CISCO SYSTEMS

Wireless Mesh Networking

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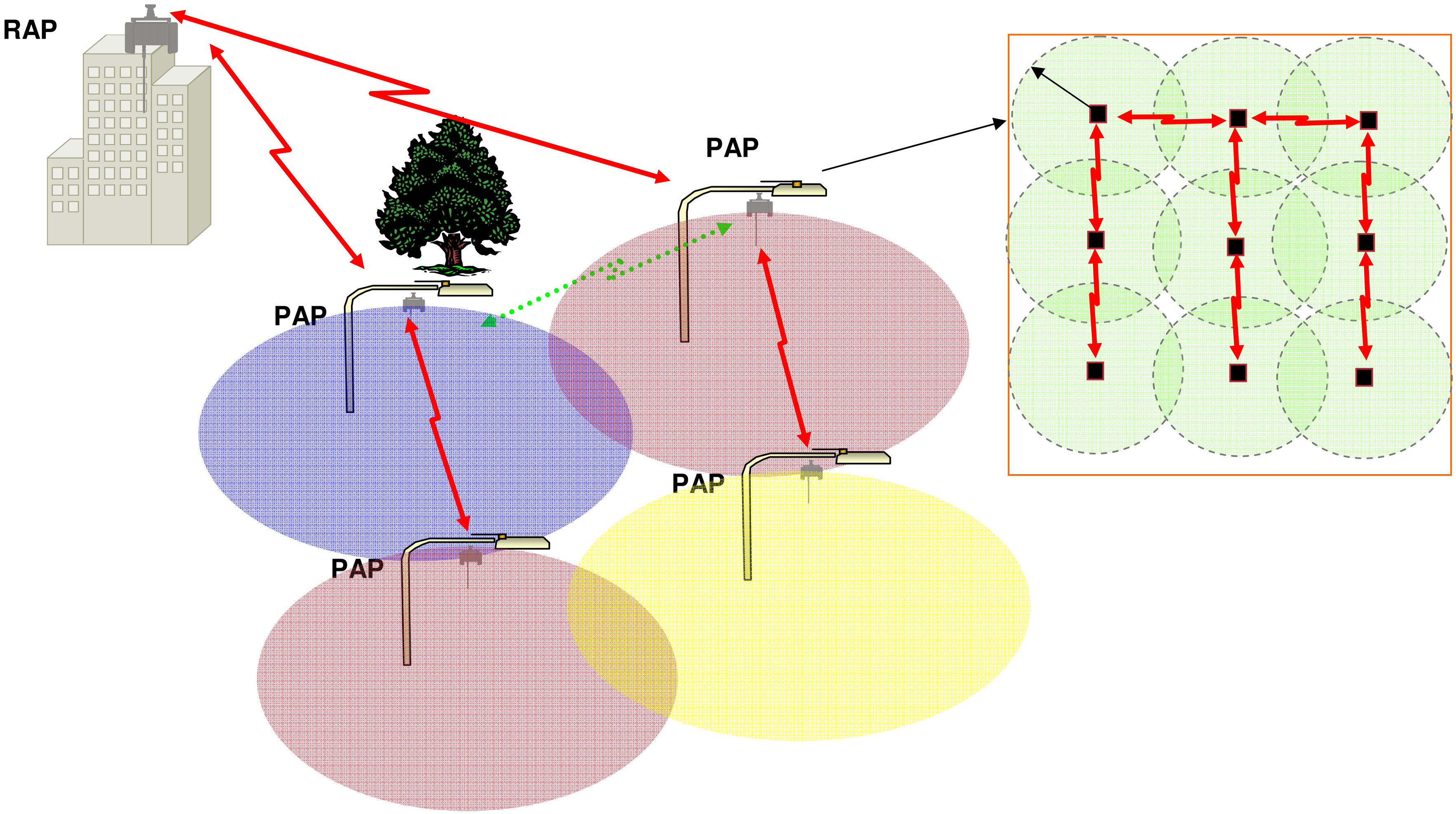
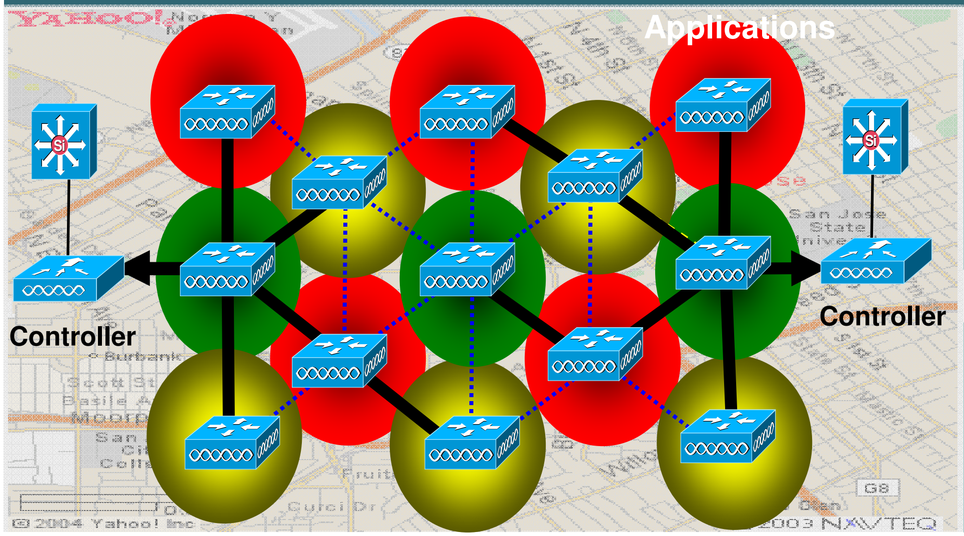
CERTIFIED INFORMATION SYSTEMS SECURITY PROFESSIONAL (CISSP)

Wireless Mesh Networking Overview



Wireless Mesh Networking Overview



The proliferation of WiFi clients is driving broader 802.11-based application adoption

Unlicensed bandwidth + wireless routing allow "micro-cells" to interconnect over wireless backhaul links, reducing costs

Value Proposition

- **Extending indoor WLAN to outdoor areas**
- **Enabling outdoor data hot zones for business, safety and public access applications**
- **Ease of Deployment and "Best-in-Class" Management reduces OPEX**
- **Unified Wired+Wireless Networks**

Applications

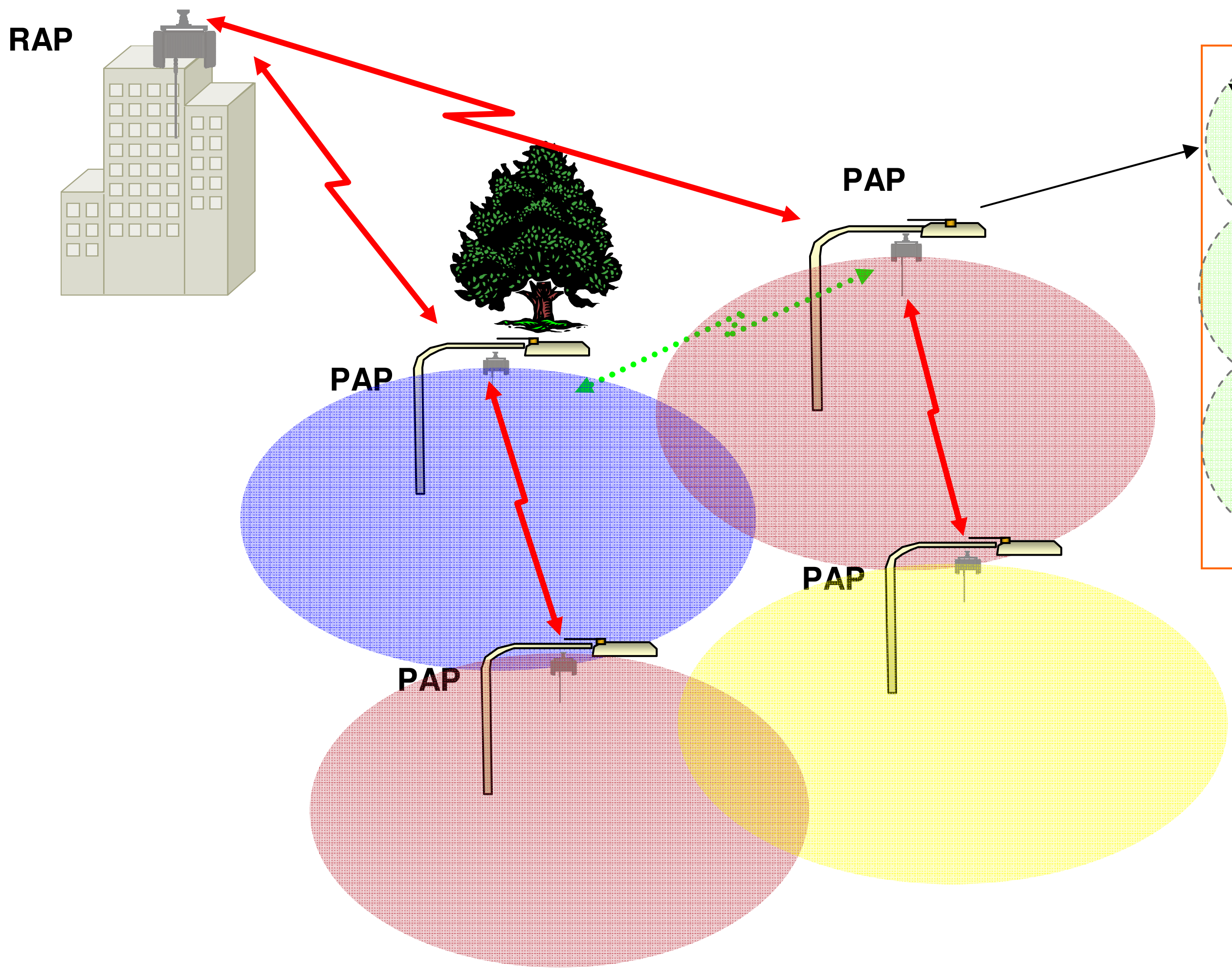
City and county wide deployments for municipal data. Permits, licenses, work orders.

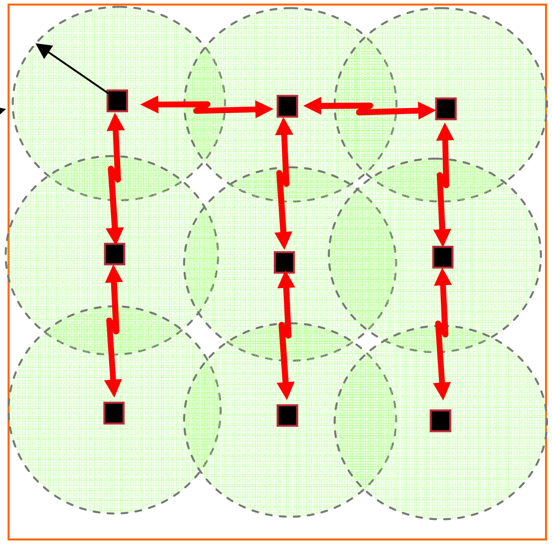
Equipment and parts inventory tracking

Video Surveillance and traffic data

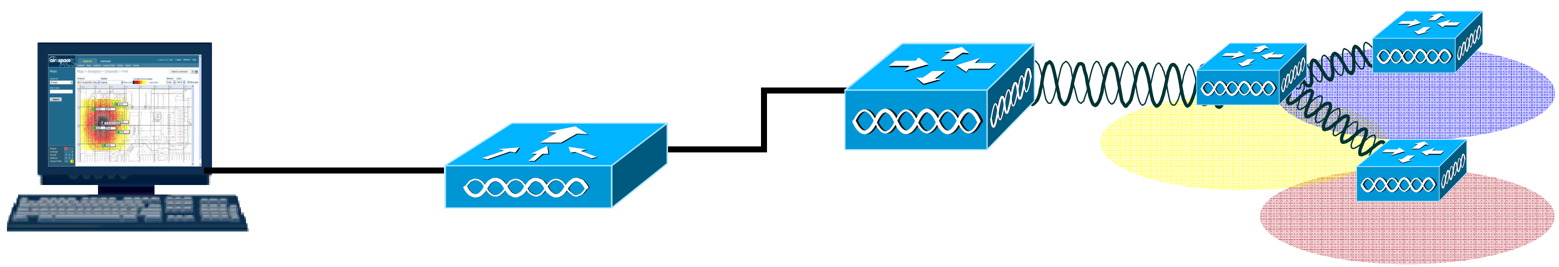
Roaming between buildings and common areas access

802.11a 5GHz, Backhaul
802.11g 2.4GHz Coverage





Outdoor Wireless Mesh Solution Components



Wireless Control Systems

- Wireless Mesh Management System
- Enables network-wide policy configuration and device management

Wireless LAN Controller

- Links the Wireless Mesh APs to the wired network
- Handles RF algorithms and optimization
- L3 Mobility
- Provides Security and Mobility Mgt

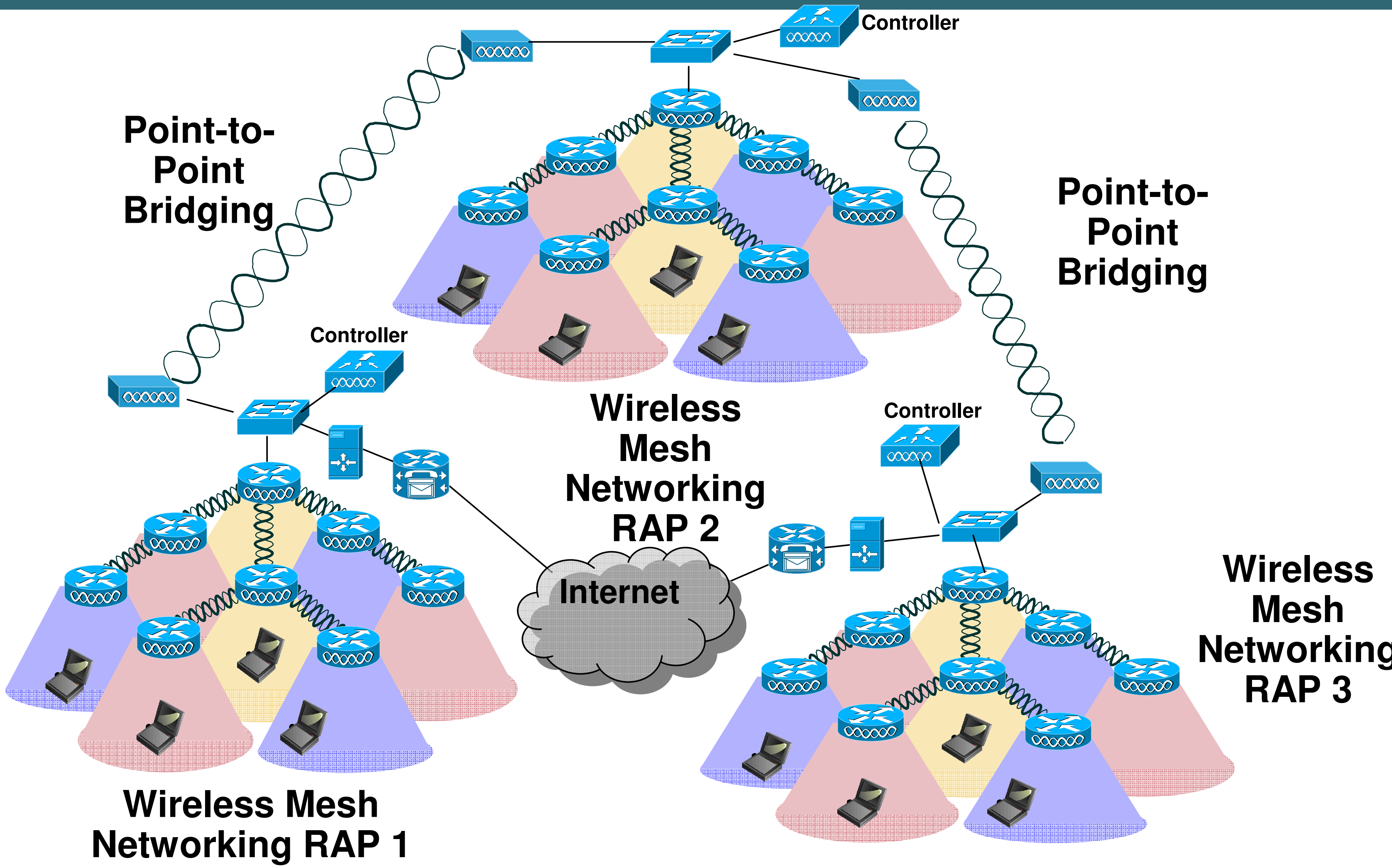
Roof-top Access Point

- Serves as "Root" or "Gateway" AP to the wired network
- Typically located on roof-tops or towers
- Connects up to 32 "Pole-top" APs using 802.11a

Mesh Access Point

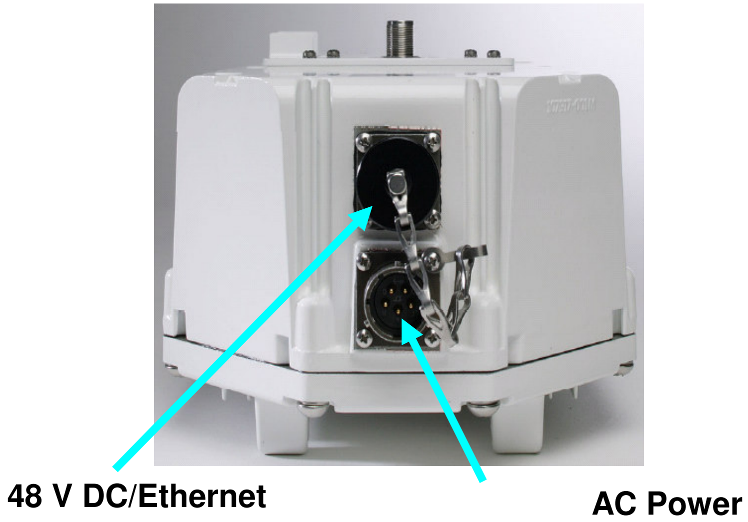
- Provides 802.11b/g client access
- Connects to Root AP via 802.11a
- Takes AC or DC power; PoE capable
- Ethernet port for connecting peripheral devices

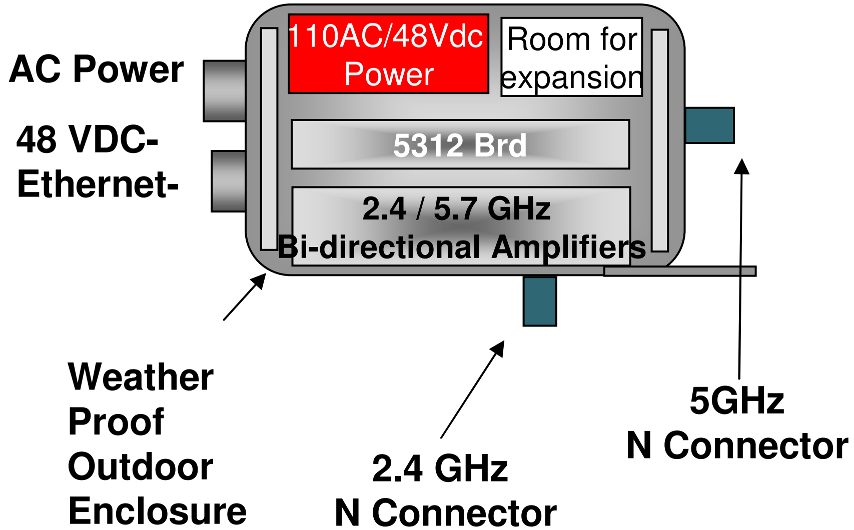
Generic Wireless MESH Topology



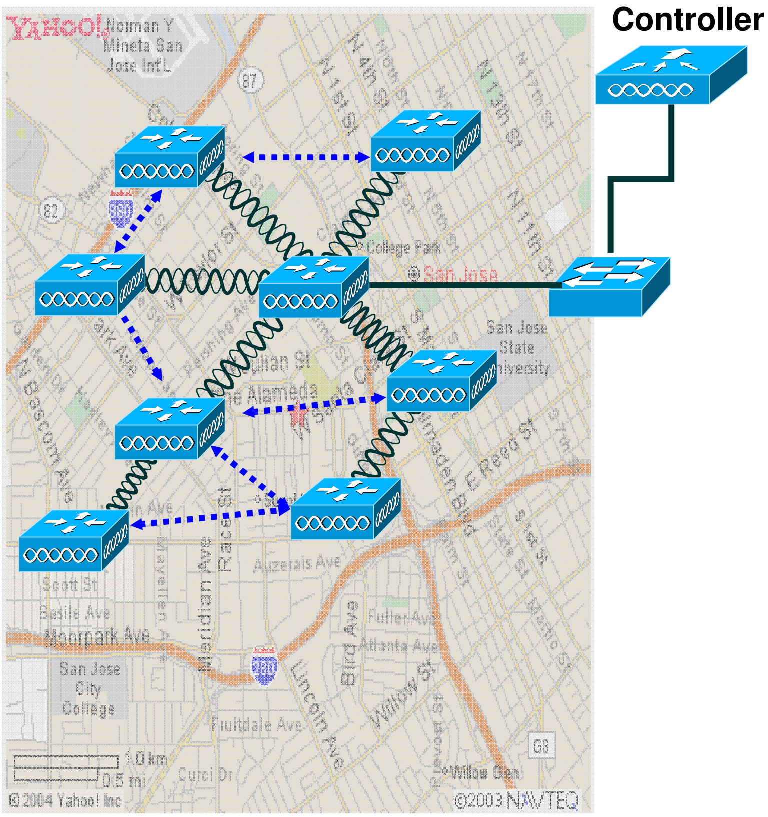
Mesh AP

- **Fixed Configuration, Dual Radio Outdoor AP**
  - **802.11b/g – access (2.4GHz)**
  - **802.11a – backhaul (5.8GHz)**
  - **4.9GHz for Municipality**
- **NEMA-4/IP66 Enclosure**
- **Industrial Grade Power Supply**
  - **Local AC Power (95 – 260 VAC, 47 to 63 Hz)**
  - **Street Light Power Tap**
  - **DC Power over CAT5 (48 VDC)**
- **Wind Loads**
  - **Sustaining: 100 Mph**
  - **Gusts: 160 Mph**
- **Temperature ranges -40C to +55C**



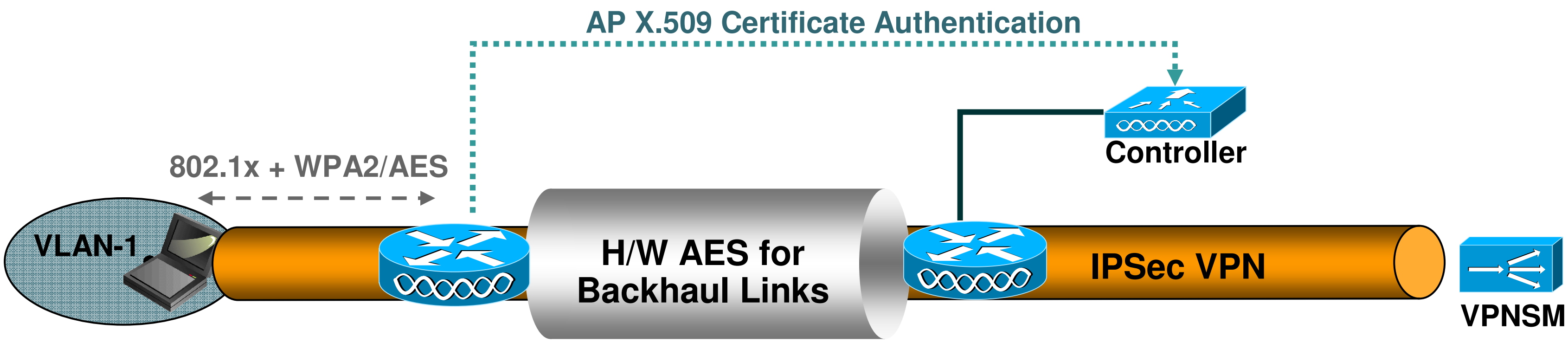


Dynamic, Intelligent Path Selection



- **Adaptive Wireless Path (AWP) Protocol**
  - **Cisco AWP is part of the IEEE 802.11s committee (SEE Mesh)**
- **AWP establishes an optimal path to Root**
- **Each AP carries feasible successor(s) if topology or link health changes**
  - **Note: AWP uses a "parent sticky" value to mitigate route flaps**

Security

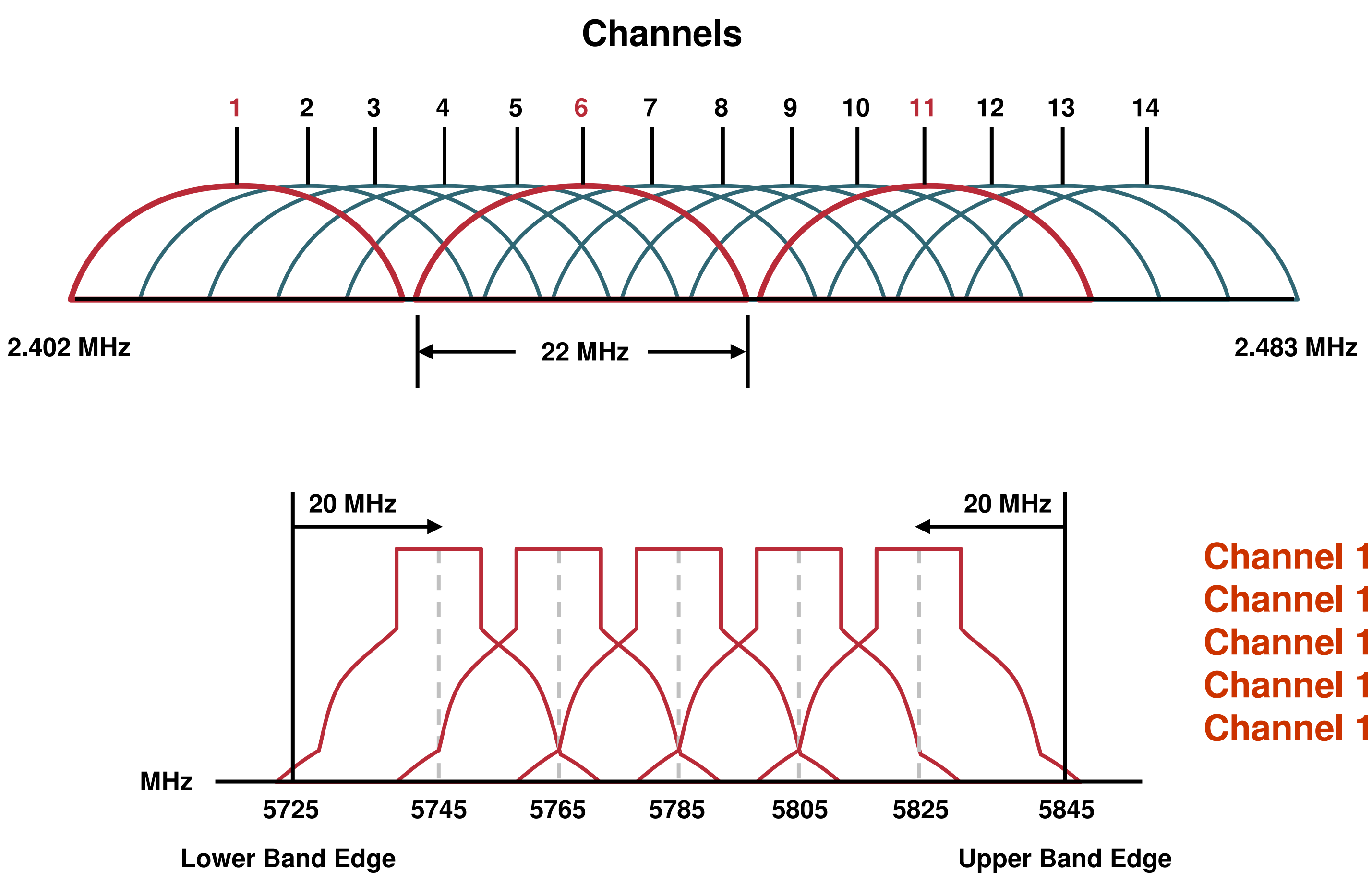


- WLAN VLAN Assignment + 802.11i WPA/WPA2 Security
- AES encrypted Backhaul Links
- Secure Control Traffic between AP and Controller
- AP Authentication protects against “imitation APs”

IPSec VPNs for “confidential” mesh client traffic

- X509 Digital Certification
- Wi-Fi client – 802.11i/WPA2,802.1x, Pre-Key, TKIP, MIC, AES

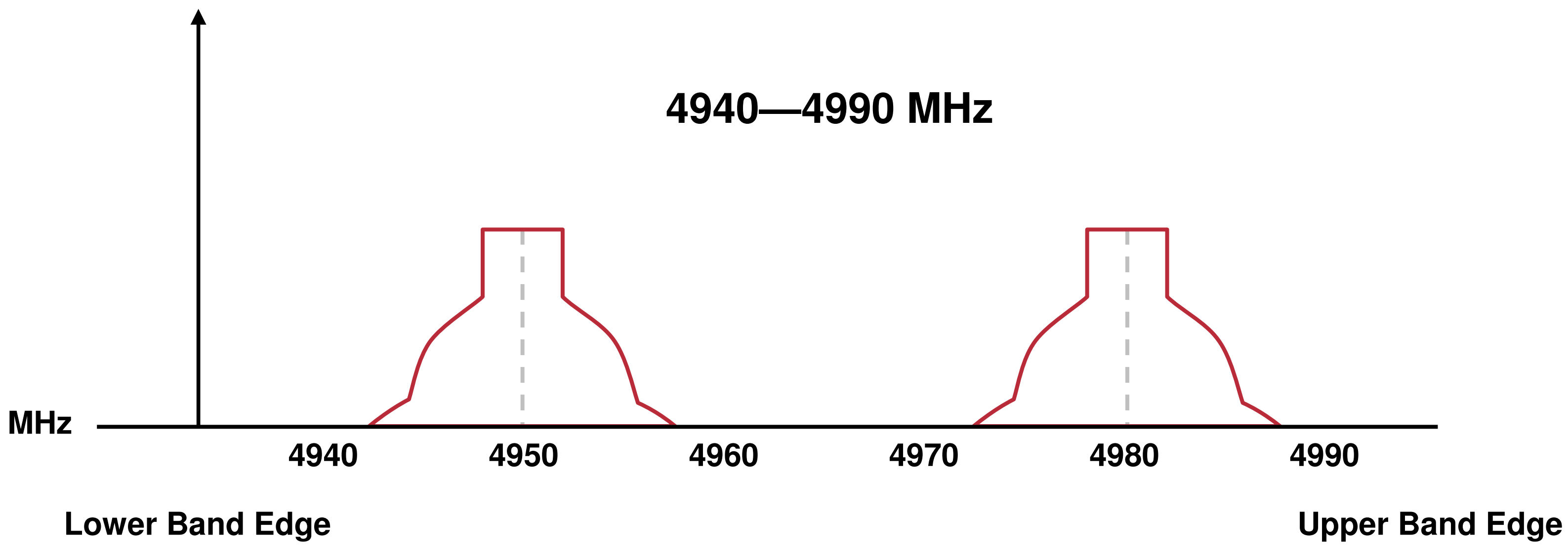
Bands available as per today



Channel 149
Channel 153
Channel 157
Channel 161
Channel 165

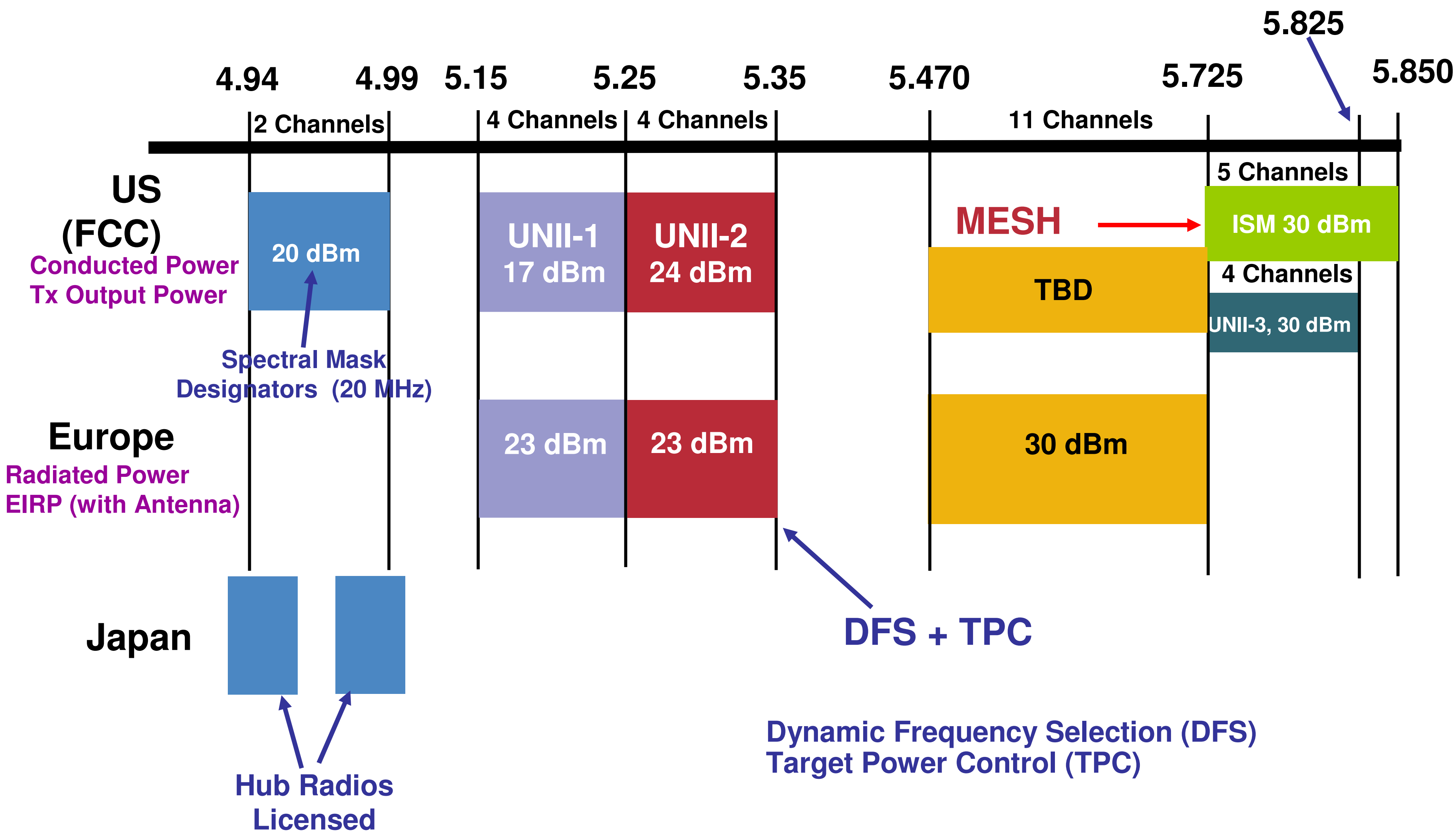
ISM Band: 5 Channels, 125 MHz band, 20 MHz spacing

4.9 GHz Band



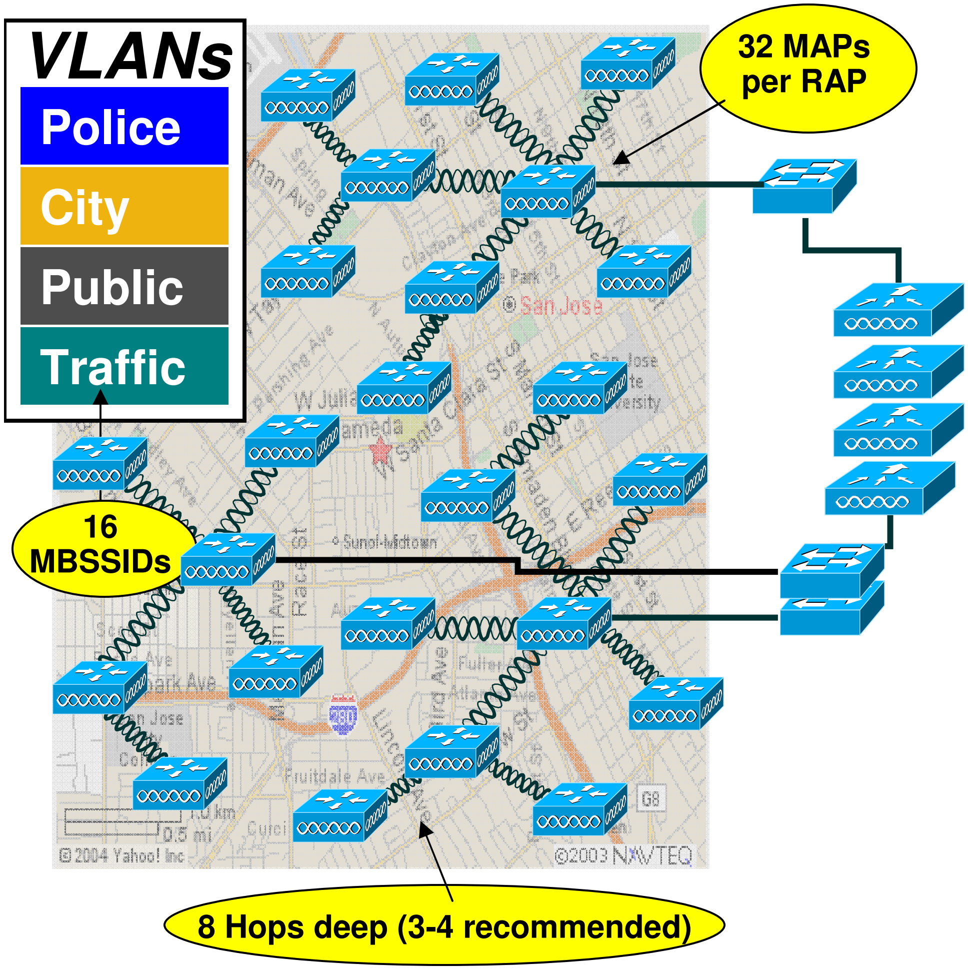
4.9 GHz Band: 2 Channels, 50 MHz band, 20 MHz channel

Current State of 5 GHz Bridging Spectrum



Dynamic Frequency Selection (DFS)
Target Power Control (TPC)

Adding Capacity and Services

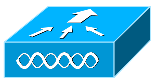
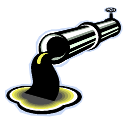
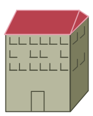
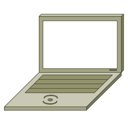


- **Increase AP Density**
- **Add Root/Gateway APs**

  Pole-top APs will join new RAPs with better path metrics
- **Architecture is ready for additional radios when extra capacity is required**

WIRELESS MESH NETWORKING DESIGN AND DEPLOYMENT

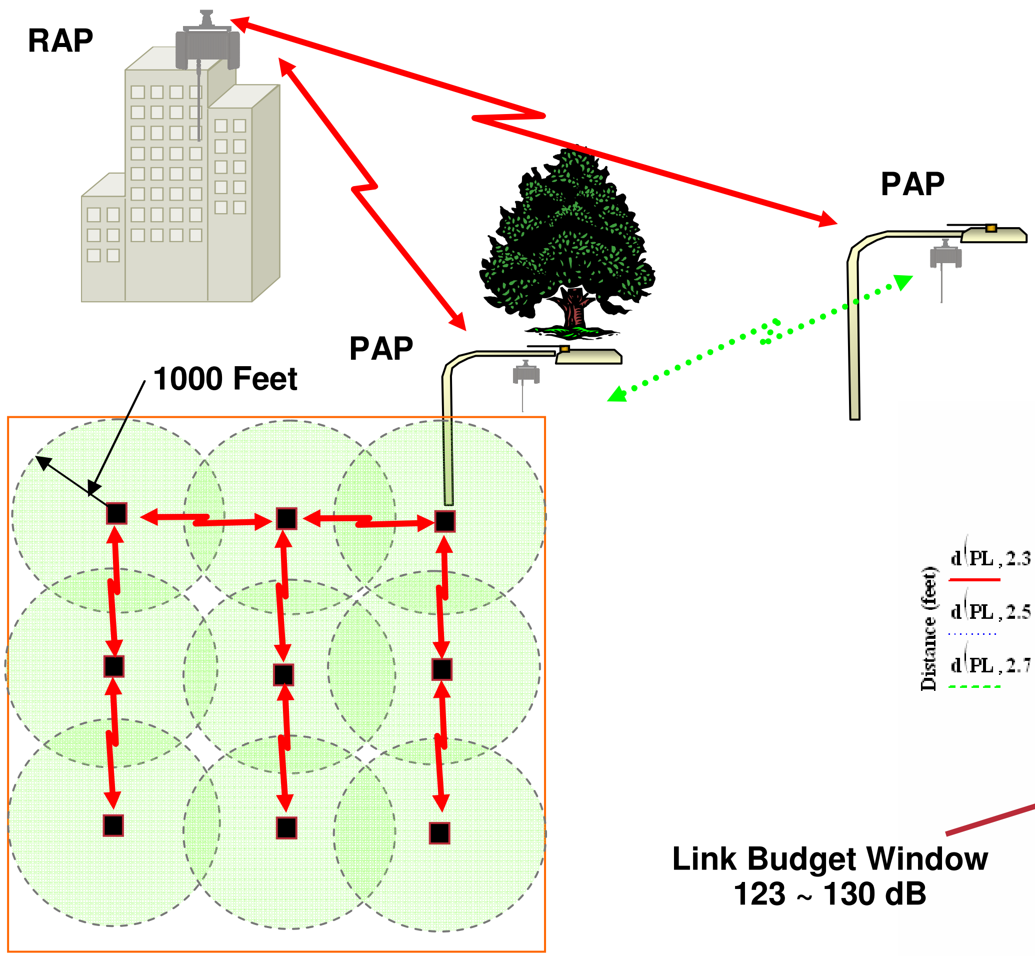
Deployment
The Basics of Mesh Deployment

	Controllers	L2 vs. L3
	Back Haul	Hop Count? Roof Top/Tower Coverage? Wired vs. Wireless? Size of Pipe
	Building Tops	Hop Count? Roof Top/Tower Coverage? Number of Radios?
	Street Lights	Clutter? Height Above the Clutter?
	Clients	CPE/Laptops/PDAs

Wireless Routing

- Typically a tree topology
- Unlicensed bands have interference
- Complex statistic packet and bit error characteristics
- More dynamic and changing environment

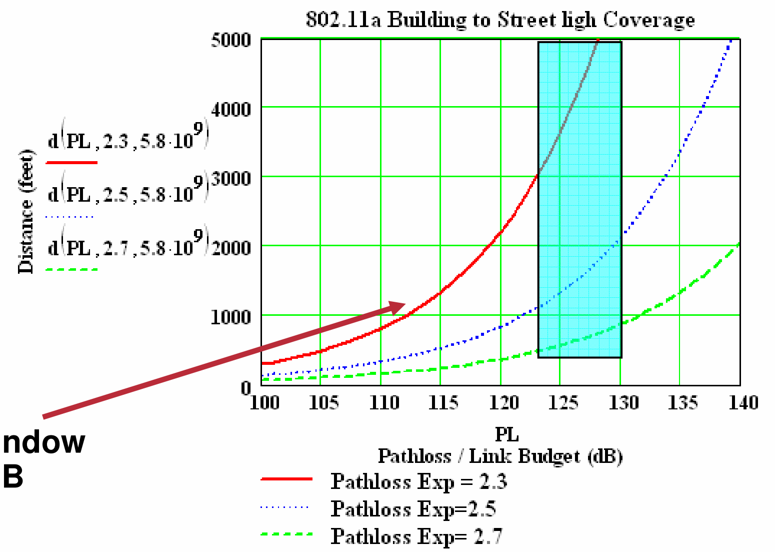
802.11a 5GHz Backhaul Distances



One Square Mile, 9 cells

1000 feet is the typical distance between the nodes

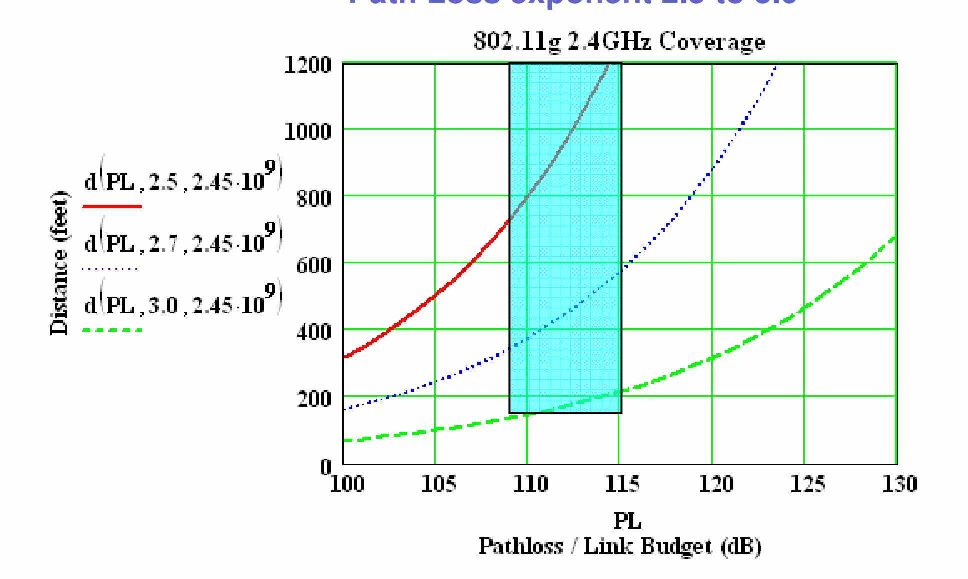
Path Loss exponent 2.3 to 2.7



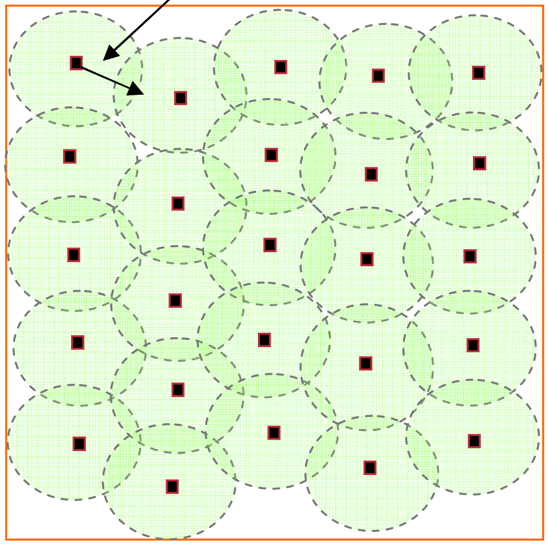
Link Budget Window
123 ~ 130 dB

2.4 GHz Local Access Distances

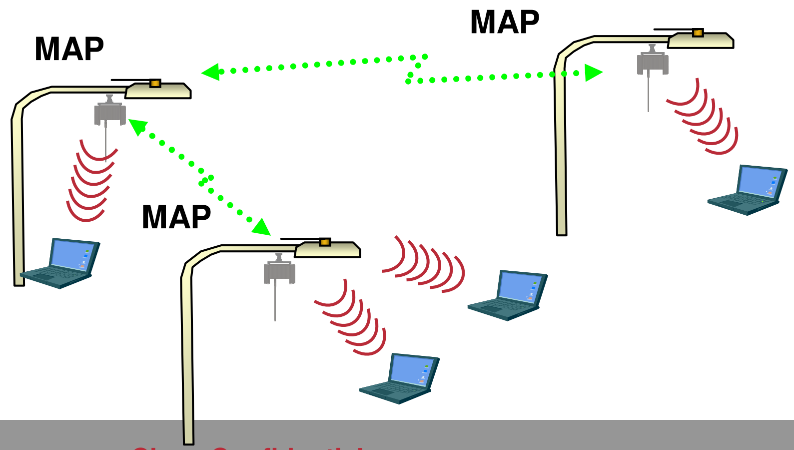
Path Loss exponent 2.5 to 3.0



600 feet (Typical distance)



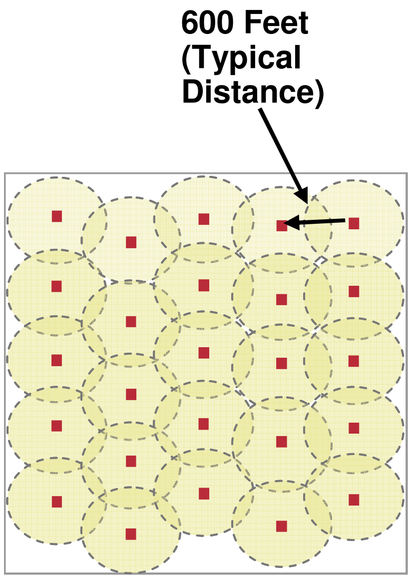
One Square Mile, 25 cells



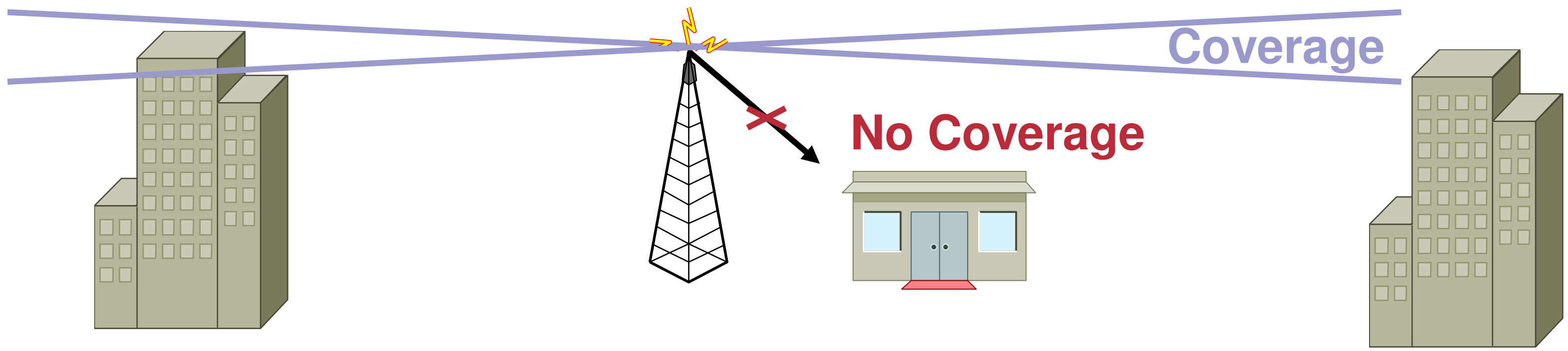
Typical Distances for Links

- Typical 5GHz RAP to PAP distances are 1000’-4000’
  - RAP locations are typically towers or tall buildings
- Typical 5GHz PAP to PAP distances are 500’-1000’
  - PAP locations are typically short building tops or streetlights
- Typical 2.4 GHz PAP to Client distances are 300’-500’
  - Client locations are typically laptops, CPEs or professionally house mounted antennas
- The distances depend upon Terrain, Clutter & Line of Site Conditions between Transmitter & Receiver
- Distance between the two Bridge (Ethernet Bridging) nodes is limited to 12000 feet

One Square Mile,
25 Cells



Omni-Directional Antenna Caveat



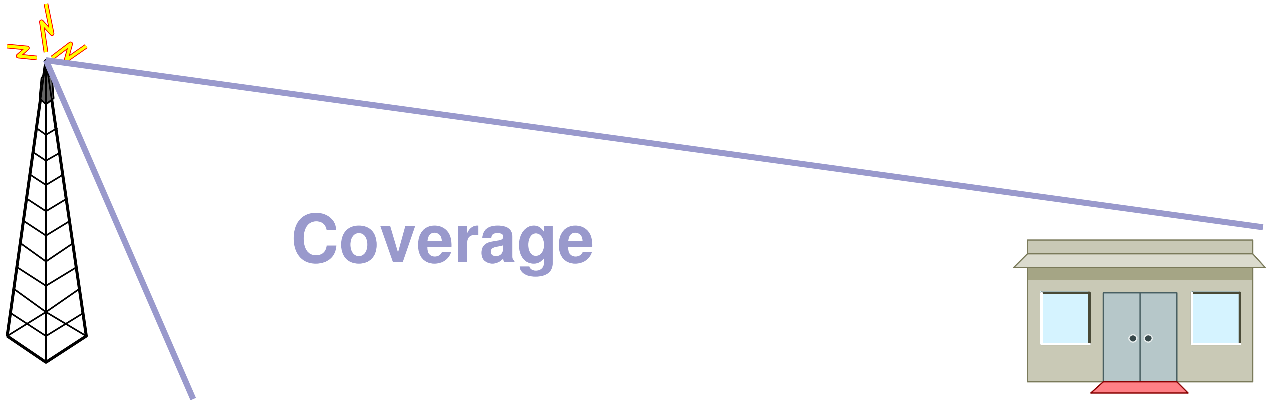
- **High gain omni-directional antennas often have a very narrow vertical beamwidth**

  Result: You may be able to communicate with far away devices, but not those very close in as the downward signal is severely attenuated

  Solution 1: If you need to communicate with near and far devices consider the use of a sector antenna

  Solution 2: Communicate with far devices via directional antennas and lower your omni antenna to communicate with near devices

Sector Antenna Deployment



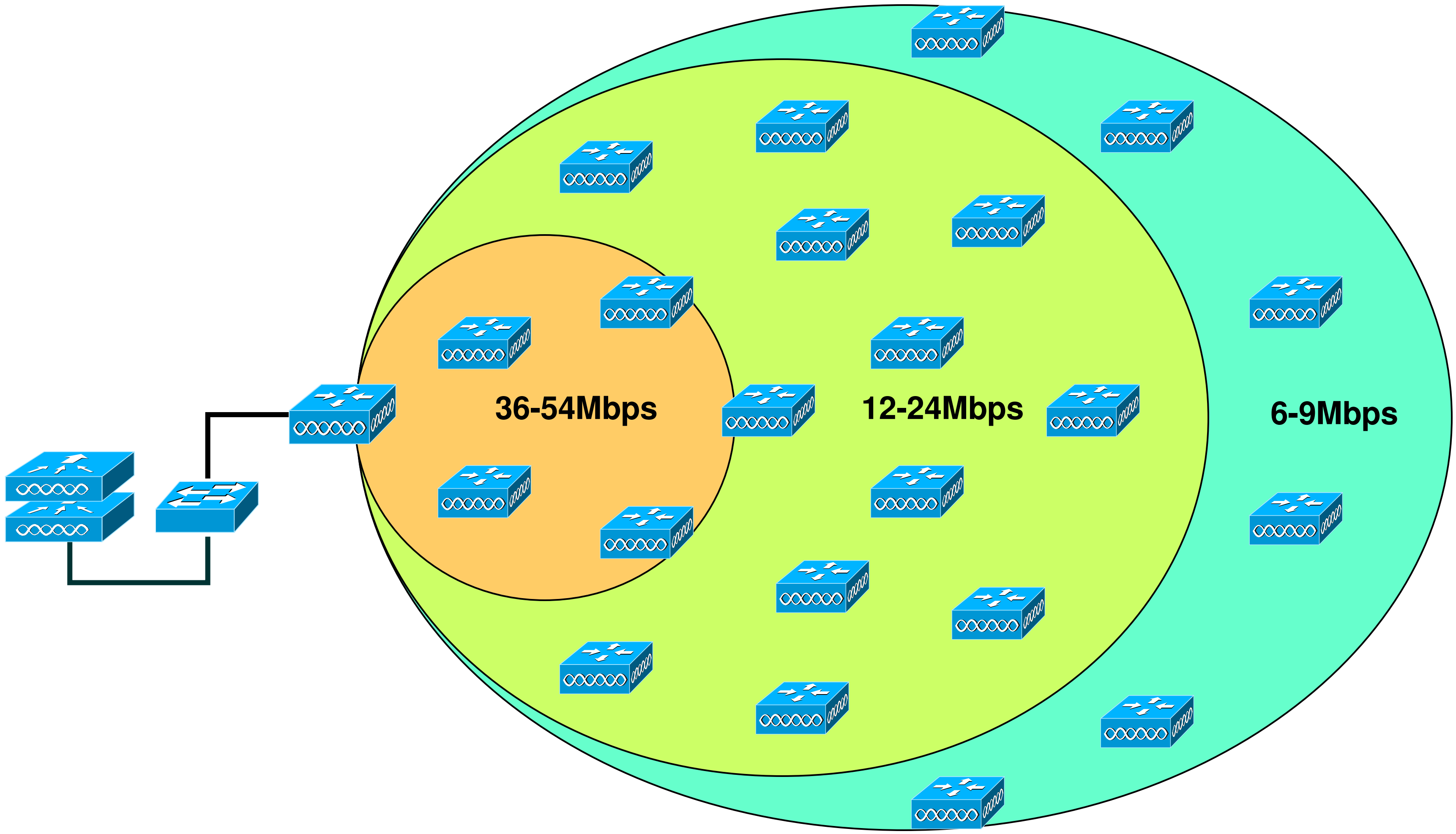
- **Very useful alternative to an omni antenna in point-to-multipoint deployments with interference sources present**
  - **Adjust sector antenna deployment to keep interferer out of main beam**
- **Utilize down tilt to maximize the signal energy in the desired coverage area**
  - **Utilizing simple geometry and considering earth bulge put the upper edge of the main beam at the furthest desired site**

Data Rates

802.11b	1,2,5.5,11
802.11g	1,2,5.5,11,6,9,12,18,24,36,48,54
802.11a	6,9,12,18,24,36,48,54

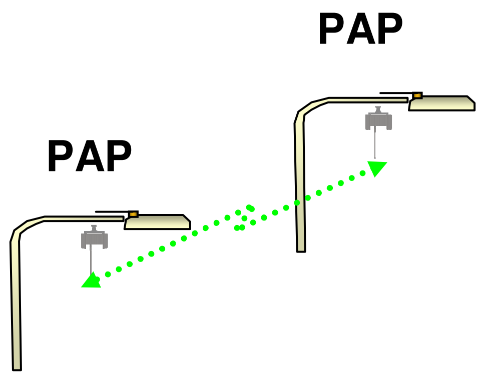
- 18 Mbps is the default fixed rate set for the backhaul
- We recommend to use 18 Mbps as the data rate for the backhaul
- Data rates for all the APs in a bridge group must match

Why is 18Mbps the "Sweet Spot"



Minimum Required Separation- 5 GHz

Tx Power dBm	6,9,12,18 Mbps	24, 36 Mbps	48 Mbps	54 Mbps
28 dBm	7 m	30 m		
25 dBm	5 m	20 m	20 m	
22 dBm	3.5 m	15 m	15 m	15 m
19 dBm	2.5 m	10 m	10 m	10 m
6 dBm	1.8 m	7.5 m	7.5 m	7.5 m



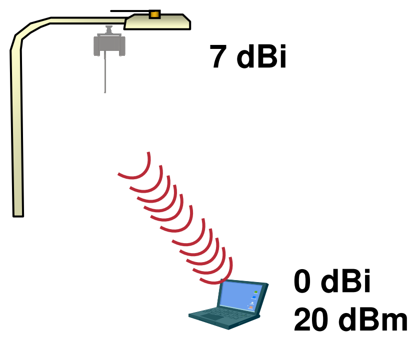
The damage level is 10 dBm for 5 GHz radio

Assuming Antenna Gain of 7dBi for each AP in the Backhaul

Max Receive input power level for 11a rates upto 0 dBm

Minimum required separation- 2.4 GHz

Transmitter Power dBm	All 11b rates & 11g 6,9,12 & 18 Mbps	11g 24, 36, 48 & 54 Mbps
20 dBm	1.8 m	5 m
18 dBm	1.2 m	2 m
14 dBm	0.89 m	1.4 m
11 dBm	0.6 m	1.0 m



Assuming Antenna Gain of 0 dBi for the client and 7 dBi for the AP

Max Receive input power level for 11b rates is +5 dBm, for 11g is -10 dBm

The damage level is 15 dBm for 2.4 GHz radio

Performance

- **Latency**

  < 10 ms per hop, 1-3 milliseconds typical

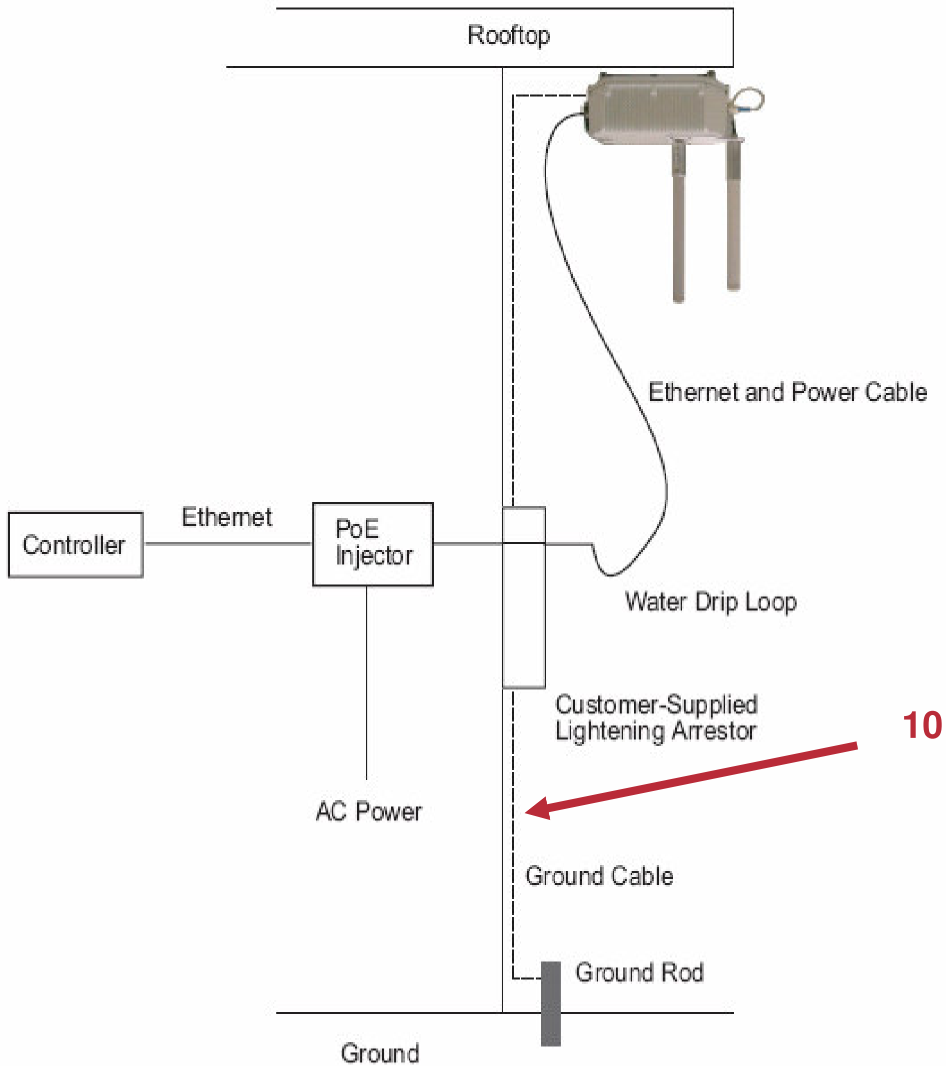
- **Hops**

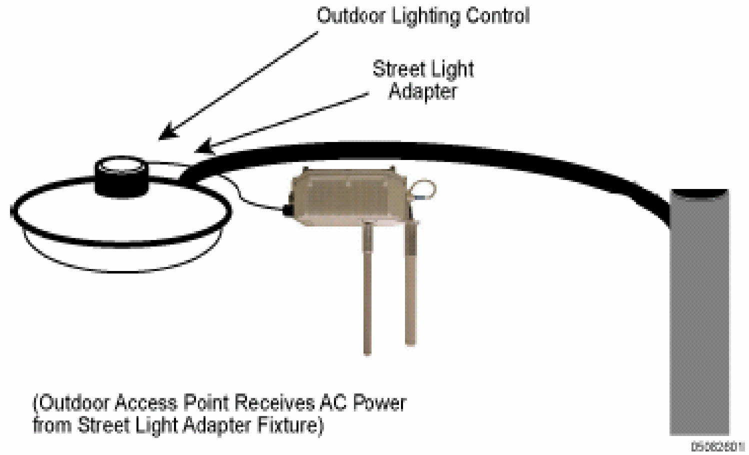
  Outdoor : Code supports 8 Hops. 3-4 hops are recommended

- **Nodes**

  One RAP supports 32 PAPs. 20 nodes are recommended

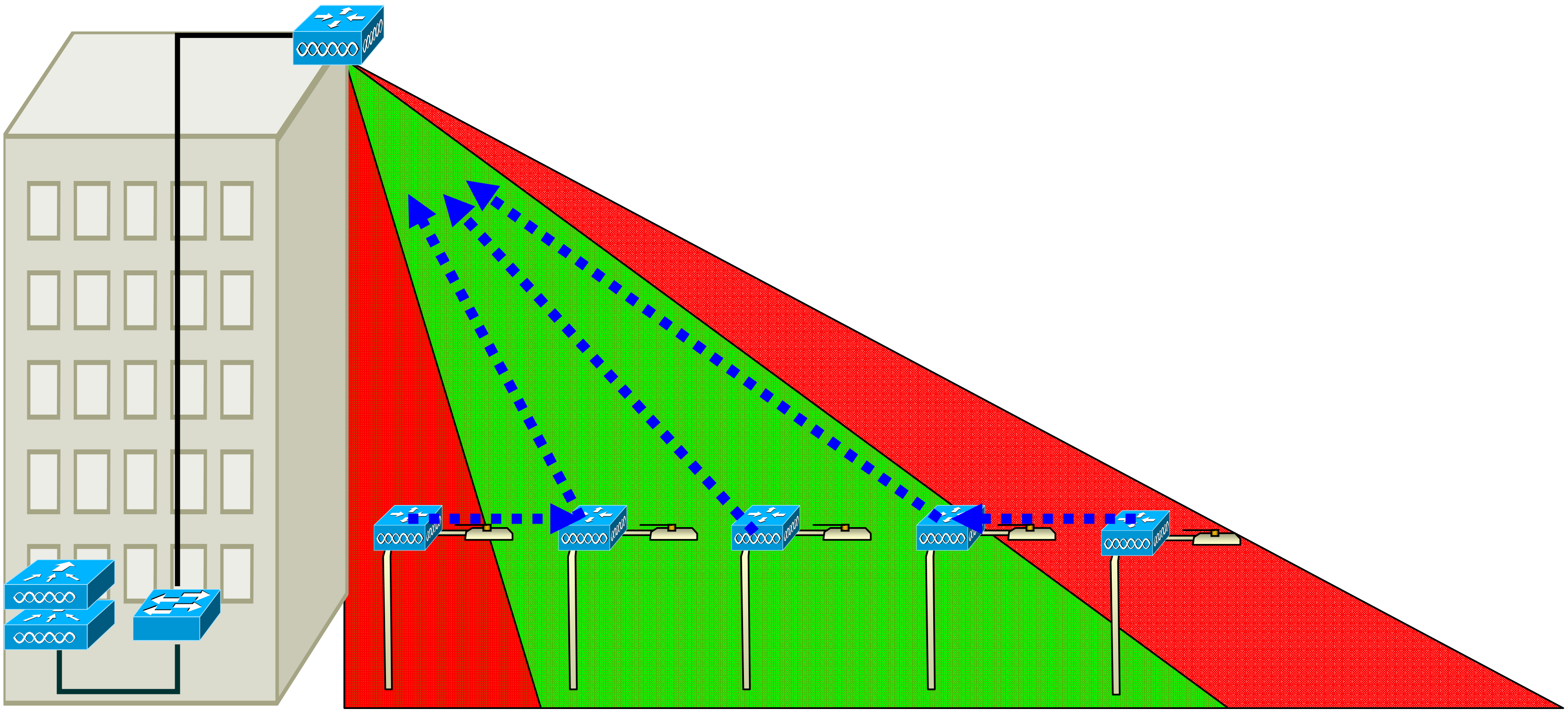
Grounding & Lightening Arrestor





10 AWG or Larger Ground wire

Understanding RAP Coverage Areas

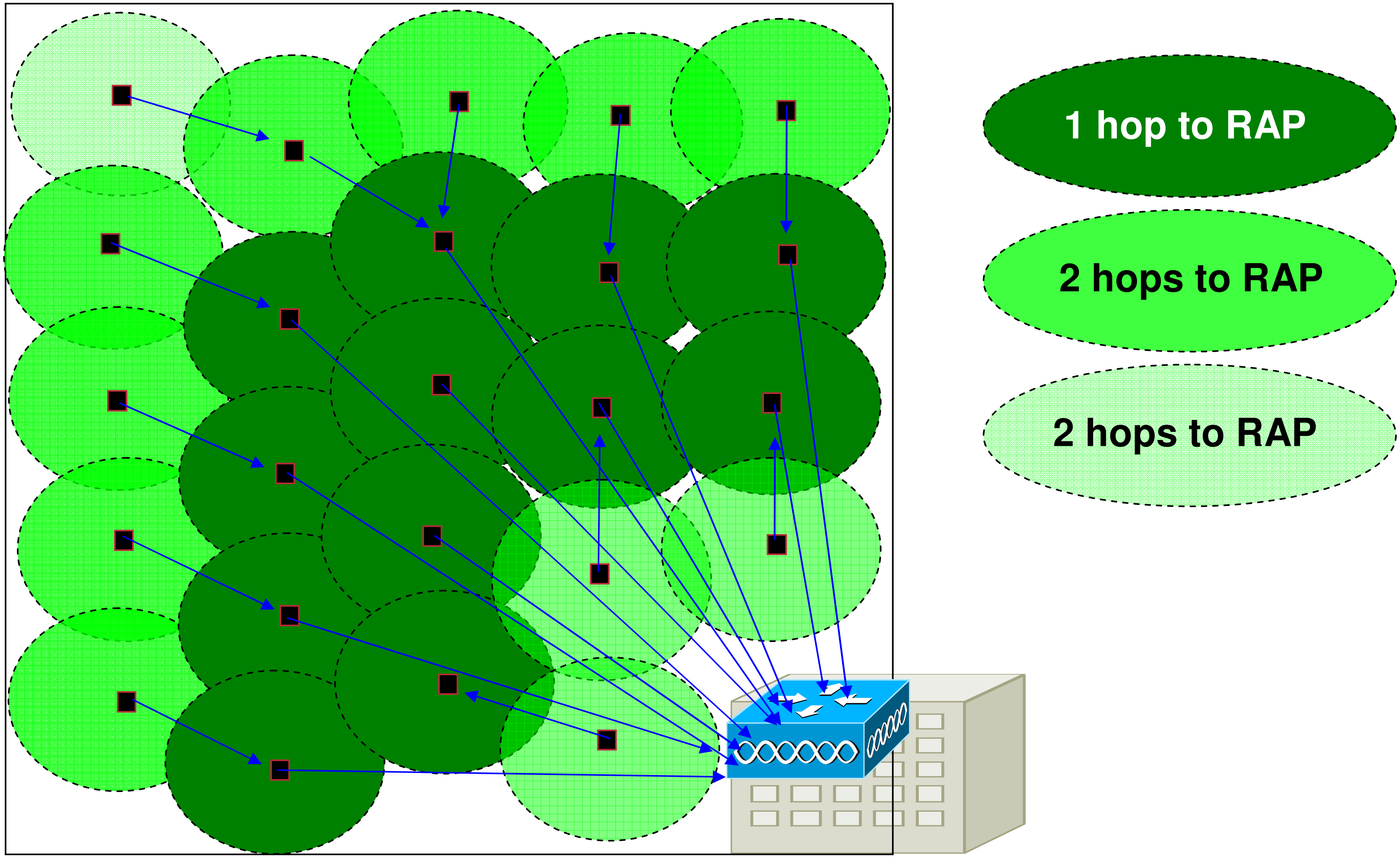


RF “Shadow” close to building; Poor SNR

18Mbps Coverage Area; SNR >20 dB

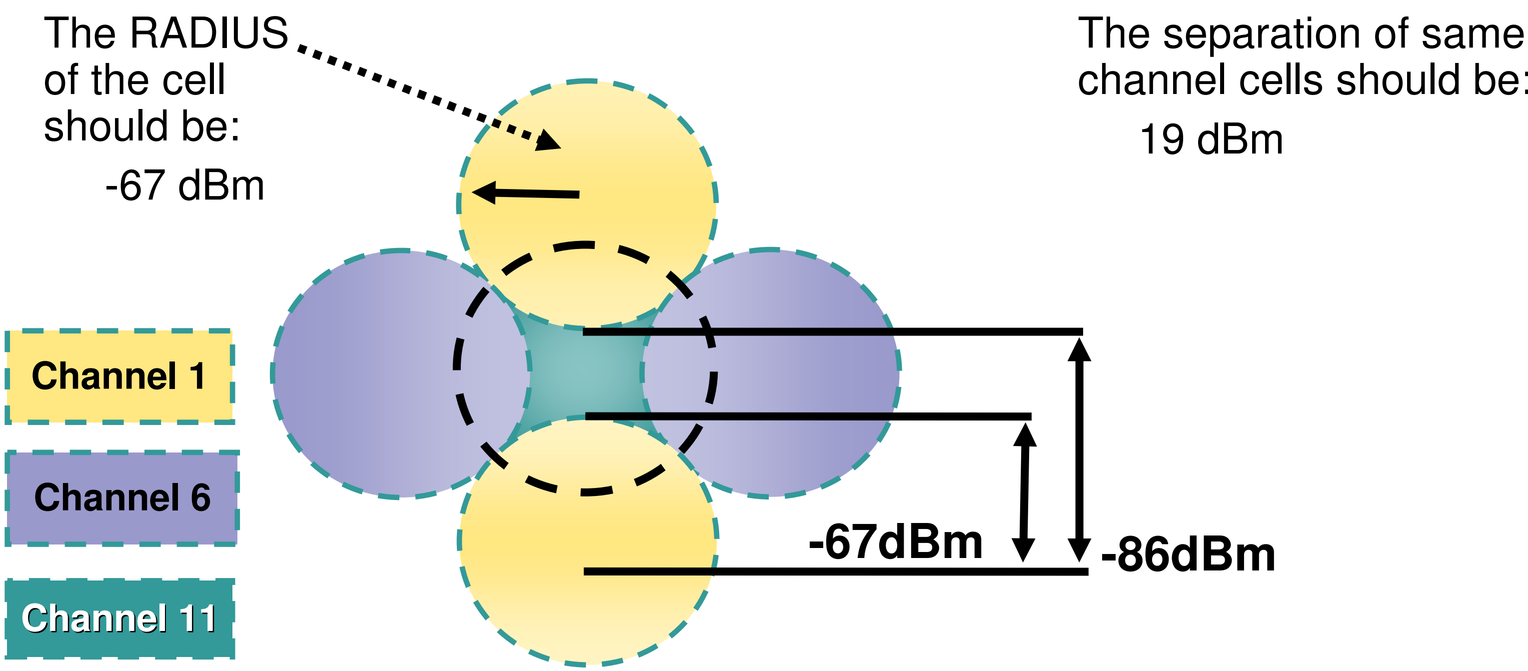
Beyond RF Coverage Area; Poor SNR

Applying RAP Coverage Areas to Designs

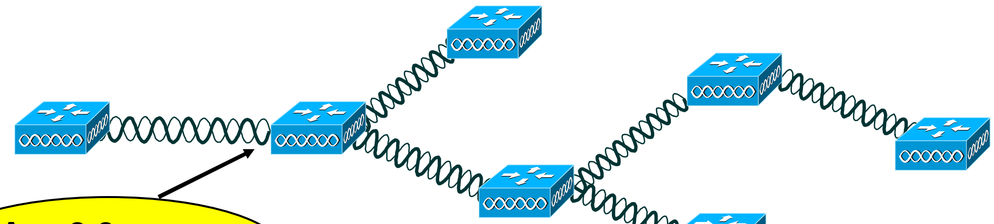


Ideal Environment

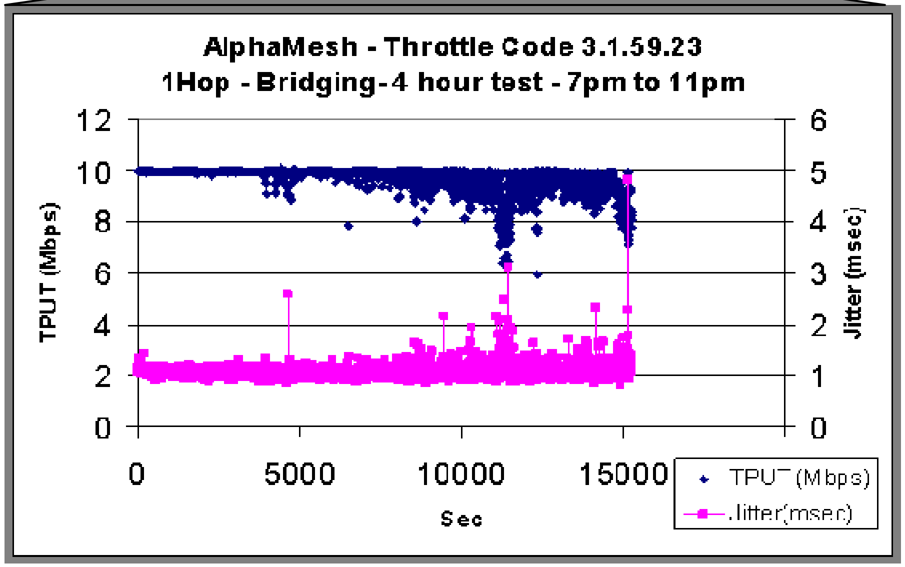
- **A typical deployment showing a 15–20% overlap from each of the adjoining cells**
- **Provides almost complete redundancy throughout the cell**



Typical Throughput and Latency



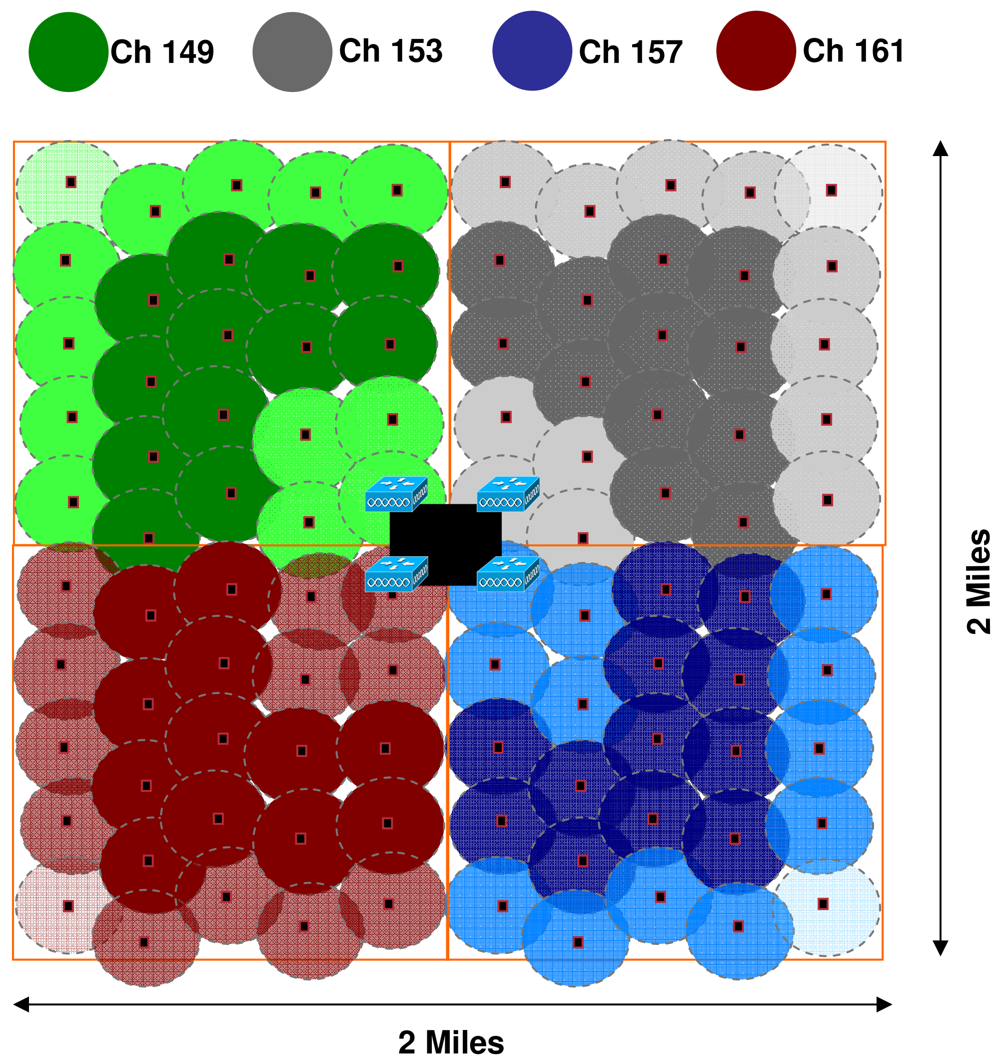
HOPS	One	Two	Three	Four
Throughput	~10Mbps	~5Mbps	~3Mbps	up to 1Mbps *



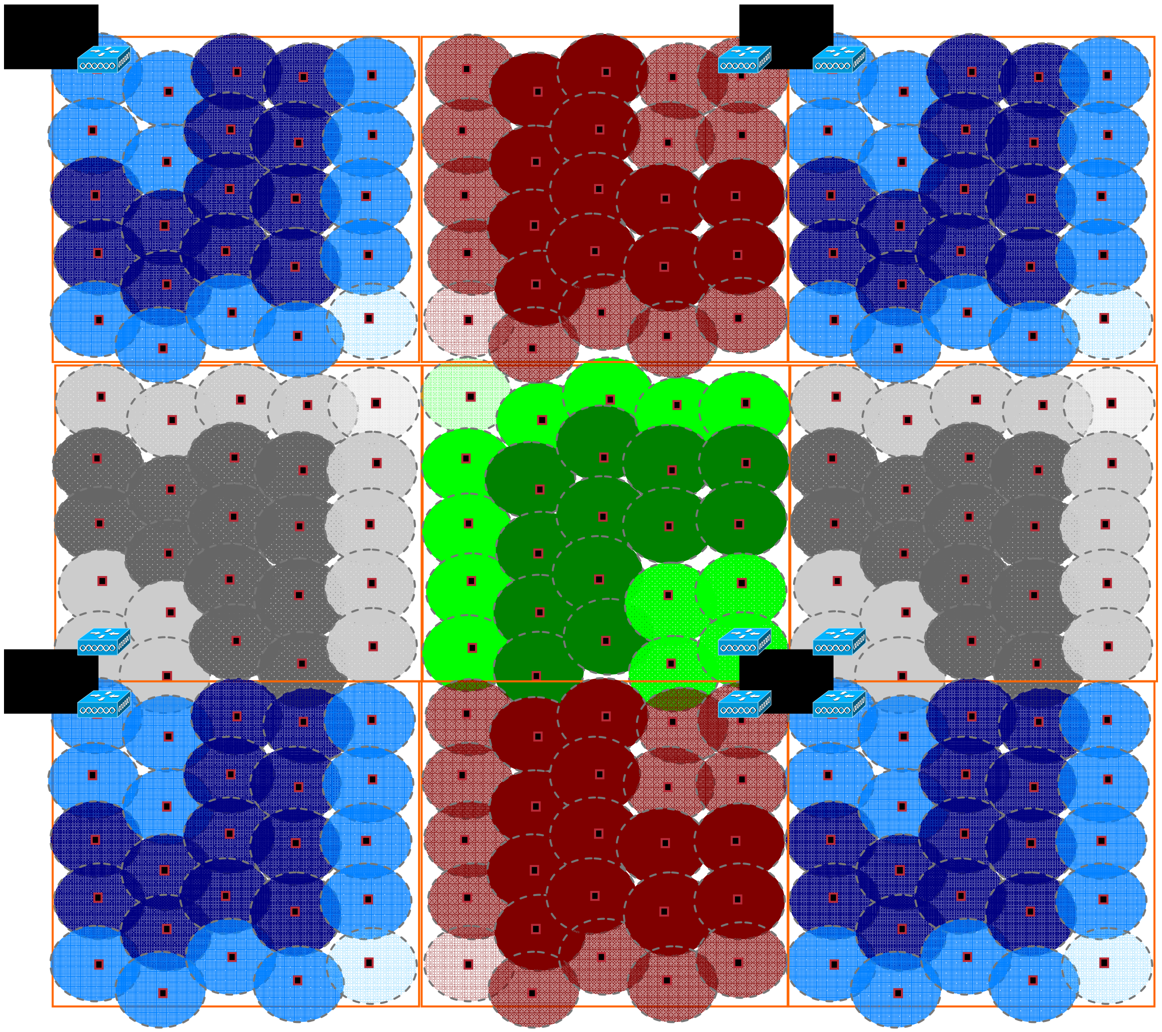
* more data to be collected

Practical Mesh Coverage Models

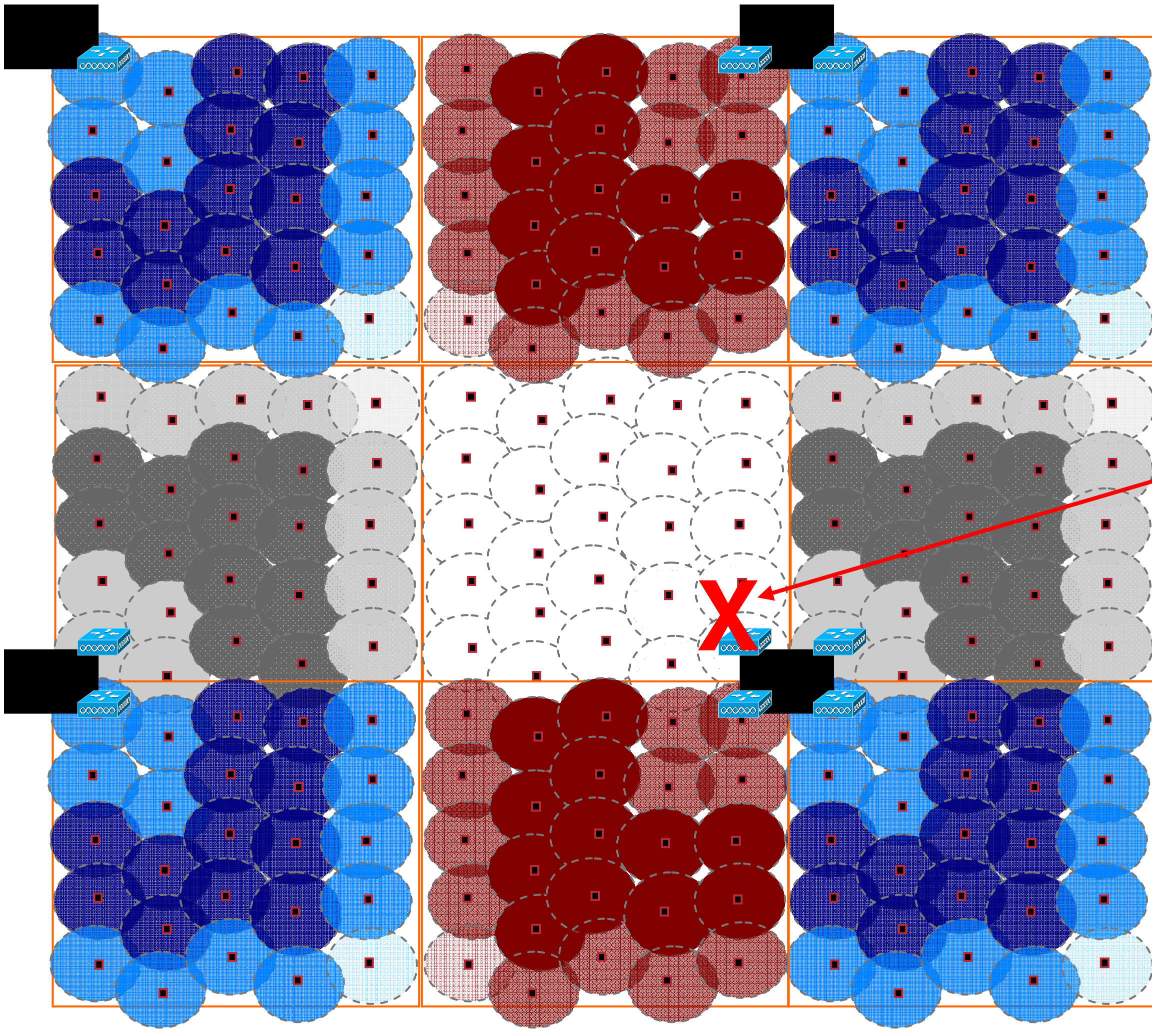
- **A Wired POP Bldg might have 4 RAPs**
- **Each RAP has 20-25 Mesh APs (MAPs)**
- **Each "Path Tree" on same 11a Channel**
- **Almost all MAPs within 1-2 hops of RAP**



How Designs Affect Mesh Convergence

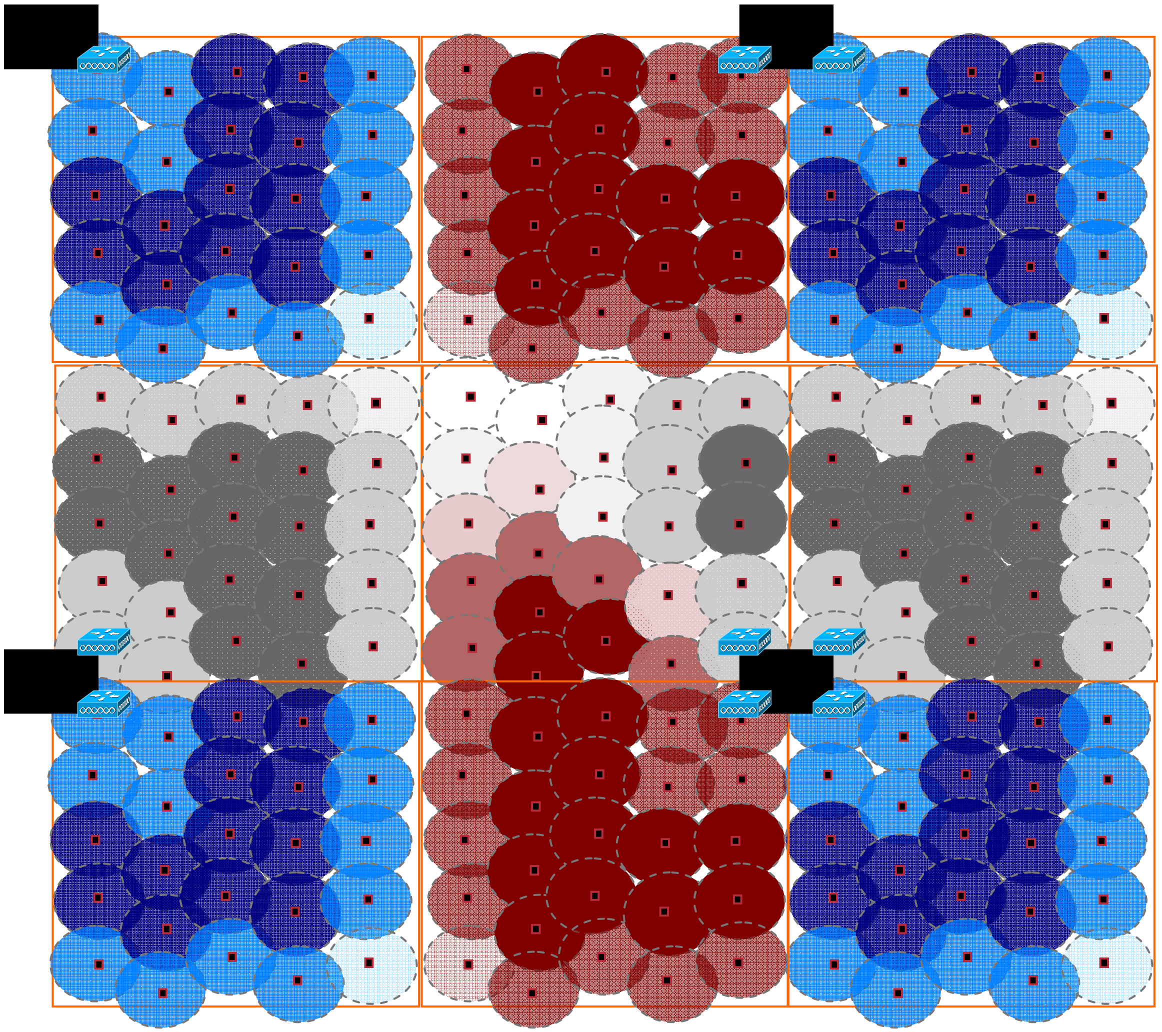


How Designs Affect Mesh Convergence, Cont.



…RAP becomes disconnected from Wired Network

How Designs Affect Mesh Convergence, Cont.



…Mesh APs link to surrounding RAP Trees

Mesh AP Re-convergence Sequence

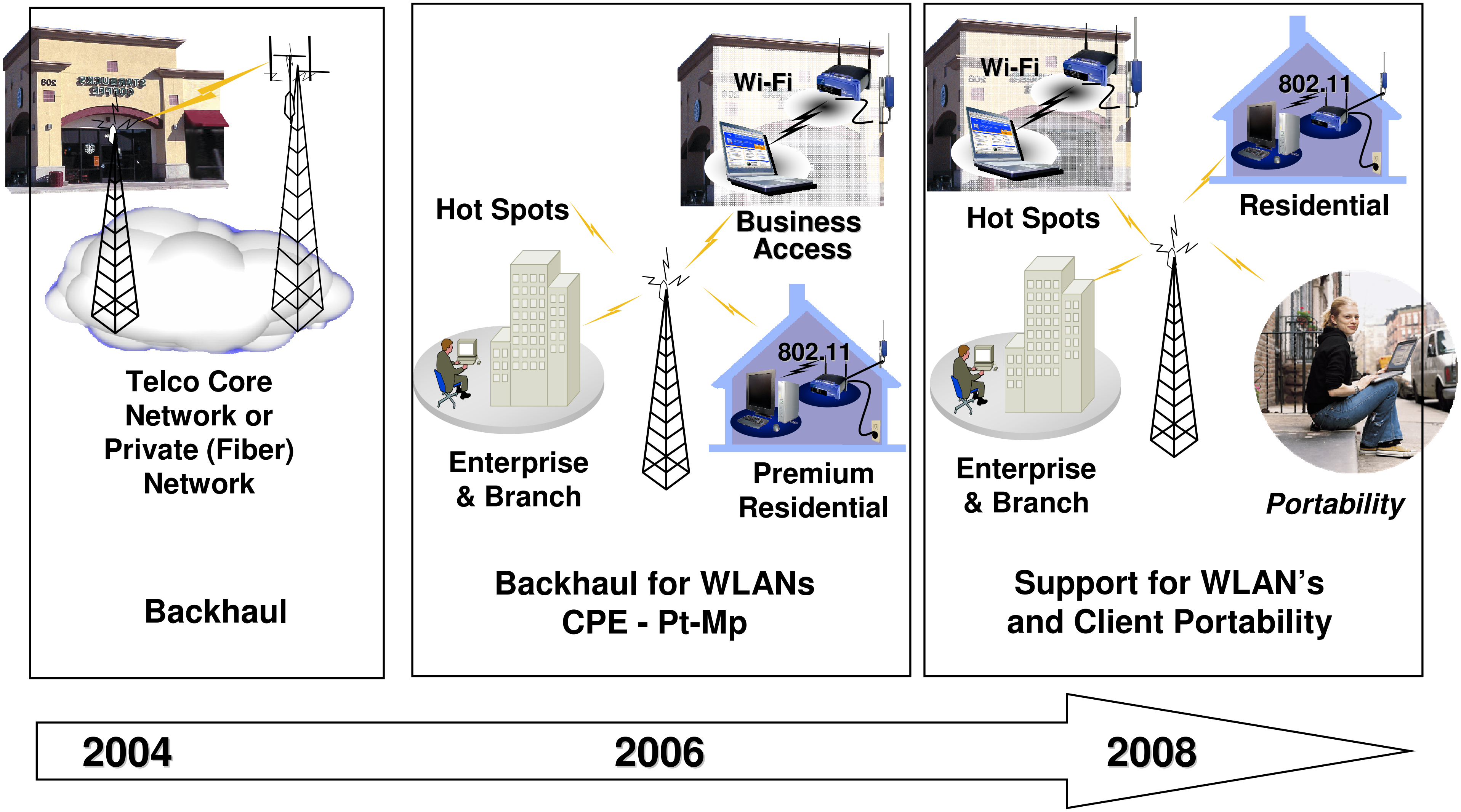
1. Sense Disconnect
2. Scan Backhaul for Neighbors
3. Establish Optimal Path (Ease) to new RAP
4. Authenticate to Parent; establish Mesh Tree
5. Re-DHCP (if necessary)
6. Connect to Controller
7. Begin Passing Traffic

- Static IP Address
- DHCP (Single VLAN)
- DHCP (Multiple VLANs)

Discussion Points on Wireless City

- **Wimax**
  - Mobility is needed, not there yet until 802.16e which will require new hardware
  - Client devices not really before 2007/2008 + renewal time
  - Capacity will require high density as one BTS delivers same capacity as 802.11 g/a but with higher EIRP
- **Hot Spots**
  - easy deployment based on DSL (telephone booth and street cabinets)
  - compatible with existing access devices today (802.11g)
- **MESH**
  - easy way to expand Hot Spots into Hot Zones
  - complete auto-configuration of neighbours (plug&play)

WiMax and WiFi - Complement



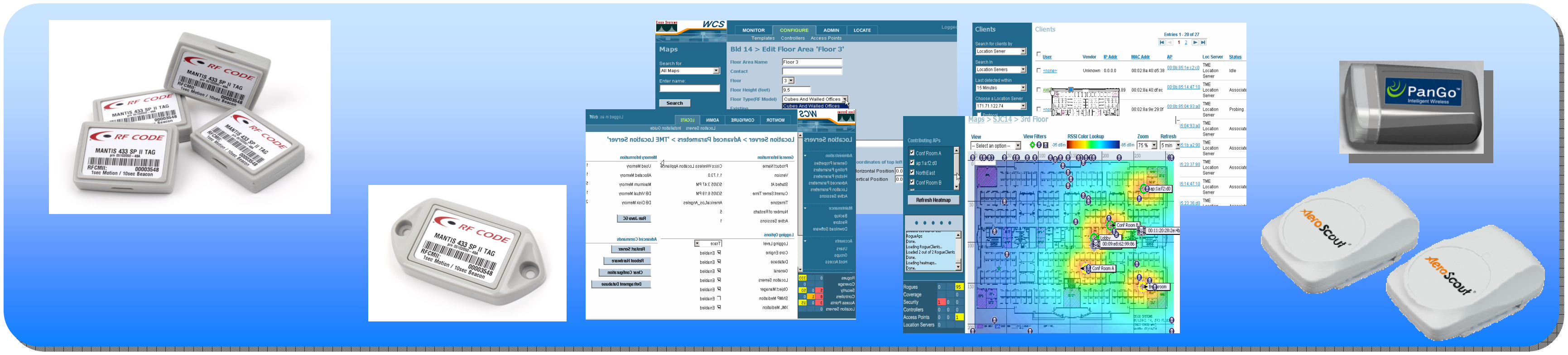
Deployment Photos

Tiradentes - MG

WIRELESS MESH APPLICATIONS

WLAN Location Services

Real-Time Location and Asset Tracking



- **Real-time Location Services**
- **Advanced RF Fingerprinting**
  - High accuracy location resolution within a few meters
  - Granular rogue detection
- **Simultaneous tracking of thousands of clients**
  - Laptops, PDAs, Tablets, Wi-Fi Phones, 802.11 RFID Tags
- **RF capacity management and historical location trending**

Surveillance

Rotterdam

Obrigado!!!