Difference between Wi-Fi that works and Wi-Fi that doesn’t

Wi-Fi Always Works...
Things I’ve Learned about Wireless LAN Design

after teaching hundreds of classes

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Wi-Fi is Easy to do wrong... Why?
If you don’t know even basic best practices or ‘rules’…

Wi-Fi still works…
Following Rules & Best Practices
10 – 20 – 30

Presentation Rules
of Guy Kawasaki
Playing with LEGO
Requirements:

8 x 16 ‘House’
4 Bricks High
Sloped Roof Lengthwise
Limited supply of Bricks
Wireless LAN
Rules to Follow

or sometimes break
Do not say the word ‘Survey’ when you mean ‘Design’
Engineer

WLAN Designs

Do NOT Use
Simplified Marketing Ratios
Know All Requirements

Design to Meet All Requirements
You Can NOT design for ALL Wi-Fi Clients

But you may design for one that works for others
Design for LCMI

Least Capable – Most Important
Use Widest Channel until you can’t

Co-Channel Interference
Use the highest Minimum Basic Rate until you can’t

Retry Rates Climb
Use the highest possible Tx Power, until you can’t

Average Data Rates Drop
Always Use DFS Channels, until you can’t

DFS Events in Logs
Do Not use RRM/ARM/Channel Fly

Unless you know how to tune it properly
Do **Not** use same SSID across frequencies
Do Not do one-for-one Access Point replacements
Choose Antennas that covers what you want while not covering what you don’t
Never Use a Captive Portal for Public Wi-Fi

Customers want Fast, Free and Frictionless
Do not believe marketing hype
Always do a Validation Survey
Always do a Passive Survey
Do Active Surveys...

Only if you know and can explain limitations and results.
Green does not mean good!
If it moves – Wireless
If it doesn’t – Wire
Until you can’t...
Use top-of-the-line Access Points
Do Not Put Access Points in Hallways
Do Not Put Access Points above the ceiling
Do Not put Access Points on the wall like a clock
Do Place Access Points as close to clients as possible
Keep Access Points minimum 2 meters away... from anything
Do Not place Access Points behind/near metal grids/girders
Do Not do ‘weird’ things with Antennas
Design for 5GHz

Then turn off two thirds of 2.4Ghz radios
Use Only Channels 1, 6, and 11
Do Not Bond Channels in 2.4GHz
Choose Access Point BEFORE Predictive Design
Comparable Access Points
Two Access Points in same area with CCI/CCA have capacity of ONE
Co-Channel Interference

- Two or more Access Points in the same area with RSSI above CCA Preamble Detect Threshold
- Share the medium – resulting in capacity of a single Access Point
- Thus not adding any more capacity
Change in number of Access Points may change your capacity.
Change in Client Device Type WILL Change your Capacity
Access Point – 3x3:3 – 1,300 Mbps Capacity

Tablet – 1x1:1 – 65-raw/30-TCP Mbps Draw
Target Application Requires 2 Mbps
Each Tablet uses 2 Mbps/30 Mbps = 6.66% Airtime

200 Tablets need 200 X 6.66% = 1,332% or 14 Airtimes
(14 Radios)
Access Point – 3x3:3 – 1,300 Mbps Capacity

Laptop – 2x2:2 – 300-raw/150-TCP Mbps Draw
Target Application Requires 2 Mbps
Each Laptop uses 2 Mbps/150 Mbps = 1.3% Airtime

200 Laptops need 200 X 1.3% = 260% or 3 Airtimes
(3 Radios)
Access Point – 3x3:3 – 1,300 Mbps Capacity

100 Laptops need 100 X 1.3% = 130%
100 Tablets need 100 X 6.66% = 666%
Total for all 200 devices = 796%
At 80% efficiency – 796% / 80% = 995% for 10 Airtimes
(10 Radios)
Learn & Understand

Things you should just Know!
Coverage is Easy
2.4GHz and 5GHz Go Same Distance

Receive Aperture
Know how to quickly convert dBm to mW

In your head!
Association is to Wireless
What a Link-Light is to Wire
Lowering Tx Power does NOT fix CCI/CCA Issues

Turning Off Radios Does
Coverage is to Wireless what Connectivity is to Wire
Clean Air Doesn’t
Increasing Tx Power

One-Way

Improved RSSI
Increasing Antenna Gain

Two-Way Improved RSSI
Double the Distance
Quarter the Power

2X distance $\rightarrow$ -6dB
+6dB $\rightarrow$ 2X Distance
Lowering Minimum Basic Rates does Not shrink cell size

Preambles sent at BPSK
KNOW
Your PHY
KNOW

Modulation Techniques
KNOW
Your Protocol
Know a Client’s RF vs Wired Situation

MCS, Data Rates, IP Address, Throughput
Many Wi-Fi Issues Aren’t
Know How to Use Professional Tools
All 802.11 Transmitters choose Modulation, Coding, Channel Width, Guard Interval for each frame
How 802.11 Tx Choose MCS
## 802.11n HT and 802.11ac VHT

### MCS, SNR and RSSI

<table>
<thead>
<tr>
<th>HT MCS VHT</th>
<th>VHT MCS</th>
<th>Modulation</th>
<th>Coding</th>
<th>20MHz</th>
<th>40MHz</th>
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<td>91</td>
<td>100</td>
<td>31</td>
<td>-57</td>
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</tbody>
</table>

### Spatial Streams

| 8 0        | BPSK    | 1/2        |        | 13    | 14.4  | 2    | -82   | 27    | 30   | 5    | -79   | 58.5  | 65   | 8     | -76   | 117   | 130  | 11    | -73  |
| 9 1        | QPSK    | 1/2        |        | 26    | 28.9  | 5    | -79   | 54    | 60   | 8    | -76   | 58.5  | 65   | 11    | -73   | 117   | 130  | 14    | -70  |
| 10 2       | QPSK    | 3/4        |        | 39    | 43.3  | 9    | -77   | 81    | 90   | 12   | -74   | 175.5 | 195  | 17    | -68   | 351   | 390  | 18    | -68  |
| 11 3       | 16-QAM  | 1/2        |        | 52    | 57.8  | 11   | -74   | 108   | 120  | 14   | -71   | 234   | 260 | 17    | -68   | 468   | 520  | 20    | -65  |
| 12 4       | 16-QAM  | 3/4        |        | 78    | 86.7  | 15   | -70   | 162   | 180  | 18   | -67   | 351   | 390 | 21    | -64   | 702   | 780  | 24    | -61  |
| 13 5       | 64-QAM  | 2/3        |        | 104   | 115.6 | 18   | -66   | 216   | 240  | 21   | -63   | 468   | 520 | 24    | -60   | 936   | 1040 | 27    | -57  |
| 14 6       | 64-QAM  | 3/4        |        | 117   | 130.3 | 20   | -65   | 243   | 270  | 23   | -62   | 526.5 | 585 | 26    | -59   | 1053  | 1170 | 29    | -56  |
| 15 7       | 64-QAM  | 5/6        |        | 130   | 144.4 | 25   | -64   | 270   | 300  | 28   | -61   | 585   | 650 | 31    | -58   | 1170  | 1300 | 34    | -55  |
| 8 8        | 256-QAM | 3/4        |        | 156   | 173.3 | 29   | -59   | 324   | 360  | 32   | -56   | 702   | 780 | 35    | -53   | 1404  | 1560 | 38    | -50  |
| 9 9        | 256-QAM | 5/6        |        | 31    | 36.0  | 34   | -54   | 780   | 866.7 | 37   | -51   | 1560  | 1733.3 | 40 | -48   |
KNOW
Regional Frequency Spectrum Rules
### 5 GHz Channel Allocations

<table>
<thead>
<tr>
<th>Frequency (GHz)</th>
<th>5.150</th>
<th>5.250</th>
<th>5.350</th>
<th>5.470</th>
<th>5.600</th>
<th>5.640</th>
<th>5.725</th>
<th>5.825</th>
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<td><strong>802.11 Allocations</strong></td>
<td>UNII-1</td>
<td>UNII-2a</td>
<td>UNII-2c (Extended)</td>
<td>TDWR</td>
<td>UNII-3</td>
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<tr>
<td><strong>Center Frequency</strong></td>
<td>5180</td>
<td>5200</td>
<td>5220</td>
<td>5240</td>
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<td>5520</td>
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<tr>
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<td>104</td>
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<tr>
<td><strong>40 MHz</strong></td>
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<td>54</td>
<td>62</td>
<td>102</td>
<td>110</td>
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<td><strong>80 MHz</strong></td>
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<td>142</td>
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<td><strong>160 MHz</strong></td>
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<td>114</td>
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</tr>
</tbody>
</table>

**FCC**
- 1,000 mW EIRP Indoor & Outdoor
- No DFS needed
- 250 mw/6dBi Indoor & Outdoor
- DFS Required
- 120, 124, 128 Devices Now Allowed

**DFS Channels**
- 1,000 mW EIRP Indoor & Outdoor
- No DFS needed
- 165 was ISM, now UNII-3

**ETSI**
- If 100 mW EIRP Indoor
- DFS/TPC
- 200 mW EIRP Indoor
- DFS/TPC
- 1,000 mW (1 Watt) EIRP Indoor
- DFS/TPC
- No 144

**UK/Ofcom**
- VNS-2030/8/3
- IR2006 & IR 2007
- Band A
- Band B
- Band C 5725-5780 (FWA)

**DFS Channels**
- Fixed Wireless Access
- 1,000 mW (1 Watt) Max EIRP Indoor/Outdoor
- No Fixed Outdoor

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**Notes:**
- TDWR: Temporal Dynamic White Space
- DFS: Dynamic Frequency Selection
- EIRP: Effective Isotropically Radiated Power
- TPC: Transmission Power Control
Does it Meet Requirements?

RF Requirements
- Frequency Allocations
- RSSI Primary (Coverage)
- RSSI Secondary (Overlap)
- Co-Channel Interference
- Device to Radio Ratios
- Special High Density Areas
- Protection Modes

Non-RF Requirements
- Jitter, Latency, Packet Loss, MOS
- Beacon Interval, DTIM Interval
- End to End QoS
- WMM Access Categories
- Codec Choice
- Distributed Forwarding
That’s All Folks!