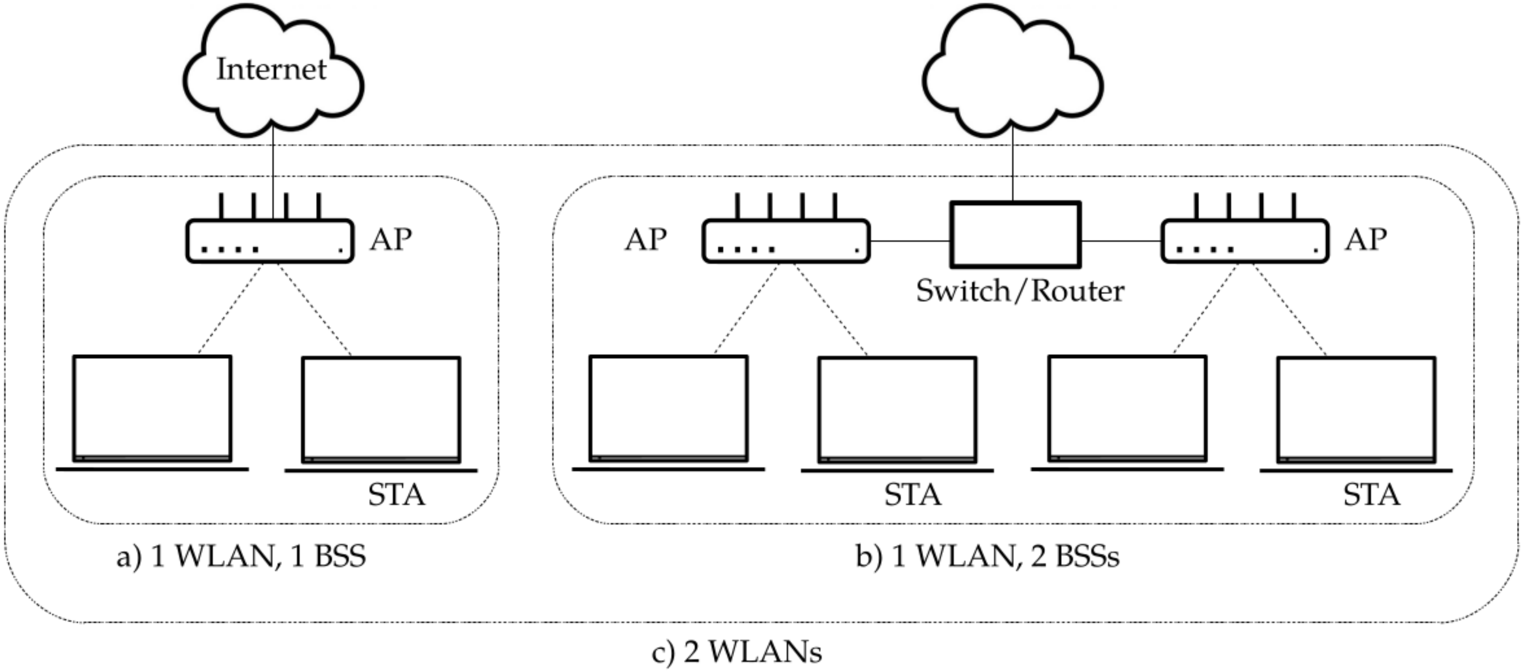
Machine Learning for Networking

Wi-Fi networks (Operation fundamentals)

Boris Bellalta: boris.bellalta@upf.edu

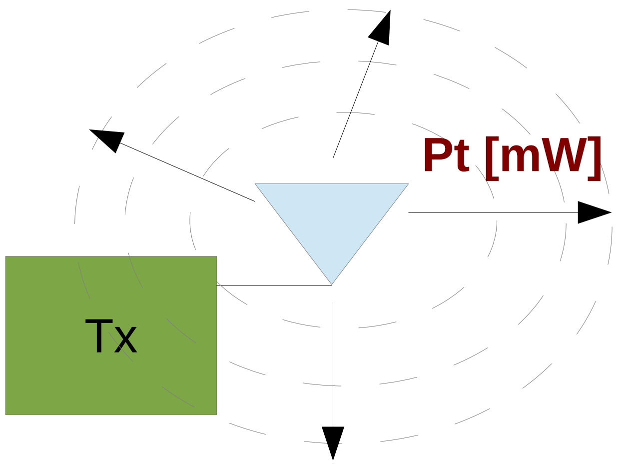
A Wi-Fi network



Wi-Fi networks work in license-exempt bands

- ISM bands (other uses rather than ‘telecommunications’)
- 1 GHz, 2.4 GHz, 5 GHz, 6 GHz, 60 GHz
- List of WLAN channels
  - https://en.wikipedia.org/wiki/List_of_WLAN_channels

Transmit Power

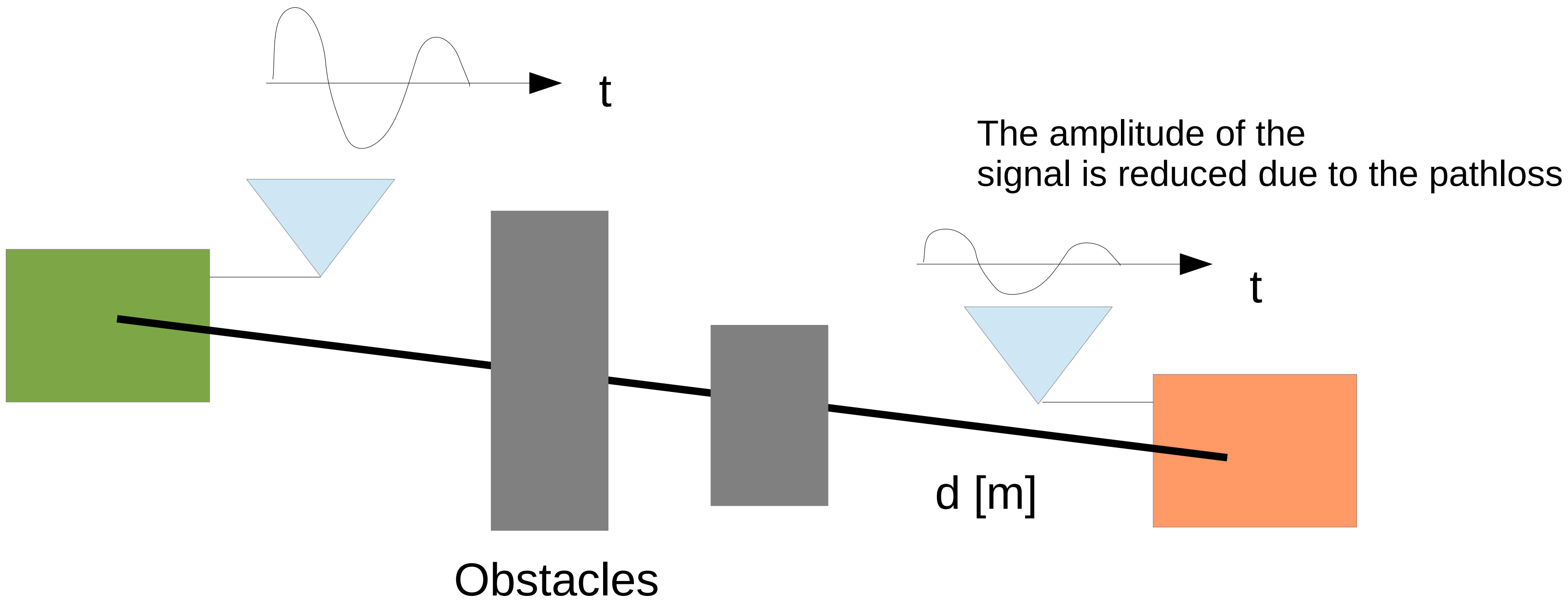


Omnidirectional
Pattern

Pt(dBm)= 10 log10(Pt [mW])

Examples:
Pt=100 mW → Pt=20 dBm
Pt=1 mW → Pt = 0 dBm
Pt=1 microW → Pt = -30 dBm
Pt=1 nanoW → Pt = -60 dBm

Path-loss

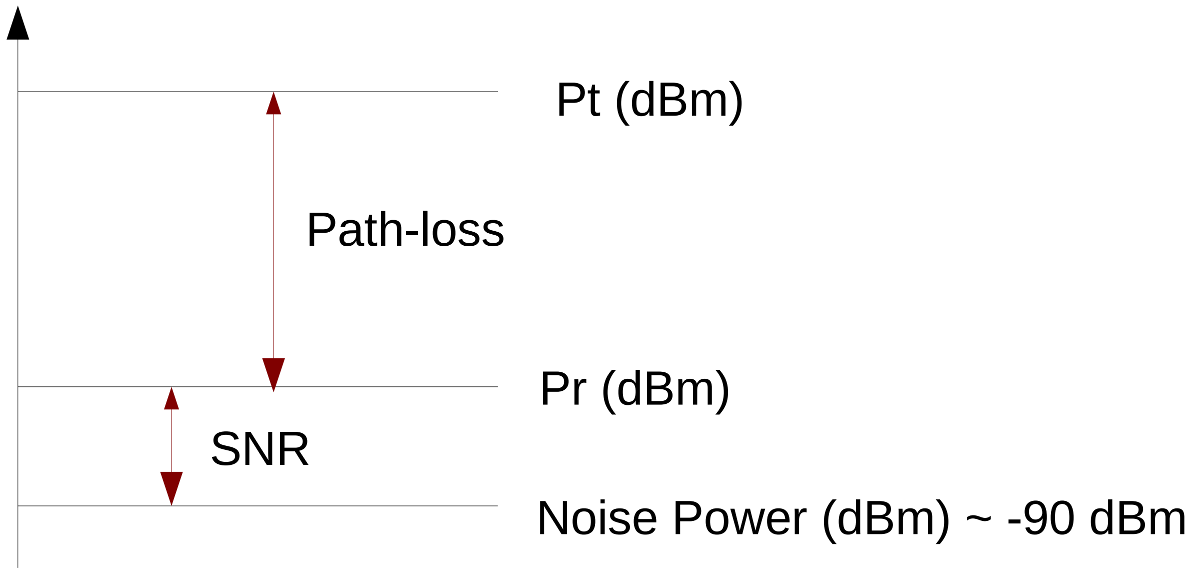


- Relation with the distance: PL [dB] = L1m [dB] + 10 γ(f,environment) log10(d) [dB]

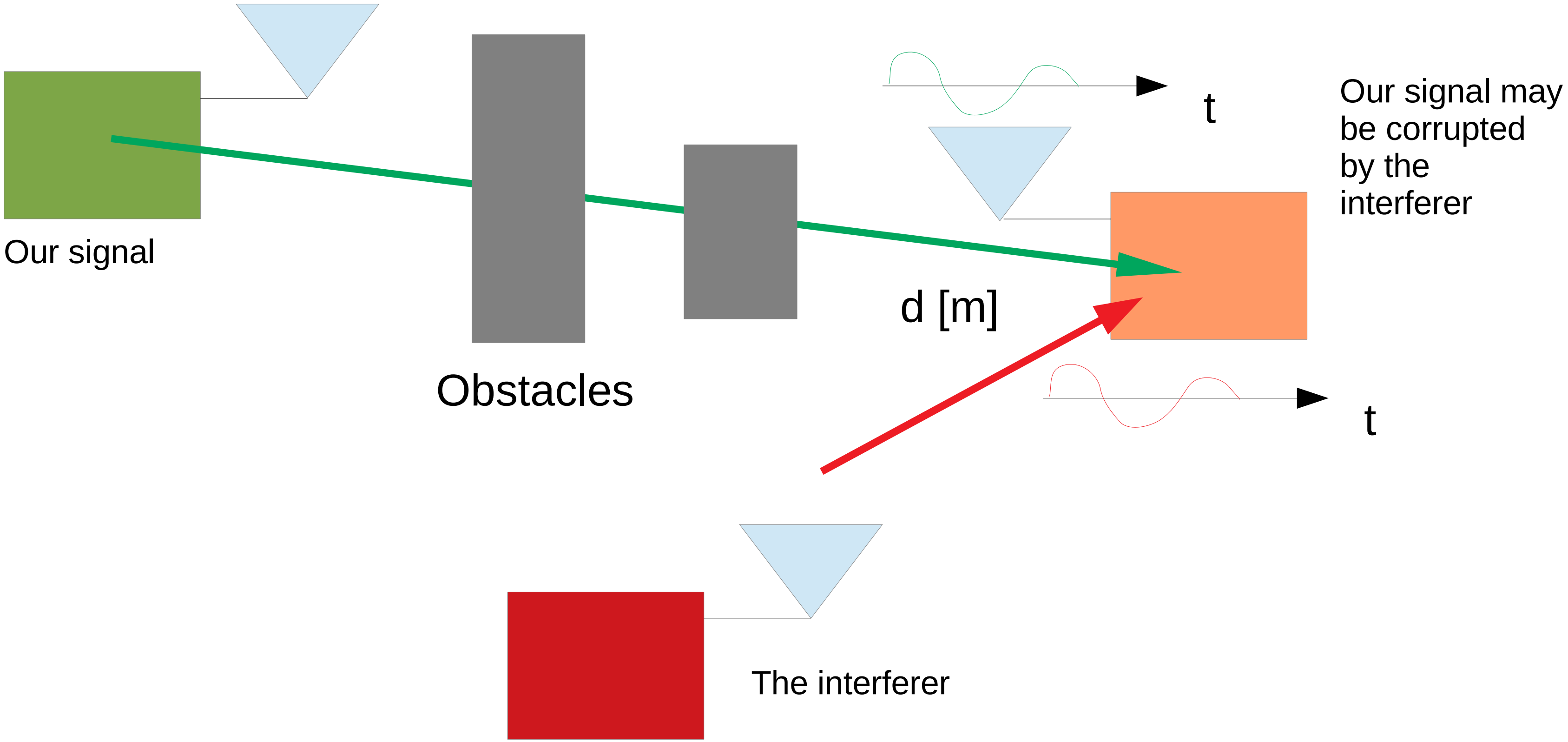
Path-loss at 1 meter
(usually, 20-25 dBs)

SNR

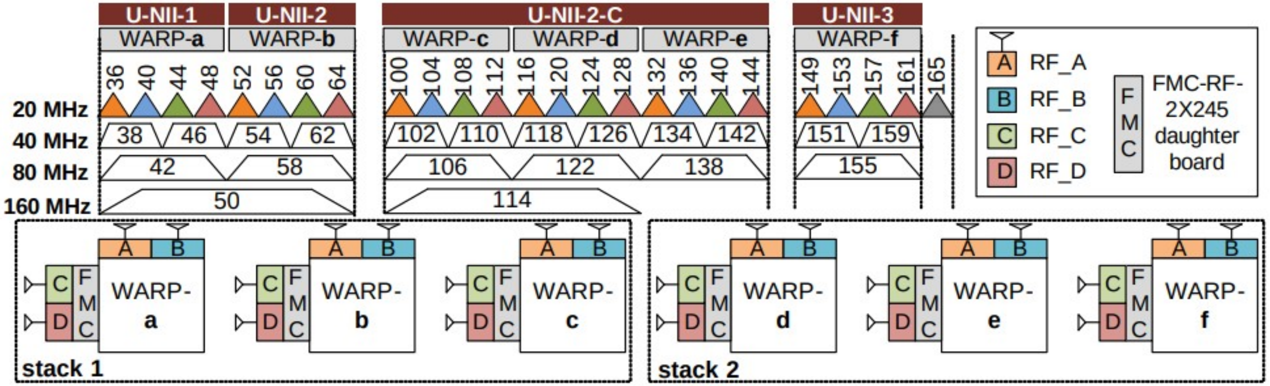
- Signal-to-Noise Ratio
  - SNR [dB] = Pr [dBm] – Noise Power [dBm]



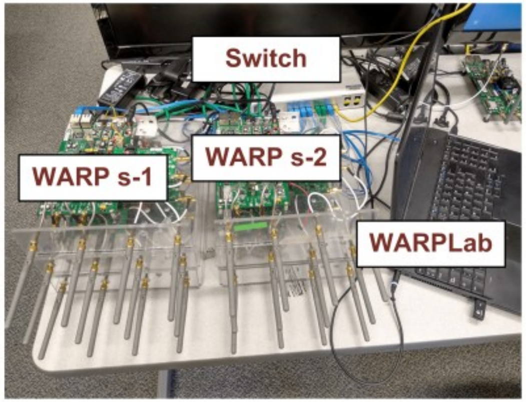
Interference



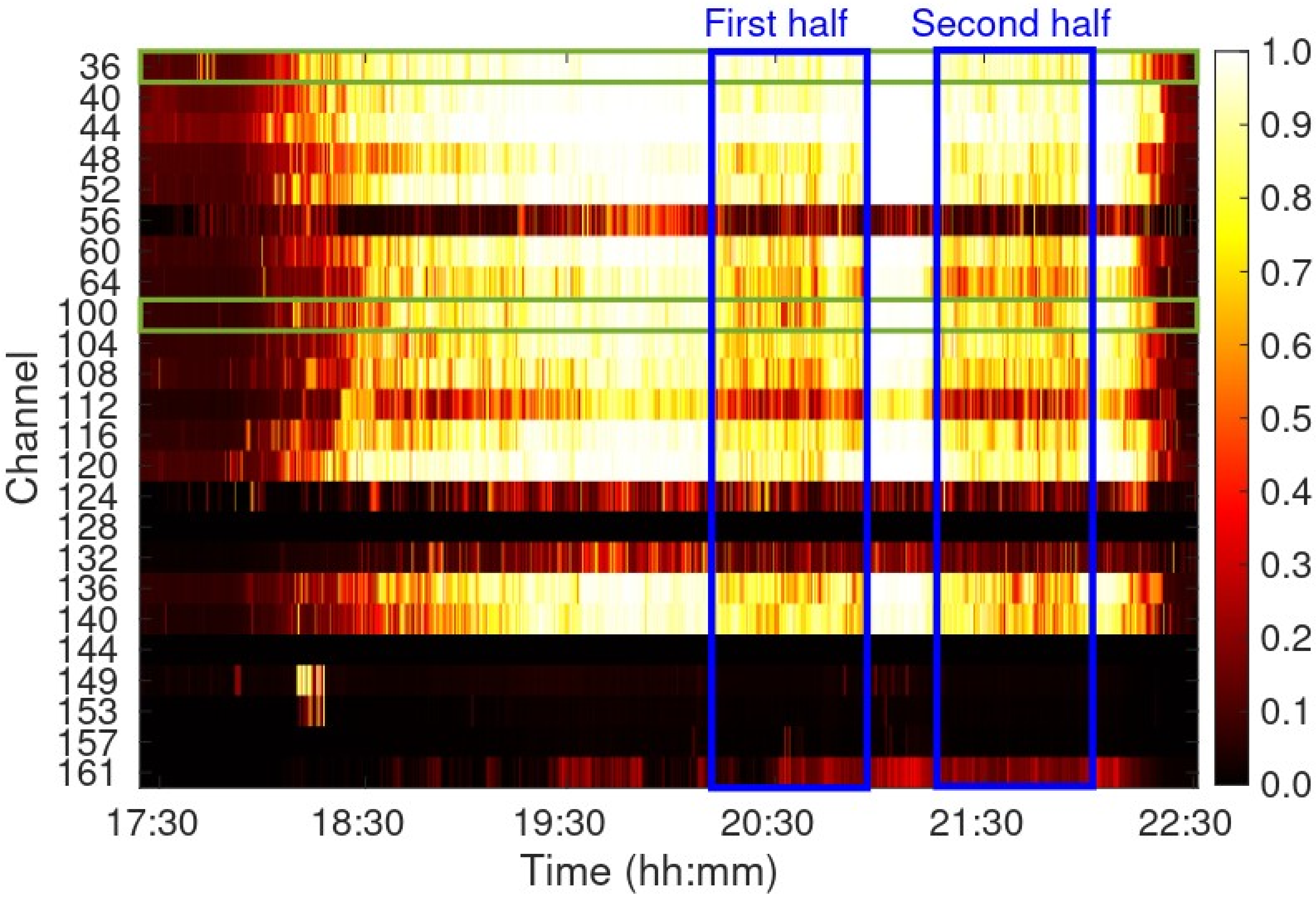
5 GHz band



(a) IEEE 802.11ac/ax channelization at the 5-GHz and assignation per RF.

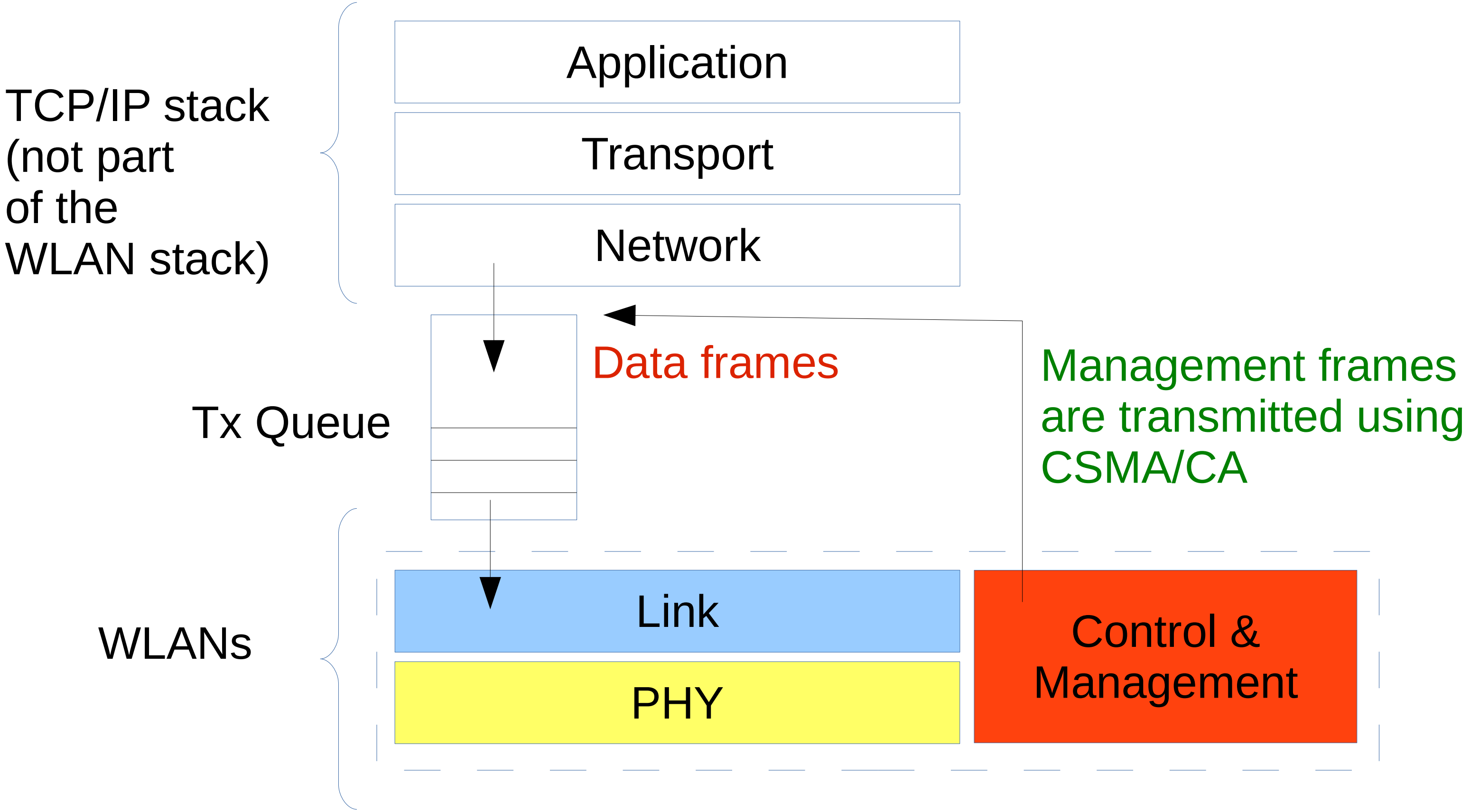


(b) Deployment schematic.

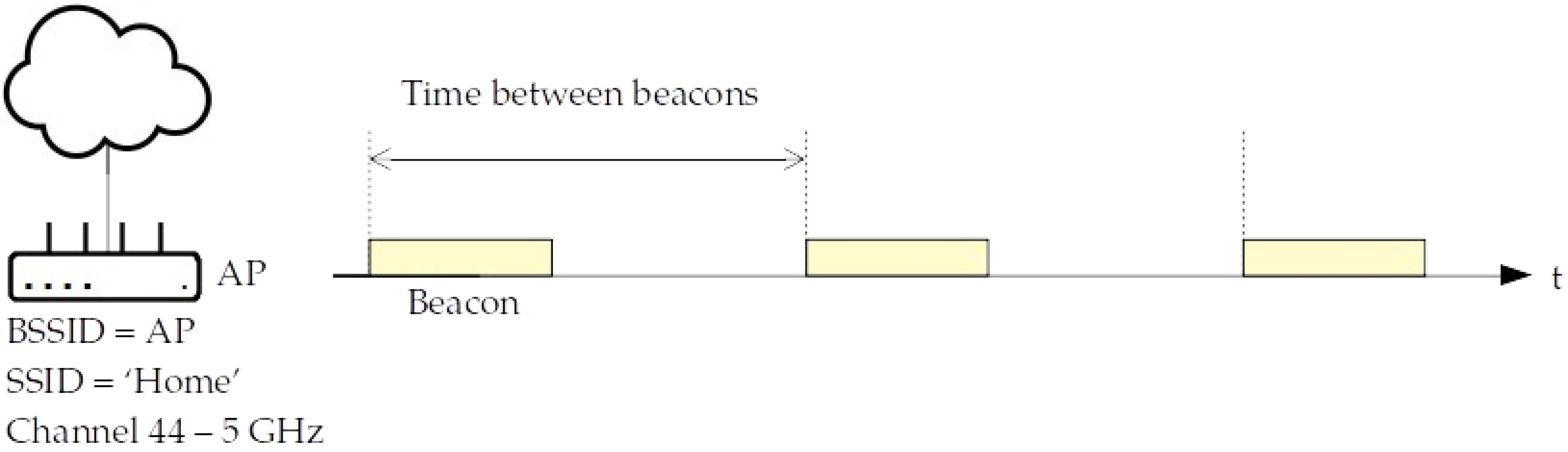


First half
Second half
36
40
44
48
52
56
60
64
100
104
108
112
116
120
124
128
132
136
140
144
149
153
157
161
Channel
17:30
18:30
19:30
20:30
21:30
22:30
Time (hh:mm)
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0

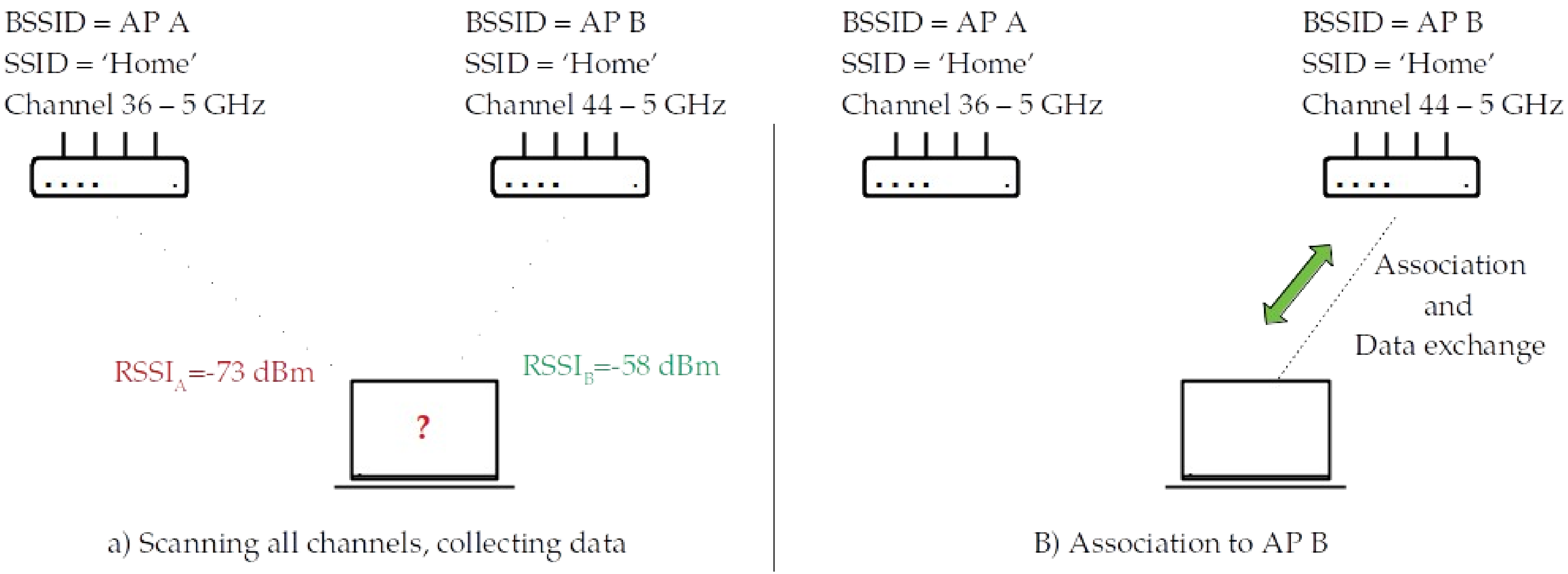
WLAN Device: Protocol Stack



Setting up a Wi-Fi network: AP 'ON'



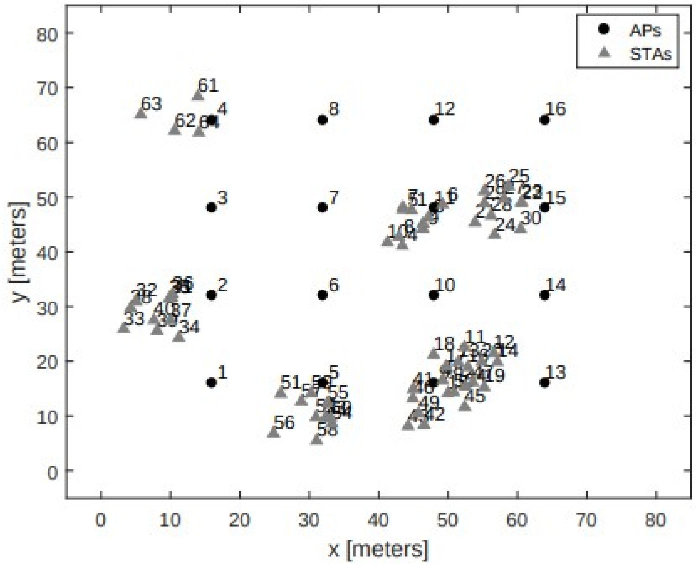
Setting up a Wi-Fi network: A new STA turns ON



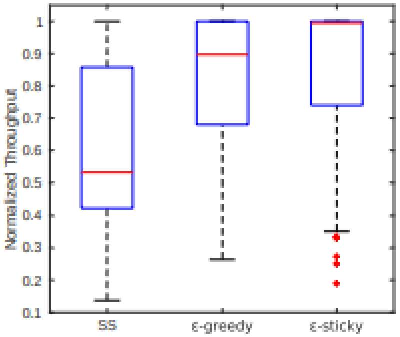
a) Scanning all channels, collecting data

B) Association to AP B

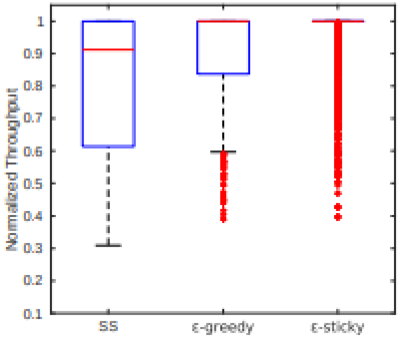
Association based on RSSI, not always the best



(b) Scenario with the STAs grouped in clusters. Clusters are generated uniformly at random.



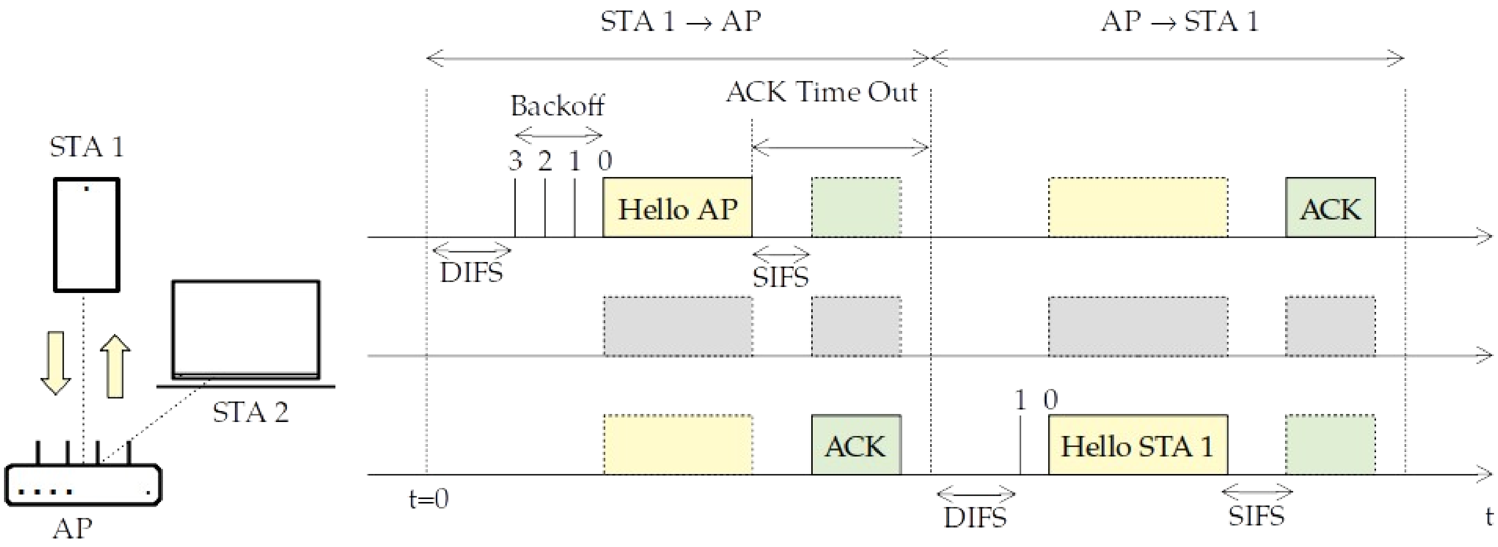
(a) 32 STAs, 8 Mbps.



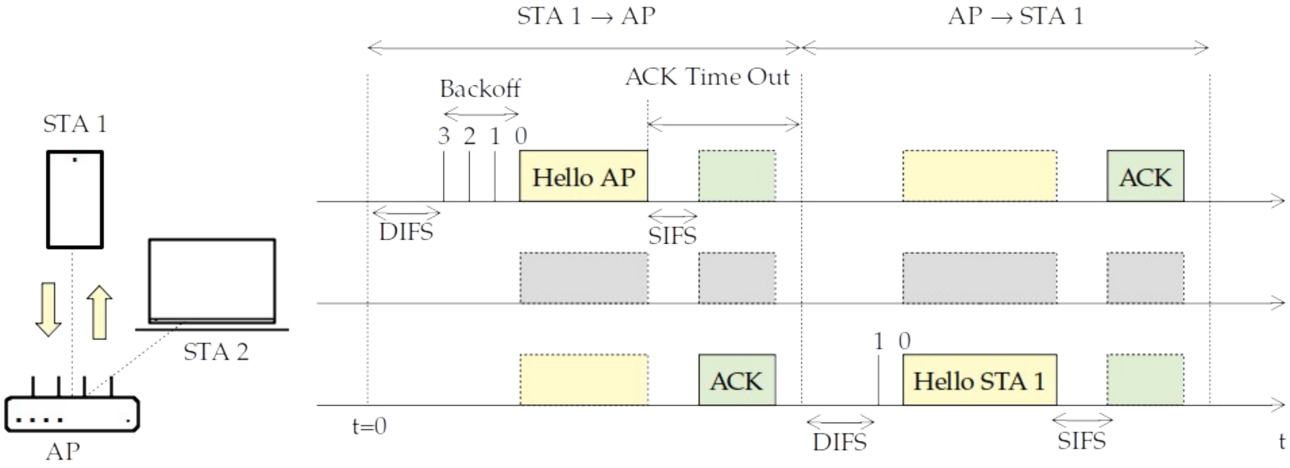
(b) 64 STAs, 4 Mbps.

We will play with this in Labs 1-2-3!

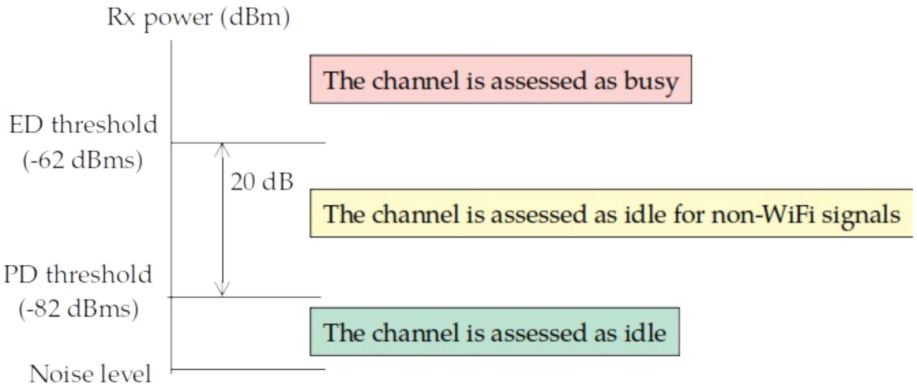
Data exchange: Distributed Coordination Function



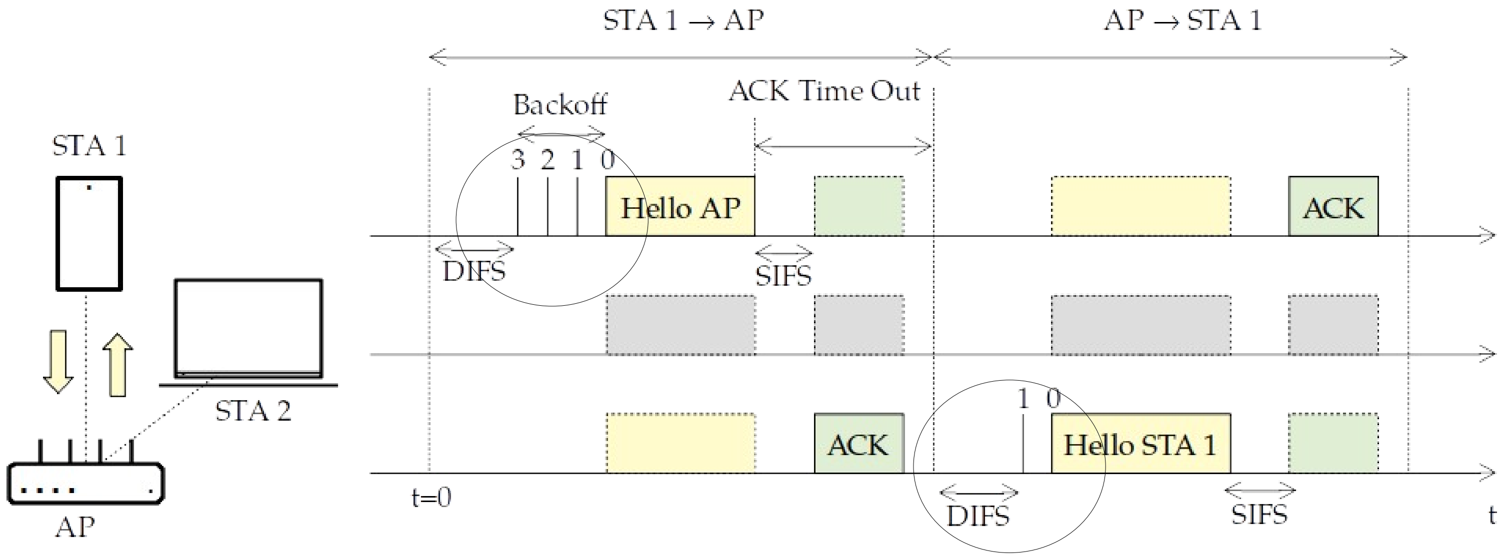
Clear channel assessment



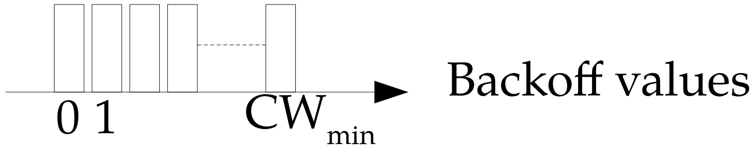
Channel assessment



Random Backoff



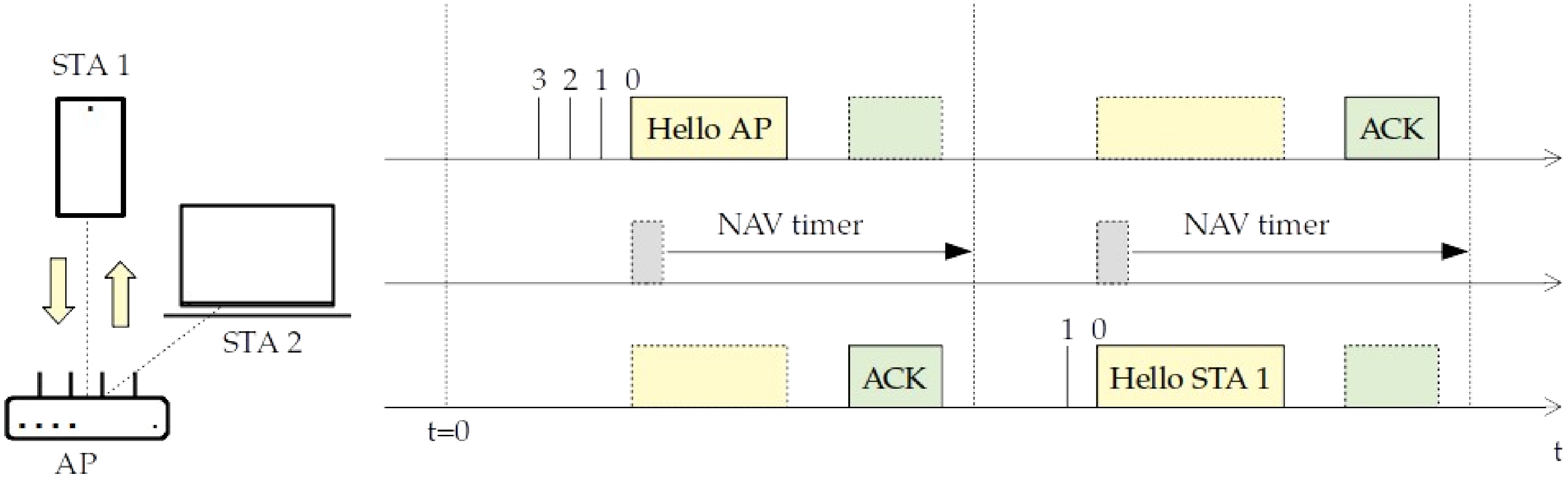
$$\text{Prob}(i) = 1/(CW_{min}+1)$$



1st transmission (0 retransmissions) for both Hello AP and Hello STA messages

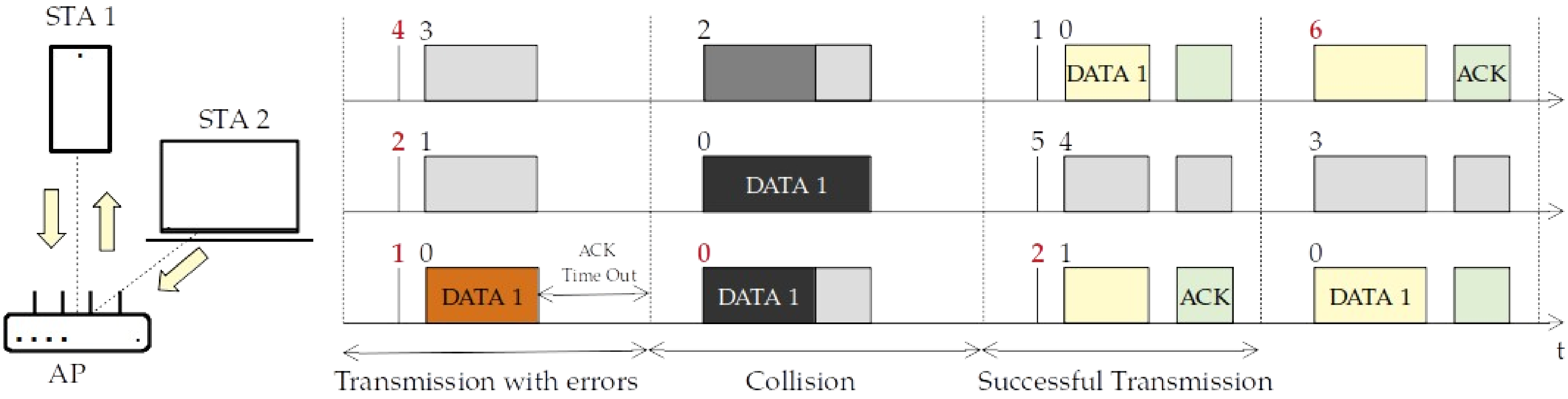
Discrete uniform distribution

Network Allocation Vector



Transmission errors and collisions

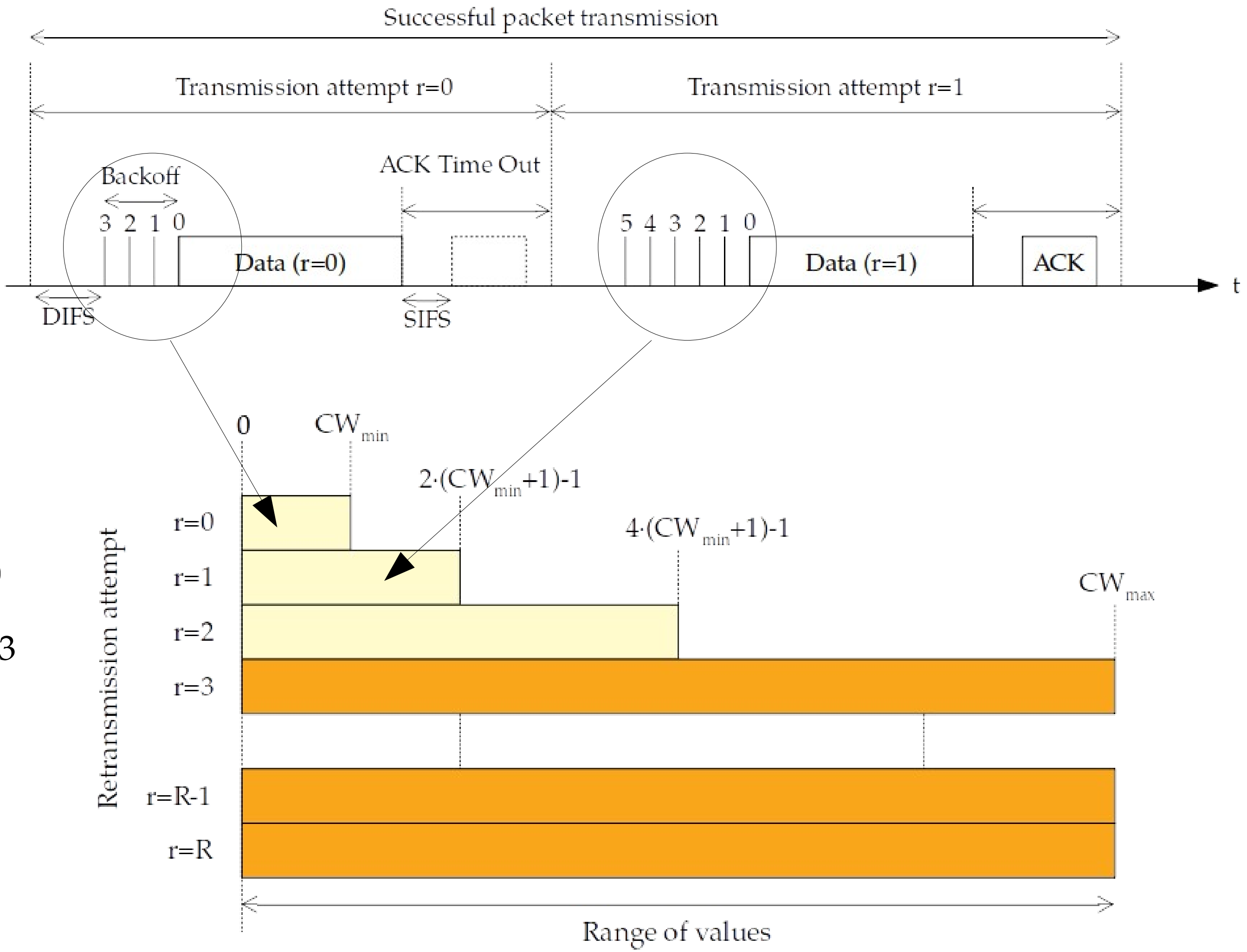
- What happens when two devices finish the backoff at the same time? → A collision.
- Are collisions the only reason to lose packets in WiFi? No, there are also transmission errors.
- Packets not correctly received are retransmitted (up to R times).



Stop & Wait ARQ

- Half-duplex channel → Stop & Wait
- ACKs are only transmitted when a packet is correctly received
- When an ACK is not received, the sender does not know if it is because ‘errors’ or collisions
- To minimize the chances of colliding again with the same devices → Exponential Backoff

Random Exponential Backoff



Number of backoff stages

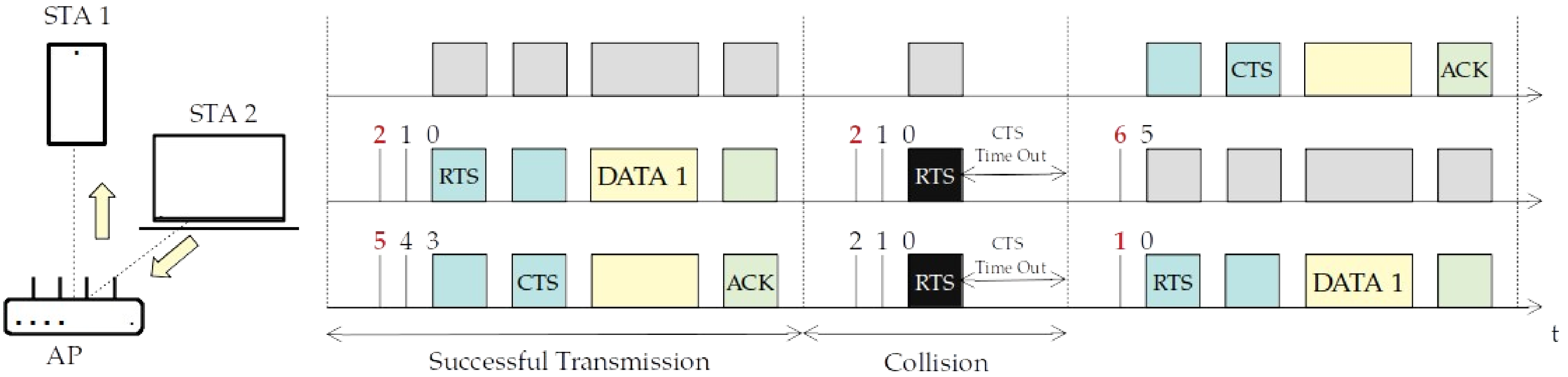
$m=\log_2((CW_{max}+1)/(CW_{min}+1))$

Example: $CW_{min}=15$, $CW_{max}=1023$

Solution: $m = 6$

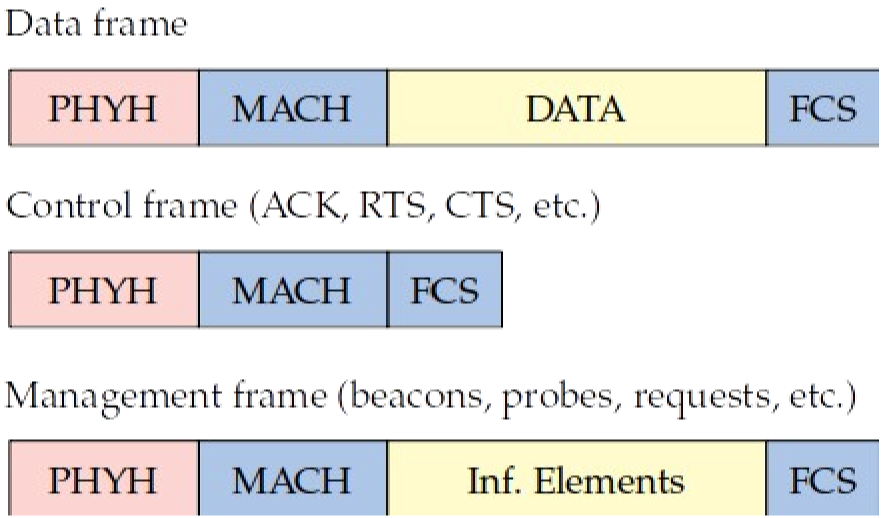
RTS/CTS

- Collisions can be costly, as they are as long as the longest packet involved in it.
- RTS/CTS → Overhead in successful transmissions, but result in a low duration of collisions.
- When to use RTS/CTS? When transmissions include a lot of data.



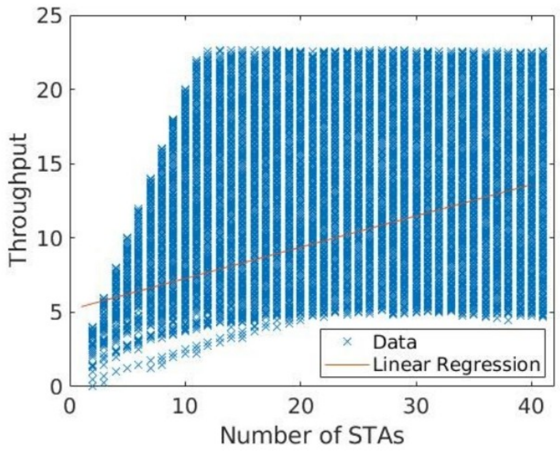
Types of packets

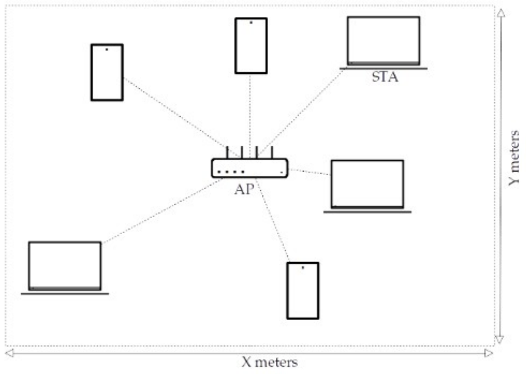
- Three types:
  - Management: beacons, probes (association), requests, etc.
  - Control: RTS, CTS, ACK, etc.
  - and DATA
- Common structure in all cases



The WiFi dataset we will use in this course

1. **Number of STAs:** 1-40
2. **Load:** 1.5-240 Mbps
3. **Size(x):** 1-40 metres
4. **Size(y):** 1-40 metres
5. **Area:** x·y
6. **Contention window:** {3, 15, 31, 63, 127, 255, 511, 1023} slots
7. **Channel width:** {20, 40, 80, 160} MHz
8. **Packet size:** {4000, 6000, 8000, 10000, 12000} bits
9. **Max RSSI:** ≥ -82 dBm
10. **Avg. RSSI:** ≥ -82 dBm
11. **Min. RSSI:** ≥ -82 dBm





- Can we build a ML model able to predict the throughput given a combination of input parameters?
- Can we build a ML model able to predict if a given configuration + scenario will offer a satisfactory performance to the stations?

Example

- Download Example Lecture 2 from the web.
- It contains a dataset with 1000 entries.
  - All devices are using a full-buffer traffic model.
  - W = 20 MHz channels only
- Open and execute the matlab script, and answer the questions inside.