Mobile Communications
Problem Set 7

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1. Consider a p-persistent CSMA time slotted system with only two independent stations. A station tries to access the medium with probability p. Assume the vulnerability period $t_P = 0$ as well as all other overhead zero. The transmission time $t_T = x$ time slots. Use the renewal reward theorem to calculate the long term average reward, i.e., the system throughput. Find the optimal value for p to increase the long term system throughput.

   Solution:

   Since every station generates a packet with probability p, the probability of a successful access is $2p(1-p) = 2p - 2p^2$. Note that the two stations are independent. The probability of a collision is p^2. The medium is idle in one slot with probability $(1-p)^2$. The process can be seen as a discrete time renewal process. It can be viewed as a series of Bernoulli experiments alternating between the states access and no access. The time Y between two access states is geometrically distributed with $E[Y] = 1/(2p - 2p^2)$. Neglecting the overheads the reward at the state access is given as $t_T = x$ slots. Hence the long term throughput of this system is given as

   $$S = x(2p - 2p^2)$$

   Next, we optimize over p. We calculate $\frac{\partial}{\partial p}(2p - 2p^2)$, set the derivative to zero and find the optimum at $p = 0.5$.

2. Name, sketch and explain two modes of operation for wireless networks.

   Solution:

   There are two modes of operation for wireless networks that are denoted as infrastructure and ad-hoc modes.

   Infrastructure

   - communication only between wireless stations and the access point; no direct communication between wireless stations
   - access point provides forwarding functions and access to other networks
   - access point can implement centrally coordinated medium access
   - simpler design
   - e.g. IEEE 802.11 Wifi

   Ad-hoc

   - wireless stations can communicate directly with each other (no AP)

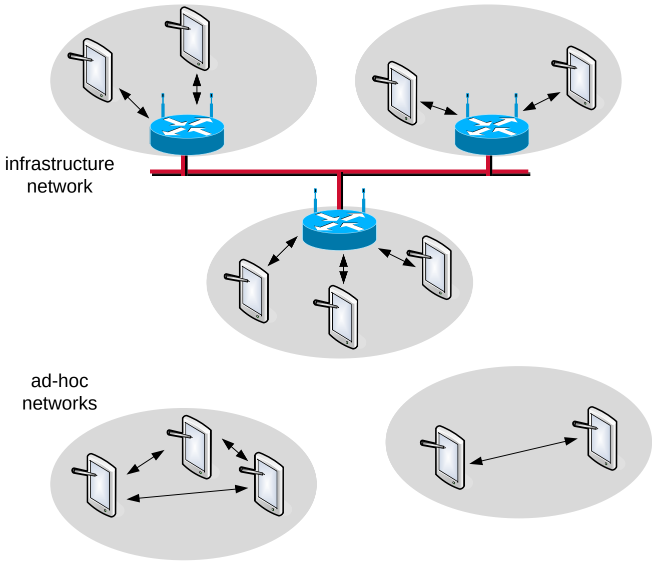

Figure 1: Network structure

- complexity of wireless stations is higher
- high flexibility
- e.g. IEEE 802.15 Bluetooth

3. Why is time synchronization crucial for 802.11 Wifi networks? Explain the mechanism for synchronizing the internal node clocks in infrastructure 802.11 networks using a sketch.

   Solution:

   802.11 networks depend on time synchronization for

   - power management (switch off the transceiver when not needed based on TIM)
   - functionality of MAC (DCF)
   - frequency hopping (old standard with $1-2$ Mbps)

   Time synchronization is carried out using beacon frames that are quasi periodic. Beacon frames contain a timestamp to which the nodes adjust the internal clock. In addition they include a traffic indication map (TIM) that contains a list of stations for which data is available. Hence, stations can sleep and wake up at the right time (power management!)

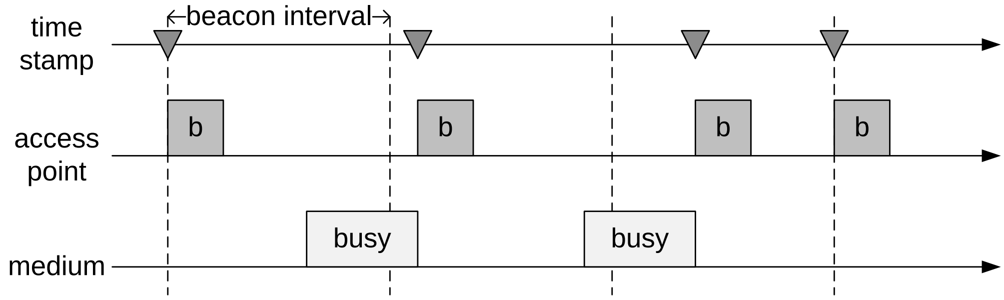

Figure 2: Beacon frames in infrastructure 802.11

- Beacon frames are transmitted according to a fixed schedule
- A beacon may be delayed if the medium is busy, however, the future schedule is not changed
- The timestamp transmitted in the beacon is the actual time of sending the beacon

4. Sketch and explain the functionality of the distributed coordination function (DCF). Explain the use of SIFS before acknowledgements. How do data collisions occur while the DCF is operating? What does the DCF implement to mitigate collisions?

   Solution:

   The functionality of the DCF

   - stations are permitted to send if the channel is idle for a DIFS period
   - acknowledgements are sent after SIFS
   - if the channel is busy stations perform random backoff
   - the countdown at different stations is carried out simultaneously
   - the station with the smallest backoff value finishes the countdown procedure first and transmits its packet
   - other stations pause their countdown procedure and resume it afterwards

   Acks are preceeded by Short inter-frame space (SIFS) that is smaller than Distributed inter-frame space (DIFS), hence SIFS have a higher priority as nodes have to wait for DIFS before trying to transmit. Thus, SIFS is used for signalling, e.g. Acks and CTS.

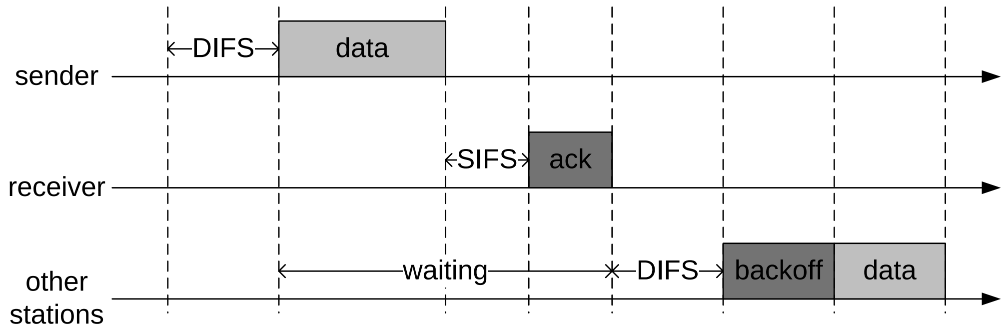

Figure 3: Functionality of the DCF

If two stations transmit at the same time they cause a collision. If one station starts transmitting a collision occurs, if the backoff at any of the remaining stations is completed within the vulnerability period. The vulnerability period is the time until the farthest node able to disturb the transmission senses the beginning of the busy medium.

The DCF mitigates the occurrence of collision through doubling the contention window. Increasing the contention window decreases the number of collisions. To control the impact of increasing the contention window on the throughput the nodes involved return to the original minimum contention window size after each successful retransmission.