Computer Networks

Exercise Session 10

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General Schedule

All exercises will follow this general schedule

- Identify potential understanding problems
  $\rightarrow$ Ask your questions
  $\rightarrow$ Recap of the lecture
- Address the understanding problems
  $\rightarrow$ Answer your questions
  $\rightarrow$ Repeat certain topics
- Walk through the exercises/solutions $\rightarrow$ Some hints and guidance
  $\rightarrow$ Work time or presentation of results

Network Layer: Routing Schemes

You have seen ...

- the requirements for a routing protocol
- how routing algorithms can be categorized
- flooding and hot-potato as examples for local routing algorithms
- the difference between source routing and hop-by-hop routing
- the difference between reactive and proactive routing algorithms
- how metrics are used to calculate the path costs

Network Layer: Distance Vector Routing

You have seen ...

- that distance vector routing protocols exchange forwarding tables between neighbors
- RIP as an example for a distance vector routing protocol
- how the Bellman-Ford Algorithm works
- what the Count-to-Infinity problem is
- how Split Horizon (with Poison Reversed) can be used to mitigate this problem

Network Layer: Link State Routing

You have seen . . .

- that link state routing protocols exchange information between all routers
- OSPF as an example for a link state routing protocol
- that OSPF allows for routing hierarchies
- how the Dijkstra Algorithm works

Network Layer: More Routing Protocols

You have seen ...

- IS-IS as another example for a link state routing protocol
- RPL as routing protocol for resource-constrained node networks (aka IOT networks)
- OLSR as link state routing protocol for wireless ad-hoc networks
- BGP as an example for an inter-domain routing protocol

Transport Layer: Characteristics

You have seen ...

- the properties, tasks, and challenges of transport layer protocols
- how port numbers are used for addressing on the transport layer
- which ranges for these port numbers are defined by the IANA
- that the common interface on the transport layer is a socket

Transport Layer: TCP

You have seen ...

- the functioning and segment structure of TCP
- how flow control works in TCP
- what congestion control is
- which enhancements for TCP exist
- how a TCP connection is implemented with sockets
- what SYN Flood DOS attack is

Transport Layer: UDP

You have seen . . .

- the functioning and segment structure of UDP
- that UDP is much simpler compared to TCP and allows for best-effort communication
- how a UDP server and client is implemented with sockets

Transport Layer: Other Protocols

You have seen . . .

- SCTP as another connection-oriented transport layer protocol
- DCCP to be used for real-time applications
- QUIC as the newest relevant transport layer protocol to deal with shortcomings of TCP for web traffic

Exercise 01: IPv4 Addressing

- An IPv4 address without a subnet mask is ambiguous
  - ⇒ Tools like *iputils* (→ `ip`) require the IPv4 address in CIDR notation
    - E.g.,
      `ip addr add 192.168.7.3/24 dev wlan0`
    - Reminder: CIDR notations specifies the number of masked bits
      ⇒ `/24` → `255.255.255.0`
- `10.1.2.3/24` is different from `10.1.2.3/16`[1]

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  - → `/28` → `11111111 11111111 11111111 11110000` → `255.255.255.240`

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  - → /28 → 11111111 11111111 11111111 11110000 → 255.255.255.240
  - What's the network address?
  - → 10.21.52.80/28

Exercise 2: Inter-Networking

- On Linux you can query your routing table with *iputils* (→ `ip route show` or simply `ip r`)
- On Windows and Linux you can also use `netstat -r[n]`
- The result may look like this:

```
Kernel IP routing table
Destination     Gateway         Genmask         Flags   MSS Window  irtt Iface
default         10.51.0.1       0.0.0.0         UG        0 0          0 wlan0
10.2.0.0        0.0.0.0         255.255.255.0   U         0 0          0 enp0s31f6
10.51.0.0       0.0.0.0         255.255.0.0     U         0 0          0 wlan0
192.168.0.0     0.0.0.0         255.252.0.0     U         0 0          0 wlan0
```

- Whenever an IPv4 packet has to be sent a longest prefix match between the destination address and the entries in the table is performed

What does it mean that we have multiple entries for the interface `wlan0`?

Exercise 3: Subnetting

IP address	172.21.240.90	10101100 00010101 11110000 01011010
Class B	255.255.0.0	11111111 11111111 00000000 00000000
Subnet mask	255.255.255.224	11111111 11111111 11111111 11100000

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- **IP address `AND` (`NOT` subnet mask) = host ID**

IP address	172.21.240.90	10101100 00010101 11110000 01011010
Subnet mask	255.255.255.224	11111111 11111111 11111111 11100000
Inverse subnet mask	000.000.000.31	~~00000000 00000000 00000000 000~~11111
Host ID	26	~~00000000 00000000 00000000 000~~11010

Exercise 4: IPv4 Checksum

RFC 791, page 14

„The checksum field is the 16 bit one's complement of the one's complement sum of all 16 bit words in the header. For purposes of computing the checksum, the value of the checksum field is zero".

- To calculate the checksum of the packet, the sum of each 2 byte word inside the header must be calculated. The checksum field itself is skipped here!
  `4500 + 0034 + B612 + 4000 + 4006 + 0A00 + 008B + 5BC6 + AEE0 = 2907D`
- Next, the result of the calculation is converted to binary:
  `2907D` $\Longrightarrow$ `10 1001 0000 0111 1101`
- The first two bits are the carry and need to be added to the rest of the value:
  `10 + 1001 0000 0111 1101 = 1001 0000 0111 1111`
- Next, every bit of the result is flipped to obtain the checksum:
  ```
     1001 0000 0111 1111
  => 0110 1111 1000 0000
  ```
- The result `0110 1111 1000 0000` is equal to the value `6F80` in hexadecimal notation, as already shown in the original IP packet header.

Exercise 4: IPv4 Checksum

- To verify a checksum, the same procedure is used as above, with a single exception: The original header checksum is not omitted.
  `4500 + 0034 + B612 + 4000 + 4006 + 6F80 + 0A00 + 008B + 5BC6 + AEE0 = 2FFFD`
- Next, the result of the calculation is converted to binary:
  `2FFFD` $\Longrightarrow$ `10 1111 1111 1111 1101`
- The first two bits are the carry and need to be added to the rest of the value:
  `10 + 1111 1111 1111 1101 = 1111 1111 1111 1111`
- Next, every bit of the result is flipped:
  ```
     1111 1111 1111 1111
  => 0000 0000 0000 0000
  ```
- This indicates: No error detected! Any result, which is $\neq 0$ indicates: Error!

Source: RFC 791 and Wikipedia

Exercise 5: Address Types and Spaces

- Private addresses (unique local addresses in IPv6)
  - "have no global meaning"[2]
  - "routing information [...] shall not be propagated"[2] in the Internet, and
  - "packets with private source or destination addresses should not be forwarded"[2]
- May be forwarded inside a LAN (→ *link-local addresses* are never forwarded)
- Edge routers ideally filter traffic using address from private address space

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- May be forwarded inside a LAN (→ *link-local addresses* are never forwarded)
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Pinging broadcast addresses

```
user@host> ping -b 10.0.34.255
PING 10.0.34.0 (10.0.34.0) from 10.0.34.197 : 56(84) bytes of data.
64 bytes from 10.0.34.197: icmp_seq=1 ttl=64 time=0.049 ms
64 bytes from 10.0.34.236: icmp_seq=1 ttl=255 time=0.163 ms (DUP!)
64 bytes from 10.0.34.206: icmp_seq=1 ttl=255 time=0.211 ms (DUP!)
64 bytes from 10.0.34.196: icmp_seq=1 ttl=255 time=0.213 ms (DUP!)
64 bytes from 10.0.34.181: icmp_seq=1 ttl=255 time=0.220 ms (DUP!)
64 bytes from 10.0.34.174: icmp_seq=1 ttl=255 time=0.243 ms (DUP!)
64 bytes from 10.0.34.133: icmp_seq=1 ttl=255 time=0.245 ms (DUP!)
```

Exercise 6: Fragmenting IP Packets

- Any router can fragment (unless the DF bit is not set)
- Only the receiver reassembles
- In IPv4:
  - Any router "must be able to forward a datagram of 68 octets without further fragmentation"[3]
  - Any host "must be able to receive a datagram of 576 octets either in one piece or in fragments to be reassembled"[3]
- "IPv6 requires that every link in the internet have an MTU of 1280"[4] octets or greater

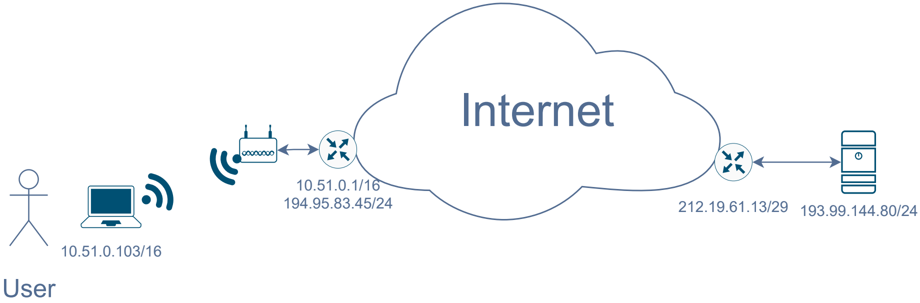
Exercise 6: Fragmenting IP Packets

No.	Time	Source	Destination	Protocol	Length	Info
3	1.686621	192.168.12.192	192.168.1.192	IPv4	1508	Fragmented IP protocol (proto=UDP 17, off=0, ID=02ba) [Reassembled in #4]
4	1.686630	192.168.12.192	192.168.1.192	UDP	91	Source port: scp-config Destination port: safetynetp
5	1.686874	192.168.1.192	192.168.12.192	IPv4	1508	Fragmented IP protocol (proto=UDP 17, off=0, ID=3054) [Reassembled in #6]
6	1.686891	192.168.1.192	192.168.12.192	UDP	91	Source port: safetynetp Destination port: scp-config

```
⊞ Frame 4: 91 bytes on wire (728 bits), 91 bytes captured (728 bits)
⊞ Ethernet II, Src: b8:ca:3a:5f:24:d2 (b8:ca:3a:5f:24:d2), Dst: InspurEl_13:7e:0b (6c:92:bf:13:7e:0b)
⊟ Internet Protocol Version 4, Src: 10.55.205.215 (10.55.205.215), Dst: 10.55.205.228 (10.55.205.228)
    0100 .... = Version: 4
    Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))
    Total Length: 77
    Identification: 0x431b (17179)
  ⊞ Flags: 0x00
    Fragment offset: 0
    Time to live: 64
    Protocol: UDP (17)
  ⊞ Header checksum: 0x875b [correct]
    Source: 10.55.205.215 (10.55.205.215)
    Destination: 10.55.205.228 (10.55.205.228)
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
⊞ User Datagram Protocol, Src Port: 53834 (53834), Dst Port: otv (8472)
⊞ Virtual eXtensible Local Area Network
⊞ Ethernet II, Src: a2:36:11:af:b9:a4 (a2:36:11:af:b9:a4), Dst: b2:8b:8e:60:e6:b9 (b2:8b:8e:60:e6:b9)
⊟ Internet Protocol Version 4, Src: 192.168.12.192 (192.168.12.192), Dst: 192.168.1.192 (192.168.1.192)
    0100 .... = Version: 4
    Header length: 20 bytes
  ⊞ Differentiated Services Field: 0x00 (DSCP 0x00: Default; ECN: 0x00: Not-ECT (Not ECN-Capable Transport))
    Total Length: 27
    Identification: 0x02ba (698)
  ⊞ Flags: 0x00
    Fragment offset: 1424
    Time to live: 64
    Protocol: UDP (17)
  ⊞ Header checksum: 0xe795 [correct]
    Source: 192.168.12.192 (192.168.12.192)
    Destination: 192.168.1.192 (192.168.1.192)
    [Source GeoIP: Unknown]
    [Destination GeoIP: Unknown]
  ⊟ [2 IPv4 Fragments (1431 bytes): #3(1424), #4(7)]
      [Frame: 3, payload: 0-1423 (1424 bytes)]
      [Frame: 4, payload: 1424-1430 (7 bytes)]
      [Fragment count: 2]
      [Reassembled IPv4 length: 1431]
⊞ User Datagram Protocol, Src Port: scp-config (10001), Dst Port: safetynetp (40000)
⊞ Data (1423 bytes)
```

Source: https://hustcat.github.io/

Exercise 7-9: Routing



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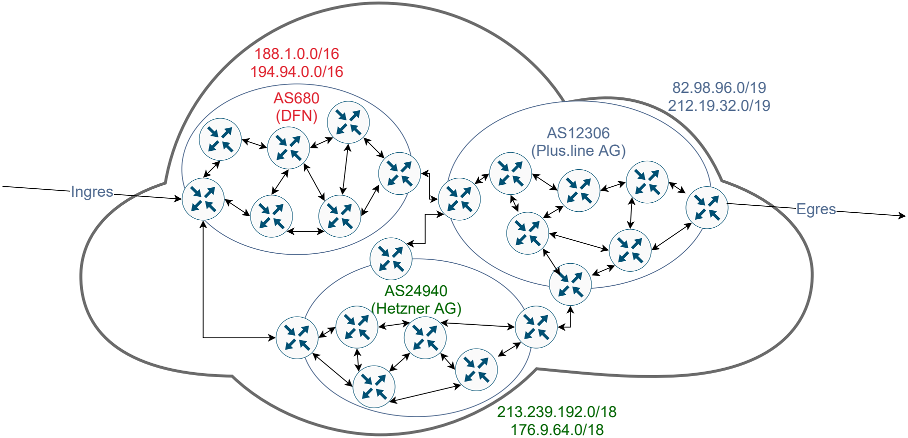
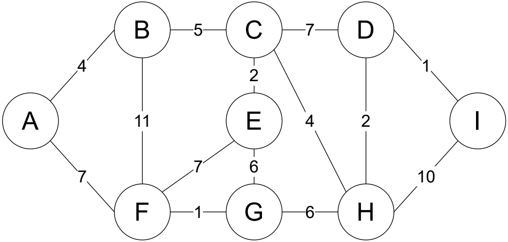


Exercise 9: Dijkstra Algorithm

- Given: The following network



1. Determine the spanning tree of shortest paths using the link state routing protocol (Dijkstra's algorithm) of node A.

Source: Jörg Roth. **Prüfungstrainer Rechnernetze: Aufgaben und Lösungen**. Vieweg (2010)