Universität Paderborn
Computer networks group

Winter term 2017/2018

Mobile communications

Homework assignment 11: Wireless LANs

Due date: 2018-01-25

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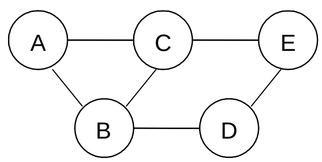
1. **Throughput in 802.11 networks**

   - Assume the topology below consisting of the nodes A, B, C, D and E.

     This following list describes which nodes try to send data to which other nodes. Starting with a free channel, provide one timing diagram for each of the 3 transmission scenarios (i.e., node A or B or E starts transmitting first); assume RTS/CTS is used.

     (a) B $\rightarrow$ D and E $\rightarrow$ D
     (b) C $\rightarrow$ B and E $\rightarrow$ D
     (c) A $\rightarrow$ B and C

     Solution: For simplicity, let's assume that only a single station starts/wins backoff.

   - Assume that in the previous scenario (a), station B wins the contention phase. For this case, calculate the overhead and effective data rate (so-called *goodput*) for the transmission of a single DLC data frame.

     Assume standard IEEE 802.11a parameters, in particular, a transmission rate of 6 Mbit/s for control frames and 12 Mbit/s for data frames of 1500 Bytes. Control frames are 20 Bytes (RTS), 14 Bytes (CTS), and 14 Bytes (ACK) in size. With IEEE 802.11a an SIFS is 16 μs and a DIFS is 34 μs.

     Solution:

     – Aggregrated length of all control frames: $48 \times 8 = 384$ bits
     – Transmission time of all control frames: $384\,\text{bits}/(6\,\text{Mbits/s}) = 64\,\mu\text{s}$

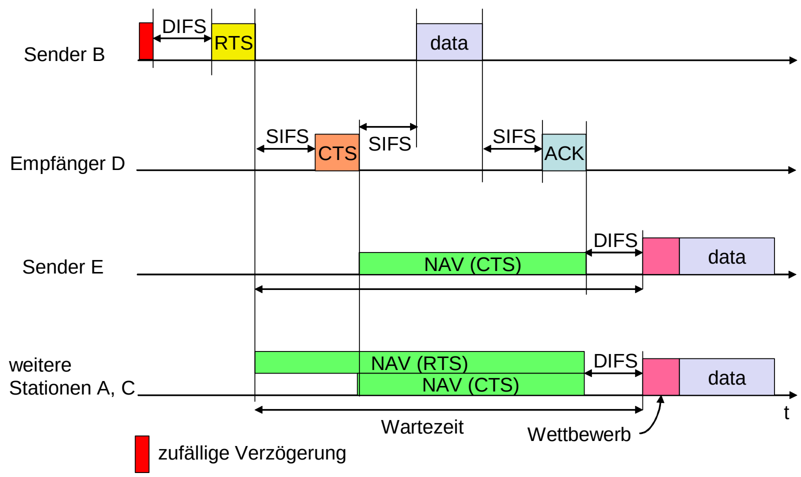


Abbildung 1: Solution for 3.b(a), Assumption: B goes first.

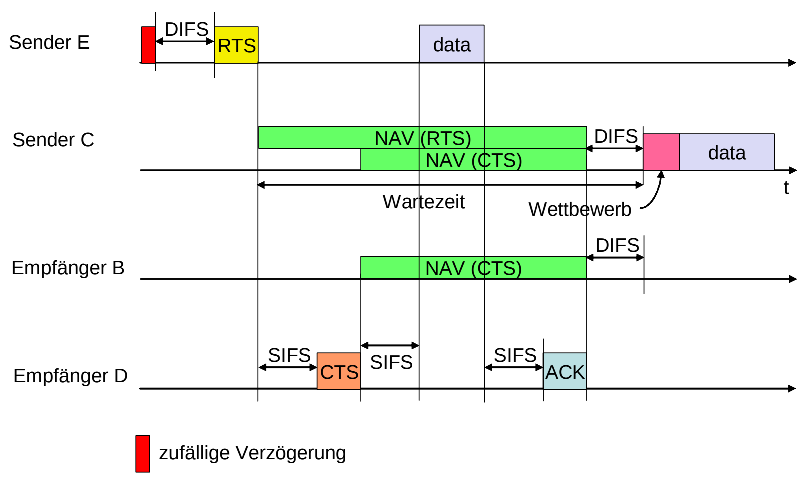


Abbildung 2: Solution for 3(b), Assumption: E goes first .

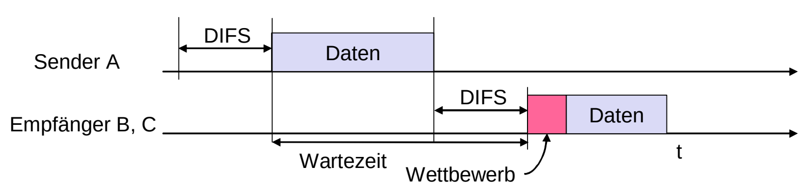


Abbildung 3: Solution for 3c (Multicast)

- Transmission time for single data frame of $1500 \times 8 = 12000$ bits: 1 ms
- Goodput: 12000 bits/$1064\,s$=11.3 Mbits

2. Assume a WLAN BSS with one station far away from the access point and several other stations close to the access point. All terminals are backlogged, i.e., they always have data to send to the AP.

   Explain why this one far away station severely limits the throughput achieved by the other stations. You might want to use equations.

   Hint: Think about the fairness model of 802.11 and its rate adaptation capabilities.

   Solution:

   - 802.11 fairness: same channel access probability for all terminals (on average)
   - rate adaptation: low rate for the far away terminal
   - Results in *harmonic* mean of the *rates*

   More concretely: Say we have n terminals, $n-1$ of which use a rate R, one uses a rate cR for some $0 < c < 1$. Let's say they all transmits packets of size m bits. 802.11 fairness results, over long time, in access fairness to all terminals, irrespective of achievable rate, etc. – so on average, every terminal gets to send one packet for every packet sent by every other terminal.

   Then, the time it takes (on average) to let every terminal send: $T_{\text{Round}} = (n-1)\frac{m}{R} + \frac{m}{cR}$. The resulting average rate per terminal is then:

   $$R_{\text{avg}} = \frac{1}{n} \cdot \frac{nm}{T_{\text{Round}}}.$$

   After simplifying and arranging terms a bit, we see that

   $$\frac{1}{R_{\text{avg}}} \cdot \frac{1}{m} = (n-1) \cdot \frac{1}{R} + 1 \cdot \frac{1}{cR},$$

   i.e., the harmonic mean of the rates.

3. Suppose there are two ISPs providing Wi-Fi access in a particular café, with each ISP operating its own AP and having its own IP address block. Further suppose that by accident, each ISP has configured its AP to operate over channel 11. (from: http://vspclil-physicallayer.wikispaces.com/file/view/High+level+exercises.pdf)

- Will the 802.11 protocol completely break down in this situation? Discuss what happens when two stations, each associated with a different ISP, attempt to transmit at the same time.

  Solution: The two APs will typically have different SSIDs and MAC addresses. A wireless station arriving to the café will associate with one of the SSIDs (that is, one of the APs). After association, there is a virtual link between the new station and the AP. Label the APs AP1 and AP2. Suppose the new station associates with AP1. When the new station sends a frame, it will be addressed to AP1. Although AP2 will also receive the frame, it will not process the frame because the frame is not addressed to it. Thus, the two ISPs can work in parallel over the same channel. However, the two ISPs will be sharing the same wireless bandwidth. If wireless stations in different ISPs transmit at the same time, there will be a collision. For 802.11b, the maximum aggregate transmission rate for the two ISPs is 11 Mbps.

- Now suppose that one AP operates over channel I and the other over channel 11.

  Solution: Now if two wireless stations in different ISPs (and hence different channels) transmit at the same time, there will not be a collision. Thus, the maximum aggregate transmission rate for the two ISPs is 22 Mbps for 802.11b.