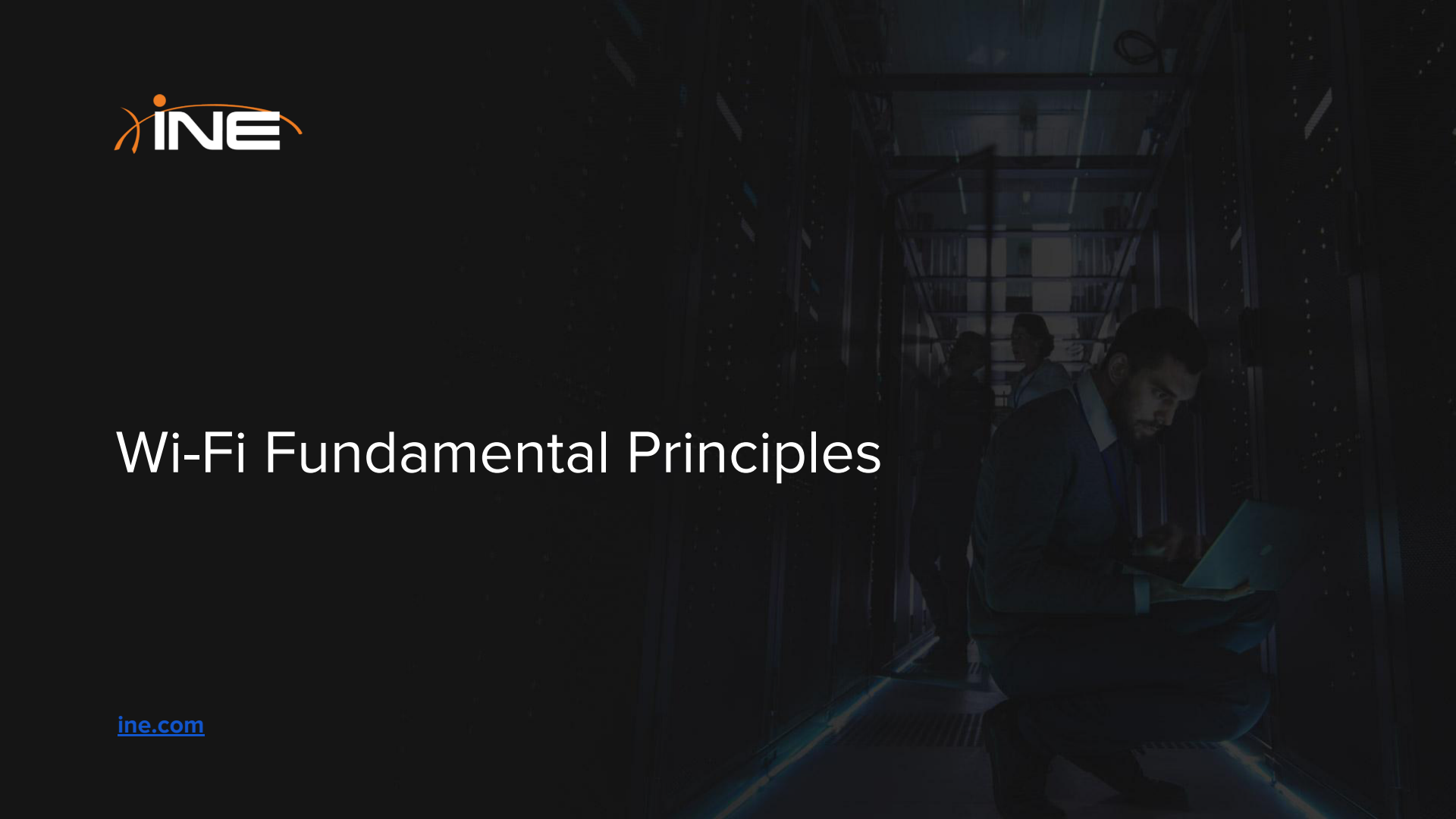

Wi-Fi Fundamental Principles

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CCIE Routing & Switching

Course Objectives

- To help you gain familiarity with basic Wi-Fi concepts, terminology and functionality.
- To provide an overview of how Radio Frequencies can be used to encode data, possible problems with Wi-Fi signal propagation, and how to effectively implement Wi-Fi channels when designing a WLAN.


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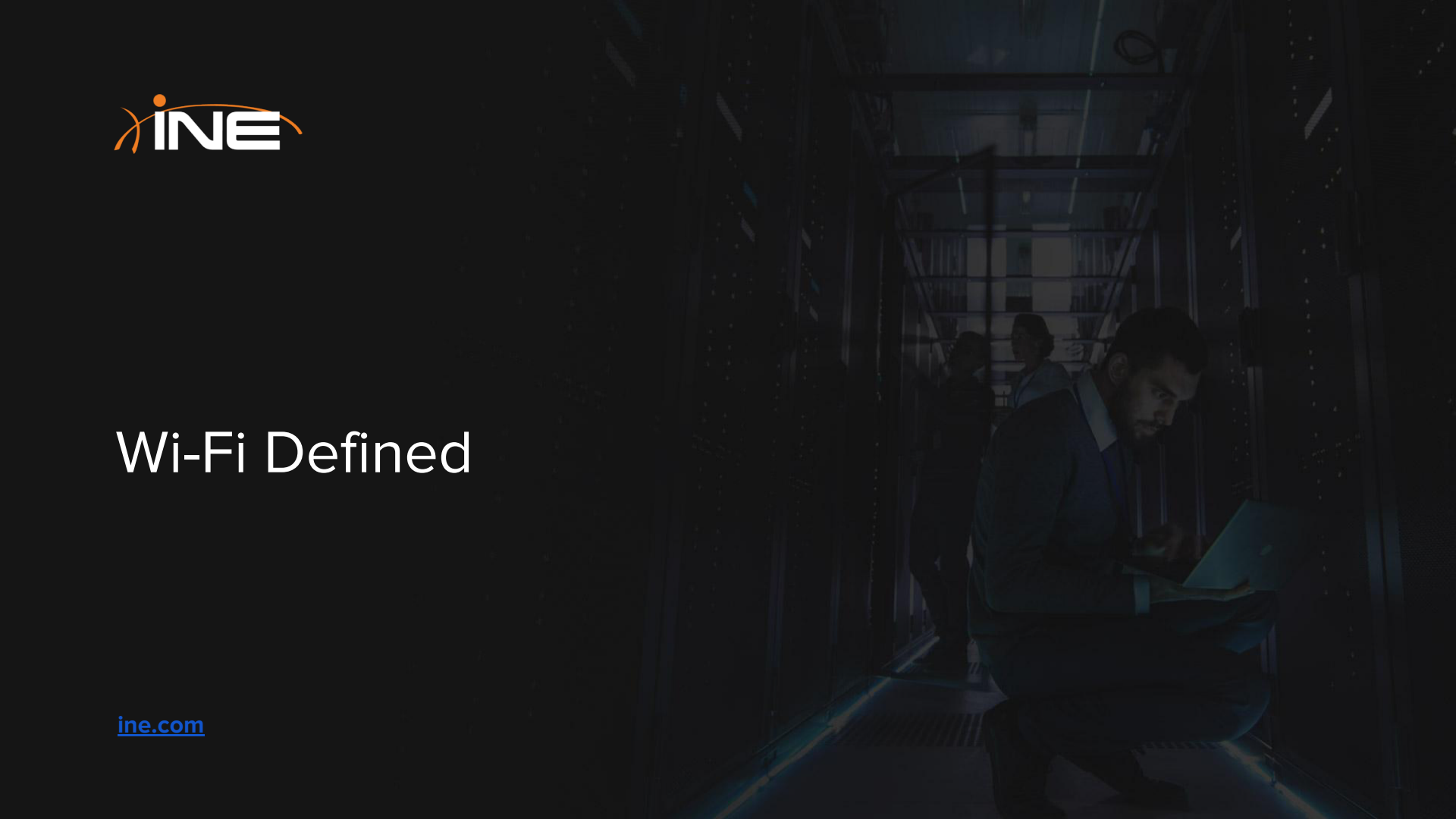

Wi-Fi Defined

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Topic Overview

- What Is Wi-Fi?
- Wi-Fi Standardization

What Is Wi-Fi?

- Wi-Fi is not an acronym
- Manipulation of electromagnetic radiation to encode data
  - Otherwise known as “Radio Frequencies”
- Sometimes called “Wireless Ethernet”...but this is wrong:
  - Totally different framing than Ethernet
  - Totally different method for detecting collisions

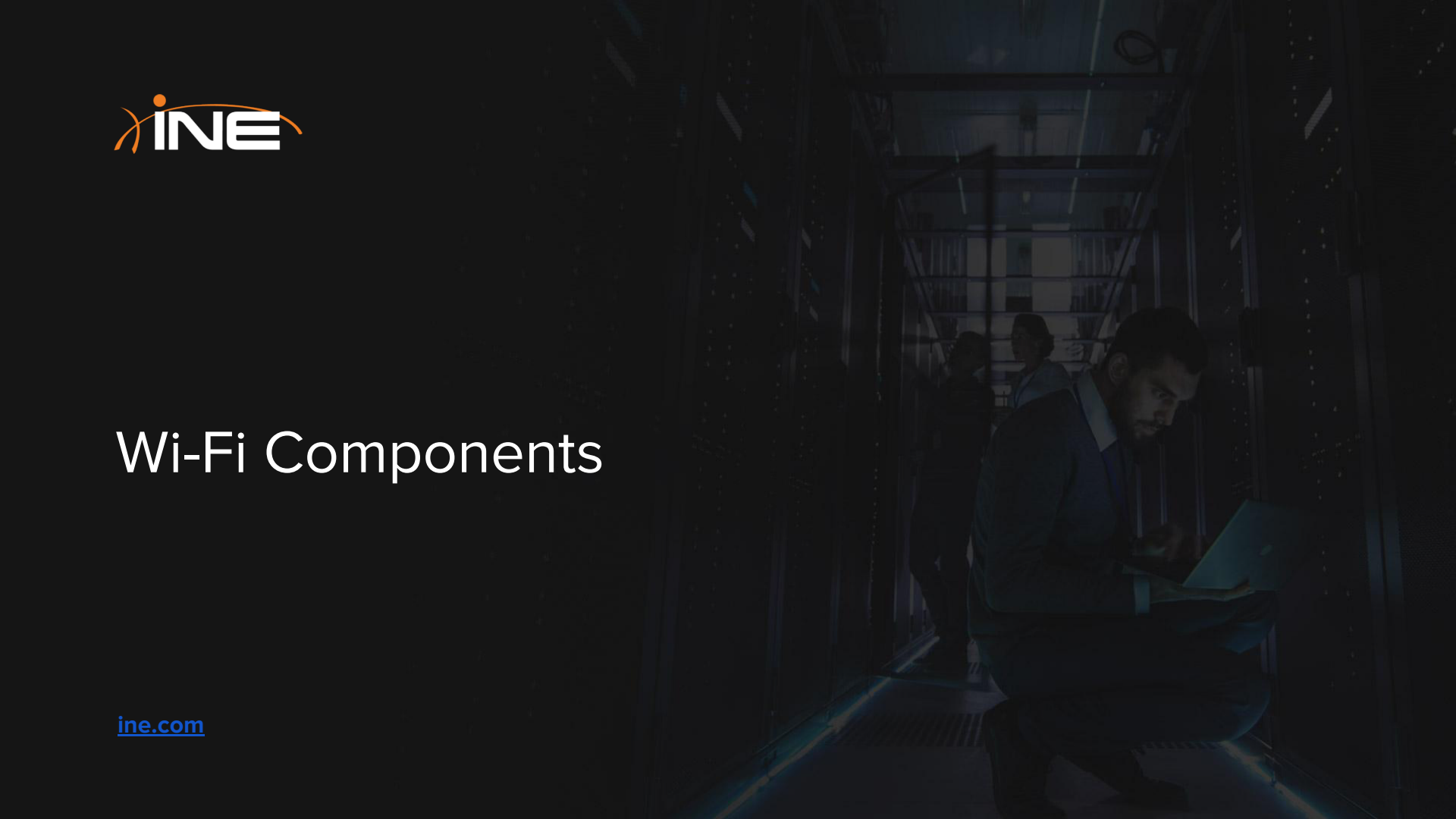
Wi-Fi Standardization

- Wi-Fi standardization done by the IEEE 802.11 Working Group.
- Wi-Fi standardization broken into two sub-categories
  - PHY (Physical Layer)
  - MAC (Media Access Control Layer)
- Each letter after 802.11 represents an amendment to the original Wi-Fi standard:
  - Original 802.11 = 1997
  - 802.11b = 1999
  - 802.11n = 2009

802.11 PHY Standards

802.11 Clause	Frequency (GHz)	Max Theoretical Data Rate	Date	Notes
802.11	2.4	2 Mbps	1997	
802.11a	5	54 Mbps	1999	
802.11b	2.4	11 Mbps	1999	
802.11g	2.4	54 Mbps	2003	
802.11n	2.4 / 5	600 Mbps	2009	
802.11ac	5	7 Gbps	2013	Also called “Wi-Fi5”
802.11ax	2.4 / 5	14 Gbps	January 2020 (estimate)	Also called, “Wi-Fi6”

Thanks for Watching!



Wi-Fi Components

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Topic Overview

+ Wi-Fi Components

Wi-Fi Components - Clients

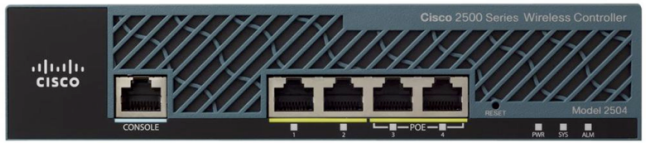
- Clients (i.e. Stations)
  - Endpoint for data
  - Wi-Fi data does not pass through a client
- Wi-Fi Client differentiations
  - Power source
    - Battery
    - AC
  - Quantity and types of antennas
    - More antennas = faster Wi-Fi
  - Quantity of types of transceivers
    - Some clients don’t support newer 802.11 standards

Wi-Fi Components – Access Points

- APs (i.e. Access Point)
  - Consolidation point for Clients
  - Bridges Wireless and Wired domains
- AP differentiators
  - Centrally Managed (“Lightweight”)
  - Individually Managed (“Autonomous” or “Standalone”)
  - Quantities and Types of transceivers (2.4GHz, 5GHz)
  - Quantities and Types of antennas
  - Indoor or Outdoor
  - Enhanced and proprietary features

Wi-Fi Components - Controllers

- Controllers
  - Central point of management for groups of Access Points
  - Control Wi-Fi access for Clients
- Controller differentiators
  - Quantity of Wi-Fi Clients supported
  - Features available
  - Appliance or Cloud-based
  - Type & quantity of uplink interfaces



Thanks for Watching!

Wi-Fi Network Types & Terminology

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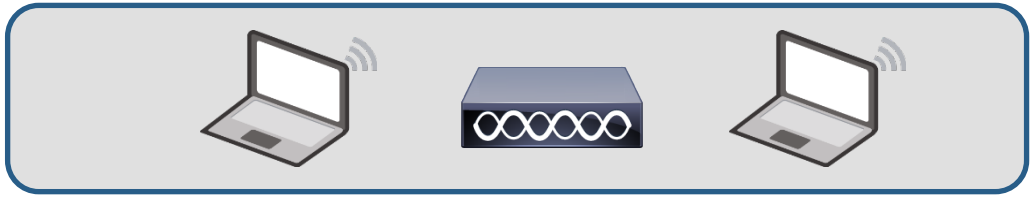
Topic Overview

+ Types of Wi-Fi Networks
+ Wi-Fi Definitions

Types Of Wi-Fi Networks

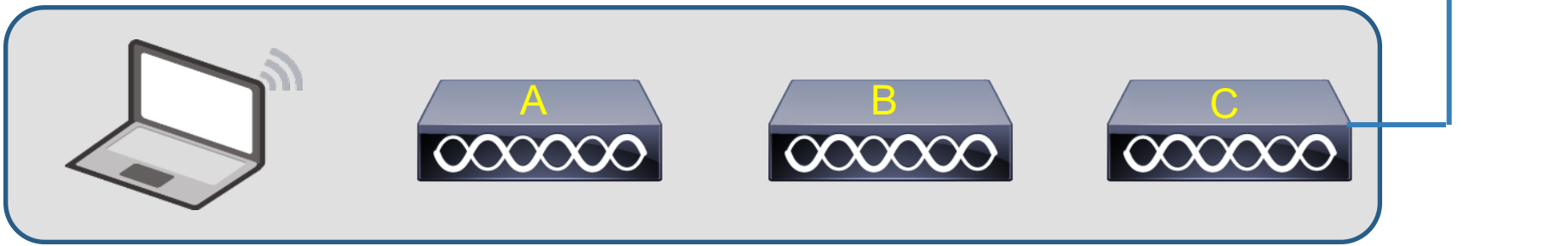
- Ad-Hoc
  - Wi-Fi Clients communicate directly, point-to-point
  - No Access Points involved
  - Infrequently used

- Infrastructure
  - Integration of an Access Point to coordinate Wi-Fi usage among multiple Clients.



Types Of Wi-Fi Networks

- Mesh
  - Access Points daisy-chained together
  - Client connects to one Access Point
  - Client's data is relayed (via Wi-Fi) from one AP to another until it reaches the wired network
  - Typically used:
    - Outdoor environments
    - Environments lacking wired Ethernet connectivity

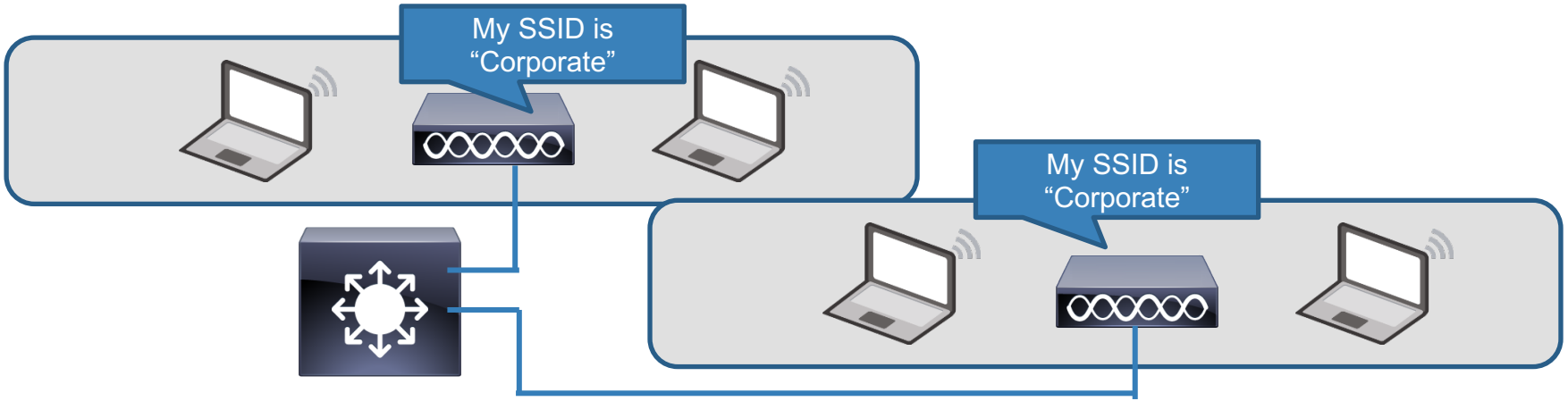


Wi-Fi Definitions

- BSS
  - Basic Service Set
  - A single Access Point and its coverage area
- BSSID
  - ID (MAC) of the Access Point
- SSID
  - Service Set Identifier
  - Configurable name of the WLAN

Wi-Fi Definitions

- Distribution System (DS) : The wired network
- Extended Service Set (ESS): A collection of Access Points connected to the same DS and offering the same WLAN (SSID)
- Extended Service Set ID (ESSID): Same as SSID



Thanks for Watching!

Radio Frequency Explained

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Topic Overview

- What Is Frequency?
- What Is Radio Frequency?
- ISM Bands

What Is Frequency?

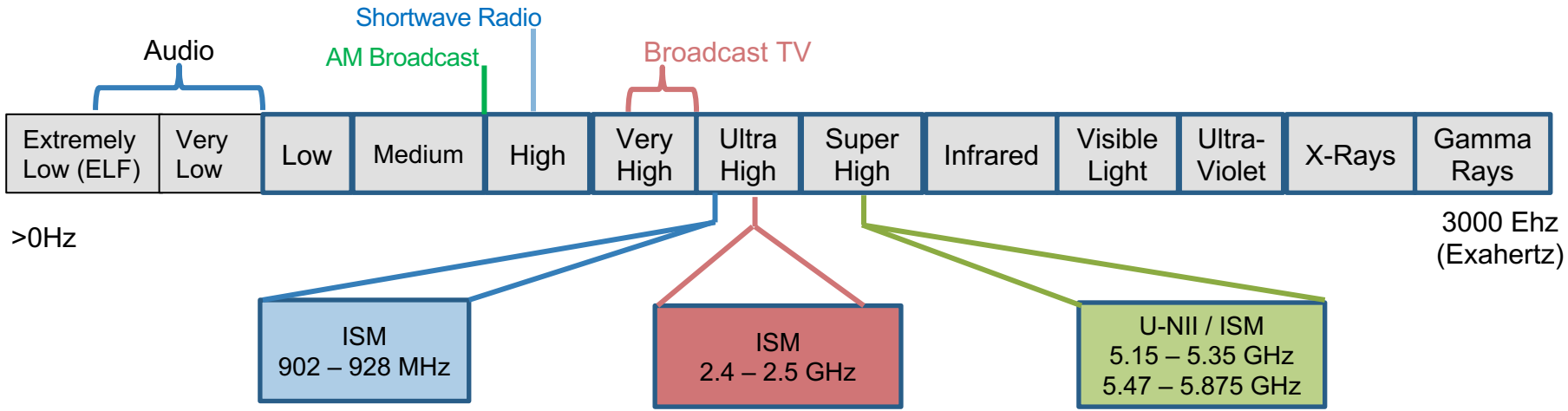
- Frequency = a measurement of how often something changes over a given time interval
- Hertz
  - No...not the car rental company
  - A measurement of how frequently something changes over 1-second
  - 1Hz = 1 change/cycle per second

What Is Radio Frequency?

- Electro Magnetic Radiation (EMR)
  - Radiation that has both electrical and magnetic properties
  - Requires no medium in order to propagate
    - Even propagates through the vacuum of space!
  - EMR has a detectable waveform (oscillates)
  - The cycling of this waveform is measured in Hertz
  - Radio Frequency = The measurement of the oscillation of EMR

ISM Bands

- EMR oscillates at certain frequencies
- All EMR frequency bands have been given labels
- ISM Bands (assigned by U.S. FCC)
  - Unlicensed bands for Industrial, Scientific and Medical use



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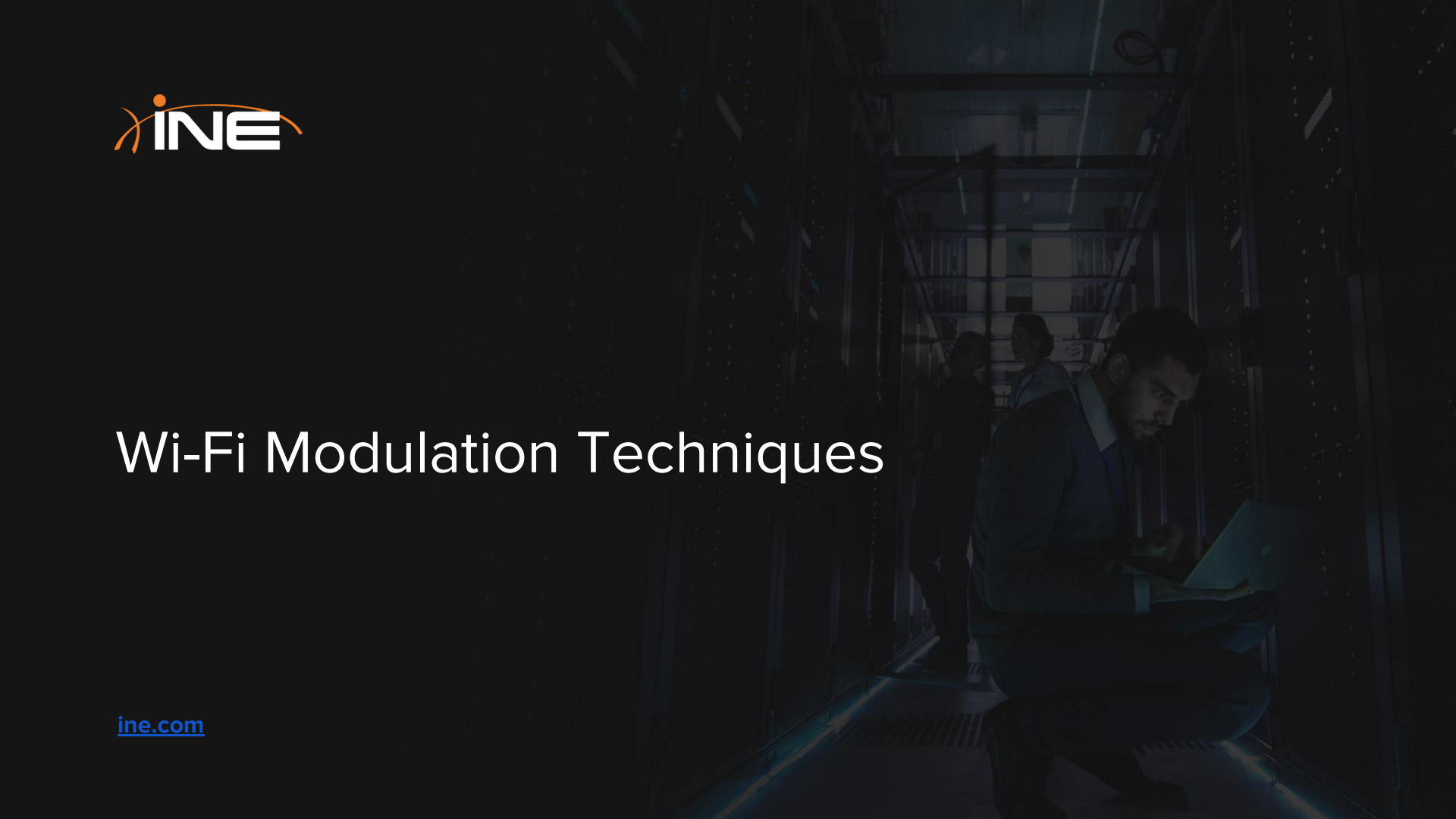

Wi-Fi Modulation Techniques

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Topic Overview

- What Is Modulation?
- RF Frequency
- Wavelength
- Amplitude
- Phase

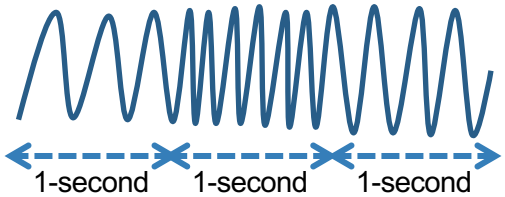
What Is Modulation?

- Radio Frequency (i.e. Electro Magnetic Radiation) has several different, descriptive properties.
- These properties can be artificially changed over time to encode data.
- This process is called “Modulation”
- So what are the aspects of RF that can be modulated?

RF Frequency

- Frequency
  - The greater the frequency, the more data that can be encoded onto a Wi-Fi signal

  - Frequency modulation (FM) involves modifying the frequency of a signal to encode data



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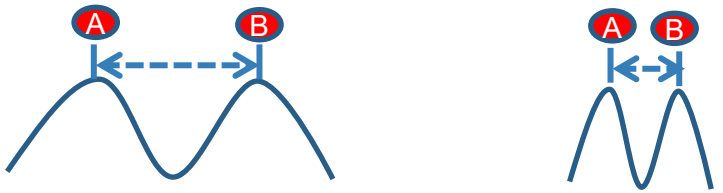
  - RF measures changes that occur in millions or billions of Hz
    - 2.4GHz = 2,400,000,000 oscillations per second

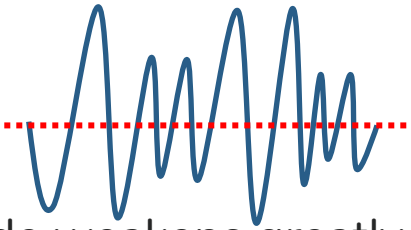
Wavelength

- Wavelength
  - Measured in meters
  - Wavelength is related to frequency
  - Inversely proportional to frequency
    - The higher the frequency, the shorter the wavelength
    - The longer the wavelength, the better a signal propagates through things

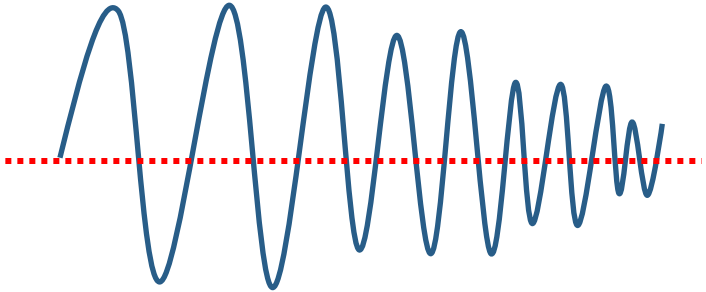


Amplitude

- Amplitude
  - The strength of the signal, a measurement of power
  - Amplitude can be modulated to encode data

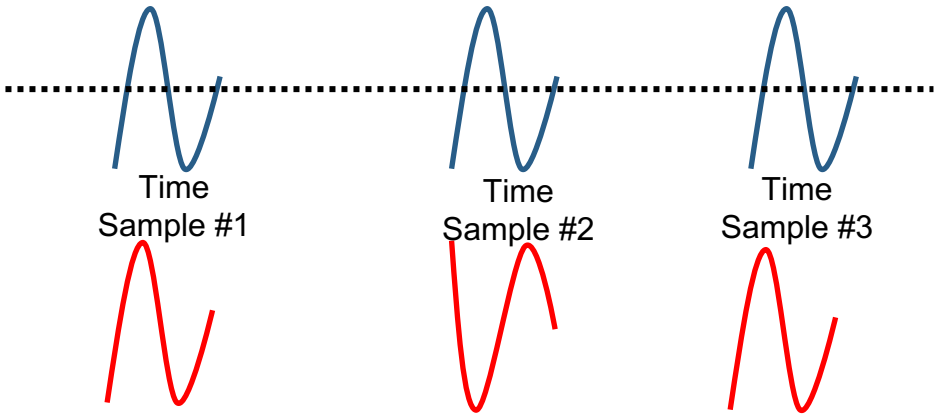


  - RF amplitude weakens greatly over distance and as it passes through objects
  - This is called Attenuation



Phase

- Phase
  - A comparison of the waveform between two RF signals
  - At the moment of comparison, two waveforms that are identical are considered to be 100% in phase
  - The phase of two RF waveforms can be intentionally modified to encode data



Thanks for Watching!

Radio Frequency Propagation

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Topic Overview

- Overview Of RF Propagation Problems
- Absorption
- Reflection & Refraction
- Diffraction & Scattering
- Free Space Path Loss
- Multipath

Propagation Problems

- As RF propagates away from the transmitter, there are several situations which could cause it to:
  - Severely attenuate
  - Be completely blocked
  - Be reflected to a different direction

Absorption

- Absorption
  - Some materials can absorb RF energy
  - Materials can either completely absorb RF energy, or severely attenuate it
    - Rock and stone
    - Water
    - Drywall
    - Your body

RF Absorption Rates by Common Materials

Material	Absorption Rate
Plasterboard/drywall	3–5 dB
Glass wall and metal frame	6 dB
Metal door	6–10 dB
Window	3 dB
Concrete wall	6–15 dB
Block wall	4–6 dB

CWNA Certified Wireless Network Administrator Official Study Guide

Reflection & Refraction

- Reflection
  - Materials that reflect RF energy into a different direction, or even back to the source
  - RF energy is not absorbed into the material at all
    - Metal
    - Bodies of water
- Refraction
  - The bending of a wave as it passes through objects of different density (i.e. from air into glass)
  - RF energy is emitted in a different direction once it has passed through
  - Different materials have different refractive indexes

Diffraction & Scattering

- Diffraction
  - The bending and spreading around of an RF signal when it encounters an obstruction
  - Hills or buildings can cause this for Wi-Fi
  - Creates RF shadows on the other side of the object, which cause dead coverage zones or degraded signals
- Scattering
  - Similar to refraction, but on a larger scale
  - Unpredictable and causes Wi-Fi signal to scatter in all directions
  - Can be caused by smog, dust, tree foliage and humidity

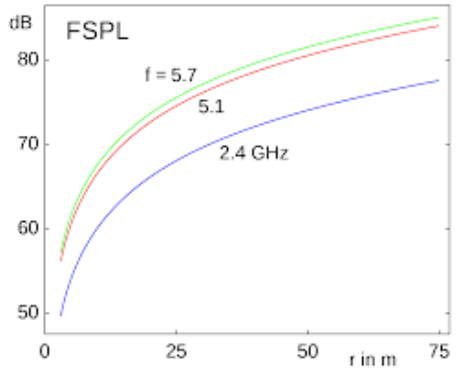
Free Space Path Loss

- FSPL = The amount of RF energy lost as a signal travels through the air
- Can be calculated

Yikes!!

$$\mathrm{FSPL(dB)} = 20\log_{10}(d) + 20\log_{10}(f) + 92.45$$

- Loss is relative to frequency and distance

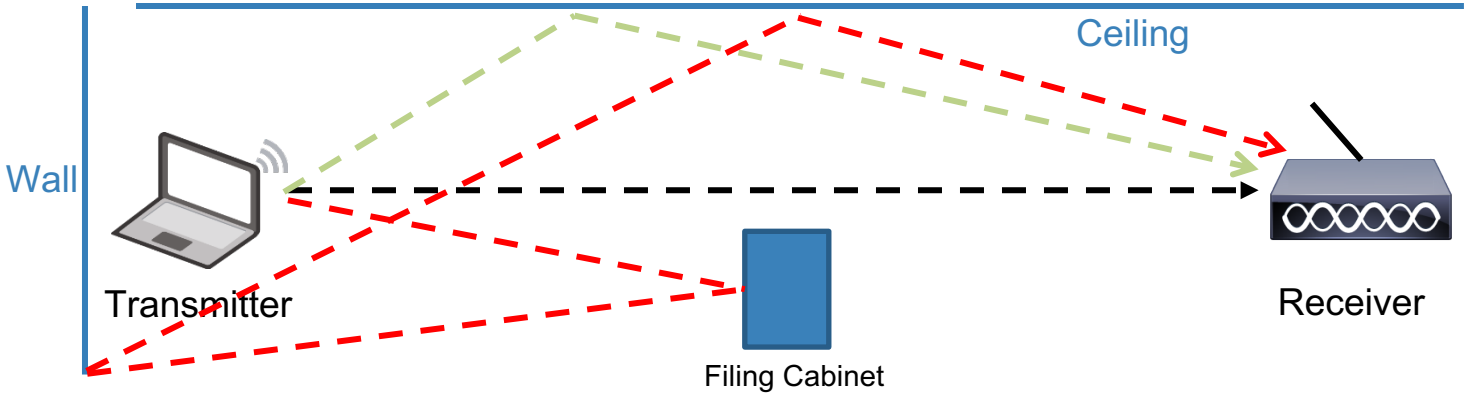


Multipath

- As an RF signal (wave) is transmitted away from a transmitter, it will expand and encounter multiple objects on its way to the receiver
  - When an RF signal is reflected off an object, multiple wavefronts are created
  - As a result of these new duplicate wavefronts, there are multiple wavefronts that reach the receiver, each taking a different path
  - Copies of the original signal are delayed as they reach the receiver
- The more metal that is in your environment, the more multipath you will experience

Multipath

- Effects of multipath
  - Data corruption
  - Signal nulling
  - Increased signal amplitude
  - Decreased signal amplitude
- Utilizing multiple antennas on the receiver can reduce the negative effects of multipath



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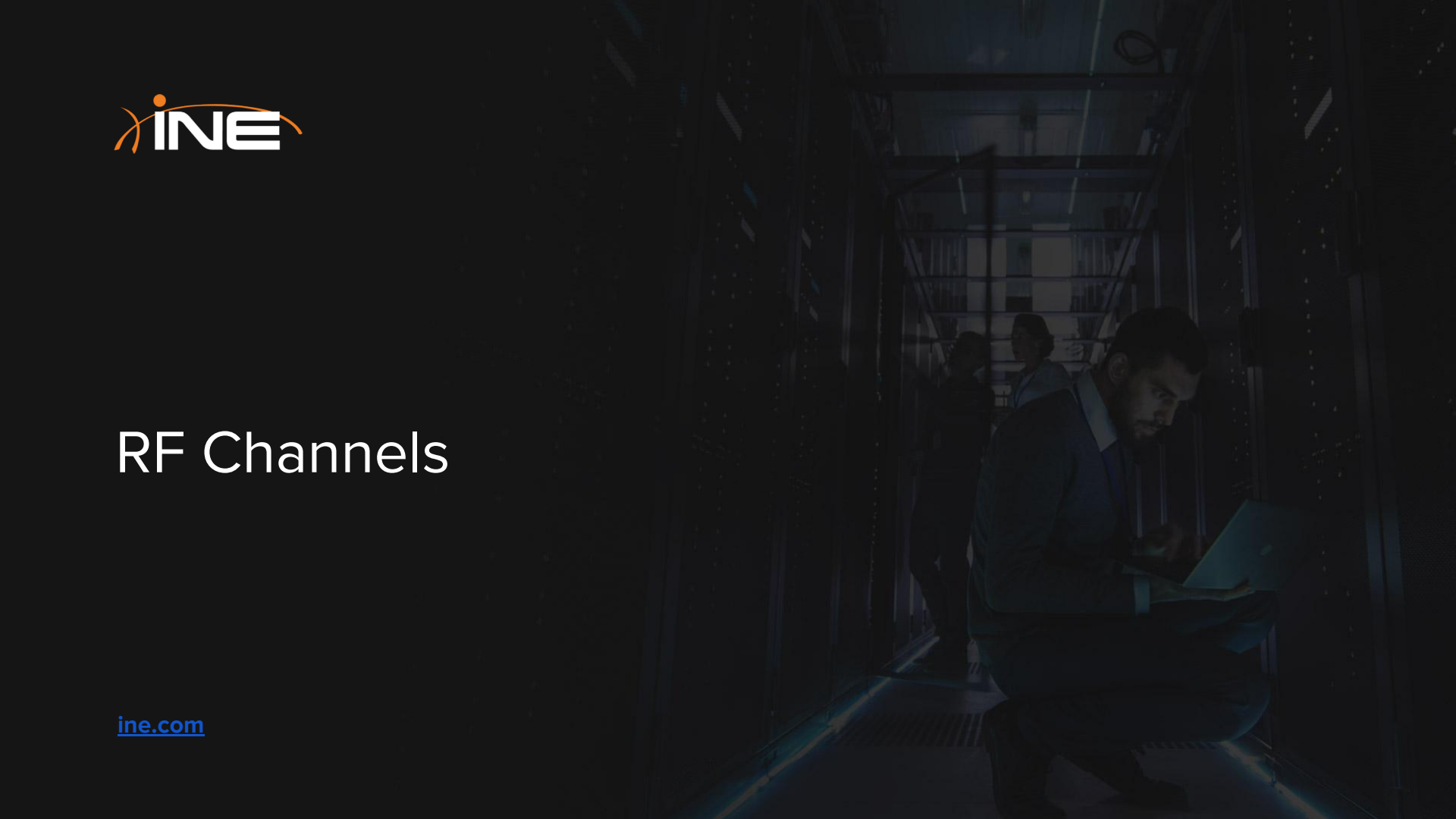

RF Channels

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Topic Overview

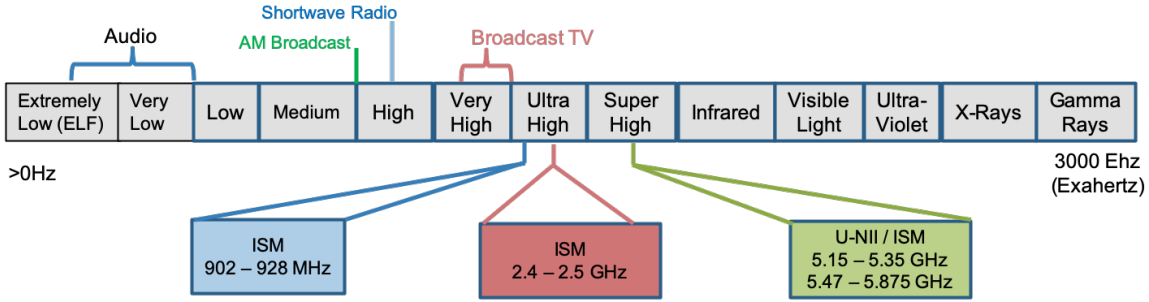
- What Is A Wi-Fi Channel?
- Wi-Fi Channel Bandwidth
- Wi-Fi Bandwidth Example

What Is A Wi-Fi Channel?

- A Wi-Fi channel number is actually a collection of different frequencies working together
- For example:
  - Channel-1 in the 2.4GHz space consists of all frequencies from:
    - 2.401 GHz through...
    - 2.423 Ghz
  - All of these frequencies can be modulated differently (at the same time) to encode data

Wi-Fi Channel Bandwidth

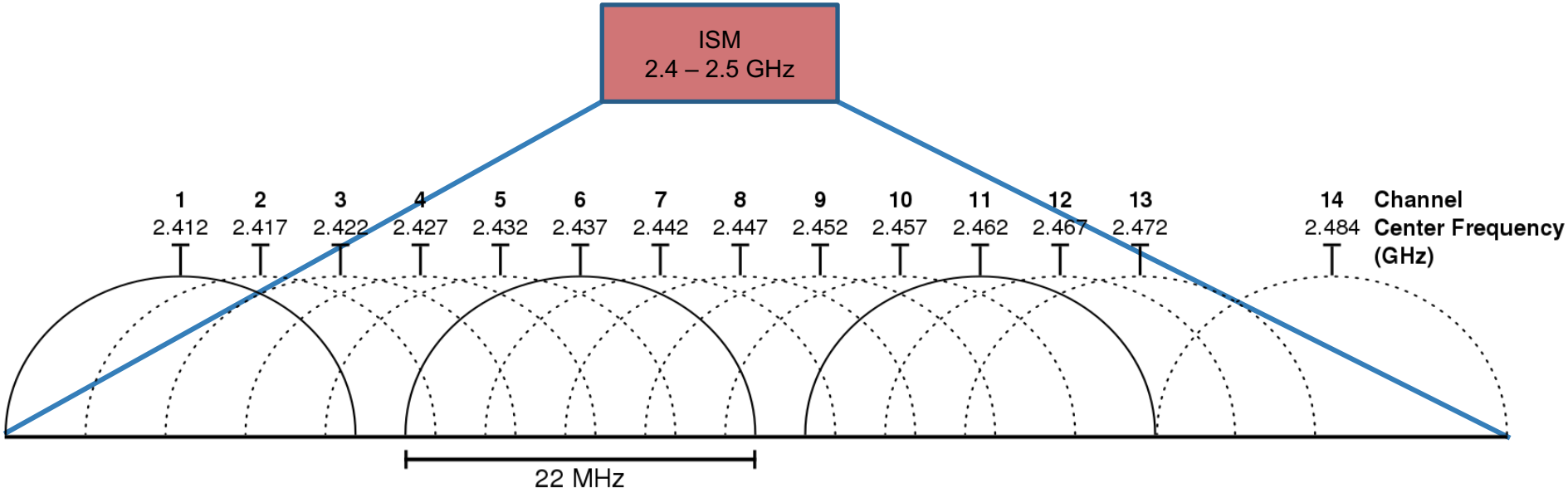
- Unlicensed Wi-Fi operates within the FCC ISM Bands



- Within each band a single Wi-Fi channel can consume:
  - 20MHz of band width (802.11b)
  - 40MHz of band width (802.11n)
  - 80MHz of band width (802.11ac)
  - 160MHz of band width (802.11ax)

Wi-Fi Bandwidth Example

- A Wi-Fi channel number is allocated at the center-point of each 22MHz bandwidth spread



Thanks for Watching!

Planning For RF Channel Implementation

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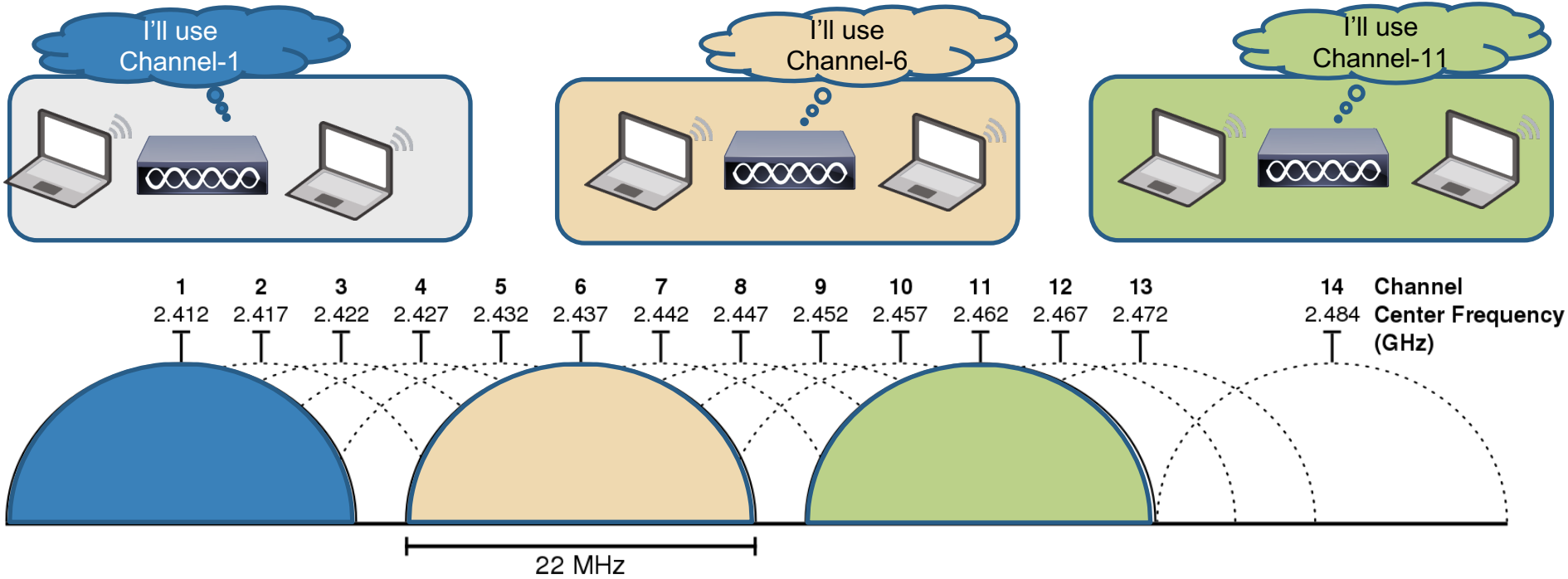
Topic Overview

- Non-Overlapping Channels
- Wi-Fi Channel Design
- What About 40MHz?
- U-NII
- Utilizing U-NII For Wider Bandwidth

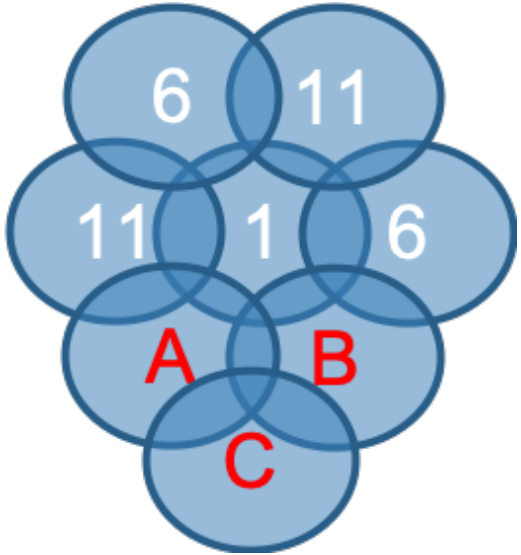
Non-Overlapping Channels

- In an environment with multiple BSS's, channels must be selected that don't overlap



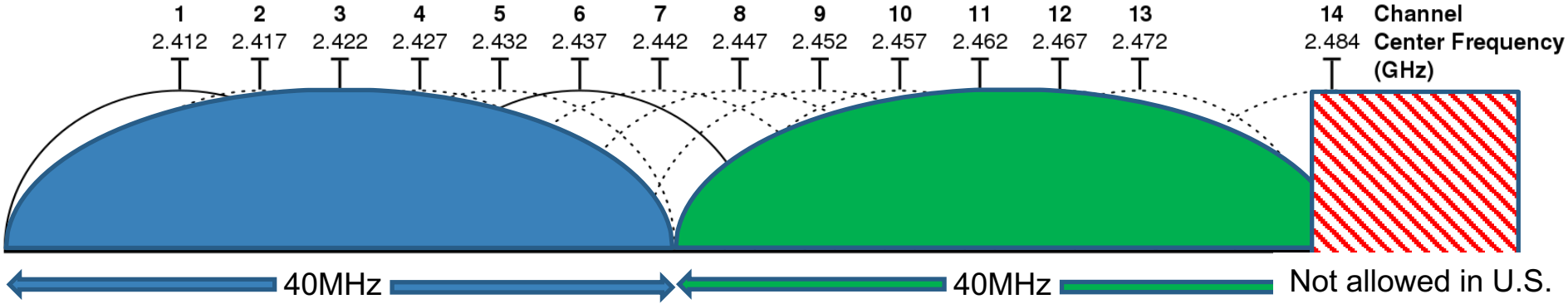
Wi-Fi Channel Design

- Given the following graphic/topology…what Wi-Fi channel should be implemented for:
  - BSS-A?
  - BSS-B?
  - BSS-C?



What About 40MHz?

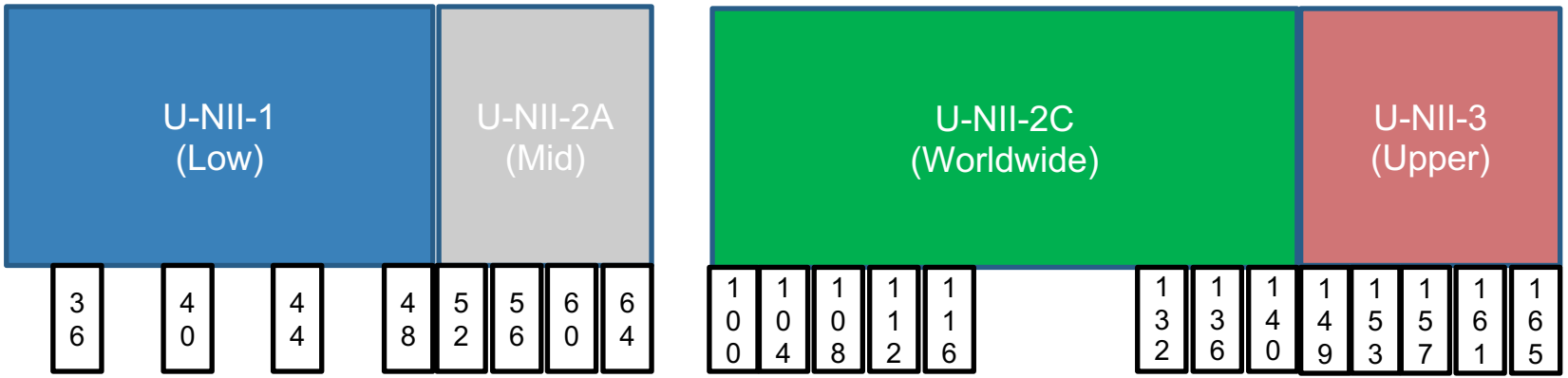
- 802.11n (and subsequent 802.11 protocols) made it possible to select channels that were 40MHz wide
- This allowed for faster speeds/datarates
- Channel overlap becomes a problem in the 2.4GHz space



- The solution? 5GHz U-NII bands!

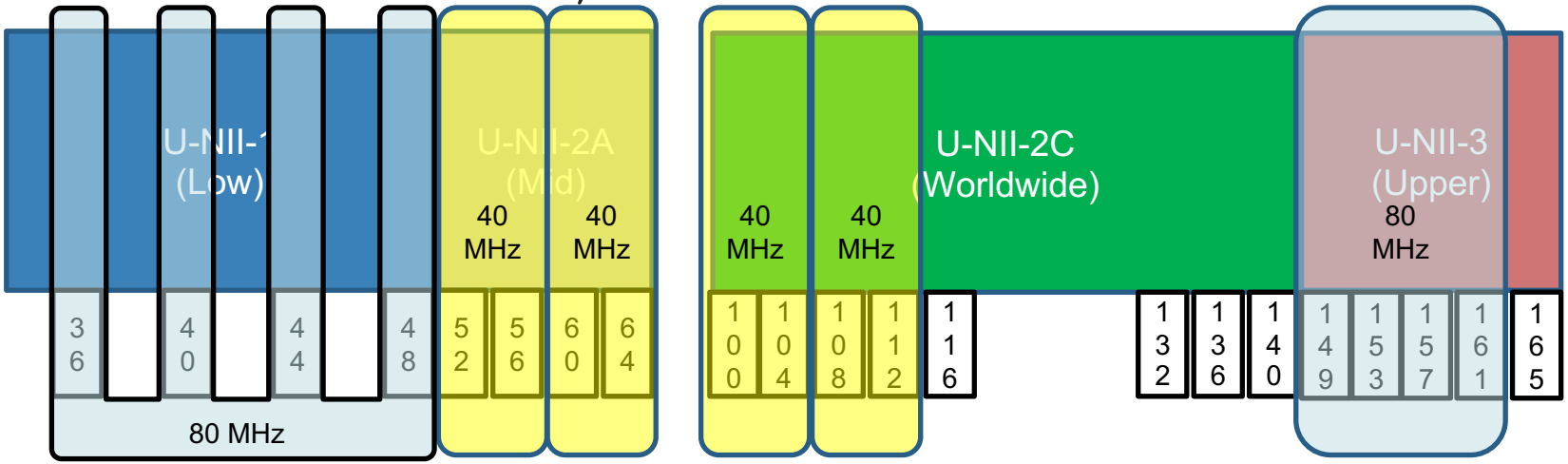
U-NII

- Unlicensed National Information Infrastructure
- Divides the 5GHz spectrum into four ranges (U.S.):
  - Each range contains several 20MHz-wide channels



Utilizing U-NII For Wider Bandwidth

- Newer Wi-Fi Standards (since 802.11n) have supported wider channels for faster datarates
  - 802.11n supports up to 40MHz channels
  - 802.11ac supports up to 160MHz channels (these would cross U-NII boundaries)



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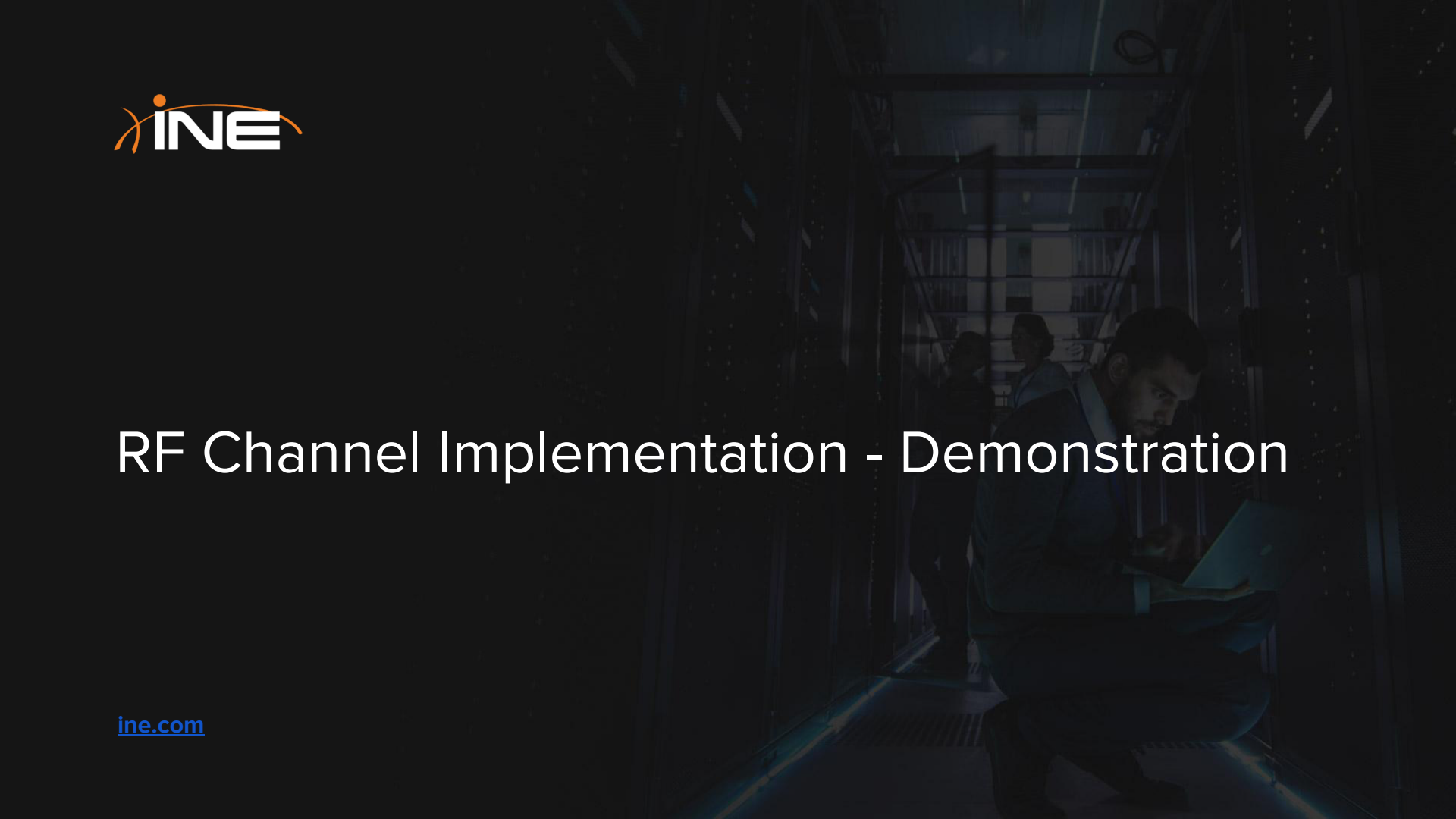

RF Channel Implementation - Demonstration

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Topic Overview

- RF Channel Implementation Demonstration

Thanks for Watching!