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High Density WLAN

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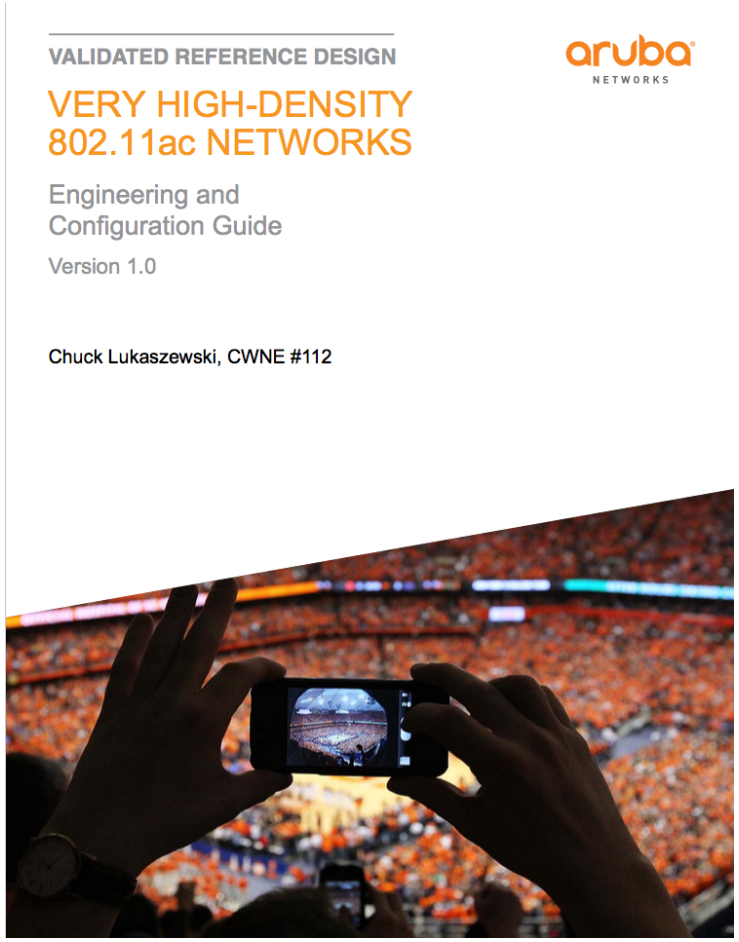
Aruba Validated Reference Designs

- Aruba is the thought leader in our industry. We produce a library of Validated Reference Designs
- The Very High Density (VHD) WLANs VRD covers ultra high capacity spaces such as auditoriums, arenas, stadiums and convention centers
- The recommendations have been field proven at dozens of customers
- VRDs are free to download from Aruba Design Guides web page:

  http://www.arubanetworks.com/VRD



HD WLANs are Challenging, but…

- Uncontrolled mix of device types, OS, driver levels, and radio types
- Multiple devices per person – up to three
- Per-user bandwidth needs can easily exceed what is allowed by Wi-Fi and physics
- Simultaneous data plane spikes during events
- Inrush/outrush demand increases load on network control plane, address space, etc.
- Most devices limited to 1x1:1 HT20 operation
- Other Issues:
  - Customer traffic need to be segregated from operational and other vendor traffic
  - Wi-Fi networks need to be optimized to support video and other high bandwidth / latency sensitive applications

Agenda

– Channel capacity

– Interference radius

– Coverage strategies

– Best Practices

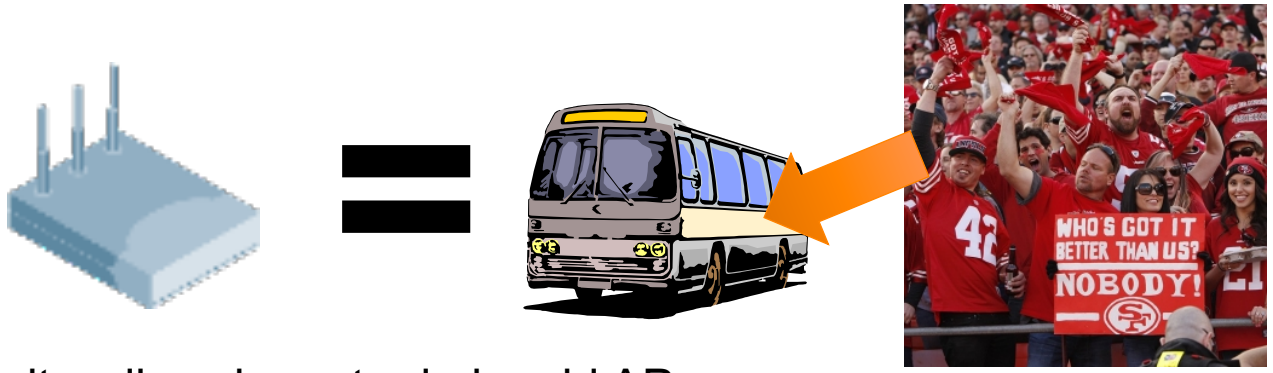
What exactly is “(Very) High Density”

- Many users
  - Many users need WiFi connectivity and speed
  - Many different device types
  - Multiple APs are needed to associate the WiFi devices
  - Use many channels to provide the bandwidth
- Many APs
  - More APs then available channels.
  - Re-use of channels = Introducing co-channel interference

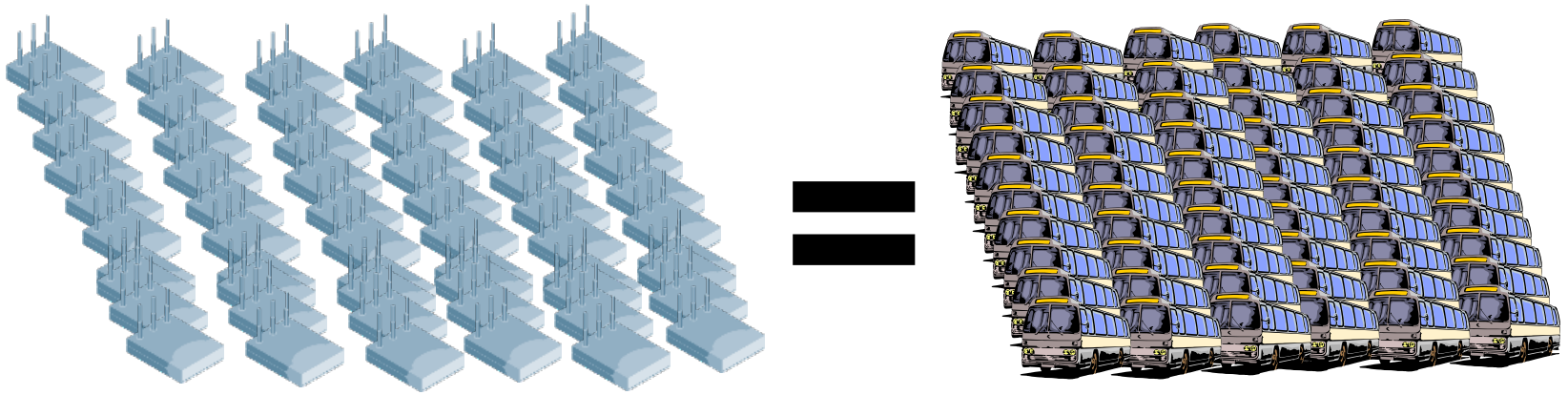
Key characteristic of a HD Wireless LAN is that there we need more APs than available channels in the area to cover where distances between APs is much smaller than the interference radius.

Many users - Understanding Association Capacity

– Association capacity means the number of devices that the HD WiFi network can “carry”.



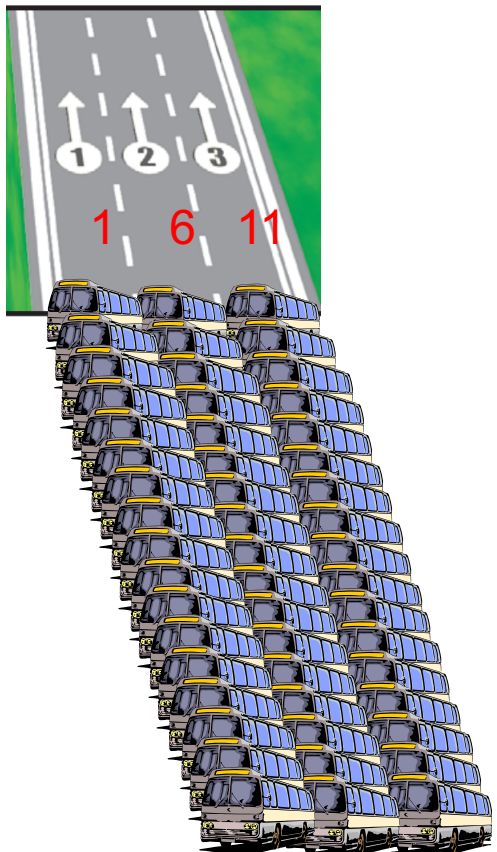
– To add association capacity, all we have to do is add APs

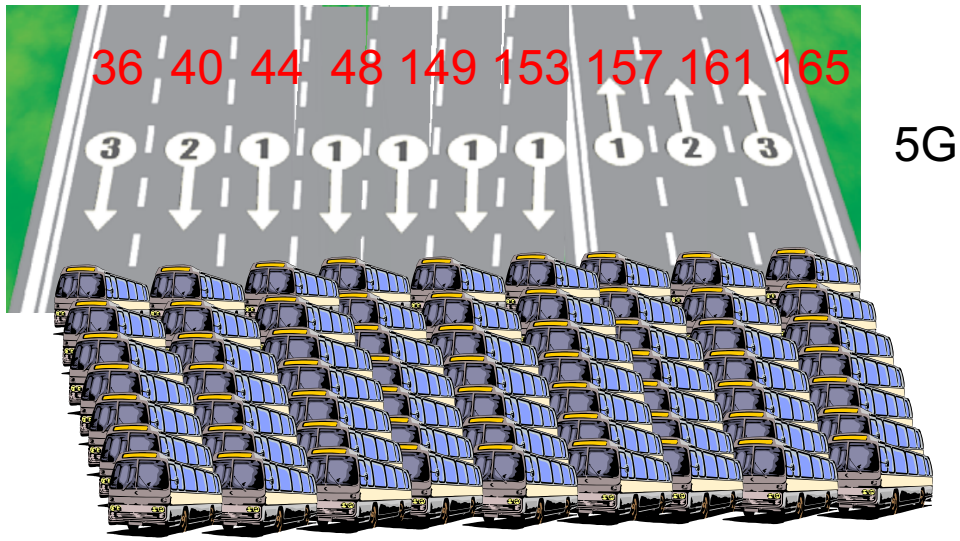


Many APs - Understanding Transmit Capacity

– Transmit capacity is the number of lanes on the road - (or out of the parking lot after the game)!

2.4GHz





5GHz

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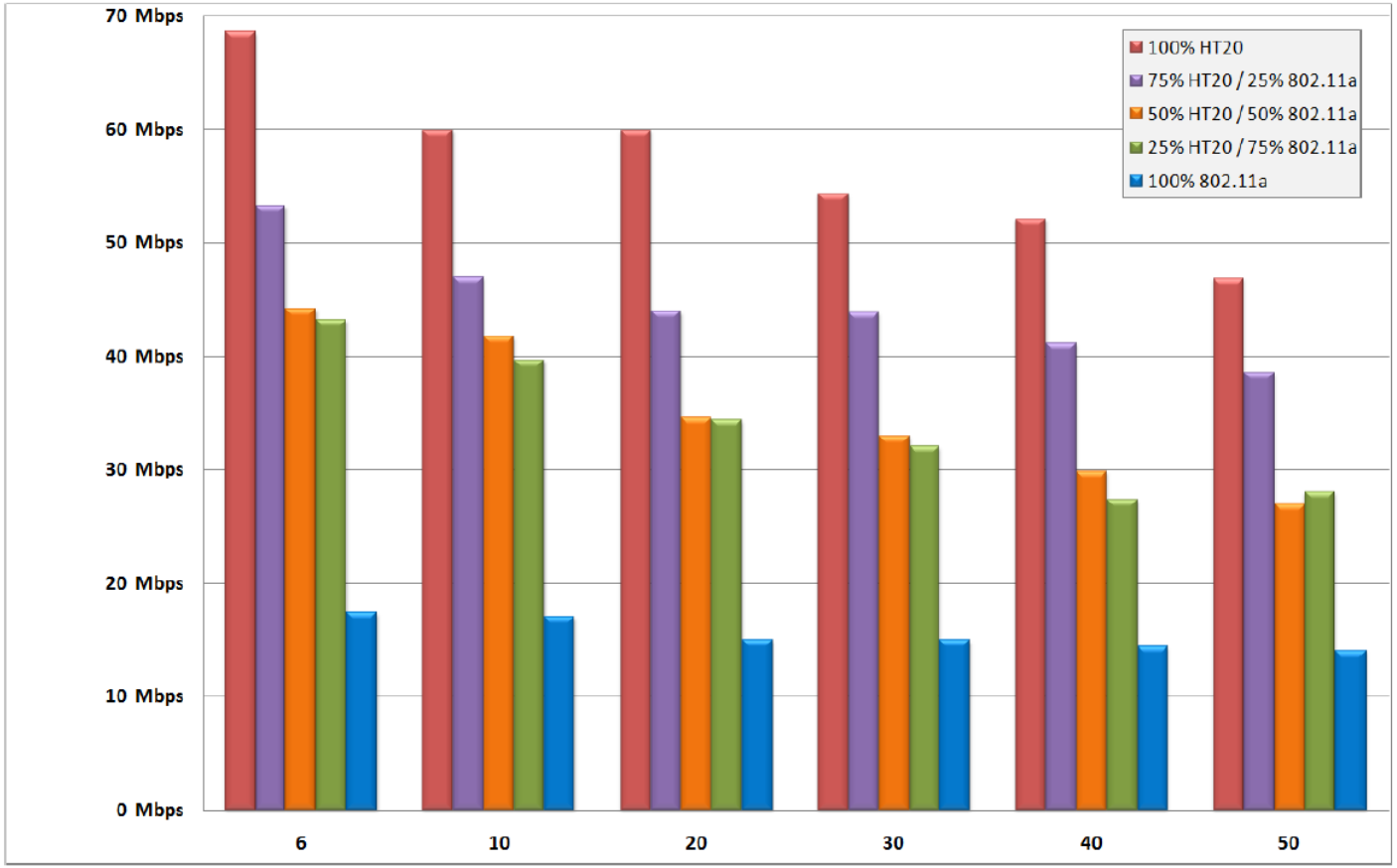
WiFi Channel

- WiFi Channel capacity is limited
  - The fact that an AP can do 600Mb/s doesn't mean the users will get 600Mb/s
- WiFi channel is shared between the devices on the ***channel*** (not just the AP radio!)
- Phy rate depends on Signal to Noise Ratio (SNR)
  - Typical Noise floor for 5Ghz:: -95dB
  - Typical Noise floor fro 2.4Ghz: -90dB
  - This depends on the environment and increases due to ACI!!
- The Transmission rate determines the airtime taken by a device/AP for sending a frame.
  - The higher transmission rate, the quicker the device/AP is "of the air".
- Client bandwidth is dependent PHY/Transmission rate and is half duplex
- Expected TCP Throughput (what you get with ADSL Speedtest) is roughly half the PHY rate in HD-WLAN as it includes channel impairment (interference, channel contention etc.)

Radio	Mbps	SNR
802.11a/g	6	4
802.11a/g	9	5
802.11a/g	12	7
802.11a/g	18	9
802.11a/g	24	12
802.11a/g	36	16
802.11a/g	48	20
802.11a/g	54	21

Radio	Mbps 20MHz	Mbps 40MHz	SNR
802.11n	7	15	6
802.11n	14	30	8
802.11n	29	60	10
802.11n	43	90	15
2.11n	58	120	20
2.11n	87	180	25
2.11n	116	240	30
2.11n	130	270	35

Measured 20MHz Channel Capacity – 11n



802.11n 5-GHz Aggregate Mixed-Mode TCP Client Scaling Performance
(AP-225, HT20, TCP Bidirectional)

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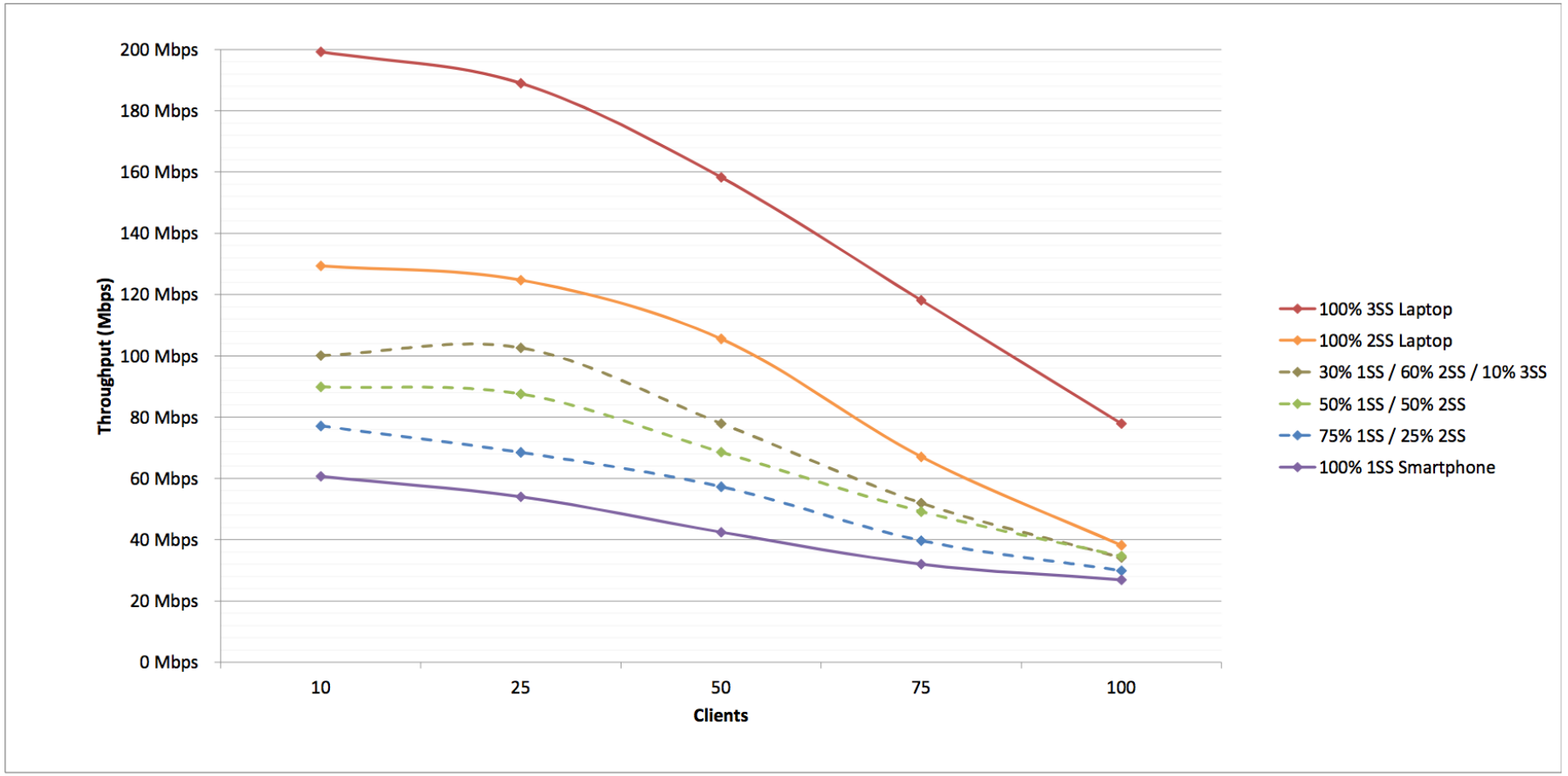
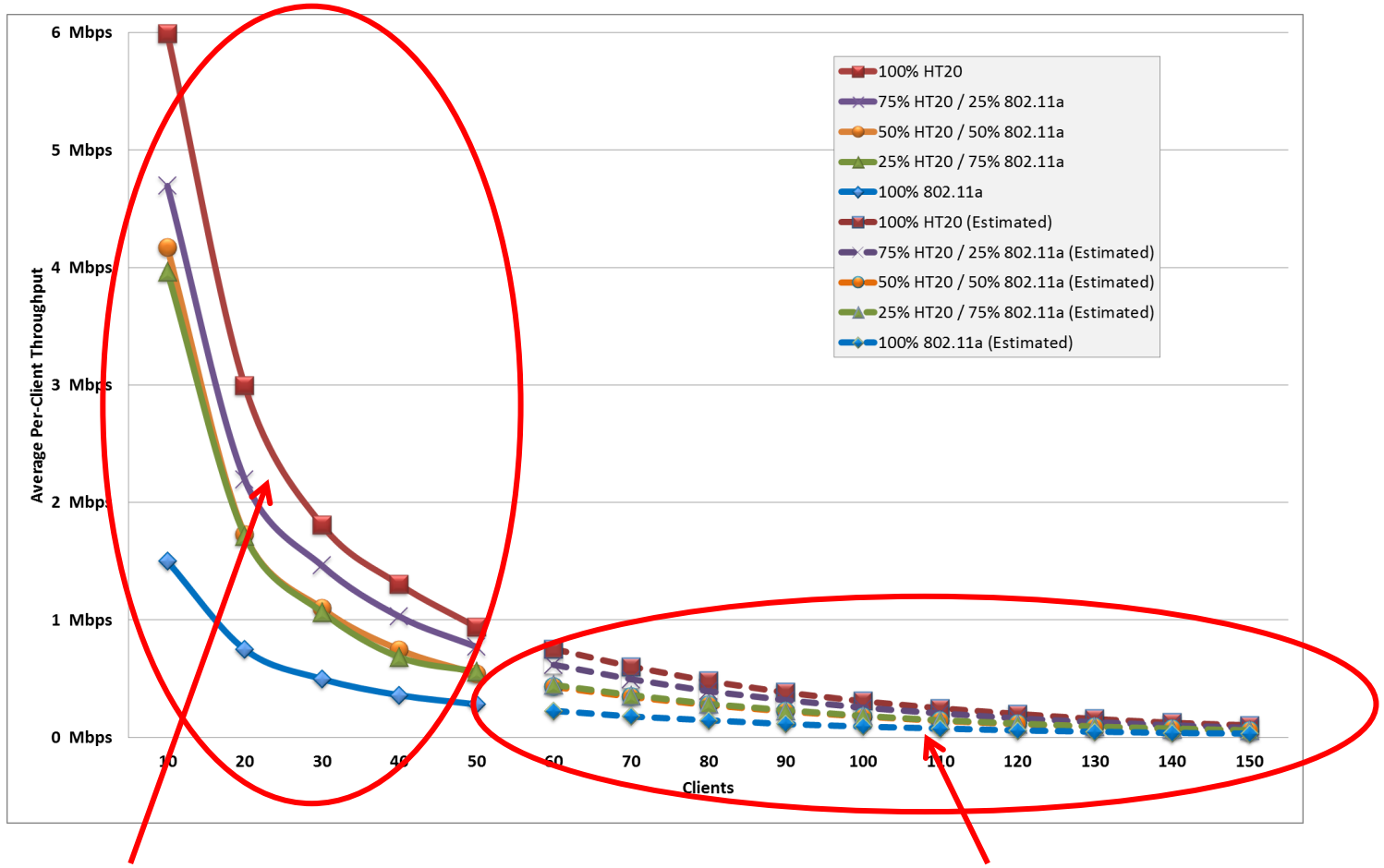
Measured 20MHz Channel Capacity – 11ac



802.11n 5-GHz Aggregate Mixed-Mode TCP Client Scaling Performance
(AP-225, VHT20, TCP Bidirectional)

Approaching the Limit of Wi-Fi Performance



Below 50 concurrent users per radio, AP count and self-interference grows dramatically

User experience is unacceptable beyond 50 concurrent users per radio

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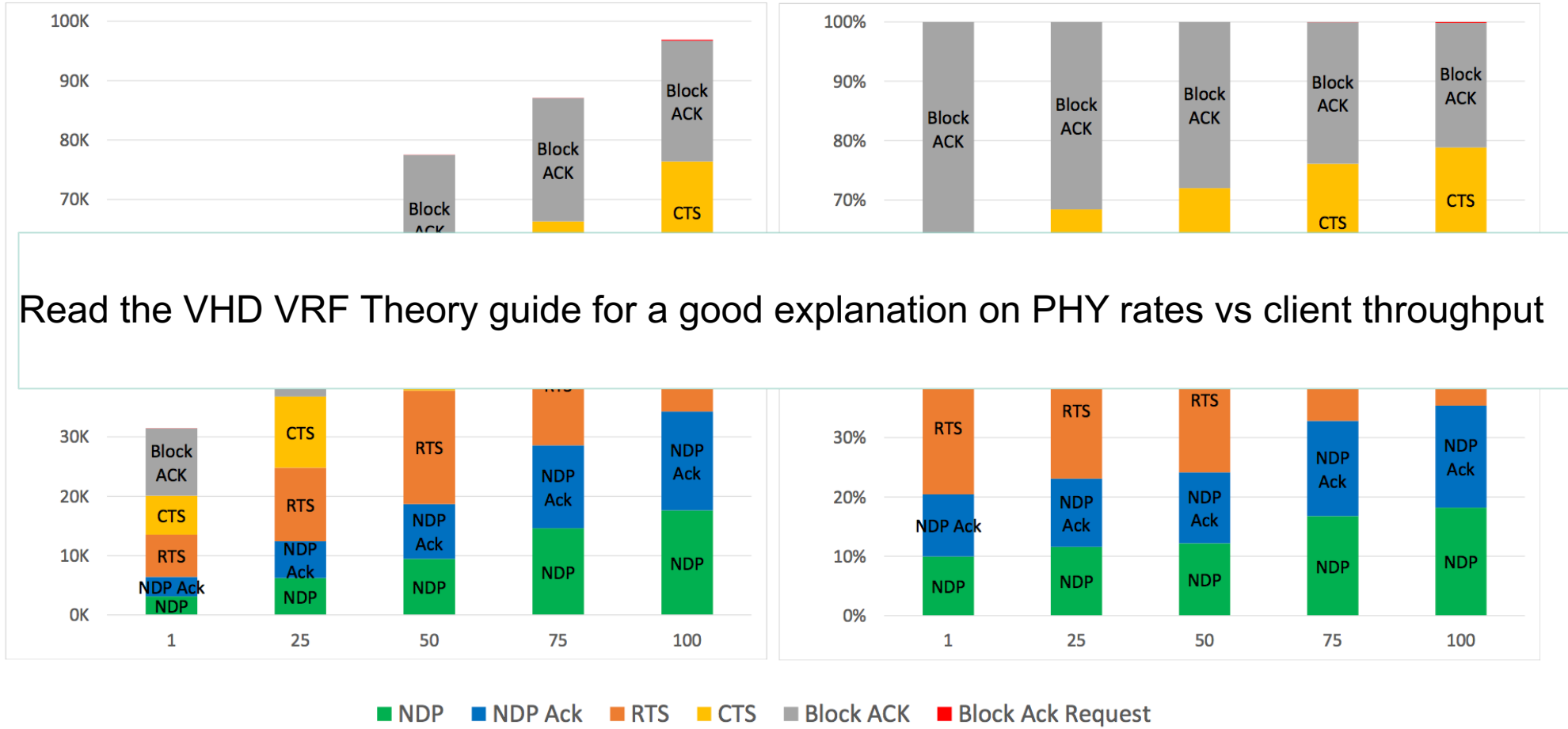
Approaching the Limit of Wi-Fi Performance – Why?



Read the VHD VRF Theory guide for a good explanation on PHY rates vs client throughput

Breakdown of 802.11 Control Frame Types (AP-225, 20-MHz Channel, TCP Up)

Available Channel Count

- Channel bonding (HT40) reduces capacity in HD WLANs
- 20MHz channels should be used in 2.4 and 5 GHz bands
- Available channel count varies from country to country.
  - Europe Channel Count is limited to 4 without DFS
- This limitation requires sophisticated engineering in LPV's to re-use channels as many time as possible
- The goal is to use structural components to isolate pico-cells

Channel	Frequency	United States & Canada	Brazil	Europe & Turkey	United Kingdom	Russia	Saudi Arabia	South Africa	Israel	China	Japan	Korea	Sin
36	5180	Yes	Indoors	Indoors	Indoors	Yes	Indoors	Indoors	Indoors	Indoors	Indoors	Indoors	
40	5200	Yes	Indoors	Indoors	Indoors	Yes	Indoors	Indoors	Indoors	Indoors	Indoors	Indoors	
44	5220	Yes	Indoors	Indoors	Indoors	Yes	Indoors	Indoors	Indoors	Indoors	Indoors	Indoors	
48	5240	Yes	Indoors	Indoors	Indoors	Yes	Indoors	Indoors	Indoors	Indoors	Indoors	Indoors	
52	5260	DFS	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Yes	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	DFS/TPC	D
56	5280	DFS	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Yes	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	DFS/TPC	D
60	5300	DFS	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Yes	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	DFS/TPC	D
64	5320	DFS	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Yes	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	Indoors/ DFS/TPC	DFS/TPC	D
100	5500	DFS	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
104	5520	DFS	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
108	5540	DFS	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
112	5560	DFS	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
116	5580	DFS	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
120	5600	DFS[1]	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
124	5620	DFS[1]	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
128	5640	DFS[1]	DFS/TPC	DFS/TPC	DFS/TPC	No	DFS/TPC	DFS/TPC	No	No	DFS/TPC	DFS/TPC	D
132	5660	DFS	DFS/TPC	DFS/TPC	DFS/TPC	Yes	DFS/TPC	DFS/TPC	No	No	DFS/TPC	No	D
136	5680	DFS	DFS/TPC	DFS/TPC	DFS/TPC	Yes	DFS/TPC	DFS/TPC	No	No	DFS/TPC	No	D
140	5700	DFS	DFS/TPC	DFS/TPC	DFS/TPC	Yes	DFS/TPC	DFS/TPC	No	No	DFS/TPC	No	D
144	5720	**Do not use for VHD areas until 802.11ac penetration > 50%**											
149	5745	Yes	No	Licensed	No	Yes	No	No	No	Yes	No	Yes	
153	5765	Yes	No	Licensed	No	Yes	No	No	No	Yes	No	Yes	
157	5785	Yes	No	Licensed	No	Yes	No	No	No	Yes	No	Yes	
161	5805	Yes	No	Licensed	No	Yes	No	No	No	Yes	No	Yes	
165	5825	Yes	No	Licensed	No	Yes	No	No	No	Yes	No	Yes	
TOTAL NON-DFS		**9**	**9**	**4**	**4**	**16**	**8**	**4**	**4**	**9**	**4**	**8**	
TOTAL DFS		**12[1] / 15**	**15**	**15**	**15**	**0**	**15**	**15**	**4**	**4**	**15**	**12**	
TOTAL		**21[1] / 24**	**24**	**19**	**19**	**16**	**23**	**19**	**8**	**13**	**19**	**20**	

1. These channels were temporarily disallowed in 2013-2014 in the US. APs released from 2015 on may use these channels if they pass DFS certification.

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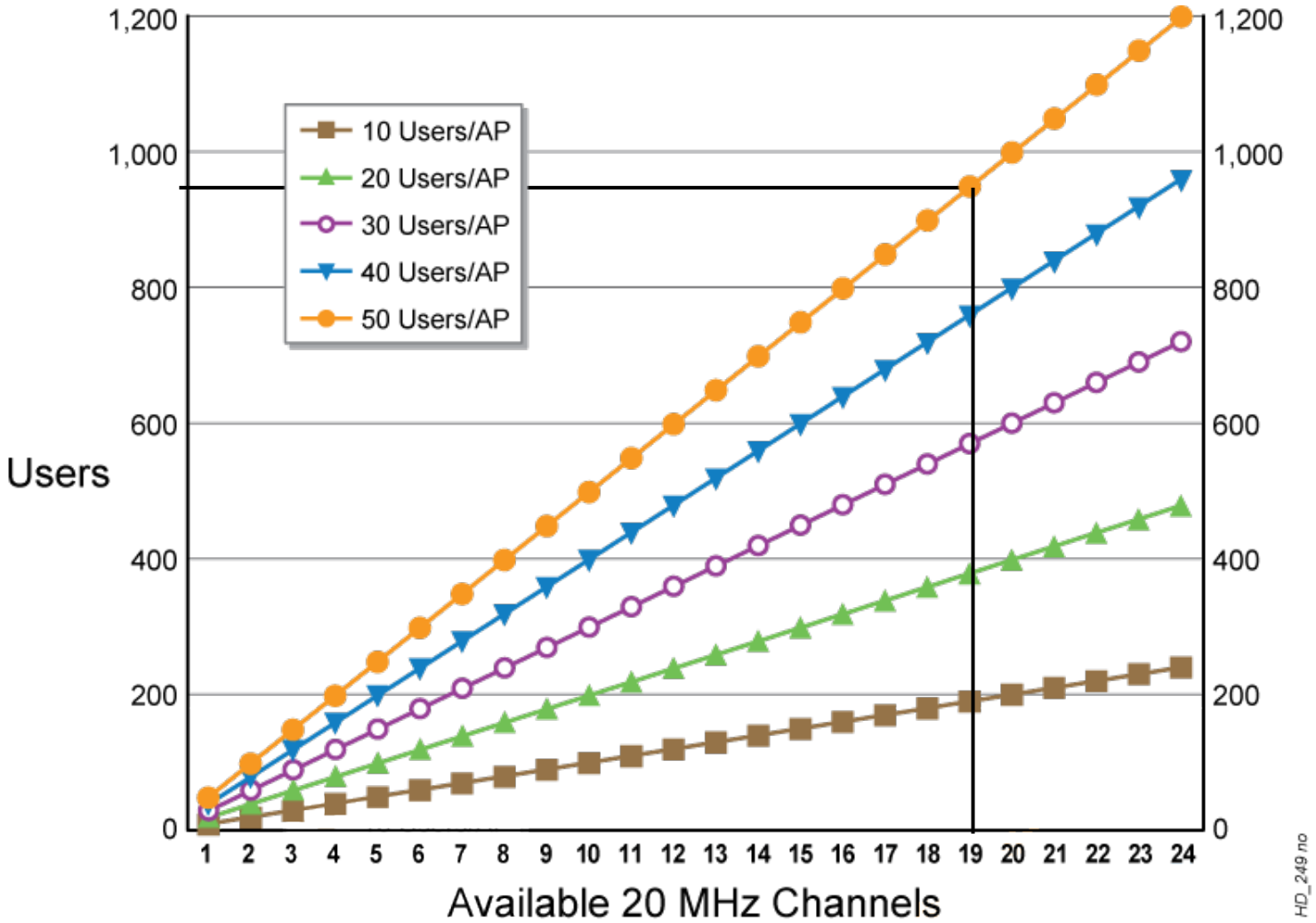
Determining Total Capacity – No Reuse



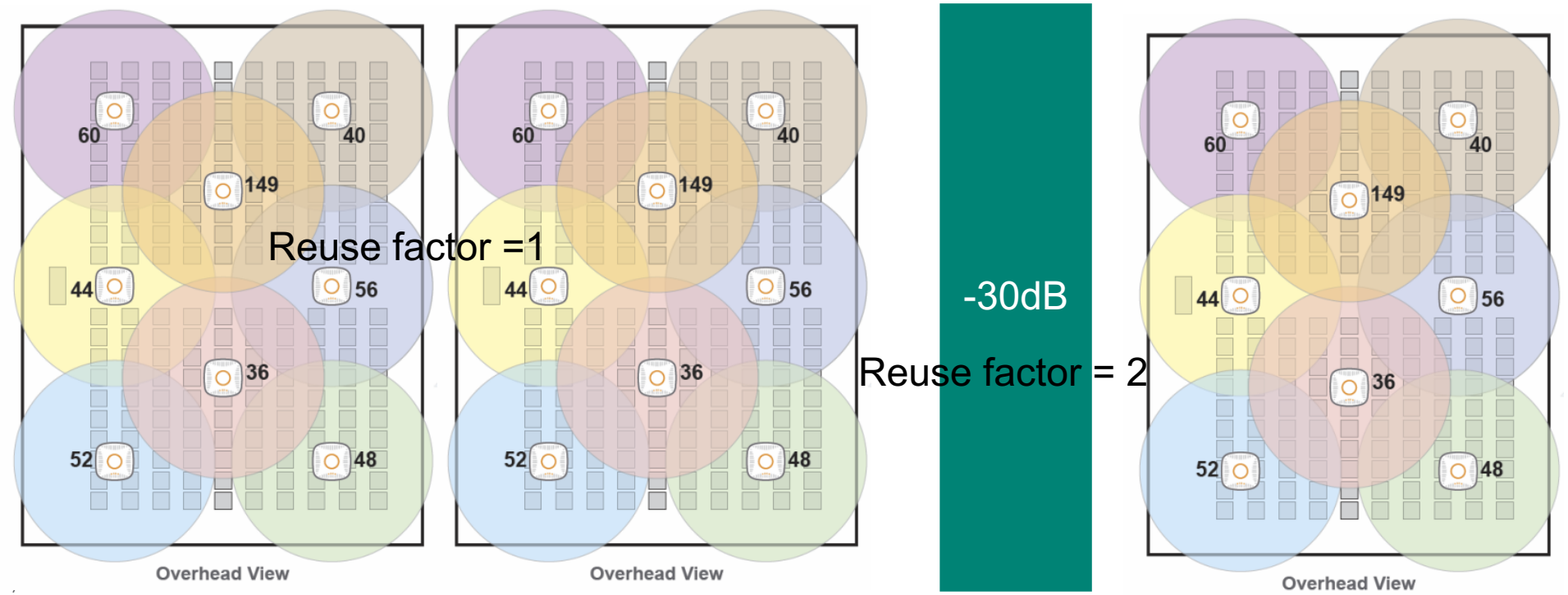
I need more APs than channels available. Now what?

– In VHD WLANs we have to use channels more than once

– Reusing a channel doesn't necessarily increases bandwidth as APs on the same channel can hear each other.

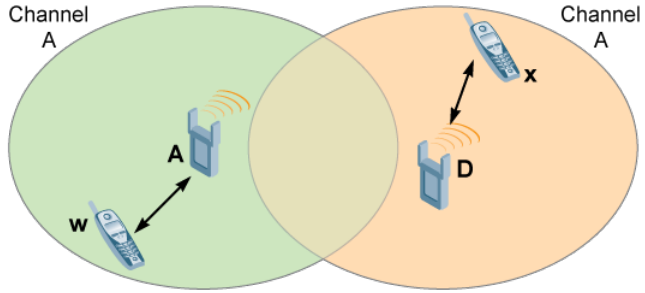
– Also a client transmitting on a channel is heard by all APs on that channel.

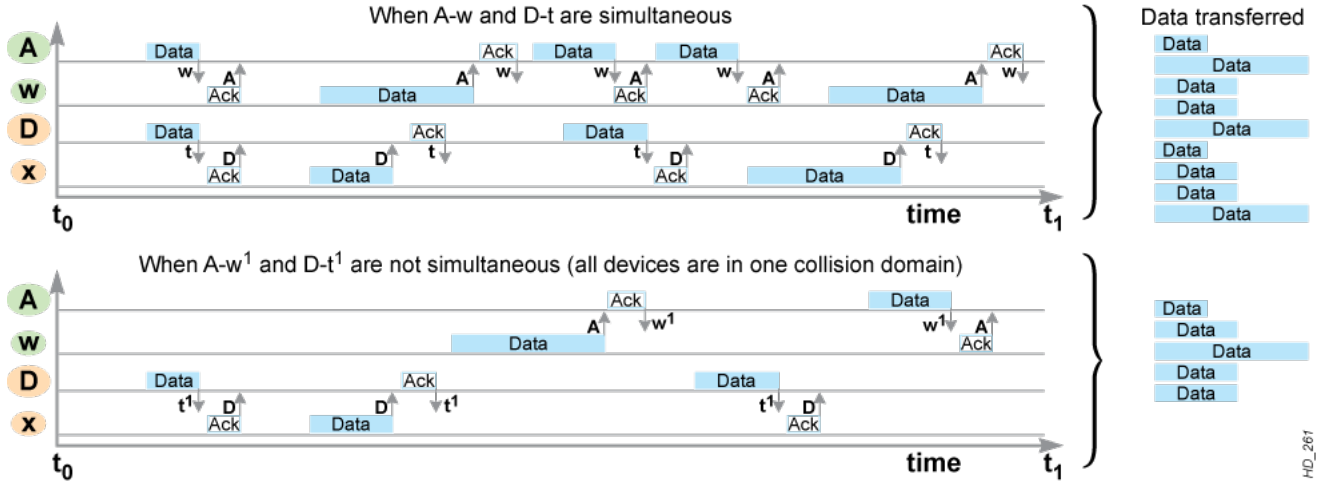
– Only when it is possible to "re-use the spectrum" we add bandwidth.



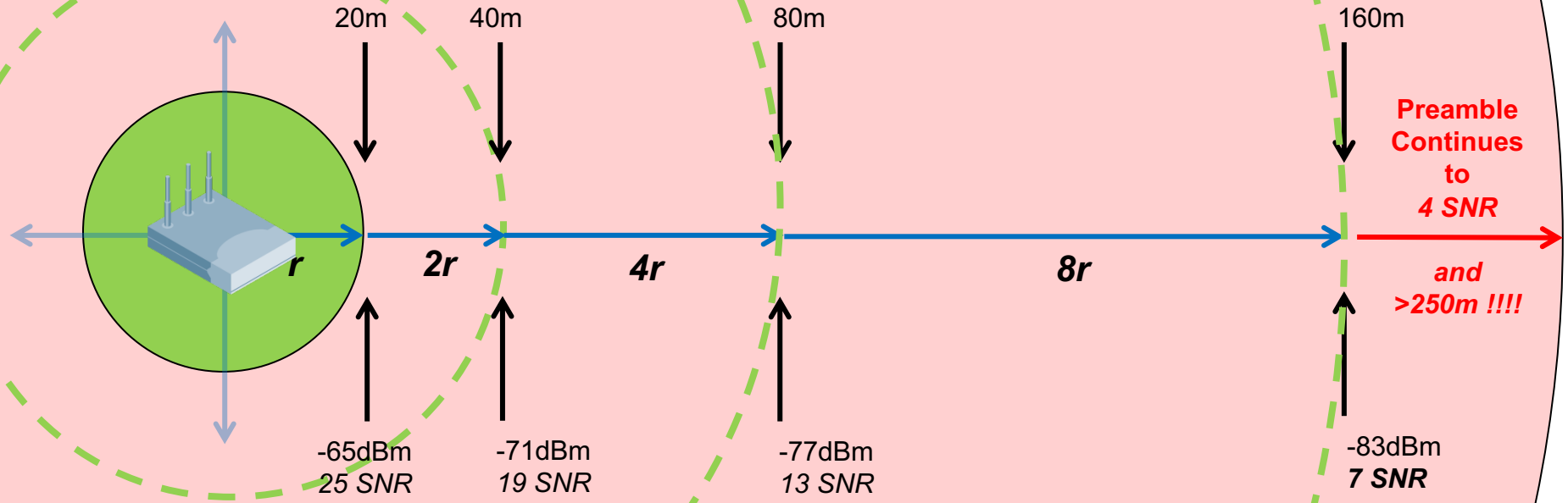
How CCI Reduces WLAN Performance

- Any Wi-Fi device detecting an 802.11 frame on the air cannot transmit/ receive until the frame has ended.
- If the transmit/receive stations are on the same channel and can decode one another's frames, it is the case.





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)

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How to control the “cell-size”

- Using Transmit power
  - RSSI = AP TX Power – FSPL – other
  - Assume Noise Floor –90dB: With RSSI of -86dB the preamble can still be decoded at lowest basic rate (6Mb/s for 5Ghz)
    - AP Tx Pwr = +3dBm; Loss of 89dB -> ~125m, interference radius! (open space)
    - AP Tx Pwr = +18dBm; Loss 104dB -> ~900m interference radius (open space)
  - The APs have no control of Client Tx power ☹
- Signal Attenuation
  - Building structures or human body (under seat coverage)
- Directional antennas
  - Focus the antenna energy to the area to cover
- Cell Size Reduction (CSR)
- X Trimming Basic Tx Rates

Doesn’t reduce interference radius. Legacy Preamble is at 6Mbps (mandatory PHY rate), but:

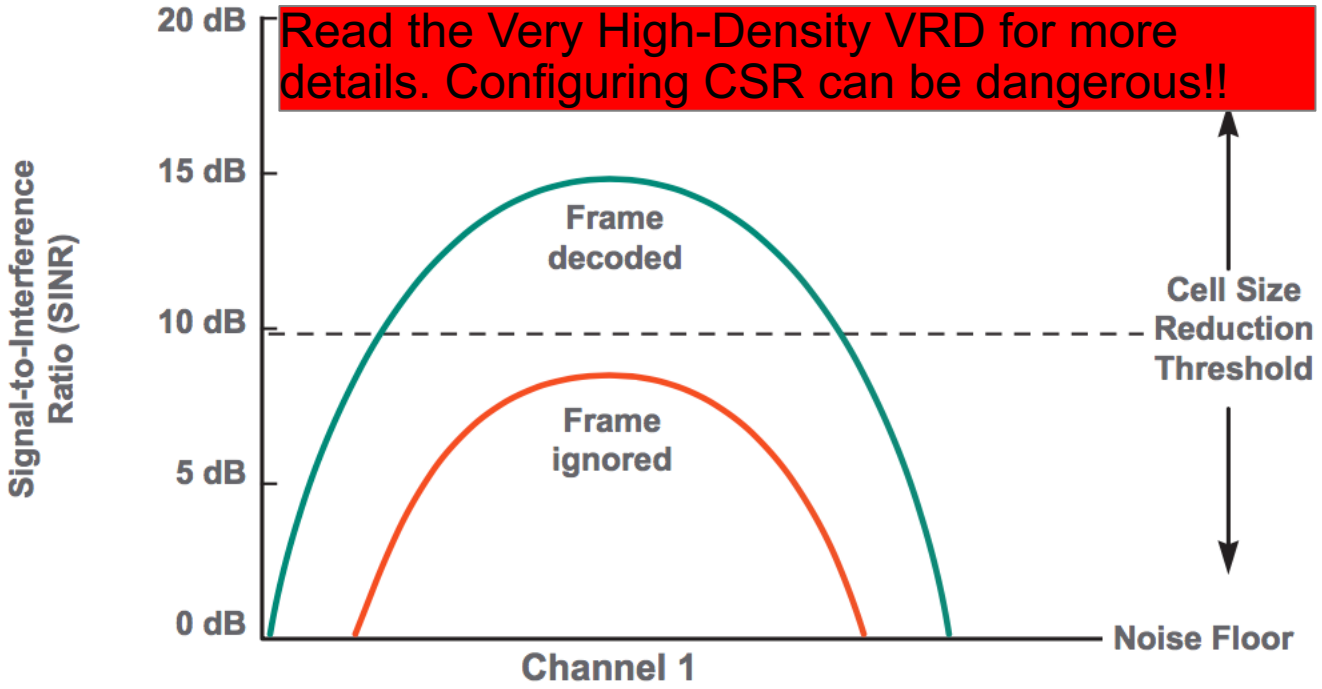
  - Limits the number of BSSs a device can hear and therefore helps the device to select the “best AP” and improves roaming
  - Reduces air time consumption
    - Mgmt/Control frames are sent with lowest configured basic rate
    - Beacons rate can be set higher than lowest basic rate

Distance	dB Loss	dB Loss
Meters	2.4 GHz	5 GHz
16000	124	130
8000	118	124
4000	112	118
2000	106	112
1000*	100.4*	106.4*
500	94	100
250	88	94
125	82	88
63	76	82
31	70	76
16	64	70
8	58	64
4	52	58
2	46	52
1	40	46
.5	34	40
.24	28	34
.12	22	28
.06	16	22

Cell Size Reduction

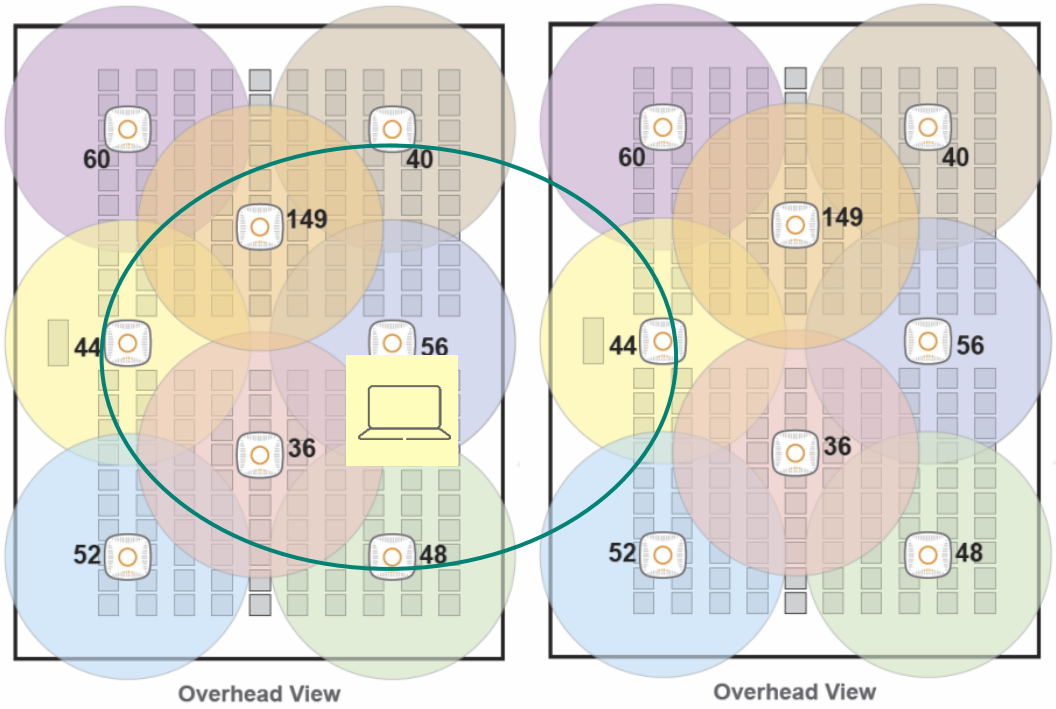
– Adjusting AP receive sensitivity with Cell Size Reduction (CSR), helps the APs to automatically reject interference from co-channel sources outside the high-density coverage area

– CSR can also provide some immunity to ACI sources within the same auditorium or high-density environment

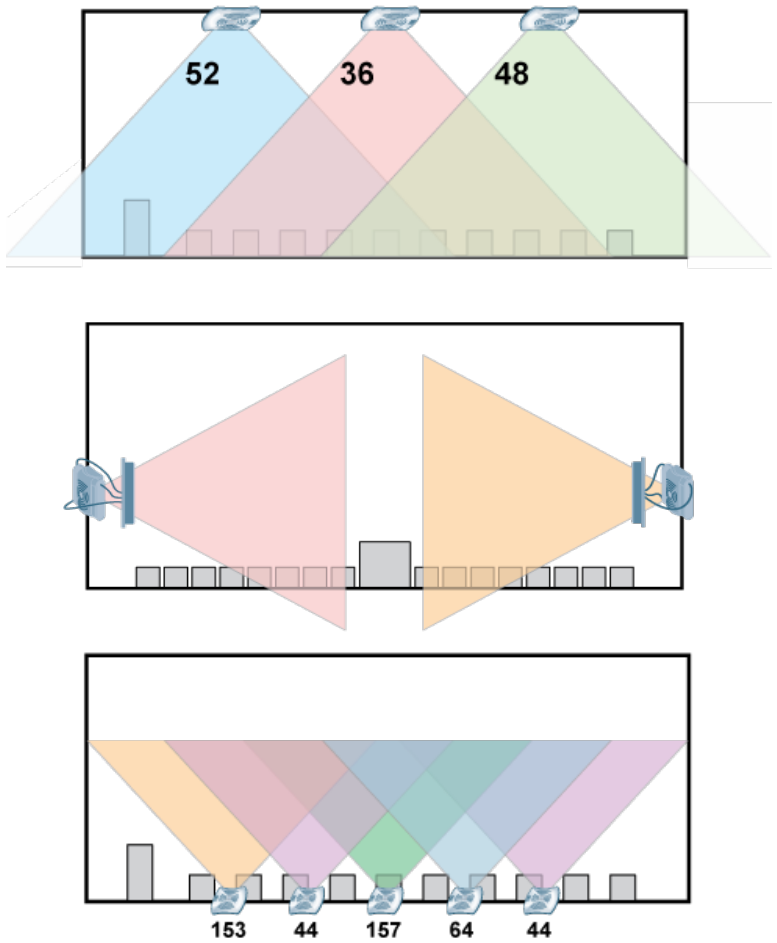


Cell size – Client Tx vs AP Tx

- Once you have carefully created you “cells”, you still have to deal with CCI caused by client devices
- Enabling TPC, 802.11h/k has mechanisms to control Client Transmit Power , but it is not or poorly implemented by clients,
- Recommend to enable 802.11h/k (default disabled)



Coverage Strategies for HD Areas



Overhead coverage is a good
when uniform signal is desired
everywhere in the target area

First Choice

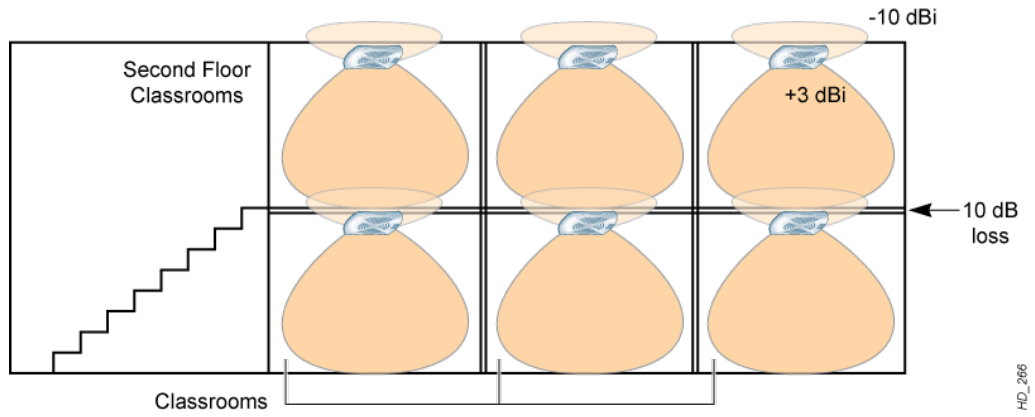
Wall installations are most oft
where ceiling or under-floor acc
not possible or too expensive.

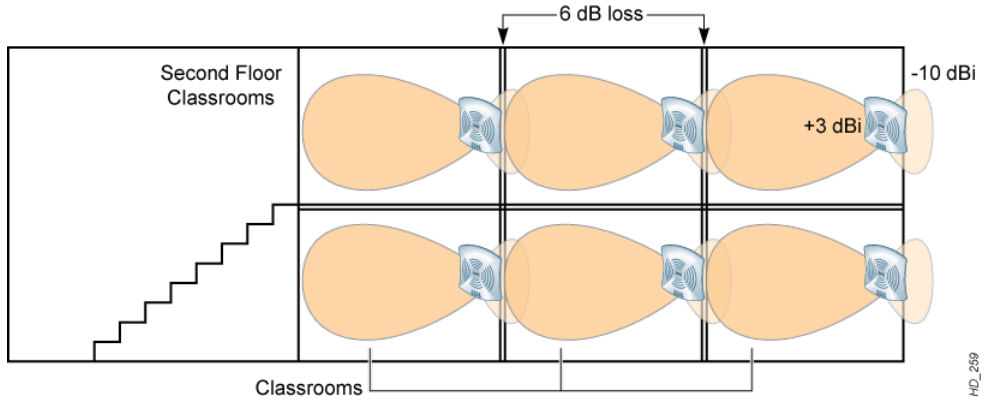
Second Choice

Under-seat or on-floor mount
also known as a "picocell" desig
uses very small cells to maximize
reuse.

Third Choice

Extend Uniformity to Adjacent HD WLANs

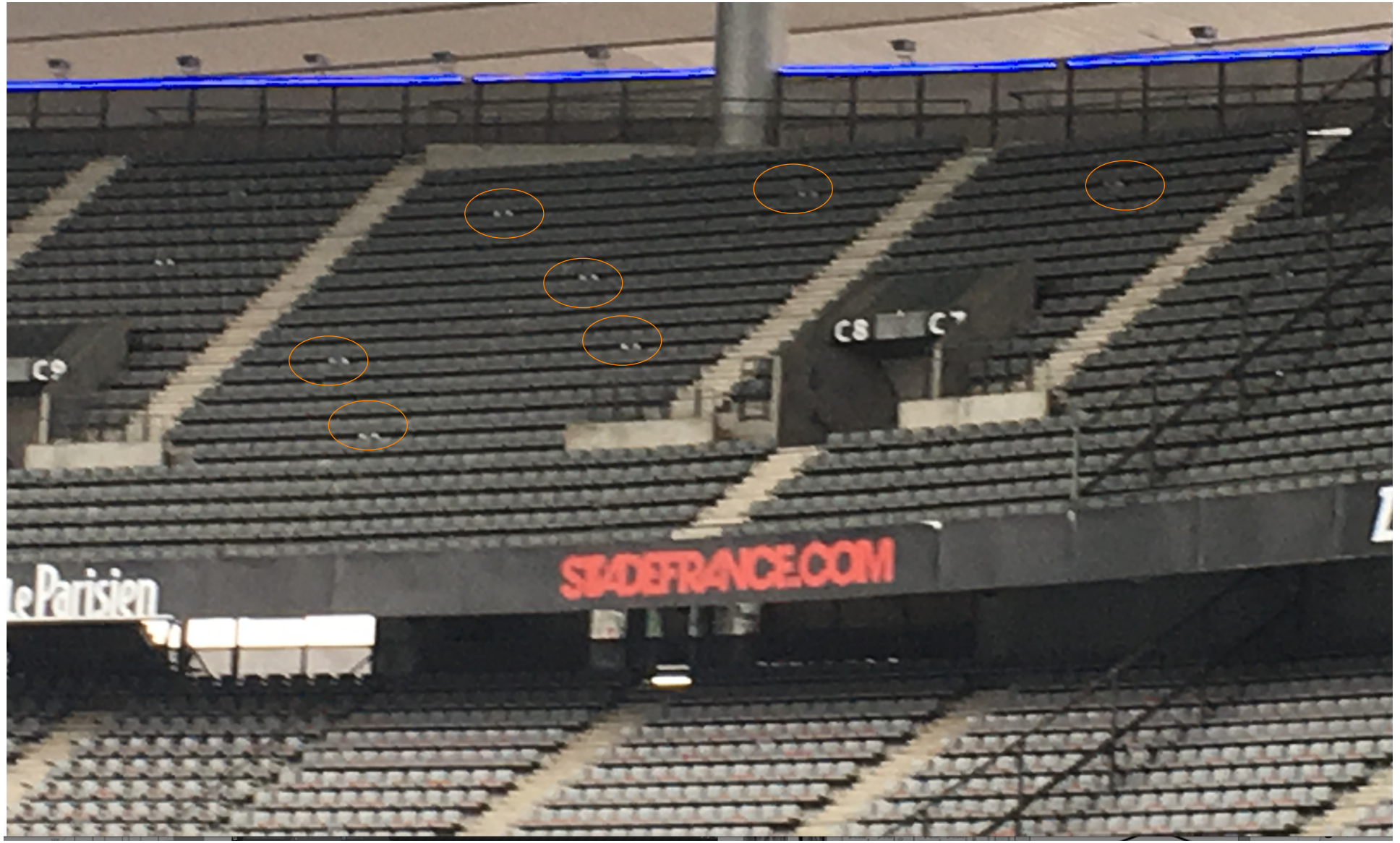




Factors that influence coverage strategy

- RF propagation
  - Distance between client and AP.
  - Distance between APs
  - Signal obstructions
- Esthetics
  - Mainly indoor venues with nice and/or acoustic wall finishing
- Mounting constraints
  - You can't always mount where you think you can mount. E.g in exhibition halls where minimal height need to be respected.
  - Presence of 3G/4G Antennas
  - Max cable length
  - AP/Antenna tampering.
    - I.e certain stadiums refuse under-seat solutions
    - Lifts, Rigging etc.
  - Maintenance

Example Pico Cell Installation



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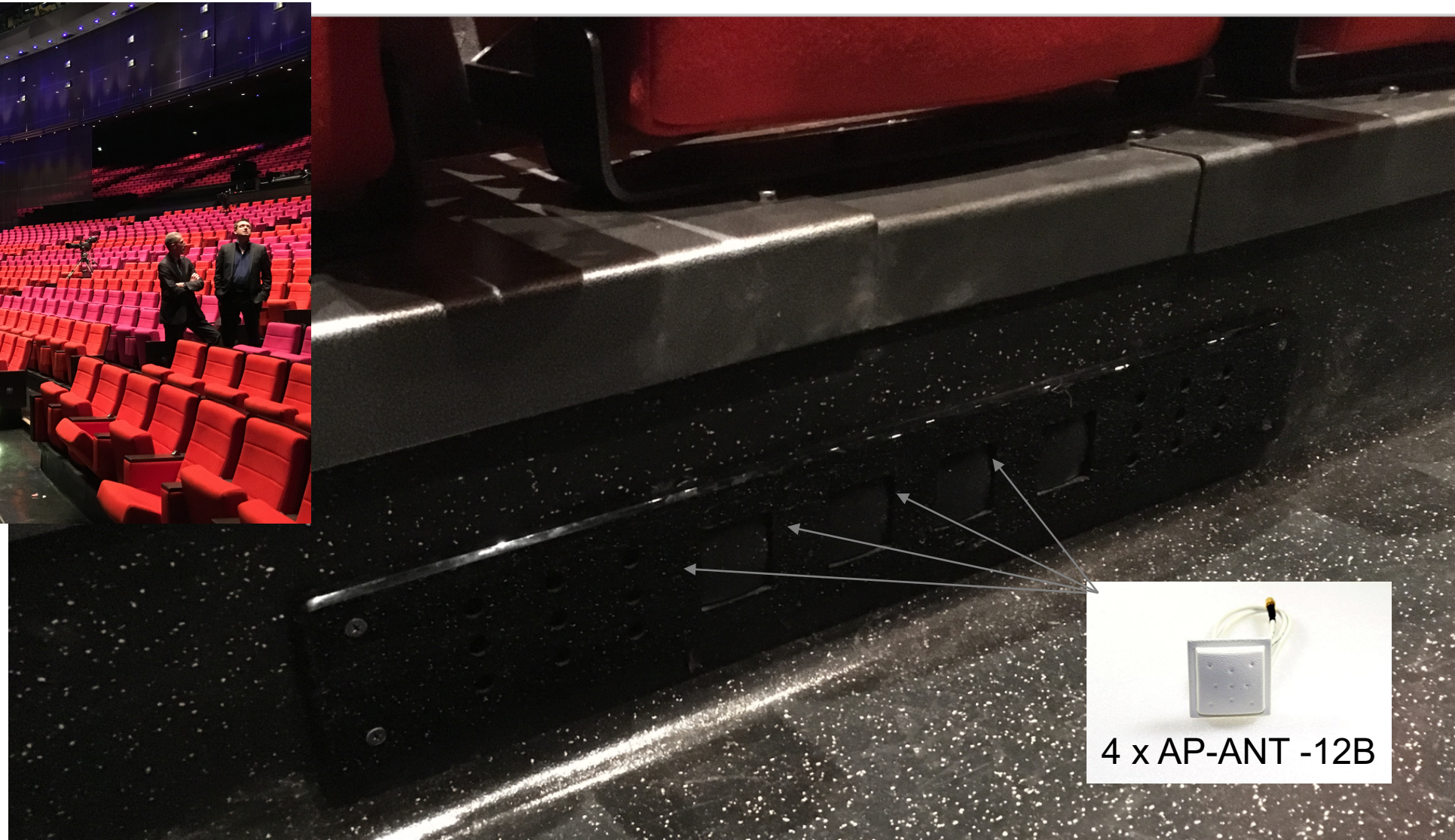
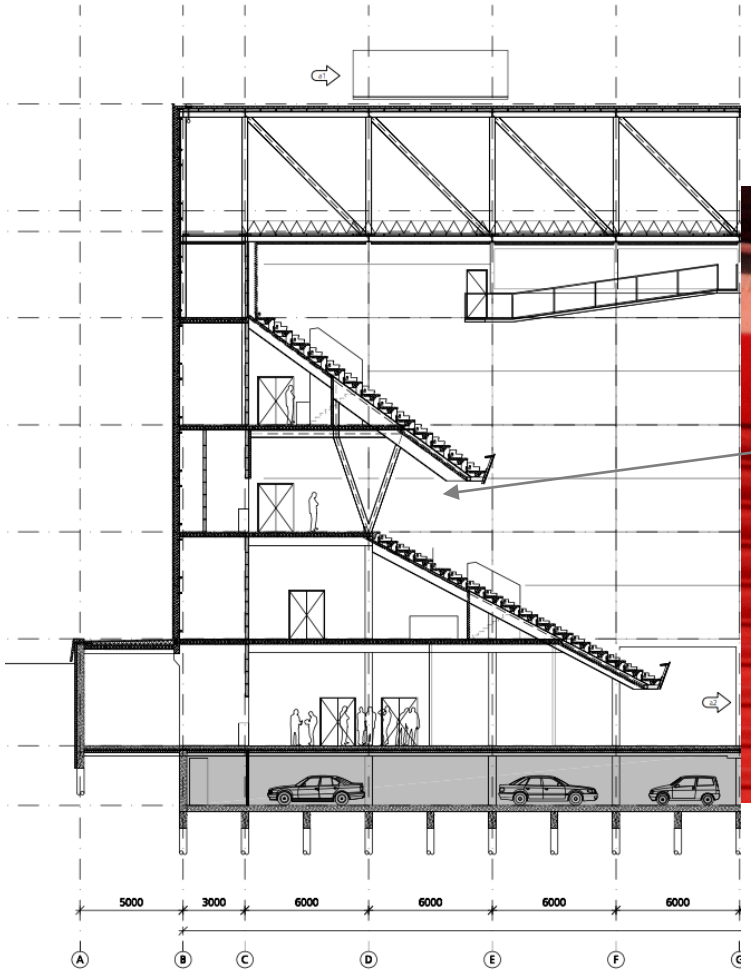
AP in a water and shock resistant box

Preferred AP model:
AP-228 with AP-ANT-32

Example Pico Cell installation (Indoor)



Example Wall-Mount

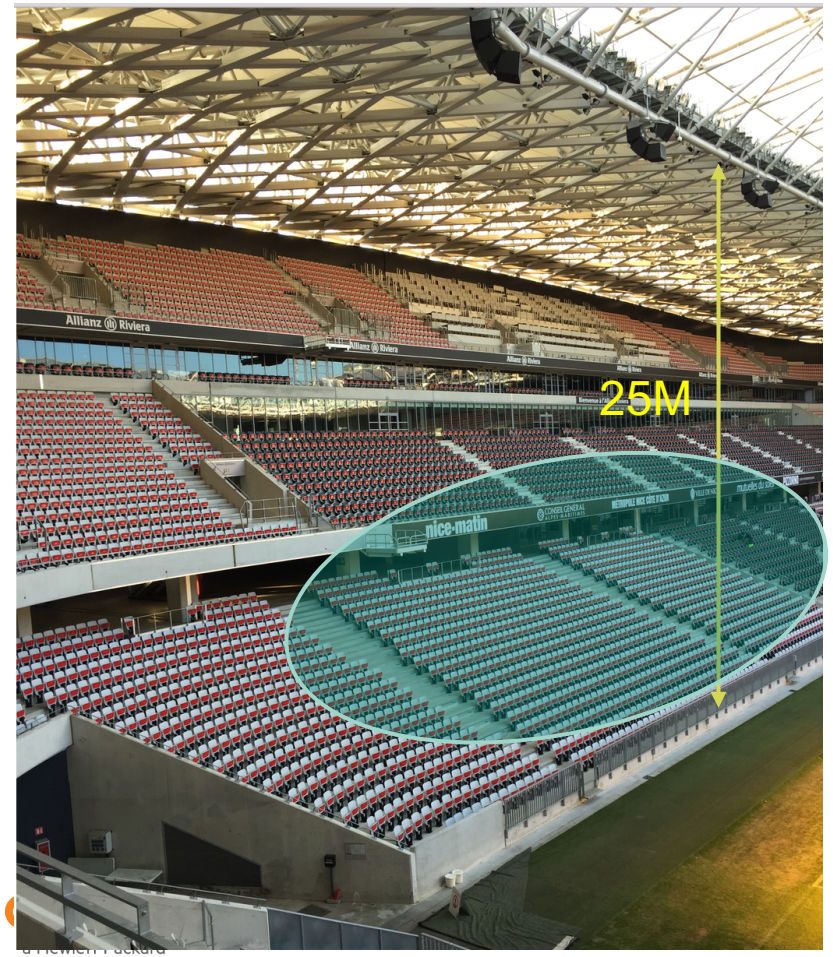


Example Ceiling Mount

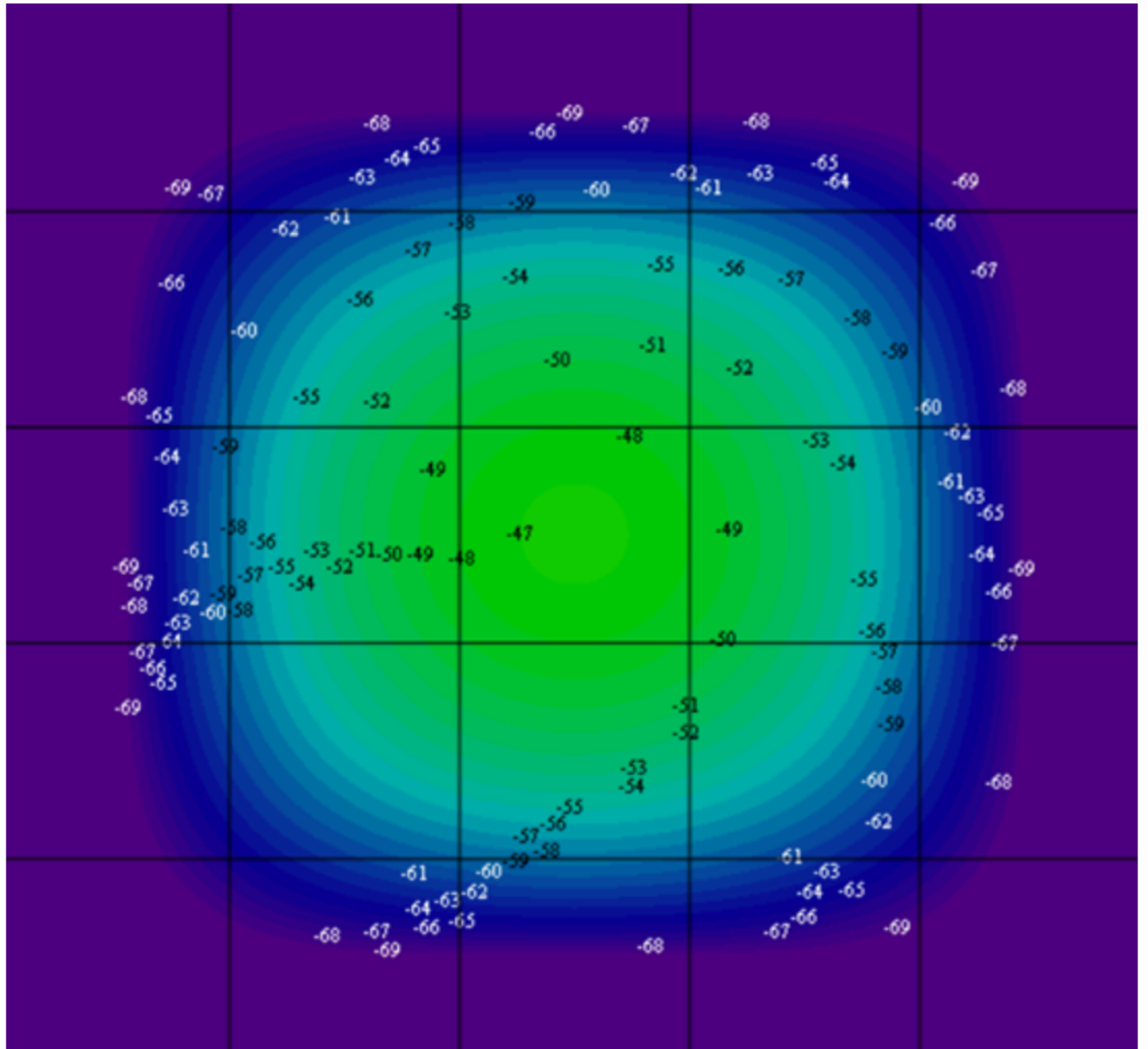
Mount Height	h < 8m	8< h >12	h >12m
	AP Integrated Antenna	60 degree sector	30 degree sector
AP	AP-335	AP-334	AP-228 or AP-274
Antenna example	n/a	AP-ANT-48 (dual-band)	AP-ANT-2314 (2.4Ghz) AP-ANT-5314 (5Ghz)

AP-ANT-5314 Foot print

– Each box represents 10x10m



30m Pointing Straight Down



VHD WLAN – Not just about APs and controllers

- Recommend using a single flat VLAN (e.g. /17)
  - (Core)switch should be able to handle many MAC address
  - Router/firewall needs to support large ARP cache
- Local high performance DNS and DHCP server
- High performance Captive portal
  - External captive portal server
  - Sufficient Controller capacity to handle redirections
- Uplink capacity
- NAT

HD WLAN – Best Practices

- Read the VHD-VRD Engineering guide
- In Summary
  - 1 AP per 150 Associations or 1 AP per 80-100 seats
  - Design for 5Ghz band. 2.4Ghz will be best effort onl
  - Static channel assignment for 2.4Ghz, unless AOS8
  - Fix channel assignment to avoid unnecessary chan
  - Look for true radar events (show log wireless all | in
  - Limit number of SSIDs in the HD areas
    - Ideally just 1 Open SSID, or 2 SSIDs (one open and one
    - Use Radius to separate users on the secure SSID (i.e em
  - Always configure MAC-caching in combination with
  - Set the right expectations!
    - WiFi has its limits, but if designed correctly, it works
    - Don't promise anything on 2.4Ghz

Co-Channel Interference (CCI)	Number of SSIDs 1	2	3	4	5
1	0,42%	0,83%	1,25%	1,67%	2,08%
2	0,83%	1,67%	**2,50%**	3,34%	4,17%
3	1,25%	2,50%	3,75%	5,00%	6,25%
4	1,67%	3,34%	5,00%	6,67%	8,34%
5	2,08%	4,17%	6,25%	8,34%	10,42%
6	2,50%	5,00%	7,51%	10,01%	12,51%
7	2,92%	5,84%	8,76%	11,68%	14,59%
8	3,34%	6,67%	10,01%	13,34%	16,68%
9	3,75%	7,51%	11,26%	15,01%	18,76%
10	4,17%	8,34%	12,51%	16,68%	20,85%
11	4,59%	9,17%	13,76%	18,35%	22,93%
12	5,00%	10,01%	15,01%	20,02%	25,02%
13	5,42%	10,84%	16,26%	21,68%	27,10%
14	5,84%	11,68%	17,51%	23,35%	29,19%
15	6,25%	12,51%	18,76%	25,02%	31,27%
16	6,67%	13,34%	20,02%	26,69%	33,36%
17	7,09%	14,18%	21,27%	28,36%	35,44%
18	7,51%	15,01%	22,52%	30,02%	37,53%
19	7,92%	15,85%	23,77%	31,69%	39,61%
20	8,34%	16,68%	25,02%	33,36%	41,70%
21	8,76%	17,51%	26,27%	35,03%	43,78%
22	9,17%	18,35%	27,52%	36,70%	45,87%
23	9,59%	19,18%	28,77%	38,36%	47,95%
24	10,01%	20,02%	30,02%	40,03%	50,04%
25	10,42%	20,85%	31,27%	41,70%	52,12%
26	10,84%	21,68%	32,53%	43,37%	54,21%
27	11,26%	22,52%	33,78%	45,04%	56,29%
28	11,68%	23,35%	35,03%	46,70%	58,38%
29	12,09%	24,19%	36,28%	48,37%	60,46%
30	12,51%	25,02%	37,53%	50,04%	62,55%

HD WLAN – Best Practices

- Every µs airtime counts
  - Set local probe threshold (6<LPTR<10) (LPTR 3dB less than cm-sticky-snr)
  - Configure ‘broadcast-filter all’
  - Use lowest Tx Power possible. Target -68dB at client. Pico-cell uses relatively high power settings
  - Trim TX rates >24Mbps
  - Deny inter-user bridging
- Use CSR carefully. Start with low value (e.g 6)
- Turn of 802.11b protection
- Use always DMO for multicast video streaming

Thank You

Questions?