# Wireless Technology Applications

## Wireless Local Area Network Technology Part I

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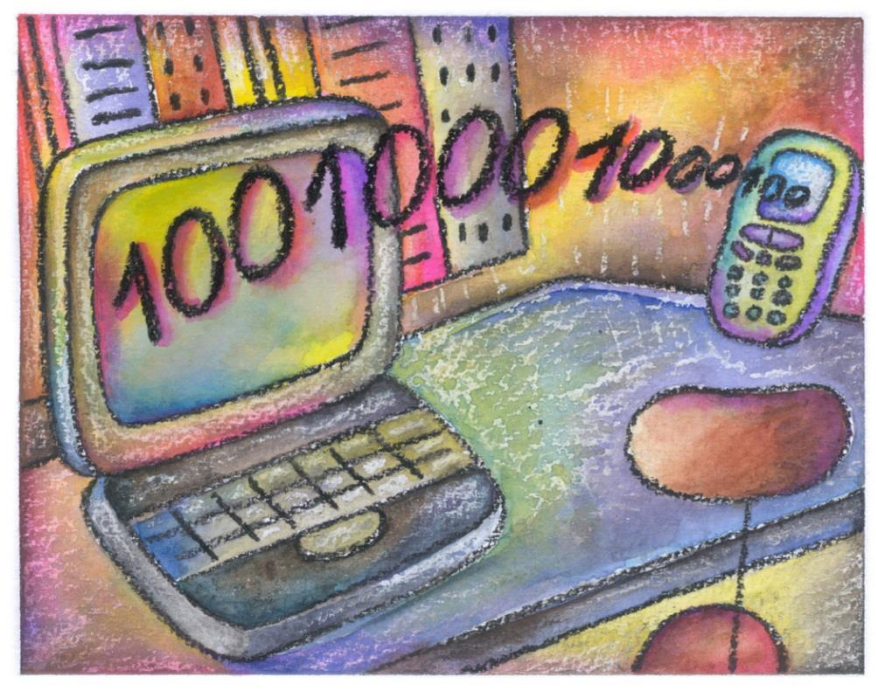


# At the end of this lecture, you should be able to:

Explain WLAN technology

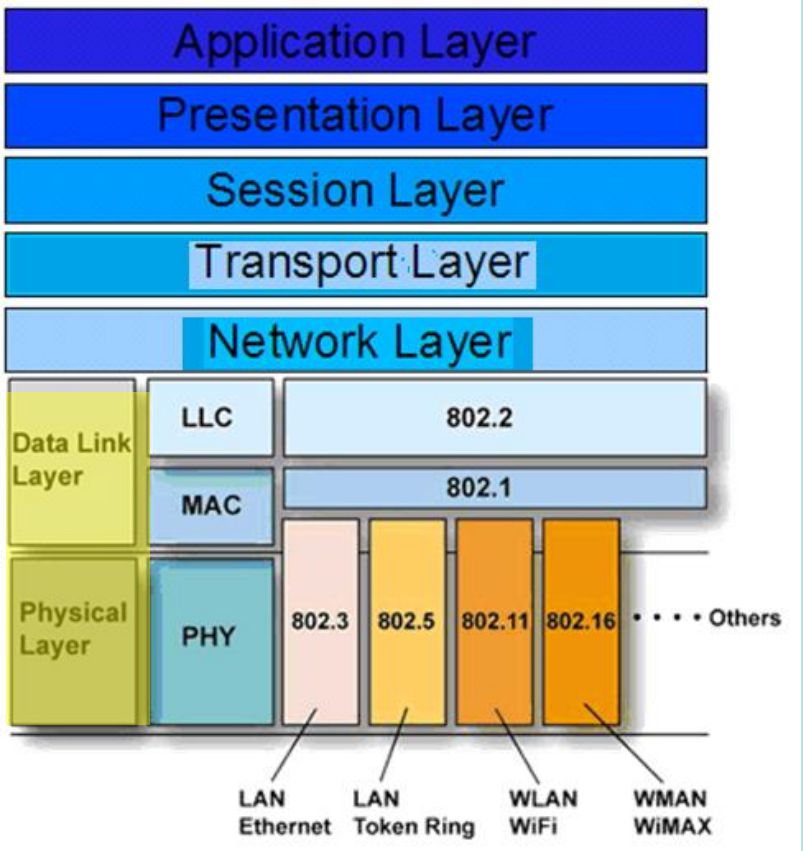
1. Architecture
2. Different Implementations of IEEE802.11a/b/g Standard
3. Explain the radio frequencies used in WLAN
4. Explain the physical layers (DSSS and OFDM) used in WLAN

# Wireless LAN

- Wireless LAN or IEEE 802.11 is the most successful wireless local area network technology
- Implements only the first 2 OSI layers
  - Physical
  - Data link


# What does this means?

- Other OSI layers are still needed to fully understand computer networking



# Example 3-1

Why does IEEE802.11 specify only Physical and Data Link layers only?

- IEEE802.11 changes the physical connection from wires to wireless.
- With the change in physical connection, the mechanism to allow multiple devices sharing the same wireless medium is also different from the mechanism used in wired networks. Therefore, the Data Link layer is also different.

# Two Modes of Operation

## Ad-hoc

- direct connection between STAs (Stations) for accessing each other information and services

## Infrastructure

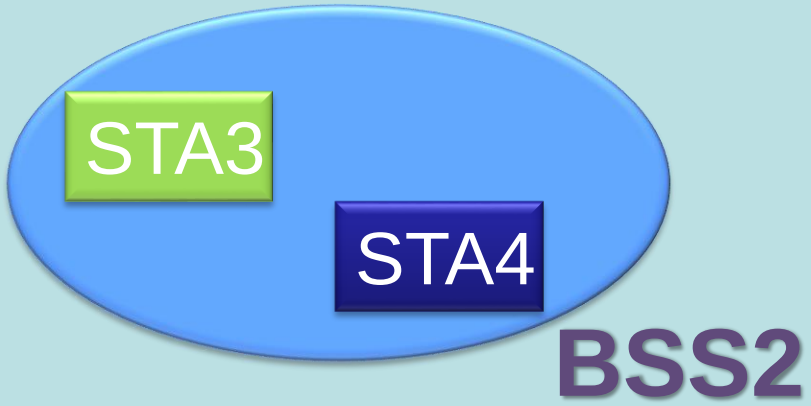
- connection to an Access Point for accessing the computer network (Intranet and Internet)

# What's the basic building block?

# Basic Service Set (BSS)


The BSS is known as Independent BSS (or IBSS) and the mode of operation is **ad-hoc**

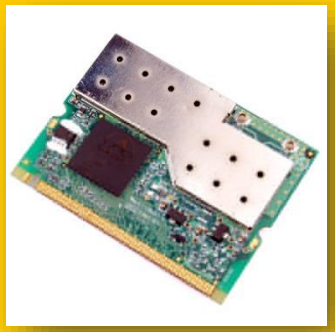
STAs in the same BSS can communicate with one another, but not across BSS



# What is an STA?

## **STA** - station






# What is an STA?

**STA**

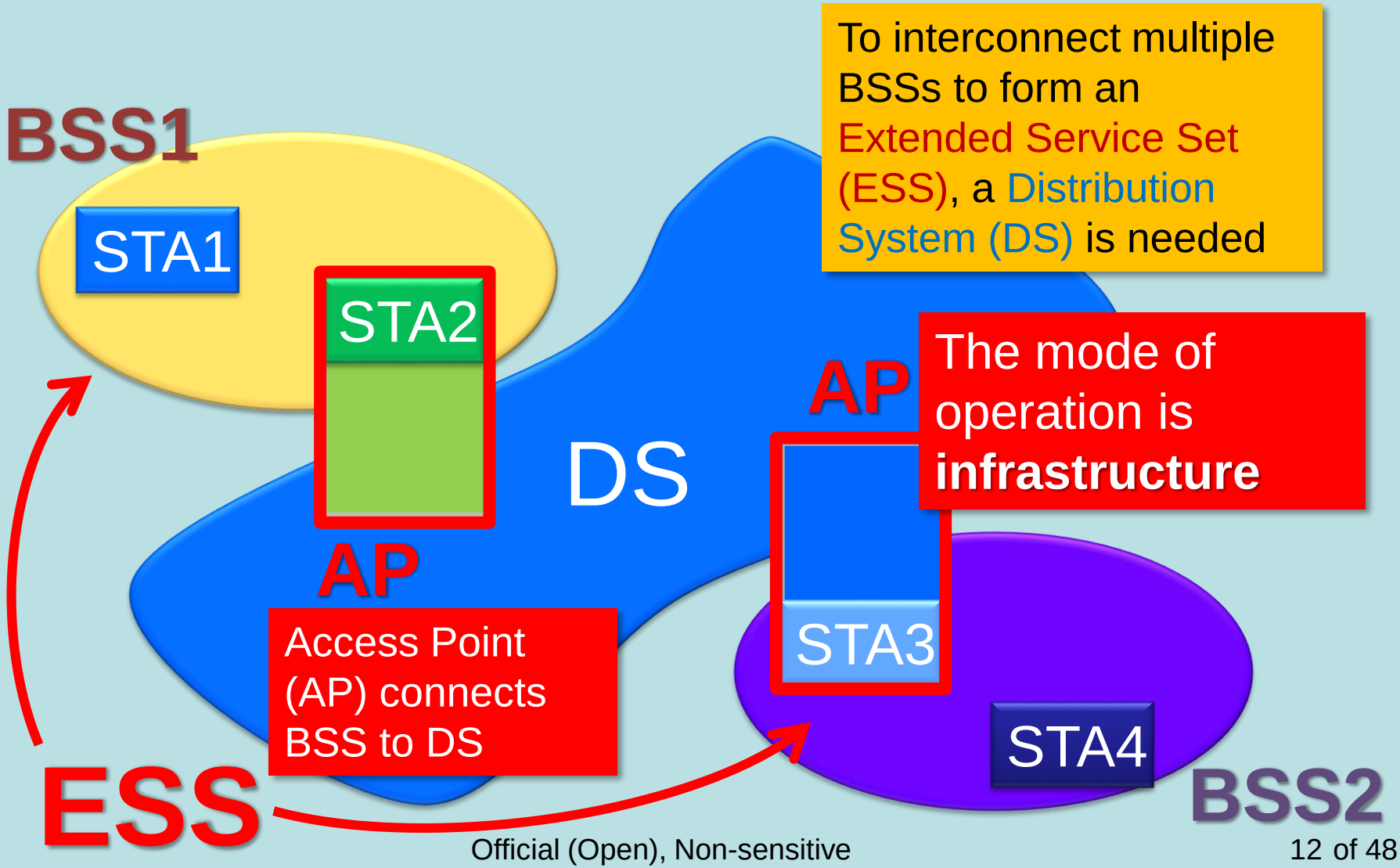
or it could be…


# What is an STA?

**STA**

It could even be…

# Extended Service Set (ESS)



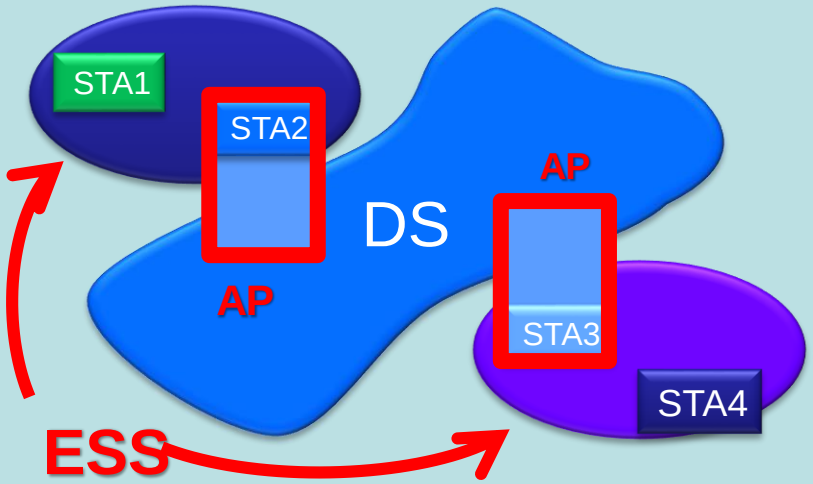
# What is an AP?

**AP** – Access Point




# In short…

- STAs that can communicate with each other forms a BSS
- Two Modes of operation
  - If no AP – **ad-hoc** mode (Independent BSS)
  - If AP – **Infrastructure** mode
- Multiple BSS connected through a DS - ESS

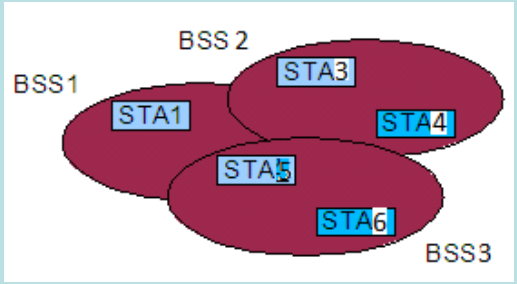


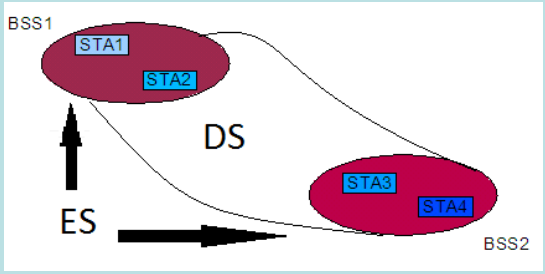
# Extended Service Set (ESS)

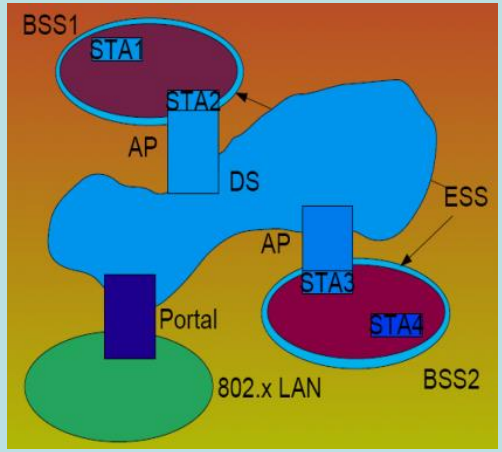
- To interconnect multiple BSSs to form Extended Service Set (ESS), a Distribution System (DS) is needed
- A DS provides logical services necessary to handle address to destination mapping and seamless integration of multiple BSSs

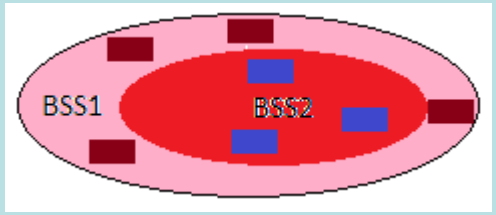
# Extended Service Set (ESS)

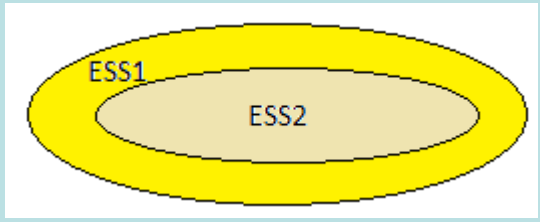
- Four different configurations of ESS
  - Partially overlap BSSs
  - Physically disjointed
  - Physically co-located
  - Co-existence of IBSS or ESS networks



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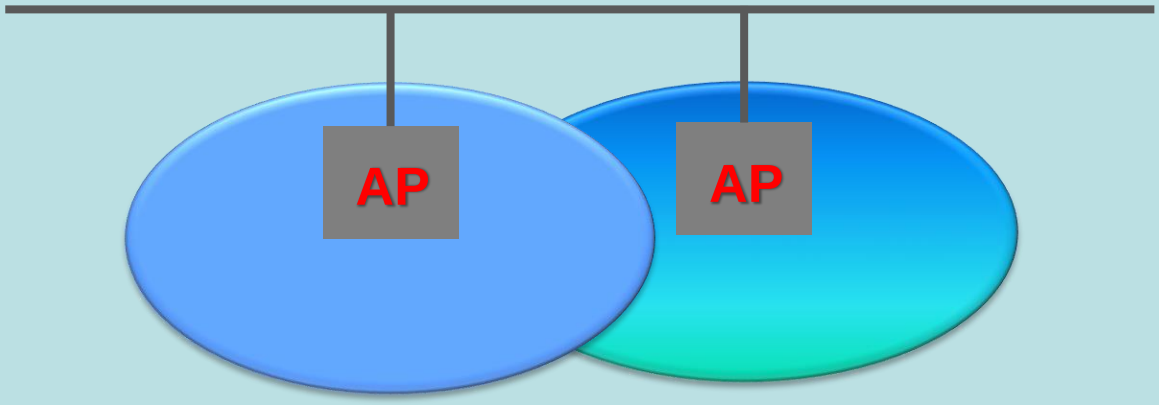

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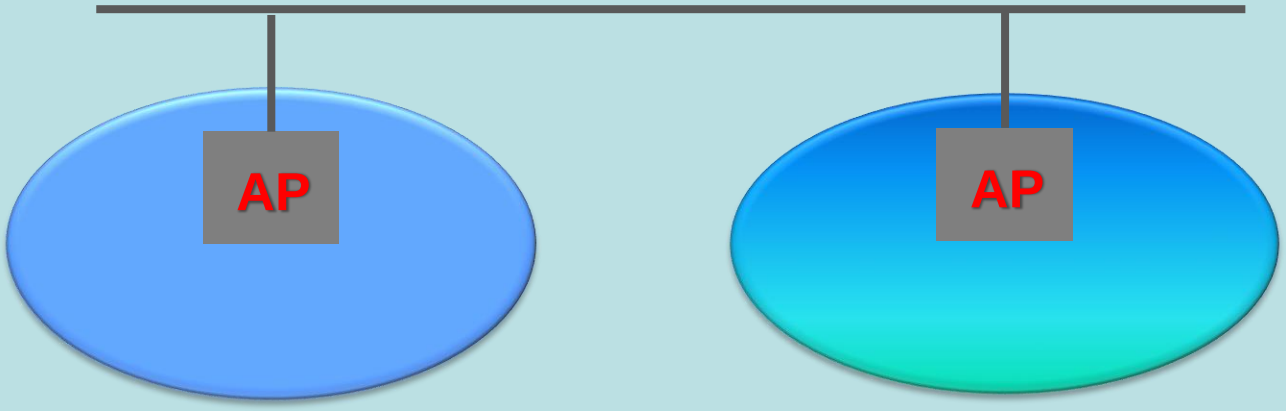

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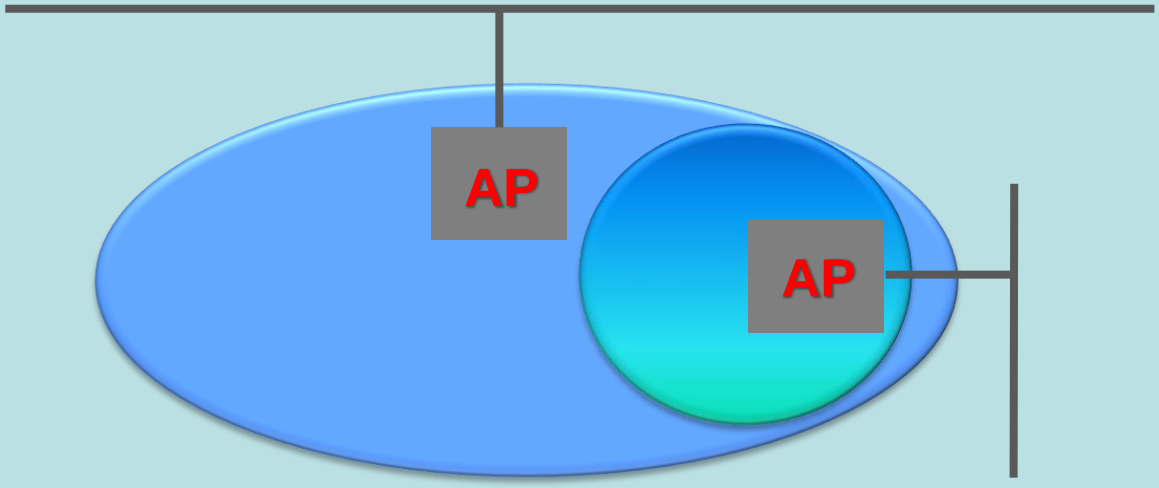

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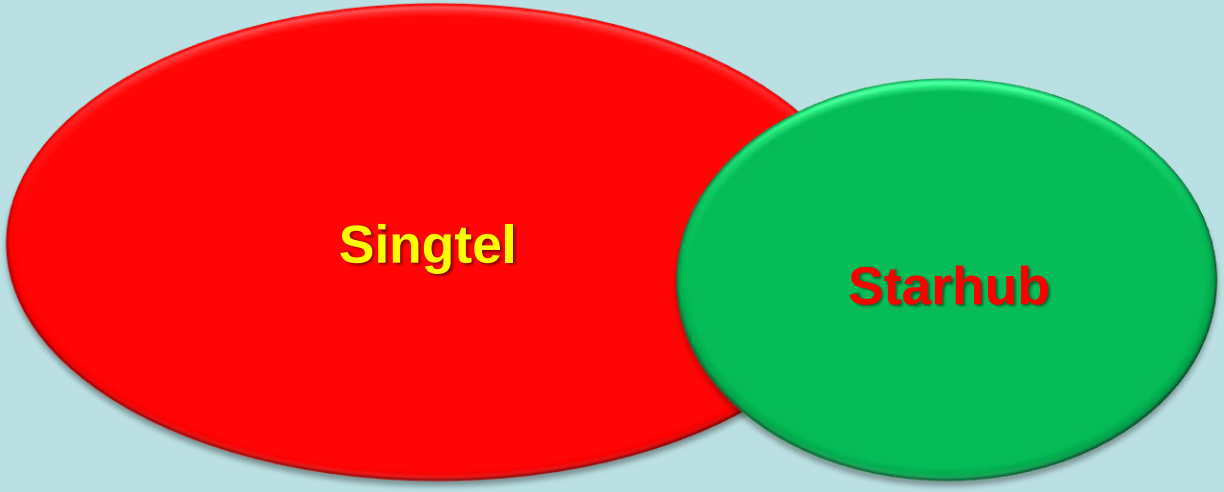
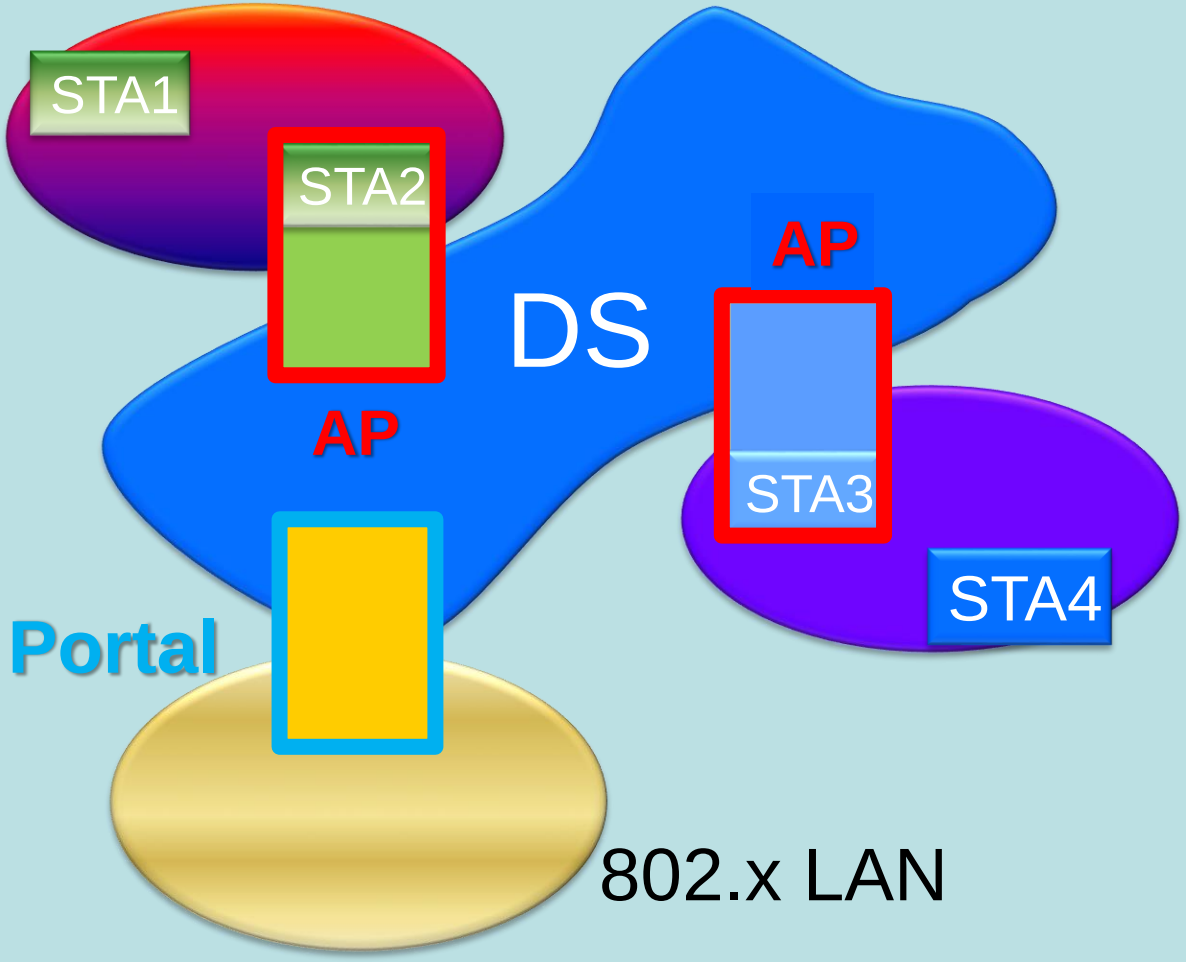


# Portal



# Example 3-2

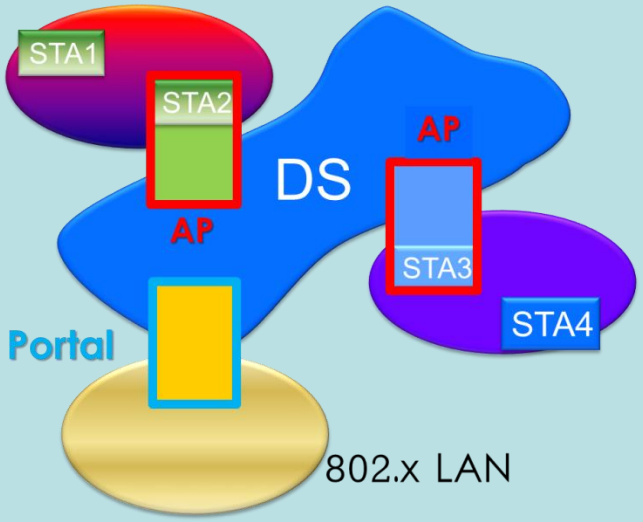
In a hotspot in Starbucks, a user can access Internet through either SingNet or StarHub systems. Which of the four configurations above is used to explain this scenario?

- Fourth configuration where one or more IBSS or ESS networks may be physically present in the same space as one or more ESS networks.

# Example 3-3

Wireless networks are inherently less secure than wired networks. Where is the best place to install firewall to filter unauthorized users from accessing sensitive information located in Intranet?

- Portal



# 3 main flavours in 802.11

802.11a

802.11g

802.11b

Toppings
- Nuts
- Chocolate chips
- Fudge
- …

# Different Implementations

| Standard | Multiple Assess Protocol | Frequency | Modulation | Bit rate |
|---|---|---|---|---|
| IEEE 802.11a | OFDM | 5.2 GHz UNII<br>5.8 GHz ISM | BPSK, QPSK, 16 QAM, 64 QAM | 6, 9, 12, 18, 24, 36, 48, 54 Mbps |
| IEEE 802.11b | DSSS, FHSS | 2.4 GHz ISM | DBPSK, DQPSK, CCK | 1, 2, 5.5, 11 Mbps |
| IEEE 802.11g | OFDM | 2.4 GHz ISM | BPSK, QPSK, 16QAM, 64QAM | 6, 9, 12, 18, 24, 36, 48, 54 Mbps |
| IEEE 802.11n | OFDM/MIMO | 2.4 GHz ISM, 5 GHz (Optional) | BPSK, QPSK, 16QAM, 64QAM | 600 Mbps (Max) |
| IEEE 802.11ac | OFDM/MU-MIMO | 5.2 GHz UNII<br>5.8 GHz ISM | BPSK, QPSK, 16QAM, 64QAM, 256QAM | 1.3 Gbps (Max) |

**Note:** ISM ➔ Industrial Science and Medical
UNII ➔ Unlicensed National Information Infrastructure
*OFDM* ➔ Orthogonal Frequency Division Multiplexing
DSSS ➔ Direct Sequence Spread Spectrum
FHSS ➔ Frequency Hopping Spread Spectrum
MIMO ➔ Multiple Input Multiple Output
MU-MIMO ➔ Multi User MIMO

**Note:** BPSK ➔ Binary Phase Shifting
QPSK ➔ Quadrature Phase Shift Keying
QAM ➔ Quadrature Amplitude Shift Keying
CCK ➔ Complementary Code Keying

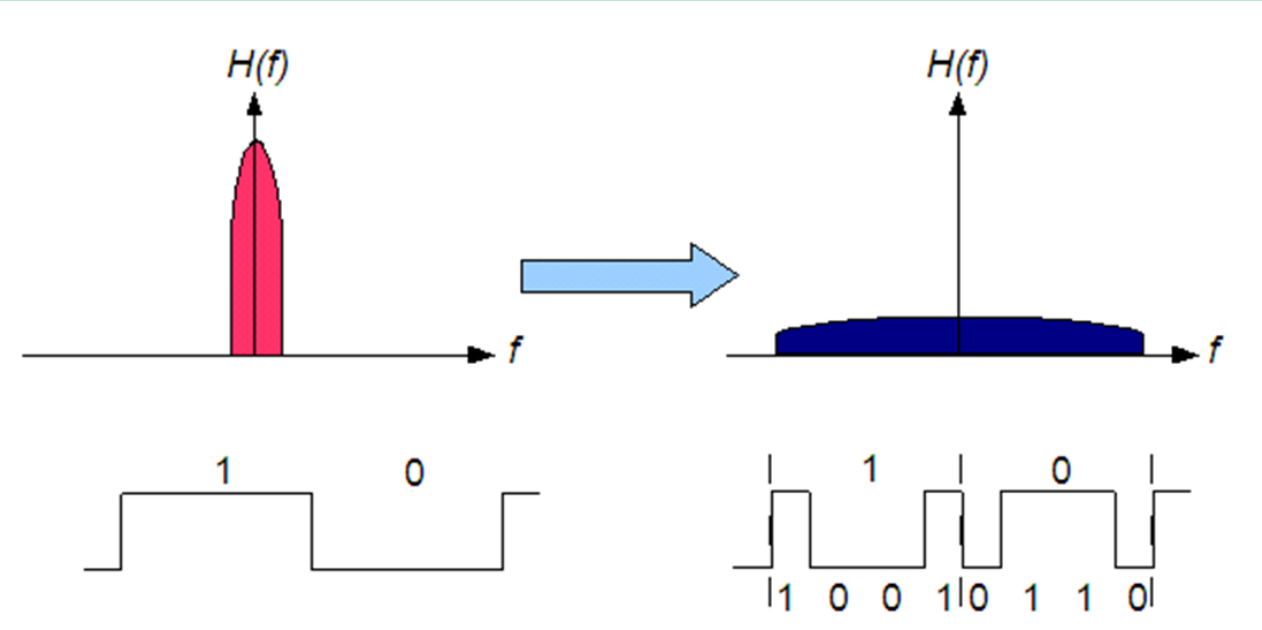
# Example 3-4

- Example 3.4
- Which of the following standards IEEE802.11a/b/g has the best features?

- IEEE802.11g has the best features since it has the highest bit rate (similar to IEEE802.11a) and also largest coverage areas (similar to IEEE802.11b).

# IEEE 802.11b - DSSS

- **Direct Sequence Spread Spectrum**
- 1 bit of info is represented by a sequence of bits (chips)
  - E.g. 1 – "1 0 0 1", 0 – "0 1 1 0"
- Chip rate – number of chips per sec, is maintained at **11Mcps**
- Bandwidth is **22MHz**



# IEEE 802.11 – bit rate

- Different bit rates supported
  - 1 Mbps, 2 Mbps, 5.5 Mbps, 11 Mbps
- Depends on wireless environment
  - Better signal received, higher bit rate
- How does bit rate change?
  - By using different modulation, symbol rate

Toppings
- Nuts
- Chocolate chips
- Fudge
- …

# How 802.11b increases bit rate?

- **1 Mbps**
  - Modulation = DBPSK
    ⇒ 1 bits/symbol
  - Symbol rate = 1 Msymbols/sec (i.e. 1 Mbaud)

  Therefore, bit rate = 1 Mbaud x 1 bits/symbol
  = **1 Mbps**
- **2 Mbps**
  - Modulation = DQPSK
    ⇒ 2 bits/symbol
  - Symbol rate = 1 Mbaud

  Therefore, bit rate = 1 Mbaud x 2 bits/symbol
  = **2 Mbps**

# How 802.11b increases bit rate?

- **5.5 Mbps**
  - Modulation = 2-DQPSK
    ⇒ 2 bits/symbol x 2 bits/sequence
  - Symbol rate = 1.375 Mbaud

  Therefore, bit rate = 1.375 Mbaud x 2 bits/symbol x 2 bits/sequence

  = **5.5 Mbps**
- **11 Mbps**
  - Modulation = 4-DQPSK
    ⇒ 2 bits/symbol x 4 bits/sequence
  - Symbol rate = 1.375 Mbaud

  Therefore, bit rate = 1.375 Mbaud x 2 bits/symbol x 4 bits/sequence

  = **11 Mbps**

# 802.11b - Chip rate

- Chip rate is 11 Mcps regardless of bitrates
- 1 Mbps

  Chip rate = 1 Mbaud x 11 chips/symbol = 11 Mcps
- 2 Mbps

  Chip rate = 1 Mbaud x 11 chips/symbol = 11 Mcps
- 5.5 Mbps

  Chip rate = 1.375 Mbaud x 8 chips/symbol = 11 Mcps
- 11 Mbps

  Chip rate = 1.375 Mbaud x 8 chips/symbol = 11 Mcps

# But more importantly…

- How to answer question in MST or exams?

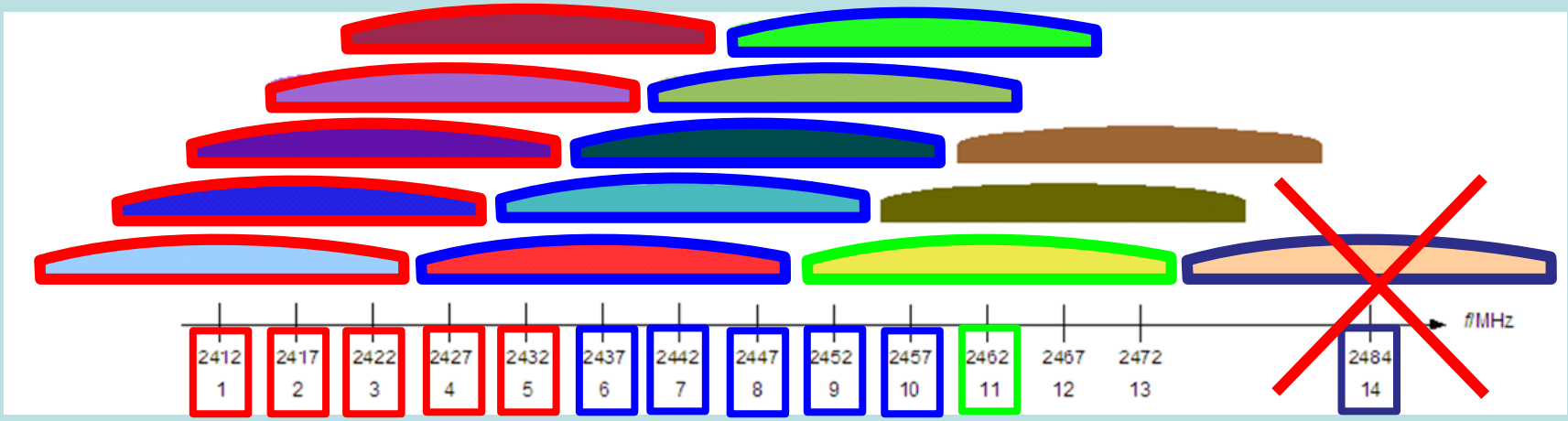
# What you need to know

- Chip rate = ***X*** Mbaud × ***Y*** chips/symbol = 11 Mcps
- For 1 Mbps and 2 Mbps
  - **Bit rate** = ***X*** Mbaud × ***a*** bits/symbol
  - **1 Mbps** uses DBPSK, where *a* = 1
  - **2 Mbps** uses DQPSK, where *a* = 2
- For 5.5 Mbps and 11 Mbps
  - **Bit rate** = ***X*** Mbaud × ***a*** bits/symbol x ***b*** bits/sequence
  - **5.5 Mbps** uses 2-DQPSK, where *a* = 2 and b = 2
  - **11 Mbps** uses 4-DQPSK, where *a* = 2 and b = 4

So you can easily find ***X*** and ***Y***

# IEEE 802.11b – Channels

- 14 frequency channels with 5 MHz apart




- 4 non-overlapping frequency channels – 1, 6, 11, 14
- Only Japan uses channel 14
- Everywhere else, non-overlapping channels are 1, 6 and 11

# 3 main flavours in 802.11

802.11a

802.11g

802.11b

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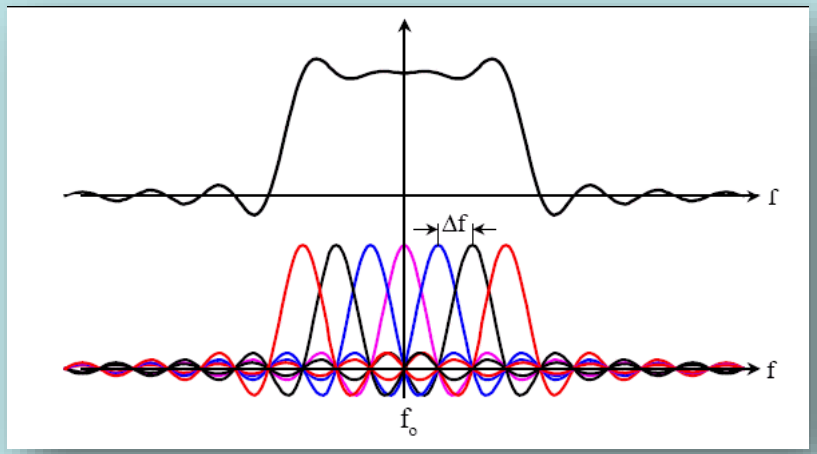
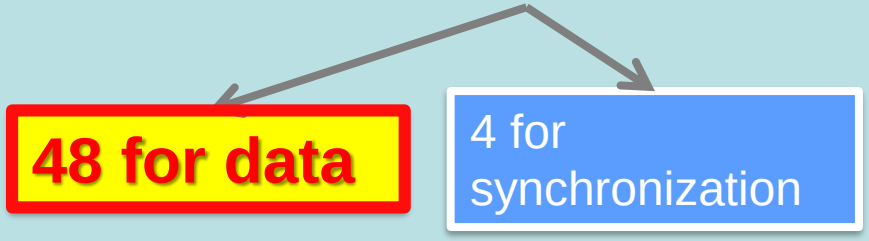
# 802.11a - OFDM

- Orthogonal Frequency Division Multiplexing
- Main protocol in 802.11a
- Each user allocated multiple sub-carriers and data is transmitted independently over these subcarriers
- The peak of any sub-carriers correspond to the null of other sub-carriers, resulting in no interference between sub-carriers



# 802.11a

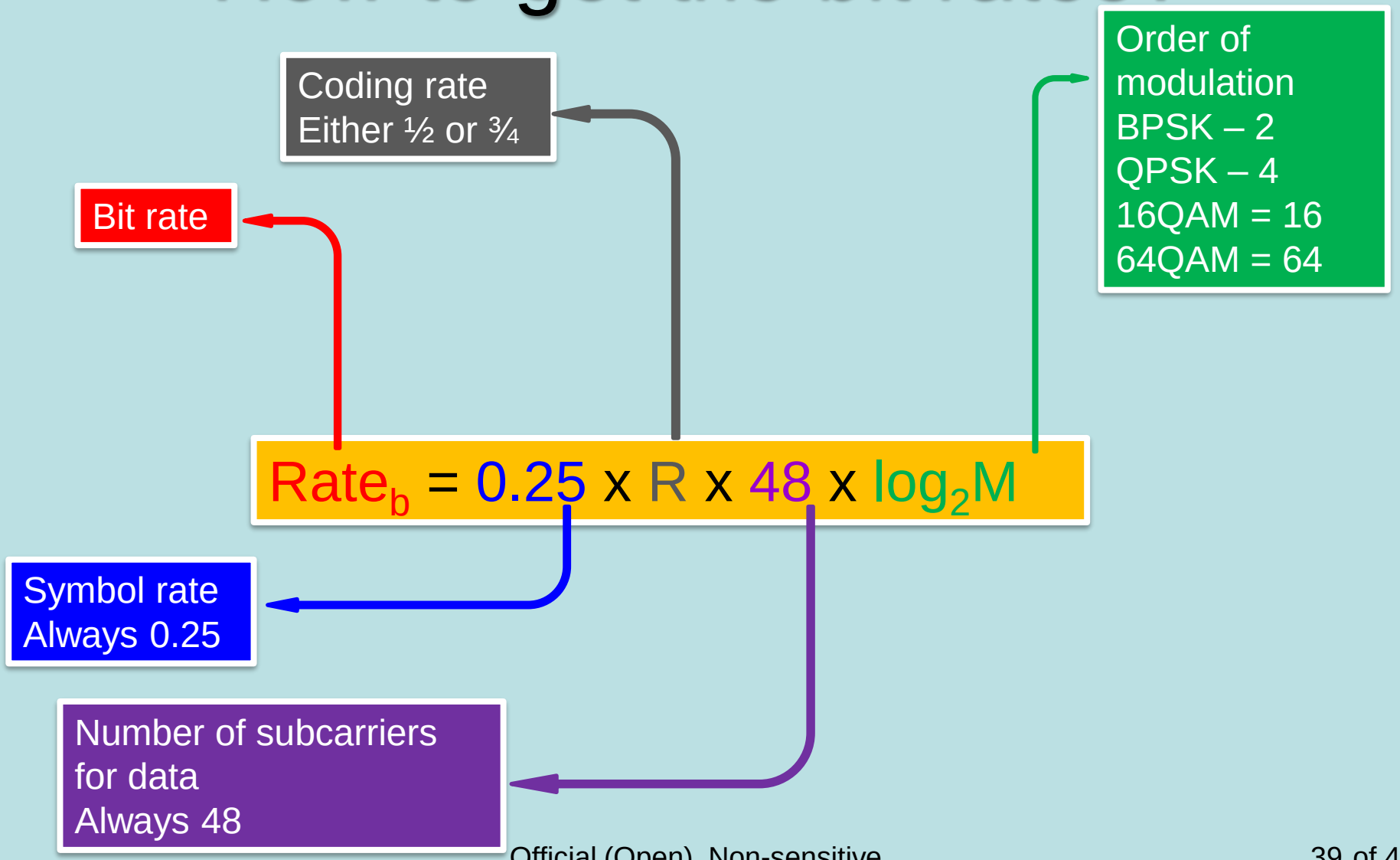
- Total number of subcarriers = 52




- Once again, we're interested in how to get different bit rates
- This time, there are 6, 9, 12, 18, 24, 36, 48, 54 Mbps possible bit rates

**Compulsory to be supported**

# How to get the bit rates?



$$Rate_b = 0.25 \times R \times 48 \times \log_2 M$$

- Example

What is the bit rate for IEEE 802.11a if the modulation is QPSK and convolutional coding rate is $\frac{3}{4}$?

- 18 Mbps
- 9 Mbps
- 6 Mbps
- 24 Mbps

$$Rate_b = 0.25 \times R \times 48 \times \log_2 M$$

| Rate | Mod | R | NBPSC | NCBPS | NDBPS |
|---|---|---|---|---|---|
| 6 | BPSK | ½ | 1 | 48 | 24 |
| 9 | | ¾ | 1 | 48 | 36 |
| 12 | QPSK | ½ | 2 | 96 | 48 |
| 18 | | ¾ | 2 | 96 | 72 |
| 24 | 16-QAM | ½ | 4 | 192 | 96 |
| 36 | | ¾ | 4 | 192 | 144 |
| 48 | 64-QAM | (2/3) | 6 | 288 | 192 |
| 54 | | ¾ | 6 | 288 | 216 |

$$Rate_b = 0.25 \times R \times 48 \times \log_2 M$$

- Bit rate computation for BPSK, ½-coding rate
- Using BPSK, (M= 2) Number of Bits per Sub-Carrier (NBPSC) = 1 bit
- With 48 sub-carriers, Number of Coded Bits per OFDM Symbol (NCBPS) =1 bit × 48 = 48 bits
- With ½-coding rate (R),
- Number of Data Bits per OFDM Symbol (NDBPS) = 48 bits × ½ = 24 bits
- With symbol rate of 0.25 Mbaud,
- $Rate_b$= 24 bits × 0.25 × $10^6$ = 6 Mbps

- $Rate_b = 0.25xRx48x\log_2 M$
  $= 0.25x(½)x48x\log_2(2) = 6$ Mbps

where R = Coding Rate
M = the order of modulation
0.25 (Mbaud) = symbol rate
48 = no. of data channels

| Rate | Mod | R | NBPSC | NCBPS | NDBPS |
|---|---|---|---|---|---|
| 6 | BPSK | ½ | 1 | 48 | 24 |
| 9 | | ¾ | 1 | 48 | 36 |

$$Rate_b = 0.25 \times R \times 48 \times \log_2 M$$

## Example 3.6

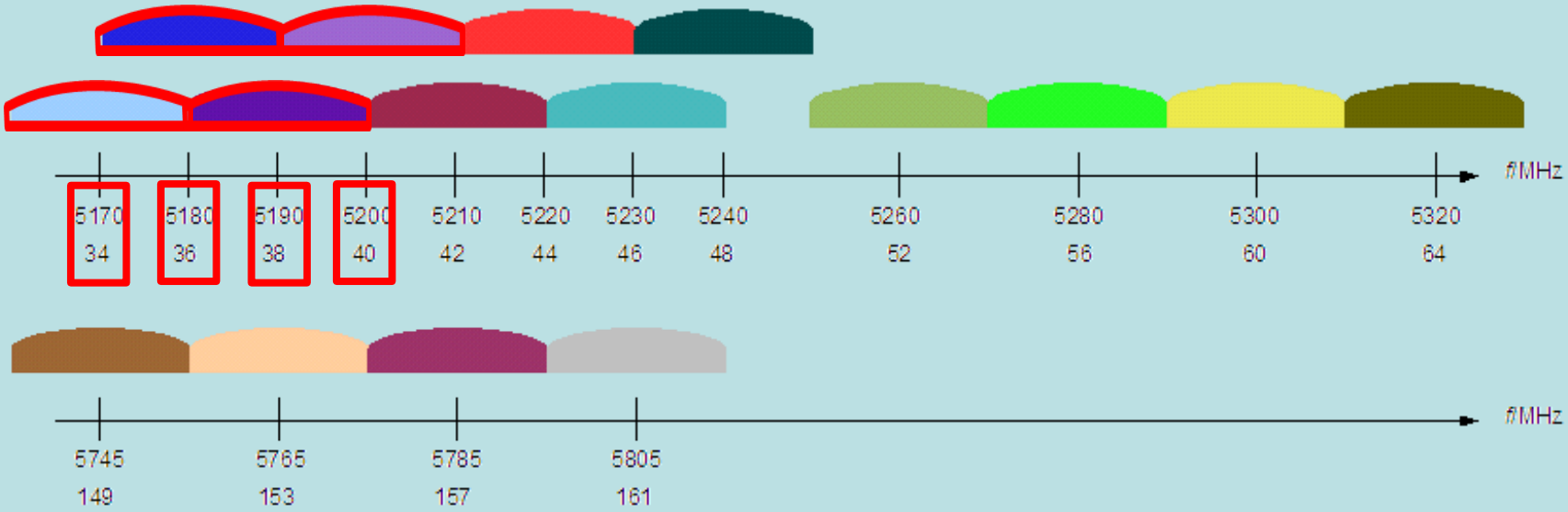
What is the bit rate if the modulation technique is 64-QAM (M = 64) and the convolutional coding is (3/4)?

- 64-QAM means six bits per symbol ($2^6 = 64$).
- With 48 data channels, the coded bits per OFDM Symbol is 48 × 6 = 288.
- Then, data bits per OFDM Symbol is 288 × (3/4) = 216. Finally, the bit rate is 0.25 * 216 = 54.
- $Rate_b = 0.25 \times R \times 48 \times \log_2 M$
  $= 0.25 \times (3/4) \times 48 \times \log_2 64 = 54$ Mbps

| Rate | Mod | R | NBPSC | NCBPS | NDBPS |
|---|---|---|---|---|---|
| 48 | 64-QAM | ½ | 6 | 288 | 192 |
| 54 | | ¾ | 6 | 288 | 216 |

# IEEE 802.11a – Channels

## Just like in 802.11b




So, how many channels are there?
How many are non-overlapping?

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802.11g

802.11b

Toppings
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# Why is there a need for 802.11g

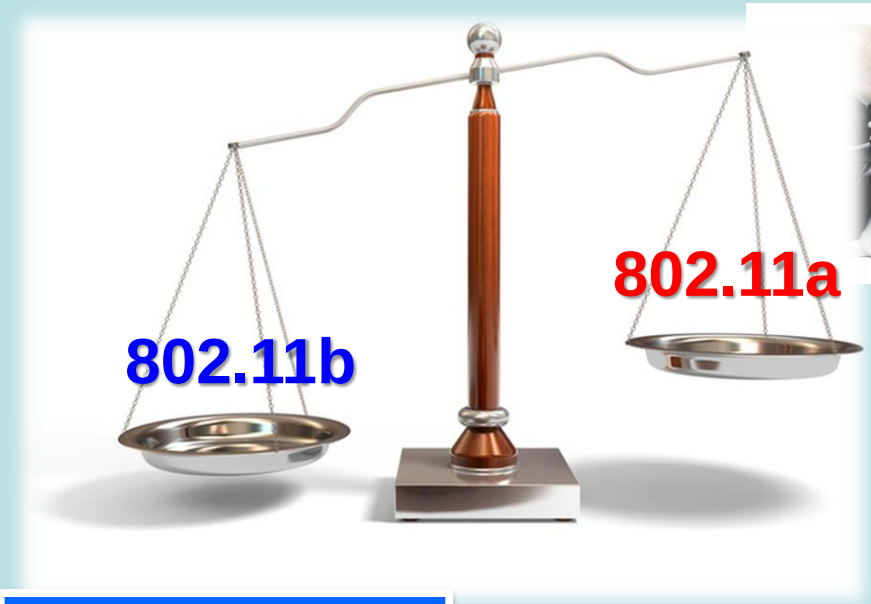
- Compare IEEE 802.11b and IEEE 802.11a


Better coverage – due to 2.4 GHz frequency


Better protocol
Higher bit rate
Better error correction

# Why is there a need for 802.11g

- IEEE 802.11g marries both advantages

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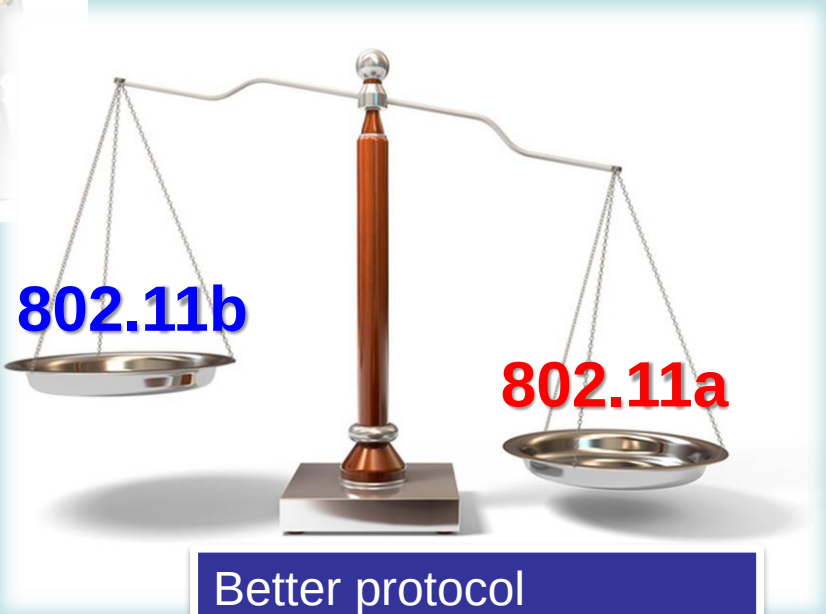


Better protocol
Higher bit rate
Better error correction

# Summary

1. WLAN Architecture
2. Explain the differences between different WLAN standards (IEEE 802.11 a/b/g)
3. Explain the radio frequencies used in WLAN
4. Explain the physical layers (DSSS and OFDM) used in WLAN