# Wi-Fi For Beginners Module 5

## Wi-Fi Clients

(Slide deck v6)

# Introduction

Hello, my name's Nigel Bowden. Welcome to module 5 of the Wi-Fi for beginners podcast. This is a series of podcasts discussing the fundamentals of wireless LAN networking.

In each episode, we'll take a look at a different aspect of Wi-Fi to build your understanding and knowledge of wireless LAN networks.

Each episode is be accompanied by a set of slides describing the topics covered in that episode. Although you don't need to review these slides whilst listening to the podcast, they will be useful for reviewing the material we discuss and may provide some visual aids to more fully understand some of the concepts and equipment described.

All recordings and supporting material can be found at WiFiForBeginners.com

# Aims of Podcast Series

- Present the fundamentals of Wi-Fi in a series of audio presentations
  - Hopefully in an easy-to-understand format
  - Useful to those on a daily commute, driving, running etc.
- Who is it aimed at?
  - Most likely IT professionals, students, people interested in career move
- Assumed knowledge:
  - Fundamentals of the 7 layer OSI model
  - Ethernet, switching and routing
  - IP addressing
  - Local Area Networks (LAN)
  - You have reviewed previous episodes! :)
- WiFi in commercial/professional environment - not home

# Who Am I?

- Nigel Bowden
- UK Based
- IT Industry for 30+ years
- Specializing in Wireless LANs for 5+ years
- Industry certifications:
  - CWNP: Certified Wireless Network Expert (CWNE #135)
  - Cisco CCNP R&S
  - Cisco CCNP Wireless
  - Miscellaneous other vendor specific certs
- Roles: Design, Consultancy & Deployment of WLANs (mainly Cisco)
- Prolific social media participant:
  - @WiFiNigel (Twitter)
  - WiFiNigel.com (Blog)

# In This Module

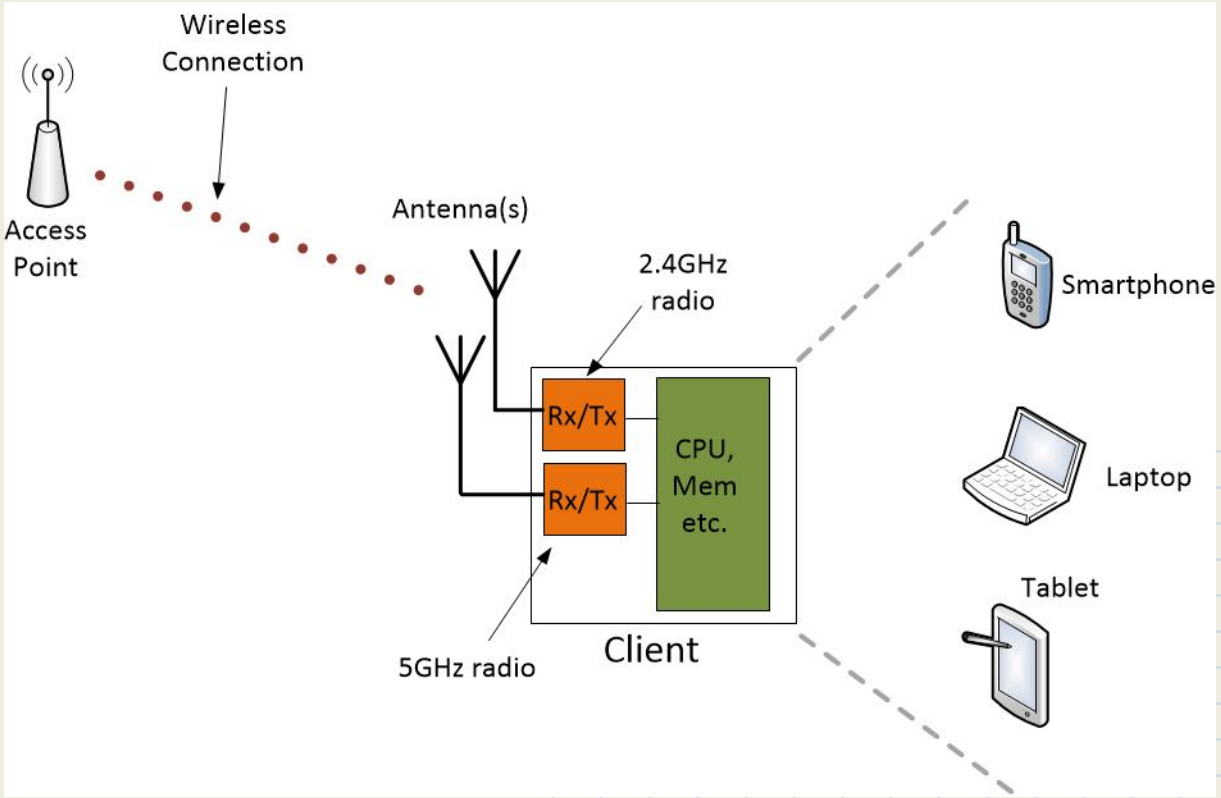
- What is a wireless client?
- Standards Review
- Evolution of Clients
- Client behaviour
- 802.11 Frame Types
- Client Speeds
- Characteristics & Requirements of Clients
- Wireless NICs
- Drivers & Utilities
- Client behaviour revisited

# What is a wireless client?

- WLANs primarily exist for one reason:
  - provide connectivity to users and devices to access services
- Wireless client devices are used to connect to a WLAN to provide the required access to services
- These devices are “wireless clients”

# What is a wireless client?

- Client device has one or two radios (2.4 GHz/5GHz)
- Antenna(s), often:
  - small
  - low gain
- Radios likely to be part of chipset that supports other radio types (e.g bluetooth)

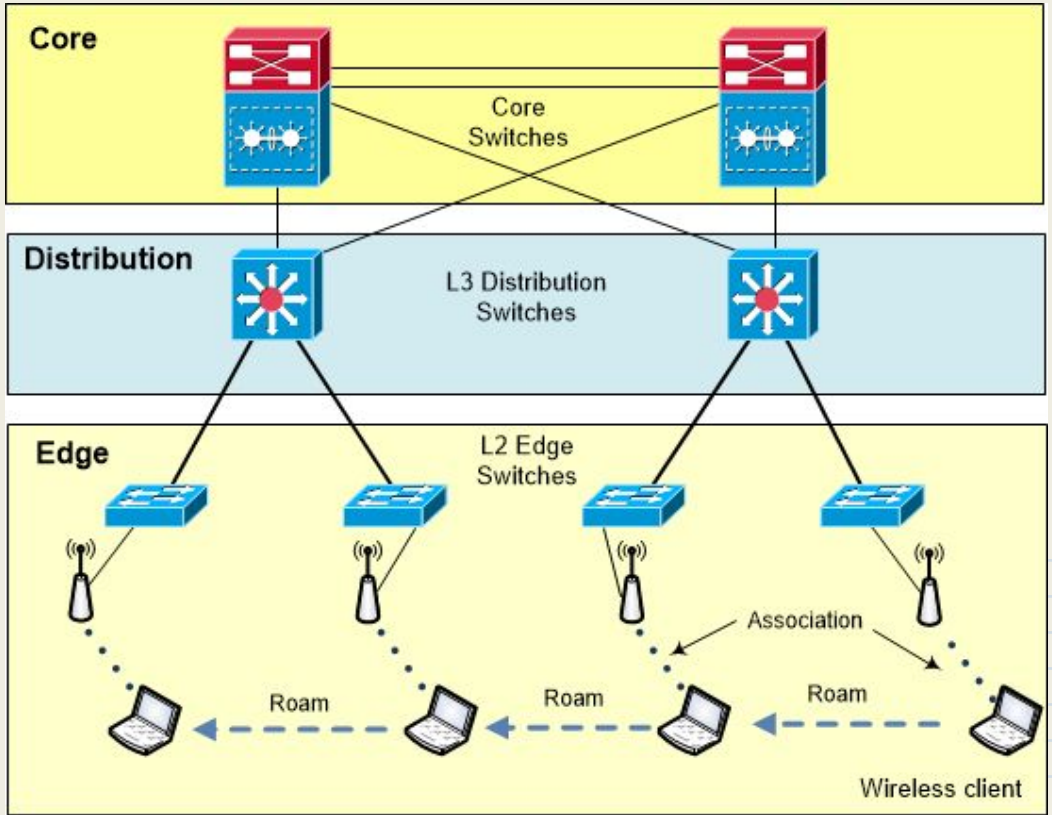


# What is a wireless client?

- What is a wireless client?
  - Device that supports 802.11
  - “Associates” (connects) to a wireless Access Point
- Examples include:
  - Laptops, tablets, smartphones, Wi-Fi voice handsets, barcode scanners, patient telemetry systems, POS units, heating controllers…. etc.
- Ideally, clients associate with access point and roam to each nearest access point as they move around a facility
  - At edge of network as we discussed in our original reference model (episode1)

# What is a wireless client?

- Reference model with roaming



# What is a wireless client?

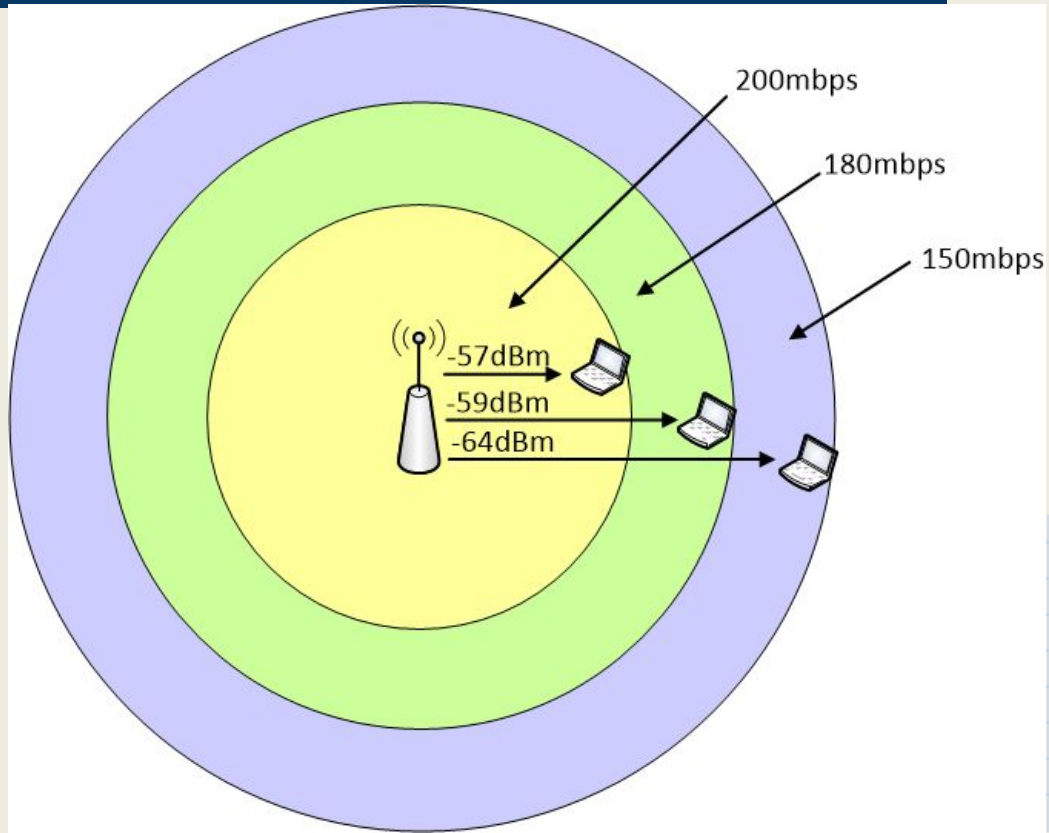
- Client connectivity process:
  - Powered on/come into range of network
  - Probes for network (discover wireless networks available)
  - Joins network
    - hopefully associates to nearest access point (“loudest”/highest signal level)
  - Client connectivity
    - RF connection to AP
    - Client traffic travels over RF link (via AP) to edge switch -> distribution switch -> core switch -> required service destination
- As client is mobile, when move around network, desired behaviour is to re-establish RF connection to nearest AP as moves around
  - maintain highest speed, best quality connection

# What is a wireless client?

- Desired operation is to use/roam to nearest AP at all times - but, why?
- Client could maintain a connection to an AP over a very large area
  - not desirable behaviour
- Remember previous free space loss discussion
  - as client moves away from RF source (AP), received power level at client reduces
- As signal level received at client reduces (with distance), the connection speed at which client can connect reduces
  - net effect: as client moves further away from AP, connection speed drops
- Obstruction attenuation also a huge factor as move around facility

# What is a wireless client?

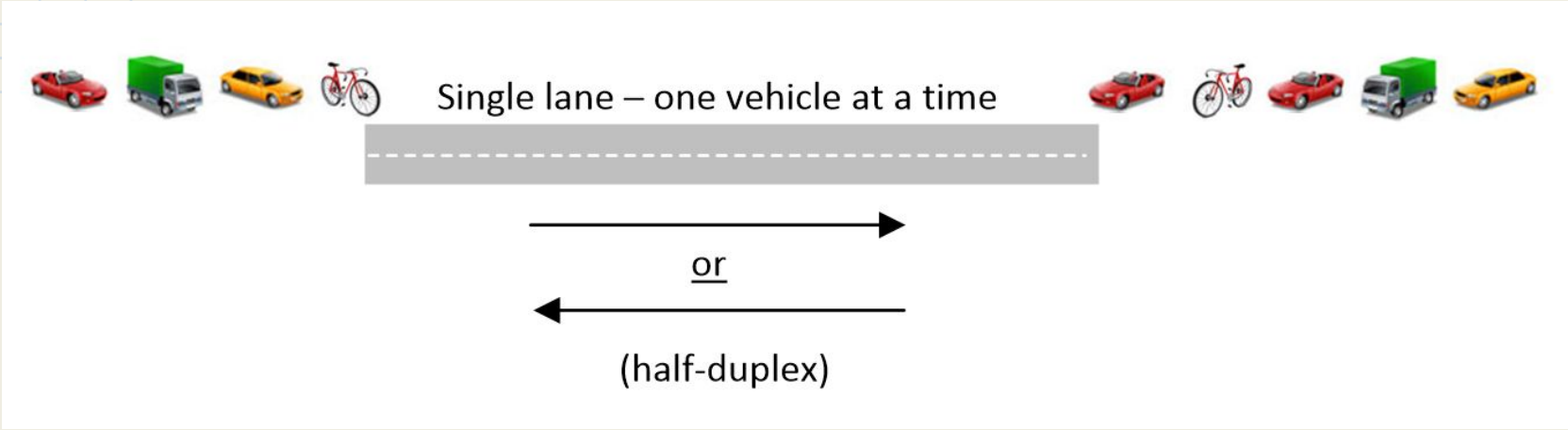
Note: Example figures only, actual figures will vary with client type and capabilities.



# What is a wireless client?

- OK, so why is reduction in client speed such a bad thing?
  - after all, only affects that one client - right?
- Remember back to discussions about RF medium being a shared medium
  - All clients in a AP cell share airtime
  - Clients take it in turns to transmit (contended medium)
  - No client can transmit until an opportunity to transmit arises
- If a client is running at slow speeds, the client takes longer than it could to send data
  - e.g. sending 1Mbyte of data is quicker at a connection speed of 450mbps compared to 54mbps
  - Consumes less “air-time”
- Clients not connected at optimal speeds have negative effect on whole cell

# What is a wireless client?




- Vehicles travel one at a time (in one direction only) down single lane highway
- Fast vehicles stuck in queue behind slow vehicles have to wait longer to use road
- Throughput of traffic on road limited by single lane (half duplex) and slower vehicles delaying faster vehicles
- Much better throughput if all sports cars!

# Wireless Client Types

- Huge variety of WiFi clients & capabilities
- Depending on age, may support different standards (802.11 amendments!) and bands
  - older clients may only support 802.11g & 802.11a
  - newer clients should support more recent standards, but low-cost devices perhaps still only 2.4GHz band
- WiFi client is anything that will associate with an 802.11 access point
- Includes: laptops, tablets, smartphones, wireless phones (802.11, not DECT), hand scanners, home automation equipment, TV, media units (set-top boxes), security cameras, medical equipment, Point of Sale (POS) devices, games consoles
- The capabilities of each client vary depending on factors such when it was built, physical size and power availability.

# Standards Review

- Brief review of standards (amendments) - small subset of amendments, but useful reference for understanding client capabilities
- Current 802.11 standard re-issued every few years
  - includes latest amendments as one definition bundle:
  - 802.11-1997
  - 802.11-2007
  - 802.11-2012
  - Specific protocol (PHY) amendments used for reference when describing capabilities
- PHY amendments
  - 802.11b (do not use unless absolutely necessary!) - 1999
    - Connection speeds up to 11mbps
    - 2.4GHz only

# Standards Review

- PHY amendments
  - 802.11a - 1999
    - Connection speeds up to 54Mbps
    - 5GHz only
  - 802.11g - 2003
    - Connection speeds up to 54Mbps
    - 2.4GHz only
  - 802.11n - 2009
    - Connection speeds up to 450Mbps (600Mbps theoretical)
    - Dual standard (2.4GHz & 5GHz)
  - 802.11ac - 2013
    - Connection speeds up to 1.3Gbps
    - 5GHz only

# Evolution of Clients

- In early days of WiFi networks, wireless was a convenience for a subset of devices
- Specialist devices for environments where required- examples:
  - Warehouse scanners - convenience, mobile
  - VoIP phones (hospitals)
  - Laptops (Enterprise, hospitals (COW) etc.) - alternative to Ethernet
- Devices were all provided by IT dept. & subject to their policies (inc security)
- Growth in mobile devices started with availability of mobile devices - no Ethernet cable:
  - Home useage
  - Guest networks
- Pressure on IT staff to provide senior staff with ability to use consumer devices (e.g. iPad) on corporate networks

# Evolution of Clients

- Many consumer grade devices did not have sufficient security
- Most organisations had no policy to cope with connecting mobile devices
- Also, no concept of accommodating users own devices
- BYOD (Bring Your Own Device):
  - Pressure to support consumer grade devices in corporate/professional environments meant that many organisations had to support concept of users bring in & using own devices (mainly senior exec driven)
  - Supposed advantages:
    - efficiency - users familiar with devices
    - cost savings - no capital outlay for organisation
  - Big issues with security & management
  - Applications for business processes may not exist

# Evolution of Clients

- BYOD (Bring Your Own Device):
  - Security:
    - Who has access to devices?
    - What about security of information on device?
    - Who supports device if used for business purposes?
    - What about lost devices?
    - Who owns data on device? personal data? corp data?
- Explosion of BYOD devices began and WiFi access slowly grew from being a complementary access method, started to become the primary (if not only) access method, with less reliance on wired switch ports

# Evolution of Clients

- Organisations had to scramble to:
  - put together BYOD policies
  - implement management solutions (e.g. MDM solutions)
  - upgrade wireless networks to cope with increased demand
- In addition, more and more devices started to use WiFi as primary access method, with new devices appearing:
  - Apple TV
  - Chromecast
  - Games consoles
  - Specialist medical devices (telemetry, monitors etc.)
- Expectations of WiFi grew beyond original requirements for web browsing to full data, voice and video connectivity

# Evolution of Clients

- Currently anticipating a potential avalanche of new devices that will require Wi-Fi connectivity:
  - IoT: “Internet of Things”
- Wi-Fi will not be only connection mechanism, others likely to be used:
  - Bluetooth, ZigBee (2.4Ghz)
  - Technologies on other bands
    - Cellular
    - TV White space
  - Better power budget requirements than Wi-Fi
- Either more WLAN capacity will be required, or spectrum will be impacted by devices using same bands
  - Wi-Fi impacted either way

# Client Behavior

- We need to understand a little more about how clients operate and behave to answer the following questions:
  - Which band will a client use? (2.4GHz/5GHz)
  - Which channel will a client use?
  - Which AP will a client use?
    - How does it join (associate) with an AP
  - When/how will a client roam to a new access point?

# Client Behavior

- 802.11 standard concerned with operation at layer 1 & 2 of OSI model
  - Layer 1 (PHY) describes RF (bands), modulation, encoding
  - Layer 2 describes datalink (frame) information
- Layer 2:
  - Ethernet (802.3) describes single frame type: data
    - only frames containing data (payload = layer 3 packets) sent back and forth between Ethernet stations
  - WLAN (802.11) standard describes 3 types of frame:
    - data (payload = layer 3 packets)
    - management
    - control

# 802.11 Frame Types

- Why do we need 3 frame types for WLANs?
- WLAN networks operate on an “unbounded” medium
  - access and contention for medium possible over a wide physical area
- WLAN networks do not have simple “plug-in” connectivity of an Ethernet networks
  - Ethernet equivalent of joining network and roaming between locations:
    - Plug in to data port in one room
      - Medium free as switch port has no cable in
    - As soon as plug in to port, full-duplex, uncontended connection available - send data
    - As move to next room, unplug from Ethernet data port and plug in to free data port in next room

# 802.11 Frame Types

## Management Frames

- Management Frames
  - Used to discover/join/leave wireless network
  - Equivalent to Ethernet action of plugging in to switch port
- Types:
  - Discovery:
    - Beacons: advertise WLAN available to clients (SSIDs)
    - Probes: request/response frames for faster discovery
  - Join (re-join):
    - Association: request/response frames to join WLAN
    - Reassociation: request/response frames to rejoin WLAN (roam)
  - Leave:
    - Disassociation: leave WLAN

# 802.11 Frame Types

## Control Frames

- Control Frames
  - Used to assist with delivery of data frames
  - Examples
    - Acknowledgment frame (remember all frames Ack'ed at layer 2)
    - Block acknowledgement
    - RTS (Request to Send) & CTS (Clear to Send)
      - used by station gain control of the channel to send data

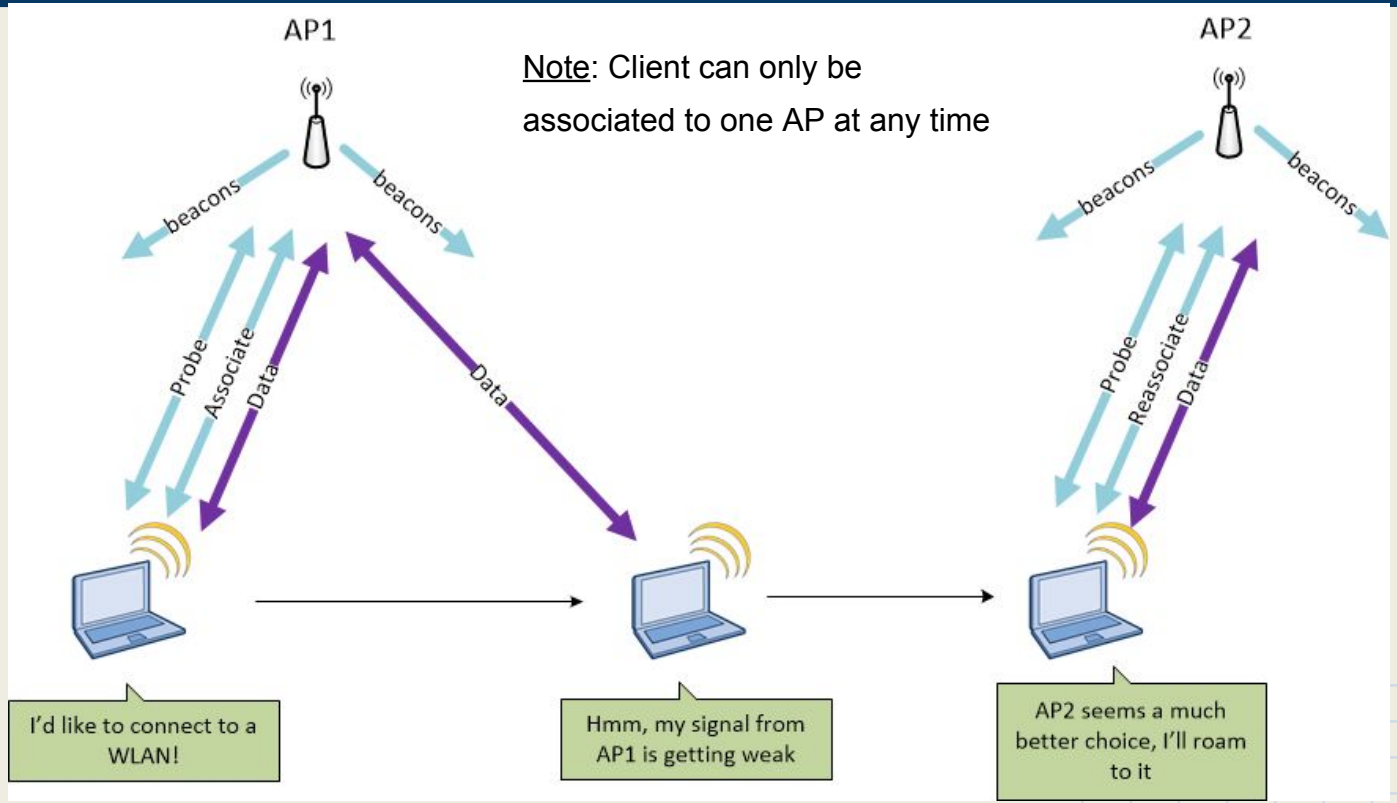
# 802.11 Frame Types

## Data Frame

- Data Frames
  - Carry data passed down from higher layer protocols
  - Payload is layers 3 - 7 of OSI stack
  - Types
    - Data frame (simple data frame)
    - QoS data frame (data frame with QoS information)
    - ….miscellaneous other data frames, but most rarely used in practice (with exception of null data frame)
  - Only frame that actually transports data from user to destination service
    - All other frames, though useful, are protocol overhead (compared to Ethernet)

# 802.11 Frame Types

## Client Frame Exchange (simplified)



# 802.11 Frame Types

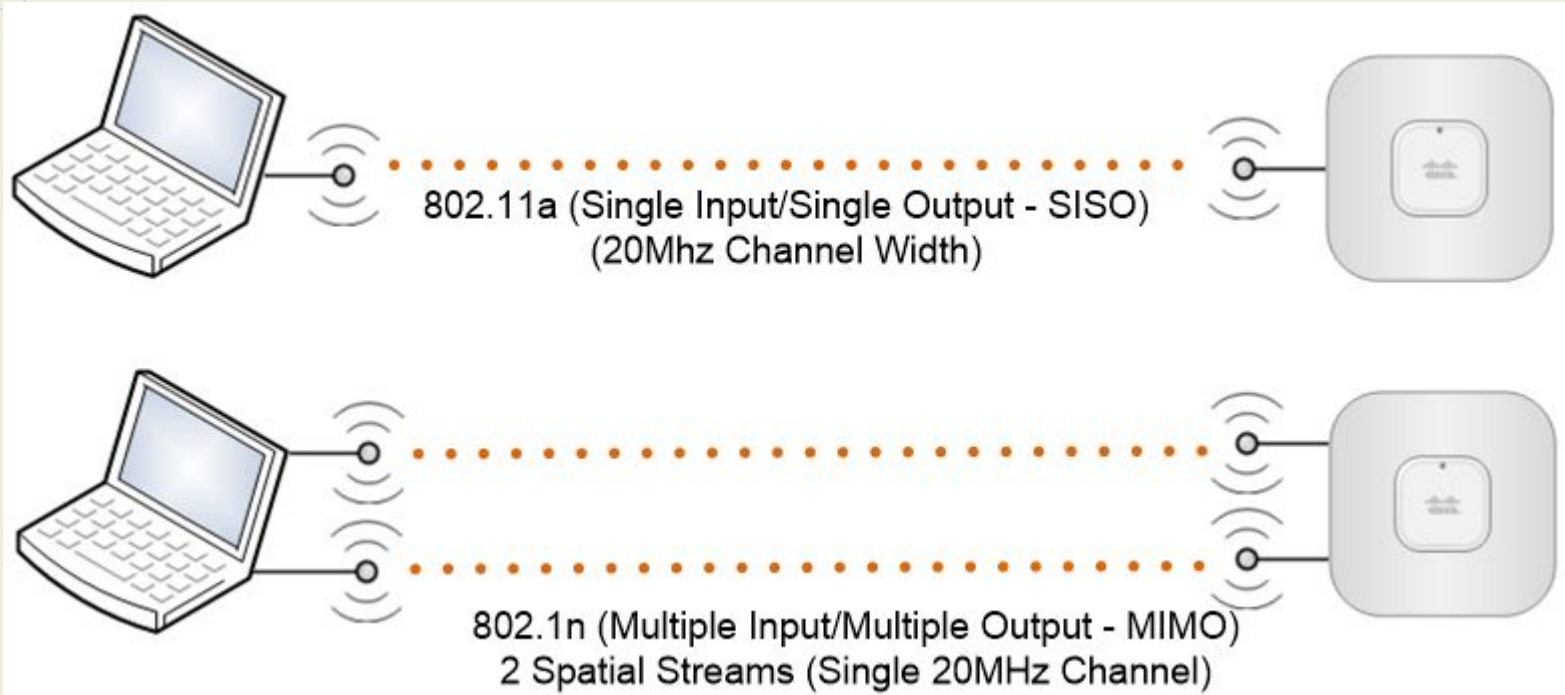
## Roaming

- Client roaming to nearest AP is a desirable behaviour to maintain optimum connection speed and mitigate effect of slow clients on AP cell (traffic jams - racing cars behind bicycles)
- Important fact to remember:
  - Client makes decision of when to roam between APs - that's right…. AP does not control client roaming decision
  - Some clients behave very badly and may be a "sticky client" that will not roam
    - consumer devices may assume only one AP (in) home and must remain associated at all costs!
- Roaming factors vary between clients:
  - AP signal level, connection speeds, errors etc.
  - No standardization around client roaming decision

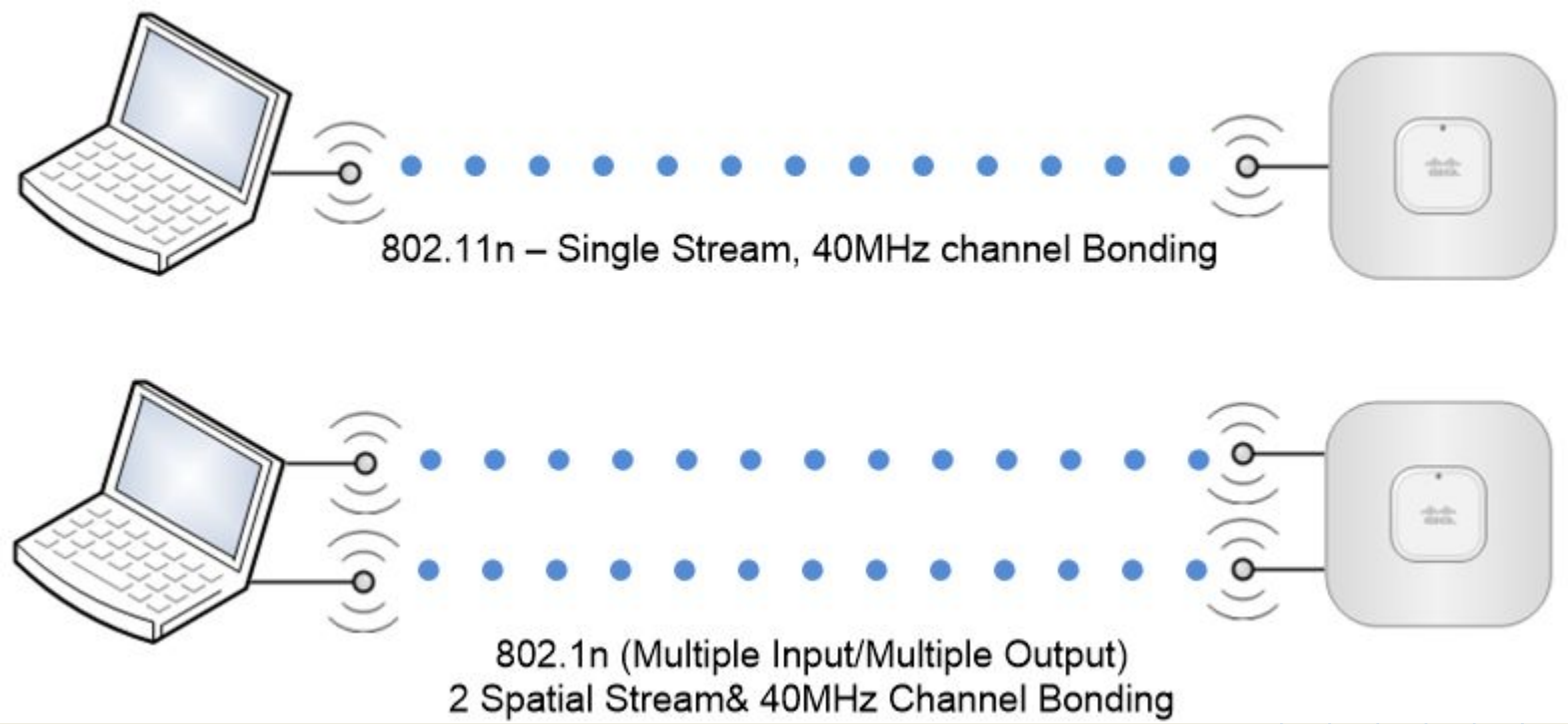
# Client Speeds

- What connection speed can a client achieve?
- Depends on quality of RF link between client and AP - Factors:
  - Signal level
  - Errors
  - Noise
- Maximum potential speed depends upon the PHY capabilities of the client
  - Band support (2.4GHz/5GHz)
  - Number of streams (& antennas) - more streams, more speed
  - Channel width - wider channels, more speed
  - 802.11 amendment support
    - available speeds vary with modulation type
      - e.g. 802.11a speeds vs 802.11ac

# Client Speeds



# Client Speeds



# Client Speeds

- Key takeaway:
  - Client speeds is not just a function of the WLAN infrastructure that is installed
  - To support 802.11ac speeds, WLAN APs must be able to support 802.11ac amendment specification
  - However, the speeds that clients will achieve (even if they are “802.11 ac” clients) dependant on:
    - Channel widths supported (20MHz, 40MHz , 80Mhz)
    - Number streams supported: 1, 2, 3
    - To achieve 802.11ac speed of 1.3Gbps, client must be 3 stream, 80MHz device!

# Characteristics & Requirements of Clients

- We now have a huge variety of clients types, which have varying capabilities and requirements
  - important to understand when designing network and to understand the way they may behave
- Typical factors that affect client characteristics are:
  - Physical size
    - antenna size
    - power supply/power budget (battery)
      - tx power (distance covered)
      - number of streams supported

# Characteristics & Requirements of Clients

- Typical factors that affect client characteristics (cont'd):
  - Radio components
    - Chipset/NIC
      - impacts number chains & 802.11 support
    - Radio type (2.4GHz/5GHz)
    - Number of antennas
    - single/multiple stream - dependant on:
      - Chipset (chains)
      - number antennas
      - manufacturer implementation
- What is a chain?
  - signal processing circuitry that splits & combines signal in to multiple streams on a single radio

# Characteristics & Requirements of Clients

- Typical factors that affect client characteristics are:
  - 802.11 amendment support:
    - power save support
    - speed of access
      - higher speeds, less tx time, higher capacity
      - lower speed clients affect other clients
    - roaming decision support
      - better decisions mean better network capacity
    - QoS support - vital for voice and video

# Characteristics & Requirements of Clients

- Two important questions when considering the performance of clients:
  - Can network provide the required features for the clients we support?
    - e.g. a network of 802.11n APs will never provide the higher speeds that an 802.11ac client is capable of achieving
  - Which clients can support features we provide on our WiFi network?
  - e.g. if our WLAN supports 802.11r (fast secure roaming), do the clients we use on our WLAN support this amendment?
- Behaviour of clients not just determined by client characteristics & capabilities, requires corresponding supported features on WLAN
  - always restricted to the lowest common denominator

# Characteristics & Requirements of Clients

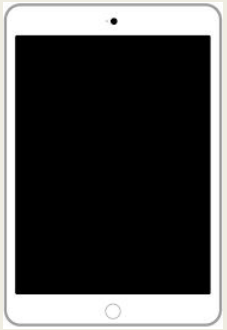
- How do we find out about the capabilities of a client?
  - Manufacturer's documentation (good luck with that…)
  - Wi-Fi Alliance Product Finder (if WFA certified)
    - https://www.wi-fi.org/product-finder
    - e.g. iphone 5: http://certifications.prod.wi-fi.org/pdf/certificate/public/download?cid=WFA20103
  - FCC web site (USA)
    - FCC ID database (https://fccid.io/)
  - Client data from wireless controller or management system
    - Connection speed, WMM support etc.
  - Wireless packet analyzer (e.g. Wireshark)
  - Google! :)

>>> Blog article:http://bit.ly/how_fast_clients <<<

# Characteristics & Requirements of Clients

- We'll have a look at four typical WLAN client types and discuss their typical characteristics
- Laptops
  - the "original" WiFi client in many organisations
  - good battery life as supporting many other devices beyond WiFI NIC & screen: mechanical disks, fans, high power processor etc.
  - generally have high spec wireless NIC, good tx power, multiple antennas (often in screen housing), multi-stream support
  - standard depends on chipset installed
    - still get some 2.4GHz NICs in budget laptops
  - Generally the highest performing of all clients
  - however, becoming less and less of overall % of clients

# Characteristics & Requirements of Clients



- Tablets
  - Main constraints:
    - battery life
    - antenna size
  - WiFi capabilities heavily constrained by battery
    - limited tx power
    - radio chipset typically only has one or (maybe) two radio ‘chains’ (transmitter/receiver) to support single/dual stream, so speed support limited - more chains = more power
  - Antenna size limited due to lack of anywhere to locate in tablet form factor
    - small antenna = lower antenna gain
    - smaller range and lower performance than laptop

# Characteristics & Requirements of Clients

- Smartphones (very similar to tablets)
  - Main constraints:
    - battery life
    - antenna size
  - WiFi capabilities heavily constrained by battery
    - limited tx power
    - radio chip only has one ‘chain’ (transmitter/receiver) to support single stream, so speed support limited - more chains = more power
  - Antenna size limited due to lack of anywhere to locate in phone form factor
    - small antenna = lower antenna gain (worse than tablets)
    - smaller range and lower performance than laptop

# Characteristics & Requirements of Clients

- Hand Scanner/Barcode Scanner (warehouse, supermarket etc.)
  - Good battery supply (charged overnight)
  - Good tx power
  - Low data requirements
  - Can support lower connection speeds over further distance
  - Often have a plug-in, removable NIC
  - Design requirements different if the only client type in environment (e.g. warehouse)
    - distance & coverage, not capacity
  - May only support older 802.11 amendments

# Characteristics & Requirements of Clients

- This is a tiny subset of clients available
- Whatever client being deployed, need to understand:
  - standards (amendment) support (802.11n, 802.11ac etc.)
  - radio capabilities (bands)
  - power capabilities
  - throughput requirements (what apps: voice/video/data)
  - antenna capabilities
  - security standard support

# Wireless NICs

- Many mobile devices have integrated (onboard) wireless chipset - fixed
- Some devices may have removable wireless NIC or have a wireless NIC added to improve capability or performance (e.g. USB wireless card)
  - typically laptops:
    - Windows, Apple, Linux
- Capabilities vary depending on form factor and power available
- NIC may or may not included integrated antenna

# Wireless NICs

- Onboard - NIC
  - on motherboard of laptop
    - often have separate antenna mounted in screen housing
  - internal to tablets and smartphones
- PCI Bus Nic
  - Usually in desktop machine
  - Generally uses a external black “rubber duck” dipole antenna

# Wireless NICs

- USB NIC
  - Most common form of removable NIC
    - plugs into USB slot of laptop generally
    - low-cost way of improving the support of a laptop (e.g. 5GHz NIC on budget machines)
    - Just be careful of damage!
    - Internal antenna (on-board dongle)
- SD (Secure Digital) NIC
  - Same form factor as SD cards put in to digital camera
  - Has built in antenna which usually protrudes outside of SD slot
- Variety of other NICs inc PCI varieties and compact flash


# Drivers and Setup Utilities

- Like any other hardware device on a desktop/laptop, wireless NICs need driver software
  - allows OS to talk to the hardware
- Clients that have a built-in or on-board NIC (e.g. tablets) will generally have driver built in to OS and should not require consideration
- Laptops/desktops (Windows/Mac/Linux) require drivers to be loaded for NIC
  - often supplied with OS or by manufacturer ← **Latest version?**
  - may require updated from time to time ← **often overlooked!**
  - if add new hardware (e.g. USB NIC), need to add correct drivers
- Need to be aware of drivers because:
  - new hardware won't work without them
  - performance of clients may be improved by driver updates

# Drivers and Setup Utilities

- Installing drivers generally relatively easy:
  - just insert hardware - OS may detect if already has drivers bundled (plug & play)
  - download drivers from support page of NIC manufacturer on to local drive
    - OS may then automatically search for drivers when plugin new NIC
  - download manufacturer NIC utility software (or obtain from bundled CD/DVD)
    - this will generally include the NIC drivers and some supporting software utilities, which can be very useful

# Drivers and Setup Utilities

- Setup Utilities allow user to perform actions such as:
  - setup NIC to use one or more SSIDs
  - setup the security used for each network
  - look at signal levels of available networks
  - configure the preferred band of a NIC (e.g. try to use 5GHz)
  - configure the (legacy) standards supported by the NIC
- In Windows, a native configuration utility is provide (not vendor specific)
  - generally can choose whether to use vendor utility or Windows
- Taking the time to correctly setup the NIC via a setup utility can improve performance of the client and whole of WLAN if you have control of all clients & their settings

# Client Behavior- Revisited

- Earlier client related questions:
  - Which band will a client use? (2.4GHz/5GHz)
    - Which band is required SSID using?
    - How is client configured?
    - What is the behaviour of the client type (i.e. different client types have differing default behaviours for band choice)
    - What 802.11 amendment(s) is/are supported?
  - Which channel will a client use?
    - Dependant upon band choice
    - Dependant upon channels used by nearby AP
      - has to use same channel as AP it joins (probing)
  -

# Client Behavior- Revisited

- Earlier client related questions:
  - Which AP will a client use?
    - Depends on AP signal strength
    - Depends on whether or not AP supports same standards as client so that AP can associate
    - Depends on whether AP supports required SSID
  - When/how will a client roam to a new access point?
    - Depends on AP RF planning
      - Client will detect signal decrease/degradation
      - Probe for other APs using same SSID
      - Reassociate to new AP
    - Depends on roaming behaviour of client

# Summary

- What is a wireless client?
- Standards Review
- Evolution of Clients
- Client behaviour
- 802.11 Frame Types
- Client Speeds
- Characteristics & Requirements of Clients
- Wireless NICs
- Drivers & Utilities
- Client behaviour revisited