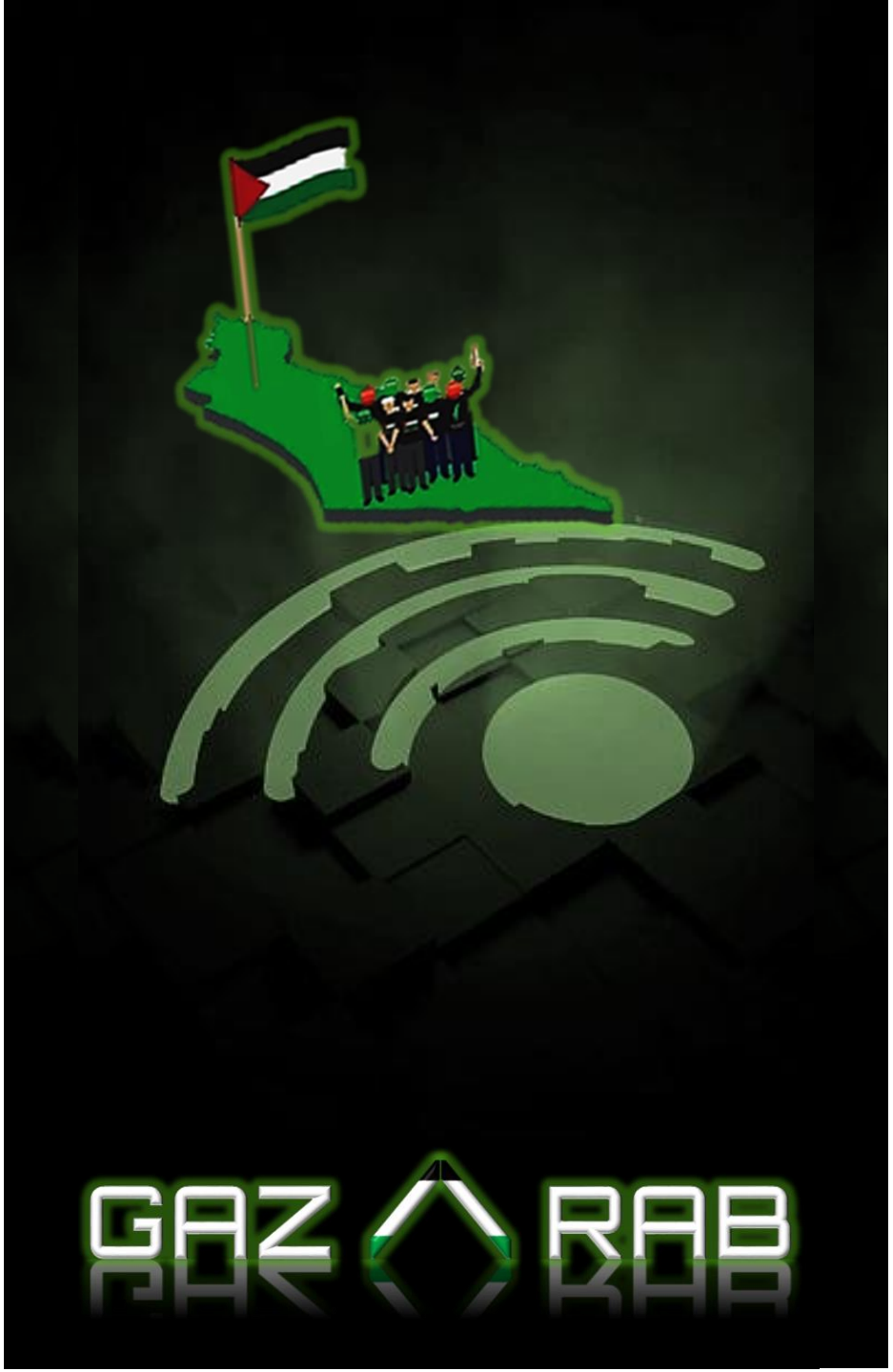



# Wireless Technology Training

ac n g b a WiFi ad ah ax ay az


# Wireless Training

RF Basics

Wi-Fi Fundamentals

New Technology

Wireless Design

Wireless Site Survey

Troubleshooting


# Wireless Training
# Part 4-Session 1

# WLAN DESIGN & SURVEY

## Introduction

# Part 4 Contents : Design & Survey

- WLAN Design Fundamentals
- Design & Planning Tools
- Wireless Site Survey
- Design Case Scenario
- Specific Case Design
- Design Tips & Best Practice


# Part 4-Session1 : Introduction

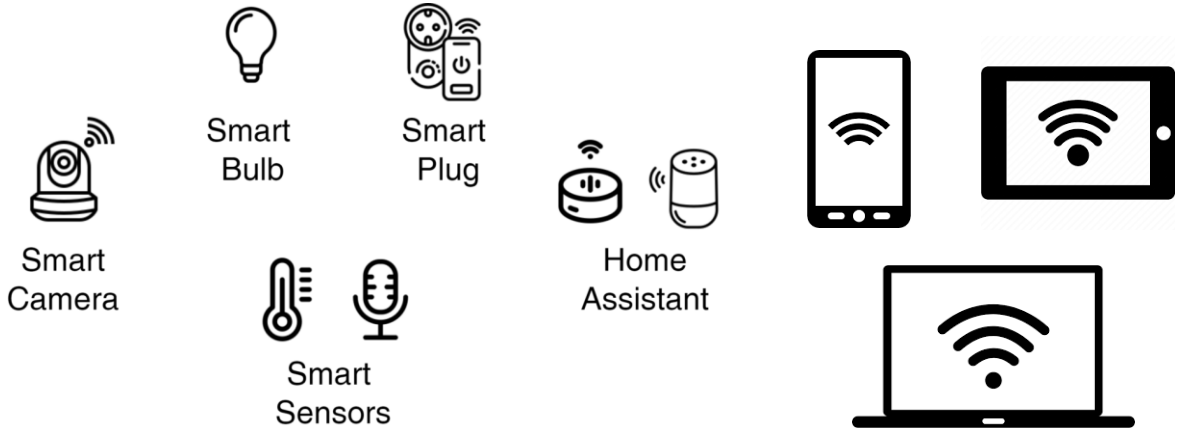
## Intro

- Why we need Wi-Fi Design
- Best Design Resources
- Course Contents & Roadmap

# WLAN New market needs

| | |
|---|---|
| Client Devices Nature Changes | Robust increase Wireless Only devices as smartphones & laptop & IOT |
| Wi-Fi as Mission Critical | Wi-Fi become as main need not as just luxury |
| WLAN Usage and Applications | Business & Operation depend on Wi-Fi not only for internet access |
| Wired Vs WLAN | Wired become as service for AP connection only in many areas not as main requirements itself |
| Wi-Fi Giga Speed | With New 6Ghz and WI-FI 6E & 7 with Giga speed and multi-user technology almost as wired |

# More Wireless Devices

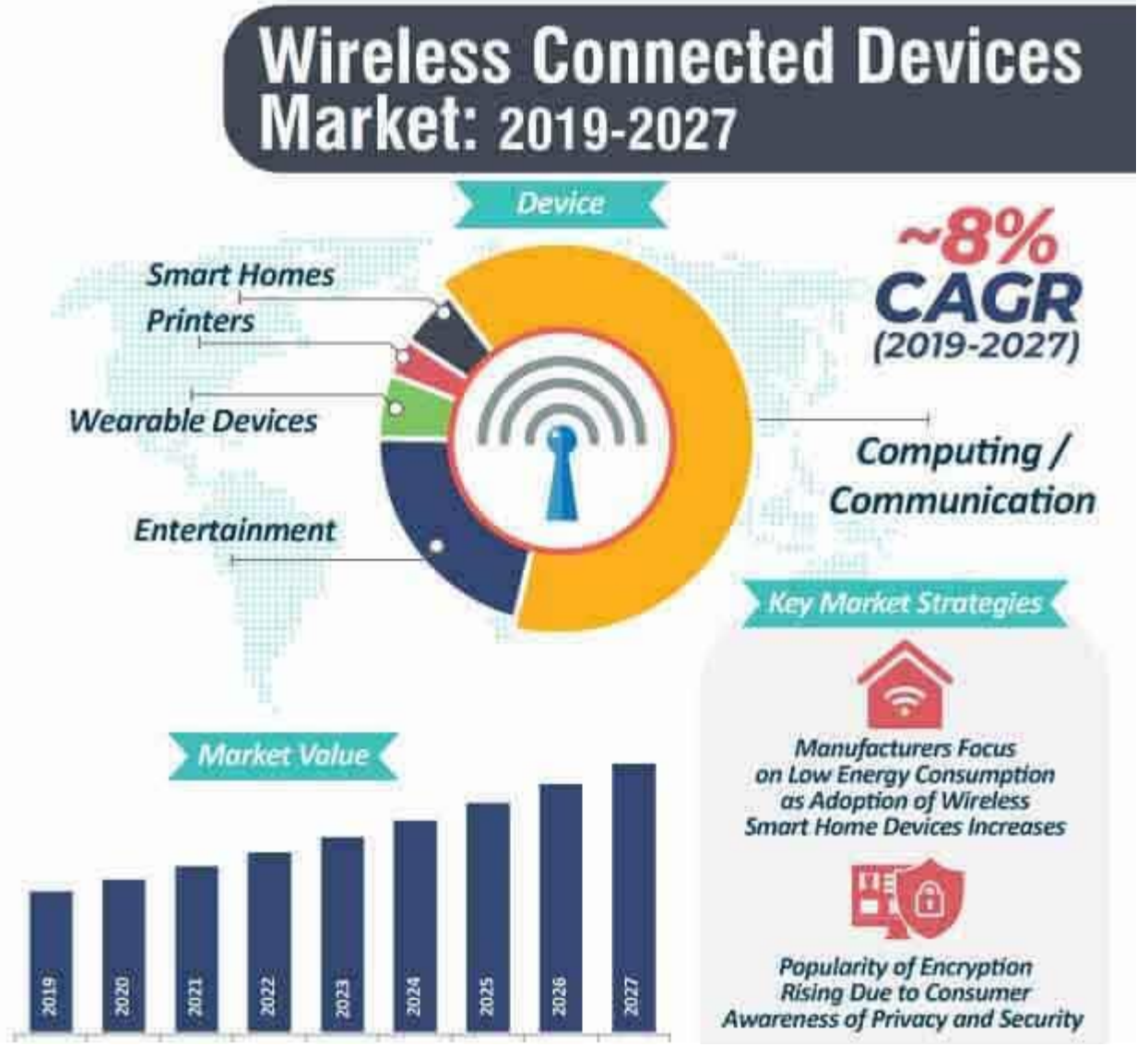



23 billion

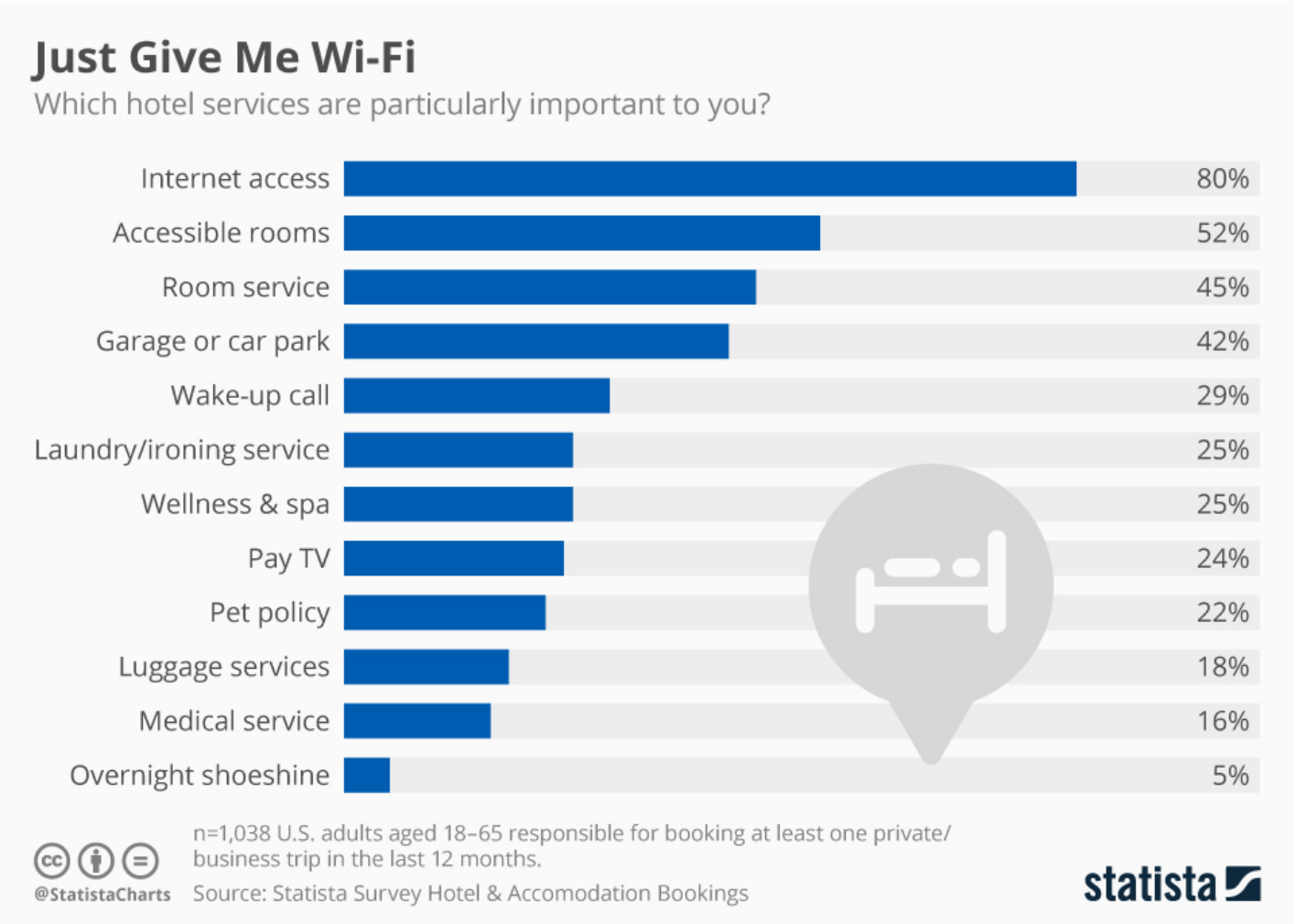
IoT connected devices utilizing Wi-Fi as their primary communication medium

75+ billion

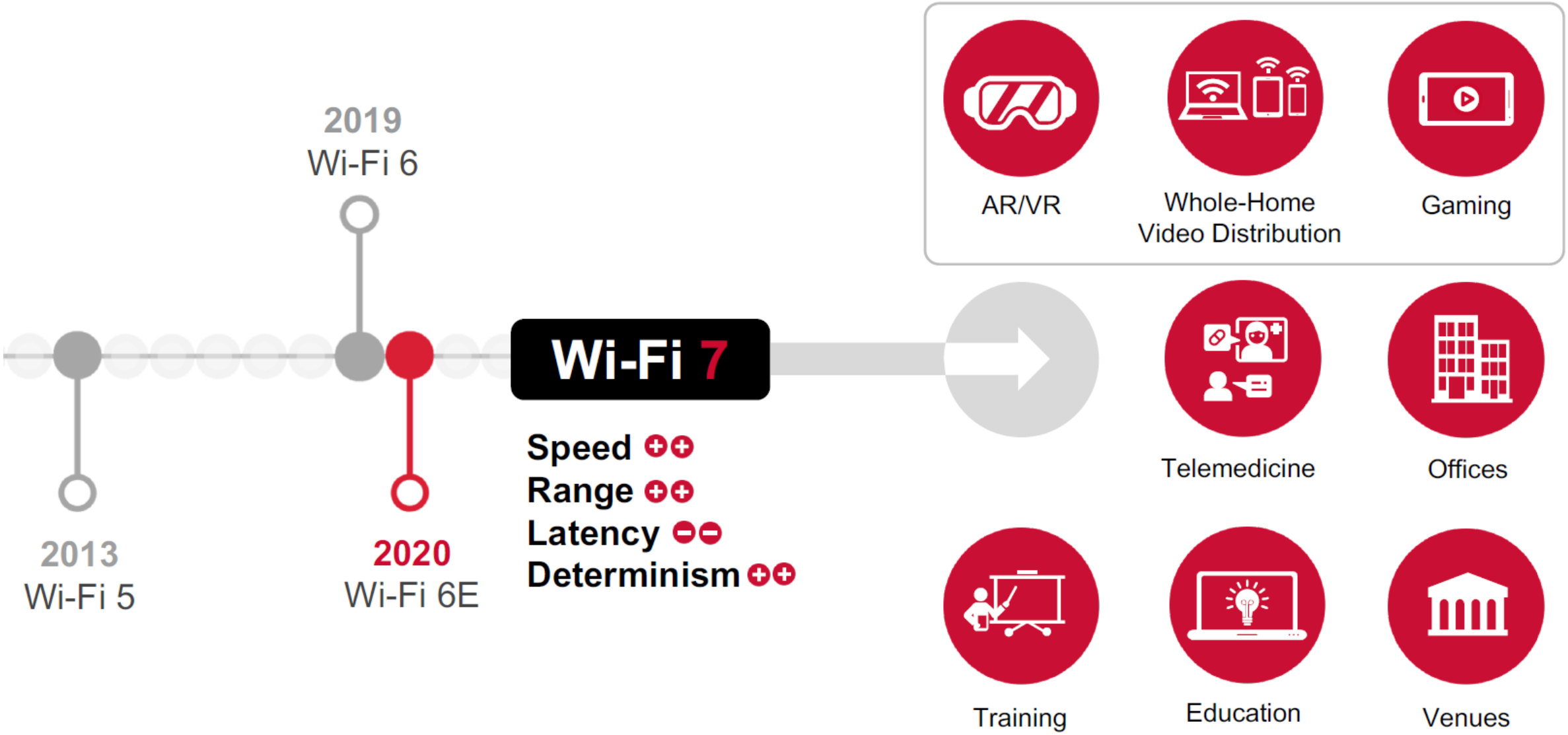
projected increase by 2025



# Wi-Fi as Mission Critical




# Giga Wi-Fi 6E & 7 - with 6Ghz



# Wi-Fi Market Growth

The growth of the Wi-Fi market is attributed to the digital transformation initiatives in businesses and widespread adoption of IoT devices.




12.3 USD BILLION 2022

31.3 USD BILLION 2027

CAGR of 20.4%

The global Wi-Fi market is projected to be worth USD 31.3 billion by 2027, growing at a CAGR of 20.4% from 2022.

Government initiatives for smart city projects is a factor expected to offer growth opportunities for the market during the forecast period.

Product launches and deals are expected to be key growth strategies adopted by market players in the next six years.

The North American market is projected to grow from USD XX billion in 2022 to USD XX billion by 2027, at a CAGR of XX% during the forecast period.

The high CAGR of Asia Pacific in the Wi-Fi market can be attributed to the increase in investments in new technologies and digital transformation across industries in the region.

# Wi-Fi Every Where


**Public Malls-Airports**

**Offices**

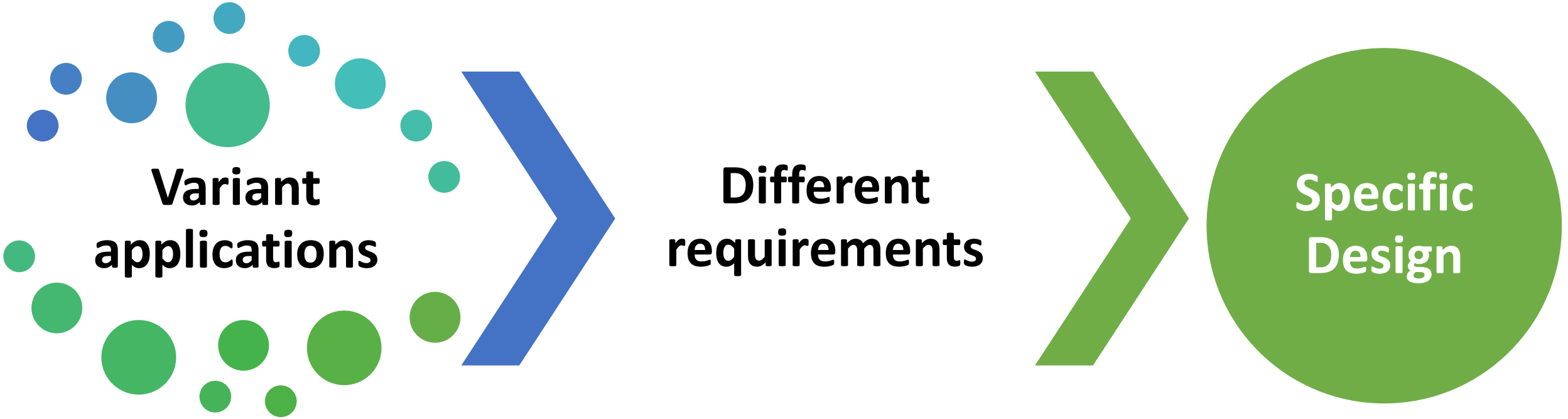
**Medical**

**Education**

**IOT & Smart City**

**Warehouse & Industry**

# Need for Accurate Wireless Design

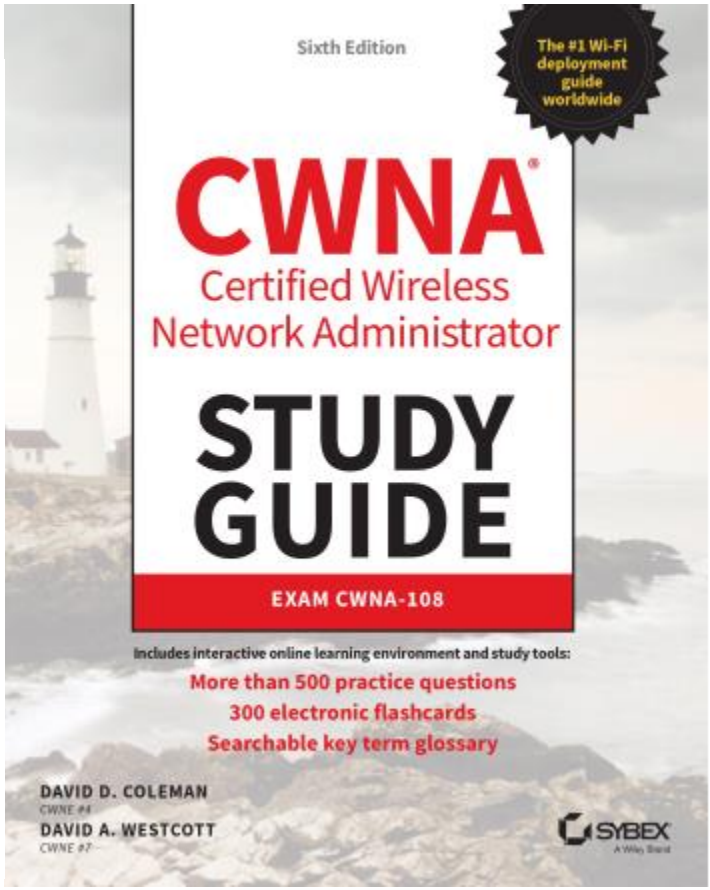



How to meet WLAN requirements for coverage and capacity
and achieve best client connection experience with
seamless roaming and faster data rate with minimum inference
While align with site aesthetics and keep beautiful shape

# Wireless Design Best Practice

## Find Best Practice
## & General Guide lines
## For Optimum WLAN Design
## & Better Client Experience
## & avoid Performance Issues

If you assemble 300 Wi-Fi experts in one room, such as the WLAN Professionals conference (www.wlanpros.com), most likely you will get 300 different opinions as to proper WLAN design for coverage, capacity, and airtime consumption. Experienced WLAN professionals will all agree about the importance of a properly designed WLAN. The bulk of trouble-shooting calls can be prevented if a WLAN is well planned and designed prior to deployment. Just as important is a post-deployment validation survey to verify the WLAN design.



# Wireless Design Resources

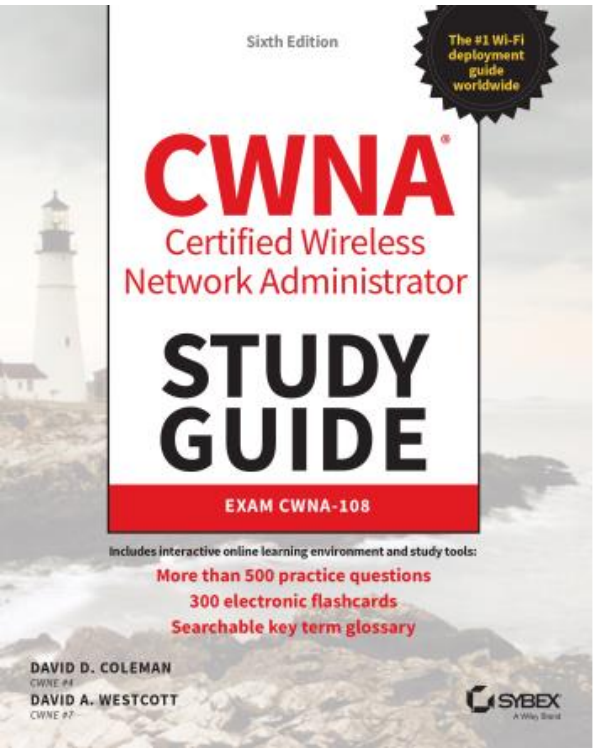
Certified Wireless Network Professionals
CWNP

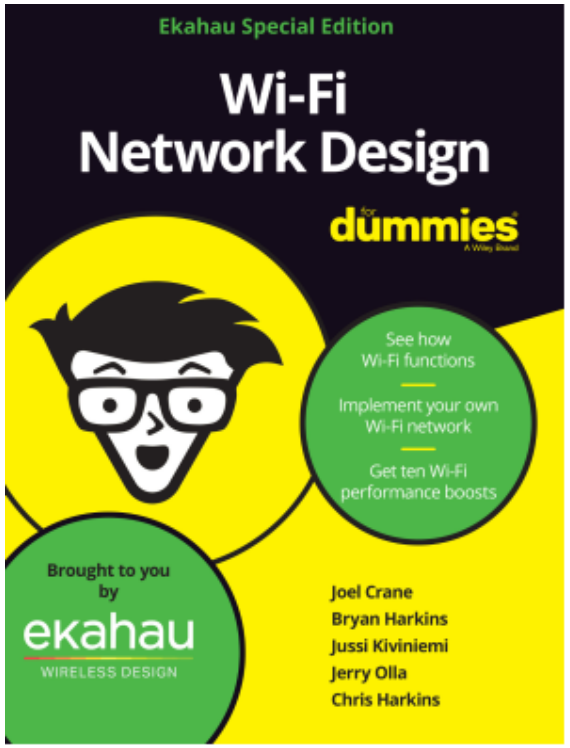
ekahau
WIRELESS DESIGN

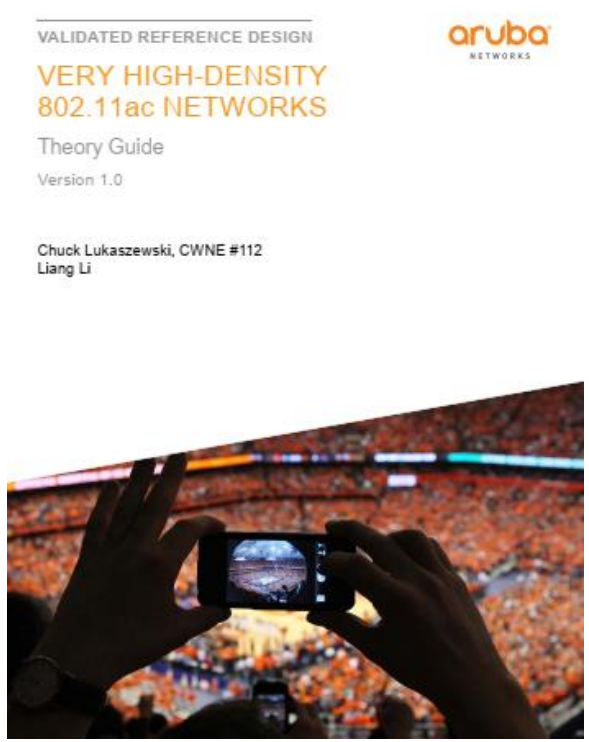
Vendor

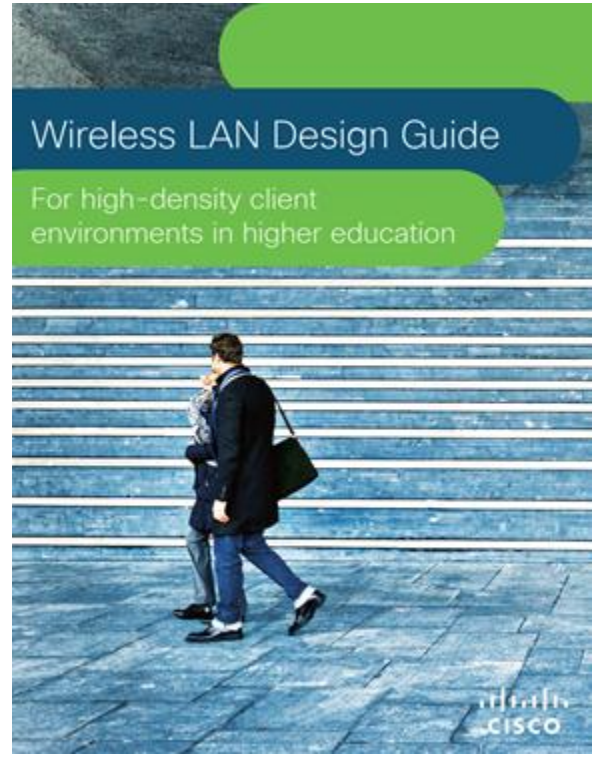
aruba
NETWORKS

CISCO




GAZA RAB

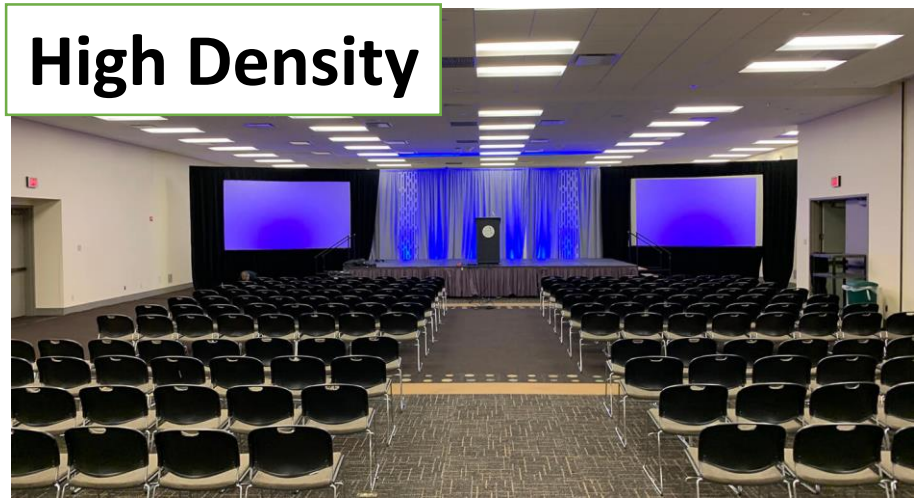
# Wireless Design Resources

Location

Warehouse

Market

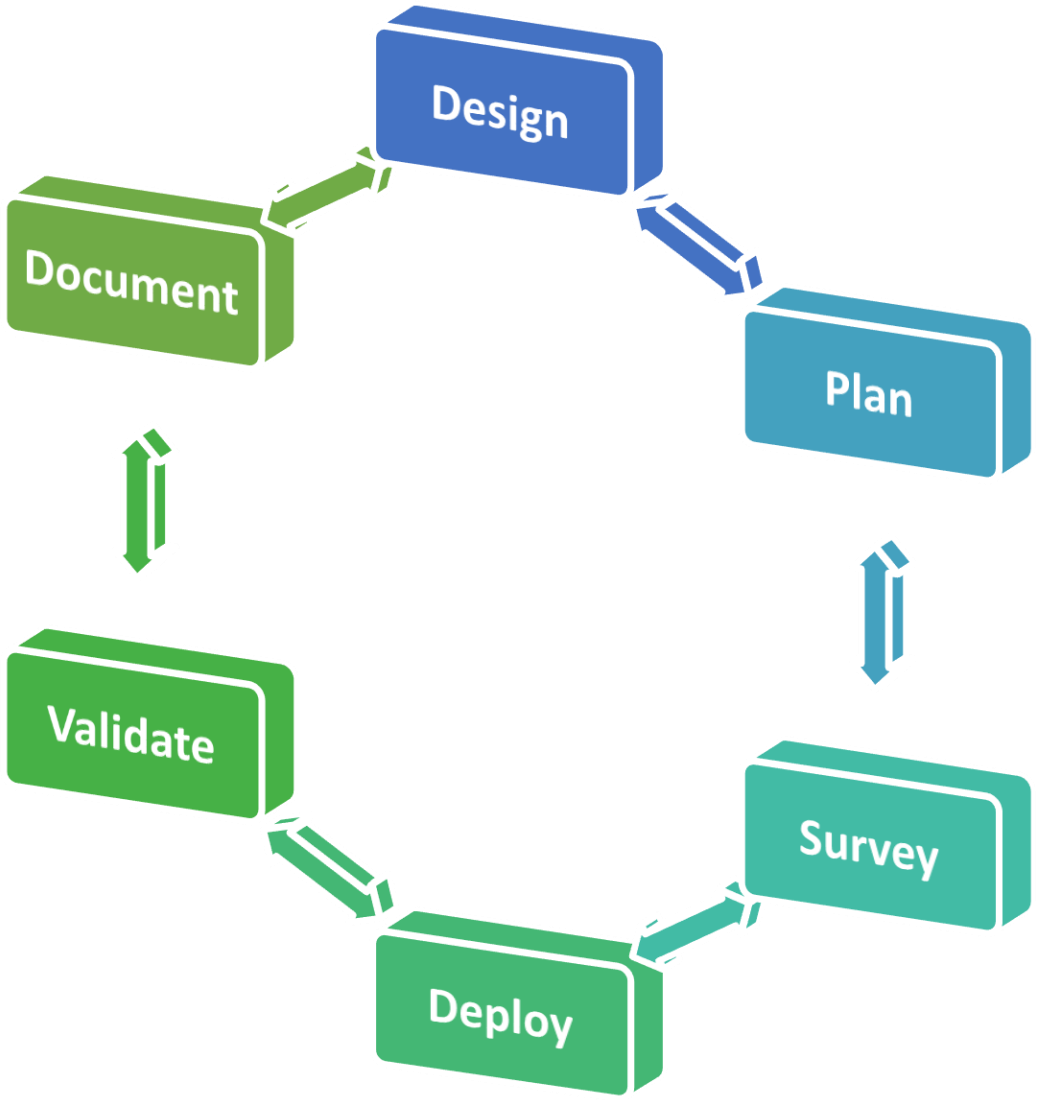
High Density



VOIP

# Design Fundamentals

- WLAN Design Procedure
- Collecting requirements
- Capacity vs Coverage
- VOIP WLAN Design
- High Density Design
- Outdoor WLAN Design
- Location Tracking & BLE
- AP & Antenna Selection
- Tips & Best Practice



# Site Survey

**Survey Types (**Active – Passive-Predictive **)**

**Predictive ( Ekahau Planner - IBWAVE)**

**Post Assessment (**Sidedeck - Ekahau**)**

**Survey Tools (** Wi-Fi Analyzer – Aircheck **)**

**Throughput Testing (**IPERF – TamoSoft **)**

**Sample Practical** Site Survey

# Design Scenarios

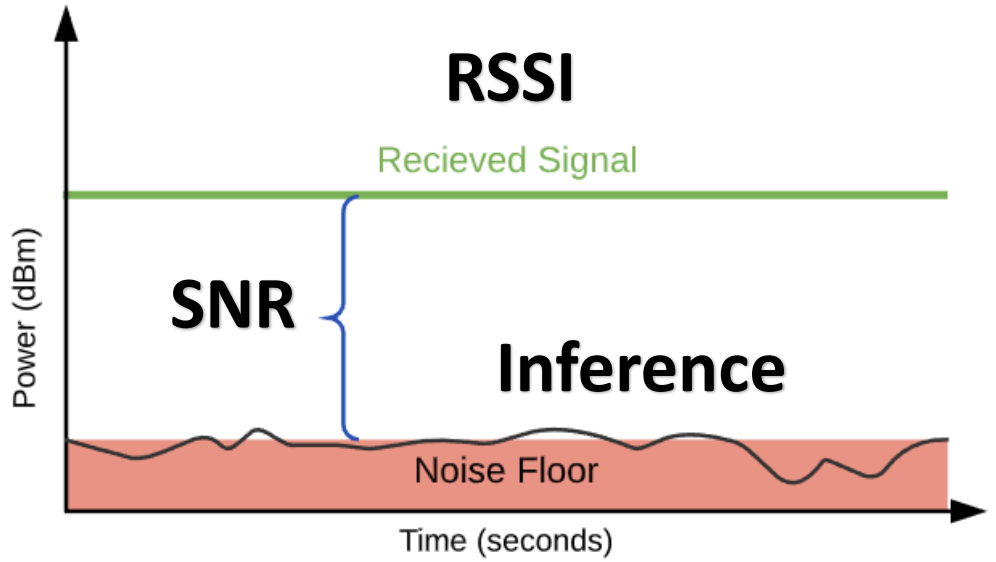
- Smart Office
- Guest Hotel
- Warehouse
- Conference
- Public Area
- Classrooms




# Wireless Training
# Part 4-Session 2

# WLAN DESIGN & SURVEY

## Design Parameters




# Session 2 : Design Parameters

## Index

- RF Power Measurements
- dB – dBm- dBi -mWatt-EIRP
- RSSI – SNR – Floor Noise
- Practical LAB

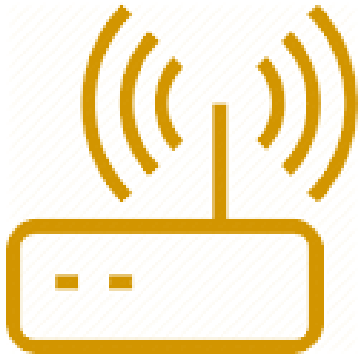
# RF Power Measurements

The decibel (dB) : is a relative unit of measurement

The unit expresses a relative change or an absolute value

$$dB = 10 \log \frac{P_2}{P_1}$$

$$P(\text{dBm}) = 10 \log \frac{P(\text{mW})}{1\,\text{mW}}$$



Indoor AP : 50 mWatt

10 log 50/1 = 17 dBm

Outdoor AP : 100 mWatt

10 log 100/1 = 20 dBm

# RF Math Rules

3 dB

**Double or Half actual power**

10 dB

**Multiply absolute power by 10**

- 3 dB gain = mW × 2
- 3 dB loss = mW ÷ 2
- 10 dB gain = mW × 10
- 10 dB loss = mW ÷ 10

- 1mW = 0dBm
- 100mW=20dBm
- 200mW=23dBm
- 1000mW=30dBm

# RF Power Measurements

**dB**

No units

Power Related to another

**dBm**

Power Related to 1 m watt

**dBi**

Antenna

Gain

Related to isotropic Antenna

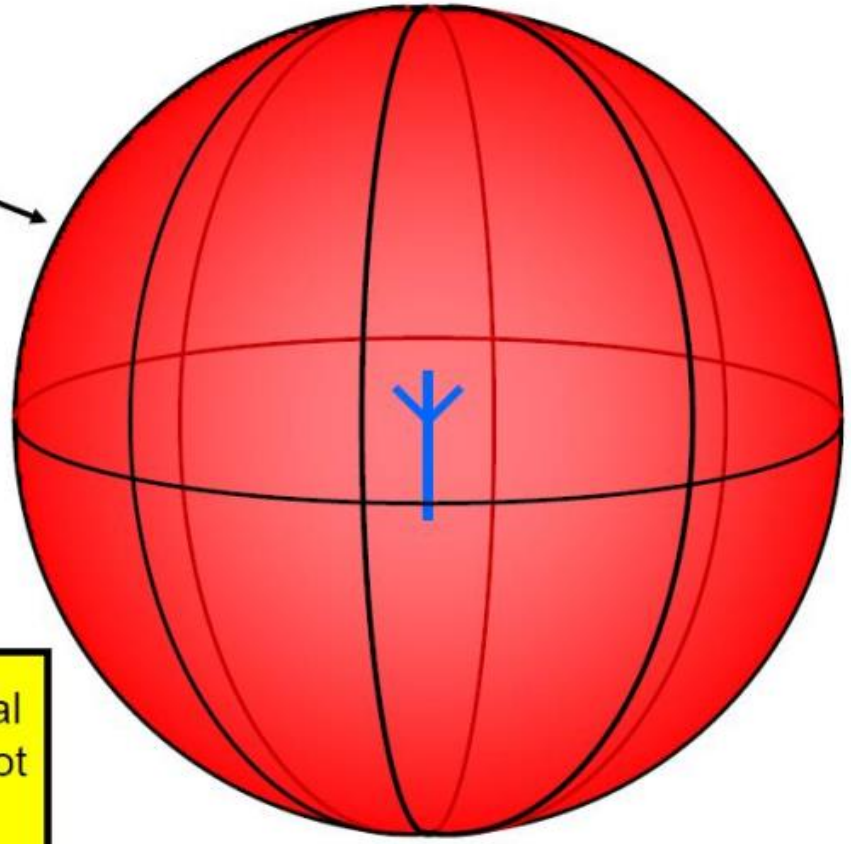
$$dB = 10\log\frac{P_2}{P_1}$$

$$P(\text{dBm}) = 10\log\frac{P(\text{mW})}{1\,\text{mW}}$$

# Antenna Gain - dBi

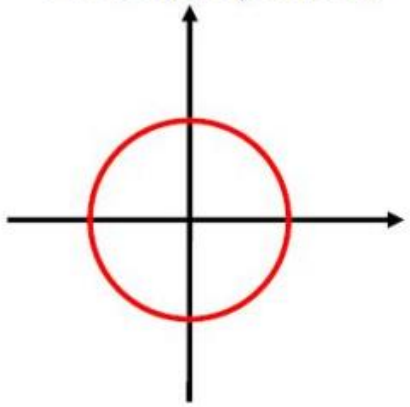
The **isotropic antenna** radiates equally in all directions

Radiation pattern is spherical

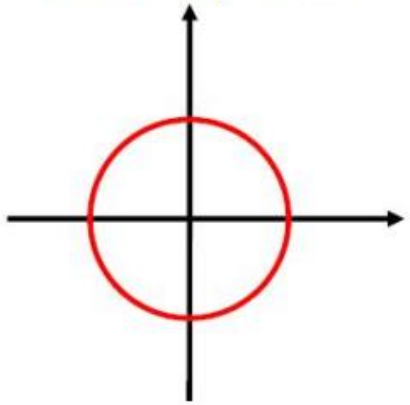


This is a theoretical antenna that cannot be built.

Elevation pattern



Azimuth pattern



# RF Signal Indicators

**RSSI**

- Received Signal from AP at TX
- Measured in dBm – always minus
- Accepted from -**55** to -**75** **dBm** and higher ( not less than -75 dBm)

**Noise**

- Unwanted signal as Interference from Wi-Fi or non Wi-Fi
- Accepted from -**85** to -**90** **dBm** and lower ( not more than -80 dBm)

**SNR**

- Difference between RSSI and Noise
- Accepted from **20** **dB** and higher



# Practical Sample

**RSSI Always Minus Value** as Signal received at RX

less than 1 mWatt Due to Path loss

-20 dBm

More Power by 10 Times

-30 dBm

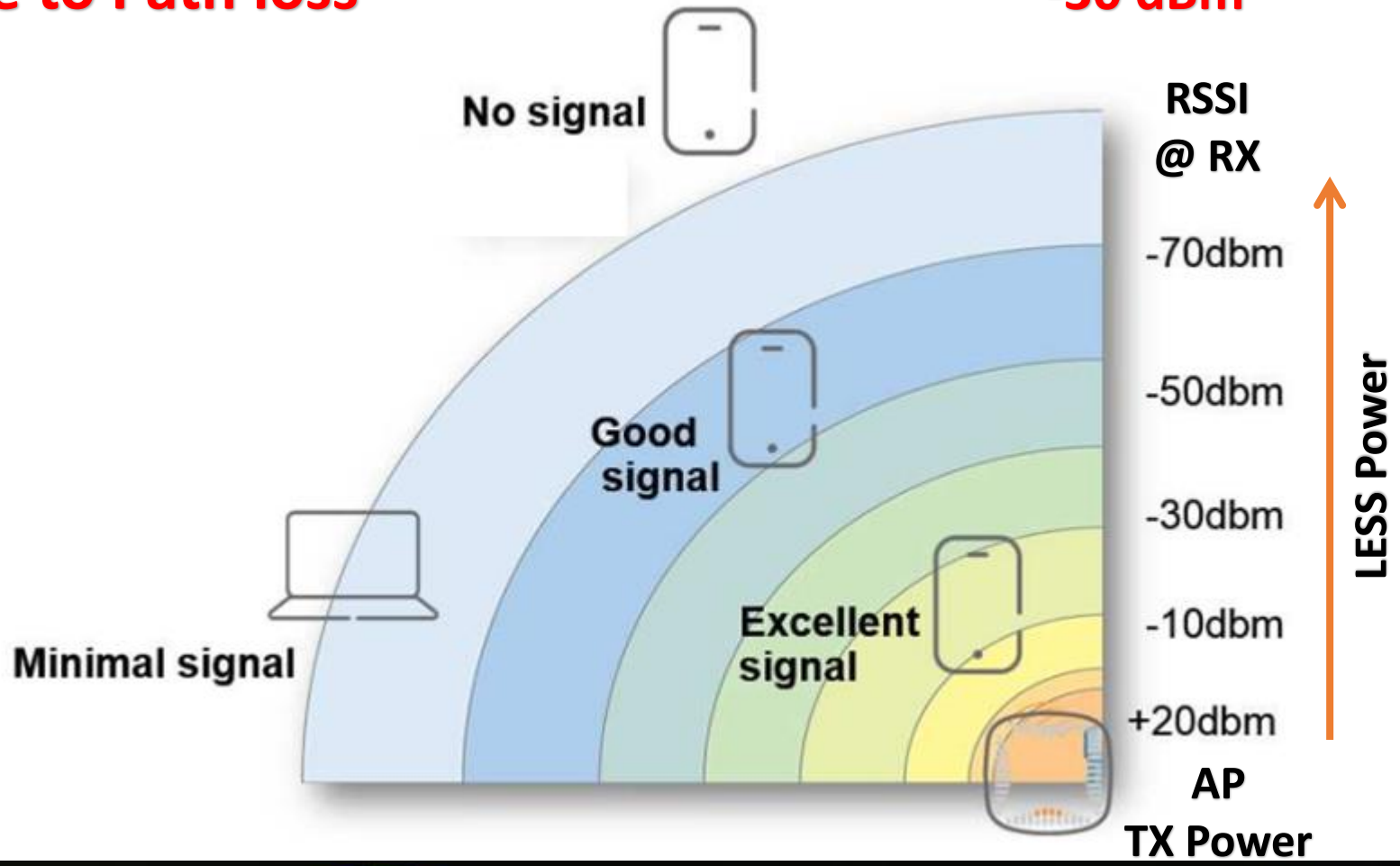
**Example**

10 log .5 / 1 = -3 dBm

10 log .25/1= -6dBm

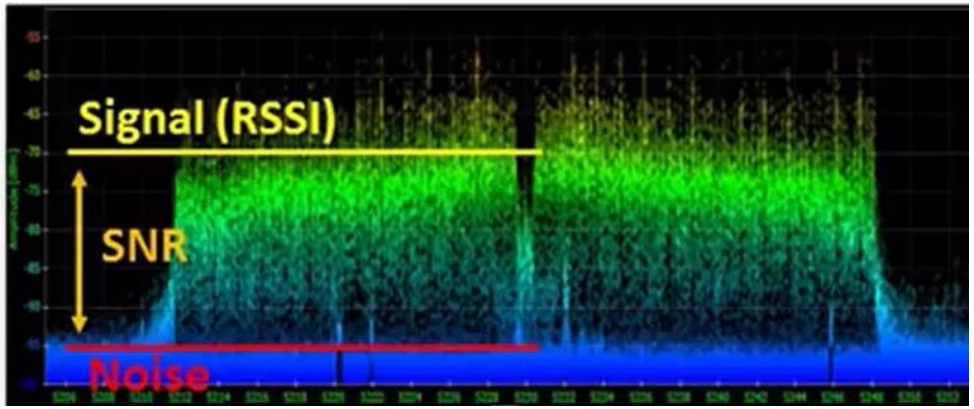
10 log .01/1 = -20 dBm

10 log .02/1 = -17dBm



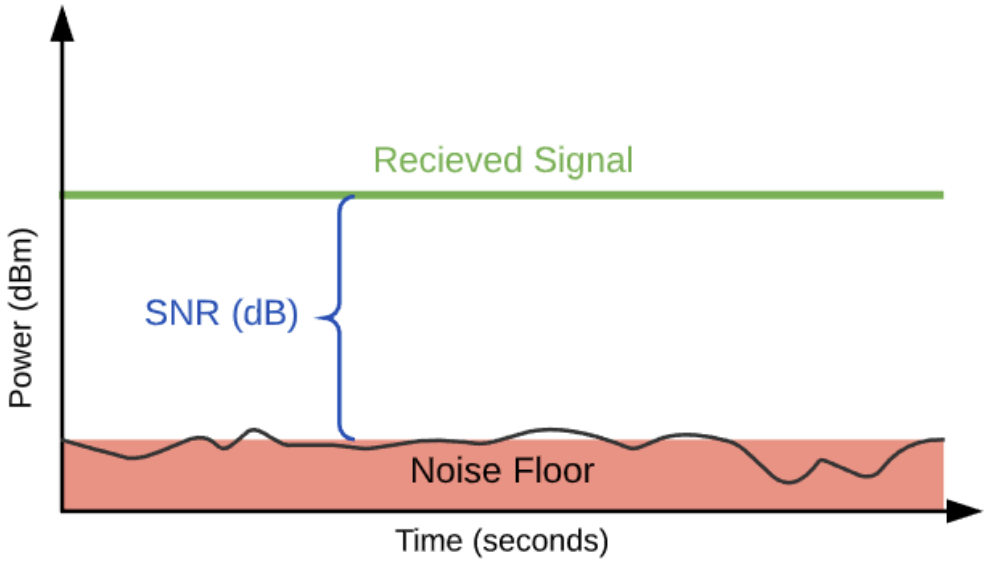
# RF Signal Measurements

- **RSSI : measured in milliwatt decibels dBm**
  - The strength that the device is hearing a AP signal.
  - Accepted Value **not less** than **-75 dB**

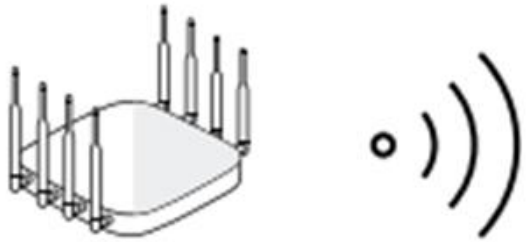



- **Noise Floor : measured in milliwatt decibels dBm**
  - Noise is any signal (interference) that is not WiFi traffic
  - Nosie Source as cordless phones, microwaves and Radar
  - Accepted value **not more** than **-85 dB**

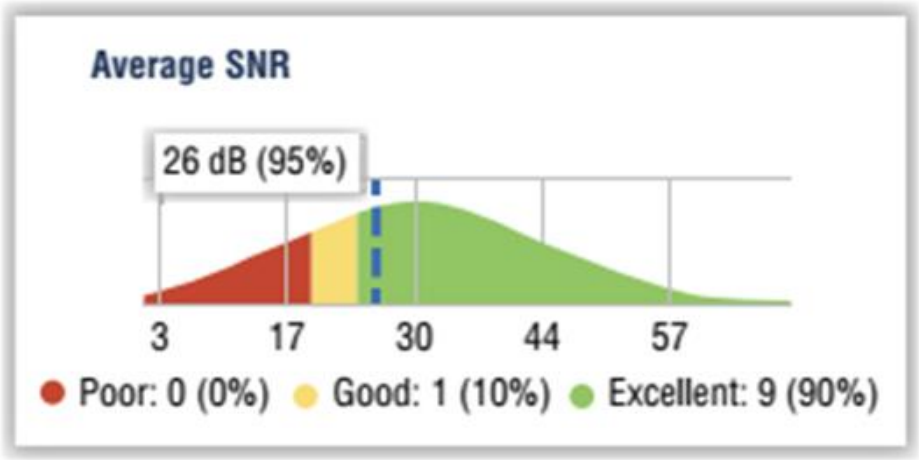
- **SNR: measured in decibels dB**
  - Ratio between Signal received RSSI and Noise level
  - Measured as a positive value between **0db** and **120db**
  - Accepted value **not less** than **25 dB**



# Signal Level Recommendation



**RSSI : Not Less Than -75 dBm ( -40 to -75 )**




Recommendations:
- 20 dB or greater
- 25 dB or greater for voice-grade Wi-Fi
- 29 dB or greater to use 256 QAM
- 35 dB or greater to use 1024 QAM

**SNR = RSSI – NOISE**

**SNR = -45 – -90 = 45 dB**

**SNR = -65 – -90 = 25 dB**

**SNR = -75 – -85 = 10 dB**

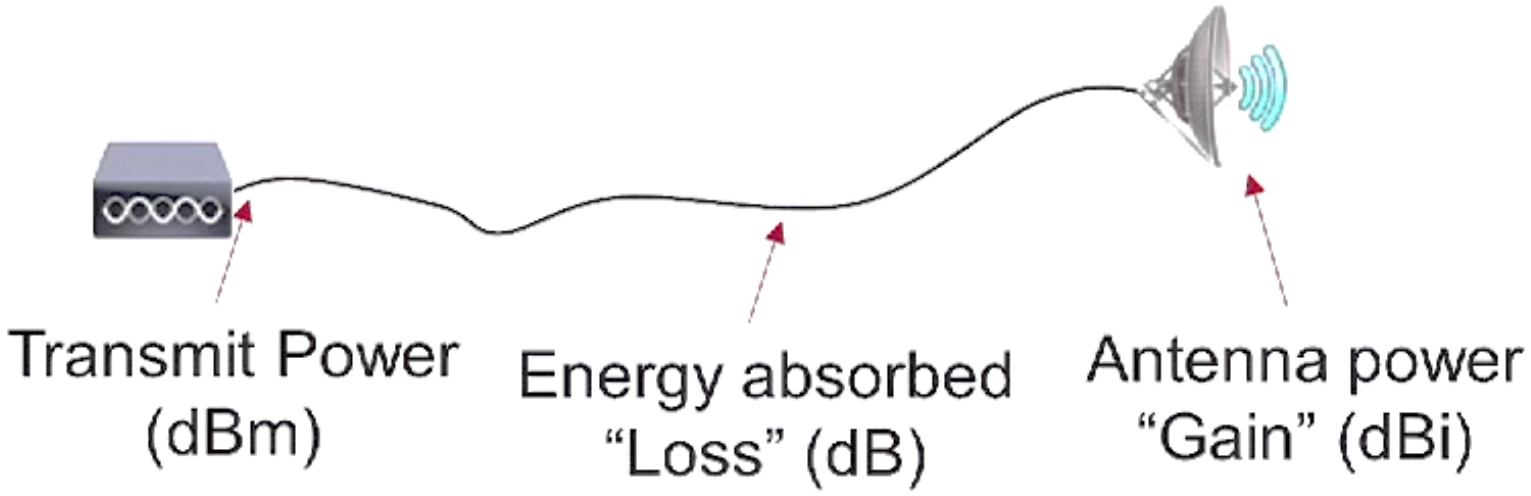
ambient noise floor

**Noise Level : Less Than -80 dBm ( -80 to -90 )**

# EIRP – Output Power

## Effective Isotropic Radiated Power

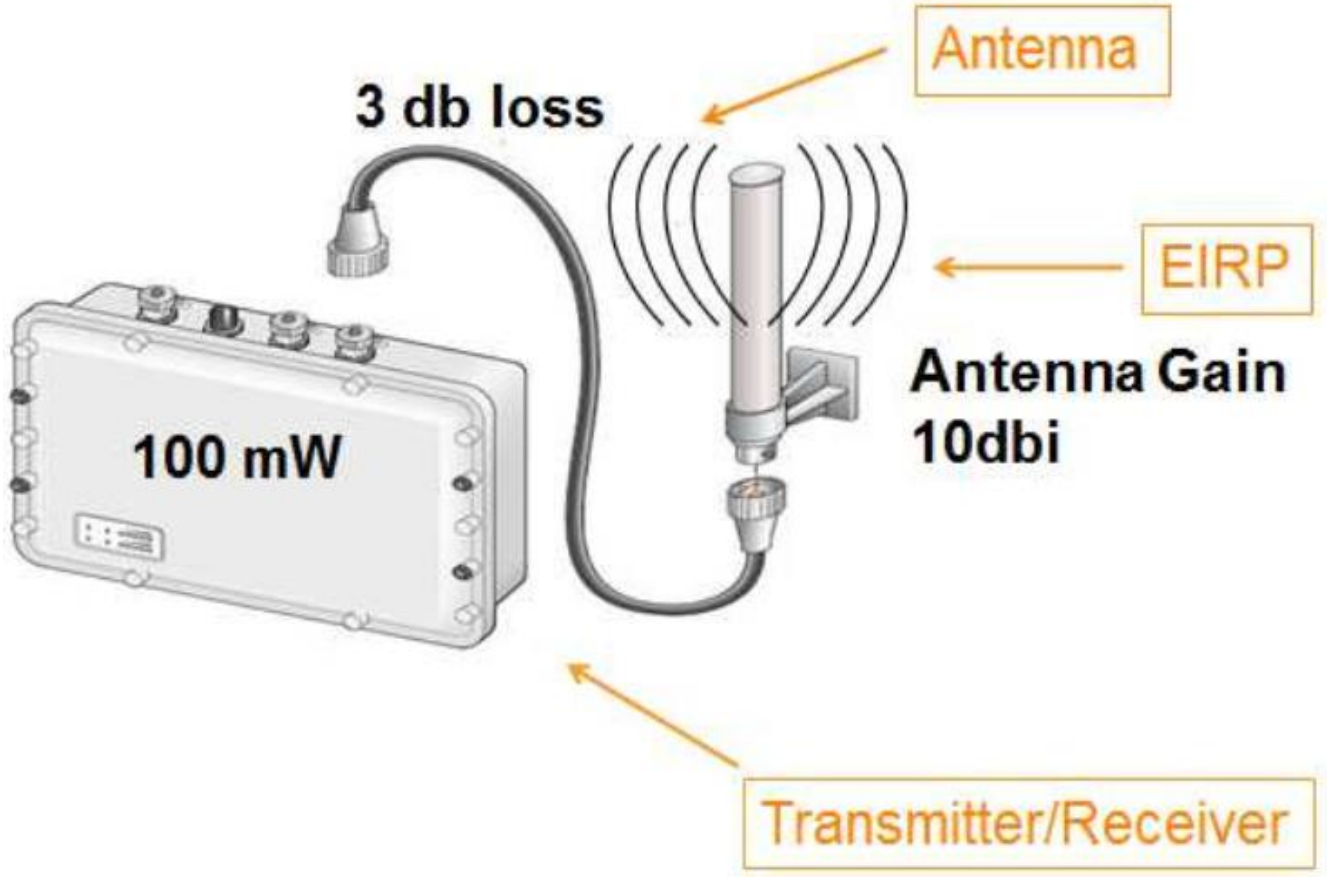
**EIRP Power O/P from AP**
**Shouldn't exceed regularity domain**



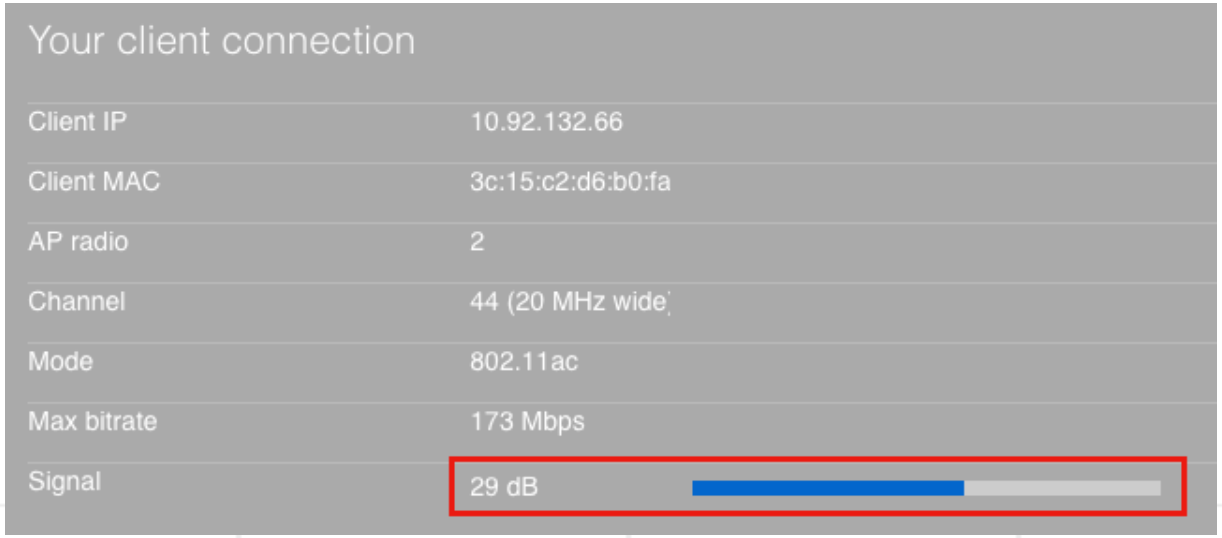

EIRP (dBm) = Tx Power (dBm) – cable loss (dB) + Antenna Gain (dBi)

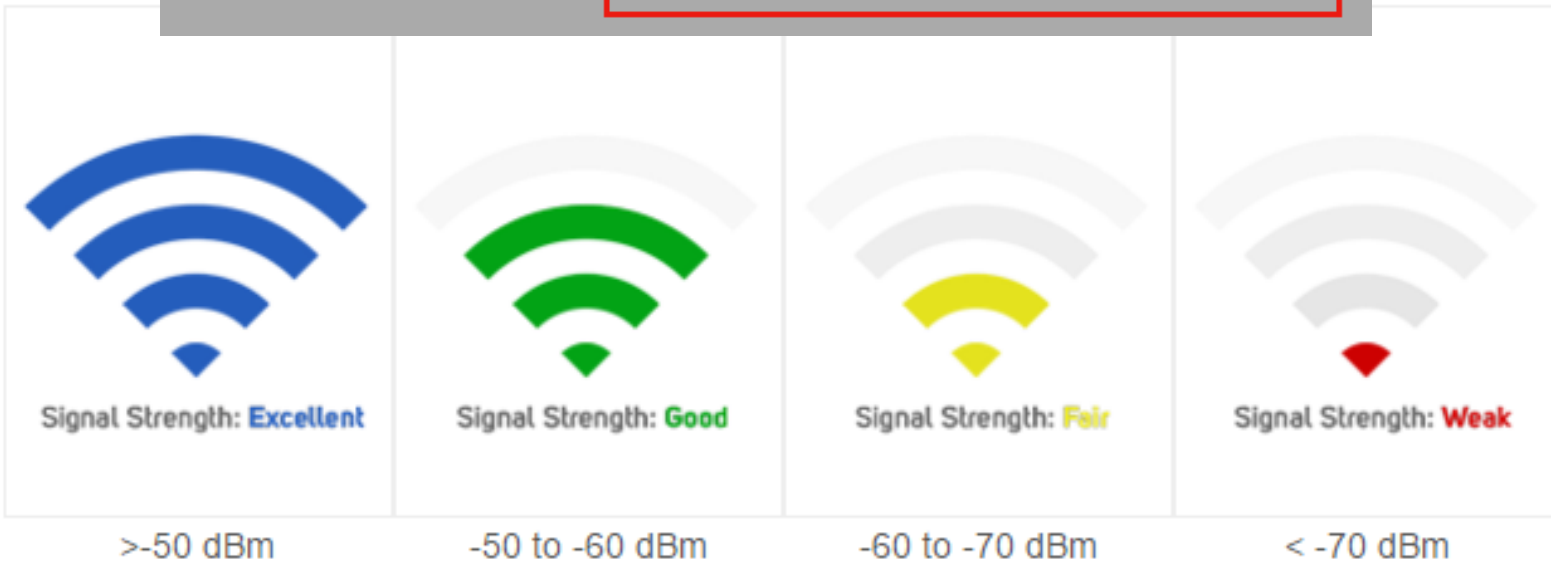
# EIRP Calculations

| | |
|---|---|
| EIRP | 27 dBm |
| = | = |
| TX Power | 100 mw (20 dbm) |
| - | - |
| Cable Loss | 3 dB |
| + | + |
| Ant Gain | 10 dB |



# RSSI Signal Indicator



# RSSI Indicator

| Quality | dBm | mW |
|---|---|---|
| Very Strong | –30 dBm | 1/1,000th of 1 milliwatt |
| Very Strong | –40 dBm | 1/10,000th of 1 milliwatt |
| Very Strong | –50 dBm | 1/100,000th of 1 milliwatt |
| Very Strong | –60 dBm | 1 millionth of 1 milliwatt |
| Strong | –70 dBm | 1 ten-millionth of 1 milliwatt |
| Fair | –80 dBm | 1 hundred-millionth of 1 milliwatt |
| Weak | –90 dBm | 1 billionth of 1 milliwatt |
| Very Weak | –95 dBm | Noise floor |

# Signal Level For Design

## Rule of 3's and 10's

- +3 dB: Double the signal strength
- -3 dB: Half the signal strength
- +10 dB: 10x more signal strength
- -10 dB: 10x less signal strength

## Why dBm?

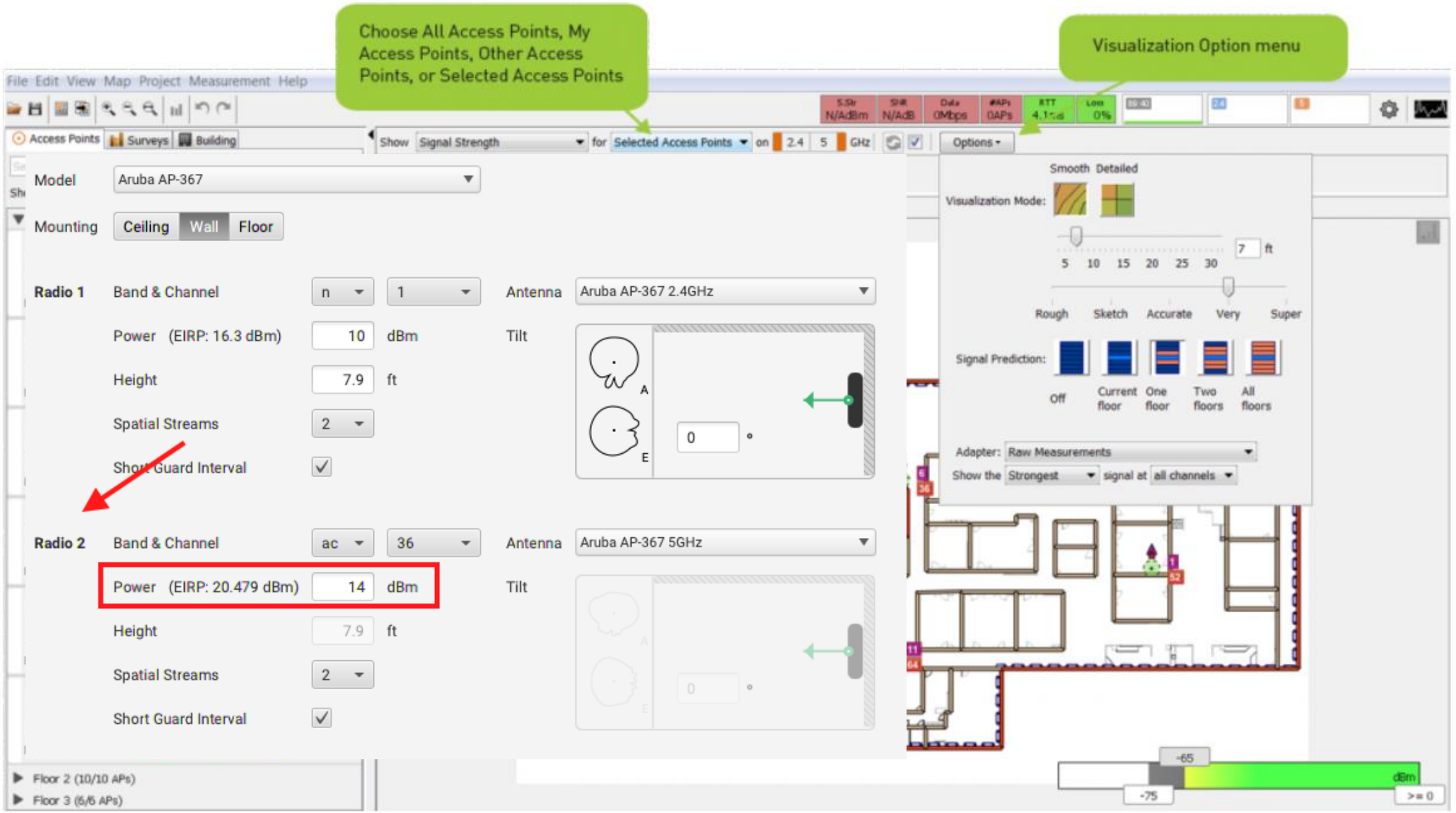
| dBm | mW |
|---|---|
| -60 dBm | .000001 mW |
| -70 dBm | .0000001 mW |
| -80 dBm | .00000001 mW |
| -90 dBm | .000000001 mW |

## What is "Good" Signal Strength?

| | |
|---|---|
| -30 dBm | Extremely good– you're likely standing underneath the AP |
| -65 dBm | Voice applications, mobile devices |
| **-67 dBm** | Streaming video |
| -75 dBm | Web browsing, email, instant messaging |
| -80 dBm | Generally unreliable |
| -90 dBm | Approaching or drowning in the noise floor |

# Practical Signal Testing Sample

# Practical Design Sample

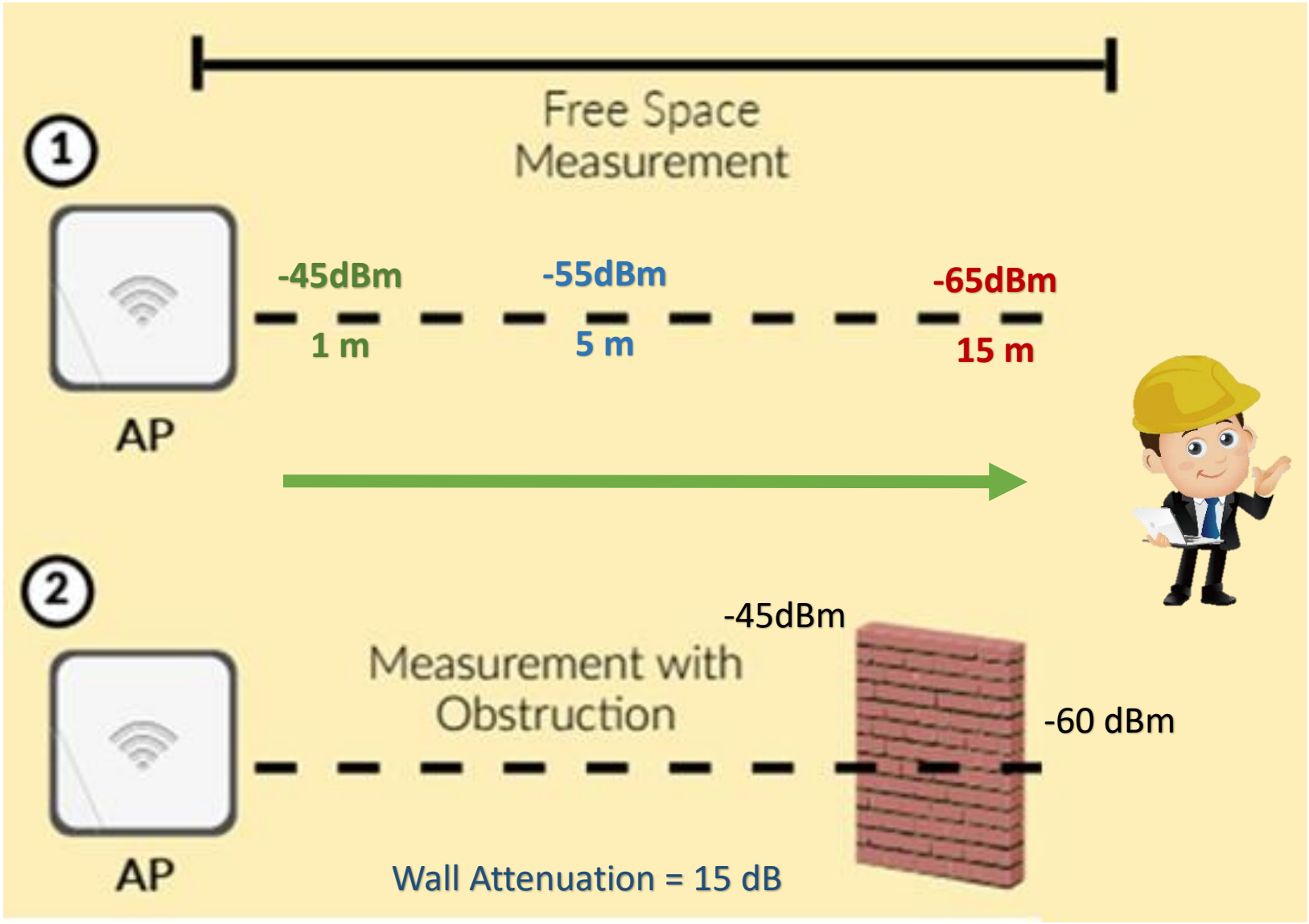


# Planning Sample



**Planning Software include common Type of walls and it's attenuation**

# Site Survey Sample




**AP On Stick Testing**
**AP Signal vs Distance**
**& Wall Attenuation**


# Wireless Training
# Part 4-Session 3

# WLAN DESIGN & SURVEY

## Wireless Design Steps


# Session 3 : WLAN Design Steps

## Index

# Don’t Skip Design

**Most**
**Wi-Fi Issues**

**Cause of**
**Bad or No Design**

# WLAN Design Steps

## Define

- Collect information about client requirements

## Survey

- Physical Investigation for coverage Area

## Planning

- Predicative analysis for WLAN performance

## Deploy

- Installation as per proposed Plan and site Survey

## Validate

- Checking real WLAN performance and fine tuning

## Document

- Note all details and steps for evaluation and maintenance

# Step 1 : Define

- Collection Information about WLAN Technical and Business requirements
- Interview with all Stockholder ( Technical – Financial – Users )
- Information collected as
  - Main Network Usage and Target
  - Available Project Budget
  - Network Users and Devices
  - Physical Environments
  - Site Floor Plans
- Output as WLAN Check list sheet

# Step 1 : Define

- Collection Information about WLAN Technical and Business requirements
- Interview with all Stockholder ( Technical – Financial – Users )
- Information collected as
  - Main Network Usage and Target
  - Available Project Budget
  - Network Users and Devices
  - Physical Environments
  - Site Floor Plans
- Output as WLAN Check list sheet

| Business Needs | | |
|---|---|---|
| WLAN Main Usage | Internet – Office Work – Barcode – Medical APP | |
| Voice over Wi-Fi | Required or not | |
| Location Tracking | Required or not | |
| **Physical Conditions** | | |
| Area Types | Indoor- Outdoor- Warehouse – Rooms | |
| Area to be covered | Reception – Offices | |
| Excluded Area | Store- Elevators – Bath room – Balcony | |
| Special High Density Area | Conference Center – Lobby | |
| Ceiling Height | 4 m offices – 8 mat lobby – 15 m at Halls | |
| Constraints and Aesthetic | AP should be hidden or visible – Special Color | |
| Walls Material Type | Open Area- Glass –Gypsum board – Wooden - Block | |
| **Clients Requirements** | | |
| Expected no of users per Area | 50 user / floor – 1000 user at Conf Center | |
| Expected Client device | Laptop Wi-Fi 6- Mix of Smart Phones | |
| Expected devices per user | 2 devices Per Staff – 1 device per Guest | |
| WLAN Applications | Internet browsing – Video Streaming – VOIP Calls – File Sharing – Medical APP – Warehouse Scan | |
| Required BW Per User | 50 for Staff at Offices– 10 Mbps for guest at Lobby | |

# Step 2 : Survey

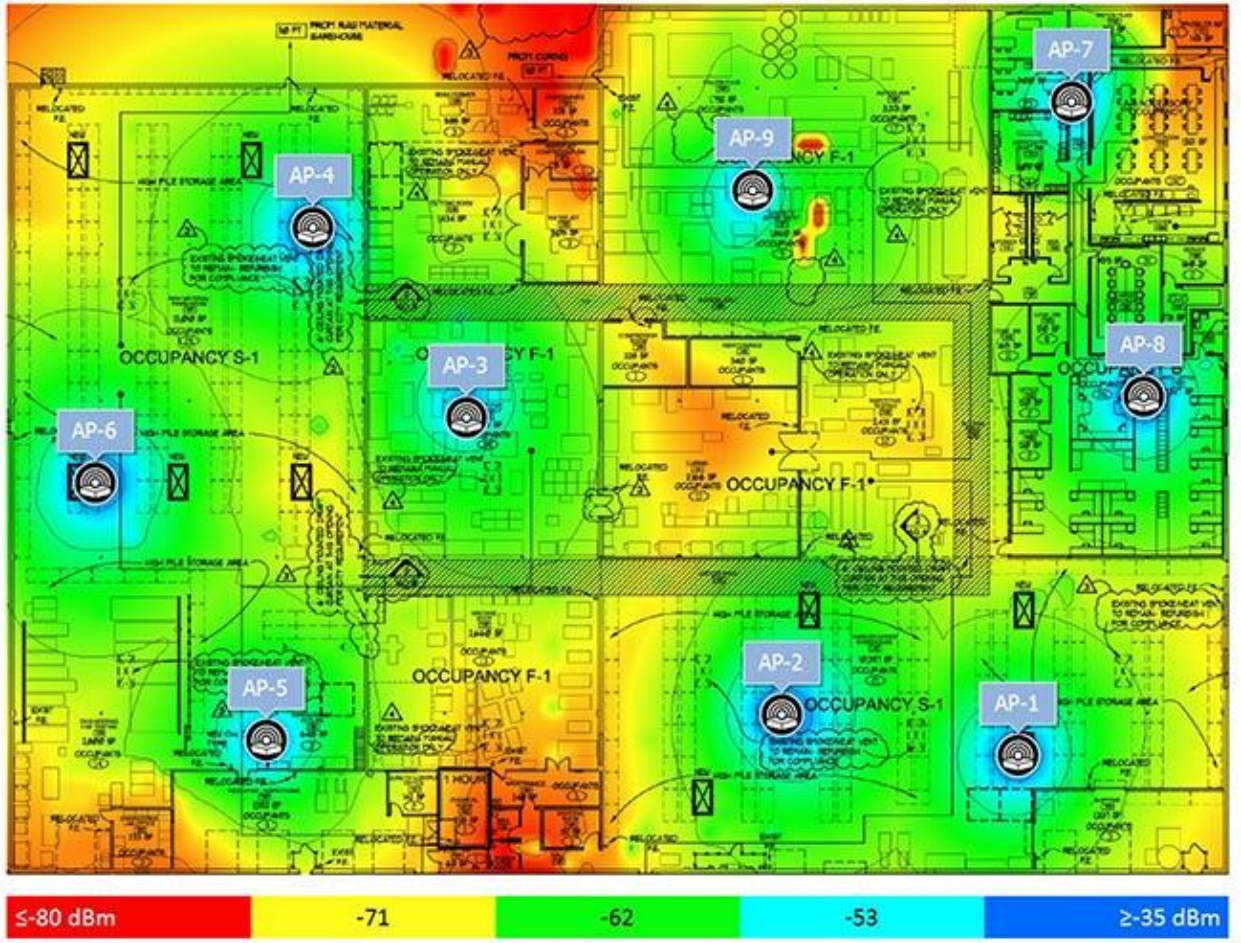
- Physical On site investigation to get more details
  - Walls materials – Ceiling High and obstacles
  - RF Environments and Interference sources
  - AP Installation restrictions & Aesthetics
  - Cable availability to AP locations
- AP on-Stick survey for testing real signal coverage
- Checking network infrastructure
- AP initial location could be marked

**Note :**

- Step 1 and Step2 could be done at same visit
- Some time this step is not applicable if site still under constructions so skip to next step
- In This case should get AutoCad to know walls material

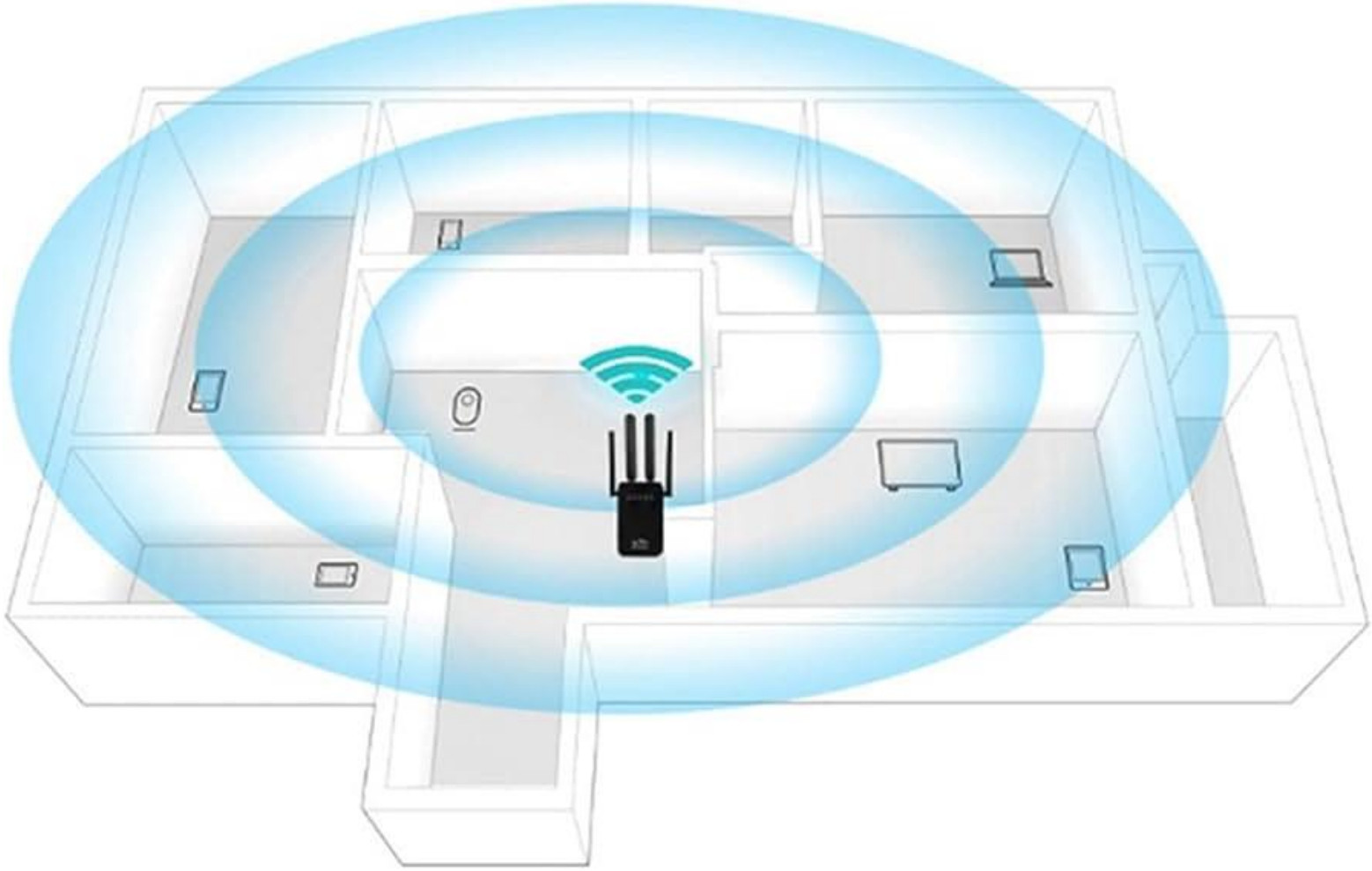
# Step 3 : Planning

- **Predictive** way to find expected WLAN performance and AP Locations
- Coverage and Capacity Analysis
- Using WLAN Planner software as
  - EKAHAU - AirMagent - IBWAVE
- Each Vendor have it’s own software
- HeatMap showing signal level with color indicator on floor maps
- Get More Details as Interference – Channel Map – TX Power



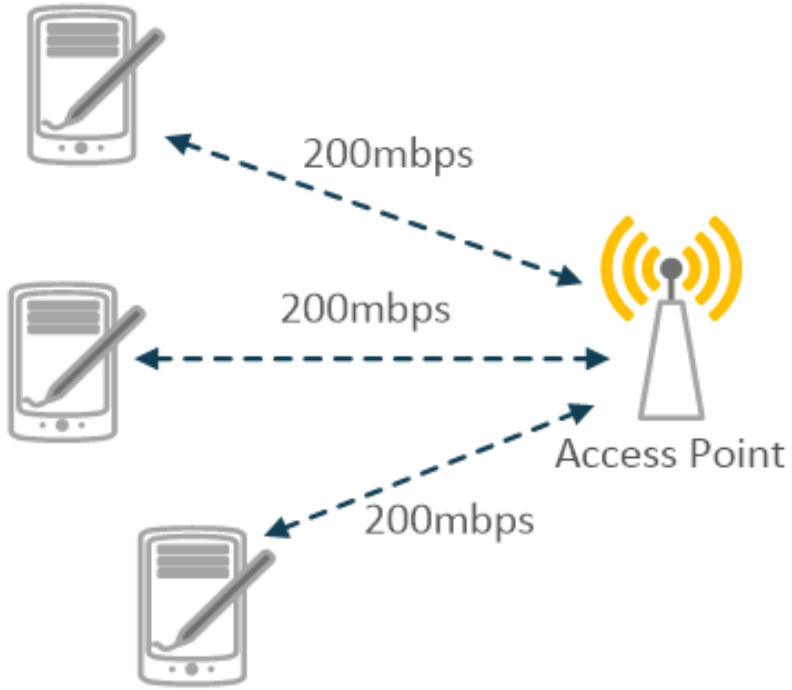
# Coverage vs Capacity

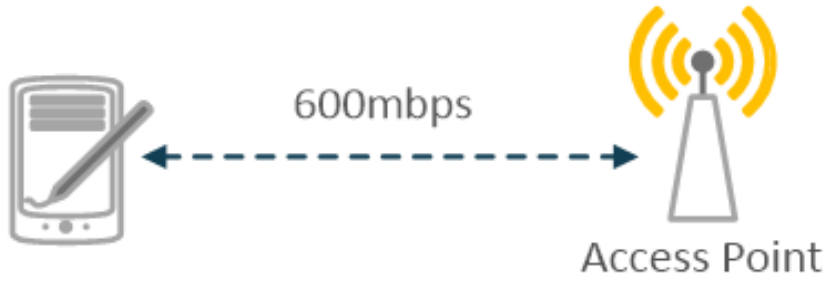
- Old School WI-FI depend on Providing good signal for large space without consideration for Data Rate and user count



# Coverage vs Capacity

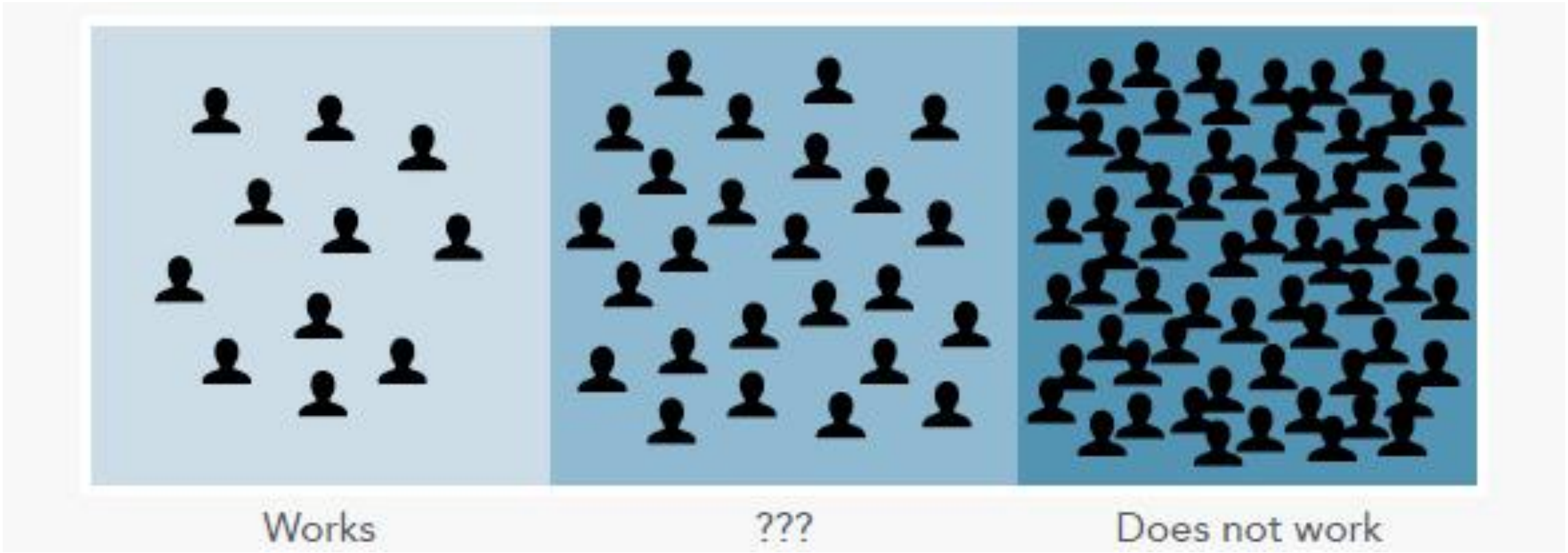
- WLAN is shared medium – so with more clients connected to same AP , final per user throughput will be decreased
- Same area could be covered with one AP only or multiple AP based on no of client and devices and application usage



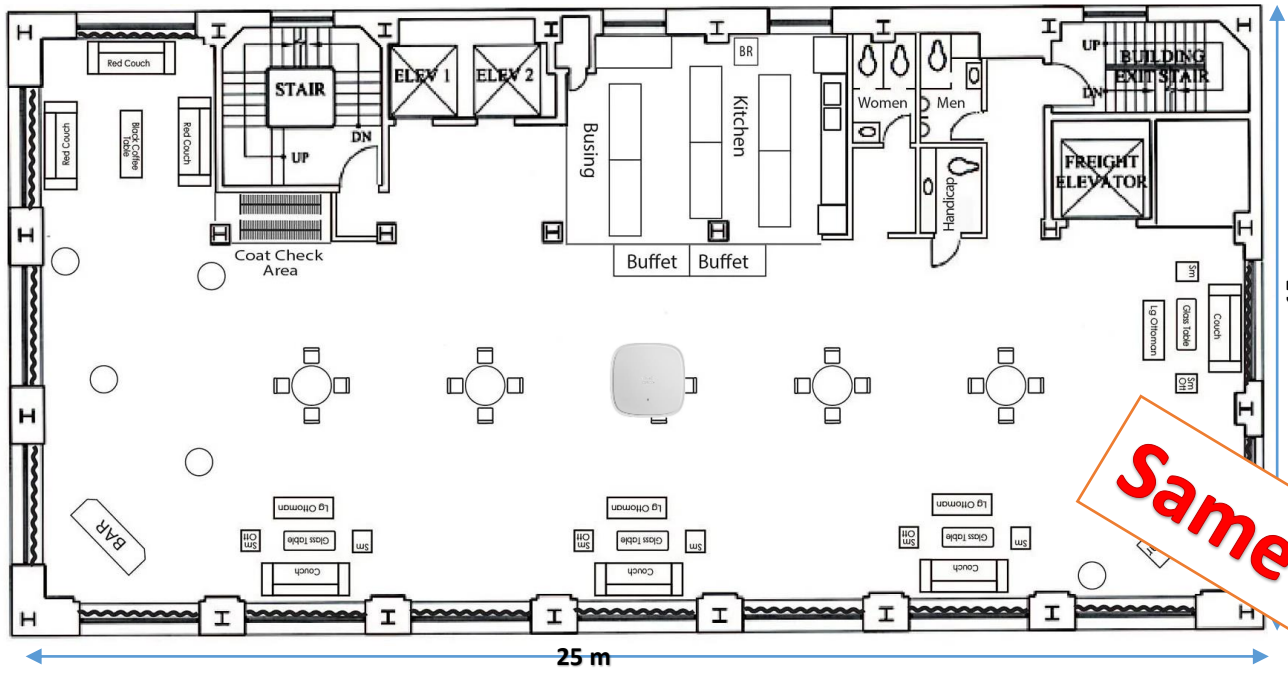



# Coverage vs Capacity

- WI-FI is shared medium and with more clients connected at Same AP will get fewer data rate and more slowness
- With increasing demand for WI-FI and new Giga speed technology should consider client load on AP



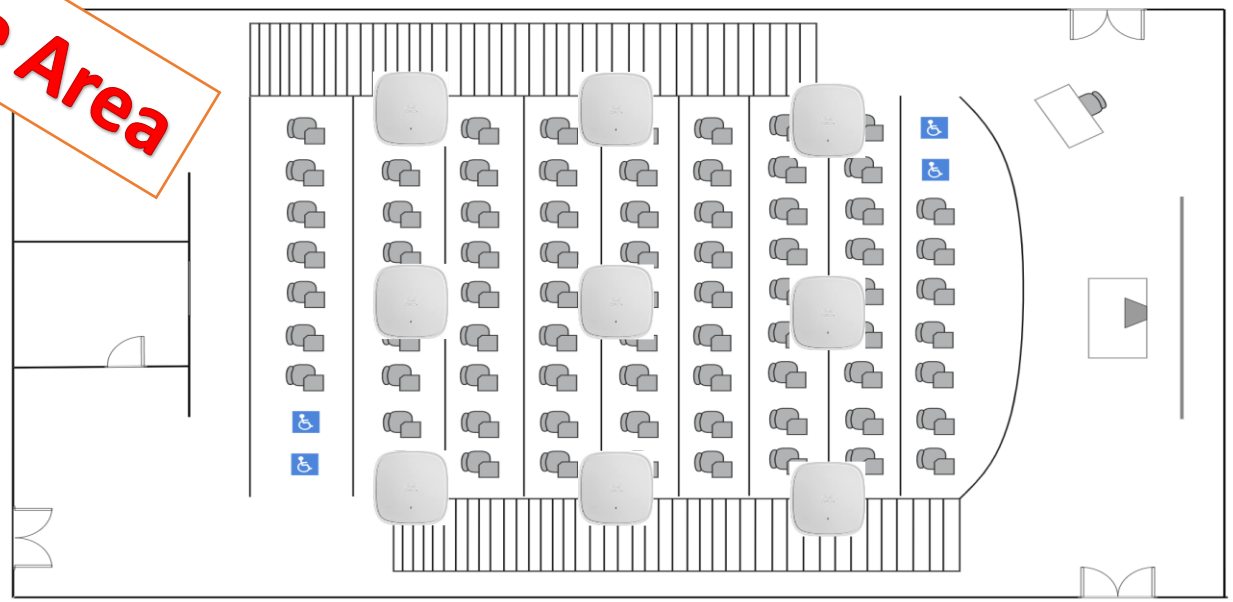
# Coverage vs Capacity




**20 Clients**
**1 AP Will be enough**

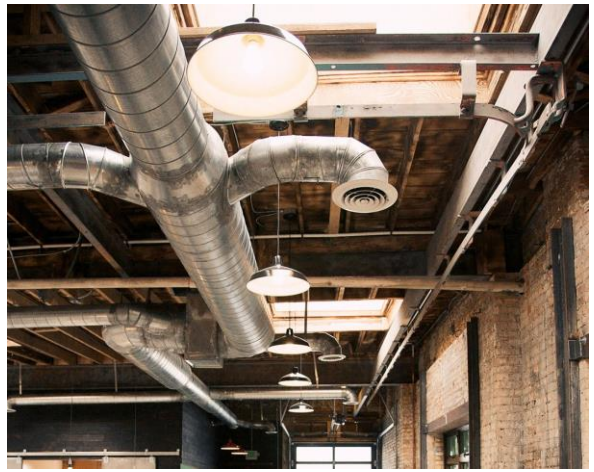
**Same Area**

**250 Clients**
**More AP required**



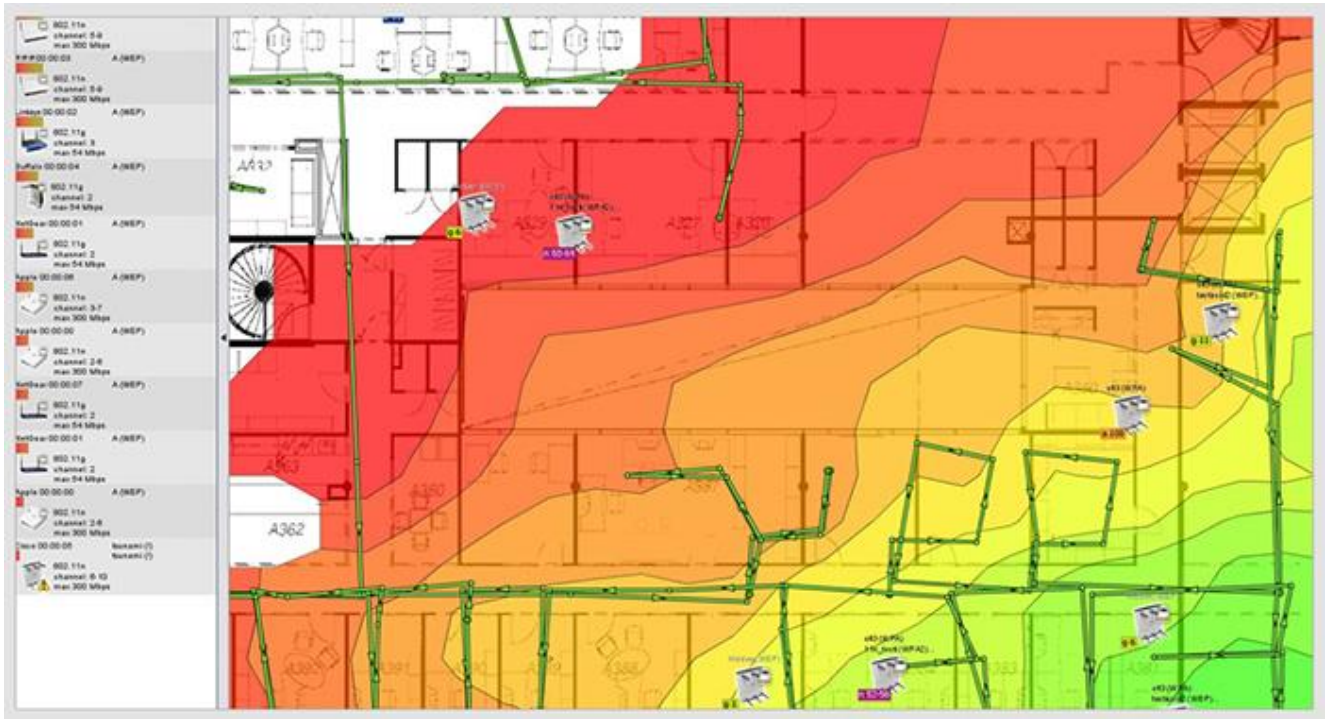
# Step 4 : Deploy

- Installation for AP as per Planning generated HeatMap
- Should be careful for AP mounting location to keep aesthetics and avoid restriction
- This was checked and agreed during step 1 ( survey )



# Step 5 : Validation

- Find real WLAN performance
- Wake Test at all Coverage Area
- Get real analysis as Signal Level – Inference – Data Rate - Roaming
- Using Tools as EKAHAU Sidekick
- Generated result should be compared with Planned HeatMap
- Fine tuning and troubleshooting to get better performance as planned



# Step 5 : Validation

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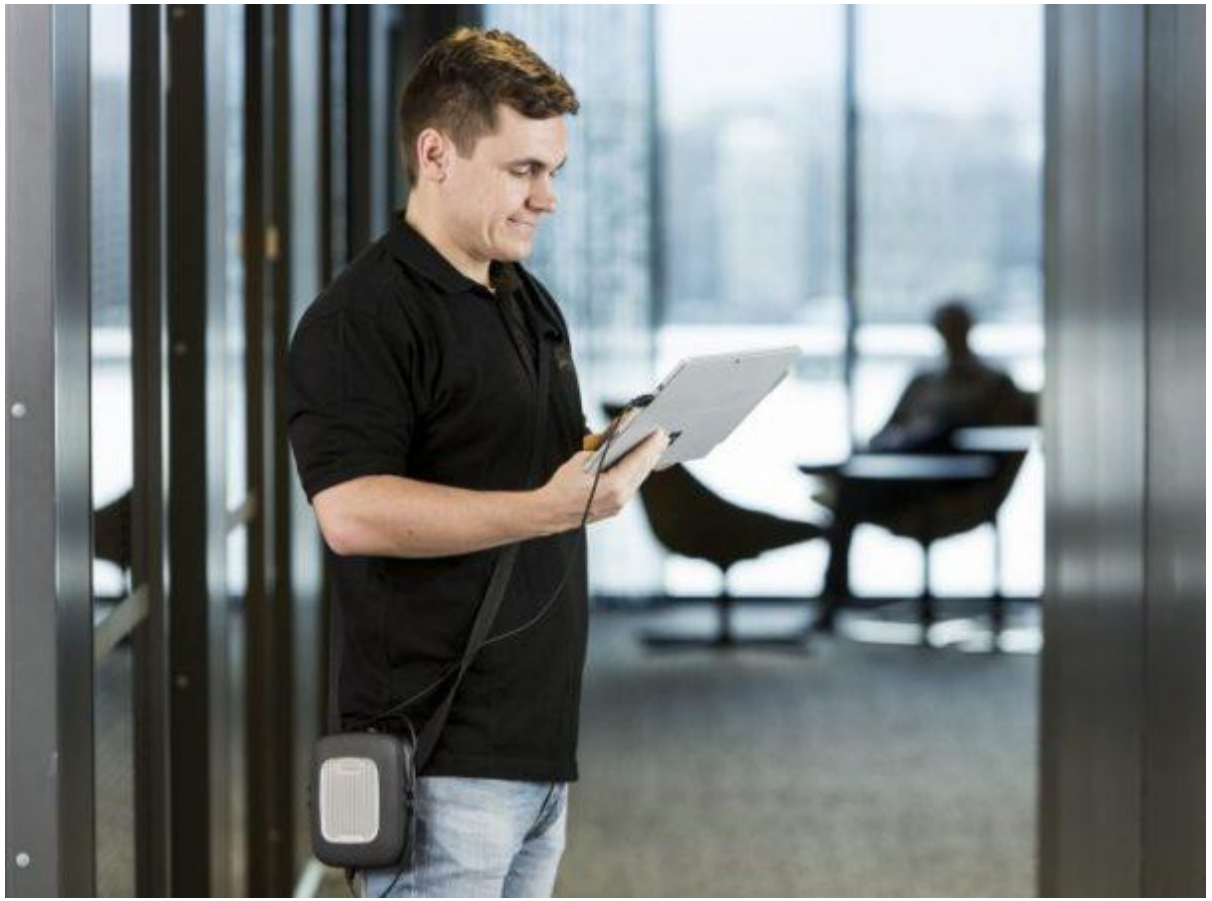
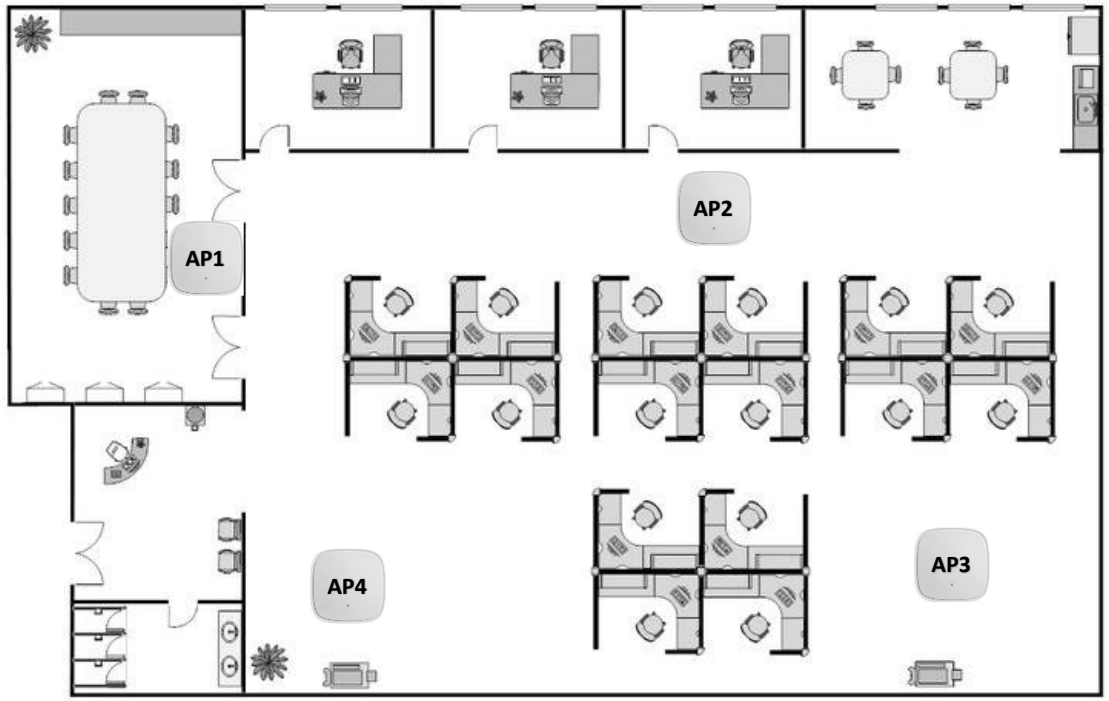


# Step 6 : Documentation

- Documents for every thing
  - AP Model and Antenna
  - AP Labeling sheet
  - AP Location MAP
  - AP Connectivity sheet
  - Post Assessment Report
- Some time AP is hidden above ceiling so need accurate AP location MAP for maintenance

| Area | AP Name | Model | Antenna | Connection |
|---|---|---|---|---|
| Floor 1 | Site-F1-AP1 | AP-505 | Built In | CAB1-SW1-P1 |
| Floor 1 | Site-F1-AP2 | AP-504 | ANT-456 | CAB1-SW1-P2 |
| Garden | Site-G-AP2 | AP-575 | Built In | CAB2-SW1-P1 |



# Design Worst Mistakes

- Skip accurate design and Allocate AP with eye vision as equal circles
- Depend of predefined templates to estimate no of AP ( 1 AP /50 mt sq )
- Ask very few questions
- Skip going to site for physical survey
- Consider coverage without capacity
- Skip validation and fine tuning
- No time for documentation


# Wireless Training
# Part 4-Session 4

# WLAN DESIGN & SURVEY

## Step 1-Define Requirements


# Session 4 : Step 1 : Define

## Index

# WLAN Design Steps

## Define

- Collect information about client requirements

## Survey

- Physical Investigation for coverage Area

## Planning

- Predicative analysis for WLAN performance

## Deploy

- Installation as per proposed Plan and site Survey

## Validate

- Checking real WLAN performance and fine tuning

## Document

- Note all details and steps for evaluation and maintenance

# Step 1 : Define


**Why You Need Wi-Fi ?**

**Where Do you need WI-FI ?**

**How You Expect Wi-Fi ?**

**What is Available Budget**

---

**High Speed Internet**

**Every Where**

**Almost Free**

# Main Wi-Fi Design Questioner

## Business Requirements

Understanding how a network will be used makes it easy to translate business needs into the specific inputs for your design software.

> What are the different types of devices that will need to connect to Wi-Fi? How many of those devices need concurrent access? What is the least capable, most important device for your business?

The answers to these questions will help you translate your business needs into Wi-Fi Design requirements for:

1. Coverage »
2. Capacity »
3. Least Capable, Most Important Device »

## Environmental RF Requirements

The physical environment plays a big role in how a network performs. Turn to the site floor plan and walk the site to gather information to help you identify the radio frequency (RF) behavior in your environment.

> How high are ceilings in the coverage area? Is there sufficient access to mount access points? What are the walls made of? How noisy are the neighboring networks?

The answers to these questions will help you translate environmental factors into RF requirements for:

4. Obstacles in the Physical Environment »
5. Wall Material Attenuation »
6. RF Spectrum Activity »

# Define – Collecting Information

| | |
|---|---|
| **Business Requirements** | Understand why & where they need Wi-Fi - if there is special features needed |
| **Coverage Requirements** | Which Area , Floors need to be Covered or could be excluded – Special Area |
| **Capacity Requirements** | Know who will use Wi-Fi – Expected no of users – Device Type – Special Devices ( VOIP – Medical – Barcode ) |
| **Physical Environments** | Check wall material – Ceiling High – AP Mounting Constrains – Aesthetic Rules & Existing Interference |
| **Ask all Stakeholders** | Decision Maker – IT - WLAN Users as Doctors – POS at Restaurant – Barcode at Warehouse |
| **What is Project Budget** | To make correct selection for the suitable solution and products |
| **Network Infrastructure** | Check network switches – cabling – POE – Uplinks – Connection Port Speed |

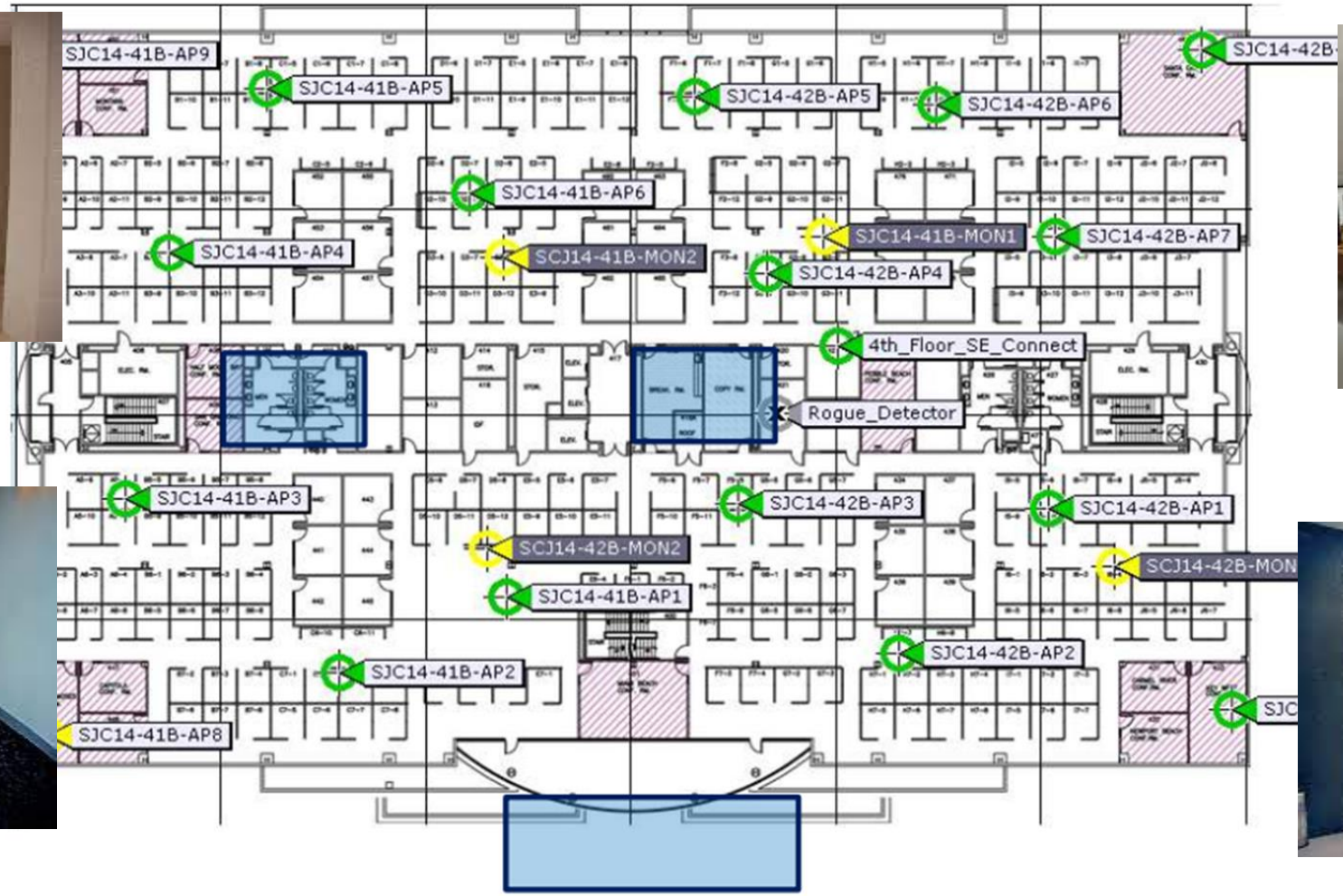
# Business Requirements


Coverage → Roaming → Data Rate → Capacity

**Each Customers have Different Requirements**

# Determine Coverage Scope

- Talk to end-users. Think what they will need and when, look for roaming paths




# Determine Business Application

Heavy Load

Internet Only


Normal Load


Rare Roaming Expected

# Application Requirements

| Application by Use Case | Nominal Throughput |
|---|---|
| Web - Casual | 500 kilobits per second (Kbps) |
| Web - Instructional | 1 Megabit per second (Mbps) |
| Audio - Casual | 100 Kbps |
| Audio - Instructional | 1 Mbps |
| On-demand or Streaming Video - Casual | 1 Mbps |
| On-demand or Streaming Video - Instructional | 2-4 Mbps |
| Printing | 1 Mbps |
| File Sharing - Casual | 1 Mbps |
| File Sharing - Instructional | 2-8 Mbps |
| Online Testing | 2-4 Mbps |
| Device Backups | 10-50 Mbps |

# Application Requirements

**TABLE 13.2** Applications and TCP Throughput Consumption

| Application | Required Throughput |
|---|---|
| Email/web browsing | 500 Kbps to 1 Mbps |
| Printing | 1 Mbps |
| SD video streaming | 1 Mbps to 1.5 Mbps |
| HD video streaming | 2 Mbps to 5 Mbps |

# Application Requirements

- VoIP – 100-1500 Kbps, 10% utilization
- E-Mail – 50-100 Kbps, 10% utilization
- Messaging – 5-20 Kbps, 5% utilization
- Data transfer – 1-10 Mbps, 10-20% utilization
- Database access – 100-500 Kbps, 10-15% utilization
- Web browsing – 500-1000 Kbps, 15-25% utilization

# Client Devices Capability and Roaming

- Continuous roaming events
- Device in-use while roaming
- Users/apps expect roaming transitions to be undetectable
- APs must continually balance client load
- APs must provide consistent performance across dynamic range of received signal strengths
- Devices more likely to encounter RF interference

Increased Need for Roaming Support

Stationary Devices

Wireless Scale

Somewhat Mobile Devices (SMD)

Laptop

Highly Mobile Devices (HMD)

# Wireless Clients Needs

1. How many devices will each user have? Today, **Aruba recommends** that you plan for at **least three devices** per user: a laptop, a tablet, and a smartphone.
2. The **number of devices** per user also has ramifications in the design of **VLANs and subnets**.
3. Consider if all devices will be **active simultaneously**, which also impacts AP density.
4. What is the **maximum number** of devices desired for **each AP**? Typically, **Aruba recommends 20–30 devices** per radio **(40–60 per dual-radio AP)**.
5. This **number** may be more or less depending on traffic type (voice or data), offered load, & connection type (802.11a, b, g,n)
6. What **applications** will be in use at the site, both **presently** and in the **future**? Bandwidth requirements help determine **coverage versus capacity** requirements.

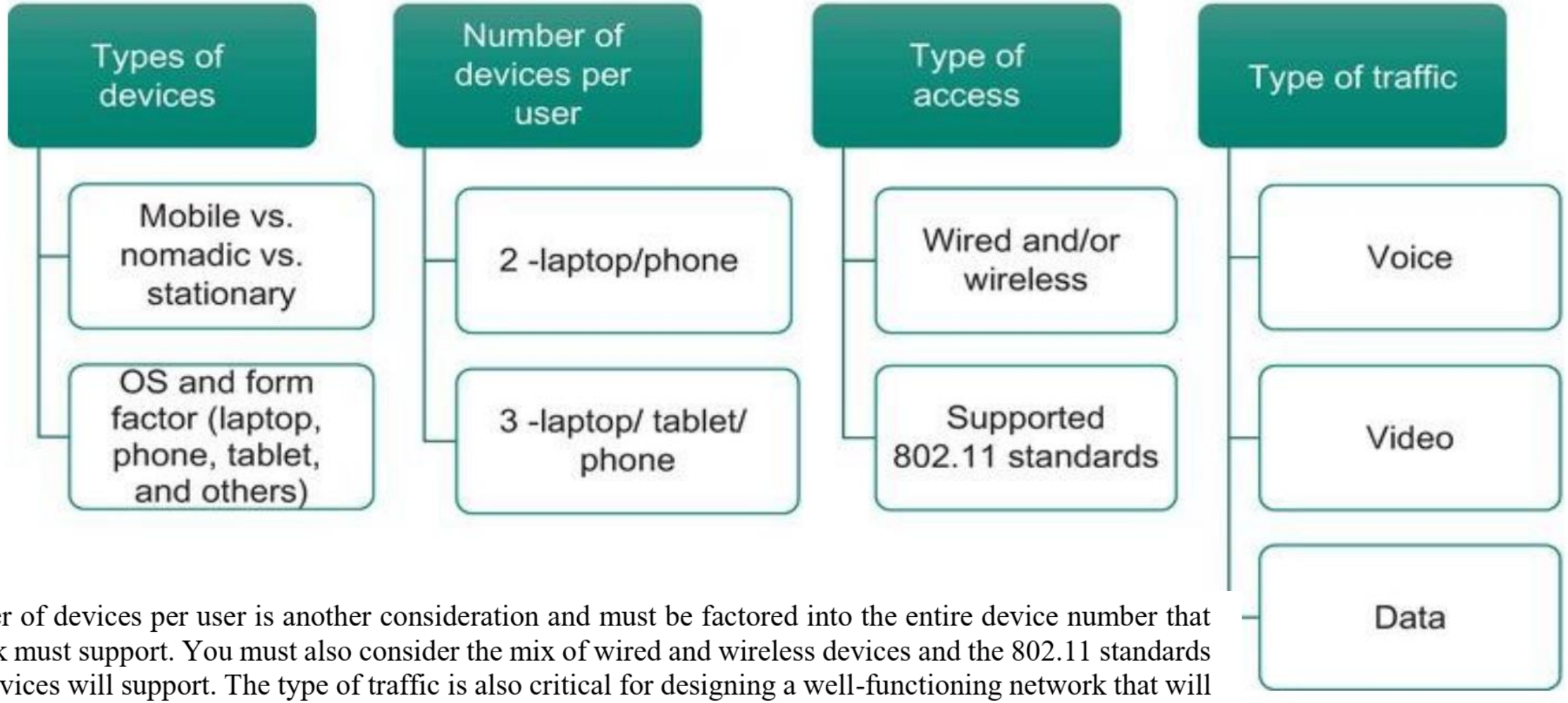
4. Are any **floor plan** images available? VisualRF Plan supports direct importation of JPEG, GIF, PNG, PDF, and CAD (.dwg and .dwf) files for floor plan formats.

5. What is the **maximum transmit power** of the **least-capable** common device in the network?

6. How many **transmit**, **receive**, and **special streams** do the most common devices support?

7. If **DFS channels** are being considered, do the devices most commonly used in the network support DFS channels?

# Wireless Clients Needs

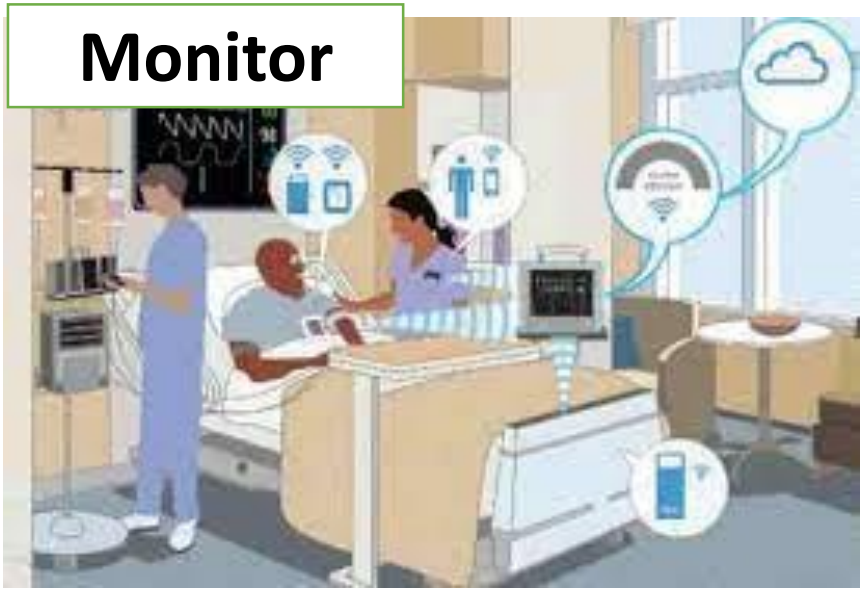



The number of devices per user is another consideration and must be factored into the entire device number that the network must support. You must also consider the mix of wired and wireless devices and the 802.11 standards wireless devices will support. The type of traffic is also critical for designing a well-functioning network that will support the number of devices and applications.

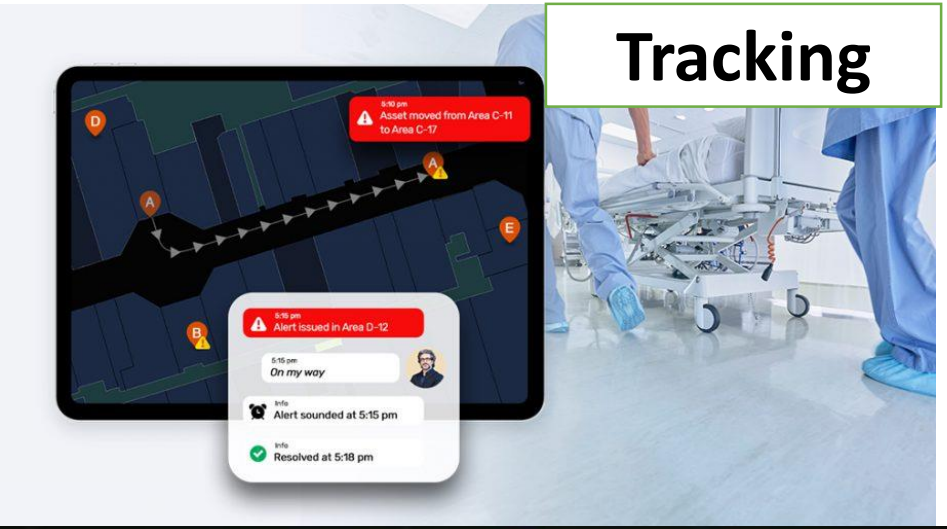
# Example Health Care

Internet

Monitor



Tracking




Calling


GAZA RAB

# Example Hotels Guest Rooms

Bed Room

Bath Room

Balcony

Different
AP Distribution

# Determine Different Area Needs


Dedicated AP


High End AP


Special Antenna


Outdoor AP

# Check Walls Material


More AP

**Specific Antenna**
**Avoid Interference**



Less AP

# Aesthetics and Restrictions

**Avoid Ceiling Decoration**
**Check Cable Paths**

**Or Could be Fixed at Walls**

**Can Hide AP above ceiling**
**If Gypsum away from metals**

# Balance Coverage & Aesthetics

You may find yourself having an awkward conversation when you say:

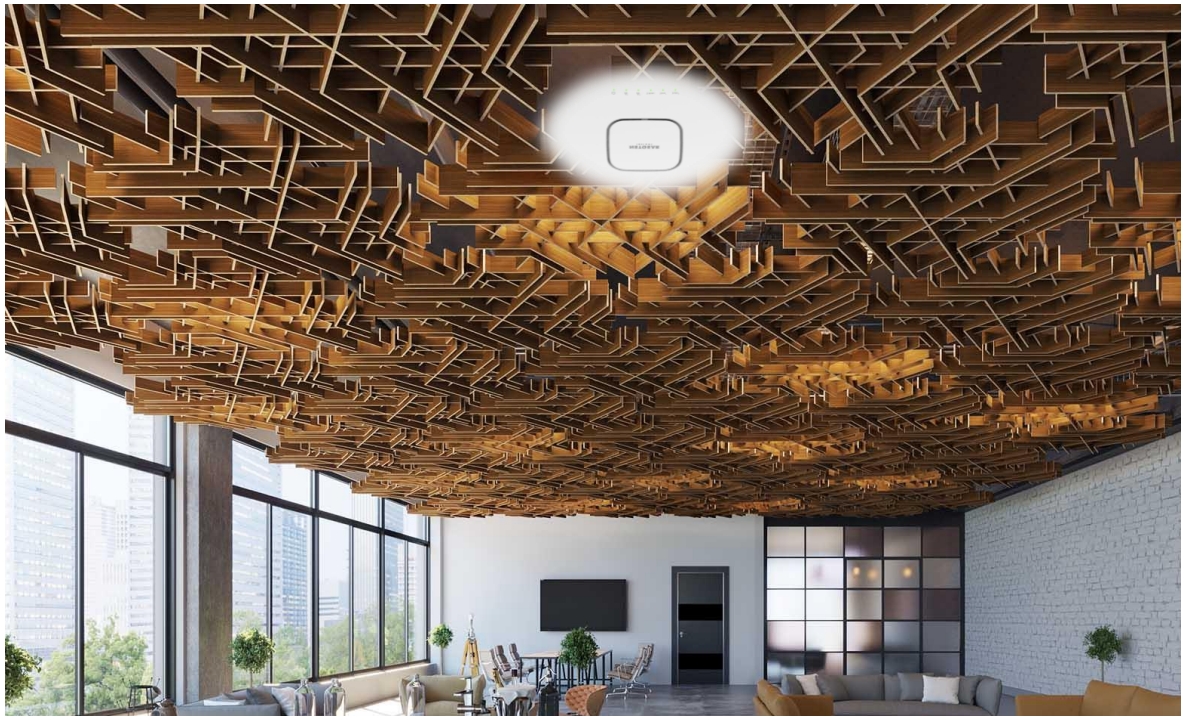
> I'd like to place an AP right here.

No, no you can't do that.

> But why not?

**Because it would look ugly.**

> If you want reliable Wi-Fi for your customers/ employees, then we need to put an AP somewhere in this area.



**Should Avoid Metals**
**AP could be covered with same color**

# Balance Coverage & Aesthetics

You may find yourself having an awkward conversation when you say:

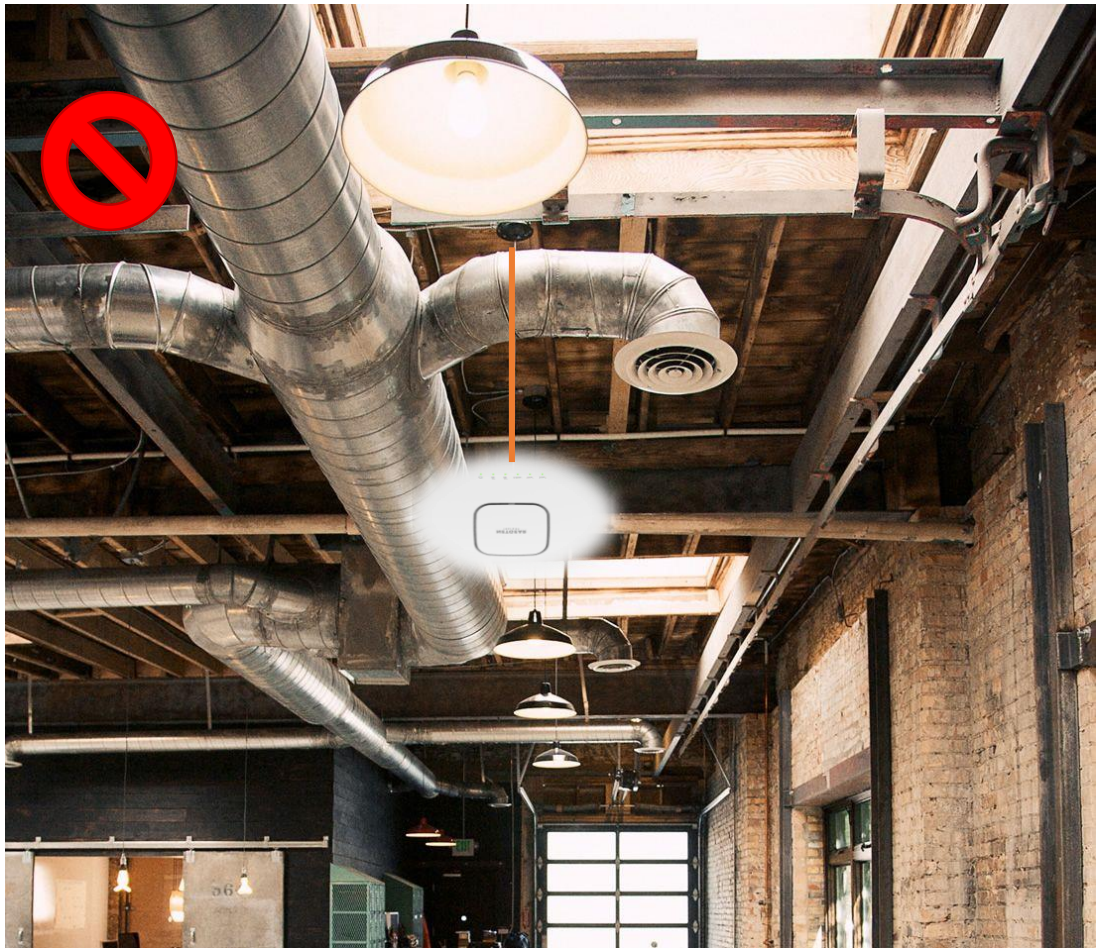
> I'd like to place an AP right here.

No, no you can't do that.

> But why not?

**Because it would look ugly.**

> If you want reliable Wi-Fi for your customers/ employees, then we need to put an AP somewhere in this area.



**AP need to be hanged with Poles Away from Metal Ducts**

# Wireless RF Questionnaire

1. What **802.11 PHY** types are required over the course of the **WLAN** lifecycle (802.11a/b/g/n/ac/ax)?
2. Which **RF** bands (**2.4 GHz, 5 GHz**) will be used? Plan to use both bands due to high client density.
3. What channel width (**20 MHz vs. 40 MHz**) will be used in each band? Typically, **20 MHz** channels are used in **2.4 GHz**, and **40 MHz** channels are used in the **5 GHz** band.
4. Will **voice over** Wi-Fi be used? This answer will affect your planning for **roaming** and access point (AP) signal strength calculations.
5. Will **multicast video** over Wi-Fi be used? Use of roaming video has a similar effect as voice.
6. What is the **minimum desired PHY-layer** data traffic rate that must be available throughout the coverage area? Do some areas have **different minimum data** rate needs?
7. What are desired **Air Monitoring** rates Are dedicated **AM** required for security or compliance purposes?

# Translate Requirement into Design

| | |
|---|---|
| Coverage | APs placed and coverage visualized on a scaled floor plan with accurate walls |
| Capacity | Usage and device profiles identified listing applications and client models in use |
| Least Capable, Most Important Device | Device profile created for the LCMID |
| Obstacles in the Physical Environment | Ceiling heights set & deployment notes cited to account for obstacles |
| Wall Material Attenuation | Appropriate wall types used throughout the floor plan including custom created wall types |
| RF Spectrum Activity | A channel plan that reduces co-channel interference and optimizes client performance |

# Translate Requirement into Design

## A bad set of requirements looks like this:

- Wi-Fi everywhere
- Super fast

## A good set of requirements looks like this:

- Minimum -67 dBm of signal strength
- Minimum signal to noise ratio of 20 dB
- Minimum data rate (signaling rate) of 24 Mbps
- Minimum of two APs audible at -75 dBm
- Maximum of two APs sharing the same channel above -85 dBm

# Network Requirements Sheet

| Category | Question | Answer |
|---|---|---|
| Business Requirements<br><br>To be defined by the customers key stakeholders. | Site Contact | |
| | Site Address | |
| | Business Objectives for the Wi-Fi Network<br>Define the desired outcome for the Wi-Fi | |
| | Wi-Fi Issues<br>Have you experienced any Wi-Fi-related issues? What have been the main reported problems from users? | |
| | Floors in Scope<br>List all the floors in scope | |
| | Floor Plans Provided<br>Preferably PDF or CAD | |

# Network Requirements Sheet

| Category | Question | Answer |
|---|---|---|
| Business Requirements<br><br>To be defined by the customers key stakeholders | How Many Users Per Floor<br>Please specify max expected headcount per floor / site | |
| | Areas in Scope<br>Specify areas like open office space, meeting rooms, corridors, outdoor spaces, etc. where coverage is needed | |
| | Areas Out of Scope<br>Specify areas like staircases, toilets, storage, etc. where coverage is not needed | |
| | AP Mounting Restrictions or Aesthetic Concerns<br>Specify preferred mounting areas like false ceilings, cable trays, etc.; Also specify mounting restrictions if any | |
| | Ceiling Height(s)<br>Are there varying heights? | |

# Network Requirements Sheet

| Category | Question | Answer |
|---|---|---|
| Technical Requirements<br><br>To be defined with customer & Wi-Fi Engineer | AP Vendor & Model Type | |
| | Antenna Vendor & Model Type | |
| | Device Types in Use<br>Laptops, tablets, smartphones, scanners, etc. Planning on connecting devices older than 10 years? | |
| | Devices Per User<br>How many? Typically, 2-3 in enterprise | |
| | Applications<br>Voice / Video / Basic Data / Heavy Data | |
| | Special High Density Areas<br>Specify areas like huge meeting rooms, town halls, etc. | |
| | AP Redundancy<br>If an AP goes down, do you still expect full coverage? | |

# Design Work Sheet

- Based on Network Requirements Collected
- Prepare Technical requirements for each area
- This sheet will be used as guideline for planning software and validation

| Area Type: | Minimum Target Value | |
|---|---|---|
| Specification | 2.4 GHz | 5 GHz |
| Primary Coverage | | |
| Secondary Coverage<br>(Roaming & Redundancy) | | |
| Signal to Noise Ratio (SNR) | | |
| Co Channel Interference (CCI) | | |
| Minimum Basic Data Rate (MBR) | | |
| Device Types<br>Wi-Fi Standard & number of supported spatial streams | | |
| Device Count<br>How many per floor / area | | |
| SLA<br>Bandwidth per device | | |


# Wireless Training
# Part 4-Session 5

# WLAN DESIGN & SURVEY

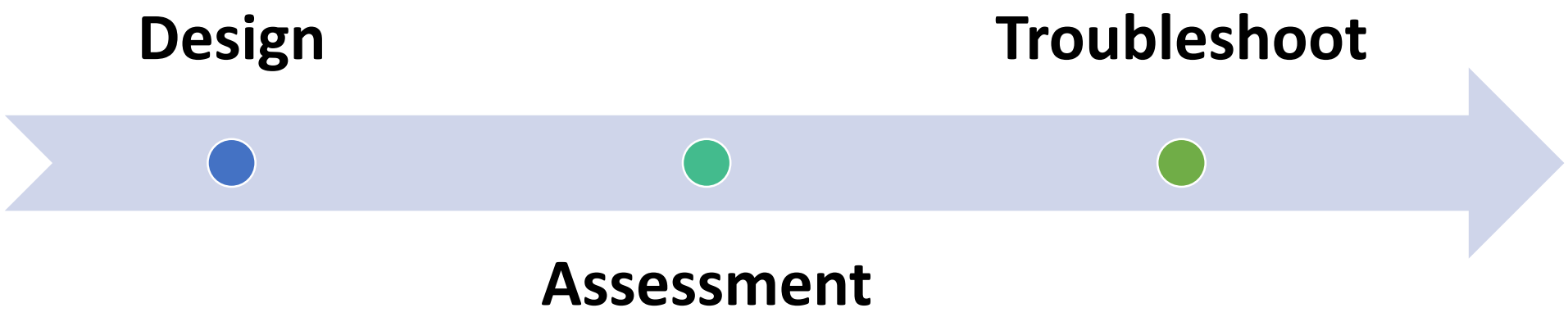
## Step 2 – Site Survey


# Session 5 : Site Survey

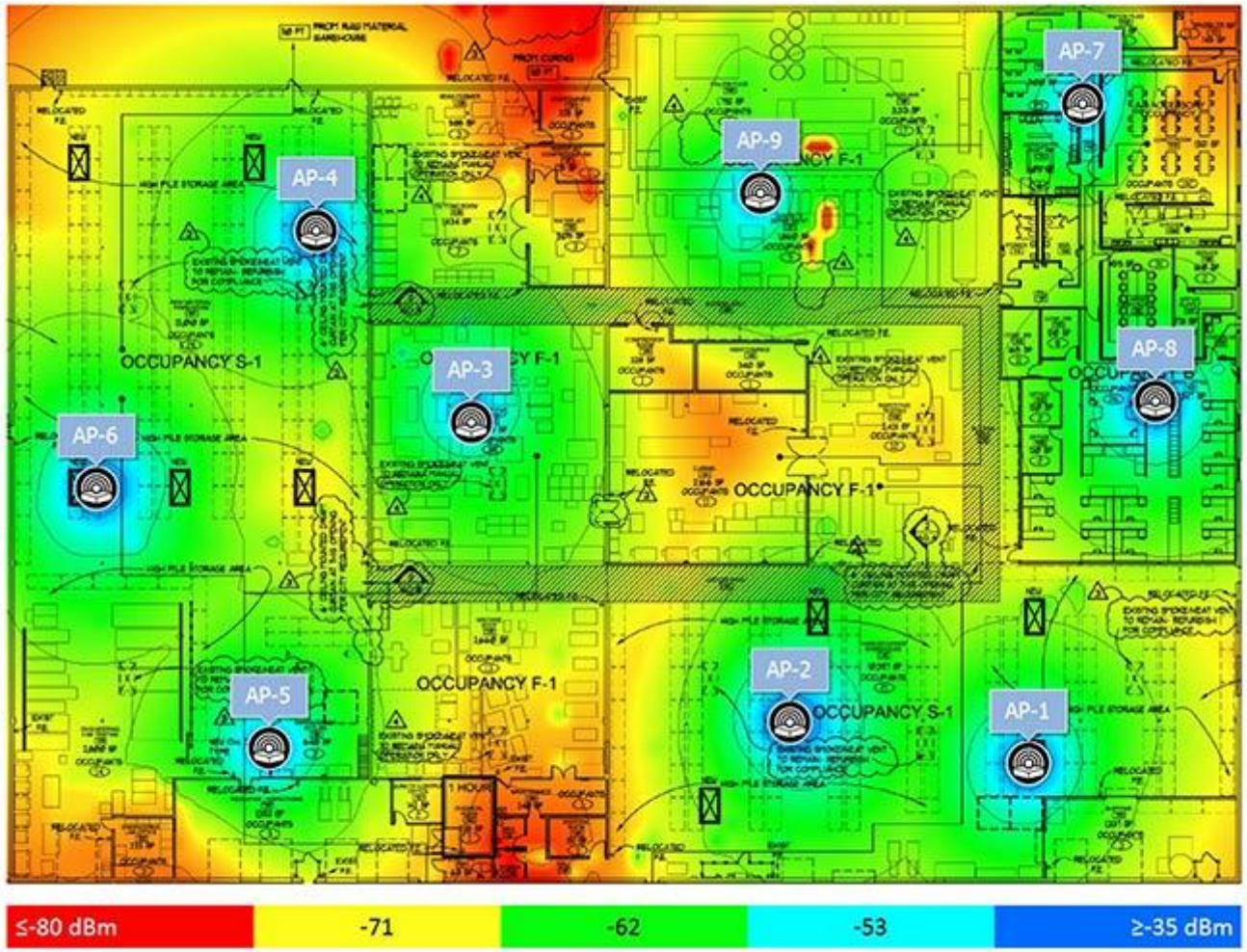
## Index

# Site Survey – WHY !!

- A Wi-Fi site survey is a site visit to capture **Wi-Fi signal** and **spectrum** data and inspect access point **mounting** and **cabling** accessibility.
- Could Estimate **how many AP** required to satisfy **customer requirements** ( **Coverage** – **Capacity** – **Aesthetics- Budget** ) with minimum cost
- Site Survey could have different purpose as



# Site Survey Results




**Output**

- AP Locations
- RSSI
- SNR
- Interference
- Throughput
- Data Rate
- Packet Loss
- Jitter & Delay
- VOICE Readiness
- Location Readiness

# Site Survey Results

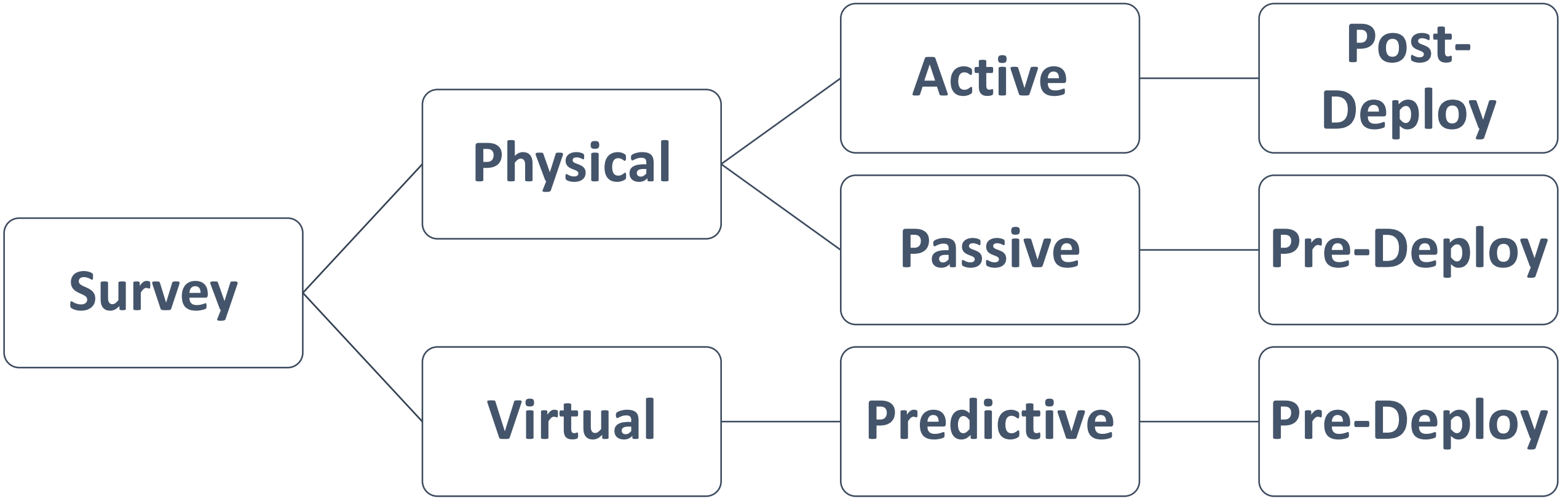
- The initial input to a wireless site survey includes a blueprint that shows the placement of walls, desks and other equipment. The survey then produces several types of output.
- It generates a heat map, which is a color-coded map that shows signal strength throughout the area based on where APs are placed.
- If the map shows that strength is too low in some places, teams can move APs or add units.
- Also Shows network noise levels, signal-to-noise ratios, interference, throughput, data rates, packet losses and retries.
- They can also display indicators of VoIP performance or Location Tracking

# Site Survey Types

| Survey Location | Collected Data | Design Phase |
| --- | --- | --- |
| • **Physical ( Manual )**<br>• **Virtual(Predictive )** | • **Active**<br>• **Passive** | • **Pre Deployment**<br>• **Post Deployment** |

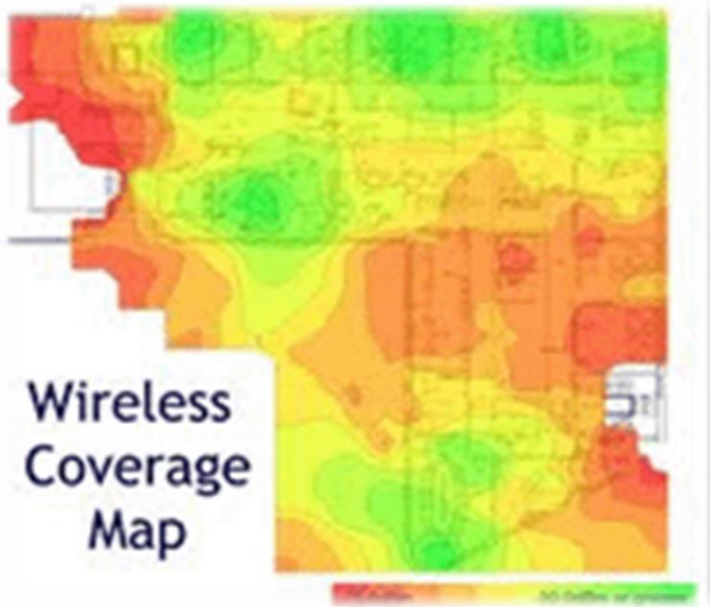
- **Virtual Survey** ( Predictive ) always pre-deployment at design phase
- **Physical** Could be pre or post deployment ( Design or Assessment )
- **Physical** Could be active or passive based on collected information and test method during survey

# Site Survey Types



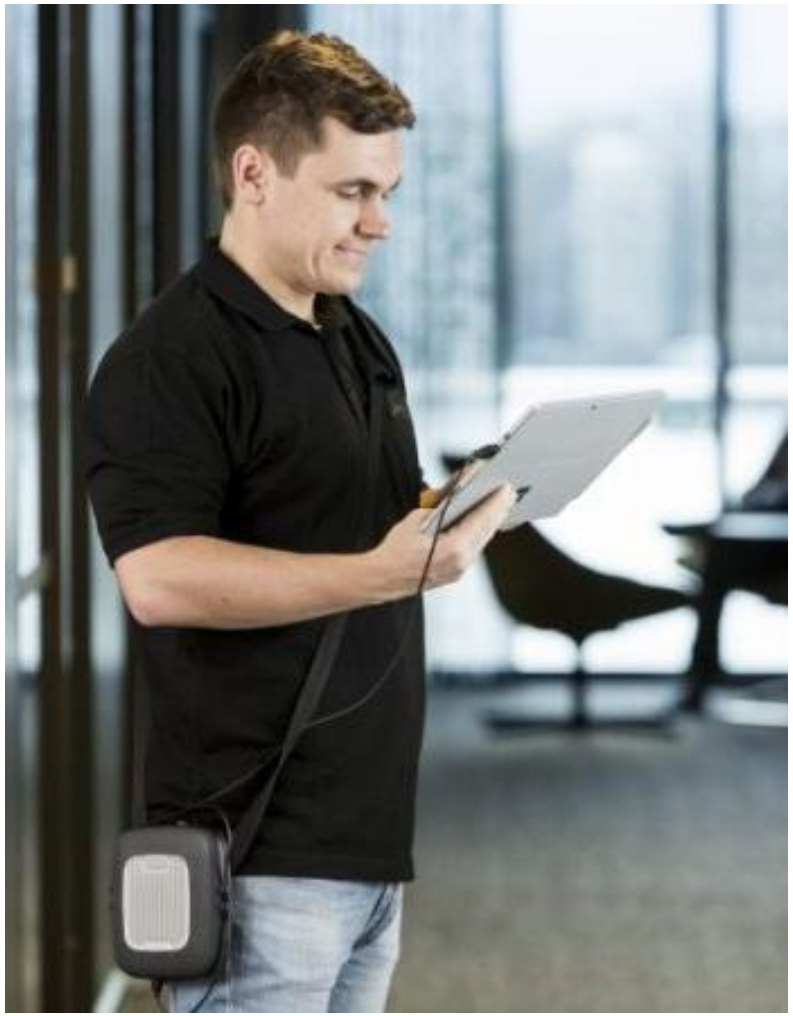
# Predictive Site Survey

- Simulated coverage and information
  - Software takes information about floor plan, building, etc and plots AP locations and expected coverage
- Can Model:
  - Channel reuse patterns
  - Coverage cell boundaries
  - Access point placement
  - Access point power settings
  - Number of access points
  - Data rates

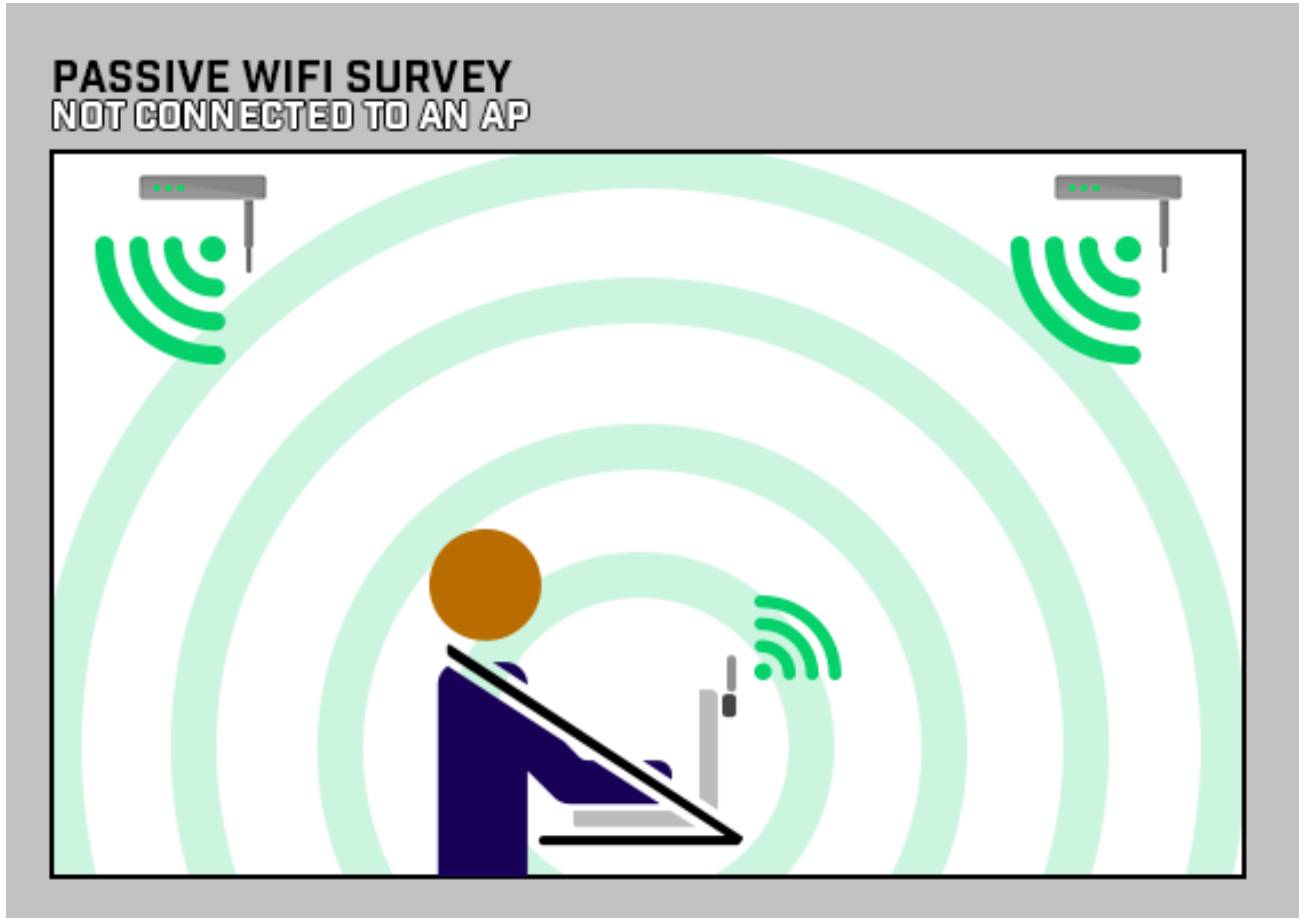


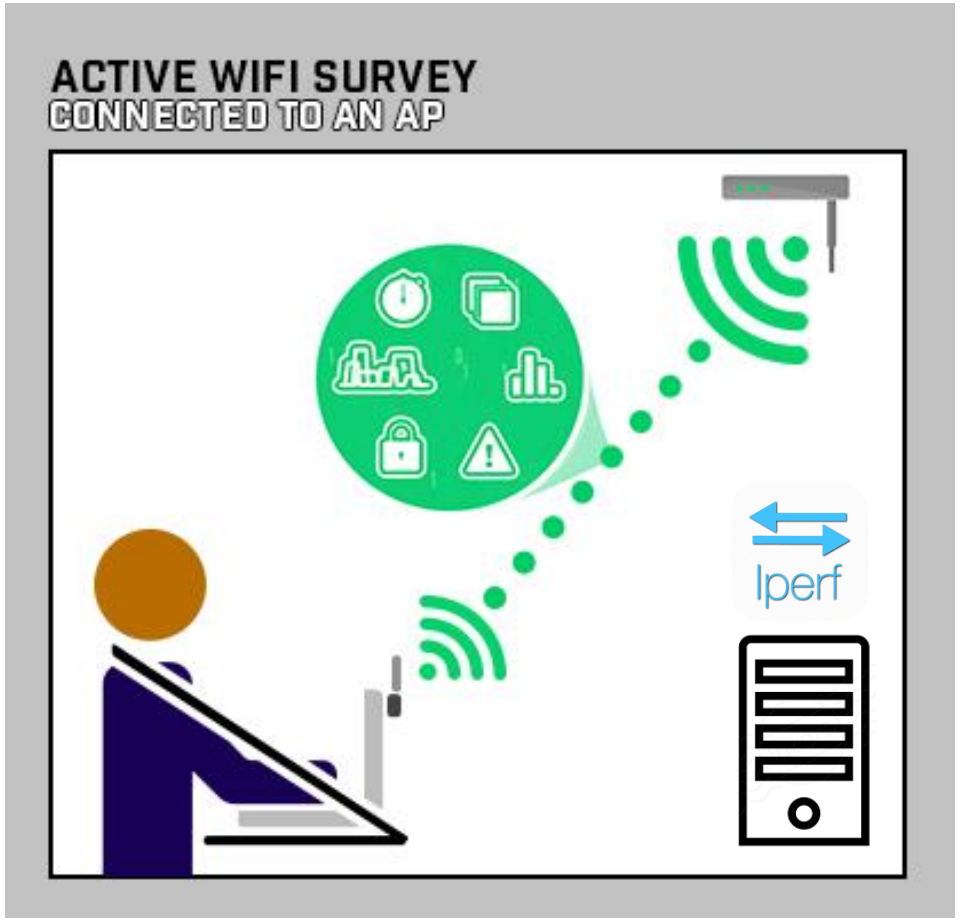
# Physical Site Survey

- **Manual site survey**: requires walking through the area of the WLAN while carrying a wireless client like a laptop or tablet computer
- Can be divided into two categories:
  - *Passive manual site survey*: client device "listens" in order to gather RF measurements such as signal strengths, noise levels, and the signal-to-noise ratio (SNR)
  - *Active manual site survey*: client device sends and receives packets to determine the status of the WLAN



# Active Vs Passive



# Active Site Survey

Client Connect to WLAN

Throughput

Ping

iPerf Server Connected to Network

Need iPerf Server

Ping GW by Default No SRV

iPerf2, iPerf3 or iperf3 Ekahau *(recommended)*

# Active Vs Passive

## Active

- Client Connect to WLAN
- Collect your WLAN RF Only
- Collect RSSI – SNR - Data Rate – Throughput – Latency – Roaming – Packet Loss
- Almost used  after deployment
- Could be used periodically for health check

## Passive

- Client not  Connected to WLAN
- Collect RF for Your WLAN and Neighbors
- RSSI – SNR – Noise – Interference
- Almost used before deployment
- Could be used periodically for health check



# Active Site Survey

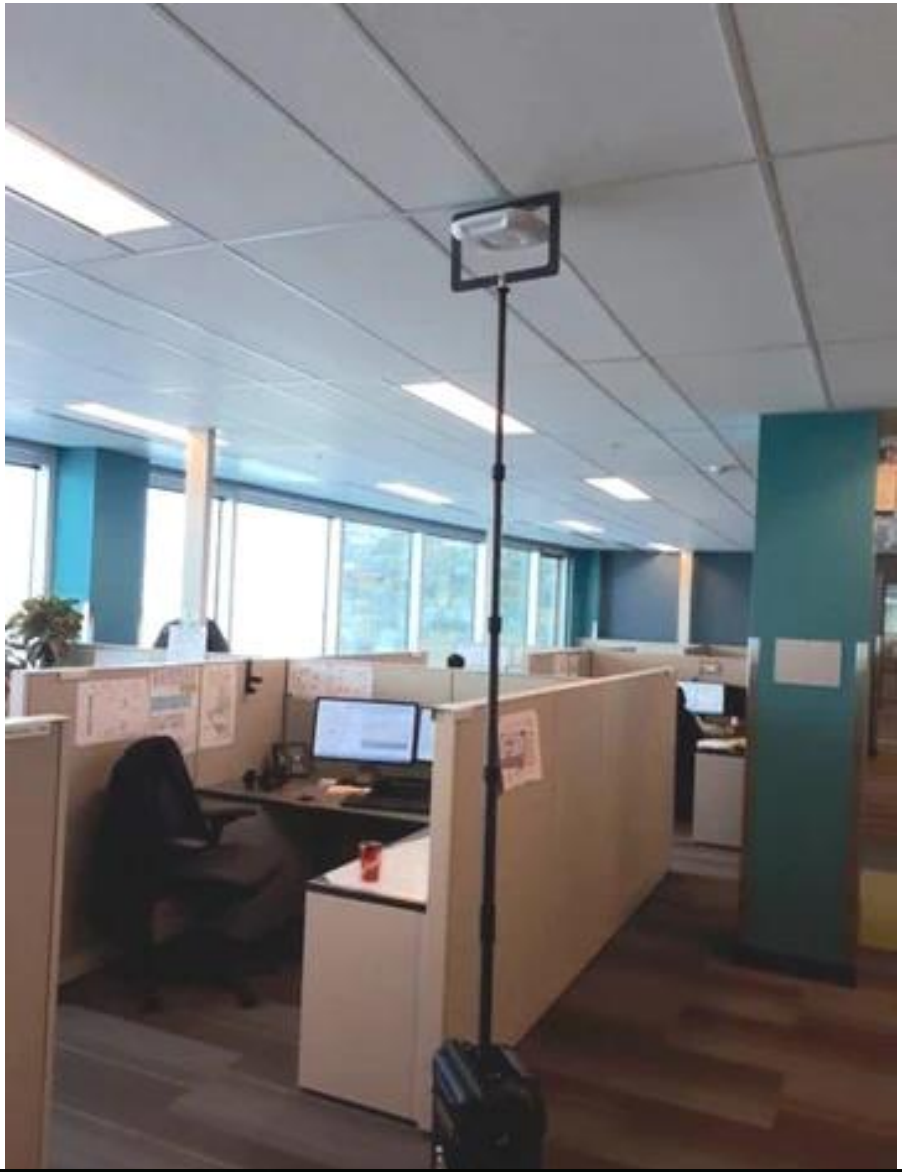
- An active WiFi survey is when a surveying device is connected to the WiFi network and records signal measurements based on the performance of the connection.
- Active surveys focus on a specific signal or set of specific signals and produce an extensive list of measurements for each AP that generates a studied signal.
- This type of survey also allows for various other metrics to be measured, as upstream and downstream data rates , ping round-trip-time (RTT), throughput using iPerf/iPerf2/iPerf3, and Internet upload/downloads.
- These measurements include signal strength, throughput, round-trip time, packet loss and retransmission rate throughout the area where the signal is used.
- Active surveys are used to troubleshoot WiFi networks.
- Might result in teams moving an AP or adding or removing an unneeded AP.
- To be able to perform throughput surveys, you will need to host an iPerf (v2 or v3) throughput server against which the active measurements are done.

# Passive Site Survey

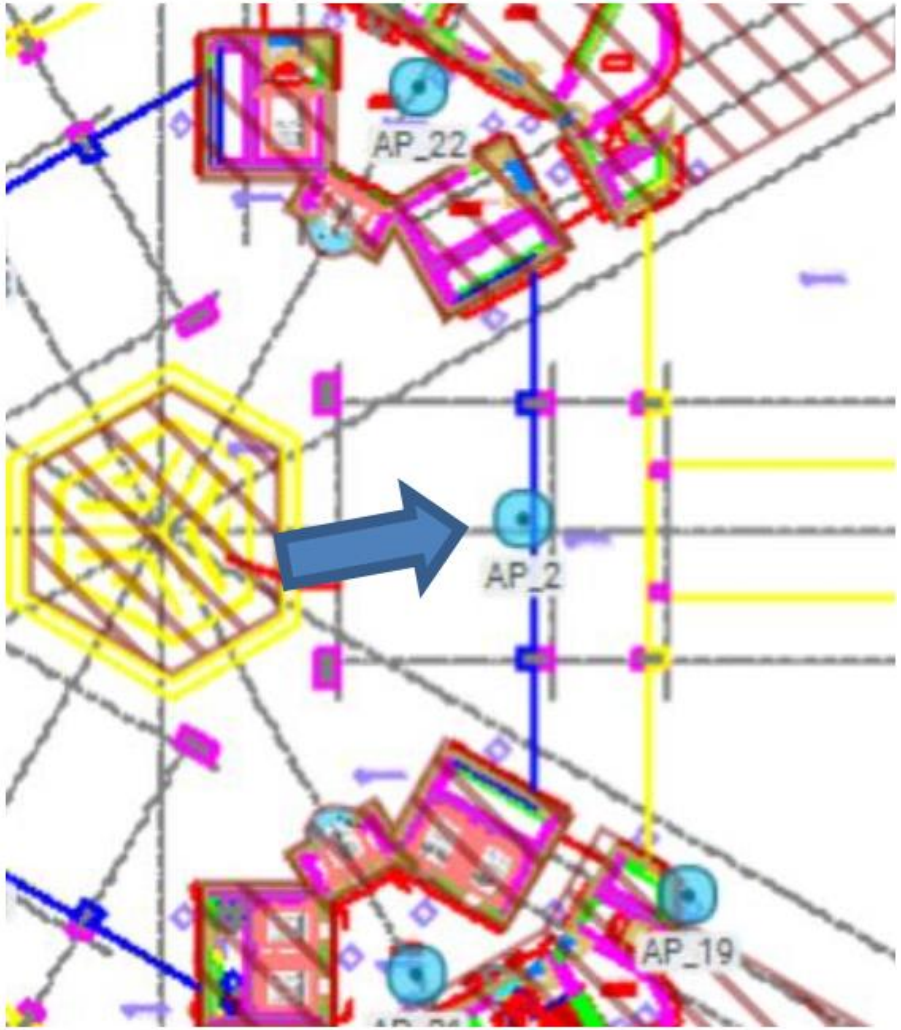
- The goal of a passive survey is to report on all signals at each location, including the installed network and signals from neighboring sites or other devices that generate noise at wireless frequencies.
- Teams should perform passive surveys periodically after they build the site, install equipment and activate the network.
- These surveys report information on APs and their characteristics, signal strength, signal-to-noise ratios and interference.
- They might reveal marginal performance changes before users notice.

# AP on Stick

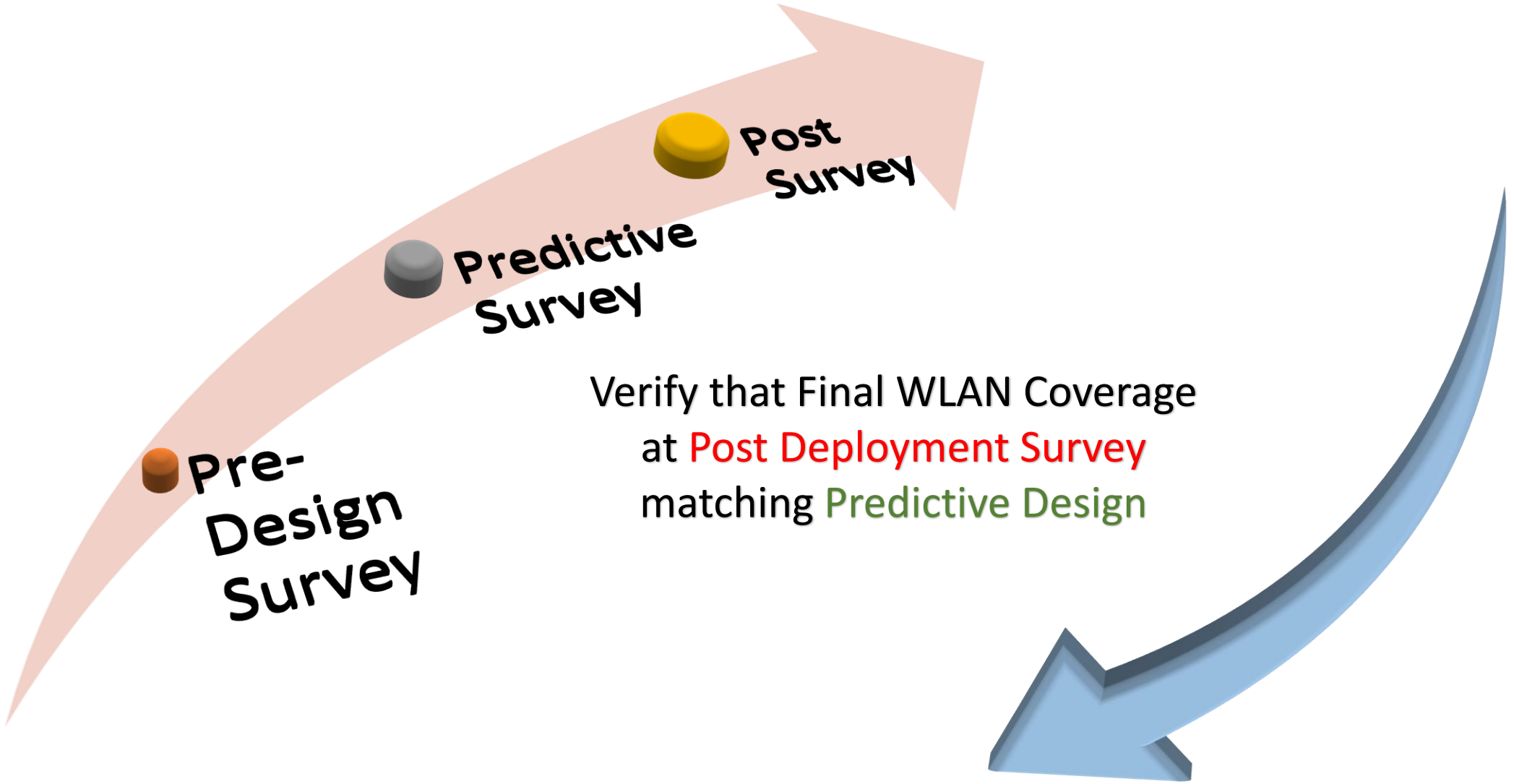
- Physical Survey used to simulate access point and antenna performance at real site
- AP is temporarily positioned in the environment, and measurements of the room and surrounding rooms are taken to measure actual signal coverage
- The results can be used to refine the predictive model by measuring actual attenuation characteristics of the walls.



# AP on Stick

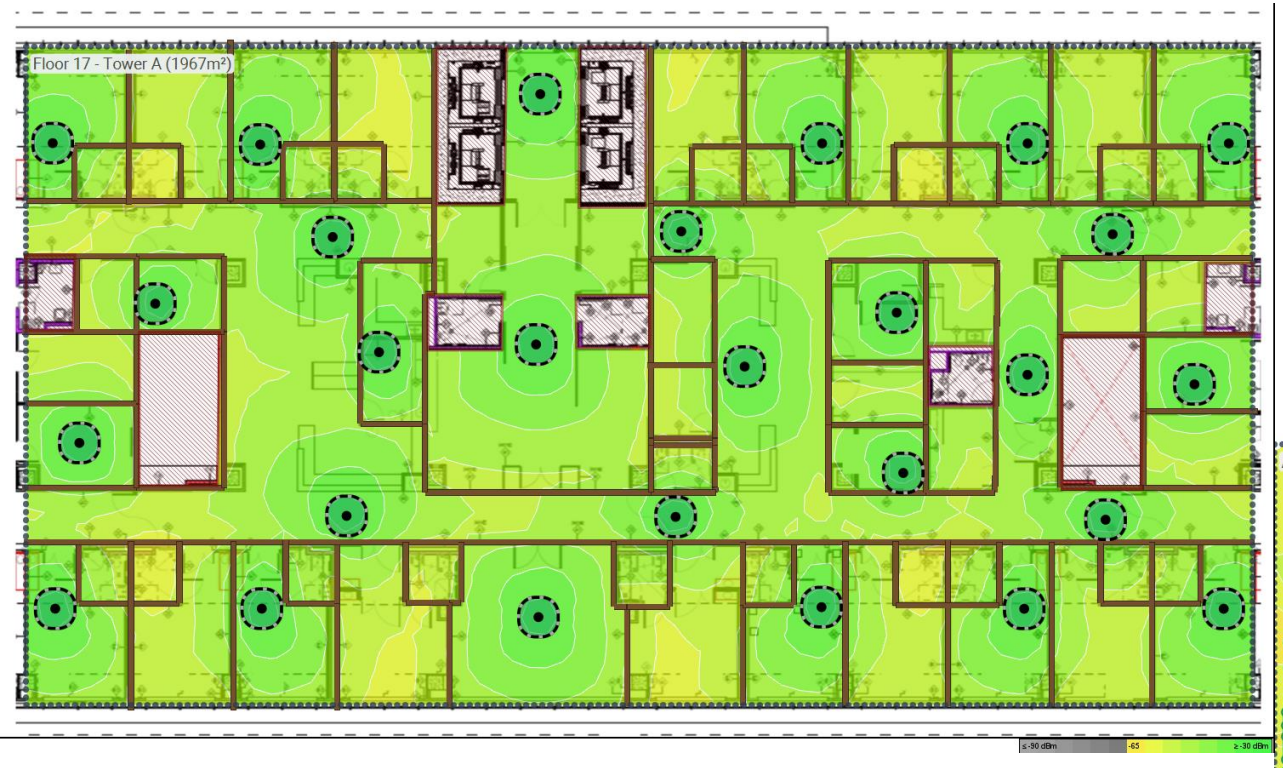



# How to Apply Survey Practically




Verify that Final WLAN Coverage
at Post Deployment Survey
matching Predictive Design

# Design Validation

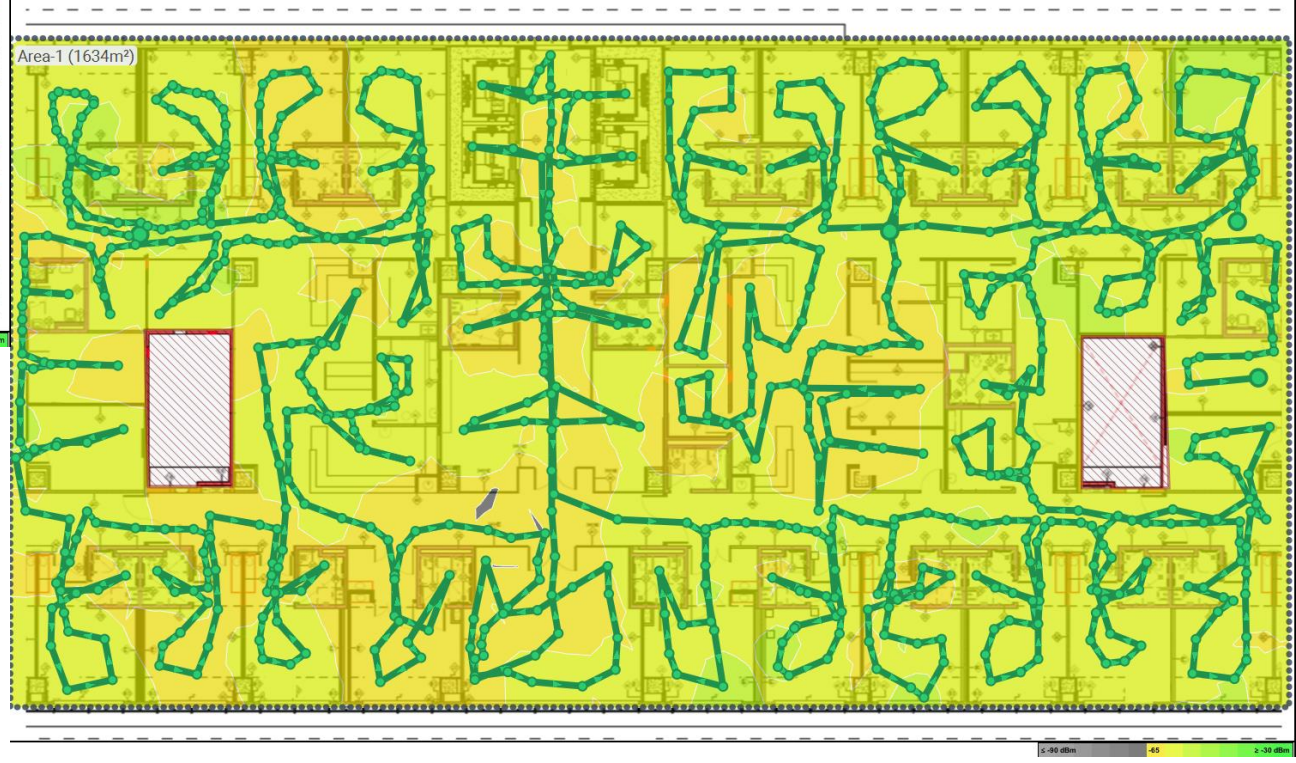



**Predictive**

**Pre-Deployment**

**Physical**

**Post-Deployment**



# Hybrid Survey

## Real World Scenario

### Hybrid Approach to Wireless Site Surveys

A surveyor can also use a hybrid approach to wireless site surveys. The hybrid method combines both the physical manual site survey and the predictive model site survey. This method can give "the best of both worlds" and enables the surveyor to check the physical installation location, make notes, place an access point to take signal readings in key areas, and get some spectrum analysis data. The surveyor can then apply the information collected to a predictive model to get more accurate results.

# Site Survey Tips

- Select AP & Antenna at First
- Adjust AP Power
- Test Wall Attenuation
- Select Mounting Location
- Select Correct Testing Client Device
- Consider Weakest Client Device



# Site Survey Devices

- Select AP Before you start Survey based on below

| Budget | Environment | Capacity | Requirements |
| --- | --- | --- | --- |
| Select Suitable Vendor | Indoor or Outdoor | Normal Density | Wi-Fi Standard |
| Controller or Standalone | Ceiling Height | High Density | Data Rate |
| AP Class ( High or low ) | Antenna or Built In | Application Usage | Uplinks – BLE |

# AP Models

## Indoor AP


## Outdoor AP

## Hospitality AP


# AP Model Selections

CISCO


HPE aruba networking

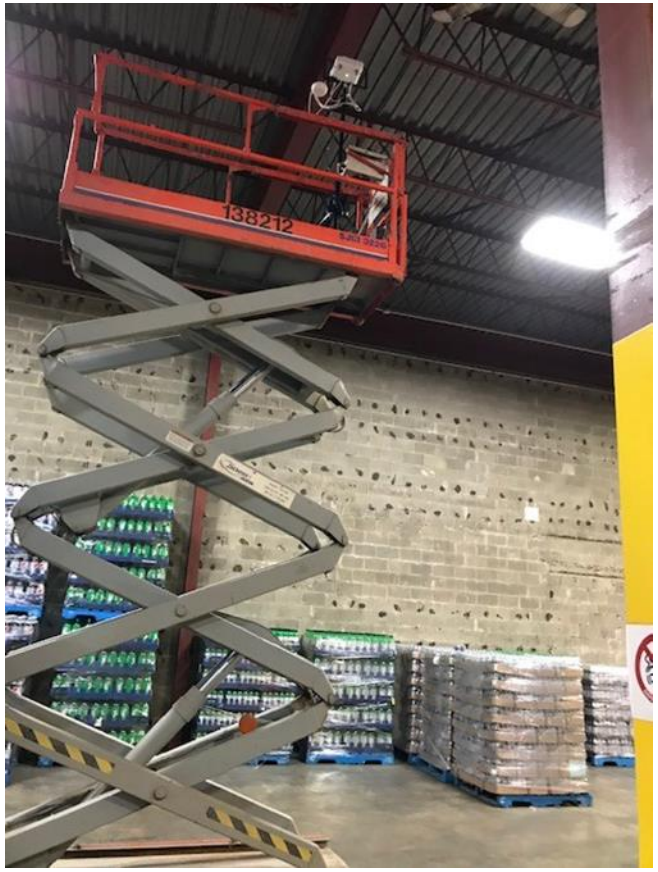

Low End → Medium → High End

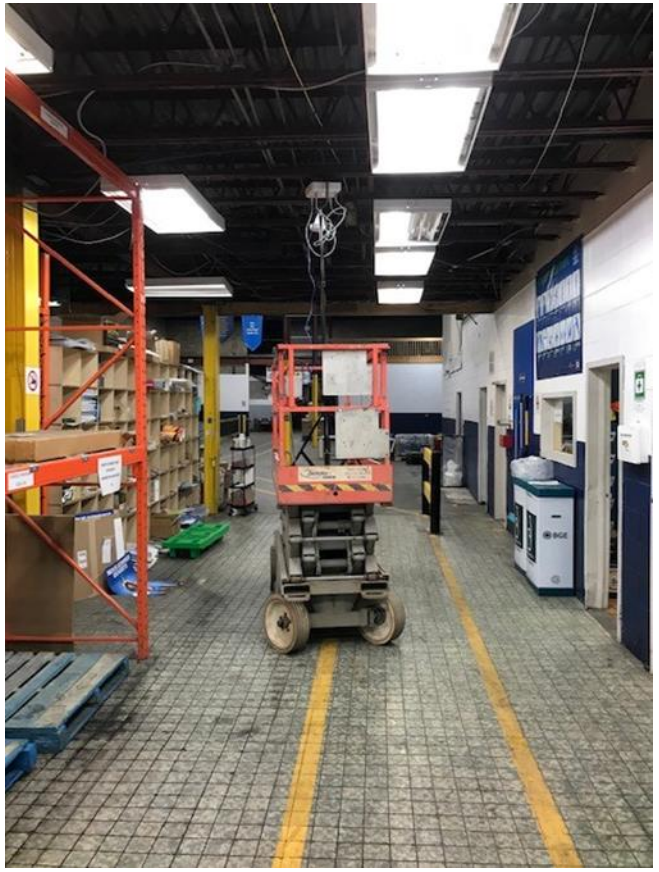
# Select Mounting AP Location

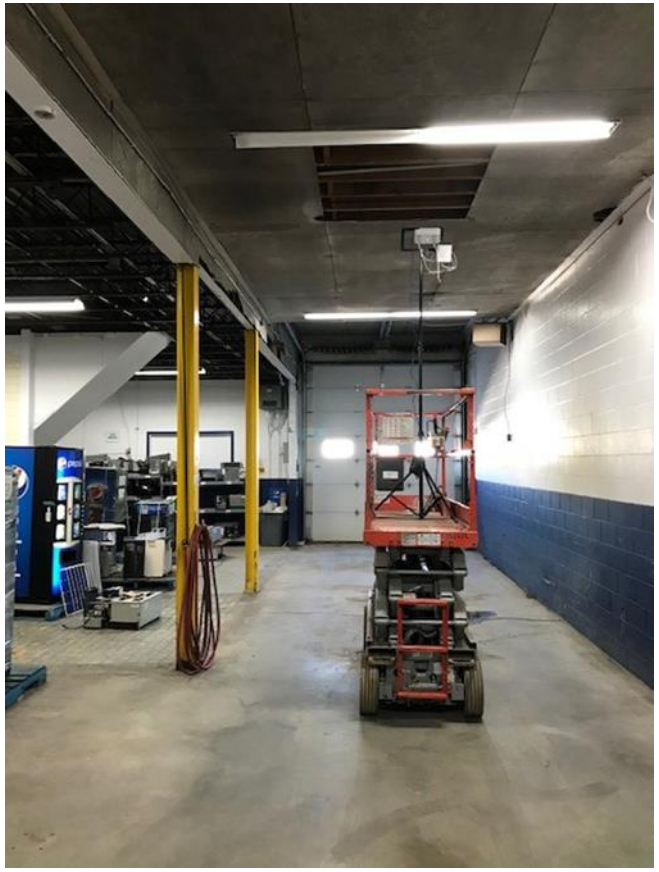
- Should test at same allowed mounting location considering restriction and aesthetics


# Select Mounting AP Location

- Should test at same allowed mounting location considering restriction and aesthetics





# Select Client Device

- **Should test with same device that will be used as Warehouse barcode scanner**

# Select Client Device

- Should test with same device that will be used as medical devices



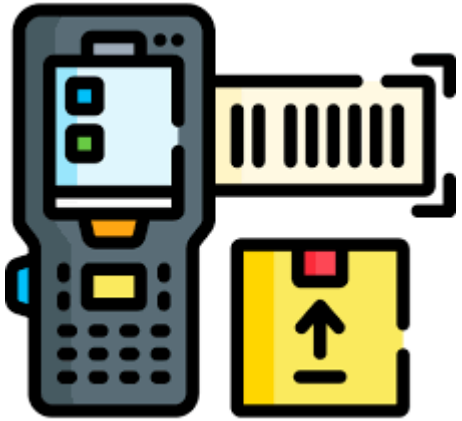
# Select Client Device

- **Should test with most week signal device as smart phone not Laptop**

**10 dB**

# Select Client Device

- **Design for Most Important Devices , even it’s old**

•**Your CEO’s laptop (simply refuses to get a new one)**

•**Old POS Scanner not planned to change now**

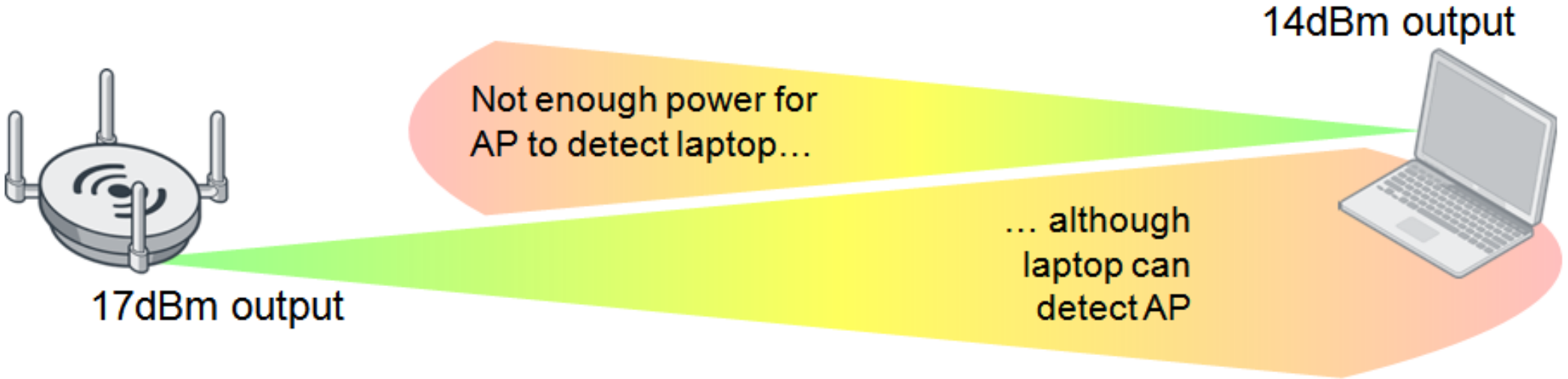
•**Maybe requires specific data rate or channels to be able to connect**

# AP Power During Survey

- **Set AP Power to it's half or third to match most of devices power**

**2.4 Ghz**
**9 dBm**

**5 Ghz**
**12 dBm**



# AP Power During Survey


We recommend that you set the test access points' output power level at about 50 percent or less during the site survey. This usually requires lowering the default power, which in many cases is set at maximum. This will allow for adjustments after installation to help compensate for potential differences from when the space was originally surveyed. The output power settings used will be determined by the individual performing the site survey. It is also important to keep in mind that if you are performing a site survey for both the 2.4 GHz and 5 GHz bands, the amount of RF transmit power as well as the gain of the antennas must be taken into consideration because of the difference in wavelength, which will in turn affect the range.

# Site Survey Kit


WIFI SURVEYKIT.COM

# Site Survey Tools





# Wireless Training
# Part 4-Session 6

# WLAN DESIGN & SURVEY

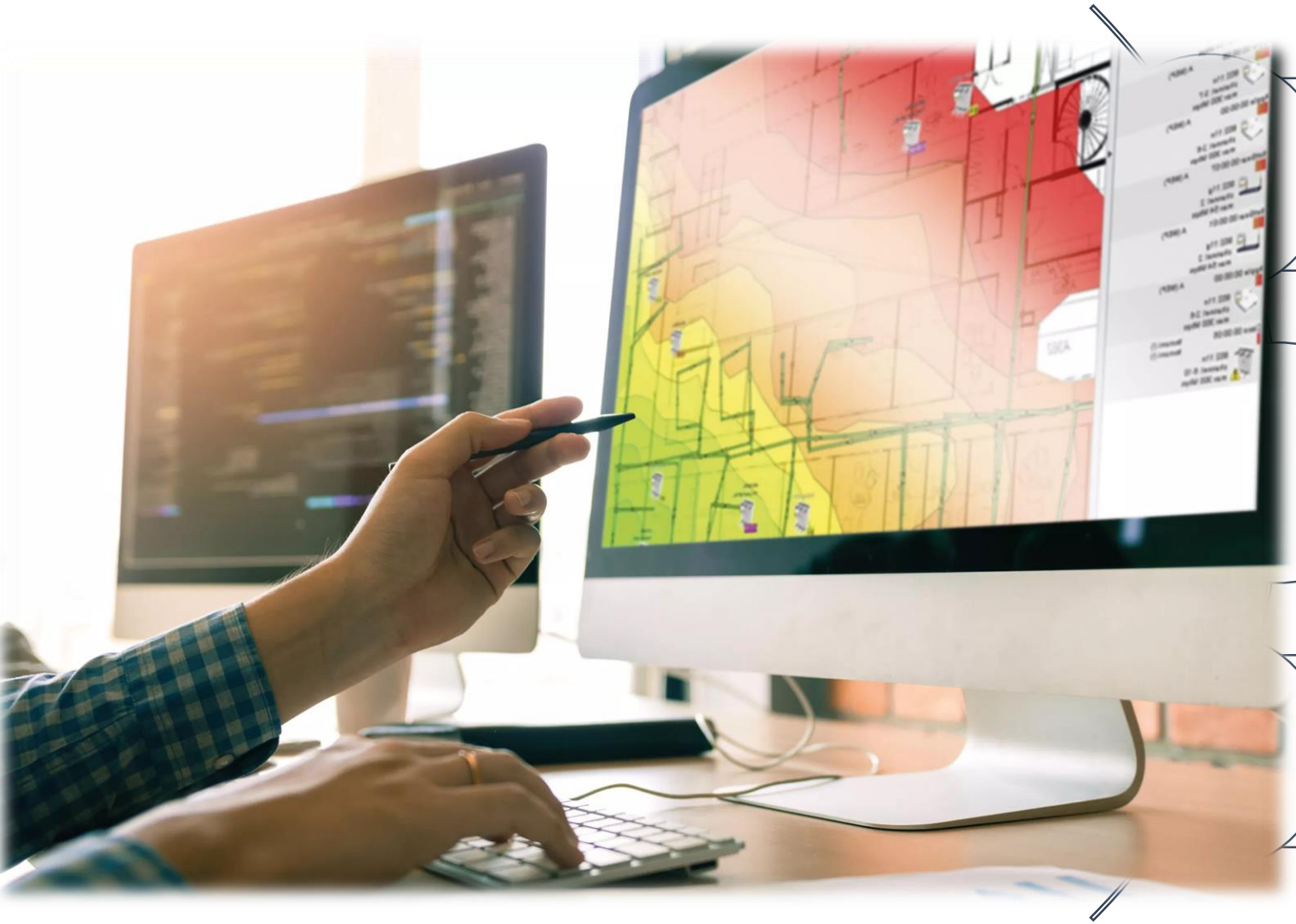
## Step 3 - Planning


# Session 6 : WLAN Planning

## Index

- Coverage Vs Capacity
- Coverage Planning
- Roaming Design
- Planning Guidelines

# WLAN Planning Why !!!



Find best Count , Location & distribution for AP at certain area

Achieve Best client connection and performance with seamless roaming

Avoid WLAN Issues as Interference , sticky clients – blind areas

# Coverage Vs Capacity

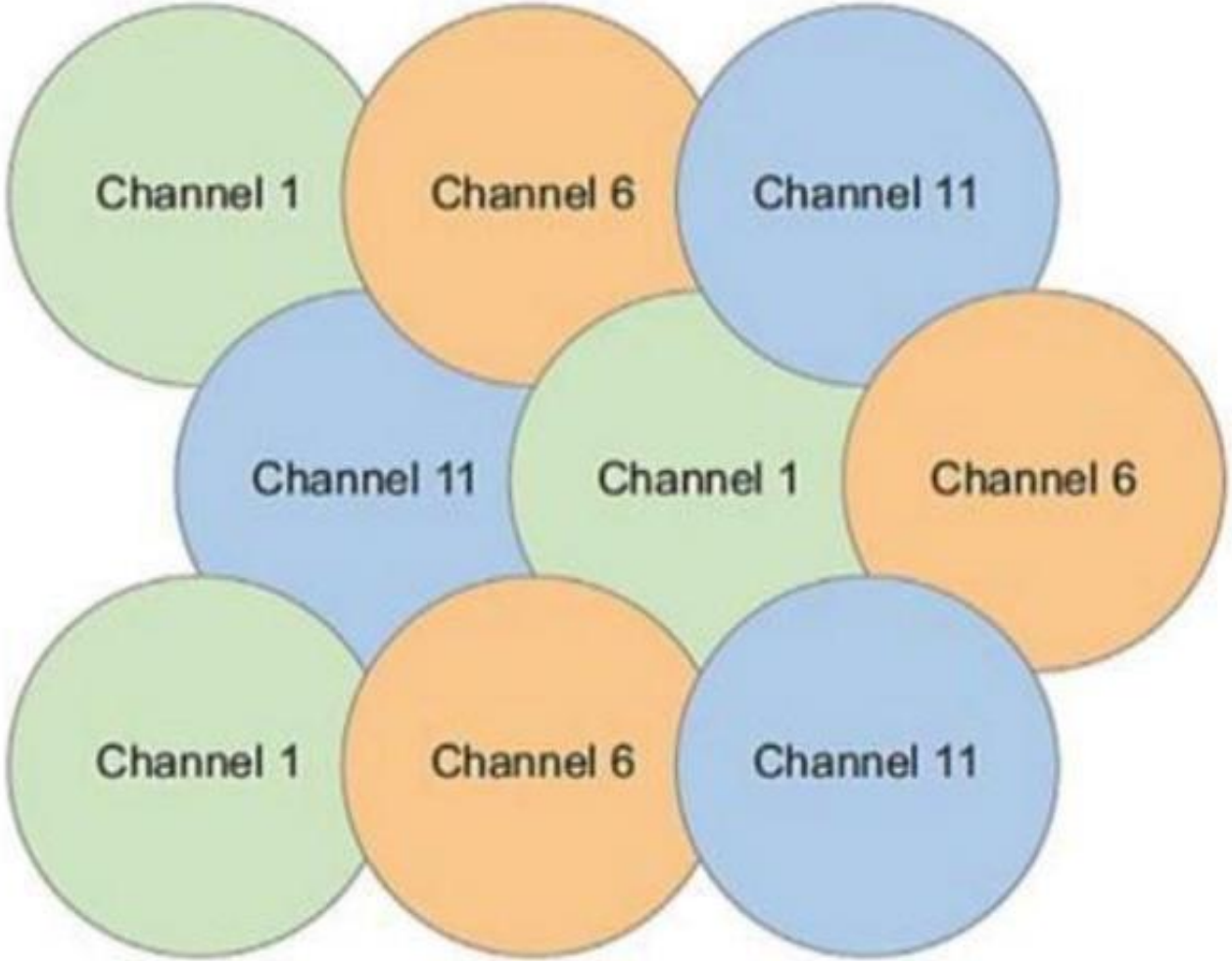
## Coverage

- Achieve RSSI & SNR Threshold
- Channel Planning - Seamless Roaming
- Consider Walls Types – Ceiling Height – Mounting Locations

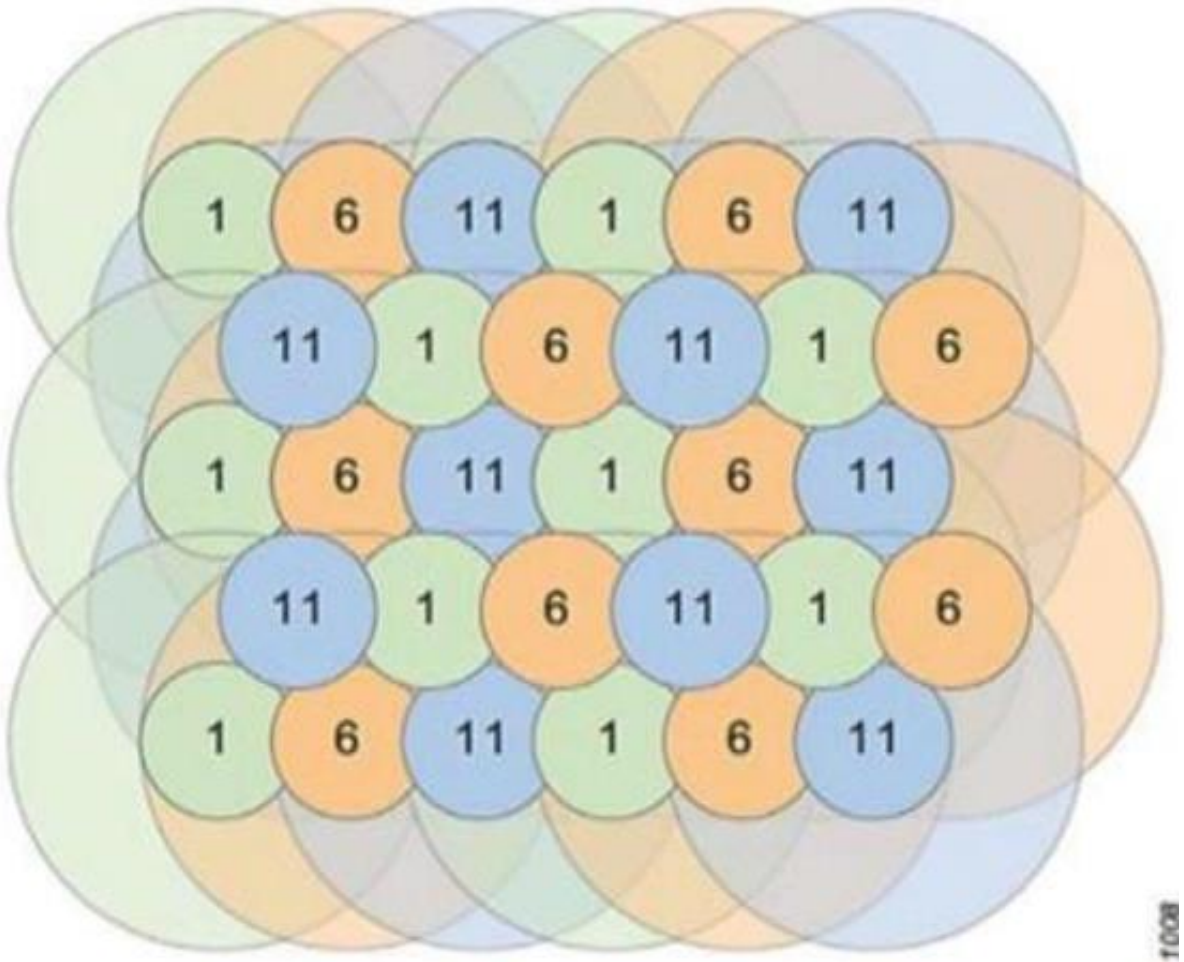
## Capacity

- Achieve targeted Bandwidth per user
- Bandwidth Calculations &  Air time
- Consider User Count – Device Type – Applications Usage

# Coverage Vs Capacity

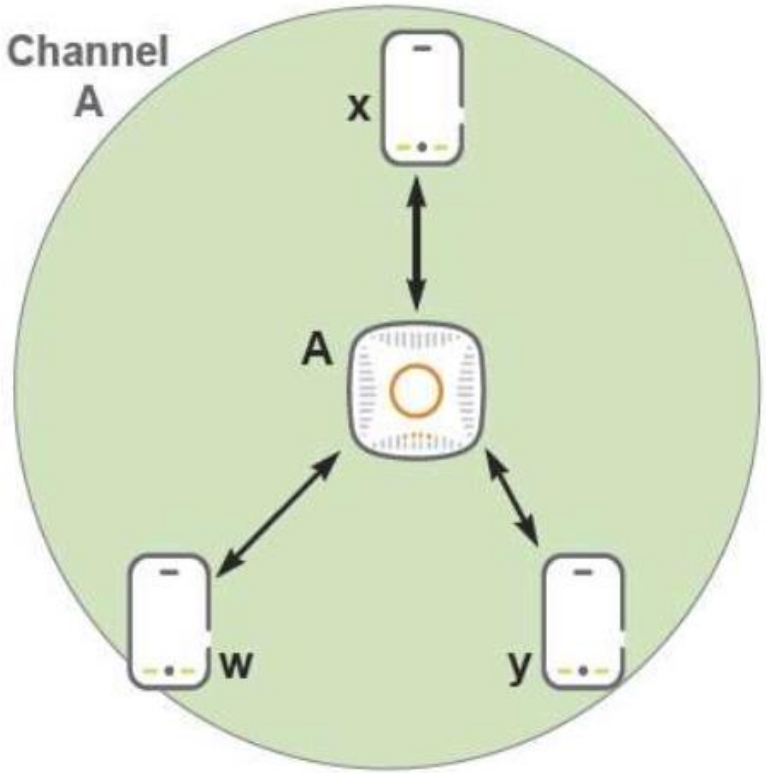



Coverage design with 7.2 Mb/s cell edge

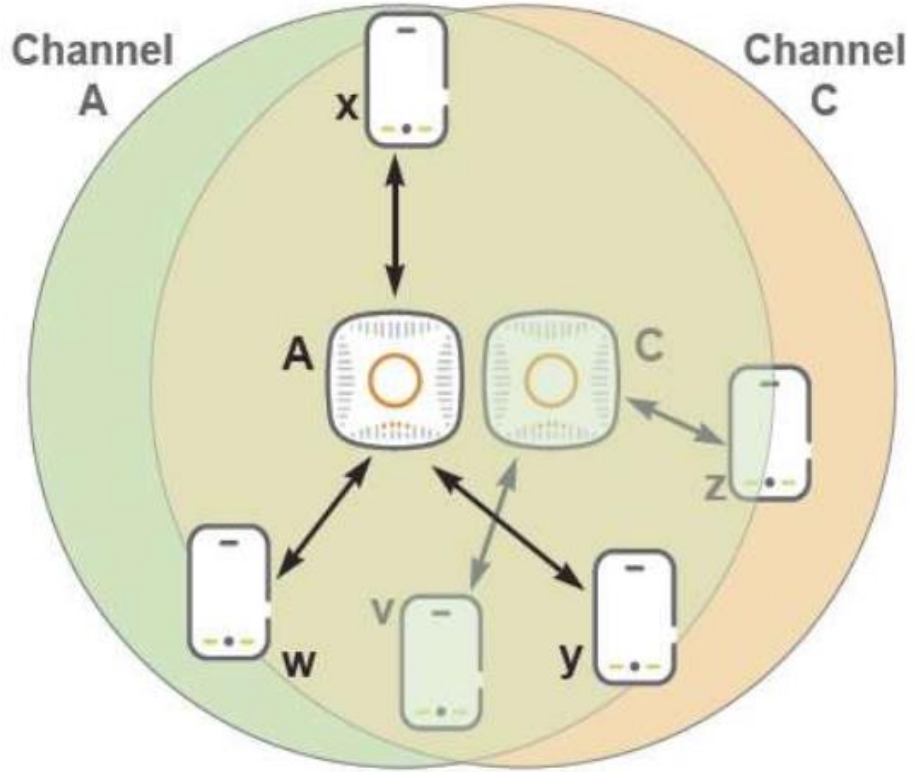



Capacity design with 216.7 Mb/s cell edge

# Define Cell Edges




If one channel provides *x* Mbps capacity…




Two APs covering the same area on
non-overlapping channels provide 2*x* Mbps capacity.

More AP → More BW → Interference → Channel Planning

# WLAN Planning Claims

## What distance Can AP Cover ?

25 mt

## How Many Users Per AP ?

200 User / AP

## How Many AP I need ?

1 AP / 50 mt Sq

## What is User Speed

1.3 Gbps – Wi-Fi 6

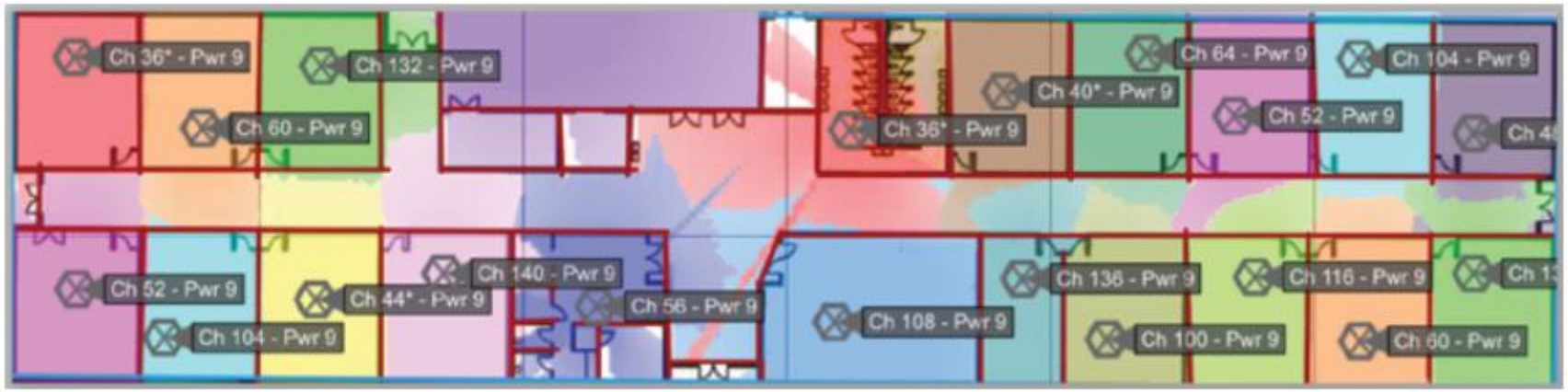


# Coverage Planning Keys

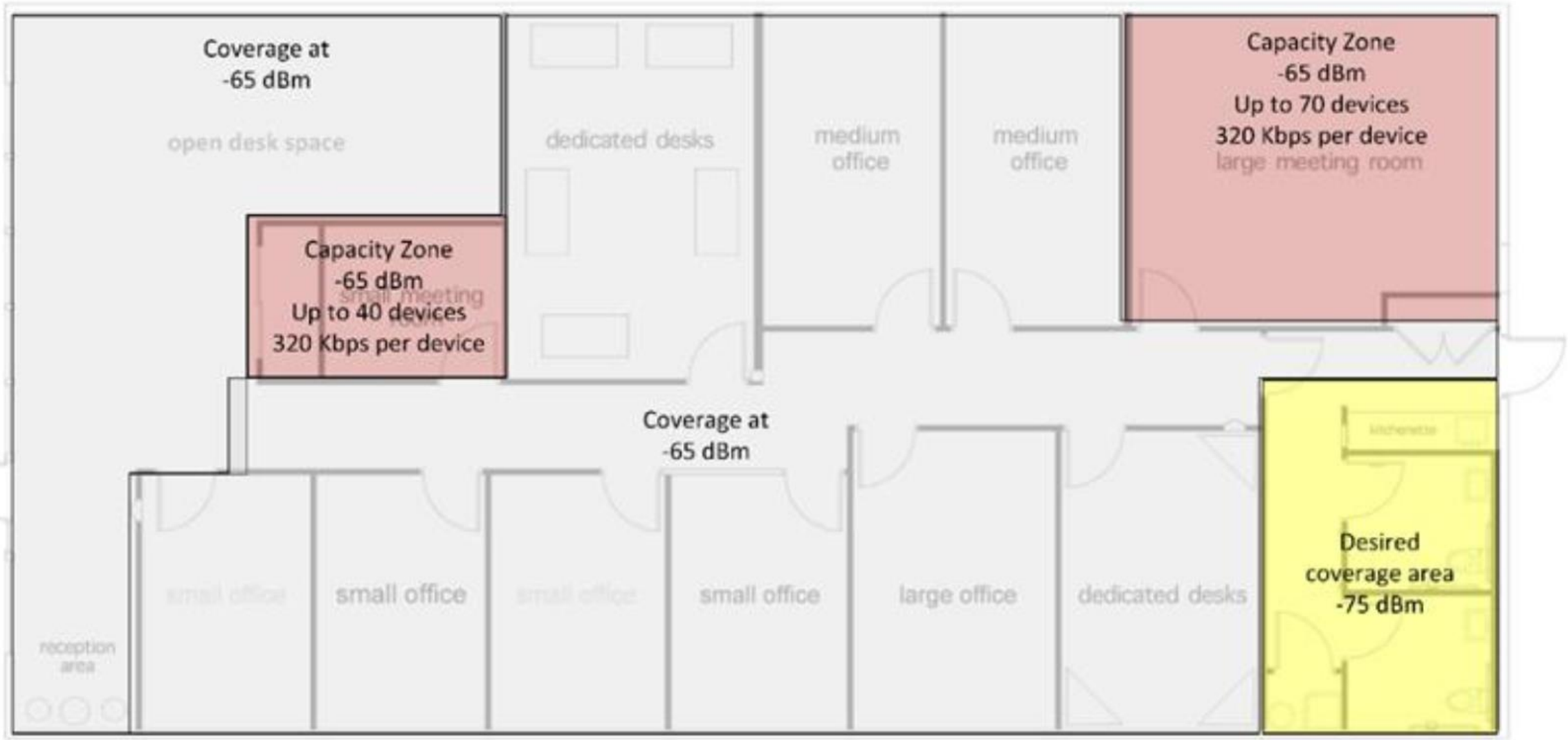
- Determine Coverage Area and Exclusion areas
- Consider Roaming and AP Coverage Overlap
- Study Wall Material Carefully & Ceiling Height
- Consider Multiple Floors for interference
- Plan for channel width and re-use and don't depend on RRM Only
- Don't Plan with Maximum AP Power ( Indoor half power 12-15 mwatt)
- Plan for -65 to -73 dBm RSSI cell size ( based on requirements )
- Recommended Average user per AP Radio 25-30 at normal Density

In many verticals, such as K–12 education, due to capacity requirements, it has become commonplace to deploy one AP per room. Please note that one AP per K–12 classroom may also be entirely unnecessary. One AP per every two or three classrooms may be sufficient to meet capacity needs. How many APs are needed depends on the capacity requirements as well as customer stipulations. Do you need to deploy one AP in every room? It once again depends on the number of devices, the type of devices, and the application traffic. However, an average of 70 or more Wi-Fi devices per classroom has become prevalent in many education environments. As shown in Figure 13.32, with proper AP placement, low transmit power, and channel reuse, deploying one AP per room using 5 GHz radios is feasible. The 5 GHz radio transmit power is normally 9 dBm (8 mW) or less, and 20 MHz channels are recommended in most cases. The walls must be made of thick material, such as concrete or brick, for attenuation purposes and to help limit CCI.

**FIGURE 13.32** One AP per room—5 GHz



# Identify Each Area requirements



# Consider User Path for Overlap

**Signal Disconnection from Room to Elevator**

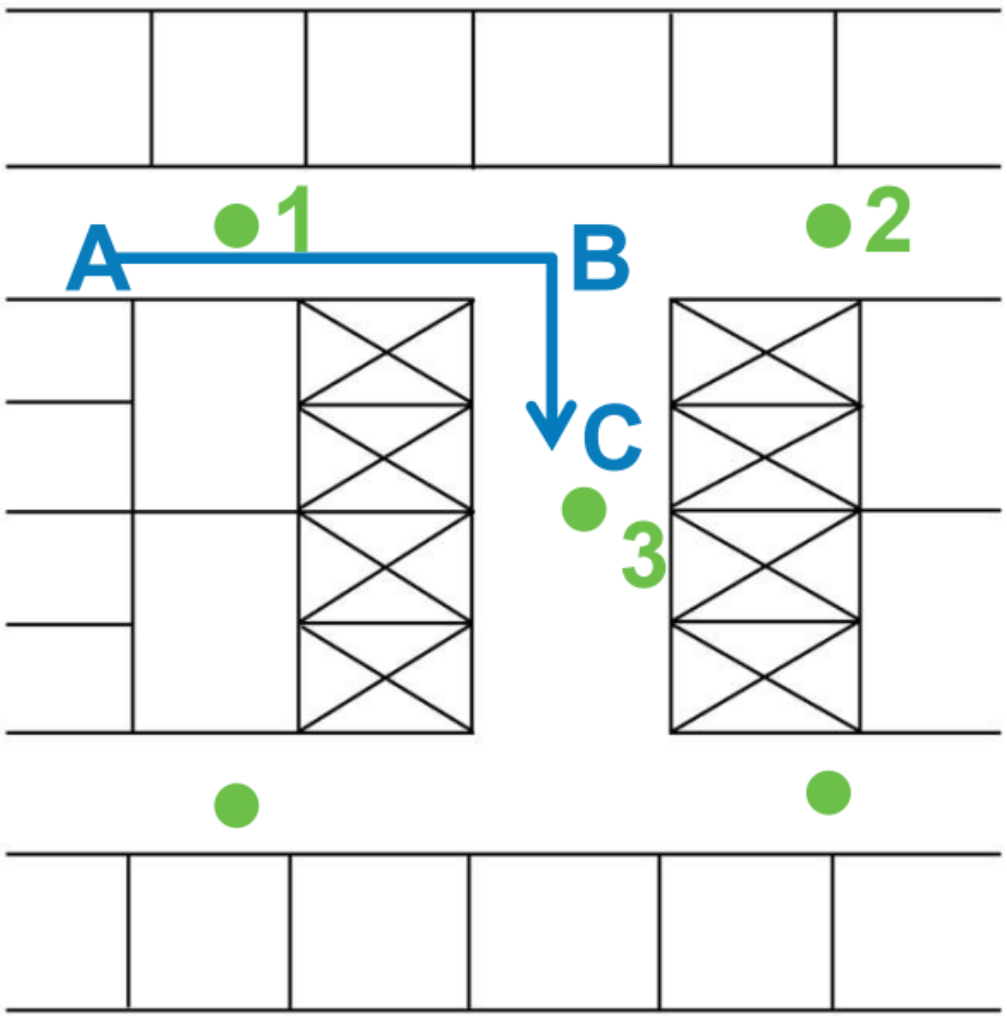
**Add Transition AP at Corridors for Roaming**

# Roaming Design & Overlap

- Cell overlap coverage is not always the only concern
- **Roaming can fail if the client device does not have enough time to properly scan for neighboring access points**

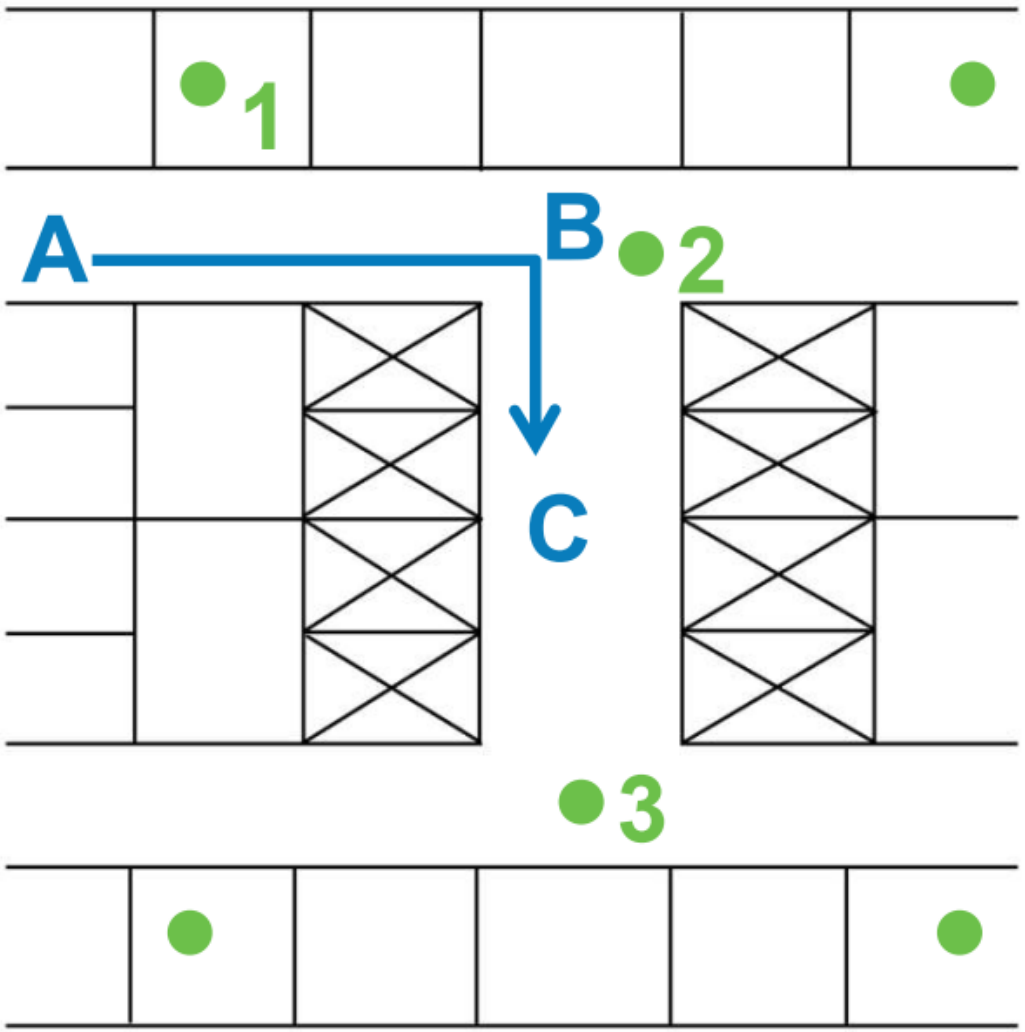
  Imagine turning the corner around a metal or high attenuation barrier – the RF environment changes very rapidly – no time for client to react
- Challenging RF obstacles need to be considered during AP placement
- A “Transition” AP that is placed at the intersection of hallways can alleviate some scenarios

# Bad Roaming Design




- At point A the phone is connected to AP 1
- At point B the phone has AP 2 in the neighbor list, AP 3 has not yet been scanned due to the RF shadow caused by the elevator bank
- At point C the phone needs to roam, but AP 2 is the only AP in the neighbor list
- The phone then needs to rescan and connect to AP 3

# Good Roaming Design




- At point A the phone is connected to AP 1
- At point B the phone has AP 2 in the neighbor list as it was able to scan it while moving down the hall
- At point C the phone needs to roam and successfully selects AP 2
- The phone has sufficient time to scan for AP 3 ahead of time

# What is AP Coverage Distance ??

## Coverage Distance

- Free Space Travelled distance
- Based on AP TX Power
- Client connectivity
- Rare Roaming
- Lower Data rates

## Effective Range

- Depends on area attenuation
- based on client’s perspective.
- Client performance
- Seamless Roaming
- High Data Rate

# AP Effective Range

Coverage Distance

Effective Range

# AP Effective Range

**AP Coverage Range**

**not only about**

**client connectivity**

**but also about**

**client performance**

**Client near AP:**

Higher PHY Rate

More Efficient

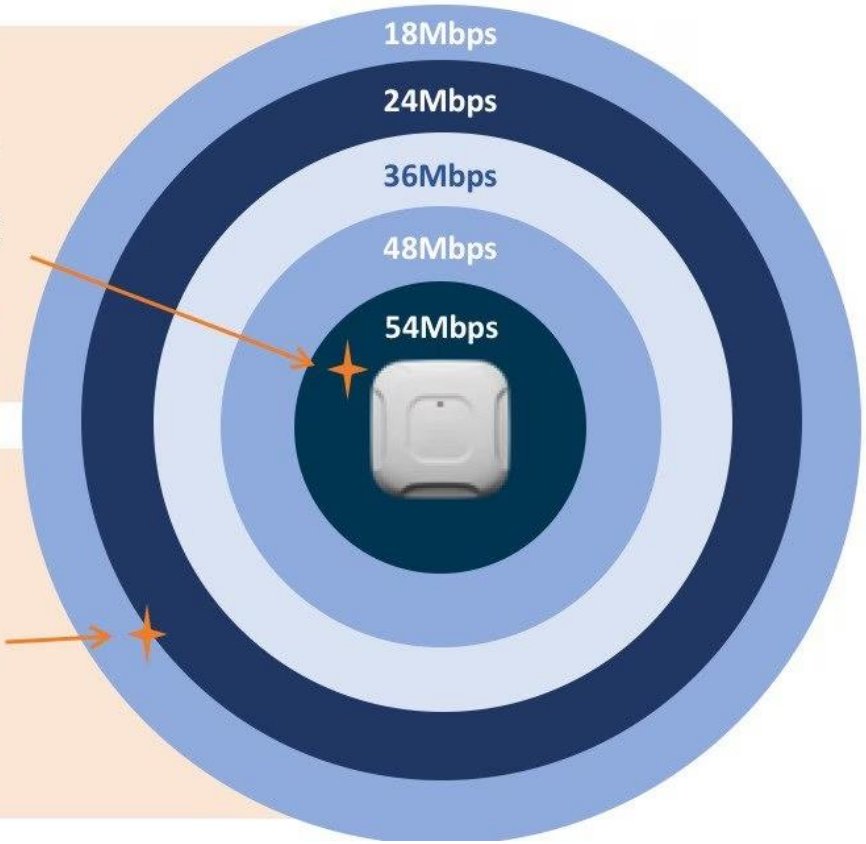
(high signal-to-noise ratio)

**Client far from AP:**

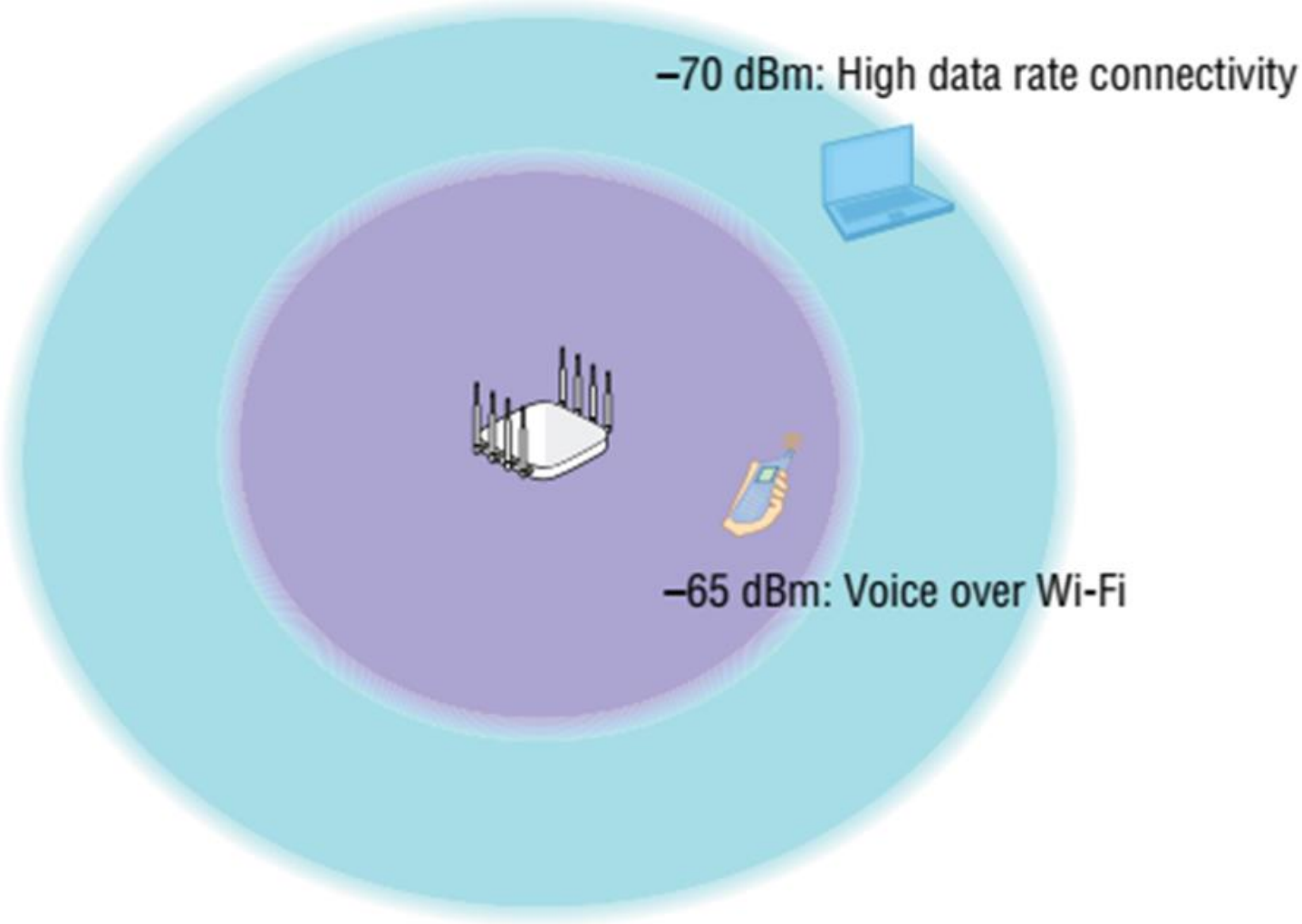
Lower PHY Rate

Less Efficient

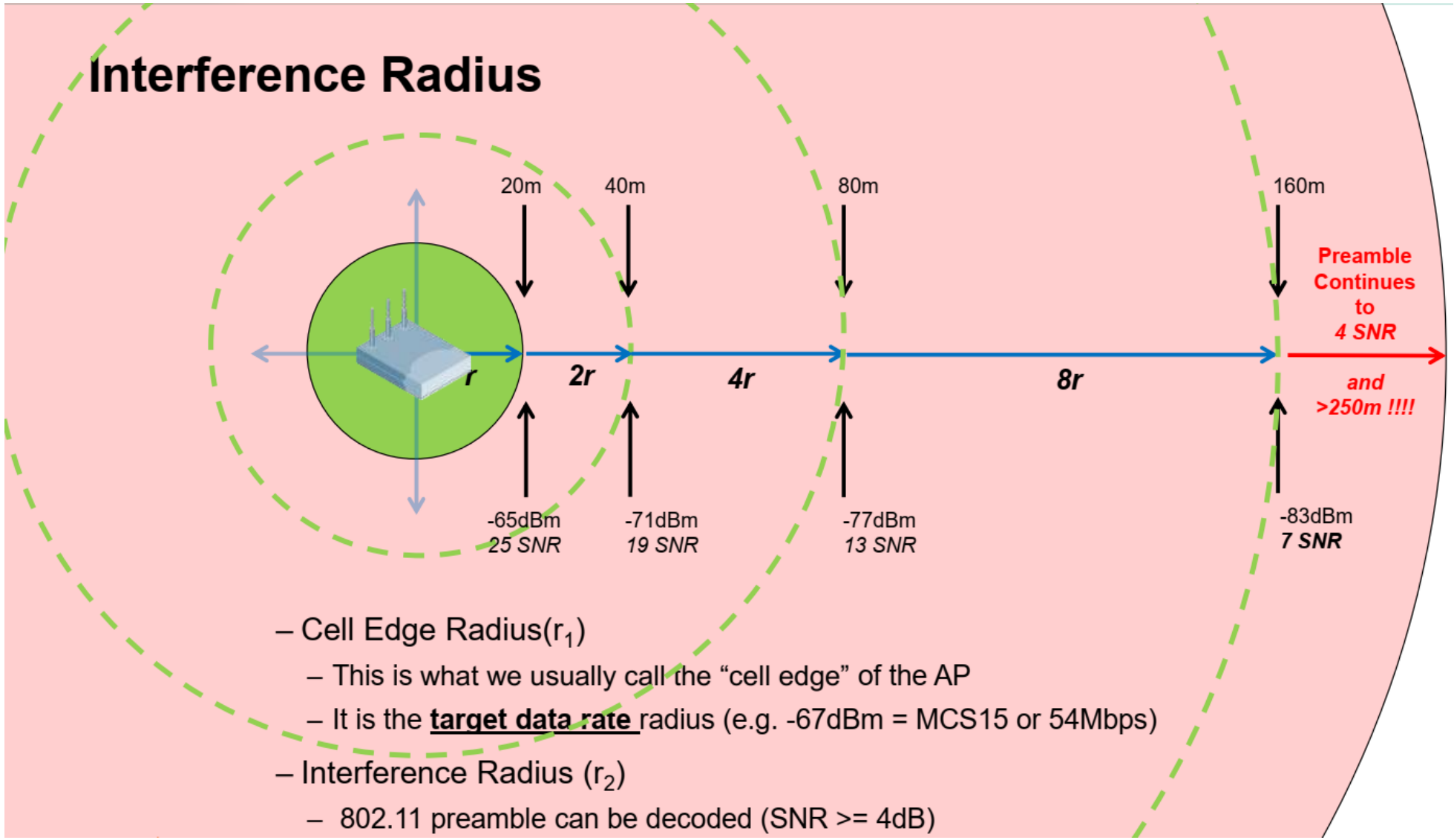
(lower signal-to-noise ratio)



# AP Effective Range

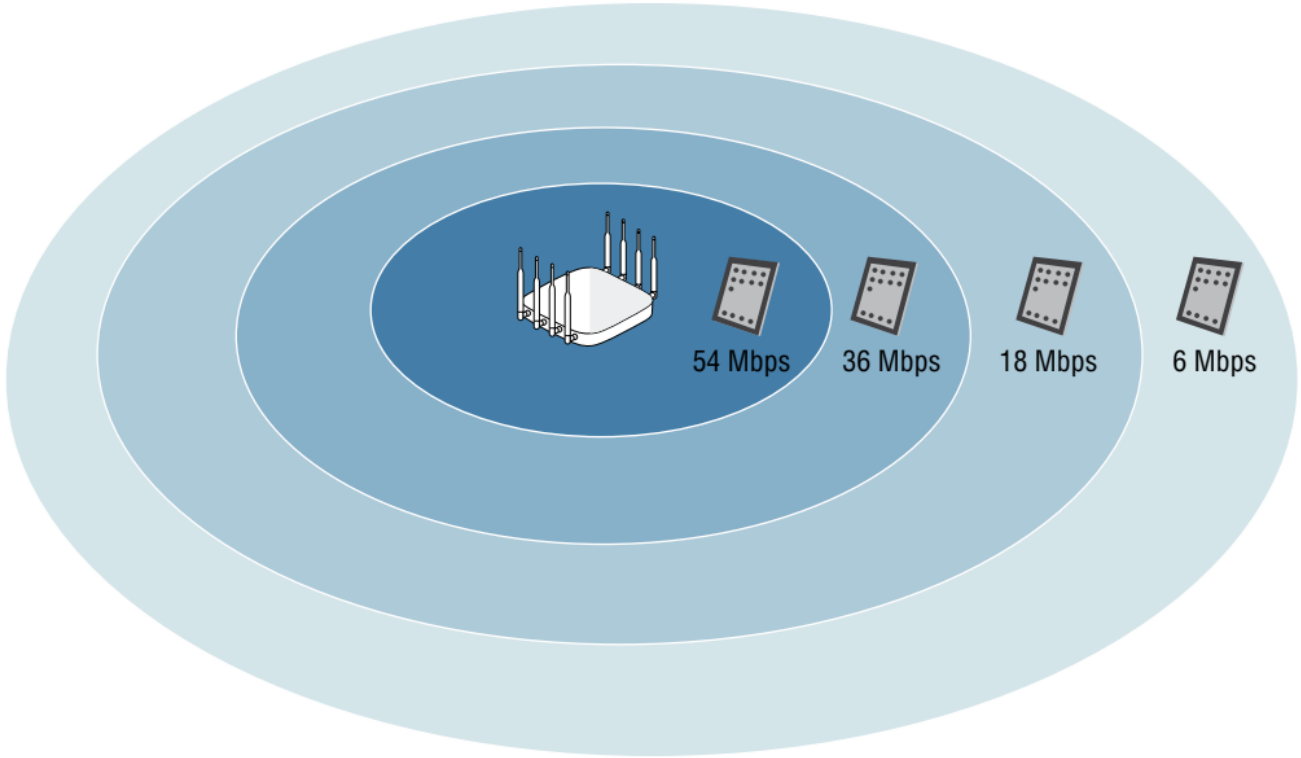


# AP Effective Range




– Cell Edge Radius($r_1$)
  – This is what we usually call the “cell edge” of the AP
  – It is the **target data rate** radius (e.g. -67dBm = MCS15 or 54Mbps)
– Interference Radius ($r_2$)
  – 802.11 preamble can be decoded (SNR >= 4dB)

# AP Effective Range

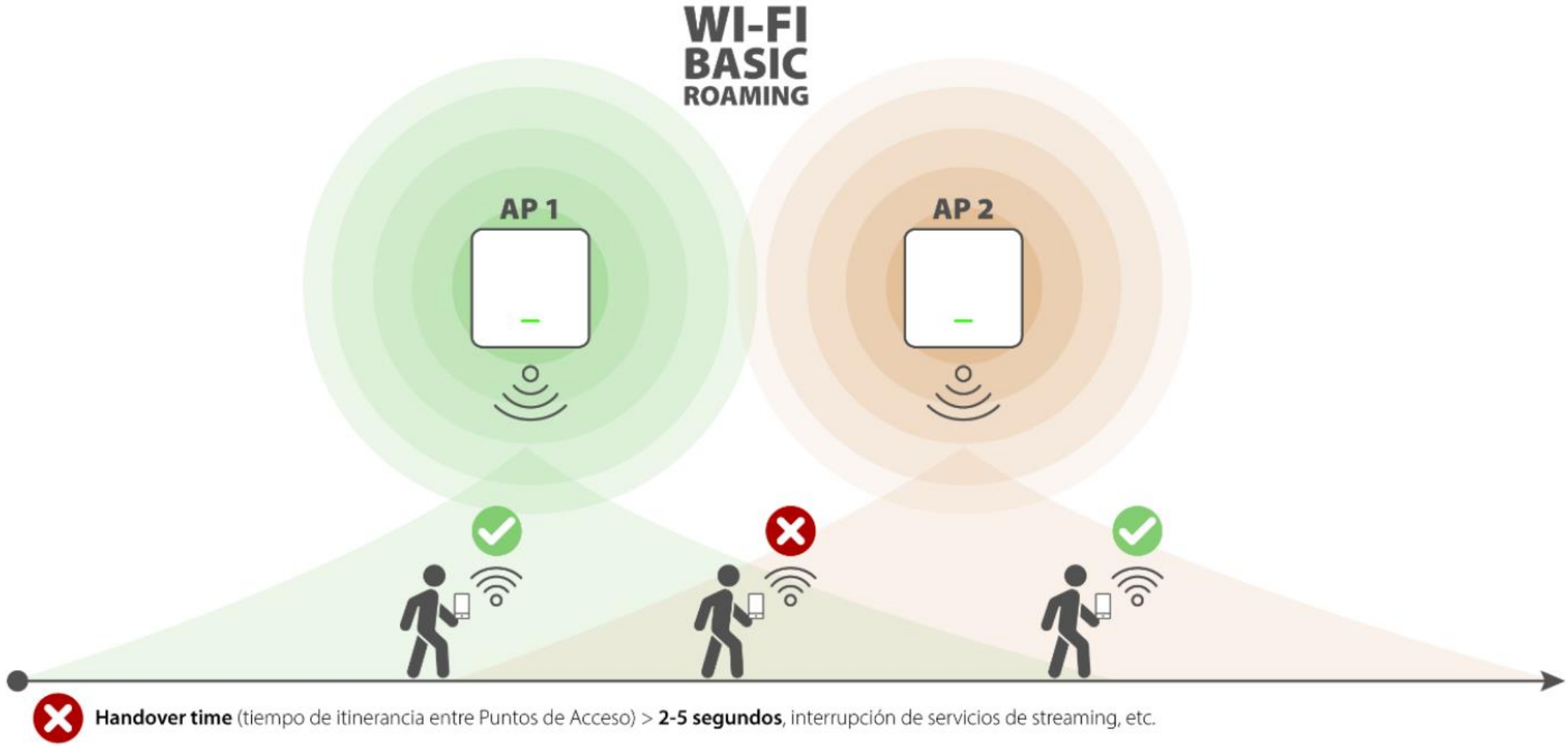



**Client devices**
**can roam efficiently**
**Multiple clients communicate**
**with AP simultaneously**
**Client could use**
**higher data rates**

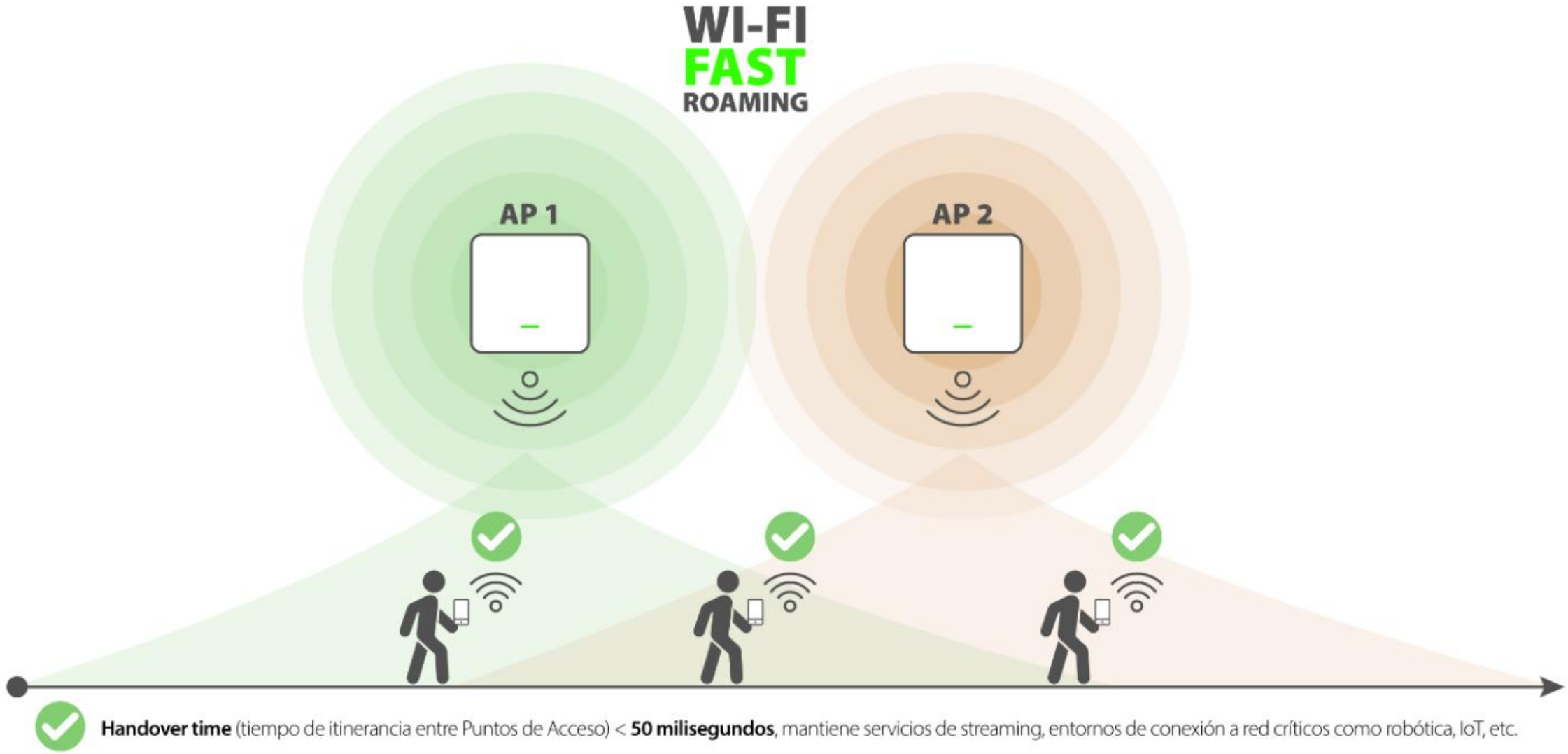
# AP Effective Range

| | |
|---|---|
| Effective Range | means the client devices can roam efficiently and can communicate with AP together with many other clients using high data rates. |
| | effective” range of an AP really depends on the attenuation environment of the facility. |
| | More importantly, the effective range of an AP should be based on the client’s perspective. |
| | AP coverage range is not just about client connectivity, but also about client performance. |

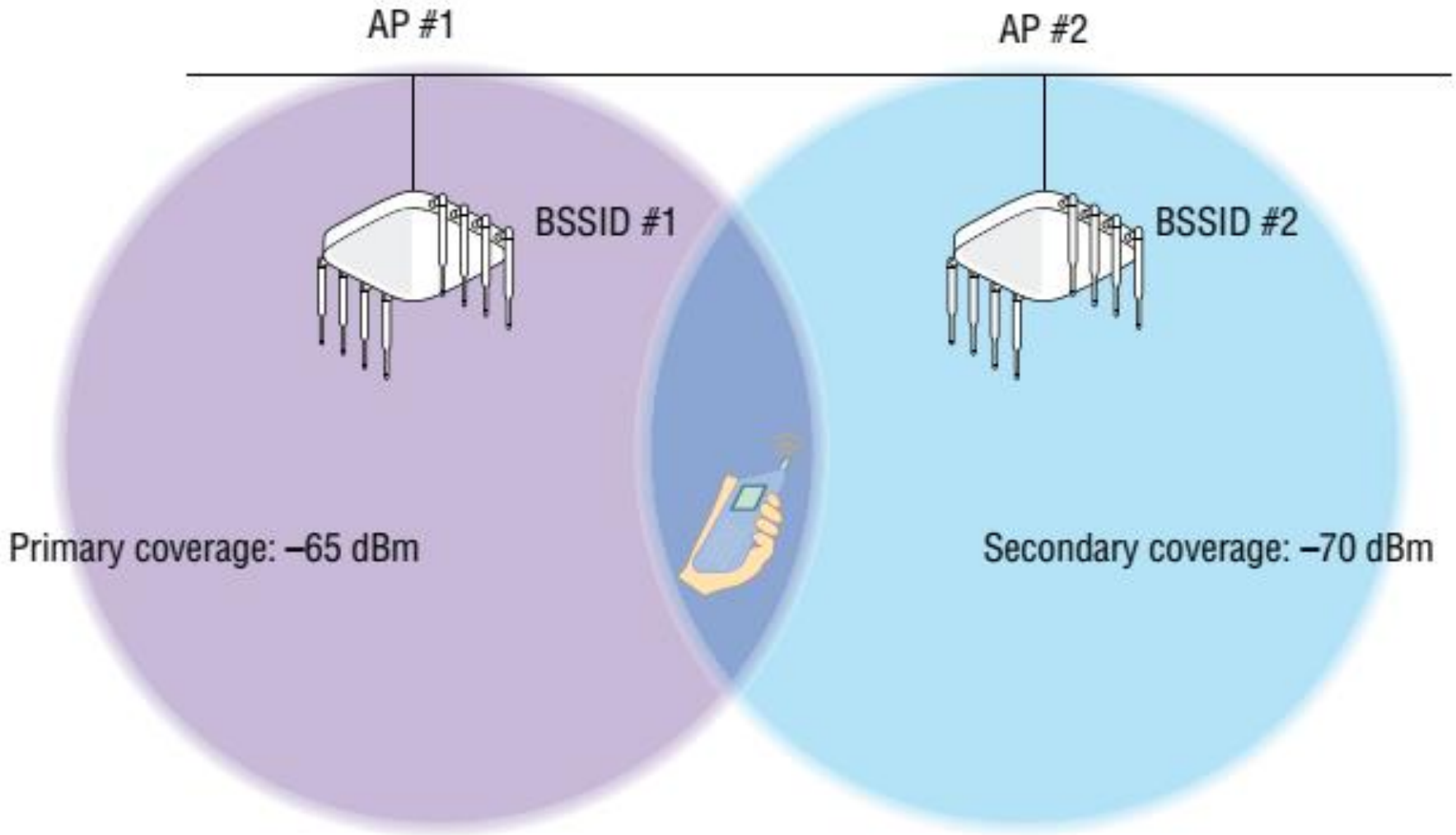
# Roaming & Overlap



# Roaming & Overlap



# Primary & Secondary Coverage



# Primary & Secondary Coverage

- Each Wi-Fi client needs to
- Hear at least one AP at a specific RSSI
- & Hear a secondary AP at a slight lower RSSI

- When associated to an AP
- a potential roaming client also hears
- at least one other AP within a 5 dB range

# Primary & Secondary Coverage

## Cell Overlap

Duplicate coverage from multiple access points

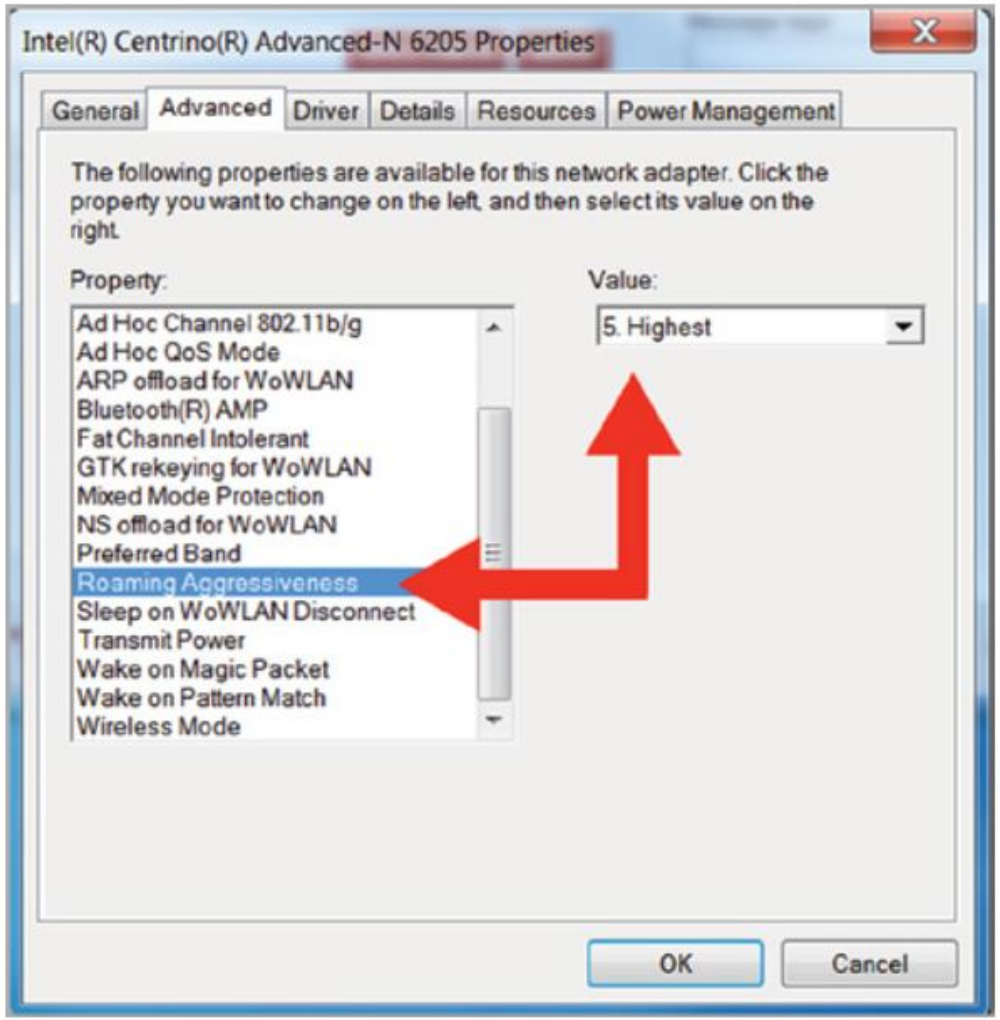
Ensure seamless roaming without disconnection

Most vendors recommend 15-30 % overlap

Guarantees redundancy in case of AP failure

Determined by survey and Planning tools

# Sticky Client Issue



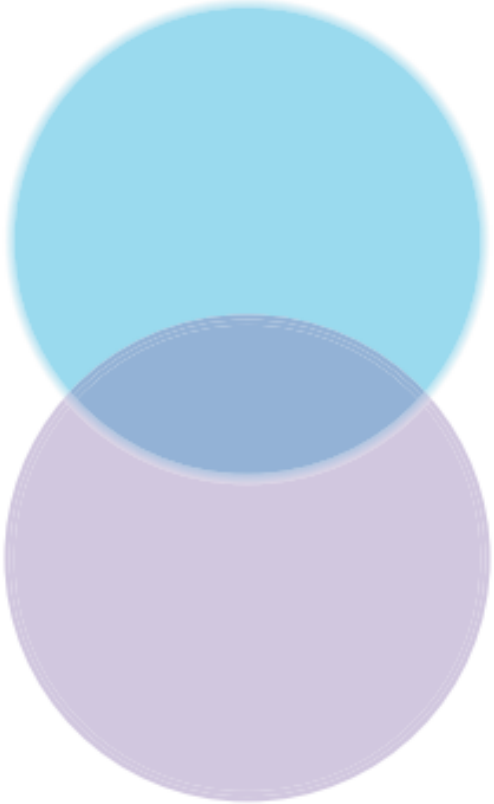

**Client is connected to original AP not moving to nearest & stronger AP**

**Roaming decision basically depend on client device**

**With Good Roaming Design could enhance roaming**

**Enable roaming enhancement protocols from WLAN System**

# Cell Overlap Measurements



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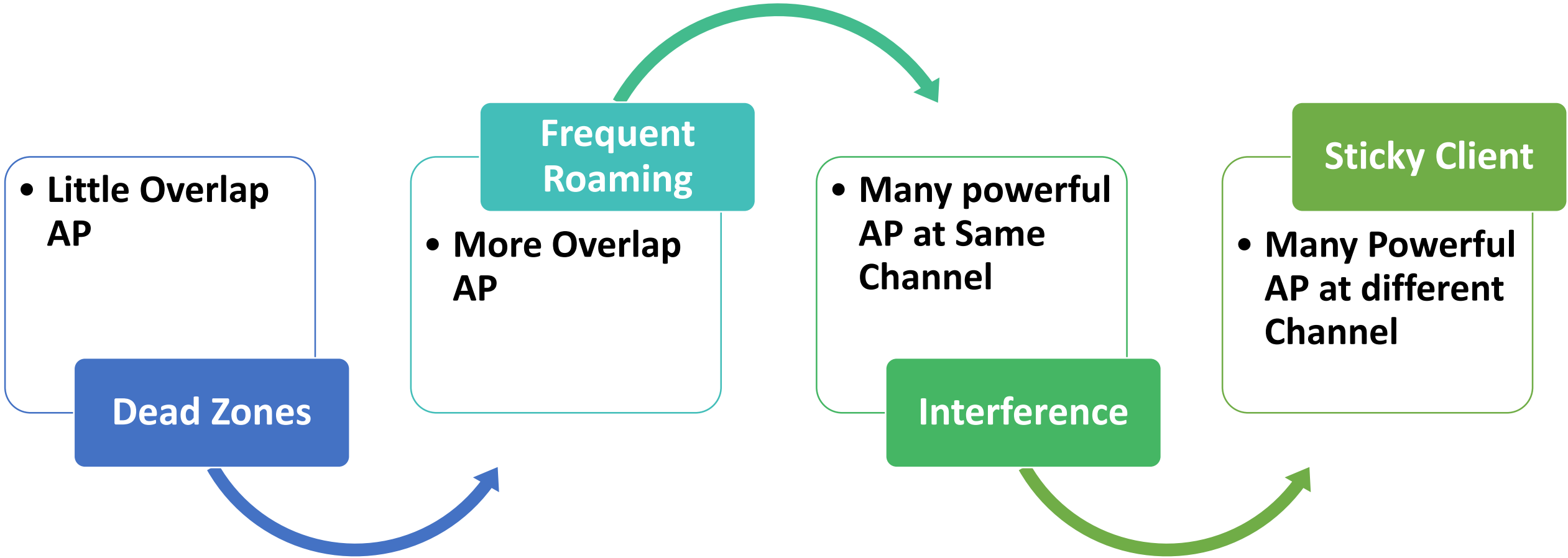
Theoretical Overlap

Real Overlap

# Cell Overlap Recommendation



# Cell Overlap Recommendation

## Too little duplicate coverage

- will effectively create a roaming dead zone, and connectivity might temporarily be lost

## Too much duplicate coverage

- will also cause frequent roaming problems.
- client device is constantly switching back and forth between two or more APs on different channels

## Too many APs with strong signals

- may cause a sticky client problem
- APs on the same channel with powerful signals, performance degradation will occur due to medium contention overhead & interference

# Find Cell Overlap in Survey

- The hardest part of physically performing a coverage analysis site survey is often finding
- where to place the **first access point** and determining the boundaries of the first RF cell.
- The following procedure explains how this can be achieved
- During this process, you should be transmitting data from the client to the AP, ensuring not only signal strength but actual transmission capabilities.
- This is the location where you place your first access point. **(–70 dBm** will be used as the desired signal level throughout the rest of this example.
- If you are using a different desired signal level, use it instead.)

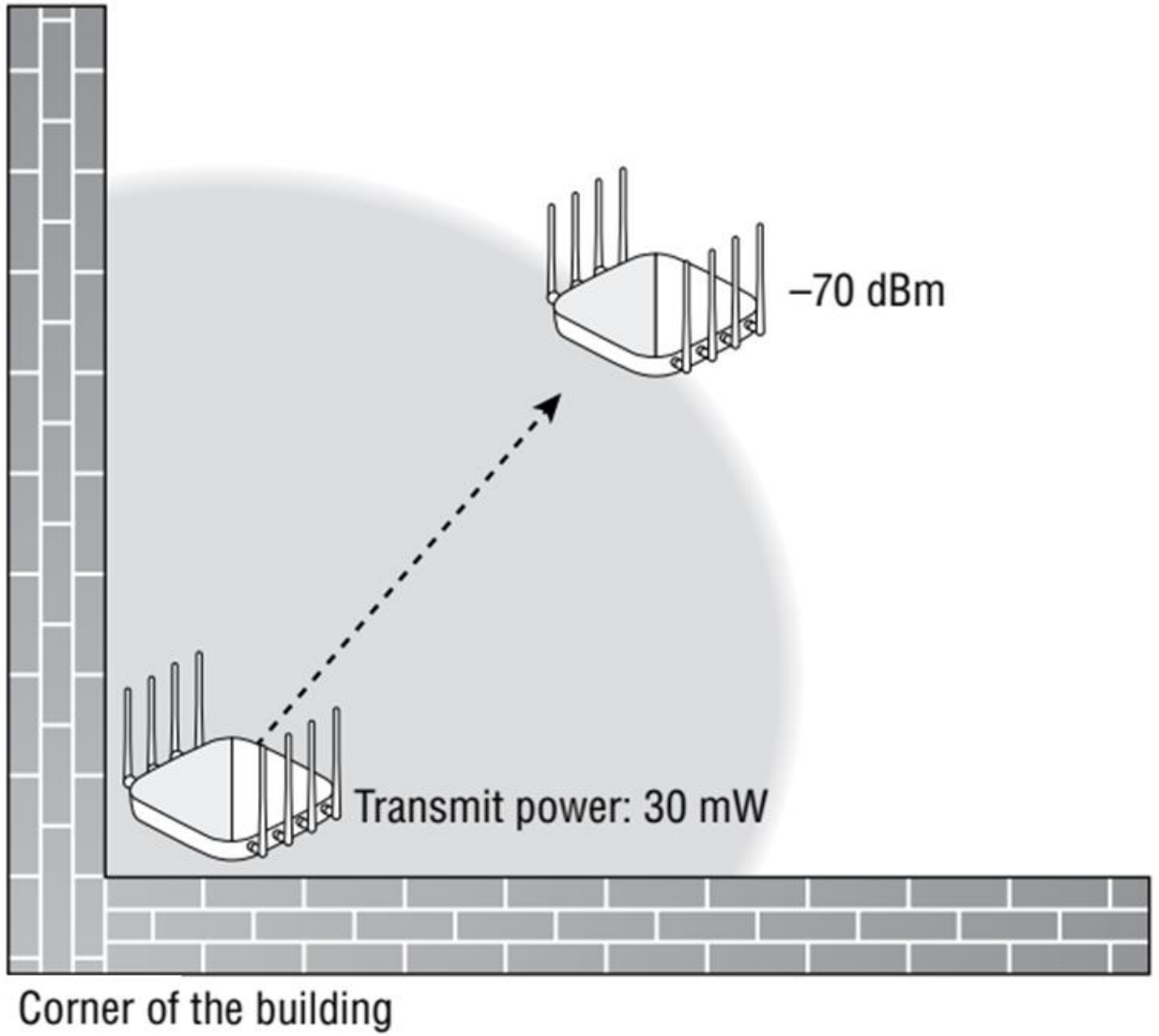
# Step 1 : Place 1st AP

1. Place an access point with a power setting of **25 mW** (or the power level that you determine is ideal for your environment) in the corner of the building.

3. Temporarily mount the AP in the **first location** and begin **walking throughout** the facility to find the **–70 dBm** endpoints, also known as **cell boundaries** or cell **edges**.

4. Depending on the **shape and size** of the **first coverage cell**, you may want to **change the power** settings and/or **move the initial** AP

4.Walk diagonally away from the access point toward the center of the building until the received signal drops to **–70 dBm**, or the signal strength that you are planning for as per customer requirements

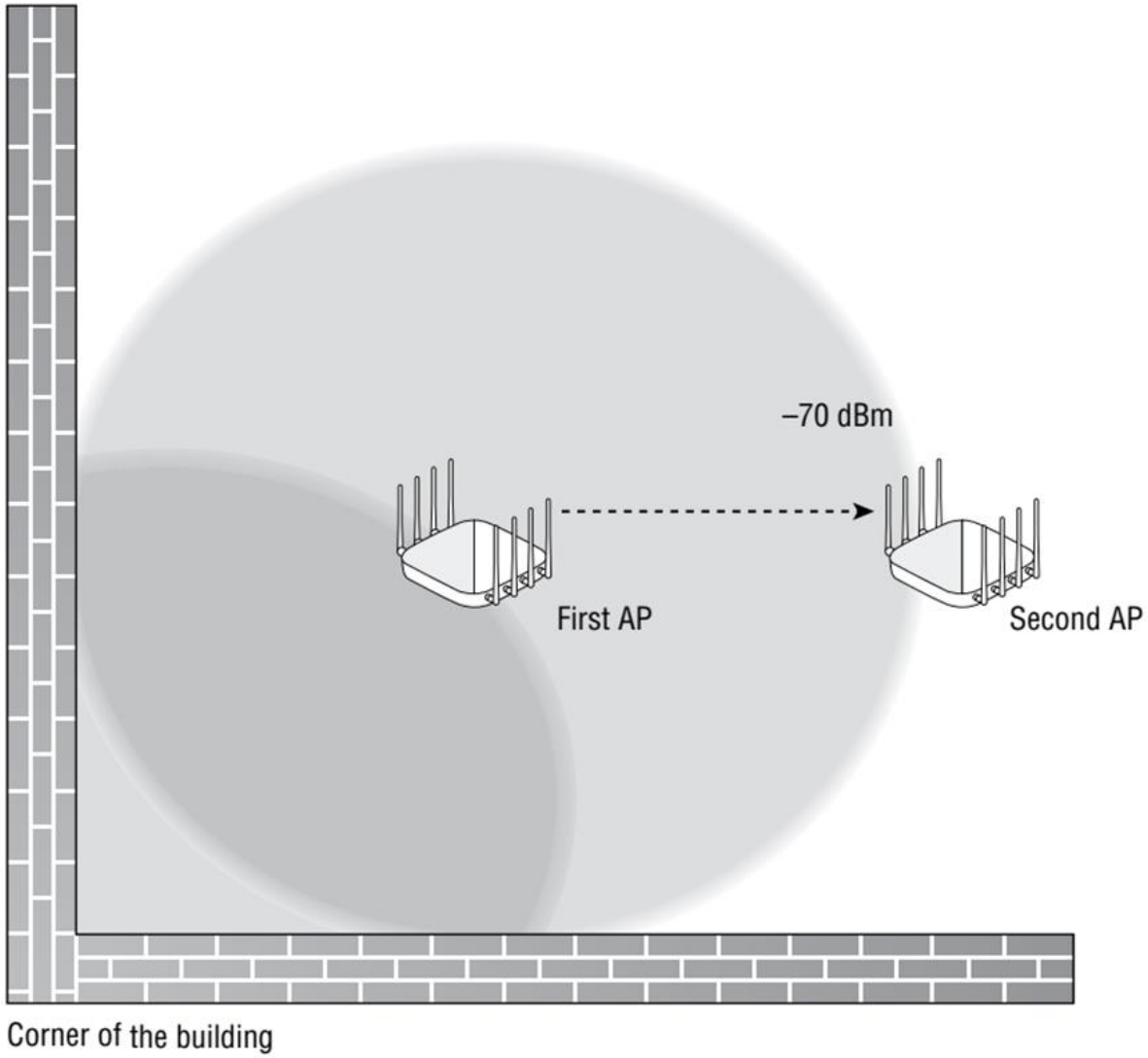


# Step 2 : Place 2nd AP

- After the first coverage cell and boundaries have been determined, the next question is
- **Where to place the next access point**. **???**
- The placement of the next **AP** is performed by using a technique that is similar to one used to place the first AP.
- Think of the **cell boundary** of the **first** access point, where the signal **is –70 dBm**, as the initial starting point, similar to the way you used the corner of the building as your initial starting point, and do the following:

# Step 2 : Place 2nd AP

1. From the **first AP ,** walk **parallel** to the **edge** of the **building** and place a **AP** at the location where the received signal **is –70 dBm**
2. **N**ow walk away from this AP , **parallel** to the **edge** of the building, until the received signal **drops** to –70 dBm.
3. Move to that location and temporarily mount the AP.
4. The AP mounted at this location will provide for the second coverage cell.
5. Begin **walking throughout** the facility to find the **–70 dBm** endpoints, or cell boundaries.
6. Again, depending on the shape and size of the first coverage cell, you may want to change the power settings and/or move this access point



# Cell Overlap Measurements

- It is important to avoid **excessive overlap**, because it can cause **frequent roaming** and performance degradation.
- The **shape and size** of the building and the attenuation caused by the **various materials of walls** and obstacles will require you to change the **distances** between **access points** to ensure proper cell overlap.
- After finding the proper placement of the **second access point** and all of its cell boundaries, repeat the procedure over again.
- The rest of a manual site survey like this one is basically repeating this procedure over and over again, effectively daisy-chaining throughout the building until all coverage needs are determined.
- In the past, WLAN design guides and white papers from various WLAN vendors have referenced **15 percent to 30** percent coverage cell overlap for roaming purposes. However, there is **no way** to **measure coverage cell overlap**.
- Coverage overlap is **really duplicate coverage** from the perspective of a Wi-Fi client station.
- A proper site survey should be conducted to ensure that a client always has proper **primary** and **secondary** coverage from multiple AP.

# Cell Overlap Measurements

In other words, each **Wi-Fi client station** needs to **hear** at least one **access point** at a specific **received signal strength** indicator (RSSI) and a **backup or secondary** access point

At the same RSSI. Typically, vendor **RSSI thresholds** require a received signal of greater than **–70 dBm** for the higher data rate communications.

Therefore, a **client station** needs to see at **least two access points** at the desired signal level so that the client can roam if necessary.

**The following cell edge measurements are taken during the site survey:**

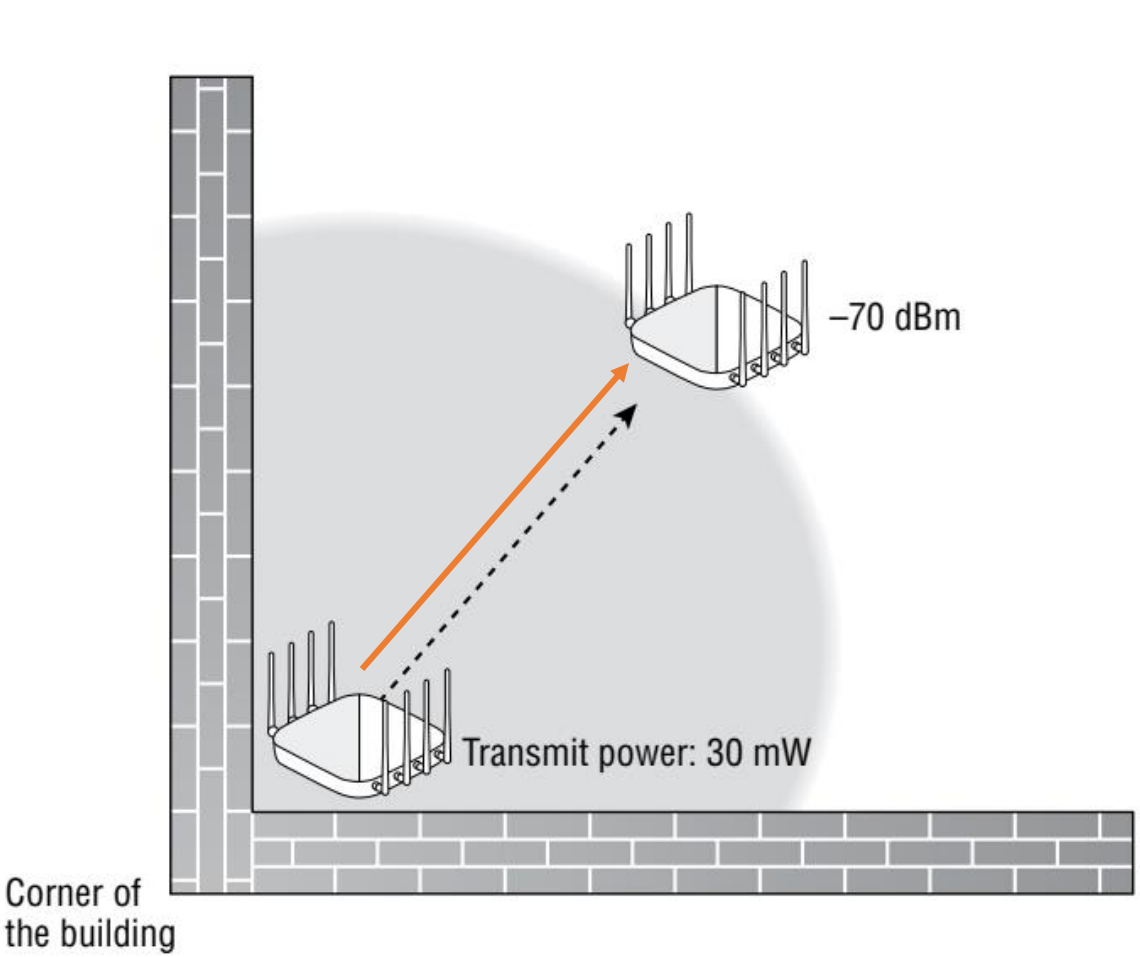
- Received signal strength (dBm), also known as received signal level (RSL)
- Noise level (dBm)
- Signal-to-noise ratio, or SNR (dB)

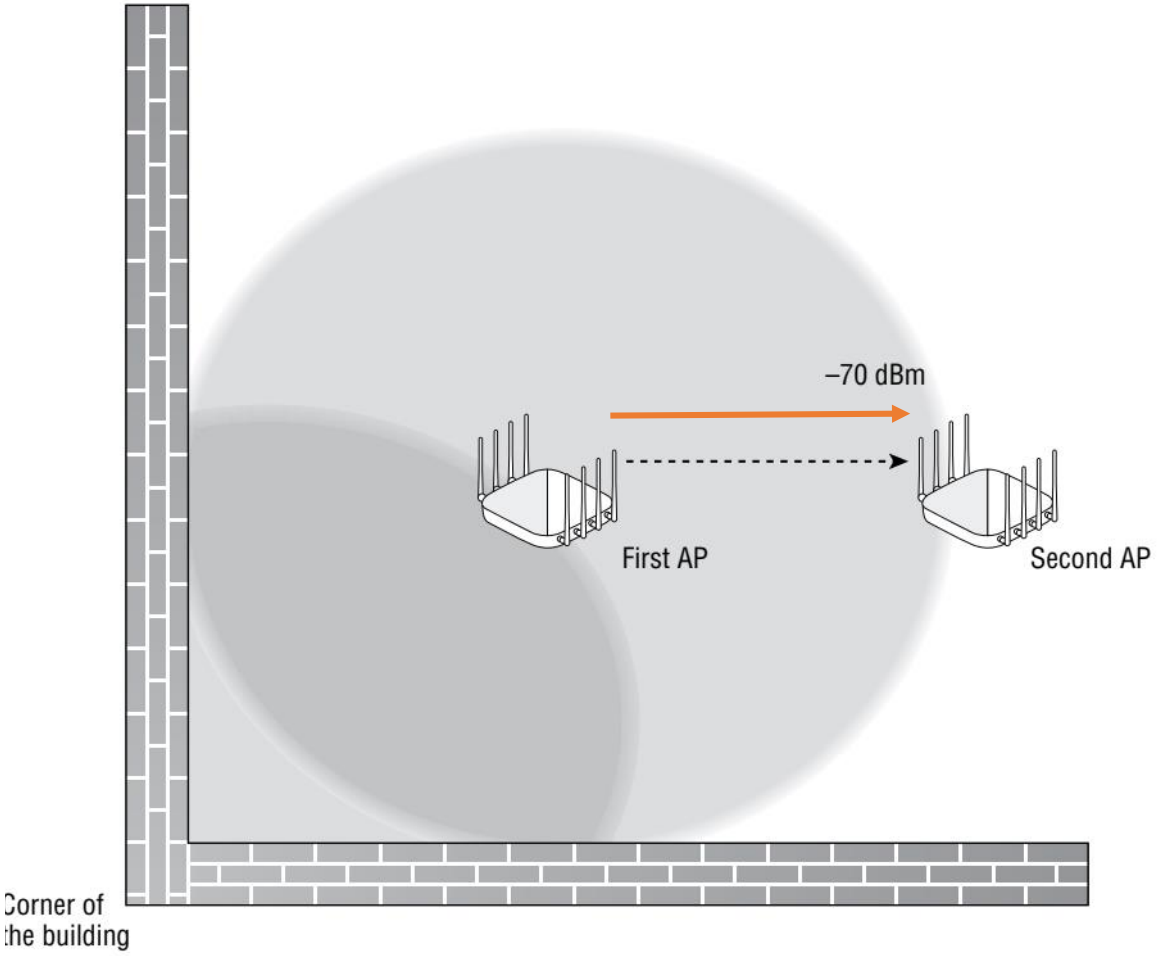
# Cell Overlap in Survey

- The received **signal strength** measurements that are recorded during a site survey **typically depend** on the **intended** use of the WLAN.
- If the **intent of the WLAN** is primarily to provide **low-density data** service versus capacity, a lower received signal of **–73 dBm** might be used as the **boundary for overlapping** cells.
- When **throughput** and **capacity** are a higher priority, using a received signal of **–70 dBm** or higher is recommended.
- When you are designing for WLANs with **VoWiFi clients**, **a –65 dBm** or stronger signal, which is even higher above the noise, is recommended.
- The **SNR** is an important value because if the **background noise** is too **close** to the received signal, data can be **corrupted** and **retransmissions** will increase.
- The **SNR** is simply the difference in decibels between the received signal and the background noise,
- Many vendors recommend a minimum **SNR** of **20 dB** for data networks and a minimum of **25 dB** for voice.


-75
dB
-75
dB
First AP Location
Second AP Location

# Cell Overlap in Survey



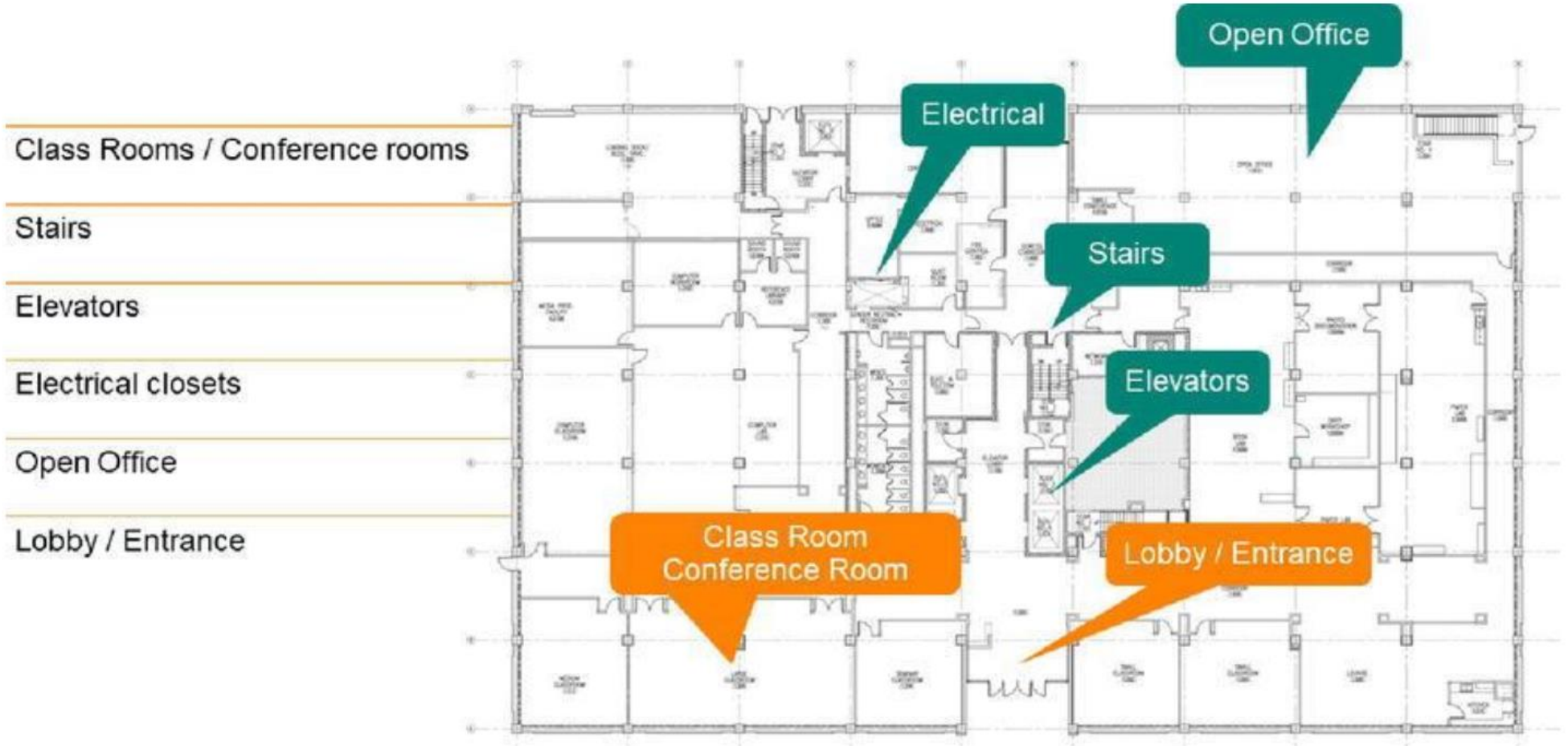




First AP Location

Second AP Location

# Define Walls Attenuation

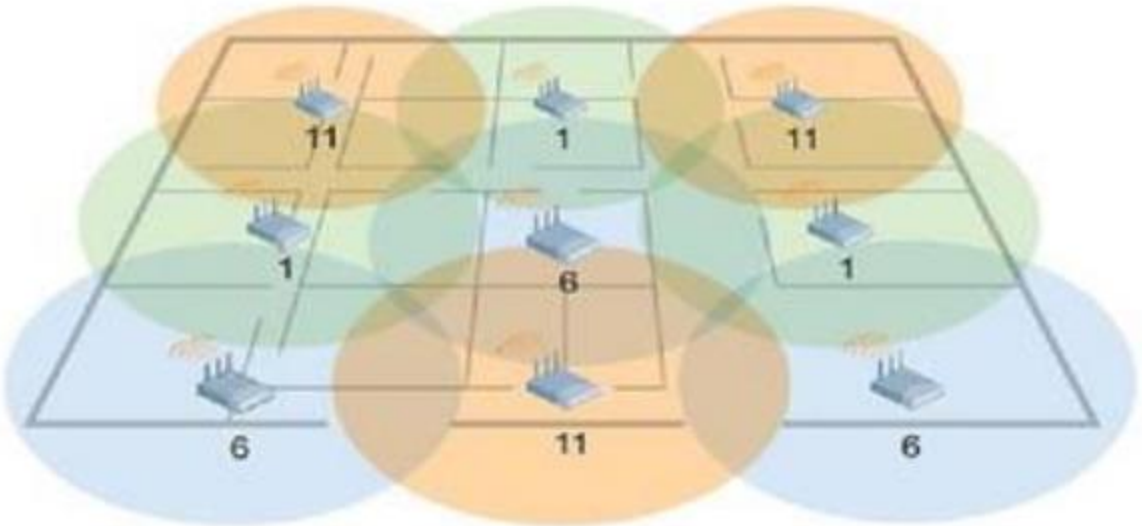
Attenuation is a decreased signal strength or amplitude that occurs when a signal passes through an object. Elevator shafts and stairwell shafts are normally heavily walled and will attenuate radio signals. Electric rooms will also cause radio attenuation. Furthermore, open office spaces are not necessarily totally open (see Figure 2-15).



# Wi-Fi Planners & Survey

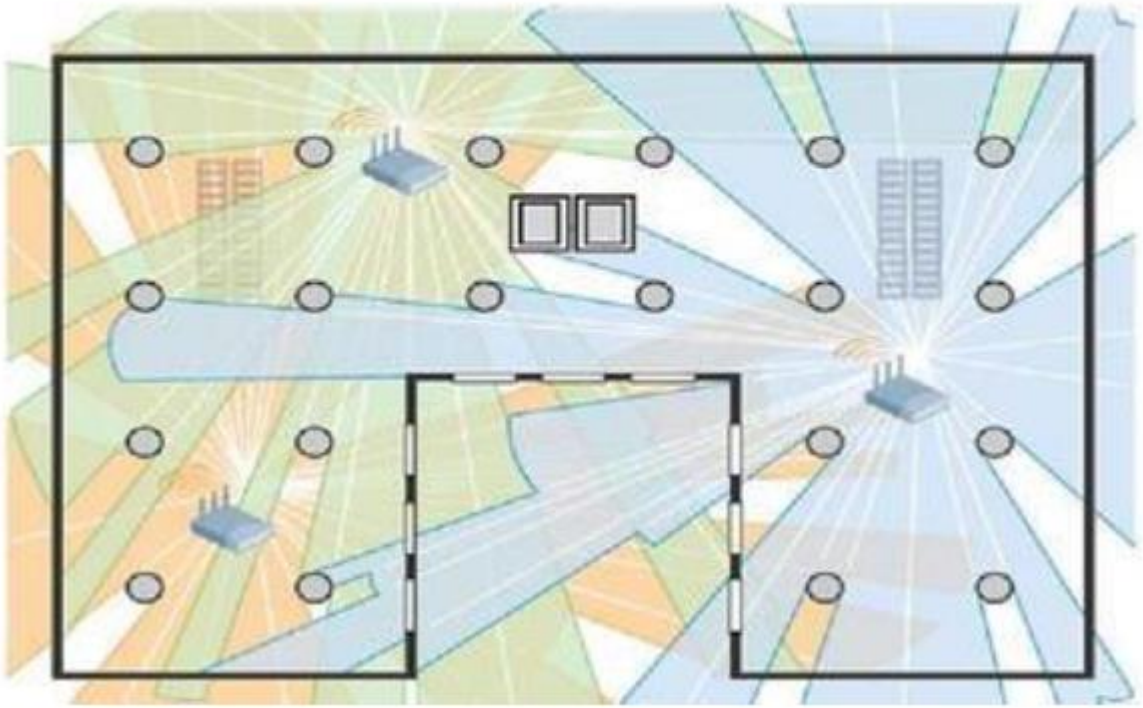
**Theoretical RF coverage**

–Virtual site survey – open office environments

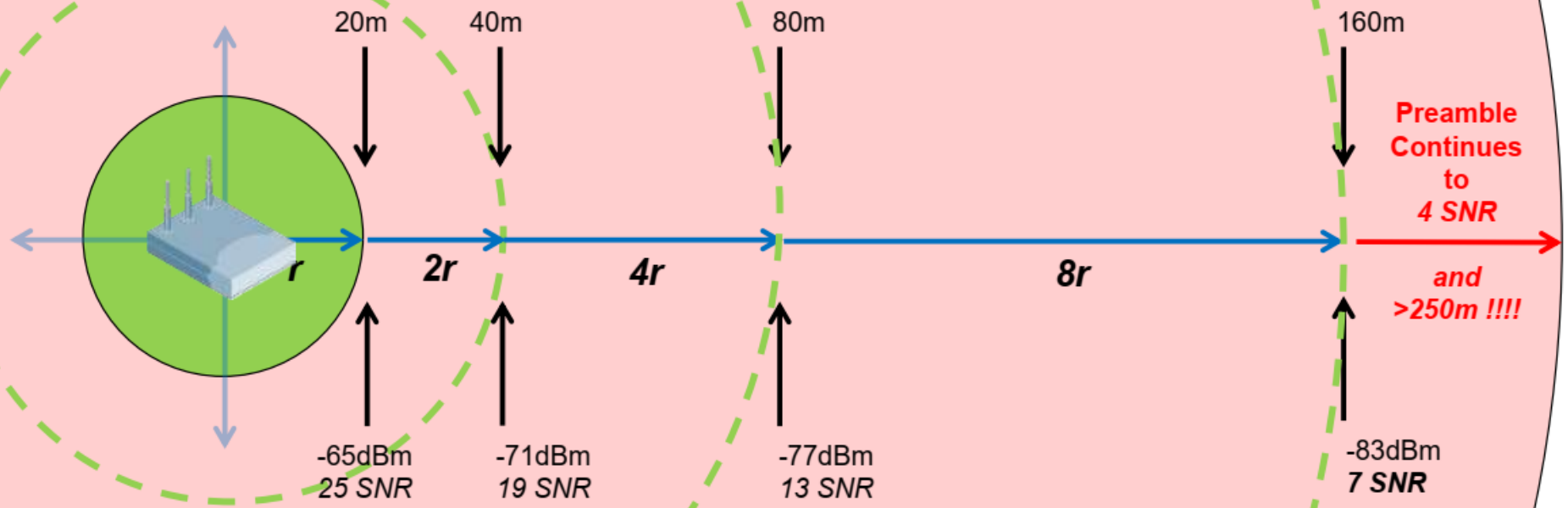



**Realistic RF coverage**

–Physical site survey – complex environments, (i.e. environmental conditions, obstructions, interference)



# Interference Radius




- Cell Edge Radius($r_1$)
  - This is what we usually call the “cell edge” of the AP
  - It is the **target data rate** radius (e.g. -67dBm = MCS15 or 54Mbps)
- Interference Radius ($r_2$)
  - 802.11 preamble can be decoded (SNR >= 4dB)

# Thanks For Watching

GAZ ARAB