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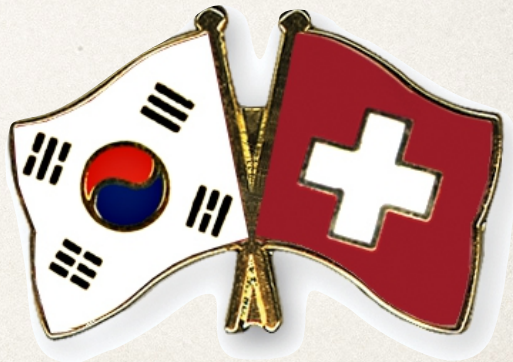
서울대학교 컴퓨터공학부
Seoul National University
Dept. of Computer Science and Engineering

Wireless Security
SU'19



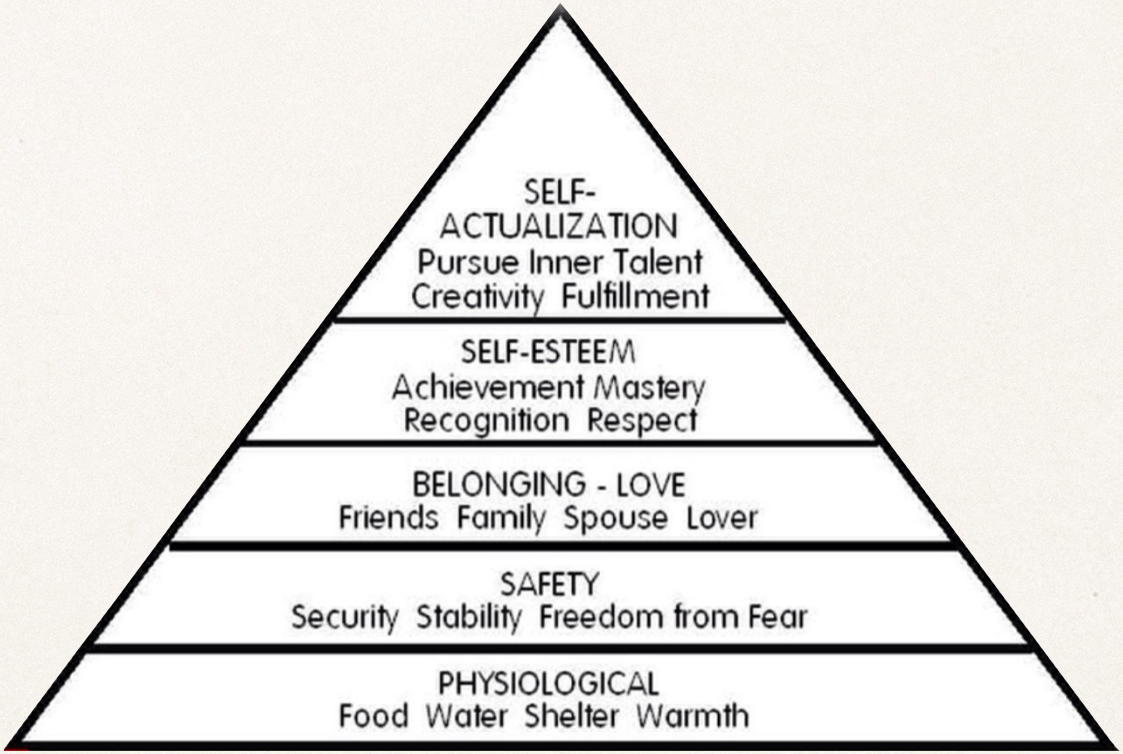
abraham.rubinstein@heig-vd.ch

Who am I?

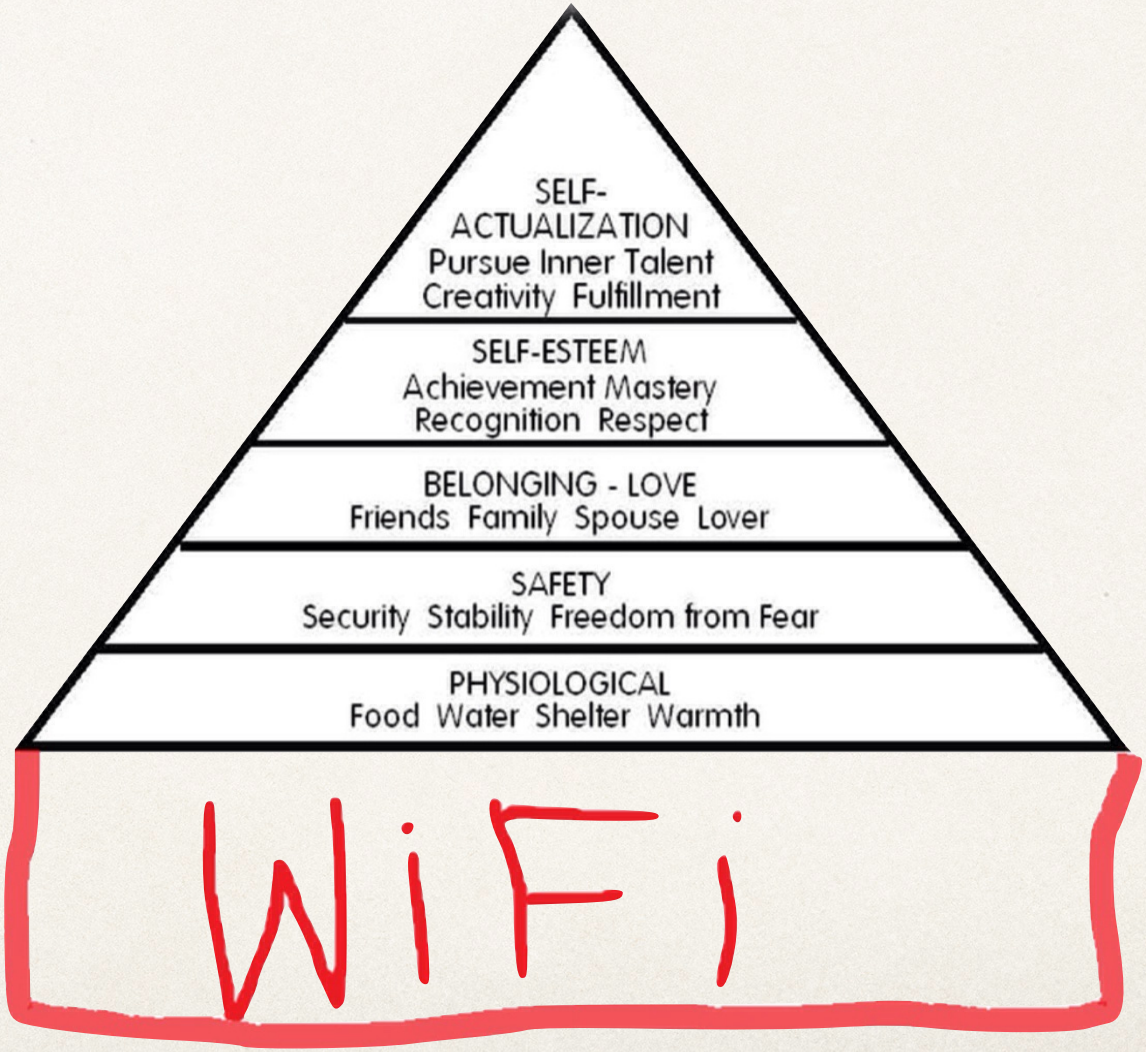
Who am I?


EtherCAT
PROFIBUS
ETHERNET POWERLINK
PROFINET
EtherNet/IP
Modbus

Why Wireless Security ?



Why Wireless Security ?



Wireless Threats

- Radio waves cross walls, floors, ceilings…
- Connected world —> Smart devices, IoT, PAN
- Most hotspots do not use any encryption method
- Weak encryption/authentication methods still in use around the world
- Badly configured networks around the world

Tokyo - 3 days ago…

```
CH  6 ][ Elapsed: 2 mins ][ 2019-08-02 23:52

BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSIDth:  0>

32:09:B4:71:1D:90   -1        0        0    0  10  -1                    <length:  0>
00:16:01:04:DB:4D  -88       16       12    0   1  54   WPA  WEP          <length: 16>
22:95:D6:A0:6A:05   -1        1        0    0  13   54  WEP  WEP          1928434135572
EA:CB:BC:88:09:98   -1        0        0    0  -1  -1                    <length:  0>
```

Seoul National University - 3 hours ago…

```
CH  5 ][ Elapsed: 1 min ][ 2019-08-04 21:53

BSSID              PWR  Beacons    #Data, #/s  CH  MB   ENC  CIPHER AUTH ESSID

00:25:00:FF:94:73   -1        0        0    0  -1  -1                    <length:  0>
3C:A3:15:02:42:D6  -64       23        0    0  13  54e  WEP  WEP          SYMIN-OFFICE
```

My hotel WiFi in Tokyo:

Wireless Threats

- New : Home automation
  - Hacker a domestic WiFi —> hack the house
  - Some automation hardware is actually the entry door…
- New : IoT
  - Sensor networks - very often wireless
  - Based on 802.15.4 —> the MAC layer proposes security services - responsibility of upper layers
  - Some IoT devices use WiFi standards

Wireless Threats

- Passive eavesdropping and traffic analysis
  - Easy: most wireless NICs have promiscuous mode
- Message injection and active eavesdropping
  - Can use common network card to generate any packet
- Message deletion and interception
  - Possible with directional antennas

- "Wireless Security in 802.11i" by Vitaly Shmatikov

Wireless Threats

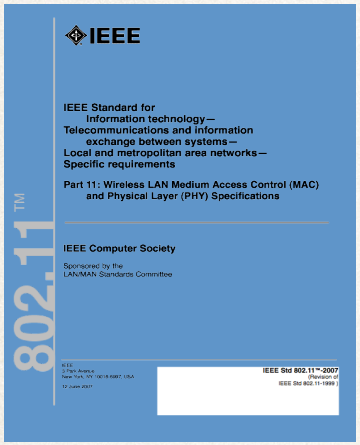
- Malicious access points
  - Easy: forge MAC, run standard HostAP software
- Session hijacking
- Denial of service (DoS)
  - Radio signals can be easily disturbed or interfered at the physical layer

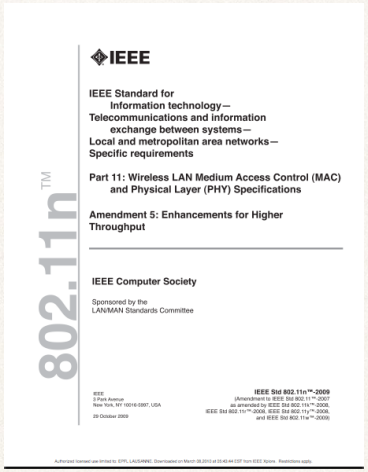
- "Wireless Security in 802.11i" by Vitaly Shmatikov
- J. Wang. Computer Network Security Theory and Practice

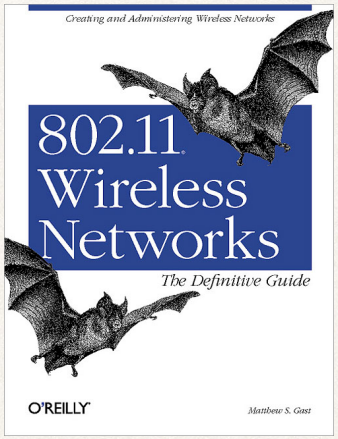
Chapter I

802.11 Networks

Bibliography







Google

IETF

Contents

Basic concepts and vocabulary for 802.11 and security

- Standards
- Architecture, topology, components
- PHY
- MAC

Wi-Fi Alliance Sponsors

Design Criteria

- Low power 
- Worldwide compatibility 
- Equivalent security to 802.3 
- Transparent for existing applications

Standards

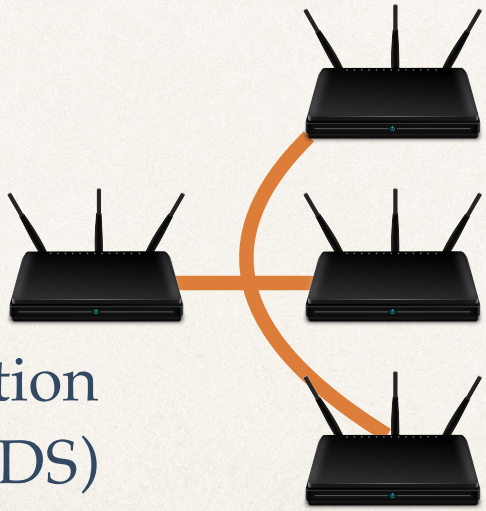
Standard	Nominal rate in Mbps	Comment	Frequency Band
IEEE 802.11	1, 2	First standard	2.4 GHz
IEEE 802.11a	6, 9, 12, 18, 24, 36, 48, 54	Shorter range but more independent	5 GHz
IEEE 802.11b	1, 2, 5.5, 11	Compatible with 802.11g and 802.11	2.4 GHz
IEEE 802.11g	1, 2, 5.5., 6, 9, 11, 12, 18, 24, 36, 48, 54	Was one of the most popular for years	2.4 GHz
IEEE 802.11n	Up to 600	Very popular	2.4 GHz/5 GHz
IEEE 802.11ac	2600	Very popular	5 GHz

Amendments

802.11 Components

Station (STA)

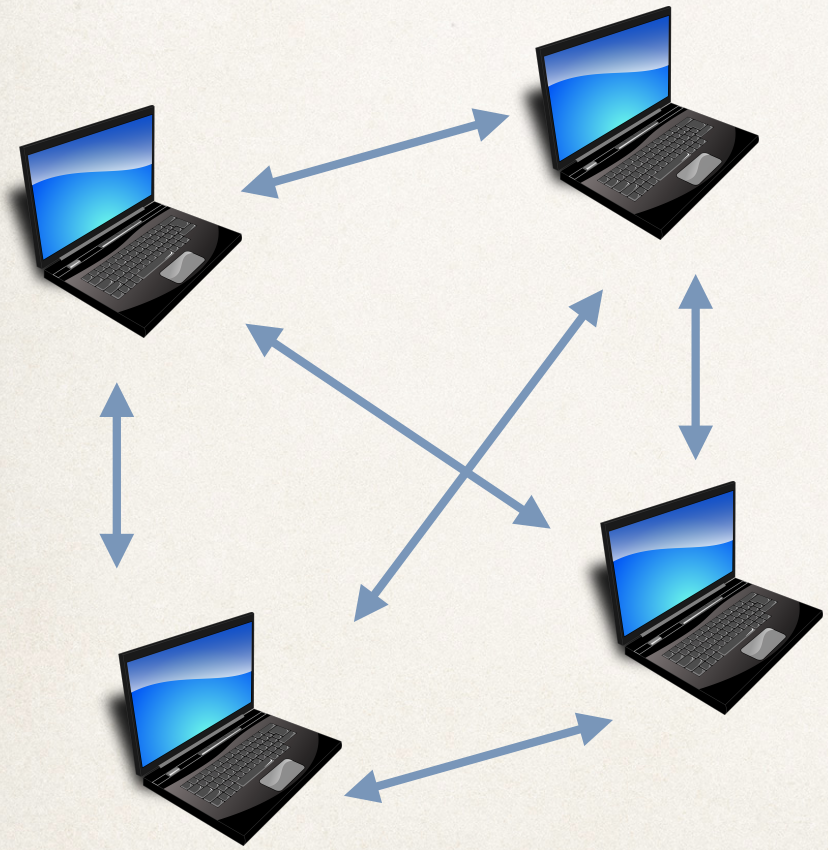
Access Point (AP)



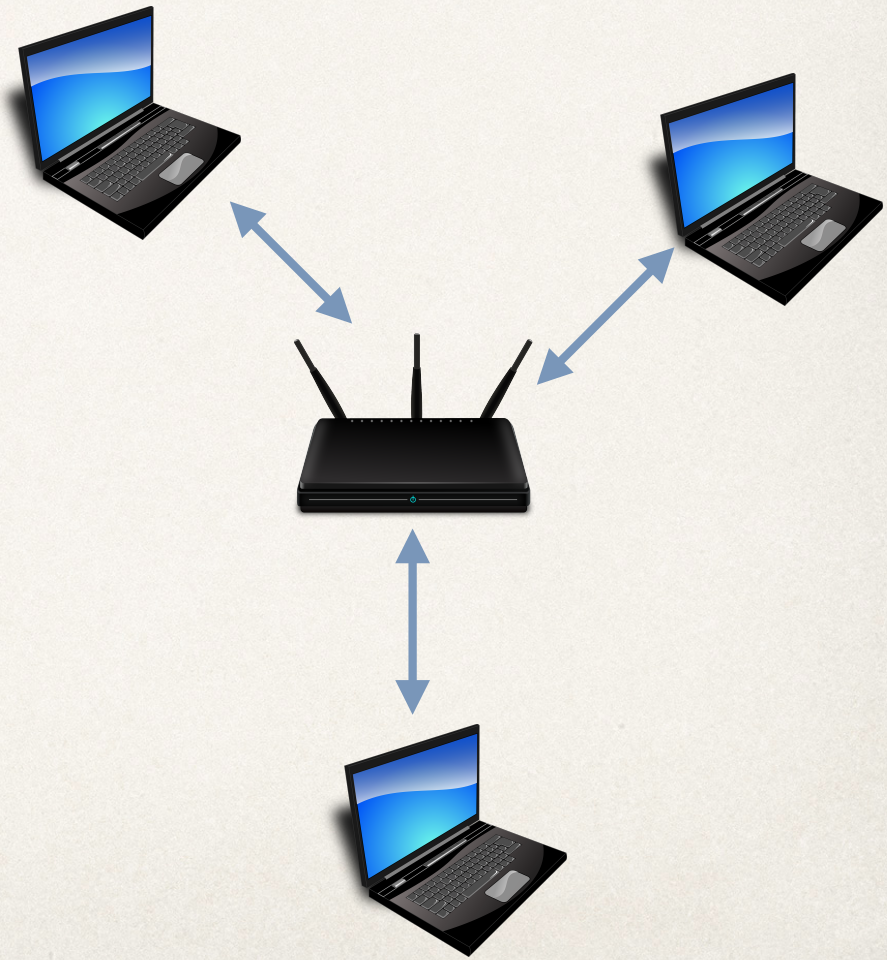
Distribution System (DS)

Operating Modes

Ad hoc



Infrastructure

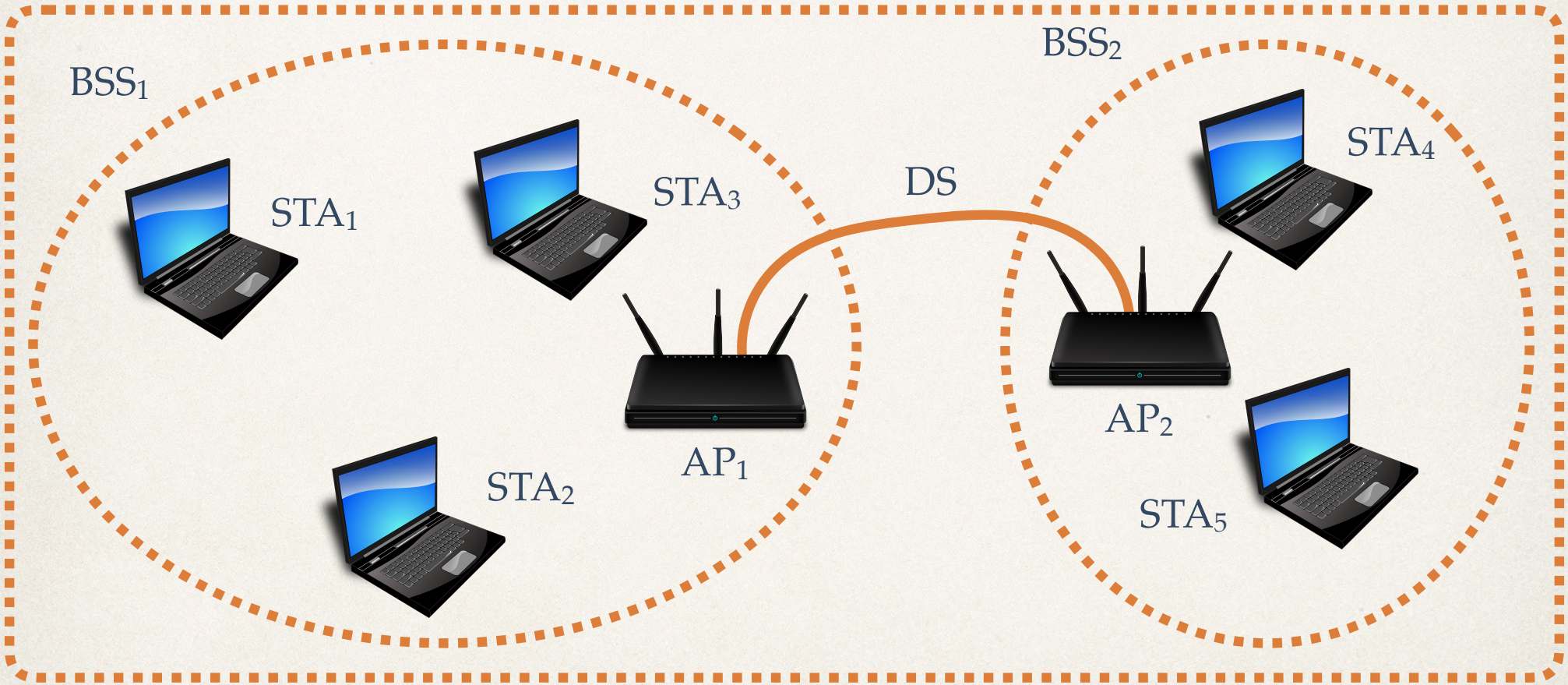


Ad hoc

IBSS : Independent Basic Service Set

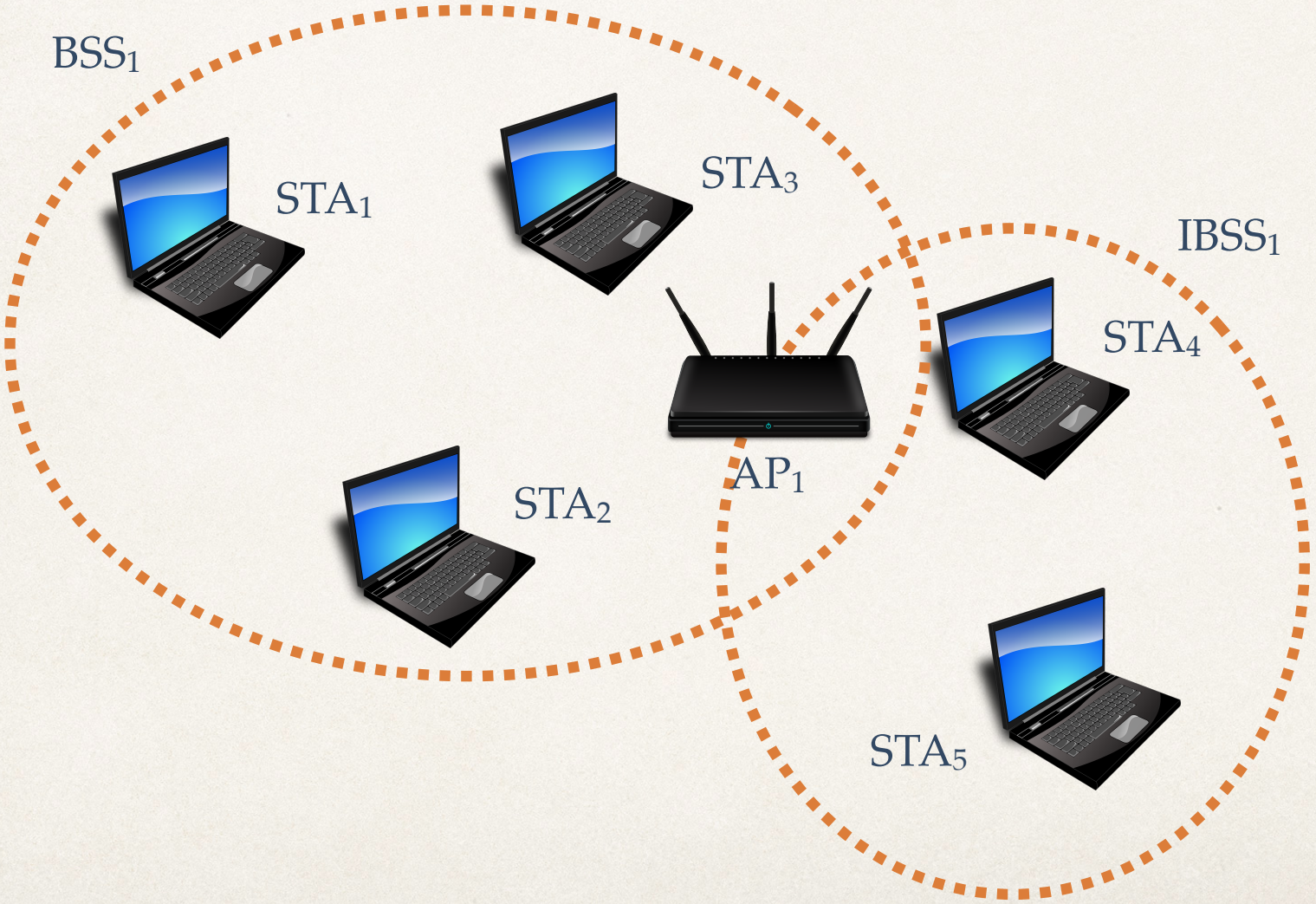
Infrastructure

ESS : **E**xtended **S**ervice **S**et



All frames go through an AP in Infrastructure mode

Networks can be co-localized



Question 1

What is the max nominal rate in 802.11a?

- 600 Mbps
- 11 Mbps
- 54 Mbps
- 5 GHz

Question 2

What is the max nominal rate in 802.11g?

- 2.4 GHz
- 2 Mbps
- 11 Mbps
- 54 Mbps

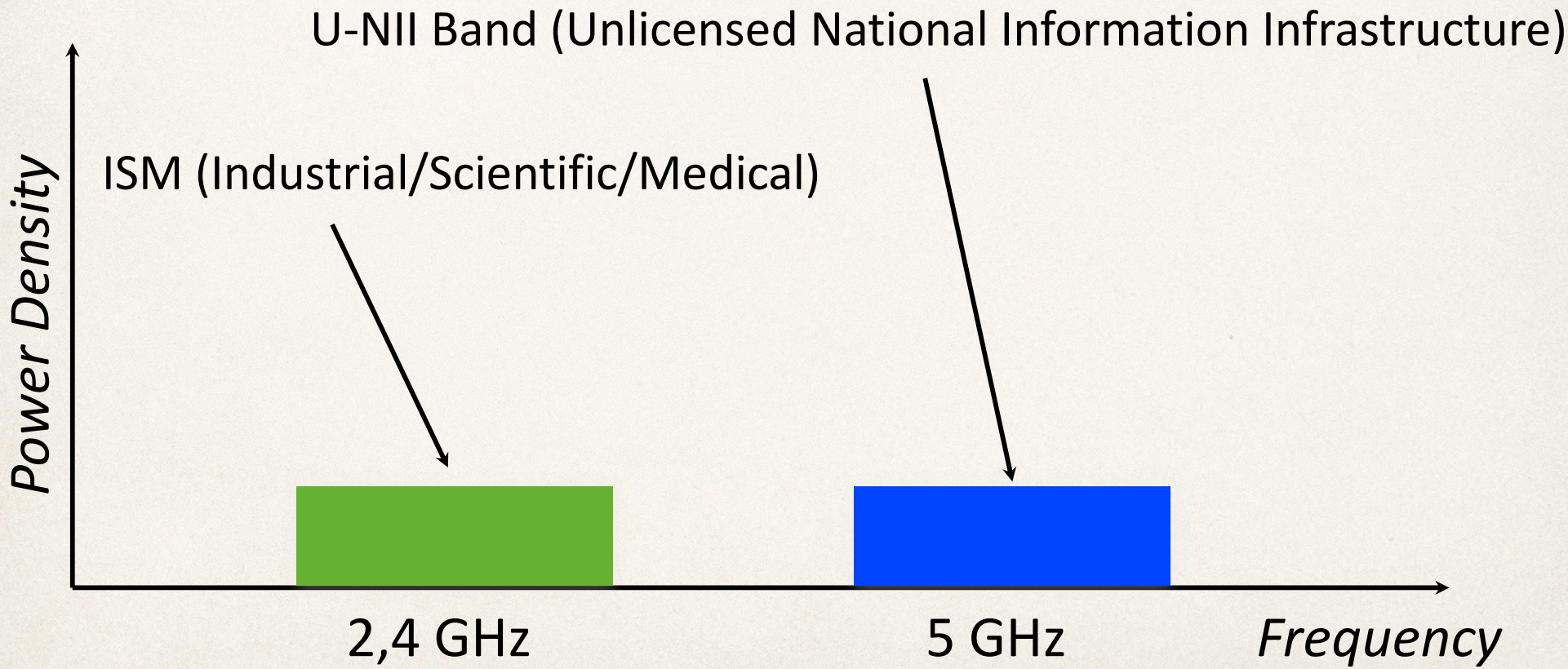
The Physical Layer (PHY)

- Channel operating frequencies
- Modulation
- Frame structure
- In practice
  - Frequency separation
  - Compatibility

Frequencies

“Knowing the operation frequency allows an attacker to inject noise in a channel and produce a DoS”

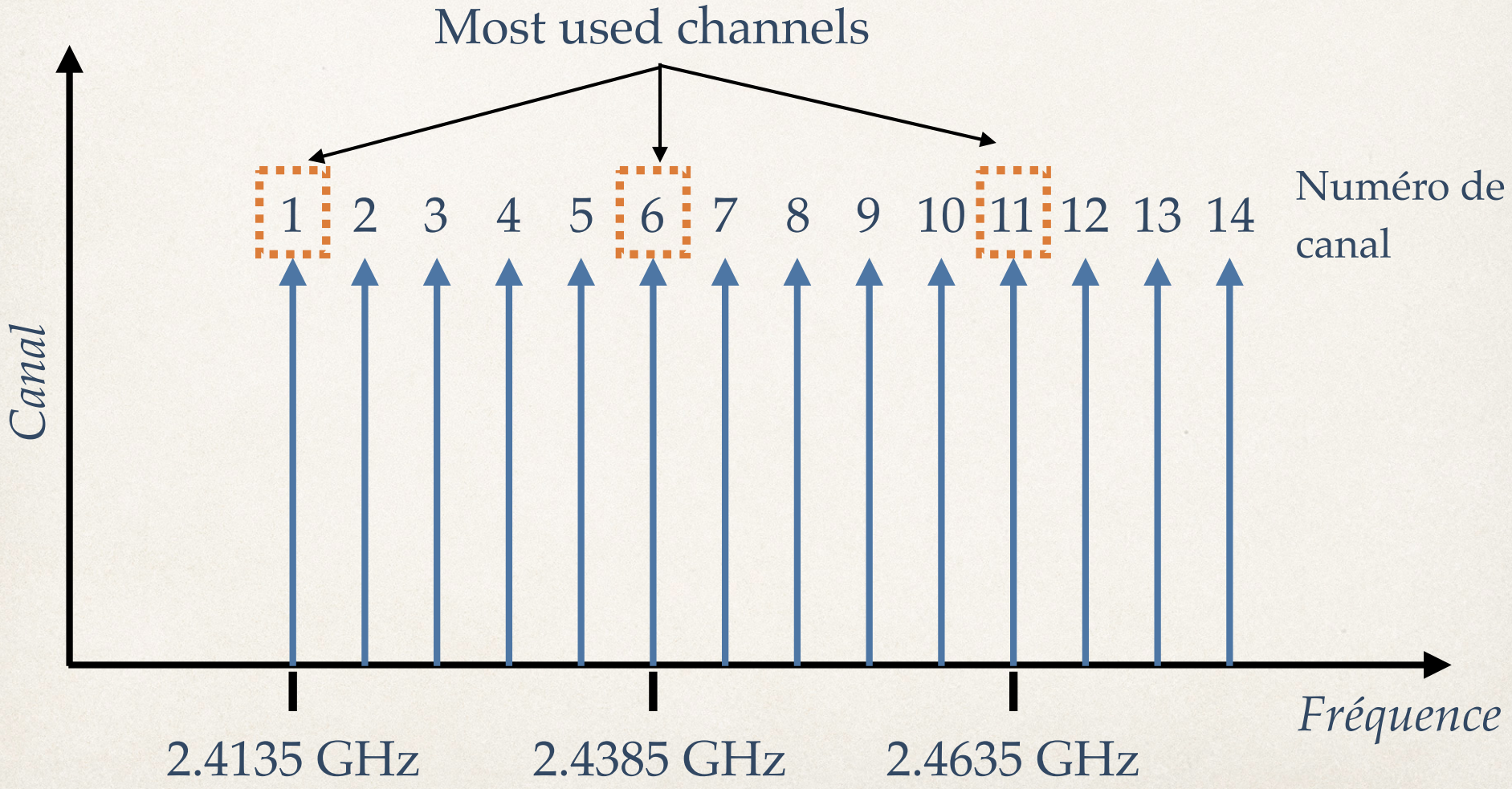
WiFi Frequency Bands



Channel selection

- Each one of these bands is divided into channels
- When a network connection is established, at least one of these channels is used

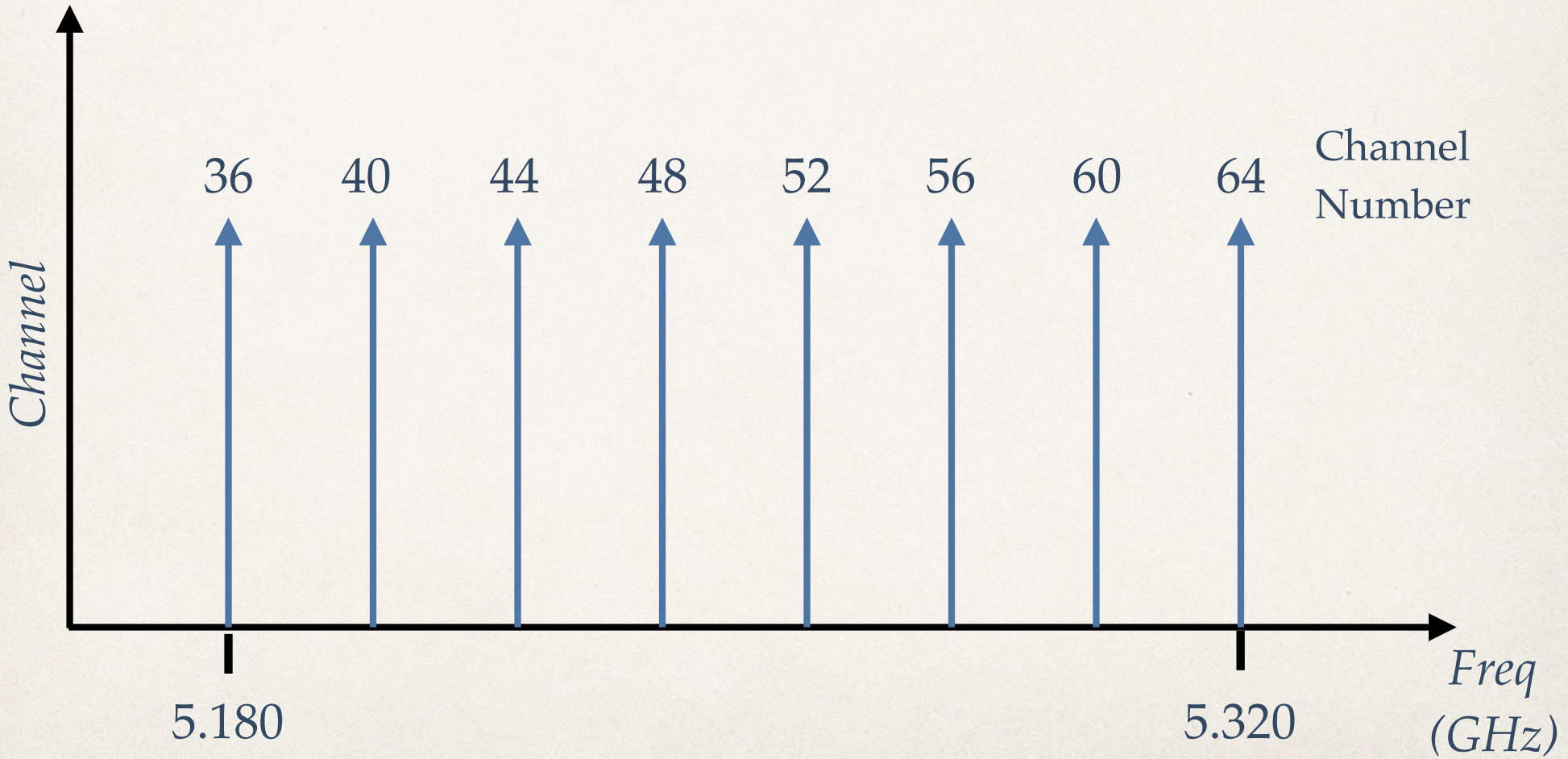
Channels in the ISM band 2,4 GHz (802.11, 802.11b, 802.11g)



Channels allowed by regulatory authorities in the 2.4 GHz Band

- In the USA and Canada: 1 à 11
- In Europe and Asia (except Spain and Japan): 1 à 13
- In Spain and Japan: 1 à 14

Channels Allowed in Switzerland for U-NII (802.11a)

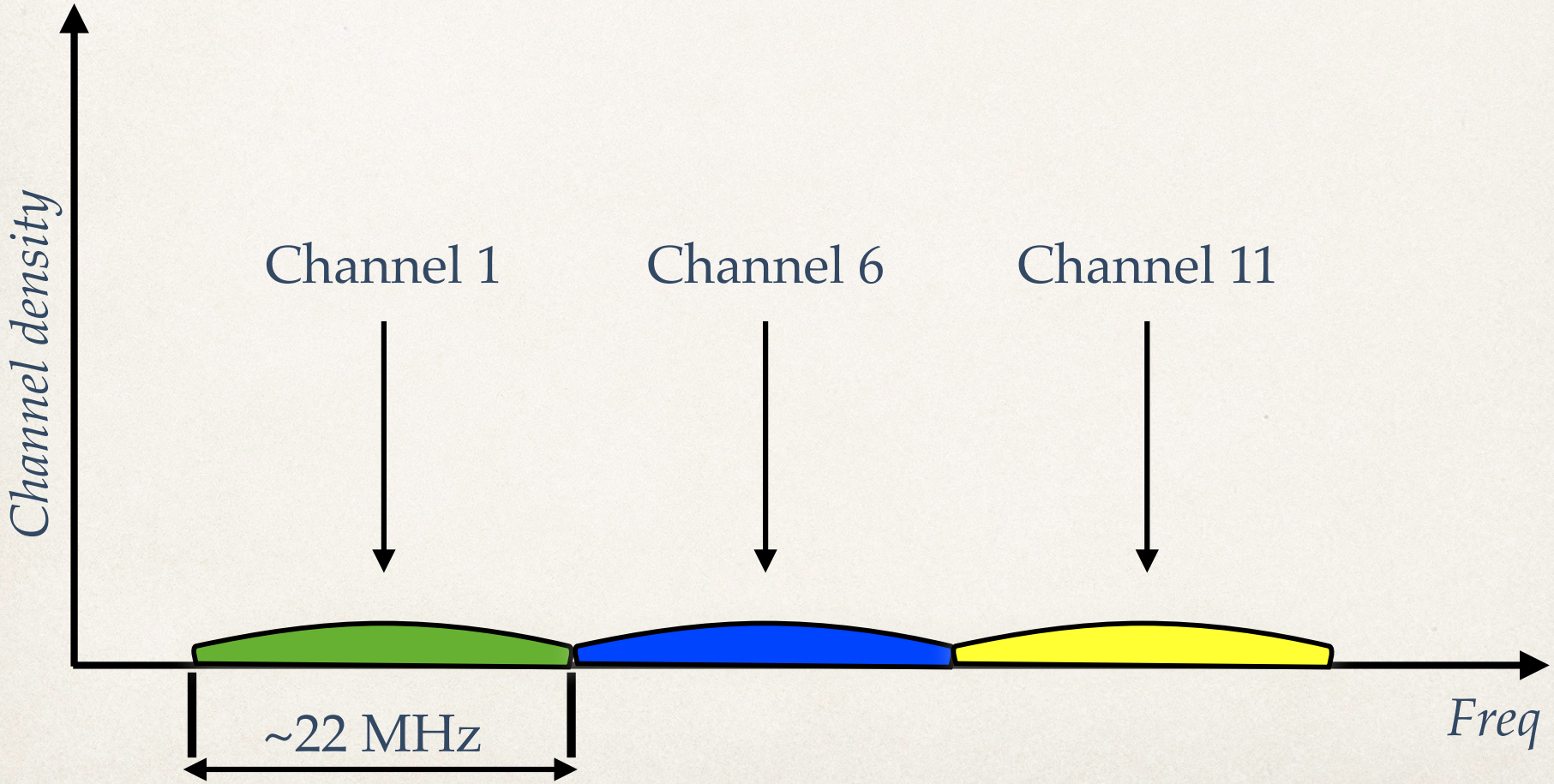


Channels Allowed in Switzerland for U-NII (802.11a)

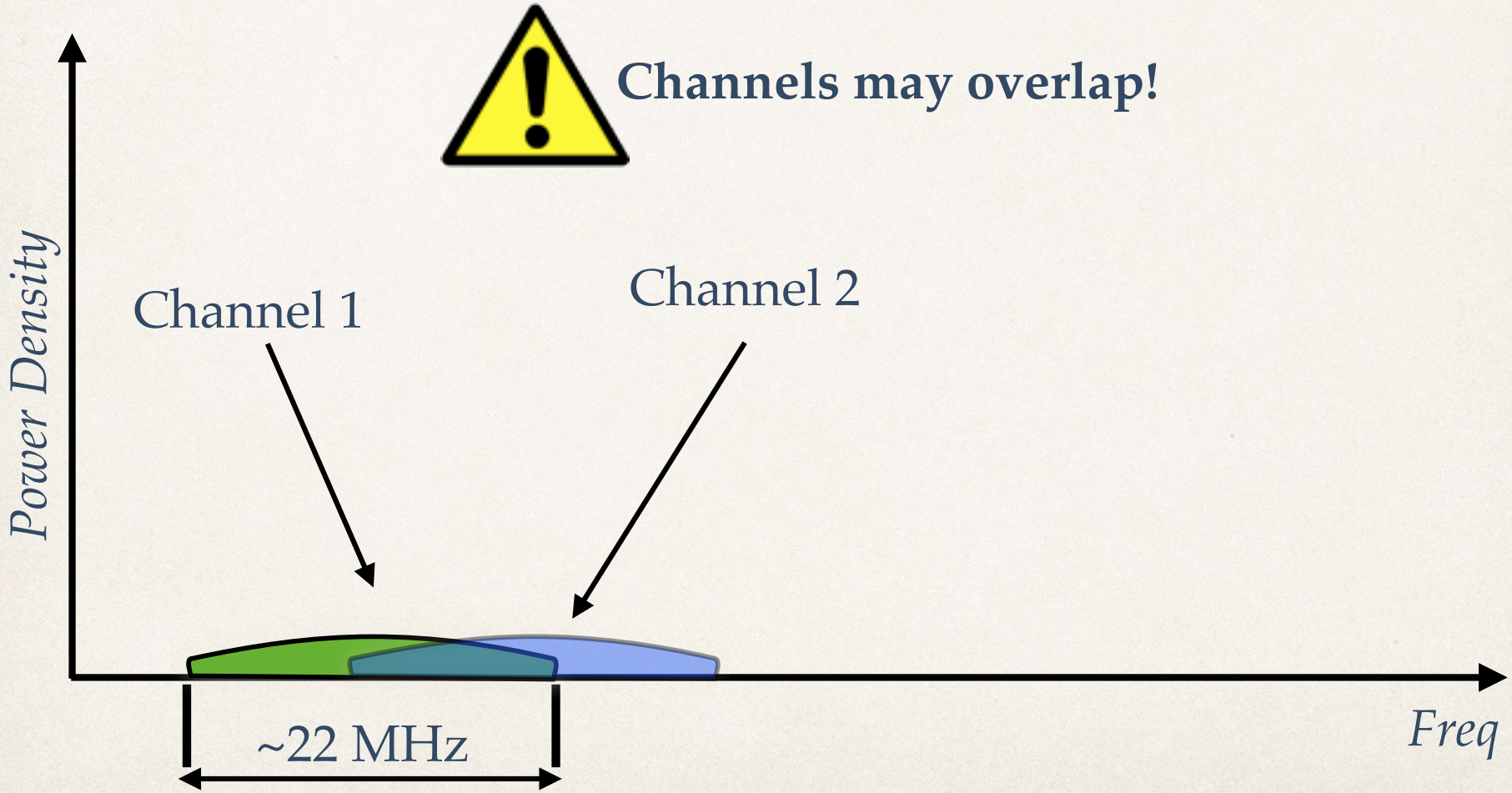
Channel selection

Channels for 802.11, 80211b and 802.11g

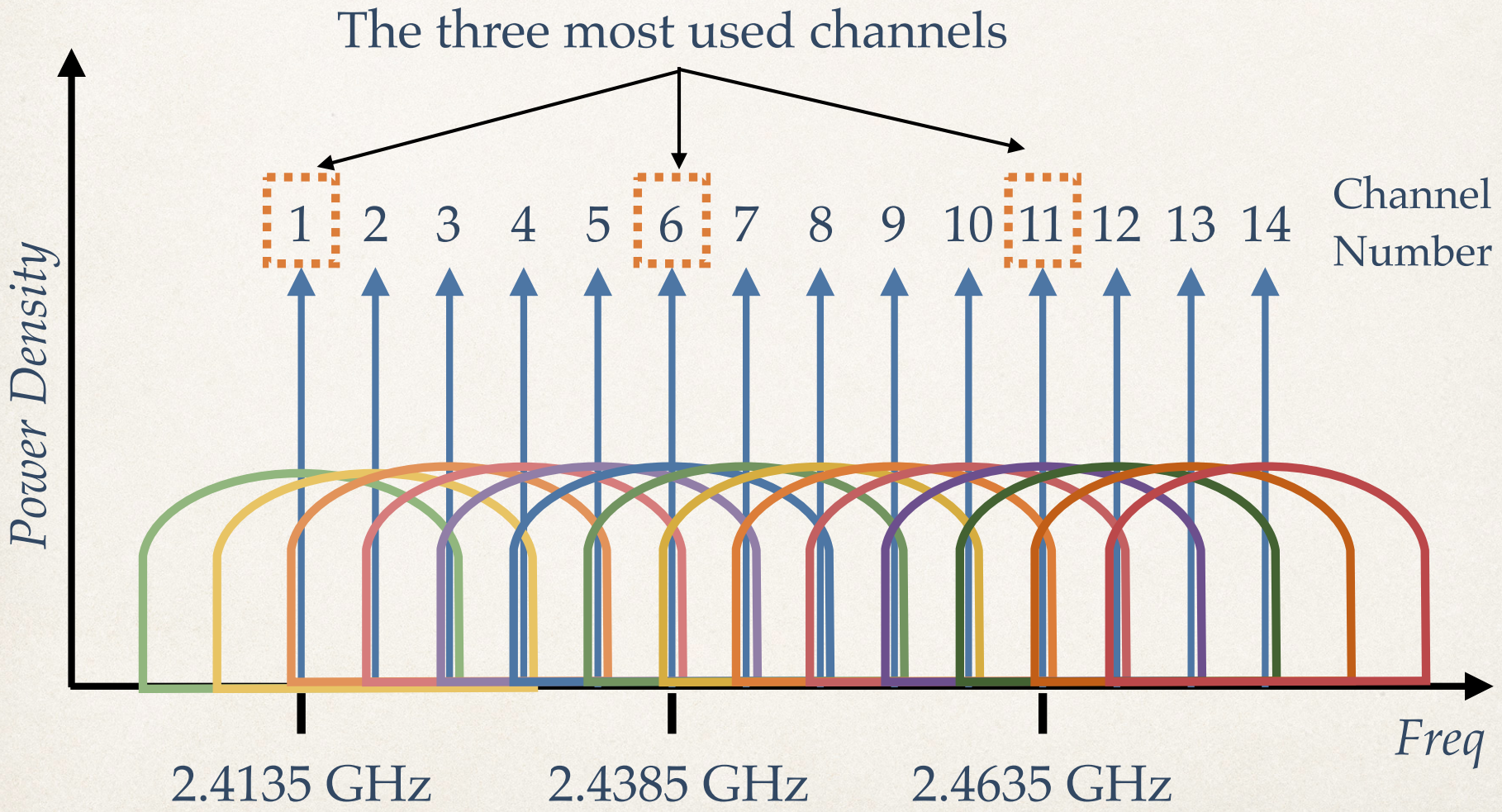
14 channels are defined in the ISM band



Channels for 802.11, 80211b and 802.11g

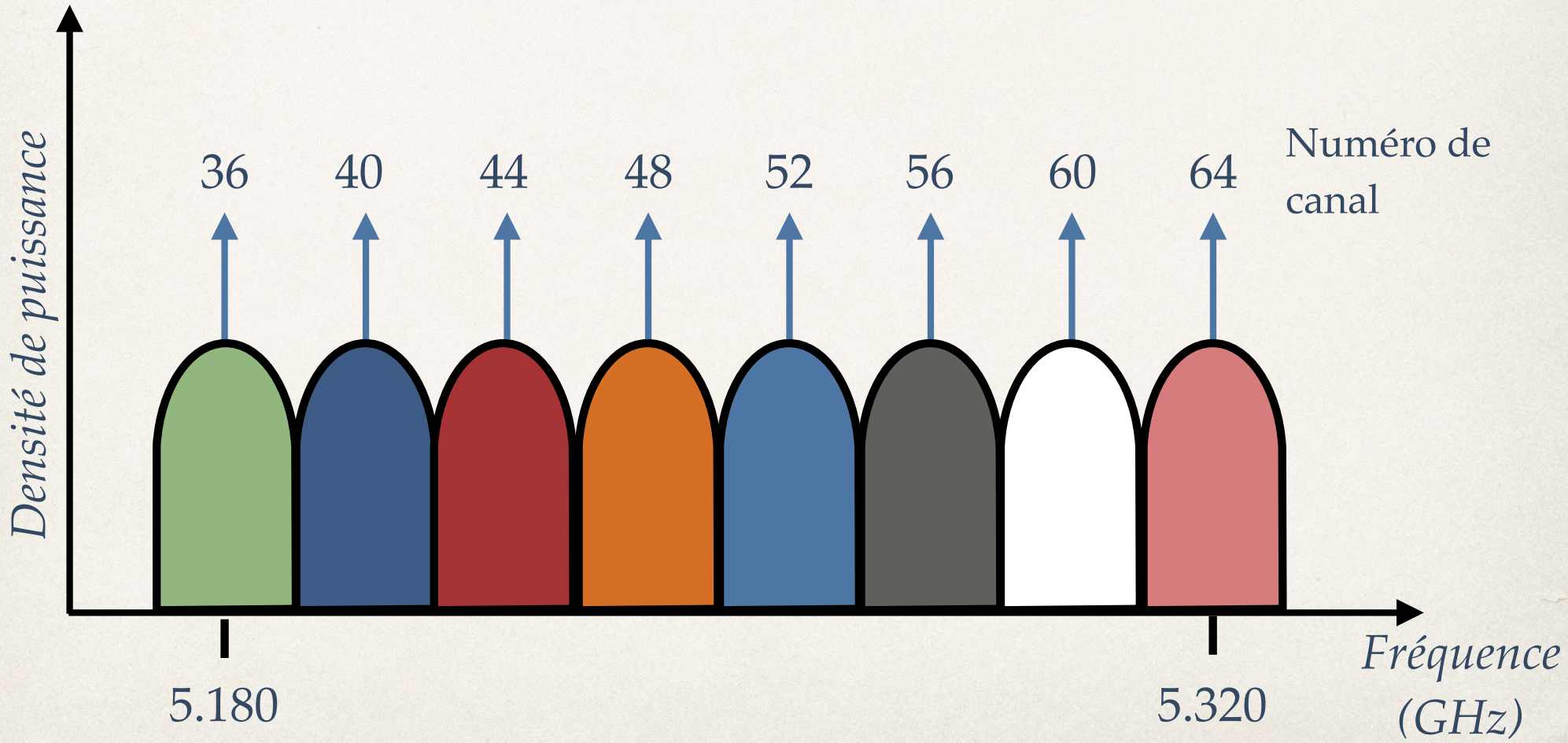


Channels in the ISM band 2,4 GHz (802.11, 802.11b, 802.11g)

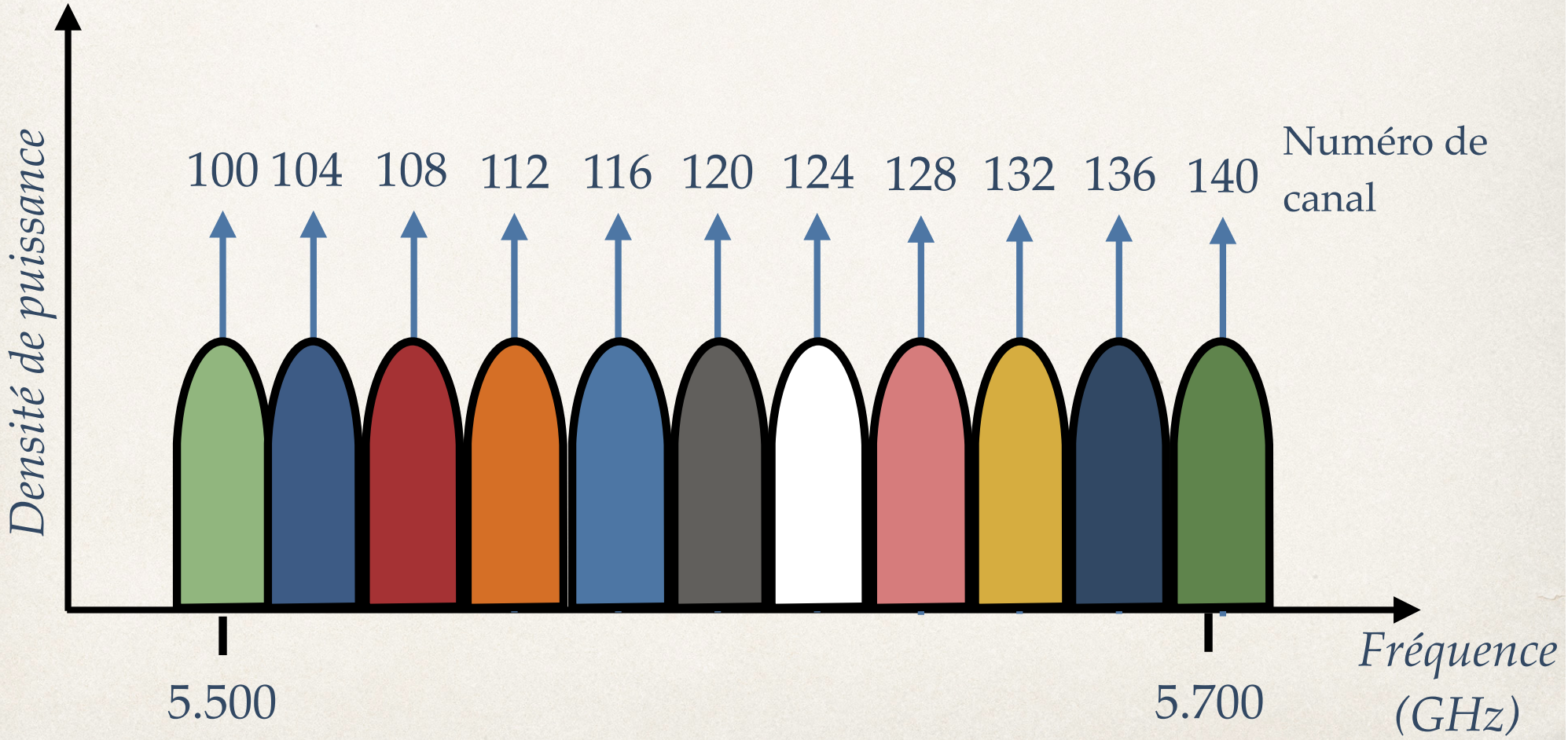


Close networks: 5 channels of separation to avoid interference!

8 first independent channels in Switzerland for 802.11a…

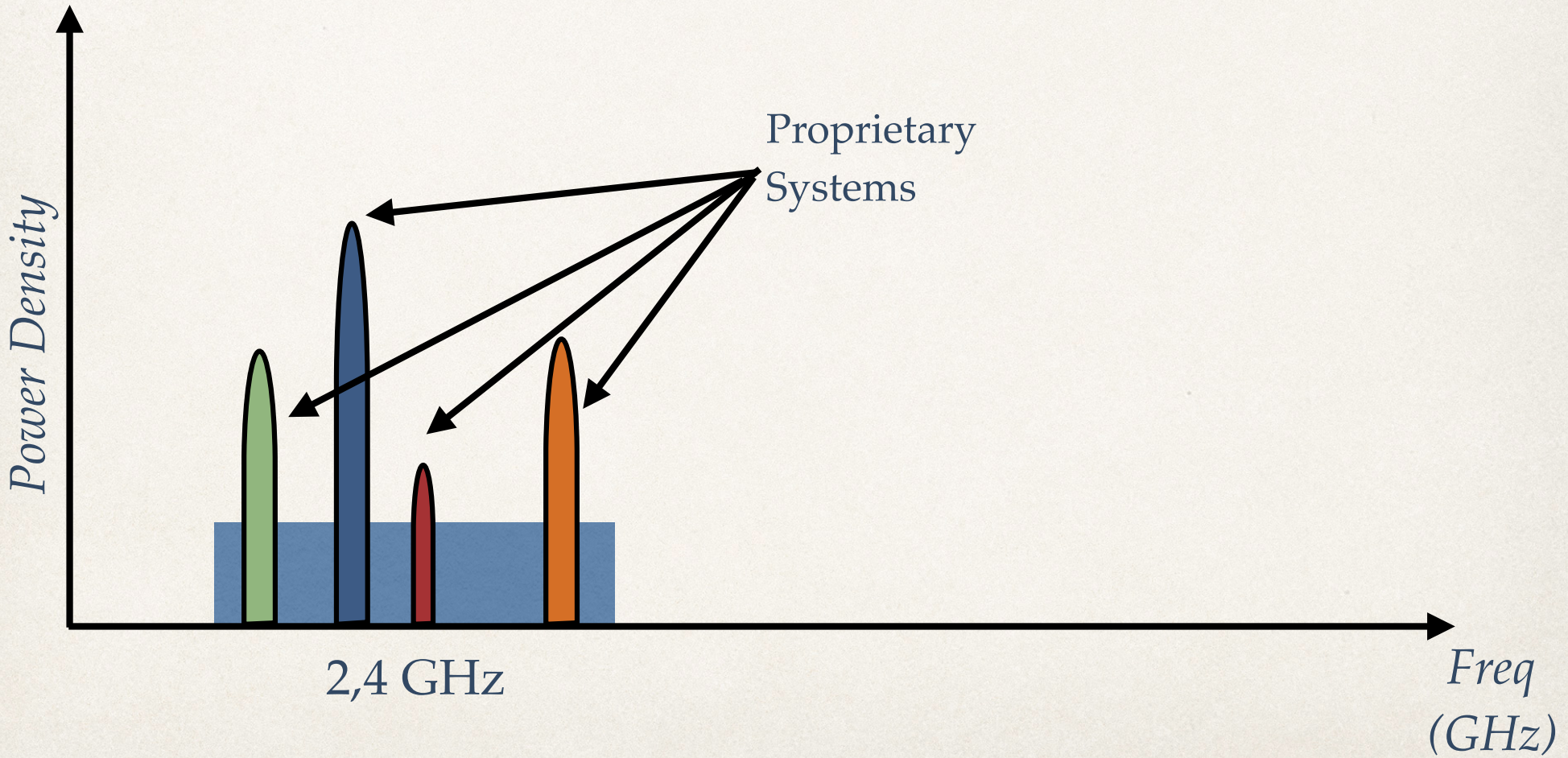


still 11 independent channels for Switzerland for 802.11a…



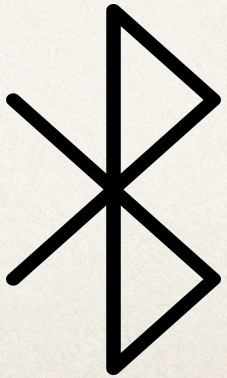
ISM and U-NII Bands are Free

Other systems use them —> interference



Some examples of devices that use the ISM Band (2,4 GHz)

802.11, 802.11b
802.11g, 802.11n

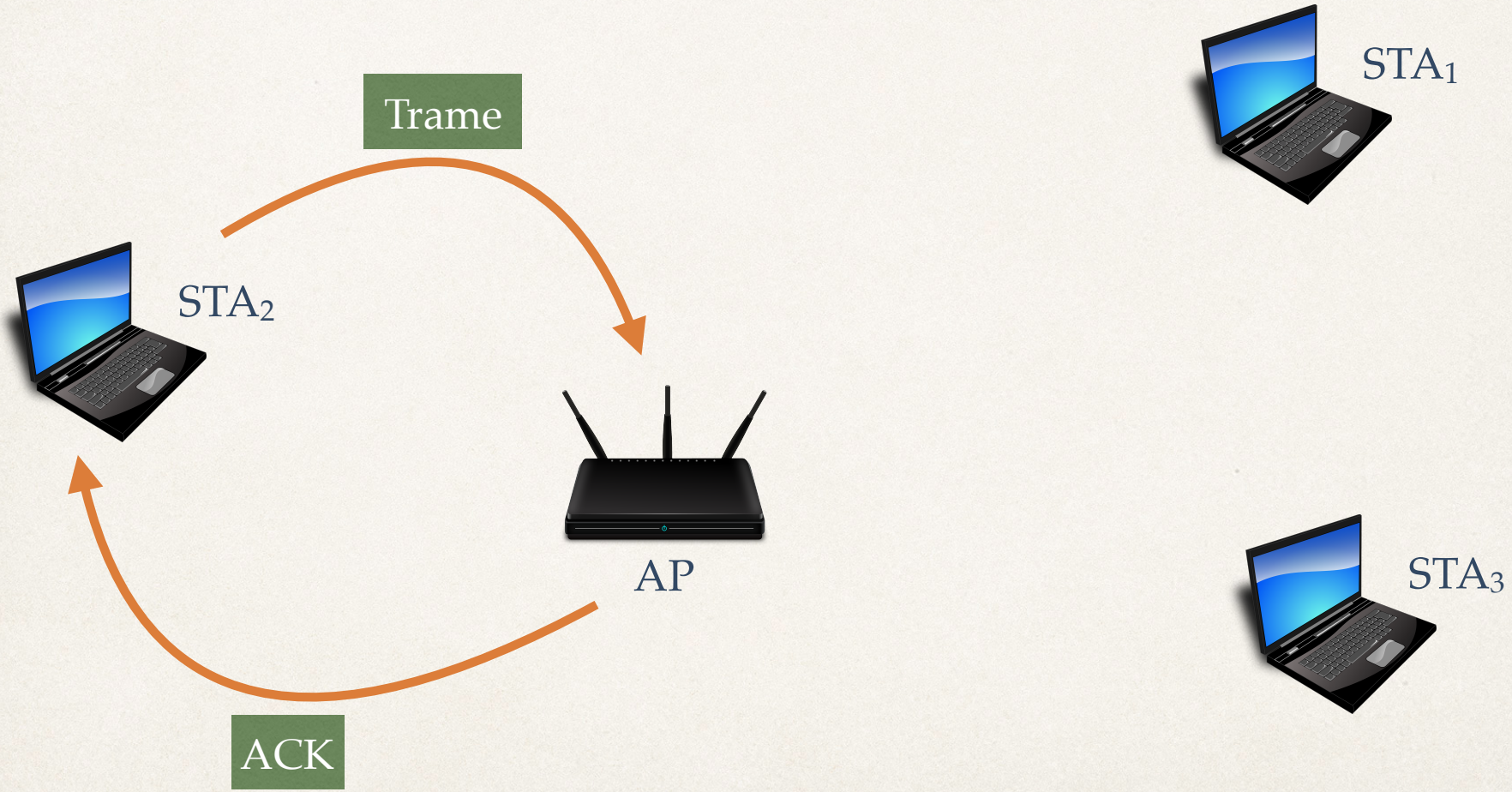


Medium Access Control (MAC)

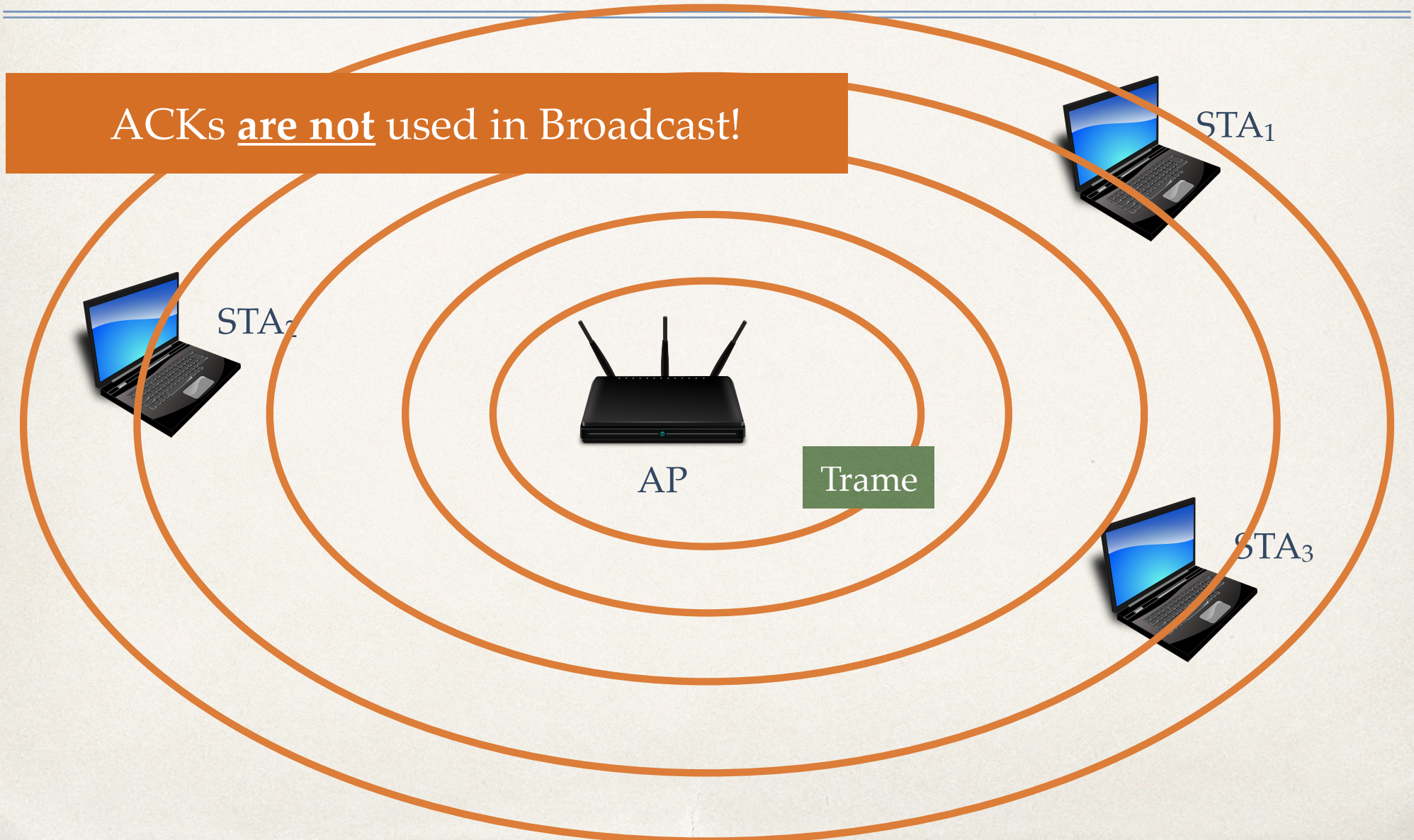
Transmission modes

- **Unicast** : one source, one destination
- **Broadcast** : one source, all destinations
- **Multicast** : one source, multiples destinations

Unicast Transmission



Broadcast Transmission



Access Methods (Arbitration)

“Knowing the arbitration methods may give an adversary the means to take control of the physical channel or to create a DoS”

Access Methods (Arbitration)

- Distributed Coordination Function (DCF)
  - CSMA/CA
  - RTS/CTS

Inter-frame Intervals

SIFS — Small Inter-Frame Space

DIFS — DCF Inter-Frame Space

Slot

CSMA/CA

- Listen to the channel during DIFS. If no activity is found, transmit
- In case of activity, wait until the end of transmission and listen to the carrier during DIFS plus a random number of slots. Transmit if channel is free
- If not free, restart the process but using the time remaining from last try
- For Unicast transmissions, the receiving station waits SIFS and sends an ACK

CSMA/CA

- Listen to the channel during DIFS. If no activity is found, transmit
- In case of activity, wait until the end of transmission and listen to the carrier during DIFS plus a random number of slots. Transmit if channel is free
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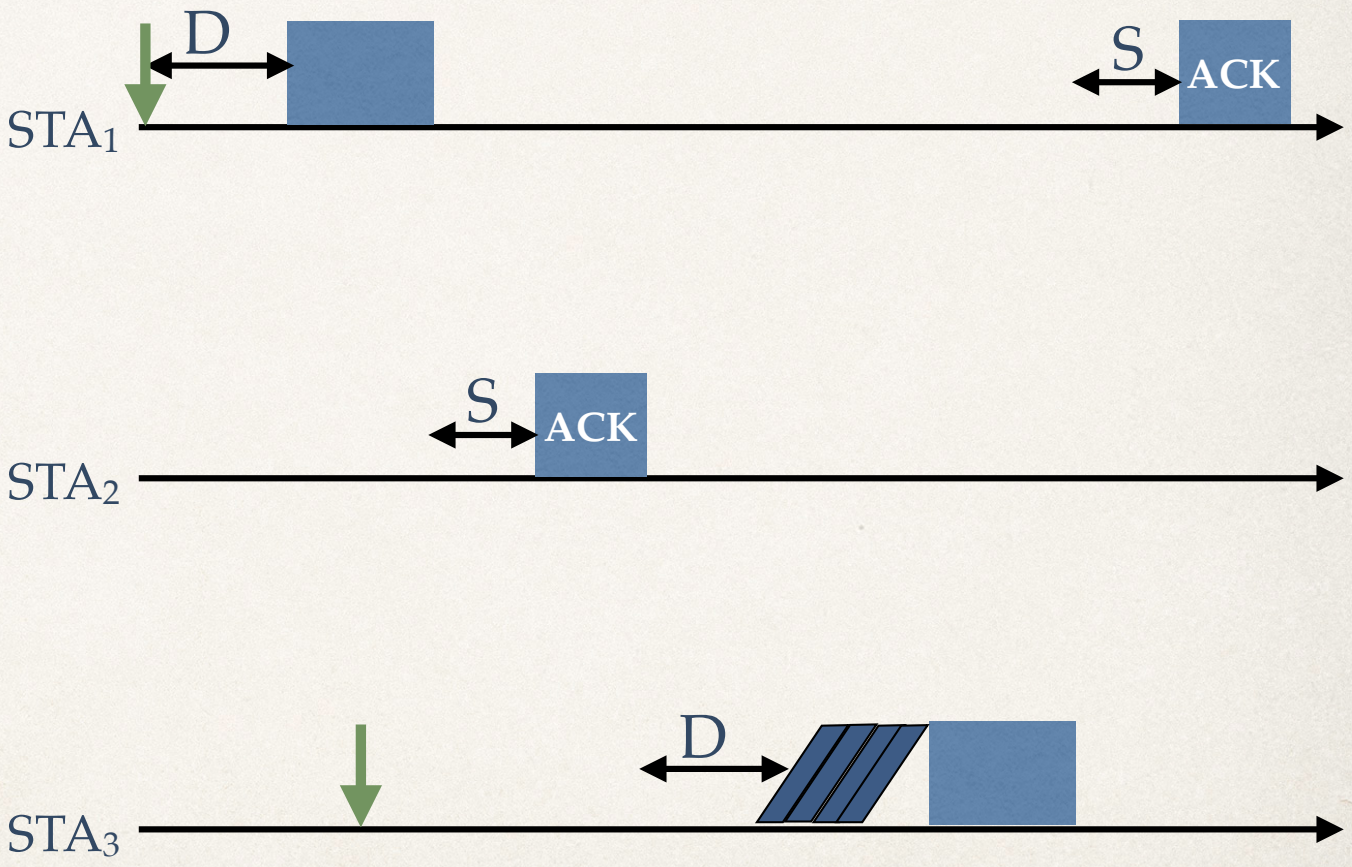
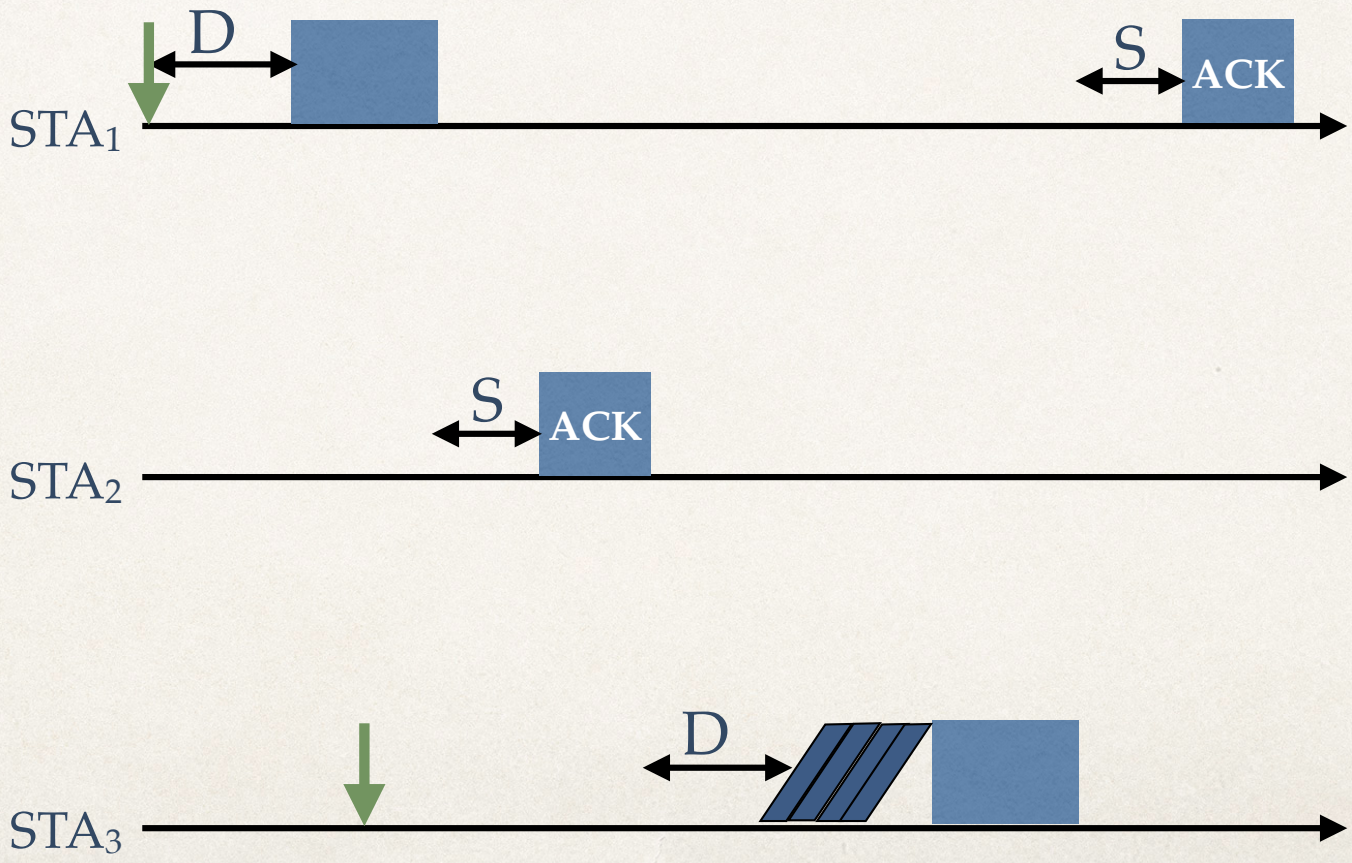


Question 3

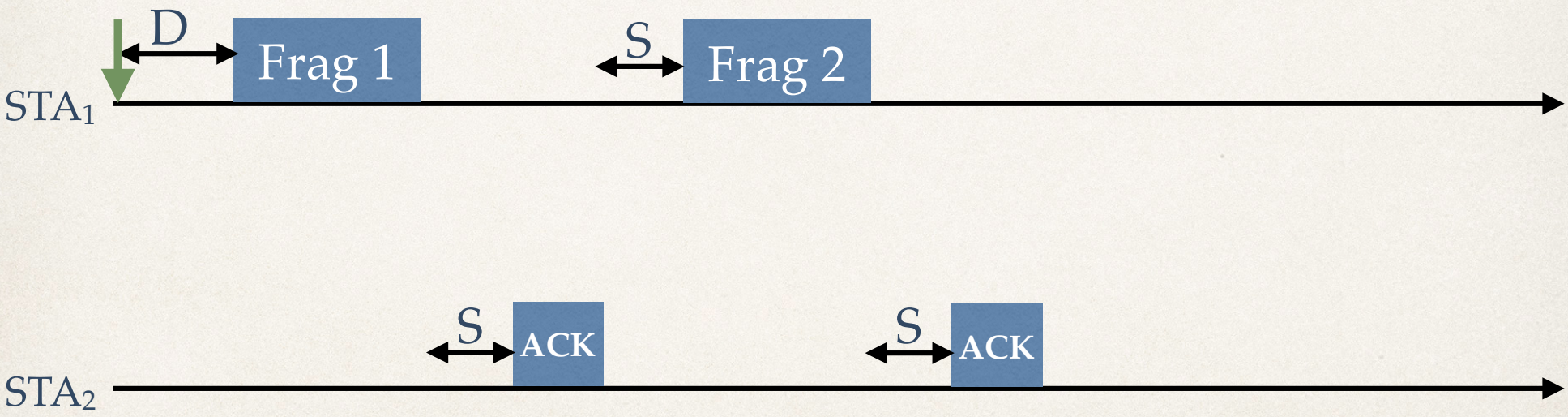
How can an attacker gain privileged access to the channel?



Fragmentation CSMA/CA

“Fragmentation in 802.11 is exploited by generating frames that, injected to a network, can help crack WEP faster”

Fragmentation CSMA/CA Unicast Frames



Exercise

Represent the frame sequence for a transmission of a **broadcast** frame sent from a station within a 802.11g infrastructure network

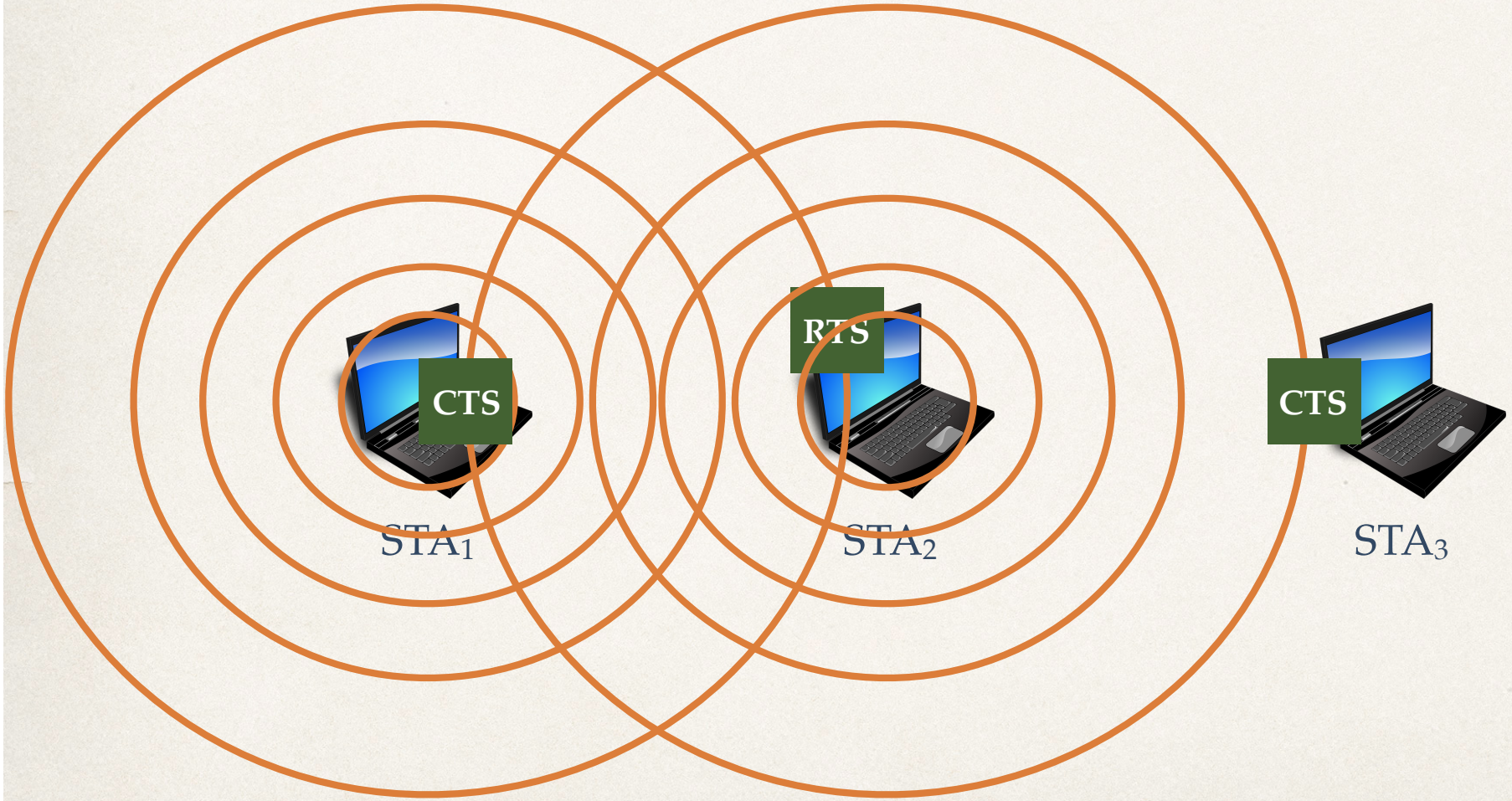
RTS/CTS

“RTS/CTS method can be exploited

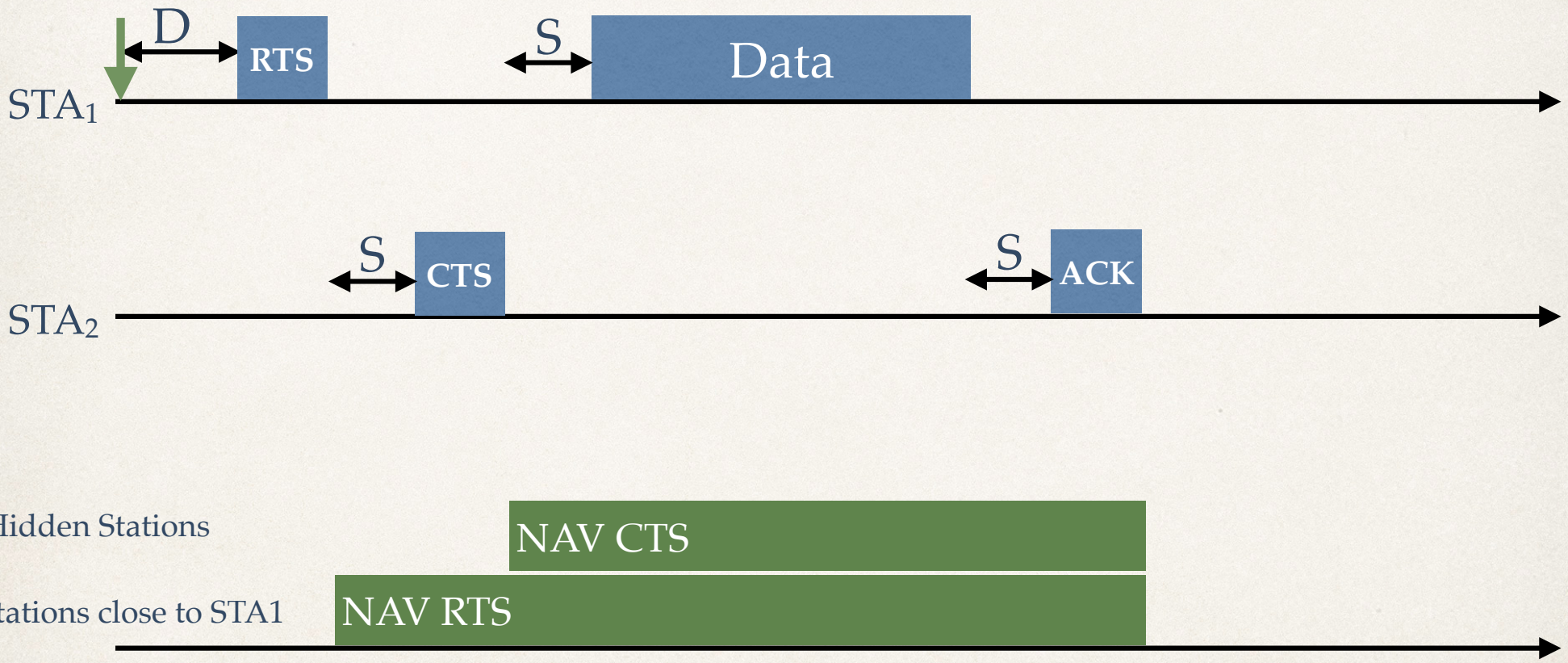
to create a DoS”

The Hidden Station Problem - RTS/CTS

RTS/CTS



RTS/CTS

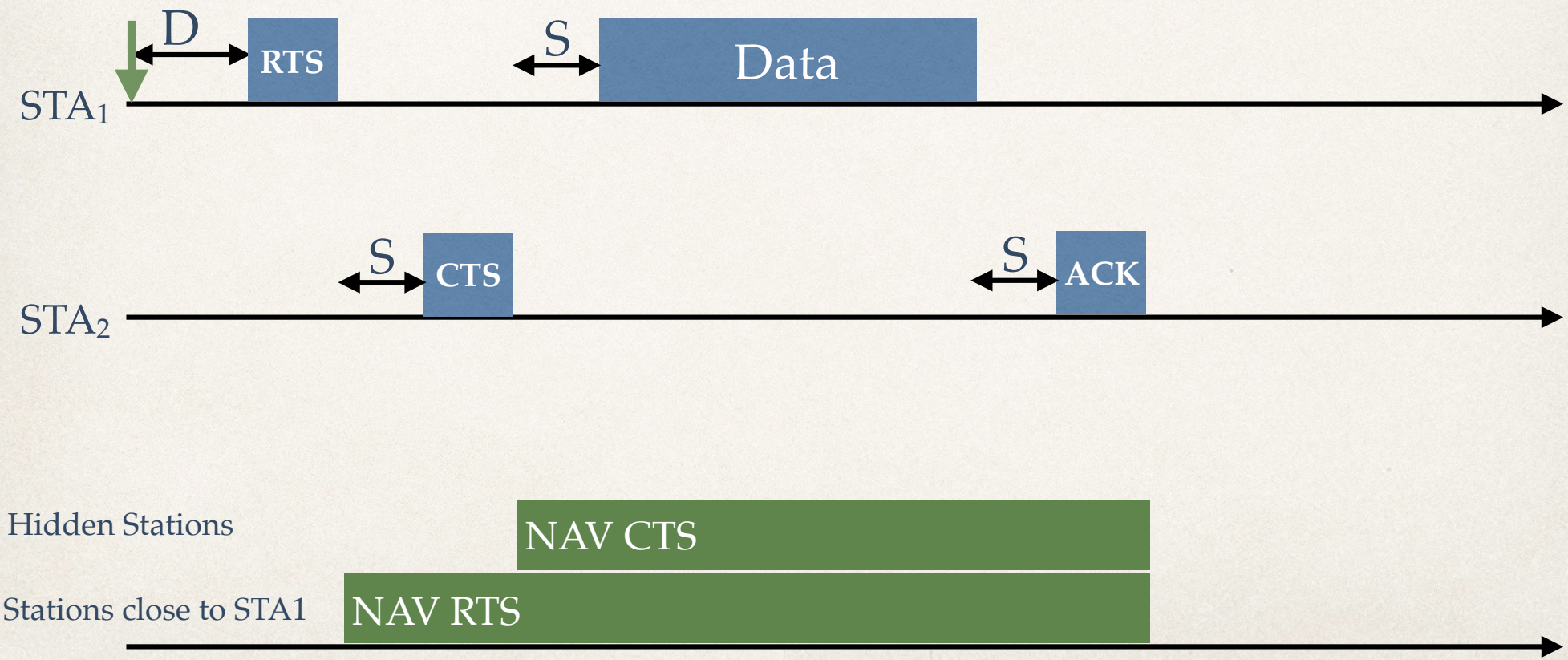


NAV : Network Allocation Vector

The NAV is a représentation of the time interval reserved for a frame

Question 4

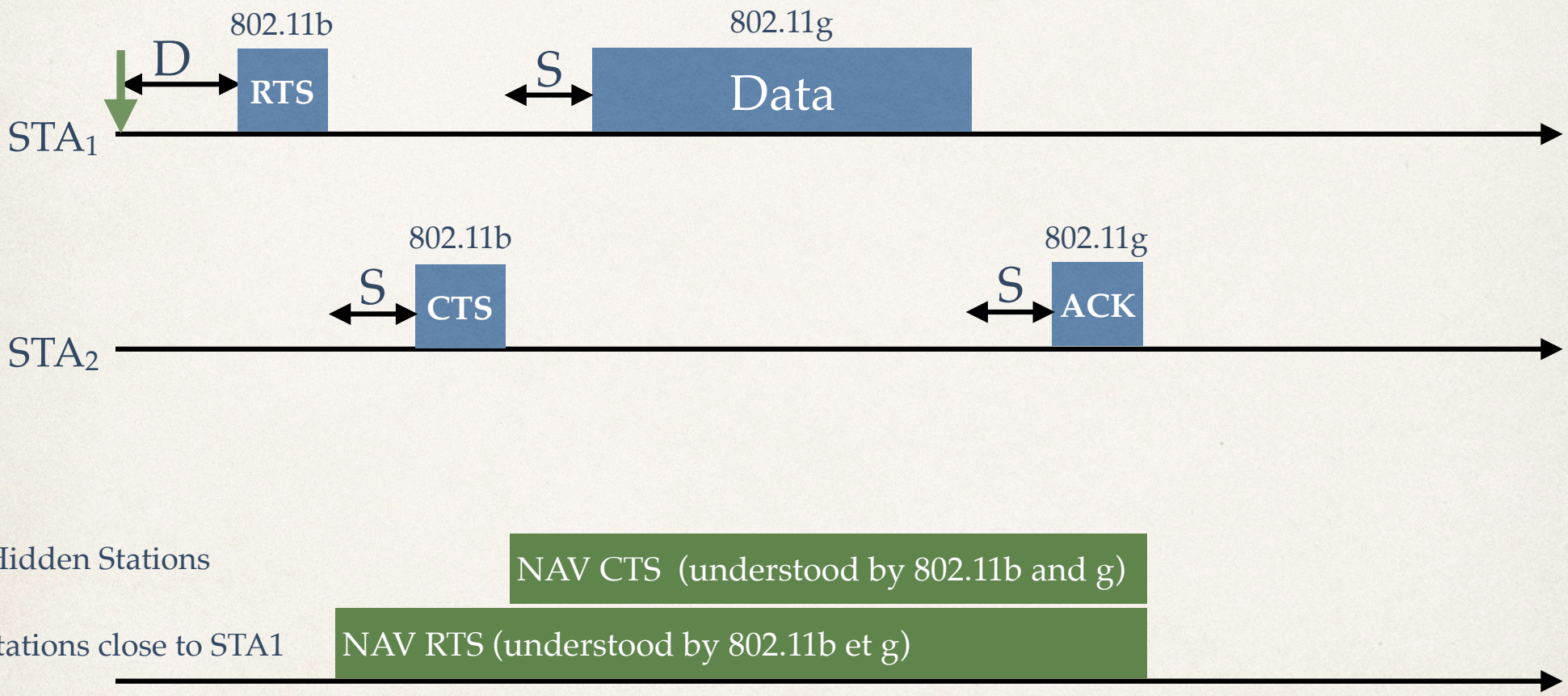
How can an attacker produce a DoS using RTS/CTS?



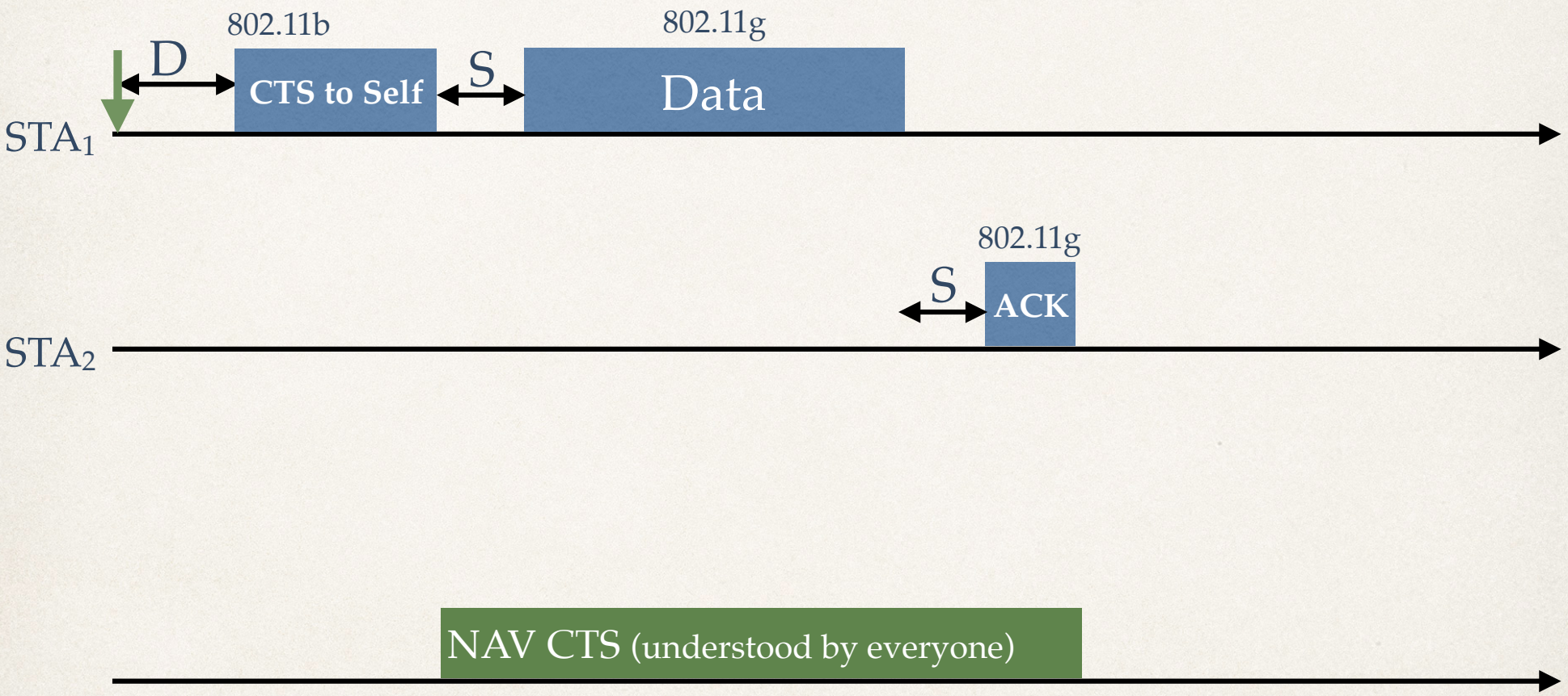
Coexistence b et g

- 802.11b stations do not understand the modulation used by modern stations using 2.4 GHz
- If 802.11b are close to a 802.11g network, for example, some problems may arise
- The 802.11g amendment introduces the **protection** mode
- The protection mode does **not** "protect"…!
  - **It has nothing to do with security… or… does it?**

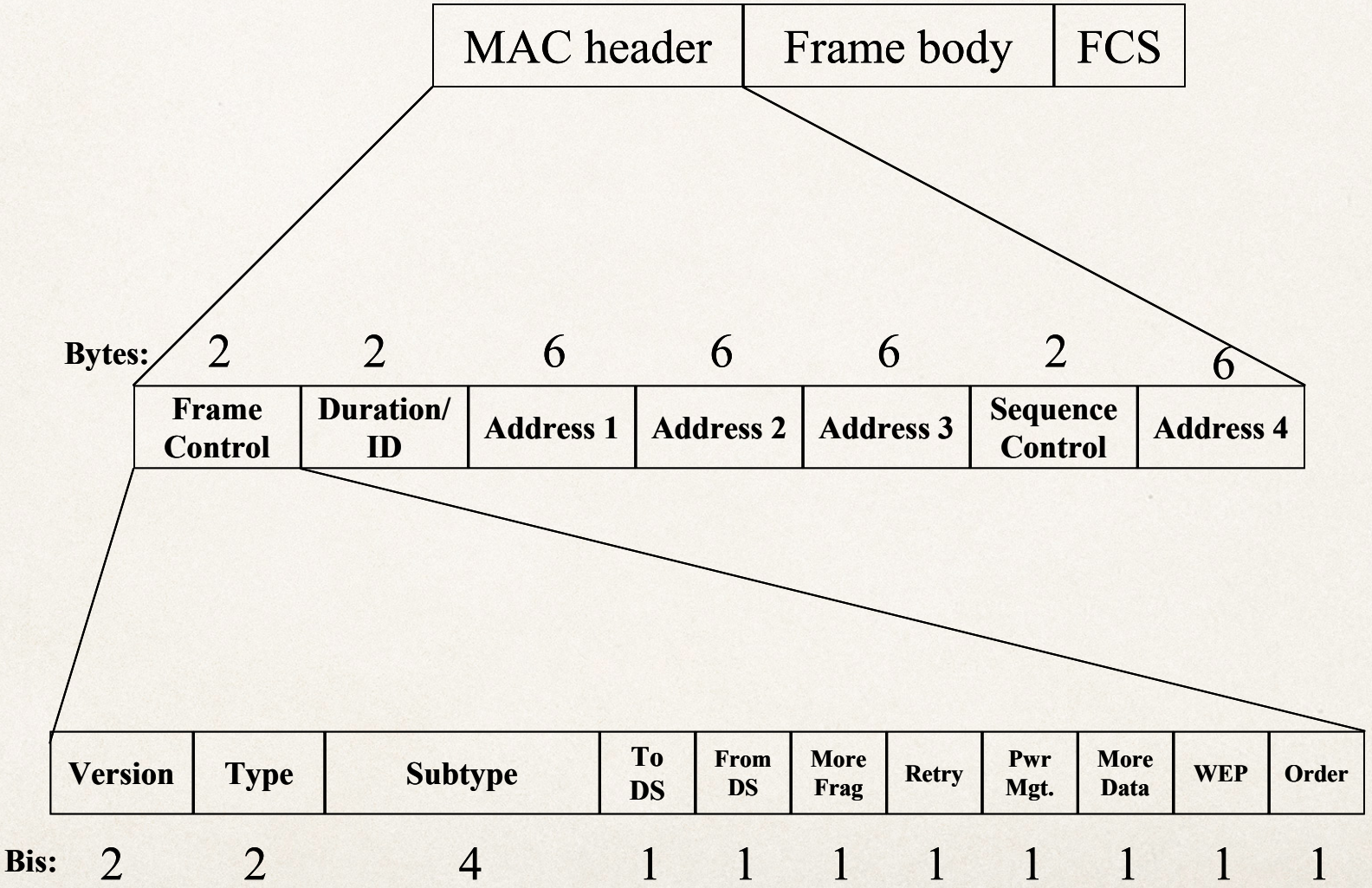
Mix b and g : Protection Mode with full RTS/CTS



Mix b and g : Protection Mode with CTS to Self



General Structure of a MAC Frame



Some Important bits and Fields

- Power Management
- More fragments (comme IP)
- Retry
- ToDS
- FromDS
- Four Addresses

More fragments

“The “more fragments” bit is important because it is used in one WEP attack”

Addresses and DS bits

ToDS	FromDS	Adresse 1	Adresse 2	Adresse 3	Adresse 4
0	0	DA	SA	BSSID	-
0	1	DA	BSSID	SA	-
1	0	BSSID	SA	DA	-
1	1	RA	TA	DA	SA

Types of Frames

- Management Frames
- Data Frames
- Control Frames

Data Transmission

- Two types of frames are used in the process of transmitting data:
  - Data Frames
  - Control Frames (ACK, RTS, CTS)

Management Frames

- Establishment of a Network
- Security
- Roaming

Management Frames

- Beacon
- Probe (request and response)
- Authentication
- Association request and response
- Re-association (request and response)
- Disassociation
- De-authentication

Establishing a Wi-Fi Network

1. Scanning
   (find the network)

3. Association
   (negotiate conditions wit)

Management Frames are used in these 3 cases

First Phase

Searching for networks

How Does a Station Find a Network ?

Scanning is the first thing to do

Active Scan

Probe requests

- Probe requests are important because your electronic devices announce to the world:
  - Your MAC address
  - The SSID of networks you have used in the past
- Privacy problem (allows tracking, among other things)
- Opens doors to more sophisticated attacks

How Does a Station Find a Network ?

Beacon

Beacon

Beacon

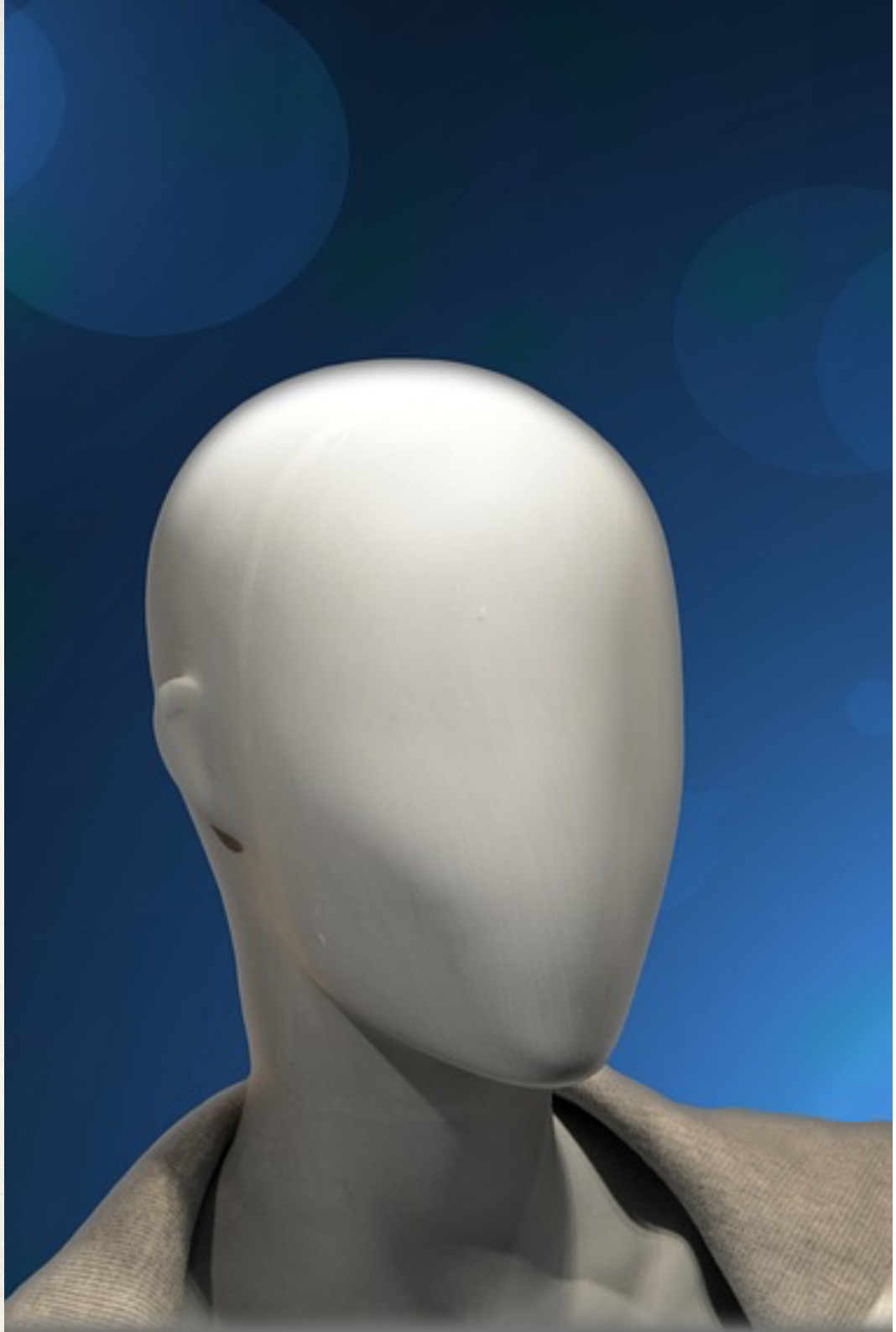
Passive Scan

Beacons

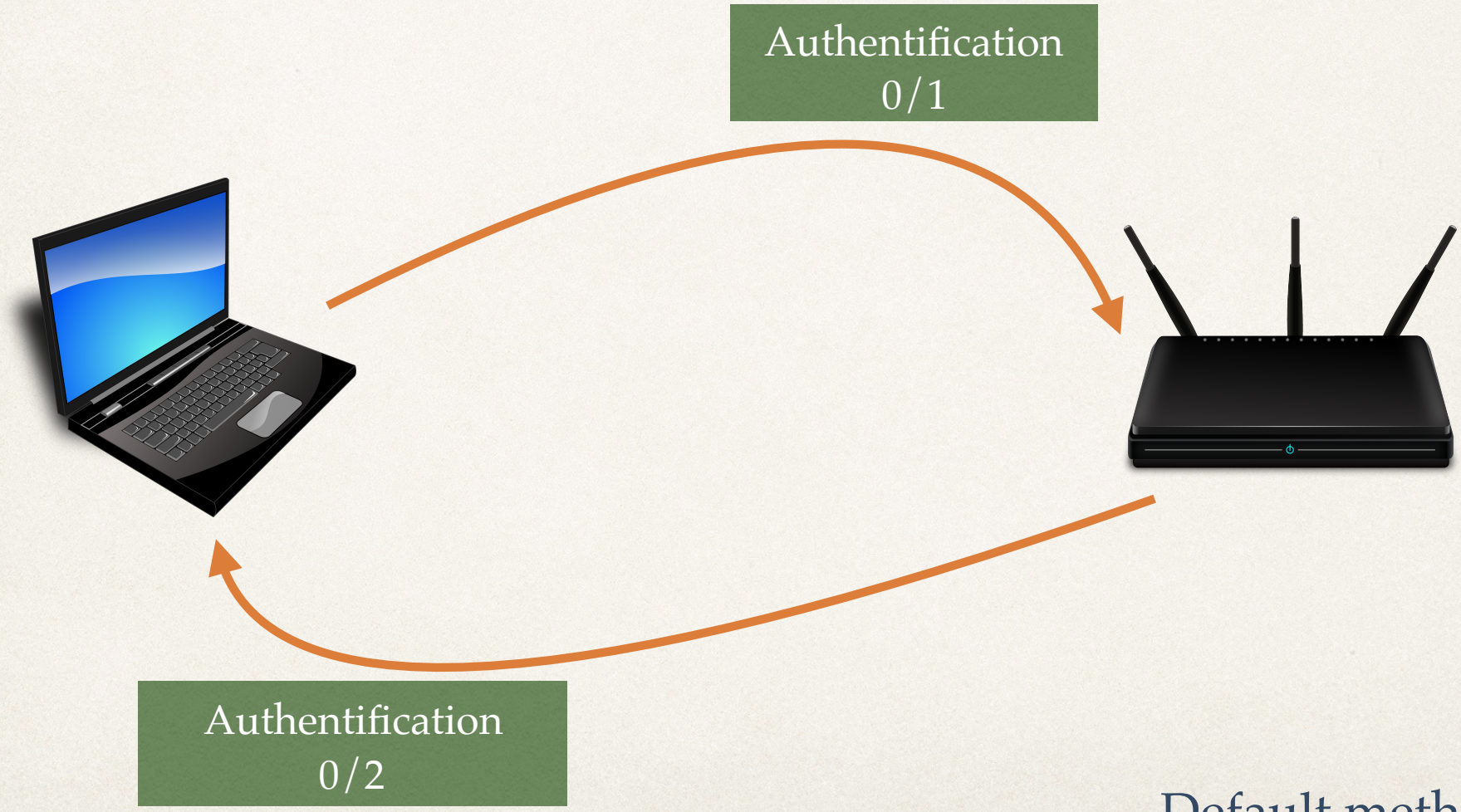
- Beacons are important because they contain information about the channel and some security information details
  - With one simple fake beacon, the clients of a 802.11 network can be disturbed
- The beacon is the **only** element used by a STA to identify a Network - beacons can be forged in order to attract victims

Second Phase

Prove your identity



Open System Authentication

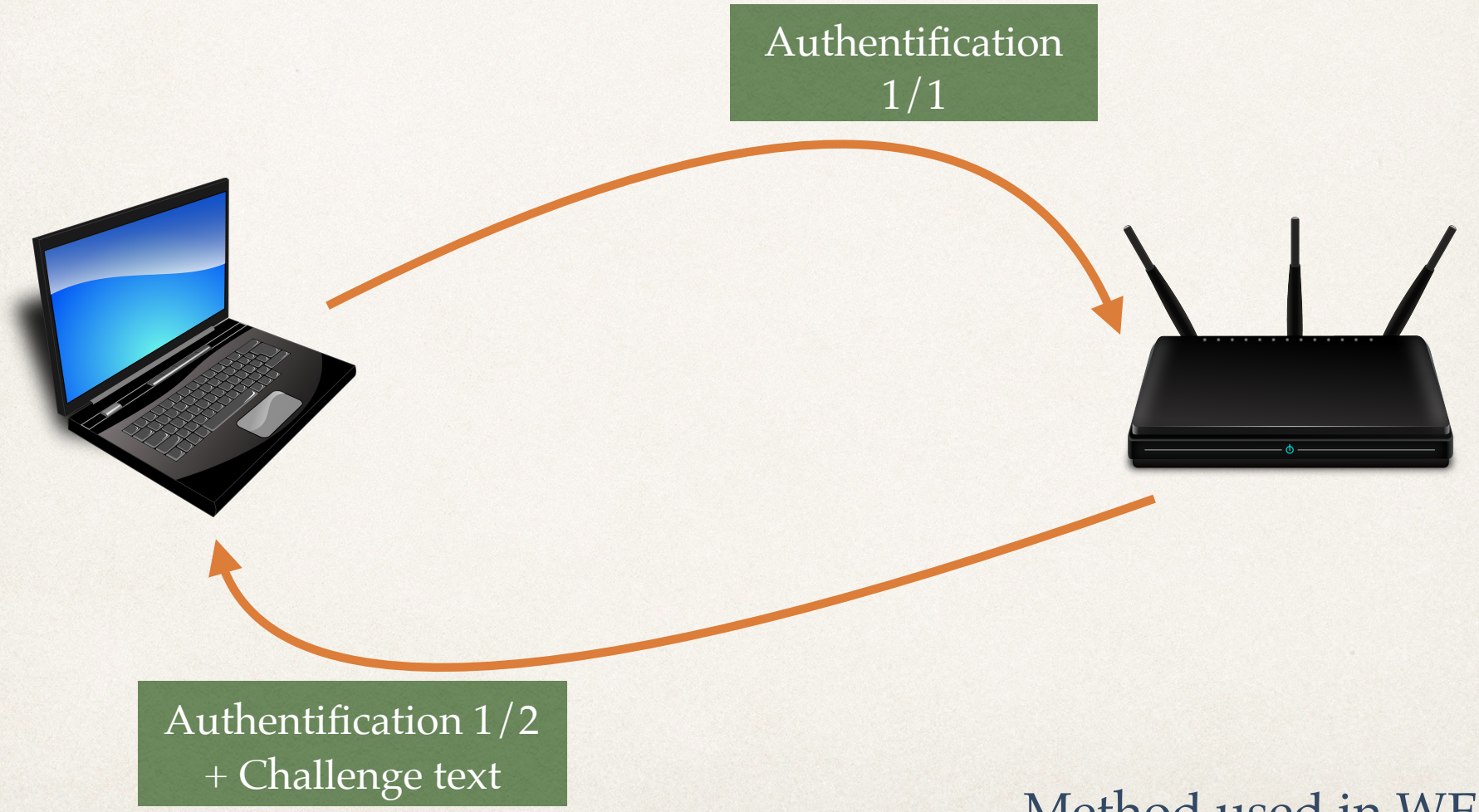


Default method

Open System Authentication

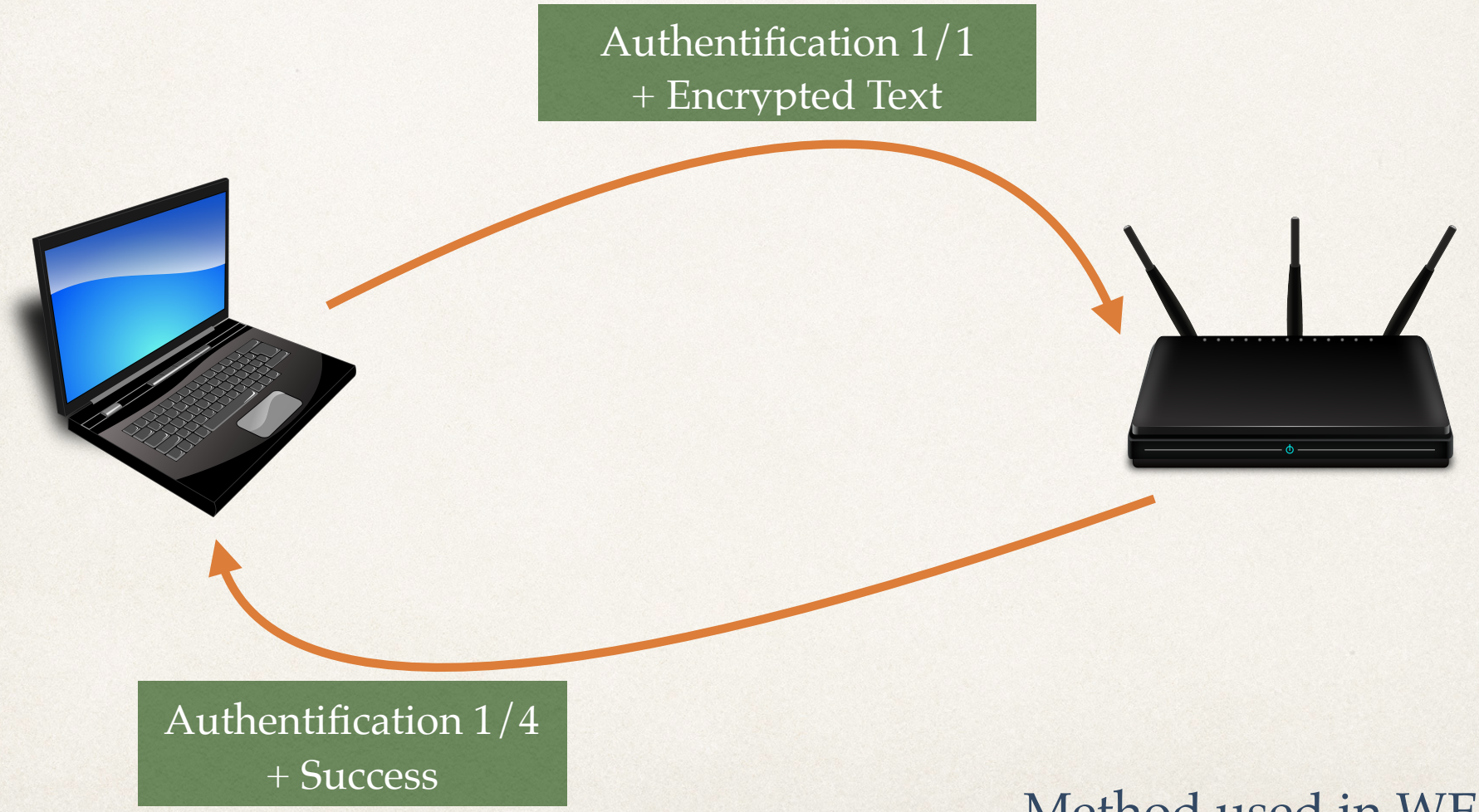
- Open System Authentication is used in open networks (hotspots, for exemple)
- It is **currently** in modern networks using WPA, WPA2, WPA Entreprise

Authentification: Shared Key (1)



Method used in WEP

Authentification: Shared Key (2)



Method used in WEP

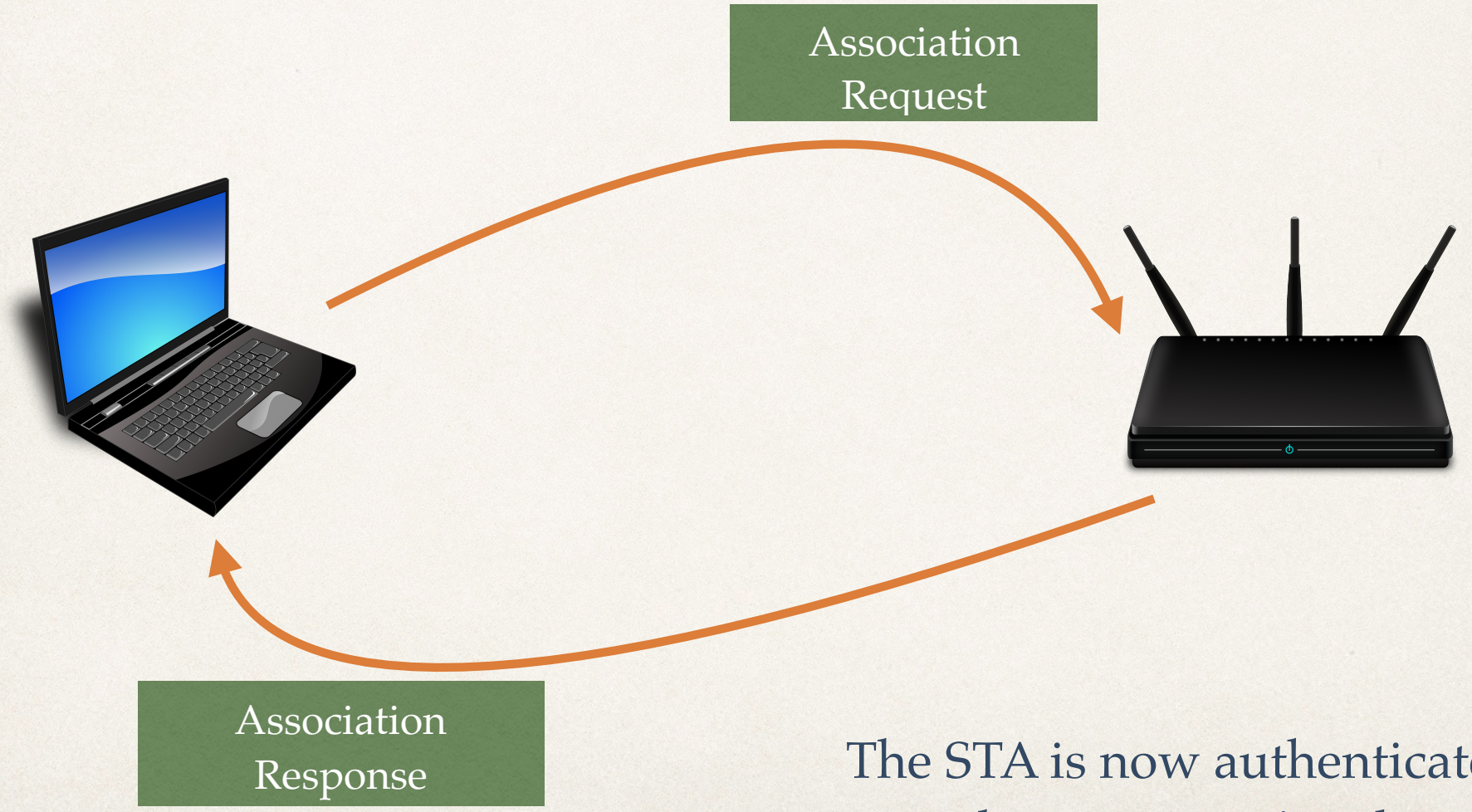
Authentification Clé partagée

- L'authentification Clé Partagée est utilisée uniquement dans les réseaux protégés avec WEP
- On peut s'authentifier auprès d'un AP sans connaitre la clé WEP
  - Il suffit de capturer une authentification d'un client légitime

Third Phase

Formality…

Association



The STA is now authenticated but not associated

Question 5

Which is the most commonly used frame?

And the second most?