Agenda

- 802.11n Technology Theory and Protocol
  - 802.11n Protocol and Technology Overview
  - Security Ramifications of 802.11n
- Design and Deployment
  - 1250 AP Power
  - Planning and Design for 802.11n in Unified Environment
  - Key Steps for Configuration of 11n in a Unified Environment
  - 11n Client Adapters
  - Troubleshooting
- Q and A

Note: A number of slides in handout are provided for reference but will not be covered in lecture

What Will Not Be Covered

- Outdoor deployments using 802.11n
- Autonomous design and configuration
- All 500+ pages of the 802.11n specification
- Optional items in 802.11n spec that Cisco does not currently support with shipping products
- Futures and Roadmaps
- Fourier Transforms
Goals of the IEEE 802.11n Standard

- Performance parity with 100 Mbps fast Ethernet
- Improved reliability
- Backward compatibility with A/B/G
- Improved immunity to noise
Key Approaches 802.11n Uses to Improve Performance

- Improve SNR
- MIMO MRC

ABG Clients
N Clients

- More in Pipe
- MIMO MSS

N Clients

- Bigger Pipe
- Double Channel Width

N Clients

- Reduce 802.11 Overhead
- Packet Aggregation

N Clients

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
- Term Legacy will be used to refer to 802.11ABG clients that do not support 802.11n
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 with 11n to refer to 11n transmissions without Legacy PHY encapsulation

802.11n HT Capability Field in Beacon
**HT Information Elements in Beacon**

**Double Wide Channel**

40-MHz Wide Channel Support

- 802.11n support 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
40 MHz-Wide Channel

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

802.11n Beacon Indicating 40 MHz-Wide Channels Support
Packet Aggregation

- All 11n devices must support receiving of either packet aggregation method A-MPDU or A-MSDU
- A-MPDU packet aggregation is what 1250 will use for packet aggregation with block acknowledge

Without packet aggregation

With packet aggregation

Packet Aggregation

A-MSDU

- Aggregate MAC service data unit
- An A-MSDU is a structure containing multiple MSDUs, transported within single (unfragmented) or multiple (fragmented) Data MPDUs
- An A-MSDU is a sequence of A-MSDU subframes; each subframe consists of a subframe header followed by an MSDU and zero through three octets of padding; each subframe (except the last) is padded so that its length is a multiple of four octets; the last subframe has no padding
Packet Aggregation
A-MPDU Setup

- Aggregate MAC protocol data unit
- An A-MPDU is a structure containing multiple MPDUs, transported as a single PSDU by the PHY
- Indication that packet is Data A-MPDU in PLCP (physical layer convergence procedure)

Packet Aggregation
A-MPDU Capability Parameters

Maximum size of MPDU will accept
- 802.11n allows support up to 64K MPDU packet
Packet Aggregation
A-MPDU Block Acknowledge

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

MIMO (Multiple Inputs Multiple Outputs)

- MIMO is pronounced mee-moh or my-moh
- 802.11n it is mandatory requirement to have at least two receivers and one transmit per band

  Optional to support up to four TXs and four RXs
- MRC—Maximum ratio combing
- MSS—Multiple spatial streams—spatial multiplexing
- BF—Beam forming

Note: MIMO provides improvements for non-n802.11 clients
MIMO Improving 802.11 ABG Performance

Comparing SISO and MIMO Signal Reception

- One radio chain
- Multipath degrades

- Three radio chains
- Multipath improves
- Better immunity to noise
- Better SNR than SISO
Illustration of Three Multipath Reflections to SISO AP

- Multipath Reflections of Original Signal
- Signal Each Antenna Sees Due to Multipath Effect
- Radio Switches to Best Signal with Least Multipath Effect

Illustration of Three Multipath Reflections to MIMO AP with MRC

- Multipath Reflections of Original Signal
- The DSP Adjusts the Received Signal Phase So They Can Be Added Together
- The Resulting Signal Is Addition of Adjusted Receive Signals
More Efficient Spectrum Utilization with MIMO Spatial Multiplexing

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

HT Data Rates
MCS—Modulation and Coding Scheme

- 77 MCS rates are defined by standard.
- 1250 supports 16
  - Eight are mandatory.
- 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.
### MCS Chart

<table>
<thead>
<tr>
<th>MCS Index</th>
<th>Number of spatial streams</th>
<th>Modulation</th>
<th>Coding Rate</th>
<th>Rate 1</th>
<th>Rate 2</th>
<th>Rate 3</th>
<th>Rate 4</th>
<th>Rate 5</th>
<th>Rate 6</th>
<th>Rate 7</th>
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<td>1</td>
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<td>105</td>
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<td>115</td>
<td>120</td>
<td>125</td>
</tr>
</tbody>
</table>

### MCS Set in HT Capabilities Field for 802.11n Beacon

**One Spatial Stream:**
- MCS Index 0 Supported - BPSK, Coding Rate: 1/2
- MCS Index 1 Supported - QPSK, Coding Rate: 1/2
- MCS Index 2 Supported - 16-QAM, Coding Rate: 1/2
- MCS Index 3 Supported - 64-QAM, Coding Rate: 1/2
- MCS Index 4 Supported - BPSK, Coding Rate: 1/2
- MCS Index 5 Supported - QPSK, Coding Rate: 1/2
- MCS Index 6 Supported - 16-QAM, Coding Rate: 1/2
- MCS Index 7 Supported - 64-QAM, Coding Rate: 1/2
- MCS Index 8 Supported - BPSK, Coding Rate: 1/2
- MCS Index 9 Supported - QPSK, Coding Rate: 1/2
- MCS Index 10 Supported - 16-QAM, Coding Rate: 1/2
- MCS Index 11 Supported - 64-QAM, Coding Rate: 1/2
- MCS Index 12 Supported - BPSK, Coding Rate: 1/2
- MCS Index 13 Supported - QPSK, Coding Rate: 1/2
- MCS Index 14 Supported - 16-QAM, Coding Rate: 1/2
- MCS Index 15 Supported - 64-QAM, Coding Rate: 1/2

**Two Spatial Streams:**
- MCS Index 0 Supported - BPSK, Coding Rate: 1/2
- MCS Index 1 Supported - QPSK, Coding Rate: 1/2
- MCS Index 2 Supported - 16-QAM, Coding Rate: 1/2
- MCS Index 3 Supported - 64-QAM, Coding Rate: 1/2
- MCS Index 4 Supported - BPSK, Coding Rate: 1/2
- MCS Index 5 Supported - QPSK, Coding Rate: 1/2
- MCS Index 6 Supported - 16-QAM, Coding Rate: 1/2
- MCS Index 7 Supported - 64-QAM, Coding Rate: 1/2
A Few More 802.11n Features Used to Increase Performance

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

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
802.11n Security Implications

- Issues that should be considered today
  - 802.11n rogue detection
  - 40 Hz 11n rogue in 2.4
  - Containment of 802.11n rogues
  - WIDS scan time for 5GHz channels

- Issues that may be threat in the future
  - Client Fuzzing attacks on 802.11n client adapters
  - 802.11n Block Acknowledge flaw
  - Detection of Greenfield HT PHY communications
802.11n Rogue Detection and Containment

- Need to be running WLC version 5.xx or greater
- Does not require 1250 for detection
  - Any LWAPP AP in local, monitor or HREAP mode can detect 802.11n rogues
- 802.11n rogue in 2.4 GHz with 40-MHz wide channel could have greatest impact to 802.11 B/G usage

Detection of 802.11n Rogue with WCS

![Detection of 802.11n Rogue with WCS](image)
Detection of 802.11n Rogue with WLC

802.11n Rogue Containment

- 802.11n rogue containment requires 5.1 or greater
WIDS Off Channel Scanning Time for 802.11a/n Channels

- WIDS detection time factors for 5 GHz channels
  - Number channel scanned
  - Time spent off channel
  - Density of AP deployment
  - If monitor mode APs are in use

- Use monitor mode AP to reduce detection time

Off Channel Scanning by LWAPP Local Mode AP on Channel 36

<table>
<thead>
<tr>
<th>Channel Scanned</th>
<th>Time Spent Off Channel</th>
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<tbody>
<tr>
<td>36</td>
<td>10s</td>
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<tr>
<td>40</td>
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<td>36</td>
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<td>36</td>
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<td>48</td>
<td>60ms</td>
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<tr>
<td>36</td>
<td>10s</td>
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<tr>
<td>52</td>
<td>60ms</td>
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<tr>
<td>36</td>
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<tr>
<td>56</td>
<td>60ms</td>
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<td>60</td>
<td>60ms</td>
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<td>36</td>
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<tr>
<td>64</td>
<td>60ms</td>
</tr>
<tr>
<td>36</td>
<td>10s</td>
</tr>
<tr>
<td>149</td>
<td></td>
</tr>
</tbody>
</table>

Scanning Large Number of 5 GHz Channels Will Take Time to Complete

Client Fuzzing Attacks 802.11n Client Adapters

- Fuzzing attack is an attack on client adapter driver flaws
- Attempts to cause driver to crash from the insertion of illegal values in the protocol fields
- The assumption is new drivers may have new flaws
  - 11n adapters and drivers are no publicized 11n adapter driver attacks are known of at this time
- Tools like metasploit exist to test known fuzzing attack vectors
- Mitigate this risk by using enterprise quality 802.11n adapters with current driver version
802.11n Block Acknowledge Flaw

- Flaw with 802.11n protocol not providing a means to authenticate block acknowledges
- In theory could DOS a client
  - No apparent value an attacker would gain from doing this
- No known attacks that exploits this to date
- IEEE 11n task force working on solution to prevent
- **Mitigation** Write WIDS signature to detect attack vector if a real attack is ever created

Detection of 802.11n Greenfield/HT PHY Only Messages

- No devices using today
- **Mitigation**
  - Detection will occur today with devices that support mixed mode since AP must send beacon with Legacy PHY
  - HT only PHY message detection would show up as interference with RRM or Cisco Spectrum Expert detecting
What About the Increased Range from 802.11n? Isn’t That a Security Threat?

- Should already assume that unless you shield your building any WiFi transmission can be heard
- A client with a directional antenna pointing toward your WLAN will pick up a signal much further away than the range increase from 802.11n
- A rogue could have a faster pipe to siphon data out

Radio History
Who Are These People?
The Aironet 1250 Series Access Point

- Modular
  - 2.4 GHz Module
  - 5 GHz Module
- 10/100/1000 Ethernet port
- Console port
- Security lock
- Mounting bracket uses same hole pattern
- Runs either LWAPP or Autonomous Cisco IOS®
1250 Power Options

Aironet® 1250

- Less Than Full Performance with Two Modules
- Full Performance
- Full 802.11n Requires More Than Standard 802.3af Power over Ethernet

1250 Antennas

- Use three antennas per band

<table>
<thead>
<tr>
<th>Frequency</th>
<th>Part Number</th>
<th>Antenna Type</th>
<th>Antenna Gain</th>
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<tbody>
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<td>2.4 GHz</td>
<td>AIR-ANT15990</td>
<td>Diversity Ceiling Omni</td>
<td>2</td>
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<tr>
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<td>AIR-ANT24200-R</td>
<td>Grooved Non-reflective Antenna w/RP-TNC</td>
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<td>AIR-ANT24841</td>
<td>Tiltable Reflector w/RP-TNC</td>
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<tr>
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<td>AIR-ANT2410x-R</td>
<td>Omni Antenna w/RP-TNC Connectors(3)</td>
<td>3</td>
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<tr>
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<td>AIR-ANT1728</td>
<td>Ceiling Mount Omni</td>
<td>5.2</td>
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<td></td>
<td>AIR-ANT2506</td>
<td>Mounting Omni</td>
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<td>AIR-ANT3213</td>
<td>Diversity Panel Omni</td>
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<td>Diversity Omni-directional</td>
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<td></td>
<td>AIR-ANT5160V-R</td>
<td>Omni directional</td>
<td>6</td>
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</tbody>
</table>
New Antennas for AP1250

- **Omni-Directional**
  
  Single enclosure with three antenna elements
  
  - 2.4 GHz 3dBi (AIR-ANT2430V-R)
  - 5 GHz 4 dBi (AIR-ANT5140V-R)

- **Dipoles**
  
  New dipole without hinge (gray)
  
  - 2.4 GHz 2.2 dBi (AIR-ANT2422DG-R)
  - 5 GHz 3.5 dBi (AIR-ANT5135DG-R)
  
  Also supports existing dipoles with hinge (black and white)

- **Three Elements**

![Three Elements](image)

Three PoE Modes Supported with 1250 AP

- **Enhanced mode use ~18.5 Watts config port for 20 Watt**
  
  - 3560-E
  - 3750-E
  - 4500E—X4648E, X4648+E
  - 1250 injector
  
  Cisco IOS Version 12.2(44)SE
  
  Cisco IOS Version 12.2(44)SE
  
  Cisco IOS Version 12.2(44)SG

- **Optimized mode 16.8 Watts**
  
  - 6500—X6148, X6148A, X6548
  
  Cisco IOS Version 12.2(33)SXH2


- **802.3 af mode 15.4 Watts**
  
  Any 802.3af switch

Cisco IOS versions are minimum to support greater than .AF PoE mode
Maximum Data Link Speed for Three PoE Modes

<table>
<thead>
<tr>
<th>Mode</th>
<th>2.4 GHz Mbps</th>
<th>5 GHz Mbps</th>
<th>Spatial Streams</th>
</tr>
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<tr>
<td>Enhanced (18.5 Watts)</td>
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<td>300</td>
<td>2</td>
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<tr>
<td>Optimized (16.8 Watts)</td>
<td>144</td>
<td>300</td>
<td>2</td>
</tr>
<tr>
<td>AF (15.4 Watts)</td>
<td>72</td>
<td>150</td>
<td>1</td>
</tr>
</tbody>
</table>

- Enhanced and optimized power mode deliver the same performance in 5 GHz because they use two spatial streams.
- Enhanced and optimized power mode deliver the same performance in 2.4 GHz for dense deployments.

The difference is Optimized Max TX drops from 20 dBm with EPoE to 14dBm with Optimized.

WLC Showing PoE Mode in Use

- **Enhanced Mode**
  - Power Over Ethernet Settings
  - Poll Status: High
  - Pre-Standard State: On
  - Power Injector State: On

- **Optimized Mode**
  - Power Over Ethernet Settings
  - Poll Status: Medium (16.8 W)
  - Pre-Standard State: On
  - Power Injector State: On

- **AF Mode**
  - Power Over Ethernet Settings
  - Poll Status: Medium (15.4 W)
  - Pre-Standard State: On
  - Power Injector State: On
Planning and Design for 802.11n

Topics to Be Covered

- Expectations, performance and goals
- Design principles for increased performance
- Design methods
  - Exiting installation migration to 11n or exiting survey
  - New WLAN will survey with 1250 WCS Planner
- Capacity planning
  - Wireless Controller capacity
  - Network capacity
What Are the Expectations?
802.11n Hype to Reality

Throughput: Example 802.11a TCP Performance Ideal Environment

- Approximately 45% of link rate
Throughput: Example 802.11n 5 GHz 40 MHz TCP Performance Ideal Environment

- Approximately 65% of link rate

Example Speed vs. Range Comparison
1240 and 1250—11A Active Survey

1240 11A Survey
Point Drawn Is to Edge
36 Mbps Coverage
92 Feet

1250 11A Survey
Point Drawn Is to Edge
36 Mbps Coverage
102 Feet
Example Speed vs. Range Comparison
1240 and 1250—11G Active Survey

1240 11G Survey
Point Drawn Is to Edge
36 Mbps Coverage
110 Feet

1250 11G Survey
Point Drawn Is to Edge
36 Mbps Coverage
149 Feet

Five Principles for Maximizing Capacity with 802.11n

1. Design for 5 GHz 40 MHz wide channels and increased cell density

2. Design for lowest common denominator legacy clients surveying with 1250
   Plan to migrate client devices to 11n
   Disable lower legacy rates

3. Minimize noise and interference effects
   Use Auto RF for interference avoidance
   Use spectrum expert to find interference source

4. Design for EPoE power and GigE to APs

5. Specify a good 802.11n client adapter
**Capacity Principles**
More Cells Creates Greater More Overall Capacity

- Number of cells times max data link rate for each band gives total max capacity for an area.
- Example for 30,000 sq ft building
  
  A voice/location design call for 10 APs
  
  Capacity equals $10 \times 144 + 10 \times 300 = 4.4$ Gbps
  
  Since is wireless is a half duplex media with 802.11 overhead the actual throughput is approximately 60% of capacity
  
  2.6 Gbps
  
  Approximate average through per user is this number divided by number of active uses
  
  With 100 active users this would be 26 Mbps per user

---

**Capacity Principles**
Channel Capacity: Use 5 GHz and 2.4 GHz

- 2.4 GHz clients using N will consume less spectrum
- 5 GHz will provide the most capacity for 802.11n clients
  
  More available spectrum—greater number of channels
  
  Greater speeds due to 40 MHz channel the fact that many devices will only support 40 MHz channel in 5 GHz
- DFS support allows up to 11–40 MHz wide channels to be used in 5 GHz band
  
  If radar is detect in the area some UNI2 and UNI2 channels may disabled

---

![5 GHz Frequency Chart](image)
Capacity Principles
Legacy Clients and Capacity

- Majority designs need to support legacy client
  Lowest common denominator approach

- Legacy communications make least efficient use of spectrum capacity
  Better their SNR the more efficient spectral use
  Improve the situation by disabling lower legacy data rates

- 11n communications make more efficient use of spectrum helping improve capacity for everyone

Design Method
Existing WLAN Migration (or Existing Survey)

- For existing WLAN determine power and port type migration plan
  Provide Gig E and EPoE for 1250s
  Option: Proceed with existing .AF PoE and 100FE ports and plan for EPoE and GigE upgrades

- For existing replace APs one-for-one with 1250s
  Survey studies have shown that 1250 provides ~110% the coverage as 1240 using the same antennas in a office environment
  Option: Survey for one existing AP and survey with 1250 to verify coverage
  Typical AP density recommendations one per 5,000 sq feet for data only or one per 3,000 sq feet for voice, location

- Evaluate WLC capacity and network capacity
  Add WLC capacity if will exceed WLC capacity
  Plan for data rates at up to 250 Mbps per AP
## Design Method

### New WLAN Survey with 1250

- Determine least common denominator for client support
- Survey using 1250 AP with EPoE using legacy adapter in survey device (if design is with AF power survey with 1250 on AF)
  - If exists, audit existing switches to determine support for EPoE, GigE
  - Optional: secondary survey with 11n adapter
- Determine number of APs and AP placement from survey results
- WLC placement and capacity design
  - WLC capacity number of Aps plus subscription rate at up to 250 Mbps AP
- Switch and power design if needed
  - EPoE and GigE support
  - Network design for subscription rate at up to 250 Mbps per AP at both AP and WLC points

### WCS Planner

- Set AP type 1250
- Select enable 11n support
- Select protocol 802.11a/n,bgn
- Select optimize for HT
- Select Voice and location if desired
- Calculate/Apply/Add APs to Map
Use WCS Heat Map to Predict Data Rate Coverage and AP Placement

- Add APs to MAP
- Set Heat Map type to Data Rates
- Set Cutoff to desired minimum data rates

WCS Planner Proposal

- Generate proposal
- Use proposal for budgetary estimates
- Use proposal with Lite or Full survey to create final install AP count and placement design
  
  Recommend survey to calibrate proposal results

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Presentation_ID.scr
Controller and Network Capacity Planning

- Assumption is WLC capacity requirements will grow as more users migrate to 802.11n adapters and wireless
- Assume throughput to be approximately 60% WLAN link rate
- Peak throughput per AP is ~250 Mbps
- Determine WLC capacity requirements using common access layer oversubscription models
- Plan to use WCS to monitor WLC utilization
- Design network for
  - Maximum upstream capacity from WLC
  - Using common network oversubscription methods between APs and WLC

WLC Oversubscription Rates

<table>
<thead>
<tr>
<th>T-Put per AP Mbps</th>
<th>WLCM-8 1 Gbps</th>
<th>WLCM-12 1 Gbps</th>
<th>2106 800 Mbps</th>
<th>4402-12 2 Gbps</th>
<th>4402-25 2 Gbps</th>
<th>4402-50 2 Gbps</th>
<th>4404-100 4 Gbps</th>
<th>WiSM 6 Gbps</th>
</tr>
</thead>
<tbody>
<tr>
<td>25</td>
<td>0.19:1</td>
<td>0.30:1</td>
<td>0.15:1</td>
<td>0.31:1</td>
<td>0.61:1</td>
<td>0.61:1</td>
<td>0.91:1</td>
<td></td>
</tr>
<tr>
<td>40</td>
<td>0.30:1</td>
<td>0.50:1</td>
<td>0.38:1</td>
<td>0.30:1</td>
<td>0.61:1</td>
<td>1.22:1</td>
<td>1.22:1</td>
<td>1.83:1</td>
</tr>
<tr>
<td>100</td>
<td>0.78:1</td>
<td>1.17:1</td>
<td>0.75:1</td>
<td>0.59:1</td>
<td>1.22:1</td>
<td>2.44:1</td>
<td>2.44:1</td>
<td>3.66:1</td>
</tr>
<tr>
<td>150</td>
<td>1.17:1</td>
<td>1.76:1</td>
<td>1.13:1</td>
<td>0.88:1</td>
<td>1.83:1</td>
<td>3.66:1</td>
<td>3.66:1</td>
<td>5.49:1</td>
</tr>
<tr>
<td>200</td>
<td>1.56:1</td>
<td>2.34:1</td>
<td>1.50:1</td>
<td>1.17:1</td>
<td>2.44:1</td>
<td>4.88:1</td>
<td>4.88:1</td>
<td>7.32:1</td>
</tr>
<tr>
<td>250</td>
<td>1.95:1</td>
<td>2.93:1</td>
<td>1.88:1</td>
<td>1.46:1</td>
<td>3.05:1</td>
<td>6.10:1</td>
<td>6.10:1</td>
<td>9.16:1</td>
</tr>
</tbody>
</table>

- Typical access network design principle use oversubscription rates between 8:1 and 20:1
Monitor WLC Traffic Utilization

- Use 11n scaling report to monitor WLC utilization
- Compare utilization to interface capacity to determine if AP load should be redistributed or additional WLC capacity is needed

Configuration of 802.11n in a Unified Environment
Enable 802.11n Mode to Support HT Rates (On by Default)

Enable 802.11n mode for the band
- 802.11a/n>High Throughput (802.11n)
- 802.11b/n>High Throughput (802.11n)

Configure AutoRF for 40 MHz Wide 5 GHz Channels

Wireless>802.11a/n>DCA
- Channel Width 40 MHz
Enable or Disable 5 GHz Channels that AutoRF Is Allowed to Assign

- Wireless>802.11a/n>DCA

Manually Configuring 40 MHz Wide Channel

- Wireless>802.11a/n>Configure AP
- Must set channel assignment to Custom
- Extension Channel is always set to one up from primary
Configure Which Packets That Are Allowed to Be Aggregated MPDU

- (Cisco Controller) > config 802.11a 11nSupport a-mpdu tx priority <0-7/all> enable
- (Cisco Controller) > show running-config
  802.11a 11nSupport a-mpdu tx priority 1 enable
  802.11a 11nSupport a-mpdu tx priority 2 enable
  802.11a 11nSupport a-mpdu tx priority 3 enable
  802.11a 11nSupport a-mpdu tx priority 4 enable
  802.11a 11nSupport a-mpdu tx priority 5 enable
  802.11a 11nSupport a-mpdu tx priority 6 enable
  802.11a 11nSupport a-mpdu tx priority 7 enable

Configure WLAN to Support HT Rates

- Configure WPA for L2 security
- Select AES encryption
- Configure QoS for WMM allowed
Configure Switches to Run 1250 in High Power Mode

- Upgrade switches to Cisco IOS version that supports EPoE
- Configure 1250 ports for maximum power of 20 Watts
  
  ```
  Enable
  #Config t
  #interface GigabitEthernet 0/11
  #power inline port maximum 20000
  ```

Enabling 802.11n Support Autonomous

On radio interface
- Enable MCS rates
- Set channel width

Enable MCS Rates

Set Channel Width
Verifying Autonomous PoE Power Level

802.11n Client Adapters
11n Client Adapter

- Make sure adapter is Draft N certified by WiFi Alliance
  [http://www.wi-fi.org](http://www.wi-fi.org)
- 802.11n adapter will have a major influence on performance levels that can be achieved
- **Built-in 11n adapters out perform external**
- Not realistic to upgrade most older laptops with internal 11n adapters
  - Need three antennas
  - Some Laptops Bios locks out adapters not sold by laptop vendor

---

11n Client Adapter (Cont.)

- Adapter choice have an effect on laptop battery life
- Adapter choice influences how well client roams
- Should update 11n adapter drivers to the latest
- The more MIMO RX radio chains in the adapter the better
- Cisco-Intel relationship means that between both organizations the Intel 11n adapter with Cisco 1250 have had the most test time
### Troubleshooting Tools

**Determining If Client Associated at 11n HT Rates with WLC**

<table>
<thead>
<tr>
<th>Monitor</th>
<th>Clients</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Summary</strong></td>
<td><strong>Current Filter</strong></td>
</tr>
<tr>
<td>Access Points</td>
<td>Change Filter</td>
</tr>
<tr>
<td>Statistics</td>
<td></td>
</tr>
<tr>
<td>COP</td>
<td></td>
</tr>
</tbody>
</table>

**Monitor >Clients**

- Protocol indicates if client associated with 802.11n HT rates
Troubleshooting Tools
Determining If Client Associated at 11n HT Rates with WCS

- Protocol shows if client associated at 11n HT rates

Client Status Windows

- 20 MHz 144
- 40 MHz 300

Warning: Depending on the Adapter, You May Not Be Able to Trust the Speed It Reports
Client Status OSX

- Applications>Utilities>Network Utility

![Network Utility Interface](image1)

11n Client Does Not List 5 GHz SSIDs in Scan List

- Does 11n adapter support 5 GHz channels?
- Does 11n adapter support UNNI 2 channels?

![5 GHz SSIDs Not in Scan List](image2)
Client Shows 11n SSID But Does Not Connect at 11n Data Rates

- Does the client have a 11n adapter?
  Some legacy clients will show that the AP support 11n even though the client does not support 11n
- Is 11n support enabled in adapter driver?

Have 11n Adapter and Still Connecting at A or G Rates

- What type of encryption is allowed for WLAN?
  Must be AES or None
  If WEP or TKIP will not support 11n HT rates
- Is WMM allowed?
  If WMM disabled will not support 11n HT rates
11n Client Is Not Able to Connect at Highest HT Rates

- 2.4 GHz 11n client will not connect faster than 70
- 5 GHz client will not connect faster than 150
- This is because AP only supports one spatial stream due to being on .AF power
- Use 1250 injector or configure switch port for high power PoE
- #power inline port maximum 20000

Client Applications Not Achieving Significant Performance Increases

- End-to-end performance is dependent on numerous variables
  - OS
  - Application
  - Server Load
- Run test with Iperf to rule out network bottlenecks
  - Client iperf -c 10.10.10.10 -t 30 -b 50M -P 6 -l 56K
  - Server iperf -s -u -l 56K
Cannot Achieve Better than 90 Mbps

- Check to make sure AP is connected to Gigabit Ethernet port
- Verify that end-to-end data path is Gigabit

Conclusion
The old way to design radios

Multipath Bad

MIMO the new way

Multipath Good
Tips for Achieving the Best Performance

1. Use 5 GHz 40 MHz wide channels
2. Consider increasing cell densities
3. Disable lower legacy data rates
4. Use full power modes by using injector or EPoE
5. Specify a good performing 802.11n client adapter
Additional Resources

- Cisco Next Generation Wireless
- Cisco Aironet 1250 Series access point
- Cisco Unified Wireless Network

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