Administration

• Solution URL
  – https://svn.systems.inf.ethz.ch/svn/systems/acn14_students/trunk/solutions

• Personal URL
  – https://svn.systems.inf.ethz.ch/svn/systems/acn14_students/trunk/NETHZ

• substats.txt
  – Please check your submission status
Bluetooth Link Types

- **SCO (Synchronous connection-oriented)**
  - Mostly used for voice
  - The master reserves two consecutive slots (forward and return slots) at fixed intervals
  - A master can support up to 3 SCO links to the same slave or to different slaves

- **ACL (Asynchronous connectionless)**
  - Typically used for data
  - Variable frame size (1, 3, 5 slots)
  - Master uses polling, a slave may only answer if addressed in the preceding slot
  - Maximum of 1 ACL link per master/slave

- No direct slave to slave communication, packet transmission only between master and slave
• Every sixth slot used for SCO link between master and slave 1
• ACL links use single or multiple slots (note: hopping sequence is independent of the transmission of packets)
Robustness

• ACL links can be protected with ARQ scheme (Automatic Repeat Request)

• One extra bit (ACK, NAK) is enough because master/slave have to send alternating
Question 1

• a) Assuming the red blizzard arrow means that the packet has been lost, explain the figure as it does not properly reflect the situation in an ACL link. Please re-draw the figure assuming all packet exchanges are part of an ACL link between the master and the slaves.

• b) Assume the red blizzard arrow means the packet has in fact been received but could not properly be decoded. Would the figure on page 32 be correct in that case?
Sensor Networks

- Form Ad Hoc Network (no fixed Infrastructure)
- Gather data and
- Forward it to the user ('sink' or gateway node)
S-MAC

• Main sources of energy waste
  – Re-transmissions
  – Overhearing: node picks up packets destined for other nodes
• Approach: coarse-grained TDMA-like sleep/awake cycles
  – All nodes choose and announce awake schedules
    – synchronize to awake schedules of neighboring nodes
• Uses RTS/CTS to resolve contention during listen intervals
  – And allows interfering nodes to go to sleep during data exchange
S-MAC

- Problem: Nodes may have to follow multiple schedules to avoid network partition
- Different schedules may increase end-to-end latency
Question 2

• S-MAC reduces the power-consumption by synchronizing wake-up and sleep periods among nodes in the network. Explain why in practice this approach can lead to higher latencies for packet transmissions.
B-MAC

- Packets transmitted with preamble
- Nodes periodically wake up and stay awake if they overhear a preamble

Shortcomings:
- Problematic in case of shorter packets: relatively long active period
Question 3

• B-MAC achieves low power consumption without requiring nodes to be synchronized. One drawback of B-MAC, however, is that it is not suitable to small packets. Explain why?
Inter Symbol Interference

- Symbols at 400 ksp/s on first ray
- Symbols at 400 ksp/s on second ray

Inter-symbol interference due to 40% overlap
Orthogonal frequency division multiplexing (OFDM)

- Idea: split the high bit rate stream into many lower bit rate streams, each stream sent using an independent carrier frequency
  - If $n$ symbols have to be transmitted, each subcarrier transmits $n/c$ symbols with $c$ being the number of subcarriers
  - One symbol could, for example, represent 2 bits as in QPSK
  - Each subcarrier uses its own modulation depending on the noise
- Primary advantage: robustness in the case of narrowband interference and frequency-selective fading due to multipath
Inter Symbol Interference with OFDM

- Symbols on first ray
  - 4 sub-carriers
  - 100 kbps per subcarrier
- Symbols on second ray
  - 4 sub-carriers
  - 100 kbps per subcarrier

Reduced inter-symbol interference due to overlap of 10% overlap.
Question 4

• Consider two rays each sends half a million symbols per second using conventional single-carrier modulation over a wireless channel, assume 1us symbol between rays.

  – Discuss about inter symbol interference in this scenario.

  – If the same million symbols per second are spread among 10 sub-channels, discuss again the inter symbol interference.
Multi-rate

- Most 802.11 PHY standards allow support for different data rates
  - 802.11b supports 4 rates between 1-11Mbits
  - 802.11g supports 11 rates between 1-54Mbits
- Bit-error rate (BER) depends on channel conditions (e.g. SINR) and data-rate
- Idea: sender chooses data rate dependent on channel conditions for optimal BER
- Basic loss estimation and rate change algorithm of “Robust Rate Adaptation for 802.11 Wireless Networks”, Mobicom'06:
Basic loss estimation and rate change algorithm

• From “Robust Rate Adaptation for 802.11 Wireless Networks”, Mobicom'06:
  – Measure loss ratio over a window of packets
  – Adjust the data rate accordingly

```c
1  R=highest_rate;
2  counter=ewnd(R);
3  while true do
4      rcv_tx_status(last_frame);
5      P = update_loss_ratio();
6      if( counter == 0 )
7          if (P > PMTL) then R = next_lower_rate();
8              elseif (P < PORI) then R = next_high_rate();
9          counter = ewnd(R);
10         send(next_frame,R);
11         counter--; 
```
Question 5

• In the paper, the author also proposed an improved algorithm with adaptive RTS filter. Explain briefly:
  – how that algorithm works?
  – how it improves over the basic algorithm?
802.11 MAC

• Access methods:
  – Distributed Coordination Function (DCF)
    • mandatory
    • CSMA/CA (carrier sense and backoff algorithm)
  – DCF + RTS/CTS
    • optional
    • Avoids hidden/exposed terminal problem
  – Point coordination function (PCF)
    • optional
    • Access point polls terminals according to a list

• DCF works in infrastructure and ad hoc mode, PCF only in infrastructure mode
Inter-frame intervals (IFS)

- Three inter-frame intervals used by stations to access the medium (access priorities)
  - SIFS (Short Inter Frame Spacing)
    - Highest priority: shortest waiting time used before short control messages (ACKs, polling response) in DCF mode
  - PIFS (PCF inter-frame spacing)
    - Medium priority, used in PCF mode
  - DIFS: lowest priority, longest waiting time used before data packet in DCF mode
Question 6

• The 802.11 MAC layer defines three intervals SIFS, PIFS, and DIFS. Thereby, SIFS is the smallest time interval. Imagine for the moment that SIFS is greater than DIFS. Explain why this would be a problem.
802.11 – CSMA/CA

- Station ready to send starts sensing the medium
- If the medium is free for the duration of DIFS, the station can start sending
- If the medium is busy, the station has to wait for a free DIFS, then the station must additionally wait a random back-off time (multiple of slot-time)
- If another station occupies the medium during the back-off time of the station, the back-off timer stops (fairness)
Simple Scenario

- **bo_e**: elapsed backoff time
- **bo_r**: residual backoff time
- **busy**: medium not idle (frame, ack etc.)
- **packet arrival at MAC**

Station 1:
- DIFS
- DIFS
- DIFS
- DIFS
- busy

Station 2:
- DIFS
- busy

Station 3:
- busy

Station 4:
- DIFS
- busy

Station 5:
- DIFS
- DIFS
- busy

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**Legend**:
- **red**: packet arrival at MAC
- **green**: busy
- **blue**: medium not idle
- **light blue**: elapsed backoff time
- **cyan**: residual backoff time
How Collisions Get Detected in CSMA/CA?

• CSMA/CA = Collision Avoidance not Collision Detection
• Unicast packets
  – Detection via missing ACK
• Broadcast packets
  – No mechanism
  – Typically have a much higher loss rate
CSMA/CA (2)

• Sending unicast packets
  – A station has to wait for DIFS before sending data
  – Receivers acknowledge at once (after waiting for SIFS) if the packet was received correctly
  – Automatic retransmission of data packets in case of transmission errors (max. number of retransmissions limited)
Question 7

• How is fairness problem regarding channel access solved in IEEE 802.11?