

MAC Performance

MAC Retries

- *Many MAC protocols use acknowledgement (ACK) frames to confirm correct data reception.*
 - *Sender receives ACK: packet was received correctly.*
 - *Sender is notified of ACK timeout: retransmit packet.*
 - *The number of retries is usually limited.*

MAC Retries

- *Expected number of tx attempts until success is a Bernoulli process:*
 - *Assumes Binary Symmetric Channel with constant BER.*
 - *Case with unlimited number of retries:*
 - $P(n \text{ attempts}) = (1 - p_{succ})^{n-1} \cdot p_{succ}$
 - $P(>n \text{ attempts}) = (1 - p_{succ})^n$
 - $\bar{n} = \sum_{i=1}^{+\infty} i \cdot (1 - p_{succ})^{i-1} \cdot p_{succ} = \frac{1}{p_{succ}}$
 - $p_{succ} = \text{probability of data+ack success of a single TX attempt} = (1 - FER_{data}) \cdot (1 - FER_{ACK})$
 - *The data will be delivered sooner or later:*
 - $p_{loss} = \text{probability that the packet will never be delivered} = \lim_{k \rightarrow +\infty} (FER_{data}^k) = 0$
 - $p_{delivery} = 1 - p_{loss} = 1$
 - *ACKs don't matter here. But RTS/CTS would complicate the matter...*
 - *Home Exercise 1: What is the expected number of failed data+ack attempts?*
 - *Home Exercise 2: What is the expected number of retries?*
 - *Home Exercise 3: p_{succ} (w/ rts+cts+data+ack)?*
- *Case with limited number of retries (R=retry limit):*
 - *There is a probability that the data frame will never be delivered:*
 - $p_{loss}(R) = FER_{data}^{R+1}$
 - $p_{delivery}(R) = 1 - p_{loss}(R)$
 - *ACKs don't matter here. But RTS/CTS would complicate the matter...*

Throughput

- *Throughput is the effective data rate:*

- $T_h = \frac{\text{number of effectively received bits during time window } T}{T}$

- *Example with IEEE 802.11 Broadcast (no errors in the PHY preamble or header)*

- $\max T_h = p_{\text{delivery}} \cdot \frac{8 \cdot L}{DIFS + T_{\text{BACKOFF}} + T_{\text{HPHY}} + \frac{8 \cdot (H_{\text{DATA}} + L)}{R_{\text{PHY}}}}$

- *L is the frame length in octets*
 - *H_X is the length of the header + tail of MAC frame of type X in octets*
 - *R_{PHY} is the physical bitrate in bits/s*
 - $p_{\text{delivery}} = 1 - FER_{\text{DATA}}$

Throughput

- *Example with IEEE 802.11 Unicast (no errors in the PHY preamble or header, infinite retries, ad-hoc WLAN w/ only one sender, no ACK losses)*

- $$\max Th = \frac{p \cdot 8 \cdot L}{(1-p) \cdot T_{fail} + p \cdot T_{succ}} = \frac{8 \cdot L}{(\bar{n}-1) \cdot T_{fail} + T_{succ}}$$

- $$T_{succ} = DIFS + \overline{T_{BACKOFF}} + 2 \cdot T_{H_{PHY}} + \frac{8 \cdot (H_{DATA} + L)}{R_{PHY}(DATA)} + SIFS + \frac{8 \cdot H_{ACK}}{R_{PHY}(ACK)}$$

- $$T_{fail} = DIFS + \overline{T_{BACKOFF}} + T_{H_{PHY}} + \frac{8 \cdot (H_{DATA} + L)}{R_{PHY}(DATA)} + ACKTIMEOUT$$

- $$p = 1 - FER_{DATA}$$