802.11n
Taking wireless to the next level

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AGENDA

Introduction to Cisco Motion & the Unified Wireless Network

802.11n technology

AP 1140 introduction

AP1250 Recap

Performance comparisons

Delivering Business Mobility

The Cisco Unified Wireless Network

Client

- 90% of laptops Cisco compatible
- Secure Services Client (CSSC)

cisco Compatible

Access Points

- Indoor and Outdoor
- Modular, 802.11a/b/g/n

Wireless LAN Controllers and Management

- Centralized management
- Flexible, scalable (1000s of APs)
- Radio resource

Wired Network Services

- Unified Security and Management services
- Mobile Unified Communications

Unified Wired and Wireless Network

Mobility Services

- Mobility Services Engine

Devices | **Access** | **Control and Visibility** | **Service and Performance** | **Mobile Applications**

Cisco Motion:
Unifying Disparate Networks

Cisco is evolving the wireless network into a true mobility network…

Unify Network Transport	▪ Consolidated control of Wi-Fi, Cellular, WiMAX, RFID, Wired, Sensor
Centralized Services Engine	▪ Open platform enables ecosystem for mobile application integration
Simplified Device and Services Management	▪ Single view for end-to-end management and provisioning of services

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WiFi – Where we are today

Continuing Development

- The number and scope of applications available that leverage WiFi have increased dramatically
- Some of the fundamental issues that exist with WiFi had been involved in long drawn out Standards based work to resolve issues around
- Security via 802.11i
- QoS via 802.11e
- Management via CAPWAP &

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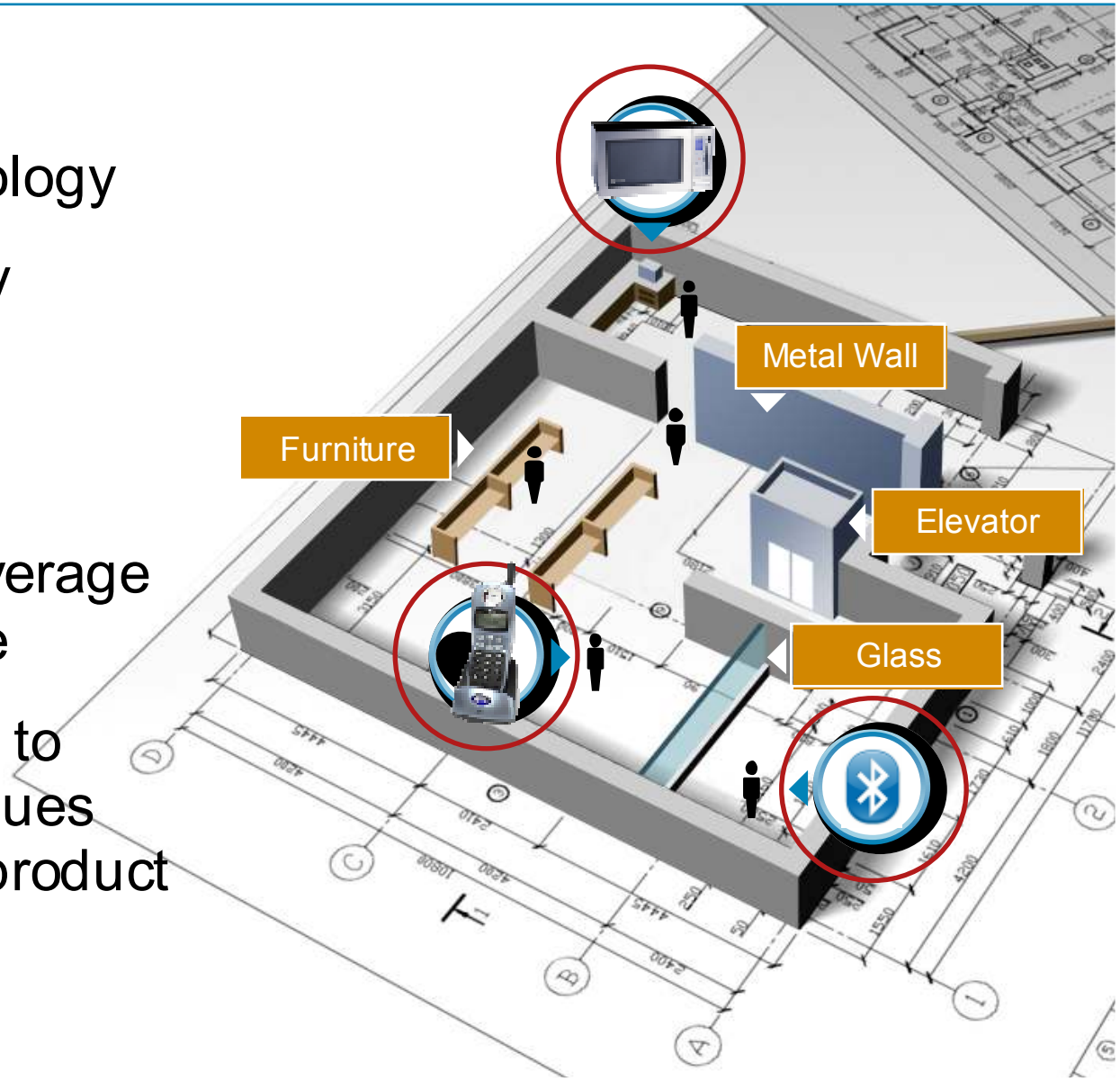
Legacy WiFi concerns

- Easy to deploy, pervasive technology
- But can be easily affected by the environment
- This can lead to reductions in coverage and performance
- Industry decided to resolve these issues with a next gen product



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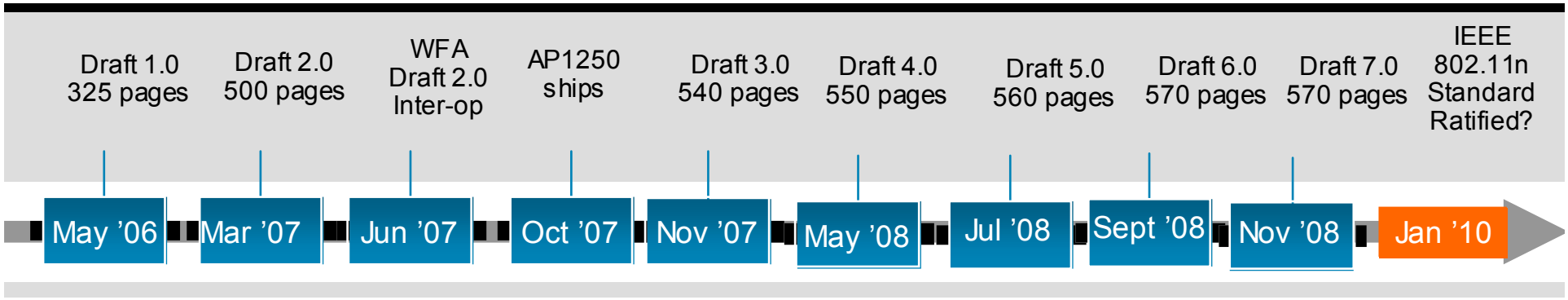
IEEE and the Wi-Fi Alliance



Current expected date for IEEE ratification is Jan 2010

- **Could be pulled in to Sept 09**
- **Low chances of mandatory features being added to 11n std.**
- **Minimal changes in specs from D 2.0 -> D 7.0**

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802.11n
Technical Update

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Goals of the IEEE 802.11n Standard

Performance

- Performance parity with 100 Mbps fast Ethernet
- Improved reliability
- More predictable coverage
- Backward compatibility with A/B/G
- Improved immunity to noise

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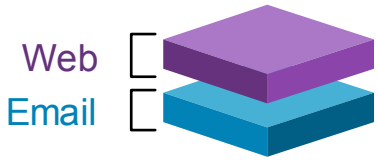
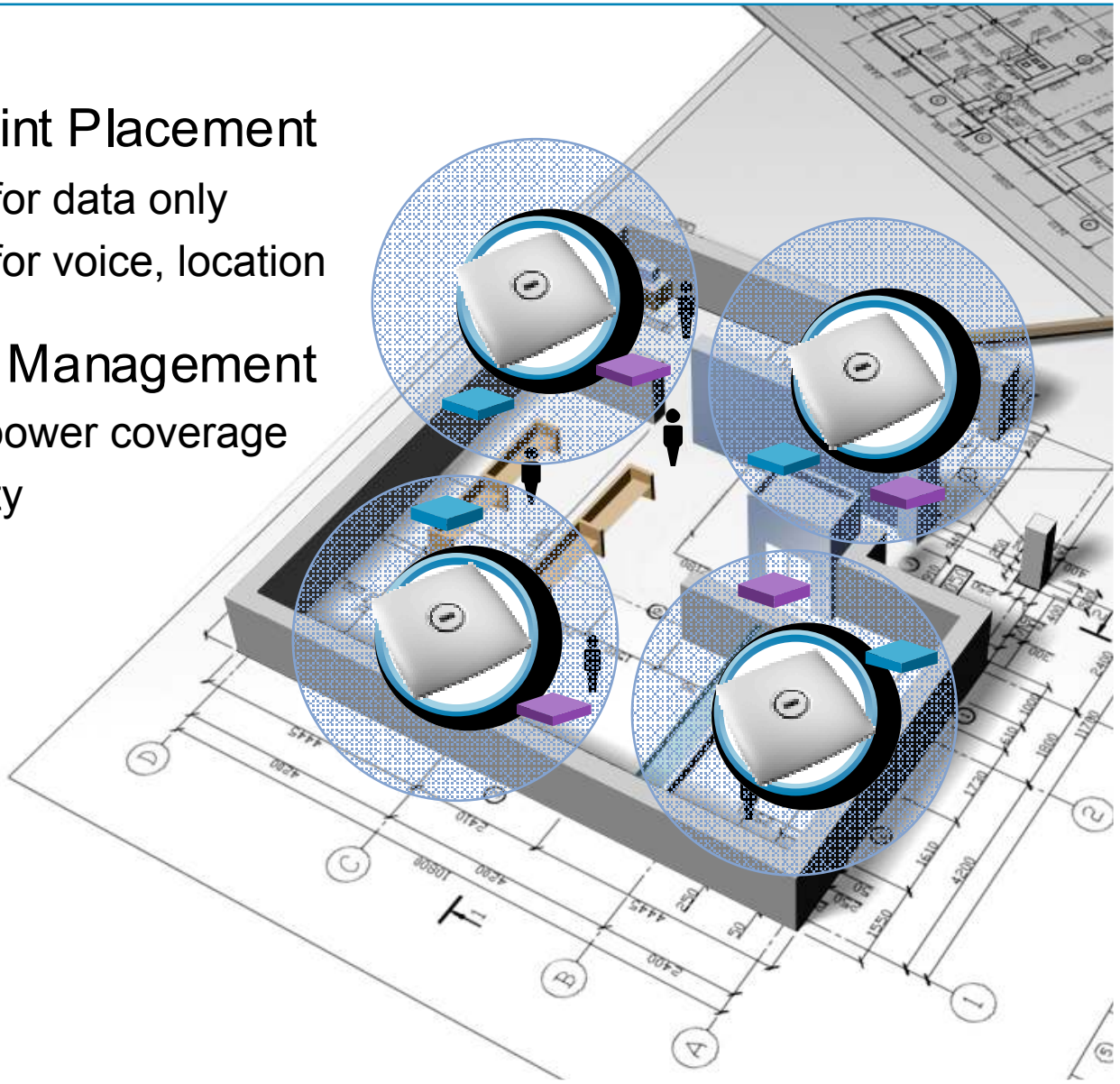
1130 Access Point Placement

Existing Deployment

- 1130 Access Point Placement
  - 1 per 5,000 sq feet for data only
  - 1 per 3,000 sq feet for voice, location
- Radio Resource Management
  - Adaptive channel / power coverage
  - Operational simplicity



Several Supported Apps



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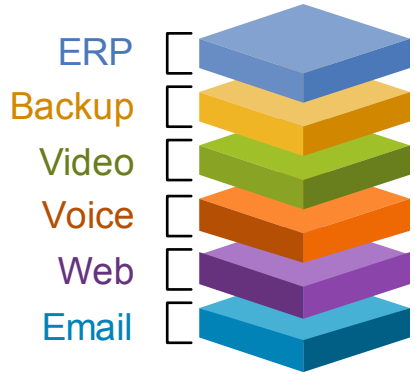
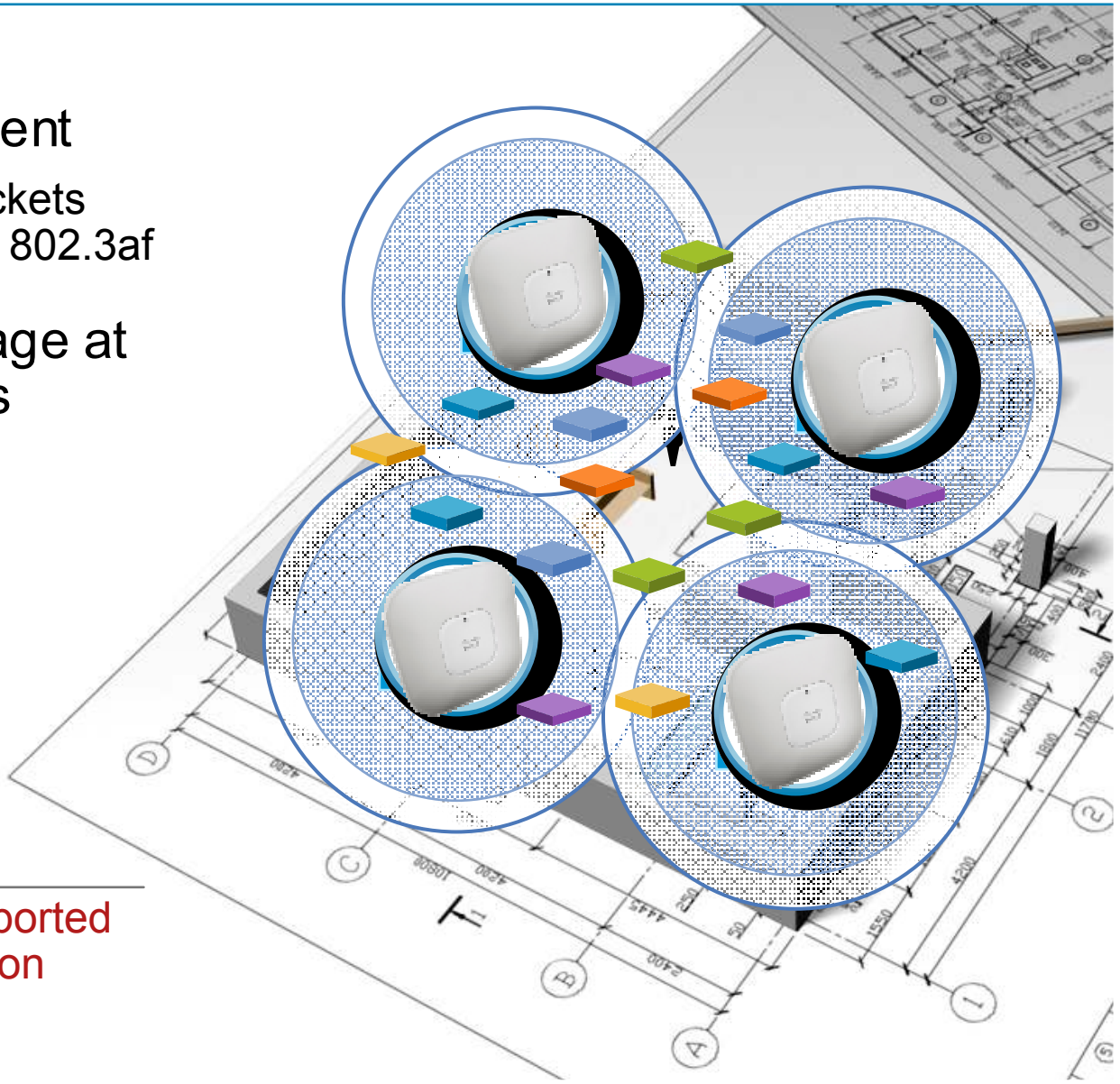
1140 Access Point Placement

- 1 for 1 replacement
  - AP1140 reuses brackets
  - AP1140 operates at 802.3af
- Improved coverage at higher data rates



More Applications Supported at Any Given Location



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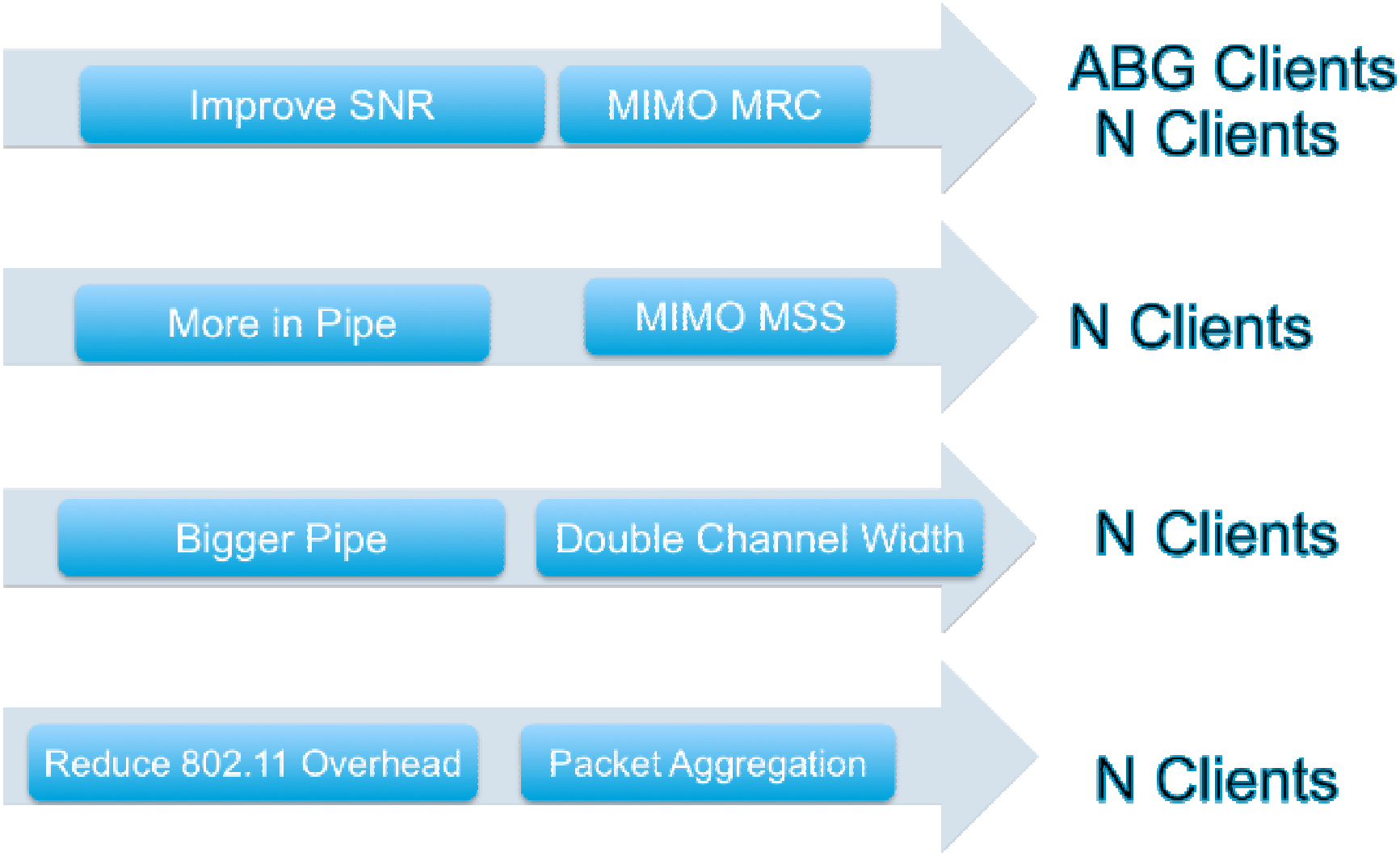
Key Approaches Used by 802.11n to Improve Performance



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802.11n Introduces a New MAC and PHY

- New High Throughput PHY (HT)
- Additions to MAC to support new HT PHY and HT data rates

  HT Capabilities element will be present in various Management frames such as Beacons, Association Request and Association Response

- Additions to MAC for reducing protocol overhead

  A-MSDU , A-MPDU , Block Ack

- Addition to MAC for power save
- **The term “legacy” will be used to refer to 802.11ABG clients that do not support 802.11n**

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802.11n HT PHY

- To provide legacy co-existence all 11n transmissions today use a mixed mode PHY that encapsulates the HT PHY in the Legacy PHY when transmitting at HT rates
- Legacy devices degrade 11n device performance based on duty cycle they use in the spectrum
- Greenfield is term used within 11n to refer to 11n transmissions without Legacy PHY encapsulation

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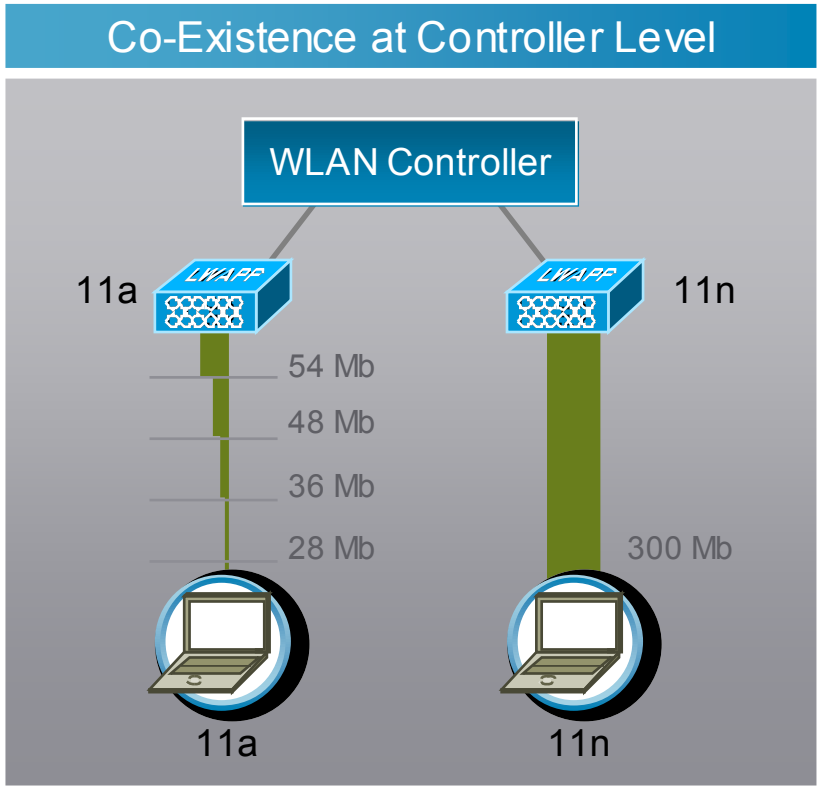
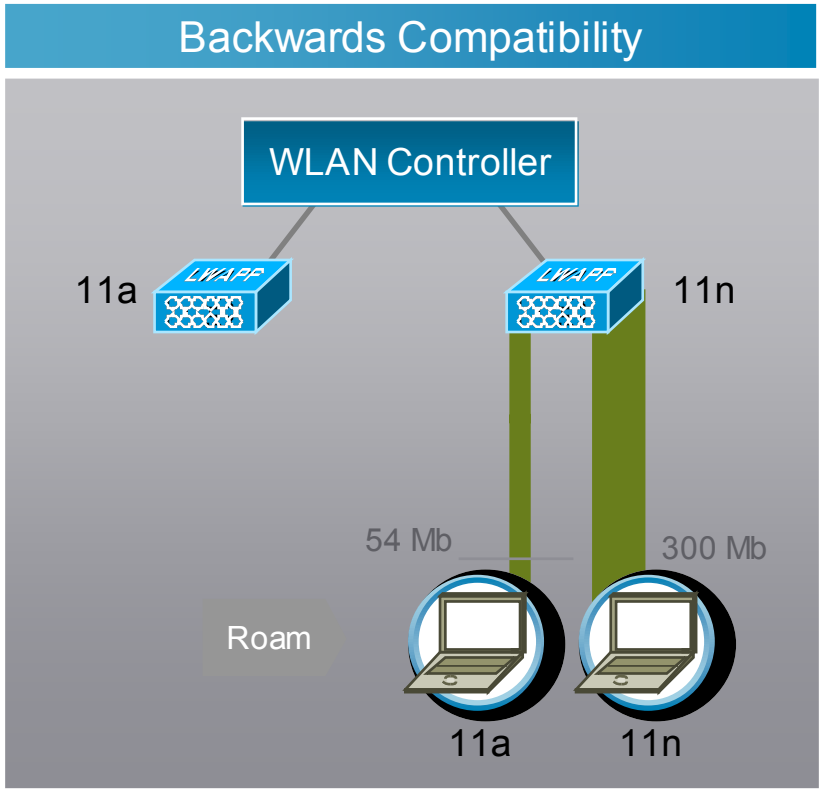
Backward Compatibility & Co-Existence

- Co-existence of ABG/N APs
- Benefits of 11n accrue to ABG clients

  MIMO benefits ABG clients on the AP receive side from MRC





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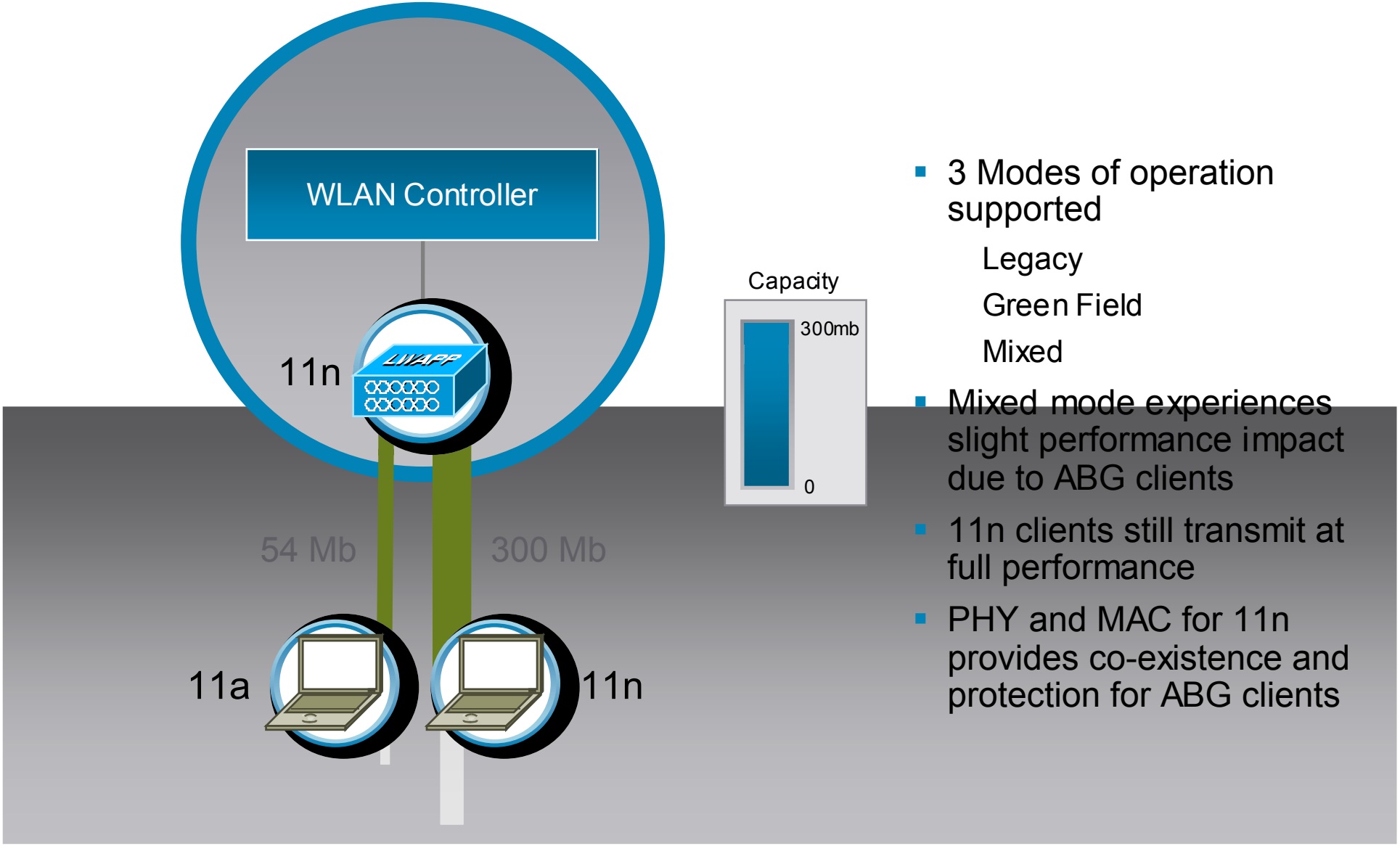
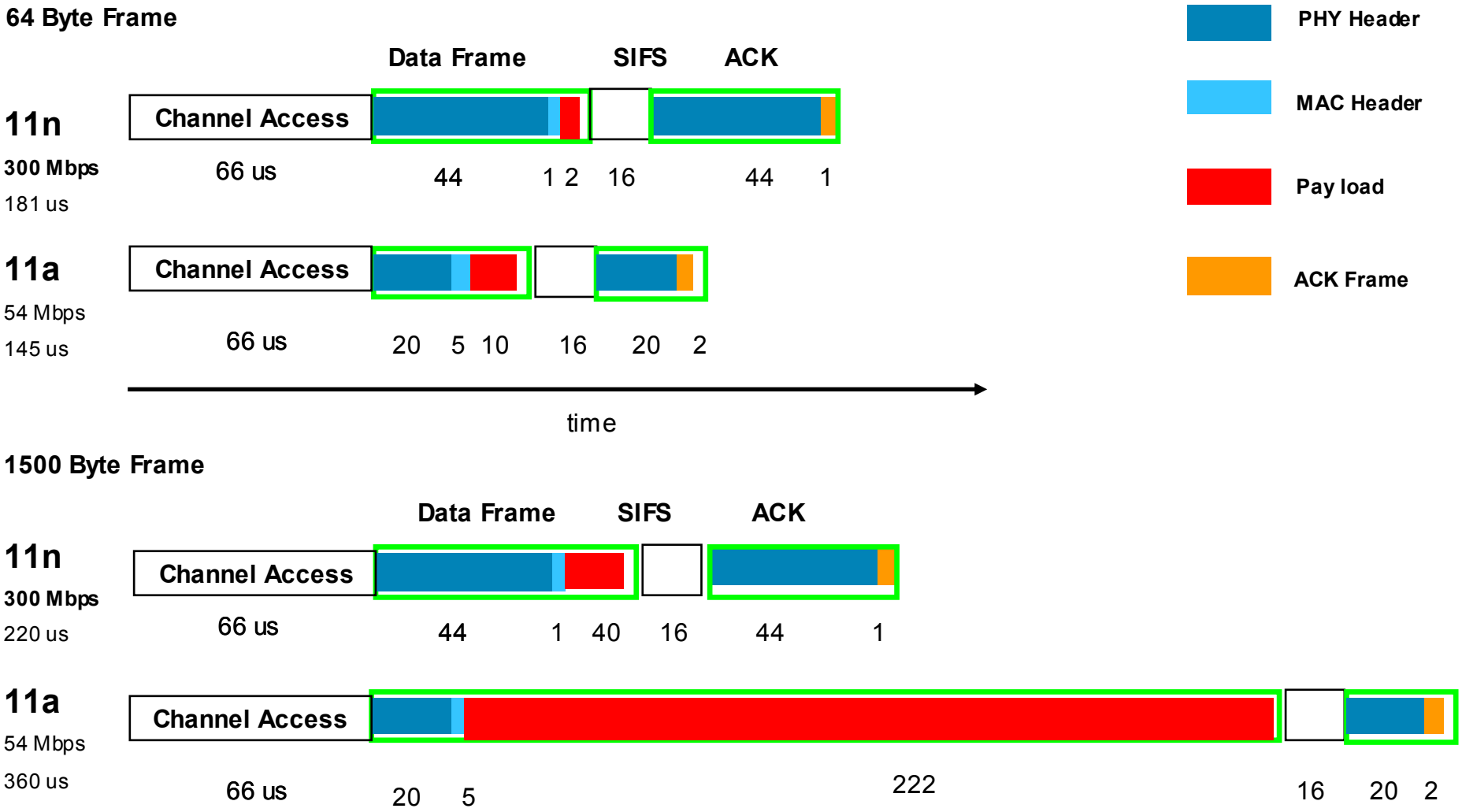
Mixed Mode Performance



- 3 Modes of operation supported
  - Legacy
  - Green Field
  - Mixed
- Mixed mode experiences slight performance impact due to ABG clients
- 11n clients still transmit at full performance
- PHY and MAC for 11n provides co-existence and protection for ABG clients

802.11n Throughput Potential
Not Optimized for Small Packets



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802.11n HT Capability Field in Beacon

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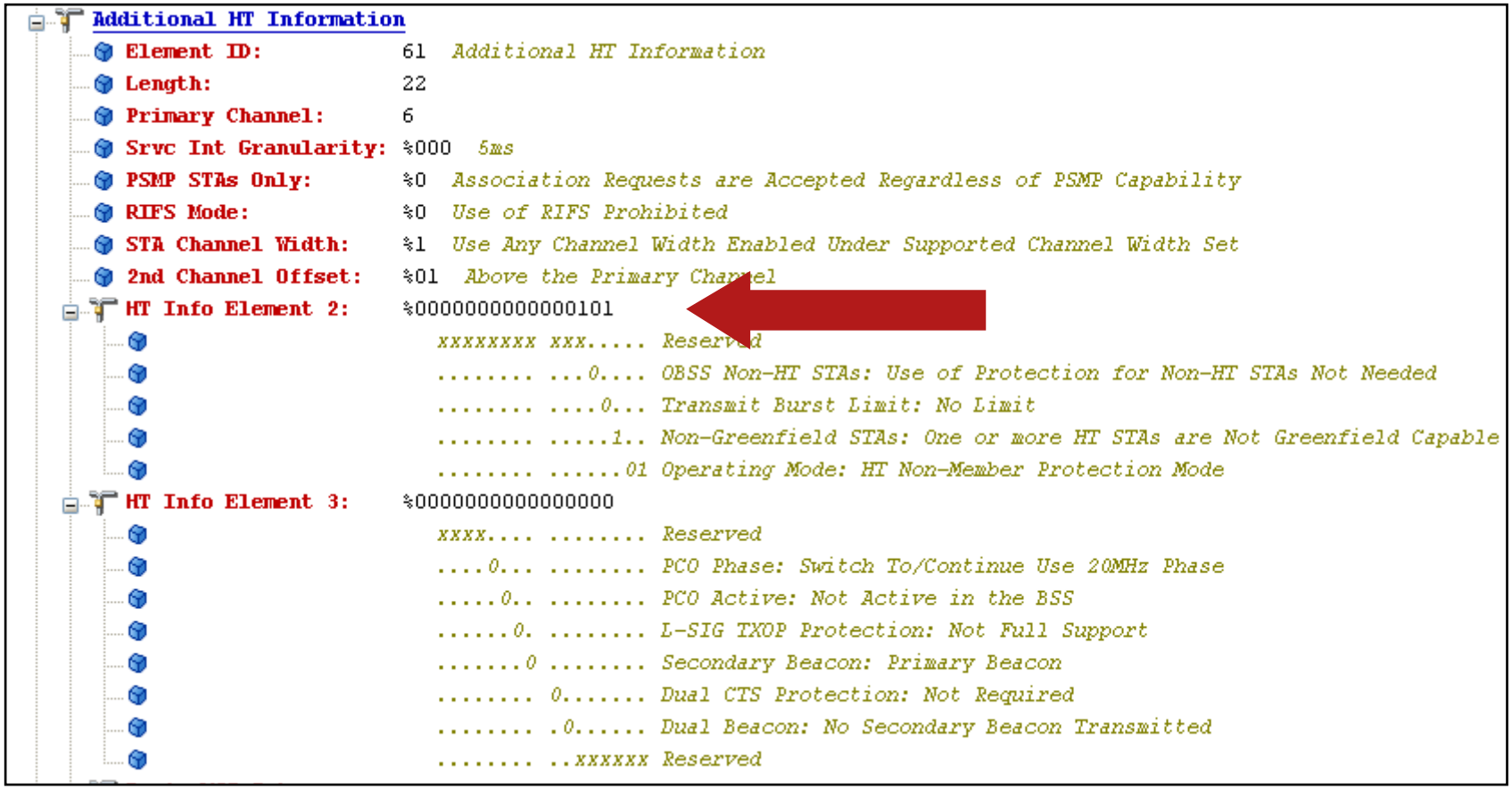
HT Information Elements in Beacon



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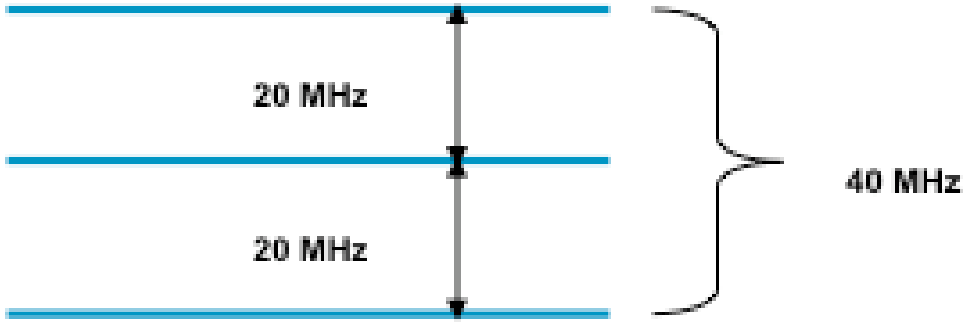
Double Wide Channel

40-MHz Wide Channel Support



- 802.11n supports both 20 and 40 MHz wide channels
  - 40 MHz wide channels recommended only for 5 GHz
- Consists of a primary channel and a secondary channel also referred to as extension channel
  - Second channel must be adjacent
  - Can be above or below primary
  - Protection provided for 20 MHz wide client use

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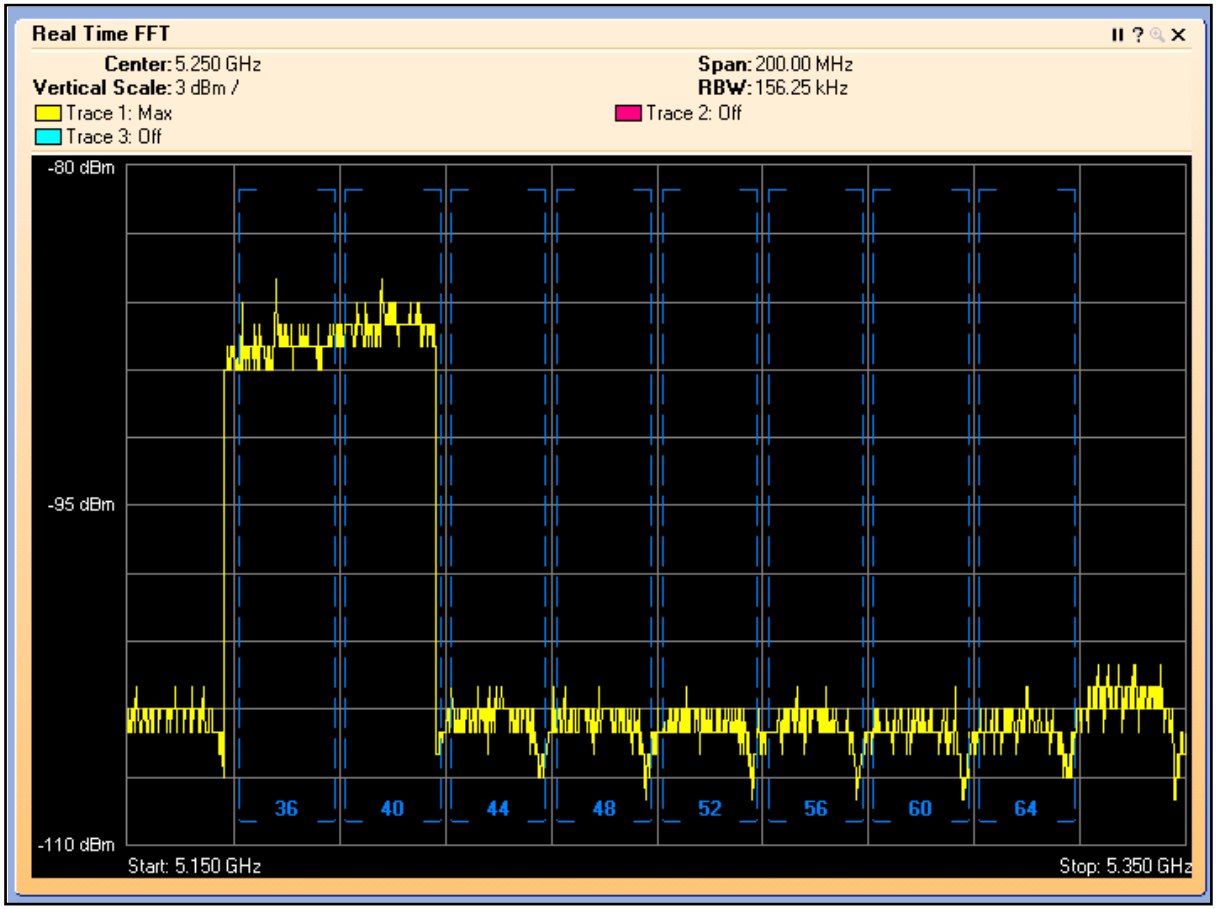
40 MHz-Wide Channel



- Spectrum Expert Trace for 40 MHz-wide channel channel 36 primary and channel 40 extension

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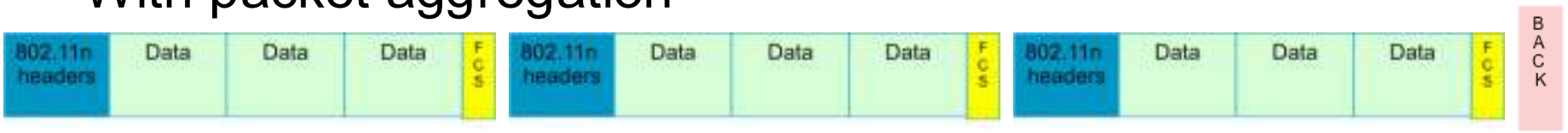
Packet Aggregation

- All 11n devices must support receiving of either packet aggregation method A-MPDU or A-MSDU
- A-MPDU packet aggregation is mechanism used by 802.11n for packet aggregation with block acknowledge

Without packet aggregation

With packet aggregation



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Packet Aggregation

A-MPDU Block Acknowledge

Source Physical	Dest. Physical	BSSID	I	.	Data Rate	802.11 Flags	Size	Size Bar
00:10:C6:D0:B4:23	00:16:01:73:03:25	00:17:DF:A6:59:60	I	.	300.0	.F..	1338	802.11 Data
00:10:C6:D0:B4:23	00:16:01:73:03:25	00:17:DF:A6:59:60	I	.	300.0	.F..	1338	802.11 Data
00:10:C6:D0:B4:23	00:16:01:73:03:25	00:17:DF:A6:59:60	I	.	300.0	.F..	1338	802.11 Data
00:10:C6:D0:B4:23	00:16:01:73:03:25	00:17:DF:A6:59:60	I	.	300.0	.F..	1338	802.11 Data
00:10:C6:D0:B4:23	00:16:01:73:03:25	00:17:DF:A6:59:60	I	.	300.0	.F..	1338	802.11 Data
00:16:01:73:03:25	00:17:DF:A6:59:60		I	.	54.0	....	32	802.11 BA

- Immediate Block Ack supported
- Aggregation of multicast data frames not supported
- Block acknowledge contains bitmap on packets not received that need to be retransmitted

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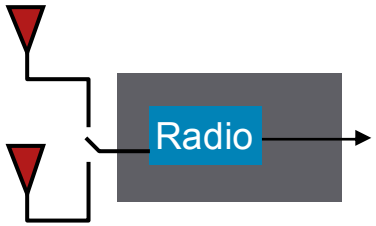
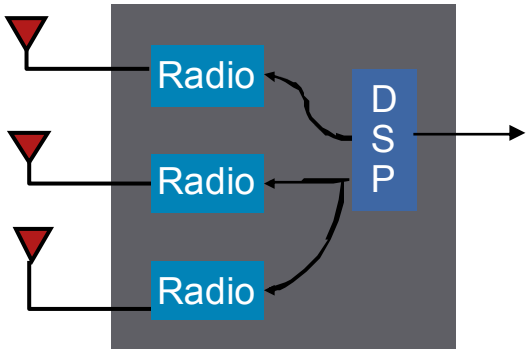
Comparing SISO and MIMO (Multiple Inputs Multiple Outputs) Signal Reception



- One radio chain
- Radio “chooses” which diversity antenna to receive on
- Multipath degrades signal



- Three radio chains
- Multipath improves signal
- Better immunity to noise
- Better SNR than SISO

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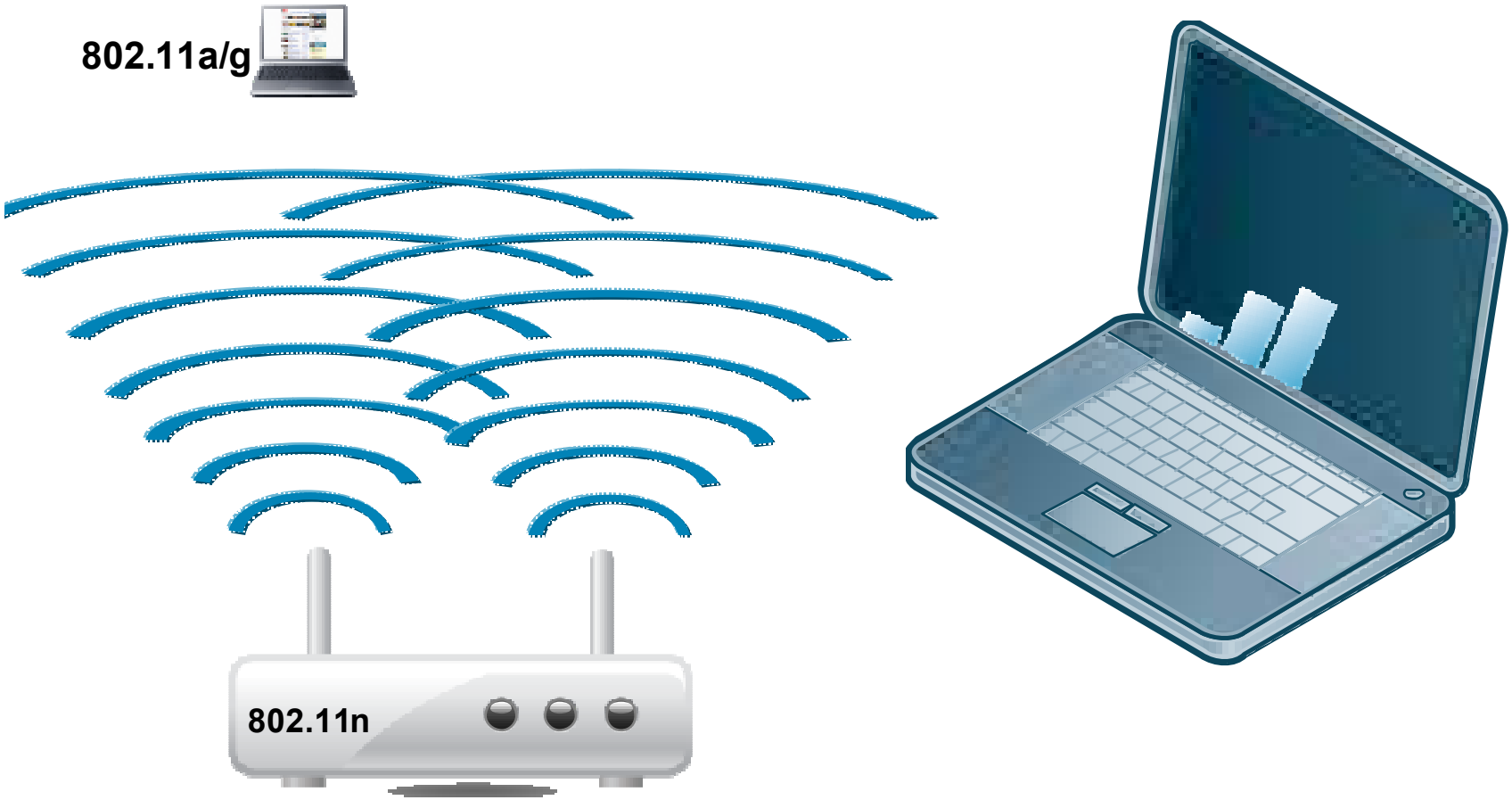
Existing 802.11n Solutions

Beam Strength Not Directed to Client



802.11a/g Client Connection Not Optimized, Creates Coverage Hole

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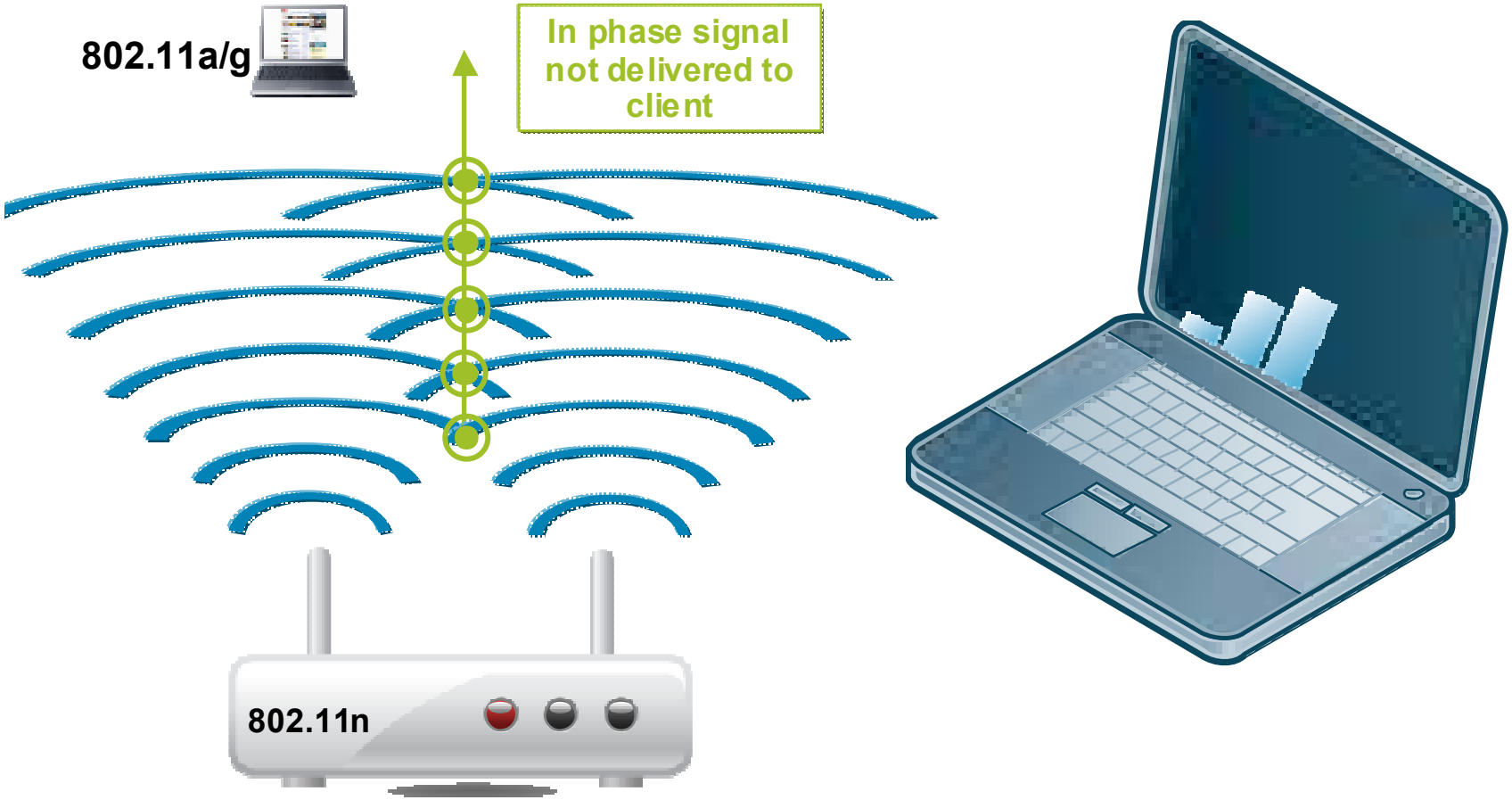
Existing 802.11n Solutions

Beam Strength Not Directed to Client



802.11a/g Client Connection Not Optimized, Creates Coverage Hole

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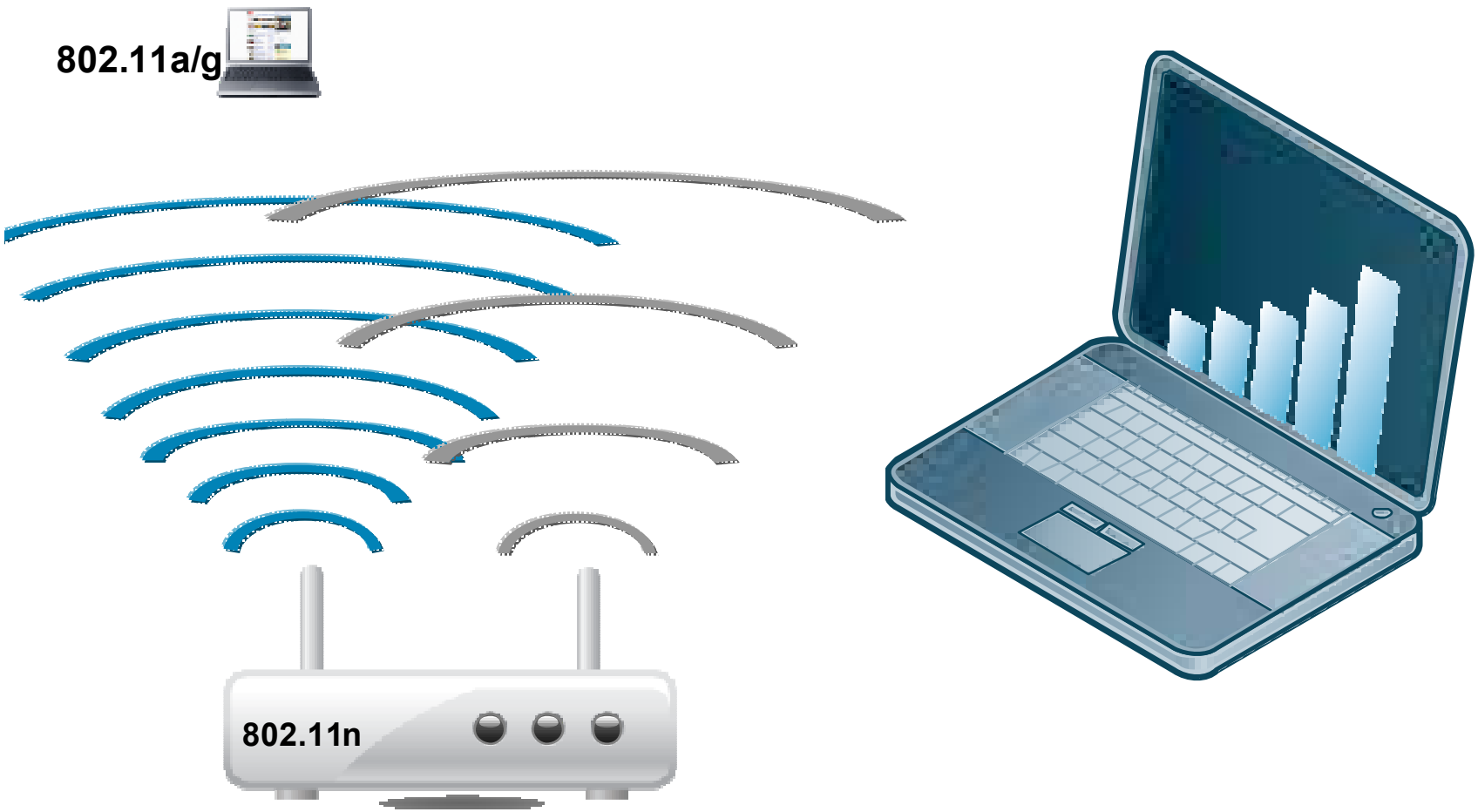
M-Drive with ClientLink

Cisco Innovation: Beam Forming Intelligence



Intelligent Beam Forming Directs Signal to Improve Performance and Coverage for 802.11a/g Devices

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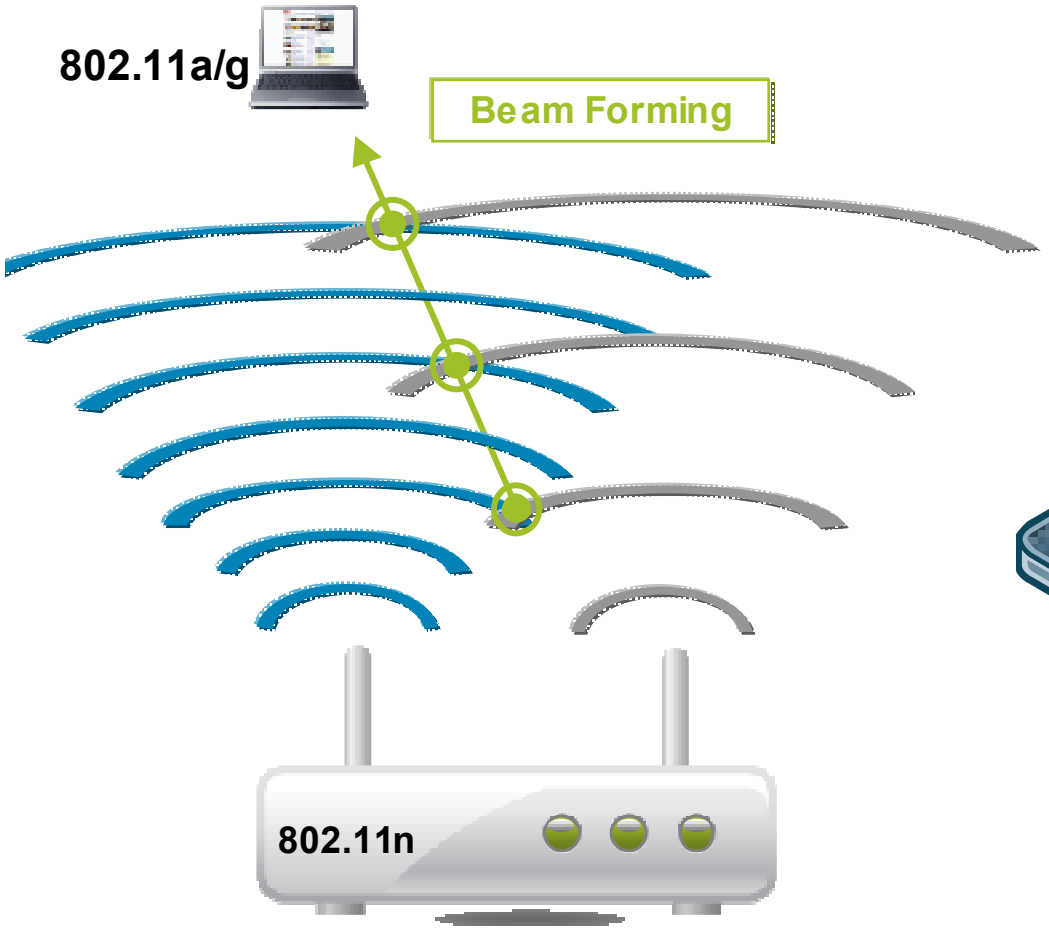
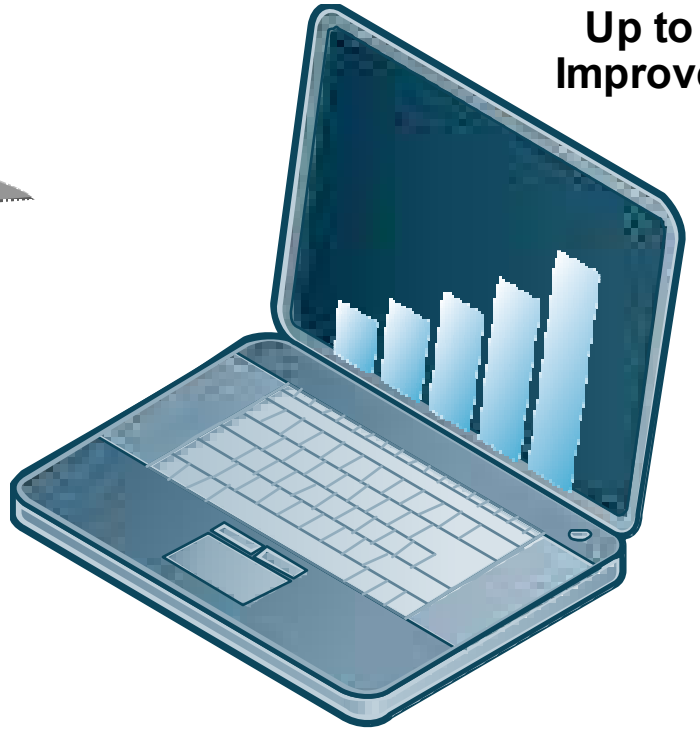
M-Drive with ClientLink

Cisco Innovation: Beam Forming Intelligence





Intelligent Beam Forming Directs Signal to Improve Performance and Coverage for 802.11a/g Devices

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Benefit #1: Higher throughput per 11a/g device

Miercom

Up to 65% Increase in Throughput

Test: 802.11a/g device with 802.11n network
Source: Miercom

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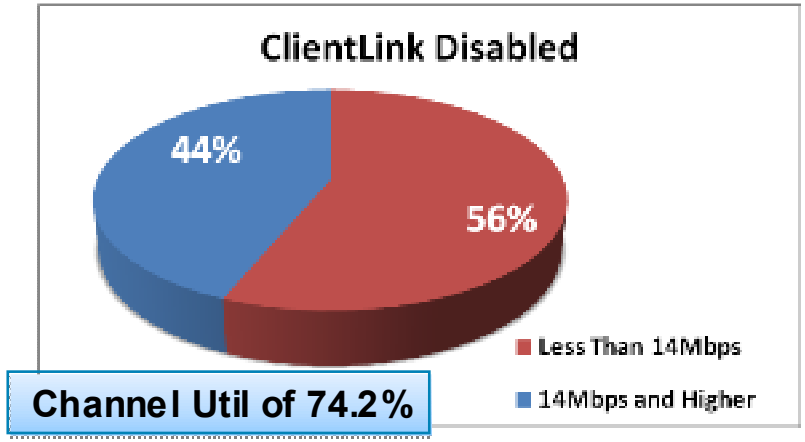
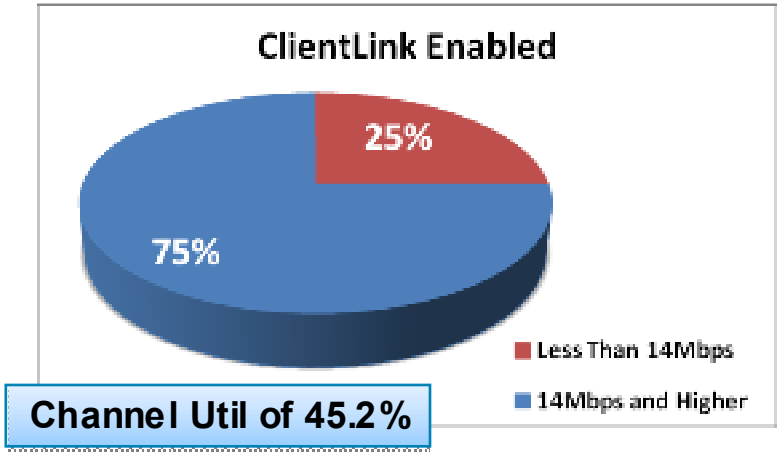
Benefit #2: Higher system capacity

Miercom

Up to 27% Improvement in Channel Capacity





- Faster data transmission, less retries = more efficient use of RF channel.
- Faster 11a/g transactions opens airtime for 11n devices, providing them improved experience

Test: 802.11a/g device measured at 16 antenna orientations w/ 802.11n network
Source: Miercom

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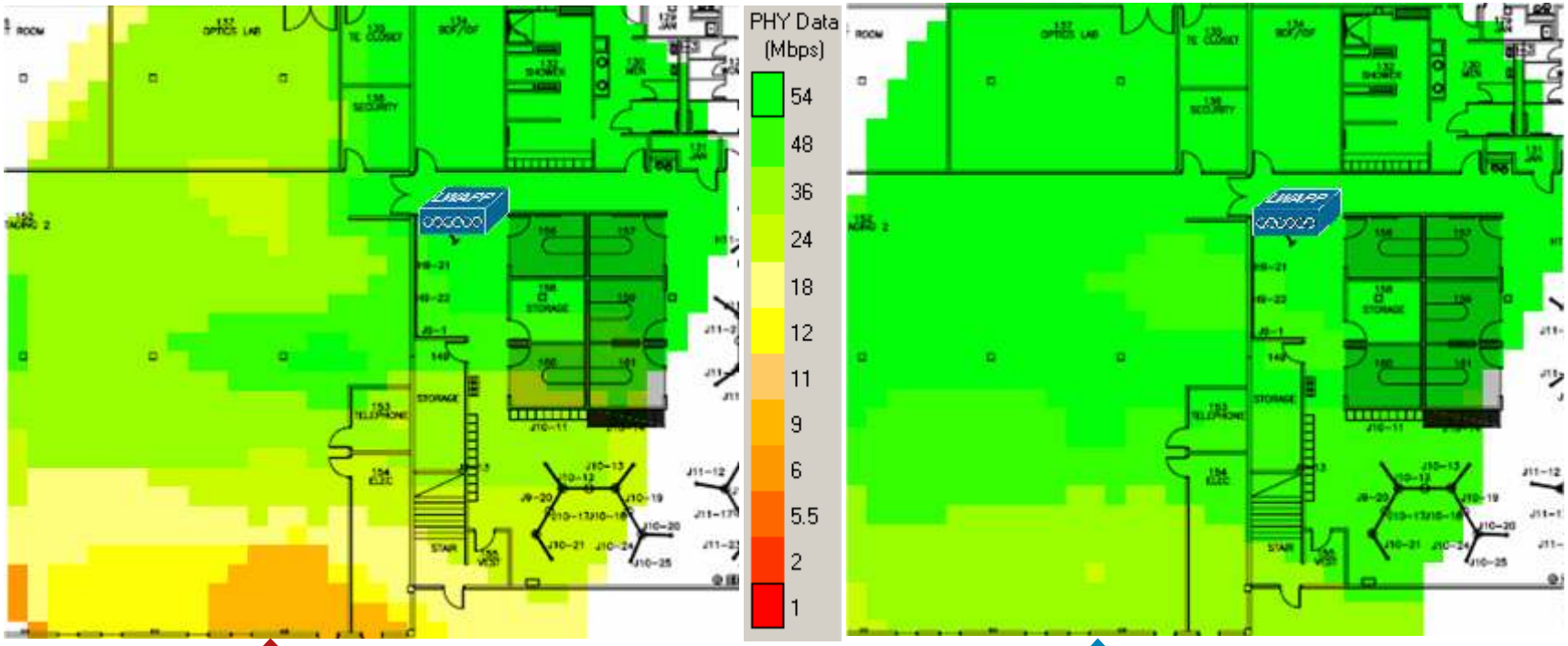
Benefit #3: Reduced Coverage Holes

Miercom

ClientLink Disabled

ClientLink Enabled



Lower Data Rates

Higher Data Rates

Source: Miercom; AirMagnet 6.0 Iperf Survey

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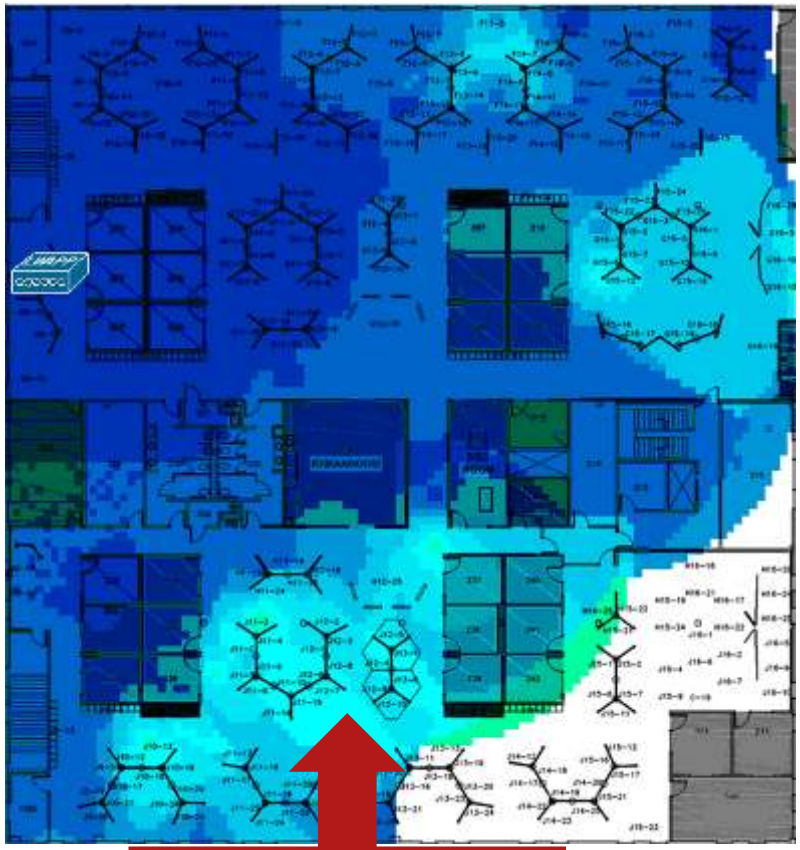
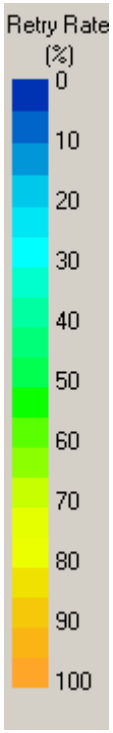
Benefit #3: Reduce Coverage Holes (cont.)

Lower retry rates

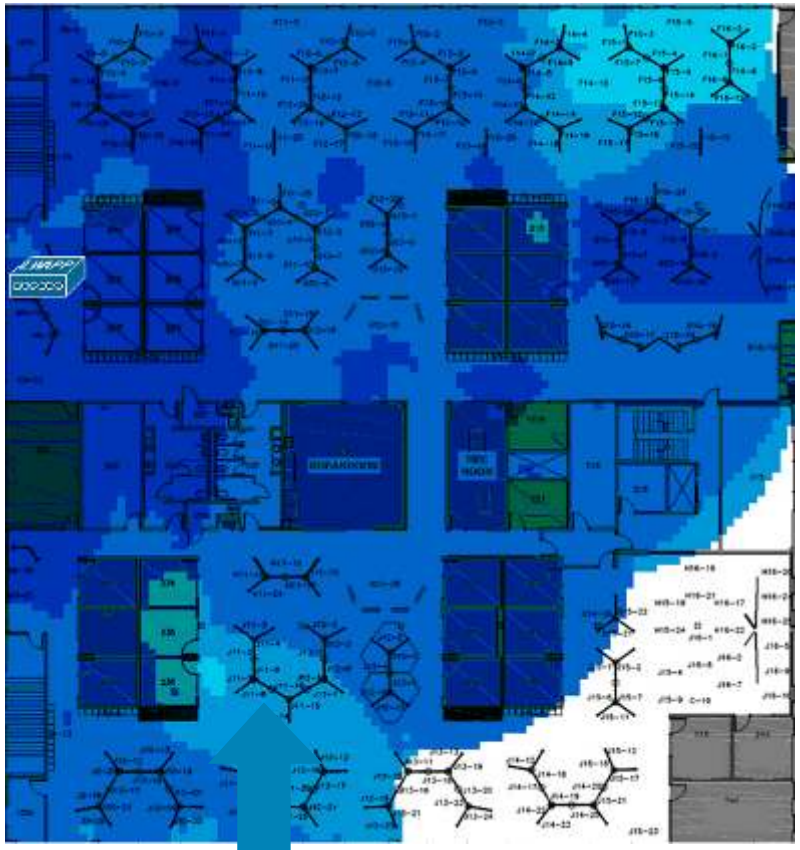
Miercom

ClientLink Disabled





ClientLink Enabled



High Retry Rates

Low Retry Rates

Source: Miercom; AirMagnet 6.0 Iperf Survey

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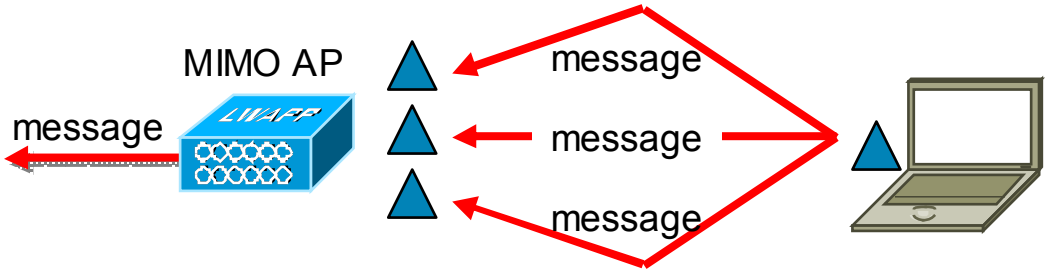
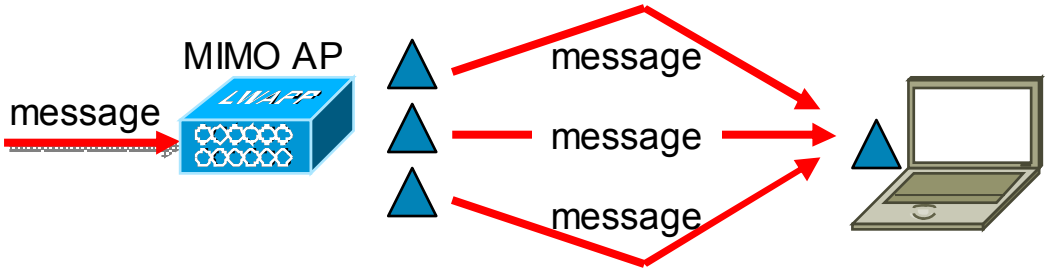
MIMO Overview

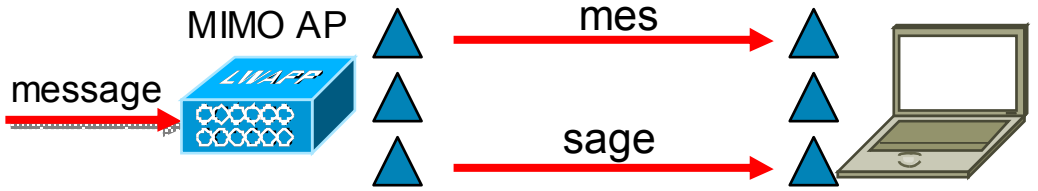
Maximal Ratio Combining
- Performed by receiver
- Combines multiple received signals
- Increases receive sensitivity
- Works with non-MIMO and MIMO clients



Transmit beam forming
- Performed by transmitter
- Ensures signal received in phase
- Increases receive sensitivity
- Works with non-MIMO and MIMO clients



Spatial Multiplexing
- Transmitter and receiver participate
- Multiple antennas txmt concurrently on same channel
- Increases bandwidth
- Requires MIMO client



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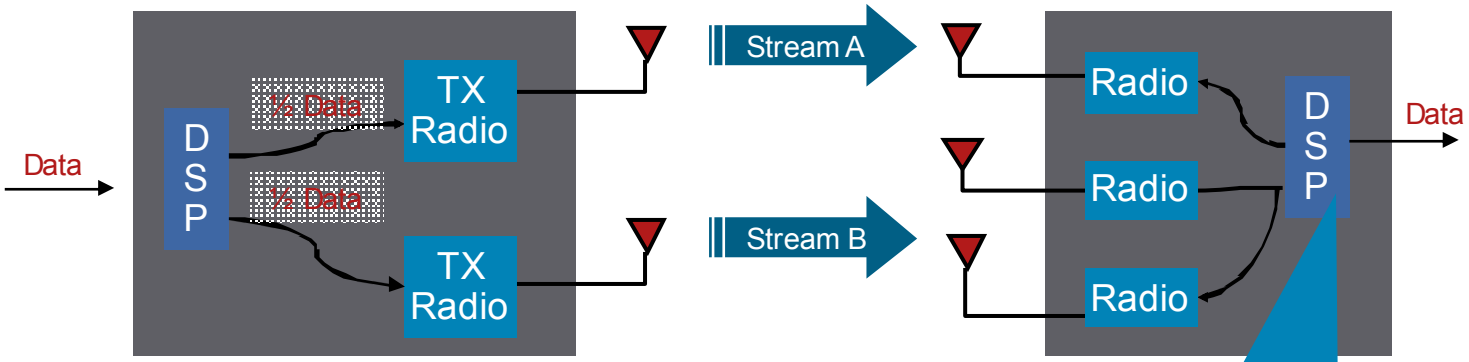
More Efficient Spectrum Utilization with MIMO Spatial Multiplexing



- The data is broken into two streams transmitted by two transmitters at the same frequency

I Can Recognize the Two Streams Transmitted at the Same Frequency Since the Transmitters Have Spatial Separation Using My Three RX Antennas with My Multipath and Math Skills

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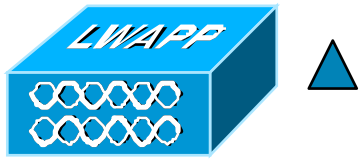
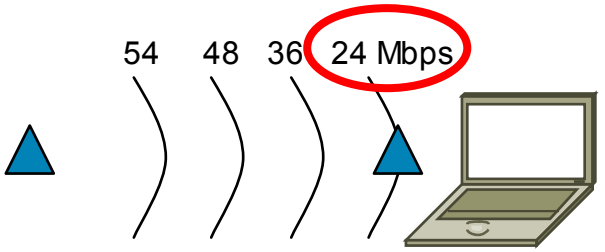
MIMO Increases PHY Data Rates for all clients

☒ Maximal Ratio Combining (MRC)
☒ Beam forming
☒ Spatial Multiplexing

802.11a/g AP (non-MIMO)

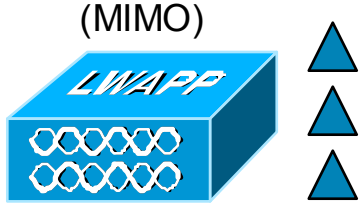


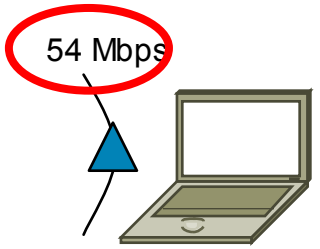


802.11a/g client (non-MIMO)

☑ Maximal Ratio Combining (MRC)
☑ Beam forming
☒ Spatial Multiplexing

802.11n AP (MIMO)

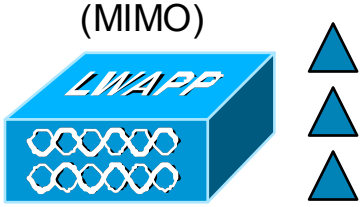


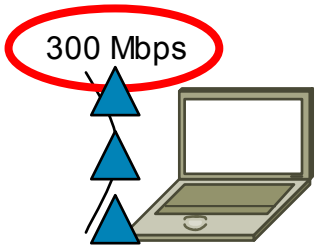


802.11a/g client (non-MIMO)

☑ Maximal Ratio Combining (MRC)
☑ Beam forming
☑ Spatial Multiplexing

802.11n AP (MIMO)





802.11n client (MIMO)

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HT Data Rates

MCS—Modulation and Coding Scheme

- 77 different MCS rates are defined by the standard
- 8 are mandatory
- AP1250/AP1140 supports 16
- Best MCS rate is chosen based on channel conditions
- MCS specifies variables such as
  - Number of spatial stream
  - Modulation,
  - Coding rate,
  - Number of forward error correction encoders,
  - Number of data subcarriers and pilot carriers,
  - Number of code bits per symbol,
  - Guard interval

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Getting the desired throughput

MCS index of the 16 x 802.11n data-rates supported by Cisco

MCS Index	Number of spatial streams	Modulation	GI = 800ns		GI = 400ns	
			Rate in 20MHz	Rate in 40MHz	Rate in 20MHz	Rate in 40MHz
0	1	BPSK	6.5	13.5	7 2/9	15
1	1	QPSK	13	27	14 4/9	30
2	1	QPSK	19.5	40.5	21 2/3	45
3	1	16-QAM	26	54	28 8/9	60
4	1	16-QAM	39	81	43 1/3	90
5	1	64-QAM	52	108	57 7/9	120
6	1	64-QAM	58.5	121.5	65	135
7	1	64-QAM	65	135	72 2/9	157.5
8	2	BPSK	13	27	14 4/9	30
9	2	QPSK	26	54	28 8/9	60
10	2	QPSK	39	81	43 1/3	90
11	2	16-QAM	52	108	57 7/9	120
12	2	16-QAM	78	162	86 2/3	180
13	2	64-QAM	104	216	115 5/9	240
14	2	64-QAM	117	243	130	270
15	2	64-QAM	130	270	144 4/9	300

GI = guard interval between frames

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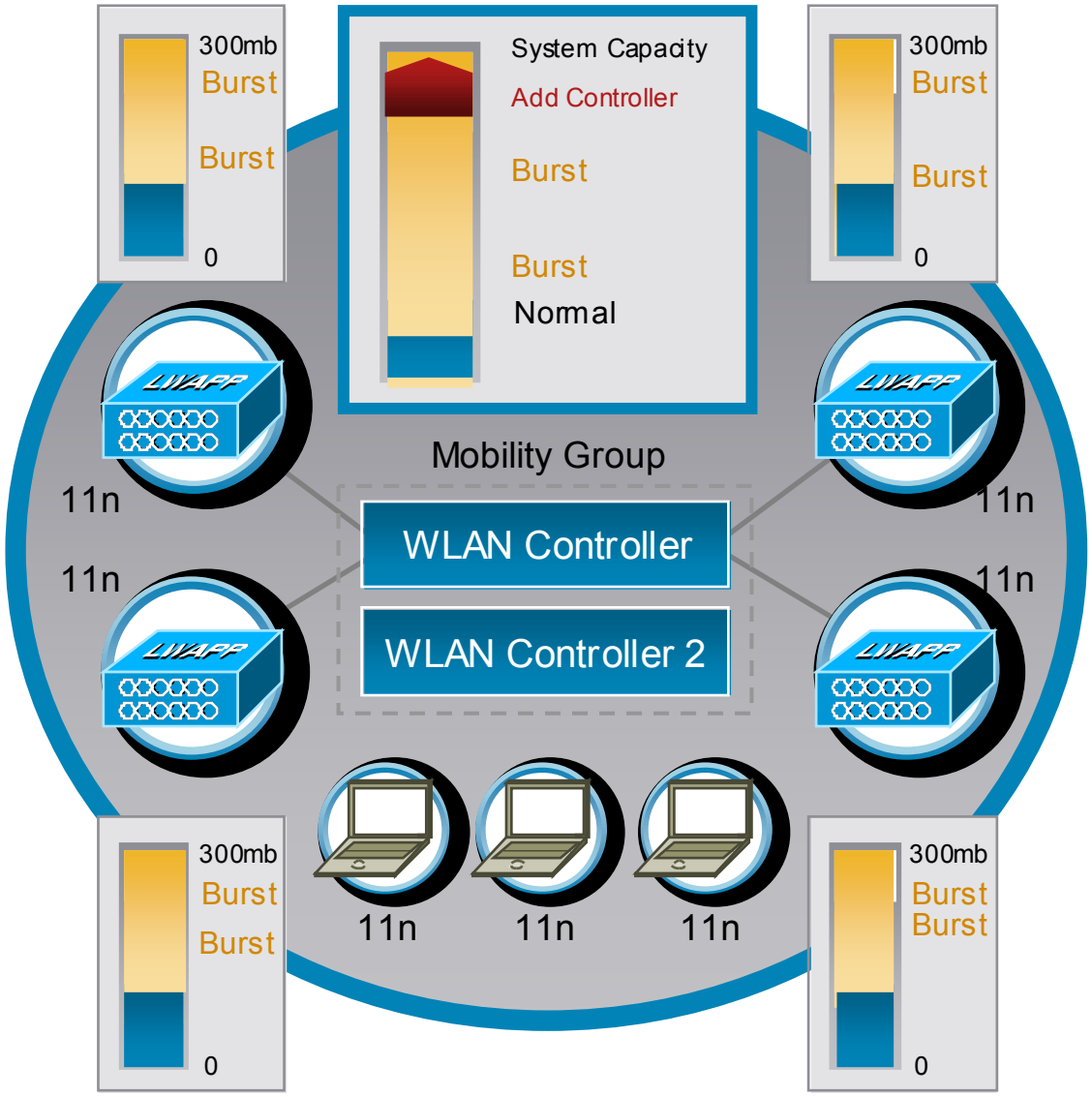
Network Capacity and Scalability



- Plan for system level capacity, not per AP capacity
- Additional controller increases capacity and improves availability
- Typical Ethernet network oversubscription is 8:1 to 20:1
- With 1250 APs at full capacity, Cisco WLAN controllers reach 12:1

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A Few More 802.11n Features Used to Increase Performance

- Reduced inter-frame spacing
- Reduced guard interval
- Fewer pilot tones when using channel extensions
- QAM 64

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802.11n Power Save

- Operating multiple transmitter for spatial multiplexing consumes more power
- 802.11n power save mode turns off all but one TX radios on the clients when in power save mode or dynamically when not in power save mode depending on adapter
- 11n power save multi poll extends power save mode to have AP buffer packets until client station is in a transmission mode to reduce power consumption

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Aironet 1140 AP introduction
Aironet 1250 AP recap

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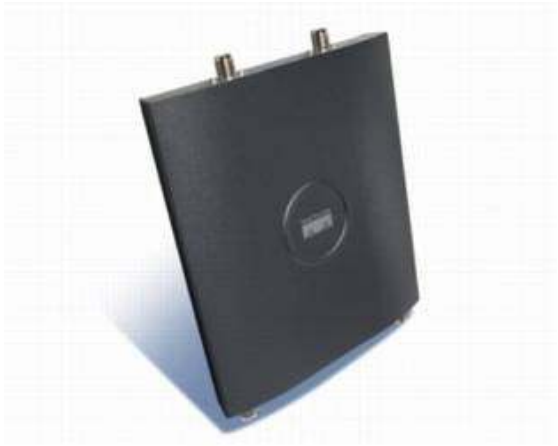
11a/g to 11n Access Point Migration

Indoor Environments

Integrated Antennas



Rugged Environments

Antenna Versatility

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Introducing the Aironet 1140 Series

- The Aironet AP-1140 is designed for carpeted areas.
  - Support for 5 GHz 802.11a/n and 2.4 GHz 802.11b/g/n radios
- Designed to run full 802.11n features using 802.3af power.
- Functionally similar to the AP1250 but with integrated antennas and lower profile.

6X performance of A/G

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1140 vs 1250 Positioning

	1140	1250
Deployment	Indoor	Ruggedized
Antennas	Integrated	External (RP-TNC)
Wired Uplink	Gigabit	Gigabit
Power Options	PoE, AC, Pwr Injector	PoE*, ePoE, AC, Pwr Injector

* 1250 runs on PoE with reduced performance

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Platform Characteristics

- First release with support for Unified modes of operation only.
- Autonomous support is coming
  - **Autonomous Software Release** estimated release in March 09
- Robust platform to support the requirements of higher speed WLAN technologies
  - **Faster CPU to handle higher data throughput**
  - **Increased memory for expanded feature set**
  - **10/100/1000 Ethernet port for high capacity uplink**
  - **Better thermal dissipation die-cast upper and lower housings with a plastic radome**
  - **Flexible mounting options and Plenum rated.**
  - **CAPWAP support (encryption for data and mgmt frames)**

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The Aironet 1250 Series Access Point

- Industry's first Wi-Fi Certified 802.11n draft 2.0/3.0 access point
- Modular platform
  - Field upgradeable radio modules/future technologies
- Higher speed WLAN technologies
  - Faster CPU to handle higher data throughput
  - Increased memory for expanded feature set
  - 10/100/1000 Ethernet port
- Available in Unified (LWAPP) and Standalone versions

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Power Considerations
Cisco Offers Flexible Power Options

Aironet 1250

Full 802.11n requires more than standard 802.3af Power over Ethernet

Standard 802.3af PoE

- Supports single radio module at full power
- Supports standard PoE with 2 radios on and 1 transmitter on each

Cisco Enhanced PoE

- Industry only single port PoE solution
- Catalyst switch family – 3750, 3560, 4500, 6500
- Full 11n performance

Power Injector

- Maintains existing switch infrastructure
- Delivers the full 18.5 watts of power needed

Local AC Power

- Power from any local power outlet

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Three PoE Modes To Support the 1250 AP

- Enhanced PoE mode (18.5 Watts)

  Full 2x3 with Full Power on Both PHY's

  3650-E (IOS version **12.2(44)SE**)[1]

  3750-E (IOS Version **12.2(44)SE**)[1]

  Catalyst 4500 (IOS Version 12.2(44)SG)[2]

  1250 Power injector

- Optimized PoE mode (16.8 Watts)

  Full 2x3 with Full Power on 5.8GHz, Lower power on 2.4Ghz

  Catalyst 6500 (IOS version 12.2(33)SXH2)[3]

- Standards Based 802.3af mode (15.4 Watts)

  Lower Power 1x3 on both radios

1 http://www.cisco.com/en/US/partner/prod/collateral/iosswrel/ps8802/ps6969/ps5012/prod_bulletin0900aecd807382e4.html
2 http://www.cisco.com/en/US/prod/collateral/switches/ps5718/ps4324/product_bulletin_c25_468227.html
3 http://www.cisco.com/en/US/docs/switches/lan/catalyst6500/ios/12.2SX/configuration/guide/voip.html#wpCisco_Enhanced_PoE_Support

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802.11n Performance testing

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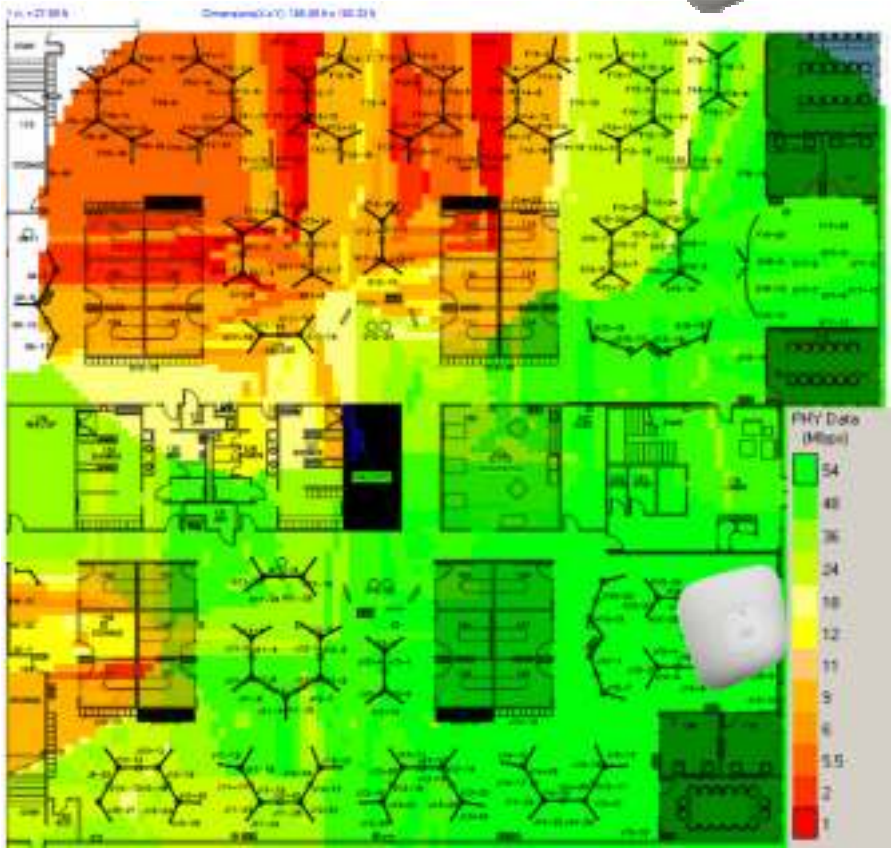
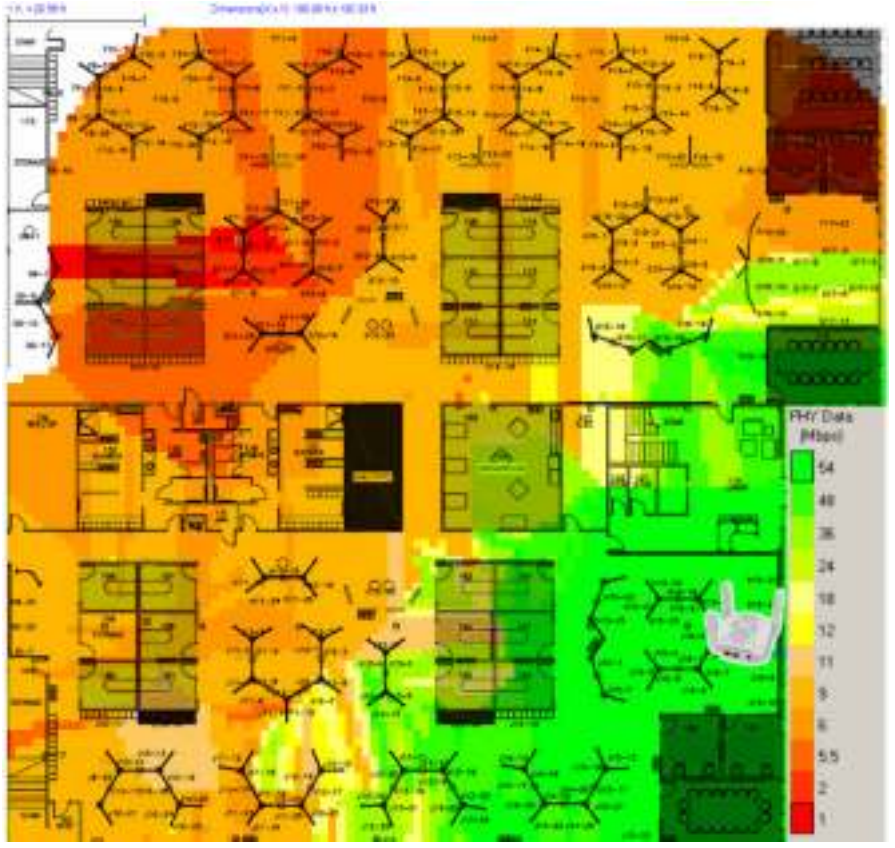
Coverage Comparison
802.11g Clients

Cisco 1140 (PoE)



Another Vendor



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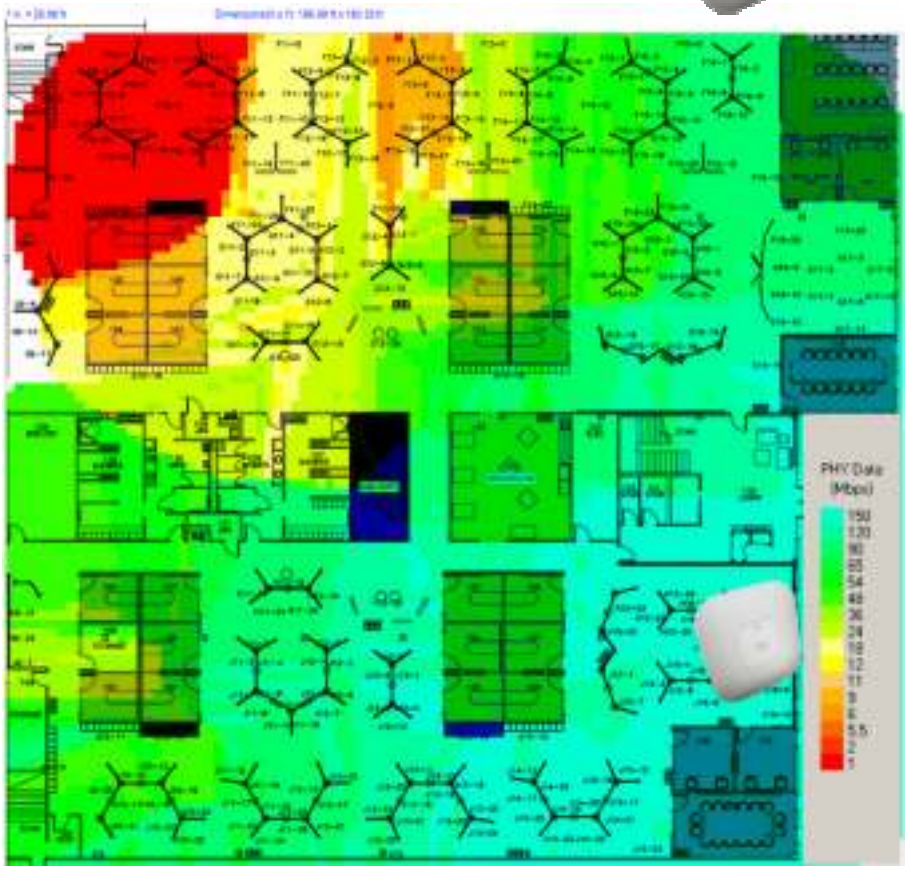
Coverage Comparison
802.11n (2.4GHz – 20MHz)

Cisco 1140 (PoE)



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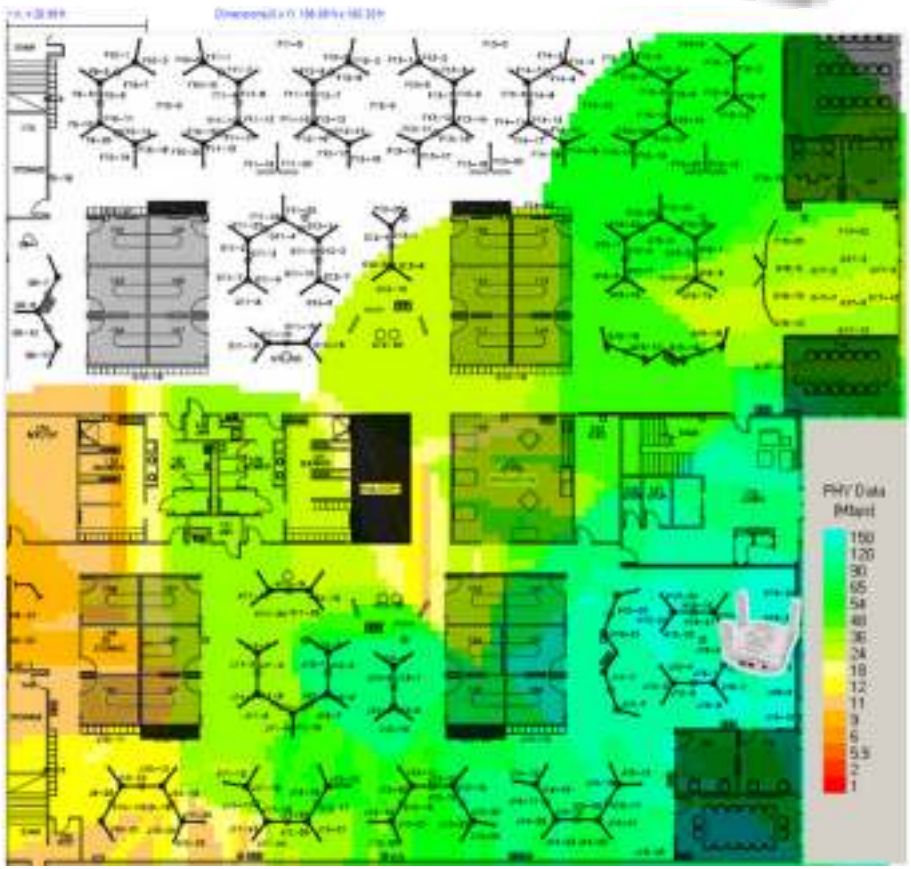

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