Wireless LAN Design & Troubleshooting

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Agenda

- Wi-Fi overview
- WLAN design principals
- Planning for high density
- Troubleshooting

Wi-Fi Fundamentals

802.11 principles and standards

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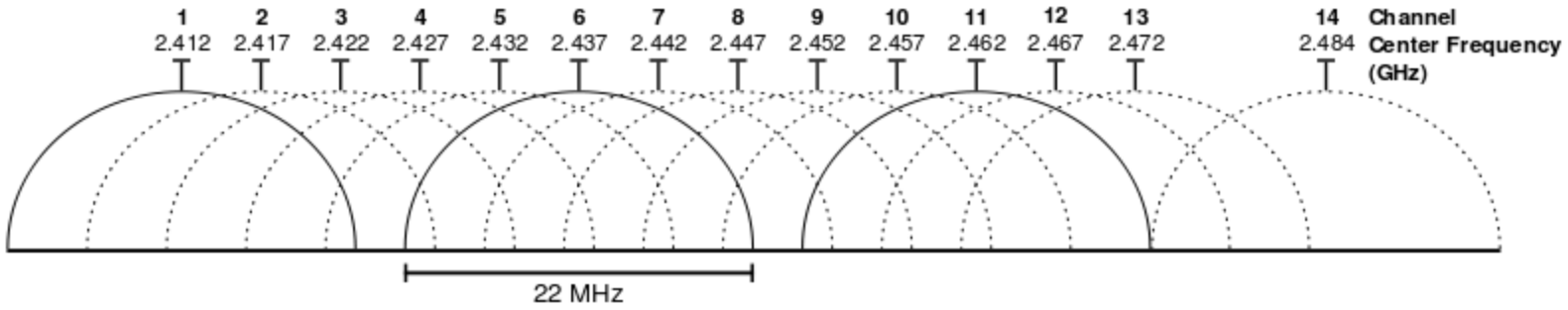
802.11 Standards

Standard	Frequency	Supported Data Rate	Modulation	Date release
802.11	2.4GHz	1, 2 Mbps	FHSS, DSSS	1997
802.11b	2.4GHz	1,2,5.5, 11 Mbps	DSSS	Sept 16th, 1999
802.11a	5GHz	6,9,12,18, 24,36,48,54	OFDM	Sept 16th, 1999
802.11g	2.4 GHz	1,2,5.5,6,9, 11,12,18,24 ,36,48,54	DSSS, OFDM	June 2003
802.11n	2.4 / 5 GHz	Up to 600Mbps	All previous, plus HT-OFDM	Sept 11th, 2009
802.11ac	5 GHz	Up to 6.93 Gbps	OFDM	Draft

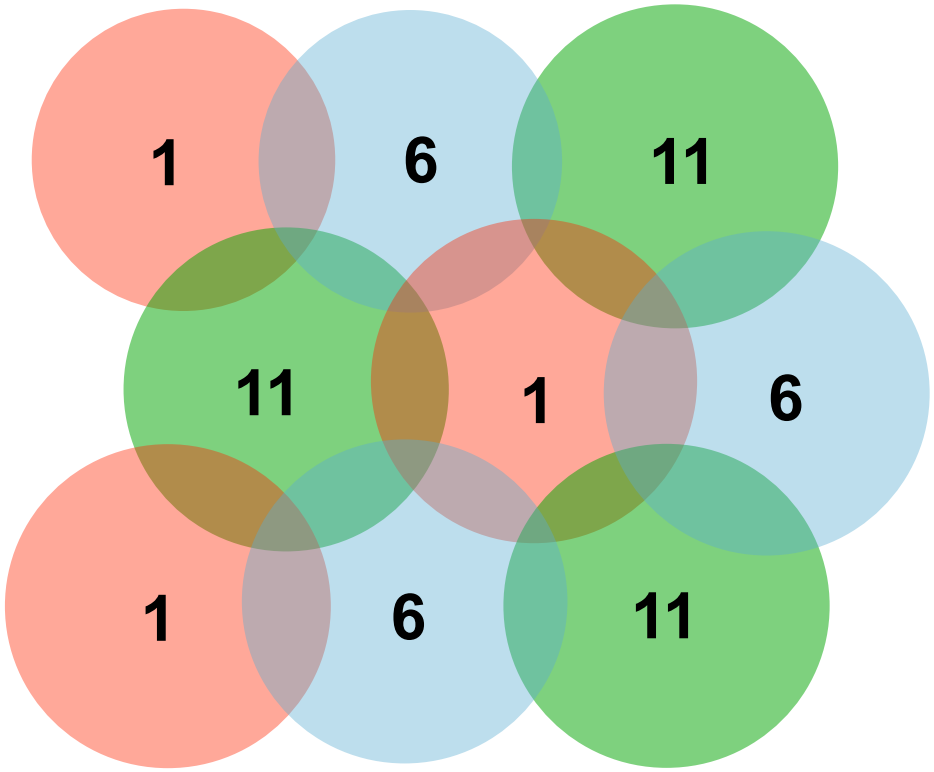
2.4 GHz Spectrum



- Only 3 non-overlapping channels (1, 6 and 11)
- Propagates better through obstructions like walls (is this a good or bad thing)
- Widely adopted frequency for millions of devices e.g. smart phones
- Heavily congested frequency
- 40MHz channels is not feasible

2.4 GHz Channel Planning

- Goal: As little interference as possible with non-overlapping channels
- Reality: Not gonna happen

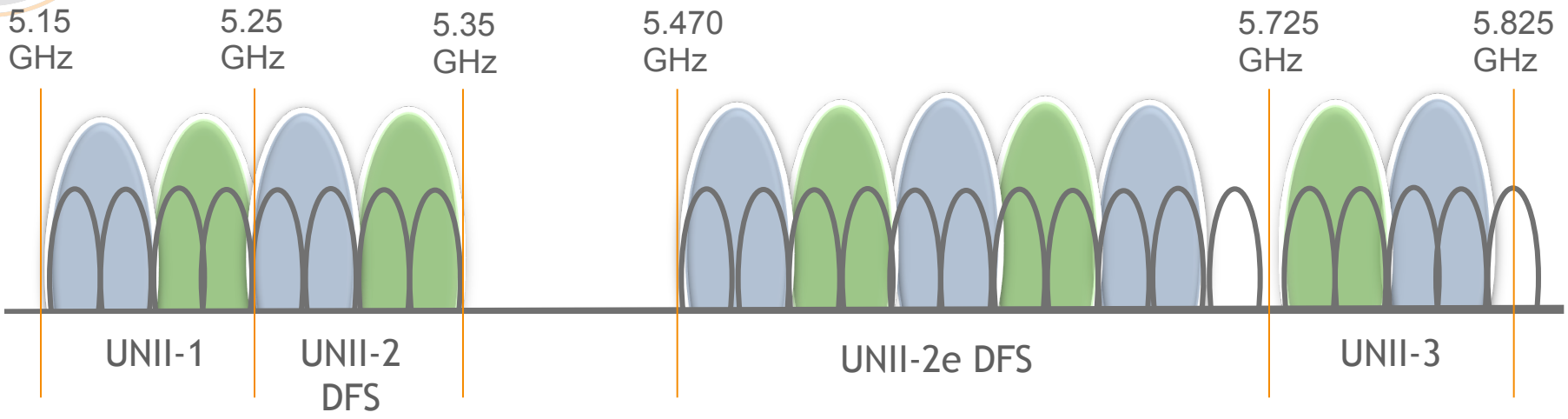


Why Channels 1, 6, and 11 Suck

- Lots of APs on these channels in urban environments
- Most of those APs are far away from our AP
- Most of those APs are using 1mbps for beacon/mgmt
- **Constant sea** of 1mbps beacons and probe responses
  - Very low rx power at our AP
  - Irrelevant to our AP
  - Can easily ‘overpower’ them for our own clients
  - … if it wasn’t for their damn preambles popping out!

- Leaving 1,6,11 can fixe this problem!

5 GHz Spectrum



NON-DFS CHANNELS

36 40	40MHz
44 48	40MHz
149 153	40MHz
157 161	40MHz

- 24 non-overlapping 20 MHz channels
- 11 non-overlapping 40 MHz channels
- Only 4 non-DFS channels for bonding
- Creates channel planning problems similar to 2.4 GHz
- 5 GHz isn't a panacea, RF management is still king

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5 GHz: The Future of Wi-Fi

- 5GHz band has 6-7 times the available bandwidth of 2.4GHz in most countries.
- Large number of channels allows frequency reuse factors of 4,7,9, or 12+ (compared to 3 for 2.4)
- Allows much denser AP placement
- 8 to 20x the mbps/m^2 of 2.4 GHz band (!)

802.11n

- Multiple Transmit/Receive chains (MIMO)
  - Uses Tx:Rx notation, e.g. 3x3
  - Fewer errors, more robust, multi-path is an advantage
- Spatial multiplexing
  - Send different data on different paths = twice the throughput!
  - Streams indicator notation: 3x3:3

	Minimum Tx/Rx Chains	Spatial Streams	Maximum Link Speed
Single stream	1x1	1	150 Mbps
2 stream	2x2	2	300 Mbps
3 stream	3x3	3	450 Mbps
4 stream	4x4	4	600 Mbps

TxBF vs. Multiple Spatial Streams

- **TxBF: Transmit Beam Forming**
  - Introduced with 802.11n, chip-based beam-forming is used to direct RF signals towards a desired area. Multiple antennas are used to send multiple copies of the same data
- Chip-based beam-forming does not work well with spatial multiplexing
  - Lose streams in favor of TxBF

802.11 MCS Rates – Your Best Friend

MCS Index	Type	Coding Rate	Spatial Streams	Data Rate (Mbps) with 20 MHz CH		Data Rate (Mbps) with 40 MHz CH	
				800 ns	400 ns (SGI)	800 ns	400 ns (SGI)
0	BPSK	1 / 2	1	6.50	7.20	13.50	15.00
1	QPSK	1 / 2	1	13.00	14.40	27.00	30.00
2	QPSK	3 / 4	1	19.50	21.70	40.50	45.00
3	16-QAM	1 / 2	1	26.00	28.90	54.00	60.00
4	16-QAM	3 / 4	1	39.00	43.30	81.00	90.00
5	64-QAM	2 / 3	1	52.00	57.80	108.00	120.00
6	64-QAM	3 / 4	1	58.50	65.00	121.50	135.00
7	64-QAM	5 / 6	1	65.00	72.20	135.00	150.00
8	BPSK	1 / 2	2	13.00	14.40	27.00	30.00
9	QPSK	1 / 2	2	26.00	28.90	54.00	60.00
10	QPSK	3 / 4	2	39.00	43.30	81.00	90.00
11	16-QAM	1 / 2	2	52.00	57.80	108.00	120.00
12	16-QAM	3 / 4	2	78.00	86.70	162.00	180.00
13	64-QAM	2 / 3	2	104.00	115.60	216.00	240.00
14	64-QAM	3 / 4	2	117.00	130.00	243.00	270.00
15	64-QAM	5 / 6	2	130.00	144.40	270.00	300.00
16	BPSK	1 / 2	3	19.50	21.70	40.50	45.00
...	...	...	...	...	...	...	...
31	64-QAM	5 / 6	4	260.00	288.90	540.00	600.00

Table 1. Some 802.11n MCS Values

Not just data rates 1, 2, 5.5 and 11 any more; Are you using a single, dual or three stream device for testing. What do your performance numbers mean?

802.11ac

- The trigger for 5GHz everywhere
- Led by Apple and other consumer specialists
  - In-home device sync, video, backup, etc
  - “Gigabit Wi-Fi” on retail shelves
- 11ac’s best feature is that it is 5GHz only

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802.11ac Performance

- Wider channels (80-160 MHz)
  - Vs. 20-40 MHz for 802.11n
- More spatial streams (up to 8)
- Multi-user MIMO
  - Multiple stations transmit/receive simultaneously
  - Streams separated spatially not by frequency
- Modulation: up to 256 QAM

WLAN Design

Define Network Requirements

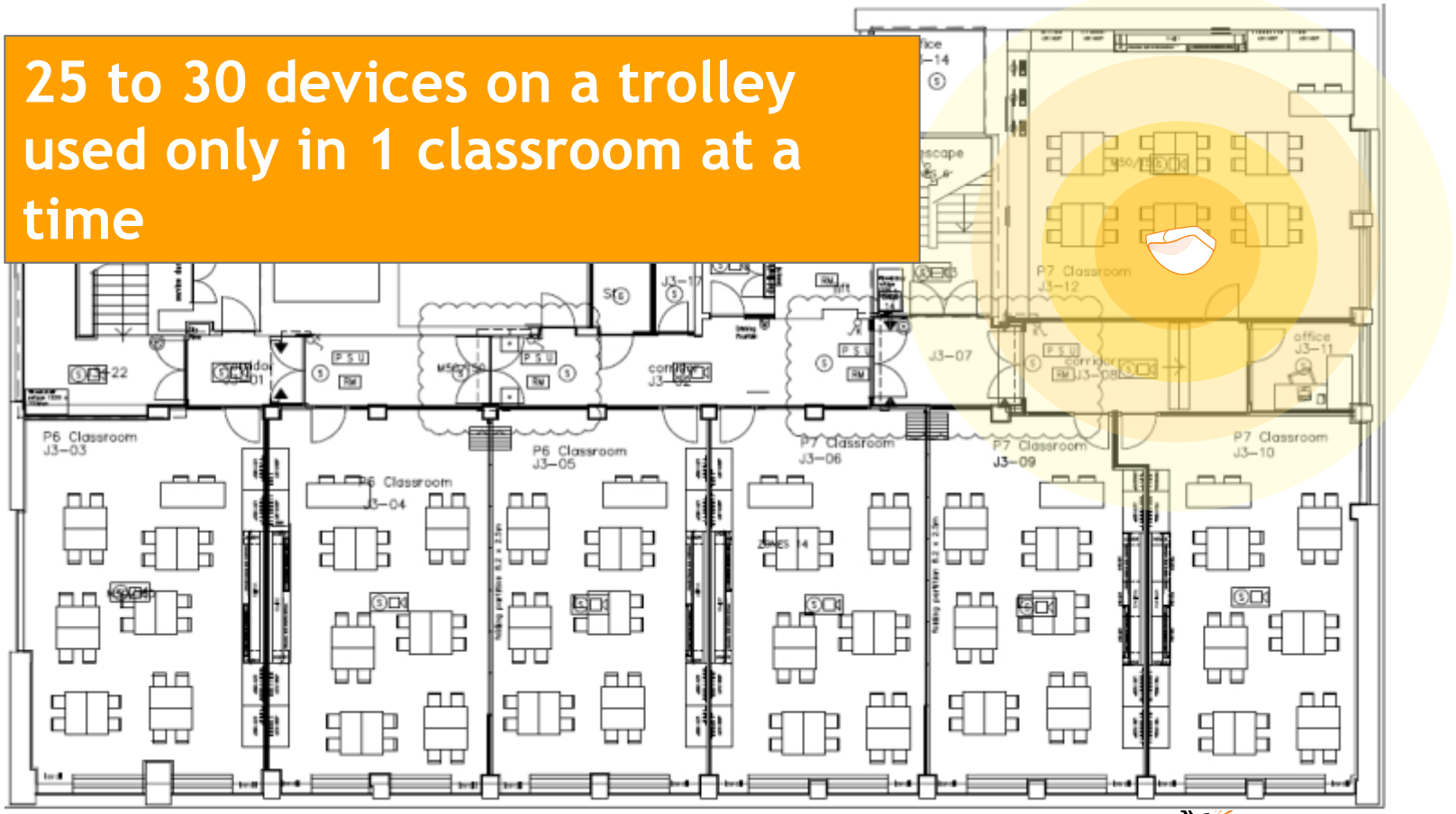
- Coverage area
- Applications
- Type of devices and performance
  - All 1x1? 3x3:3?
- Number of expected devices
- Number of simultaneous devices

Coverage vs. Capacity

	Coverage	Capacity
AP count	Low	High
Limiting factor	Distance	Interference
Obstacles	Bad	Good
Client speed	N/A	High as possible
Design metric	SNR	SINR
Number of channels	Conservative	Every channel possible

Low Density

- Low bandwidth
- Medium to low usage



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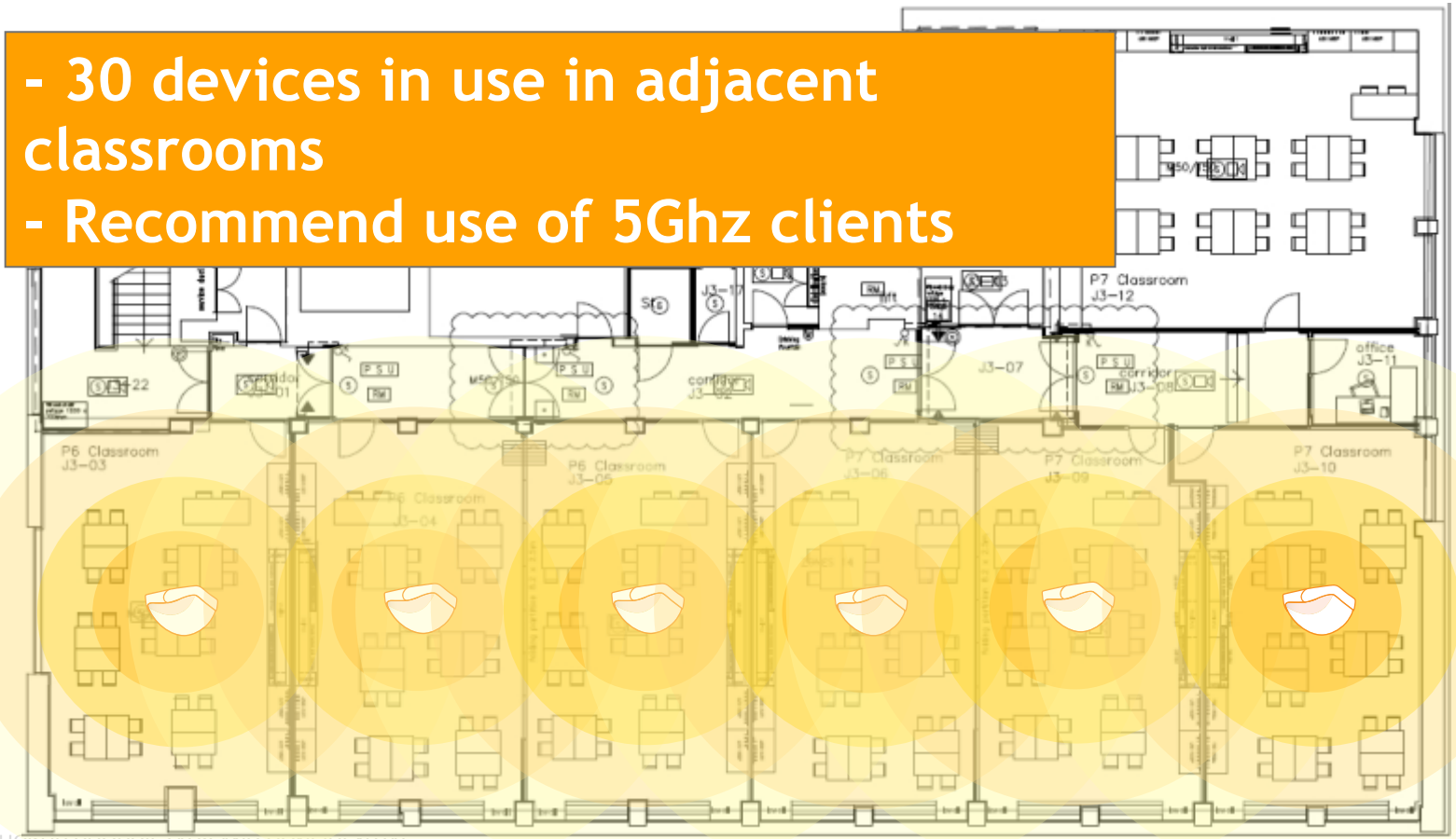
High Density

- High concurrent usage
- 1 AP every other or every room

- 30 devices in use in adjacent classrooms
- Recommend use of 5Ghz clients



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High Density Strategies

- 5GHz
- Increase AP count to the extent possible
- Use attenuation (obstacles)
- Frequency re-use via structural separation
- Non-traditional 2.4GHz channel plans
- Use RF simulation tools to optimize design
- Configuration optimizations & adaptive algorithms

Reducing Transmit Power

- Does not help signal to interference
- Guaranteed to reduce signal to external interference
  - Not good! Your clients should hear you better than someone else
- Lower power = lower transmit speed = clients take longer to get on/off the air
- Reduces capacity

More Strategies

- OFDM Only
- Disable background scanning
- Limit # of SSIDs if possible
- Disable ‘services’ that potentially deny service

Troubleshooting

Identify the Problem

- "It doesn't work" is not useful

- Can the client connect?
- Can it authenticate?
- Low performance?
- Roaming?
- Are certain types of clients affected or all?

Client Can’t Connect

- RF interference may prevent this
- Client is not configured correctly
- Client does not support network configuration
  - OFDM-only will block 802.11b clients
- Are there APs nearby that it can hear strongly?

Classic Symptoms of RF Interference

- Classic symptoms:
  - Clients drop off network randomly or have difficulty connecting
  - High latency or data loss
  - Huge number of PHY errors (>2500 per second)

- Can be difficult to detect without an RF analyzer

RF Interference Mitigation

Things you can do:

- Eliminate source of interference
- Change channel assignments (if clear ones exist)
- Lower transmit power
- Move clients to 5 GHz – band steering or change WLAN adapter

Client Can’t Authenticate

- Misconfigured authentication
- User name/password incorrect
- Client blacklisted
  - WIPS/WIDS
- Trying to connect to the wrong SSID

Low Performance

- No strong signal available (no nearby AP)
- High interference
- Low connection rate (MCS)
- Client stickiness
  - Roaming
- Too many clients per AP radio
- High latency
- The client just ain’t that fast

Performance Fixes

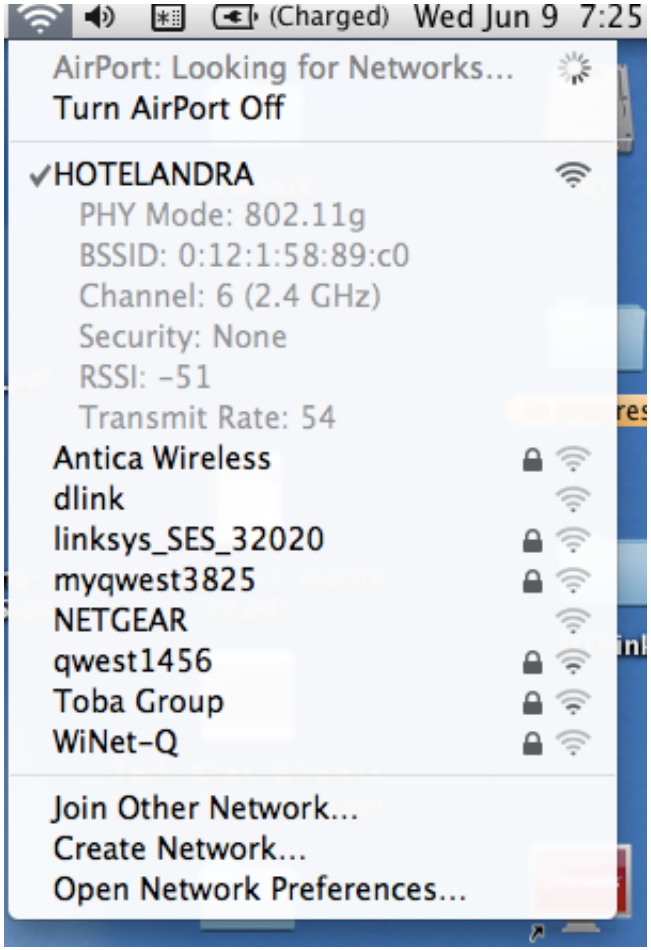
- Add more APs if coverage is too sparse, i.e. clients can get too far away=lower connection rate
- Reduce interference
- More channels
- Increase capacity in areas with excessive number of clients per AP
- Airtime fairness – allows differently capable clients to share medium in a managed fashion

Essential Troubleshooting Tools

- Different types of clients
  - Isolate driver-specific issues
- Performance test tools
  - Ruckus SWAT,
  - SpeedFlex (Ruckus)
  - Ruckus Zapper
  - iPerf
  - MetaGeek inSSIDer
- RF analyzer (MetaGeek, AirMagnet, etc.)

Apple-specific Tools

- Check Wi-Fi connection on Mac
  - Hold down Option key and click airport icon in top menu bar
- Learn and use the command line airport tool



- http://osxdaily.com/2007/01/18/airport-the-little-known-command-line-wireless-utility/

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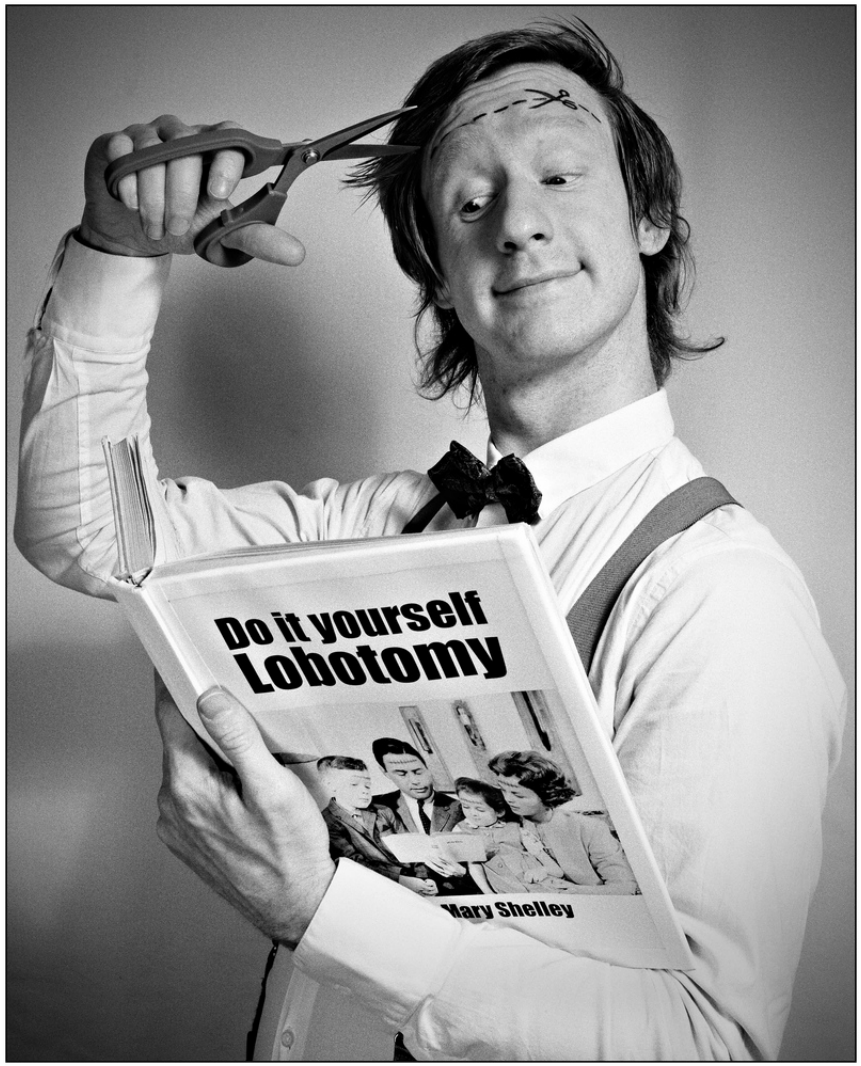
Do-It-Yourself Performance Testing



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Ruckus Mobile Apps

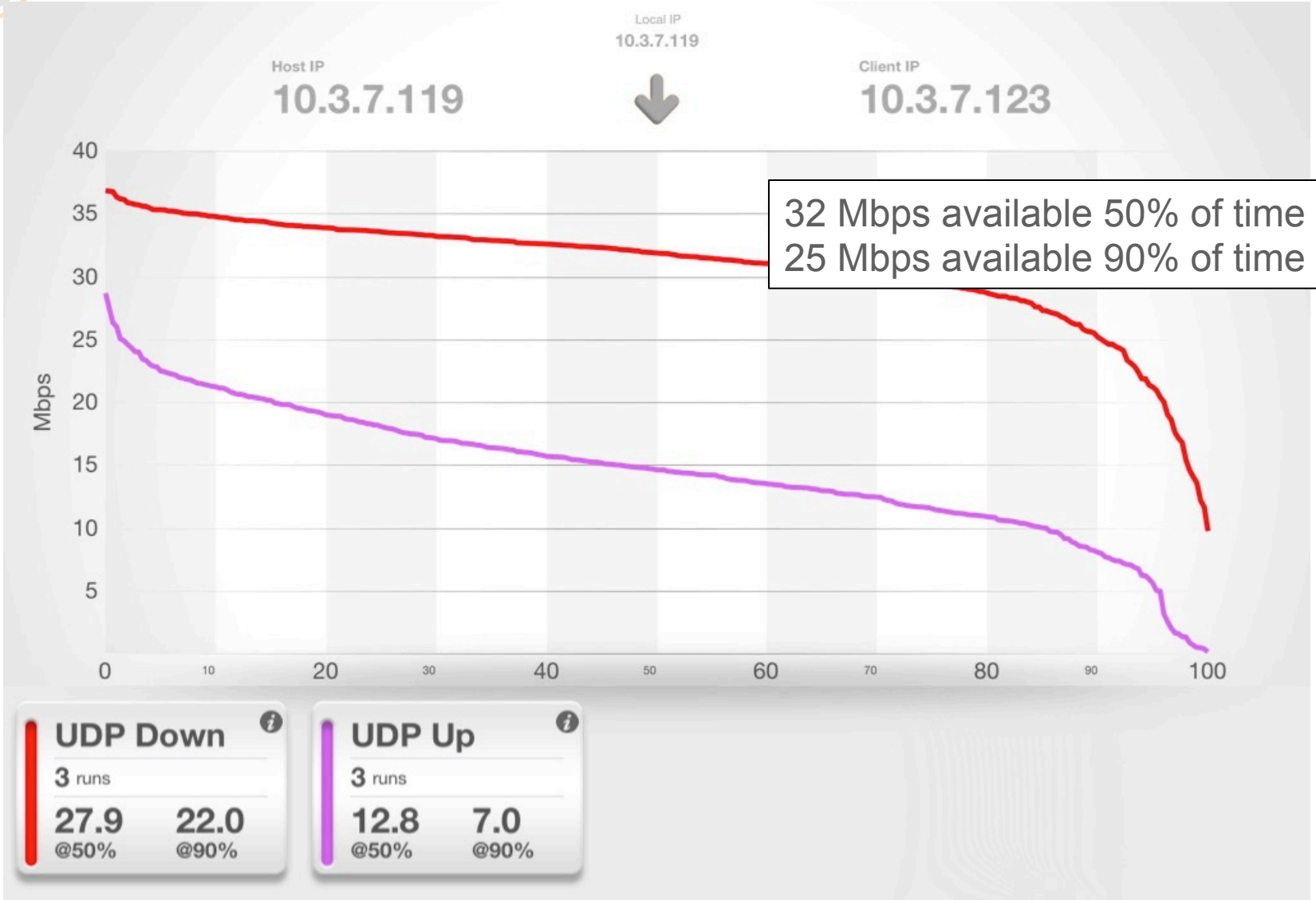
Apple iOS
- SWAT
- Zapper/SpeedFlex
- ZD Remote
- Product Guide

Mac OS/Windows
- SpeedFlex

Android
- SWAT

More coming soon!

Zapper (Ruckus)



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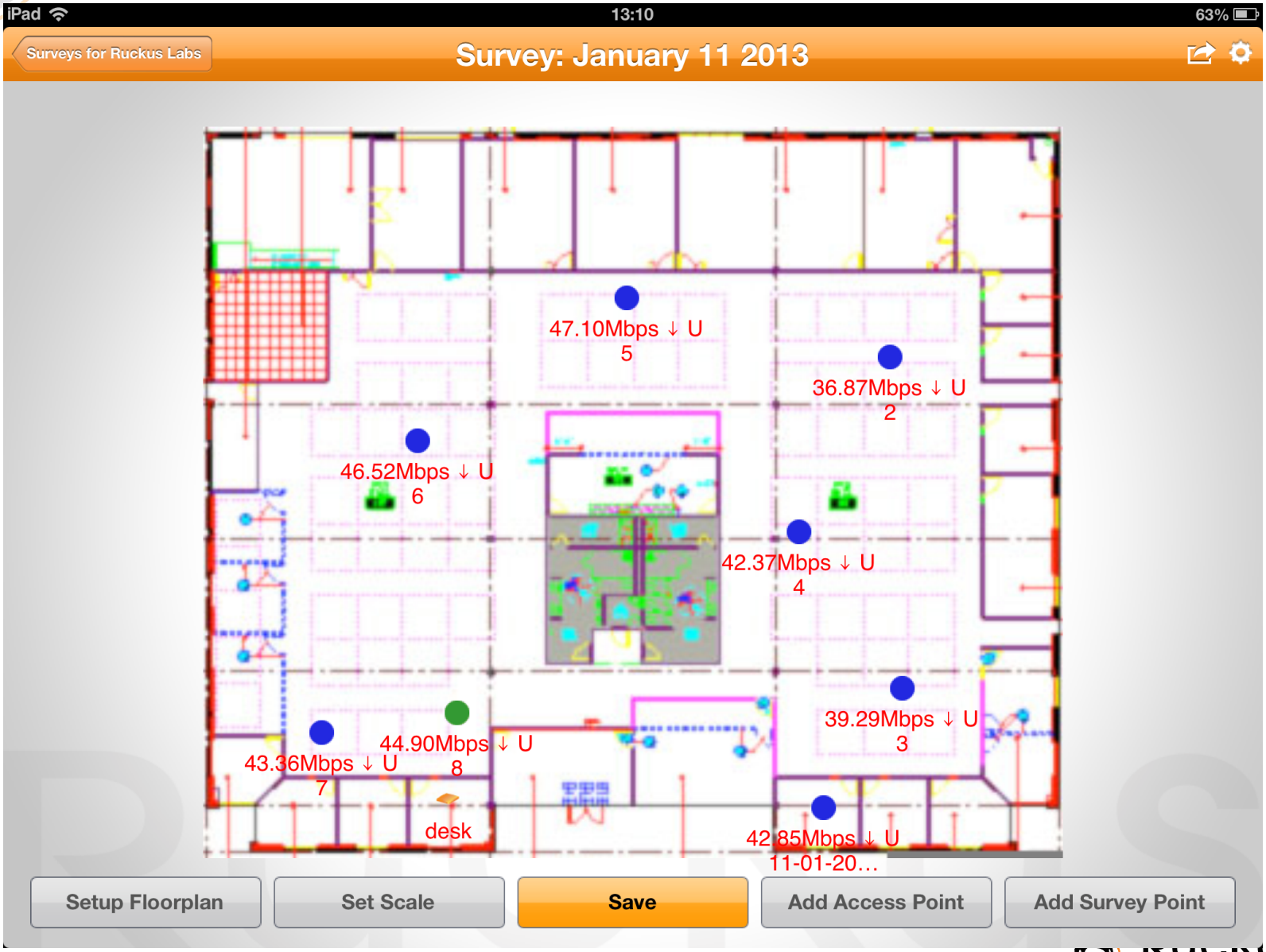
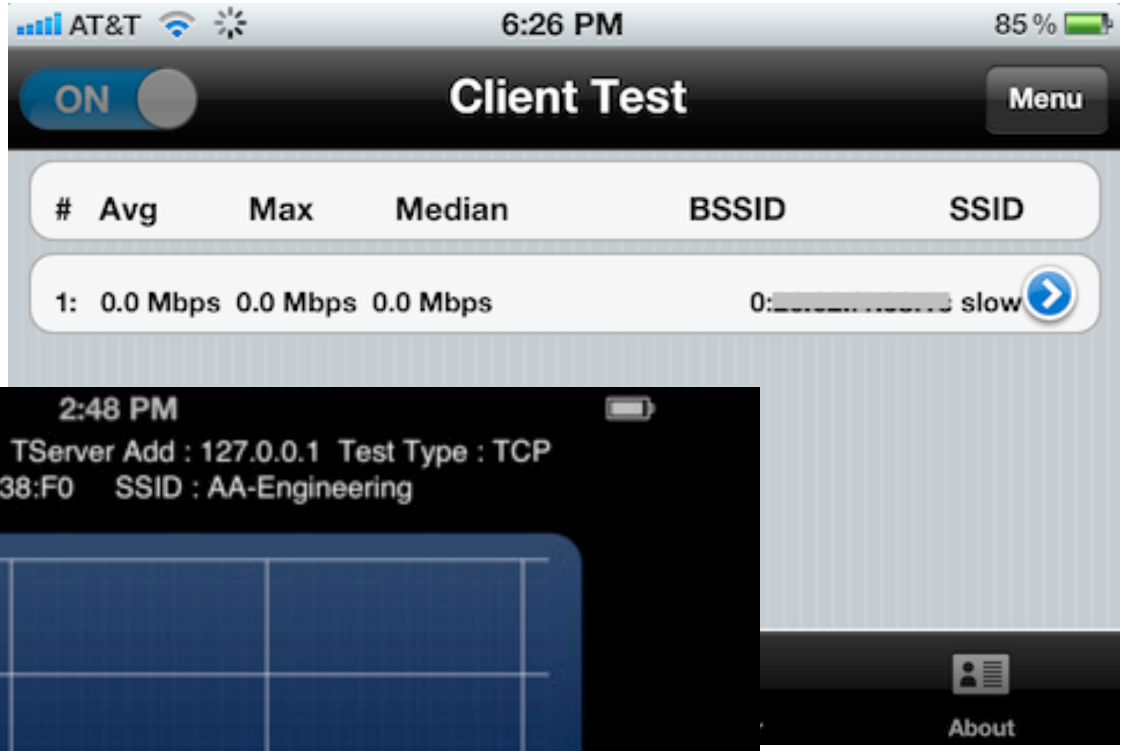
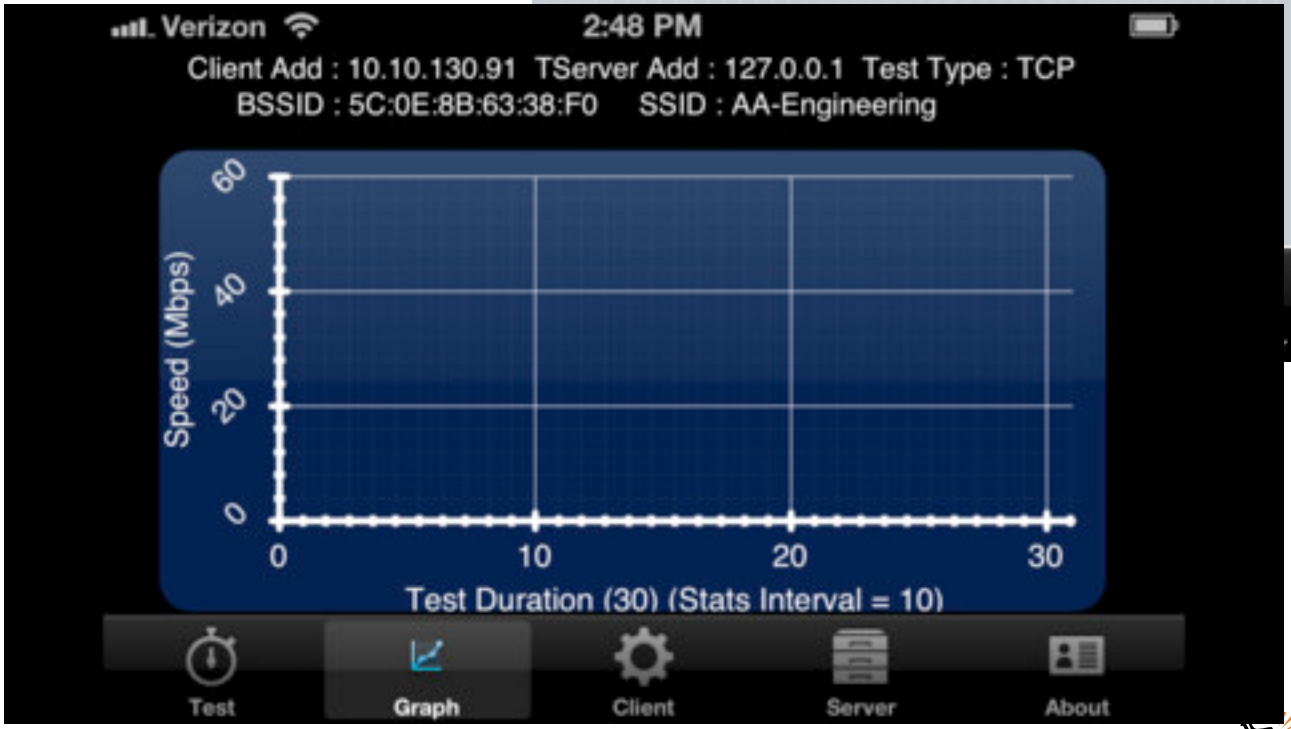
SWAT (Ruckus)



ZapPerf and iPerf2 (Access Agility)

- Based on zap/iperf
- Available for iOS





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