part covers the exercises related to TCP. The final chapter describes the exercises for the new versions of ICMP and IP (v6). These exercises were done together with my lab-partner Antonio Parotta.

2 IP/ICMP analysis

In this first part of the laboratory the program Wireshark was used to capture and analyse packages of different network protocols. The traffic was generated by PING-commands to send the observable packages from one lab PC to another. The following network protocols were analyzed:

- Internet Protocol version 4 (IPv4)
- Internet Control Message Protocol version 4 (ICMPv4)
- Address Resolution Protocol (ARP)
- Carrier Sense Multiple Access/Collision Detection (CSMA/CD)

To understand how these protocols work and to be able to explain how they behave in different situations, having a look on the protocol's headers is necessary.

The PING-commands generate packages consisting of different protocol headers and transferable data. Each Ping is transformed into an Ethernet frame containing the IP and ICMP headers. Table **??** is an representation of the basic ICMP Header while Table **??** shows the header for the echo request/reply packages that can be observed via Wireshark when executing the PING-commands.

bits	0-7	8-15	16-23	24-31
bytes	0	1	2	3
offset 0	Type	Code	Checksum	
offset 32	Data			

Table 2.1: ICMP header

bits	0-7	8-15	16-23	24-31
bytes	0	1	2	3
offset 0	Type	Code	Checksum	
offset 32	Identifier		Sequence Number	
offset 64	data			

Table 2.2: ICMP type 8 echo request/reply packet

Table **??** shows the header for the Internet Protocol v4. Noteable here are the entered destination address as well as the source address of the sender. The Time to Live is also an important segment of the header, which will be significant later on for an specific PING-Command. IP provides the possibility to specify options for the transfered packet. This will also be used in one of the PING-Commands.

bits	0-3	4-7	8-11	12-15	16-18	19-23	24-27	28-31
bytes	0		1		2		3	
offset 0	Version	IHL	Type of Service		Total Length			
offset 32	Identification				Flags	Fragment Offset		
offset 64	Time to Live		Protocol		Header Checksum			
offset 96	Source Address							
offset 128	Destination Address							
offset 160	Options							

Table 2.3: IPv4 Header

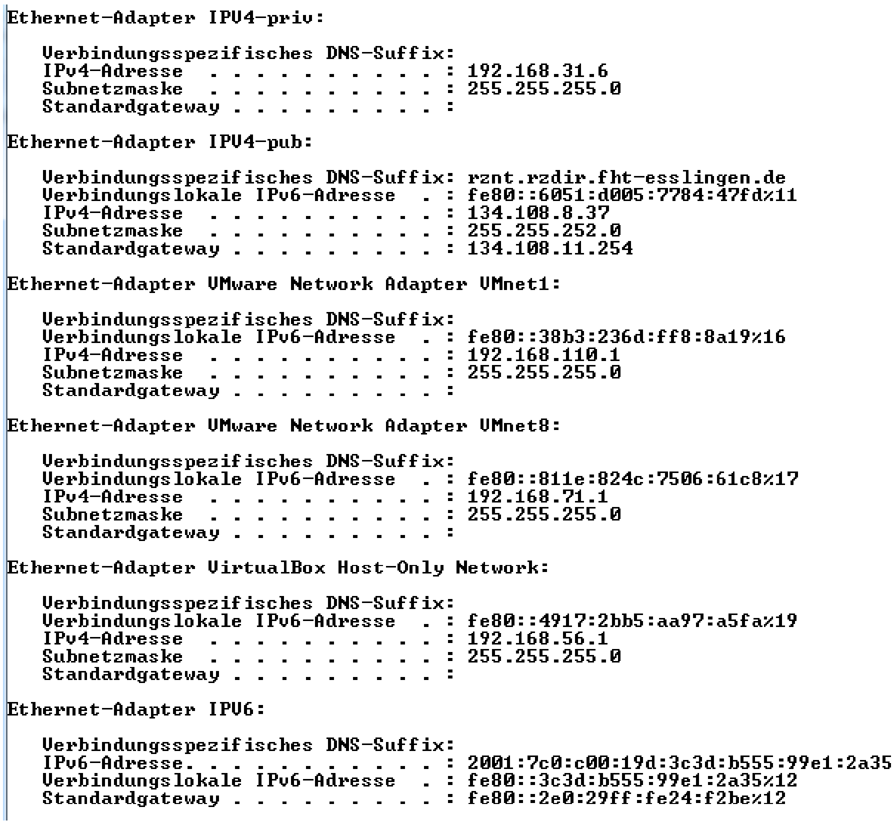
Table **??** shows the abstract Ethernet II frame. This frame contains the MAC-addresses for source and destination, a type segment as well as the checksum for the frame. Interesting here is the Payload field. This segments contains the headers for ICMP and IP as well as the transferable data. The maximal size for this segment is 1500 bytes for one packet. But because is must contain the headers for each networking protocol (ICMP and IP), it can't be fully occupied by transferable data. This is why the Maximum Transmission Unit (MTU) is smaller. It is only 1472 bytes, because the size of the headers must be subtracted from the payload field.
$\text{MTU} = \text{Payload} - \text{IP Header} - \text{ICMP Header}$
$1500\text{ byte} - 20\text{ byte} - 8\text{ byte} = 1472\text{ byte}$

Size in bit	24	24	8	184-6000	16
Size in byte	6	6	2	46 - 1500	4
Frame segments	Destination Address	Source Address	Type	Payload (Data)	FCS

Table 2.4: Ethernet II frame

2.1 Node configuration

Figure 2.1 shows the node configuration and settings for the computer used for the exercises in this workshop:



```
Ethernet-Adapter IPV4-priv:

   Verbindungsspezifisches DNS-Suffix:
   IPv4-Adresse  . . . . . . . . . . : 192.168.31.6
   Subnetzmaske  . . . . . . . . . . : 255.255.255.0
   Standardgateway . . . . . . . . . :

Ethernet-Adapter IPV4-pub:

   Verbindungsspezifisches DNS-Suffix: rznt.rzdir.fht-esslingen.de
   Verbindungslokale IPv6-Adresse  . : fe80::6051:d005:7784:47fd%11
   IPv4-Adresse  . . . . . . . . . . : 134.108.8.37
   Subnetzmaske  . . . . . . . . . . : 255.255.252.0
   Standardgateway . . . . . . . . . : 134.108.11.254

Ethernet-Adapter VMware Network Adapter VMnet1:

   Verbindungsspezifisches DNS-Suffix:
   Verbindungslokale IPv6-Adresse  . : fe80::38b3:236d:ff8:8a19%16
   IPv4-Adresse  . . . . . . . . . . : 192.168.110.1
   Subnetzmaske  . . . . . . . . . . : 255.255.255.0
   Standardgateway . . . . . . . . . :

Ethernet-Adapter VMware Network Adapter VMnet8:

   Verbindungsspezifisches DNS-Suffix:
   Verbindungslokale IPv6-Adresse  . : fe80::811e:824c:7506:61c8%17
   IPv4-Adresse  . . . . . . . . . . : 192.168.71.1
   Subnetzmaske  . . . . . . . . . . : 255.255.255.0
   Standardgateway . . . . . . . . . :

Ethernet-Adapter VirtualBox Host-Only Network:

   Verbindungsspezifisches DNS-Suffix:
   Verbindungslokale IPv6-Adresse  . : fe80::4917:2bb5:aa97:a5fa%19
   IPv4-Adresse  . . . . . . . . . . : 192.168.56.1
   Subnetzmaske  . . . . . . . . . . : 255.255.255.0
   Standardgateway . . . . . . . . . :

Ethernet-Adapter IPV6:

   Verbindungsspezifisches DNS-Suffix:
   IPv6-Adresse. . . . . . . . . . . : 2001:7c0:c00:19d:3c3d:b555:99e1:2a35
   Verbindungslokale IPv6-Adresse  . : fe80::3c3d:b555:99e1:2a35%12
   Standardgateway . . . . . . . . . : fe80::2e0:29ff:fe24:f2be%12
```

Figure 2.1: Node configuration for 134.108.8.37

2.2 Subnet internal IP Destination

In the first exercise we created traffic by using the PING-Command to send packets to another PC within the same subnet. Figure 2.2 shows the simplified architecture for this environment:

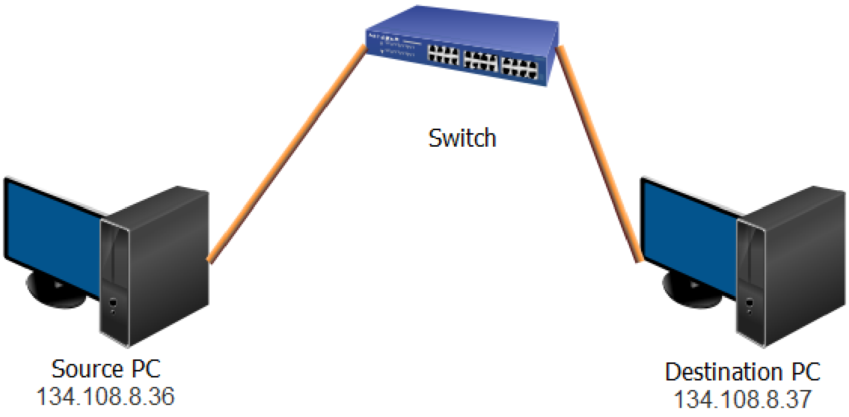


Figure 2.2: Source and Destination PC connected with a switch in the network lab

2.2.1 a) Basic PING command

The first task was sending a basic ping from one PC to another within the same subnet and capturing the sent packets using Wireshark. The PING-Command was:

ping -n 1 -l 64 134.108.8.37

Listing **??** shows the Wireshark trace for the captured packets. For this simple PING command, two ICMP packet were captured. One ICMP echo request was send from the source PC to the Destination PC and after this the Destination PC answers with an ICMP echo reqly. Both packets contain the Ethernet II frame as well as the IP and ICMP headers as discussed in chapter 2. Each packet has the source and destination address from the IP header as well as same sequence number. The total size of each packet is 106. It contains the source and target MAC-addresses from the Ethernet frame (both 6 byte), the type of the Ethernet frame (2 byte), the IP-header (20 byte), the ICMP-header (8 byte) and the transmitted data (64 byte).

,

```
No.     Time           Source               Destination    Protocol  Length Info
445 32.125568    134.108.8.36        134.108.8.37        ICMP     106    Echo (ping) request id=0x0001
    , seq=25/6400, ttl=128 (reply in 448)

Frame 445: 106 bytes on wire (848 bits), 106 bytes captured (848 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 09:46:22.558509000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510908382.558509000 seconds
    [Time delta from previous captured frame: 0.000092000 seconds]
    [Time delta from previous displayed frame: 0.000000000 seconds]
    [Time since reference or first frame: 32.125568000 seconds]
    Frame Number: 445
    Frame Length: 106 bytes (848 bits)
    Capture Length: 106 bytes (848 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
    Destination: Dell\_88:97:76 (90:b1:1c:88:97:76)
        Address: Dell\_88:97:76 (90:b1:1c:88:97:76)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
```

```
        Address: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
        0000 00.. = Differentiated Services Codepoint: Default (0)
        .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 92
    Identification: 0x30fb (12539)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 128
    Protocol: ICMP (1)
    Header checksum: 0xec84 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.8.36
    Destination: 134.108.8.37
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
Internet Control Message Protocol
    Type: 8 (Echo (ping) request)
    Code: 0
    Checksum: 0x856a [correct]
    [Checksum Status: Good]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 25 (0x0019)
    Sequence number (LE): 6400 (0x1900)
    [Response frame: 448]
    Data (64 bytes)

0000  61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 abcdefghijklmnop
0010  71 72 73 74 75 76 77 61 62 63 64 65 66 67 68 69 qrstuvwabcdefghi
0020  6a 6b 6c 6d 6e 6f 70 71 72 73 74 75 76 77 61 62 jklmnopqrstuvwab
0030  63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 71 72 cdefghijklmnopqr
    Data: 6162636465666768696a6b6c6d6e6f7071727374757677761...
    [Length: 64]

No.     Time           Source                Destination           Protocol Length Info
448 32.125797     134.108.8.37          134.108.8.36          ICMP     106    Echo (ping) reply    id=0x0001, seq=25/6400, ttl=128 (request in 445)

Frame 448: 106 bytes on wire (848 bits), 106 bytes captured (848 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
```

```
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 09:46:22.558738000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510908382.558738000 seconds
    [Time delta from previous captured frame: 0.000005000 seconds]
    [Time delta from previous displayed frame: 0.000229000 seconds]
    [Time since reference or first frame: 32.125797000 seconds]
    Frame Number: 448
    Frame Length: 106 bytes (848 bits)
    Capture Length: 106 bytes (848 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
    Destination: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
        Address: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: Dell\_88:97:76 (90:b1:1c:88:97:76)
        Address: Dell\_88:97:76 (90:b1:1c:88:97:76)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
        0000 00.. = Differentiated Services Codepoint: Default (0)
        .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 92
    Identification: 0x3021 (12321)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 128
    Protocol: ICMP (1)
    Header checksum: 0x0000 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.8.37
    Destination: 134.108.8.36
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
Internet Control Message Protocol
    Type: 0 (Echo (ping) reply)
    Code: 0
    Checksum: 0x8d6a [correct]
    [Checksum Status: Good]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 25 (0x0019)
    Sequence number (LE): 6400 (0x1900)
    [Request frame: 445]
    [Response time: 0.229 ms]
    Data (64 bytes)

0000  61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 abcdefghijklmnop
0010  71 72 73 74 75 76 77 61 62 63 64 65 66 67 68 69 qrstuvwabcdefghi
0020  6a 6b 6c 6d 6e 6f 70 71 72 73 74 75 76 77 61 62 jklmnopqrstuvwab
0030  63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 71 72 cdefghijklmnopqr
    Data: 6162636465666768696a6b6c6d6e6f7071727374757677761...
    [Length: 64]
```

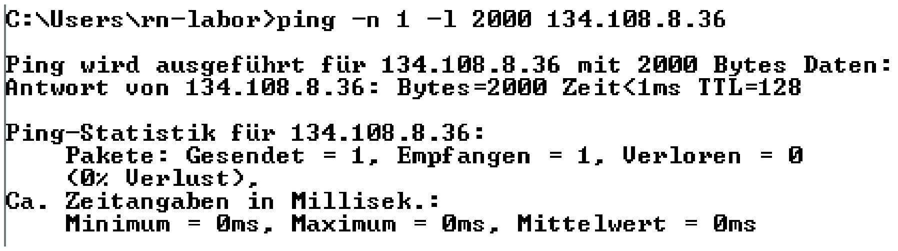
Listing 2.1: Wireshark trace for simple PING command

2.2.2 b) PING command with large data package

For the second exercise we had to execute a PING-Command with a very large data package of 2000 byte. The PING-Command was:

ping -n 1 -l 2000 134.108.8.36

Figure 2.3 shows the console output for this ping:



```
C:\Users\rn-labor>ping -n 1 -l 2000 134.108.8.36

Ping wird ausgeführt für 134.108.8.36 mit 2000 Bytes Daten:
Antwort von 134.108.8.36: Bytes=2000 Zeit<1ms TTL=128

Ping-Statistik für 134.108.8.36:
    Pakete: Gesendet = 1, Empfangen = 1, Verloren = 0
    (0% Verlust),
Ca. Zeitangaben in Millisek.:
    Minimum = 0ms, Maximum = 0ms, Mittelwert = 0ms
```

Figure 2.3: Console output for PING-Command with 2000 bytes data

It seems that the protocol ICMP does not have any problems with this as the console output shows no warning. IP however does have a problem with this large packet size. As the data exceeds the Maximum Transmission Unit, the packet must be fragmented and separated into two packets. The following listing is shortened, but shows the four packages sent between both lab-PCs:

,

```
No.     Time       Source              Destination        Protocol Length DestPort Info
                                                       Delta Time
236 0.000000   134.108.8.37        134.108.8.36        ICMP     1514           Echo (ping) request id=0
    x0001, seq=25/6400, ttl=128 (reply in 240) 0.000000

Frame 236: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
    Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 09:58:38.374317000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510909118.374317000 seconds
    [Time delta from previous captured frame: 0.000024000 seconds]
    [Time delta from previous displayed frame: 0.000000000 seconds]
    [Time since reference or first frame: 36.388239000 seconds]
    Frame Number: 236
    Frame Length: 1514 bytes (12112 bits)
    Capture Length: 1514 bytes (12112 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
Ethernet II, Src: 90:b1:1c:88:97:76, Dst: 90:b1:1c:87:b7:aa
    Destination: 90:b1:1c:87:b7:aa
        Address: 90:b1:1c:87:b7:aa
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    0000 00.. = Differentiated Services Codepoint: Default (0)
    .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 1500
    Identification: 0x3e7e (15998)
    Flags: 0x01 (More Fragments)
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..1. .... = More fragments: Set
    Fragment offset: 0
    Time to live: 128
    Protocol: ICMP (1)
    Header checksum: 0x0000 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.8.37
    Destination: 134.108.8.36
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
Internet Control Message Protocol
    Type: 8 (Echo (ping) request)
    Code: 0
    Checksum: 0x7b5e [unverified] [fragmented datagram]
    [Checksum Status: Unverified]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 25 (0x0019)
    Sequence number (LE): 6400 (0x1900)
    [Response frame: 240]
    Data (1472 bytes)

No.    Time       Source              Destination        Protocol Length DestPort Info
                                                      Delta Time
237 0.000007  134.108.8.37        134.108.8.36        IPv4    562           Fragmented IP protocol (
    proto=ICMP 1, off=1480, ID=3e7e)  0.000007

No.    Time       Source              Destination        Protocol Length DestPort Info
                                                      Delta Time
240 0.000488  134.108.8.36        134.108.8.37        ICMP    1514          Echo (ping) reply  id=0
    x0001, seq=25/6400, ttl=128 (request in 236) 0.000488

No.    Time       Source              Destination        Protocol Length DestPort Info
                                                      Delta Time
241 0.000002  134.108.8.36        134.108.8.37        IPv4    562           Fragmented IP protocol (
    proto=ICMP 1, off=1480, ID=332d)  0.000002
```

Listing 2.2: Wireshark trace for PING command with 2000 bytes data

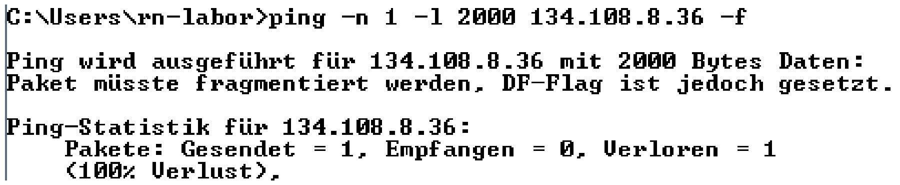
It can be observed that the first packet occupies all 1514 bytes that can be sent in one ICMP packet. Subtracting the segments from the Ethernet frame (14 byte), the IP-header (20 byte) and the ICMP-header (8 byte), there is room for 1472 byte of raw data. The remaining 528 byte of data can't be transmitted in the same packet. So the data must be fragmented and sent inside another packet. As ICMP doesn't play a role in the fragmentation, it's header isn't needed anymore in the second packet. However the second packet contains the IP-header (20 byte) as it is the protocol that manages the fragmentation and transmission controlling. The segments for the Ethernet frame (14 byte) are also included, because without that there could not be any transmission at all. So summed up the second packet has a size of 562 byte.

2.2.3 c) PING command with 'don't fragment' flag

For this last exercise another PING with 2000 byte of data was executed. But this time the 'don't fragment' flag **-f** was set:

ping -n 1 -l 2000 134.108.8.36 -f

This causes a problem, because as discussed in the previous chapter this large amount of data cannot be transmitted in one single packet. So IP needs to fragment it into two separate packets. But in this case it receives the 'don't fragment' command. This contradicts the functionality of IP and it throws and error that ICMP recognizes and displays a message in the console:



```
C:\Users\rn-labor>ping -n 1 -l 2000 134.108.8.36 -f

Ping wird ausgeführt für 134.108.8.36 mit 2000 Bytes Daten:
Paket müsste fragmentiert werden, DF-Flag ist jedoch gesetzt.

Ping-Statistik für 134.108.8.36:
    Pakete: Gesendet = 1, Empfangen = 0, Verloren = 1
    (100% Verlust),
```

Figure 2.4: Console output for PING-Command with 2000 bytes data

There is no Wireshark trace for this exercise, because there were no packets sent to the destination PC.

2.3 Subnet external IP Destination

For this second part of the laboratory, we moved on to PING-commands where the destination address was located in another subnet. Both subnets were connected by a router that assigned a range of addresses to the computers inside each subnet. Each computer inside one of these subnets was connected to a switch that had a connection to the router and the router provided a host IP-address for both subnets. Figure 2.5 shows all involved network node and their IP-addresses.

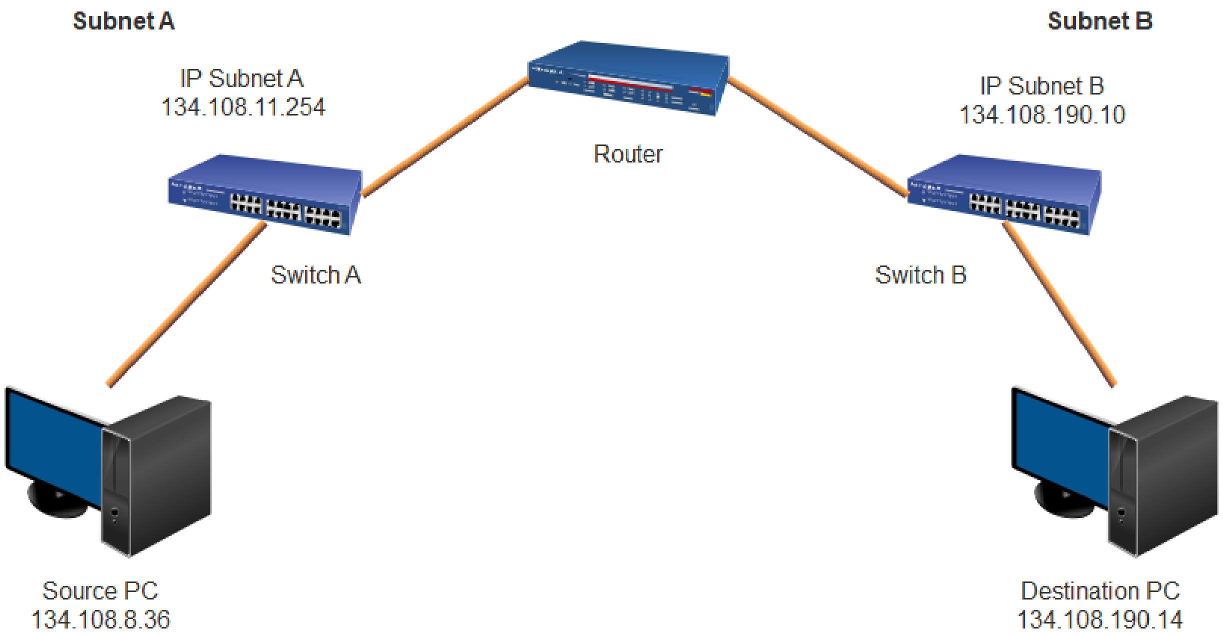


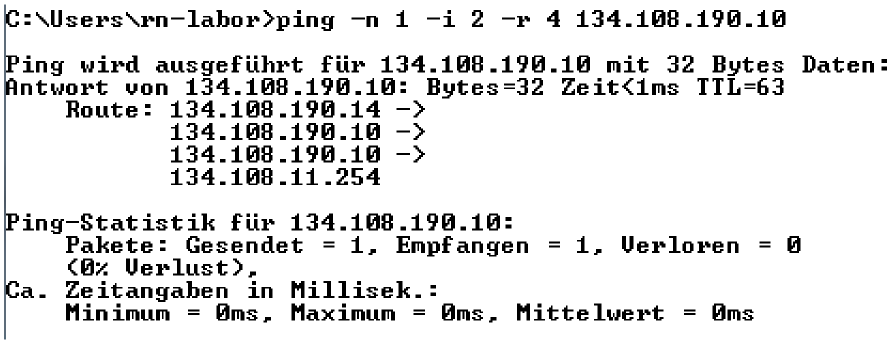
Figure 2.5: Two subnets in the network lab

2.3.1 d) Basic PING command with destination in another subnet

For this exercise the following PING-Command was used:

ping -n 1 -i 2 -r 4 134.108.190.10

The parameter **-r** activates the recoding of the route and sets the maximal number of records. **-i** indicates the 'Time to Live' in the IP-header (s. Chapter 2) and is basically nothing more than a hop-count that decrements, when the packet passes a network node (PCs or Routers in this case). When 'Time to Live' reaches zero, the packet will be abandoned. Figure 2.6 shows the output of the console command:



```
C:\Users\rn-labor>ping -n 1 -i 2 -r 4 134.108.190.10

Ping wird ausgeführt für 134.108.190.10 mit 32 Bytes Daten:
Antwort von 134.108.190.10: Bytes=32 Zeit<1ms TTL=63
    Route: 134.108.190.14 ->
           134.108.190.10 ->
           134.108.190.10 ->
           134.108.11.254

Ping-Statistik für 134.108.190.10:
    Pakete: Gesendet = 1, Empfangen = 1, Verloren = 0
    (0% Verlust),
Ca. Zeitangaben in Millisek.:
    Minimum = 0ms, Maximum = 0ms, Mittelwert = 0ms
```

Figure 2.6: PING Command with Destination in another subnet

The output shows the recorded route, the reply packet from the destination PC took trough the network. The sent packets are shown in the following listing:

,

```
No.     Time       Source              Destination        Protocol Length DestPort Info
                                                       Delta Time
49 0.000000   134.108.8.37        134.108.190.10      ICMP     94           Echo (ping) request id=0
    x0001, seq=37/9472, ttl=2 (reply in 50) 0.000000

Frame 49: 94 bytes on wire (752 bits), 94 bytes captured (752 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 10:21:22.503562000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510910482.503562000 seconds
    [Time delta from previous captured frame: 0.187068000 seconds]
    [Time delta from previous displayed frame: 0.000000000 seconds]
    [Time since reference or first frame: 2.480985000 seconds]
    Frame Number: 49
    Frame Length: 94 bytes (752 bits)
    Capture Length: 94 bytes (752 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
    Ethernet II, Src: 90:b1:1c:88:97:76, Dst: 00:23:04:52:1c:00
    Destination: 00:23:04:52:1c:00
        Address: 00:23:04:52:1c:00
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.190.10
    0100 .... = Version: 4
    .... 1010 = Header Length: 40 bytes (10)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    0000 00.. = Differentiated Services Codepoint: Default (0)
    .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 80
    Identification: 0x42d5 (17109)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 2
    [Expert Info (Note/Sequence): "Time To Live" only 2]
    ["Time To Live" only 2]
    [Severity level: Note]
    [Group: Sequence]
    Protocol: ICMP (1)
    Header checksum: 0x0000 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.8.37
    Destination: 134.108.190.10
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
    Options: (20 bytes), Record Route
        IP Option - Record Route (19 bytes)
            Type: 7
            0... .... = Copy on fragmentation: No
            .00. .... = Class: Control (0)
            ...0 0111 = Number: Record route (7)
            Length: 19
            Pointer: 4
            Empty Route: 0.0.0.0 <- (next)
            Empty Route: 0.0.0.0
            Empty Route: 0.0.0.0
            Empty Route: 0.0.0.0
        IP Option - End of Options List (EOL)
            Type: 0
            0... .... = Copy on fragmentation: No
            .00. .... = Class: Control (0)
            ...0 0000 = Number: End of Option List (EOL) (0)
Internet Control Message Protocol
    Type: 8 (Echo (ping) request)
    Code: 0
    Checksum: 0x4d36 [correct]
    [Checksum Status: Good]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 37 (0x0025)
    Sequence number (LE): 9472 (0x2500)
    [Response frame: 50]
    Data (32 bytes)

    0000  61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 abcdefghijklmnop
    0010  71 72 73 74 75 76 77 61 62 63 64 65 66 67 68 69 qrstuvwabcdefghi
    Data: 6162636465666768696a6b6c6d6e6f7071727374757677761...
    Text: abcdefghijklmnopqrstuvwabcdefghi
    [Length: 32]

No.    Time       Source              Destination         Protocol Length DestPort Info
                                                      Delta Time
```

```
50 0.000692  134.108.190.10      134.108.8.37        ICMP     94           Echo (ping) reply  id=0x0001, seq=37/9472, ttl=63 (request in 49) 0.000692

Frame 50: 94 bytes on wire (752 bits), 94 bytes captured (752 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 10:21:22.504254000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510910482.504254000 seconds
    [Time delta from previous captured frame: 0.000692000 seconds]
    [Time delta from previous displayed frame: 0.000692000 seconds]
    [Time since reference or first frame: 2.481677000 seconds]
    Frame Number: 50
    Frame Length: 94 bytes (752 bits)
    Capture Length: 94 bytes (752 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
Ethernet II, Src: 00:23:04:52:1c:00, Dst: 90:b1:1c:88:97:76
    Destination: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: 00:23:04:52:1c:00
        Address: 00:23:04:52:1c:00
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
        Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.190.10, Dst: 134.108.8.37
    0100 .... = Version: 4
    .... 1010 = Header Length: 40 bytes (10)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    0000 00.. = Differentiated Services Codepoint: Default (0)
    .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 80
    Identification: 0x048f (1167)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 63
    Protocol: ICMP (1)
    Header checksum: 0xafa3 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.190.10
    Destination: 134.108.8.37
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
    Options: (20 bytes), Record Route
        IP Option - Record Route (19 bytes)
             Type: 7
             0... .... = Copy on fragmentation: No
             .00. .... = Class: Control (0)
             ...0 0111 = Number: Record route (7)
             Length: 19
             Pointer: 20
             Recorded Route: 134.108.190.14
             Recorded Route: 134.108.190.10
             Recorded Route: 134.108.190.10
             Recorded Route: 134.108.11.254
        IP Option - End of Options List (EOL)
             Type: 0
             0... .... = Copy on fragmentation: No
             .00. .... = Class: Control (0)
             ...0 0000 = Number: End of Option List (EOL) (0)
Internet Control Message Protocol
    Type: 0 (Echo (ping) reply)
    Code: 0
    Checksum: 0x5536 [correct]
    [Checksum Status: Good]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 37 (0x0025)
    Sequence number (LE): 9472 (0x2500)
    [Request frame: 49]
    [Response time: 0.692 ms]
    Data (32 bytes)

0000  61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 abcdefghijklmnop
0010  71 72 73 74 75 76 77 61 62 63 64 65 66 67 68 69 qrstuvwabcdefghi
Data: 6162636465666768696a6b6c6d6e6f7071727374757677761...
Text: abcdefghijklmnopqrstuvwabcdefghi
[Length: 32]
```

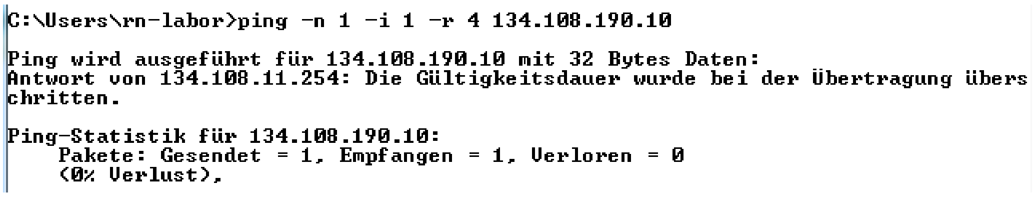
Listing 2.3: Wireshark trace for PING command in another subnet

2.3.2 e) PING command with reduced 'time to live'

In this exercise the 'Time to Live' was reduced to 1 in the PING-Command:

ping -n 1 -i 1 -r 4 134.108.190.10

This causes a Time-To-Live-Exceeded error that was displayed in the console output:



```
C:\Users\rn-labor>ping -n 1 -i 1 -r 4 134.108.190.10

Ping wird ausgeführt für 134.108.190.10 mit 32 Bytes Daten:
Antwort von 134.108.11.254: Die Gültigkeitsdauer wurde bei der Übertragung übers
chritten.

Ping-Statistik für 134.108.190.10:
    Pakete: Gesendet = 1, Empfangen = 1, Verloren = 0
    (0% Verlust),
```

Figure 2.7: PING Command with reduced Time to Live

As the 'Time to Live' is reduced to 1, it cannot reach the destination PC. When bypassing the router, the TTL is decreased to zero. So the router will drop the packet and send the Time-To-Live-Exceeded error back to the source, while the destination PC never receives any traffic. The only packet sent is from the source to the router. This can be seen in the following Wireshark trace:

,

```
No.    Time       Source               Destination         Protocol Length DestPort Info
                                                        Delta Time
37 0.000000   134.108.8.37        134.108.190.10      ICMP     94             Echo (ping) request id=0
    x0001, seq=38/9728, ttl=1 (no response found!) 0.000000

Frame 37: 94 bytes on wire (752 bits), 94 bytes captured (752 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 10:23:18.619066000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510910598.619066000 seconds
    [Time delta from previous captured frame: 0.145036000 seconds]
    [Time delta from previous displayed frame: 0.000000000 seconds]
    [Time since reference or first frame: 5.672194000 seconds]
    Frame Number: 37
    Frame Length: 94 bytes (752 bits)
    Capture Length: 94 bytes (752 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
    Ethernet II, Src: 90:b1:1c:88:97:76, Dst: 00:23:04:52:1c:00
    Destination: 00:23:04:52:1c:00
        Address: 00:23:04:52:1c:00
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.190.10
    0100 .... = Version: 4
    .... 1010 = Header Length: 40 bytes (10)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
        0000 00.. = Differentiated Services Codepoint: Default (0)
        .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 80
    Identification: 0x42d9 (17113)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 1
    [Expert Info (Note/Sequence): "Time To Live" only 1]
    ["Time To Live" only 1]
    [Severity level: Note]
    [Group: Sequence]
    Protocol: ICMP (1)
    Header checksum: 0x0000 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.8.37
    Destination: 134.108.190.10
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
    Options: (20 bytes), Record Route
        IP Option - Record Route (19 bytes)
            Type: 7
            0... .... = Copy on fragmentation: No
            .00. .... = Class: Control (0)
            ...0 0111 = Number: Record route (7)
            Length: 19
            Pointer: 4
                Empty Route: 0.0.0.0 <- (next)
                Empty Route: 0.0.0.0
                Empty Route: 0.0.0.0
                Empty Route: 0.0.0.0
    IP Option - End of Options List (EOL)
        Type: 0
        0... .... = Copy on fragmentation: No
        .00. .... = Class: Control (0)
        ...0 0000 = Number: End of Option List (EOL) (0)
Internet Control Message Protocol
    Type: 8 (Echo (ping) request)
    Code: 0
    Checksum: 0x4d35 [correct]
    [Checksum Status: Good]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 38 (0x0026)
    Sequence number (LE): 9728 (0x2600)
    [No response seen]
    [Expert Info (Warning/Sequence): No response seen to ICMP request]
    [No response seen to ICMP request]
    [Severity level: Warning]
    [Group: Sequence]
Data (32 bytes)

    0000  61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 abcdefghijklmnop
    0010  71 72 73 74 75 76 77 61 62 63 64 65 66 67 68 69 qrstuvwabcdefghi
    Data: 6162636465666768696a6b6c6d6e6f7071727374757677761...
    Text: abcdefghijklmnopqrstuvwabcdefghi
    [Length: 32]
```

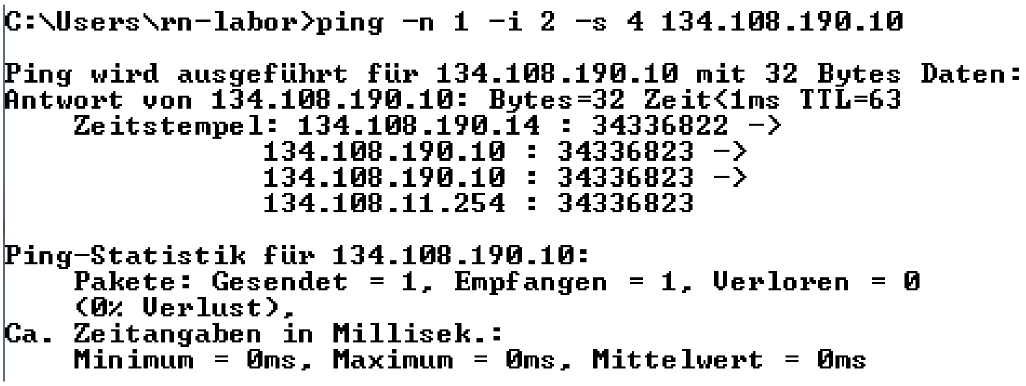
Listing 2.4: Wireshark trace for PING command with reduced TTL

2.3.3 f) PING command with timestamps

In this exercise the ’timestamp’ option was used in the PING-Command:

ping -n 1 -i 2 -s 4 134.108.190.10

The timestamp option has the effect that a timestamp which represents the amount of time from midnight to the exact moment, the packet bypasses a network node, is recorded in milliseconds:



```
C:\Users\rn-labor>ping -n 1 -i 2 -s 4 134.108.190.10

Ping wird ausgeführt für 134.108.190.10 mit 32 Bytes Daten:
Antwort von 134.108.190.10: Bytes=32 Zeit<1ms TTL=63
    Zeitstempel: 134.108.190.14 : 34336822 ->
                 134.108.190.10 : 34336823 ->
                 134.108.190.10 : 34336823 ->
                 134.108.11.254 : 34336823

Ping-Statistik für 134.108.190.10:
    Pakete: Gesendet = 1, Empfangen = 1, Verloren = 0
    (0% Verlust),
Ca. Zeitangaben in Millisek.:
    Minimum = 0ms, Maximum = 0ms, Mittelwert = 0ms
```

Figure 2.8: PING Command with timestamp option

The time difference between the sending from the destination PC and the bypassing of the router is only 1 ms as seen in Figure 2.8. The Options Field in the IP-header contains the timestamps as seen in the following listing: ,

```

No.     Time       Source               Destination         Protocol Length DestPort Info
                                                         Delta Time
51 0.000778  134.108.190.10      134.108.8.37        ICMP     110            Echo (ping) reply  id=0
    x0001, seq=43/11008, ttl=63 (request in 50) 0.000778

Frame 51: 110 bytes on wire (880 bits), 110 bytes captured (880 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 10:32:16.698574000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510911136.698574000 seconds
    [Time delta from previous captured frame: 0.000778000 seconds]
    [Time delta from previous displayed frame: 0.000778000 seconds]
    [Time since reference or first frame: 3.015108000 seconds]
    Frame Number: 51
    Frame Length: 110 bytes (880 bits)
    Capture Length: 110 bytes (880 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:icmp:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
    Ethernet II, Src: 00:23:04:52:1c:00, Dst: 90:b1:1c:88:97:76
    Destination: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: 00:23:04:52:1c:00
        Address: 00:23:04:52:1c:00
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.190.10, Dst: 134.108.8.37
    0100 .... = Version: 4
    .... 1110 = Header Length: 56 bytes (14)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
    0000 00.. = Differentiated Services Codepoint: Default (0)
    .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 96
    Identification: 0x0490 (1168)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 63
    Protocol: ICMP (1)
    Header checksum: 0x0901 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.190.10
    Destination: 134.108.8.37
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
    Options: (36 bytes), Time Stamp
        IP Option - Time Stamp (36 bytes)
            Type: 68
                0... .... = Copy on fragmentation: No
                .10. .... = Class: Debugging and measurement (2)
                ...0 0100 = Number: Time stamp (4)
            Length: 36
            Pointer: 37
            0000 .... = Overflow: 0
            .... 0001 = Flag: Time stamp and address (0x1)
            Address: 134.108.190.14
            Time stamp: 34336822
            Address: 134.108.190.10
            Time stamp: 34336823
            Address: 134.108.190.10
            Time stamp: 34336823
            Address: 134.108.11.254
            Time stamp: 34336823
Internet Control Message Protocol
    Type: 0 (Echo (ping) reply)
    Code: 0
    Checksum: 0x5530 [correct]
    [Checksum Status: Good]
    Identifier (BE): 1 (0x0001)
    Identifier (LE): 256 (0x0100)
    Sequence number (BE): 43 (0x002b)
    Sequence number (LE): 11008 (0x2b00)
    [Request frame: 50]
    [Response time: 0.778 ms]
Data (32 bytes)

    0000  61 62 63 64 65 66 67 68 69 6a 6b 6c 6d 6e 6f 70 abcdefghijklmnop
    0010  71 72 73 74 75 76 77 61 62 63 64 65 66 67 68 69 qrstuvwabcdefghi
    Data: 6162636465666768696a6b6c6d6e6f7071727374757677761...
    Text: abcdefghijklmnopqrstuvwabcdefghi
    [Length: 32]
```

Listing 2.5: Wireshark trace for PING command with timestamps

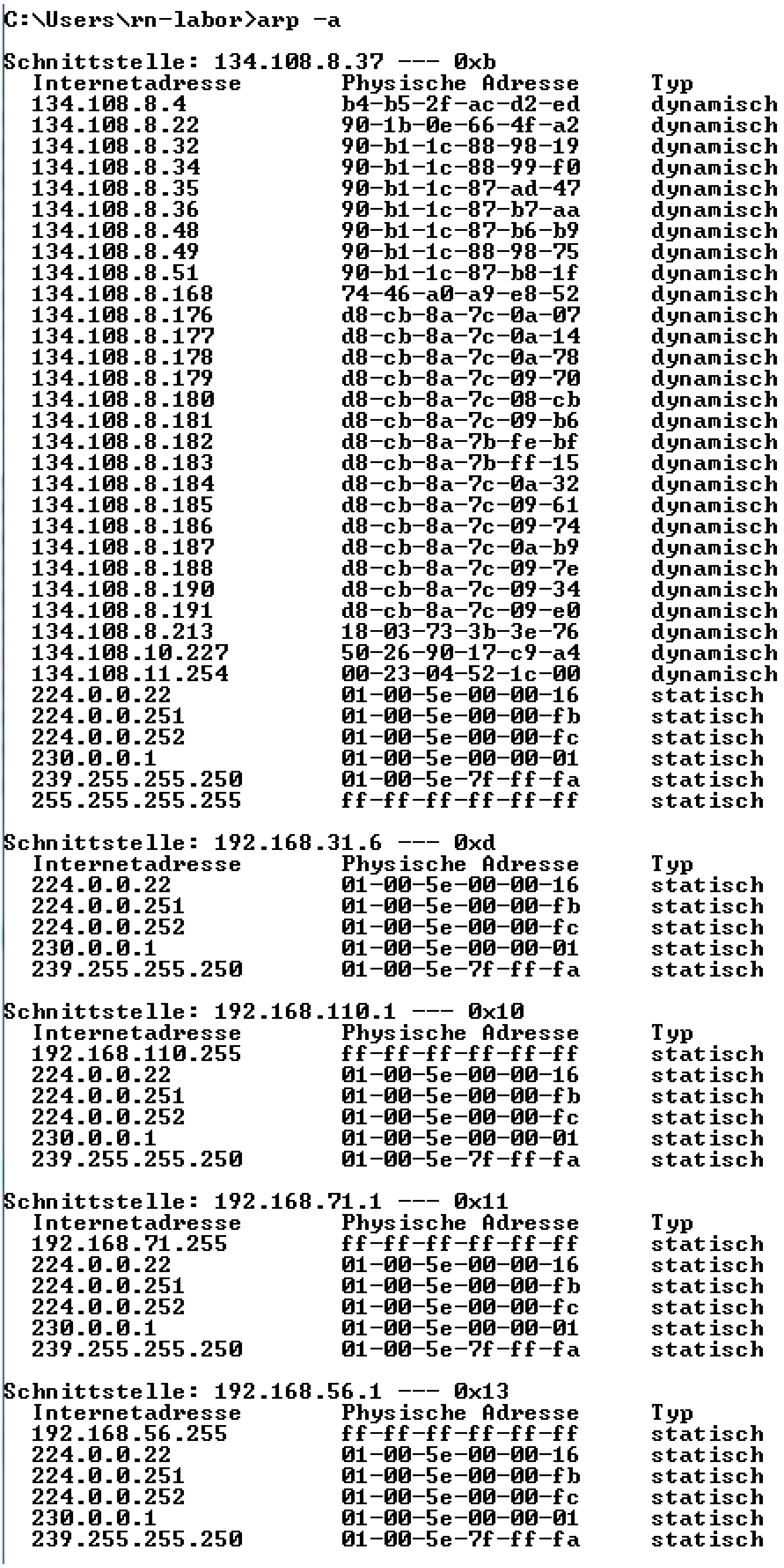
2.4 ARP analysis

In the following exercises the Address Resolution Protocol was analyzed to achieve a better understanding how IP-Addresses are mapped to actual Hardware MAC-Addresses. ARP does exactly this by putting both address in relation together into a cache, also called the ARP table. Table **??** shows the header for ARP:

bits	0-7	8-15	16-23	24-31
bytes	0	1	2	3
Offset 0	Hardware-Addresstype (HTYPE)		Network Protocol Type (PTYPE)	
Offset 32	Hardware Address Length (HLEN)	Protocol Address Length (PLEN)	Operation	
Offset 64	Sender MAC-Address			
Offset 128	Sender MAC-Address		Sender IP Address	
Offset 160	Sender IP Address		Target MAC-Address	
Offset 192	Target MAC-Address			
Offset 224	Target IP-Address			

Table 2.5: Address Resolution Protocol Header

The following Figure 2.9 shows the ARP table obtained by typing ’arp -a’ into the console from one of the network lab PCs before it was deleted for the next exercise:



```
C:\Users\rn-labor>arp -a

Schnittstelle: 134.108.8.37 --- 0xb
  Internetadresse       Physische Adresse     Typ
  134.108.8.4           b4-b5-2f-ac-d2-ed     dynamisch
  134.108.8.22          90-1b-0e-66-4f-a2     dynamisch
  134.108.8.32          90-b1-1c-88-98-19     dynamisch
  134.108.8.34          90-b1-1c-88-99-f0     dynamisch
  134.108.8.35          90-b1-1c-87-ad-47     dynamisch
  134.108.8.36          90-b1-1c-87-b7-aa     dynamisch
  134.108.8.48          90-b1-1c-87-b6-b9     dynamisch
  134.108.8.49          90-b1-1c-88-98-75     dynamisch
  134.108.8.51          90-b1-1c-87-b8-1f     dynamisch
  134.108.8.168         74-46-a0-a9-e8-52     dynamisch
  134.108.8.176         d8-cb-8a-7c-0a-07     dynamisch
  134.108.8.177         d8-cb-8a-7c-0a-14     dynamisch
  134.108.8.178         d8-cb-8a-7c-0a-78     dynamisch
  134.108.8.179         d8-cb-8a-7c-09-70     dynamisch
  134.108.8.180         d8-cb-8a-7c-08-cb     dynamisch
  134.108.8.181         d8-cb-8a-7c-09-b6     dynamisch
  134.108.8.182         d8-cb-8a-7b-fe-bf     dynamisch
  134.108.8.183         d8-cb-8a-7b-ff-15     dynamisch
  134.108.8.184         d8-cb-8a-7c-0a-32     dynamisch
  134.108.8.185         d8-cb-8a-7c-09-61     dynamisch
  134.108.8.186         d8-cb-8a-7c-09-74     dynamisch
  134.108.8.187         d8-cb-8a-7c-0a-b9     dynamisch
  134.108.8.188         d8-cb-8a-7c-09-7e     dynamisch
  134.108.8.190         d8-cb-8a-7c-09-34     dynamisch
  134.108.8.191         d8-cb-8a-7c-09-e0     dynamisch
  134.108.8.213         18-03-73-3b-3e-76     dynamisch
  134.108.10.227        50-26-90-17-c9-a4     dynamisch
  134.108.11.254        00-23-04-52-1c-00     dynamisch
  224.0.0.22            01-00-5e-00-00-16     statisch
  224.0.0.251           01-00-5e-00-00-fb     statisch
  224.0.0.252           01-00-5e-00-00-fc     statisch
  230.0.0.1             01-00-5e-00-00-01     statisch
  239.255.255.250       01-00-5e-7f-ff-fa     statisch
  255.255.255.255       ff-ff-ff-ff-ff-ff     statisch

Schnittstelle: 192.168.31.6 --- 0xd
  Internetadresse       Physische Adresse     Typ
  224.0.0.22            01-00-5e-00-00-16     statisch
  224.0.0.251           01-00-5e-00-00-fb     statisch
  224.0.0.252           01-00-5e-00-00-fc     statisch
  230.0.0.1             01-00-5e-00-00-01     statisch
  239.255.255.250       01-00-5e-7f-ff-fa     statisch

Schnittstelle: 192.168.110.1 --- 0x10
  Internetadresse       Physische Adresse     Typ
  192.168.110.255       ff-ff-ff-ff-ff-ff     statisch
  224.0.0.22            01-00-5e-00-00-16     statisch
  224.0.0.251           01-00-5e-00-00-fb     statisch
  224.0.0.252           01-00-5e-00-00-fc     statisch
  230.0.0.1             01-00-5e-00-00-01     statisch
  239.255.255.250       01-00-5e-7f-ff-fa     statisch

Schnittstelle: 192.168.71.1 --- 0x11
  Internetadresse       Physische Adresse     Typ
  192.168.71.255        ff-ff-ff-ff-ff-ff     statisch
  224.0.0.22            01-00-5e-00-00-16     statisch
  224.0.0.251           01-00-5e-00-00-fb     statisch
  224.0.0.252           01-00-5e-00-00-fc     statisch
  230.0.0.1             01-00-5e-00-00-01     statisch
  239.255.255.250       01-00-5e-7f-ff-fa     statisch

Schnittstelle: 192.168.56.1 --- 0x13
  Internetadresse       Physische Adresse     Typ
  192.168.56.255        ff-ff-ff-ff-ff-ff     statisch
  224.0.0.22            01-00-5e-00-00-16     statisch
  224.0.0.251           01-00-5e-00-00-fb     statisch
  224.0.0.252           01-00-5e-00-00-fc     statisch
  230.0.0.1             01-00-5e-00-00-01     statisch
  239.255.255.250       01-00-5e-7f-ff-fa     statisch
```

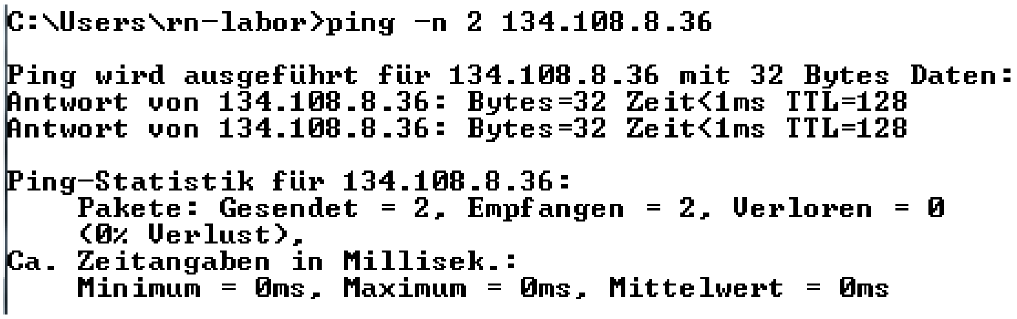
Figure 2.9: ARP table

2.4.1 a) Deleting the ARP cache

Now the ARP table on the source PC (134.108.8.37) was deleted using the console command 'arp -d'. After executing this, the ARP table was empty. After that another PING-Command was executed:

ping -n 2 134.108.8.36

The following figure shows the output of this Ping:



```
C:\Users\rn-labor>ping -n 2 134.108.8.36

Ping wird ausgeführt für 134.108.8.36 mit 32 Bytes Daten:
Antwort von 134.108.8.36: Bytes=32 Zeit<1ms TTL=128
Antwort von 134.108.8.36: Bytes=32 Zeit<1ms TTL=128

Ping-Statistik für 134.108.8.36:
    Pakete: Gesendet = 2, Empfangen = 2, Verloren = 0
    (0% Verlust),
Ca. Zeitangaben in Millisek.:
    Minimum = 0ms, Maximum = 0ms, Mittelwert = 0ms
```

Figure 2.10: PING Command Output after ARP table was deleted

Because the ARP table is now empty, IP has the problem that the target IP-Address cannot be resolved. This leads to the ARP request packet sent from the Source PC into the network via Broadcast as seen in Listing ?? asking who has the required Target IP Address. The PC inside the same subnet who owns this IP Address now answers with an ARP reply packet containing it's MAC-Address. Following this the source PC inserts a new mapping with the target PC's IP- and MAC-Address into it's ARP table. After that the two PINGs are executed as seen in the following Wireshark trace:

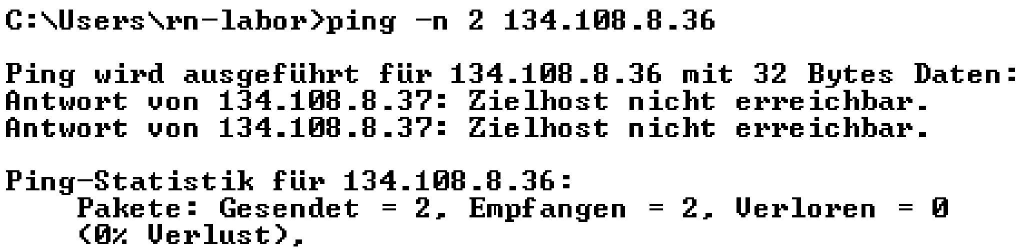
,

```
No.     Time       Source               Destination          Protocol Length DestPort Info
                                                           Delta Time
162 0.459379   90:b1:1c:88:97:76   ff:ff:ff:ff:ff:ff    ARP      42              Who has 134.108.8.36?
    Tell 134.108.8.37                     0.459379

Frame 162: 42 bytes on wire (336 bits), 42 bytes captured (336 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 10:50:47.561364000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510912247.561364000 seconds
    [Time delta from previous captured frame: 0.397775000 seconds]
    [Time delta from previous displayed frame: 0.459379000 seconds]
    [Time since reference or first frame: 1.803262000 seconds]
    Frame Number: 162
    Frame Length: 42 bytes (336 bits)
    Capture Length: 42 bytes (336 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:arp]
    [Coloring Rule Name: ARP]
    [Coloring Rule String: arp]
Ethernet II, Src: 90:b1:1c:88:97:76, Dst: ff:ff:ff:ff:ff:ff
    Destination: ff:ff:ff:ff:ff:ff
        Address: ff:ff:ff:ff:ff:ff
        .... ..1. .... .... .... .... = LG bit: Locally administered address (this is NOT the
            factory default)
        .... ...1 .... .... .... .... = IG bit: Group address (multicast/broadcast)
    Source: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: ARP (0x0806)
Address Resolution Protocol (request)
    Hardware type: Ethernet (1)
    Protocol type: IPv4 (0x0800)
    Hardware size: 6
    Protocol size: 4
    Opcode: request (1)
    Sender MAC address: 90:b1:1c:88:97:76
    Sender IP address: 134.108.8.37
    Target MAC address: 00:00:00:00:00:00
    Target IP address: 134.108.8.36

No.    Time       Source              Destination        Protocol Length DestPort Info
                                                      Delta Time
163 0.000164   90:b1:1c:87:b7:aa   90:b1:1c:88:97:76   ARP     60             134.108.8.36 is at 90:b1
    :1c:87:b7:aa                      0.000164

Frame 163: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 10:50:47.561528000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510912247.561528000 seconds
    [Time delta from previous captured frame: 0.000164000 seconds]
    [Time delta from previous displayed frame: 0.000164000 seconds]
    [Time since reference or first frame: 1.803426000 seconds]
    Frame Number: 163
    Frame Length: 60 bytes (480 bits)
    Capture Length: 60 bytes (480 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:arp]
    [Coloring Rule Name: ARP]
    [Coloring Rule String: arp]
Ethernet II, Src: 90:b1:1c:87:b7:aa, Dst: 90:b1:1c:88:97:76
    Destination: 90:b1:1c:88:97:76
        Address: 90:b1:1c:88:97:76
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: 90:b1:1c:87:b7:aa
        Address: 90:b1:1c:87:b7:aa
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: ARP (0x0806)
    Padding: 000000000000000000000000000000000000
Address Resolution Protocol (reply)
    Hardware type: Ethernet (1)
    Protocol type: IPv4 (0x0800)
    Hardware size: 6
    Protocol size: 4
    Opcode: reply (2)
    Sender MAC address: 90:b1:1c:87:b7:aa
    Sender IP address: 134.108.8.36
    Target MAC address: 90:b1:1c:88:97:76
    Target IP address: 134.108.8.37

No.    Time       Source              Destination         Protocol Length DestPort Info
                                                      Delta Time
164 0.000018  134.108.8.37        134.108.8.36        ICMP     74             Echo (ping) request id=0
    x0001, seq=52/13312, ttl=128 (reply in 165) 0.000018


No.    Time       Source              Destination         Protocol Length DestPort Info
                                                      Delta Time
165 0.000168  134.108.8.36        134.108.8.37        ICMP     74             Echo (ping) reply  id=0
    x0001, seq=52/13312, ttl=128 (request in 164) 0.000168


No.    Time       Source              Destination         Protocol Length DestPort Info
                                                      Delta Time
176 1.005949  134.108.8.37        134.108.8.36        ICMP     74             Echo (ping) request id=0
    x0001, seq=53/13568, ttl=128 (reply in 177) 1.005949


No.    Time       Source              Destination         Protocol Length DestPort Info
                                                      Delta Time
177 0.000271  134.108.8.36        134.108.8.37        ICMP     74             Echo (ping) reply  id=0
    x0001, seq=53/13568, ttl=128 (request in 176) 0.000271
```

Listing 2.6: Wireshark trace for PING command after deleting the ARP table

2.4.2 b) Shutting down one PC

For this second exercise the ARP-table on the source PC was deleted again. But this time, the target PC was shut down before the same Ping command as in ?? was executed. The following figure 2.11 shows the console output for the Ping-Command:



```
C:\Users\rn-labor>ping -n 2 134.108.8.36

Ping wird ausgeführt für 134.108.8.36 mit 32 Bytes Daten:
Antwort von 134.108.8.37: Zielhost nicht erreichbar.
Antwort von 134.108.8.37: Zielhost nicht erreichbar.

Ping-Statistik für 134.108.8.36:
    Pakete: Gesendet = 2, Empfangen = 2, Verloren = 0
    (0% Verlust),
```

Figure 2.11: PING Command Output after ARP table was deleted and target PC was shut down

Because the ARP table is empty, the source PC has to send another ARP request packet. But this time he receives no answer because the PC owning the required IP address is not reachable. The console output shows that the source PC tries to reach the target PC with another ARP request, but again there is no answer. So the communication is canceled after this. Listing ?? shows the two ARP request packet that were sent from the source PC via Broadcast.

,

```
No.     Time           Source                Destination           Protocol Length Info
21 2.895675      Dell\_88:97:76       Broadcast             ARP      42     Who has 134.108.8.36? Tell
    134.108.8.37

Frame 21: 42 bytes on wire (336 bits), 42 bytes captured (336 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
Address Resolution Protocol (request)

No.     Time           Source                Destination           Protocol Length Info
31 3.798686      Dell\_88:97:76       Broadcast             ARP      42     Who has 134.108.8.36? Tell
    134.108.8.37

Frame 31: 42 bytes on wire (336 bits), 42 bytes captured (336 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Broadcast (ff:ff:ff:ff:ff:ff)
Address Resolution Protocol (request)
```

Listing 2.7: Wireshark trace for PING command after deleting the ARP table and shutting down target PC

2.4.3 c) Reconnect after Reboot

After rebooting the target PC and reconnecting it to the network, the same PING-Command as in 2.4.1 was sent again from the source PC. Because now the target PC was reachable, the process and the outcome was exactly the same as in exercise 2.4.1.

2.5 IP multicast addressing

IP multicast addressing is used to send packets to groups of different IP addresses without broadcasting into the network. The are different protocols that are able to do this such as the Virtual Router Redundancy Protocol (VRRP), the Internet Group Management Protocol (IGMP), the routing protocol OSPF, the Network Time Protocol (NTP), the Simple Service Discovery Protocol (SSDP) and the Spanning Tree Protocol (STP).

The range for IP-Multicast Addresses is from 224.0.0.0 to 239.255.255.255. This can be seen when observing the intranet traffic of the Hochschule Esslingen. As a multicast packet contains a range of target IP-addresses, they cannot be exclusively mapped to a single MAC-address. So a trick is used here. The 23 lowest bits from the IP-address are put into the MAC-address. This leads to a range of MAC-addresses from 01-00-5e-00-00-00 to 01-00-5e-7f-ff-ff. The Downside is, that it is possible, that a single MAC-address can be referenced by multiple IP-Addresses. The following listing shows an SSDP packet captured from the traffic of the Hochschule Esslingen:

,

```
No.    Time           Source               Destination         Protocol Length Info
4 0.461068     134.108.8.33        239.255.255.250     SSDP     175    M-SEARCH * HTTP/1.1

Frame 4: 175 bytes on wire (1400 bits), 175 bytes captured (1400 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF})
        Interface name: \\Device\\NPF\_{55902047-E973-4FFC-B9C0-B0FAC2DA73AF}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 17, 2017 11:09:15.825997000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1510913355.825997000 seconds
    [Time delta from previous captured frame: 0.115495000 seconds]
    [Time delta from previous displayed frame: 0.115495000 seconds]
    [Time since reference or first frame: 0.461068000 seconds]
    Frame Number: 4
    Frame Length: 175 bytes (1400 bits)
    Capture Length: 175 bytes (1400 bits)
    [Frame is marked: False]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ip:udp:ssdp]
    [Coloring Rule Name: UDP]
    [Coloring Rule String: udp]
    Ethernet II, Src: Dell\_87:b4:26 (90:b1:1c:87:b4:26), Dst: IPv4mcast\_7f:ff:fa (01:00:5e:7f:ff:fa)
    Destination: IPv4mcast\_7f:ff:fa (01:00:5e:7f:ff:fa)
        Address: IPv4mcast\_7f:ff:fa (01:00:5e:7f:ff:fa)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...1 .... .... .... .... = IG bit: Group address (multicast/broadcast)
    Source: Dell\_87:b4:26 (90:b1:1c:87:b4:26)
        Address: Dell\_87:b4:26 (90:b1:1c:87:b4:26)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv4 (0x0800)
Internet Protocol Version 4, Src: 134.108.8.33, Dst: 239.255.255.250
    0100 .... = Version: 4
    .... 0101 = Header Length: 20 bytes (5)
    Differentiated Services Field: 0x00 (DSCP: CS0, ECN: Not-ECT)
        0000 00.. = Differentiated Services Codepoint: Default (0)
        .... ..00 = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    Total Length: 161
    Identification: 0x2fc2 (12226)
    Flags: 0x00
        0... .... = Reserved bit: Not set
        .0.. .... = DonÂ´t fragment: Not set
        ..0. .... = More fragments: Not set
    Fragment offset: 0
    Time to live: 1
    Protocol: UDP (17)
    Header checksum: 0x0b03 [validation disabled]
    [Header checksum status: Unverified]
    Source: 134.108.8.33
    Destination: 239.255.255.250
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
User Datagram Protocol, Src Port: 53552, Dst Port: 1900
    Source Port: 53552
    Destination Port: 1900
    Length: 141
    Checksum: 0x01c6 [unverified]
    [Checksum Status: Unverified]
    [Stream index: 0]
Simple Service Discovery Protocol
    M-SEARCH * HTTP/1.1\r\\n
        [Expert Info (Chat/Sequence): M-SEARCH * HTTP/1.1\r\\n]
            [M-SEARCH * HTTP/1.1\r\\n]
            [Severity level: Chat]
            [Group: Sequence]
        Request Method: M-SEARCH
        Request URI: *
        Request Version: HTTP/1.1
    Host:239.255.255.250:1900\r\\n
    ST:urn:schemas-upnp-org:device:InternetGatewayDevice:1\r\\n
    Man:"ssdp:discover"\r\\n
    MX:3\r\\n
    \r\\n
    [Full request URI: http://239.255.255.250:1900*]
    [HTTP request 1/19]
    [Next request in frame: 206]
```

Listing 2.8: A single SSDP packet

3 TCP analysis

In this second part of the laboratory the Transmission Control Protocol (TCP) was examined through various exercises showing it's functionality.
TCP is one layer above the protocols ICMP and IP in the transport layer of the OSI-model. It's main goal is to establish a stable connection between two hosts to ensure transmission of information without data loss. Other than the protocols one layer down in the Network Layer such as ICMP or IP, TCP provides enhanced functionality for transmission control, error recovery and handling for protocol errors. These functionalities will be shown in the exercises of this laboratory. Table **??** shows the TCP Header.

bits	0-3	4-7	8	9	10	11	12	13	14	15	16-23	24-31
bytes	0		1								2	3
Offset 0	source port										destination port	
Offset 32	sequence number											
Offset 64	acknowledgment number											
Offset 96	data offset	reserved	C W R	E C E	U R G	A C K	P S H	R S T	S Y N	F I N	window	
Offset 128	checksum										urgent pointer	
Offset 160	options											

Table 3.1: Transmission Control Protocol Header

TCP does not handle the networking part of the communication. This task is still handled by IP, which is one layer below TCP in the protocol stack. This is why there are no source- or target address fields in the TCP header. Instead it has segments for source- and target ports. These are necessary because a program such as *Traffic*[1] is needed for the TCP communication and these programs run on a port on both hosts. Sequence and acknowledgment numbers are used for the synchronization and error recovery between server and client. These will be important for the exercises. The control flags (each of them is only one bit) are used for traffic handling. The protocol decides how to interpret the sent data based on the set flags. They are also used for connection establishment, connection reset and for terminating a connection.

[1] bla

3.1 Traffic generator handling

As mentioned above, simple PING-commands weren't enough for generating traffic using the Transmission Control Protocol. A program which occupies ports on both PCs (server and client) is needed to establish a TCP connection. For this exercise a tool named *Traffic* was used. The tool provides the functionality of a socket and can perform simple socket routines such as *socket*, *bind()*, *listen()*, *accept()*. It also provides a simple user interface where all functionalities are accessible for a user.

3.2 Simple TCP Communication

The first task in this laboratory was to establish a simple TCP-connection between a Server PC and a Client PC, sending multiple messages from client to server and vice versa, and finally releasing the connection.

3.2.1 Connection establishment

To establish a connection between server and client, TCP performs a routine known as the Three-Way-Handshake. The Three-Way-Handshake consists of three packets being transmitted between client and server. First, the client sends a TCP packet with the SYN-Flag containing a random number x as sequence number (s. header in chapter 3) to the server. If the server is reachable, it replies with a TCP packet with the SYN and ACK-flags being enabled. Furthermore this packet contains the incremented sequence number *x+1* from the client as acknowledgment number and a newly generated random number y as sequence number. Finally the client performs the last step of the Three-Way-Handshake by replying with another ACK-flagged TCP-packet, containing the incremented sequence number from the server *y+1* as acknowledgment number.

After these steps were successful, a stable connection is established and both client and server can begin to send data to each other. The following figure 3.1 shows the steps of the Three-Way-Handshake.

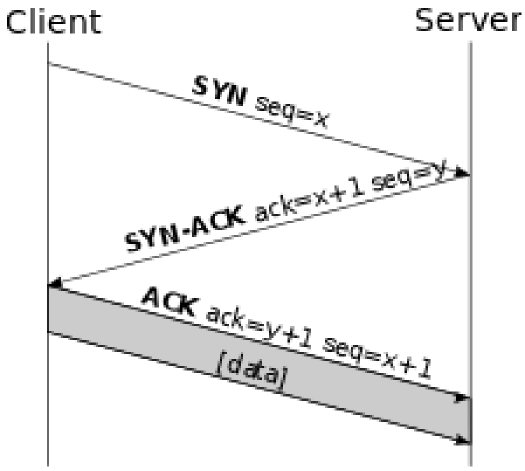


Figure 3.1: Three-Way-Handshake

The Wireshark-trace reveals some more details about the Three-Way-Handshake. As seen in listing **??** client and server also exchange information about the Maximum Segment Size (MSS). Furthermore both parties, the client and the server, set their window size which corresponds to the size of the buffer. When the buffer is completely occupied with data, no more data can be transfered until the buffer is cleaned by the receiver.

,

```
No.    Time          Source             Destination         Protocol Length Info
129 14.773660    134.108.8.37       134.108.8.36       TCP      66     51444 -> 6777 [SYN] Seq=0 Win
    =8192 Len=0 MSS=1460 WS=256 SACK\_PERM=1

Frame 129: 66 bytes on wire (528 bits), 66 bytes captured (528 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 0, Len: 0

No.    Time          Source             Destination         Protocol Length Info
130 14.773711    134.108.8.36       134.108.8.37       TCP      66     6777 -> 51444 [SYN, ACK] Seq
    =0 Ack=1 Win=8192 Len=0 MSS=1460 WS=256 SACK\_PERM=1

Frame 130: 66 bytes on wire (528 bits), 66 bytes captured (528 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 0, Ack: 1, Len: 0

No.    Time          Source             Destination         Protocol Length Info
131 14.773828    134.108.8.37       134.108.8.36       TCP      60     51444 -> 6777 [ACK] Seq=1 Ack
    =1 Win=65536 Len=0

Frame 131: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
```

```
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 1, Ack: 1, Len: 0
```

Listing 3.1: Wireshark trace for Three-Way-Handshake

3.2.2 Data transfer

After the successful establishment of the TCP connection, multiple messages were transmitted between client and server. the Wireshark trace ?? shows all the packets in chronological order. All packets have in common that the PSH and ACK flags are enabled.

The first message was sent from client to server and contained 100 bytes of data. Because this was the first packet after the Three-Way-Handshake, both acknowledgment and sequence numbers are 1. The server answers with an ACK-packet, where the acknowledgment number is now 101. This is because the data size of the previous packet sent from client to server is added to the acknowledgment number. Also the data size is subtracted from the buffer size.

The second message sent from client to server is much larger, containing 1000 bytes of data. The procedure is the same as for the first message. The only difference is, that the sequence number of the packet is now 101 because of the previous ACK-Packet from the server. The server answers with and ACK-packet where the acknowledgment number is now 1101. Again the data size was added here and subtracted from the buffer size of the server. The sequence number is still 1, because the server hasn't sent any data to the client yet. The window-size of the server however is now reduced to 252, because the data has not been read from the buffer yet.

The third message follows the same procedure as message 1, but of cause this time the acknowledgment number in the server's reply packet is 1201, because there were again 100 bytes transmitted. The window size of the server is now reduced to 251.

The last message was sent from server to client. Here the sequence number is still 1 while the acknowledgment number is already 1201. The client replies with a ACK-packet containing a acknowledgment number increased to 101, because the previous packet was the first data packet it received since the Three-Way-Handshake.

,

```
No.     Time           Source                Destination         Protocol Length Info
41 7.691788     134.108.8.37        134.108.8.36        TCP      154    51444 -> 6777 [PSH, ACK] Seq=1
     Ack=1 Win=256 Len=100

Frame 41: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
```

```
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 1, Ack: 1, Len: 100
Data (100 bytes)

No.     Time           Source                Destination           Protocol Length Info
46 7.892984      134.108.8.36          134.108.8.37          TCP      54     6777 -> 51444 [ACK] Seq=1 Ack
    =101 Win=256 Len=0

Frame 46: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 1, Ack: 101, Len: 0

No.     Time           Source                Destination           Protocol Length Info
90 19.684399     134.108.8.37          134.108.8.36          TCP      1054   51444 -> 6777 [PSH, ACK] Seq
    =101 Ack=1 Win=256 Len=1000

Frame 90: 1054 bytes on wire (8432 bits), 1054 bytes captured (8432 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 101, Ack: 1, Len: 1000
Data (1000 bytes)

No.     Time           Source                Destination           Protocol Length Info
92 19.889133     134.108.8.36          134.108.8.37          TCP      54     6777 -> 51444 [ACK] Seq=1 Ack
    =1101 Win=252 Len=0

Frame 92: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 1, Ack: 1101, Len: 0

No.     Time           Source                Destination           Protocol Length Info
1875 165.393174   134.108.8.37          134.108.8.36          TCP      154    51444 -> 6777 [PSH, ACK] Seq
    =1101 Ack=1 Win=256 Len=100

Frame 1875: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 1101, Ack: 1, Len: 100
Data (100 bytes)

No.     Time           Source                Destination           Protocol Length Info
1879 165.608164   134.108.8.36          134.108.8.37          TCP      54     6777 -> 51444 [ACK] Seq=1
    Ack=1201 Win=251 Len=0

Frame 1879: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
```

```
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 1, Ack: 1201, Len: 0

No.     Time           Source                Destination           Protocol Length Info
2086 201.626400    134.108.8.36          134.108.8.37          TCP      154    6777 -> 51444 [PSH, ACK] Seq
    =1 Ack=1201 Win=251 Len=100

Frame 2086: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 1, Ack: 1201, Len: 100
Data (100 bytes)

No.     Time           Source                Destination           Protocol Length Info
2088 201.832292    134.108.8.37          134.108.8.36          TCP      60     51444 -> 6777 [ACK] Seq=1201
     Ack=101 Win=256 Len=0

Frame 2088: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 1201, Ack: 101, Len: 0
```

Listing 3.2: Wireshark trace for TCP messages

3.2.3 Connection release

To terminate an active connection, one of the two connected nodes sends a TCP-packet with the FIN-Flag enabled to the other node. In this case the client releases the connection first. The server answers with an ACK-packet where the acknowledgment number is increased to 102 because of the FIN-Flag. At this point, the connection is half-closed. The server can still send data to the client, but the client cannot send any data to the server, because it already released the connection. Now the server sends a FIN-enabled TCP packet to the client to terminated it's side of the connection. The client answers with an ACK-packet where the sequence number is 102 as before and the acknowledgment number is increased from 1201 to 1202 because of the server's FIN-flag in the previous packet. Now the connection is fully terminated. The following Wireshark-trace shows the captured packets:

,

```
No.     Time           Source                Destination           Protocol Length Info
3752 554.875797    134.108.8.36          134.108.8.37          TCP      54     6777 -> 51444 [FIN, ACK] Seq
    =101 Ack=1201 Win=251 Len=0

Frame 3752: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
```

```
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 101, Ack: 1201, Len: 0

No.     Time           Source                Destination           Protocol Length Info
3755 554.876001    134.108.8.37          134.108.8.36          TCP      60     51444 -> 6777 [ACK] Seq=1201
     Ack=102 Win=256 Len=0

Frame 3755: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 1201, Ack: 102, Len: 0

No.     Time           Source                Destination           Protocol Length Info
3869 569.922788    134.108.8.37          134.108.8.36          TCP      60     51444 -> 6777 [FIN, ACK] Seq
    =1201 Ack=102 Win=256 Len=0

Frame 3869: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51444, Dst Port: 6777, Seq: 1201, Ack: 102, Len: 0

No.     Time           Source                Destination           Protocol Length Info
3870 569.922807    134.108.8.36          134.108.8.37          TCP      54     6777 -> 51444 [ACK] Seq=102
    Ack=1202 Win=251 Len=0

Frame 3870: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51444, Seq: 102, Ack: 1202, Len: 0
```

Listing 3.3: Wireshark trace for Connection Release

3.3 TCP flow control

For this exercise another connection between server and client was established the same way as before. Now the task was to send a burst of 100 message from one host to another, while each message contained 1000 bytes of data. The intention behind this is to completely occupy the server's receive buffer with data and to observe what happens next. As seen in the Wireshark-trace, the client sends packet after packet to the server until the Window-size in the Servers corresponding ACK-packet is decreased to a value beneath 1000 bytes. When the client now tries to send the next packet, the server answers with a **TCP Zero Window** packet, where the window-size is decreased to 0, so the client cannot send another packet, no matter how small it is. This causes the client to stop sending the data packets. Instead it asks the server regulary if the receiver-buffer was cleared using a **TCP Zero Window Probe** packet. While the buffer is still occupied, the server answers with another TCP Zero Window packet. When the buffer is cleared by the server, it sends a **Zero Window Update** packet with the new buffer size to the client. As soon as the client receives this packet, it answers with an ACK-packet and continues to send the data packets. The following Wireshark trace shows an example for each of the packets mentioned above.

,

```
No.     Time           Source                Destination           Protocol Length Info
711 94.044149    134.108.8.37        134.108.8.36        TCP      60     [TCP ZeroWindowProbe] 51484
    -> 6777 [ACK] Seq=73467 Ack=1 Win=256 Len=1

Frame 711: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51484, Dst Port: 6777, Seq: 73467, Ack: 1, Len: 1
Data (1 byte)

0000  53                                          S

No.     Time           Source                Destination           Protocol Length Info
714 94.255811    134.108.8.36        134.108.8.37        TCP      54     [TCP ZeroWindow] [TCP ACKed
    unseen segment] 6777 -> 51484 [ACK] Seq=1 Ack=73468 Win=0 Len=0

Frame 714: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51484, Seq: 1, Ack: 73468, Len: 0

No.     Time           Source                Destination           Protocol Length Info
1795 204.639823   134.108.8.36        134.108.8.37        TCP      54     [TCP Window Update] 6777 ->
    51484 [ACK] Seq=1 Ack=73469 Win=18 Len=0

Frame 1795: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51484, Seq: 1, Ack: 73469, Len: 0
```

Listing 3.4: Wireshark trace example for Zero Window packets

3.4 TCP transmission error recovery/abort

For this exercise TCP's error recovery and abort functionality was analyzed. In the first case, a transmission recovery happens after the server answers before the client's timeout. In the second case, the server does not answer before the timeout and the client aborts the transmission.

3.4.1 transmission error recovery

For this first part, a new connection between server and client was initialized the same way as in chapter 3.2.1. After that the server blocks any TCP-traffic for the port, *Traffic* is running on using a firewall. Now the clients sends a message to the server, but of course the related TCP-packet is blocked by the firewall. When the client does not receive an ACK-Packet for it's sent message, it sends a **TCP Retransmission** message. But there is still no answer, because the server still blocks any communication. Now the client keeps sending TCP Retransmission messages and for each packet the retransmission timeout (RTO) is increased. In this case the server is reconnected to the network again by turning off the firewall and answers with an acknowledge, before the client's RTO reaches a critical value. When the client receives this ACK-packet, the transmission was successfully recovered and the client can send it's message. The following Wireshark trace shows the client's original PSH-packet, the first and the last TCP Retransmission packet with unnecessary parts beeing collapsed and the server's ACK-packet.

,

```
No.     Time           Source                Destination           Protocol Length Info
115 20.815330     134.108.8.37          134.108.8.36          TCP      154    51693 -> 6777 [PSH, ACK] Seq
    =1 Ack=1 Win=65536 Len=100

Frame 115: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51693, Dst Port: 6777, Seq: 1, Ack: 1, Len: 100
Data (100 bytes)


No.     Time           Source                Destination           Protocol Length Info
117 21.123944     134.108.8.37          134.108.8.36          TCP      154    [TCP Retransmission] 51693 ->
     6777 [PSH, ACK] Seq=1 Ack=1 Win=65536 Len=100

Frame 117: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51693, Dst Port: 6777, Seq: 1, Ack: 1, Len: 100
    Source Port: 51693
    Destination Port: 6777
    [Stream index: 0]
    [TCP Segment Len: 100]
    Sequence number: 1  (relative sequence number)
    [Next sequence number: 101 (relative sequence number)]
    Acknowledgment number: 1  (relative ack number)
    0101 .... = Header Length: 20 bytes (5)
    Flags: 0x018 (PSH, ACK)
        000. .... .... = Reserved: Not set
        ...0 .... .... = Nonce: Not set
        .... 0... .... = Congestion Window Reduced (CWR): Not set
        .... .0.. .... = ECN-Echo: Not set
        .... ..0. .... = Urgent: Not set
        .... ...1 .... = Acknowledgment: Set
        .... .... 1... = Push: Set
        .... .... .0.. = Reset: Not set
        .... .... ..0. = Syn: Not set
        .... .... ...0 = Fin: Not set
        [TCP Flags: Â·Â·Â·Â·Â·Â·Â·APÂ·Â·Â·]
    Window size value: 256
    [Calculated window size: 65536]
    [Window size scaling factor: 256]
    Checksum: 0xabc8 [unverified]
    [Checksum Status: Unverified]
    Urgent pointer: 0
    [SEQ/ACK analysis]
    [iRTT: 0.000295000 seconds]
    [Bytes in flight: 100]
    [Bytes sent since last PSH flag: 100]
    [TCP Analysis Flags]
        [Expert Info (Note/Sequence): This frame is a (suspected) retransmission]
            [This frame is a (suspected) retransmission]
            [Severity level: Note]
            [Group: Sequence]
        [The RTO for this segment was: 0.308614000 seconds]
        [RTO based on delta from frame: 115]
    TCP payload (100 bytes)
    Retransmitted TCP segment data (100 bytes)

No.    Time         Source              Destination         Protocol Length Info
164 27.738317    134.108.8.37        134.108.8.36        TCP      154    [TCP Retransmission] 51693 -> 6777 [PSH, ACK] Seq=1 Ack=1 Win=65536 Len=100

Frame 164: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51693, Dst Port: 6777, Seq: 1, Ack: 1, Len: 100
    Source Port: 51693
    Destination Port: 6777
    [Stream index: 0]
    [TCP Segment Len: 100]
    Sequence number: 1  (relative sequence number)
    [Next sequence number: 101 (relative sequence number)]
    Acknowledgment number: 1 (relative ack number)
    0101 .... = Header Length: 20 bytes (5)
    Flags: 0x018 (PSH, ACK)
        000. .... .... = Reserved: Not set
        ...0 .... .... = Nonce: Not set
        .... 0... .... = Congestion Window Reduced (CWR): Not set
        .... .0.. .... = ECN-Echo: Not set
        .... ..0. .... = Urgent: Not set
        .... ...1 .... = Acknowledgment: Set
        .... .... 1... = Push: Set
        .... .... .0.. = Reset: Not set
        .... .... ..0. = Syn: Not set
        .... .... ...0 = Fin: Not set
        [TCP Flags: Â·Â·Â·Â·Â·Â·Â·APÂ·Â·Â·]
    Window size value: 256
    [Calculated window size: 65536]
    [Window size scaling factor: 256]
    Checksum: 0xabc8 [unverified]
    [Checksum Status: Unverified]
    Urgent pointer: 0
    [SEQ/ACK analysis]
        [iRTT: 0.000295000 seconds]
        [Bytes in flight: 100]
        [Bytes sent since last PSH flag: 100]
        [TCP Analysis Flags]
            [Expert Info (Note/Sequence): This frame is a (suspected) retransmission]
                [This frame is a (suspected) retransmission]
                [Severity level: Note]
                [Group: Sequence]
            [The RTO for this segment was: 6.922987000 seconds]
            [RTO based on delta from frame: 115]
    TCP payload (100 bytes)
    Retransmitted TCP segment data (100 bytes)

No.     Time           Source                Destination           Protocol Length Info
    166 27.951282      134.108.8.36          134.108.8.37          TCP      54     6777 -> 51693 [ACK] Seq=1
          Ack=101 Win=65536 Len=0

Frame 166: 54 bytes on wire (432 bits), 54 bytes captured (432 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51693, Seq: 1, Ack: 101, Len: 0
    Source Port: 6777
    Destination Port: 51693
    [Stream index: 0]
    [TCP Segment Len: 0]
    Sequence number: 1  (relative sequence number)
    Acknowledgment number: 101 (relative ack number)
    0101 .... = Header Length: 20 bytes (5)
    Flags: 0x010 (ACK)
        000. .... .... = Reserved: Not set
        ...0 .... .... = Nonce: Not set
        .... 0... .... = Congestion Window Reduced (CWR): Not set
        .... .0.. .... = ECN-Echo: Not set
        .... ..0. .... = Urgent: Not set
        .... ...1 .... = Acknowledgment: Set
        .... .... 0... = Push: Not set
```

```
          .... .... .0.. = Reset: Not set
          .... .... ..0. = Syn: Not set
          .... .... ...0 = Fin: Not set
          [TCP Flags: Â·Â·Â·Â·Â·Â·Â·AÂ·Â·Â·Â·]
     Window size value: 256
     [Calculated window size: 65536]
     [Window size scaling factor: 256]
     Checksum: 0x1d3c [unverified]
     [Checksum Status: Unverified]
     Urgent pointer: 0
     [SEQ/ACK analysis]
          [This is an ACK to the segment in frame: 115]
          [The RTT to ACK the segment was: 7.135952000 seconds]
          [iRTT: 0.000295000 seconds]
```

Listing 3.5: Wireshark trace for TCP transmission error recovery

3.4.2 transmission error abort

In this second case, the server wasn't reconnected to the network before the client's TCP-packet RTO reached a critical value. To set up the same starting situation as in the exercise before, a burst of 10 messages was sent from client to server to reduce the RTO to a minimum. Now the server blocks all TCP traffic again using it's firewall. After that the client sends another message, but this time the server does not reconnect to the network. After seven TCP Retransmission messages, the RTO reaches a critical value and the client now sends a RST-packet to the server to close it's side of the connection. When the server tries to send another message to the client, the client does not reply with an acknowledge but with an reset (RST). These packets can be seen in the following Wireshark trace:

,

```
No.     Time           Source                Destination           Protocol Length Info
1182 150.782224    134.108.8.37          134.108.8.36          TCP      60     51685 -> 6777 [RST, ACK] Seq
    =101 Ack=1 Win=0 Len=0

Frame 1182: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51685, Dst Port: 6777, Seq: 101, Ack: 1, Len: 0

No.     Time           Source                Destination           Protocol Length Info
1971 264.235460    134.108.8.36          134.108.8.37          TCP      154    6777 -> 51685 [PSH, ACK] Seq
    =1 Ack=1 Win=65536 Len=100

Frame 1971: 154 bytes on wire (1232 bits), 154 bytes captured (1232 bits) on interface 0
Ethernet II, Src: Dell\_87:b7:aa (90:b1:1c:87:b7:aa), Dst: Dell\_88:97:76 (90:b1:1c:88:97:76)
```

```
Internet Protocol Version 4, Src: 134.108.8.36, Dst: 134.108.8.37
Transmission Control Protocol, Src Port: 6777, Dst Port: 51685, Seq: 1, Ack: 1, Len: 100
Data (100 bytes)

No.     Time           Source                Destination           Protocol Length Info
1974 264.235679    134.108.8.37         134.108.8.36          TCP      60     51685 -> 6777 [RST] Seq=1
    Win=0 Len=0

Frame 1974: 60 bytes on wire (480 bits), 60 bytes captured (480 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51685, Dst Port: 6777, Seq: 1, Len: 0
```

Listing 3.6: Wireshark trace for TCP transmission error abort

3.5 TCP protocol errors (synchronization errors)

In this exercise it was examined what TCP does when client and server are not synchronised correctly. In the first case, the client tries to connect to the server before the server's TCP socket has called *listen()*. In this case the client tries to connect to a non-existing server. When the client does not receive a [SYN, ACK]-packet from the server, it starts to send TCP Retransmission messages. When the server performs a listen before the RTO reaches a critical value, the rest of the Three-Way-Handshake is done normally. Otherwise the client aborts the procedure. The following Wireshark-trace shows the related packets for SYN and TCP Retransmission messages:

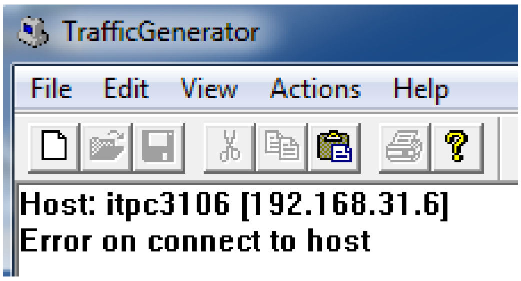
,

```
No.     Time           Source                Destination           Protocol Length Info
111 19.236136     134.108.8.37        134.108.8.36          TCP      66     51700 -> 6777 [SYN] Seq=0 Win
    =8192 Len=0 MSS=1460 WS=256 SACK\_PERM=1

Frame 111: 66 bytes on wire (528 bits), 66 bytes captured (528 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51700, Dst Port: 6777, Seq: 0, Len: 0

No.     Time           Source                Destination           Protocol Length Info
120 22.245072     134.108.8.37        134.108.8.36          TCP      66     [TCP Retransmission] 51700 ->
     6777 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 WS=256 SACK\_PERM=1

Frame 120: 66 bytes on wire (528 bits), 66 bytes captured (528 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51700, Dst Port: 6777, Seq: 0, Len: 0
```

```
No.     Time           Source                Destination           Protocol Length Info
155 28.250924    134.108.8.37        134.108.8.36        TCP      62      [TCP Retransmission] 51700 ->
     6777 [SYN] Seq=0 Win=8192 Len=0 MSS=1460 SACK\_PERM=1

Frame 155: 62 bytes on wire (496 bits), 62 bytes captured (496 bits) on interface 0
Ethernet II, Src: Dell\_88:97:76 (90:b1:1c:88:97:76), Dst: Dell\_87:b7:aa (90:b1:1c:87:b7:aa)
Internet Protocol Version 4, Src: 134.108.8.37, Dst: 134.108.8.36
Transmission Control Protocol, Src Port: 51700, Dst Port: 6777, Seq: 0, Len: 0
```

Listing 3.7: Connect before listen

The same thing happens in the second case. When the server performs a *listen* before blocking all TCP traffic for the related port, it does not notice any attempts to establish a connection. The Wireshark Trace for this looks the same as in the first case. In both cases the client's user screen shows an error message as seen in figure 3.2:



Host: itpc3106 [192.168.31.6]
Error on connect to host

Figure 3.2: Connection failed!

4 IPv6/ICMPv6 analysis

In the third and last part of the laboratory we analyzed the new versions of the protocols IPv6 and ICMPv6 using Wireshark. There are some major differences to the version 4 headers of both protocols. The first thing to notice are the much larger address segments in the headers. Those segments now support much larger address spaces to handle IPv6-addresses.

Table **??** shows the header for the Internet Protocol v6. There is a new segment simply called 'Next Header' in the IP header, that handles the type of the next header. The next header usually specifies the transport layer protocol used by a packet's payload. But there can also be extension headers for IP which are specified using this field. Also the Time to Life in the IP-header has finally been renamed to what it actually is: a Hop Limit, that is decreased when the packet bypasses a network node.

bits	0-3	4-7	8-11	12-15	16-19	20-23	24-27	28-31
bytes	0		1		2		3	
Offset 0	Version	Traffic Class		Flow Label				
Offset 32	Payload Length				Next Header		Hop Limit	
Offset 64	Source Address							
Offset 96								
Offset 128								
Offset 160								
Offset 192	Destination Address							
Offset 224								
Offset 256								
Offset 288								

Table 4.1: Internet Protocol v6 Header

Table **??** shows the header for the Internet Control Message Protocol v6. ICMP now does the same thing ARP did in version 4. It maps IPv6 Addresses to actual MAC-Addresses using the Neighbour Discovery Protocol (NDP).

bits	0-7	8-15	16-23	24-31
bytes	0	1	2	3
Offset 0	Type	Code	Checksum	
Offset 32	Message Body			

Table 4.2: Internet Control Message Protocol v6 Header

Table ?? shows the abstract header for the Internet Control Message Protocol v6.

bits	0-7	8-15	16-23	24-31
bytes	0	1	2	3
Offset 0	Source Address			
Offset 32				
Offset 64				
Offset 96				
Offset 128	Destination Address			
Offset 160				
Offset 192				
Offset 224				
Offset 256	ICMPv6 length			
Offset 288	Zeros			Next Header

Table 4.3: Abstract Internet Control Message Protocol v6 Header

4.1 Node configuration

The first task in this laboratory was the same as in laboratory 1: Checking the IP-Addresses of the PCs used in the lab to find out to whom the PING-Commands (s. chapter 4.2) should be sent. This can be done using Window’s ’ipconfig \all’-command in the console or by using the advanced ’netsh int IPv6 show addresses’-command to show all relevant network interfaces for the PC.

4.1.1 IPv6 configuration

The following listing ?? shows the output for the console command ’ipconfig \all’. Unnecessary configurations such as the configurations for IPv4 were removed for this listing:

’

```
Windows-IP-Konfiguration

    Hostname . . . . . . . . . . . . . : itpc3105
    PrimÃ¤res DNS-Suffix . . . . . . . : rznt.rzdir.fht-esslingen.de
    Knotentyp . . . . . . . . . . . . : Hybrid
    IP-Routing aktiviert . . . . . . : Nein
    WINS-Proxy aktiviert . . . . . . : Nein
    DNS-Suffixsuchliste . . . . . . . : rznt.rzdir.fht-esslingen.de
                                        rzdir.fht-esslingen.de
                                        hs-esslingen.de
Ethernet-Adapter IPV6:

    Verbindungsspezifisches DNS-Suffix:
    Beschreibung. . . . . . . . . . . : Broadcom BCM5709C NetXtreme II GigE (NDISVBD Client)
    Physikalische Adresse . . . . . . : 00-0A-F7-0F-68-30
    DHCP aktiviert. . . . . . . . . . : Ja
    Autokonfiguration aktiviert . . . : Ja
    IPv6-Adresse. . . . . . . . . . . : 2001:7c0:c00:19d:518b:9700:9521:f813(Bevorzugt)
    TemporÃ¤re IPv6-Adresse. . . . . . : 2001:7c0:c00:19d:8873:ffa4:3014:bee(Bevorzugt)
    Verbindungslokale IPv6-Adresse  . : fe80::518b:9700:9521:f813%12(Bevorzugt)
    Standardgateway . . . . . . . . . : fe80::2e0:29ff:fe24:f2be%12
    DNS-Server  . . . . . . . . . . . : fec0:0:0:ffff::1%1
                                        fec0:0:0:ffff::2%1
                                        fec0:0:0:ffff::3%1
    NetBIOS Ã¼ber TCP/IP . . . . . . . : Deaktiviert
```

Listing 4.1: IP Config

4.1.2 interfaces for IPv6

The following listing **??** shows the network interfaces for the Internet Protocol v6. These were displayed using the console command ’netsh int IPv6 show addresses’.

’

```
Schnittstelle 1: Loopback Pseudo-Interface 1

Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Andere    Bevorzugt    infinite  infinite ::1

Schnittstelle 19: 6TO4 Adapter

Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Andere    Bevorzugt    infinite  infinite 2002:866c:824::866c:824

Schnittstelle 11: IPV4-pub

Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Andere    Bevorzugt    infinite  infinite fe80::8b8:182:9a03:a4fc%11

Schnittstelle 18: VirtualBox Host-Only Network

Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Andere    Bevorzugt    infinite  infinite fe80::184e:5e69:8495:6dec%18

Schnittstelle 12: IPV6

```

```
Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Oeffentlich Bevorzugt 29d23h59m58s 6d23h59m58s 2001:7c0:c00:19d:518b:9700:9521:f813
Temporaer  Bevorzugt 6d23h40m27s 6d23h40m27s 2001:7c0:c00:19d:8873:ffa4:3014:bee
Andere    Bevorzugt    infinite  infinite fe80::518b:9700:9521:f813%12

Schnittstelle 16: VMware Network Adapter VMnet1

Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Andere    Bevorzugt    infinite  infinite fe80::e4fd:7474:65e0:77cc%16

Schnittstelle 17: VMware Network Adapter VMnet8

Adresstyp DAD-Status Gueltigkeit Bevorzugt Adresse
--------- ----------- ---------- ---------- ------------------------
Andere    Bevorzugt    infinite  infinite fe80::61f6:ca2c:cd5e:9d1e%17
```

Listing 4.2: IPv6 netsh interfaces

4.2 PING commands

For the following exercises the PING-command was used again to generate ICMP/IPv6 traffic in the network. These packets were again captured by Wireshark and analyzed to point out the differences between the new versions (v6) of these protocols compared to the older versions (v4) from the first laboratory in this workshop. The protocol stack however still stays the same. ICMPv6 request or reply packets are embedded in the IPv6 packet. And of course the IPv6 packet occupies parts of the payload segment of the Ethernet II frame (s. chapter 2).

4.2.1 a) Basic ICMPv6 PING command

This PING-Command is equivalent to the very first PING-command in this workshop (s. chapter 2.2.1). The only difference here is, that now ICMPv6/IPv6 is used instead of v4. The following PING-command does this:

ping -6 -n1 -l 64 2001:7c0:c00:19d:518b:9700:9521:f813

Again Wireshark captured two sent packets for this PING-Command: An ICMPv6 request packet and an ICMPv6 reply packet. The size of the ICMPv6 packets however is larger than the size of the ICMPv4 packets, because the IPv6 header occupies 40 bytes instead of 20 as the

IPv4 header does. This is why the ICMPv6 request packet has 126 bytes, while the ICMPv4 request packet from chapter 2.2.1 had only 106 bytes, although the amount of sent data is the same in both cases (64 bytes). The following listing shows the ICMPv6 request and reply packets:

,

```
No.     Time           Source                Destination           Protocol Length Info
155 183.058271   2001:7c0:c00:19d:3c3d:b555:99e1:2a35 2001:7c0:c00:19d:518b:9700:9521:f813 ICMPv6
    126 Echo (ping) request id=0x0001, seq=13, hop limit=128 (reply in 156)

Frame 155: 126 bytes on wire (1008 bits), 126 bytes captured (1008 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{4B57F170-DC25-4B98-9415-3FA58C45E7F6})
        Interface name: \\Device\\NPF\_{4B57F170-DC25-4B98-9415-3FA58C45E7F6}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 18, 2017 12:38:14.859626000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1511005094.859626000 seconds
    [Time delta from previous captured frame: 0.000019000 seconds]
    [Time delta from previous displayed frame: 0.000019000 seconds]
    [Time since reference or first frame: 183.058271000 seconds]
    Frame Number: 155
    Frame Length: 126 bytes (1008 bits)
    Capture Length: 126 bytes (1008 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ipv6:icmpv6:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
Ethernet II, Src: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28), Dst: Broadcom\_0f:68:30 (00:0a:f7:0f
    :68:30)
    Destination: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30)
        Address: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28)
        Address: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Type: IPv6 (0x86dd)
    Internet Protocol Version 6, Src: 2001:7c0:c00:19d:3c3d:b555:99e1:2a35, Dst: 2001:7c0:c00:19d
        :518b:9700:9521:f813
    0110 .... = Version: 6
        .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
        .... 0000 00.. .... .... .... .... .... = Differentiated Services Codepoint: Default (0)
    .... .... ..00 .... .... .... .... .... = Explicit Congestion Notification: Not ECN-Capable
        Transport (0)
    .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
    Payload Length: 72
    Next Header: ICMPv6 (58)
    Hop Limit: 128
    Source: 2001:7c0:c00:19d:3c3d:b555:99e1:2a35
    Destination: 2001:7c0:c00:19d:518b:9700:9521:f813
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
Internet Control Message Protocol v6
    Type: Echo (ping) request (128)
    Code: 0
    Checksum: 0x76cc [correct]
    [Checksum Status: Good]
    Identifier: 0x0001
    Sequence: 13
    [Response In: 156]
Data (64 bytes)


No.     Time           Source                Destination           Protocol Length Info
156 183.058370    2001:7c0:c00:19d:518b:9700:9521:f813 2001:7c0:c00:19d:3c3d:b555:99e1:2a35 ICMPv6
    126 Echo (ping) reply id=0x0001, seq=13, hop limit=64 (request in 155)

Frame 156: 126 bytes on wire (1008 bits), 126 bytes captured (1008 bits) on interface 0
    Interface id: 0 (\\Device\\NPF\_{4B57F170-DC25-4B98-9415-3FA58C45E7F6})
        Interface name: \\Device\\NPF\_{4B57F170-DC25-4B98-9415-3FA58C45E7F6}
    Encapsulation type: Ethernet (1)
    Arrival Time: Nov 18, 2017 12:38:14.859725000 MitteleuropÃ¤ische Zeit
    [Time shift for this packet: 0.000000000 seconds]
    Epoch Time: 1511005094.859725000 seconds
    [Time delta from previous captured frame: 0.000099000 seconds]
    [Time delta from previous displayed frame: 0.000099000 seconds]
    [Time since reference or first frame: 183.058370000 seconds]
    Frame Number: 156
    Frame Length: 126 bytes (1008 bits)
    Capture Length: 126 bytes (1008 bits)
    [Frame is marked: True]
    [Frame is ignored: False]
    [Protocols in frame: eth:ethertype:ipv6:icmpv6:data]
    [Coloring Rule Name: ICMP]
    [Coloring Rule String: icmp || icmpv6]
Ethernet II, Src: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30), Dst: Broadcom\_0f:68:28 (00:0a:f7:0f
    :68:28)
    Destination: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28)
        Address: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
    Source: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30)
        Address: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30)
        .... ..0. .... .... .... .... = LG bit: Globally unique address (factory default)
        .... ...0 .... .... .... .... = IG bit: Individual address (unicast)
Type: IPv6 (0x86dd)
```

```
    Internet Protocol Version 6, Src: 2001:7c0:c00:19d:518b:9700:9521:f813, Dst: 2001:7c0:c00:19d:3
        c3d:b555:99e1:2a35
    0110 .... = Version: 6
        .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
        .... 0000 00.. .... .... .... .... .... = Differentiated Services Codepoint: Default (0)
    .... .... ..00 .... .... .... .... .... = Explicit Congestion Notification: Not ECN-Capable
        Transport (0)
    .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
    Payload Length: 72
    Next Header: ICMPv6 (58)
    Hop Limit: 64
    Source: 2001:7c0:c00:19d:518b:9700:9521:f813
    Destination: 2001:7c0:c00:19d:3c3d:b555:99e1:2a35
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
Internet Control Message Protocol v6
    Type: Echo (ping) reply (129)
    Code: 0
    Checksum: 0x75cc [correct]
    [Checksum Status: Good]
    Identifier: 0x0001
    Sequence: 13
    [Response To: 155]
    [Response Time: 0.099 ms]
Data (64 bytes)
```

Listing 4.3: Simple ICMPv6 Ping

4.2.2 b) ICMPv6 PING command with large data package

For this exercise another PING-Command was used to send a large data packet from one PC to another. The data field of this packet was large enough to enforce fragmentation.

ping -6 -n1 -l 2000 2001:7c0:c00:19d:518b:9700:9521:f813

As the maximal size of an Ethernet frame is 1510 bytes, this large amount of data must be fragmented into two separate packets by IPv6. As seen in chapter 2 the Ethernet II segments occupy 14 bytes of data. Having a look on the introduction of this laboratory (s. chapter 4), one can see that the ICMPv6 header still only occupies 8 bytes. But the IPv6 header now has a size of 40 bytes and the packet must must also contain information about the fragmentation in an additional fragmentation header (another 8 bytes) as routers cannot fragment IPv6 packets. Subtracting these segments from the Ethernet frame's maximal size determines the MTU for one IPv6 fragment:

$$MTU = 1510 \text{ bytes } -14 \text{ bytes } -8 \text{ bytes } -40 \text{ bytes } -8 \text{ bytes } = \underline{1440 \text{ bytes}}$$

This first data packet is sent using an IPv6 packet with an IP fragmentation header and contains the first 1440 bytes of transmitted data. The second packet that is immediately sent after the IPv6 fragment is a ICMPv6 request packet containing the remaining 560 bytes of data, the ICMPv6 header (8 bytes), the IPv6 header (40 bytes) , and the Ethernet segments (14 bytes). So summed up this second packet has a size of 622 bytes. The reply packets are fragmented the same way. The following Wireshark trace shows all four collapsed packets transmitted between both PCs.

,

```
No.     Time           Source                Destination           Protocol Length Info
9 1.250164     2001:7c0:c00:19d:3c3d:b555:99e1:2a35 2001:7c0:c00:19d:518b:9700:9521:f813 IPv6 1510
    IPv6 fragment (off=0 more=y ident=0x00000000 nxt=58)

Frame 9: 1510 bytes on wire (12080 bits), 1510 bytes captured (12080 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28), Dst: Broadcom\_0f:68:30 (00:0a:f7:0f
    :68:30)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:3c3d:b555:99e1:2a35, Dst: 2001:7c0:c00:19d:518b
    :9700:9521:f813
Data (1448 bytes)

No.     Time           Source                Destination           Protocol Length Info
10 1.250167     2001:7c0:c00:19d:3c3d:b555:99e1:2a35 2001:7c0:c00:19d:518b:9700:9521:f813 ICMPv6 622
     Echo (ping) request id=0x0001, seq=14, hop limit=128 (reply in 13)

Frame 10: 622 bytes on wire (4976 bits), 622 bytes captured (4976 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28), Dst: Broadcom\_0f:68:30 (00:0a:f7:0f
    :68:30)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:3c3d:b555:99e1:2a35, Dst: 2001:7c0:c00:19d:518b
    :9700:9521:f813
Internet Control Message Protocol v6

No.     Time           Source                Destination           Protocol Length Info
12 1.250367     2001:7c0:c00:19d:518b:9700:9521:f813 2001:7c0:c00:19d:3c3d:b555:99e1:2a35 IPv6 1510
    IPv6 fragment (off=0 more=y ident=0x00000000 nxt=58)

Frame 12: 1510 bytes on wire (12080 bits), 1510 bytes captured (12080 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30), Dst: Broadcom\_0f:68:28 (00:0a:f7:0f
    :68:28)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:518b:9700:9521:f813, Dst: 2001:7c0:c00:19d:3c3d:
    b555:99e1:2a35
Data (1448 bytes)

No.     Time           Source                Destination           Protocol Length Info
13 1.250368     2001:7c0:c00:19d:518b:9700:9521:f813 2001:7c0:c00:19d:3c3d:b555:99e1:2a35 ICMPv6 622
     Echo (ping) reply id=0x0001, seq=14, hop limit=64 (request in 10)

```

```
Frame 13: 622 bytes on wire (4976 bits), 622 bytes captured (4976 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30), Dst: Broadcom\_0f:68:28 (00:0a:f7:0f
    :68:28)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:518b:9700:9521:f813, Dst: 2001:7c0:c00:19d:3c3d:
    b555:99e1:2a35
Internet Control Message Protocol v6
```

Listing 4.4: IPv6 Fragmentation

4.2.3 c) Rebooting PC

For this exercise the PC from where the previous PING-Commands were executed was shut down and rebooted, while the network activity was observed using the second PC. The aim was to get an idea of the Neighbor Discovery Protocol (NDP) and the Stateless Address Auto Configuration (SLAAC), that replace the Address Resolution Protocol (ARP) in IPv6.

4.2.4 d) Enforcing Neighbor discovery

The linked layer communication requires actual MAC-addresses for all involved network-nodes. The mapping between IPv6 Addresses and MAC-addresses was done by the NDP (Neighbor Discovery Protocol) and the mapping itself is registered in the neighbor cache on each PC. For this exercise it was examined what happens when this mapping does not exist on a PC executing a PING-command to an unresolved IPv6 Address. To do this the following steps had to be done first:

- Diplay the contents of the neighbor cache using *'netsh interface ipv6 show neigbors'*.
- Delete the contents of the neighbor cache using *'netsh interface ipv6 delete neigbors'*.
- Display the neighbor cache again to verify the deletion.
- Execute the PING-command.

The ping used for this exercise was:

ping -6 -n2 -l 64 2001:7c0:c00:19d:518b:9700:9521:f813

The following listing shows the neighbor cache after the deletion: ,

```
Schnittstelle 12: IPV6

Internetadresse                            Physische Adresse Typ
-------------------------------------------- ----------------- -----------
fe80::2e0:29ff:fe24:f2be                    00-00-00-00-00-00 Nicht erreichbar
ff02::1:ff24:f2be                           33-33-ff-24-f2-be Permanent
```

Listing 4.5: Neighbor cache after deletion

When executing the PING-command the PC has to do the Neighbor Discovery first to resolve the destination PC's MAC-address by sending an **Neighbor Solicitation** packet using the multicast-address *ff02::1:ff21:f813*. After that the router sends another Neighbor Solicitation packet using the multicast-address *ff02::1:ffae:be48* to resolve the source-PC's MAC-address. Both PCs answer with a **Neighbor Advertisement** packet containing their MAC-addresses. After that the neighbor-cache on the source-PC has the required entries and the PING can be executed. The following Wireshark-trace shows this procedure:

,

```
No.     Time           Source                  Destination         Protocol Length Info
2 0.752761     2001:7c0:c00:19d:fd5d:23c9:5ae:be48 ff02::1:ff21:f813 ICMPv6 86    Neighbor
    Solicitation for 2001:7c0:c00:19d:518b:9700:9521:f813 from 00:0a:f7:0f:68:28

Frame 2: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28), Dst: IPv6mcast\_ff:21:f8:13 (33:33:ff:21:
    f8:13)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:fd5d:23c9:5ae:be48, Dst: ff02::1:ff21:f813
Internet Control Message Protocol v6

No.     Time           Source                  Destination         Protocol Length Info
3 0.753012     2001:7c0:c00:19d:8873:ffa4:3014:bee ff02::1:ffae:be48 ICMPv6 86    Neighbor
    Solicitation for 2001:7c0:c00:19d:fd5d:23c9:5ae:be48 from 00:0a:f7:0f:68:30

Frame 3: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30), Dst: IPv6mcast\_ff:ae:be:48 (33:33:ff:ae:
    be:48)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:8873:ffa4:3014:bee, Dst: ff02::1:ffae:be48
Internet Control Message Protocol v6

No.     Time           Source                  Destination         Protocol Length Info
4 0.753130     2001:7c0:c00:19d:fd5d:23c9:5ae:be48 2001:7c0:c00:19d:8873:ffa4:3014:bee ICMPv6 86
    Neighbor Advertisement 2001:7c0:c00:19d:fd5d:23c9:5ae:be48 (sol, ovr) is at 00:0a:f7:0f:68:28

Frame 4: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28), Dst: Broadcom\_0f:68:30 (00:0a:f7:0f
    :68:30)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:fd5d:23c9:5ae:be48, Dst: 2001:7c0:c00:19d:8873:
    ffa4:3014:bee
```

```
Internet Control Message Protocol v6

No.     Time          Source                 Destination         Protocol Length Info
5 0.753253     2001:7c0:c00:19d:518b:9700:9521:f813 2001:7c0:c00:19d:fd5d:23c9:5ae:be48 ICMPv6 86
    Neighbor Advertisement 2001:7c0:c00:19d:518b:9700:9521:f813 (sol, ovr) is at 00:0a:f7:0f:68:30

Frame 5: 86 bytes on wire (688 bits), 86 bytes captured (688 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:30 (00:0a:f7:0f:68:30), Dst: Broadcom\_0f:68:28 (00:0a:f7:0f
    :68:28)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:518b:9700:9521:f813, Dst: 2001:7c0:c00:19d:fd5d
    :23c9:5ae:be48
Internet Control Message Protocol v6

....
Ping-packets
....
```

Listing 4.6: Neighbor discovery

The following listing shows the restored neighbor cache:

,

```
Schnittstelle 12: IPV6

Internetadresse                         Physische Adresse Typ
------------------------------------------ ----------------- -----------
2001:7c0:c00:19d:518b:9700:9521:f813     00-0a-f7-0f-68-30 Abgelaufen
2001:7c0:c00:19d:8873:ffa4:3014:bee      00-0a-f7-0f-68-30 Abgelaufen
fe80::2e0:29ff:fe24:f2be                 00-e0-29-24-f2-be Abgelaufen (Router)
ff02::1:ff21:f813                        33-33-ff-21-f8-13 Permanent
ff02::1:ff24:f2be                        33-33-ff-24-f2-be Permanent
```

Listing 4.7: Neighbor cache after PING-command

4.2.5 e) ICMPv6 PING command with destination in another subnet

For this exercise another PING-command was used to send packets to a PC in another subnet. The first subnet had the subnet-mask *2001:7C0:C00:19d::/64*, the second had the subnet-mask *2001:7C0:C00:19e::/64*. For the exercise the following PING-command was used:

ping -6 -n1 -l 64 2001:7c0:c00:19e:20a:f7ff:fe0f:67b8

The hop-limit indicates the bypassing of a network-node such as a router. When the packet runs through a router, the hop limit is decremented. In this case the hop-limit in the IP-header of the ICMPv6 echo reply packet is decreased from it's standard value 64 to 63, because it 'hopped' from one subnet into another. The other way round, the hop-limit in the ICMPv6 request header should be 127 instead of 128, when the trace would haven been captured on the destination PC. But because it was captured on the source-PC, it hadn't passed the router yet. So the hop limit is still 128. The following listing shows both packets with an expanded IP-header segment:

,

```
No.     Time           Source                Destination           Protocol Length Info
3 0.920360     2001:7c0:c00:19d:fd5d:23c9:5ae:be48 2001:7c0:c00:19e:20a:f7ff:fe0f:67b8 ICMPv6 126 Echo (ping) request id=0x0001, seq=19, hop limit=128 (reply in 4)

Frame 3: 126 bytes on wire (1008 bits), 126 bytes captured (1008 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28), Dst: SmcEther\_24:f2:be (00:e0:29:24:f2:be)
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:fd5d:23c9:5ae:be48, Dst: 2001:7c0:c00:19e:20a:f7ff:fe0f:67b8
    0110 .... = Version: 6
    .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
        .... 0000 00.. .... .... .... .... .... = Differentiated Services Codepoint: Default (0)
        .... .... ..00 .... .... .... .... .... = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
    Payload Length: 72
    Next Header: ICMPv6 (58)
    Hop Limit: 128
    Source: 2001:7c0:c00:19d:fd5d:23c9:5ae:be48
    Destination: 2001:7c0:c00:19e:20a:f7ff:fe0f:67b8
    [Destination SA MAC: Broadcom\_0f:67:b8 (00:0a:f7:0f:67:b8)]
    [Source GeoIP: Unknown]
[Destination GeoIP: Unknown]
Internet Control Message Protocol v6


No.     Time           Source                Destination           Protocol Length Info
4 0.920788     2001:7c0:c00:19e:20a:f7ff:fe0f:67b8 2001:7c0:c00:19d:fd5d:23c9:5ae:be48 ICMPv6 126 Echo (ping) reply id=0x0001, seq=19, hop limit=63 (request in 3)

Frame 4: 126 bytes on wire (1008 bits), 126 bytes captured (1008 bits) on interface 0
Ethernet II, Src: SmcEther\_24:f2:be (00:e0:29:24:f2:be), Dst: Broadcom\_0f:68:28 (00:0a:f7:0f:68:28)
Internet Protocol Version 6, Src: 2001:7c0:c00:19e:20a:f7ff:fe0f:67b8, Dst: 2001:7c0:c00:19d:fd5d:23c9:5ae:be48
    0110 .... = Version: 6
    .... 0000 0000 .... .... .... .... .... = Traffic Class: 0x00 (DSCP: CS0, ECN: Not-ECT)
        .... 0000 00.. .... .... .... .... .... = Differentiated Services Codepoint: Default (0)
        .... .... ..00 .... .... .... .... .... = Explicit Congestion Notification: Not ECN-Capable Transport (0)
    .... .... .... 0000 0000 0000 0000 0000 = Flow Label: 0x00000
    Payload Length: 72
```

```
     Next Header: ICMPv6 (58)
     Hop Limit: 63
     Source: 2001:7c0:c00:19e:20a:f7ff:fe0f:67b8
     Destination: 2001:7c0:c00:19d:fd5d:23c9:5ae:be48
     [Source SA MAC: Broadcom\_0f:67:b8 (00:0a:f7:0f:67:b8)]
     [Source GeoIP: Unknown]
[Destination GeoIP: Unknown]
Internet Control Message Protocol v6
```

Listing 4.8: PING to a PC in another subnet

4.2.6 f) PING to a remote tunnel end

For the last exercise a PING was sent to a remote tunnel end at IP: 2001:7C0:0:FFDB::1 (frankfurt2.belwue.de) in the 6WiN network via static tunnel. The following PING-command was used to to this:

ping -6 -n 1 -l 1452 2001:7C0:0:FFDB::1

After executing this PING-command the first ICMPv6-packet captured has a size of 1514 bytes, which is exactly the maximal size of an Ethernet II frame (s. chapter 2) containing the Ethernet II segments (14 bytes), the IPv6 header (40 bytes), the ICMPv6 header (8 bytes) and the raw data (1452 bytes). When this packet passes the router at the remote tunnel end, the original IPv6-packet must be encapsulated in an additional IPv4 packet, as the communication in the tunnel is still based on IPv4. So the IPv4-header (20 bytes) is added to the original packet and this makes the packet to big to be transmitted in a single frame. This causes the second captured packet **Packet Too Big** sent from the remote tunnel end to the source PC. After receiving this message, the Source PC uses fragmentation to split the data into an IPv6 fragment packet and an ICMPv6 echo request packet the same way as in chapter 4.2.2. The IPv6 packet transfers the first 1432 bytes of data and contains the headers mentioned in chapter 4.2.2 (62 bytes) and has a maximal size of 1492 bytes to leave room for the additional IPv4-header. The ICMPv6-packet transfers the remaining 20 bytes. For both packets, the source PC now received an answer from the other side of the tunnel. All mentioned packets are shown in the following Wireshark-trace:

,

```
No.    Time          Source                  Destination          Protocol Length Info
7 4.129551     2001:7c0:c00:19d:a05e:db5f:7343:2551 2001:7c0:0:ffdb::1 ICMPv6 1514 Echo (ping)
    request id=0x0001, seq=27, hop limit=128 (no response found!)

Frame 7: 1514 bytes on wire (12112 bits), 1514 bytes captured (12112 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:67:b0 (00:0a:f7:0f:67:b0), Dst: SmcEther\_24:f2:be (00:e0:29:24:f2:be
    )
```

```
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:a05e:db5f:7343:2551, Dst: 2001:7c0:0:ffdb::1
Internet Control Message Protocol v6

No.    Time           Source               Destination         Protocol Length Info
8 4.129933     2001:7c0:c00:19d::1 2001:7c0:c00:19d:a05e:db5f:7343:2551 ICMPv6 1294 Packet Too Big

Frame 8: 1294 bytes on wire (10352 bits), 1294 bytes captured (10352 bits) on interface 0
Ethernet II, Src: SmcEther\_24:f2:be (00:e0:29:24:f2:be), Dst: Broadcom\_0f:67:b0 (00:0a:f7:0f:67:b0
    )
Internet Protocol Version 6, Src: 2001:7c0:c00:19d::1, Dst: 2001:7c0:c00:19d:a05e:db5f:7343:2551
Internet Control Message Protocol v6

No.    Time           Source               Destination         Protocol Length Info
16 10.499710    2001:7c0:c00:19d:a05e:db5f:7343:2551 2001:7c0:0:ffdb::1 IPv6  1494  IPv6 fragment (
    off=0 more=y ident=0x00000008 nxt=58)

Frame 16: 1494 bytes on wire (11952 bits), 1494 bytes captured (11952 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:67:b0 (00:0a:f7:0f:67:b0), Dst: SmcEther\_24:f2:be (00:e0:29:24:f2:be
    )
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:a05e:db5f:7343:2551, Dst: 2001:7c0:0:ffdb::1
Data (1432 bytes)

No.    Time           Source               Destination         Protocol Length Info
17 10.499716    2001:7c0:c00:19d:a05e:db5f:7343:2551 2001:7c0:0:ffdb::1 ICMPv6 90   Echo (ping)
    request id=0x0001, seq=28, hop limit=128 (reply in 19)

Frame 17: 90 bytes on wire (720 bits), 90 bytes captured (720 bits) on interface 0
Ethernet II, Src: Broadcom\_0f:67:b0 (00:0a:f7:0f:67:b0), Dst: SmcEther\_24:f2:be (00:e0:29:24:f2:be
    )
Internet Protocol Version 6, Src: 2001:7c0:c00:19d:a05e:db5f:7343:2551, Dst: 2001:7c0:0:ffdb::1
Internet Control Message Protocol v6

No.    Time           Source               Destination         Protocol Length Info
18 10.506693    2001:7c0:0:ffdb::1  2001:7c0:c00:19d:a05e:db5f:7343:2551 IPv6 90    IPv6 fragment (
    off=1432 more=n ident=0x0000009d nxt=58)

Frame 18: 90 bytes on wire (720 bits), 90 bytes captured (720 bits) on interface 0
Ethernet II, Src: SmcEther\_24:f2:be (00:e0:29:24:f2:be), Dst: Broadcom\_0f:67:b0 (00:0a:f7:0f:67:b0
    )
Internet Protocol Version 6, Src: 2001:7c0:0:ffdb::1, Dst: 2001:7c0:c00:19d:a05e:db5f:7343:2551
Data (28 bytes)

No.    Time           Source               Destination         Protocol Length Info
19 10.506968    2001:7c0:0:ffdb::1  2001:7c0:c00:19d:a05e:db5f:7343:2551 ICMPv6 1494 Echo (ping)
    reply id=0x0001, seq=28, hop limit=63 (request in 17)

Frame 19: 1494 bytes on wire (11952 bits), 1494 bytes captured (11952 bits) on interface 0
Ethernet II, Src: SmcEther\_24:f2:be (00:e0:29:24:f2:be), Dst: Broadcom\_0f:67:b0 (00:0a:f7:0f:67:b0
    )
Internet Protocol Version 6, Src: 2001:7c0:0:ffdb::1, Dst: 2001:7c0:c00:19d:a05e:db5f:7343:2551
Internet Control Message Protocol v6
```

Listing 4.9: PING to a remote tunnel end

5 Conclusion

In this workshop we analyzed traffic based on the most common and important network protocols to get an idea of how networks work in general.

For the first laboratory in this workshop we analyzed the protocols **Internet Protocol v4** (IPv4), **Internet Message Control Protocol v4** (ICMPv4) and **Address Resolution Protocol** (ARP). By using the PING-commands in the console and varying the options of this command we generated traffic between two PCs and observed that traffic using the program *Wireshark*.

The second laboratory was about the **Transmission Control Protocol** (TCP). We used a program called *Traffic*, that offers the functionality of a simple TCP-Socket with a graphical user interface to generate traffic between two PCs. We observed the connection establishment in TCP, communication in TCP and TCP's error recovery behavior.

For the third and last laboratory we had a look on the new versions of the protocols IPv6 and ICMPv6 to work out the changes that had been made to these protocols and to try out new enhanced functionality such as the **Neighbor Discovery Protocol** (NDP) and the **Stateless Address Auto Configuration** (SLAAC).

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