Computer Networks

Exercise Session 07

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General Schedule

All exercises will follow this general schedule

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

Contention-based Medium Access

You have seen ...

- that participants must compete for medium access in contention-based MAC protocols
- collisions reduce the performance of the network
- they should be detected and avoided
- the trade-off between throughput and latency

Contention-free Medium Access

You have seen . . .

- how resources like time or frequencies can be allocated in advance for contention-free medium access
- that (particularly static) contention-free MAC protocols provide less throughput compared to contention-based protocols on low utilization of the network
- that combination of MAC protocols is feasible

Data Link Layer: Error Control

You have seen . . .

- that errors may occur on the Physical Layer and it is one of the services provided by the Data Link Layer to handle these errors
- what checksums are and how they can be built with parity bits or CRCs
- what a Hamming distance is and what needs to be fulfilled to allow for errors to be detected or corrected
- how CRC works in detail
- how FEC could work

Data Link Layer: Flow Control

You have seen . . .

- that flow control can be used to prevent a receiver from having to discard data
- the flow control is mostly done on the upper layers

Data Link Layer: Address Resolution

You have seen ...

- how logical address (IP addresses) can be mapped to physical addresses (MAC addresses)
- that ARP is used for IPv4 networks and NDP for IPv6 networks
- how broadcast messages are used for ARP to resolve the MAC address of a given IP address

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  - $\longrightarrow$ increased frame sizes
  - $\Rightarrow$ less goodput
- If no error control is in place on the data link layer, upper layers need to verify the validity of the data and request retransmissions

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  - If the allowed code words comprise only 10000 and 01111, the minimum hamming distance is 5. Hence, up to two bit errors can be corrected. E.g., which word has been sent, if the receiver gets 11100?

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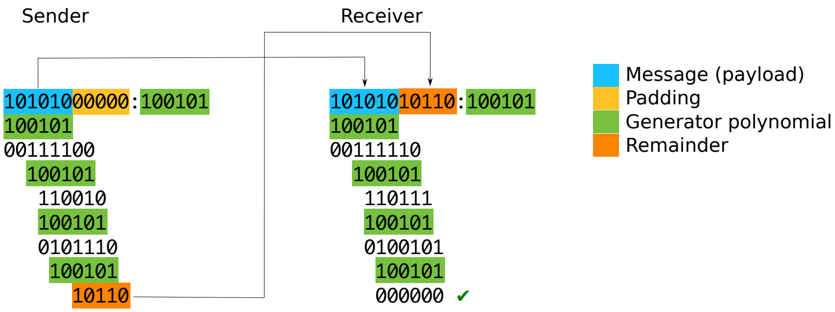
    - 10000

Exercise 2: CRC



The CRC checksum is the remainder of the division of the message itself by the generator polynomial. The same calculation for the message plus appended remainder results to 0 if no transmission error has occurred.

Error-correction: Hamming Code

Error correction can be realized via Hamming code

- The bits of a data block are numbered from left to right, starting with 1
  - Bits, which are powers of 2 (1, 2, 4, 8, 16, etc.) are parity (or check) bits
  - The remaining bits are the payload
- Example:
  - 8 bits payload: 01001100

Position:	1	2	3	4	5	6	7	8
Payload:	0	1	0	0	1	1	0	0

Position:	1	2	3	4	5	6	7	8	9	10	11	12
Data to be transmitted:	?	?	0	?	1	0	0	?	1	1	0	0

Hamming Code – Parity Bits

- Each position in the data block can be expressed by the same amount of digits that we have as parity bits
- $\rightarrow$ In our example, we have four parity bits and each position can be expressed by four binary digits
- Examples:

Position: 1	$\Longrightarrow$	Value: 0001
Position: 2	$\Longrightarrow$	Value: 0010
Position: 3	$\Longrightarrow$	Value: 0011
Position: 4	$\Longrightarrow$	Value: 0100
...		
Position: 12	$\Longrightarrow$	Value: 1100

Hamming Code – Sender Procedure

- The sender calculates the parity bits values
- → it performs an XOR operation for those positions that contain a 1
  - In the example it is position 5, position 9 and position 10

Position:	1	2	3	4	5	6	7	8	9	10	11	12
Data to be transmitted:	?	?	0	?	1	0	0	?	1	1	0	0

```
    0101   Position 5
    1001   Position 9
XOR 1010   Position 10
--------
 =  0110
```

- The result are the values of the parity bits
  - These are inserted into the transmission

Position:	1	2	3	4	5	6	7	8	9	10	11	12
Data to be transmitted:	0	1	0	1	1	0	0	0	1	1	0	0

Hamming Code – Receiver Procedure (error-free)

- The receiver can verify if a bit sequence is correct
  - It performs the same operation as the sender to calculate the parity bits
  - Then, it performs another XOR operation of the calculated and received parity bits

```
Received data: 1  2  3  4  5  6  7  8  9 10 11 12
               0  1  0  1  1  0  0  0  1  1  0  0
```

```
    0101   Position 5
    1001   Position 9
XOR 1010   Position 10
--------
    0110   Parity bits calculated
XOR 0110   Parity bits received
--------
=   0000   => Correct transmission
```

Hamming Code – Receiver Procedure (bit error)

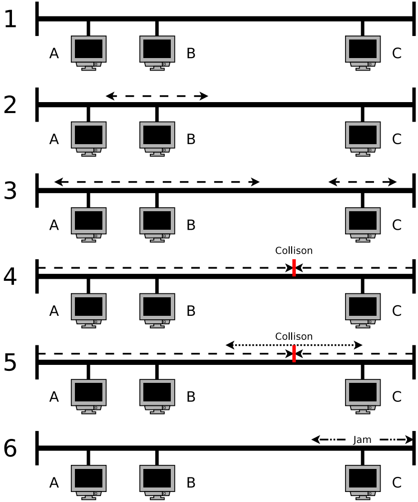
```
Received data: 1  2  3  4  5  6  7  8  9 10 11 12
               0  1  0  1  1  0  0  0  0  1  0  0

    0101   Position 5
XOR 1010   Position 10
--------
    1111   Parity bits calculated
XOR 0110   Parity bits received
--------
=   1001   => Bit 9 is defective!
```

- Possible results of the calculation:
  - Position number of the modified bit
  - 0 if the transmission was correct

- If ≥ 2 bits have been modified, the only statement that can be made is, that bits have been modified at all
  - The positions can not be determined this way

Example of CSMA/CD



B wants to transmit frames and monitors the transmission medium
From the perspective of B, the medium is free

B begins the transmission and continues to monitor the medium

C wants to transmit frames and monitors the transmission medium
From the perspective of C, the medium is free

C begins the transmission and continues to monitor the medium

A collision occurs
The voltage on the cable changes
This leads to a sort of senseless noise

The collision spreads and reaches C first

C stops to transmit the frame and sends the jam signal

As soon as the collision reaches B, this participant stops the transmission too and sends the jam signal

Network Size and Collision Detection

- A collision must be detected by the sender
  - It is important that the transmission of a frame is not completed when a collision occurs
    - Otherwise, the network device might already be finished with sending the frame and assumes the transmission was successful
- Each frame must have a certain minimum length
  - It has to be guaranteed that its transmission duration is longer than the maximum RTT (round trip time)
    - → Remember: The RTT is the time it takes for a frame to travel from one end of the network to the most distant end and return back
  - **This ensures that a collision reaches the sender before its transmission is finished**
    - If a sender detects a collision, it knows that its frame has not arrived correctly at the receiver, and can try the transmission again later

Example: Minimum Frame Length and Collision Detection

- Ethernet specifies a maximum network size and a minimum frame length
- The minimum frame length, where collision detection is still possible, is calculated as follows:

$$P = 2 * U * \frac{D}{V}$$

P = Minimum frame length in bits
U = Data rate of the transmission medium in bits per second (bps)
D = Network length in meters
V = Signal speed on the transmission medium in meters per second)

- Calculation example for 10BASE5 with 10 Mbps and coaxial cables:
  - $U = 10\,\text{Mbps} = 10{,}000{,}000\,\text{bps}$
  - $D = 2,500$ meters (this is the maximum length for 10BASE5)
  - V = speed of light $*$ velocity factor
    - Speed of light = 299,792,458 m/s
    - Velocity factor = 0.77 for coaxial cables
    - $V = 299,792,458\,\text{m/s} * 0.77 \approx 231,000,000\,\text{m/s}$

$$P = 2 * 10 * 10^6\,\text{bps} * \frac{2{,}500\,\text{m}}{231 * 10^6\,\text{m/s}} \approx 217\ \text{bits} \approx 28\ \text{bytes}$$

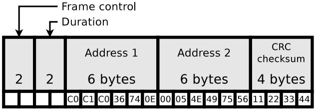
- Outcome: The minimum frame length of 64 bytes for Ethernet is more than enough

WLAN Control Frames (Special Frames) – RTS Frame

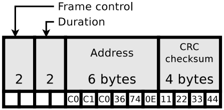
> The control frames RTS, CTS and ACK have a different structure compared with data frames

- Length of RTS frames: 20 bytes
- With the RTS frame, a station, which wants to transmit frames, sends a reservation request for the transmission medium to the Access Point
- 1^{st} address field = MAC address of the Access Point
- 2^{nd} address field = MAC address of the station, which sends the request

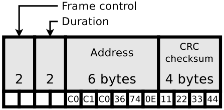
RTS frame



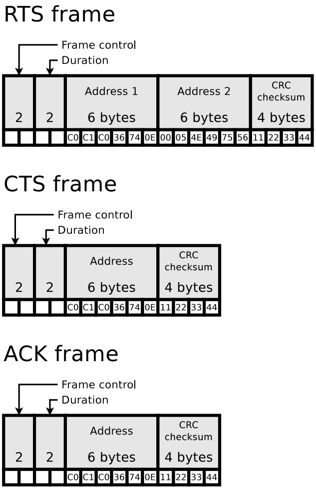
CTS frame



ACK frame



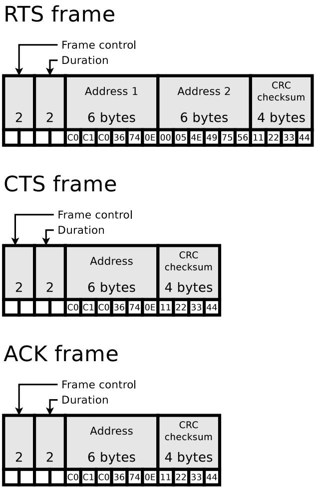
WLAN Control Frames (Special Frames) – CTS Frame



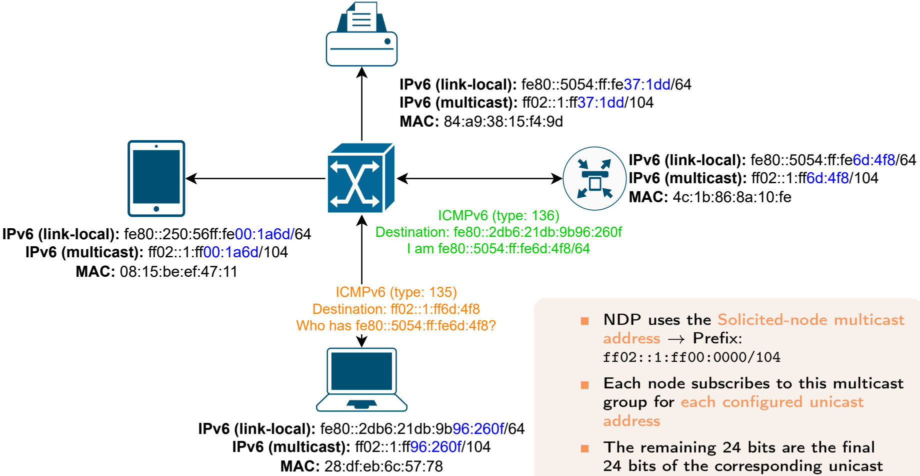
- Length of CTS frames: 14 bytes
- With a CTS frame, an Access Point confirms the reservation request for the transmission medium
- `address` = MAC address of the station, which sent the reservation request

WLAN Control Frames (Special Frames) – ACK Frame

- Length of ACK frames: 14 bytes
- With an ACK frame, the receiver confirms the successful transmission of a frame at the sender
- `address` = MAC address of the station, which transmitted the frame successfully



Exercise 5: NDP



- NDP uses the Solicited-node multicast address → Prefix: `ff02::1:ff00:0000/104`
- Each node subscribes to this multicast group for each configured unicast address
- The remaining 24 bits are the final 24 bits of the corresponding unicast address
- Only nodes registered to this address will receive the ICMP message