# K-12 WLAN Design

Keith R. Parsons – CWNE #3

IT Professional Wi-Fi Trek 2015
#wifitrek

Certified Wireless Network Professional
CWNP

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Designed Wi-Fi for over 3,000 Classrooms

15 years experience in Wireless LANs

*Define, Design, Implement, Validate, Troubleshoot*

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# Just because it works…

# Doesn’t mean it works…

# MCS Index - 802.11n and 802.11ac

802.11n | 802.11ac

| HT MCS Index | VHT MCS Index | Spatial Streams | Modulation | Coding | 20MHz Data Rate No SGI | 20MHz Data Rate SGI | 40MHz Data Rate No SGI | 40MHz Data Rate SGI | 80MHz Data Rate No SGI | 80MHz Data Rate SGI | 160MHz Data Rate No SGI | 160MHz Data Rate SGI |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 0 | 1 | BPSK | 1/2 | 6.5 | 7.2 | 13.5 | 15 | 29.3 | 32.5 | 58.5 | 65 |
| 1 | 1 | 1 | QPSK | 1/2 | 13 | 14.4 | 27 | 30 | 58.5 | 65 | 117 | 130 |
| 2 | 2 | 1 | QPSK | 3/4 | 19.5 | 21.7 | 40.5 | 45 | 87.8 | 97.5 | 175.5 | 195 |
| 3 | 3 | 1 | 16-QAM | 1/2 | 26 | 28.9 | 54 | 60 | 117 | 130 | 234 | 260 |
| 4 | 4 | 1 | 16-QAM | 3/4 | 39 | 43.3 | 81 | 90 | 175.5 | 195 | 351 | 390 |
| 5 | 5 | 1 | 64-QAM | 2/3 | 52 | 57.8 | 108 | 120 | 234 | 260 | 468 | 520 |
| 6 | 6 | 1 | 64-QAM | 3/4 | 58.5 | 65 | 121.5 | 135 | 263.3 | 292.5 | 526.5 | 585 |
| 7 | 7 | 1 | 64-QAM | 5/6 | 65 | 72.2 | 135 | **150** | 292.5 | 325 | 585 | 650 |
|  | 8 | 1 | 256-QAM | 3/4 | 78 | 86.7 | 162 | 180 | 351 | 390 | 702 | 780 |
|  | 9 | 1 | 256-QAM | 5/6 | n/a | n/a | 180 | **200** | 390 | **433.3** | 780 | 866.7 |
| 8 | 0 | 2 | BPSK | 1/2 | 13 | 14.4 | 27 | 30 | 58.5 | 65 | 117 | 130 |
| 9 | 1 | 2 | QPSK | 1/2 | 26 | 28.9 | 54 | 60 | 117 | 130 | 234 | 260 |
| 10 | 2 | 2 | QPSK | 3/4 | 39 | 43.3 | 81 | 90 | 175.5 | 195 | 351 | 390 |
| 11 | 3 | 2 | 16-QAM | 1/2 | 52 | 57.8 | 108 | 120 | 234 | 260 | 468 | 520 |
| 12 | 4 | 2 | 16-QAM | 3/4 | 78 | 86.7 | 162 | 180 | 351 | 390 | 702 | 780 |
| 13 | 5 | 2 | 64-QAM | 2/3 | 104 | 115.6 | 216 | 240 | 468 | 520 | 936 | 1040 |
| 14 | 6 | 2 | 64-QAM | 3/4 | 117 | 130.3 | 243 | 270 | 526.5 | 585 | 1053 | 1170 |
| 15 | 7 | 2 | 64-QAM | 5/6 | 130 | 144.4 | 270 | **300** | 585 | 650 | 1170 | 1300 |
|  | 8 | 2 | 256-QAM | 3/4 | 156 | 173.3 | 324 | 360 | 702 | 780 | 1404 | 1560 |
|  | 9 | 2 | 256-QAM | 5/6 | n/a | n/a | 360 | **400** | 780 | **866.7** | 1560 | 1733.3 |

# 7 Myths about Wireless LANs

Simple & Easy - Only Need Ratios

Wi-Fi scales easily - “It works at home!”

Wi-Fi is like Ethernet

Wi-Fi is like Cellular

More Access Points equals More Capacity

Wireless LANs must support legacy clients

All Access Points are basically the same…

# Myth #1 - Simple & Easy

## Ratios Rule!

One Access Point Every _____

- 2,000 Square Feet
- 300 Attendees
- Classroom

Simple - Enticing - Sales Driven

# #1 - Reality

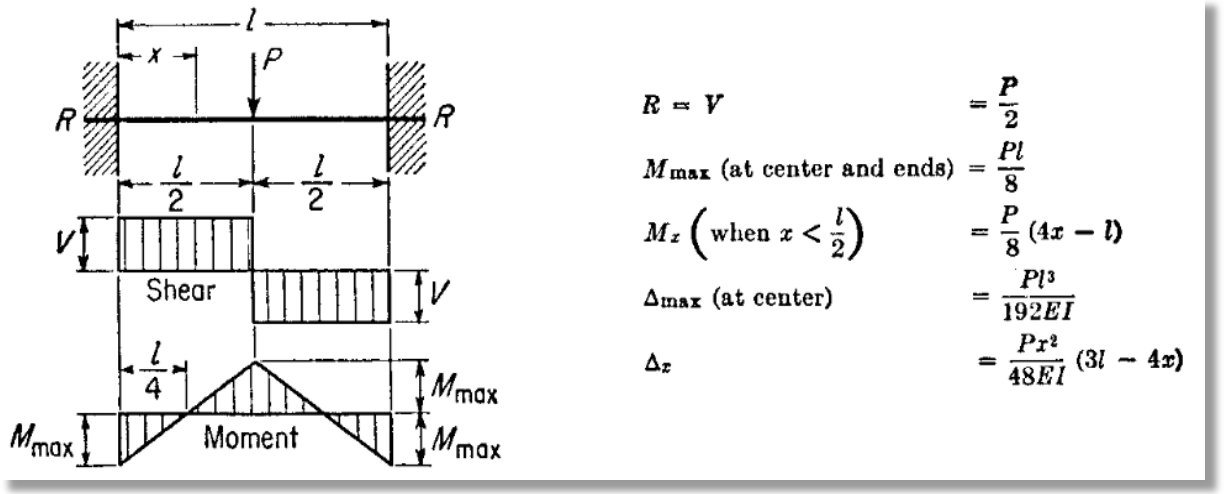
Engineering for Radio Frequency and 802.11 Protocols is heavily dependent on complex mathematics

Meeting specific requirements far more important than mere ratios can express

# Engineering Examples

- Structural Engineering
- Sound Engineering
- Civil Engineering
- Materials Engineering

- All highly dependent on complex math, equations, formulas and advanced software




$R = V = \frac{P}{2}$

$M_{max}$ (at center and ends) $= \frac{Pl}{8}$

$M_x \left(\text{when } x < \frac{l}{2}\right) = \frac{P}{8}(4x - l)$

$\Delta_{max}$ (at center) $= \frac{Pl^3}{192EI}$

$\Delta_x = \frac{Px^2}{48EI}(3l - 4x)$

# WLAN Engineering

- Also highly dependent on complex math, formulas, and advanced software to Model Radio Frequencies

**Characteristic Impedance of Free Space**

$$\eta_o = \sqrt{\frac{\mu_o}{\varepsilon_o}} = 120\pi\Omega = 377\Omega$$

where: $\mu_o$ = free space permeability
$= 4.0\pi \times 10^{-7}$(H/m)
$\varepsilon_o$ = free space permitivity
$= \left(\frac{10^{-9}}{36\pi}\right)$(F/m)

$$c = \frac{1}{\sqrt{\mu_o \varepsilon_o}} = \text{propagation velocity} = 2.997925 \times 10^8 \text{ m/s}$$
$(\cong 3 \times 10^8$ m/s)

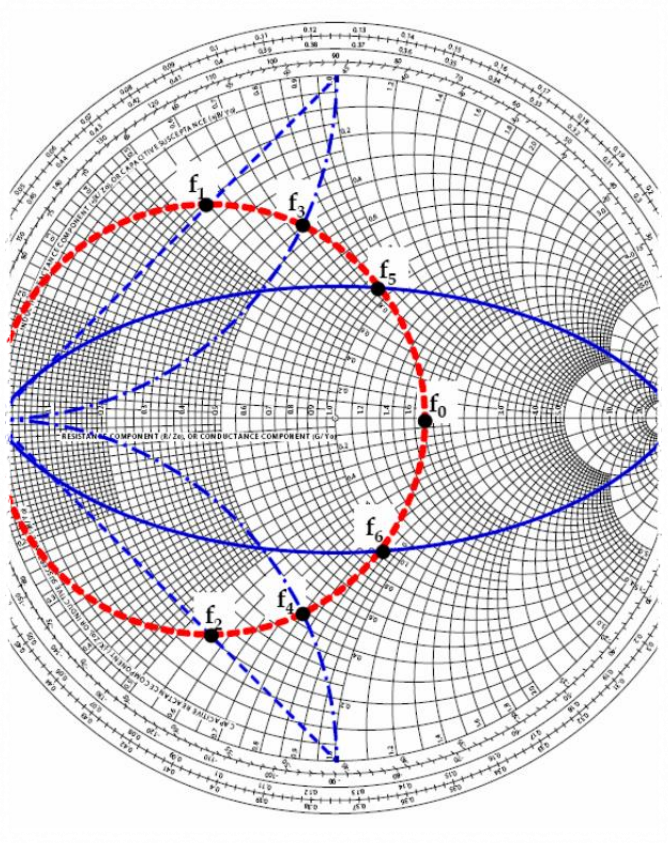
In free space the wavelength is:

$$\lambda = \frac{c}{f}$$

For a nonmagnetic dielectric:

$$\lambda_d = \frac{c}{f\sqrt{\varepsilon_r}} = \frac{\lambda_o}{\sqrt{\varepsilon_r}}$$

where: $\varepsilon_r$ is relative dielectric from Table 1.1



# Myth #2 - Wi-Fi is Scalable

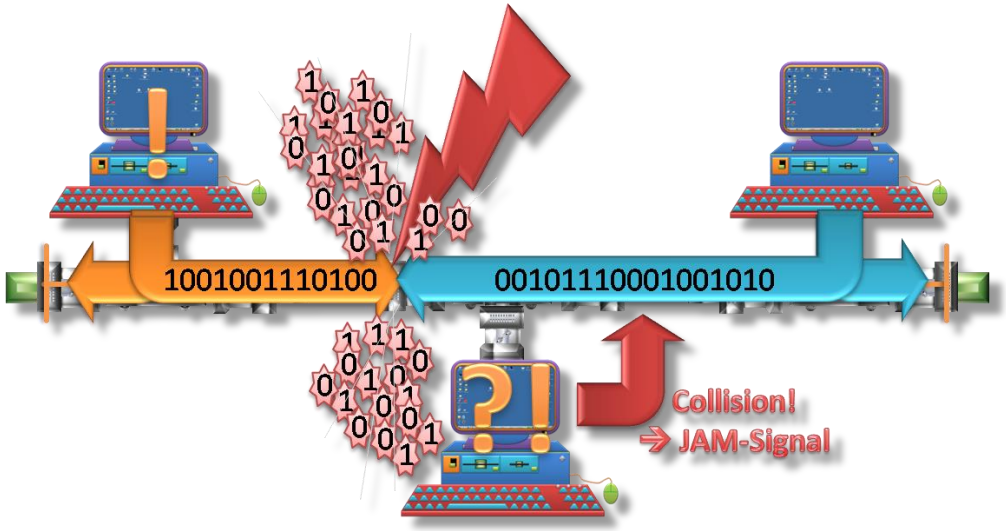
- It works at home…
- Setting up Wi-Fi at home is easy and simple… so why so difficult to scale up to provide same service at school?

# #2 - Reality

Scale requires different level of engineering

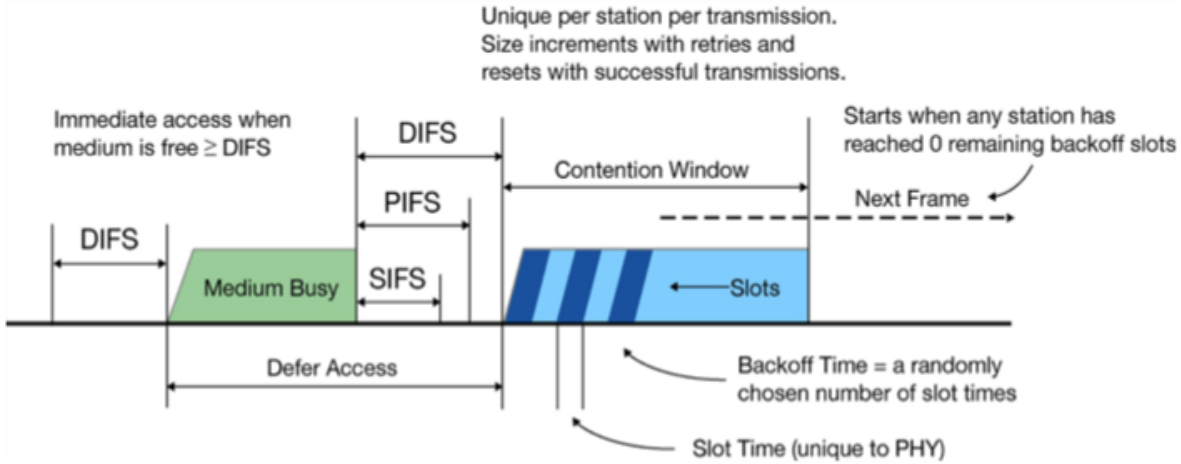
# Myth #3 - Wi-Fi is like Ethernet

- Ethernet Uses CSMA/CD - Collision Detection
- Ethernet NICs can talk and listen simultaneously
- Collisions happen during Preamble
- If collision, then random back-off
- Then Retransmit



# #3 - Reality

- 802.11 uses CSMA/CA
- NICs cannot talk and listen
- No Collision Detection
- Random back-off BEFORE EVERY Tx
- If collision, don't know until after entire payload Tx (lack of ACK)
- Contention/Collisions with all others on same frequency (above CCA thresholds)

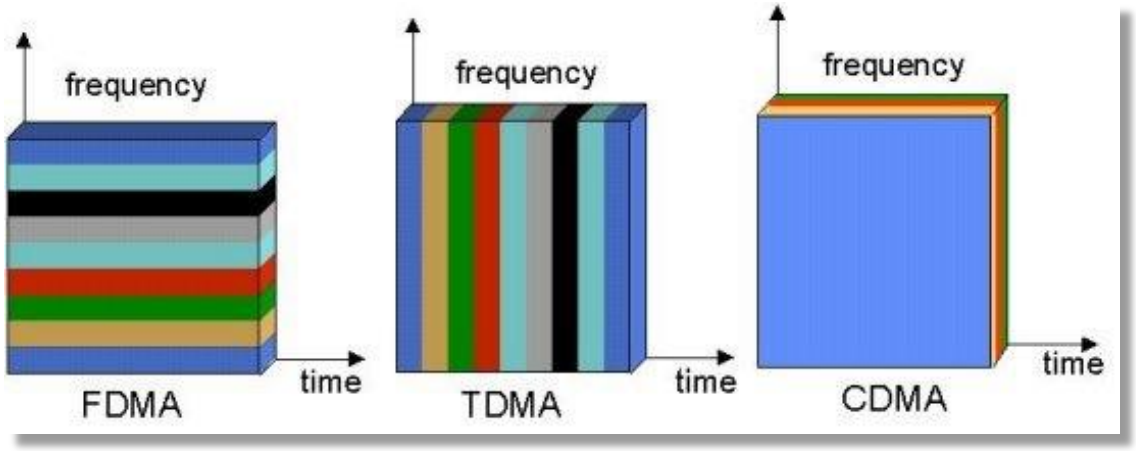


# Myth #4 - Wi-Fi is like Cellular

- Cellular the tower controls client connections and power settings
- Cellular uses technologies to share limited frequencies
- Cellular uses Licensed Frequencies ($$)
- Cellular frequencies have pretty good penetration and distance

# #4 - Reality

- Wi-Fi and 802.11 Protocols have the Client choose the Access Point to join
- Clients choose their Tx power
- Limited frequencies (only 3 in 2.4GHz)
- Shared Collision/Contention domains
- Frequencies limited in penetration and distance
- Frequencies are Unlicensed

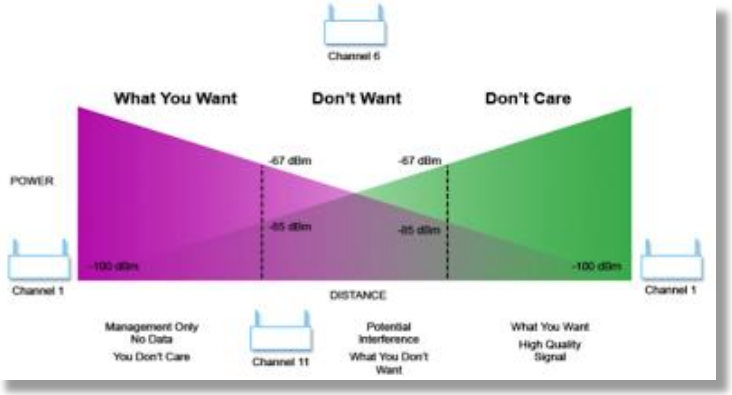


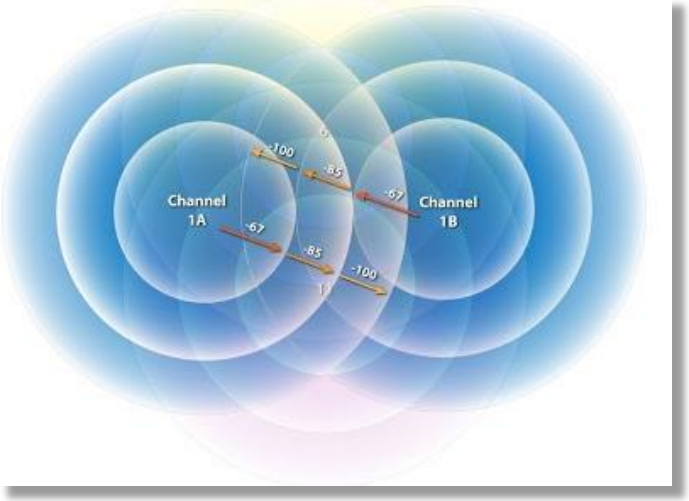
# Myth #5 - More Access Points = More Capacity

- If you need more capacity add more Access Points
- If you need more coverage add more Access Points
- Access Points are like Switch Ports… Right?

# #5 - Reality

- All client devices and all Access Points on the same frequency SHARE the limited resource of frequency together
- Adding more AP's in the same frequency that can see each other actually lowers capacity



# Myth #6 - WLANs must support Legacy Devices

- “But we have all these older 802.11b clients we need to support.”
- “We *have to* support all the 2.4GHz only devices.”
- “Don’t you understand… that is the scanners we have - make it work.”

# #6 - Reality


- 802.11 protocols ARE backwards compatible - supporting legacy devices is possible
- Huge cost in throughput and efficiency in order to do so
- Allowing slow devices on WLAN is very expensive and hugely inefficient
- You would NEVER do this with wired infrastructure
- Think about the “Sunk Cost Fallacy”

# Myth #7 - All Access Points are basically the Same

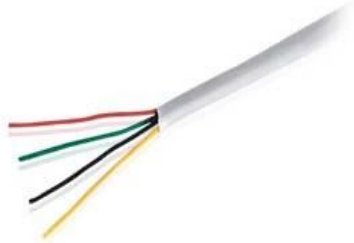

- “Why spend hundreds of dollars on an Access Point - I picked up my home WAP Router at Best Buy for under $100”
- “Save money on the Access Points by going with the cheaper version”

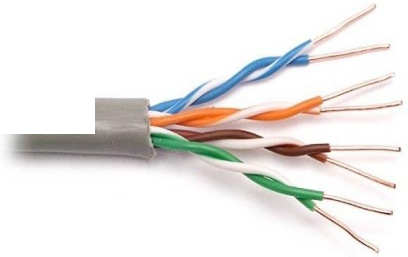
# #7 - Reality

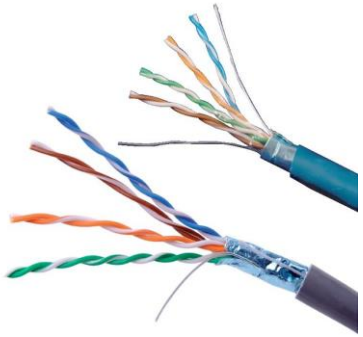

- Extreme differences between various vendor solutions
- Cost of Goods Sold Example
- Requirements for Home, Small Office and high-density schools very different
- Match solutions to meet your requirements
- Don’t “Drag Race School Busses”

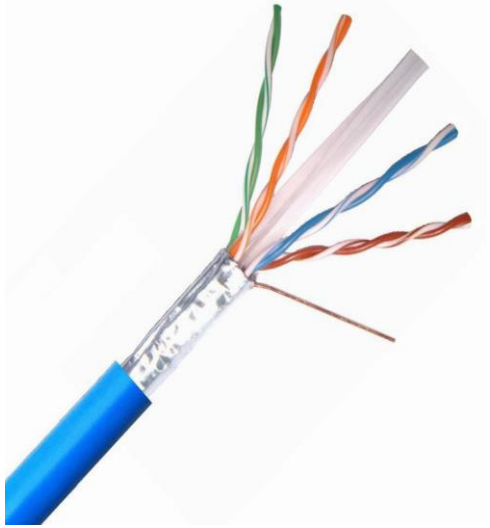

RAIN BIRD

# How does newer cable support higher speeds?









# How to Properly Engineer WLANs

- Define - specific and detailed requirements
- Design - engineer to meet requirements within constraints using complex math & advanced tools
- Deploy - Test Wired Network, Install AP's and Configure Management
- Validate - Verify WLAN meets all requirements
- Note: Just like CatX cable, it's all about meeting specs!

# Define

- Don’t succumb to enticing simplicity of mere ratios - NON-Engineered Solution
- Spend time and energy to gather detailed and specific requirements correctly
- Think and plan for future
- Don’t forget the constraints
- Entire WLAN success hinges on this step!

# Know Your Devices

- Device Types
- Device Capabilities
- App Needs
- Active vs Passive
- Associated vs High Data Usage

# Define Realistic Requirements

- “All students to use Wi-Fi simultaneously”
- “We need Wi-Fi coverage everywhere”
- Compare with Cafeterias, Recess, Teacher Breaks, AM/PM Students, etc.

# Design

- **Iterative** process of meeting requirements while staying within defined constraints
- Sometimes can’t get there from here
- Based on RF fundamentals and 802.11 Protocols
- Use explicit and complex math with professional software and tools
- Calculate base assumptions on device types, counts and app traffic flows
- Achieving Frequency Reuse is paramount and trumps all else
- Use on-site measurements to increase predictive accuracy

# Constraints

- Budget
- RF Characteristics of buildings & walls
- 802.11 Protocol Issues
- Aesthetics
- Cabling Accessibility & Distances

- **Every requirement and constraint has a trade-off!**

# Deploy

- Easiest of all steps
- Test wired side of network BEFORE installing each and every Access Point
- Lots of moving parts in addition to RF and 802.11 pieces

# Validate

- Most Important Step
- Don’t test Cat6 cable on the spool… only after installed
- How else can you know if invisible RF will meet your design requirements?
- This MUST be included in every WLAN installation
- Make sure to include in your bids and RFPs

- Adjust when necessary

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# Final Myth

- K-12 merely needs One Access Point per Classroom
- Don’t be fooled by this sales technique
- It is NOT engineering - merely an easy way to sell
- Simple ratios are NOT a way to engineer a correct WLAN infrastructure that meets your requirements AND saves schools funds

# Final - Reality

- K-12 needs a properly ENGINEERED Wireless LAN that meets all design requirements within defined constraints
- No more… No less…
- Just because it ‘works’ does NOT make it the proper solution!
- Make sure your vendor/VAR will spend the time and effort necessary to:

Define, Design, Deploy and especially Validate your WLAN solution

# Conclusions

Create best possible solution to your schools Wi-Fi needs by:

- Spend time to define specific requirements
- Use math, software and tools to design to meet all requirements
- Validate to confirm/verify WLAN meets requirements
- Most efficient use of funds is to engineer a proper solution

# Recommendations

- Coverage is Easy - Getting rid of CCI is difficult
- Stop purchasing any 2.4GHz only devices - Focus on 5GHz deployments
- Costs per AP include installation, cabling, PoE switch port, licensing & more
- Shorthand - provide minimum 4-radio coverage

  (2-3 in 2.4GHz and 2 in 5GHz at -67dBm or better)
- Plan and budget for faster refreshes of WLAN infrastructure

# Questions

# Resources

http://WLANPros.com

http://revolutionwifi.net

Twitter

WLAN Blogs

CWNP Program & Training

Vendor Websites & Conferences